6.5 INVESTIGATION OF AN UNUSUAL STORM STRUCTURE ASSOCIATED WITH WEAK TO OCCASIONALLY STRONG TORNADOES OVER THE EASTERN UNITED STATES

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1. INTRODUCTION

For several years, forecasters at the Greenville-Spartanburg, South Carolina, Weather Forecast Office (KGSP) have observed a severe storm structure which forms, usually in the cool season, in an environment characterized by marginal instability and strong, lower tropospheric wind flow. This structure, occurring with rapidly moving, low-topped Mesoscale Convective Systems (MCS), begins as a slight bulge in an otherwise linear MCS. This bulge develops into an S-shaped inflection point and eventually breaks into two separate line segments, with the southern member accelerating ahead of the line. Often, little in the way of straight-line wind damage is observed with the line, but where the break forms, weak to occasionally strong tornadoes sometimes occur. In fact, we suspect this feature, referred to as the broken S-signature , to be the most common tornadic signature in our County Warning and Forecast Area (CWFA). This feature is similar to a Line Echo Wave Pattern (LEWP) (Nolen 1959).

In this paper, we look at three events: the 26 November 1999 F1 in Chester County, Pennsylvania; the 21 February 1997 event with 3 separate broken S-signature tornadoes extending from northeast Georgia to southern North Carolina, which reached up to F2 intensity; and the 7 November 1995 F0 in Greenwood County, South Carolina. An overview of the synoptic and mesoscale environments typical of all three events will be presented. A sample of radar products from each event will then be presented, particularly those which argue against these tornadoes forming as weak shear vortices at the apex of a bowing line segment (Funk et al. 1999). We have shown in actual events that a radar operator, understanding the synoptic and mesoscale environment, can achieve short tornado warning lead times, particularly for the strongest events.

2. SYNOPTIC SCALE PATTERN

In the three cases reviewed, the synoptic pattern was quite similar. A longwave trough was located west of the region. A strong 850 mb jet, on the order of 25 to 30 m s^{-1}, was over the area of interest, and weak

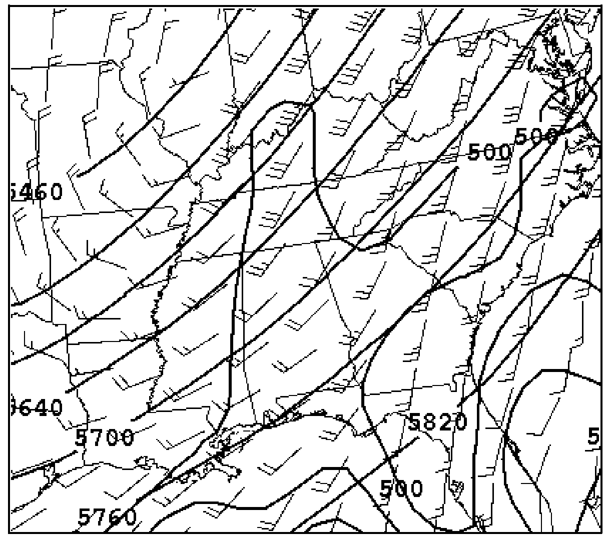

Figure 1: 500 mb Heights, 850 mb winds (m s^{-1}) and CAPE (J $kg^{-1)}$ from the 21 February 1997 event.

instability was present, with CAPE values of around 500 J kg^{-1} or less (Fig. 1). Strong upper divergence was associated with each event.

3. THREE CASES OF BROKEN LINE-SEGMENT TORNADOES

3.1 The Honey Brook, Pennsylvania Tornado

In the Honey Brook event, there was more mid-level drying than with the other two events reviewed. The 00 UTC Brookhaven, New York (OKX) sounding, modified to represent the conditions ahead of the line, had CAPE values of around 500 J kg^{-1} and 15 m s^{-1} of speed shear in the lowest 3 km (Fig. 2). Winds in the lowest 3 km were about 5 m s^{-1} stronger on the Wrightstown (KDIX) VAD Wind Profile (VWP) than on the OKX sounding.

There were only two reports of severe weather with this line as it moved through the Philadelphia CWFA (NOAA 1999). The first report of damage (at 2257 UTC) resulted from the tornado and straight line winds. One other report was received three minutes later of straight line wind damage a few kilometers to the north.

