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

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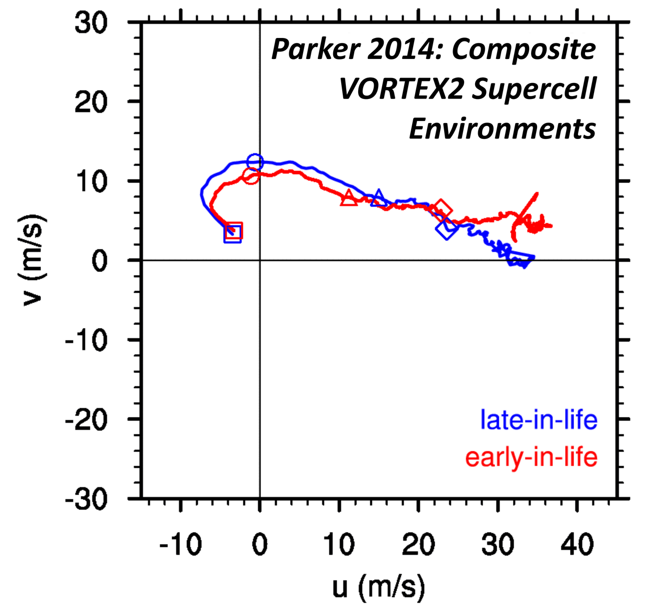
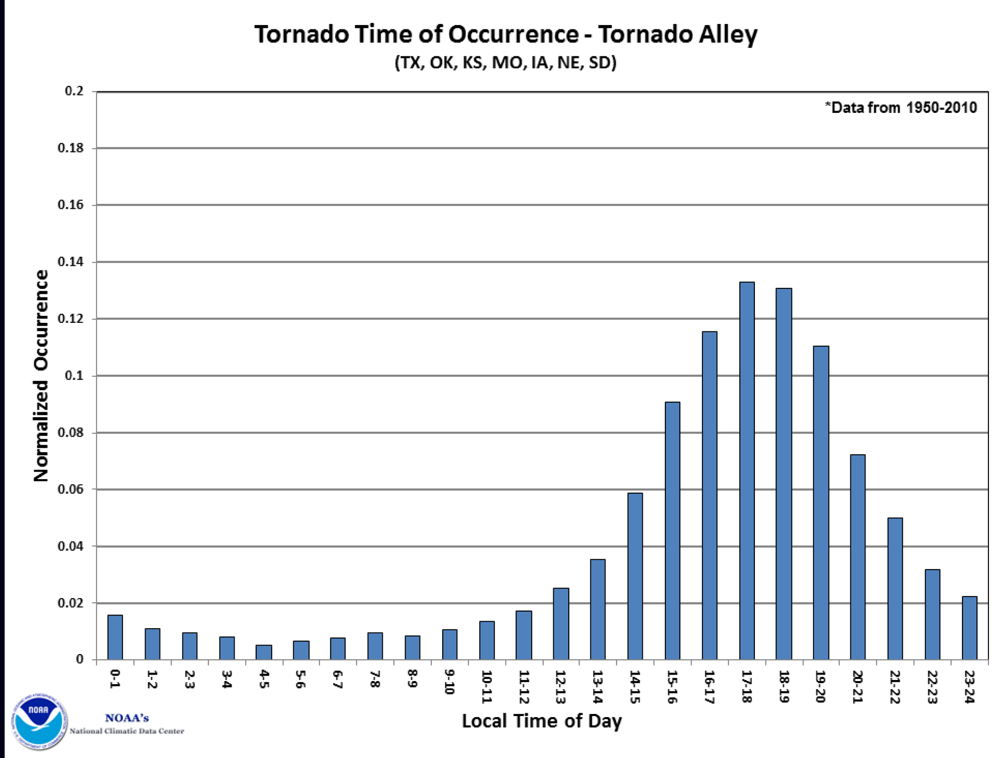
Introduction

Environmental forecast parameters have been shown to possess substantial skill in forecasting tornadoes, including the low-level environmental shear. The physical explanation for this 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?**

