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

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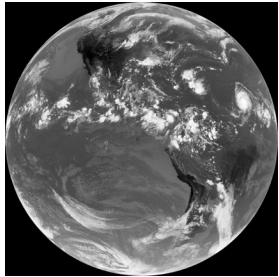*Stony Brook University, Stony Brook, New York*

Funing Li & Daniel Chavas

Department of Earth, Atmospheric and Planetary Sciences

Purdue University, West Lafayette, Indiana
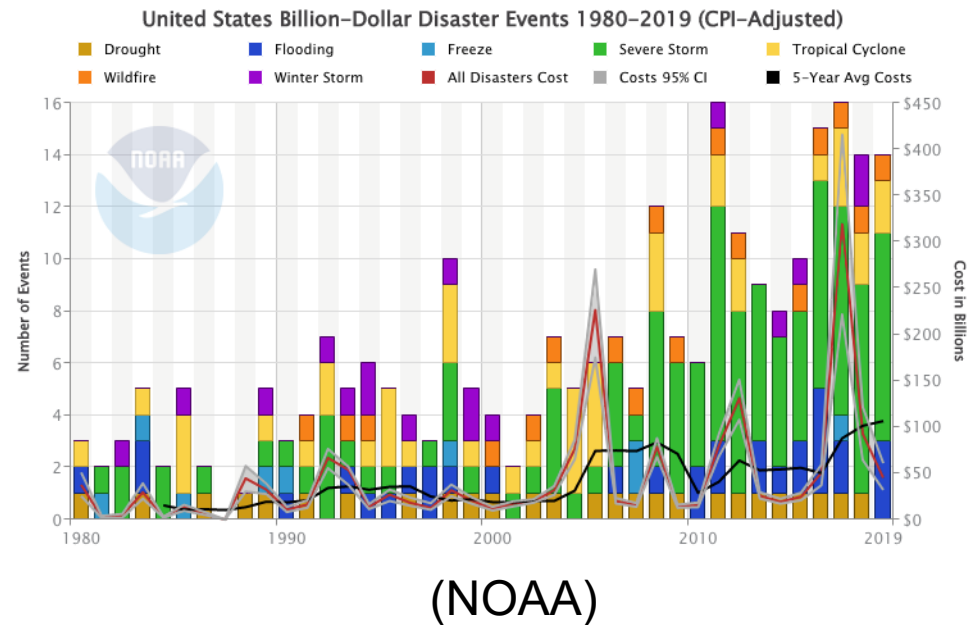
Nan Rosenbloom

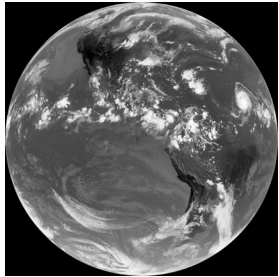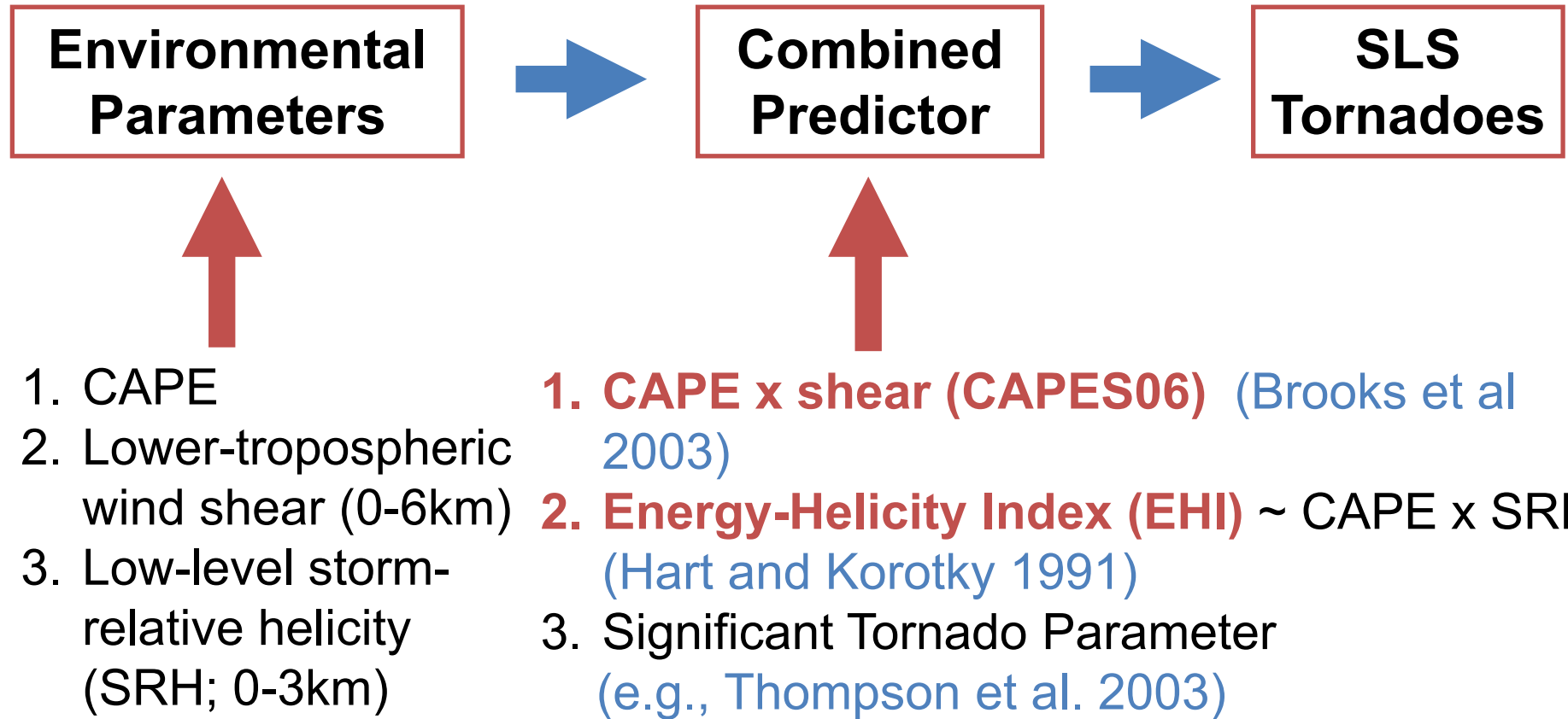*National Center for Atmospheric Research*

Motivation

U.S. National Climate Assessment:

