**14.6 TORNADOGENESIS AND THE ROLE OF A LAKE BREEZE BOUNDARY ON 14 JUNE 2003 IN NORTHWEST ILLINOIS**

Ray A. Wolf*
NOAA/National Weather Service
Davenport, Iowa

## 1. Introduction

On 14 June 2003, a series of weak tornadoes occurred in northwest Illinois in close proximity to a lake breeze boundary. Six tornadoes and one funnel cloud were observed by trained spotters in the extreme northwest part of the state between 315 and 405 pm CDT (NCDC 2003) (Fig. 1). The slow moving, short-lived tornadoes produced no damage (F0), though they were highly visible to the public since they occurred on a Saturday afternoon when many people were outdoors.

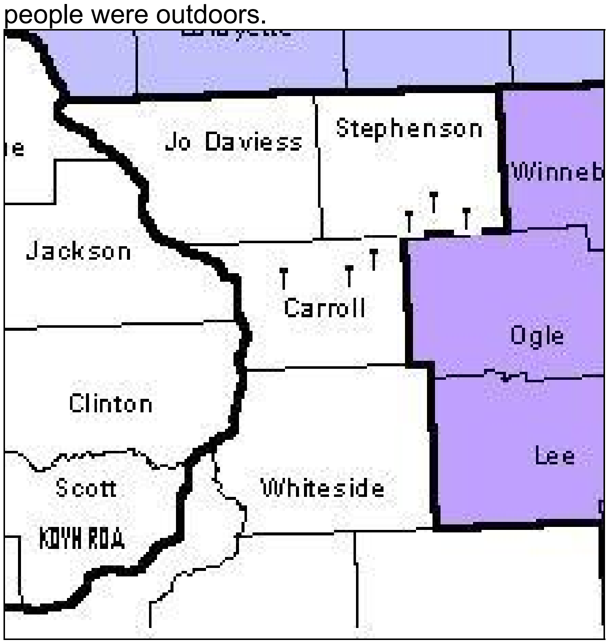


Figure 1. The location of the tornadoes in northwest Illinois is denoted by a T. The KDVN WSR-88D is located to the southwest, in the lower left corner.

The meteorological conditions this day were similar to those observed by Brady and Szoke (1989) and Wakimoto and Wilson (1989) for landspouts in northeast Colorado. Both wind speed and shear were quite weak and instability was moderate. Persistent moisture convergence was observed along the quasi-stationary boundary through the day, while radar imagery indicated that even the most modest convective showers were generating observable outflow.

A synoptic and mesoscale analysis of this event will be presented. Similar occurrences of lake breeze or lake-enhanced boundaries associated with tornadoes and/or funnel clouds as far west as eastern Iowa have been observed locally, thus a better understanding of these events is desired to better anticipate the tornadic threat in future cases. In addition to similarities to landspouts in northeast Colorado, many aspects of this case resemble the cold air funnel (hereafter CAF) cases described by Cooley and Soderberg (1973) and Cooley (1978). The relationships amongst this case, landspouts in northeast Colorado, and CAFs will be discussed.

## 2. Synoptic and Mesoscale Analysis

A complex synoptic pattern over North America on 14 June 2003 was dominated by split flow in the middle and upper troposphere. The strongest branch of the upper tropospheric jet was located in Canada north of a ridge, while a second branch extended from Texas into the Ohio River Valley (not shown). Eastern Iowa and northern Illinois were located between the jet axes in a weak flow regime. At 500mb, a very weak trough was moving eastward across the upper Midwest, south of the Canadian ridge (Fig. 2).

