Assessing ice microphysics parameterization in the new ICON model using triple-frequency Doppler cloud radar observations

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The proper representation of cloud microphysical processes is essential for the accurate simulation of weather and climate in numerical models. Despite the continuous scientific advancements, the parameterizations employed in microphysical schemes are still affected by large uncertainties. Due to the limited computational resources, even state-of-the-art two-moment schemes, such as the one implemented in the ICOsahedral Nonhydrostatic (ICON) model, have to assume predefined properties for hydrometeors (shape, mass, terminal fall speed, etc.) that will generally describe the "representative" particle properties regardless of their natural variability. Such properties have a significant impact on the cloud microphysical processes (such as aggregation, riming, precipitation, etc.) and, together with large scale dynamics, drive the evolution of clouds and precipitation.

Cloud microphysical properties leaves distinctive fingerprints on multi-frequency Doppler radar observations. The reflectivity differences in the triple-frequency observations have been previously shown to contain information about the average ice particle size and density, moreover the Doppler velocity provides additional constraint to the average particle fallspeed which is a critical quantity in model parameterizations. We evaluate potential model-observation discrepancies by comparing forward simulated synthetic radar observations with real measurements. In this study, we leverage on novel triple-frequency Doppler cloud radar observations to evaluate and improve the parameterizations of cloud microphysical models.

The observational basis are data of three ground-based vertically pointing Doppler radars (X, Ka and W band) which have been continuously recorded at the Jülich Observatory of Cloud Evolution (JOYCE) in Jülich, Germany since 2018. During intensive observation periods, we also continuously run 100 km wide nested ICON simulations with 600 m horizontal resolution centered over the JOYCE site. The ICON forecasts are forward simulated using the Passive and Active Microwave TRAnsfer (PAMTRA) tool 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 rather long-term dataset of high-resolution model simulations and multi-frequency radar measurements, we are able to identify major inconsistencies between model and observations statistics which we can relate to microphysical processes. Thanks to the flexibility of the presented modeling framework, we are able to link the observed discrepancies to specific microphysical parameterizations. In fact, we run several experiments for case studies to test the influence of parameter choices such as particle geometry, fall speeds, or particle size distribution on depositional growth and aggregation and their associated simulated radar observations. 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, especially regarding the small snowflakes. By better representing the snow fall velocity in the simulations we aim to improve the modeling of the snow aggregation process itself which is known to be directly linked to ice particle fallspeed.