JP1.10 A DETAILED ANALYSIS OF THE NOCTURNAL QLCS TORNADOES THAT MOVED THROUGH OMAHA, NEBRASKA, ON 8 JUNE 2008

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1. INTRODUCTION

Nocturnal tornadoes in the National Weather Service (NWS) Weather Forecast Office (WFO) Omaha/Valley County Warning Area (CWA) are relatively rare, with only 6% of tornadoes since 1950 occurring between midnight and 11:00 AM local time (per local study). Given a favorable meteorological environment, however, nocturnal tornadoes can and do occur. During the early morning hours of 8 June 2008, two tornadoes (rated EF1 and EF2) cut through the southwest part of Omaha, Nebraska. These tornadoes were produced within a quasi-linear convective system (QLCS). In this case, the tornadoes formed within a QLCS that weakened for some time before re-intensifying briefly near the Omaha metropolitan area. The event was one in a series of significant severe weather events to impact the Omaha metro area directly during the late spring and early summer of 2008.

This study will investigate the synoptic environment that supported convective development and maintenance, as well as the mesoscale parameters that supported the brief re-intensification of the QLCS. In addition, the study will present a detailed overview of the radar presentation of the storm as well as a comparison between radar data and damage survey data. Finally, the impact of this event will be discussed as one in a series of significant severe weather events to impact the Omaha metropolitan area.

2. DATA AND METHODOLOGY

The synoptic and mesoscale environment on 8 June 2008 were analyzed utilizing archived observational and model data. In this review, the 0700 UTC 8 June RUC II (40 km horizontal resolution) analysis was used to examine the mesoscale environment, with observed 00 UTC 8 June soundings and a suite of 06 UTC 8 June model analysis fields. Data were plotted utilizing the General Meteorological Package (GEMPAK) software (DesJardines et al., 1991). Archived KOAX WSR-88D radar data, with visualizations in both an AWIPS environment and using GRLevel2 software, was utilized to investigate storm evolution in detail. The tornadoes occurred about 18-22 km (10-12 nmi) from KOAX, which was utilizing the newly available super-resolution data, providing detailed fine-scale resolution of the event.

An extensive damage survey was conducted over three days following the event using GPS precision and GIS mapping. The technology provided high-resolution ground truth of the damage points caused by the tornadoes. The damage survey data points were then spatially correlated with the radar data, which allowed for a fine scale examination of the precise location of the tornadoes in relation to the QLCS. The radar presentation and damage track, in correlation with indicators such as the radial velocity shear as a function of height and time, were used to examine the evolution of the tornadoes and their parent mesovortices.

3. STORM OVERVIEW AND IMPACTS

Convection developed in the evening hours on 7 June 2008 in central Nebraska, moving into eastern Nebraska and weakening during the evening hours, with a few reports of hail around 0.75 to 0.88 inches. Later in the evening, a thunderstorm segment intensified in Butler and Seward counties in east central Nebraska around 0600 UTC, producing the largest hail report in the area that evening (1.75 inches in Seward, Nebraska at 0621 UTC), with no reports of severe weather after that time until the QLCS reached the Omaha metro area. The segment evolved into a QLCS as it moved through eastern Nebraska, and as it neared Omaha, developed a mesovortex. The first tornado touched down at 0710 UTC in the Millard neighborhood in southwest Omaha, and the second lifted by around 0730 UTC. The QLCS produced no further severe weather downstream beyond western Omaha.

3.1 Synoptic and Mesoscale Environment

At 0000 UTC 8 June, the central Plains were entrenched in southwesterly upper-level flow, with an upper-level jet segment extending from the Rockies toward North Dakota (Fig. 1a). A 500 hPa low was centered in southwestern Manitoba (Fig. 1b), with the trough axis extending southwestward toward Montana

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and Idaho. An 850 hPa low was centered in southeastern Colorado, with a stationary front extending east-northeastward through south central Nebraska toward east central Nebraska, then toward the western tip of Lake Superior (Fig. 1c). A strong 15-20 m s^{-1} (30-40 kt) low-level jet was impinging on the boundary. At the surface, a low also was centered in southeastern Colorado, with a stationary front extending east-northeastward toward western Lake Superior (Fig. 1d). The surface and mid-level moisture axis was concentrated along and just south of the surface front, with moisture pooling in east central and southeast Nebraska.

