P11.5 THE 2001 INDEPENDENCE, IOWA TORNADO:
ISSUES ASSOCIATED WITH NON-SUPERCELL TORNADOGENESIS FAR FROM THE RADAR

Ray Wolf* and James Meyer
NOAA/National Weather Service
Davenport, Iowa

1. INTRODUCTION

A tornado developed rapidly in the city of Independence, Iowa on the morning of 23 April 2001. It produced three minor injuries, F0 to F1 damage to 50 homes and businesses, and narrowly missed a school where children were congregating to start the day. The tornado was on the ground for approximately 10 minutes, and produced a continuous path about 3.5 miles (5.6 km) long and 1/8 mile (200 m) wide.

There was NO lightning associated with the storm while the tornado was on the ground (as reported by spotters and the National Lightning Detection Network). The National Weather Service's (NWS) Storm Prediction Center did not have the area in a risk of severe weather, and there was no anticipation of tornadic storms that morning by the NWS office in Davenport. Instability was low (CAPE < 1000Jkg^{-1}), though shear was high (SREH ~650 m^{2}s^2) and absolute wind speeds were rather strong. This is in contrast to landspout events which typically occur in weak shear environments (Brady and Szoke 1988, Wakimoto and Wilson 1989).

Radar data provided little, if any, evidence that a tornado even occurred. The highest reflectivity values observed in the Independence area during the tornado were 35-40 dBZ, and there was no evidence of a circulation in the velocity data. Several issues contributed to the lack of quality radar data. These included distance of the event from the radar, the sampling rate of the radar, and the inability of the algorithms to identify cells and accurately unfold velocity data.

The evolution of the reflectivity signatures and lack of lightning suggests this tornado developed early in the storm's evolution and in a non-descending mode, i.e., via mode II tornadogenesis (Trapp and Davies-Jones 1997). Fortunately, citizens in Buchanan County and the city of Independence have actively participated in NWS-sponsored spotter training programs. Spotters immediately sighted the tornado which led to the sounding of sirens in Independence and the issuance of a Tornado Warning by the NWS before it had dissipated.

This paper provides a brief synoptic and mesoscale overview of the event, reviews the radar imagery associated with this unique tornadic storm, discusses the radar's limitations in this event, and documents the importance of a well trained spotter network, especially in areas far from the WSR-88D and for rapidly developing mode II tornado events.

2. SYNOPTIC AND MESOSCALE BACKGROUND

Upper air data from 12 UTC 23 April 2001 depicted an upper tropospheric jet streak stretching from eastern Kansas across Iowa into Upper Michigan. A nearly closed 500 mb low was evident in eastern South Dakota with a 95 kt (~ 50 ms^{-1}) southwest wind measured at Davenport, Iowa (KDVN). A strong low-level jet was apparent at 850 mb from Missouri through the upper Great Lakes and a 60 kt (30 ms^{-1}) southwest wind was observed at KDVN.

The surface pattern was complex with a low pressure center located in south-central Minnesota. Three distinct boundaries were associated with the surface low including a warm front stretching northeastward into the upper Great Lakes, a dry line/cold front bisecting Iowa and Missouri, and a secondary cold front from northwest Iowa into Nebraska and Kansas. Convection developed along the dry line/cold frontal boundary in Iowa and southern Minnesota shortly after sunrise. The boundary separated south winds gusting to around 25 kts (~13 ms^{-1}) from southwest winds gusting up to 40 kts (20 ms^{-1}), and had a 10-15 °F thermal contrast over a 50 mile (80 km) distance.

