



2020 National Emissions Inventory Technical Support Document: Biogenics -Vegetation and Soil

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2020 National Emissions Inventory Technical Support Document: Biogenics – Vegetation and
Soil

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Office of Air Quality Planning and Standards
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8 Biogenics -Vegetation and Soil

8.1 Biogenics Overview

Biogenic emissions are emissions that come from natural sources. They need to be accounted for in photochemical grid models, as most types are widespread and ubiquitous contributors to background air chemistry. In the NEI, only the emissions from vegetation and soils are included. Other relevant sources not included in the NEI are volcanic emissions (geogenic), lightning oxides of nitrogen (NOx), and sea salt. Biogenic emissions from vegetation and soils are computed using a model that utilizes spatial information on vegetation, land use and environmental conditions of temperature and solar radiation. The model inputs are typically horizontally allocated (gridded) data, and the outputs are gridded biogenic emissions, which can then be speciated and utilized as input to photochemical grid models.

In the 2020 NEI, biogenic emissions are included in the nonpoint data category, in the EIS sector “Biogenics – Vegetation and Soil.” Table 8-1 lists the two source classification codes (SCCs) used in the 2020 NEI that comprise this sector. The level 1 and 2 SCC description for both SCCs is “Natural Sources; Biogenic” and the full Tier 3 description for both SCCs is “Natural Resources; Biogenic; Vegetation”. These two SCCs have distinct pollutants: SCC 2701220000 has only NOX emissions, and SCC 2701200000 has emissions for carbon monoxide (CO), volatile organic compounds (VOC) and three VOC hazardous air pollutants (HAPs): formaldehyde, acetaldehyde, and methanol. Note that there is a fertilizer adjustment for some of the soils during the growing season in the SCC 2701220000.

Table 8-1: SCCs for biogenic sources

SCC	SCC Level 3	SCC Level 4
2701200000	Vegetation	Total
2701220000	Vegetation/Agriculture	Total

8.2 Sources of data

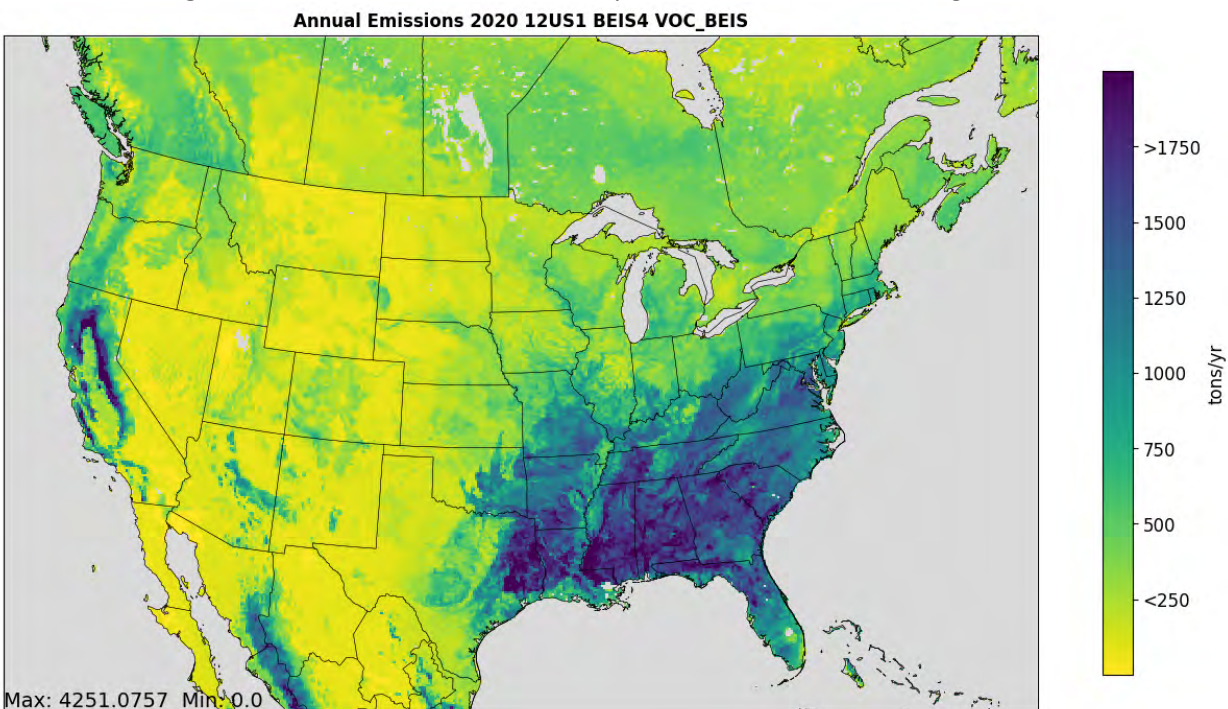
To be consistent across all geographic areas and with our emissions modeling platform, for the 2020 NEI, we tagged out all SLT-submitted biogenics data to ensure EPA estimates were used everywhere.

