Geophysical Research Abstracts
Vol. 20, EGU2018-5076, 2018
EGU General Assembly 2018

Small-scale horizontal distribution of cloud thermodynamic phase of Arctic mixed-phase clouds derived from airborne imaging spectral cloud reflectivity observations during ACLOUD

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The distribution of ice and liquid water within Arctic mixed-phase clouds might be a key parameter to understand their frequently observed persistence. Furthermore, the small-scale cloud-phase horizontal distribution is suspected to significantly influence their cloud radiative forcing by changing the reflected solar radiation.

To investigate these issues, spectral solar imaging observations of cloud top reflectivity collected during the Arctic CLoud Observations Using airborne measurements during polar Day (ACLOUD) campaign (Svalbard, May-June 2017) are used to characterize the small-scale variability of horizontal cloud phase distribution at scales of less than 100 m. Traditional phase discrimination methods are based on the different absorption signatures of liquid water and ice imprinted onto the cloud top spectral reflectivity. For clouds over bright snow or sea ice surfaces, the surface absorption features will imprint as well onto the cloud top reflectivity and may bias the cloud phase discrimination. However, radiative transfer simulations assuming clouds with different microphysical and optical properties indicate that the spectral slope of cloud reflectivity in the region between 1500 and 1800 nm wavelength is most suited as a phase indicator for clouds with high optical thickness over both dark (i.e. open ocean) and bright (i.e. snow) surfaces. The method was applied to 19 scientific flights performed during ACLOUD with the Polar 5 research aircraft. 80 flight hours of cloud imaging remote sensing provide a comprehensive data set of Arctic cloud reflectivity under different scenarios. Based on the measured maps of spectral cloud reflectivity the spatial distributions of the so-called phase index are derived which exhibit a significant variability of the cloud phase on different spatial scales. Stratiform clouds show a higher phase index at small scales of about 100 m associated with thin cloud filaments in their downdraft areas. Additional cloud layers in slightly higher altitudes were frequently observed to change the observed cloud phase on larger horizontal scales (5 km). The analysis of the remote sensing observations shows that the synergy with other instruments onboard Polar 5 (e.g., cloud radar, lidar and 180° fish-eye camera) improve the interpretation of the cloud phase index by considering the small scale horizontal variability of cloud optical thickness and the cloud vertical structure.