General requirements/recommendations of anthropogenic, biomass burning, and volcanic emissions for AeroCom Phase III model experiments

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For the currently proposed AeroCom Phase III model experiments, it is required to use the same prescribed anthropogenic, biomass burning, and volcanic emission datasets. This document lists the emission datasets, their accessibility, and general recommendations.

1. Anthropogenic emission

a) 1750-2014:
- Source: Community Emission Data System (CEDS) for CMIP6. Available at: https://esgf-node.llnl.gov/search/input4mips/
- Spatial resolution: 0.5° (finer resolution up to 0.1° can be generated on request)
- Temporal resolution: Monthly
- Data format: netcdf, with 50-years per data file
- Bulk emissions (BC, OC, SO_2, NO_x, NH_3, CO, NMVOC, CO_2, CH_4):
  - 8 sectors: sector_ids = "0: Agriculture; 1: Energy; 2: Industrial; 3: Transportation; 4: Residential, Commercial, Other; 5: Solvents production and application; 6: Waste; 7: International Shipping"
  - Filename: [em_species]-em-anthro_input4MIPs_emissions_CMIP_CEDS-2017-05-18_gn_YYYY01-ZZZZ12.nc (where YYYY is the starting year contained in this file, and ZZZZ is the ending year)
- Aircraft emissions (BC, OC, SO_2, NO_x, NH_3, CO, NMVOC, CO_2, CH_4):
  - 25 vertical layers
  - Filename: [em_species]-em-AIR-anthro_input4MIPs_emissions_CMIP_CEDS-2017-05-18_gn_YYYY01-ZZZZ12.nc
- Reference: Hoesly, R. M., Smith, S. J., Feng, L., Klimont, Z., Janssens-Maenhout, G., Pitkanen, T., Seibert, J. J., Vu, L., Andres, R. J., Bolt, R. M., Bond, T. C., Dawidowski, L., Kholod, N., Kurokawa, J.-I., Li, M., Liu, L., Lu, Z., Moura, M. C. P., O'Rourke, P. R., and Zhang, Q.: Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS), Geosci. Model Dev., 11, 369-408, https://doi.org/10.5194/gmd-11-369-2018, 2018.

b) after 2014:
- CEDS emission for 2015-2017 is expected to be available in the near-term (per Steve Smith, PNNL). Please check the data availability soon. Otherwise, the recommendation is to extend the emissions in the latest year to the years beyond.

Figure 1 shows the anthropogenic emission of CO, SO_2, BC, OC, NH_3, NO_x, and NMVOC in 2010 from the CEDS emission dataset.

