RAMBOLL

ENVIRONMENT
& HEALTH

RUN SPECIFICATION SHEET

Weighted Emissions Potential (WEP) and Area of Influence (AOI) Analyses for Alaska and Hawaii

WRAP 2014 Modeling Study
May 18, 2020

Run Name:	**Weighted Emissions Potential/Area of Influence: (1) Alaska; and (2) Hawaii**
Model:	HYSPLIT
Domains:	EPA 2016 27 km CMAQ Modeling Domains for Alaska and Hawaii
Period:	2014 – 2018 IMPROVE MID Data
Emissions:	EPA 2016 Alaska and Hawaii Emissions Potentially Point Source Emissions from Each State
Boundary Conditions:	NA
Source Apportionment:	NA
Purpose:	Conduct Residence Time (RT) Area of Influence (AOI) and EWRT analysis using HYSPLIT back trajectories to regional haze IMPROVE monitoring sites on Most Impaired Days (MID). RT/AOI analysis is overlaid with gridded emissions and point source emissions to obtain Weighted Emissions Potential (WEP) that rank source regions and point sources for probability of contributing to visibility impairment at Class I Areas on the MID.

OVERVIEW

HYSPLIT[1] v4 for Linux (revision 805) will be run in back trajectory mode to arrive at IMPROVE sites that represent Class I Areas (CIA) in Alaska and Hawaii on the Most Impaired Days (MID) during the 2014-2018 5-year period. The Residence Time (RT) of the CIA MID back trajectories will be calculated for the grid cells of EPA's Alaska and Hawaii 27-km resolution modeling domains (see Figures 1 and 2 at the end of this document). The RT analysis provides an Area of Influence (AOI) or frequency of occurrence that back trajectories that passed over a grid cell and arrived at the CIA on the MID. The RT analysis will be extended to Extinction Weighted Residence (EWRT) analysis by weighting the HYSPLIT back trajectories by the daily extinction during the MID at the CIA for specific species. The Weighted Emissions Potential (WEP) is then obtained for each CIA and visibility precursor by overlaying the gridded emissions by source sector on the EWRT to obtain the relative probability that sources of the visibility precursor in a grid cell contributed to extinction at the specified CIA on the MID. Major point source facility emissions will also be overlaid with the EWRT for a CIA to obtain a tabular relative ranking of the facility's visibility precursor emissions potential to contribute to visibility impairment at the CIA for the MID.

[1] https://www.ready.noaa.gov/HYSPLIT.php

WEP/AOI ANALYSIS

IMPROVE Data

The MID (i.e. impairment group90) from IMPROVE observations for the 5-year period of 2014-2018 will be used in the AOI/WEP analysis for most IMPROVE sites. All IMPROVE sites representing CIAs in Alaska and Hawaii will be included in the analysis (e.g., IMPROVE protocol sites will not be used). The Bering Sea Wilderness Area of in Alaska does not have an IMPROVE site and will not be included in the analysis.[2] This results in back trajectories being calculated for 7 IMPROVE sites representing 5 Class I Areas in Alaska and Hawaii:

Alaska IMPROVE Sites (5)

- Denali National Park and Preserve (Denali NP): The IMPROVE sites at both Denali Headquarters (DENA1) and Trapper Creek (TRCR1) have been used to assess visibility for Denali NP in Alaska Regional Haze progress reports.[3] Both will be included in the WEP/AOI analysis. Both sites have a complete data record for the 5-year period of analysis (2014-2018).
- Simeonof Wilderness Area: The Simeonof IMPROVE site (SIME1) will be used and has a complete data record for the 5-year period of analysis.
- Tuxedni National Wildlife Refuge: The Tuxedni IMPROVE site was moved during the 2014-2018 5-year period. For 2014 and earlier years, IMPROVE data are available for the TUXE1 site that was moved across the inlet in 2015 so for 2016 and later years IMPROVE data are available from the Kenai Peninsula Borough IMPROVE site (KPBO1), there is no data for 2015. Back trajectories will be calculated for both sites using 3-uyears pf data; for the TUXE1 site for the years 2012-2014 and for the 2016-2018 years for the KPBO1 site.

