Impacts of Cell Interaction on Storm Intensification: A Dynamical and Microphysical Perspective

Ann M. Syrowski

Brian F. Jewett

The University of Illinois at Urbana-Champaign

Department of Atmospheric Sciences

Robert B. Wilhelmson

National Center for Supercomputing Applications

ann.syrowski@gmail.com

How can cell interactions occur?

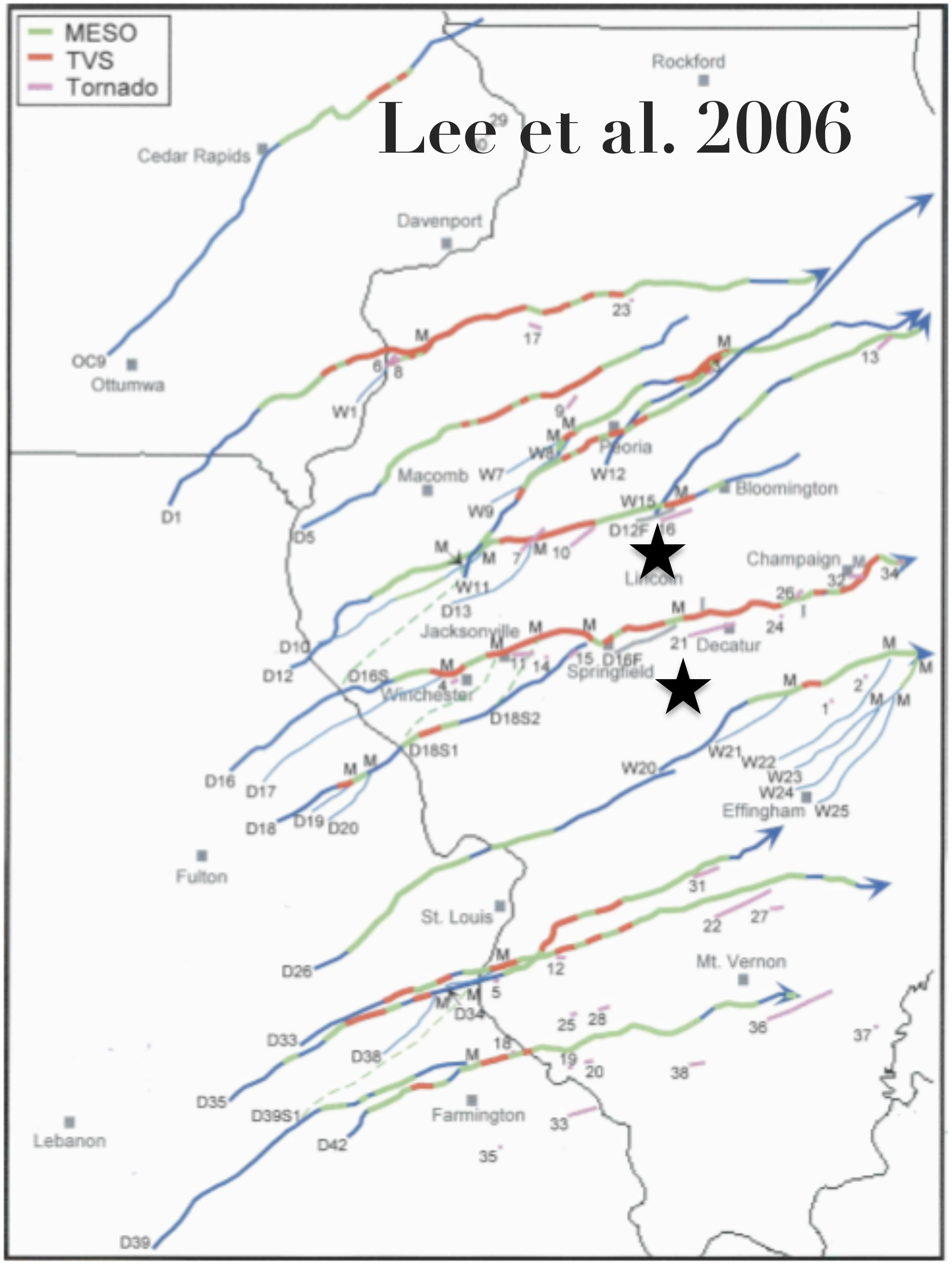
Zeitler and Bunkers (2005):

1. Numerous thunderstorms (moisture, instability, and large upward motion)
2. Differing storm motions
3. Strong linear forcing

Why is understanding cell interaction important?

Interactions can be favorable or destructive. Understanding the mechanisms for intensification could improve prediction accuracy during events with cell interaction

Tornadogenesis after interaction often occurs rapidly, posing a challenge to forecasters and a threat to the public (Wolf 2010)



