THE MID SOUTH DERECHO - 22 JULY 2003

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1. INTRODUCTION

On 22 July 2003, one of the most costly derechos ever struck the Mid South. Thunderstorms developed over Southwest Missouri around 0600 UTC and evolved into a bow echo over Northern Arkansas with wind gusts greater than 25 m s^{-1}. Maximum intensity was attained upon reaching very unstable air over the Mississippi Delta. The bow echo then moved across the Memphis Metropolitan area around 1200 UTC with wind gusts greater than 40 m s^{-1}. The highest wind report was 46 m s^{-1} in downtown Memphis. The system then moved rapidly along the Tennessee and Mississippi border into Northern Alabama by 1500 UTC, producing wind gusts from 25-35 m s^{-1} (Fig. 1).

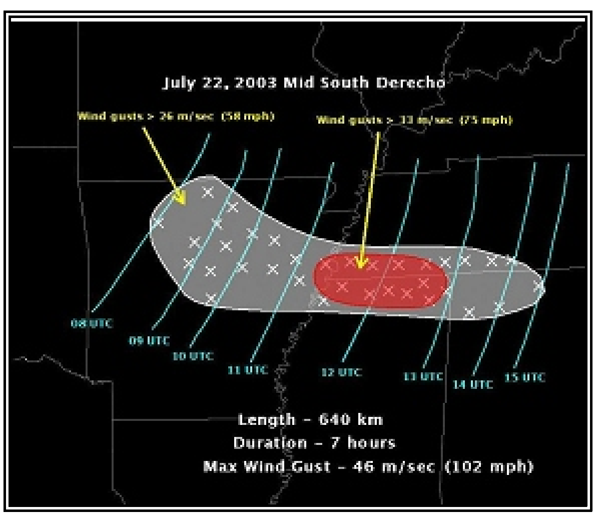

FIG 1. 22 July 2003 event overview. Hatched area - wind gusts > 26 m s^{-1}. Counties (X) reporting wind damage.

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This derecho produced more than 500 million dollars in damage, mostly across the Memphis Metropolitan area. There was one direct fatality and six indirect fatalities. During the hours following the event more than 750,000 people in the Memphis area were without electrical power. Transportation systems were paralyzed with more than 75 percent of traffic signals not working and the world's largest cargo airport closed. One week later 100,000 people were still without power. The widespread effect on human activity ranks this storm as probably the most significant straight line wind event in Mid South history.

2. BACKGROUND

In 1888, Gustavus Hinrichs used the word derecho to describe convectively induced straight line wind damage. Johns and Hirt (1987) revived the use of the term almost a century later while examining the conditions associated with warm season cases. Using radar information Johns and Hirt (1987) observed that two general patterns of derechos occur during the warm season. The *serial* pattern usually involves an extensive squall line while the more common *progressive* pattern is usually identified as a short curved squall line oriented nearly perpendicular to the mean wind. The following criteria were used by Johns and Hirt (1987) to identify derecho events:

(a) There must be a concentrated area of reports consisting of convectively induced wind damage and/or convective gusts > 26 m s^{-1}. This area must have a major axis length of at least 400 km.

(b) The reports within this area must also exhibit a nonrandom pattern of occurrence. That is, the reports must show a pattern of chronological progression, either as a singular swath (progressive) or as a series of swaths (serial).

(c) Within the area there must be at least three reports, separated by 64 km or more, of either F1 damage on the Fujita scale and/or convective gusts of 33 m s^{-1} or greater.

(d) No more than 3 h can elapse between successive wind damage events.

The 22 July 2003 Mid South derecho was a progressive, warm season event and met all the above criteria.

3. PRE-STORM ENVIRONMENT

a. Surface Conditions

The regional surface analysis during the early morning hours of 22 July 2003 indicated a weak stationary surface front from central Arkansas through west Tennessee and into southern Kentucky (Fig. 2). A meso high was apparent across northwest Arkansas, a result of the cold pool generated by ongoing thunderstorms. Moisture was pooling south of the front where surface dewpoints were in the mid 70s. The LAPS (Local Analysis and Prediction System) analysis at 0900 UTC revealed a very unstable airmass with surface-based CAPES of 3400 J kg^{-1} and lifted indices of -8°C over the Mississippi Delta including the Memphis Metropolitan area. Surface patterns from this event are similar to conditions associated with long-track progressive derechos studied by Johns et al. (1990).

