P5A.5 WSR-88D ANALYSIS OF VORTICES EMBEDDED WITHIN A SURFACE LOW PRESSURE TROUGH AND SUBSEQUENT CONVECTION INITIATION

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1. INTRODUCTION

On the early evening of 2 July 2002 spatially isolated, deep moist convection initiated along a quasi-stationary surface trough of low pressure in north central Nebraska. Two hours prior to initiation, numerous vertically oriented, cyclonic vortices embedded along the trough were detected within 85 km of the North Platte, NE, Weather Surveillance Radar-1988 Doppler (KLNX WSR-88D). The vortices exhibited 3-6 km horizontal diameters with a wavelength of ~12 km. The largest circulations persisted over 120 min as they propagated northeast along the boundary. Of interest are five non-supercellular storms that developed along the boundary. The storms initiated in a successive manner, southward along the surface trough in the vicinity of the vortices and exhibited a similar spatial separation as the vortices.

Previous research has documented the existence of vortices along boundaries. Studies of the Denver Convergence Vorticity Zone revealed rotational instabilities as vertically oriented vortices 4 km down to 200 m in diameter flowing along the boundary (e.g., Wilson et al. 1988; Szoke and Brady 1989; Wilczak and Christian 1990; Wilson et al. 1992; Pietrycha and Rasmussen 2001a). Additionally, Pietrycha and Rasmussen (2001b) documented vortices along the Great Plains dryline. The vortices were resolved concurrent with a deceleration of dryline movement to nearly stationary, and while moisture differentials strengthened. The authors hypothesized that the vortices protect an ascending air parcel by minimizing entrainment and theta-e dilution, thus allowing the parcel to reach its local lifted condensation level and level of free convection with relatively greater buoyancy than parcels not contained in vortices.

Based on the research and hypotheses documented above, in utilizing the KLNX WSR-88D data there is circumstantial evidence that a cause-and-effect relationship occurred between the vortices and the locations of convection initiation.

2. WSR-88D ANALYSIS

On 2 July 2003 a northeast southwest aligned surface trough moved east into north-central Nebraska. Late that afternoon, the boundary passed over the KLNX WSR-88D and became nearly stationary immediately east of the radar (Fig. 1). The boundary appeared as a ‘fine-line’ in the reflectivity imagery. As the forward propagation of the trough slowed, cyclonic vortices became identifiable in the base radar products (e.g., reflectivity and velocity), within 85 km of the radar (Fig. 2). Reflectivity and velocity cross-sectional analysis indicated the vortices sloped with height toward the northeast, similar to the orientation of the boundary, while exhibiting a coherent structure up to a height of 3.5 km AGL (not shown). The circulations exhibited 3-6 km horizontal diameters, with a wavelength of ~12 km. The largest vortices persisted over 120 min as they propagated along the boundary at ~5 m s^{-1}. The maximum radial shear associated with a vortex prior to convection initiation was 23 m s^{-1} across a distance of 1.5 km.

The first of five non-supercellular storms rapidly developed at 2323 UTC in Brown County, NE. The storm propagated south, adjacent (east) to the boundary and vortices. Over the next 60 min, each new storm of the remaining four initiated southwest of the previous storm along the boundary. Of interest, the points of convection initiation maintained a similar 12 km spatial separation as the vortices (Fig. 3-4).

It is plausible that convection initiation was manifested where convergence and resultant vertical motion was locally stronger along the surface trough. Larger stretching of uniform ambient vorticity associated with the convergence and increased vertical velocities was enhanced by the vortices. It is not known what processes induced the vortices and a lack of surface and upper air data across the boundary precludes assertion of the hypothesis.

Studies have produced evidence of convection initiation occurring where horizontal convective roles (HCRs) intersect a boundary (e.g., Wilson et al 1992; Atkins et al 1998; and numerous others).

