The effects of ice nucleating particle types in the immersion mode on ice formation and precipitation in a convective cloud: model simulations with COSMO-SPECS

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Model simulations are performed with the 3D cloud-resolving model COSMO-SPECS which provides a direct link between aerosol particles, cloud properties, and precipitation (Grützun *et al.,* 2008). It contains a spectral microphysical scheme for aerosols and hydrometeors including all processes proceeding during the development of clouds and precipitation. In the present study the focus lies on the effects of immersion freezing which is supposed to represent the most important heterogeneous freezing process (e.g., de Boer *et al.*, 2011).

Idealized test cases are investigated by using Weisman-Klemp profiles (Weismann and Klemp, 1982) for the initial atmosphere and an initial uni-modal particle number size distribution (Kreidenweis *et al.,* 2003). The complete model domain includes 80 x 80 km^2 with an altitude of 18 km. The resolutions are 1 km horizontally and up to 600 m vertically. The initial wind is set to zero. A convective cloud is initialized by a temperature disturbance of 1.5K in the centre of the model domain, extending over 20 km in horizontal diameter.

The cloud microphysics includes two hydrometeor spectra. The first one contains inactivated aerosol particles as well as cloud and rain drops, the second one mixed phase and completely frozen hydrometeors. The aerosol particles are internally mixed with a soluble fraction of 0.5. This soluble fraction is solved in the drops and may cause a freezing point depression.

A new version of immersion freezing has been incorporated where it is initiated by the insoluble mass fractions contained in the drops. It is described particle-type dependant and based on the outcome of laboratory experiments (Diehl and Mitra, 2015). Simulated ice nucleating particle types (INP) are mineral dust (feldspar, illite, and kaolinite) and biological particles (bacteria, plant debris, and pollen). These active INPs are defined as part of the initial particle spectrum, i.e. variable fractions F_{INP}. Also newly included is a description of homogeneous freezing according to the volume and the molality of the solution drops (Diehl and Wurzler, 2004). It leads to the absence of liquid drops at temperatures below -40°C.

The spectral description of the cloud microphysics allows to demonstrate via immersion freezing larger ice particles are formed, as shown in the example in Figure 1. This is due to the fact that after collision/coalescence of drops and because of impaction scavenging of aerosol particles the larger drops contain more insoluble material. Afterwards, the ice particles grow further by the deposition of water vapour and by riming.

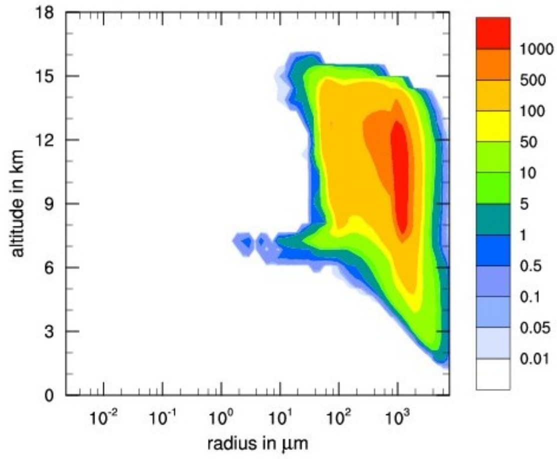

Figure 1. Ice particle concentration in m^{-3} after 30 min model run time, immersion freezing with 10% feldspar ice nucleating particles.

Currently sensitivity studies are performed where the fractions of active ice nucleating particles F_{INP} are varied according to the presence of these particle types in atmospheric cloud droplets: mineral dust particles between 0.01% and 1%, biological particles 0.001%. The effects of ice nucleating particle amounts and types on ice formation and precipitation are investigated.

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