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Aerosol processing in stratiform clouds in ECHAM6-HAM

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Aerosol processing in stratiform clouds by uptake into cloud particles, collision-coalescence, chemical processing inside the cloud particles and release back into the atmosphere has important effects on aerosol concentration, size distribution, chemical composition and mixing state.

Aerosol particles can act as cloud condensation nuclei. Cloud droplets can take up further aerosol particles by collisions. Atmospheric gases may also be transferred into the cloud droplets and undergo chemical reactions, e.g. the production of atmospheric sulphate. Aerosol particles are also processed in ice crystals. They may be taken up by homogeneous freezing of cloud droplets below -38˚C or by heterogeneous freezing above -38˚C. This includes immersion freezing of already immersed aerosol particles in the droplets and contact freezing of particles colliding with a droplet. Many clouds do not form precipitation and also much of the precipitation evaporates before it reaches the ground. The water soluble part of the aerosol particles concentrates in the hydrometeors and together with the insoluble part forms a single, mixed, larger particle, which is released.

We have implemented aerosol processing into the current version of the general circulation model ECHAM6 (Stevens et al., 2013) coupled to the aerosol module HAM (Stier et al., 2005). ECHAM6-HAM solves prognostic equations for the cloud droplet number and ice crystal number concentrations. In the standard version of HAM, seven modes are used to describe the total aerosol. The modes are divided into soluble/mixed and insoluble modes and the number concentrations and masses of different chemical components (sulphate, black carbon, organic carbon, sea salt and mineral dust) are prognostic variables. We extended this by an explicit representation of aerosol particles in cloud droplets and ice crystals in stratiform clouds similar to Hoose et al. (2008a,b). Aerosol particles in cloud droplets are represented by 5 tracers for the chemical components as well as 5 tracers for aerosol particles in ice crystals. This allows simulations of aerosol processing in warm, mixed-phase (e.g. through the Bergeron-Findeisen process) and ice clouds. The fixed scavenging ratios used for wet deposition in clouds in standard HAM are replaced by an explicit treatment of collision of cloud droplets/ice crystals with interstitial aerosol particles. Nucleation scavenging of aerosol particles by acting as cloud condensation nuclei or ice nuclei, freezing and evaporation of cloud droplets and melting and sublimation of ice crystals are treated explicitly. In extension to previous studies, aerosol particles from evaporating precipitation are released to modes which correspond to their size. Cloud processing of aerosol particles changes their size distribution and hence influences cloud droplet and ice crystal number concentrations as well as precipitation rate, which in turn affects aerosol concentrations. Results will be presented at the conference.

Hoose et al., JGR, 2008a, doi: 10.1029/2007JD009251

Hoose et al., ACP, 2008b, doi: 10.5194/acp-8-6939-2008

Stevens et al., 2013, submitted

Stier et al., ACP, 2005, doi: 10.5194/acp-5-1125-2005