11.3 Radar Characteristics of the 15 July 1995 Northeastern U.S. Derecho

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1. INTRODUCTION

Strong derechos in the northeastern part of the United States are rare. During the early morning of 15 July 1995, a severe derecho accelerated southeast from Ontario Province in Canada, across New York and into western New England at speeds up to 30 m s^{-1} (Fig. 1). In its wake it left eight dead and one of the largest tree blowdowns ever observed in the Adirondack Mountains with an estimated million acres of forest damaged (New York State Department of Environmental Conservation 1996). Archived WSR-88D data was available from Albany, NY (KENX) and Rome, NY (KRMX) radars, positioned in the direct path of the storm. This radar data provided a unique opportunity to examine the synoptic and mesoscale structure and evolution of this storm, including the role of isolated convection that developed in advance of the main derecho.

2. SYNOPTIC DISCUSSION

This derecho closely resembled the progressive (warm season) derecho pattern outlined by Johns and Hirt (1987). An unusually intense upper level ridge covered the center of the United States during mid July 1995. The ridge strengthened (500 hPa height 5960 m) and was centered over Ohio at 0000 UTC 15 July 1995, with a northwest flow downstream of the ridge over the northeastern United States. At 0000 UTC 15 July, several hours prior to the derecho formation, 300 hPa wind speeds of greater than 50 m s^{-1} were observed north of the Great Lakes as a strong jet rotated around the periphery of the upper-level high. The right-rear quadrant of the jet produced upper-level divergence over the northern Great Lakes which induced an area of upward vertical motion. At 500 hPa, a short-wave trough was approaching the western Great Lakes. Temperatures at 850 hPa were as high as 26°C over eastern Michigan, with dewpoints to 18°C. ETA analyses for 0000 UTC showed little or no warm advection at 850 hPa with weak warm advection at 700 hPa over Lake Michigan and Lake Superior. Significant low-level (1000-850 hPa) moisture convergence was present over the Great Lakes. A surface a cold front extended from Wisconsin across the north shores of Lake Huron to northern Maine and sagged slowly south during the night. Moisture pooling allowed surface dew points to reach 27°C as far north as New York. Convection developed north of the front across Wisconsin and Lake Superior, and crossed the front into the warm moist airmass. Surface-based CAPE (obtained from the Storm Prediction Center in Norman, Oklahoma) showed maximum values of 7000 J kg^{-1} west of Lake Erie at 0000 UTC. By 0900 UTC, an axis of 3000-5000 J kg^{-1} CAPE was located ahead of the approaching system from northern New York to northeast Pennsylvania. Vertical wind shear was large. At Sault Ste. Marie (extreme northern Michigan),

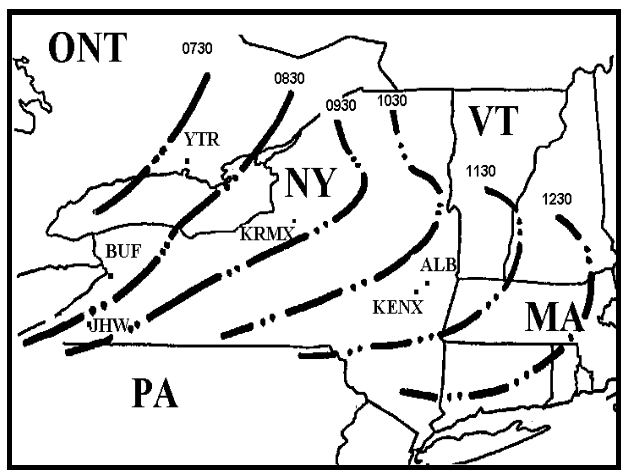

Figure 1. Track of the derecho across the northeast United States on 15 July 1995. Times are in UTC.

