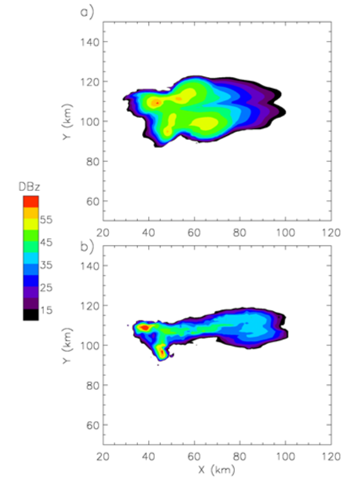
Comparison of Microphysics Schemes in Idealized Supercell Thunderstorm Simulations

Research Highlight

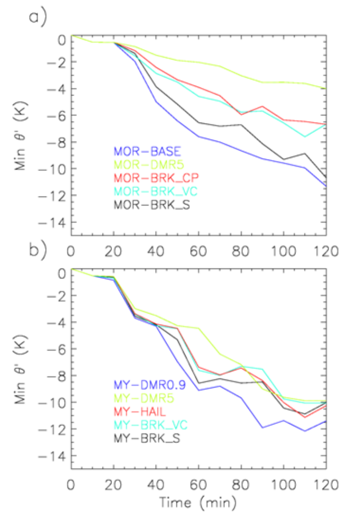
The parameterization of cloud and precipitation microphysics is a major challenge in the numerical simulation of moist deep convection. Microphysical processes directly impact buoyancy, and hence convective fluxes, through condensate loading and latent heating/cooling due to phase changes. The representation of these effects is becoming increasingly important since regional-scale numerical weather prediction and climate models are now commonly run at the deep-convective scale, with a horizontal grid spacing of the order of 1 km. The use of two-moment bulk microphysics schemes that predict both mass mixing ratios and number concentrations of various hydrometeor species has become increasingly common for the simulation of organized deep convection. Despite improvements in simulations using two-moment schemes compared to using simpler schemes, there still remains a great deal of uncertainty in the parameterization of several specific processes in microphysics schemes in general, from which two-moment schemes are not immune.

The two-moment schemes of Morrison et al. and Milbrandt-Yau were examined using a common modeling framework (Weather Research and Forecasting model, WRF) applied to idealized supercell thunderstorms. Despite general similarities in these schemes, the simulations were found to produce distinct differences in storm structure, precipitation, and cold pool strength. In particular, the Morrison scheme produced much higher surface precipitation rates and a stronger cold pool, especially in the early stages of storm development. A series of sensitivity experiments was conducted to identify the primary differences between the two schemes that resulted in the large discrepancies in the simulations. Different approaches in treating graupel and hail were found to be responsible for many of the key differences between the baseline simulations.



Near-surface radar reflectivity after one-hour simulation using the (a) Morrison and (b) Milbrandt-Yau schemes. These plots highlight large differences produced by the two schemes.

The inclusion of hail in the baseline simulation using the Milbrant-Yau scheme with two rimed-ice categories (graupel and hail) had little impact, and therefore resulted in a much different storm than the baseline run with the single-category (hail) Morrison scheme. With graupel as the choice of the single rimed-ice category, the simulated storms had considerably more frozen condensate in the anvil region, a weaker cold pool, and reduced surface precipitation compared to the runs with only hail, whose higher terminal fall velocity inhibited lofting. The cold pool strength was also found to be sensitive to the parameterization of raindrop breakup, particularly for the Morrison scheme, due to the effects on the drop size distributions and the corresponding evaporative cooling rates. The use of a more aggressive implicit treatment of drop breakup in the baseline Morrison scheme, by limiting the mean-mass raindrop diameter to a maximum of 0.9 mm, opposed the tendency of this scheme to otherwise produce large mean drop sizes and a weaker cold pool compared to the hail-only run using the Milbrandt-Yau scheme.



Minimum low-level perturbation potential temperature (y-axis) as a function of simulation time (x-axis) using the (a) Morrison and (b) Milbrandt-Yau schemes. Each lines shows results using different formulations for raindrop breakup in the model. These plots highlight large sensitivity to drop breakup, especially using the Morrison scheme.

While two-moment bulk microphysics schemes have been shown to improve aspects of storm simulations relative to using one-moment schemes, the large differences in results produced by the Morrison and Milbrandt-Yau schemes highlight uncertainties associated with two-moment schemes in general. As modelers move away from the use of one-moment bulk schemes and add more degrees of freedom in the representation of cloud microphysical processes, they must be cognizant of such uncertainties and take care not to assume that simulations using multi-moment parameterizations will converge simply due to the added complexity. These results also highlight the critical need for further observational studies of hydroemeteor size distributions and ice particle properties, such as density and fall velocities, to appropriately specify parameter settings in the microphysics schemes.

Reference(s)

Morrison H and JA Milbrandt. 2011. "Comparison of two-moment bulk microphysics schemes in idealized supercell thunderstorm simulations." Monthly Weather Review, 139, 1103-1130.

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Cloud Life Cycle