12.4 THE ROLE OF THE PREEXISTING BOUNDARY ON TORNADOGENESIS IN THE 27 MAY 1997 CENTRAL TEXAS EVENT

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1. OBJECTIVES AND HYPOTHESIS

The high-CAPE and low-shear that characterized the environment associated with the 27 May 1997 central Texas tornadic storms would not have traditionally been associated with long-lived, rotating, tornadic thunderstorms. However, there is an increasing body of anecdotal evidence that suggests that these environments can support long-lived, severe, and occasionally tornadic thunderstorms *especially when a preexisting boundary is present*. The precise role that preexisting boundaries play in such cases is not well understood.

An examination of the 27 May 1997 case by Magsig et al. (1998a,b; henceforth collectively referred to as M98) clearly demonstrated that the tornadoes in this case formed well away from the preexisting wind-shift boundary. Furthermore, they found that the most destructive tornado of the sequence, the Jarrell tornado, was coincident with the intersection of two storm induced gust fronts. They concluded that the tornadoes of this case were not directly stretched out of the pool of vertical vorticity along the preexisting boundary and that the boundary served only to initiate new storms. The open question regarding this case is, was there an indirect role played by the preexisting boundary in tornadogenesis? In as far as the preexisting boundary was responsible for storm initiation, an implicit relationship exists between the boundary and tornadogenesis. However our hypothesis is that the preexisting boundary played a more substantial, albeit complex, indirect role in tornadogenesis in the 27 May 1997 central Texas storms.

Specifically we propose that the preexisting boundary ultimately promoted tornadogenesis by generating updrafts that were stronger and *more persistent* than they would have been in the absence of the boundary. These stronger, more persistent updrafts served to amplify self-induced low-level vorticity (M98) into frequent, occasionally strong tornadoes. Updrafts were made stronger and more persistent through intensification of the mid-level mesocyclone and the promotion of cell mergers. Mesocyclones were amplified through vertical advection of vertical vorticity off of the preexisting boundary. Cell mergers directly resulted from the parade of new cells that developed on the preexisting boundary, propagated (generally) to the east-northeast, and merged with the primary, right-moving updrafts. We propose that the role of the cell mergers was to amplify both the vertical velocities and vertical vorticities of the conglomerated updrafts while the role of the persistent mid-level mesocyclones was to sweep precipitation out of the downwind cores toward the west thereby both prolonging the updrafts' lives and presumably increasing their intensity by slowing the undercutting of the updraft by the spreading outflow.

2. APPROACH

To address these issues we have undertaken a detailed analysis of the radar data for this case with the intent of establishing spatial and temporal relationships between discrete updrafts, surface boundaries, and reported tornadoes. The full radar data set consists of WSR-88D level II data from New Braunfels, TX (EWX) and Fort Worth, TX (FWS) as well as level IV data from Granger, TX (GRK). We chose to use the level II data from EWX and FWS for updraft identification. Although further away from the storms than GRK, the level II format is more comprehensive and can be visualized more flexibly using WATADS (WATADS 2000).

When deciding which radar to use for a specific updraft, preference was given to the closest radar. Multiple elevation angles along with vertical cross-sections were analyzed to establish vertical continuity. Multiple times were analyzed to establish temporal continuity and to develop cell tracks. Special attention was paid to the location of storm summits and weak echo regions (WERs) or bounded weak echo regions

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(BWERs). Each final cell position was refined based on cell age: cell position was coincident with elevated reflectivity maxima for new cells and low-level reflectivity maxima for decaying cells.

Surface boundary positions were identified using the closer GRK radar; as the higher spatial resolution and lower beam elevation were better able represent these features. Tornado tracks were gleaned from the analysis of M98 combined with Storm Data (NOAA 1997).

3. RESULTS AND WORK IN PROGRESS

3.1. Cell development

Analysis of the relationship between the locations of cell initiation and boundary position revealed that many cells developed on the southern end of meso-γ (Orlanski 1975) cyclonic gyres present on the preexisting boundary (Fig. 1). It appears that these gyres developed in response to the interaction of the preexisting boundary and the southernmost extent of the expanding storm-induced outflow.

3.2. Mergers

Analysis of cell tracks revealed that numerous cell mergers occurred during the evolution of the storms in this case. We are proposing that cell mergers served to intensify both cell rotation and vertical motion, a behavior that has precedence in observations of mergers (Lemon 1976; Westcott 1984) and modeling studies (Finley 2001), and that the prolific generation of new cells by the preexisting boundary accounts for the frequent mergers. Fig. 2 illustrates one such merger.

