P12.1 WSR-88D OBSERVATIONS OF NON-DESCENDING TORNADOGENESIS IN PROXIMITY TO A SYNOPTIC-SCALE FRONTAL BOUNDARY: A CASE STUDY OF 18 MAY 2000 IN NORTHERN ILLINOIS

Casey Crosbie* and Ray Wolf[1]
NOAA/National Weather Service/Storm Prediction Center
Norman, Oklahoma

[1] NOAA/National Weather Service
Davenport, Iowa

1. INTRODUCTION

One of many challenges faced by meteorologists warning for severe convective storms is providing lead time for tornadoes associated with bow echoes. Typically bow echo tornadoes form within the comma head of the bow (Wakimoto 1983, Pfost and Gerard 1997), on the cyclonic shear side of the bow echo's apex (Fujita 1979, Forbes and Wakimoto 1983, Funk et al. 1999), or occasionally at the intersection of the bow with an external boundary (Schmocker 2000, Wolf 2002). They usually form quite rapidly (< ~5 minutes), and frequently there is no indication of tornadic potential in the mid-levels of the storm before tornadogenesis (Trapp 1999). Thus, issuing timely warnings is even more challenging when storms are far from the radar, where the beam elevation extends above the lower levels of the storm.

Studies of tornadic supercells have documented the association of boundaries with tornadogenesis (Weaver and Nelson 1982, Weaver et al. 1994, Wolf and Szoke 1996, Markowski et al 1998, and Ramussen et al. 2000). Elson (1996), Schmocker et al. (2000), DeWald and Funk (2000) and Wolf (2002) have likewise documented the occurrence of convective boundaries intersecting squall lines which resulted in tornadoes north of the bow's apex. The event studied here extends those squall line studies by showing the occurrence of a bow echo tornado south of the bow's apex at the intersection of the squall line and synoptic-scale frontal boundary. Additionally, it documents the merger of a supercell with the squall line resulting in tornadogenesis.

Between 16 and 22 UTC 18 May 2000, a cluster of severe thunderstorms moved across parts of eastern Iowa and northern Illinois. A combination of supercell and bow echo storm types were observed which generated numerous reports of large hail, damaging wind, and several weak tornadoes (F0 damage). All tornadoes were of non-descending mode (Trapp and Davies-Jones 1997), occurred within 15 miles of a quasi-stationary synoptic-scale front, and were associated with either bow echo or supercell storm types.

Evolution of two tornadic storms will be described. The interaction between the synoptic-scale frontal boundary with the bow echo, a supercell with the bow echo, and their relationships to tornadogenesis will be shown.

2. SYNOPTIC AND MESOSCALE OVERVIEW

At 12 UTC on 18 May 2000, the synoptic environment was characterized by a closed 500 mb low pressure system centered over eastern Nebraska. The system was fairly progressive as evident by a 90-120 meter height fall/rise couplet at 500mb. At 850mb, a 50-70kt low level jet extended from northern Louisiana northeastward into the Ohio Valley, while at 250mb, a 110kt jet maximum was located over the northern Texas panhandle. A surface low pressure center was located in the vicinity of Omaha, with a dryline extending southward into northeast Oklahoma and a cold front extending southwestward into southeast Colorado. East of the low, a stationary front extended across northern Iowa into northern Illinois. In the warm sector, dew points in the mid to upper 60s were present over northern Missouri, southeast Iowa and central Illinois.

By 16 UTC, the primary surface low had begun to occlude as it moved into central Iowa, and a new surface low was developing over south central Iowa. A dryline extended south of this low into north central Missouri. The stationary front over northeast Iowa and northern Illinois had transitioned into a southward moving cold front due to increasing cold advection aided by a persistent northeast wind down the length of the cold waters of Lake Michigan. Convection initiated across central and south central Iowa near the mid-level thermal trough and in a region of strong mid to upper level divergence and surface convergence. The 1706Z VAD wind profile from the Davenport (KDVN) WSR-88D indicated a 0-6 km shear of 60kts and storm-relative helicity of 180 m^2/s^2 (0-3 km). The 12 UTC DVN sounding, modified using 17 UTC surface observations (Fig. 1), yielded a CAPE of 3400 Jkg^{-1}.

By 18 UTC, an area of 1 - 2 mb/2 hr pressure falls had formed in advance of a developing mesolow north of Burlington, Iowa, which aided in enhancing low-level shear and convergence. Also by this time, at least two surface confluence axes had developed over far western Illinois and southeastern Iowa ahead of the main surface dryline. Convective initiation was occurring along these confluence axes across southeast Iowa and northeast Missouri. The surface cold front had shifted south and extended roughly along the Interstate 80 corridor.