Weak wind speeds and minimal shear were observed on the 12Z Davenport, Iowa sounding (Fig. 3). Surface flow was also weak during the day, although a 20Z LAPS (Local Area Prediction System) analysis indicated persistent moisture convergence along a lake-enhanced boundary which had pushed west into northwest Illinois the previous day (Fig. 4). Afternoon temperatures

* *Corresponding author address:* Ray A. Wolf NOAA/National Weather Service, 9050 Harrison Street, Davenport, Iowa 52806-7326
e-mail: ray.wolf@noaa.gov

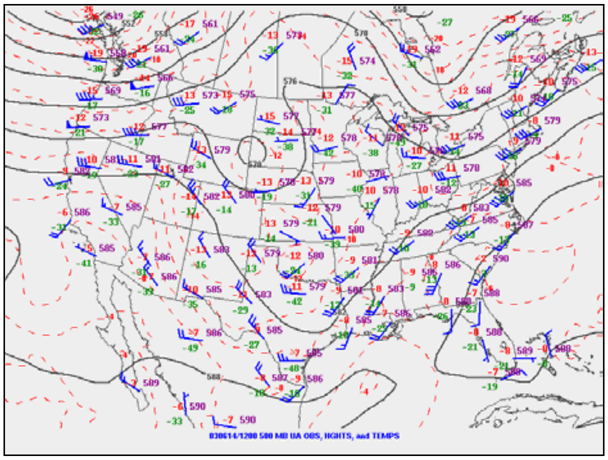

Figure 2. 12Z 14 June 2003 500mb data and analyses. Height in dkm, temperatures °C in red, dew points °C in green, wind kts in blue. (Courtesy of SPC)

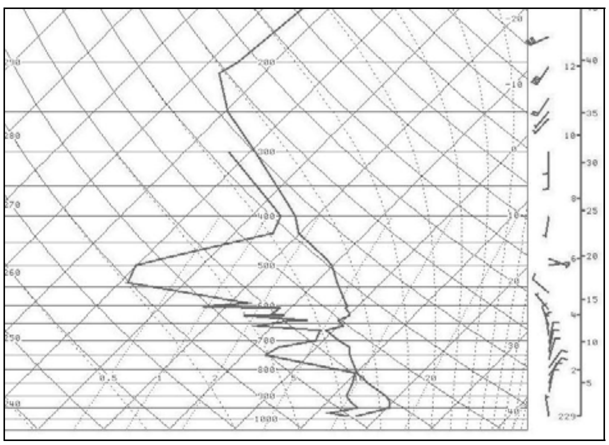

Figure 3. 12Z 14 June 2003 Davenport, Iowa sounding.

in the area were in the upper 20s °C (lower 80s °F) and dew points in the mid teens °C (around 60 °F). LAPS surface-based CAPE values at 20Z were around 1400 $Jkg^{-1}$ (Fig. 5). VAD wind data from the Davenport WSR-88D (KDVN) at 21Z indicated the wind profile had changed little in the lower 4km (~13kft) of the atmosphere since the morning sounding. Flow was front the northeast at 2.5-5$ms^{-1}$ (5-10kts) (Fig. 6).

KDVN radar imagery between 1940Z and 2030Z depicted a southwest to northeast line of rapidly developing but short-lived convective cells oriented along and near the lake-enhanced boundary in northwest Illinois (Fig 7). Most of the showers and all of the tornado and funnel reports occurred in this area.

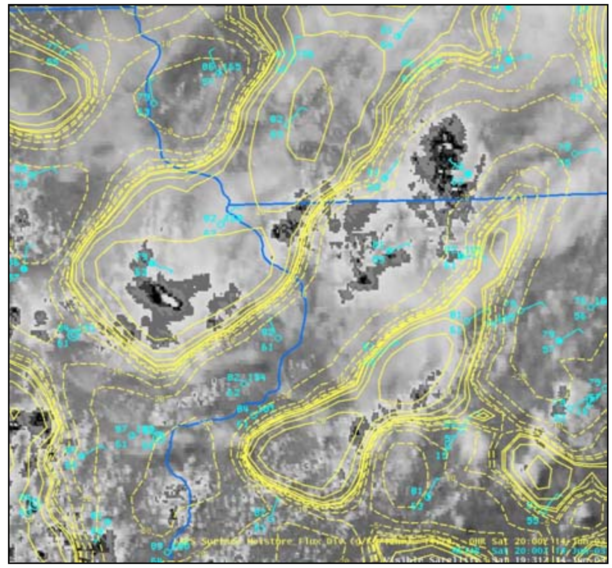

Figure 4. 20Z LAPS moisture convergence (g/kg/12hr; dashed yellow), surface observations and visible satellite imagery with cold cloud tops enhanced (darker shading).

