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Can ice-ice fragmentation explain the typical radar signatures in the dendritic growth layer? An investigation combining polarimetric multi-frequency radar observations wth Lagrangian Monte-Carlo particle modeling

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The dendritic growth layer (DGL), centered around -15℃, plays a key role in the formation of precipitable ice and snow particles. Particle growth by vapor deposition and subsequent aggregation are strongly enhanced in the DGL. As a result, multiple radar observables display distinct features related to the plate-like particle shapes as well as rapid formation of aggregates. Specifically, enhanced ZDR and KDP are frequently interpreted as the depositional growth of plate-like particles and the increase in DWR as aggregation. However, radars only observe the effect of ice microphysical processes (IMPs) on the observed particle distribution, not the IMPs themselves. Therefore, especially the origin of the plate-like particles which might cause enhanced ZDR and KDP are not fully understood. Common hypotheses include ice crystals which sediment into the DGL from colder temperatures, primary nucleation due to an updraft and local activation of INP and secondary ice production (SIP), possibly ice-ice collisional fragmentation.
In this contribution, we combine zenith triple-frequency (X, Ka, W-band) and slant-viewing W-band spectral polarimetric radar observations with Monte-Carlo Lagrangian particle modeling to shed light on the typical DGL radar signatures. The Monte-Carlo particle model McSnow allows us to describe and investigate IMPs on the detailed particle level. Recently, a habit prediction scheme which simulates the evolution of ice crystal shape and density has been implemented. Ice habit, particle size, density and fall velocity are core information for radar forward simulations, facilitating the comparison with radar observations and allowing to link the radar observations to specific IMPs. New laboratory studies on ice-ice collisional fragmentation allowed us to implement a fragmentation scheme in McSnow. To make full use of the rich information content of the McSnow simulations, a new radar forward operator has been developed. The forward operator is based on DDA calculations of more than 1500 ice crystals with varying habits, as well as 600 aggregates with varying degrees of riming. McSnow simulations suggest that the particles responsible for the increase in ZDR need to be produced within the DGL, either via primary or secondary ice production. The simulations further suggest that the increase in KDP at -15℃ might be linked to fragmentation. Surprisingly, our study also suggests that the increase in KDP is not only caused by ice crystals, aggregates also have a significant contribution to KDP.

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