Role of the rear-flank-downdraft in the evolution of an occluding mesocyclone in a tornadic supercell

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1. Introduction

- On 19 June 2010, the two C-band (5-cm wavelength) Shared Mobile Atmospheric Research and Teaching (SMART) Radars (Biggerstaff et al. 2005) collected 110 minutes of dual-Doppler data of a tornadic supercell near Concordia, KS.
- The storm observed was formed along a stalled frontal zone in northern Kansas as low level convergence was enhanced due to a strong outflow boundary to the east and a southerly low-level jet to the south, which also aided in low level warm air advection, and created enough forcing to initiate convection.
- Soundings taken at 12Z and 00Z at Topeka, KS (Fig. 1) also showed favorable environmental conditions for supercell development.

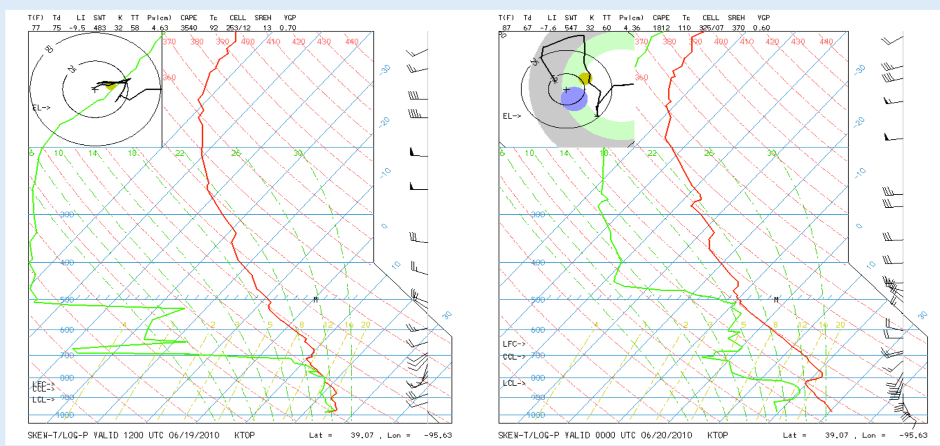

Figure 1. Soundings from Topeka, KS. The first at 19 June 12Z; the second at 20 June 00Z.

2. SMART Radar Data & Methods

- This study is focused on the time period from 0021-0054 UTC, during which 11 volumetric sector scans, each 3 minutes long, were collected by the SMART Radars (Table 1).
- The SMART-R's were along a 35 km baseline, with a bearing of 75° (Fig. 2).
- The data during this time period were edited using SOLOII, interpolated to Cartesian grid (with grid spacing of 500m in the horizontal and vertical directions) using REORDER. Finally, the winds were then synthesized using CEDRIC.

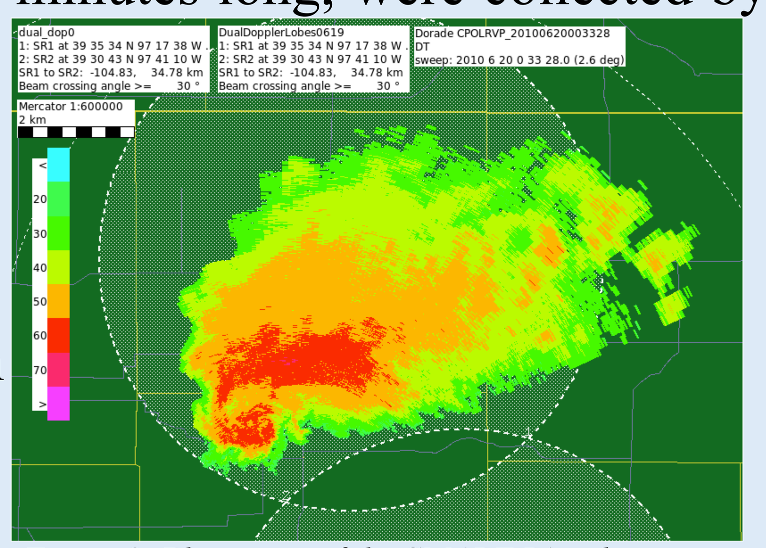

Figure 2. Placement of the SMART-R's relative to the storm at 0033Z with Dual-Doppler lobes.

