P.163 INTEGRATED OBSERVATIONS OF A NEAR-SURFACE BASED SUPERCELL LOCATED BEHIND A GUST FRONT

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1. INTRODUCTION

On 11 April 2013, a long-lived supercell traveled from east-central Mississippi to north-central Alabama. After producing a large, long-tracked tornado near the Mississippi-Alabama border, this supercell merged with a quasi-linear convective system (QLCS) that had formed to the west. Even after the merger, the supercell maintain a distinct identity, producing four additional tornadoes across northwestern Alabama.

The supercell was slowly weakening as it moved into the Tennessee Valley in north-central Alabama and the gust front of the QLCS propagated under the supercell mesocyclone. As the supercell moved into the Huntsville area, it passed over an array of in-situ and remote sensing platforms operated by the University of Alabama in Huntsville (UAH) and the National Weather Service (NWS). In this paper, these instruments are used to show that, despite being undercut by the QLCS gust front, the supercell still maintained near-surface inflow into the mesocyclone.

2. DATA COLLECTION AND METHODOLOGY

The University of Alabama in Huntsville's (UAH's) Severe Weather Institute and Radar & Lightning Laboratories (SWIRLL) operates within a high-density in-situ and remote sensing observational domain across northern Alabama. Some of the remote sensing platforms include UAH and WHNT's C-band Advanced Radar for Meteorological and Observational Research (ARMOR; Peterson et al. 2005), operating in a three-tilt RAIN-1 scheme, providing data from 0.7°, 1.3°, and 2.0° tilts with a completion time of 66 to 69 seconds per complete RAIN-1 scan; the Weather Surveillance Radar-88 Doppler (WSR-88D) located at Hytop, Alabama, (KHTX), and the UAH Mobile Integrated Profiling System (MIPS; Karan and Knupp 2006). MIPS features a vertically-pointed X-band radar (XPR), a 915-MHz Doppler wind profiler, a 12-channel microwave profiling radiometer (MPR), and a lidar ceilometer (Fig. 1). In addition to the remote sensing platforms, a variety of in-situ observational platforms exist across the Tennessee Valley. A pair of automatic surface observing stations (ASOSs) are located at Huntsville (KHSV) and Decatur (KDCU), each collecting at 1-min. temporal resolution. UAH operates a 5-sec. resolution observation site on the UAH campus on the west side of Huntsville. This observation site is used to provide surface data in this paper.

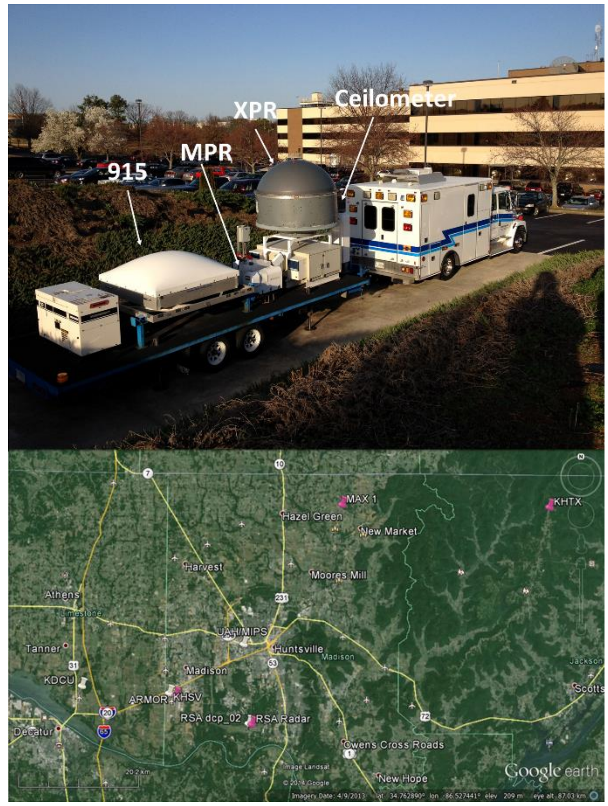

Figure 1: Picture of MIPS (top) with labeled 915-MHz Doppler wind profiler (915), multi-channel profiling radiometer (MPR), X-band Doppler profiling radar (XPR), and a ceilometer, along with a map of the northern Alabama observational array (bottom).