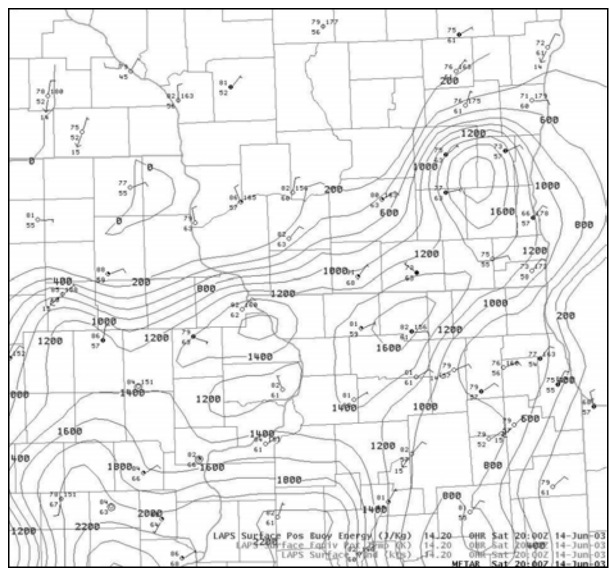

Figure 5. 20Z LAPS surface-based CAPE (J/kg) and surface observations.

The upper level flow was steering the showers to the southwest, parallel to the lake-enhanced boundary. Thus the residence time of the convective updrafts over the boundary was on the order the convective cells' life cycle. A few showers developed on convective outflow away from the lake-enhanced boundary, but none of these prompted a tornado or funnel cloud report.

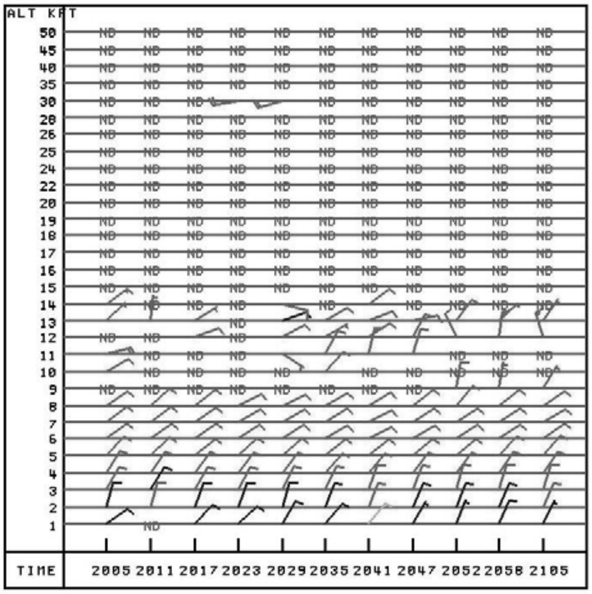


Figure 6. KDVN VAD wind profile 20-21Z. Y-axis is altitude (kft), x-axis is time (Z), and wind barbs are in knots (1/2 barb = 5kts, full bard = 10kts).

