A Preliminary Assessment of Future Changes in the Severe Thunderstorm Environment in North America

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Funded by NSF SGER Grant to Drs. David Karoly and Harold Brooks

Background

- Accuracy of climate change predictions hinge on understanding current climatologies
- Global Climate Models (GCMs) easily resolve synoptic scale features
- GCMs cannot resolve storm scale features

Background

- "…there is little guidance from AOGCMs concerning the future behavior of tornadoes, hail, or lightning."

- "Due to the fact that these severe weather phenomena are sub-grid scale…we cannot reach any definitive conclusions concerning possible future increases in hail and lightning, and there is no information from AOGCMs concerning future change in tornado activity."

- IPCC Third Assessment

Background

- CAPE and 0-6km shear are good parameters to use in combination to discriminate between significant severe thunderstorms and less severe events.

  - Rassmussen and Blanchard, 1998; Craven et al.,2002

- In general, significant severe thunderstorms are associated with high CAPE and high 0-6km shear.

  - Brooks et al, 2003

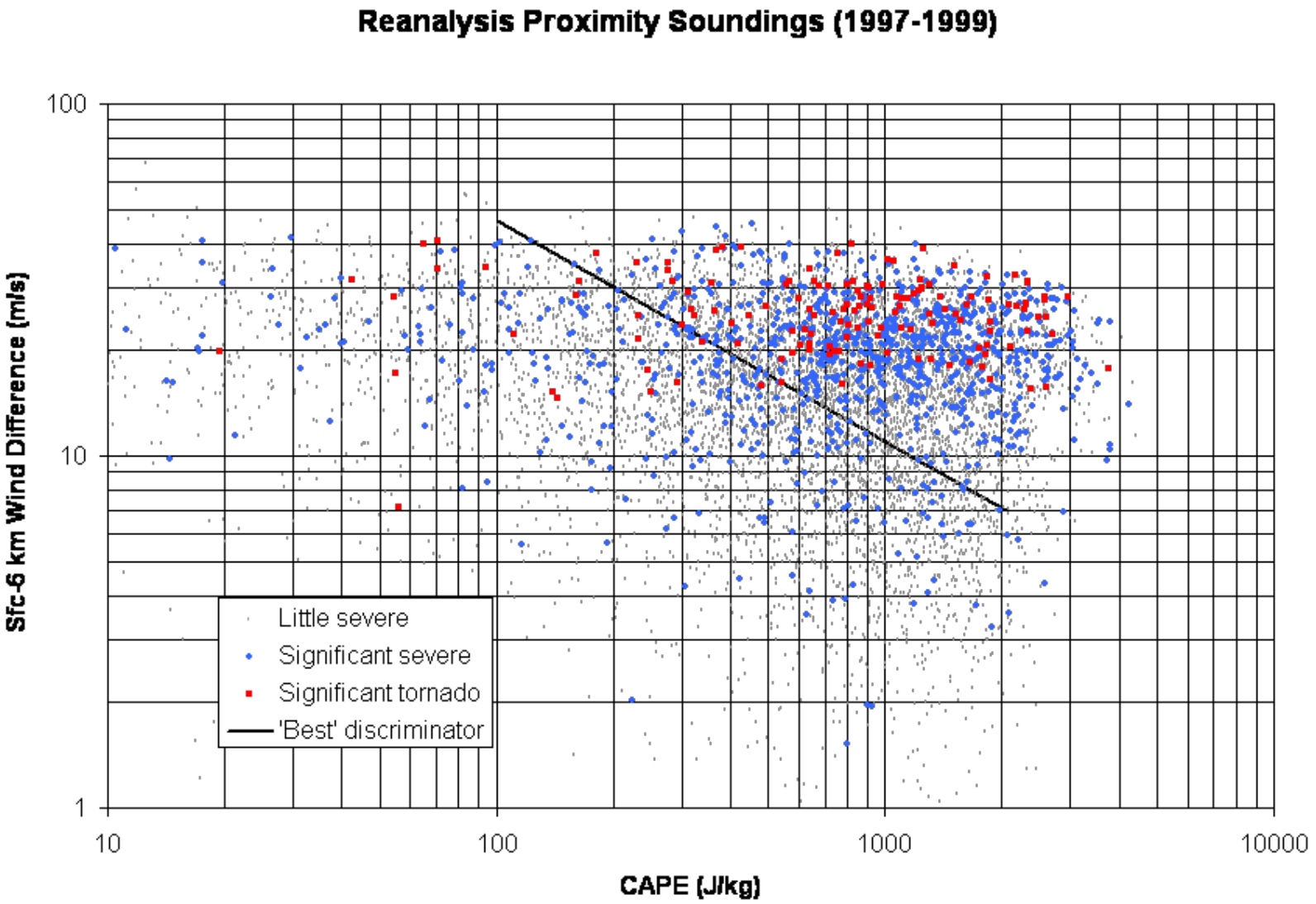


Image taken from Brooks et al., 2003

Objectives

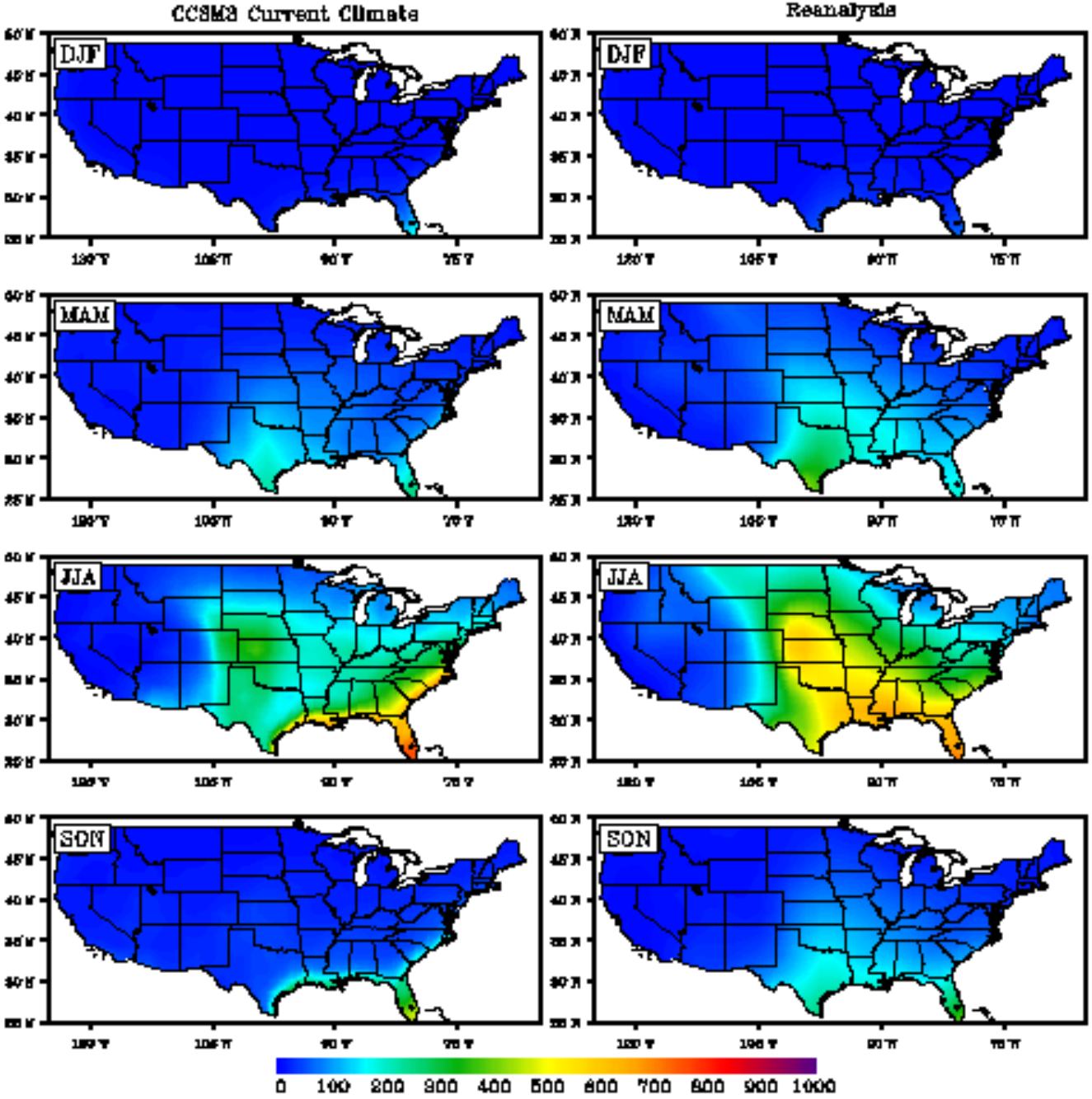
- Global Reanalysis data resolution is similar to that of the CCSM3 – Previous studies have shown the severe weather environment (SWE) of the CCSM3 is similar to that of the Global Reanalysis *(Marsh et al., 2007)*