cmip6_em-anthro_so2_glb_2010 (mg/m2/s) total=113.89 Tg/yr

cmip6_em-anthro_co_glb_2010 (mg/m2/s) total=617.23 Tg/yr

cmip6_em-anthro_nox_glb_2010 (mg/m2/s) total=137.85 Tg/yr

cmip6_em-anthro_oc_glb_2010 (mg/m2/s) total=18.78 Tg/yr

cmip6_em-anthro_nh3_glb_2010 (mg/m2/s) total=58.45 Tg/yr

cmip6_em-anthro_bc_glb_2010 (mg/m2/s) total=7.76 Tg/yr

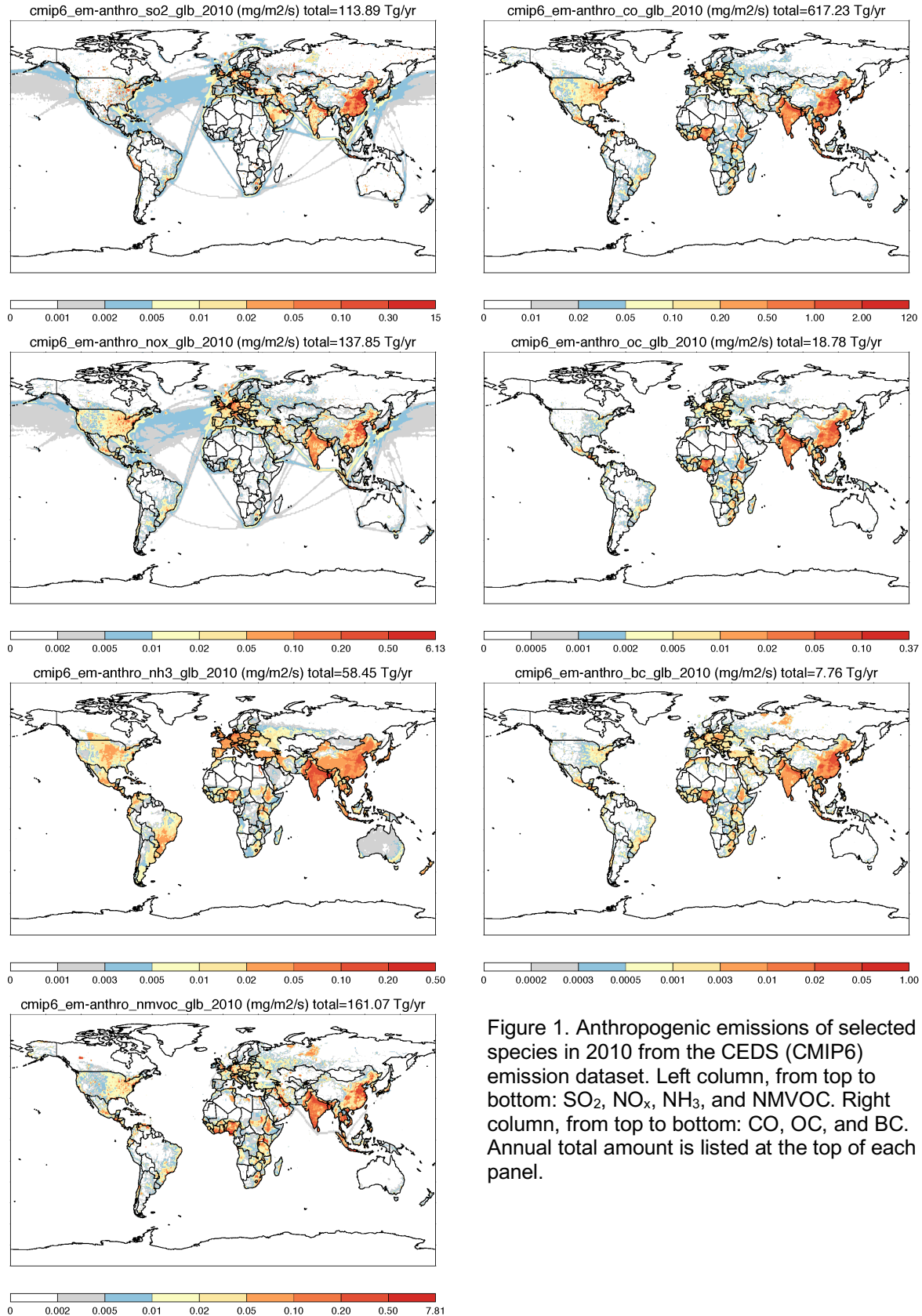cmip6_em-anthro_nmvoc_glb_2010 (mg/m2/s) total=161.07 Tg/yr

Figure 1. Anthropogenic emissions of selected species in 2010 from the CEDS (CMIP6) emission dataset. Left column, from top to bottom: SO_2, NO_x, NH_3, and NMVOC. Right column, from top to bottom: CO, OC, and BC. Annual total amount is listed at the top of each panel.

