Effects of Environmental Shear and Buoyancy on Simulated Supercell Interactions

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Objective

- To understand how instability and vertical shear modulate the relationship between thunderstorm interaction and storm structure and evolution.
- This study extends earlier work (Syrowski et al. 2012) addressing how supercell longevity and rotation was altered in the presence of additional storm cells.

Background

- The presence of other storms can significantly alter storm morphology and severity (Goodman and Knupp, 1993; Lee et al., 2006; Wurman et al., 2007; French and Parker, 2012). The possibility of rapid intensification of a storm beyond severe limits is of great operational importance.
- Idealized modeling studies have related storm environment to storm characteristics (e.g. McCaul and Weisman, 2001)
- Previous work (Syrowski et al., 2012; Bluestein and Weisman 2000) has demonstrated significant dependence of storm interaction outcomes on initial cell spatial configuration.

Methods

Environment:

- Instability and hodograph parameters were representative of typical supercell environments based on climatologies (Thompson et al., 2003; Grams et al. 2012)
- Initial vertical thermodynamic and wind profiles were generated similar to Weisman and Klemp (1984). Only one instability case (2500 J/kg) is shown here.
- Five hodographs were used, each with varying curvature in the 1-3 km layer; 0-6 km bulk shear ranges from 25 ms^{-1} (straight/control) to 26.1 ms^{-1} (quarter semi-circle)
- Winds from 3 to 6 km increase linearly and are constant above 6 km (Fig. 1).

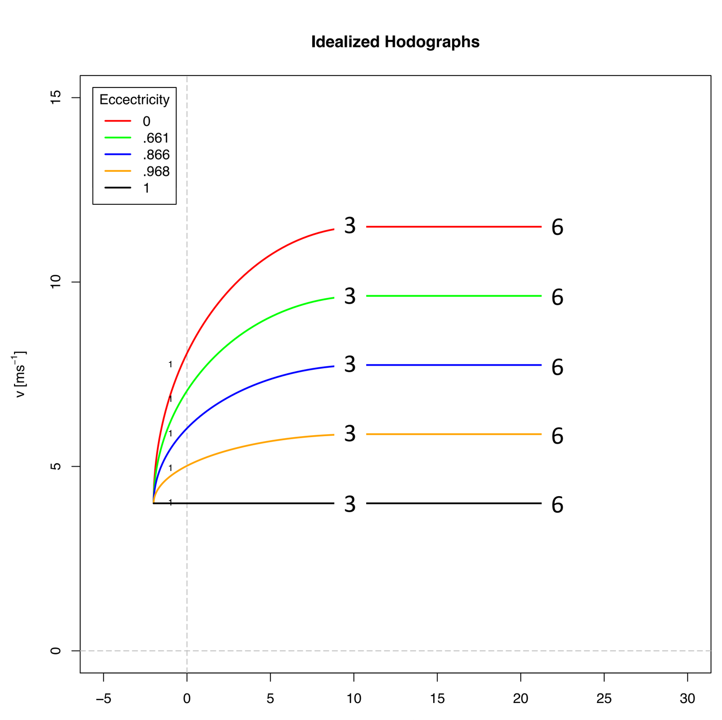


Fig. 1: Hodographs used for simulations. Eccentricity in color (see legend) and height annotated in km.

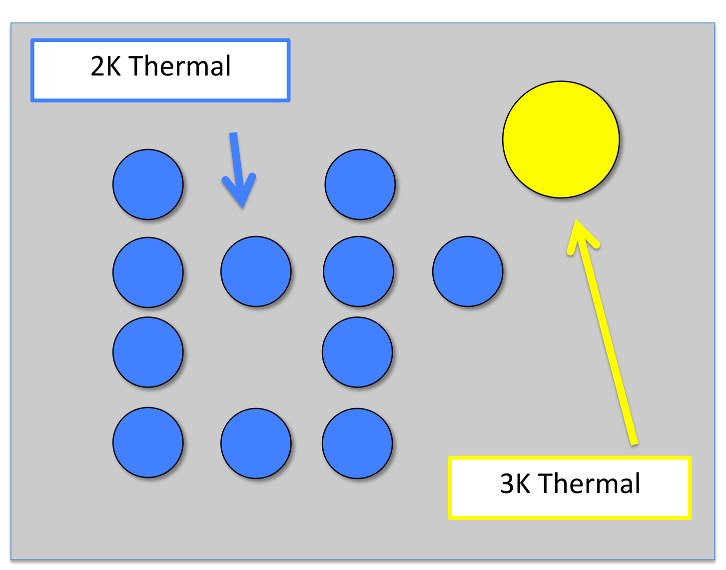


Fig. 2: Schematic of thermal locations in domain. 2K secondary thermal locations will be varied.

