A MULTI-MOMENT, MULTI-HYDROMETEOR CLASS, BULK MICROPHYSICS PARAMETERIZATION SCHEME

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I. INTRODUCTION

The primary purpose of the model presented here in is to attempt to make up for deficiencies found in bulk parameterization three ice category models. Whereas some of these deficiencies do not appear in the higher ice category bulk models, many still do and this will be discussed through out the manuscript. Although the bin model framework is now becoming fast enough for three-dimensional NWP simulations, we feel that an alternative and equally logical approach is to approximate a spectral category model with numerous ice species, liquid species, and mixed phase species.

One motivation for developing the 24-class (1 vapor class, 6 liquid classes, and 17-ice classes), scheme was our disappointment with the low-level outflow beneath supercells that seemed notoriously too cool in simulations with the 3-ICE and other similar codes when compared to observations. It appeared that the inverse exponential distribution present in such schemes, which biases evaporation on the low end of the distribution (particles re-appear there every time step from the large-drop end of the distribution as the distribution is re-fit) might be resulting in an overly aggressive evaporation and melting rates. Instead, by using generalized gamma functions as in the current model, one can better represent observed distributions and this has the additional effect of limiting the number of small particles. Models such as CSU-RAMS have had that option for over 10 years. Furthermore, with "cutoff diameters" and partial gamma functions, one can better represent species such as rain, which do not reach sizes much bigger than 8 mm and consequently improve the accuracy of accretion rates. Improving the distribution shapes affords a better representation of observed particle size distributions. This paper describes some of the model's features and justification, an example from an early version, and a strategy for comparing the model results against observations.

II. MICROPHYSICS DESCRIPTION

As described in Straka and Gilmore (2008), the model now uses two- (and soon, three-moments) for prediction of microphysical field evolution including number concentration, mixing ratio, and if desired, reflectivity. In all, 17 ice habits (seven are crystal habits) are used and five liquid habits are used. Cotton and Anthes (1989) note that it is essential for a model to have the capability to not only predict the amount of hydrometeors, but the type. The main categories in the model are cloud water, raindrops, ice crystals, snow aggregates, graupel, frozen raindrops, and hail. That is about the same number of categories as in the CSU-RAMS model. The seven categories have sub-categories, which are designed to complement the main categories based on various physical bases. For example, there are columns, plates, dendrites, needles, sectors, bullet rosettes, and side planes, which form at different temperatures and start to rime at different sizes. There are also snow aggregates. As crystals, frozen drizzle, and snow aggregates rime, they grow into graupel particles. The riming rate encountered in different parts of the updraft and its influence on particle density is predicted so that the tremendous graupel density variation observed in nature can be represented (from 50 to 890 kg m^{-3}). Having three separate graupel categories covering smaller pieces of this large range in density affords three separate modes in the graupel distribution within the same grid volume. Only the higher-density graupel, which are larger than a specified size (5 mm), become hail. Frozen raindrops also are also a source for hail if larger than 5 mm. Cotton and Anthes (1989) also have noted "it is quite important, for example, to be able to distinguish between the occurrence of graupel and freezing rain, or the occurrence of numerous graupel and a few large hail stones." In the model, hail has sub-categories of small hail ($5<D<20$ mm) and large hail ($D>20$mm). The small hail is sub-categorized by embryo type (either frozen drops or graupel) so that the model can be compared against observations of hailstones that reach ground. Finally there are drizzle drops, big rain drops from melting of small hail, small rain drops from melt water shed from larger hail, medium sized rain drops from melting of graupel and snow, and a variety of sizes of rain drops from warm processes. Through prediction of mixing ratio, number density, and reflectivity, the shape of the gamma distribution can be diagnosed (following Milbrandt and Yau 2005).

Although the microphysics was designed primarily within the Straka Atmospheric Model (SAM), it was written in such a way that it would be easy to port. We are currently running the primary scheme in two different cloud models while the simpler version of the scheme (used by Cronce et al. 2007, this volume) runs in three different cloud models. A basic description of the SAM can be found in Gilmore et al. (2004).

III. EXAMPLE SIMULATION

An example simulation was made with the model while it was in development using a standard analytical sounding and hodograph from Weisman and Klemp (1984; Us = 50 m s^{-1} case). Several panels of the same cross-section are shown to clearly to distinguish between the different species within the storm (Fig. 1).