- Assess future changes in the SWE from various future greenhouse gas scenarios

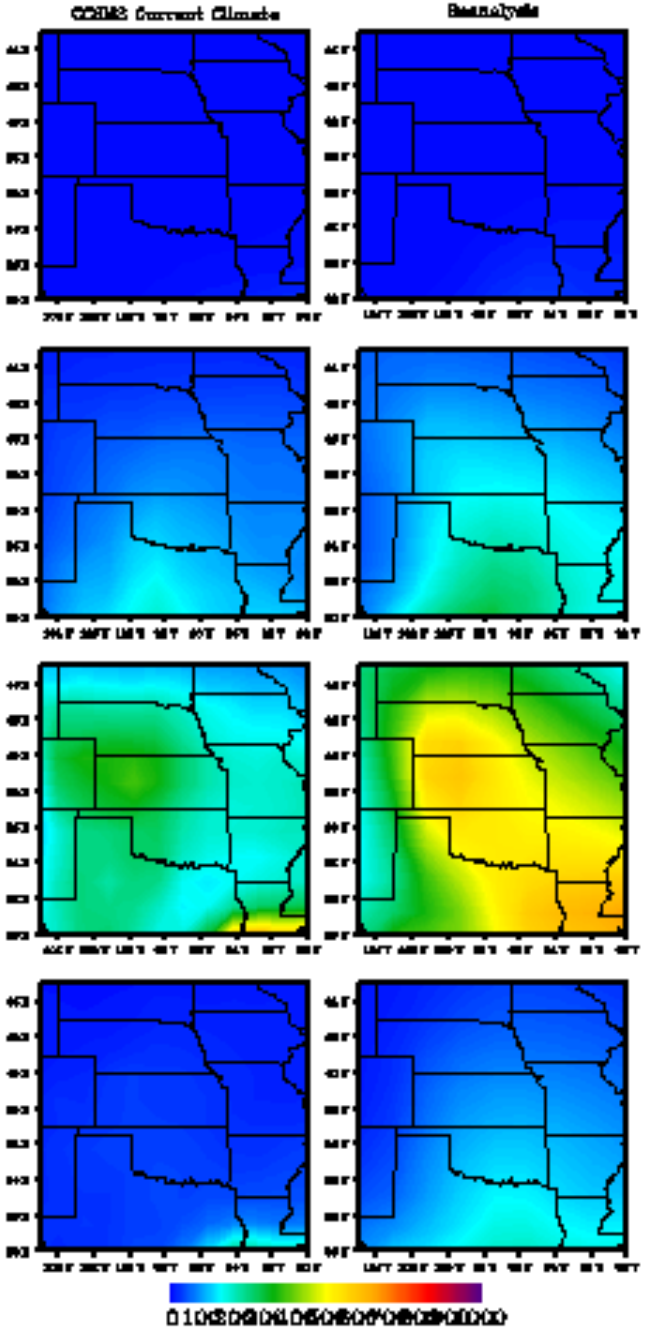
Brief CCSM3 Description

- Fully coupled atmosphere land surface, sea-ice, and ocean
- Forcing with observed greenhouse gas and aerosol variations from 1880 through end of 20th century
- ~1.4º horizontal resolution
- 26 terrain following vertical levels
- Data output every 6 hours for 1980-99

Seasonal Mean CAPE ($J\ kg^{-1}$)

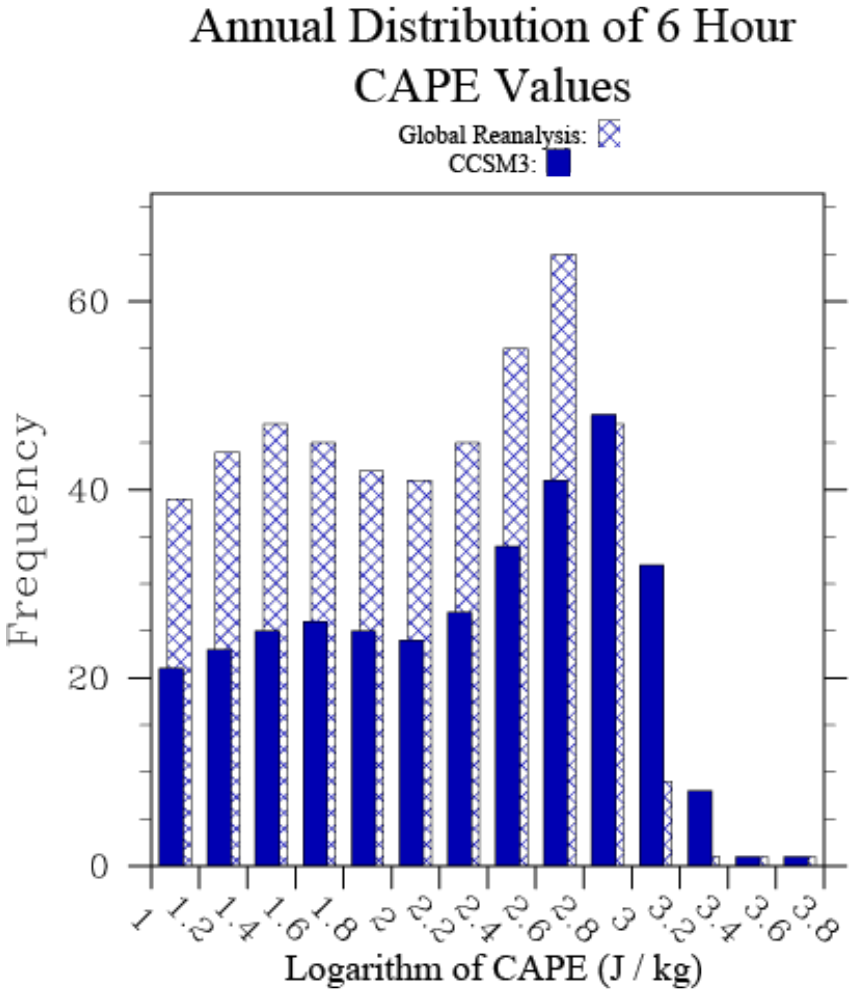


Seasonal Mean CAPE ($J\ kg^{-1}$)

