Reduced Complexity Frameworks for Investigating the Geographic Controls of Severe Local Storm Environments in CAM6

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Motivation

U.S. National Climate Assessment:

“Changes in extreme weather events are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events.”

1. CAPE
2. Lower-tropospheric wind shear (0-6km)
3. Low-level storm-relative helicity (SRH; 0-3km)

1. CAPE $\times$ shear (CAPES06) (Brooks et al. 2003)
2. Energy-Helicity Index (EHI) $\sim$ CAPE $\times$ SRH (Hart and Korotky 1991)
3. Significant Tornado Parameter (e.g., Thompson et al. 2003)
Severe Local Storm (SLS) Environments

SLS Environments are necessary conditions for severe weather:

99th percentile Sfc CAPE x 0-6 km bulk shear

EF1+ Tornadoes
Why do these environments exist in the first place?

Recent work:
- Tornadoes trends (e.g., Agee et al. 2017, Gensini and Brooks 2018)
- Climate change effects (e.g., Seeley and Romps 2015, Agard and Emanuel 2017, Singh et al. 2017, Trapp and Hoogewind 2016)
Differential advection: *warm moist low-level air* undercuts *elevated mixed layer*

Key factors:
1. Elevated terrain upstream
2. Gulf of Mexico to the south

Are these geographic features essential to the production of SLS environments over North America?
Model Experiments

• National Center for Atmospheric Research’s (NCAR) Community Atmosphere Model version 6 (CAM6).
• Standard CMIP6 horizontal resolution ($\Delta x \sim 100$km) with Finite Volume core with 32 vertical levels is used.
• Prescribed observed (or projected) SSTs, ozone, CO$_2$, solar forcing, etc.
• Will be compared to ERA5 reanalysis ($\Delta x = 31$ km).
Test the role of North American geographical features using global climate model experiments with CAM6.

Experiments:
1. **Control**: Earth-like present day climate
2. **noTOPO**: North American topography set to zero
3. **noGOM**: Gulf of Mexico converted to land

**Thermodynamic parameters:**
- Surface-based CAPE
- 0-6km bulk shear \( S_{06} \)
- 0-3km SRH

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**Model Experiments**

Mar. 9, 2020

**Goal: Simplicity**
Results: Control

Annual 99th percentile

Control experiment produces reasonable **climatology of SLS environments** (as well as the seasonal and daily cycles).

Mar. 9, 2020  [Li et al., 2020, J. Climate in review]
Results: Control

Annual 99th percentile

Control experiment produces reasonable climatology of environment parameters.

[Li et al., 2020, J. Climate in review]
The ability to simulate these environments can be attributed to representing the synoptic-scale mechanisms.
Results: noTOPO & noGOM

SLS Environment is reduced in continental interior for noTOPO, more complex for noGOM.

Mar. 9, 2020 [Li et al., 2020, J. Climate in prep.]
Results: noTOPO & noGOM

Annual 99th percentile

High CAPE environments are reduced in continental interior in both cases.
Results: noTOPO & noGOM

noTOPO simulations suggests impact on circulations, which impact SLS environments, not so for noGOM.

Mar. 9, 2020

[Li et al., 2020, J. Climate in prep.]
CAM6 reproduces climatological SLS environments from ERA5 over the central US, as well as their strong seasonal and diurnal cycles (not shown here).

Topography is crucial for inland SLS environments, predominantly associated with a reduction in CAPE, but not for their existence in general.

When Gulf of Mexico is altered there is also a decrease in extreme inland SLS environments.

*Note:* We cannot address changes in SLS events (i.e., SLS production efficiency).
Next Steps: Idealized Configurations

This work is a crucial first step to building a reduced-complexity framework to quantify how land-ocean contrast and elevated terrain control SLS environments.
Use **CAM6** in an aquaplanet setup with and without a *simple continent*.
Next Steps: Idealized Configurations

Aqua

Continent

99th percentile CAPES06

Mar. 9, 2020 [Preliminary Work]
Thank You
Results: noTOPO / noGOM

Annual
99\textsuperscript{th} percentile

Percentage of Great Plains Low-Level Jets

CTRL

noTOPO-CTRL

noGOM-CTRL

Mar. 9, 2020

[Li et al., 2020, J. Climate in prep.]
Results: noTOPO / noGOM

Annual
99\textsuperscript{th} percentile

Storm Tracks and Mean Eddy Kinetic Energy

[Li et al., 2020, J. Climate in prep.]