

## SMALL TORNADIC SUPERCELLS IN THE CENTRAL PLAINS

Jonathan M. Davies

Wichita, Kansas 67278

### 1. INTRODUCTION

Tornado-producing supercell storms that are small in both vertical (e.g., tops under 30,000 ft) and horizontal extent are not rare. A number of cases have been documented. For example, McCaul (1987 and 1990) has described and also simulated numerically the small tornadic supercells associated with Hurricane Danny in August 1985. Murphy and Woods (1992) discussed a small tornado-producing supercell in northern Georgia. Another example is the storm that produced the West Bend, Wisconsin tornado in April 1981 (Wakimoto 1983).

The storms referred to above occurred east of the Mississippi River. This paper will focus on small tornado-producing supercells that are associated with surface drylines and cores of cold air aloft in the central plains of the United States. Although synoptic patterns associated with cold lows aloft have long been recognized as having potential to produce tornadoes (e.g., Miller 1972, and Goetsch 1988), supercell storms associated with such patterns have not been discussed in detail. Such storms are visually deceptive regarding potential for severe weather due to lack of size, particularly vertical extent. Often, little or no lightning is associated with these supercells. This study calls attention to such storms for purposes of better detection and recognition by meteorologists and spotters.

Section 2 of the paper will be devoted to visual documentation of two events involving small tornadic supercells in Kansas. Section 3 will briefly describe synoptic-scale features derived from these cases and one additional case. Representative thermodynamic and wind profiles will be presented in Section 4, followed by a concluding discussion in Section 5.



*Fig. 1. Small supercell developing on 3/11/90, looking north from near Pratt, Kansas. A small clear slot (CS) is visible at lower left, and the south end of a short flanking line (FL) is at left center. Bands of stratocumulus (Sc) at lower right suggest strong inflow from the east. Photo by Jon Davies.*



*Fig. 2. Supercell as in Fig. 1, except about 30 minutes later near Stafford/Reno county line, looking northeast. Clear slot (CS) is seen south of tornado (at tip of arrow), with short flanking line (FL) at right. Photo by Jon Davies.*

### 2. VISUAL OBSERVATIONS AND PHOTOGRAPHY

The author has observed and photographed two cases involving small tornado-producing supercells in south-central Kansas. In both cases, the tops of the parent storms observed by radar were less than 30,000 ft, and the appearance of the storms was visually small.

Fig. 1 shows a small supercell on March 11, 1990 near Pratt, Kansas at about 2230 UTC, roughly twenty minutes prior to producing the first of a family of tornadoes. Although no wall cloud is evident, a clear slot implying a rear flank downdraft (Lemon and Doswell 1979) is visible, along with low-level bands of stratocumulus moving into the storm from the east, suggesting strong inflow (southeast surface winds gusted over 30 knots as the storm passed north of the author's location). The south end of a short flanking line of cumulus towers also appears near the center of Fig. 1.

Fig. 2 is a view from the southwest approximately 30 minutes later, with the storm's second tornado visible on its south flank over western Reno county. A clear slot, short flanking line, and overshooting top are also visible. The small size of the storm is striking when one considers that the photo in Fig. 2 was taken from a distance not more than eight miles to the southwest of the tornado.

The author observed at least three tornadoes in succession with the storm (*Storm Data* lists only two), and reports of funnels aloft continued from spotters as the supercell moved northeast into north-central Kansas. Fig. 3 shows the third tornado in the family from a vantage point near Alden. The strong surface inflow and rapid forward movement of the storm and its tornadoes (at times more than 40 knots) suggest that

tornadoes with this storm were capable of reaching strong intensity (e.g., F2 category). Fortunately, the tornadoes struck almost entirely in open country and were not rated stronger than F1. Only a handful of farmsteads suffered damage and no ground survey was performed.

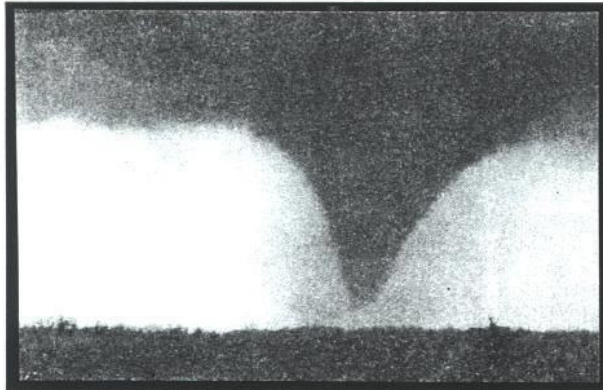
Wichita and Garden City radar observations during the tornadoes indicated tops only between 25,000 and 28,000 ft. Brief heavy rains and some small hail fell north of the storm's updraft region, and the storm as seen in Figs. 1 and 2 had some visual characteristics indicative of a classic supercell (Doswell et al. 1990), though diminutive in size. No lightning or thunder was noted by the author.