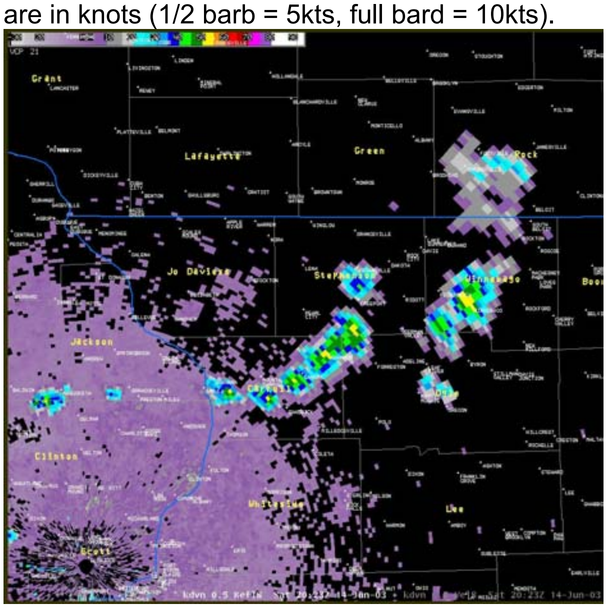

Figure 7. 2023Z KDVN 0.5° reflectivity image. Color curve in the upper left indicates intensity in dBz.

Interestingly, the first report of a tornado occurred about 30 minutes after the shower activity initiated. The final reported tornado occurred less than one hour later after the merger of two cells, shortly after the 0.5°reflectivity reached a maximum of 63 dBz.

Figure 8. Photo of one of the six tornadoes that occurred in northwest Illinois. (Courtesy of Greg Munda)

In general, 0.5° reflectivity values of cells associated with the tornadoes would typically increase from about 35-40dBz to 55 to 60dBz in a six minute period just prior to tornadogenesis. The storms occurred between 75-110km (40 and 60nm) from the radar, thus no evidence of rotation is apparent in the velocity data. The 0.5° elevation at this distance is 1-1.5km (3-5kft) above ground level.

## 3. Discussion

### 3.1 *Relation to landspouts*

The synoptic setting of weak shear, moderate instability, and a well-mixed boundary layer as observed in this case is similar to the environment in northeast Colorado landspout cases studied by Brady and Szoke (1989) and Wakimoto and Wilson (1989). In landspout cases, the collocation of intersecting boundaries with a convective updraft apparently lead to tornadogenesis. Wakimoto and Wilson (1989) hypothesized that vortex stretching of vertical vorticity at the intersection of the boundaries (from a misocyclone) lead to tornadogenesis. They state such a vortex could produce damage as significant as F2. Later numerical modeling studies by Lee and Wilhelmson (1997) showed that the combination of low-level misocyclones and sub-cloud layer convergence actually initiates the convective updraft that in some cases leads to tornadogenesis.

Other similarities to the Colorado cases include their visual appearance (Fig. 8), short life spans and path lengths, proximity to a quasi-stationary boundary experiencing moisture flux convergence, and association with a convective cell increasing in intensity. It is interesting to note that showers occurred for over a 30-minute period prior to the first tornado, suggesting the possibility that the outflows from the initial showers were critical to subsequent tornadogenesis and without their presence, tornadogenesis would not have occurred. Unfortunately, the tornadoes were too far from the radar to confirm this.

The case of tornadoes associated with land-water generated boundaries was addressed by Holle and Maier (1980). They noted the interrelationship of convective cells when they observed the formation of weak tornadoes in Florida. They stated these tornadoes are likely due to strength of vertical updrafts and their interaction with the cloud scale or mesoscale flow. The tornadoes occurred in a weak shear environment and where a gust front and the land-sea breeze intersected.

King et al (2003) noted in a Canadian study centered in Ontario an enhanced likelihood of tornadoes in areas of frequent lake-breeze activity. Though their focus was primarily on organized convection, they stated some of their cases fit the landspout scenario (e.g., merging of breezes from Lakes Huron and St. Clair). They also noted the axis of greatest density of tornado activity stretched from southwest lower Michigan into Ontario.

### 3.2 *Relation to cold air funnels*

Many similarities exist between this case and cold air funnel cases (CAF) in western Michigan described by Cooley and Soderberg (1973) and Cooley (1978). In both cases, the synoptic pattern is not suggestive of tornadoes from organized convection. CAF cases generally occur under a mid-tropospheric cold core low while only a weak trough passage was observed in Illinois case. Surface lows were located to the east in both cases. Both environments exhibit soundings with weak shear, lower tropospheric moisture, mid-tropospheric drying, and a well-mixed boundary layer.

