12.6 HOW ACCURATE IS THE DISCRETE DIPOLE APPROXIMATION FOR MODELING THE SINGLE SCATTERING PROPERTIES OF PARTIALLY MELTED SNOWFLAKES

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As a consequence of the expanding availability of computing resources, the modeling of hydrometeors single scattering properties using increasingly detailed and complex shape models becomes more and more popular within the radar science community. The Discrete Dipole Approximation (DDA) has proven to be a reliable numerical tool to calculate scattering properties of realistically shaped pristine ice crystals, snow aggregates and rimed particles.

Only a few DDA calculations for partially melted particles have been performed due to the demands of modelling the melting process and the increased computational cost of calculating single scattering properties of heterogeneous targets. However, the importance of melting particles for simulating radar polarimetry and attenuation properties of the melting layer makes these melting particles the next logical “target” for DDA calculations.

The computation of snowflake single scattering properties using DDA is of great importance considering the increasing deployment of ground-based and space-borne millimeter-wavelength radars for which simplified models like homogeneous sphere and spheroids have been proven to not adequately represent snow scattering signatures. Moreover, those simplified models rely on the usage of effective-medium approximations (EMA) which are known to give inaccurate results in case of three or more components in the dielectric mixture.

The accuracy of the DDA method in case of melting ice particles has been debated. DDA is known to give less accurate results in case of larger refractive index values. Moreover the liquid component in the melting snowflake is expected to be distributed as small and sparse droplets whose shape would be difficult to approximate using a regular grid.

In this study, the accuracy of the DDA technique for representing scattering properties of melting particles has been investigated in the special case of layered spheres for which an analytical solution of the scattering problem exists. In order to separate the distinct sources of modeling error, namely the geometric (shape) representation of the particle and the resolution error with respect to the electromagnetic wavelength, tests with increased volumetric resolution have been performed. The accuracy of the DDA algorithm has been tested for different particle sizes (up to 20 mm) and frequencies (from 9.6 to 220 GHz). An in-depth analysis has been carried out by comparing internal electric fields in cases where largest discrepancies in the simulated radiative properties have been observed.

As expected, largest errors are found when the outer water layer is thinnest and the DDA resolution becomes coarser. Results suggest that the numerical error introduced by DDA in the computation of the scattering properties of melting ice particles can be kept within acceptable values if the grid resolution assumed in the DDA computations is fine enough. The ultimate goal of this study is to provide guidelines for future melting snowflake scattering computations in order to assure sufficiently accurate results.