In-Situ Thermodynamic and Doppler Radar Observations of a Circulation within the Rear-Flank Downdraft of a Tornadic Supercell during VORTEX2 on 19 May 2010

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1. Introduction

A Doppler on Wheels (DOW) radar intercepted a tornadic supercell east of Kingfisher, Oklahoma, on 19 May 2010 during the second field phase of the Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2). The storm initiated along a dryline in western Oklahoma around 1945 UTC and it progressed eastward into a region characterized by 40-50 knots of 0-6 km bulk shear, 0-3 km storm relative helicities around 300 $m^2\ s^{-2}$, and MLCAPE of around 3000 J Kg^{-1}. This environment was conducive to the development of right moving, tornadic supercell thunderstorms.

The DOW initially intercepted the storm around 2154 UTC, but this research focuses only on the last of three deployments which began at 2345 UTC. The storm had a history of producing tornadoes and was still a well-organized right-moving supercell at the beginning of the this deployment. Prior to this deployment, the mobile radars and other instrumented vehicles were caught in a traffic jam consisting of other storm intercept teams and severe weather enthusiasts unrelated to the VORTEX2 project, thus only around 6 minutes of stationary radar data were collected. These 6 minutes of single-Doppler radar data are analyzed herein, as well as in situ thermodynamic and wind data collected by a mobile mesonet vehicle that was co-located with the DOW during radar data collection. After the storm passed, the VORTEX2 armada followed the storm eastward.

This storm is of interest because its close proximity to the mobile radar provides a relatively rare chance to objectively analyze high spatial resolution reflectivity and radial velocity data near a small vortex that developed along the rear-flank gust front of the supercell. Documentation of the kinematic properties of this vortex and the thermodynamic characteristics of the environment surrounding it is the primary focus of this paper. Methodology and data collection details can be found in section 2. Section 3 contains the radar data analysis, the mobile mesonet data analysis can be found in section 4, and section 5 includes the conclusions and suggestions for future work.

2. Methodology

Data from the mobile Doppler radar are presented after extensive editing using the SOLO3 software was performed. Ground clutter and data with low normalized coherent power were removed and velocities were dealiased. After editing was completed, the data were mapped to a regular Cartesian grid using OPAWS software. The Cartesian grid resolutions are 200 m for the domain including the entire storm, and 100 m for the domain including only the hook echo. The smoothing parameter for the larger domain is 0.419 km^2 and 0.0464 km^2 for the smaller domain. The mobile Doppler radar is a dual-polarization X-band radar with a wavelength of 3 cm and a beam width of 0.95°. Three full volumetric scans, as well as an incomplete fourth scan, were collected every 2 minutes and the complete volumes contain elevation scans of 0.5°, 1°, 2°, 3°, 4°, 5°, 6°, 8°, 10°, 12°, and 14°. Data from the KTLX WSR-88D were also retrieved and are presented. Time series of temperature, relative humidity, pressure, and wind speed and direction were created from the mobile mesonet data.

3. Doppler Radar Observations

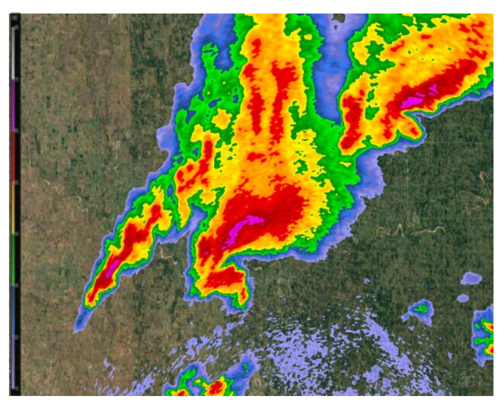

Figure 1: Smoothed reflectivity from the KTLX WSR-88D at 2348:13 UTC.

This mobile radar intercept occurred approximately four hours after storm initiation. Observations of the storm by the DOW began at 2345:14 UTC and continued until 2350:45 UTC. At the beginning of the observations, the storm had a well-developed hook echo and inflow notch (Fig. 1). At 2351 UTC, the DOW ceased data collection to follow the storm eastward. No further mobile radar were collected on this storm, however, because it began to weaken as VORTEX2 followed it eastward (not shown).

When the DOW began recording data at 2345 UTC, the radar was located southwest of Cimarron City, OK (Fig. 2), within the hook echo. The storm was relatively discrete at this time (Fig. 1). During the radar intercept, the maximum reflectivity observed by the DOW was only around 55 dBZ, while the maximum reflectivity observed by the KTLX WSR-88D was around 70 dBZ. These differences in reflectivity are a result of severe attenuation of the X-band DOW beam within heavy rain and hail within the forward-flank region of the storm; most of the forward-flank is not apparent in the DOW data due to this attenuation.

