AeroCom Phase III: Biomass Burning Emission Injection Height experiment (BBEIH)

Wiki website: https://wiki.met.no/aerocom/phase3-experiments
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Importance of biomass burning injection height: Smoke aerosols can adversely affect surface air quality and visibility near emission sources and even hundreds to thousands of km downwind, and thus create health and aviation hazards. They also have impacts on air temperature, cloud properties and precipitation. The environmental impact of smoke aerosols depends not only on the emitted mass, but also on the injection height. This is especially true for large boreal forest fires that often emit smoke above planetary boundary layer (PBL) into the free troposphere and even the lower stratosphere. However, most atmospheric chemistry transport models (CTMs) assume that fire emissions are dispersed only within PBL, or use simple plume-rise parameterizations. The importance of assigning accurate heights to smoke emissions in CTMs derives from three factors: (1) unlike winds in the free troposphere, winds in PBL do not favor smoke to transport over long distances downwind; (2) both dry and wet removal process are more efficient in PBL than in the free troposphere; (3) chemical processes within the plume are sensitive to ambient relative humidity, temperature, smoke-cloud interactions, and photolysis rates – all of which depend on smoke injection height.

The objectives of this project: to test the sensitivity of various model results to biomass burning smoke injection height, where the biomass burning injection height is based on MISR (Val Martin et al., 2010; 2018), as compared to the nominal model value. We aim to answer the following scientific questions:

I. To what extent are model simulations sensitive to the assumed biomass burning injection height, in terms of near-source characteristics and downwind plume evolution: (a) vertical aerosol distribution, (b) near-surface aerosol concentration, (c) aerosol optical depth, and more generally (d) net radiative forcing of BB-related aerosols, (e) BB-related aerosol transport time in the atmosphere, (f) cloud fraction, and (g) precipitation?
II. In which regions/seasons/surface-types are the aforementioned sensitivities significant?
III. To what extent do the aforementioned sensitivities vary across different models?

Methodology and datasets

1. **Model basic setups:**
   - Simulation period: 2008
   - Anthropogenic emission: monthly CMIP6

- Biomass burning emission: daily GFED4.1s is used in BASE and BBIH experiments; but daily FEER daily is used in BBEM (model experiments are described in section 2 below).

- Adding the biomass burning emission injection height to your model (for BBIH experiment only)
    - A global, gridded (0.25 degree in horizonal dimension) file of percentage of biomass burning emission at each vertical layer with the dimensions of [longitude, latitude, altitude, month] will be available for participating modelers. The vertical resolution of the altitude dimension is 250 m, from surface to 6 km (total 25 altitudes). The vertical percentage profiles are originally created based on the 2008-2010 MISR plume height statistical data retrieved by the MINX tool from MISR data, reported as a function of 6 land cover types in 7 geographic regions for each month. These data were provided by Maria Val Martin (see Table S4 in Val Martin et al., 2018).
    - This gridded data is available at https://…. (we will provide to modelers soon)
    - Modelers will have to re-grid/interpolate this data to their own lon-lat-alt grid space in order to distribute the 3-D [longitude, latitude, time] biomass burning emissions (GFED4.1s) vertically. Then, at each model vertical level, you will multiple GFED4.1s emission with the fraction (%) provided by this data. The resulting biomass burning emission will be 4-D [longitude, latitude, altitude, time] as aircraft emission. ***Note that this step is actually something like you did when you re-gridded CMIP6 aircraft emission to your model resolution.***

Note: See document in the AeroCom wiki section for locations of the emission files: "Common requirement: Harmonized anthropogenic, biomass burning, and volcanic emission datasets" at https://wiki.met.no/aerocom/phase3-experiments

2. Model experiments:

I. **BASE**: all emissions including GFED4.1s, using model-default biomass burning injection height.

II. **BBIH**: same as BASE but using MISR plume injection height to distribute biomass burning emissions vertically.

III. **NOBB**: no biomass burning emissions

IV. **BBEM** (optional): same as BASE, but using daily FEER biomass burning emission instead of GFED4.1s. Daily FEERv1.0-G1.2 biomass burning emissions can be downloaded at https://feer.gsfc.nasa.gov/data/emissions/.