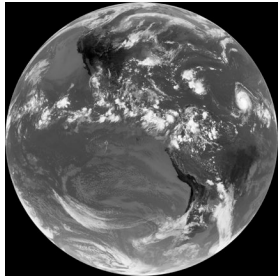"*Changes in **extreme weather events** are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events.*"
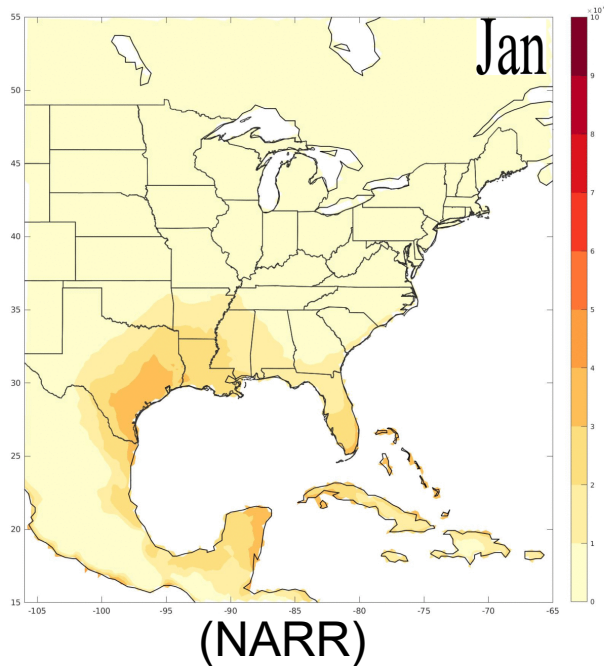

United States Billion-Dollar Disaster Events 1980–2019 (CPI-Adjusted)

(NOAA)

SLS-Climate Framework

Environmental Parameters → **Combined Predictor** → **SLS Tornadoes**

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

1. **CAPE x shear (CAPES06)** (Brooks et al 2003)
2. **Energy-Helicity Index (EHI)** ~ CAPE x SRH (Hart and Korotky 1991)
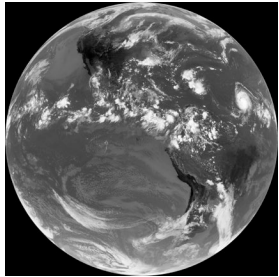3. Significant Tornado Parameter (e.g., Thompson et al. 2003)

SLS Environments are **necessary conditions** for severe weather:

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

EF1+ Tornadoes

(NARR)

(SPC)

SLS-Climate Framework

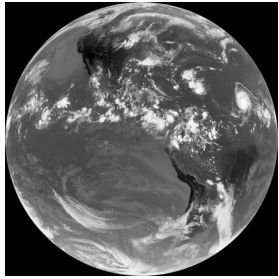**Environmental Parameters** → **Combined Predictor** → **SLS Tornadoes**

?
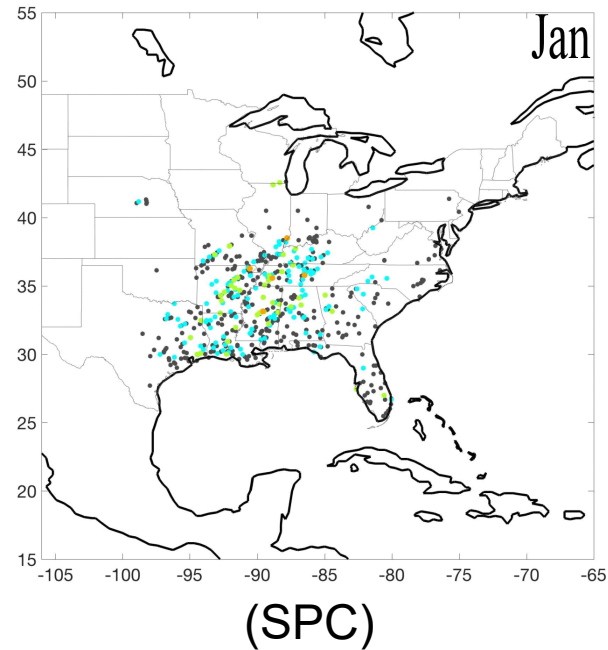
Climate

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)

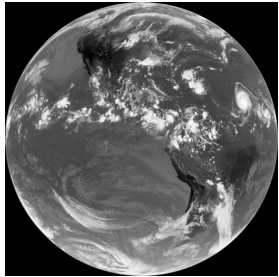**Why do these environments exist in the first place?**

Prevailing Model

Differential advection: *warm moist low-level air undercuts elevated mixed layer*

Dry mixed layer aloft
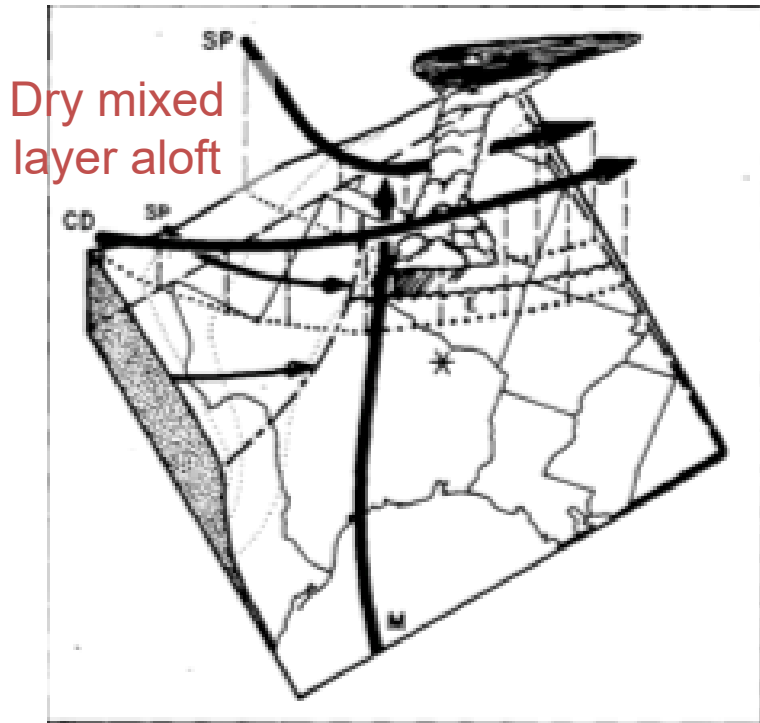
Key factors:
1. Elevated terrain upstream
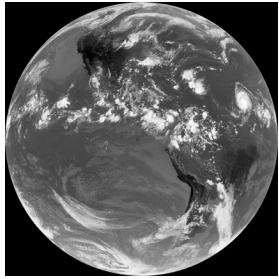2. Gulf of Mexico to the south

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.

- Full physics with Atmospheric Model Intercomparison Project (AMIP) protocols for 1980-2005.

- Prescribed observed (or projected) SSTs, ozone, CO_2, solar forcing, etc.