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winds increased from less than 2 m s^{-1} from the northwest at the surface to west at almost 30 m s^{-1} at 5 km above ground level. A capping inversion was well established over the northeastern states which prevented significant convection from developing during the afternoon and evening of 14 July and allowed further moisture pooling. A detailed discussion of the synoptic-scale conditions associated with the development and intensification of this derecho can be found in this preprint volume in Bosart et al. (1998).

3. RADAR CHARACTERISTICS

Przybylinski and Decaire (1985) and Przybylinski (1995) examined 23 derecho events and classified them into four types based on variations in echo configuration. The 15 July 1995 northeastern derecho closely resembled a type II classification. Type II derechos begin as a cluster of intense storms and evolve into a short, intense, bulging line 100 to 150 km long. A band of scattered to broken convection extends downwind (east) from the north end of the derecho. There is usually one predominant bow, but smaller bows may exist. A strong low-level reflectivity gradient is found at the leading edge with one or more prominent rear inflow notches (RIN) on the rear side. RINs delineate areas of evaporatively-cooled, lower θ_e air that have been advected toward the front of the derecho and may indicate locations of rear inflow jets. A distinguishing feature of type II derechos is the development of isolated convective elements up to 50 to 80 km ahead of the main derecho. These cells often intensify rapidly and eventually merge with the main derecho (Przybylinski and Decaire 1985 and Przybylinski 1995).

The 15 July derecho was characterized by a long-lived convective line up to 250 km long, which at times exhibited multiple bow structures. Distinct areas of more intense convection were observed along the line. Radar data from KRMX and KENX showed a well-defined northern (cyclonic) bookend vortex (BEV) that maintained rotational velocities (V_r) of 20 to 30 m s^{-1} for several hours, with less distinct southern BEVs present. Damage occurred from the shores of Lake Huron and Georgian Bay across Ontario to New York and New England. Narrow swaths of significant

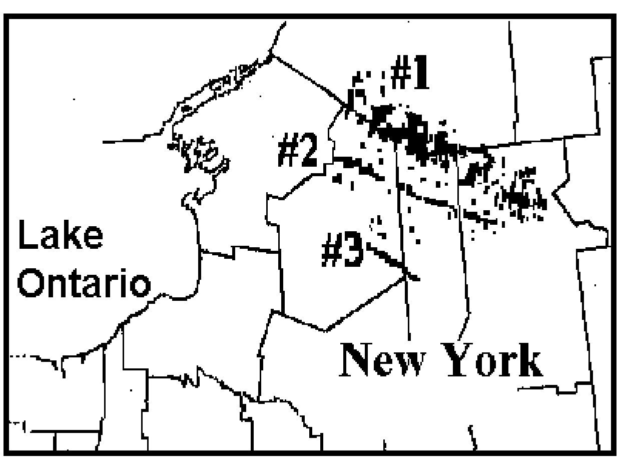

Figure 2. A portion of the damage in the Adirondacks (N.Y. State Department of Environmental Conservation 1996). Shaded areas indicate locations where 30% or more of forest was destroyed.

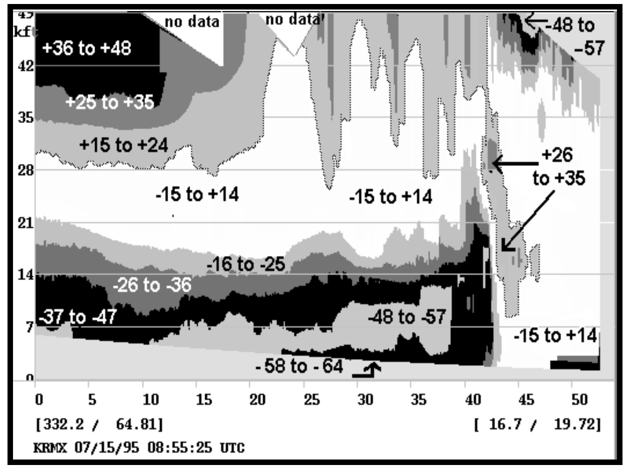

Figure 3. Storm-relative velocity (kt) cross-section from northwest (left) to southeast (right) across the derecho from KRMX (radar located to the right). The X axis is in n mi and the Y axis in thousands of ft above the radar elevation (.5 km MSL). Negative velocities are inbound, positive velocities outbound.