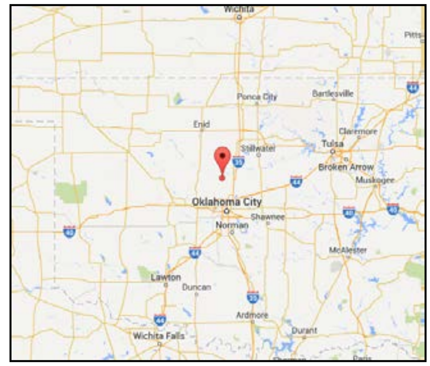

Figure 2: Google Maps image of the DOW deployment site.

A small vortex is visible in the first volume scan along the rear-flank gust front (Fig. 3a). This vortex had a maximum velocity differential of around 40 m s^{-1}, and can be identified up through the 8° scan. In the short period of radar observations, the vortex progressed eastward along with the rear-flank gust front. The rear-flank gust front, however, was moving faster than the vortex, so it likely became embedded within the outflow and dissipated. The rear-flank gust front was located at the eastern edge of the hook echo (this was determined from identifying a wind shift in this region in the unanalyzed radar data; not shown). Note that no

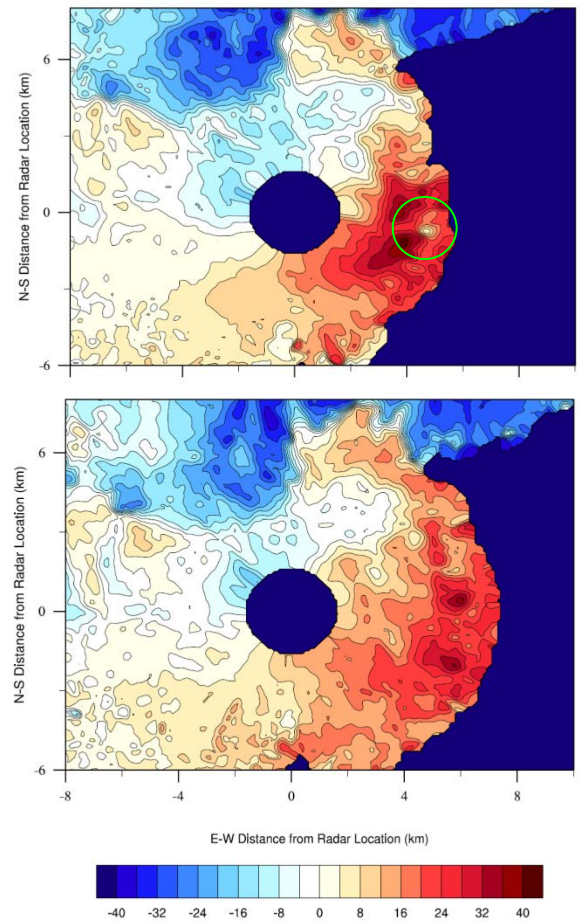

Figure 3: Objectively analyzed radial velocity fields (m s^{-1}) from DOW7 at (a) 2345:14 UTC and (b) 2347:43 UTC. Data are at 100 m above ground level (AGL) and the vortex is circled in (a).

objectively analyzed radar data are present east of this gust front owing to few scatterers within the inflow region of the storm (Fig. 4). There is a small appendage along with leading edge of the hook echo that is co-located with the vortex (Fig. 4). The vortex dissipated by the time the second volume scan began. No data are available on the development of this vortex, and it is too small to be detected by the WSR-88D radars, so any estimation of its lifespan or supposition of mechanisms that resulted in its formation would not be practical.

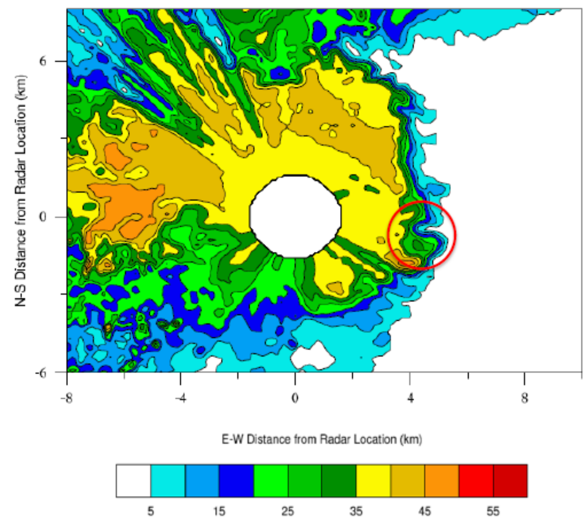

Figure 4: Objectively analyzed radar reflectivity factor (dBZ) from DOW7 at 2345:14 UTC. Data are at 100 m above ground level (AGL) and the vortex is circled.

4. Mobile Mesonet Observations

A mobile mesonet vehicle that was co-located with the DOW during this deployment recorded in situ observations of the thermodynamic environment and winds (Fig. 5). Wind and pressure data are not reliable while the mesonet was accelerating, so only data collected after the vehicle stopped at 2342 UTC were examined. The mobile mesonet recorded a 4°C drop in temperature as well as an increase in relative humidity as the rear-flank gust front progressed eastward and the vehicle became deeper embedded within the outflow (Fig. 5a). A pressure increase of over 2 mb in 60 seconds was observed as the vortex progressed east of the probe between 2342-2343 UTC (Fig. 5b). This sharp increase in pressure can likely be accredited to the buoyancy-driven pressure changes associated with the gust front passage, as well as the movement of the vortex away from the vehicle.

