1B.1 Evolution of the 30 June 2014 Double Derecho Event in Northern Illinois & Northwest Indiana

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1. INTRODUCTION

In a seven hour period on the evening of 30 June 2014, two separate quasi-linear convective systems (QLCSs) exhibited derecho characteristics as they tracked across northern Illinois. As the first derecho gradually waned and moved northeast, the second derecho intensified behind it and progressed southeast. Both lines of storms resulted in widespread wind damage, gusts of 26-35 m s^{-1} (58-80 mph) or higher, sporadic reports of large hail, and areas of flooding. The second derecho also was responsible for 29 documented tornadoes across northern Illinois and northern Indiana. While the late spring and early summer period is favored for QLCS events in the Corn Belt states, the rapid succession of these two organized convective features with the latter being more pronounced made this event especially noteworthy.

This presentation explores the synoptic and mesoscale processes that contributed to this unusual event. It also describes how the atmospheric evolution after the first derecho enabled the second one to be such a prolific tornado producer. Key factors include a limited cold pool imprint from the first derecho, strengthening of a surface theta-e boundary, more pronounced deep layer shear, and enhanced storm relative helicity in advance of the second storm complex. These stronger dynamics in the presence of only slightly elevated instability favored storm-scale structures and interactions in the second QLCS that were more conducive for tornado development. Paper 1B.2 (Lenning et al. 2015) further examines the mesoscale and storm-scale evolution of this event, and specifically the role of a bore in driving the behavior of the second QLCS.

2. EVENT OVERVIEW

The National Weather Service (NWS) logged over 600 severe weather reports on the evening of 30 June into 1 July 2014. The greatest concentration of reports was associated with two QLCSs across the Corn Belt and Lower Great Lakes (Figure 1). Both QLCSs satisfied the definition of a derecho established by Fujita and Wakimoto (1981) and amended by Johns and Hirt (1987). Both also persisted five to six hours, and together generated over 230 reports of severe wind speeds of 26 m s^{-1} or higher, or wind damage attributed to such speeds.

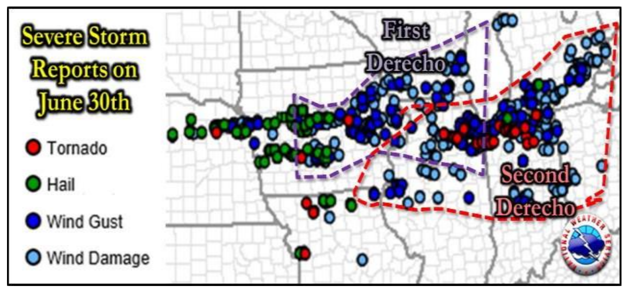

Figure 1. Severe weather reports and the outline of the two derecho swaths from 30 June 2014.

Table 1 shows that the second derecho brought far more tornadoes than the first, all occurring across northeast Illinois and northern Indiana (Figure 2). Figure 3 and Figure 4 show some of the damage that occurred from the second derecho, while Figure 5 provides evidence of a tornado path near Earlville, IL, the first tornado in the second derecho. The most notable aspect of this event, beyond the large number of tornadoes in such a concentrated area, was that the tornadoes in the second QLCS developed within the remnant cold pool of the first QLCS. Quite often a cold pool will have the opposite effect and inhibit additional severe weather after the initial storms have passed.

	First Derecho	Second Derecho
Time	1845-0030	0100-0700
Severe Wind	112	119
Tornadoes	2	29
Hail	28	3

Table 1. Derecho times (UTC) and report counts from 30 June – 01 July 2014.