A similar but less intense event occurred on April 28, 1991. Figures 4 and 5 show from opposing vantage points a tornado in progress over northwest Pratt county shortly before 22 UTC. In particular, Fig. 4 is similar to Fig. 2 from the 3/11/90 case, depicting the small vertical extent of the parent storm. In Fig. 5, cloud striations suggesting rotation are visible on the south and east flank of the storm, and there is no flanking line. Although not easy to see in the figures, a well-defined clear slot/rear flank downdraft was also present, confirmed by photos taken from other locations (not shown). Inflow observed with this storm was not as strong as on 3/11/90, and the translational speed of the supercell and tornado was slower. The author's storm survey the same evening suggested F1 intensity damage at farmsteads in the tornado's path.

While the 3/11/90 event appeared to involve only one long-lived supercell, several tiny and short-lived rotating cells were

observed on 4/28/91. The tornado in Figs. 4 and 5 occurred with the fourth cell from the south end of a broken line of storms; the next two cells to the south later produced brief "dust-whirl" tornadoes with no condensation funnels. One of these (see Fig. 6) occurred under a base that was somewhat "flanged" at its edges and that was visibly rotating, with a clear slot on its southwest flank. Fig. 7 shows a full composite view of the same storm as it passed just north of the author, with a cloud base estimated at not more than two miles wide. The "dust-whirl" appearance of the latter tornadoes is typical of many non-supercell tornadoes (Wakimoto and Wilson 1989). However, the aforementioned characteristics of the parent storms on this day were suggestive of supercells with small mesocyclones that lasted on the order of tens of minutes. After 2230 UTC, surface inflow diminished considerably, and tornado production ceased while storms became distinctly more multicellular in appearance (not shown).

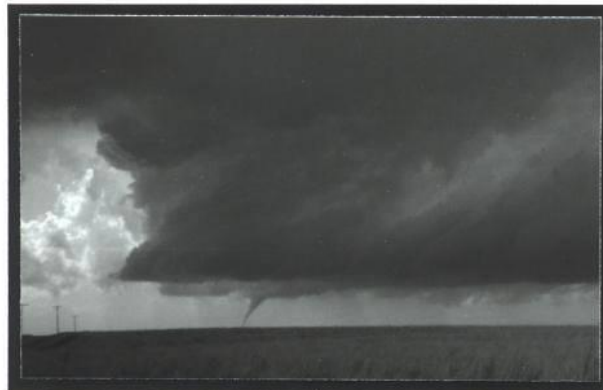
As with the 3/11/90 storm, there was virtually no electrical activity (the author does recall one lightning "flash" accompanied by one instance of audible thunder). Unlike the 3/11/90 case, this storm had visual characteristics more suggestive of a "low-precipitation" (LP) supercell (Bluestein and Parks 1983; Doswell et al. 1990). The author observed only a few large drops of rain as one of the cells passed over his location, and Garden City radar shortly before the first tornado indicated only a rain shower with a 21,000 ft top. The "flanged" base previously noted on one of the cells, and the lack of a flanking line are also indicative of LP storms.



**Fig. 3.** Third tornado produced by same supercell as in Figs. 1 and 2, near Alden, Kansas on 3/11/90. Photo by Larry Swank, courtesy Hutchinson News.



**Fig. 4.** Small supercell and tornado (at tip of arrow) over northwest Pratt County on 4/28/91. Photo by Pam Corrigan, looking northeast from near Haviland, Kansas.



**Fig. 5.** Supercell and tornado as in Fig. 4, except looking west from near Iuka, Kansas. Striations are present on the storm's east and south flank, suggesting rotation. Photo by Jon Davies.



**Fig. 6.** "Dust-whirl" tornado from a different cell than in Fig. 5, looking west near Iuka, Kansas on 4/28/91. Note clear slot (CS) suggesting rear flank downdraft. Photo by Jon Davies.



Fig. 7. Composite view of small rotating cell in Fig. 6, looking northwest through northeast, after tornado had dissipated. The diameter of the cloud base was estimated to be less than two miles. Only a few drops of rain fell from this "storm" as it earlier passed over the author's location. Photo by Jon Davies.