Climatologically, locations in the central Plains typically experience decoupling at night during the summer months, with a temperature inversion and weakening surface winds as the low-level jet increases. Thus, while elevated convection is often noted at night, surface-based convection is relatively rare. In the late evening to early morning hours of 7-8 June, in a very localized band in east central Nebraska, the atmosphere remained uncapped, with zero convective inhibition (CIN; Fig. 2a). Mixed-layer convective available potential energy (MLCAPE) around 1000-1500 J kg^{-1} was noted in that small area, as well (Fig. 2a). Thus, the atmosphere very near the Omaha metro was unstable to surface-based convection, and as convection moved in from central Nebraska, it was briefly able to become surface-based.

Along the length of the surface boundary, including the same small area of east central Nebraska, an enhanced area of 0-1 km storm relative helicity (SRH) was noted, with values as high as 300 m^2 s^{-2} in the uncapped area of east central Nebraska (Fig. 2c). Surface to 6 km bulk shear values of around 30 m s^{-1} in east central Nebraska also supported organized convection (Fig. 2b). Surface vorticity, often an indicator of non-supercell tornadic potential, was also enhanced along the boundary, at 15-20 10^{-5} s^{-1} in east central Nebraska (Fig. 2d). With the orientation of around 30 m s^{-1} (around 60 kt) 0-6 km shear vectors nearly parallel to the surface boundary (Fig. 2c), convection did tend to organize toward a linear mode, with individual cells and multicells organizing into linear segments, including the Omaha area QLCS, as the convection progressed.

Based on mesoscale analysis at 0700 UTC 8 June, the window of opportunity for elevated convection to become surface-based, in a location with enough low-level shear and vorticity to allow rapid tornadogenesis, was limited to a very small area in east central Nebraska. In this case, that window of opportunity was indeed realized in the brief but rapid development of two tornadoes directly within that bullseye of mesoscale support.

3.2 Storm Evolution and Radar Interpretation

The radar evolution of the QLCS is presented in Fig. 3, with 0.5 degree reflectivity and storm-relative velocity data from 0711 UTC to 0729 UTC. The QLCS displayed two evident mesovortices, C1 (north) and C2 (south), the tracks of which are subjectively analyzed on Fig. 3. The distinct mesovortices were evident between 0711-0720 UTC, though a tornadic couplet is lacking prior to 0715 UTC. At 0725-0729 UTC, only one mesovortex (C1) is apparent. During much of the lifecycle of C2, there were tornadoes on the ground associated with both C1 and C2. Both circulations were shallow, remained along the leading edge of convection, and were associated with inflow notches along the forward flank of the system.

Figure 4 represents the time-height cross-section of rotational velocity magnitudes for C1 (shaded) and C2 (contoured) between 0619 and 0734 UTC. C1 was first detected at 0619 UTC. From 0619 until 0638 UTC, C1 remained shallow and relatively weak. After 0638 UTC, C1 increased in strength but remained shallow. At 0701 UTC, C2 was detected along the leading edge of the QLCS and south of C1. Over the next several volume scans, just prior to tornadogenesis, both C1 and C2 rapidly intensified at low-levels. This rapid intensification just prior to tornadogenesis has been observed in other tornadic QLCS cases (Martinelli et al., 2007 and 2008).

Trapp et al. (1999) characterized tornadic vortices as descending or non-descending based on their morphologies prior to tornado occurrence. Descending vortices were observed to originate in mid-levels and extend downward toward the surface prior to tornado occurrence, while non-descending vortices tended to be detected initially near the surface and extend upward prior to tornado occurrence. In their relatively small dataset (n=6), they found that QLCS non-descending tornadic vortices typically exhibited their maximum pre-tornadic ΔV (28.2 m s^{-1}) approximately 1 km above ground level and were detected, on average, only one volume scan prior to tornado occurrence. These characteristics accurately describe the attributes of C2. However, it is interesting to note that although C1 exhibits many of the characteristics that typify a non-descending tornadic vortex, C1 was first evident in the radar data at 0619 UTC, approximately 60 minutes prior to tornado occurrence. The authors hypothesize that the environment encountered after 0701 UTC was significantly more favorable for a tornado beneath a parent mesovortices. Given their often small diameters, shallow depth, and rapid morphology, mesovortices within a QLCS that spawn tornadoes are typically associated with a decreased lead time.

