M.S. Defense Announcement
Sean Freeman
Thursday, October 11, 2018 at 1:00pm

Sean Freeman
M.S. Defense

October 11, 2018
1:00pm

Defense
ATS Large Classroom (101 ATS)

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Susan van den Heever (advisor)
Kristen Rasmussen
Richard Eykholt (Physics)

Assessing the Impacts of Microphysical and Environmental Controls on Simulated Supercell Storms

Supercell thunderstorms are some of the most dangerous single-cell storms on the planet. These storms produce many hazards to life and property, including tornadoes, floods, damaging straightline winds, strong updrafts and downdrafts, and lightning. Although these hazards are not unique to supercells, they are often at their strongest when supercell-produced. Because of the destructive power of supercell hazards, supercells have been the subject of scientific research for decades. In this thesis, two of these hazards will be examined: supercell rainfall and supercell tornadoes, with the overarching goal to improve both our process-level understanding and forecasts of these hazards.

The first part of this study focuses on supercell rainfall forecasts. Rainfall prediction by weather forecasting models, including supercell rainfall prediction, is strongly dependent on the microphysical parameterization being utilized in the model. As forecasting models have become more advanced, they are more commonly using double moment bulk microphysical parameterizations, which typically predict the hydrometeor number concentration and mass mixing ratio. While these double moment schemes are more sophisticated and require fewer *a priori* parameters than single moment parameterizations, a number of parameter values must still be fixed for quantities that are not prognosed or diagnosed. Two such parameters, the width of the drop size distribution and the choice of liquid collection efficiencies, are examined in Chapter 2. Simulations of a supercell were performed in which the collection efficiency dataset and the *a priori* width of the rain drop size distribution (DSD) were independently and simultaneously modified. Analysis of the results show that the *a priori* width of the DSD was a larger control on the total accumulated precipitation (a change of up to 130%) than the choice of the collection efficiency dataset used (a change of up to 10%). While the total precipitation difference when changing collision efficiency is relatively small, it does have a larger control on the warm rain process rates (including autoconversion and liquid accretion) than changing the rain DSD width does. The decrease in rainfall as the DSD width narrows is due to a combination of three main factors: (a) decreased rain production due to increased evaporation, (b) decreased rain production due to decreased ice melting, and (c) slower raindrop fall speeds which leads to longer residency times and changes in rain self-collection. The decreasing precipitation rate and accumulated precipitation with narrower DSD is consistent with observations of continental convection. This part of the study emphasizes that, in order to improve rainfall and flooding forecasts, the number of *a priori* parameters required by microphysical parameterizations should be reduced. Improvements in rainfall forecasts can be made immediately through the further development and implementation of triple-moment microphysical schemes, which do not require an *a priori* specified DSD width.

The second part of this study focuses on supercell tornado forecasts. Supercell-produced tornadoes make up a majority of the most violent tornadoes and result in 90% of tornado-related deaths. Improving lead times and reducing false alarm rates is therefore critical. However, this requires an enhanced understanding of the controls that environmental conditions have on supercell tornadogenesis as well as improved observational platforms that are able to better detect environments that can produce tornadic supercells in advance. Therefore, the goals of the research presented in Chapter 3 are to (1): understand the storm processes that change as environmental conditions of supercells are perturbed and (2): determine how sensitive platforms, especially space based platforms, would need to be in order to distinguish between environments that can produce tornadic supercells from those that will produce nontornadic supercells. To address the goals, a suite of experiments were performed with a numerical model where the Convective Available Potential Energy (CAPE), Lifted Condensation Level (LCL), and low level wind shear are independently perturbed. The presented research shows that a sufficiently accurate platform can add value to supercell tornado forecasting. Further, several processes that influenced tornadogenesis, including cold pool strength and the role of horizontal vorticity, were found to have an impact on tornadogenesis. This part of the study emphasizes the need for new observational platforms that can more accurately observe environmental conditions in order to improve supercell tornado forecasting.

Overall, the research presented here highlights supercell flooding and tornado forecast improvements that can be made with forecasting models and observational systems. Careful selection of *a priori* parameters, such as the width of the rain DSD, or reducing the number of those parameters required by microphysical parameterizations could improve supercell rainfall forecasts, therefore improving flooding forecasts. Supercell tornado forecasts can be improved by the addition of accurate space-based observational platforms which can help to distinguish between tornadic and nontornadic environmental conditions.