Cloud Phase Determination in the Arctic from Downwelling Infrared Radiance Spectra

D.D. Turner*[1,2] and S.A. Ackerman[1]
[1]CIMSS/SSEC, University of Wisconsin-Madison, Madison, WI
[2]Pacific Northwest National Laboratory, Richland, WA

In the Arctic, longwave energy lost to space over an annual cycle is much larger than the shortwave energy absorbed. However, energy from the mid-latitudes is transported into the region via the ocean and atmosphere, and thus the cooling of the Arctic serves to cool the planet in general and makes the Arctic one of the primary heat sinks for the Earth. Clouds can have large impacts on the radiative transfer, and thus the energy budget, depending on the optical properties of the clouds (i.e., optical depth, single scatter albedo, and scattering phase function). These optical properties are dictated by the physical properties of the cloud such as its thermodynamic phase, particle size, number density, temperature, and geometrical thickness. Cloud phase is very important, as the refractive indices of ice and liquid water are different across most of the EM spectrum. However, until recently, there have been precious few cloud property data sets collected in the Arctic, and none of them covered a large enough time range from which seasonal statistics could be inferred.

The Department of Energy's Atmospheric Radiation Measurement (ARM) program has established a long term (>10 yr) site at Barrow, Alaska (71.3°N, 156.6°W) in 1998. This site has a broad range of in-situ and remote sensing instrumentation to measure and infer atmospheric and cloud properties. While it has active sensors such as a millimeter cloud radar and lidar, neither have polarization diversity to provide information on cloud phase. We have developed an algorithm that determines cloud phase from downwelling high-spectral resolution radiance observations made by the Atmospheric Emitted Radiance Interferometer (AERI) at the ARM site. This algorithm takes advantage of the distinct differences in the absorption coefficient of ice and liquid water at 12 μm (where the ice is more absorbing than water) and at 18 μm (where the opposite is true). Simulations were used to characterize the performance of the algorithm, demonstrating that the cloud phase was accurately determined for all cases, with the only exceptions occurring when the fraction of the optical depth due to liquid water was over 70%. This algorithm was applied to AERI data collected during the Surface Heat Budget of the Arctic Ocean (SHEBA), during which a co-located polarization diverse lidar was available to evaluate the skill of the AERI's phase determination algorithm. Case studies and monthly statistics on cloud phase from the two methods will be presented and discussed.

Building upon the success of the phase determination algorithm, we have also developed an algorithm to physically retrieve the optical depth and effective particle sizes of the water and ice components of Arctic clouds from the observed AERI radiance spectrum. Retrievals from simulated AERI data were used to demonstrate the accuracy of the algorithm and its sensitivity to various perturbations. Results from several case studies will also be shown and discussed.

*Corresponding Author: Dave Turner, dturner@ssec.wisc.edu