3.3 Damage Survey and Storm Impacts

Post-event damage surveys were conducted by eight different NWS personnel over three days, with the duration due to the extensive city area to cover as well as new reports of damage filtering into the NWS office. Based on the surveys, the tornado associated with C1 (the more persistent circulation) was given an EF2 rating, while C2 was associated with an EF1 tornado. A map of the tornado tracks is presented in Fig. 5. The tornadoes caused roof, siding, and window damage to several houses and businesses, as well as significant tree damage. In the hardest hit areas of Millard, in southwest Omaha, some homes also exhibited exterior wall damage. Fig. 6 shows a few snapshots of the damage.

Several indirect impacts of the tornadoes were noted in an around Omaha. The 8 June tornadoes contributed to changes in the policy for sounding the sirens in Douglas County, Nebraska, in which Omaha resides. In addition to sounding sirens based on a tornado warning, emergency management personnel can now sound the sirens based on credible reports of a tornado or tornado damage, or for the threat of winds exceeding "hurricane force." The change process began shortly after the 8 June tornadoes, in time to allow its practice on 27 June, when a non-tornadic convective wind event moved across the Omaha metropolitan area (Smith and Mayes, 2009).

Area stores noted an increase in the sale of NOAA Weather Radios, and anecdotally, residents of Omaha discussed heightened awareness to weather conditions and a higher likelihood to heed warnings and sirens. The heightened awareness of severe weather and sensitivity to warnings was exacerbated by both the 11 June tornado event that included a fatal tornado affecting the Little Sioux Scout Ranch and the 27 June wind event that caused two fatalities as well as significant property damage in and around the Omaha metropolitan area.

4. SUMMARY

A QLCS traversed the NWS Omaha/Valley CWA in the early morning on 8 June 2008, spawning two tornadoes in the Omaha metropolitan area. Two mesovortices were initially detected at low-levels along the leading edge of the QLCS and maintained their strongest rotations persistently below 3 km AGL. Just prior to tornadogenesis, both circulations rapidly intensified and deepened. It is likely that a narrow corridor of surface-based instability and enhanced SRH, as well as a corridor of enhanced surface vorticity, ahead of the QLCS played a key factor in the tornadogenesis process.

