Assessment of Ku- and Ka-band Dual-Frequency Radar for Snow Estimates

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Dual-frequency radars have been increasingly used for detecting and retrieving cloud and precipitation, such as the Ku- and Ka-band Dual-frequency Precipitation Radar (DPR) aboard the Global Precipitation Measurement (GPM) core satellite. The objective of this study is to evaluate performance of the standard dual-frequency technique, which uses the differential frequency ratio (DFR), defined as the difference of radar reflectivities between two wavelengths, for the estimation of snow microphysical properties and the associated bulk parameters from Ku- and Ka-band as well as Ka- and W-band dual-frequency radars. Although the DFR-based technique is effective in obtaining snow properties, its retrieval accuracy depends on the model assumptions, which include parameterization of particle size distribution (PSD), empirical mass-size relation that links the observed geometrical size of particle to its mass, and the radar scattering model. The complex nature of snowflakes regarding shape, structure, and the inability of the modeled PSD to represent actual snow spectra, lead to errors in the estimates of snow parameters. Additionally, uncertainties associated with scattering computations of snowflakes also affect the accuracy of the dual-wavelength radar retrieval of snow. Therefore, understanding the uncertainties in snow precipitation estimation that depend on PSD parameterizations and scattering models of individual particles is important in evaluating the overall performance of dual-frequency retrieval techniques. Furthermore, separation of the uncertainties associated with the PSD models and the scattering models and their respective contributions to overall uncertainties are useful for gaining insight into ways to improve the retrieval methods.

Snow PSD is usually modelled as a gamma distribution with 2 or 3 free parameters depending on whether its shape factor is fixed or taken as a function of $D_m$. In this study, our focus is on an assessment of the uncertainties in snow estimates arising from the PSD parameterization and the mass-size relation. To do this, measured PSD data are employed. The snow mass spectra, which can be converted from measured PSD using an empirical mass-size relation, are used to obtain PSD parameters, e.g., the liquid-equivalent mass-weighted diameter ($D_m$) and the normalized intercept of a gamma PSD ($N_0$), and the snow bulk parameters, such as snow water content (SWC) and liquid-equivalent snowfall rate ($R$) if a measured fall velocity-size relationship is utilized. Coupling measured PSD with particle scattering model, measured radar parameters can be
computed, which are subsequently used as inputs to the standard dual-frequency algorithm. An evaluation of the retrieval accuracy is conducted by comparing the radar estimates of $D_m$, $N_w$, SWC and $R$ with the same quantities directly computed from the PSD spectra (or truth). In this study, measurements of the snow PSD and fall velocity acquired from the Snow Video Imager/Particle Image Probe (SVI/PIP) at the NASA Wallops flight facility site in Virginia are employed. There are several scattering databases available that provide the scattering properties of snow aggregates in accordance with various snow and ice crystal growth models. Variability of the snow estimates caused by the differences of various scattering tables will be analyzed to explore the uncertainties associated with the scattering tables.