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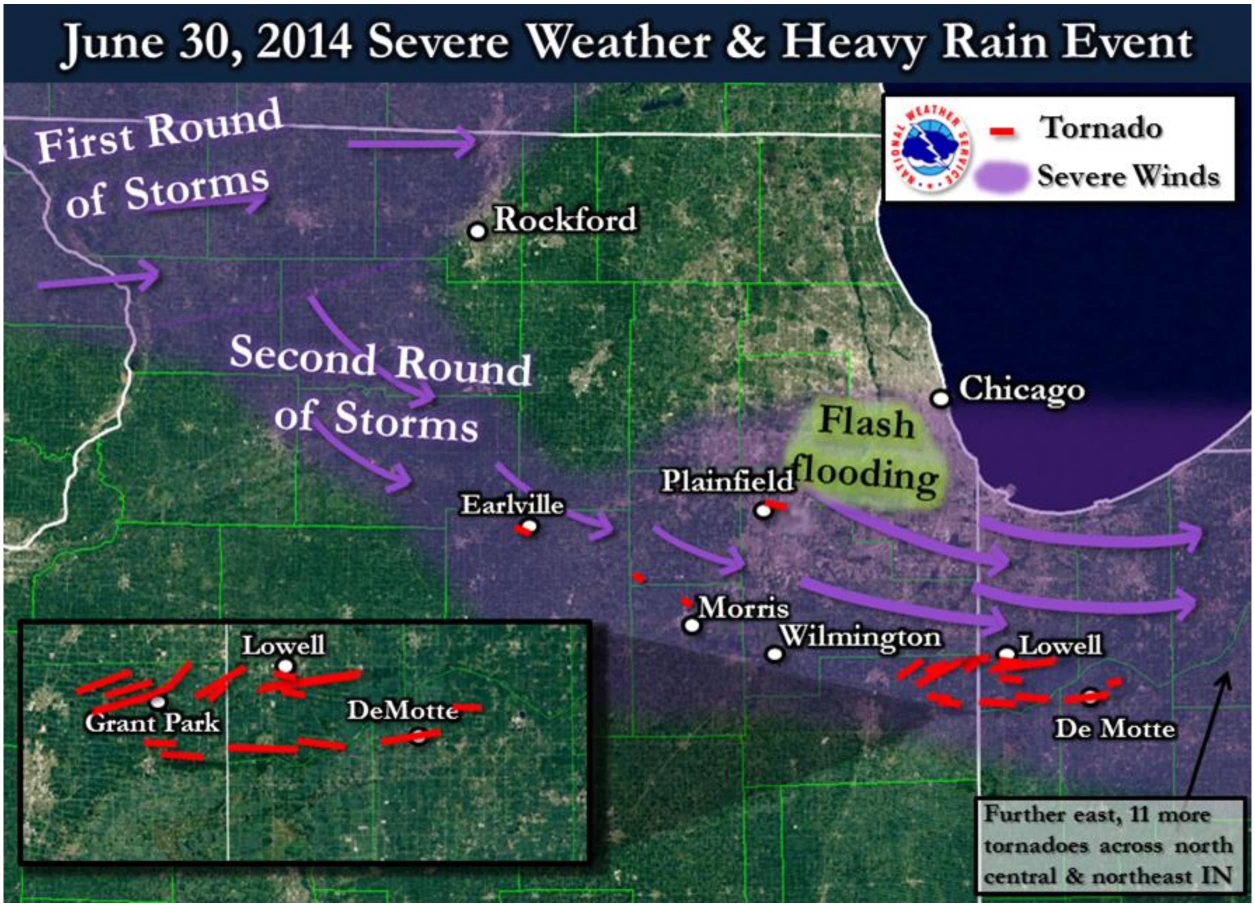

Figure 2. The location of tornado tracks and swaths of wind damage on 30 June 2014.

Figure 3. Northeast Illinois impacts from the second derecho of 30 June 2014.

Figure 4. Northwest Indiana impacts from the second derecho of 30 June 2014.

Figure 5. Evident tornado path within fields near Earlville, IL as taken and shared by media entity ABC7 Chicago.

3. DERECHO CLIMATOLOGY

As already mentioned, the region hardest hit by the prolific tornado producing derecho of 30 June 2014 was northern Illinois and northwest Indiana. Multiple climatological studies from the 1980s to as recently as 2015 have noted the high frequency of warm season derecho events in this area. A pair of spatial data plots from these studies (Figure 6) shows this region lies near the center of highest derecho frequency across the Midwest and lower Great Lakes.

While the derecho frequency in this area is well-documented, this region of the country is not considered to be part of the traditional “Tornado Alley” or “Dixie Alley” where tornadoes occur with the greatest frequency (Gagan et al., 2010). There is, however, some evidence this region sees a greater share of QLCS tornadoes. The climatology has not been studied extensively, though Smith et al. (2012) investigated the convective mode of tornadoes per season. Their results suggest that some areas of the country do see a greater frequency of QLCS tornadoes during the summer relative to tornadoes associated with other modes of convection (Figure 7). One such area includes northeast Illinois and northwest Indiana.

Even though the climatology of derechos and QLCS tornadoes suggests this was not a rare event from those perspectives, the rapid succession of derechos over partially overlapping areas is far less common. From a dataset containing 256 progressive derechos from 1996 to 2013, Guastini (2015) noted there were not two in such quick succession, let alone over the same area. It is therefore worth seeking to understand the synoptic and mesoscale environment that led to this unusual event.