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2. Biomass burning emission

a) 1850-2015:
- Source: BB for CMIP6. Available at: https://esgf-node.llnl.gov/search/input4mips/
- Spatial resolution: 0.25° x 0.25°
- Temporal resolution: Monthly
- Emitted species: aerosol (BC, OC) and aerosol precursor and reactive compounds (SO_2, N_2O, NO_x, NH_3, CH_4, CO, NMVOC, H_2)
- NMVOC consists of the sum of: C_2H_6, CH_3OH, C_2H_5OH, C_3H_8, C_2H_2, C_2H_4, C_3H_6, C_5H_8, $C_{10}H_{16}$, C_7H_8, C_6H_6, C_8H_{10}, Toluene_lump, Higher_Alkenes, Higher_Alkanes, CH_2O, C_2H_4O, C_3H_6O, C_2H_6S, HCN, HCOOH, CH_3COOH, MEK, CH_3COCHO, $HOCH_2CHO$. These NMVOCs are also provided separately
- Data format: netcdf, 185001-201512 in a data file
- Filename: [em_species]-em-biomassburning_input4MIPs_emissions_CMIP_V-2017-05-18_gn_YYYY01-ZZZZ12.nc (where YYYY is the starting year contained in this file, and ZZZZ is the ending year)
- Reference: van Marle, M. J. E., Kloster, S., Magi, B. I., Marlon, J. R., Daniau, A.-L., Field, R. D., Arneth, A., Forrest, M., Hantson, S., Kehrwald, N. M., Knorr, W., Lasslop, G., Li, F., Mangeon, S., Yue, C., Kaiser, J. W., and van der Werf, G. R.: Historic global biomass burning emissions for CMIP6 (BB4CMIP) based on merging satellite observations with proxies and fire models (1750–2015), Geosci. Model Dev., 10, 3329-3357, https://doi.org/10.5194/gmd-10-3329-2017, 2017

b) 2016 – 2018:
- Recommended: Global Fire Emission Dataset Version 4.1s (GFED4.1s), 2016-2018. This is because CMIP6 biomass burning emission from 1997 to 2015 is based on GFED4, so using GFED4.1s provides consistency for simulations beyond 2015.
  - Source: https://www.geo.vu.nl/~gwerf/GFED/GFED4/. Please read the Readme.pdf for detailed information
  - Spatial resolution: 0.25° x 0.25°
  - Temporal resolution: Monthly and daily with estimated diurnal cycles
  - Data format: hdf5
  - Note: 2017 and 2018 emissions are currently labeled as "beta" version, which is extended based relationships between MODIS active fire and GFED4s emissions for 2003-2016. (The beta version will be renamed as "extended".)
  - Reference: van der Werf et al., Earth Syst. Sci. Data, 9, 697–720, https://doi.org/10.5194/essd-9-697-2017, 2017

c) Additional/alternative biomass burning emission dataset: Fire Energetics and Emissions Research (FEER) (2003-current (2019)):
- FEER is a "top down" biomass burning emission dataset based on the MODIS fire radiative power. The daily emissions of aerosols and tracer gases are produced near real time. Because the biomass burning emissions from FEER is much higher than GFED4s (by a factor of ~2), FEER and GFED4s emissions can be used to assess the model sensitivity and performance with different biomass burning emission datasets.
  - Source: NASA GSFC. Available at https://feer.gsfc.nasa.gov/data/emissions/.

- o Spatial resolution (version G1.2): 0.1° x 0.1°
- o Temporal resolution: Daily
- o Reference: Ichoku, C., and Ellison, L. (2014). Global top-down smoke-aerosol emissions estimation using satellite fire radiative power measurements. Atmospheric Chemistry and Physics, 14(13), 6643–6667. doi:10.5194/acp-14-6643-2014.

Figure 2 displays the CO, OC, BC biomass burning emissions from CEDS and FEER in 2010.

