P 7.5 RADAR DOCUMENATION OF A CYCLIC SUPERCELL IN THE SAN JOAQUIN VALLEY, CALIFORNIA

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1. INTRODUCTION

This study is a documentation of the evolution and structure of a right-moving cyclic supercell thunderstorm on the basis of WSR-88D radar information. The study is somewhat unique because the supercell did not occur in the Great Plains, but was observed at the Lemoore Naval Air Station in the San Joaquin Valley of California on November 22, 1996. The storm produced a mesocyclone-induced F0 and a subsequent F1 tornado that caused significant wind and hail damage. This storm was the first California supercell tornado event to occur near a WSR-88D radar [that at Hanford (KHNX)]. Furthermore, because of the flat expanse of the San Joaquin Valley, the Doppler radar had an unobstructed view of the tornadic storm that resulted in unprecedented quality of the low (0.5°) elevation radar scans for this storm. Hence, this case study is the first observation and documentation in California of a tornado cyclone signature (TCS) from WSR-88D storm-relative radial velocity (SRV) data.

2. DYNAMIC AND THERMODYNAMIC SUMMARY

The severe storm was the southernmost cell in a line of strong thunderstorms that developed in the cold sector of a wave cyclone and upstream of a progressive post-frontal subsynoptic trough. This trough was associated with cyclonic isothermal vorticity advection (CIVA) that contributed to mid-tropospheric forcing of a quasi-geostrophic omega upward motion field and mid-tropospheric destabilization. Furthermore, upper-tropospheric jet-streak-induced divergence was related with an augmented mid-tropospheric vertical motion field over the central San Joaquin Valley (not shown).

The storm matured in an environment characterized by strong vertical wind shear and near a localized region of maximum CAPE. Values of convective and rotational parameters (i.e. BRN) associated with the storm were within ranges observed with previous mesocyclone induced tornadic thunderstorms in California and elsewhere (Monteverdi et al., 2003; Johns et al., 1993). Additionally, the development of a low-level mesocyclone and tornado was suggested by the modified hodograph of the actual storm environment.

3. STORM EVOLUTION

Radar reflectivity and radial wind velocity signatures showed well-defined supercell structure (Fig. 1) was present during the nearly 1.5 hour life span of the storm. The supercell was also cyclic with numerous updraft redevelopments (Fig. 2) during the maturation stage

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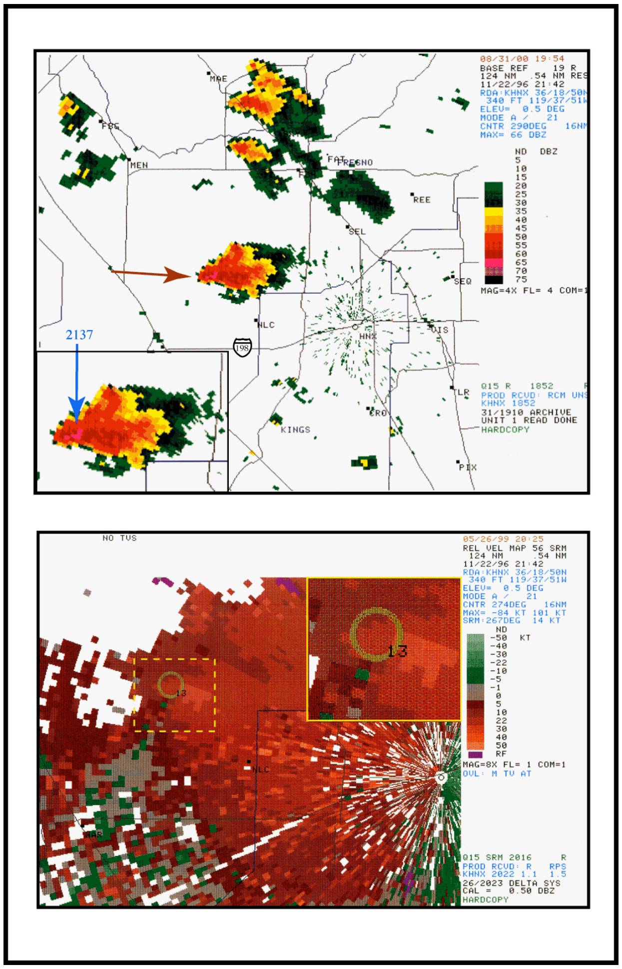

Fig. 1. 0.5° KHNX WSR-88D base reflectivity (top) with storm magnified in bottom left corner and storm-relative velocity (bottom) with dashed box indicating magnified area in top right at 21:42 UTC 22 November 1996. Blue arrow indicates storm updraft location and brown arrow locates reflectivity hook echo. Note: Top and bottom images not to scale.

