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RESEARCH TRIANGLE PARK, NC 27711

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OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Availability of Modeling Data and Associated Technical Support Document for the EPA's Updated 2028 Visibility Air Quality Modeling

FROM: Richard A. Wayland Richard A. Wayland
Director, Air Quality Assessment Division

TO: Regional Air Division Directors

Through this memorandum, the U.S. Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards is communicating the availability of updated 2028 visibility modeling data and results, including domestic and international source contributions to Class I areas, with an associated technical support document (TSD). EPA committed to performing and releasing these modeling results in the September 2018 Regional Haze Reform Roadmap.[1]

The goal of this modeling effort was to project 2028 visibility conditions and source sector contribution information, including international anthropogenic impacts, for each mandatory Class I federal area/IMPROVE site. EPA conducted this visibility modeling to inform the regional haze state implementation plan (SIP) development process for the second implementation period.[2] In particular, this modeling provides our first comprehensive estimate of international anthropogenic emissions contributions to visibility impairment at Class I areas.

Summary of Modeling Results

The attached TSD details EPA's modeling platform, modeling results, model performance, and uncertainties in these modeling results. Specifically, the document contains information on EPA's 2016 modeling platform and associated base year model performance, 2028 projected visibility impairment, comparison of the 2028 projected visibility impairment with the

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[1] See https://www.epa.gov/sites/production/files/2018-09/documents/regional_haze_reform_roadmap_memo_09-11-2018.pdf

[2] On January 10, 2017 (82 FR 3078), the EPA revised the Regional Haze Rule to clarify and streamline certain planning requirements for states. The rule also extended the deadline for second implementation period plans by three years, to July 31, 2021, but did not change the dates for the beginning and end of the implementation period. The second implementation period ends in 2028.

unadjusted uniform rate of progress line (glidepath), and 2028 sector-based source apportionment results. In addition, source apportionment results are used to calculate the estimated source contribution of international anthropogenic emissions to visibility impairment at Class I areas on the 20 percent most impaired days. These estimated contributions are used to derive an adjusted glidepath endpoint for each area as allowed by the 2017 regional haze rule[3]. The TSD includes modeling results for each Class I area (represented by IMPROVE sites) to provide an understanding of the unique situation in each area.

Model Science and Platform Improvements

There are numerous updates and improvements in the 2016/2028 regional haze modeling platform compared to EPA's previous 2011/2028 based platform including:

- Updated 2016 emissions and 2028 emissions projections derived from the "beta" version of the National Emissions Inventory Collaborative process.
- Use of a larger 36km modeling domain for the Comprehensive Air quality Model with eXtensions (CAMx) with two-way nesting (12km nested domain) that covers most of Canada and Mexico.
- Boundary conditions for the CAMx 36/12km regional modeling was derived from outputs from a hemispheric version of the Community Multi-scale Air Quality (CMAQ) model that used updated global emissions.
- Added dimethyl sulfide (DMS) emissions and chemistry (a natural source of sulfate over the oceans) to CAMx.
- Updated CAMx source apportionment capabilities that can track multiple boundary conditions components to allow separate account of the international anthropogenic and natural emissions coming into the regional modeling domain.

Model Results

At most eastern Class I areas, visibility on the 20% most anthropogenically impaired days is projected to be below the unadjusted glidepath in 2028, with a relatively higher percentage of the light extinction due to U.S. anthropogenic sources. At many western Class I areas, visibility is projected to be above the unadjusted glidepath, with a relatively lower percentage of light extinction due to U.S. anthropogenic sources. As mentioned above, the Regional Haze Rule allows states to optionally propose an adjustment of the 2064 URP to account for international anthropogenic impacts,[4] if the adjustment has been developed using scientifically valid data and methods. The URP can be adjusted by adding an estimate of the visibility impact of international

[3] See 40 CFR 51.308(f)(1)(vi)(B).

[4] The regional haze rule also allows an adjustment of the glidepath endpoint to account for certain prescribed fire impacts. Modeled prescribed fire contributions were calculated by EPA, with results presented in the modeling TSD. However, consistent with the focus of the December 2018 Technical Guidance and the Administrator's Regional Haze Roadmap, the glidepath adjustments presented here only include the international anthropogenic contributions. Additionally, the prescribed fire impacts are relatively small (~0-5 Mm^{-1}) compared to the international anthropogenic impacts (~3-19 Mm^{-1}).

anthropogenic sources to the value of the natural visibility conditions to get an adjusted 2064 endpoint. EPA's December 2018 Technical Guidance on Tracking Visibility Progress[5] provided a general framework for estimating this adjustment. For the purposes of this modeling, EPA has estimated a default international adjustment based on relative modeling results (consistent with SIP Modeling guidance) and the ambient-based estimate of natural conditions (consistent with standard practice in the regional haze program).

Through a combination of hemispheric CMAQ zero-out modeling and CAMx source apportionment modeling, EPA estimated the total visibility impairment contribution from international anthropogenic emissions sources to Class I areas (at representative IMPROVE monitoring sites) on the 20 percent most anthropogenically impaired days. Adding the estimated default international anthropogenic adjustment to the 2064 natural conditions endpoint allows for comparison of the 2028 model projected impairment to an adjusted glidepath. After adjusting the glidepath endpoint, the number of IMPROVE sites in the contiguous US projected to be above the 2028 glidepath decreased from 47 sites to 8 sites (out of 99 sites evaluated).[6]

Use of EPA's Model Results and Glidepath Adjustments

Based on our assessment of these results, we identified uncertainties and modeling issues that are relevant to consider when evaluating the potential use of EPA's 2028 visibility estimates and glidepath adjustments in regional haze SIP development. In spite of some lingering model performance issues, (e.g., overprediction of sulfate along the west coast and secondary organic mass in the southeast) the 2016/2028 based modeling platform is much improved over the previous 2011/2028 based modeling. In general, the new 2028 projected visibility impairment values and comparisons to the unadjusted 2028 glidepath are consistent with the previous EPA regional haze modeling. However, the new modeling results represent our first attempt to quantify the international anthropogenic (and prescribed fire) emissions impacts on visibility impairment. Therefore, additional scrutiny of these initial glidepath adjustments is warranted.

The modeling TSD data tables and associated IMPROVE site specific plots show the 2028 projected visibility impairment values compared to both the unadjusted and default adjusted 2028 glidepath (using relative model results and international anthropogenic impacts). In recognition of the uncertainty in the adjusted glidepath values, additional adjustment method values are also presented in both tables and the site-specific plots. States should consult with their EPA Regional office to determine the appropriate glidepath and related analyses for any particular Class I area. Analyses can examine the magnitude of each of the components of the adjusted glidepath (including model bias), the natural conditions value(s), the international anthropogenic contribution values, and the prescribed fire contribution values.

[5] https://www.epa.gov/visibility/technical-guidance-tracking-visibility-progress-second-implementation-period-regional

[6] Some IMPROVE sites represent multiple Class I areas. The 99 IMPROVE sites (in the contiguous US) evaluated in this modeling represent 142 Class I areas.

In addition to the projection of 2028 visibility impairment and comparison to a glidepath (unadjusted or adjusted), there remain additional regional haze SIP requirements that must be satisfied. See the Regional Haze Rule[7] and the Guidance on Regional Haze SIPs for the Second Implementation Period[8] for information on regional haze SIP requirements.

Next Steps

EPA will follow the release of the regional haze modeling TSD with a public webinar presentation in October on the results. The webinar will provide a more detailed explanation of the modeling and methodologies and give others a chance to ask questions.

We have also identified several aspects of this modeling that can be further examined and improved through coordination with others, including:

- Improved treatment of natural sources of fugitive dust.
- Improved secondary organic aerosol (SOA) chemistry.
- Further review of "natural visibility conditions" used in the glidepath framework which can be informed by the findings of this modeling and other source apportionment modeling and data analysis.
- Further review of the classification and magnitude of prescribed fire emissions.

We look forward to continuing to work with EPA Regional offices; state, local, and tribal air agencies; and interested stakeholders to further interpret, analyze, and improve the regional haze modeling as part of future collaborative efforts.

The TSD is available electronically on EPA's SCRAM website at: (https://www3.epa.gov/ttn/scram/reports/Updated_2028_Regional_Haze_Modeling-TSD-2019.pdf). Questions and requests for the detailed data used to generate summary plots (Excel spreadsheets) should be sent to Brian Timin of EPA's Air Quality Modeling Group at timin.brian@epa.gov. EPA will also provide associated inputs and outputs for this modeling via hard drives upon request (total file size of approximately 20 TB).

[7] See 82 FR 3078.
[8] https://www.epa.gov/visibility/guidance-regional-haze-state-implementation-plans-second-implementation-period

Technical Support Document for EPA's Updated 2028 Regional Haze Modeling

Office of Air Quality Planning and Standards
United States Environmental Protection Agency
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1.0 Background

The Regional Haze Rule (RHR) requires states to develop and submit state implementation plans (SIP) that evaluate reasonable progress for implementation periods in approximately 10-year increments. The next regional haze SIP is due in 2021, for the second implementation period which ends in 2028.[1] The EPA conducted visibility modeling for 2028 with the intention of informing the regional haze SIP development process.

This modeling provides a number of outputs and metrics that may be helpful in the state regional haze SIP planning process. These include:

1) Projected 2028 visibility impairment on the 20% most anthropogenically impaired and 20% clearest days at 142 Class I areas (99 IMPROVE sites)
2) Estimated source sector contributions to visibility impairment at Class I areas for 22 emissions sectors.
3) Estimated international anthropogenic and prescribed fire contributions to visibility impairment at Class I areas.

A prior version of EPA 2028 visibility modeling (EPA, 2017), using a 2011 basecase, provided estimated 2028 visibility impairment at Class I areas and estimated source sector contributions from a number of anthropogenic (EGUs, onroad mobile, etc.) and natural (biogenics, wildfires, etc.) source sectors. In that modeling, we identified a number of uncertainties and model performance issues that needed to be addressed in future modeling. This new 2016 based modeling platform makes numerous improvements to the previous 2011/2028 modeling platform, including using updated emissions, science algorithms, and boundary conditions.

The EPA is releasing this information as part of the collaborative work with states, tribes, multi-jurisdictional organizations, and federal land managers. Our goal is that this information, along with future collaborative work, will improve the technical foundation of modeling used in regional haze SIP development. States should consult with their EPA Regional Office to determine the usefulness of these model results for any particular Class I area.

[1] On January 10, 2017 (82 FR 3078), the EPA revised the Regional Haze Rule to clarify and streamline certain planning requirements for states. The rule also extended the deadline for second implementation period plans by three years, to July 31, 2021. The second implementation period covers 2019 to 2028.

1.1 Introduction

In this technical support document (TSD) we describe the air quality modeling performed to examine regional haze in 2028. For this assessment, air quality modeling is used to project visibility levels at individual Class I areas (represented by IMPROVE monitoring sites) to 2028 and to estimate national emissions sector contributions to 2028 particulate matter (PM) concentrations and visibility. The projected 2028 PM concentrations are converted to light extinction coefficients and then to deciviews and used to evaluate visibility progress in 2028. The modeling also used CAMx particulate source apportionment technology (PSAT) to calculate 2028 visibility contribution information by major emissions source sector. A new PSAT feature (CAMx version 7) allows for tracking of separate components of the model boundary conditions. This allowed the separate tracking of international anthropogenic and natural emissions contributions. The sector contribution information allows for a better understanding and accounting of sources of future visibility impairment (including domestic anthropogenic, international anthropogenic, and natural sources).

The remaining sections of this TSD are as follows. Section 2 describes the air quality modeling platform and the evaluation of model predictions using measured concentrations. Section 3 defines the procedures for projecting regional haze deciview values to 2028, with comparisons to the "unadjusted" glidepath. Section 4 describes (1) the PM source contribution (i.e., particulate source apportionment) modeling and (2) the procedures for quantifying contributions to visibility at individual IMPROVE monitoring sites. Section 5 describes the calculation of regional haze glidepath adjustments and comparisons to the adjusted glidepath. Section 6 summarizes the modeling results.

2.0 Air Quality Modeling Platform

The EPA used a 2016-based air quality modeling platform which includes emissions, meteorology, and other inputs for 2016 as the base year for the modeling described in this TSD. The 2016 base year emissions were projected to a future year base case scenario, 2028. The 2016 modeling platform and projected 2028 emissions were used to drive the 2016 base year and 2028 base case air quality model simulations. The 2016 and projected 2028 emissions were derived from the "beta" version of the National Emissions Inventory Collaborative process (NEIC, 2019). A group of state, local, tribal, regional, and federal air planning agencies initiated a collaborative process to build a national emissions modeling platform (EMP) for simulating air quality in the U.S. The 2016beta EMP is the first product from the National Emissions Inventory Collaborative that includes a full suite of base year (2016) and future year inventories, ancillary emissions data, and scripts and software for preparing the emissions for air quality modeling

The 2016 base year emissions and methods for projecting these emissions to 2028 are further described in Technical Support Document (TSD) "Preparation of Emissions Inventories for the Version 7.2 2016 North American Emissions Modeling Platform" (EPA, 2019a). The meteorological data was derived from the WRF model and the initial and boundary concentrations were derived from hemispheric scale runs of the CMAQ model. The meteorological modeling and initial and boundary conditions used for this regional haze assessment are further described below.

2.1 Air Quality Model Configuration

The photochemical model simulations performed for this ozone transport assessment used a pre-release version of the Comprehensive Air Quality Model with Extensions (CAMx version 7.0 beta) (Ramboll, 2018). CAMx is a three-dimensional grid-based Eulerian air quality model designed to simulate the formation and fate of oxidant precursors, primary and secondary particulate matter concentrations, and deposition over regional and urban spatial scales (e.g., the contiguous U.S.). Consideration of the different processes (e.g., transport and deposition) that affect primary (directly emitted) and secondary (formed by atmospheric processes) pollutants at the regional scale in different locations is fundamental to understanding and assessing the effects of emissions on air quality concentrations.

Figure 2-1 shows the geographic extent of the modeling domain that was used for air quality modeling in this analysis. The domain covers the 48 contiguous states along with the large portions of Canada and Mexico. The modeling domain contains 35 vertical layers with a top at about 17,550 meters, or 50 millibars (mb), and horizontal grid resolution of 36km x 36km for the outer domain and 12 km x 12 km for the nested domain. The model simulations produce hourly air quality concentrations for each 36km and 12 km grid cell across the modeling domain.

CAMx requires a variety of input files that contain information pertaining to the modeling domain and simulation period. These include gridded hourly emissions estimates and meteorological data, and boundary concentrations. Separate emissions inventories were prepared for the 2016 base year and the 2028 base case. All other inputs (i.e., meteorological fields, initial concentrations, and boundary concentrations) were specified for the 2016 base year model application and remained unchanged for the future-year model simulations.[2]

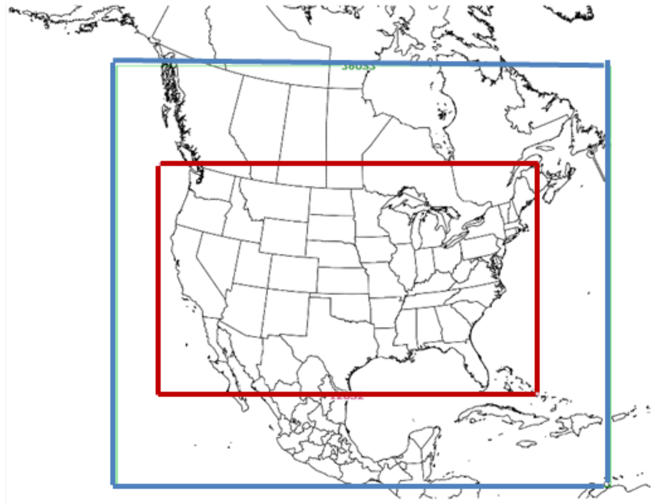

Figure 2-1. *Map of the CAMx modeling domain used for regional haze modeling. The blue rectangle is the 36km domain and the red rectangle is the 12km domain.*

Table 2-1 below list the four CAMx model runs which were performed for this analysis. There is a 2016 base case model run, a 2028 future base case model run, and two separate 2028 PSAT source apportionment runs.

Table 2-1. CAMx model runs for 2016 and 2028

Scenario Name	Scenario	CAMx Version	Description
2016fg	2016 base case	v7 beta 2	Historical base case
2028fg	2028 future base case	v7 beta 2	Future year “on the books” base case
2028fg_psat	2028 PSAT 22 sector source apportionment case	v7 beta 3	Source apportionment case which produces both 2028 “bulk outputs” and source sector tag outputs
2028fg_psat_ICBC	2028 PSAT with IC/BC tagging	v7 beta 4 patch 2	Source apportionment with IC/BC tagging

[2] The CAMx 2016fg and 2028fg scenarios were each performed using a single time segment with a 10-day ramp-up period at the end of December 2015. The CAMx PSAT scenarios were performed using two time segments (January 1 through June 30, 2016 with a 10-day ramp-up period at the end of December 2015, and July 1 through December 31, 2016 with a 20-day ramp-up period at the end of June 2016).

The CAMx model runs for this project were complicated by the fact that development of the CAMx version 7 code was ongoing during the project. Over the course of the project, EPA received several different beta versions of the version 7 pre-release model code. In order to complete the modeling as quickly as possible, three different versions of the pre-release code were used in the course of the regional haze modeling (as described above in Table 2-1). Below are further details on each beta version of the CAMx v7 code.

Version 7 beta 2- The first working version of the version 7 code. This was used for the 2016 and 2028 non-source apportionment base cases. The major new features in this version are the addition of dimethyl sulfide (DMS) emissions and chemistry, and the ability to run with multiple emissions input files. Beta 2 (and subsequent versions) also has "bidi" (bi-directional flux) ammonia flux implemented, however, due to model performance concerns, all CAMx scenarios were run with bidi turned off.

Version 7 beta 3- This version enabled source apportionment capability within version 7. No other major features were added. This version was used for the 22-tag emissions sector PSAT run (and did not have IC/BC PSAT tagging enabled).

Version 7 beta 4 patch 2- This version was the first working CAMx version with PSAT IC/BC tagging capability ("patch 2" was the 1st stable version of the beta 4 code and the last version used in this round of modeling). This allows the initial and boundary conditions to be tagged and tracked as multiple tags. This code was used for the IC/BC tagging PSAT run which separately tagged the anthropogenic and natural components of the boundary conditions.

Version 7 beta 6- This is the most recent version of the pre-release version 7 CAMx code. It was not used to run the regional haze scenarios documented in this TSD. However, it is the code that should be used to replicate the EPA regional haze modeling results. Several additional bugs have been fixed since beta 4, and beta 6 has been configured to use the same subroutines (e.g. chemistry and time steps) to produce the same core model results as both beta 3 and beta 4. Note that the final public (non-beta) release version of CAMx 7.0 may differ from this version.

In order to complete the 2028fg_psat_ICBC scenario as efficiently as possible, the model (beta 4 patch 2) was run with a single PSAT tag that combined all 22 emissions sectors into 1 tag, with IC/BC tagging enabled. Therefore, the PSAT results presented in this TSD are a combination of results from the two PSAT scenarios. The 22 tag results come from the 2028fg_psat scenario, and the IC/BC results come from the 2028fg_psat_ICBC scenario. Even though the underlying code versions for the two scenarios differ, the "bulk" model results (total sulfate, nitrate, etc.) are exactly the same.

2.2 Meteorological Data for 2016

The 2016 meteorological data for the air quality modeling of 2016 and 2028 were derived from running Version 3.8 of the Weather Research and Forecasting Model (WRF) (Skamarock, et al., 2008). The meteorological outputs from WRF include hourly-varying horizontal wind components (i.e., speed and direction), temperature, moisture, vertical diffusion rates, and rainfall rates for each vertical layer in each grid cell. Selected physics options used in the WRF simulation include Pleim-Xiu land surface model (Xiu and Pleim, 2001; Pleim and Xiu, 2003), Asymmetric Convective Model version 2 planetary boundary layer scheme (Pleim 2007a,b), Kain-Fritsch cumulus parameterization (Kain, 2004) utilizing the moisture-advection trigger (Ma and Tan, 2009), Morrison double moment microphysics (Morrison, et al., 2005; Morrison and Gettelman, 2008), and Rapid Radiative Transfer Model-Global (RRTMG) longwave and shortwave radiation schemes (Iacono, et.al., 2008).

The WRF model simulation was initialized using the 12km North American Model (12NAM) analysis product provided by the National Climatic Data Center (NCDC). Where 12NAM data were unavailable, the 40km Eta Data Assimilation System (EDAS) analysis (ds609.2) from the National Center for Atmospheric Research (NCAR) was used. Analysis nudging for temperature, wind, and moisture was applied above the boundary layer only. The model simulations were conducted in 5.5 day blocks with soil moisture and temperature carried from one block to the next via the "ipxwrf" program (Gilliam and Pleim, 2010). Land use and land cover data were based on the 2011 National Land Cover Database (NLCD, 2011) data.[3] Sea surface temperatures at 1 km resolution were obtained from the Group for High Resolution Sea Surface Temperatures (GHRSST) (Stammer, et al., 2003). Additionally, efforts were made to improve precipitation forecasts by utilizing lightning data assimilation to suppress (force) deep convection where lightning is absent (present) (Heath, et. al., 2016). As shown in Table 2-2, the WRF simulations were performed with 35 vertical layers up to 50 mb, with the thinnest layers being nearest the surface to better resolve the planetary boundary layer (PBL). The WRF 35-layer structure was maintained in the CAMx air quality model simulations, as shown in Table 2-2.

[3] The 2011 NLCD data are available at 2011 NLCD from MRLC

Table 2-2. WRF and CAMx layers and their approximate height above ground level.

CAMx Layers	WRF Layers	Sigma P	Pressure (mb)	Approximate Height (m AGL)
35	35	0.00	50.00	17,556
34	34	0.05	97.50	14,780
33	33	0.10	145.00	12,822
32	32	0.15	192.50	11,282
31	31	0.20	240.00	10,002
30	30	0.25	287.50	8,901
29	29	0.30	335.00	7,932
28	28	0.35	382.50	7,064
27	27	0.40	430.00	6,275
26	26	0.45	477.50	5,553
25	25	0.50	525.00	4,885
24	24	0.55	572.50	4,264
23	23	0.60	620.00	3,683
22	22	0.65	667.50	3,136
21	21	0.70	715.00	2,619
20	20	0.74	753.00	2,226
19	19	0.77	781.50	1,941
18	18	0.80	810.00	1,665
17	17	0.82	829.00	1,485
16	16	0.84	848.00	1,308
15	15	0.86	867.00	1,134
14	14	0.88	886.00	964
13	13	0.90	905.00	797
12	12	0.91	914.50	714
11	11	0.92	924.00	632
10	10	0.93	933.50	551
9	9	0.94	943.00	470
8	8	0.95	952.50	390
7	7	0.96	962.00	311
6	6	0.97	971.50	232
5	5	0.98	981.00	154
4	4	0.99	985.75	115

CAMx Layers	WRF Layers	Sigma P	Pressure (mb)	Approximate Height (m AGL)
3	3	0.99	990.50	77
2	2	1.00	995.25	38
1	1	1.00	997.63	19

Details of the annual 2016 meteorological model simulation and evaluation are provided in a separate technical support document (U.S. EPA, 2019b) which can be found at https://www3.epa.gov/ttn/scram/reports/Met_Model_Performance-2016_WRF.pdf.

The meteorological data generated by the WRF simulations were processed using wrfcamx v4.3 (Ramboll Environ, 2014) meteorological data processing program to create model-ready meteorological inputs to CAMx. In running wrfcamx, vertical eddy diffusivities (Kv) were calculated using the Yonsei University (YSU) (Hong and Dudhia, 2006) mixing scheme. We used a minimum Kv of 0.1 m^2/sec except for urban grid cells where the minimum Kv was reset to 1.0 m^2/sec within the lowest 200 m of the surface in order to enhance mixing associated with the nighttime “urban heat island” effect. In addition, we invoked the subgrid convection and subgrid stratiform cloud options in our wrfcamx run for 2016.

2.3 Initial and Boundary Concentrations

The lateral boundary and initial species concentrations are based on a hemispheric modeling platform. The standard hemispheric simulation is described in detail in the Hemispheric CMAQ 2016 Simulation TSD (EPA, 2019c). The hemispheric simulation is summarized in Section 2.3.1 and processing to boundary conditions is summarized in Section 2.3.2. Section 2.3.3 describes the processing of hemispheric simulations to isolate the international contribution at the boundary.

2.3.1 Hemispheric Simulation

The hemispheric modeling platform that uses the Weather Research and Forecasting model (WRF v3.8) meteorological model, the Sparse Matrix Operating Kernel for Emissions (SMOKE v4.5) emissions model, and the Community Multiscale Air Quality model (CMAQ) version 5.2.1 with the Carbon Bond mechanism (CB6r3) and the non-volatile aerosol option (AE6).

The hemispheric scale model uses a polar stereographic projection at 108 kilometer (km) resolution to completely and continuously cover the Northern Hemisphere. The hemispheric scale allows for long-range free tropospheric transport with 44 layers between the surface and

50 hPa (~20 km asl). The hemispheric modeling system was initiated on May 1st 2015 and run continuously through December 31st, 2016.

The regional inventories over North America are based on the Inventory Collaborative 2016 emissions modeling platform (http://views.cira.colostate.edu/wiki/wiki/9169), which was developed through the summer of 2019. The hemispheric modeling analysis used the 2016 "alpha release" (specifically the modeling case abbreviated 2016fe) that is publicly available from https://www.epa.gov/air-emissions-modeling/2016-alpha-platform.

For the hemispheric emissions modeling platform, there are thirty anthropogenic sectors of emissions including nine sectors based on the Hemispheric Transport of Air Pollution Version 2 inventory (EDGAR-HTAPv2) inventory and 15 sectors that represent emissions in China which together comprise the anthropogenic emissions outside of North America. The international emission inventories are synthesized from the EDGAR-HTAP v2 harmonized emission inventory and country specific databases where updates were likely to be influential.

The EDGAR-HTAP v2 inventories were projected to represent the year 2014. Projection factors were calculated from the Community Emissions Data System (CEDS) inventory at a country-sector level. This allowed our inventory to evolve without the risks associated with transitioning to a new inventory system. Especially because EDGAR-HTAP v2 is superseded for critical counties, this was the optimal approach. Details of scaling factor development are described in Section 2.1.5 of the 2016v7.1 Hemispheric Modeling Platform Technical Support Document (U. S. EPA, 2019c).

The China emission inventory was developed at Tsinghua University (THU) and documented in (Zhao et al., 2018). This inventory was extensively compared to the EDGAR-HTAP v2 and EDGAR v4.3 inventories before use. The largest differences for NOx in 2016 occurred in individual emissions sectors rather than inventory totals. The SO2 emissions were more different than NOx emissions between the two inventories because the THU inventory applies controls to the metal industry that have been adopted by China.

More details on the 2016 hemispheric CMAQ modeling are available in (EPA, 2019c) and more details on the hemispheric emissions inventories are available in the Emissions Technical Support Documents (U. S. EPA, 2019d, 2019e).

2.3.2 Processing Boundaries from the Hemispheric Simulation

The 108 km resolution hemispheric CMAQ predictions were used to provide one-way dynamic boundary concentrations at one-hour intervals and an initial concentration field for the CAMx simulations. The hemispheric CMAQ results are spatially interpolated to lateral boundary and initial boundary conditions. Dimethyl sulfide (DMS) was not included in the simulation, but was added to the initial and boundary conditions files to more fully account for natural sources of haze. Finally, these results were translated to CAMx speciation and formats.

Boundary conditions for the regional CAMx domain require mapping hemispheric results from the polar stereographic grid and the vertical layer structure. Both lateral and initial conditions use nearest neighbor horizontal interpolation and vertical mass conserving interpolation. The lateral boundaries perform the interpolation along the perimeter for each hour, while the initial boundaries perform the interpolation for the entire domain at only specific hours. The initial boundaries were created for 2015-12-22 and 2016-06-11 at 00:00:00 UTC. These results are directly usable for CMAQ v5.2.1 but required additional species for visibility and additional processing for use by CAMx.

The CMAQ-ready files were updated to account for dimethyl sulfide (DMS). DMS is an important natural source of sulfur that may be particularly important for visibility at coastal sites. Standard CMAQ v5.2.1 does not include sulfur from naturally occurring DMS, but EPA's Office of Research and Development (ORD) has added DMS capability for future public versions (including the recently released CMAQ v5.3). ORD supplied results from their DMS evaluation simulations with and without DMS enabled (Sarwar, personal communication). This allows us to patch standard boundary conditions to account for DMS and oxidation products (MSA, SO2, ASO4I, ASO4J, and ASO4K). The DMS and oxidation products were interpolated to create alternative sulfur boundary conditions, both with and without DMS. Additional sulfur in the "with DMS" simulation was saved as the increment attributed to DMS emissions (i.e., max(with - without, 0)). The sulfur increment was then added to the standard boundary conditions. These supplemented files are CMAQ-ready (v5.2.1) with additional sulfur mass that represents effect from DMS emissions.

The CMAQ-ready boundary conditions required minimal translation to match CAMx gas and aerosol speciation. The translations were performed using cmaq2camx, which requires a translation table. The translation table was updated to reflect recent updates to CAMx. For Example, IC/BC DMS was mapped to CAMx DMS and primary PM elemental species (Ca, Si, Ti, etc.) were directly mapped to the new elemental CAMx species. Also, coarse mode (K-mode) sulfate, nitrate, and ammonium were previously mapped to the CAMx fine mode sulfate, nitrate, and ammonium species (CAMx does not have coarse mode sulfate, nitrate, or ammonium). This was found to be inappropriate and those CMAQ coarse mode species were instead mapped to CAMx coarse mode PM (CCRS).

2.3.3 Tagged Boundary Conditions

The hemispheric modeling platform included sensitivity simulations to isolate contributions from international anthropogenic emissions. The hemispheric platform included a base simulation with all emissions sources as well as zero-out sensitivity simulations to estimate specific emission sources. The international anthropogenic contribution is estimated at the boundary by differencing the base and “Zero-out Rest of the World” scenarios (Intl = Base - ZROW). Zero-out for particles is subject to strong non-linearities, but those are expected to be small over the ocean where boundary conditions are being estimated. The differencing is performed by the “Source Apportionment ICBC” processor developed by Ramboll (dated 28June19, hereafter SAICBC) (Ramboll, 2019). The SAICBC processor attributes the difference between Base and ZROW as an international anthropogenic BC tag and the remainder as an “other BC” tag. The other BC tag is primarily natural in origin (particularly at the Western boundary), but contains some small amount of US contributions. As described above, DMS and related oxidation products were included in the boundary conditions processing of both the base and ZROW scenarios. Because DMS is in both simulations, it will be included in the “other BC” tag that is largely natural.

2.4 Emissions Inventories

CAMx requires detailed emissions inventories containing temporally allocated (i.e., hourly) emissions for each grid-cell in the modeling domain for a large number of chemical species that act as primary pollutants and precursors to secondary pollutants. Annual emission inventories for 2016 and 2028 were preprocessed into CAMx-ready inputs using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (Houyoux et al., 2000).[4]

Most of the emissions data in the 2016 platform were developed through the Inventory Collaborative process. The types of emissions include point sources, nonpoint sources, commercial marine vessels (CMV), onroad and nonroad mobile sources and fires for the United States, Canada, and Mexico, along with CMV emissions in the areas outside of U.S. and Canada waters but within the modeling domain. The onroad mobile source emissions were generated using the released 2014b version of the Motor Vehicle Emissions Simulator (MOVES2014b). The 2016 emissions were projected to 2028 using various sector dependent methodologies. Onroad and nonroad mobile source emissions were created for 2028 using MOVES2014b. Electric generating unit (EGU) emissions for 2028 were derived from the Integrated Planning Model

[4] The SMOKE output emissions case name for the 2016 base year is “2016fg _16j” and the emissions case name for the 2028 base case is “2028fg_16j”.

(IPM v6).[5] Fugitive dust emissions from anthropogenic sources (i.e., agricultural tilling and unpaved roads) are included in the nonpoint sector of the inventory, but wind-blown dust from natural sources is not accounted for in the inventory. Detailed information on the emissions inventories used as input to the 2016 and 2028 CAMx model simulations can be found in the emissions inventory technical support document "Preparation of Emissions Inventories for the Version 7.2 2016 North American Emissions Modeling Platform" (EPA, 2019a).

2.5 Air Quality Model Evaluation

An operational model performance evaluation was performed for particulate matter ($PM_{2.5}$ species components and coarse PM) and regional haze to examine the ability of the CAMx v7 modeling system to simulate 2016 measured concentrations. This evaluation focused on graphical analyses and statistical metrics of model predictions versus observations. Regional statistics and summaries are presented by the NOAA Climate Regions shown in Figure 2-2 below. Details on the calculation of performance statistics, and results are provided in Appendix A.

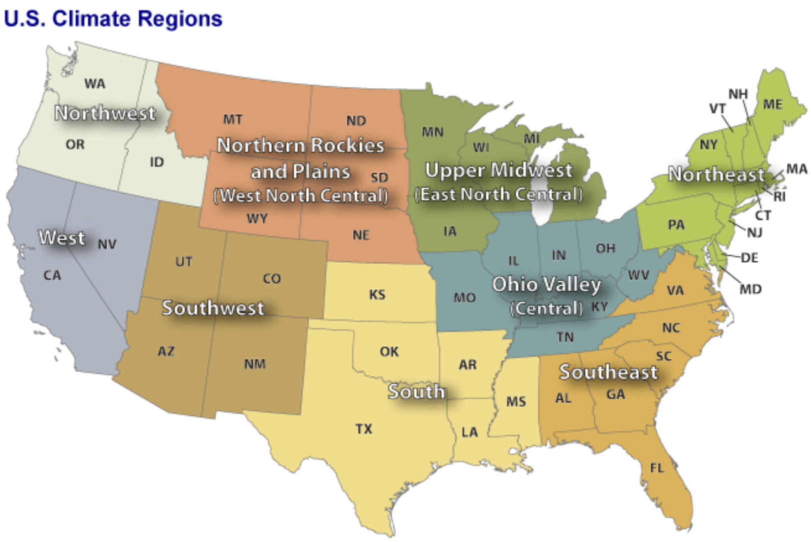

***Figure 2-2**. Climate regions used for aggregating model performance.*

Source: https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php

[5] The 2028 EGU emissions (from IPM) were based on a run from November, 2018. See https://www.epa.gov/airmarkets/epas-power-sector-modeling-platform-v6-using-ipm-november-2018-reference-case.

The model evaluation was focused on the ability of the model to predict visibility related PM components at Class I areas (represented by IMPROVE monitoring sites). The analysis looked at monthly and seasonal average PM species component performance at IMPROVE and other PM monitoring networks, and performance on the 20% most impaired (and 20% clearest) days[6] at individual IMPROVE sites. This provides a comprehensive assessment of the components that make up visibility performance.

The measured concentrations of PM components such as sulfate and nitrate on the 20% most impaired days at many Class I areas in the West are extremely small. Numerous Western Class I areas have average sulfate and nitrate observations (on the 20% most impaired days) of less than 1 $\mu g/m^3$. This makes it challenging to correctly model observed visibility. Assumptions regarding particular emissions categories and boundary conditions can have a large impact on model performance. Even when model performance appears to be accurate, it is sometimes difficult (without further sensitivity modeling and analysis) to determine if the model is getting the right answer for the right reasons.

Overall, the visibility performance for 2016 was generally good, with some regional exceptions. In different parts of the country, varying PM components contribute to visibility impairment, which also varies by season. The modeling system was generally able to correctly simulate the relatively high sulfate contributions to visibility impairment in the Upper Midwest, Ohio Valley, and Southeast, although sulfate concentrations (and extinction levels) in those regions were somewhat underpredicted. However, sulfate in the Northeast was overpredicted.

Sulfate performance was generally good on the 20% most impaired days in many areas. But there were notable underpredictions in the Southwest and overpredictions in the Northwest. Sulfate in the Southwest was underpredicted in the summer, but overpredicted in the winter and spring. Sulfate in the Northwest was overpredicted in all seasons. In particular, sulfate was overpredicted at many western coastal sites where modeled sulfate from DMS may be too high in the summer.

In the Northern Rockies, Northwest, Southwest, and West, sulfate is often the largest contributor to visibility impairment, but nitrate, coarse mass, and organic carbon can also be important contributors. Nitrate on the 20% most impaired days was underpredicted in the southern portion of the domain, especially in the Southwest. Nitrate was also underpredicted in

[6] The values for the 20% most impaired and clearest days are calculated according to the draft recommended method in the draft EPA guidance document "Draft Guidance for the Second Implementation Period of the Regional Haze Rule" posted at https://www.epa.gov/visibility/regional-haze-guidance-technical-support-document-and-data-file.

the Northern Plains, especially in the winter. However, nitrate on the 20% most impaired days was overpredicted in the Northwest and parts of the Northern Rockies regions.

Organic carbon performance was mixed, with overpredictions in most seasons in the Northwest and Northeast. Organic carbon in the Southeast was largely overpredicted in the summer, likely due to overestimates of biogenic secondary OC. There were some underpredictions of OC in the Northern Rockies on the 20% most impaired days, but performance varies by site.

Both coarse mass and fine crustal mass was underpredicted in many areas of the Southwest and West where it can be an important contributor to visibility impairment. The underpredictions were largest in the summer and fall when natural sources of windblown dust are likely to comprise a large fraction of the measured coarse and fine crustal mass.

Appendix A contains detailed maps, tables, and figures, including individual IMPROVE site PM species component performance information for the 20% most impaired days. Performance issues seen in the 2016 operational performance evaluation, combined with the 2028 source apportionment results indicate uncertainty in the model results at some Class I areas (especially at some western sites where important PM components were largely underpredcited). However, visibility performance at many Class I areas is quite good, adding to confidence in the future year contribution analyses and calculations. Further improvements in emissions inputs, boundary conditions, and model chemistry may help improve model performance in specific regions, particularly in the Northern Rockies and Plains, Northwest, West, and the Southwest.

3.0 Projection of Future Year 2028 Visibility

The PM predictions from the 2016 and 2028 CAMx model simulations were used to project 2014-2017[7] IMPROVE visibility data to 2028 following the approach described in EPA's ozone, $PM_{2.5}$ and regional haze modeling guidance (US EPA, 2018a).[8] The SIP Modeling Guidance describes the recommended modeling analysis used to help set reasonable progress goals (RPGs) that reflect the regional haze SIP's long-term strategy containing adopted emissions control measures .

[7] Based on EPA modeling guidance, a five-year average centered on the base modeling year (2014-2018) would be the appropriate ambient data base period. However, as of September 2019, the 2018 IMPROVE data is not available. Therefore, a four-year average (2014-2017) period was used instead. The ambient data can be updated when the final 2018 IMPROVE data becomes available.

[8] The EPA's ozone, $PM_{2.5}$, and regional haze modeling guidance is referred to as "the SIP Modeling Guidance" in the remainder of this document.

3.1 Regional Haze Rule Requirement

As required by the Regional Haze Rule (RHR) RPGs must provide for an improvement in visibility for the 20 percent most anthropogenically impaired days relative to baseline visibility conditions and ensure no degradation in visibility for the 20 percent clearest days relative to baseline visibility conditions.[9] The baseline for each Class I area is the average visibility (in deciviews) for the years 2000 through 2004.[10] The visibility conditions in these years are the benchmark for the "provide for an improvement" and "no degradation" requirements. In addition, states are required to determine the rate of improvement in visibility needed to reach natural conditions by 2064 for the 20 percent most anthropogenically impaired days.[11] A line drawn between the end of the 2000-2004 baseline period and 2064 (dv/year) shows a uniform rate of progress (URP) or "glidepath" between these two points. The glidepath represents a linear or uniform rate of progress and is the amount of visibility improvement needed in each implementation period to stay on the glidepath. The URP is a framework for consideration but there is no rule requirement to be on or below the glidepath. An example glidepath plot is shown in Figure 3-1.

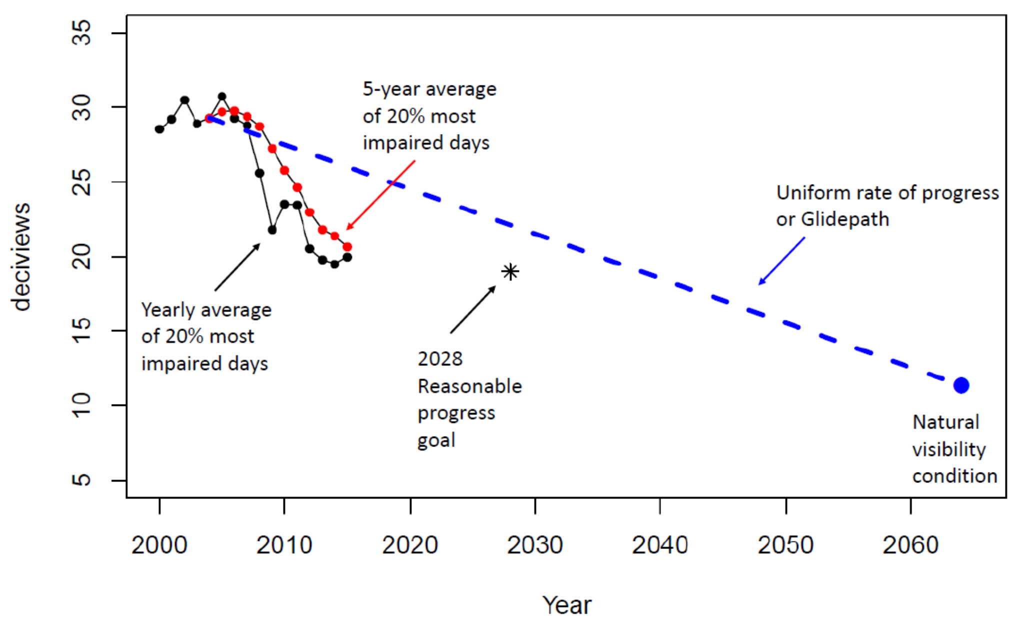

Figure 3-1 *Example Glidepath Plot.*

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[9] 40 CFR 51.308(f)(3)(i).

[10] 40 CFR 51.308(f)(1) and definitions in 51.301.

[11] 40 CFR 51.308(f)(1).

The RHR requires states to submit an implementation plan that evaluates and contains measures found necessary to make reasonable progress for implementation periods in approximately ten-year increments. The next regional haze SIP is due in July 2021, for the implementation period which ends in 2028. Therefore, modeling was used to project visibility to 2028 using a 2028 emissions inventory with "on-the-books" controls. The EPA Software for Model Attainment Test- Community Edition (SMAT-CE) tool was used to calculate 2028 deciview values on the 20% most anthropogenically impaired and 20% clearest days at each Class I Area (IMPROVE site).[12] SMAT-CE is an EPA software tool which implements the procedures in the SIP Modeling Guidance to project visibility to a future year.[13]

3.2 Calculation of 2028 Visibility

The visibility projections follow the procedures in section 5 of the SIP Modeling Guidance. Based on the recommendation in the modeling guidance, the observed base period visibility data is linked to the base modeling year. This is the 5-year ambient data base period centered about the base modeling year. In this case, for a base modeling year of 2016, the ambient IMPROVE data should be from the 2014-2018 period.[14] However, since 2018 IMPROVE data is not yet available (as of 9/19), the most recent four-year average 2014-2017 base period was used.

The visibility calculations use the "revised" IMPROVE equation (Hand, 2006); (Pitchford, 2007), which has been used in most regional haze SIPs over the last 10 years. The IMPROVE equation (or algorithm) uses PM species concentrations and relative humidity data to calculate visibility impairment or beta extinction (bext) in units of inverse megameters (Mm^{-1}) as follows:

bext = 2.2 x f_S(RH) x [Small Sulfate] + 4.8 x f_L(RH) x [Large Sulfate]
+ 2.4 x f_S(RH) x [Small Nitrate] + 5.1 x f_L(RH) x [Large Nitrate]
+ 2.8 x {Small Organic Mass] + 6.1 x [Large Organic Mass]

[12] The base year (2014-2017) IMPROVE data for the 20% most impaired and 20% clearest days was calculated based on the EPA recommended method described in "Technical Guidance for the Second Implementation Period of the Regional Haze Rule." (December 2018).

[13] SMAT-CE is available here: https://www.epa.gov/scram/photochemical-modeling-tools

[14] The *baseline period* for the regional haze program continues to be 2000-2004, and the uniform rate of progress is calculated using that historical data. However, the modeled visibility projections should use ambient data from a 5-year *base period* that corresponds to the modeled base year meteorological and emissions data. Also, unlike the ozone and $PM_{2.5}$ attainment tests, the ambient data averaging calculation is a 5-year mean, where each year counts equally (unlike the 5-year weighted average values recommended for the ozone and $PM_{2.5}$ attainment test).

+ 10 x [Elemental Carbon]
+ 1 x [Fine Soil]
+ 1.7 x f_{ss}(RH) x [Sea Salt]
+ 0.6 x [Coarse Mass]
+ Rayleigh Scattering (site specific)

The total sulfate, nitrate, and organic mass concentrations are each split into two fractions, representing small and large size distributions of those components. Site-specific Rayleigh scattering is calculated based on the elevation and annual average temperature of each IMPROVE monitoring site. See (Hand, 2006) for more details.

The 2028 future year visibility on the 20% most anthropogenically impaired days and 20% clearest days at each Class I area is estimated by using the observed IMPROVE data (2014-2017) and the relative *percent modeled* change in PM species between 2016 and 2028. The process is described in the following six steps (see the SIP Modeling Guidance for a more detailed description and examples).

1) For each Class I area (IMPROVE site), estimate anthropogenic impairment on each day using observed speciated $PM_{2.5}$ data plus PM_{10} data (and other information) for each of the 5 years comprising the base period (four years, 2014-2017 in this case) and rank the days on this indicator.[15] This ranking will determine the 20 percent most anthropogenically impaired days. For each Class I area, also rank observed visibility (in deciviews) on each day using observed speciated $PM_{2.5}$ data plus PM_{10} data for each of the 5 years comprising the base period. This ranking will determine the 20 percent clearest days.
2) For each of the 5 years comprising the base period, calculate the mean deciviews for the 20 percent most anthropogenically impaired days and 20 percent clearest days. For each Class I area, calculate the 5 year mean deciviews for most impaired and clearest days from the 5 year-specific values.
3) Use an air quality model to simulate air quality with base period (2016) emissions and future year (2028) emissions. Use the resulting information to develop site-specific

[15] The EPA recommended methodology for determining the most anthropogenically impaired days (which includes the explanation of how anthropogenic vs. natural daily light extinction was determined) can be found in Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program.

relative response factors (RRFs) for each component of PM[16] identified in the “revised” IMPROVE equation. The RRFs are an average percent change in species concentrations based on the *measured* 20% most impaired and 20% clearest days from 2016 (the calendar days from 2016 identified from the IMPROVE data above are matched by day to the modeled days).

4) Multiply the species-specific RRFs by the measured daily species concentration data during the 2014-2017 base period (for each day in the measured 20% most impaired day set and each day in the 20% clearest day set), for each site. This results in daily future year 2028 PM species concentration data.
5) Using the results in Step 4 and the IMPROVE algorithm, calculate the future daily extinction coefficients for the previously identified 20 percent most impaired days and 20 percent clearest days in each of the five base years.
6) Calculate daily deciview values (from total daily extinction) and then compute the future year (2028) average mean deciviews for the 20 percent most impaired days and 20 percent clearest days for each year. Average the five years together to get the final future mean deciview values for the 20 percent most impaired days and 20 percent clearest days.

The SMAT-CE tool outputs individual year and 5-year average base year and future year deciview values on the 20% most impaired days and 20% clearest days. Additional SMAT output variables include the results of intermediate calculations such as species specific extinction values (both base and future year) and species specific RRFs (on the 20% most impaired and clearest days).

Table 3-1 details the settings used for the SMAT runs to generate the 2028 future year deciview projections:

Table 3-1. SMAT settings for 2028 visibility calculations

SMAT Option	**Setting or File Used**
IMPROVE algorithm	Use new version
Grid cells at monitor or Class I area centroid?	Use grid cells at monitor

[16] Relative response factors (RRFs) are calculated for sulfate, nitrate, organic carbon mass, elemental carbon, fine soil mass, and coarse mass. Since observed sea salt is primarily from natural sources which are not expected to be year-sensitive, and the modeled sea salt is uncertain, the sea salt RRF for all sites is assumed to be 1.0.

IMPROVE data file	ClassIareas_NEWIMPROVEALG_2000to2017_2019_feb11_IMPAIRMENT.csv[17]
Baseline file	smat_small.PM.CAMx.12US2.2016fg_camx7b2_dms_16j.PM25_OM.csv
Forecast file	smat_small.PM.CAMx.12US2.2028fg_camx7b2_dms_16j.PM25_OM.csv
Temporal adjustment at monitor	3 x 3
Start monitor year	2014
End monitor year	2017
Base Model year	2016
Minimum years required for a valid monitor	1

Table 3-2 shows the base and future year deciview values on the 20% clearest and most impaired days at each Class I area for the base model period (2014-2017) and future year (2028).[18]

Table 3-2. Base and future year deciview values on the 20% clearest and 20% most impaired days at each Class I area for the base model period (2014-2017) and future year (2028)

Class I Area Site ID	Class I Area Name	IMPROVE Site ID	Base Year (2014-2017) 20% Clearest Days (dv)	Future Year (2028) 20% Clearest Days (dv)	Base Year (2014-2017) 20% Most Impaired Days (dv)	Future Year (2028) 20% Most Impaired Days (dv)
ACAD	Acadia NP	ACAD1	6.59	6.34	14.78	13.9
AGTI	Agua Tibia Wilderness	AGTI1	7	6.8	16.33	15.48
BADL	Badlands NP	BADL1	5.42	5.36	12.17	11.71
BALD	Mount Baldy Wilderness	BALD1	1.78	1.73	7.24	6.92
BAND	Bandelier NM	BAND1	3.08	2.89	8.31	8
BIBE	Big Bend NP	BIBE1	5.22	5.08	14.28	14.09
MOKE	Mokelumne Wilderness	BLIS1	1.8	1.71	9.35	9.15

[17] The IMPROVE ambient data file has the 20% most impaired days identified as "group 90" days and 20% clearest days identified as "group 10" days. The definition of the most impaired days uses the EPA recommended methodology from Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program. The IMPROVE data file used for this analysis included patched and/or substituted data.

[18] The 2028 results are calculated for 142 Class I areas which are represented by 99 IMPROVE sites. Results are not shown for Class I areas which are outside of the modeling domain (outside of the contiguous U.S.), and for Class I areas which did not have complete IMPROVE data in 2016.

Class I Area Site ID	Class I Area Name	IMPROVE Site ID	Base Year (2014-2017) 20% Clearest Days (dv)	Future Year (2028) 20% Clearest Days (dv)	Base Year (2014-2017) 20% Most Impaired Days (dv)	Future Year (2028) 20% Most Impaired Days (dv)
DESO	Desolation Wilderness	BLIS1	1.8	1.71	9.35	9.15
BOAP	Bosque del Apache	BOAP1	4.59	4.45	10.36	10.16
BOWA	Boundary Waters Canoe Area	BOWA1	4.59	4.62	14.07	13.19
FITZ	Fitzpatrick Wilderness	BRID1	0.84	0.77	6.59	6.43
BRID	Bridger Wilderness	BRID1	0.84	0.77	6.59	6.43
BRIG	Brigantine	BRIG1	11.4	10.82	19.80	18.45
BRET	Breton	BRIS1	11.8	11.31	19.15	18.23
CABI	Cabinet Mountains Wilderness	CABI1	2.52	2.41	9.81	9.69
CACR	Caney Creek Wilderness	CACR1	8.24	7.84	18.54	16.97
ARCH	Arches NP	CANY1	2.13	2.01	6.75	6.5
CANY	Canyonlands NP	CANY1	2.13	2.01	6.75	6.5
CAPI	Capitol Reef NP	CAPI1	2.4	2.3	7.04	6.85
CHAS	Chassahowitzka	CHAS1	12.41	11.85	17.45	16.17
CHIW	Chiricahua Wilderness	CHIR1	3.91	3.8	9.41	8.95
GALI	Galiuro Wilderness	CHIR1	3.91	3.8	9.41	8.95
CHIR	Chiricahua NM	CHIR1	3.91	3.8	9.41	8.95
COHU	Cohutta Wilderness	COHU1	8.42	7.94	17.80	16.57
DIPE	Diamond Peak Wilderness	CRLA1	0.97	0.91	8.24	8.09
GEMO	Gearhart Mountain Wilderness	CRLA1	0.97	0.91	8.24	8.09
MOLA	Mountain Lakes Wilderness	CRLA1	0.97	0.91	8.24	8.09
CRLA	Crater Lake NP	CRLA1	0.97	0.91	8.24	8.09
CRMO	Craters of the Moon NM	CRMO1	2.69	2.56	8.60	8.2
DOME	Dome Land Wilderness	DOME1	4.33	4.21	15.07	14.47
DOSO	Dolly Sods Wilderness	DOSO1	7.03	6.53	17.73	16.21
OTCR	Otter Creek Wilderness	DOSO1	7.03	6.53	17.73	16.21
EVER	Everglades NP	EVER1	10.26	9.88	14.85	13.95
GAMO	Gates of the Mountains Wilderness	GAMO1	0.64	0.57	7.31	7.24
GICL	Gila Wilderness	GICL1	2.06	1.97	7.56	7.25
GLAC	Glacier NP	GLAC1	5.35	5.09	13.57	13.32
GRCA	Grand Canyon NP	GRCA2	1.45	1.37	6.82	6.56
GRGU	Great Gulf Wilderness	GRGU1	5.15	4.83	13.17	12.17
PRRA	Presidential Range-Dry River Wilderness	GRGU1	5.15	4.83	13.17	12.17
GRSA	Great Sand Dunes NM	GRSA1	2.88	2.72	7.91	7.71

Class I Area Site ID	Class I Area Name	IMPROVE Site ID	Base Year (2014-2017) 20% Clearest Days (dv)	Future Year (2028) 20% Clearest Days (dv)	Base Year (2014-2017) 20% Most Impaired Days (dv)	Future Year (2028) 20% Most Impaired Days (dv)
GRSM	Great Smoky Mountains NP	GRSM1	8.73	8.3	17.40	16.08
JOYC	Joyce-Kilmer-Slickrock Wilderness	GRSM1	8.73	8.3	17.40	16.08
CAVE	Carlsbad Caverns NP	GUMO1	4.51	4.3	12.63	12.48
GUMO	Guadalupe Mountains NP	GUMO1	4.51	4.3	12.63	12.48
HECA	Hells Canyon Wilderness	HECA1	4.06	3.95	12.71	12.21
HEGL	Hercules-Glades Wilderness	HEGL1	9.75	9.18	18.76	17.44
HOOV	Hoover Wilderness	HOOV1	0.96	0.93	7.87	7.73
PIMO	Pine Mountain Wilderness	IKBA1	4.18	3.98	9.32	8.99
MAZA	Mazatzal Wilderness	IKBA1	4.18	3.98	9.32	8.99
ISLE	Isle Royale NP	ISLE1	5.52	5.42	15.73	14.87
JARB	Jarbidge Wilderness	JARB1	1.82	1.74	7.90	7.82
JARI	James River Face Wilderness	JARI1	9.63	8.95	18.03	16.4
JOSH	Joshua Tree NM	JOSH1	4.81	4.67	12.95	12.5
ANAD	Ansel Adams Wilderness (Minarets)	KAIS1	1.48	1.43	11.13	10.72
JOMU	John Muir Wilderness	KAIS1	1.48	1.43	11.13	10.72
KAIS	Kaiser Wilderness	KAIS1	1.48	1.43	11.13	10.72
KALM	Kalmiopsis Wilderness	KALM1	5.85	5.76	11.93	11.74
SOWA	South Warner Wilderness	LABE1	2.44	2.37	9.83	9.64
LABE	Lava Beds NM	LABE1	2.44	2.37	9.83	9.64
CARI	Caribou Wilderness	LAVO1	2.13	2.05	10.05	9.81
THLA	Thousand Lakes Wilderness	LAVO1	2.13	2.05	10.05	9.81
LAVO	Lassen Volcanic NP	LAVO1	2.13	2.05	10.05	9.81
LIGO	Linville Gorge Wilderness	LIGO1	7.75	7.28	16.59	15.15
LOST	Lostwood	LOST1	7.42	7.18	15.68	15.26
LYBR	Lye Brook Wilderness	LYEB1	5.1	4.75	14.80	13.94
MACA	Mammoth Cave NP	MACA1	11.57	10.86	21.13	19.5
MELA	Medicine Lake	MELA1	6.02	5.92	14.76	14.45
MEVE	Mesa Verde NP	MEVE1	2.3	2.18	6.54	6.3
MING	Mingo	MING1	11.21	10.78	20.14	18.88
MOHO	Mount Hood Wilderness	MOHO1	1.41	1.36	9.25	8.95
BOMA	Bob Marshall Wilderness	MONT1	2.46	2.36	9.41	9.26
SCAP	Scapegoat Wilderness	MONT1	2.46	2.36	9.41	9.26
MIMO	Mission Mountains Wilderness	MONT1	2.46	2.36	9.41	9.26
MOOS	Moosehorn	MOOS1	6.62	6.46	13.34	12.73

Class I Area Site ID	Class I Area Name	IMPROVE Site ID	Base Year (2014-2017) 20% Clearest Days (dv)	Future Year (2028) 20% Clearest Days (dv)	Base Year (2014-2017) 20% Most Impaired Days (dv)	Future Year (2028) 20% Most Impaired Days (dv)
ROCA	Roosevelt Campobello International Park	MOOS1	6.62	6.46	13.34	12.73
MORA	Mount Rainier NP	MORA1	3.88	3.77	12.65	12.22
MOZI	Mount Zirkel Wilderness	MOZI1	0.15	0.07	5.36	5.17
RAWA	Rawah Wilderness	MOZI1	0.15	0.07	5.36	5.17
NOAB	North Absaroka Wilderness	NOAB1	0.78	0.74	6.93	6.8
WASH	Washakie Wilderness	NOAB1	0.78	0.74	6.93	6.8
NOCA	North Cascades NP	NOCA1	2.55	2.49	10.19	9.95
GLPE	Glacier Peak Wilderness	NOCA1	2.55	2.49	10.19	9.95
OKEF	Okefenokee	OKEF1	11.73	11.22	17.85	16.83
WOLF	Wolf Island	OKEF1	11.73	11.22	17.85	16.83
OLYM	Olympic NP	OLYM1	3.54	3.42	11.91	11.62
PASA	Pasayten Wilderness	PASA1	1.63	1.54	9.32	9.09
PEFO	Petrified Forest NP	PEFO1	3.2	2.97	8.27	7.97
VENT	Ventana Wilderness	PINN1	7.65	7.36	14.22	13.49
PINN	Pinnacles NM	PINN1	7.65	7.36	14.22	13.49
RAFA	San Rafael Wilderness	RAFA1	4.79	4.54	14.05	13.4
REDW	Redwood NP	REDW1	5.19	5.11	12.69	12.5
ROMA	Cape Romain	ROMA1	11.96	11.42	17.95	16.95
ROMO	Rocky Mountain NP	ROMO1	1.33	1.25	8.42	7.98
SACR	Salt Creek	SACR1	6.67	6.52	15.04	14.49
SAGA	San Gabriel Wilderness	SAGA1	2.82	2.64	13.50	12.5
CUCA	Cucamonga Wilderness	SAGA1	2.82	2.64	13.50	12.5
SAGO	San Gorgonio Wilderness	SAGO1	3.31	3.17	14.55	13.2
SAJA	San Jacinto Wilderness	SAGO1	3.31	3.17	14.55	13.2
SAGU	Saguaro NM	SAGU1	6.19	5.88	10.80	10.29
SAMA	St. Marks	SAMA1	11.22	10.73	17.53	16.42
SAPE	San Pedro Parks Wilderness	SAPE1	0.41	0.33	6.42	6.21
SAWT	Sawtooth Wilderness	SAWT1	2.38	2.31	8.45	8.31
SENE	Seney	SENE1	5.4	5.3	17.77	16.82
SEQU	Sequoia NP	SEQU1	6.91	6.57	18.40	17.16
KICA	Kings Canyon NP	SEQU1	6.91	6.57	18.40	17.16
SHEN	Shenandoah NP	SHEN1	7.05	6.48	17.50	15.82
SHRO	Shining Rock Wilderness	SHRO1	4.65	4.23	15.76	14.33
SIPS	Sipsey Wilderness	SIPS1	10.75	10.23	19.26	18
ALLA	Alpine Lake Wilderness	SNPA1	3.46	3.29	12.89	12.28
STMO	Strawberry Mountain Wilderness	STAR1	2.71	2.62	11.31	10.88

Class I Area Site ID	Class I Area Name	IMPROVE Site ID	Base Year (2014-2017) 20% Clearest Days (dv)	Future Year (2028) 20% Clearest Days (dv)	Base Year (2014-2017) 20% Most Impaired Days (dv)	Future Year (2028) 20% Most Impaired Days (dv)
EACA	Eagle Cap Wilderness	STAR1	2.71	2.62	11.31	10.88
SELW	Selway-Bitterroot Wilderness	SULA1	1.46	1.41	7.91	7.79
ANAC	Anaconda-Pintler Wilderness	SULA1	1.46	1.41	7.91	7.79
SWAN	Swanquarter	SWAN1	10.67	10.29	16.82	15.75
SYCA	Sycamore Canyon Wilderness	SYCA2	4.27	4.05	11.97	11.8
THRO	Theodore Roosevelt NP	THRO1	5.88	5.77	13.37	12.83
THIS	Three Sisters Wilderness	THSI1	2.58	2.52	11.42	11.26
MOJE	Mount Jefferson Wilderness	THSI1	2.58	2.52	11.42	11.26
MOWA	Mount Washington Wilderness	THSI1	2.58	2.52	11.42	11.26
SUPE	Superstition Wilderness	TONT1	5.03	4.7	10.40	9.97
ULBE	UL Bend	ULBE1	3.66	3.6	10.88	11.03
UPBU	Upper Buffalo Wilderness	UPBU1	8.42	8.01	18.18	16.92
VOYA	Voyageurs NP	VOYA2	5.42	5.41	14.12	13.26
WEMI	Weminuche Wilderness	WEMI1	1.62	1.49	6.65	6.46
BLCA	Black Canyon of the Gunnison NM	WEMI1	1.62	1.49	6.65	6.46
LAGA	La Garita Wilderness	WEMI1	1.62	1.49	6.65	6.46
WHIT	White Mountain Wilderness	WHIT1	2.57	2.46	10.04	9.84
GORO	Goat Rocks Wilderness	WHPA1	1.01	0.96	8.05	7.87
WHPA	Mount Adams Wilderness	WHPA1	1.01	0.96	8.05	7.87
MABE	Maroon Bells-Snowmass Wilderness	WHRI1	-0.23	-0.34	4.89	4.71
EANE	Eagles Nest Wilderness	WHRI1	-0.23	-0.34	4.89	4.71
FLTO	Flat Tops Wilderness	WHRI1	-0.23	-0.34	4.89	4.71
WEEL	West Elk Wilderness	WHRI1	-0.23	-0.34	4.89	4.71
WICA	Wind Cave NP	WICA1	3.51	3.43	10.39	9.93
WIMO	Wichita Mountains	WIMO1	8.39	8.14	18.11	16.93
YELL	Yellowstone NP	YELL2	1.37	1.24	7.51	7.38
GRTE	Grand Teton NP	YELL2	1.37	1.24	7.51	7.38
REDR	Red Rock Lakes	YELL2	1.37	1.24	7.51	7.38
TETO	Teton Wilderness	YELL2	1.37	1.24	7.51	7.38
YOSE	Yosemite NP	YOSE1	2.75	2.69	11.61	11.44
EMIG	Emigrant Wilderness	YOSE1	2.75	2.69	11.61	11.44
ZION	Zion NP	ZICA1	3.78	3.62	8.50	8.31

Figure 3-2 shows the predicted change in deciviews at each Class I area (IMPROVE site) on the 20% most impaired days between 2016 and 2028 (2028 deciviews minus 2016 deciviews). The visibility improvement in the east is generally in the range of a 1-2 deciview improvement. Most sites in the west show a relatively small deciview improvement of less than 0.5 deciviews. There is one Class I areas in the west (UL Bend in Montana) with a projected slight deciview degradation of 0.15 deciviews.

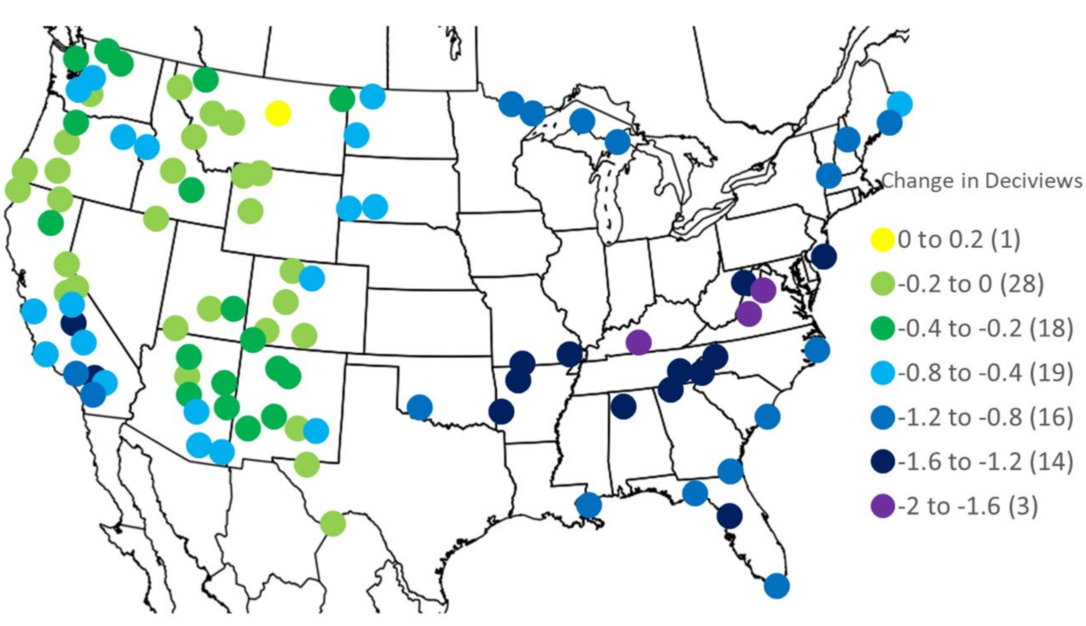

Figure 3-2*- Projected change in deciviews at IMPROVE sites[19] between 2016 and 2028 (2028 – 2016).*

3.3 Comparison to Regional Haze "Glidepath"

The future year 2028 deciview projections can be compared to the unadjusted visibility "glidepath" at each Class I area, as defined above.[20] The unadjusted "glidepath" represents the amount of visibility improvement needed in each implementation period, starting from the baseline 2000-2004 period, to stay on a linear path to natural visibility conditions by 2064. Visibility on the 20% most impaired days is compared to the relevant value of the glidepath, in this case for a future year of 2028. Since the glidepath is a linear path between

[19] The map shows results at 99 IMPROVE sites with complete data in the base period. Note that many IMPROVE sites represent more than one Class I area.

[20] The projected 2028 visibility level is compared to the "unadjusted" glidepath for each Class I area. In this calculation, no adjustments have been made for impacts from international anthropogenic sources or wildland prescribed fires.

2004 and 2064, a glidepath value (in deciviews) can be calculated for any future year, using a simple equation. The following formula was used to calculate the 2028 unadjusted glidepath value:

$Glidepath_{2028}$= Baseline avg deciview – (((Baseline avg deciview – Natural conditions)/60)*24)

Where

Baseline avg deciview = average observed deciview value on the 20% most impaired days for 2000-2004 (in dv)

Natural conditions= Natural conditions on the 20% most impaired days at the Class I area (in dv)

Table 3-3 shows the 2028 glidepath values (in dv) at each Class I area, including the data needed to calculate the glidepath (natural conditions and the 2000-2004 baseline deciview values).[21] The observed 2014-2017 values and projected 2028 values are repeated from Table 3-2.

Table 3-3 Natural conditions, 2000-2004 baseline visibility, observed 2014-2017 visibility, 2028 projected visibility, and 2028 unadjusted glidepath values (all in deciviews)

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Natural Conditions 20% Most Impaired Days (dv)	Observed 00-04 Baseline 20% Most Impaired Days(dv)	Observed 14-17 Impairment 20% Most Impaired Days(dv)	Projected 2028 Impairment 20% Most Impaired Days(dv)	2028 Unadjusted Glidepath 20% Most Impaired Days(dv)
ACAD	Acadia NP	ME	ACAD1	10.39	22.01	14.78	13.9	17.36
AGTI	Agua Tibia Wilderness	CA	AGTI1	7.63	21.62	16.33	15.48	16.03
BADL	Badlands NP	SD	BADL1	6.09	14.98	12.17	11.71	11.42
BALD	Mount Baldy Wilderness	AZ	BALD1	4.09	8.93	7.24	6.92	6.99
BAND	Bandelier NM	NM	BAND1	4.59	9.70	8.31	8	7.65
BIBE	Big Bend NP	TX	BIBE1	5.33	15.57	14.28	14.09	11.47
MOKE	Mokelumne Wilderness	CA	BLIS1	4.91	10.06	9.35	9.15	8.00
DESO	Desolation Wilderness	CA	BLIS1	4.91	10.06	9.35	9.15	8.00
BOAP	Bosque del Apache	NM	BOAP1	5.36	11.61	10.36	10.16	9.11

[21] The values for the 20% most impaired and clearest days and natural conditions are calculated according to the draft recommended method in the draft EPA guidance document "Draft Guidance for the Second Implementation Period of the Regional Haze Rule" posted at https://www.epa.gov/visibility/regional-haze-guidance-technical-support-document-and-data-file.

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Natural Conditions 20% Most Impaired Days (dv)	Observed 00-04 Baseline 20% Most Impaired Days(dv)	Observed 14-17 Impairment 20% Most Impaired Days(dv)	Projected 2028 Impairment 20% Most Impaired Days(dv)	2028 Unadjusted Glidepath 20% Most Impaired Days(dv)
BOWA	Boundary Waters Canoe Area	MN	BOWA1	9.09	18.31	14.07	13.19	14.62
FITZ	Fitzpatrick Wilderness	WY	BRID1	3.90	7.96	6.59	6.43	6.34
BRID	Bridger Wilderness	WY	BRID1	3.90	7.96	6.59	6.43	6.34
BRIG	Brigantine	NJ	BRIG1	10.69	27.43	19.80	18.45	20.74
BRET	Breton	LA	BRIS1	9.33	24.91	19.15	18.23	18.67
CABI	Cabinet Mountains Wilderness	MT	CABI1	5.65	10.73	9.81	9.69	8.70
CACR	Caney Creek Wilderness	AR	CACR1	9.47	23.99	18.54	16.97	18.18
ARCH	Arches NP	UT	CANY1	4.11	8.79	6.75	6.5	6.92
CANY	Canyonlands NP	UT	CANY1	4.11	8.79	6.75	6.5	6.92
CAPI	Capitol Reef NP	UT	CAPI1	3.96	8.78	7.04	6.85	6.85
CHAS	Chassahowitzka	FL	CHAS1	8.97	24.52	17.45	16.17	18.30
CHIW	Chiricahua Wilderness	AZ	CHIR1	4.93	10.50	9.41	8.95	8.27
GALI	Galiuro Wilderness	AZ	CHIR1	4.93	10.50	9.41	8.95	8.27
CHIR	Chiricahua NM	AZ	CHIR1	4.93	10.50	9.41	8.95	8.27
COHU	Cohutta Wilderness	GA	COHU1	9.73	29.12	17.80	16.57	21.36
DIPE	Diamond Peak Wilderness	OR	CRLA1	5.22	9.36	8.24	8.09	7.70
GEMO	Gearhart Mountain Wilderness	OR	CRLA1	5.22	9.36	8.24	8.09	7.70
MOLA	Mountain Lakes Wilderness	OR	CRLA1	5.22	9.36	8.24	8.09	7.70
CRLA	Crater Lake NP	OR	CRLA1	5.22	9.36	8.24	8.09	7.70
CRMO	Craters of the Moon NM	ID	CRMO1	4.97	11.91	8.60	8.2	9.13
DOME	Dome Land Wilderness	CA	DOME1	6.18	17.20	15.07	14.47	12.79
DOSO	Dolly Sods Wilderness	WV	DOSO1	8.92	28.29	17.73	16.21	20.54
OTCR	Otter Creek Wilderness	WV	DOSO1	8.92	28.29	17.73	16.21	20.54
EVER	Everglades NP	FL	EVER1	8.34	19.54	14.85	13.95	15.06
GAMO	Gates of the Mountains Wilderness	MT	GAMO1	4.66	8.95	7.31	7.24	7.23
GICL	Gila Wilderness	NM	GICL1	4.22	8.93	7.56	7.25	7.05
GLAC	Glacier NP	MT	GLAC1	6.89	15.89	13.57	13.32	12.29
GRCA	Grand Canyon NP	AZ	GRCA2	4.18	7.94	6.82	6.56	6.44
GRGU	Great Gulf Wilderness	NH	GRGU1	9.78	21.93	13.17	12.17	17.07
PRRA	Presidential Range-Dry River Wilderness	NH	GRGU1	9.78	21.93	13.17	12.17	17.07
GRSA	Great Sand Dunes NM	CO	GRSA1	4.45	9.66	7.91	7.71	7.58

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Natural Conditions 20% Most Impaired Days (dv)	Observed 00-04 Baseline 20% Most Impaired Days(dv)	Observed 14-17 Impairment 20% Most Impaired Days(dv)	Projected 2028 Impairment 20% Most Impaired Days(dv)	2028 Unadjusted Glidepath 20% Most Impaired Days(dv)
GRSM	Great Smoky Mountains NP	TN	GRSM1	10.05	29.16	17.40	16.08	21.51
JOYC	Joyce-Kilmer-Slickrock Wilderness	TN	GRSM1	10.05	29.16	17.40	16.08	21.51
CAVE	Carlsbad Caverns NP	TX	GUMO1	4.83	14.60	12.63	12.48	10.69
GUMO	Guadalupe Mountains NP	TX	GUMO1	4.83	14.60	12.63	12.48	10.69
HECA	Hells Canyon Wilderness	OR	HECA1	6.57	16.51	12.71	12.21	12.53
HEGL	Hercules-Glades Wilderness	MO	HEGL1	9.30	25.17	18.76	17.44	18.82
HOOV	Hoover Wilderness	CA	HOOV1	4.91	8.97	7.87	7.73	7.35
PIMO	Pine Mountain Wilderness	AZ	IKBA1	5.22	11.19	9.32	8.99	8.80
MAZA	Mazatzal Wilderness	AZ	IKBA1	5.22	11.19	9.32	8.99	8.80
ISLE	Isle Royale NP	MI	ISLE1	10.15	19.53	15.73	14.87	15.78
JARB	Jarbidge Wilderness	NV	JARB1	5.23	8.73	7.90	7.82	7.33
JARI	James River Face Wilderness	VA	JARI1	9.48	28.08	18.03	16.4	20.64
JOSH	Joshua Tree NM	CA	JOSH1	6.09	17.74	12.95	12.5	13.08
ANAD	Ansel Adams Wilderness (Minarets)	CA	KAIS1	6.00	12.96	11.13	10.72	10.18
JOMU	John Muir Wilderness	CA	KAIS1	6.00	12.96	11.13	10.72	10.18
KAIS	Kaiser Wilderness	CA	KAIS1	6.00	12.96	11.13	10.72	10.18
KALM	Kalmiopsis Wilderness	OR	KALM1	7.80	13.35	11.93	11.74	11.13
SOWA	South Warner Wilderness	CA	LABE1	6.16	11.29	9.83	9.64	9.24
LABE	Lava Beds NM	CA	LABE1	6.16	11.29	9.83	9.64	9.24
CARI	Caribou Wilderness	CA	LAVO1	6.14	11.50	10.05	9.81	9.36
THLA	Thousand Lakes Wilderness	CA	LAVO1	6.14	11.50	10.05	9.81	9.36
LAVO	Lassen Volcanic NP	CA	LAVO1	6.14	11.50	10.05	9.81	9.36
LIGO	Linville Gorge Wilderness	NC	LIGO1	9.70	28.05	16.59	15.15	20.71
LOST	Lostwood	ND	LOST1	5.88	18.27	15.68	15.26	13.31
LYBR	Lye Brook Wilderness	VT	LYEB1	10.23	23.57	14.80	13.94	18.23
MACA	Mammoth Cave NP	KY	MACA1	9.79	29.83	21.13	19.5	21.81
MELA	Medicine Lake	MT	MELA1	5.95	16.63	14.76	14.45	12.36
MEVE	Mesa Verde NP	CO	MEVE1	4.20	9.22	6.54	6.3	7.22

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Natural Conditions 20% Most Impaired Days (dv)	Observed 00-04 Baseline 20% Most Impaired Days(dv)	Observed 14-17 Impairment 20% Most Impaired Days(dv)	Projected 2028 Impairment 20% Most Impaired Days(dv)	2028 Unadjusted Glidepath 20% Most Impaired Days(dv)
MING	Mingo	MO	MING1	9.24	26.31	20.14	18.88	19.48
MOHO	Mount Hood Wilderness	OR	MOHO1	6.60	12.10	9.25	8.95	9.90
BOMA	Bob Marshall Wilderness	MT	MONT1	5.43	10.84	9.41	9.26	8.68
SCAP	Scapegoat Wilderness	MT	MONT1	5.43	10.84	9.41	9.26	8.68
MIMO	Mission Mountains Wilderness	MT	MONT1	5.43	10.84	9.41	9.26	8.68
MOOS	Moosehorn	ME	MOOS1	9.97	20.66	13.34	12.73	16.38
ROCA	Roosevelt Campobello International Park	ME	MOOS1	9.97	20.66	13.34	12.73	16.38
MORA	Mount Rainier NP	WA	MORA1	7.66	16.53	12.65	12.22	12.98
MOZI	Mount Zirkel Wilderness	CO	MOZI1	3.16	7.29	5.36	5.17	5.64
RAWA	Rawah Wilderness	CO	MOZI1	3.16	7.29	5.36	5.17	5.64
NOAB	North Absaroka Wilderness	WY	NOAB1	4.54	8.78	6.93	6.8	7.08
WASH	Washakie Wilderness	WY	NOAB1	4.54	8.78	6.93	6.8	7.08
NOCA	North Cascades NP	WA	NOCA1	6.88	12.57	10.19	9.95	10.29
GLPE	Glacier Peak Wilderness	WA	NOCA1	6.88	12.57	10.19	9.95	10.29
OKEF	Okefenokee	GA	OKEF1	9.47	25.34	17.85	16.83	18.99
WOLF	Wolf Island	GA	OKEF1	9.47	25.34	17.85	16.83	18.99
OLYM	Olympic NP	WA	OLYM1	6.88	14.93	11.91	11.62	11.71
PASA	Pasayten Wilderness	WA	PASA1	5.97	10.41	9.32	9.09	8.63
PEFO	Petrified Forest NP	AZ	PEFO1	4.21	9.82	8.27	7.97	7.57
VENT	Ventana Wilderness	CA	PINN1	6.96	17.02	14.22	13.49	12.99
PINN	Pinnacles NM	CA	PINN1	6.96	17.02	14.22	13.49	12.99
RAFA	San Rafael Wilderness	CA	RAFA1	6.81	17.27	14.05	13.4	13.08
REDW	Redwood NP	CA	REDW1	8.54	13.64	12.69	12.5	11.60
ROMA	Cape Romain	SC	ROMA1	9.79	25.25	17.95	16.95	19.07
ROMO	Rocky Mountain NP	CO	ROMO1	4.93	11.12	8.42	7.98	8.64
SACR	Salt Creek	NM	SACR1	5.50	16.54	15.04	14.49	12.12
SAGA	San Gabriel Wilderness	CA	SAGA1	6.12	17.89	13.50	12.5	13.18
CUCA	Cucamonga Wilderness	CA	SAGA1	6.12	17.89	13.50	12.5	13.18
SAGO	San Gorgonio Wilderness	CA	SAGO1	6.19	20.43	14.55	13.2	14.74
SAJA	San Jacinto Wilderness	CA	SAGO1	6.19	20.43	14.55	13.2	14.74

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Natural Conditions 20% Most Impaired Days (dv)	Observed 00-04 Baseline 20% Most Impaired Days(dv)	Observed 14-17 Impairment 20% Most Impaired Days(dv)	Projected 2028 Impairment 20% Most Impaired Days(dv)	2028 Unadjusted Glidepath 20% Most Impaired Days(dv)
SAGU	Saguaro NM	AZ	SAGU1	5.16	12.64	10.80	10.29	9.65
SAMA	St. Marks	FL	SAMA1	9.16	24.60	17.53	16.42	18.42
SAPE	San Pedro Parks Wilderness	NM	SAPE1	3.36	7.66	6.42	6.21	5.94
SAWT	Sawtooth Wilderness	ID	SAWT1	4.67	9.62	8.45	8.31	7.64
SENE	Seney	MI	SENE1	11.11	23.62	17.77	16.82	18.62
SEQU	Sequoia NP	CA	SEQU1	6.28	23.17	18.40	17.16	16.41
KICA	Kings Canyon NP	CA	SEQU1	6.28	23.17	18.40	17.16	16.41
SHEN	Shenandoah NP	VA	SHEN1	9.52	28.32	17.50	15.82	20.80
SHRO	Shining Rock Wilderness	NC	SHRO1	10.22	27.97	15.76	14.33	20.87
SIPS	Sipsey Wilderness	AL	SIPS1	9.55	27.71	19.26	18	20.44
ALLA	Alpine Lake Wilderness	WA	SNPA1	7.25	15.37	12.89	12.28	12.12
STMO	Strawberry Mountain Wilderness	OR	STAR1	6.59	14.53	11.31	10.88	11.35
EACA	Eagle Cap Wilderness	OR	STAR1	6.59	14.53	11.31	10.88	11.35
SELW	Selway-Bitterroot Wilderness	MT	SULA1	5.48	10.06	7.91	7.79	8.23
ANAC	Anaconda-Pintler Wilderness	MT	SULA1	5.48	10.06	7.91	7.79	8.23
SWAN	Swanquarter	NC	SWAN1	9.65	23.70	16.82	15.75	18.08
SYCA	Sycamore Canyon Wilderness	AZ	SYCA2	4.68	12.16	11.97	11.8	9.17
THRO	Theodore Roosevelt NP	ND	THRO1	5.95	16.35	13.37	12.83	12.19
THIS	Three Sisters Wilderness	OR	THSI1	7.30	12.80	11.42	11.26	10.60
MOJE	Mount Jefferson Wilderness	OR	THSI1	7.30	12.80	11.42	11.26	10.60
MOWA	Mount Washington Wilderness	OR	THSI1	7.30	12.80	11.42	11.26	10.60
SUPE	Superstition Wilderness	AZ	TONT1	5.09	11.65	10.40	9.97	9.03
ULBE	UL Bend	MT	ULBE1	5.87	12.76	10.88	11.03	10.00
UPBU	Upper Buffalo Wilderness	AR	UPBU1	9.43	24.25	18.18	16.92	18.32
VOYA	Voyageurs NP	MN	VOYA2	9.33	17.75	14.12	13.26	14.38
WEMI	Weminuche Wilderness	CO	WEMI1	3.98	7.81	6.65	6.46	6.28
BLCA	Black Canyon of the Gunnison NM	CO	WEMI1	3.98	7.81	6.65	6.46	6.28
LAGA	La Garita Wilderness	CO	WEMI1	3.98	7.81	6.65	6.46	6.28

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Natural Conditions 20% Most Impaired Days (dv)	Observed 00-04 Baseline 20% Most Impaired Days(dv)	Observed 14-17 Impairment 20% Most Impaired Days(dv)	Projected 2028 Impairment 20% Most Impaired Days(dv)	2028 Unadjusted Glidepath 20% Most Impaired Days(dv)
WHIT	White Mountain Wilderness	NM	WHIT1	4.89	11.31	10.04	9.84	8.74
GORO	Goat Rocks Wilderness	WA	WHPA1	6.15	10.48	8.05	7.87	8.75
WHPA	Mount Adams Wilderness	WA	WHPA1	6.15	10.48	8.05	7.87	8.75
MABE	Maroon Bells-Snowmass Wilderness	CO	WHRI1	3.02	6.30	4.89	4.71	4.99
EANE	Eagles Nest Wilderness	CO	WHRI1	3.02	6.30	4.89	4.71	4.99
FLTO	Flat Tops Wilderness	CO	WHRI1	3.02	6.30	4.89	4.71	4.99
WEEL	West Elk Wilderness	CO	WHRI1	3.02	6.30	4.89	4.71	4.99
WICA	Wind Cave NP	SD	WICA1	5.64	13.09	10.39	9.93	10.11
WIMO	Wichita Mountains	OK	WIMO1	6.92	22.15	18.11	16.93	16.06
YELL	Yellowstone NP	WY	YELL2	3.98	8.30	7.51	7.38	6.57
GRTE	Grand Teton NP	WY	YELL2	3.98	8.30	7.51	7.38	6.57
REDR	Red Rock Lakes	WY	YELL2	3.98	8.30	7.51	7.38	6.57
TETO	Teton Wilderness	WY	YELL2	3.98	8.30	7.51	7.38	6.57
YOSE	Yosemite NP	CA	YOSE1	6.29	13.52	11.61	11.44	10.63
EMIG	Emigrant Wilderness	CA	YOSE1	6.29	13.52	11.61	11.44	10.63
ZION	Zion NP	UT	ZICA1	5.08	10.72	8.50	8.31	8.47

The 2028 future year projected deciview values can be compared to the unadjusted glidepath for 2028. While the RHR requires future year projected visibility impairment be compared to the glidepath, it does not require the RPGs be on or below the glidepath. However, the rule has different requirements depending on whether the projected value (RPG) is above or below the glidepath.[22]

Figure 3-3 shows the difference between the 2028 projected visibility impairment (in deciviews at each IMPROVE site on the 20% most impaired days) and the 2028 unadjusted glidepath (2028 projected minus 2028 unadjusted glidepath). Negative values are below the unadjusted glidepath and positive values are above the unadjusted glidepath.

[22] See 40 CFR 51.308(f)(3)(ii) and (iii)

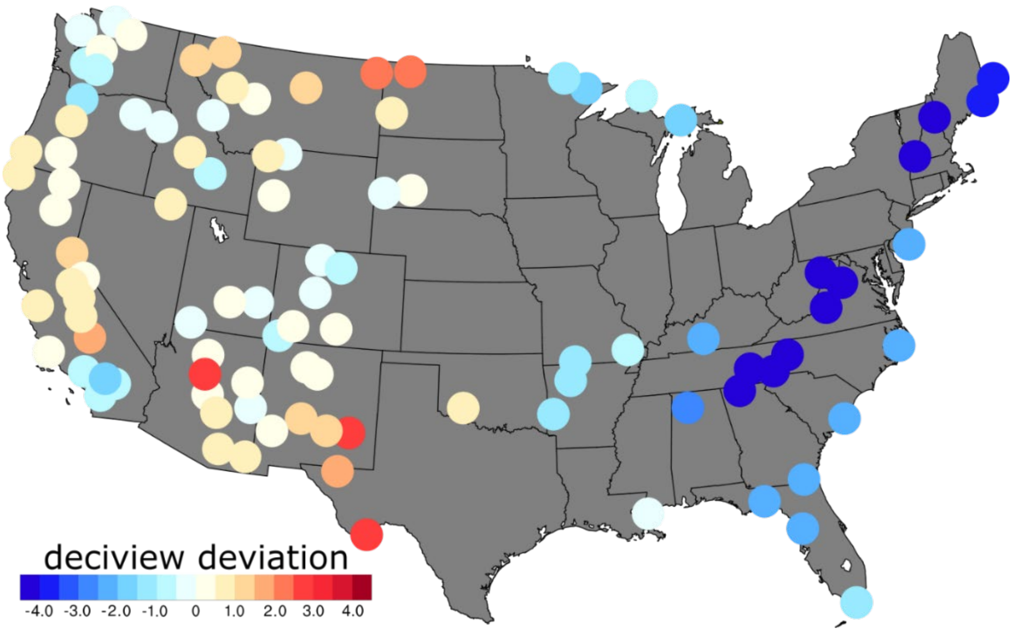

Figure 3-3 *Map of deviation (in deciviews) from the 2028 unadjusted glidepath at IMPROVE sites (2028 projected – 2028 unadjusted glidepath). Negative values are below the 2028 unadjusted glidepath.*

There are two major features that can be seen in Figure 3-3. First, Class I areas east of the Mississippi River tend to be significantly below the unadjusted glidepath. West of the Mississippi River, the results are more mixed. For example, several sites in Southern California and other parts of the West are projected to be below the unadjusted glidepath. But the majority of western sites have a positive deviation from the unadjusted glidepath (they are above the glidepath). There is a total of 47 IMPROVE sites above the 2028 unadjusted glidepath and 52 sites below the 2028 unadjusted glidepath.

3.4 Adjusted Glidepath- International Anthropogenic and Prescribed Fire Impacts

Visibility at Class I areas is impacted not only by natural and anthropogenic emissions from within the U.S., but also by natural and anthropogenic *international* emissions. Due to the fact that international anthropogenic emissions are beyond the control of states preparing regional haze SIPs, the Regional Haze Rule allows states to optionally propose an adjustment of the 2064 URP endpoint to account for international anthropogenic impacts, if the adjustment has been developed using scientifically valid data and methods.[23] The URP can be adjusted by adding an estimate of the visibility impact of international anthropogenic sources to the value of the

[23] See 40 CFR 51.308(f)(1)(vi)

natural visibility conditions to get an adjusted 2064 endpoint. See the Technical Guidance on Tracking Visibility Progress for more details.

The regional haze rule also allows for an optional adjustment to the URP relating to certain prescribed fires. Specifically, the rule also allows states to optionally propose an adjustment of the 2064 URP endpoint to account for impacts from certain wildland prescribed fires.

The EPA modeling calculates estimated Class I area (IMPROVE site) contributions from international anthropogenic and prescribed fire emissions using a combination of hemispheric scale CMAQ zero-out model runs and regional scale CAMx source apportionment modeling. The details of the source apportionment modeling and the estimated adjustments are contained below in section 4.

4.0 PSAT Source Apportionment

In order to gain a better understanding of the source contributions to modeled visibility (including contributions from international anthropogenic and prescribed fire sources), the EPA used CAMx Particulate Source Apportionment Technology (PSAT) modeling. PSAT uses multiple tracer families to track the fate of both primary and secondary PM (Yarwood et al., 2004). PSAT is designed to apportion the following classes of CAMx PM species:

- Sulfate (PSO4)
- Particulate nitrate (PNO3)
- Ammonium (PNH4)
- Secondary organic aerosol (SOA)
- Primary PM (PEC, POA, FCRS, FPRM, CCRS, and CPRM)
- Particulate mercury (HgP)

As part of the development of CAMx Version 7, several science improvements were made to PSAT.

1) Eight additional primary $PM_{2.5}$ elemental species were added to PSAT and are tracked individually as primary PM. Those elements are: Al, Ca, Fe, K, Mg, Mn, Si, and Ti.
2) The formation of sulfate from DMS (dimethyl sulfide) emissions is tracked as part of sulfate PSAT.
3) Boundary conditions (and initial conditions) can be tracked as multiple tags if provided to CAMx as separate species whose concentrations add up to the total boundary condition concentration. For example, anthropogenic and natural components of the boundary conditions can be tracked separately.

PSAT allows emissions to be tracked (tagged) by various combinations of sectors and geographic areas (e.g., by state). For this application, 2028 emissions were tagged by nationwide major source sector (not by individual state). Table 4-1 below shows the sector tags that were modeled in 2028 using the CAMx PSAT. Each of these emissions source sectors were processed through SMOKE and tracked in PSAT as individual source tags. Each sector tag is labelled as either a natural, US anthropogenic, or international anthropogenic source (prescribed fires are treated as a separate category). “Notes” included in the table add more information about the nature of some individual source sector tags. For this application, sulfate, nitrate, ammonium, SOA, and primary PM were tracked using PSAT.

Table 4-1. CAMx source sector PSAT tags for 2028.

Tag #	Sector Description	Classification of the Sector	Notes
1	Biogenics	Natural	Biogenic NOx and VOC
2	EGUs	US Anthropogenic	
3	On-road	US Anthropogenic	
4	Nonroad	US Anthropogenic	
5	C1C2 Marine	US Anthropogenic	Within state waters and offshore
6	US C3 Marine (w/in ECA)	US Anthropogenic	Within state waters and US ECA region
7	Non-US C3 Marine (outside ECA)	International Anthropogenic	C3 marine outside US ECA region
8	Rail	US Anthropogenic	
9	Agricultural Fires	US Anthropogenic	
10	Agricultural Ammonia	US Anthropogenic	Ammonia only
11	Oil & Gas	US Anthropogenic	Point and Nonpoint O&G
12	Non-EGU Point	US Anthropogenic	
13	Residential Wood	US Anthropogenic	
14	Wildfires (US only)	Natural	
15	Prescribed Fires	Prescribed Fires	
16	Anthro. Dust	US Anthropogenic	Only anthropogenic dust (paved and unpaved roads, ag tilling, etc.)
17	Non-Point	US Anthropogenic	

18	Canada Fires	Natural	
19	Canada Anthropogenic	International Anthropogenic	
20	Mexico Fires	Natural	
21	Mexico Anthropogenic	International Anthropogenic	
22	Ocean (sulfate)	Natural	Natural sulfate from DMS and sea salt
1BC	Boundary Conditions-International Anthropogenic	International Anthropogenic	
1IC	Initial Conditions-International Anthropogenic	International Anthropogenic	
2BC	Boundary Conditions-Natural	Natural	
2IC	Initial Conditions-other	N/A	Natural + US anthropogenic
TOPCON	Top Concentrations	N/A	

As noted above, the new version of CAMx PSAT allows for tracking of multiple initial and boundary conditions tags. In this case, the anthropogenic international component of the initial and boundary conditions (1IC and 1BC) was calculated separately from the natural component (2IC and 2BC). See more details on the development of the boundary conditions in section 2.3.3.

4.1 PSAT Emissions Sectors

As shown in Table 4-1, there are 22 tagged emissions sectors plus tagged initial and boundary conditions, and top concentrations. In summarizing the results, some tags were further post-processed, or were not used in the accounting of contributions, or have special circumstances. Below are more detailed notes on certain emissions tags.

Biogenics (tag 1)- The biogenics tag includes emissions from biogenic VOC and NOx. Those emissions can contribute to nitrate and biogenic SOA. The contributions from the tag were assumed to be “natural” and were added to the natural contributions at each IMPROVE site. However, a large percentage of the biogenic NOx emissions are from long-term fertilizer use in agricultural areas. Therefore, depending on the interpretation, those emissions may or may not be strictly biogenic or “natural”. In addition, all biogenic SOA contributions are assigned to biogenic VOC emissions even though biogenic SOA is somewhat controllable through anthropogenic NOx and SO2 reductions. It has been shown that NOx and SO2 emissions reductions (and to a lesser extent primary organic emissions) lead to reductions in atmospheric oxidants (Carlton, 2018), which can lead to lower biogenic SOA concentrations.

EGUs (Tag 2)- The 2028 EGU emissions used in this modeling were from the November 2018 version of the IPM model. There is also an updated version of IPM emissions (May, 2019), as well as alternative EGU emissions estimates available from the Eastern Regional Technical Advisory Committee (ERTAC).

C3 Commercial Marine (Tags 6 and 7)- The C3 marine emissions were split into two tags. All emissions within the US ECA region were put into tag 6 and were considered to be US emissions. All other C3 emissions outside of the US ECA regional were put into tag 7 and were considered to be international anthropogenic emissions. Since nearly all C3 vessels are foreign flagged (~99%), there is no one way to split the C3 emissions between US and international sources. We decided to use the ECA region as a way to split the emissions since the US can implement emissions controls through maritime treaties and regulations within the identified ECA region. Outside of the ECA region, the US government has no direct authority over emissions sources.

Prescribed Fires (Tag 15)- The prescribed fire emissions are for the 2016 base year and (along with the rest of the fire emissions) were held constant in 2028. The prescribed fire impacts therefore only represent a single year of emissions and may vary considerably from year-to-year. The interannual variability of prescribed fire emissions should be considered when evaluating the modeled contributions. In addition, fires are assigned to the prescribed fire category (tracked as Tag 15) in this assessment based on location and time of year when prescribed fire would be more likely than wild fire. For areas such as the southeast U.S. where wild fires are less common, the prescribed fire category is likely representative of prescribed fires. However, in areas such as the western U.S. this assignment approach has much less certainty and is more likely to include both wild and prescribed fire.

Anthropogenic Dust (Tag 16)- Due to a lack of accurate emissions information, the modeling platform did not include natural windblown dust emissions within the regional 36/12km domains. The dust emissions tracked to tag 16 are from anthropogenic dust emissions (e.g. unpaved roads and agricultural tilling). The impacts of these emissions are mostly confined to coarse PM and fine crustal PM. Both coarse PM and fine crustal PM may be a sizable fraction of light extinction at some Class I areas (especially in the Southwest), however, it is likely that most of the measured coarse and crustal impairment is from natural dust sources. Due in part to the lack of natural windblown dust in the model, in the default relative contribution calculations, the anthropogenic dust comprises up to 80% of the modeled fine crustal and 92% of the modeled coarse PM extinction. Coarse PM and fine crustal PM are often underpredicted, especially at Western IMPROVE sites with high measured coarse and fine crustal concentrations/extinction. If natural wind-blown dust had been included in the regional modeling platform, the overall dust would have been more accurately modeled and the anthropogenic dust would have been a smaller fraction of the total coarse and fine crustal PM.

In order to derive a more reasonable split between the estimated anthropogenic dust and natural dust contributions, the results of the default relative contribution calculations were modified to better account for natural sources of dust. Instead of directly assigning the relative contribution results for tag 16 to anthropogenic dust, ambient data was used to estimate the natural and anthropogenic components of coarse and fine crustal PM at each IMPROVE site. The Tag 16 impacts were split into estimated anthropogenic (16A) and natural (16B) dust impacts. The coarse and fine crustal material[24] from tag 16 was split according to the natural fraction used in calculating the ambient impairment metric. For both coarse and crustal material, the natural fraction is calculated from the ratio of the annual average natural conditions estimate (NC-II) and the non-episodic observed 2016 annual average. Using the natural fraction, natural coarse and crustal extinction is moved to 16B and the remainder of tag 16 is assigned to 16A.

In spite of the adjustment, there are a number of IMPROVE sites (especially in the Southwest) where the post-processed model results show a large fraction of the US anthropogenic impairment is from “anthropogenic” dust. Due to the noted limitations of the emissions characterization, this may not be accurate (some or most of the “anthropogenic” dust may be natural) and should be further examined. Future modeling using high quality wind-blown dust emissions will help eliminate some of these performance issues and related uncertainties.

Mexico anthropogenic (Tag 21)- There was a minor error in the PSAT emissions processing that put some of the Canadian anthropogenic primary PM sources in the Mexico anthropogenic tag. The emissions were a small part of the impacts from Canada and are not seen in the secondary PM impacts (sulfate, nitrate, and SOA). This has a small impact on the apportionment between Canada and Mexico but does not affect the total international

[24] Also note that there are smaller dust contributions to sulfate, nitrate, elemental carbon, and organic carbon. But due to the relatively small impact of dust sources on those species, the contributions to those species were not adjusted.

anthropogenic contribution estimates since that is a total of *all* international anthropogenic contributions from Canada, Mexico, C3 marine, and international boundary conditions.

International anthropogenic boundary conditions (Tag 1BC)- The boundary conditions were derived from a 2016 hemispheric CMAQ run and were held constant for 2028. We believe this is a reasonable assumption since we do not have specific information on expected emissions changes between now and 2028 in areas outside the 36/12km domain. One exception is a global fuel sulfur limit on C3 commercial marine vessels that is expected to go into effect in 2020. The impact of the global sulfur fuel limit was accounted for within the regional 36/12km domain (outside of the US and Canadian ECA regions), but was not accounted for in the boundary conditions from hemispheric CMAQ.

Initial Conditions and Top Concentrations (Tags 1IC, 2IC, and TOPCON)- The initial conditions and top concentrations were tracked in the PSAT modeling, but due to their small contributions to visibility impairment, were not included in the summary information. The largest total contribution from initial conditions on the 20% most impaired days at any IMPROVE site was 0.04 Mm-1, and the largest top concentration contribution was 3.4×10^{-5} Mm-1.

4.2 PSAT Post-processing

The CAMx 2016 and 2028 model output was post-processed using a "species definition file" that cross references raw CAMx output species names with PM species needed for SMAT. The results of the post-processing are 24-hour average PM species (converted to NetCDF format) with the "combine file" output names. These are matched to the SMAT species as shown in Table 4-2.

Table 4-2 Matching of CAMx raw output species to SMAT input variables.

SMAT Species	"Combine File" Output Name	Raw CAMx 7.0 Species
Sulfate	PM25_SO4	PSO4
Nitrate	PM25_NO3	PNO3
Ammonium[25]	PM25_NH4	PNH4

[25] Modeled ammonium concentrations are not used in the post-processing of the 2028 visibility values because the IMPROVE network does not measure ammonium. The IMPROVE equation assumes that sulfate and nitrate is fully neutralized by ammonia.

Organic carbon	PM25_OM	POA+SOA1+SOA2+SOPA+SOA3+SOA4+SOPB
Elemental carbon	PM25_EC	PEC
Crustal	PM25_SOIL	2.2*PAL+2.49*PSI+1.63*PCA+2.42*PFE+1.94*PTI
Coarse PM	PMC_TOT	CCRS+CPRM
PM2.5	PM25_TOT	CRUSTAL+PSO4+PNO3+PNH4+PEC+NA+PCL+SOA1+ SOA2+SOA3+SOA4+SOPA+SOPB+POA

4.2.1 Process for creating PSAT sector contributions for Class I Areas

The PSAT raw "tag" model outputs were post-processed to create SMAT input files. This involves processing both the 2028 "bulk outputs" and the sector specific source apportionment outputs. The "bulk outputs" are the total "bulk" PM species concentrations (e.g. sulfate, nitrate, etc.) that are identical to the total species concentrations from the non-source apportionment model run for 2028.

SMAT input files for the 2028 bulk species and sector tag species were created as a first step in calculating the relative PM and visibility contributions from each tag/sector. The 2028 bulk species SMAT input files contain the 24-hr average daily modeled species concentrations for each grid cell. The "sector tag" SMAT input files contain the 24-hr average daily modeled species concentrations for each sector tag, for each grid cell. The SMAT input files for the 2028 bulk case and the 2028 sector tags were then used to calculate sector tag extinction fractions. See Appendix C for a more detailed explanation of the PSAT sector contribution calculations.

The individual sector tags have been summed into categories and summarized in "Class I area summary plots", contained in Appendix B. The emissions summary categories are shown in table 4-4.

Table 4-4. Source apportionment emissions summary categories.

Emissions Summary Category	**Emissions Sectors (PSAT tags)**	**Notes**
U.S. Anthropogenic	On-road mobile, Non-road mobile, EGUs, C1&C2 commercial marine, US C3 commercial marine (w/in ECA), Rail, Agricultural fires, Agricultural ammonia, Oil & Gas, Non-EGU point, Residential wood, Anthropogenic dust, Nonpoint,	US anthropogenic visibility contributions.
International Anthropogenic	Anthropogenic Canada and Mexico, C3 commercial marine (outside ECA), Boundary conditions- international anthropogenic	Contribution from Canadian and Mexican emissions within the 36 and 12km domains, and from the rest of the Northern hemisphere through boundary conditions.
Natural	Biogenic, US wildfires, Canada wildfires, Mexico wildfires, Ocean sulfate (DMS and sea salt), sea salt, natural dust[26], Rayleigh	Contributions to natural visibility from US sources as well as international sources.
Prescribed Fires	US Prescribed fires	Prescribed fire contributions.

The summary plots also list the largest U.S. anthropogenic sector contributions for each IMPROVE site (in a pie plot). See Appendix B for the summary plots, including a detailed explanation of the plots.

4.3 Sector Tag Results

The sector tag modeling results were evaluated to better understand the individual source sector contributions to regional haze at Class I areas. See Appendix B for individual IMPROVE site summary plots which contain model performance, 2028 projection, and 2028 source apportionment information. The sector results can also be examined by individual PM species to learn more about which species are the largest contributors to regional haze. Although PM concentration does not linearly correspond to visibility impairment, it is a good surrogate for

[26] In order to derive a more reasonable split between the estimated anthropogenic dust and natural dust contributions, the relative contribution calculations were modified to better account for natural sources of dust. The dust impacts were split into estimated anthropogenic dust and natural dust impacts.

examining sector contributions to visibility. A convenient way to examine the sector tag results is to look at spatial maps of the raw source apportionment outputs (in modeled concentration units). Below are example plots of monthly average concentrations (in µg/m^3) for several example source sector tags.

The sector source apportionment tag results show that international anthropogenic boundary conditions account for a sizable fraction of sulfate concentrations in the west in certain months, and to a lesser extent nitrate. Figure 4-3 below shows the 2028 March monthly average sulfate contribution (left plot in ug/m3)[27] and fraction of total sulfate (right plot, fraction from 0 to 1) from international anthropogenic boundary conditions. This shows a relatively large contribution to sulfate (> 0.5 ug/m3 monthly average) in the southwest which comprises up to 80% of the modeled sulfate in that region in March.

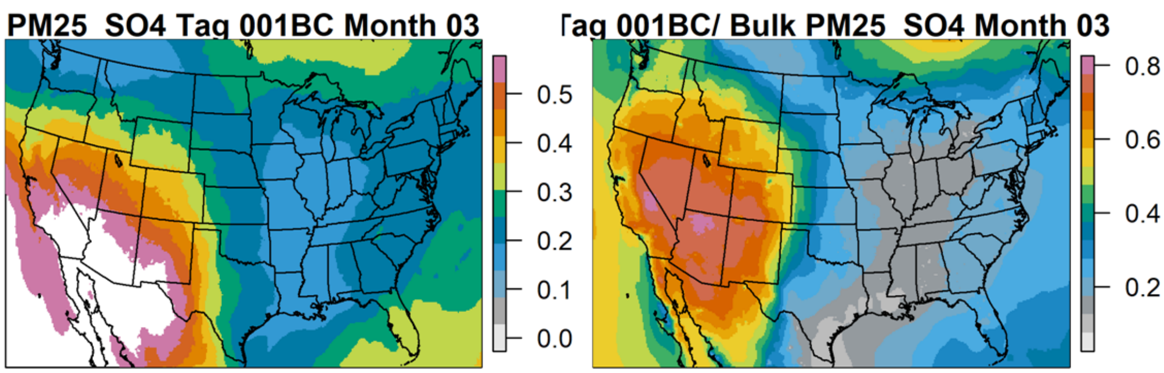

Figure 4-3 (Left) March 2028 monthly average sulfate contribution (in ug/m3) and (Right) fractional contribution to total sulfate from international anthropogenic boundary conditions.

Figure 4-4 shows the same international anthropogenic visibility impacts for August. The magnitude of the sulfate impacts are similar to March, except the highest concentrations are farther north, focused on the west coast and inland areas of of California, Nevada, and the Pacific Northwest.

[27] The white color in the concentration plots represents concentrations that are greater than the top of the scale.

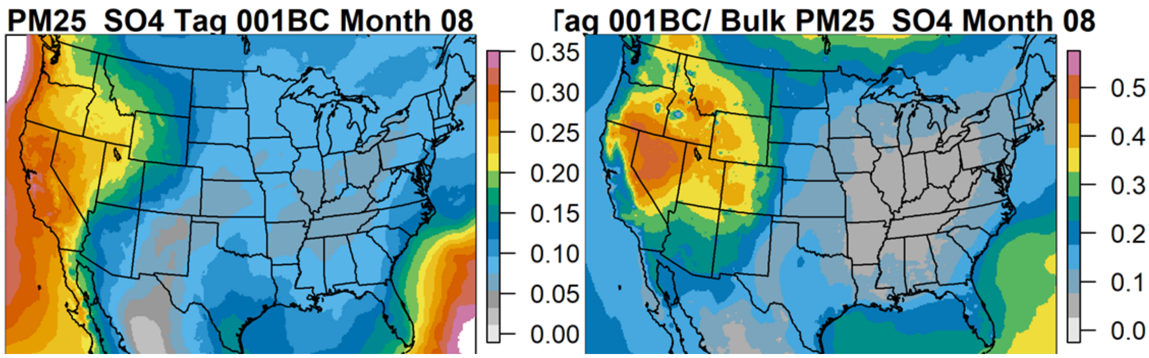

Figure 4-4 *(Lest) August 2028 monthly average sulfate contribution (in ug/m3) and (Right) fractional contribution to total sulfate from international anthropogenic boundary conditions*

Figure 4-5 shows March average nitrate contributions from international anthropogenic boundary conditions. The international contributions from nitrate are generally smaller than the sulfate contributions, but can still comprise a relatively large fraction of modeled nitrate, particularly in northern California and Oregon in this case.

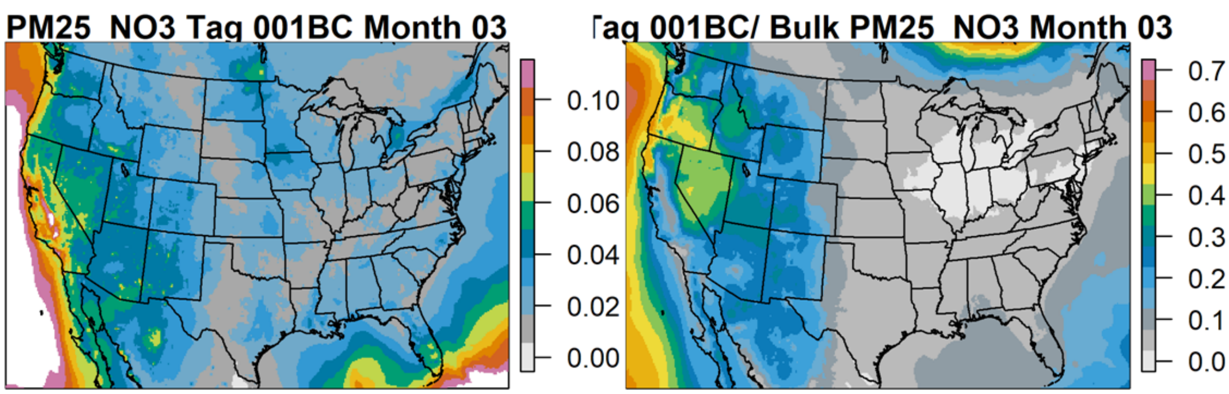

Figure 4-5 *(Left) March 2028 monthly average nitrate contribution (in ug/m3) and (Right) fractional contribution to total nitrate from international anthropogenic boundary conditions.*

Relatively high sulfate concentrations can also be seen coming from the boundaries from natural sources. Figure 4-6 shows the 2028 August monthly average sulfate contribution from the natural component of boundary conditions. The natural sulfate contributions are relatively high along the west coast and in Florida (up to 40% of the monthly average modeled sulfate). The natural sulfate is mostly from DMS emissions over the oceans.

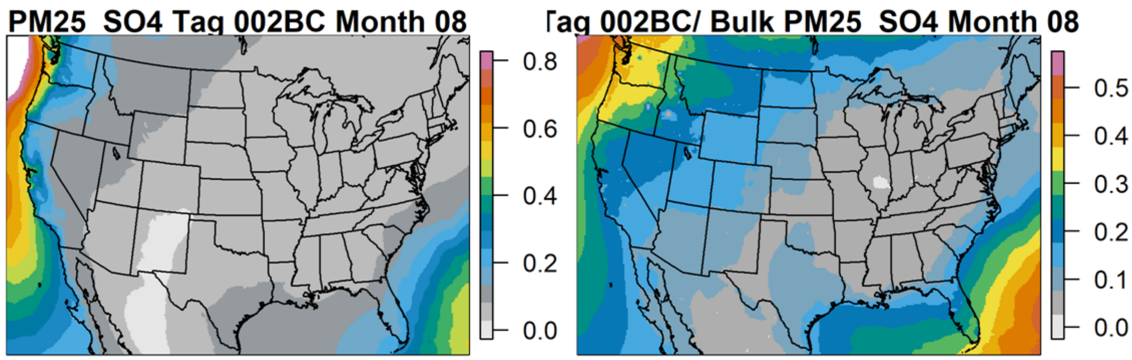

Figure 4-6 *(Left) August 2028 monthly average sulfate contribution (in ug/m3) and (Right) fractional contribution to total sulfate from natural international boundary conditions*

Figures 4-7 and 4-8 show the January 2028 monthly average nitrate contributions and February monthly average sulfate contributions from Canadian anthropogenic emissions. Both the nitrate and sulfate impacts are relatively large in the northern tier of states, especially the Northern Plains and New England. The Candian January nitrate impacts represent up to 70% of the modeled nitrate In Northern Montana and North Dakota. The Canadian February sulfate impacts represent 30-50% of the modeled sulfate concentrations in a large part of the Northern US.

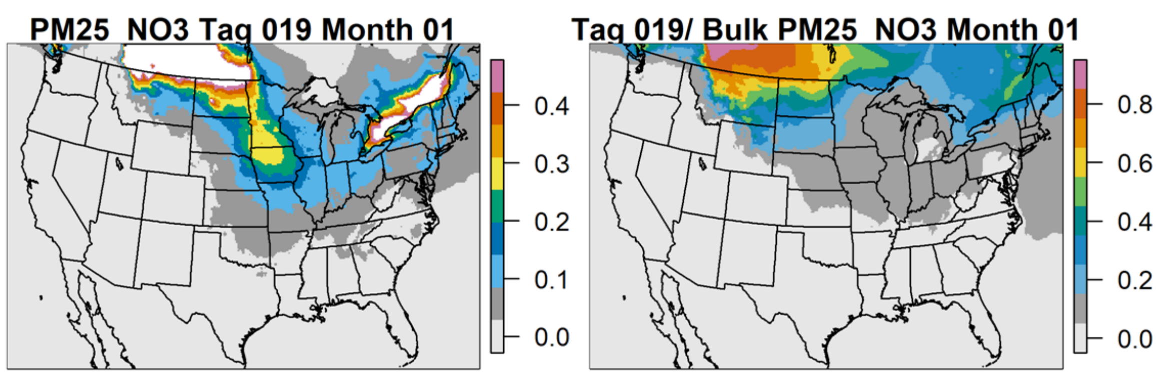

Figure 4-7 *(Left) January 2028 monthly average nitrate contribution (in ug/m3) and (Right) fractional contribution to total nitrate from Canadian anthropogenic emissions.*

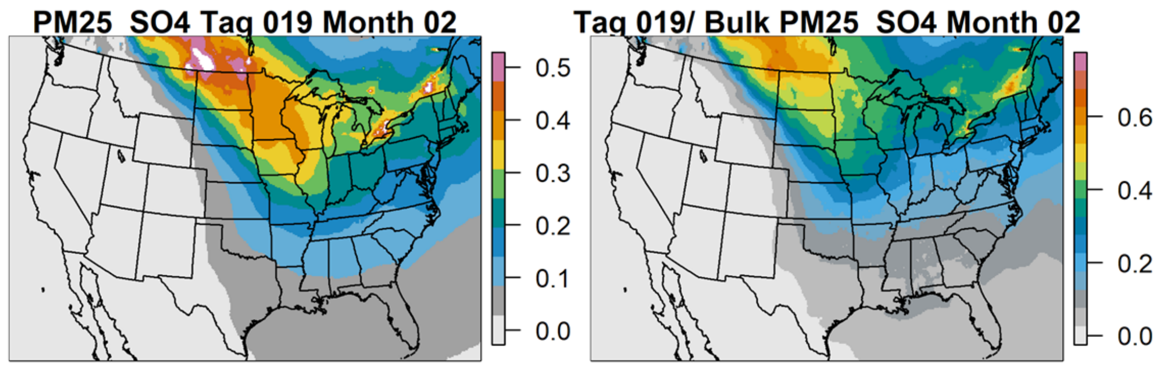

Figure 4-8 *(Left) February 2028 monthly average sulfate contribution (in ug/m3) and (Right) fractional contribution to total sulfate from Canadian anthropogenic emissions.*

Figure 4-9 shows the August 2028 monthly average sulfate contributions from Mexican anthropogenic emissions. The sulfate impacts are relatively large in the Southwest, especially in Texas near the Mexican border. The Mexican August sulfate impacts represent 30-70% of the modeled sulfate concentrations in parts of Texas, New Mexico, and Arizona.

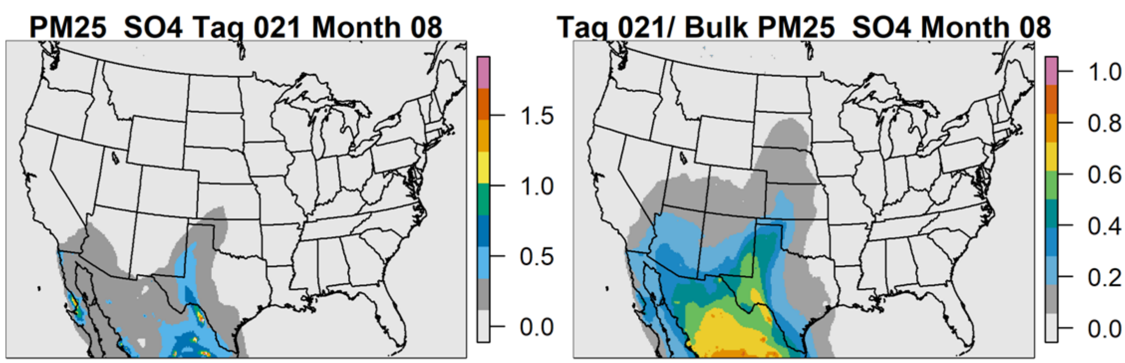

Figure 4-9 *(Left) August 2028 monthly average sulfate contribution (in ug/m3) and (Right) fractional contribution to total sulfate from Mexican anthropogenic emissions.*

5.0 Glidepath Endpoint Adjustment

The regional haze rule allows for the optional adjustment of the 2064 glidepath endpoint to account for both international anthropogenic and certain prescribed fire impacts at Class I areas. The CAMx PSAT modeling described in section 4 provides modeling results that can be used to quantify the international and prescribed fire contributions on the 20% most anthropogenically impaired days. Consistent with the 2028 visibility projections, the sector contributions were calculated using projected (2028) ambient IMPROVE data and relative model results (percent contribution of each sector to the total modeled impairment in 2028, by species).

Table 5-1 shows the average relative contributions to visibility impairment in 2028 on the 20% most impaired days for the international anthropogenic and prescribed fire components. The "Total International Anthropogenic" (dark blue) is the sum of the four international anthropogenic components (light blue) and prescribed fire impacts are shown as a separate category (red), all in Mm-1.

Table 5-1 Relative modeled 2028 contributions to visibility impairment on the 20% most impaired days for the international anthropogenic and prescribed fire components (in Mm-1).

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
ACAD	Acadia NP	ME	ACAD1	0.03	5.15	0.24	3.39	8.82	0.32
AGTI	Agua Tibia Wilderness	CA	AGTI1	0.39	0.07	2.08	4.94	7.47	0.43
BADL	Badlands NP	SD	BADL1	0.01	4.14	0.33	3.45	7.92	0.72
BALD	Mount Baldy Wilderness	AZ	BALD1	0.04	0.01	2.48	1.72	4.25	0.16
BAND	Bandelier NM	NM	BAND1	0.02	0.07	1.79	1.91	3.79	0.11
BIBE	Big Bend NP	TX	BIBE1	0.16	0.14	14.39	2.62	17.31	0.25
DESO	Desolation Wilderness	CA	BLIS1	0.01	0.07	0.10	3.71	3.89	1.24
MOKE	Mokelumne Wilderness	CA	BLIS1	0.01	0.07	0.10	3.71	3.89	1.24
BOAP	Bosque del Apache	NM	BOAP1	0.03	0.06	2.40	1.62	4.11	0.33

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
BOWA	Boundary Waters Canoe Area	MN	BOWA1	0.01	4.94	0.29	3.55	8.78	2.02
BRID	Bridger Wilderness	WY	BRID1	0.01	0.07	0.31	2.48	2.88	0.08
FITZ	Fitzpatrick Wilderness	WY	BRID1	0.01	0.07	0.31	2.48	2.88	0.08
BRIG	Brigantine	NJ	BRIG1	0.04	3.50	0.53	2.47	6.55	0.73
BRET2	Breton	LA	BRIS1	1.18	0.86	3.62	4.57	10.24	0.85
CABI	Cabinet Mountains Wilderness	MT	CABI1	0.00	0.57	0.13	3.32	4.02	3.96
CACR	Caney Creek Wilderness	AR	CACR1	0.28	0.85	1.37	2.39	4.88	1.88
ARCH	Arches NP	UT	CANY1	0.02	0.04	0.70	2.80	3.56	0.08
CANY	Canyonlands NP	UT	CANY1	0.02	0.04	0.70	2.80	3.56	0.08
CAPI	Capitol Reef NP	UT	CAPI1	0.03	0.01	0.87	3.44	4.36	0.07
CHAS	Chassahowitzka	FL	CHAS1	1.30	0.62	1.01	3.81	6.75	1.49
CHIR	Chiricahua NM	AZ	CHIR1	0.09	0.03	3.95	1.53	5.60	0.08
CHIW	Chiricahua Wilderness	AZ	CHIR1	0.09	0.03	3.95	1.53	5.60	0.08
GALI	Galiuro Wilderness	AZ	CHIR1	0.09	0.03	3.95	1.53	5.60	0.08
COHU	Cohutta Wilderness	GA	COHU1	0.10	1.31	0.68	3.20	5.29	1.22
CRLA	Crater Lake NP	OR	CRLA1	0.01	0.20	0.03	5.36	5.60	1.41
DIPE	Diamond Peak Wilderness	OR	CRLA1	0.01	0.20	0.03	5.36	5.60	1.41

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
GEMO	Gearhart Mountain Wilderness	OR	CRLA1	0.01	0.20	0.03	5.36	5.60	1.41
MOLA	Mountain Lakes Wilderness	OR	CRLA1	0.01	0.20	0.03	5.36	5.60	1.41
CRMO	Craters of the Moon NM	ID	CRMO1	0.01	0.32	0.27	4.24	4.85	0.42
DOME	Dome Land Wilderness	CA	DOME1	0.04	0.12	0.36	7.97	8.49	0.39
DOSO	Dolly Sods Wilderness	WV	DOSO1	0.05	2.11	0.53	2.31	4.99	0.84
OTCR	Otter Creek Wilderness	WV	DOSO1	0.05	2.11	0.53	2.31	4.99	0.84
EVER	Everglades NP	FL	EVER1	2.28	0.48	0.36	4.65	7.77	0.31
GAMO	Gates of the Mountains Wilderness	MT	GAMO1	0.00	1.27	0.16	2.78	4.22	1.41
GICL	Gila Wilderness	NM	GICL1	0.04	0.02	2.88	1.19	4.13	0.07
GLAC	Glacier NP	MT	GLAC1	0.03	2.50	0.14	4.89	7.56	4.23
GRCA	Grand Canyon NP	AZ	GRCA2	0.03	0.01	1.37	2.34	3.75	0.04
GRGU	Great Gulf Wilderness	NH	GRGU1	0.01	4.87	0.48	3.53	8.89	0.56
PRRA	Presidential Range-Dry River Wilderness	NH	GRGU1	0.01	4.87	0.48	3.53	8.89	0.56
GRSA	Great Sand Dunes NM	CO	GRSA1	0.02	0.04	1.13	2.50	3.68	0.30
GRSM	Great Smoky Mountains NP	TN	GRSM1	0.09	1.38	0.54	2.83	4.84	1.13

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
JOYC	Joyce-Kilmer-Slickrock Wilderness	TN	GRSM1	0.09	1.38	0.54	2.83	4.84	1.13
CAVE	Carlsbad Caverns NP	TX	GUMO1	0.13	0.05	9.96	2.42	12.57	0.16
GUMO	Guadalupe Mountains NP	TX	GUMO1	0.13	0.05	9.96	2.42	12.57	0.16
HECA	Hells Canyon Wilderness	OR	HECA1	0.03	0.39	0.26	7.39	8.08	1.31
HEGL	Hercules-Glades Wilderness	MO	HEGL1	0.10	1.83	1.57	2.19	5.69	3.74
HOOV	Hoover Wilderness	CA	HOOV1	0.01	0.05	0.22	3.65	3.93	0.13
MAZA	Mazatzal Wilderness	AZ	IKBA1	0.06	0.02	2.48	2.33	4.89	0.12
PIMO	Pine Mountain Wilderness	AZ	IKBA1	0.06	0.02	2.48	2.33	4.89	0.12
ISLE	Isle Royale NP	MI	ISLE1	0.01	4.52	0.39	4.14	9.06	1.77
JARB	Jarbidge Wilderness	NV	JARB1	0.00	0.10	0.20	3.71	4.02	0.11
JARI	James River Face Wilderness	VA	JARI1	0.04	2.01	0.38	2.56	4.99	1.01
JOSH	Joshua Tree NM	CA	JOSH1	0.16	0.03	1.76	5.22	7.17	0.04
ANAD	Ansel Adams Wilderness (Minarets)	CA	KAIS1	0.03	0.12	0.19	5.60	5.93	0.56
JOMU	John Muir Wilderness	CA	KAIS1	0.03	0.12	0.19	5.60	5.93	0.56

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
KAIS	Kaiser Wilderness	CA	KAIS1	0.03	0.12	0.19	5.60	5.93	0.56
KALM	Kalmiopsis Wilderness	OR	KALM1	0.05	0.46	0.03	3.93	4.46	2.15
LABE	Lava Beds NM	CA	LABE1	0.01	0.21	0.15	4.49	4.86	0.83
SOWA	South Warner Wilderness	CA	LABE1	0.01	0.21	0.15	4.49	4.86	0.83
CARI	Caribou Wilderness	CA	LAVO1	0.01	0.16	0.09	4.31	4.58	0.52
LAVO	Lassen Volcanic NP	CA	LAVO1	0.01	0.16	0.09	4.31	4.58	0.52
THLA	Thousand Lakes Wilderness	CA	LAVO1	0.01	0.16	0.09	4.31	4.58	0.52
LIGO	Linville Gorge Wilderness	NC	LIGO1	0.04	1.42	0.39	2.26	4.10	0.84
LOST	Lostwood	ND	LOST1	0.02	14.97	0.42	3.02	18.43	0.61
LYBR2	Lye Brook Wilderness	VT	LYEB1	0.02	4.98	0.50	2.57	8.07	0.53
MACA	Mammoth Cave NP	KY	MACA1	0.02	3.34	0.30	3.28	6.94	1.37
MELA	Medicine Lake	MT	MELA1	0.02	15.49	0.40	3.43	19.33	0.35
MEVE	Mesa Verde NP	CO	MEVE1	0.02	0.04	0.93	2.29	3.28	0.15
MING	Mingo	MO	MING1	0.08	1.89	0.90	2.25	5.13	4.11
MOHO	Mount Hood Wilderness	OR	MOHO1	0.02	0.40	0.05	3.88	4.35	2.85
BOMA	Bob Marshall Wilderness	MT	MONT1	0.00	0.51	0.07	2.89	3.47	2.32
MIMO	Mission Mountains Wilderness	MT	MONT1	0.00	0.51	0.07	2.89	3.47	2.32

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
SCAP	Scapegoat Wilderness	MT	MONT1	0.00	0.51	0.07	2.89	3.47	2.32
MOOS	Moosehorn	ME	MOOS1	0.02	6.40	0.24	4.51	11.17	0.34
ROCA	Roosevelt Campobello International Park	ME	MOOS1	0.02	6.40	0.24	4.51	11.17	0.34
MORA	Mount Rainier NP	WA	MORA1	0.02	0.97	0.06	5.25	6.30	0.35
MOZI	Mount Zirkel Wilderness	CO	MOZI1	0.01	0.16	0.44	2.59	3.20	0.13
RAWA	Rawah Wilderness	CO	MOZI1	0.01	0.16	0.44	2.59	3.20	0.13
NOAB	North Absaroka Wilderness	WY	NOAB1	0.01	0.11	0.18	2.92	3.21	0.25
WASH	Washakie Wilderness	WY	NOAB1	0.01	0.11	0.18	2.92	3.21	0.25
GLPE	Glacier Peak Wilderness	WA	NOCA1	0.02	1.20	0.08	4.82	6.11	0.19
NOCA	North Cascades NP	WA	NOCA1	0.02	1.20	0.08	4.82	6.11	0.19
OKEF	Okefenokee	GA	OKEF1	0.99	0.98	2.23	4.60	8.80	1.37
WOLF	Wolf Island	GA	OKEF1	0.99	0.98	2.23	4.60	8.80	1.37
OLYM	Olympic NP	WA	OLYM1	0.03	1.66	0.06	4.50	6.24	0.08
PASA	Pasayten Wilderness	WA	PASA1	0.01	0.78	0.06	4.60	5.45	1.94
PEFO	Petrified Forest NP	AZ	PEFO1	0.04	0.02	1.67	2.24	3.96	0.27
PINN	Pinnacles NM	CA	PINN1	0.05	0.32	0.11	5.20	5.68	0.31

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
VENT	Ventana Wilderness	CA	PINN1	0.05	0.32	0.11	5.20	5.68	0.31
RAFA	San Rafael Wilderness	CA	RAFA1	0.08	0.09	0.35	5.31	5.84	0.16
REDW	Redwood NP	CA	REDW1	0.08	0.55	0.02	3.39	4.05	0.11
ROMA	Cape Romain	SC	ROMA1	0.50	0.81	1.24	3.68	6.23	1.71
ROMO	Rocky Mountain NP	CO	ROMO1	0.01	0.30	0.65	2.53	3.49	0.16
SACR	Salt Creek	NM	SACR1	0.09	0.25	6.16	2.52	9.02	0.42
CUCA	Cucamonga Wilderness	CA	SAGA1	0.26	0.05	0.72	4.38	5.40	0.05
SAGA	San Gabriel Wilderness	CA	SAGA1	0.26	0.05	0.72	4.38	5.40	0.05
SAGO	San Gorgonio Wilderness	CA	SAGO1	0.12	0.09	0.85	5.26	6.33	0.14
SAJA	San Jacinto Wilderness	CA	SAGO1	0.12	0.09	0.85	5.26	6.33	0.14
SAGU	Saguaro NM	AZ	SAGU1	0.10	0.02	2.75	2.08	4.95	0.03
SAMA	St. Marks	FL	SAMA1	0.59	0.76	1.43	3.78	6.57	1.75
SAPE	San Pedro Parks Wilderness	NM	SAPE1	0.03	0.02	1.67	1.81	3.53	0.08
SAWT	Sawtooth Wilderness	ID	SAWT1	0.00	0.11	0.10	2.82	3.03	0.40
SENE	Seney	MI	SENE1	0.01	6.10	0.19	4.14	10.45	1.92
KICA	Kings Canyon NP	CA	SEQU1	0.05	0.06	0.25	11.73	12.10	1.55
SEQU	Sequoia NP	CA	SEQU1	0.05	0.06	0.25	11.73	12.10	1.55
SHEN	Shenandoah NP	VA	SHEN1	0.02	1.98	0.30	2.42	4.72	0.66

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
SHRO	Shining Rock Wilderness	NC	SHRO1	0.09	1.01	1.00	2.61	4.70	0.87
SIPS	Sipsey Wilderness	AL	SIPS1	0.09	1.45	0.74	2.83	5.12	2.64
ALLA	Alpine Lake Wilderness	WA	SNPA1	0.03	1.59	0.05	5.21	6.88	1.95
EACA	Eagle Cap Wilderness	OR	STAR1	0.03	0.72	0.25	6.69	7.69	1.42
STMO	Strawberry Mountain Wilderness	OR	STAR1	0.03	0.72	0.25	6.69	7.69	1.42
ANAC	Anaconda-Pintler Wilderness	MT	SULA1	0.00	0.46	0.11	3.44	4.02	0.80
SELW	Selway-Bitterroot Wilderness	MT	SULA1	0.00	0.46	0.11	3.44	4.02	0.80
SWAN	Swanquarter	NC	SWAN1	0.16	1.91	0.65	2.42	5.13	1.11
SYCA2	Sycamore Canyon Wilderness	AZ	SYCA2	0.03	0.01	1.24	3.18	4.47	0.62
THRO	Theodore Roosevelt NP	ND	THRO1	0.01	6.63	0.29	3.69	10.61	0.59
MOJE	Mount Jefferson Wilderness	OR	THSI1	0.02	0.35	0.06	5.62	6.04	5.15
MOWA	Mount Washington Wilderness	OR	THSI1	0.02	0.35	0.06	5.62	6.04	5.15
THIS	Three Sisters Wilderness	OR	THSI1	0.02	0.35	0.06	5.62	6.04	5.15

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
SUPE	Superstition Wilderness	AZ	TONT1	0.09	0.02	2.88	2.24	5.23	0.09
ULBE	UL Bend	MT	ULBE1	0.01	9.77	0.37	4.38	14.52	0.34
UPBU	Upper Buffalo Wilderness	AR	UPBU1	0.18	1.42	3.13	2.29	7.02	3.68
VOYA	Voyageurs NP	MN	VOYA2	0.01	6.43	0.26	2.74	9.44	0.74
BLCA	Black Canyon of the Gunnison NM	CO	WEMI1	0.02	0.02	0.99	2.25	3.27	0.13
LAGA	La Garita Wilderness	CO	WEMI1	0.02	0.02	0.99	2.25	3.27	0.13
WEMI	Weminuche Wilderness	CO	WEMI1	0.02	0.02	0.99	2.25	3.27	0.13
WHIT	White Mountain Wilderness	NM	WHIT1	0.07	0.07	4.77	2.26	7.17	0.13
GORO	Goat Rocks Wilderness	WA	WHPA1	0.01	0.38	0.05	4.59	5.03	1.41
WHPA	Mount Adams Wilderness	WA	WHPA1	0.01	0.38	0.05	4.59	5.03	1.41
EANE	Eagles Nest Wilderness	CO	WHRI1	0.02	0.04	0.65	2.39	3.10	0.07
FLTO	Flat Tops Wilderness	CO	WHRI1	0.02	0.04	0.65	2.39	3.10	0.07
WEEL	West Elk Wilderness	CO	WHRI1	0.02	0.04	0.65	2.39	3.10	0.07
MABE	Maroon Bells-Snowmass Wilderness	CO	WHRI1	0.02	0.04	0.65	2.39	3.10	0.07
WICA	Wind Cave NP	SD	WICA1	0.01	1.87	0.56	3.10	5.53	1.57

Class I Site ID	Class I Area Name	State	IMPROVE Site ID	Non-US C3 Marine (Mm-1)	Canada Anthro. (Mm-1)	Mexico Anthro. (Mm-1)	Boundary Inter. Anthro (Mm-1)	Total Inter. Anthro (Mm-1)	Prescribed Fire (Mm-1)
WIMO	Wichita Mountains	OK	WIMO1	0.14	1.50	3.77	2.30	7.72	1.63
GRTE	Grand Teton NP	WY	YELL2	0.01	0.15	0.16	2.71	3.02	0.17
REDR	Red Rock Lakes	WY	YELL2	0.01	0.15	0.16	2.71	3.02	0.17
TETO	Teton Wilderness	WY	YELL2	0.01	0.15	0.16	2.71	3.02	0.17
YELL	Yellowstone NP	WY	YELL2	0.01	0.15	0.16	2.71	3.02	0.17
EMIG	Emigrant Wilderness	CA	YOSE1	0.01	0.06	0.25	5.70	6.02	0.19
YOSE	Yosemite NP	CA	YOSE1	0.01	0.06	0.25	5.70	6.02	0.19
ZION2	Zion NP	UT	ZICA1	0.03	0.02	1.05	2.88	3.98	0.07

Figure 5-1 shows a spatial map of the makeup and relative magnitude of the international anthropogenic and prescribed fire components (from Table 5-1). The individual components are C3 marine from outside the ECA region (yellow), Canada anthropogenic (light blue), Mexico anthropogenic (orange), international anthropogenic from boundary conditions (purple), and prescribed fire (brown). The pies are scaled based on the magnitude of the total contribution of the components (international anthropogenic plus prescribed fires). The total magnitude of the pies range from 3.0 to 19.7 Mm-1.

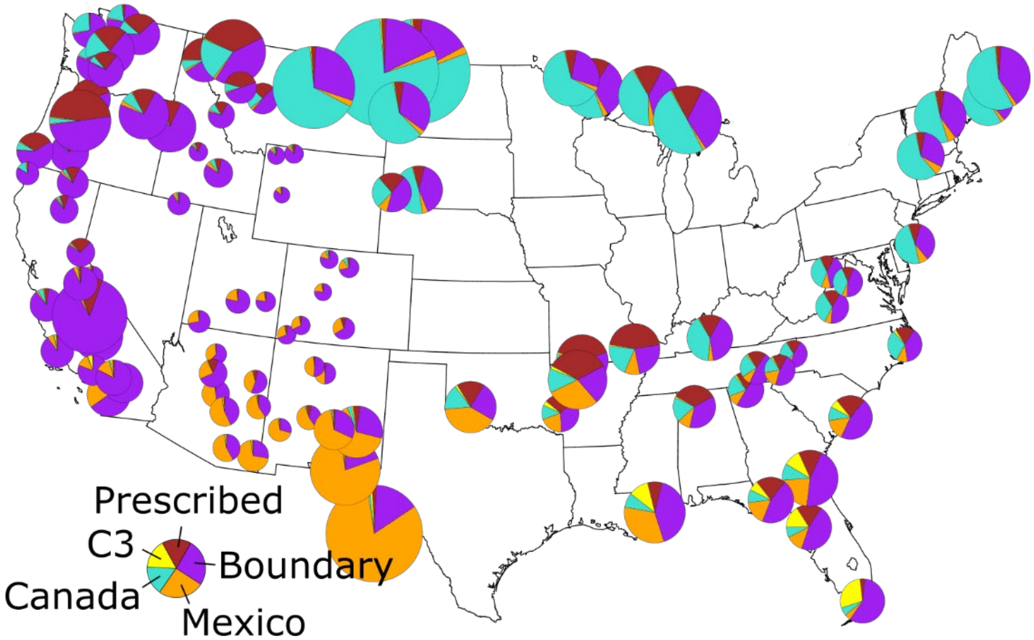

Figure 5-1- 2028 International anthropogenic and prescribed fire components- contribution to impairment on the 20% most impaired days

5.1 Calculation of Adjusted Endpoints

Table 5-2 below shows a range of 2028 adjusted glidepath values for each Class I area, including a "default" adjusted glidepath value and a minimum and maximum value. Although the prescribed fire contributions have been quantified (as shown in Table 5-1 and Figure 5-1 above) the "default" adjusted glidepath values in Table 5-2 only include the international anthropogenic contributions.

There are a number of reasons why the prescribed fire contributions were not included in the default adjustment:

1) The prescribed fire emissions represent a single year (2016) and do not take into account year-to-year variability.
2) Assignment of simulated fires emissions to wild and prescribed categories uses a heuristic land-use based methodology that adds uncertainty to the tagged estimate. This is especially true in the West where wild fires are more common.
3) The prescribed fire impacts are relatively small (~0-5 Mm-1) compared to the international anthropogenic impacts (~3-19 Mm-1).
4) Prescribed fire (along with other fire) impacts are likely already included (or partially included) in the estimated ambient natural conditions on the 20% most impaired days. The ambient methodology assigns all episodic fire contributions to natural, and splits the remaining fire contributions based on a constant fraction. Therefore, there is some question as to the appropriateness of adding the modeled prescribed fire impacts to the

ambient natural conditions. More analysis of both the model and ambient data is needed to further explore this issue.

In addition to the technical reasons, the international anthropogenic impacts were the focus of both the December 2018 Technical Guidance and the September 2018 Administrator's Regional Haze Reform Roadmap. The methodologies and handling of the prescribed fire emissions and modeled impacts have not been fully explored and vetted.

The default glidepath adjustment is one of several possible adjustment methodologies, each with its own assumptions. The default adjustment makes several assumptions:

1) bias correction (using relative modeling results) is proportional to the absolute modeled contribution,
2) the ambient natural conditions estimate can be consistently combined with the year-specific simulation, and
3) adding prescribed fires to ambient natural conditions may create double counting.

Bias correction (relative modeled results) can incorrectly assume that contributing sources account for observed bias. This is obviously incorrect when sources are known to be missing (e.g., windblown dust). In the case of a missing source, all other sources, including international impacts are inflated to account for the missing sources. An alternative to the assumption of proportional bias correction is to use absolute modeled international contributions.

Combining ambient natural conditions with modeled international and/or prescribed impacts assumes the two are consistent. This is obviously incorrect at 12 IMPROVE sites where the adjusted 2064 endpoint using international and prescribed fires added to the ambient natural conditions is greater than the present observed values (2014-2017 average data). An alternative is to use modeled natural (relative or absolute) with modeled international. One benefit of using modeled natural is that prescribed fire can be included without concern of double counting.

Due to the assumptions and associated uncertainty in the default adjustment calculations, we calculated alternative adjustment values using a combination of the absolute and relative model outputs, ambient-based and modeled natural conditions, and prescribed fire impacts. The full range of adjustment calculations are based on the following combinations of modeled and ambient data:

1) [**Default**] Relative international anthropogenic model contributions + ambient natural conditions
2) Absolute international anthropogenic model contributions + ambient natural conditions

3) Relative international anthropogenic and prescribed fire model contributions + relative modeled natural conditions
4) Absolute international anthropogenic and prescribed fire model contributions + absolute modeled natural conditions
5) Relative international anthropogenic and prescribed fire model contributions + ambient natural conditions

The results of the analysis are presented below in Table 5-2. The table includes the 2028 projected visibility impairment on the 20% most impaired days (green), the 2028 unadjusted and "default" adjusted glidepaths (light brown), and the low and high range of the 2028 alternative adjusted glidepath values (grey). See Appendix E for the unadjusted and adjusted 2064 endpoint values.

Table 5-2- 2028 visibility on the 20% most impaired days, the 2028 unadjusted glidepath, the 2028 "default" adjusted glidepath, and minimum and maximum alternative adjusted glidepath values.

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
ACAD	Acadia NP	ME	ACAD1	13.9	17.36	18.45	17.42	18.48
AGTI	Agua Tibia Wilderness	CA	AGTI1	15.48	16.03	17.22	16.76	17.85
BADL	Badlands NP	SD	BADL1	11.71	11.42	12.86	11.95	12.97
BALD	Mount Baldy Wilderness	AZ	BALD1	6.92	6.99	7.99	6.98	8.02
BAND	Bandelier NM	NM	BAND1	8	7.65	8.51	7.88	8.54
BIBE	Big Bend NP	TX	BIBE1	14.09	11.47	14.28	12.93	14.65
MOKE	Mokelumne Wilderness	CA	BLIS1	9.15	8.00	8.86	8.86	10.51
DESO	Desolation Wilderness	CA	BLIS1	9.15	8.00	8.86	8.86	10.51
BOAP	Bosque del Apache	NM	BOAP1	10.16	9.11	9.97	9.88	10.30

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
BOWA	Boundary Waters Canoe Area	MN	BOWA1	13.19	14.62	15.83	14.37	16.07
FITZ	Fitzpatrick Wilderness	WY	BRID1	6.43	6.34	7.05	6.73	7.11
BRID	Bridger Wilderness	WY	BRID1	6.43	6.34	7.05	6.73	7.11
BRIG	Brigantine	NJ	BRIG1	18.45	20.74	21.55	20.61	21.63
BRET2	Breton	LA	BRIS1	18.23	18.67	20.03	18.92	20.17
CABI	Cabinet Mountains Wilderness	MT	CABI1	9.69	8.70	9.52	9.52	10.76
CACR	Caney Creek Wilderness	AR	CACR1	16.97	18.18	18.88	18.70	19.39
ARCH	Arches NP	UT	CANY1	6.5	6.92	7.77	6.82	7.78
CANY	Canyonlands NP	UT	CANY1	6.5	6.92	7.77	6.82	7.78
CAPI	Capitol Reef NP	UT	CAPI1	6.85	6.85	7.88	7.17	7.90
CHAS	Chassahowitzka	FL	CHAS1	16.17	18.30	19.27	19.03	19.61
CHIW	Chiricahua Wilderness	AZ	CHIR1	8.95	8.27	9.45	8.48	9.46
GALI	Galiuro Wilderness	AZ	CHIR1	8.95	8.27	9.45	8.48	9.46
CHIR	Chiricahua NM	AZ	CHIR1	8.95	8.27	9.45	8.48	9.46
COHU	Cohutta Wilderness	GA	COHU1	16.57	21.36	22.09	21.53	22.24
DIPE	Diamond Peak Wilderness	OR	CRLA1	8.09	7.70	8.85	8.75	9.54

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
GEMO	Gearhart Mountain Wilderness	OR	CRLA1	8.09	7.70	8.85	8.75	9.54
MOLA	Mountain Lakes Wilderness	OR	CRLA1	8.09	7.70	8.85	8.75	9.54
CRLA	Crater Lake NP	OR	CRLA1	8.09	7.70	8.85	8.75	9.54
CRMO	Craters of the Moon NM	ID	CRMO1	8.2	9.13	10.17	9.81	10.26
DOME	Dome Land Wilderness	CA	DOME1	14.47	12.79	14.30	13.68	15.57
OTCR	Otter Creek Wilderness	WV	DOSO1	16.21	20.54	21.29	20.40	21.40
DOSO	Dolly Sods Wilderness	WV	DOSO1	16.21	20.54	21.29	20.40	21.40
EVER	Everglades NP	FL	EVER1	13.95	15.06	16.22	15.86	16.70
GAMO	Gates of the Mountains Wilderness	MT	GAMO1	7.24	7.23	8.17	8.09	8.53
GICL	Gila Wilderness	NM	GICL1	7.25	7.05	8.00	7.30	8.02
GLAC	Glacier NP	MT	GLAC1	13.32	12.29	13.58	13.21	14.35
GRCA	Grand Canyon NP	AZ	GRCA2	6.56	6.44	7.32	7.19	7.59
PRRA	Presidential Range-Dry River Wilderness	NH	GRGU1	12.17	17.07	18.22	16.63	18.28
GRGU	Great Gulf Wilderness	NH	GRGU1	12.17	17.07	18.22	16.63	18.28

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
GRSA	Great Sand Dunes NM	CO	GRSA1	7.71	7.58	8.42	7.38	8.55
JOYC	Joyce-Kilmer-Slickrock Wilderness	TN	GRSM1	16.08	21.51	22.17	21.40	22.30
GRSM	Great Smoky Mountains NP	TN	GRSM1	16.08	21.51	22.17	21.40	22.30
CAVE	Carlsbad Caverns NP	TX	GUMO1	12.48	10.69	12.99	11.32	13.25
GUMO	Guadalupe Mountains NP	TX	GUMO1	12.48	10.69	12.99	11.32	13.25
HECA	Hells Canyon Wilderness	OR	HECA1	12.21	12.53	13.93	13.23	14.29
HEGL	Hercules-Glades Wilderness	MO	HEGL1	17.44	18.82	19.63	19.53	20.18
HOOV	Hoover Wilderness	CA	HOOV1	7.73	7.35	8.21	7.76	8.33
PIMO	Pine Mountain Wilderness	AZ	IKBA1	8.99	8.80	9.82	9.43	9.92
MAZA	Mazatzal Wilderness	AZ	IKBA1	8.99	8.80	9.82	9.43	9.92
ISLE	Isle Royale NP	MI	ISLE1	14.87	15.78	16.91	15.13	17.10
JARB	Jarbidge Wilderness	NV	JARB1	7.82	7.33	8.19	7.82	8.26
JARI	James River Face Wilderness	VA	JARI1	16.4	20.64	21.35	20.52	21.48
JOSH	Joshua Tree NM	CA	JOSH1	12.5	13.08	14.40	14.01	14.73

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
ANAD	Ansel Adams Wilderness (Minarets)	CA	KAIS1	10.72	10.18	11.31	10.61	11.71
JOMU	John Muir Wilderness	CA	KAIS1	10.72	10.18	11.31	10.61	11.71
KAIS	Kaiser Wilderness	CA	KAIS1	10.72	10.18	11.31	10.61	11.71
KALM	Kalmiopsis Wilderness	OR	KALM1	11.74	11.13	11.87	11.87	13.28
SOWA	South Warner Wilderness	CA	LABE1	9.64	9.24	10.17	10.17	10.55
LABE	Lava Beds NM	CA	LABE1	9.64	9.24	10.17	10.17	10.55
CARI	Caribou Wilderness	CA	LAVO1	9.81	9.36	10.24	10.24	10.51
THLA	Thousand Lakes Wilderness	CA	LAVO1	9.81	9.36	10.24	10.24	10.51
LAVO	Lassen Volcanic NP	CA	LAVO1	9.81	9.36	10.24	10.24	10.51
LIGO	Linville Gorge Wilderness	NC	LIGO1	15.15	20.71	21.29	20.70	21.40
LOST	Lostwood	ND	LOST1	15.26	13.31	16.13	15.22	16.20
LYBR2	Lye Brook Wilderness	VT	LYEB1	13.94	18.23	19.25	17.65	19.31
MACA	Mammoth Cave NP	KY	MACA1	19.5	21.81	22.74	21.51	22.90
MELA	Medicine Lake	MT	MELA1	14.45	12.36	15.26	13.87	15.30
MEVE	Mesa Verde NP	CO	MEVE1	6.3	7.22	8.00	7.24	8.03
MING	Mingo	MO	MING1	18.88	19.48	20.22	20.10	20.73

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
MOHO	Mount Hood Wilderness	OR	MOHO1	8.95	9.90	10.71	10.62	12.86
BOMA	Bob Marshall Wilderness	MT	MONT1	9.26	8.68	9.41	9.41	10.11
SCAP	Scapegoat Wilderness	MT	MONT1	9.26	8.68	9.41	9.41	10.11
MIMO	Mission Mountains Wilderness	MT	MONT1	9.26	8.68	9.41	9.41	10.11
ROCA	Roosevelt Campobello International Park	ME	MOOS1	12.73	16.38	17.76	16.62	17.80
MOOS	Moosehorn	ME	MOOS1	12.73	16.38	17.76	16.62	17.80
MORA	Mount Rainier NP	WA	MORA1	12.22	12.98	14.01	14.01	14.50
RAWA	Rawah Wilderness	CO	MOZI1	5.17	5.64	6.48	5.81	6.51
MOZI	Mount Zirkel Wilderness	CO	MOZI1	5.17	5.64	6.48	5.81	6.51
WASH	Washakie Wilderness	WY	NOAB1	6.8	7.08	7.82	7.25	7.88
NOAB	North Absaroka Wilderness	WY	NOAB1	6.8	7.08	7.82	7.25	7.88
GLPE	Glacier Peak Wilderness	WA	NOCA1	9.95	10.29	11.36	11.31	11.43
NOCA	North Cascades NP	WA	NOCA1	9.95	10.29	11.36	11.31	11.43
WOLF	Wolf Island	GA	OKEF1	16.83	18.99	20.17	19.73	20.45
OKEF	Okefenokee	GA	OKEF1	16.83	18.99	20.17	19.73	20.45

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
OLYM	Olympic NP	WA	OLYM1	11.62	11.71	12.80	12.80	13.61
PASA	Pasayten Wilderness	WA	PASA1	9.09	8.63	9.68	9.66	10.21
PEFO	Petrified Forest NP	AZ	PEFO1	7.97	7.57	8.50	8.14	8.61
VENT	Ventana Wilderness	CA	PINN1	13.49	12.99	13.99	13.99	14.79
PINN	Pinnacles NM	CA	PINN1	13.49	12.99	13.99	13.99	14.79
RAFA	San Rafael Wilderness	CA	RAFA1	13.4	13.08	14.12	14.07	15.28
REDW	Redwood NP	CA	REDW1	12.5	11.60	12.24	12.24	13.31
ROMA	Cape Romain	SC	ROMA1	16.95	19.07	19.91	18.87	20.11
ROMO	Rocky Mountain NP	CO	ROMO1	7.98	8.64	9.42	8.40	9.45
SACR	Salt Creek	NM	SACR1	14.49	12.12	13.80	12.68	13.98
CUCA	Cucamonga Wilderness	CA	SAGA1	12.5	13.18	14.21	13.91	14.48
SAGA	San Gabriel Wilderness	CA	SAGA1	12.5	13.18	14.21	13.91	14.48
SAJA	San Jacinto Wilderness	CA	SAGO1	13.2	14.74	15.91	15.68	15.95
SAGO	San Gorgonio Wilderness	CA	SAGO1	13.2	14.74	15.91	15.68	15.95
SAGU	Saguaro NM	AZ	SAGU1	10.29	9.65	10.68	10.09	10.69
SAMA	St. Marks	FL	SAMA1	16.42	18.42	19.36	19.01	19.59
SAPE	San Pedro Parks Wilderness	NM	SAPE1	6.21	5.94	6.84	5.72	6.86

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
SAWT	Sawtooth Wilderness	ID	SAWT1	8.31	7.64	8.33	8.00	8.93
SENE	Seney	MI	SENE1	16.82	18.62	19.80	17.98	19.98
KICA	Kings Canyon NP	CA	SEQU1	17.16	16.41	18.41	17.53	19.78
SEQU	Sequoia NP	CA	SEQU1	17.16	16.41	18.41	17.53	19.78
SHEN	Shenandoah NP	VA	SHEN1	15.82	20.80	21.47	20.28	21.56
SHRO	Shining Rock Wilderness	NC	SHRO1	14.33	20.87	21.50	20.46	21.60
SIPS	Sipsey Wilderness	AL	SIPS1	18	20.44	21.16	20.86	21.74
ALLA	Alpine Lake Wilderness	WA	SNPA1	12.28	12.12	13.27	13.27	13.54
EACA	Eagle Cap Wilderness	OR	STAR1	10.88	11.35	12.69	12.04	12.90
STMO	Strawberry Mountain Wilderness	OR	STAR1	10.88	11.35	12.69	12.04	12.90
ANAC	Anaconda-Pintler Wilderness	MT	SULA1	7.79	8.23	9.07	9.04	9.30
SELW	Selway-Bitterroot Wilderness	MT	SULA1	7.79	8.23	9.07	9.04	9.30
SWAN	Swanquarter	NC	SWAN1	15.75	18.08	18.80	18.08	18.93
SYCA2	Sycamore Canyon Wilderness	AZ	SYCA2	11.8	9.17	10.15	9.93	11.47
THRO	Theodore Roosevelt NP	ND	THRO1	12.83	12.19	14.04	13.04	14.12

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
MOJE	Mount Jefferson Wilderness	OR	THSI1	11.26	10.60	11.62	11.62	13.09
MOWA	Mount Washington Wilderness	OR	THSI1	11.26	10.60	11.62	11.62	13.09
THIS	Three Sisters Wilderness	OR	THSI1	11.26	10.60	11.62	11.62	13.09
SUPE	Superstition Wilderness	AZ	TONT1	9.97	9.03	10.12	9.76	10.37
ULBE	UL Bend	MT	ULBE1	11.03	10.00	12.37	10.92	12.41
UPBU	Upper Buffalo Wilderness	AR	UPBU1	16.92	18.32	19.29	19.18	19.72
VOYA	Voyageurs NP	MN	VOYA2	13.26	14.38	15.64	14.01	15.73
BLCA	Black Canyon of the Gunnison NM	CO	WEMI1	6.46	6.28	7.07	6.36	7.10
LAGA	La Garita Wilderness	CO	WEMI1	6.46	6.28	7.07	6.36	7.10
WEMI	Weminuche Wilderness	CO	WEMI1	6.46	6.28	7.07	6.36	7.10
WHIT	White Mountain Wilderness	NM	WHIT1	9.84	8.74	10.20	8.79	10.26
WHPA	Mount Adams Wilderness	WA	WHPA1	7.87	8.75	9.71	9.32	10.60
GORO	Goat Rocks Wilderness	WA	WHPA1	7.87	8.75	9.71	9.32	10.60
EANE	Eagles Nest Wilderness	CO	WHRI1	4.71	4.99	5.81	5.12	5.83

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	2028 Projected 20% most impaired days (dv)	2028 Unadjusted Glidepath 20% most Impaired days(dv)	2028 Default Adjusted Glidepath (dv)	2028 Minimum Alternative Adjusted Glidepath (dv)	2028 Maximum Alternative Adjusted Glidepath (dv)
FLTO	Flat Tops Wilderness	CO	WHRI1	4.71	4.99	5.81	5.12	5.83
WEEL	West Elk Wilderness	CO	WHRI1	4.71	4.99	5.81	5.12	5.83
MABE	Maroon Bells-Snowmass Wilderness	CO	WHRI1	4.71	4.99	5.81	5.12	5.83
WICA	Wind Cave NP	SD	WICA1	9.93	10.11	11.21	10.75	11.47
WIMO	Wichita Mountains	OK	WIMO1	16.93	16.06	17.36	16.62	17.79
GRTE	Grand Teton NP	WY	YELL2	7.38	6.57	7.31	7.31	7.77
REDR	Red Rock Lakes	WY	YELL2	7.38	6.57	7.31	7.31	7.77
TETO	Teton Wilderness	WY	YELL2	7.38	6.57	7.31	7.31	7.77
YELL	Yellowstone NP	WY	YELL2	7.38	6.57	7.31	7.31	7.77
EMIG	Emigrant Wilderness	CA	YOSE1	11.44	10.63	11.74	11.37	12.42
YOSE	Yosemite NP	CA	YOSE1	11.44	10.63	11.74	11.37	12.42
ZION2	Zion NP	UT	ZICA1	8.31	8.47	9.33	8.85	9.40

Appendix B contains individual IMPROVE site (Class I area) plots of the 2016 modeled and 2028 projected visibility impairment, components, sector contributions, and unadjusted and adjusted glidepaths. Appendix E contains additional tabular information for the 2064 unadjusted and adjusted endpoints.

Figure 5-2 shows the total international anthropogenic impact on the 20% most impaired days (in deciviews). This is the adjustment that was applied to ambient natural conditions to get the "default" adjusted 2064 endpoint.