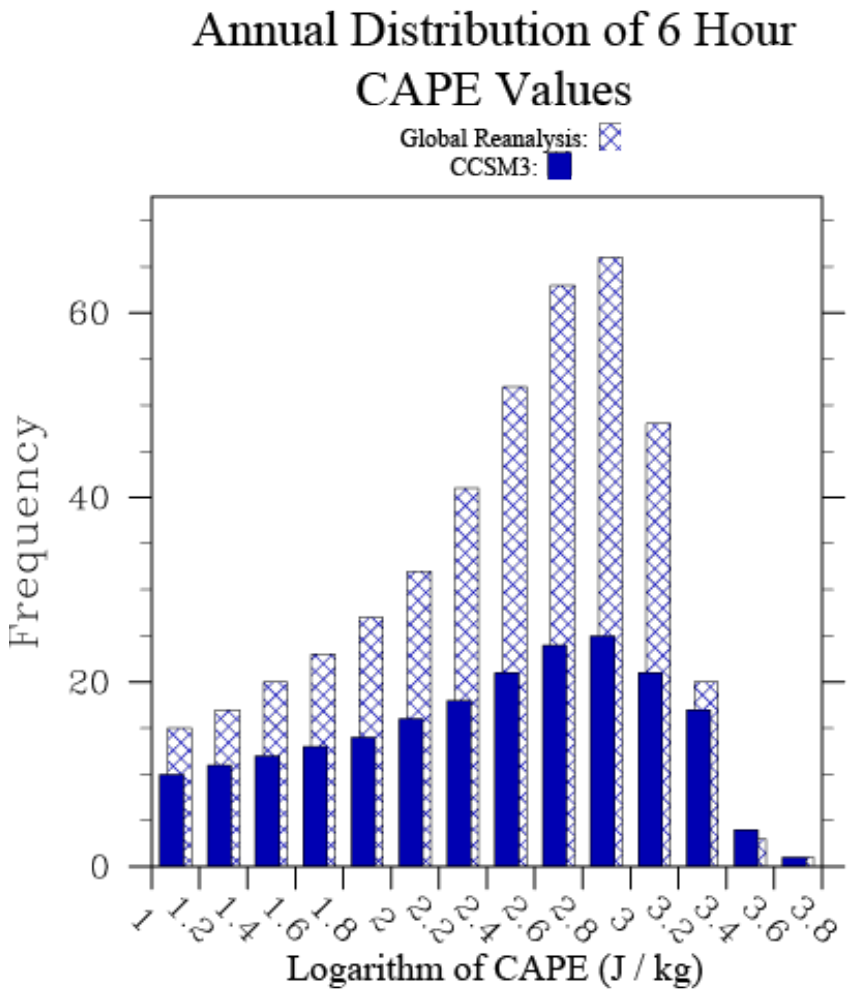


CAPE Distributions

North America

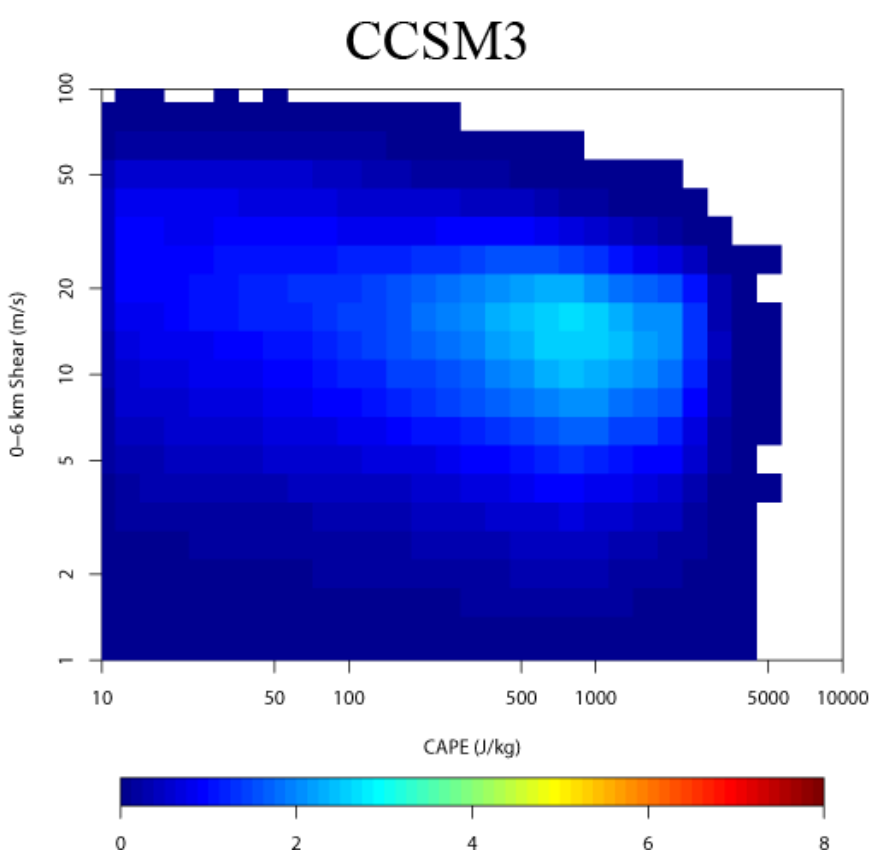


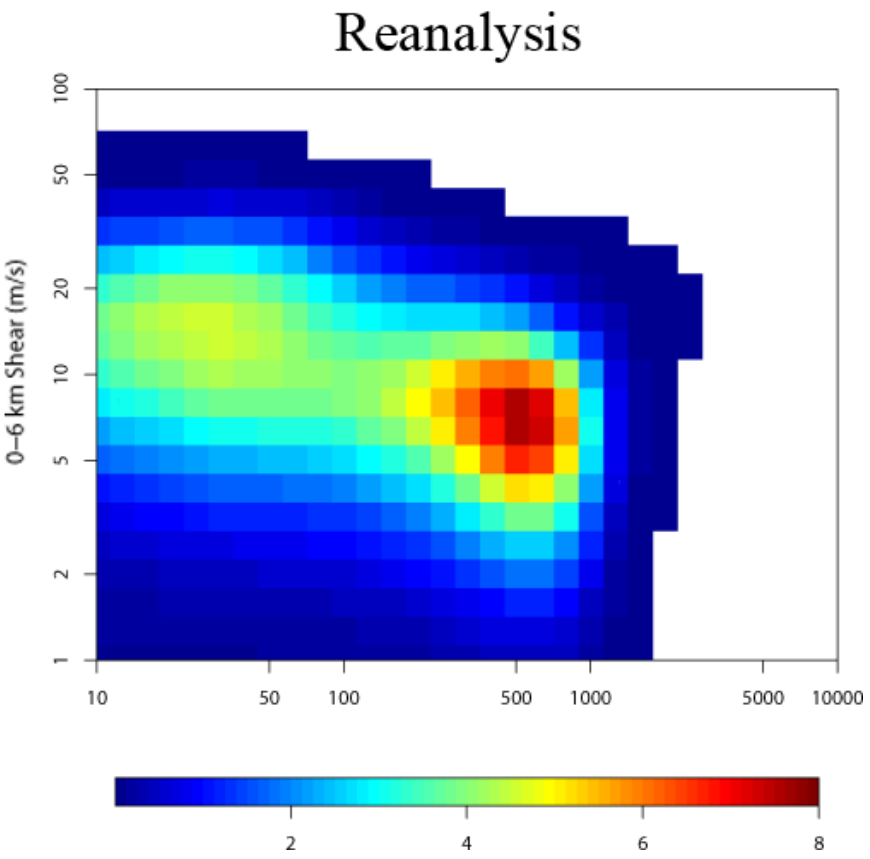
Central US



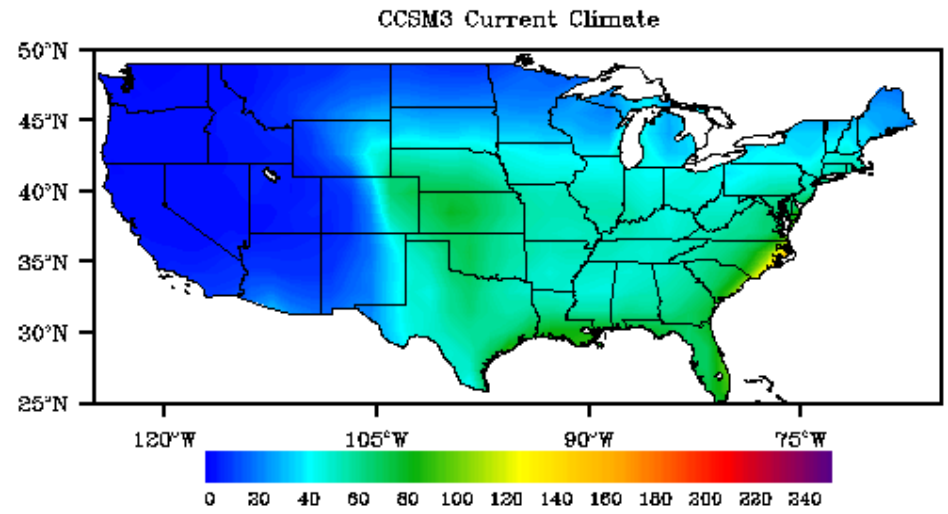
CAPE - Shear Distributions

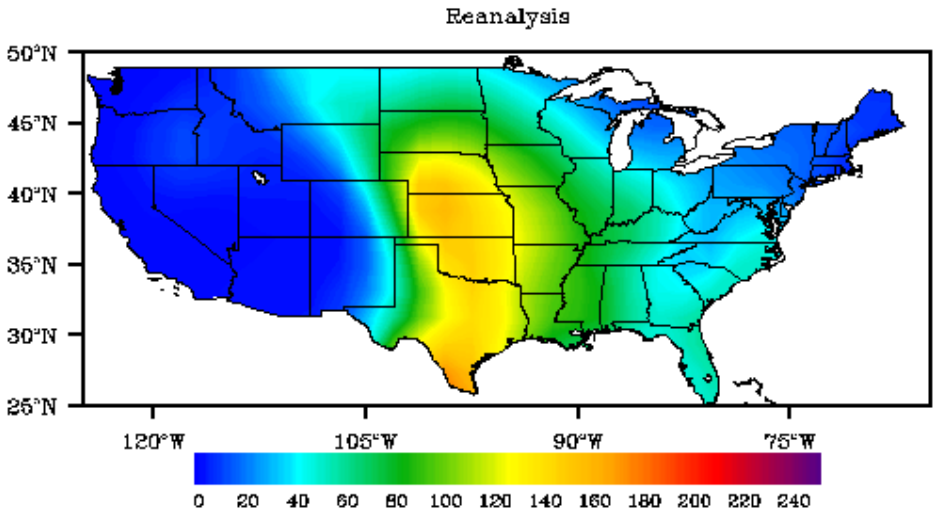
Annual Distribution of 6 Hour CAPE and Deep Layer Shear Values



