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Ice nucleation rates: Cloud regime sensitivity

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Quantitative knowledge on homogeneous and heterogeneous ice nucleation rates of cloud droplets and aerosols represents an important aspect of a better understanding of mixed-phase and ice clouds. The behaviour of pure and mixed ice clouds in turn is a major source of uncertainty for both climate and weather predictions via radiative and precipitation effects.

As one part of the High Definition Clouds and Precipitation for advancing Climate Prediction (HD(CP)^2) project, ICON-model large-eddy 156m one-day hindcast simulations were performed over the domain area of Germany. We are interested in the ice nucleation rates of especially the project‘s CCN sensitivity simulation day: The warm 2nd of May 2013, on which diverse cloud types including convective areas were present. However, ice nucleation rates were not output.

In this work, we present a recalculation method to obtain ice nucleation rates and equilibrium ice concentrations from ICON standard output. We used the model‘s saturation adjustment plus full microphysics and combined it with a simple advection and cooling scheme. We tested the method‘s validity with an idealized warm bubble simulation by adding outputs for the different ice nucleation process rates and comparing them to the recalculated rates. As a result, we quantify the contributions of homogeneous and immersion freezing, deposition nucleation and ice multiplication to the total ice number concentration. We find a dominance of homogeneous cloud droplet freezing below 235 K and a dominance of deposition over immersion freezing in the range 235 K < T < 244 K.

We also applied the 3D cloud classification scheme of Van den Heever et al. (2011) to distinguish cloud regimes (e.g. convective clouds, cirrus clouds) with distinct ice nucleation behaviour. Convective clouds dominate overall homogeneous cloud droplet freezing and constitute above the average of other cloud types to the domain ice number concentration.