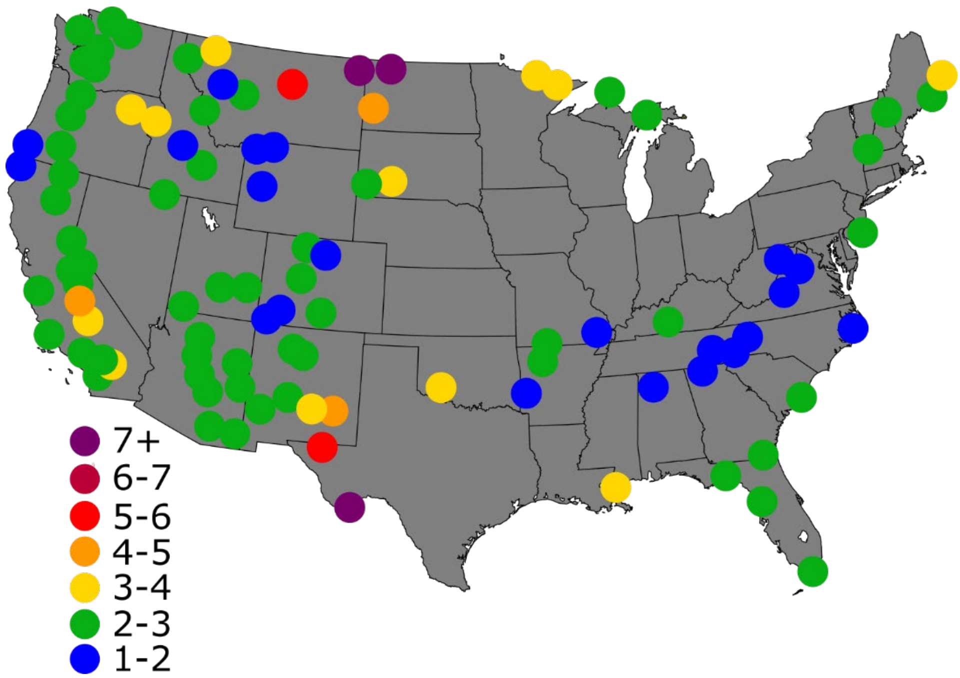

Figure 5-2 Adjustment to 2064 endpoint from international anthropogenic impacts on the 20% most impaired days (in deciviews)

Given the range of the default and alternative adjusted glidepath values, we recommend further evaluation of both the adjusted glidepath and natural conditions values on an area-by-area basis. The individual IMPROVE site plots (Appendix B) show the default adjusted endpoint as well as the full range of alternative glidepath adjustment values. Many sites (especially in the East) are below the range of potential 2028 adjusted glidepath values, as well as the unadjusted glidepath. Although more can be learned from further examination of the modeled and ambient data at these sites, it is very likely that these sites will be below the 2028 glidepath. However, there are large number of sites where the 2028 projected impairment is within the range of alternative glidepath values (higher than the minimum but lower than the maximum). Further data analysis at these sites may help bolster the understanding of the range of values and evaluate the likelihood that the area will be below an appropriate adjusted glidepath.

The EPA modeling results, state/RPO modeling results, and ambient data analyses can be used to further evaluate both the natural conditions values and potential endpoint adjustments. Analyses can examine the magnitude of each of the components of the adjusted glidepath (including model bias); the natural conditions value(s), the international anthropogenic contribution values, and the prescribed fire contribution values.

6.0 Summary

The goal of this modeling effort was to project 2028 visibility conditions and calculate source sector contribution information, including international anthropogenic impacts, for each mandatory Class I federal area/IMPROVE site. In particular, this modeling provides the first comprehensive estimate of international anthropogenic emissions contributions to visibility impairment at Class I areas.

In the updated modeling, 47 out of 99 IMPROVE sites are projected to be above the 2028 unadjusted glidepath. After applying the "default" glidepath adjustment to account for international anthropogenic emissions sources, there are only 8 IMPROVE sites projected to be above the adjusted glidepath in 2028. However, that number climbs to 26 sites (above the adjusted glidepath) when comparing 2028 projected visibility impairment to the "minimum alternative" adjusted glidepath. Due to the uncertainty in many of the calculations and modeling and ambient data, additional scrutiny of the initial glidepath adjustments are warranted. States should consult with their EPA Regional Office to determine the usefulness of these model results (including glidepath adjustments) for any particular Class I area.

We have also identified several aspects of this modeling that can be further examined and improved through coordination with interested stakeholders. These include, but are not limited to:

- Improved treatment of natural sources of fugitive dust.
    - Inclusion of natural wind-blown dust emissions may help reduce the uncertainty associated with the source of fugitive dust.
- Improved secondary organic aerosol (SOA) chemistry.
    - Improvements in the SOA chemistry have already been made in CAMx version 7, but SOA is still largely overpredicted in the summer in the Southeast.
- Further review of "natural visibility conditions" used in the glidepath framework which can be informed by the findings of this modeling and other modeling and data analyses.
    - Comparison of the modeled natural conditions and ambient natural conditions indicates that ambient natural conditions values at some sites may be too high or too low.
- Further review of the classification and magnitude of prescribed fire emissions.
    - For a number of reasons, outlined in section 5.1, the prescribed fire contributions are uncertain. Additional analysis of the prescribed fire emissions and the appropriateness of adding modeled prescribed fire impacts to ambient derived natural conditions values is needed.

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Appendix A

Model Performance Evaluation Plots

Contents

1. Model Evaluation Statistics and Regions

In order to estimate the ability of CAMx to replicate the 2011 base year concentrations of $PM_{2.5}$ and its speciated components, an operational model performance evaluation was conducted. For this evaluation, mean bias and normalized mean bias, mean error and normalized mean error, and Pearson's correlation coefficient were used.

Mean bias (MB) is the average difference between predicted (P) and observed (O) concentrations for a given number of samples (n):

$$MB\ (\mu g\ m^{-3}) = \frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)$$

Mean error (ME) is the average absolute value of the difference between predicted and observed concentrations for a given number of samples:

$$ME\ (\mu g\ m^{-3}) = \frac{1}{n}\sum_{i=1}^{n}|P_i - O_i|$$

Normalized mean bias (NMB) is the sum of the difference between predicted and observed values divided by the sum of the observed values:

$$NMB\ (\%) = \frac{\sum_1^n(P - O)}{\sum_1^n(O)} * 100$$

Normalized mean error (NME) is the sum of the absolute value of the difference between predicted and observed values divided by the sum of the observed values:

$$NME\ (\%) = \frac{\sum_1^n|P - O|}{\sum_1^n(O)} * 100$$

Pearson's correlation coefficient is defined as:

$$r = \frac{\sum_{i=1}^{n}(P_i - \bar{P})(O_i - \bar{O})}{\sqrt{\sum_{i=1}^{n}(P_i - \bar{P})^2}\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2}}$$

Model predictions were paired in space and time with observational data from the AQS (ozone), IMPROVE, CSN, and CASTNET monitoring networks. These results were organized by network, season (winter (DJF), spring (MAM), summer (JJA), and fall (SON)), and NOAA climate region (Figure 1).

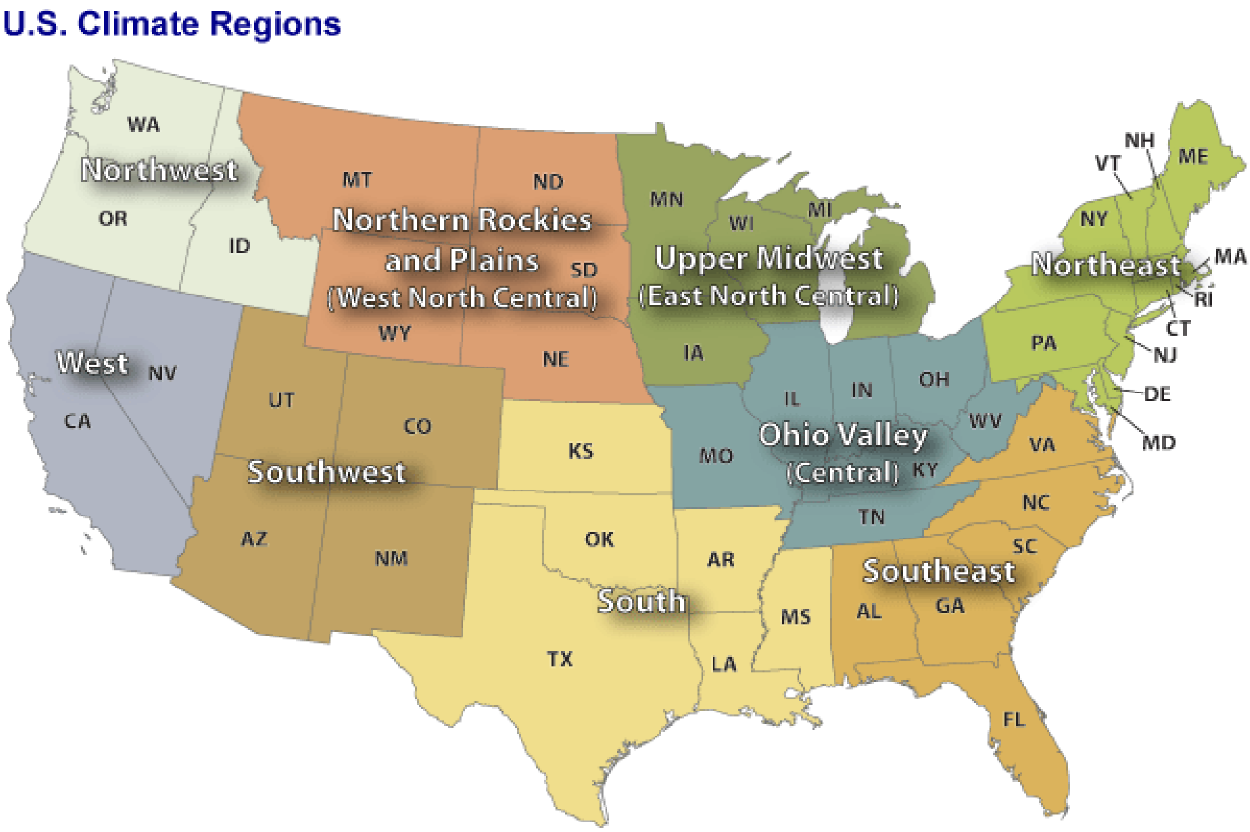


Figure 1. Climate regions used for aggregating model performance. Source: https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php

2. 8-hour maximum ozone

Table 2-1 summarizes model performance statistics for 8-hour average ozone. Boxplot comparisons of model predictions and observations (AQS and CASTNET) by month for each climate region are shown in Figures 1 and 2.

Table 2-1. Model performance statistics for 8-hour maximum ozone by region, network, and season.

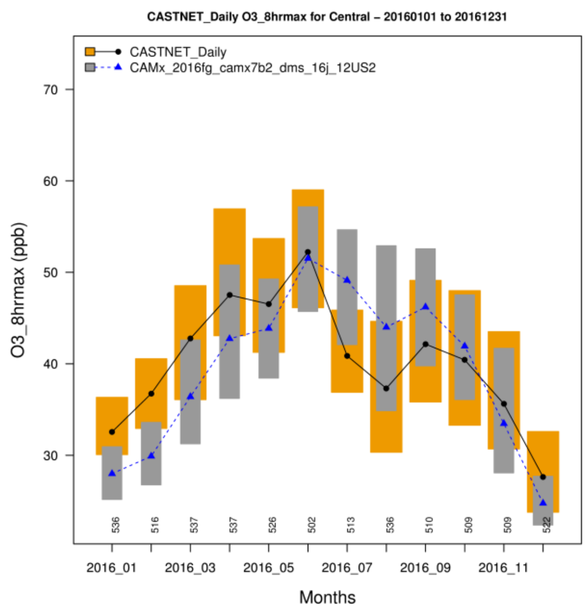
Region	Network	Season	N	Avg. Obs. ppb	Avg. Mod. ppb	R	NMB (%)	NME (%)	MB ppb	ME ppb
Northeast	AQS (MDA8)	**Winter**	11462	32.3	25.0	0.7	-22.6	23.9	-7.3	7.7
		Spring	15701	44.3	36.5	0.8	-17.8	19.8	-7.9	8.8
		Summer	16686	45.3	47.9	0.8	5.7	14.5	2.6	6.6
		Fall	13780	34.4	34.7	0.8	0.8	14.5	0.3	5.0

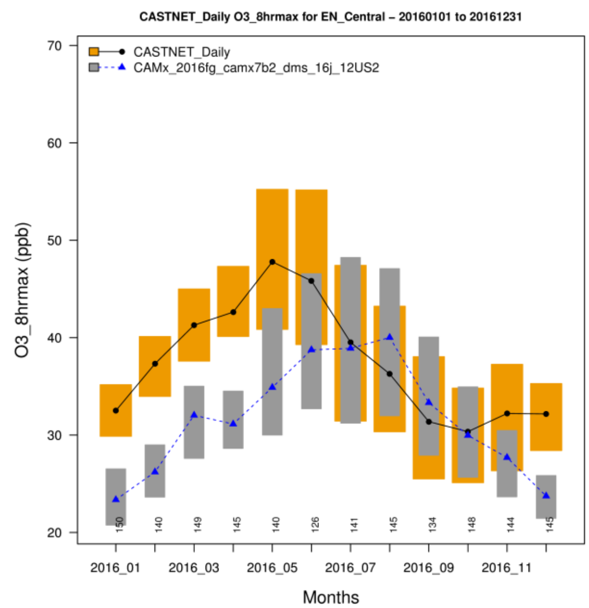
Region	Network	Season	N	Avg. Obs. ppb	Avg. Mod. ppb	R	NMB (%)	NME (%)	MB ppb	ME ppb
		All	57629	39.9	37.1	0.8	-7.0	17.6	-2.8	7.0
	CASTNET (MDA8)	**Winter**	1283	34.4	26.5	0.7	-23.2	23.8	-8.0	8.2
		Spring	1336	45.0	36.5	0.8	-18.8	20.4	-8.5	9.2
		Summer	1315	42.5	44.5	0.8	4.8	14.1	2.0	6.0
		Fall	1306	33.8	34.5	0.8	2.1	14.5	0.7	4.9
		All	5240	39.0	35.5	0.8	-8.8	18.1	-3.4	7.1
Southeast	**AQS (MDA8)**	**Winter**	7196	36.0	32.1	0.8	-10.8	15.5	-3.9	5.6
		Spring	14569	46.5	43.8	0.8	-5.8	11.4	-2.7	5.3
		Summer	15855	39.4	42.9	0.8	8.8	16.4	3.5	6.5
		Fall	12589	40.6	42.2	0.8	4.0	12.5	1.6	5.1
		All	50209	41.3	41.4	0.8	0.4	13.7	0.2	5.7
	CASTNET (MDA8)	**Winter**	887	37.2	31.6	0.8	-15.1	17.3	-5.6	6.5
		Spring	947	47.9	43.6	0.8	-9.1	12.2	-4.4	5.8
		Summer	926	39.0	43.0	0.8	10.2	16.8	4.0	6.6
		Fall	928	41.6	42.7	0.7	2.7	13.0	1.1	5.4
		All	3688	41.5	40.3	0.7	-2.9	14.6	-1.2	6.1
Ohio Valley	**AQS (MDA8)**	**Winter**	4178	30.2	24.7	0.8	-18.1	20.4	-5.5	6.2
		Spring	15498	45.3	40.5	0.8	-10.6	14.5	-4.8	6.6
		Summer	20501	45.4	48.8	0.7	7.5	16.2	3.4	7.4
		Fall	14041	38.7	40.6	0.9	5.0	12.0	2.0	4.6
		All	54218	42.5	42.5	0.8	0.0	14.9	0.0	6.3
	CASTNET (MDA8)	**Winter**	1574	32.9	27.8	0.8	-15.4	17.9	-5.1	5.9
		Spring	1600	46.3	41.6	0.8	-10.2	13.6	-4.7	6.3
		Summer	1551	43.7	47.8	0.7	9.2	17.1	4.0	7.5
		Fall	1528	40.0	41.1	0.8	2.7	11.7	1.1	4.7
		All	6253	40.7	39.5	0.8	-3.0	15.0	-1.2	6.1
		Winter	1719	31.1	22.8	0.7	-26.6	27.4	-8.3	8.5

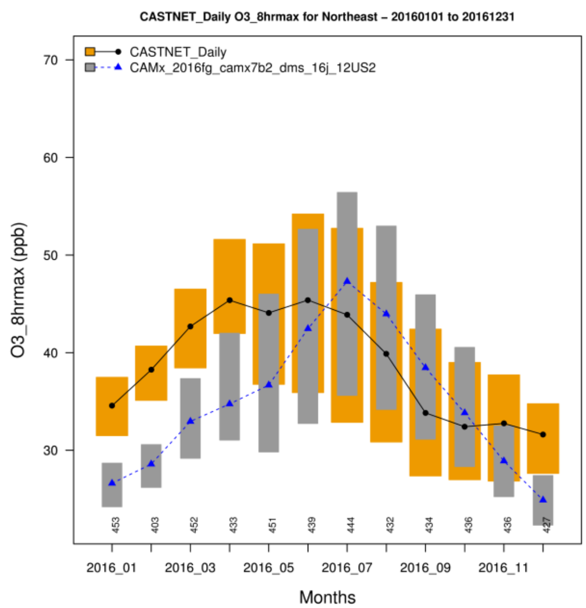
Region	Network	Season	N	Avg. Obs. ppb	Avg. Mod. ppb	R	NMB (%)	NME (%)	MB ppb	ME ppb
Upper Midwest	**AQS (MDA8)**	**Spring**	6892	44.6	35.4	0.8	-20.7	21.8	-9.3	9.7
		Summer	9742	42.2	42.4	0.8	0.4	14.7	0.2	6.2
		Fall	6050	31.7	32.8	0.8	3.7	12.4	1.2	3.9
		All	24403	39.5	36.7	0.8	-7.2	17.2	-2.8	6.8
	CASTNET (MDA8)	**Winter**	435	33.5	24.5	0.7	-27.0	27.4	-9.0	9.2
		Spring	434	44.9	34.0	0.9	-24.4	24.4	-10.9	11.0
		Summer	412	41.3	39.8	0.8	-3.6	12.9	-1.5	5.3
		Fall	426	31.6	30.9	0.8	-2.0	12.1	-0.6	3.8
		All	1707	37.8	32.2	0.8	-14.8	19.5	-5.6	7.4
South	**AQS (MDA8)**	**Winter**	11432	33.5	29.5	0.8	-12.1	16.5	-4.1	5.5
		Spring	13093	43.8	42.0	0.7	-4.2	14.0	-1.8	6.1
		Summer	12819	38.4	40.4	0.8	5.1	17.6	2.0	6.8
		Fall	12443	39.6	40.8	0.8	3.0	12.5	1.2	5.0
		All	49787	39.0	38.4	0.8	-1.6	15.0	-0.6	5.9
	CASTNET (MDA8)	**Winter**	523	36.2	31.9	0.8	-11.9	15.3	-4.3	5.5
		Spring	532	45.1	42.3	0.7	-6.4	13.1	-2.9	5.9
		Summer	508	38.9	39.3	0.7	1.2	16.6	0.5	6.4
		Fall	528	39.0	40.5	0.8	4.0	11.3	1.6	4.4
		All	2091	39.8	38.5	0.7	-3.3	14.0	-1.3	5.6
Southwest	**AQS (MDA8)**	**Winter**	9695	38.7	34.5	0.6	-10.8	16.0	-4.2	6.2
		Spring	10608	51.1	44.5	0.7	-12.9	14.8	-6.6	7.6
		Summer	10549	53.9	51.3	0.6	-4.8	11.7	-2.6	6.3
		Fall	10298	40.9	41.8	0.6	2.2	12.2	0.9	5.0
		All	41150	46.4	43.2	0.7	-6.8	13.6	-3.1	6.3
	CASTNET (MDA8)	**Winter**	757	44.8	37.4	0.5	-16.6	17.4	-7.4	7.8
		Spring	810	52.6	43.6	0.6	-17.0	17.5	-9.0	9.2
		Summer	812	53.4	49.7	0.6	-6.8	10.3	-3.6	5.5

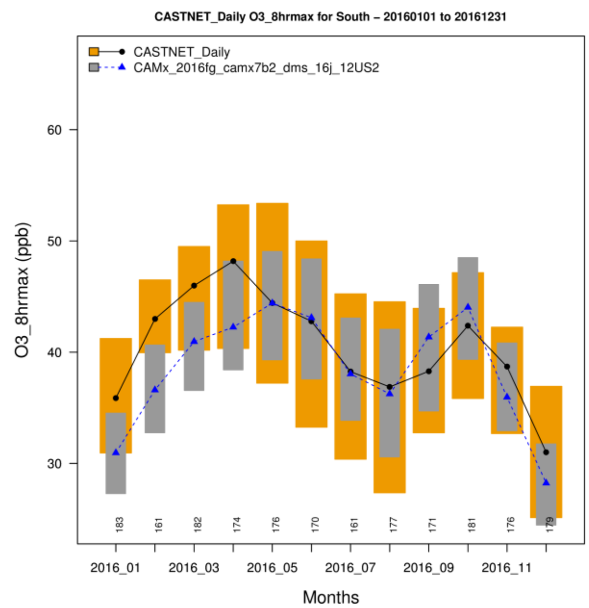
Region	Network	Season	N	Avg. Obs. ppb	Avg. Mod. ppb	R	NMB (%)	NME (%)	MB ppb	ME ppb
		Fall	791	43.7	42.4	0.7	-2.9	8.8	-1.3	3.9
		All	3170	48.7	43.4	0.7	-10.9	13.5	-5.3	6.6
Northern Rockies & Plains	**AQS (MDA8)**	**Winter**	4740	37.1	30.4	0.8	-18.1	19.8	-6.7	7.3
		Spring	5066	43.6	36.1	0.7	-17.2	18.7	-7.5	8.2
		Summer	5134	46.2	43.8	0.7	-5.2	11.4	-2.4	5.3
		Fall	4940	33.8	33.3	0.8	-1.5	12.8	-0.5	4.3
		All	19880	40.3	36.0	0.8	-10.6	15.5	-4.3	6.3
	CASTNET (MDA8)	**Winter**	748	38.6	31.8	0.7	-17.4	20.2	-6.7	7.8
		Spring	783	45.9	36.9	0.8	-19.7	20.2	-9.1	9.3
		Summer	783	48.4	44.4	0.7	-8.3	11.5	-4.0	5.6
		Fall	687	36.7	34.8	0.8	-5.2	12.6	-1.9	4.6
		All	3001	42.6	37.1	0.8	-13.0	16.1	-5.5	6.9
Northwest	**AQS (MDA8)**	**Winter**	677	32.3	26.2	0.8	-18.8	23.5	-6.1	7.6
		Spring	1288	40.3	34.3	0.6	-14.9	20.2	-6.0	8.1
		Summer	2444	37.5	37.3	0.8	-0.6	16.1	-0.2	6.0
		Fall	1236	31.3	31.5	0.6	0.6	19.1	0.2	6.0
		All	5645	36.1	34.0	0.7	-6.0	18.5	-2.2	6.7
	CASTNET (MDA8)	**Winter**	-	-	-	-	-	-	-	-
		Spring	-	-	-	-	-	-	-	-
		Summer	-	-	-	-	-	-	-	-
		Fall	-	-	-	-	-	-	-	-
		All	-	-	-	-	-	-	-	-
West	**AQS (MDA8)**	**Winter**	14550	34.6	32.3	0.7	-6.4	16.0	-2.2	5.5
		Spring	17190	46.1	41.2	0.8	-10.6	14.6	-4.9	6.7
		Summer	18046	53.3	51.8	0.8	-2.7	15.6	-1.4	8.3
		Fall	16163	43.1	41.9	0.8	-2.8	13.6	-1.2	5.9
		All	65949	44.8	42.3	0.8	-5.5	14.9	-2.4	6.7

Region	Network	Season	N	Avg. Obs. ppb	Avg. Mod. ppb	R	NMB (%)	NME (%)	MB ppb	ME ppb
	CASTNET (MDA8)	**Winter**	506	39.7	36.2	0.5	-8.6	14.1	-3.4	5.6
		Spring	519	48.0	41.4	0.8	-13.9	15.7	-6.7	7.5
		Summer	526	60.6	53.4	0.8	-11.8	14.5	-7.2	8.8
		Fall	530	46.6	43.5	0.8	-6.8	11.4	-3.2	5.3
		All	2081	48.8	43.7	0.8	-10.5	14.0	-5.1	6.8









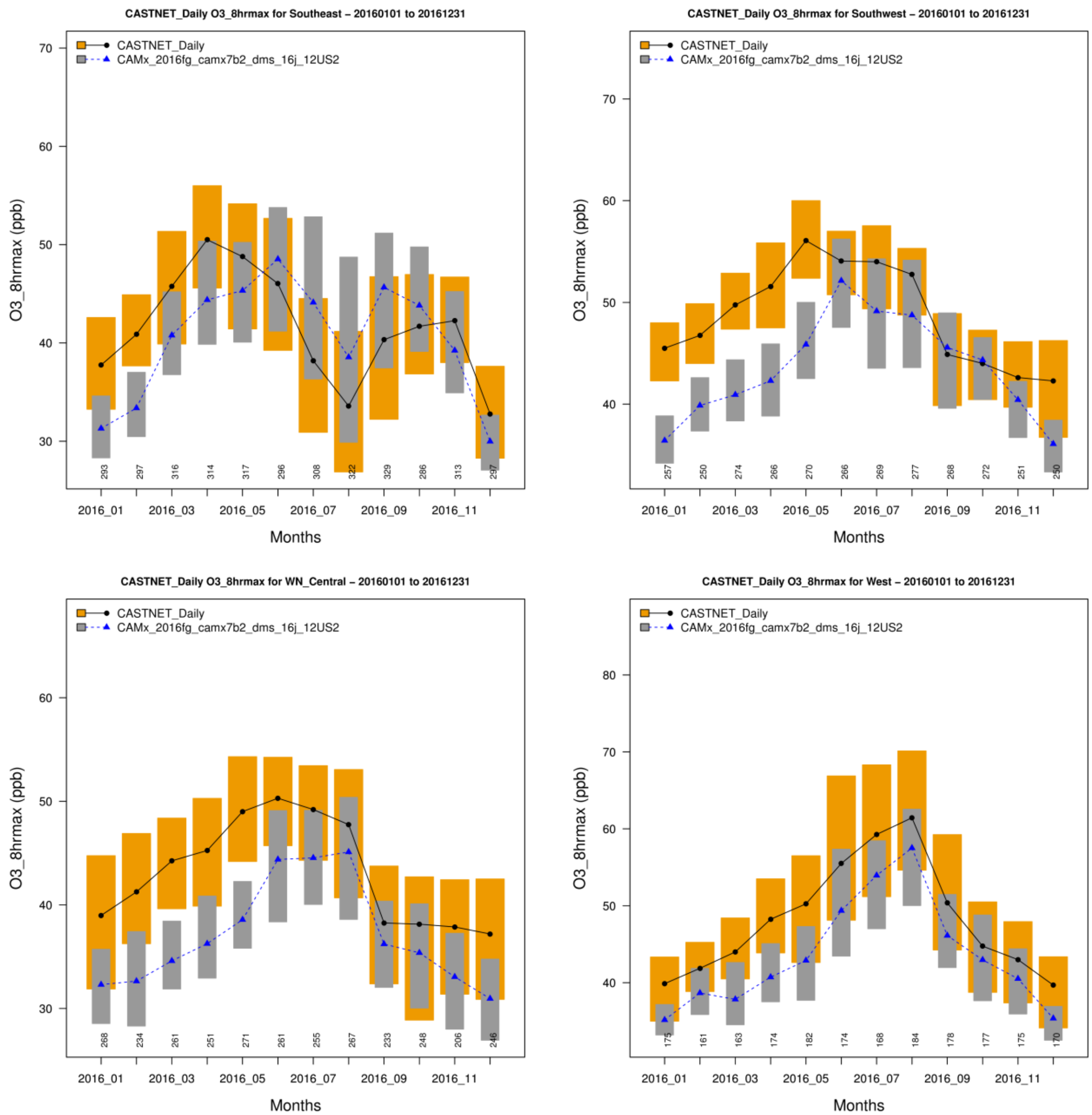
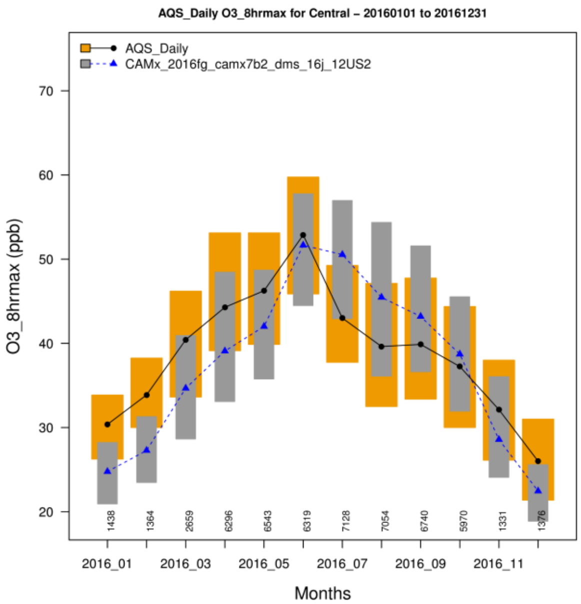


Figure 1. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CASTNET_Daily 8-hour maximum ozone observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.


AQS_Daily O3_8hrmax for Central – 20160101 to 20161231
AQS_Daily
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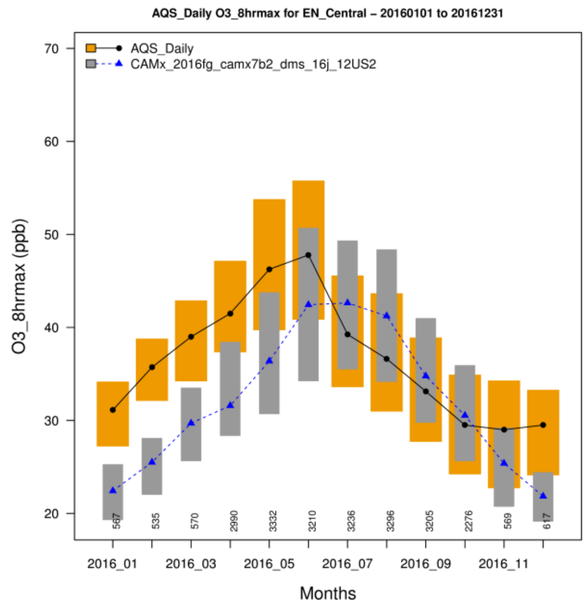
O3_8hrmax (ppb)
Months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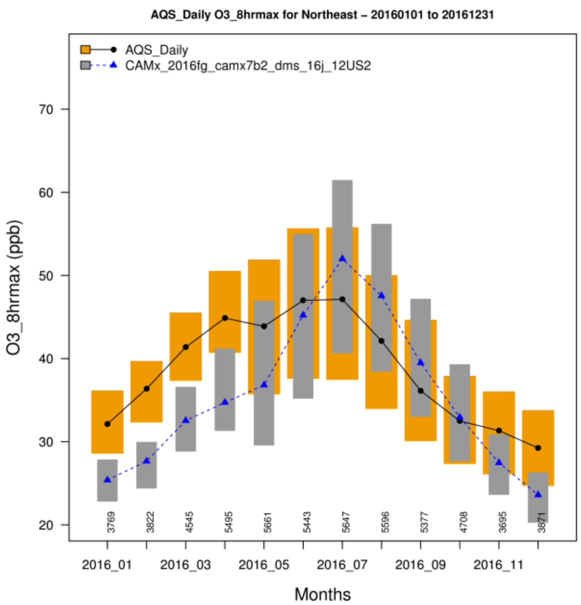
O3_8hrmax (ppb)
Months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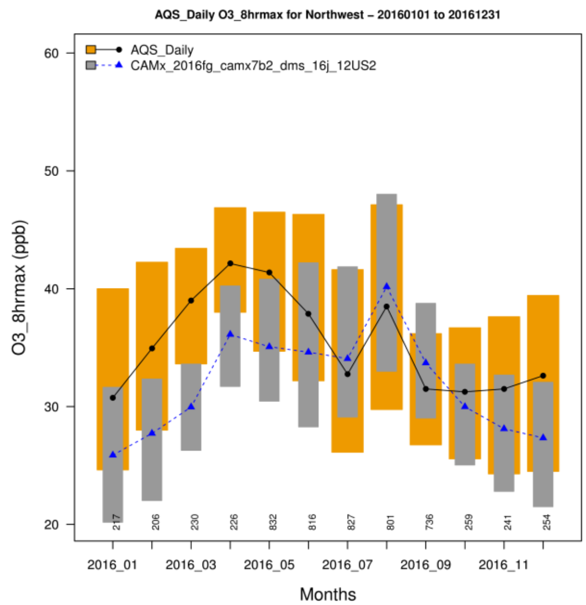
O3_8hrmax (ppb)
Months


AQS_Daily O3_8hrmax for Northwest – 20160101 to 20161231
AQS_Daily
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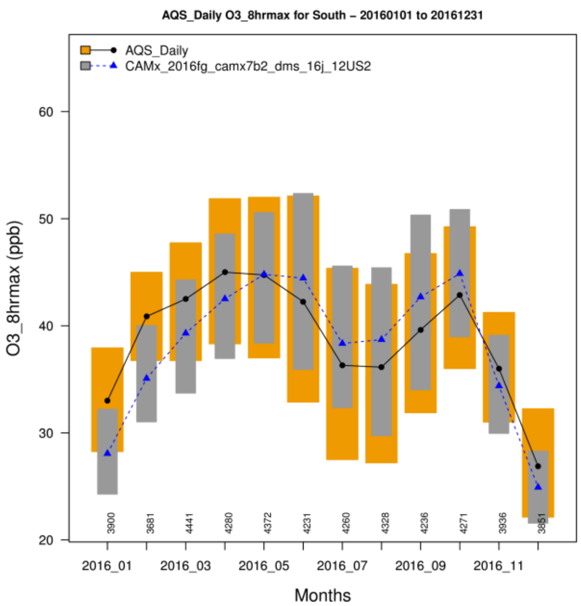
O3_8hrmax (ppb)
Months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Months
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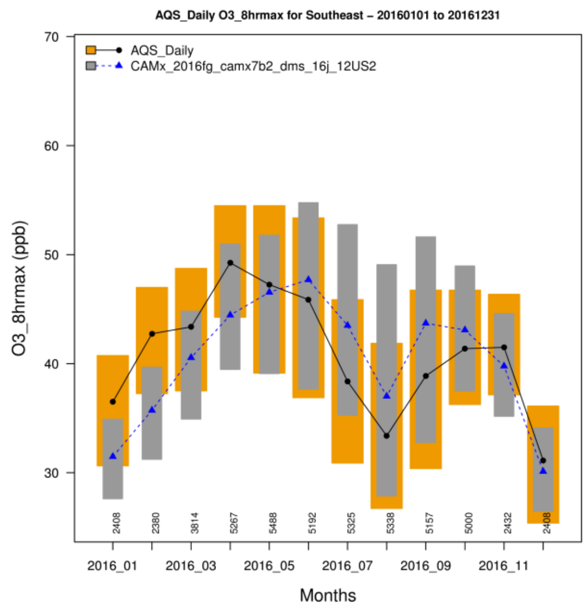
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11


AQS_Daily O3_8hrmax for Southeast – 20160101 to 20161231
AQS_Daily
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O3_8hrmax (ppb)
Months
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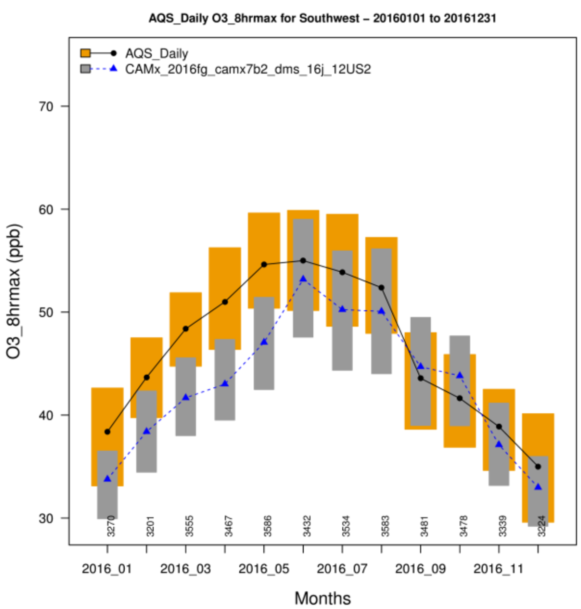
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11


AQS_Daily O3_8hrmax for Southwest – 20160101 to 20161231
AQS_Daily
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O3_8hrmax (ppb)
Months
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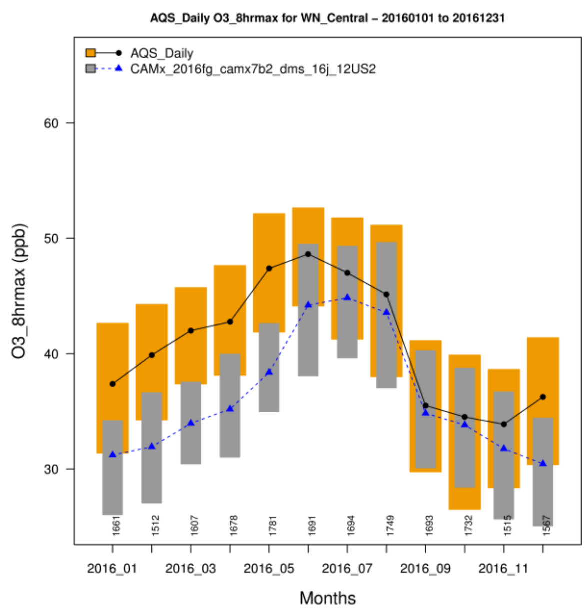
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11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Months
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2016_01 2016_03 2016_05 2016_07 2016_09 2016_11

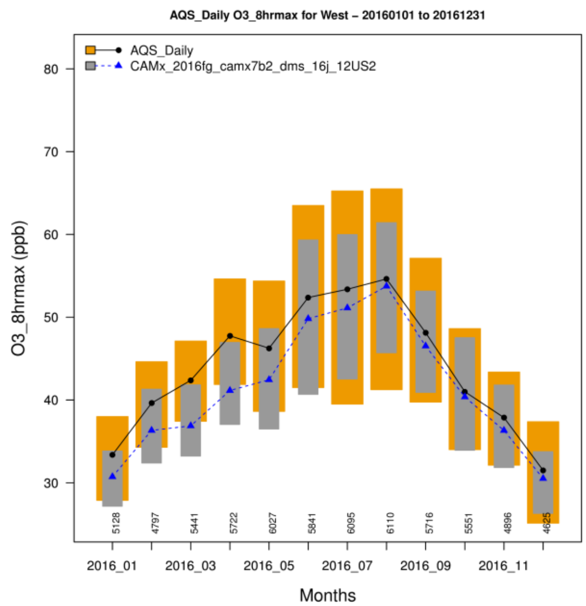


Figure 2. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily 8-hour maximum ozone observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

3. PM2.5 sulfate

Table 3-1 summarizes model performance statistics for PM2.5 sulfate. Figures 3 and 4 are national statistical tile plots with performance by region and season. Boxplot comparisons of model predictions and observations (IMPROVE, CSN, and CASTNET) by month for each climate region are shown in Figures 5, 6, 7 and 8. Nationwide spatial plots of NMB and NME for each season are shown in Figures 9 and 10.

Table 3-1. Model performance statistics for PM2.5 sulfate by region, network, and season.

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Northeast	IMPROVE	Winter	404	0.74	0.87	0.49	18.3	44.6	0.14	0.33
		Spring	450	0.77	0.96	0.70	25.5	38.7	0.20	0.30
		Summer	455	0.76	1.01	0.84	32.1	44.5	0.25	0.34
		Fall	427	0.62	0.96	0.73	54.4	63.4	0.34	0.40
		All	1736	0.72	0.95	0.72	31.8	46.9	0.23	0.34
	CSN	Winter	721	1.04	1.26	0.23	21.6	53.2	0.22	0.55
		Spring	768	0.92	1.27	0.68	38.8	50.5	0.36	0.46

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Summer	755	1.15	1.33	0.77	15.7	33.7	0.18	0.39
		Fall	728	0.87	1.40	0.65	61.2	69.9	0.53	0.61
		All	2972	0.99	1.32	0.57	32.4	50.4	0.32	0.50
	CASTNET	**Winter**	221	0.95	0.96	0.69	0.1	20.0	0.00	0.19
		Spring	242	1.00	1.11	0.83	10.5	20.3	0.11	0.20
		Summer	239	1.09	1.21	0.92	11.0	17.8	0.12	0.19
		Fall	237	0.81	1.04	0.74	29.1	35.1	0.24	0.28
		All	939	0.96	1.08	0.82	12.2	22.6	0.12	0.22
Southeast	**IMPROVE**	**Winter**	342	0.95	1.15	0.54	20.4	43.6	0.20	0.42
		Spring	381	1.24	1.33	0.41	6.8	33.1	0.08	0.41
		Summer	394	1.21	1.13	0.56	-6.6	36.8	-0.08	0.45
		Fall	366	1.04	1.26	0.73	21.1	34.3	0.22	0.36
		All	1483	1.12	1.22	0.54	8.9	36.5	0.10	0.41
	CSN	**Winter**	482	0.91	1.35	0.61	48.1	59.1	0.44	0.54
		Spring	522	1.11	1.48	0.58	34.3	45.7	0.38	0.51
		Summer	492	1.10	1.29	0.46	17.0	41.8	0.19	0.46
		Fall	475	0.97	1.42	0.72	47.1	53.6	0.46	0.52
		All	1971	1.02	1.39	0.58	35.6	49.4	0.36	0.51
	CASTNET	**Winter**	150	1.11	1.10	0.47	-0.6	27.2	-0.01	0.30
		Spring	164	1.41	1.27	0.36	-10.1	23.2	-0.14	0.33
		Summer	164	1.34	1.16	0.43	-14.0	25.6	-0.19	0.34
		Fall	154	1.20	1.25	0.39	4.7	24.5	0.06	0.29
		All	632	1.27	1.19	0.40	-5.8	25.0	-0.07	0.32
Ohio Valley	**IMPROVE**	**Winter**	220	1.10	1.18	0.63	7.5	35.1	0.08	0.39
		Spring	244	1.16	1.21	0.64	4.4	27.5	0.05	0.32
		Summer	239	1.48	1.58	0.66	6.8	37.7	0.10	0.56

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Fall	227	1.30	1.46	0.80	12.4	29.0	0.16	0.38
		All	930	1.26	1.36	0.69	7.8	32.5	0.10	0.41
	CSN	**Winter**	518	1.36	1.35	0.47	-1.1	37.8	-0.02	0.52
		Spring	531	1.19	1.43	0.47	20.2	40.6	0.24	0.48
		Summer	522	1.65	1.90	0.65	15.0	35.5	0.25	0.58
		Fall	511	1.24	1.59	0.63	28.8	44.2	0.36	0.55
		All	2082	1.36	1.57	0.59	15.2	39.1	0.21	0.53
	CASTNET	**Winter**	212	1.35	1.23	0.68	-8.6	20.5	-0.12	0.28
		Spring	228	1.36	1.33	0.74	-2.1	12.4	-0.03	0.17
		Summer	224	1.63	1.62	0.79	-1.0	16.3	-0.02	0.27
		Fall	226	1.40	1.46	0.83	4.0	15.2	0.06	0.21
		All	890	1.44	1.41	0.78	-1.7	16.0	-0.02	0.23
Upper Midwest	**IMPROVE**	**Winter**	200	0.76	0.81	0.72	6.9	36.3	0.05	0.28
		Spring	208	0.76	0.90	0.59	17.7	38.6	0.14	0.29
		Summer	210	0.68	0.80	0.84	17.9	39.1	0.12	0.27
		Fall	214	0.62	0.86	0.83	37.4	49.7	0.23	0.31
		All	832	0.71	0.84	0.76	19.4	40.6	0.14	0.29
	CSN	**Winter**	298	1.03	1.21	0.69	18.0	39.8	0.19	0.41
		Spring	323	0.94	1.29	0.66	38.0	48.6	0.36	0.46
		Summer	285	1.04	1.34	0.80	29.7	44.7	0.31	0.46
		Fall	280	0.76	1.26	0.73	66.1	72.1	0.50	0.55
		All	1186	0.94	1.28	0.72	35.6	49.7	0.34	0.47
	CASTNET	**Winter**	71	1.00	0.93	0.48	-6.6	26.8	-0.07	0.27
		Spring	76	0.93	1.02	0.85	9.7	18.1	0.09	0.17
		Summer	76	0.76	0.90	0.93	18.6	20.2	0.14	0.15
		Fall	70	0.74	0.91	0.81	23.1	27.1	0.17	0.20

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	293	0.86	0.94	0.76	9.9	22.9	0.08	0.20
South	**IMPROVE**	**Winter**	240	0.78	0.98	0.63	26.0	48.1	0.20	0.37
		Spring	272	0.95	1.02	0.68	7.2	35.7	0.07	0.34
		Summer	251	1.45	1.02	0.55	-29.2	41.9	-0.42	0.61
		Fall	264	1.12	1.24	0.68	10.8	36.3	0.12	0.41
		All	1027	1.07	1.07	0.59	-0.7	40.0	-0.01	0.43
	CSN	**Winter**	272	1.02	1.36	0.59	33.0	50.2	0.34	0.51
		Spring	287	1.23	1.36	0.71	10.9	42.1	0.13	0.52
		Summer	279	1.49	1.27	0.46	-14.4	39.1	-0.21	0.58
		Fall	269	1.33	1.61	0.69	21.1	38.3	0.28	0.51
		All	1107	1.27	1.40	0.60	10.4	41.9	0.13	0.53
	CASTNET	**Winter**	92	1.15	1.05	0.82	-8.8	19.2	-0.10	0.22
		Spring	102	1.37	1.15	0.78	-15.7	21.9	-0.22	0.30
		Summer	96	1.68	1.07	0.48	-36.3	37.8	-0.61	0.64
		Fall	102	1.36	1.28	0.67	-5.5	19.0	-0.07	0.26
		All	392	1.39	1.14	0.62	-17.9	25.3	-0.25	0.35
Southwest	**IMPROVE**	**Winter**	864	0.24	0.50	0.38	106.0	121.0	0.26	0.29
		Spring	949	0.38	0.70	0.55	84.3	90.3	0.32	0.35
		Summer	955	0.64	0.50	0.43	-21.0	41.0	-0.13	0.26
		Fall	932	0.46	0.55	0.43	21.2	52.9	0.10	0.24
		All	3700	0.43	0.57	0.36	30.5	65.7	0.13	0.29
	CSN	**Winter**	244	0.52	0.66	0.27	26.2	82.8	0.14	0.43
		Spring	255	0.43	0.83	0.57	92.4	95.2	0.40	0.41
		Summer	250	0.79	0.65	0.33	-17.9	40.3	-0.14	0.32
		Fall	260	0.55	0.70	0.37	28.8	51.0	0.16	0.28
		All	1009	0.57	0.71	0.23	24.4	62.7	0.14	0.36

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
	CASTNET	**Winter**	101	0.24	0.44	0.31	83.6	96.5	0.20	0.23
		Spring	115	0.40	0.64	0.74	59.5	59.9	0.24	0.24
		Summer	114	0.59	0.48	0.29	-19.5	30.5	-0.12	0.18
		Fall	115	0.44	0.51	0.36	15.3	36.7	0.07	0.16
		All	445	0.42	0.52	0.32	22.3	47.8	0.09	0.20
Northern Rockies & Plains	**IMPROVE**	**Winter**	513	0.33	0.55	0.74	67.6	85.9	0.22	0.28
		Spring	514	0.39	0.63	0.74	61.0	67.7	0.24	0.27
		Summer	544	0.37	0.53	0.36	42.8	64.5	0.16	0.24
		Fall	540	0.35	0.55	0.68	58.0	74.0	0.20	0.26
		All	2111	0.36	0.56	0.67	56.8	72.4	0.21	0.26
	CSN	**Winter**	137	0.53	0.69	0.66	29.5	63.7	0.16	0.34
		Spring	145	0.54	0.79	0.59	47.2	64.5	0.25	0.35
		Summer	135	0.54	0.66	0.71	22.9	51.3	0.12	0.28
		Fall	136	0.48	0.71	0.85	48.6	60.9	0.23	0.29
		All	553	0.52	0.71	0.69	37.0	60.2	0.19	0.31
	CASTNET	**Winter**	138	0.43	0.50	0.75	15.5	46.2	0.07	0.20
		Spring	152	0.47	0.60	0.81	27.2	35.4	0.13	0.17
		Summer	151	0.50	0.53	0.66	5.7	26.7	0.03	0.13
		Fall	142	0.44	0.53	0.74	22.3	36.1	0.10	0.16
		All	583	0.46	0.54	0.72	17.4	35.5	0.08	0.16
Northwest	**IMPROVE**	**Winter**	425	0.14	0.38	0.62	165.0	175.0	0.24	0.25
		Spring	482	0.30	0.68	0.69	125.0	125.0	0.38	0.38
		Summer	487	0.35	0.80	0.46	129.0	131.0	0.45	0.46
		Fall	471	0.24	0.59	0.61	145.0	149.0	0.35	0.36
		All	1865	0.26	0.62	0.63	136.0	139.0	0.36	0.37
	CSN	**Winter**	141	0.29	0.64	0.27	118.0	137.0	0.34	0.40

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Spring	146	0.40	0.89	0.60	124.0	126.0	0.49	0.50
		Summer	153	0.52	1.14	0.40	118.0	123.0	0.62	0.64
		Fall	146	0.35	0.85	0.53	143.0	149.0	0.50	0.52
		All	586	0.39	0.88	0.48	125.0	132.0	0.49	0.52
	CASTNET	**Winter**	-	-	-	-	-	-	-	-
		Spring	-	-	-	-	-	-	-	-
		Summer	-	-	-	-	-	-	-	-
		Fall	-	-	-	-	-	-	-	-
		All	-	-	-	-	-	-	-	-
West	**IMPROVE**	**Winter**	565	0.21	0.51	0.38	142.0	160.0	0.30	0.34
		Spring	608	0.49	0.80	0.47	63.3	74.9	0.31	0.37
		Summer	603	0.71	0.88	0.32	23.3	53.7	0.17	0.38
		Fall	576	0.46	0.68	0.54	47.3	63.6	0.22	0.29
		All	2352	0.47	0.72	0.49	52.5	73.1	0.25	0.35
	CSN	**Winter**	339	0.49	0.78	0.34	60.7	88.4	0.30	0.43
		Spring	352	0.84	1.10	0.49	32.0	61.7	0.27	0.52
		Summer	349	1.45	1.46	0.31	0.9	44.2	0.01	0.64
		Fall	330	0.84	1.03	0.59	22.8	47.1	0.19	0.40
		All	1370	0.91	1.10	0.48	21.1	54.9	0.19	0.50
	CASTNET	**Winter**	69	0.27	0.47	0.42	78.1	97.7	0.21	0.26
		Spring	73	0.64	0.76	0.44	17.7	39.5	0.11	0.25
		Summer	75	0.94	0.84	0.28	-11.5	41.7	-0.11	0.39
		Fall	77	0.62	0.68	0.56	11.0	37.1	0.07	0.23
		All	294	0.62	0.69	0.53	10.7	45.5	0.07	0.28

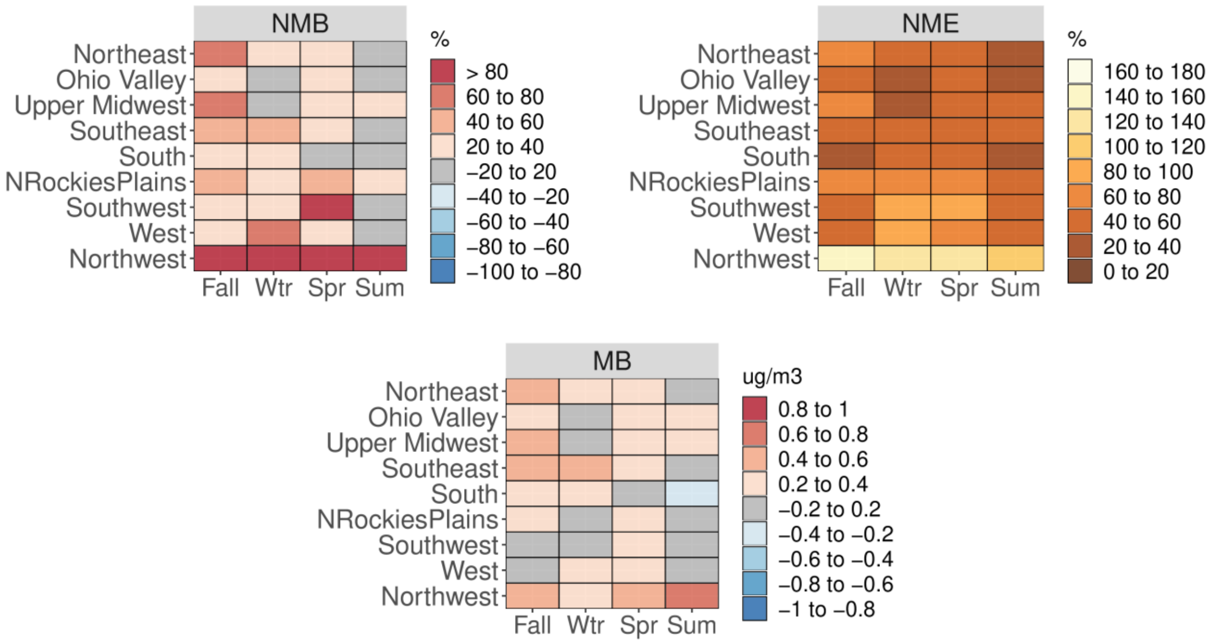


Figure 3. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for CSN PM2.5 sulfate observations.

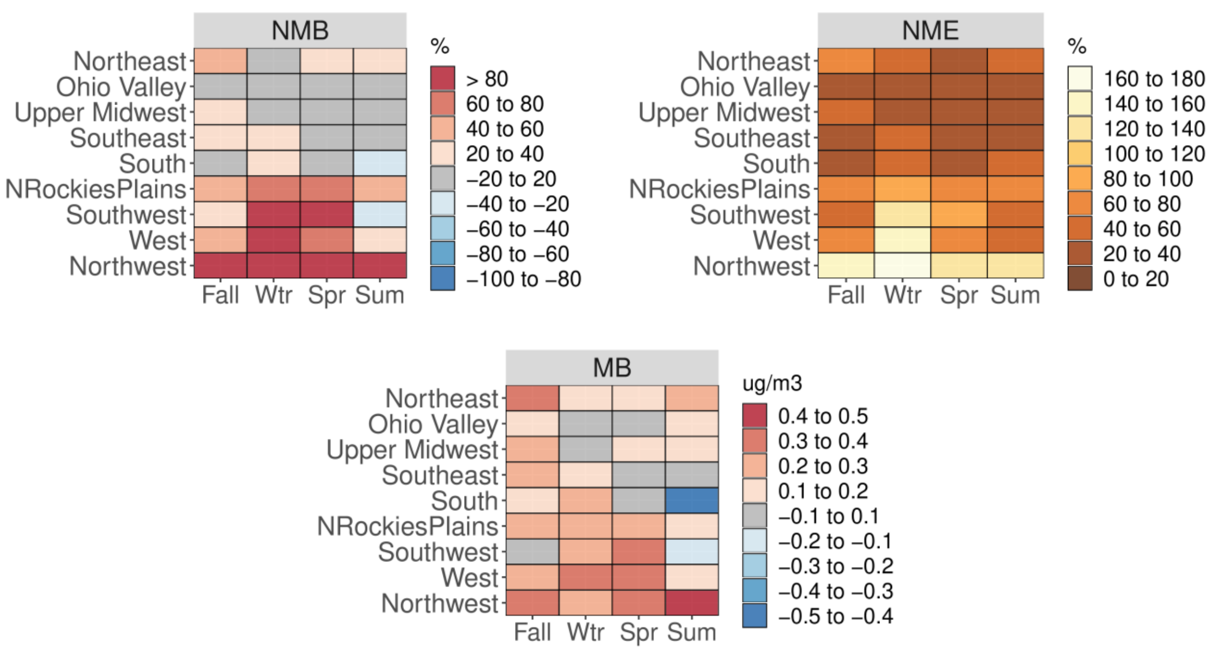
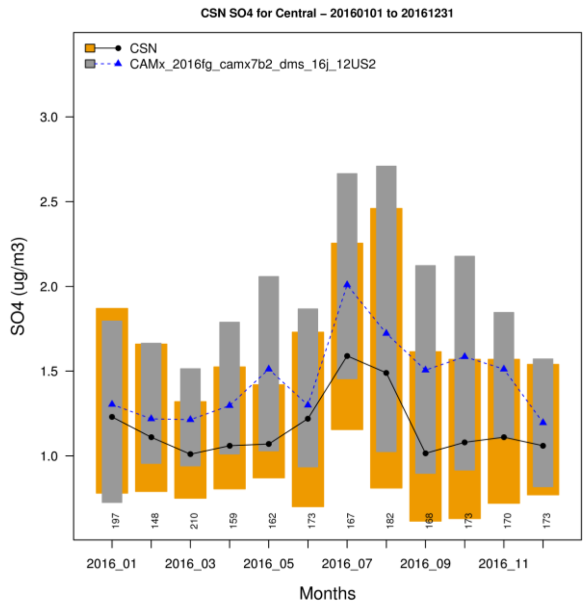
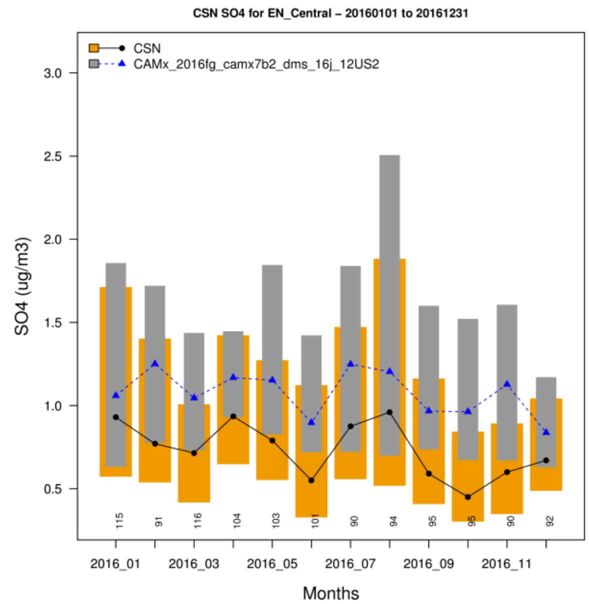


Figure 4. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for IMPROVE PM2.5 sulfate observations.


CSN SO4 for Central – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


CSN SO4 for EN_Central – 20160101 to 20161231
CSN
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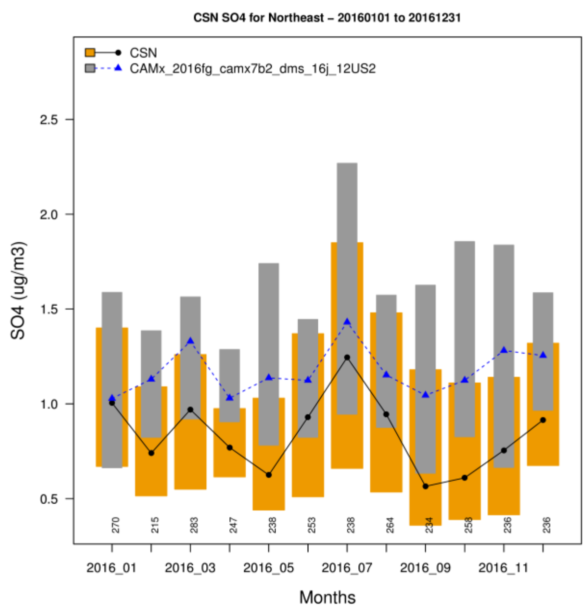
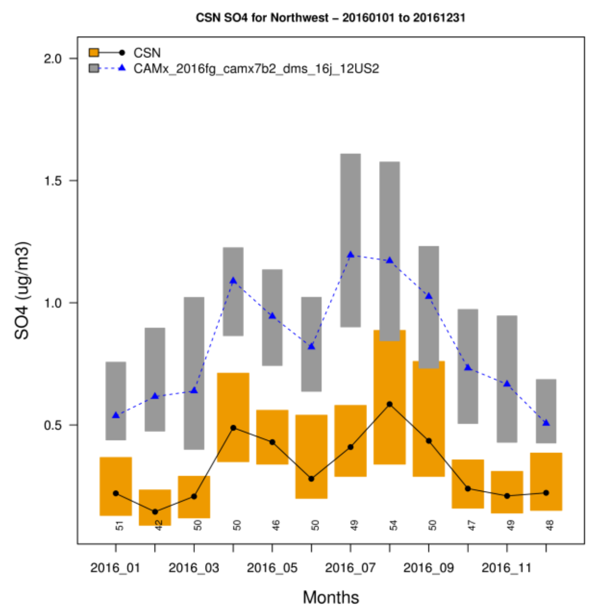
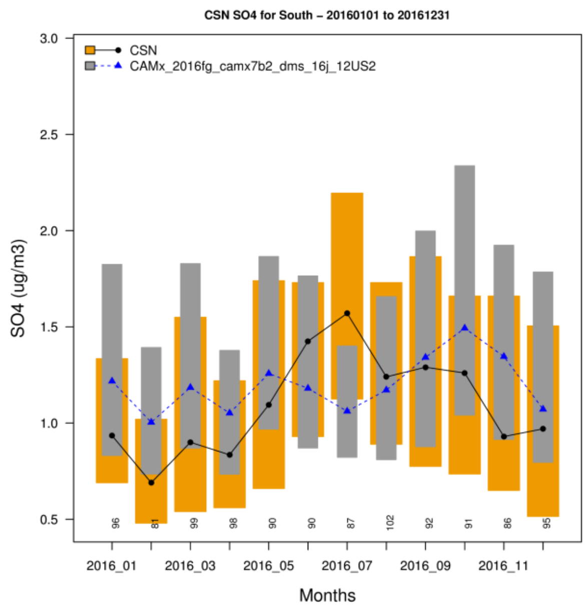
SO4 (ug/m3)
Months


CSN SO4 for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


CSN SO4 for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


CSN SO4 for South – 20160101 to 20161231
CSN
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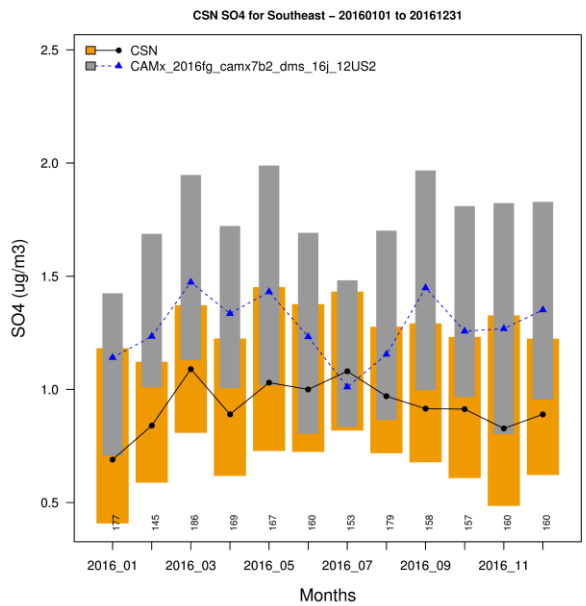
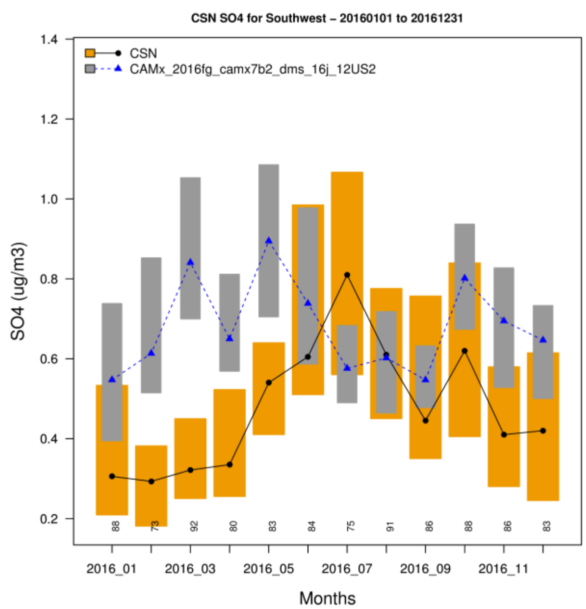
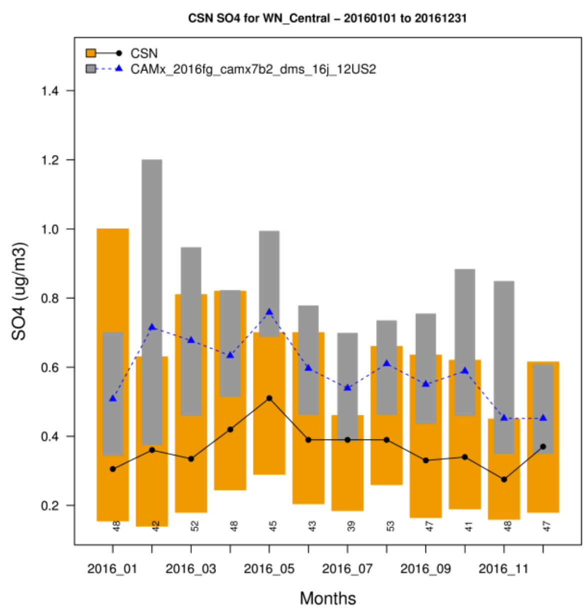
SO4 (ug/m3)
Months


CSN SO4 for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


CSN SO4 for Southwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


CSN SO4 for WN_Central – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months

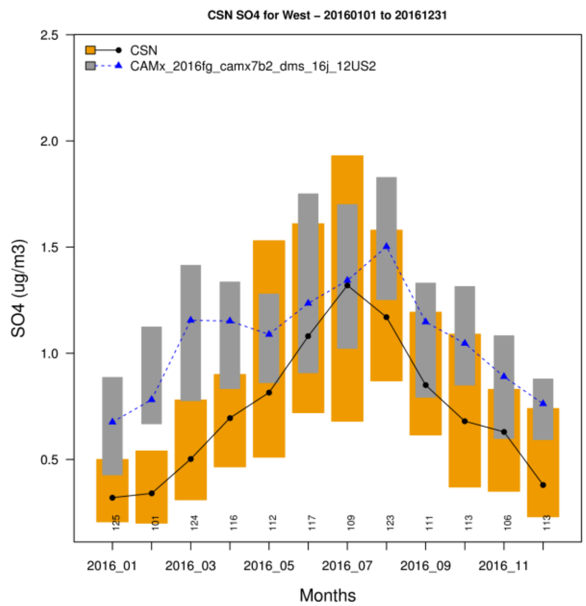
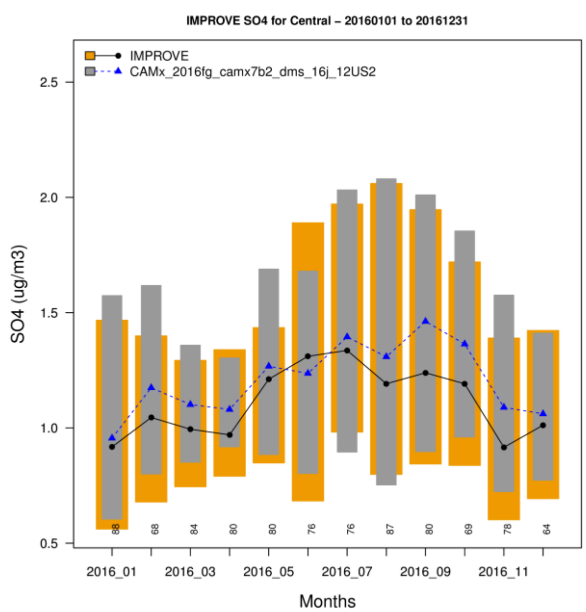
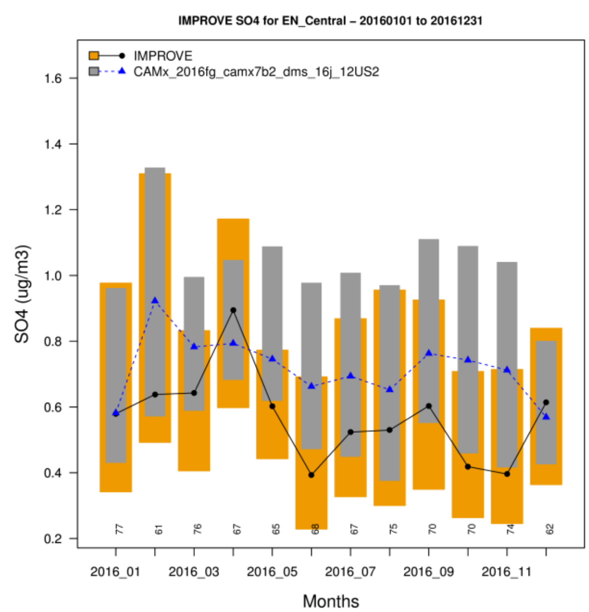
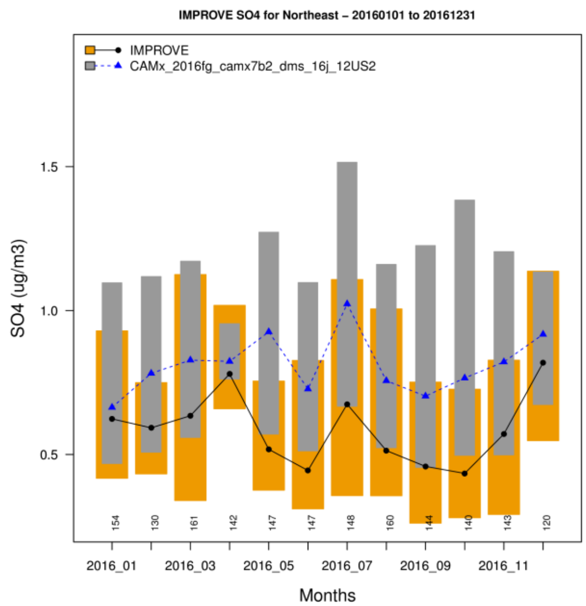
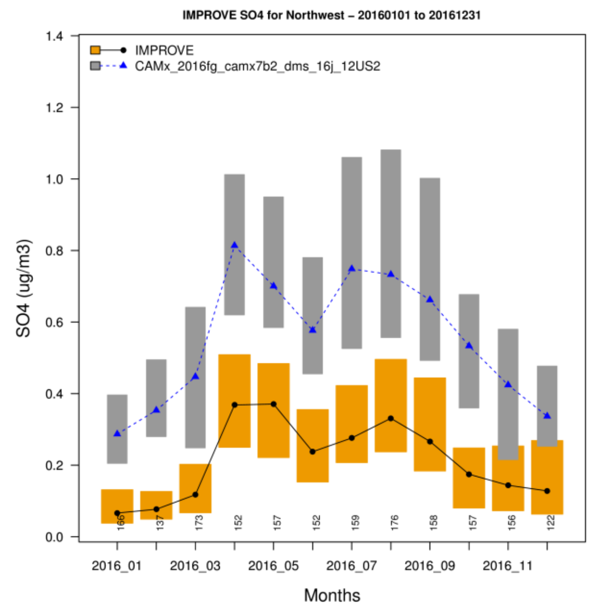


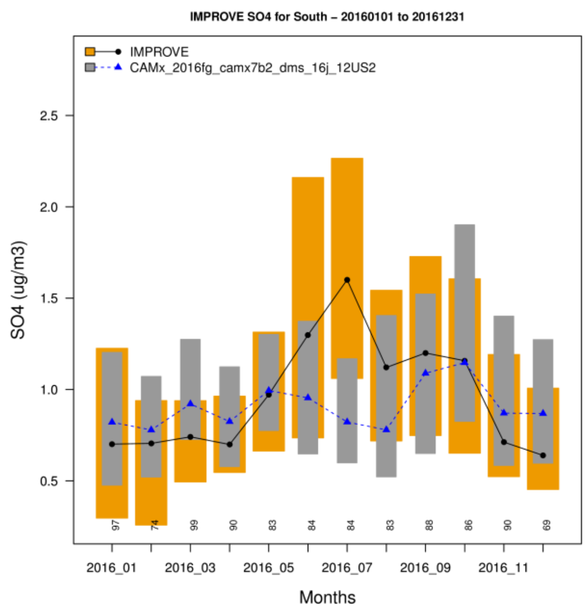
Figure 5. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN PM2.5 sulfate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

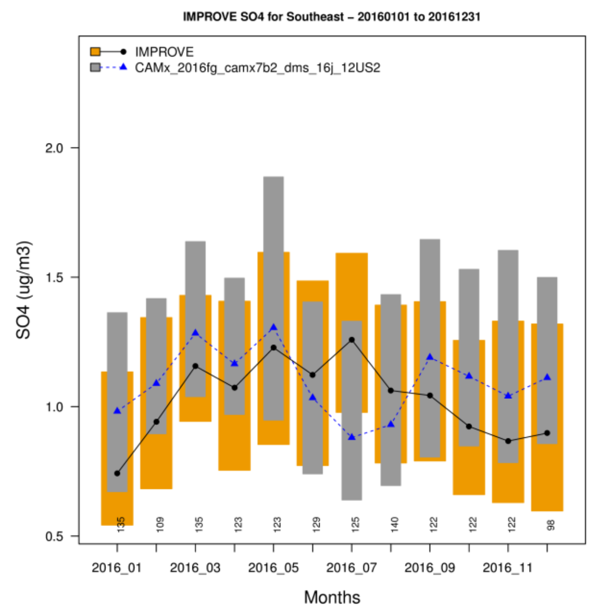





IMPROVE SO4 for Northeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


IMPROVE SO4 for Northwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


IMPROVE SO4 for South – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


IMPROVE SO4 for Southeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months

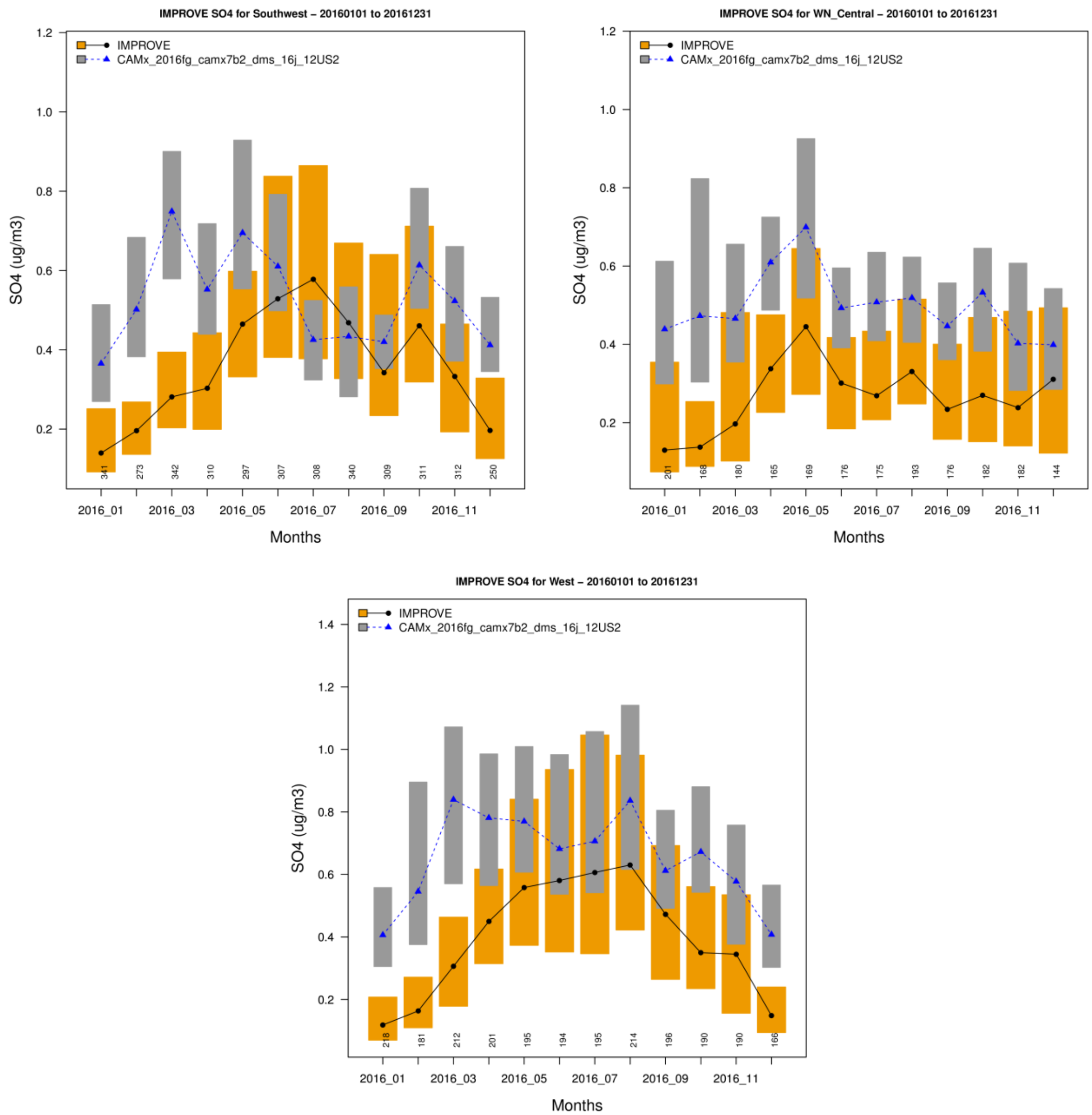
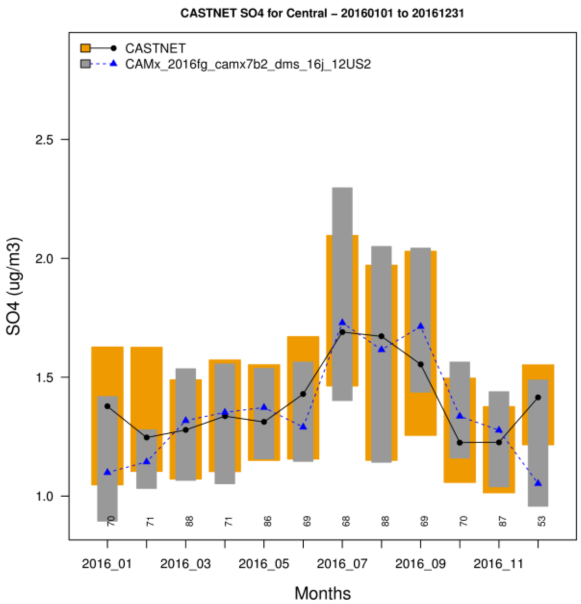
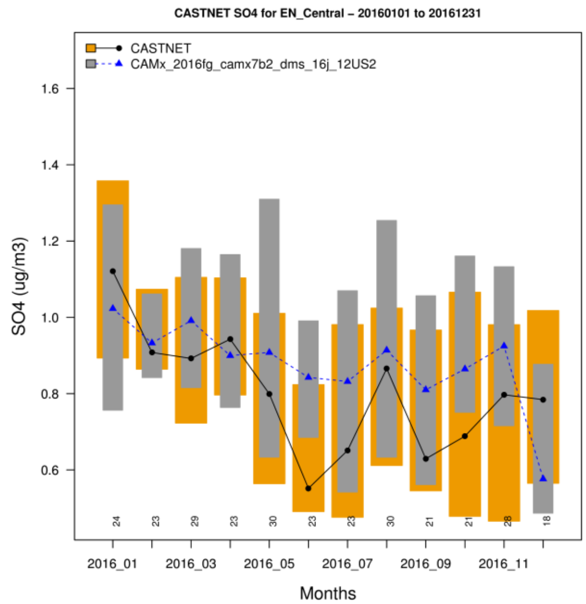
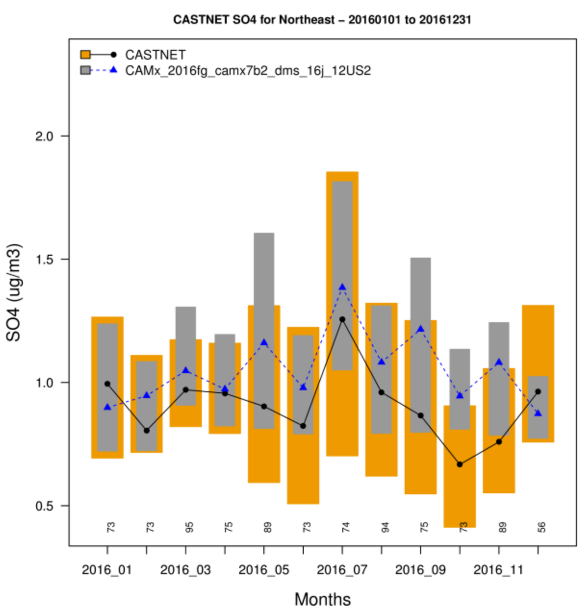
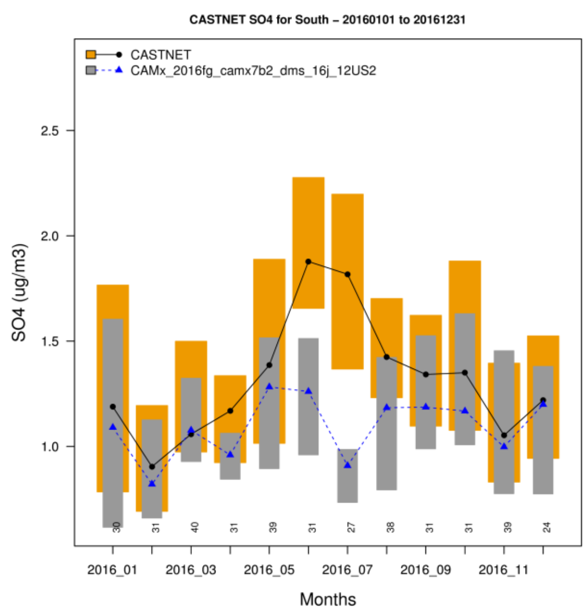


Figure 6. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median IMPROVE PM2.5 sulfate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.


CASTNET SO4 for Central – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CASTNET SO4 for EN_Central – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CASTNET SO4 for Northeast – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CASTNET SO4 for South – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

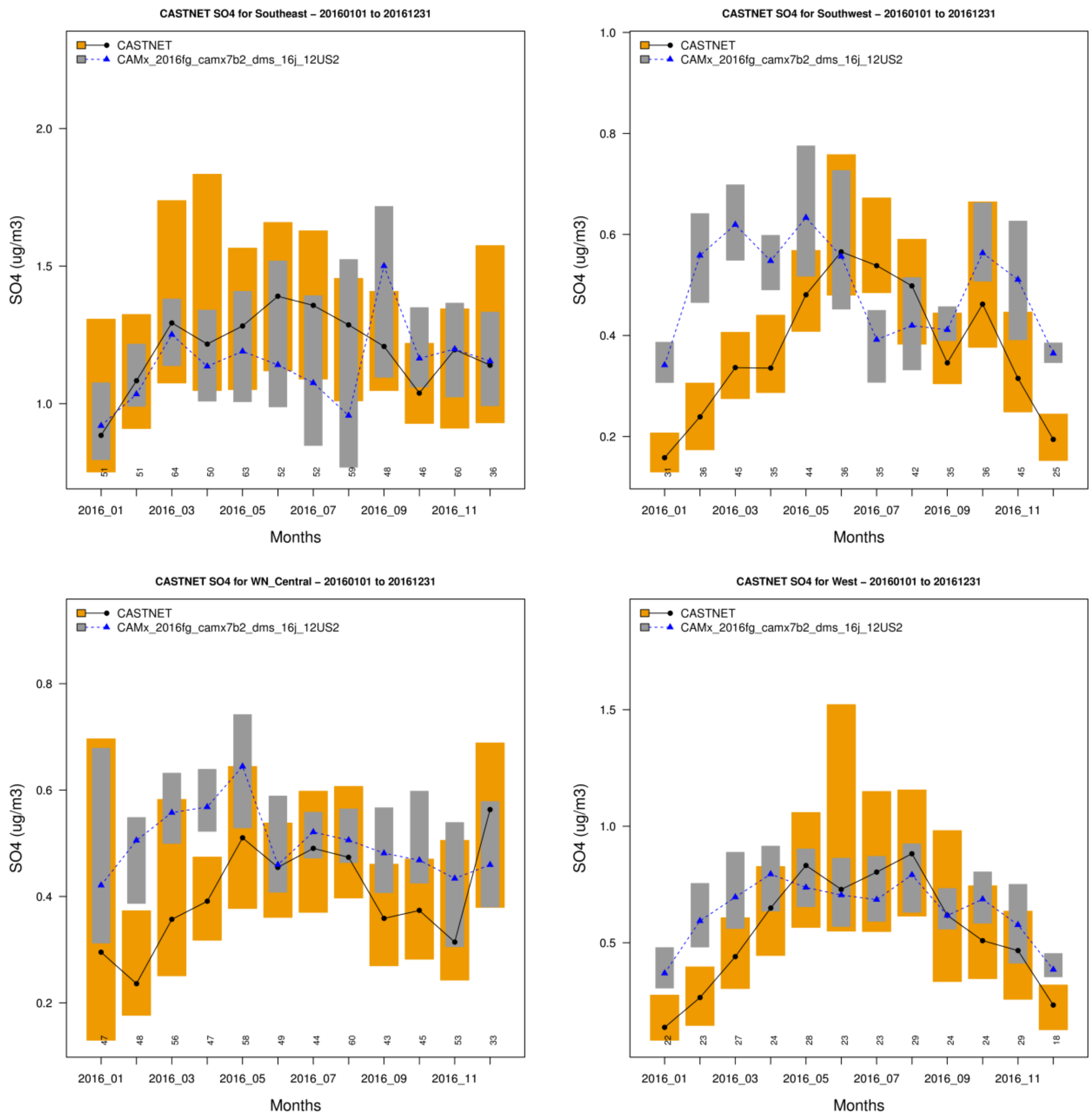
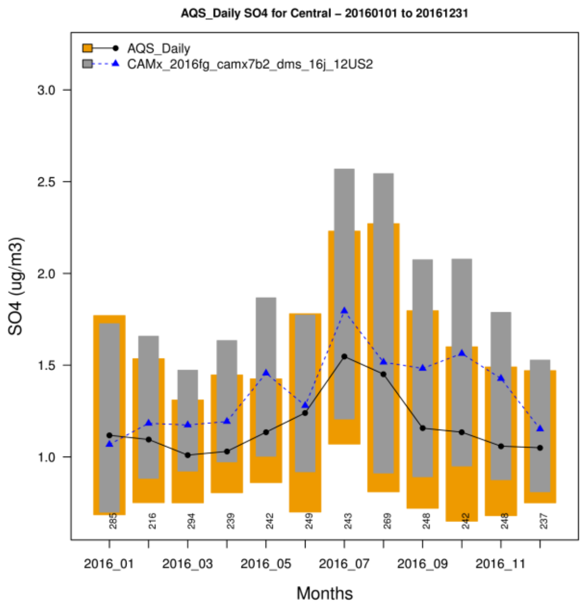
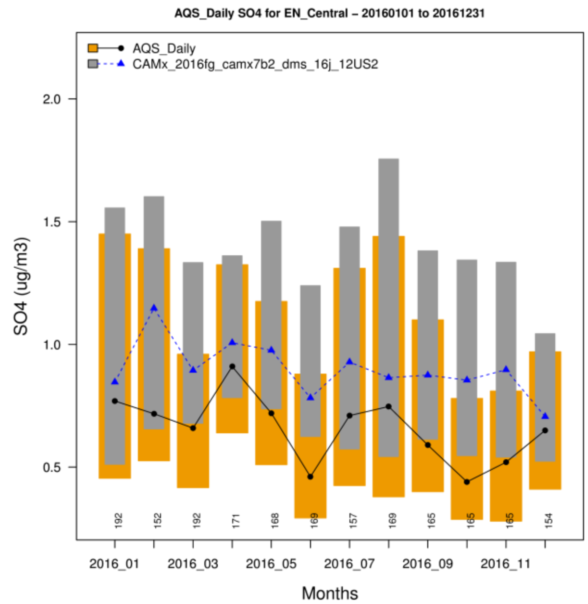
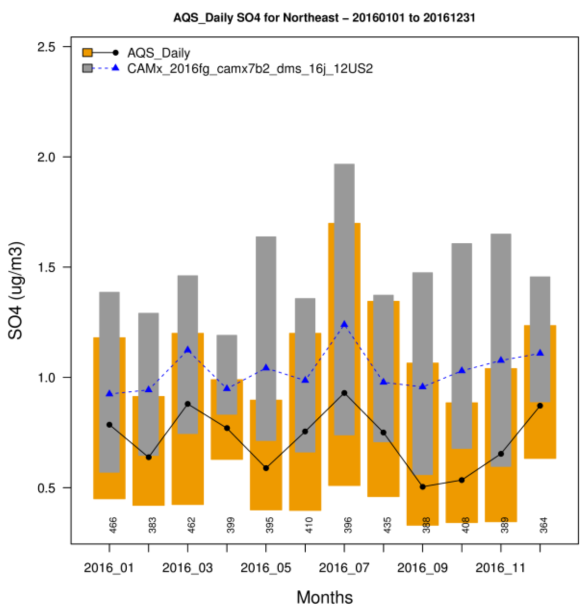
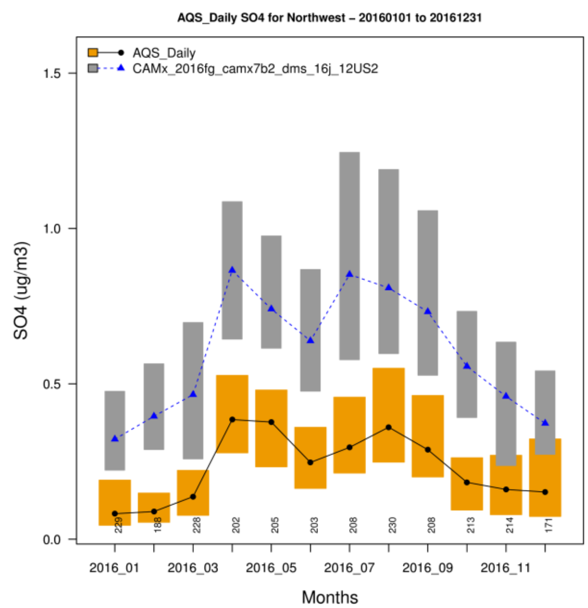


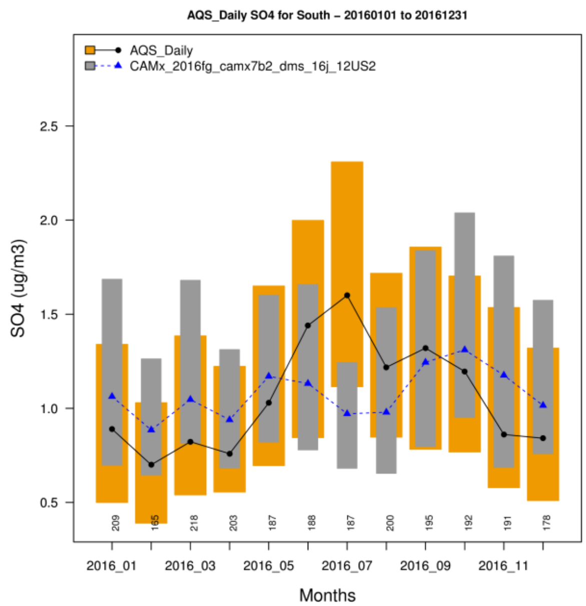
Figure 7. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CASTNET PM2.5 sulfate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

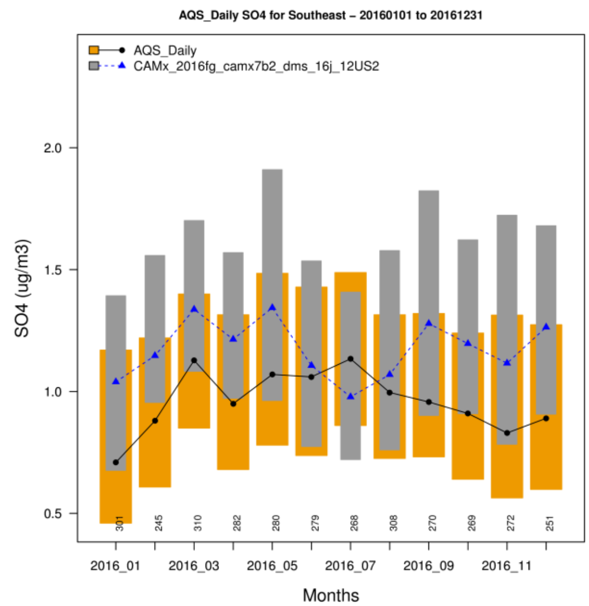

AQS_Daily SO4 for Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months

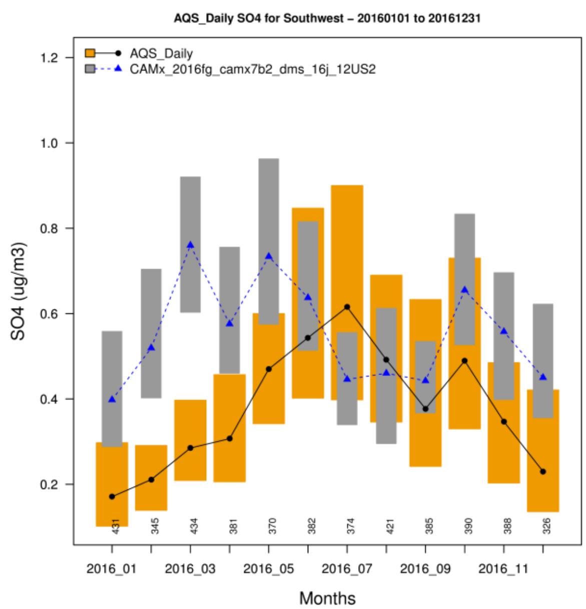

AQS_Daily SO4 for EN_Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months

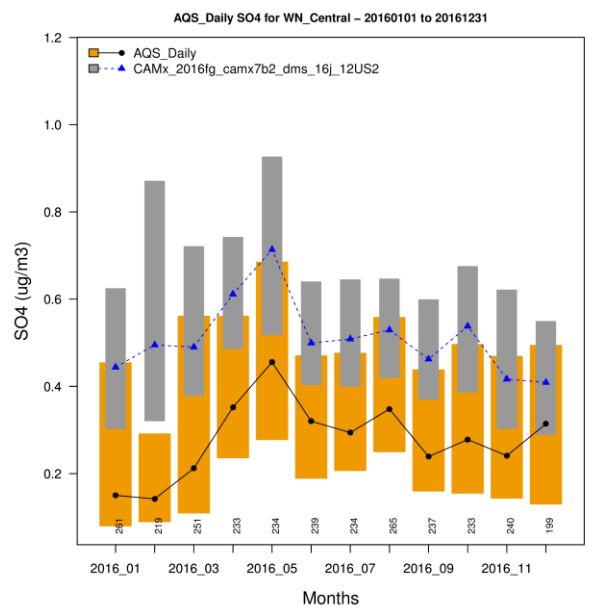

AQS_Daily SO4 for Northeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


AQS_Daily SO4 for Northwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months


AQS_Daily SO4 for South – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


AQS_Daily SO4 for Southeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


AQS_Daily SO4 for Southwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


AQS_Daily SO4 for WN_Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
SO4 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

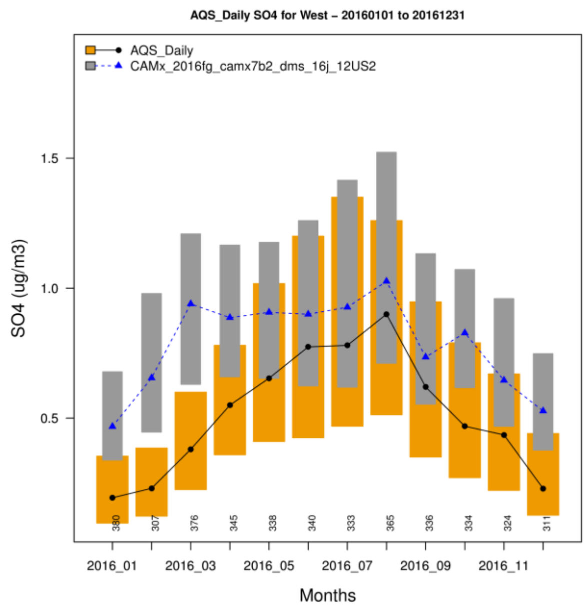


Figure 8. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily PM2.5 sulfate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

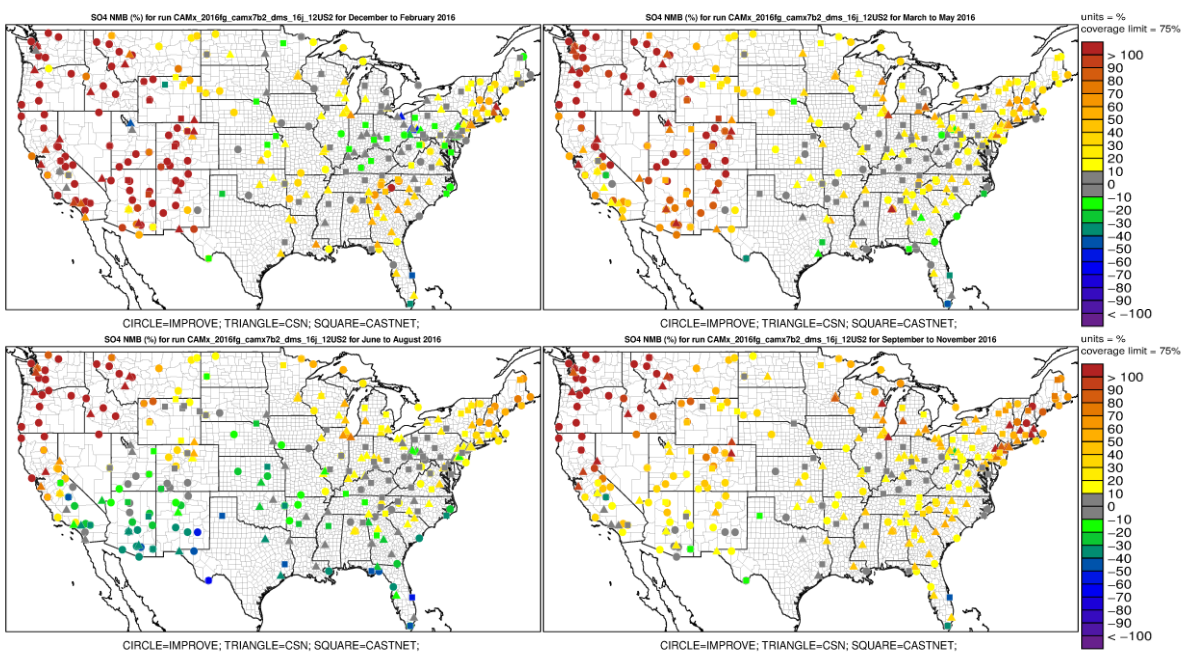


Figure 9. Spatial plot of PM2.5 sulfate NMB (%) by season and network.

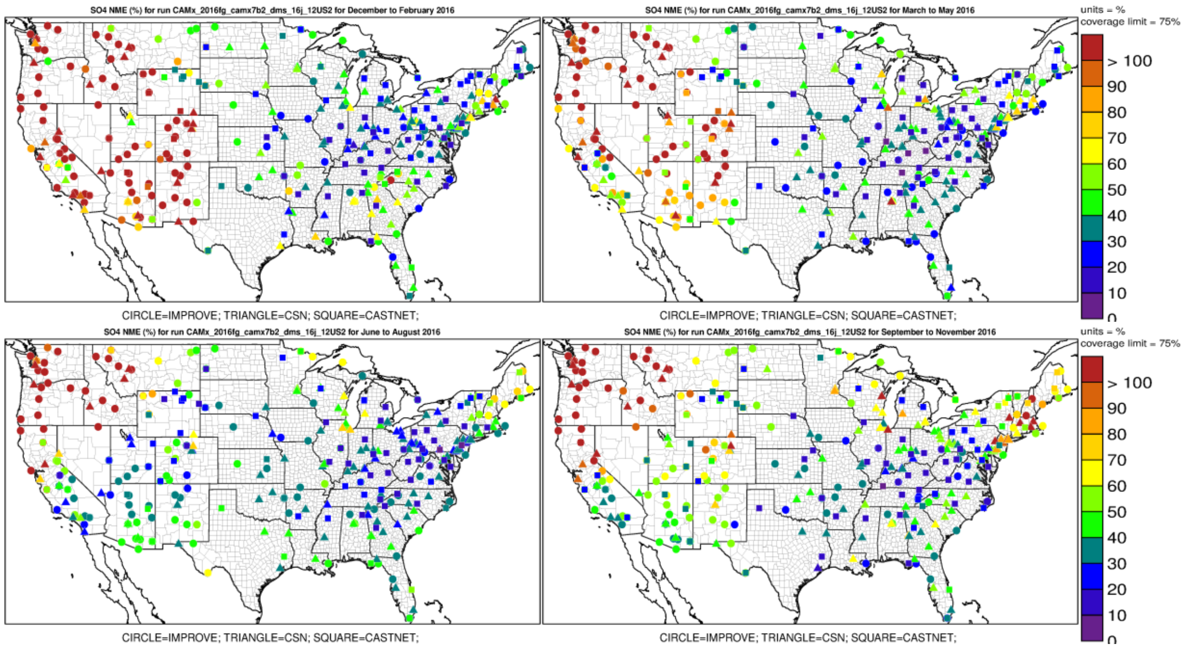


Figure 10. Spatial plot of PM2.5 sulfate NME (%) by season and network.

4. PM2.5 nitrate

Table 4-1 summarizes model performance statistics for $PM_{2.5}$ nitrate. Figures 11 and 12 are national statistical tile plots with performance by region and season. Boxplot comparisons of model predictions and observations (IMPROVE, CSN, and CASTNET) by month for each climate region are shown in Figures 13, 14, 15, and 16. Nationwide spatial plots of NMB and NME for each season are shown in Figures 17 and 18.

Table 4-1. Model performance statistics for PM2.5 nitrate by region, network, and season.

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Northeast	IMPROVE	**Winter**	404	0.51	0.65	0.67	26.2	67.0	0.13	0.34
		Spring	450	0.32	0.36	0.74	11.8	59.7	0.04	0.19
		Summer	455	0.15	0.13	0.54	-12.5	58.2	-0.02	0.09
		Fall	427	0.25	0.36	0.61	44.2	87.6	0.11	0.22

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	1736	0.30	0.37	0.70	20.7	67.9	0.06	0.21
	CSN	**Winter**	720	1.71	2.09	0.69	22.0	52.6	0.38	0.90
		Spring	770	0.85	1.22	0.72	43.0	71.5	0.37	0.61
		Summer	751	0.33	0.40	0.56	23.8	61.8	0.08	0.20
		Fall	729	0.64	1.36	0.69	112.0	128.0	0.72	0.83
		All	2970	0.88	1.26	0.72	43.7	71.9	0.38	0.63
	CASTNET	**Winter**	221	0.99	0.86	0.77	-13.2	36.6	-0.13	0.36
		Spring	242	0.51	0.47	0.62	-9.6	48.5	-0.05	0.25
		Summer	239	0.20	0.18	0.43	-10.2	53.4	-0.02	0.11
		Fall	237	0.42	0.47	0.61	11.6	59.5	0.05	0.25
		All	939	0.52	0.49	0.75	-7.0	45.9	-0.04	0.24
Southeast	**IMPROVE**	**Winter**	342	0.49	0.59	0.45	19.1	69.1	0.09	0.34
		Spring	381	0.34	0.36	0.30	6.5	65.8	0.02	0.22
		Summer	394	0.19	0.18	0.23	-0.9	67.0	-0.00	0.12
		Fall	366	0.29	0.34	0.50	17.8	73.0	0.05	0.21
		All	1483	0.32	0.36	0.49	12.3	68.8	0.04	0.22
	CSN	**Winter**	483	0.62	1.29	0.46	107.0	122.0	0.67	0.76
		Spring	522	0.33	0.54	0.28	64.8	91.3	0.21	0.30
		Summer	491	0.20	0.28	0.26	42.9	70.9	0.09	0.14
		Fall	480	0.30	0.65	0.61	114.0	129.0	0.35	0.39
		All	1976	0.36	0.69	0.57	89.7	109.0	0.33	0.39
	CASTNET	**Winter**	150	0.74	0.70	0.30	-6.0	53.4	-0.04	0.40
		Spring	164	0.65	0.39	0.14	-39.5	58.5	-0.26	0.38
		Summer	164	0.41	0.19	0.06	-52.5	68.0	-0.21	0.28
		Fall	154	0.58	0.45	0.27	-22.4	60.3	-0.13	0.35
		All	632	0.59	0.43	0.31	-27.8	59.1	-0.16	0.35

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Ohio Valley	IMPROVE	Winter	220	1.33	0.91	0.40	-31.3	63.7	-0.42	0.85
		Spring	244	0.52	0.47	0.53	-8.8	61.8	-0.05	0.32
		Summer	239	0.19	0.26	0.42	36.6	72.9	0.07	0.14
		Fall	227	0.49	0.52	0.47	5.1	69.5	0.03	0.34
		All	930	0.62	0.53	0.54	-13.9	65.1	-0.09	0.40
	CSN	Winter	515	2.46	2.07	0.43	-15.8	51.1	-0.39	1.26
		Spring	531	0.91	1.06	0.36	16.8	70.7	0.15	0.64
		Summer	521	0.37	0.65	0.26	74.4	105.0	0.28	0.39
		Fall	508	0.82	1.24	0.56	51.1	82.3	0.42	0.68
		All	2075	1.14	1.25	0.55	10.1	65.0	0.12	0.74
	CASTNET	Winter	212	1.79	1.09	0.64	-38.7	47.7	-0.69	0.85
		Spring	228	0.75	0.69	0.63	-7.5	47.2	-0.06	0.35
		Summer	224	0.33	0.39	0.36	18.8	62.2	0.06	0.20
		Fall	226	0.76	0.70	0.58	-8.5	47.5	-0.06	0.36
		All	890	0.89	0.71	0.68	-20.2	48.9	-0.18	0.44
Upper Midwest	IMPROVE	Winter	200	1.44	0.88	0.68	-38.9	51.3	-0.56	0.74
		Spring	208	0.58	0.53	0.62	-8.1	61.7	-0.05	0.36
		Summer	210	0.12	0.26	0.52	117.0	136.0	0.14	0.16
		Fall	214	0.34	0.51	0.44	49.6	103.0	0.17	0.35
		All	832	0.61	0.54	0.64	-11.1	65.4	-0.07	0.40
	CSN	Winter	298	2.75	2.26	0.68	-17.7	44.2	-0.49	1.21
		Spring	323	1.15	1.31	0.55	14.8	63.3	0.17	0.73
		Summer	284	0.35	0.53	0.34	51.6	95.4	0.18	0.33
		Fall	277	0.82	1.14	0.73	39.7	67.5	0.33	0.55
		All	1182	1.28	1.32	0.72	3.4	55.7	0.04	0.71
	CASTNET	Winter	71	1.98	0.95	0.79	-52.1	52.3	-1.03	1.03

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Spring	76	0.62	0.61	0.65	-2.4	47.7	-0.01	0.30
		Summer	76	0.21	0.20	0.51	-4.3	38.2	-0.01	0.08
		Fall	70	0.65	0.61	0.60	-6.4	54.7	-0.04	0.36
		All	293	0.85	0.59	0.75	-31.2	50.9	-0.27	0.43
South	**IMPROVE**	**Winter**	240	0.89	0.73	0.45	-18.5	67.9	-0.17	0.61
		Spring	272	0.34	0.36	0.58	5.7	58.3	0.02	0.20
		Summer	251	0.22	0.14	0.17	-36.8	65.9	-0.08	0.14
		Fall	264	0.26	0.30	0.46	16.5	73.8	0.04	0.19
		All	1027	0.42	0.38	0.55	-10.1	66.5	-0.04	0.28
	CSN	**Winter**	272	0.95	1.20	0.49	25.6	70.2	0.24	0.67
		Spring	285	0.36	0.56	0.49	55.9	89.1	0.20	0.32
		Summer	278	0.26	0.31	0.16	22.3	72.0	0.06	0.18
		Fall	270	0.35	0.62	0.48	76.4	102.0	0.27	0.36
		All	1105	0.48	0.67	0.56	40.1	79.8	0.19	0.38
	CASTNET	**Winter**	92	1.09	0.75	0.62	-31.6	48.6	-0.35	0.53
		Spring	102	0.57	0.43	0.69	-23.4	45.6	-0.13	0.26
		Summer	96	0.58	0.15	0.24	-73.3	74.9	-0.43	0.44
		Fall	102	0.58	0.37	0.63	-36.4	53.7	-0.21	0.31
		All	392	0.70	0.42	0.63	-39.4	54.4	-0.28	0.38
Southwest	**IMPROVE**	**Winter**	864	0.24	0.16	0.44	-33.1	70.7	-0.08	0.17
		Spring	949	0.17	0.17	0.44	-1.0	48.0	-0.00	0.08
		Summer	955	0.15	0.06	0.31	-60.0	64.4	-0.09	0.10
		Fall	932	0.12	0.08	0.52	-30.2	54.4	-0.04	0.06
		All	3700	0.17	0.12	0.44	-30.4	60.5	-0.05	0.10
	CSN	**Winter**	245	2.54	0.75	0.53	-70.6	74.7	-1.79	1.90
		Spring	255	0.44	0.35	0.49	-21.6	56.1	-0.10	0.25

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Summer	250	0.27	0.18	0.01	-33.2	64.1	-0.09	0.18
		Fall	257	0.55	0.33	0.48	-40.9	65.6	-0.23	0.36
		All	1007	0.94	0.40	0.60	-57.6	70.3	-0.54	0.66
	CASTNET	**Winter**	101	0.30	0.09	0.26	-68.4	76.1	-0.20	0.23
		Spring	115	0.23	0.16	0.07	-28.8	45.0	-0.07	0.10
		Summer	114	0.22	0.06	0.05	-72.0	72.8	-0.16	0.16
		Fall	115	0.17	0.07	0.10	-59.8	62.1	-0.10	0.11
		All	445	0.23	0.10	0.13	-57.4	64.6	-0.13	0.15
Northern Rockies & Plains	**IMPROVE**	**Winter**	513	0.41	0.18	0.60	-55.0	73.3	-0.23	0.30
		Spring	514	0.17	0.18	0.53	4.8	67.4	0.01	0.12
		Summer	544	0.08	0.08	0.29	2.7	56.4	0.00	0.05
		Fall	540	0.11	0.14	0.57	30.0	86.0	0.03	0.10
		All	2111	0.19	0.15	0.52	-22.8	72.1	-0.04	0.14
	CSN	**Winter**	137	1.22	0.94	0.62	-22.9	57.1	-0.28	0.70
		Spring	145	0.50	0.57	0.72	13.4	65.3	0.07	0.33
		Summer	135	0.17	0.21	0.55	27.1	72.0	0.05	0.12
		Fall	135	0.32	0.48	0.53	49.2	95.3	0.16	0.31
		All	552	0.55	0.55	0.66	-0.3	65.6	-0.00	0.36
	CASTNET	**Winter**	138	0.58	0.21	0.70	-63.2	67.6	-0.37	0.39
		Spring	152	0.20	0.20	0.76	1.3	40.0	0.00	0.08
		Summer	151	0.20	0.09	0.65	-51.8	54.3	-0.10	0.11
		Fall	142	0.22	0.17	0.62	-21.4	50.1	-0.05	0.11
		All	583	0.29	0.17	0.64	-42.1	57.2	-0.12	0.17
Northwest	**IMPROVE**	**Winter**	425	0.32	0.23	0.33	-26.4	99.7	-0.08	0.32
		Spring	482	0.15	0.26	0.54	75.1	100.0	0.11	0.15
		Summer	487	0.14	0.11	0.48	-22.5	67.0	-0.03	0.09

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Fall	471	0.17	0.21	0.38	24.0	100.0	0.04	0.17
		All	1865	0.19	0.20	0.33	6.1	93.7	0.01	0.18
	CSN	**Winter**	142	1.26	0.92	0.40	-27.0	74.8	-0.34	0.95
		Spring	146	0.40	0.77	0.40	94.5	112.0	0.37	0.44
		Summer	153	0.26	0.38	0.43	49.6	80.3	0.13	0.21
		Fall	146	0.51	0.76	0.28	48.1	101.0	0.25	0.52
		All	587	0.60	0.70	0.33	17.6	87.2	0.11	0.52
	CASTNET	**Winter**	-	-	-	-	-	-	-	-
		Spring	-	-	-	-	-	-	-	-
		Summer	-	-	-	-	-	-	-	-
		Fall	-	-	-	-	-	-	-	-
		All	-	-	-	-	-	-	-	-
West	**IMPROVE**	**Winter**	565	0.47	0.41	0.77	-12.6	66.6	-0.06	0.31
		Spring	608	0.38	0.41	0.74	5.8	59.2	0.02	0.23
		Summer	603	0.32	0.13	0.30	-60.7	72.7	-0.20	0.24
		Fall	576	0.41	0.26	0.82	-37.2	65.4	-0.15	0.27
		All	2352	0.39	0.30	0.74	-24.3	65.7	-0.10	0.26
	CSN	**Winter**	340	3.29	1.86	0.62	-43.3	60.2	-1.42	1.98
		Spring	352	1.57	1.28	0.64	-18.6	51.9	-0.29	0.82
		Summer	348	1.26	0.81	0.52	-35.2	64.7	-0.44	0.81
		Fall	332	1.96	1.20	0.62	-38.7	63.4	-0.76	1.24
		All	1372	2.01	1.29	0.62	-36.0	60.0	-0.72	1.21
	CASTNET	**Winter**	69	0.42	0.28	0.71	-33.2	62.5	-0.14	0.26
		Spring	73	0.48	0.32	0.49	-33.8	49.7	-0.16	0.24
		Summer	75	0.57	0.11	0.06	-81.2	83.6	-0.46	0.48
		Fall	77	0.53	0.20	0.20	-62.9	72.6	-0.33	0.38

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	294	0.50	0.22	0.42	-55.5	68.4	-0.28	0.34

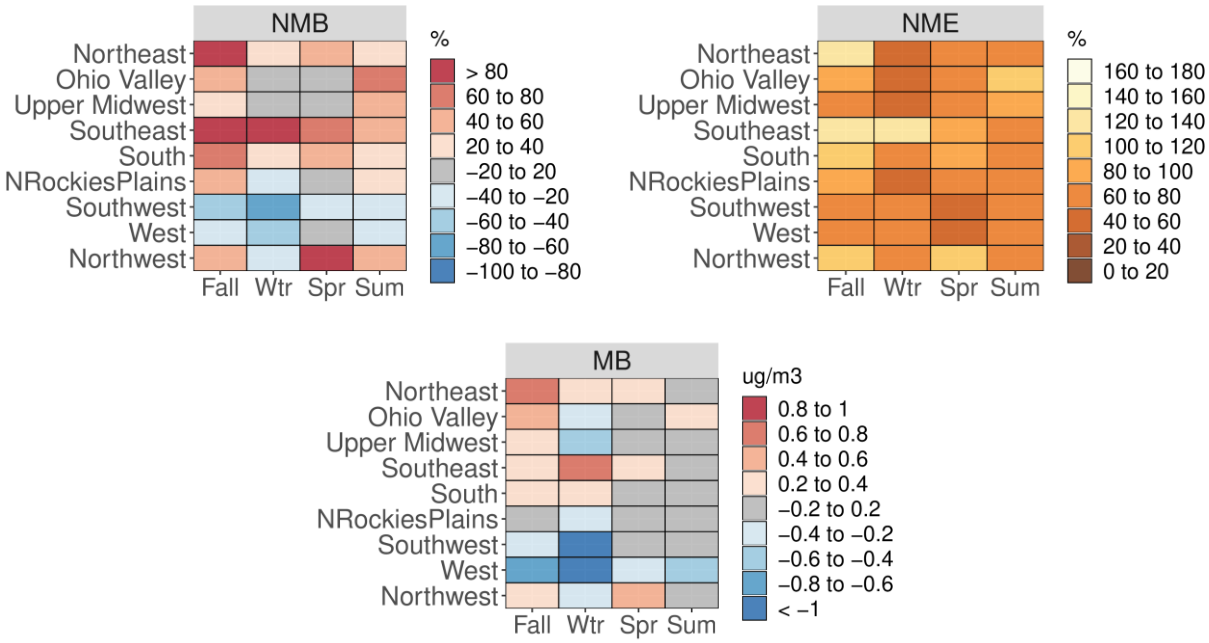


Figure 11. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for CSN PM2.5 nitrate observations.

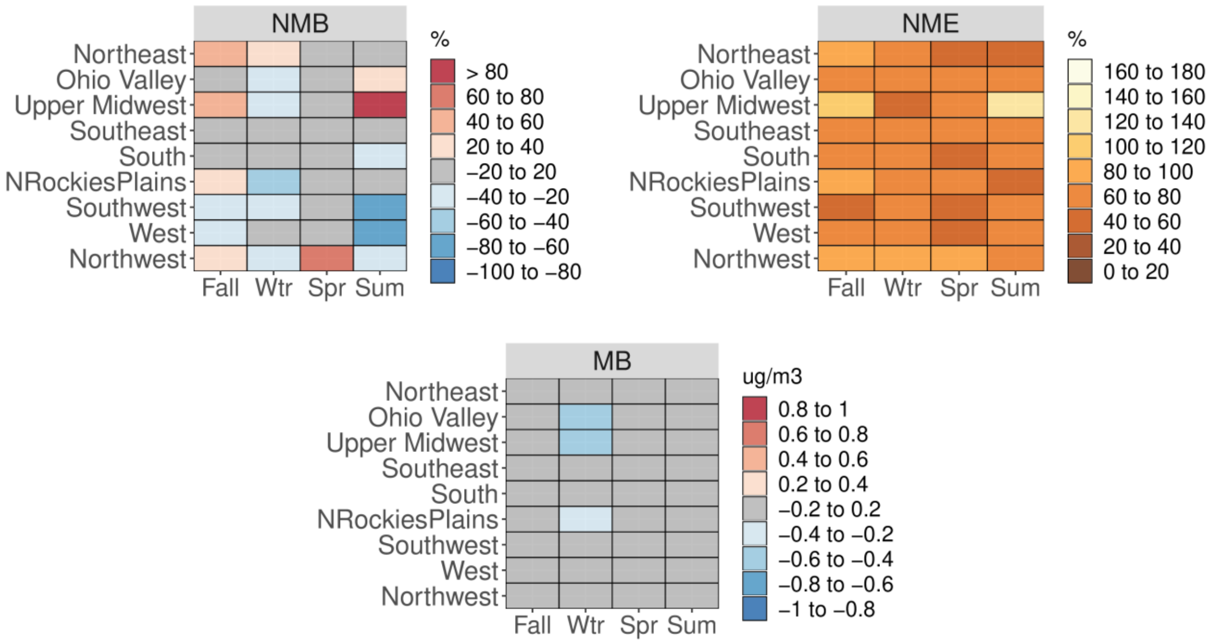
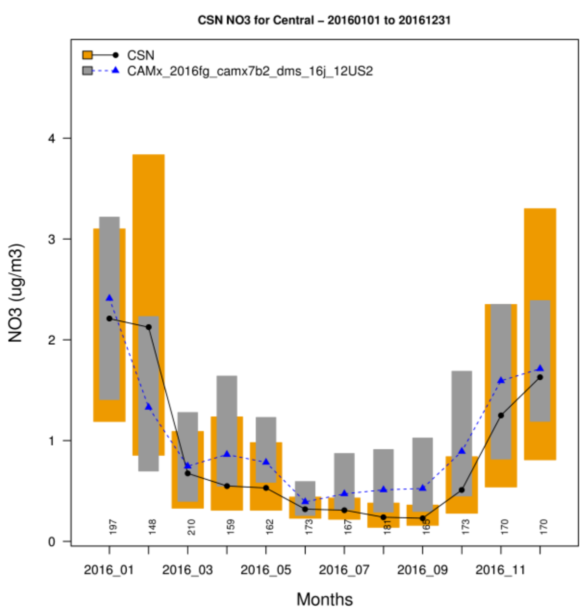
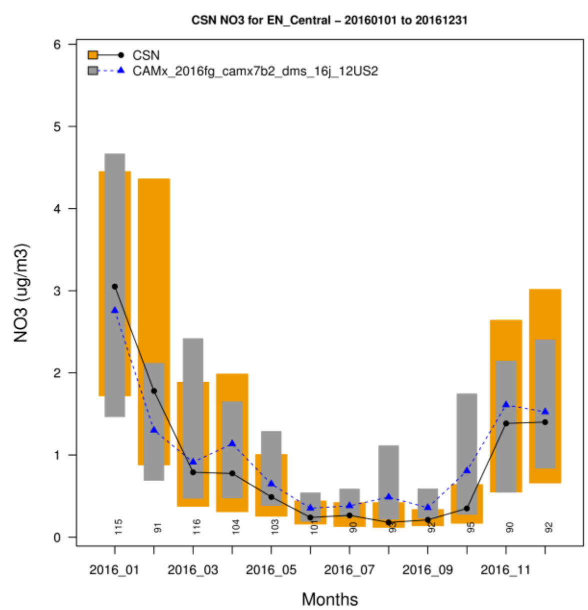
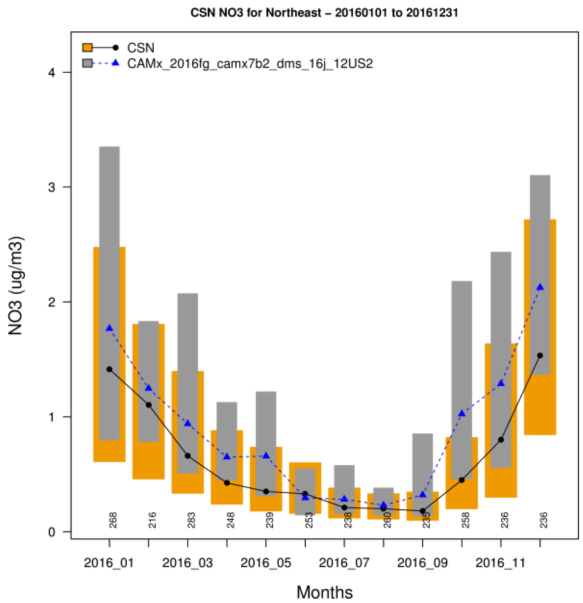
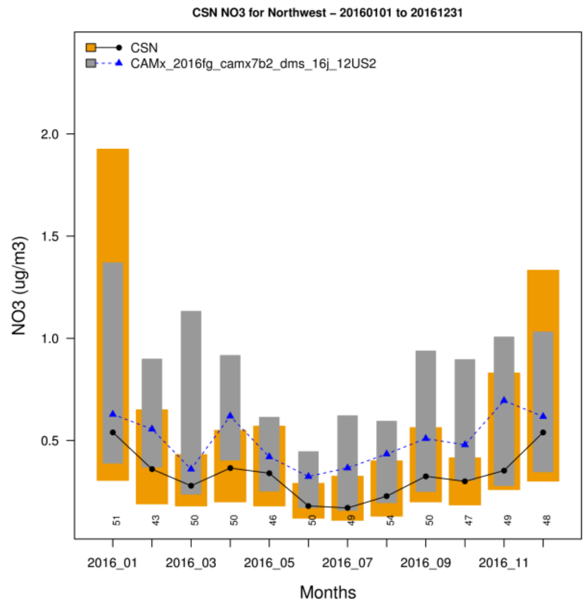


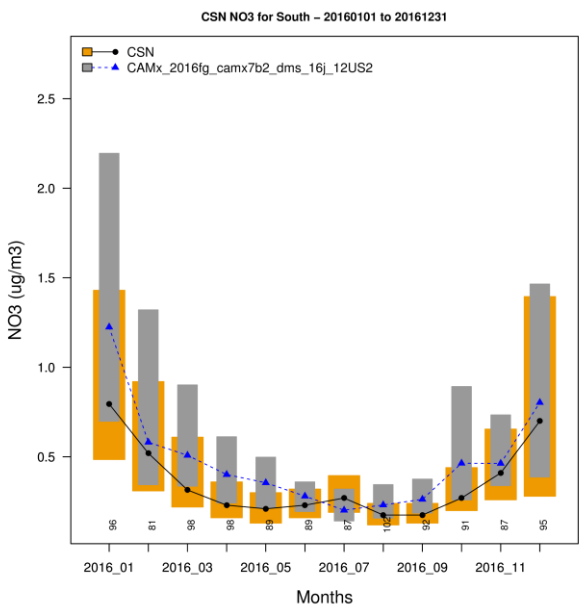
Figure 12. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for IMPROVE PM2.5 nitrate observations.

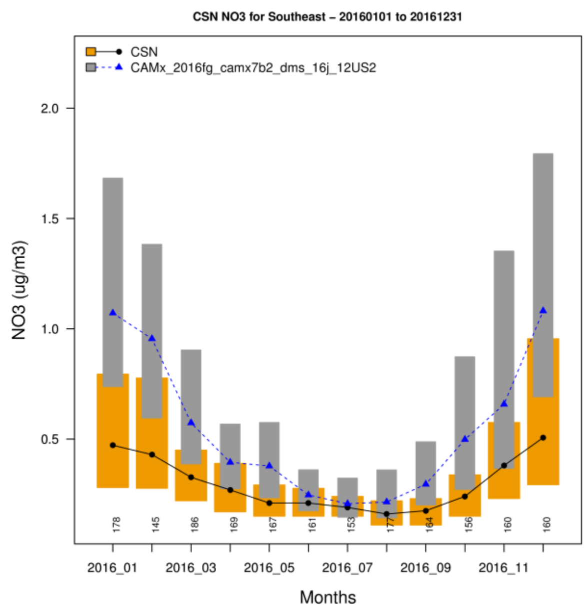





CSN NO3 for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CSN NO3 for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CSN NO3 for South – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CSN NO3 for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

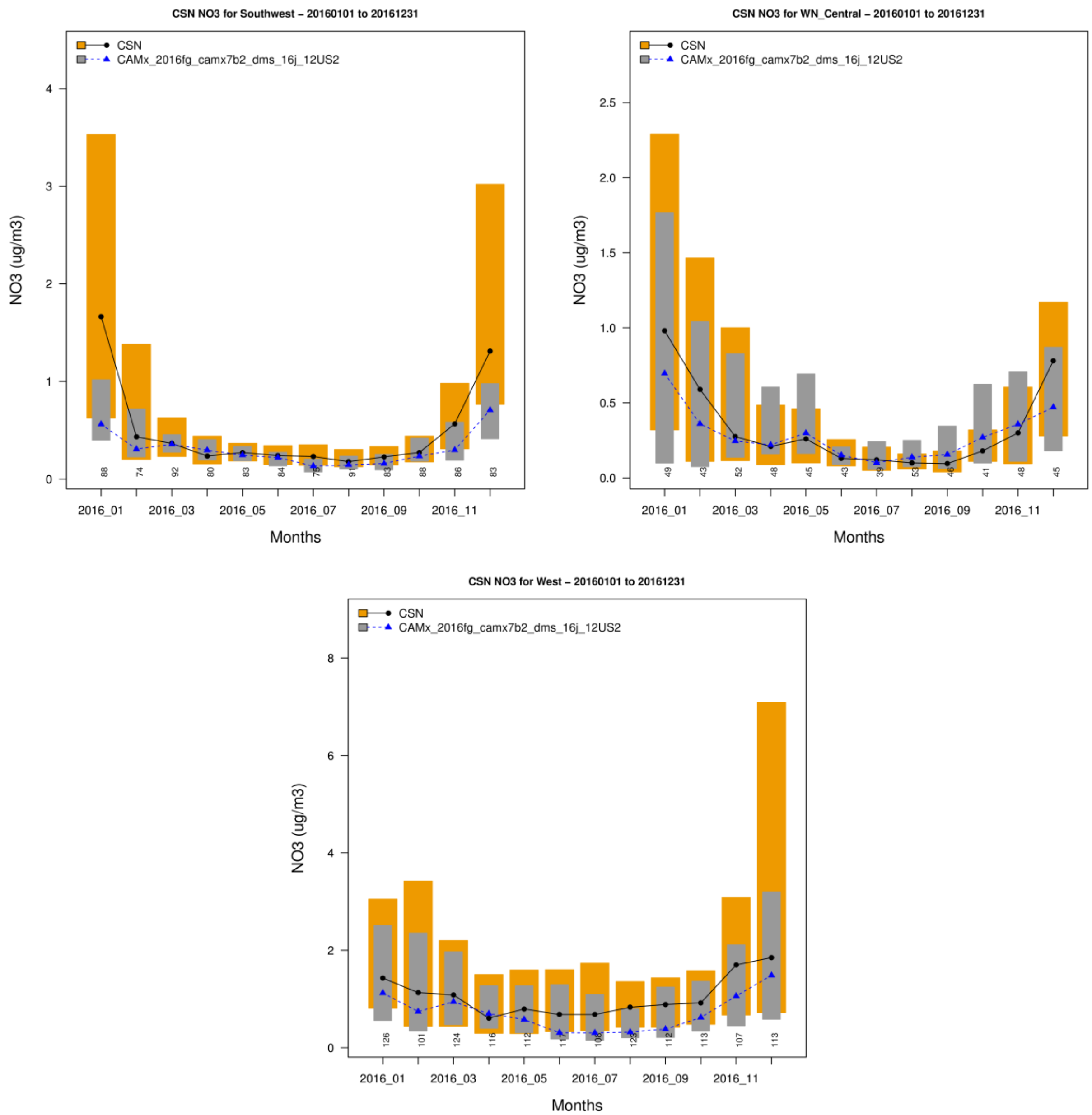
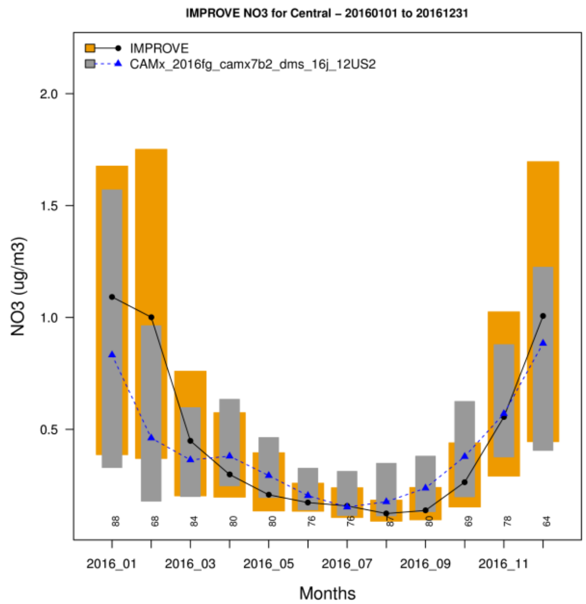
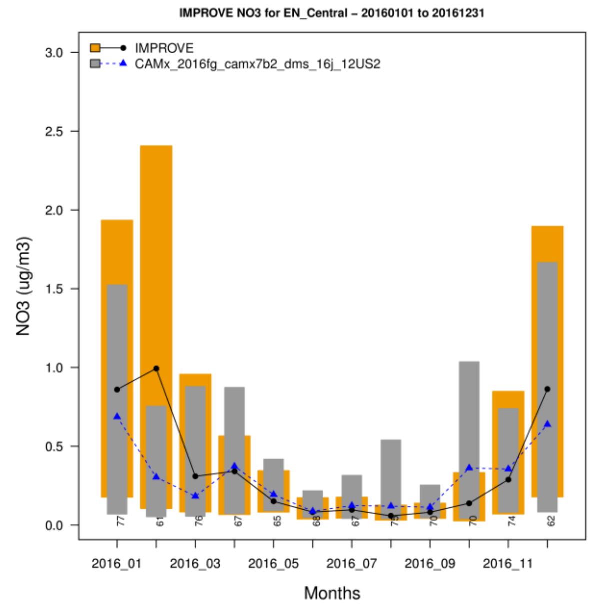
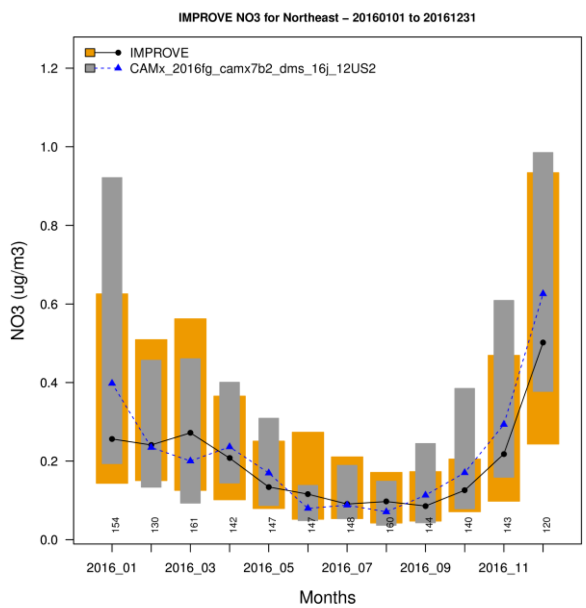
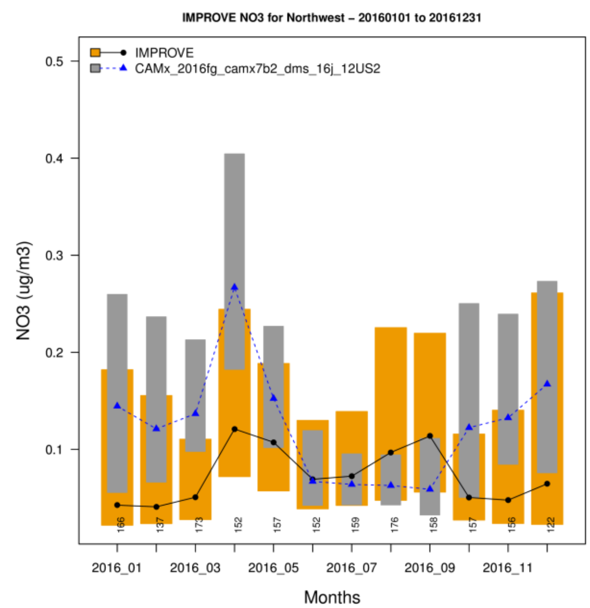


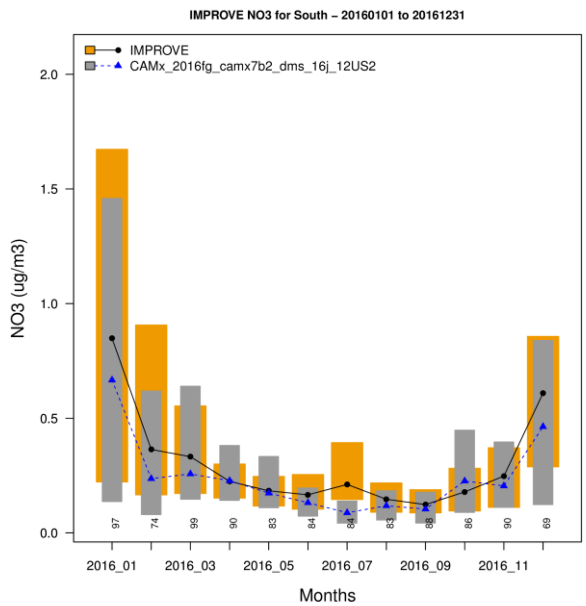
Figure 13. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN PM2.5 nitrate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

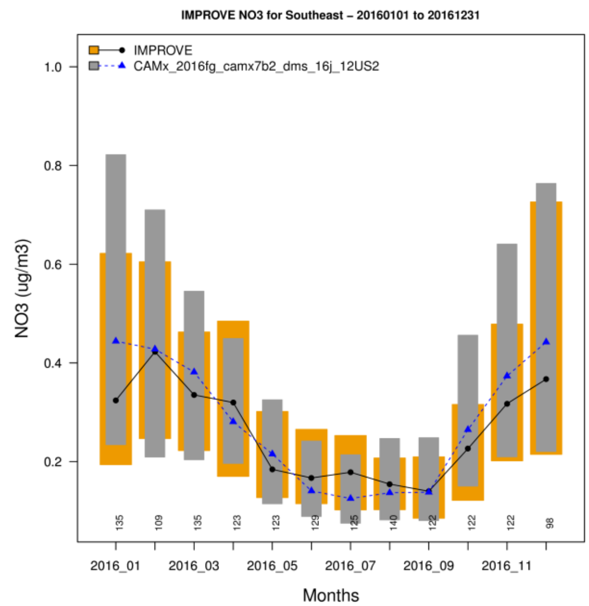

IMPROVE NO3 for Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months

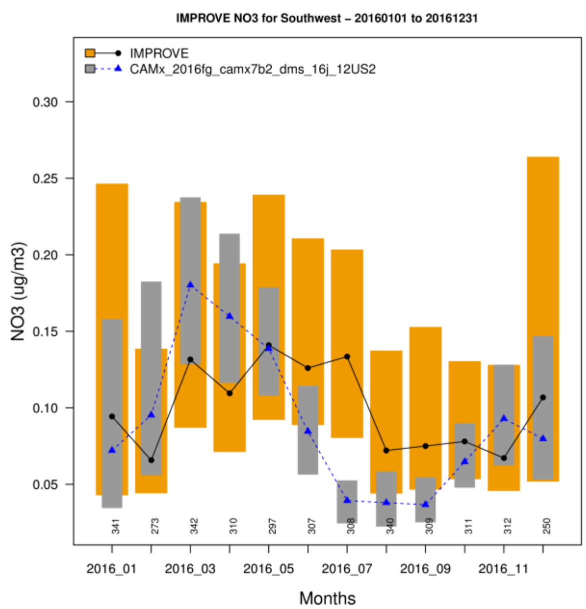

IMPROVE NO3 for EN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months

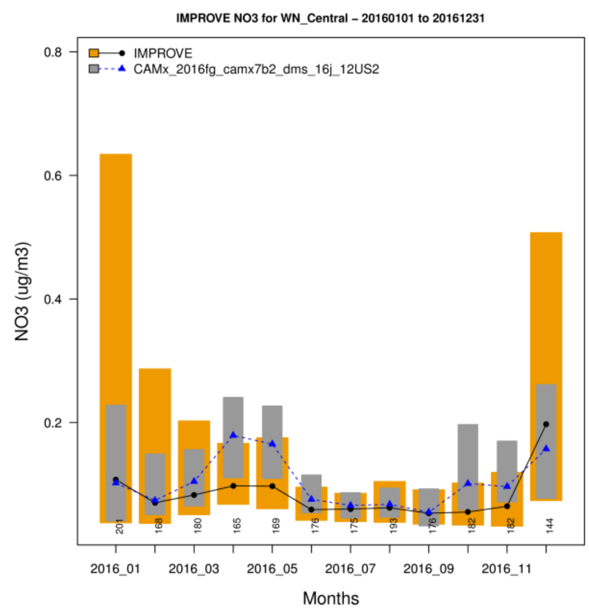

IMPROVE NO3 for Northeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months


IMPROVE NO3 for Northwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months


IMPROVE NO3 for South – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
97
74
99
90
83
84
84
83
88
86
90
69
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE NO3 for Southeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
135
109
135
123
123
129
125
140
122
122
122
98
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE NO3 for Southwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
341
273
342
310
297
307
308
340
309
311
312
250
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE NO3 for WN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
201
168
180
165
169
176
175
193
176
182
182
144
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

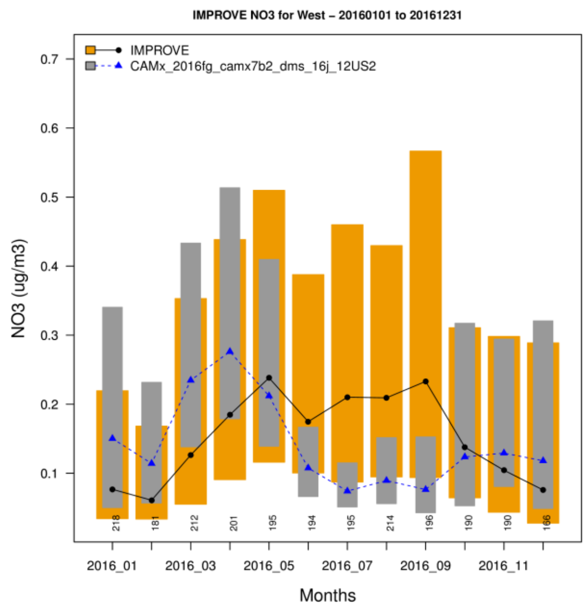
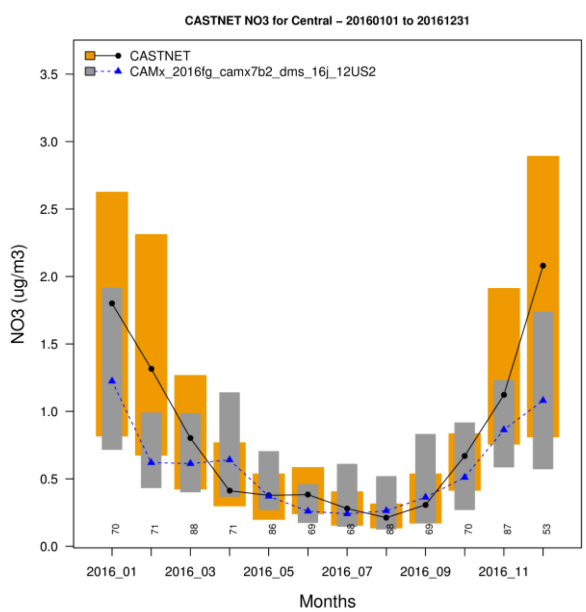
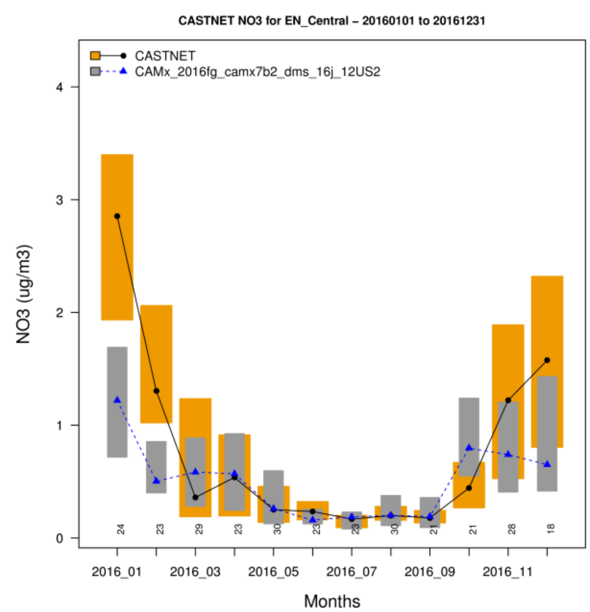
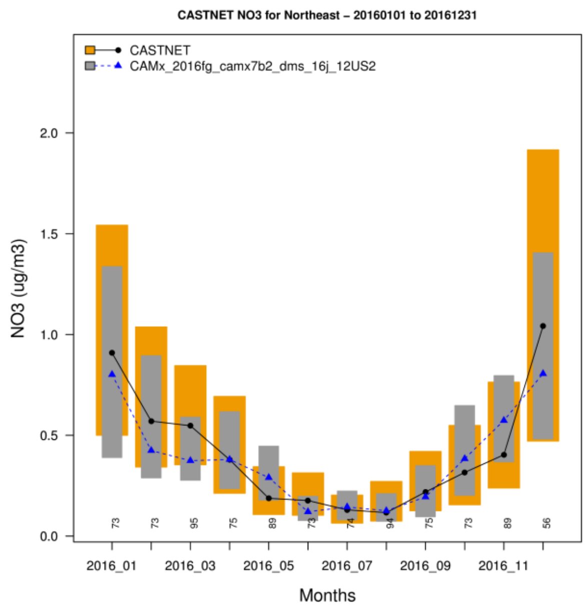
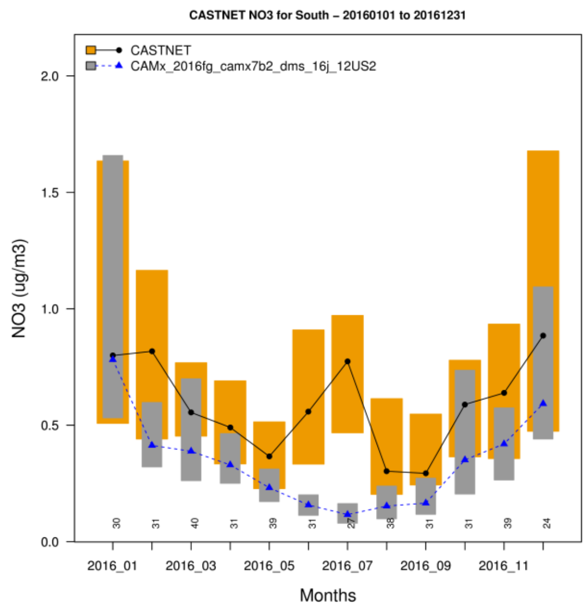


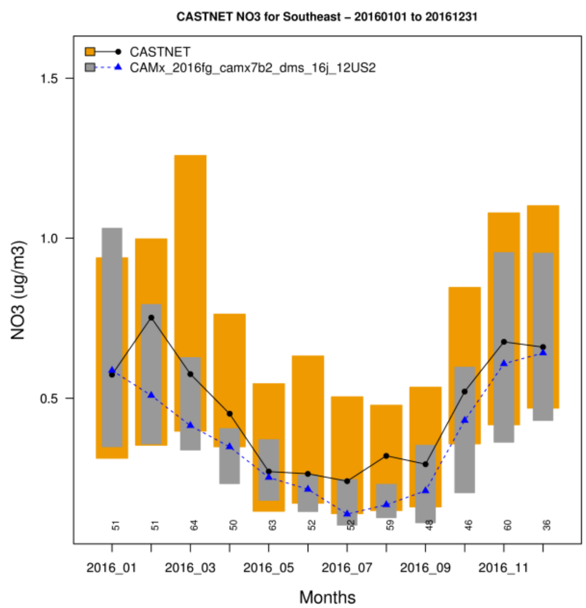
Figure 14. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median IMPROVE PM2.5 nitrate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

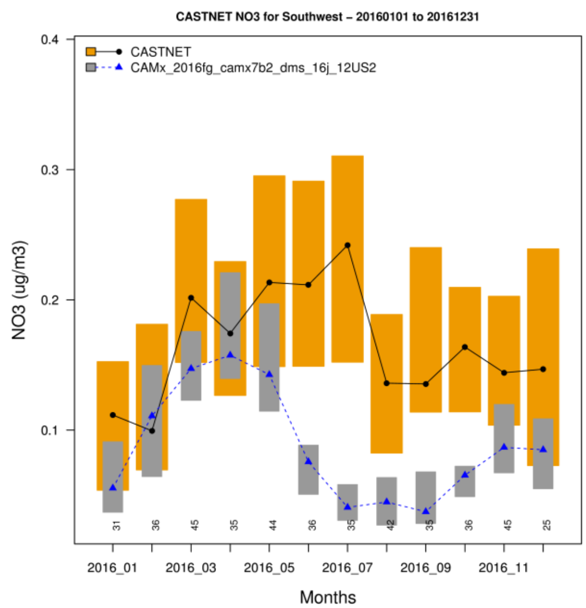





CASTNET NO3 for Northeast – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CASTNET NO3 for South – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CASTNET NO3 for Southeast – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CASTNET NO3 for Southwest – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

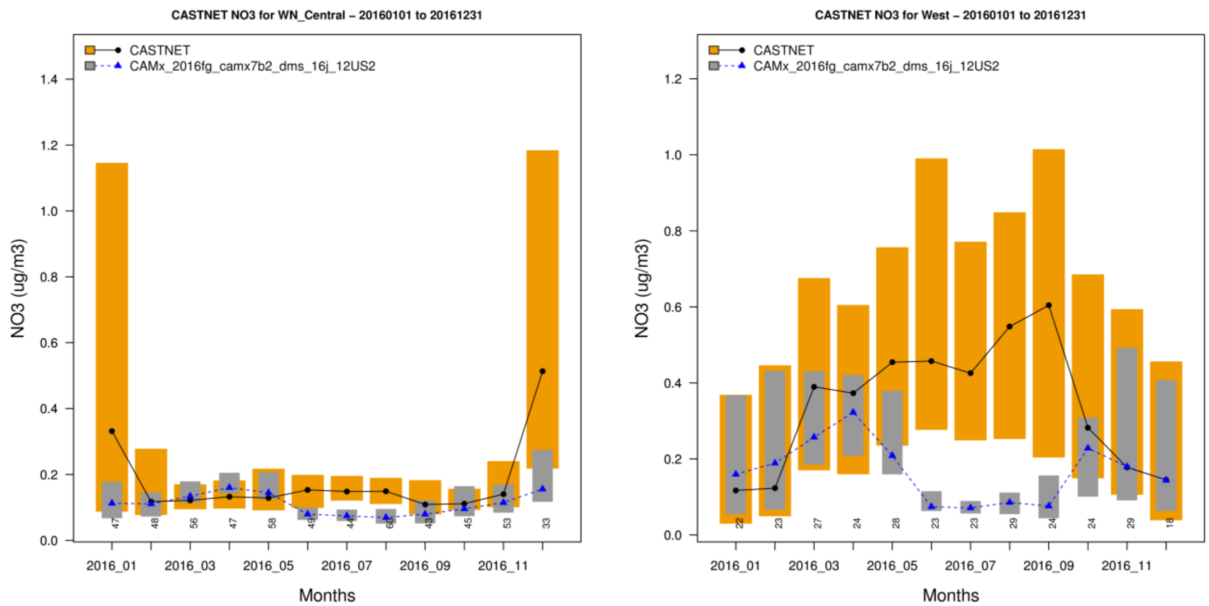
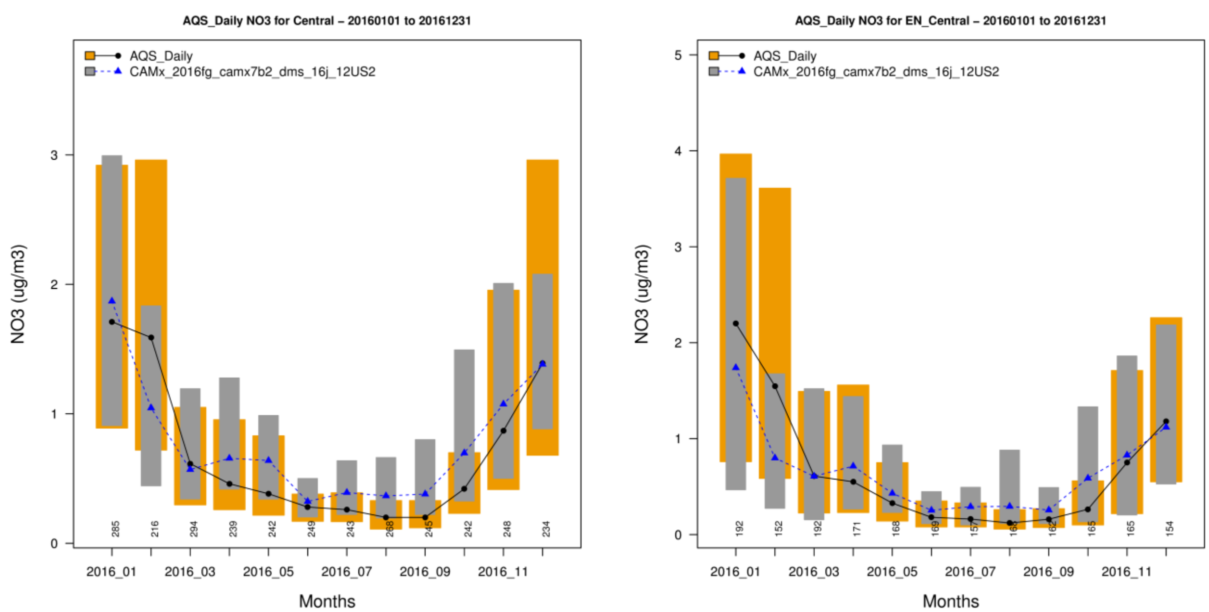
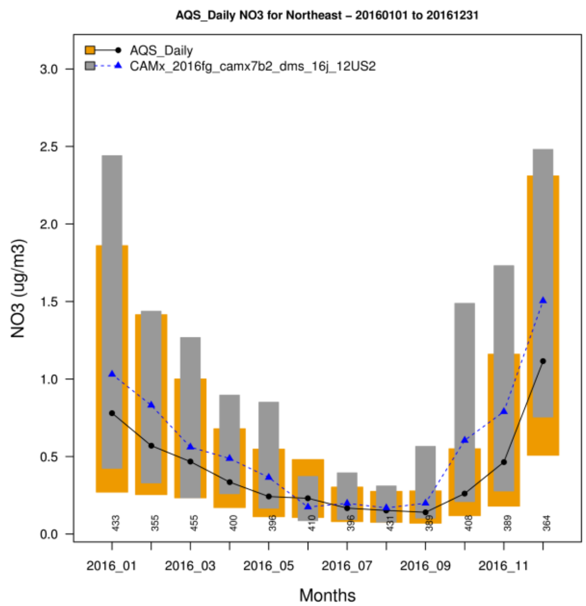
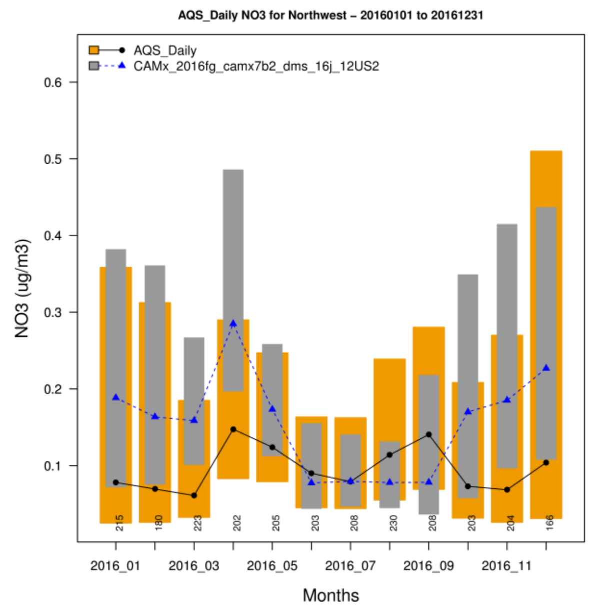
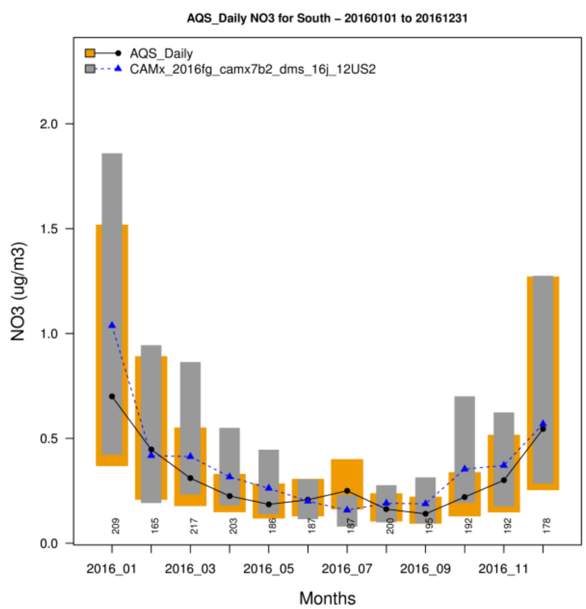


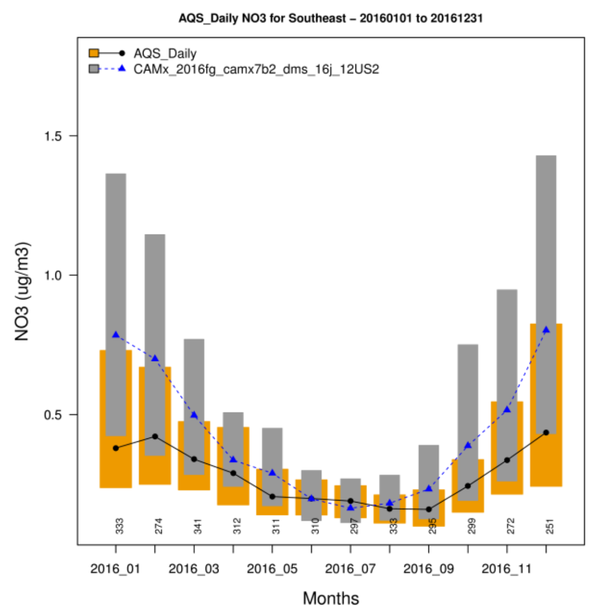
Figure 15. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CASTNET PM2.5 nitrate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.