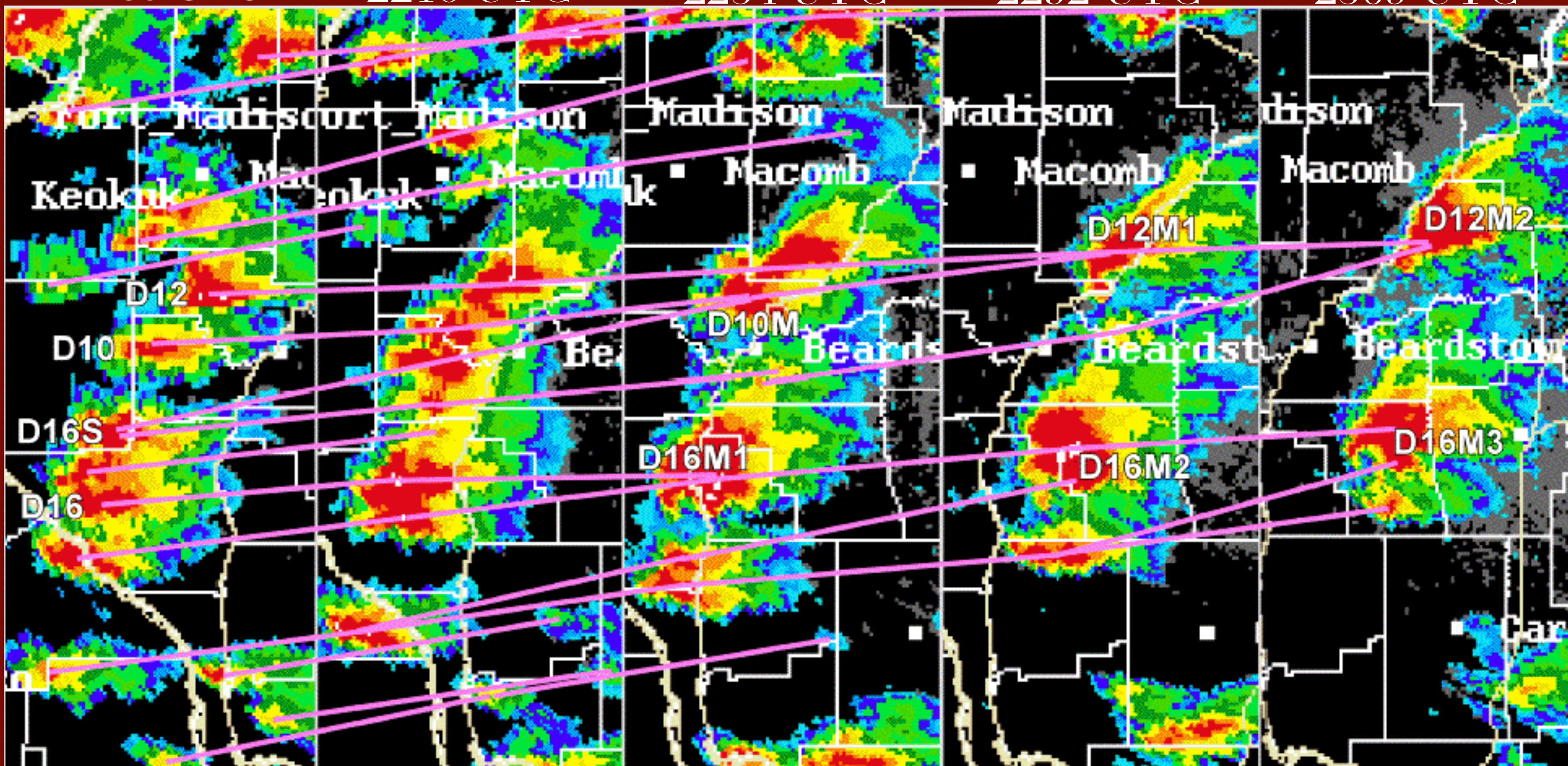
Illinois tornado outbreak

April 19th, 1996

- 39 tornadoes in Illinois, 20 in Iowa, Indiana, and Missouri
- 54% of tornadoes formed 15 minutes before or after a cell merger
- 57% of mergers were associated with tornadogenesis
- Supercells D12 and D16 experienced a combined 13 mergers

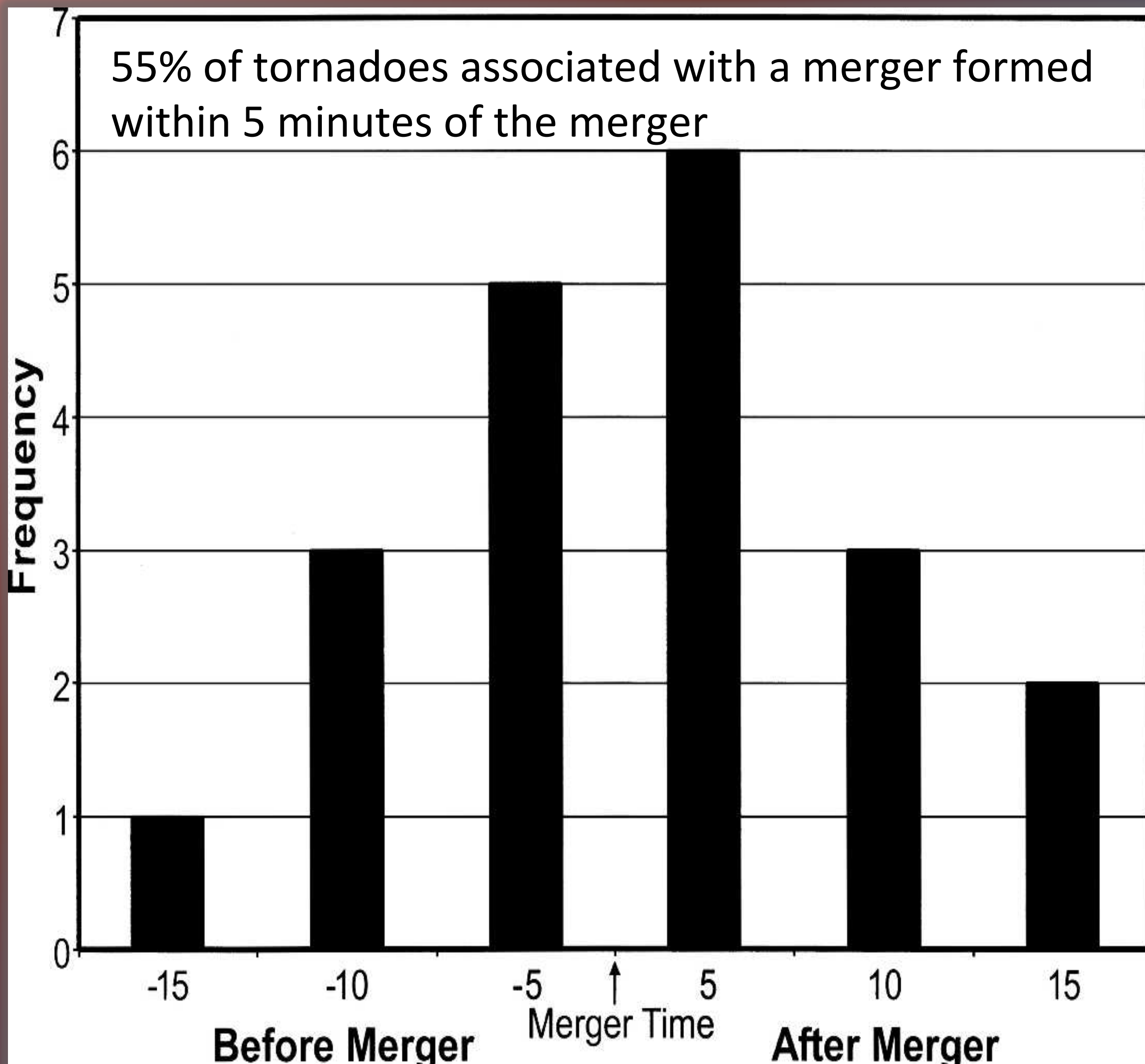
April 19th, 1996 - KILX 0.5° radar reflectivity

2159 UTC 2216 UTC 2234 UTC 2252 UTC 2309 UTC



Lee et al. 2006

Lee et al. 2006



Other related studies

- Wolf and Szoke (1996)
  - July 21st, 1993 northeast Colorado tornadoes
  - Hypothesized the FFD of a supercell to the southwest was enhanced by the RFD of a storm in close proximity to the north
  - Suggested this type of interaction could enhance the baroclinic vorticity generation along the FFD

