Radiative Heating Rate Profiles over the ACRF NSA Site

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Introduction
A multi-sensor conditional cloud property retrieval algorithm has been developed for the ARM NSA site. This “microbase” algorithm was used to determine the cloud properties over the NSA site for 2 years (Mar ’04 - Feb ’06). These cloud properties were input into the Broadband Heating Rate Profile (BBHRP) framework to compute radiative fluxes at the surface and TOA as well as radiative heating rate profiles.

Surface Flux Comparison
The retrieved cloud properties, at 1-min resolution, were input into the RRTM and the computed fluxes were then averaged to 5-min resolution and compared against the ARM observations. The data were separated into different classes: “single-layer” and “double-layer” clouds of liquid-only, mixed-phase, and ice-only clouds.

• A cloud layer is a vertically continuous region of the atmosphere that contains hydrometeors.
• A cloud layer is considered mixed-phase if ice and liquid hydrometeors exist anywhere in the cloud layer (i.e., not necessarily in the same volume).

A couple of comments:
• Some optically thin cloud cases are being classified as clear sky, which inflates the StDev and bias (esp. for the LW results)
• All of the SW StDev values are similar for cloudy cases
• Mean bias values for single-vs double-layer cases (for the respective cloud phase) are similar except for liquid-only clouds in SW (a 20 W/m² change)

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Yearly Distribution of LWC and IWC
Previous results have highlighted the prevalence of mixed-phase clouds across the annual cycle in the Arctic. Our retrievals allow the number of vertical cloud levels to be determined, as well the vertical distribution of LWC and IWC. Interestingly, liquid water exists as high as 8 km!

Yearly Distribution of Longwave (LW) and Shortwave (SW) Radiative Heating
The BBHRP framework provides vertical profiles of radiative heating. The annual cycle of the radiative heating rate show a strong seasonal dependence both in the lowest 2 km and in the mid-troposphere. The patterns in the annual heating rates match the distribution of liquid water content well. The SW heating rate forcing (computed as all-sky minus clear sky) shows heating in the 4-8 km range in the summer (liquid water absorption in mixed-phase clouds) with cooling in the 1-3 km range below due to the shading effect of the mid-tropospheric clouds. Both the LW and SW results show strong sensitivity to the boundary layer liquid clouds, which increase in height into the fall.

Vertical Heating Rate Distribution by Cloud Type
The vertical distributions of liquid water content (LWC) and LW heating rate for different cloud situations illustrate how dependent the radiation is on the cloud properties and vertical distribution (and in particular the liquid water).

• Little LWC above 4 km in liquid-only clouds, but significant LWC above 4 km for mixed-phase clouds (orange ovals)
• Strong radiative cooling in lowest 1 km for single-layer clouds with liquid water, but much less cooling when there are multiple liquid layers (red ovals)
• LW warming from 2-6 km in mixed-phase clouds may help to maintain upper-level liquid layer (cyan ovals)

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