### 3. SYNOPTIC-SCALE FEATURES

Synoptic-scale features associated with the above cases, and a small tornadic supercell case in central Kansas in early May 1988, are similar to those associated with the type D pattern in Miller (1972). Significant features are shown in the subjective composite in Fig. 8. These include: (1) a cold upper low positioned above and slightly upwind of a surface low, associated with mid-level temperatures of around  $-20^{\circ}\text{C}$  or less, (2) a surface dryline that essentially takes the place of the occluded front extending southeast of the surface low in Miller's Type D pattern, (3) a band of moderate to strong mid-level winds to the south and east of the upper low, and (4) a mid-level dry punch that extends east and northeast over the surface dryline, driven by the mid-level winds. Surface dew points ahead of the dryline in the cases examined were no higher than the mid 50's.

In this scenario, a favored area for development of storms with small supercell characteristics is along the dryline southeast of the surface low in close proximity to the mid-level winds and the north edge of the mid-level dry punch. If the cold air aloft is elongated further southward along a north-northwest/south-southeast axis, small supercells can also develop where the south edge of the mid-level dry punch extends back west near the surface dryline. An example of this occurred on May 2, 1988 in south-central Oklahoma.

Underneath the cold upper low, low-topped non-supercell storms can produce weak tornadoes or funnels, as noted in Johns and Doswell (1992) and Cooley (1978). These can occur along or behind an occluded front or cold front that extends through the surface low, and are normally associated with steep lapse rates but weak wind fields. This contrasts with the environment further southeast where stronger wind fields in proximity to the mid-level jet are more favorable for supercells.

### 4. THERMODYNAMIC & WIND PROFILES

Because of the close proximity of a cold upper low or core of cold air aloft, the most striking feature of the thermodynamic profiles for the supercell cases examined in section 3 is the low equilibrium level (EL) due to a low tropopause. A thermodynamic diagram constructed for the 3/11/90 case discussed in section 2, using the Dodge City and Topeka evening soundings and the 22 UTC surface observation at Hutchinson, Kansas, is

shown in Fig. 9. The highest EL is obtained by using a surface-based parcel, yet this is only 24,000 ft MSL. The small vertical extent of the storms that day is no surprise given the low equilibrium level, and this likely plays a part in the low amount of electrical activity associated with small supercell storms.

Another feature of interest is the low values of CAPE (convective available potential energy) that seem to be associated with small supercell cases. Using a surface-based parcel to obtain the largest possible value, Fig. 9 yields a CAPE of only  $915 \text{ j kg}^{-1}$ . However, this may be misleading when one considers the vertical distribution of CAPE. Comparison with soundings from Johns et al. (1993) that exhibit similar CAPE values (yet are not associated with cold core lows aloft) reveals that the CAPE in Fig. 9 is "squeezed" into roughly one half to two thirds the vertical distance associated with typical severe storm environments. This implies a steep lapse rate. In fact, the lapse rate between 850 mb and 600 mb in Fig. 9 is  $8.2^{\circ}\text{C km}^{-1}$ , which implies rapid acceleration of updrafts though this layer. Therefore, a thermodynamic environment like that shown in Fig. 9 may actually be more "unstable" than would first appear when computing CAPE without reference to vertical distribution (see also Davies 1993b).

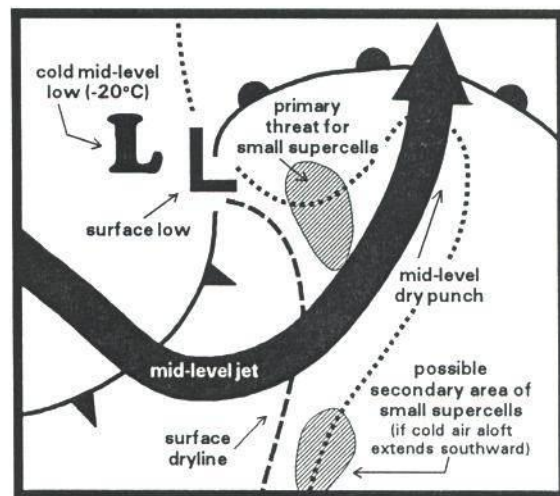


Fig. 8. Composite diagram of significant synoptic features associated with cases examined in section 3.