Other related studies

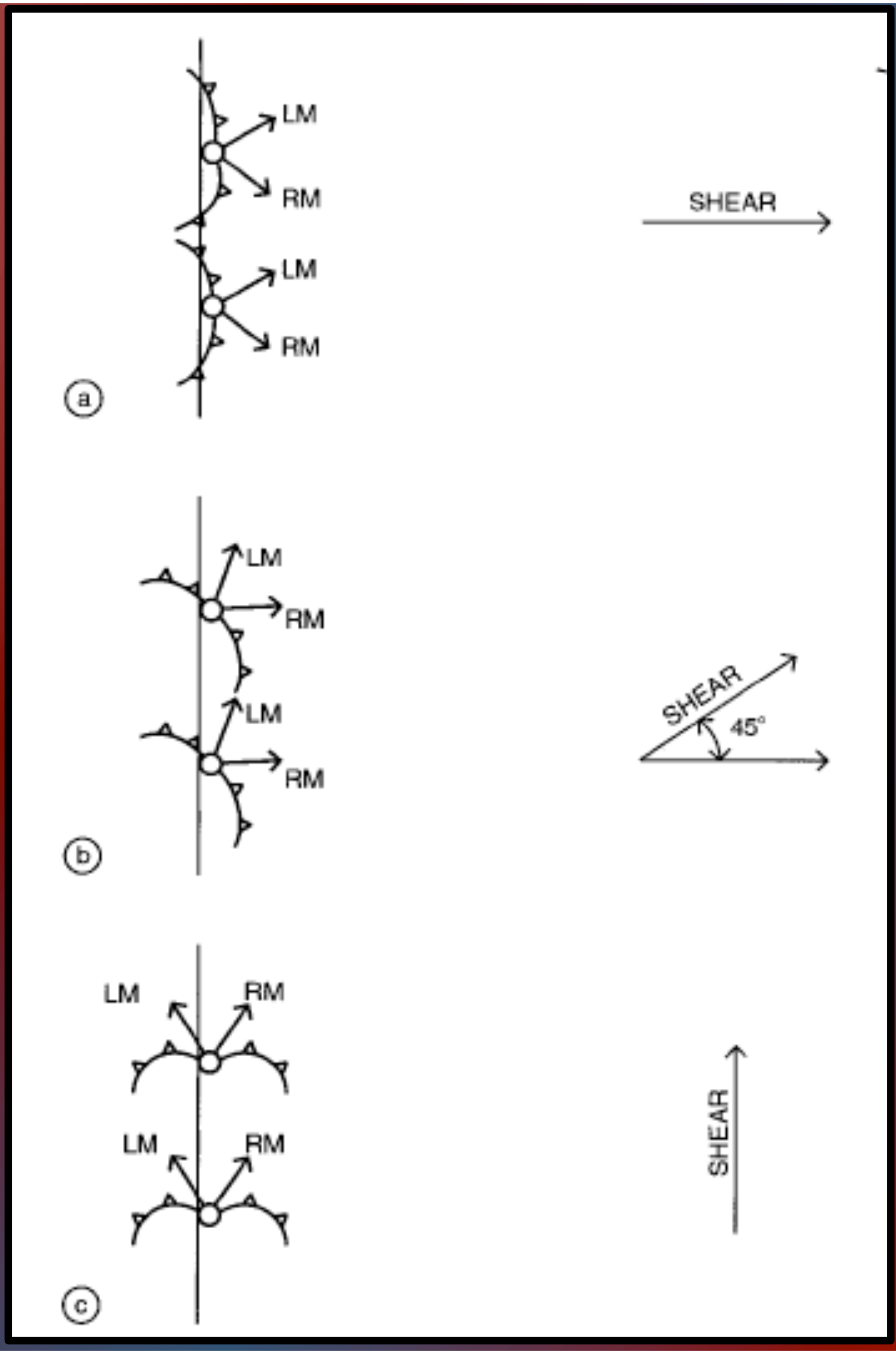
- Bluestein and Weisman (2000)
  - +Determined the importance of the vertical wind shear profile and its orientation to the initiating boundary on cell interaction

Bluestein and Weisman (2000)

Deep-layer shear vector normal to the boundary: Cyclonically and anticyclonically rotating RM and LM supercells develop at the end of the line. Embedded RM and LM collide

45° to boundary: Cyclonic RMs persist; LMs move into outflow of neighboring storm and weaken

Parallel to boundary: Cyclonic RMs form on the downshear side of the line



Cell interaction has been observed and studied, but the mechanisms responsible for storm intensification and long-lived rotation remain poorly understood

Through what mechanisms can cell interaction modulate the intensity of the individual cells (in terms of low-level vorticity and longevity)?

1. What role does the interaction of multiple cells' near-surface vorticity have in the intensification of either or both of the cells?

2. How does the strength and behavior of the cells' interacting cold pools affect their intensities?

- The emphasis of this study is on favorable interactions, but any cases showing significant weakening will also be examined

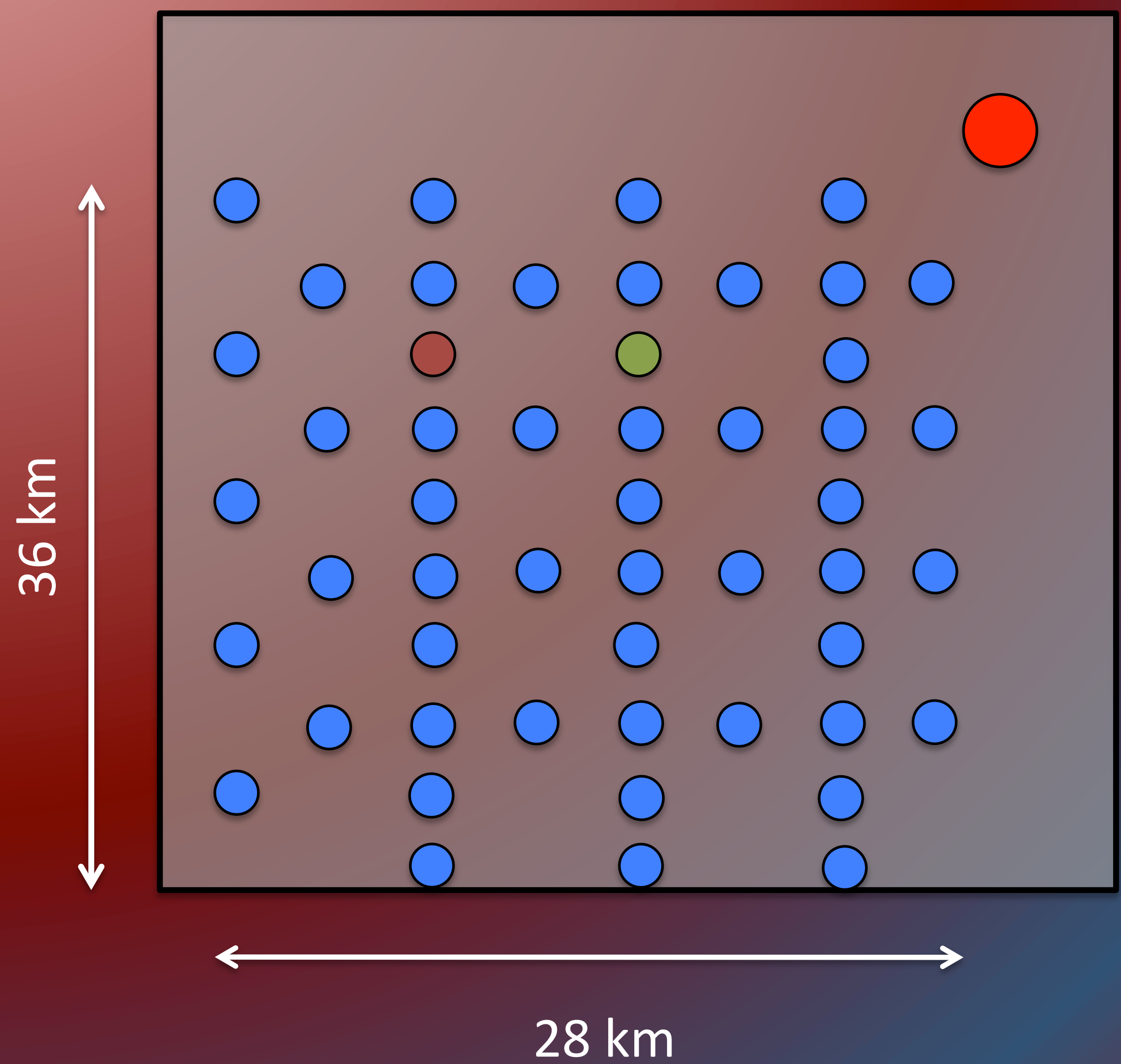
Methodology

- Use idealized, horizontally homogeneous numerical simulations to evaluate processes necessary for storm intensification
- Two-thermal simulations restrict the parameter space, minimizing the ambiguities of a multi-cell interaction