AQS_Daily NO3 for Northeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
433
355
455
400
396
410
396
431
389
408
389
364


AQS_Daily NO3 for Northwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
215
180
223
202
205
203
208
230
208
203
204
166


AQS_Daily NO3 for South – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
209
165
217
203
186
187
187
200
195
192
192
178


AQS_Daily NO3 for Southeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NO3 (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
333
274
341
312
311
310
297
333
295
299
272
251

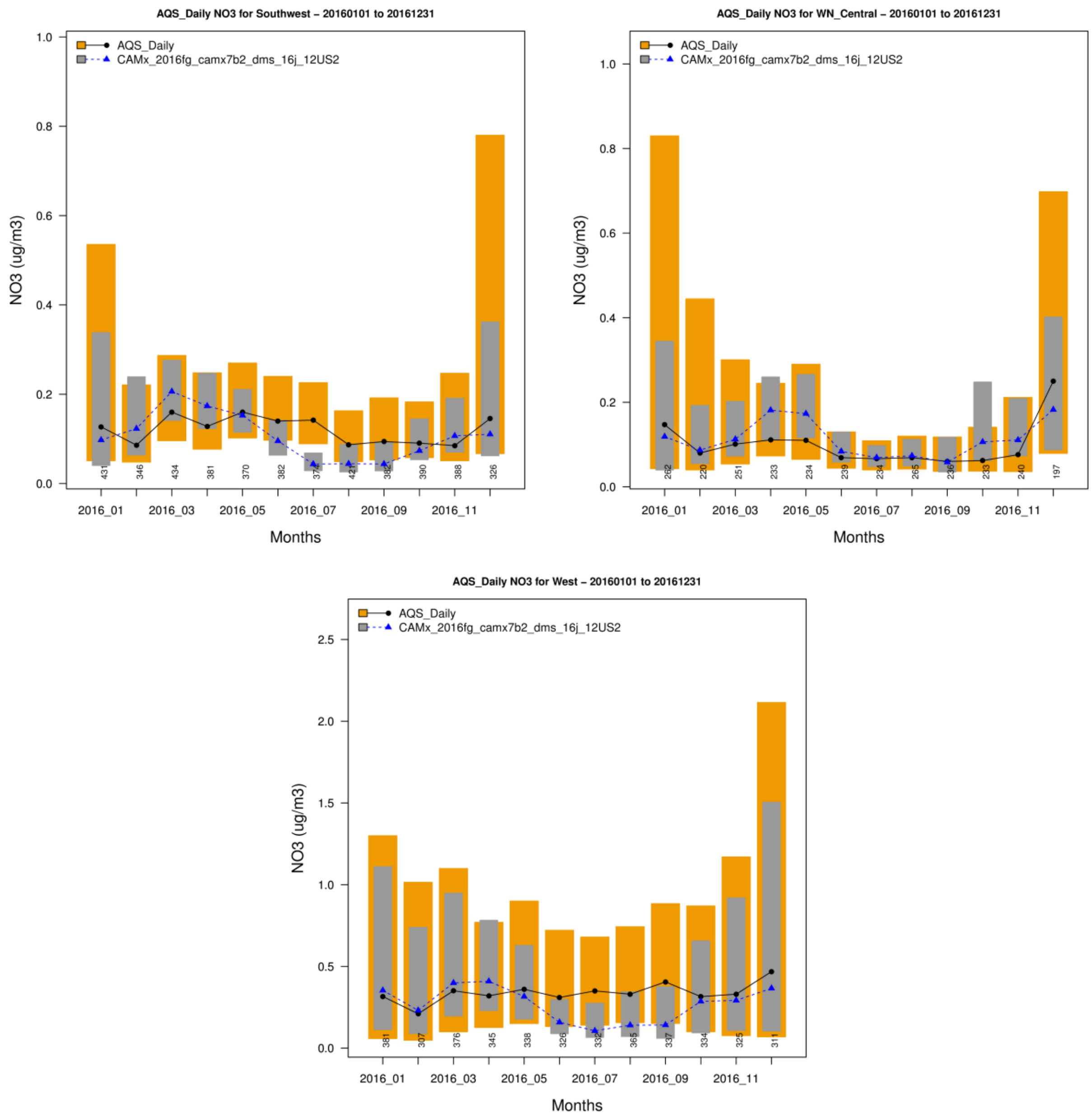


Figure 16. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily PM2.5 nitrate observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

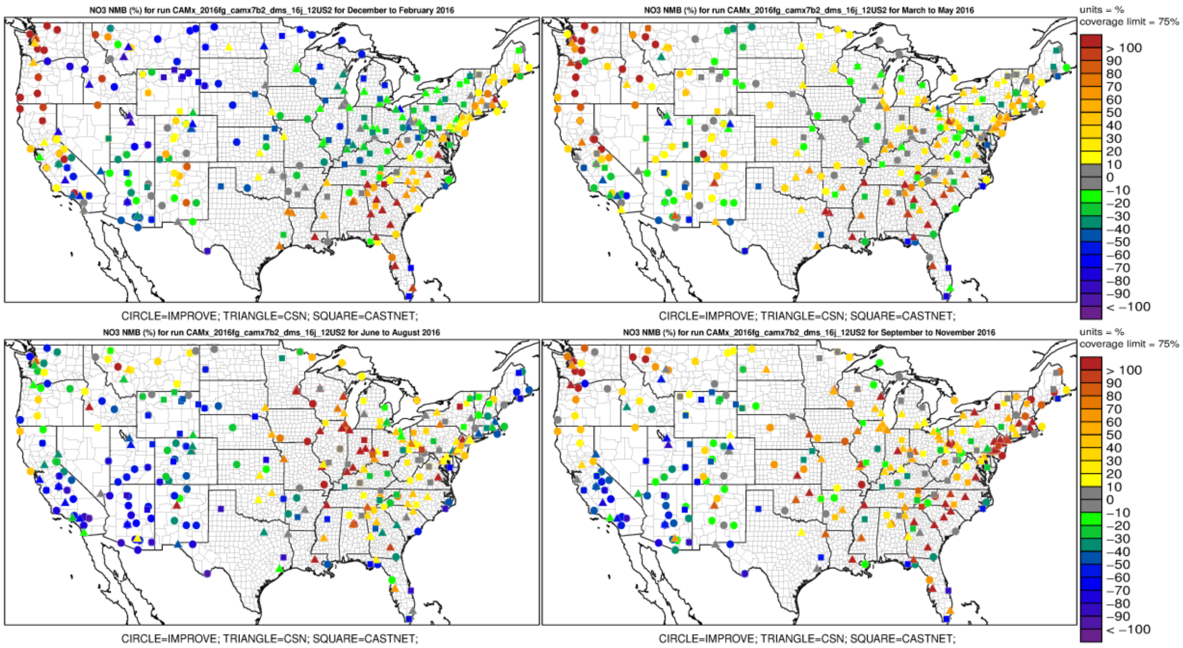


Figure 17. Spatial plot of PM2.5 nitrate NMB (%) by season and network.

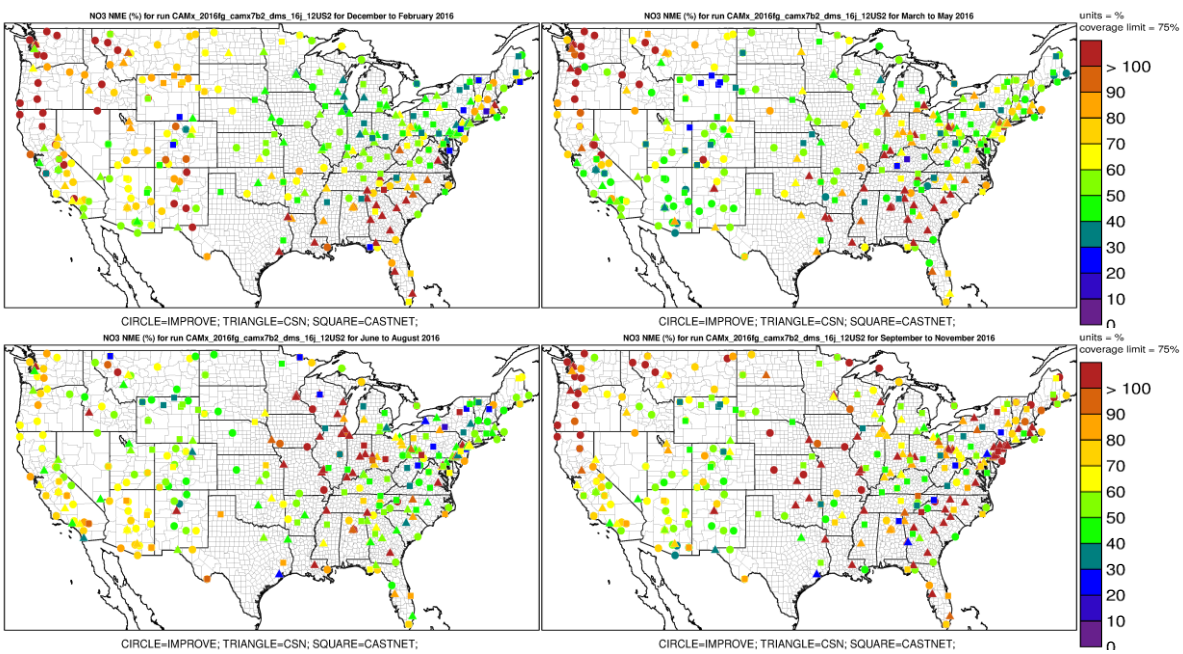


Figure 18. Spatial plot of PM2.5 nitrate NME (%) by season and network.

5. PM2.5 ammonium

Table 5-1 summarizes model performance statistics for $PM_{2.5}$ ammonium. Boxplot comparisons of model predictions and observations (CSN and CASTNET) by month for each climate region are shown in Figures 19, 20, and 21. Nationwide spatial plots of NMB and NME for each season are shown in Figures 22 and 23 (note that the IMPROVE network does not measure ammonium).

Table 5-1. Model performance statistics for PM2.5 ammonium by region, network, and season.

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Northeast	IMPROVE	Winter	404	0.42	0.42	0.63	-1.0	42.8	-0.00	0.18
		Spring	450	0.38	0.35	0.74	-7.3	33.5	-0.03	0.13
		Summer	455	0.33	0.32	0.79	-4.4	34.9	-0.01	0.12
		Fall	427	0.31	0.34	0.71	10.2	45.5	0.03	0.14
		All	1736	0.36	0.36	0.71	-1.2	38.9	-0.00	0.14
	CSN	Winter	723	0.49	1.00	0.50	103.0	124.0	0.51	0.61
		Spring	770	0.28	0.72	0.65	161.0	176.0	0.44	0.49
		Summer	755	0.25	0.52	0.64	109.0	123.0	0.27	0.31
		Fall	729	0.24	0.79	0.50	229.0	244.0	0.55	0.59
		All	2977	0.31	0.75	0.56	141.0	159.0	0.44	0.50
	CASTNET	Winter	221	0.50	0.51	0.73	2.2	29.7	0.01	0.15
		Spring	242	0.39	0.45	0.66	15.0	30.3	0.06	0.12
		Summer	239	0.38	0.41	0.89	8.9	17.8	0.03	0.07
		Fall	237	0.31	0.41	0.62	31.4	42.9	0.10	0.14
		All	939	0.39	0.45	0.72	13.0	29.6	0.05	0.12
Southeast	IMPROVE	Winter	342	0.50	0.43	0.45	-14.2	44.8	-0.07	0.22
		Spring	381	0.56	0.41	0.15	-26.5	44.5	-0.15	0.25
		Summer	394	0.51	0.33	0.45	-34.9	49.4	-0.18	0.25

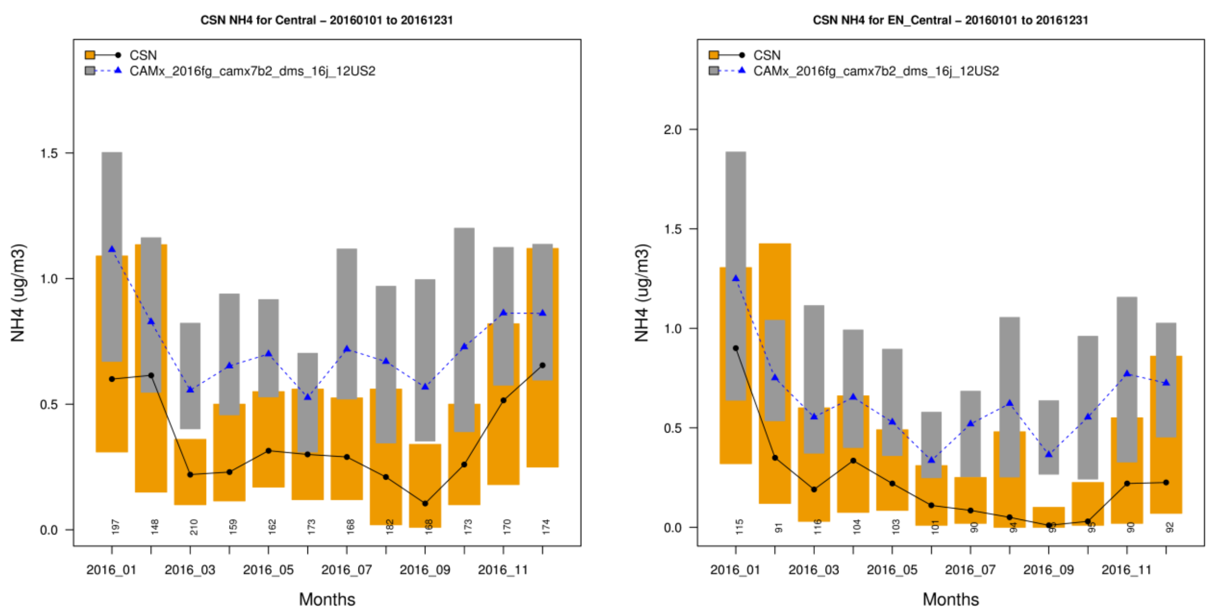
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Fall	366	0.47	0.40	0.59	-15.8	38.3	-0.07	0.18
		All	1483	0.51	0.39	0.40	-23.5	44.4	-0.12	0.23
	CSN	**Winter**	483	0.29	0.74	0.51	151.0	158.0	0.45	0.46
		Spring	522	0.29	0.53	0.57	83.7	95.8	0.24	0.28
		Summer	493	0.23	0.41	0.56	77.2	94.5	0.18	0.22
		Fall	473	0.26	0.56	0.60	116.0	127.0	0.30	0.33
		All	1971	0.27	0.56	0.54	108.0	119.0	0.29	0.32
	CASTNET	**Winter**	150	0.39	0.46	0.75	18.6	33.7	0.07	0.13
		Spring	164	0.40	0.42	0.56	6.2	26.9	0.02	0.11
		Summer	164	0.38	0.36	0.85	-4.5	23.2	-0.02	0.09
		Fall	154	0.39	0.46	0.78	16.9	30.8	0.07	0.12
		All	632	0.39	0.42	0.74	9.1	28.5	0.04	0.11
Ohio Valley	**IMPROVE**	**Winter**	220	0.80	0.60	0.40	-24.6	47.4	-0.20	0.38
		Spring	244	0.59	0.48	0.58	-17.9	31.9	-0.11	0.19
		Summer	239	0.61	0.54	0.61	-12.1	37.6	-0.07	0.23
		Fall	227	0.63	0.56	0.68	-10.7	31.6	-0.07	0.20
		All	930	0.65	0.54	0.53	-16.7	37.7	-0.11	0.25
	CSN	**Winter**	519	0.80	1.02	0.38	27.2	69.5	0.22	0.56
		Spring	531	0.35	0.72	0.42	103.0	121.0	0.37	0.43
		Summer	523	0.36	0.73	0.58	101.0	109.0	0.37	0.39
		Fall	511	0.39	0.80	0.57	106.0	119.0	0.41	0.46
		All	2084	0.48	0.81	0.48	71.4	96.7	0.34	0.46
	CASTNET	**Winter**	212	0.84	0.65	0.63	-21.9	33.3	-0.18	0.28
		Spring	228	0.58	0.59	0.59	1.0	24.5	0.01	0.14
		Summer	224	0.55	0.59	0.73	7.2	22.5	0.04	0.12
		Fall	226	0.56	0.62	0.41	11.0	31.1	0.06	0.17

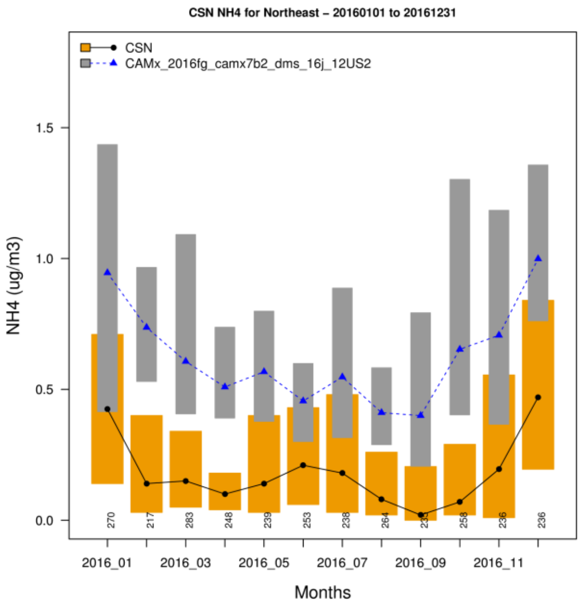
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	890	0.63	0.61	0.56	-2.6	28.3	-0.02	0.18
Upper Midwest	**IMPROVE**	**Winter**	200	0.70	0.46	0.76	-34.7	42.9	-0.24	0.30
		Spring	208	0.45	0.40	0.66	-12.2	39.9	-0.06	0.18
		Summer	210	0.29	0.32	0.82	9.7	36.7	0.03	0.11
		Fall	214	0.33	0.38	0.70	15.2	48.9	0.05	0.16
		All	832	0.44	0.39	0.69	-11.8	42.3	-0.05	0.19
	CSN	**Winter**	298	0.77	1.03	0.69	32.9	62.1	0.25	0.48
		Spring	323	0.39	0.75	0.56	93.5	114.0	0.36	0.44
		Summer	285	0.20	0.54	0.64	171.0	177.0	0.34	0.35
		Fall	280	0.22	0.68	0.63	203.0	213.0	0.45	0.47
		All	1186	0.40	0.75	0.67	87.9	109.0	0.35	0.44
	CASTNET	**Winter**	71	0.83	0.51	0.72	-38.6	40.6	-0.32	0.34
		Spring	76	0.42	0.47	0.63	11.0	32.3	0.05	0.14
		Summer	76	0.28	0.34	0.87	19.5	23.8	0.05	0.07
		Fall	70	0.36	0.43	0.55	17.5	46.0	0.06	0.17
		All	293	0.47	0.43	0.62	-7.6	37.1	-0.04	0.17
South	**IMPROVE**	**Winter**	240	0.55	0.48	0.55	-13.7	48.1	-0.08	0.27
		Spring	272	0.46	0.37	0.47	-18.7	36.5	-0.09	0.17
		Summer	251	0.61	0.32	0.40	-46.4	52.8	-0.28	0.32
		Fall	264	0.49	0.42	0.61	-14.4	37.7	-0.07	0.19
		All	1027	0.52	0.40	0.49	-24.3	44.2	-0.13	0.23
	CSN	**Winter**	273	0.31	0.71	0.43	133.0	155.0	0.41	0.48
		Spring	287	0.25	0.51	0.49	102.0	132.0	0.26	0.34
		Summer	279	0.21	0.41	0.43	96.6	119.0	0.20	0.25
		Fall	271	0.27	0.62	0.56	131.0	140.0	0.35	0.38
		All	1110	0.26	0.56	0.47	117.0	138.0	0.30	0.36

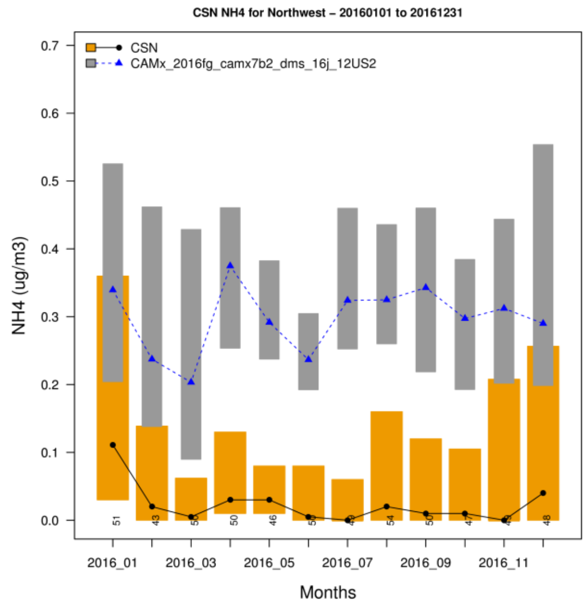
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
	CASTNET	Winter	92	0.51	0.50	0.63	-2.3	38.4	-0.01	0.20
		Spring	102	0.41	0.43	0.09	5.7	34.0	0.02	0.14
		Summer	96	0.41	0.34	0.37	-16.9	31.8	-0.07	0.13
		Fall	102	0.41	0.47	0.26	14.4	36.7	0.06	0.15
		All	392	0.43	0.44	0.43	0.3	35.4	0.00	0.15
Southwest	IMPROVE	Winter	864	0.16	0.15	0.42	-3.4	56.7	-0.01	0.09
		Spring	949	0.19	0.21	0.54	7.6	36.3	0.01	0.07
		Summer	955	0.28	0.15	0.40	-45.1	51.1	-0.13	0.14
		Fall	932	0.21	0.17	0.48	-18.6	37.8	-0.04	0.08
		All	3700	0.21	0.17	0.39	-18.9	45.3	-0.04	0.10
	CSN	Winter	245	0.66	0.36	0.43	-45.8	88.2	-0.30	0.58
		Spring	255	0.11	0.26	0.20	149.0	191.0	0.16	0.20
		Summer	250	0.14	0.20	0.22	44.6	139.0	0.06	0.20
		Fall	260	0.15	0.24	0.23	64.9	145.0	0.10	0.22
		All	1010	0.26	0.27	0.43	2.7	114.0	0.01	0.30
	CASTNET	Winter	101	0.14	0.12	0.18	-14.1	63.9	-0.02	0.09
		Spring	115	0.14	0.19	0.58	42.0	46.4	0.06	0.06
		Summer	114	0.22	0.15	0.19	-30.2	35.0	-0.07	0.08
		Fall	115	0.17	0.15	0.37	-9.5	29.1	-0.02	0.05
		All	445	0.17	0.15	0.14	-6.2	41.4	-0.01	0.07
Northern Rockies & Plains	IMPROVE	Winter	513	0.24	0.17	0.79	-31.3	55.9	-0.08	0.14
		Spring	514	0.20	0.21	0.66	6.9	41.1	0.01	0.08
		Summer	544	0.16	0.18	0.25	7.4	44.4	0.01	0.07
		Fall	540	0.16	0.18	0.65	8.1	45.8	0.01	0.07
		All	2111	0.19	0.18	0.61	-4.5	47.4	-0.01	0.09
	CSN	Winter	141	0.25	0.45	0.67	82.0	120.0	0.20	0.30

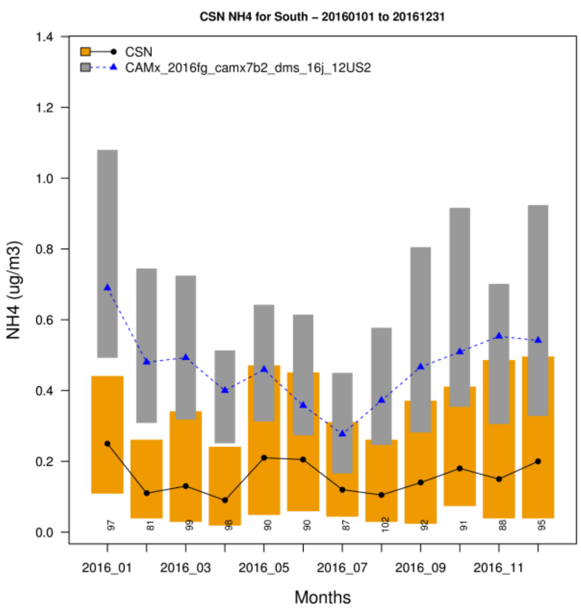
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Spring	145	0.12	0.39	0.59	227.0	244.0	0.27	0.29
		Summer	135	0.06	0.25	0.62	338.0	345.0	0.19	0.19
		Fall	139	0.06	0.33	0.73	419.0	423.0	0.27	0.27
		All	560	0.12	0.35	0.65	190.0	215.0	0.23	0.26
	CASTNET	**Winter**	138	0.27	0.17	0.82	-38.7	50.6	-0.11	0.14
		Spring	152	0.18	0.21	0.84	16.9	27.4	0.03	0.05
		Summer	151	0.20	0.18	0.72	-9.3	21.4	-0.02	0.04
		Fall	142	0.16	0.18	0.58	16.9	37.3	0.03	0.06
		All	583	0.20	0.18	0.66	-7.6	35.3	-0.02	0.07
Northwest	**IMPROVE**	**Winter**	425	0.15	0.12	0.48	-17.5	75.0	-0.03	0.11
		Spring	482	0.16	0.20	0.61	27.6	52.1	0.04	0.08
		Summer	487	0.17	0.20	0.42	18.3	54.8	0.03	0.09
		Fall	471	0.14	0.17	0.52	20.3	59.7	0.03	0.08
		All	1865	0.15	0.17	0.47	13.4	59.6	0.02	0.09
	CSN	**Winter**	142	0.26	0.40	0.43	52.4	133.0	0.14	0.35
		Spring	146	0.09	0.36	0.31	276.0	296.0	0.26	0.28
		Summer	153	0.09	0.33	0.33	254.0	286.0	0.24	0.27
		Fall	146	0.10	0.37	0.26	277.0	308.0	0.27	0.30
		All	587	0.14	0.36	0.34	167.0	220.0	0.23	0.30
	CASTNET	**Winter**	-	-	-	-	-	-	-	-
		Spring	-	-	-	-	-	-	-	-
		Summer	-	-	-	-	-	-	-	-
		Fall	-	-	-	-	-	-	-	-
		All	-	-	-	-	-	-	-	-
West	**IMPROVE**	**Winter**	565	0.21	0.22	0.75	3.1	65.3	0.01	0.14
		Spring	608	0.29	0.26	0.64	-10.3	45.8	-0.03	0.14

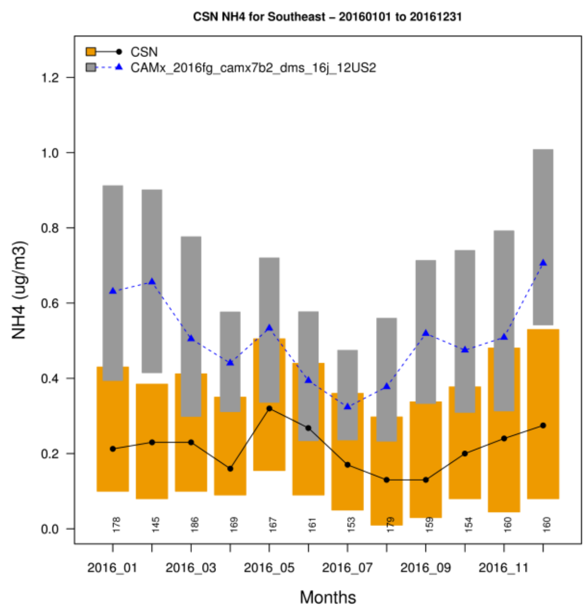
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Summer	603	0.36	0.23	0.41	-37.2	50.5	-0.13	0.18
		Fall	576	0.29	0.22	0.77	-25.3	48.2	-0.07	0.14
		All	2352	0.29	0.23	0.68	-20.2	51.3	-0.06	0.15
	CSN	Winter	340	0.85	0.72	0.61	-15.1	79.5	-0.13	0.67
		Spring	352	0.45	0.56	0.64	26.3	89.4	0.12	0.40
		Summer	349	0.40	0.56	0.61	39.3	87.8	0.16	0.35
		Fall	332	0.53	0.56	0.59	5.9	88.4	0.03	0.47
		All	1373	0.55	0.60	0.61	8.3	85.1	0.05	0.47
	CASTNET	Winter	69	0.16	0.17	0.58	7.4	81.9	0.01	0.13
		Spring	73	0.20	0.24	0.49	19.9	47.2	0.04	0.09
		Summer	75	0.33	0.23	0.08	-29.6	51.0	-0.10	0.17
		Fall	77	0.22	0.21	0.35	-7.8	40.6	-0.02	0.09
		All	294	0.23	0.21	0.39	-7.5	52.6	-0.02	0.12




CSN NH4 for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


CSN NH4 for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


CSN NH4 for South – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


CSN NH4 for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months

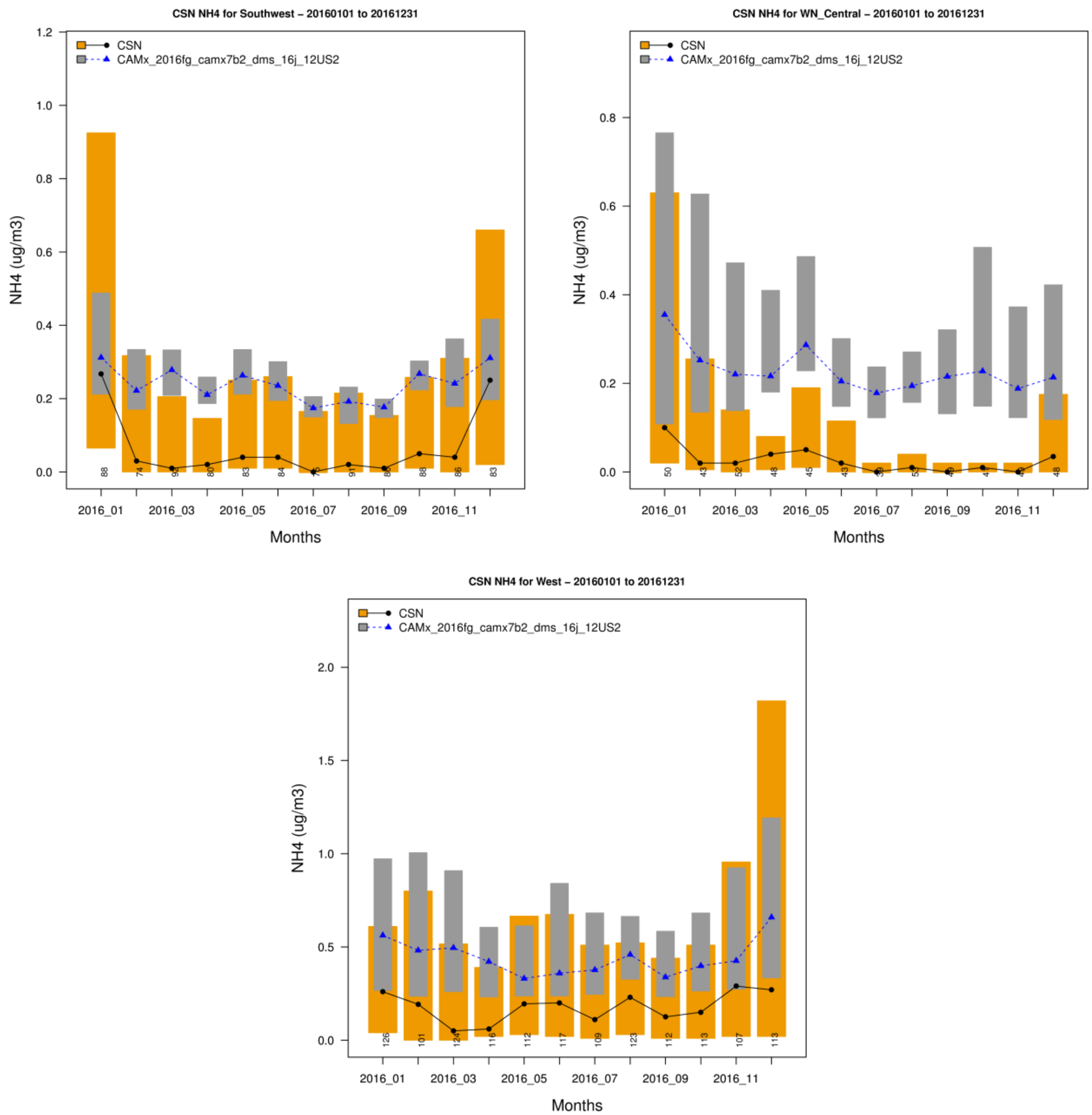
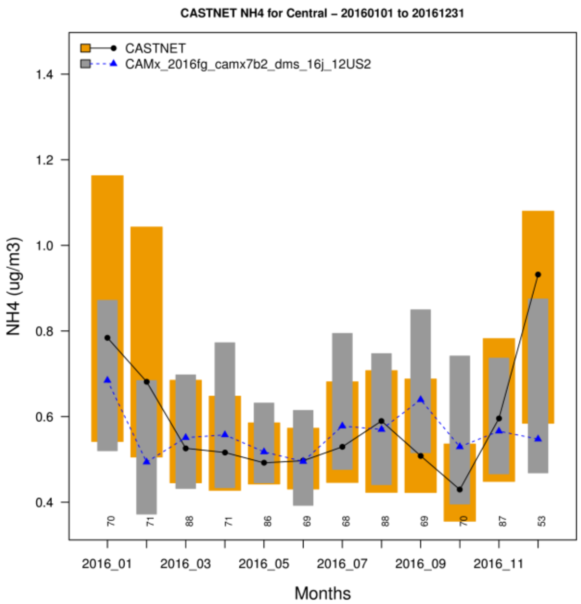
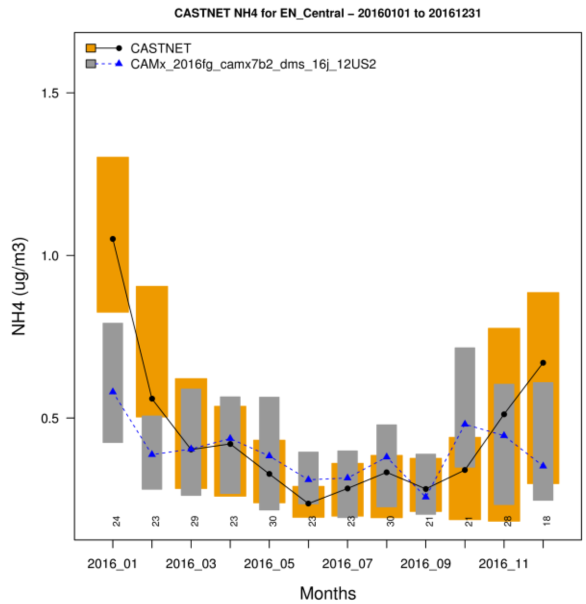
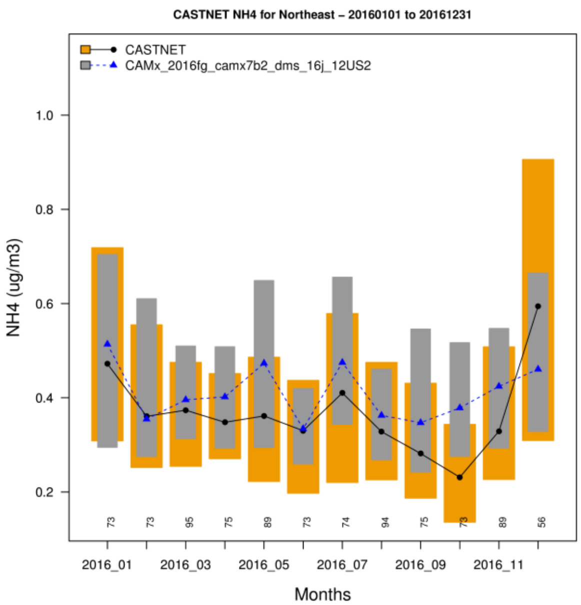
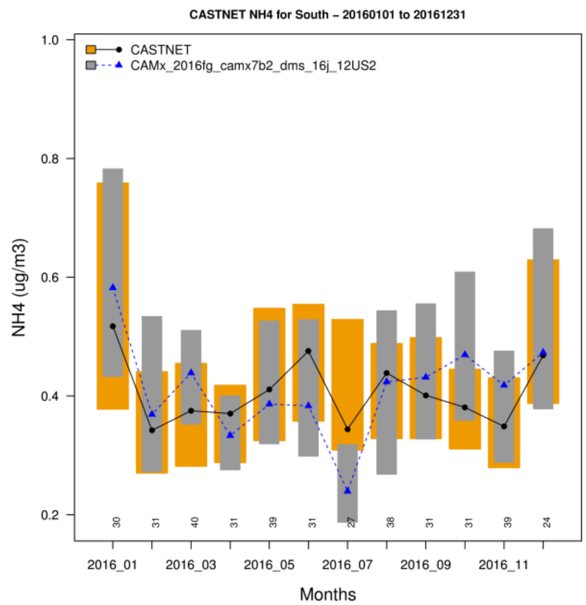


Figure 19. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN PM2.5 ammonium observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.


CASTNET NH4 for Central – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


CASTNET NH4 for EN_Central – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


CASTNET NH4 for Northeast – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


CASTNET NH4 for South – 20160101 to 20161231
CASTNET
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months

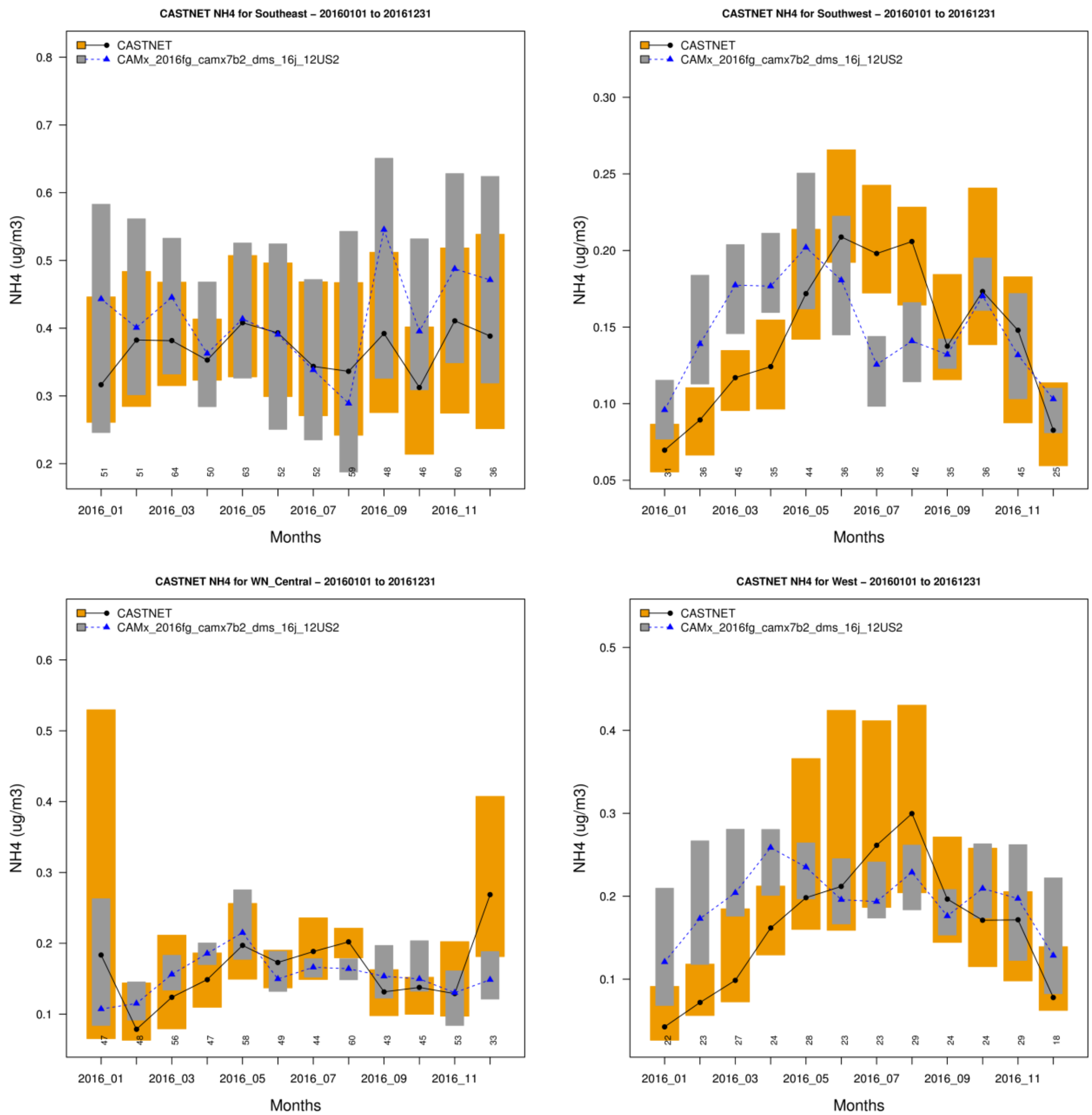
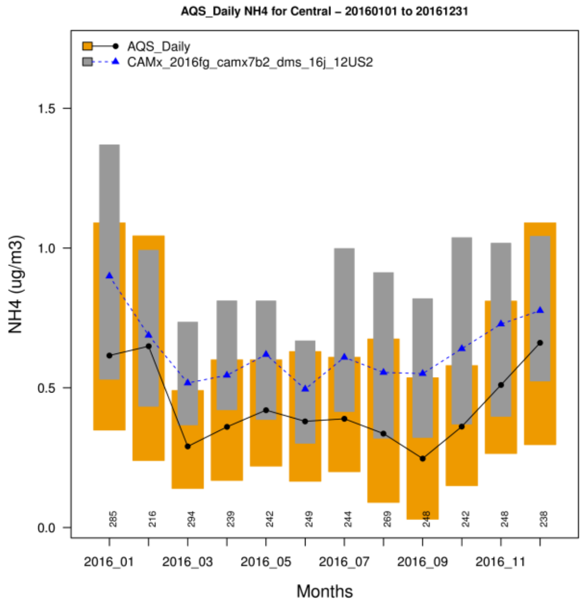
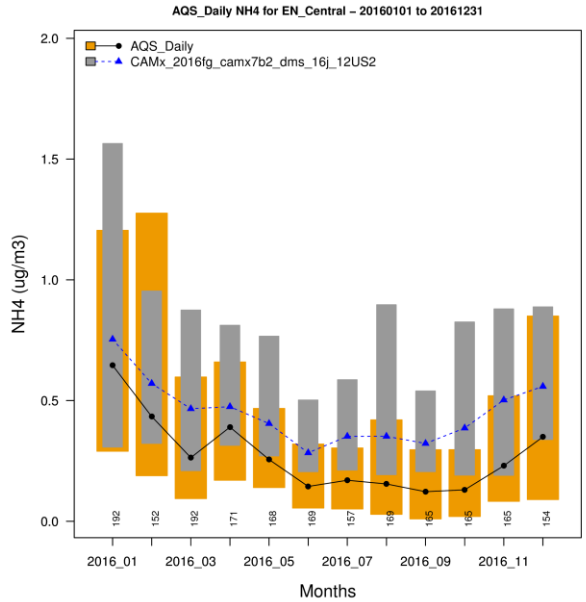
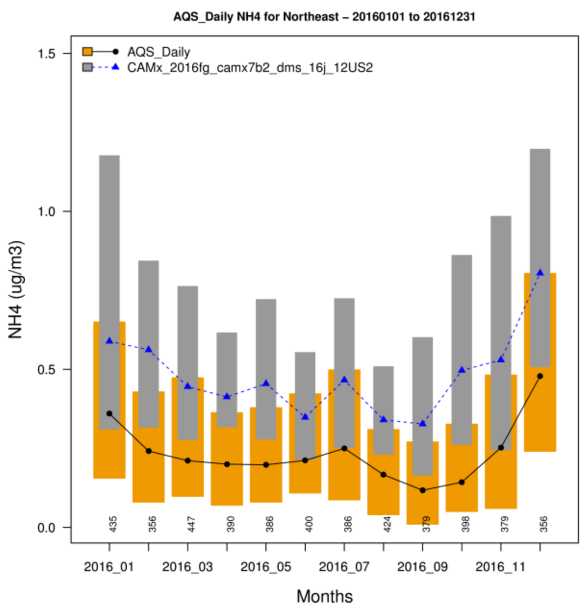
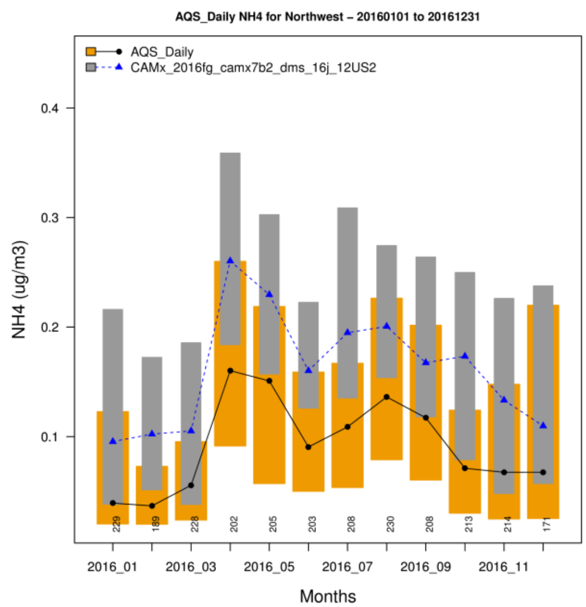


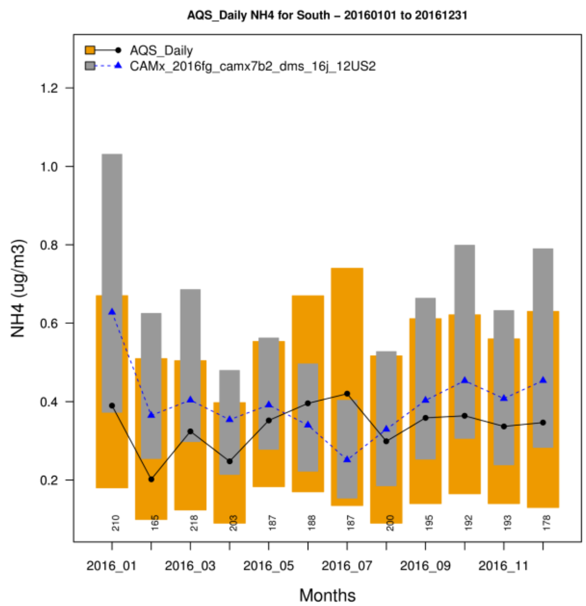
Figure 20. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CASTNET PM2.5 ammonium observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

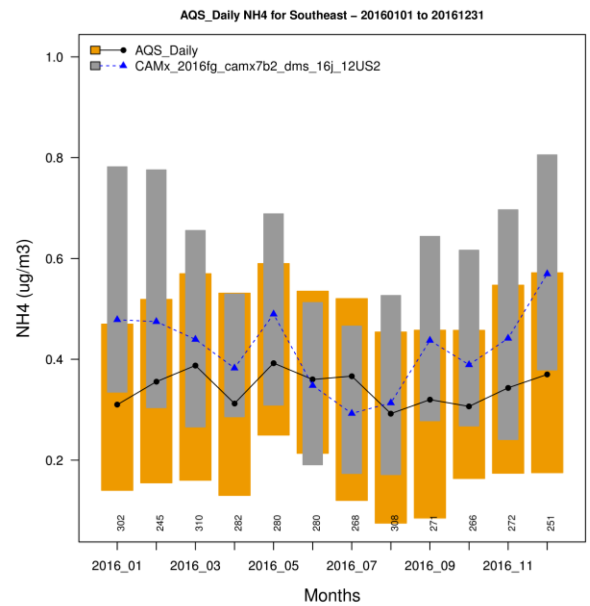

AQS_Daily NH4 for Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months

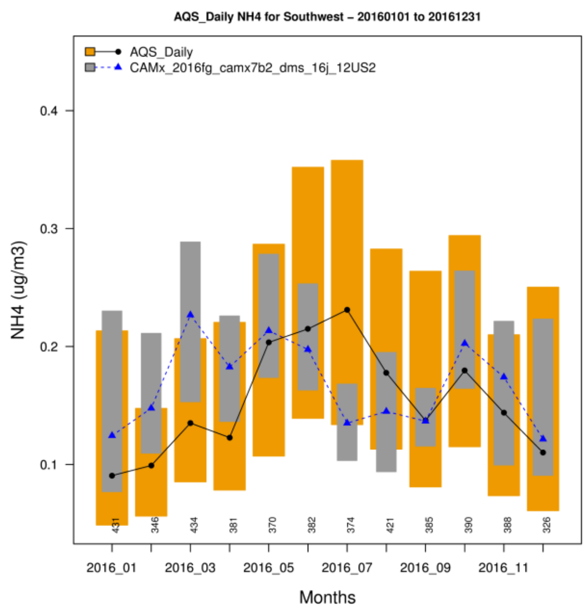

AQS_Daily NH4 for EN_Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months

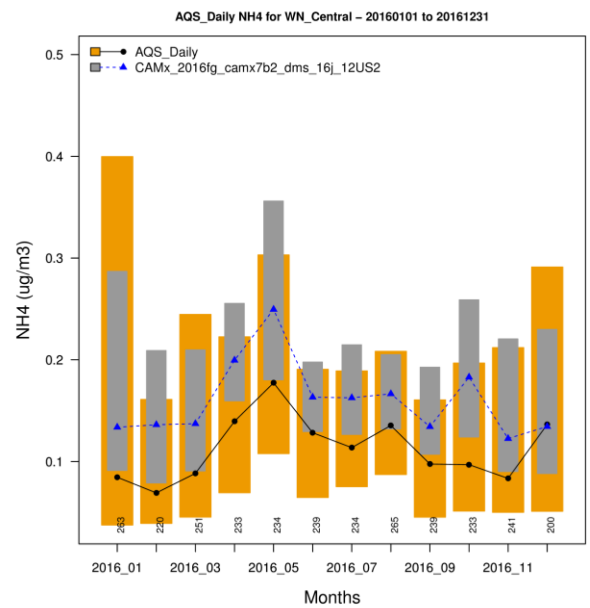

AQS_Daily NH4 for Northeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


AQS_Daily NH4 for Northwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


AQS_Daily NH4 for South – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


AQS_Daily NH4 for Southeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


AQS_Daily NH4 for Southwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months


AQS_Daily NH4 for WN_Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
NH4 (ug/m3)
Months

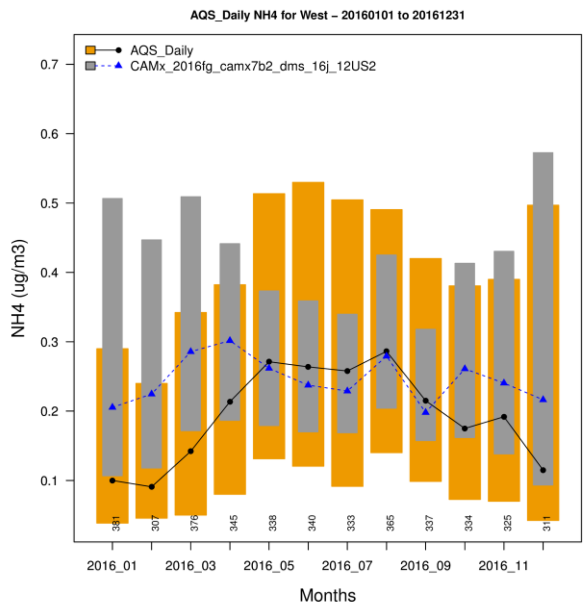


Figure 21. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily PM2.5 ammonium observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

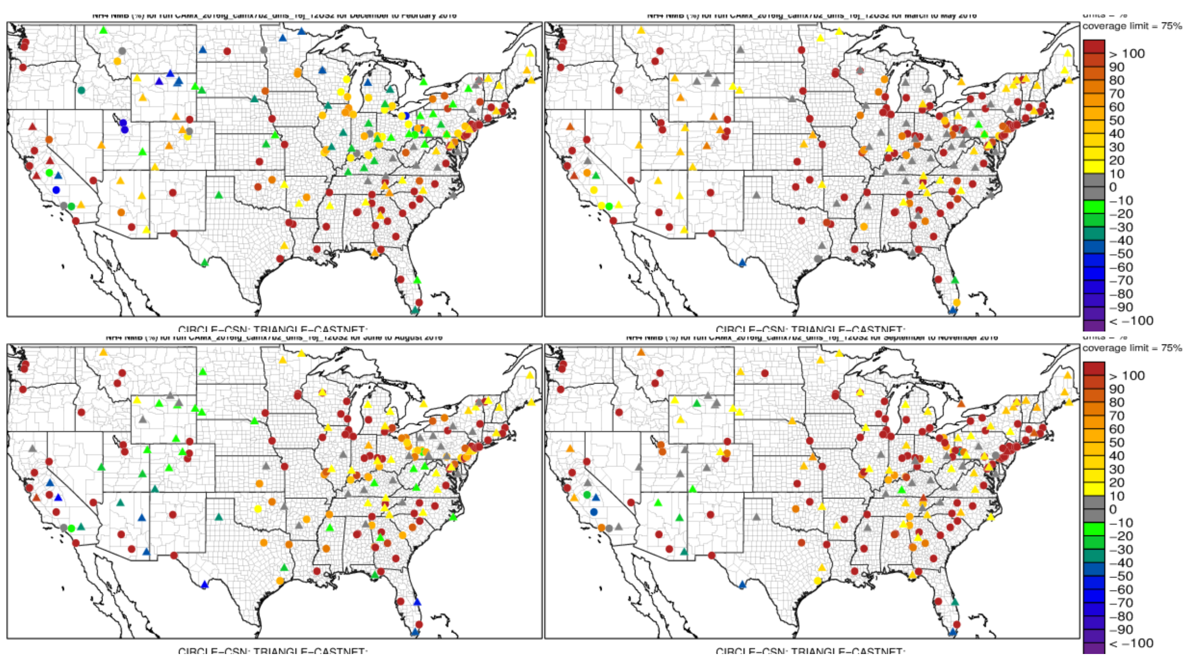


Figure 22. Spatial plot of PM2.5 ammonium NMB (%) by season and network.

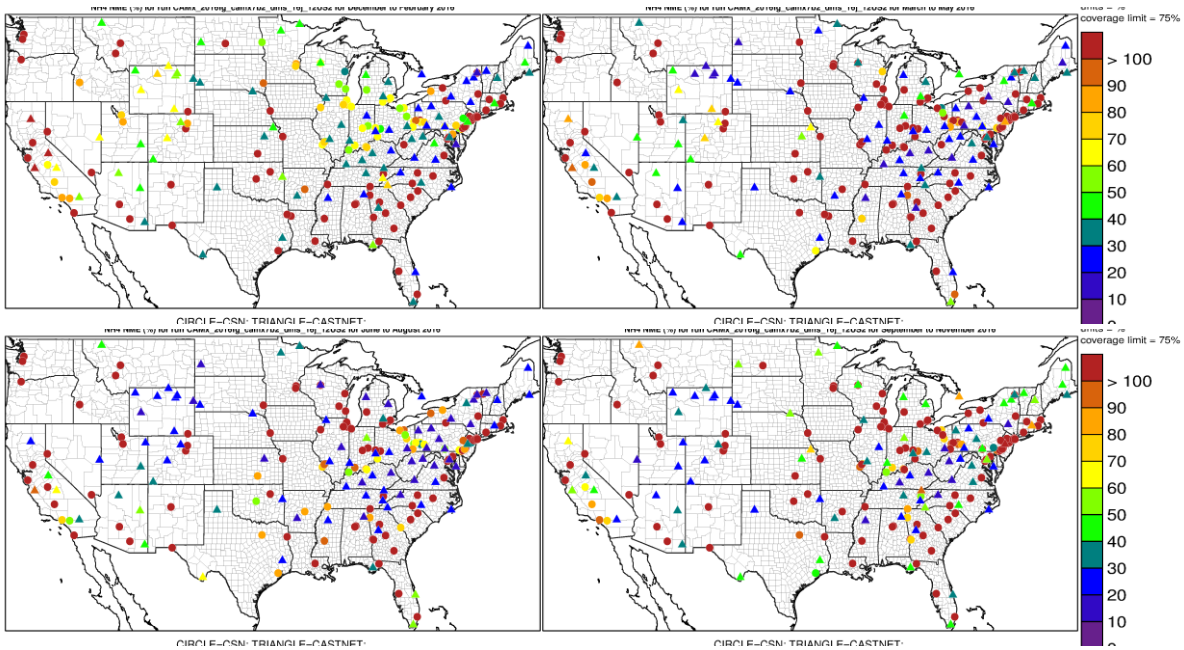


Figure 23. Spatial plot of PM2.5 ammonium NME (%) by season and network.

6. PM2.5 OC

Table 6-1 summarizes model performance statistics for $PM_{2.5}$ organic carbon (OC). Figures 24 and 25 are national statistical tile plots with performance by region and season. Boxplot comparisons of model predictions and observations (IMPROVE, CSN and CASTNET) by month for each climate region are shown in Figures 26, 27, and 28. Nationwide spatial plots of NMB and NME for each season are shown in Figures 29 and 30.

Table 6-1. Model performance statistics for PM2.5 OC by region, network, and season.

Region	**Network**	**Season**	**N**	**Avg. Obs. (µg m^{-3})**	**Avg. Mod. (µg m^{-3})**	**R**	**NMB (%)**	**NME (%)**	**MB (µg m^{-3})**	**ME (µg m^{-3})**
Northeast	**IMPROVE**	**Winter**	399	0.68	1.63	0.74	139.0	143.0	0.95	0.98
		Spring	450	0.71	1.17	0.79	63.8	71.6	0.46	0.51
		Summer	451	1.08	1.55	0.65	43.2	52.8	0.47	0.57
		Fall	429	0.83	1.45	0.78	73.7	82.6	0.62	0.69
		All	1729	0.83	1.44	0.72	73.4	81.6	0.61	0.68

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
	CSN	Winter	710	1.80	3.65	0.62	103.0	112.0	1.85	2.01
		Spring	785	1.56	2.47	0.61	58.0	68.5	0.91	1.07
		Summer	766	1.94	2.35	0.55	21.4	38.5	0.42	0.75
		Fall	771	1.85	2.83	0.61	52.9	65.7	0.98	1.21
		All	3032	1.79	2.81	0.58	57.2	69.7	1.02	1.24
Southeast	IMPROVE	Winter	398	1.14	1.90	0.26	66.1	92.1	0.76	1.05
		Spring	447	6.26	2.15	0.06	-65.6	92.1	-4.10	5.76
		Summer	455	1.42	2.44	0.16	72.1	102.0	1.02	1.45
		Fall	423	1.89	2.41	0.49	27.6	70.3	0.52	1.33
		All	1723	2.73	2.23	0.04	-18.0	89.7	-0.49	2.45
	CSN	Winter	395	2.05	3.16	0.60	54.4	66.6	1.11	1.36
		Spring	449	2.05	3.43	0.74	67.4	70.9	1.38	1.45
		Summer	414	1.95	4.18	0.63	115.0	115.0	2.23	2.24
		Fall	400	2.90	3.73	0.43	28.7	61.8	0.83	1.79
		All	1658	2.23	3.63	0.47	62.7	76.8	1.40	1.71
Ohio Valley	IMPROVE	Winter	217	0.95	2.88	0.22	203.0	220.0	1.93	2.10
		Spring	242	1.09	1.62	0.47	49.4	63.3	0.54	0.69
		Summer	242	1.25	2.03	0.59	62.8	69.6	0.78	0.87
		Fall	232	1.73	2.22	0.57	28.7	55.5	0.50	0.96
		All	933	1.26	2.17	0.19	72.8	89.9	0.91	1.13
	CSN	Winter	508	1.62	2.57	0.59	58.9	71.5	0.95	1.16
		Spring	559	1.62	2.08	0.57	28.7	49.3	0.46	0.80
		Summer	531	1.89	2.34	0.40	24.1	40.0	0.46	0.76
		Fall	531	2.48	2.69	0.73	8.6	36.2	0.21	0.90
		All	2129	1.90	2.42	0.63	27.1	47.3	0.52	0.90
	IMPROVE	Winter	224	0.57	1.21	0.83	112.0	114.0	0.64	0.65

Region	Network	Season	N	Avg. Obs. (μg m^{-3})	Avg. Mod. (μg m^{-3})	R	NMB (%)	NME (%)	MB (μg m^{-3})	ME (μg m^{-3})
Upper Midwest		**Spring**	238	0.88	1.18	0.35	33.9	69.0	0.30	0.61
		Summer	237	1.08	1.35	0.53	24.9	44.0	0.27	0.48
		Fall	242	0.81	1.12	0.77	38.9	49.8	0.32	0.40
		All	941	0.84	1.21	0.48	44.8	63.3	0.38	0.53
	CSN	**Winter**	296	1.19	2.79	0.55	135.0	137.0	1.61	1.63
		Spring	316	1.56	2.16	0.39	38.5	64.3	0.60	1.00
		Summer	305	1.65	2.11	0.49	27.5	40.8	0.45	0.68
		Fall	308	1.59	2.26	0.64	42.6	55.3	0.68	0.88
		All	1225	1.50	2.32	0.41	55.1	69.4	0.83	1.04
South	**IMPROVE**	**Winter**	238	0.82	1.33	0.57	61.6	81.2	0.51	0.67
		Spring	272	1.04	1.50	0.51	44.0	75.7	0.46	0.79
		Summer	249	1.06	1.66	0.69	55.8	72.6	0.59	0.77
		Fall	264	1.07	1.49	0.59	39.7	57.7	0.42	0.62
		All	1023	1.00	1.50	0.52	49.2	71.0	0.49	0.71
	CSN	**Winter**	237	2.17	2.69	0.55	23.9	50.3	0.52	1.09
		Spring	266	1.56	2.17	0.48	39.3	57.5	0.61	0.90
		Summer	222	1.63	2.67	0.52	64.2	79.4	1.04	1.29
		Fall	207	2.33	3.24	0.56	39.1	53.1	0.91	1.24
		All	932	1.90	2.66	0.53	39.9	58.7	0.76	1.12
Southwest	**IMPROVE**	**Winter**	836	0.55	0.53	0.38	-2.7	72.5	-0.01	0.40
		Spring	941	0.39	0.58	0.36	48.2	74.7	0.19	0.29
		Summer	949	0.78	0.95	0.37	21.6	58.1	0.17	0.46
		Fall	934	0.51	0.74	0.17	44.3	78.2	0.23	0.40
		All	3660	0.56	0.71	0.21	26.2	69.0	0.15	0.39
	CSN	**Winter**	219	2.52	2.86	0.39	13.7	52.6	0.35	1.33
		Spring	254	1.05	1.52	0.45	45.4	59.8	0.48	0.63

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Summer	237	1.38	1.53	0.38	10.8	42.4	0.15	0.59
		Fall	240	1.61	1.77	0.46	9.6	43.5	0.16	0.70
		All	950	1.61	1.90	0.47	17.6	49.4	0.28	0.80
Northern Rockies & Plains	**IMPROVE**	**Winter**	521	0.28	0.37	0.36	33.0	75.5	0.09	0.21
		Spring	536	0.62	0.54	0.61	-12.4	57.2	-0.08	0.35
		Summer	578	1.10	1.13	0.21	2.4	55.5	0.03	0.61
		Fall	568	0.55	0.52	0.31	-6.3	52.2	-0.04	0.29
		All	2203	0.65	0.65	0.31	0.2	57.2	0.00	0.37
	CSN	**Winter**	124	1.05	1.19	0.02	12.7	105.0	0.13	1.10
		Spring	145	0.87	0.89	0.51	2.5	57.0	0.02	0.50
		Summer	161	1.45	1.00	0.35	-31.5	43.8	-0.46	0.64
		Fall	146	1.01	0.80	0.24	-21.0	49.0	-0.21	0.50
		All	576	1.11	0.96	0.20	-13.3	60.1	-0.15	0.67
Northwest	**IMPROVE**	**Winter**	390	0.36	0.79	0.67	118.0	162.0	0.43	0.59
		Spring	473	0.52	0.87	0.52	65.2	89.6	0.34	0.47
		Summer	486	1.26	1.34	0.55	6.2	70.5	0.08	0.89
		Fall	465	0.71	1.25	0.58	76.1	112.0	0.54	0.80
		All	1814	0.73	1.07	0.45	46.3	94.1	0.34	0.69
	CSN	**Winter**	124	2.42	4.60	0.44	90.1	113.0	2.18	2.73
		Spring	135	1.31	3.04	0.36	132.0	135.0	1.73	1.77
		Summer	146	1.42	2.79	0.65	95.7	99.6	1.36	1.42
		Fall	140	1.90	3.75	0.41	98.0	113.0	1.86	2.14
		All	545	1.74	3.51	0.46	101.0	114.0	1.77	1.99
West	**IMPROVE**	**Winter**	548	0.59	0.49	0.81	-16.6	58.5	-0.10	0.35
		Spring	599	0.58	0.57	0.71	-1.7	40.0	-0.01	0.23
		Summer	609	1.65	1.62	0.33	-2.1	62.1	-0.03	1.03

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Fall	574	1.00	1.01	0.62	0.7	48.6	0.01	0.49
		All	2330	0.97	0.93	0.46	-3.4	54.7	-0.03	0.53
	CSN	**Winter**	275	3.71	2.75	0.53	-26.0	40.9	-0.97	1.52
		Spring	294	1.54	1.67	0.77	8.1	30.5	0.12	0.47
		Summer	289	2.47	2.44	0.52	-1.3	38.0	-0.03	0.94
		Fall	277	2.82	2.65	0.62	-6.1	31.5	-0.17	0.89
		All	1135	2.62	2.36	0.57	-9.6	36.2	-0.25	0.95

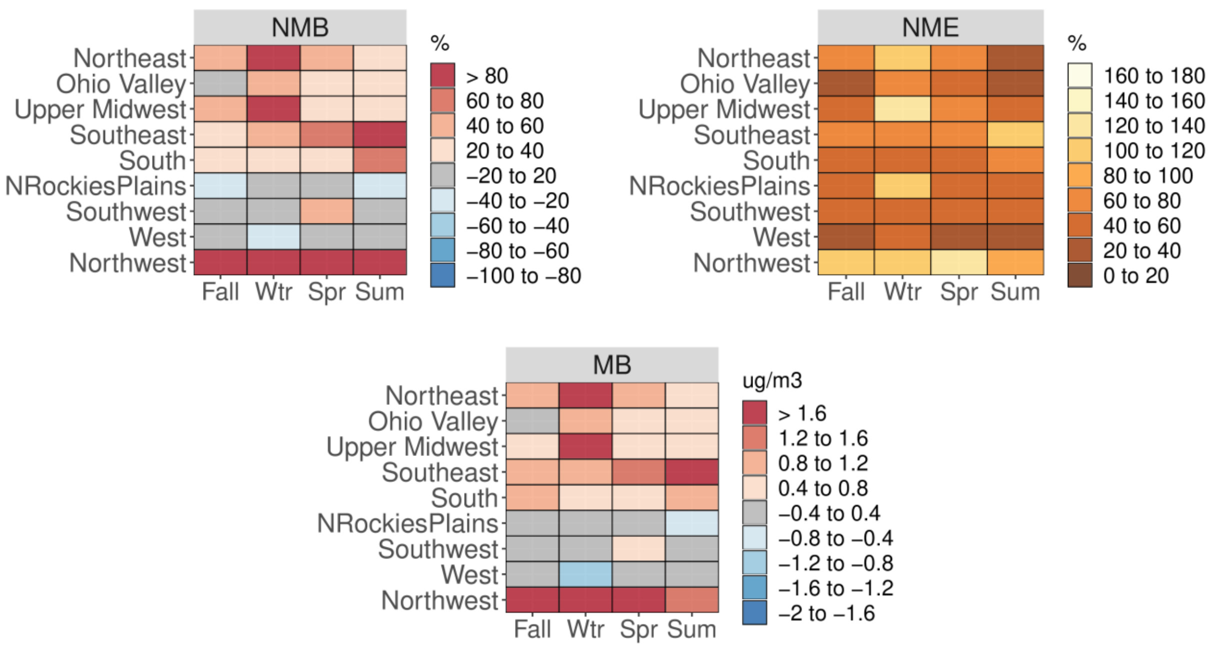


Figure 24. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for CSN PM2.5 OC observations.

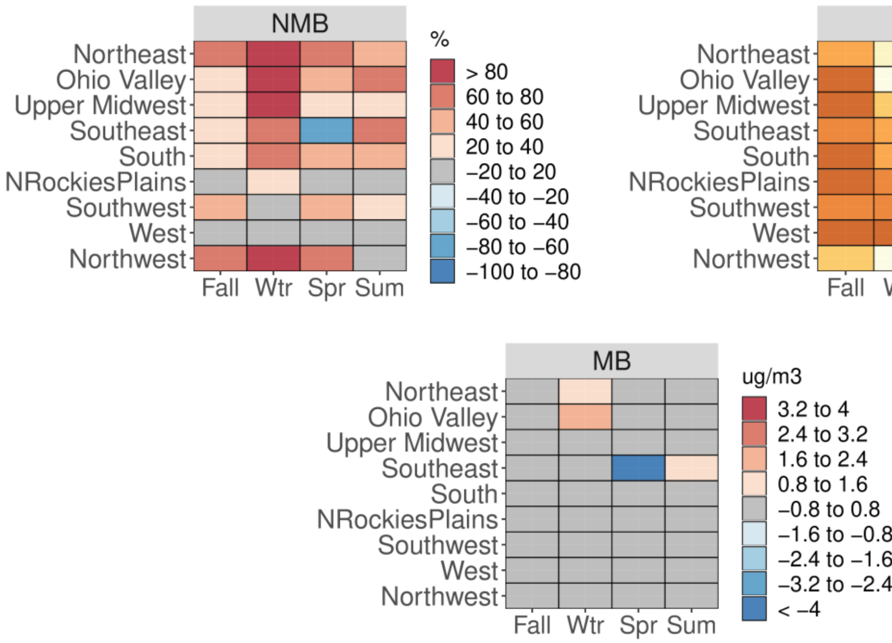
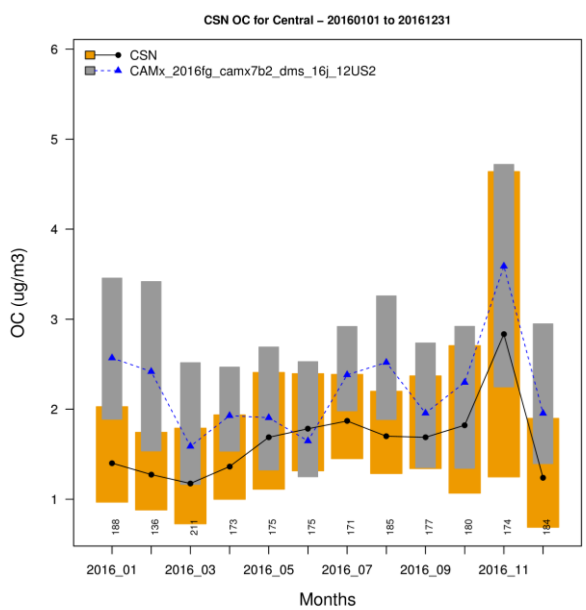
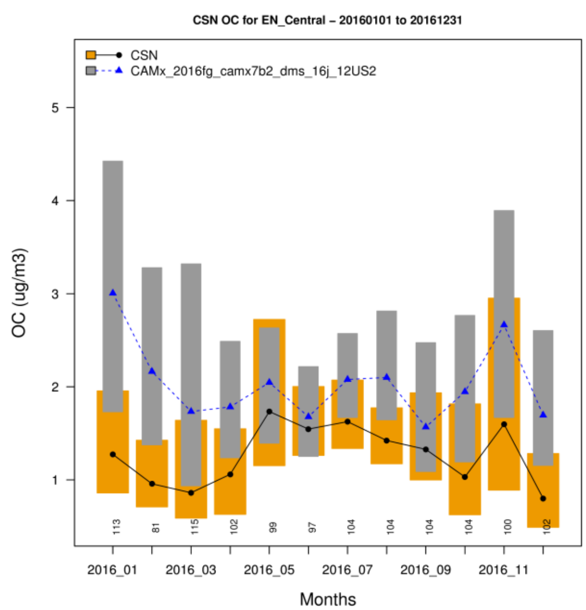
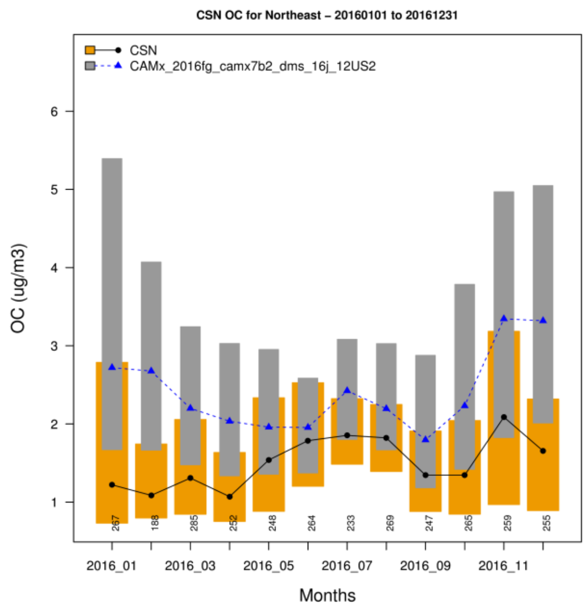
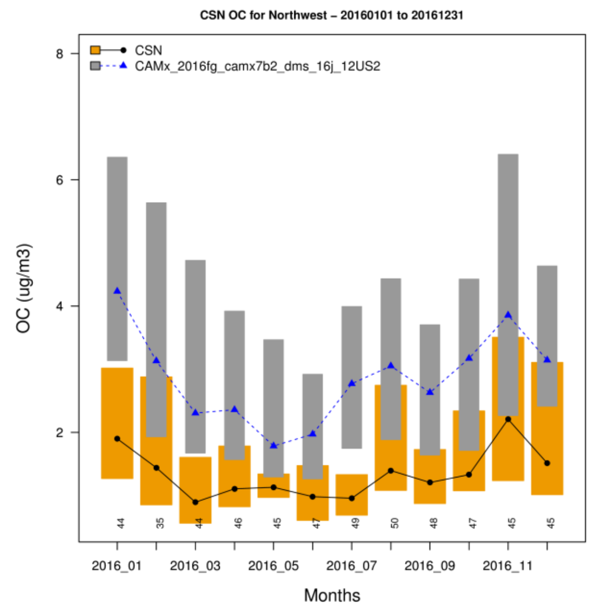


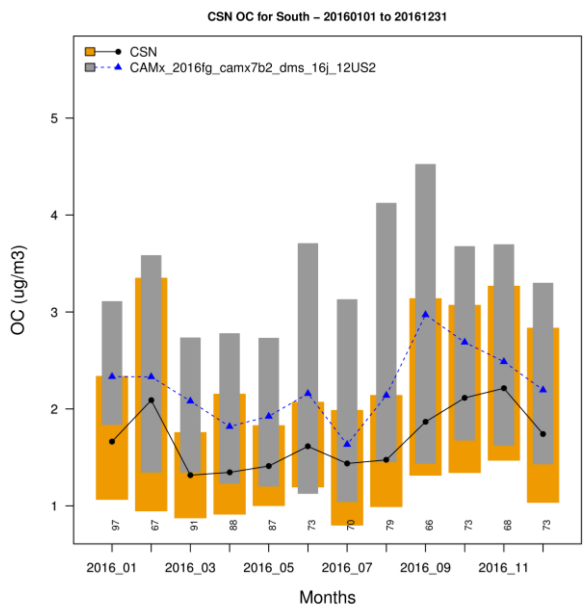
Figure 25. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for IMPROVE PM2.5 OC observations.

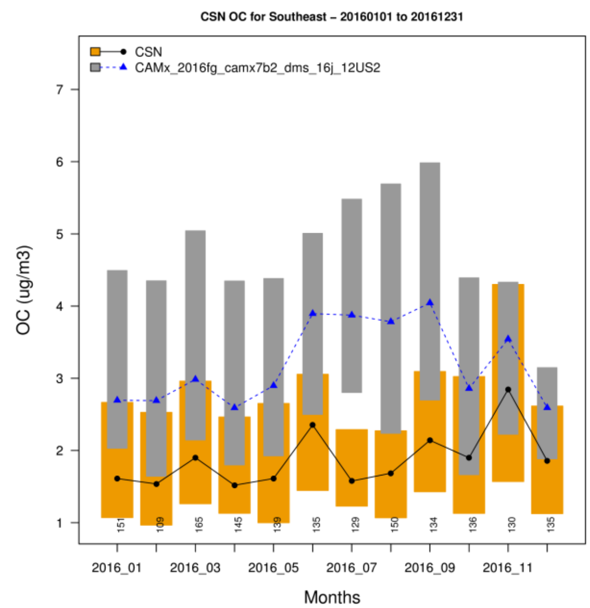





CSN OC for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
267 188 285 252 248 264 233 269 247 265 259 255


CSN OC for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
44 35 44 46 45 47 49 50 48 47 45 45


CSN OC for South – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
97 67 91 88 87 73 70 79 66 73 68 73


CSN OC for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
151 109 165 145 139 135 129 150 134 136 130 135

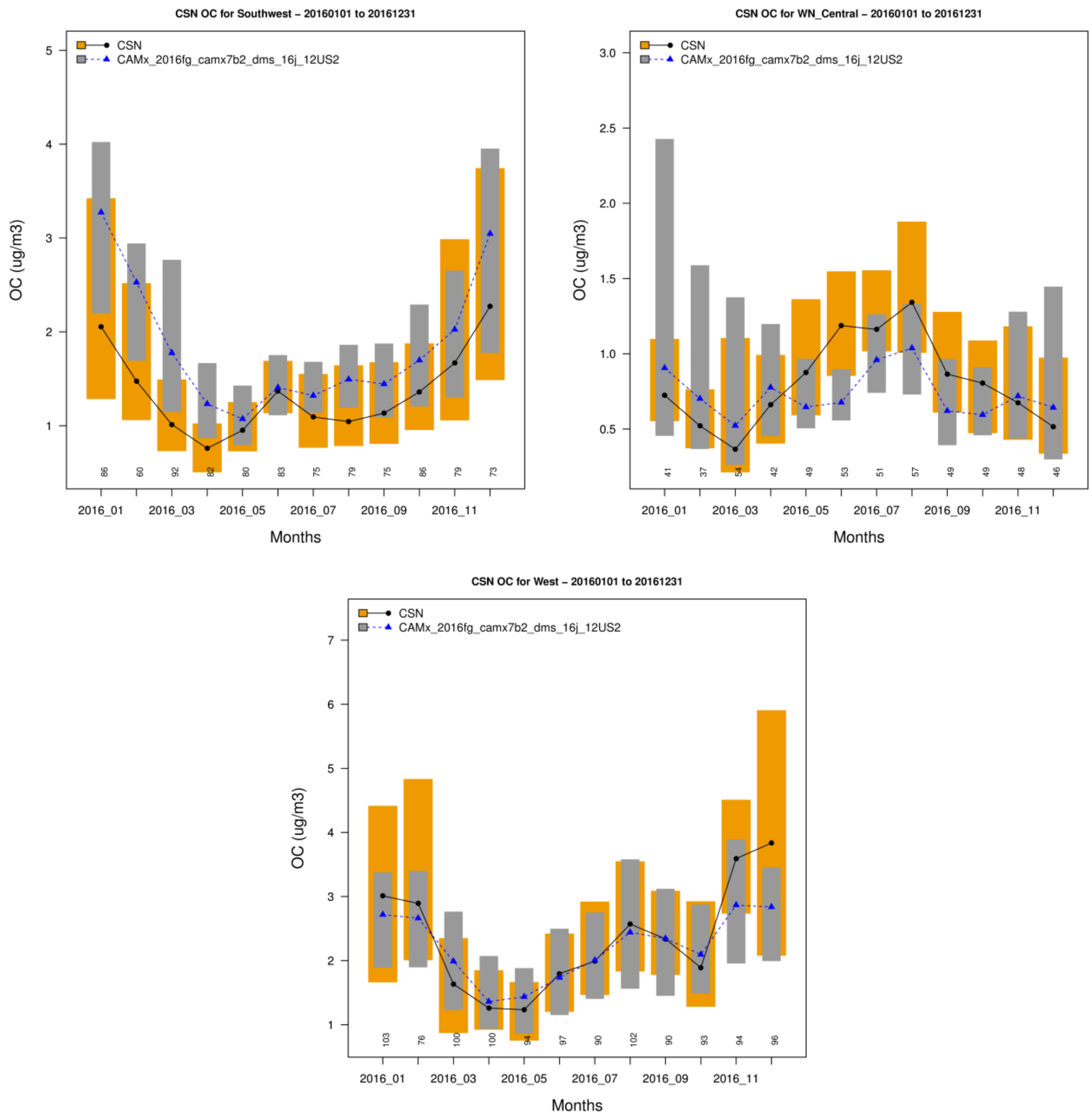
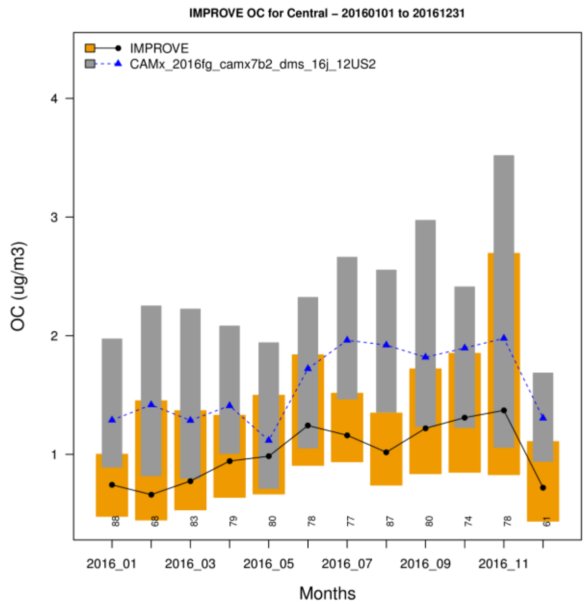
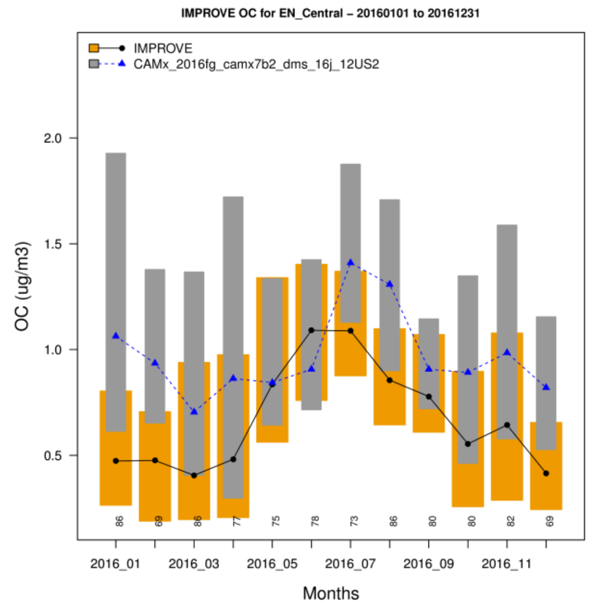


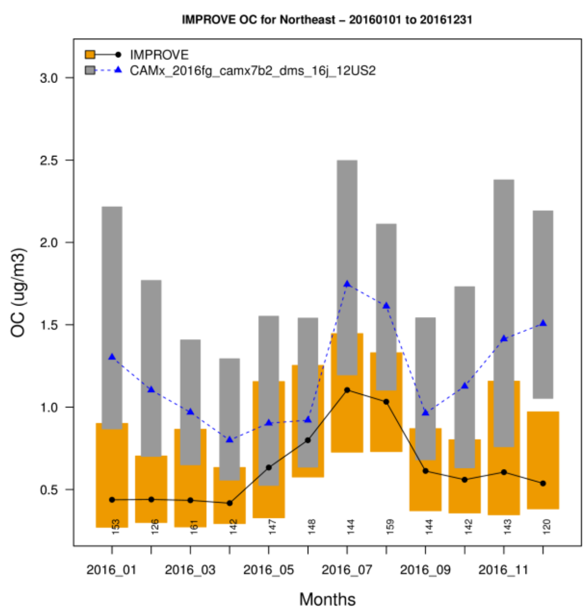
Figure 26. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN PM2.5 OC observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.



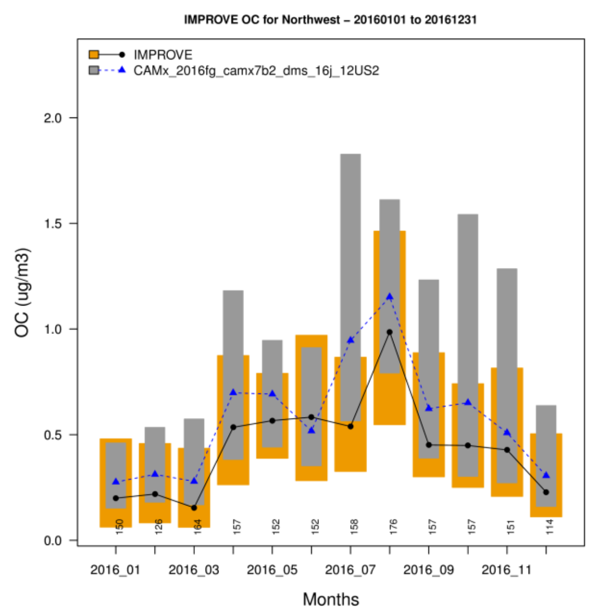
IMPROVE OC for Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months



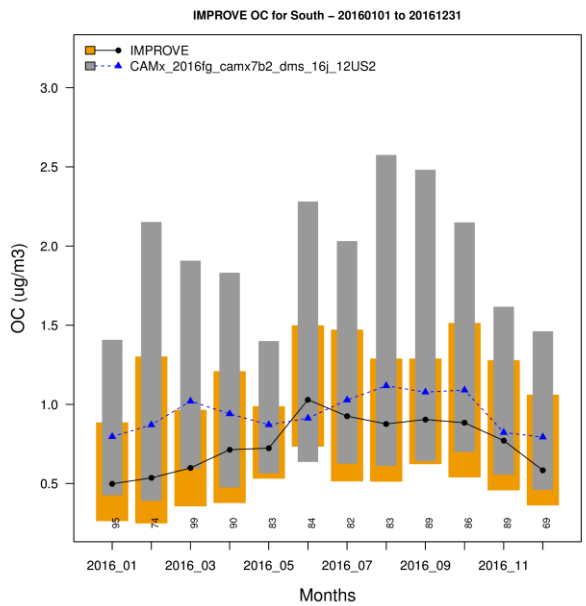
IMPROVE OC for EN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months

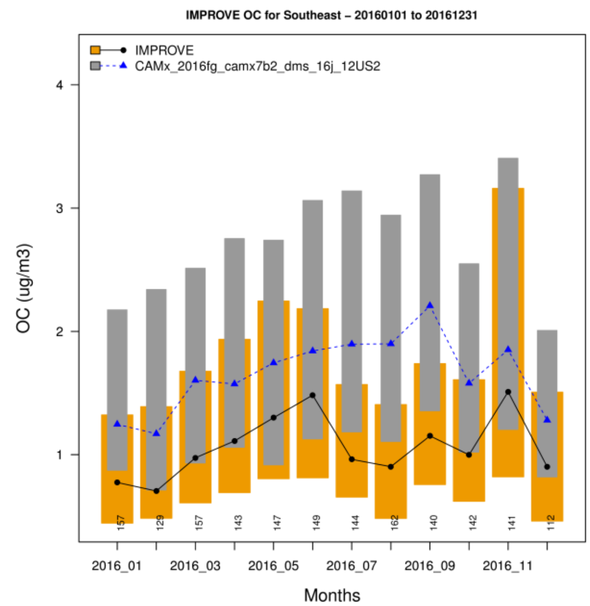


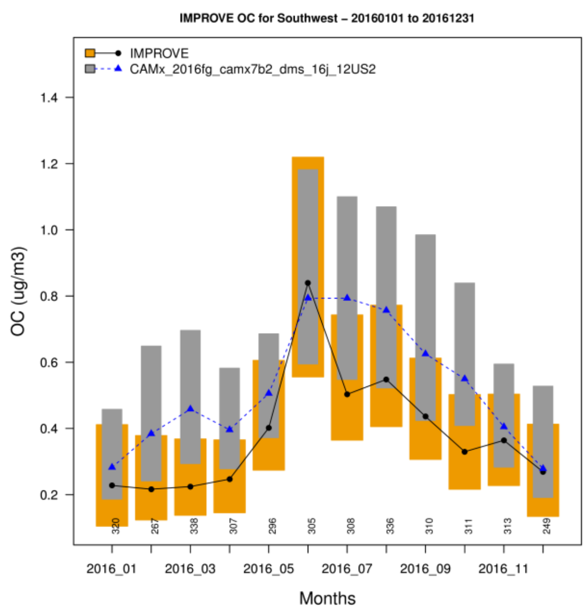
IMPROVE OC for Northeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months

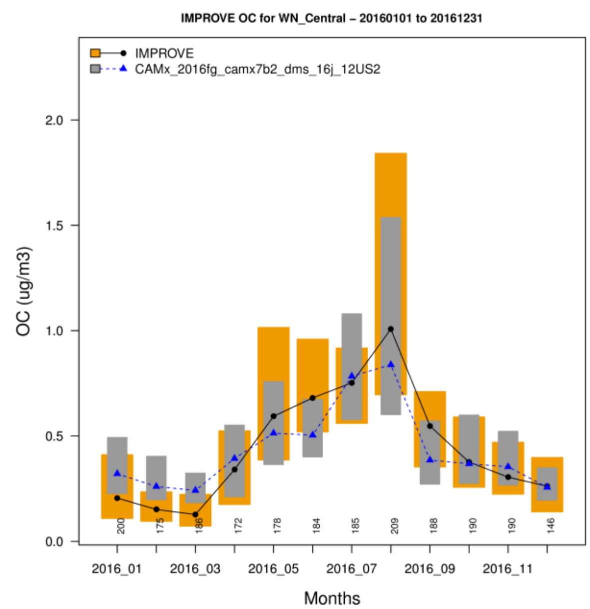


IMPROVE OC for Northwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months


IMPROVE OC for South – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
0.5
1.0
1.5
2.0
2.5
3.0
95 74 99 90 83 84 82 83 89 86 89 69
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months


IMPROVE OC for Southeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
1
2
3
4
157 129 157 143 147 149 144 162 140 142 141 112
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months


IMPROVE OC for Southwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
0.2
0.4
0.6
0.8
1.0
1.2
1.4
320 267 338 307 296 305 308 336 310 311 313 249
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months


IMPROVE OC for WN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
0.0
0.5
1.0
1.5
2.0
200 175 186 172 178 184 185 209 188 190 190 146
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months

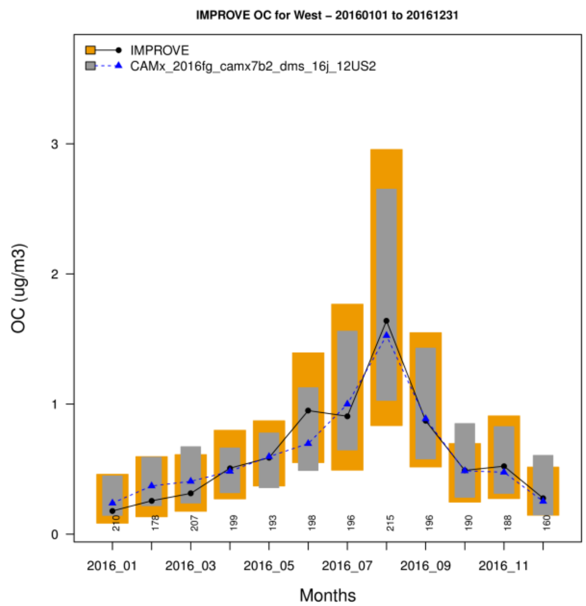
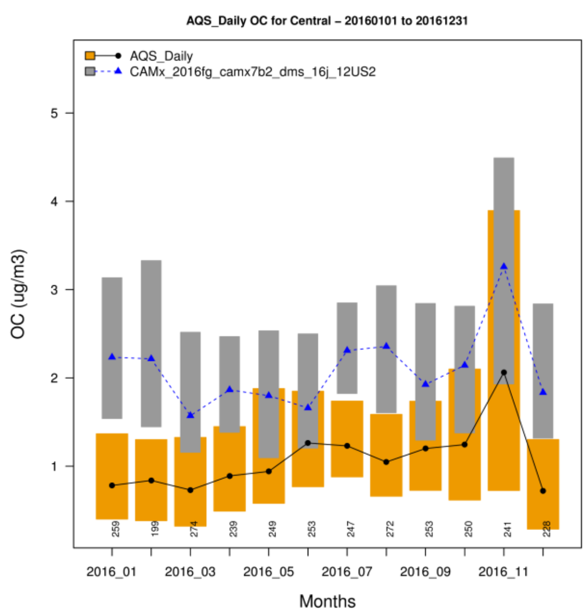
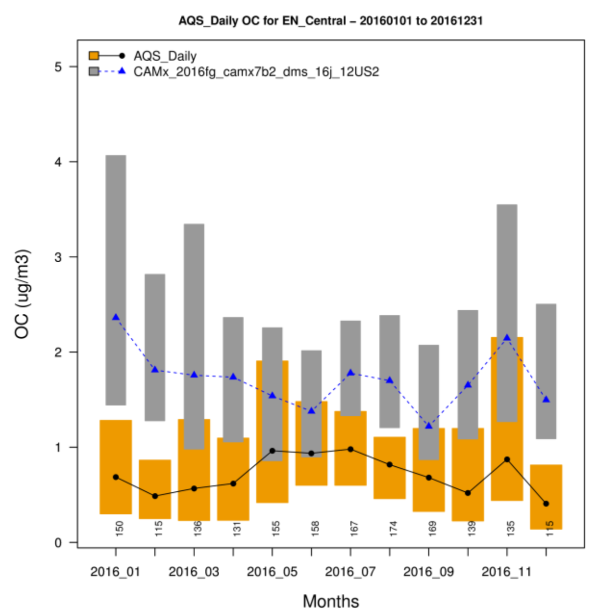
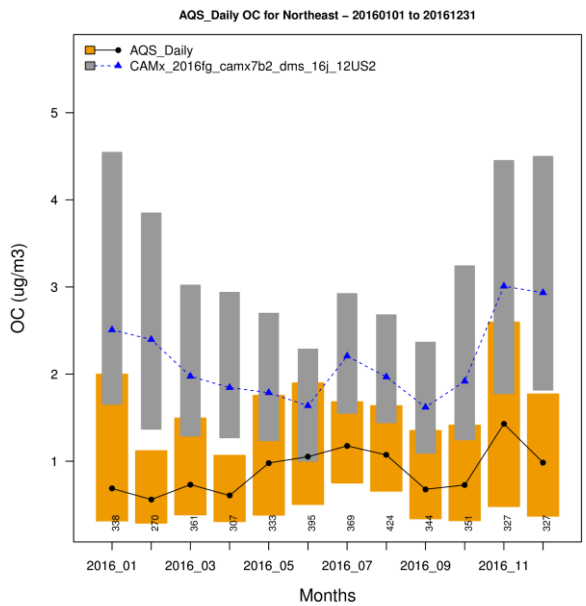
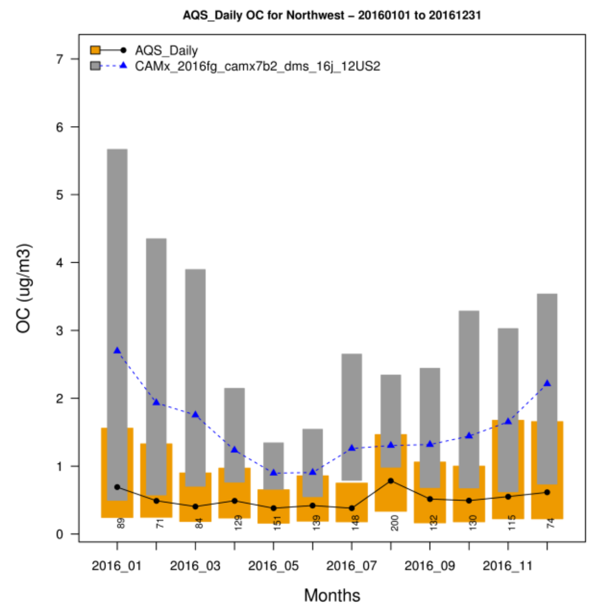


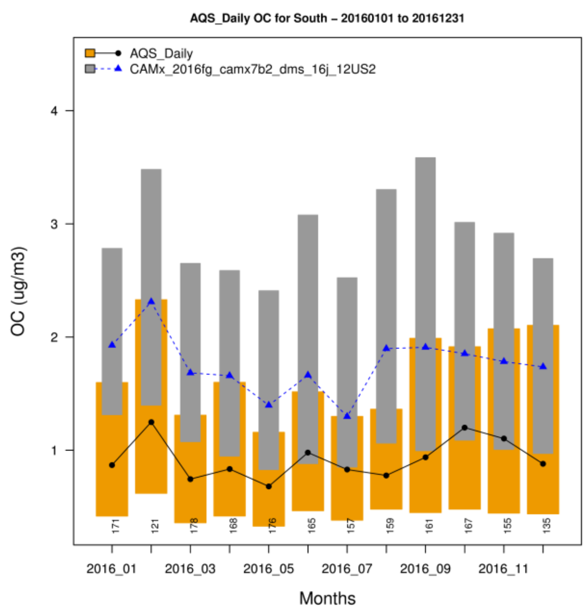
Figure 27. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median IMPROVE PM2.5 OC observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

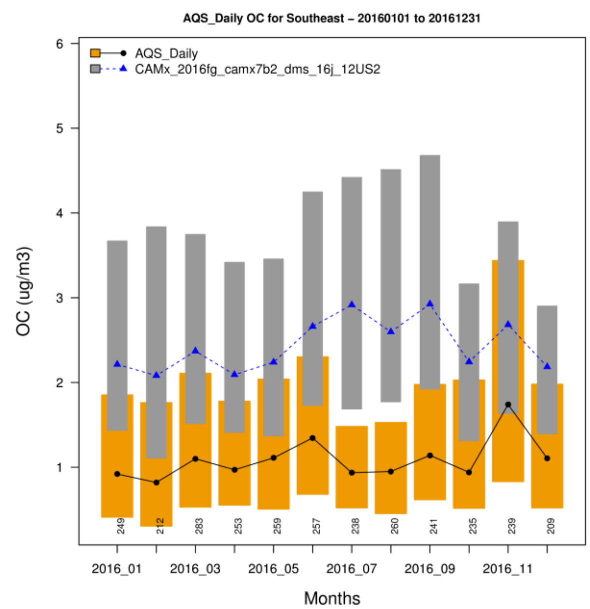





AQS_Daily OC for Northeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
338 270 361 307 333 395 369 424 344 351 327 327
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11


AQS_Daily OC for Northwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
89 71 84 129 151 139 148 200 132 130 115 74
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11


AQS_Daily OC for South – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
171 121 178 168 176 165 157 159 161 167 155 135
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11


AQS_Daily OC for Southeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
OC (ug/m3)
Months
249 212 283 253 259 257 238 260 241 235 239 209
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11

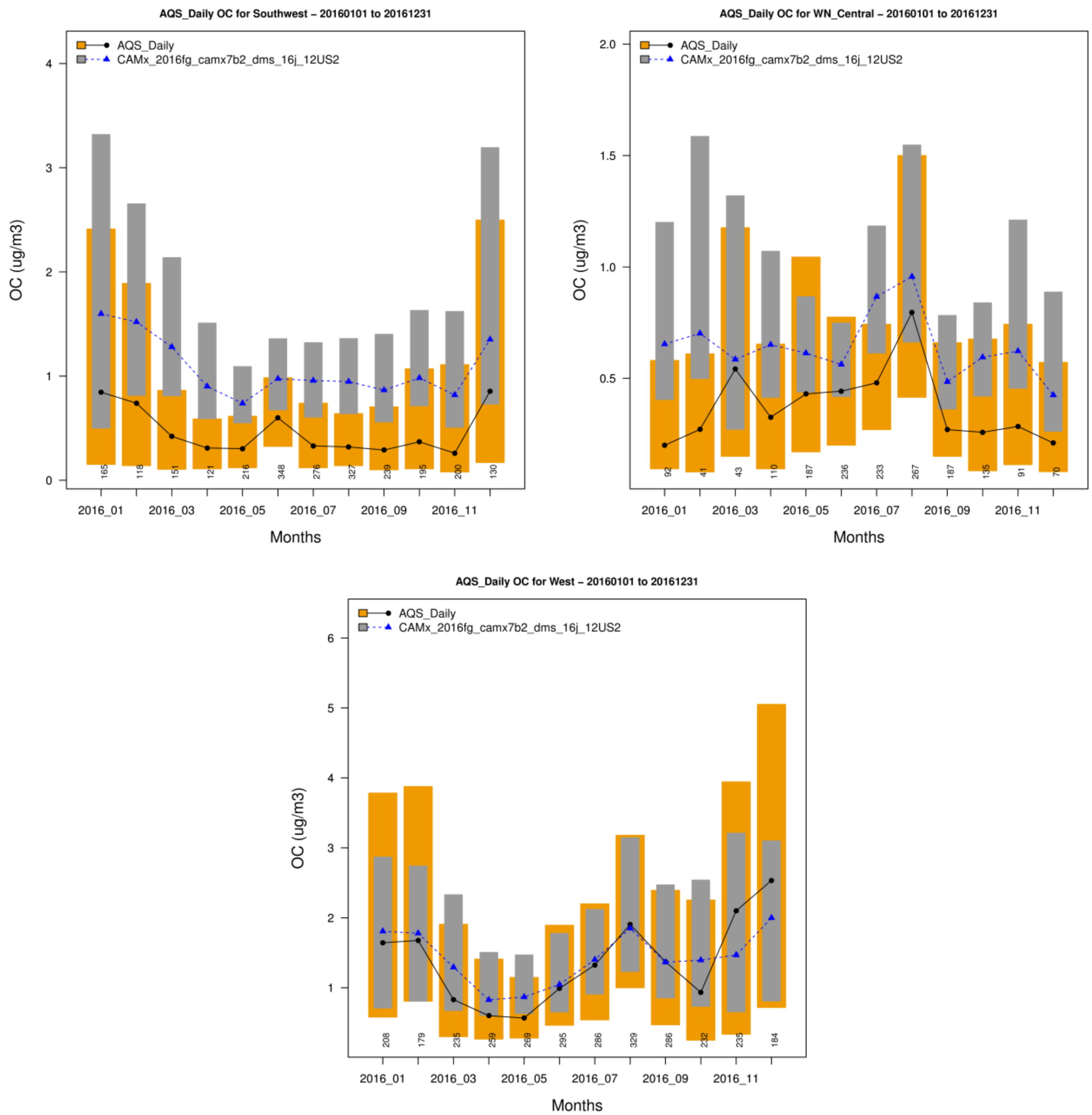


Figure 28. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily PM2.5 OC observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

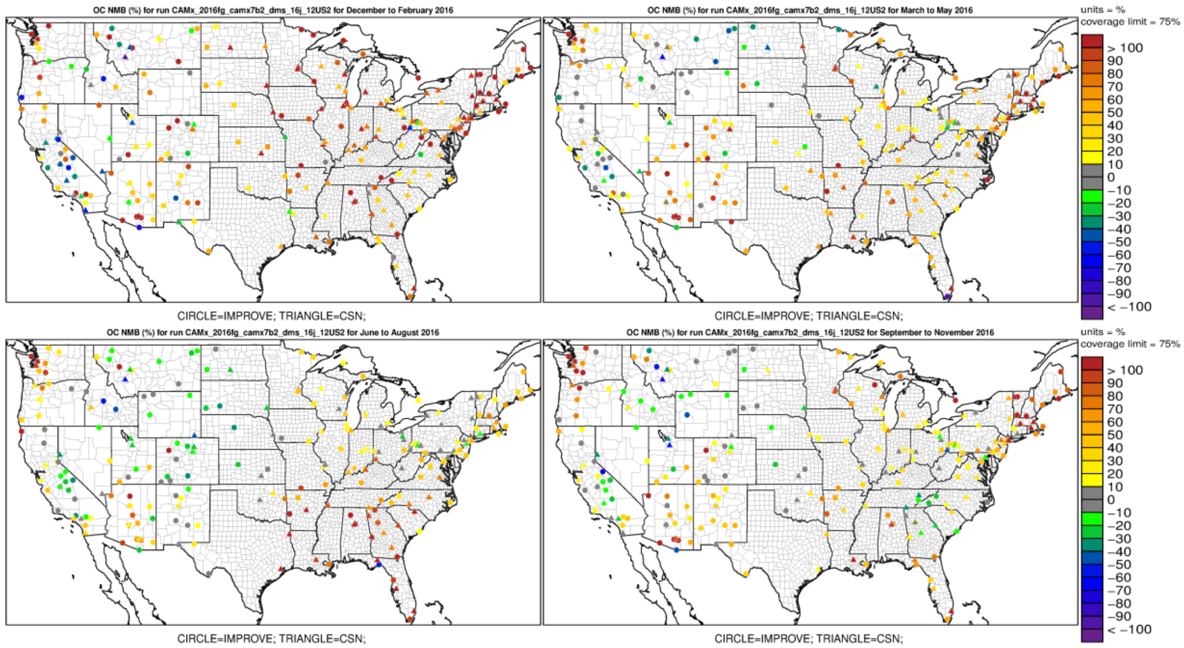


Figure 29. Spatial plot of PM2.5 OC NMB (%) by season and network.

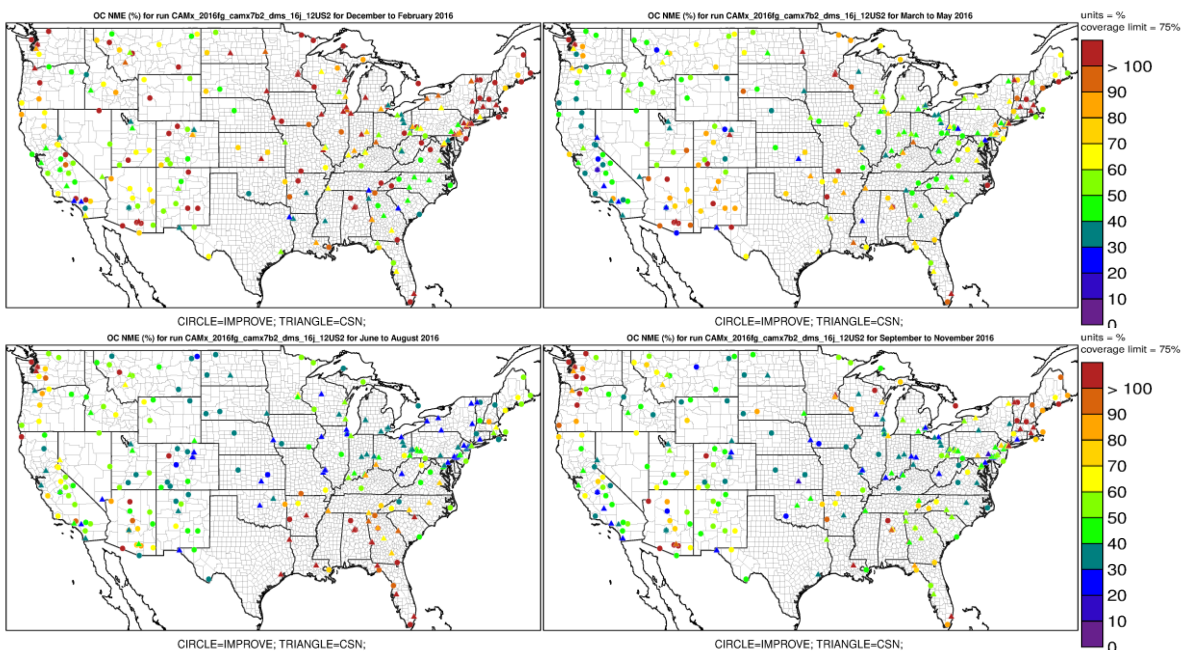


Figure 30. Spatial plot of PM2.5 OC NME (%) by season and network.

7. PM2.5 EC

Table 7-1 summarizes model performance statistics for PM2.5 elemental carbon (EC). Figures 31 and 32 are national statistical tile plots with performance by region and season. Boxplot comparisons of model predictions and observations (IMPROVE, CSN and CASTNET) by month for each climate region are shown in Figures 33, 34, and 35. Nationwide spatial plots of NMB and NME for each season are shown in Figures 36 and 37.

Table 7-1. Model performance statistics for PM2.5 EC by region, network, and season.

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Northeast	IMPROVE	**Winter**	401	0.16	0.30	0.76	88.9	106.0	0.14	0.17
		Spring	450	0.13	0.22	0.87	74.8	82.5	0.10	0.11
		Summer	450	0.12	0.21	0.83	71.1	78.2	0.09	0.09
		Fall	429	0.15	0.26	0.86	66.7	81.1	0.10	0.13
		All	1730	0.14	0.25	0.83	75.5	87.4	0.11	0.12
	CSN	**Winter**	710	0.67	0.92	0.57	38.4	66.2	0.26	0.44
		Spring	785	0.57	0.71	0.54	24.2	55.1	0.14	0.32
		Summer	766	0.58	0.62	0.55	6.9	44.8	0.04	0.26
		Fall	771	0.63	0.84	0.56	33.5	59.8	0.21	0.38
		All	3032	0.61	0.77	0.56	26.1	56.7	0.16	0.35
Southeast	IMPROVE	**Winter**	398	0.25	0.37	0.32	49.0	83.1	0.12	0.21
		Spring	447	0.33	0.34	0.18	1.3	70.2	0.00	0.24
		Summer	452	0.18	0.24	0.56	28.6	66.7	0.05	0.12
		Fall	422	0.32	0.33	0.82	5.4	44.1	0.02	0.14
		All	1719	0.27	0.32	0.33	17.6	64.8	0.05	0.18
	CSN	**Winter**	395	0.58	0.74	0.54	26.2	55.5	0.15	0.32
		Spring	449	0.56	0.66	0.55	17.1	49.1	0.10	0.28
		Summer	414	0.45	0.57	0.43	25.6	60.5	0.12	0.28
		Fall	400	0.68	0.68	0.64	0.4	46.4	0.00	0.32

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	1658	0.57	0.66	0.55	16.2	52.1	0.09	0.30
Ohio Valley	**IMPROVE**	**Winter**	216	0.19	0.58	0.19	212.0	224.0	0.40	0.42
		Spring	242	0.19	0.27	0.35	44.7	68.4	0.08	0.13
		Summer	242	0.14	0.18	0.60	30.5	47.0	0.04	0.07
		Fall	232	0.26	0.34	0.61	31.5	50.9	0.08	0.13
		All	932	0.19	0.34	0.19	74.9	93.3	0.15	0.18
	CSN	**Winter**	508	0.50	0.69	0.53	38.4	63.0	0.19	0.31
		Spring	559	0.54	0.60	0.50	9.3	46.9	0.05	0.26
		Summer	532	0.62	0.60	0.35	-3.2	42.6	-0.02	0.26
		Fall	534	0.70	0.76	0.58	7.3	43.3	0.05	0.31
		All	2133	0.59	0.66	0.51	11.3	47.9	0.07	0.28
Upper Midwest	**IMPROVE**	**Winter**	227	0.12	0.25	0.88	101.0	102.0	0.12	0.13
		Spring	239	0.17	0.24	0.50	41.5	71.2	0.07	0.12
		Summer	236	0.14	0.19	0.85	39.1	55.4	0.05	0.08
		Fall	244	0.17	0.21	0.85	29.5	47.5	0.05	0.08
		All	946	0.15	0.22	0.70	49.2	66.9	0.07	0.10
	CSN	**Winter**	296	0.35	0.67	0.55	94.1	101.0	0.33	0.35
		Spring	316	0.46	0.57	0.53	23.2	54.0	0.11	0.25
		Summer	306	0.42	0.52	0.47	22.4	47.2	0.09	0.20
		Fall	308	0.48	0.62	0.64	29.5	52.3	0.14	0.25
		All	1226	0.43	0.59	0.51	38.6	61.0	0.17	0.26
South	**IMPROVE**	**Winter**	240	0.15	0.25	0.57	73.8	93.3	0.11	0.14
		Spring	271	0.15	0.26	0.55	72.1	94.3	0.11	0.14
		Summer	247	0.08	0.12	0.60	44.9	64.5	0.04	0.05
		Fall	264	0.15	0.18	0.54	26.2	49.9	0.04	0.07
		All	1022	0.13	0.21	0.56	55.4	76.9	0.07	0.10

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
	CSN	Winter	237	0.62	0.71	0.56	15.0	45.9	0.09	0.29
		Spring	266	0.47	0.52	0.52	11.6	43.2	0.05	0.20
		Summer	222	0.41	0.50	0.38	19.7	57.4	0.08	0.24
		Fall	208	0.60	0.71	0.43	19.1	50.9	0.11	0.31
		All	933	0.52	0.61	0.51	16.1	48.6	0.08	0.26
Southwest	IMPROVE	Winter	860	0.14	0.12	0.54	-16.1	76.0	-0.02	0.11
		Spring	947	0.06	0.10	0.40	62.6	123.0	0.04	0.08
		Summer	945	0.07	0.12	0.38	59.8	101.0	0.04	0.07
		Fall	933	0.09	0.12	0.28	33.8	90.9	0.03	0.08
		All	3685	0.09	0.11	0.35	26.4	93.1	0.02	0.08
	CSN	Winter	219	0.87	0.97	0.57	12.6	42.3	0.11	0.37
		Spring	254	0.31	0.56	0.69	81.6	90.9	0.25	0.28
		Summer	237	0.29	0.49	0.28	67.1	84.8	0.20	0.25
		Fall	240	0.55	0.71	0.54	29.6	56.2	0.16	0.31
		All	950	0.49	0.68	0.65	36.9	60.6	0.18	0.30
Northern Rockies & Plains	IMPROVE	Winter	535	0.04	0.07	0.35	76.6	119.0	0.03	0.05
		Spring	541	0.06	0.09	0.61	36.3	88.0	0.02	0.06
		Summer	576	0.07	0.16	0.19	119.0	138.0	0.09	0.10
		Fall	570	0.06	0.08	0.24	29.6	78.5	0.02	0.05
		All	2222	0.06	0.10	0.27	66.3	106.0	0.04	0.06
	CSN	Winter	124	0.27	0.33	0.05	23.9	120.0	0.06	0.33
		Spring	145	0.20	0.24	0.44	21.1	74.8	0.04	0.15
		Summer	161	0.22	0.24	0.41	7.8	54.3	0.02	0.12
		Fall	146	0.24	0.24	0.15	-0.7	78.3	-0.00	0.19
		All	576	0.23	0.26	0.18	12.4	81.6	0.03	0.19
Northwest	IMPROVE	Winter	423	0.07	0.19	0.84	169.0	196.0	0.12	0.14

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Spring	480	0.06	0.21	0.75	226.0	239.0	0.14	0.15
		Summer	483	0.12	0.28	0.44	126.0	179.0	0.15	0.22
		Fall	470	0.09	0.31	0.73	244.0	263.0	0.22	0.24
		All	1856	0.09	0.25	0.54	184.0	215.0	0.16	0.19
	CSN	**Winter**	125	0.67	1.19	0.35	77.4	107.0	0.52	0.72
		Spring	135	0.37	1.04	0.35	183.0	189.0	0.68	0.70
		Summer	146	0.33	1.08	0.32	229.0	231.0	0.75	0.76
		Fall	140	0.51	1.41	0.31	174.0	188.0	0.90	0.97
		All	546	0.46	1.18	0.32	154.0	169.0	0.72	0.79
West	**IMPROVE**	**Winter**	561	0.11	0.11	0.76	-2.9	74.8	-0.00	0.08
		Spring	602	0.06	0.10	0.76	72.8	99.4	0.04	0.06
		Summer	609	0.15	0.26	0.31	68.8	121.0	0.11	0.19
		Fall	574	0.12	0.19	0.64	56.2	91.0	0.07	0.11
		All	2346	0.11	0.17	0.44	48.7	98.9	0.05	0.11
	CSN	**Winter**	276	1.06	0.86	0.47	-18.7	40.7	-0.20	0.43
		Spring	294	0.41	0.56	0.76	37.4	55.8	0.15	0.23
		Summer	290	0.43	0.67	0.60	55.3	64.5	0.24	0.28
		Fall	277	0.68	0.82	0.63	20.7	43.5	0.14	0.29
		All	1137	0.64	0.72	0.59	13.5	48.0	0.09	0.31

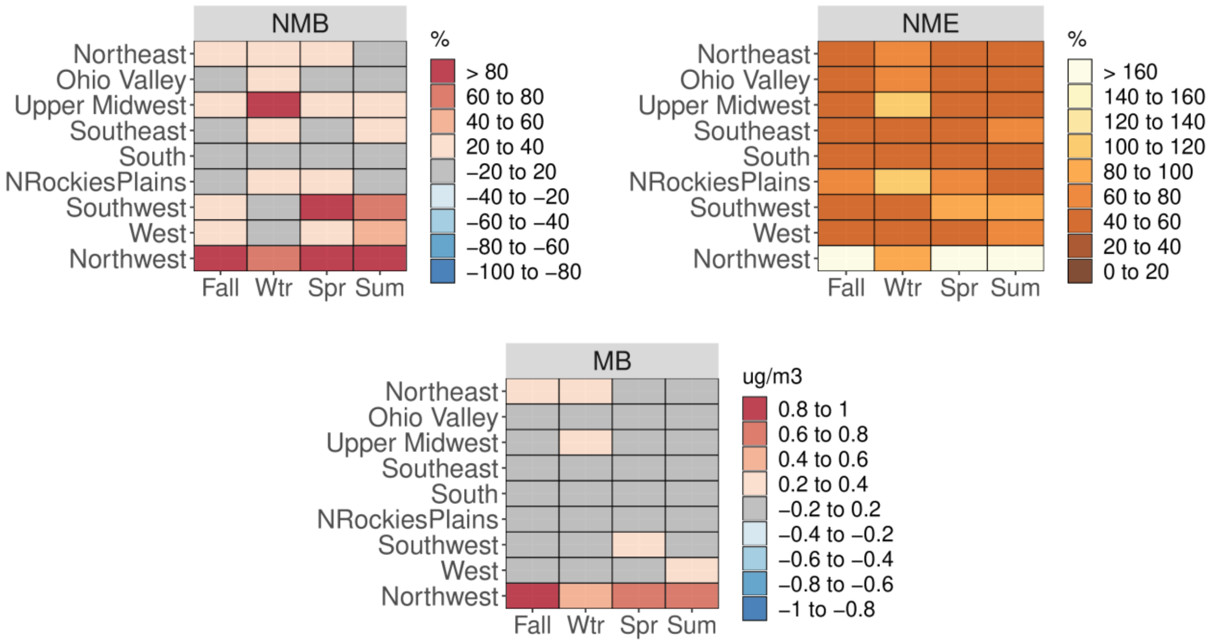


Figure 31. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for CSN PM2.5 EC observations.

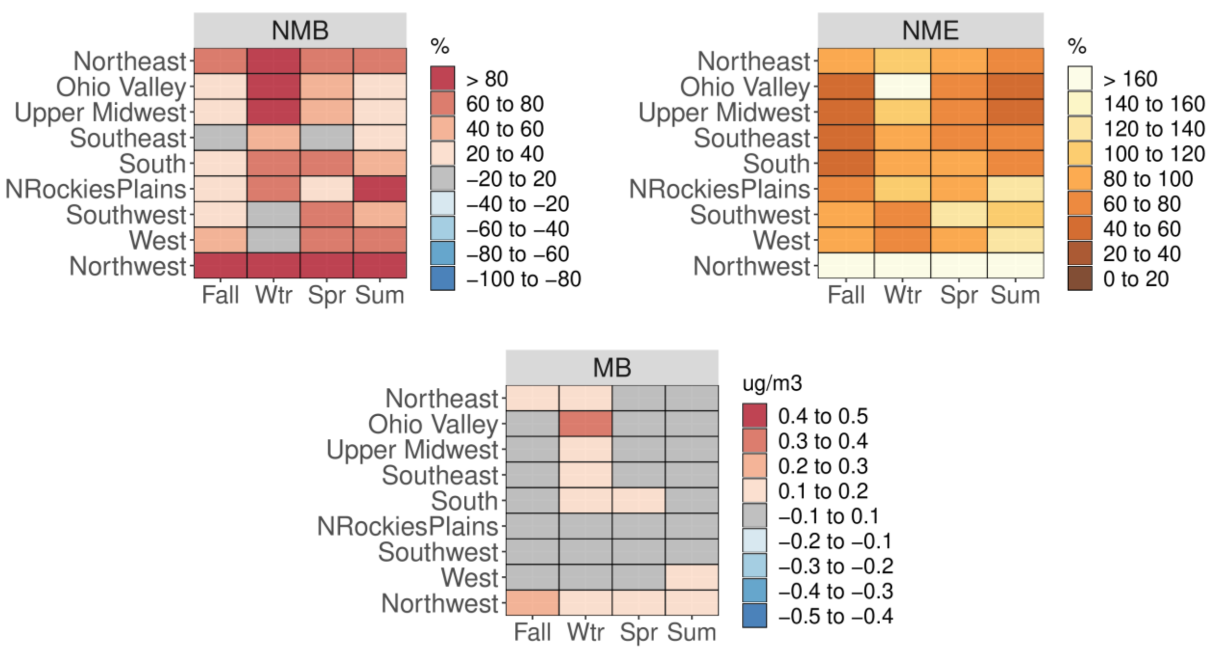
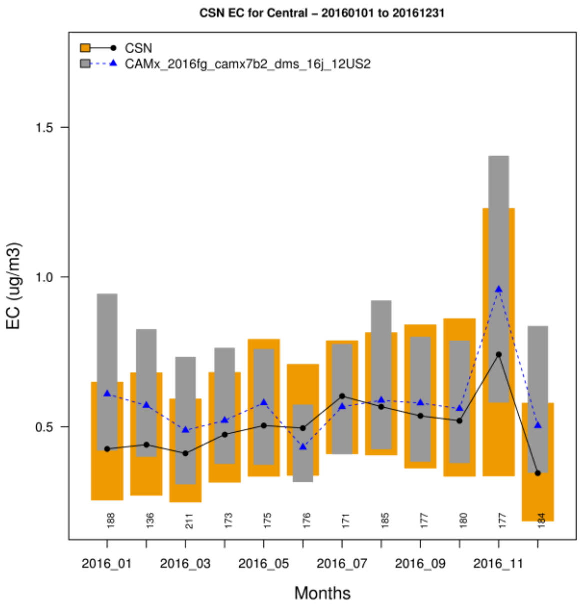
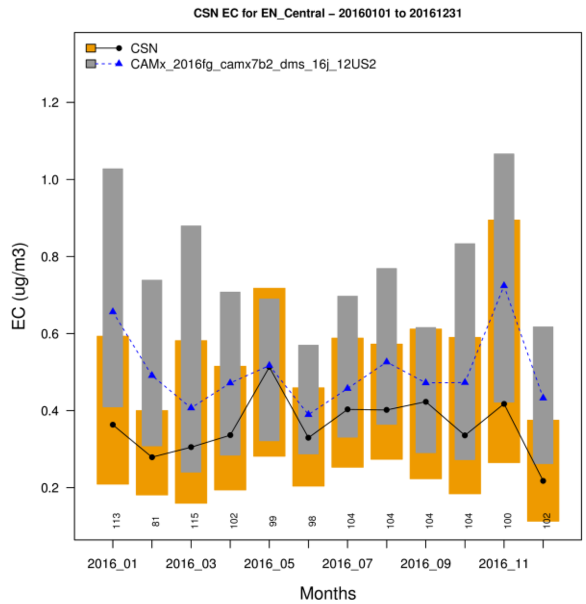


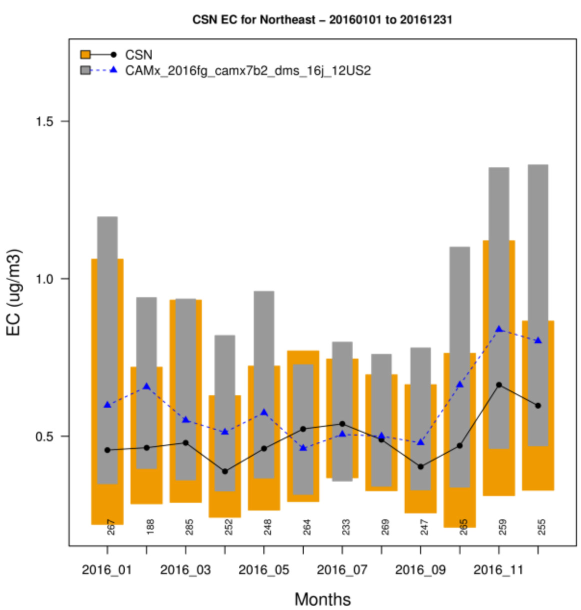
Figure 32. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for IMPROVE PM2.5 EC observations.



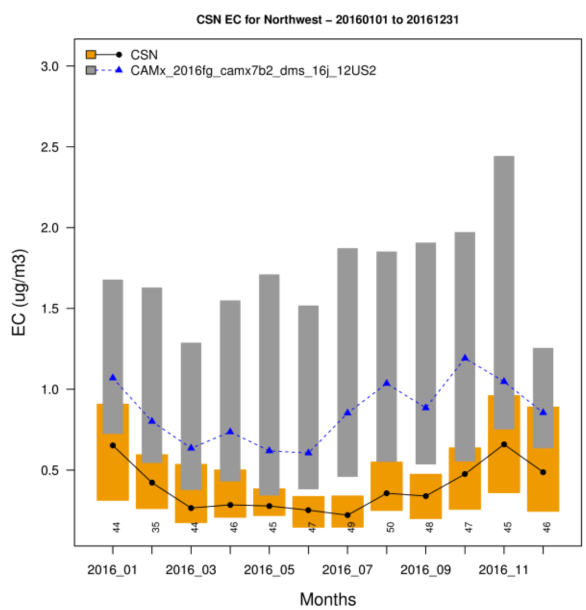
CSN EC for Central – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
188 136 211 173 175 176 171 185 177 180 177 184
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11



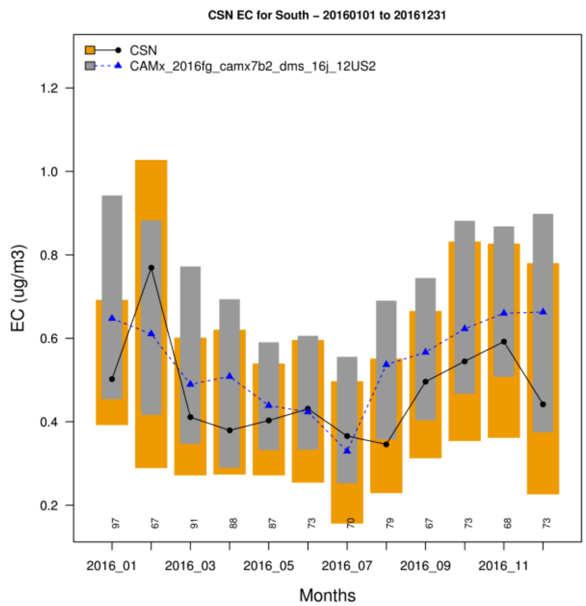
CSN EC for EN_Central – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
113 81 115 102 99 98 104 104 104 104 100 102
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11

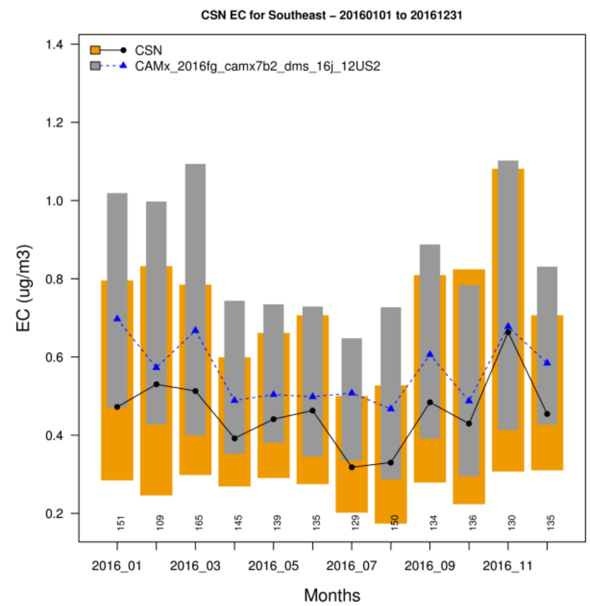


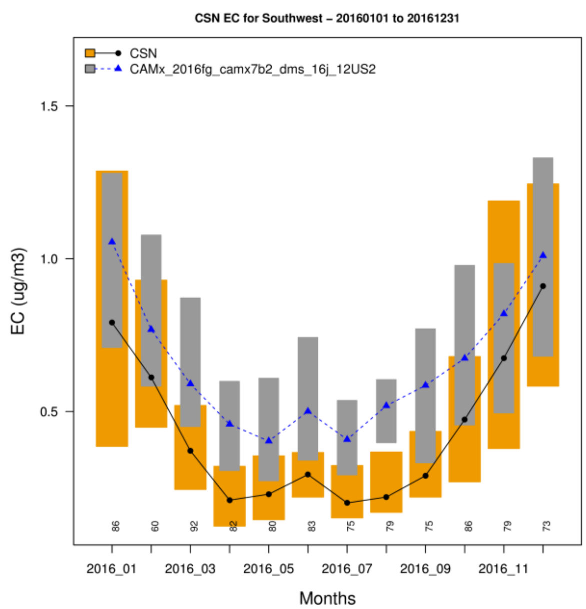
CSN EC for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
267 188 285 252 248 264 233 269 247 265 259 255
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11

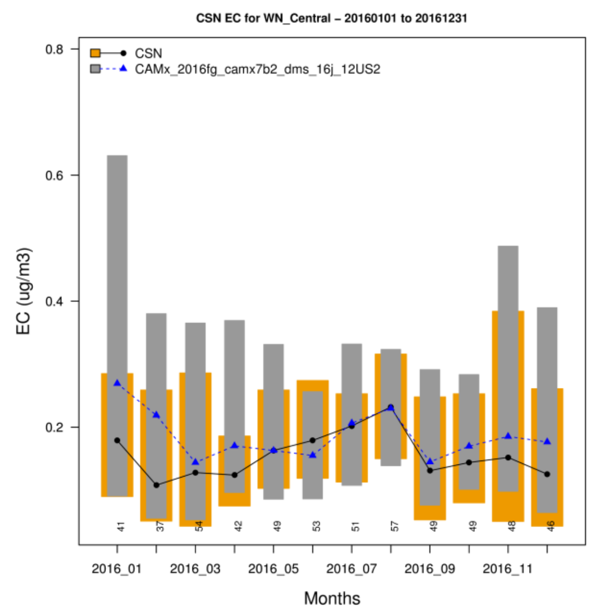


CSN EC for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
44 35 44 46 45 47 49 50 48 47 45 46
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11


CSN EC for South – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CSN EC for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CSN EC for Southwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


CSN EC for WN_Central – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

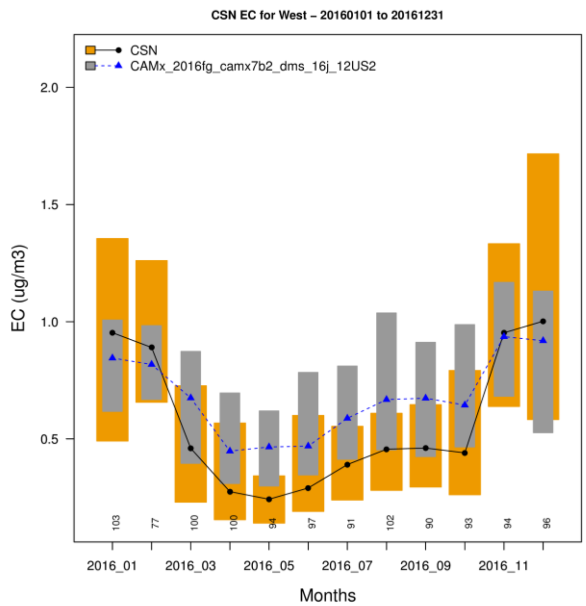
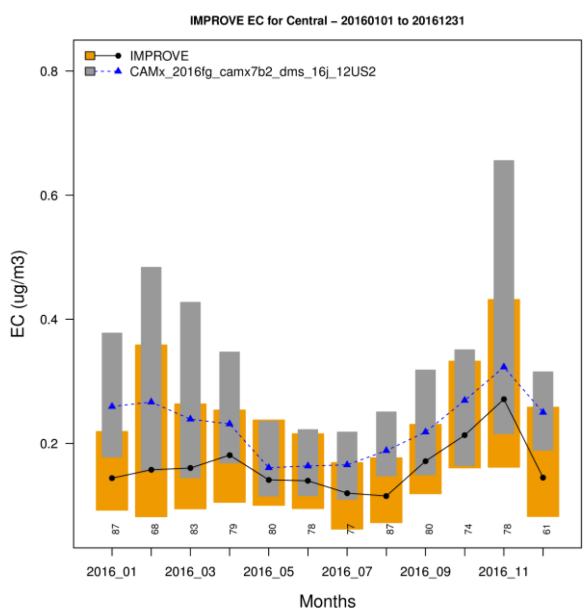
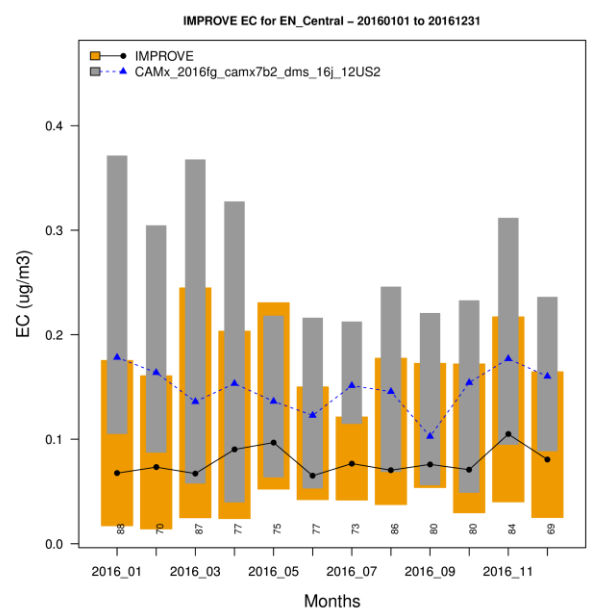
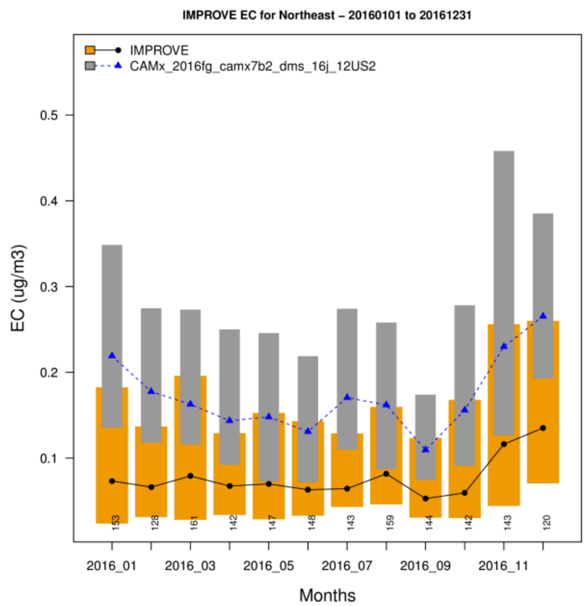
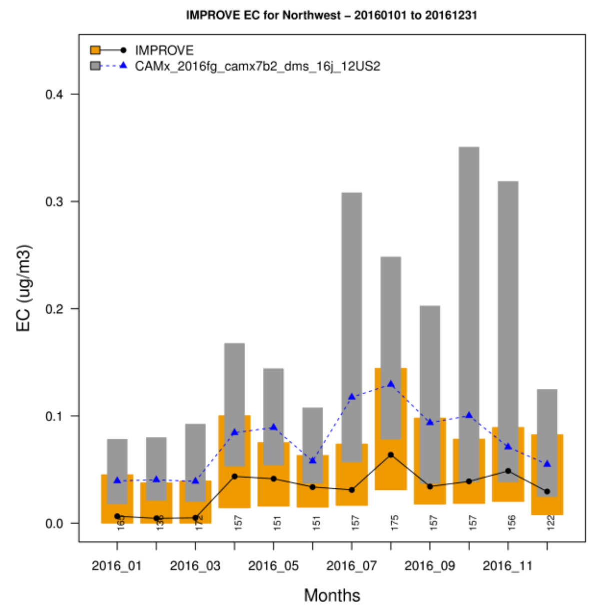


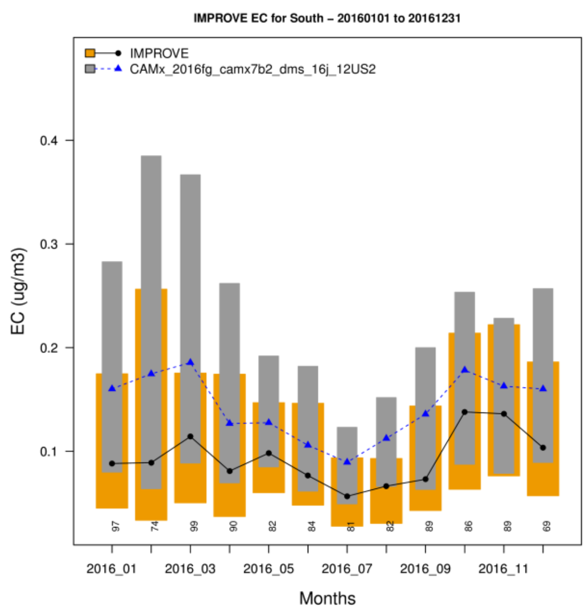
Figure 33. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN PM2.5 EC observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

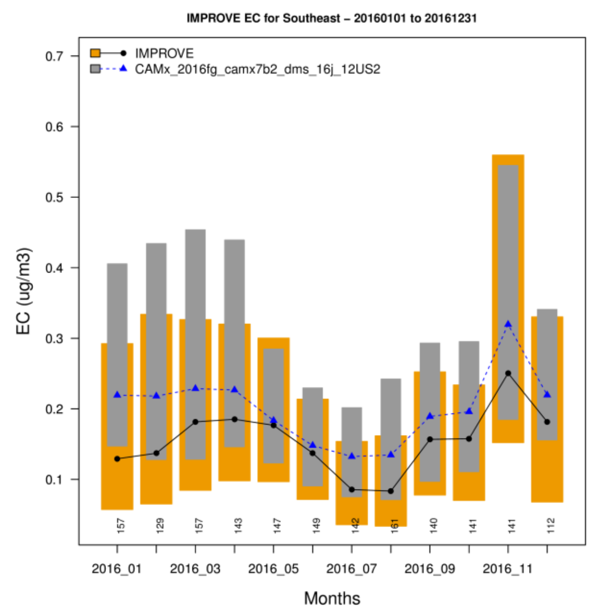





IMPROVE EC for Northeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE EC for Northwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE EC for South – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE EC for Southeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

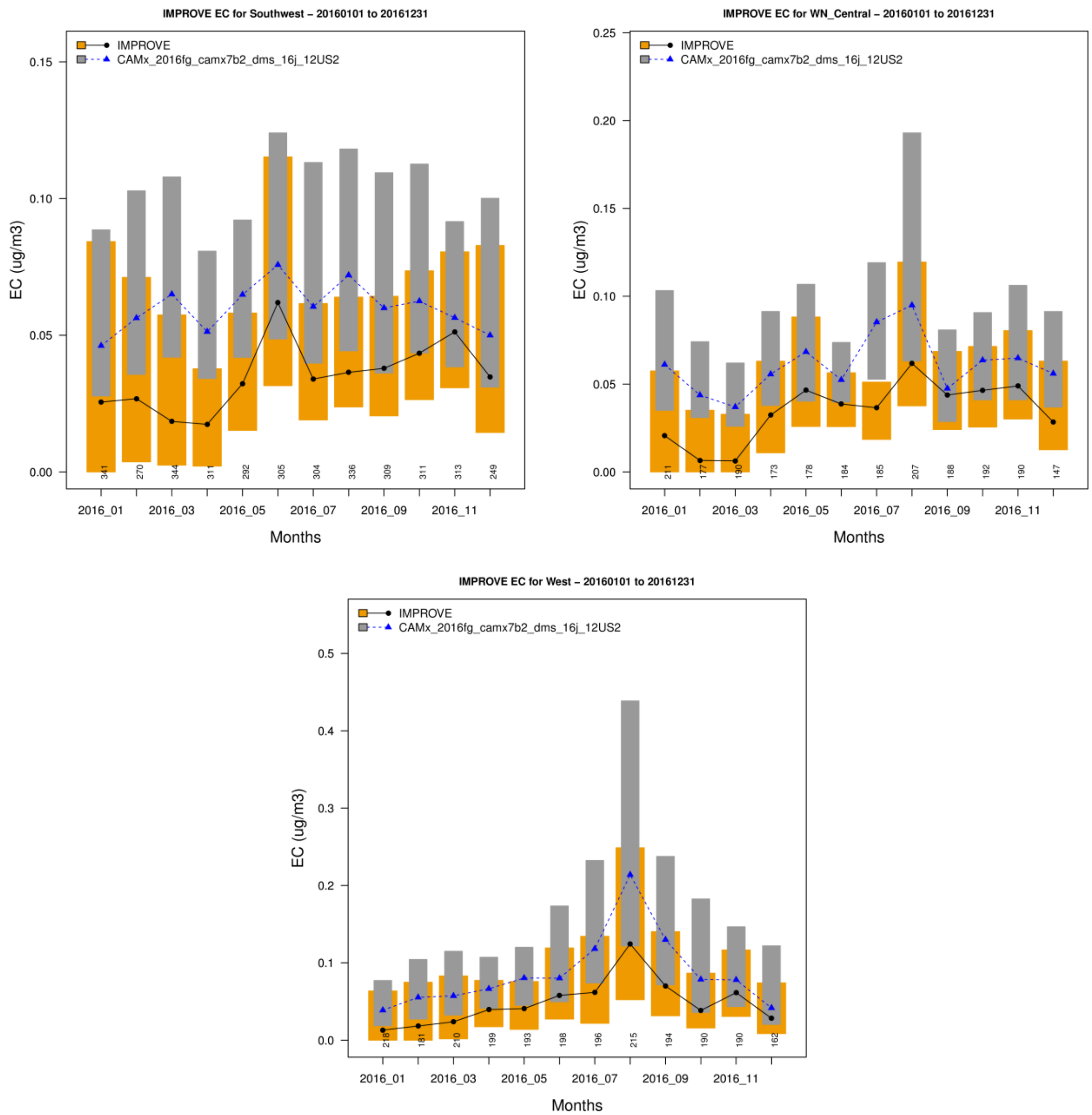
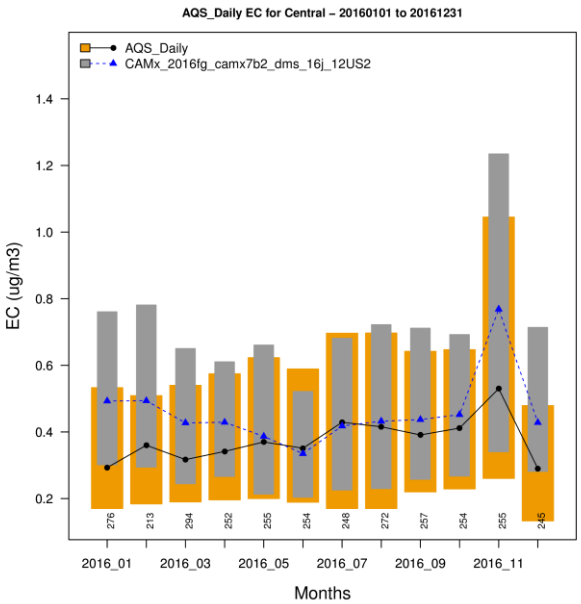
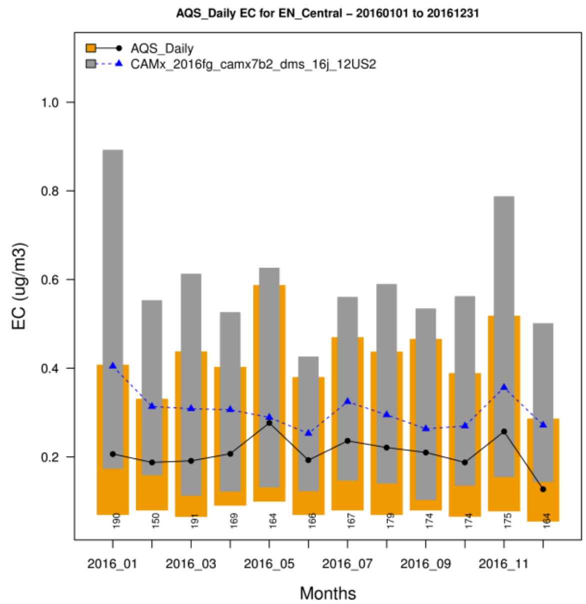
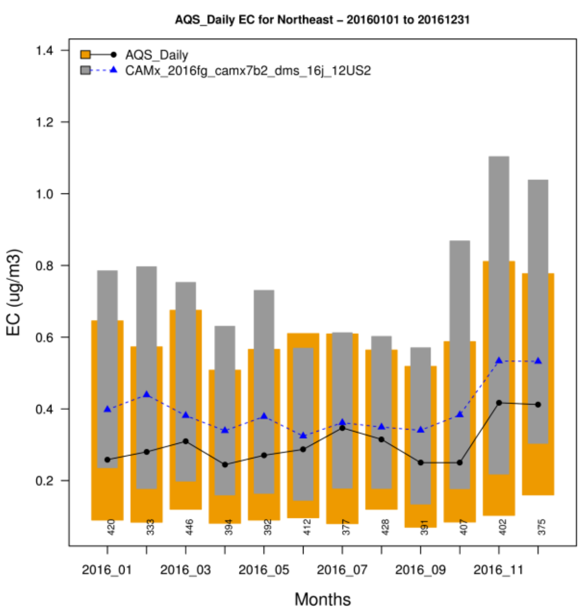
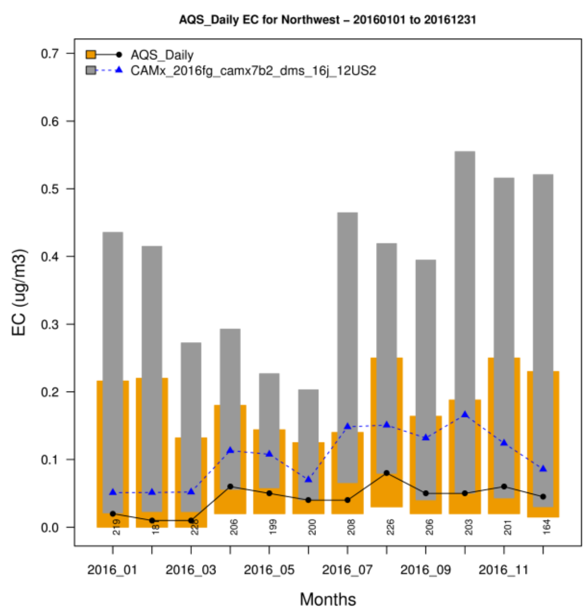


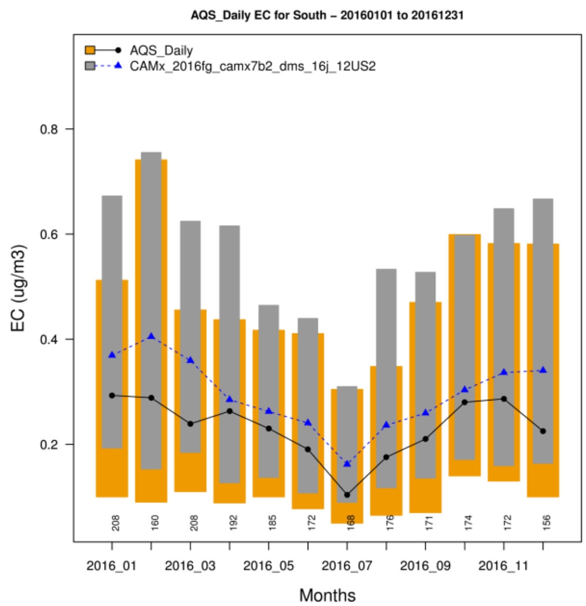
Figure 34. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median IMPROVE PM2.5 EC observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

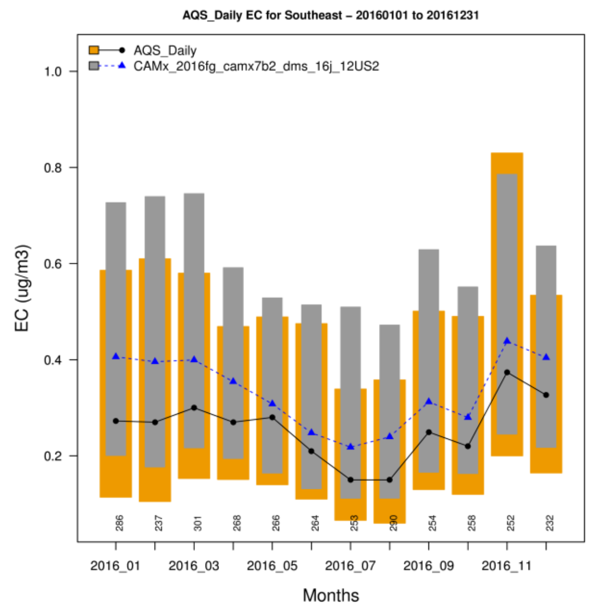

AQS_Daily EC for Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months

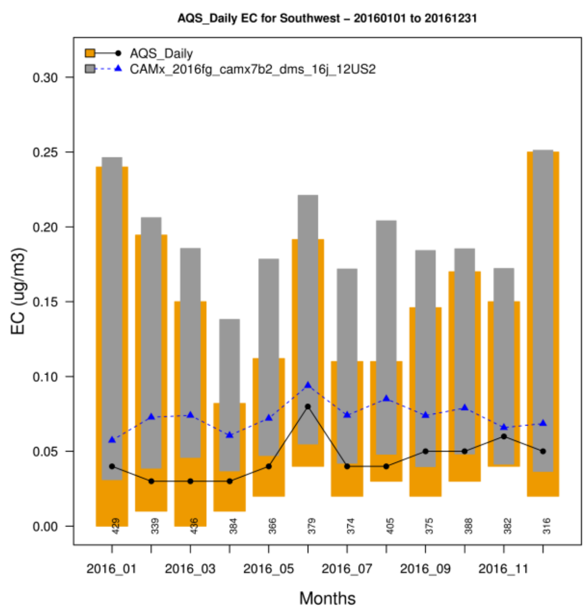

AQS_Daily EC for EN_Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months

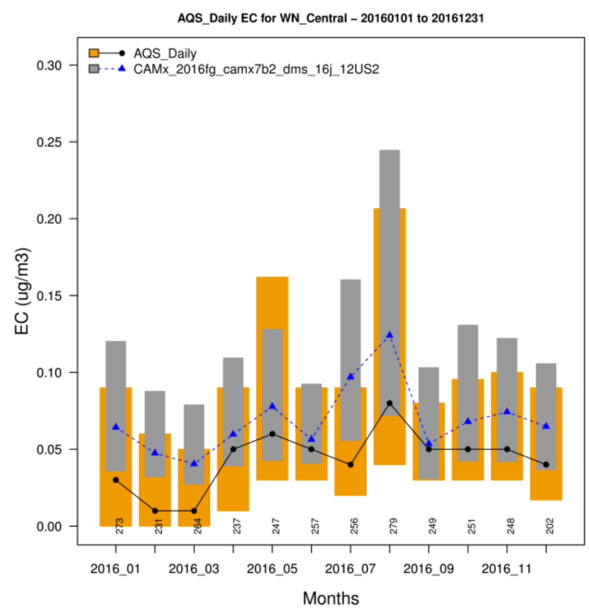

AQS_Daily EC for Northeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months


AQS_Daily EC for Northwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months


AQS_Daily EC for South – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months


AQS_Daily EC for Southeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months


AQS_Daily EC for Southwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months


AQS_Daily EC for WN_Central – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
EC (ug/m3)
Months

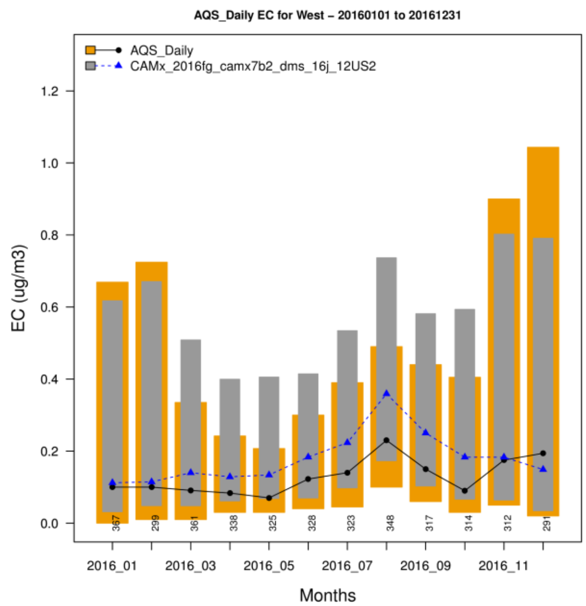


Figure 35. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily PM2.5 EC observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

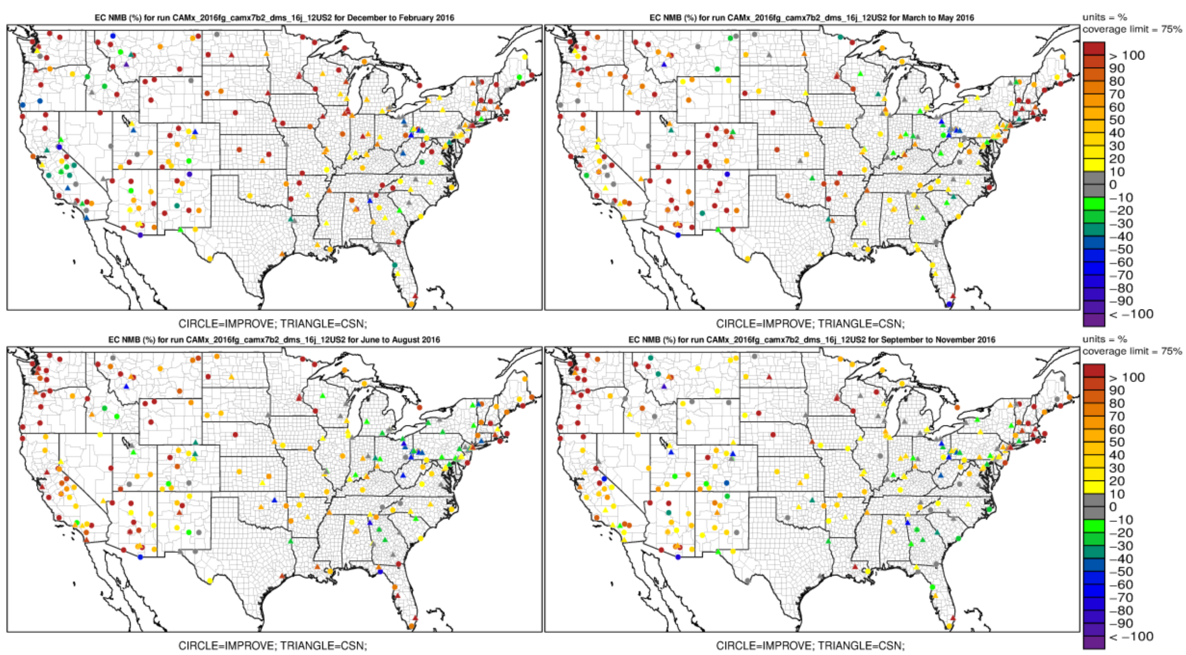


Figure 36. Spatial plot of PM2.5 EC NMB (%) by season and network.

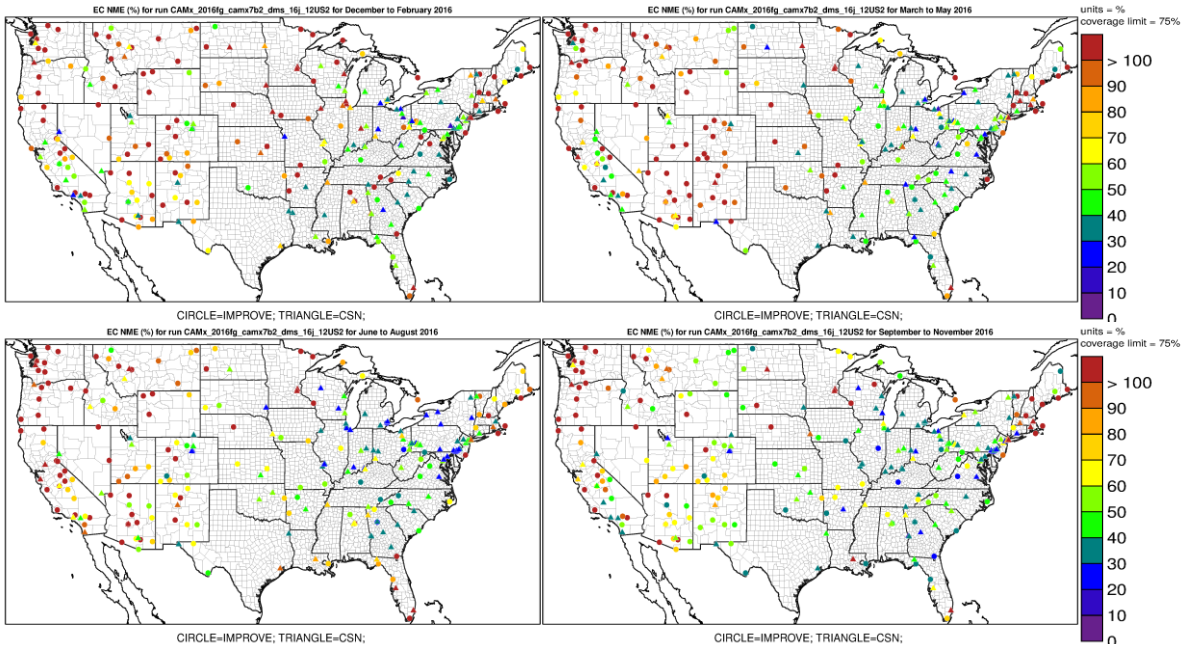


Figure 37. Spatial plot of PM2.5 EC NME (%) by season and network.

8. PM2.5 soil

Table 8-1 summarizes model performance statistics for PM2.5 soil (fine crustal). Figures 37 and 38 are national statistical tile plots with performance by region and season. Boxplot comparisons of model predictions and observations (IMPROVE, CSN and CASTNET) by month for each climate region are shown in Figures 39, 40, and 41. Nationwide spatial plots of NMB and NME for each season are shown in Figures 42 and 43.