Equilibrium levels were around 7 km based on the modified sounding, and echo tops averaged between 4.5 km and 6 km during this phase of the MCS s existence. Figure 3 is a 0.5 degree reflectivity image taken 9 minutes before the reported tornado which

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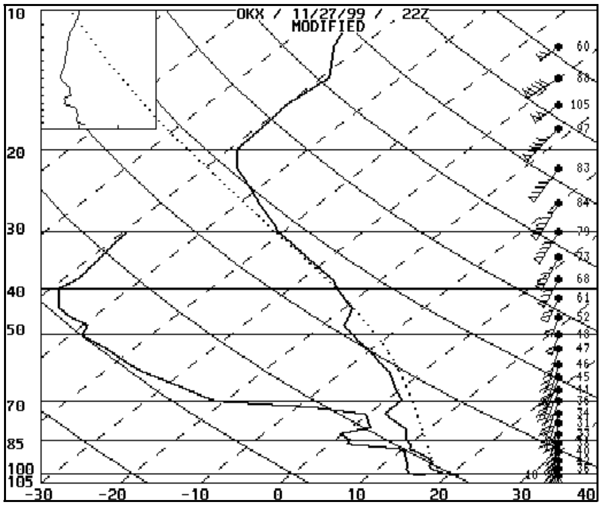

Figure 2: 00 UTC 26 November 1999 OKX sounding, modified to approximate conditions at the time of the Honey Brook tornado.

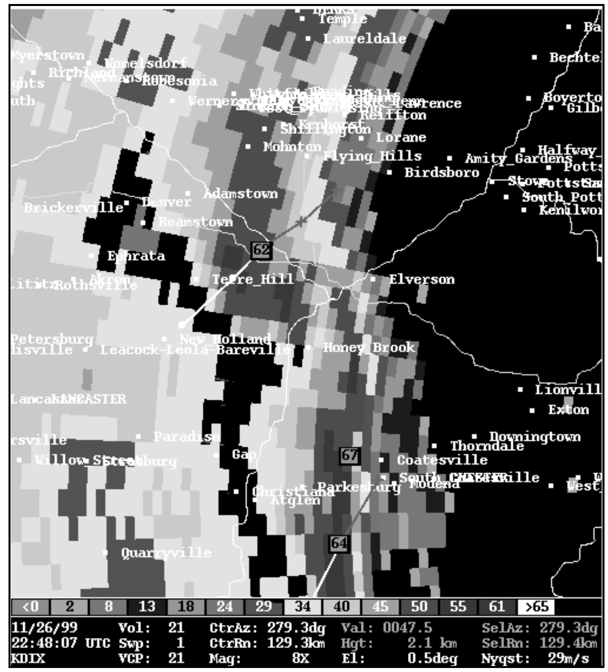

Figure 3: 2248 UTC KDIX 0.5 deg reflectivity.

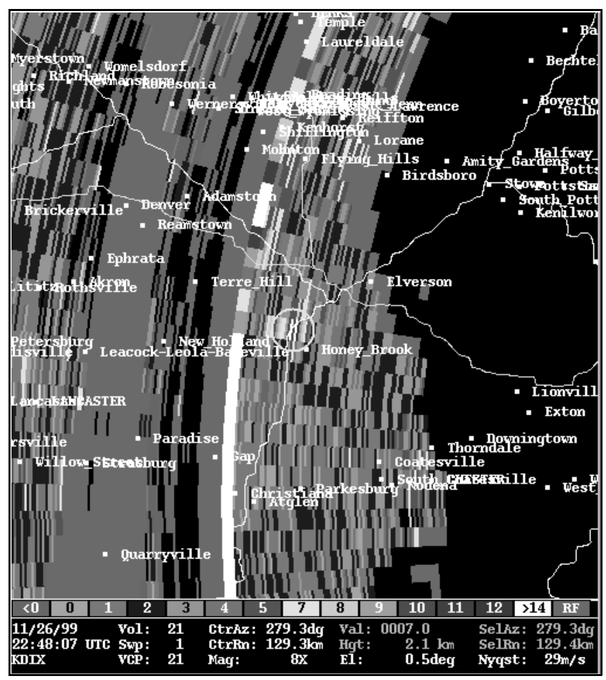

Figure 4: 2248 UTC KDIX 0.5 deg spectrum width.

shows the break in the line had already commenced. It would appear that the tornado is likely occurring at this time, prior to the time of the damage report.

In fact, this break existed at least 30 minutes prior to the tornado occurrence. In events of this nature, damage sometimes begins after a break forms. At this time the southern member in the line shifted ahead of the northern segment, one of the key features of these broken S-signature tornadoes based on our observations. The NSSL Mesocyclone Detection Algorithm indicated a weak circulation along the break in the line several minutes before the tornado. A mesocyclone was never identified, though there was broad rotation of about 10 m s^{-1} across the break during the time the tornado occurred.

Coincident with tornado development, an area of higher spectrum width developed in association with the break in the line as seen in Fig. 4 (Buller and Mentzer 1997). This feature existed for several volume scans, and was co-located with an area of weak shear at the time of the tornado. Interestingly, this is *behind* the leading, southern line segment and appears to exist in an area of cyclonic shear between the two segments. A reflectivity cross-section taken a volume scan later showed storm tops of only around 4.5 km, as well as some slight overhang of the southern line segment (not shown). The cross section showed no associated overhang or suspended reflectivities indicative of a strong updraft between the two lines.

