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Comparison of MADE3-simulated and observed aerosol distributions with a focus on aerosol vertical profiles

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The reliability of aerosol radiative forcing estimates from climate models depends on the accuracy of simulated global aerosol distribution and composition, as well as on the models' representation of the aerosol–cloud and aerosol–radiation interactions. To help improve on previous modeling studies, we recently developed the new aerosol microphysics submodel MADE3 that explicitly tracks particle mixing state in the Aitken, accumulation, and coarse mode size ranges. We implemented MADE3 into the global atmospheric chemistry general circulation model EMAC and evaluated it by comparison of simulated aerosol properties to observations. Compared properties include continental near-surface aerosol component concentrations and size distributions, continental and marine aerosol vertical profiles, and nearly global aerosol optical depth.

Recent studies have shown the specific importance of aerosol vertical profiles for determination of the aerosol radiative forcing. Therefore, our focus here is on the evaluation of simulated vertical profiles. The observational data is taken from campaigns between 1990 and 2011 over the Pacific Ocean, over North and South America, and over Europe. The datasets include black carbon and total aerosol mass mixing ratios, as well as aerosol particle number concentrations.

Compared to other models, EMAC with MADE3 yields good agreement with the observations – despite a general high bias of the simulated mass mixing ratio profiles. However, BC concentrations are generally overestimated by many models in the upper troposphere. With MADE3 in EMAC, we find better agreement of the simulated BC profiles with HIPPO data than the multi-model average of the models that took part in the AeroCom project.

There is an interesting difference between the profiles from individual campaigns and more "climatological" datasets. For instance, compared to spatially and temporally localized campaigns, the model simulates a more continuous decline in both total aerosol and black carbon mass mixing ratio with altitude than found in the observations. In contrast, measured profiles from the HIPPO project are qualitatively captured well. Similar conclusions hold for the comparison of simulated and measured aerosol particle number concentrations. On the one hand, these results exemplify the difficulty in evaluating the representativeness of the simulated global climatological state of the aerosol by means of comparison with individually measured vertical profiles. On the other hand, it highlights the value of aircraft campaigns with large spatial and temporal coverage for model evaluation.