Once collected, the ARMOR data were corrected for attenuation using the methodology from Bringi et al. (2001). Velocity data were dealiased using NCAR's SOLOii software (Oye et al. 1995). A velocity-azimuth display (VAD; Browning and Wexler 1968) analysis of divergence was performed within the cold pool of the 11 April 2013 QLCS and a control case on 21 February 2014. This control case is used to verify the methodology employed in analyzing the 11 April 2013 case.

3. PROFILING OF THE SUPERCELL STRUCTURE

Around 1600 UTC, a supercell formed ahead of a developing squall line in eastern Mississippi. At 1633 UTC, a large (1200-m wide), long-tracked (109.8 km) EF3 tornado formed in Kemper County, Mississippi, eventually moving across Noxubee County, Mississippi,

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and into Pickens County, Alabama (NCDC 2014). As the EF3 tornado dissipated, the supercell was absorbed into the QLCS as it progressed eastward. Instead of losing its identity, the supercell maintained its structure embedded in the QLCS and produced 4 additional tornadoes across Walker and Winston Counties in northwestern Alabama (NCDC 2014). After moving into the Tennessee Valley, the gust front from the QLCS finally undercut the gust front, and the supercell began to slowly weaken (Fig. 1).

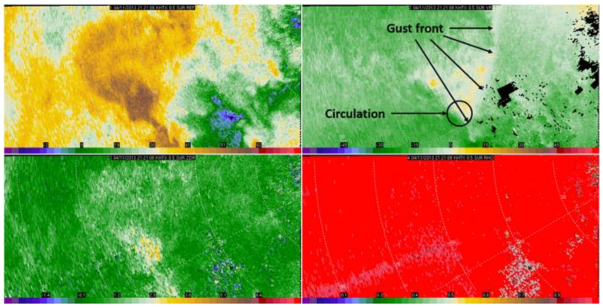

Figure 2: Four-panel plan position indicator (PPI) display of equivalent radar reflectivity factor (Z_e; upper-left), dealiased base radial velocity (V_r; lower-top), attenuation-corrected differential reflectivity (Z_{DR}; lower-left), and cross-polar correlation coefficient (ρ_{hv}, lower-right), for the ARMOR 0.7° sweep at 21:21:08 UTC 11 April 2013, showing the circulation behind the gust front.

The supercell propagated direction over Huntsville International Airport (KHSV), where ARMOR is located, and the UAH campus, where MIPS was located. As mentioned in Section 1, a 5-sec. surface station is also located on the UAH campus. Figure 3 illustrates the surface observations from UAH during the passage of the QLCS and supercell. The most notable observation is the evolution of the pressure trace, with significant differs from the typical QLCS pressure pattern described in Fujita (1955, 1981). Instead of the hydrostatic pressure rise associated with the mesohigh as the cold pool propagates over the station, the pressure begins to drop coincident with the temperature drop and drops 1.25 hPa for 11 min. After the pressure falls subside, a rapid increase in pressure of 3.5 hPa over a 5-min. period is observed. This pressure fall implies that the supercell mesocyclone was still impacting the surface layer, despite being embedded within the cold pool.

To verify the impact of the updraft within the cold pool, data from the XPR, 915-MHz Doppler wind profiler, and ARMOR were utilized. Figure 4 shows the 915-MHz wind profiler and XPR observations. Both instruments clearly depict the supercell updraft, with a peak vertical particle velocity (W) value of 11.47 m s^{-1} measured with the wind profiler. The XPR clearly depicts the 0.8-km-deep cold pool ahead of the updraft, with the updraft apparently rooted within the cold pool, as was anticipated based off of the surface observations at UAH. To further confirm this observation, a VAD profile of divergence was constructed from the 2.0° sweep at 21:17:01 UTC, with a

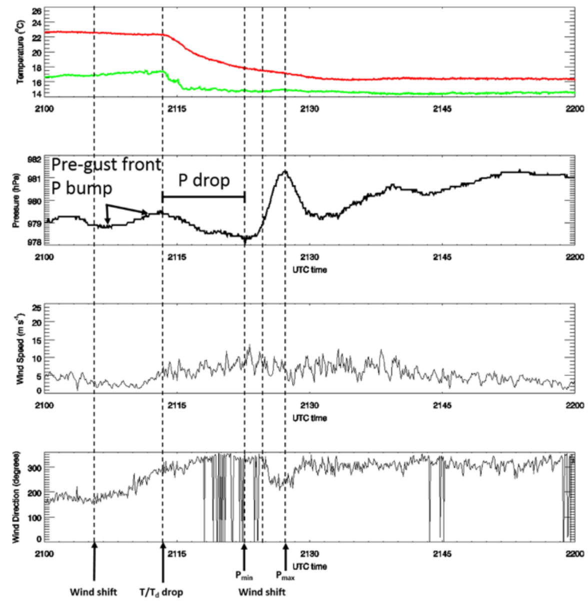

Figure 3: Time series of temperature (T) and dewpoint (T_d), pressure (P), wind speed (m s^{-1}), and wind direction (°) at UAH from 2100-2200 UTC 11 April 2013. Note the pressure drop of ~1.25 hPa after the gust front passage, along with the wind direction changes as the circulation passes overhead.

