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Importance of secondary ice production over a large temperature range in Arctic mixed-phase clouds

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The cloud radiative feedbacks are particularly complex and uncertain in the Arctic, which is a region of amplified warming. Within mixed-phase clouds (MPCs), the radiation fluxes are influenced by the thermodynamic phase and cloud particle concentrations. However, the processes responsible for ice crystal formation, particularly secondary ice production (SIP) processes, are still poorly understood.

We conducted in-situ cloud microphysical measurements in Ny-Ålesund, Svalbard, as part of the Ny-Ålesund AeroSol Cloud ExperimeNT campaign (NASCENT, Pasquier et al., BAMS, in revision). The main instrument used was a holographic cloud probe mounted on a tethered balloon system to image cloud particles. Additionally, ambient ice nucleating particles (INPs) and cloud condensation nuclei (CCN) were measured at ground level, remote sensing instruments (e.g. cloud radar) profiled the entire troposphere, and radiosondes were launched to determine the in-cloud temperature profiles.

Here we discuss the SIP occurrence in Arctic MPCs measured in autumn 2019 and spring 2020. We defined local SIP as occurring when the concentration of pristine ice crystals smaller than 100 µm in diameter is larger than the INP concentration. During the six days of measurements in MPCs, regions with local SIP were observed in 40% of the in-cloud measurements. Regions with high concentrations of small pristine ice crystals (>10 L^{-1}) coincided with the presence of large frozen and broken drops, providing evidence for SIP during the freezing of drizzle drops. We suggest that the formation of drizzle drops initiating high SIP upon freezing was determined by the low CCN concentration in the pristine Arctic environment. Furthermore, SIP occurred at all observed temperatures (-24 °C to -2 °C). The frequency of SIP occurrence was highest in the temperature range between -24 °C and -18 °C (up to 96%), whereas the concentration of small pristine ice crystal peaked between -5 °C and -3 °C (up to 95 L^{-1}). Our observations demonstrate the high importance of SIP for ice crystal formation in Arctic MPCs over a larger temperature range. Thereby, SIP influences the radiative properties of Arctic MPCs and hence the surface radiative energy budget.