- Will be compared to **ERA5 reanalysis** ($\Delta x = 31$ km).
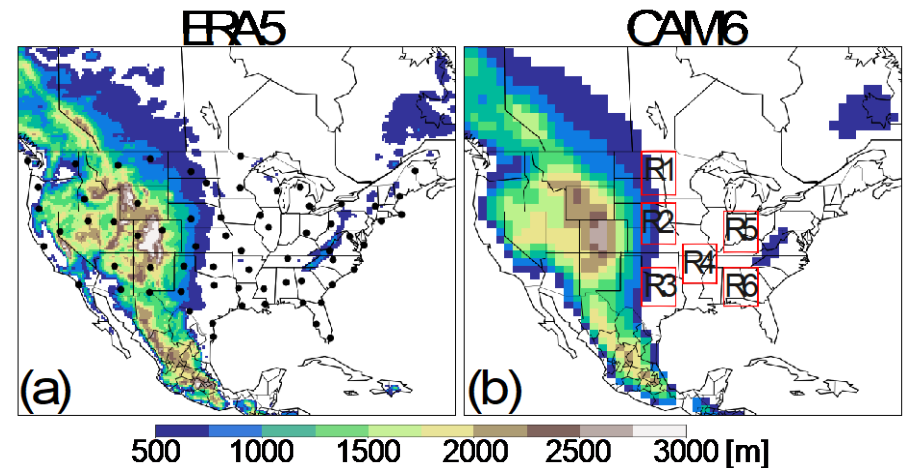
Model Experiments

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:
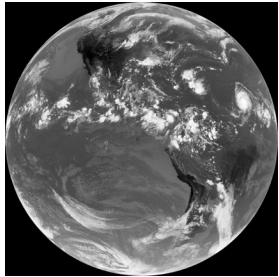- Surface-based CAPE
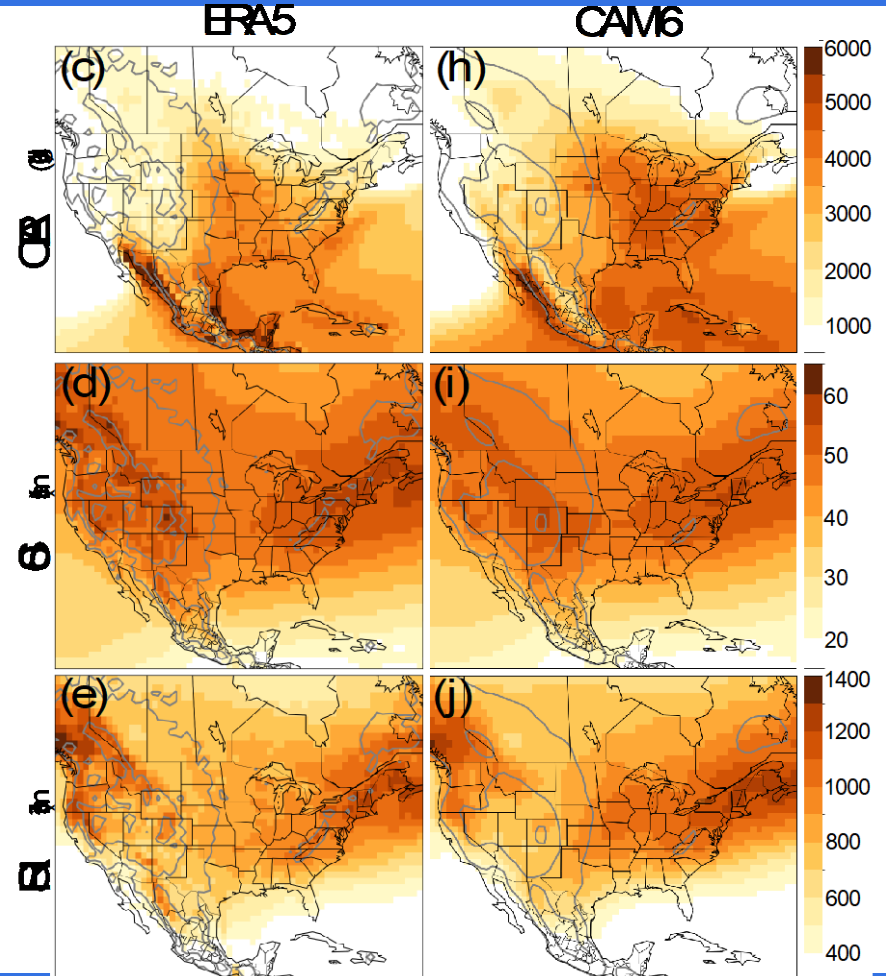- 0-6km bulk shear S06
- 0-3km SRH
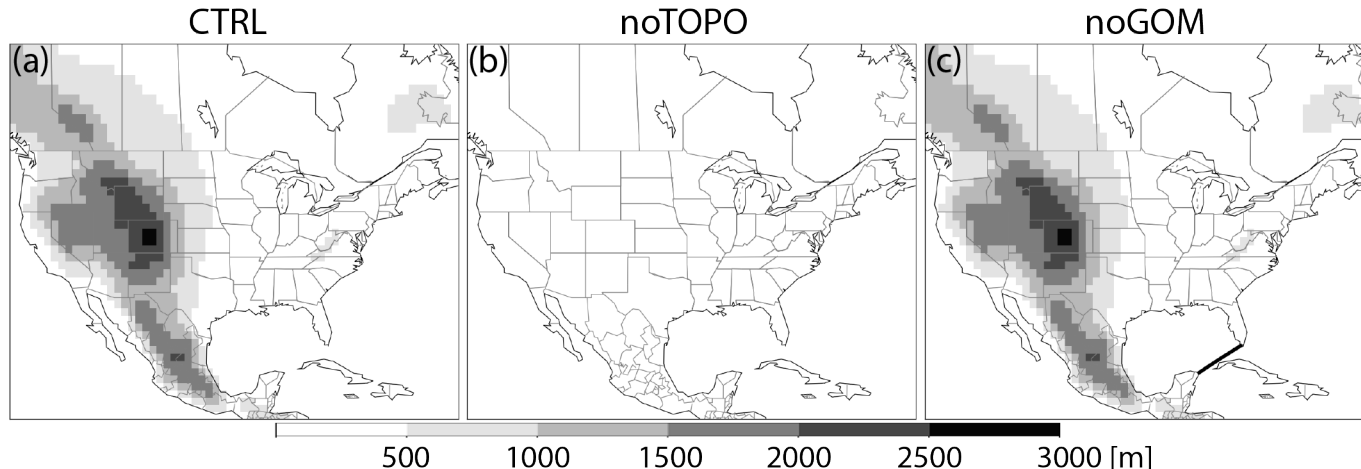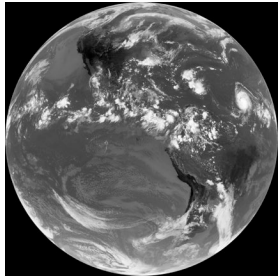
Annual 99th percentile
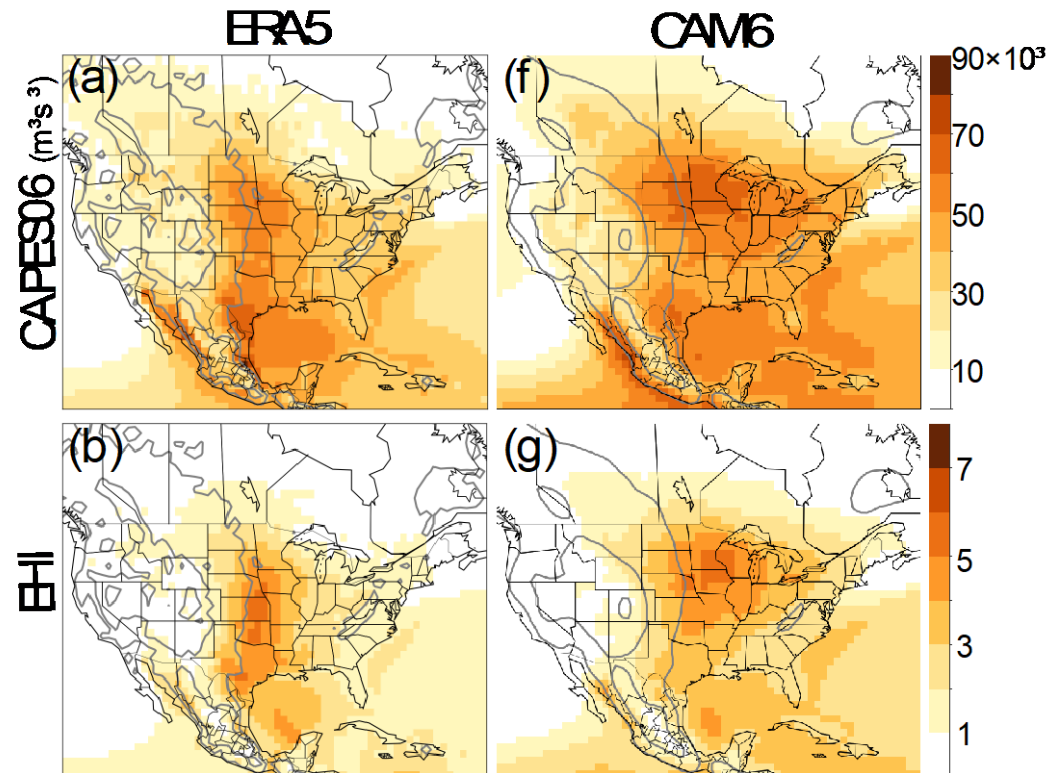
Control experiment produces reasonable **climatology of SLS environments** (*as well as the seasonal and daily cycles*).
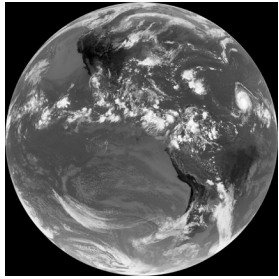
Annual 99th percentile

