Observations of Z_{DR} Columns in Supercells in 2019 by a Mobile, Dual-Polarized, Phased-Array Radar

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In previous research, it has been hypothesized that measurable properties of polarimetric radar features may be linked to tornadogenesis.

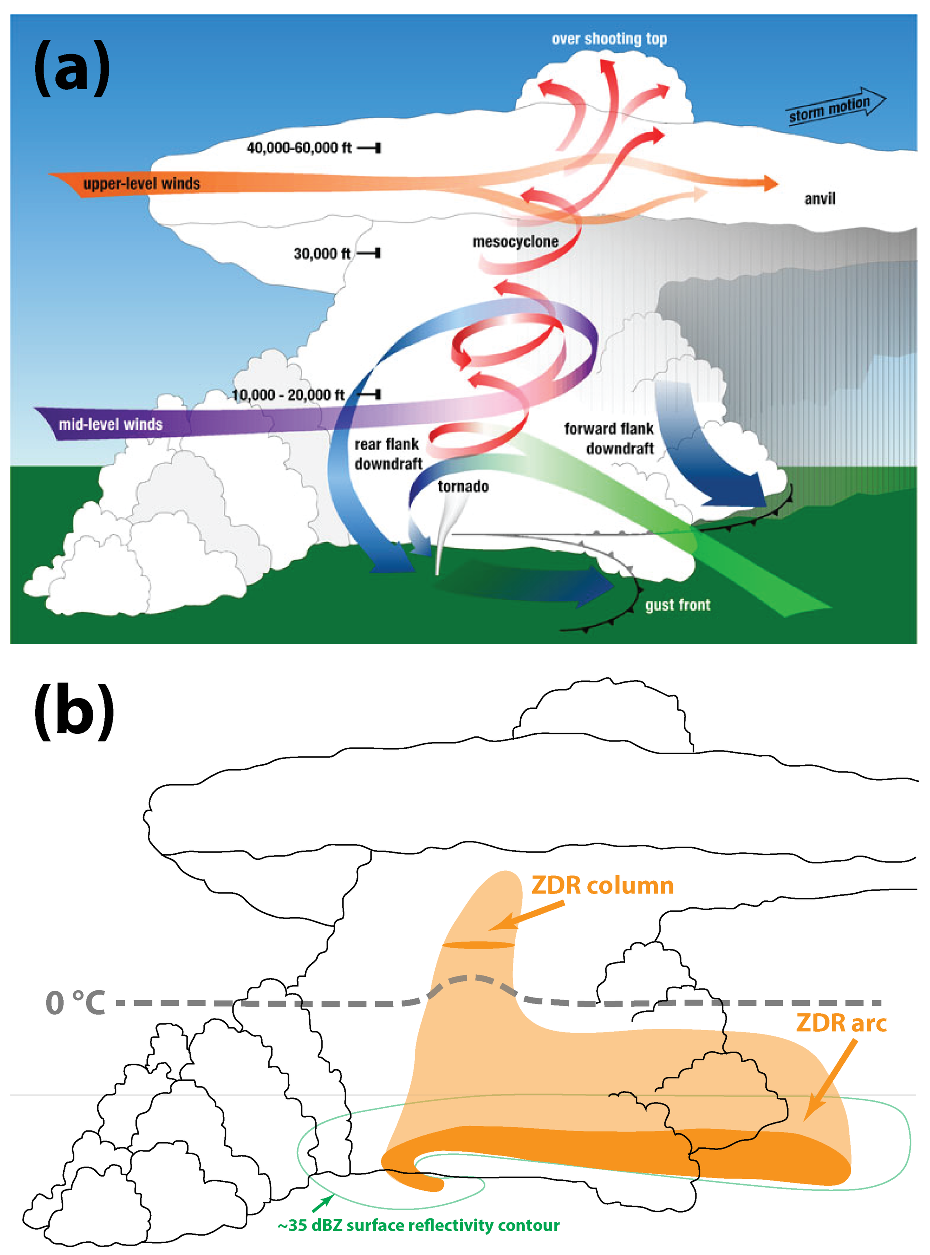

Figure 1:(a) Schematic diagram (courtesy of NOAA) of a cyclonically rotating, right-moving supercell thunderstorm in the Northern Hemisphere as viewed from the right with respect to storm motion. Annotated features of interest include the mesocyclone (rotating updraft) and inflow sector (green arrow directed into the storm at low levels). (b) As in (a), but showing the relative positions of the ZDR arc and column within the storm. The environmental freezing level is denoted by a gray-dashed line. The orange shading encloses a volume of space where Z_{DR} would be expected to exceed ~ 3 dB. Darker orange shading highlights horizontal cross sections through this volume near the surface (where a polarimetric radar would observe a Z_{DR} arc) and above the freezing level (where a polarimetric radar would observe the Z_{DR} column). The thin green line encloses the surface 35 dBZ reflectivity contour.

- We seek to quantify these relationships (if any exist) and assess their prognostic utility.
- For the present study, we focus on the evolution of Z_{DR} columns (Fig. 1) in supercells in the 5 min prior to tornadogenesis or tornadogenesis failure. These polarimetric radar features evolve on time scales of 1–2 min, and are poorly resolved by the WSR-88D VCPs, which only resample the mid-levels (2–6 km) every 5–6 min (Kuster et al., 2019). Additionally, Z_{DR} columns are poorly sampled in the vertical by WSR-88Ds at medium to long range ($\geq$ 10 km) (Snyder et al., 2015).
