Analysis of DDSCAT-based Phase Matrix Symmetry for 3-D Radiative Transfer Model Development

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A scattering-based Radiative Transfer (RT) model is required in the development of either retrieval algorithms or microwave radiance assimilation methods under the severe weather conditions to provide an accurate forward transfer model and the sensitivity functions. The analytical solution to the scattering-based RT equations must be obtained with inherent numerical stability and repeatability under conditions of arbitrary scattering hydrometeor distributions. The Unified Microwave Radiative Transfer (UMRT) algorithm developed at University of Colorado at Boulder (CU) provides a fast layer-adding 1-dimentional solution to the RT equations with inherent stability using the analytical factorization technique based on the symmetry of the phase matrix under the assumption of planar stratification and spherical scattering particles. The symmetry of the phase matrix in UMRT is embodied not only in an individual polarization, e.g. horizontal or vertical, under scattering path reversal, but in a polarization-coupled 2x2 phase matrix in a planar stratified medium. The approximation of scattering particles as spherical in UMRT doesn't well match the shape of large size precipitating hydrometeors (e.g. snowflakes, ice needles and graupel) in reality. One of the existing algorithms to deal with the non-spherical scattering problem is the Discrete Dipole Approximation (DDA). The Discrete Dipole Approximation Scattering (DDSCAT) is an open-source software package to compute scattering and absorption of electromagnetic waves by dielectric particles with arbitrary shape and complex refractive index using DDA. The DDSCAT package calculates the Stokes matrix of a single scattering particle centered at origin of a coordinate system where the incident wave is assumed to propagate along one of the axis.

In this study, the Stokes matrix of a wide range of hydrometeor types (e.g. shape and size) were computed using DDSCAT as a function of incident and scattered directions and particle orientations at multiple microwave absorption bands, including 118.75 GHz Oxygen absorption line and 183.31 GHz water vapor line. The phase matrix of an ensemble of non-spherical hydrometeors was obtained by averaging the Stokes matrices over target orientations and incident/scattering azimuthal angles. The reciprocity and mirror symmetry of the resulting phase matrix will be illustrated for a group of aggregated ice/snow particles covering the full spectrum of the available modeled hydrometeors. On the basis of the phase matrix symmetry, UMRT is being extended to a horizontally inhomogeneous version (HI-UMRT) based on the 1-D UMRT model and a horizontally inhomogeneous iterative perturbation solution to the 3-D RT equations. The study of the radiative effects of horizontally inhomogeneous clouds, e.g. near rain bands and convective towers, will be discussed.