3.2 The Gastonia, North Carolina Tornado

This tornado was part of a larger event in which several weak, broken S-signature tornadoes occurred across three states on 21 February 1997. This tornado produced F1, bordering on F2, damage in southern Gaston County (county west of Charlotte (CHARLT) in Fig. 5) between 2222 UTC and 2235 UTC . This was another event with limited instability but strong speed shear. The KGSP VWP registered winds of 30 m s^{-1} beginning at 1.5 km and 20 m s^{-1} of speed shear in the lowest 3 km ahead of the line. CAPE was around 500 J kg^{-1}. In Fig. 5, the line was already slightly bowed, with F0 damage occurring in extreme northwest

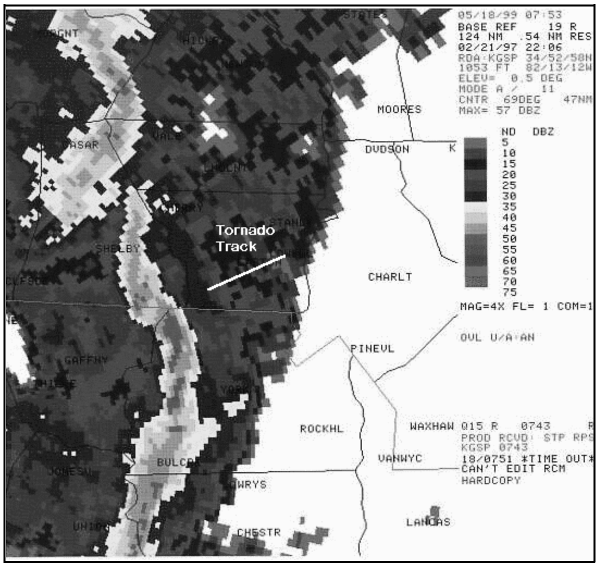

Figure 5: 2206 UTC KGSP 0.5 deg reflectivity.

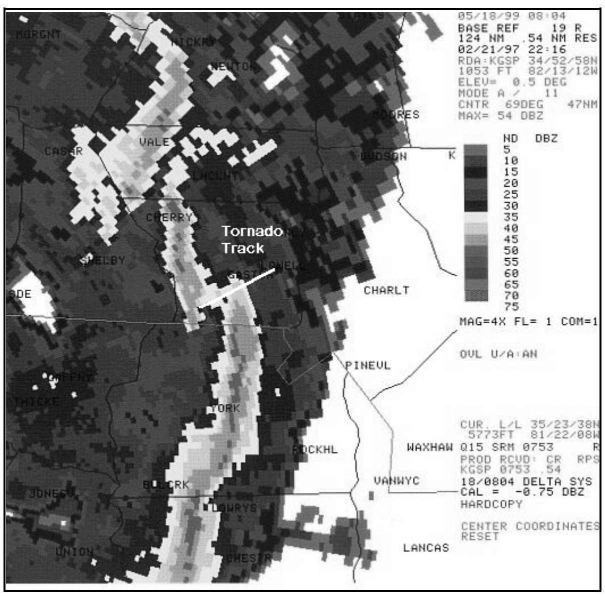

Figure 6: 2216 UTC KGSP 0.5 deg reflectivity.

York County, South Carolina. A few minutes later, the S-signature had formed a complete break (Fig. 6). It appears that the time of reported damage was again a few minutes off as the 2216 UTC image would imply.

Rotational velocities increased to 15 m s^{-1} at an elevation of 1.4 km by 2211 UTC and were sustained until F1 damage began to occur. Thereafter, velocities decreased. Spectrum width data could not be retrieved as archive level 2 data were unavailable from the KGSP radar. Still, the track of the tornado follows exactly along the broken segment and appears to be a little north of the weakly bowing southern segment.

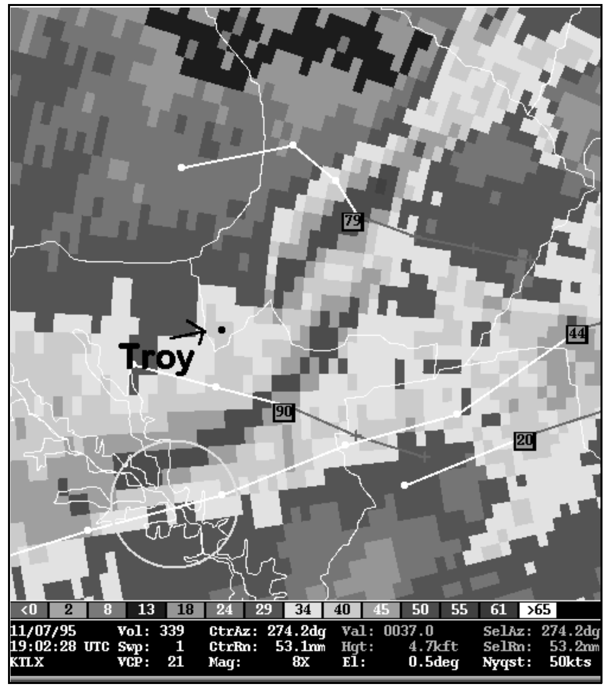

Figure 7: 1902 UTC KCAE 0.5 deg reflectivity.