During the next several hours, convection continued to

**Corresponding author address:* Casey Crosbie, NOAA/NWS/SPC, 1313 Halley Circle, Norman, OK 73069;
e-mail: casey.crosbie@noaa.gov

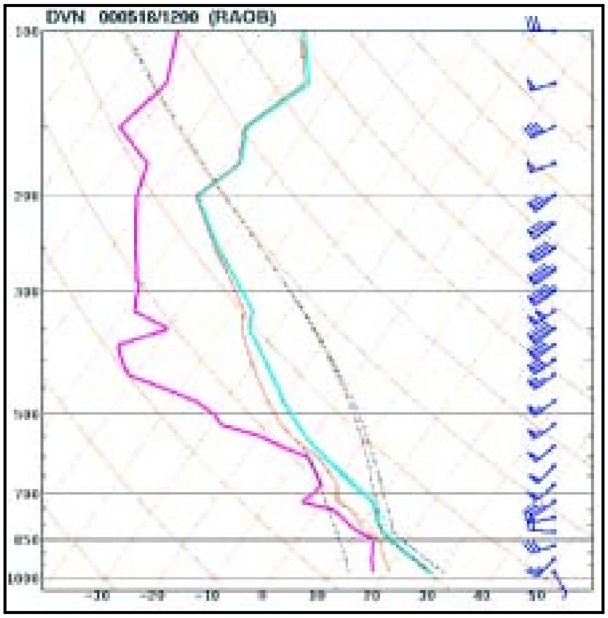

Figure 1. DVN 12 UTC sounding modified based on 17 UTC surface observations.

intensify over southeast Iowa while moving into northwest Illinois. Although the main cold front shifted winds to the northeast across northern Illinois, the 18 UTC surface observation from MLI (Moline, IL) indicated that temperatures immediately behind the front had only fallen into the lower 70s. At the same time, low level shear had increased greatly, as evident by the 1842 UTC VAD wind profile from KDVN (not shown).

3. RADAR EVOLUTION

3.1 Orion Storm

Between 1849 and 1904 UTC, a large HP supercell traveled northeast across extreme east central Iowa, southwest of KDVN. Additional strong to severe thunderstorms developed southeast of this supercell and began to merge with the supercell between 1917 UTC and 1932 UTC. By 1938 UTC, the convection over northwest Illinois in the vicinity of KDVN had evolved into a large bow echo complex. At the southern extent of this complex, the near surface gust front had moved ahead of the convection by about 2-4 miles. The synoptic boundary at this time was also clearly depicted extending from northeastern Mercer County eastward across central Henry County (see arrow in Fig 2 (left) at 1948 UTC). New convection was developing along the gust front in southeast Mercer County.

As this convection moved northeast, it began to intensify as the bow echo gust front interacted with the synoptic-scale cold front. Modest rotation was evident at 1938 UTC at 1.4 to 3.4 deg (2.9 to 6.2kft agl) as indicated on the Vr shear diagram in Figure 3. This was associated with the supercell thunderstorm on the southern flank of the bow echo complex over southern Rock Island/northern Mercer County. At 1943 UTC, very strong low level outflow was observed with the supercell thunderstorm, with greater than 64 kts observed from KDVN 0.5 deg base velocity image.

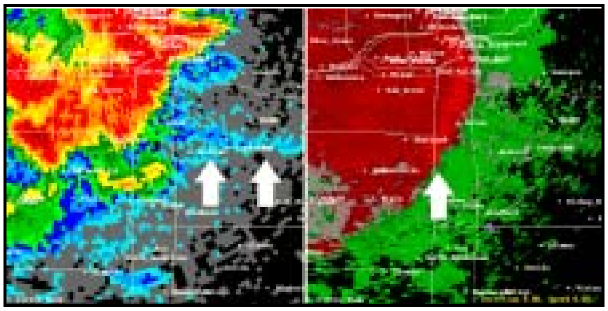

Figure 2. 1948 UTC 0.5° reflectivity (left) and velocity imagery from KDVN, which is located northwest of the storm. Arrows indicate the synoptic boundary (left) and cyclonic circulation (right). As this storm interacted with gust front/supercell storm on the southern periphery of the bow echo complex, very strong gate to gate shear was evident on SRM image.

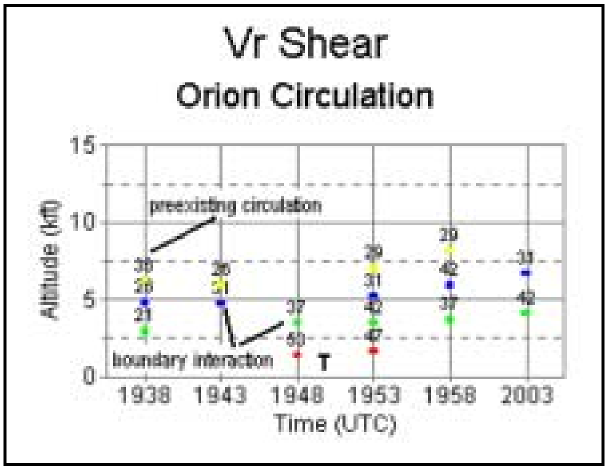

Figure 3. Rotational velocities (kts) for the Orion circulation. The tornado occurred from 1950 to 1954 UTC.

