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New particle dependant parameterizations of heterogeneous freezing processes.

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For detailed investigations of cloud microphysical processes an adiabatic air parcel model with entrainment is used. It represents a spectral bin model which explicitly solves the microphysical equations. The initiation of the ice phase is parameterized and describes the effects of different types of ice nuclei (mineral dust, soot, biological particles) in immersion, contact, and deposition modes. As part of the research group INUIT (Ice Nuclei research UnIT), existing parameterizations have been modified for the present studies and new parameterizations have been developed mainly on the basis of the outcome of INUIT experiments.
Deposition freezing in the model is dependant on the presence of dry particles and on ice supersaturation. The description of contact freezing combines the collision kernel of dry particles with the fraction of frozen drops as function of temperature and particle size. A new parameterization of immersion freezing has been coupled to the mass of insoluble particles contained in the drops using measured numbers of ice active sites per unit mass. Sensitivity studies have been performed with a convective temperature and dew point profile and with two dry aerosol particle number size distributions. Single and coupled freezing processes are studied with different types of ice nuclei (e.g., bacteria, illite, kaolinite, feldspar). The strength of convection is varied so that the simulated cloud reaches different levels of temperature. As a parameter to evaluate the results the ice water fraction is selected which is defined as the relation of the ice water content to the total water content. Ice water fractions between 0.1 and 0.9 represent mixed-phase clouds, larger than 0.9 ice clouds.
The results indicate the sensitive parameters for the formation of mixed-phase and ice clouds are: 1. broad particle number size distribution with high number of small particles, 2. temperatures below -25°C, 3. specific mineral dust particles as ice nuclei such as illite or montmorillonite. Coupled cases of deposition and contact freezing show that they are hardly in competition because of differences in the preferred particle sizes. In the contact mode, small particles are less efficient for collisions as well as less efficient as ice nuclei so that these are available for deposition freezing. On the other hand, immersion freezing is the dominant process when it is coupled with deposition freezing. As it is initiated earlier the formed ice particles consume water vapor for growing. The competition of combined contact and immersion freezing leads to lower ice water contents because more ice particles are formed via the immersion mode. In general, ice clouds and mixed-phase clouds with high ice water fractions are not directly the result of primary ice formation but of secondary ice formation and growth of ice particles at the expense of liquid drops.