Project report

Carbonaceous aerosol strongly absorbs visible light and has been ranked as the 2nd largest warming agent after CO2. Quantifying the impacts of carbonaceous aerosol on climate requires us to develop faithful model representations of its burden and its climate-relevant properties, such as CCN activity and optical properties. Currently, large uncertainties of black carbon (BC) burden and its climate forcing exist in global scale climate models (GCMs). The goal of our project is to assess and enhance the representation of carbonaceous aerosols in the latest version of the global Community Atmosphere Model with Chemistry (CAM-chem) model.

One key process that needs to be captured in GCMs is the BC ‘aging’ process, that is the conversion of fresh, hydrophobic black carbon into aged, hydrophilic black carbon, which directly contributes to CCN activation and wet removal and impacts black carbon’s optical properties. In current models, the BC aging timescale is either assumed to be a fixed value (1-2 days) or is determined with mechanistic transfer rates based on ad hoc aging aging criteria. Both approaches are very sensitive to the choices of assumed parameters. The representation of BC aging in CAM-chem model falls into the latter category and uses a four-mode version of the modal aerosol model (MAM4), where BC aerosol is transferred from a fresh, hydrophobic mode (primary carbon mode) to an aged, hydrophilic mode (accumulation mode) after condensing a certain amount of secondary aerosol material or through coagulation.

For a one-year simulations with CAM-chem we explored the sensitivity of the simulated BC burden and BC radiative forcing to the aging criterion used in CAMChem, and compared BC aging rates in CAM-chem to an aging parameterization based on more detailed particle-resolved simulations with PartMC-MOSAIC. Our results show that the simulated BC burden is most sensitive to the choices of the aging criterion in the high-latitude regions, with maximum differences in the annual averaged BC mixing ratio of 16% near the surface. These differences can be higher in the monthly averaged BC mixing ratio (e.g., we observe 65% relative difference at an elevation of 10km in the Arctic for March). We also observe strong seasonal variations of BC burden for major source regions (e.g., amazon forest, India, east Asia, etc.), where the BC mixing ratios are up to ten times higher in September than in March because of the massive biomass burning emissions during July to October. The aging timescales in the CAM-chem model range from less than one hour (South America) to several days (over the ocean), and these values are broadly consistent with the aging timescales from the PartMC-MOSAIC parameterization (showing the closest linear-regression slope to 1 at an elevation of 1km). Our comparison also indicates that the default aging rates around the surface are faster by a factor of 1.3 compared to the aging parameterization based on PartMC-MOSAIC, and a number of 6-monolayer criterion instead shows the best agreements.

While this work focuses on the treatment of black carbon aging, we plan to extend our effort to the confidence level of the simulated BC burden and its climate effect in the Arctic region. Our preliminary results show that most BC aerosols (>90%) are internally mixed at the middle and low latitudes, whereas more than 80% of them are externally mixed at high latitudes and in the Arctic. For future comparison with observations, this result should be taken into consideration, together with the mass fraction of BC in the size range corresponding to SP2 measurements.

Meetings and Conferences:

1. Visit MAM4 model developing group at Pacific Northwest National Laboratory, Richland, WA, June 27-July 1, 2016.
2. Oral presentations at the Los Alamos National Laboratory, September 20, 2016.
   1. A multi-scale modeling framework for simulating climate impacts of carbonaceous aerosol
   2. Analysis of BC aging with CAM-chem Model
3. Poster presentation at the Fourth Santa Fe Conference on Global & Regional Climate Change, February 5-10, 2017: “Sensitivity of black carbon aging to modeling assumptions in CAM-chem”.