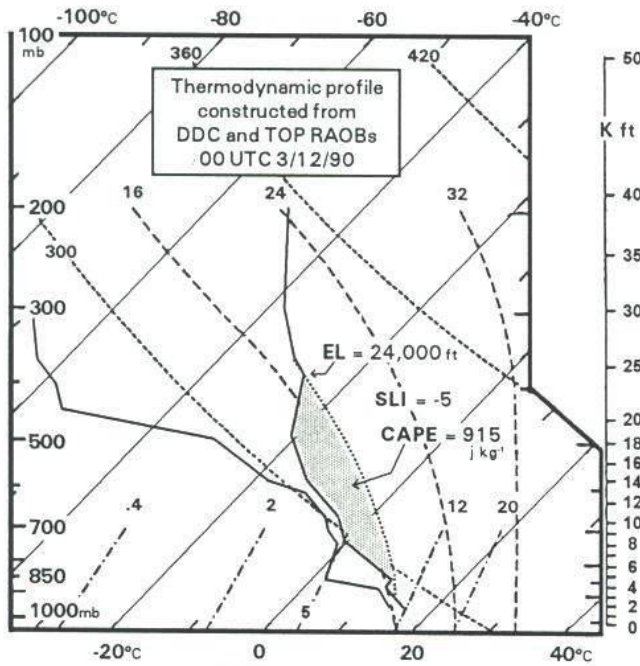


Fig. 9. Skew-T diagram constructed using Dodge City and Topeka soundings at 00 UTC 3/12/90. Shaded positive area (CAPE) is obtained by lifting a surface-based parcel.

The wind profile associated with the 3/11/90 case (see Fig. 10) is strong, and contains significant amounts of 0-3 km AGL storm-relative helicity (Davies-Jones et al. 1990) and 0-2 km AGL storm-relative inflow (Lazurus and Droegemeier 1990). Mid-level winds (3-6 km AGL) are also strong. These parameters, when combined with adequate instability, are well within the magnitudes found by Davies (1993a and 1993c) to be associated with tornadic supercells. Using a formulation of the energy-helicity index (EHI; Hart and Korotky 1991) that utilizes the surface-based lifted index (see Davies 1993c), Figs. 9 and 10 yield an EHI of 3.7, which is indicative of tornadic supercells.

These wind and instability parameters emphasize the point that, if the proper combination of wind and thermodynamic characteristics is present in a given environment, storms that develop in that environment can become supercells and produce tornadoes, regardless of vertical extent.

Davies (1993a, 1993b, 1993c) showed that fields of rotational parameters generated from numerical weather prediction model data can be useful in distinguishing between some tornadic and non-tornadic environments. This probably extends to environments supporting small supercells. Using parameters and computations as in the referenced work by Davies, Fig. 11 shows selected parameters generated from NGM-based forecast winds and temperatures aloft (from NMC's FD products) blended with surface observations on the afternoon of 4/28/91, corresponding to the second case discussed in section 2. The 12 hr model forecast wind profile valid 00 UTC 4/29/91 for Wichita is combined with 21 UTC surface observations and interpolated forecast mid-level temperatures for Hutchinson and Medicine Lodge (located west of Wichita closer to the dryline) to obtain data points that supplement the winds aloft forecast locations. It is interesting that the magnitudes of EHI, storm-relative inflow, and mid-level winds are significant and suggestive of tornadic supercells (i.e., EHI > 3.0, inflow > 20 kts, mid-level winds > 30 kts) over south-central

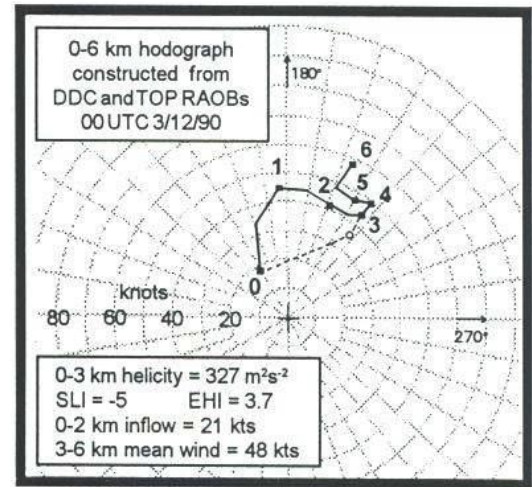


Fig. 10. Hodograph constructed for same sounding as in Fig. 9. Heights (km AGL) are indicated on the hodograph, and estimated storm motion is shown by open dot. Helicity is area between hodograph curve and dashed lines.

Kansas, which is where tornadoes occurred with storms along the dryline.