Control experiment produces reasonable **climatology of environment parameters**.
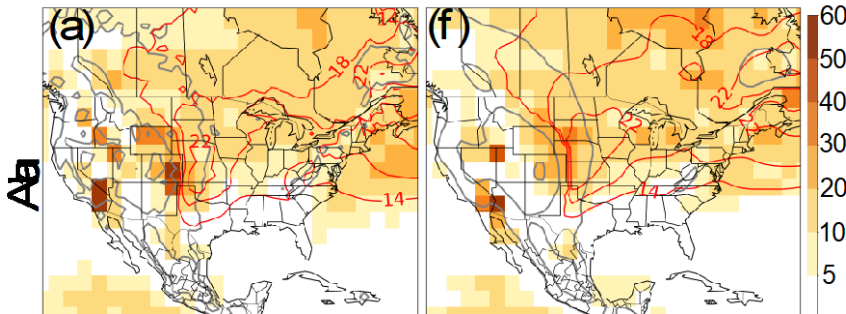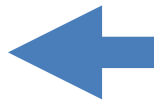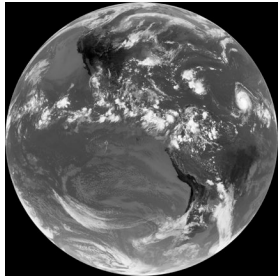
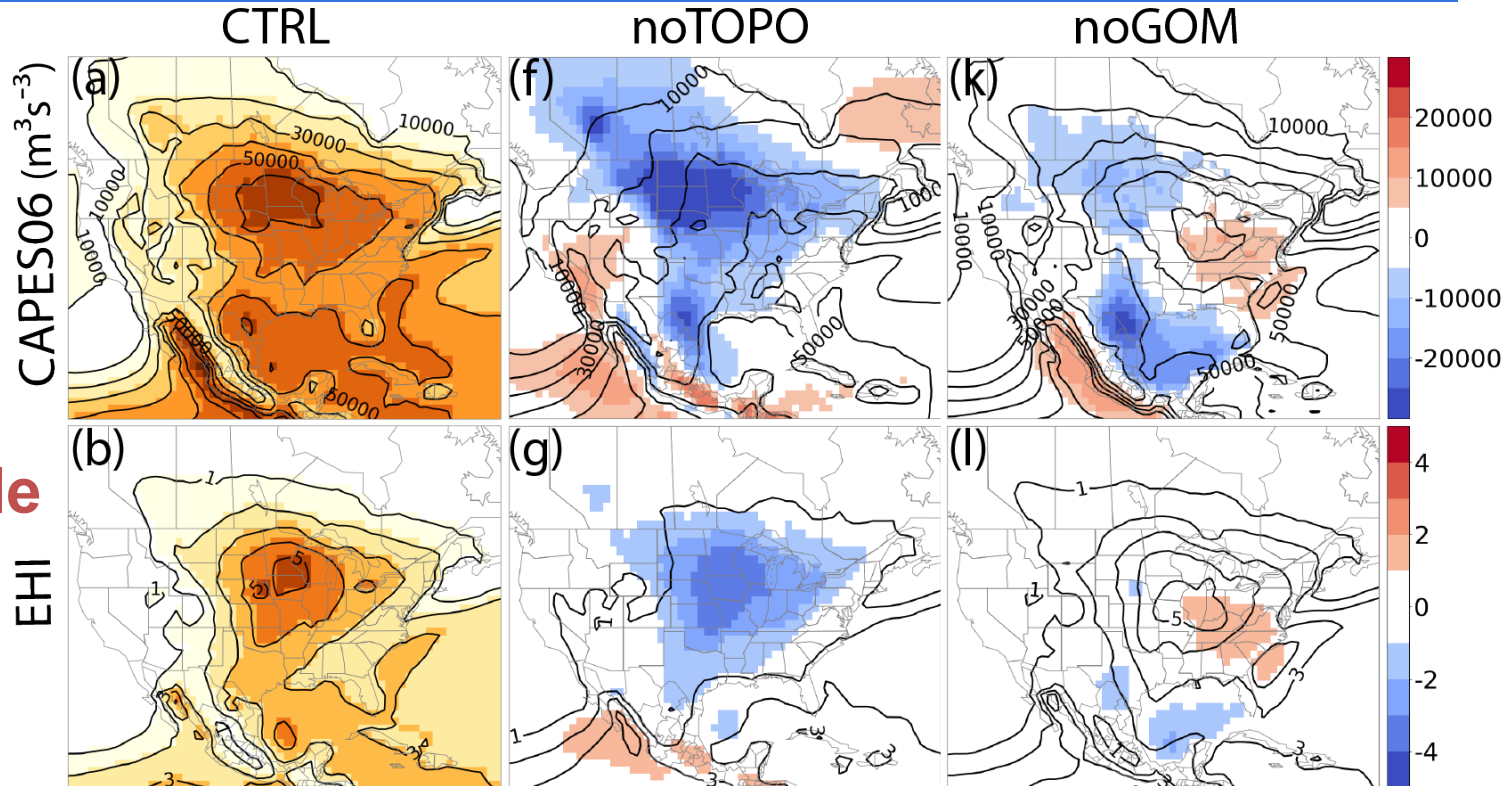**Percentage of Great Plains Low-Level Jets** →
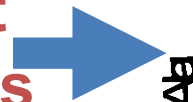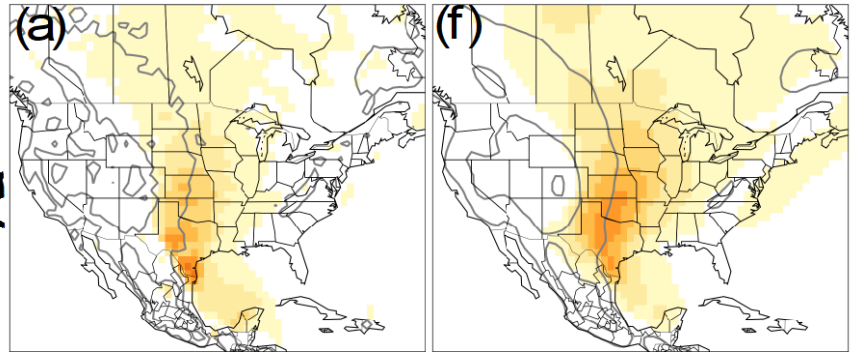
← **Storm Tracks and Mean Eddy Kinetic Energy**