At the point where HCRs intersect a boundary, localized updraft enhancement occurs and clouds initiate. With the 2 July event, no HCRs were identifiable in the radar data, intersecting the surface trough at or near the points of initiation. However, the lack of resolved HCRs in the radar data does not imply their absence.

Lastly, after the initiation of each storm the diameter of the adjacent vortex decreased while rotation increased, both at the surface and aloft. Concurrently, an enhanced channel of low-level inflow was observed in the base velocity data terminating at the circulations (Fig. 3). Over time, several of the circulation ascended in the parent updrafts (not shown). Two F0 tornadoes occurred in Brown County, NE associated with these circulations and parent storms. The evolution of tornado genesis appears consistent with documented non-supercell tornado events; the genesis of non-supercellular tornadoes is due to the collocation of vortices embedded within a convergent surface boundary with a rapidly developing storm (e.g., Brady and Szoke 1989; Wakimoto and Wilson 1989).

3. ADVANCED DETECTION APPLICATIONS

The National Severe Storms Laboratory's (NSSL) Weather Decision Support System - Integrated Information (WDSS-II) was utilized to examine the vortices. The algorithms of specific interest were the Azmuthal Shear and Azmuthal Convergence products employing a linear least squares derivative, across a 2500 m (azimuth) by 500 m (range) elevation scan domain, of the radial velocity data (Elmore 1994). In addition to the above, the Azmuthal Shear product can be "composited" over time to create a Rotation-Tracks Composite (Smith et al. 2003).

The Azmuthal Shear product yielded the greatest amount of information with this case. Sampling of the circulations prior to the initiation of convection yielded values over 7^{-3} s^{-1}. As a benchmark, a MDA detected mesocyclone of rank 5 with a rank 1 TDA detection, exhibited an Azmuthal Shear value of just over 1^{-2} s^{-1} (Stumpf et al. 1998; Mitchell et al. 1998).

Figure 5 is the Azmuthal Shear field that coincides with the velocity image in Figure 4. Vortices, *v1* and *v2* are coincident with the southern most circulations in Figure 4 and are not yet associated with any convective storm cells. Figure 6 depicts a vertical cross-section of the Azmuthal Shear product. The pre-storm vortices exhibited a coherent structure up to 2.5 km (AGL).

The Rotation Tracks Composite did not detect the pre-storm circulations prior to 0051 UTC. However, after 0051 UTC the tracks of the vortices were resolved in the product due to increased vortex rotation. Figure 7 depicts two tracks of pre-convective vortices near the radar. The bright regions at the tip of the arrows represent the location of pre-storm circulations prior to the development of convection at that coinciding location.

4. SUMMARY

The KLNX WSR-88D data obtained for 2 July 2002 resolved numerous cyclonic vortices embedded along a surface trough, 120 min prior to initiation of deep moist convection along the boundary. The circulations were readily identifiable within 85 km of the radar in the radar base data shortly after the boundary became quasi-stationary. The vortices exhibited 3-6 km horizontal diameters with a depth of 3.5 km AGL, and having a wavelength of ~12 km. The largest circulations persisted over 120 min while propagating northeast at ~5 m s^{-1} along the boundary. The maximum radial shear associated with a vortex prior to convection initiation was 23 m s^{-1} across a distance of 1.5 km. Convection initiated along and immediately adjacent to the trough exhibiting a 12 km wavelength, similar to that of the vortices.

Based on the KLNX WSR-88D data there is circumstantial evidence that a cause-and-effect relationship occurred between the vortices and the locations of convection initiation. It is plausible the vortices represented regions of enhanced convergence and increased vertical velocities along the surface trough, thereby aiding in the initiation of deep moist convection at the locations of the vortices.

Shortly after the initiation of each storm the diameter of the adjacent vortex decreased while rotation increased. Several of the circulations ascended in the parent updrafts with two of the storms producing two non-supercell tornadoes.