## 5. SUMMARY AND DISCUSSION

Small supercell storms that are associated with nearby cold core low pressure centers aloft are not a rare occurrence in the central plains. In Kansas alone, the author has found three tornado episodes since 1986 that fit into this category, and three additional cases that may in some aspects belong there as well.

Although detailed radar data was not examined for this study, radar observations for the two cases discussed in section 2 showed low storm tops (less than 30,000 ft). Visually, the size

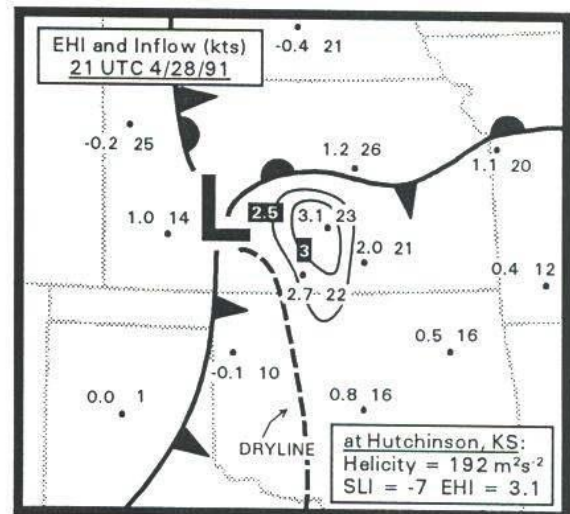


Fig. 11. EHI and 0-2 km inflow (kts) computed from 12 hr model forecast valid 00 UTC 4/29/91 blended with surface observations at 21 UTC 4/28/91. EHI  $\geq$  2.5 and 3.0 are analyzed. Mid-level winds (not shown) are 40-50 kts over central and eastern Kansas. 0-3 km helicity and surface-based lifted index are shown for Hutchinson, Kansas.

and appearance of the storms was small, and virtually no lightning activity was observed with these cases. These observations serve as a reminder that relatively benign appearance on radar and lack of lightning activity are typical of many tornadic events associated with a cold core low pressure system aloft. Although the vertical extent of the dryline storms in section 2 was small, characteristics representative of classic and LP supercells were observed.

The associated thermodynamic profiles exhibit low CAPE values, but steep lapse rates. Wind fields are moderate to strong and exhibit significant low-level storm-relative helicity, low-level storm-relative inflow, and mid-level winds. These characteristics emphasize that, when instability is adequate and wind fields contain significant rotational potential, the lack of vertical height or radar intensity with storms in synoptic settings similar to those examined in this paper has little bearing on a storm's ability to become supercellular in nature, or to produce tornadoes.

There is some confusion with the media, spotters, and even a few professional meteorologists concerning terminology and perceptions about storms of the type discussed in this paper. For example, the author has heard the term *cold air funnel* used incorrectly to describe tornadoes that occurred in two of the cases examined in section 3.

True cold-air funnels (Cooley 1978) do not typically descend to the ground; if they do become tornadic, they are usually brief and weak in intensity. As discussed in section 3, these are typically non-supercell in nature and tend to occur *under* the cold core aloft where extreme lapse rates exist, often *behind* cold fronts where low-level moisture is wrapped around into the rear quadrant of a surface low. Wind fields in these situations are usually weak, and probably have little to do with tornado/funnel formation. Public perception of "cold air funnels" properly tends to be associated with this type of event, which involves relatively little risk to life and property.

In contrast, tornadoes associated with the small supercells in this study occurred well within the warm sector southeast of the surface low and upper cold low, in relative close proximity to the cold air aloft, yet also close to the mid-level jet. Low-level and mid-level wind fields were moderate to strong, contributing to the production of supercells and mesocyclones. Tornadoes associated with this scenario can on occasion reach the strong category (i.e., F2 or F3 intensity), and also occur in families. For example, the tornadoes on 3/11/90 discussed in section 2 were a tornado family, and the tornado shown in Figure 3 is not small; the visual appearance is suggestive of a tornado capable of producing considerable damage. As another example, at least one tornado occurring with low-topped supercells in central Kansas on 5/2/88 was rated strong in intensity. Although tornadoes occurring with small supercells in the plains are normally associated with a synoptic pattern that involves a cold core low aloft, it is misleading to the public and inappropriate to refer to them as "cold air funnels". Because of their supercell nature, such tornadoes can pose a significant threat.

Numerical and observational studies of small supercell storms by researchers are ongoing (e.g., Stalker et al. 1993).

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