IV. MODEL-OBS INTERCOMPARISON

It is quite difficult to compare observed and modeled hydrometeor categories in precipitating clouds regardless of the number of hydrometeor categories represented in a model, as there are not much microphysical data, except some ground and aircraft observations. Simulated radar reflectivity patterns are useful for comparison with actual radar images to insure that the values are reasonable. A T-matrix model or a radar model that uses Maxwell-Garnett theory can be used to incorporate Mie scattering (e,g, see Gilmore et al. 2007; this volume). In ongoing work, dominant hydrometeor type within the multi-ice and liquid species model is being compared to species retrieved from dual-polarimetric radar observations using a fuzzy logic technique (Straka et al. 2000). Supercells are particularly good test case since most of the microphysics classes are likely active in such storms. It is hoped these studies will provide means for adequately judging whether the model is

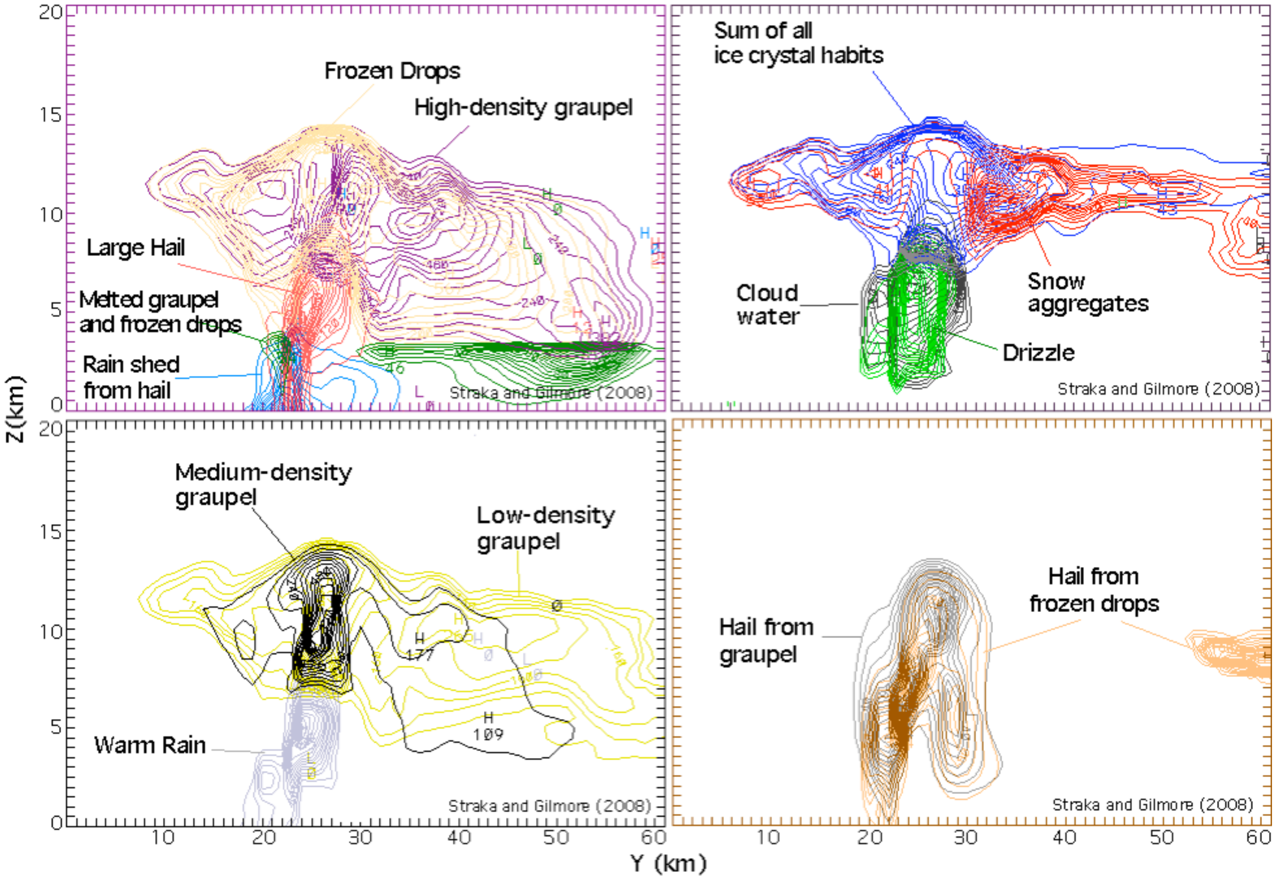

FIG. 1: Microphysics species mixing ratio in a vertical cross section through the updraft region of a simulated supercell. Each panel shows different groups of species for the same location of the cross section.

behaving reasonably. Although supercells provide an interesting and important test case, the microphysics scheme was designed with many types of cloud systems in mind and it is our hope that enough processes have been included that it will work well for a number of different cloud system types with minimal tuning. Further testing is planned.

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