By 1948 UTC, low-level rotation had increased markedly from the previous volume scan, with gate to gate rotational velocities in excess of 50 kts (Figs. 2 and 3). The center of rotation was located in extreme west central Henry county, southwest of the town of Orion. However, the circulation remained very shallow as noted in Figure 3. At 1953 UTC, the mesocyclonic circulation had decreased in horizontal extent and deepened rapidly to over 7kft. A weak tornado (F0) was observed to develop at 1950 UTC and lasted approximately 4 minutes before weakening.

At 1958 UTC, the circulation at 0.5 deg had completely diminished while a moderate mesocyclonic circulation remained from 1.5 to 3.4 deg. By 2003 UTC, the circulation had shrunk in vertical extent and weakened, with very little observable circulation apparent at any elevation at 2008 UTC.

3.2 Woodhull Storm

The Woodhull storm developed rapidly south of the bow echo around 1953 UTC. It moved north northeast and had a maximum reflectivity of 54 dBZ by 1958 UTC. Mid-level rotation was apparent at this time as depicted by the Vr shear diagram in figure 4. By 2003 UTC, the circulation had deepened and strengthened slightly in the mid levels. At 2008 UTC, the most intense shears were apparent in the two lowest elevation angles, and were about twice as strong as the previous volume scan. A weak echo region had developed by this time.

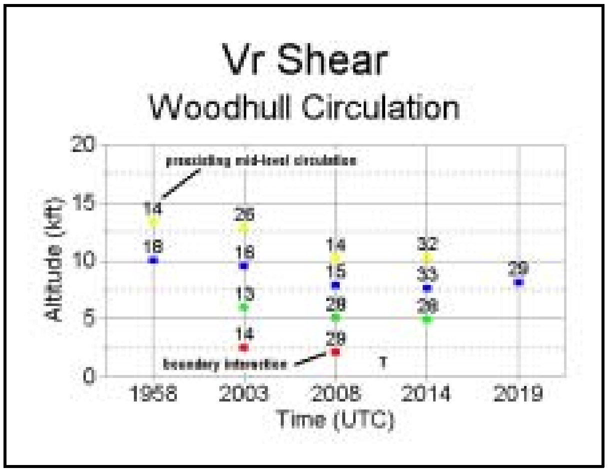

Figure 4. Rotational velocities (kts) for the Woodhull circulation. The tornado occurred at 2011 UTC.

KDVN 0.5° reflectivity imagery shows the Woodhull storm south of the bowing structure at 2008 UTC (Fig. 5, left). The cell was approaching an outflow boundary from the bow echo, which is clearly apparent in both the storm-relative velocity (Fig. 5, right) and spectrum width data (not shown). A tornado was reported 3 minutes after this volume scan in close proximity to where the cell crossed the boundary.

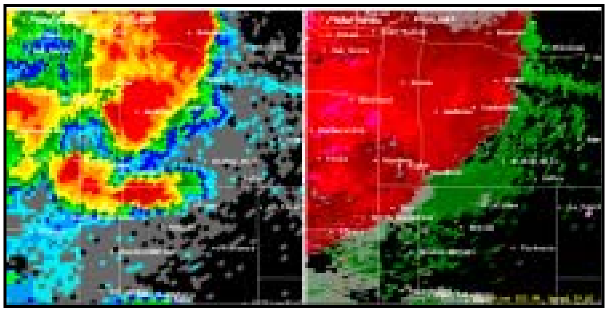

Figure 5. 2008 UTC 0.5° reflectivity (left) and storm relative velocity (right) from KDVN, which is located northwest of the storms.

In summary, the Woodhull storm quickly developed supercell characteristics including mid and low-level rotation and a weak echo region. As the storm interacted with the outflow boundary from the bow echo, the shear in the lower elevations increased and eventually a tornado developed. The tornado was short-lived, however, the mesocyclone persisted for another 40 minutes. The cell turned right, tracked along the bow echo's outflow boundary, and produced another weak tornado (F0) at 2034 UTC.

