Impacts of Increasing Low-Level Shear on Supercells During the Evening Transition

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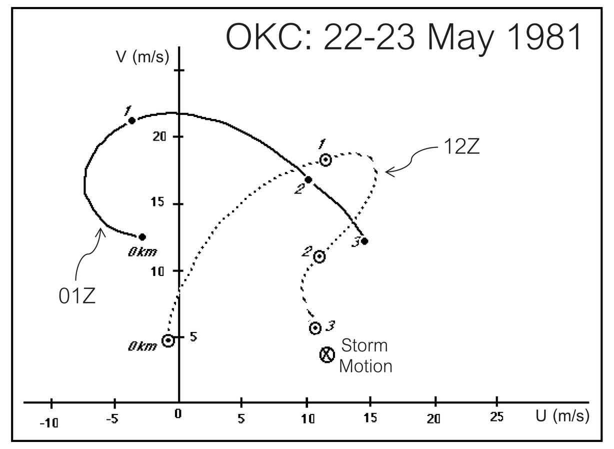
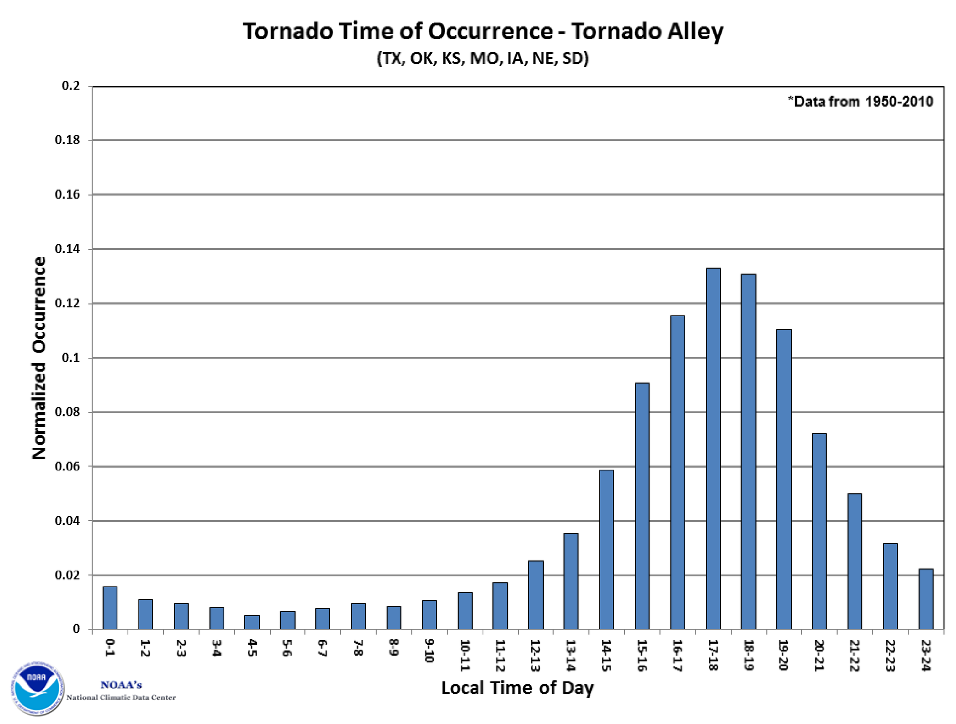
Introduction

Several environmental forecast parameters have been shown to possess substantial skill in forecasting tornadoes, including the environmental bulk shear in the lowest kilometer. The physical explanation for this skill is not yet fully understood. **Since recent studies have reiterated the significance of *downdrafts* in the tornadogenesis process, why are the kinematic properties of the *inflow* important?**