Model Set-up

- WRF v3.2.1
- Thompson et al. (2007) microphysics (option 98)
- Δx=540m, dt=1.5s, 90 vertical levels
- Free-slip
- 3-D Smagorinsky diffusion
- Control run-single thermal simulation
- 51 simulations with second cell + control

Schematic of southwest quadrant of 138.2 x 138.2 km domain



Jewett et al. (2008)

Red dot: control thermal
Blue dots: Varied position of second cell for 51 simulations

Warm bubble initiation:

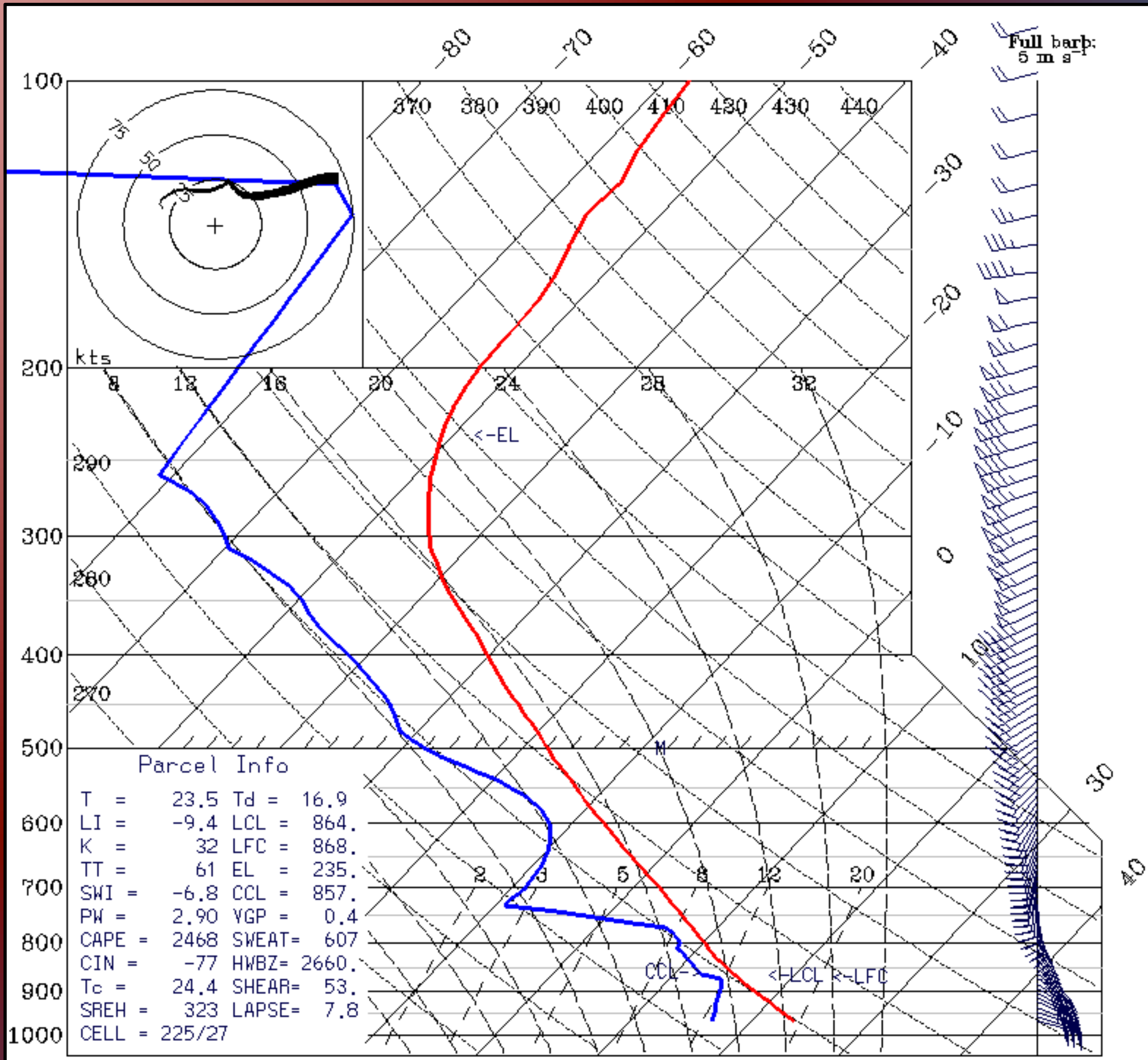
3.0° C thermal perturbation for control

2.0° C thermal perturbation for second cell