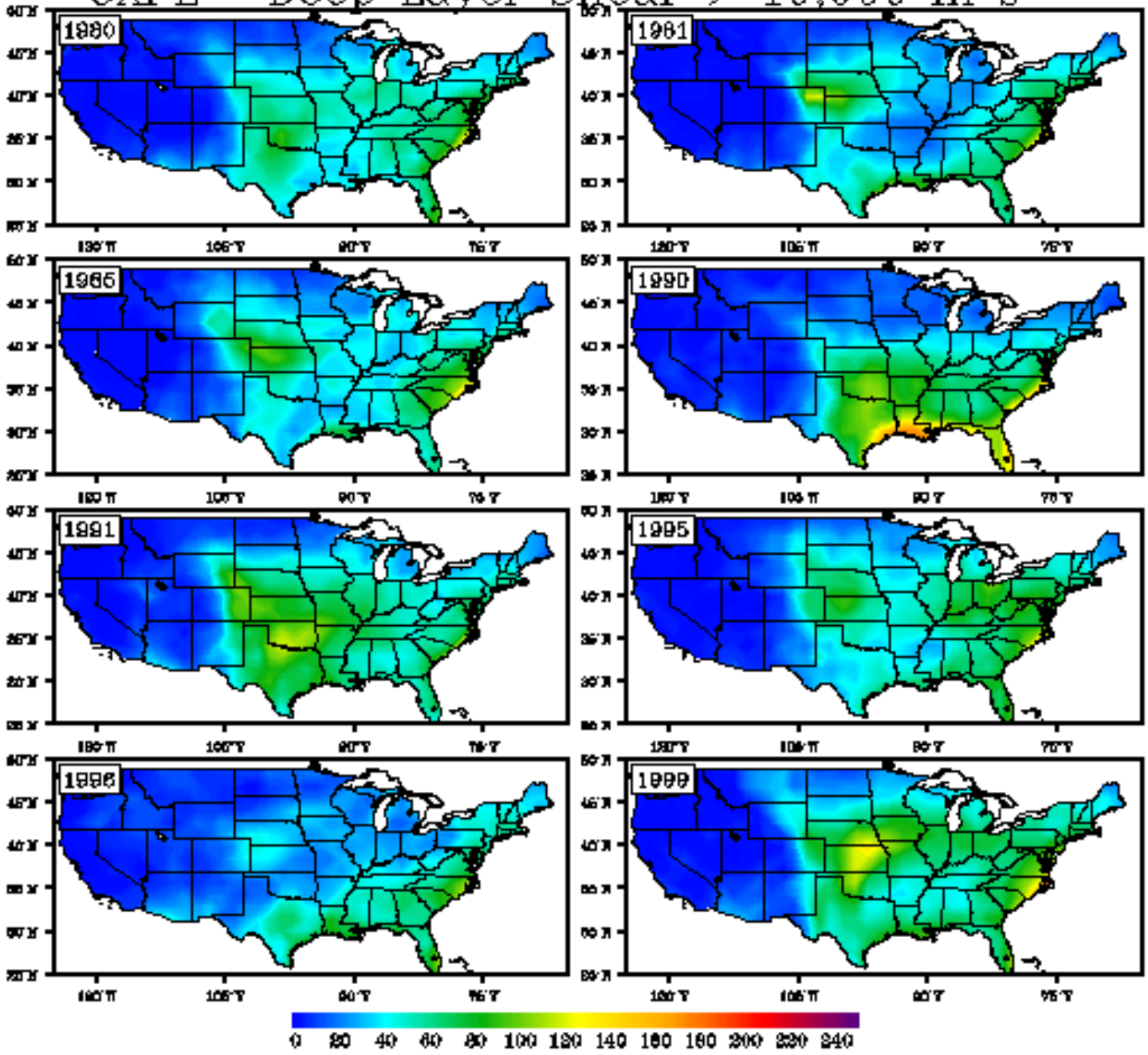


*Average number of 6 hour periods per year with CAPE*Shear > 10,000 m^3 s^{-3}*

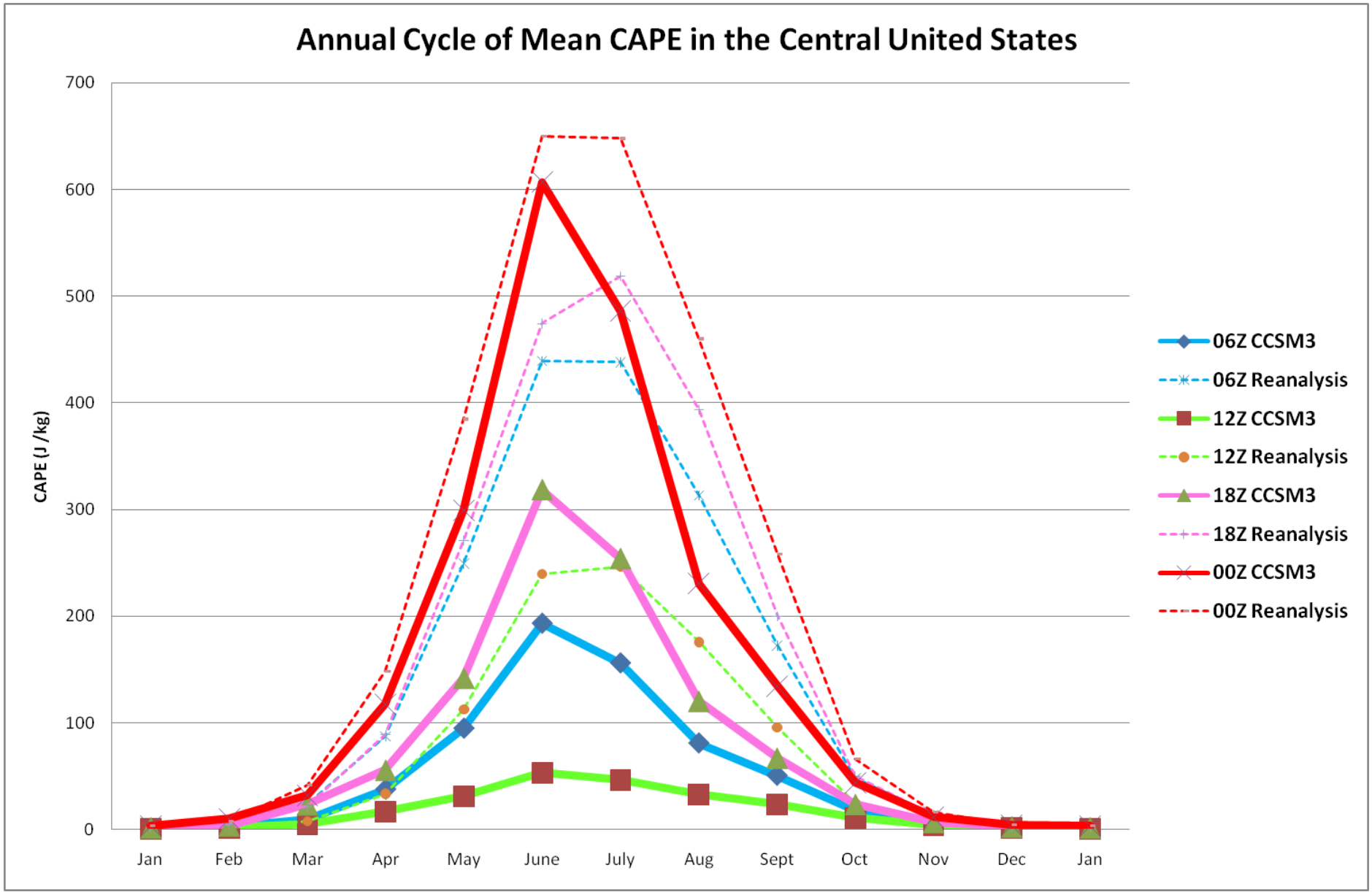




Number of 6 Hour Periods
CAPE * Deep Layer Shear > 10,000 $m^3 s^{-3}$



Mean CAPE by Month per 6 hour period



FUTURE SIMULATION

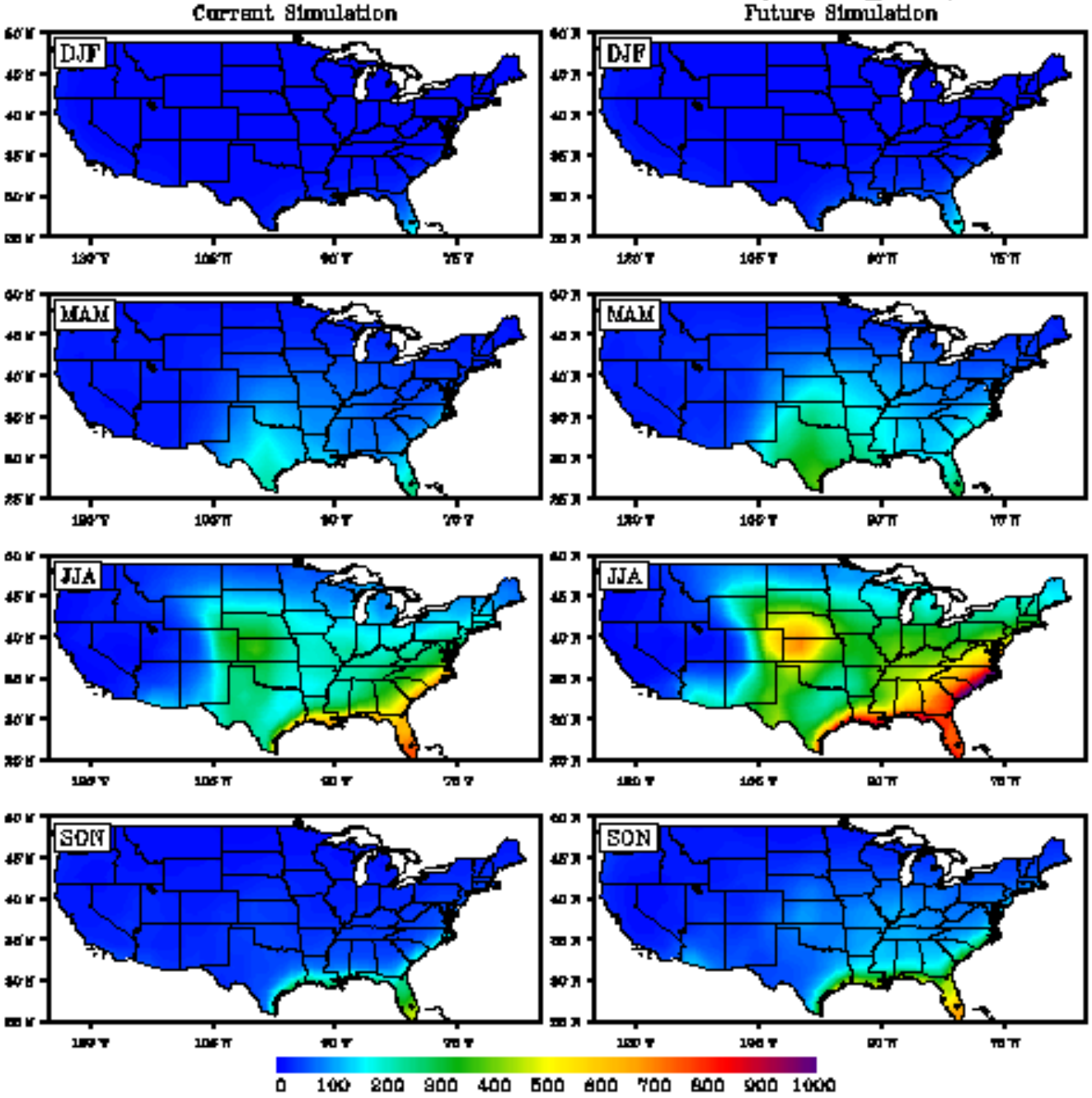
CCSM3 run from 2000 to 2099 with SRES A2 emissions scenario (high C02 and aerosol emissions)

Data examined for 2080-99

Future Simulation

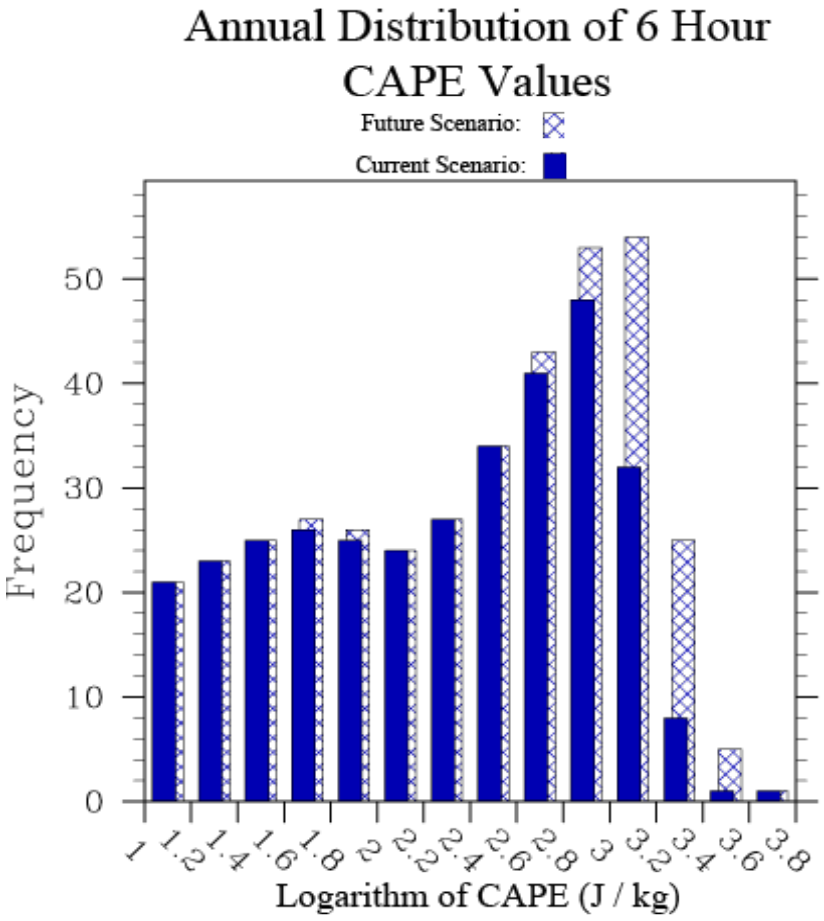
- CO2 increase from 369ppm to 856ppm between 2000 and 2100
- A2 scenario ensemble temperature increase of 3.1ºC
- CCSM3 member is in the lower half (~30%) of this ensemble

Seasonal Mean CAPE (J kg^{-1})