4. CONCLUSIONS

Elson (1996), Schmocker et al. (2000), DeWald and Funk (2000) and Wolf (2002) have documented the occurrence of convective boundaries intersecting squall lines which resulted in tornadoes north of the bow's apex. The Orion event studied here extends those squall line studies by showing the occurrence of a bow echo tornado south of the bow's apex, at the intersection of the squall line with a synoptic-scale frontal boundary. In addition, an example of a supercell-bow echo merger leading to a tornado was shown. Both mesocyclones studied here exhibited modest mid level rotation prior to tornadogenesis. In Orion case, tornadogenesis occurred10-20 miles south of the bow's apex, when the gust front interacted with developing convection and a synoptic-scale frontal boundary in a region of very strong shear. In the Woodhull case, tornadogenesis occurred when a well defined supercell interacted with the outflow boundary generated from the bow echo complex. Although both circulations had mid-level origins, they exhibited non-descending tornadogenesis characteristics upon interaction with a boundary, i.e., the strongest shears occurred in the lowest levels of the storm and were stronger than the preexisting mid-level circulations. Both exhibit the need for a strong awareness of both the meso and storm scale environment when assessing the potential for tornadic development associated with bow echoes, and the short period of time in which these types of tornadoes can develop.

5. REFERENCES

DeWald, V. L. and T. W. Funk, 2000: WSR-88D reflectivity and velocity trends of a damaging squall line event on 20 April 1996 over south-central Indiana and central Kentucky. Preprints, *20th Conf. of Severe Local Storms,* Orlando, FL, Amer. Meteor. Soc., 177-180.

Elson, D. B., 1996: On the role of outflow boundary interactions with bow echoes in the development of non-supercell tornadoes. Preprints, *18th Conf. on Severe Local Storms,* San Francisco, CA, Amer. Meteor. Soc., 751-755.

Forbes, G. S., and R. M. Wakimoto, 1983: A concentrated outbreak of tornadoes, downbursts, and microbursts, and implications regarding vortex classification. *Mon. Wea. Rev.,* **111**, 220-235.

Fujita, T. T., 1979: Objectives, operation, and results of Project Nimrod. Preprints *11th Conf. on Severe Local Storms,* Kansas City, MO, Amer. Meteor. Soc., 259-266.

Funk, T. W., K. E. Darmofal, J. D. Kirkpatrick, V. L. DeWald, R. W. Przybylinski, G. K. Schmocker, and Y. J. Lin, 1999: Storm reflectivity and mesocyclone evolution associated with the 15 April 1994 squall line over Kentucky and southern Indiana. *Wea. Forecasting*, **14**, 976-993.

Markowski, P. M., E. N. Rasmussen, and J. M. Straka, 1998: The occurrence of tornadoes in supercells interacting with boundaries during VORTEX-95. *Wea. Forecasting,* **13**, 852-859.

Pfost, R. L., and A. E. Gerard, 1997: “Bookend vortex” induced tornadoes along the Natchez Trace. *Wea. Forecasting.,* **12**, 572-580.

Rasmussen, E. N., S. Richardson, J. M. Straka, P. M. Markowski, and D. O. Blanchard, 2000: The association of significant tornadoes with a baroclinic boundary on 2 June 1995. *Mon. Wea. Rev.,* **128**, 174-191.

Schmocker, G. K., R. W. Przybylinski, and E. N. Rasmussen, 2000: The severe bow echo event of 14 June 1998 over the mid-Mississippi Valley region: A case of vortex development near the intersection of a preexisting boundary and a convective line. Preprints, *20th Conf. on Severe Local Storms,* Orlando, FL, Amer. Meteor. Soc., 169-176.

Trapp, R.J., and R. Davies-Jones, 1997: Tornadogenesis with and without a dynamic pipe effect. *J. Atmos. Sci.*, **54**, 113-133.

Trapp, R. J., E. D. Mitchell, G. A. Tipton, D. W. Effertz, A. I. Watson, D. L. Andra Jr., and M. A. Magsig, 1999: Descending and nondescending tornadic vortex signatures detected by WSR-88Ds. *Wea. Forecasting,* **14**, 625-639.

Wakimoto, R. M., 1983: The West Bend Wisconsin storm of 4 April 1981. A problem in operational meteorology. *J. Climate Appl. Meteor.,* **22**, 181-189.

Weaver, J. F., and S. P. Nelson, 1982: Multiscale aspects of thunderstorm gust fronts and their effects on subsequent storm development. *Mon. Wea. Rev.,* **110**, 707-718.

Weaver, J. F., J. F. W. Purdom, and E. J. Szoke, 1994: Some mesoscale aspects of the 6 June 1990 Limon, Colorado, Tornado case. *Wea.. Forecasting,* **9**, 45-61

Wolf, R, and E. Szoke, 1996: A multiscale analysis of the 21 July 1993 northeast Colorado tornadoes. Preprints, *18th Conf. on Severe Local Storms*, San Francisco, CA, Amer. Meteor. Soc., 403-407.

Wolf, R., 2002: Doppler radar observations of squall line tornadogenesis near the KDVN WSR-88D. Preprints, *21st Conf. on Severe Local Storms*, San Antonio, TX, Amer. Meteor. Soc., this volume.