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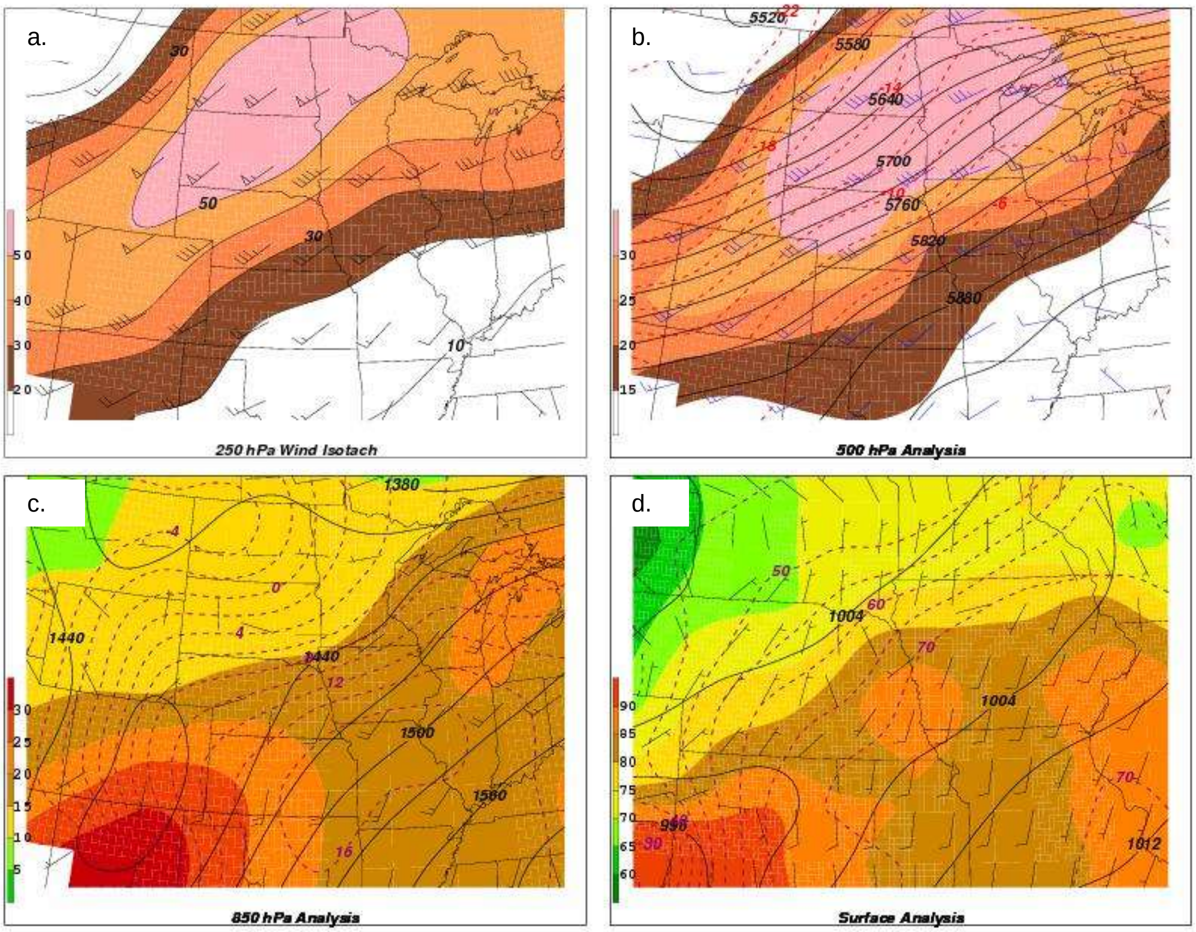

Figure 1. 0000 UTC 8 June observational data, interpolated using a Barnes scheme within GEMPAK: (a) 250 hPa winds ($m\ s^{-1}$, barbs) and isotachs ($m\ s^{-1}$, shaded); (b) 500 hPa geopotential height (m, solid contours), winds (barbs), isotachs (shaded), and temperature (°C, red dashed contours); (c) 850 hPa geopotential height (solid contours), winds (barbs), temperatures (shaded), and dewpoint temperatures (°C, purple dashed contours); and (d) surface mean sea level pressure (hPa, solid contours), winds (barbs), temperatures (shaded), and dewpoint temperatures (purple dashed contours).