CEDS (CMIP6) biomass burning emissions, 2010

cmip6_em-biomassburning_co_glb_2010 (mg/m2/s) total=336.78 Tg/yr

FEER biomass burning emissions, 2010

feer_em-biomassburning_co_glb_2010 (mg/m2/s) total=599.74 Tg/yr

cmip6_em-biomassburning_oc_glb_2010 (mg/m2/s) total=15.88 Tg/yr

feer_em-biomassburning_oc_glb_2010 (mg/m2/s) total=29.22 Tg/yr

cmip6_em-biomassburning_bc_glb_2010 (mg/m2/s) total=1.91 Tg/yr

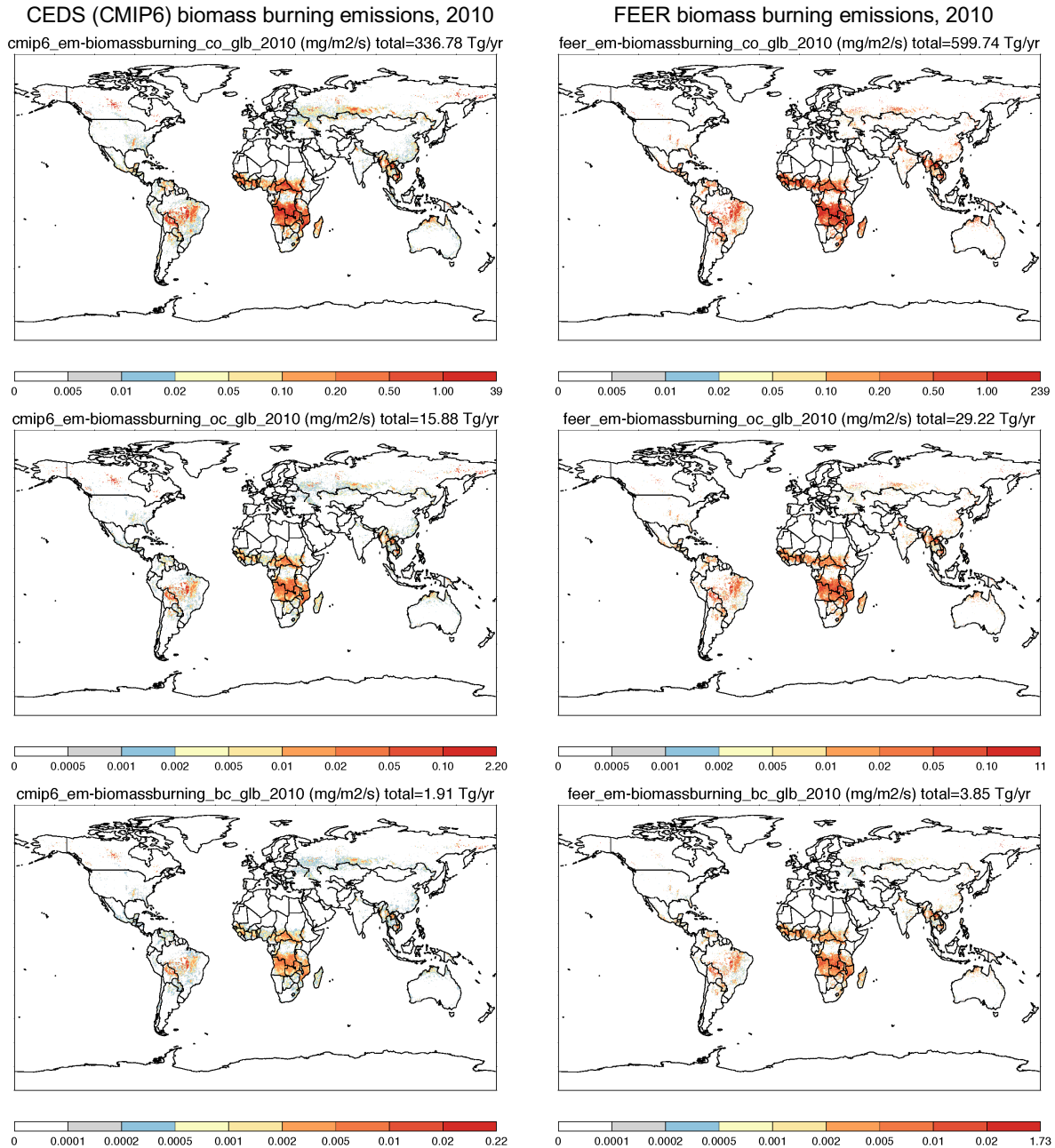feer_em-biomassburning_bc_glb_2010 (mg/m2/s) total=3.85 Tg/yr

Figure 2. Biomass burning emissions of CO (top row), OC (middle row), and BC (bottom row) in 2010. Left column: from the CEDS (CMIP6) emission dataset. Right column: from FEER.

