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Global aerosol effects on convective clouds

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Atmospheric aerosols affect cloud properties, and thereby the radiation balance of the planet and the water cycle. The influence of aerosols on clouds is dominated by increase of cloud droplet and ice crystal numbers (CDNC/ICNC) due to enhanced aerosols acting as cloud condensation and ice nuclei. In deep convective clouds this increase in CDNC/ICNC is hypothesised to increase precipitation because of cloud invigoration through enhanced freezing and associated increased latent heat release caused by delayed warm rain formation. Satellite studies robustly show an increase of cloud top height (CTH) and precipitation with increasing aerosol optical depth (AOD, as proxy for aerosol amount).

To represent aerosol effects and study their influence on convective clouds in the global climate aerosol model ECHAM-HAM, we substitute the standard convection parameterisation, which uses one mean convective cloud for each grid column, with the convective cloud field model (CCFM), which simulates a spectrum of convective clouds, each with distinct values of radius, mixing ratios, vertical velocity, height and en/detrainment. Aerosol activation and droplet nucleation in convective updrafts at cloud base is the primary driver for microphysical aerosol effects. To produce realistic estimates for vertical velocity at cloud base we use an entraining dry parcel sub cloud model which is triggered by perturbations of sensible and latent heat at the surface. Aerosol activation at cloud base is modelled with a mechanistic, Köhler theory based, scheme, which couples the aerosols to the convective microphysics.

Comparison of relationships between CTH and AOD, and precipitation and AOD produced by this novel model and satellite based estimates show general agreement. Through model experiments and analysis of the model cloud processes we are able to investigate the main drivers for the relationship between CTH / precipitation and AOD.