P 11.4 THE EFFECTS OF LOW-LEVEL BOUNDARIES ON THE DEVELOPMENT OF THE PANHANDLE, TX TORNADIC STORM ON 29 MAY 2001

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1. INTRODUCTION

On 29 May 2001 several supercells developed in west Texas ahead of a dryline. However, only one storm became a prolific tornado producer. Detailed radar and satellite analyses revealed the tornadic storm (herein called the Panhandle storm) interacted with surface boundaries produced by earlier convection. This storm also interacted with the forward flank downdraft of another supercell just to the southeast (herein called the Conway storm). The authors believe that the presence of surface boundaries and interaction with a nearby storm enhanced wind and moisture convergence in the Panhandle storm aiding in tornadogenesis. This case study illustrates how mesoscale factors influence storm behavior and present difficulties in forecasting and warning.

2. METEOROLOGICAL OVERVIEW

Early on 29 May 2001, a line of thunderstorms developed in west Texas in response to a vorticity maximum that moved through the area. These storms produced a number of outflow boundaries. Analysis of the 1200 UTC (coordinated universal time) upper air maps revealed an open trough with positive tilt axis centered over the four-corners region in the southwestern United States. A 500 mb jet of 50 knots rounded the base of the trough and extended into west Texas. At 250 mb, the diffluence axis extended from El Paso, TX to Oklahoma City, OK. Ample gulf moisture had been transported into west Texas by a 30 knot jet. The morning sounding at Amarillo had the classic "bell-shaped" profile recognized by Miller (1972) as favorable for the development of severe storms. In addition, southeast surface winds veered to southwesterly aloft, and wind speeds increased with height giving rise to a broad-looped hodograph recognized by Rasmussen and Wilhelmson (1983) as favorable for rotating storms. The convective temperature of 25º C (77ºF) would easily be reached in the afternoon.

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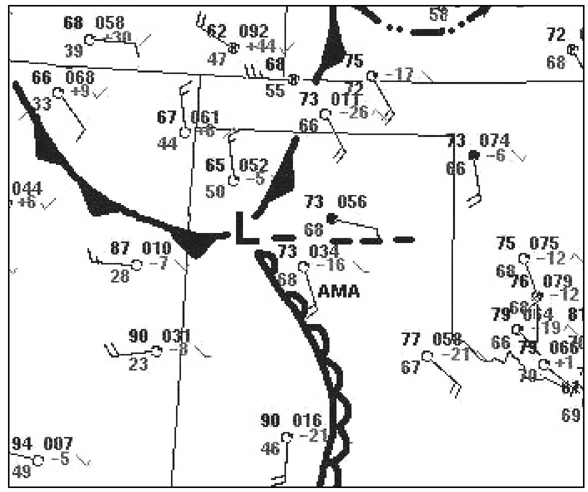

Figure 1. Surface weather map for the Texas panhandle region at 0000 UTC on 30 May 2001 showing cold front, dryline, and outflow boundary.

Surface low-pressure was centered near Springfield, CO that morning. A dryline extended southward from the surface low along the Texas - New Mexico border. Winds were west-southwest behind the dryline and southeasterly ahead of it. Maximum moisture convergence occurred in a narrow region just ahead of the dryline. Morning RUC (Rapid Update Cycle) model data indicated a dryline bulge would form during the afternoon southwest of Amarillo. Tegtmeier (1974) has shown that regions northeast of a dryline bulge are favored areas for supercells. Thus, it was anticipated that severe storms would form in the Amarillo vicinity by late afternoon.

By 0000 UTC, the surface low had moved southeast into the northwest Texas panhandle (Fig. 1). In addition, the dryline had moved east of Lubbock. Severe storms developed along the dryline throughout west Texas.

3. SATELLITE ANALYSIS

A short-wave trough was evident on satellite imagery that morning as indicated by a comma-head cloud formation over Colorado. Isolated thunderstorms developed at the tail-end of this cloud formation before noon in southeast Colorado and quickly became tornadic. These storms eventually formed a squall line as they moved into western Kansas. Three cloud-free areas were visible in the Texas panhandle by early afternoon. The cloud-free areas contained more stable, stratified air left in the wake of early morning convection. However, surface air and dewpoint temperatures were not significantly lower in these cloud-free areas. As Purdom (1983) showed, the edges of such cloud-free areas represent boundaries where deep convection can occur. The southern edge of the cloud-free areas was positioned just north of Amarillo. As the afternoon progressed, towering cumulus developed in an arc along the south and west edges of the outflow boundaries.

