Investigating Micro-Physical Processes In Arctic Mixed-Phase Clouds Using Cloud Radar Doppler Spectra

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Low level mixed-phase clouds occur frequently in the Arctic, and are known to be important for the surface energy balance while not well represented in climate models. The aim of our work is to get a more detailed understanding of the processes in Arctic mixed-phase clouds (MPC) and the interaction between the clouds and their environment using a combination of remote sensing instruments operating at the French-German Arctic Research Base AWIPEV in Ny-Ålesund, Svalbard. The corner stone of our study is a frequency modulated continuous wave 94 GHz cloud radar installed at the station in June 2016 within the frame of the Arctic Amplification: Climate Relevant Atmospheric and Surface Processes and Feedback Mechanisms $(AC)^3$ -project. The high vertical (4 m in the lowest layer) and temporal (3 sec) resolution allows for a detailed description of the cloud structures. Synergistic approaches for classifying hydrometeor phase (i.e. Cloudnet) are applied.

Higher moments of the cloud radar Doppler spectra have rarely been utilized for Arctic MPCs. Similar to Kalesse *et al.* (2016), we find features in the skewness profiles that relate to changes in the partitioning between liquid and ice. At cloud top, where liquid is abundant, the skewness is positive as the liquid is dominating the radar signal (positive Doppler velocity indicating downwards motion). Lower in the cloud, owing to the growth of the ice particles, ice starts to dominate the signal and skewness turns negative. An algorithm to detect the positive-turning-negative skewness profile in the cloud top liquid layer was developed. Initial analysis suggests that the feature is found in 2/3 of the persistent low-level MPCs identified in the data set. Selected case studies have been analyzed in detail to identify connections between skewness and other (radar) parameters. Figure 1 illustrates the relationship between skewness and reflectivity in the vertical profile in a cloud present above AWIPEV for 5.5 hours on the 8 January 2018.

The work presented contributes to the understanding on how the moments of the Doppler spectra, especially skewness, can be used for interpreting micro-physical properties and processes in MPCs. Furthermore, by using a radar forward operator we will be able to evaluate model simulations of MPCs directly in the observational space.

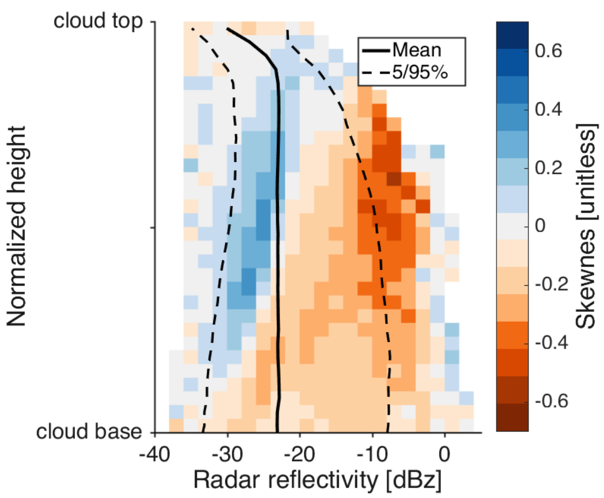

Figure 1. The solid and dashed black lines show the mean and 5/95 percentiles of radar reflectivity at each height, respectively. The color indicates the mean skewness of each normalized height-reflectivity bin. When skewness is positive (negative), the radar signal is dominated by super-cooled liquid (ice). Positive Doppler velocity indicates downwards motion.