- Because of the rapid evolution of Z_{DR} arcs and columns, rapid, dual-pol, volume scanning is essential. Platforms such as RaXPol (Pazmany et al., 2013) are designed to rapidly collect DP data in severe storms, but past field campaigns using this radar have tended to concentrate on low altitudes and may not capture the entire depth of the Z_{DR} column when volume scans are used. Another option is dual pol phased array radar (DPPAR). Most DPPARs are currently in development or suffer from relatively wide beam width ($\geq$2.0°) (Bluestein et al., 2014).

University of Massachusetts Low-Power Radar (UMass LPR) is a mobile, dual-polarized, phased array radar.

- In this project, UMass LPR (Fig. 2) was mobilized for severe storms research by MIRSL students and faculty and fielded by EAPS students and faculty.

Figure 2:Purdue students enrolled in the course 'Severe Storms Field Work' practice deploying UMass LPR in May 2019. Photo by the first author.

Table 1:Selected parameters of the UMass LPR.

Parameter	Value
Frequency	9.6 GHz
Half-power beam width	1.9° az., 2.1° el.
Polarization	Dual linear
Polarization scheme	ATAR
Max. unambiguous range	40 km
Max. unambiguous velocity	18.8 m s^{-1}
Range resolution	60 m
Azimuthal sector	90°
Elevation angles	0° - 30° every 1°
Volume update time	$\sim$ 60–90 s
Antenna elements	2,580 (20 tiles 128 elements)

During 2019, six supercells were sampled, bringing our total number of sampled supercells to 10.