4. SYNOPTIC ENVIRONMENT

Multiple aspects of the evolving synoptic environment on 30 June 2014 contributed to the initiation and maintenance of both derechos that evening. This is examined from the hourly archive of mesoscale analysis imagery from the NWS Storm Prediction Center (SPC), a dataset widely used in real-time by operational forecasters. This mesoanalysis is created by merging recent surface observations with fields from the 40km RAP model (Hart et al. 2015).

The factors that proved to be important on this evening are typical of many derecho synoptic environments. This was especially true at 500mb (Figure 8), where high speed mid-level flow with a shortwave trough and its associated forcing for ascent were approaching the area of interest during the early afternoon of 30 June 2014. This served as an impetus for the first derecho, and a second short wave trough analyzed from western Minnesota through the High Plains became one of the triggering mechanisms for the second derecho.

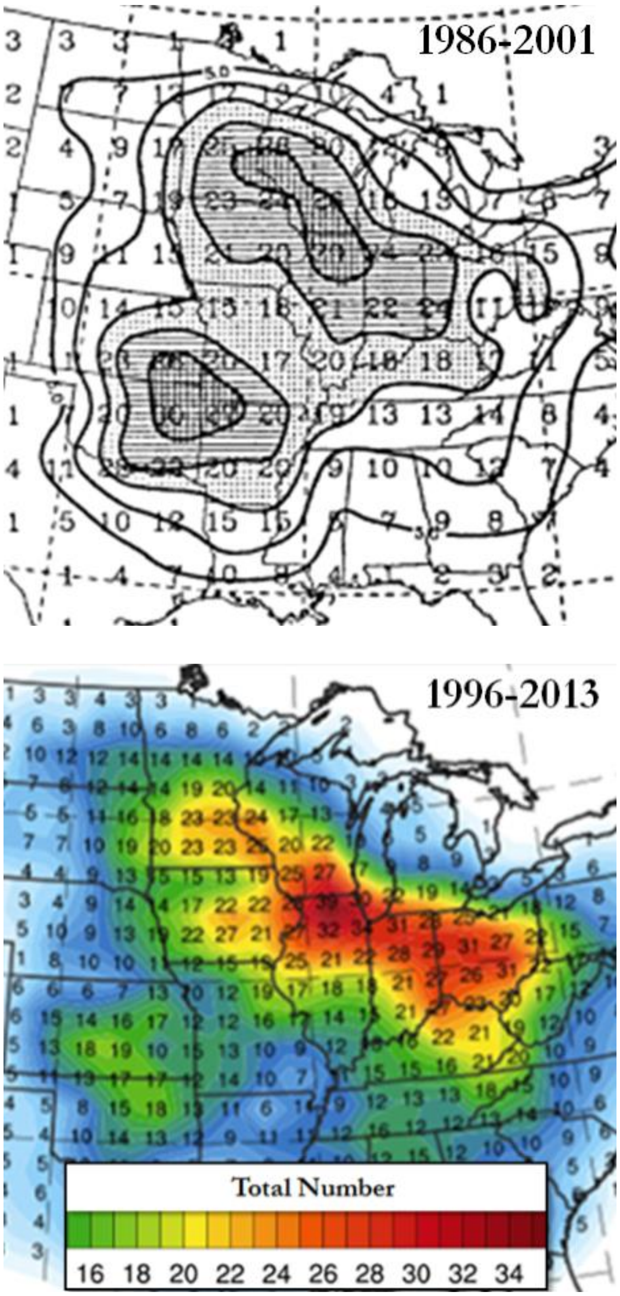

Figure 6. Number of derecho occurrences in the time spans identified as defined by Coniglio & Strensrud (2004, top) and Guastini (2015, bottom).

