Supplement of Atmos. Chem. Phys., 26, 8001–8020, 2026
https://doi.org/10.5194/acp-26-8001-2026-supplement

Supplement of

Quasi-Lagrangian observations of cloud transitions during the initial phase of marine cold air outbreaks in the Arctic – Part 2: Vertical cloud structure

Anna Weber et al.

Correspondence to: Anna Weber (weber.ann@physik.uni-muenchen.de)

S1 Vertical distribution of cloud thermodynamic phase

Similar to the profiles of the ice index and ice fraction as a function of temperature, pseudo-vertical profiles of both quantities as a function of height can be constructed by combing the measured ice indices and ice fractions with the corresponding cloud top heights from the stereographic retrieval. The resulting profiles for different time ranges above open ocean are shown in Fig. S1. Similar to the profiles as a function of temperature, the ice index in the first 15 min above open ocean is mostly below 20, indicating a pure liquid water cloud. The ice fraction is affected by sea ice in this first time range and hence overestimated. Afterward, the ice index and ice fraction both increase with time and height, and the clouds are in a mixed-phase regime throughout the vertical profiles. This agrees with the temperature dependence of the cloud thermodynamic phase, as the temperature typically decreases with altitude. At the very top, the ice fraction shows a strong and sharp decrease for most time ranges. This decrease is also partly captured in the vertical profiles of the ice index, but it is less pronounced for the ice index. This confirms the existence of a geometrically thin, more liquid-dominated mixed-phase layer at cloud top compared to the altitudes directly below. This layer has a geometrical thickness of approximately 100 m to 200 m. For times above open ocean larger than 210 min, the cloudbow range was outside the field of view of the specMACS instrument due to large solar zenith angles and no ice fractions could be derived.

S2 Influence of 3D radiative effects on retrieved ice indices

To investigate the influence of 3D radiative effects on the retrieved ice indices and quantify the corresponding uncertainty, the retrieved ice indices were divided into two groups, depending on their cloud optical thickness. To this end, the classical bispectral retrieval method by Nakajima and King (1990) assuming liquid water clouds was applied to the measurements of the SWIR to determine the cloud optical thickness of every measured pixel. The assumption of entirely liquid clouds introduces an additional uncertainty, but the bispectral retrieval method exists only for either liquid water clouds or ice clouds and the aim is to obtain a rough estimate of the cloud optical thickness only. Pixels with an optical thickness smaller than 10 (which was the median of all derived optical thicknesses) were classified as optically thin and pixels with a larger optical thickness as optically thick. Afterwards, pseudo-vertical profiles for different time ranges above open ocean were constructed for both groups of ice indices, similar to the analyses presented in Fig. 2. The resulting profiles are displayed in Fig. S2. Even though some smaller differences between the pseudo-vertical profiles for optically thin and optically thick clouds are visible, the agreement between both is generally very good. This indicates that 3D radiative effects do not have a significant impact on the derived pseudo-vertical profiles and the corresponding analyses.