Hawaii IMPROVE Sites (2)

- Haleakala National Park: The Haleakala Crater IMPROVE site (HACR1) will be used and has a complete data record for the 2014-2018 5-year period of analysis
- Hawaii Volcanoes National Park: The Hawaii Volcanoes IMPROVE site (HAVO1) will be used. This site has insufficient data for 2018, so the analysis will be based on 4-years of back trajectory data for the MID (2014–2017)

The current Regional Haze tracking metric and associated IMPROVE datasets (dated December 2019) that represents recent updates including patching and filling for the 1988-2018 period will be used to define the MID for each CIA IMPROVE site. These data were download from the IMPROVE RHR Summary Data website[4] on January 10, 2020 and verified it had the same MID and concentrations/extinction as on the current WRAP TSS[5] and Fed[6] websites.

[2] https://dec.alaska.gov/air/air-monitoring/improve-network

[3] https://www.federalregister.gov/documents/2018/02/16/2018-03269/approval-and-promulgation-of-state-implementation-plans-alaska-regional-haze-progress-report

[4] http://vista.cira.colostate.edu/Improve/rhr-summary-data/

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

[6] http://views.cira.colostate.edu/fed/QueryWizard/Default.aspx

HYSPLIT Back Trajectory Modeling

HYSPLIT v4 for Linux (revision 805) will be used to calculate back trajectories to arrive at the CIA IMPROVE sites on the MID during 2014-2018, or for the 3-years of data for the TUXE1 (2012-2014) and KPBO1 (2016-2018) sites and 4 years of available data (2014-2017) for the HAVO1 IMPROVE sites. The HYSPLIT model will be used to simulate 72-hour (3-day) back trajectories arriving at each of the IMPROVE sites on the MID at four times a day local standard time (LST):

- 06:00
- 12:00
- 18:00
- 24:00

The back trajectories will be calculated to arrive at the IMPROVE sites on the MID at four different heights above ground level (AGL):

- 100 m
- 200 m
- 500 m
- 1,000 m

Thus, for each MID at an IMPROVE site, 16 back trajectories will be calculated to characterize the frequency of occurrence of emissions in upwind grid cells arriving at the IMROVE site on the MID. With a complete year-long data record, there would be 24 MID a year. This results in up over 10,000 back trajectories to be calculated in the WEP/AOI analysis.

Area of Influence (AOI) Residence Time Analysis

A gridded field of AOI Residence Time (RT) will be generated for the MIDs at each IMPROVE site representing a CIA. The AOI RT is the cumulative time that trajectories reside in a specific geographical area and provides an estimate of the amount of time an air parcel resides over a particular region. We calculate the AOI RT by counting the number of 10-minute back trajectory time-step endpoints over each grid cell for the 27-km domains and then normalize the AOI RT to display percentage of total trajectories time:

$$\tau_{ij} = \left(\frac{1}{N} \sum_{k=1}^{N} \frac{\tau_{ijk}}{T_k} \right) \times 100$$

where τ_{ijk} is the count of the k^{th} trajectory in the grid cell (i, j), N is the total number of trajectories, and T_k is the total number of trajectory time steps for the k^{th} trajectory (i.e. 72 hours @ 10 minute increments in this analysis if the trajectory remains within the 27 km domain). A gridded field of AOI residence time will be generated using a grid resolution of 27-km.

The gridded field of AOI RT for each IMPROVE monitor will be aggregated over all five years (or four or three years in some cases), all MIDs and all four starting hours for each MID. They will be generated for each of the four different heights AGL and combined for all four heights and generated for the two grid resolutions mentioned above. This results in up to 60 AOI RT analyses. (60 = 6 x (4+1) x 2).