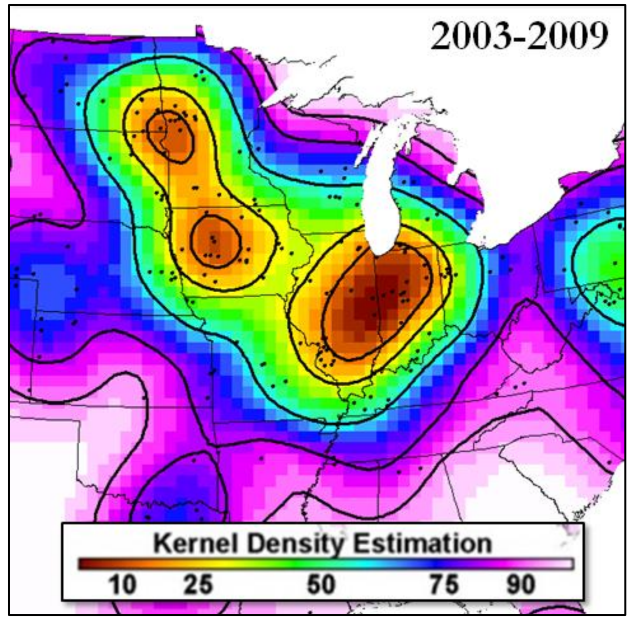

Figure 7. Relative frequency of summer QLCS tornadoes to all summer (Jun-Aug) tornadoes from 2003-2009 by Smith et al. (2012).

In addition to these upper level features, the thermodynamic environment on this afternoon and evening also was very supportive of strong vertical ascent. Southerly flow into the area was producing surface temperatures in the low 80s and dewpoints in the middle to upper 70s. As lapse rates steepened aloft, values of CAPE for parcels rooted in this very warm and moist surface layer exceeded 4000 J kg-1 (Figure 9). Generally a value exceeding 1000 J kg^{-1} is considered sufficient for support of deep moist convection (Evan and Doswell, 2002).

Favorable deep layer shear also has been shown to support thunderstorm strength and longevity (Evans, 2002). The earlier noted mid-level winds of 37 m s^{-1} contributed to deep layer shear values in excess of 30 m s^{-1} across the Corn Belt by early afternoon (~1900 UTC). This area of higher shear gradually expanded east in conjunction with the second derecho. However, the first derecho, which formed in the early afternoon, had tracked ahead of this maximum by late afternoon (Figure 10). This would likely be a factor in the first derecho gradually weakening by the time it reached Lake Michigan and adjacent parts of Illinois, Michigan, and Wisconsin.

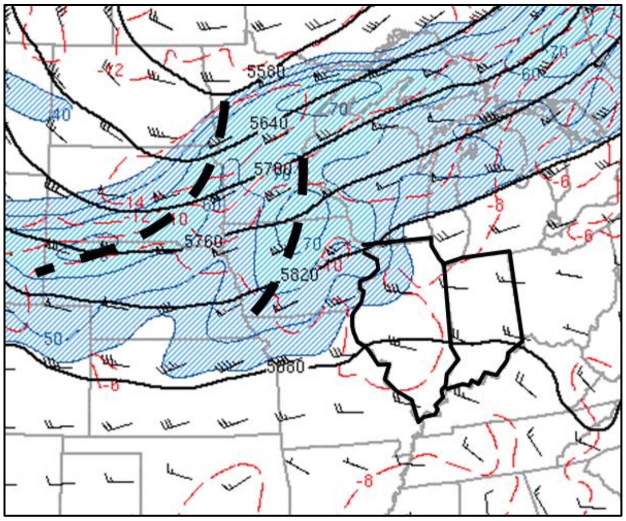

Figure 8. SPC Mesoanalysis of 500mb height (m), temperature (C), and wind (kts) from 1900 UTC on 30 June 2014.

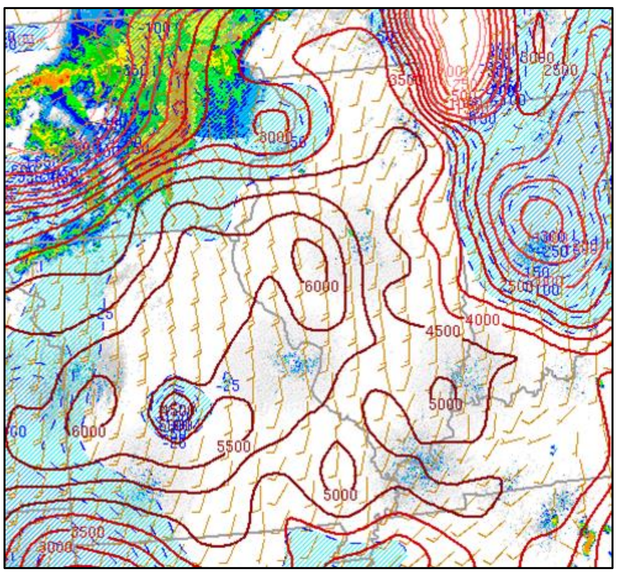

Figure 9. Surface-based CAPE (contours, J kg^{-1}) and CIN (shaded, J kg^{-1}) at 1900 UTC 30 June 2014.