Several products being developed for NSSL's WDSS-II provided a "first glance" opportunity that might otherwise go unnoticed with conventional WSR-88D products. The Azmuthal Shear product was the best determiner of pre-existing areas of vorticity associated with the vortices, while the Rotation Tracks product allows the user to trace the position of the vortices when their rotation was sufficiently strong.

At the time of this paper, NSSL’s WDSS-II is still under development and has yet to be deployed to the National Weather Service forecast offices.

However, by utilizing the current capabilities of the WSR-88D and employing upcoming forecasting tools it is believed a greater lead-time for the detection of storm initiation can be achieved.

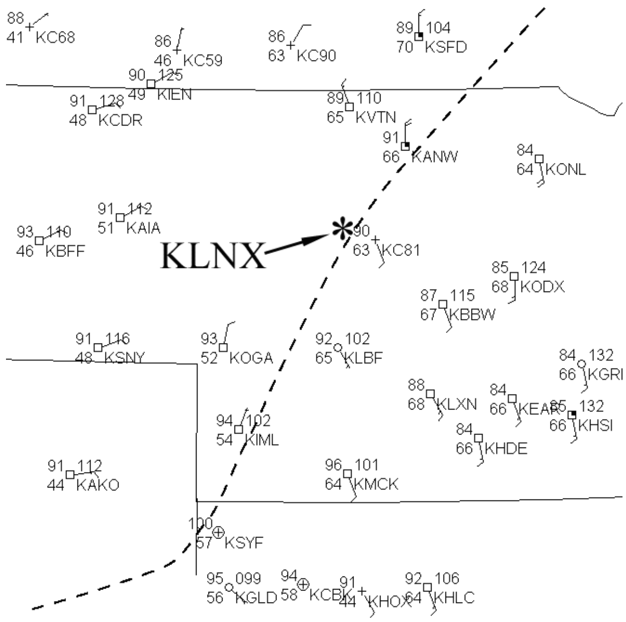


Figure 1. Surface map for 0000 UTC 3 July 2002. Standard station model used; temperature and dewpoint (°F), pressure (mb) and sky conditions. Winds in knots with one full barb and one half barb equal to 10 and 5 knots, respectively. Trough (dash) and location of KLNX depicted.

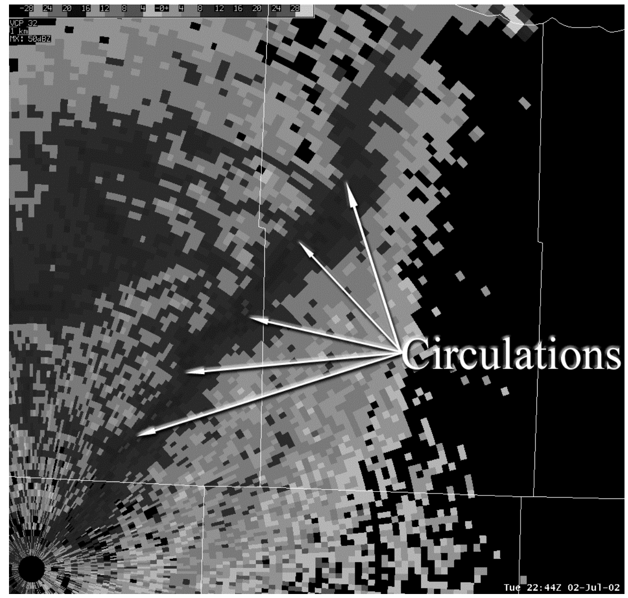


Figure 2. KLNX 0.5° reflectivity at 2244 UTC 2 July 2002. Pertinent features depicted. Note the 'bow' in the fine-line associated with upper most circulation.