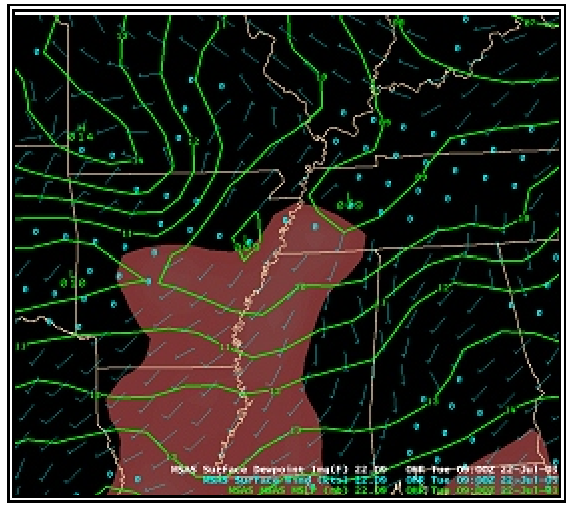

FIG 2. Surface isobars (mb) (green), wind barbs (kts) (blue) and surface dewpoints exceeding 75°F (shaded red) at 09 UTC, 22 July 2003.

b. Upper Air Conditions

An upstream trough at 500 and 250 mb, extended from the Great Lakes into Missouri at 1200 UTC while a weak ridge axis extended from Texas into northern Mississippi. A 60 m s^{-1} 250 mb jet maximum was digging across South Dakota and Nebraska while another 60 m s^{-1} jet was lifting over Ohio Valley. The Mid South was in the right entrance region of the Ohio Valley jet maximum; in an area of strong diffluence and divergence. Upper level winds were relatively weak along the derecho track - generally less than 15 m s^{-1} at all levels. Winds aloft were generally west to northwest - parallel to the derecho track.

The pooling of low level moisture was also apparent at 850 mb. Dewpoints were greater than 16°C along the approximate east-west location of the surface front. Above the moist low layer, drier air was apparent in the mid levels. Dewpoints depressions were 10°C or greater at 700 and 500 mb along the derecho track. Upper air patterns are also similar to findings in Johns et al. (1990).

c. Soundings and Vertical Cross Sections

The 0000 UTC, 22 July 2003 Little Rock, Arkansas (LZK) sounding points toward a very unstable airmass. Surface based CAPES were 6584 J kg^{-1} while the lifted index was -13°C. 850 to 500 mb lapse rates were very steep for late July at 7.6°C km^{-1}. Mid level dry air was apparent between 600 mb and 400 mb.

Perhaps the most impressive data obtained from this sounding was the DCAPE value of 1992 J kg^{-1}. DCAPE can be considered as an estimate of the potential cold pool strength before thunderstorm development (Evans and Doswell 2001). Evans and Doswell (2001) conducted an examination of derecho environments using proximity soundings. Of the 51 soundings associated with weakly forced events the highest DCAPE value found was 1758 J kg^{-1}. The 0000 UTC LZK sounding does not meet the proximity definition set forth by Evans and Doswell (2001) but it does illustrate the unique nature of the airmass.

A vertical cross section was created from southern Missouri through Memphis into northeast Mississippi. The cross section was generated from the 3-hour forecast from the 0600 UTC, 22 July 2003 ETA model valid at 0900 UTC. This is about 3 hours before the derecho moved through the Memphis area. The cross sections reveal high θ_e air in the low levels overlaid with low θ_e in the mid levels. The θ_e difference between the surface and the minimum value aloft was 31 K. Atkins and Wakimoto (1991) found values greater than 20 K on days when microbursts were common.

4. EVOLUTION AND RADAR ANALYSIS

State-scale reflectivity imagery during the event suggests that the derecho was produced by a large bow echo that cycled through various levels of intensity. However, a closer look at storm-scale radar data reveals a more complicated picture involving supercells collapsing into a severe bow echo.