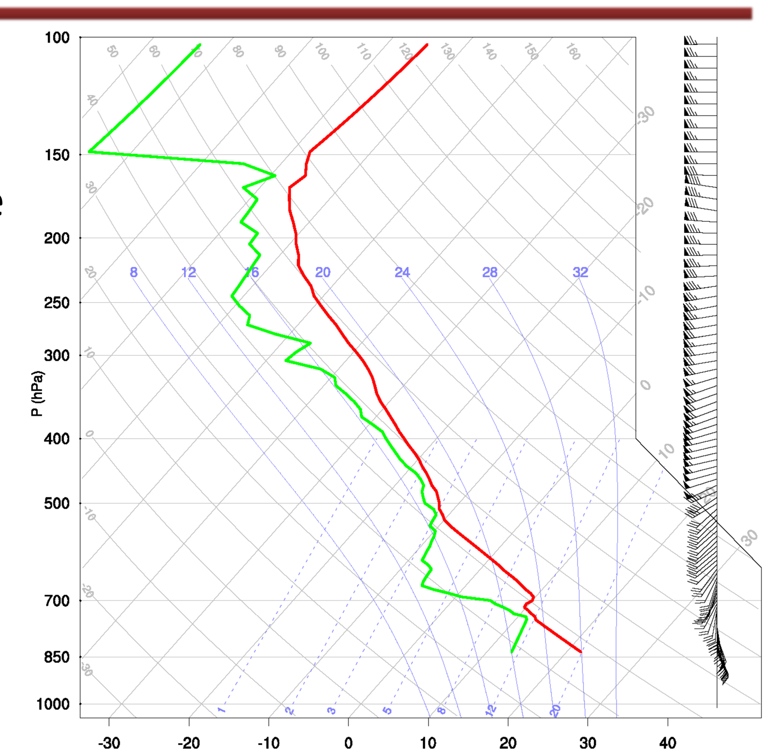




A common characteristic of severe weather events in the central United States is an increase in low-level shear during the early evening hours, as a nocturnal low-level jet begins to develop. **It is unclear how storms directly respond to this change in shear.** Perhaps this increase in low-level shear 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 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 straight hodograph in the early afternoon, gradually transitioning into a strongly curved hodograph in the 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. **The advantage of this 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.**



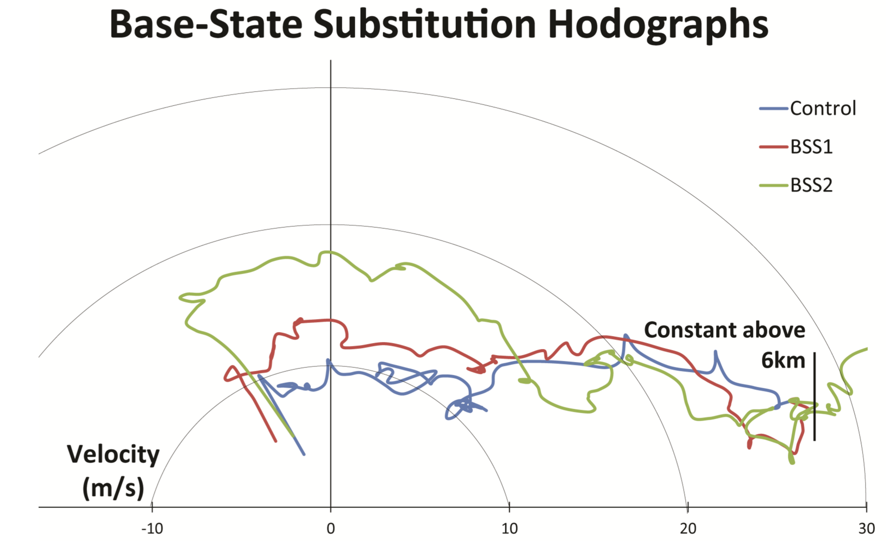
	6 km Shear (m/s)	3 km SRH (m^2/s^2)	1 km SRH (m^2/s^2)	1 km Shear (m/s)	CAPE (J/kg)	LCL (m)	SCP	STP
Control	29.7	79	37	6.5	2837	1100	3.3	.93
BSS1	31.2	183	88	7.2	2837	1100	8.1	2.3
BSS2	30.2	401	137	12.4	2837	1100	17.2	8.1

