High-Resolution Analyses of Tornadogenesis in the 31 May 2013 El Reno, Oklahoma Supercell

Patrick S. Skinner[1,2], Louis J. Wicker[2], Howard B. Bluestein[3], Jeffrey C. Snyder[1,2], and Kyle Thiem[3]
[1] - Cooperative Institute for Mesoscale Meteorological Studies/The University of Oklahoma;
[2] - NOAA/OAR/National Severe Storms Laboratory; [3] - The University of Oklahoma

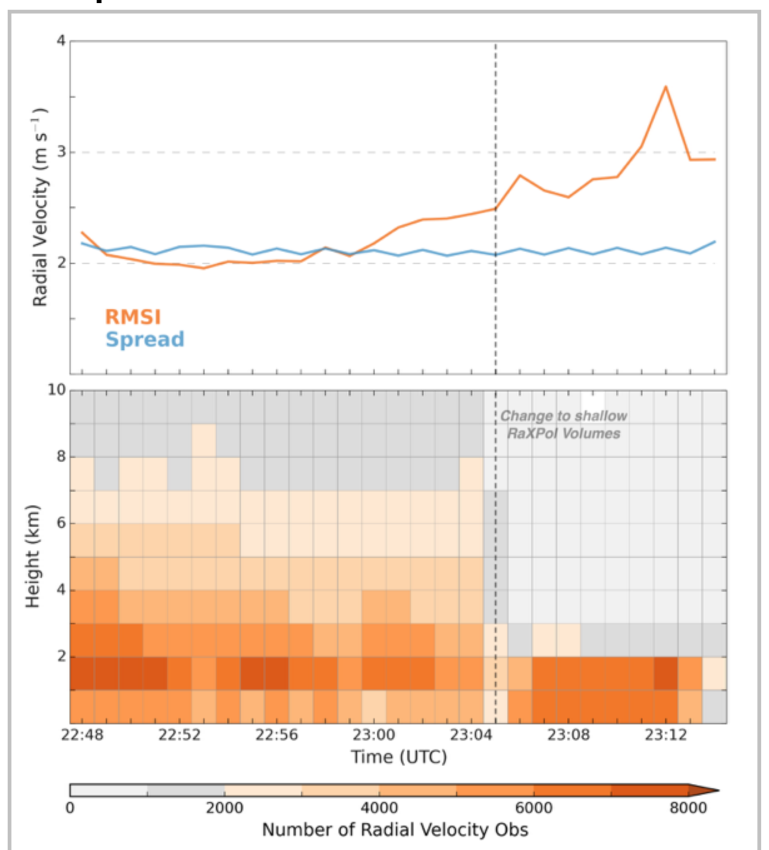
Cooperative Institute for Mesoscale Meteorological Studies

Motivation

- The short spatial and temporal scales of supercell thunderstorms make coordinated dual-Doppler deployments of mobile radars difficult
- As a result, retrieval of the atmospheric state through EnKF-based assimilation of single-Doppler radar data has emerged as a valuable analysis tool (Marquis et al. 2012; Tanamachi et al. 2013; Skinner et al. 2015)
- This study compares kinematic features in ensemble mean analyses with polarimetric signatures in mobile radar data

Methodology

- 54-member ensemble of NCOMMAS (Coniglio et al. 2006) simulations with 500 m horizontal grid spacing across El Reno supercell
- NSSL two-moment microphysics (Mansell et al. 2010)
- Radial velocity and radar reflectivity from the National Weather Radar Testbed Phased Array Radar (PAR; Zrnic et al. 2007) are assimilated from 22:20 UTC
- LETKF (Hunt et al. 2007; Thompson et al. 2015) assimilation of RaXPol radial velocity data from 22:48 to 23:15 UTC with 1-min analysis cycles
- Adaptive inflation and additive noise used for spread maintenance



Time series of (top) posterior radial velocity RMSI and ensemble spread (m s^{-1}) and (bottom) number of observations per 500 m vertical bin for each assimilation cycle.