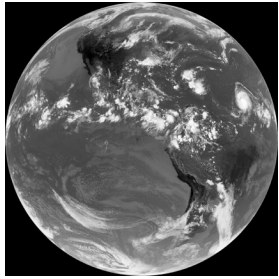The ability to simulate these environments can be attributed to representing the **synoptic-scale mechanisms**.
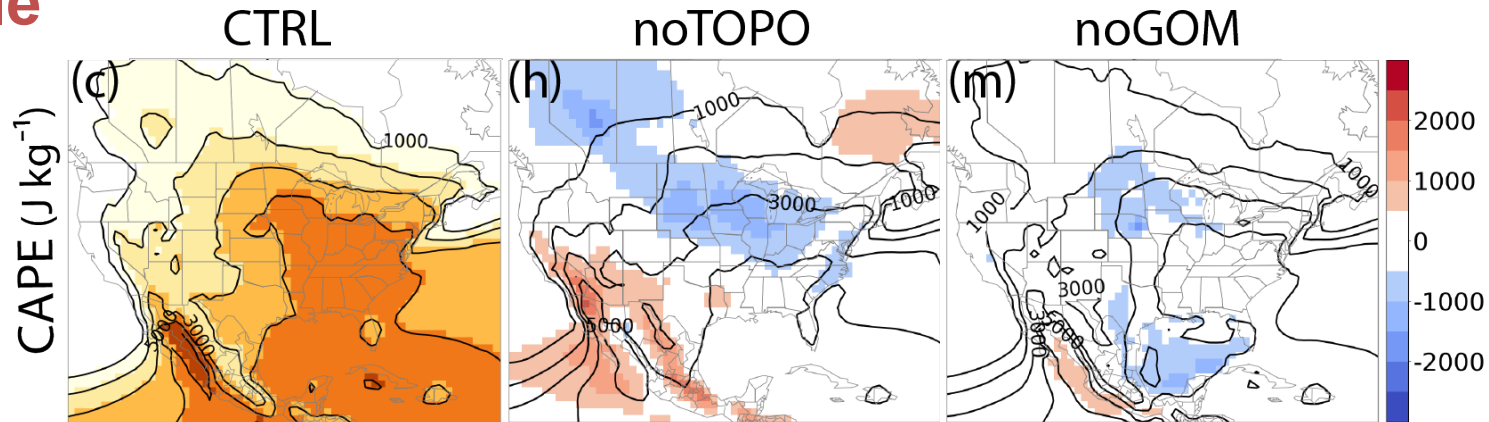
Annual 99th percentile