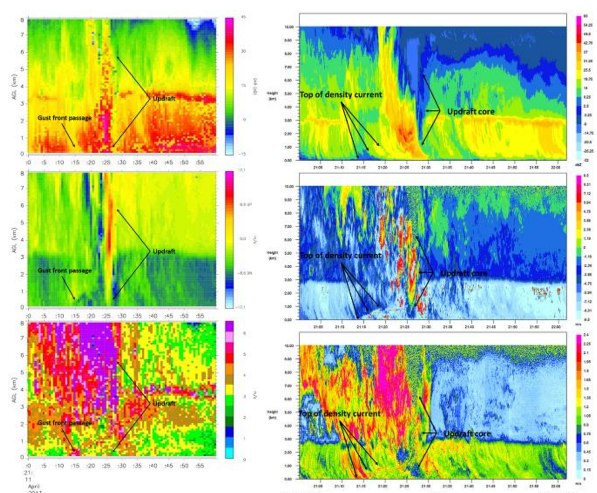

Figure 4: Time-height plots of signal-to-noise ratio (SNR; upper-left)/Z_e (upper-right), vertical particle velocity (W, middle), and spectrum width (bottom) from the MIPS 915-MHz Doppler wind profiler (left) and XPR (right) for 2100-2200 UTC 11 April 2013. The cold pool can be seen in V_r and spectrum width and is approximately 0.8 km deep as the mesocyclone moves over MIPS.

set diameter of 7.5 km to avoid sampling the gust front. The plan position indicator (PPI) plot clearly shows convergence along the zero isodop, and the VAD profile shows convergence within the cold pool (cold pool depth of 0.8 km), which is the opposite of the divergence expected with a mesohigh (Fig. 5). The synthesis of the surface observations, MIPS data, and ARMOR data shows that the supercell updraft was still rooted near the surface, despite being undercut by the QLCS cold pool.

