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Evaluating ice microphysics in the new ICON model using triple-frequency cloud radar observations

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Understanding ice microphysical processes is equally challenging for modelers and observationalists because of the vast number of degrees of freedom involved. Even state-of-the-art two-moment schemes, such as implemented in the new German ICOsahedral Nonhydrostatic (ICON) model, are still facing problems to correctly reproduce basic ice microphysical processes such as depositional growth and aggregation. Retrieval algorithms based on remote sensing observations face similar challenges due the necessary assumptions in the inversion methods. In this study, we combine novel multi-frequency cloud radar observations with a versatile model framework which allows us to perform specific experiments to explore the potential sources of model-observation discrepancies. This contribution aims to exemplarily show how we can utilize the rich microphysical fingerprint in modern remote sensing observations to evaluate and improve the parametrizations of microphysical processes.

The observational basis are data of three ground-based vertically pointing Doppler radars (X, Ka and W band) which are continuously recorded at the Jülich Observatory of Cloud Evolution (JOYCE) in Jülich, Germany since 2018. The reflectivity differences in the triple-frequency observations have been previously shown to contain information about the average ice particle size and density. The Doppler velocity provides additional constraint to the average particle sedimentation velocity which is a very critical quantity in model parametrizations.

During intensive observation periods, we also continuously run 200 km wide nested ICON simulations with 600 m horizontal resolution centered over the JOYCE site. In order to compare the model simulations with the radar observations, we use the Passive and Active Microwave Transfer Tool (PAMTRA) which allows to exactly match the ICON assumptions about ice and snow particles (e.g. mass-size relation) using the self-similar Rayleigh-Gans Approximation for their scattering properties.

Thanks to the long-term statistics of high-resolution model simulations together with multi-frequency radar observations, we are able to identify discrepancies between model and observations statistics which we can relate to microphysical processes using the information in the multi-frequency space. After this identification, we run several microphysical experiments for case studies to test the influence of microphysical choices such as particle geometry, fall speeds, or particle size distribution on depositional growth and aggregation and their associated simulated radar reflectivities and Doppler velocities. First results reveal for example that a major difference between model and observations origins from fall velocity parametrizations for the snow component which cause the snow to fall much faster in the model than observed. This discrepancy in fall velocities has a direct impact on the aggregation process itself.