8.3 EPA-developed estimates

8.3.1 Continental U.S.

The biogenic emissions for the 2020 National Emissions Inventory (NEI) were computed based on 2020 meteorology data from the Weather Research and Forecasting (WRF) model version 3.8 (WRFv3.8) and using the Biogenic Emission Inventory System, version 4 (BEIS4) model within the [Sparse Matrix Operator Kernel Emissions \(SMOKE\) modeling system version 4.9](#). The BEIS4 model creates gridded, hourly, model-species emissions from vegetation and soils at 12-kilometer horizontal resolution. The 12-kilometer gridded hourly data are summed to monthly and annual level (see Figure 8-1) and are mapped from 12-kilometer grid cells to counties using a standard mapping file.

Figure 8-1: Annual VOC emissions for year 2020 for 12km modeling domain



BEIS produces biogenic emissions for a modeling domain which includes the contiguous 48 states in the U.S., parts of Mexico, and Canada. The NEI uses the biogenic emissions from counties from the contiguous 48 states and Washington, DC. The model-species are those associated with the Carbon Bond mechanism version 6 (CB6). The NEI pollutants produced are CO, VOC, NO_x, methanol, formaldehyde, and acetaldehyde. VOC is the sum of all biogenic species except CO and nitrogen oxide (NO). Mapping of BEIS species to NEI pollutants is as follows:

- NO maps to NO_x
- FORM maps to formaldehyde
- ALD2 maps to acetaldehyde
- MEOH maps to methanol
- VOC is the sum of all biogenic species except CO and NO

BEIS4 has some important updates from earlier versions of BEIS. These include the incorporation of Version 6 of the Biogenic Emissions Landuse Database (BELD6), the option to include seasonality of emissions using the 1-meter soil temperature (SOIT2) instead of the BIOSEASON file, and canopy temperature and radiation environments are now modeled using the driving meteorological model's (WRFv3.8) representation of LAI rather than the estimated LAI values just from BELD data. See [these CMAQ Release Notes](#) for more technical information on BEIS4.

BEIS4 includes a two-layer canopy model. Layer structure varies with light intensity and solar zenith angle. Both layers of the canopy model include estimates of sunlit and shaded leaf area based on solar zenith angle and light intensity, direct and diffuse solar radiation, and leaf temperature [ref 1]. The new algorithm requires additional meteorological variables over previous versions of BEIS. The meteorology input data fields used by BEIS are shown in Table 8-2.