damage were common. While damage was due mostly to straight line winds, there was some evidence of tornadic damage in Ontario Province and along the path of the northern BEV in northern New York. There were three distinct damage swaths in the Adirondacks (Fig. 2); a broad northern swath (#1) and two narrow swaths (#2 and #3). The pronounced northern BEV was associated with the broad damage swath (#1 in Fig. 2) in the Adirondacks.

As the derecho approached KRMX, base velocity data showed a wall of wind at the leading edge of the derecho with inbound (northwest) winds rapidly increasing to greater than 35 m s^{-1}. Strong inbound winds extended through a depth of about 5 km. Fig. 3 is a storm-relative velocity cross section (KRMX) taken on a line northwest to southeast across the storm system at 0854 UTC. From a storm-relative perspective, strong (30 m s^{-1}) rear inflow (northwest to southeast) was evident in the low-levels. The flow reversed above about 7 km above mean sea level (MSL) with front to rear flow. Near the leading edge of the derecho, the depth of the rear inflow deepened to about 10 km MSL as it encountered strong, nearly erect updrafts. Buoyancy gradients between the low-level cool pool air and rearward flowing buoyant air create a meso-low which is the primary contributor to the development of the rear-inflow jet (see Weisman 1990 and Weisman et al. 1990). However, numerical simulations (Weisman 1990) suggest that the flow induced by the BEVs may contribute 30 to 40 percent of the strength of the rear inflow jet.

In addition to the presence of the large BEVs, smaller scale (5 km or less diameter) vortices were observed along the leading edge of the derecho. In base velocity data these appeared as areas of enhanced shear, while in a storm-relative frame of reference small scale circulations were sometimes present. Fig. 4a is a 1.5° elevation storm-relative velocity image for 0906 UTC (KRMX) showing such

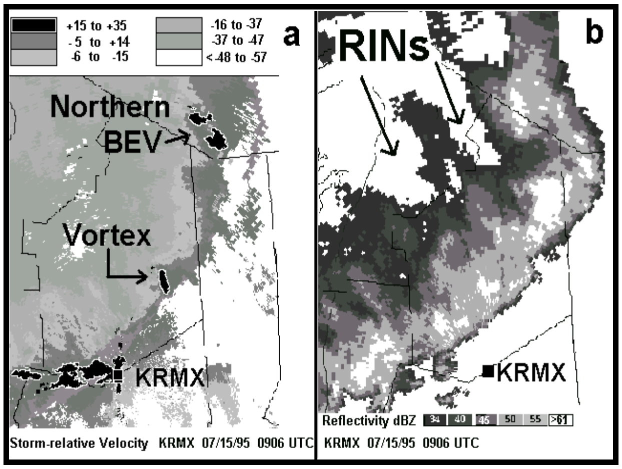

Figure 4. The 1.5° 0906 UTC KRMX (a) storm-relative velocity (kt) and (b) reflectivity. Reflectivity greater than 34 dBZ is displayed. Negative velocities are inbound, positive velocities are outbound.

a vortex. V_r in this couplet was nearly 20 m s^{-1}. This area of enhanced shear persisted for over an hour and was associated with damage swath #3 in Fig. 2. Przybylinski (1995) documented similar areas of intense shear at the leading edge of derechos, and found them to be associated with transient tornadoes. A ground survey of a portion of damage swath #3 indicated only straight line wind damage.

Several pronounced RINs on the trailing side of the system were observed in the reflectivity data (Fig. 4b). Diameters were as large as 25 km. RINs combined with strong reflectivity gradients along the leading edge of the system indicate areas where downburst winds are strongest (Przybylinski 1995).

