P2.7 A TECHINQUE FOR DEVELOPING THE RATIO OF SUPERCELL TO NON-SUPERCELL THUNDERSTORMS

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1. INTRODUCTION

A thunderstorm is an area of deep moist convection in which lightning is present. There are two primary types of thunderstorms; supercell and non-supercell. Several attempts have been made to quantify the discrimination of supercells and non-supercells (e.g., Moller 1994; Thompson et al. 2003, hereafter T03; Hocker 2006) but common to each is the basic premise that a supercell is a thunderstorm possessing a deep, persistent mesocyclone: a storm-scale vortex spanning a significant depth of the convective storm, and persisting on the order of tens of minutes (the approximate convective timescale)

The tools most commonly used for identifying supercell thunderstorms are numerical and visual examination of radar data. Typical supercell characteristics include the visual presence of a "hook echo", inflow notch, bounded weak echo region (BWER), and motion deviating from that of the mean wind. Numerical characteristics include the magnitude and persistence of azimuthal shear.

One topic of concern is the suggestion that supercells tend to produce a disproportionately high number of casualties and damage in comparison to non-supercells (Moller et al., 1994; Doswell, 2001). However, the true frequency of supercells relative to non-supercells remains unknown. The work of T03 represents the most complete attempt to create a U.S. supercell climatology to date. However, T03 relied on a database of springtime cyclonic supercells, neglected elevated and anticyclonic supercells, and relied heavily on the manual analysis of the aforementioned visual supercell characteristics.

In this study, we propose a new technique to construct a climatology of supercell and non-supercell thunderstorms. The technique is strictly quantitative, and accounts for both anticyclonic and elevated supercells. Because it will be fully automated, it will be able to quickly and accurately process large amounts of data, and may easily be applied to more than just springtime storms. This technique will be used in future work to build a robust climatology of supercell frequency and severity.

2. DATA

In this study, we will be using level II radar data from the WSR-88D radar network. Level II data represents the most complete radar data form available. This includes but is not limited to all radar elevation angles of reflectivity and velocity

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data. Lightning data from the National Lightning Detection Network (NLDN) is also incorporated into the study. The lightning dataset is comprised of all cloud-to-ground strike locations. Upper air soundings will also be used to establish first guesses in the cell tracking process.

3. METHODOLOGY

There are three stages to this technique: 1) identify individual thunderstorms, 2) associate thunderstorms with any mesocyclones that may be present, and 3) track all of these storms through the area of interest. A slightly modified version of the Storm Cell Identification and Tracking (SCIT) algorithm (Johnson 1998) is used in identifying the presence of thunderstorms. The algorithm uses a minimum threshold of 30 dBZ present through at least two elevation scans and two radar beam widths. SCIT locates the storm cell centroid, and documents the cell location in terms of latitude and longitude.

The first condition that must be met for thunderstorm identification is that lightning must be associated with the SCIT-identified cell. In order to do this, the cell centroids must first be extrapolated to their location at the time of the lightning strike. After this, all cells within 5 km of the flash location are assigned to the flash. If no cell is found within the 5 km, it is assigned to the closest cell within 35 km of the flash location (Williams 1999).

The second condition that must be met for thunderstorm identification is that the SCIT-identified cell must persist for at least two consecutive radar scans (5-6 min). Quantifying cell persistence requires developing a storm track for each cell. The SCIT algorithm has its own method of tracking. However, it is designed in such a manner that it may be run in real-time and does not incorporate knowledge of future cell positions. This study has the advantage of knowing what the next radar scan looks like, and even what cells are identified by SCIT in the future. It was determined that a new method of tracking using this knowledge of the future, and based on the minimal mean track error, would be optimal in order to increase the overall track accuracy.

This method will be similar to the SCIT in that it predicts a future cell centroid position. This is predicted by the mean storm motion derived from the cell's previous storm track. If there is no previous storm motion vector, the motion will be determined using the sounding for the given day. It is also similar to the SCIT in that it searches the following radar scan in a 12 km radius surrounding the predicted centroid location for other SCIT identified cells.

However, this method differs from SCIT in that it accepts all cells within the radius as possible matches. The error from the expected centroid location and the observed cell centroid location is calculated for each possible match. The process is then repeated over the following radar scan for every cell within the radius, and in this manner multiple potential storm tracks are created for each individual cell. The track with the smallest mean error for its duration is deemed the best track for the cell. All cell locations used in this track are then discarded and the process is repeated for any other cells present.