Initial storm configuration:

- Primary thermal perturbation is fixed; initial position of 2nd cell varies. In these preliminary tests, the 2-cell orientation follows Syrowski, 2012 (Fig. 2).
- WRF version 3.5.1 was used; settings appear at right.

Model Parameter	Value
Grid Spacing	180 m
Vertical Levels	90 (to 18 km)
Microphysics	Morrison
Integration Time	4 hours

Results

These figures show differences in storm evolution after 3 hours. All plots are of the the same sub-domain. Hodograph curvature increases left to right. Top row: 2-thermal initialization. Bottom: single-cell (control) cases for the same shear profile as above it. Simulated reflectivity at 500m elevation is shaded, with surface wind vectors (every 15th) shown.

In terms of reflectivity, the storms initiated with the secondary thermal were all stronger than the primary storm. In the single thermal control runs, storms propagated further south than the two-cell cases, exhibiting greater deviant motion (right of the mean wind).

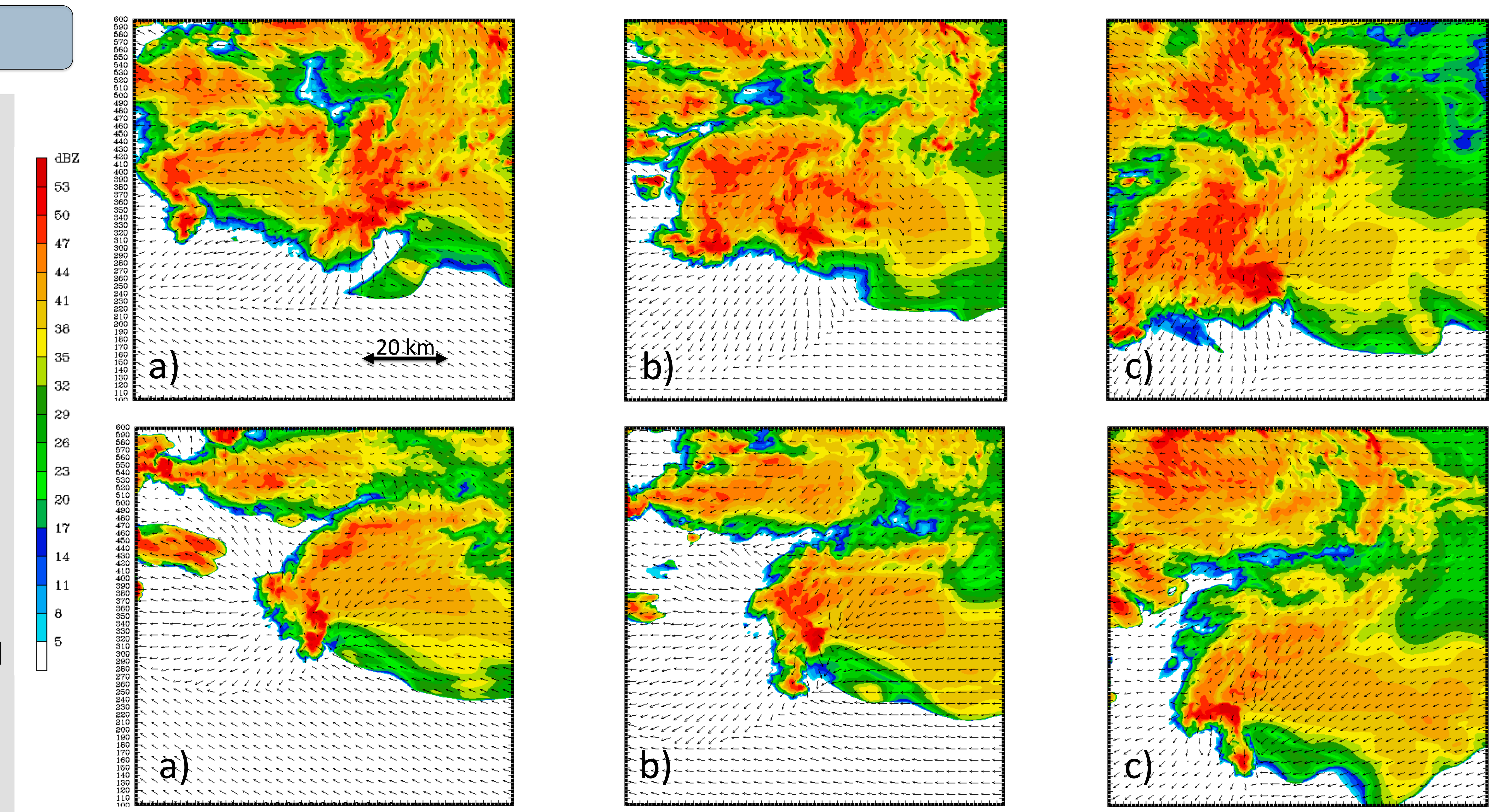


Fig. 3: 500 m simulated reflectivity (dBZ) and surface storm-relative winds (ms^{-1}) for a) **no**, b) **moderate**, and c) **high** 0-3 km hodograph curvature. Two-thermal runs are on top; one-thermal controls on bottom. All plots are T = 3 hrs.

