Using Ground-Based Cloud Radars for GPM Validation and Snowfall Algorithm Development Purposes

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I. Overview

Long-term snowfall radar signatures are studied using the Ka-band (35 GHz) millimeter wavelength cloud radar (MMCR) at the North Slope Alaska (NSA; Fig. 1) Atmospheric Radiation Measurement (ARM) Climate Research Facility. This project has the following primary goals:

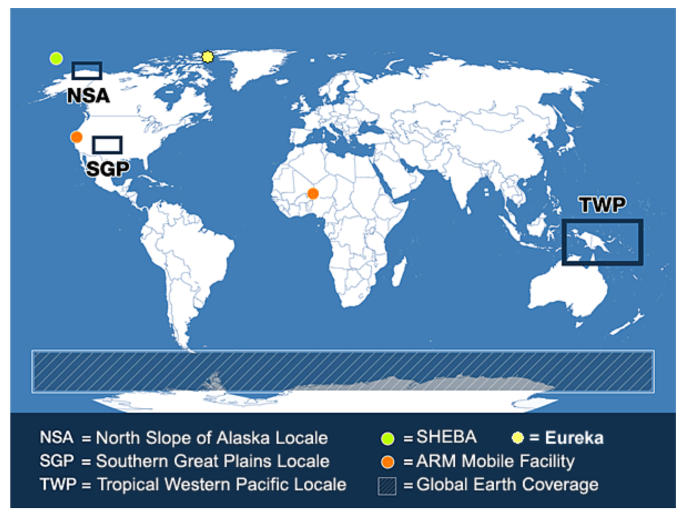

Fig. 1: ARM radar sites. Data from the NSA site are used in this study. (Image courtesy of the ARM Data Archive website)

- Compile long-term snowfall radar statistics to compare with vertically-pointing radar sites around the world;
- Provide near-surface snowfall reflectivity profile information to correct space-based snowfall estimates (e.g., Fig. 2);
- Provide ground-based radar comparisons for space-based sensors [e.g., the Global Precipitation Measurement (GPM) Dual-Frequency Precipitation Radar (DPR)];
- Infer microphysical details of snowfall.