	SMART-R2		SMART-R1			
Location (Lat, Lon, Alt)	39.51207°, -97.68600°, 496m ASL		39.59285°, -97.29383°, 412m ASL			
Sectors Collected	130° (before 0045Z) / 135° (after 0045)		120° (before 0045Z) / 140° (after 0045Z)			
Mean Range to Mesocyclone	13 km		36 km			
Elevation angles / Height ARL Relative to Mean Range to Storm	0021Z – 0051Z		0021Z -0045Z		0045Z-0051Z	
	0.8°/0.2km	13.3°/3.1km	0.8°/0.5km	18.6°/12.1km	0.8°/0.5km	22.4°/14.8km
	1.7°/0.4km	17.5°/4.1km	2.0°/1.3km	21.6°/14.3km	1.7°/1.1km	27.4°/18.7km
	2.6°/0.6km	22.4°/5.4km	3.4°/2.1km	24.9°/16.7km	4.0°/2.5km	33.3°/23.6km
	3.5°/0.8km	27.4°/6.7km	4.8°/3.0km	28.7°/19.7km	6.9°/4.4km	40.0°/30.2km
	5.4°/1.2km	33.3°/8.5km	6.6°/4.2km	33.0°/23.6km	9.8°/6.2km	48.0°/40.0km
	6.3°/1.4km	40.0°/10.9km	8.6°/5.4km	38.0°/28.1km	13.3°/8.5km	57.0°/55.4km
	7.2°/1.6km	48.0°/14.4km	10.9°/6.9km	43.6°/34.3km	17.5°/11.4km	66.0°/80.9km
	8.3°/1.9km	57.0°/20.0km	13.3°/8.5km	50.5°/43.7km		
	9.8°/2.2km	66.0°/29.2km	16.0°/10.3km	58.0°/57.6km		

Table 1. SMART Radar's locations and scanning strategies on 20 June, 2010, during 0021-0054 UTC.

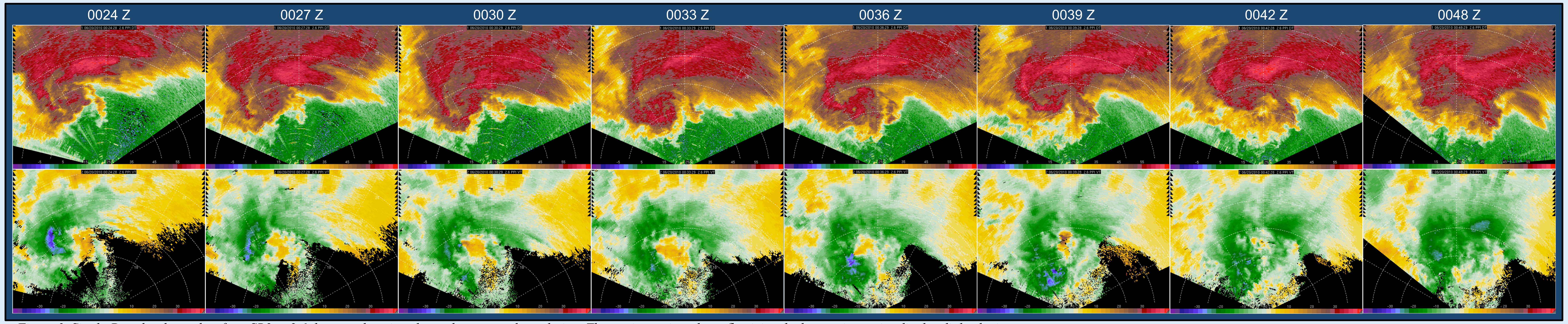

Figure 3. Single-Doppler data taken from SR2 at 2.6 degrees elevation shows the mesoscale evolution. The top image is radar reflectivity, the bottom image is edited radial velocity.

3. Results

- Single Doppler data collected from SR2 (Fig. 3) show a broad circulation that tightened from 0024Z – 0027Z. A Tornado Vortex Signature (TVS) was observed between 0027Z through 0039Z within the circulation. At 0039Z low-level occlusion of the radar hook echo took place, coincident with a surge in the RFD and associated secondary gust front, causing the mesocyclone to weaken through 0048Z.