Table 8-1. Model performance statistics for PM2.5 soil by region, network, and season.

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Northeast	IMPROVE	Winter	431	0.10	0.30	0.25	191.0	208.0	0.19	0.21
		Spring	449	0.23	0.44	0.68	91.4	102.0	0.21	0.23
		Summer	450	0.18	0.40	0.38	114.0	139.0	0.21	0.26

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Fall	428	0.12	0.45	0.51	258.0	268.0	0.32	0.33
		All	1758	0.16	0.39	0.46	145.0	160.0	0.23	0.26
	CSN	**Winter**	715	0.40	0.95	0.23	135.0	175.0	0.55	0.71
		Spring	779	0.50	1.06	0.36	113.0	135.0	0.56	0.68
		Summer	739	0.50	1.14	0.29	125.0	148.0	0.63	0.75
		Fall	718	0.53	1.41	0.28	168.0	195.0	0.88	1.03
		All	2951	0.48	1.14	0.28	135.0	162.0	0.65	0.79
Southeast	**IMPROVE**	**Winter**	403	0.14	0.74	0.75	419.0	423.0	0.60	0.60
		Spring	412	0.36	0.97	0.52	174.0	181.0	0.62	0.64
		Summer	419	0.85	0.88	0.15	3.4	97.7	0.03	0.83
		Fall	390	0.32	1.02	0.57	220.0	234.0	0.70	0.75
		All	1624	0.42	0.90	0.25	114.0	168.0	0.48	0.71
	CSN	**Winter**	381	0.30	1.47	0.41	387.0	393.0	1.17	1.19
		Spring	424	0.54	1.63	0.21	204.0	227.0	1.09	1.21
		Summer	401	1.05	1.67	0.14	58.4	117.0	0.62	1.24
		Fall	394	0.60	1.82	0.46	201.0	210.0	1.21	1.27
		All	1600	0.63	1.65	0.21	163.0	196.0	1.02	1.23
Ohio Valley	**IMPROVE**	**Winter**	203	0.14	0.67	0.27	364.0	372.0	0.53	0.54
		Spring	209	0.36	0.91	0.66	153.0	155.0	0.55	0.56
		Summer	211	0.65	1.14	0.20	73.7	133.0	0.48	0.87
		Fall	198	0.39	1.41	0.36	257.0	275.0	1.01	1.08
		All	821	0.39	1.03	0.30	163.0	195.0	0.64	0.76
	CSN	**Winter**	516	0.48	1.17	0.33	143.0	175.0	0.69	0.85
		Spring	527	0.59	1.51	0.53	158.0	172.0	0.92	1.01
		Summer	528	0.72	1.99	0.20	178.0	192.0	1.28	1.37
		Fall	513	0.67	2.29	0.29	241.0	251.0	1.62	1.69

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	2084	0.61	1.74	0.34	183.0	200.0	1.13	1.23
Upper Midwest	**IMPROVE**	**Winter**	216	0.12	0.31	0.52	159.0	174.0	0.19	0.21
		Spring	208	0.28	0.64	0.72	128.0	132.0	0.36	0.37
		Summer	210	0.39	0.65	0.56	66.9	92.6	0.26	0.36
		Fall	213	0.26	0.75	0.65	193.0	196.0	0.50	0.50
		All	847	0.26	0.59	0.59	125.0	138.0	0.33	0.36
	CSN	**Winter**	275	0.33	0.94	0.21	182.0	204.0	0.61	0.68
		Spring	288	0.54	1.51	0.45	178.0	192.0	0.97	1.05
		Summer	276	0.70	1.68	0.25	139.0	158.0	0.98	1.11
		Fall	279	0.64	1.96	0.28	208.0	229.0	1.32	1.46
		All	1118	0.55	1.52	0.35	175.0	194.0	0.97	1.07
South	**IMPROVE**	**Winter**	250	0.32	0.58	0.01	80.0	138.0	0.26	0.44
		Spring	267	0.74	0.71	0.29	-4.5	68.4	-0.03	0.51
		Summer	247	1.48	0.62	0.46	-58.2	74.6	-0.86	1.10
		Fall	265	0.54	0.78	0.11	45.0	106.0	0.24	0.57
		All	1029	0.76	0.67	0.24	-11.9	85.2	-0.09	0.65
	CSN	**Winter**	269	0.59	1.35	0.10	128.0	173.0	0.76	1.03
		Spring	287	0.73	1.28	0.13	74.3	123.0	0.55	0.91
		Summer	286	2.06	1.41	0.38	-31.4	79.0	-0.65	1.62
		Fall	270	0.93	1.76	0.06	89.9	144.0	0.83	1.33
		All	1112	1.09	1.45	0.20	33.1	113.0	0.36	1.22
Southwest	**IMPROVE**	**Winter**	929	0.50	0.47	0.29	-7.2	86.1	-0.04	0.43
		Spring	973	1.16	0.83	0.47	-28.9	50.0	-0.34	0.58
		Summer	971	1.02	0.34	0.41	-67.0	68.6	-0.69	0.70
		Fall	954	0.80	0.41	0.25	-48.5	66.0	-0.39	0.53
		All	3827	0.88	0.51	0.35	-41.6	64.2	-0.36	0.56

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
	CSN	Winter	247	1.00	1.43	0.05	42.8	86.0	0.43	0.86
		Spring	253	1.40	1.60	0.12	14.0	65.7	0.20	0.92
		Summer	247	1.57	1.11	-0.18	-29.6	59.8	-0.47	0.94
		Fall	257	1.87	1.57	-0.08	-16.0	75.2	-0.30	1.40
		All	1004	1.46	1.43	-0.02	-2.5	70.6	-0.04	1.03
Northern Rockies & Plains	IMPROVE	Winter	525	0.13	0.24	0.50	79.2	113.0	0.11	0.15
		Spring	512	0.42	0.61	0.67	46.1	66.5	0.19	0.28
		Summer	540	0.61	0.47	0.38	-22.8	47.0	-0.14	0.29
		Fall	538	0.36	0.52	0.41	42.2	93.2	0.15	0.34
		All	2115	0.38	0.46	0.49	19.9	69.0	0.08	0.27
	CSN	Winter	140	0.29	0.46	0.19	58.7	121.0	0.17	0.35
		Spring	134	0.46	0.97	0.63	113.0	120.0	0.52	0.55
		Summer	131	0.70	0.88	0.47	26.7	62.6	0.19	0.44
		Fall	139	0.54	1.05	0.39	94.8	127.0	0.51	0.68
		All	544	0.49	0.84	0.44	70.3	102.0	0.35	0.50
Northwest	IMPROVE	Winter	437	0.07	0.23	0.70	235.0	251.0	0.17	0.18
		Spring	479	0.34	0.71	0.45	113.0	135.0	0.38	0.46
		Summer	479	0.49	0.49	0.05	0.7	94.2	0.00	0.46
		Fall	464	0.21	0.43	0.16	109.0	174.0	0.22	0.36
		All	1859	0.28	0.47	0.23	68.9	131.0	0.19	0.37
	CSN	Winter	146	0.27	1.18	0.40	335.0	340.0	0.91	0.92
		Spring	147	0.43	1.94	0.50	351.0	355.0	1.51	1.53
		Summer	152	0.47	1.97	0.45	319.0	322.0	1.50	1.52
		Fall	145	0.41	1.95	0.31	373.0	384.0	1.54	1.58
		All	590	0.40	1.77	0.42	344.0	350.0	1.37	1.39
West	IMPROVE	Winter	618	0.20	0.34	0.54	66.7	104.0	0.14	0.21

Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Spring	626	0.52	0.73	0.57	40.1	62.5	0.21	0.33
		Summer	632	0.95	0.41	0.25	-56.9	63.9	-0.54	0.61
		Fall	605	0.72	0.35	0.14	-51.7	72.8	-0.37	0.52
		All	2481	0.60	0.46	0.20	-23.7	69.6	-0.14	0.42
	CSN	Winter	344	0.73	1.11	0.62	51.4	70.6	0.38	0.52
		Spring	352	0.76	1.26	0.62	65.6	77.8	0.50	0.59
		Summer	349	1.23	0.92	0.14	-25.0	56.4	-0.31	0.69
		Fall	328	1.35	1.10	0.28	-18.5	53.7	-0.25	0.73
		All	1373	1.02	1.10	0.29	8.4	62.2	0.09	0.63

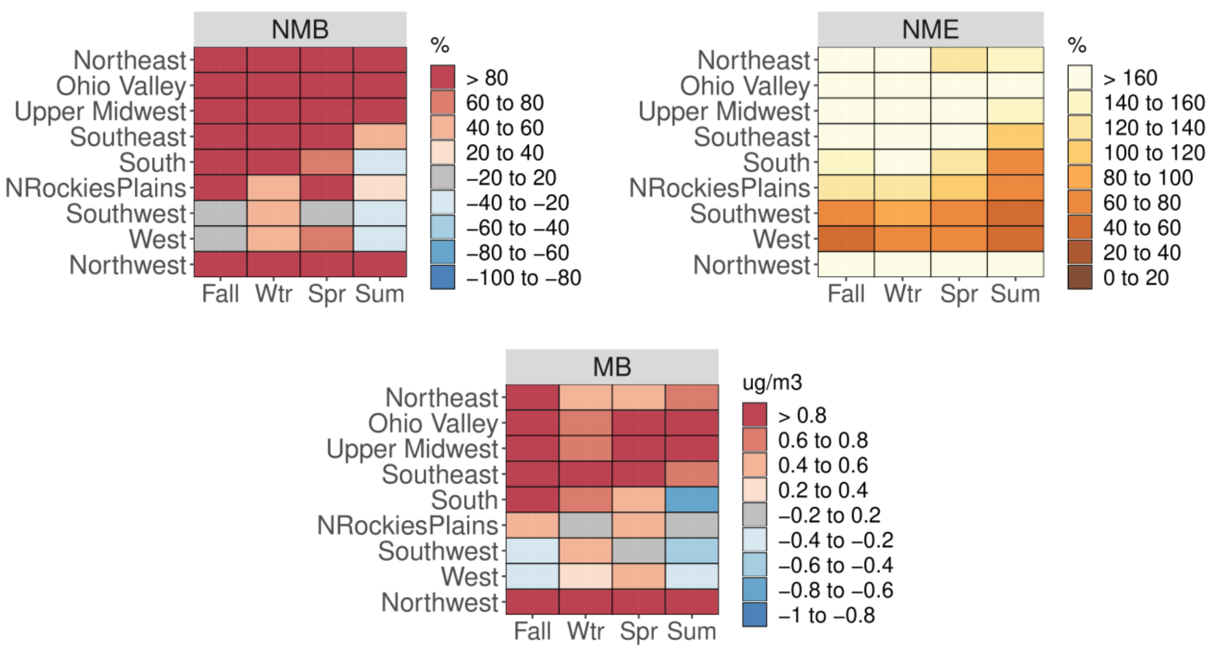


Figure 38. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for CSN PM2.5 soil observations.

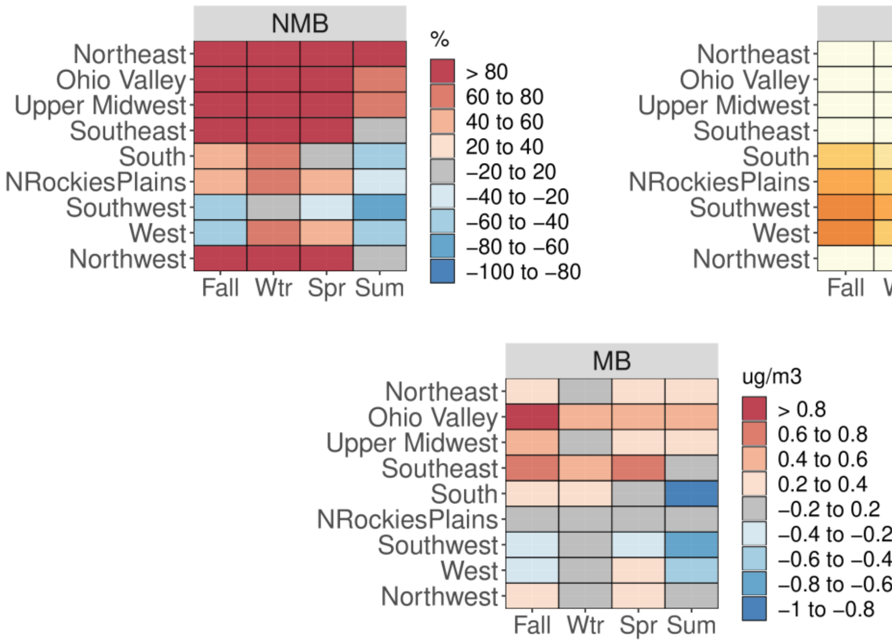
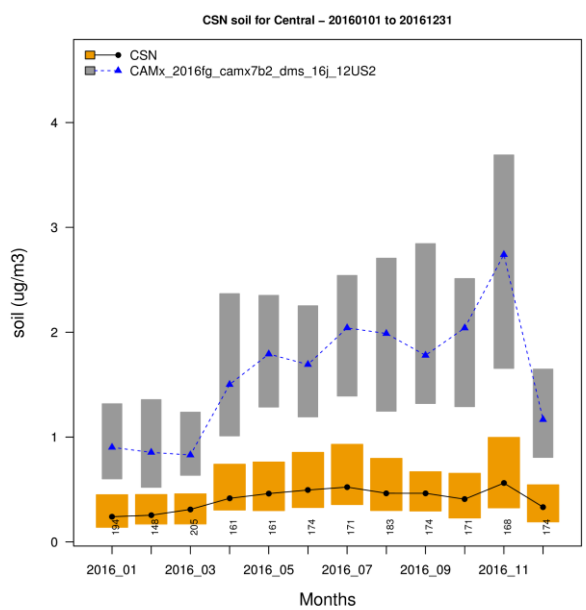
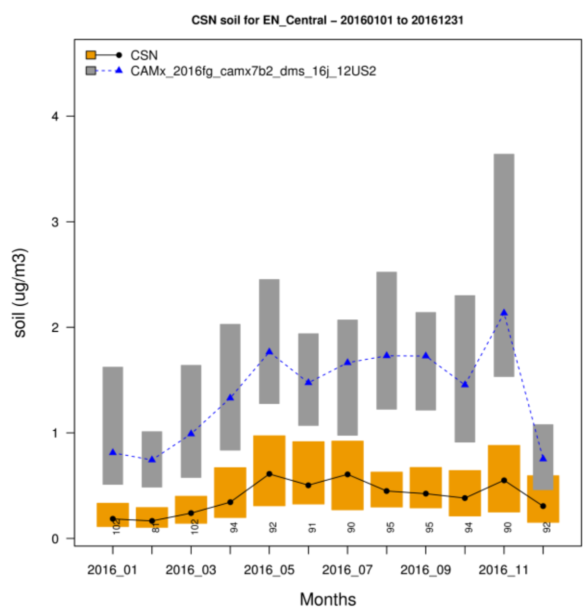
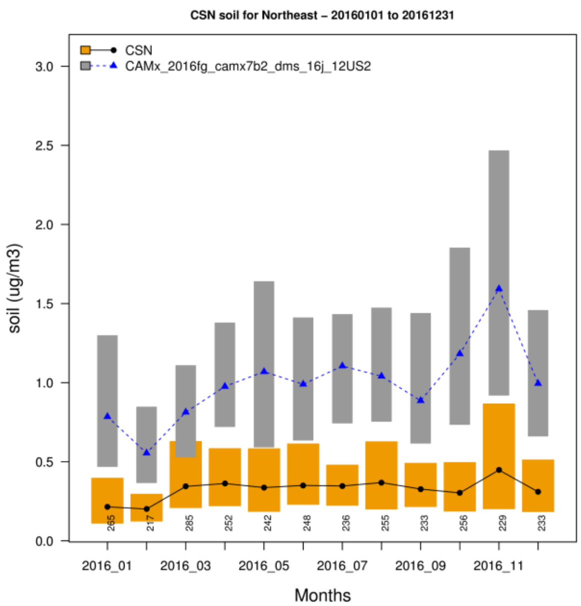
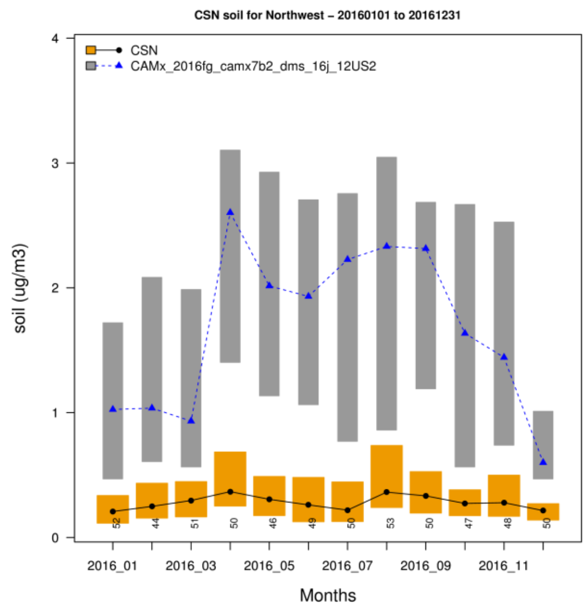


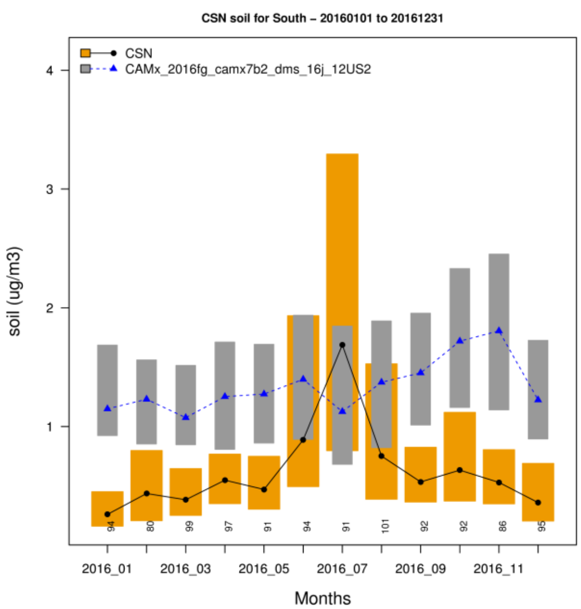
Figure 39. Normalized mean bias (NMB), normalized mean error (NME), and mean bias (MB) for IMPROVE PM2.5 soil observations.

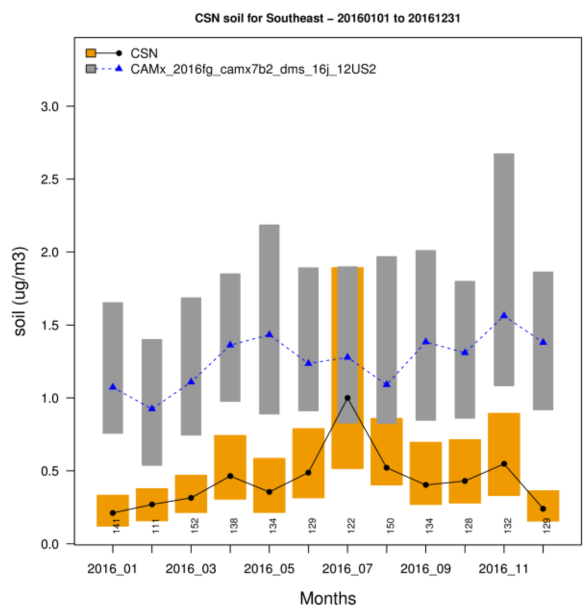





CSN soil for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months


CSN soil for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
0
1
2
3
4
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months


CSN soil for South – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
1
2
3
4
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months


CSN soil for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11
Months

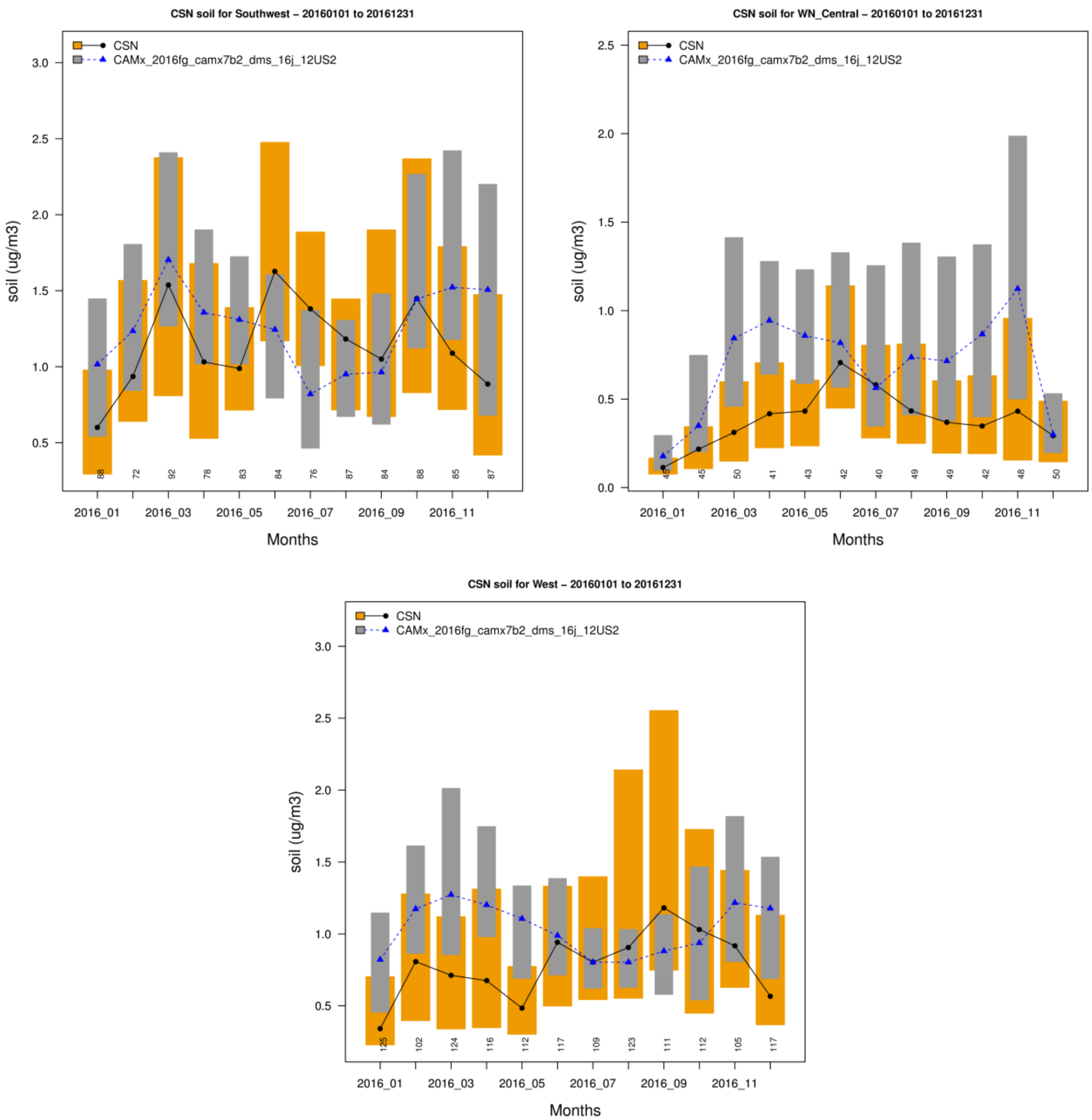
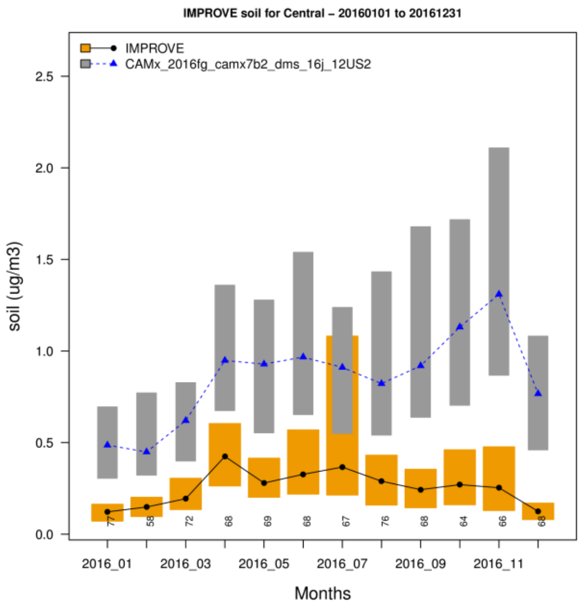
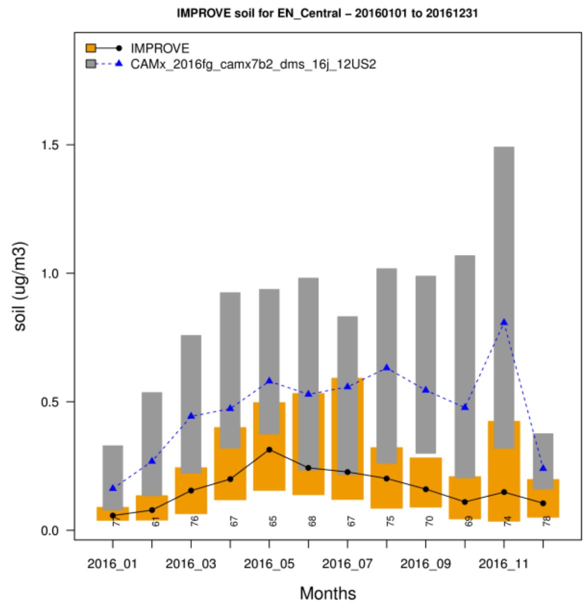
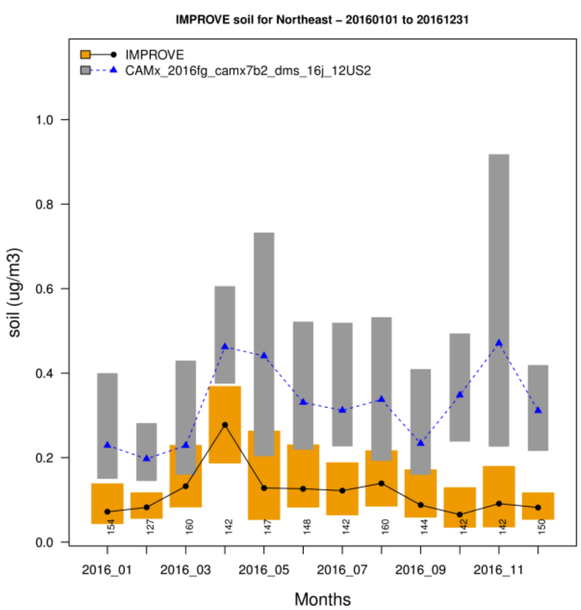
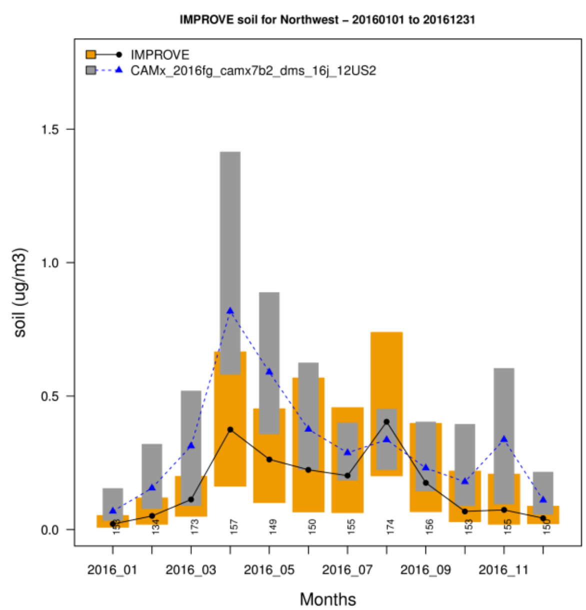


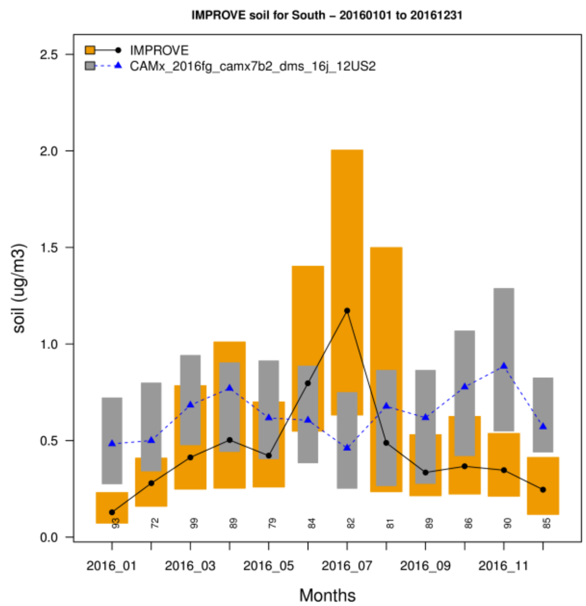
Figure 40. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN PM2.5 soil observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

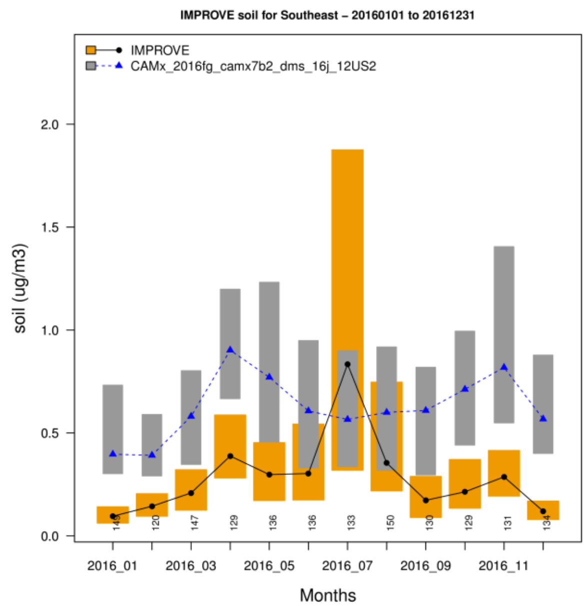

IMPROVE soil for Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months

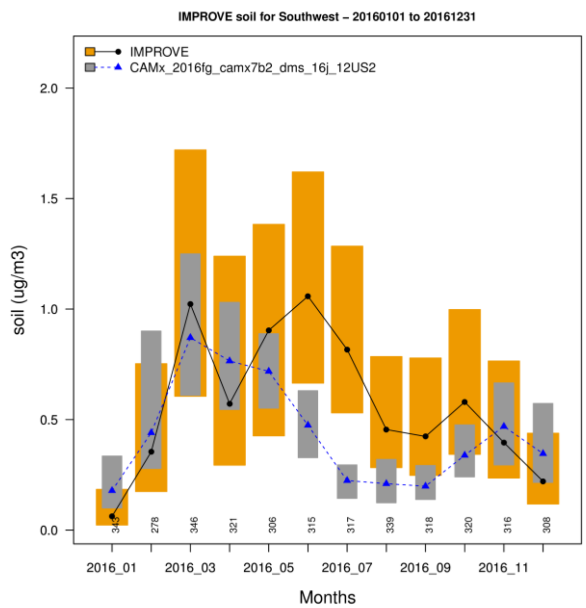

IMPROVE soil for EN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months

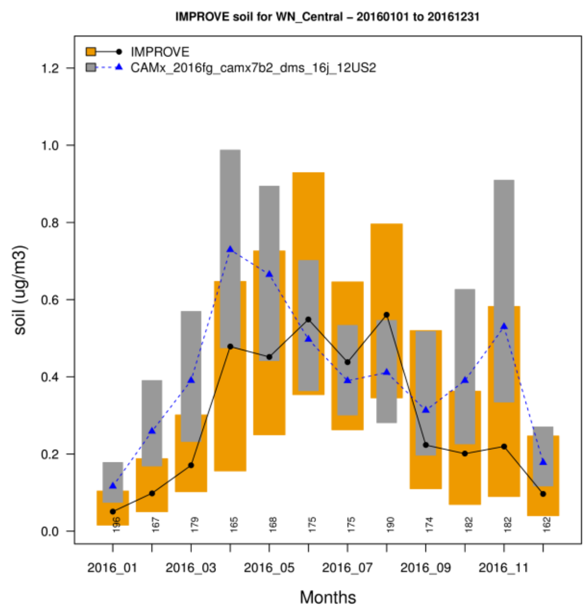

IMPROVE soil for Northeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months


IMPROVE soil for Northwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months


IMPROVE soil for South – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months


IMPROVE soil for Southeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months


IMPROVE soil for Southwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months


IMPROVE soil for WN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
soil (ug/m3)
Months

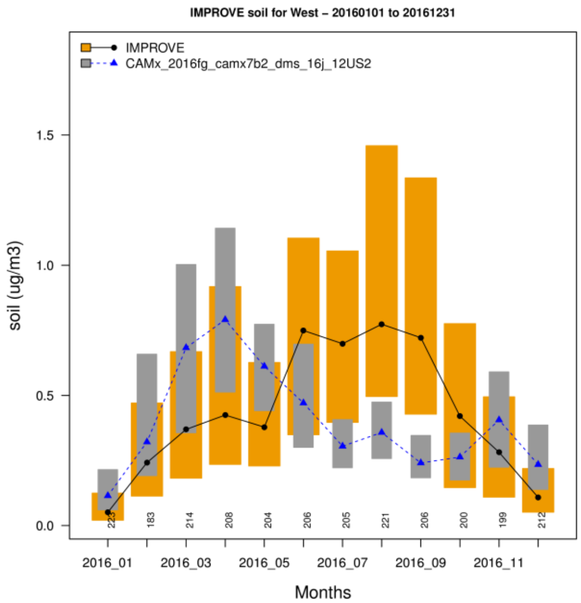


Figure 41. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median IMPROVE PM2.5 soil observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

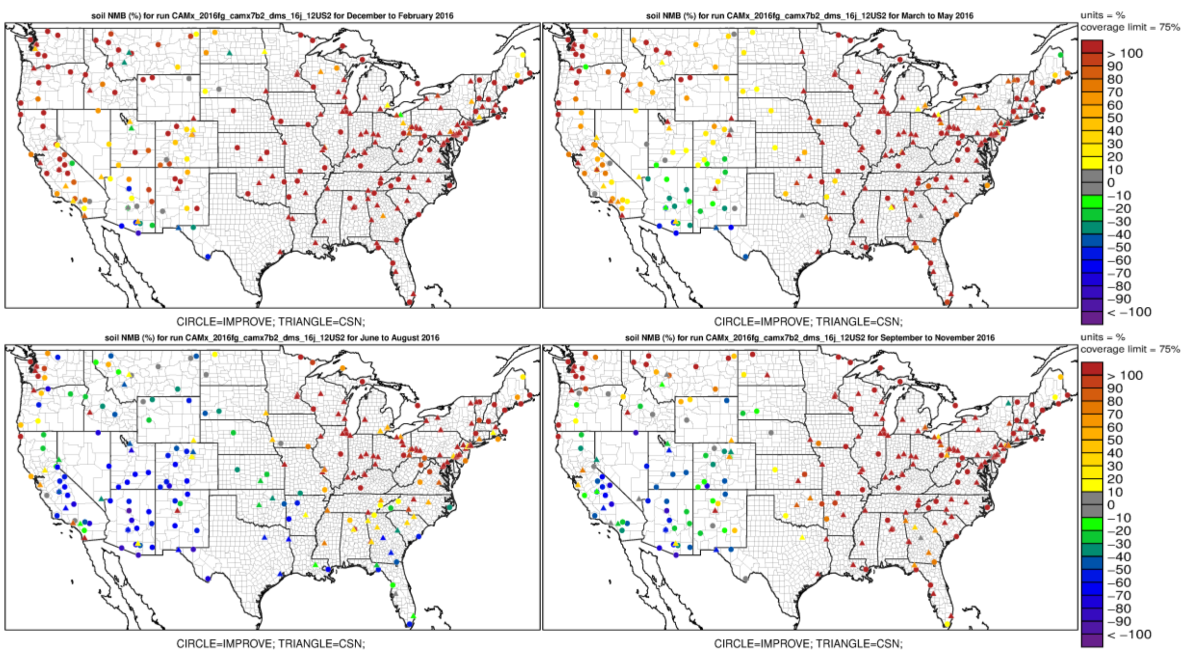


Figure 42. Spatial plot of PM2.5 soil NMB (%) by season and network.

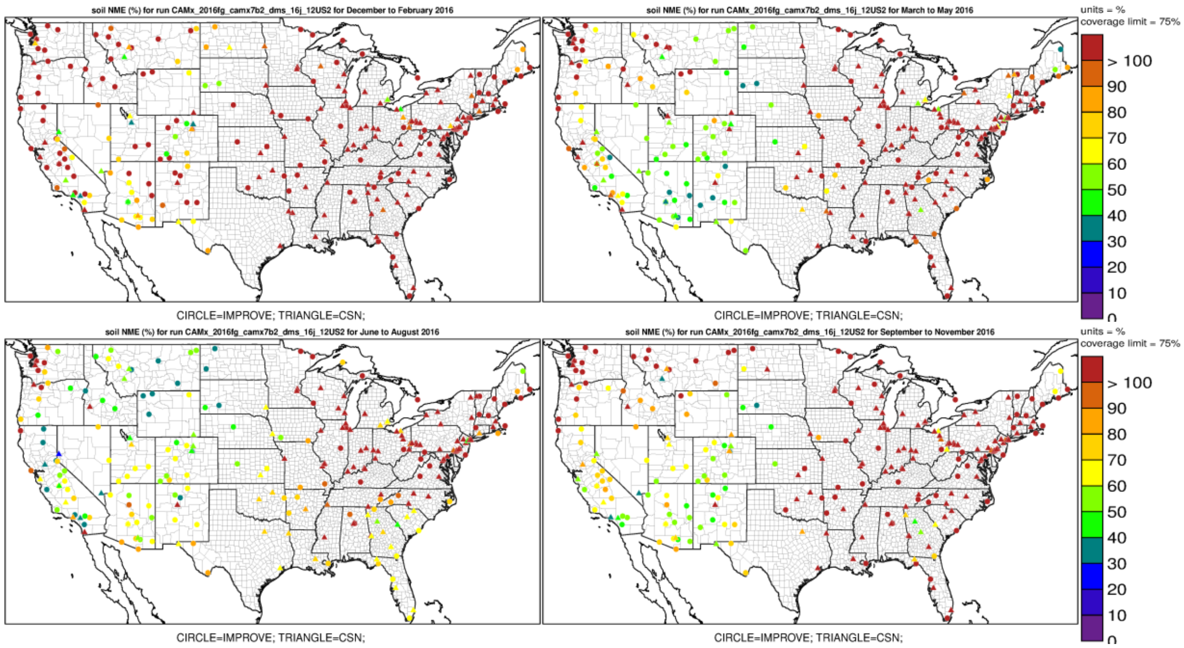


Figure 43. Spatial plot of PM2.5 soil NME (%) by season and network.

9. Total PM2.5

Table 9-1 summarizes model performance statistics for total $PM_{2.5}$. Boxplot comparisons of model predictions and observations (IMPROVE and CSN) by month for each climate region are shown in Figures 44, 45, and 46. Nationwide spatial plots of NMB and NME for each season are shown in Figures 47 and 48.

Table 9-1. Model performance statistics for Total PM2.5 by region, network, and season.

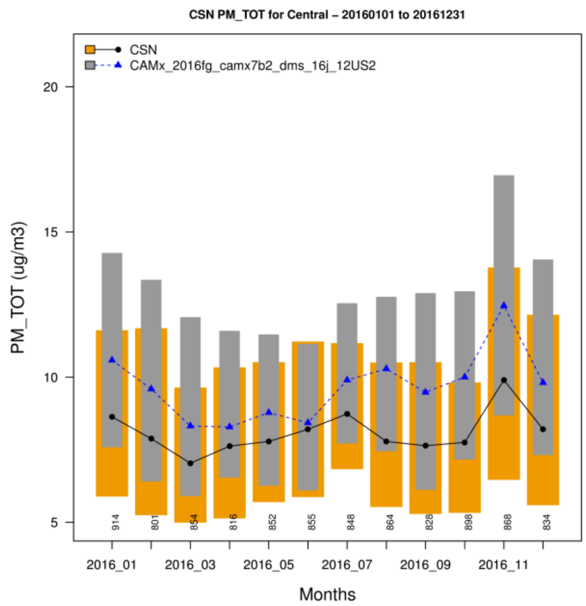
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
Northeast	**IMPROVE**	**Winter**	433	3.21	4.95	0.61	54.2	69.6	1.74	2.23
		Spring	449	3.49	4.19	0.80	19.9	37.1	0.70	1.30
		Summer	450	4.52	4.62	0.75	2.2	26.3	0.10	1.19
		Fall	427	3.25	4.68	0.72	44.1	58.6	1.43	1.90
		All	1759	3.63	4.60	0.69	27.0	45.4	0.98	1.65
	CSN	**Winter**	4258	9.23	12.10	0.58	31.2	50.4	2.88	4.65
		Spring	4325	7.90	9.58	0.63	21.2	41.4	1.68	3.27

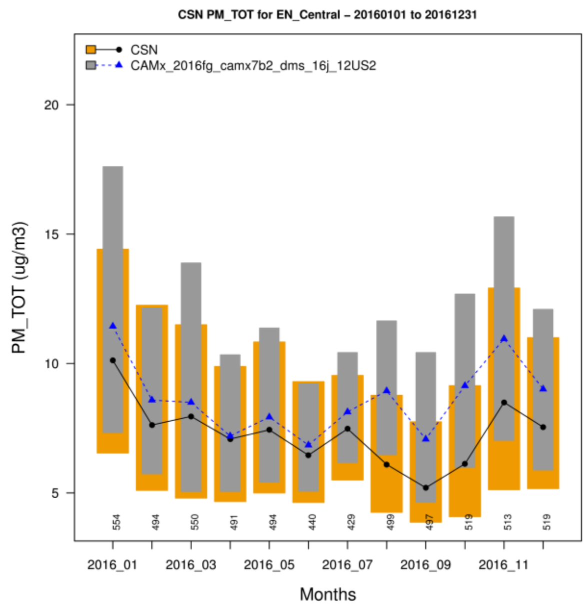
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Summer	4480	8.59	8.64	0.43	0.6	31.4	0.05	2.70
		Fall	4251	8.00	10.65	0.59	33.2	51.4	2.65	4.11
		All	17314	8.43	10.22	0.56	21.3	43.5	1.79	3.67
Southeast	**IMPROVE**	**Winter**	402	4.66	6.52	0.38	39.7	61.0	1.85	2.85
		Spring	413	6.38	7.24	0.46	13.5	44.1	0.86	2.82
		Summer	419	6.98	6.95	0.21	-0.5	46.8	-0.03	3.27
		Fall	391	6.82	7.70	0.55	13.0	42.0	0.89	2.86
		All	1625	6.22	7.10	0.39	14.2	47.5	0.88	2.95
	CSN	**Winter**	2079	7.84	10.52	0.56	34.2	48.6	2.68	3.81
		Spring	2201	8.38	10.34	0.69	23.4	34.4	1.96	2.88
		Summer	2276	8.34	10.99	0.55	31.7	42.5	2.65	3.54
		Fall	2185	9.70	11.34	0.60	16.9	37.9	1.64	3.67
		All	8741	8.57	10.80	0.58	26.0	40.5	2.23	3.47
Ohio Valley	**IMPROVE**	**Winter**	203	4.88	7.66	0.20	57.0	79.2	2.78	3.86
		Spring	209	5.24	6.09	0.53	16.3	36.4	0.85	1.91
		Summer	211	6.82	7.32	0.63	7.3	28.4	0.50	1.94
		Fall	198	6.64	8.08	0.73	21.7	31.7	1.44	2.11
		All	821	5.89	7.28	0.31	23.4	41.5	1.38	2.45
	CSN	**Winter**	2549	9.13	11.04	0.59	20.9	41.8	1.91	3.82
		Spring	2522	8.13	9.37	0.46	15.3	36.9	1.24	3.00
		Summer	2567	8.73	9.88	0.53	13.2	32.1	1.15	2.80
		Fall	2594	8.98	11.08	0.72	23.4	37.1	2.10	3.34
		All	10232	8.74	10.35	0.59	18.3	37.0	1.60	3.24
Upper Midwest	**IMPROVE**	**Winter**	215	4.14	4.34	0.79	4.8	36.7	0.20	1.52
		Spring	208	3.90	4.54	0.48	16.3	44.5	0.64	1.74
		Summer	210	4.29	4.44	0.76	3.6	26.7	0.15	1.14

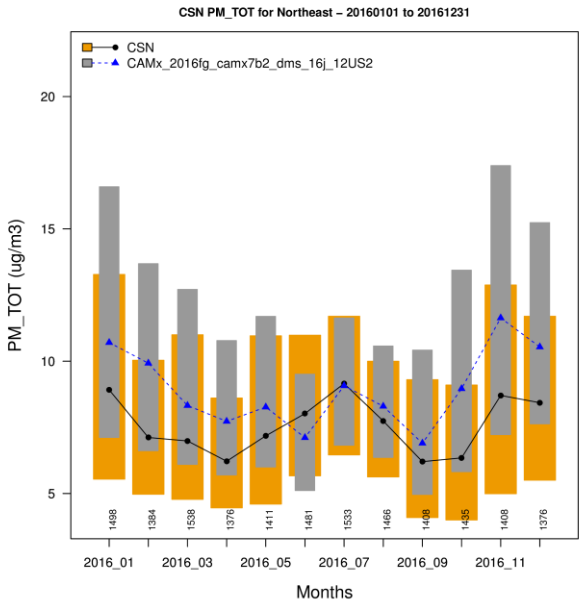
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		Fall	214	3.34	4.40	0.78	31.7	43.6	1.06	1.46
		All	847	3.92	4.43	0.66	13.1	37.4	0.51	1.46
	CSN	**Winter**	1567	9.52	10.76	0.63	13.0	39.1	1.24	3.72
		Spring	1535	8.23	8.96	0.55	8.8	37.6	0.73	3.09
		Summer	1368	7.29	8.32	0.49	14.1	37.5	1.03	2.74
		Fall	1529	7.43	9.77	0.69	31.5	46.1	2.34	3.43
		All	5999	8.15	9.49	0.61	16.4	40.0	1.34	3.26
South	**IMPROVE**	**Winter**	250	4.18	5.28	0.56	26.4	55.0	1.10	2.30
		Spring	267	4.94	5.39	0.55	9.0	41.7	0.45	2.06
		Summer	246	6.91	5.26	0.55	-23.9	42.4	-1.65	2.93
		Fall	265	5.35	5.63	0.64	5.3	31.6	0.28	1.69
		All	1028	5.33	5.39	0.54	1.2	41.9	0.06	2.23
	CSN	**Winter**	1581	8.16	10.27	0.50	25.8	44.6	2.10	3.64
		Spring	1589	8.37	8.57	0.43	2.3	33.2	0.20	2.78
		Summer	1487	9.68	9.24	0.21	-4.6	45.3	-0.44	4.39
		Fall	1574	9.11	11.14	0.53	22.3	40.7	2.03	3.71
		All	6231	8.82	9.81	0.42	11.2	41.0	0.99	3.62
Southwest	**IMPROVE**	**Winter**	926	2.20	2.36	0.56	7.6	56.9	0.17	1.25
		Spring	972	2.99	3.08	0.52	3.1	37.6	0.09	1.12
		Summer	970	4.20	2.89	0.41	-31.1	40.4	-1.31	1.70
		Fall	954	2.91	2.67	0.22	-8.3	37.5	-0.24	1.09
		All	3822	3.09	2.76	0.37	-10.6	41.9	-0.33	1.29
	CSN	**Winter**	1047	11.17	8.88	0.18	-20.5	58.3	-2.29	6.51
		Spring	1144	4.28	5.75	0.33	34.2	53.1	1.47	2.27
		Summer	1105	6.99	5.24	0.12	-25.0	42.7	-1.75	2.98
		Fall	1242	6.41	6.12	0.35	-4.5	41.8	-0.29	2.68

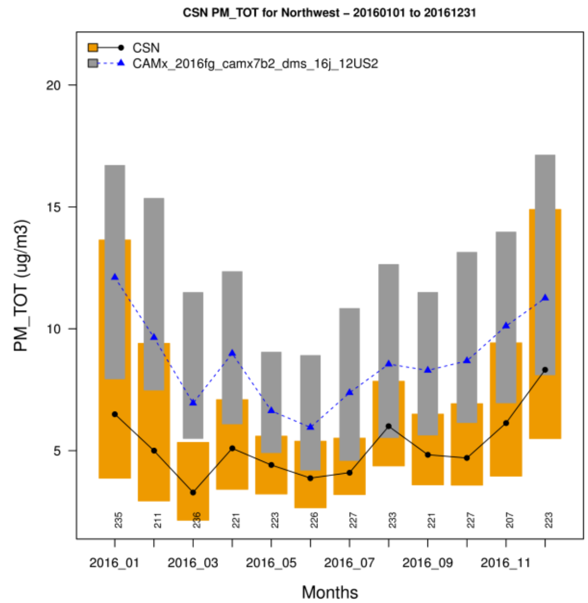
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
		All	4538	7.11	6.45	0.31	-9.3	49.7	-0.66	3.54
Northern Rockies & Plains	**IMPROVE**	**Winter**	523	1.59	1.92	0.59	20.9	62.4	0.33	0.99
		Spring	508	2.58	2.72	0.60	5.5	45.7	0.14	1.18
		Summer	540	3.92	3.48	0.19	-11.2	44.6	-0.44	1.75
		Fall	535	2.34	2.44	0.42	4.6	44.8	0.11	1.05
		All	2106	2.62	2.65	0.32	1.2	47.6	0.03	1.24
	CSN	**Winter**	-	-	-	-	-	-	-	-
		Spring	-	-	-	-	-	-	-	-
		Summer	-	-	-	-	-	-	-	-
		Fall	-	-	-	-	-	-	-	-
		All	-	-	-	-	-	-	-	-
Northwest	**IMPROVE**	**Winter**	445	1.35	2.67	0.63	97.6	126.0	1.32	1.70
		Spring	481	2.25	3.71	0.62	64.9	75.3	1.46	1.69
		Summer	480	4.09	4.34	0.47	6.1	58.9	0.25	2.41
		Fall	468	2.35	4.00	0.59	69.7	94.6	1.64	2.23
		All	1874	2.53	3.70	0.46	45.8	79.4	1.16	2.01
	CSN	**Winter**	669	9.48	13.10	0.34	38.2	79.6	3.62	7.54
		Spring	680	4.76	8.92	0.53	87.4	93.9	4.16	4.47
		Summer	686	5.10	8.23	0.53	61.2	72.6	3.12	3.70
		Fall	655	6.06	10.11	0.43	66.8	80.5	4.05	4.88
		All	2690	6.34	10.07	0.44	58.9	81.1	3.73	5.14
West	**IMPROVE**	**Winter**	621	2.42	2.50	0.83	3.1	58.6	0.07	1.42
		Spring	626	3.38	3.48	0.61	2.9	39.3	0.10	1.33
		Summer	632	6.38	4.87	0.48	-23.8	48.9	-1.52	3.12
		Fall	605	4.40	3.64	0.60	-17.2	43.5	-0.76	1.91
		All	2484	4.15	3.63	0.62	-12.7	47.0	-0.53	1.95

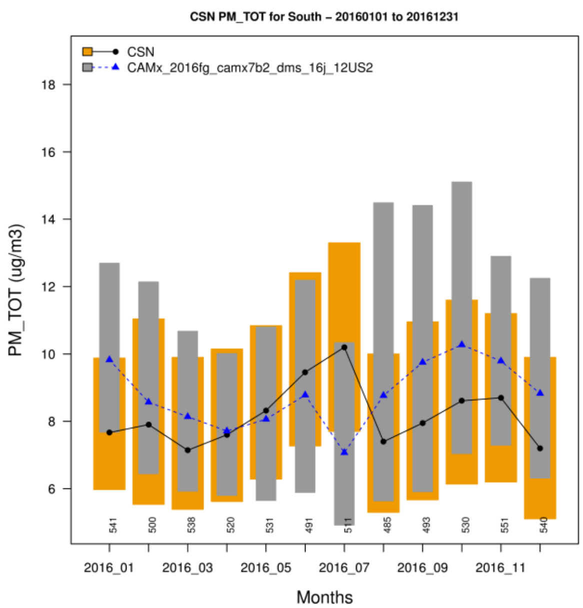
Region	Network	Season	N	Avg. Obs. (µg m^{-3})	Avg. Mod. (µg m^{-3})	R	NMB (%)	NME (%)	MB (µg m^{-3})	ME (µg m^{-3})
	CSN	**Winter**	1543	14.95	10.82	0.64	-27.6	42.1	-4.13	6.29
		Spring	1557	8.58	7.95	0.75	-7.3	29.8	-0.63	2.56
		Summer	1633	10.99	9.14	0.47	-16.9	35.2	-1.86	3.87
		Fall	1619	11.83	9.55	0.61	-19.3	34.5	-2.28	4.09
		All	6352	11.58	9.36	0.62	-19.2	36.2	-2.22	4.19

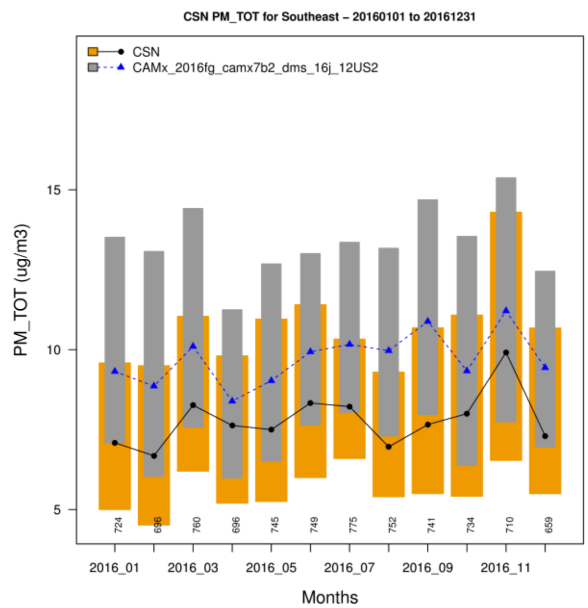





CSN PM_TOT for Northeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
20
15
10
5
1498 1384 1538 1376 1411 1481 1533 1466 1408 1435 1408 1376
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
Months


CSN PM_TOT for Northwest – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
20
15
10
5
235 211 236 221 223 226 227 233 221 227 207 223
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
Months


CSN PM_TOT for South – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
18
16
14
12
10
8
6
541 500 538 520 531 491 511 485 493 530 551 540
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
Months


CSN PM_TOT for Southeast – 20160101 to 20161231
CSN
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
15
10
5
724 696 760 696 745 749 775 752 741 734 710 659
2016_01 2016_03 2016_05 2016_07 2016_09 2016_11
Months

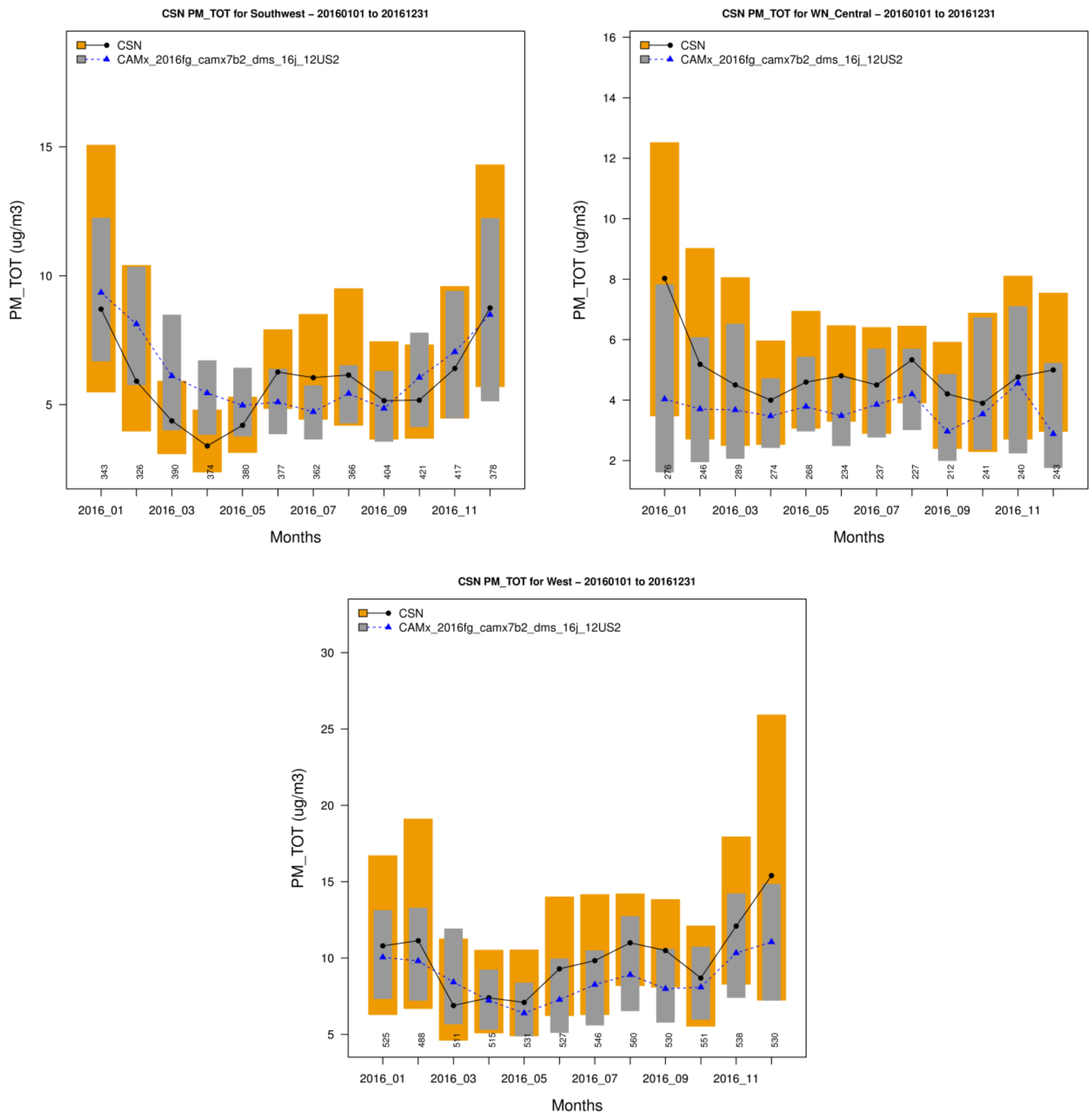
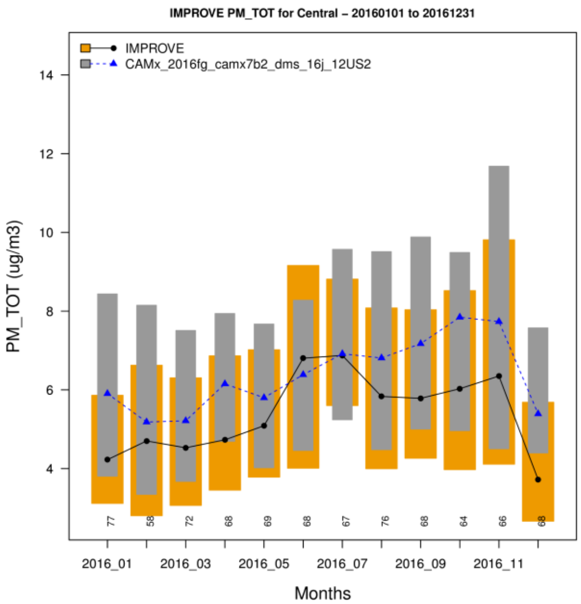
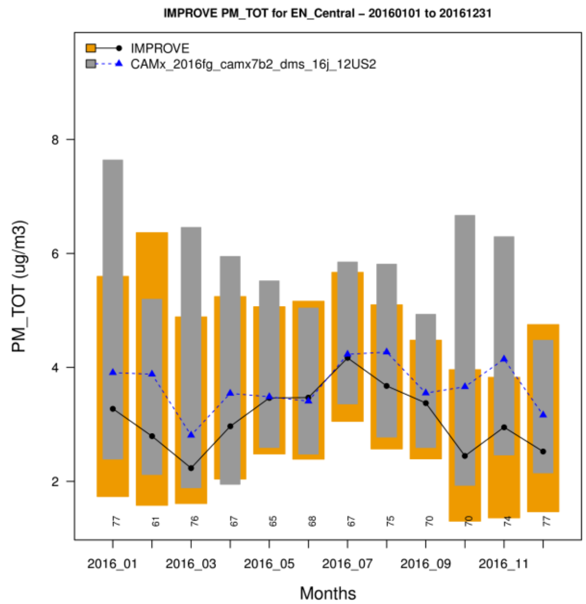
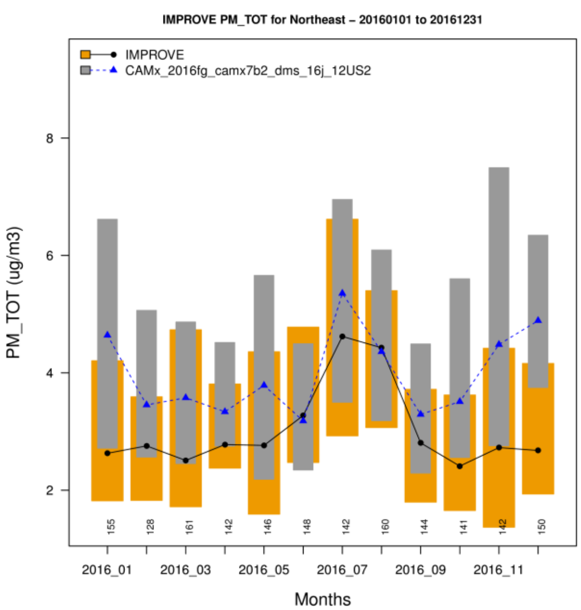
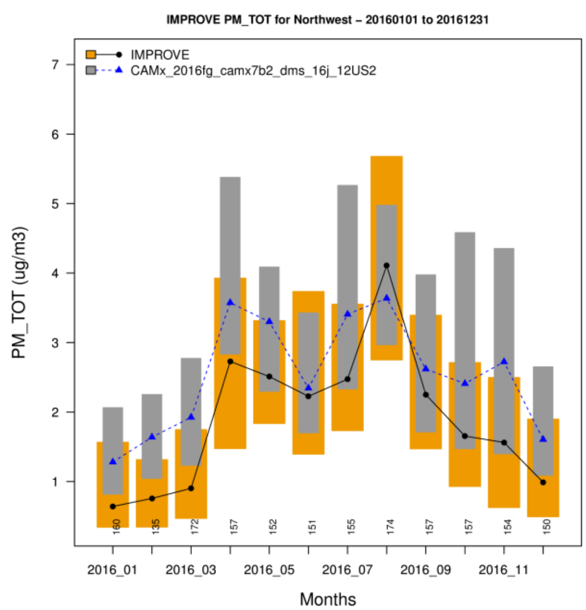


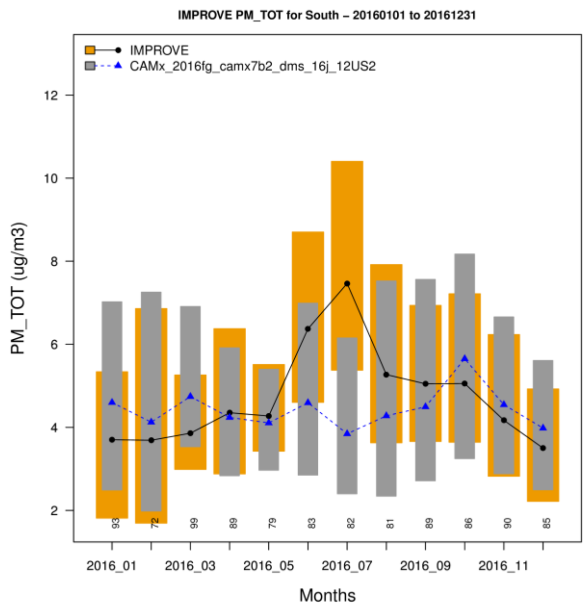
Figure 44. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median CSN Total PM2.5 observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

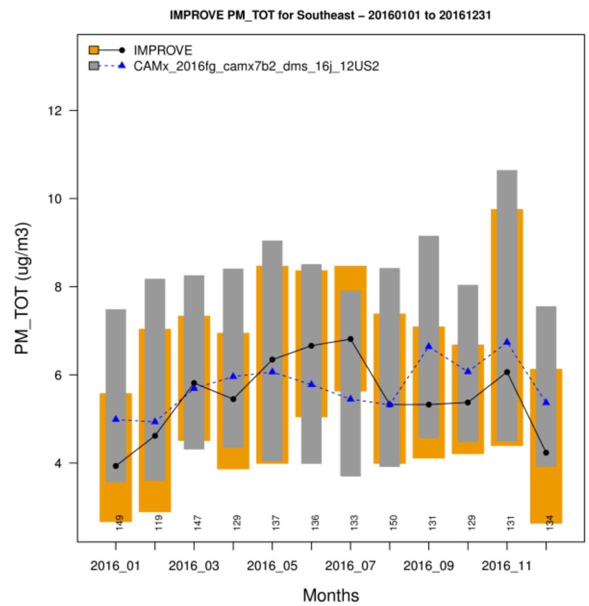

IMPROVE PM_TOT for Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

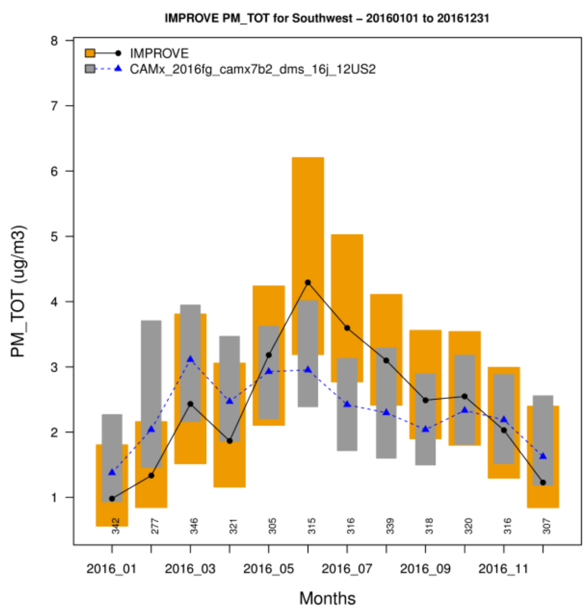

IMPROVE PM_TOT for EN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

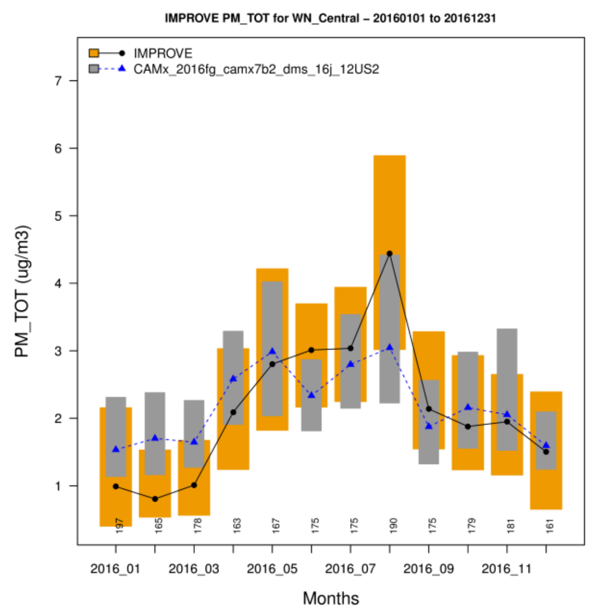

IMPROVE PM_TOT for Northeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE PM_TOT for Northwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE PM_TOT for South – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE PM_TOT for Southeast – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE PM_TOT for Southwest – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


IMPROVE PM_TOT for WN_Central – 20160101 to 20161231
IMPROVE
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

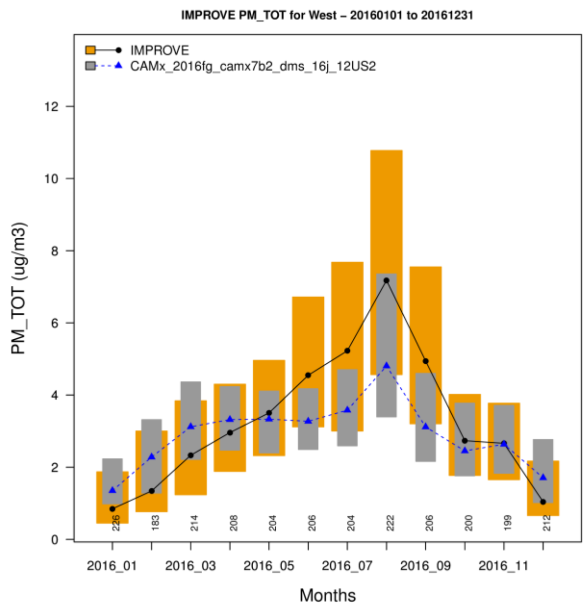
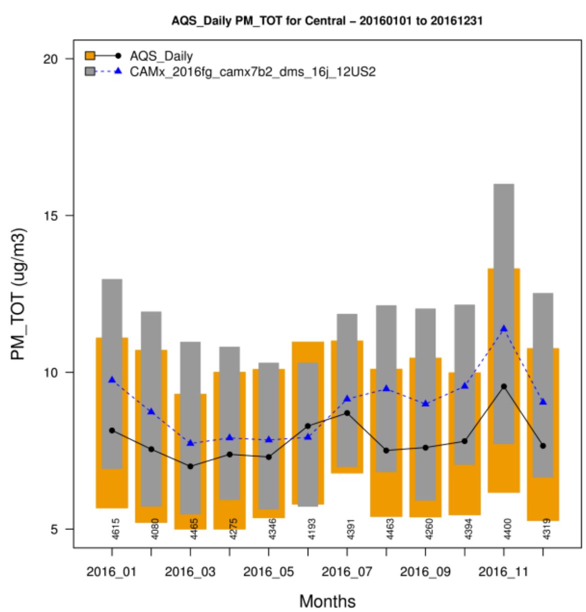
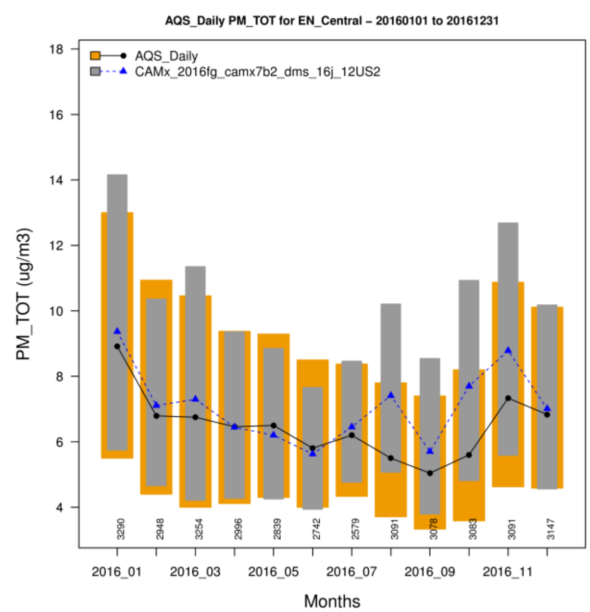
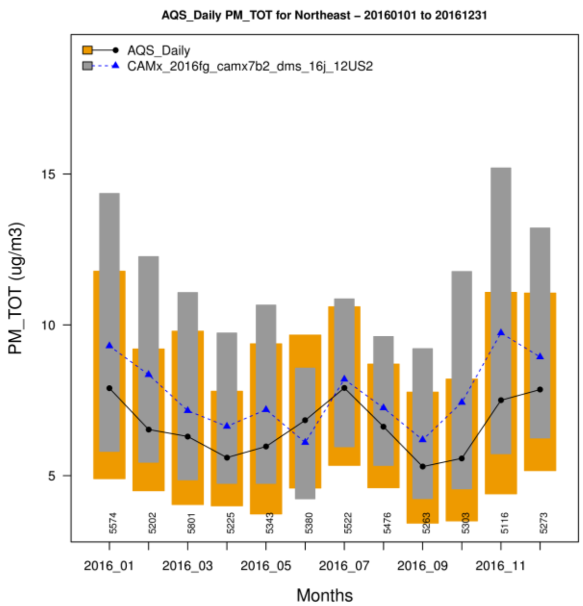
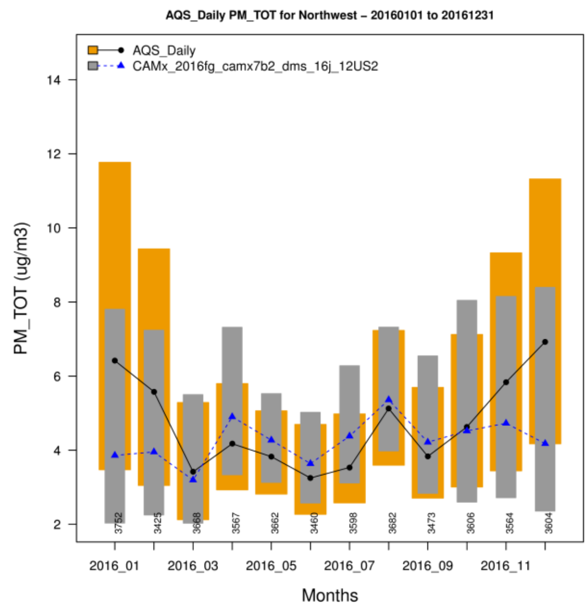


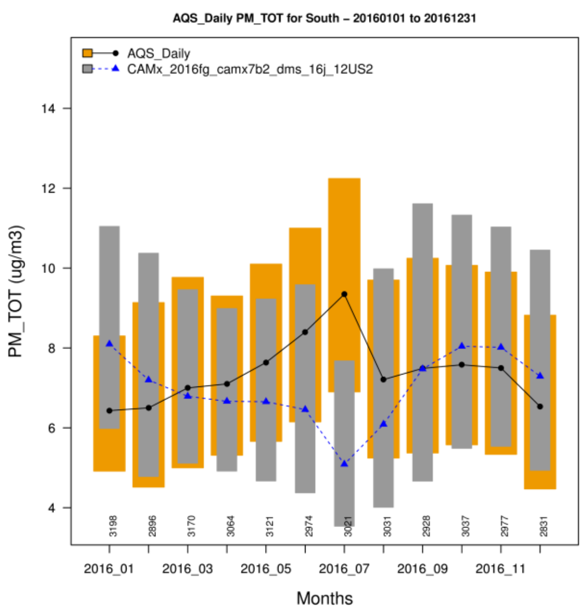
Figure 45. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median IMPROVE Total PM2.5 observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

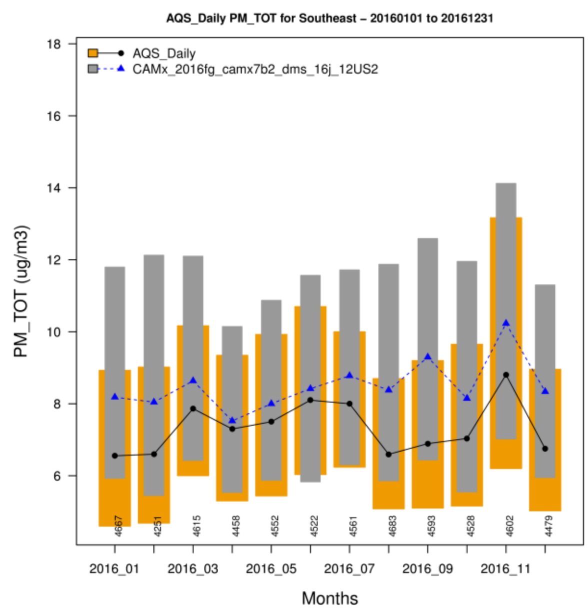





AQS_Daily PM_TOT for Northeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
5574
5202
5801
5225
5343
5380
5522
5476
5263
5303
5116
5273
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


AQS_Daily PM_TOT for Northwest – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
3752
3425
3668
3567
3662
3460
3598
3682
3473
3606
3564
3604
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


AQS_Daily PM_TOT for South – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
3198
2896
3170
3064
3121
2974
3021
3031
2928
3037
2977
2831
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11


AQS_Daily PM_TOT for Southeast – 20160101 to 20161231
AQS_Daily
CAMx_2016fg_camx7b2_dms_16j_12US2
PM_TOT (ug/m3)
Months
4667
4251
4615
4458
4552
4522
4561
4683
4593
4528
4602
4479
2016_01
2016_03
2016_05
2016_07
2016_09
2016_11

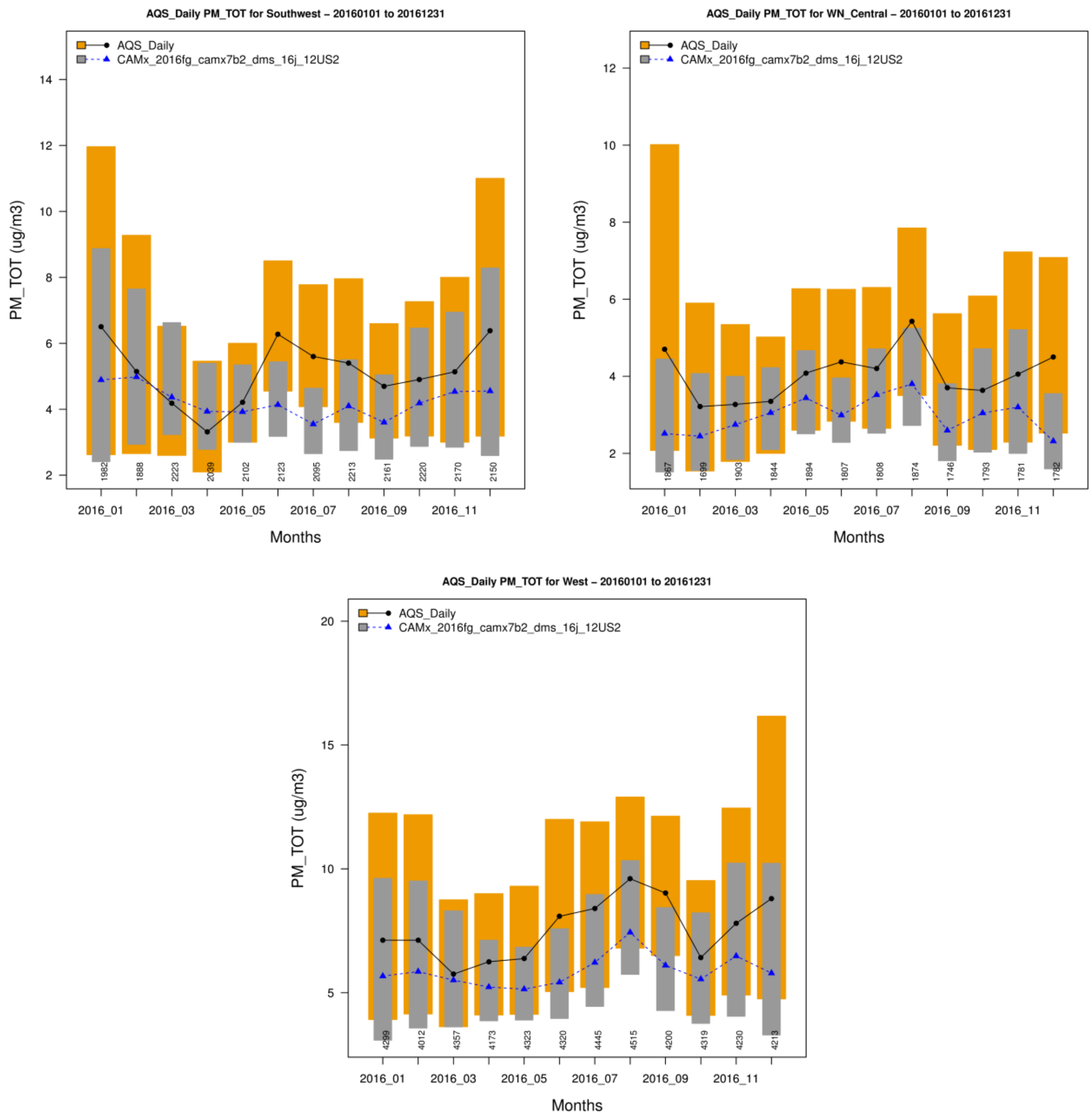


Figure 46. Boxplot comparisons of median model predictions (blue triangles) with a 25-75% interquartile range (gray boxes) and median AQS_Daily Total PM2.5 observations (black circles) with a 25-75% interquartile range (orange boxes) for each climate region by month.

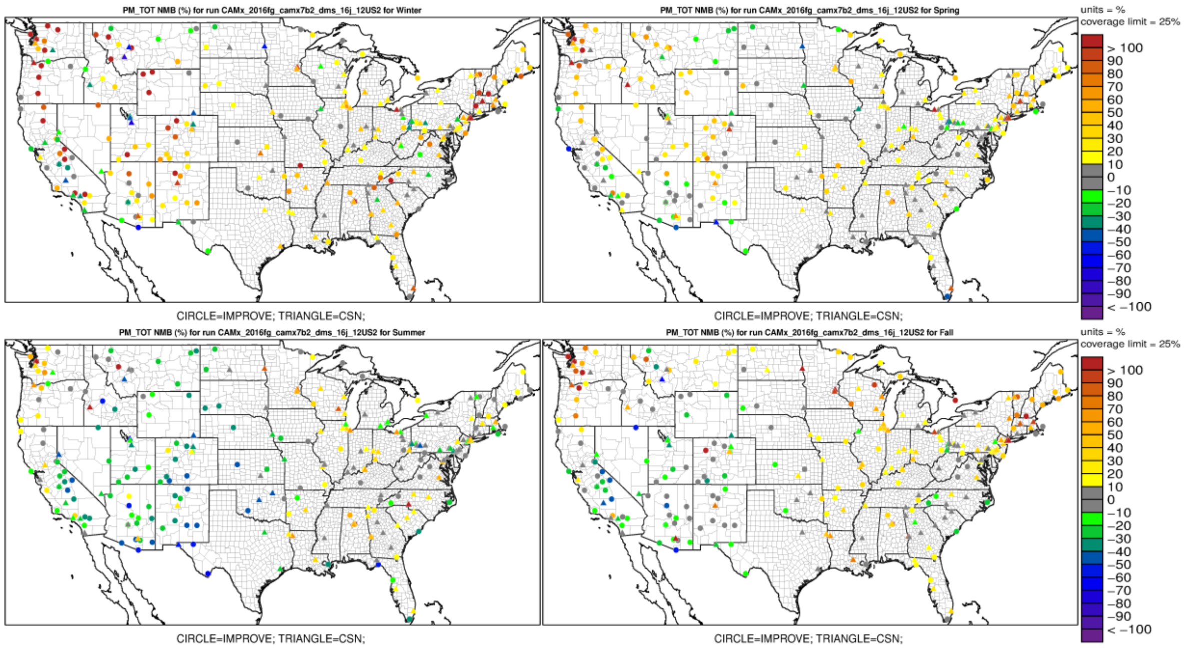


Figure 47. Spatial plot of Total PM2.5 NMB (%) by season and network.

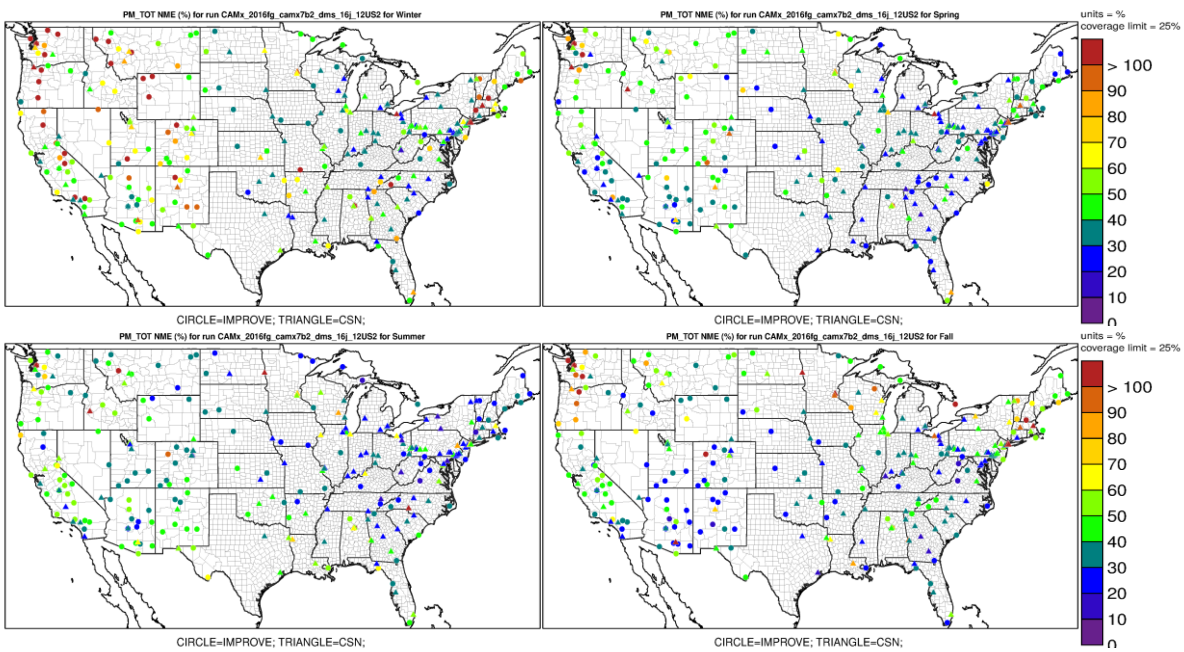


Figure 48. Spatial plot of Total PM2.5 NME (%) by season and network.

10. Performance on 20% Most-Impaired Days

Spatial plots summarizing IMPROVE observations and model NMB on the 20% most-impaired days are shown in Figures 49 through 54. The top map in each figure is the absolute modeled concentration averaged over the 20% most impaired days (based on 2016 ambient data). The bottom map in each figure is the normalized mean bias for the 20% most impaired days.

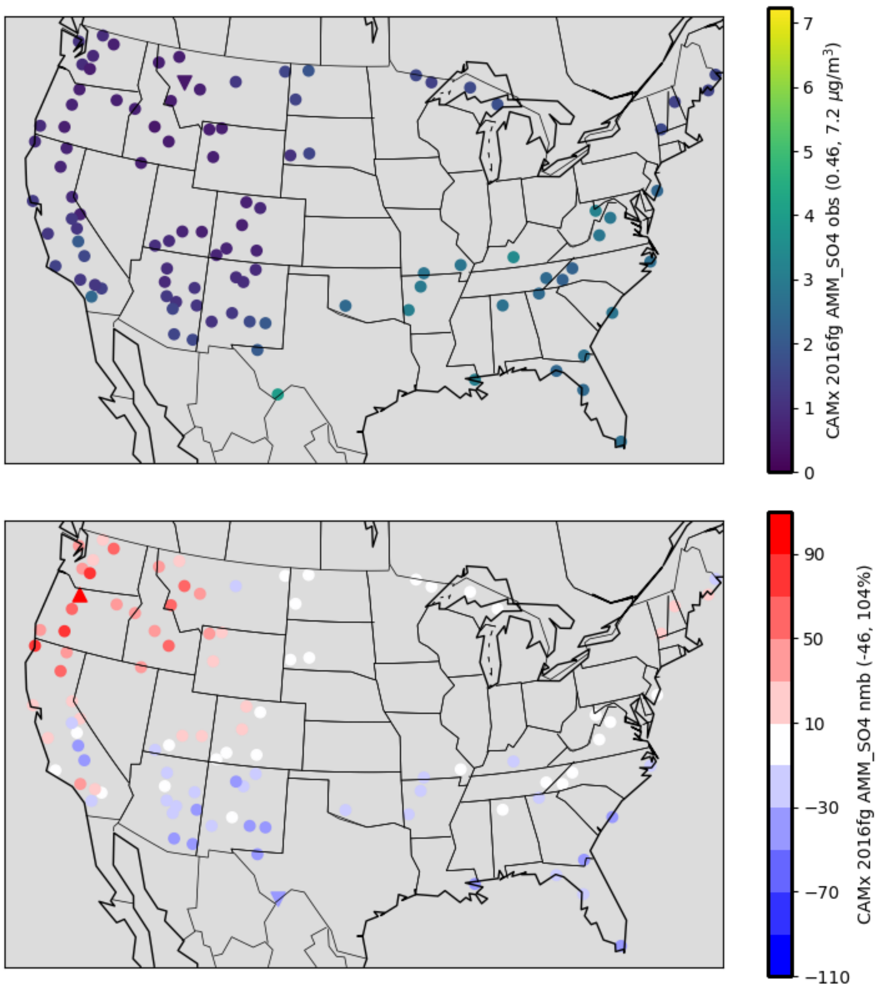


Figure 49. Observed Ammonium sulfate (top) and modeled NMB (bottom) for the 20% most-impaired days at IMPROVE monitor locations.

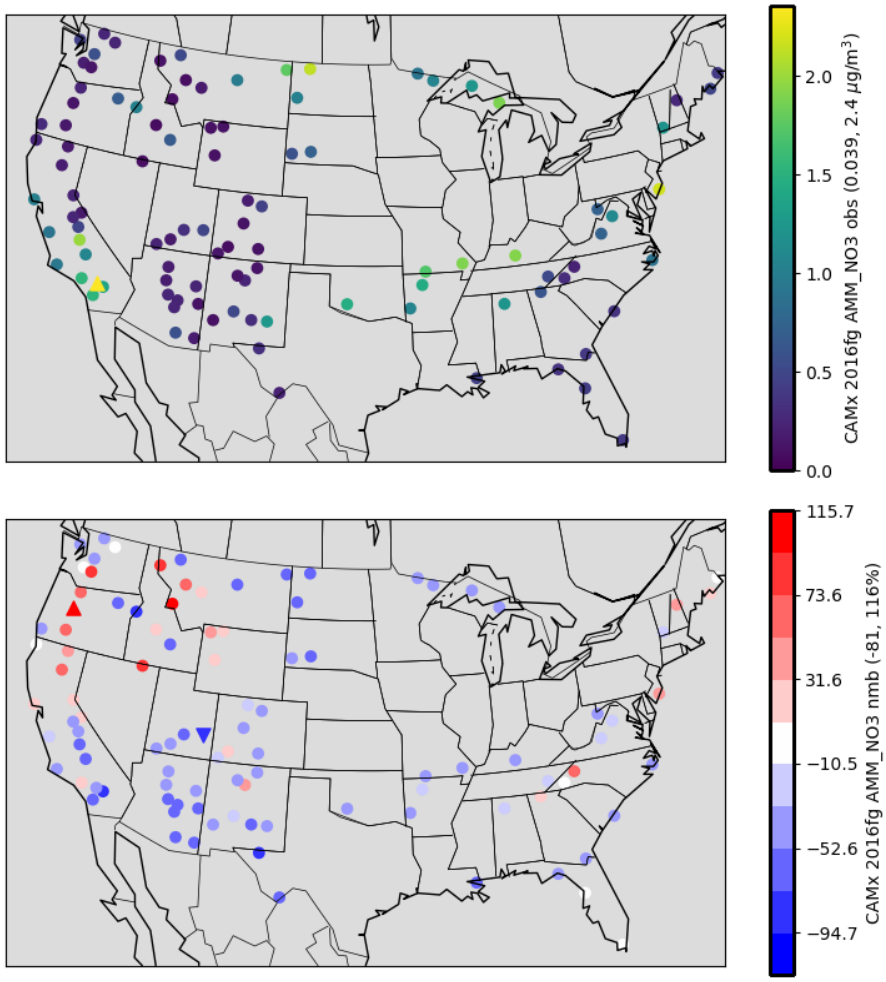


Figure 50. Observed Ammonium nitrate (top) and modeled NMB (bottom) for the 20% most-impaired days at IMPROVE monitor locations.

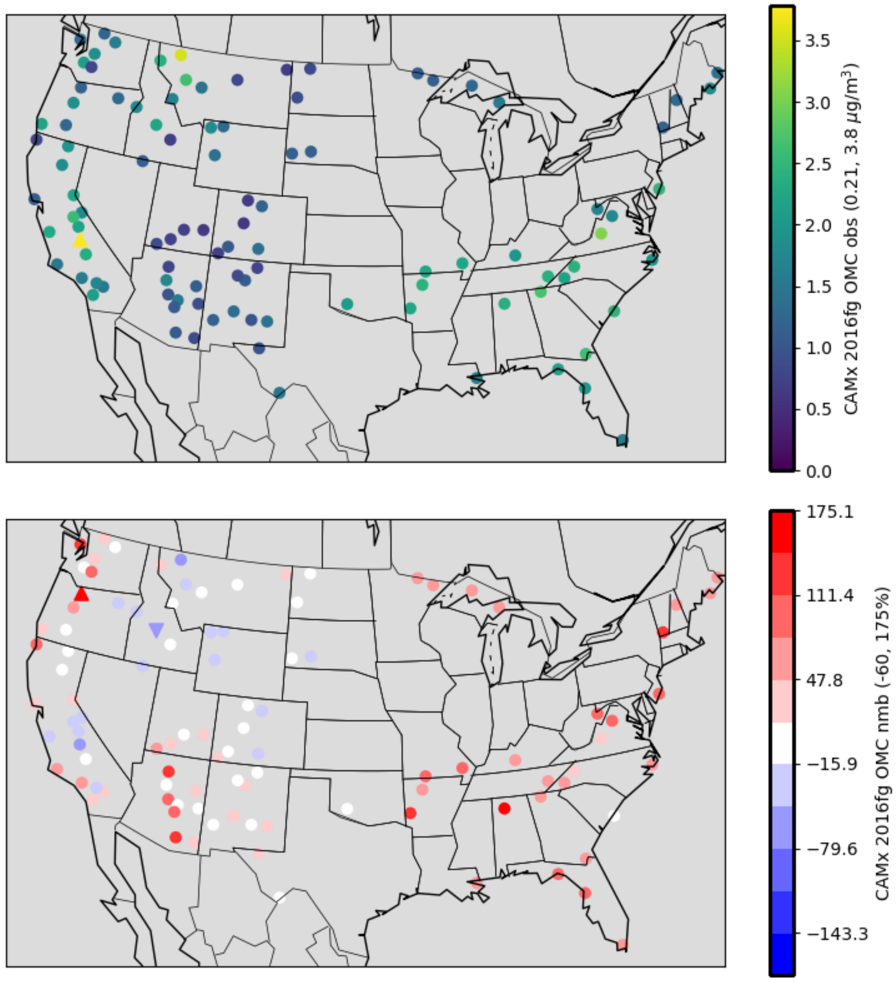


Figure 51. Observed OC (top) and modeled NMB (bottom) for the 20% most-impaired days at IMPROVE monitor locations.

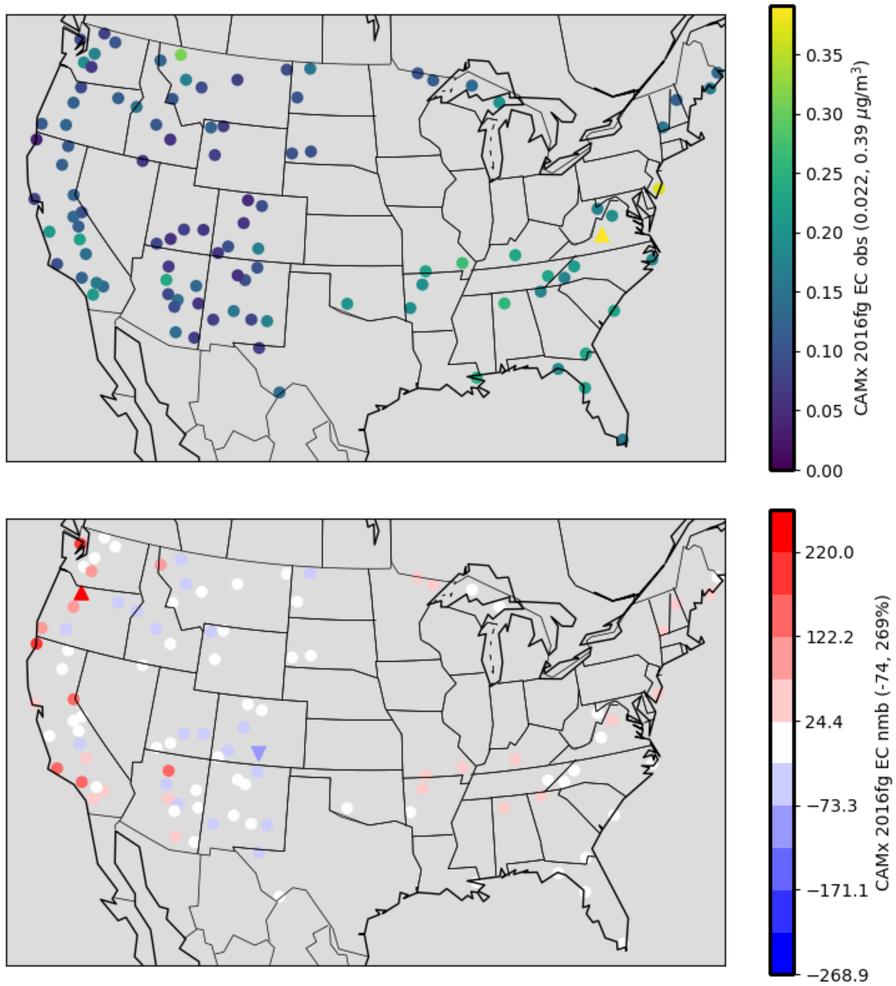


Figure 52. Observed PM2.5 EC (top) and modeled NMB (bottom) for the 20% most-impaired days at IMPROVE monitor locations.

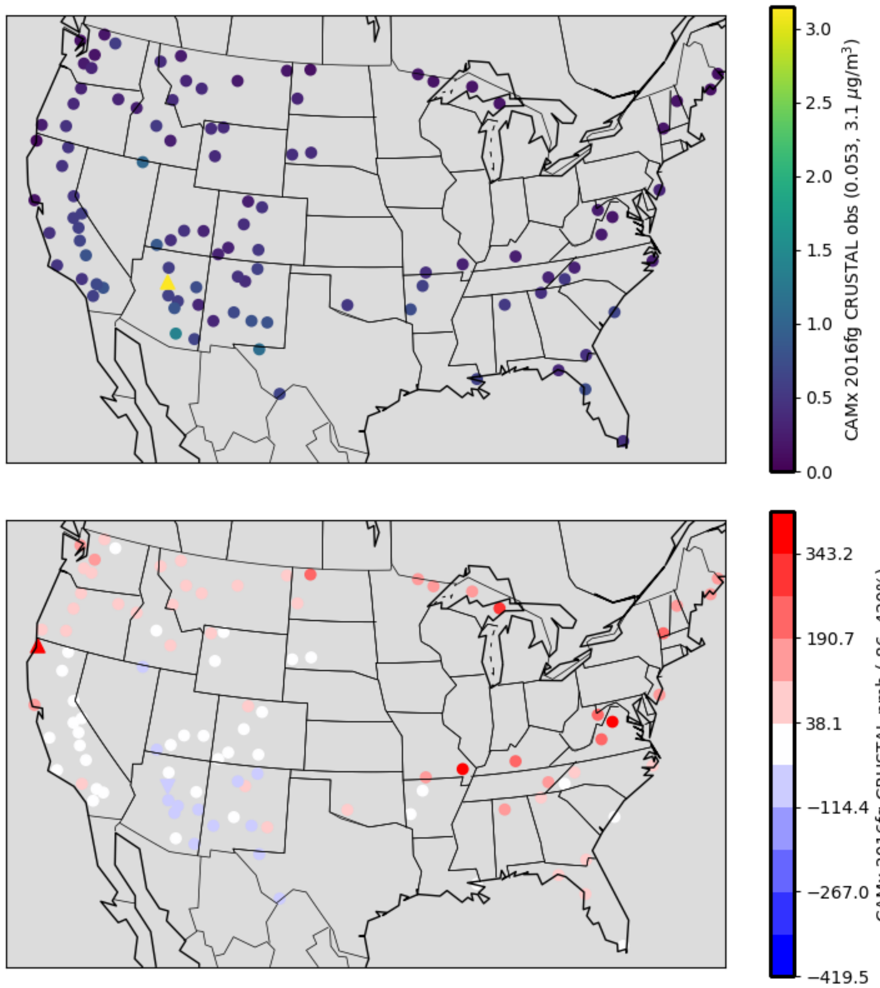


Figure 53. Observed Crustal PM2.5 (top) and modeled NMB (bottom) for the 20% most-impaired days at IMPROVE monitor locations.

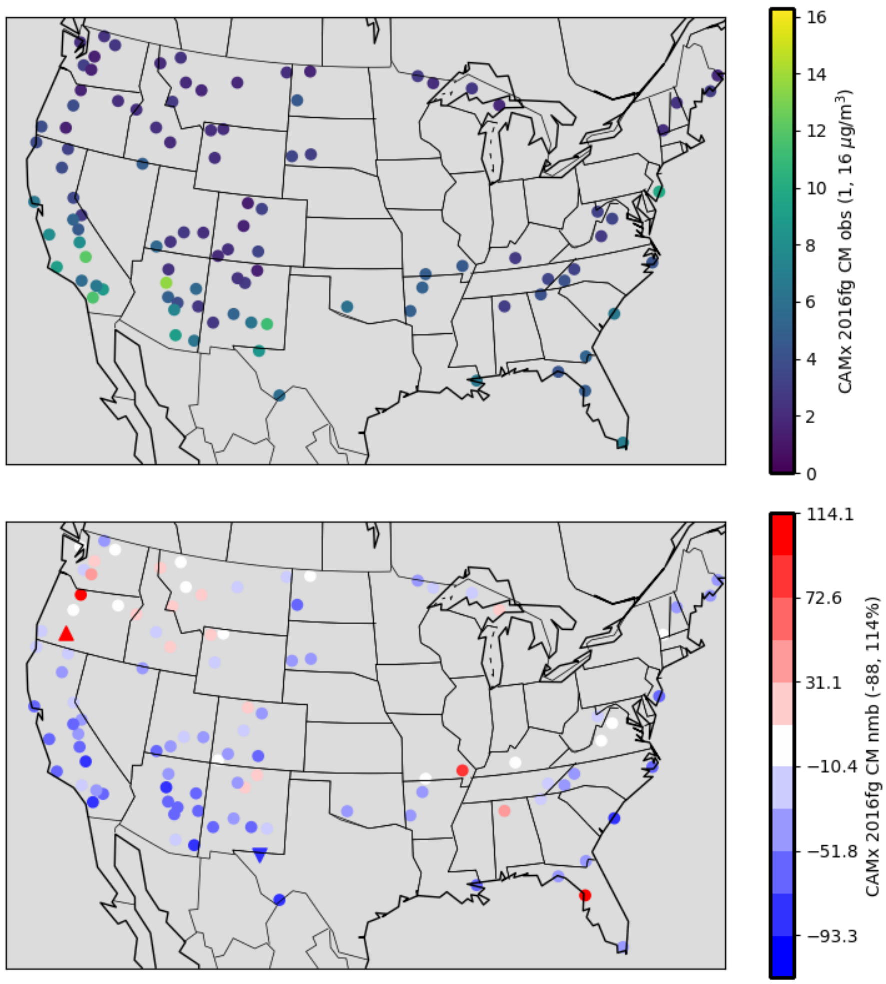


Figure 54. Observed Coarse PM (top) and modeled NMB (bottom) for the 20% most-impaired days at IMPROVE monitor locations.

11. PM2.5 Composition and Contributions to Light Extinction

Figures 55 – 157 display stacked bar charts detailing the composition of $PM_{2.5}$ on the 20% most impaired and clearest days for both modeled and observed concentration (µg/m3) and light extinction ($bext^{-1}$) at each IMPROVE monitoring site. The plots on the left display the amount of total particle mass using concentrations of coarse mass, crustal (soil), ammonium nitrate (NO3), ammonium sulfate (SO4), elemental carbon (EC), organic mass carbon (OMC), and sea salt. The amount of light extinction due to each aforementioned species is displayed in the rightmost plot. Rayleigh scattering in the extinction plots is site specific Rayleigh scattering for that site, which does not vary by day (not modeled or observed).

Northwest

- Mount Rainier National Park (WA)(MORA1)
- Glacier Peak Wilderness (WA) and North Cascades National Park (WA)(NOCA1)
- Olympic National Park (WA)(OLYM1)
- Pasayten Wilderness (WA)(PASA1)
- Alpine Lake Wilderness (WA)(SNPA1)
- Goat Rocks Wilderness (WA) and Mount Adams Wilderness (WA)(WHPA1)

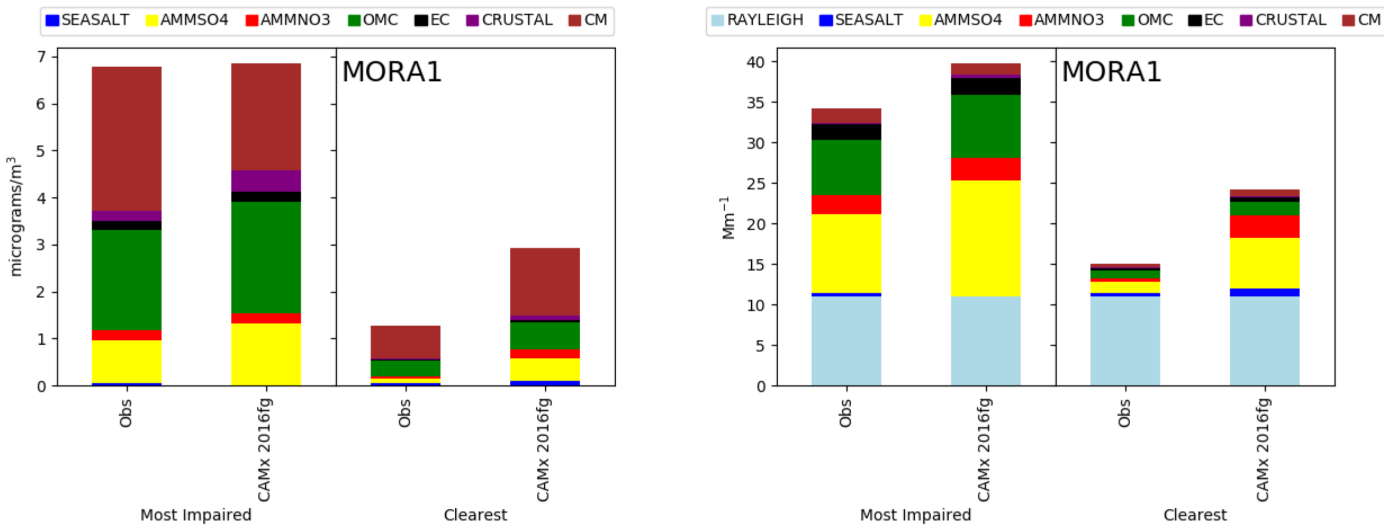


Figure 55. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mount Rainier National Park (WA) on the observed 20% most impaired and observed 20% clearest days.

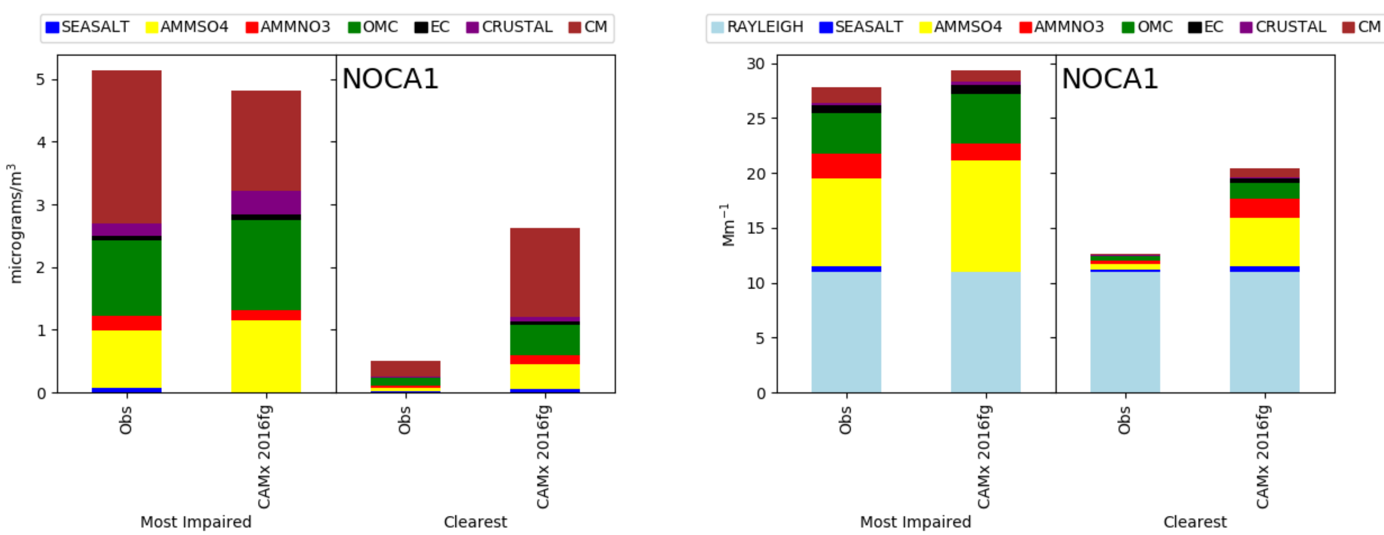
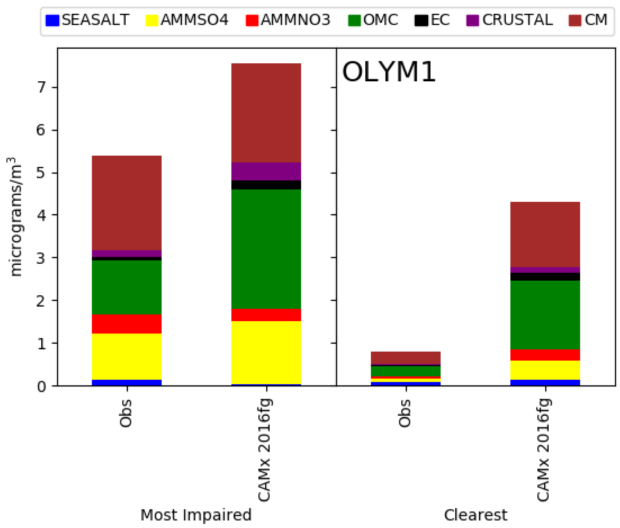


Figure 56. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Glacier Peak Wilderness (WA) and North Cascades National Park (WA) on the observed 20% most impaired and observed 20% clearest days.



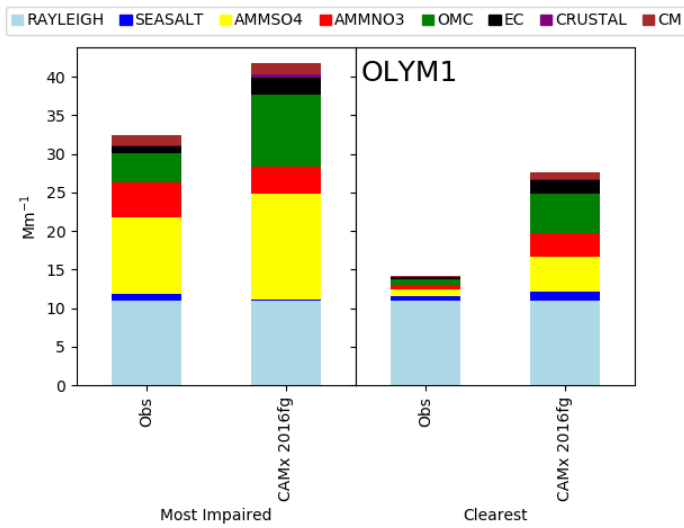
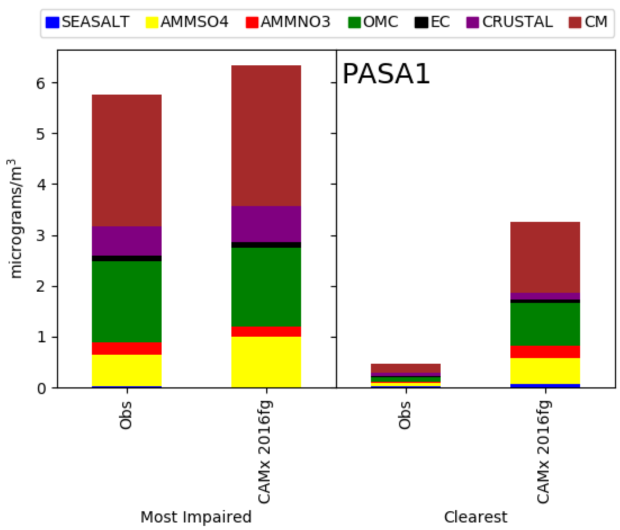


Figure 57. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Olympic National Park (WA) on the observed 20% most impaired and observed 20% clearest days.



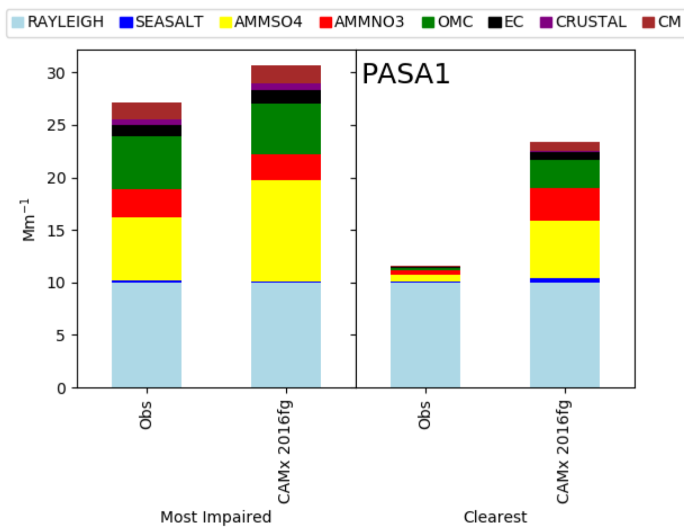


Figure 58. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Pasayten Wilderness (WA) on the observed 20% most impaired and observed 20% clearest days.

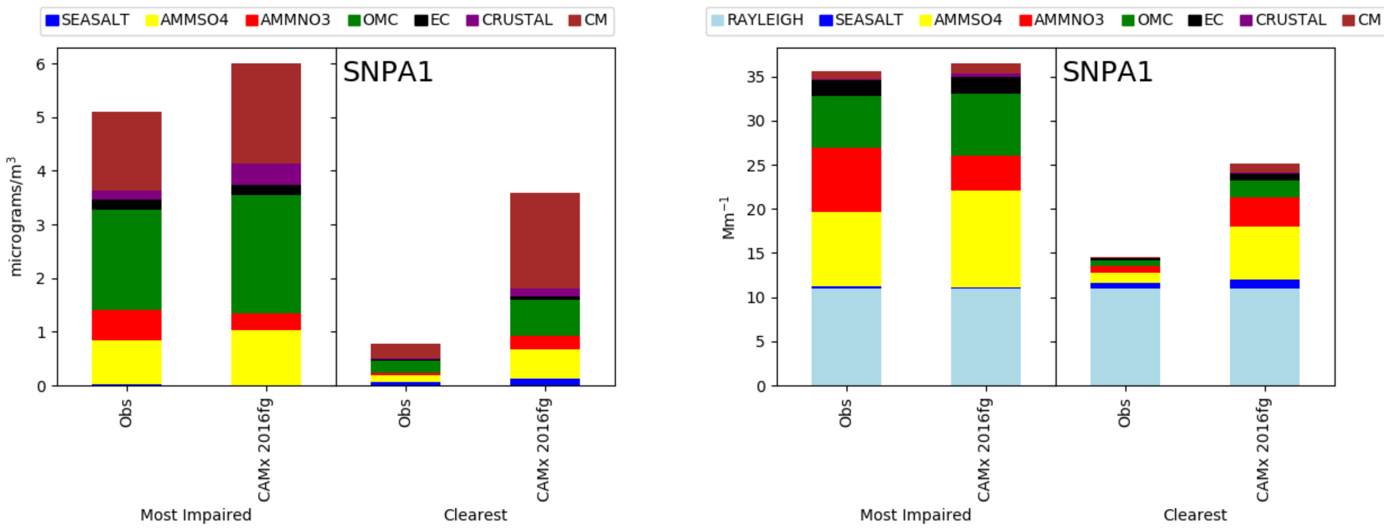


Figure 59. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Alpine Lake Wilderness (WA) on the observed 20% most impaired and observed 20% clearest days.

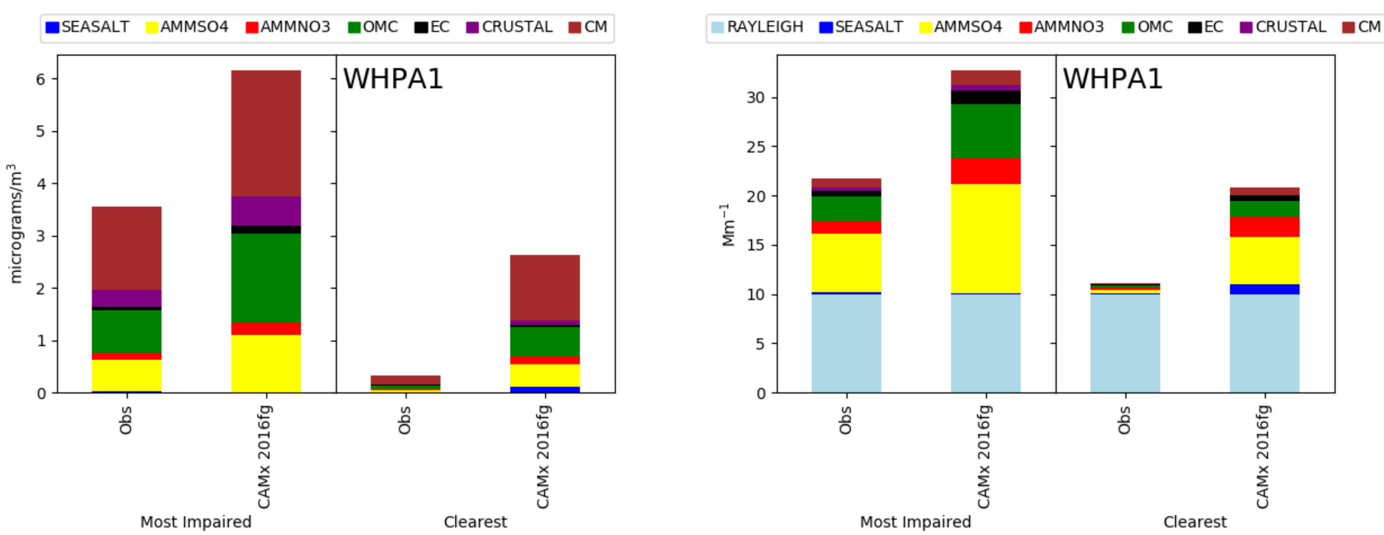


Figure 60. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Goat Rocks Wilderness (WA) and Mount Adams Wilderness (WA) on the observed 20% most impaired and observed 20% clearest days.

Oregon and Northern California

- Desolation Wilderness (CA) and Mokelumne Wilderness (CA)(BLIS1)
- Crater Lake National Park (OR), Diamond Peak Wilderness (OR), Gearhart Mountain Wilderness (OR), and Mountain Lakes Wilderness (OR)(CRLA1)
- Kalmiopsis Wilderness (OR)(KALM1)
- Lava Beds National Monument (CA) and South Warner Wilderness (CA)(LABE1)
- Caribou Wilderness (CA), Lassen Volcanic National Park (CA), and Thousand Lakes Wilderness (CA)(LAVO1)
- Mount Hood Wilderness (OR)(MOHO1)
- Redwood National Park (CA)(REDW1)
- Mount Jefferson Wilderness (OR), Mount Washington Wilderness (OR), and Three Sisters Wilderness (OR)(THSI1)

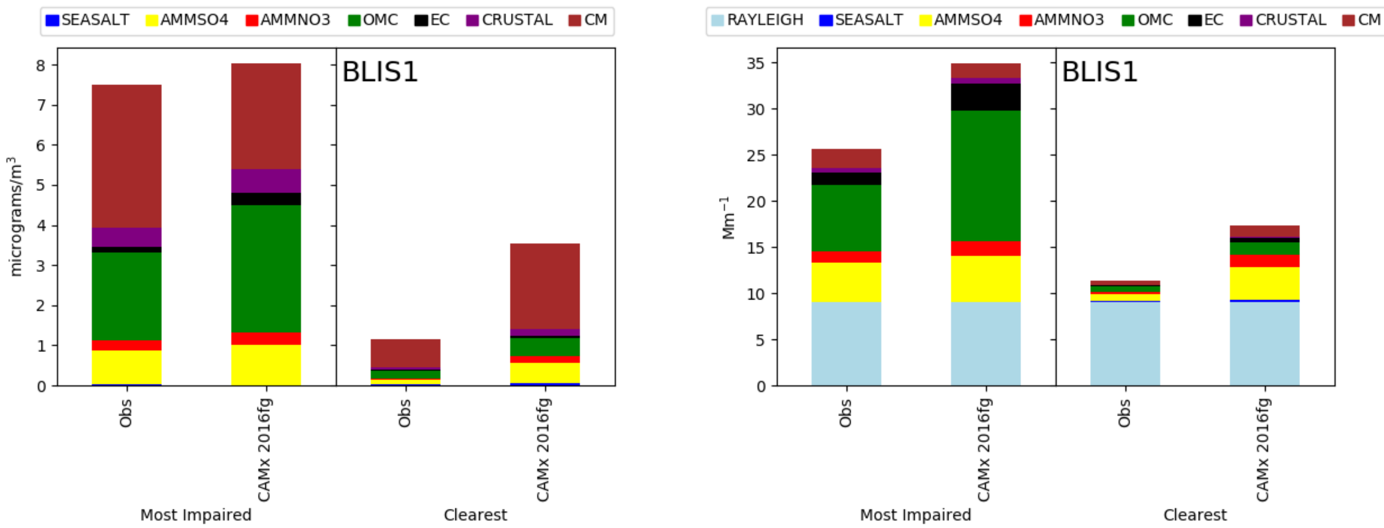


Figure 61. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Desolation Wilderness (CA) and Mokelumne Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

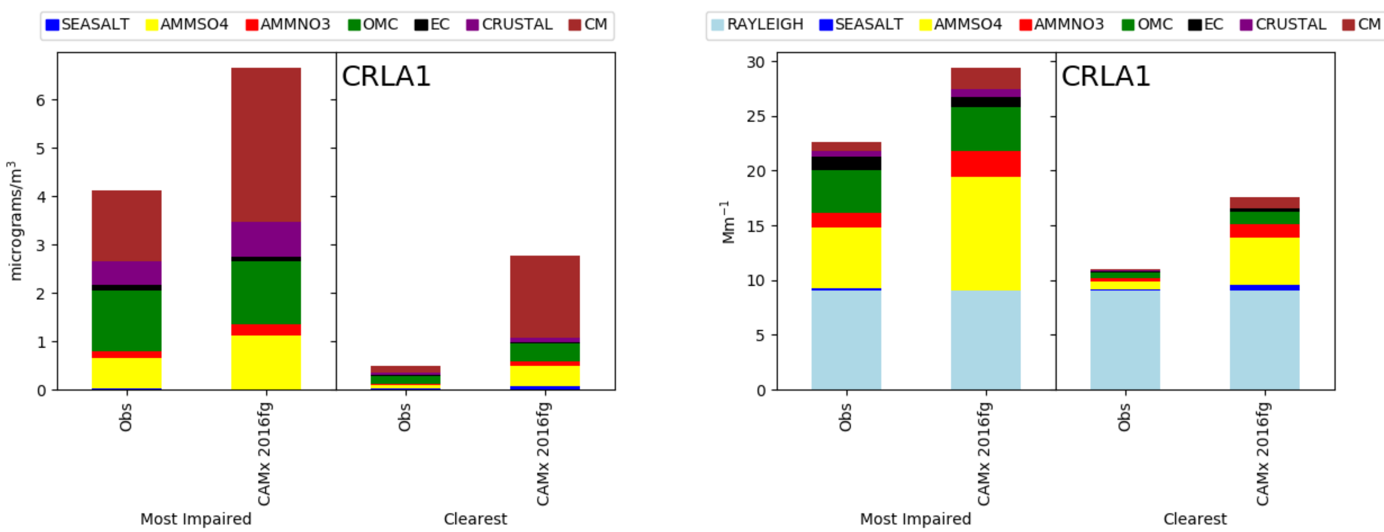


Figure 62. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Crater Lake National Park (OR), Diamond Peak Wilderness (OR), Gearhart Mountain Wilderness (OR), and Mountain Lakes Wilderness (OR) on the observed 20% most impaired and observed 20% clearest days.

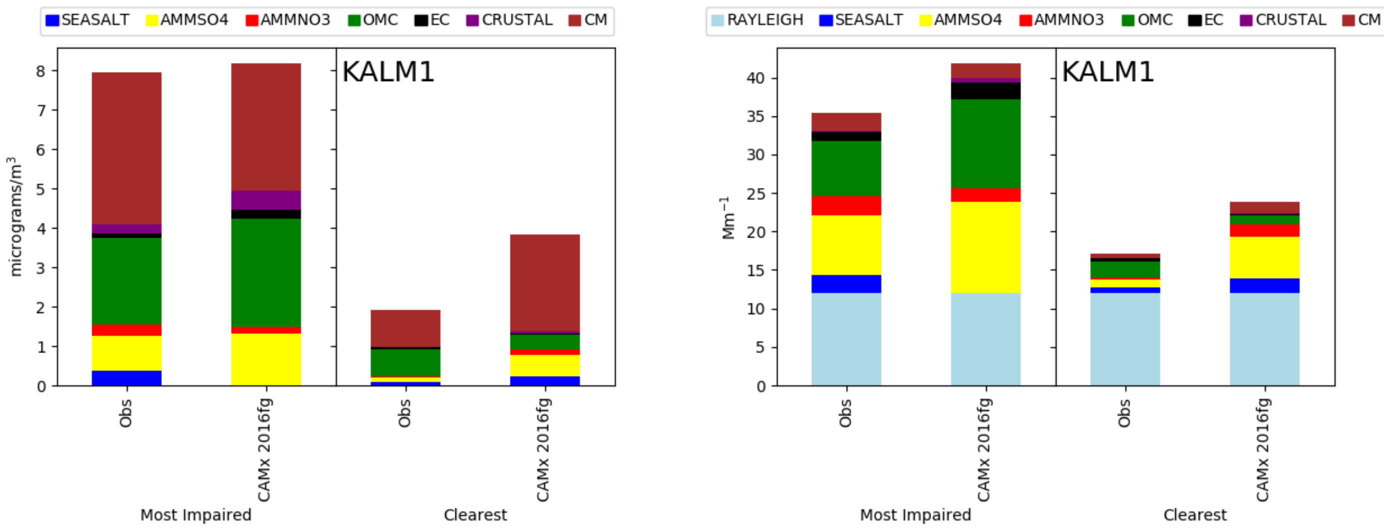


Figure 63. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Kalmiopsis Wilderness (OR) on the observed 20% most impaired and observed 20% clearest days.

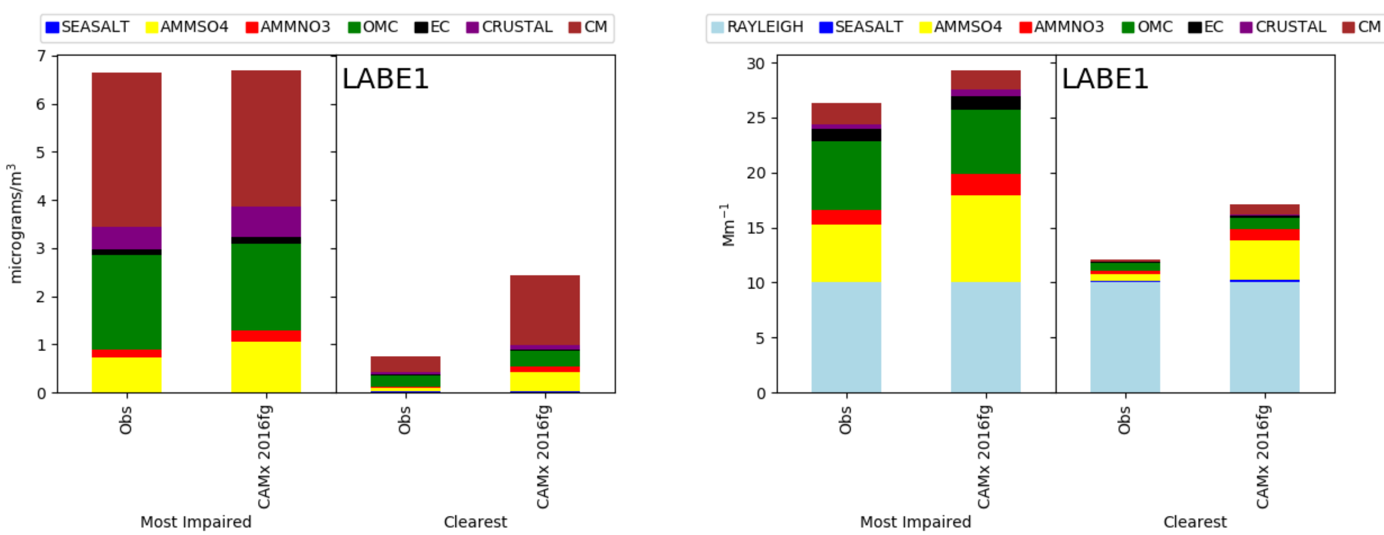


Figure 64. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Lava Beds National Monument (CA) and South Warner Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

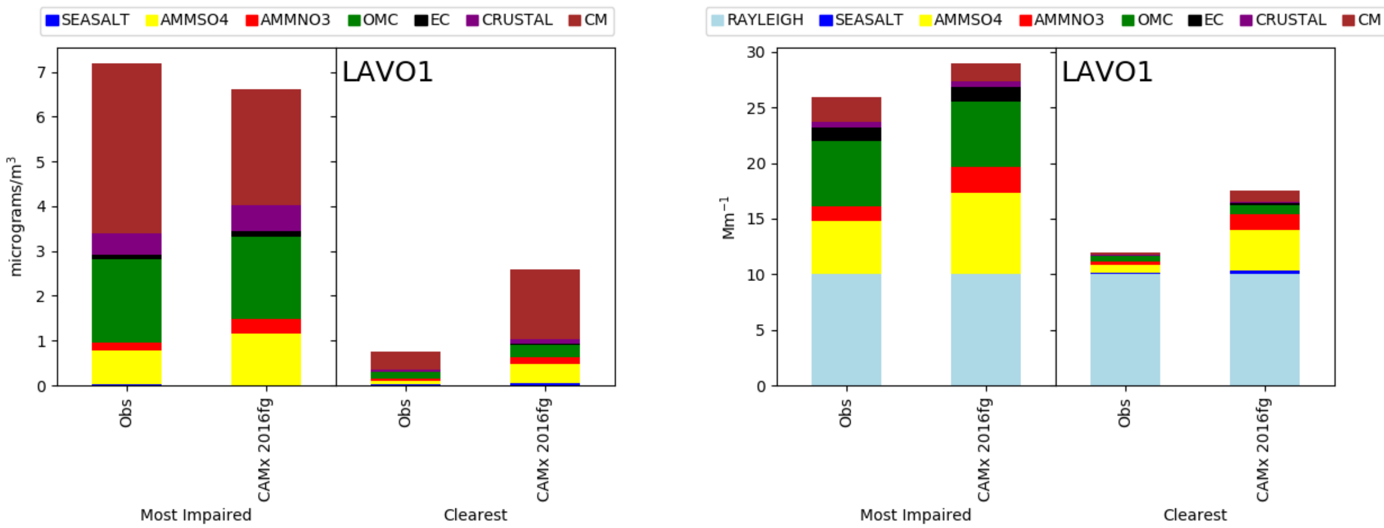


Figure 65. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Caribou Wilderness (CA), Lassen Volcanic National Park (CA), and Thousand Lakes Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

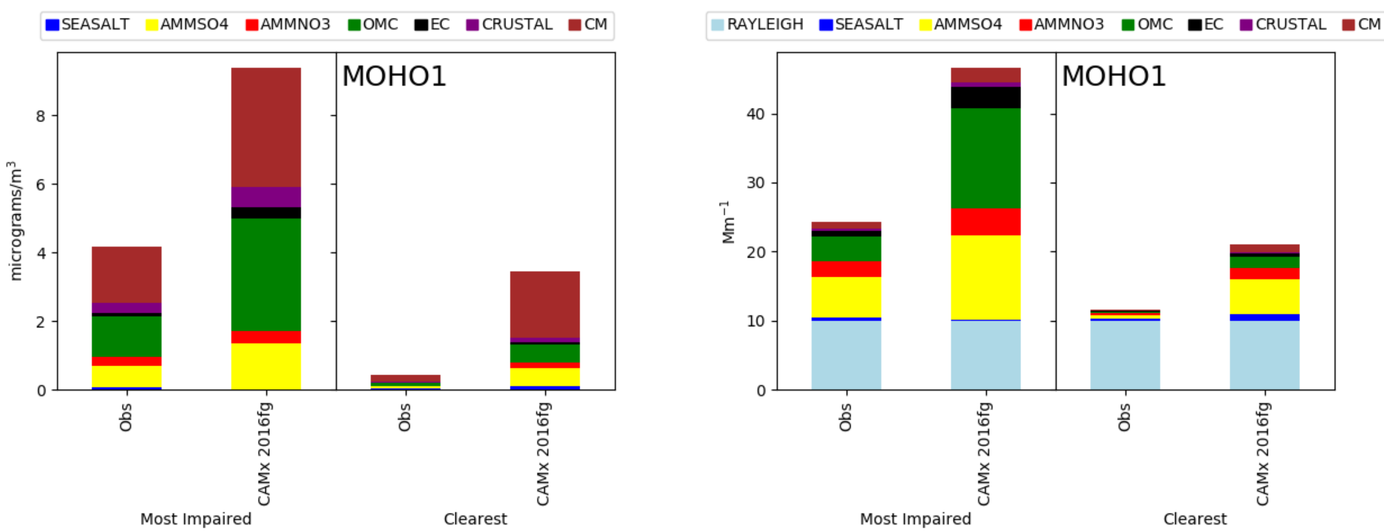


Figure 66. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mount Hood Wilderness (OR) on the observed 20% most impaired and observed 20% clearest days.

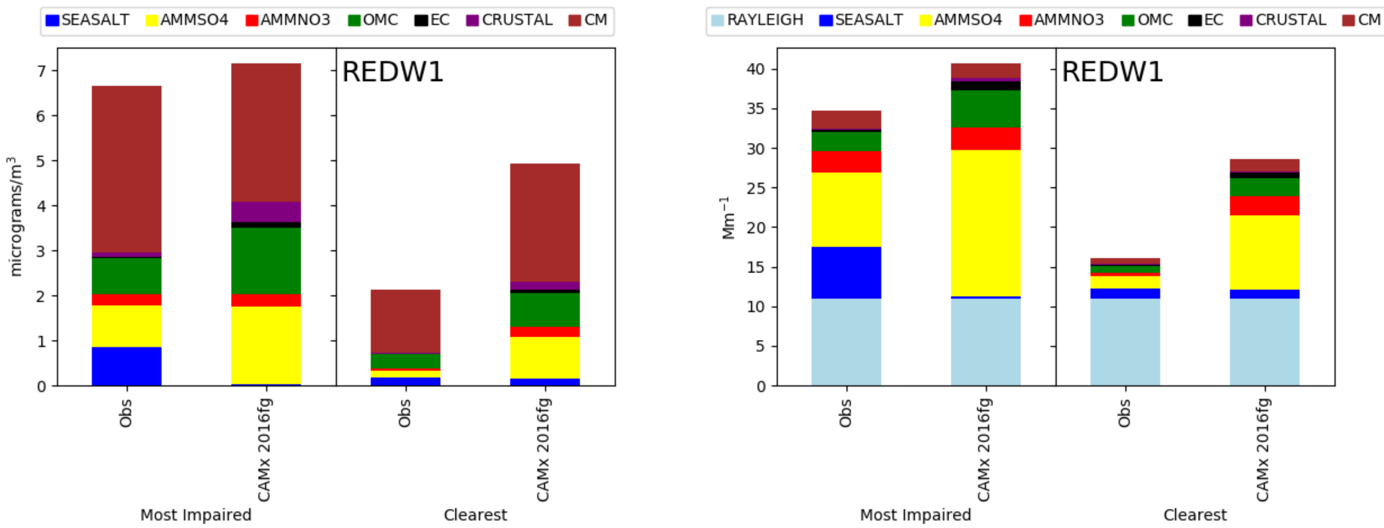


Figure 67. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Redwood National Park (CA) on the observed 20% most impaired and observed 20% clearest days.

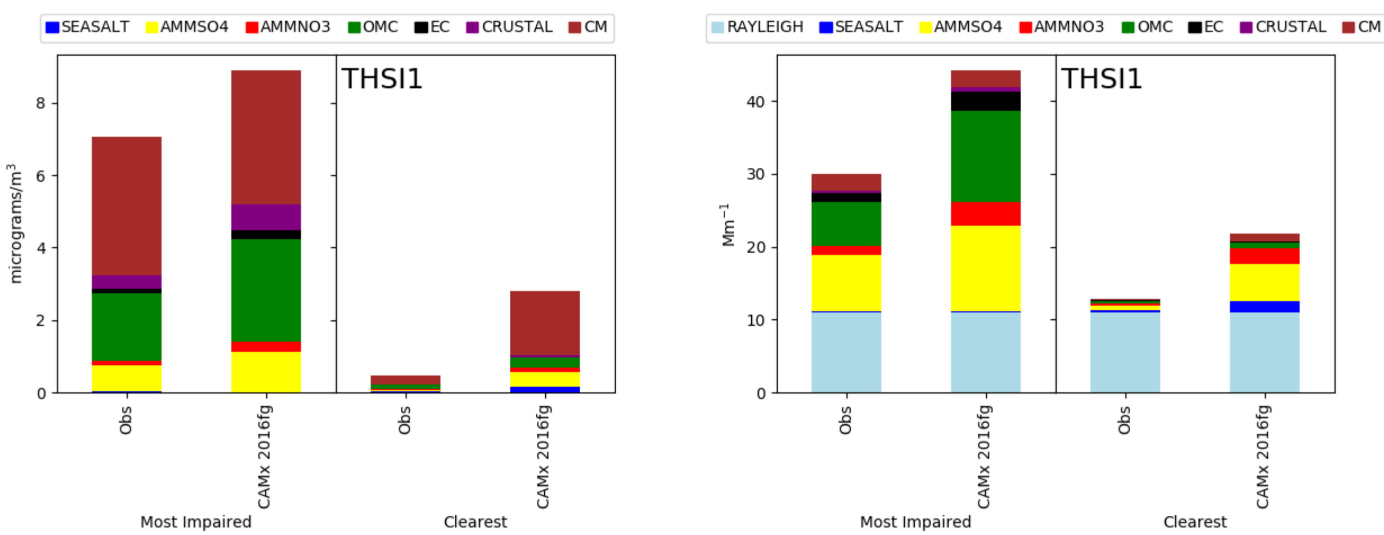


Figure 68. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mount Jefferson Wilderness (OR), Mount Washington Wilderness (OR), and Three Sisters Wilderness (OR) on the observed 20% most impaired and observed 20% clearest days.

California Coast

- Pinnacles National Monument (CA) and Ventana Wilderness (CA)(PINN1)
- Point Reyes NS (CA)(PORE1)
- San Rafael Wilderness (CA)(RAFA1)

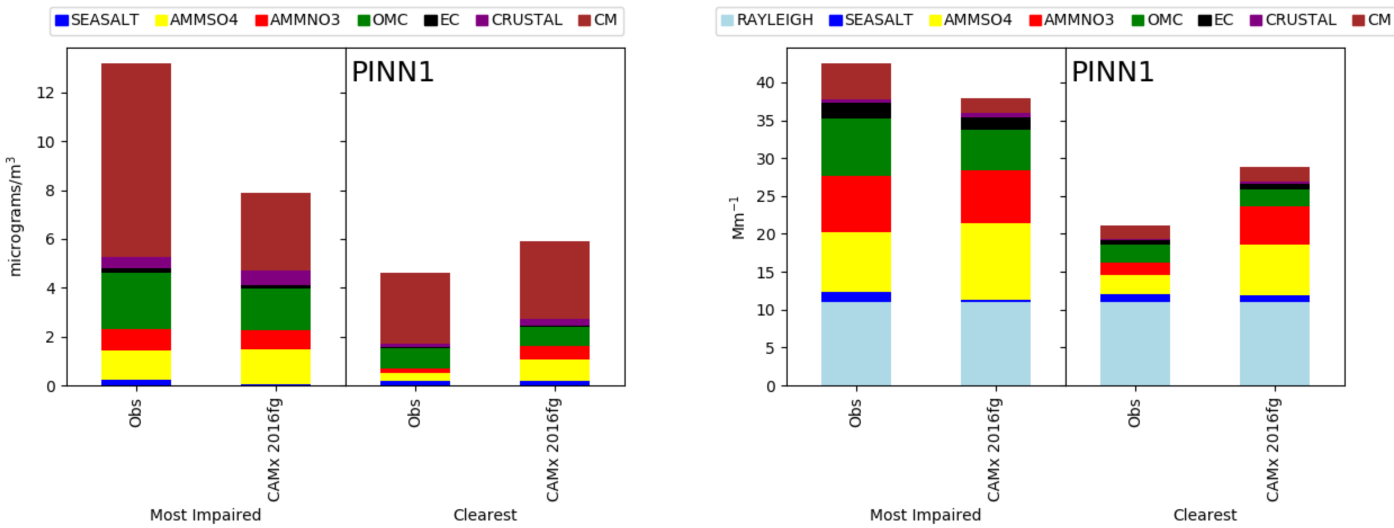


Figure 69. Observed (Obs) and predicted (CAMx) concentrations (µg/m³) on left and extinctions (MM⁻¹) on right at the Pinnacles National Monument (CA) and Ventana Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

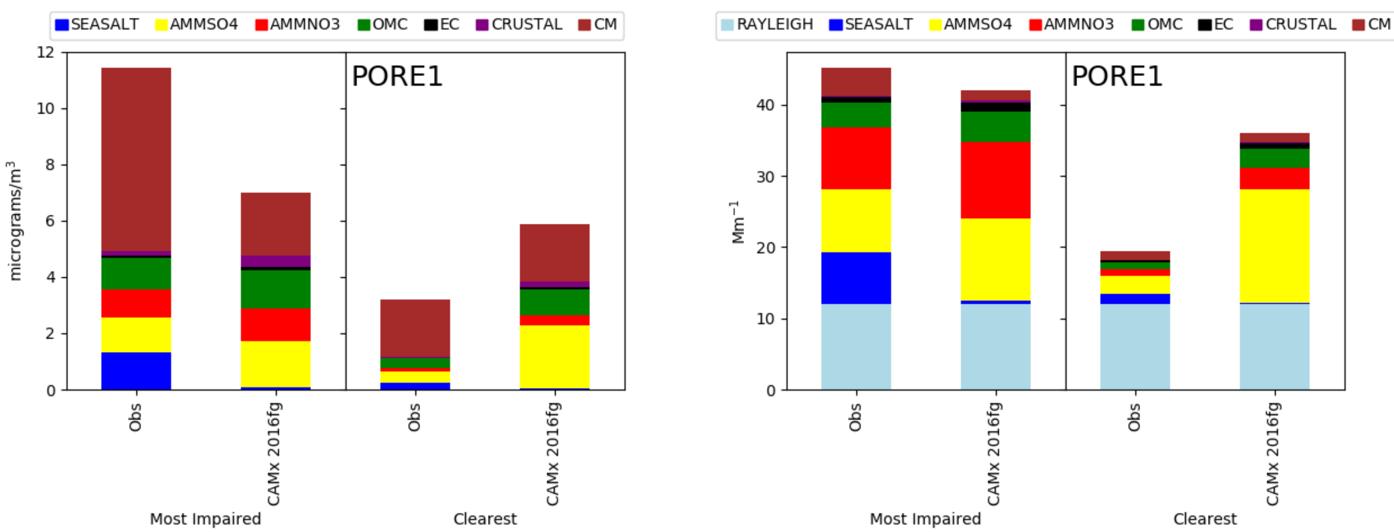


Figure 70. Observed (Obs) and predicted (CAMx) concentrations (µg/m³) on left and extinctions (MM⁻¹) on right at the Point Reyes NS (CA) on the observed 20% most impaired and observed 20% clearest days.

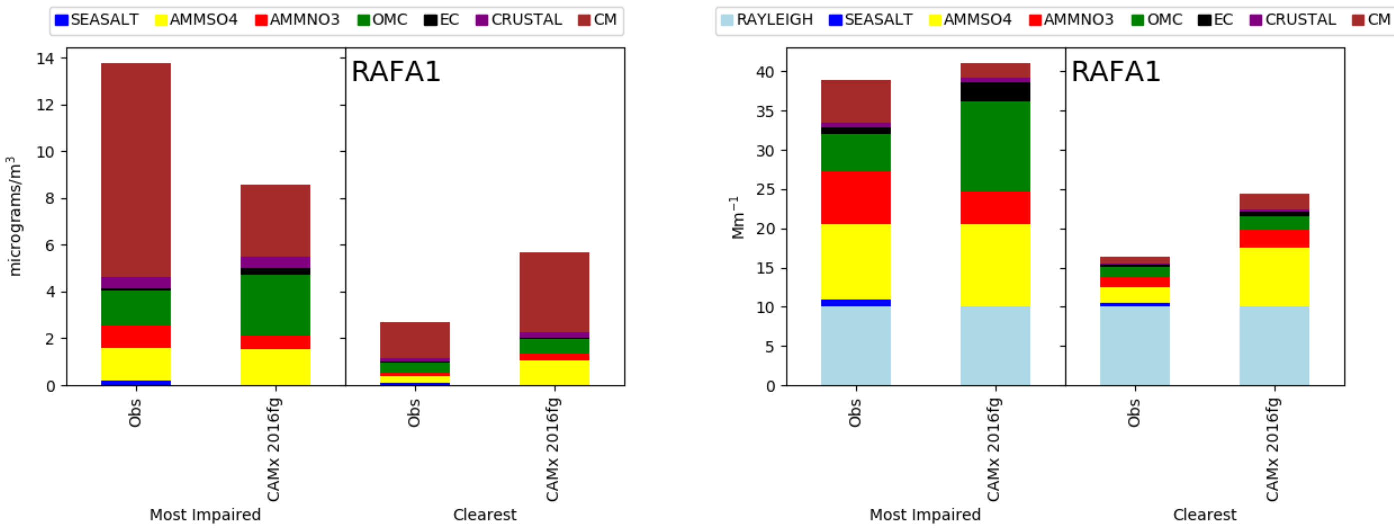


Figure 71. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the San Rafael Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

Sierra Nevada

- Dome Land Wilderness (CA)(DOME1)
- Hoover Wilderness (CA)(HOOV1)
- Ansel Adams Wilderness (Minarets) (CA), John Muir Wilderness (CA), and Kaiser Wilderness (CA)(KAIS1)
- Kings Canyon National Park (CA) and Sequoia National Park (CA)(SEQU1)
- Emigrant Wilderness (CA) and Yosemite National Park (CA)(YOSE1)

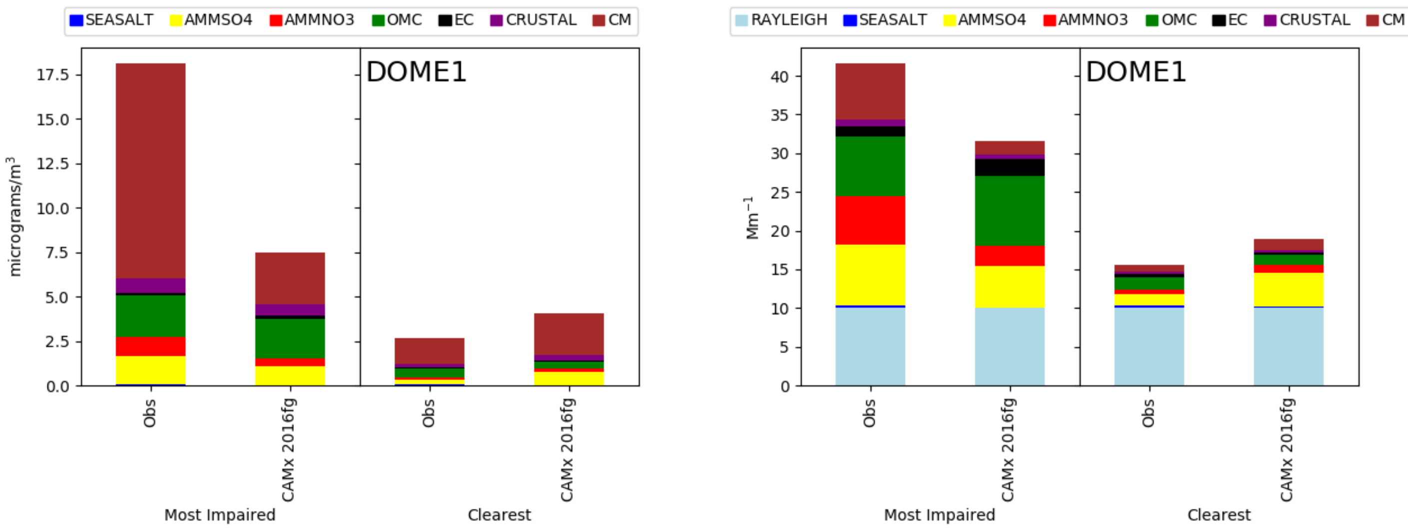


Figure 72. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Dome Land Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

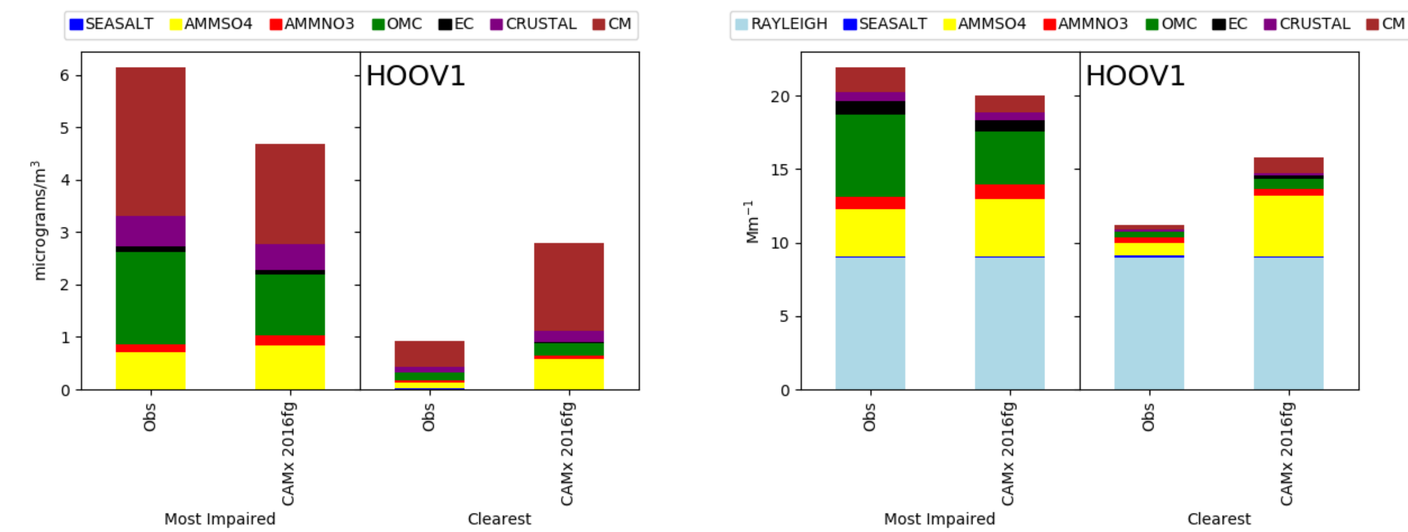


Figure 73. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Hoover Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

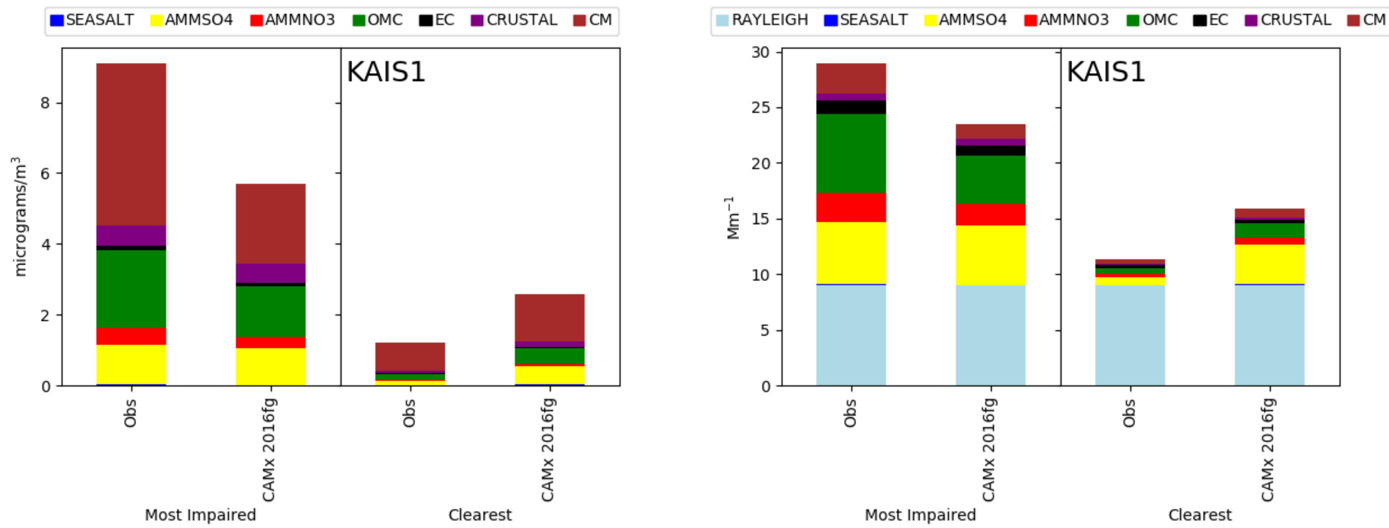


Figure 74. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Ansel Adams Wilderness (Minarets) (CA), John Muir Wilderness (CA), and Kaiser Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

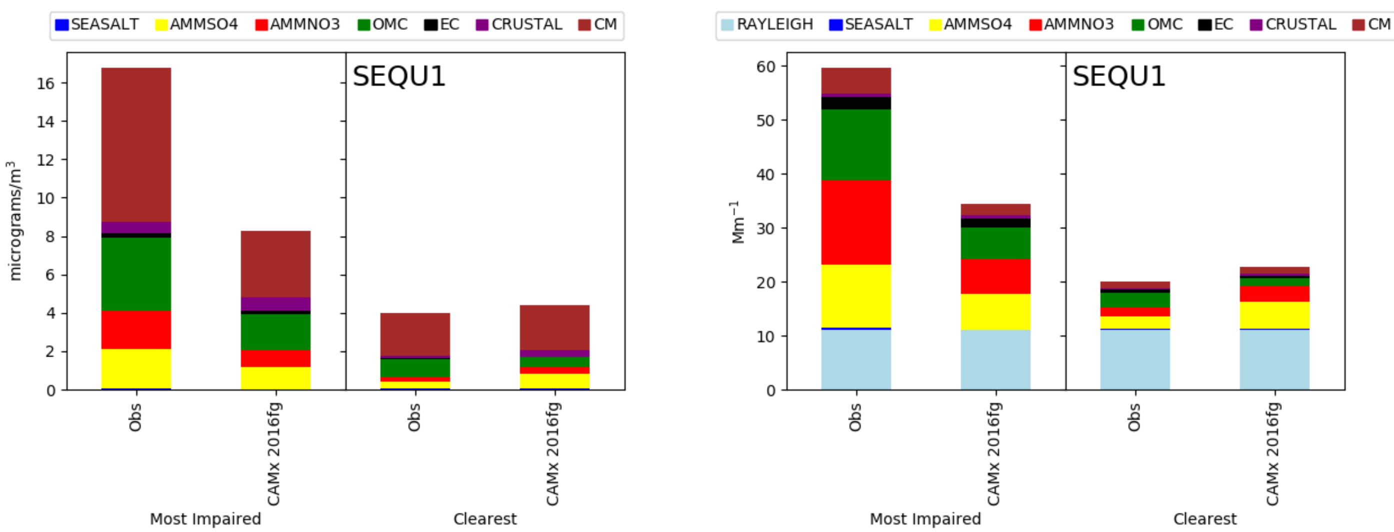


Figure 75. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Kings Canyon National Park (CA) and Sequoia National Park (CA) on the observed 20% most impaired and observed 20% clearest days.

