EGU22-4889
https://doi.org/10.5194/egusphere-egu22-4889
EGU General Assembly 2022

Arctic low-level mixed-phase clouds produce large aggregates predominantly at dendritic-growth temperatures: evidence from long-term remote sensing observations in Ny-Ålesund

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Low-level mixed-phase clouds (MPCs) occur widely and frequently in the Arctic, and on average introduce a strong positive radiative forcing. While precipitation is expected to affect radiative characteristics of Arctic MPCs, the relevancy of precipitation-formation processes, such as aggregation and riming, has been widely overlooked. An incomplete understanding of precipitation-formation processes in Arctic MPCs is likely to impact our ability to accurately simulate their evolution, macrophysical characteristics, and radiative effects.

We employ a 3-year dataset of remote sensing observations from Ny-Ålesund, Svalbard, including two vertically-pointing Doppler radar systems, measuring at K- and W-band, to statistically assess the relevancy of aggregation and riming in Arctic low-level MPCs. We use the ratio of radar reflectivities measured at the two frequencies as a proxy for particle size, and match it with Doppler velocity information and temperature retrievals, to identify situations when the ice-particle growth is dominated by either aggregation or riming.

We find observational evidence that large ice particles (mass median diameter > 1mm) mostly form when the mixed-phase layer of the low-level MPC is at temperatures compatible with dendritic growth (-15 to -10°C). Fall speeds of these larger particles are incompatible with significant riming. While mixed-phase layer temperatures between -15 and -10°C seem to be essential for the formation of large aggregates, these larger hydrometeors are not uniformly distributed across the cloud field. They are in fact observed in small pockets, suggesting that further dynamical processes might be needed to fully explain these signatures.

Surprisingly, we find no evidence of enhanced aggregation at temperatures above -5°C in Arctic low-level MPCs. This is typically observed in mid-latitude clouds, and in deeper cloud systems in Ny-Ålesund as well. We hypothesize that ice particles sedimenting from higher levels might be an essential component needed to trigger enhanced aggregation above -5°C. We will discuss potential reasons for the absence of this feature, which are likely connected to the specific ice habits growing at these temperatures, as well as enhanced riming.