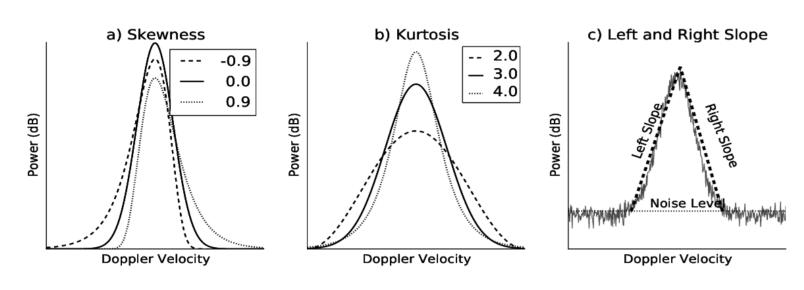
Using Higher Radar Moments to Study Ice Clouds Evaluating Ice Cloud Parameterizations

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1. Motivation

- There are still gaps in the understanding of microphysical properties and processes of ice clouds. Almost any attempt to fill these gaps requires that ice cloud properties such as particles number, mass or area have to be expressed by in dependence of a size descriptor (D).
- Evaluating these laws and the methods to gain the required coefficients using remote sensing instruments is challenging because errors in the various parameterizations and assumptions can cancel each other out.
- Radars do not only observe reflectivity and mean Doppler velocity, but a full Doppler spectrum. The higher moments spectral width, skewness and kurtosis together with the slope of the peaks provide additional information which makes cancelation of errors less likely.



 We use the Pamtra model developed at U Cologne as a forward operator. It can simulate active and passive microwave measurements using the T-Matrix approach for calculation of scattering properties.

2. Setup Measurements of number Aircraft concentration N, area A and IWC have to be parameterized measurements to gain formulas and coefficients for N(D), A(D) and Parameterization mass m(D). We use maximum diameter as size descriptor Pamtra Radar Forward operator One cannot compare aircraft **Statistical** observations and remote sensing observations directly, Comparison because the observed volumes do not match. It is Radar observations possible, though, to do the comparison statistically, e.g.

→ Which parameterizations work best?

3. Statistical Comparison using Histograms ISDAC aircraft observations closer than 10 km to Barrow Kolmogorow-Smirnow Parameterizations used + Pamtra forward model statistic Offset of medians MMCR observations, Barrow, Alaska of the same time Mass: Brown-Francis relation 0.12 -0.63 🚺 0.076 -15 Area: Measurement **PSD: Measurement** Mass: Fractal geometry Area: Measurement **PSD:** Measurement **Parameterizations** Mass: Fractal geometry Area: Power law fit **PSD: Measurement** _{0.36} Mass: Fractal geometry Area: Power law fit + Noise PSD: Measurement \(\nabla_{\text{*}} \) Mass: Fractal geometry Area: Power law fit +Noise PSD: Least Square Gamma Mass: Fractal geometry Area: Power law fit +Noise **PSD: Normalized Gamma** 0.3 0.6 0.9 1.2 -9 -3 3 9 1 2 3 4 5 6 7 30 60 90 120 -120-90-60-300.2 Reflectivity Z_{ϵ} [dB] Skewness Sk [-] Spectral Width σ [m/s] Kurtosis Ku [-] Left Slope S_l [dB/m/s] Right Slope S_r [dB/m/s] Fall Velocity W [m/s] Radar moments

Fractal geometry (Schmitt and Heymsfield 2010) providing m(D) for every profile works better than general Brown-Francis relation

by comparing histograms

Applying a power law to each measured area profile results in offsets in skewness

This offset can be reduced by applying noise to the result of the area-size relation

Deviations from the area-size relation are required to gain realistic results

Applying a least squares fit to gain the coefficients for a gamma distribution results in poor agreement of skewness and other higher moments

Using the normalization approach by Delanoë et al. 2005, which keeps the IWC constant, works better

Normalization approach works better than least square fit

4. Conclusions & Outlook

to measure with in-situ aircraft instruments.

- We are able to simulate higher radar moments. Simulations are consistent with observations
- The use of additional radar moments gives new possibilities to evaluate the use of various microphysical parameterizations of number concentration, area and mass of ice clouds.

Not all radar moments are equally well suited for evaluation: Reflectivity might be biased by calibration offsets,

Doppler velocity by vertical air motion. The right slope is highly influenced by rare, large particles, which are difficult

- In the future, higher moments can be also used for testing NWP models or as additional closure for retrievals.
- The parameterizations found in this study can be used to investigate the potential of higher moments for retrieval development.

Maahn, M., U. Löhnert, P. Kollias, R. C. Jackson, and G. M. McFarquhar, 2014: Observing ice clouds with Doppler radar higher moments. Part 1: Evaluating ice cloud parameterizations. Journal of Atmospheric & Oceanic Technology, submitted.

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