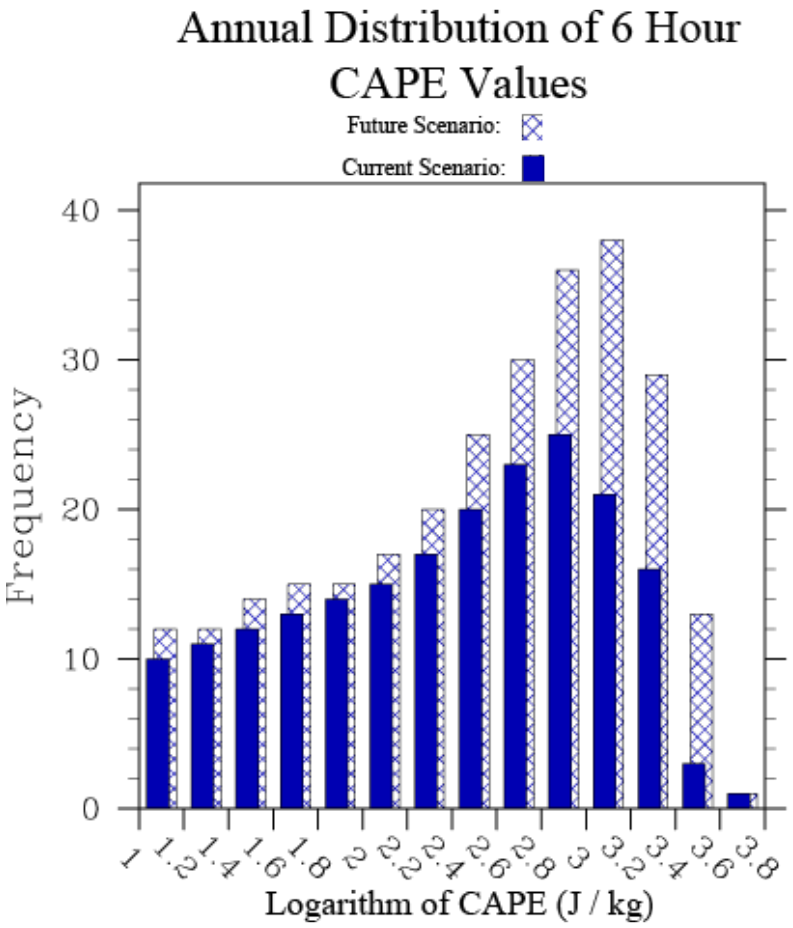


CAPE Distributions

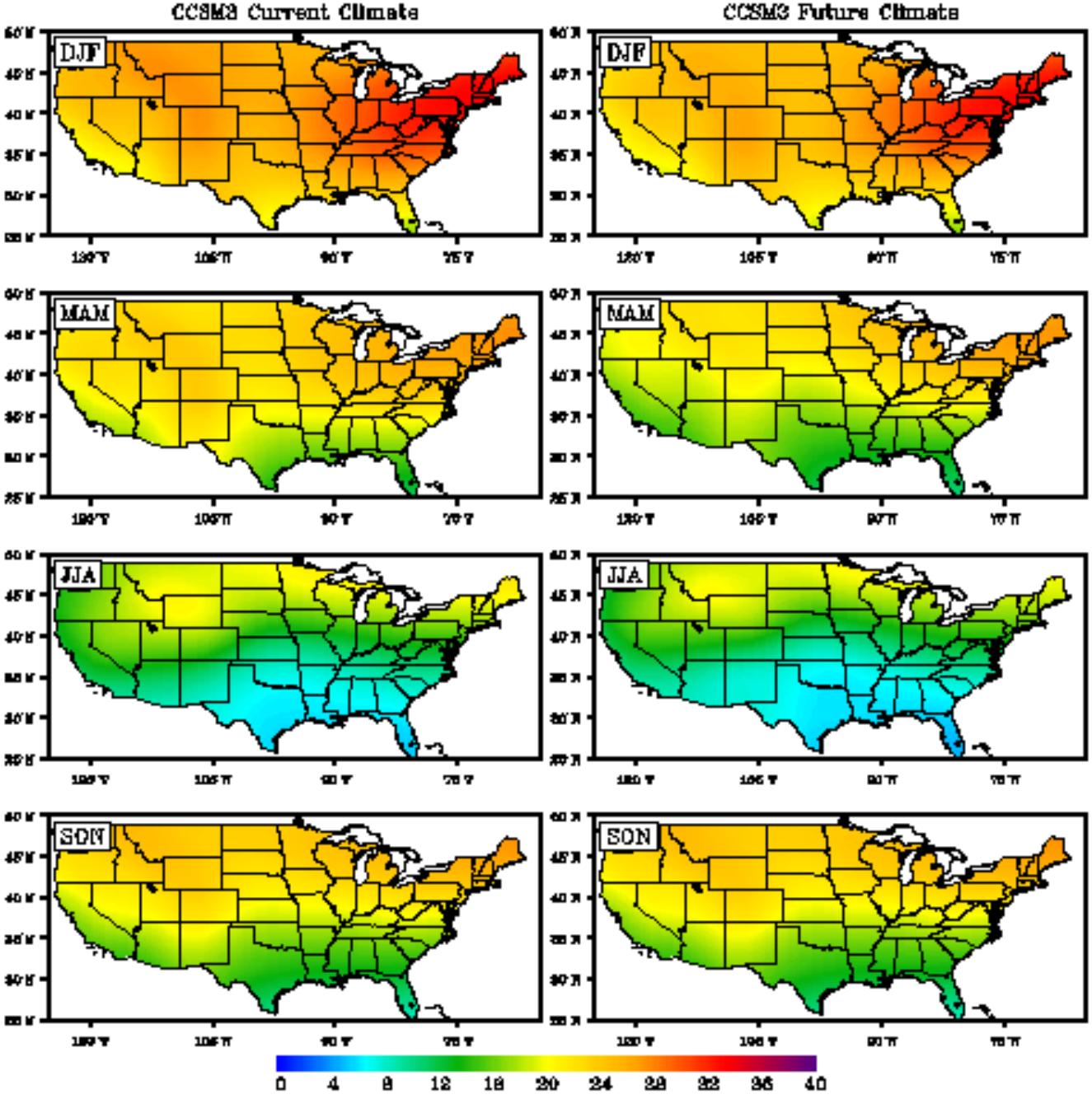
North America



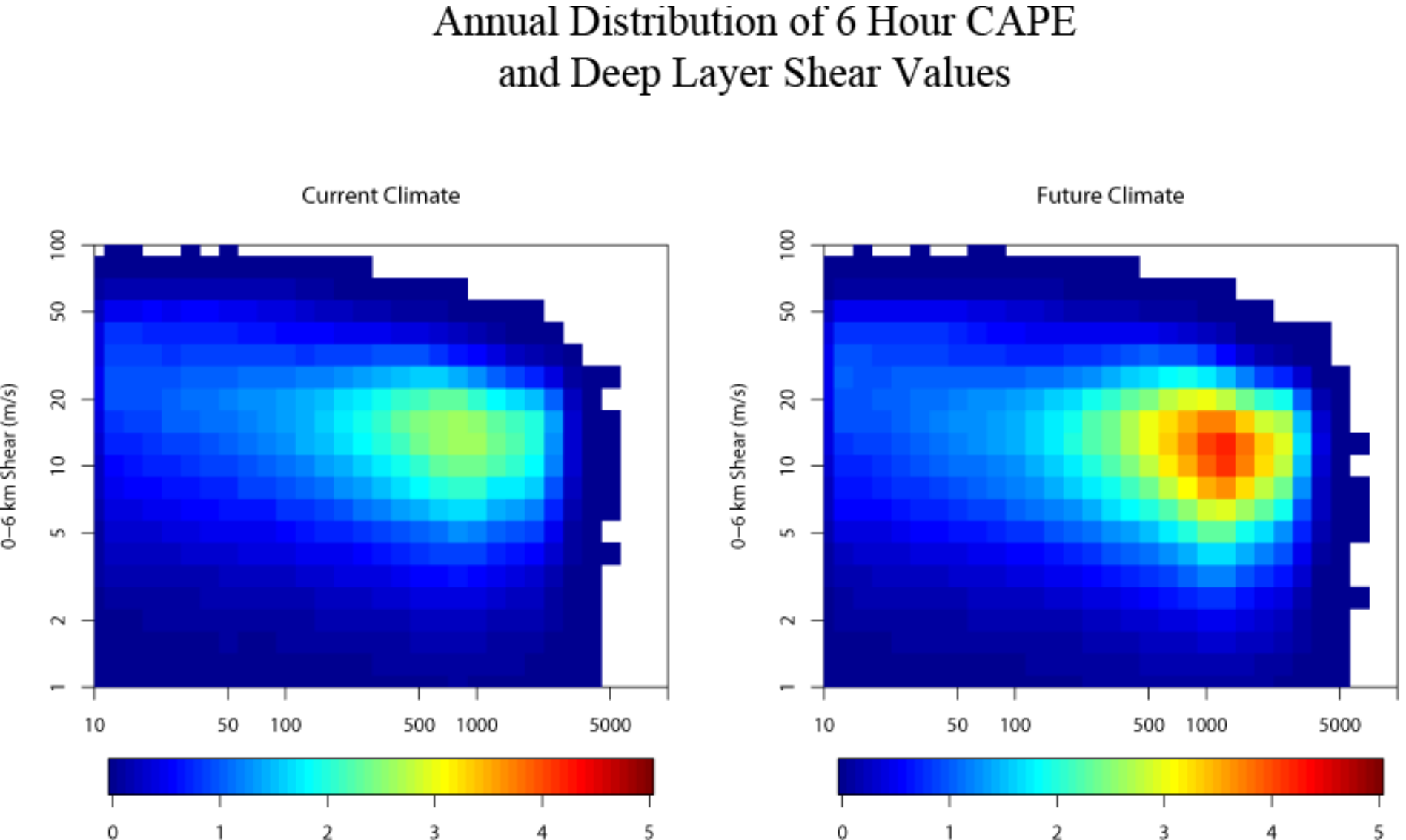
Central US

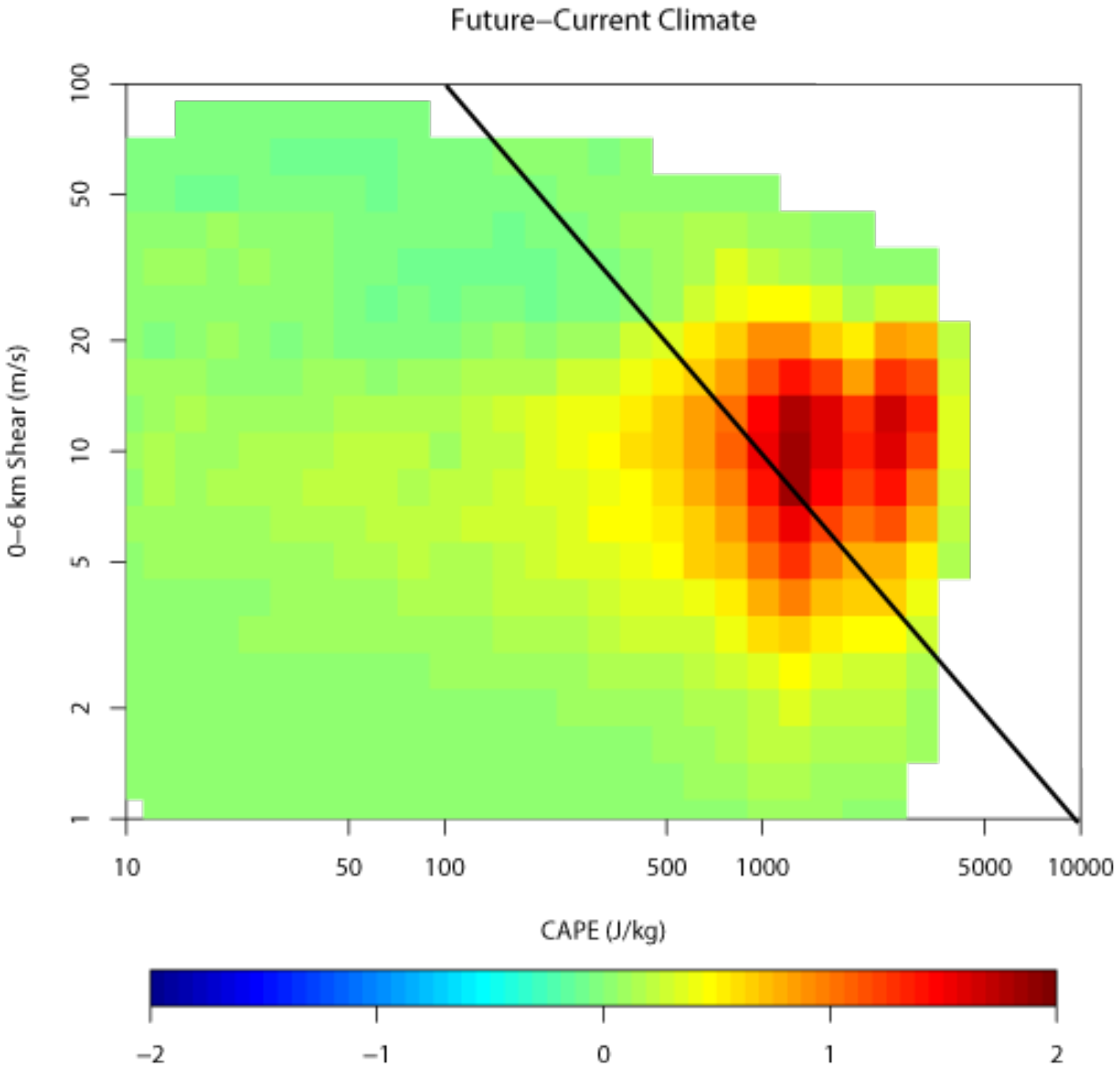


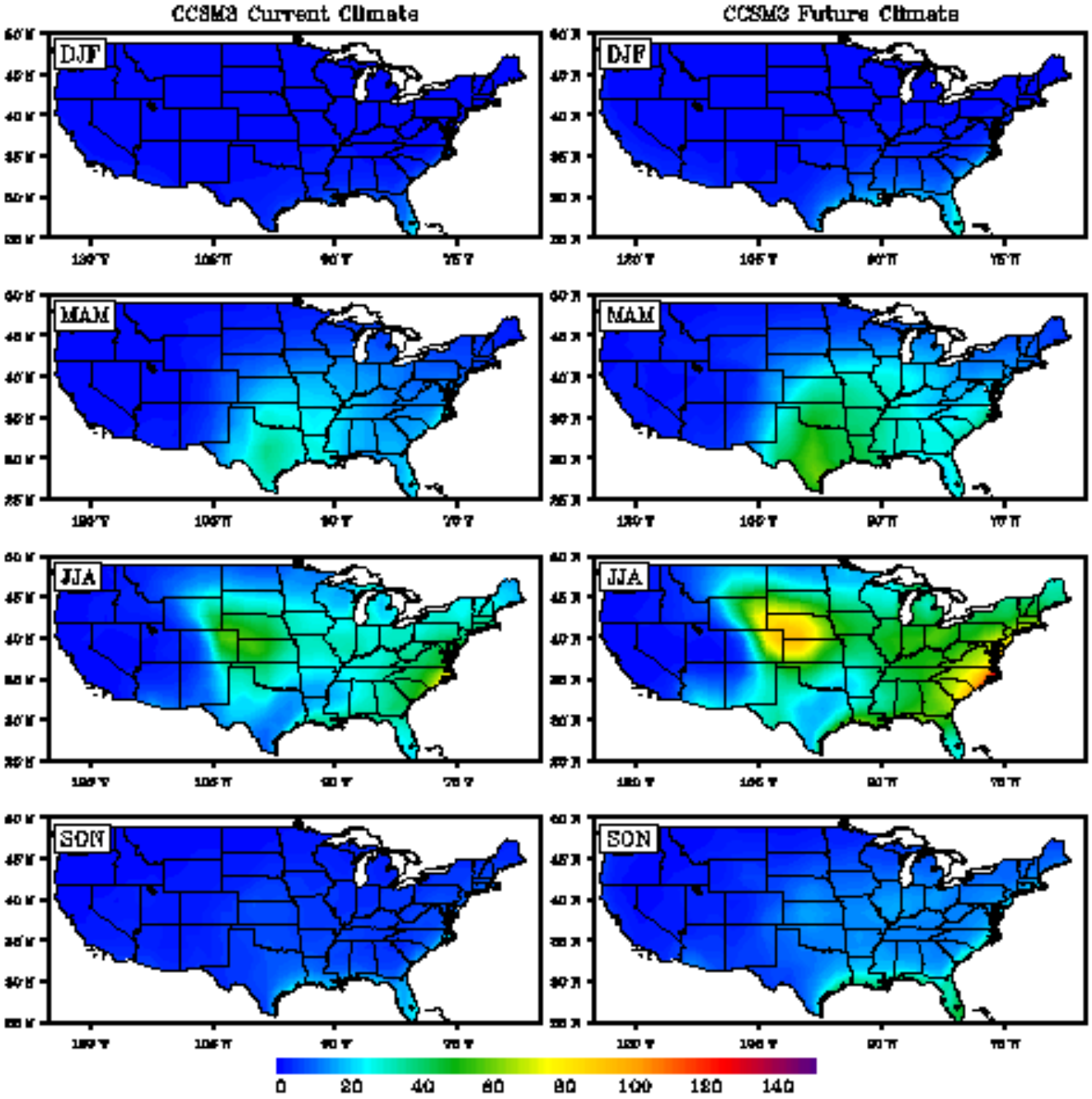
Seasonal 0–6km Mean Shear



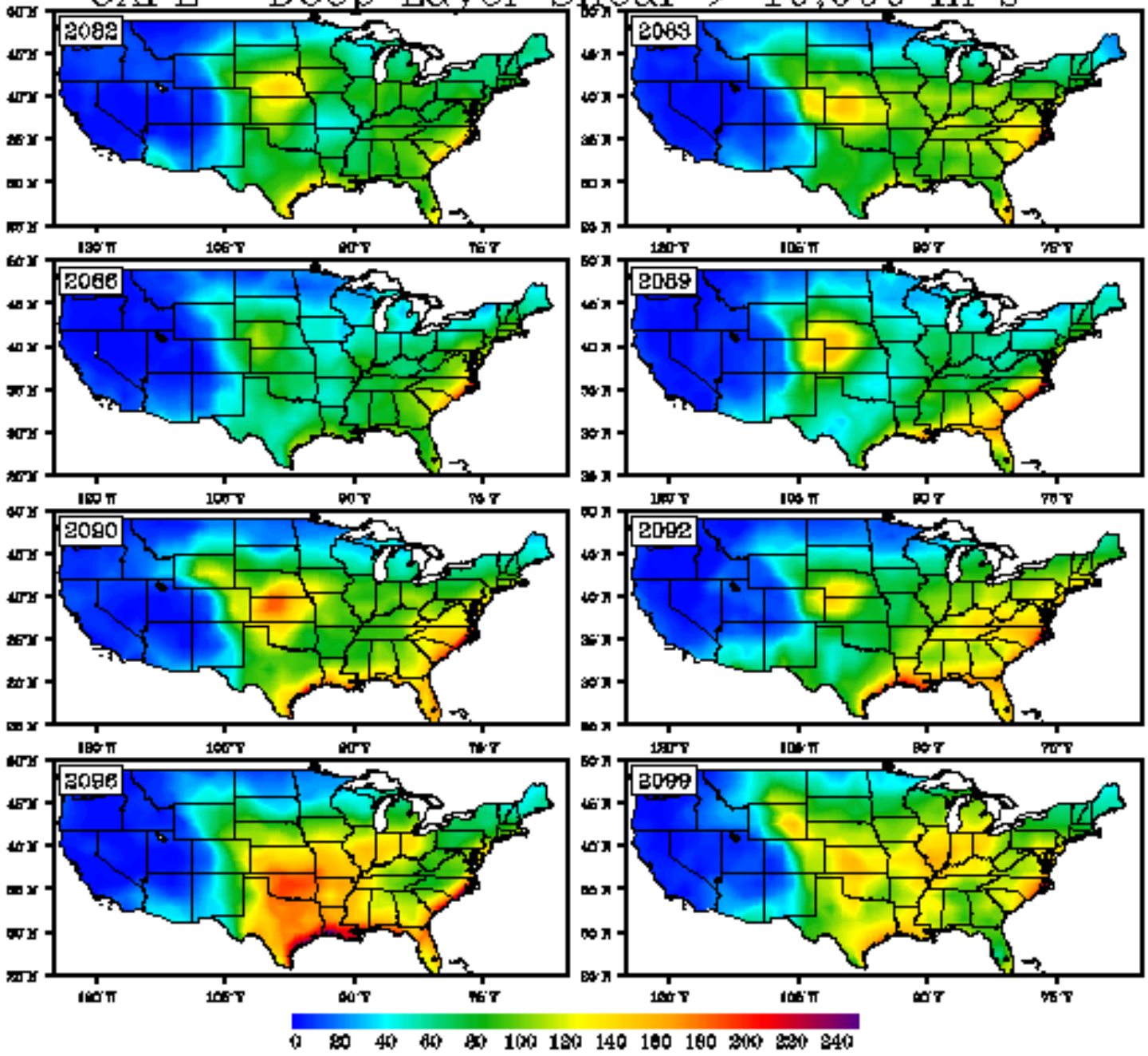