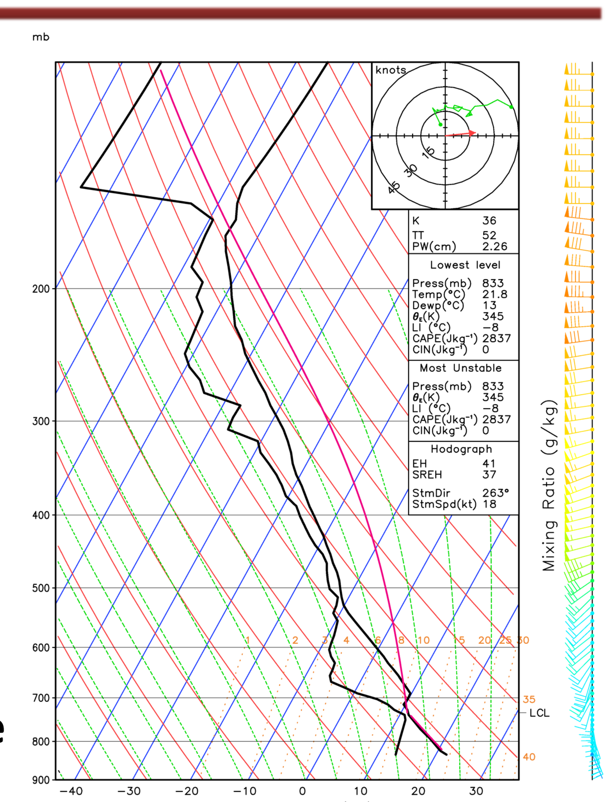
Maddox (1993)



A common characteristic of severe weather events in the central United States is an increase in low-level shear during the early evening hours, as a nocturnal low-level jet begins to develop. **It is unclear how storms directly respond to this change in shear, nor how changes in shear interplay with changes in stability.** Perhaps this increase in low-level shear is related to why tornadoes most frequently occur at this time of day.

Methods

Using the Bryan Cloud Model 1, we have been investigating this problem with **full-physics simulations initialized with soundings from VORTEX2**. The Goshen County, WY tornadic supercell of 5 June 2009 was selected as an ideal case. The environment was characterized by a rather straight hodograph in the early afternoon, which gradually transitioned into a strongly curved hodograph in the early evening. Using a modeling technique called base-state substitution (BSS), we are mimicking this transition in the wind profile in our simulations, without altering the thermodynamics. **One advantage of BSS, is the ability to analyze how a *mature* supercell responds to increasing low-level shear, as opposed to how the supercell initially *develops* in different background environments.**



	6 km Shear (m/s)	3 km SRH (m^2/s^2)	1 km SRH (m^2/s^2)	1 km Shear (m/s)	CAPE (J/kg)	LCL (m)	SCP	STP
Control	29.7	79	37	6.5	2837	1100	3.3	.93
BSS1	31.2	183	88	7.2	2837	1100	8.1	2.3
BSS2	30.2	401	137	12.4	2837	1100	17.2	8.1

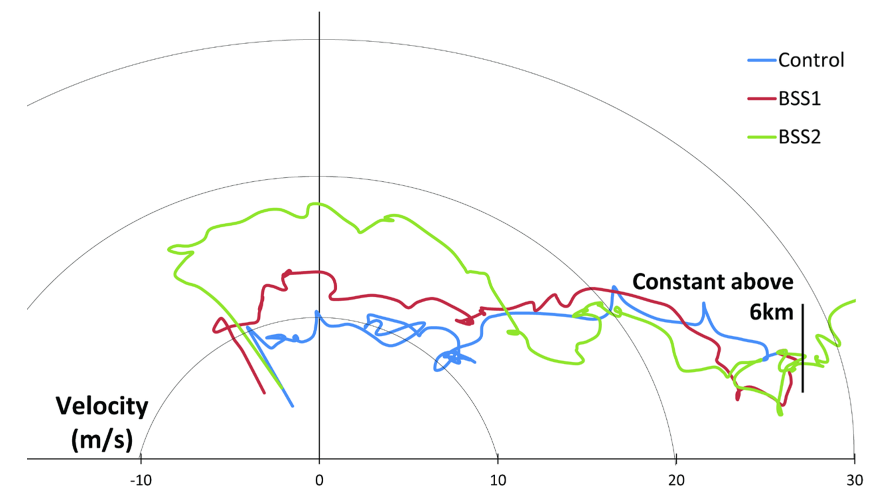
- Control, BSS1, and BSS2 refer to the respective base-state wind profiles to the upper right