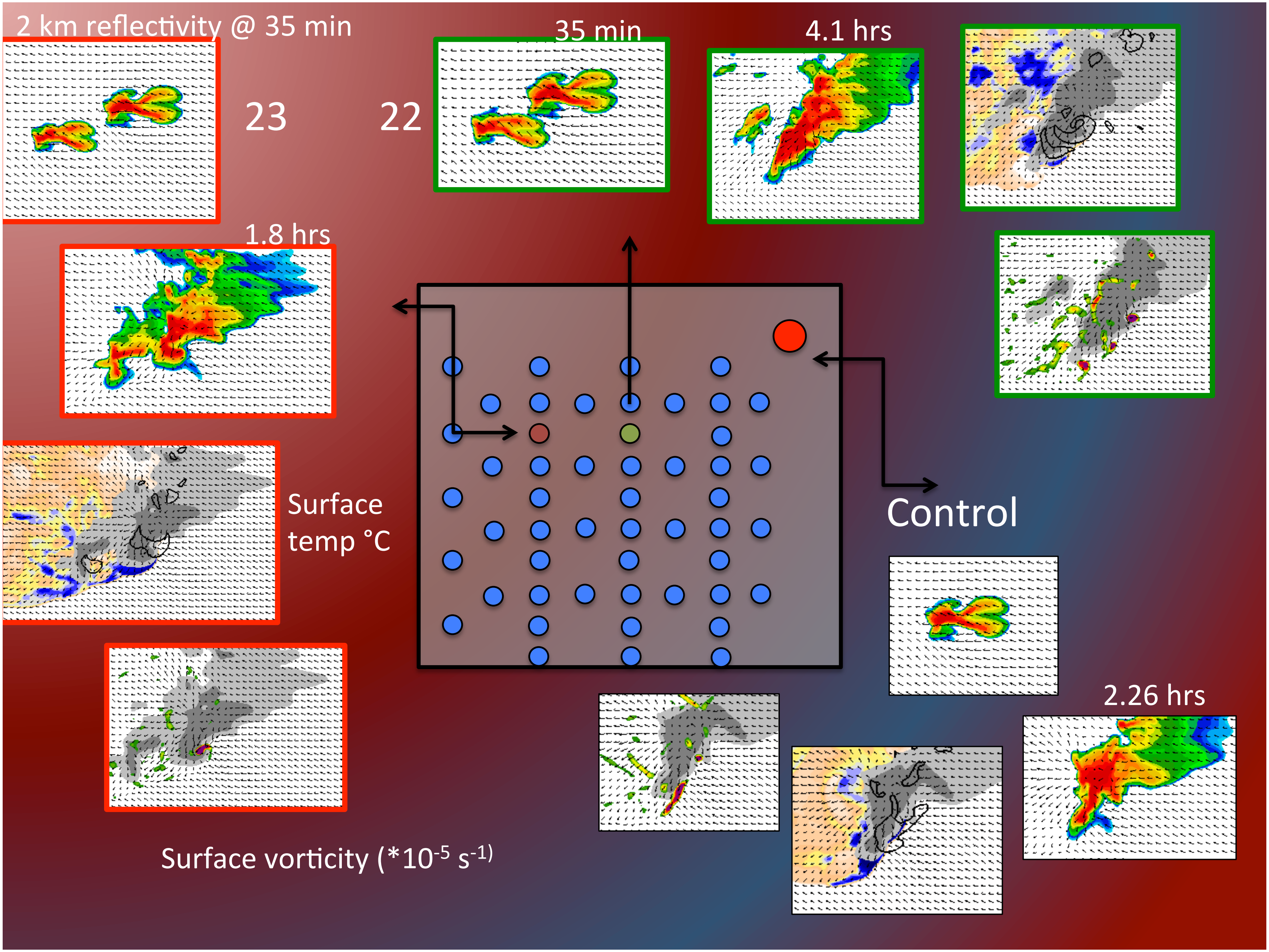
5-hour simulations

Run 22

Run 23

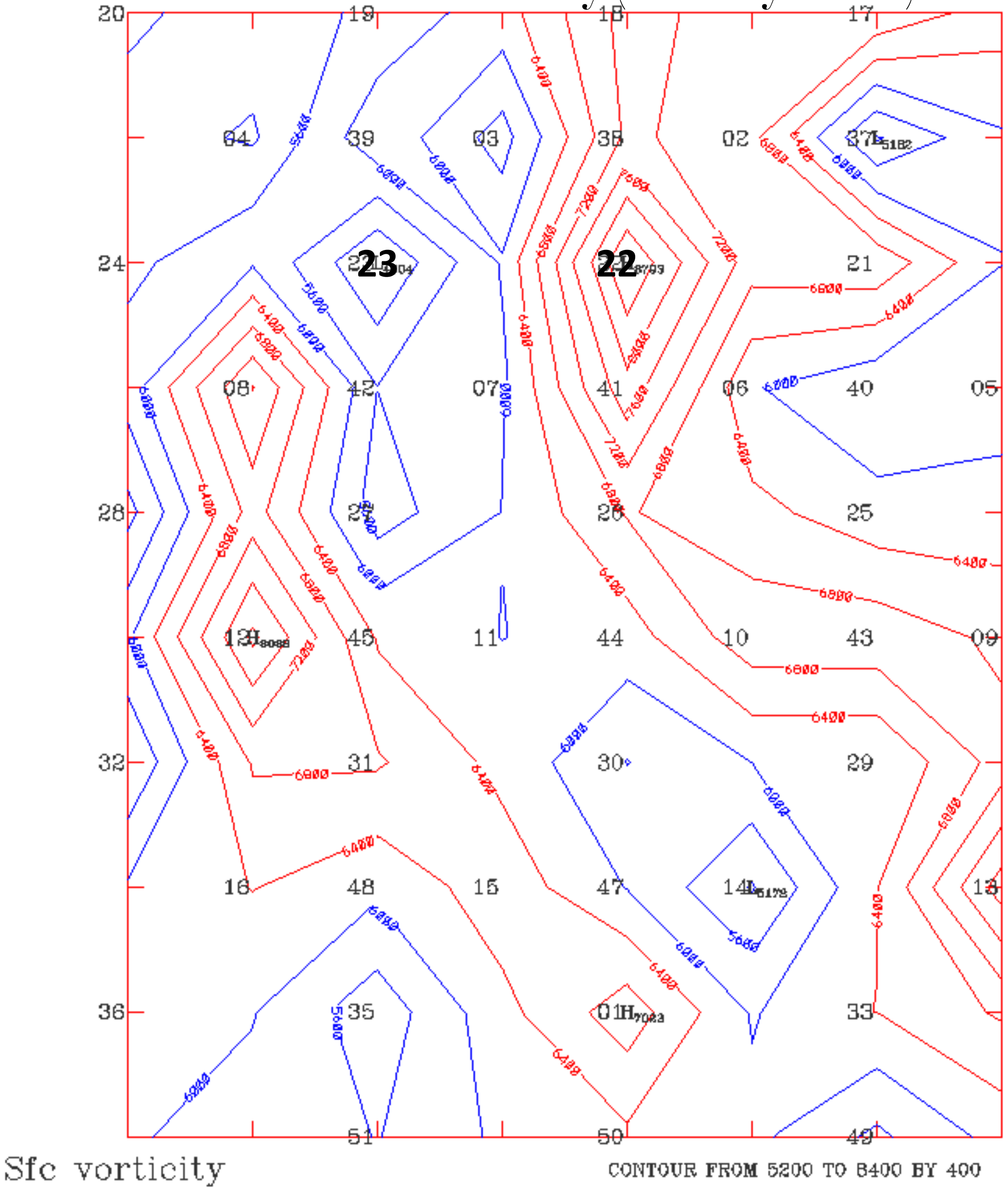


Full barb: 5 m s-1
kts
<-EL
CCL
<-LCL <-LFC
Parcel Info
T = 23.5 Td = 16.9
LI = -9.4 LCL = 864.
K = 32 LFC = 868.
TT = 61 EL = 235.
SWI = -6.8 CCL = 857.
PW = 2.90 VGP = 0.4
CAPE = 2468 SWEAT= 607
CIN = -77 HWBZ= 2660.
Tc = 24.4 SHEAR= 53.
SREH = 323 LAPSE= 7.8
CELL = 225/27



2 km reflectivity @ 35 min
23
22
35 min
4.1 hrs
1.8 hrs
Surface temp °C
Control
2.26 hrs
Surface vorticity (*10-5 s-1)

Surface Vorticity (vorticity*10^{-5}/s)



