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Variabilities of ice water content, total number concentration and mean volume diameter for improved parametrizations using polarimetric retrievals

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Radar polarimetry and novel developed microphysical retrievals offer great potential for evaluating and improving the parameterization of numerical models. In this study, we intend to inform the subgrid parameterizations of the ICON general circulation model (ICON-GCM), more specifically, to assess and improve the spatial heterogeneity of ice water content at ICON subgrid scales. QVPs (Quasi-Vertical Profiles), generated by azimuthal averaging of various polarimetric radar variables from PPIs (Plan Position Indicators) acquired during standard conical scans at antenna elevation angles of 18°, successfully reduce statistical errors or uncertainties, especially in phase-based measurements such as K_{DP} (specific differential phase). The QVP method, with a horizontal resolution of about 50 km and a vertical resolution of 30-300 m, provides the ideal data basis for various robust polarimetric microphysical retrievals of ice water content (IWC), total number concentration (Nt), and mean volume diameter (Dm). Moreover, an attempt is made to improve the specific threshold used in ICON-GCM for the onset of aggregation (particle diameter < 0.1 mm for ice and > 0.1 mm for snow) by using estimated particle size distributions (PSD) assuming an exponential function. Although BoXPol (the polarimetric X-band radar in Bonn, Germany) is not sensitive to the smallest ice particles, this indirect method opens the possibility to determine and analyze the variabilities of ice and snow separately and finally evaluate and improve the parameterizations of ICON-GCM. However, the use of QVPs reduces information on sub-grid scale variability compared to the higher-resolved PPIs. A key question is therefore how much averaging is required for robust estimates of IWC, Nt, and Dm, and how we can separate spatial variability from noise. Statistical errors and spatial variabilities/azimuthal standard deviations of different IWC retrievals are analyzed using measurements from BoXPol. It is assumed that the real spatio-temporal variability equals the difference between the azimuthal standard deviation and the standard error of the mean computed over different ranges/heights. The standard error of the mean is calculated by Gaussian error propagation using Bienaymé's law, and it is investigated to what extent the azimuthal window size of 360° in the QVP methodology can be reduced while still guarantee acceptable statistical errors of the IWC, Dm, and Nt retrievals. Finally, based on a large BoXPol data set, statistics of the real IWC variability as a function of height are presented and compared to simulations of ICON-GCM. A new method is presented in which Shannon's information entropy is used to test the distribution of Zlin (linear

reflectivity) for homogeneity within the PPIs.