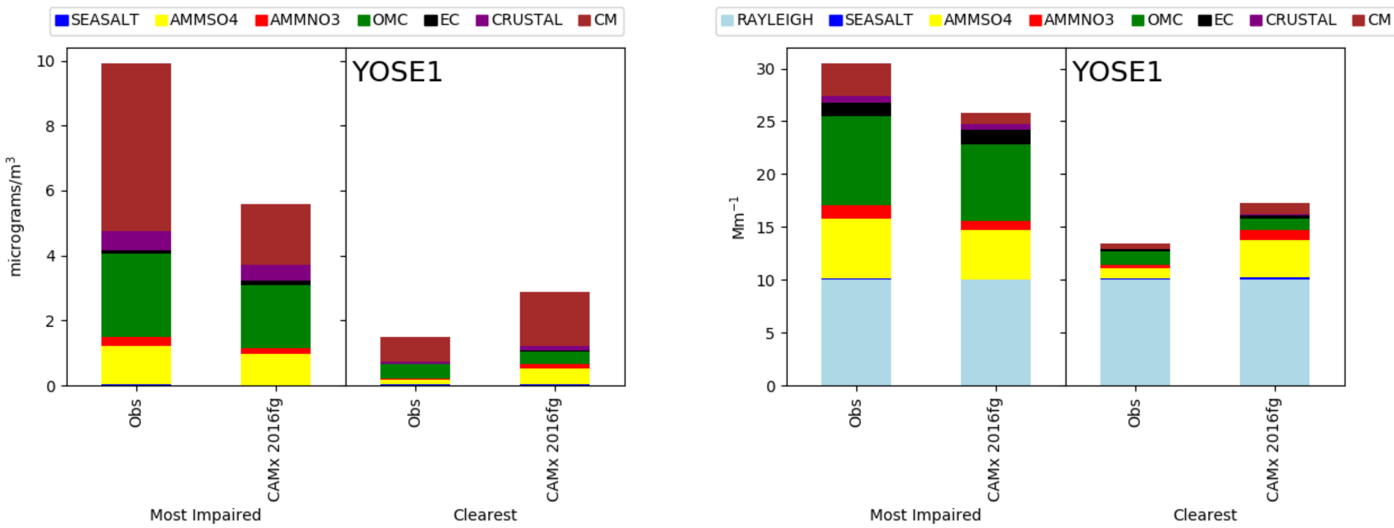


Figure 76. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Emigrant Wilderness (CA) and Yosemite National Park (CA) on the observed 20% most impaired and observed 20% clearest days.

Southern California

- Agua Tibia Wilderness (CA)(AGTI1)
- Joshua Tree National Monument (CA)(JOSH1)
- Cucamonga Wilderness (CA) and San Gabriel Wilderness (CA)(SAGA1)
- San Gorgonio Wilderness (CA) and San Jacinto Wilderness (CA)(SAGO1)

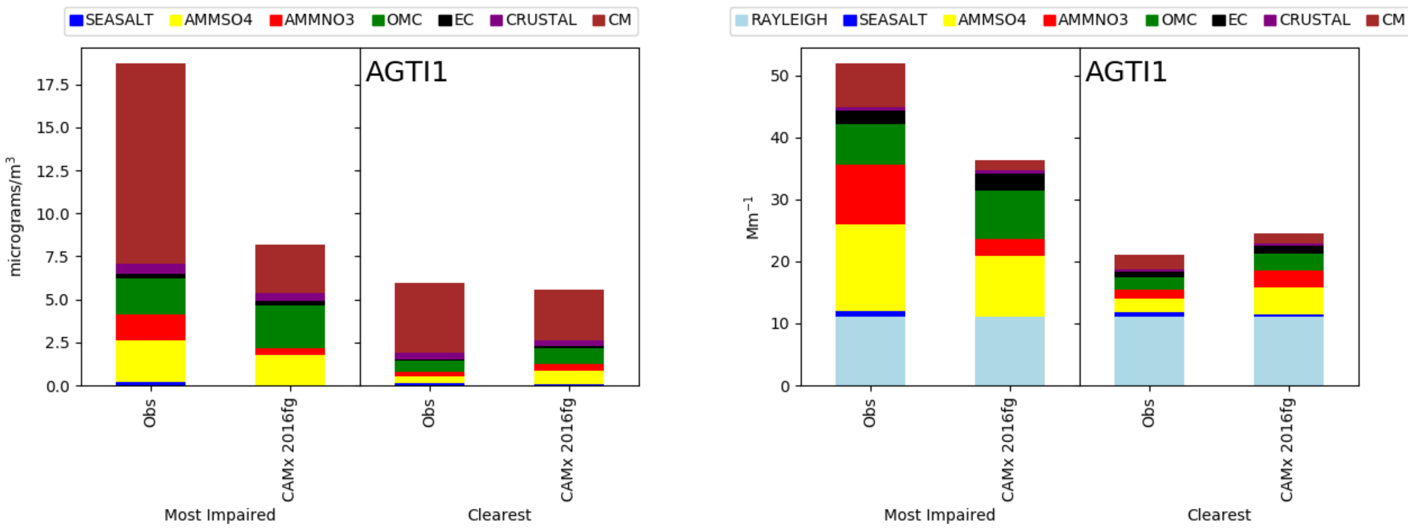


Figure 77. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Agua Tibia Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

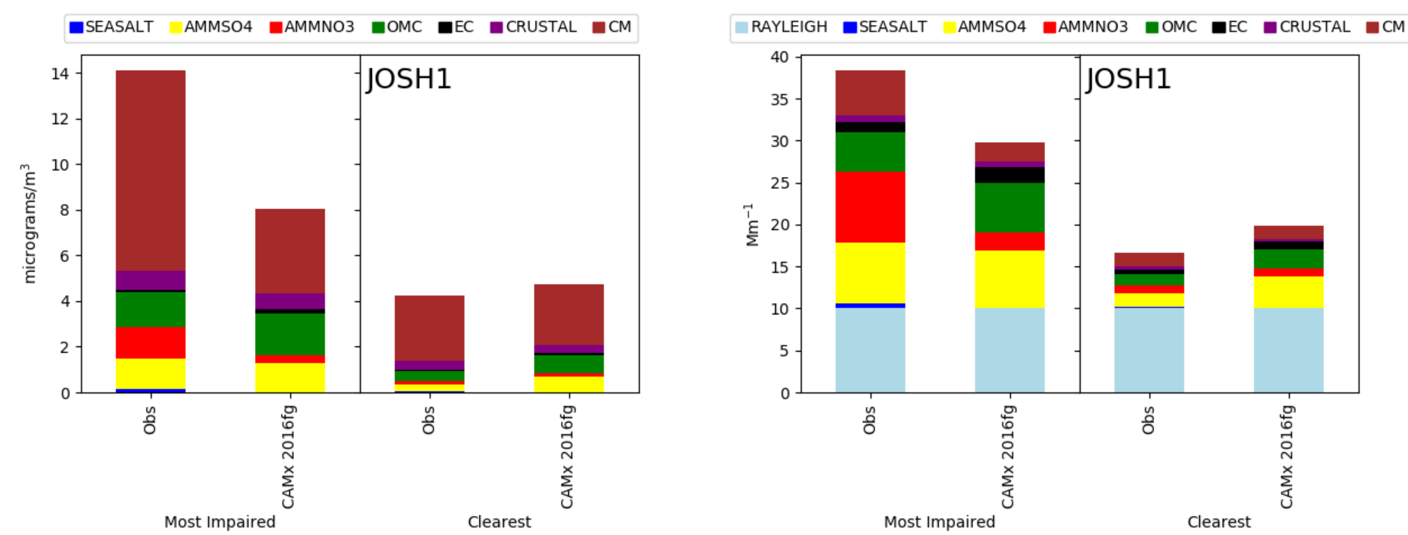


Figure 78. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Joshua Tree National Monument (CA) on the observed 20% most impaired and observed 20% clearest days.

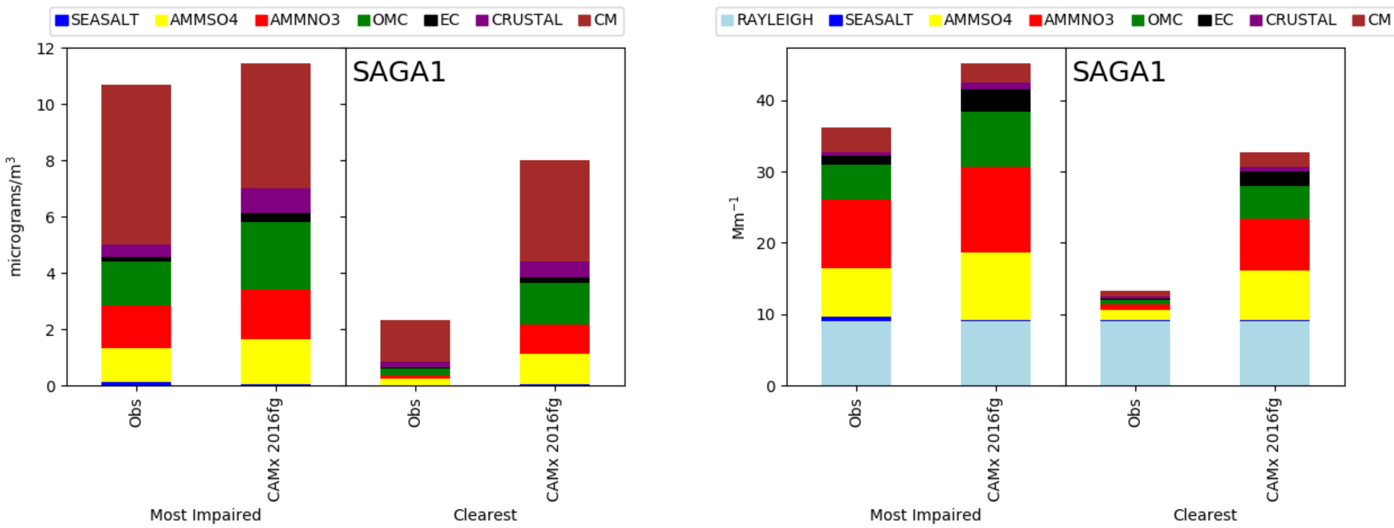


Figure 79. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Cucamonga Wilderness (CA) and San Gabriel Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

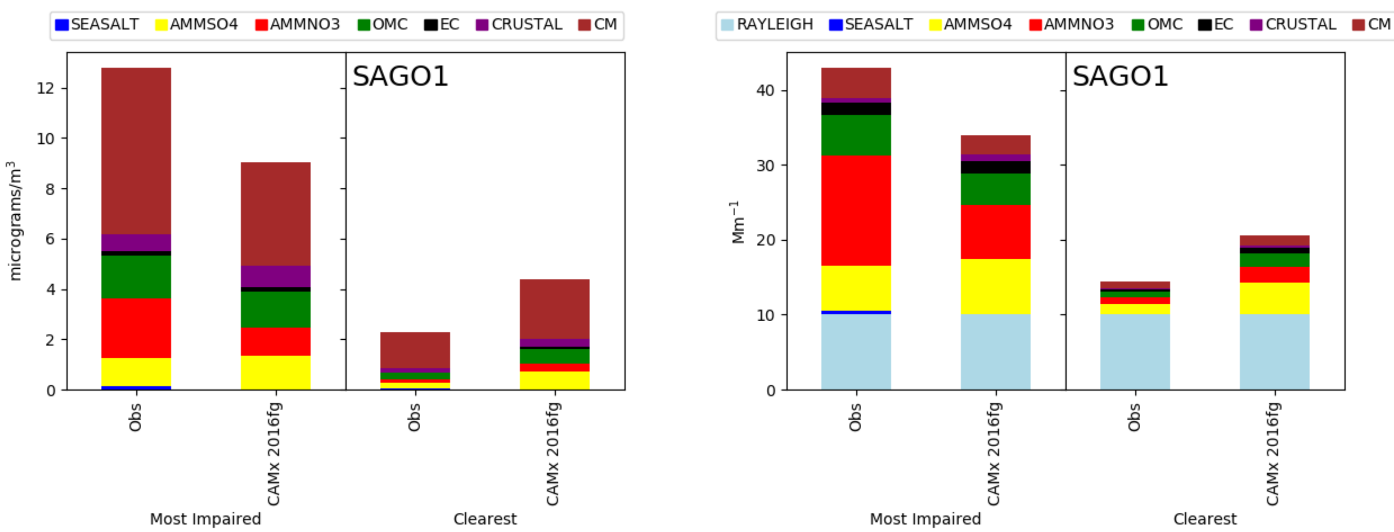


Figure 80. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the San Gorgonio Wilderness (CA) and San Jacinto Wilderness (CA) on the observed 20% most impaired and observed 20% clearest days.

Northern Rocky Mountains

- Bridger Wilderness (WY) and Fitzpatrick Wilderness (WY)(BRID1)
- Cabinet Mountains Wilderness (MT)(CABI1)
- Gates of the Mountains Wilderness (MT)(GAMO1)
- Glacier National Park (MT)(GLAC1)
- Bob Marshall Wilderness (MT), Mission Mountains Wilderness (MT), and Scapegoat Wilderness (MT)(MONT1)
- North Absaroka Wilderness (WY) and Washakie Wilderness (WY)(NOAB1)
- Anaconda-Pintler Wilderness (MT) and Selway-Bitterroot Wilderness (MT)(SULA1)
- Grand Teton National Park (WY), Red Rock Lakes (WY), Teton Wilderness (WY), and Yellowstone National Park (WY)(YELL2)

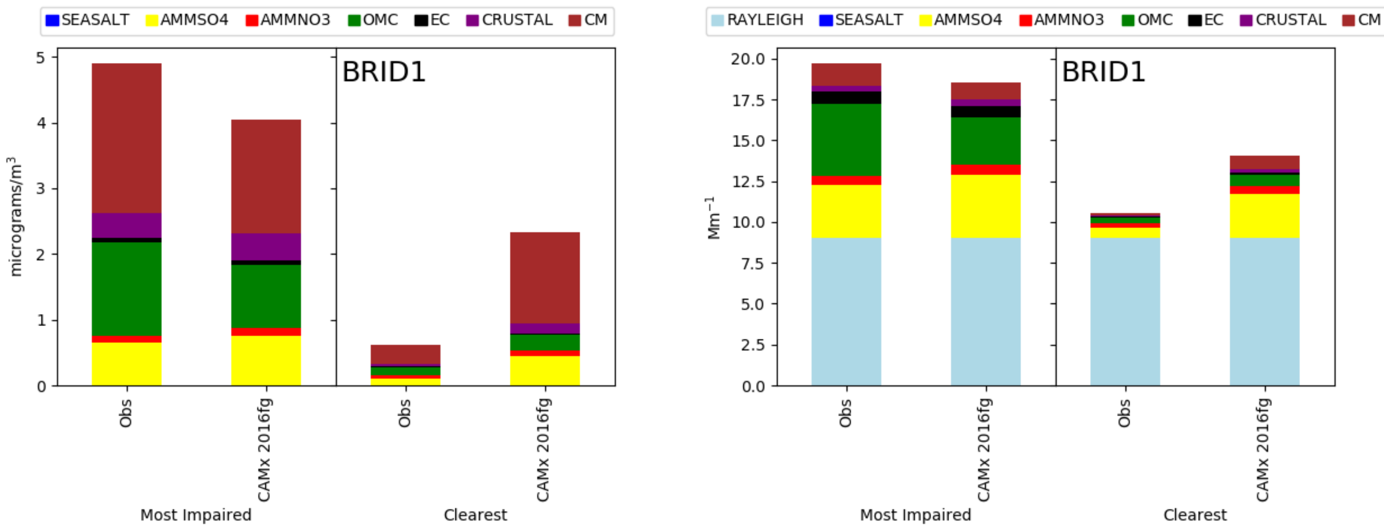


Figure 81. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Bridger Wilderness (WY) and Fitzpatrick Wilderness (WY) on the observed 20% most impaired and observed 20% clearest days.

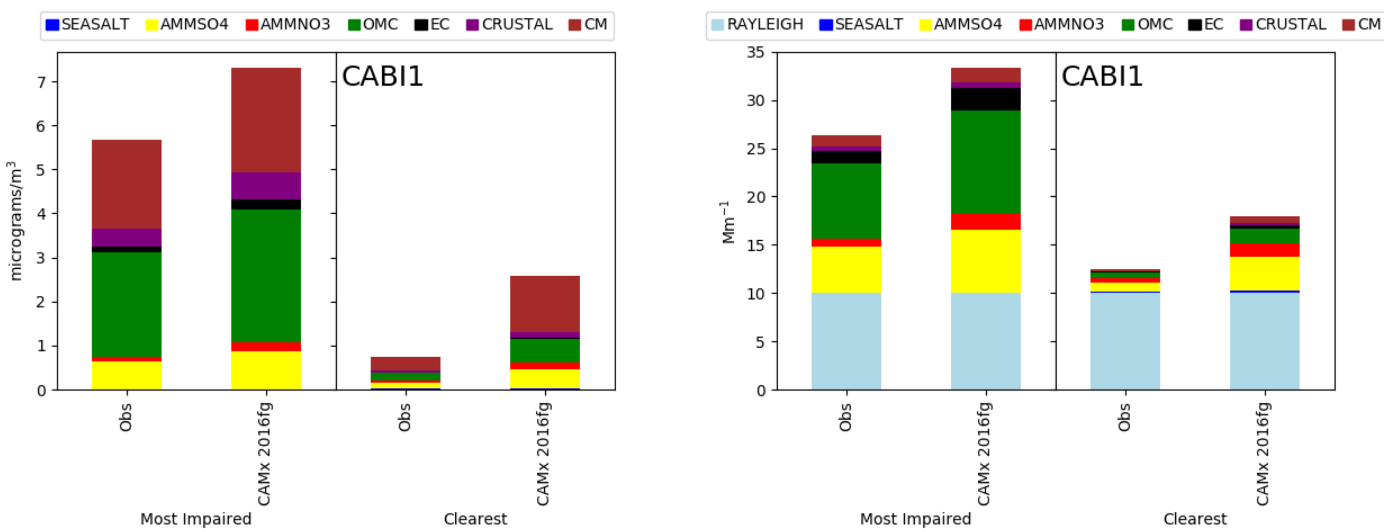


Figure 82. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Cabinet Mountains Wilderness (MT) on the observed 20% most impaired and observed 20% clearest days.

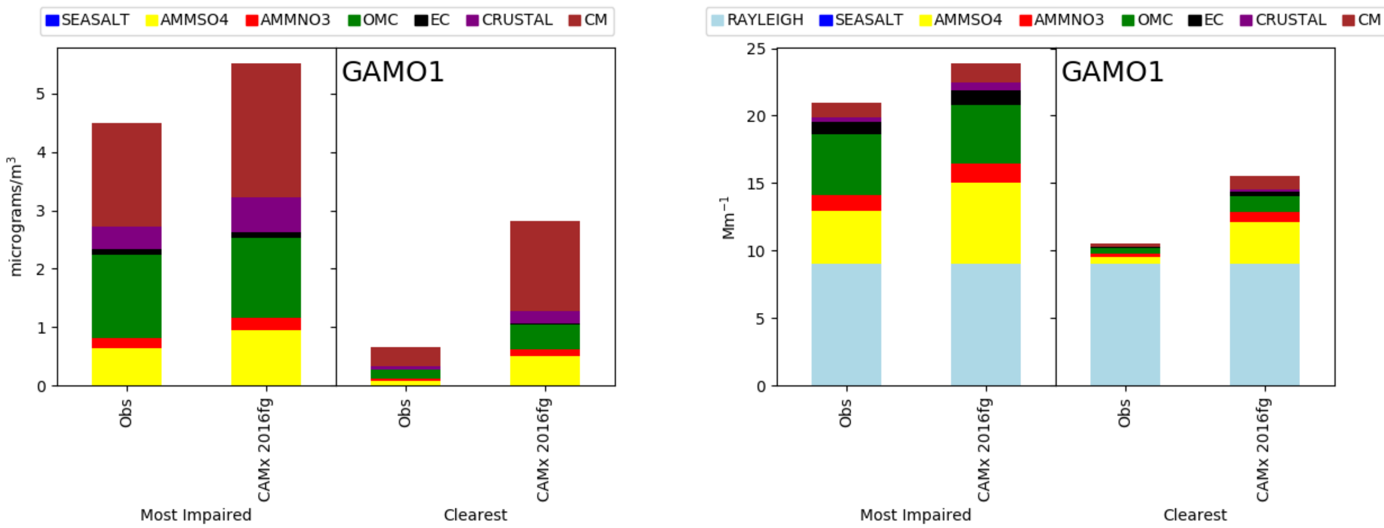


Figure 83. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Gates of the Mountains Wilderness (MT) on the observed 20% most impaired and observed 20% clearest days.

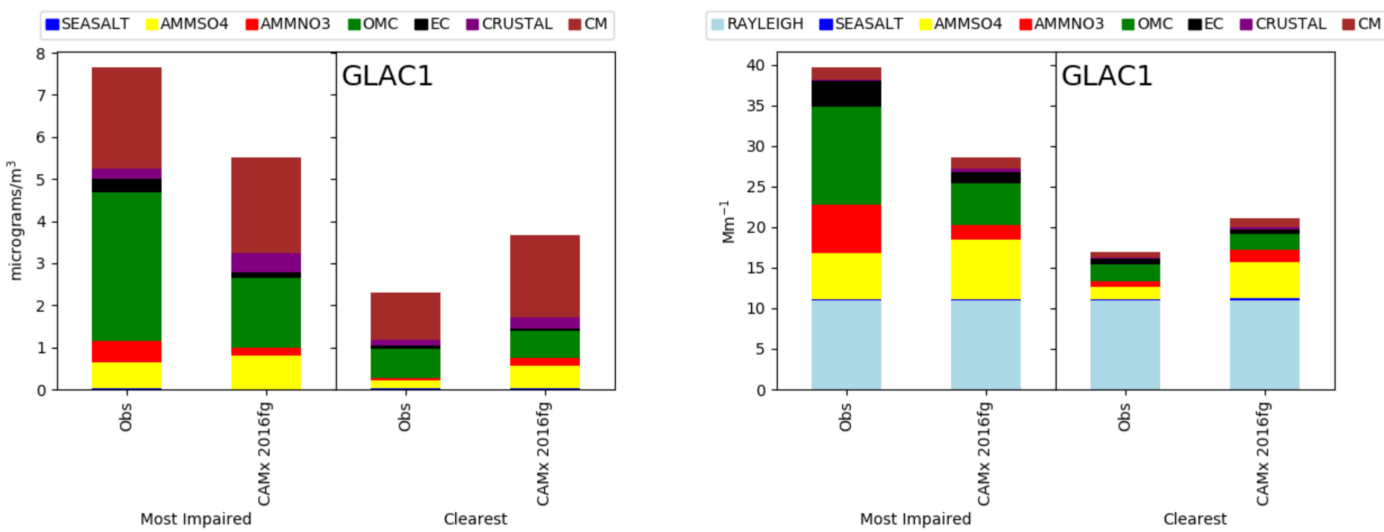


Figure 84. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Glacier National Park (MT) on the observed 20% most impaired and observed 20% clearest days.

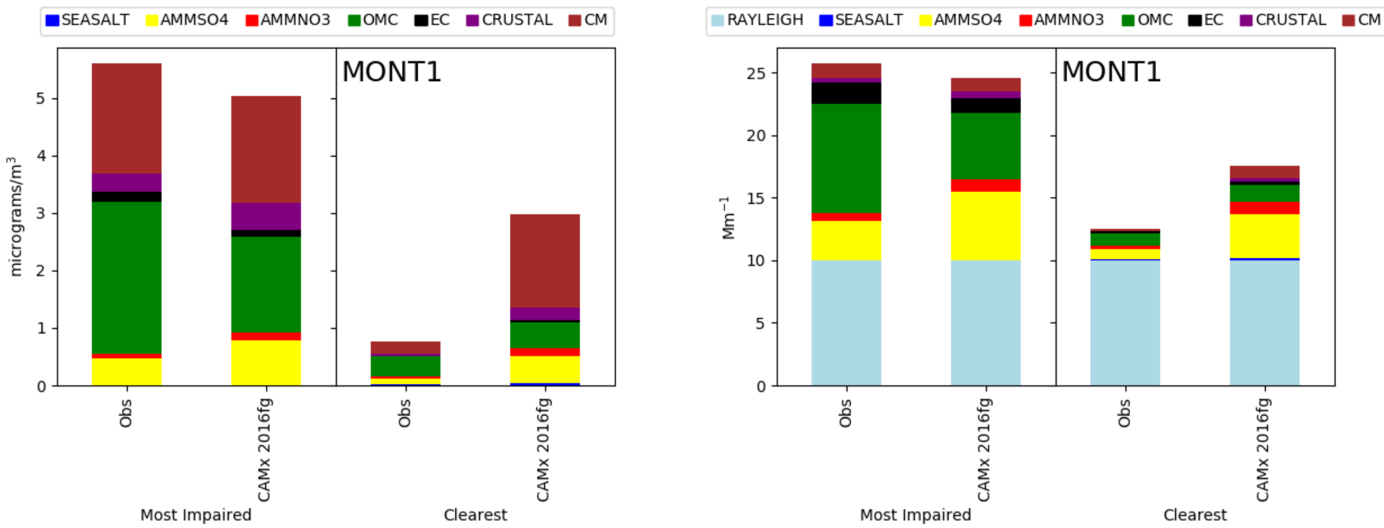


Figure 85. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Bob Marshall Wilderness (MT), Mission Mountains Wilderness (MT), and Scapegoat Wilderness (MT) on the observed 20% most impaired and observed 20% clearest days.

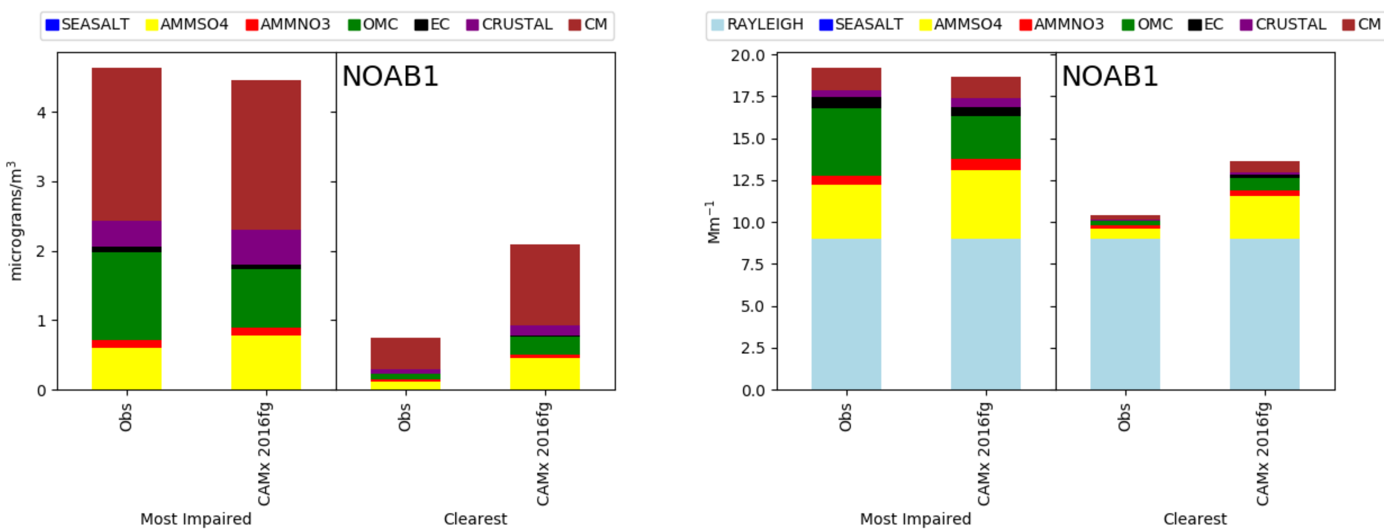


Figure 86. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the North Absaroka Wilderness (WY) and Washakie Wilderness (WY) on the observed 20% most impaired and observed 20% clearest days.

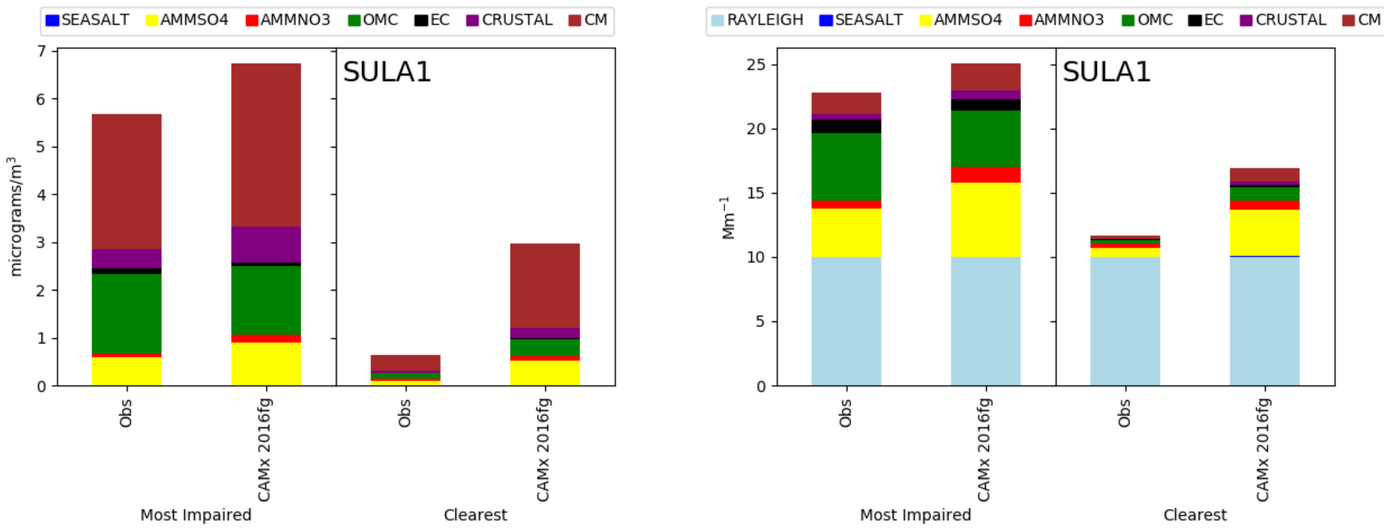


Figure 87. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Anaconda-Pintler Wilderness (MT) and Selway-Bitterroot Wilderness (MT) on the observed 20% most impaired and observed 20% clearest days.

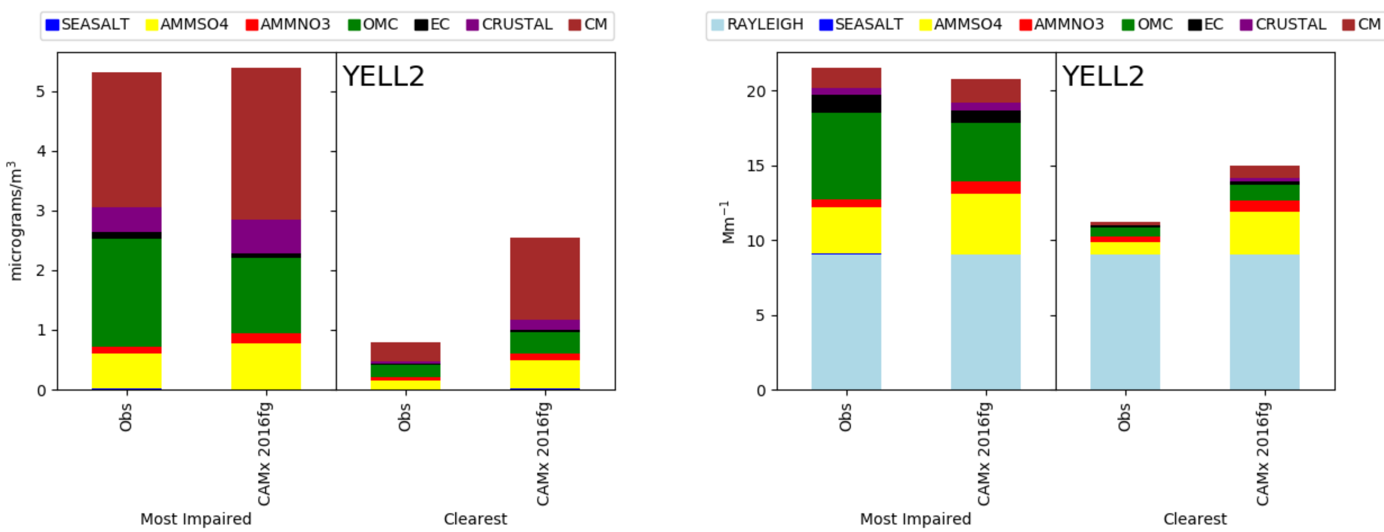


Figure 88. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Grand Teton National Park (WY), Red Rock Lakes (WY), Teton Wilderness (WY), and Yellowstone National Park (WY) on the observed 20% most impaired and observed 20% clearest days.

Hells Canyon

- Craters of the Moon National Monument (ID)(CRMO1)
- Hells Canyon Wilderness (OR)(HECA1)
- Sawtooth Wilderness (ID)(SAWT1)
- Eagle Cap Wilderness (OR) and Strawberry Mountain Wilderness (OR)(STAR1)

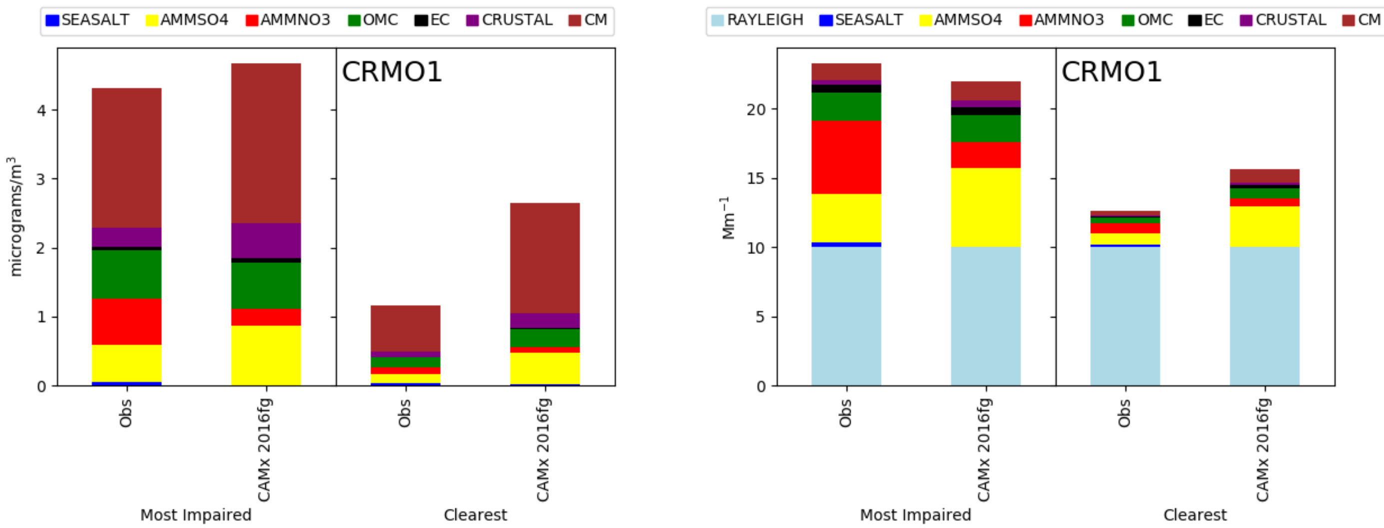


Figure 89. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Craters of the Moon National Monument (ID) on the observed 20% most impaired and observed 20% clearest days.

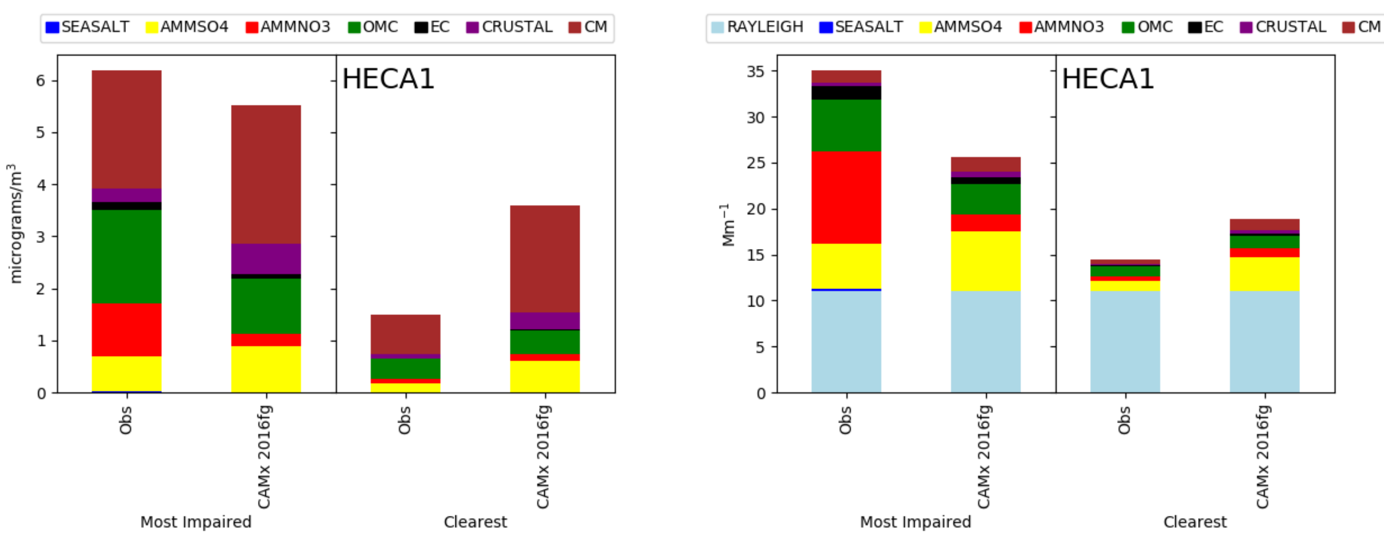


Figure 90. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Hells Canyon Wilderness (OR) on the observed 20% most impaired and observed 20% clearest days.

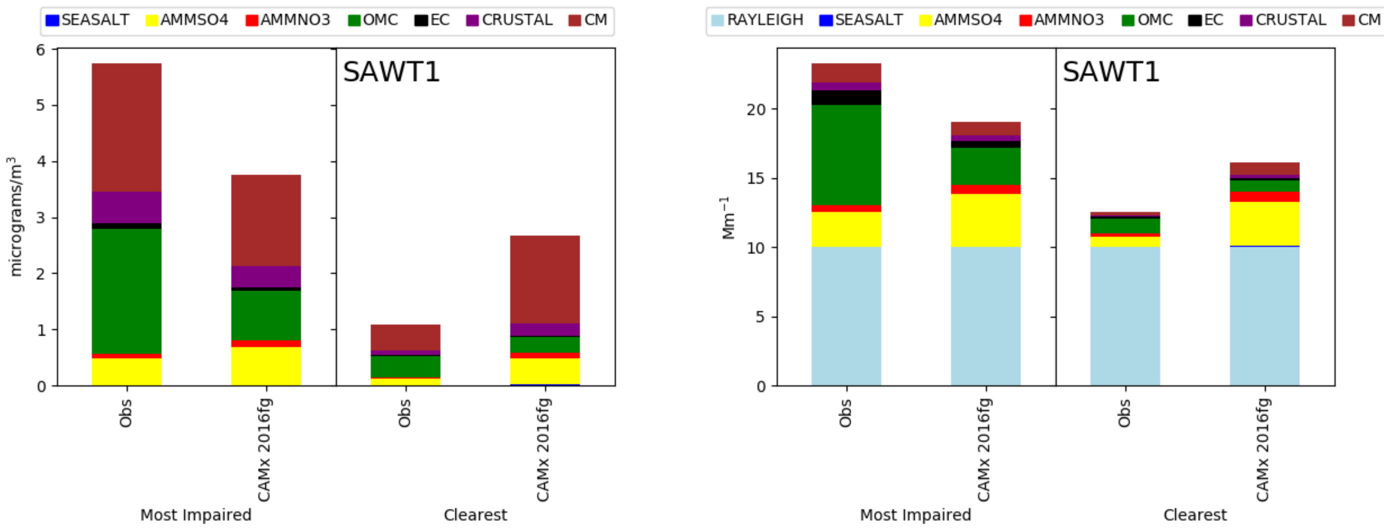


Figure 91. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Sawtooth Wilderness (ID) on the observed 20% most impaired and observed 20% clearest days.

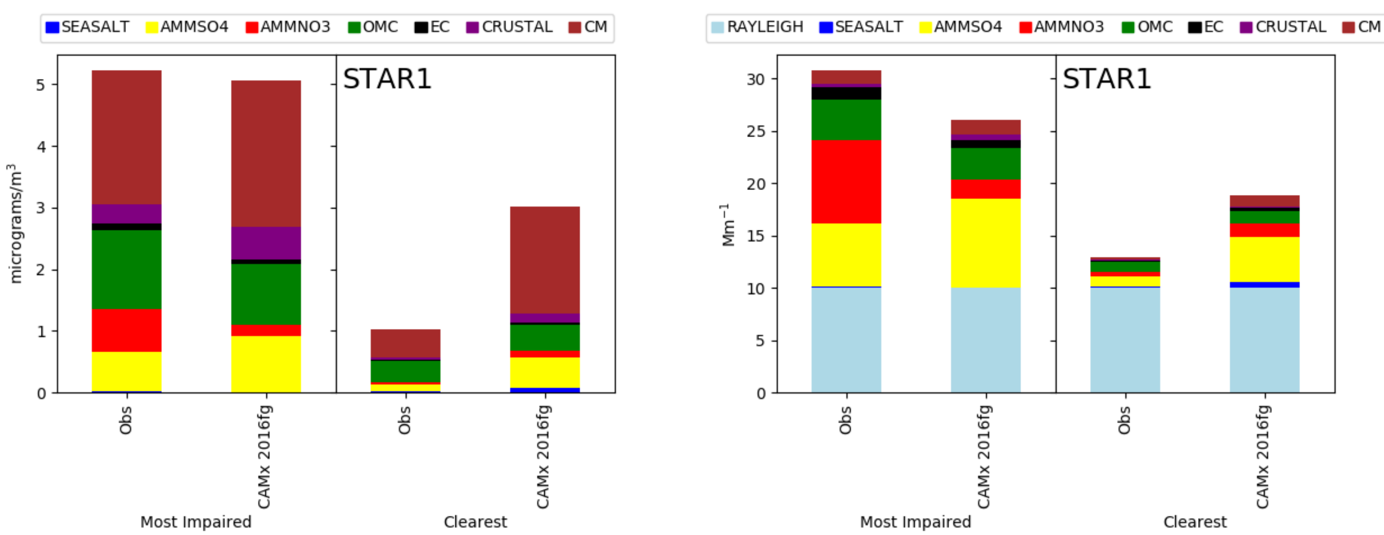


Figure 92. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Eagle Cap Wilderness (OR) and Strawberry Mountain Wilderness (OR) on the observed 20% most impaired and observed 20% clearest days.

Great Basin

- Jarbidge Wilderness (NV)(JARB1)

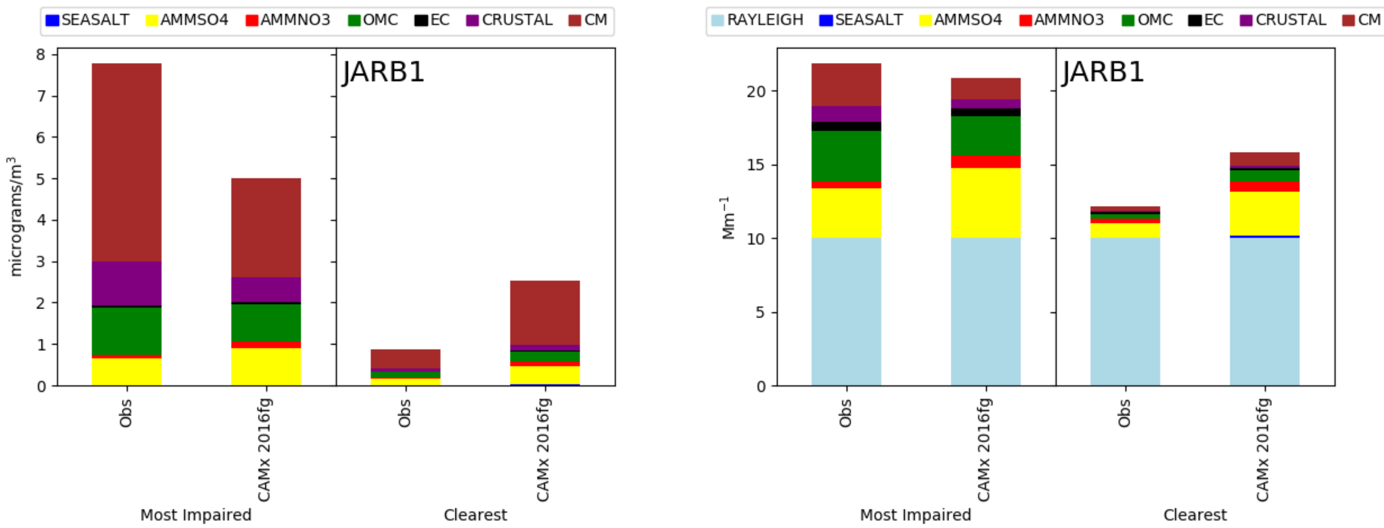


Figure 93. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Jarbidge Wilderness (NV) on the observed 20% most impaired and observed 20% clearest days.

Central Rocky Mountains

- Great Sand Dunes National Monument (CO)(GRSA1)
- Mount Zirkel Wilderness (CO) and Rawah Wilderness (CO)(MOZI1)
- Rocky Mountain National Park (CO)(ROMO1)
- Pecos Wilderness (NM) and Wheeler Peak Wilderness (NM)(WHPE1)
- Eagles Nest Wilderness (CO), Flat Tops Wilderness (CO), Maroon Bells-Snowmass Wilderness (CO), and West Elk Wilderness (CO)(WHRI1)

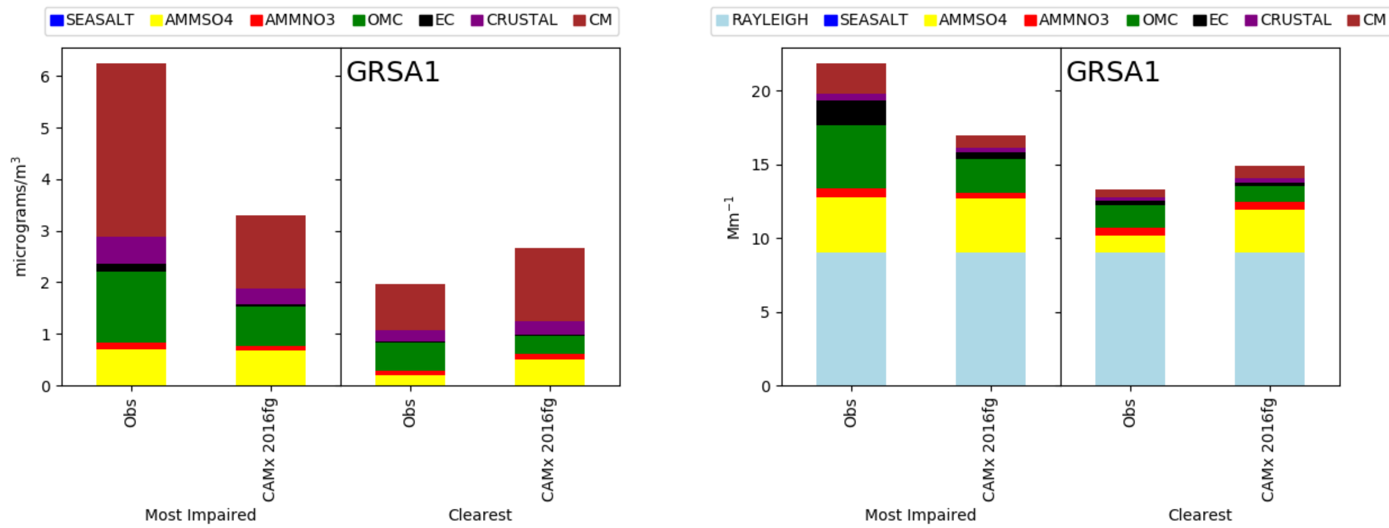


Figure 94. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Great Sand Dunes National Monument (CO) on the observed 20% most impaired and observed 20% clearest days.

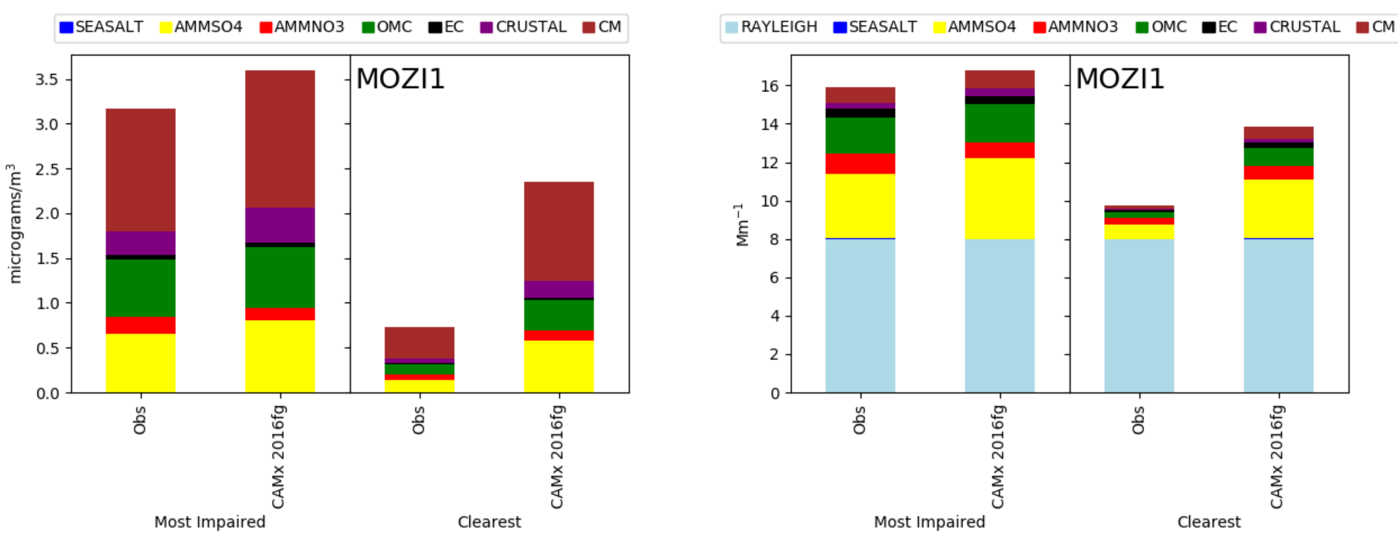


Figure 95. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mount Zirkel Wilderness (CO) and Rawah Wilderness (CO) on the observed 20% most impaired and observed 20% clearest days.

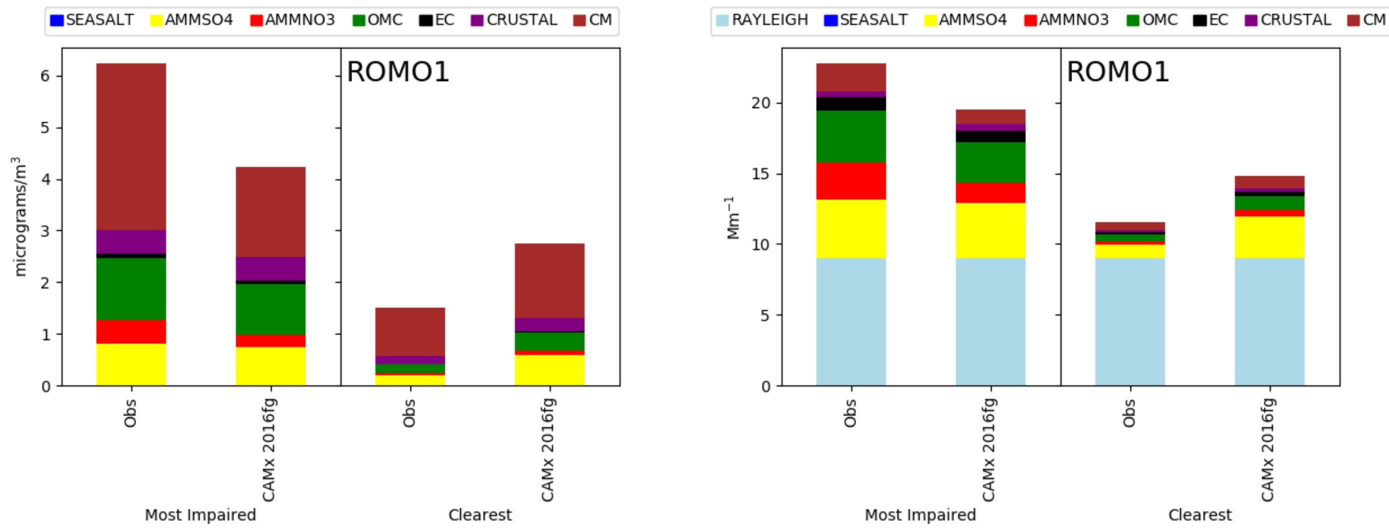


Figure 96. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Rocky Mountain National Park (CO) on the observed 20% most impaired and observed 20% clearest days.

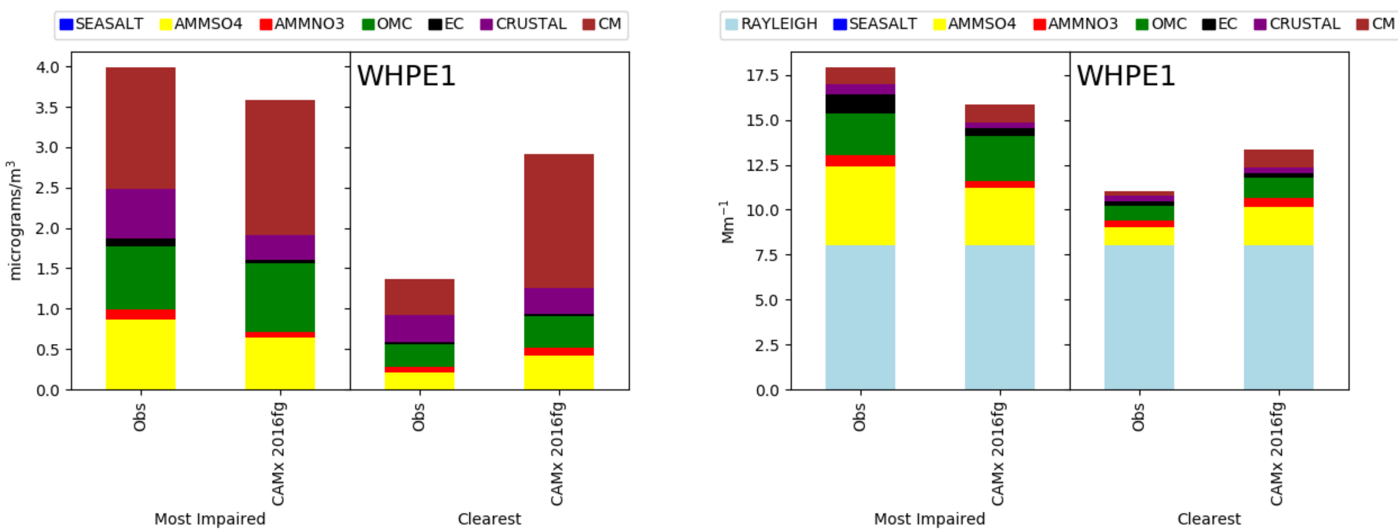


Figure 97. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Pecos Wilderness (NM) and Wheeler Peak Wilderness (NM) on the observed 20% most impaired and observed 20% clearest days.

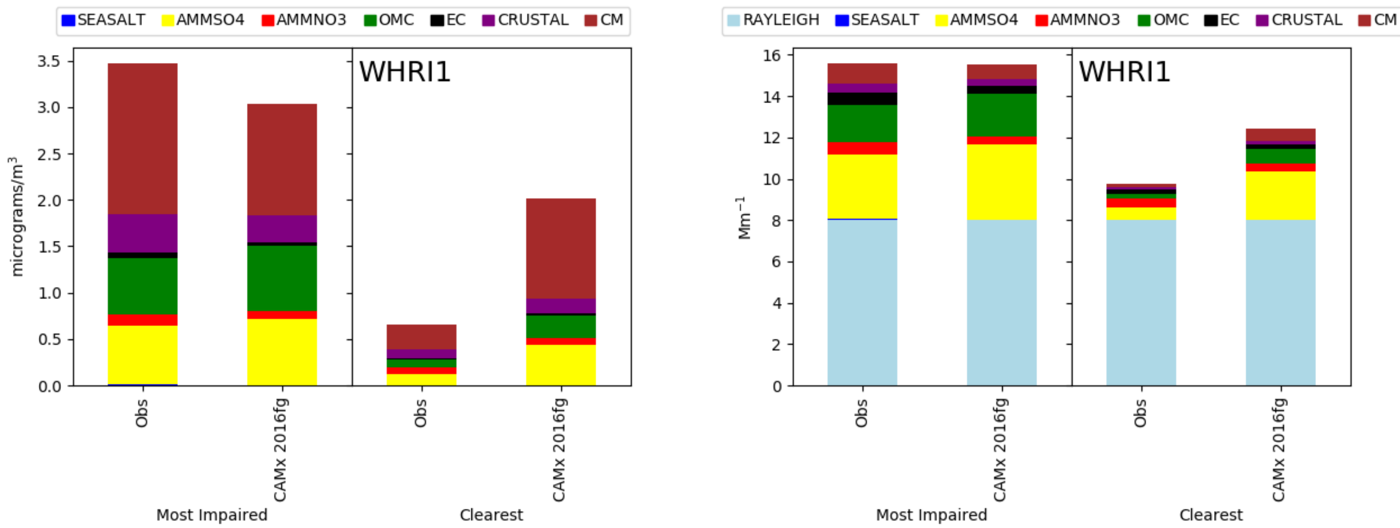


Figure 98. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Eagles Nest Wilderness (CO), Flat Tops Wilderness (CO), Maroon Bells-Snowmass Wilderness (CO), and West Elk Wilderness (CO) on the observed 20% most impaired and observed 20% clearest days.

Colorado Plateau

- Bandelier National Monument (NM)(BAND1)
- Bryce Canyon National Park (UT)(BRCA1)
- Arches National Park (UT) and Canyonlands National Park (UT)(CANY1)
- Capitol Reef National Park (UT)(CAPI1)
- Grand Canyon National Park (AZ)(GRCA2)
- Mesa Verde National Park (CO)(MEVE1)
- San Pedro Parks Wilderness (NM)(SAPE1)
- Black Canyon of the Gunnison National Monument (CO), La Garita Wilderness (CO), and Weminuche Wilderness (CO)(WEMI1)
- Zion National Park (UT)(ZICA1)

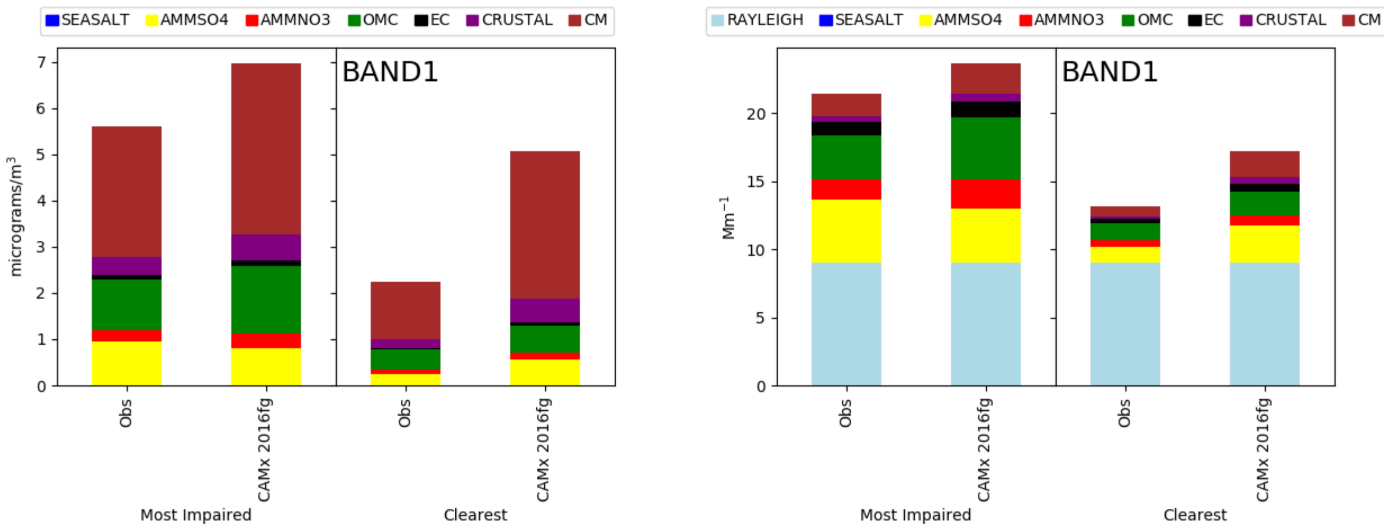


Figure 99. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Bandelier National Monument (NM) on the observed 20% most impaired and observed 20% clearest days.

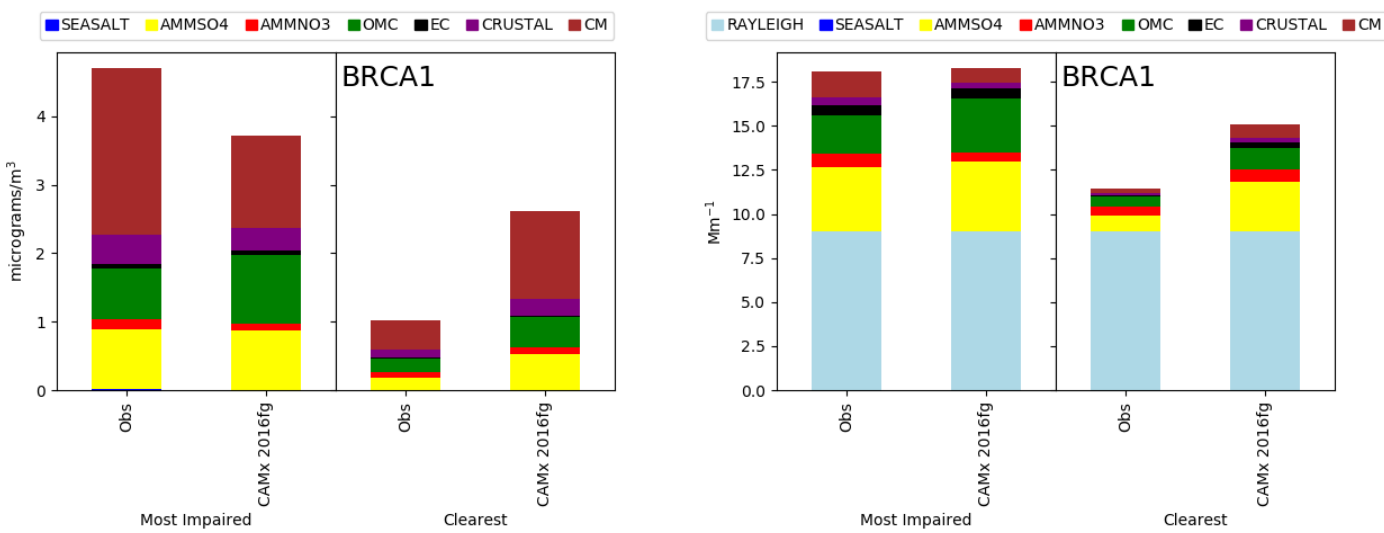


Figure 100. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Bryce Canyon National Park (UT) on the observed 20% most impaired and observed 20% clearest days.

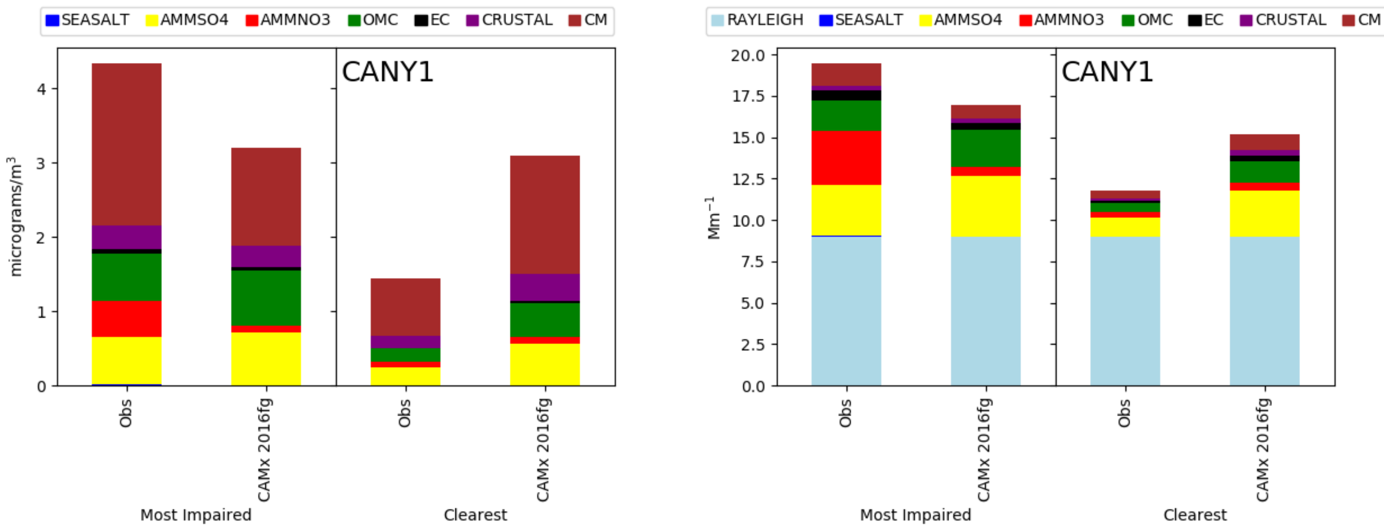


Figure 101. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Arches National Park (UT) and Canyonlands National Park (UT) on the observed 20% most impaired and observed 20% clearest days.

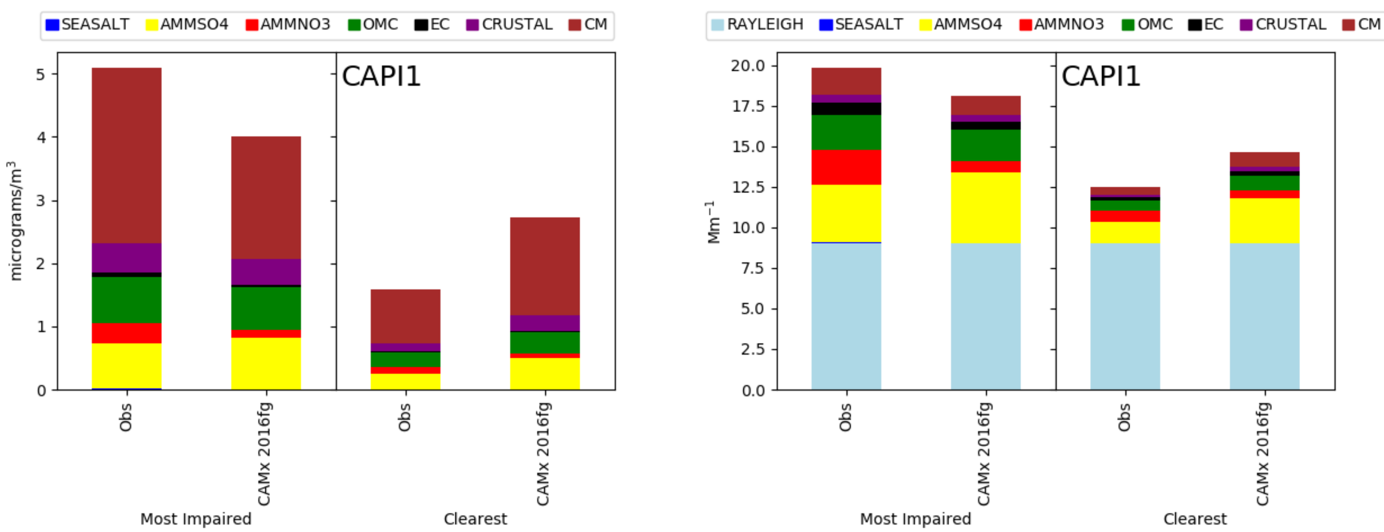


Figure 102. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Capitol Reef National Park (UT) on the observed 20% most impaired and observed 20% clearest days.

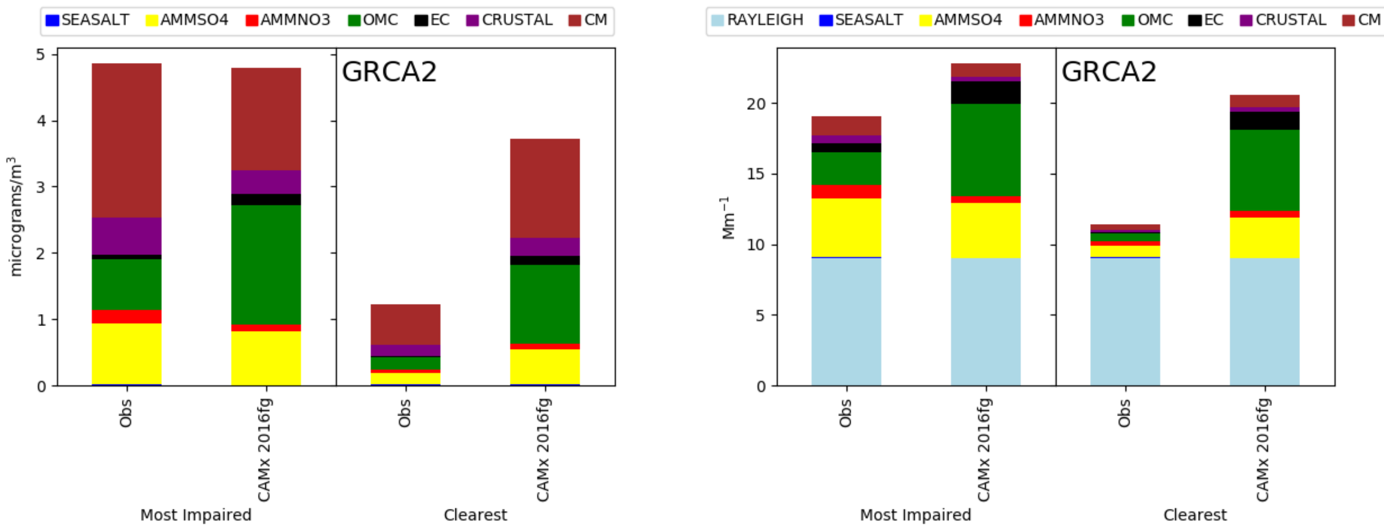


Figure 103. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Grand Canyon National Park (AZ) on the observed 20% most impaired and observed 20% clearest days.

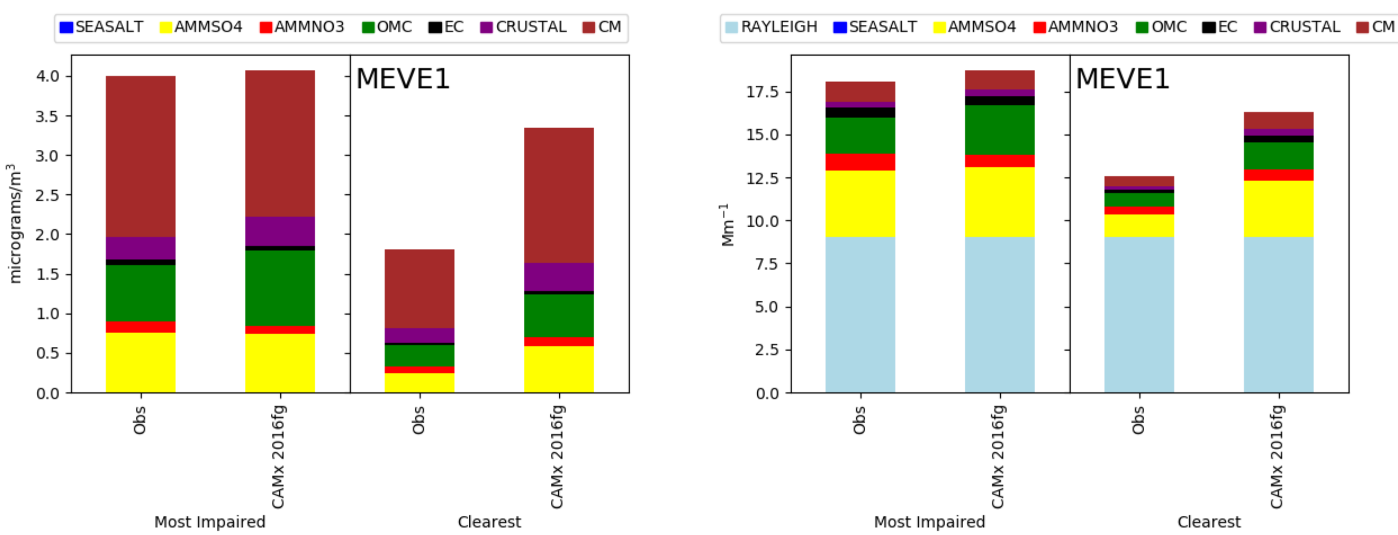


Figure 104. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mesa Verde National Park (CO) on the observed 20% most impaired and observed 20% clearest days.

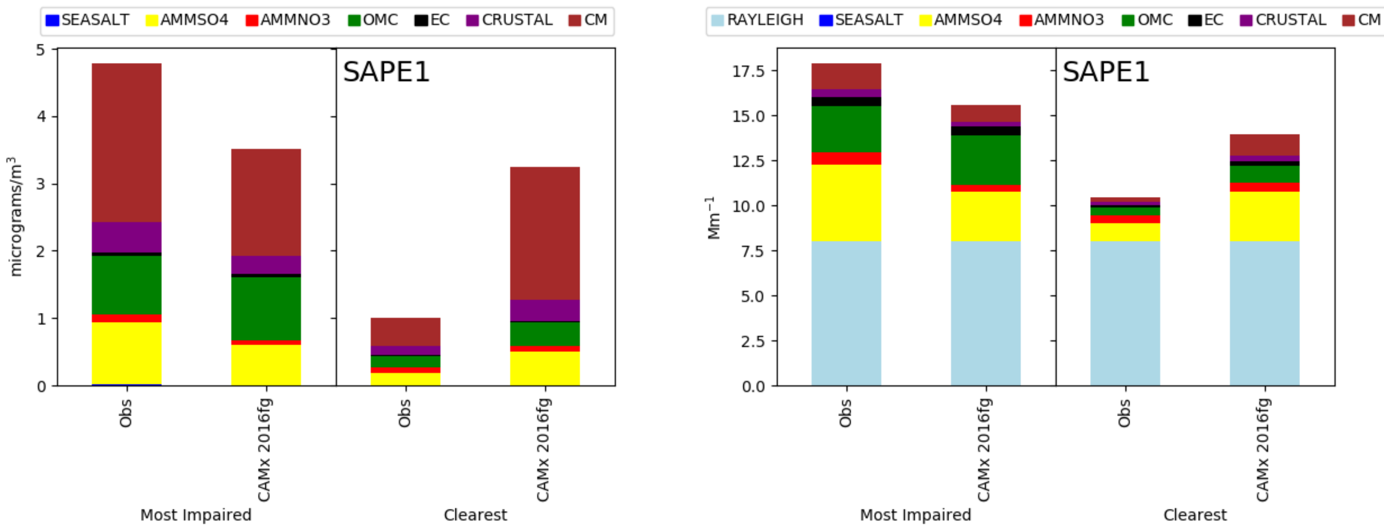


Figure 105. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the San Pedro Parks Wilderness (NM) on the observed 20% most impaired and observed 20% clearest days.

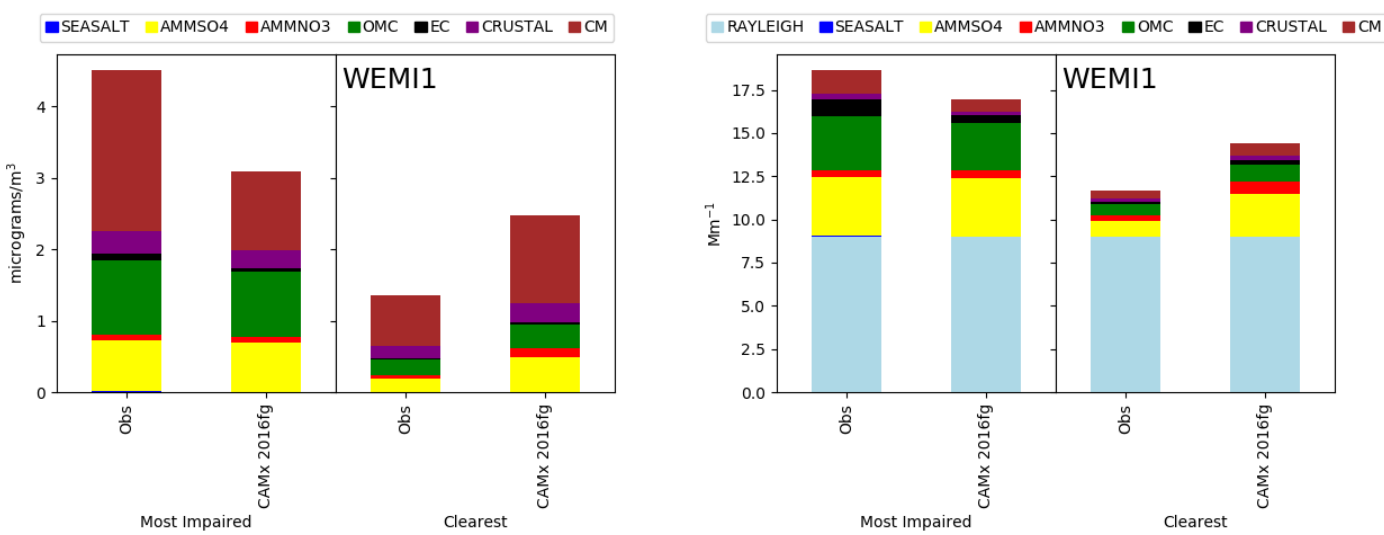


Figure 106. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Black Canyon of the Gunnison National Monument (CO), La Garita Wilderness (CO), and Weminuche Wilderness (CO) on the observed 20% most impaired and observed 20% clearest days.

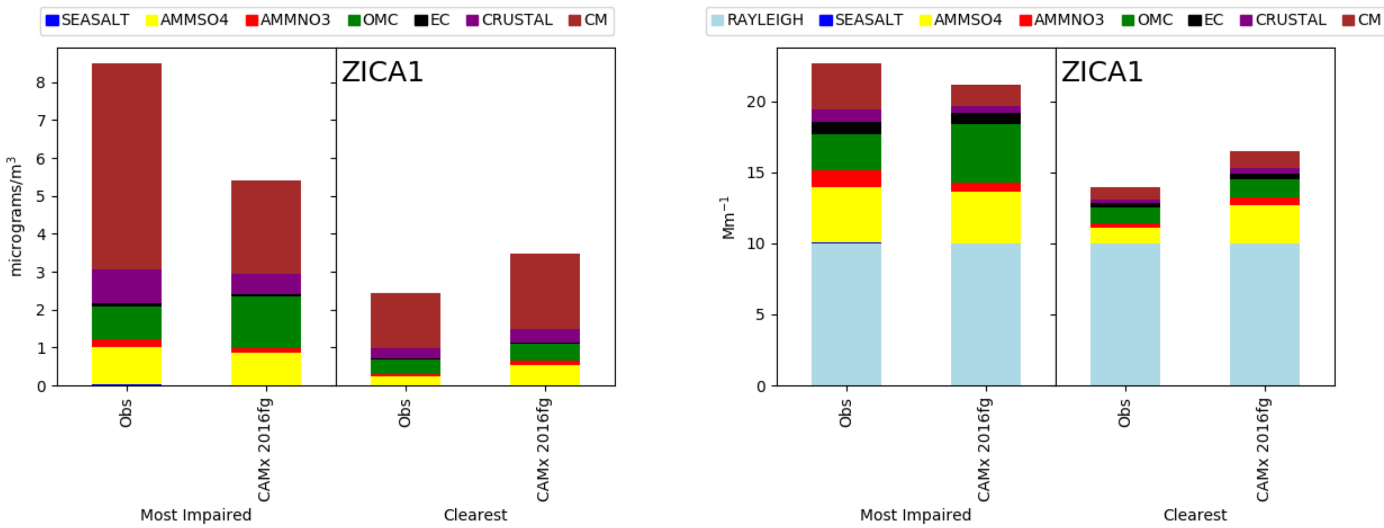


Figure 107. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Zion National Park (UT) on the observed 20% most impaired and observed 20% clearest days.

Mogollon Plateau

- Mount Baldy Wilderness (AZ)(BALD1)
- Bosque del Apache (NM)(BOAP1)
- Gila Wilderness (NM)(GICL1)
- Mazatzal Wilderness (AZ) and Pine Mountain Wilderness (AZ)(IKBA1)
- Petrified Forest National Park (AZ)(PEFO1)
- Sierra Ancha Wilderness (AZ)(SIAN1)
- Sycamore Canyon Wilderness (AZ)(SYCA2)
- Superstition Wilderness (AZ)(TONT1)
- White Mountain Wilderness (NM)(WHIT1)

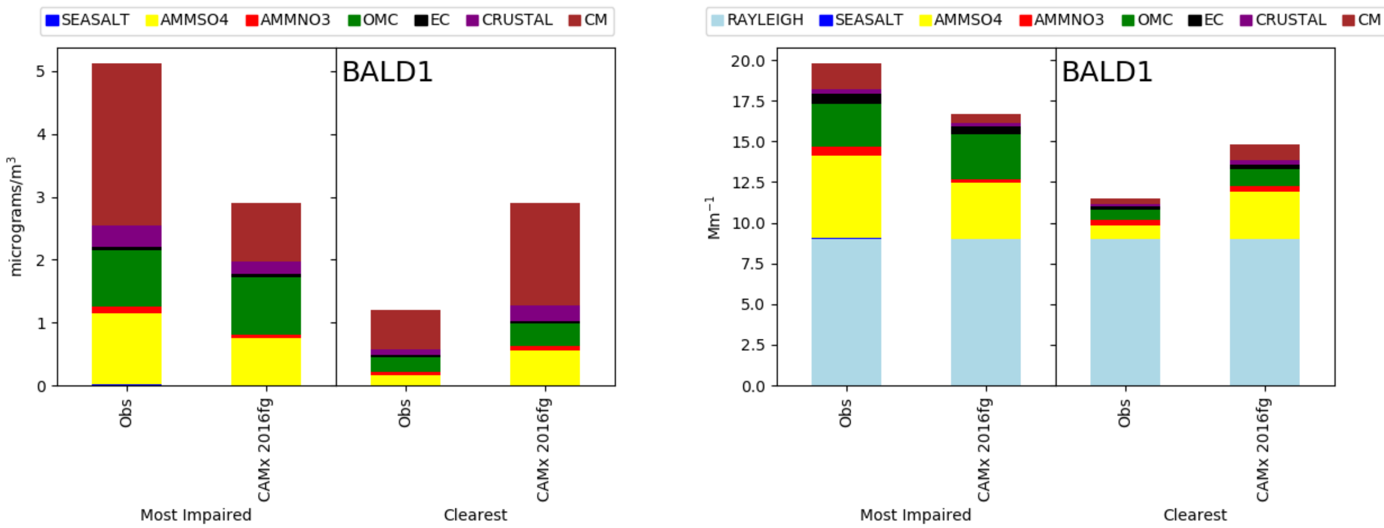


Figure 108. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mount Baldy Wilderness (AZ) on the observed 20% most impaired and observed 20% clearest days.

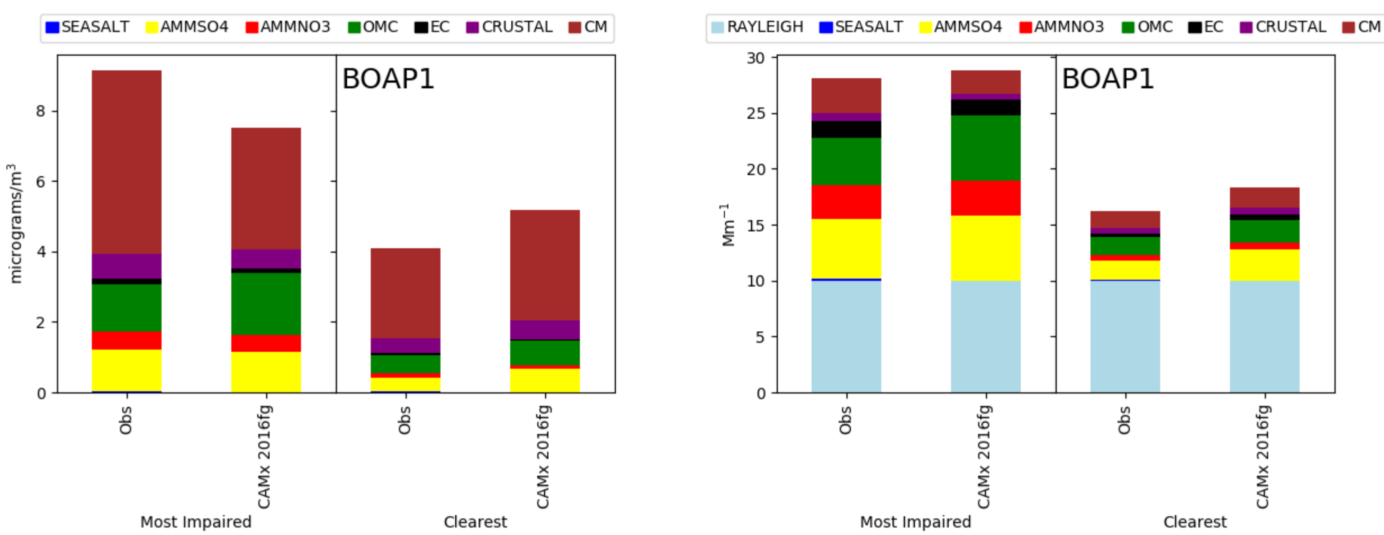


Figure 109. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Bosque del Apache (NM) on the observed 20% most impaired and observed 20% clearest days.

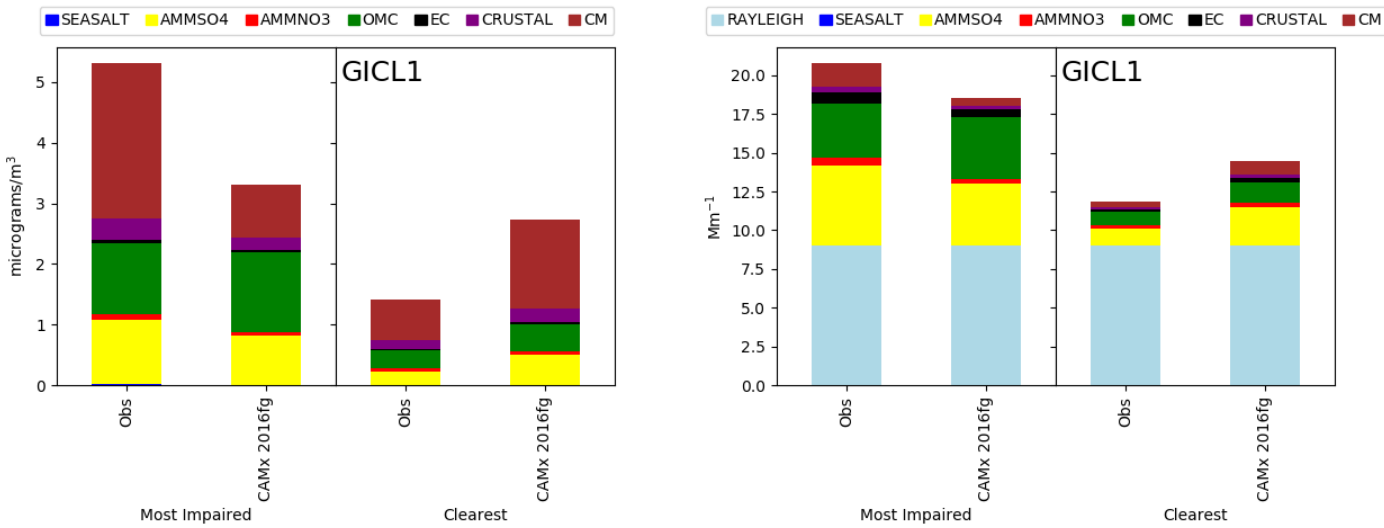


Figure 110. Observed (Obs) and predicted (CAMx) concentrations (µg/m³) on left and extinctions (MM^{-1}) on right at the Gila Wilderness (NM) on the observed 20% most impaired and observed 20% clearest days.

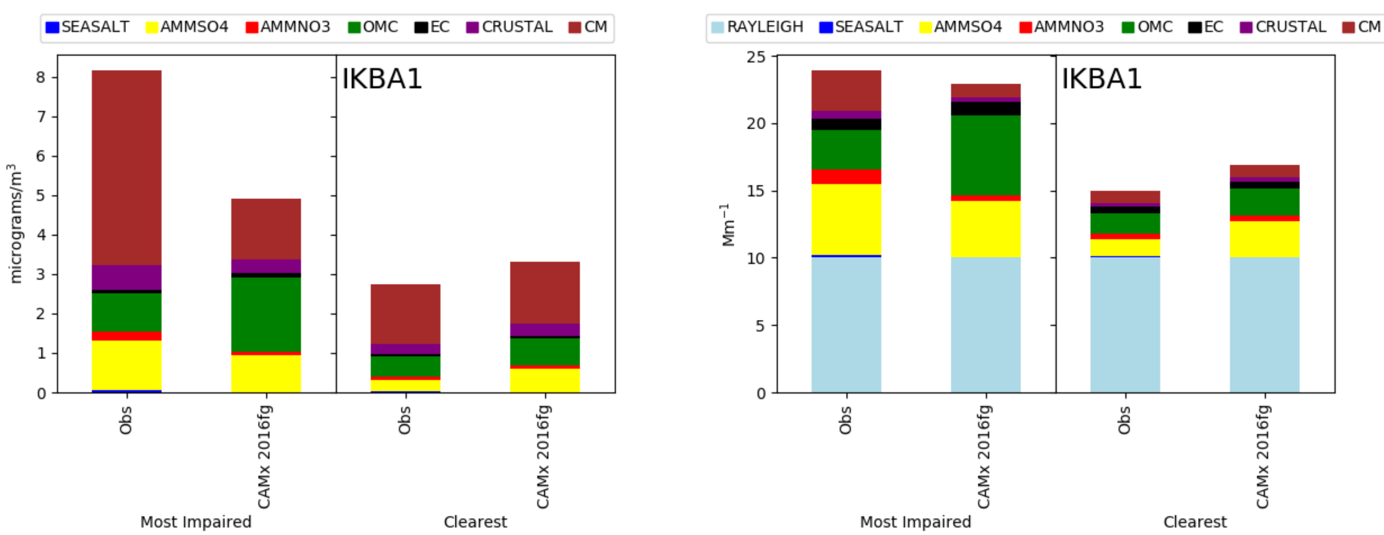


Figure 111. Observed (Obs) and predicted (CAMx) concentrations (µg/m³) on left and extinctions (MM^{-1}) on right at the Mazatzal Wilderness (AZ) and Pine Mountain Wilderness (AZ) on the observed 20% most impaired and observed 20% clearest days.

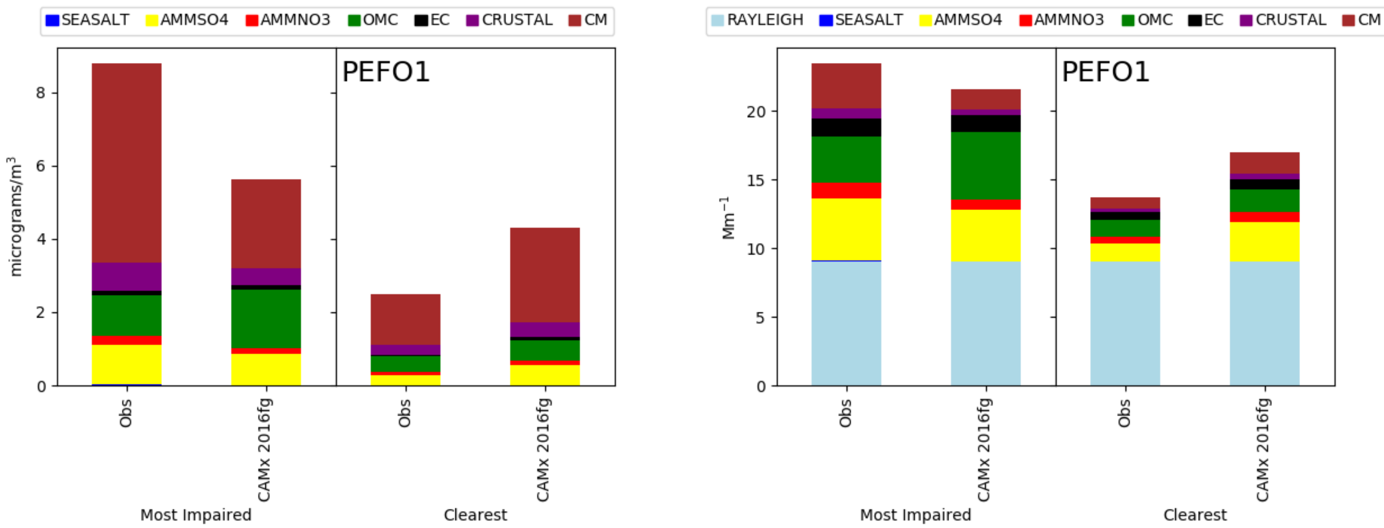


Figure 112. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Petrified Forest National Park (AZ) on the observed 20% most impaired and observed 20% clearest days.

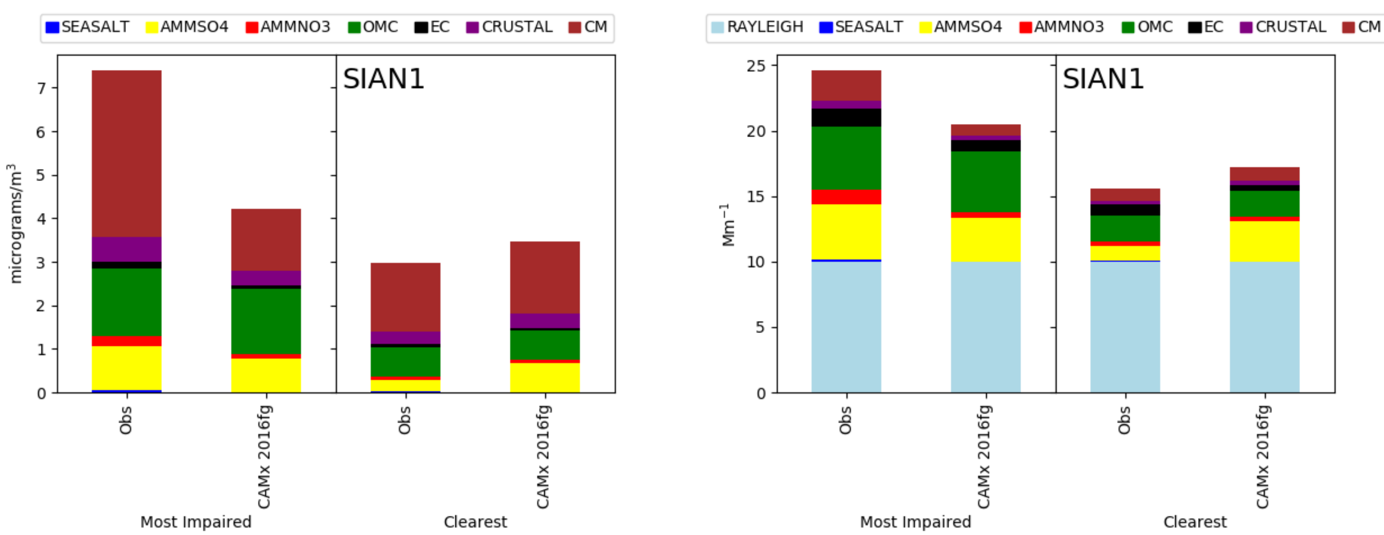


Figure 113. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Sierra Ancha Wilderness (AZ) on the observed 20% most impaired and observed 20% clearest days.

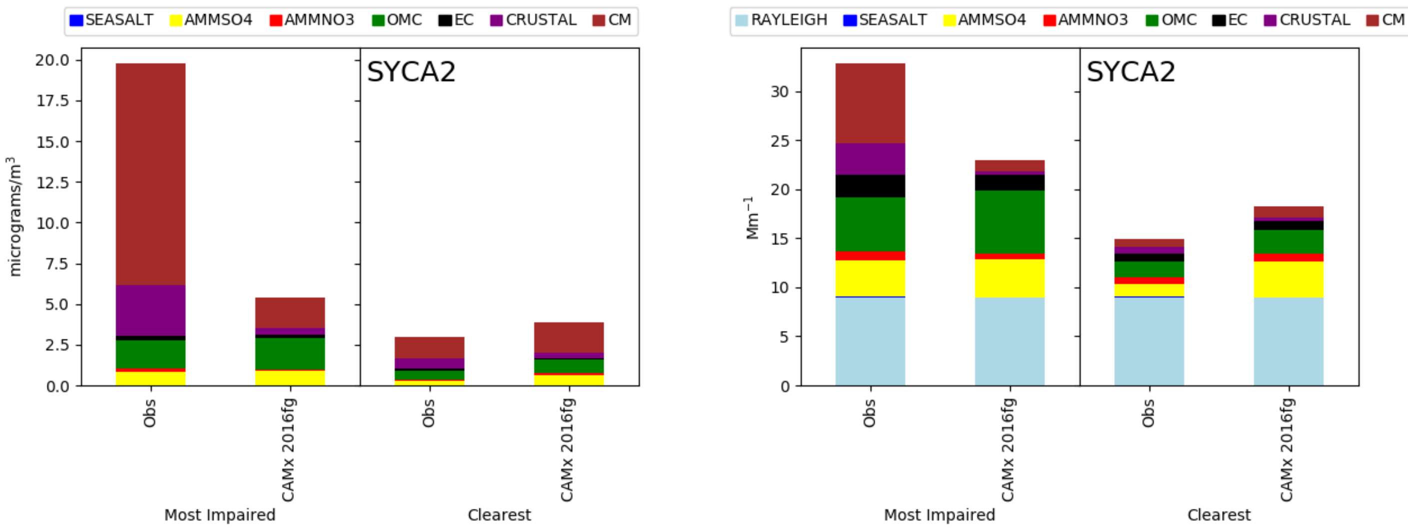


Figure 114. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Sycamore Canyon Wilderness (AZ) on the observed 20% most impaired and observed 20% clearest days.

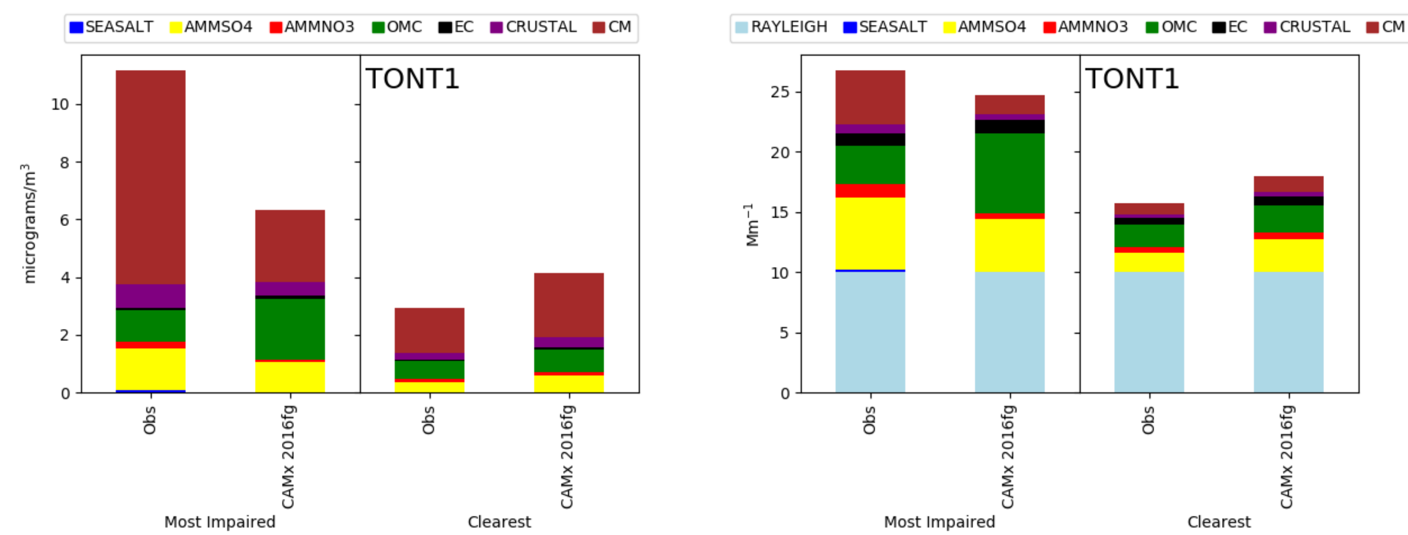


Figure 115. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Superstition Wilderness (AZ) on the observed 20% most impaired and observed 20% clearest days.

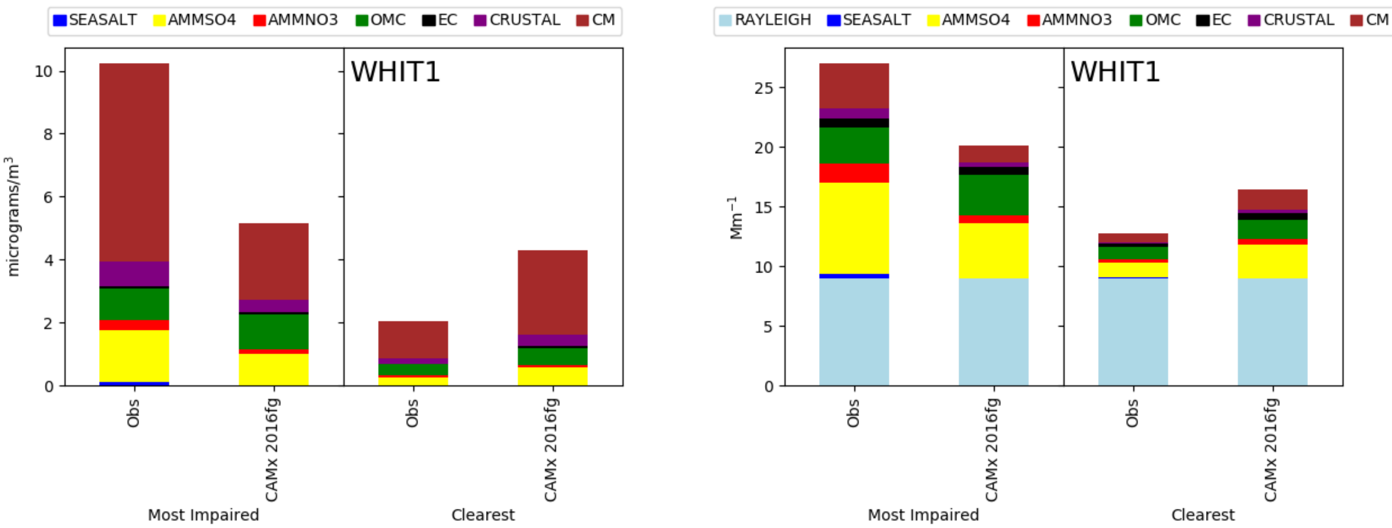


Figure 116. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the White Mountain Wilderness (NM) on the observed 20% most impaired and observed 20% clearest days.

Southern Arizona

- Chiricahua National Monument (AZ), Chiricahua Wilderness (AZ), and Galiuro Wilderness (AZ)(CHIR1)
- Saguaro National Monument (AZ)(SAGU1)

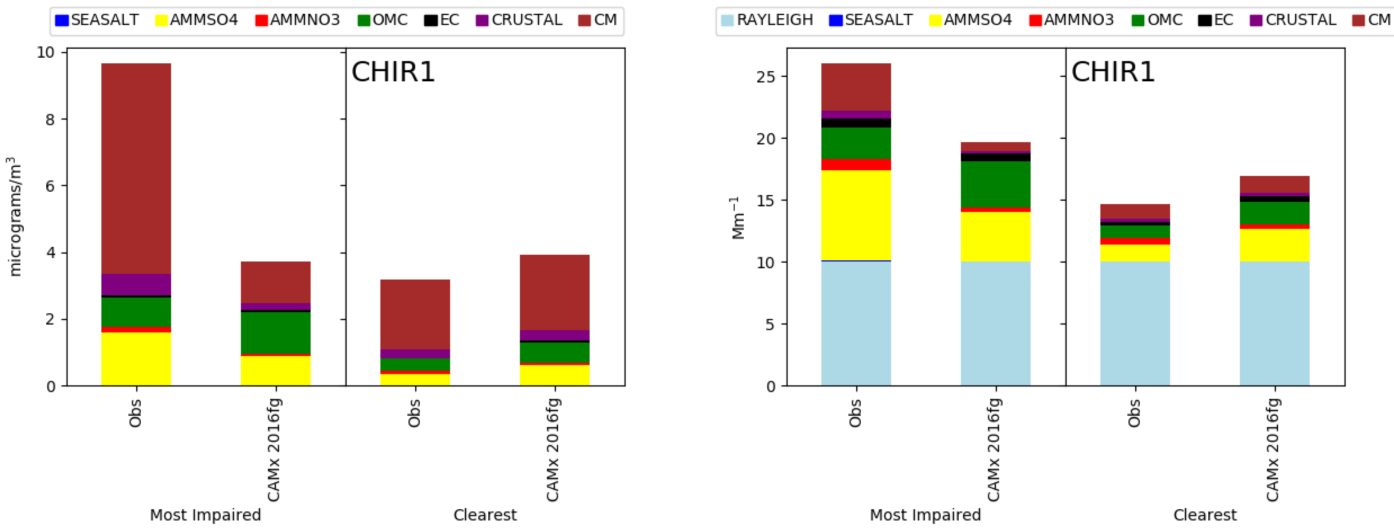


Figure 117. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Chiricahua National Monument (AZ), Chiricahua Wilderness (AZ), and Galiuro Wilderness (AZ) on the observed 20% most impaired and observed 20% clearest days.

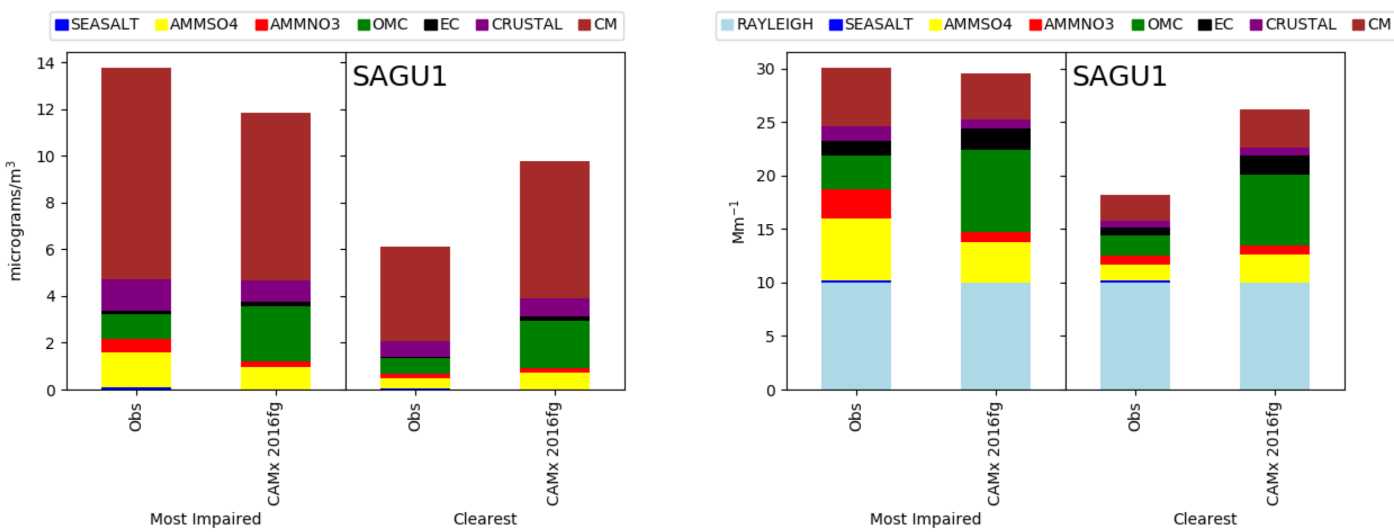


Figure 118. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Saguaro National Monument (AZ) on the observed 20% most impaired and observed 20% clearest days.

West Texas

- Big Bend National Park (TX)(BIBE1)
- Carlsbad Caverns National Park (TX) and Guadalupe Mountains National Park (TX)(GUMO1)
- Salt Creek (NM)(SACR1)

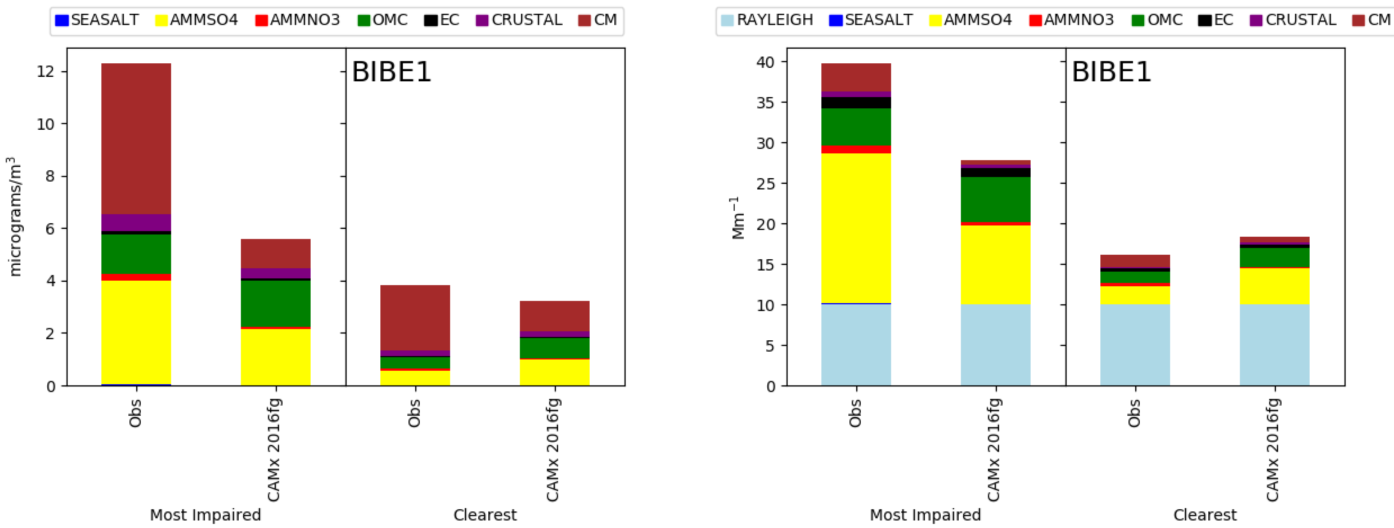


Figure 119. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Big Bend National Park (TX) on the observed 20% most impaired and observed 20% clearest days.

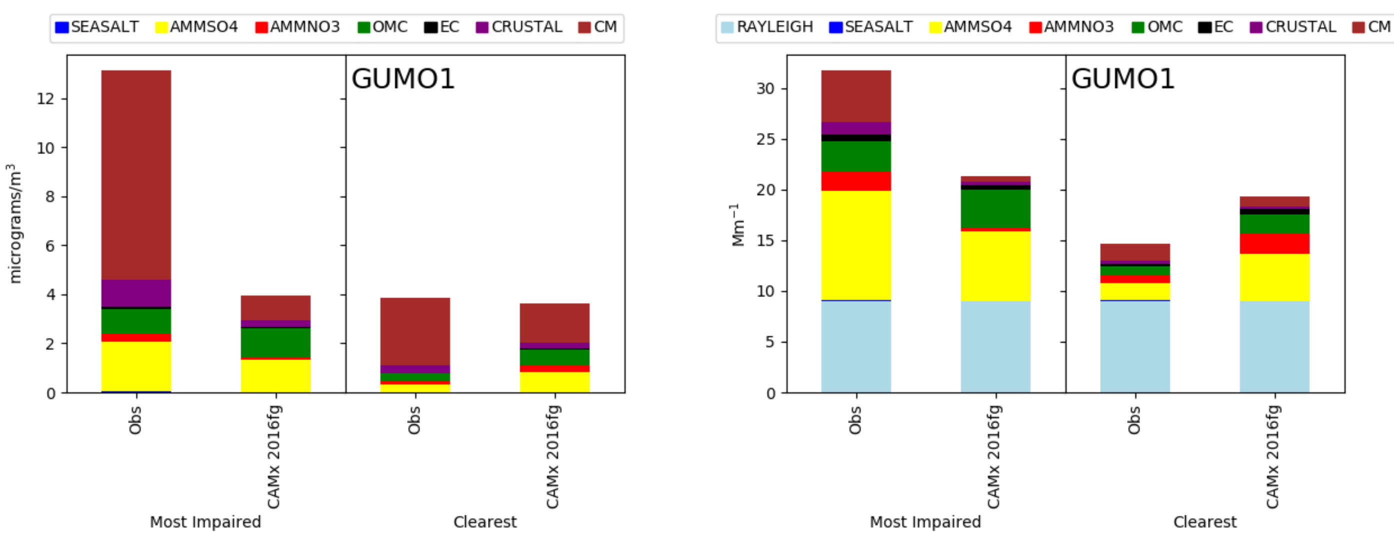


Figure 120. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Carlsbad Caverns National Park (TX) and Guadalupe Mountains National Park (TX) on the observed 20% most impaired and observed 20% clearest days.

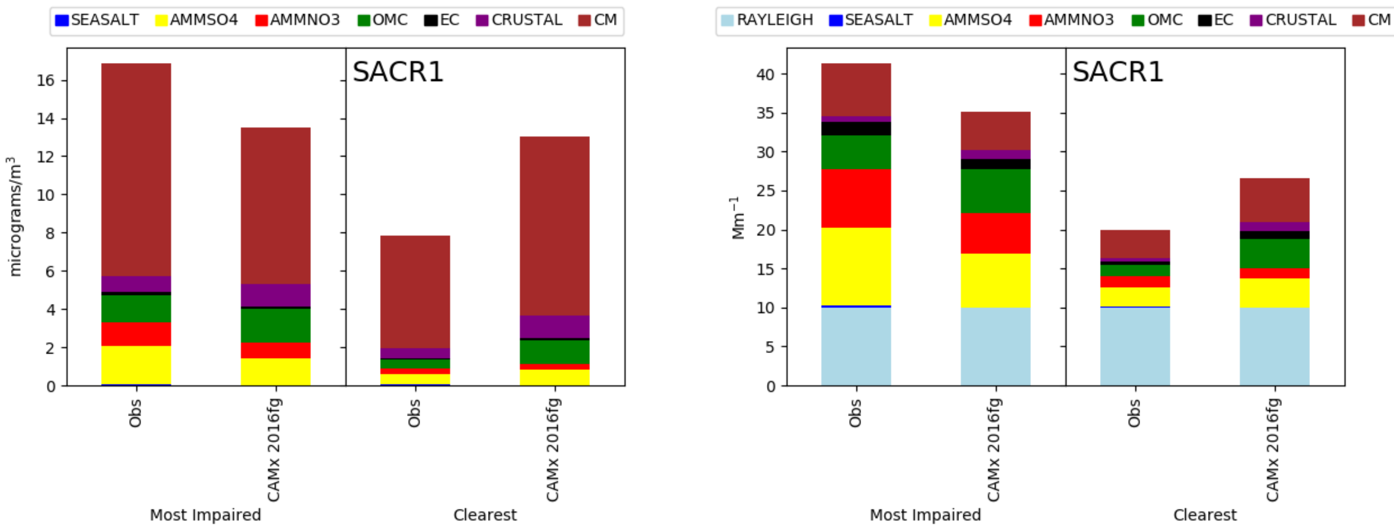


Figure 121. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Salt Creek (NM) on the observed 20% most impaired and observed 20% clearest days.

Northern Great Plains

- Badlands National Park (SD)(BADL1)
- Lostwood (ND)(LOST1)
- Medicine Lake (MT)(MELA1)
- Theodore Roosevelt National Park (ND)(THRO1)
- UL Bend (MT)(ULBE1)
- Wind Cave National Park (SD)(WICA1)

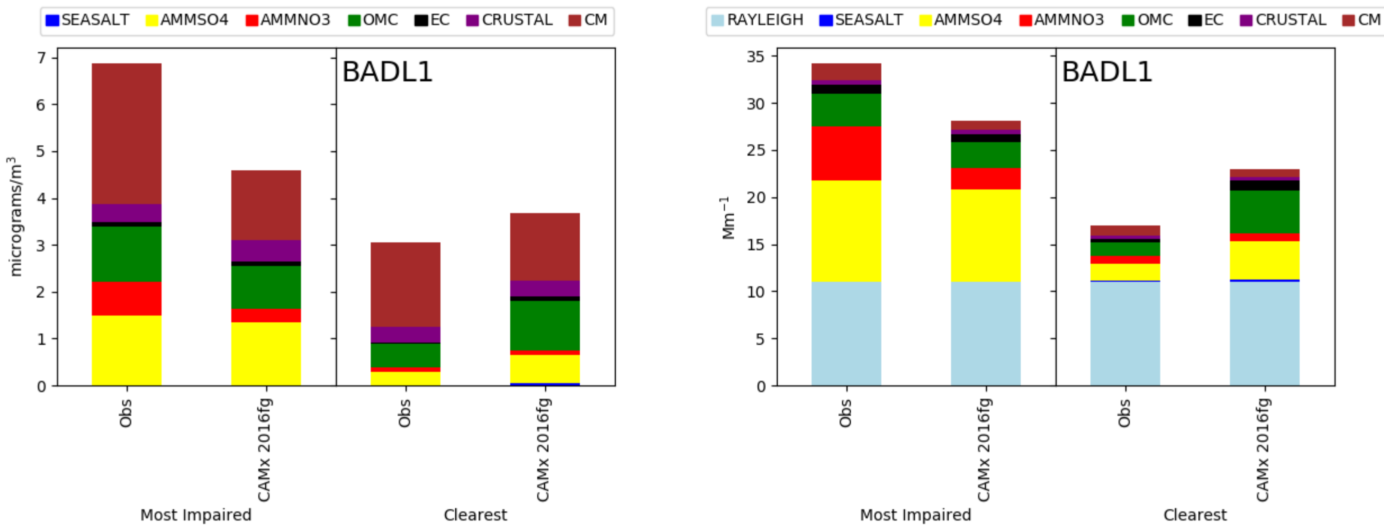


Figure 122. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Badlands National Park (SD) on the observed 20% most impaired and observed 20% clearest days.

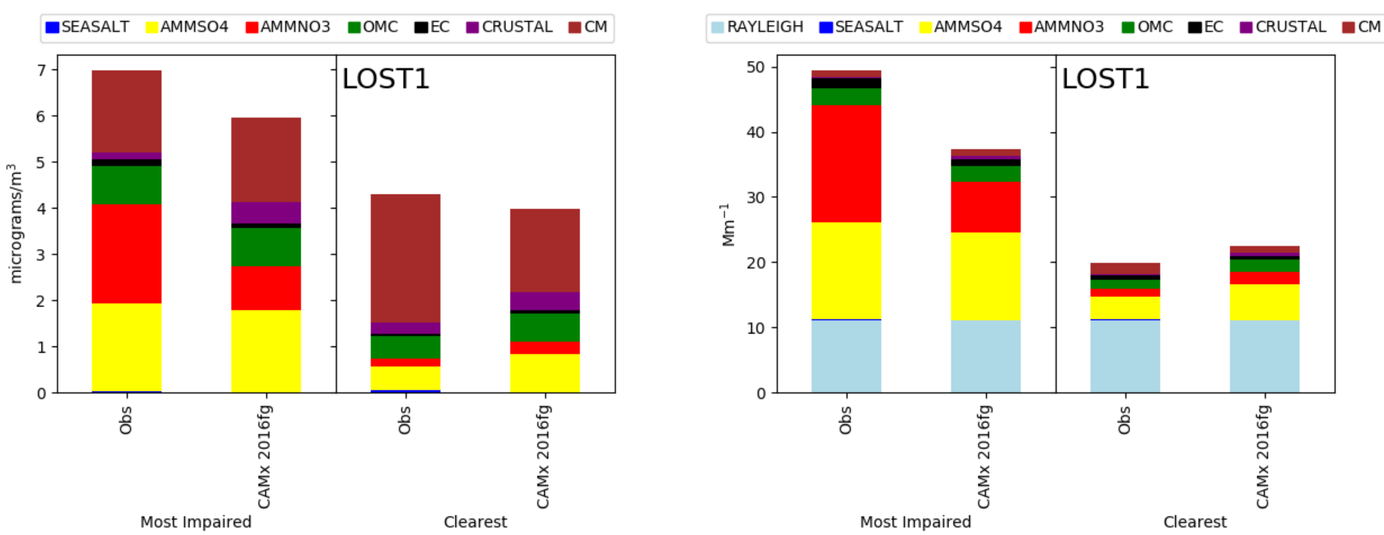


Figure 123. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Lostwood (ND) on the observed 20% most impaired and observed 20% clearest days.

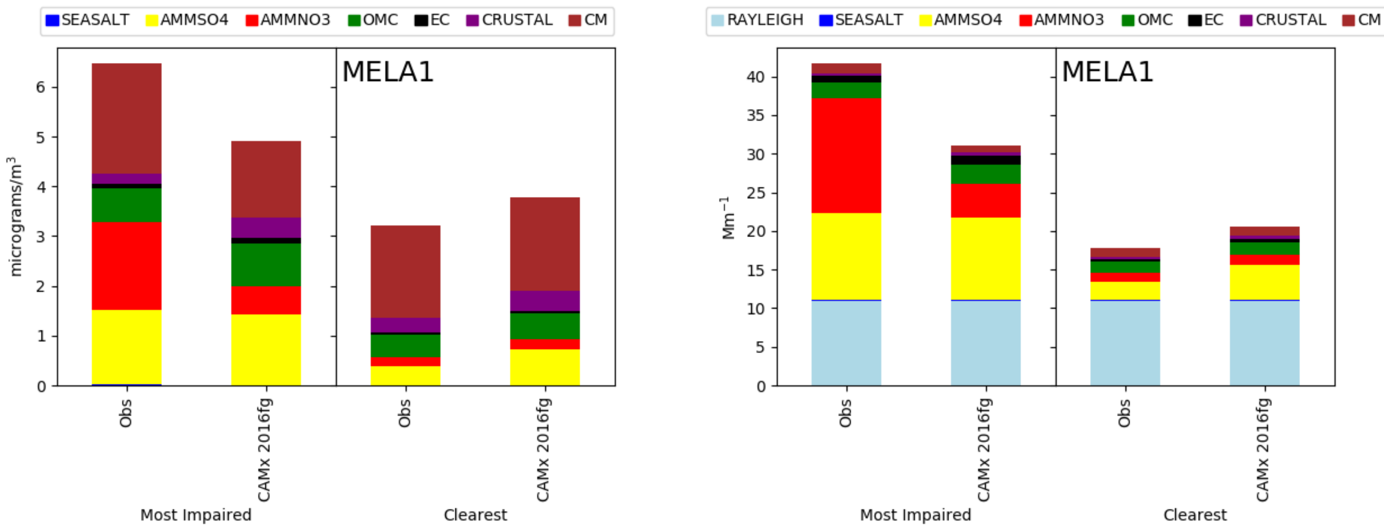


Figure 124. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Medicine Lake (MT) on the observed 20% most impaired and observed 20% clearest days.

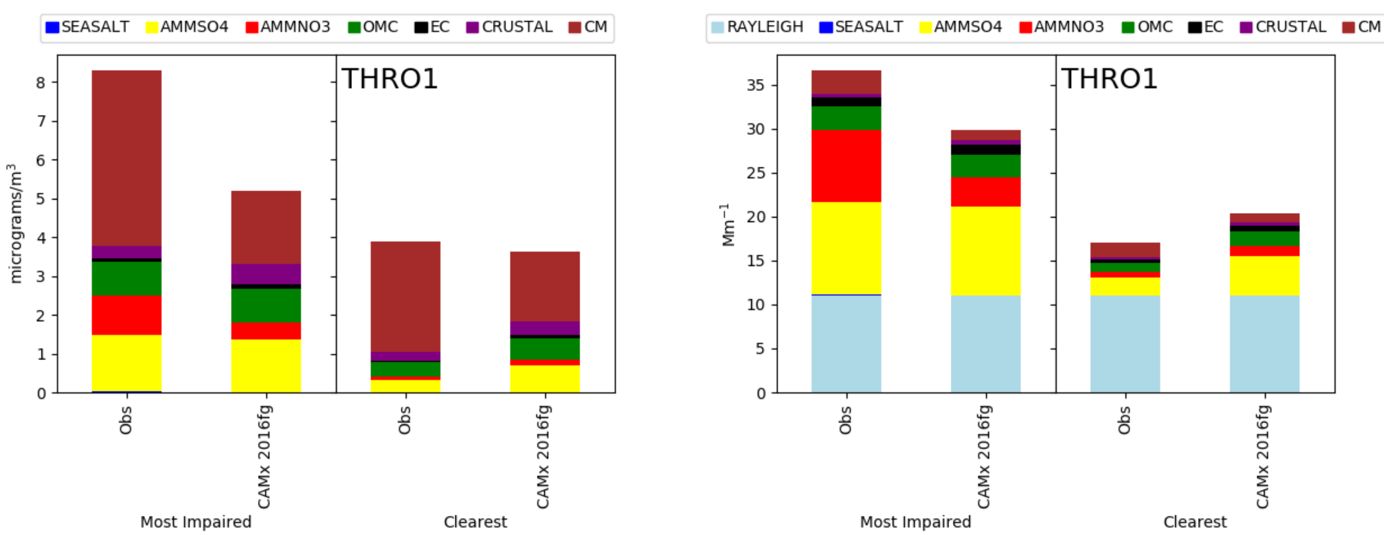


Figure 125. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Theodore Roosevelt National Park (ND) on the observed 20% most impaired and observed 20% clearest days.

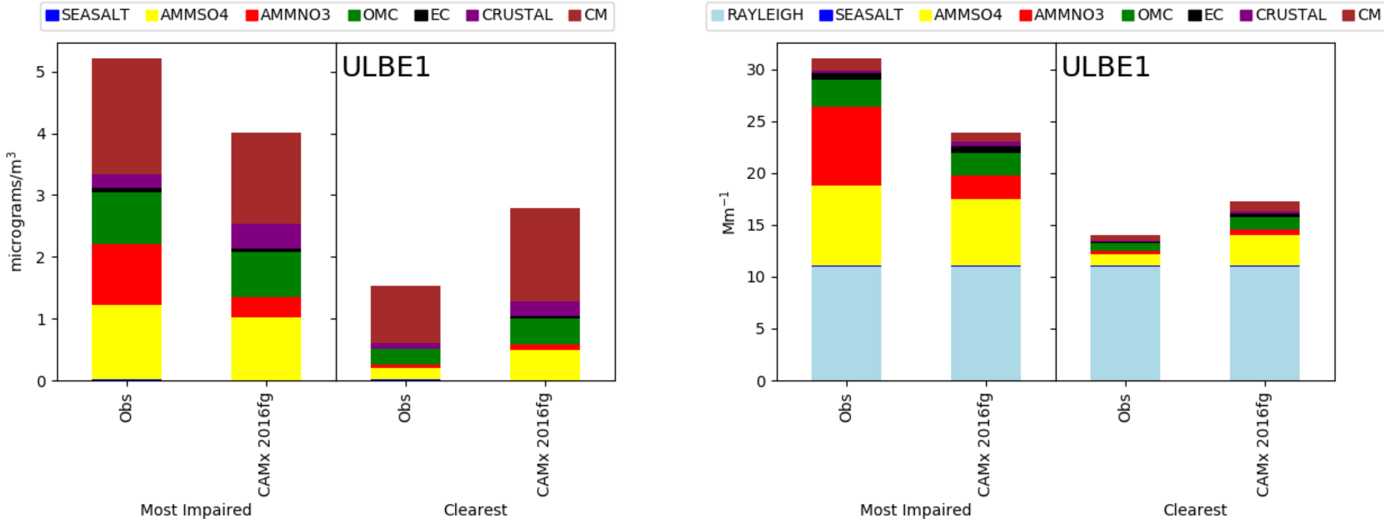


Figure 126. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the UL Bend (MT) on the observed 20% most impaired and observed 20% clearest days.

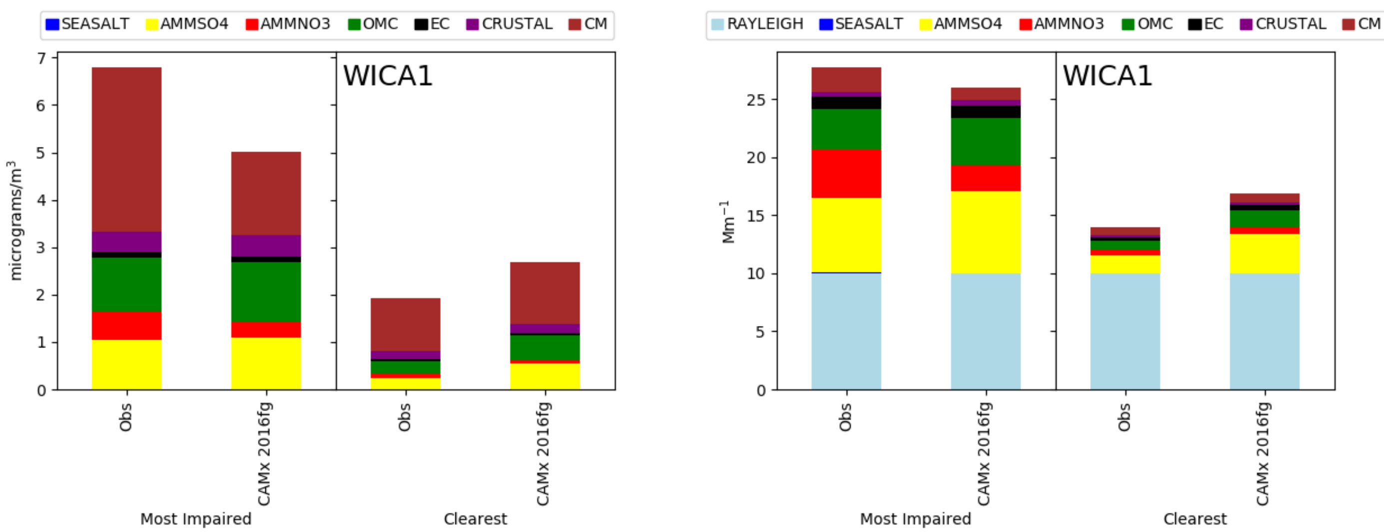


Figure 127. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Wind Cave National Park (SD) on the observed 20% most impaired and observed 20% clearest days.

Mid South

- Caney Creek Wilderness (AR)(CACR1)
- Hercules-Glades Wilderness (MO)(HEGL1)
- Upper Buffalo Wilderness (AR)(UPBU1)
- Wichita Mountains (OK)(WIMO1)

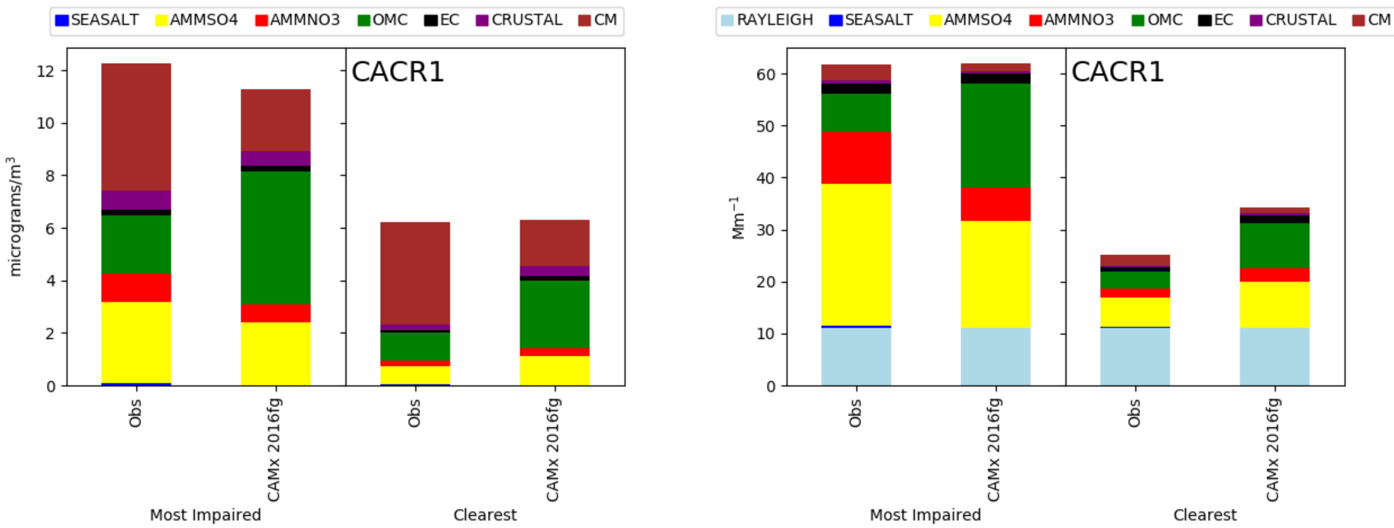


Figure 128. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Caney Creek Wilderness (AR) on the observed 20% most impaired and observed 20% clearest days.

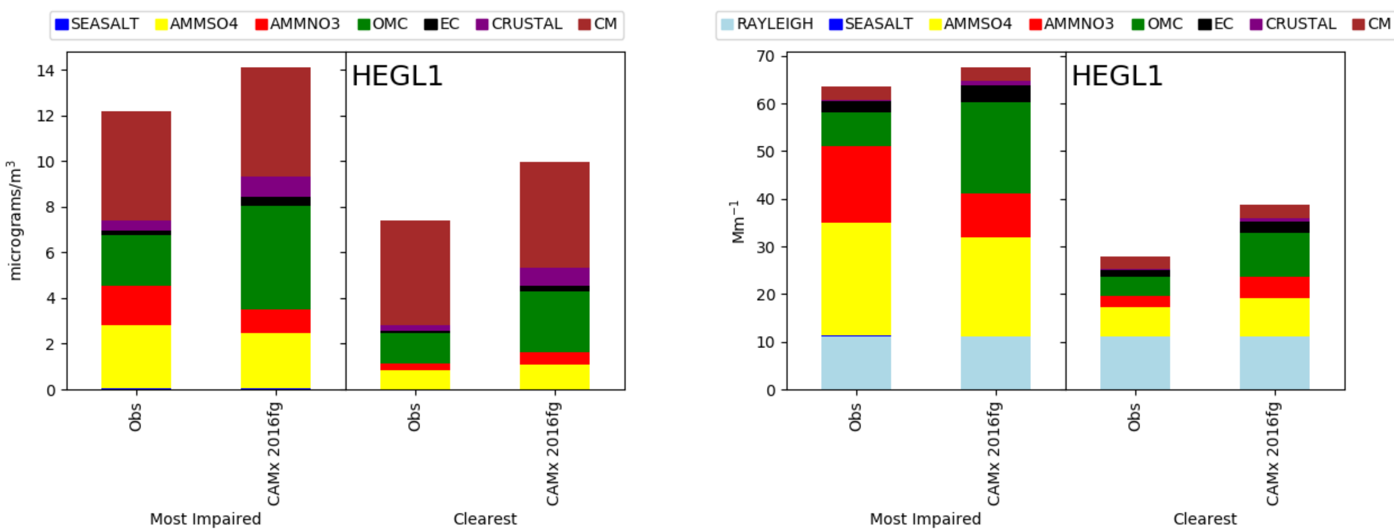


Figure 129. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Hercules-Glades Wilderness (MO) on the observed 20% most impaired and observed 20% clearest days.

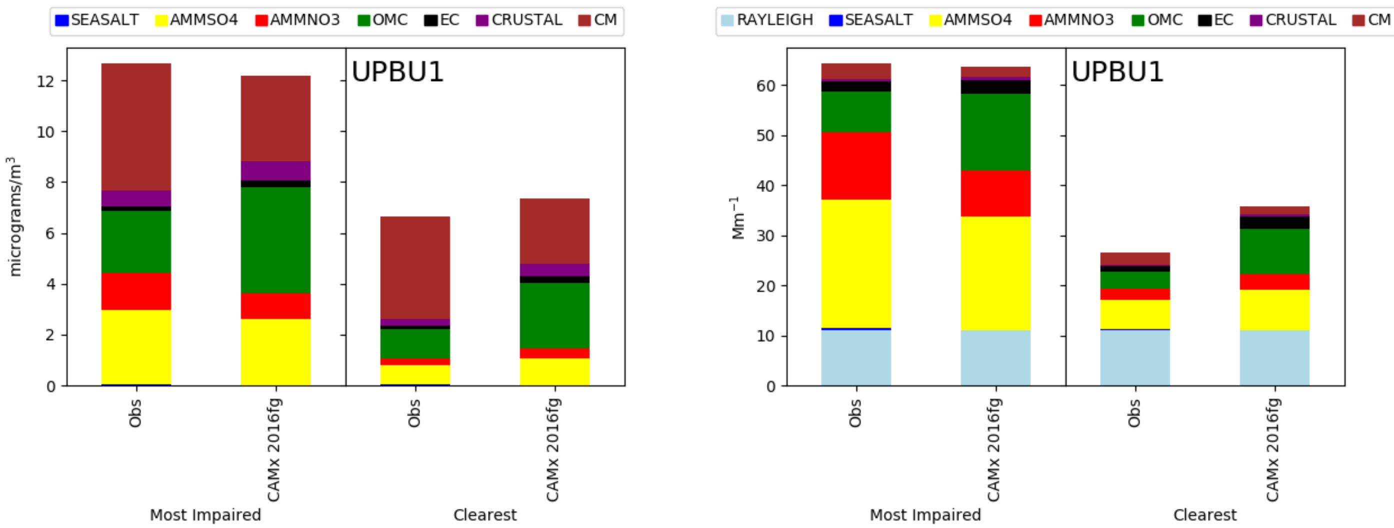


Figure 130. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Upper Buffalo Wilderness (AR) on the observed 20% most impaired and observed 20% clearest days.

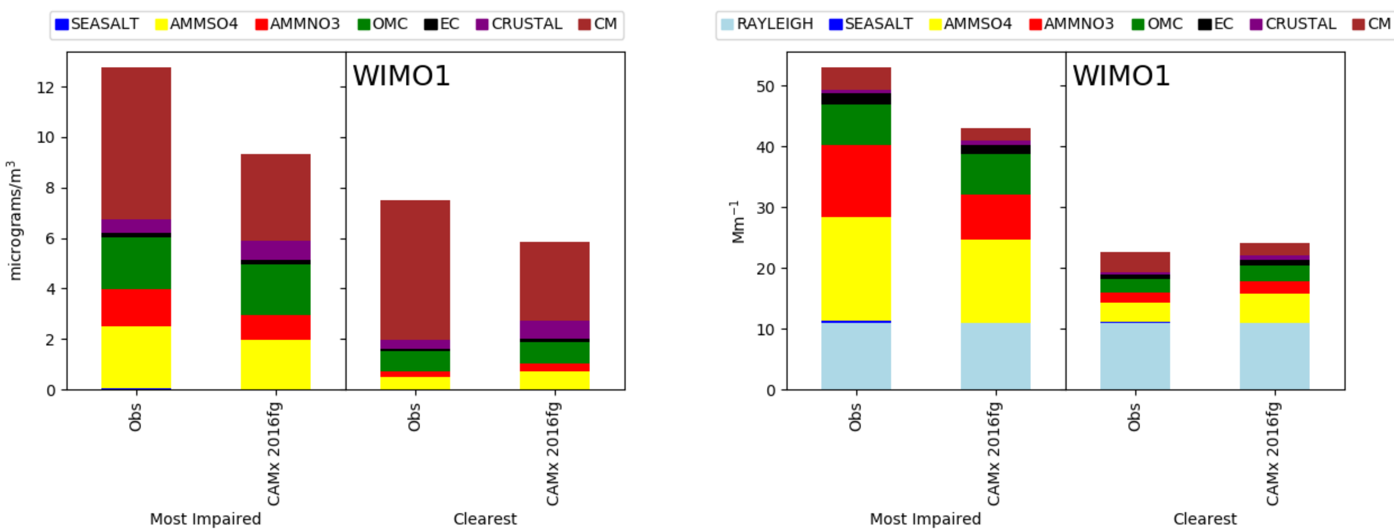


Figure 131. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Wichita Mountains (OK) on the observed 20% most impaired and observed 20% clearest days.

Boundary Waters

- Boundary Waters Canoe Area (MN)(BOWA1)
- Isle Royale National Park (MI)(ISLE1)
- Seney (MI)(SENE1)
- Voyageurs National Park (MN)(VOYA2)

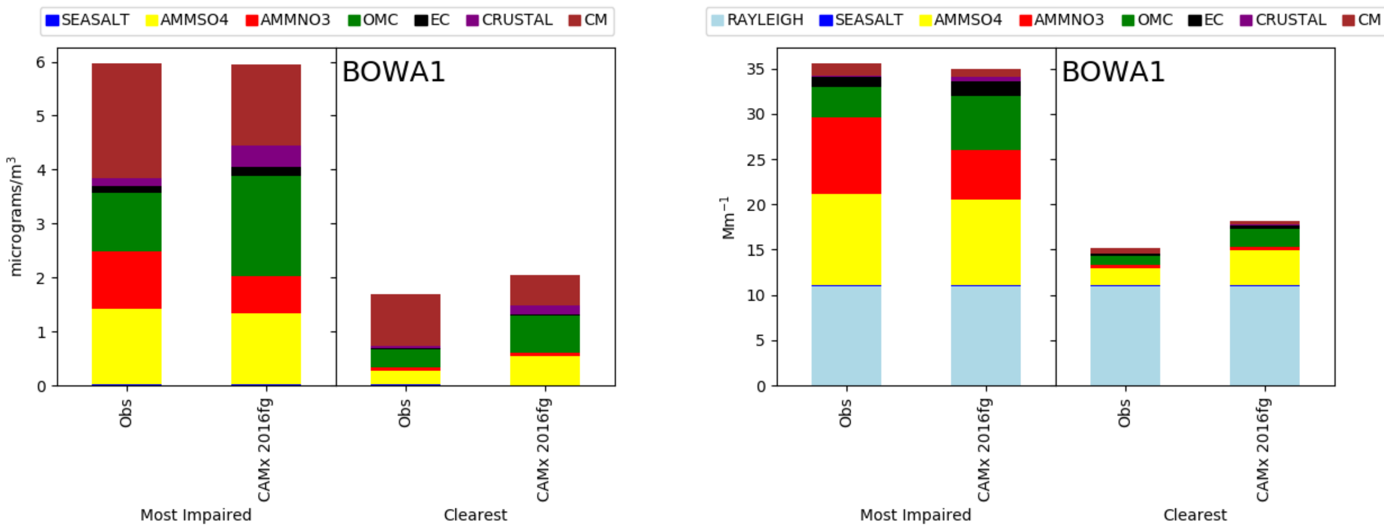


Figure 132. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Boundary Waters Canoe Area (MN) on the observed 20% most impaired and observed 20% clearest days.

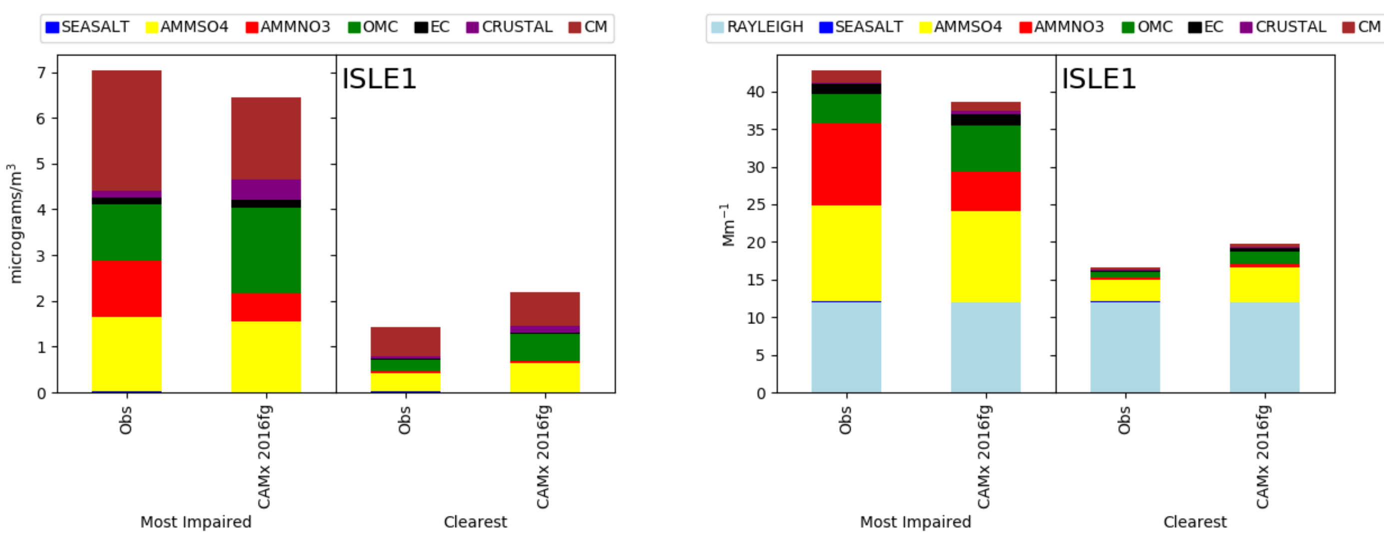


Figure 133. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Isle Royale National Park (MI) on the observed 20% most impaired and observed 20% clearest days.

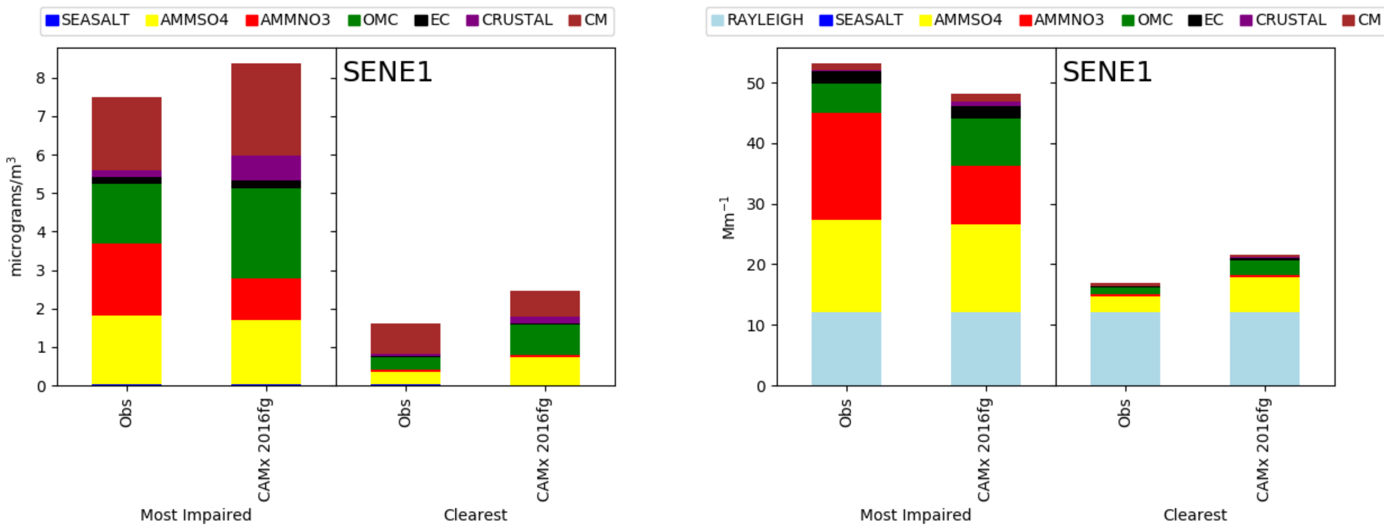


Figure 134. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Seney (MI) on the observed 20% most impaired and observed 20% clearest days.

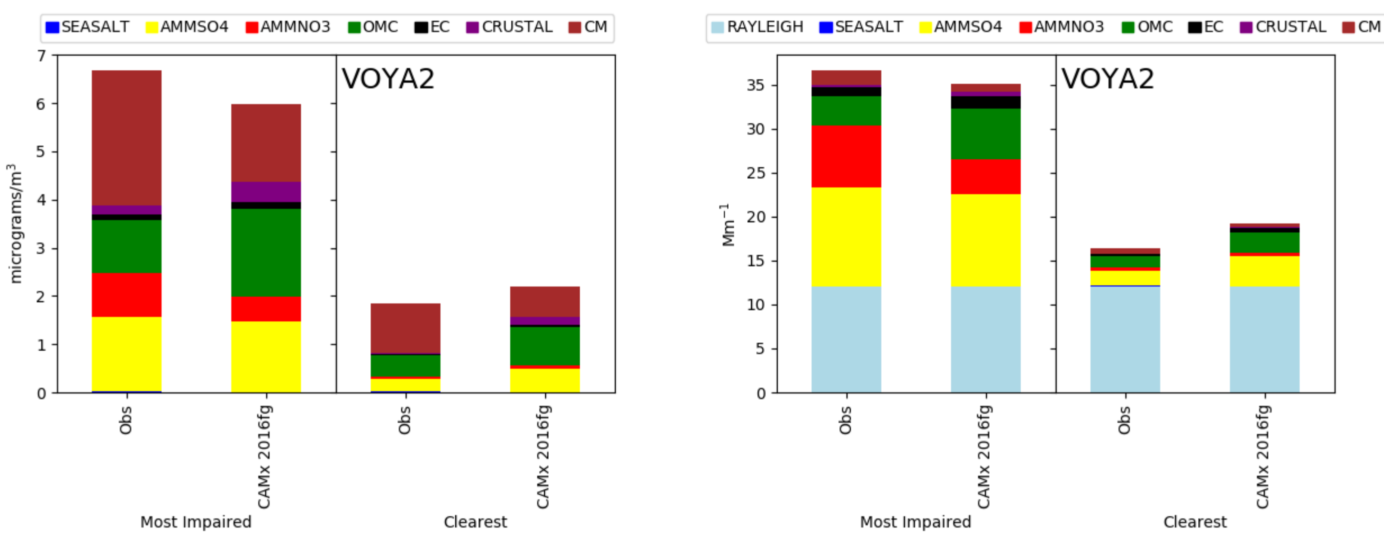


Figure 135. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Voyageurs National Park (MN) on the observed 20% most impaired and observed 20% clearest days.

Appalachia

- Cohutta Wilderness (GA)(COHU1)
- Dolly Sods Wilderness (WV) and Otter Creek Wilderness (WV)(DOSO1)
- Great Smoky Mountains National Park (TN) and Joyce-Kilmer-Slickrock Wilderness (TN)(GRSM1)
- James River Face Wilderness (VA)(JARI1)
- Linville Gorge Wilderness (NC)(LIGO1)
- Shenandoah National Park (VA)(SHEN1)
- Shining Rock Wilderness (NC)(SHRO1)
- Sipsey Wilderness (AL)(SIPS1)

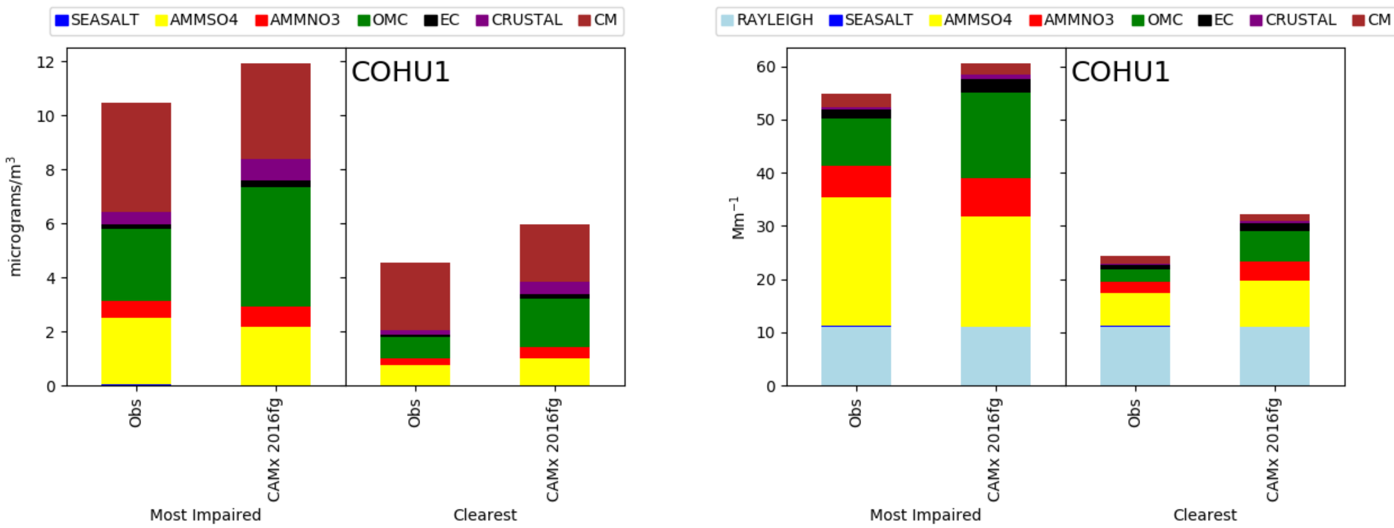


Figure 136. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Cohutta Wilderness (GA) on the observed 20% most impaired and observed 20% clearest days.

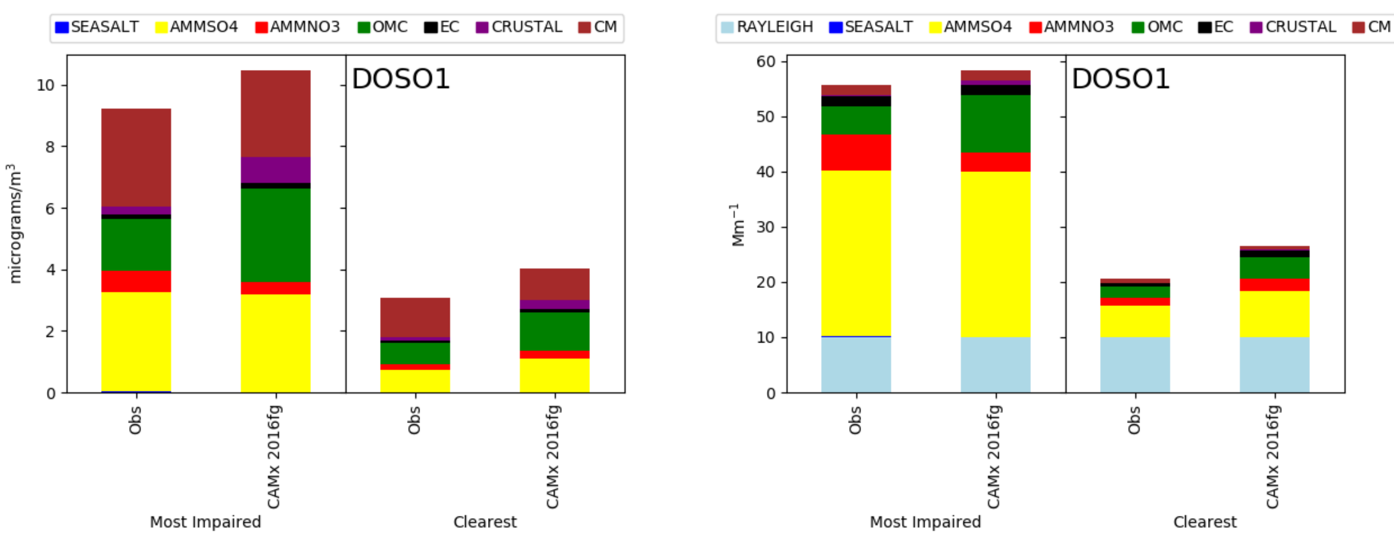


Figure 137. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Dolly Sods Wilderness (WV) and Otter Creek Wilderness (WV) on the observed 20% most impaired and observed 20% clearest days.

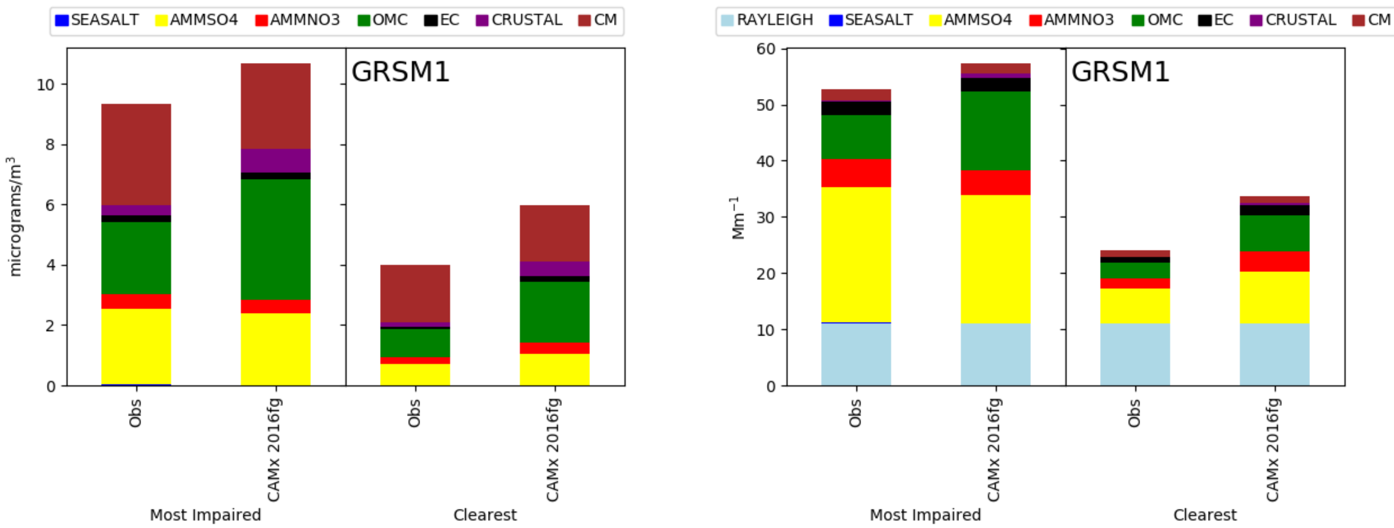


Figure 138. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Great Smoky Mountains National Park (TN) and Joyce-Kilmer-Slickrock Wilderness (TN) on the observed 20% most impaired and observed 20% clearest days.