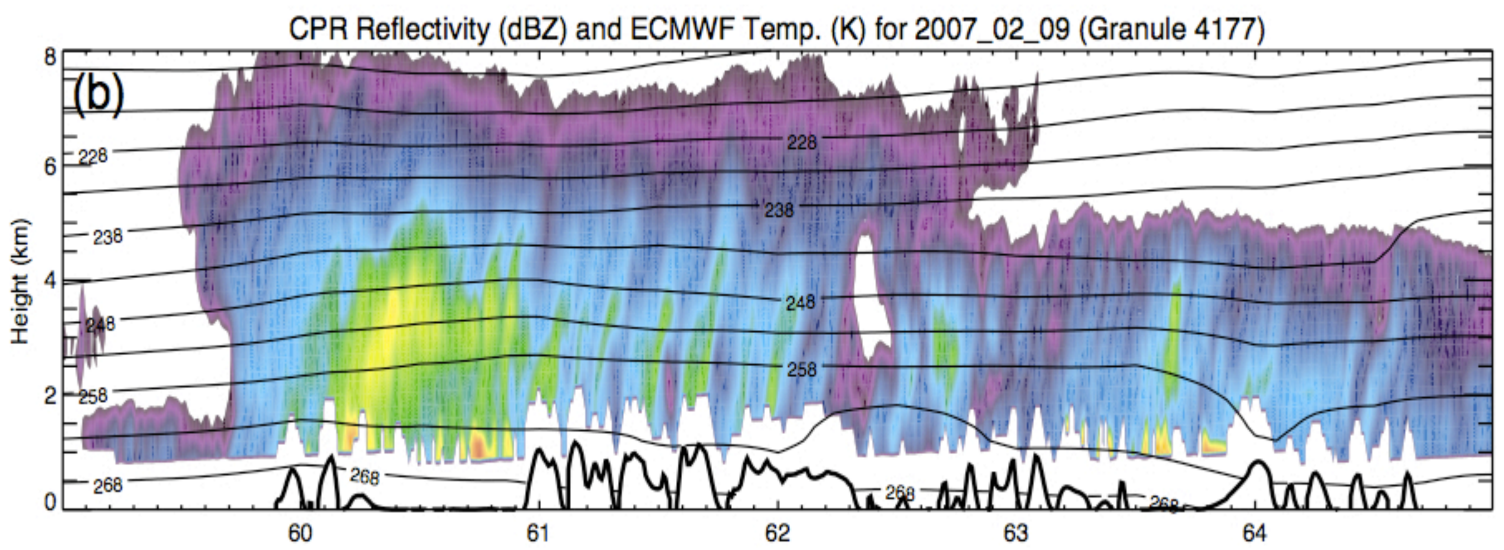

Fig. 2: CloudSat radar observations of a Greenland snowfall event. Thick, solid line indicates surface terrain. Note the data gap in the lowest ~1km AGL due to potential clutter contamination.

III. Reflectivity Profile Analysis

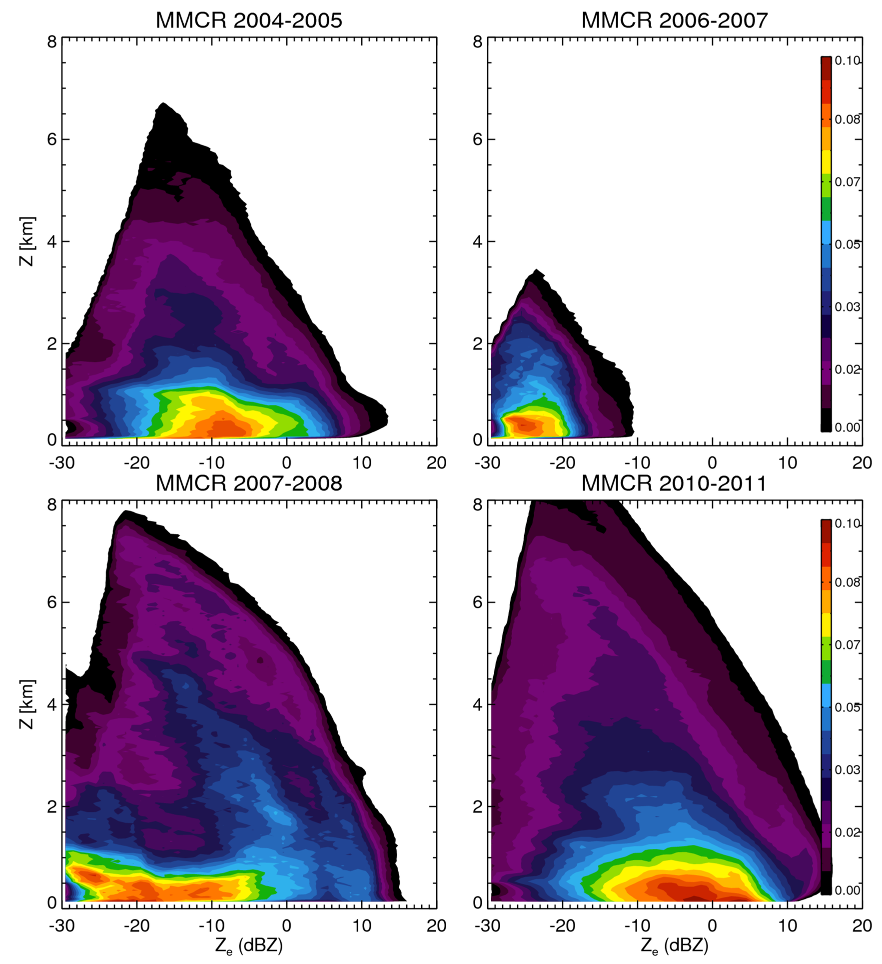

Fig. 4: Normalized frequency of occurrence (scaled by 100) for MMCR reflectivity versus height for select winter seasons.

