Snowfall retrievals using mm-wavelength cloud radar measurements

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Purpose: Extending ARM column hydrometeor retrievals to include solid precipitation cases

Approach: Z_e –S relations customized for the use with mm-wavelength radars. Using the Doppler information (moments and spectra) for quantitative retrievals in snowfall is limited because snowflake fall velocities do not exhibit clear size dependence (for D>2 mm or so).The Doppler information, however, provides valuable qualitative information on degree of snowflake riming thus separating "dry" snowfall from cases with substantial amounts of liquid water.

Z_e – S relations at mm-wavelengths:

Modeling with realistic snowflake shapes, mass- size relations, drag coefficients, and experimental snowflake size distributions result in the relations shown here →

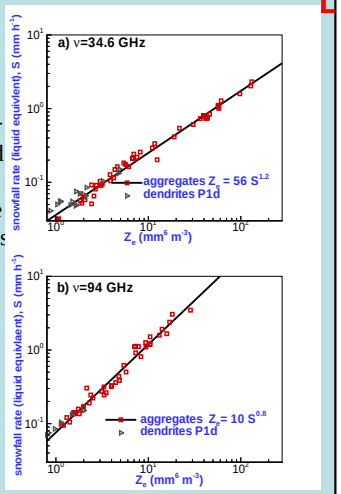

Fig.1. Z_e-S relations at K_a and W band frequencies

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MMCR-based snowfall retrievals

An example of snowfall retrievals using the NSA MMCR measurements is shown in Fig. 2. for the case 27 September 2004. Relatively small observed vertical Doppler velocities (less than 1.5 m/s except for last half hour) indicate either no riming or very limited riming aloft. Attenuation in "dry" snow at K_a-band is small and can generally be neglected.

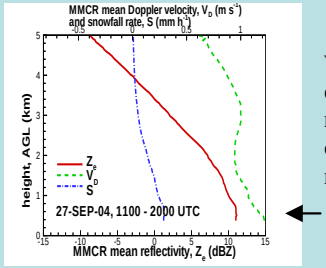

Fig.3. Mean profiles on 9/27/04.

While vertical variability of instantaneous snowfall reflectivity and intensity can be rather substantial mean profiles are usually smooth (Fig. 3).

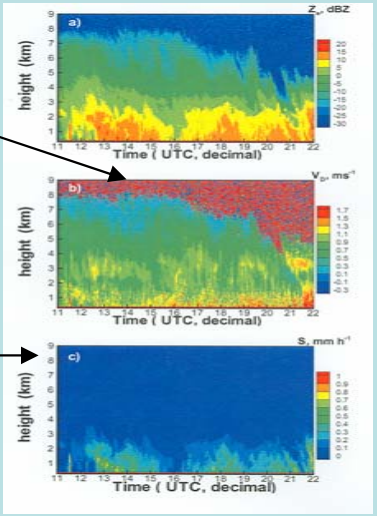

Fig.2. An example of NSA snowfall retrievals

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W-band snowfall retrievals

Due to a shorter wavelength, the reflectivity at W-band changes slower than at K_a-band as snow rate increases. In spite of strong non-Rayleigh scattering effects, W-band radar measurements can still be used for quantitative estimates of snowfall. Combination of K_a- and W-band radars at the SGP site can potentially provide more accurate retrievals of snowfall compared with single frequency measurements because of possibility of independent estimates of snowflake characteristic size. Meanwhile, the W-band CloudSat radar provides a unique opportunity for global observations of snowfall.

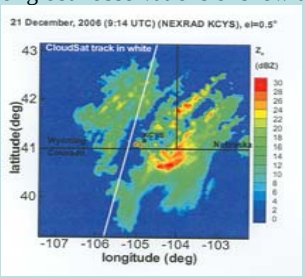

Fig. 5 The CloudSat track and NEXRAD reflectivities

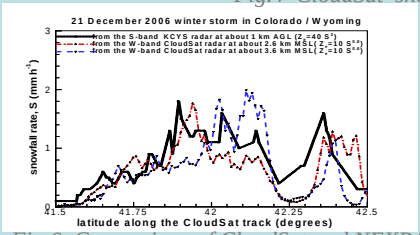

Fig.6. Comparison of CloudSat and NEXRAD

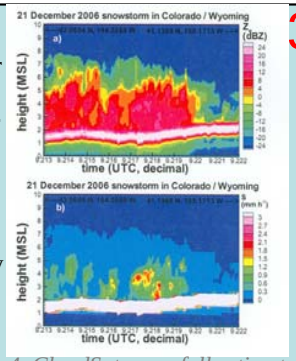

Fig.4 CloudSat snowfall estimates

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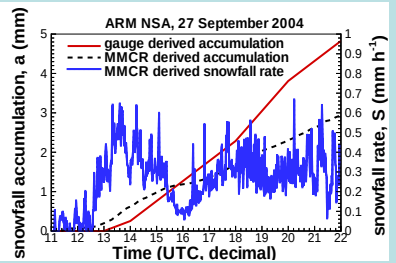
Uncertainties of mm - wavelength radar snowfall retrievals

Changes in microphysical properties of snowflakes and their size distribution details cause the variability in the Z_e – S radar relations. Comparisons with controlled surface snowfall measurements indicate that uncertainties can be as high as a factor of 2 (or even higher), which is comparable to errors that are typical for cm-wavelength precipitation radars.

Fig.7. An example of comparisons of MMCR snowfall retrievals (at the lowest gate) with gauge accumulations →



Conclusions:

- mm-wavelength vertically (or nadir) pointing radars can provide valuable information on snowfall
- snowfall vertical profile retrievals complement ARM cloud retrievals in the atmospheric column
- Doppler information (while not used for snow rate retrievals) provides information on snow riming
- uncertainties of snow retrievals with mm-wavelength radars are comparable with errors that are typical for precipitation radars