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Low-level clouds in a complex Arctic environment

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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 processes that lead to the commonality and persistence (from hours to even days) are not well understood. The aim of our work is to get a more detailed understanding of the processes in Arctic mixed-phase clouds and the interaction between the clouds and their environment using a combination of instruments operating at AWIPEV station in Ny Ålesund, Svalbard. The Svalbard archipelago lies in the warmest part of the Arctic and is influenced by relatively large mean transport of moisture and heat from the lower latitudes, and a large variability in this transport. Moreover, the surroundings of the station exhibit large variations in surface properties (glaciers, seasonal snow cover, and open water) as well as orography. These features modify the local boundary layer and the associated clouds.

The corner stone of our study is a novel frequency modulated continuous wave cloud radar (94 GHz) installed at the AWIPEV 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 (2.5 sec) resolution allows for a detailed description of the structure of the cloud. Supplementary instruments operated by AWI are used to detect super-cooled liquid inside the cloud: a ceilometer and a microwave radiometer. We take advantage of synergistic approaches developed for classifying hydrometeor phase (i.e. Cloudnet algorithm). For evaluating the coupling of the cloud to the surface in a temporally continuous manner, a new method based on microwave-radiometer and surface observations has been developed and evaluated through comparison with simultaneous radiosonde observations.

We present an objective algorithm for identifying persistent (duration longer than one hour) low-level mixed-phase clouds observed above Ny Ålesund. From all clouds appearing, such clouds occur in 19% of the time, with a median duration of two hours and a maximum duration of 34 hours. These numbers show that persistent low-level mixed-phase clouds are important factors also in the complex coastal environment of Svalbard. The occurrence of these clouds has been evaluated considering the height of the cloud, the extent of coupling with the surface, and the direction of free-tropospheric wind that drives the advection of clouds. From the two-year time series of cloud observations, we find many interesting features, such as: clouds predominantly coupled to the surface bear more liquid water and have a higher liquid fraction, while predominantly decoupled clouds produce more ice. Independent of the coupling state, clouds advected from over the sea contain more ice than those advected to the site from over the island, although cloud top temperatures are similar.

The results presented here are a first step for studying a multi-year time series of Arctic mixed-phase clouds in Svalbard. There is great potential to use these observations to evaluate numerical models and their inherent microphysical parameterizations.