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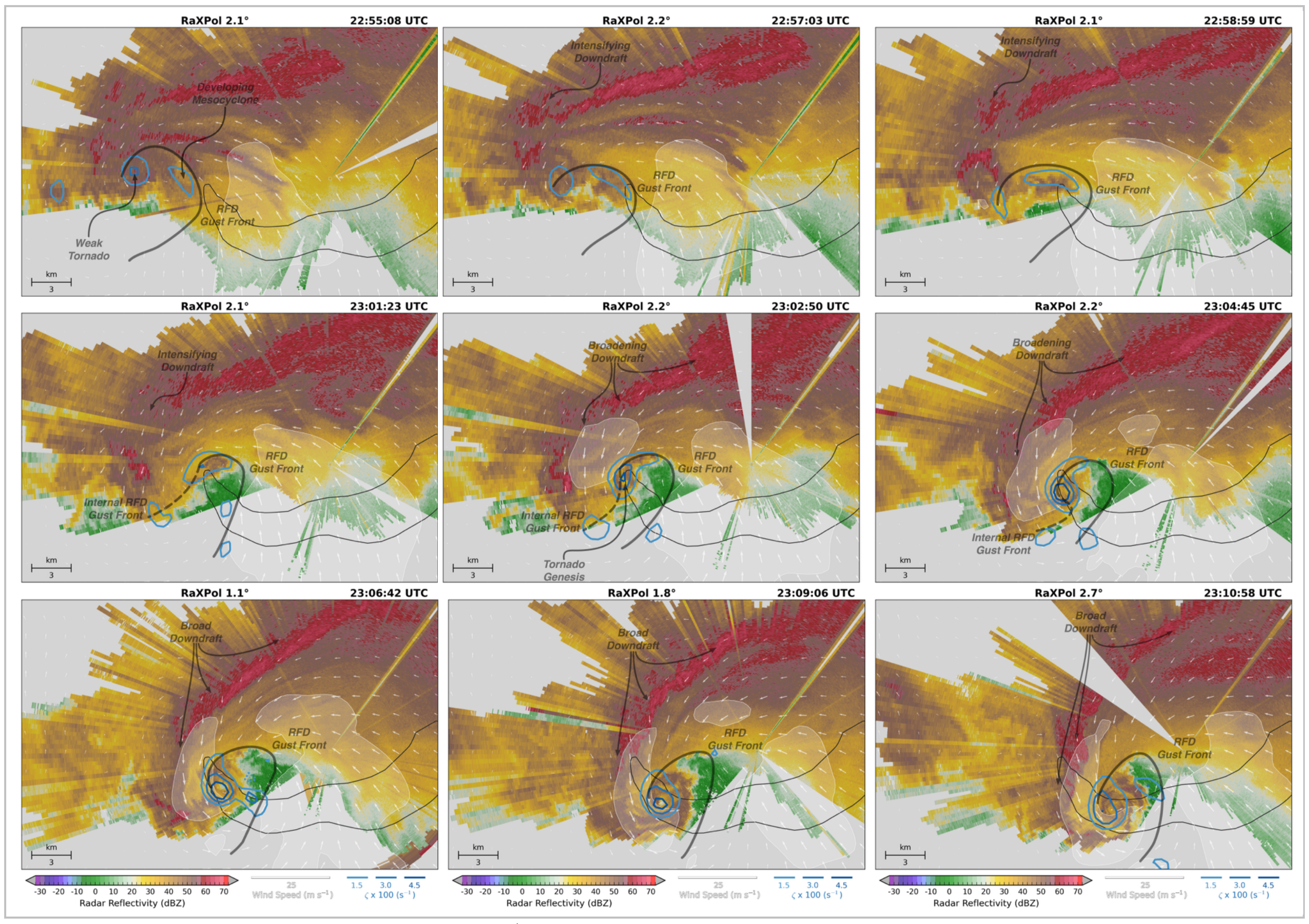
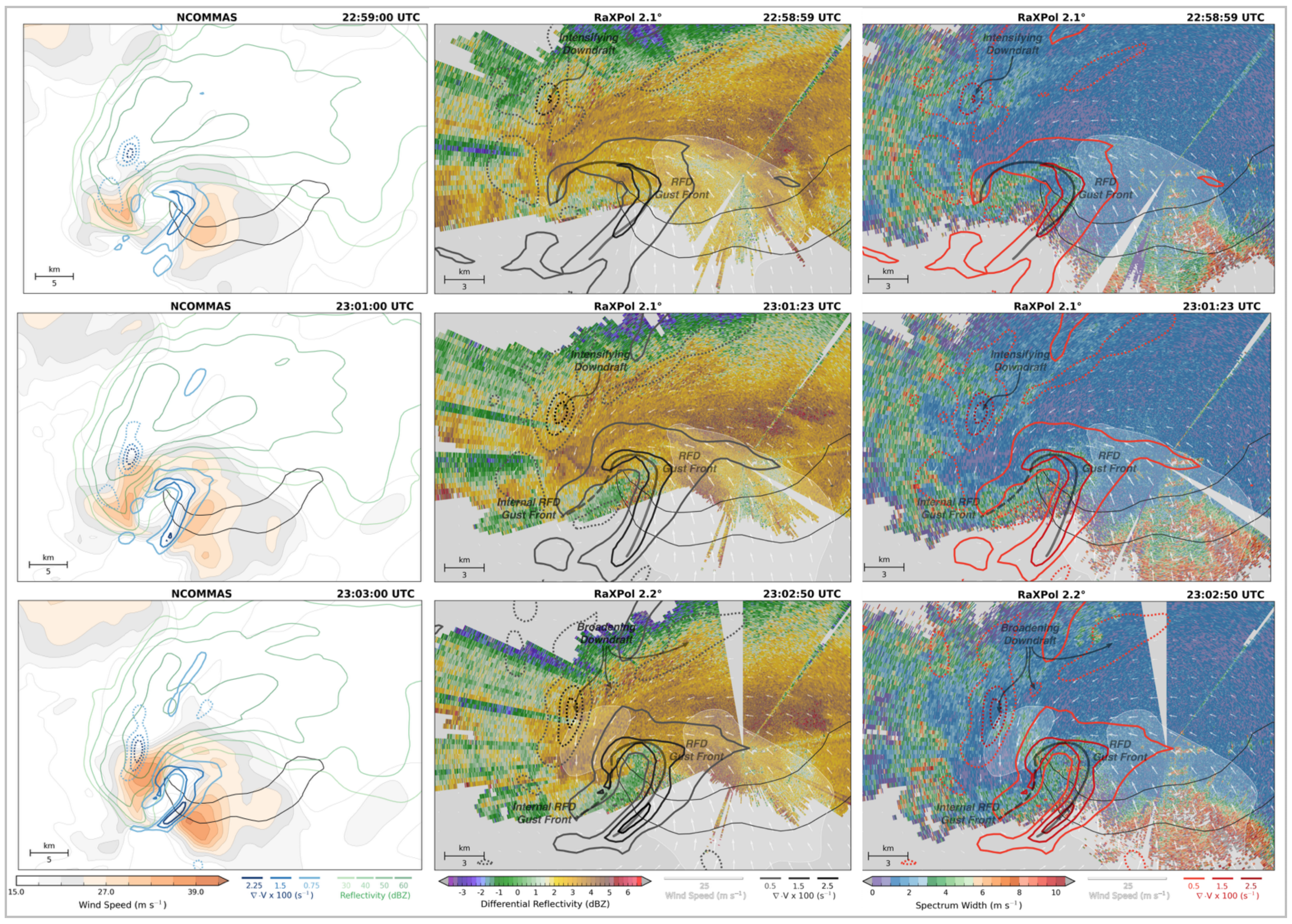
*Corresponding Author Address: Patrick Skinner CIMMS/OU 120 David L. Boren Blvd., Suite 4380 Norman, OK 72072
patrick.skinner@noaa.gov