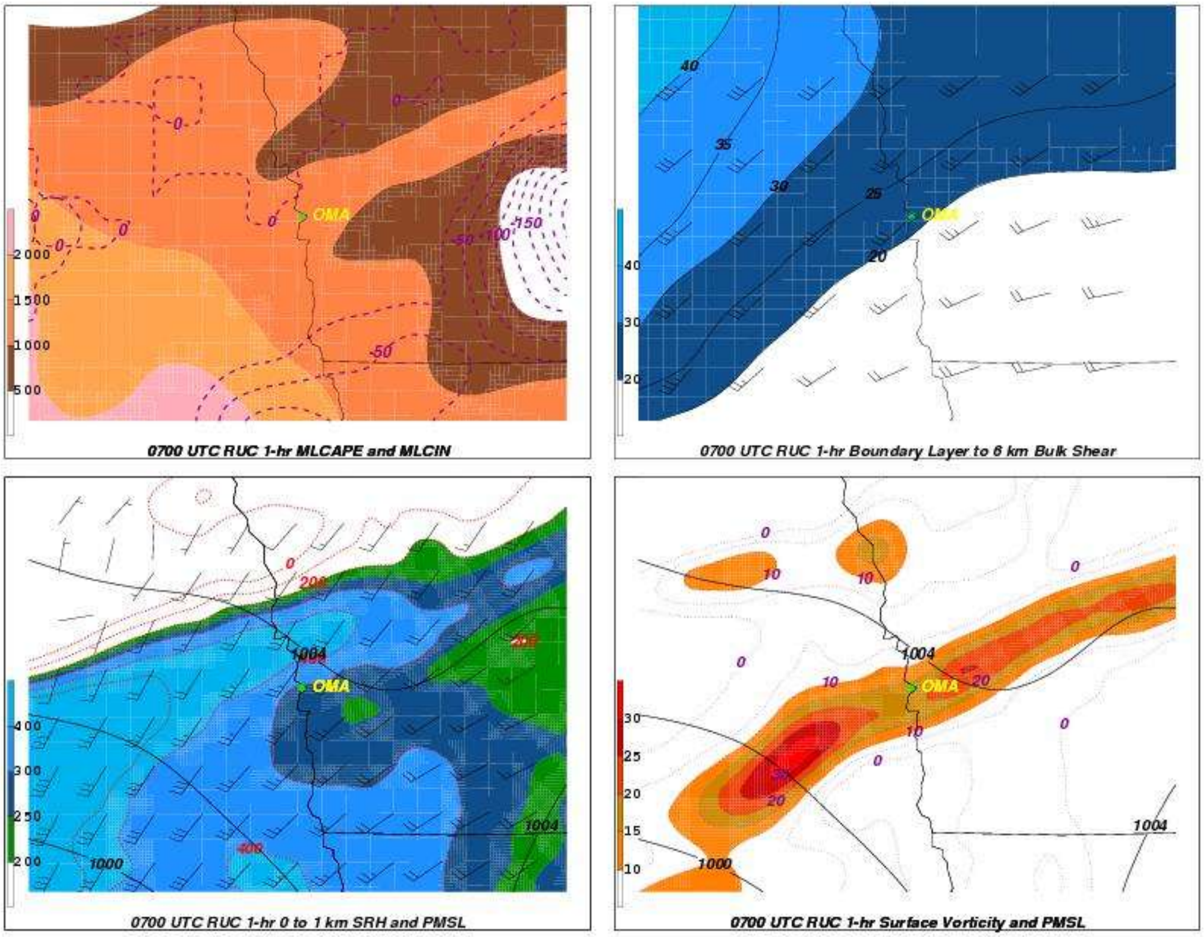

Figure 2. 0700 UTC 8 June RUC analysis: (a) MLCAPE (J kg^{-1}, shaded) and MLCIN (J kg^{-1}, contoured); (b) boundary layer to 6 km bulk shear (m s^{-1}); (c) 0-1 km storm-relative helicity (m^2 s^{-2}, shaded) and mean sea-level pressure (hPa, contoured); and (d) surface vorticity (10^{-5} s^{-1}, shaded) and mean sea level pressure (hPa, contoured).