The 12 UTC KDVN sounding (figure 1) measured a

Corresponding author address: Ray Wolf, NOAA/NWS, 9050 Harrison St., Davenport, IA 52748; e-mail: ray.wolf@noaa.gov

CAPE of 750 Jkg^{-1} and strong winds veering from the surface to around 600 mb. The Local Analysis and Prediction System (LAPS) analysis at 13 UTC, closer to the location of the tornado, yielded CAPE values between 800 and 1000 Jkg^{-1} (figure 2). Figure 2 also depicts the line of convective clouds along dry line/cold frontal boundary as seen from GOES-8 visible satellite imagery, plus ASOS/AWOS and Iowa

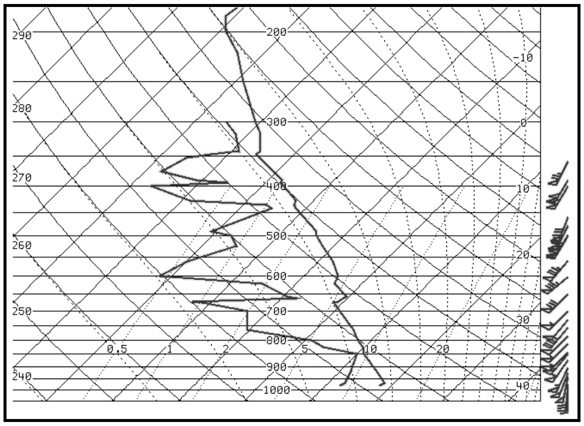

Figure 1. 12 UTC 23 April 2001 DVN sounding.

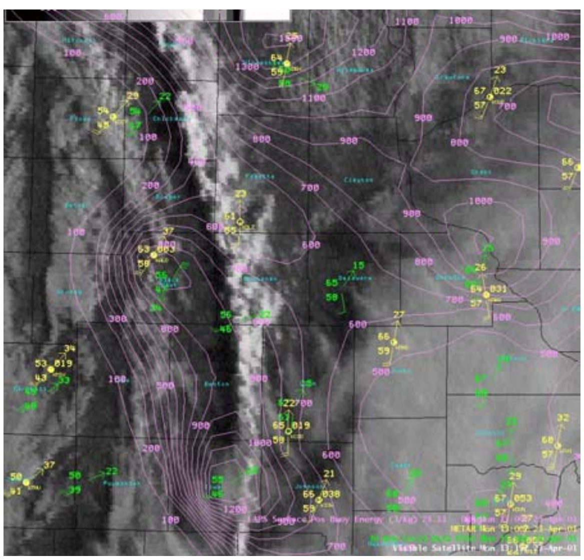

Figure 2. 13 UTC GOES-8 visible satellite imagery, surface observations (standard plot) and LAPS CAPE (Jkg^{-1}).

Department of Transportation surface weather observations.

3. RADAR PERSPECTIVE

A series of three reflectivity images from the KDVN WSR-88D captures the evolution of two distinct cells (Cell A and Cell B) which appeared in the Independence area during the time of the tornado. Velocity data provided no discernible signatures or evidence regarding a tornado, mesocyclone or any circulation, and thus is not included in the figures.

In figure 3a at 1315 UTC, Cell A has a 30-35 dBZ core and is located south of Independence. A weaker cell, Cell B, is apparent southwest of Cell A. By 1321 UTC (figure 3b), Cell A has moved north-northeastward to a location northeast of Independence, while Cell B has moved to just southwest of the city. At 1327 UTC (figure 3c), Cell A was in the northeast part of the county, while Cell B had moved just north of the city and increased in intensity by 5-10 dBZ. The tornado occurred while Cell B moved from southwest of Independence to north of the city. Thus, the weaker-appearing Cell B produced the tornado which moved through the northwest half of Independence.

We hypothesize that Cell B produced the tornado in a nondescending mode at the intersection of the frontal boundary and outflow from Cell A in an area of high shear and strong convergence. The relative proximity of the cells to each other and the frontal boundary suggests this is a plausible explanation. However, it is not possible based on radar data alone to determine the precise role each boundary may have played in the evolution of the tornado. This proposed scenario is not too unlike the bow echo - boundary interaction leading to tornadogenesis as described in Schmocker et al (2000), Wolf (2002), and Crosbie and Wolf (2002).