A peak wind gust of 23 m s^{-1} from the west was recorded just after 2342 UTC as the vortex passed just to the north of the vehicle (Fig. 5c). As the vortex moved away, the wind speed decreased to 5-10 m s^{-1} over the next three minutes (note that radar data were not available until 2345 UTC). This calming of the winds occurred simultaneously with a shift in the wind direction from westerly to north-northwesterly owing to the influence of the mesocyclonic circulation within the storm.

5. Conclusions and Future Work

The analysis of high-resolution Doppler radar observations and thermodynamic data of a vortex along the rear-flank gust front of a tornadic supercell presented herein exhibits interesting results. The velocity differential across this vortex was 40 m s^{-1}. Doppler radar observations of this vortex began just before its dissipation, however, so little can be said about its genesis. This vortex likely passed within 500 m of the radar and mobile mesonet around 2342 UTC, affording the collection of in situ thermodynamic and wind data prior to the initiation of radar observations.

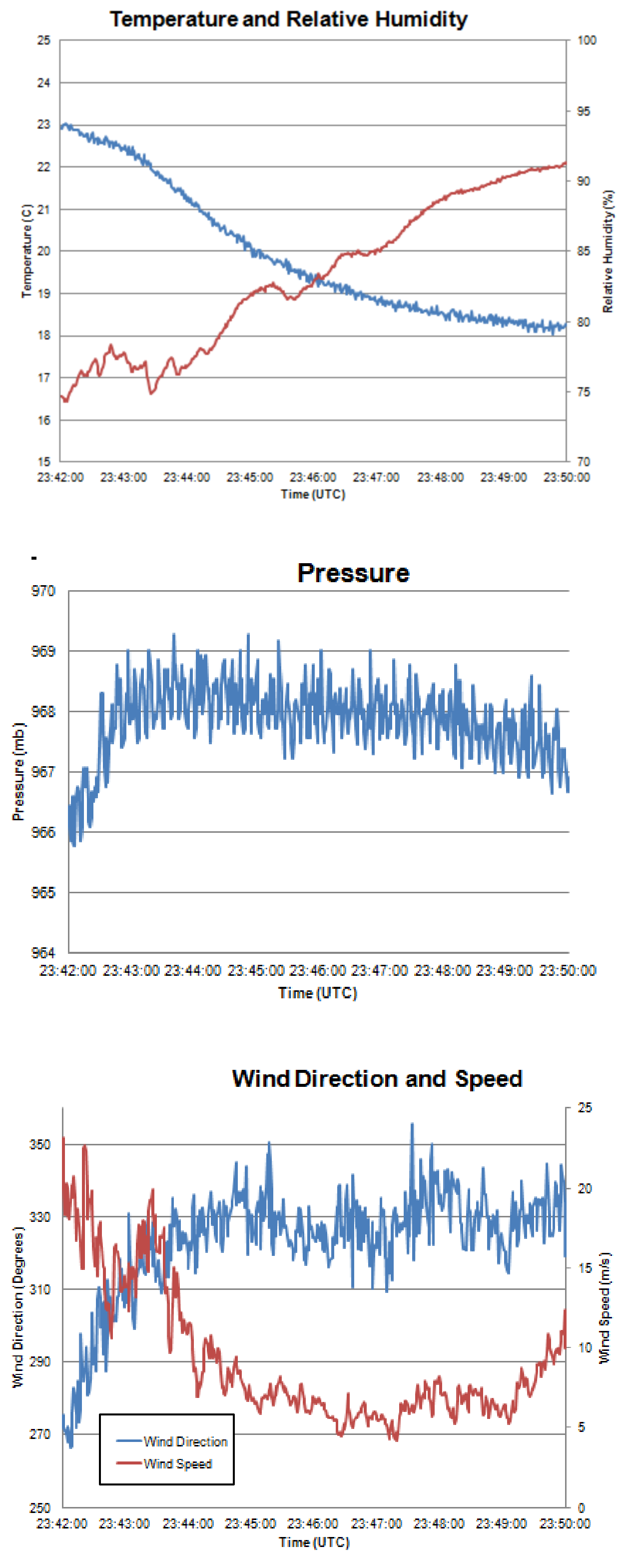

Figure 5: Time series of (a) Temperature (°C; blue) and relative humidity (%; red), (b) station pressure (hPa), and (c) wind direction (degrees; blue) and wind speed (m s^{-1}; red).

A rapid pressure increase, on the order of 2 mb in 60 seconds, was recorded by the mobile mesonet vehicle as the vortex pulled away from the mesonet, along with a maximum wind speed of 23 m s^{-1}.

In the future, further analysis of the thermodynamic data recorded by this mobile mesonet, as well as that from other mesonet vehicles will be conducted to obtain a better understanding of the thermodynamic environment around the vortex. Additional analysis of the radar data may also aid us in better understanding its structure and intensity, including how these parameters varied with altitude.

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