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Aerosol indirect effects in the ECHAM5-HAM2 climate model with subgrid cloud microphysics in a stochastic framework

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Representing cloud properties in global climate models remains a challenging topic, which to a large extent is due to cloud processes acting on spatial scales much smaller than the typical model grid resolution. Several attempts have been made to alleviate this problem. One such method was introduced in the ECHAM5-HAM2 climate model by Tonttila et al. (2013), where cloud microphysical properties, along with the processes of cloud droplet activation and autoconversion, were computed using an ensemble of stochastic subcolumns within the climate model grid columns. Moreover, the subcolumns were sampled for radiative transfer using the Monte Carlo Independent Column Approximation approach.

The same model version is used in this work (Tonttila et al. 2014), where 5-year nudged integrations are performed with a series of different model configurations. Each run is performed twice, once with pre-industrial (PI, year 1750) aerosol emission conditions and once with present-day (PD, year 2000) conditions, based on the AEROCOM emission inventories. The differences between PI and PD simulations are used to estimate the impact of anthropogenic aerosols on clouds and the aerosol indirect effect (AIE).

One of the key results is that when both cloud activation and autoconversion are computed in the subcolumn space, the aerosol-induced PI-to-PD change in the global-mean liquid water path is up to 19 % smaller than in the reference with grid-scale computations. Together with similar changes in the cloud droplet number concentration, this influences the cloud radiative effects and thus the AIE, which is estimated as the difference in the net cloud radiative effect between PI and PD conditions. Accordingly, the AIE is reduced by 14 %, from $1.59\ \mathrm{W\ m^{-2}}$ in the reference model version to $1.37\ \mathrm{W\ m^{-2}}$ in the experimental model configuration. The results of this work explicitly show that careful consideration of the subgrid variability in cloud microphysical properties and consistent treatment of related physical processes make an important contribution towards reducing biases in the model representation of the aerosol-cloud interactions.

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