Preliminary analysis revealed circumstantial evidence suggesting that mergers may have resulted in the intensification of the tornado that struck Jarrell. Storm Data (NOAA 1997) reports that shortly after 2040 (all times are UTC) the tornado "expanded quickly into a very large vortex nearly ½ mile in width". The cell merger occurred at approximately 2037 and the spatial relationship to the tornado can be seen in Fig. 2 (the tornado was located on the west flank of the updraft at the "triple-point" of the storm-induced gust fronts).

Further analysis will focus on assessing the proposed intensification of the mesocyclone associated with cell mergers by identifying the temporal relationship between cell mergers and the enhancement of horizontal shear. We will also attempt to establish whether cell mergers coincided with increases in cell reflectivities, presumably associated with enhanced vertical velocities.

3.3. Mid-level mesocyclones

Preliminary analysis revealed that frequent, persistent, and occasionally strong mid-level mesocyclones were associated with the primary updrafts in this case. It is our belief that the *primary* function of the mid-level mesocyclones in this case was to prolong the life of the parent updrafts by transporting precipitation out of the downwind cascade and depositing it on the west/northwest flank of the updrafts. This serves to retard the undercutting of the updraft by the surface outflow. Some evidence for this claim can be found in the relationship between the low-level reflectivity field and updraft position (Fig. 2). Note that the low-level precipitation is displaced to the west/northwest/north of the updraft.

We are also proposing that one of the mechanisms responsible for mid-level mesocyclone formation acts to increase overall storm intensity by promoting cell mergers. Specifically, we hypothesize that mid-level mesocyclone formation can be attributed, in part, to the tilting by the updraft of horizontal vorticity associated with the vertical shear. This, in turn, leads to deviate motion that favors cell mergers. Ostensibly the weak vertical shear that characterized the environment of this case would preclude the development of mid-level mesocyclones through this method. However, we believe that, as proposed by Rasmussen and Blanchard (1998), because the tilting term ($\omega \bullet \nabla w$; where ω is the horizontal vorticity vector and w is the vertical velocity) in the vertical vorticity tendency equation is dependent on the vertical shear *and* the vertical velocity, the large CAPE in this case is able to partially compensate for the modest vertical shear thereby generating weak mesocyclones. Qualitative support for this argument can be found in the observation that despite mean environmental winds from the west-southwest, the primary updrafts propagated to the southeast. The tracks of three such updrafts are illustrated in Fig. 1. (Each cell appearing in Fig. 1 successively became the primary updraft in the Jarrell storm.) We intend to pursue this issue by comparing the onset of deviate motion with the development of mid-level rotation. A high correlation between the two would suggest that the tilting of environmental horizontal vorticity may be enhancing deviate motion and mesocyclogenesis and may dominate the alternative forcing for deviate cell motion, forced ascent along gust fronts. We also intend to track cell motion relative to gust front motion to determine if cells become anchored to the gust fronts. Anchoring may be an indication that deviate cell motion may instead be controlled by forced ascent along gust fronts.

Admittedly, this argument alone may not sufficiently explain the strength of the observed mid-level mesocyclones. Therefore we also propose that mid-level vertical vorticity is further augmented through the vertical advection of vertical vorticity in place along the preexisting boundary. For this mechanism to be relevant though, cells must remain near their low-level source, in this case, the preexisting boundary. Although only 2 of the 7 primary updrafts were found to be quasi-stationary, none of the cells were observed to rapidly decouple from the boundary. Additional efforts will focus on tracking rotation vertically through the cells. The ascent of horizontal shear off of the surface would indicate that the preexisting boundary might indeed be contributing vertical vorticity to the mid-level mesocyclone.

3.4. Tornadogenesis

Through comparison of surface boundary positions and the locations of observed tornadoes, M98 concluded that all of the tornadoes in the two best-sampled storms formed on storm-induced gust fronts. They concluded that tornadogenesis was largely the result of "storm-generated" processes. We are proposing the complementary hypothesis that in the absence of the preexisting boundary, storms would not have been strong enough or persistent enough to produce tornadoes through these "storm-generated" processes. Specifically, we feel that the stronger, more persistent updraft-downdraft couplets result in larger low-level vertical vorticity production through enhanced low-level buoyancy and horizontal momentum gradients and larger vertical vorticity amplification through stretching.

4. SUMMARY

It is our opinion that on 27 May 1997 tornadogenesis was not the result of an arbitrary juxtaposition of intense updrafts with vorticity residing on gust fronts but instead a coordinated interaction between convection and a preexisting boundary. The aim of this study is to identify the nature of this interaction. Preliminary analysis has illuminated several potential connections between the preexisting boundary and tornadogenesis including (1) the occurrence of mergers and their temporal coincidence with intensification of the Jarrell tornado, (2) a dominant mechanism of cell redevelopment on the preexisting boundary, and (3) the presence of persistent, occasionally strong mid-level mesocyclones. Future radar analysis will focus on identifying (1) the contribution of vertical vorticity on the boundary to the mid-level mesocyclone, (2) the role of mergers in the intensification of the mid-level mesocyclone and vertical velocities, and (3) the role of the tilting of environmental horizontal vorticity to mid-level mesocyclogenesis and deviate motion.