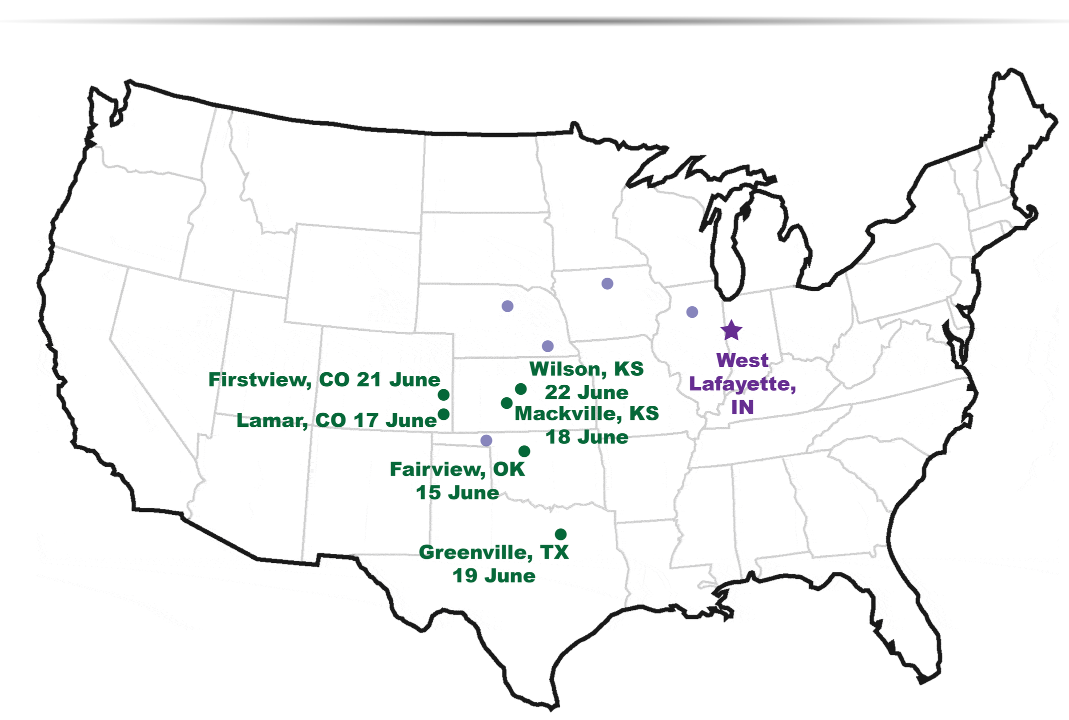

Figure 3:Map of UMass LPR deployments in 2019 for storm observations (green dots) relative to the location of West Lafayette, Indiana (purple star). Deployments sites from 2018 are also plotted as unlabeled light blue dots (Tanamachi et al. 2018) highlighting the geographic extent of deployments during this project.

Table 2:Deployment dates, locations, and brief descriptions of UMass LPR deployments in 2019.

Date	Time (UTC)	Location	Description
24 May	1330–1345	West Lafayette, IN	Elevated supercell
15 June	2000–2030 and 0308–0320	Fairview, OK	Merging supercells
17 June	2310–2335	Lamar, CO	Isolated supercell
18 June	2010–2050	Macksville, KS	Decaying supercell
19 June	2225–2238	Campbell, TX	Splitting supercell
21 June	0200–0216	Firstview, CO	Receding hail storm
22 June	2108–2225	Wilson, KS	Merging supercells

The 19 June 2019 Campbell/Greensville, TX deployment captured a supercell that inflicted severe straight-line wind damage.

- On 19 June 2019, the Purdue and MIRSL teams deployed UMass LPR near Campbell, Texas, to sample a powerful supercell bearing down on Greenville, Texas (Fig. 4). As it approached the team, the supercell began to deviate to the right of its previous track, bringing the projected path of the hook directly over UMass LPR and forcing the crew to beat a hasty retreat to the south. This deployment lasted about 15 minutes.

Figure 4:UMass LPR deployed near Campbell, Texas, scanning an approaching supercell on 19 June 2019. This supercell caused extensive straight-line wind damage in nearby Greenville, Texas, but no tornado was documented. The view is toward the west. Photo by the first author.

- A rotating supercell with a hook echo was observed in the low-level reflectivity and velocity data (Fig. 5).
- This supercell was nontornadic, despite its occurrence in an environment with high surface-based CAPE ($\geq$ 7,400 J kg^{-1}), high 0–6 km bulk shear (42 kt), and relatively high 0–1 km storm-relative helicity (151 m^2 s^{-2}; not shown).

