Hail Generation and Melting in Deep Convective Clouds from the Perspective of Dual-polarization

Research Highlight

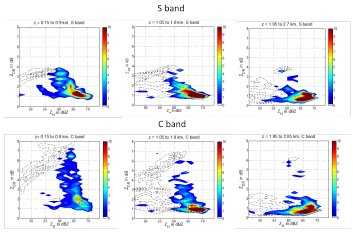
Large hail is generated in vigorous convective updrafts which are commonly associated with columnar regions of enhanced differential reflectivity (ZDR columns) often capped with the depression of the cross-correlation coefficient #hv measured by dual-polarization radars. After hailstones fall below the freezing level, they melt and produce large raindrops making a hail/rain mixture, which is characterized by very pronounced polarimetric radar signatures from which a dominant or maximal hail size can be determined.

Two types of spectral bin models are utilized to simulate hail growth and melting as well as the corresponding polarimetric radar variables. One of them is a columnar steady-state one-dimensional (1D) model and another one is the two-dimensional (2D) nonhydrostatic mixed-phase Hebrew University of Jerusalem Cloud Model (HUCM), both of which are combined with a sophisticated polarimetric radar observation operator.

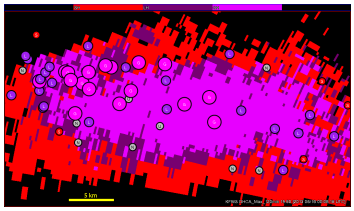
It has been discovered that due to the effect of water shedding from melting hailstones the hail particles of different sizes may end up as large raindrops of almost identical sizes, causing skewing of the raindrop spectrum towards very large drops. Analysis of relative contributions of different parts of the hail/rain size spectrum to the radar variables allows explanations of a number of experimentally observed features such as differences in Z of hail at different radar wavelengths, unusually high values of ZDR at C band, and relative insensitivity of the measurements at C and X bands to the presence of large hail exceeding 2.5 cm in diameter.

Modeling results are consistent with S- and C-band polarimetric radar observations and are utilized for devising practical algorithms for hail detection and hail size discrimination (HSDA) as well as attenuation correction and rainfall estimation in the presence of hail. The HSDA algorithm was developed for discrimination between small hail (with maximal size of less than 2.5 cm), large hail (with diameters between 2.5 and 5.0 cm), and giant hail with size exceeding 5.0 cm. HSDA was tested for about 1800 hail reports as part of the Severe Hazard Analysis and Verification Experiment (SHAVE) and is slated for operational implementation.

The study will help cloud modelers to optimize microphysical parametrization of the processes of hail generation and melting in deep convective clouds either via polarimetric radar microphysical retrievals or via conversion of the model output into the fields of polarimetric radar variables using forward radar observation operators. The model should be modified until it reproduces adequate “polarimetric fingerprints” of the microphysical processes involving hail, which are documented in the study. The polarimetric hail detection and classification algorithm will identify localization of hail of different size within a storm.



Frequency distributions of large hail mass (shading) and small hail mass (dashed contours) on the Z - Zdr plane that are based on output from HUCM at S and C bands. The title above each panel indicates the height interval (AGL) from which the distributions are computed. The environmental freezing level is at 2.5 km.



Spatial distribution of the HSDA output integrated over a period of 2 hours during a hailstorm on 15-16 May 2013. The color of a pixel in the map indicates the maximal hail size estimated by HSDA within a 2-hour period in this particular location. The overlaid circles of different size and color show locations of the SHAVE ground reports within the same time period. Small, large, and giant hail reprots are designated as S in red circles, L in purple circles, and G in magenta circles, respectively.

Reference(s)

Ryzhkov AV, MR Kumjian, SM Ganson, and AP Khain. 2014. "Polarimetric radar characteristics of melting hail. Part I: Theoretical simulations using spectral microphysical modeling." Journal of Applied Meteorology and Climatology, 52(12), doi:10.1175/JAMC-D-13-073.1.

Ryzhkov AV, MR Kumjian, SM Ganson, and P Zhang. 2013. "Polarimetric radar characteristics of melting hail. Part II: Practical implications." Journal of Applied Meteorology and Climatology, 52(12), doi:10.1175/JAMC-D-13-074.1.

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Cloud Life Cycle