4. DISCUSSION

a. Radar issues

Independence is about 80 nmi (~150 km) northwest of the radar, which places the 0.5° beam centerline at 17400 ft (~5300 m) assuming standard propagation. Also, the beam width at that range is in excess of 1 nmi (~2000 m). The ability to detect and resolve a circulation associated with a non-supercell tornado is limited to within about 45 km of the WSR-88D (Wilson 1986). Specifically for this storm, the beam would clearly not be able to resolve the tornadic circulation (figure 4) since the lowest elevation scan would only have sampled the upper portion of the storm.

Even if the storm had been closer to the radar, issuing a warning with useful lead time would have been problematic. Trapp et al (1999) noted that non-descending vortices associated with TVS signatures observed by WSR-88Ds only had an average lead

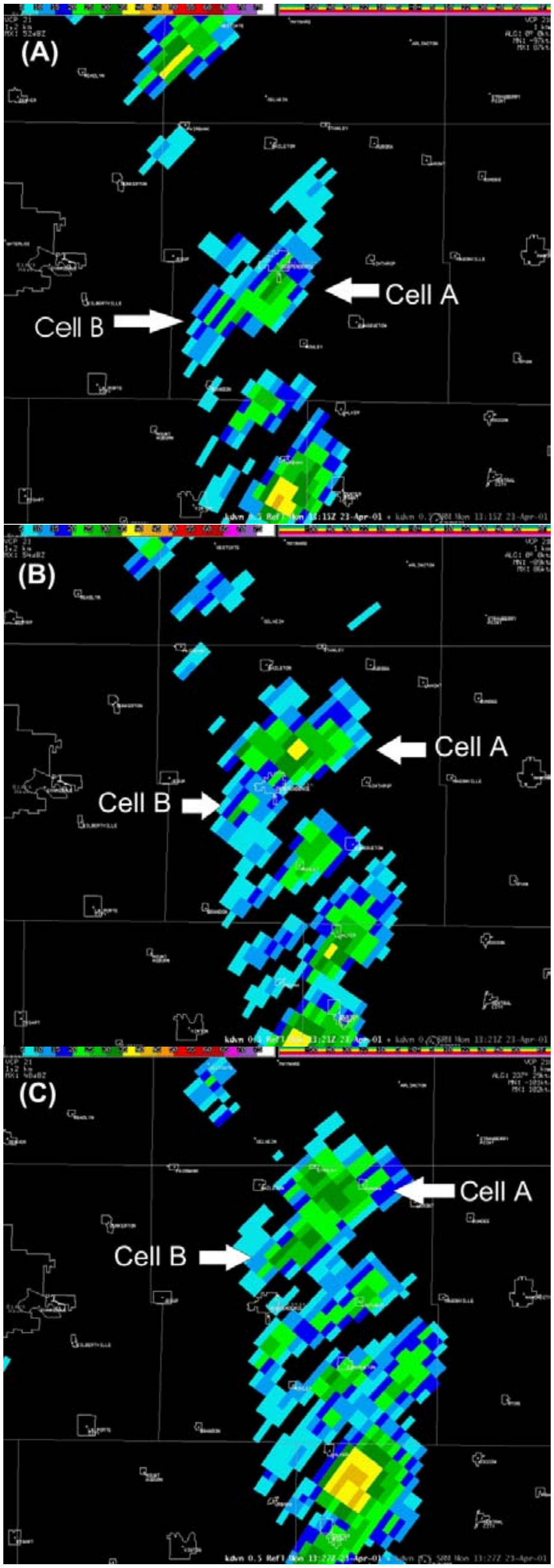

Figure 3. KDVN 0.5° base reflectivity at 1315 (a), 1321 (b) and 1327 UTC (c).

time of 5 minutes before tornadogenesis, while descending TVS signatures averaged about a 25 minute lead time. While a TVS was not evident in the Independence storm, its nondescending development mode suggests, based on local experience, that lead time would have been quite limited as observed in the Trapp study.