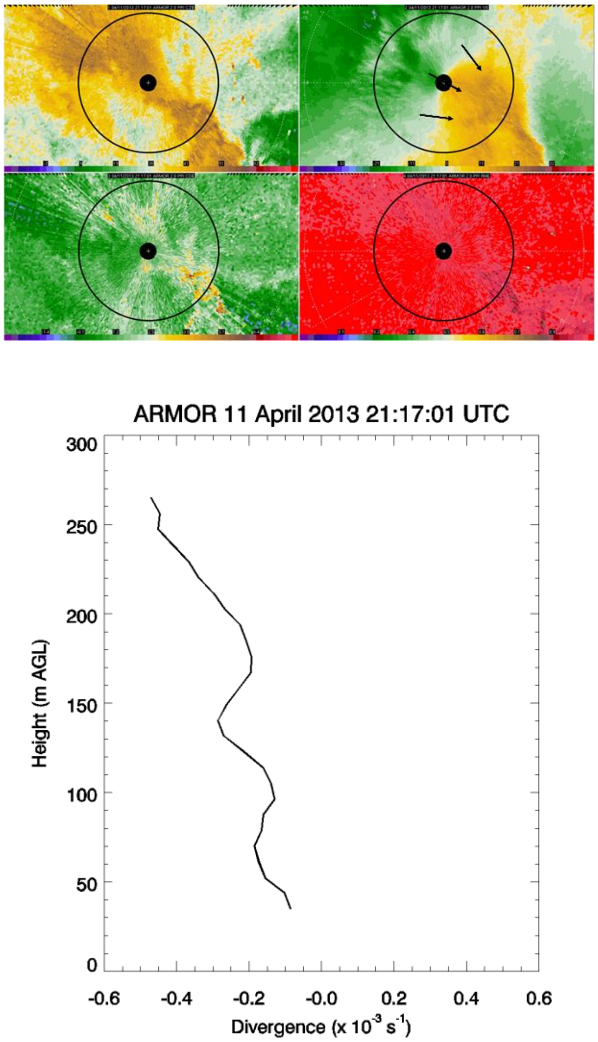

Figure 5: Four-panel PPI display of Z_e (upper-left), V_r (upper-right), Z_{DR} (middle-left), and ρ_{hv}, (middle-right), along with a velocity-azimuth display (VAD) derived vertical profile of divergence for the ARMOR 2.0° sweep at 21:17:01 UTC 11 April 2013. The black circle on the PPIs shows the 7.5-km radius of the VAD analysis domain. The V_r PPI and VAD divergence profile indicate near-surface convergence underneath the supercell updraft, despite evidence from MIPS-XPR and the UAH surface observations that the gust front from the QLCS had propagated ahead of the updraft.

4. CONTROL CASE: 21 FEBRUARY 2014 QLCS

To verify the validity of analyzing the 11 April 2013 case using the UAH surface data, MIPS data, and ARMOR data, a control case was similarly analyzed. The control case for this paper occurred on 20-21 February 2014. The QLCS that impacted northern Alabama during this event produced widespread wind damage and 8 tornadoes (NCDC 2014). When the QLCS passed over UAH, there were no mesovortices or embedded supercells present in the vicinity. Similar to the 11 April 2013 case, a VAD analysis was performed within the cold pool of the 21 February 2014 QLCS. For this control case, the PPI image clearly shows divergence over the radar, and the VAD divergence profile confirms divergence in the surface layer (Fig. 6).

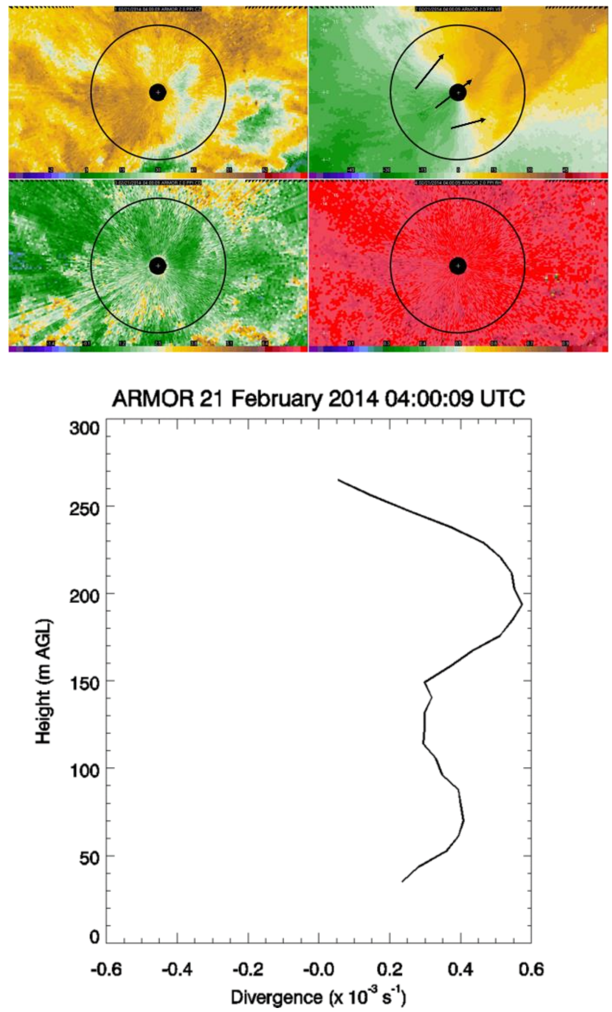

Figure 6: As in Fig. 5 for the ARMOR 2.0° sweep at 04:00:09 UTC 21 February 2014, used as a control case for showing divergence in the cold pool using a VAD profile. The V_r PPI and VAD divergence profile indicate the typical near-surface divergence associated with the cold pool of the QLCS. Divergence decreases rapidly above 200 m AGL due to the domain catching a small portion of the convergence along the gust front.

The surface observations from UAH also support the more typical structure of the 21 February 2014 QLCS, without a pressure drop coincident with the temperature drop (Fig. 7). Finally, the 915-MHz wind profiler and XPR observations from MIPS also show a typical QLCS structure, with a leading-edge updraft and substantial cold pool passage observed (Fig. 8).

