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The Radiative Effect of Thin Boundary Layer Clouds in the Arctic

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Thin boundary layer clouds are important for the shortwave Arctic surface energy budget, and may have an influence on melt processes near the marginal ice zone – especially leading up to the sea ice minimum in September. Unfortunately, the only viable approach to date for estimating low-cloud radiative effects in the Arctic is active remote sensing because passive imagery retrievals have small skill detecting and characterizing low-level clouds. Infrared retrievals lack the necessary temperature contrast between the clouds and the underlying surface, and are often hampered by low-level inversions. Similarly, shortwave retrievals of clouds above bright surfaces lack dynamic range in reflectance to provide meaningful retrievals, and incomplete knowledge about the surface properties translates into unacceptably high uncertainties. The shortcoming of passive imagery in the Arctic constitutes a considerable obstacle for attaining spatial coverage of cloud radiative effects in the high Arctic. A possible way around this problem is to use reflectance observations in the shortwave infrared wavelength range, where snow reflects less than in the visible, thus increasing the useable dynamic range for cloud property retrievals. For example, the state-of-the-art retrieval employed by MODIS (Moderate Resolution Imaging Spectroradiometer) operates with two channels in this "sweet spot" of the shortwave wavelength range. However, information content analysis, presented in this contribution, shows that two channels in the shortwave infrared are actually insufficient to attain reliable retrievals of cloud optical thickness, thermodynamic phase, and effective radius (the key parameters for cloud radiative effects) for thin low-level clouds above snow. We will discuss how many channels in this wavelength range are optimal to provide reliable cloud retrievals, given the variability of the underlying surface albedo. Our analysis is supported by field data from two NASA experiments: ARCTAS (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites, Spring 2008) and ARISE (Arctic Radiation - IceBridge Sea&Ice Experiment, Autumn 2014). Specifically, we use shortwave spectral irradiance measured by aircraft as below- and above-cloud validation of cloud radiative effects derived from MODIS retrievals. Spectral cloud albedo measurements, on the other hand, are the basis for validating MODIS retrieval products, and for exploring the more advanced multi-channel approaches. We show that the addition of shortwave infrared channels would significantly advance our capability to derive cloud radiative effects from satellite observations in the Arctic. Finally, we discuss ways to plan field missions in the Arctic to optimize their benefit for satellite remote sensing, and to decrease the uncertainty of surface cloud radiative effects in this data-sparse region of the globe.