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Microphysical Pathways Active within Thunderstorms and Their Sensitivity to CCN Concentration and Wind Shear

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Previous studies have obtained contradicting results on the impact of Cloud condensation nuclei (CCN) concentration on microphysical processes within thunderstorms and the resulting surface precipitation. In this work, an analysis of the "microphysical pathways" occurring in these clouds, with a particular emphasis on the formation of large hail and heavy precipitation, is proposed to systematically investigate and understand these sensitivities.

Thunderstorms were simulated using convection-permitting (1 km horizontal grid spacing) idealised simulations with the ICON model, which included the Seifert and Beheng 2-moment microphysics parameterization. CCN concentrations were increased from 100 to 3200 CCN/cm3, in five different wind shear environments ranging from 18 to 50 m/s. Large and systematic decreases of surface precipitation (up to 35%) and hail (up to 90%) were found as CCN was increased. Wind shear changes the details, but not the sign, of the sensitivity to CCN. These decreases result from microphysical processes becoming less efficient at forming precipitation and not from changes to the updraft.

The microphysical process rates were tracked throughout each simulation, allowing the mass budget to be closed for each hydrometeor class. The microphysical processes were collected together into "microphysical pathways", which describe and quantify the different growth processes leading to surface precipitation (see Figure). Almost all surface precipitation occurred through the mixed-phase pathway, where graupel and hail grow by riming and later melt as they fall to the surface. The mixed-phase pathway is also sensitive to CCN concentration changes, as a result of changes to the riming rate. Potential causes for the riming rate changes were systematically evaluated. Supercooled water content was almost insensitive to increasing CCN concentration, but decreased cloud drop size led to a large reduction in the riming efficiency (from 0.79 to 0.24) between supercooled cloud drops and graupel or hail. Therefor the graupel and hail stones grow more slowly, reach smaller sizes and are less likely to reach the surface. Additional simulations using a constant collection efficiency (either 0.5 or 1.0) for all cloud drop sizes removed the systematic sensitivity of precipitation to CCN concentration, but hail remained sensitive to CCN due to differences in hail embryo formation pathways.

Category

Meteorology / Atmospheric Physics

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