Table 8-2: Meteorological variables required by BEIS 4

Variable	Description
LAI	leaf-area index
PRSFC	surface pressure
Q2	mixing ratio at 2 m
RC	convective precipitation per meteorological time step
RGRND	solar rad reaching surface
RN	non-convective precipitation per meteorological time step
RSTOMI	inverse of bulk stomatal resistance
SLYTP	soil texture type by USDA category
SOIM1	volumetric soil moisture in top cm
SOIT1	soil temperature in top cm
TEMPG	skin temperature at ground
USTAR	cell averaged friction velocity
RADYNI	inverse of aerodynamic resistance
TEMP2	temperature at 2 m
WSAT_PX	soil saturation from (Pleim-Xiu Land Surface Model) PX-LSM

The Biogenic Emissions Landcover Database version 6 (BELD6) was used as the input gridded land use information in generating 2020NEI estimates. BELD version 5 (BELD5) was used to generate 2017NEI estimates. The other input dataset change involved updating the dry leaf biomass (grams/m²) values for various vegetation types.

The BELD6 includes the following datasets:

- High resolution tree species and biomass data from Wilson et al. 2013a [ref 2], and Wilson et al. 2013b [ref 3] for which species names were changed from non-specific common names to scientific names
- Tree species biogenic volatile organic carbon (BVOC) emission factors for tree species were taken from the NCAR Enclosure database (Wiedinmyer, 2001)
 - <https://www.sciencedirect.com/science/article/pii/S1352231001004290>
- Agricultural land use from [US Department of Agriculture \(USDA\) crop data layer](#)
- Global Moderate Resolution Imaging Spectroradiometer (MODIS) 20 category data with enhanced lakes and Fraction of Photosynthetically Active Radiation (FPAR) for vegetation coverage from [National Center for Atmospheric Research \(NCAR\)](#)
- [Canadian BELD4 Landuse](#)

Bug fixes included in BEIS4 included the following:

- Solar radiation attenuation in the shaded portion of the canopy was using the direct beam photosynthetically active radiation (PAR) when the diffuse beam PAR attenuation coefficient should have been used.
 - This update had little impact on the total emissions but did result in slightly higher emissions in the morning and evening transition periods for isoprene, methanol and Methylbutenol (MBO).
- The fraction of solar radiation in the sunlit and shaded canopy layers, SOLSUN and SOLSHADE respectively were estimated using a planar surface. These should have been estimated based on the PAR intercepted by a hemispheric surface rather than a plane.

- This update can result in an earlier peak in leaf temperature, approximately up to an hour.
- The quantum yield for isoprene emissions (ALPHA) was updated to the mean value in [Niinemets et al. 2010a](#) and the integration coefficient (CL) was updated to yield 1 when PAR = 1000 following [Niinemets et al 2010b](#).
 - This updated resulted in a slight reduction in isoprene, methanol, and MBO emissions.

The SMOKE-BEIS4 modeling system consists of two programs named: 1) Normbeis4 and 2) Tmpbeis4. Normbeis4 uses emissions factors and BELD6 landuse and gridded biomass data to compute gridded normalized emissions for chosen model domain (see Figure 8-2). The BEIS4 emissions factor file (BEISFAC) contains leaf-area-indices (LAI), dry leaf biomass, winter biomass factor, indicator of specific leaf weight, Agricultural land type Yes/No (AG_YN), and normalized emission fluxes for 35 different species/compounds. The BELD6 file is the gridded landuse for 200+ different landuse types. The output gridded domain is the same as the input domain for the land use data. Output emission fluxes (BEIS_NORM_EMIS) are normalized to 30°C, and isoprene and methyl-butenol fluxes are also normalized to a photosynthetic active radiation of 1000 $\mu\text{mol}/\text{m}^2\text{s}$.

The normalized emissions output from Normbeis4 (BEIS_NORM_EMIS) are input into Tmpbeis4 along with the MCIP meteorological data, chemical speciation profile to use for desired chemical mechanism, and soil moisture data file. Figure 8-3 illustrates the data flows for the Tmpbeis4 program. The output from Tmpbeis includes gridded, speciated, hourly emissions both in moles/second (B4GTS_L) and tons/hour (B4GTS_S). Biogenic emissions do not use an emissions inventory and do not have SCCs. Please see the [SMOKEv4.9 User's Manual](#) for more information on BEIS4.

