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The Impact of CCN Concentrations on the Thermodynamic Properties of Arctic Mixed-Phase Clouds

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Low-level mixed-phase clouds, abundant in the Arctic climate, significantly affect the surface radiative budget. Moreover, they are expected to play an important role in the currently ongoing Arctic Amplification. Unfortunately, these clouds are still not properly represented in weather forecast models and in climate models. While there has been an increasing number of field observations of the ice clouds in Arctic, the model studies of low-level clouds in the Arctic have rarely examined the impact of cloud nucleation on the resulting properties of clouds.

This model study aims to partially fill this gap in the current understanding of low-level Arctic clouds. The main focus is on the impact of the cloud condensation nuclei (CCN) concentration on the cloud development and turbulent mixed-layer dynamics. We configure semi-idealised model scenarios with a semi-Lagrangian frame of reference, based on the weather situation observed during ACLOUD and PASCAL campaigns which took place Northwest of Svalbard. The large-scale forcings as well as initial conditions are constructed from a combination of ECMWF analyses and short-range forecasts. For each scenario, we perform an ensemble of model runs with a different initial setting of CCN. All runs are performed in the modified version of the Dutch Atmospheric Large Eddy Simulation (DALES) with the extension for a full double-moment five-species mixed phase microphysics. The results of model runs are compared with the airborne observations.

The results show that while the ice phase forms just a fraction of the mass of cloud water, it is responsible for most of the precipitation. A lower initial CCN concentration results into a faster glaciation of the cloud, leading to a faster removal of the cloud water. However the effect is not proportional to the differences in CCN concentrations. Implications for the role of mixed-phase clouds in Arctic warming will be discussed.