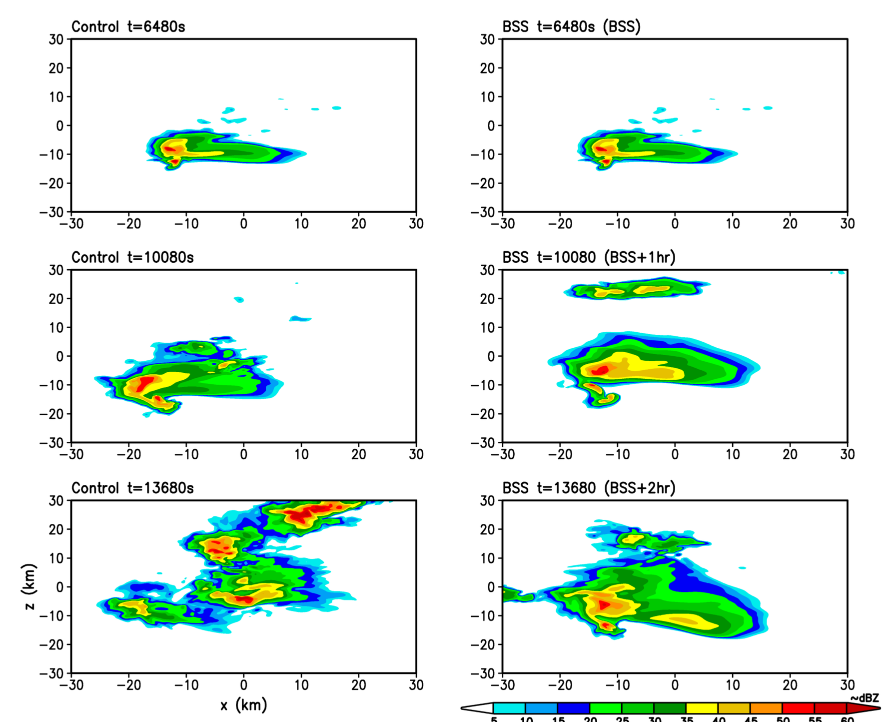
Simulation Overview

Wind Profiles

- Once a supercell matured in the control simulation, the base-sate wind profile was gradually modified to have stronger low-level shear (as observed), evolving through the BSS1 profile to the final BSS2 profile depicted at right.

