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AN ANALYSIS OF TERMINAL DOPPLER WEATHER AND PHASED ARRAY RADAR VELOCITY AND REFLECTIVITY SIGNATURES OF THE 20 MAY 2013, MOORE, OKLAHOMA TORNADO

Vincent T. Wood[1], Pamela L. Heinselman[1], Rodger A. Brown[1],
David L. Priegnitz[2], Donald W. Burgess[2], and Christopher D. Karstens[2]
[1]NOAA/OAR/National Severe Storms Laboratory, Norman, Oklahoma
[2]Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), University of Oklahoma, Norman, Oklahoma

INTRODUCTION

- On 20 May 2013, a supercell thunderstorm in central Oklahoma produced a tornado that developed west of Moore, rapidly intensified and attained EF4 intensity 3 minutes later, and eventually reached EF5 intensity (Fig. 1).
- The deadly tornado tore through a heavily populated section of Moore, killing 24 people and injuring scores of others.

OBJECTIVE

- The objective of the study is to analyze and compare the detailed high-resolution Doppler velocity and reflectivity signatures in and around the tornado as viewed simultaneously from two different radars -- Oklahoma City-Terminal Doppler Weather Radar (TOKC) located south of Moore and Phased Array Radar (PAR) located in Norman (Fig. 1).

TABLE 1. Radar Operating Characteristics

	TOKC	PAR
Pulse Depth (m)	150	239
Wavelength (cm)	5	9.4
Transmitted Peak Power (kW)	250	750
Half-power Beamwidth (°)	0.55	1.5→2.1*
Effective Beamwidth (°)	1.2	1.5→2.1*
Nyquist Velocity (m s^{-1})	16–22	29
Transmitter Frequency	C-Band	S-Band
Azimuthal Gate Spacing (°)	1.0	0.75→1.06

**This beamwidth gradually increases to 2.1° at a 45° angle from boresight.*

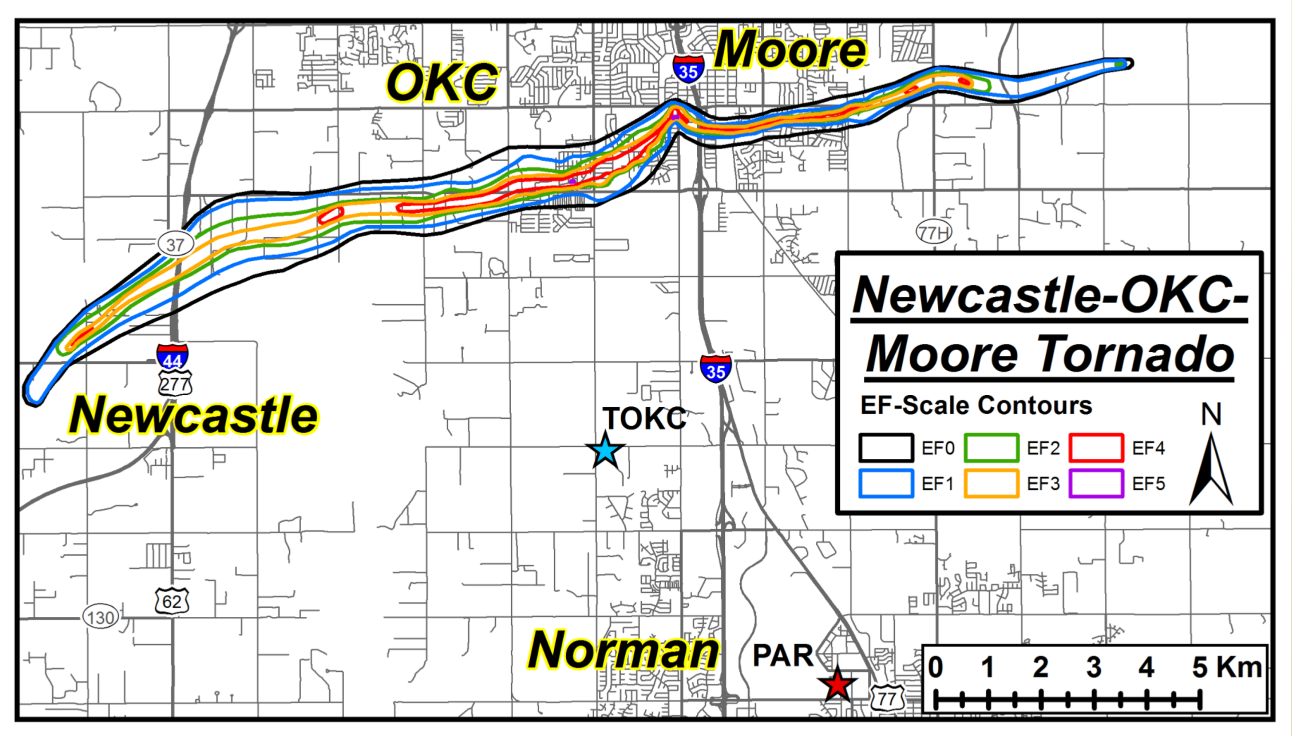
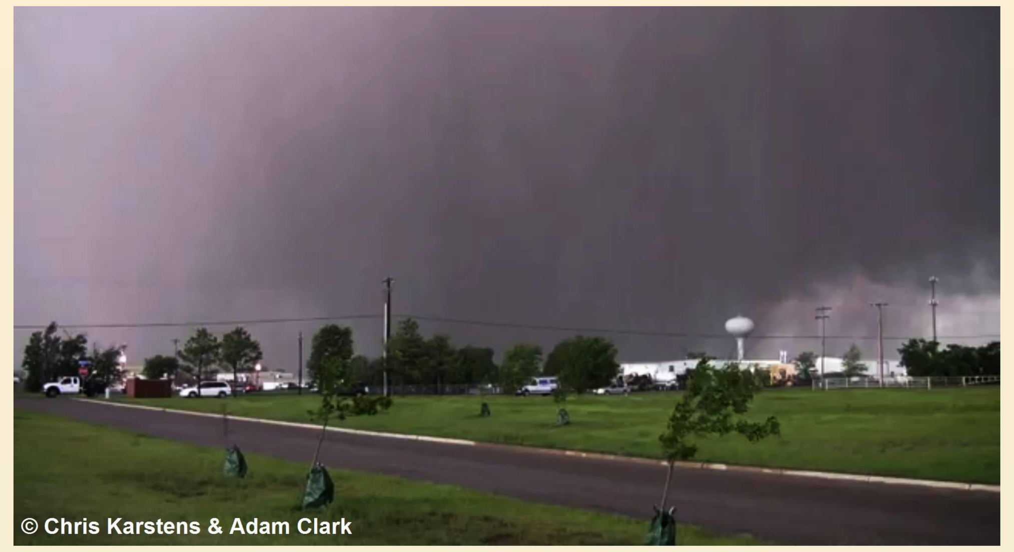