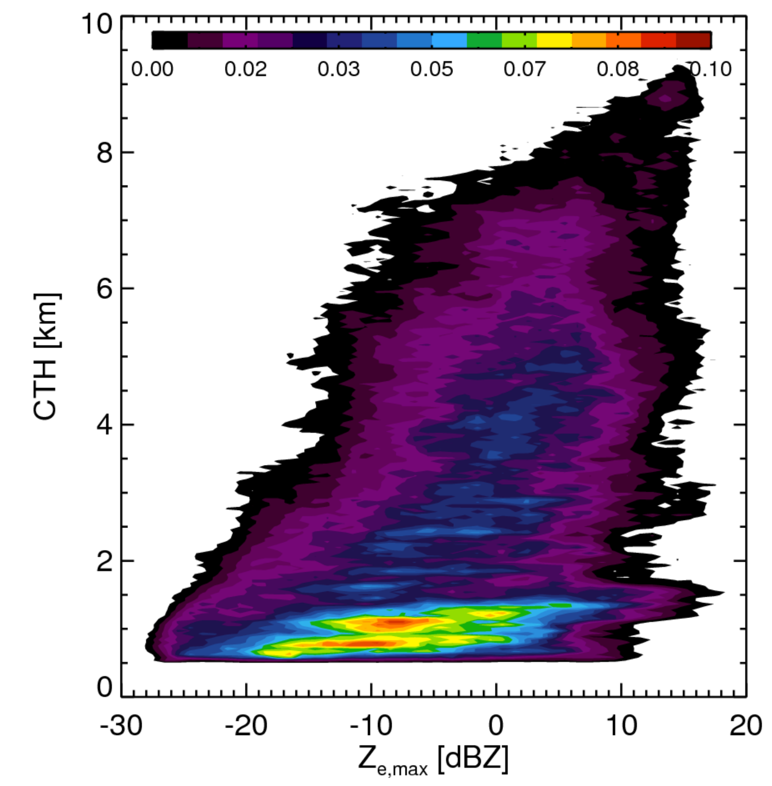

Fig. 5: Normalized frequency of occurrence (scaled by 100) for maximum columnar reflectivity versus cloud top height (CTH).

