Radiative Heating Rate Profiles over the ACRF NSA Site

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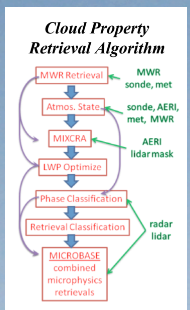
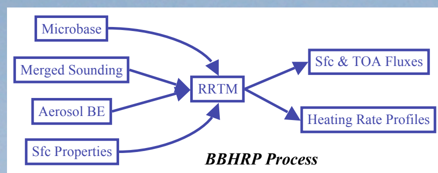
Introduction



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.

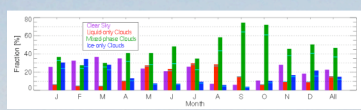


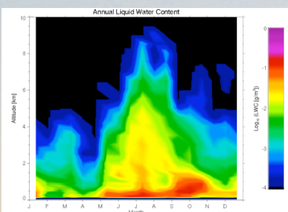
Acknowledgments

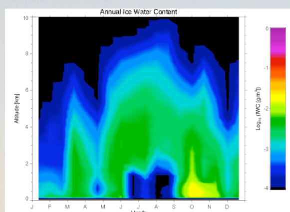
We would like to thank Sally McFarlane (for coordinating the BBHRP runs), Connor Flynn (for aerosol best-estimate product), and Mike Jensen and David Troyan (for the Merged Sounding product)

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!







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)

Longwave Surface Flux Residuals (Obs minus Calc) [W/m²]

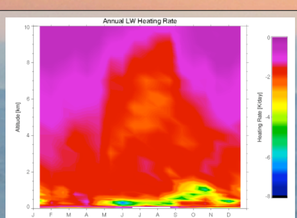
		Mean Diff	StDev Diff	Median Diff	N
	Clear Sky	0.9	15.2	-2.8	27971
Single layer Cloud	Liquid-only	-4.5	15.3	-6.7	16606
	Mixed-phase	-4.3	10.3	-6.2	29148
	Ice-only	7.9	16.9	2.8	11131
Double layer Cloud	Liquid-only	-10.6	20.5	-7.5	491
	Mixed-phase	-4.1	11.1	-5.0	12848
	Ice-only	7.1	16.6	3.6	2172

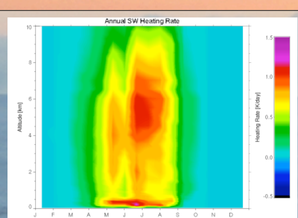
Shortwave Surface Flux Residuals (Obs minus Calc) [W/m²]

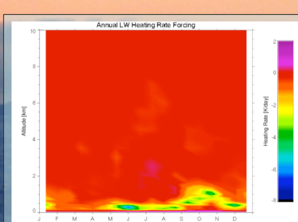
		Mean Diff	StDev Diff	Median Diff	N
	Clear Sky	-13.7	40.7	-9.1	13293
Single layer Cloud	Liquid-only	-9.9	59.9	-9.0	6447
	Mixed-phase	-12.4	53.2	-9.5	7231
	Ice-only	-28.8	58.5	-14.5	4094
Double layer Cloud	Liquid-only	10.7	73.9	-1.0	240
	Mixed-phase	-17.6	59.1	-14.3	5143
	Ice-only	-29.4	55.0	-19.5	851

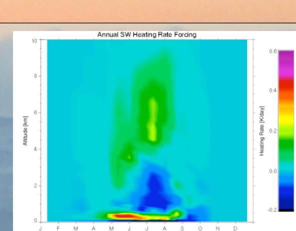
Yearly Distribution of Longwave (LW) and Shortwave (SW) Radiative Heating

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.







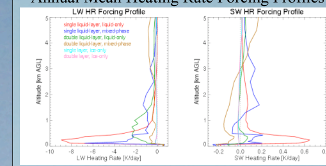


Vertical Heating Rate Distribution by Cloud Type

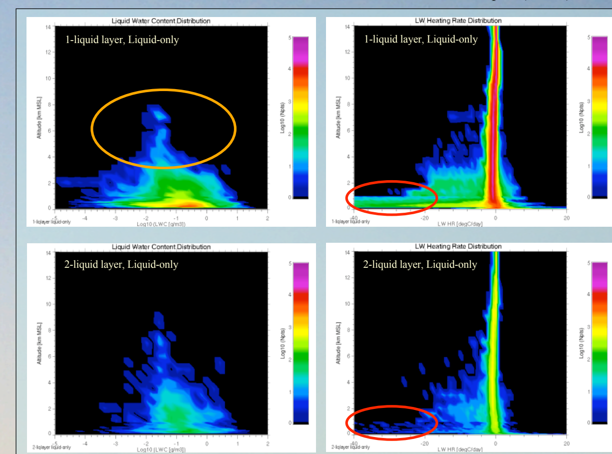
The vertical distributions of liquid water content (LWC) and LW heating rate for different cloud situations illustrate how dependent the radiation is on the cloud properties and vertical distribution (and in particular the liquid water).

- 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*)

Annual Mean Heating Rate Forcing Profiles



- Radiative heating in ice-only clouds is much smaller than clouds with liquid (above)



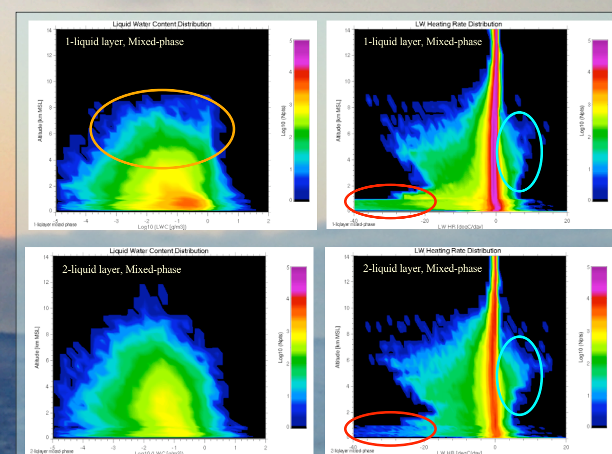


Photo by D. Turner at NSA site, Mar 2007