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Aerosol effects on deep convective clouds: Impact of changes in aerosol size distribution and aerosol activation parameterization

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Atmospheric aerosols act as cloud condensation nuclei (CCN) and are therefore important in cloud formation processes. Anthropogenic CCN generally cause an increase of the cloud droplet number concentration, which for a constant amount of liquid water reduces the average cloud droplet size and increases cloud albedo (first indirect effect). As a consequence, precipitation and cloud life time may be altered (second indirect effect). For mixed-phase clouds, such as deep convective clouds, the effect of an increased aerosol concentration is more complex. Some model studies of single deep convective clouds show a decrease in precipitation rate with increasing aerosol concentration, whereas others show a precipitation increase with increasing aerosol concentration. These cloud-resolving models often utilize a simplified description of the aerosol population chemistry and dynamics where an initial aerosol size distribution or concentration is assumed and the initial aerosol composition is prescribed. In some models the aerosol population is advected and scavenged throughout the simulation whereas other models utilize a time-invariant aerosol concentration. Some models utilize Köhler theory to activate the aerosols whereas other models utilize empirical relationships.

In the present study, we examine the sensitivity of a single deep convective cloud to varying aerosol concentrations and how this aerosol-induced sensitivity may depend on the complexity of the aerosol model as well as the aerosol activation parameterization. We also examine how the size of the aerosols may affect the aerosol-induced sensitivity. We find that for the simulated case, all versions of the model give an increase in updraft with increasing aerosol concentration. However, the magnitude of the change in updraft is dependent on the size of the aerosols and the aerosol activation formulation used. In addition, graupel formation and surface precipitation formation is not always directly linked to the increase in average updraft.