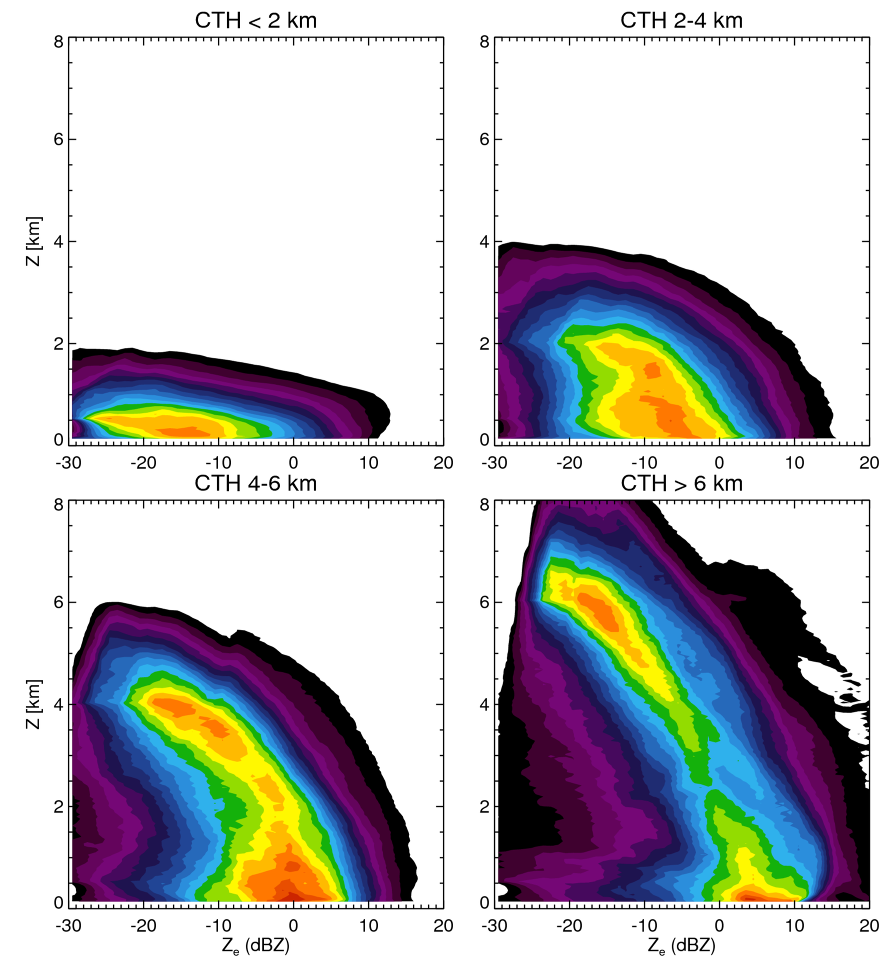

Fig. 6: Same as Fig. 4, but categorized by four cloud top height (CTH) regimes.

- The inter-annual variability of snowfall-associated reflectivities is depicted in Fig. 4. Some winters have almost exclusively shallow snowfall associated with very light reflectivities (e.g., 2006-2007), while other winters frequently experience snowfall from deeper systems associated with higher reflectivities (e.g., 2010-2011). The shallow precipitation mode is associated with sometimes persistent mixed-phase clouds that have been well-documented at the NSA site.
- The maximum columnar MMCR reflectivity is generally dependent on cloud top height (Fig. 5), except for the shallow snowfall mode that can sometimes produce larger reflectivities with low cloud top heights.
- Reflectivity profiles are dependent on the cloud top height (Fig. 6) and can be used for near-surface reflectivity profile corrections to space-based radar observations.
- Multi-frequency GPM Microwave Imager simulations can be made using ARM radar and ancillary datasets (e.g., soundings, ground-based microwave radiometer temperature and moisture retrievals, etc.) to build the atmospheric column.