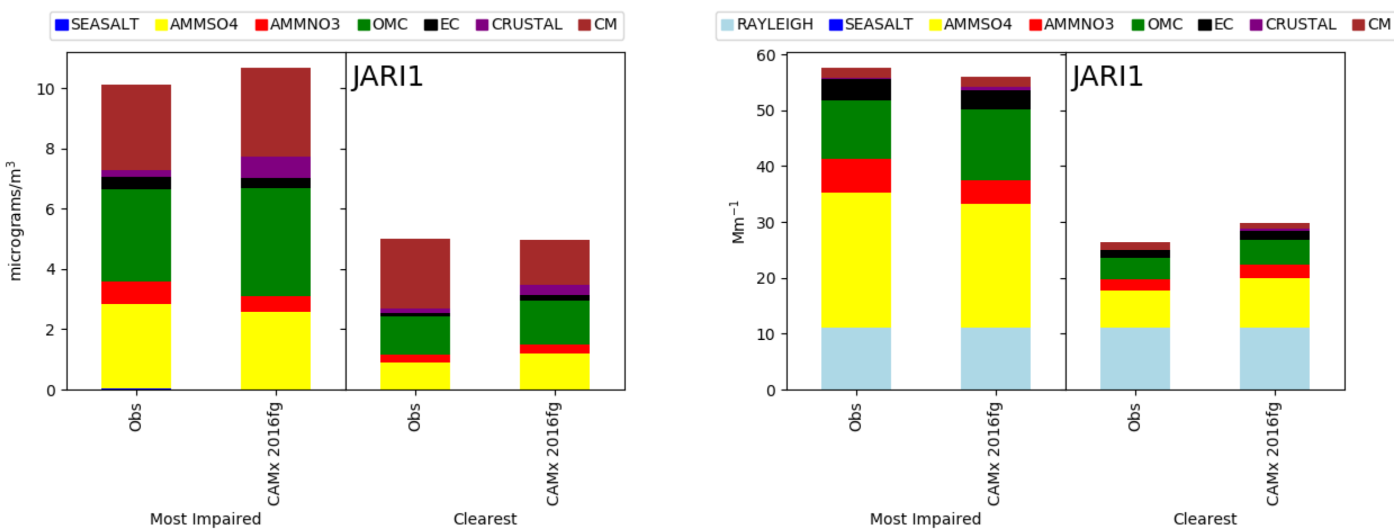


Figure 139. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the James River Face Wilderness (VA) on the observed 20% most impaired and observed 20% clearest days.

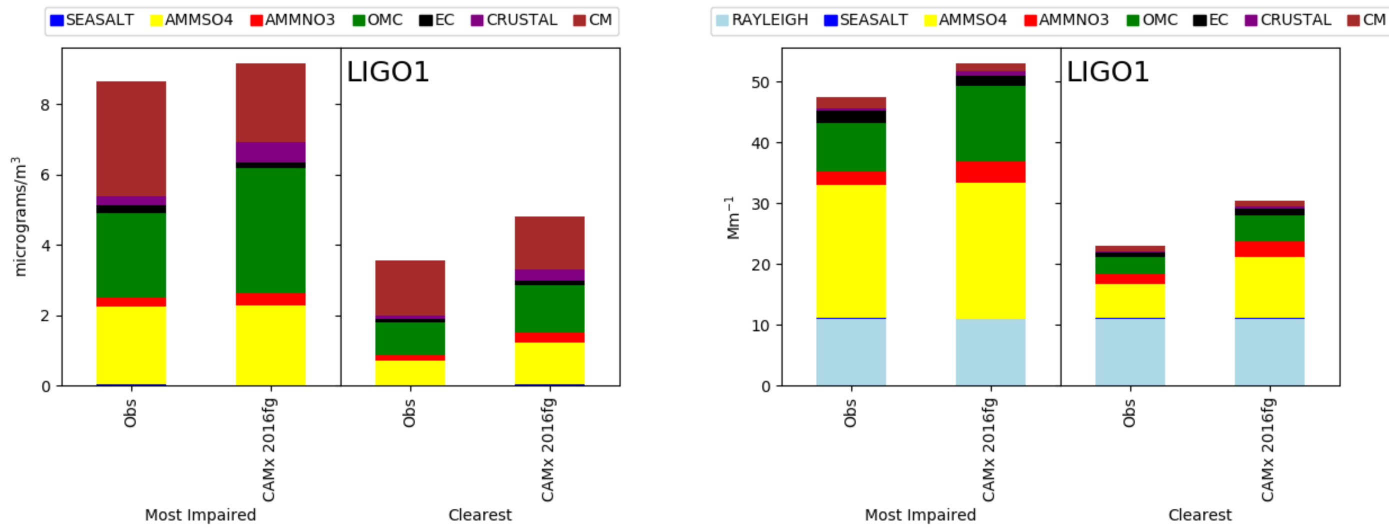


Figure 140. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Linville Gorge Wilderness (NC) on the observed 20% most impaired and observed 20% clearest days.

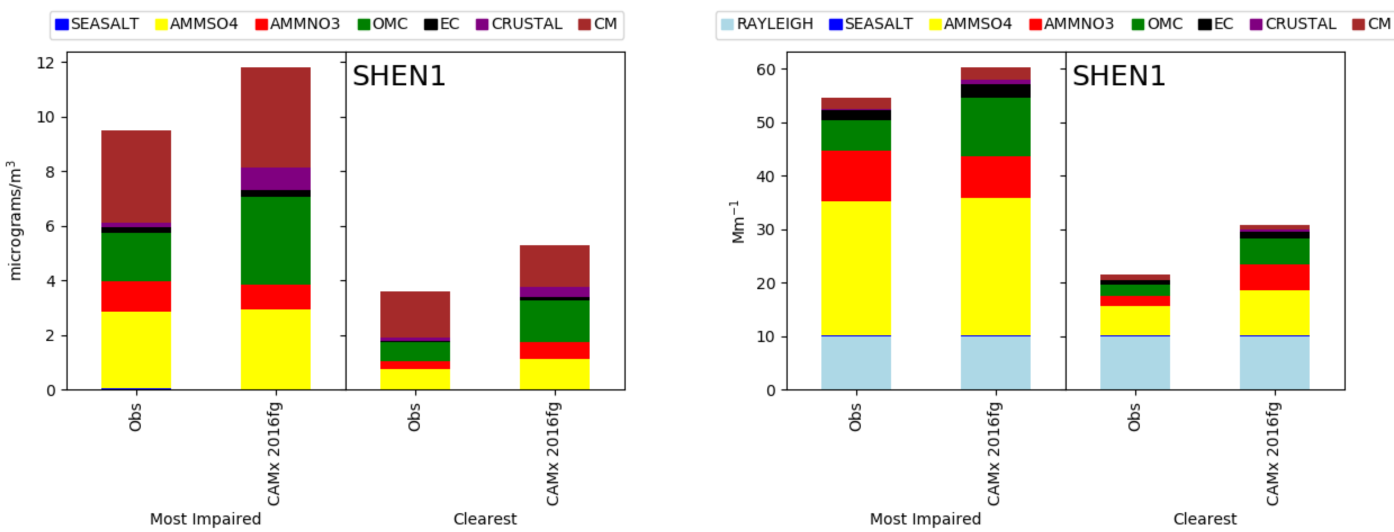


Figure 141. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Shenandoah National Park (VA) on the observed 20% most impaired and observed 20% clearest days.

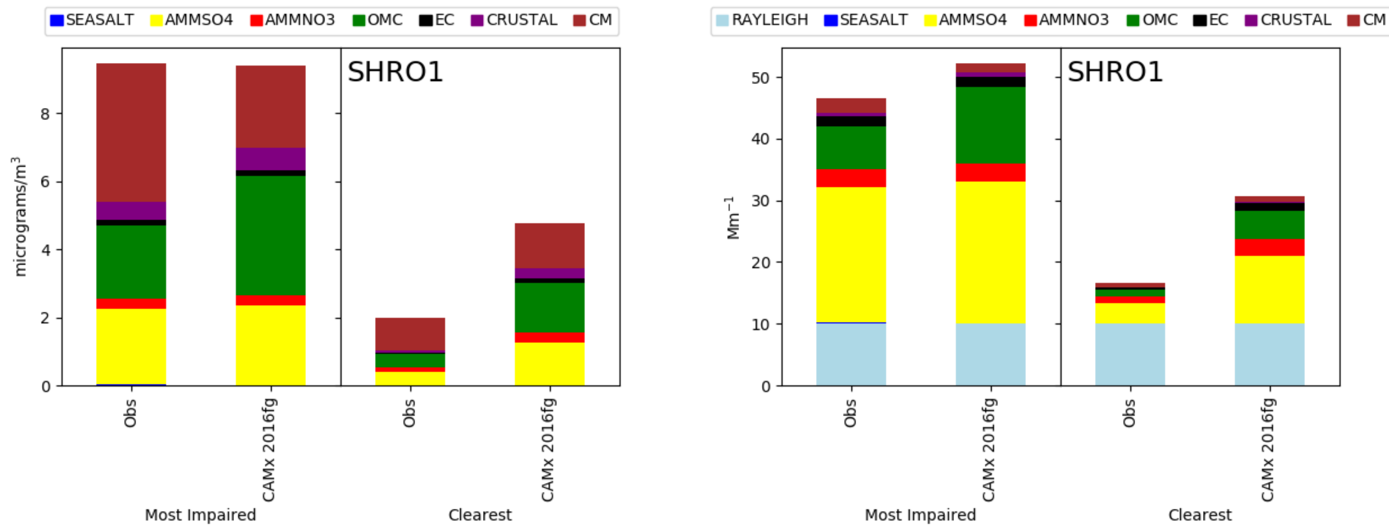


Figure 142. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Shining Rock Wilderness (NC) on the observed 20% most impaired and observed 20% clearest days.

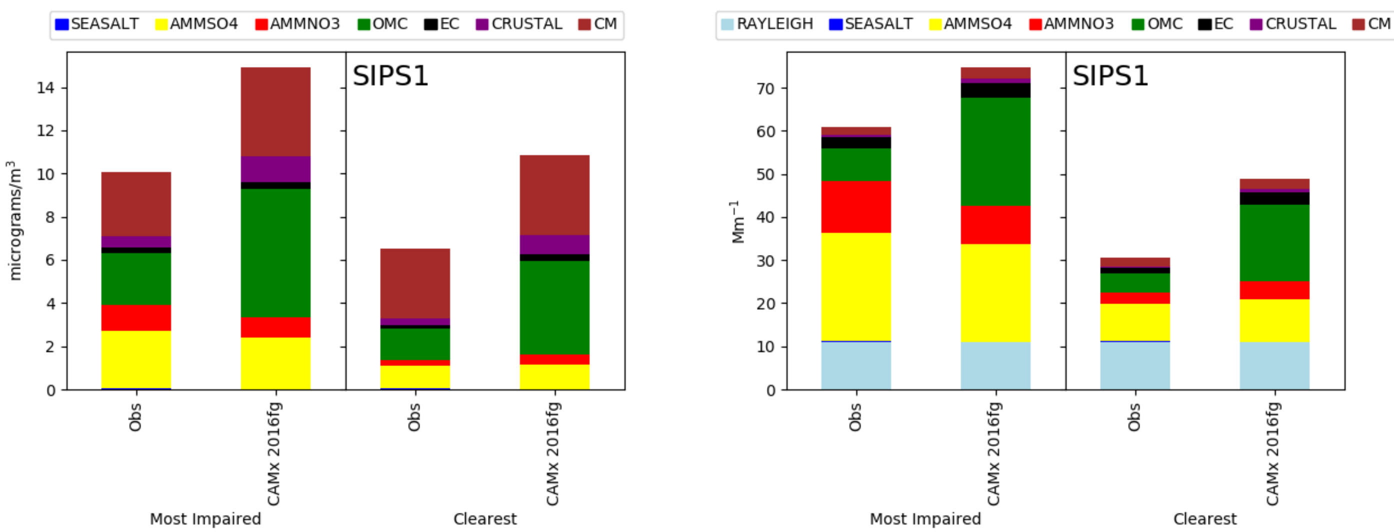


Figure 143. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Sipsey Wilderness (AL) on the observed 20% most impaired and observed 20% clearest days.

Ohio River Valley

- Mammoth Cave National Park (KY)(MACA1)
- Mingo (MO)(MING1)

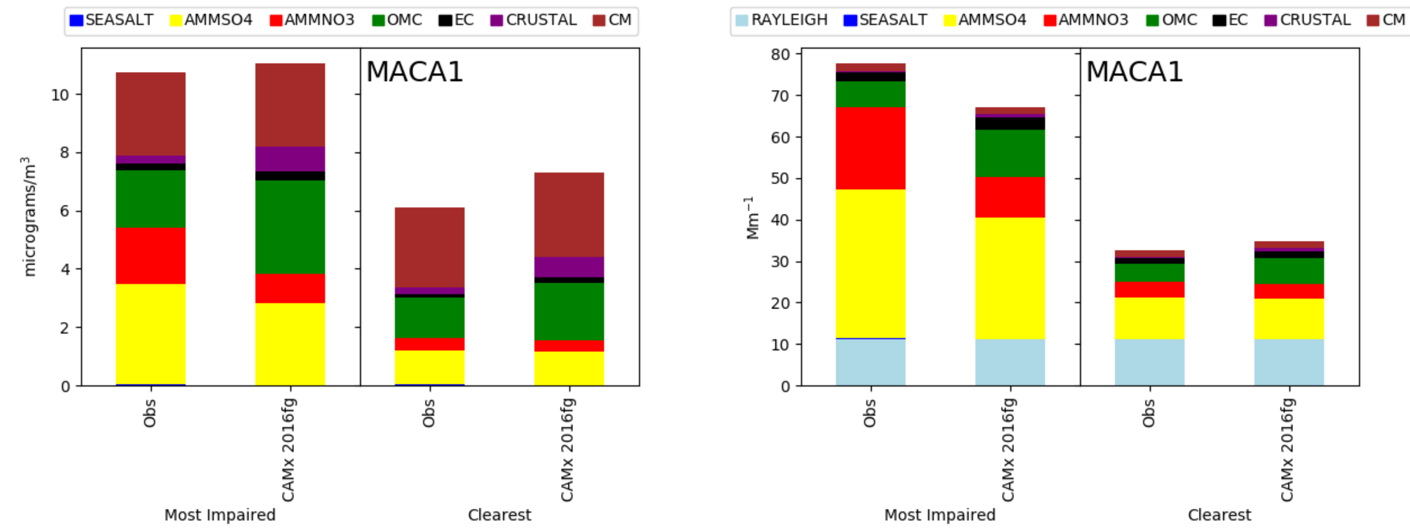


Figure 144. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mammoth Cave National Park (KY) on the observed 20% most impaired and observed 20% clearest days.

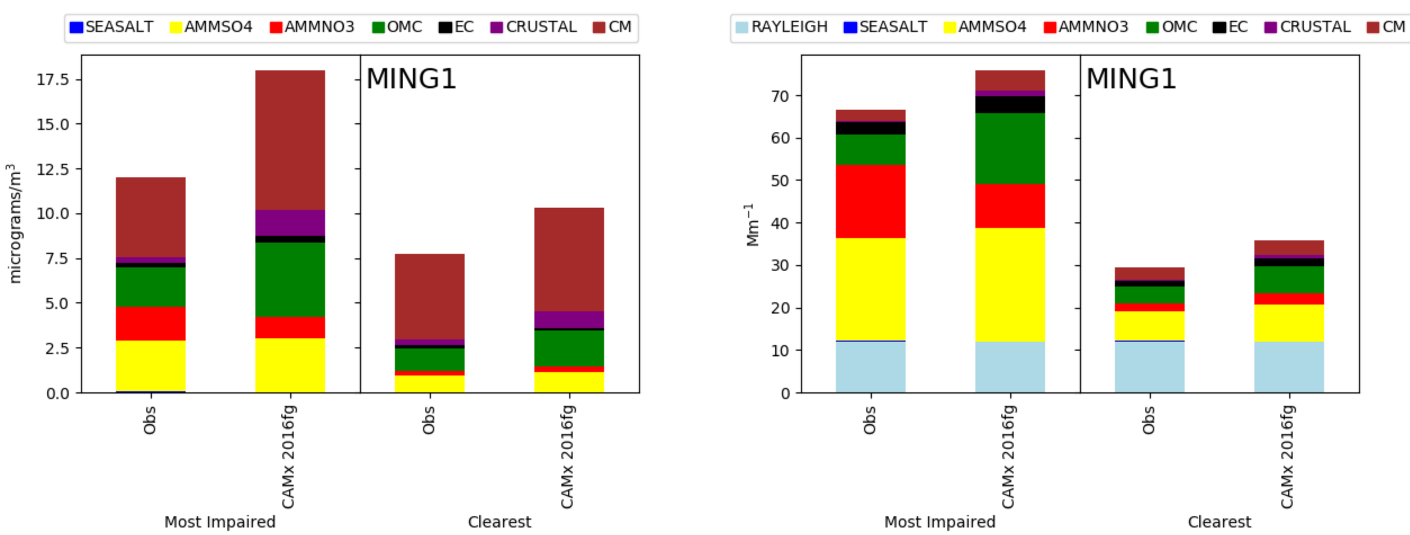


Figure 145. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Mingo (MO) on the observed 20% most impaired and observed 20% clearest days.

Southeast

- Breton (LA)(BRIS1)
- Chassahowitzka (FL)(CHAS1)
- Everglades National Park (FL)(EVER1)
- Okefenokee (GA) and Wolf Island (GA)(OKEF1)
- Cape Romain (SC)(ROMA1)
- St. Marks (FL)(SAMA1)

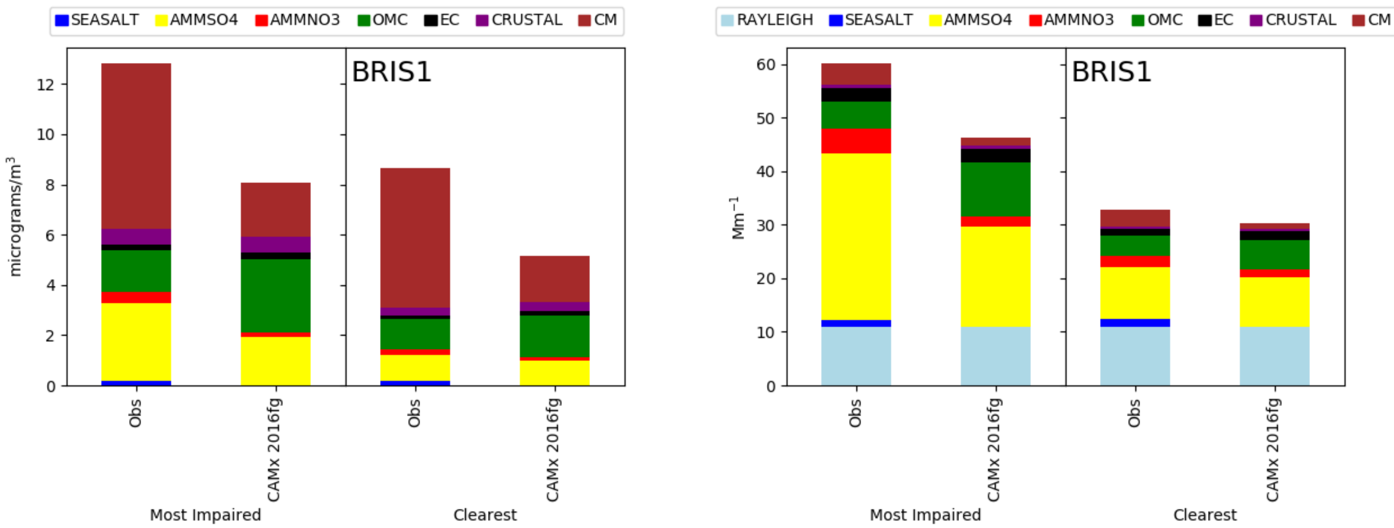


Figure 146. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Breton (LA) on the observed 20% most impaired and observed 20% clearest days.

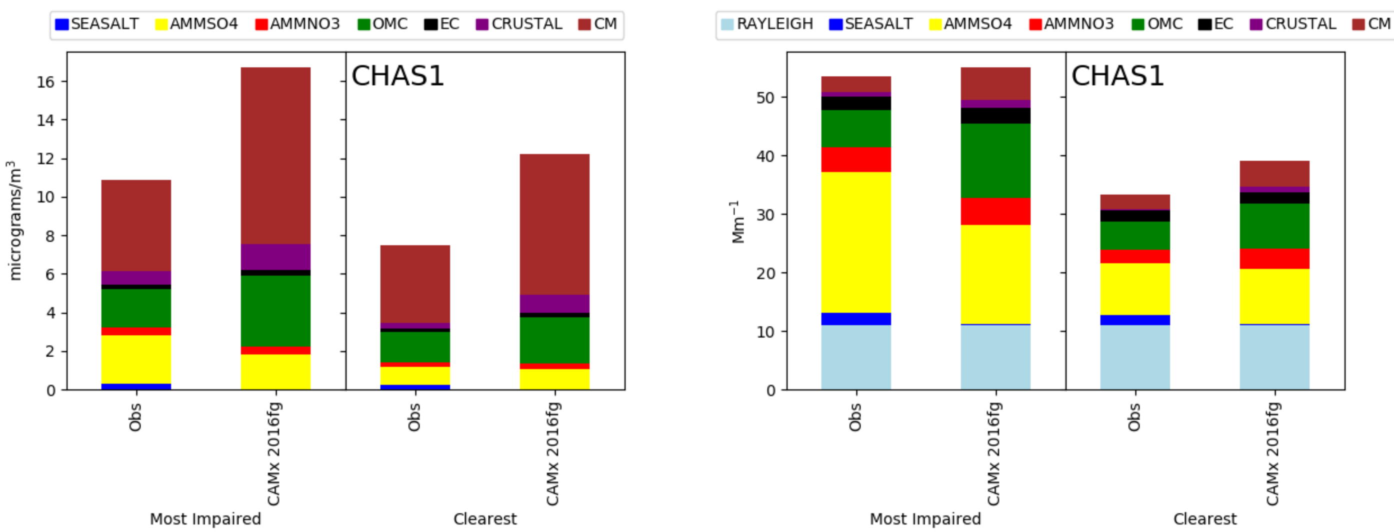


Figure 147. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Chassahowitzka (FL) on the observed 20% most impaired and observed 20% clearest days.

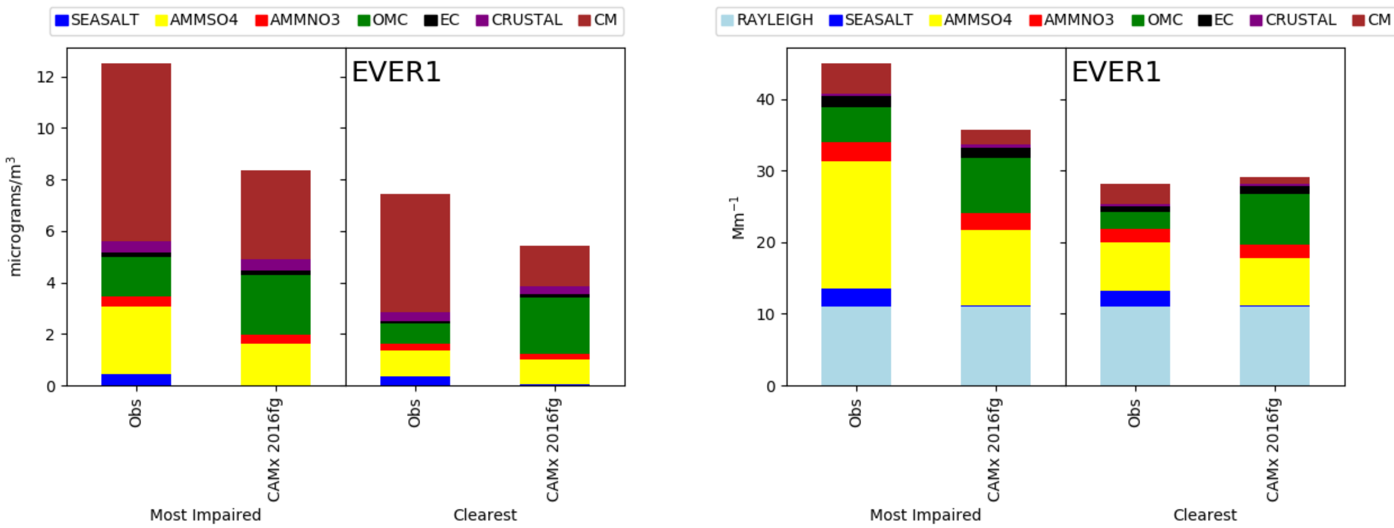


Figure 148. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Everglades National Park (FL) on the observed 20% most impaired and observed 20% clearest days.

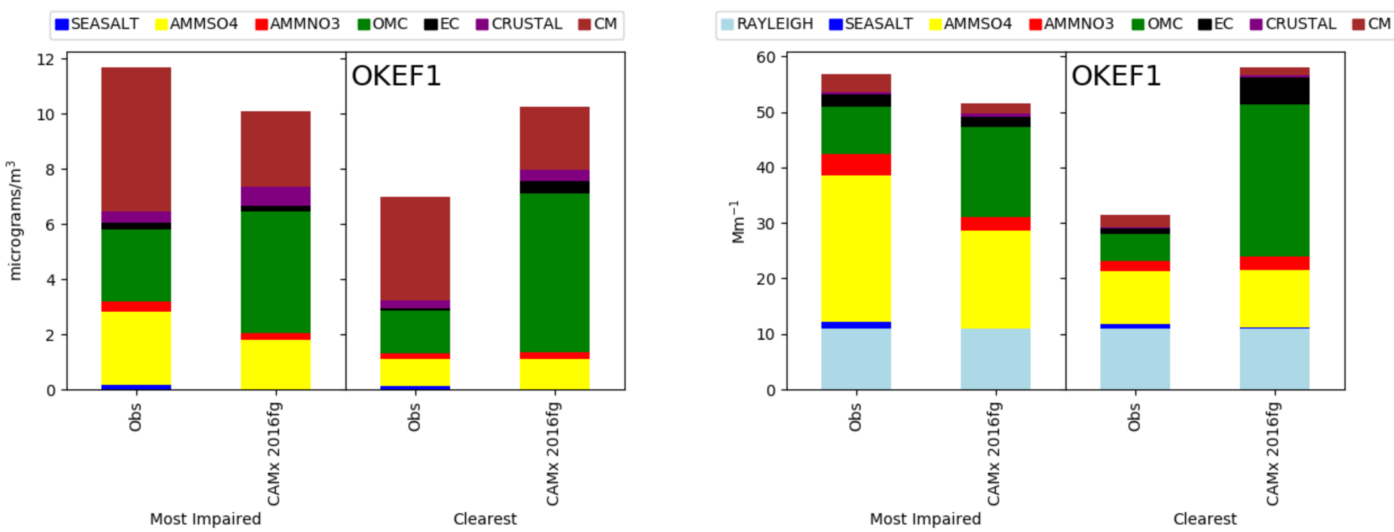


Figure 149. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Okefenokee (GA) and Wolf Island (GA) on the observed 20% most impaired and observed 20% clearest days.

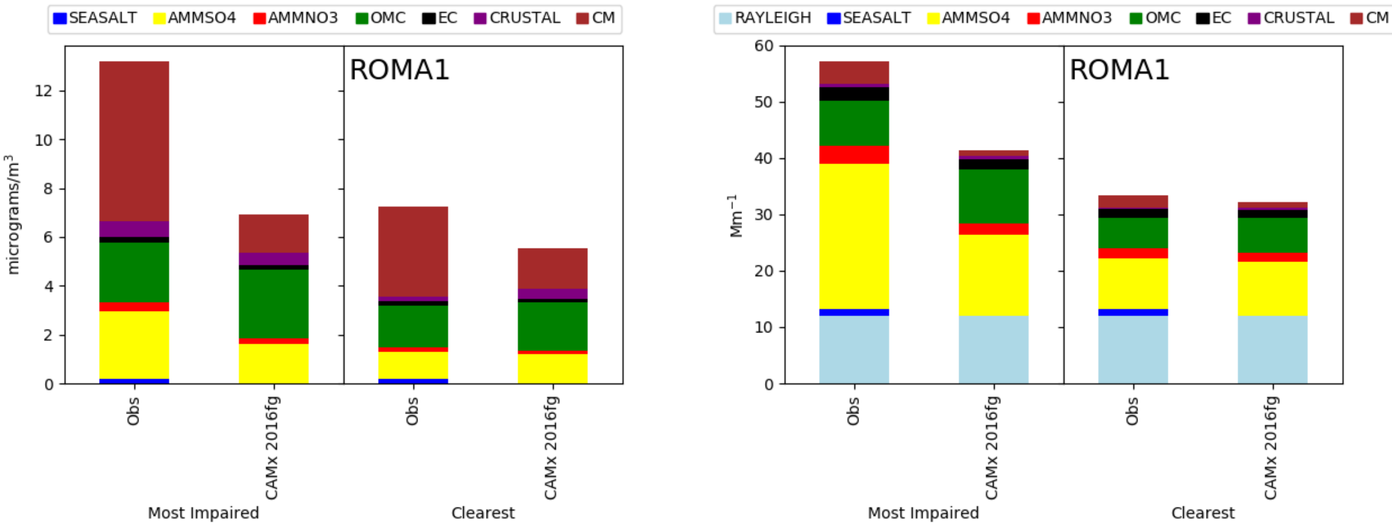


Figure 150. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Cape Romain (SC) on the observed 20% most impaired and observed 20% clearest days.

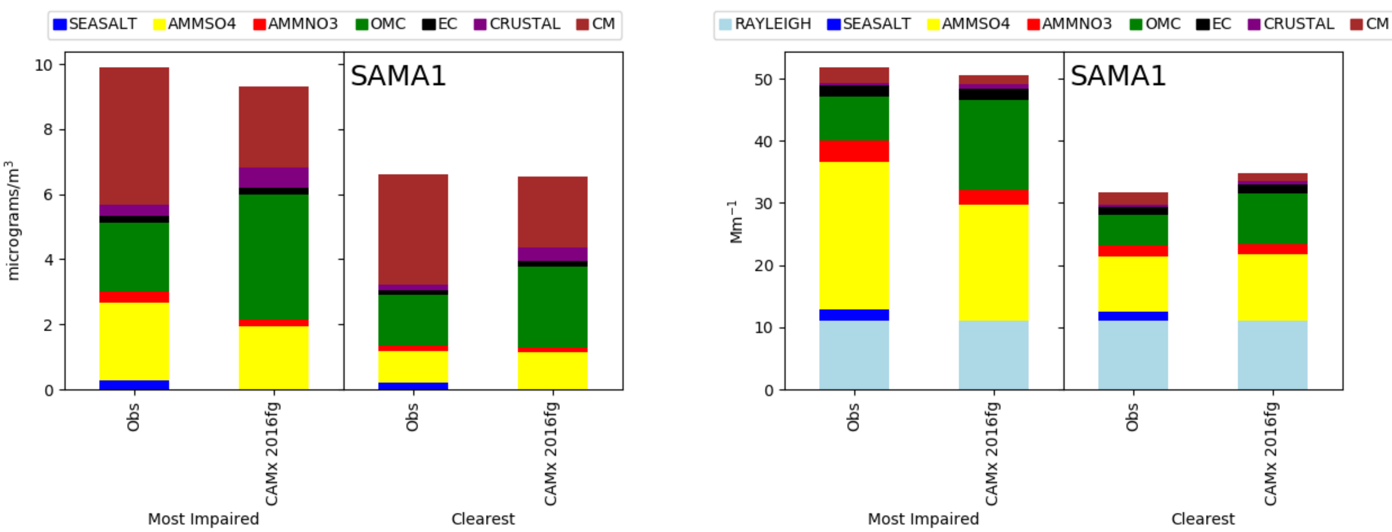


Figure 151. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the St. Marks (FL) on the observed 20% most impaired and observed 20% clearest days.

East Coast

- Brigantine (NJ)(BRIG1)
- Swanquarter (NC)(SWAN1)

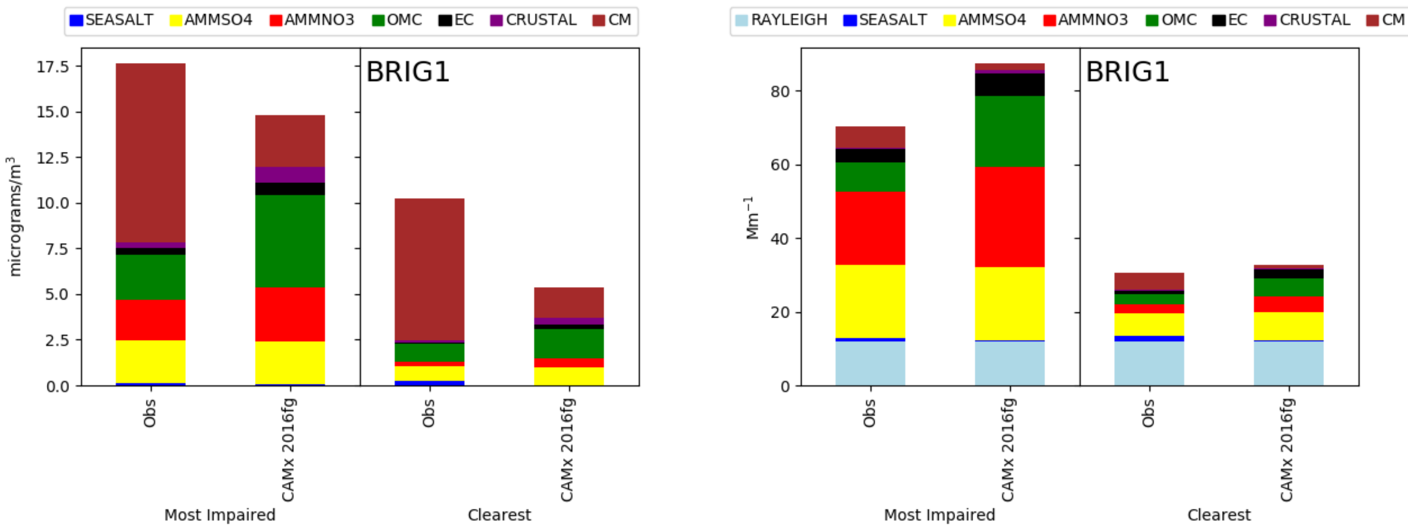


Figure 152. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Brigantine (NJ) on the observed 20% most impaired and observed 20% clearest days.

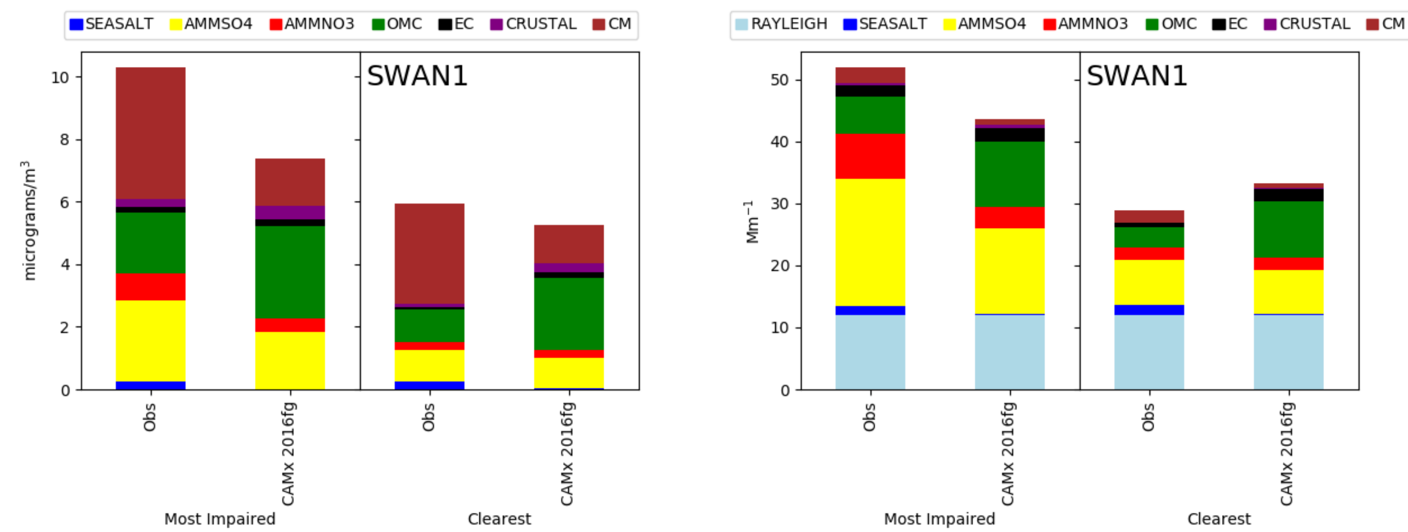


Figure 153. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Swanquarter (NC) on the observed 20% most impaired and observed 20% clearest days.

Northeast

- Acadia National Park (ME)(ACAD1)
- Great Gulf Wilderness (NH) and Presidential Range-Dry River Wilderness (NH)(GRGU1)
- Lye Brook Wilderness (VT)(LYEB1)
- Moosehorn (ME) and Roosevelt Campobello International Park (ME)(MOOS1)

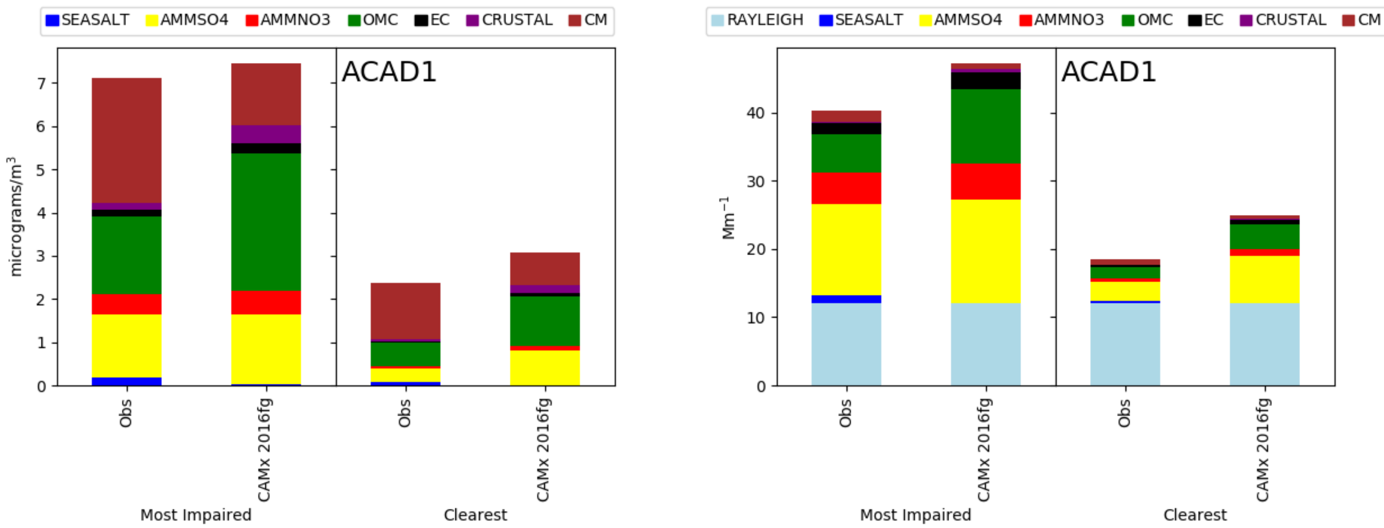


Figure 154. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Acadia National Park (ME) on the observed 20% most impaired and observed 20% clearest days.

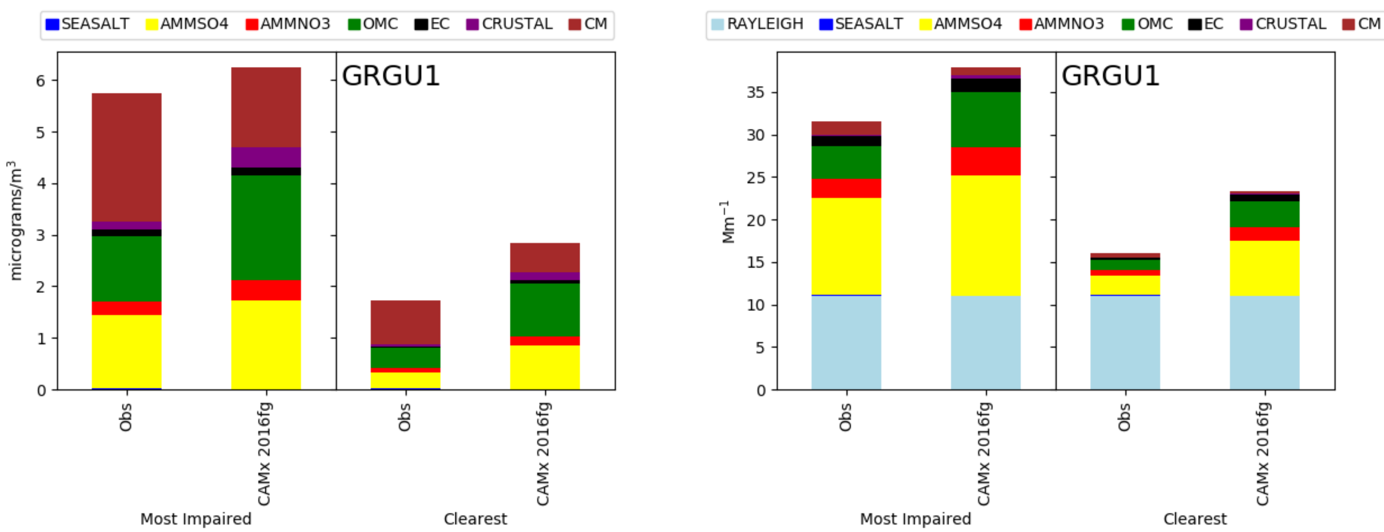


Figure 155. Observed (Obs) and predicted (CAMx) concentrations (µg/m^3) on left and extinctions (MM^{-1}) on right at the Great Gulf Wilderness (NH) and Presidential Range-Dry River Wilderness (NH) on the observed 20% most impaired and observed 20% clearest days.

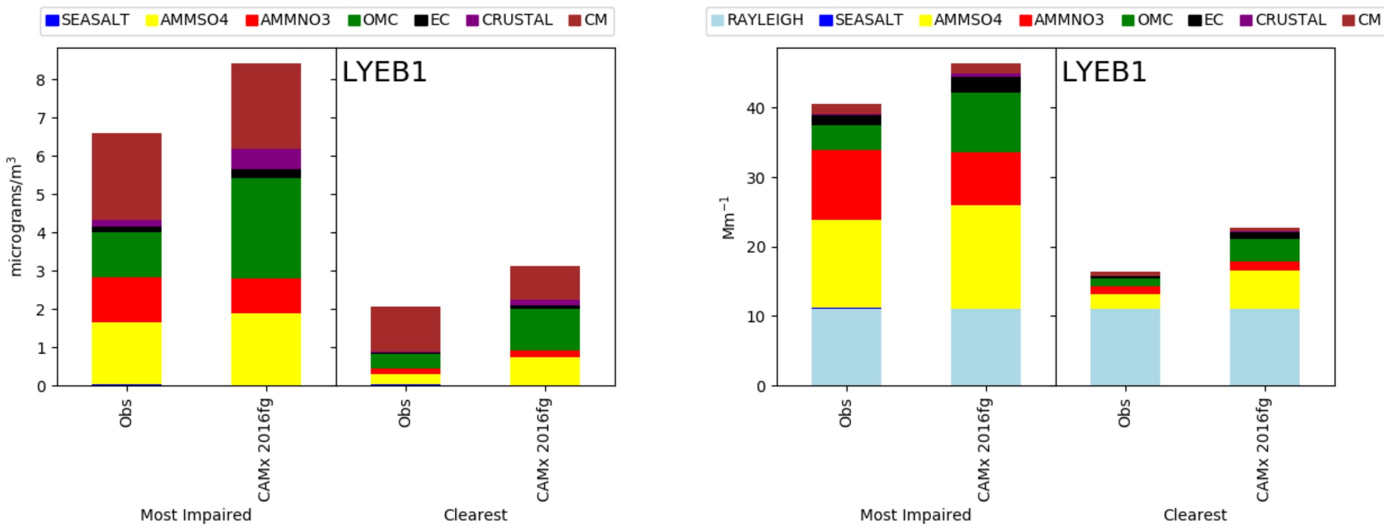


Figure 156. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Lye Brook Wilderness (VT) on the observed 20% most impaired and observed 20% clearest days.

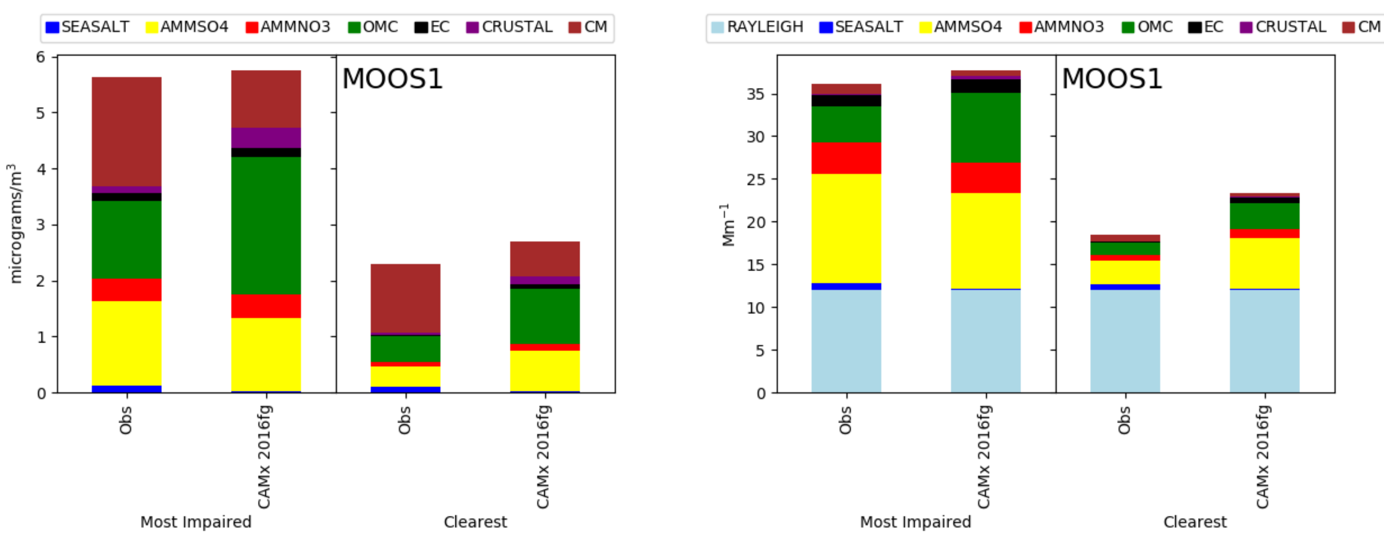


Figure 157. Observed (Obs) and predicted (CAMx) concentrations (μg/m^3) on left and extinctions (MM^{-1}) on right at the Moosehorn (ME) and Roosevelt Campobello International Park (ME) on the observed 20% most impaired and observed 20% clearest days.

Appendix B
Regional Haze Site Summaries

The following plots provide a summary of relevant observational and modeling data at each IMPROVE station. To help orient the reader, each figure is labeled with the main Class I area represented by the IMPROVE site and has an inset map with a red dot to indicate the geographic location of the IMPROVE station.

- The 2014-2017 observed annual average light extinction values (1/Mm) on the 20% most impaired days are shown as (up to 4) black dots with the (up to) 4-year average as a horizontal blue line over the same time period (labeled as “Current Avg”).

- For the 2016 year, the average observed magnitude and composition of extinction (on the 20% most impaired days) is indicated by the left-most stacked bar (labeled “OBS2016”). The 2016 observation is broken down into Rayleigh (light blue), sea salt (blue), organic carbon matter (green), elemental carbon (black), ammonium sulfate (yellow), ammonium nitrate (red), fine crustal material (purple) and coarse mass (brown). Rayleigh scattering is site-specific, depending on the site elevation (higher elevation has lower Rayleigh scattering) and varies between 8 and 12 Mm^{-1} for all areas.

- The second diagonally hatched stacked bar (“MOD2016”) shows the CAMx 2016 modeled PM light extinction magnitude and composition on the 20% most impaired days. The site-specific Raleigh scattering is used directly and does not change between the observed and modeled, or the base and future.

- A species-specific relative response factor was calculated using the raw 2016 simulated PM species concentrations and the raw 2028 simulated PM species concentrations and used to project observations. The effective net relative change in extinction between 2016 and 2028 is seen by comparing the 4-year average (solid horizontal blue line) with the top of the 2028 stacked bar labeled “SMAT2028”. The SMAT2028 bar is the relative projected 2028 visibility impairment (calculated using the SMAT software). See the modeling technical support document (TSD) for more details on the calculations.

- The 2028 stacked bars are grouped into summary categories that represent US anthropogenic visibility contributions (orange), international anthropogenic contributions (dark blue), prescribed fire contributions (brick red), and natural source contributions (green). Ambient 2016 sea salt (blue) and Rayleigh scattering (light blue) are at the bottom of the 2028 stacked bars. See Table B-1 below for the definition of the emissions summary categories.

- The diagonally hatched “MOD2028” stacked bar shows the absolute 2028 modeled impairment by summary categories (the same categories and colors as the SMAT2028 bar).

Table B-1 Source apportionment emissions summary categories

Emissions Summary Category	Emissions Sectors (PSAT tags)	Notes
U.S. Anthropogenic	On-road mobile, Non-road mobile, EGUs, C1&C2 commercial marine, US C3 commercial marine (w/in ECA), Rail, Agricultural fires, Agricultural ammonia, Oil & Gas, Non-EGU point, Residential wood, Anthropogenic dust[1], Nonpoint	U.S. anthropogenic visibility contributions.
International Anthropogenic	Anthropogenic Canada and Mexico, C3 commercial marine (outside ECA), International anthropogenic boundary conditions	Explicit Canadian and Mexican contribution is from within the 36 and 12km domains.
Natural	Biogenic, US wildfires, Canada wildfires, Mexico wildfires, Ocean sulfate (DMS and sea salt), Sea salt, Natural dust[2], Natural boundary conditions, Rayleigh	Contributions to natural visibility from US sources as well as international
Prescribed Fires	US Prescribed fires	Prescribed fire contributions.

- The “2028 US anthro” (above the pie) is the US anthropogenic fraction of the total projected anthropogenic (US + international) extinction. The US anthropogenic sources (orange part of the SMAT2028 bar) are then normalized and further identified in the pie chart, where unique categories total to ≥75% and the remaining are indicated as “Other Sectors.” Thus, the sector’s percentage

[1] The anthropogenic dust impacts should be used with caution. Due to the lack of natural wind-blown dust in the model, the anthropogenic dust impacts may be artificially high. This especially affects Class I area in the southwest.

[2] The “natural dust” category is an estimate of natural dust. Instead of directly assigning the relative contribution results for the anthropogenic dust tag, ambient data was used to estimate the natural and anthropogenic components of coarse and fine crustal PM. The data was used to split the dust impacts into estimated anthropogenic dust (US anthropogenic) and natural dust (natural).

in the pie chart represents that sector's percentage of total US anthropogenic extinction.

- The solid black line, the dashed blue line, and the grey "range" represent different versions of the URP glidepath.
    - The black line (Glidepath) is the unadjusted glidepath that runs from the 2000-2004 baseline value to natural conditions in 2064.
    - The blue dotted line (Adj Glidepath) is the default adjusted glidepath that runs from the 2000-2004 baseline value to the default adjusted 2064 endpoint.
    - The grey "range" represents the full range of calculated alternative glidepaths using different combinations of relative and absolute modeled data, natural conditions, and prescribed fires. The range is represented by the adjustments calculated from following combinations of modeled and ambient data:
        - Relative international anthropogenic model contributions + ambient natural conditions **(default)**
        - Absolute international anthropogenic model contributions + ambient natural conditions
        - Relative international anthropogenic and prescribed fire model contributions + relative modeled natural conditions
        - Absolute international anthropogenic and prescribed fire model contributions + absolute modeled natural conditions
        - Relative international and prescribed fire model contributions + ambient natural conditions

- The short solid black line on the right side of the plot represents the unadjusted 2064 endpoint (ambient natural conditions)

- The short dashed blue line on the right side of the plot represents the default adjusted 2064 endpoint.

Table B-2 Sector category abbreviations in the summary plots

Summary plot US anthropogenic sector abbreviations	Full sector name
EGUs	Electric generating units (EGU)
Non-EGU Point	NonEGU point sources
Oil & Gas	Oil and gas (point and nonpoint)
Ag_Fires	Agricultural fires
Rail	Rail
RWC	Residential wood combustion
Non-point	Nonpoint (area) sources
On-road	On-road mobile
US C3 Marine (w/in ECA)	C3 commercial marine vessels within US ECA region
C1C2 Marine	C1 and C2 commercial marine vessels
Anthro Dust	Anthropogenic dust (primary PM)
Nonroad	Non-road mobile
Prescribed_Fires	Prescribed fires

Figure B-1 Location of Federal Class I areas

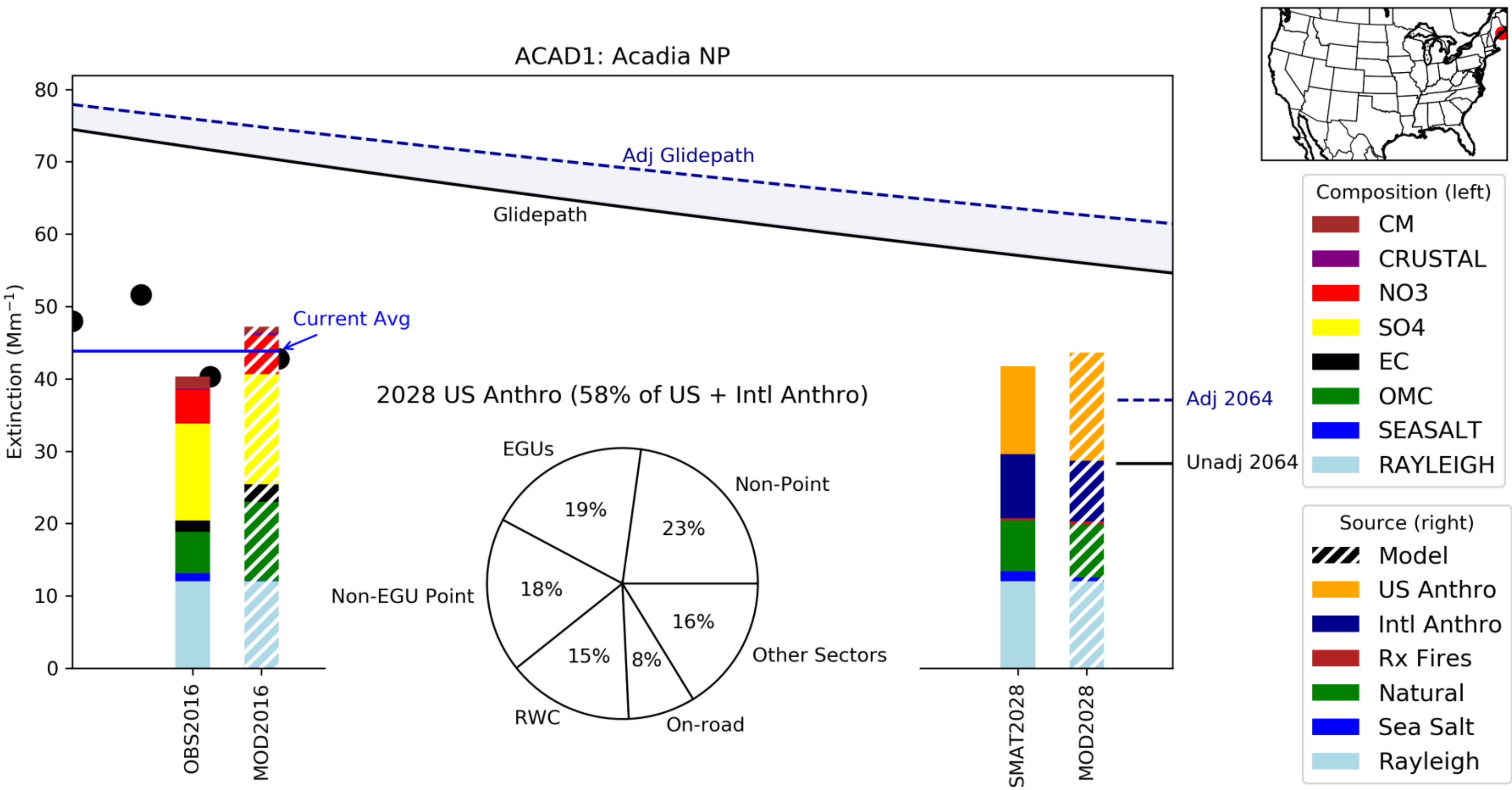


Figure 2: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at ACAD1. Used for Class I areas: Acadia NP.

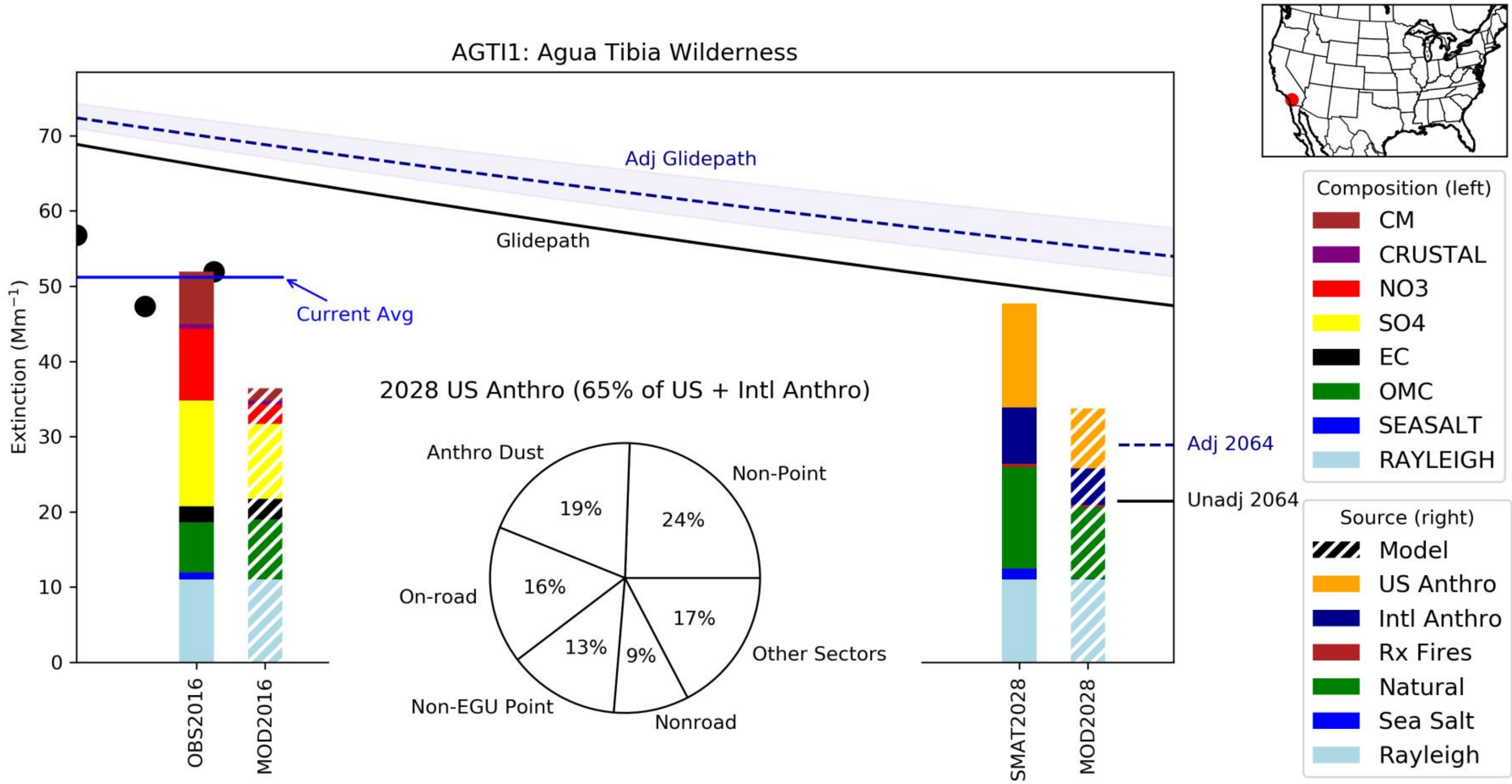


Figure 3: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at AGTI1. Used for Class I areas: Agua Tibia Wilderness.

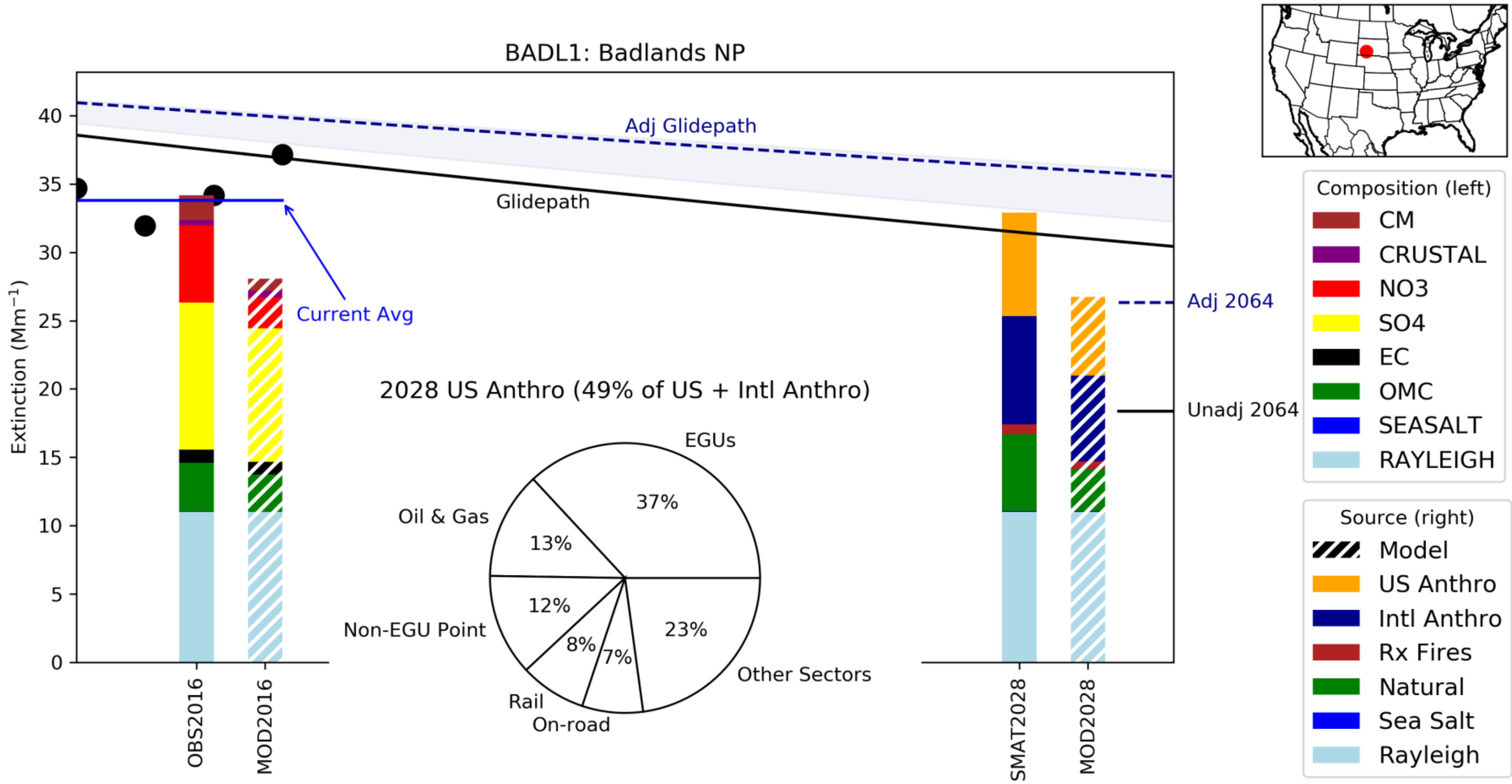


Figure 4: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BADL1. Used for Class I areas: Badlands NP.

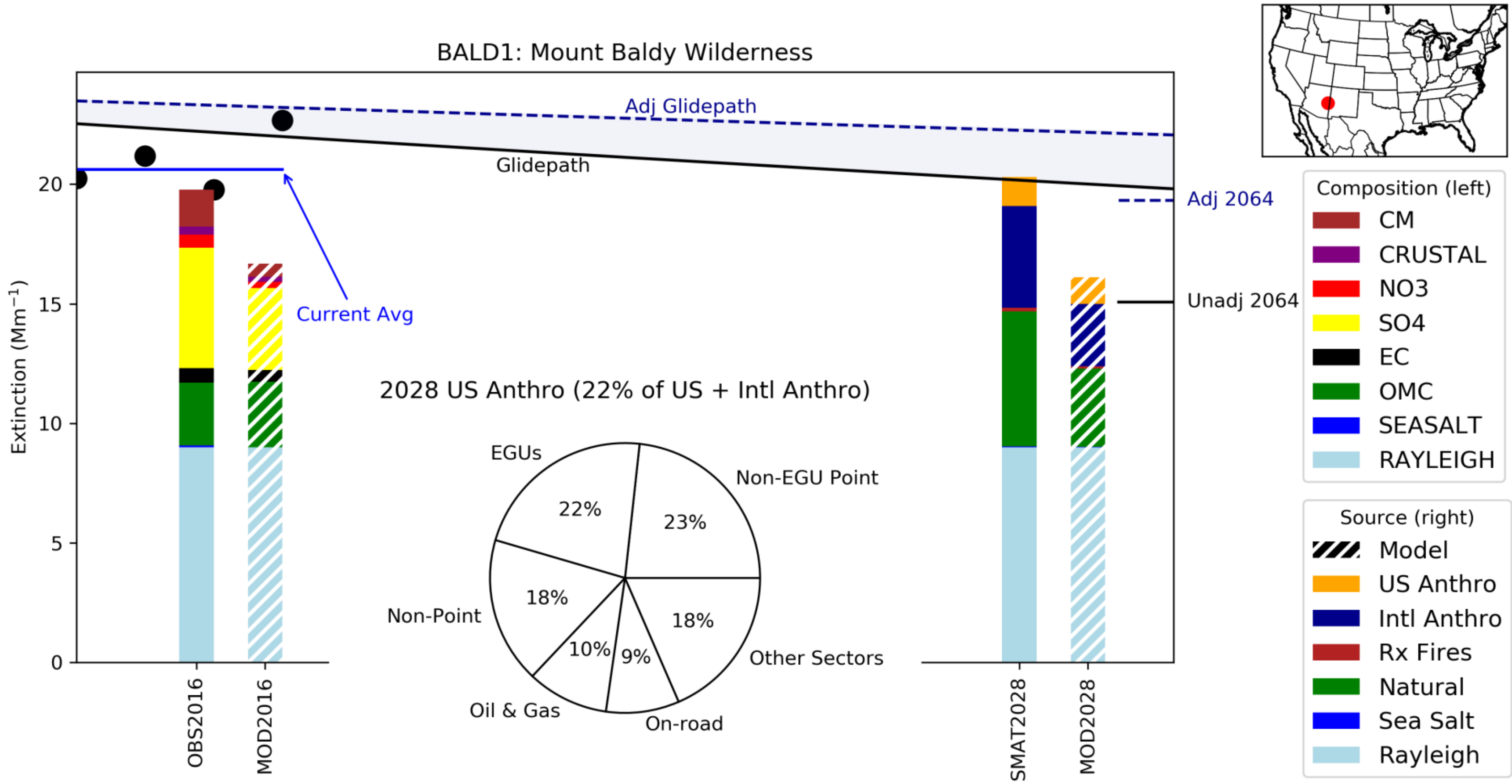


Figure 5: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BALD1. Used for Class I areas: Mount Baldy Wilderness.

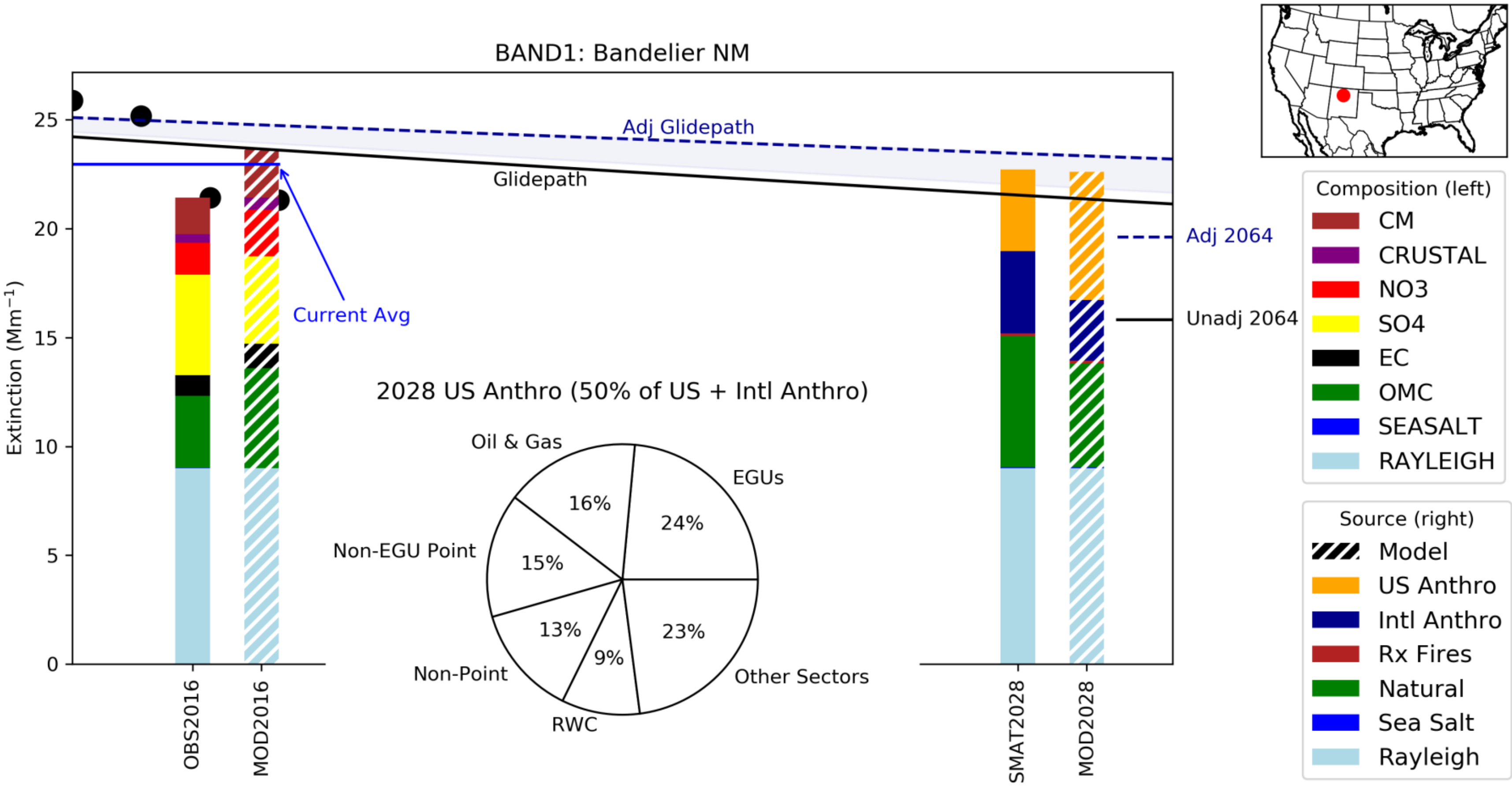


Figure 6: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BAND1. Used for Class I areas: Bandelier NM.

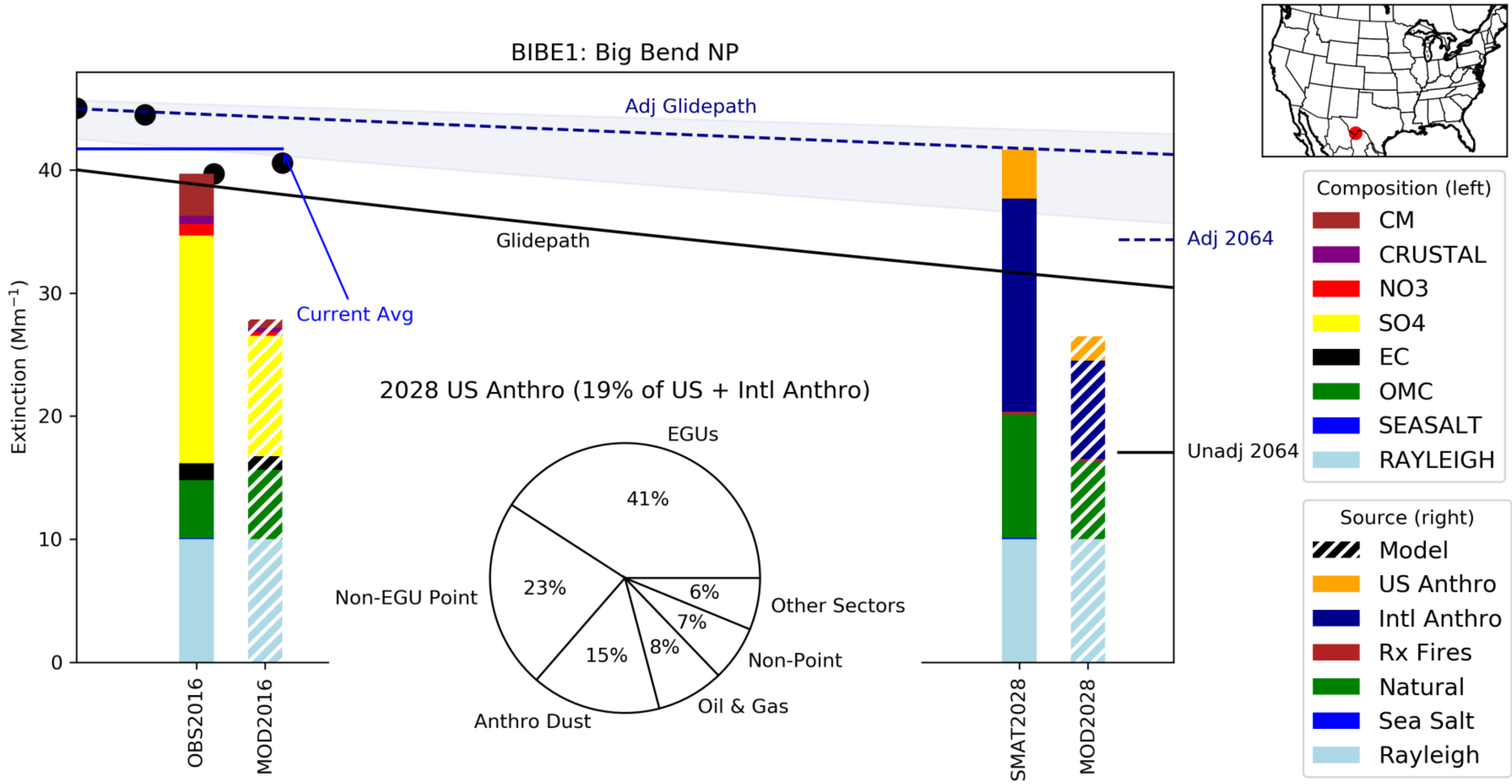


Figure 7: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BIBE1. Used for Class I areas: Big Bend NP.

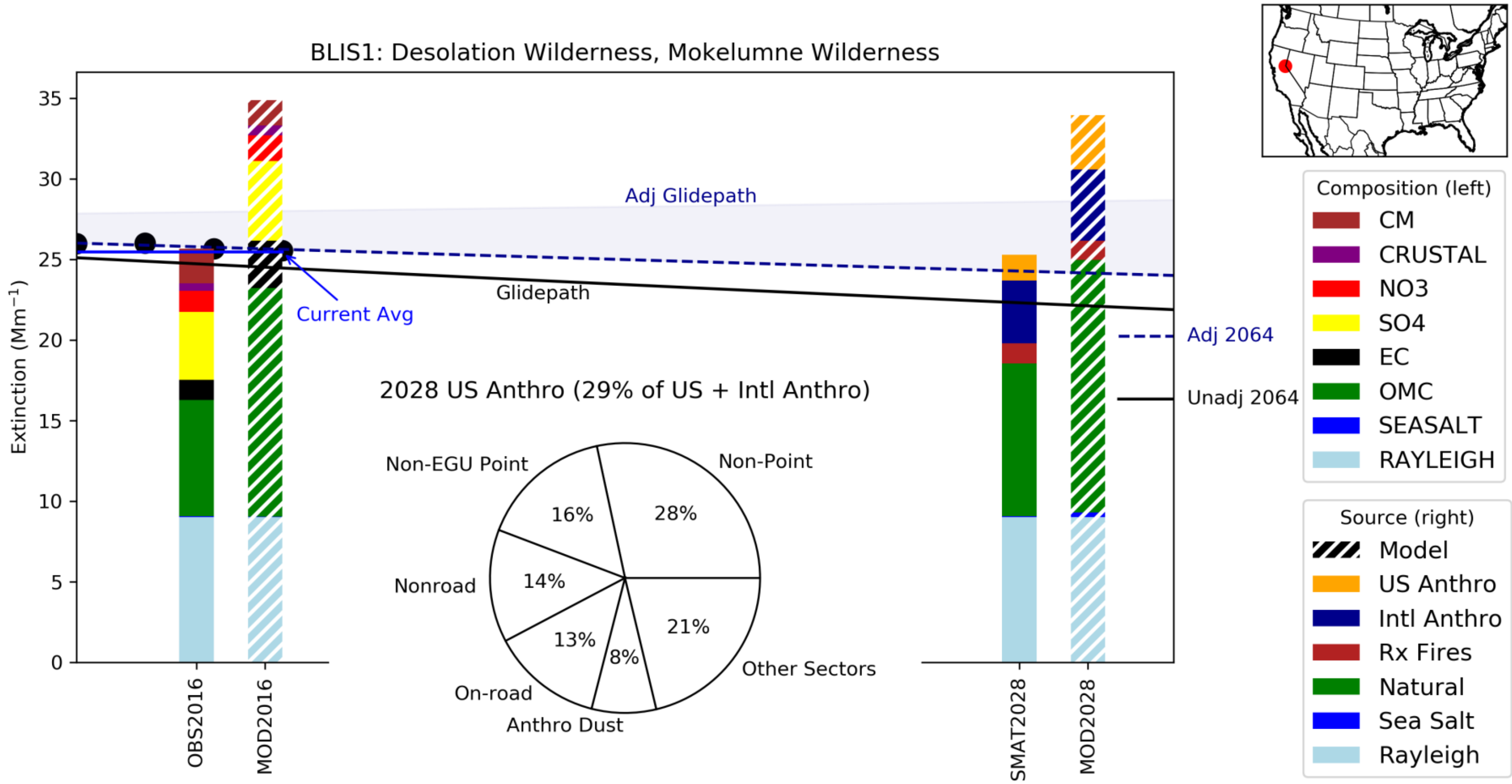


Figure 8: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BLIS1. Used for Class I areas: Desolation Wilderness, Mokelumne Wilderness.

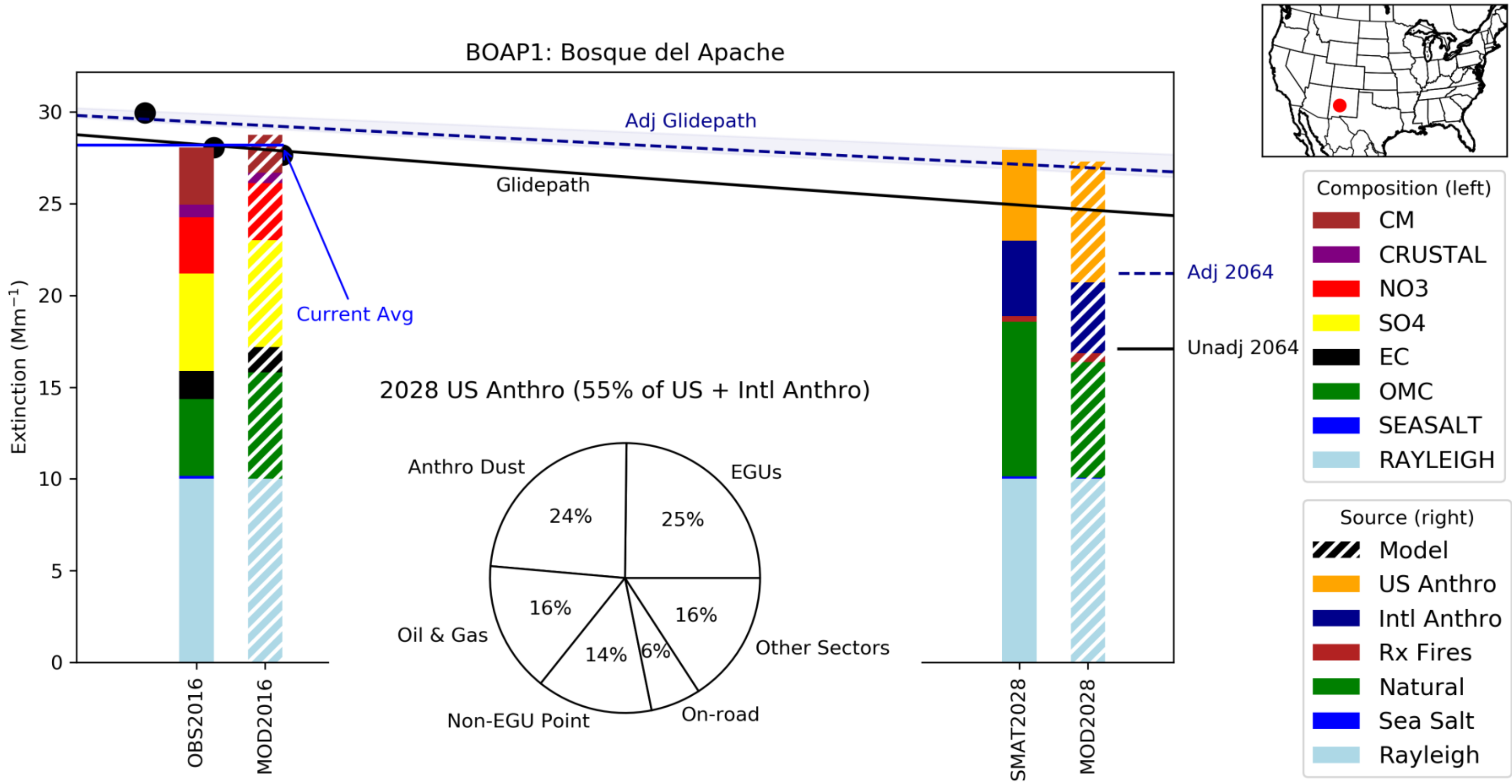


Figure 9: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BOAP1. Used for Class I areas: Bosque del Apache.

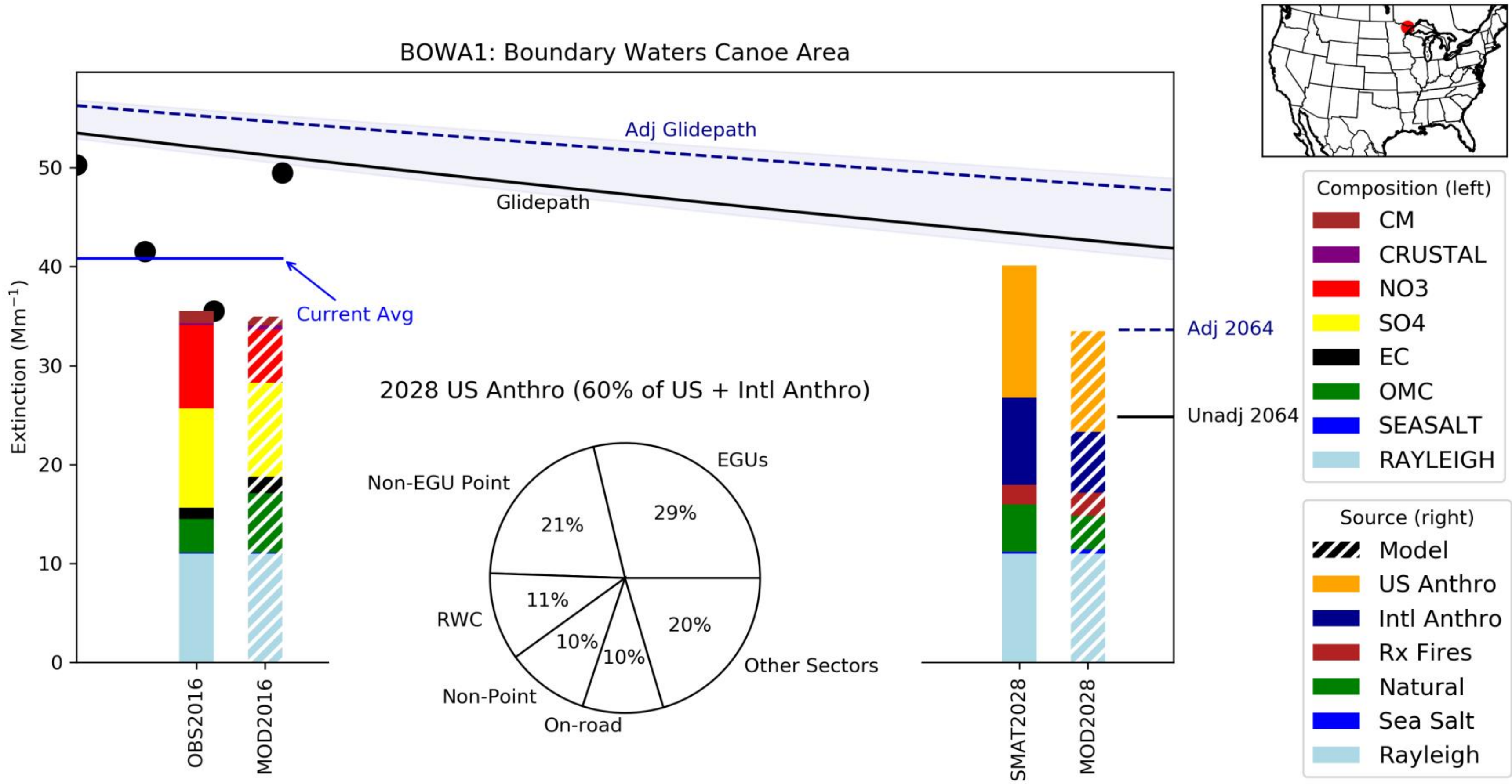


Figure 10: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BOWA1. Used for Class I areas: Boundary Waters Canoe Area.

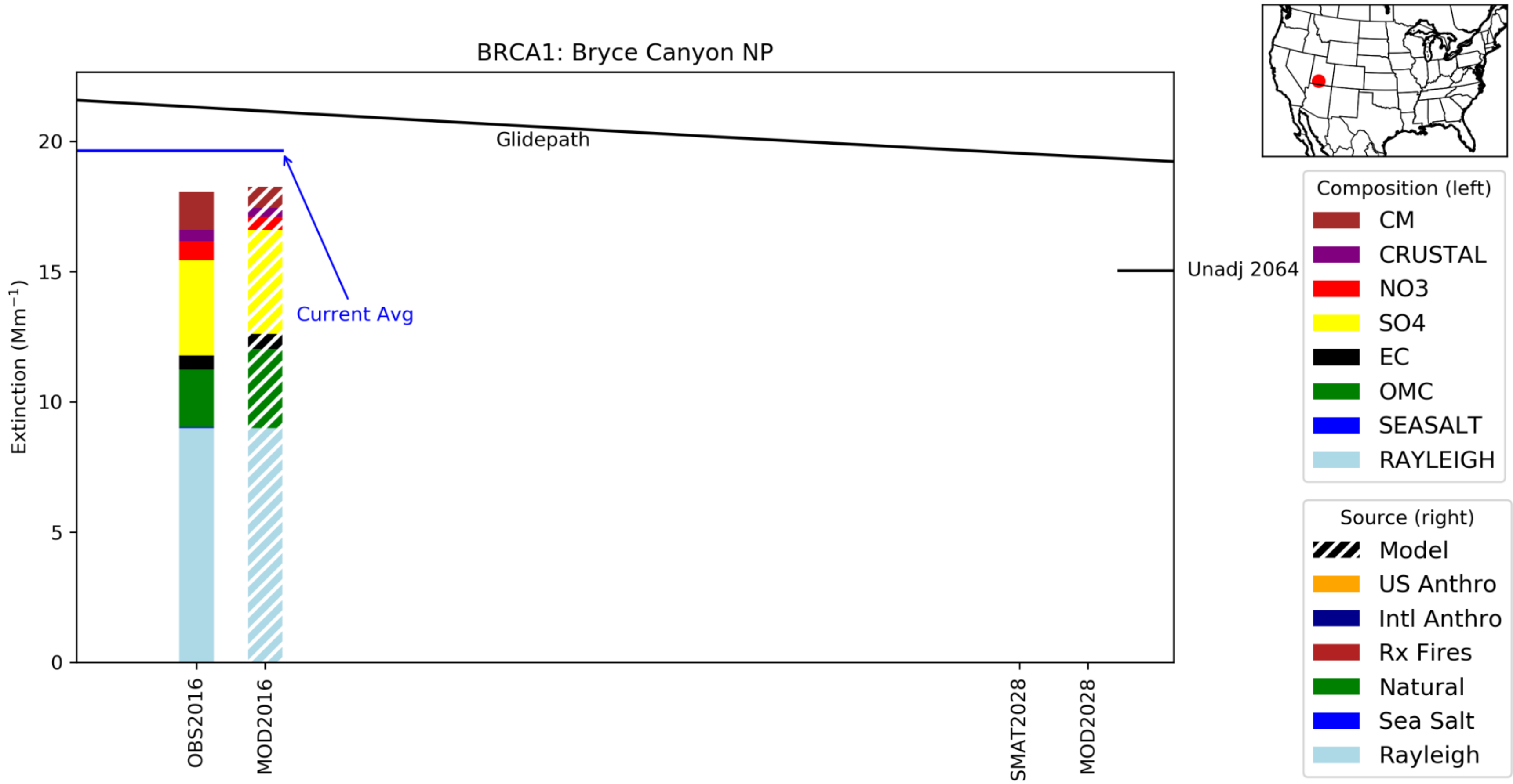


Figure 11: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BRCA1. Used for Class I areas: Bryce Canyon NP.

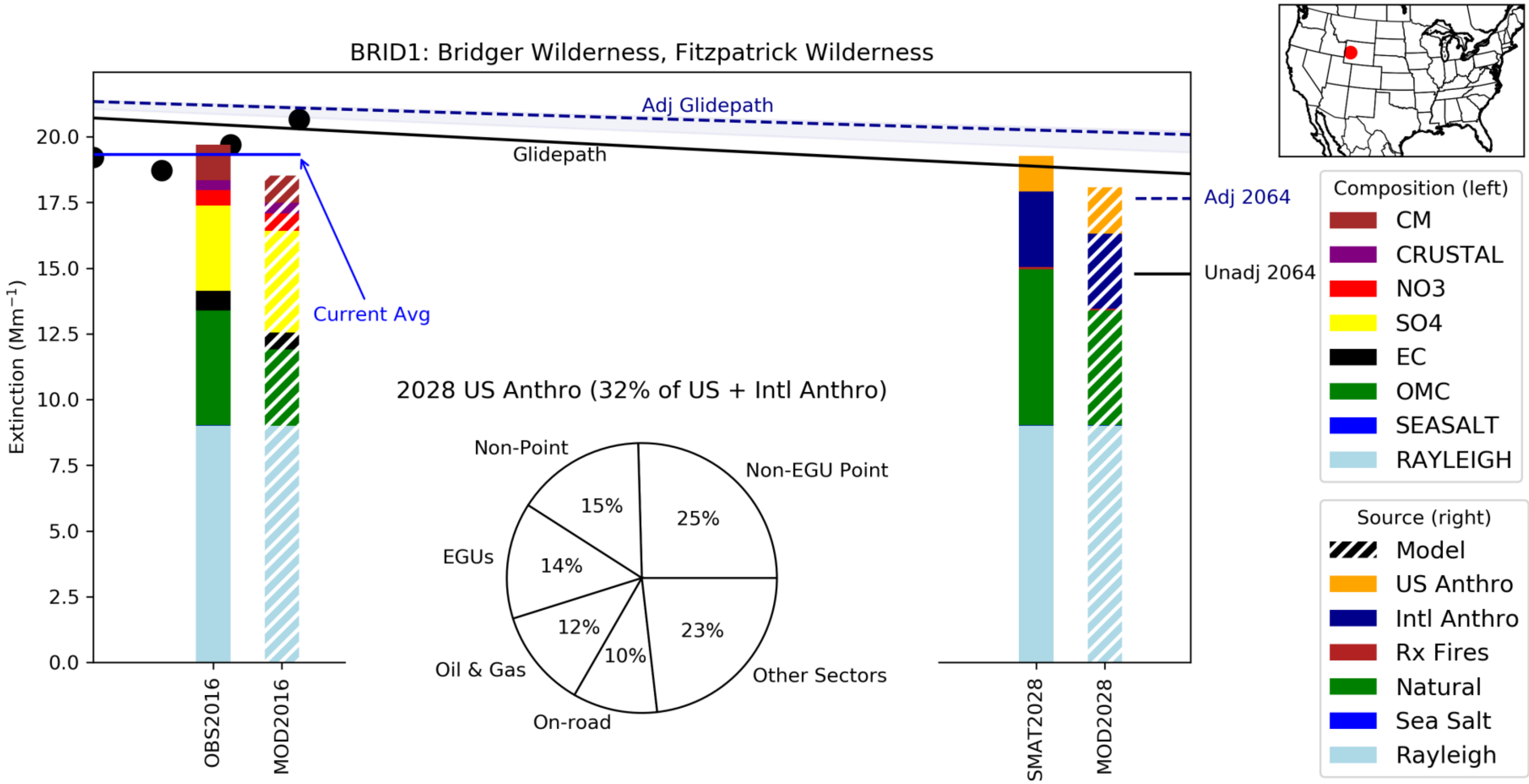


Figure 12: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BRID1. Used for Class I areas: Bridger Wilderness, Fitzpatrick Wilderness.

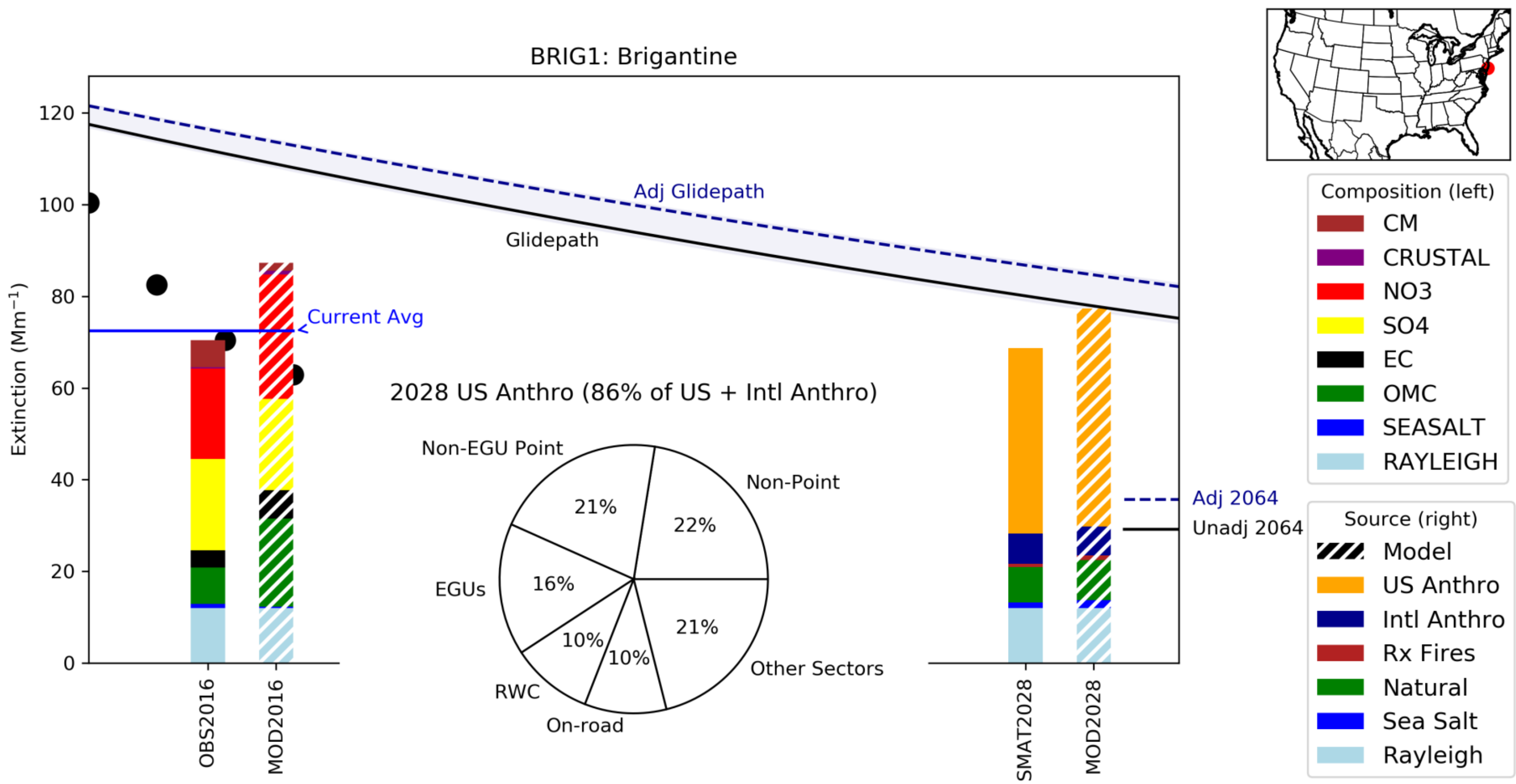


Figure 13: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BRIG1. Used for Class I areas: Brigantine.

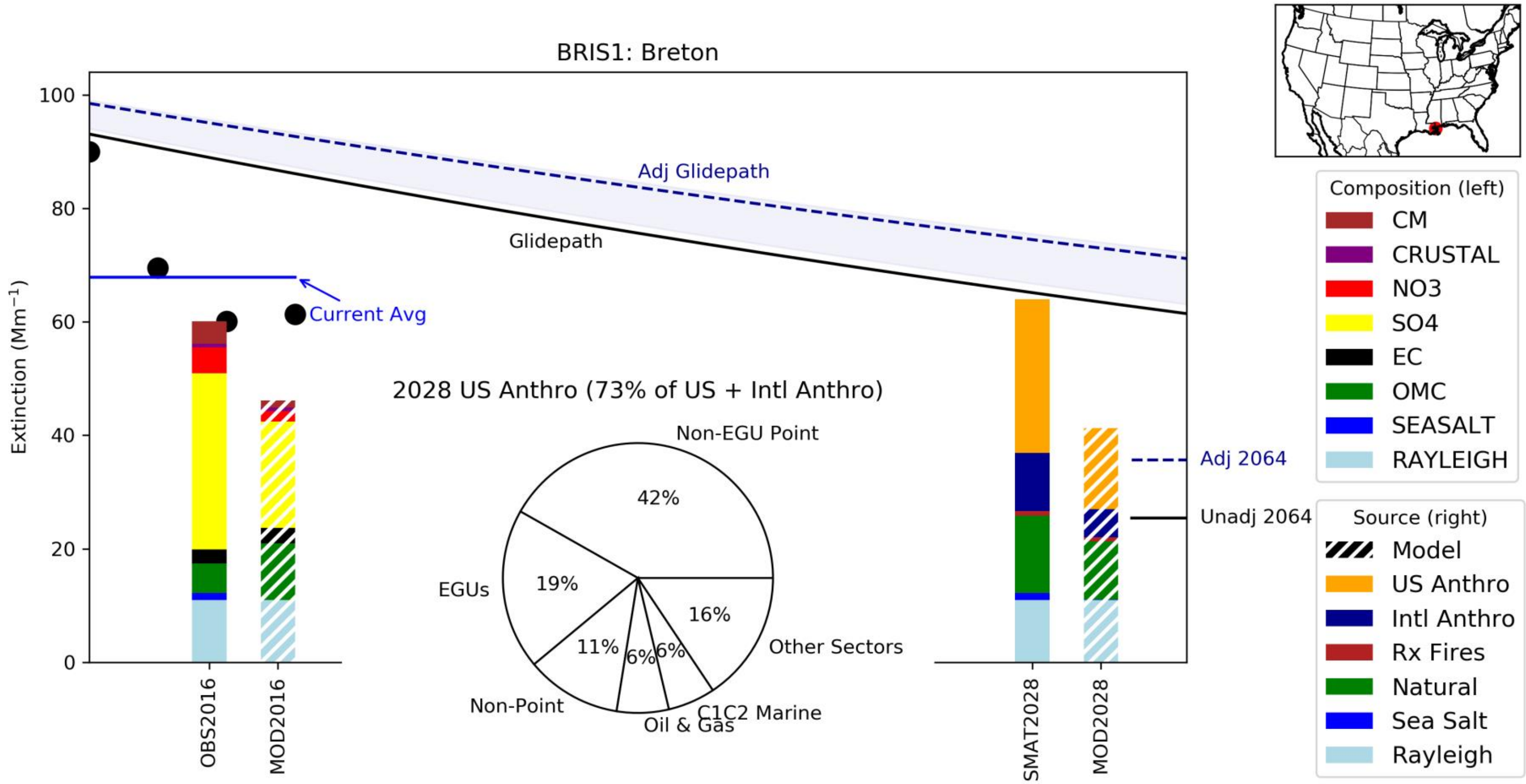


Figure 14: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at BRIS1. Used for Class I areas: Breton.

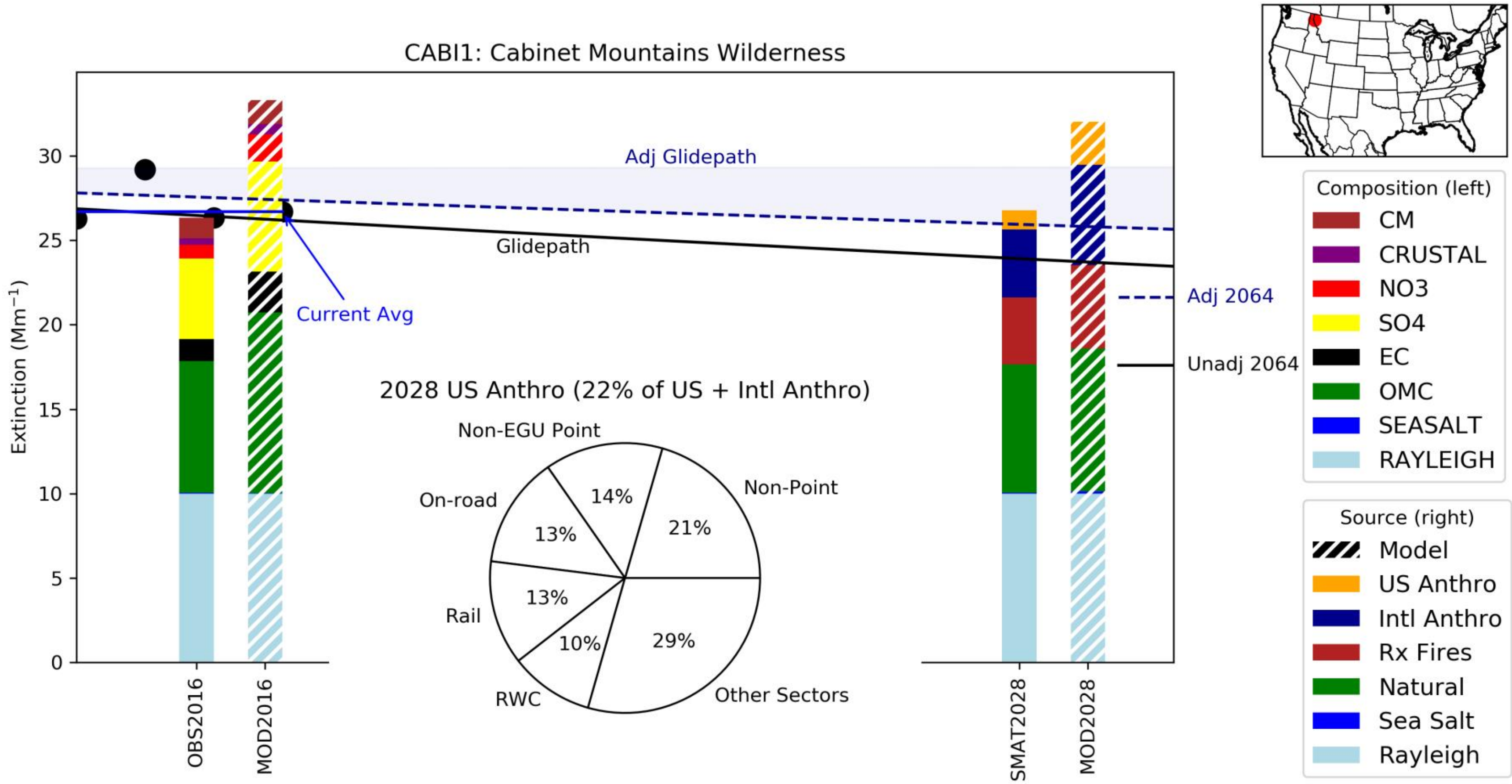


Figure 15: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CABI1. Used for Class I areas: Cabinet Mountains Wilderness.

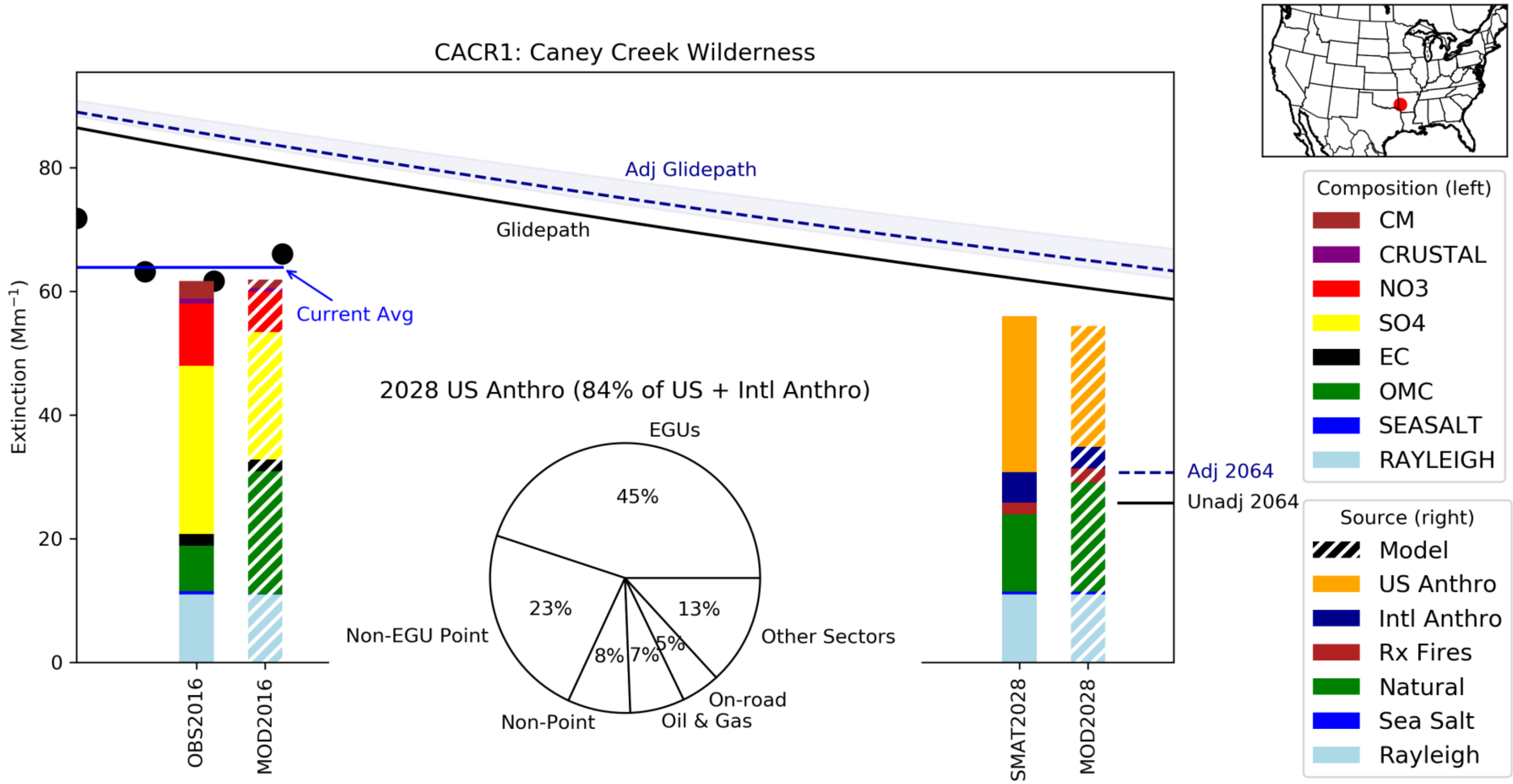


Figure 16: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CACR1. Used for Class I areas: Caney Creek Wilderness.

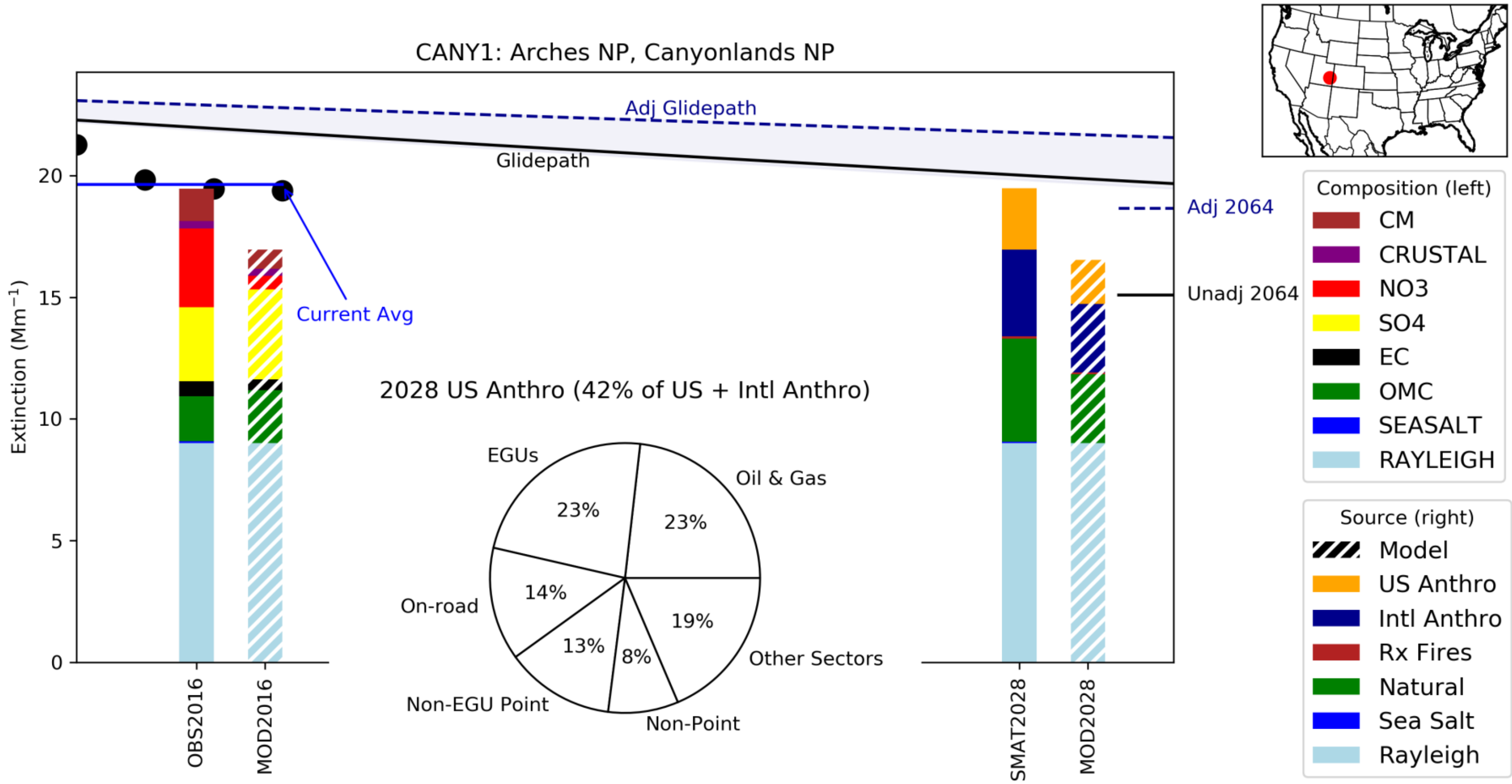


Figure 17: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CANY1. Used for Class I areas: Arches NP, Canyonlands NP.

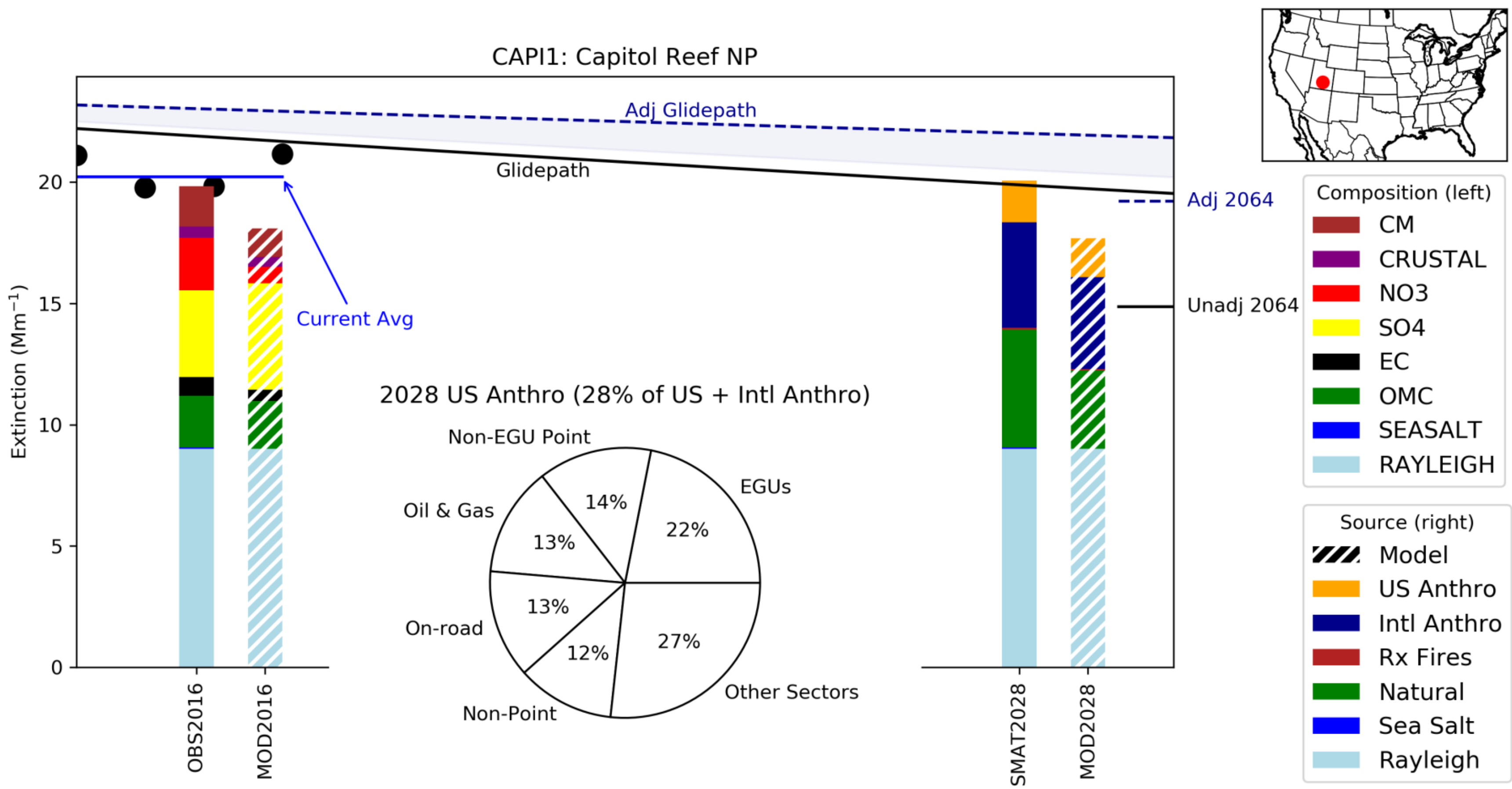


Figure 18: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CAPI1. Used for Class I areas: Capitol Reef NP.

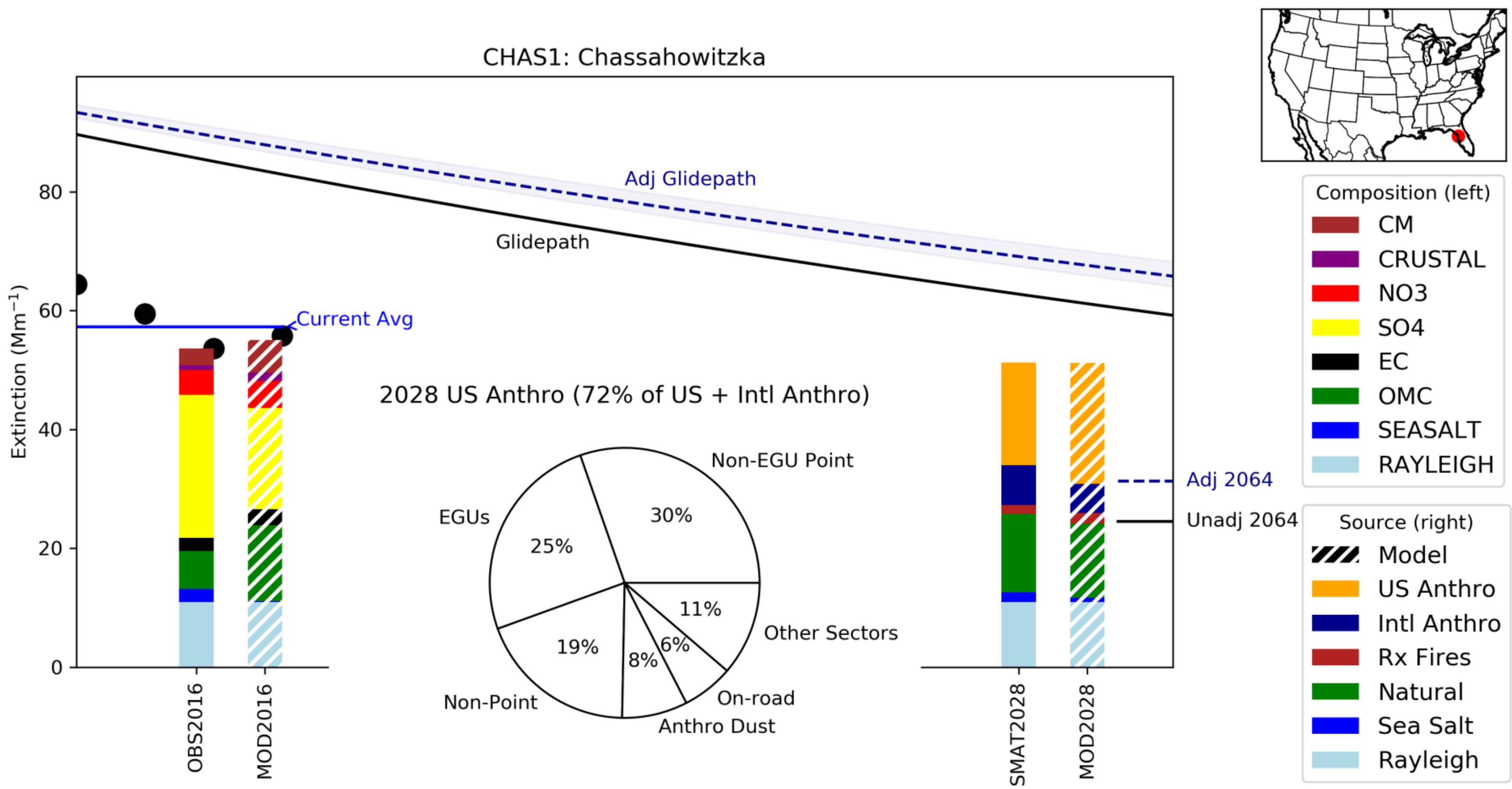


Figure 19: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CHAS1. Used for Class I areas: Chassahowitzka.

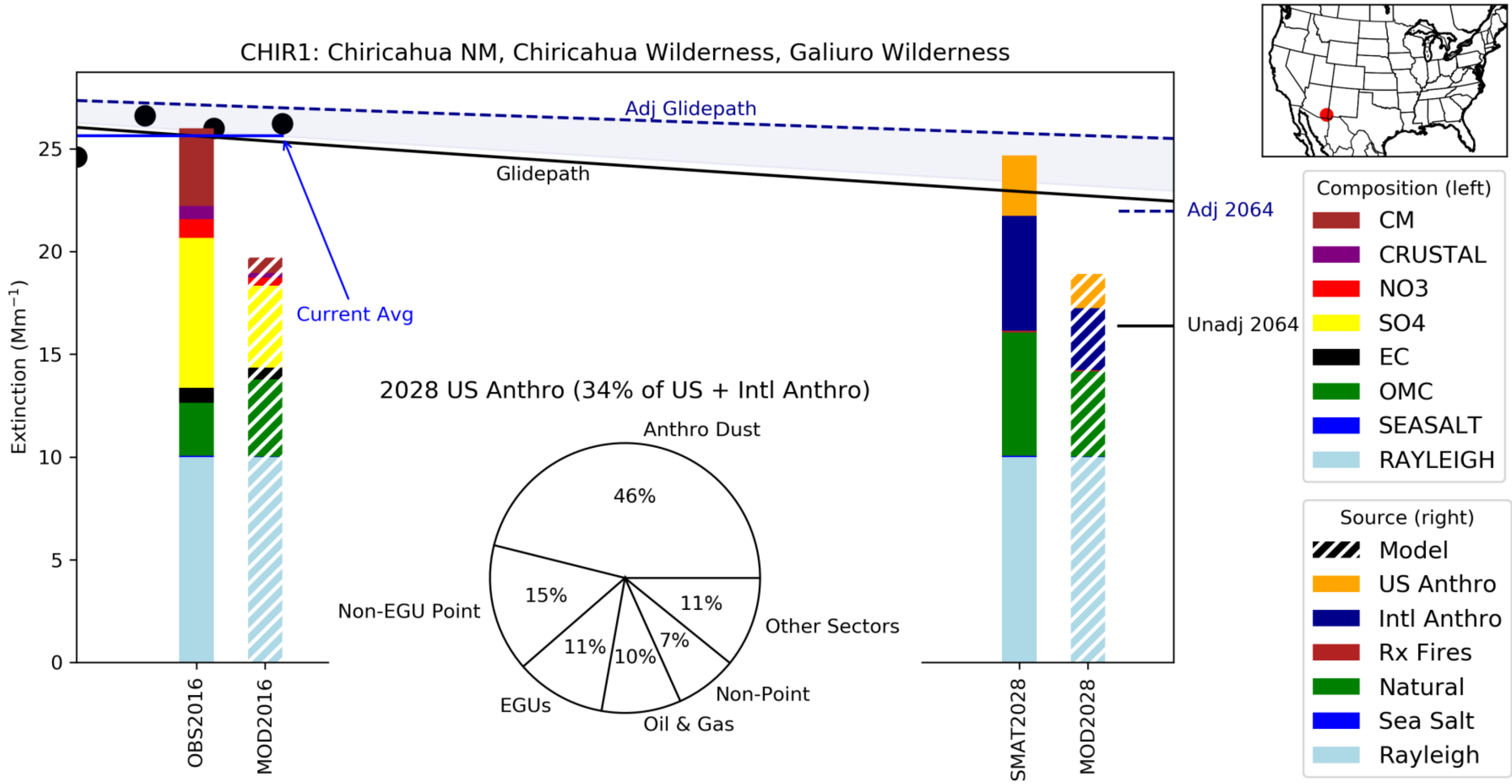


Figure 20: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CHIR1. Used for Class I areas: Chiricahua NM, Chiricahua Wilderness, Galiuro Wilderness.

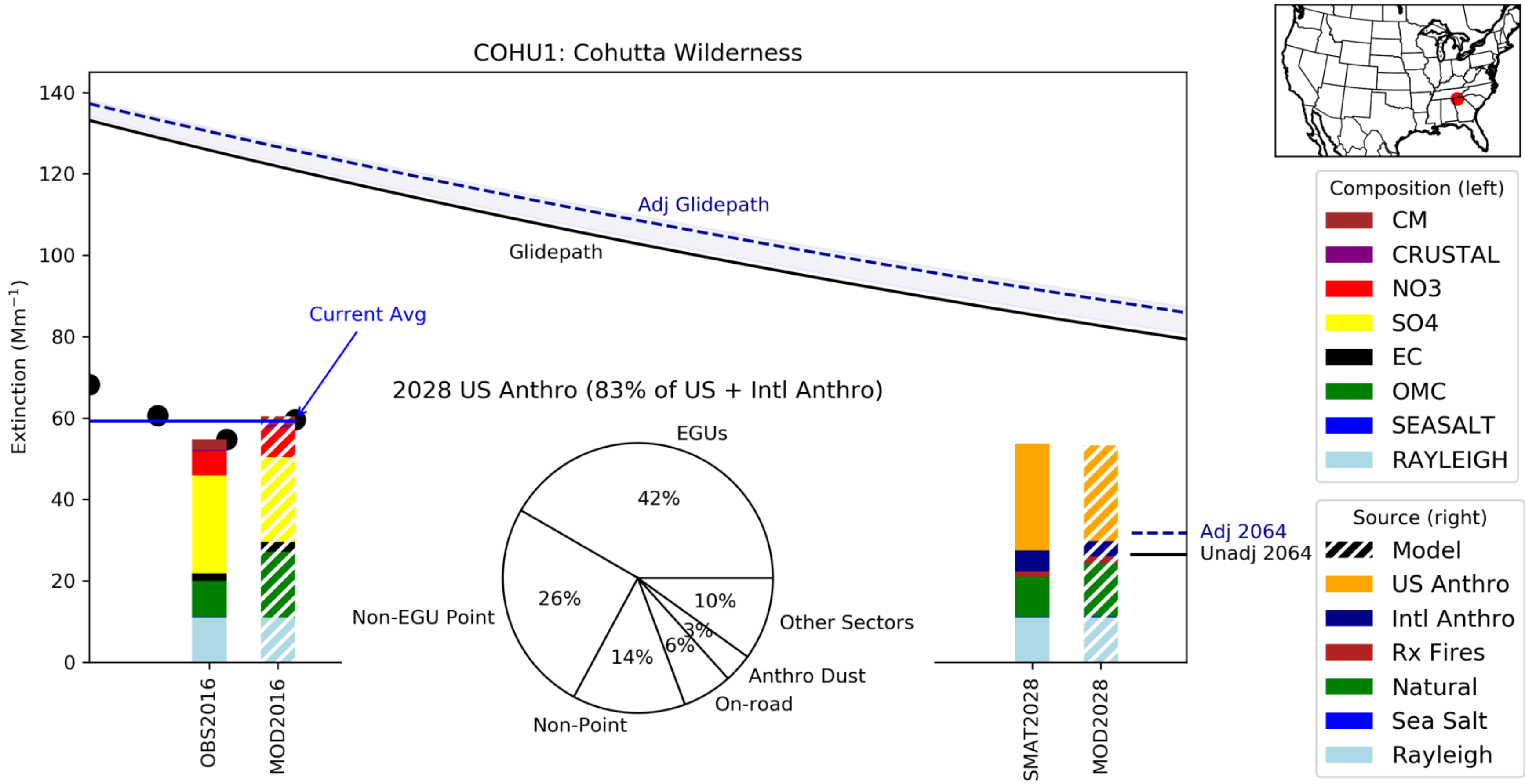


Figure 21: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at COHU1. Used for Class I areas: Cohutta Wilderness.

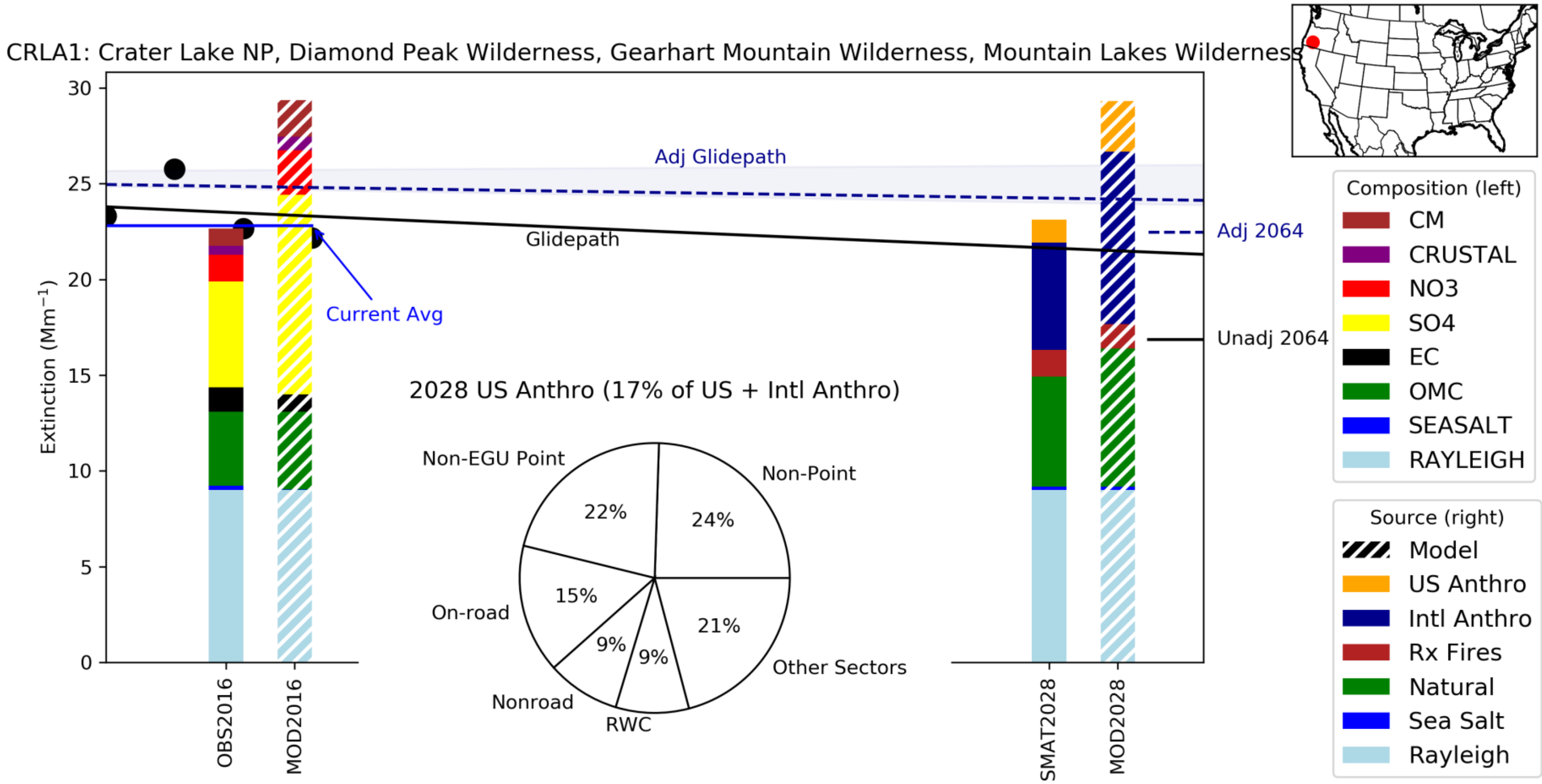


Figure 22: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CRLA1. Used for Class I areas: Crater Lake NP, Diamond Peak Wilderness, Gearhart Mountain Wilderness, Mountain Lakes Wilderness.

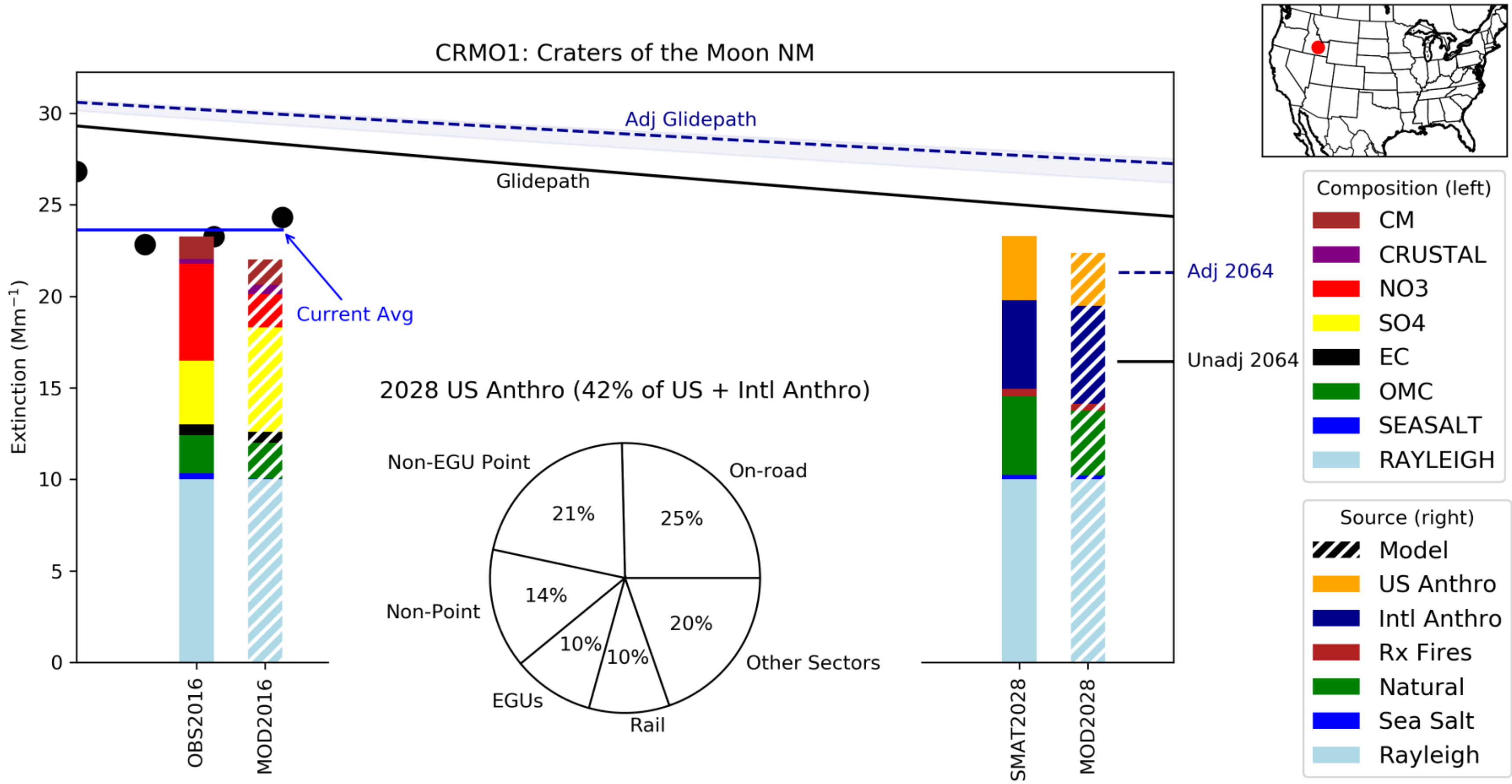


Figure 23: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at CRMO1. Used for Class I areas: Craters of the Moon NM.

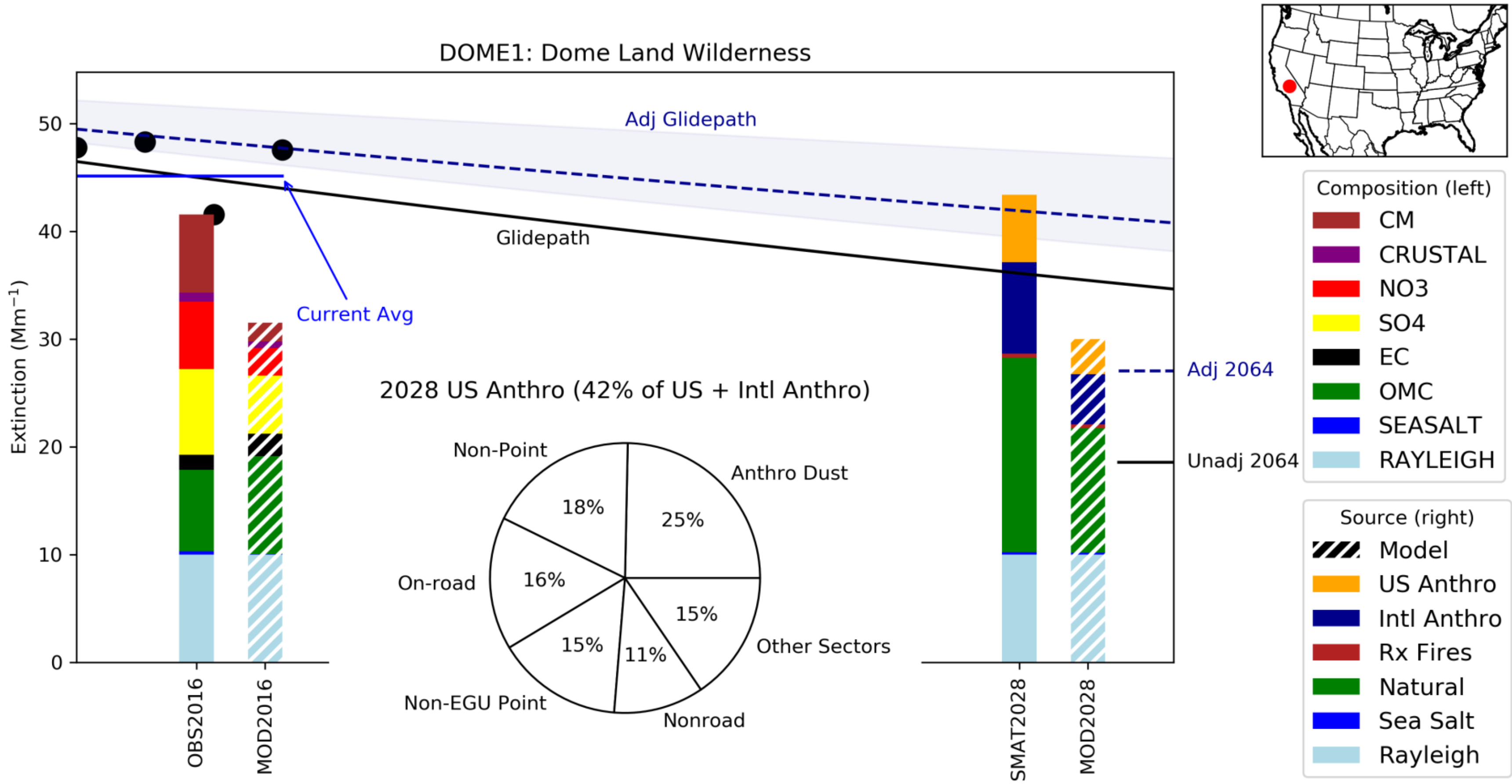


Figure 24: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at DOME1. Used for Class I areas: Dome Land Wilderness.

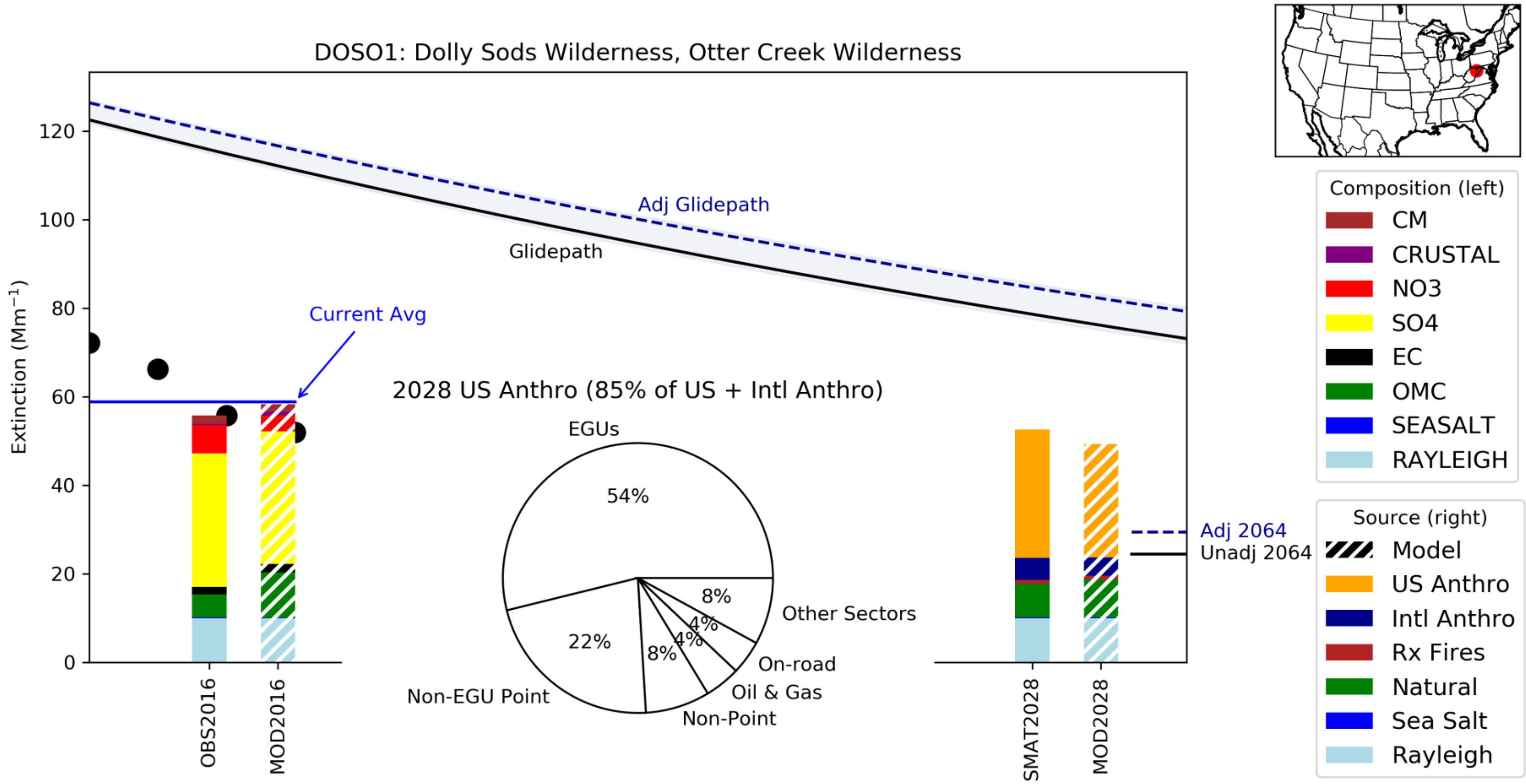


Figure 25: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at DOSO1. Used for Class I areas: Dolly Sods Wilderness, Otter Creek Wilderness.

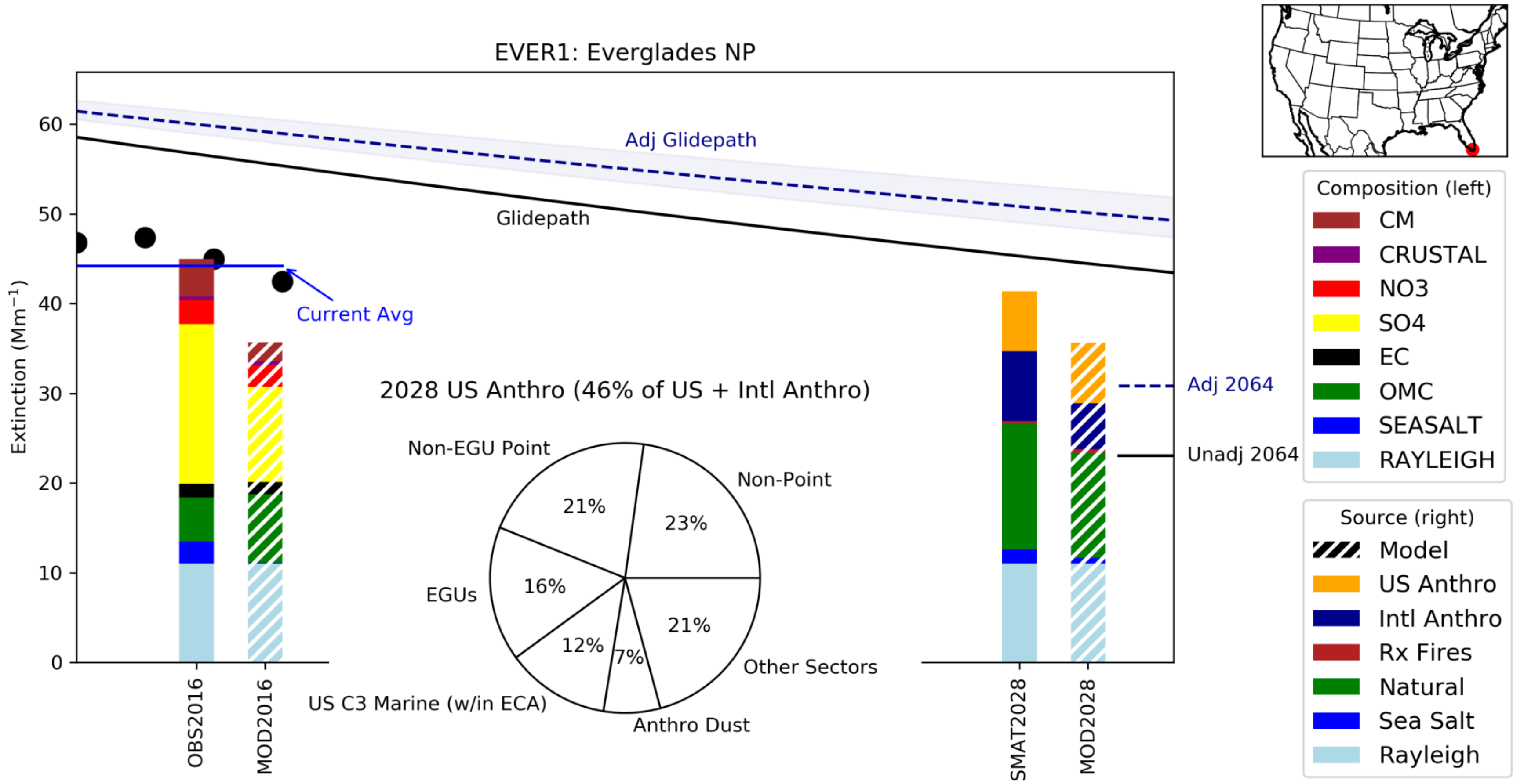


Figure 26: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at EVER1. Used for Class I areas: Everglades NP.

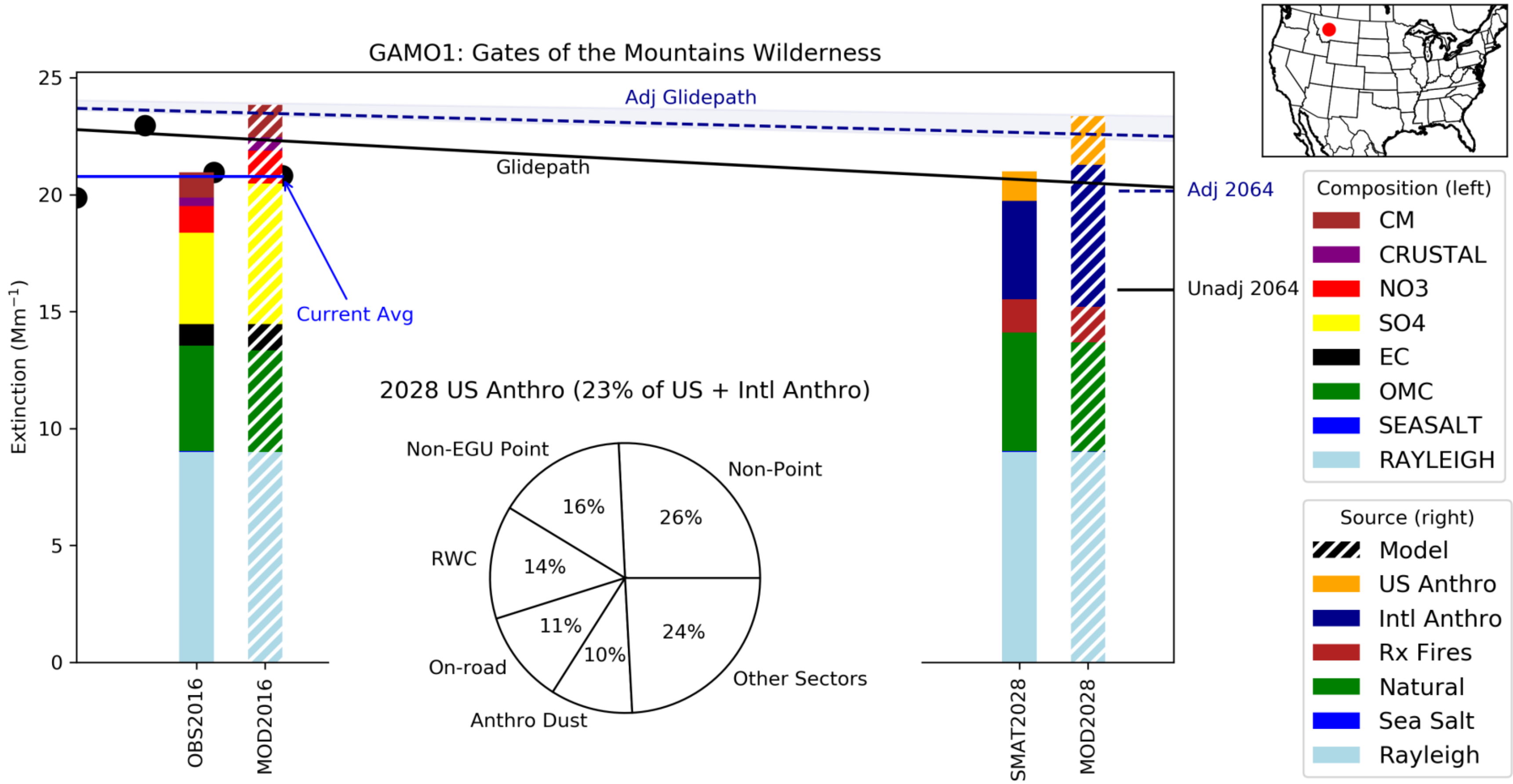


Figure 27: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GAMO1. Used for Class I areas: Gates of the Mountains Wilderness.

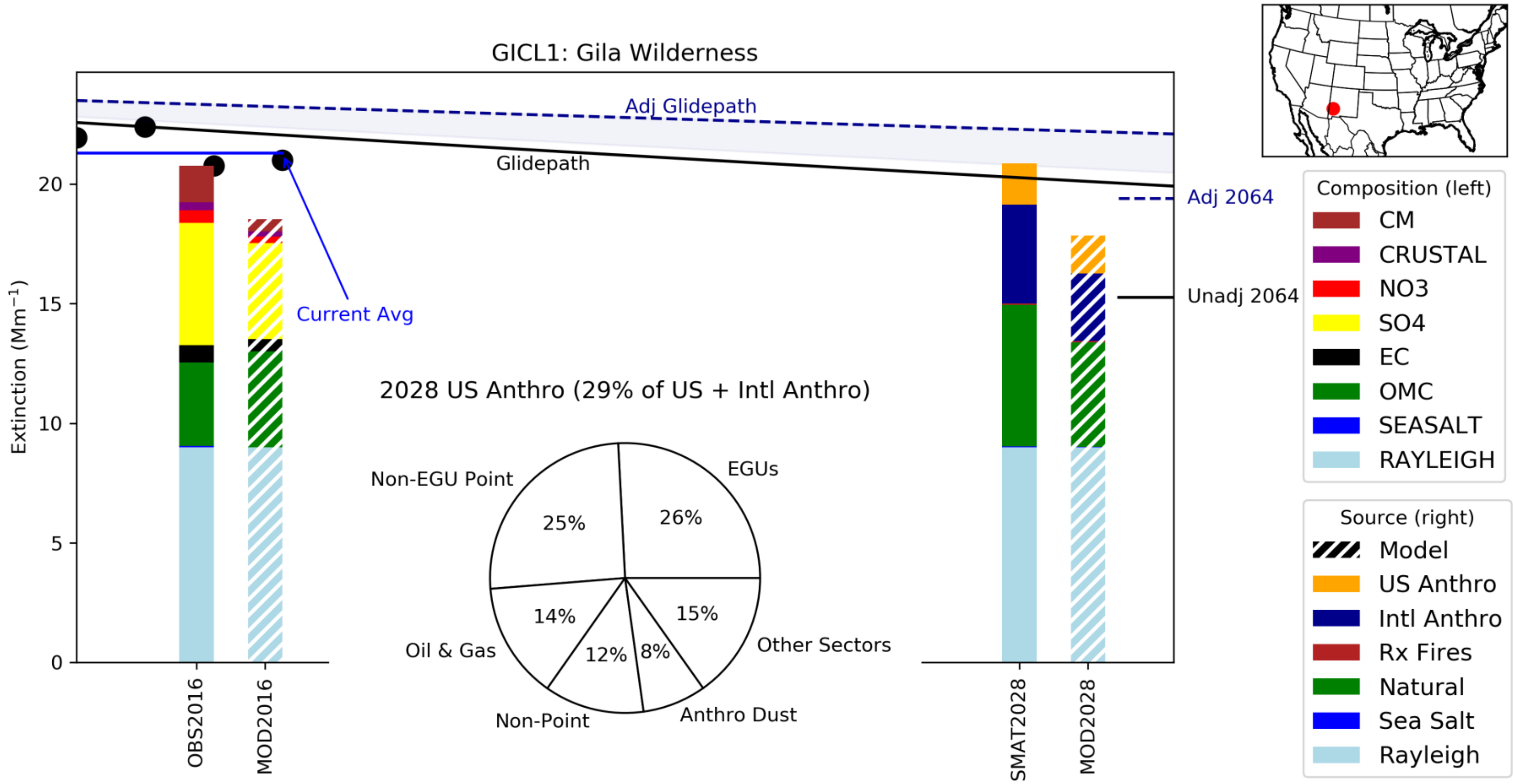


Figure 28: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GICL1. Used for Class I areas: Gila Wilderness.

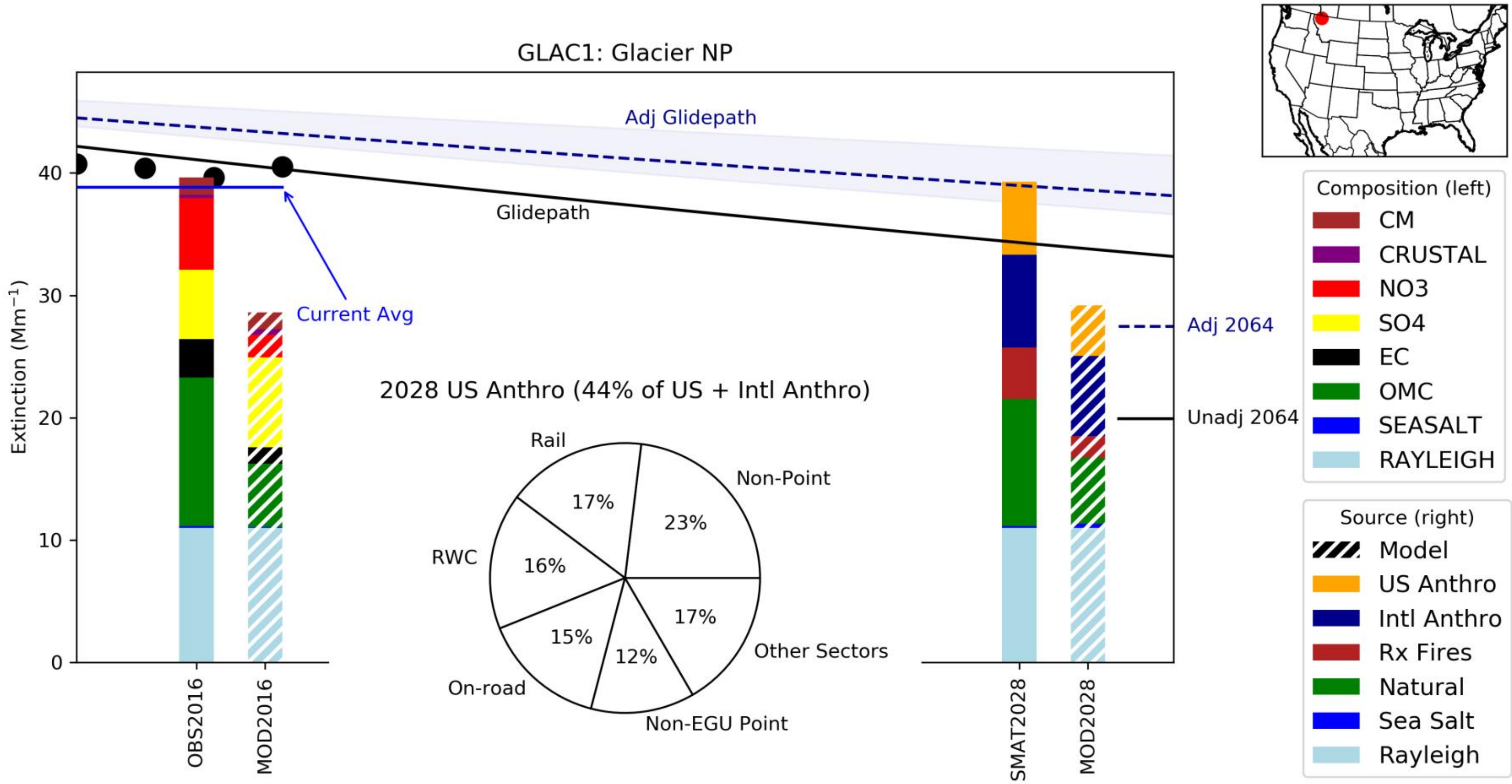


Figure 29: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GLAC1. Used for Class I areas: Glacier NP.