Extinction-Weighted Residence Time (EWRT)

The EWRT is obtained by weighting the back trajectories AOI RT by the measured visibility impairment extinction by species on the MID for the trajectories IMPROVE end point site. The species-specific (e.g., sulfate extinction) EWRT can be combined with the visibility precursor emissions from sources (e.g., SO_2) to rank the source's potential for contributing to visibility impairment for that species on the MID at a CIA.

$$EWRT_{ij} = \sum_{k=1}^{N} b_{ext_k} \tau_{ijk}$$

where b_{ext_k} is the extinction coefficient attributed to the pollutant (e.g., SO_4 or NO_3) measured upon arrival of the k^{th} trajectory at the IMPROVE site. The gridded EWRT values are normalized to display the percentage of the domain total EWRT.

Separate gridded EWRT will be generated for several species using the second IMPROVE reconstructed mass extinction equation as follows:

- Sulfate (as ammonium sulfate extinction)
- Nitrate (as ammonium nitrate extinction)
- Organic Carbon (as organic aerosol extinction)
- Elemental Carbon

At this time we do not see any benefits for estimating EWRT for the other components of extinction as they are either all natural (e.g., sea salt) or have a large natural component (e.g., Soil and Coarse Mass) so would not be subject to emission controls.

Using the same trajectory aggregation procedures as for the AOI RT analyses will result in 240 EWRT analyses (60 x 4).

Weighted Emissions Potential (WEP)

The overlay of the gridded emission sources with the gridded EWRT generates the WEP that provides a relative ranking of the potential for emissions in a given grid cell to contribute to visibility impairment at the selected IMPROVE site (CIA) for the MID. The sulfate EWRT will overlay with the gridded SO_2 emissions for all sources and for each source sector (e.g., EGU, non-EGU Point, on-road mobile, etc.) as well as all anthropogenic emissions. Similarly, for nitrate EWRT and NO_X emissions, OA EWRT and primary organic aerosol (POA emissions), and EC EWRT and EC emissions. The species-specific EWRT will also be used with tabular emissions from major facilities to rank their relative potential for contributing to visibility impairment at a CIA on the MID. The gridded and point source emissions will be obtained from EPA who have developed 2016 CMAQ modeling platforms for Alaska and Hawaii (see domains in Figures 1 and 2). Point source emissions for the WEP may also be obtained from the states.

To incorporate the effects of dispersion, deposition and chemical transformation along the path of the trajectories, emissions are inversely weighted by the distance (d) between the centers of the grid cell emitting the emissions and the grid cell containing the IMPROVE site. Each grid cell has a horizontal resolution of 27 km x 27 km. In the case that the monitoring grid cell also contains emissions (i.e., d is zero), we set the distance to half of the grid cell size (i.e., 13.5 km).

$$\frac{Q_{ij}}{d_{ij}} EWRT_{ij}$$

Tabular summaries of point source WEP will also be generated for each IMPROVE CIA and species.

Visualization of WEP/AOI Analysis

Ramboll will generate spatial map displays of the WEP/AOI analysis for each of the 7 IMPROVE sites representing CIAs in Alaska and Hawaii.

DATA TRANSFER AND DISPLAYS ON THE WRAP TSS

The WEP/AOI plots and data will be transferred to the WRAP Technical Support System (TSS) for visualization. All of the gridded AOI and EWRT and gridded emissions data will be transferred to the WRAP TSS website for visualization and download. Graphical displays of the RT and EWRT analyses for each of IMPROVE site representing Class I Areas in Alaska and Hawaii at all 5 different back trajectory heights. The gridded pre-merged emissions source categories for NO_X, SO_2, OA and EC visibility precursor will be overlaid with the corresponding EWRT visibility impairment (i.e., NO3, SO4, OA and EC) to identify the 27-km grid cell locations that have the most potential to contribute to the selected Class I area on the IMPROVE MID during 2014-2018.