4. RADAR ANALYSIS AND STORM OBSERVATIONS

By mid afternoon, three boundaries were evident on radar. A cold front extended northeast-southwest through the northern Texas panhandle. Severe thunderstorms already were in progress along the front. Another boundary extended east-northeast from Claude to Wheeler, TX, left over from the previous day's convection. This outflow boundary separated lower LCL (lifting condensation level) air to the north from higher LCL air to the south. A sharp dryline boundary extended across west Texas from Vega southward to Dimmit to just west of Littlefield. There was a slight bulge in the dryline near Hereford, Texas. The first storm along the dryline formed in Lamb County around 2045 UTC (3:45 p.m.). This storm quickly organized into a supercell as it moved northeast toward Tulia and later evolved into an HP (high precipitation) supercell. Ten minutes after the Tulia storm developed, the Panhandle storm formed 20 miles east of the dryline, about 15 miles west-northwest of Amarillo. This storm developed just north of the surface boundary in the lower LCL air.

By 2130 UTC, a strong mesocyclone had developed on the western edge of the Panhandle storm, becoming a "classic" type supercell. A severe thunderstorm warning was issued when the storm was located 21 km northwest of Amarillo. Our chase team (the lead author, Carson Eads, and Sam Barricklow) departed the Amarillo NWS for this storm. Initially, we observed a round, rain-free cloud base to our west just north of the city (Fig. 2). However, the storm continued to build westward into a region of clear sky while the cloud base elongated east-west. At 2204 UTC, the mesocyclone gate-to-gate shear peaked at 82 knots, and the first weak hook signature was detected at 2214 UTC (Fig. 3). Surface winds backed to the east in front of the storm, however, the storm appeared to have difficulty in concentrating its rotation. At 2240 UTC, a wall cloud formed at the very western edge of the cloud base and began to rotate rapidly. However, the wall cloud was undercut by outflow from the north, and the circulation center shifted a few miles east as the storm moved east.

By 2300 UTC, the Panhandle storm weakened when a smaller storm from the south merged with its forward flank precipitation region (Fig. 4). Gate-to-gate shears gradually decreased from 76 knots to 17 knots during the period from 2259 to 2339 UTC.

Figure 2. View looking west of the rain free base on the Panhandle storm at 2206 UTC.

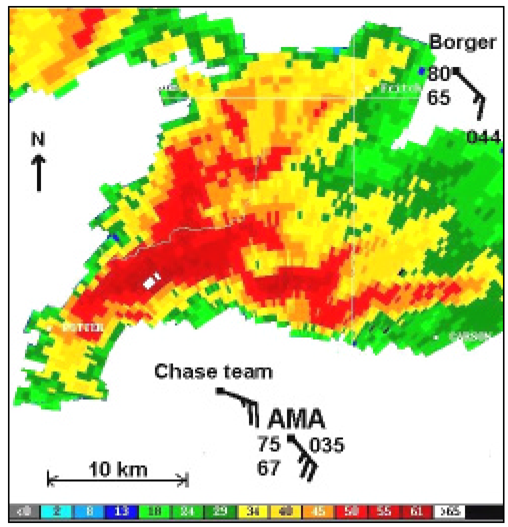

Figure 3. Radar reflectivity image of the Panhandle storm at 2214 UTC. AMA is the Amarillo radar site. Surface weather observations were taken at 2200 UTC.