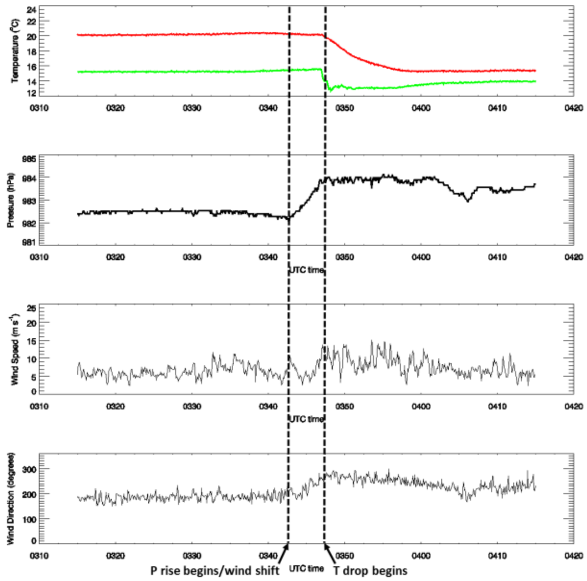

Figure 7: As in Fig. 3 from 0315-0415 UTC during the 21 February 2014 control case.

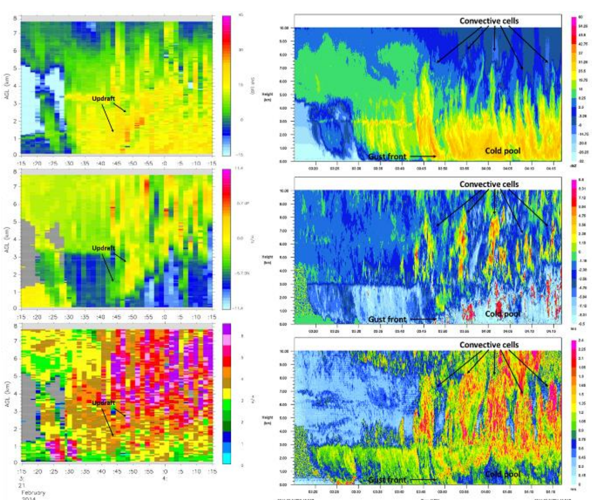

Figure 8: As in Fig. 4 for 0315-0415 UTC during the 21 February 2014 control case.

5. DISCUSSION

This paper presents the rare profiling observations of a supercell undercut by a gust front with high-resolution remote sensing and in-situ platforms. The integration of these platforms allowed for the diagnosis of the updraft still being rooted near the surface despite being undercut by the cold pool. The control case of 21 February 2014 affirmed the use of VAD analysis of divergence in a typical QLCS cold pool to add confidence of the convergence observed in the 11 April 2013 case. This case highlights the value of a high-resolution network of both remote sensing and in-situ observations in the observation of an event rarely observed in such fine detail.

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REFERENCES

Bringi, V. N., T. D. Keenan, and V. Chandrasekar, 2001: Correcting C-Band Radar Reflectivity and Differential Reflectivity Data for Rain Attenuation: A Self-Consistent Method With Constraints. *IEEE Transactions on Geoscience and Remote Sensing*, **39**, 1906-1915.

Browning, K. A., R. Wexler, 1968: The Determination of Kinematic Properties of a Wind Field Using Doppler Radar. *J. Appl. Meteor.*, **7**, 105–113.

Fujita, T., 1955: Results of Detailed Synoptic Studies of Squall Lines. *Tellus*, **7**, 405-436.

____, 1981: Tornadoes and Downbursts in the Context of Generalized Planetary Scales. *J. Atmos. Sci.*, **38**, 1511–1534.

Karan, H., and K. Knupp, 2006: Mobile Integrated Profiler System (MIPS) Observations of Low-Level Convergent Boundaries during IHOP. *Mon. Wea. Rev.*, **134**, 92–112.

National Climate Data Center, cited 2014: Storm Events Database. [Available online at http://www.ncdc.noaa.gov/stormevents/]

Oye, R., C. Mueller, and S. Smith, 1995: Software for radar translation, visualization, editing, and interpolation. Preprints, *27th Conf. on Radar Meteorology*, Vail, CO, Amer. Meteor. Soc., 359-361.

Peterson, W. A., K. Knupp, J. Walters, W. Deierling, M. Gauthier, B. Dolan, J. P. Dice, D. Satterfield, C. Davis, R. Blakeslee, S. Goodman, S. Podgorny, J. Hall, M. Budge, and A. Wooten, 2005: The UAH-NSSTC/WHNT ARMOR C-band Dual-Polarimetric Radar: A unique collaboration in research, education, and technology transfer. Preprints, *32nd Conference on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.