J3.5 **THE KELLERVILLE TORNADO DURING VORTEX: DAMAGE SURVEY AND DOPPLER RADAR ANALYSES**

Roger M. Wakimoto[1*], Hanne V. Murphey[1], David C. Dowell[2], and Howard B. Bluestein[3]

[1]Department of Atmospheric Sciences
UCLA
Los Angeles, CA 90095-1565

[2]National Center for Atmospheric Research
Advanced Study Program
Boulder, CO 80307-3000

[3]School of Meteorology
University of Oklahoma
Norman, OK 73019

1. INTRODUCTION

Detailed aerial and ground surveys of damage caused by tornadoes have been instrumental in advancing our understanding of tornadoes. One of the intriguing discoveries revealed in early damage surveys was the nonlinear nature of some of the tornado tracks. There have been well-documented cases of tornadoes making unusual and large deviations in their movements even though there were no obvious changes in the parent storm's overall propagation. The prevailing theory for explaining the turns, bends and cusp-like tornado paths documented by post-storm surveys is that the trochoidal track[1] is a result of the tornado revolving within a larger-scale mesocyclone circulation. There had been no data collected to date, however, to confirm this possible mechanism.

2. THE KELLERVILLE TORNADO

A tornadic supercell formed over the Texas Panhandle on 8 June 1995 and produced a family of tornadoes during VORTEX (Verification of the Origins of Rotation in Tornadoes Experiment). High-resolution airborne Doppler radar data were collected on this storm by NCAR's ELDORA, 3-cm airborne radar system, over a nearly two-hour period. One of the tornadoes near Kellerville, Texas was rated F5 and was extensively surveyed on the ground and from the air using a small aircraft. Part of the damage track is shown in Fig. 1. The tornado exhibited unusual nonlinear movements in its track in at least two locations. A prominent cusp-like pattern was apparent in one section of the track.

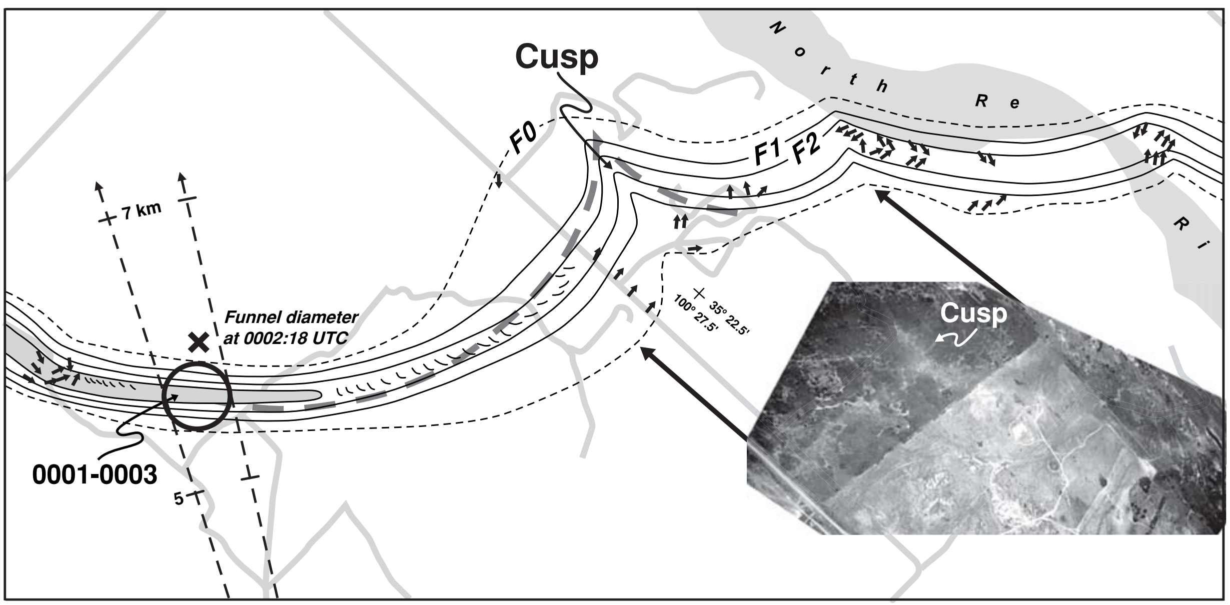

Fig. 1. Part of the damage track for the Kellerville tornado. F-scale damage contours are shown. An aerial photo of a cusp-like tornado path is also shown. The gray, dashed line represents the trochoid that best fits the damage track at that location.