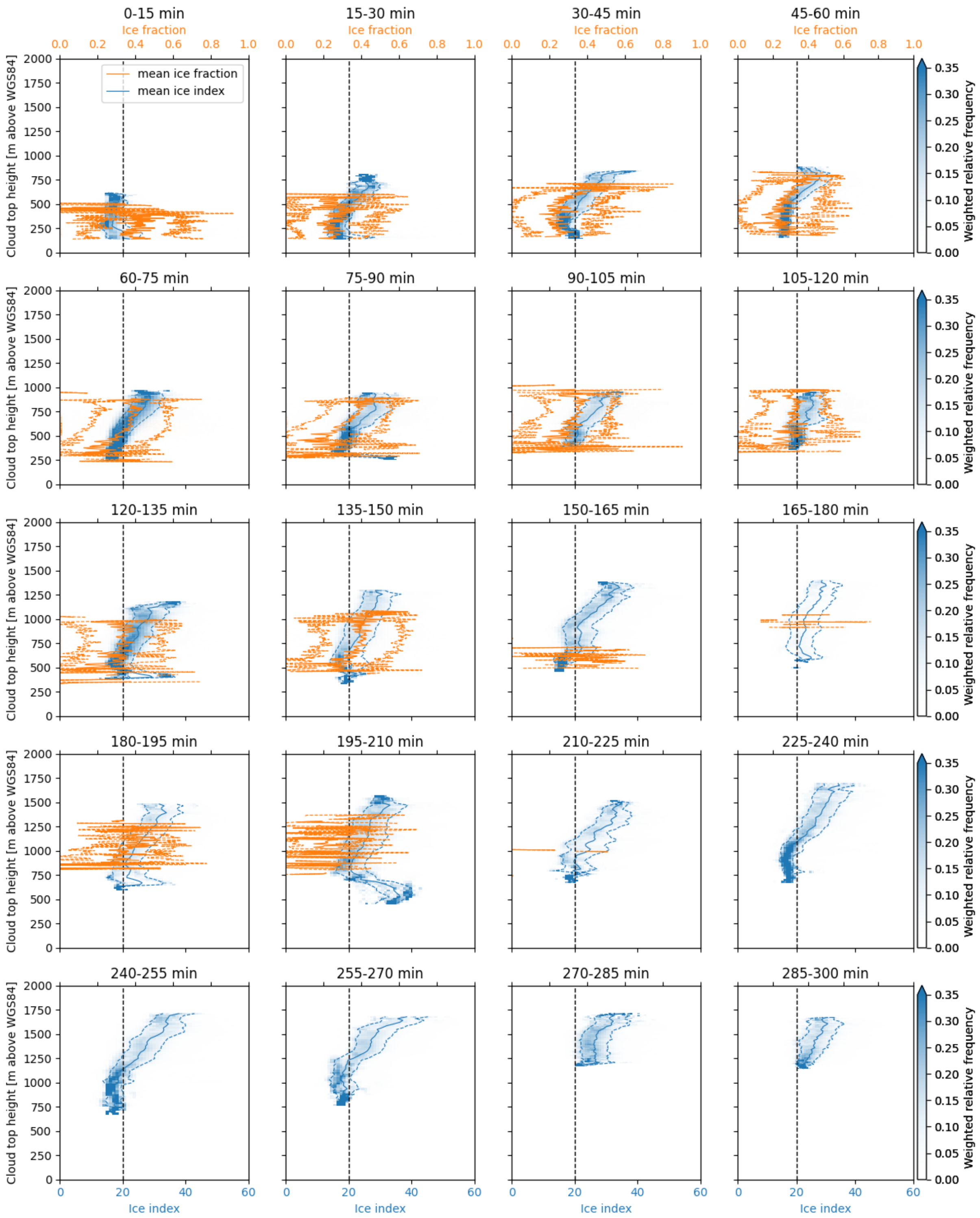

Figure S1: Histograms of ice index (blue) and ice fraction (orange) as a function of cloud top height for different time ranges above open ocean retrieved from specMACS observations. The solid lines denote the respective means and the dashed lines the standard deviation. The black dashed line indicates the threshold value between liquid water and mixed-phase clouds for the ice index. For the ice fraction, the standard deviation (orange dashed lines) is partly at the borders or outside the panels. The ice fraction was derived with the IDEFAX parameterization of 3D cloud geometry for the cloudbow range and only saturated observations were included in the analysis.