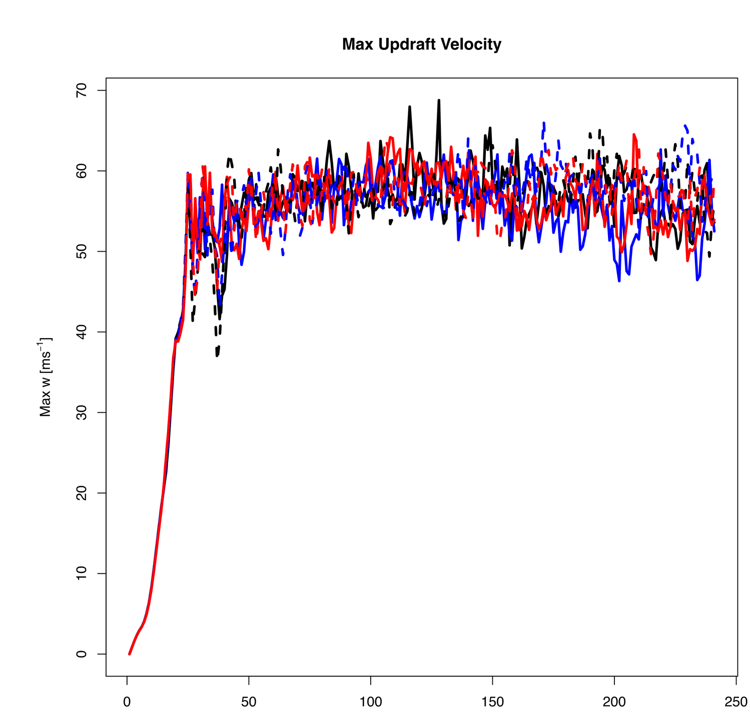


Fig. 4: Time series of maximum updraft speed ($m\ s^{-1}$) for no (black), moderate (blue), and high (red) 0-3 km hodograph curvature. Single cell runs have dashed lines.

