SMOKE Emissions Processing

Utah Division of Air Quality

June 10, 2020

Introduction

Utah DAQ used the SMOKE v4.7emissions processing software to prepare inventoried emissions for air quality modeling. SMOKE (Sparse Matrix Operator Kernel Emissions)[1] is a state-of-the-art emissions model whose purpose is to distribute inventoried pollutants in time and space. SMOKE also speciates volatile organic carbon (VOC) and particulate matter (PM) estimates.

Inputs for SMOKE consist of inventory data in the form of county-wide criteria pollutant (CAP) totals (NO_x, VOC, direct $PM_{2.5}$, and CO). Inventory data exists for four (five) distinct sectors: area, nonroad, mobile, biogenics, and point.

The area, nonroad, and mobile emissions inventories consist of pollutants summarized by county and EPA Source Classification Code (SCC). An SCC is an eight-to-ten digit number that identifies the process or technology that directly emitted the associated pollutants.

Biogenic sources are run through BEIS v3.61 model in SMOKE, which uses landcover and meteorological data to determine the emissions rates of different plant-based landcover types during modelling episodes.

Point sources encompass large emitters such as oil refineries, power plants, and big mining operations. Inventory input is comprised of pollutants totaled for each component of a facility (e.g., electric generators, storage tanks, etc.). Additionally, oil and gas sources in the Uintah basin were processed as point sources in order to more accurately reflect the geospatial distribution of each equipment type. Point source oil and gas emissions were based off of the state of Utah's oil and gas emission inventory. Point source emissions are placed at precise locations using latitude/ longitude coordinates.

Other inputs for SMOKE include spatial, temporal, and speciation profiles. A profile is assigned to an individual source in the inventory by linking its SCC to a profile code. These references are important for correctly characterizing the time, space, and VOC/PM composition for a given emissions source.

Modeling Domain

UDAQ used a single modeling domain that is 4 km resolution and covers the State of Utah and portions of surrounding states. A vertical resolution of 42 layers is used, matching the WRF inputs (no layer collapsing).

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

Mobile

Utah DAQ worked with the metropolitan planning organizations (MPO's) that serve those counties included (even partially) in the two 8-hr ozone nonattainment areas. Mobile emissions were calculated and projected using the MOVES 2014b model, which were then input into SMOKE as precomputed mobile inventory numbers.

Spatial Allocation

For spatial processing, SMOKE requires text files that describe relevant geographical information as a function of normalized grid-cell values. Within each county in the modeling domain, these normalized grid-cell values sum up to one. Arc GIS software was used for translating various geographical data-sets to the required text format used by SMOKE.

Population density at gridded 4 km resolution was developed using three separate data sets. For counties in the 8- hr ozone nonattainment counties, population by traffic analysis zone is provided by the appropriate metropolitan planning organizations (MPO's). The MPO's and the counties for which they are responsible for (in parenthesis) are: Wasatch Front Regional Council (Salt Lake, Weber, Davis, Box Elder, and Tooele), and Mountainland Association of Governments (Utah). The remaining counties in the domain relied on 2010 Census population block groups.

Population by traffic analysis zone is very high-resolution data, especially in densely populated areas. The data is first converted to densities at 25-meter resolution to capture the fine scale boundaries of the traffic analysis zones. It is then aggregated to a four-kilometer resolution to create the population surrogates. The same process was applied to 2010 Census block groups for outlying counties.

Finally, all three data sets are combined into one gridded population data set for the entire modeling domain.

Mobile source emissions data is distributed to the modeling grid using a combination of link-based data and county totals. The data based on county-wide vehicle miles traveled (VMT) is distributed using population density as a surrogate. As with the population data, the VMT distribution is based on several different data sources. The MPO's provided link-based data for VMT on arterial roads and freeways for the five Wasatch Front counties. UDOT provided link based VMT for state roads and interstates in the outlying counties as well as estimates of VMT driven on local roads.