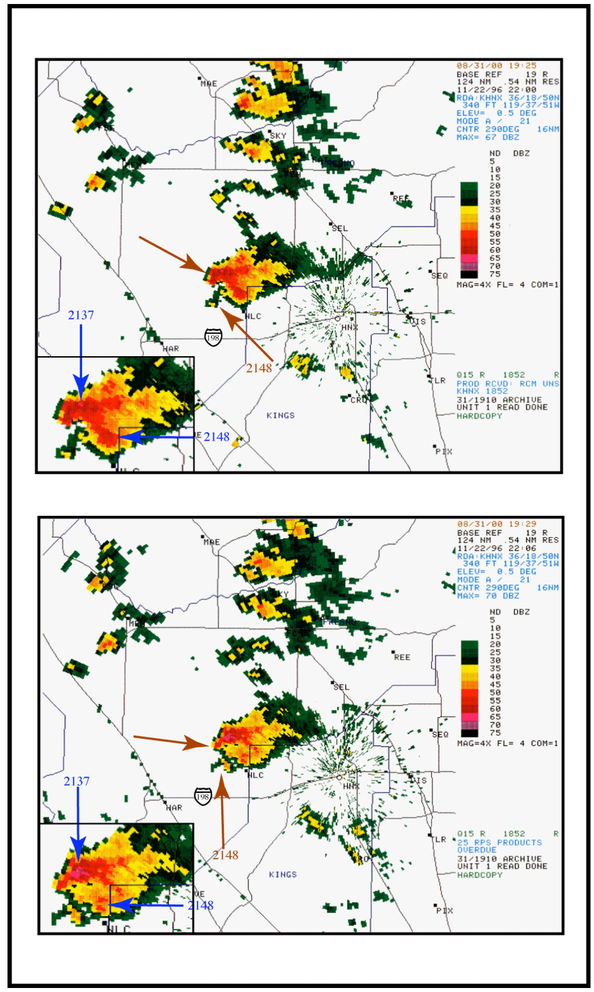

Fig. 2. 0.5° KHNX WSR-88D base reflectivity with storm magnified in bottom left corner valid at 22:00 (top) and 22:06 (bottom) UTC 22 November 1996. Blue arrows indicate storm updraft locations and brown arrows locate reflectivity hook echoes.

before becoming tornadic. Base-reflectivity images showed the storm evolved from a classic supercell with a hook echo (Fig. 1; top image, brown solid arrow) and a highly reflective (>68-dBZ) updraft core (Fig. 1; top image, blue solid arrow) into a high-precipitation (HP) supercell with strong returns across a wide swath of a more distinctive and reflective (68-dBZ) hook appendage (Fig. 3; top image, brown arrow) during the F1 tornado event. SRV volume scans during the storm's life span showed the presence of mid-level mesocyclone indicated by numerous detections of a deep circulation by the WSR-88D mesocyclone algorithm (Fig. 1 and others not shown).

During the tornado phase, the (VIL) product (not shown) showed that large hail was likely associated with these intense updrafts and especially with an updraft in the hook-echo region where base reflectivity scans detected returns of 71 dBZ (not shown). This coincides with the report of large hail (6.73 cm /2.5" in diameter) in the Lemoore Naval Air Station at 2250 UTC that

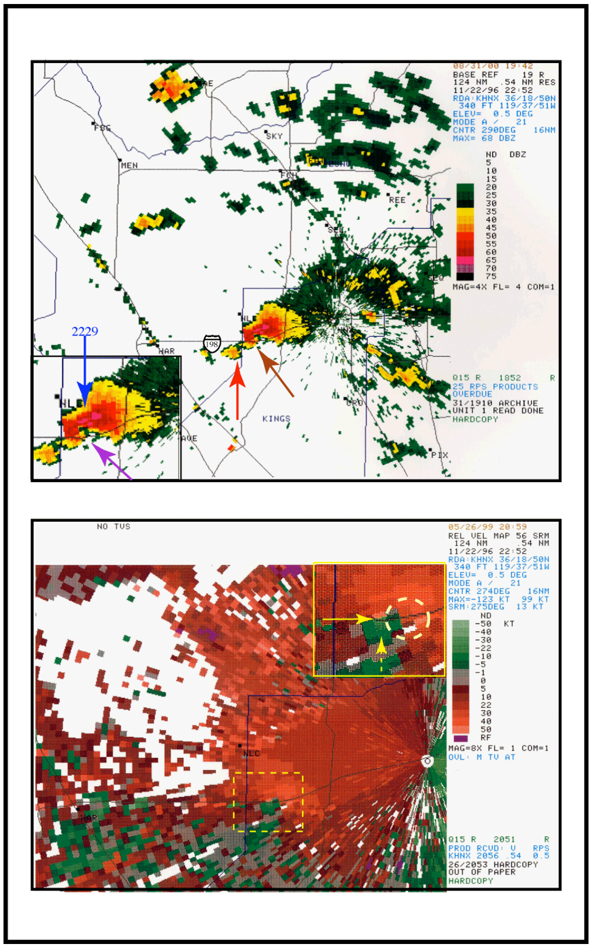

Fig. 3. Same as Fig. 1 except valid at 22:52 UTC 22 November 1996. Purple arrow is discussed in text. Red arrow identifies a flanking cell.