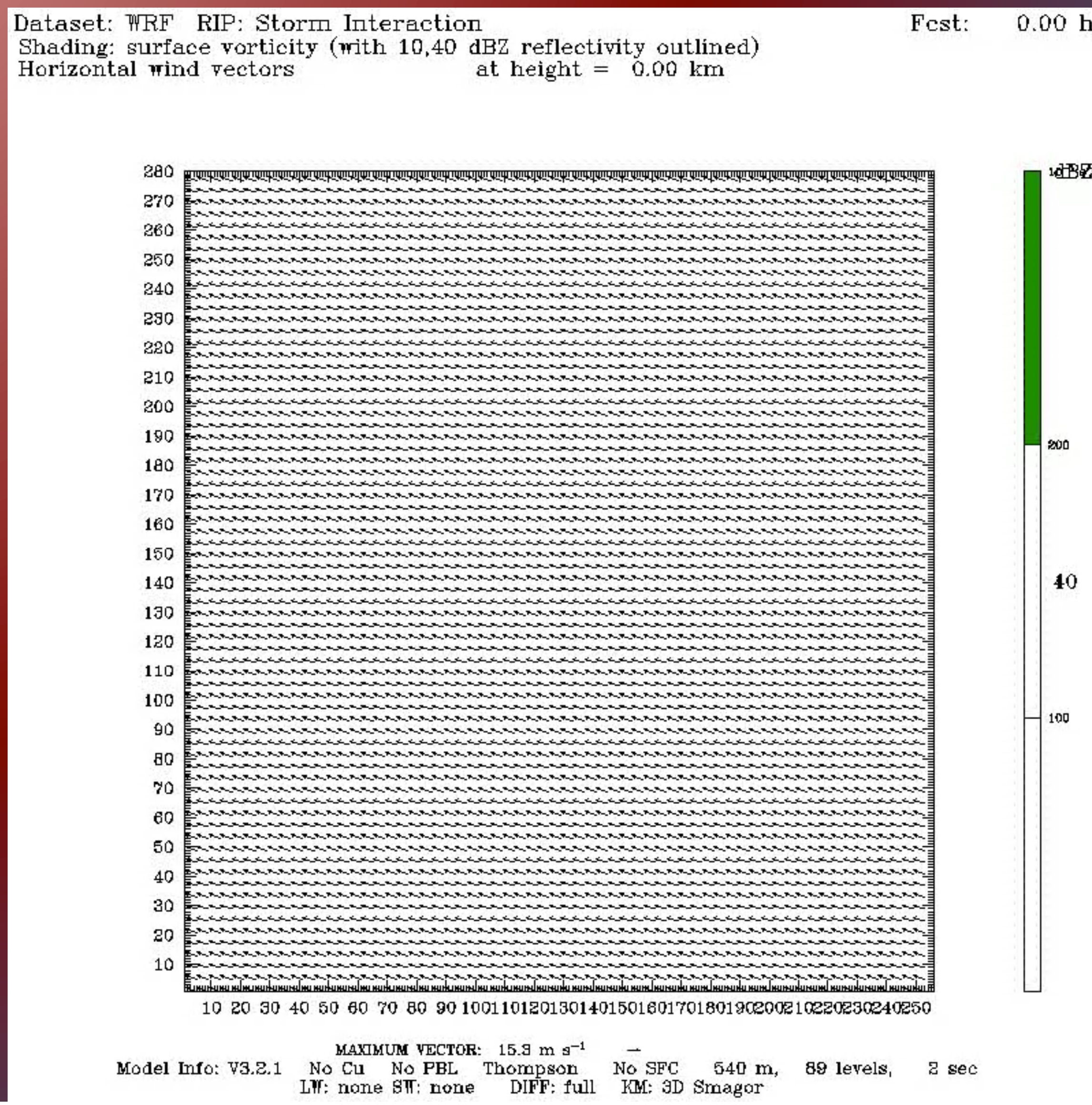
Vorticity maxes for all 51 runs + control