CAPE - Shear Distributions



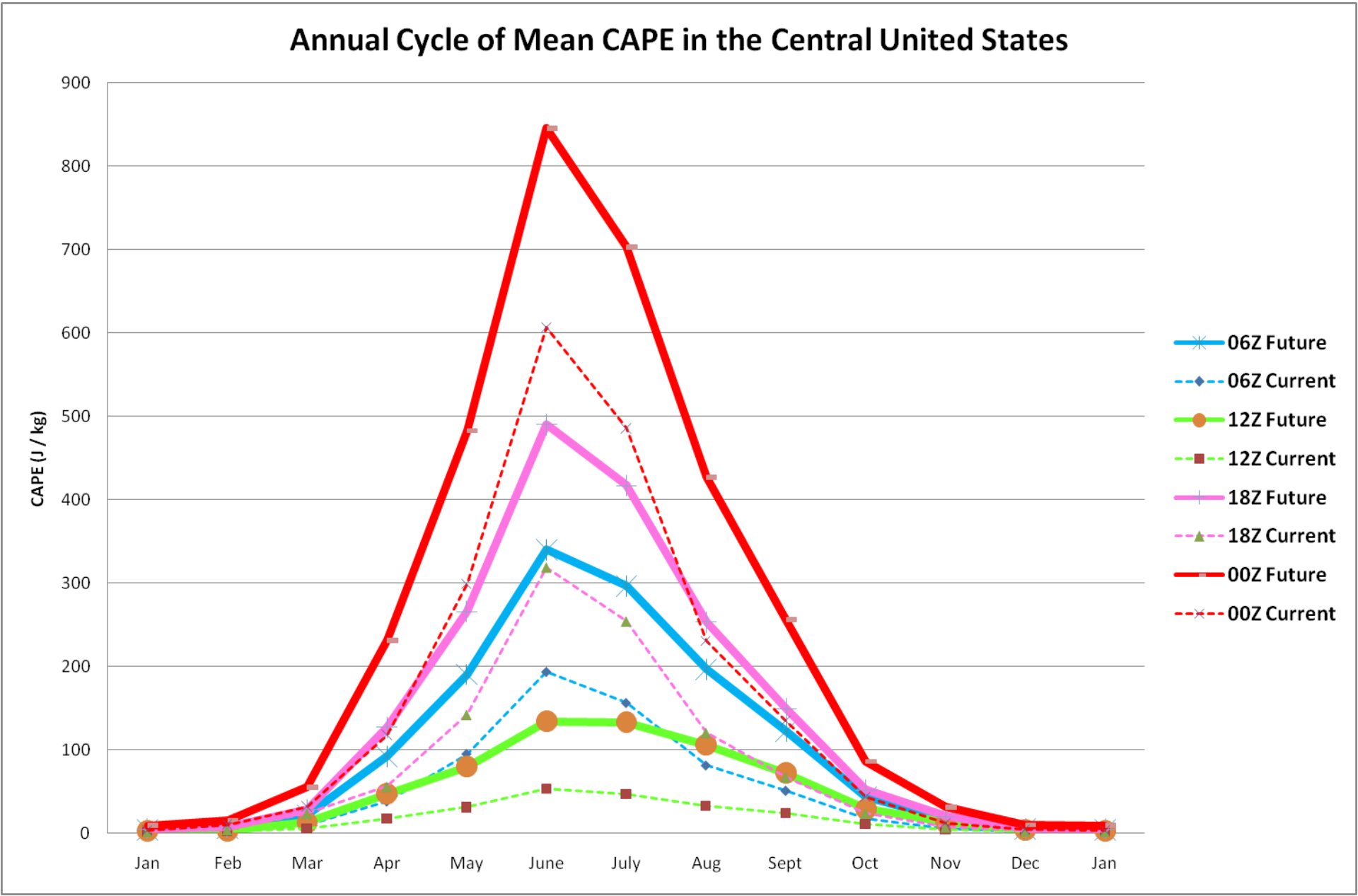

Future−Current Climate
0−6 km Shear (m/s)
100
50
20
10
5
2
1
10
50
100
500
1000
5000
10000
CAPE (J/kg)
−2
−1
0
1
2


Mean Number of Favorable Severe Environments Per Season
CCSM3 Current Climate
CCSM3 Future Climate
DJF
DJF