FIG. 1. Damage survey compiled by National Weather Center teams for the Moore, Oklahoma tornado of 20 May 2013. The EF-ratings along the damage path are contoured according to different colors. The tornado existed for about 40 minutes over a 23-km path. The damage path was up to 1.7 km wide.

2003 UTC

2017 UTC

2019-2020 UTC



2003 UTC 2009 UTC 2017 UTC 2025 UTC 2035 UTC

PAR

TOKC

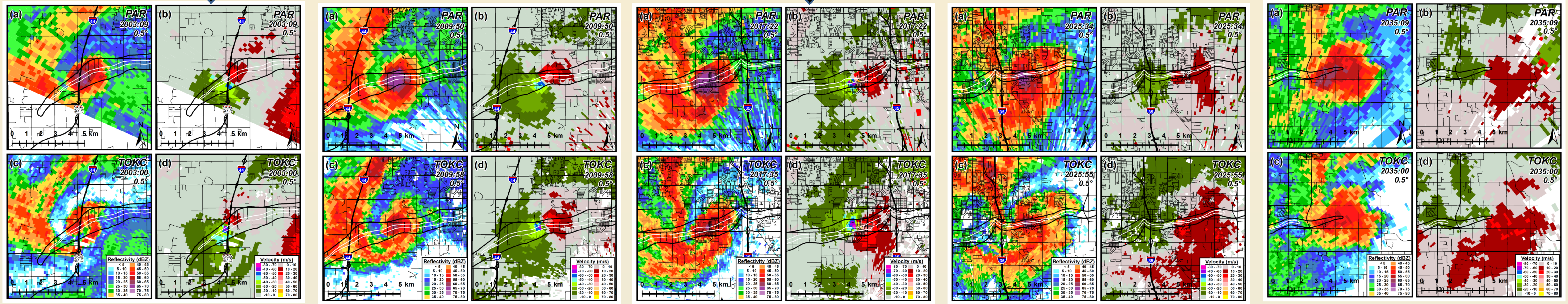


FIG. 2. Evolution of ground-relative Doppler velocity and reflectivity fields associated with the Moore tornado as seen simultaneously from PAR and TOKC (10-km X 10-km panels) at 0.5° elevation angle. The EF0 (black) and EF3 (white) ratings along the damage path are contoured. The slight misalignments between the Doppler velocity measurements and the damage path apparently are due to slight ranging errors associated with the radars.