Although the work outlined here approaches the problem through analysis of radar data, the complete scope of this research also includes a modeling component. A description of this work can be found in paper P6.4 elsewhere in these proceedings.

For the latest results please refer to the following URL: http://redrock.ncsa.uiuc.edu/~ahous/Supercell-DC/

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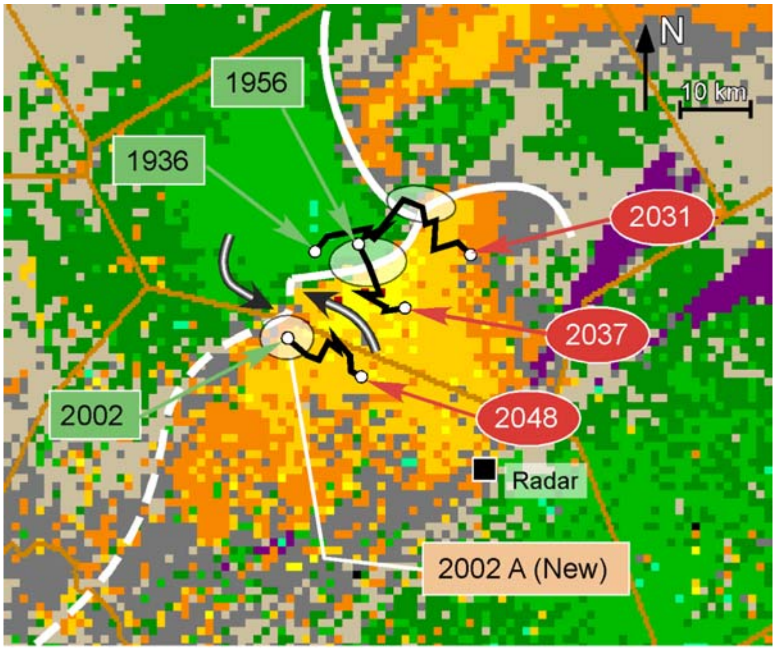

Figure 1: 0.5° storm-relative velocity from GRK at 2002 UTC. Storm-induced gust fronts are indicated with solid curves while the preexisting boundary appears as a dashed curve. Cell positions at this time appear as semi-transparent ovals. Tracks of three primary cells appear as solid black lines. Cell initiation times are indicated with the "box pointers" while cell decay times are indicated with the "oval pointers". Thicker arrows represent approximate streamlines associated with the gyre.

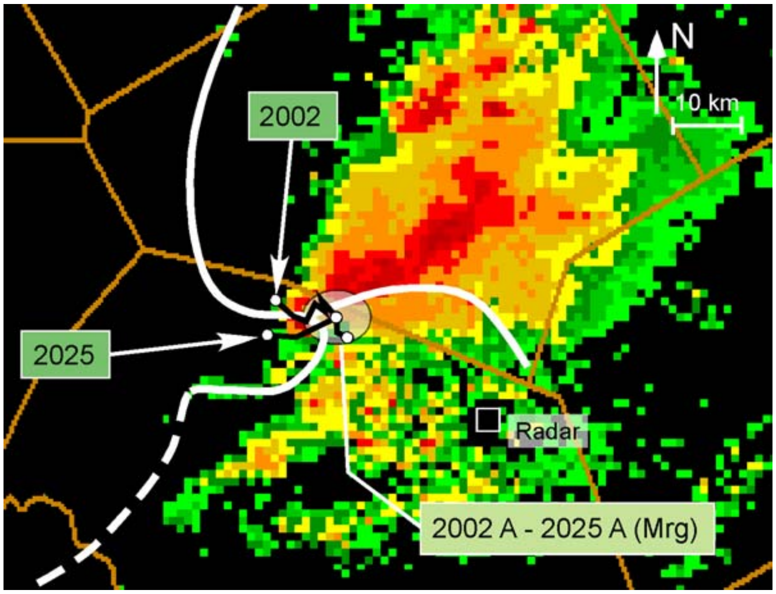

Figure 2: 0.5° base reflectivity from GRK at 2038 UTC. Storm-induced gust fronts are indicated with solid curves while the preexisting boundary appears as a dashed curve. Tracks of the merging cells appear as solid black lines. Cell initiation times are indicated with the "box pointers". The position of the merged cell appears as a semi-transparent oval.