THE RELATIVE IMPACT OF ICE FALL SPEEDS AND MICROPHYSICS PARAMETERIZATION COMPLEXITY ON SUPERCELL EVOLUTION

Nicholas M. Falk, Matthew R. Igel, Adele L. Igel
University of California Davis

1. INTRODUCTION

There are currently two common, but fundamentally different approaches to parameterizing cloud microphysics: bin schemes and bulk schemes. Bulk schemes assume a functional form for the size distribution of hydrometeors. In bin schemes, each hydrometeor size distribution is instead discretized into bins that together span the size range of that species. Bin schemes simulate microphysics more realistically, but they have high computational cost. It is unclear if differences in simulations arise primarily due to the different fundamental construction of bulk and bin schemes, or due to different assumptions that the schemes make when parameterizing the same processes.

2. EXPERIMENTAL DESIGN

Four supercell simulations were run using the Regional Atmospheric Modeling System (RAMS) (Cotton et al., 2003) to test the relative sensitivity of these storms to changes in microphysical parameterizations. Simulations were run with either the RAMS double-moment bulk microphysics scheme (Saleeby & Cotton, 2004; Saleeby & Van den Heever, 2013), or the Hebrew University Spectral Bin Model (SBM) (Khain, Pokrovsky, Pinsky, Seifert, & Phillips, 2004). One striking difference between the schemes is the diameter-fall speed relationships of aggregated snow crystals, graupel, and hail; we collectively call these ‘big ice’. Figure 1 shows each relationship for 1000 mb. The bulk scheme simulation with its standard fall speeds will be called BULK-H and the SBM simulation with the standard SBM fall speeds will be called BIN-L. A second bulk scheme simulation was run with the standard bulk scheme fall speeds for big ice reduced to half. This simulation with the SBM-like fall speeds will be called BULK-L. Finally, a second SBM simulation was run using the bulk scheme fall speeds for big ice and will be called BIN-H.

3. RESULTS

The immediately notable difference Figure 2 demonstrates is that both high fall speed simulations split with distinct right- and left-movers, while neither of the low fall speed simulations exhibit a classic split. The surprising conclusion we draw is that the behavior of simulated supercells seems to depend more strongly on fall speed parameterization than on microphysics scheme type.

The immediate result of differing fall speeds is on the vertical structure of hydrometeors in the storms. Higher fall speeds allow big ice to precipitate faster out of the anvil and core where it can begin to melt. Figure 3 shows the mass freezing in the storms depends more on the microphysics scheme than the fall speed relationship until splitting occurs. As freezing is due to updrafts, and as freezing only changes after the left-movers intensify, this result indicates that the differing fall speeds have little impact on the updrafts of the right-movers. Figure 3 indicates that mass melting is sensitive to the fall speed relationship from the start, with the high fall speed simulations having more melting.

The result of this increase in melting in the high fall speed simulations is stronger downdrafts at low levels. After 30 minutes, BULK-H and BIN-H have discernably stronger and more widespread downdrafts than BULK-L and BIN-L. Figure 4 shows BULK-H has the largest, coldest cold pool, BIN-H and BULK-L both have smaller cold pools, and BIN-L has the smallest cold pool. In the high fall speed simulations, the cold pools are pushing air outward, and then upward at their edge. It is notable that the left-mover updrafts are also situated on the edge of their respective cold pools. Further analysis shows that the left movers appear initially near the surface but not at higher level. This leads to our conclusion that splitting in the high fall speed simulations is due to surface cold pools enhancing updrafts.

4. CONCLUSION

Four model simulations were conducted with the Regional Atmospheric Modeling System bulk and bin schemes which have differing built-in diameter-fall speed relationships for aggregates, graupel, and hail. One simulation was run with each microphysics scheme and fall speed relationship combination. Both high fall speed simulations developed left-movers while neither low fall speed simulation did. We suggest that the following chain of events caused this Higher fall speeds led to more hydrometeor mass at low levels, which led to greater melting. This led to stronger downdrafts and colder cold pools, which intensified the left-movers in simulations with high fall speeds. We have shown that the primary difference in these bulk and bin simulations was due to choice of fall speed-diameter relationships.

