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Sensitivity of C-band Polarimetric Radar-based Drop Size Distribution Measurements to Maximum Diameter Assumptions

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The estimation of rain drop size distribution (DSD) parameters from polarimetric radar observations is accomplished by first establishing a relationship between differential reflectivity (Z_{dr}) and the central tendency of the rain DSD such as the median volume diameter (D0). Since Z_{dr} does not provide a direct measurement of DSD central tendency, the relationship is typically derived empirically from rain drop and radar scattering models (e.g., D0 = F[Z_{dr}]). Past studies have explored the general sensitivity of these models to temperature, radar wavelength, the drop shape vs. size relation, and DSD variability. Much progress has been made in recent years in measuring the drop shape and DSD variability using surface-based disdrometers, such as the 2D Video disdrometer (2DVD), and documenting their impact on polarimetric radar techniques. In addition to measuring drop shape, another advantage of the 2DVD over earlier impact type disdrometers is its ability to resolve drop diameters in excess of 5 mm. Despite this improvement, the sampling limitations of a disdrometer, including the 2DVD, make it very difficult to adequately measure the maximum drop diameter (D_{max}) present in a typical radar resolution volume. As a result, D_{max} must still be assumed in the drop and radar models from which D0 = F[Z_{dr}] is derived. Since scattering resonance at C-band wavelengths begins to occur in drop diameters larger than about 5 mm, modeled C-band radar parameters, particularly Z_{dr}, can be sensitive to D_{max} assumptions. In past C-band radar studies, a variety of D_{max} assumptions have been made, including the actual disdrometer estimate of D_{max} during a typical sampling period (e.g., 1-3 minutes), D_{max} = C (where C is constant at values from 5 to 8 mm), and Dmax = M*D0 (where the constant multiple, M, is fixed at values ranging from 2.5 to 3.5). The overall objective of this NASA Global Precipitation Measurement Mission (GPM/PMM Science Team)-funded study is to document the sensitivity of DSD measurements, including estimates of D0, from C-band Z_{dr} and reflectivity to this range of D_{max} assumptions.

For this study, GPM Ground Validation 2DVD's were operated under the scanning domain of the UAHuntsville ARMOR C-band dual-polarimetric radar. Approximately 7500 minutes of DSD data were collected and processed to create gamma size distribution parameters using a truncated method of moments approach. After creating the gamma parameter datasets the DSD's were then used as input to a T-matrix model for computation of polarimetric radar moments at C-band. All necessary model parameterizations, such as temperature, drop shape, and drop fall mode, were fixed at typically accepted values while the D_{max} assumption was allowed to vary in sensitivity tests. By hypothesizing a DSD model with D_{max}(fit) from which the empirical fit to D0 = F[Z_{dr}] was derived via non-linear least squares regression and a separate reference DSD model with D_{max}(truth), bias and standard error in D0 retrievals were estimated in the presence of Z_{dr} measurement error and hypothesized mismatch in D_{max} assumptions.

Although the normalized standard error for D0 = F[Z_{dr}] can increase slightly (as much as from 11% to 16% for all 7500 DSDs) when the D_{max}(fit) does not match D_{max}(truth), the primary impact of uncertainty in D_{max} is a potential increase in normalized bias error in D0 (from 0% to as much as 10% over all 7500 DSDs, depending on the extent of the mismatch between D_{max}(fit) and D_{max}(truth)). For DSDs characterized by large Z_{dr} (Z_{dr} > 1.5 to 2.0 dB), the normalized bias error for D0 estimation at C-band is sometimes unacceptably large (> 10%), again depending on the extent of the hypothesized D_{max} mismatch. Modeled errors in D0 retrievals from Z_{dr} at C-band are demonstrated in detail and compared to similar modeled retrieval errors at S-band and X-band where the sensitivity to D_{max} is expected to be less. The impact of D_{max} assumptions to the retrieval of other DSD parameters such as N_w, the liquid

water content normalized intercept parameter, are also explored. Likely implications for DSD retrievals using C-band polarimetric radar for GPM are assessed by considering current community knowledge regarding D_{max} and quantifying the statistical distribution of Z_{dr} from ARMOR over a large variety of meteorological conditions. Based on these results and the prevalence of C-band polarimetric radars worldwide, a call for more emphasis on constraining our observational estimate of D_{max} within a typical radar resolution volume is made.