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An intercomparison and evaluation of aerosol microphysical properties among AeroCom global aerosol models of a range of complexity.

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Many of the next generation of climate models will include aerosol schemes which explicitly simulate the microphysical processes that determine the particle size distribution. Such aerosol microphysics schemes ensure that aerosol optical properties and cloud condensation nuclei concentrations are determined by fundamental aerosol processes, which should lead to a more physically based simulation of aerosol direct and indirect radiative forcings.

This study, as part of the second phase of the international AeroCom initiative, examines how the particle size distribution is simulated in the current generation of global aerosol microphysics models. We use 12 models to quantify the mean and diversity of size-resolved particle concentrations on a global scale and map areas of particular model uncertainty (based on their central diversity) and identify biases through evaluation against observations.

In regions of strong anthropogenic emissions, the diversity of simulated concentrations of particles larger than 30nm (N30) is large (factor 2 to 6), while the diversity of sulphate mass (factor 1.2 to 3) and N100 (factor 1.5 to 2) are lower. We attribute the higher N30 diversity in emissions regions to inter-model differences in nucleation and growth processes, and also to different size assumptions for primary emitted particles. In clean marine regions, the pattern of size-resolved diversity is opposite to polluted regions, with N30 diversity (factor 1.5 to 2) much lower than N100. At high latitudes, N30 has relatively low diversity (factor 2 to 7), compared to much higher diversity in simulated sulphate, black carbon and N100 (factor 5 to 30). The higher N30 diversity in polluted continental regions indicates that simulated CCN concentrations are more diverse among models than the >100nm sizes, which mainly determine aerosol optical properties. However, the relatively low N30 diversity in marine and remote regions gives confidence that current global aerosol microphysics models have good agreement on background aerosol properties.

Despite large inter-model diversity, multi-model mean total particle concentrations agree well with observations, both on the annual mean and in the seasonal cycle. The multi-model mean sub-micron aerosol size distribution compares reasonably well against observations from the EUSAAR/GUAN network of aerosol supersites, but there is a strong underestimation of the winter-time accumulation mode, which could be caused by a significant underprediction of particle growth (up to a factor 2 in diameter) or underprediction of particle number (up to a factor 5). Multi-model size-resolved number concentrations in marine regions are quite well captured with Aitken mode concentrations dominating at remote and higher latitudes, as seen in the observations. Considering vertical profiles, the models capture well the peak in total particle concentrations in the upper troposphere due to new particle formation, although this feature is too strong in the models over Europe.

Taking all models and metrics together, there is no evidence that the simpler aerosol microphysics schemes are universally further from the observations than more complex ones. Overall, the results suggest that, despite large diversity, the global aerosol microphysics models as a whole are capable of simulating a fairly realistic distribution of aerosol microphysical properties. The results suggest that improved understanding of size-resolved particle emissions and better treatment of sources of primary and secondary particles would help reduce model bias and diversity.