Accurate Electromagnetic Modeling of Melting Hail

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Analysis of electromagnetic scattering from hailstones has conventionally been done using the *T*-matrix method. This method, which reduces exactly to the Lorenz-Mie scattering theory when the scattering particle is a homogeneous or layered piecewise homogeneous sphere, worked well so far when we tried to understand the measurements. However the measurements have become fairly sophisticated with many decades of multiple polarization measurements and the current models are not able to explain many of the nuances in the measurements, because the current model is not well suited for analysis of arbitrarily shaped and non-layered particles.

This paper presents a numerically rigorous full-wave electromagnetic analysis of scattering from melting hail based on the method of moments (MoM) in the volume integral equation (VIE) formulation. The method employs generalized curved hexahedral volume elements of arbitrary geometrical-mapping orders, current polynomial vector basis functions of arbitrarily high expansion orders (B. M. Notaroš, "Higher Order Frequency-Domain Computational Electromagnetics," IEEE Transactions on Antennas and Propagation, vol. 56, pp. 2251–2276, Aug. 2008), and higher order modeling of inhomogeneous lossy materials. The new higher order MoM-VIE modeling approach to analysis of scattering from melting hail is able to overcome shortcomings of the *T*-matrix method.

The paper presents results for scattering from dry, wet, and melting hailstones of various realistic shapes and material compositions, including layered models and continuous variations of the dielectric permittivity. Examples show computations of monostatic and bistatic dual-polarization scattering and evaluation of scattering matrices in *S*-, *C*-, *X*-, and *Ka*-bands. When appropriate, the analysis is performed also using our higher order MoM in the surface integral equation (SIE) formulation and our higher order finite element method (FEM). These results are compared directly with the traditional T-Matrix method. Results demonstrate significant differences between simulated radar cross sections of realistically shaped hailstone models and the corresponding equivalent spherical scatterers with the same volume (and with the averaged permittivity in cases of inhomogeneous hailstone models, e.g., melting hail models). The results thus indicate the advantages of the proposed higher order computational electromagnetic approach to realistic melting hail scattering and the necessity for such numerically rigorous and efficient modeling in hail scattering applications. Overall, the higher order full-wave electromagnetic analysis shows values and advantages in modeling of both smoothly surfaced particles of various shapes and particles with sharp edges, corners, and spikes, and in modeling of different material complexities and inhomogeneities of particles, in analysis of scattering from hail, graupel, and snow particles.