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A methodology for simulation of ice crystal habits in 3D Eulerean numerical weather prediction model

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The Kessler/Orville approach to ice microphysics, which is based on categorization of solid hydrometeors, has been widely used in operational weather prediction for its computational efficiency. Even though recent works have achieved improvement in comparison with in-stu or remote-sensed observation, the scheme may not be appropriate to study cloud microphysics not only due to the prescribed decision tree and arbitrary categories, but also the inability to reflect the growth history of solid hydrometeors. In addition, recent rapidly growing remote sensing technology shows the importance of proper representation of phase, distribution, shape, and density of solid hydrometeors in radiation transfer calculation. This research describes a methodology to simulate ice crystal habit (or shape) explicitly which can be used in 3D Eulerean Numerical Weather Prediction (NWP) Model.

In Eulerean NWP model the prognostic variables are predicted using a mass conservation equation requiring the predictive variable to be extensive. To predict the evolving habit structure of cloud physics variables in such a model framework, we introduce divide the predicted crystal mass into mass components which are extensive variables containing the essential information necessary to reconstruct the probable geometry of the ice crystals. The crystal mass growth is divided into mass components lying along the a, c and dendritic axes, and the mass accumulated through cloud droplet and rain riming. This distribution of these mass components evolves a function of the history of atmospheric conditions through which the ice passes. At any given point, we can retrieve the geometry of ice crystals, such as dendrite, plate, column, needle or rosette from these mass components using statistical techniques described in this paper.

A database of the mass components and geometry for a pristine ice crystal was constructed by using Lagrangean simulation of vapor deposition process of an ice crystal under fixed temperature and ice supersaturation. Evaluation of the method with mass-geometry mapping indicates the relative error of 35 % maximum in mass over the course of 60 minutes simulation under fixed temperature and supersaturation. The error stems from the error in fitting statistical model to the database and use of large time step (>=1.0s). In the simulation under which temperature sinusoidal varies with fixed saturation, the relative error may become large due to the use of the database constructed on fixed temperature and saturation condition.

We will present more details of our habit diagnosis scheme and results of tests we have made. We are now implementing this scheme in a bin model which represents all the solid hydrometeors by one distribution. Then, it will be built into University of Wisconsin Nonhydrostatic Modeling System so that the habit prediction in real storm can be validated with observation.