REFERENCES

Cotton, W. R., Pielke Sr., R. A., Walko, R. L., Liston, G. E., Tremback, C. J., Jiang, H., … McFadden, J. P. (2003). RAMS 2001: Current status and future directions. *Meteorology and Atmospheric Physics*, *82*(1–4), 5–29. https://doi.org/10.1007/s00703-001-0584-9

Khain, A., Pokrovsky, A., Pinsky, M., Seifert, A., & Phillips, V. (2004). Simulation of Effects of Atmospheric Aerosols on Deep Turbulent Convective Clouds Using a Spectral Microphysics Mixed-Phase Cumulus Cloud Model. Part I: Model Description and Possible Applications. *Journal of Atmospheric Sciences*, *61*(24), 2963–2982. https://doi.org/10.1175/JAS-3350.1

Saleeby, S. M., & Cotton, W. R. (2004). A Large-Droplet Mode and Prognostic Number Concentration of Cloud Droplets in the Colorado State University Regional Atmospheric Modeling System (RAMS). Part I: Module Descriptions and Supercell Test Simulations. *Journal of Applied Meteorology*, *43*(1), 182–195. https://doi.org/10.1175/1520-0450(2004)043<0182:ALMAPN>2.0.CO;2

Saleeby, S. M., & Van den Heever, S. C. (2013). Developments in the CSU-RAMS aerosol model: Emissions, nucleation, regeneration, deposition, and radiation. *Journal of Applied Meteorology and Climatology*, *52*(12), 2601–2622. https://doi.org/10.1175/JAMC-D-12-0312.1

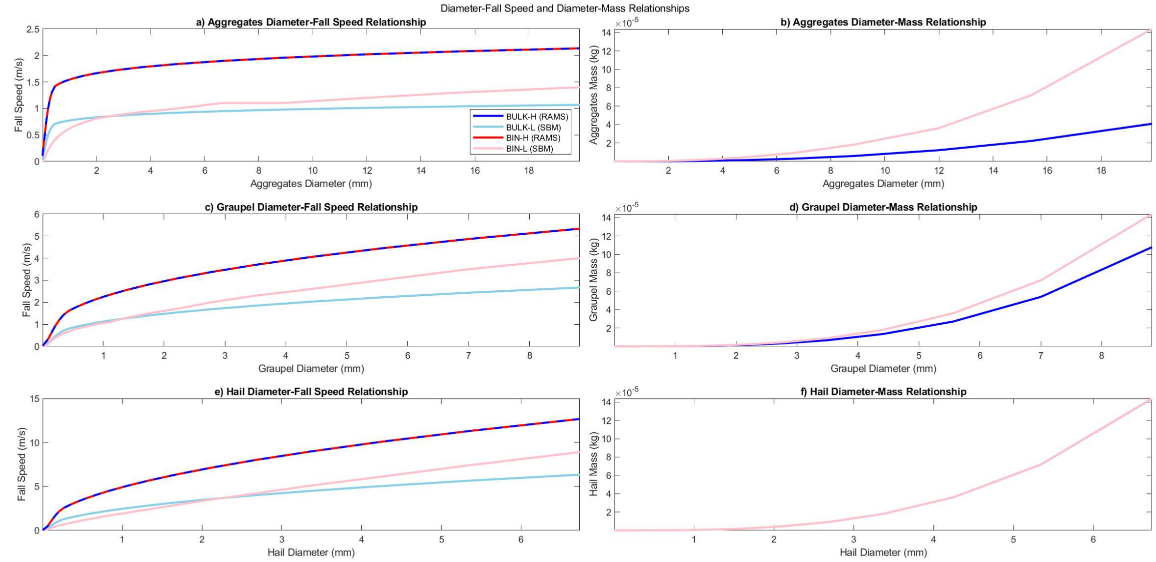

Figure 1. Fall speed-diameter and mass-diameter relationships.

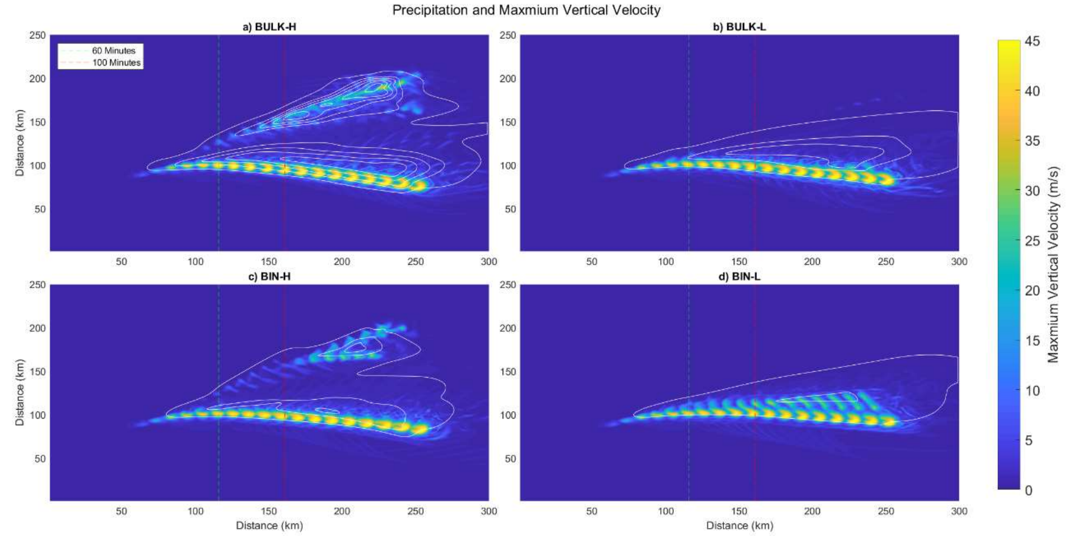

Figure 2. Accumulated precipitation and time and column maximum vertical velocity. Precipitation contours are drawn in white every 3 mm with the first at 0.1 mm. Vertical velocity data are taken every 10 minutes. The green line indicates the 60-minute mark for each storm. The red line indicates the 100-minute mark for each storm.

