



Simulations of Convective Storms in Low CAPE, High Shear Environments

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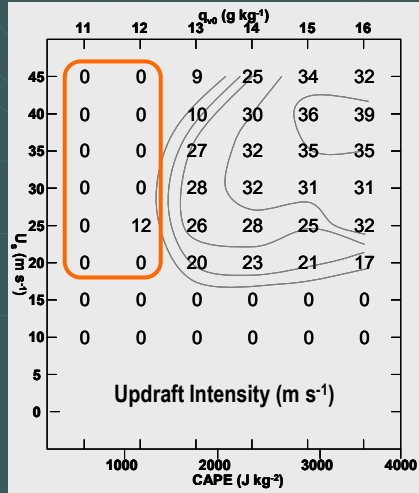
Motivation

- ▣ Describe the unique behavior of convective storms when:
 - CAPE is “low”
 - Tropospheric, deep-layer shear is “high”

- ▣ Representative environments:
 - Convection associated with tropical cyclones
 - Cool-season severe weather events
 - High-latitude convection

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These storms are difficult to model...



...and to predict!

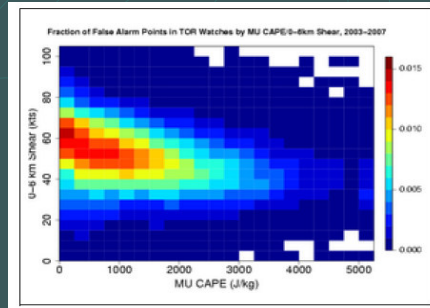


Fig. 20. Distribution of tornado watch false alarm hours for 2003-2007 by MU CAPE/0-6km Shear bin, normalized by the total number of tornado watch false alarm hours in the sample.

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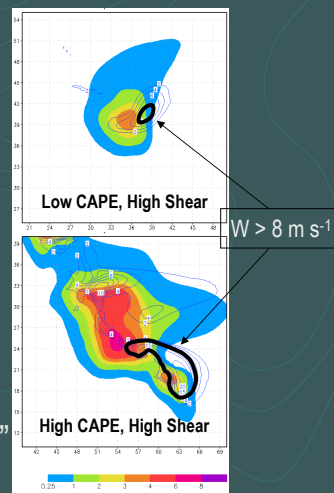
Storms in Low CAPE, High Shear

General observations

- Updrafts are more susceptible to entrainment, dilution
- Storms are smaller, more shallow than in higher CAPE

Environmental description:

- Common to use Bulk Richardson Number
- Here, all our "low CAPE/high shear" environments have BRN < 25



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Our model dataset

- 216 simulations from the Convection Morphology Parameter Space Study (COMPASS)
 - Broad spectrum of convective environments and modes
 - LCL-conserving thermal bubble, in a 75 km × 75 km homogeneous domain; 500 m horizontal mesh

Focus in this paper is on **lowest CAPE**, **highest shear** environments

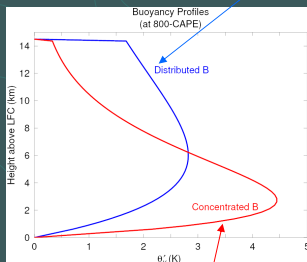
Parameter	Possible Values
Bulk CAPE	800, 2000, 3200 J kg ⁻¹
Semicircular hodo. radius	8, 12, 16 m s ⁻¹
Shape of buoyancy profile	Two choices per CAPE
Shape of shear profile	Two choices per CAPE
LCL-LFC configuration	0.5-0.5, 0.5-1.6, 1.6-1.6 km
Precipitable water (PW)	Roughly 30 or 60 mm
RH above LFC	Constant, 90%

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Critical factor: low-level buoyancy

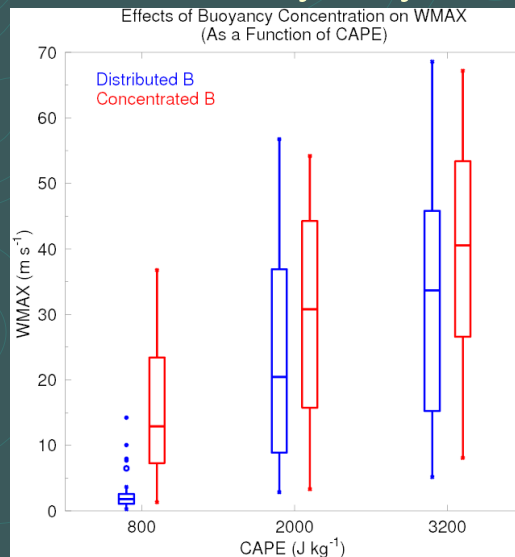
Distributed buoyancy:

- weaker LL lapse rates
- taller, narrower CAPE profile



Concentrated buoyancy:

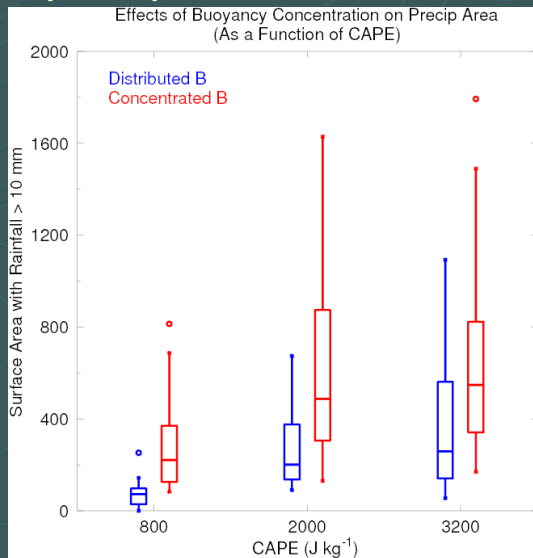
- stronger LL lapse rates
- more CAPE at low levels



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Implications for precipitation

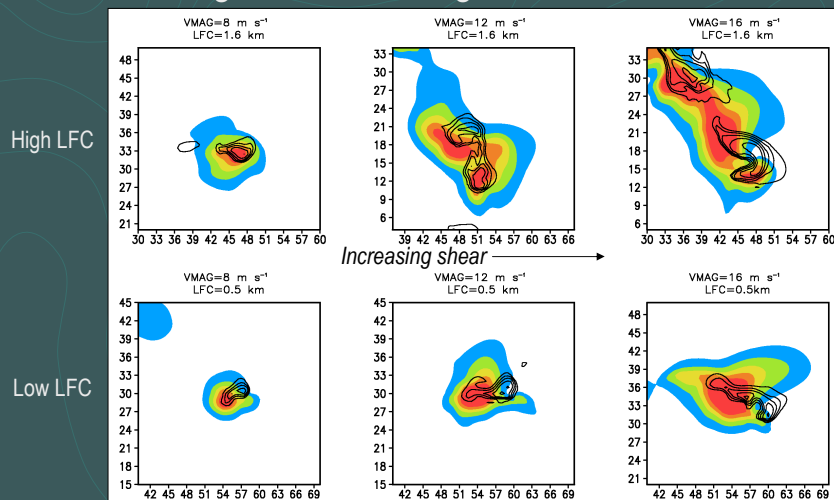
- Nearly two-fold increase in
 - Total precip mass
 - Area of >10 mm rainfall
- Threefold increase in amount of liquid water being produced aloft



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Implications for updraft size

- LFC height exerts strong influence



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Implications for low-level rotation

- Linear correlations between ζ_0 and environment:

	800-CAPE	2000- & 3200-CAPE
VMAG	0.12	0.63
ZMAXB	-0.33	-0.27
ZMAXV	-0.42	-0.25
LCL	-0.05	-0.25
LFC	-0.18	-0.35
T_{LCL} (PW)	-0.40	0.07

- Correlations nearly inverted for low-CAPE storms
 - Strong low-level shear and buoyancy needed
 - Relatively less PW (and updraft water loading)

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How do these environments occur?

- One example: cyclone undergoing extratropical transition
 - Steeper lapse rates as continental air modifies lower troposphere; role of dry intrusions
 - PW tends to moderate with latitude (and as storms weaken)
 - Shear
 - Deep layer: interaction with jet stream
 - Low level: topography, friction, etc.

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RCAPE vs. PCAPE

CAPE calculation methods

$$w = \sqrt{2 \text{CAPE}}$$

- Pseudoadiabatic: remove all water mass upon formation
- Reversible: parcel retains all water mass
 - (Issues: convert to ice? at what temperature? etc.)

Environments with similar PCAPE may have very different RCAPE!

Example: high PW → reduced RCAPE

Of course, parcel theory has its limitations...

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RCAPE vs. PCAPE

Parcel theory predictions of w are improved when RCAPE is used

- Most improvement when PW is high
- Best performance when CAPE is low

CAPE	PW	MAE (RCAPE)	MAE (PCAPE)	Difference
800	Low	18.7	27.8	+ 9.1
	High	6.1	34.9	+28.8
2000	Low	23.4	28.9	+ 5.5
	High	29.2	44.4	+15.3
3200	Low	30.2	34.4	+ 4.2
	High	41.1	52.6	+11.5

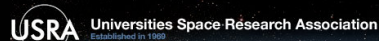
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Summary

- ▣ Low CAPE, high shear storms are fundamentally different from other types of convection.
 - Low level buoyancy is critical to storm persistence
 - Unique response to environmental conditions
 - Can double the amount of precipitation observed at the ground
 - Different metrics account for low-level rotation, storm size
- ▣ RCAPE may be preferable to PCAPE in forecasting updraft speeds, especially in tropical settings.
 - (Better in 215 of our 216 simulations!)

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Project website: <http://space.hsv.usra.edu/COMPASS>

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