Model simulations on the effects of deposition freezing in convective clouds

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Keywords: Deposition freezing, air parcel model
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For detailed investigations of cloud microphysical processes adiabatic parcel models with entrainment are often employed. The air parcel model of Diehl *et al.* (2006) 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 and contact modes. Results indicated that certain aerosol types significantly alter cloud microphysics (Diehl *et al.*, 2006).

In the present study a parameterization of deposition freezing has been developed on the basis of the outcome of experiments (Ardon-Dryer and Levin, 2012; Danielczok and Bingemer, 2012). These were performed with the vapor diffusion chamber FRIDGE (Bingemer et al., 2012) for atmospheric particles and two types of mineral dust. The parameterization equations give the fraction of activated ice nuclei in dependence of ice supersaturation.

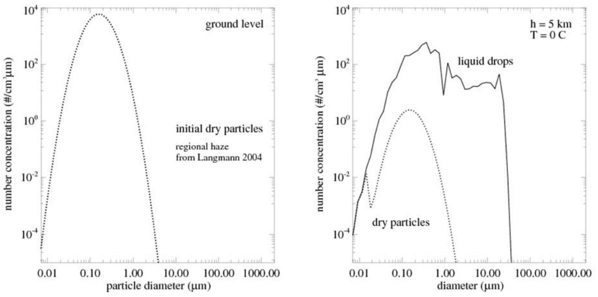

Figure 1. Initial particle number size distribution and liquid drop and interstitial particle size distributions.

The model has been initiated by a dry aerosol particle number size distribution (Figure 1, left panel) and by a temperature difference of 1.5K between parcel and environment. During the air parcel rise, aerosol particles are activated as drops due to their size and soluble fraction. Additional particles are mixed in by entrainment. Thus, interstitial aerosol particles are available during the ascent of the parcel which may serve as deposition ice nuclei (Figure 1, right panel).

In dependence of the available dry particles and the ice supersaturation, the number of ice particles formed by deposition freezing has been calculated. Potential deposition ice nuclei have to exceed the critical germ size dependant on temperature and ice supersaturation to become active. Threshold values of temperature and ice supersaturation have been set based on measurements. Cases with atmospheric particles and mineral dust have been simulated. Simulations with biological particles will also be included.

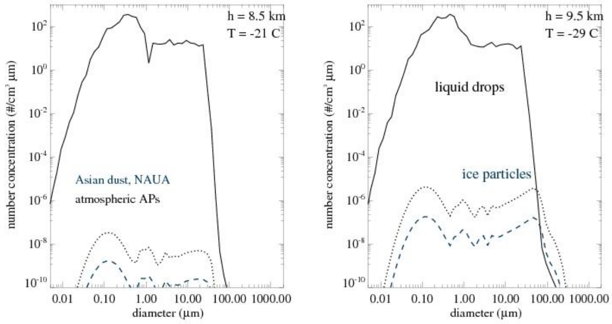

Figure 2. Development of number concentrations of liquid drops and ice particles with height for two cases.

Figure 2 shows the development of the number concentration of liquid drops and ice particles with increasing altitude and corresponding decreasing temperature. Example cases are Asian dust and atmospheric particles. At –21°C deposition freezing has set in. In comparison to the number concentration of liquid drops, only a small fraction of ice is produced. The spectrum shows a maximum at 0.15 µm and smaller maxima at larger sizes. This indicates that firstly, as primary ice formation, very small ice particles are formed due to the size of the involved particles. Afterwards, these pristine ice particles serve as nuclei for secondary ice formation, i.e. by collisions with supercooled liquid drops. This process produces ice particles of larger sizes which are further growing by the deposition of water vapor and by riming. At the end of the air parcel rise at –29°C, still a mixed-phase cloud is present with only a small ice fraction.

In comparison to immersion and contact freezing where larger sizes are preferred (Diehl *et al.*, 2006) the importance of deposition freezing in clouds lies in the formation of pristine ice particles which extend the ice particle spectra towards smaller sizes and affect secondary ice formation. Model simulations with coupled freezing in all three modes will demonstrate the competition of the different processes.

This work is part of the research group INUIT and is supported by the Deutsche Forschungsgemeinschaft under grant DI 1539/1-1.

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