At the surface, low pressure centered near the Iowa/Missouri border gradually evolved eastward in tandem with the upper level support (Figure 11). This is in the latter part of the first derecho's lifecycle as well as the beginning phase of storms in eastern to central Iowa that would become the second derecho. Figure 11 also shows isallobaric pressure rises and falls. The area of pressure falls of 1-2 mb per 3 hr (shaded in red as of 23 UTC) is in the immediate wake of the first derecho. Typically an immediate post-derecho air mass is one characterized by a rain-driven cold pool and one of rising surface pressures. These falls indicate a limited cold pool footprint from the first derecho and show the influence of the surface low moving from Missouri into northern Illinois.

An additional feature within the low-level cyclonic flow ahead of the advancing low pressure center and second derecho was a warm front. Conceptual models for both progressive and serial derechos address the importance of nearby stationary or warm fronts (Johns and Hirt, 1987). The first derecho tracked just north of the area where this front became established. In fact, it is likely that the passage of the first derecho significantly influenced the strength of this front, as described in the next section.

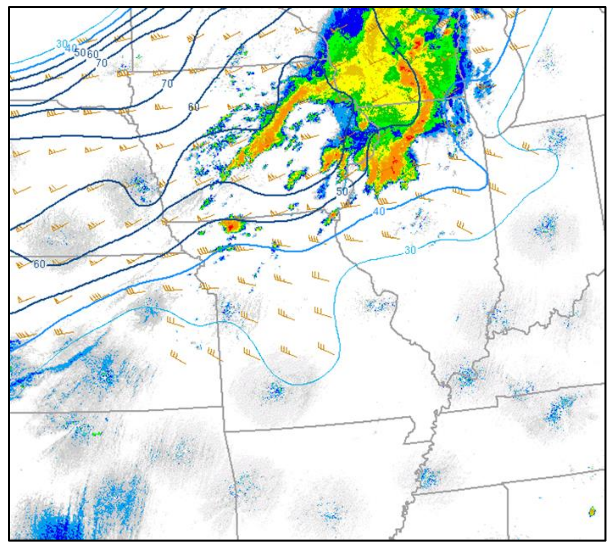

Figure 10. SPC Mesoanalysis of 0-6km shear (kts) from 22 UTC and concurrent radar mosaic on 30 June 2014.

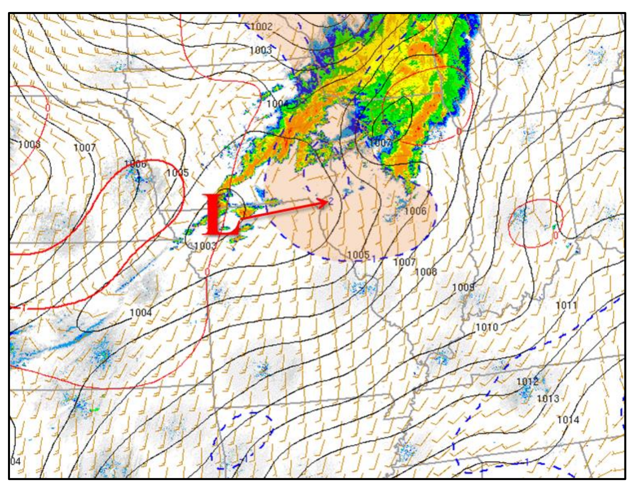

Figure 11. SPC Mesoanalysis of mean sea level pressure (mb), wind barbs, and 2hr pressure falls from 23 UTC and concurrent radar mosaic on 30 June 2014.

5. MESOSCALE ENVIRONMENT

From the brief synoptic overview, it is clear that the environment was quite favorable for support of strong and sustained convection on the afternoon and evening of 30 June 2014. It is less clear how the second derecho maintained its severity in the wake of the first event, and why it was capable of generating so many tornadoes. A closer look at the evolution of the mesoscale environment in the wake of the first derecho will provide some insights.

One notable aspect of the mesoscale environment in advance of the second derecho was falling pressures and heights. This served to intensify the low level wind field with a strong low level jet already present. This also caused a rapid increase in low level shear/effective storm relative helicity (E-SRH) as the second derecho approached. E-SRH values of 300-500 $m^2\ s^{-2}$ (Figure 12) rank in the upper echelon of E-SRH distribution for significant tornadoes in supercell environments as shown by Thompson et al. (2003, Figure 13). A nearby warm-sector sounding at WFO ILX on 00Z 01 July 2014 also indicated the presence of a large amount of instability (Figure 14) and captured the low-level wind strengthening and veering.

