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Using the Convective Cloud Field Model (CCFM) to investigate aerosol–convection interactions in ECHAM6–HAM

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Convection plays an important role in the climate system through its effects on radiation, precipitation, large-scale dynamics and vertical transport of aerosols and trace gases. The effects of aerosols on the development of convective cloud and precipitation are a source of considerable uncertainty in current climate modelling.

Most current global climate models use "mass-flux" convection schemes, which represent the ensemble of convective clouds in a GCM column by a single "mean" updraught. In addition to over-simplifying the representation of such clouds, this presents particular problems in the context of aerosol–convection interactions: firstly because the relationship between aerosol and the droplet size distribution depends on the vertical velocity distribution, about which little or no information is available, and secondly because the effects of convective transport and scavenging may vary nonlinearly over the ensemble (e.g. between precipitating and non-precipitating clouds and due to different loadings).

The Convective Cloud Field Model (CCFM) addresses these limitations by simulating a spectrum of updraughts with different cross-sectional areas within each GCM column, based on the quasi-equilibrium approach of Arakawa and Schubert. For each cloud type, an entraining Lagrangian parcel model is initiated by perturbations at the surface, allowing a realistic vertical velocity to develop by cloud base so that detailed size-resolved microphysics can be represented within the cloud above. These different cloud types interact via competition for resolved-scale convective available potential energy (CAPE). Transport of water, aerosol and other tracers is calculated separately for each cloud type, allowing for different entrainment and scavenging behaviours.

By using CCFM embedded within the ECHAM6–HAM aerosol–climate model, we show how this approach can both improve the distribution of convective precipitation events compared to a typical mass-flux scheme, and also enable the physically-based representation of aerosol indirect effects to be extended to include sub-grid-scale convective cloud and precipitation.