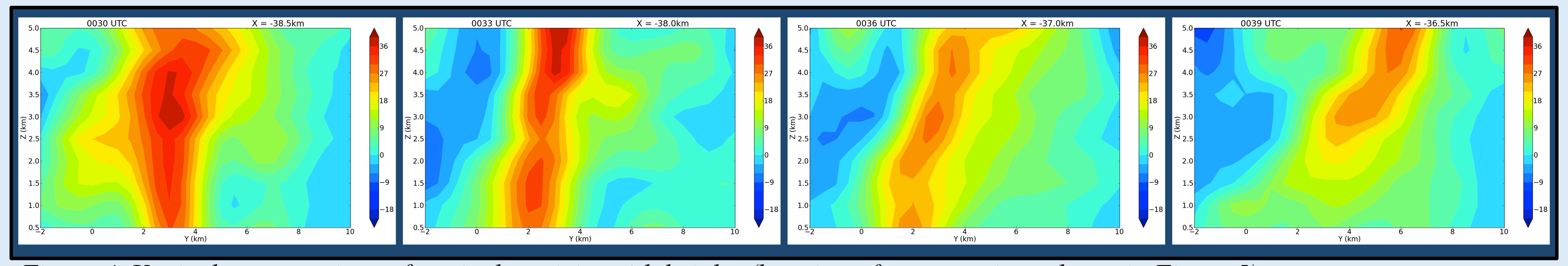

Figure 4. Vertical cross sections of vertical vorticity with height. (location of cross sections shown in Figure 5)

- Vertical cross sections of vertical vorticity from 0030Z – 0039Z (Fig. 4) show the column of higher vorticity associated with the circulation became tilted to the north with height over time, augmenting forcing for an occlusion downdraft.

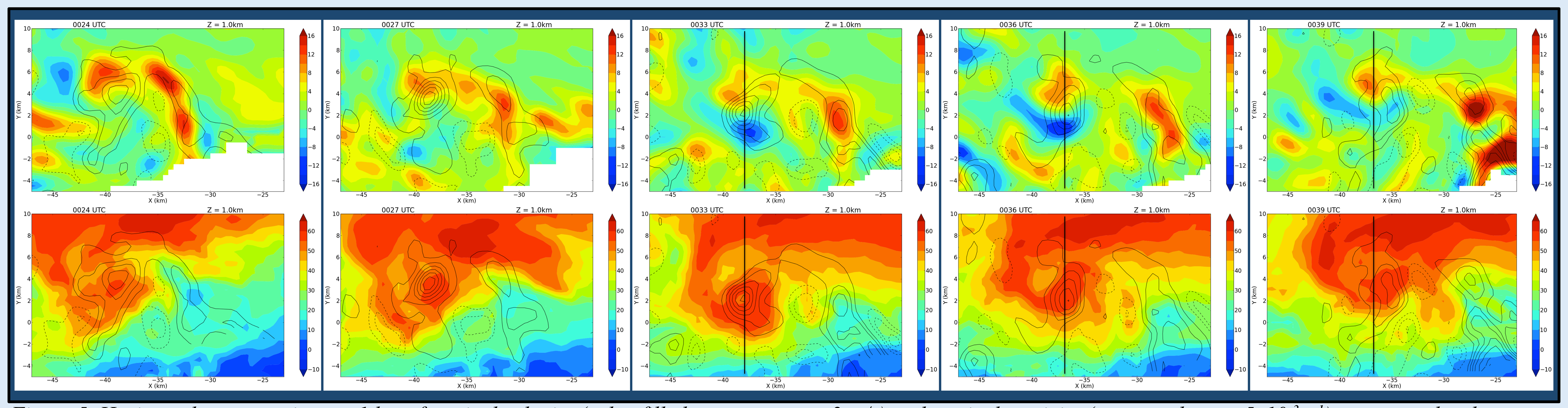

Figure 5. Horizontal cross-sections at 1 km of vertical velocity (color-filled contours every 2 m/s) and vertical vorticity (contoured every $5x10^{-3}$ s^{-1}) on top, and radar reflectivity (color-filled contours every 5dBZ) and vertical vorticity underneath. Lines on the 0033Z – 0039Z plots show the locations of the vertical cross sections of Fig. 4

- At 1km AGL, Fig.5 shows the mesocyclone embedded in updraft at 0024Z, an increase in vertical vorticity through 0027Z, the development of an occlusion downdraft as the vortex became tilted and the weakening of the circulation between 0036-0039Z as the circulation became downdraft dominated.

4. Conclusions

- During 0024-0027Z, the mesocyclone was embedded in upward motion and intensified through stretching, leading to a vertically aligned vortex.
- Later (0030Z – 0033Z), the vertical gradient of the square of vertical vorticity became negative above 1.5 km AGL as the vortex became tilted toward the N-NE aloft, producing a downward dynamic pressure gradient (Klemp & Rotunno 1983), creating subsidence that was reflected at the surface in the occlusion downdraft. At 0036Z, the column of vorticity tilted more, enhancing this effect.
- Single Doppler data showed a TVS from 0027Z–0039Z, indicating a possible tornado before the mesocyclone obtained a divided structure. However, the vorticity in the TVS and mesocyclone was highest once the mesocyclone developed a divided structure between the updraft and rear-flank-downdraft (Lemon & Doswell III 1979).

5. References

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6. Acknowledgements

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