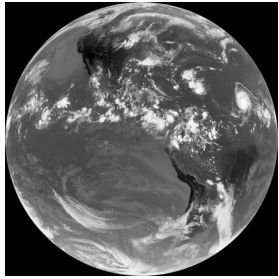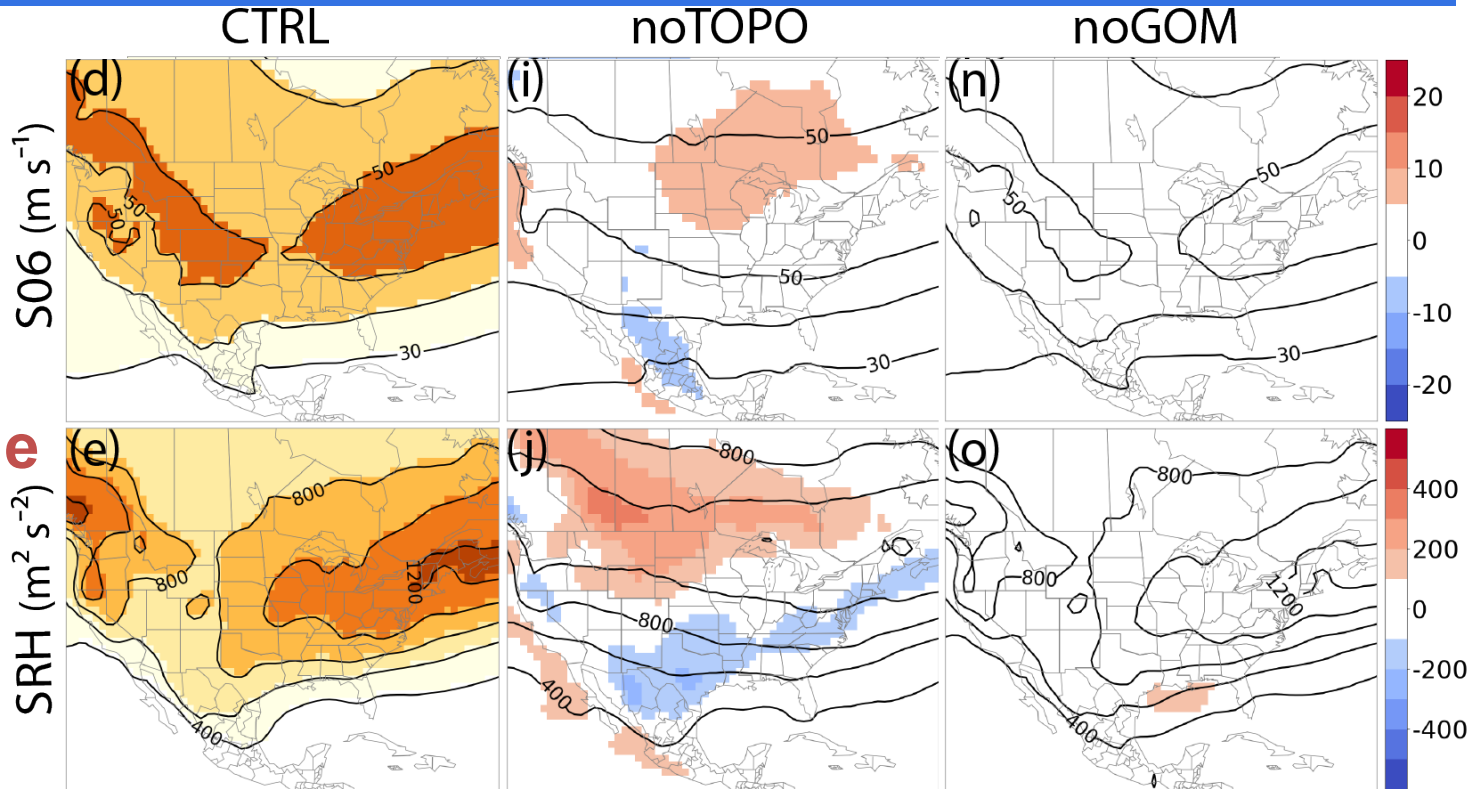SLS Environment is **reduced in continental interior** for noTOPO, more complex for noGOM.

**Annual
99th percentile**

High CAPE environments are **reduced in continental interior** in both cases.
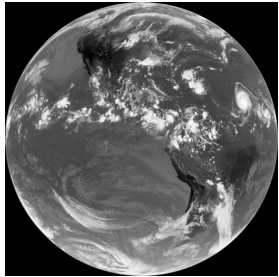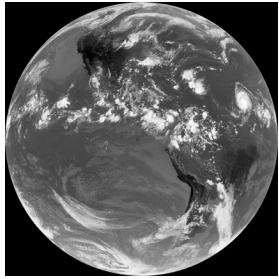
Annual 99th percentile

noTOPO simulations suggests impact on circulations, which impact SLS environments, not so for noGOM.
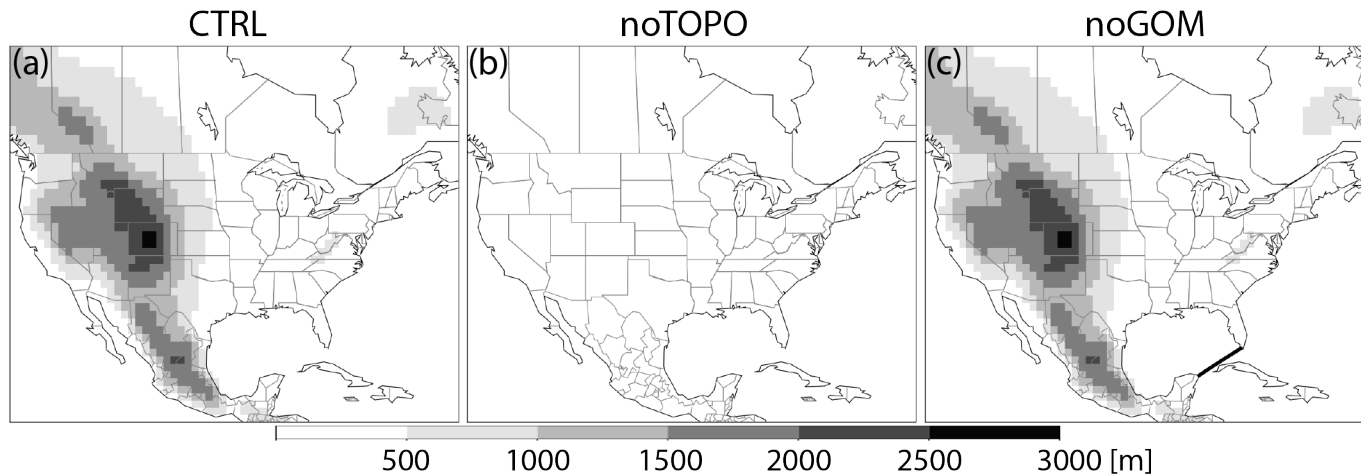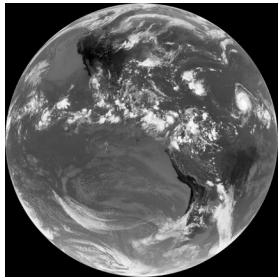
Takeaways & Ongoing Work

