Long-term Analysis of Vertically Resolved Cloud Observations at Ny-Ålesund (Svalbard) from Self-supervised Deep Learning

Kerstin Ebell, Nils Risse, Dwaypayan Chatterjee, Andreas Walbröl, Marion Maturilli, Simone Bauer, Susanne Crewell and Mario Mech

Climate change is strongly pronounced in the Arctic. In particular, Arctic warming from 1979 to 2001 is three times higher than the global mean warming (Zhou et al., 2024). However, this temperature increase is not uniform over the Arctic: for example, the Svalbard archipelago, which is located in the warmest region of the Arctic, reveals the highest temperature increase (Dahlke and Maturilli, 2017).
Understanding the specific role of clouds in the rapidly changing Arctic climate system and the associated processes is still a key challenge. Detailed cloud observations are needed, but only a few sites exist in the Arctic where continuous cloud observations with a high vertical resolution are performed. One of these sites is the German-French Arctic Research Base AWIPEV, which is part of the Ny-Ålesund Research Station, Svalbard. Here, a 94 GHz cloud radar has been installed as part of the Transregional Collaborative Research Centre TR172 on Arctic Amplification $(AC)^3$ (http://www.ac3-tr.de; Wendisch et al., 2023) in 2016. Together with the existing remote sensing capabilities, e.g., ceilometer and microwave radiometer, clouds are continuously monitored with a high temporal and vertical resolution. This presentation will highlight some of the results of these multi-year cloud radar observations.

We find an average cloud occurrence of 78% at Ny-Ålesund, with low-level clouds between 0.5 to 1.5 km showing the highest cloud occurrence. While pure liquid water clouds show a distinct seasonal cycle, mixed-phase clouds, which contain both liquid and ice, occur all year long (on average 42% of the time). These liquid-containing clouds have a crucial impact on the surface radiative fluxes with an overall net cloud warming effect of about 11 Wm^{-2}.

A new way to characterize the various cloud states at Ny-Ålesund is the application of a self-supervised learning framework. This framework learns sub-hourly radar reflectivity features that represent the vertical and temporal cloud structures of the Ny-Ålesund column. Analyzing this representation of the entire cloud radar time series provides insights into cloud evolution and its relation to environmental conditions.

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