II. Reflectivity Histograms

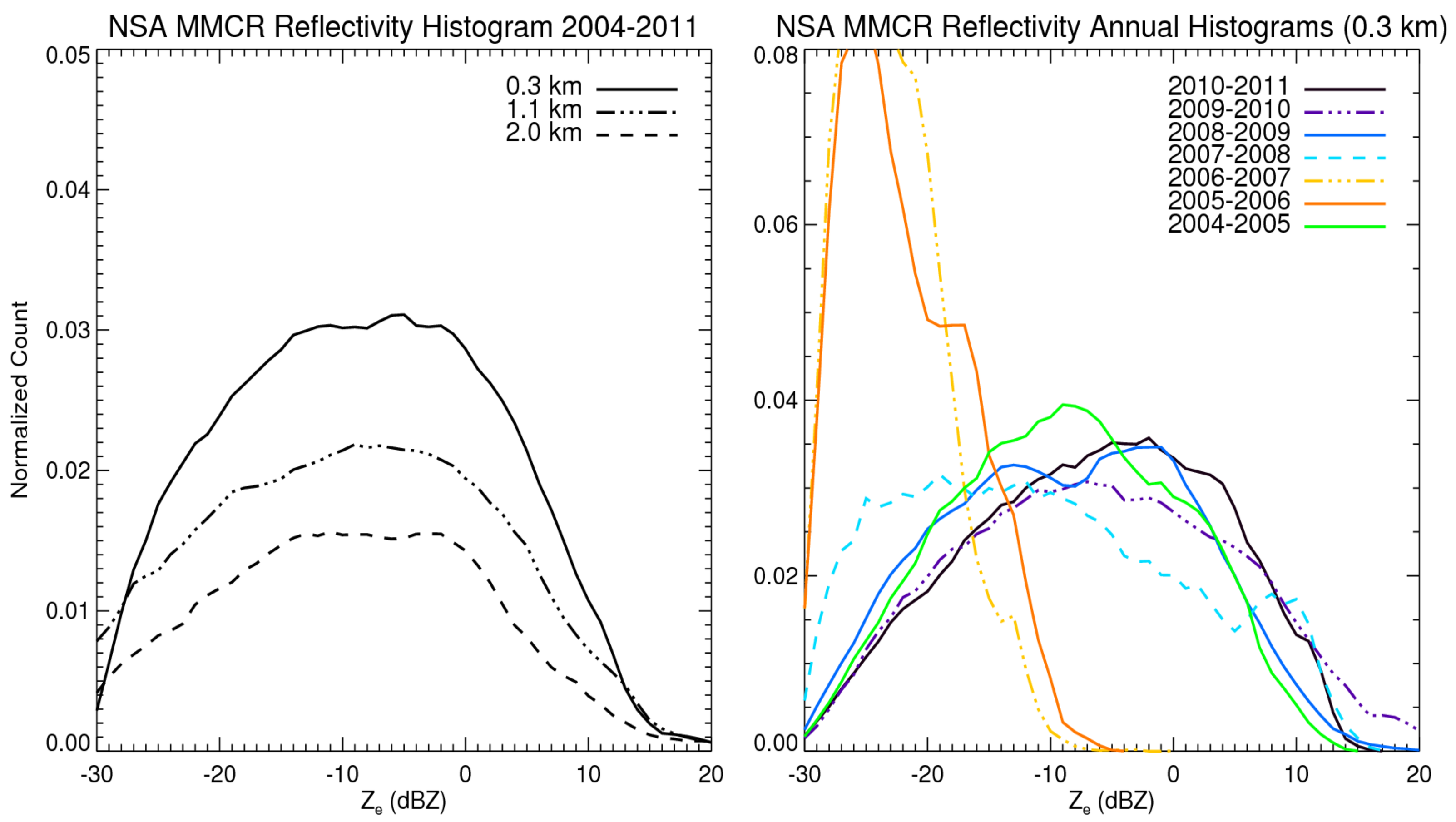

Fig. 3: Radar reflectivity histograms for the 2004-2011 dataset shown at various heights AGL (left) and annual histograms at 0.3 km AGL (right).

•MMCR radar reflectivity histograms associated with NSA 2004-2011 snowfall events are shown in Fig. 3 .

•Reflectivity data are included in the histograms only if they exceed -30 dBZ in data bins 2 through 5 and the surface temperature is sub-freezing. A -10 dB reflectivity correction was applied to 2008-2011 data (see ARM web site for details).

•There can be significant inter-annual NSA snowfall reflectivity variability. The 2006-2008 winter seasons are dominated by light and shallow snowfall events, although snowfall frequency is considerably less than other years (not shown). Other years show differences, but are also sensitive to the reflectivity bias correction applied to post-2008 data.

•These histograms are useful for GPM validation purposes and for probability of detection statistics. The NSA snowfall histograms indicate that lighter snowfall dominates snowfall event frequency at this site and may be indicative of snowfall characteristics at other high latitude locations.

IV. Future Work

- Further analysis of this dataset and other ground-based radar datasets (e.g., ARM SGP and Eureka sites, Summit Greenland, GCPEx).
- Long-term Doppler velocity and polarization fields can be analyzed to study “dry” versus “wet” snowfall frequency and typical reflectivity signatures.
- Multi-frequency microwave radiometer simulations will be performed using radar + ancillary datasets.
- Micro Rain Radar and Precipitation Video Imager deployment dedicated to GPM validation and snowfall retrieval development purposes will occur during the 2013-2014 and 2014-2015 winters in northern Michigan.

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