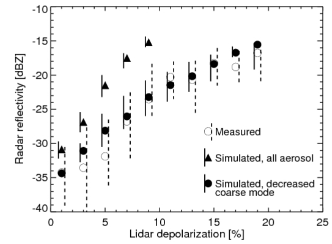
Influence of Humidified Aerosols on Lidar Depolarization Below Ice-Precipitating Arctic Clouds

Research Highlight

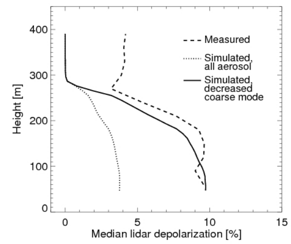
A key objective of the Atmospheric System Research (ASR) program is to advance understanding of Arctic clouds using a collection of long-term remote-sensing measurements from the North Slope of Alaska. Lidars are an indispensable part of the instrument suite because they can provide a wealth of information about macro- and microphysical properties of aerosols and clouds over the ground site. For instance, lidar depolarization measurements can be used to study and classify ice crystals because depolarization depends upon the microphysical properties of the ice crystals present, including their habit, aspect ratio, and orientation as they fall. Under mixed-phase conditions (when liquid water and ice are both present), depolarization also provides information about the relative concentrations of ice crystals, which result in relatively high depolarization values, and water drops, which lead to depolarization values near zero.

In this study we focus on linear depolarization measurements by the Depolarization and Backscatter Unattended Lidar (DABUL) during the Surface Heat Budget of the Arctic Ocean (SHEBA) Intensive Operation Period (IOP). In a well-observed case of long-lived Arctic stratus with low liquid water path and light ice precipitation, depolarization measurements beneath cloud base were consistently below the range of theoretical values associated with different ice habits. Investigating this further, we found that depolarization ratios correlate well with radar reflectivities measured by the millimeter wavelength cloud radar (MMCR), suggesting that depolarization variability is associated with ice water content variability rather than ice habit variability. However, no liquid droplets were observed (or expected) below cloud base to explain the low depolarization values in the regions with low ice concentrations. We therefore adopted the hypothesis that such low depolarization values are associated with humidified aerosol particles. To test this hypothesis, we calculated the depolarization values that would result from a realistic mixture of aerosol and precipitating ice (provided by large-eddy simulations that were known to reproduce mean observed MMCR reflectivities and Doppler velocities, as well as mean ice particle size distribution features observed in situ from aircraft).

Using reasonable assumptions about the aerosol size distribution, we were able to match the observed low depolarization values and their correlation with radar reflectivity, as well as their vertical profile decrease with elevation. However, we note that model results indicated that lidar depolarization under such conditions is strongly dependent upon the properties of the largest particles, which were not measured in this case and would need to be measured accurately in order to strongly constrain results. These calculations demonstrate that humidified aerosol need to be taken into account when interpreting lidar depolarization measurements for cloud and precipitation phase discrimination or ice habit classification, at least under conditions similar to those observed during SHEBA. Future work will consider whether evaporating drizzle can generate a contrasting impact on depolarization below cloud base.



Correlated MMCR radar reflectivities and DABUL lidar depolarizations below cloud base calculated with a reasonably low number of large, coarse-mode particles (filled circles) reproduces measured values (open circles).



Below cloud base height of about 280 m, the profile of median depolarization simulated with a reasonably low number of large aerosol (solid line) reproduces the main vertical trend of measured vales (dashed line). Calculations neglect multiple-scattering, which is important above cloud base.

Reference(s)

van Diedenhoven B, AM Fridlind, and AS Ackerman. 2011. "Influence of humidified aerosol on lidar depolarization measurements below ice-precipitating Arctic stratus." Journal of Applied Meteorology and Climatology, 50(10), doi:10.1175/JAMC-D-11-037.1.

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