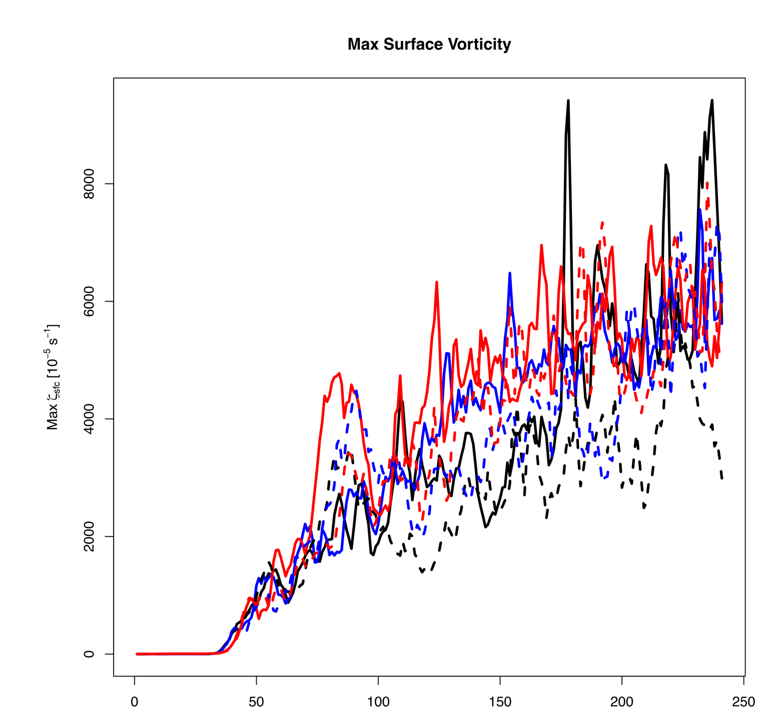
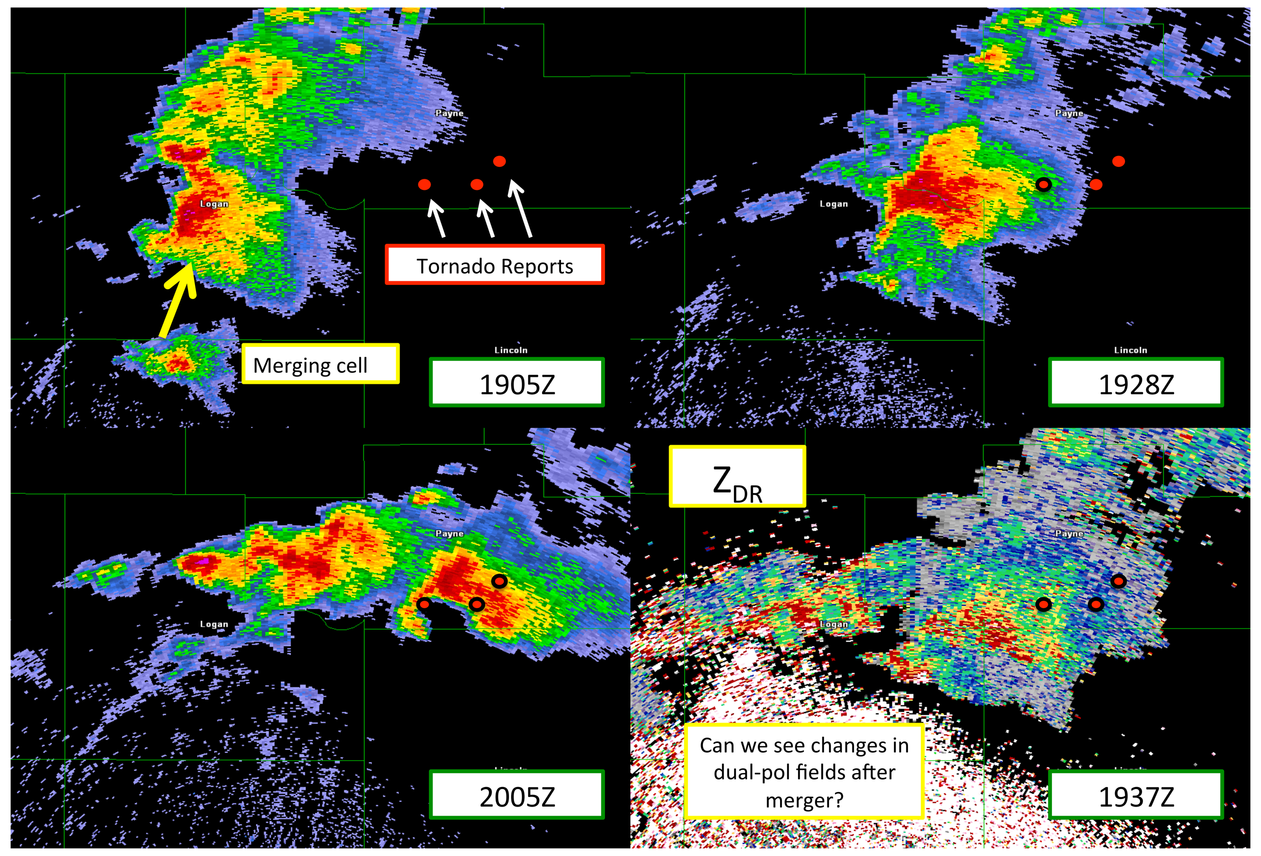


Fig. 5: As in Fig. 4, but for maximum surface vorticity ($10^{-5}\ s^{-1}$).

Preliminary findings

- Numerical simulations are utilized to understand how instability and vertical shear modulate the relationship between thunderstorm interaction and storm structure and evolution.
- Single thermal "isolated" control cases produced supercells with more deviant (right of the mean wind) motion than did two-thermal runs. Secondary storms tended to dominate the primary storms.
- Peak updraft speeds are not significantly affected by the shear profile (see Fig. 4)
- Peak surface vorticity is, on average, greater for cases with larger hodograph curvature; two thermal cases are greater than single thermal runs (see Fig. 5).
- Further analyses are planned to clarify the physical mechanisms at work.



A complimentary case study is being carried out to further understand the physical processes leading to storm intensification after interaction.

← Fig. 6: KTLX radar from May 30, 2013. 0.5° elevation base reflectivity and Z_{DR}. Important features labeled.

Future Work

- Repeat experiments with lower and higher CAPE
- Vary location of secondary thermal to see if the same spatial organization versus storm intensity relationships hold true in varied shear (i.e., compare to Syrowski et al., 2012)
- Utilize trajectory analysis to help understand sources of storm intensification and vorticity generation
- Investigate selected cases of storm interactions and tornadogenesis. Are microphysical process changes evident from dual-pol radar? (see Fig. 6)

Simulations were carried out on TACC's Stampede supercomputer, under XSEDE Award TG-ATM050014N.

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