Because link based VMT does not exist for VMT on local roadways, the distribution of local VMT was created by the use of population surrogates. This was done for all counties in the modeling domain. Spatial surrogates for urban, forest, and water areas were developed using U.S. Geological Survey (USGS) land use and land cover data. The following table (Table 2) provides a full list of the spatial surrogates used for emissions allocation:

Profile Code	Profile Description
20	Interstate Highways
40	Arterial Roads
50	Population
110	Housing
150	Residential Heating - Natural Gas
160	Residential Heating - Wood
200	Urban Primary Road Miles
260	Total Railroad Miles
310	Total Agriculture
340	Land
400	Rural Land Area
500	Commercial Land
501	Commercial Property Point
505	Industrial Land
510	Commercial plus Industrial
515	Commercial plus Institutional Land
535	Residential + Commercial + Industrial + Institutional + Government
692	Oil and Gas Spud Count
700	Airport Areas
861	Construction and Mining

Table 2: List of spatial surrogates used for the spatial allocation of emissions in SMOKE.

For area and nonroad sources where spatial surrogate assignments were unobtainable, *Population* was used as the spatial surrogate. In other words, *Population* was used as the default spatial surrogate for area and nonroad sources. Mobile sources were fully specified in terms of spatial surrogate assignment.

Temporal Allocation

Temporal profiles are meant to characterize large-scale emissions behavior over time. Emissions were distributed in time according to temporal profiles and source assignments gathered from the EPA's 2016v1 modelling platform. In the few instances where temporal profiles didn't exist in the 2016v1 modeling platform for a given SCC, temporal profile assignments were assigned based on SCC description.

Temporal allocation in SMOKE consists of defining emissions distribution across three time-domains:

1. Monthly
2. Weekly
3. Hourly ("ALLDAY")

Monthly profiles determine how emissions are distributed month-to-month. For example, lawnmower emissions in winter months are small. However, snow blower emissions during that same period are relatively large. Next, weekly profiles determine how emissions are distributed day-

to-day during a week. Emissions are often different between weekday and weekend days for example. Finally, hourly (ALLDAY) profiles determine the hour-by-hour behavior of emissions sources for a given day.

Speciation

Inventoried VOC estimates were converted to total organic gas (TOG) and then speciated according to source-specific TOG profiles. Speciation profiles and their associated SCC assignments generally came from EPA's 2016v1 modeling platform. When a source assignment wasn't found in the 2016v1 modeling platform, assignments were either based on SMOKE defaults or inferred from the source's SCC description. VOC emissions were speciated for use with the CB6r2h photochemical mechanism. PM was speciated for use with the AERO6 aerosol module. Speciation profiles for some oil and gas activities were constructed using data collected from actual sites in the Uintah Basin in order to more accurately represent this unique geological formation.

SMOKE Output Summary

The new implementation rule requires that emissions values shall be either annual total emissions, average-season-day emissions, or both, as appropriate for the relevant (8-hour) ozone NAAQS. Also, that the state shall include as part of the plan a rationale for providing annual or seasonal emissions, and the justification for the period used for any seasonal emissions calculations.

Utah's summertime ozone issues are characterized as a seasonal problem during the warmer months when meteorological conditions cause the local airmass to stagnate and accumulate pollutants. Combined with the direct sunlight, levels of ozone have been recorded to exceed the 8-hour ozone NAAQS mostly between May and late August. Thus, in addressing the problem through quantitative SIP analyses, emissions inventories have historically been adjusted to reflect this seasonality.

"Average-season-day emissions" are defined, in 40 CFR 51.1000, as the sum of all emissions during the applicable season divided by the number of days in that season. Again, Utah's inventory is compiled using a variety of different averaging periods, and is then gridded into the air model along with an hourly temporal component for each 24 hour period.

Emissions are extracted from SMOKE and reported in time averaged units of "tons-per-day". Each projection of the emissions inventory is modeled with meteorology reflecting the actual episode used to validate the air quality model.

For the marginal summertime Wasatch front inventory only Wednesday, July 12, 2017 is used as a representative summer day. Thus to report the inventory, emissions are calculated as the 24-hour average for this period. The Emissions Inventory (EI) submittal also includes the original calculations as part of the Technical Support Document (TSD).