Ph.D. Defense Announcement
Erik Nielsen
Tuesday, March 12 at 11:00am

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Defense
ATS Large Classroom (101 ATS)

Post Defense Meeting
Riehl Conference Room (211 ACRC)

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INSIGHTS INTO EXTREME SHORT-TERM PRECIPITATION ASSOCIATED WITH SUPERCELLS AND MESOVORTICES

Overall, this manuscript aims to holistically evaluate the relationship between rotation and extreme precipitation processes, since radar and rain gauge observations in several flash flooding events have suggested that the heaviest short-term rainfall accumulations were associated with supercells or mesovortices embedded within larger convective systems.

A specific subclass of these events, when tornadoes and flash floods are both concurrent and collocated (referred to here at TORFF events), present a unique set of concerns, since the recommended life-saving actions for each threat are contradictory. Given this, Chapter 2 aims to evaluate the climatological and meteorological characteristics associated with TORFF events over the United States. Two separate datasets, one based on overlapping tornado and flash flood warnings and the other based on observations, were used to arrive at estimations of the instances when a TORFF event was deemed imminent and verified to have occurred, respectively. These datasets, combined with field project data, were then used to discern the geographical and meteorological characteristics of recent TORFF events. The results show that TORFF scenarios commonly occur, are not easily distinguishable from tornadic events that fail to produce collocated flash flooding, and present difficult challenges both from the perspective of forecasting and public communication.

The research in Chapter 3 strives to identify the influence that rotation has on the storm-scale processes associated with heavy precipitation. Five total idealized simulations of a TORFF event, where the magnitude of the 0–1 km shear was varied, were performed to test the sensitivity of precipitation processes to rotation. In the simulations with greater environmental low-level shear and associated rotation, more precipitation fell, both in a point maximum and area-averaged sense. Intense, rotationally induced low-level vertical accelerations associated with the dynamic nonlinear perturbation vertical pressure gradient force were found to enhance the low-to-mid level updraft strength, total vertical mass flux, and allowed access to otherwise inhibited sources of moisture and CAPE in the higher shear simulations. The dynamical accelerations, which increased with the intensity of the low-level shear, dominated over buoyant accelerations in the low levels and were responsible for inducing more intense, low-level updrafts that were sustained despite a stable boundary layer.

Chapter 4 aims to explore how often extreme short-term rain rates in the United States are associated with storm-scale or mesoscale vortices, since significant low-level rotation does not always yield a tornado (i.e., not all extreme rainfall events are TORFFs). Five years of METAR observations and three years of Stage-IV analyses were obtained and filtered for hourly accumulations over 75 and 100 mm, respectively. Local dual-pol radar data was then obtained for the remaining events for the hour leading up to the METAR observation. Nearly 50% of the cases were associated with low-level rotation in high precipitation supercells and/or mesoscale vortices embedded in more organized storm modes. These results support recent modeling results, presented in Chapter 3, suggesting that rotationally induced dynamic vertical pressure accelerations are important to the precipitation formation mechanisms that lead to extreme short-term rainfall rates.

The upper Texas Coast, in and around the Houston, TX area, has experienced many intense TORFF events over the recent years. The research in Chapter 5 focuses on examining the horizontally heterogeneous environmental characteristics associated with one of those events, the Tax Day flood of 2016, which was identified as a "verified" TORFF event in Chapter 2. Radar and local mesonet rain gauge observations were used to examine the storm scale characteristics to identify the locations and structures of extreme rain rate producing cells. To supplement the observational based analysis above, a WRF-ARW simulation of the Tax Day flood in 2016, based upon a real-time forecast from the HRRR, was examined. Convective cells that produced the most intense short-term (i.e., sub-hourly to hourly) accumulations within the MCS were examined for the influence of any attendant rotation on both the dynamics and microphysics of the precipitation processes. Results show that the most intense rainfall accumulations, as in the observations analysis, are associated with rotating convective elements, and the results of this chapter confirm that the processes described in Chapter 3 apply outside of the idealized framework.