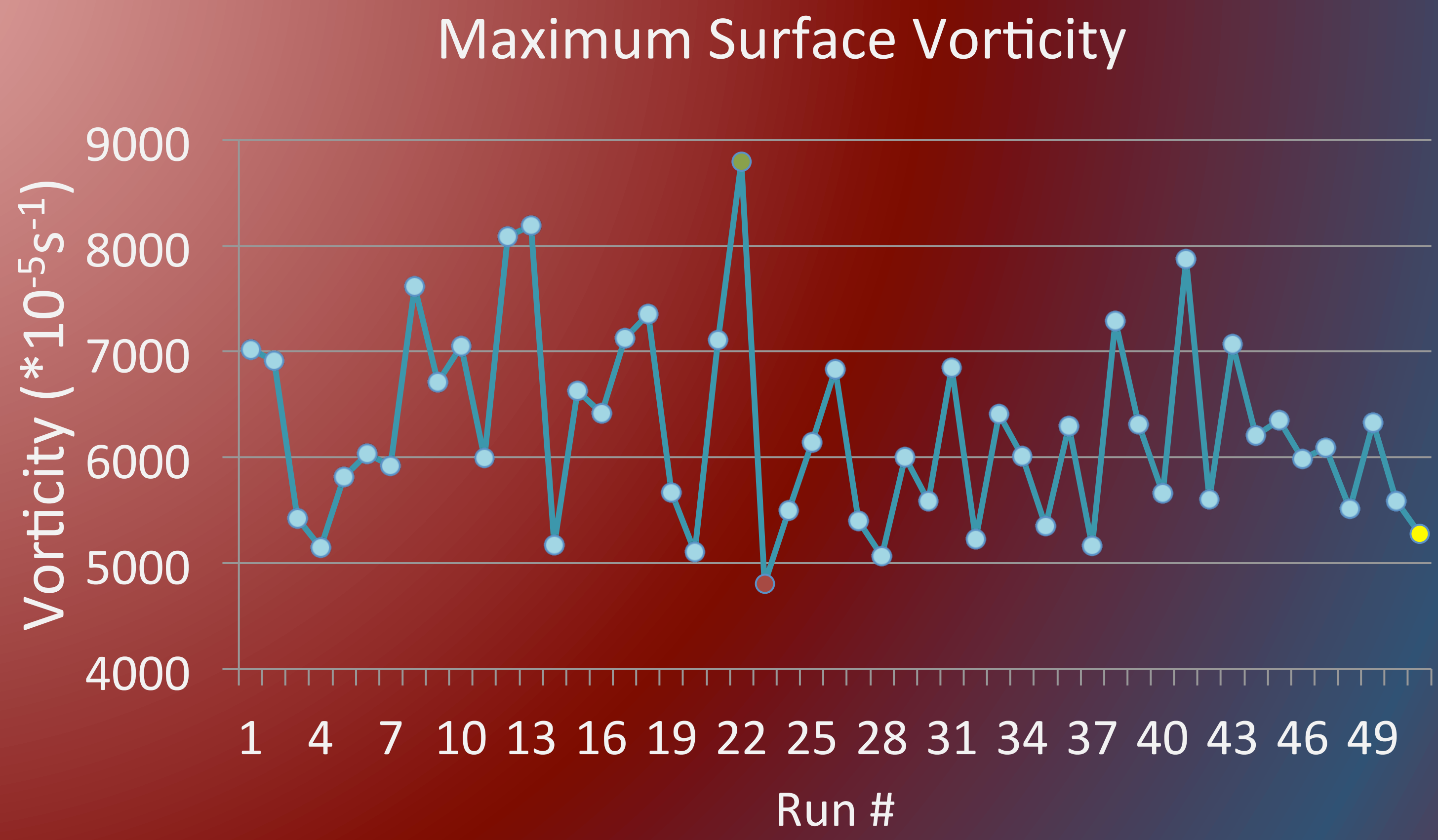
Strongest surface rotation: 22

Weakest surface rotation: 23

8 km between runs 22 + 23

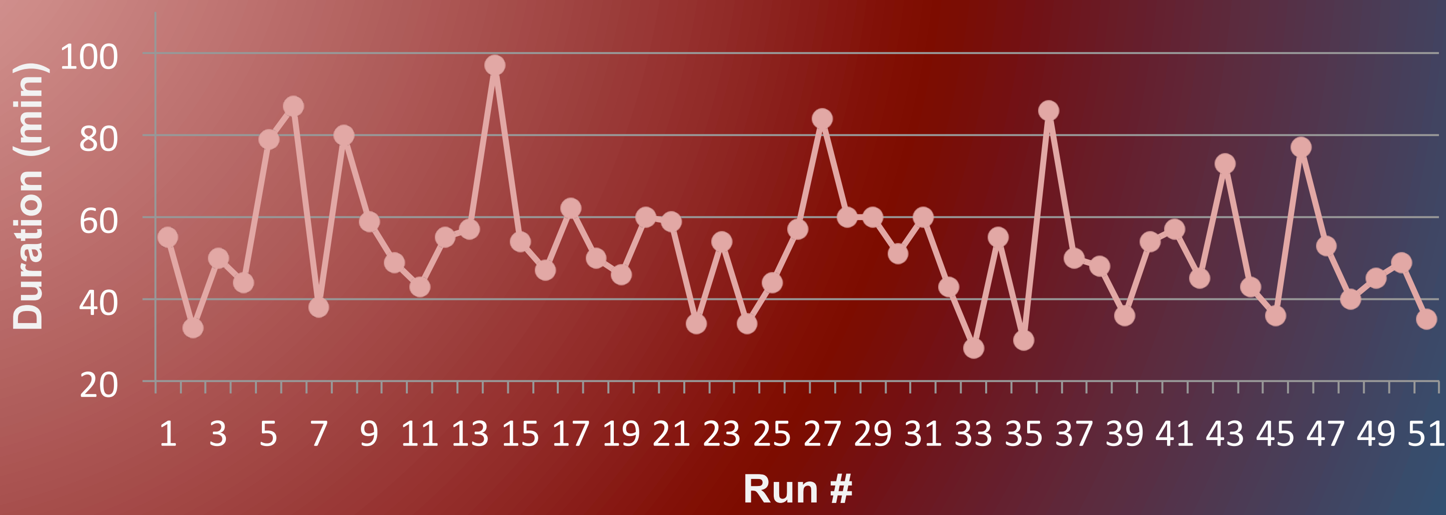
Surface Vorticity-Run 22



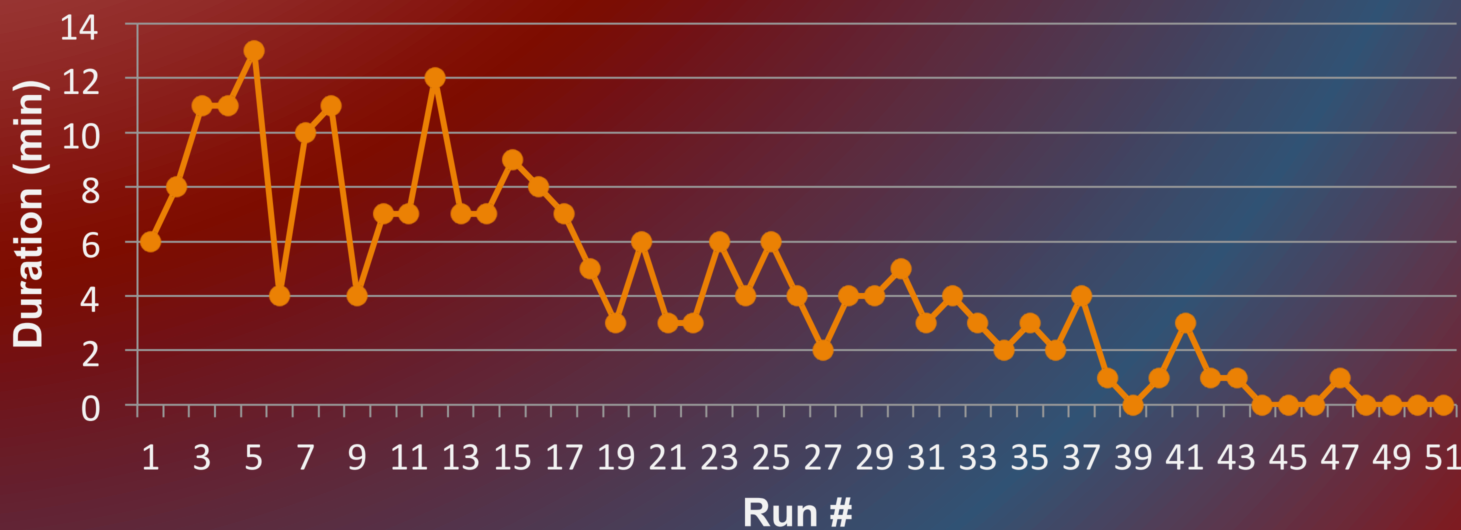


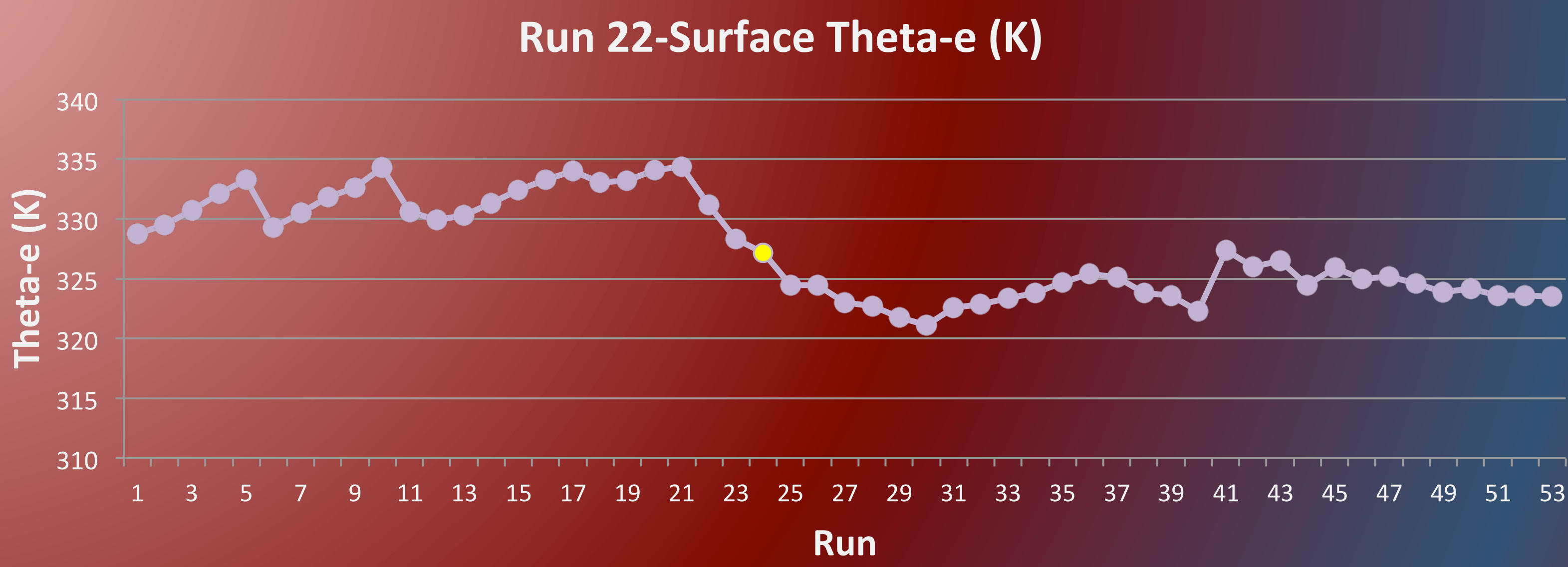
42 simulations with two initial thermals produced larger surface vorticity values than the isolated control cell run