The sounding at ILX was taken approximately 50 miles south of the warm frontal boundary mentioned in the previous section. This front, which stretched across the Kankakee River valley into northern Indiana (Figure 15), likely helped focus localized amounts of even larger low-level helicity (Thompson, 2007). As such, this front may have influenced the severity of the first derecho, but it appeared to be much more important for the second derecho. In fact, the first derecho very likely created or at least strengthened this feature along the southern extent of its cold outflow. By 02 UTC on 1 July 2014 the temperature and moisture (theta-e) gradient in the frontal zone had become very pronounced (Figure 16). Soon after, the greatest concentration of tornadoes in the second derecho occurred along this boundary.

As the warm front was strengthening across the Kankakee River valley, pressures continued falling and helicity values continued to increase. During this time, an ACARS descent sounding into Midway Airport at 0237 UTC on 1 July 2014 sampled the extremely favorable QLCS tornado environment that was developing. This sounding was characterized by a long looping hodograph and balance between MUCAPE and strong deep layer shear (Figure 17). The fast forward motion of the QLCS and presence of the thermal boundary further increased SRH beyond SPC analyzed values, shown via EVAD analysis from the KLOT WSR-88D leading up to the passage of the second derecho (Figure 18). Overall, the synoptic and mesoscale evolution of this event made it uniquely conducive to prolific tornadogenesis. For additional analysis of the role the shallow stable layer and bore propagation played in the prolific tornado production by the second derecho, refer to paper 1B.2.

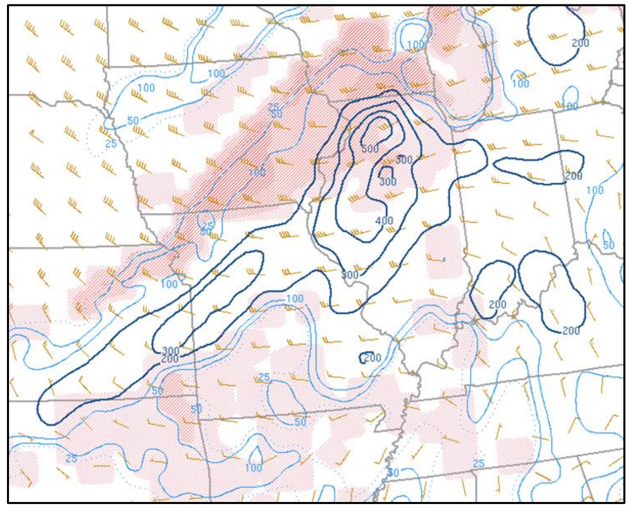

Figure 12. SPC Mesoanalysis of effective SRH ($m^2\ s^{-2}$) and effective inflow base (m AGL, shaded) from 02 UTC 01 July 2014.

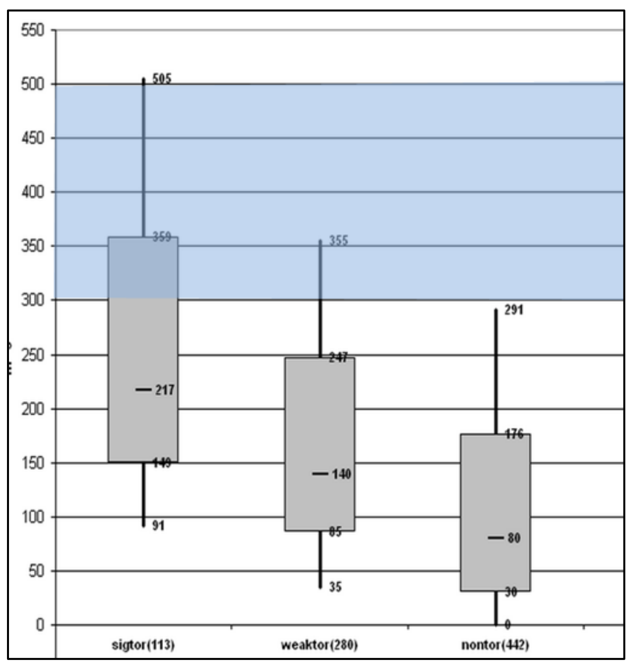

Figure 13. Effective SRH ($m^2\ s^{-2}$) distribution with respect to significant, weak, and non-tornado events (Thompson et al., 2003).