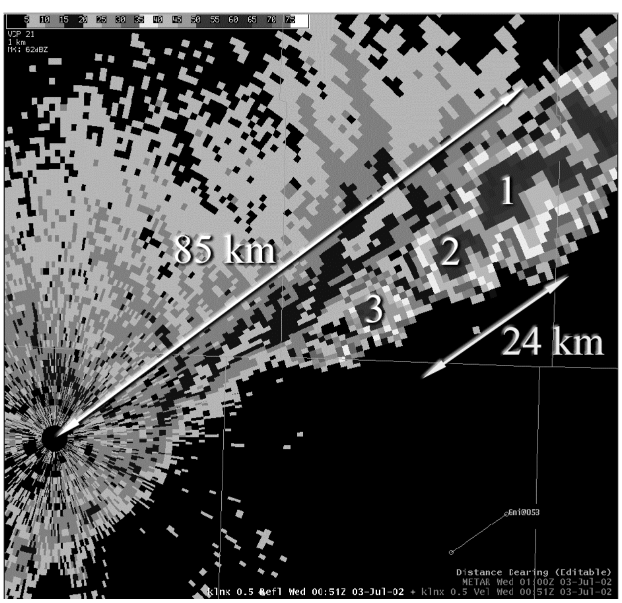


Figure 3. KLNX 0.5° reflectivity at 0051 UTC 3 July 2002. The first three of five storms are labeled. The remaining two storms initiated shortly after this time.

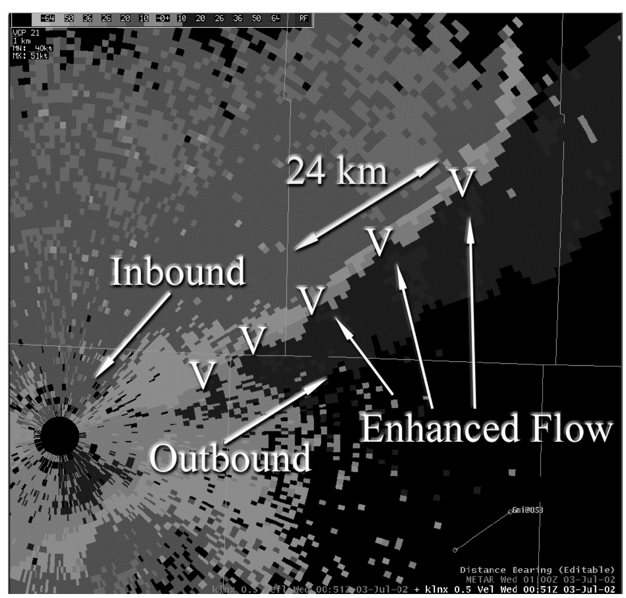
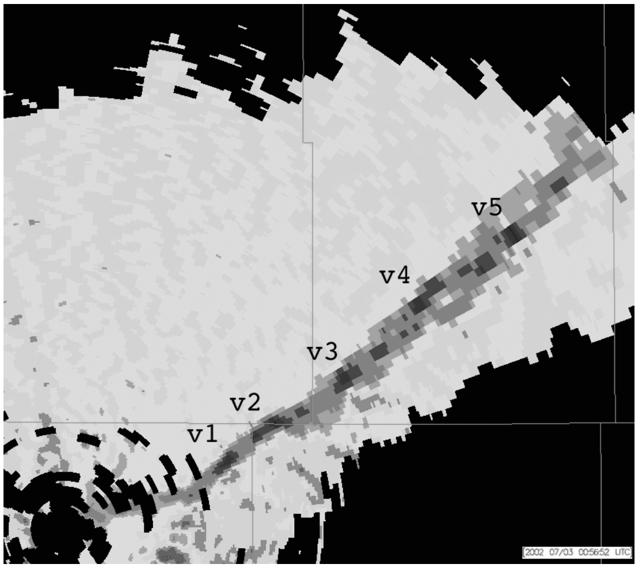


Figure 4. KLNX 0.5° base velocity at 0051 UTC 3 July 2002. The V represents locations of the vortices.