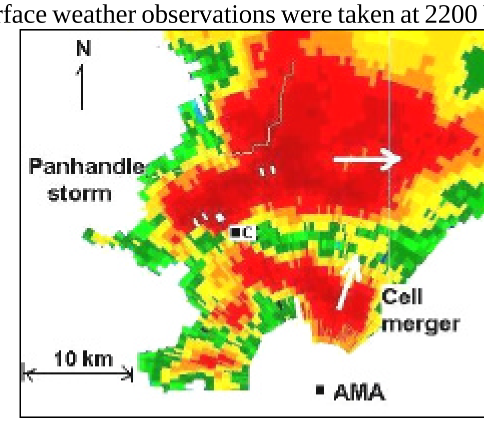

Figure 4. Radar reflectivity image of the Panhandle storm during showing cell merger at 2253 UTC. Bold arrows indicate storm motions. Chase team is at "C".

We believe the Panhandle storm weakened as it crossed the less buoyant, rain-cooled air left in the wake of the smaller storm. Cloud bases lowered to a few hundred meters above ground, and during the next 40 minutes, the Panhandle storm reorganized. Cloud striations formed on the east side of the main updraft and mid-level cloud bands extended east-southeast.

Meanwhile, the Conway storm approached the Panhandle storm from the south. The Conway storm was moving east-northeast at a forward speed slightly faster than the Panhandle storm. Photographs taken of this storm by other chasers indicated the Conway storm was an LP (low-precipitation) type. The anvil of the Conway storm soon intersected the forward flank of the Panhandle storm. Easterly surface winds increased during this time, suggesting that inflow air was being funneled between the storms (Fig. 5).

By 2349 UTC, gate-to-gate shear on the Panhandle storm increased rapidly to 107 knots, and a TVS (tornado vortex signature) appeared. A rear flank downdraft descended around the south side of the storm base, and a brief funnel formed extending about one-third of the way to the ground. Winds south of the storm base shifted to strong west, and a cloud free "clear slot" formed. At 2355 UTC, the first tornado developed at the back edge of the occluding and shrinking updraft. This cylindrically-shaped tornado lasted only two minutes. At 2358 UTC, strong outbound winds were detected on the radial velocity scans south of the mesocyclone, denoting a broad rear flank downdraft. Surface northwesterlies from the cold front also were impinging on the back edge of the storm. This likely enhanced vertical vorticity around the mesocyclone causing it to strengthen.

At 0000 UTC, the reflectivity gradient became well defined on the south side of the Panhandle storm with high reflectivities in the elongated precipitation core. It appeared that air descending from the FFD (forward flank downdraft) of the Conway storm was being wrapped into the inflow region east-northeast of the Panhandle storm. As a result, a second, strong mesocyclone rapidly formed on the forward flank of the Panhandle storm, about seven kilometers east of the old mesocyclone (Fig. 5). A small, rope-shaped tornado developed quickly from this new mesocyclone and lasted two minutes (Fig. 6) followed by another tornado beneath the old mesocyclone to the northwest.

At 0005 UTC, a hook echo developed on the Panhandle storm in association with the new mesocyclone. A TVS was indicated at 0010 UTC, and gate-to-gate shears increased to 111 knots. (This began 45-minutes of continuous TVS's.) At 0015 UTC, a multivortex tornado began north of town beneath a large rotating wall cloud (Figs. 7 and 8).

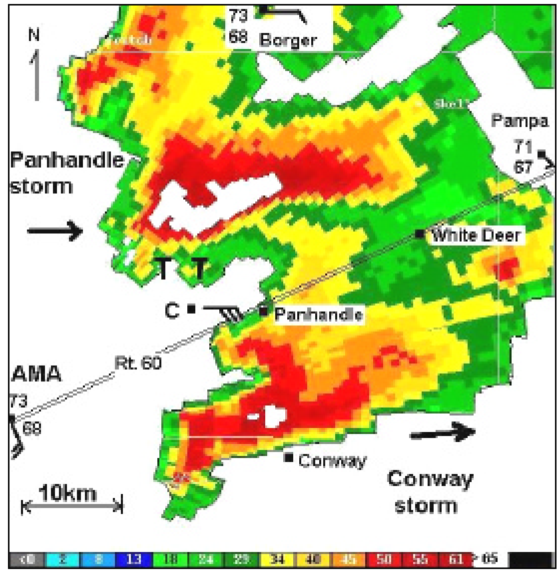

Figure 5. Radar reflectivity of the Panhandle and Conway, TX storms at 0004 UTC. Tornadoes are at "T" and the chase team is at "C".