Base-State Substitution Hodographs



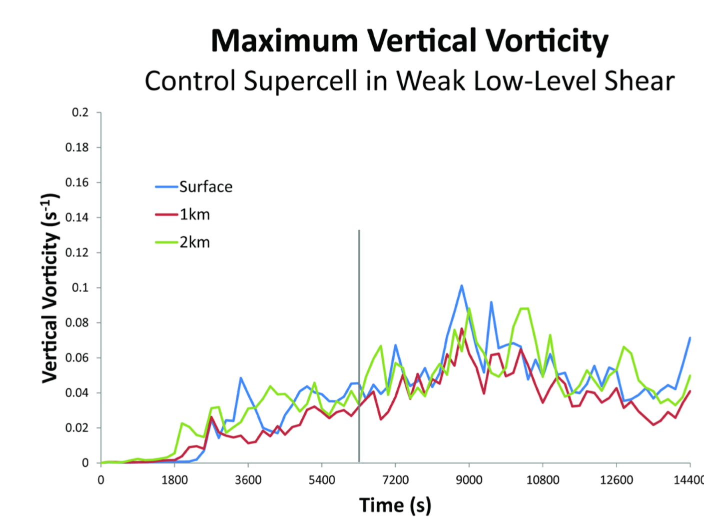


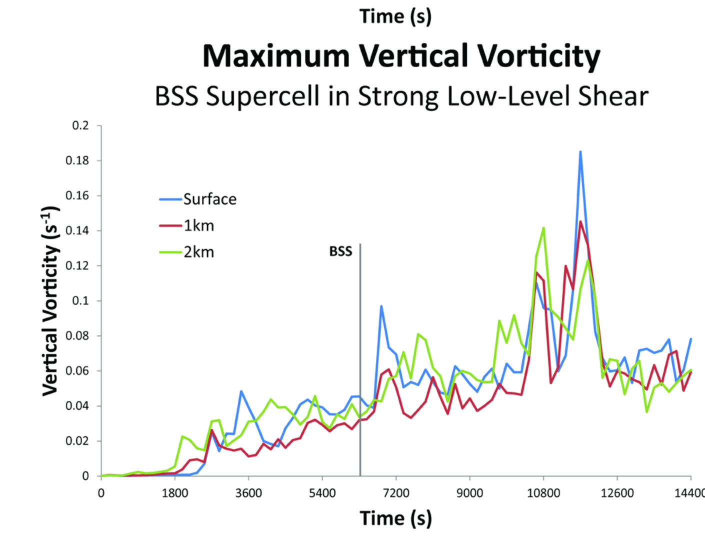
Convective Mode

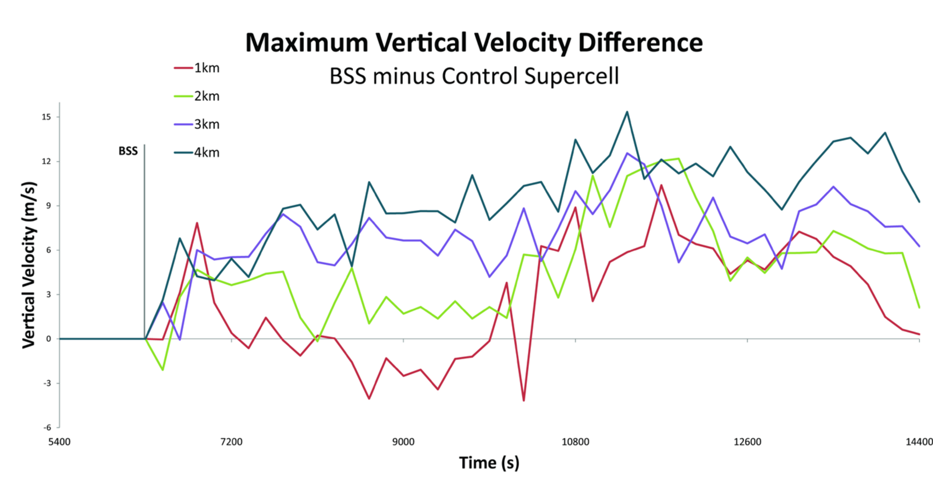
- Both the Control and BSS storms maintain "classic" supercell structures through the first hour.
- Eventually, the outflow from the Control storm completely undercuts the updraft, leading to a more disorganized multicellular structure.
- The BSS storm remains an isolated, intense supercell.

Vertical Vorticity Profile

- The Control and BSS supercells consistently produce appreciable vertical vorticity near the surface.
- Although these simulations are not tornado-resolving, the BSS supercell produces a surface vortex that strengthens to almost .2 s^{-1}, which is twice as strong as any produced by the Control storm.
- The vertical vorticity of the BSS storm was enhanced throughout the entire depth of the storm in comparison to the Control storm.







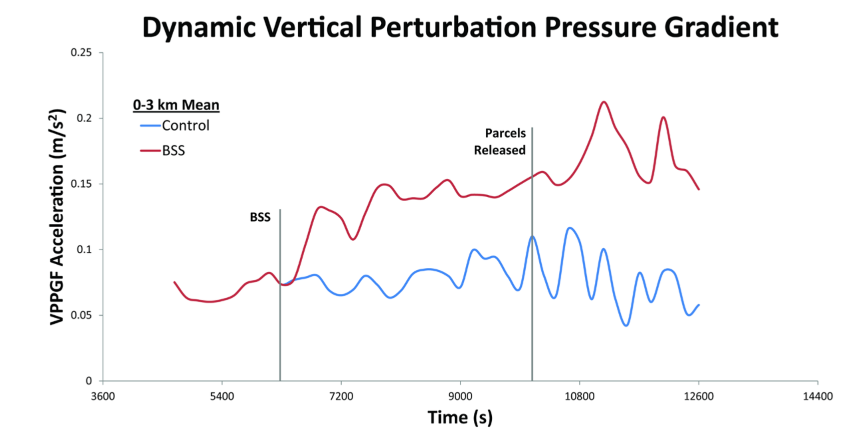
Updraft Intensity

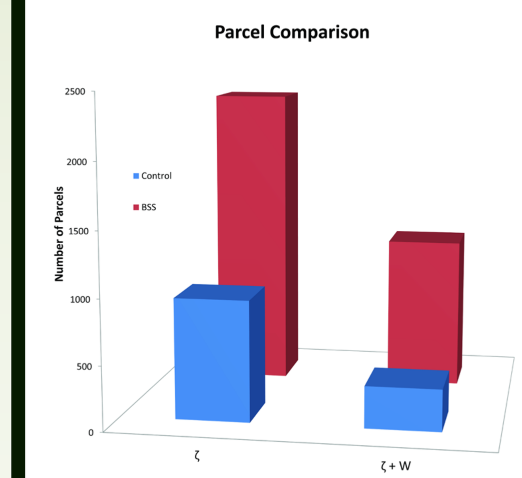
- The BSS storm has a stronger updraft throughout the lower and middle troposphere.
- This may be due to the dynamical effects of enhanced shear or differences in the simulated cold pools.