Type II derechos are characterized by a scattered to broken band of convection extending downwind from the northern end of the system. In this case, scattered convection off the north end of the system persisted downwind (east to southeast) from about 0730 to 0900 UTC. Smith (1990) and Przybylinski (1995) indicated that this convection was associated with a surface front or zone of strong low-level warm advection. NCEP numerical model forecasts for 1000, 850 and 700 hPa at 0600 and 1200 UTC showed little or no warm advection. A cold front sagging south through the Great Lakes region and Ontario Province reached northern Lake Ontario and near the Canadian border of New York by 0900 UTC. The orientation of this front, east-northeast to west-southwest, was nearly perpendicular to the orientation of the convection off the northern end of the derecho, suggesting it was not likely a major causative factor. The counter-clockwise circulation associated with the northern BEV may have created a localized zone of warm advection to its east and southeast, helping to initiate convection off the northern end of the derecho (Smith 1990).

In addition to the band of scattered convection off the northern end of the derecho, isolated convection developed further south, in advance of the main line of storms. This is typical of type II derechos. Terrain features may have played a role in the development of some these advanced cells. The advanced cells developed at varying distances (up to 50 km) ahead of the main line of storms. Weak (<18 dBZ) low-level reflectivities were precursors to advanced cell development. Advance cells then developed a strong reflectivity core aloft (about 6 km) and intensified rapidly. The convection eventually merged with the main line of storms. As some advance cells neared merger they became significantly more intense than the upstream portion of the derecho, and during cell merger the main portion of the derecho intensified. In some cases RINs developed shortly after mergers.

An excellent example of advance cell development occurred near the north shore of Lake Ontario just prior to 0800 UTC. At 0744 UTC the 0.5° KMRX reflectivity imagery indicated a 15 km wide band of widely scattered very weak reflectivities (<10 dBZ) from about Trenton (YTR), Ontario (Fig. 1), southeastward over Lake Ontario. The band was oriented perpendicular to the main derecho. There were reflectivities as high as 30 dBZ at about 7 km MSL. Frictional differences between the lake surface to the south, and land to the north would favor some convergence along the north shore of the lake. Given the air temperature over land was a little warmer than lake water, there also may have been some tendency for a weak lake breeze flow. A peninsula (oriented west-northwest to east-southeast) extends into the northeast portion of Lake Ontario further complicating the area's topography. At 0750 UTC 0.5° reflectivity data indicated a single small 35 dBZ cell a little north of Picton, Ontario (35 km east-southeast of YTR). Reflectivity increased to 55 dBZ at 7-8 km MSL indicating a strong updraft had developed. The portion of the derecho immediately upwind of the developing advance cell was relatively weak compared to other portions of the system. By 0755 UTC two cells were present along the north shore of the lake between about Picton and Amherst Island (60 km east of YTR). These cells grew larger by 0801 UTC with the southwestern most cell showing a strong reflectivity gradient on the northwest side.

Upwind of the advance cells, the relative weakness in the derecho persisted as the newly developed cells may have disrupted inflow into the line of storms. By 0807 UTC, the advance cells were merging with the derecho along the north shore of Lake Ontario forming a donut type structure with a core of weak reflectivity nearly surrounded by higher reflectivities. At this time the 0.5° velocity data showed a break in a large area of 32+ m s^{-1} winds near the cell location. The 1.5° velocity data showed an apparent small intense couplet near the center of the donut cell with maximum velocities of 46 m s^{-1} inbound and 26 m s^{-1} outbound. Velocity data adjacent to the couplet indicated the radar was having difficulty diagnosing the velocity field and casts doubt on the validity of this intense velocity couplet. By 0813 UTC the merger was complete and the break in the 32+ m s^{-1} inbound winds had filled. The velocity couplet initially observed at 0808 UTC could be tracked in subsequent velocity images as a region of enhanced shear (see previous discussion) on the leading edge of the derecho and was associated with damage swath #3 (Fig. 2). In this case the RIN seemed to develop as the merger occurred and became very pronounced after the merger.