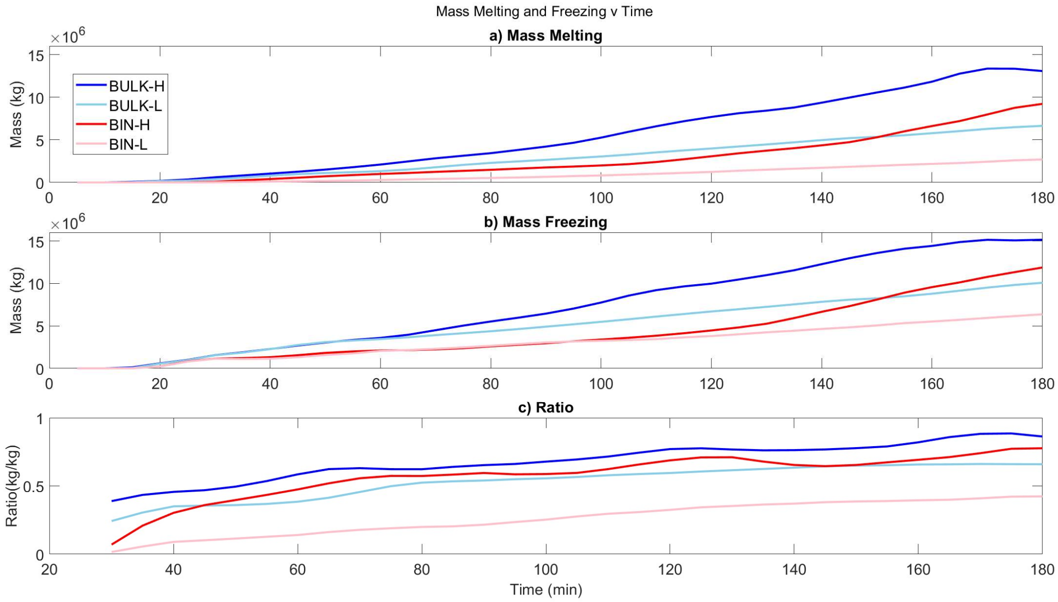

Figure 3. a) Mass melting, b) mass freezing, and c) the ratio of mass melting to mass freezing for each 5-minute output.

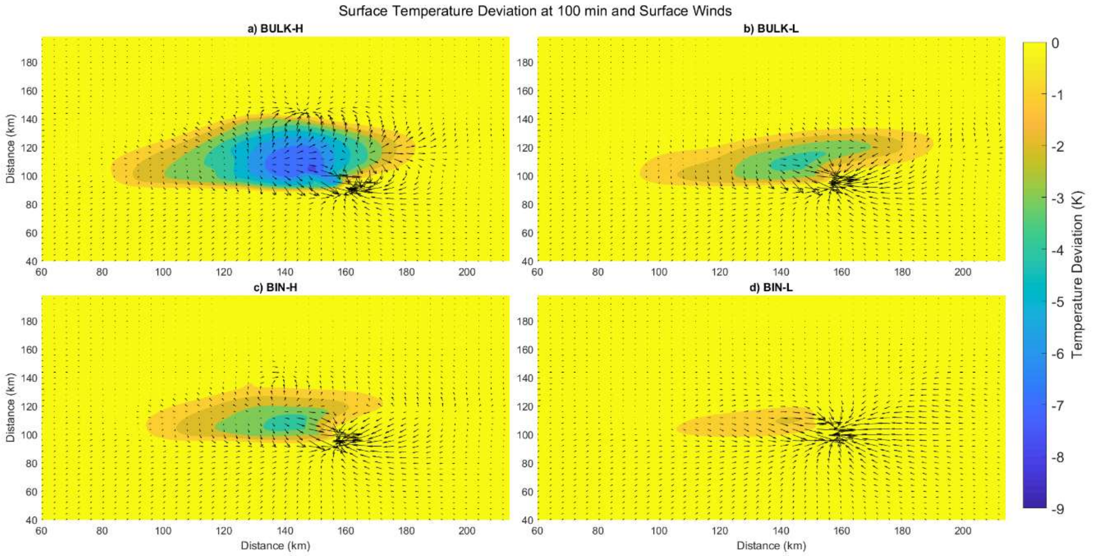

Figure 4. Surface temperature deviation at 100 min with surface winds