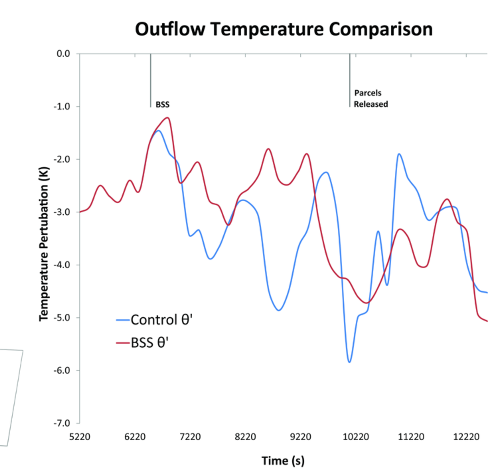
Details of Simulated Processes

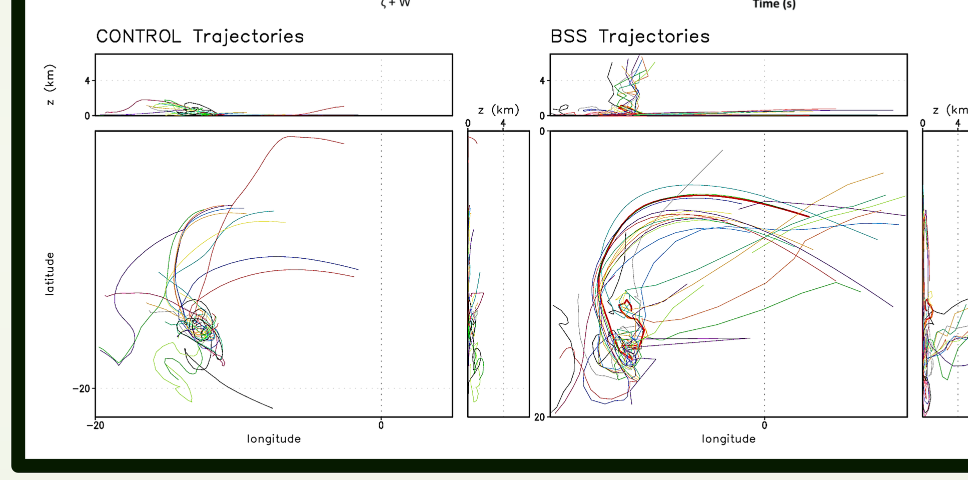
Perturbation Pressure

- A stronger dynamic vertical perturbation pressure gradient was observed at low-levels in BSS storm.









Outflow Ingestion

- Many more parcels launched entered the surface vortices in the BSS supercell. Those parcels also more frequently participated in the parent storm's updraft.
- Despite similar outflow temperatures, trajectories that acquired surface vorticity often stagnated in the Control storm, instead of participating in the updraft, as in the BSS storm.

Preliminary Conclusions

Previous work has indicated a relationship between strong low-level shear and the development of intense surface vorticity in supercells. The interplay between a storm and its environment during the afternoon-evening transition is of particular interest, as this corresponds to the time of day when many tornadoes occur. **Our simulations in an observed environment show that:**

- As low-level shear increases, the supercell stays more organized, the profile of vertical vorticity increases in magnitude, and the updraft strengthens.
- There is evidence of both a stronger dynamic VPPGF and more outflow "participation" in the stronger-shear storm.

Future Work

- Test sensitivity of simulation results to the timing and duration of the BSS.
- Assess the role of dynamic and buoyant accelerations of updraft parcels.
- Add BSS of thermodynamic profiles to address relative importance of increasing shear versus surface stabilization during the evening transition.
- Investigate another well-observed VORTEX2 case study for comparison.

Acknowledgements

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