Ongoing Studies of Winter Precipitation within the MASCRAD Project and Advances to the Observation and Analysis Process

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This paper presents our extensive ongoing studies of winter precipitation within the NSF MASCRAD (MASC + Radar) project, whose principal goal is to establish a novel approach to characterization of winter precipitation and modeling of associated polarimetric radar observables, and improve the radar-based quantitative precipitation estimation. Our field measurement site at the Easton Valley View Airport in La Salle, Colorado, includes two advanced optical imaging disdrometers within a 2/3-scaled double fence intercomparison reference (SDFIR) wind shield, snow measuring gauge, weather station, and radio sounding system all under the umbrella of CSU-CHILL Radar.

Within the MASCRAD field site, a multi-angle snowflake camera (MASC), which simultaneously captures multiple different high-resolution views of a snowflake in free-fall, along with the snowflake's fall-speed, and a collocated 2-dimentional video disdrometer (2DVD), which captures two orthogonal scanline contours of a snowflake as well as the snowflake's fall-speed, are used in conjunction with the visual hull geometrical method and "stacked ellipse" reconstruction method, respectively, to perform scattering analysis. The fall-speed from the MASC and the 2DVD is used, along with state parameters measured at the MASCRAD site, to estimate the particle mass (Böhm's method), and then, using the volume of 3D reconstructions, estimate the permittivity of the particles, based on a Maxwell-Garnet formula. Scattering analysis of the 3D reconstructed snowflakes is performed on a particle-by-particle basis by means of our higher order method of moments (MoM) for solving surface integral equations (SIEs) and is used to compute polarimetric radar measurables (horizontal reflectivity, Z_h, differential reflectivity, Z_{dr}, linear depolarization ratio, LDR, specific differential phase, K_{dp}, and co-polar correlation coefficient, ρ_{hv}). These results are compared against the corresponding data collected by CSU-CHILL Radar, featuring excellent polarization purity.

We present and discuss further advances to the 3D reconstruction methods, visual hull and stacked ellipse, used with the high resolution MASC images and 2DVD scan line contours, respectively, to software self-calibration of the instruments, and to the conversion of reconstructed geometries into meshes of quadrilateral patches suitable for electromagnetic scattering modeling and analysis. We also present the entire process that is streamlined from the handling of the images, to the 3D shape reconstruction, the creation of meshes that adequately represent features of the geometry, to the estimation of the dielectric constant, and finally the scattering analysis.

For a selected set of winter events observed at the MASCRAD site, the radar observables obtained from the scattering analysis of the 3D snowflakes reconstructed from the MASC and 2DVD measurements are compared against those using the T-matrix method for idealized spheroidal shapes for ice particles in place of the more complicated and realistic 3D shapes, as well as to radar data.