3. Volcanic emission of SO$_2$

1979-2018:

- Carn et al. (2015, 2017, 2019), TOMS- and OMI-based estimates for eruptive and degassing volcanic emissions (an excel sheet of all data is available from the AeroCom wiki).
  - Source for explosive volcanic eruptions (1979-2018): An ascii table from https://disc.gsfc.nasa.gov/datacollection/MSVOLSO2L4_3.html
  - Source for degassing volcanic emissions (2005-2015): An excel table from https://www.nature.com/articles/srep44095#supplementary-information
  - A combined eruptive and degassing volcanic emission database is available (excel sheet with two tabs) from the AeroCom wiki page
  - Recommendation of using degassing volcanic emission: using 2005-2015 average for years before 2005 and after 2015
  - Recommendation of SO$_2$ injection height: For degassing volcanic emissions, inject SO$_2$ at the altitude of the volcano (v_alt in the data table). For eruptive volcanic emissions, inject SO$_2$ at the top 1/3 column between the altitudes of volcano (v_alt) and the plume top height (p_alt in the data table)
  - Data citation: (a) Simon Carn (2019), Multi-Satellite Volcanic Sulfur Dioxide L4 Long-Term Global Database V3, Greenbelt, MD, USA, Goddard Earth Science Data and Information Services Center (GES DISC), 10.5067/MEASURES/SO2/DATA404. (b) Carn, S. A., V. E. Fioletov, C. A. McLinden, C. Li, and N. A. Krotkov (2017), A decade of global volcanic SO$_2$ emissions measured from space, Nature SREP, 7, doi:10.1038/srep44095

Figure 3 summarizes the time series of eruptive volcanic SO$_2$ emission amount and plume height from the late 1979 to early 2019.
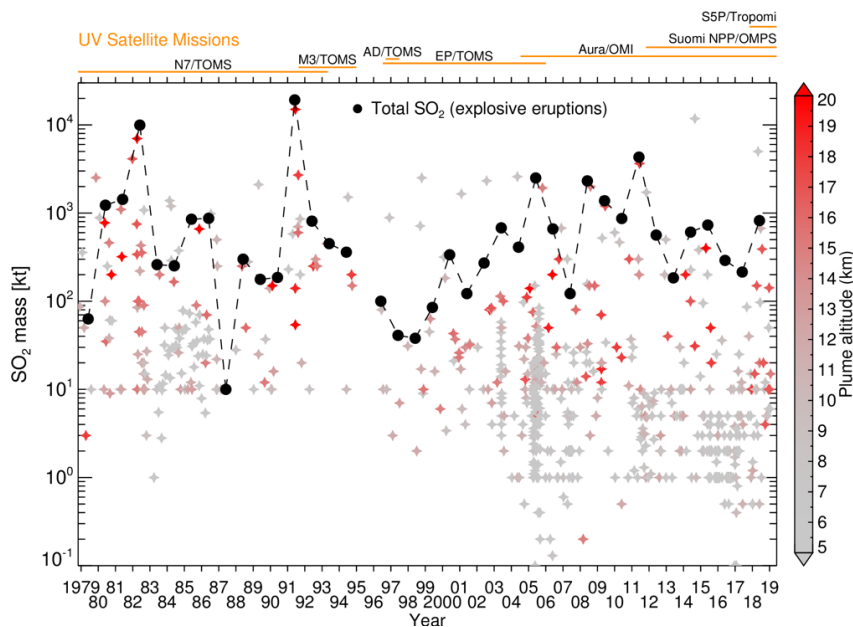

Figure 3. Eruptive volcanic SO$_2$ emission time series and plume top height. Figure from https://disc.gsfc.nasa.gov/datasets/MSVOLSO2L4_3/summary