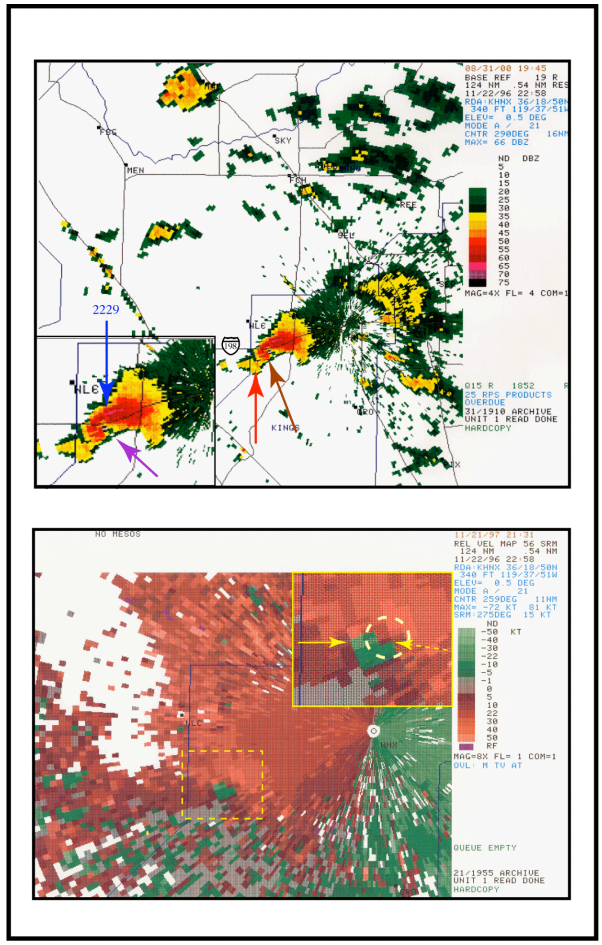

Fig. 4. Same as Fig. 1 and Fig. 3 except valid at 22:58 UTC 22 November 1996.

smashed the sides and fronts of vehicles.

The large hail was also likely a factor in the initiation of a storm-scale occlusion downdraft within the rear flank downdraft (RFD). SRV signatures confirm this RFD acceleration reached the lower-levels since radial inbound winds increase from 0.5 ms^{-1} (1 knot) at 22:34 UTC (not shown) to 20.6 ms^{-1} (40 knots) at 22:52 UTC (Fig. 3, bottom image inset–dashed yellow arrow) in the area near the tip of the hook appendage. This was nearly simultaneous with the development of a low-level mesocyclone (Fig. 3; bottom image, dashed circle) and just prior to tornadogenesis.

Subsequent SRV images show that the downdraft accelerations within the RFD likely increased the baroclinic generation of low-level vorticity leading to the strengthening of the low-level mesocyclone. Furthermore, reflectivity cross-section (not shown) and 0.5° tilt base reflectivity images indicated a bounded weak echo region (BWER) (Fig. 3 and Fig. 4; top image, purple arrow) adjacent to a tilted updraft vault containing strong mid-level echo overhang.

Two distinct circulations were evident on the SRV data embedded within the storm during both tornado episodes. During the F1 tornado event, the larger (3.5

km/~1.75 nm), weaker (rotational shear 14.6 X $10^{-3} s^{-1}$) circulation (Fig. 3 and Fig. 4; bottom image, dashed yellow circle) was the low-level mesocyclone. This strength of mesocyclone shear was in the middle to upper ranges of known rotational shear magnitudes for the occurrence of a tornado to be possible (Falk and Parker, 1998).

The smaller (1 km/0.5 nm), intense (rotational shear 51.4 X $10^{-3} s^{-1}$) vortex was likely a TCS (Fig. 3 and Fig. 4; bottom image, solid yellow arrow). The strength and size of this circulation is very similar to other TCSs observed elsewhere (Straka et al. 1996, Rasmussen and Straka, 1996). The TCS evolved from small-scale downdrafts in the RFD that descended to near the surface and developed into an area of intense and increasingly rotational convergence. In this region of strong vertical shear is where the tornadoes occurred. The author believes this feature and the small-scale circulation that was detected on the SRV data with the first F0 tornado (not shown) is the first documentation of a TCS in California.

4. CONCLUDING REMARKS

The evolution of the radar structure of a tornadic supercell storm in California was deduced on the basis of analyses of KHNX WSR-88D radar data. From this information and due to the close proximity of the storm to the KHNX Doppler site, the detailed reflectivity (i.e. BWER, hook echoes) and radial wind velocity (i.e. TCS) data of the severe storm's structure yielded evidence that a mesocyclone-induced tornado was likely associated with the storm. The author also believes that this is the first documentation of a TCS in the WSR-88D radial velocity data for a California tornadic storm.

The study of this cyclic tornadic supercell highlights the usefulness of Doppler radar for analyzing the evolution and structure of severe storms in flat expanse of the Central Valley of California.

5. REFERENCES

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