EGU22-5159, updated on 12 Aug 2022
https://doi.org/10.5194/egusphere-egu22-5159
EGU General Assembly 2022

Exploring the origin of increasing ice particle number in the dendritic growth zone combining polarimetric radar observations and novel Lagrangian particle modeling

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The dendritic growth zone (DGZ) plays a significant role in the production of precipitation and life cycle of clouds. Previous studies have shown that the DGZ is the region where the ice particle size first starts to increase through aggregation. This increase in ice particle size immensely influences the precipitation on the ground. In-situ cloud observations as well as polarimetric and Doppler radar observations of the DGZ have also shown an increase of ice particle number above the available ice nucleating particles concentration. It is unclear and often case study specific where this large number of new ice particles originates from and if this increase in ice particle concentration influences or even triggers the strong increase in particle size in the DGZ.

In our work, we combine multi-frequency Doppler and polarimetric Doppler cloud radar observations with Monte-Carlo Lagrangian particle modeling linked by a polarimetric forward operator to test these hypotheses. While polarimetric radar observations are sensitive to small, asymmetric ice particles, the multi-frequency approach can provide information about aggregation and riming. This observational setup allows us to look at the size and shape of ice particles. However, detailed evolution of the particle's properties and the interaction between ice microphysical processes, such as the aggregation of ice particles and generation of new particles in the DGZ, are difficult to identify using only remote-sensing observations.

The Lagrangian super-particle model McSnow allows us to describe the microphysical process on the detailed particle level and with that track their individual history. The newly implemented habit prediction scheme includes ice shape effects that represent various aspects of the particle properties and growth, such as a shape-dependent depositional growth rate, fall velocity, and density evolution, more realistically. Ice habit, fall velocity, and density are core information for radar forward simulations, facilitating the comparison with polarimetric observations.

This setup enables us to test observation-based hypotheses such as an increase in number concentration of small, asymmetric ice crystals in the DGZ due to secondary ice or seeder-feeder processes. First results show that the temperature at which the particle is first nucleated is crucial for the particle's habit development. To match the polarimetric radar observations around -15°C, the particles need to be nucleated within the plate-like growth regime at temperatures warmer than -20°C. Particles nucleated at colder temperatures and falling into the plate-like growth regime do not reach the expected habit and the needed aspect ratios to explain the polarimetric radar observations. It is therefore likely that the small particles that cause the distinct polarimetric features at -15°C do not stem from seeder-feeder processes but rather are generated close to the -15°C level. One possible generation process is ice fragmentation which has been found in previous studies to be particularly enhanced at this temperature regime.