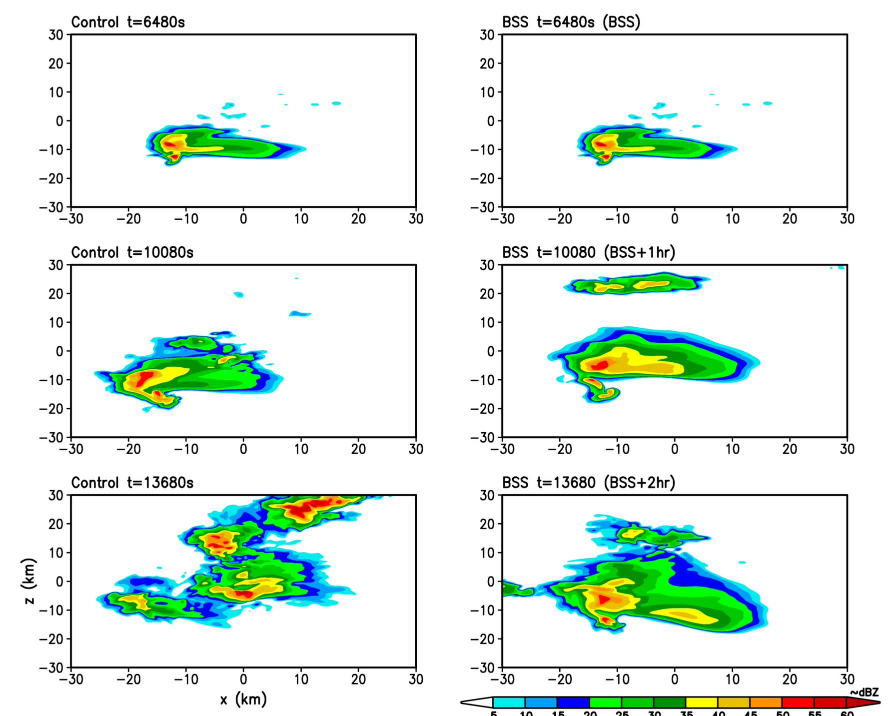
- Control, BSS1, and BSS2 refer to the respective base-state wind profiles to the upper right

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 three hodographs on the right.