Another isolated cell developed in advance of the derecho over the southeast portion of Lake Ontario. At 0813 UTC there was little evidence of any significant convection over the southeast portion of the lake. From 0755 UTC through 0813 UTC there was a persistent area of shallow, weak (<15 dBZ) returns. Explosive development occurred by 0819 UTC about 40 km ahead of the main derecho with echo tops exceeding 14 km. By 0832 UTC the advanced cell was approaching the southeast lake shore with a strong reflectivity gradient on its northwest side (Fig. 5). The upstream portion of the derecho remained weaker with significantly lower tops. By 0854 UTC the lead cell was nearing merger and had grown very large (diameter about 20 km) with reflectivity greater than 65 dBZ. The upstream portion of the derecho had weakened with a significant decrease in echo tops. By 0900 UTC the cell was merging with the main line of storms.

The first indication of the formation of advance cells was often an area of scattered weak returns (<18 dBZ). These echoes may have delineated areas of low-level convergence or enhanced instability where cumulus or cumulus congestus were developing. Several areas were especially favored for the development of weak echoes. Speed convergence was likely along the east shore of Lake Ontario as the northwest low-level flow moved onshore and was slowed by frictional effects of the land. Time lapse loops (1.5° elevation) suggest this process does in fact contribute to the initial convective growth as the weak returns remained quasi-stationary along the east end of the Lake. Where the air was forced up the Tug Hill Plateau (east of Lake Ontario) a cluster of cells formed which was eventually absorbed into the main system. Another area of isolated cell formation occurred over the southeast portion of Lake Ontario. Finally, as the northwest flow encountered the higher terrain southeast of Lake Ontario, terrain forced lifting may have contributed to the development of weak returns and subsequently a large number of thunderstorm cells (0845-0915 UTC). These cells were absorbed by the derecho by 1000 UTC. There was little or no advance cell development after about 1000 UTC.

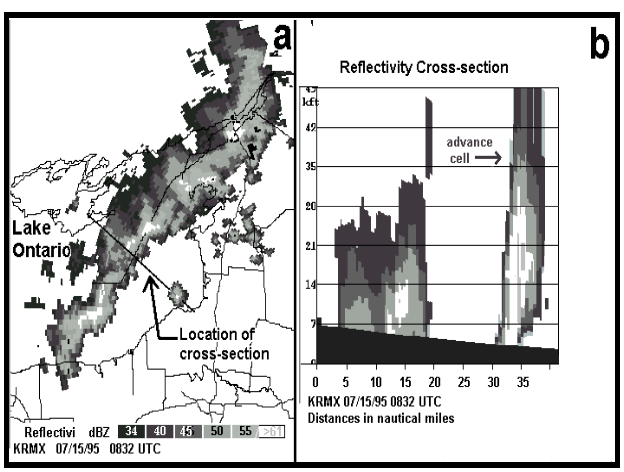

Figure 5. The 0832 UTC (a) reflectivity and (b) reflectivity cross-section from KRMX. Reflectivity of 34 dBZ or greater shown.

There was a southwestward development of the main derecho between 0745 and 0900 UTC between Buffalo and Jamestown, NY. The orientation of this development suggests it was related to lake breeze induced convergence off Lakes Erie and Ontario. Typically at night, a land breeze would prevail. However, with pre-dawn temperatures near 27 °C, Lake Ontario waters were likely a bit cooler than the land.

4. SUMMARY

Archived radar data provided a unique opportunity to examine the synoptic and mesoscale structure and evolution of the 15 July 1995 northeast United States derecho. The derecho was characterized by a long-lived bowing convective line, which at times exhibited multiple bow structures and bookend vortices. Also documented were pronounced RINs, shear zones and vortices on the leading edge of the derecho, and convective development in advance of the main line of convection. Terrain forcing may have played a role in the development of some advance cells.

5. ACKNOWLEDGMENT

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