## 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 atmospheric composition 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:

1. 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) surface aerosol concentration, (c) aerosol optical depth, and more generally (d) net radiative forcing of BB-related aerosols, (e) lift-time of BB-related aerosols in the atmosphere, (f) cloud fraction, and (g) precipitation?
2. In which regions/seasons/surface-types are the aforementioned sensitivities significant?
3. To what extent do the aforementioned sensitivities vary across different models?

**Methodology and datasets**

1. **Model basic setups:**
* Simulation period: 2008
* Emission: Anthropogenic: CMIP6
* Biomass burning emission: GFED4.1s, daily
1. **Model experiments:**
2. BASE: all emissions, models’ default of biomass burning injection height
3. MISRIH: using MISR plume height for injecting biomass burning emissions
4. BBEM: same as BASE, but using FEER biomass burning emission (https://feer.gsfc.nasa.gov/data/emissions/)
5. NOBB: no biomass burning emissions

 **Note:** we design the experiments similar to the work by Zhu et al. (2018), referring to their Figure 2.



Figure 2. (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.

1. **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”.*

1. **Smoke aerosol injection percentage height derived from MISR**
	1. **The introduction of smoke aerosol injection percentage height file:** MISR-based vertical distribution percentage of smoke injection heights are stratified by (a) altitude (250 m vertical resolution, from 0 to 8 km above ground level), (b) region, (c) land cover type within region, and (d) season. Both pixel-weighted and AOD-weighted percentages are included in the database (Val Martin et al., 2018, Supplemental Material).
2. 12 land cover types: evergreen needleleaf forest, evergreen broad-leaf forest, deciduous needleleaf forest, deciduous broad-leaf forest, mixed forest, closed shrub, open shrub, woody savanna, savanna, grassland, wetland, and cropland at a spatial resolution of 0.005° \* 0.005°.
3. 12 months
4. 8 regions: North America, South America, Africa, Europe, boreal Eurasia, South

Asia, and Australia.

* 1. **Preparation of re-griding the smoke aerosol injection percentage height file into your model spatial resolution and season, following the steps below:**
1. Re-grid the vertical distribution percentage of smoke injection heights from 250 m resolution (32 levels) into model vertical grid (nlev), i.e.,

 from height\_percentage\_orig (12landType\*8region\***32lev\***12month)

to height\_percentage\_tmp (12landType\*8region**\*nlev**\*12month).

1. Re-grid the land cover map (36000 \* 18000) into model grid (nlon\*nlat, in lower spatial resolution), obtaining the percentages of various land cover types within each model grid, i.e.,

from land\_cover\_orig(**36000 \* 18000**)

 to land\_cover\_new(**nlon \* nlat**\*12landType)

1. Re-grid the region file (36000 \* 18000) into model grid (nlon\*nlat), i.e.,

from region\_orig (**36000 \* 18000**)

 to region\_new(**nlon \* nlat**)

1. Map the height\_percentrage\_tmp(12landType\*8region\*nlev\*12month) to the model grid based on the land\_cover\_new(nlon \* nlat\*12landType) and region\_new(nlon \* nlat) information, with the vertical profiles within each grid weighted by the percentages of the land types, i.e.,

from height\_percentage\_tmp (**12landType\*8region**\*nlev\*12month)

 to height\_percentage\_final (**nlon\*nlat**\*nlev\*12month).

**Note**: the vertical profiles already include a correction to account for the small fires, with assuming that the small fires detected by GFED-4s inject into the PBL only.

**Note:**

1. The prepared input file should contain the percentage of biomass burning emissions at the model levels in each model grid box for each month that can be used as the model input.
2. We will provide the following data and codes (To be provided)
	* Original Data:
		+ height\_percentage\_orig (12landType\*8region\*32\*12month)
		+ land\_cover\_orig (36000 \* 18000)
		+ region\_orig (36000 \* 18000)
	* Codes used for processing data in steps I-IV. Then you can adapt these codes to your model resolution easier.
	1. **Application of the re-gridded smoke aerosol injection percentage height file into your model:** You may have to modify the model code to distribute the biomass burning emission mass flux (units: kg m-2 s-1) into the model layers according to the vertical percentage (units: %) at each model grid, which is prepared in 4.2.
3. **Observation dataset used for evaluating models:** AERONET, MODIS, MISR, field campaign, surface aerosol concentration network (to be completed)

**Timetable** (tentative)

02.2019 – finalize the experiment plan and send it to the AeroCom group

06.2019 - 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](https://science.gsfc.nasa.gov/sed/index.cfm?fuseAction=people.jumpBio&iphonebookid=21325), 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](http://dx.doi.org/10.3390/rs10101609)]