Finally, storm motion estimates were not initially available because the cell in question, and others nearby, were too small and/or too far away from the radar to trigger the storm cell identification and tracking algorithm. Thus, velocity data were not initially adjusted for storm movement. In addition, range folding degraded the quality of the velocity data.

Sampling limitations for small, rapidly developing features at long range from the radar must be considered in the warning process. Use of other observational tools is critical in the warning process, especially in these type of cases. New VCPs planned for the WSR-88D (Steadham et al 2002) should address the temporal sampling issues and some of the range folding problems. However, the issue of beam elevation and width at great distances from the radar will remain.

b. Spotter issues

The relative importance of spotters at longer ranges from the radar has been discussed by Burgess et al (1995). While quality spotters are important anywhere under the radar umbrella, their observations at longer ranges helps counterbalance the shortcomings inherent in radar sampling. In addition, when tornadogenesis is of the mode II variety, i.e., non-descending, quality spotter reports are again relatively more important than in mode I events because of the rapid development which typically occurs in these events in contrast to mode I events. This indeed was the case with the Independence tornado.

c. Other issues

The association of a boundary to tornadogenesis has been documented in numerous other cases (e.g. Markowski et al 1998)) and was likely a key factor in this case. The presence of the dry line/cold frontal boundary was important in convective initiation, and it may have been important for tornadogenesis due to its possible interaction with a convective scale boundary and/or Cell B. This case is an excellent and unusual example of mode II tornadogenesis in a low instability - high shear environment, in contrast to the modest instability - weak shear environments associated with landspouts.

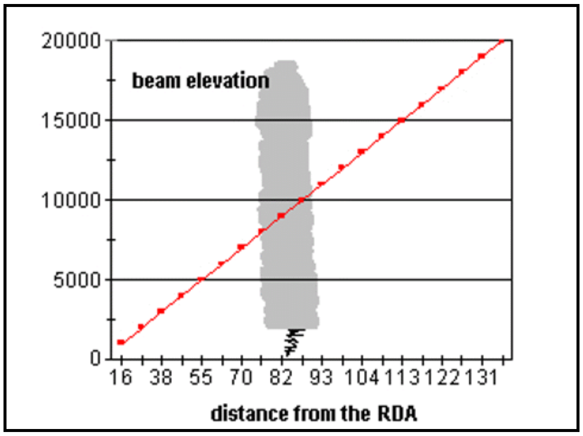

Figure 4. Diagram of the 0.5° beam center line intersection through the Independence storm. The beam width at the storm is just over 1 nmi wide.

5. REFERENCES

Brady, R.H. and E. Szoke, 1988: The landspout - A common type of northeast Colorado tornado. Preprints, *15th Conf. on Severe Local Storms*, Indianapolis, IA, Amer. Meteor. Soc., 312-315.

Burgess, D. W., R. R. Lee, S. S. Parker, D. L. Floyd, and D. L. Andra, 1995: A study of mini supercells observed by WSR-88D radars. Preprints, *27th Conf. on Radar Meteorology*, Vail, CO, Amer. Meteor. Soc., 4-6.

Crosbie, C. and R. Wolf, 2002: 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. Preprints, *21st Conf. on Severe Local Storms,* San Antonio, TX, Amer. Meteor. Soc., this volume.

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.

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.

Steadham, R.M., R.A. Brown, and V.T. Wood, 2002: Prospects for faster and denser WSR-88D scanning strategies. Preprints, *Interactive Symposium on the Advanced Weather Interactive Processing System (AWIPS)*, Orlando, FL, Amer. Meteor. Soc., J89-J91.

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. and J.W. Wilson, 1989: Non-supercell tornadoes. *Mon. Wea. Rev.*, **117**, 1113-1140.

Wilson, J.W., 1986: Tornadogenesis by nonprecipitation induced wind shear lines. *Mon. Wea. Rev.*, **114**, 270-284.

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.