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Partitioning of ice nucleating particles: Which modes matter?

Luke Hande and Corinna Hoose
Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology

Ice particles in clouds have a large impact on cloud lifetime, precipitation amount, and cloud radiative properties through the indirect aerosol effect. Thus, correctly modelling ice formation processes is important for simulations preformed on all spatial and temporal scales. Ice forms on aerosol particles through several different mechanisms, namely deposition nucleation, immersion freezing, and contact freezing. However there is conflicting evidence as to which mode dominates, and the relative importance of the three heterogeneous ice nucleation mechanisms, as well as homogeneous nucleation, remains an open question.

The environmental conditions, and hence the cloud type, have a large impact on determining which nucleation mode dominates. In order to understand this, simulations were performed with the COSMO-LES model, utilising state of the art parameterisations to describe the different nucleation mechanisms for several semi-idealised cloud types commonly occurring over central Europe. The cloud types investigated include a semi-idealised, and an idealised convective cloud, an orographic cloud, and a stratiform cloud.

Results show that immersion and contact freezing dominate at warmer temperatures, and under most conditions, deposition nucleation plays only a minor role. In clouds where sufficiently high levels of water vapour are present at colder temperatures, deposition nucleation can play a role, however in general homogeneous nucleation dominates at colder temperatures. Since contact nucleation depends on the environmental relative humidity, enhancements in this nucleation mode can be seen in areas of dry air entrainment. The results indicate that ice microphysical processes are somewhat sensitve to the environmental conditions and therefore the cloud type.