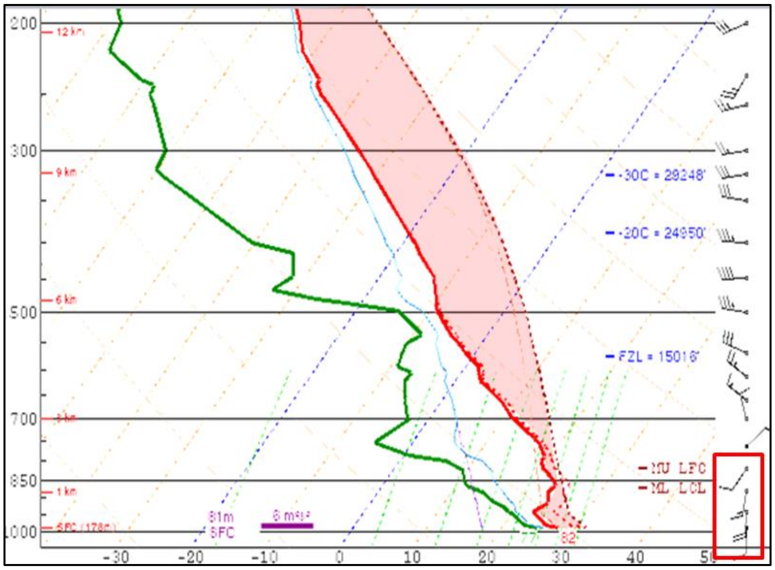

Figure 14. ILX (Central Illinois) sounding plot from 0000 UTC on 1 July 2014.

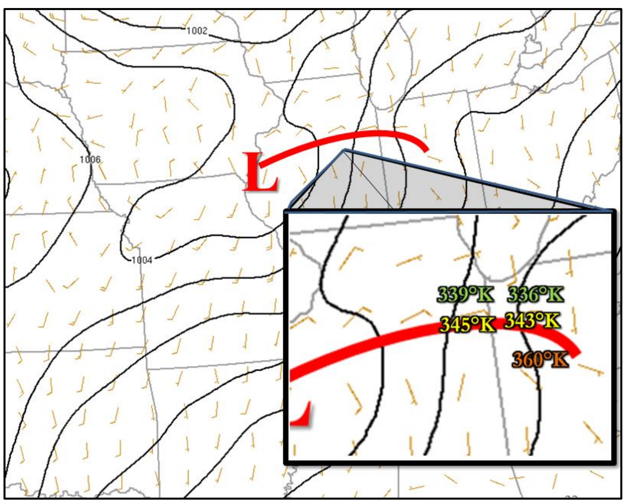

Figure 15. SPC Mesoanalysis of mean sea level pressure and wind in knots, with a zoomed-in inset along the warm front, from 02Z on 01 July 2014.

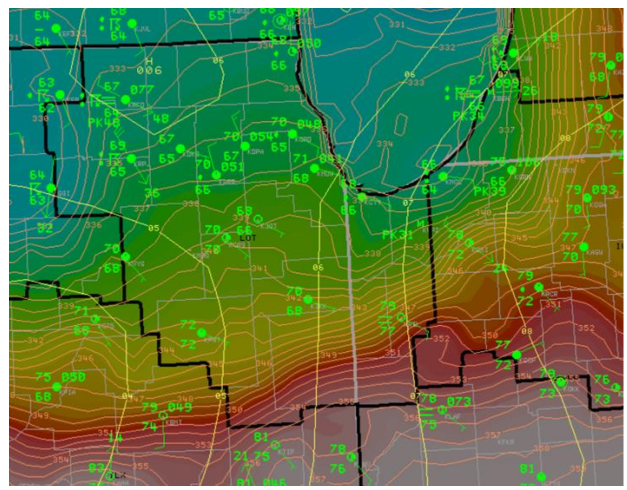

Figure 16. Surface observations and RAP surface analysis of surface theta-e (K) from 0200 UTC 1 July 2014.

6. CONCLUSION

The successive derechos across the Corn Belt and southern Great Lakes on 30 June 2014 generated over 230 severe wind reports and at least 29 tornadoes. This area of the U.S. that was hit hardest by the two derechos has been highlighted by climatological studies of derechos and QLCS tornadoes. However, the rapid succession of these two events was something much more rare.

The synoptic environment supported organized and longer-lived, progressive storms. The nature of the two derechos was different however, in that the second became much more of a tornado producer.

This different evolution was likely contributed to by an effective warm frontal boundary that was enhanced by the outflow of the first derecho. While rain-cooled outflow could be considered a deterrent to immediate robust surface-based convection, the outflow from the first derecho was characterized by limited pressure rises over northern Illinois and northwest Indiana and a sign that the footprint was quite minimal. A strengthening low-level jet and veering with height as shown by soundings and profilers illustrated the tornado threat. Within two to three hours of the first derecho passage, a severe QLCS produced at least 29 tornadoes across northern Illinois and northern Indiana.