Radar indicated showers, perhaps a few strong enough to produce lightning in both cases. While not mentioned explicitly in the Michigan cases, the lake boundary was likely a factor because more CAFs occurred with onshore flow when the westerly winds would have driven the lake boundary inland. Storms moved slowly in the Michigan cases and the CAFs were reported near the maximum radar echo tops, both similar to the Illinois case. Finally, photos of cold air funnels are very similar to the Illinois tornadoes, except of course the tornadoes are seen touching down.

Another case of CAFs in central Illinois on 24 May 1998 was documented by Rauber and Scott (2001). The CAFs occurred along a stationary frontal boundary in an environment of weak shear and weak instability and the presence of convective showers. Though reported as CAFs, they could not confirm the lack of touchdowns in the rural area in which they occurred. They speculate the funnels formed as described by Lee and Wilhelmson (1997), i.e., vortex sheet breakdown due to horizontal shearing instabilities.

## 4. Conclusions

A number of points pertinent to operational forecasting can be made or extrapolated from this study.

(1) Lake breeze or lake-enhanced boundaries can serve as an effective initiation point for the generation of landspouts and funnel clouds under conditions of weak shear and weak-moderate instability, even in areas not traditionally considered to be affected by Lake Michigan. Moreover, the study by King et al (2003) suggests the lake boundary can be important in organized convective events too.

(2) The synoptic and mesoscale environment in this case is generally similar to that observed in northeast Colorado landspout cases AND western Michigan CAF cases, especially with respect to CAPE and shear.

(3) The visual appearance of the tornadoes in this case is similar to northeast Colorado landspouts and funnel clouds in western Michigan, except of course the funnels do not *appear* to have touched down.

(4) There is no apparent physical reason to differentiate the CAF cases reported in Cooley and Soderberg (1973) and Cooley (1978) from landspout cases in northeast Colorado or from the case studied here.

The fact that CAFs occurred in a well-mixed boundary layer in the largely rural area of western Michigan suggests the possibility that not all touchdowns were reported. This is especially true in an era when public awareness, reporting, spotter training, verification, and radar observing were not at the level of today. Moreover, landspout damage paths tend to be short and narrow (~10-50ft) (Ed Szoke, personal communication) and would be easy to not observe in a rural area. Thus, the combination of a rural setting, reporting standards of the era, F0 strength winds, and short and narrow tracks could provide an alternate explanation as to why damage is rarely reported in the CAF events studied by Cooley and Soderberg (1973). Also, the King et al (2003) study noted an axis of increase tornado density starting in southwest lower Michigan, the area of the Cooley studies.

Although CAFs occur under a closed 500mb low and associated cold pool, there is nothing unique about the stability profile in these cases that differentiates them from the Illinois case or Colorado cases. While both surface and 500mb temperatures might be colder in the Michigan cases, the net effect on stability is similar since all cases occurred with a well-mixed boundary layer.

(5) A forecaster who assesses an event as "cold air funnels" and dismisses the possibility of tornadoes risks not properly alerting the public to the tornado threat. While the risk is not as substantial as that associated with significant tornadoes (F2+), the same could be said for most tornado events in this geographical area. Eighty-three percent of the tornadoes in the eastern Iowa and northwest Illinois in the WSR-88D era have been rated F0 or F1 (NCDC 1994-2004).

(6) The fact that this type of tornado occasionally occurs in families suggests that some warning lead time is possible, at least for events subsequent to the first event if forecasters are aware of the synoptic setting, warn aggressively and quickly, and spotter reports are timely. In some cases, the misocyclones may be observed by the WSR-88D if the circulations are close enough to the radar (~<45km) (Wilson 1986).

(7) Why some vortices touchdown and others do not is not apparent from this study or the published literature to date. This question plus the challenges of issuing timely warnings are the two biggest issues facing forecasters who deal with landspouts.

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