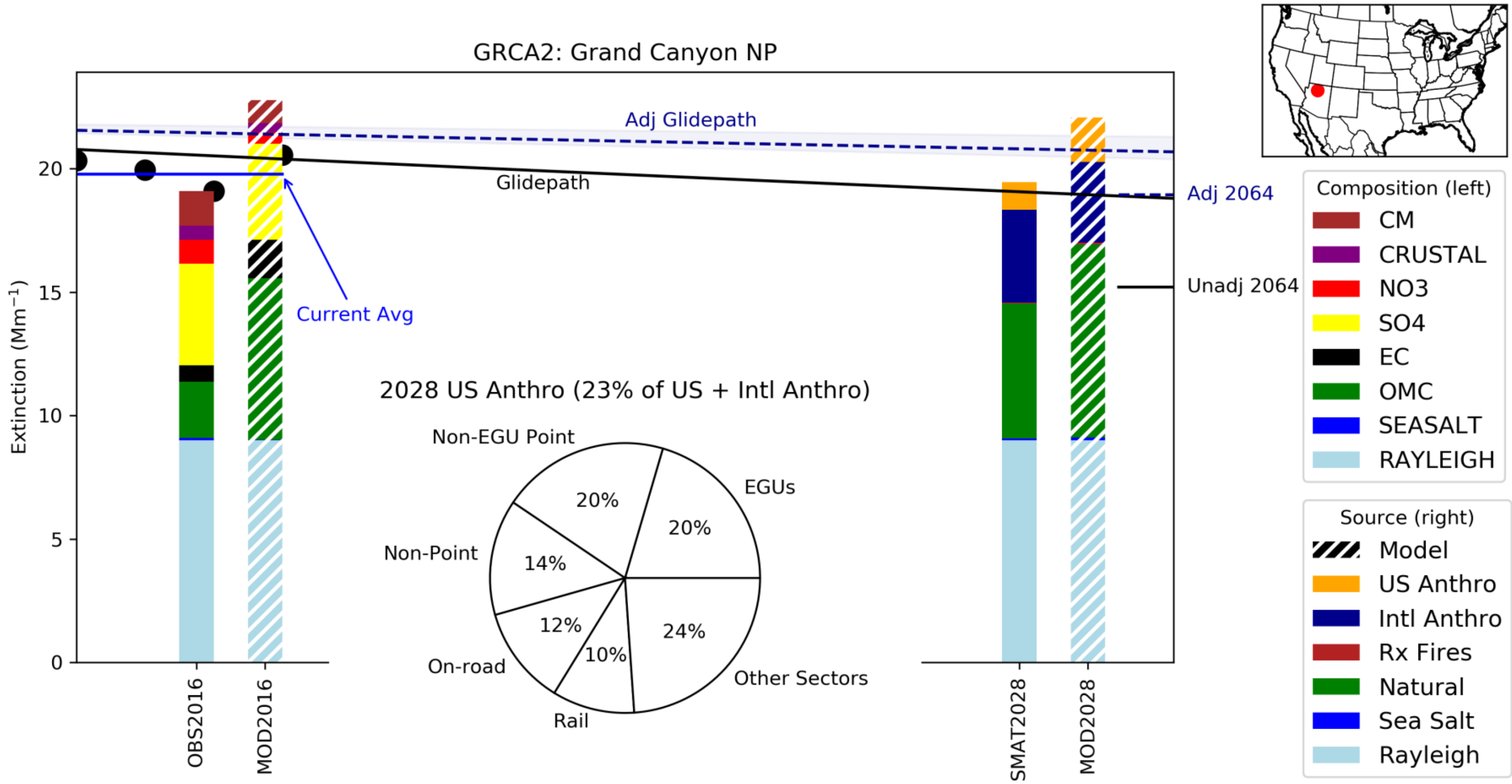


Figure 30: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GRCA2. Used for Class I areas: Grand Canyon NP.

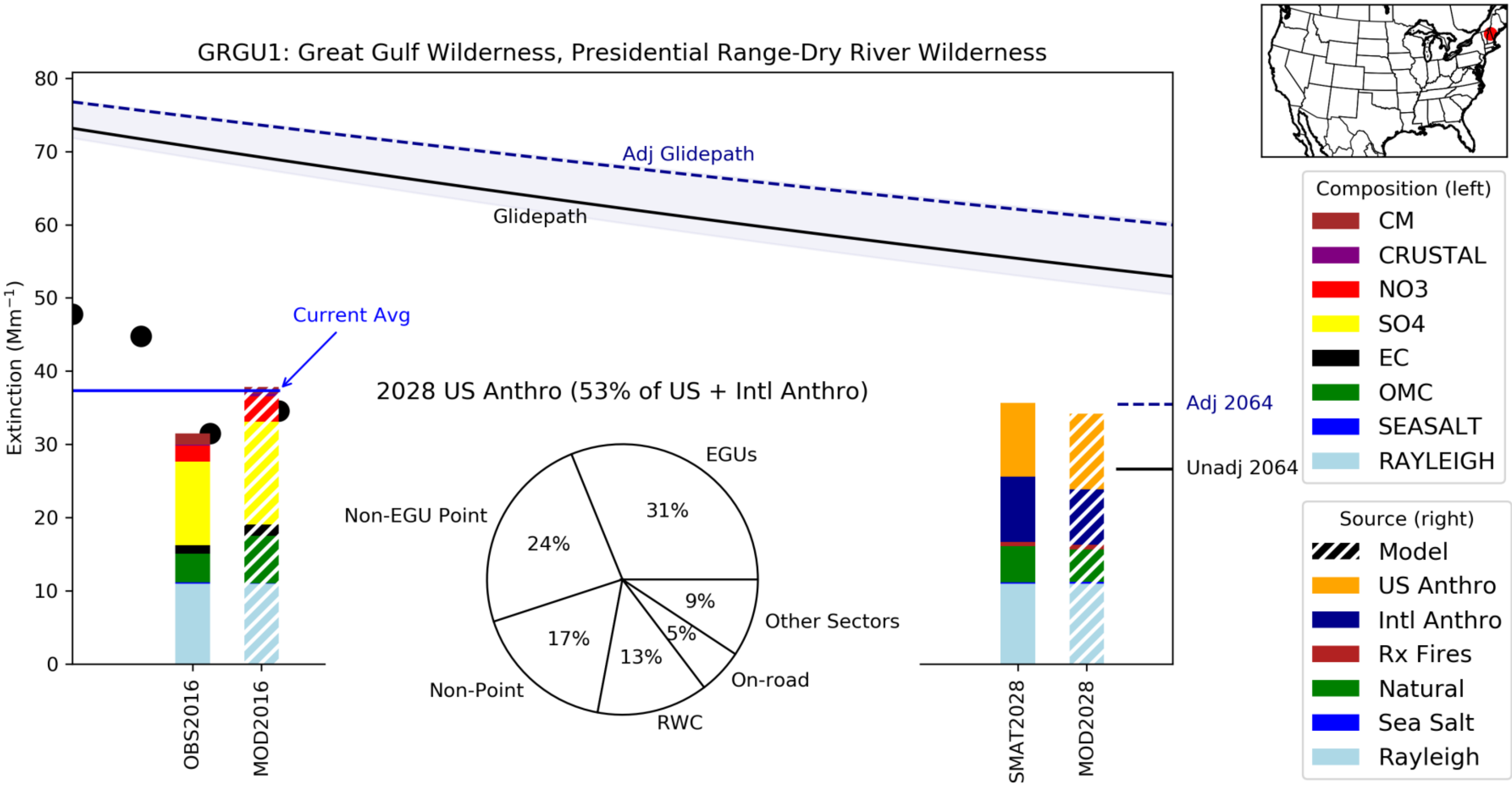


Figure 31: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GRGU1. Used for Class I areas: Great Gulf Wilderness, Presidential Range-Dry River Wilderness.

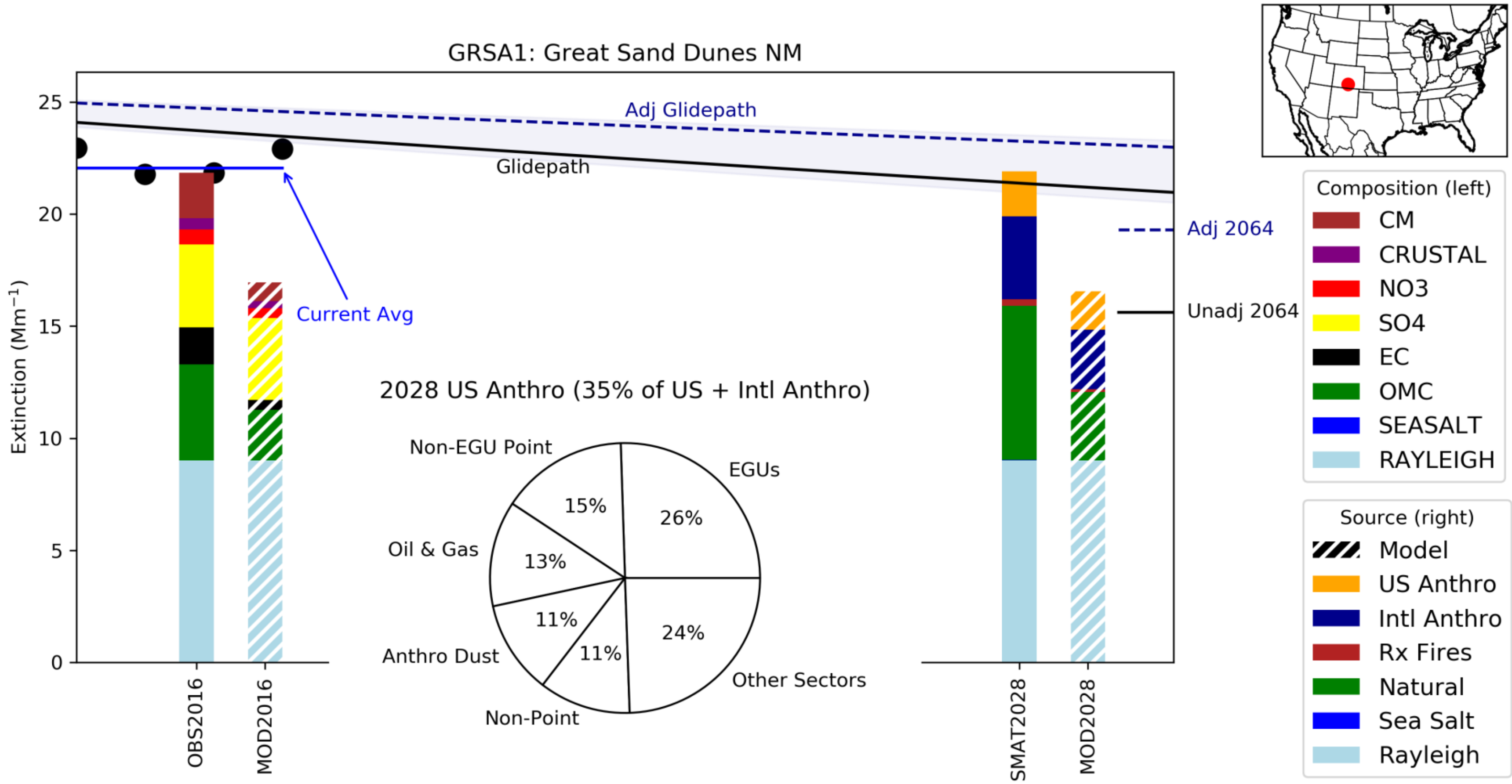


Figure 32: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GRSA1. Used for Class I areas: Great Sand Dunes NM.

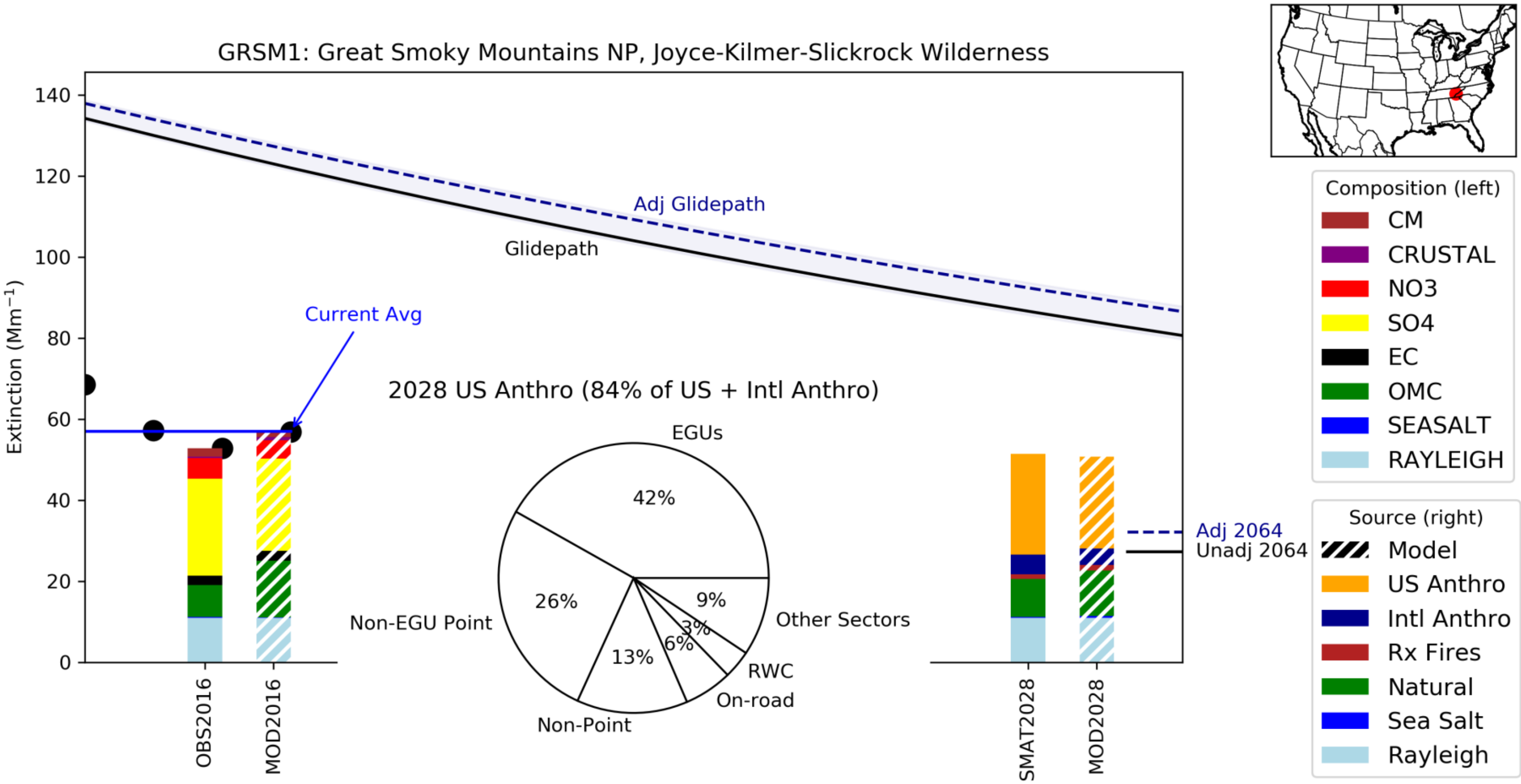


Figure 33: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GRSM1. Used for Class I areas: Great Smoky Mountains NP, Joyce-Kilmer-Slickrock Wilderness.

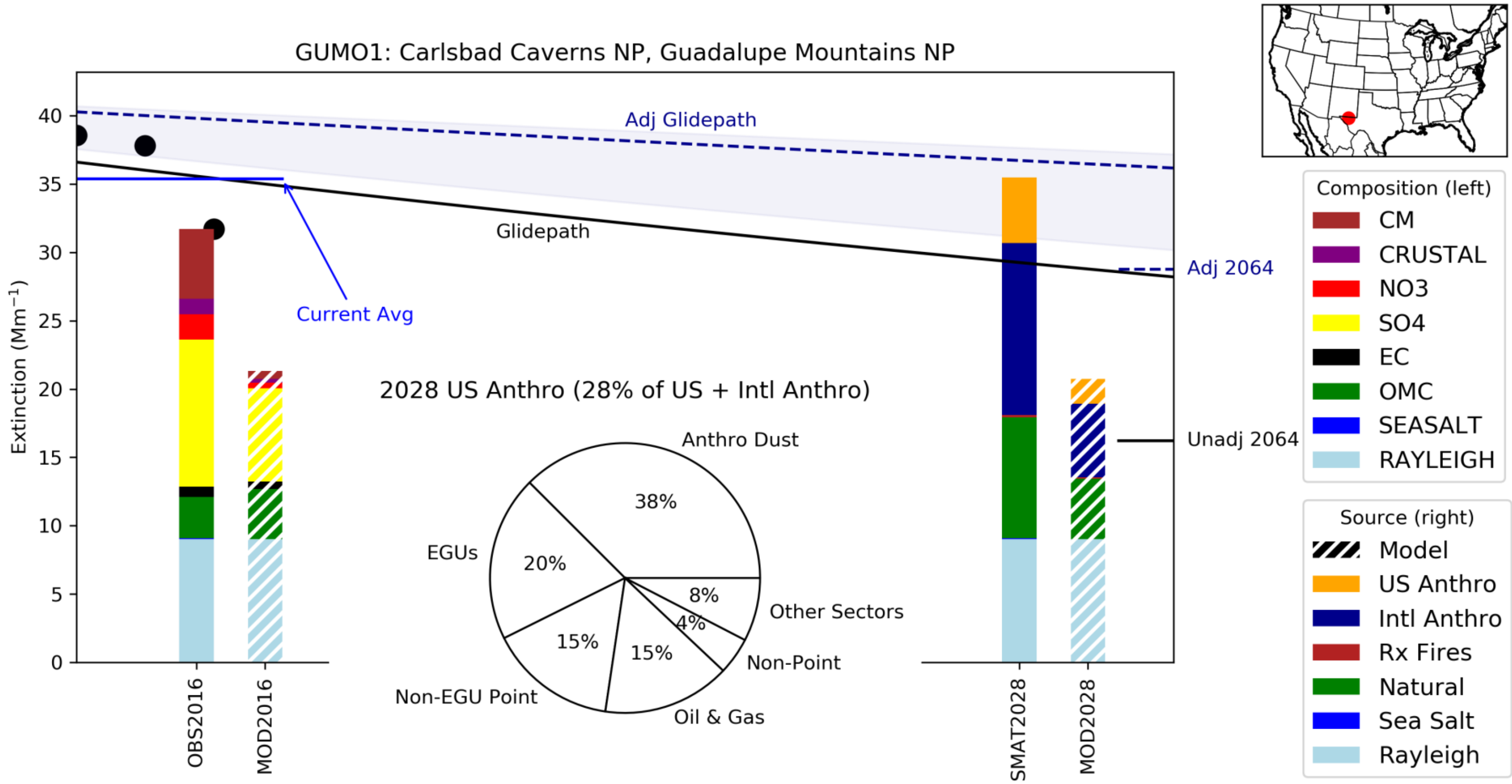


Figure 34: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at GUMO1. Used for Class I areas: Carlsbad Caverns NP, Guadalupe Mountains NP.

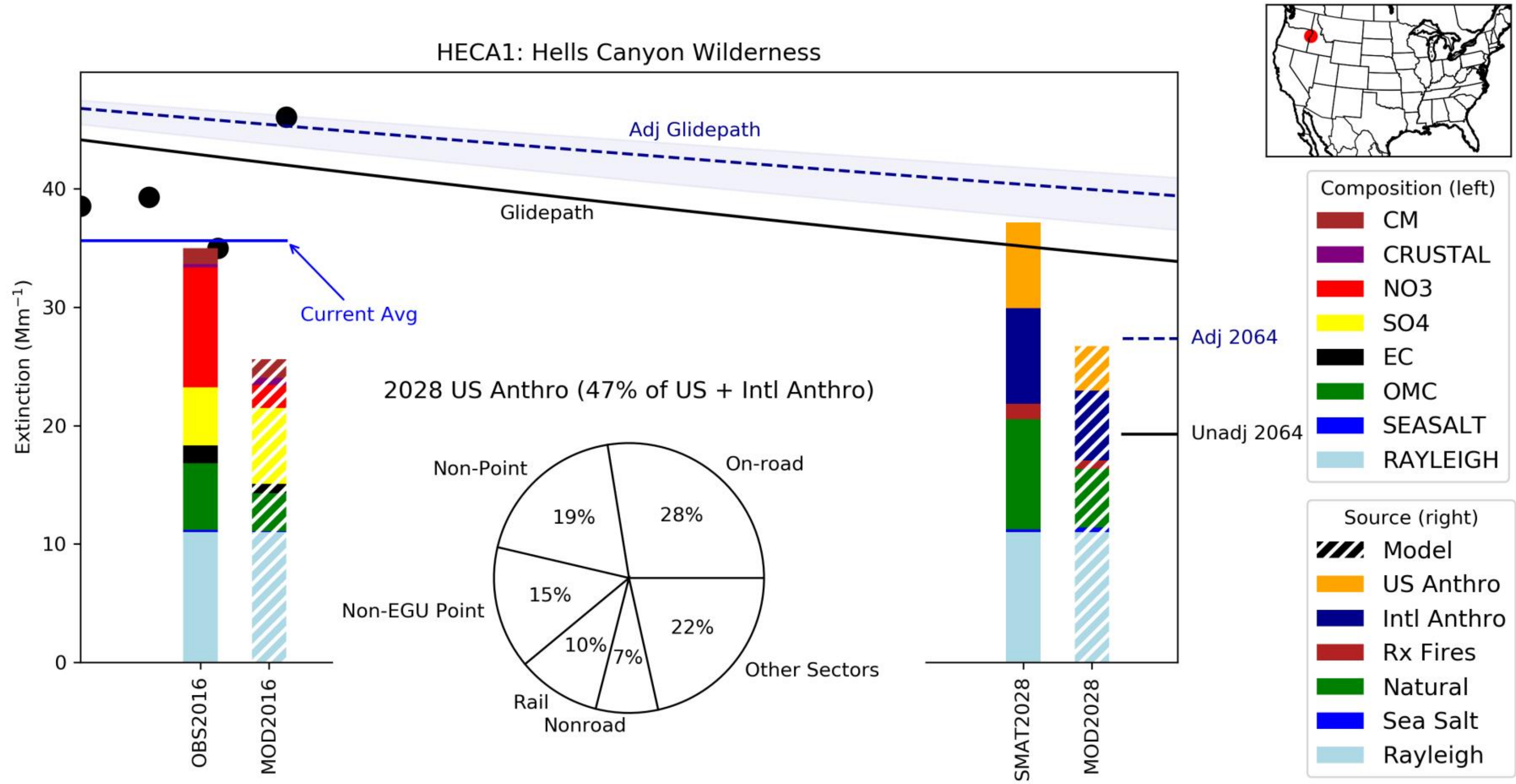


Figure 35: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at HECA1. Used for Class I areas: Hells Canyon Wilderness.

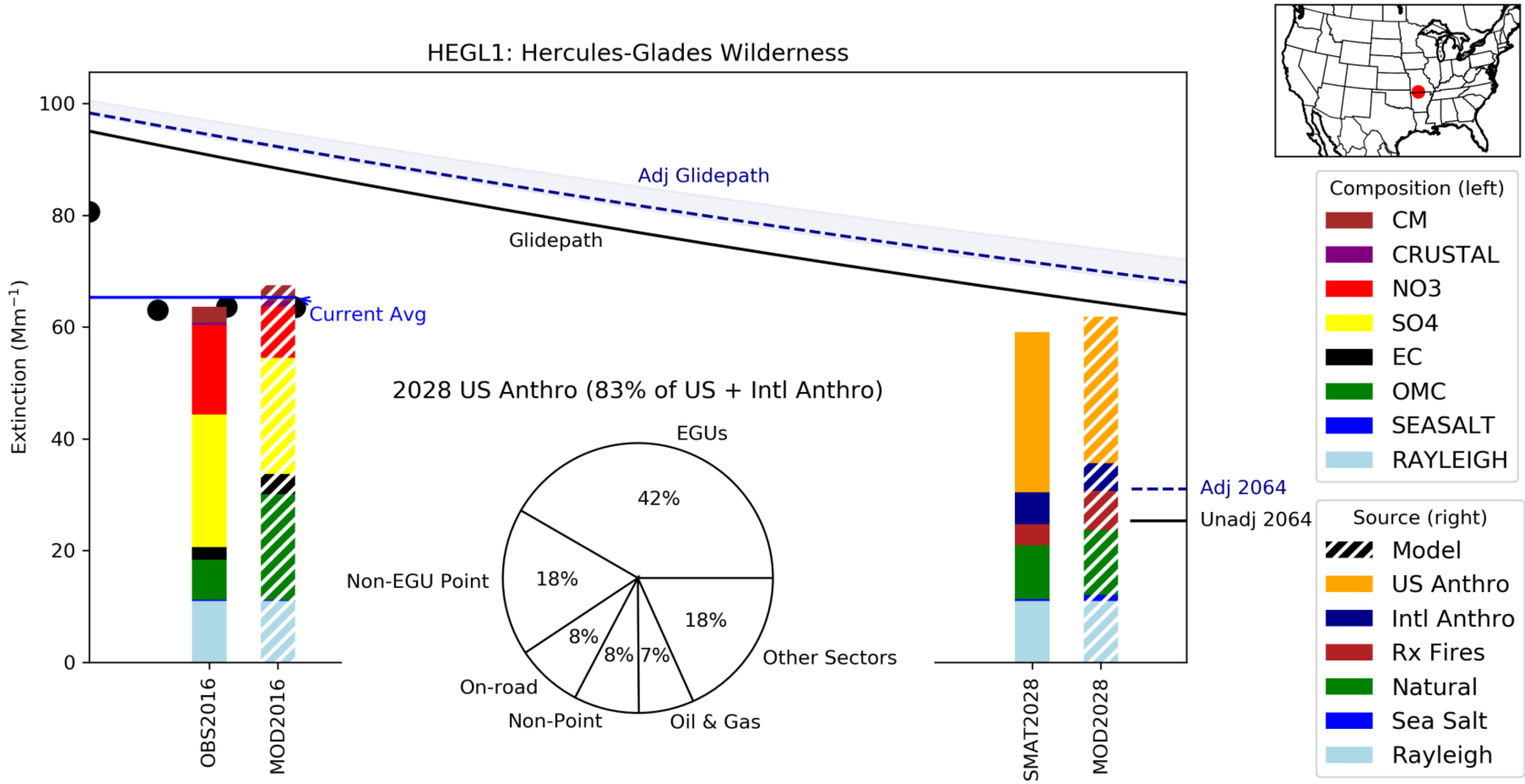


Figure 36: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at HEGL1. Used for Class I areas: Hercules-Glades Wilderness.

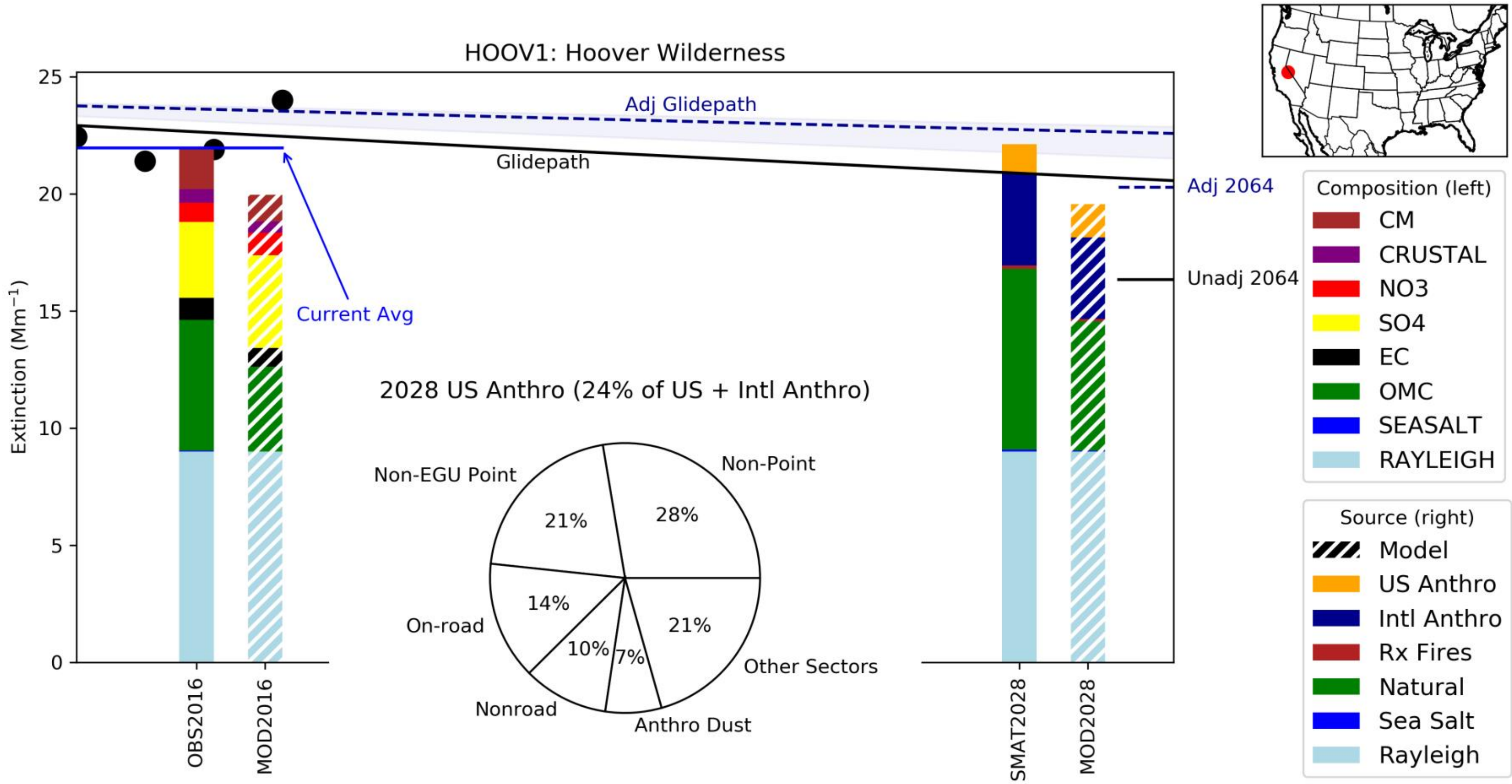


Figure 37: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at HOOV1. Used for Class I areas: Hoover Wilderness.

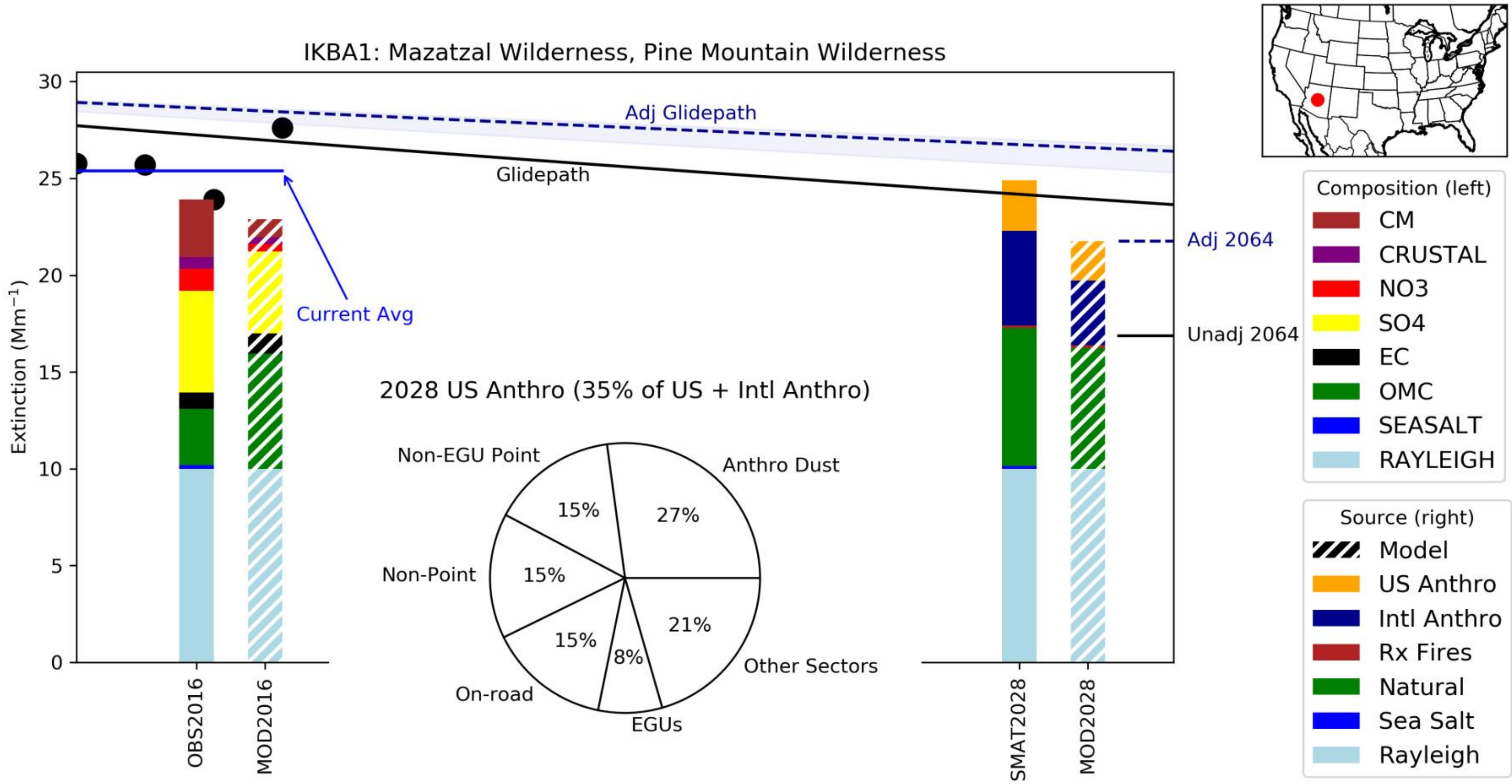


Figure 38: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at IKBA1. Used for Class I areas: Mazatzal Wilderness, Pine Mountain Wilderness.

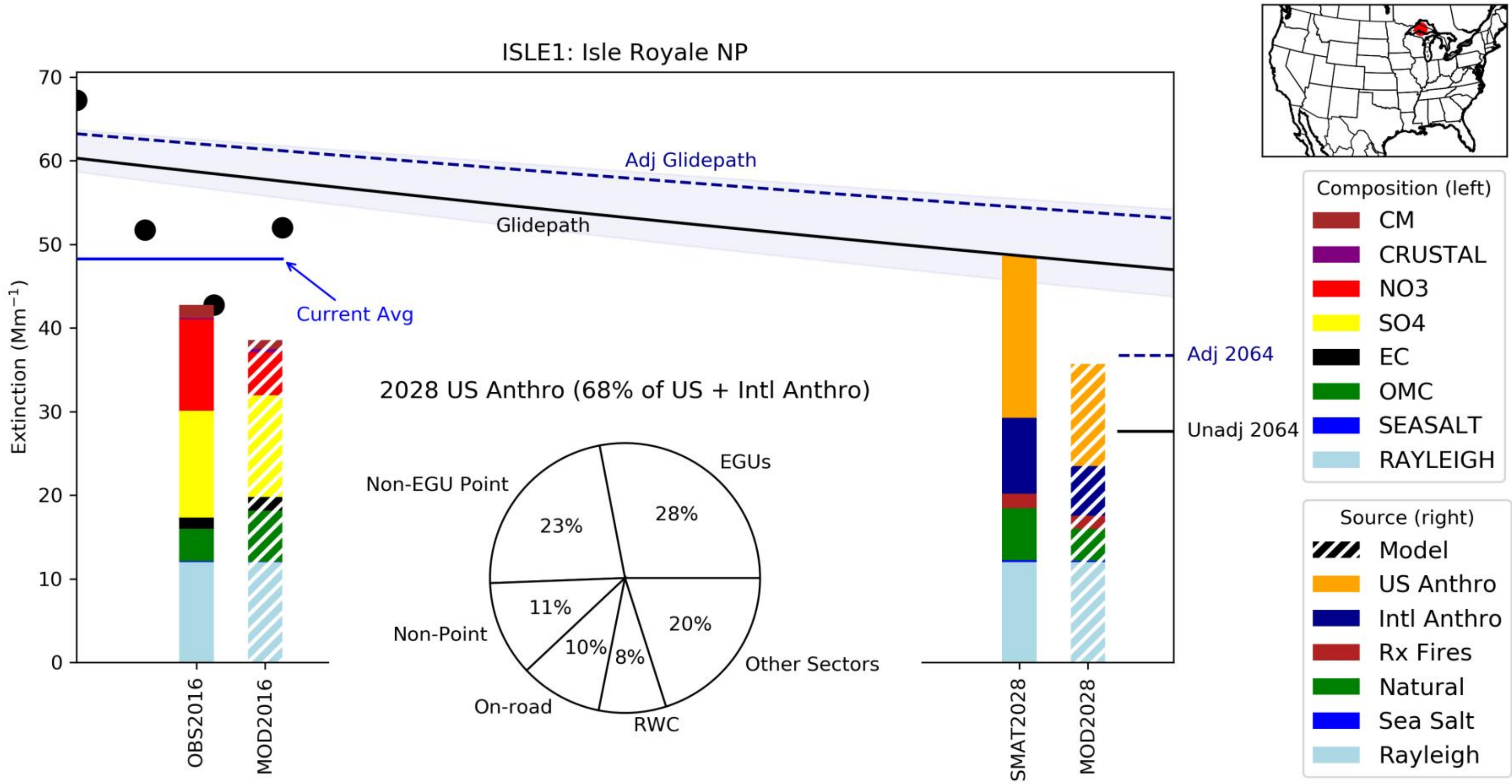


Figure 39: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at ISLE1. Used for Class I areas: Isle Royale NP.

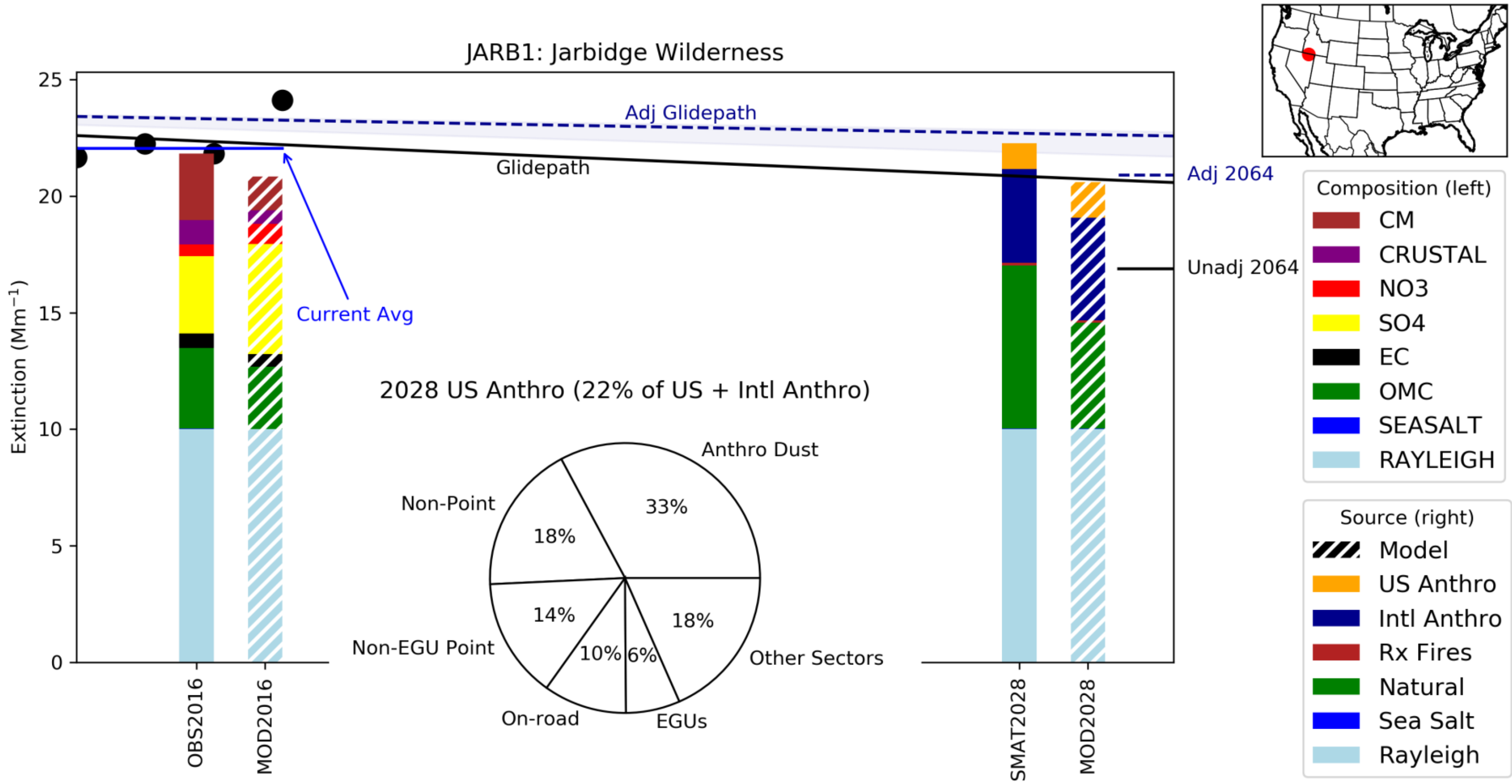


Figure 40: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at JARB1. Used for Class I areas: Jarbidge Wilderness.

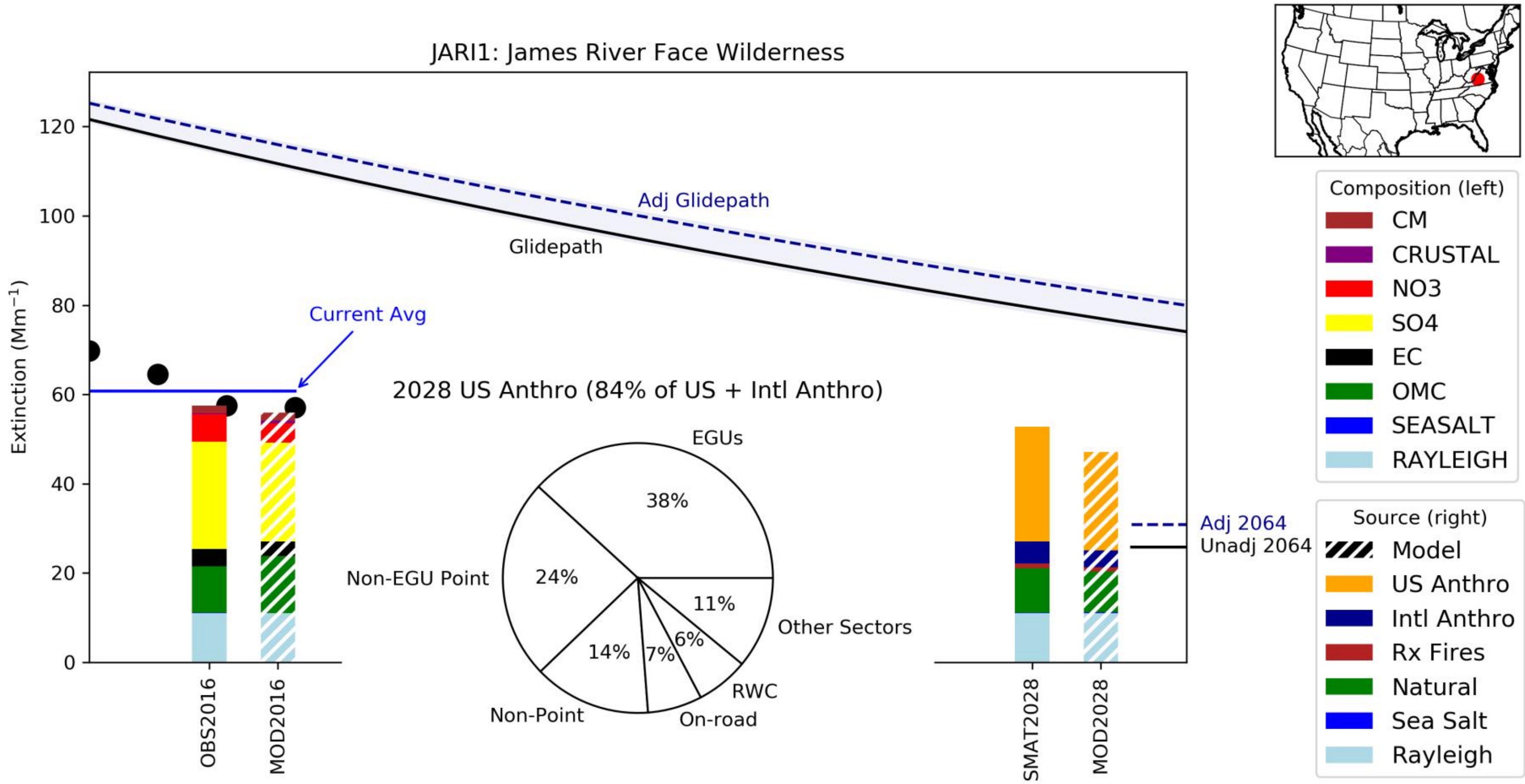


Figure 41: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at JARI1. Used for Class I areas: James River Face Wilderness.

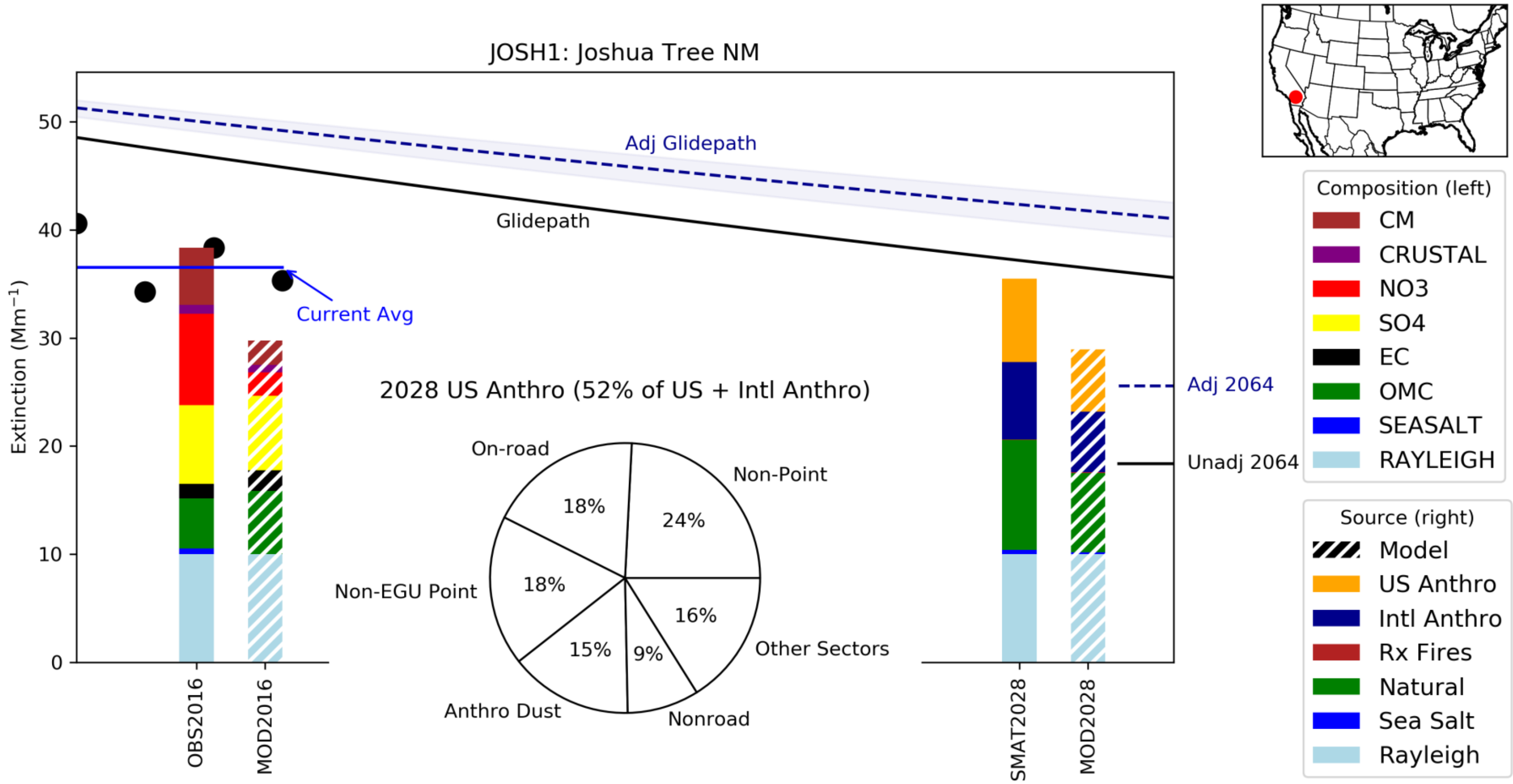


Figure 42: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at JOSH1. Used for Class I areas: Joshua Tree NM.

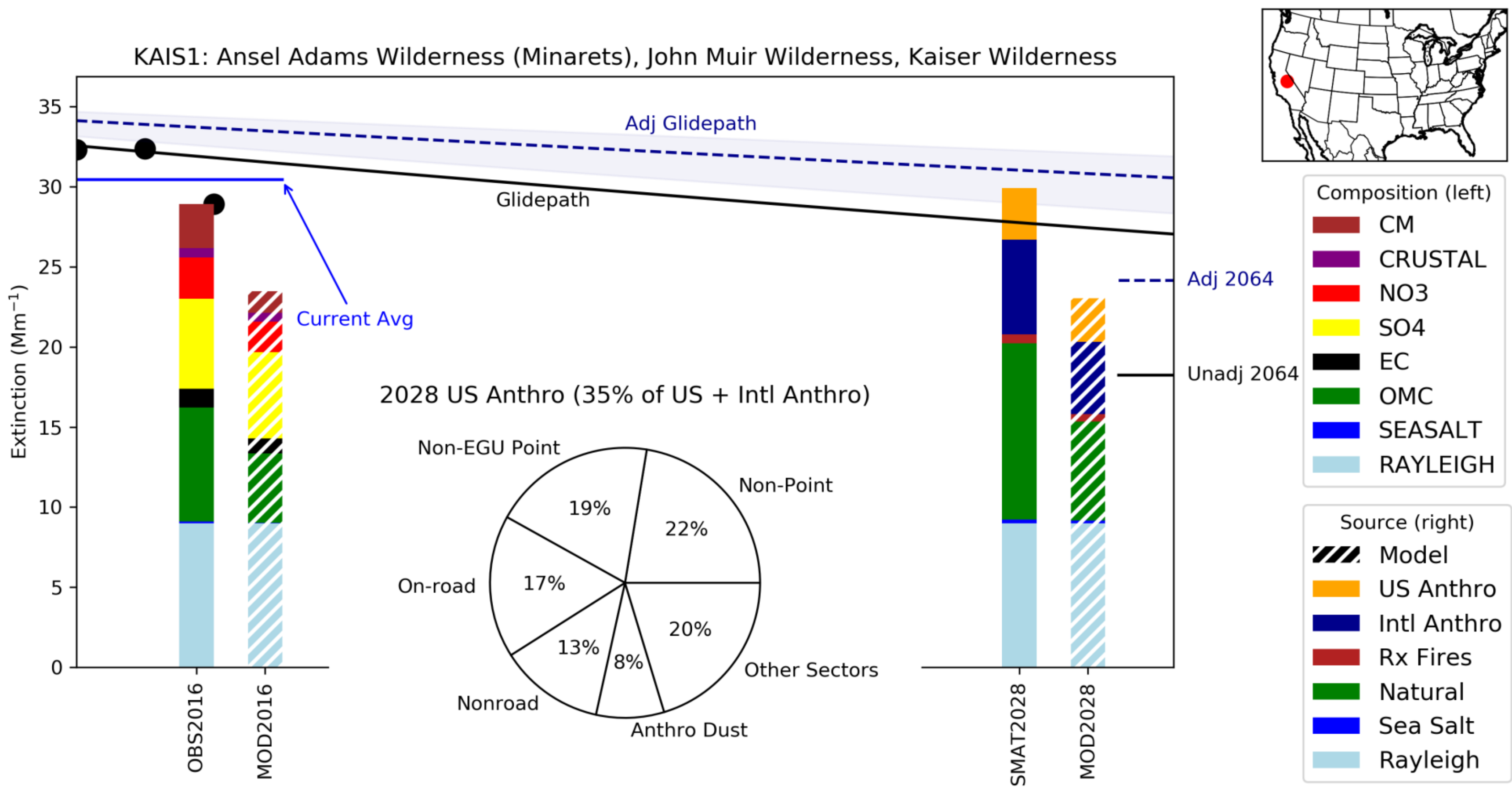


Figure 43: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at KAIS1. Used for Class I areas: Ansel Adams Wilderness (Minarets), John Muir Wilderness, Kaiser Wilderness.

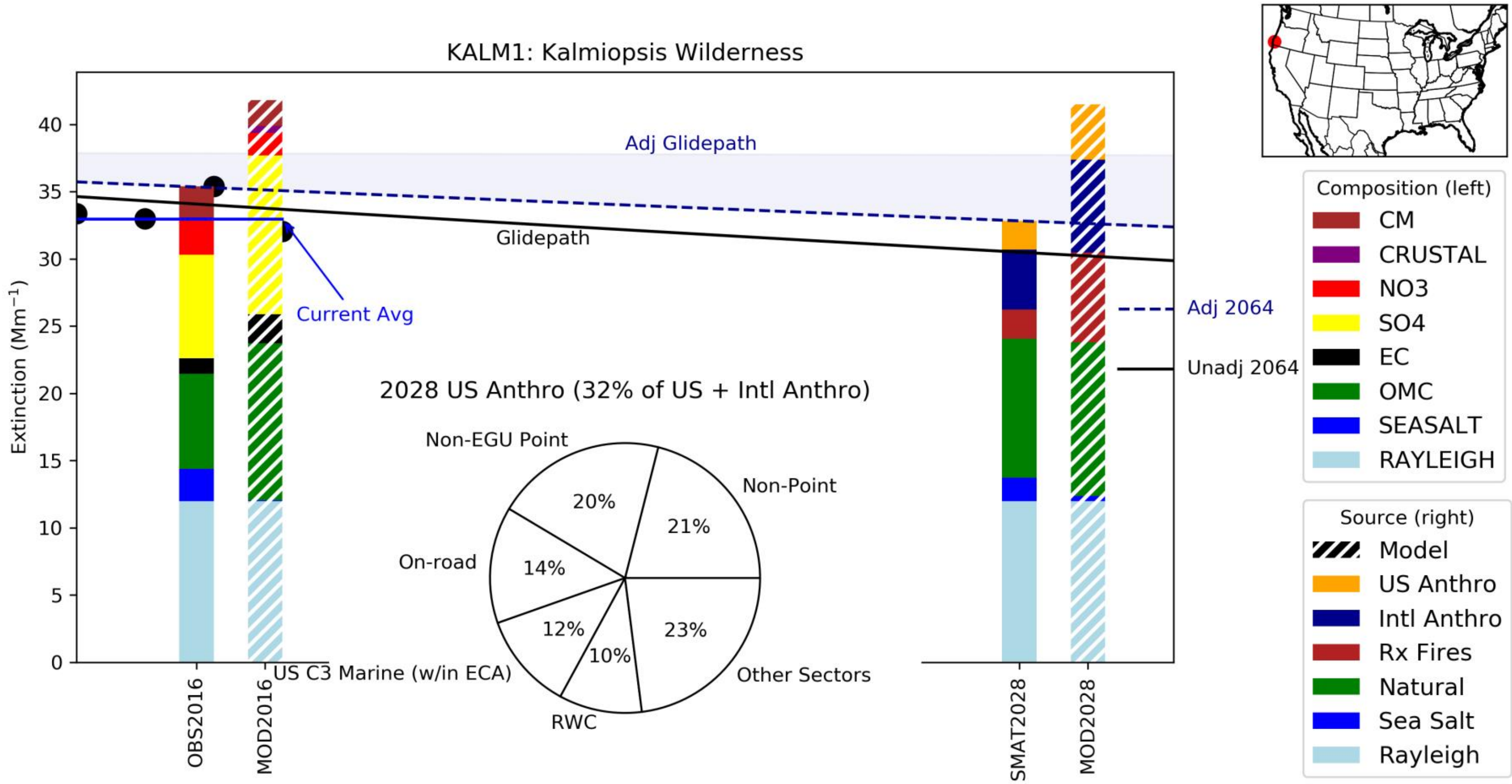


Figure 44: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at KALM1. Used for Class I areas: Kalmiopsis Wilderness.

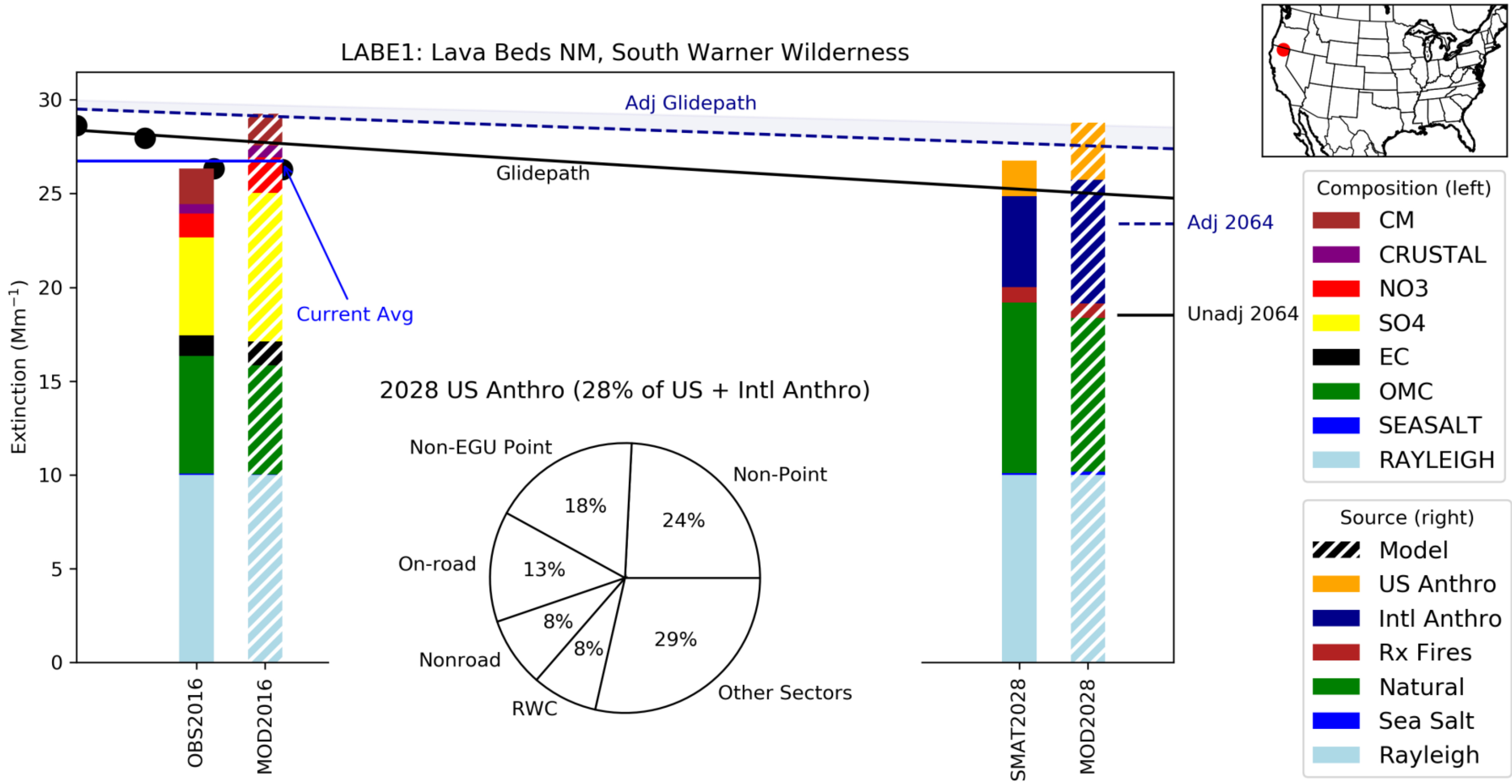


Figure 45: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at LABE1. Used for Class I areas: Lava Beds NM, South Warner Wilderness.

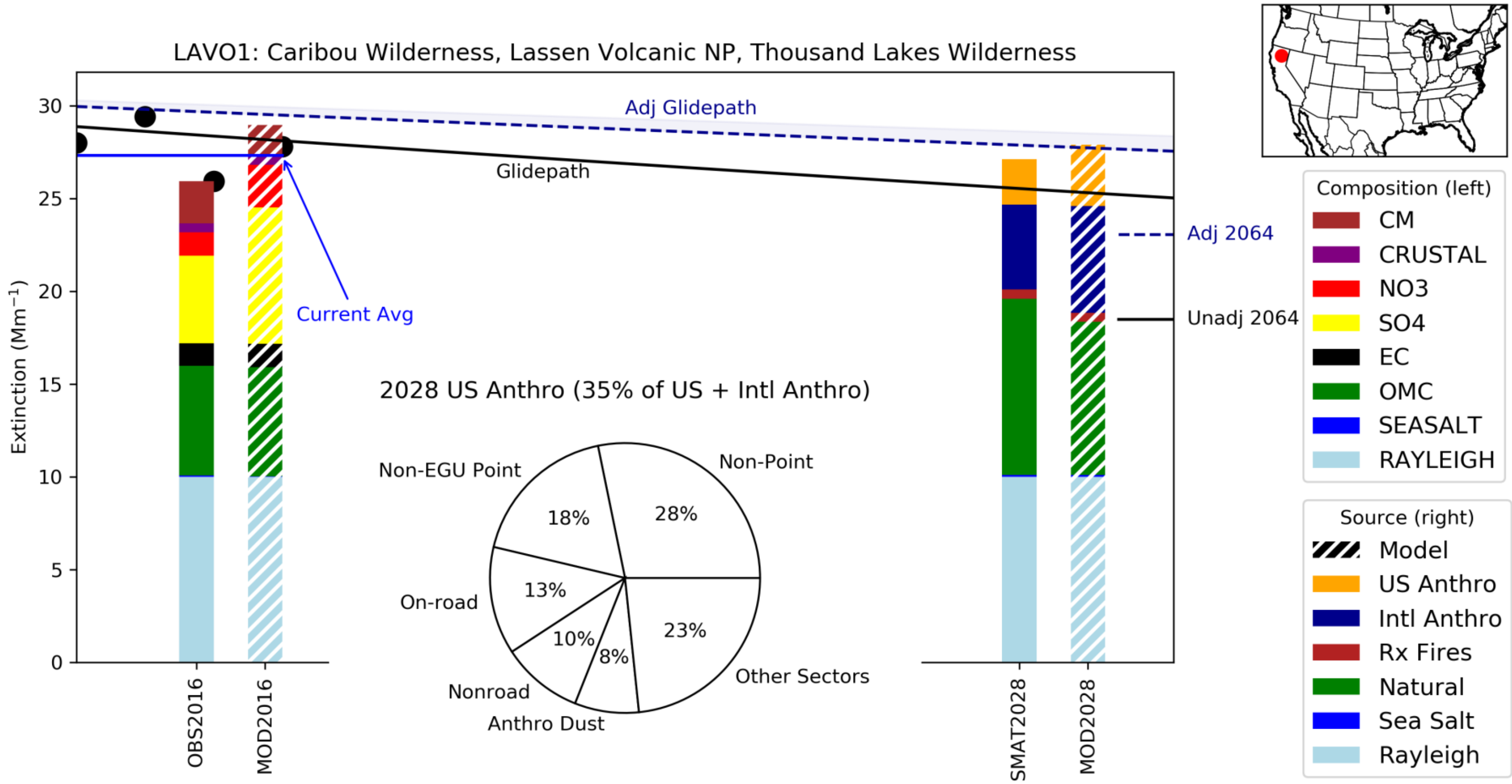


Figure 46: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at LAVO1. Used for Class I areas: Caribou Wilderness, Lassen Volcanic NP, Thousand Lakes Wilderness.

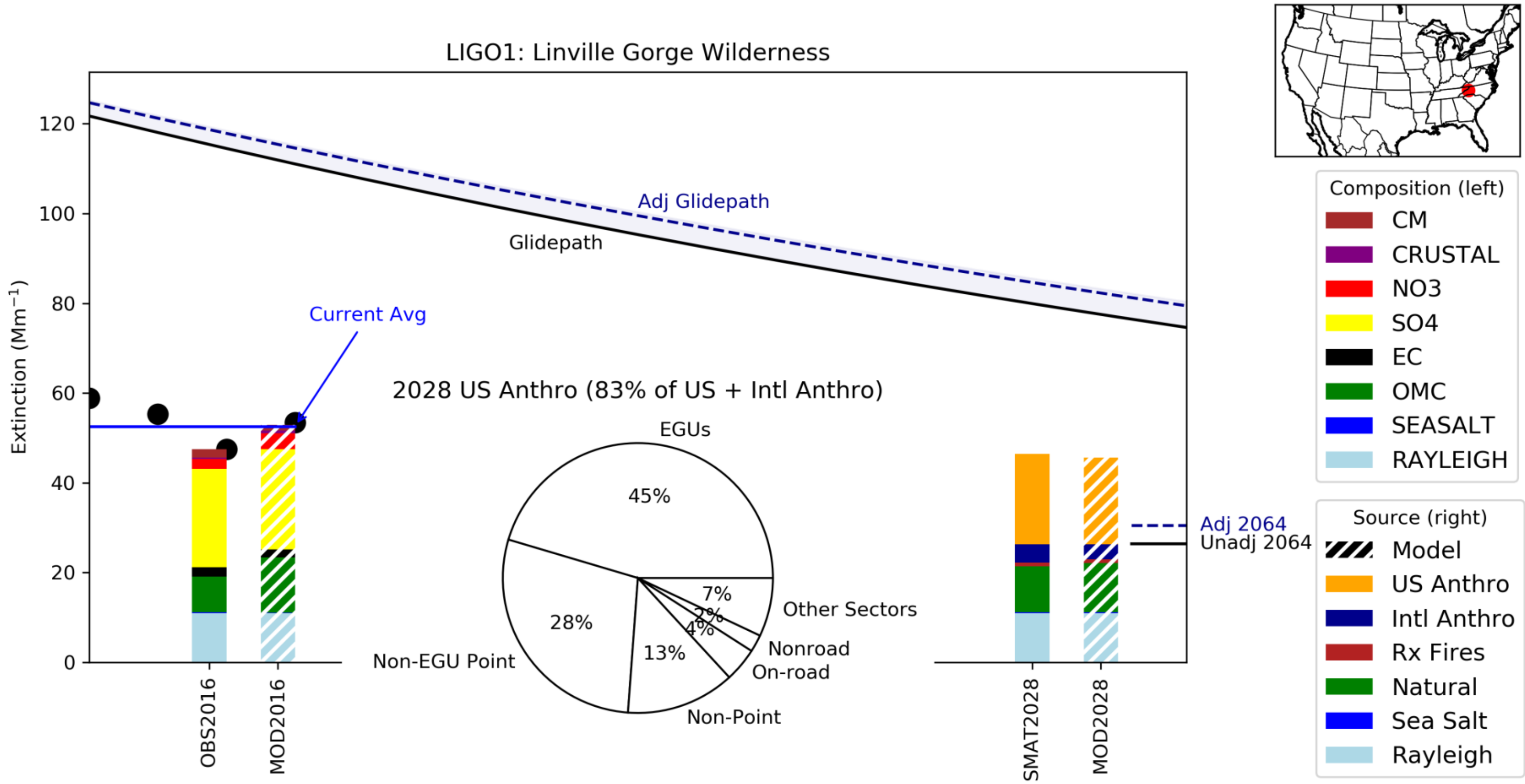


Figure 47: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at LIGO1. Used for Class I areas: Linville Gorge Wilderness.

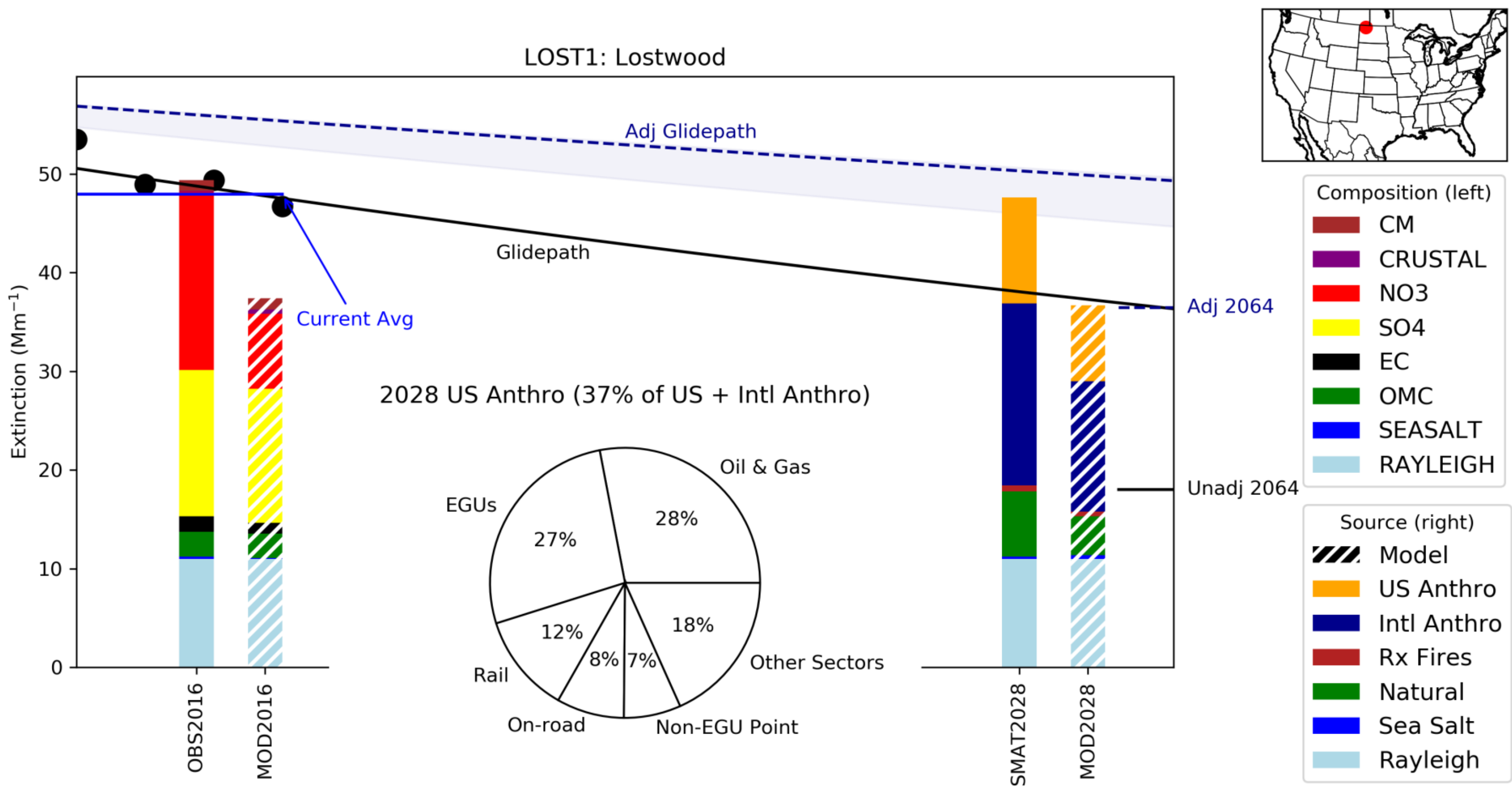


Figure 48: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at LOST1. Used for Class I areas: Lostwood.

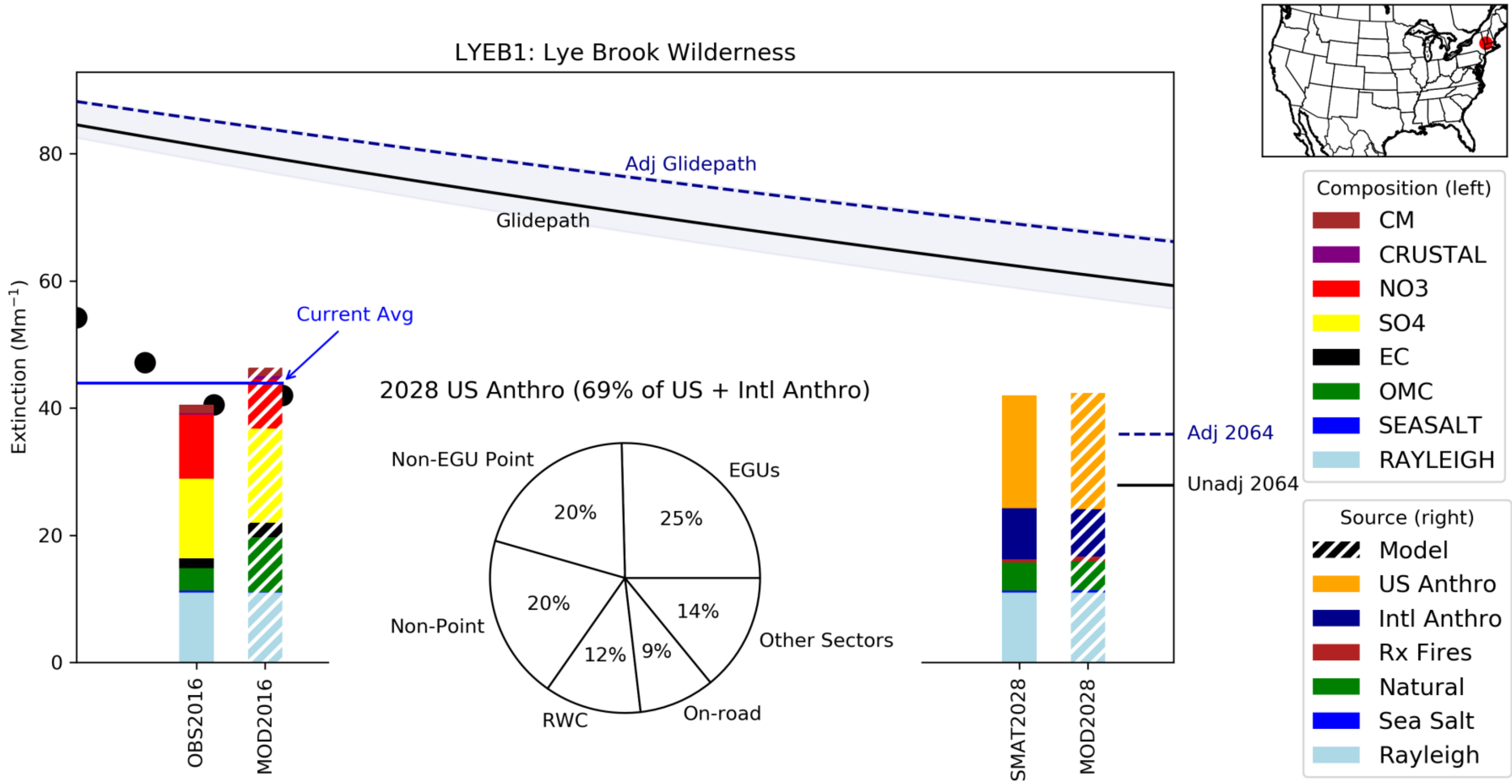


Figure 49: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at LYEB1. Used for Class I areas: Lye Brook Wilderness.

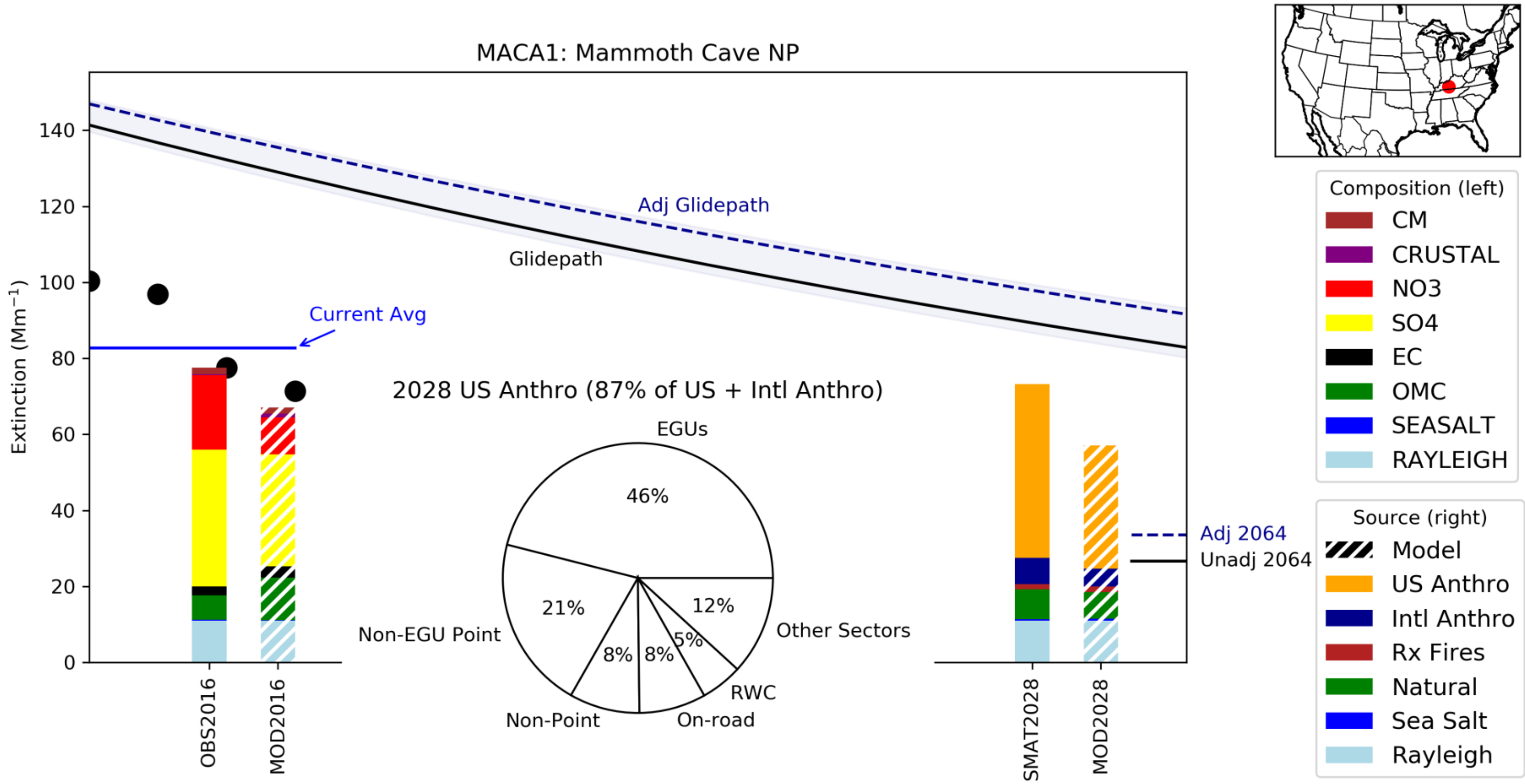


Figure 50: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MACA1. Used for Class I areas: Mammoth Cave NP.

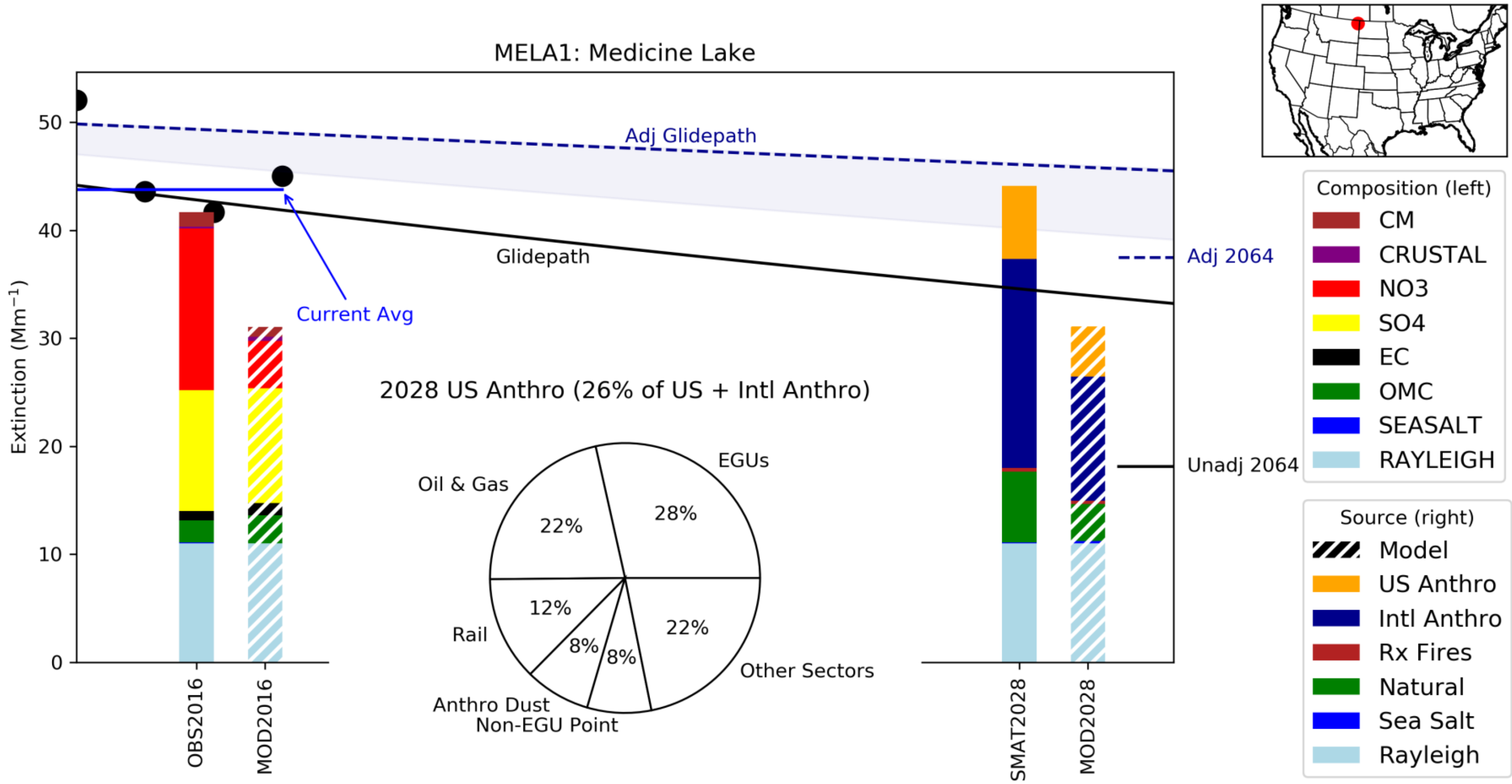


Figure 51: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MELA1. Used for Class I areas: Medicine Lake.

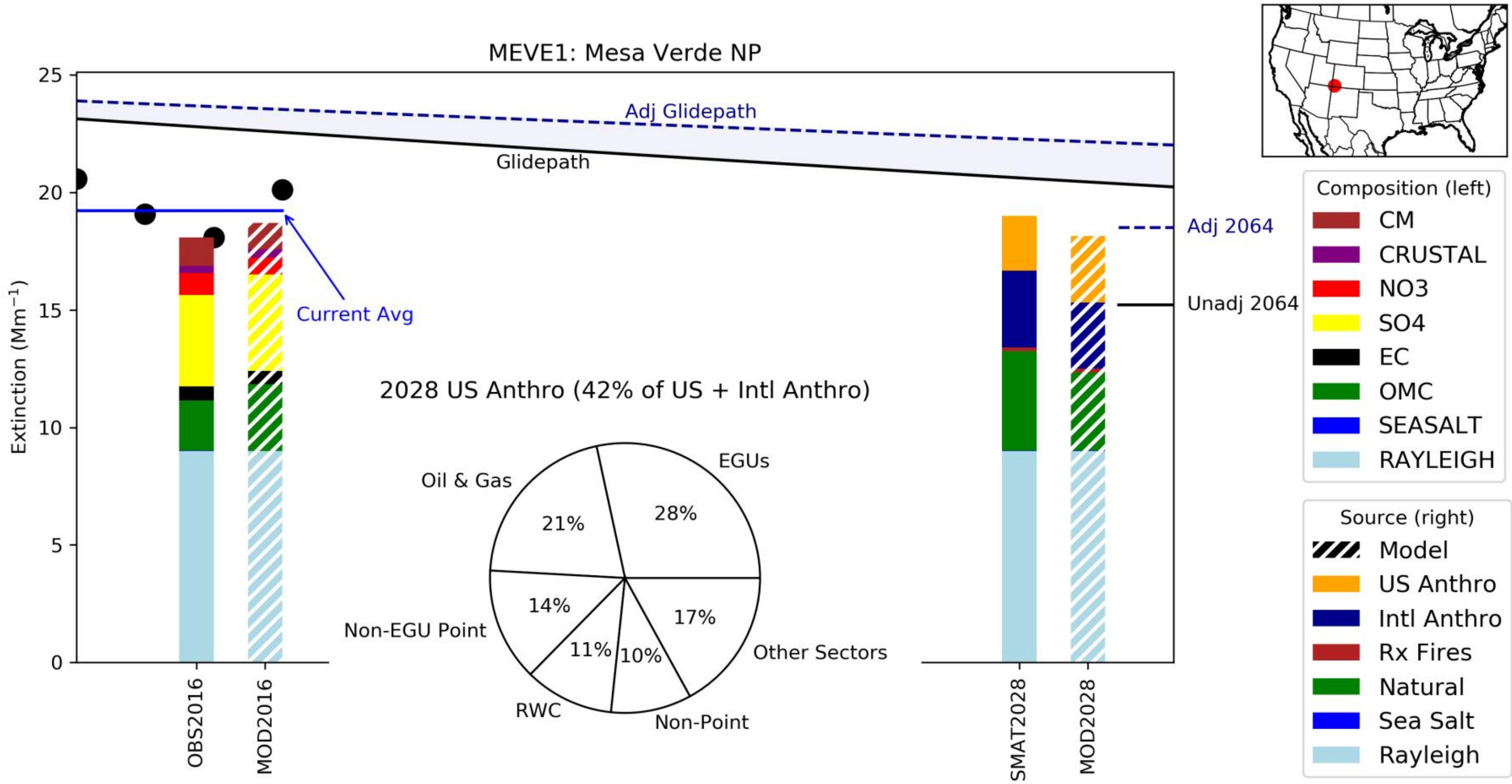


Figure 52: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MEVE1. Used for Class I areas: Mesa Verde NP.

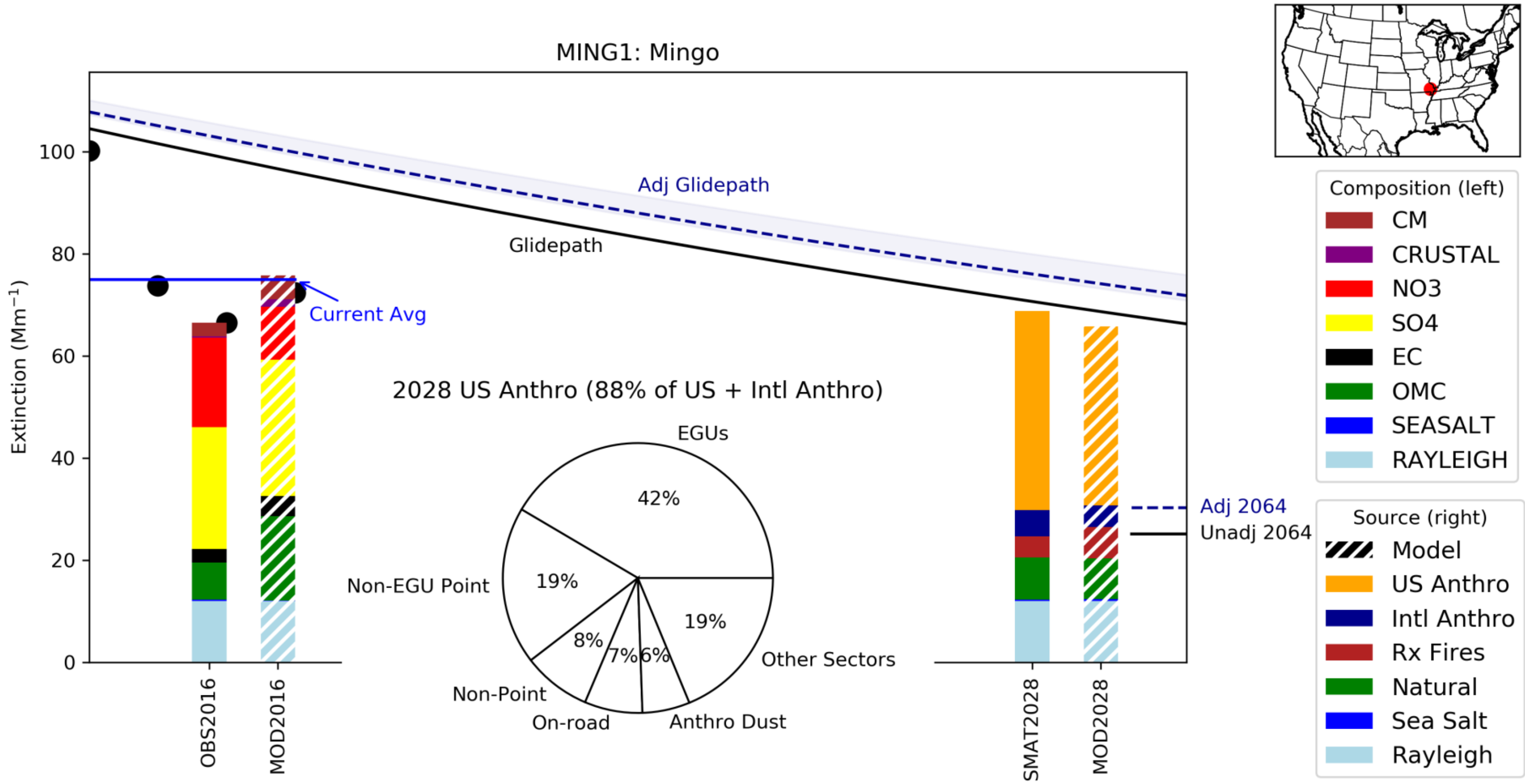


Figure 53: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MING1. Used for Class I areas: Mingo.

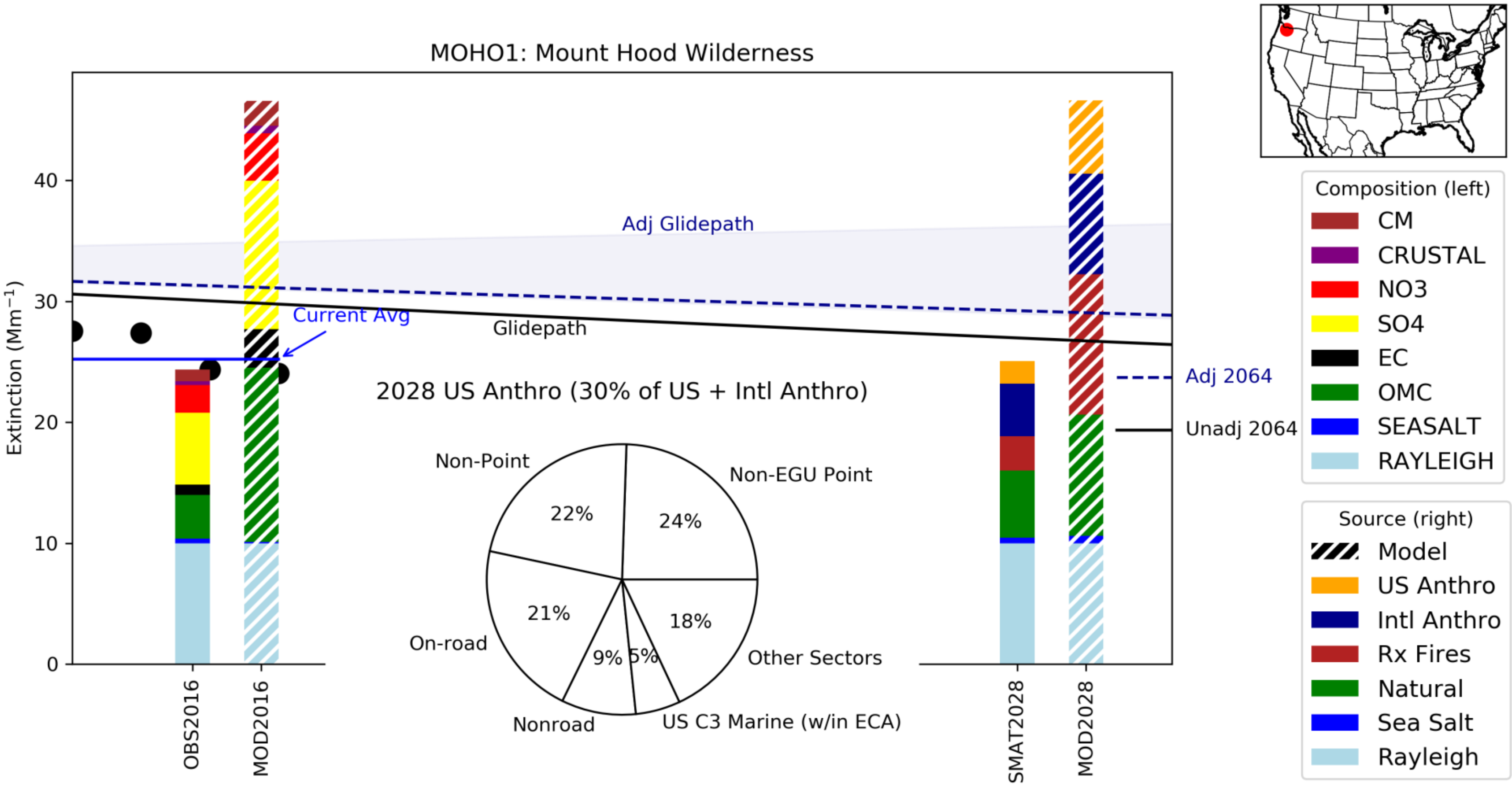


Figure 54: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MOHO1. Used for Class I areas: Mount Hood Wilderness.

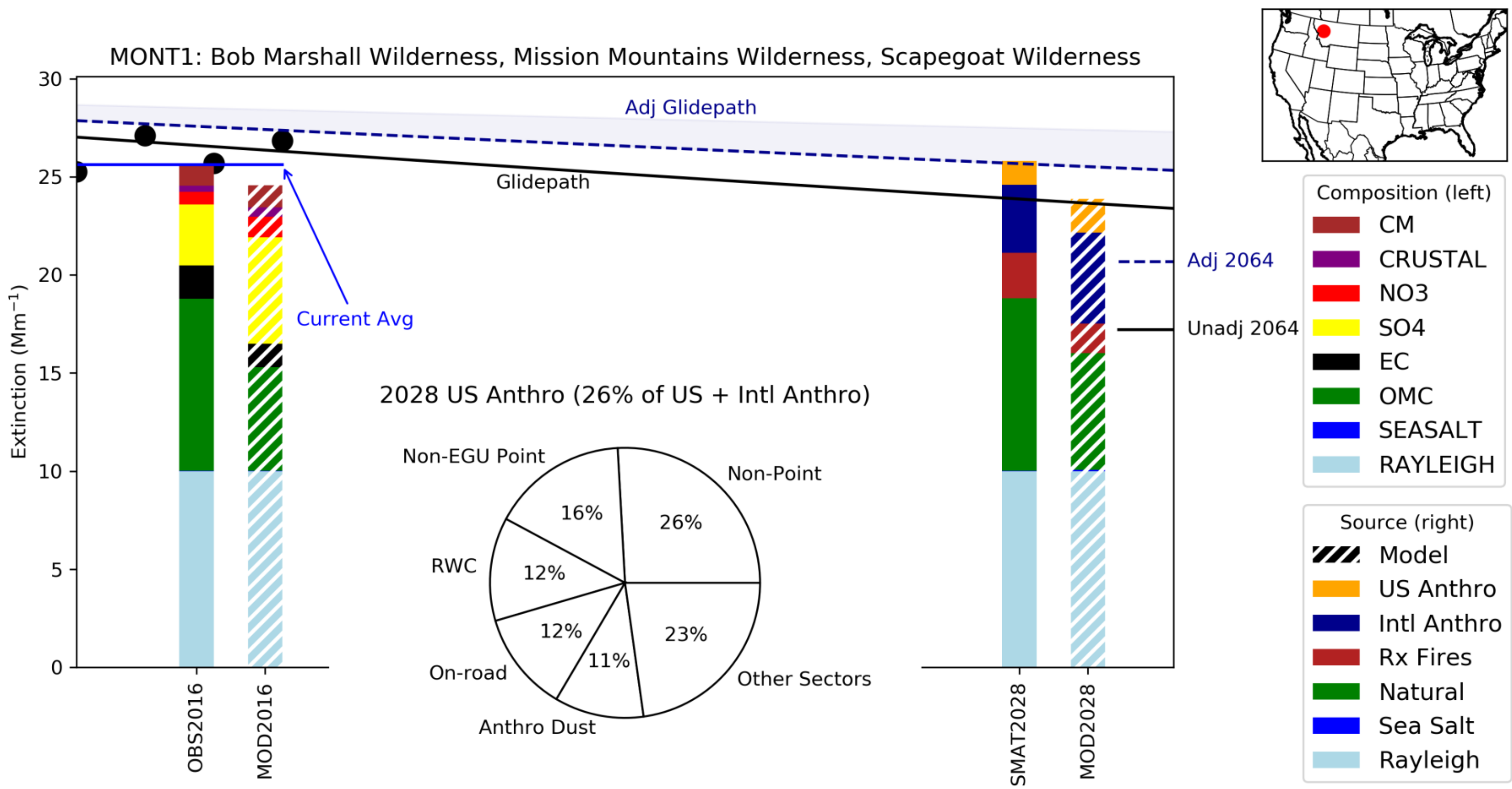


Figure 55: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MONT1. Used for Class I areas: Bob Marshall Wilderness, Mission Mountains Wilderness, Scapegoat Wilderness.

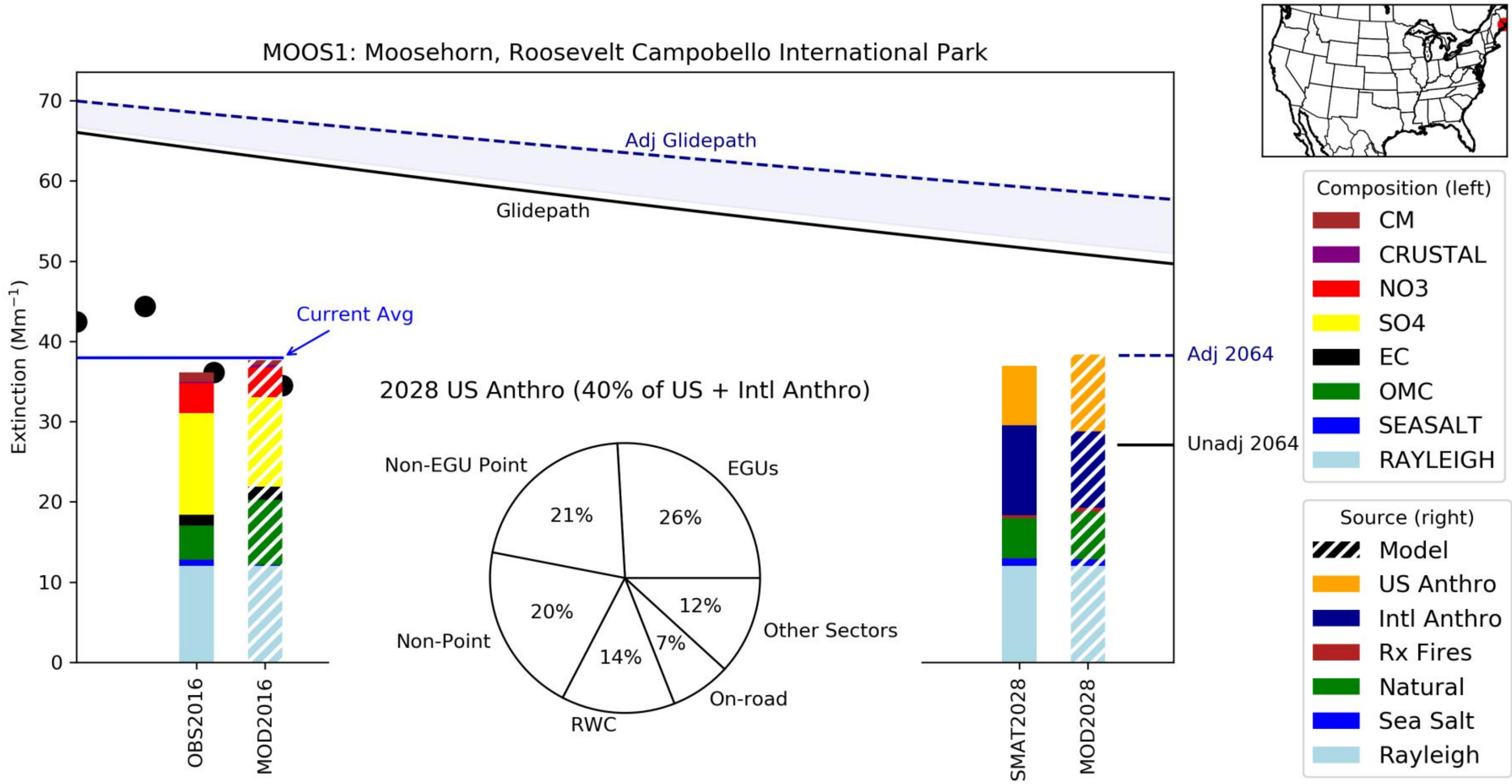


Figure 56: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MOOS1. Used for Class I areas: Moosehorn, Roosevelt Campobello International Park.

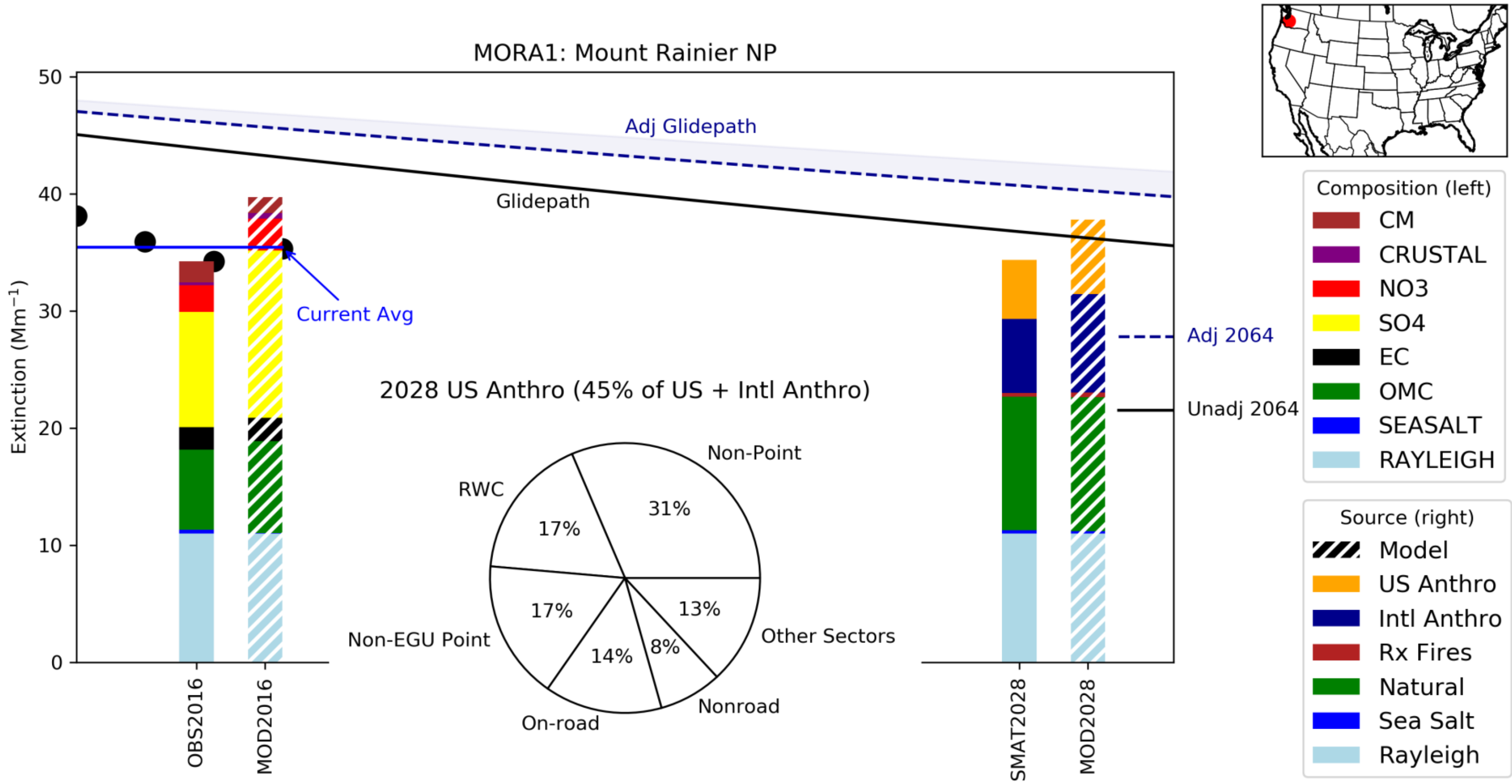


Figure 57: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MORA1. Used for Class I areas: Mount Rainier NP.

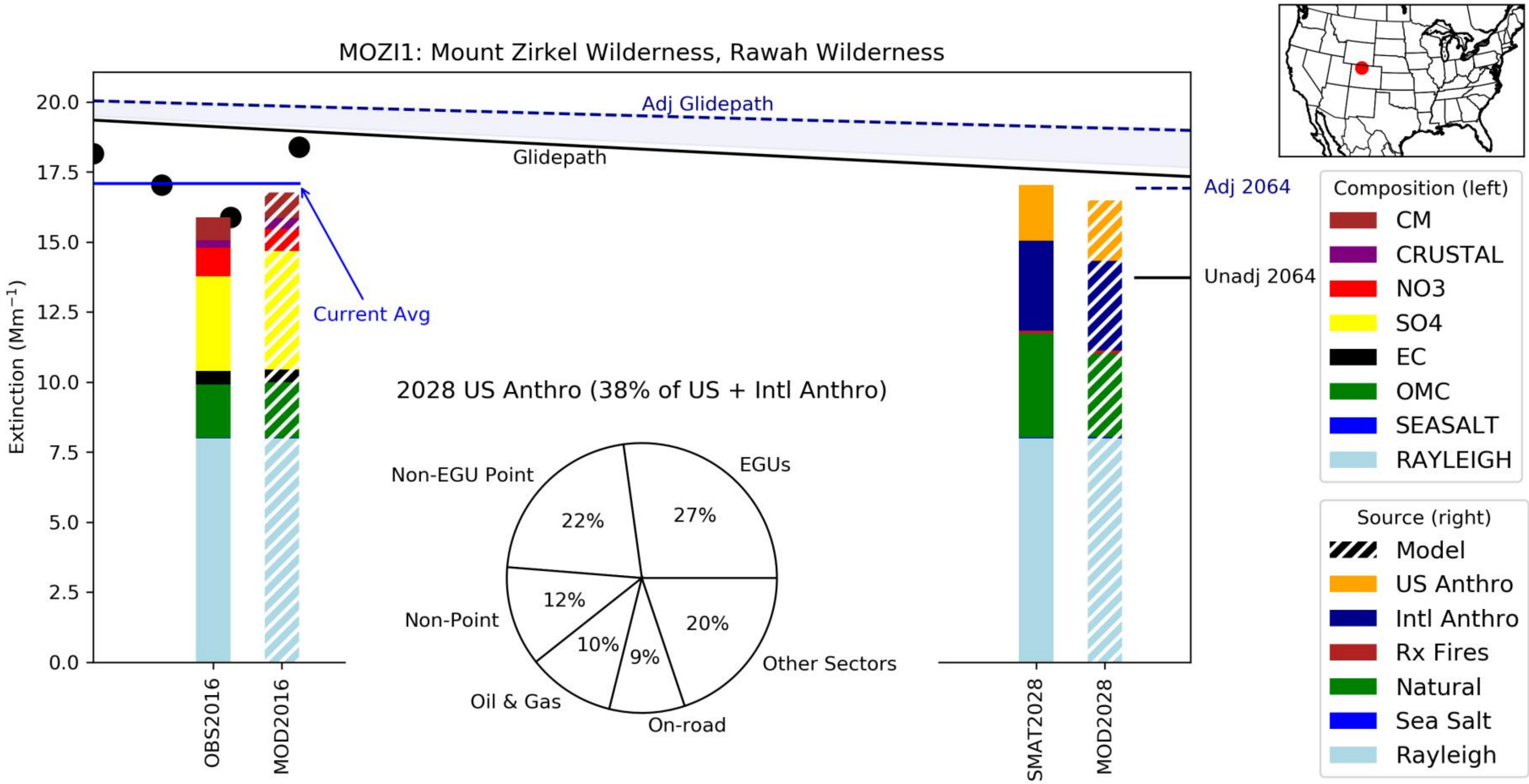


Figure 58: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at MOZI1. Used for Class I areas: Mount Zirkel Wilderness, Rawah Wilderness.

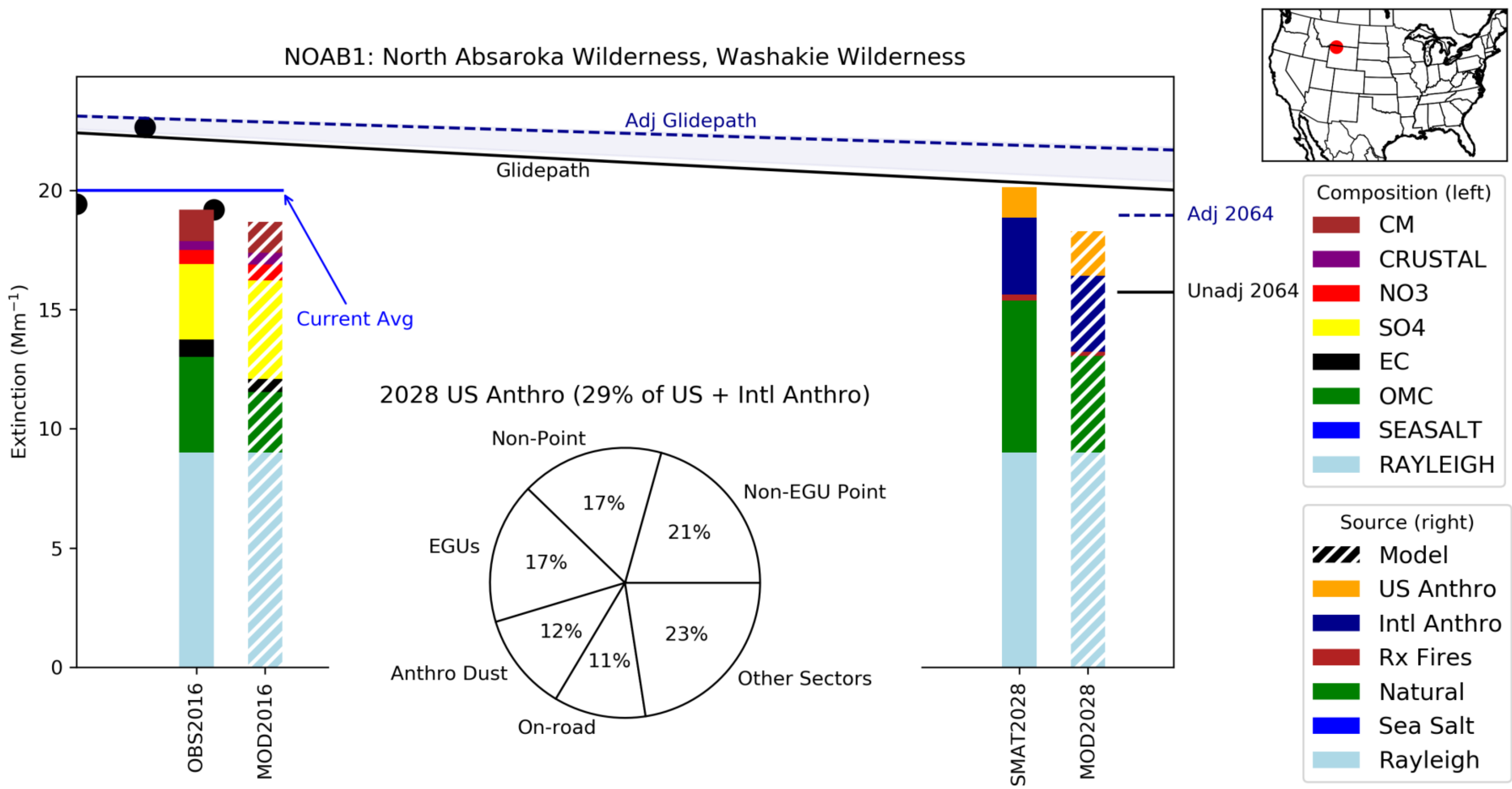


Figure 59: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at NOAB1. Used for Class I areas: North Absaroka Wilderness, Washakie Wilderness.

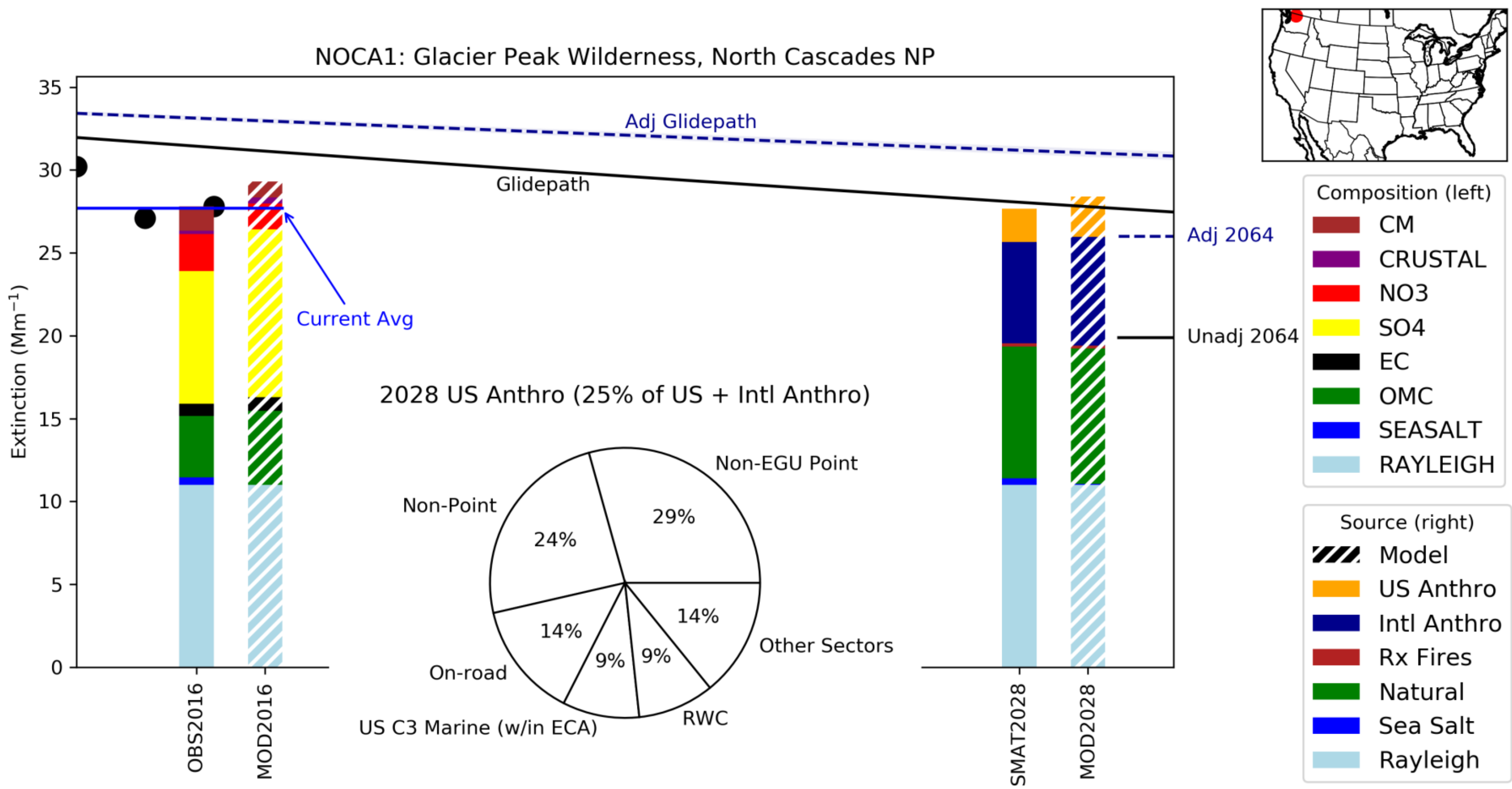


Figure 60: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at NOCA1. Used for Class I areas: Glacier Peak Wilderness, North Cascades NP.

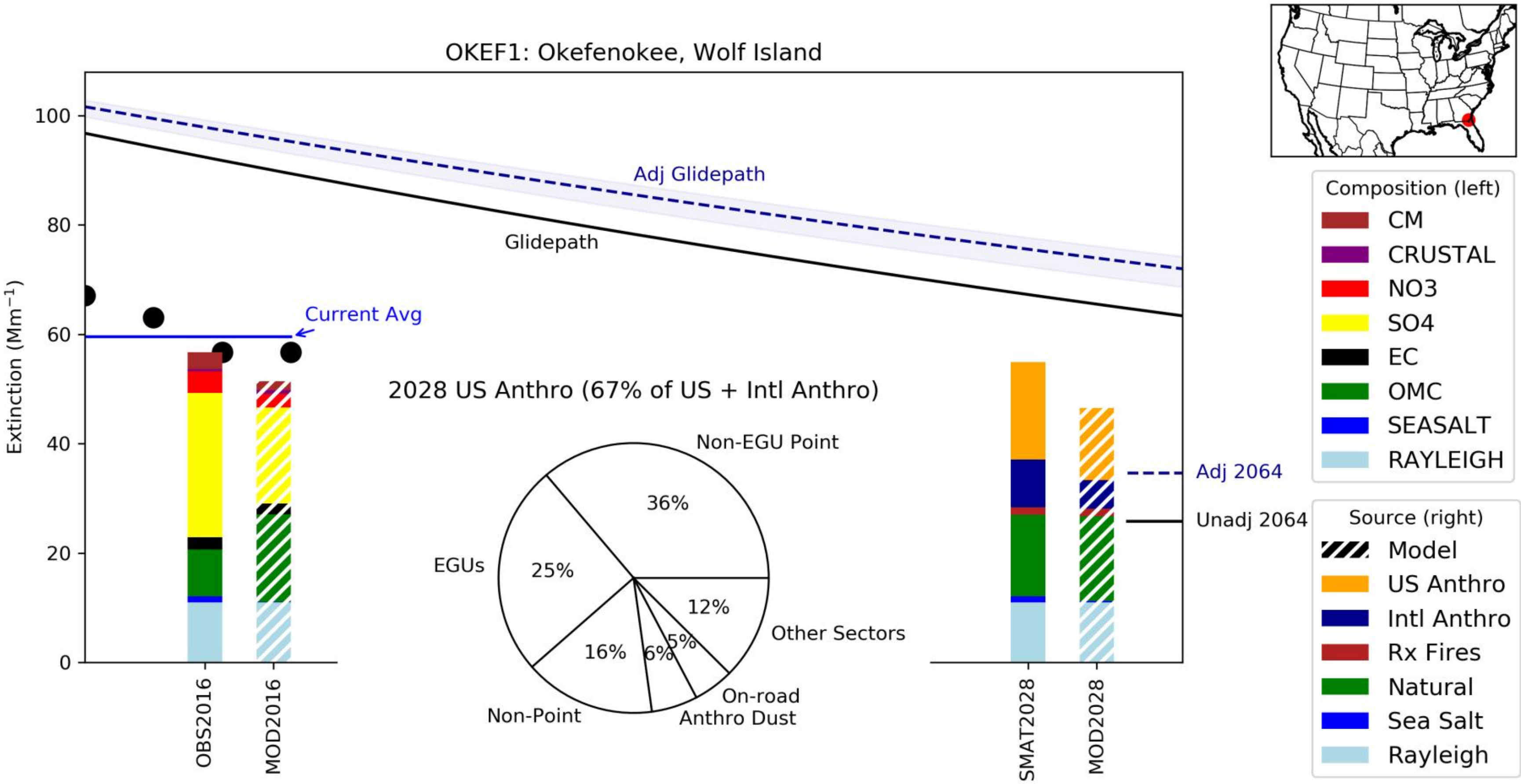


Figure 61: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at OKEF1. Used for Class I areas: Okefenokee, Wolf Island.

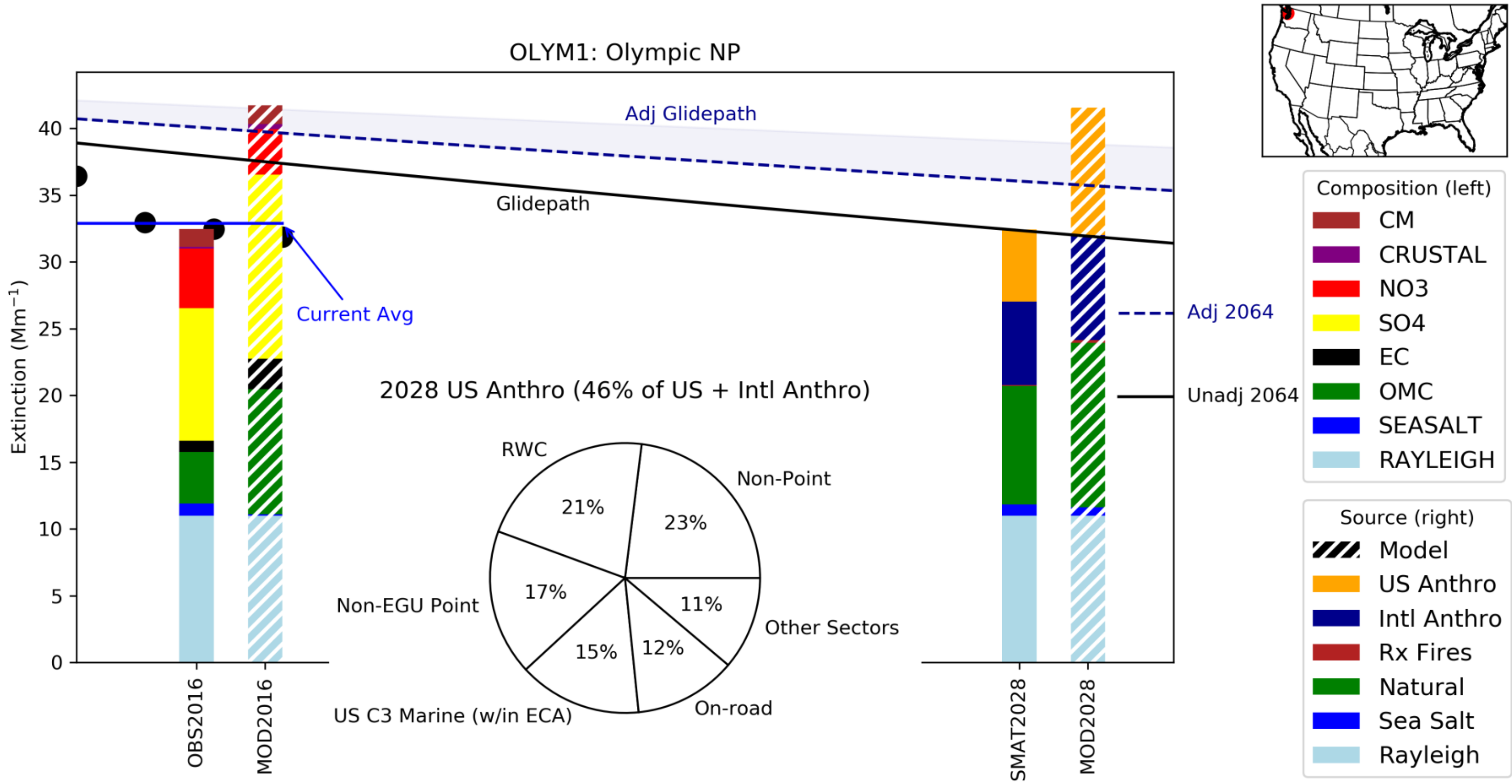


Figure 62: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at OLYM1. Used for Class I areas: Olympic NP.

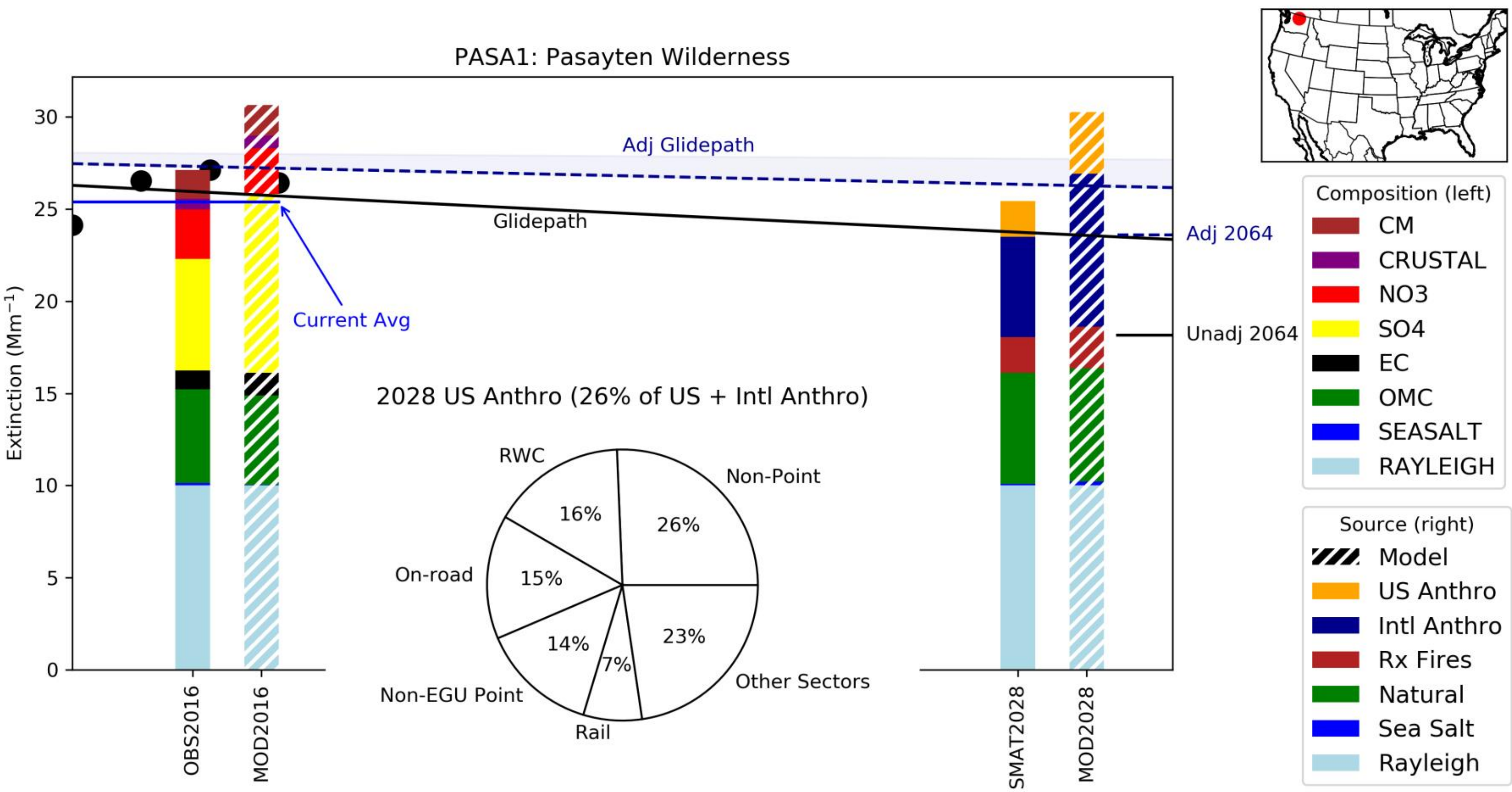


Figure 63: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at PASA1. Used for Class I areas: Pasayten Wilderness.

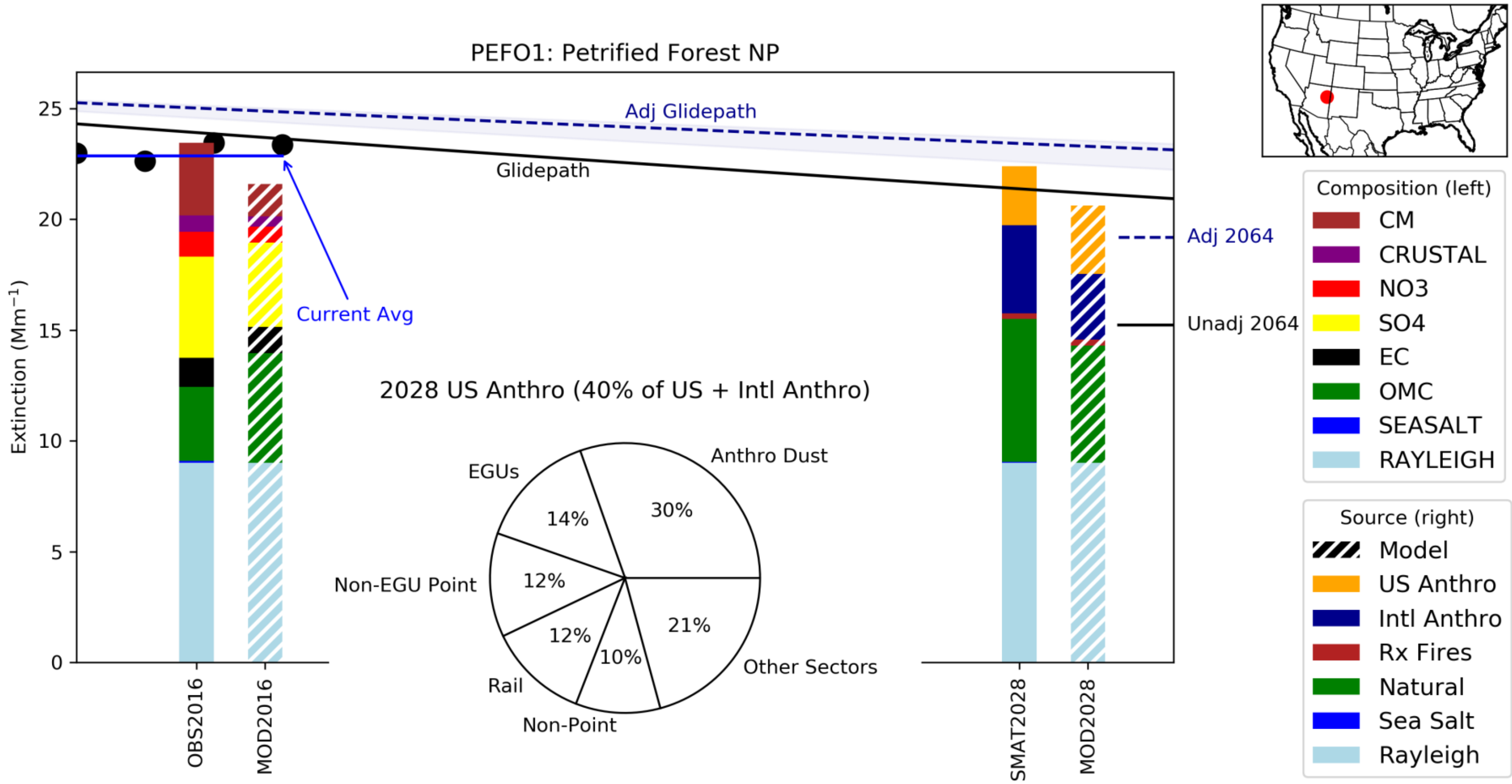


Figure 64: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at PEFO1. Used for Class I areas: Petrified Forest NP.

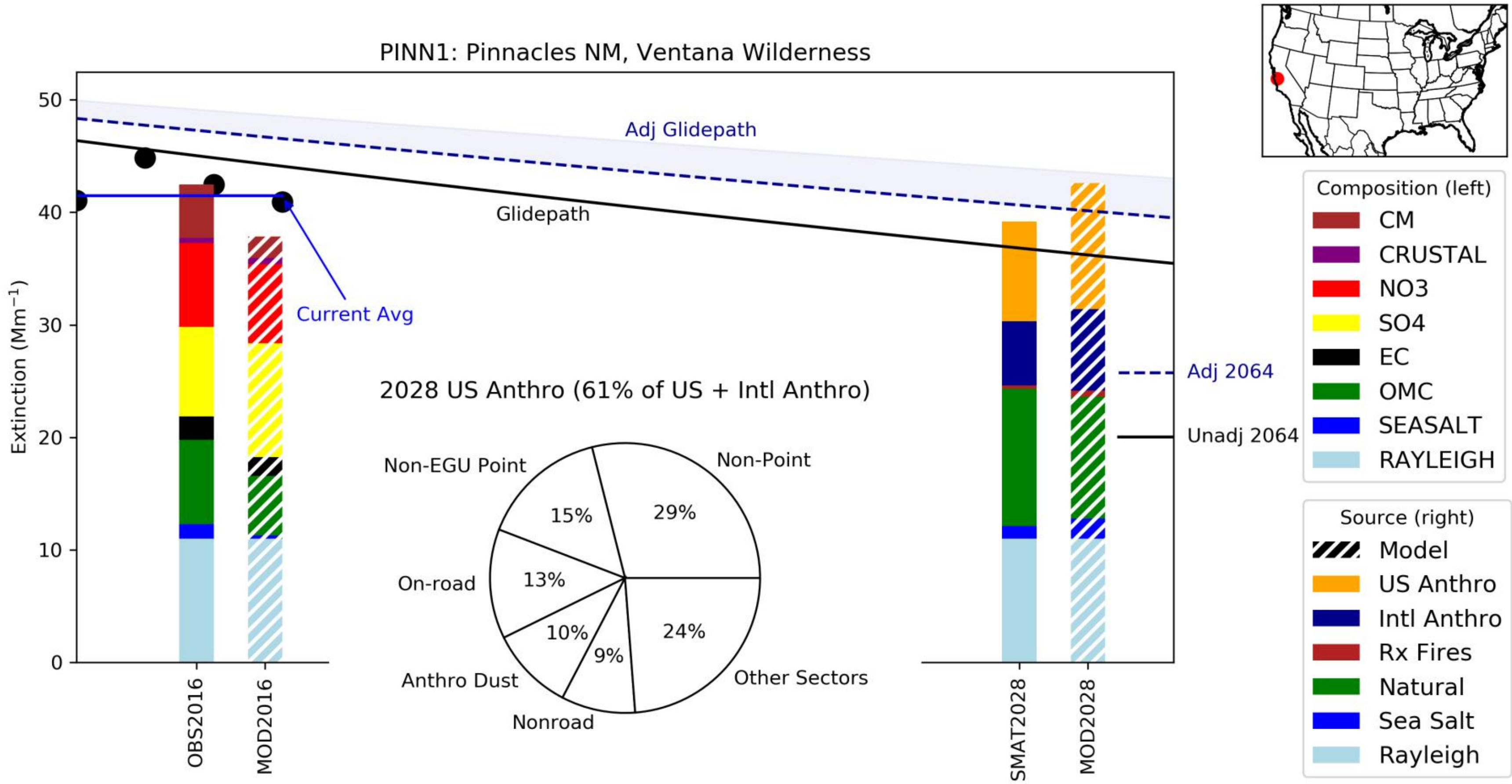


Figure 65: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at PINN1. Used for Class I areas: Pinnacles NM, Ventana Wilderness.

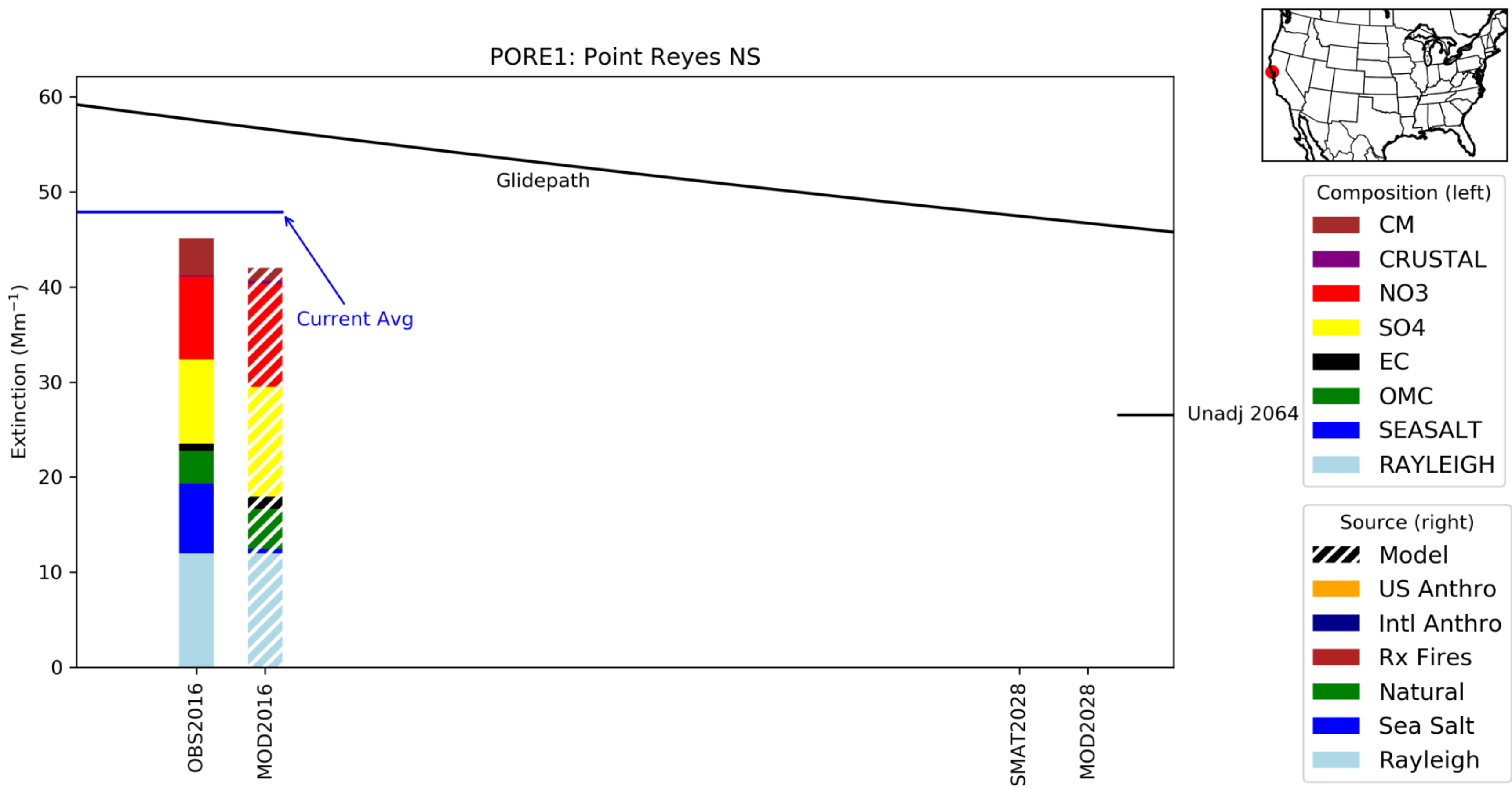


Figure 66: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at PORE1. Used for Class I areas: Point Reyes NS.

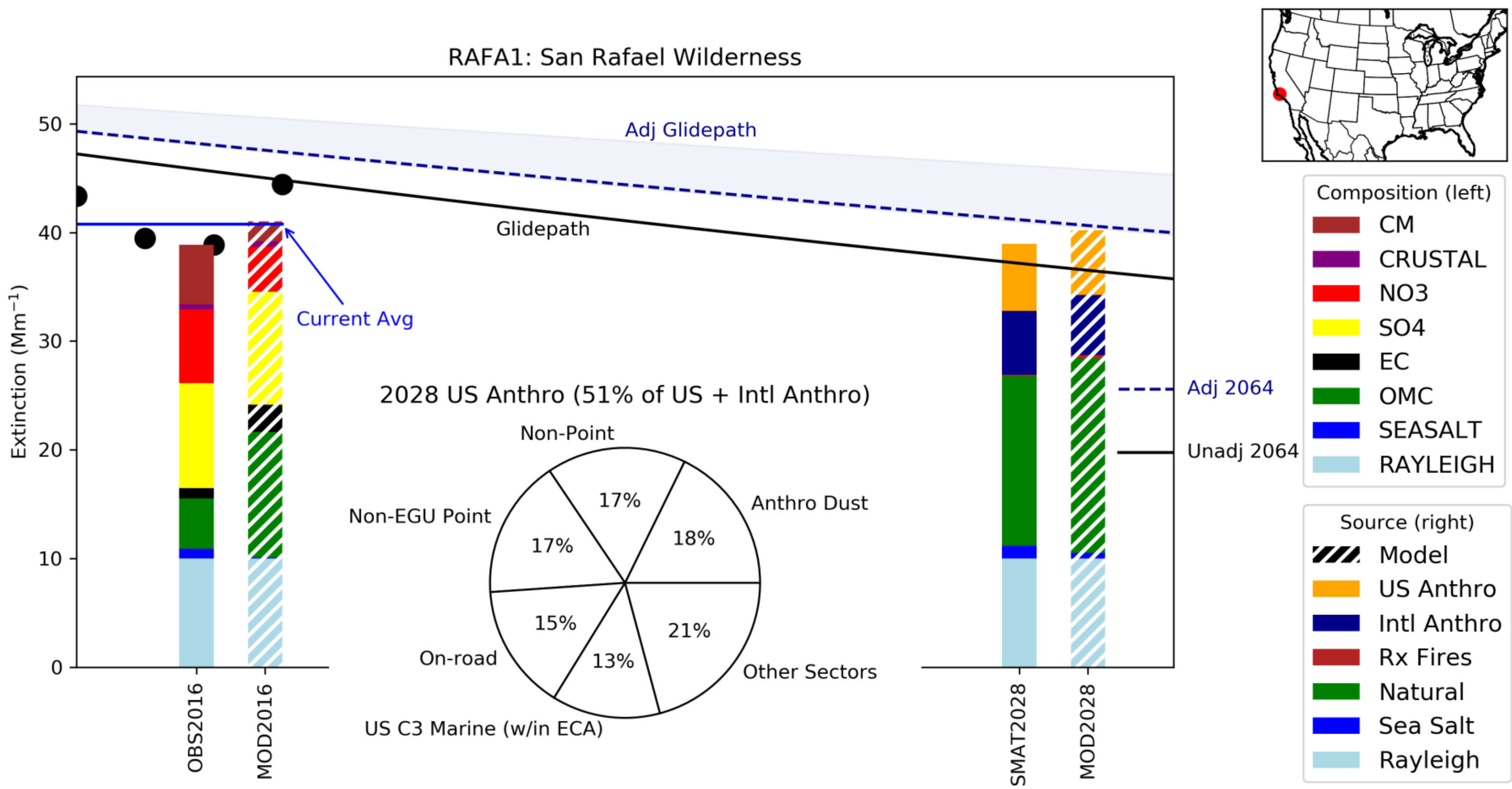


Figure 67: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at RAFA1. Used for Class I areas: San Rafael Wilderness.

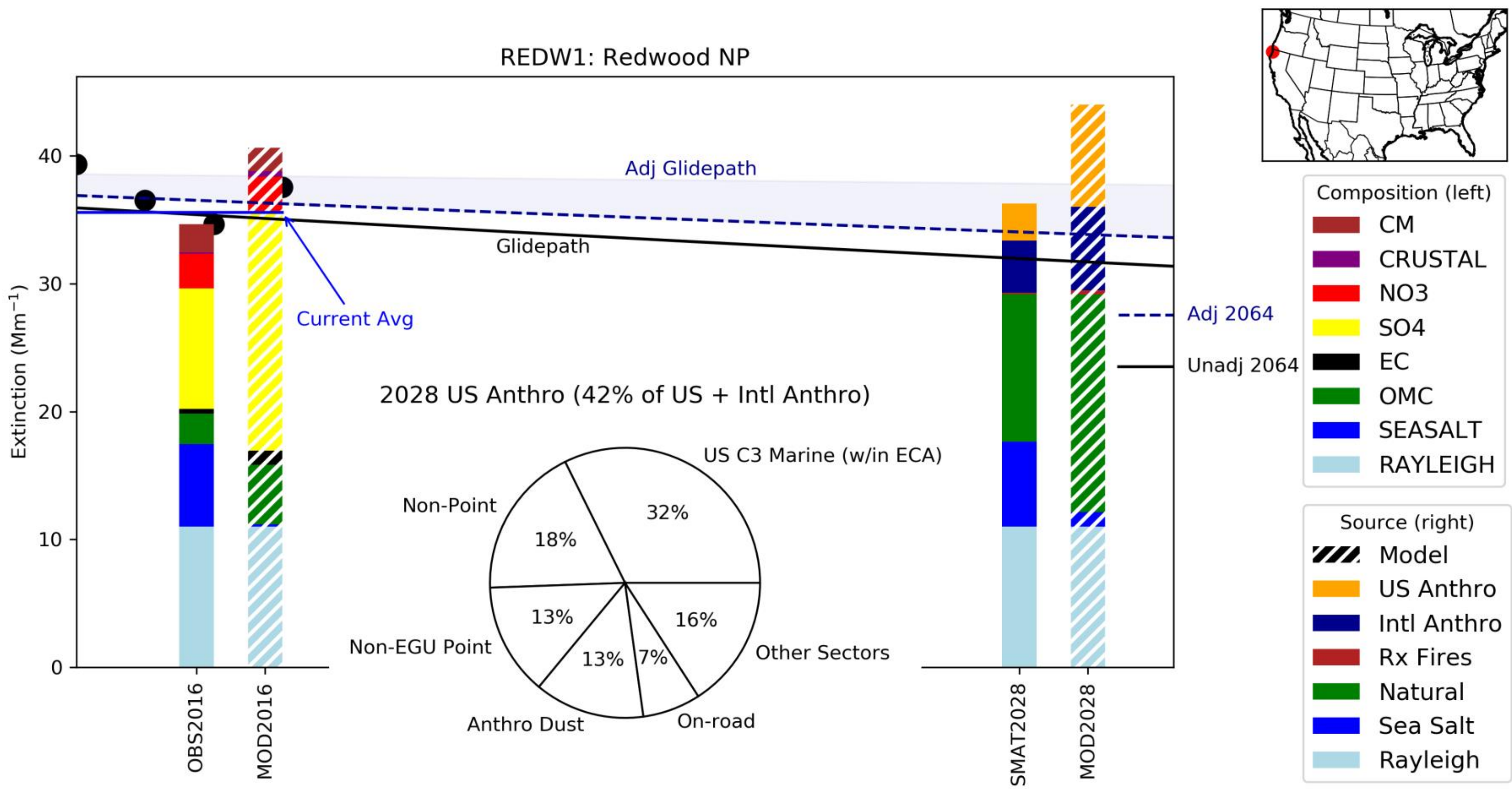


Figure 68: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at REDW1. Used for Class I areas: Redwood NP.

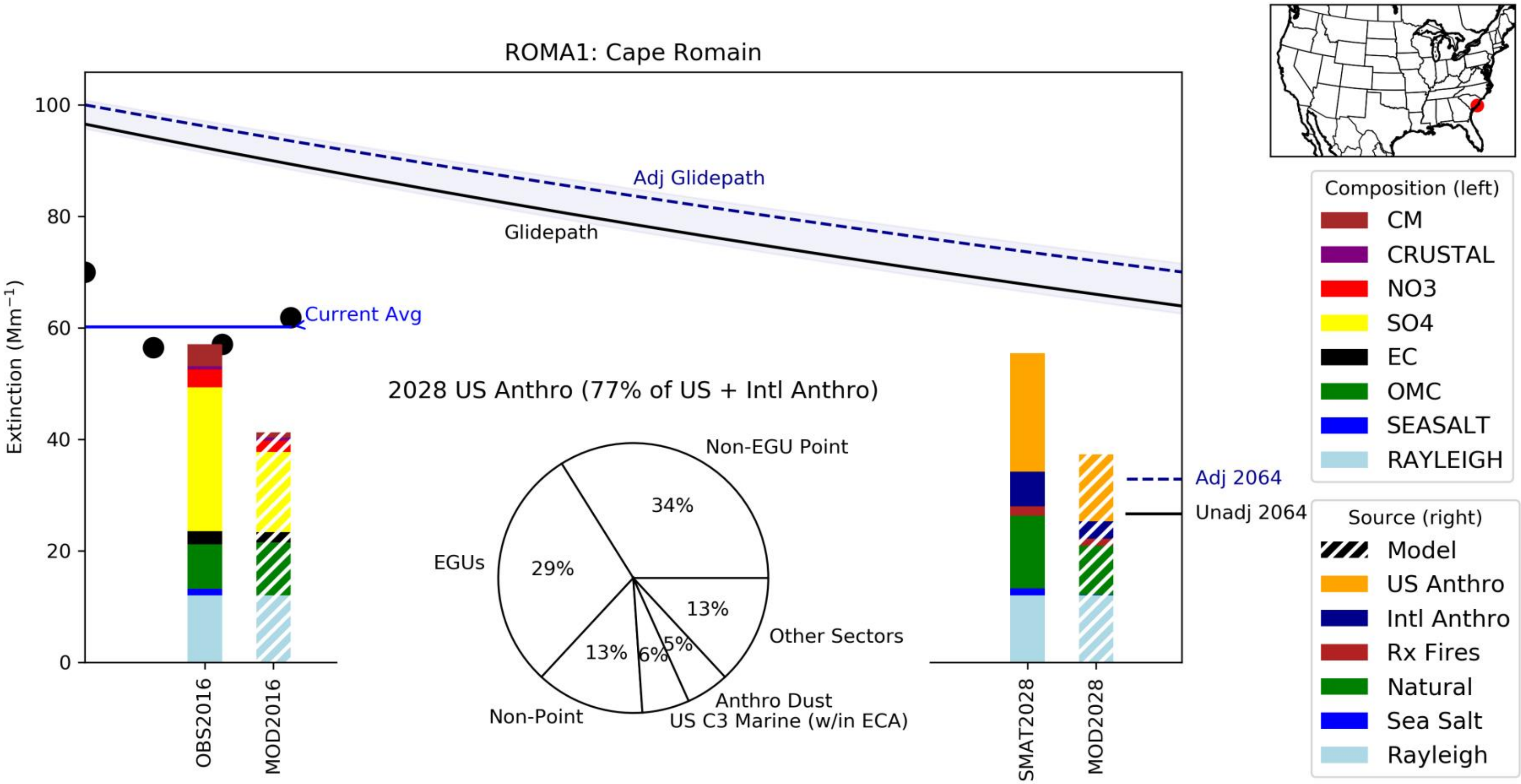


Figure 69: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at ROMA1. Used for Class I areas: Cape Romain.

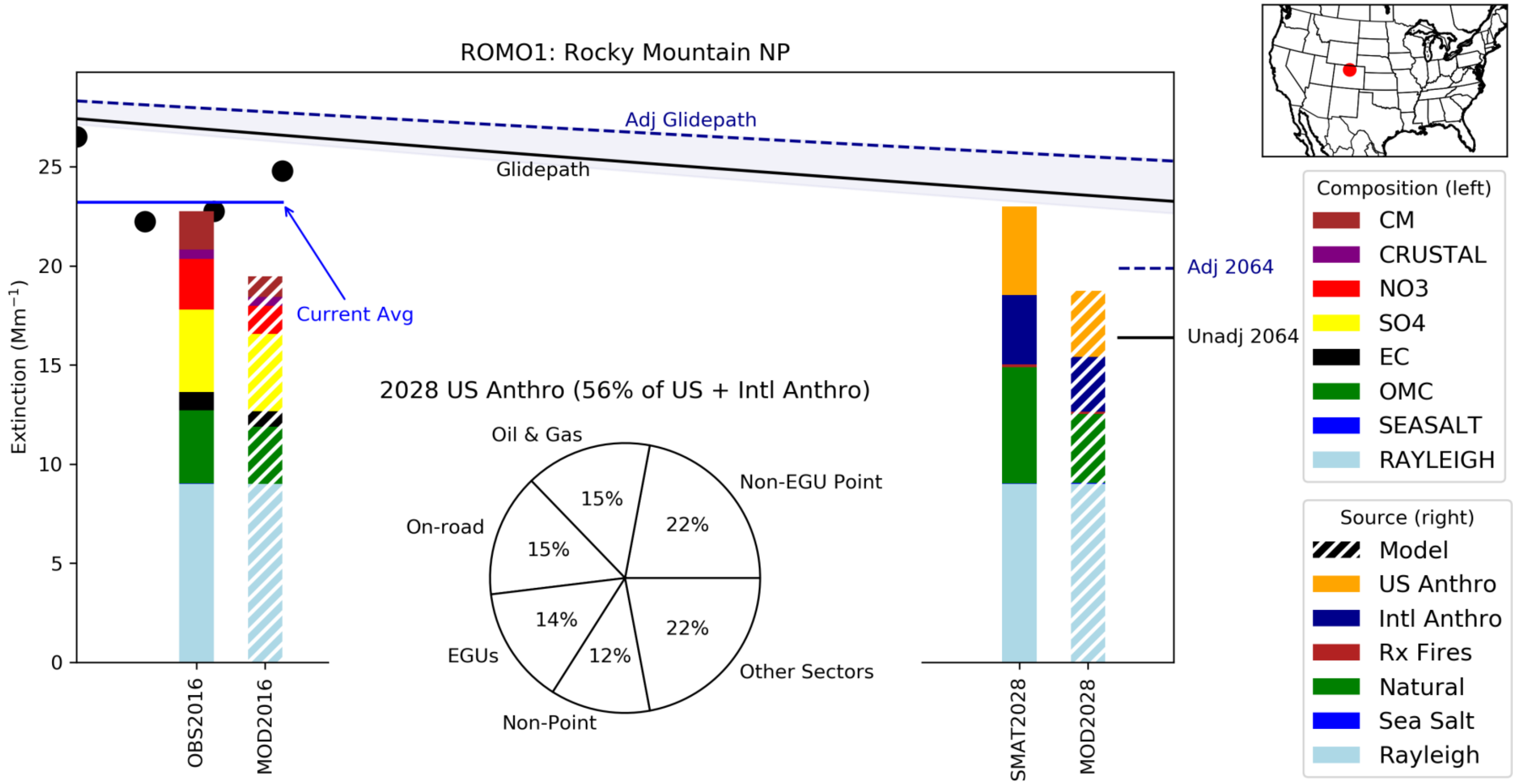


Figure 70: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at ROMO1. Used for Class I areas: Rocky Mountain NP.

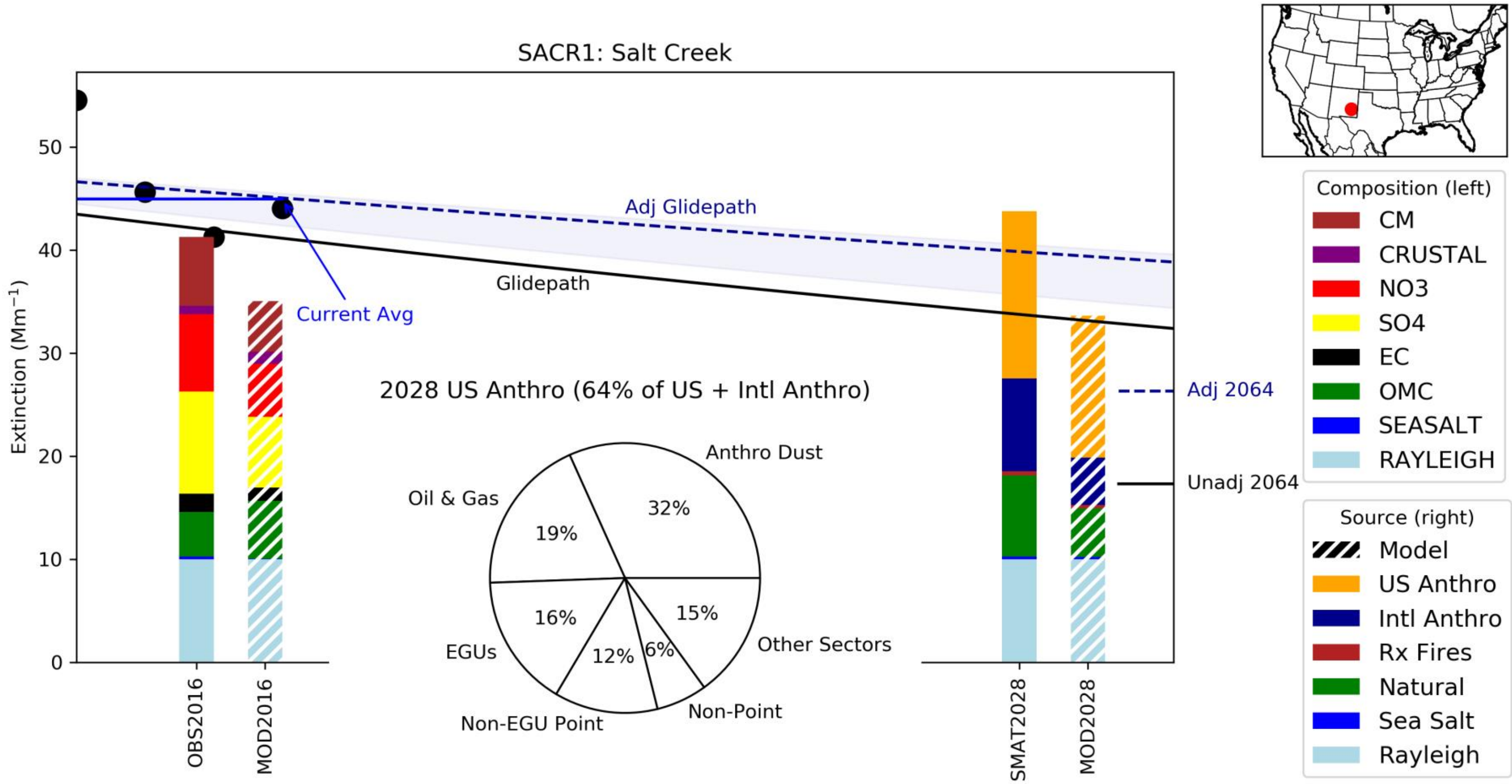


Figure 71: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SACR1. Used for Class I areas: Salt Creek.