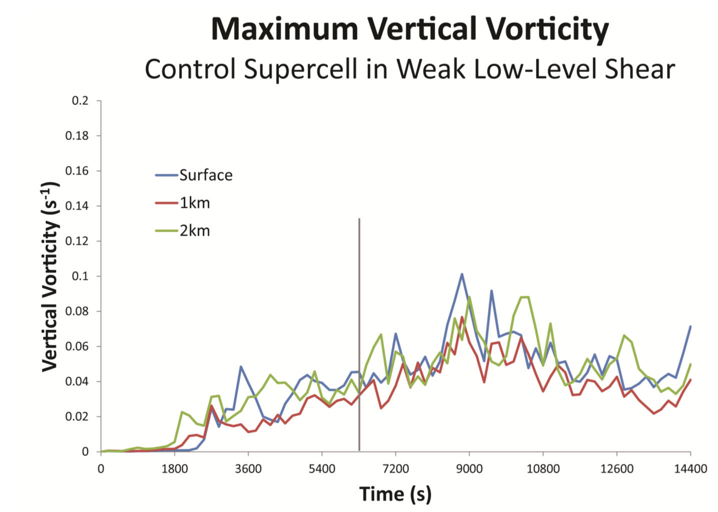


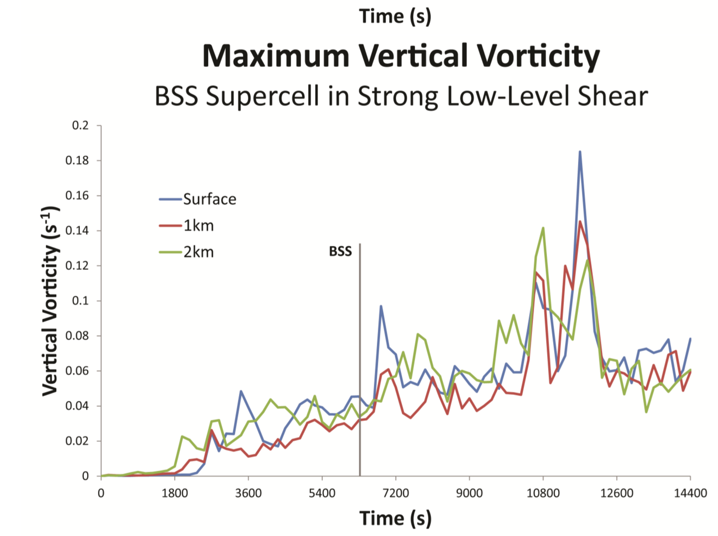
Convective Mode

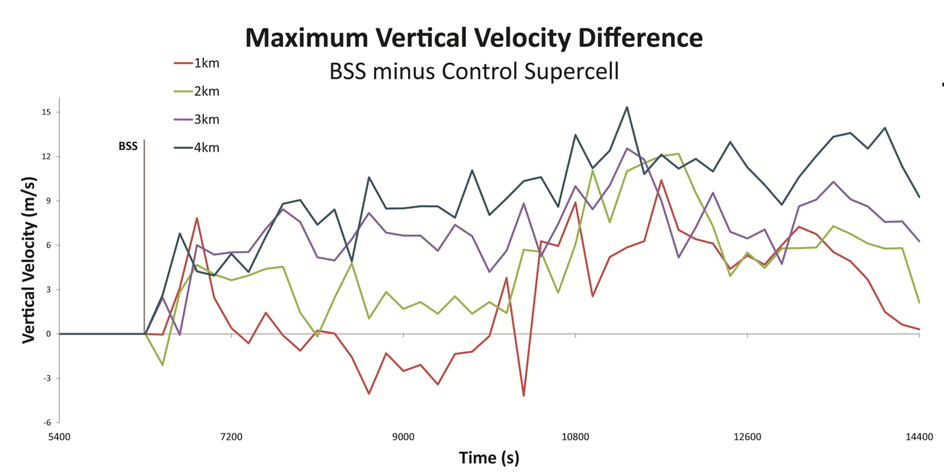
- Both storms initially maintain classic supercell structures.
- Eventually, outflow in the low-shear storm completely undercuts the updraft, leading to a disorganized multicellular structure.
- The strong shear storm remains an isolated, intense supercell.

Vertical Vorticity Profile

- Both supercells produce appreciable vertical vorticity near the surface.
- Although these simulations are not tornado-resolving, the stronger shear supercell produces a surface vortex that is almost twice as strong as any produced by the lower shear storm.
- The vertical vorticity in the stronger shear storm was also enhanced throughout the supercell.