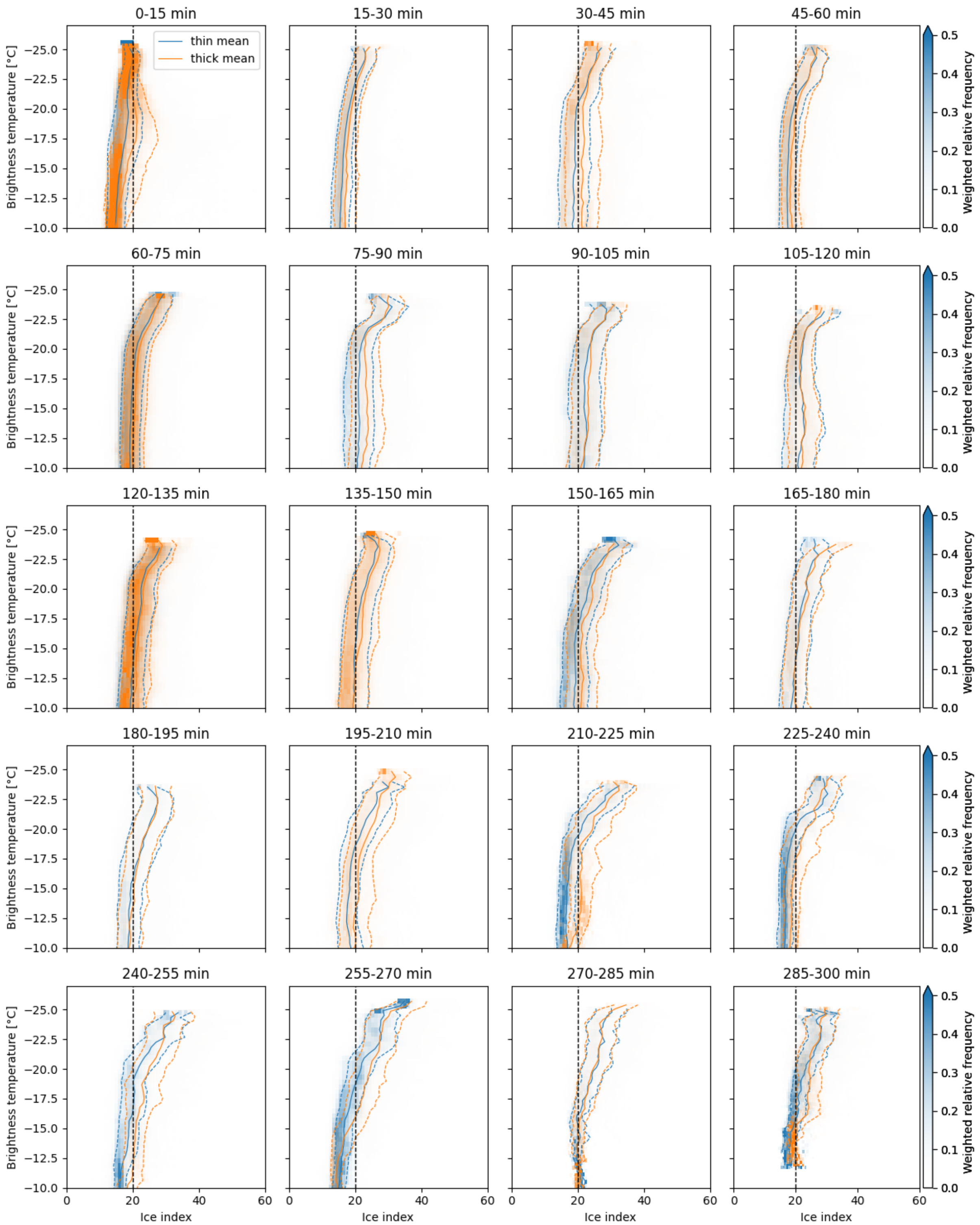

Figure S2: Histograms of the ice index for optically thin (blue) and optically thick clouds (orange) as a function of brightness temperature for different time ranges above open ocean retrieved from specMACS observations. The solid lines denote the respective means and the dashed lines the standard deviation. The black dashed line indicates the threshold value between liquid water and mixed-phase clouds for the ice index.

References

Nakajima, T., and M. D. King: Determination of the Optical Thickness and Effective Particle Radius of Clouds from Reflected Solar Radiation Measurements. Part I: Theory. J. Atmos. Sci., 47, 1878–1893, https://doi.org/10.1175/1520-0469(1990)047<1878:DOTOTA>2.0.CO;2, 1990.