- 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).
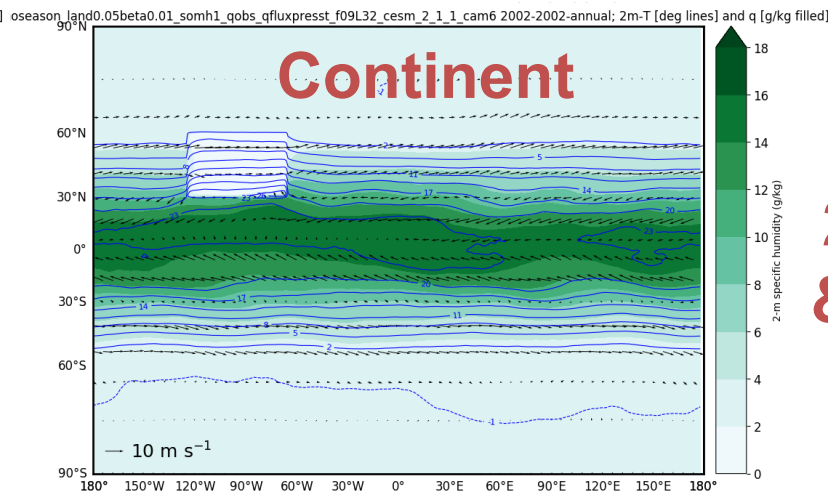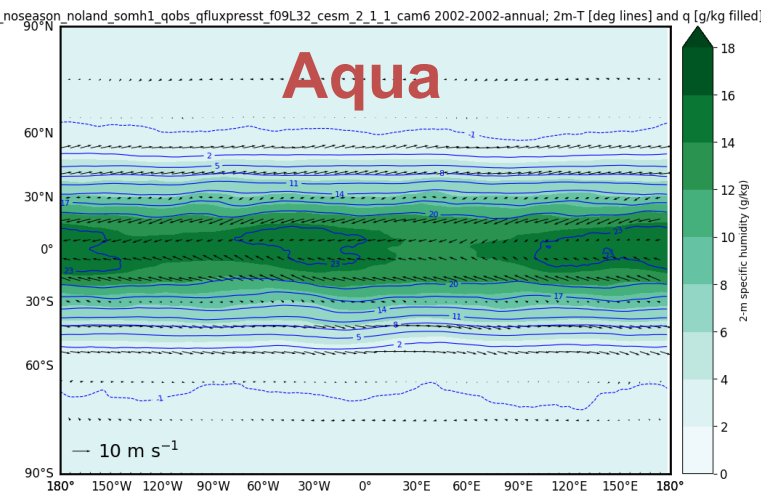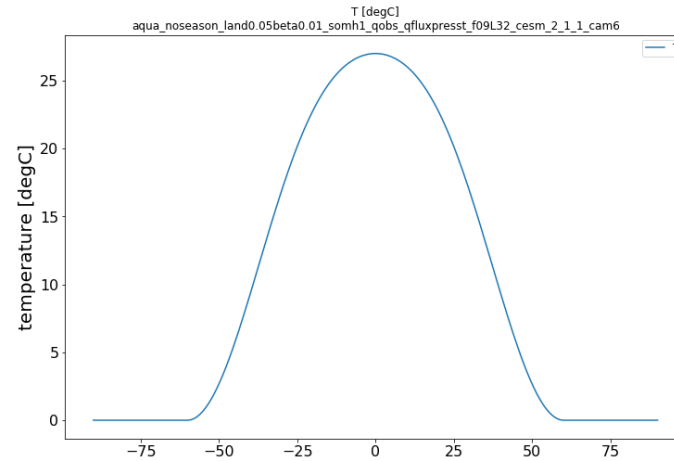
Next Steps: Idealized Configurations

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.
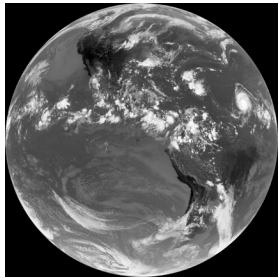

CTRL   noTOPO   noGOM

500   1000   1500   2000   2500   3000 [m]

Use **CAM6** in an aquaplanet setup with and without a *simple continent*

Aqua

Continent

2-m Temp & Humidity

Aqua
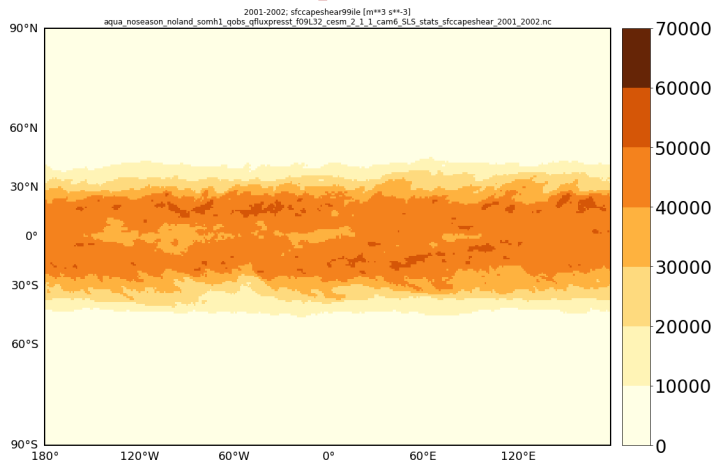
Continent
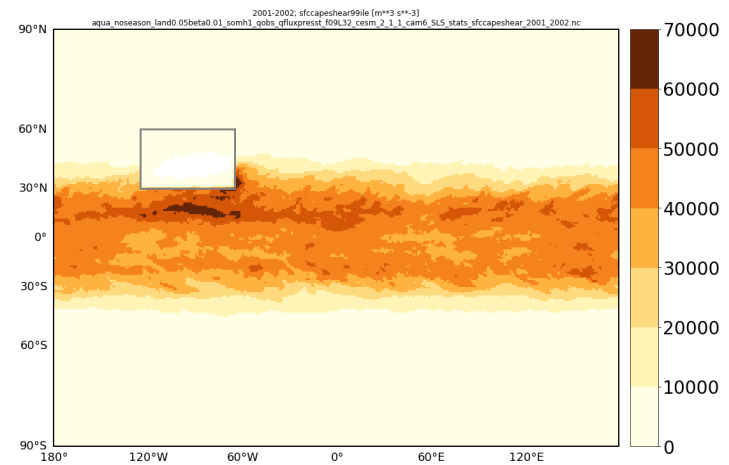
99th percentile CAPES06