Figure 8-2: Normbeis4 data flows for 2020NEI

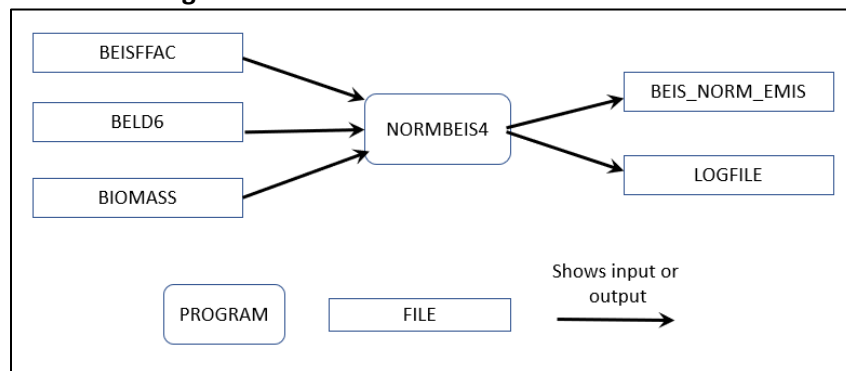
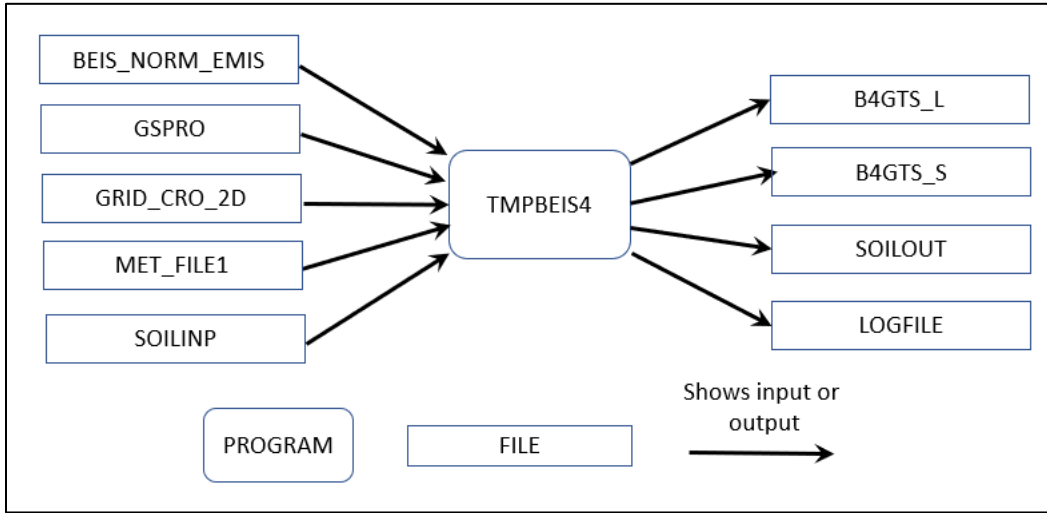


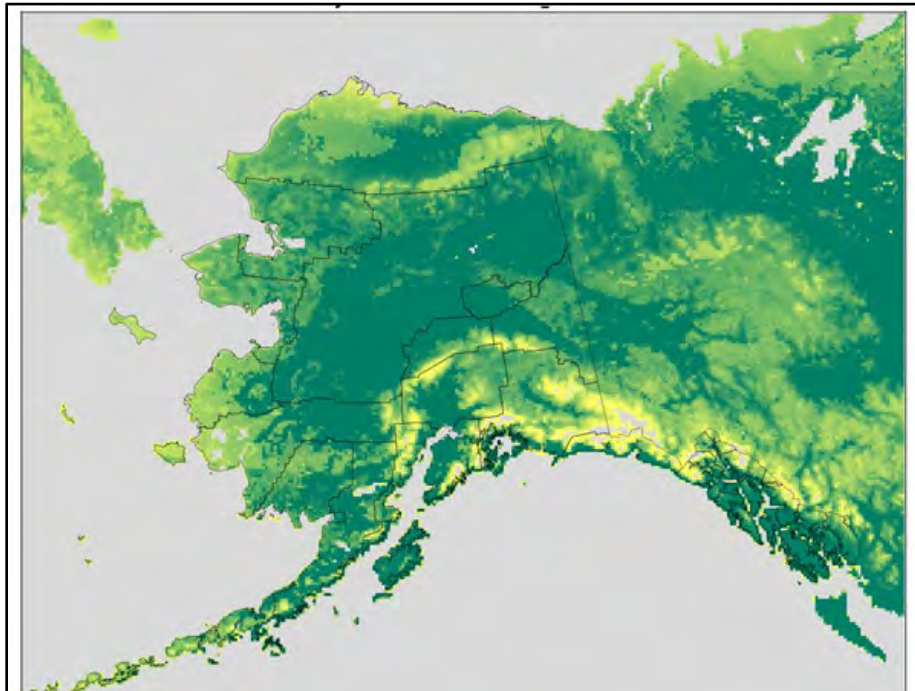
Figure 8-3: Tmpbeis4 data flow diagram for 2020NEI