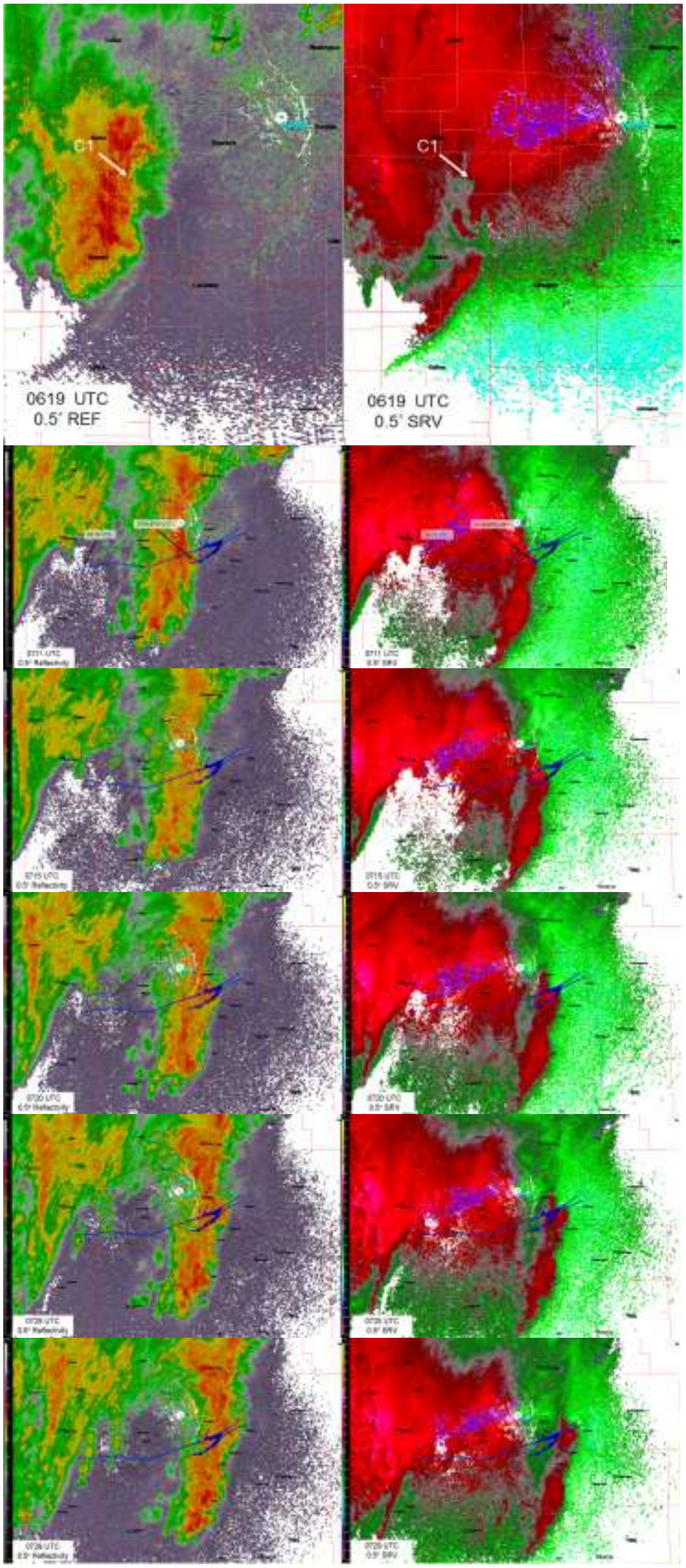

Figure 3. KOAX WSR-88D reflectivity (left column) and velocity (right column) images, taken at 0619, 0711, 0715, 0720, 0725, and 0729 UTC.