Thunderstorms developed across Southwest Missouri before 0600 UTC. These thunderstorms produced a large cold pool that continued to generate thunderstorms as it pushed southeast into northern Arkansas. At 0900 UTC radar reflectivity imagery from the KNQA WSR-88D indicated a bow echo moving across northern Arkansas. Scattered tree damage was reported with this feature. At 1100 UTC the bow echo weakened just before reaching the Mississippi Delta west of Memphis. At this time the Mississippi Delta was bisected by a weak east-west surface front. Very moist and unstable air was pooling along and to the south of the front. Thunderstorms then intensified rapidly as they interacted with this front and tapped the very unstable air. Johns et al. (1990) found that the most damaging winds usually occur as the system encounters the most unstable air along their path.

Volumetric radar imagery at 1117 UTC indicates 3 discreet supercells to the west of the city of Memphis (Fig 3). The 2 most northern supercells had evidence of low-level reflectivity pendants and bounded weak echo regions while the southernmost storm was the most intense. The southernmost storm had a strong low level mesocyclone along with a bounded weak echo region and a distinct rear flank downdraft.

Also at 1117 UTC a mesoscale rear inflow jet is observed as a notch in the low level reflectivity in the stratiform precipitation region (Smull and Houze 1985). It is also apparent in the base velocity imagery as an inbound maximum of 25-32 m s^{-1}. Smull and Houze (1987) also postulated that the rear inflow jet may penetrate well into the storm - perhaps even as far as the leading gust front. The 1117 UTC velocity data seems to support this possibility.

At 1132 UTC reflectivity indicated that the two southern supercells merged just west of Memphis. Low-level reflectivity data shows intersecting rear flank downdrafts. At this time extreme damaging winds (Miller and Johns 2000) were occurring just southwest of downtown Memphis. 8 bit low-level velocity data indicates inbound velocities of 26 ms^{-1} over this area. However, the velocities were probably higher since winds were at a component tangent to the radar beam.

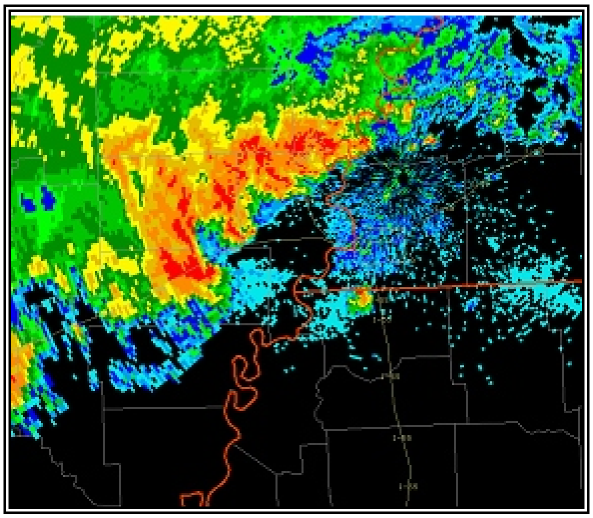

FIG 3. 0.5 degree base reflectivity image from the KNQA WSR-88D at 1117 UTC, 22 July 2003.

At 1152 UTC, as the supercell was collapsing, the rear flank downdraft accelerates eastward as a bow echo (Fig 4). A rear inflow notch (RIN) is depicted in the low level reflectivity at 1152 UTC. RINs combined with a strong low-level reflectivity gradient along the leading edge often signals the location where damaging winds are occurring (Przybylinski 1995). Extreme damaging winds occurred along the path of the bow echo from downtown Memphis starting at 1145 UTC into the eastern suburbs by 1215 UTC. Maximum winds gusts exceeded 45 m s^{-1} in this corridor. Another unusual occurrence with this event was the duration of the strong winds at a particular point, generally 10 to 15 minutes. This is similar to findings by Miller and Johns (2000) and Miller et al. (2002) and their work regarding extreme damaging wind events and supercells.

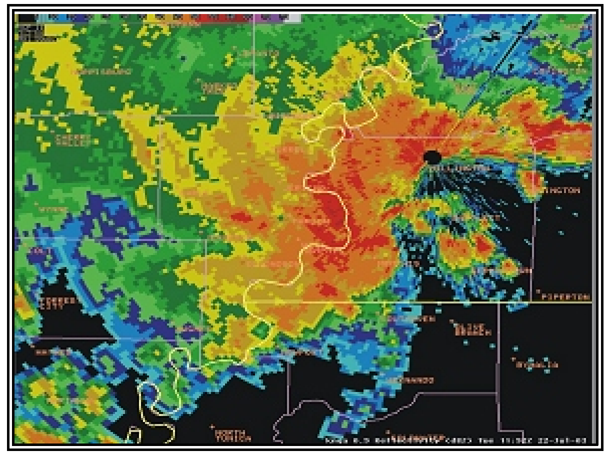

FIG 4. 0.5 degree base reflectivity image from the KNQA WSR-88D at 1152 UTC, 22 July 2003.