8.3.2 Alaska, Hawaii, Puerto Rico, and Virgin Islands

The 2020NEI also include biogenic emissions estimates for counties in the states of Alaska and Hawaii, and for the territories of Puerto Rico and Virgin Islands. The BEIS3.61 modeling system and WRFv3.8 meteorology data for year 2020 were used to produce gridded biogenic emissions for 3 separate modeling domains at 9-km horizontal resolution. BELD6 data was not available for these modeling domains so BEIS4 was not used for these states/territories. The modeling domain for Alaska is shown in Figure 8-4. The land use data used for generating input data for BEIS3.61 included the MODIS 20 category dataset and the FIA version 8.0 used for estimating biomass input information.

Figure 8-4: Alaska 9-km modeling domain



The modeling domains for Hawaii, Puerto Rico and Virgin Islands are shown in Figure 8-5 and Figure 8-6, respectively. Both Puerto Rico and Virgin Islands territories are in the same 9-km modeling domain. The MODIS 20 category land use dataset was the only dataset used for land use/vegetation input into BEIS3.61.

Figure 8-5: Hawaii 9-km modeling domain

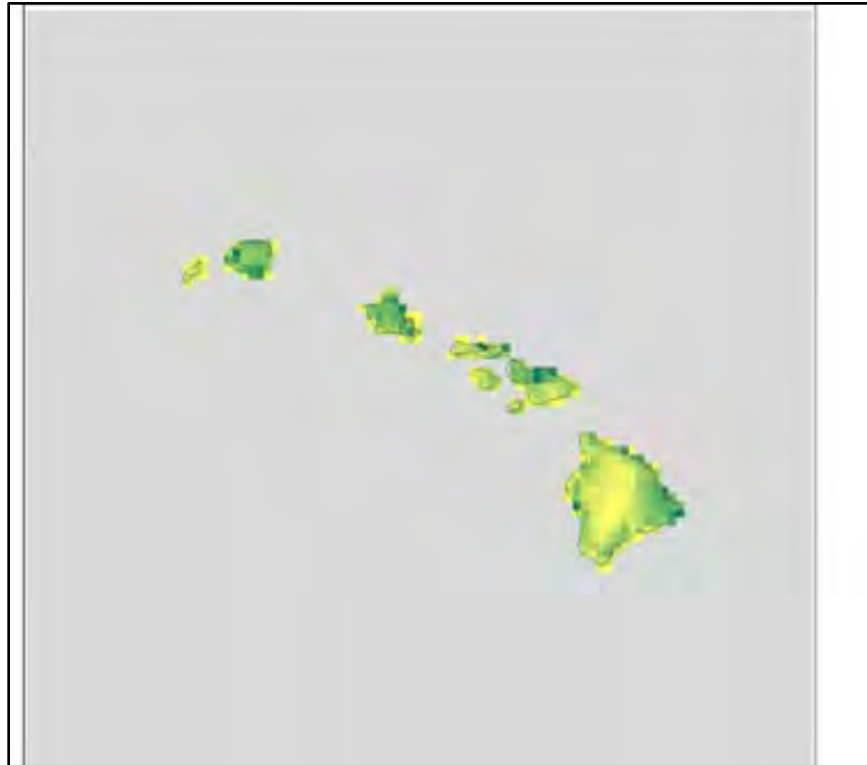
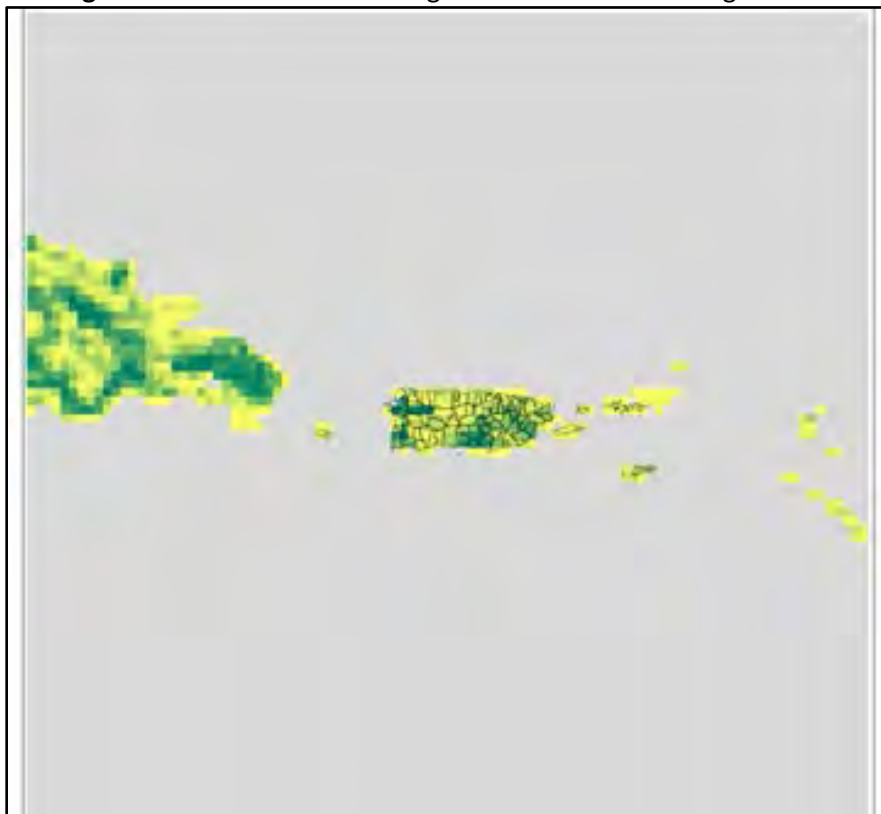


Figure 8-6: Puerto Rico and Virgin Islands 9-km modeling domain



The 9-kilometer gridded hourly data from these modeling domains are summed to monthly and annual level and are mapped from 9-kilometer grid cells to counties using a standard mapping file in a similar manner as was done for the contiguous 48 states. The mapping of BEIS species to NEI pollutants for these states and territories was also done in the same manner as the contiguous 48 states.

8.4 References for biogenics

1. Bash, J.O., Baker, K.R., Beaver, M.R., Park, J.-H., Goldstein, A.H., 2016. Evaluation of improved land use and canopy representation in BEIS with biogenic VOC measurements in California.
2. Wilson, Barry Tyler; Lister, Andrew J.; Riemann, Rachel I.; Griffith, Douglas M. 2013a. Live tree species basal area of the contiguous United States (2000-2009). Newtown Square, PA: USDA Forest Service, Rocky Mountain Research Station. <https://doi.org/10.2737/RDS-2013-0013>
3. Wilson, Barry Tyler; Woodall, Christopher W.; Griffith, Douglas M. 2013b. Forest carbon stocks of the contiguous United States (2000-2009). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. <https://doi.org/10.2737/RDS-2013-0004>

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