Application of the full wave electromagnetic approach to the calculation of polarimetric variables for ensembles of rough and nonspheroidal hydrometeors

Djordje Mirkovic

Djordje Mirković*[1,3,4], Dušan Zrnić[2] and Alexander Ryzhkov[1]

[1]*National Severe Storm Laboratory, University of Oklahoma CIMMS, Norman OK*
[2] *National Severe Storm Laboratory, NOAA, Norman OK*
[3] *School of Electrical and Computer Engineering, University of Oklahoma, Norman OK*
[4] *School of Electrical Engineering, University of Belgrade, Serbia*

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1 Introduction

Hydrometeor scattering, until now, has been investigated using simple spheroidal models to represent most of the observed precipitation. These simple models provide satisfying interpretation of reflectivity values from most precipitation observed with the recently upgraded network of polarimetric WSR-88D radars. This upgrade has provided opportunities to discern large hail, insects, or birds all of which can differ substantially from oblate or prolate bodies. Thus, researchers are studying ways to quantitatively discriminate between different precipitation types on the basis of the measured differential reflectivity Z_{DR}, backscattered differential phase δ, and correlation coefficient ρ_{HV}. Furthermore, the dual polarization capability has set a new demand to modeling of scattering in the resolution volumes to better replicate data observed by radars. Application of spheroidal based modeling has proven to have difficulties quantitatively replicating observed low values of cross-correlation coefficient of wet snow in the melting layer and hail in severe storms, especially in cases when rough hail was observed on the ground.

The aforementioned difficulties of spheroidal models are inherent to the widely accepted T-Matrix method and similar techniques, as they solely rely on spheroidal geometry. Therefore, such approaches are unsuccessful despite the fact that they can account for different hydrometeor axis ratios and dielectric properties. In order to overcome these deficiencies, new ensemble models need to include rough, spiky hail, as previous studies discovered that the low ρ_{HV} values are related to the protuberances of the hail surface or to the spike-like protrusions.

2 Proposed approach

The proposed approach relies on using an electromagnetic (EM) solver that uses EM Method of Moments (MoM) software for modeling complex geometries of hydrometeors that can be part of larger ensembles. These complex geometries as shown in fig. 1 may have protuberances of different ratio of radius and distribution, axis ratio, coating (dry, “wet”(water coated) etc.) spikes etc.

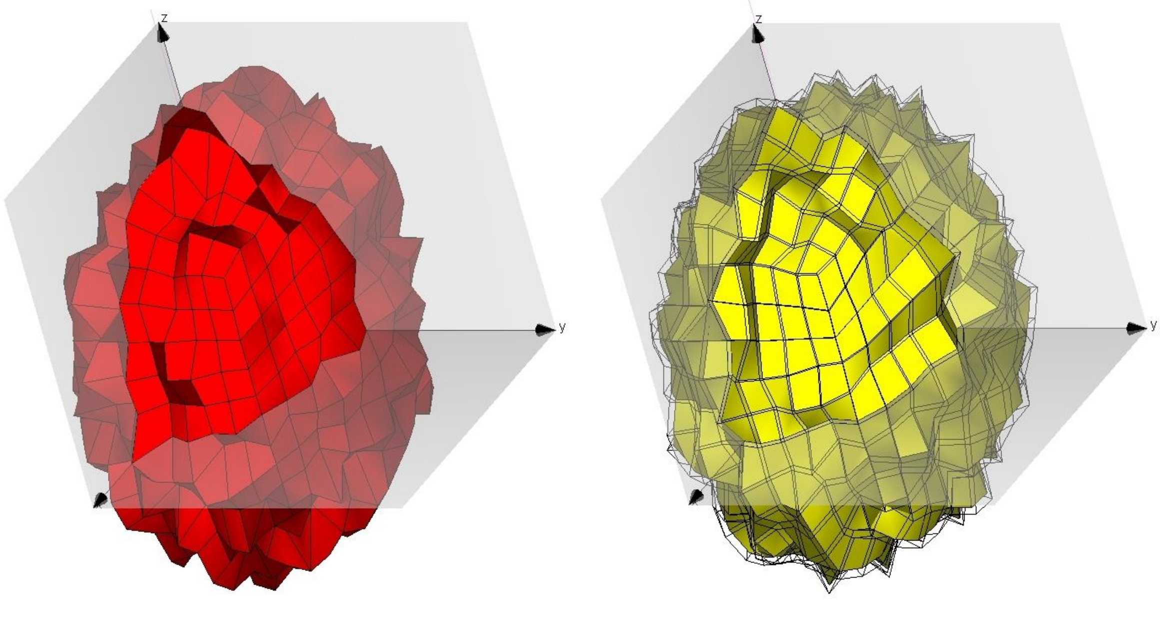

Fig. 1 – Rough hail models of dry 40mm hailstone of axis ratio 0.6 with non-uniform distribution of protuberances up to 14% of radius (left), 80mm water coated (“wet”) hailstone with 0.6 axis ratio and uniform distribution of protuberances up to 10% of radius (right).

The complete modeling process is separated into three operations using the WIPL-D software for the first, electromagnetic scattering part of the calculation. In this operation, scattering coefficients for every particular hydrometeor are calculated. Scattering matrices for different types of meteorological scatterers (rough hail, etc.) are calculated by the WIPL-D software that has a demonstrated capability of modeling scattering of complex objects and can store this data in a scattering library. All WIPL-D created scattering coefficients, dependent on solid angle, are stored in the overall precipitation library which may be extended and further developed at any time for any desired object. Hence, the overall precipitation library allows limitless options regarding its content including any possible size shape axis ratio etc. of hydrometeors.

Second portion is the ensemble creation part for the purpose of gathering the hydrometeor ensemble with the required statistical properties regarding the size, shape, protrusion type and characteristics, and orientation of the every single hydrometeor type in the ensemble. Every hydrometeor type is averaged over the set of user defined orientation, allowing for the possibility of the orientation studies of large and giant hail. These, orientation averaged scattering coefficients, are then used for the calculation of the polarimetric variables.

Final stage of the simulation includes the calculation of the polarimetric variables including reflectivities Z_H, Z_V, Z_{DR}, the correlation coefficient ρ_{HV}, and the backscattered differential phase δ for the required size, shape and roughness distribution. We are purposely differentiating this from the statistical properties used in the second part as the purpose of this distribution is to allow for studies of hail size distribution that later on could be extended to include other available parameters such as roughness etc.

3 Conclusion

The proposed modeling architecture proves to be useful in a variety of cases, as it assumes that ensembles are created off of the statistically independent objects. This therefore allows for the characterization of coupling between scatterers in the EM modeling while still treating them as independent statistical elements in the ensemble creation. Furthermore, as the ensemble creation topology is “unaware” of the objects, it allows for the ensembles of non-meteorological scatterers such as insects or birds, ipso facto providing a new tool for the research in this area.

To the best of our knowledge, this is the first application of WIPL-D, and one of the first attempts to use MoM for hydrometeor scattering. We suggest specific topologies, orientations, sizes, distribution and EM properties for the sampled scatterers. Specifically we suggest models of giant hail resembling observations to replicate observations made by weather radars.