3. DOPPLER RADAR SYNTHESES

* Corresponding author address: Roger M. Wakimoto, Dept. of Atmospheric Sciences, UCLA, Los Angeles, CA 90095-1565; e-mail: roger@atmos.ucla.edu

[1] Trochoid: the curve generated by a point on the radius of a circle as the circle rolls along a straight line.

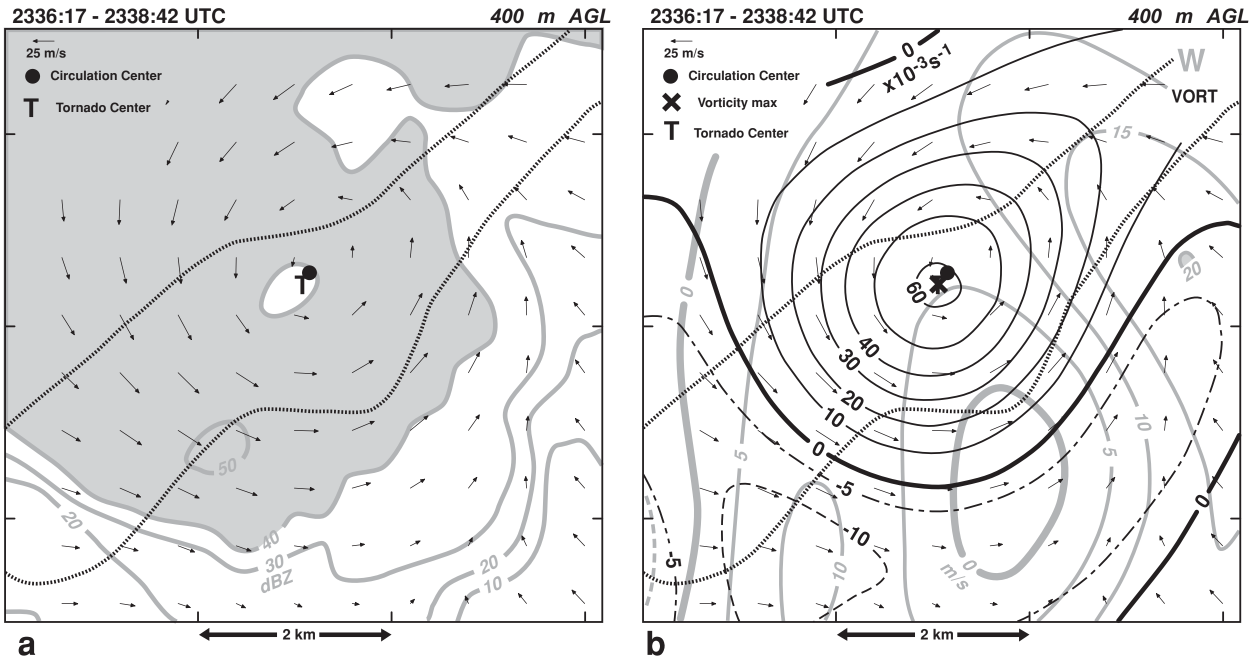

Fig. 2. Storm-relative winds at 400 m AGL at 2336:17-2338:42 UTC superimposed onto a) radar reflectivity, and b) vertical vorticity and velocity. Short dashed line denotes the F0 isopleth of the tornado track. The black dot, cross, and the letter "T" denote the location of the storm-relative circulation center, the maximum vertical vorticity, and the tornado, respectively.

The dual-Doppler synthesis at low levels (400 m AGL) for the first pass by the Kellerville tornado is shown in Fig. 2. The hook echo and weak-echo eye are apparent in Fig. 2a. The resolved circulation shown in the figure cannot be interpreted as the tornado owing to the characteristics of the observations and the imposed filtering routine but it should be representative of the mesocyclone. The tornado is large at this formative stage (~2 km wide) as indicated by the F0 contours, and the mesocyclone (indicated by the $10 \times 10^{-3} s^{-1}$ vorticity contour) is nearly twice the diameter of the tornado.