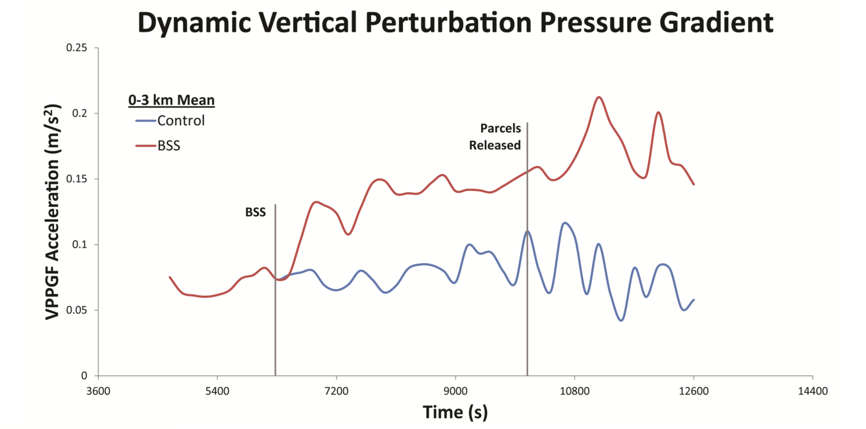
Updraft Intensity

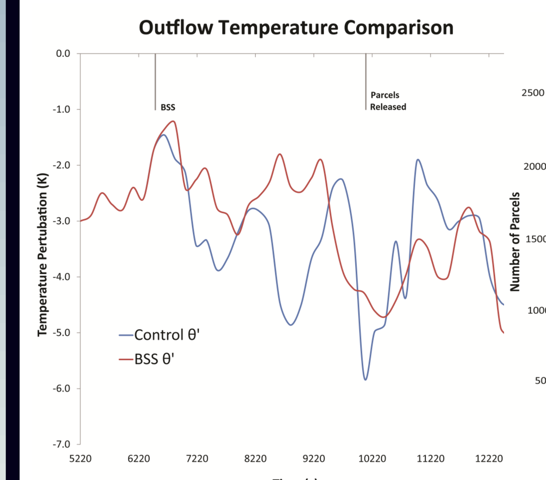
- The stronger shear storm has a more intense updraft throughout the mid-troposphere.
- This may be due to the dynamical effects of enhanced shear or differences in the cold pools.

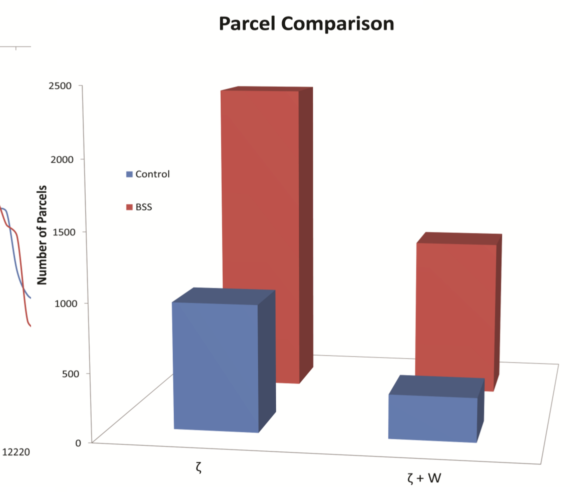
Details of Simulated Processes

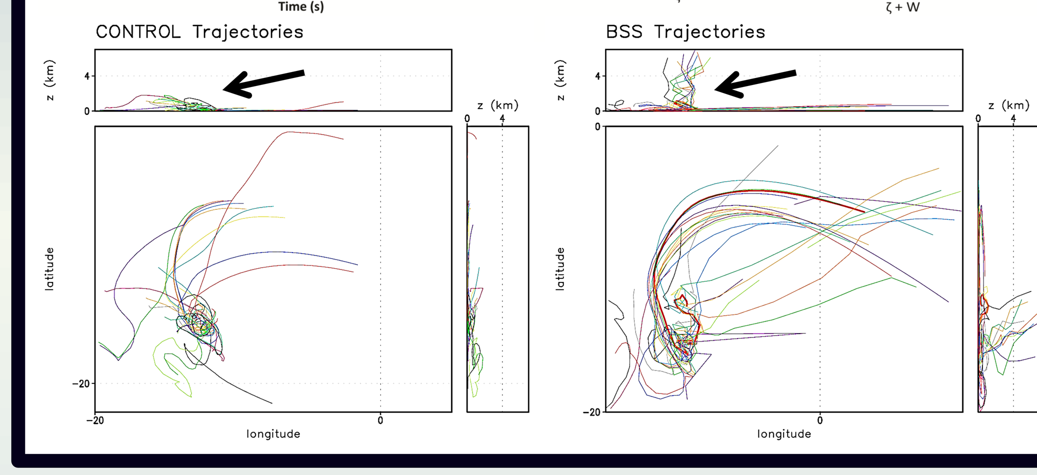
Perturbation Pressure

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









Outflow Ingestion

- Both simulations have similar outflow temperatures.
- Despite this, trajectories that acquired surface vorticity often stagnated in the lower-shear storm, instead of participating in the parent supercell's overlying updraft, as in the stronger-shear 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 lifting and more outflow "participation" in the stronger-shear storm.

Future Work

- Introduce surface cooling to address relative importance of increasing shear versus surface stabilization during the evening transition.
- Investigate another well-observed VORTEX2 case study, 12 May 2010.
- Assess the role of dynamic and buoyant accelerations of updraft parcels.

Acknowledgements

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