2003 UTC 2009 UTC 2017 UTC 2025 UTC 2035 UTC

PAR

TOKC

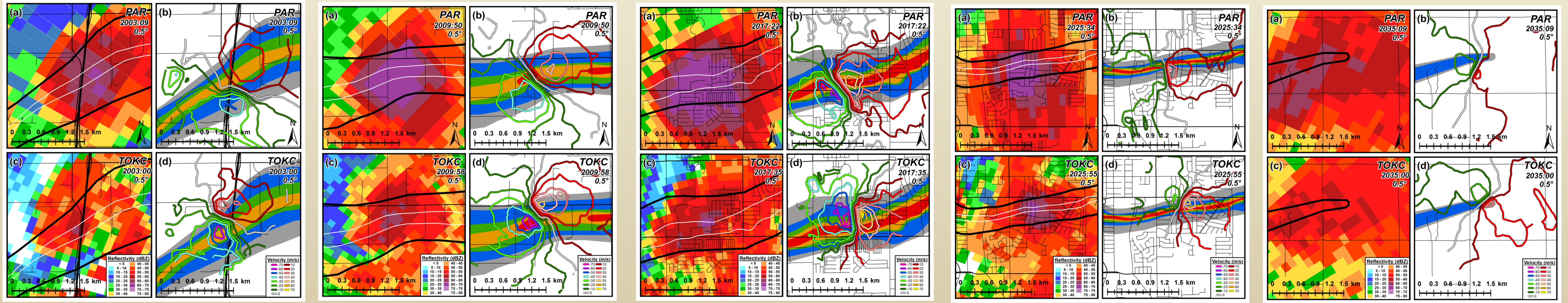


FIG. 3. Evolution of (a) and (c) radar reflectivity and (b) and (d) ground-relative Doppler velocity fields associated with the Moore tornado as seen from PAR and TOKC (3-km X 3-km panels) at 0.5° elevation angle. In (a) and (c), the EF0 (black) and EF3 (white) ratings along the damage path are contoured and superimposed on reflectivity fields. In (b) and (d), colored Doppler velocity contours are superimposed with the EF-ratings along the damage path.

TOKC (PAR)						
Time [hhmm:ss]	R_C [km]	Z_C [m, AGL]	BW_E [°, m]	BW_V [°, m]	V_{ROT} [m s^{-1}]	CD [m]
2003:00 (2003:09)	9.08 (14.40)	83 (137)	1.2, 190 (1.87, 471)	0.55, 87 (1.50, 471)	53 (40)	578 (948)
2009:58 (2009:50)	6.83 (12.70)	61 (120)	1.2, 143 (1.51, 334)	0.55, 66 (1.50, 334)	68 (48)	394 (595)
2017:35 (2017:22)	5.40 (10.80)	48 (101)	1.2, 113 (1.50, 283)	0.55, 52 (1.50, 283)	75 (62)	293 (430)
2025:55 (2025:34)	7.35 (10.50)	67 (98)	1.2, 154 (1.51, 276)	0.55, 71 (1.50, 276)	46 (37)	261 (210*)
2035:00 (2035:09)	12.23 (12.49)	116 (118)	1.2, 256 (1.51, 329)	0.55, 117 (1.50, 329)	31 (25)	266* (328*)

TABLE 2. Near-synchronous times, rotational velocity (V_{ROT}), core diameter (CD), range (R_C) and height (Z_C) to the Doppler vortex signature center, effective beamwidth (BW_E), vertical beamwidth (BW_V) as calculated from TOKC and PAR at 0.5° elevation angle. Note that the parenthesis refers to the PAR data. The asterisk in the CD column indicates that the radar beam is wider than the tornado.

RESULTS

- For data editing, we used the Solo3 software.
- TOKC has finer resolution because it is up to half the distance to the tornado compared to PAR and its pulse depth and beamwidth (especially vertical) are smaller.
- Most Doppler velocity peaks are not at the same range from TOKC and PAR because target motion in the tornado vortex is slightly divergent, resulting from debris centrifuging.
- TOKC and PAR measured strongest rotational velocities exceeding 70 and 60 m s^{-1}, respectively, in the lowest 50 –100 m AGL when the tornado was closest to the TOKC and PAR at 2017 UTC -- at a time when the tornado was intense.

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Contact: Vincent.Wood@noaa.gov