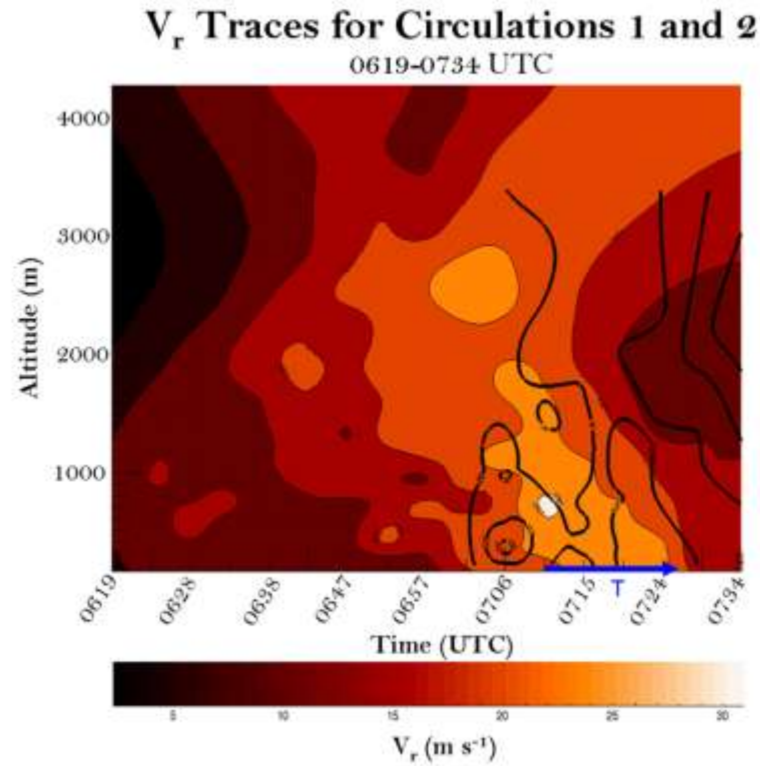

Figure 4. Rotational velocity for mesovortices C1 (shaded) and C2 (contoured), from 0619 UTC to 0734 UTC.

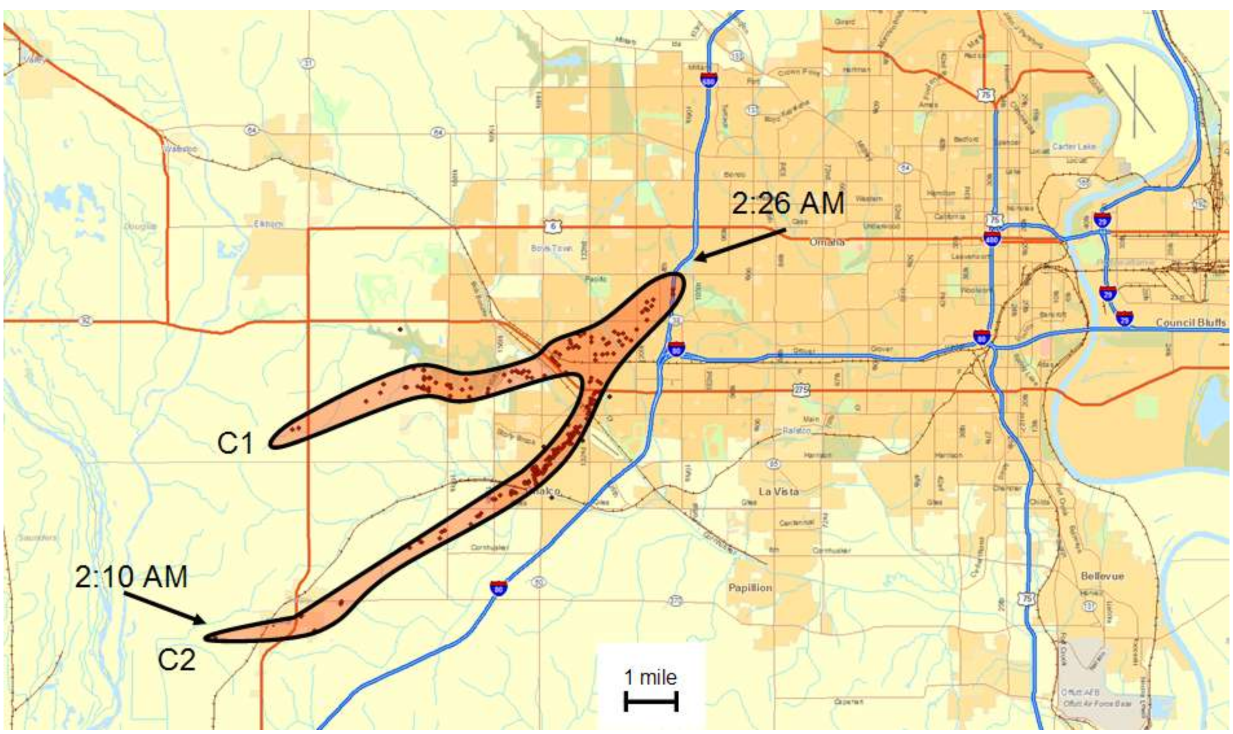

Figure 5. Surveyed paths of tornadoes associated with mesovortices C1 and C2, overlaid on a map of the Omaha metropolitan area. Tornado C1 was rated an EF2, while tornado C2 was rated an EF1.

Figure 6. Pictures of damage in the Millard area of southwest Omaha associated with tornadoes on 8 May 2008.