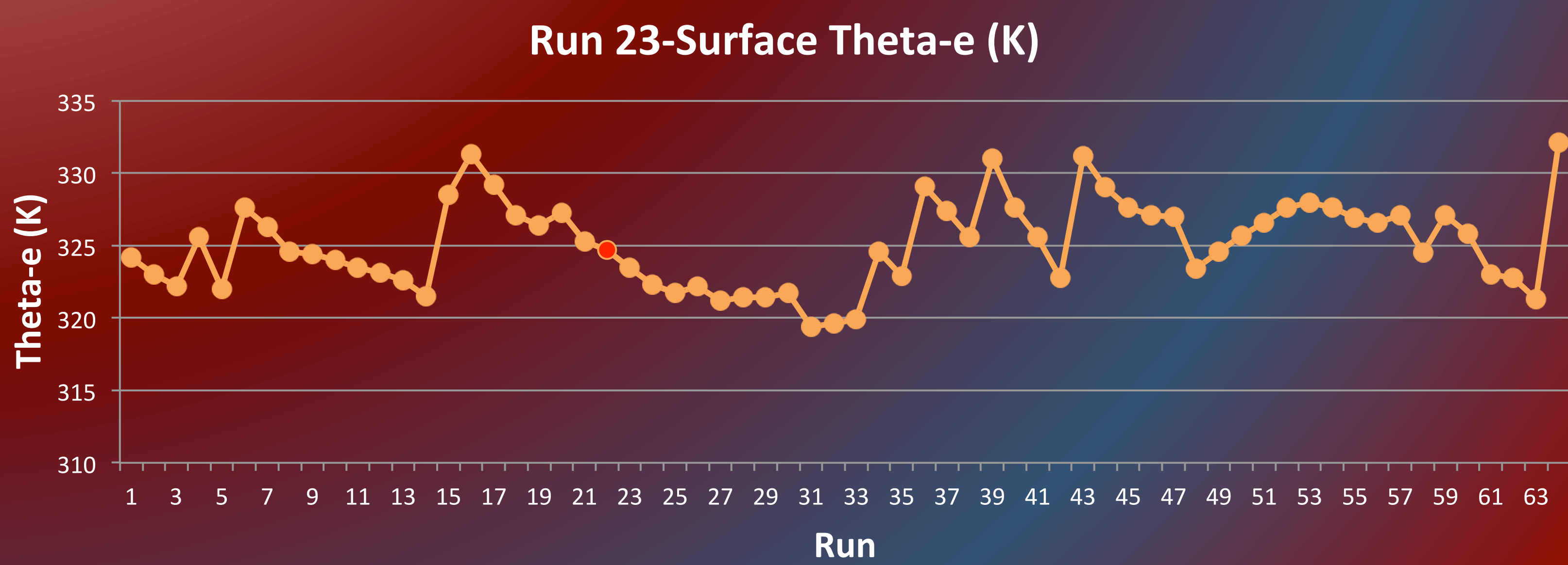
Surface Vorticity Longevity (>0.02 s^{-1})



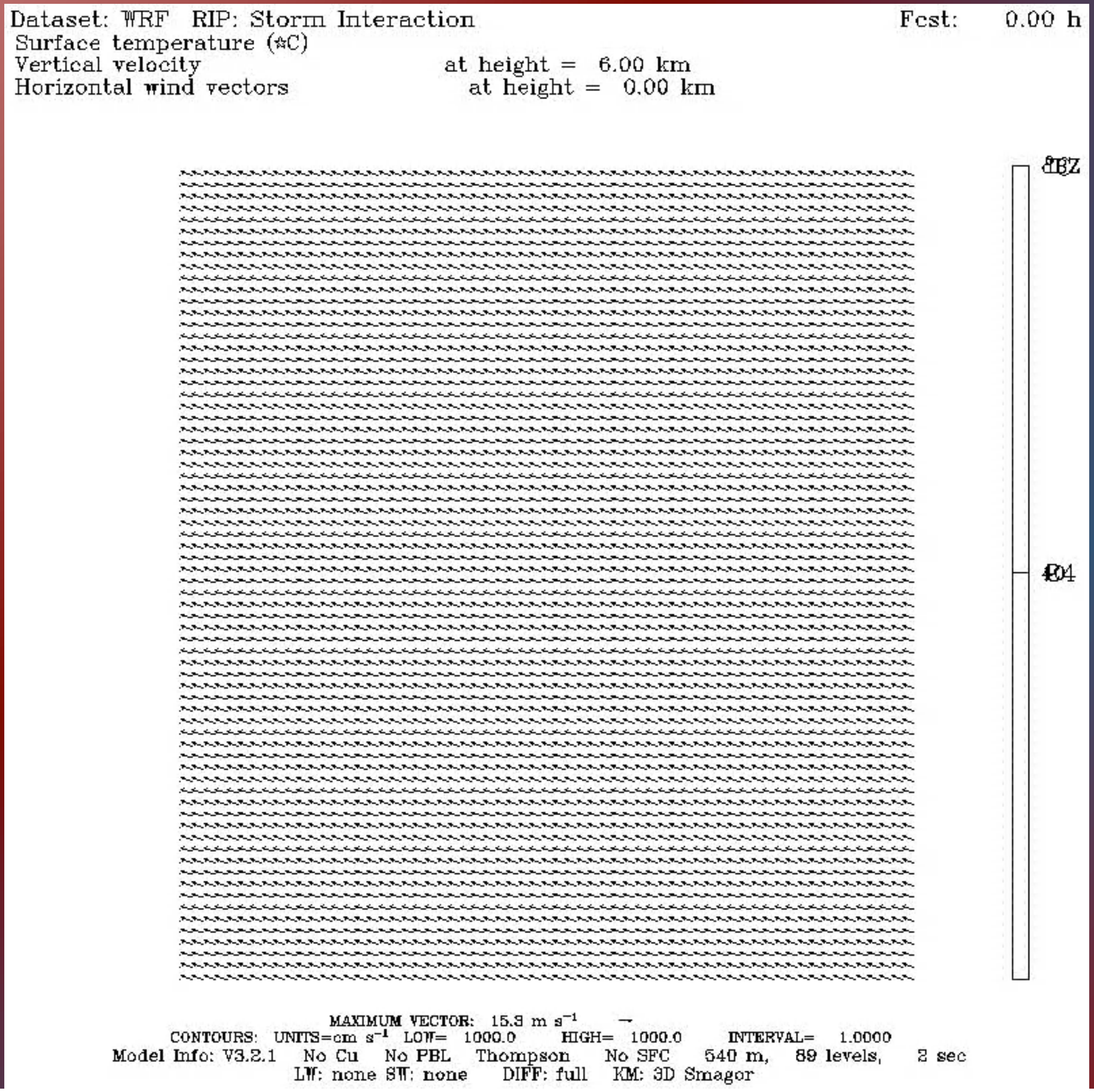
Surface Vorticity Center Longevity (>0.05 s^{-1})




Run 22-Surface Theta-e (K)
340
335
330
325
320
315
310
Theta-e (K)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53
Run


Run 23-Surface Theta-e (K)
335
330
325
320
315
310
Theta-e (K)
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63
Run

Surface Temperature (K)-Run 22



What we take from this so far…

- Surface vorticity originating in the FFD appears to be an important source of vorticity for the two-celled system
- Downdraft temperature fluctuations are frequent and behavior is pulse-like
- The degree of storm intensification owing to interaction is highly sensitive to the orientation of the two initial thermals

Next Steps

- Examine trajectory data from all 51 two-celled simulations + control
- Use 3-D visualization to analyze updraft/downdraft interactions and their impact on storm intensification
- Continue work on studying surface temperature fluctuations using statistical analyses
- Evaluate the role of the FFD outflow on storm intensification

Thanks!

- NSF AGS-0843566
- ann.syrowski@gmail.com