ESTIMATIONS OF SNOWFALL PARAMETERS FROM RADAR MEASUREMENTS AT DIFFERENT FREQUENCIES

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1. INTRODUCTION

Radar-based quantitative precipitation estimations (QPE) of snowfall are important in many meteorological, hydrological and climate study applications. Most of the existing snowfall QPE approaches use measurements of radar reflectivity, Z_e, and were developed for the use with radars operating at frequencies at S and C bands (i.e, for radar wavelengths, λ, of about 10 cm and 5 cm, respectively) [1]. However, shorter wavelength low cost scanning radars that operate at X-band frequencies (λ~3 cm) have lately gained considerable interest as a tool for high resolution precipitation measurements at closer ranges [2]. Ground-based and airborne/spaceborne vertically profiling K_a (λ~0.8 cm) and W (λ~0.3 cm) band millimeter-wavelength radars, while first designed for studies of non-precipitating clouds, also have been recently shown to be useful in retrieving snowfall information [3].

Although dual-wavelength radar approaches are potentially very promising for snowfall QPE [4], most operational and research radars operate at a single frequency. Most of the recent attention in shorter wavelength radar meteorological and hydrological applications was generally paid to rainfall studies and snowfall technique developments and observations have been relatively scarce. This study presents developments and validations of reflectivity-based radar approaches for retrievals of liquid equivalent snowfall rates, *S*, from X-, K_a- and W- band radar measurements.

2. APPROACH

Realistic snowflake models and theoretical and experimental particle size distributions from different geographical areas were used to derive $Z – S$ relations for "dry" snowfalls, which typically consist of snowflakes with only a limited degree of riming. Modeled and observational data on snowflake terminal fall velocities and their dependence on snowflake size were used in these derivations. Aggregate and single shape ice crystal (e.g., dendrites) habits were considered. It was shown that accounting for particle shapes when calculating their backscatter properties is more important at shorter radar wavelengths such as those at W-band.

The non-Rayleigh scattering effects, which are already present at X-band frequencies for snowflakes larger than 4 - 5 mm, are very strong at K_a- and especially at W-band. This results in a fact that shorter radar wavelength $Z_e – S$ relations are substantially different from the ones used with traditional precipitation radar frequencies at S- and C- bands. The variability in snowflake size - mass relations (i.e., the snowflake effective bulk density variability) to a large extent is responsible for the uncertainty of these relations. The variability in snowflake fall velocity – size relations and snowflake size distribution details also noticeably contribute to the uncertainty of $Z_e – S$ relations. Snowflake shapes and orientations (i.e., falling attitudes) also influence snowfall $Z_e – S$ relations but to a lesser extent compared to the factors mentioned above (especially at longer wavelengths).

3. RESULTS

The proposed $Z_e - S$ relations were tested with scanning X-band radar measurements performed as a part of the Hydrometeorlogical Testbed (HMT) field project in California's Sierra Nevada Mountains, vertically-pointing K_a-band radar measurements at the US Department of Energy's climate research facilities and nadir-pointing spaceborne W-band radar measurements from CloudSat. The radar retrieved snowfall parameters were compared with available ground-based observations obtained with surface disdrometers, snow gauges, estimates from S-band weather surveillance radars and other relevant observations. It was shown that the uncertainty of the radar-based estimates of snowfall can be as high as a factor of 2 and even higher in some instances. This uncertainty is typically larger than the uncertainty of reflectivity-based retrievals of rainfall rates. Since the snowfall reflectivity exhibits strong vertical gradients, accounting for these gradients (at least in a mean sense) for surface-based estimates of S is essential if the radar resolution volume is located at a significant height above the ground.

The vertical Doppler velocity measurements (when available) can be used to reduce uncertainties of the $Z_e - S$ relations and also for discriminating between "dry" and "wet" snowfalls. Polarimetric measurements can also result in enhancing the radar estimates of snowfalls that consist of snowflakes with simpler shapes. While polarimetric signatures of aggregate snowflakes are often rather weak and difficult to interpret quantitatively, these signatures from pristine snowflakes (e.g., dendrites) are very strong and can be used in combination with radar reflectivity measurements to get better snowfall parameter retrieval information.

4. REFERENCES

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