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Improving Tornado Watch and Warning Lead Time: A Case Study of the April 25, 2014 Severe Weather Event in Eastern North Carolina

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Abstract
The ability of ground-based radars to detect severe weather is critical in providing information that helps protect lives and property. The Weather Surveillance Radar 1988 Doppler (WSR-88D) network provides a continuous suite of data and products which, in tandem with other observational information, are vital for timely issuance of watches and warnings in advance of and during severe weather events. This study initially developed a tornado climatology for North Carolina from 1950 through 2018. The second part of this study investigated the pre-storm environment and the associated radar signatures of a notable supercell thunderstorm which occurred on April 25, 2014 utilizing the full suite of legacy and dual-polarization base products. It is hypothesized that examining the radar characteristics along with the mesoscale environments of this case will provide key information for identifying local thresholds. These have the potential to improve warning decision-making strategies, enhance detection of tornado events, and benefit forecast offices as well as emergency managers in the state of North Carolina and other Mid-Atlantic states.

Supercell thunderstorms are the least-common type of thunderstorm but are the most prolific producer of a variety of dangerous and potentially deadly hazards, including large hail, strong to violent tornadoes, and heavy rainfall/flooding (Markowski & Richardson, 2010, p. 213; Smith, et al., 2001; NWS Louisville, n.d.). This study focused on a particularly notable supercell which produced two strong tornadoes in eastern North Carolina on April 25, 2014 (see tracks in Fig. 1). This supercell produced one short track (1 mile) EF-2 tornado approximately thirteen minutes before it produced a much longer track (21 miles) EF-3 tornado. The first tornado flipped vehicles and damaged mobile homes during its short lifespan but caused no injuries. Meanwhile, the latter tornado severely damaged or destroyed 197 homes and structures during its thirty-five-minute lifespan and caused 16 injuries (NWS Newport/Morehead City, 2014; NCDPS, 2014).

Methodology

The first step of this project focused on updating the tornado climatology for the state of North Carolina. A tornado climatology is a collection of all recorded tornado events, including their date of occurrence, starting and ending latitude and longitude, maximum intensity, number of casualties, and other relevant information. Another student developed the initial climatology (1950-2014) utilizing data from the Storm Prediction Center's (SPC) Severe Weather Database and the National Centers for Environmental Information's (NCEI) Storm Events Database. Both databases should include the same tornado events, but the NCEI database stratifies each event by county whereas the SPC database considers one tornado, regardless of how many counties it tracked through, as one event. Some quality-control measures that were taken to ensure a robust data set started with comparing the two databases to identify inconsistencies, such as missing events in one database or different start and end points for the same event in each database, or duplicate events in the same database (Campbell, Blaes, & Locklear, 2015). Upon finding an inconsistency, further investigation included searching for case studies or journal articles or even downloading and viewing archived radar data to determine either which database is correct or how an error should be corrected. These measures and others were followed to update the climatology through 2018 using the same exact methods that were used to initially create it.

The second step of this project involved gathering surface and upper-air analyses from April 25, 2014 to evaluate the pre-storm environment and determine which factors contributed to the ultimate development of this supercell. The SPC and Weather Prediction Center retain archives of all the maps needed for this study. The third and final step of this project required the use of GR2Analyst, an advanced radar visualization program, to interrogate the archived radar data. These data included legacy base products, such as Base Reflectivity (Z) and Base Velocity (BV), along with dual-polarization products such as Differential Reflectivity (ZDR) and Correlation Coefficient (CC). Z is often displayed as weather radar seen on the news and on smartphone applications with a color bar ranging from green for light rain to red or purple for heavy rain and hail. BV is a measure of the component of wind headed directly toward or away from the radar site and is useful for identifying rotation and other signatures. ZDR compares the horizontal and vertical dimension of hydrometers (rain, hail, snow, etc.) to determine their shape and size. Lastly, CC compares the shape and size of all hydrometers that the radar can see to determine if precipitation is similar (all rain) or mixed (rain mixed with hail).

Findings/Conclusion

The supercell is still under investigation, which has consisted of following the storm from its initial formation through its lifetime to determine how the storm evolved. It was determined that the storm developed off a dewpoint boundary separating mid-50s dewpoints to the west from mid-60s dewpoints to the east and interacted through a split and merger with another storm. It produced large hail just under two hours after it initially formed and produced its first of two tornadoes about forty-five minutes after the first hail report. Marked changes in the storm intensity (Fig. 2) and appearance on radar are currently being related to the evolution of the storm based on the environment in which it was embedded. This investigation will lead to a distinct set of guidelines to anticipate tornado development with greater lead time in the future.