A synthesis for a later time when the tornado had narrowed significantly and was located approximately at the midpoint of the damage track is presented in Fig. 3. A dramatic deviation of the tornado track occurred immediately after the synthesis time. The track had a cusp-like pattern (see Fig. 1) that was similar to the trochoid that is produced when the rotation around a circulation is equal to the

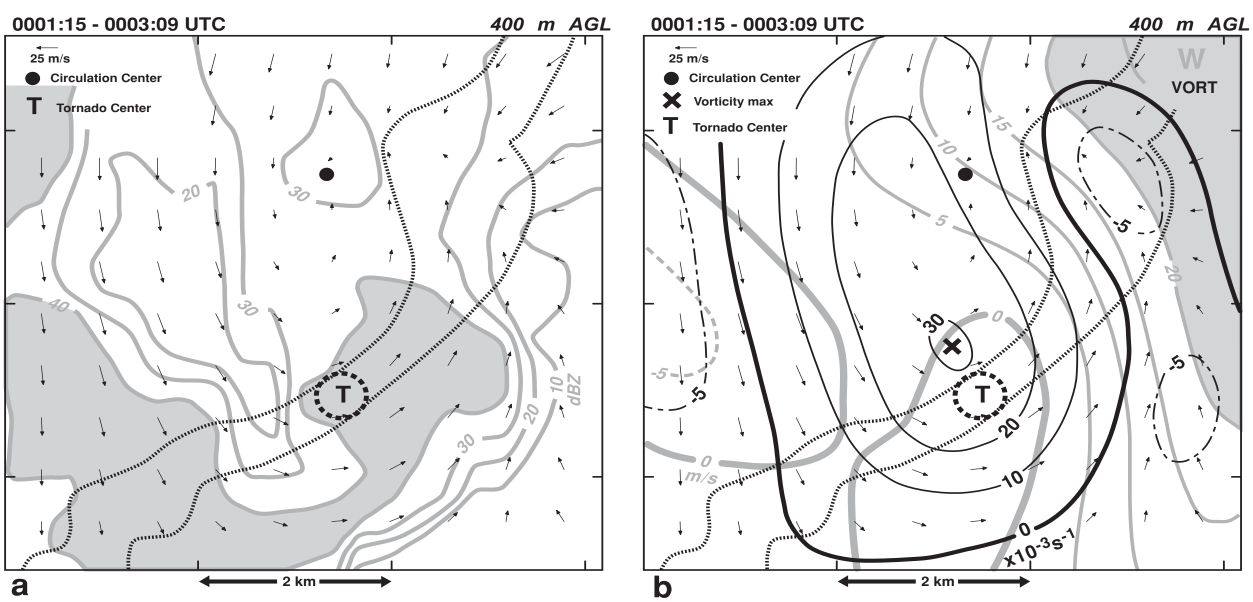

Fig. 3. Same as Fig. 2 except for 0001:15 - 0003:09 UTC.

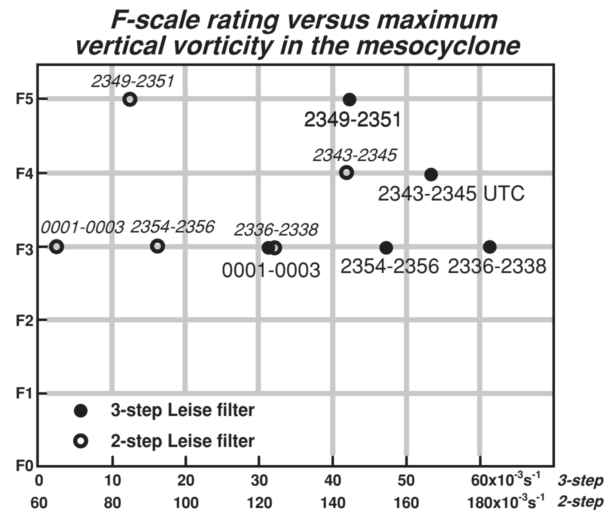

Fig. 4. Estimated F-scale rating versus maximum vertical vorticity in the low-level mesocyclone for the Doppler wind syntheses.

translation speed of the circulation. Note that the circulation center, tornado and maximum in vorticity are in disparate locations in Fig. 3 in contrast to the results shown in Fig. 2. Indeed, the storm-relative circulation center is ~3 km north of the tornado, and the position of the maximum in vorticity is displaced 640 m from the tornado. The trochoid that provides the best fit to the Kellerville damage track is shown by the dashed gray line drawn on Fig. 1. The 580 m radius of the trochoid is nearly the same as the 640 m distance between the tornado and vorticity maximum.