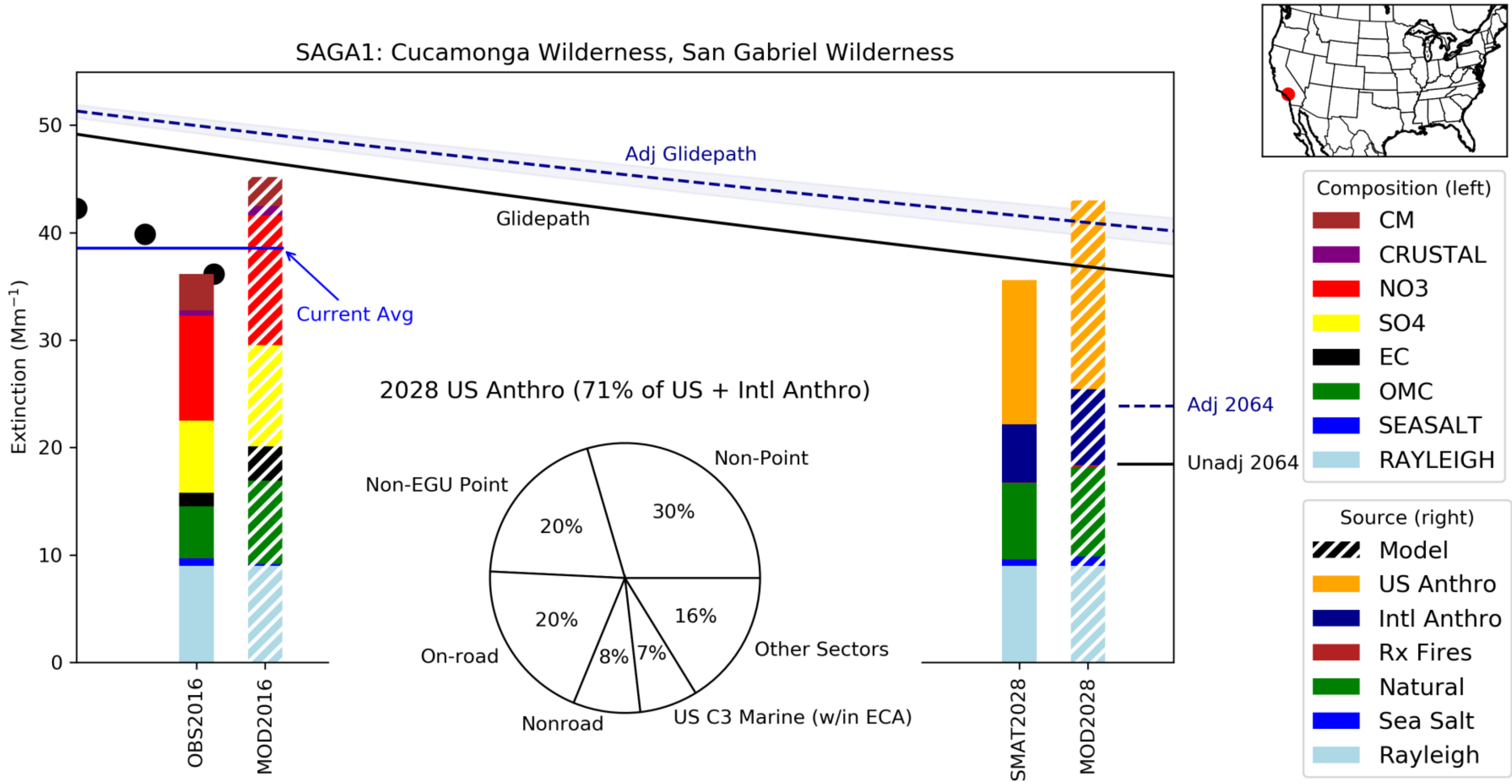


Figure 72: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SAGA1. Used for Class I areas: Cucamonga Wilderness, San Gabriel Wilderness.

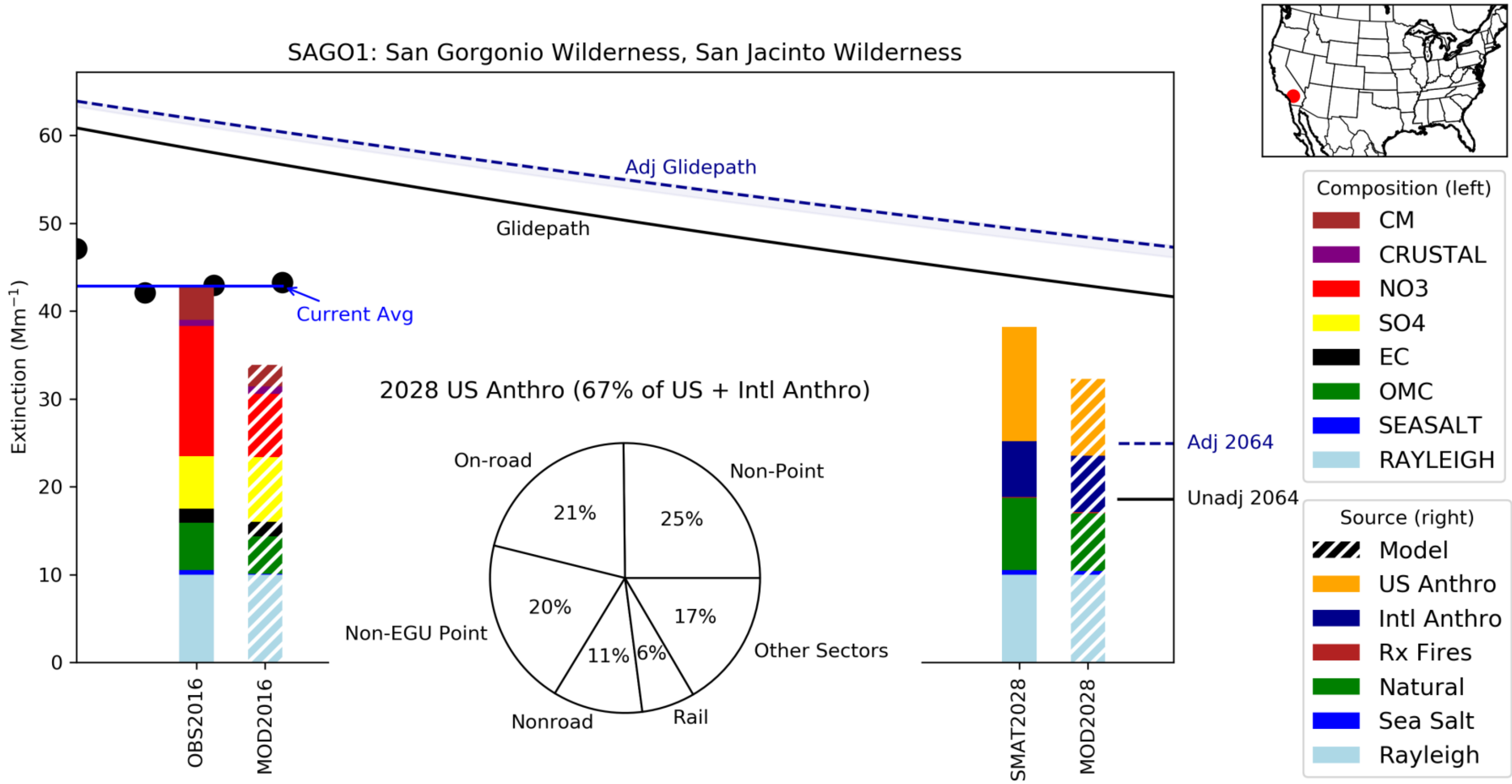


Figure 73: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SAGO1. Used for Class I areas: San Gorgonio Wilderness, San Jacinto Wilderness.

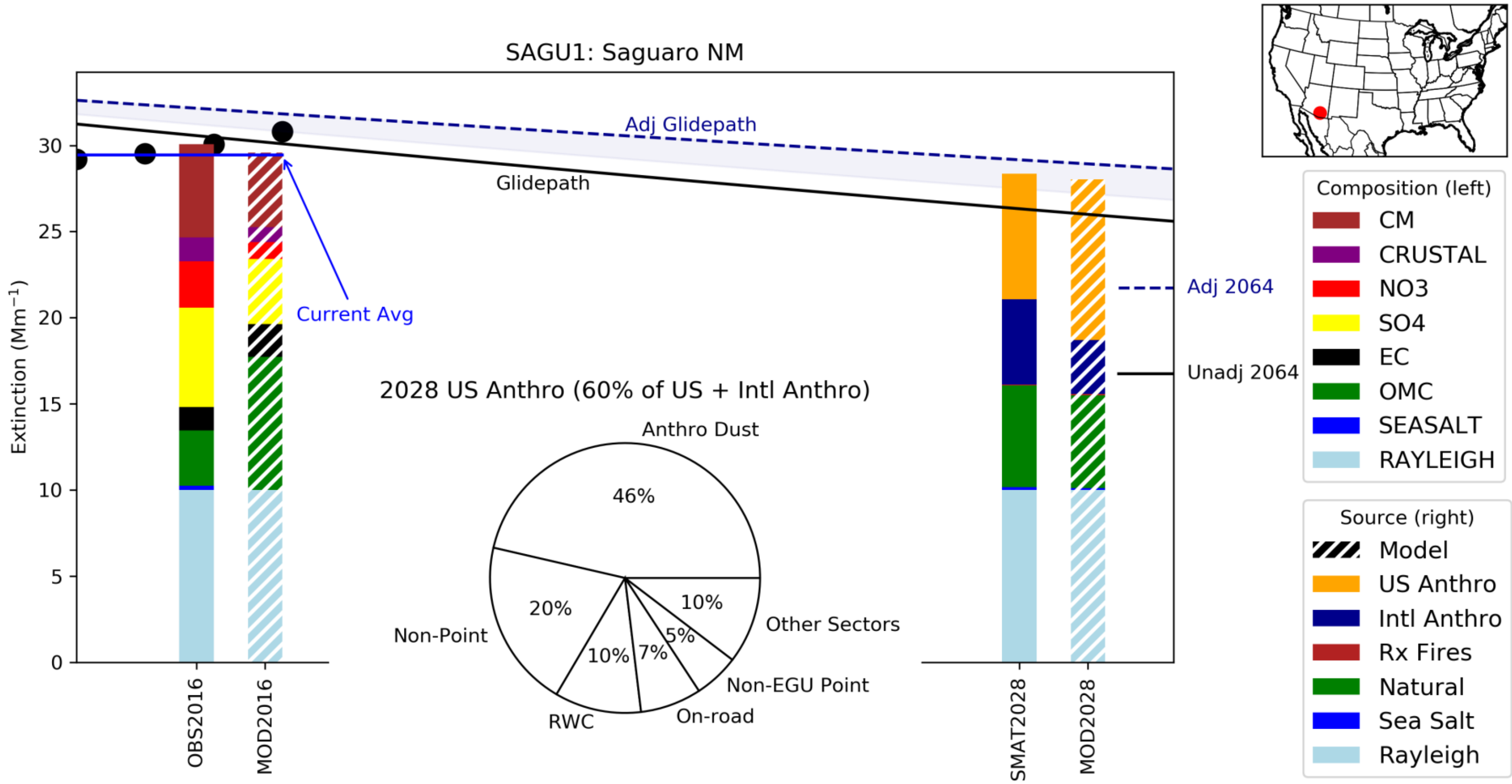


Figure 74: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SAGU1. Used for Class I areas: Saguaro NM.

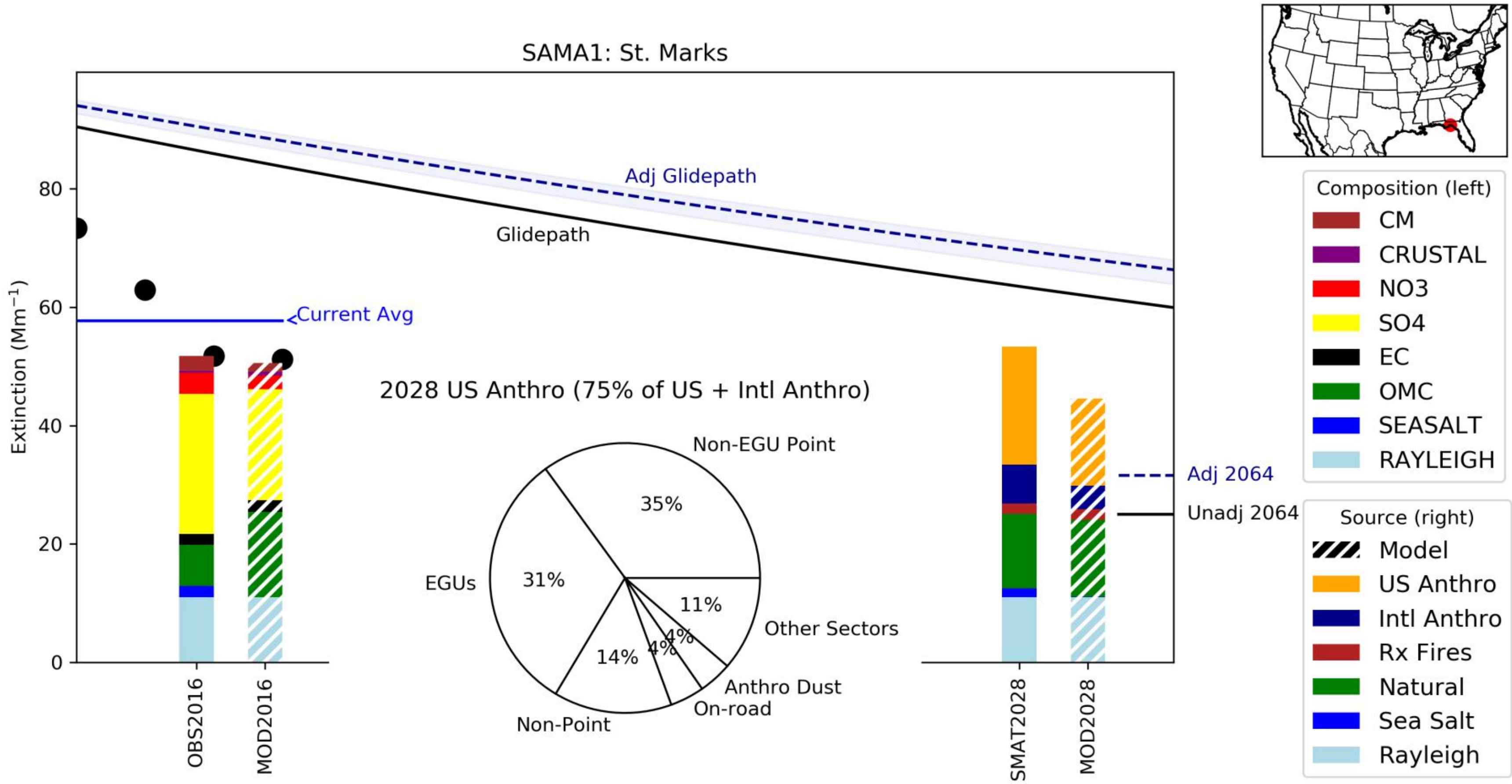


Figure 75: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SAMA1. Used for Class I areas: St. Marks.

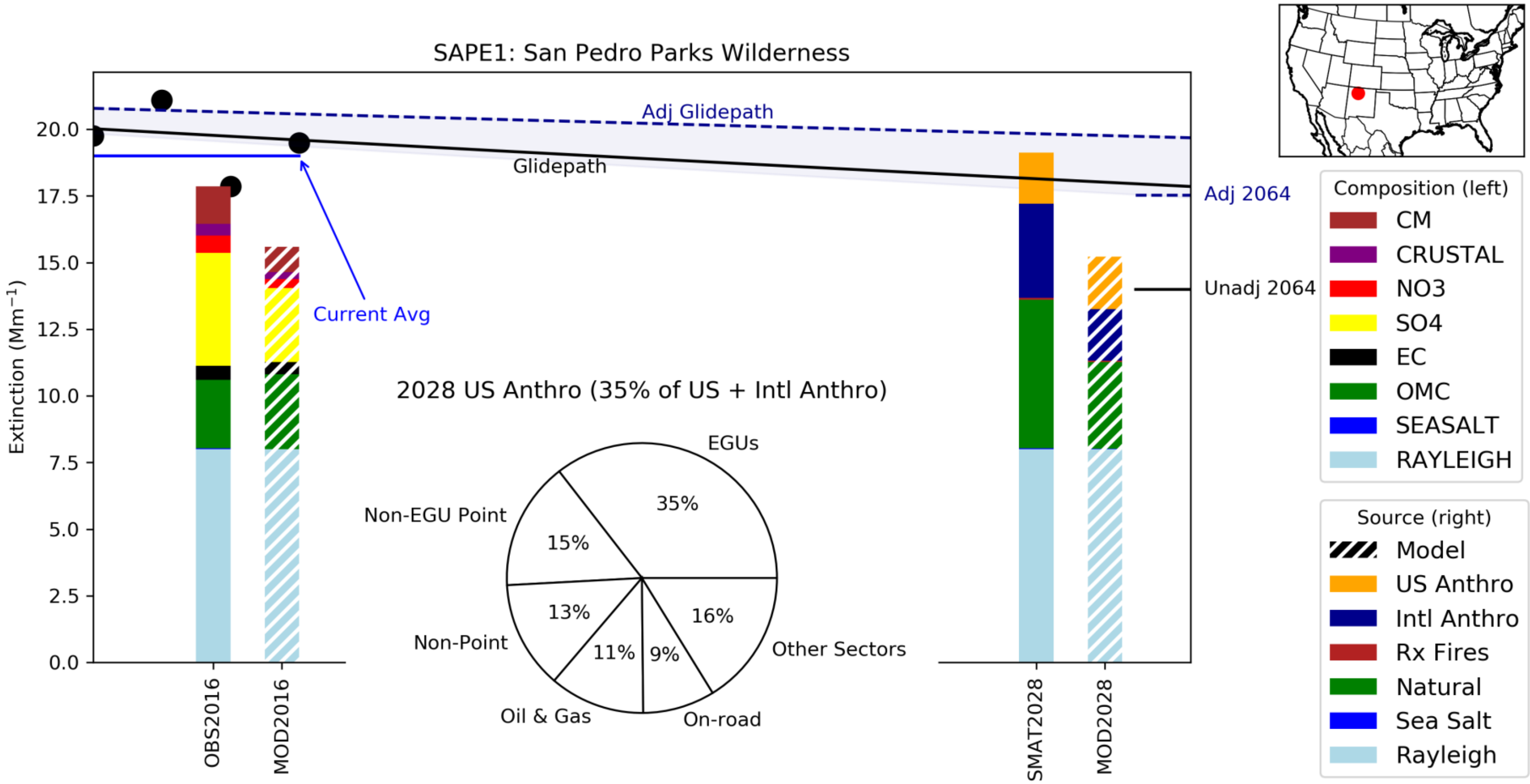


Figure 76: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SAPE1. Used for Class I areas: San Pedro Parks Wilderness.

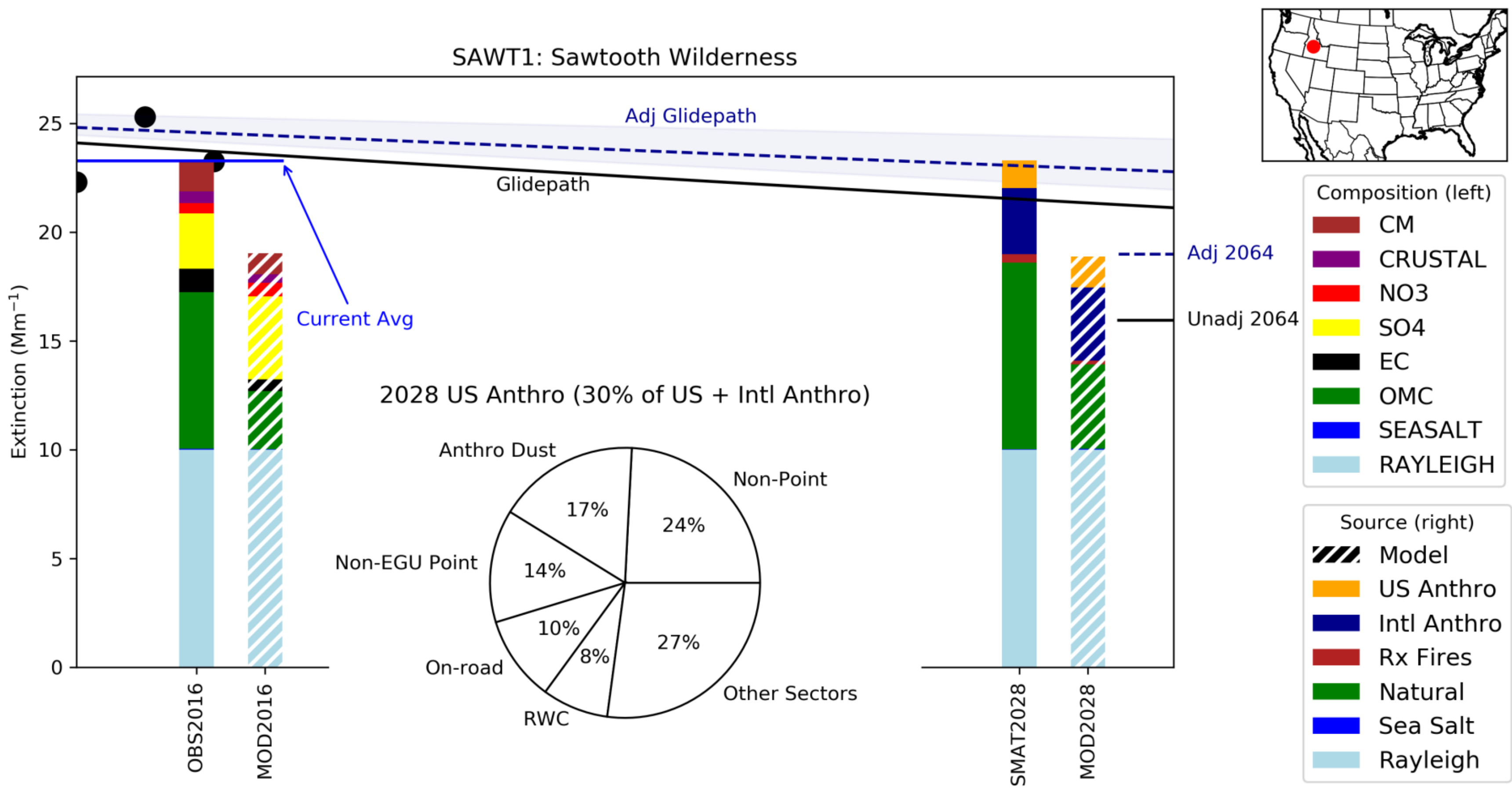


Figure 77: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SAWT1. Used for Class I areas: Sawtooth Wilderness.

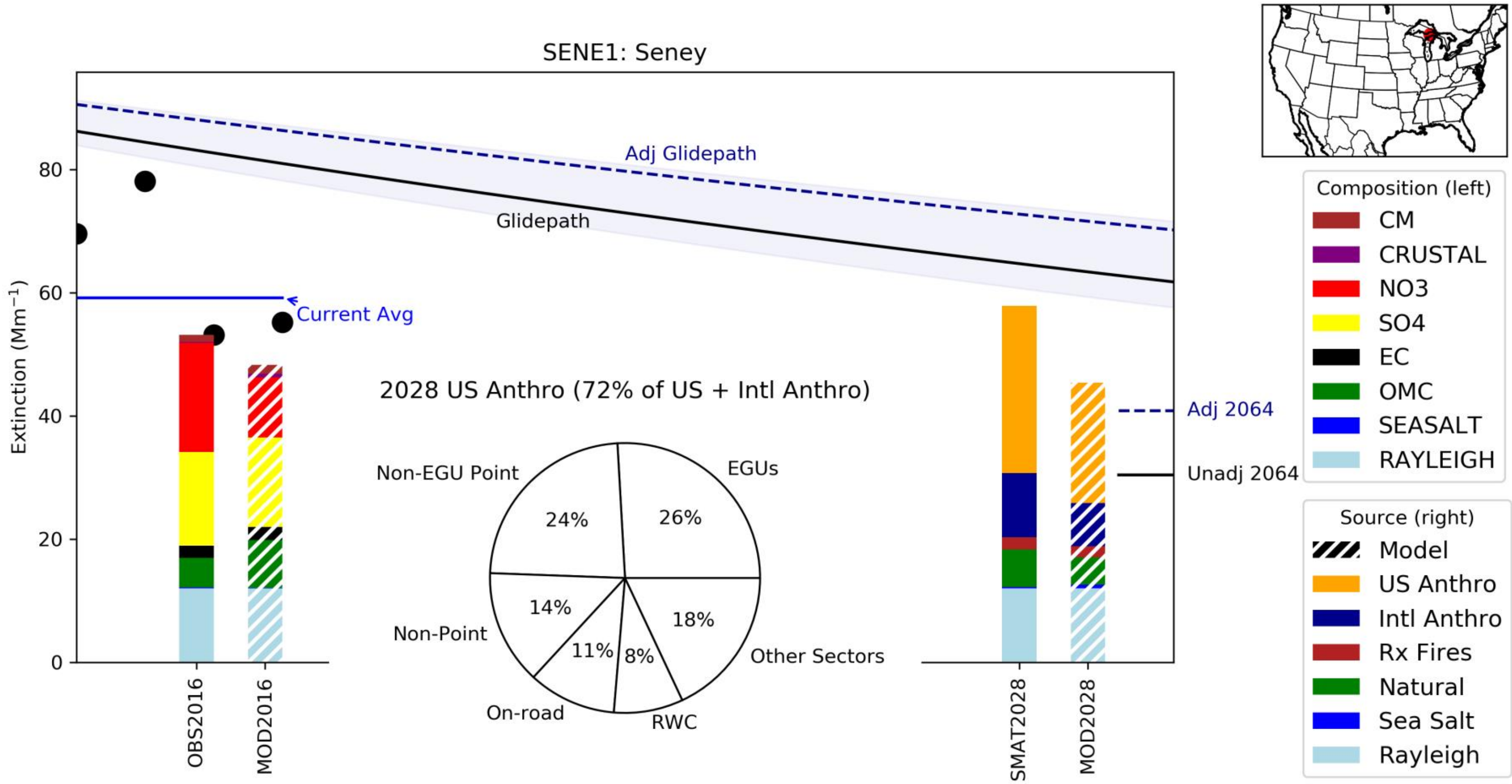


Figure 78: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SENE1. Used for Class I areas: Seney.

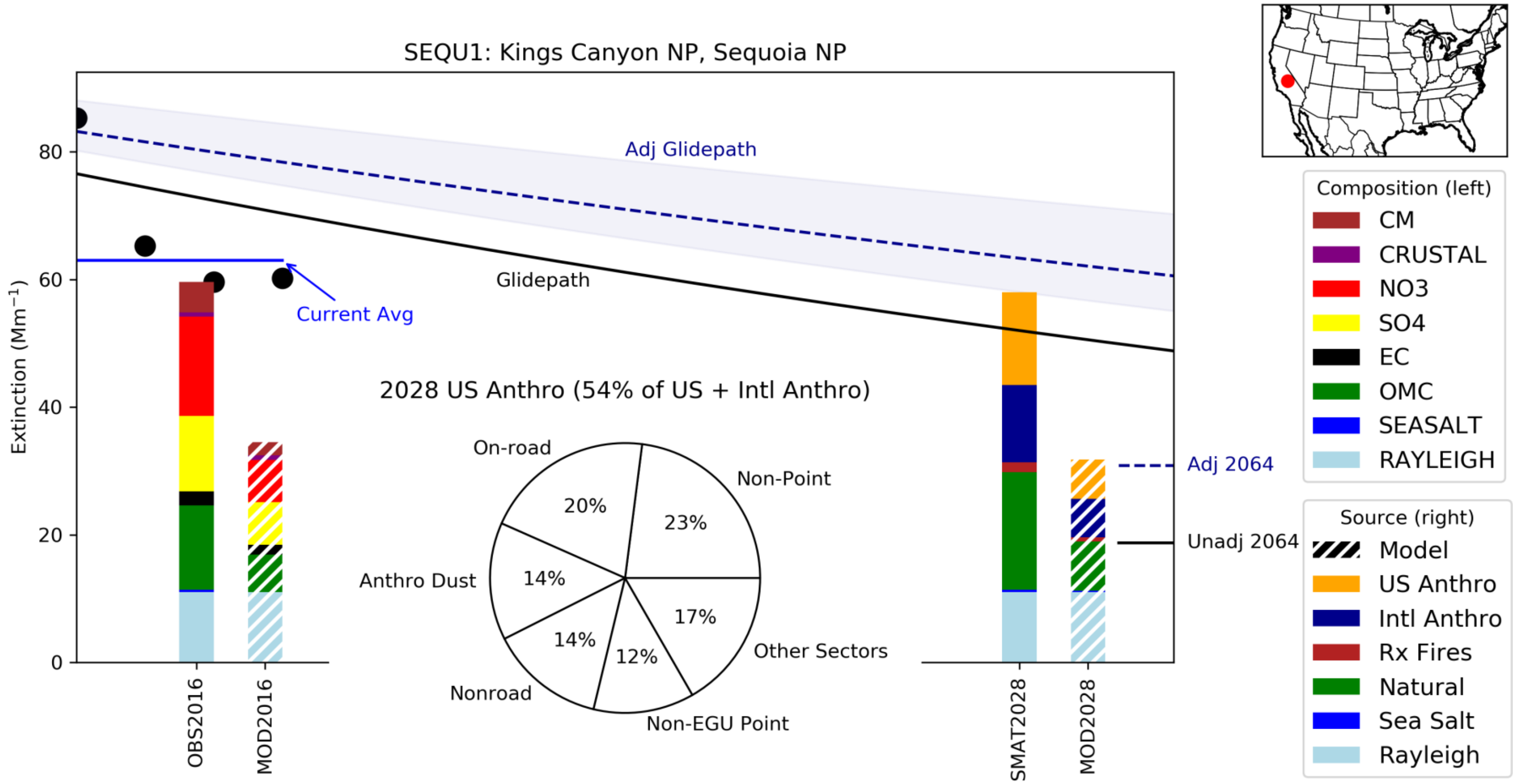


Figure 79: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SEQU1. Used for Class I areas: Kings Canyon NP, Sequoia NP.

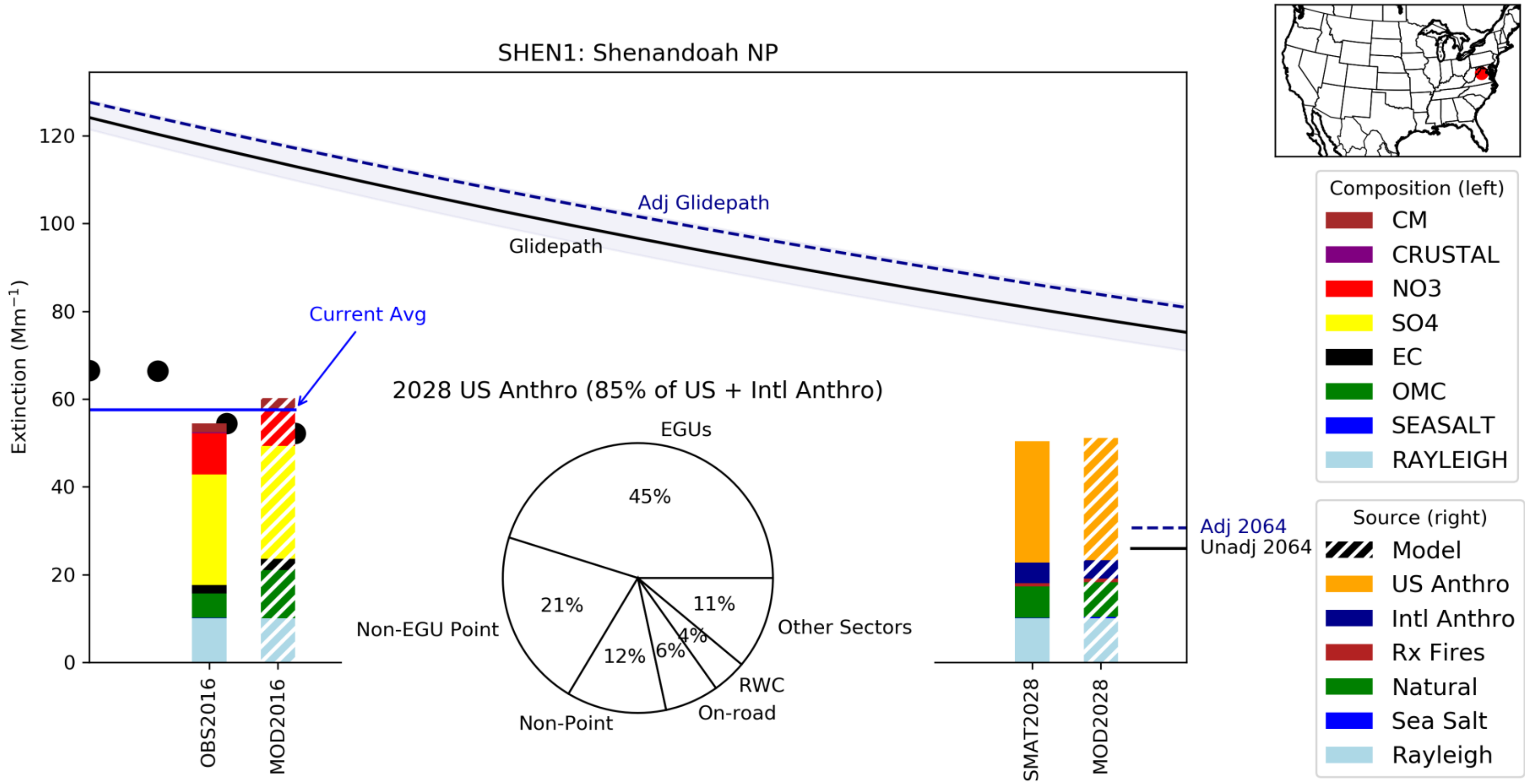


Figure 80: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SHEN1. Used for Class I areas: Shenandoah NP.

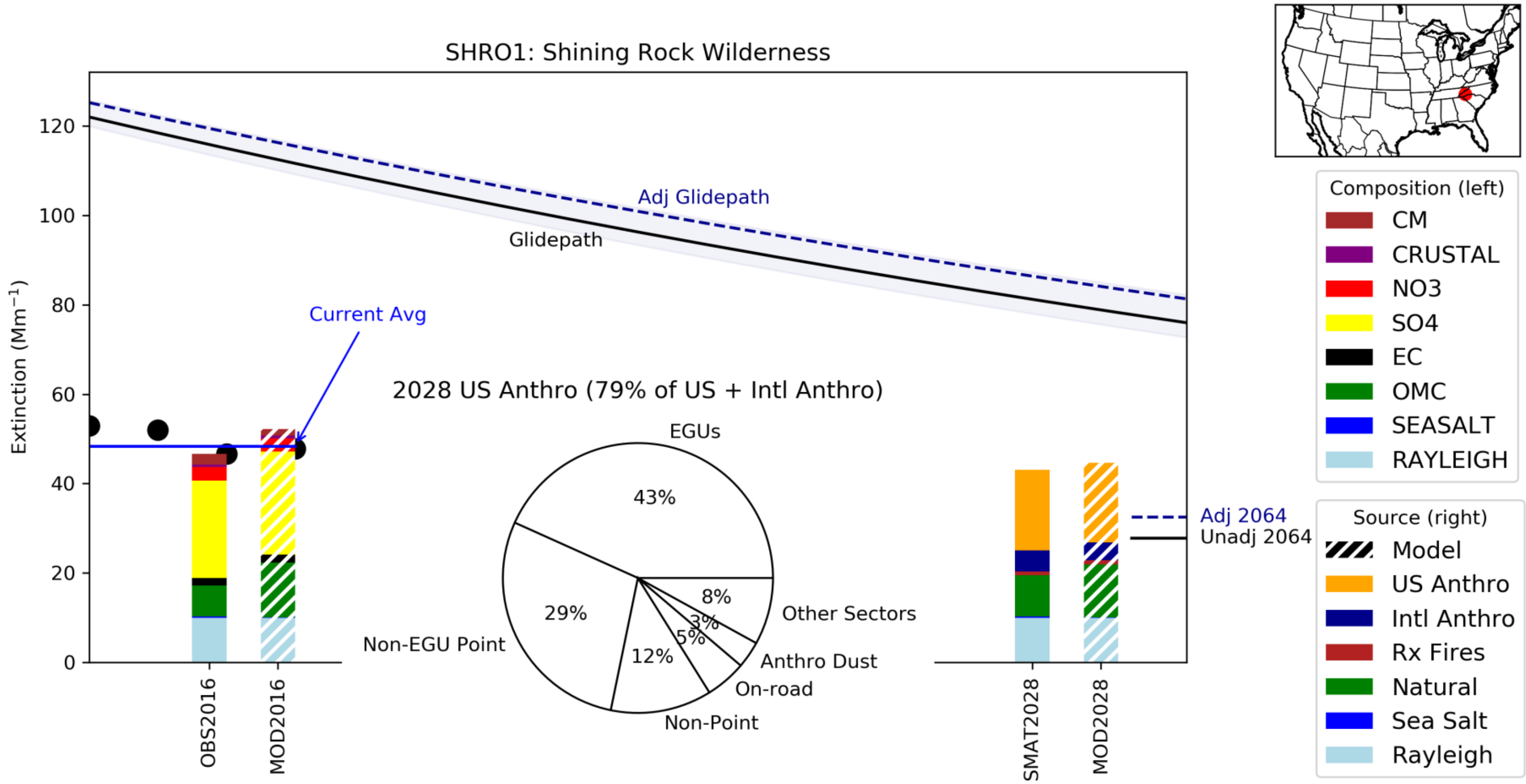


Figure 81: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SHRO1. Used for Class I areas: Shining Rock Wilderness.

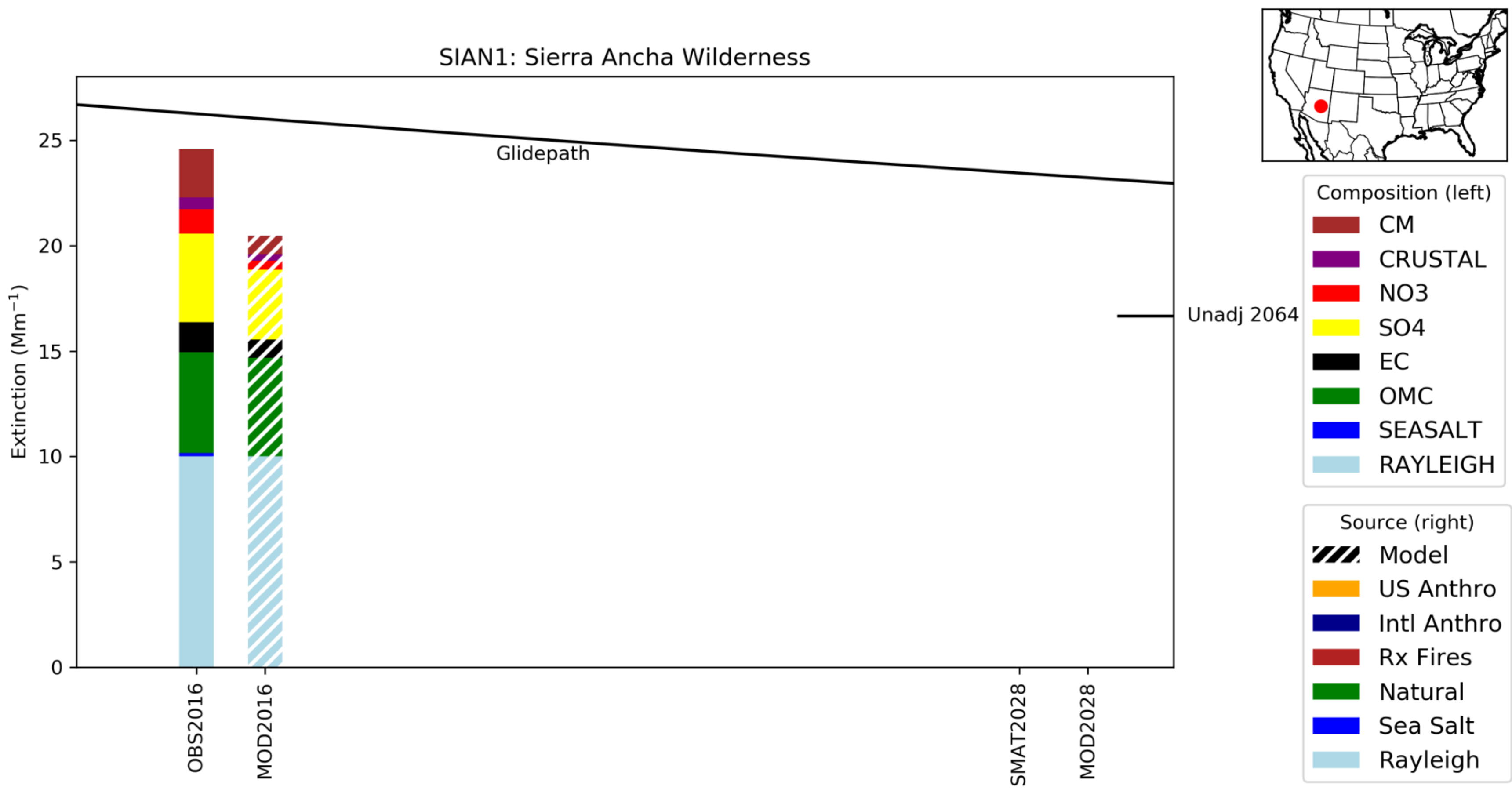


Figure 82: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SIAN1. Used for Class I areas: Sierra Ancha Wilderness.

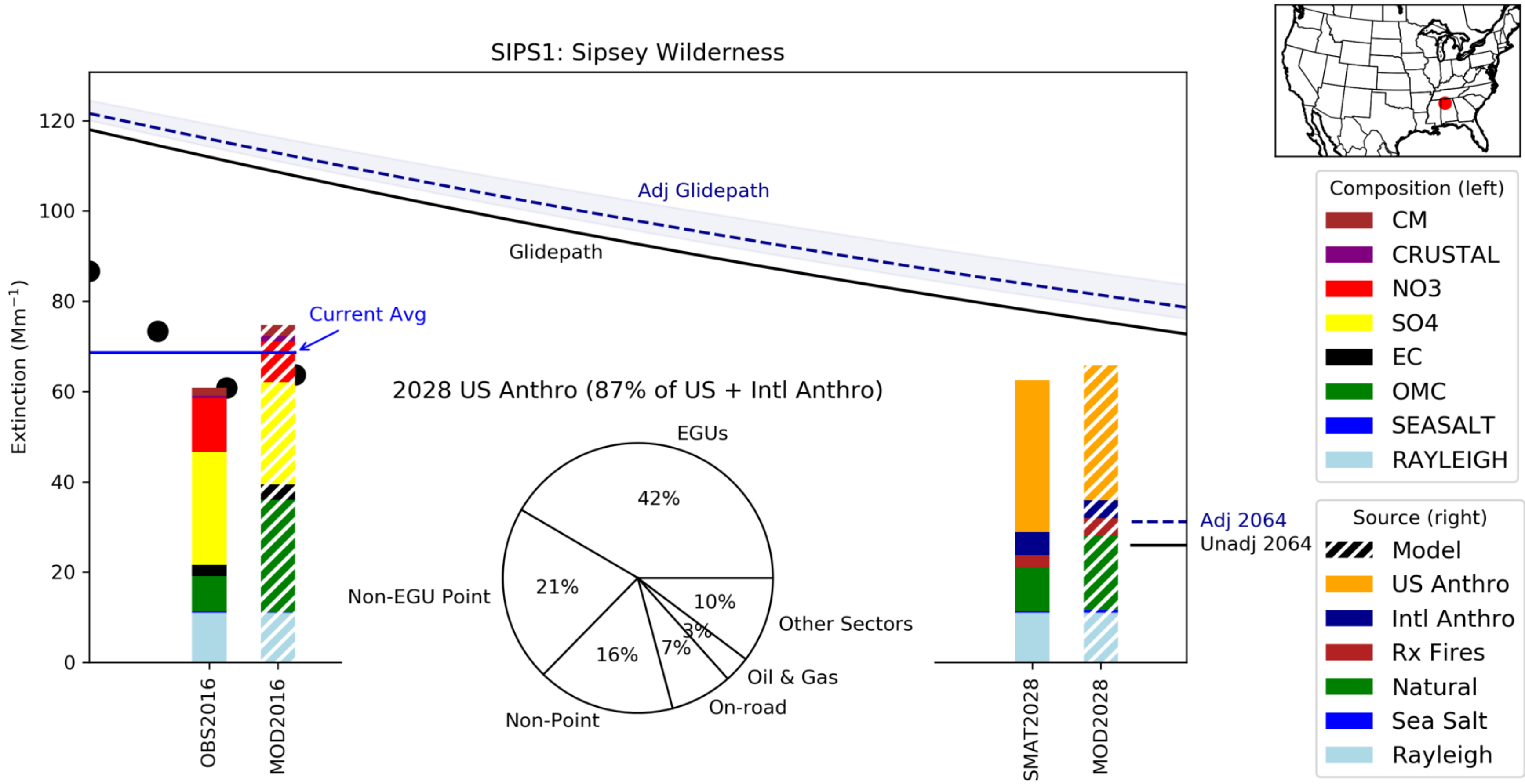


Figure 83: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SIPS1. Used for Class I areas: Sipsey Wilderness.

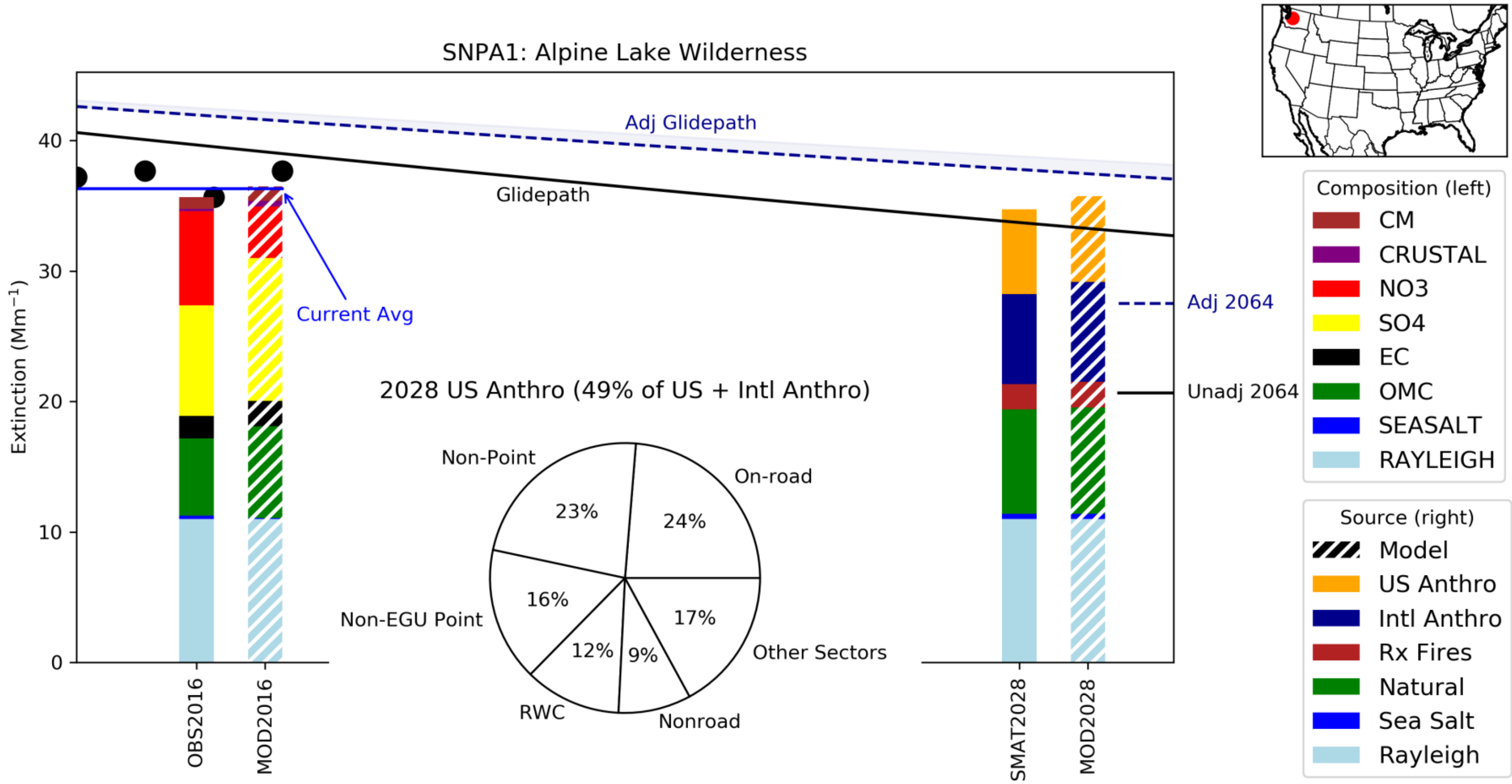


Figure 84: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SNPA1. Used for Class I areas: Alpine Lake Wilderness.

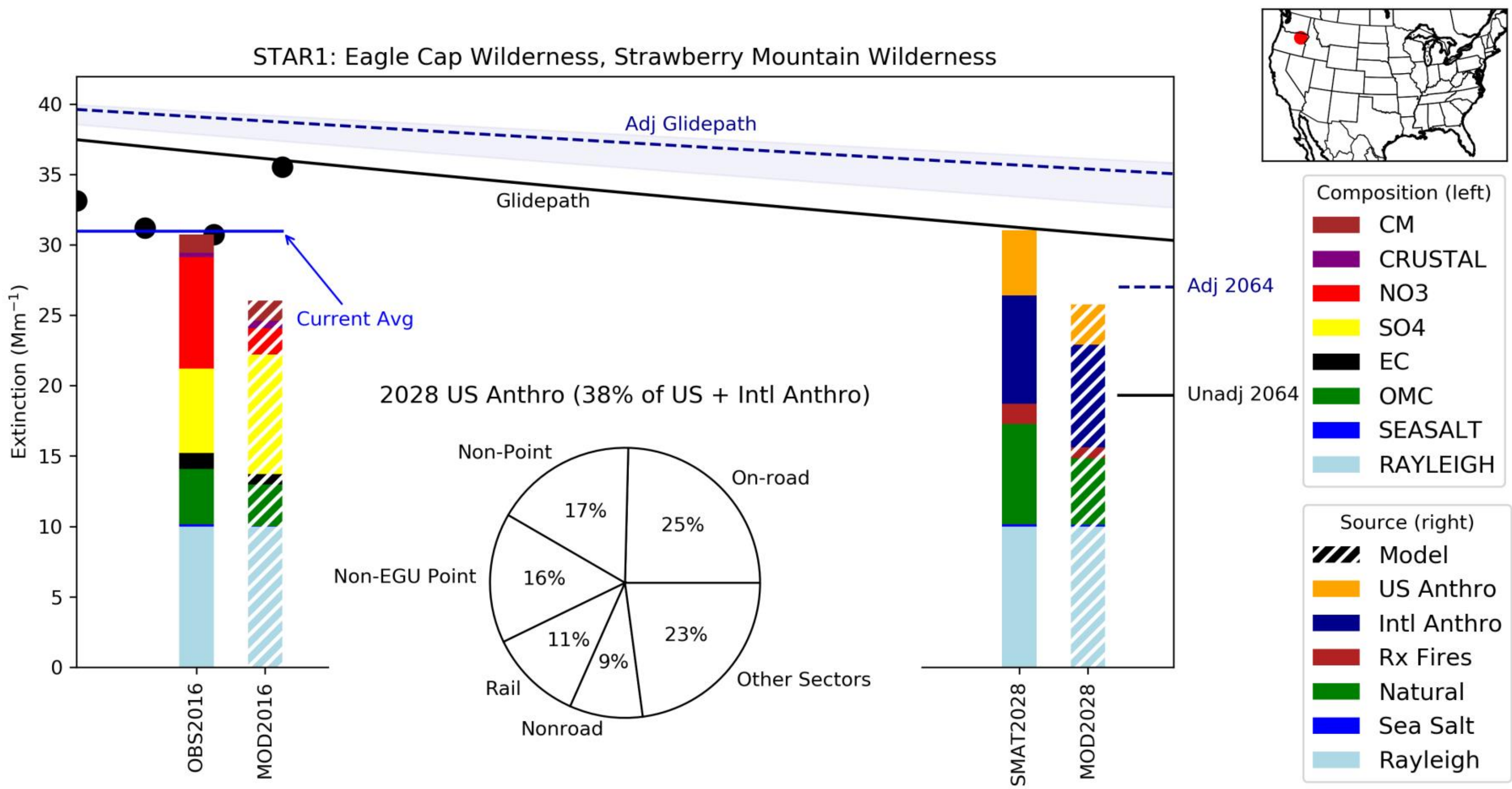


Figure 85: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at STAR1. Used for Class I areas: Eagle Cap Wilderness, Strawberry Mountain Wilderness.

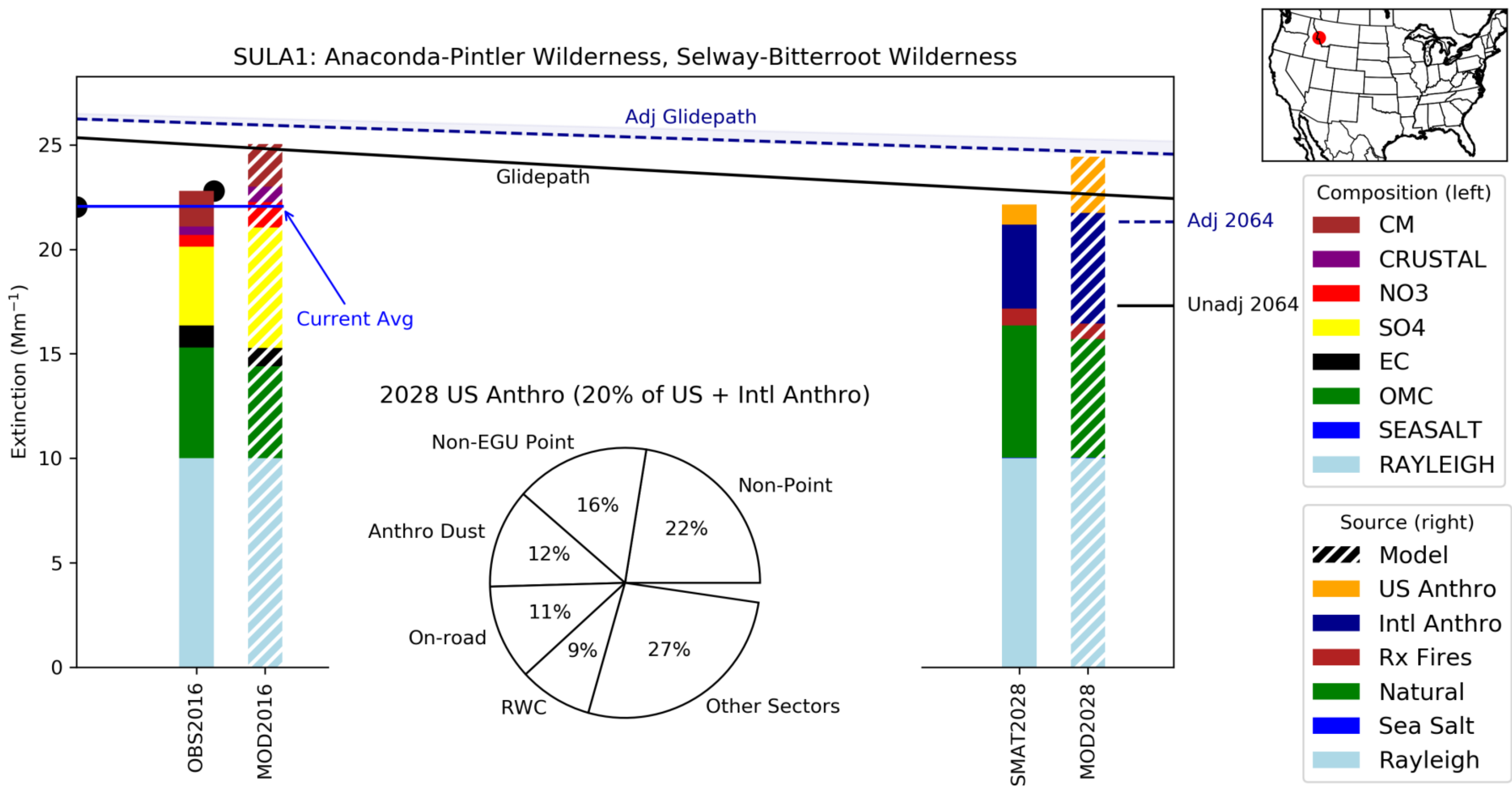


Figure 86: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SULA1. Used for Class I areas: Anaconda-Pintler Wilderness, Selway-Bitterroot Wilderness.

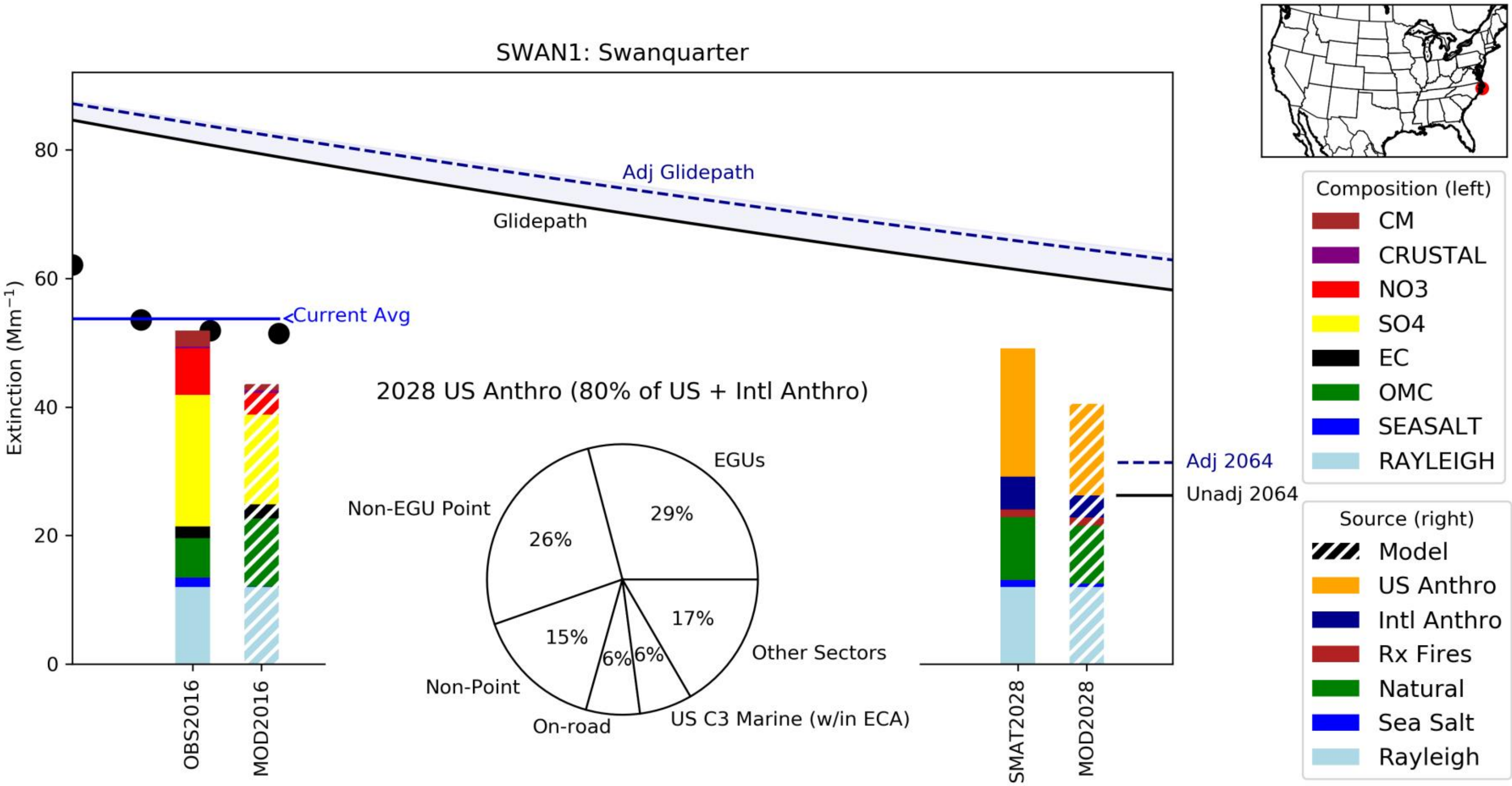


Figure 87: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SWAN1. Used for Class I areas: Swanquarter.

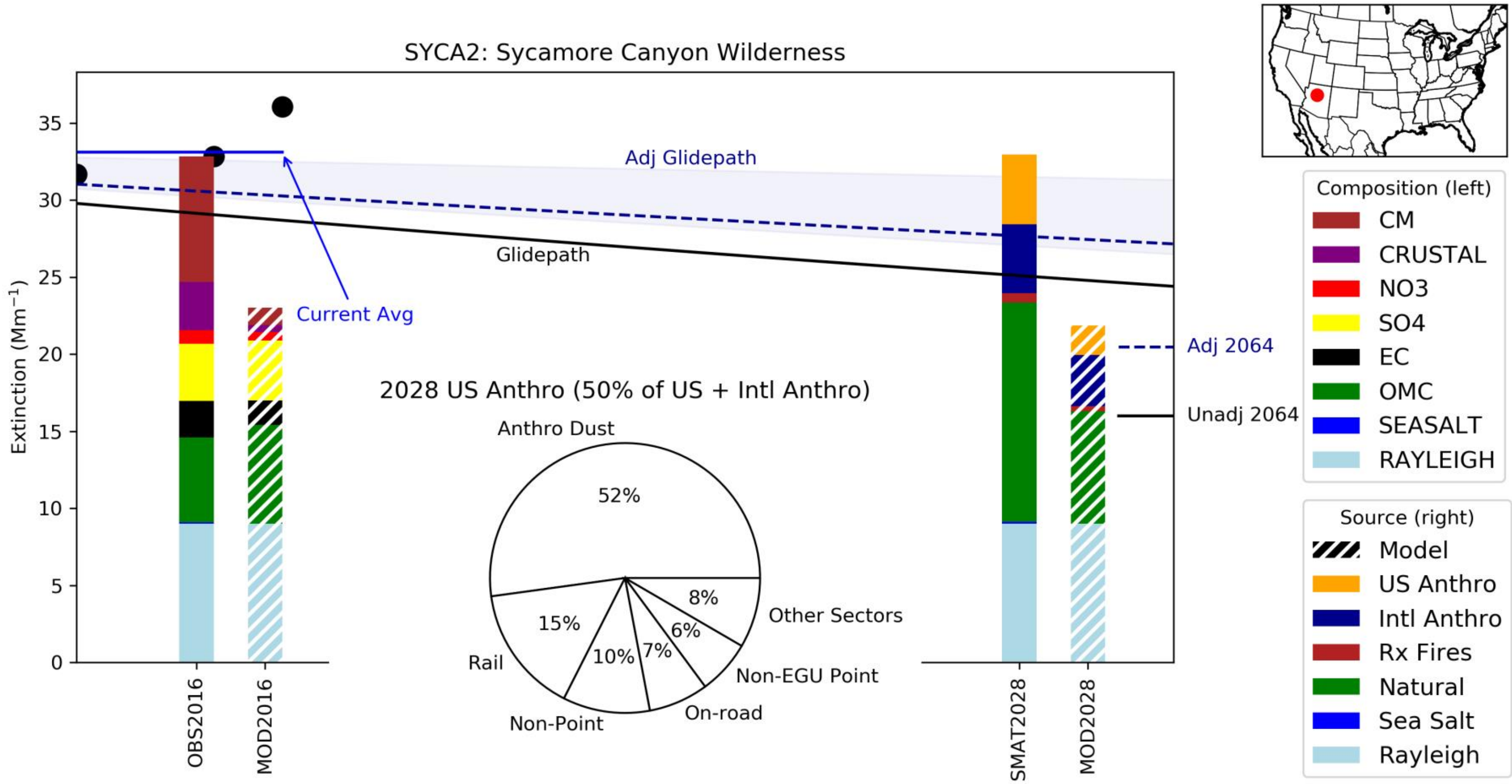


Figure 88: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at SYCA2. Used for Class I areas: Sycamore Canyon Wilderness.

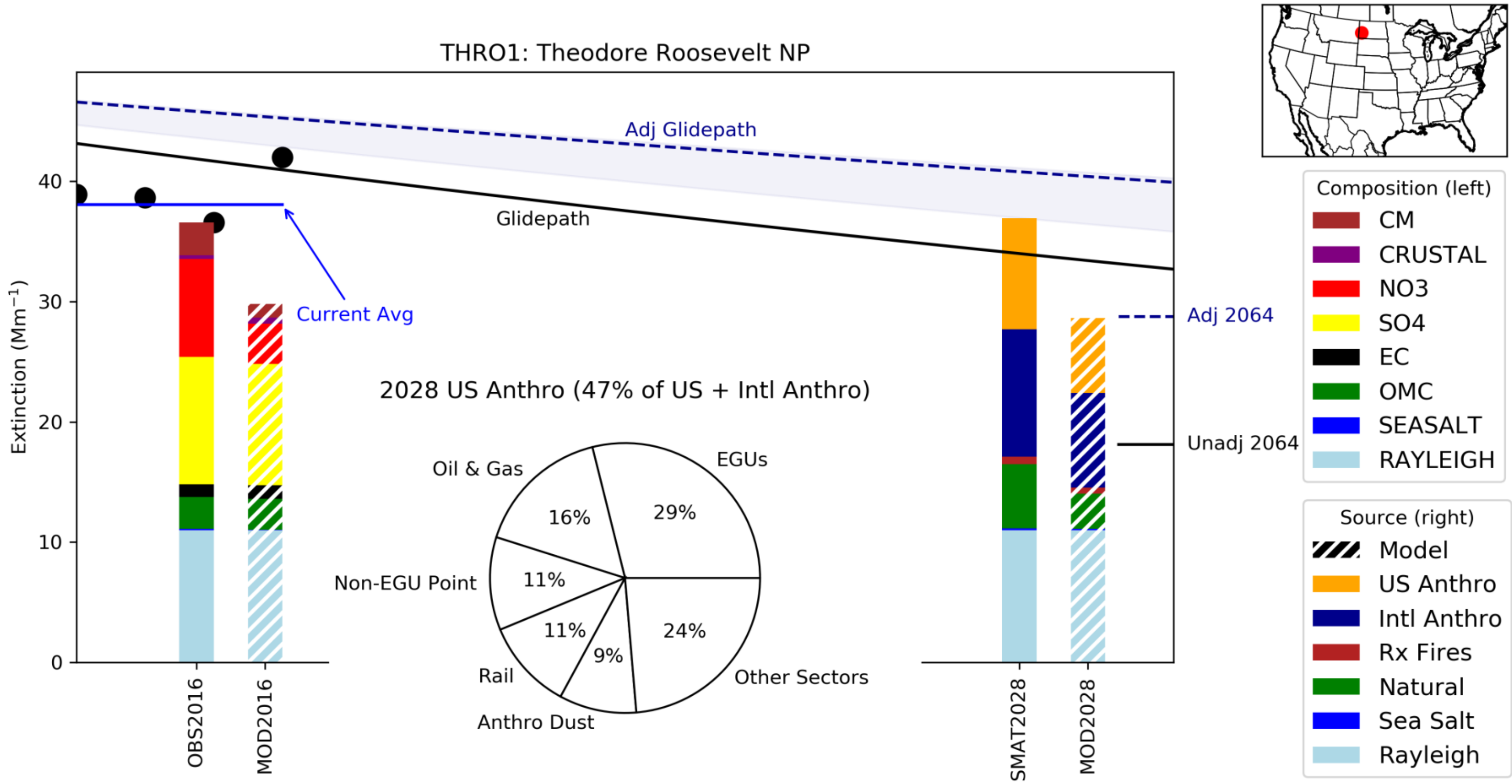


Figure 89: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at THRO1. Used for Class I areas: Theodore Roosevelt NP.

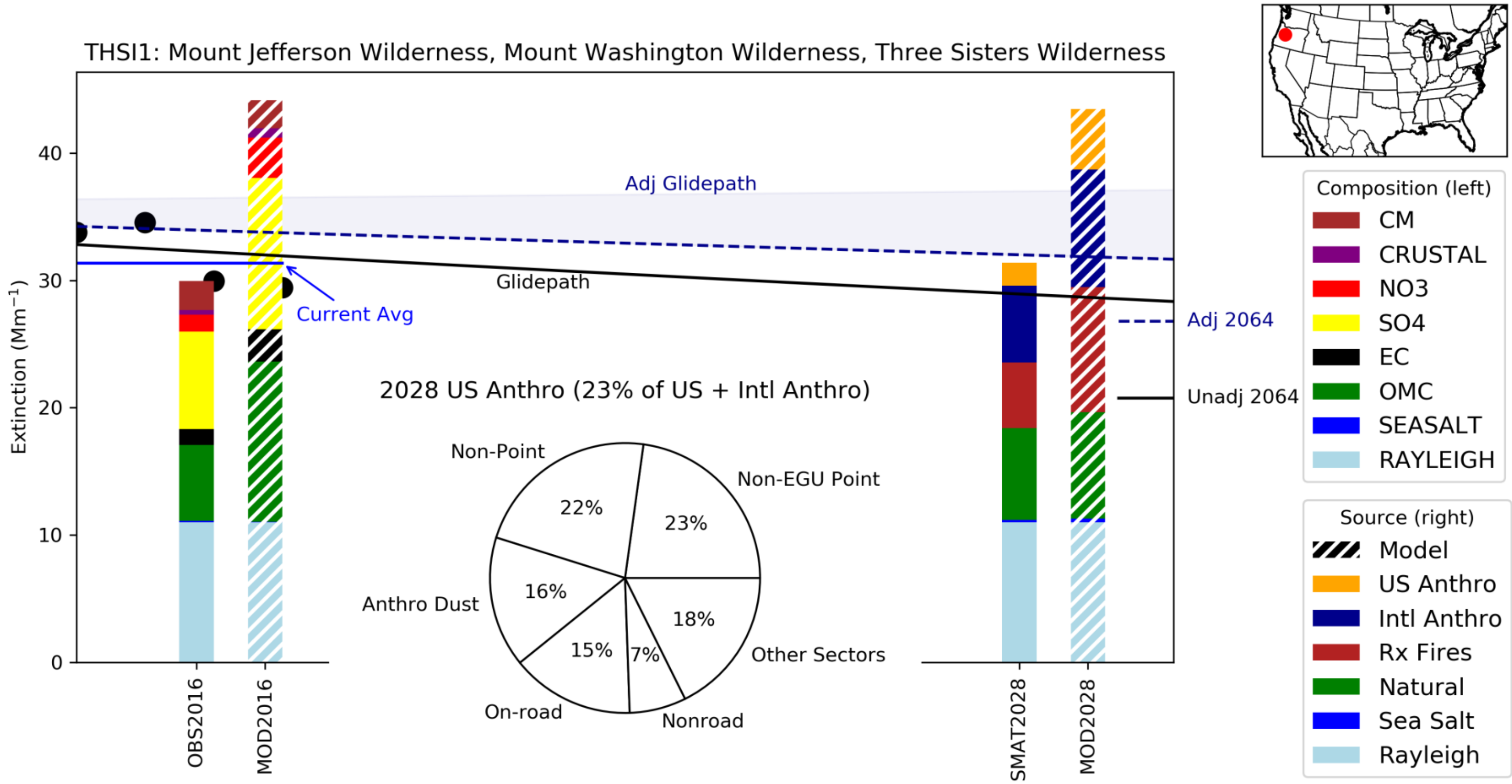


Figure 90: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at THSI1. Used for Class I areas: Mount Jefferson Wilderness, Mount Washington Wilderness, Three Sisters Wilderness.

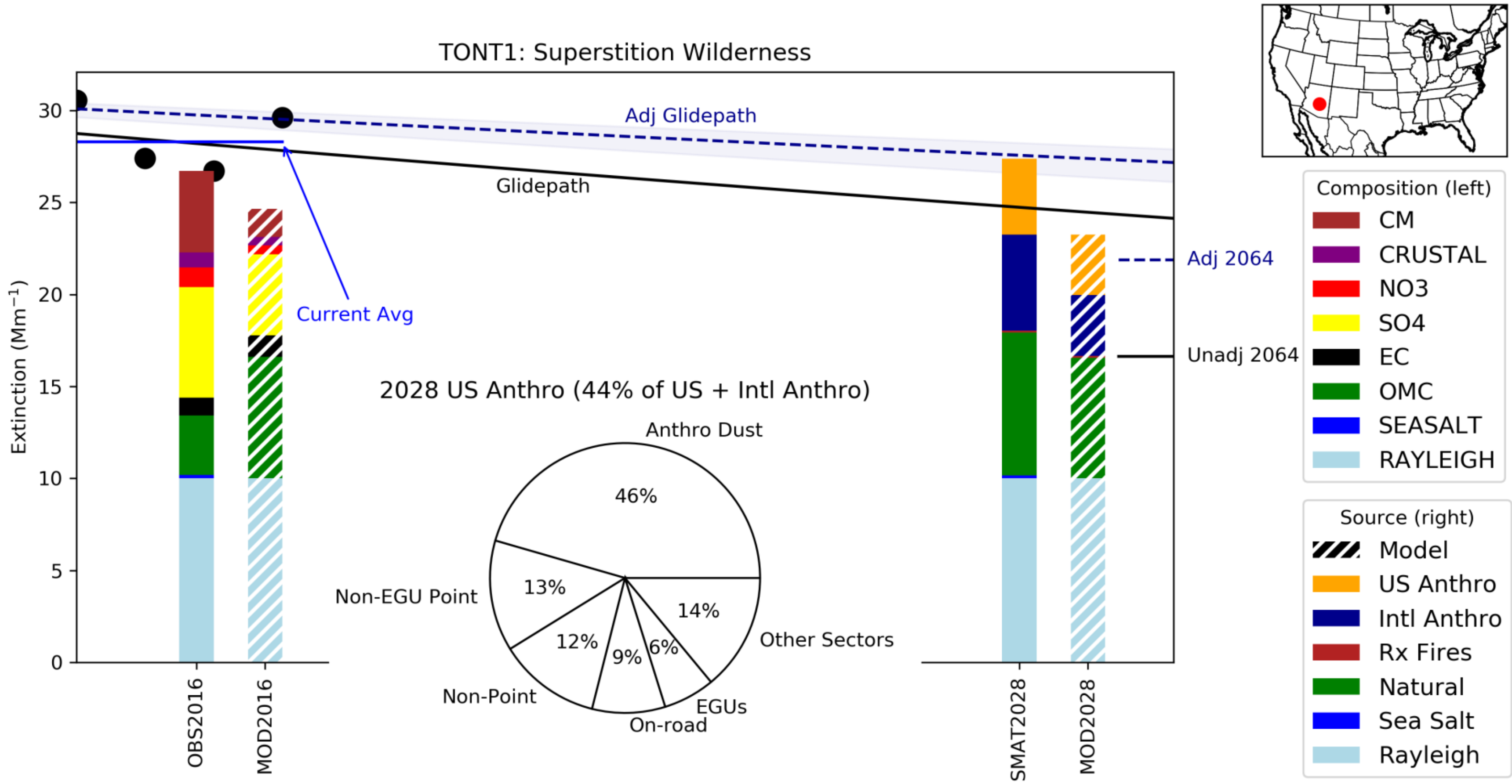


Figure 91: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at TONT1. Used for Class I areas: Superstition Wilderness.

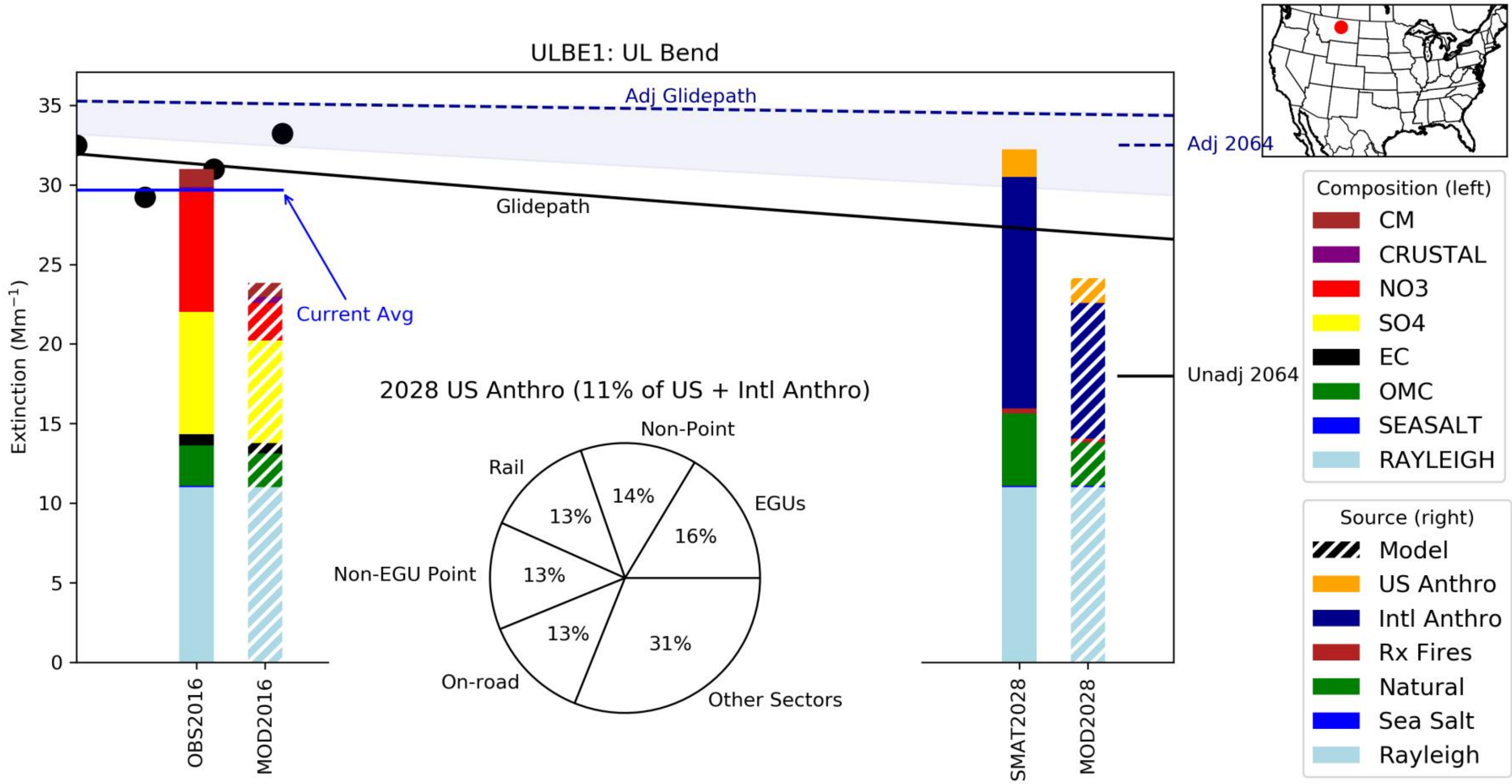


Figure 92: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at ULBE1. Used for Class I areas: UL Bend.

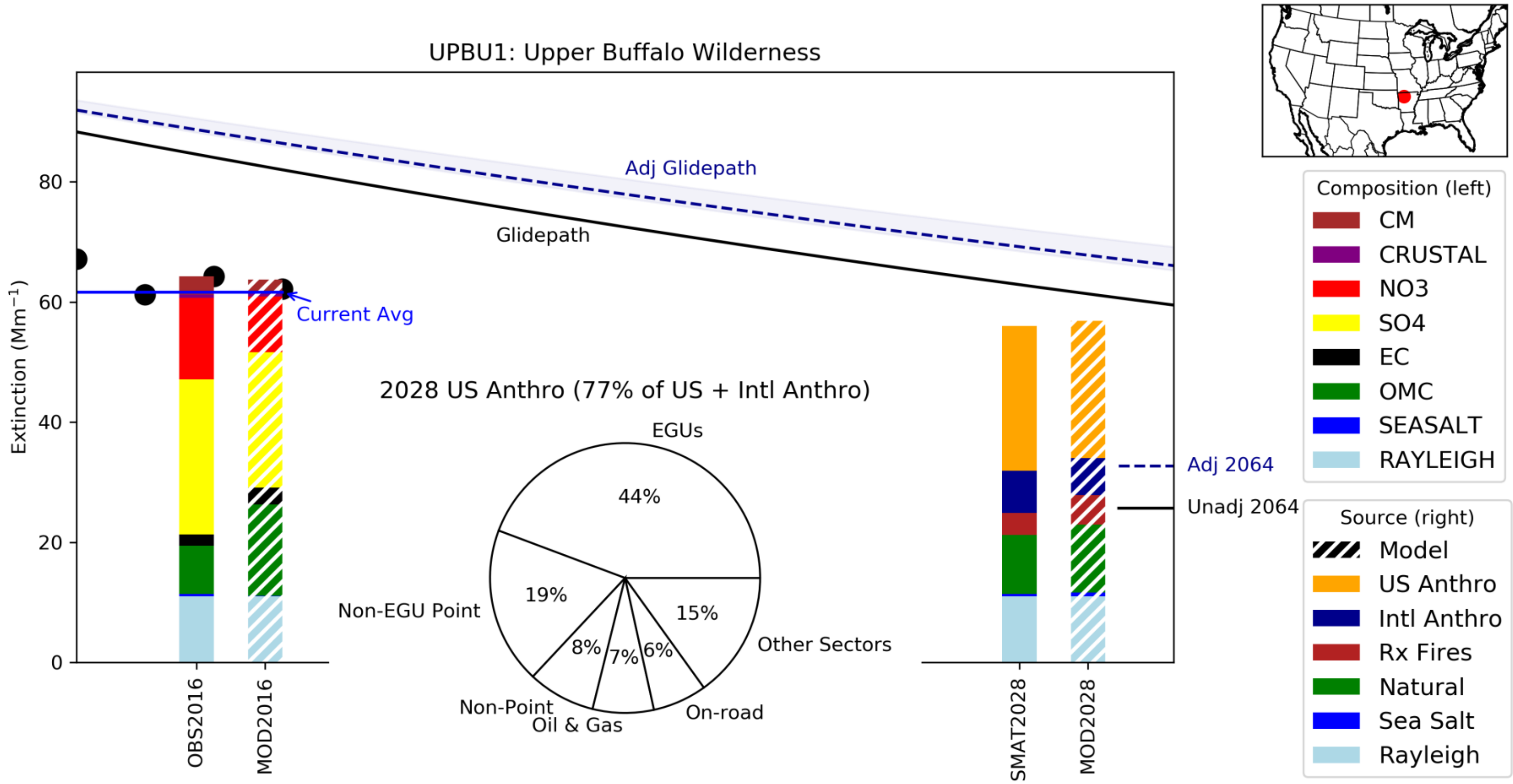


Figure 93: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at UPBU1. Used for Class I areas: Upper Buffalo Wilderness.

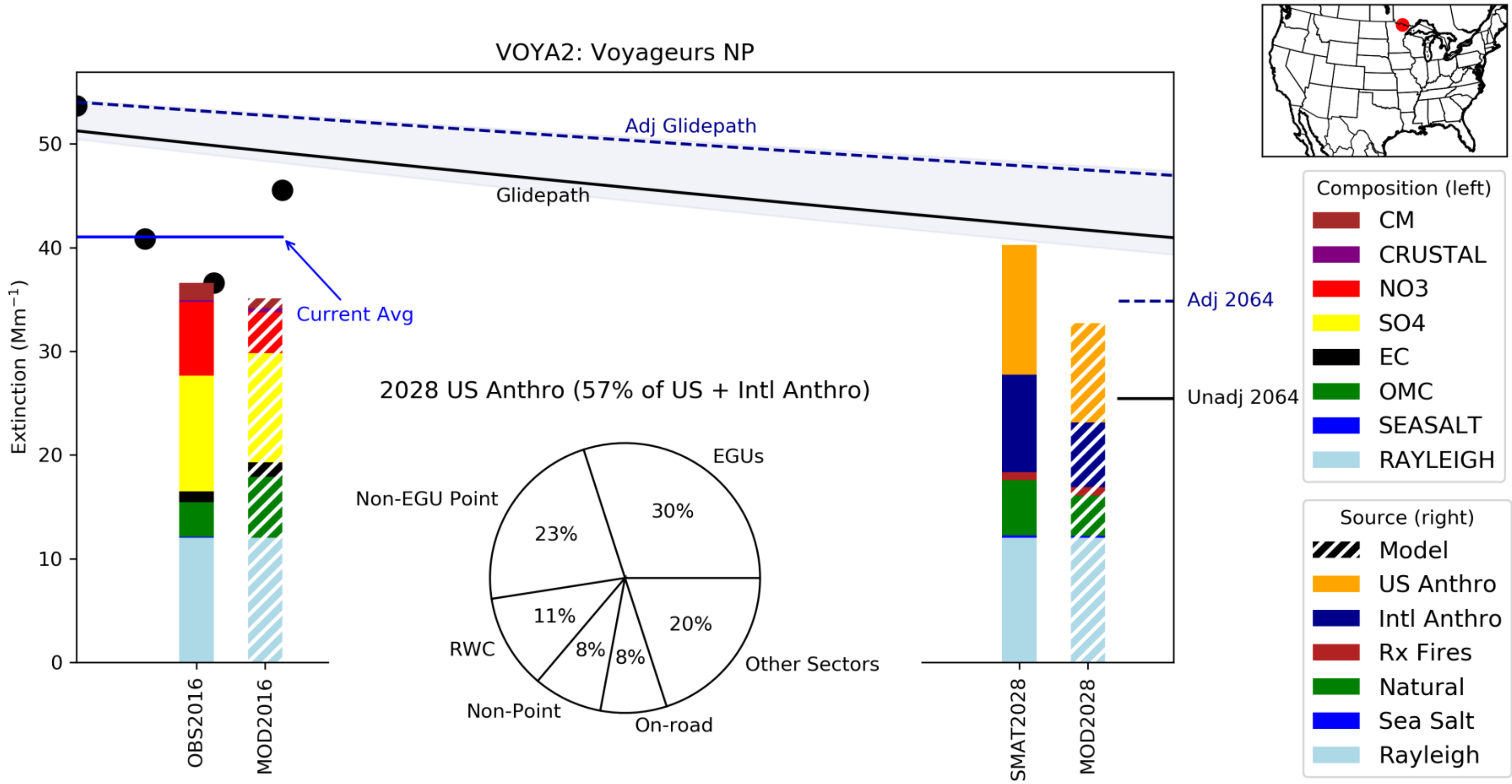


Figure 94: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at VOYA2. Used for Class I areas: Voyageurs NP.

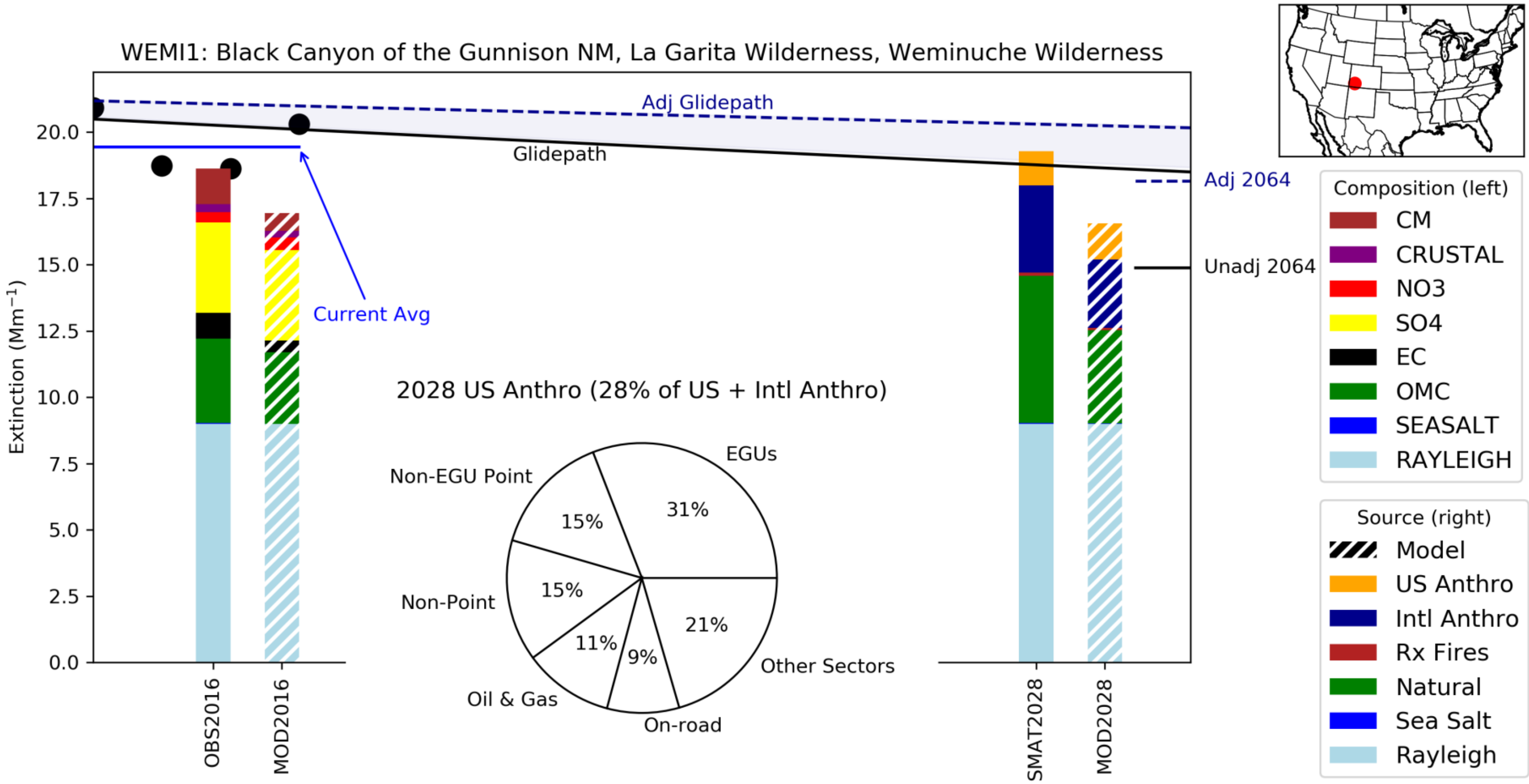


Figure 95: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WEMI1. Used for Class I areas: Black Canyon of the Gunnison NM, La Garita Wilderness, Weminuche Wilderness.

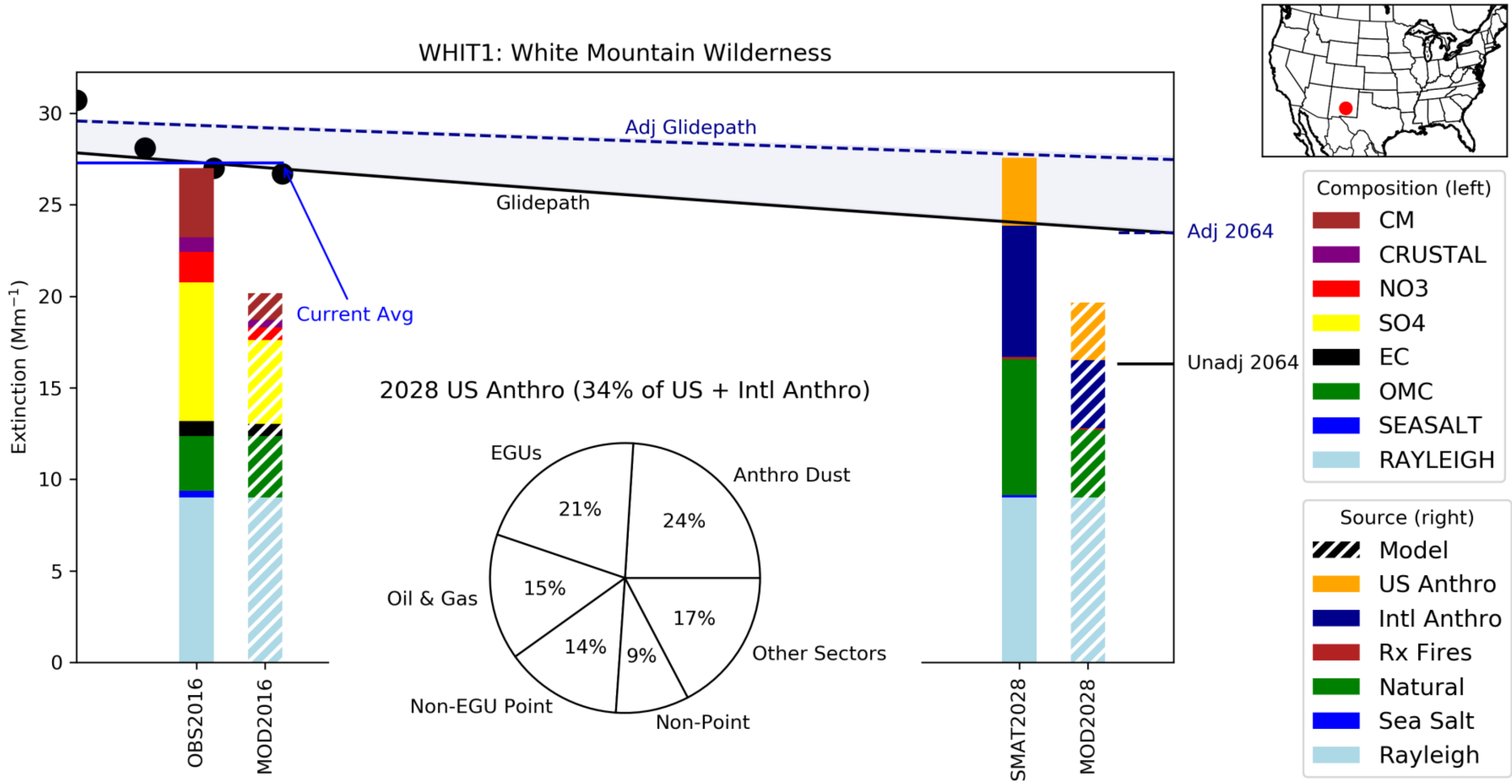


Figure 96: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WHIT1. Used for Class I areas: White Mountain Wilderness.

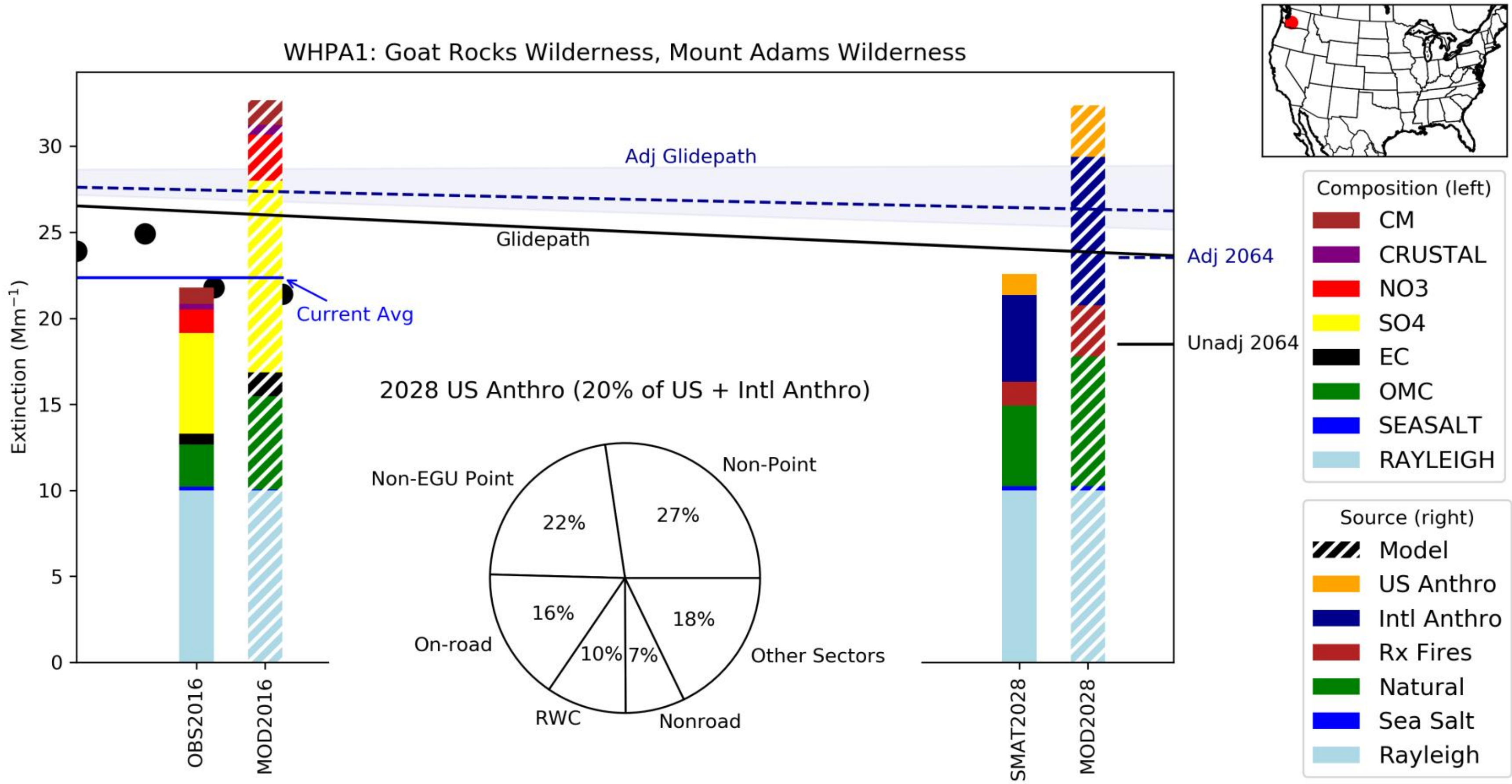


Figure 97: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WHPA1. Used for Class I areas: Goat Rocks Wilderness, Mount Adams Wilderness.

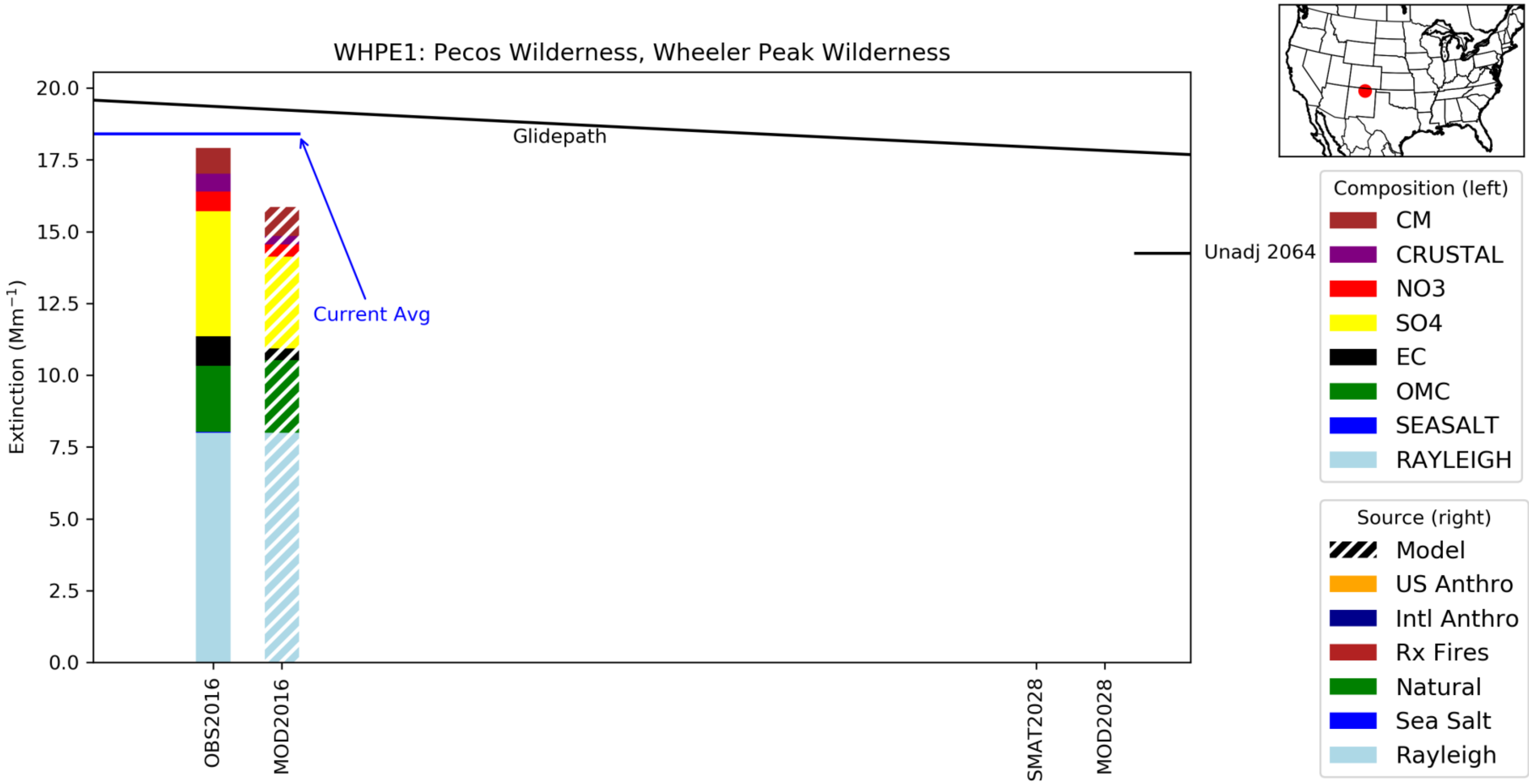


Figure 98: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WHPE1. Used for Class I areas: Pecos Wilderness, Wheeler Peak Wilderness.

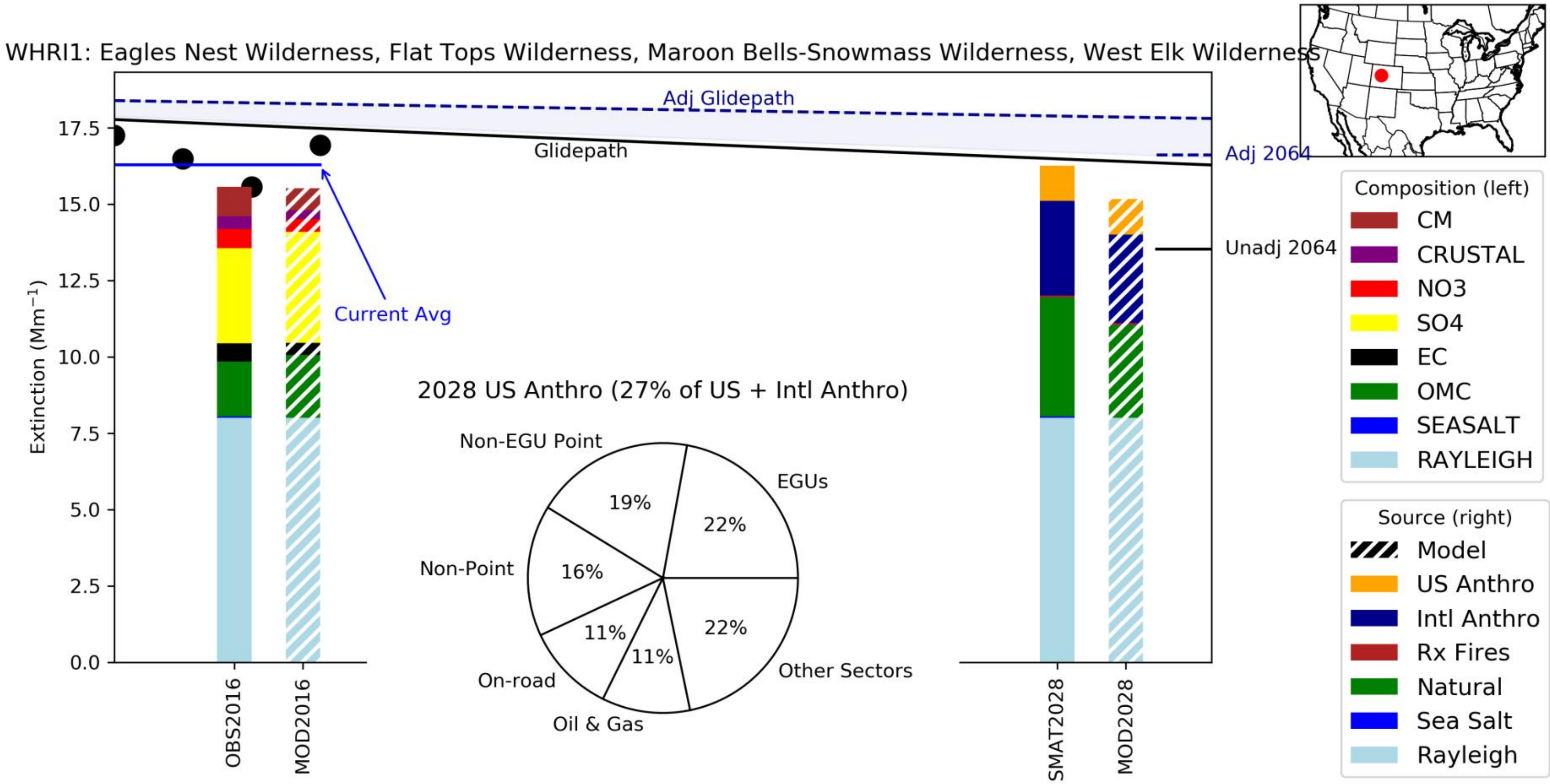


Figure 99: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WHRI1. Used for Class I areas: Eagles Nest Wilderness, Flat Tops Wilderness, Maroon Bells-Snowmass Wilderness, West Elk Wilderness.

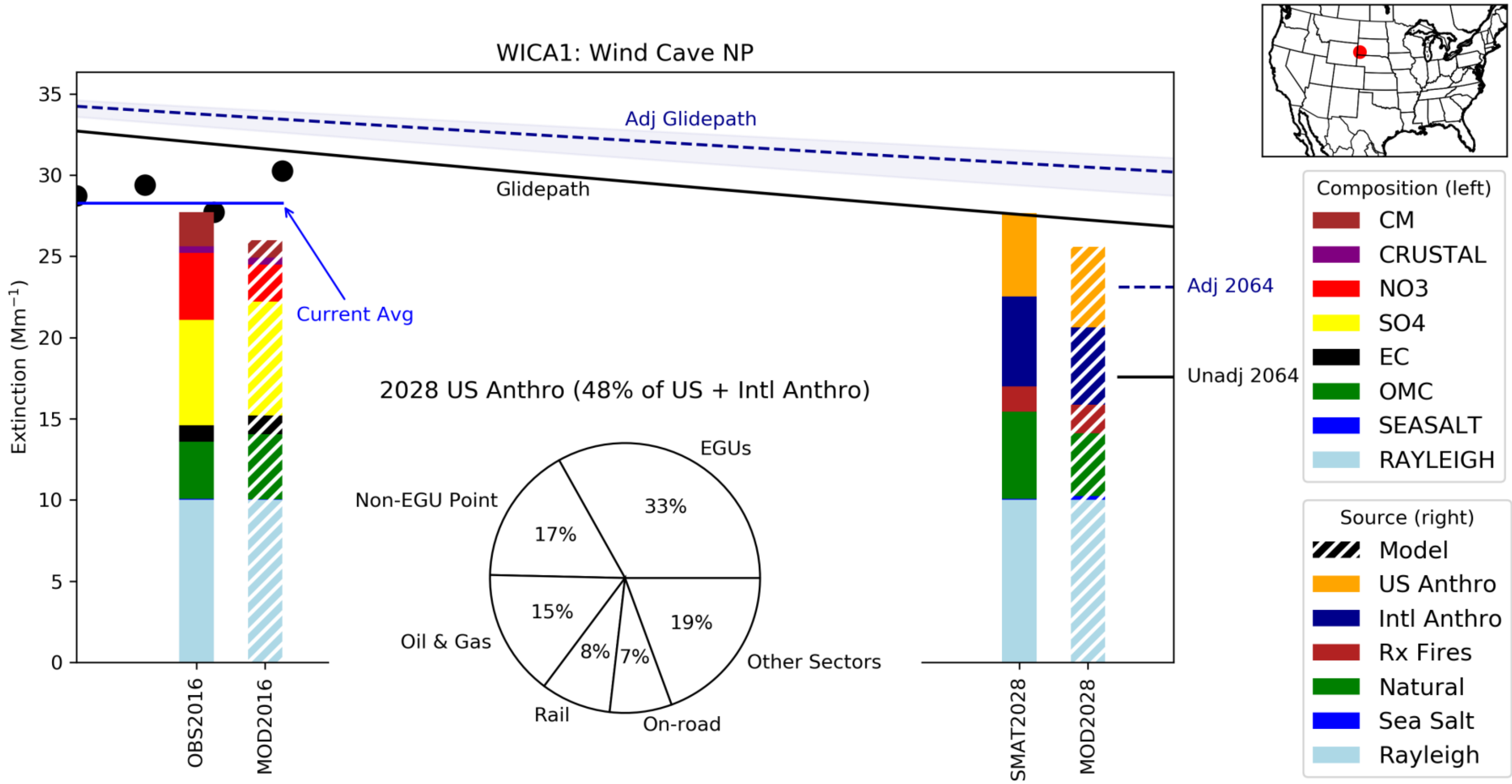


Figure 100: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WICA1. Used for Class I areas: Wind Cave NP.

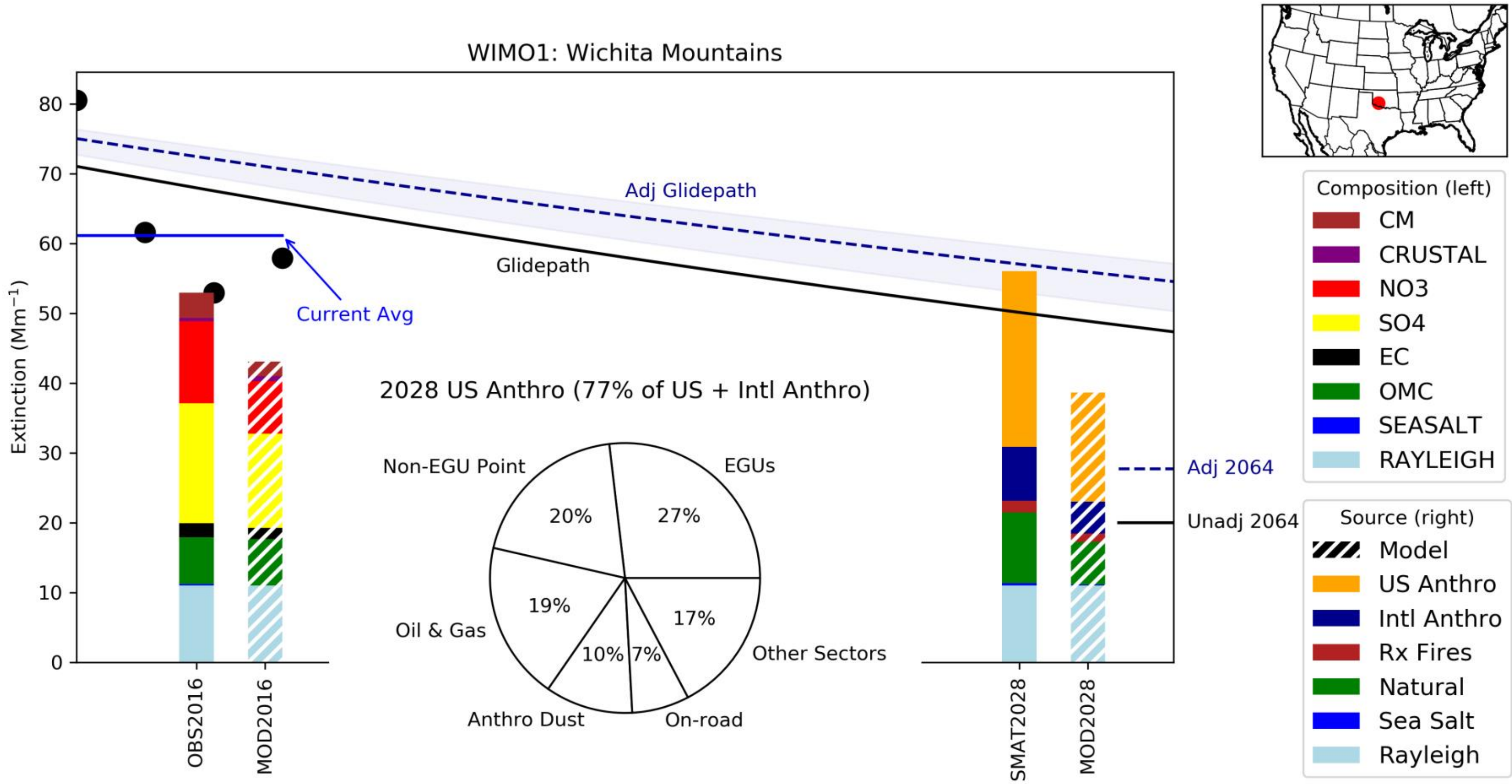


Figure 101: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at WIMO1. Used for Class I areas: Wichita Mountains.

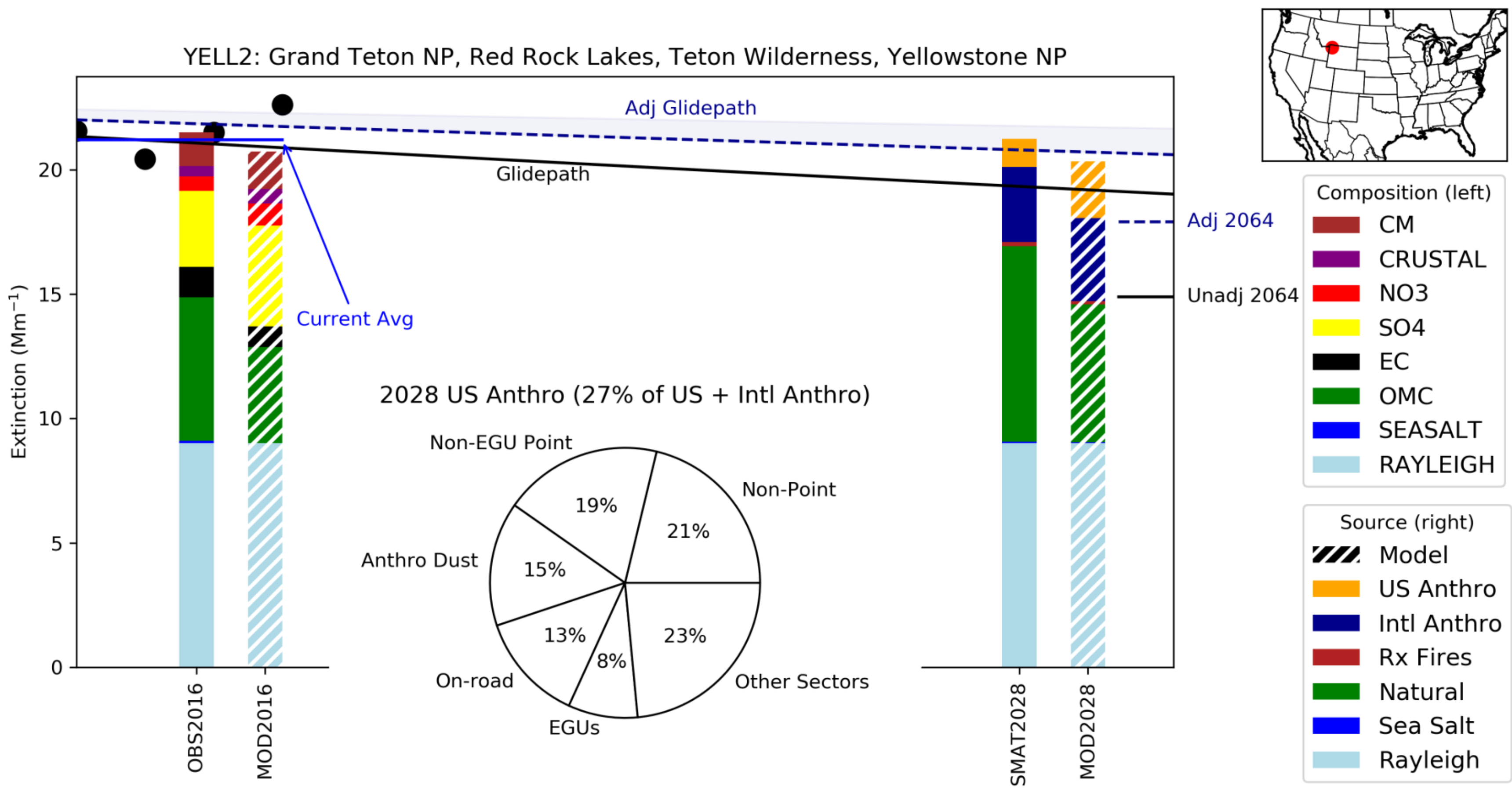


Figure 102: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at YELL2. Used for Class I areas: Grand Teton NP, Red Rock Lakes, Teton Wilderness, Yellowstone NP.

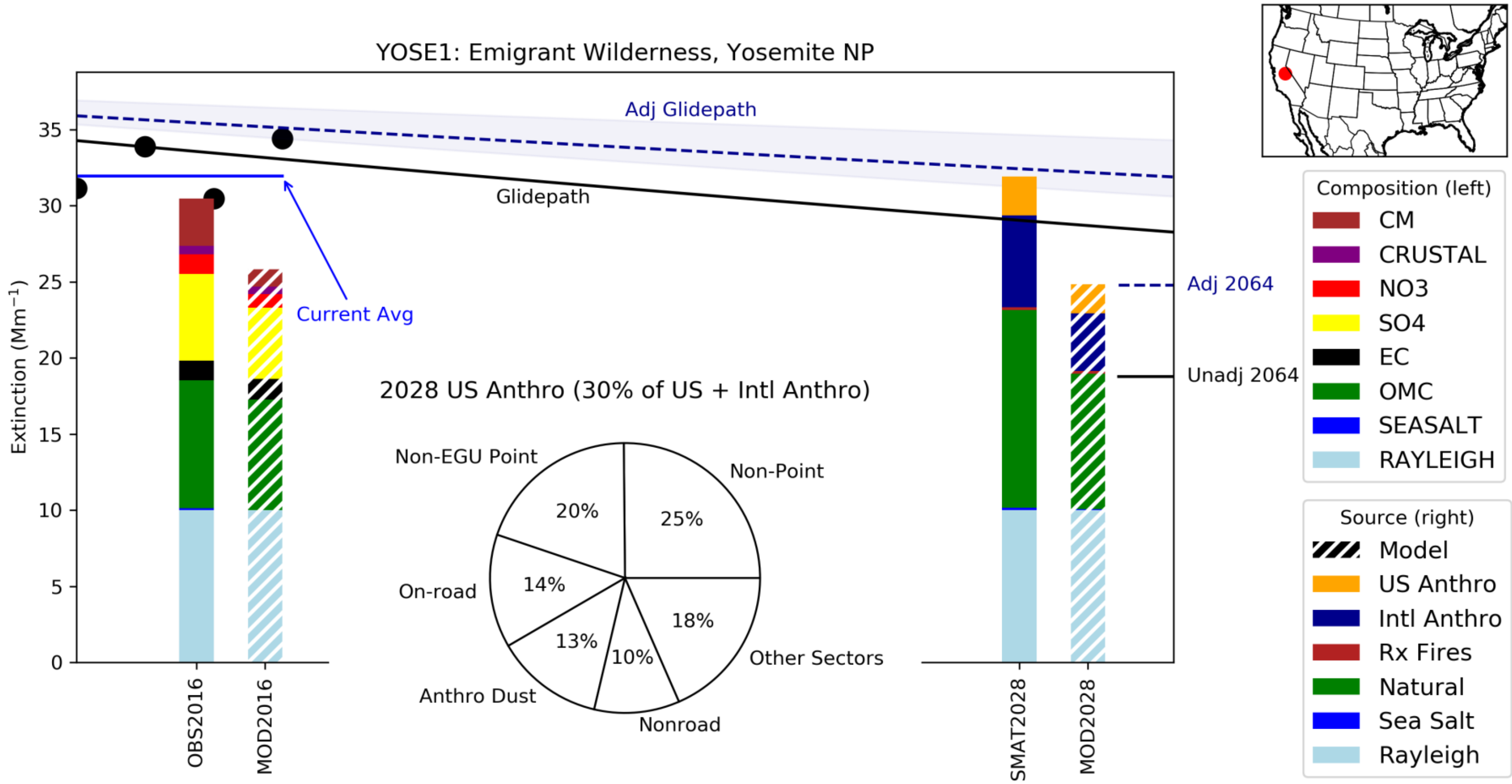


Figure 103: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at YOSE1. Used for Class I areas: Emigrant Wilderness, Yosemite NP.

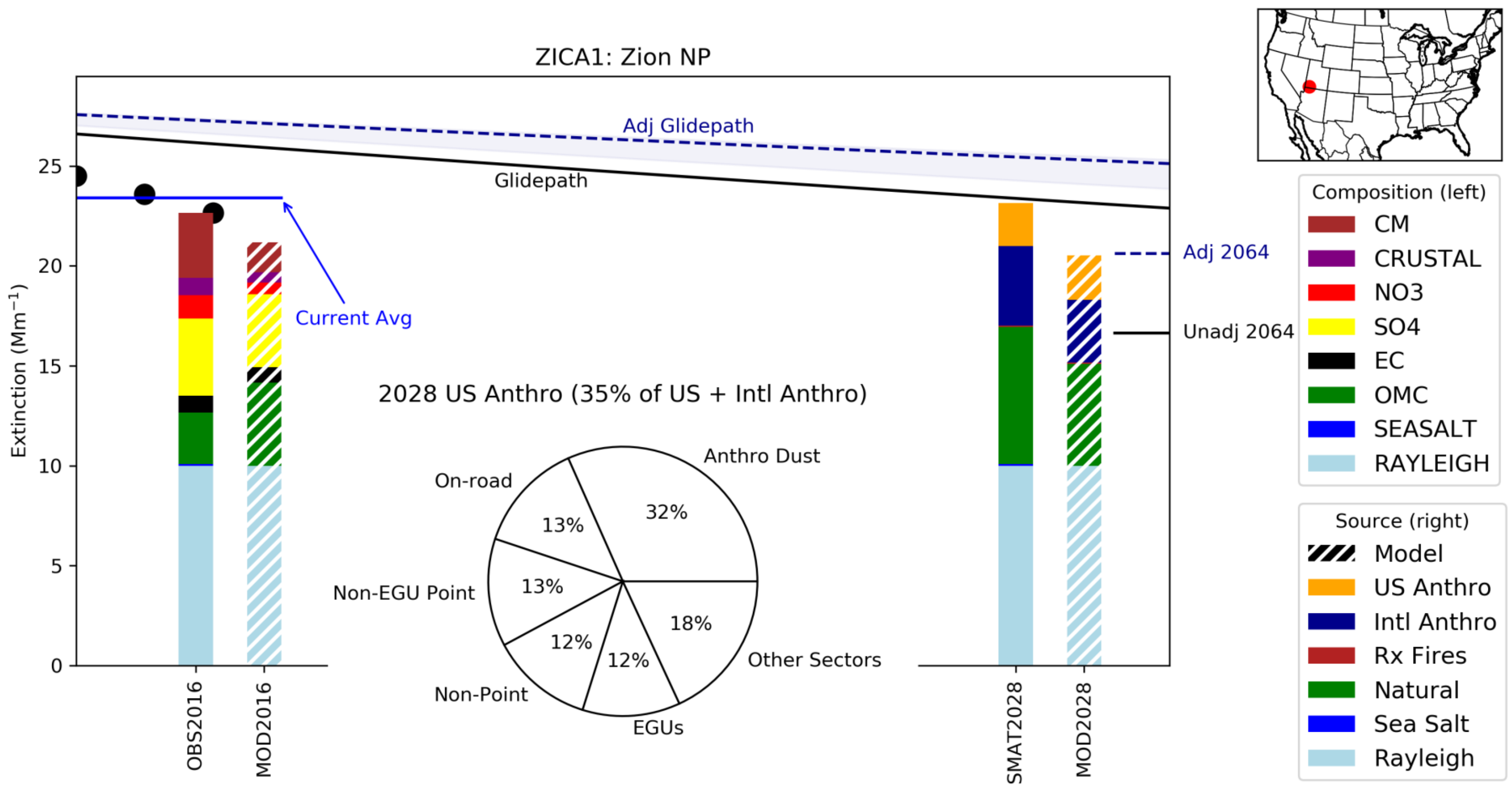


Figure 104: 2014-2017 IMPROVE observations, 2016 CAMx model predictions, 2028 modeled projection, and 2028 sector contributions at ZICA1. Used for Class I areas: Zion NP.

Appendix C- PSAT Post-processing Details

The PSAT raw "tag" model outputs were post-processed to create SMAT input files. This involves processing both the 2028 "bulk outputs" and the sector specific source apportionment outputs. The "bulk outputs" are the total "bulk" PM species concentrations (e.g. sulfate, nitrate, etc.) that are identical to the total species concentrations from the non-source apportionment model run for 2028. However, the source apportionment tracking of PM species uses slightly different variables names for the source apportionment outputs. Table C-1 below shows the SMAT species definitions and matching for the 2028 bulk and 2028 source apportionment results.

Table C-1 Matching of "bulk raw species, PSAT output species, and SMAT input variables.

SMAT species	"Combine file" output species	2028 Bulk raw species	2028 Source apportionment tag raw species
Sulfate	PM25_SO4	PSO4	PS4
Nitrate	PM25_NO3	PNO3	PN3
Ammonium [1]	PM25_NH4	PNH4	PN4
Organic carbon	PM25__OM_P +PM25_OM_S	POA + SOA1+ SOA2+ SOPA+ SOA3+ SOA4+ SOPB	POA+PO1+PO2+PO3+PO4+PPA+PPB
Crustal	Fine_CRUSTAL	2.2*PAL+2.49*PSI+1.63*PCA+2.42*PFE+1.94*PTI	2.2*PAL+2.49*PSI+1.63*PCA+2.42*PFE+1.94*PTI
Coarse PM	Coarse_CRUSTAL	CPRM+CCRS	PCS+PCC
Elemental carbon	PM25_EC	PEC	PEC
PM2.5[2]	PM25_Bulk	PSO4+PNO3+PNH4+POA+PEC+ SOA1+ SOA2+ SOPA+ SOA3+ SOA4+ SOPB+2.2*PAL+2.49*PSI+1.63*PCA +2.42*PFE+1.94*PTI	PS4+PN3+PN4+POA+PEC+PO1+PO2+PO3+PO4+PPA+PPB+2.2*PAL+2.49*PSI+1.63*PCA+2.42*PFE+1.94*PTI

[1] Modeled ammonium concentrations are not used in the post-processing of the 2028 visibility source apportionment results because the IMPROVE network does not measure ammonium and the IMPROVE equation assumes that sulfate and nitrate is fully neutralized by ammonia.

[2] Note that total $PM_{2.5}$ concentration data is needed as a SMAT input variable, but it is not used in the visibility calculations for regional haze. Visibility calculations only use the species specific model outputs.

The “SMAT species” are the standard PM species needed as input to SMAT. The “Combine file output species” are the species names after post-processing the raw model bulk and PSAT species. “Bulk raw species” are the CAMx v7 raw output species (from the 2028 “bulk” results) variables that were matched to the SMAT species. The “2028 source apportionment tag raw species” are the CAMx v7 raw source apportionment tag output species variables (these are the default raw tag species names in CAMx) that were matched to the SMAT species.

SMAT input files for the 2028 bulk species and sector tag species were created as a first step in calculating the relative PM and visibility contributions from each tag/sector. The 2028 bulk species SMAT input files contain the 24-hr average daily modeled species concentrations for each grid cell. The “sector tag” SMAT input files contain the 24-hr average daily modeled species concentrations for each sector tag, for each grid cell. The sector tag SMAT input files are created as the *difference* between the baseline 2028 bulk model species concentrations and the concentration from each sector tag group such that the “sector tag” SMAT input files are 2028 baseline concentrations *minus* 2028 sector tag concentrations.

The SMAT input files for the 2028 bulk case and the 2028 sector tags were then used to calculate sector tag extinction fractions using the following process:

1) Regional haze SMAT was run for the 2028 future case using “standard” 2016 and 2028 SMAT input files. In this SMAT run, the advanced option “Create forecast IMPROVE visibility file” was invoked (see picture below). This creates an output file with future year (2028) daily species extinction values at each IMPROVE monitor for each of the 20% best and most impaired days (based on 2016 ambient data). These are the extinction values that can be added and averaged to get the 2028 base case projected deciview values for each site. SMAT generates a new output file called “*scenario_name* Forecast IMPROVE Daily Data.csv” that can be re-used to calculate the sector tag fractions.

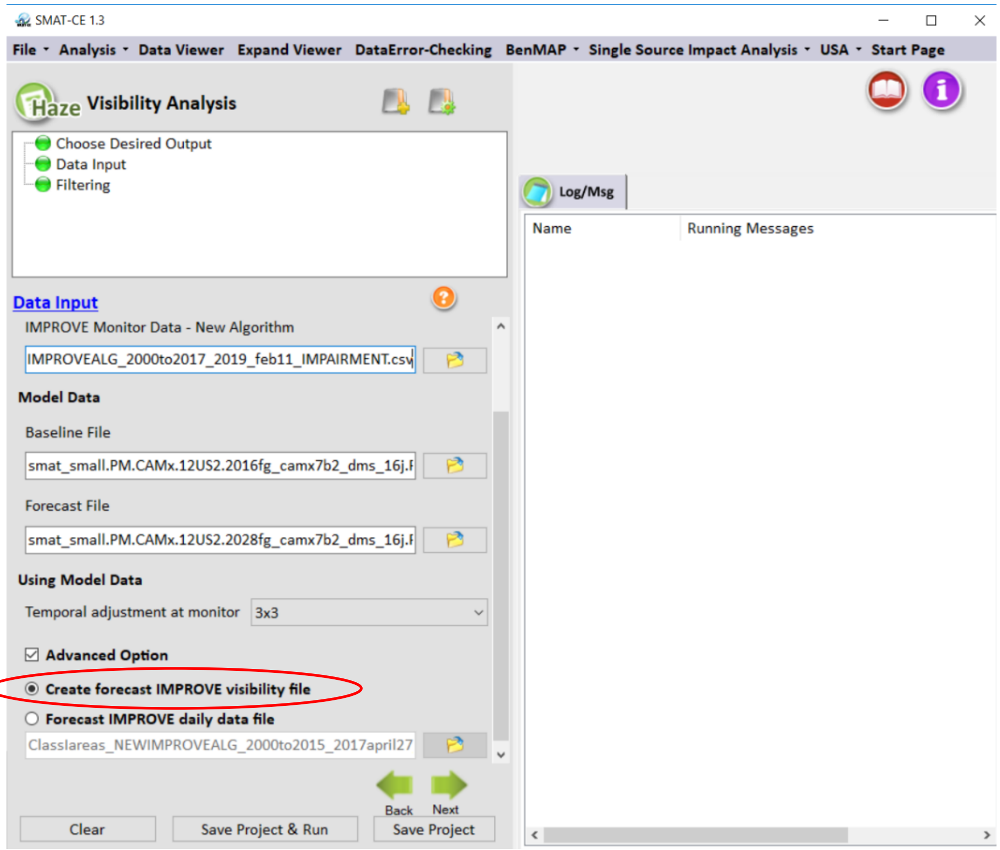


Figure C-1 **SMAT advanced option "Create forecast IMPROVE visibility file".**

2) SMAT was then run again for each sector tag (22 tags plus initial and boundary conditions), using the "advanced options" shown below. For each SMAT run, the "Forecast IMPROVE Daily Data" file (created as an output file from step 1 above) is used as the "advanced option" input file, the 2028 bulk SMAT input file is used as the "Baseline file", and each 2028 sector tag SMAT input file is used as the "Forecast file". For each sector tag, this creates sector tag species specific RRFs that are multiplied by the 2028 forecast extinction data for each IMPROVE site.

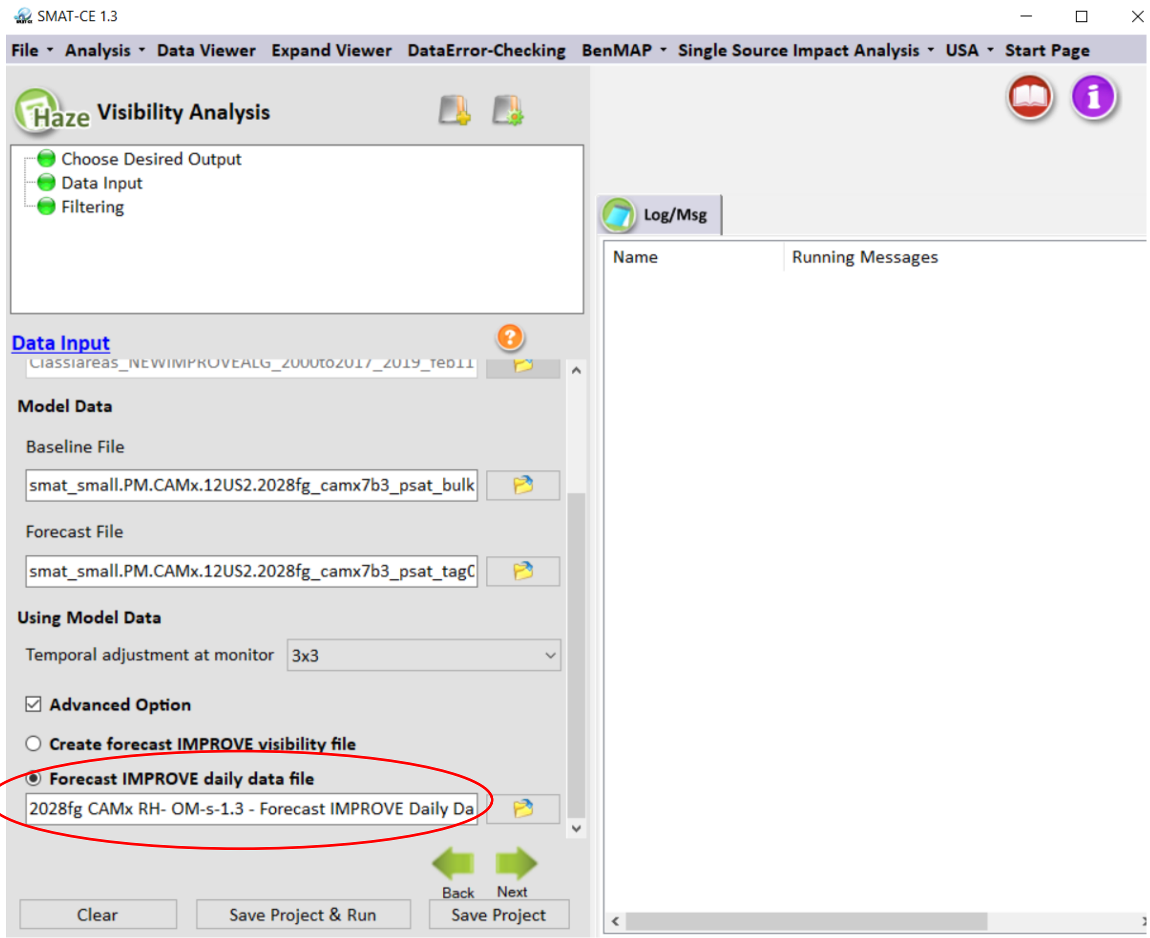


Figure C-2 **SMAT advanced option "Forecast IMPROVE daily data file".**

3) The total extinction (on the 20% most impaired days) for each sector tag is calculated from the SMAT bulk output file and each of the sector tag output files. The total extinction variable (20% most impaired days) from the bulk file (tbext_g90_f) is subtracted from the total extinction variable from each sector tag output file. The difference is the contribution from the sector tag on the 20% most impaired days (at each IMPROVE site/Class I area). The same calculation can be done for the 20% clearest days by subtracting the total extinction variable on the 20% clearest days (tbext_g10_f) from both files.
4) As a final step, there are several other extinction components that are calculated separately. Rayleigh scattering is a constant value (which varies slightly based on elevation) and is added to the sector tag totals at each site. Next, the measured extinction from sea salt (E_sea_salt_g90_f) is added directly from the bulk SMAT output file (sea salt is held constant between years and was not tracked by source apportionment).

The individual sector tags have been summed into categories and summarized in “Class I area summary plots”, contained in Appendix B. The emissions summary categories are shown in table C-2.

Table C-2 Source apportionment emissions summary categories.

Emissions Summary Category	**Emissions Sectors (PSAT tags)**	**Notes**
U.S. Anthropogenic	On-road mobile, Non-road mobile, EGUs, C1&C2 commercial marine, US C3 commercial marine (w/in ECA), Rail, Agricultural fires, Agricultural ammonia, Oil & Gas, Non-EGU point, Residential wood, Anthropogenic dust, Nonpoint,	U.S. anthropogenic visibility contributions.
International Anthropogenic	Anthropogenic Canada and Mexico, C3 commercial marine (outside ECA), Boundary conditions- international anthropogenic	Contribution from Canadian and Mexican emissions within the 36 and 12km domains
Natural	Biogenic, US wildfires, Canada wildfires, Mexico wildfires, Ocean sulfate (DMS and sea salt), sea salt, natural dust, Rayleigh	Contributions to natural visibility from US sources as well as international
Prescribed Fires	US Prescribed fires	Prescribed fire contributions.

Appendix D

Source apportionment Tag Emissions Summary Table

		2016fg Annual Emissions (TPY)					2028fg Annual Emissions (TPY)				
Tag #	Tag Name	NH3	NOX	PM2.5	SO2	VOC	NH3	NOX	PM2.5	SO2	VOC
1	Biogenics	-	975,807	-	-	43,161,614	-	975,807	-	-	43,161,614
2	Point EGUs	23,977	1,290,226	133,515	1,540,557	33,771	39,555	804,093	111,632	878,680	29,816
3	Onroad mobile	100,856	4,066,815	130,614	27,550	1,986,602	83,643	1,354,187	63,060	11,550	886,243
4	Nonroad mobile	1,783	1,081,598	102,159	2,198	1,164,615	2,028	604,942	55,094	1,536	825,951
5	C1 & C2 commercial marine	309	514,611	13,720	3,130	9,546	312	287,866	7,945	1,252	5,904
6	C3 commercial marine	96	567,284	6,870	15,144	25,013	139	486,975	9,968	21,969	36,328
7	C3 commercial marine - non-US	-	1,043,852	81,432	657,836	37,557	-	1,482,984	116,059	133,509	53,535
8	Railroads	323	558,732	16,158	364	26,062	340	588,788	17,036	383	27,469
9	Agricultural burning	54,454	10,825	28,632	3,909	18,323	54,454	10,825	28,632	3,909	18,323
10	Agricultural ammonia	2,862,779	-	-	-	186,941	2,990,703	-	-	-	198,161
11	Nonpoint and point oil and gas	4,376	955,824	26,021	57,475	3,092,777	4,394	930,941	30,783	72,187	3,577,561
12	Point non-EGU sources	63,613	1,087,999	261,565	675,797	816,127	64,188	1,140,722	144,393	641,564	820,105
13	Residential wood combustion	15,554	31,492	318,999	7,739	342,959	14,627	32,128	300,284	6,722	326,350
14	US wildfires	125,577	110,960	665,171	59,430	1,804,428	125,577	110,960	665,171	59,430	1,804,428
15	US prescribed fires	128,554	121,368	640,518	56,376	1,513,923	128,554	121,368	640,518	56,376	1,513,923
16	Area source fugitive dust	-	-	1,006,412	-	-	-	-	1,017,675	-	-
17	Non-point	121,721	759,882	499,779	161,732	3,718,709	123,021	763,173	543,498	119,048	3,937,967
18	Canada fires	104,683	134,301	580,958	60,914	1,501,988	104,683	134,301	580,958	60,914	1,501,988
19	Canada anthropogenic	533,657	1,926,159	584,899	1,147,090	2,023,308	730,509	1,244,887	588,794	1,245,794	1,905,101
20	Mexico fires	120,627	347,132	746,107	45,222	2,260,695	120,627	347,132	746,107	45,222	2,260,695
21	Mexico anthropogenic	925,033	3,029,834	677,215	2,344,667	4,649,026	936,519	3,352,508	802,946	2,865,746	5,349,517
22	Oceanic sea salt and DMS	-	-	-	-	-	-	-	-	-	-
	US Anthropogenic Total	**3,249,840**	**10,925,288**	**2,544,443**	**2,495,595**	**11,421,444**	**3,377,404**	**7,004,640**	**2,329,998**	**1,758,801**	**10,690,177**
	Percent change in US anthropogenic between 2016 and 2028						**3.9%**	**-35.9%**	**-8.4%**	**-29.5%**	**-6.4%**

Appendix E

2064 Glidepath Endpoints

Table E-1 2064 Unadjusted and Adjusted Endpoints (deciviews)

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Unadjusted 2064 Endpoint 20% most Impaired days (dv)	Default Adjusted 2064 Endpoint (dv)	Minimum Alternative Adjusted 2064 Endpoint (dv)	Maximum Alternative Adjusted 2064 Endpoint (dv)
ACAD	Acadia NP	ME	ACAD1	10.39	13.10	10.54	13.19
AGTI	Agua Tibia Wilderness	CA	AGTI1	7.63	10.62	9.46	12.20
BADL	Badlands NP	SD	BADL1	6.09	9.67	7.41	9.94
BALD	Mount Baldy Wilderness	AZ	BALD1	4.09	6.58	4.05	6.66
BAND	Bandelier NM	NM	BAND1	4.59	6.73	5.15	6.79
BIBE	Big Bend NP	TX	BIBE1	5.33	12.34	8.97	13.27
MOKE	Mokelumne Wilderness	CA	BLIS1	4.91	7.05	7.05	11.17
DESO	Desolation Wilderness	CA	BLIS1	4.91	7.05	7.05	11.17
BOAP	Bosque del Apache	NM	BOAP1	5.36	7.52	7.28	8.33
BOWA	Boundary Waters Canoe Area	MN	BOWA1	9.09	12.12	8.46	12.71
FITZ	Fitzpatrick Wilderness	WY	BRID1	3.90	5.68	4.89	5.83
BRID	Bridger Wilderness	WY	BRID1	3.90	5.68	4.89	5.83
BRIG	Brigantine	NJ	BRIG1	10.69	12.72	10.38	12.92

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Unadjusted 2064 Endpoint 20% most Impaired days (dv)	Default Adjusted 2064 Endpoint (dv)	Minimum Alternative Adjusted 2064 Endpoint (dv)	Maximum Alternative Adjusted 2064 Endpoint (dv)
BRET2	Breton	LA	BRIS1	9.33	12.71	9.94	13.06
CABI	Cabinet Mountains Wilderness	MT	CABI1	5.65	7.71	7.71	10.81
CACR	Caney Creek Wilderness	AR	CACR1	9.47	11.21	10.76	12.49
ARCH	Arches NP	UT	CANY1	4.11	6.23	3.87	6.28
CANY	Canyonlands NP	UT	CANY1	4.11	6.23	3.87	6.28
CAPI	Capitol Reef NP	UT	CAPI1	3.96	6.53	4.74	6.57
CHAS	Chassahowitzka	FL	CHAS1	8.97	11.40	10.79	12.24
CHIW	Chiricahua Wilderness	AZ	CHIR1	4.93	7.87	5.44	7.91
GALI	Galiuro Wilderness	AZ	CHIR1	4.93	7.87	5.44	7.91
CHIR	Chiricahua NM	AZ	CHIR1	4.93	7.87	5.44	7.91
COHU	Cohutta Wilderness	GA	COHU1	9.73	11.55	10.14	11.93
DIPE	Diamond Peak Wilderness	OR	CRLA1	5.22	8.09	7.85	9.81
GEMO	Gearhart Mountain Wilderness	OR	CRLA1	5.22	8.09	7.85	9.81
MOLA	Mountain Lakes Wilderness	OR	CRLA1	5.22	8.09	7.85	9.81
CRLA	Crater Lake NP	OR	CRLA1	5.22	8.09	7.85	9.81

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Unadjusted 2064 Endpoint 20% most Impaired days (dv)	Default Adjusted 2064 Endpoint (dv)	Minimum Alternative Adjusted 2064 Endpoint (dv)	Maximum Alternative Adjusted 2064 Endpoint (dv)
CRMO	Craters of the Moon NM	ID	CRMO1	4.97	7.56	6.66	7.79
DOME	Dome Land Wilderness	CA	DOME1	6.18	9.95	8.41	13.12
OTCR	Otter Creek Wilderness	WV	DOSO1	8.92	10.78	8.57	11.07
DOSO	Dolly Sods Wilderness	WV	DOSO1	8.92	10.78	8.57	11.07
EVER	Everglades NP	FL	EVER1	8.34	11.25	10.35	12.44
GAMO	Gates of the Mountains Wilderness	MT	GAMO1	4.66	7.01	6.80	7.89
GICL	Gila Wilderness	NM	GICL1	4.22	6.62	4.87	6.66
GLAC	Glacier NP	MT	GLAC1	6.89	10.11	9.17	12.03
GRCA	Grand Canyon NP	AZ	GRCA2	4.18	6.39	6.06	7.07
PRRA	Presidential Range-Dry River Wilderness	NH	GRGU1	9.78	12.66	8.69	12.82
GRGU	Great Gulf Wilderness	NH	GRGU1	9.78	12.66	8.69	12.82
GRSA	Great Sand Dunes NM	CO	GRSA1	4.45	6.57	3.95	6.88
JOYC	Joyce-Kilmer-Slickrock Wilderness	TN	GRSM1	10.05	11.68	9.78	12.03
GRSM	Great Smoky Mountains NP	TN	GRSM1	10.05	11.68	9.78	12.03

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Unadjusted 2064 Endpoint 20% most Impaired days (dv)	Default Adjusted 2064 Endpoint (dv)	Minimum Alternative Adjusted 2064 Endpoint (dv)	Maximum Alternative Adjusted 2064 Endpoint (dv)
CAVE	Carlsbad Caverns NP	TX	GUMO1	4.83	10.57	6.38	11.21
GUMO	Guadalupe Mountains NP	TX	GUMO1	4.83	10.57	6.38	11.21
HECA	Hells Canyon Wilderness	OR	HECA1	6.57	10.06	8.31	10.96
HEGL	Hercules-Glades Wilderness	MO	HEGL1	9.30	11.32	11.08	12.70
HOOV	Hoover Wilderness	CA	HOOV1	4.91	7.07	5.95	7.36
PIMO	Pine Mountain Wilderness	AZ	IKBA1	5.22	7.77	6.80	8.01
MAZA	Mazatzal Wilderness	AZ	IKBA1	5.22	7.77	6.80	8.01
ISLE	Isle Royale NP	MI	ISLE1	10.15	12.99	8.52	13.47
JARB	Jarbidge Wilderness	NV	JARB1	5.23	7.37	6.45	7.55
JARI	James River Face Wilderness	VA	JARI1	9.48	11.25	9.18	11.58
JOSH	Joshua Tree NM	CA	JOSH1	6.09	9.38	8.41	10.22
ANAD	Ansel Adams Wilderness (Minarets)	CA	KAIS1	6.00	8.82	7.09	9.82
JOMU	John Muir Wilderness	CA	KAIS1	6.00	8.82	7.09	9.82
KAIS	Kaiser Wilderness	CA	KAIS1	6.00	8.82	7.09	9.82

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Unadjusted 2064 Endpoint 20% most Impaired days (dv)	Default Adjusted 2064 Endpoint (dv)	Minimum Alternative Adjusted 2064 Endpoint (dv)	Maximum Alternative Adjusted 2064 Endpoint (dv)
KALM	Kalmiopsis Wilderness	OR	KALM1	7.80	9.66	9.66	13.19
SOWA	South Warner Wilderness	CA	LABE1	6.16	8.49	8.49	9.45
LABE	Lava Beds NM	CA	LABE1	6.16	8.49	8.49	9.45
CARI	Caribou Wilderness	CA	LAVO1	6.14	8.36	8.36	9.03
THLA	Thousand Lakes Wilderness	CA	LAVO1	6.14	8.36	8.36	9.03
LAVO	Lassen Volcanic NP	CA	LAVO1	6.14	8.36	8.36	9.03
LIGO	Linville Gorge Wilderness	NC	LIGO1	9.70	11.14	9.67	11.41
LOST	Lostwood	ND	LOST1	5.88	12.93	10.65	13.09
LYBR2	Lye Brook Wilderness	VT	LYEB1	10.23	12.78	8.78	12.93
MACA	Mammoth Cave NP	KY	MACA1	9.79	12.11	9.04	12.51
MELA	Medicine Lake	MT	MELA1	5.95	13.21	9.73	13.30
MEVE	Mesa Verde NP	CO	MEVE1	4.20	6.15	4.27	6.23
MING	Mingo	MO	MING1	9.24	11.09	10.78	12.36
MOHO	Mount Hood Wilderness	OR	MOHO1	6.60	8.62	8.41	14.00
BOMA	Bob Marshall Wilderness	MT	MONT1	5.43	7.27	7.27	9.00
SCAP	Scapegoat Wilderness	MT	MONT1	5.43	7.27	7.27	9.00

Class I Area ID	Class I Area Name	State	IMPROVE Site ID	Unadjusted 2064 Endpoint 20% most Impaired days (dv)	Default Adjusted 2064 Endpoint (dv)	Minimum Alternative Adjusted 2064 Endpoint (dv)	Maximum Alternative Adjusted 2064 Endpoint (dv)
MIMO	Mission Mountains Wilderness	MT	MONT1	5.43	7.27	7.27	9.00
ROCA	Roosevelt Campobello International Park	ME	MOOS1	9.97	13.42	10.56	13.51
MOOS	Moosehorn	ME	MOOS1	9.97	13.42	10.56	13.51
MORA	Mount Rainier NP	WA	MORA1	7.66	10.23	10.23	11.45
RAWA	Rawah Wilderness	CO	MOZI1	3.16	5.26	3.60	5.34
MOZI	Mount Zirkel Wilderness	CO	MOZI1	3.16	5.26	3.60	5.34
WASH	Washakie Wilderness	WY	NOAB1	4.54	6.39	4.95	6.53
NOAB	North Absaroka Wilderness	WY	NOAB1	4.54	6.39	4.95	6.53
GLPE	Glacier Peak Wilderness	WA	NOCA1	6.88	9.56	9.42	9.73
NOCA	North Cascades NP	WA	NOCA1	6.88	9.56	9.42	9.73
WOLF	Wolf Island	GA	OKEF1	9.47	12.41	11.31	13.12
OKEF	Okefenokee	GA	OKEF1	9.47	12.41	11.31	13.12
OLYM	Olympic NP	WA	OLYM1	6.88	9.61	9.61	11.63
PASA	Pasayten Wilderness	WA	PASA1	5.97	8.59	8.55	9.90
PEFO	Petrified Forest NP	AZ	PEFO1	4.21	6.52	5.61	6.79

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VENT	Ventana Wilderness	CA	PINN1	6.96	9.45	9.45	11.44
PINN	Pinnacles NM	CA	PINN1	6.96	9.45	9.45	11.44
RAFA	San Rafael Wilderness	CA	RAFA1	6.81	9.40	9.27	12.31
REDW	Redwood NP	CA	REDW1	8.54	10.13	10.13	12.81
ROMA	Cape Romain	SC	ROMA1	9.79	11.89	9.29	12.40
ROMO	Rocky Mountain NP	CO	ROMO1	4.93	6.87	4.32	6.95
SACR	Salt Creek	NM	SACR1	5.50	9.69	6.88	10.14
CUCA	Cucamonga Wilderness	CA	SAGA1	6.12	8.69	7.96	9.37
SAGA	San Gabriel Wilderness	CA	SAGA1	6.12	8.69	7.96	9.37
SAJA	San Jacinto Wilderness	CA	SAGO1	6.19	9.13	8.56	9.23
SAGO	San Gorgonio Wilderness	CA	SAGO1	6.19	9.13	8.56	9.23
SAGU	Saguaro NM	AZ	SAGU1	5.16	7.75	6.26	7.77
SAMA	St. Marks	FL	SAMA1	9.16	11.49	10.63	12.07
SAPE	San Pedro Parks Wilderness	NM	SAPE1	3.36	5.61	2.82	5.65
SAWT	Sawtooth Wilderness	ID	SAWT1	4.67	6.41	5.56	7.89
SENE	Seney	MI	SENE1	11.11	14.07	9.50	14.53
KICA	Kings Canyon NP	CA	SEQU1	6.28	11.26	9.06	14.70

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SEQU	Sequoia NP	CA	SEQU1	6.28	11.26	9.06	14.70
SHEN	Shenandoah NP	VA	SHEN1	9.52	11.19	8.21	11.41
SHRO	Shining Rock Wilderness	NC	SHRO1	10.22	11.78	9.20	12.04
SIPS	Sipsey Wilderness	AL	SIPS1	9.55	11.35	10.60	12.78
ALLA	Alpine Lake Wilderness	WA	SNPA1	7.25	10.12	10.12	10.81
EACA	Eagle Cap Wilderness	OR	STAR1	6.59	9.94	8.29	10.45
STMO	Strawberry Mountain Wilderness	OR	STAR1	6.59	9.94	8.29	10.45
ANAC	Anaconda-Pintler Wilderness	MT	SULA1	5.48	7.58	7.50	8.16
SELW	Selway-Bitterroot Wilderness	MT	SULA1	5.48	7.58	7.50	8.16
SWAN	Swanquarter	NC	SWAN1	9.65	11.44	9.64	11.79
SYCA2	Sycamore Canyon Wilderness	AZ	SYCA2	4.68	7.15	6.58	10.45
THRO	Theodore Roosevelt NP	ND	THRO1	5.95	10.56	8.06	10.76
MOJE	Mount Jefferson Wilderness	OR	THSI1	7.30	9.86	9.86	13.53

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MOWA	Mount Washington Wilderness	OR	THSI1	7.30	9.86	9.86	13.53
THIS	Three Sisters Wilderness	OR	THSI1	7.30	9.86	9.86	13.53
SUPE	Superstition Wilderness	AZ	TONT1	5.09	7.83	6.91	8.44
ULBE	UL Bend	MT	ULBE1	5.87	11.79	8.14	11.89
UPBU	Upper Buffalo Wilderness	AR	UPBU1	9.43	11.84	11.57	12.91
VOYA	Voyageurs NP	MN	VOYA2	9.33	12.49	8.39	12.69
BLCA	Black Canyon of the Gunnison NM	CO	WEMI1	3.98	5.96	4.19	6.03
LAGA	La Garita Wilderness	CO	WEMI1	3.98	5.96	4.19	6.03
WEMI	Weminuche Wilderness	CO	WEMI1	3.98	5.96	4.19	6.03
WHIT	White Mountain Wilderness	NM	WHIT1	4.89	8.53	5.01	8.69
WHPA	Mount Adams Wilderness	WA	WHPA1	6.15	8.56	7.58	10.78
GORO	Goat Rocks Wilderness	WA	WHPA1	6.15	8.56	7.58	10.78
EANE	Eagles Nest Wilderness	CO	WHRI1	3.02	5.08	3.36	5.12
FLTO	Flat Tops Wilderness	CO	WHRI1	3.02	5.08	3.36	5.12

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WEEL	West Elk Wilderness	CO	WHRI1	3.02	5.08	3.36	5.12
MABE	Maroon Bells-Snowmass Wilderness	CO	WHRI1	3.02	5.08	3.36	5.12
WICA	Wind Cave NP	SD	WICA1	5.64	8.38	7.23	9.03
WIMO	Wichita Mountains	OK	WIMO1	6.92	10.19	8.33	11.27
GRTE	Grand Teton NP	WY	YELL2	3.98	5.83	5.83	6.99
REDR	Red Rock Lakes	WY	YELL2	3.98	5.83	5.83	6.99
TETO	Teton Wilderness	WY	YELL2	3.98	5.83	5.83	6.99
YELL	Yellowstone NP	WY	YELL2	3.98	5.83	5.83	6.99
EMIG	Emigrant Wilderness	CA	YOSE1	6.29	9.07	8.13	10.77
YOSE	Yosemite NP	CA	YOSE1	6.29	9.07	8.13	10.77
ZION2	Zion NP	UT	ZICA1	5.08	7.23	6.04	7.41