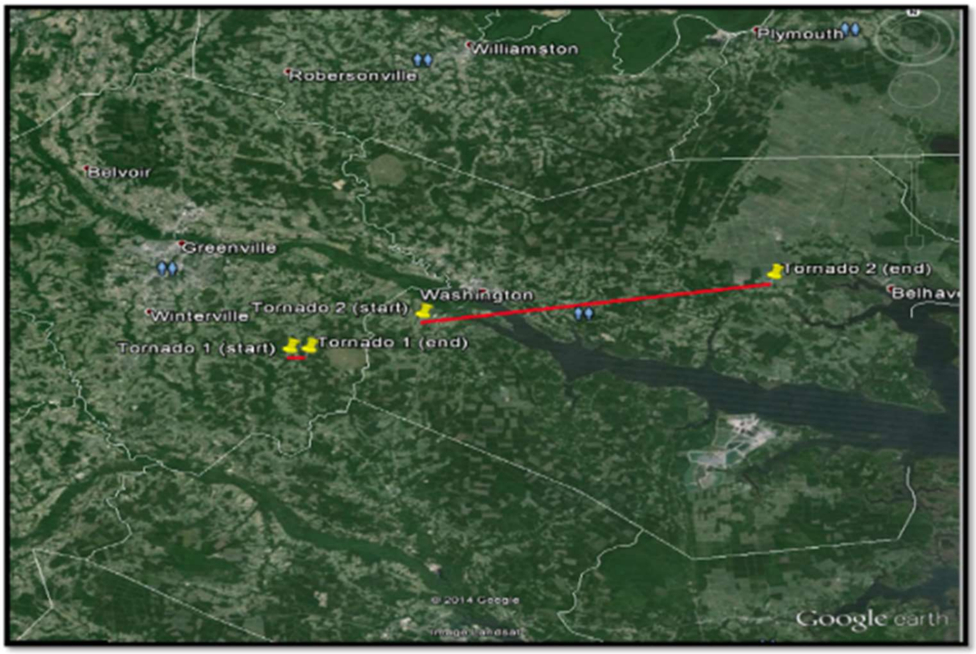

Figure 1. Map of tornado damage paths on April 25, 2014. This Google Earth map (NWS Newport/Morehead City, 2014) shows the start and end points of each tornado event with corresponding approximate paths of each tornado.

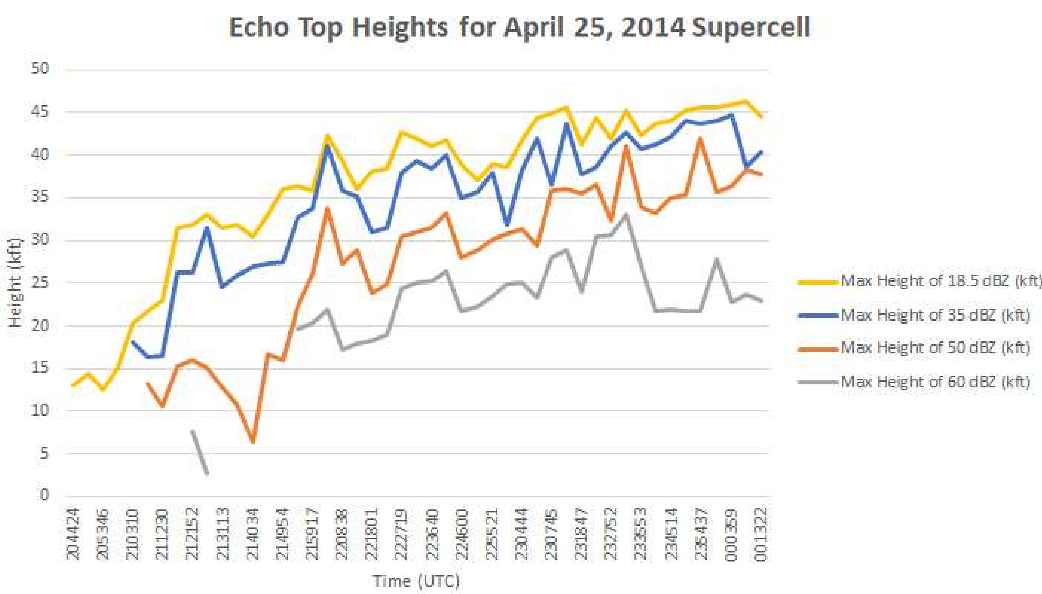

Figure 2. Time-height plot of echo top height. This is a measure of cloud top height (18.5 dBZ), cell height (35 dBZ) (Smith, et al., 2012)., and potential hail height (50 dBZ and 60 dBZ) (Frugis & Wasula, 2012), from initiation until the supercell merged with a squall line. As expected, increasing reflectivity should appear at lower heights since either large rain drops, a high concentration of rain, or large hail is embedded within those values and these are much heavier than smaller rain drops or ice crystals, which are associated with the lower reflectivity values.

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