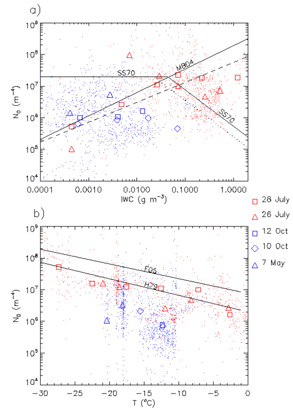
Snow Particle Observations in Arctic Clouds

Research Highlight

Arctic clouds are a critical component of climate, in part by impacting surface radiative fluxes and hence the surface energy budget and evolution of sea ice. In this study, in situ aircraft observations gathered during the 2004 Mixed-Phase Arctic Cloud Experiment (M-PACE) and 1997–98 Surface Heat Budget of the Arctic Ocean/ First ISCCP Regional Experiment - Arctic Clouds Experiment (SHEBA/FIRE-ACE) field projects were analyzed. The focus was on observations of ice crystals and snowflakes with size greater than 0.4 mm, which are less affected by contamination from shattering on instrument probes compared to smaller particles. In particular, this study analyzed how ice particle characteristics vary between two important Arctic cloud types: shallow, low-level mixed-phase clouds and deep frontal clouds. It is important to characterize ice particle microphysical properties, given their impact on cloud microphysical and macrophysical evolution.

Overall, the shallow cases had much lower values of ice particle concentration and ice water content than the deep frontal cases, indicating large differences in ice initiation and growth between these regimes. Within a given case for both the shallow and deep frontal systems, and for the data set as a whole, crystal concentration had little correlation with temperature (height), despite an active aggregation process that was indicated by large aggregates (> 5 mm) observed in four out of the five cases. Exponential size distributions were fitted to the observations, allowing a direct comparison with snow particle size distributions that are represented with exponential functions in weather and climate models. Values of the fitted size distribution intercept parameter were generally 2–10 times smaller for the shallow compared to the deep frontal cases as a result of the differences in crystal concentration between these regimes. Values of intercept parameter specified in many models are broadly consistent with fitted values for the deep cases but much larger than values for the shallow cases. The deep frontal cases also exhibited a relationship between intercept parameter and temperature consistent with previous observations of midlatitude frontal systems. However, there were no consistent differences in intercept parameter between the shallow and deep cases when partitioned by ice water content.

Specification of the size distribution intercept parameter for snow leads to uncertainty in many weather and climate models given its impact on several important microphysical processes. Previous modeling studies have shown that reducing the intercept parameter for snow by about an order of magnitude from typical values specified in these models (generally based on midlatitude frontal cloud observations) leads to more realistic simulations of shallow, low-level Arctic mixed-phase clouds. The present study provides observational evidence for relatively low values of intercept parameter in these cloud systems relative to Arctic and midlatitude deep frontal systems. These findings can also be used to evaluate models that utilize more detailed microphysical parameterizations that predict rather than specify the snow intercept parameter. Generalization of these results will require analysis of additional cases from Arctic field experiments as these data become available. Ground and space-borne remote retrievals will also help to characterize snow microphysical characteristics in this region from a longer-term perspective.



Fitted size distribution intercept parameter (N0) as a function of a) ice water content, IWC, and b) temperature, T, for 10-sec data (dots) and case average spectra (symbols). Results for the shallow and deep cases are shown in blue and red, respectively. Also shown are relationships based on lower-latitude observations (SS70, H79, MB04, F05). The dash line indicates the best-fit N0-IWC relationship.

Reference(s)

Morrison H, P Zuidema, GM McFarquhar, A Bansemer, and AJ Heymsfield. 2011. "Microphysical observations in shallow mixed-phase and deep frontal Arctic cloud systems." Quarterly Journal Royal Meteorological Society, 137(659), doi:10.1002/qj.840.

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Cloud Life Cycle