RaXPol reflectivity with ensemble mean vertical vorticity (s^{-1}) at 437 m AGL and wind vectors at the lowest model level overlain. Wind speeds greater than 25 m s^{-1} are shaded white, thin black lines denote the damage track of the El Reno tornado, and prominent storm features are annotated.

RFD Surge and Tornadogenesis

- An intensifying downdraft NW of the low-level mesocyclone precedes a surge in horizontal momentum within the RFD
- Increased convergence along the RFD surge gust front coincides with rapid intensification of the low-level mesocyclone and tornadogenesis
- The RFD surge gust front roughly marks the leading edge of the forward-flank high-Z_{DR} arc wrapping around the mesocyclone
- The strongest wind speeds within the RFD surge are co-located with a relative minimum in spectrum width, suggesting a small turbulent component to the wind
- Z_{DR} values in the RFD decrease prior to tornadogenesis, which indicates an increasing concentration of small rain-drops (Kumjian 2011; French et al. 2015)
- Z_{DR} decreases ahead of the RFD surge, suggesting the potential for horizontal advection of small raindrops across the RFD surge gust front

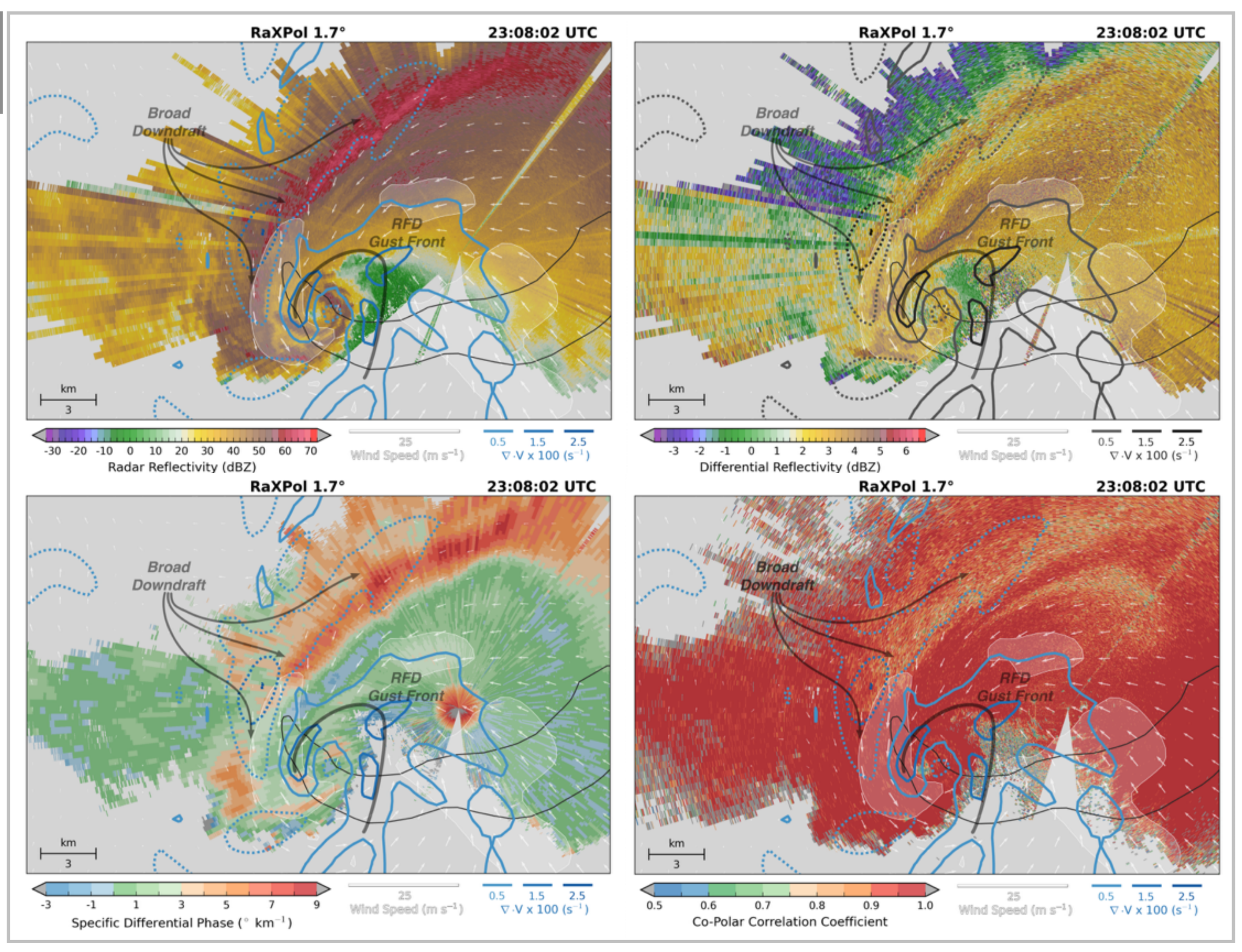


(left column) Ensemble mean simulated reflectivity (dBZ), wind speed (m s^{-1}), and divergence (s^{-1}) at the lowest model level, (middle column) ensemble mean divergence (s^{-1}) and wind (m s^{-1}) overlain on RaXPol differential reflectivity (dBZ), and (right column) ensemble mean divergence overlain on RaXPol spectrum width (m s^{-1}). The El Reno damage path is marked in thin black and select features are annotated.

Near-Surface Flow Field During the Tornado

- Rapid intensification of the tornado coincides with development of an organized near-surface wind field consisting of a broad, arcing downdraft bounding strong winds wrapping from the storm inflow to the rear of the tornado
- The downdraft is co-located with X-band polarimetric signatures indicative of hail; including attenuation in Z_H and Z_{DR}, CC values below 0.9, and very large K_{dp} values that are normally associated with a large amount of melting hail (Kumjian 2013)
- The forward flank south of the downdraft is characterized by relatively low K_{dp}, moderate Z_{DR}, and CC near 1, consistent with a low concentration of large raindrops falling into the storm inflow

▶ Ensemble mean divergence (s^{-1}) and wind field at the lowest model level overlain on RaXPol (upper left) radar reflectivity (dBZ), (upper right) differential reflectivity (dBZ), (lower left) specific differential phase (deg km^{-1}), and (lower right) co-polar correlation coefficient. Select features are annotated and the El Reno damage path is outlined in black.



Summary

- Radial velocity data from two rapid-scan radars have been assimilated using a LETKF to produce 1-minute analyses of the El Reno supercell
- Features in the ensemble mean analyses are co-located with signatures in un-assimilated radar data
- Tornadogenesis occurs following intensification of a downdraft and internal RFD momentum surge NW of the low-level mesocyclone
- The RFD surge is associated with strong wind speeds, high Z_{DR}, and low spectrum width, with decreasing Z_{DR} values ahead of the surge
- A broad downdraft containing hail develops following tornadogenesis