Note: we designed the experiments to be similar to the work by Zhu et al. (2018):

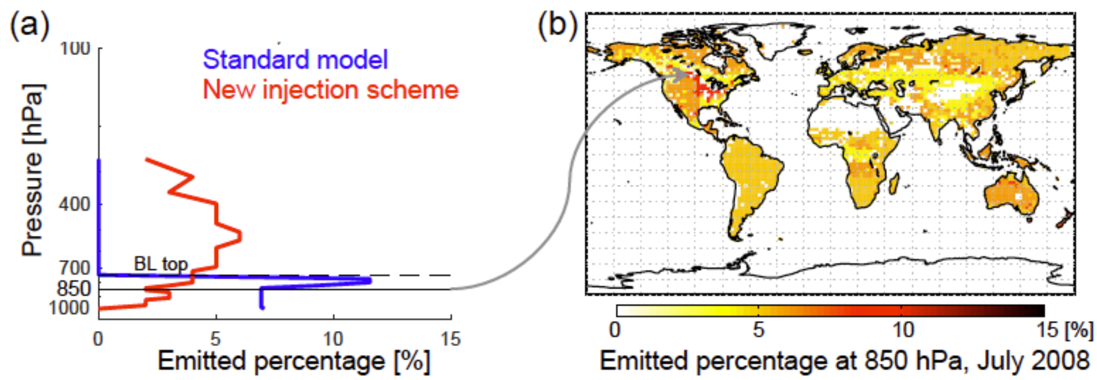

Figure. (a) Vertical profile of the percent of emissions in each model level for a sample location over boreal Canada (56◦ N, 105◦ W) from the public-release version of GEOS-Chem (blue) and the new observationally based injection scheme (red). The dashed line indicates the averaged boundary layer top of this month. The solid black line is at 850 hPa, corresponding to the layer shown in (b). (b) Percent of total-column biomass burning emissions emitted into the 850 hPa layer in each model grid cell for July 2008. Figure from Zhu et al., 2018.

3. **Model output:**
   Please refer to AeroCom III-BBEIH output specifications for detailed requirements (https://docs.google.com/spreadsheets/d/1EaZO6_FEH6nDhWKE9PvUNpfVkU9RdR2ZT6ahLL2VVEo/edit?usp=sharing). *The required diagnostic fields are listed under column "BBEIH".*

4. **Observation dataset used for evaluating models:**
   AERONET, MODIS, MISR, field campaign, surface aerosol concentration network (to be completed).

Timetable (tentative)
03.2019 – finalize the experiment plan and send it to the AeroCom group
07.2019 – submit model results to AeroCom server
09.2019 – preliminary results reported at the annual AeroCom meeting
02.2020 – drafts circulated among co-authors
05.2020 – Submission of manuscripts

Prototype works
Zhu, L., Val Martin, M., Gatti, L. V., Kahn, R., Hecobian, A., and Fischer, E. V.: Development and implementation of a new biomass burning emissions injection height scheme (BBEIH v1.0) for the **GEOS-Chem model** (v9-01-01), Geosci. Model Dev., 11, 4103-4116, https://doi.org/10.5194/gmd-11-4103-2018, 2018.

References
Kahn, R. A., Chen, Y., Nelson, D. L., Leung, F.-Y., Li, Q., Diner, D. J., and Logan, J. A.: Wildfire smoke injection heights: Two perspectives from space, Geophys. Res. Lett., 35, L04809, https://doi.org/10.1029/2007GL032165, 2008.

Val Martin, M., Logan, J. A., Kahn, R. A., Leung, F.-Y., Nelson, D. L., and Diner, D. J.: Smoke injection heights from fires in North America: analysis of 5 years of satellite observations, Atmos. Chem. Phys., 10, 1491–1510, https://doi.org/10.5194/acp- 10-1491-2010, 2010.

Val Martin, M., R. Kahn, and M. Tosca. 2018. "A Global Analysis of Wildfire Smoke Injection Heights Derived from Space-Based Multi-Angle Imaging." Remote Sensing, **10 (10):** 1609 [10.3390/rs10101609]