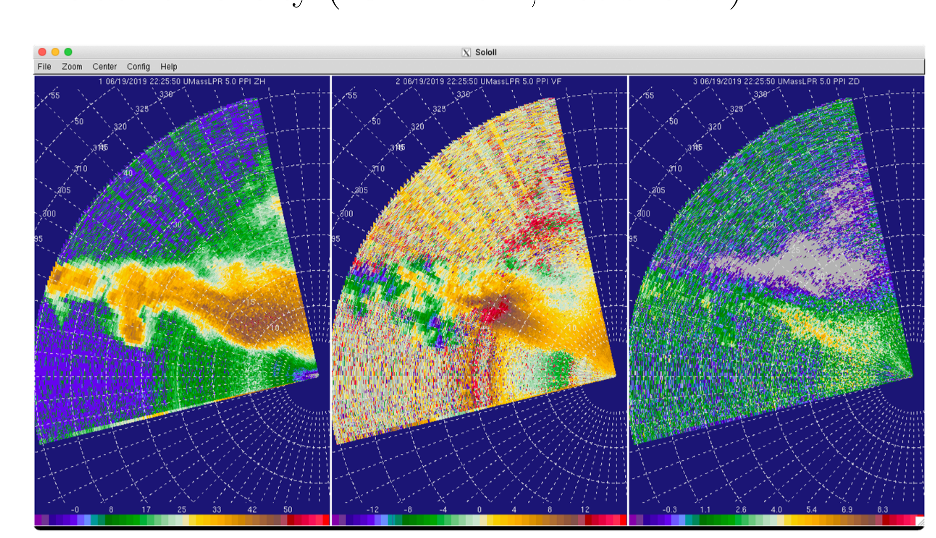

Figure 5:UMass LPR observations of (a) reflectivity (in dBZ), (b) Doppler velocity (in m s^{-1}), and (c) Z_{DR} in the Greenville, Texas supercell. These data were collected at an elevation angle of 5.0°, at 2226 UTC. Range rings (azimuth spokes) are plotted every 5 km (10°). While the Z_{DR} arc can be seen east of the hook echo, but the Z_{DR} column cannot because the PPI is plotted below the environmental freezing label.

Rapid, volumetric scanning allows for identification and tracking of Z_{DR} columns.

- Additionally, the Z_{DR} column could be seen splitting in volumetric renderings of the UMass LPR data (6) just as the supercell appeared to split in reflectivity from the KFWD WSR-88D (not shown).