A plot of maximum vertical vorticity within the mesocyclone versus F-scale rating for all synthesis times is shown in Fig. 4. This figure reveals that the maximum vorticity associated with the mesocyclone at low levels is an unreliable indicator of the tornado's intensity. *Note that the F-scale damage rating decreases between 2349-2351 and 2354-2356 even though the maximum vorticity associated with mesocyclone increases.*

4. PHOTOGRAMMETRIC ANALYSIS

In using Doppler radar to define the airflow near and within the tornado, it is important that the visual characteristics of the tornado are known in order to remove possible ambiguities in interpreting the Doppler velocity fields. The most important characteristics are the tornado's width and its relationship to the radar beamwidth. The diameter of the tornado condensation funnel can be determined using photogrammetric techniques. The vertical cross section shown in Fig. 5 is through the center of the tornado. Weak downdrafts along the rear-flank are evident to the left of the tornado and the storm-scale updraft/downdraft interface near the surface is located at the center of the tornado. The relationship between the tornado and the mesocyclone is shown by the superposition of the vertical vorticity field on the photograph. The mesocyclone was 3-4 times larger than the visible funnel at this time. Also apparent in the figure is the anticyclonic vorticity behind the rear-flank gust front.

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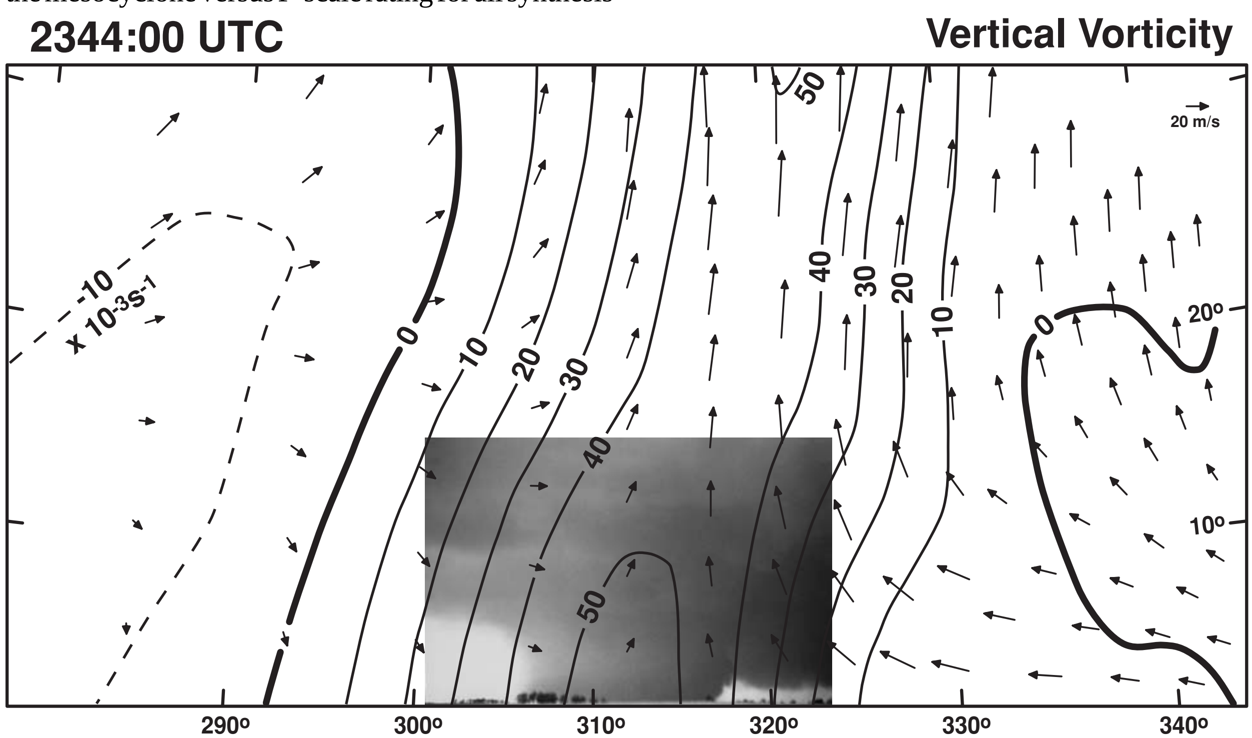

Fig. 5. Vertical cross section through the Kellerville tornado at 2344:00 UTC superimposed onto a photograph and vertical vorticity and the storm-relative winds. Photo taken by Bruce Haynie.