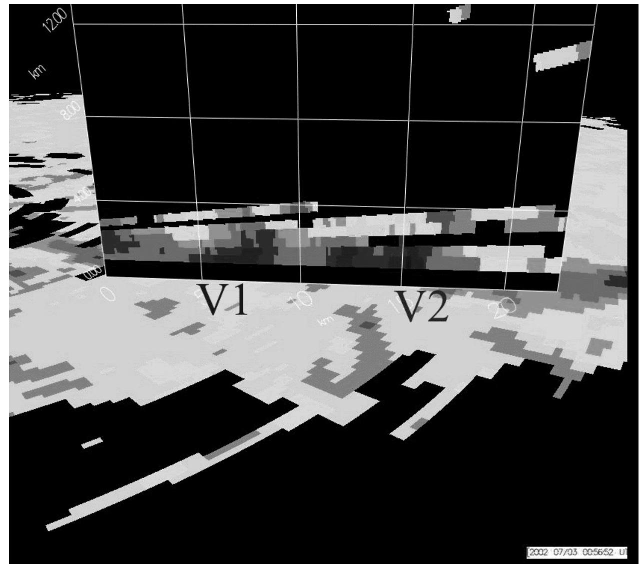


Figure 5. KLNX 0.5° Azmuthal Shear product at 0051 UTC 3 July 2002. Placement of the V corresponds to Fig. 4.

Figure 6. KLNX Azmuthal Shear cross-section at 0051 UTC 3 July 2002. Vertical grid lines are 5 km; horizontal 4 km. V1 and V2 correspond to Fig. 5.

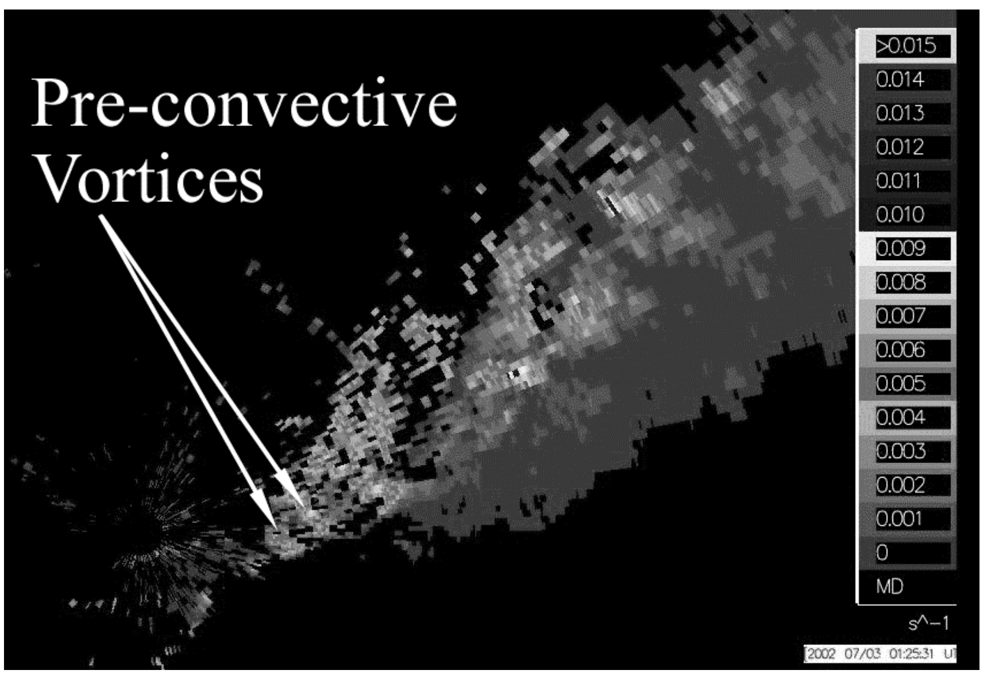


Figure 7. KLNX 0.5° 2-hour Rotation Tracks Composite at 0121 UTC 3 July 2002. The two areas depicted are tracks of pre-storm vortices.

5. REFERENCES

Available upon request.