3.3 The Greenwood County, South Carolina Tornado

The Greenwood County event occurred around 1900 UTC, not close to a scheduled upper air release. However, using the VWP data from the Columbia, South Carolina (KCAE) WSR-88D, and noting that there was little temperature advection from 12 UTC to 00 UTC in the Charleston, SC (CHS) sounding, a reasonable estimate of 19 UTC conditions can be constructed from the 12 UTC sounding from CHS, about 260 km to the southeast of where the tornado occurred. CAPE was only around 500 J kg^{-1} with winds of 30 m s^{-1} beginning at 1.5 km. The shear in the lowest 3 km was 25 m s^{-1}.

This event was more subtle than the other two, and was accompanied by no discernable rotation as sampled by the KCAE radar, 99 km to the east. The KGSP radar also sampled the storm, and while some weak cyclonic convergence was noted in the lowest scan, there was very little to cause alarm about the cell other than the reflectivity pattern. Figure 7 shows the line a few kilometers east of the town of Troy. The path of this F0 tornado extended from just north of Troy to a point 10 kilometers east northeast of the town. Figure 8 shows the 0.5 degree spectrum width valid the same time as Fig. 7. Notice an area of high spectrum width just behind the lead segment, right at the tip of the trailing northern member. A successful tornado warning decision was made for this storm based on pattern recognition.

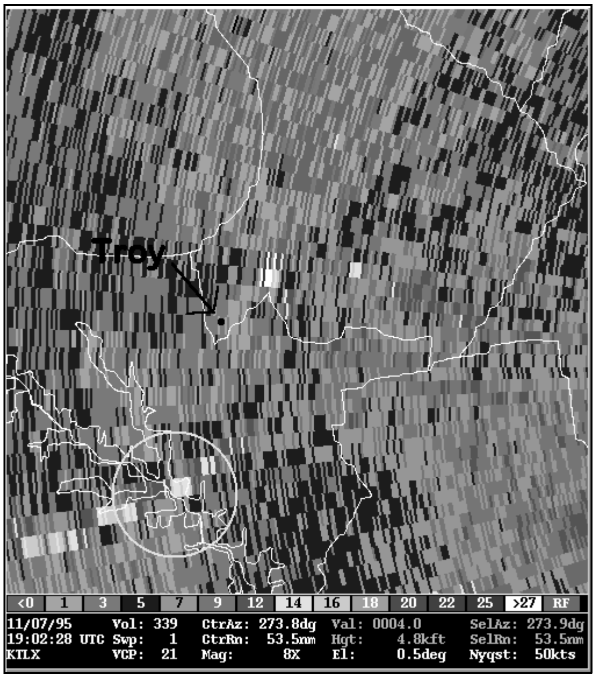

Figure 8: 1902 UTC KCAE 0.5 deg spectrum width.

4. CONCLUSION

We feel certain that some process is at work in high shear, low instability environments which leads to the development of tornadoes along fractures in low-topped MCS s. Frequently these events are associated with little other severe weather. In fact, due to the lack of steep lapse rates and a rather warm air mass well east of an advancing longwave trough, these lines often produce little or no lightning.

The relative paucity of tornadic development away from the actual break itself would seem to imply that there must be some mechanism at work other than a spin-up along the bowing segment of a LEWP in at least some of these events. The high spectrum width values located along the developing discontinuity in the line indicate chaotic motion on a very small, possibly sub beam-width scale. This may be the tornado circulation. Often there is weak rotation across the break, suggesting that the strongest events may be associated with a meso-low (Lee and Jones 1998), causing cyclic tornado production.

The breaking segment may act to enhance vertical vorticity on a very small scale. Considering the rapid translation of the convection, a shear couplet of only 15 to 20 m s^{-1} would be needed to produce a strong F1 tornado. This effect will need to be modeled before it can be validated. Figure 9 is a rough schematic of how the bow and eventual break in the line appear to a radar operator. If radar operators are aware of the evolution of this reflectivity pattern, effective warnings can be issued, albeit with relatively short lead times. Spectrum width data, while not providing lead time, may be a strong indicator of an ongoing tornado, at least aiding in the decision to issue subsequent warnings.

Figure 9: Diagram of the evolution of the broken S-signature tornado.

5. REFERENCES

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