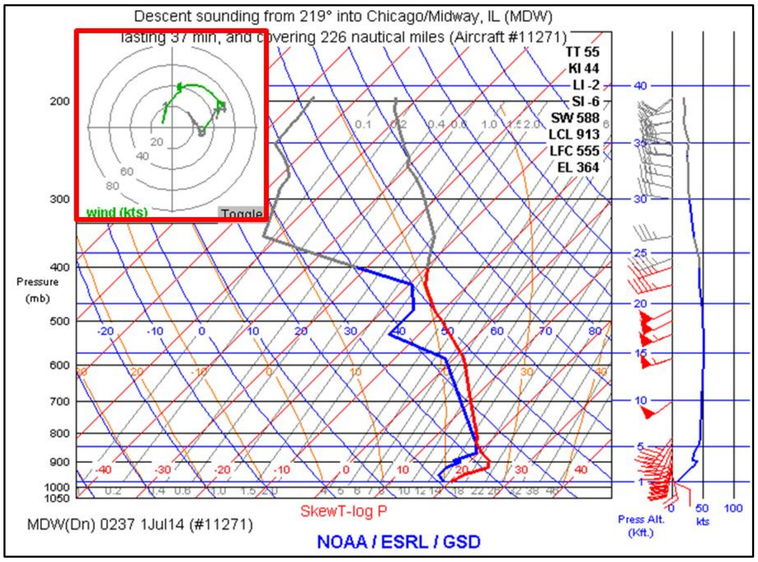

Figure 17. ACARS sounding data from descent into Chicago Midway International Airport at 0237 UTC 01 July 2014.

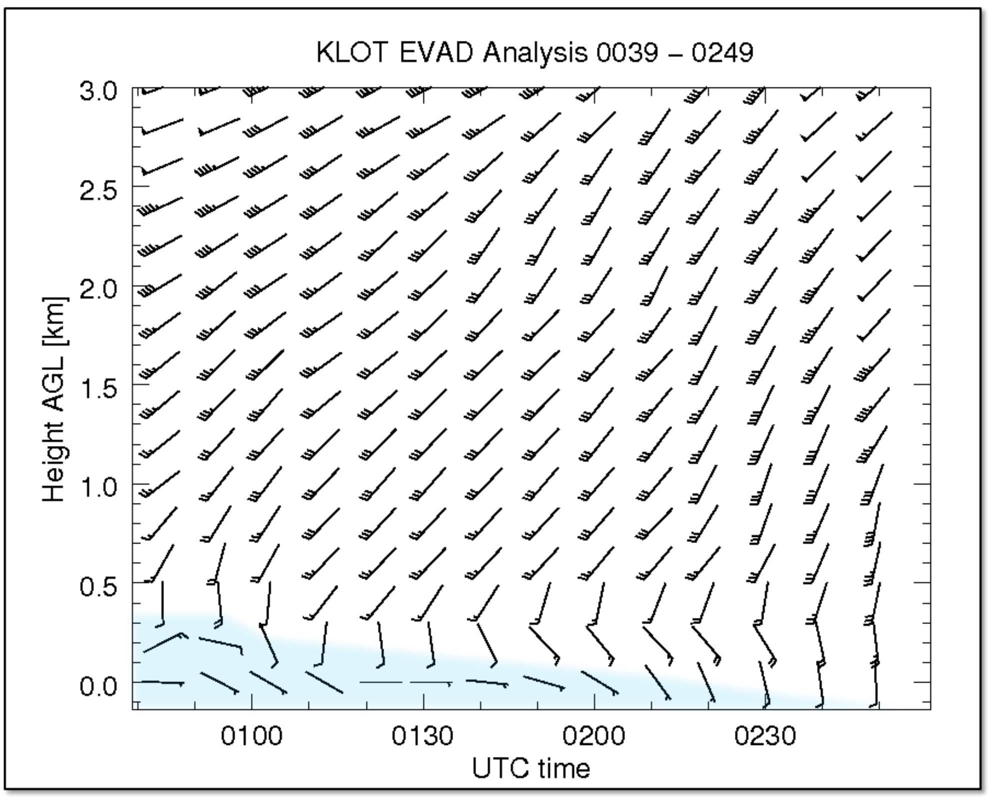

Figure 18. KLOT EVAD analysis prior to the arrival of the second derecho at the radar site.

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