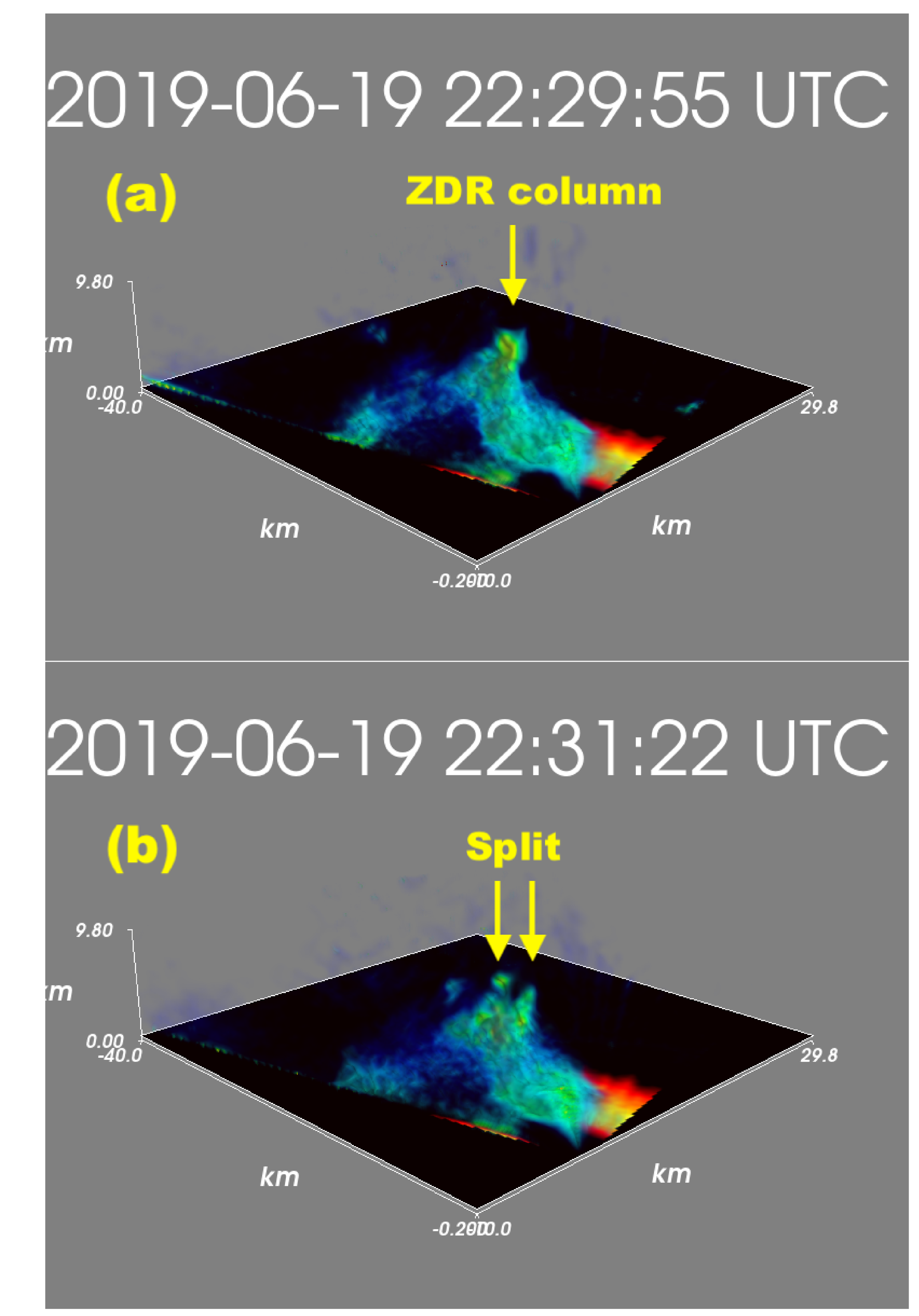

Figure 6:Volumetric rendering of UMass LPR observations of Z_{DR} in the Greenville, Texas supercell at (a) 2230 UTC and (b) 2231 UTC. In the 90 seconds between these two volumes, the Z_{DR} column split into two.

- Presently, efforts are underway to objectively identify and track Z_{DR} columns in the data collected by UMass LPR and by other, rapidly-scanned, X-band polarimetric radars during previous projects (Dalman et al., 2018).
- In a related presentation at this conference, (Heberling et al., 2020, EIPT 9B.2) will discuss Z_{DR} calibration of UMass LPR.

Acknowledgements

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References

Bluestein, H. B., R. M. Rauber, D. W. Burgess, B. Albrecht, S. M. Ellis, Y. P. Richardson, D. P. Jorgensen, S. J. Frasier, P. Chilson, R. D. Palmer, and et al., 2014: Radar in atmospheric sciences and related research: Current systems, emerging technology, and future needs. *Bulletin of the American Meteorological Society*, **95 (12)**, 1850–1861, doi:10.1175/BAMS-D-13-00079.1.

Dalman, D. M., R. L. Tanamachi, P. E. Saunders, B. L. Cheong, D. Bodine, H. B. Bluestein, and Z. B. Wienhoff, 2018: Cataloging rapid scan observations of ZDR columns in supercells. *29th Conf. on Severe Local Storms*, American Meteorological Society, P89–P89, URL `https://ams.confex.com/ams/29SLS/webprogram/Paper348610.html`.

Heberling, W., S. J. Frasier, C. Wolsieffer, and J. Adam, 2020: X-Band Phased-Array Weather-Radar Polarimetry Testbed: Tilted Aperture Bias Correction Results. American Meteorological Society, 9B.2, URL `https://ams.confex.com/ams/2020Annual/meetingapp.cgi/Paper/366423`.

Kuster, C. M., J. C. Snyder, T. J. Schuur, T. T. Lindley, P. L. Heinselman, J. C. Furtado, J. W. Brogden, and R. Toomey, 2019: Rapid-update radar observations of ZDR column depth and its use in the warning decision process. *Weather and Forecasting*, **34 (4)**, 1173–1188, doi:10.1175/WAF-D-19-0024.1.

Pazmany, A. L., J. B. Mead, H. B. Bluestein, J. C. Snyder, and J. B. Houser, 2013: A mobile, rapid-scanning, x-band, polarimetric, (raxpol) doppler-radar system. *Journal of Atmospheric and Oceanic Technology*, **30 (7)**, 1398–1413, doi:10.1175/jtech-d-12-00166.1.

Snyder, J. C., A. V. Ryzhkov, M. R. Kumjian, and J. Picca, 2015: A ZDR column detection algorithm to examine convective storm updrafts. *Weather and Forecasting*, **30 (6)**, 1819–1844, doi:10.1175/WAF-D-15-0068.1.