Thank You

Mar. 9, 2020
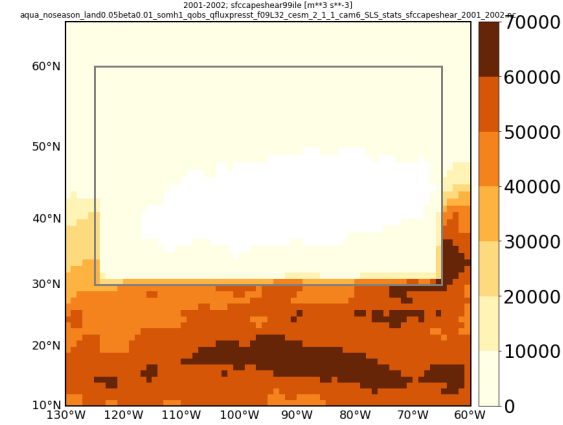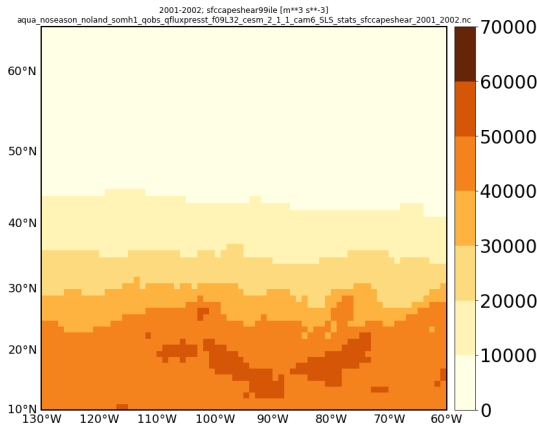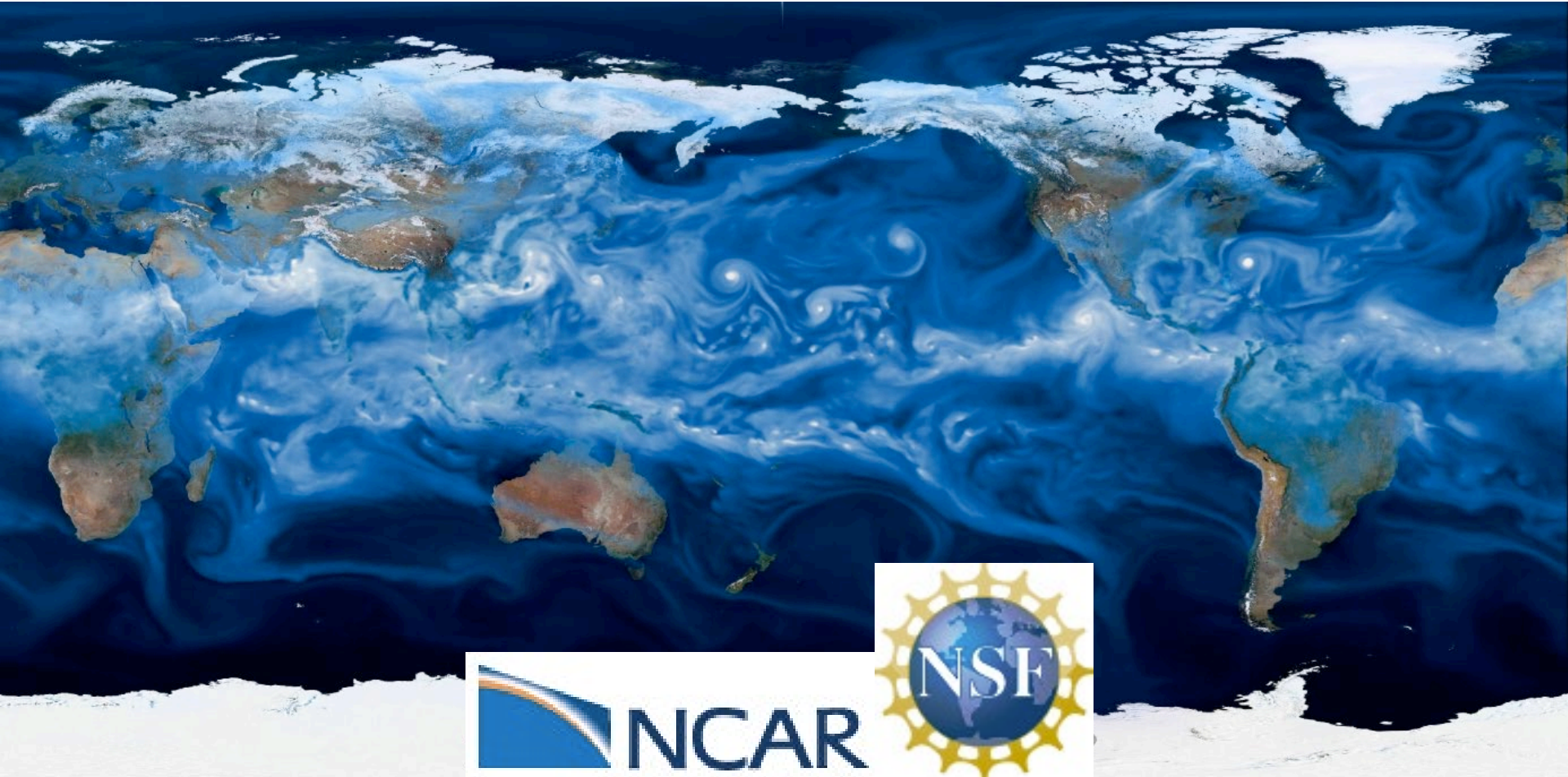
Annual
99th percentile

Percentage of Great Plains Low-Level Jets

CTRL   noTOPO-CTRL   noGOM-CTRL
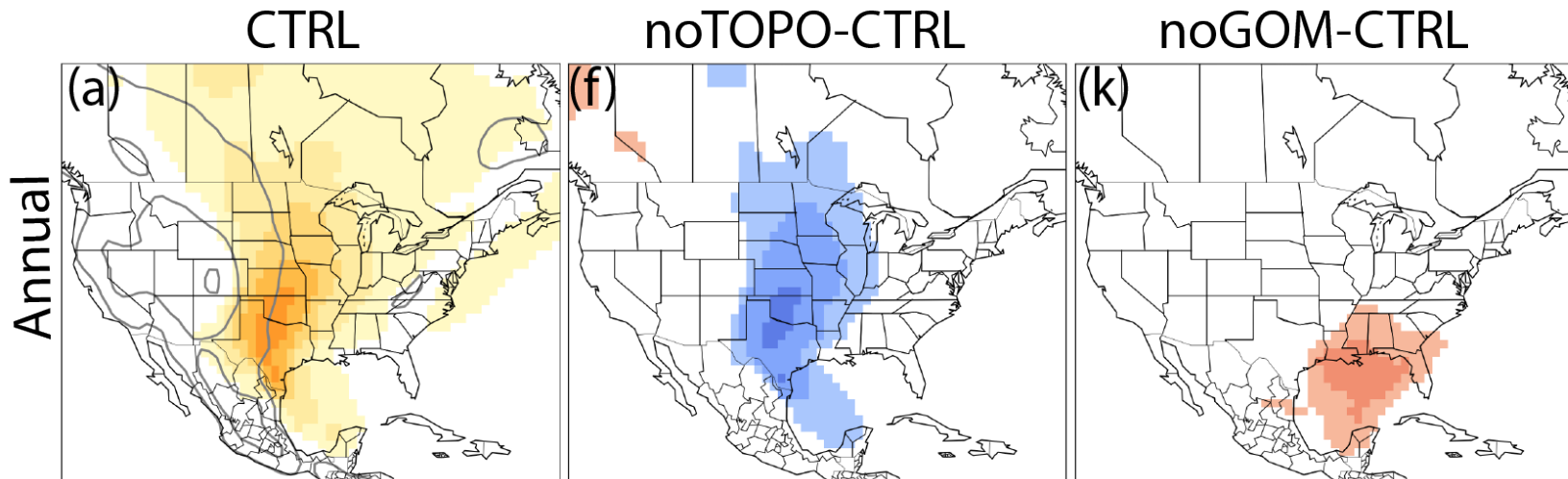
**Annual
99th percentile**

**Storm Tracks and Mean
Eddy Kinetic Energy**

CTRL   noTOPO-CTRL   noGOM-CTRL