Due to the direction of movement and the proximity of the KNQA 88D radar, velocity data was obscured as the system moved across the city of Memphis. Using an assumed wind direction, a quick cosine calculation yields winds at 240 m agl of over 50 m s^{-1} over east Memphis at 1157 UTC. By 1226 UTC the bow echo had moved far enough to the east so that low level velocities were once again revealed. The 8 bit data indicated 48 m s^{-1} outbound velocities at 450 m just to the east of Memphis.

Like Miller and Johns (2000) found in their cases, extremely tight gradients of extreme damage were noted during storm surveys in the main damage corridor over the city of Memphis. Some streets suffered F2 damage on the Fujita scale while locations 2 blocks away had comparatively little damage.

The derecho producing bow echo weakened after 1230 UTC causing scattered damage as it raced along the Mississippi and Tennessee borders and into northern Alabama. The bow echo did briefly intensify after 1300 UTC to produce significant damage near Corinth, MS.

5. SUMMARY

The derecho that struck the Mid South on the morning of 22 July 2003 produced a tremendous amount of damage. Extreme damaging winds of over 45 m s^{-1} were associated with merging supercells that collapsed and formed a bow echo that raced across the city of Memphis. As noted by Miller and Johns (2000) these events differ from more typical bow echoes because of their long duration at a particular point. Also these events tend to have extremely tight damage gradients.

One difference noted from the Miller and Johns (2000) and the Miller et al. (2002) is the possible importance of the mesoscale rear inflow jet in this particular case. It is unknown just how important this feature is. It is likely that a combination of storm scale and mesoscale features created this extreme event.

These rapidly evolving events offer huge challenges to the forecasting community. Forecasters need to be aware that discrete supercells present in a mesoscale convective system may be capable of producing long duration extreme damaging straight-line winds. Furthermore, wind events close to the radar provide even more challenges due to the loss of velocity data. Hopefully, tools can be created with the WSR-88D that will help warning decision makers rapidly apply cosine calculations to help estimate wind speeds in close to proximity to the radar.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Atkins, N. T., and R. M. Wakimoto, 1991: Wet microburst activity over the southeastern U.S.: Implications for forecasting. *Wea. Forecasting*, **6**, 470-482.

Evans, J. S. and C. A. Doswell, 2001: Examination of derecho environments using proximity soundings. *Wea. Forecasting*, **16**, 329-342.

Johns, R. H. and W. D. Hirt, 1987: Derechos: widespread convectively induced windstorms. *Wea. Forecasting*., **2**, 32-49.

------, K. W. Howard and R. A. Maddox, 1990: Conditions associated with long-lived derechos - An examination of the large-scale environment. Preprints, *16th Conf. On Severe Local Storms*, Kananaskis Park, AB, Canada, Amer. Metero. Soc., 408-412.

Miller, D. J., and R. H. Johns, 2000: A detailed look at extreme wind damage in derecho events. Preprints, *20th Conf. on Severe Local Storms*, Orlando, FL, Amer. Meteor. Soc., 52-55.

------, Andra, D. L., Evans, J. S., and R. H. Johns, 2002: Observations of the 27 May 2001 high-end derecho event in Oklahoma. Preprints, *21st Conf. on Severe Local Storms*, San Antonio, TX, Amer. Meteor. Soc., 13-16.

Przybylinski, R. W., 1995: The bow echo: Observations, numerical simulations, and severe weather detection methods. *Wea. Forecasting*, **10**, 203-218.

Smull, B. F. and R. A. Houze, Jr., 1985: A midlatitude squall line with a trailing region of stratiform rain: Radar and satellite observations. *Mon Wea. Rev*., **113**, 117-133.

------, and ------, 1987: Rear inflow in squall lines with trailing stratiform precipitation. *Mon. Wea. Rev*., **115**, 2869-2889.