A Climatological Perspective on Tornado Outbreaks Spawned by Landfalling Tropical Cyclones Across the Eastern U.S.

Jordan McLeod and Chip Konrad
The Southeast Regional Climate Center (SERCC), The University of North Carolina at Chapel Hill

Background

- Upon making landfall, tropical cyclones (TCs) typically spawn tornadoes within their right-forward quadrant, but the strength and frequency of these tornadoes can be quite variable on a case-by-case basis. For example, Hurricane Ivan (2004) generated an extraordinary 3-day outbreak of 116 tornadoes across 9 states, while Hurricane Dennis (2005), despite a remarkably similar surface strength and landfall location, produced a mere 10 tornadoes, with all but one occurring in the state of Florida (Fig. 1).

- Previous studies (e.g., Curtis (2004) and Baker et al. (2009)) have associated TC tornado outbreaks with strong mid-level vorticity, high convective available potential energy (CAPE), and the presence of a dry air intrusion.

- In order to determine how the most prolific tornado outbreaks are generated, this paper examines 33 landfalling TCs along the Gulf Coast of the United States (excluding Texas). They are analyzed through a synoptic conceptual framework that distinguishes the TCs in terms of their location with respect to the mid-latitude westerlies.

Methodology

- The study examined all tornadoes associated with TCs that made landfall along the Gulf Coast from 1985-2009. Atlantic landfalling TCs were not included in this study as 88% of TC tornadoes in the U.S. are associated with Gulf landfalling systems.

- For this analysis, the total tornado production for each Gulf TC was segregated into daily “mini-outbreaks” (days with >5 tornadoes) or “non-outbreaks” (days with <5 tornadoes) using Roger Edwards’ TC/03 database.

- Each tornado day (i.e., mini-outbreak or non-outbreak) was assigned to one of four synoptic stages on the basis of the location of the TC relative to the mid-latitude circulation (Fig. 2).

- The aggregate power or destructive potential of the tornado observed on each day was estimated through the calculation of “Fujita miles” (Box 1).

Box 1: The “Fujita Miles” Concept

Fujita miles is defined as the F/EF level of a tornado multiplied by its track length. Mathematically, this translates into the following formula: F/EF level (0-5) * track length (miles) = Fujita miles

- Because the reported F/EF level represents the maximum level assigned along the tornado track, this metric overestimates the true intensity of a tornado. However, this overestimation bias should be minimal as most TC tornadoes are weak (i.e., F/EF-0 or F/EF-1).

- Previous studies (e.g., Curtis (2004) and Baker et al. (2009)) have associated TC tornado events with large TCs. The tercile analysis (Fig. 4) reveals that the first life cycle stage (“Tropical”) contains the greatest proportion of TCs with small Fujita miles across the four TC life cycle stages.

- The third life cycle stage (“Strong ET Influence”) contains the greatest proportion of TCs with large Fujita miles across the four TC life cycle stages.

- The most prolific tornado-spawning TCs tend to be large in size and possess strong upper-level circulations at the 850-mb level, particularly during the third life cycle stage. This suggests that strong shear (i.e., rapid increase in wind speed with height) is associated with large TCs and increases the threat for land-based tornadogenesis.

- This suggests that the size and 850-mb strength of a Gulf-landfalling TC can serve as useful predictors of the potential for enhanced tornadogenesis.

Conclusions and Future Work

- Significant tornado outbreaks can occur within any of the four TC life cycle stages, but the greatest frequency are by far associated with the third stage, when the TC accelerates with an eastward component of motion.

- The most prolific tornado-spawning TCs tend to be large in size and possess strong circulations at the 850-mb level, particularly during the third life cycle stage. This suggests that strong shear (i.e., rapid increase in wind speed with height) is associated with large TCs and increases the threat for land-based tornadogenesis.

- Based on the results of the tercile analysis and Student’s t-tests presented (Fig. 6), the 850-mb height and wind speed variables are not statistically significant indicators of prolific TC tornado production. The 500-mb wind speeds in the second life cycle stage are.

- The statistically insignificant results associated with the fourth life cycle stage may be tied to an insufficient sample size.