A file of emissions from individual point source facilities will also be overlaid with the EWRT to rank the NO_X, SO_2, OA and EC point sources that most likely contribute to visibility impairment at the IMPROVE site for the 2014-2018 MID. Multiple versions of the point source emissions WEP analysis may be generated using emissions from the states' data and/or EPA's 2016 base year modeling platform.

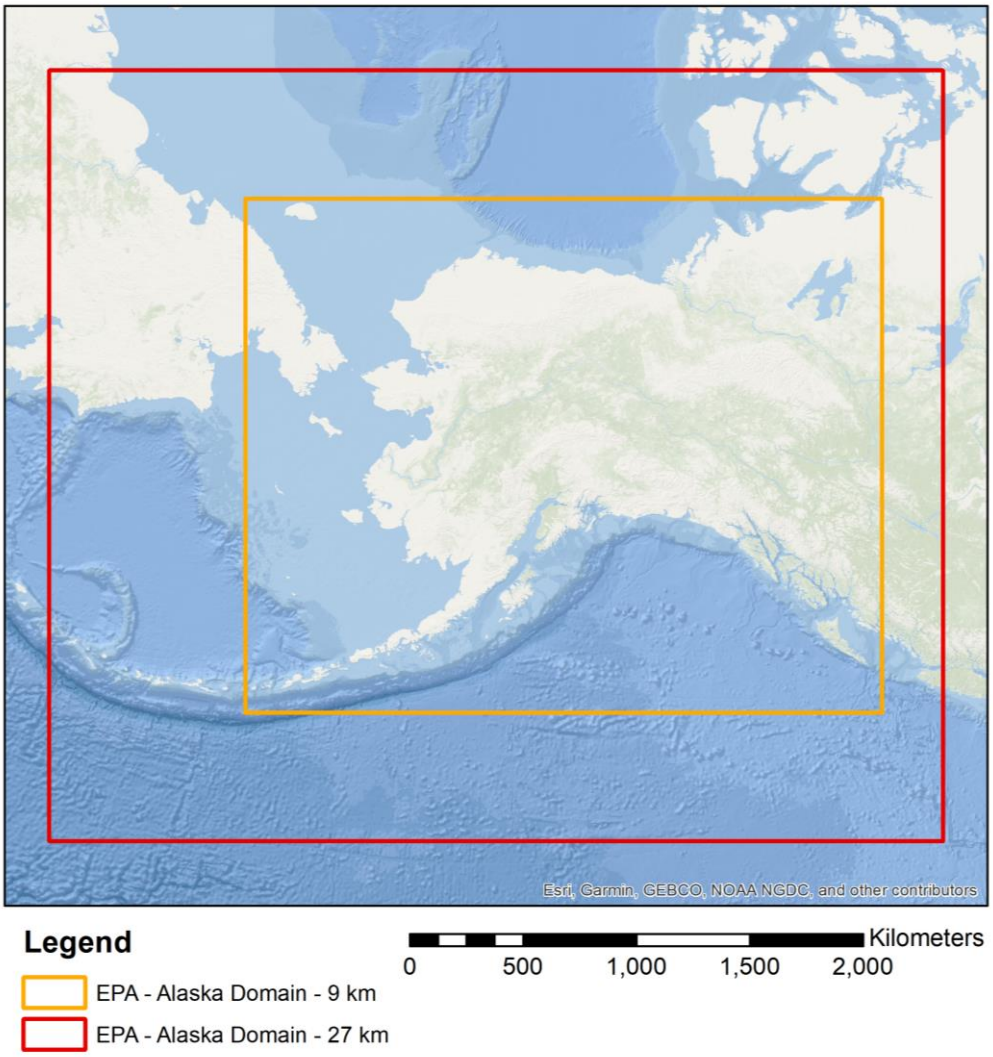

Figure 1. EPA's Alaska 27/9-km CMAQ modeling domains.

