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Explicit simulations of aerosol physics in a cloud-resolving model: a sensitivity study based on an observed convective cloud

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Abstract. The role of convection in introducing aerosols and promoting the formation of new particles to the upper troposphere has been examined using a cloud-resolving model coupled with an interactive explicit aerosol module. A baseline simulation suggests good agreement in the upper troposphere between modeled and observed results including concentrations of aerosols in different size ranges, mole fractions of key chemical species, and concentrations of ice particles. In addition, a set of 34 sensitivity simulations has been carried out to investigate the sensitivity of modeled results to the treatment of various aerosol physical and chemical processes in the model. The size distribution of aerosols is proved to be an important factor in determining the aerosols' fate within the convective cloud. Nucleation mode aerosols (here defined by 0≤d≤5.84 nm) are quickly transferred to the larger modes as they grow through coagulation of aerosols and condensation of H_2SO_4. Accumulation mode aerosols (here defined by d≥31.0 nm) are almost completely removed by nucleation (activation of cloud droplets) and impact scavenging. However, a substantial part (up to 10% of the boundary layer concentration) of the Aitken mode aerosol population (here defined by 5.84 nm≤d≤31.0 nm) reaches the top of the cloud and the free troposphere. These particles may continually survive in the upper troposphere, or over time form ice crystals, both that could impact on the atmospheric radiative budget. The sensitivity simulations performed indicate that critical processes in the model causing a substantial change in the upper tropospheric number concentration of Aitken mode aerosols are coagulation of aerosols, condensation of H_2SO_4, nucleation scavenging, nucleation of aerosols and the transfer of aerosol mass and number between different aerosol bins. In particular, for aerosols in the Aitken mode to grow to CCN size, coagulation of aerosols appears to be more important than condensation of H_2SO_4. Less important processes are dry deposition, impact scavenging and the initial vertical distribution and concentration of aerosols. It is interesting to note that in order to sustain a vigorous storm cloud, the supply of CCN must be continuous over a considerably long time period of the simulation. Hence, the treatment of the growth of particles is in general much more important than the initial aerosol concentration itself.

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