After identifying all thunderstorms, the next step is to identify all mesocyclones. This is done primarily using the Mesocyclone Detection Algorithm (MDA) (Stumpf, et al. 1997). This algorithm identifies cyclonic and anticyclonic shear segments of varying magnitude across at least two radar elevation scans and two radar beam widths. The MDA then assigns them a mesocyclone strength rank from 1-25. Previous mesocyclone studies (Jones 2004; T03; Trapp 2005) have used varying values of minimum strength and persistency. For the purposes of this study, a shear segment will be considered a mesocyclone if it has a strength rank of 1 (10 m s^{-1} of radial velocity differential and/or 3 m s^{-1} km^{-1} of horizontal shear), and persists for at least 30 minutes.

It should also be noted that the radar range is adjusted to account for the distance that a supercell will travel in a 30 minute time period. The original circular radar velocity coverage (230 km radius) will be trimmed to a quasi-lens shape oriented normal to the mean storm motion. A distance of 36 km, oriented normal to the storm motion, is eliminated from the periphery of the radar range. This value is calculated to contain the 90^{th} percentile of supercell thunderstorm velocities based on several hundred supercell events from the T03 database. Without this filter, the occurrence of supercells could be spuriously low on the outer fringes of the SCIT and MDA detection ranges.

When all thunderstorms and mesocyclones are identified, they must be associated with each other for supercell identification. Mesocyclones are paired with the nearest thunderstorm cell within a 12km radius. To be classified as a supercell, a mesocyclone must be associated with a thunderstorm at every point along its track for a time period of 30 consecutive minutes. All mesocyclones unassociated with a nearby thunderstorm are discarded.

Statistical analysis of all supercells and non-supercells requires partitioning the analysis domain into a mesh of isotropic grid boxes. The total number of storm tracks will dictate grid box size: if more total storm tracks are available, resolution can be increased while maintaining statistical significance. All supercell and non-supercell tracks passing through a given grid box will then be tabulated, facilitating statistical analysis.

4.) FUTURE ANALYSIS

The first step in data analysis is to test the method on one full thunderstorm event. The chosen event spans from 0001 UTC on 15 April 2006 through 1200 UTC on 16 April 2006 in the KOAX (Valley NE NWSFO) radar range. This is a case in which isolated supercells, a squall line, supercells embedded in a squall line, isolated thunderstorms, and stratiform precipitation are all present within the radar range

As soon as the full methodology has been tested on the aforementioned case, and meets accuracy requirements, it will be implemented on progressively larger datasets. Our long-term objective is to apply this technique to the entire United States, and perhaps even other countries where supercells occur with some significance and adequate radar and lightning data are available.

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6.) REFERENCES

Doswell, C. A., III, 2001: Severe convective storms - an overview. *Severe Convective Storms, Meteor. Monogr.*, C. A. Doswell III, Ed., No. 28, Amer. Meteor. Soc., 1-26.

Hocker, J. E., J.B. Basara, 2006: A Twelve Year Climatological Analysis of Severe Local Storms Observed by the Oklahoma Mesonet. *Symposium of the Challenges of Severe Convective Storms*, Atlanta, GA.

Johnson, J. T., P.L. MacKeen, A. Witt, E.D. Mitchell, G.J. Stumpf, M.D. Eilts, K.W. Thomas, 1998: The Storm Cell Identification and Tracking Algorithm: An Enhanced WSR-88D Algorithm. *Weather and Forecasting*, **13,** 263-276.

Jones, T. A., K. M. McGrath, J. T. Snow, 2004: Assocation between NSSL Mesocyclone Detection Algorithm-Detected Vortices and Tornadoes. *Weather and Forecasting*, **19,** 872-890.

Moller, A. R., Doswell, C. A., Foster, M.P., Woodall, G.R., 1994: The Operational Recognition of Supercell Thunderstorm Environments and Storm Structures. *Weathe and Forecasting*, **9,** 327-347.

Stumpf, G. J., A. Witt, E. D. Mitchell, P. L. Spencer, J.T. Johnson, M. D. Eilts, K. W. Thomas, D. W. Burgess, 1997: The National Severe Storms Laboratory Mesocyclone Detection Algorithm for the WSR-88D. *Weather and Forecasting*, **13,** 304-326.

Thompson, R. L., R. Edwards, J. A. Hart, K. L. Elmore, P. Markowski, 2003: Close Proximity Soundings within Supercell Environments Obtained from the Rapid Update Cycle. *Weather and Forecasting*, **18,** 1243-1261.

Trapp, R. J., G.J. Stumpf, K.L. Manross, 2005: A Reassessment of the Percentage of Tornadic Mesocyclones. *Weather and Forecasting*, **20,** 680-687.

Williams, E., B. Boldi, A Matlin, M. Weber, S. Hodanish, D. Sharp, S. Goodman, R. Raghavan, D. Buechler, 1999: The Behavior of Total Lightning Activity in Severe Florida Thunderstorms. *Jouranl of Atmospheric Research*, **51,** 245-265.