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

Climate change is particularly evident in the Arctic, where warming between 1979 and 2021 was almost four times faster than the global average (Rantanen et al., 2022). However, this temperature increase is not uniform across the region. For example, the Svalbard archipelago, situated in the warmest part of the Arctic, has experienced the most significant warming (Dahlke and Maturilli, 2017). Understanding the role of clouds in the rapidly changing Arctic climate system, along with the underlying processes, remains a major challenge. While detailed cloud observations are crucial, only a few Arctic locations with continuous, high-resolution vertical cloud measurements exist. One of these sites is the German-French Arctic Research Base AWIPEV, located at the Ny-Ålesund Research Station in Svalbard. Here, a 94 GHz cloud radar has been operational since 2016 as part of the Transregional Collaborative Research Centre TR172 on Arctic Amplification (AC)³ (http://www.ac3-tr.de; Wendisch et al., 2023). Combined with existing remote sensing tools such as ceilometers and microwave radiometers, this setup enables continuous monitoring of clouds with high temporal and vertical resolution. This presentation will showcase key findings from these multi-year cloud radar observations.A novel approach to efficiently characterize the long-term observations of diverse cloud systems over Ny-Ålesund is applied by using a self-supervised deep learning framework. This machine learning approach has been recently applied to satellite images of trade-wind cumulus clouds to describe their organizational variability (Chatterjee et al., 2024). For Ny-Ålesund, the method has been adapted to time-height images of cloud radar measurements. During training, it captures the non-linear, orthogonal aspects of the clouds' vertical and temporal structure over Ny-Ålesund and extracts the essential low-dimensional features. The extracted cloud features will be combined with additional measurements, e.g., cloud water amount, thermodynamics, radiation, and precipitation observations. In this way, we will gain valuable insights into cloud evolution and its dependency on the environmental conditions.