Figure 6. Tornado associated with new mesocyclone near the time of the radar image in Figure 5.

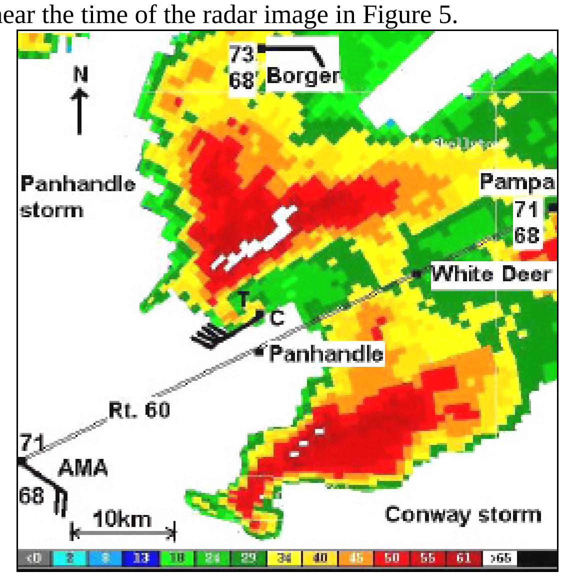

Figure 7. Radar reflectivity image at 0014 UTC showing Panhandle and Conway storms. Multi-vortex tornado ("T") begins north of the town of Panhandle. The chase team is at "C".

Figure 8. Multi-vortex tornado north of Panhandle, TX near the time of the radar image in Figure 7.

The chase team encountered rain and a windshift to the west up to 40 knots as the rear flank downdraft wrapped around the south side of the circulation.

The tornado continued east and evolved into a large cone-shape as it approached Highway 60. The tornado became stationary for a few minutes just west of the road, then widened into a wedge-shape with satellite tornadoes rotating around the south side of the circulation. Gate-to-gate shears on the mesocyclone increased to 134 knots at 0035 UTC and to 150 knots at was absorbed into the precipitation core and the chase team lost sight of the tornado.

By 0045 UTC, the hook echo had been wrapped completely in precipitation and absorbed into the forward flank downdraft. The fourth tornado in the series had dissipated after 30 minutes on the ground. The cold front, that earlier had spawned storms in the northern Texas panhandle, began to overtake the Panhandle storm, causing it to weaken.

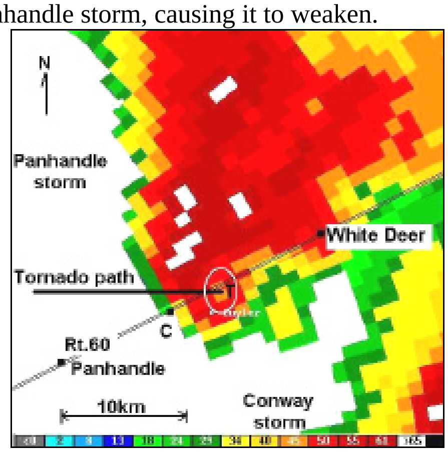

Figure 9. Radar reflectivity image of Panhandle, TX storm as a large tornado "T" was crossing Rt. 60 at 0040 UTC. Closed hook echo is circled and chase team is at "C".

5. SUMMARY

This case study illustrates the complexities involved with tornadogenesis when multiple storms develop within close proximity to each other in conjunction with surface boundaries. The Panhandle storm developed just east of a dryline-outflow boundary intersection, and exhibited strong rotation for more than an hour, but never produced a tornado. The rear flank downdraft kept overwhelming the cloud base circulation pushing it further east. Next, the Panhandle storm diminished in intensity when a smaller storm merged with its forward flank precipitation region. Almost another hour elapsed before the storm strengthened to previous levels.

The approach of the Conway storm had a profound impact on the Panhandle storm. It is theorized that the forward flank downdraft from the Conway storm enhanced inflow into the Panhandle storm leading to rapid intensification of a new mesocyclone and subsequent formation of a large tornado.

Figure 10. Large tornado on Rt. 60 with satellite tornado near the time of the radar image in Figure 9.

6. ACKNOWLEDGMENTS

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