MAM
MAM
JJA
JJA
SON
SON
0
20
40
60
80
100
120
140

Number of 6 Hour Periods
CAPE * Deep Layer Shear > 10,000 $m^3 s^{-3}$



Mean CAPE by Month per 6 hour period



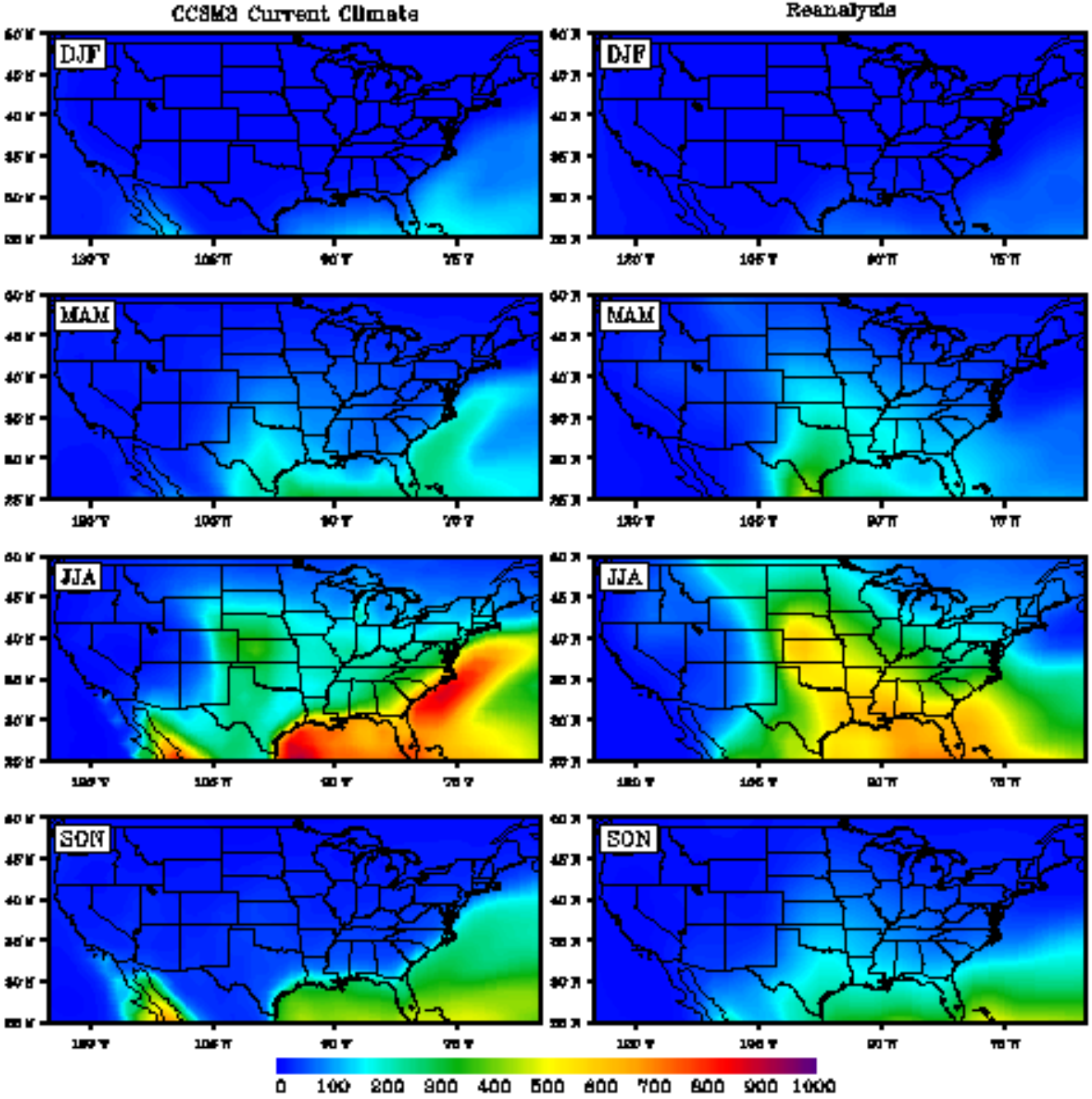
What happens when we include the oceans?

Current Simulation

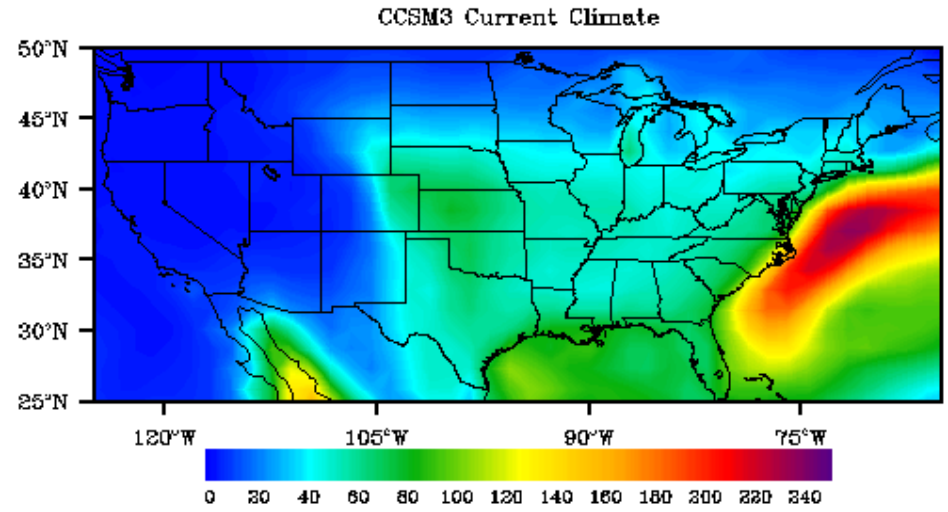
vs.