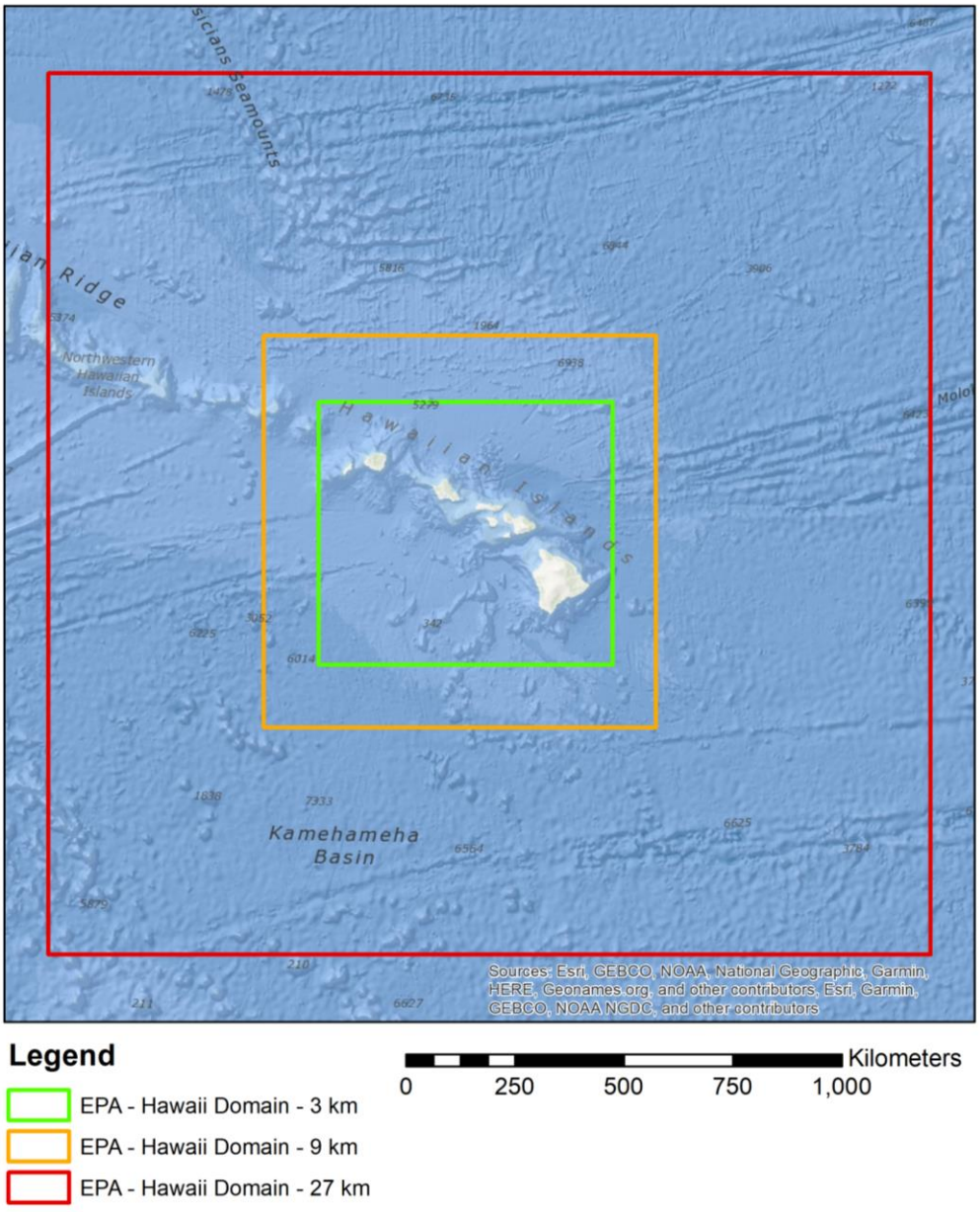

Figure 2. EPA's Hawaii 27/9/3-km CMAQ modeling domains.