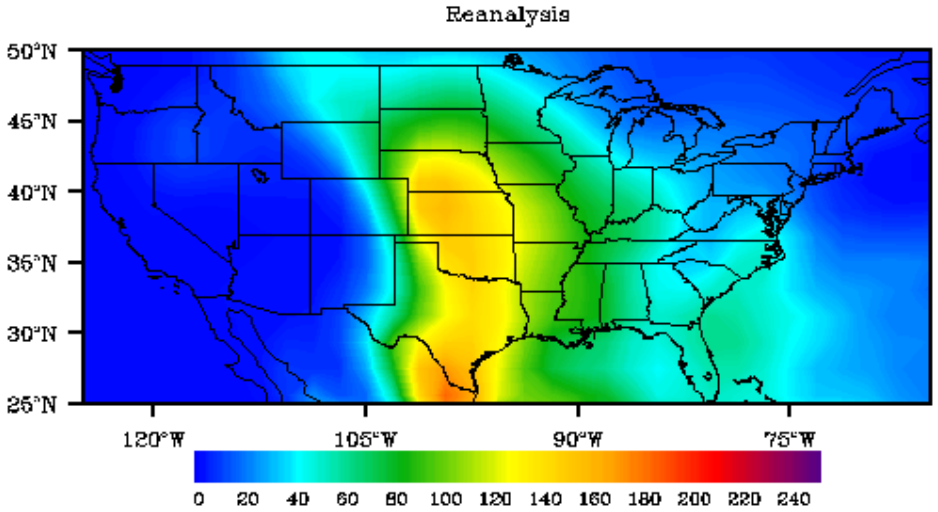
Reanalysis

Seasonal Mean CAPE ($J\ kg^{-1}$)

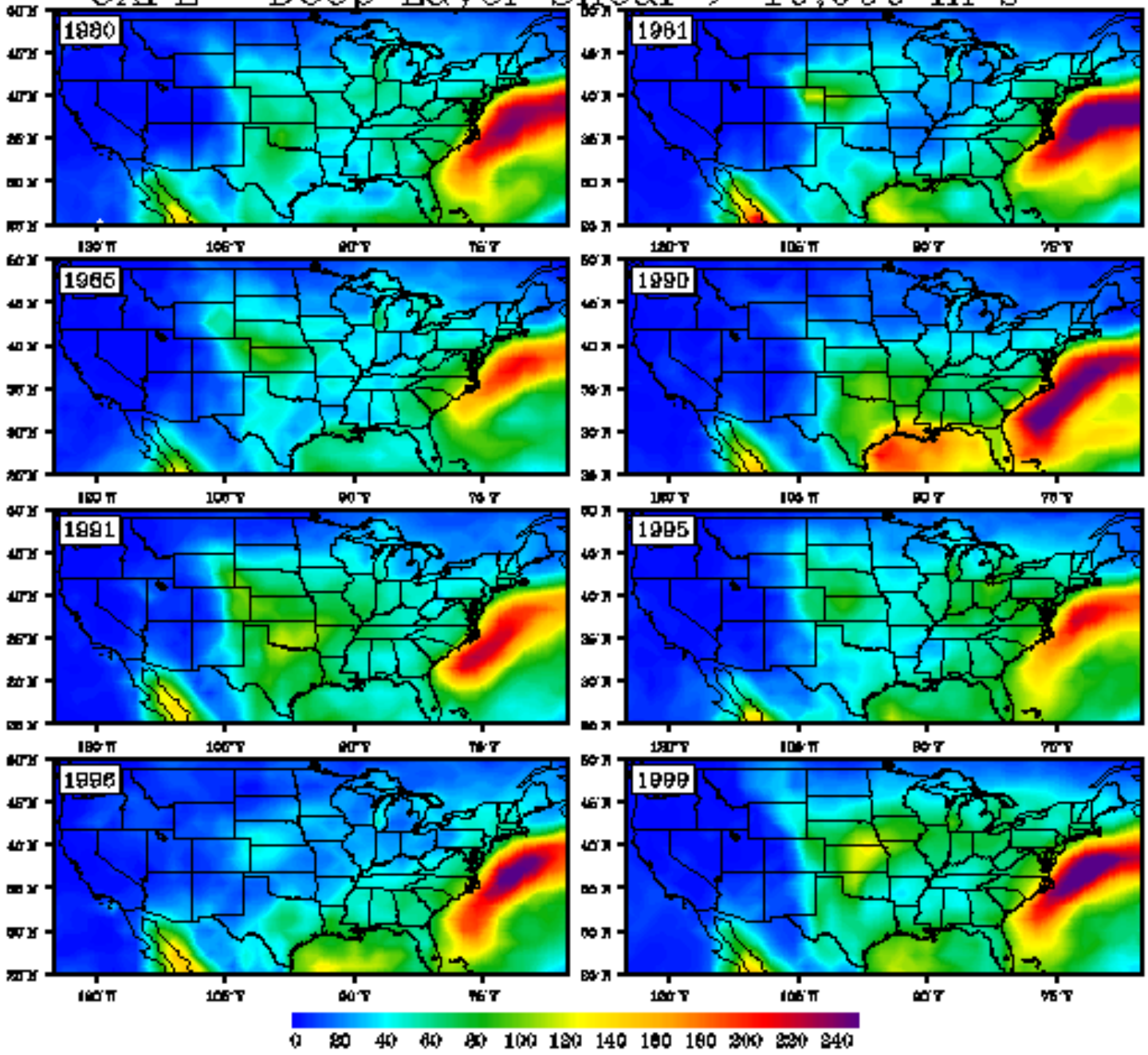


Favorable Severe Parameters





Number of 6 Hour Periods
CAPE * Deep Layer Shear > 10,000 $m^3 s^{-3}$



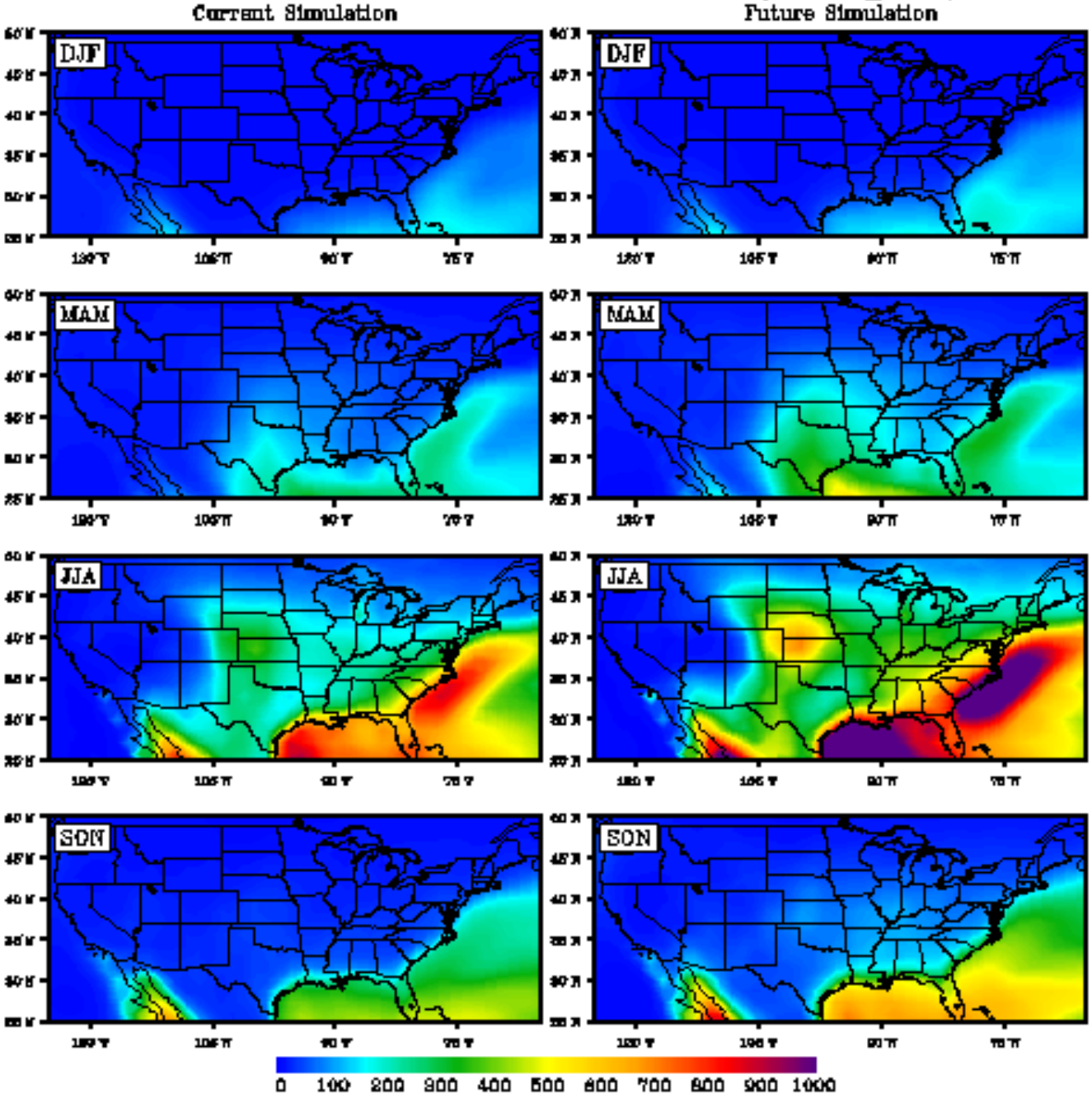
Future Simulation

Future Simulation

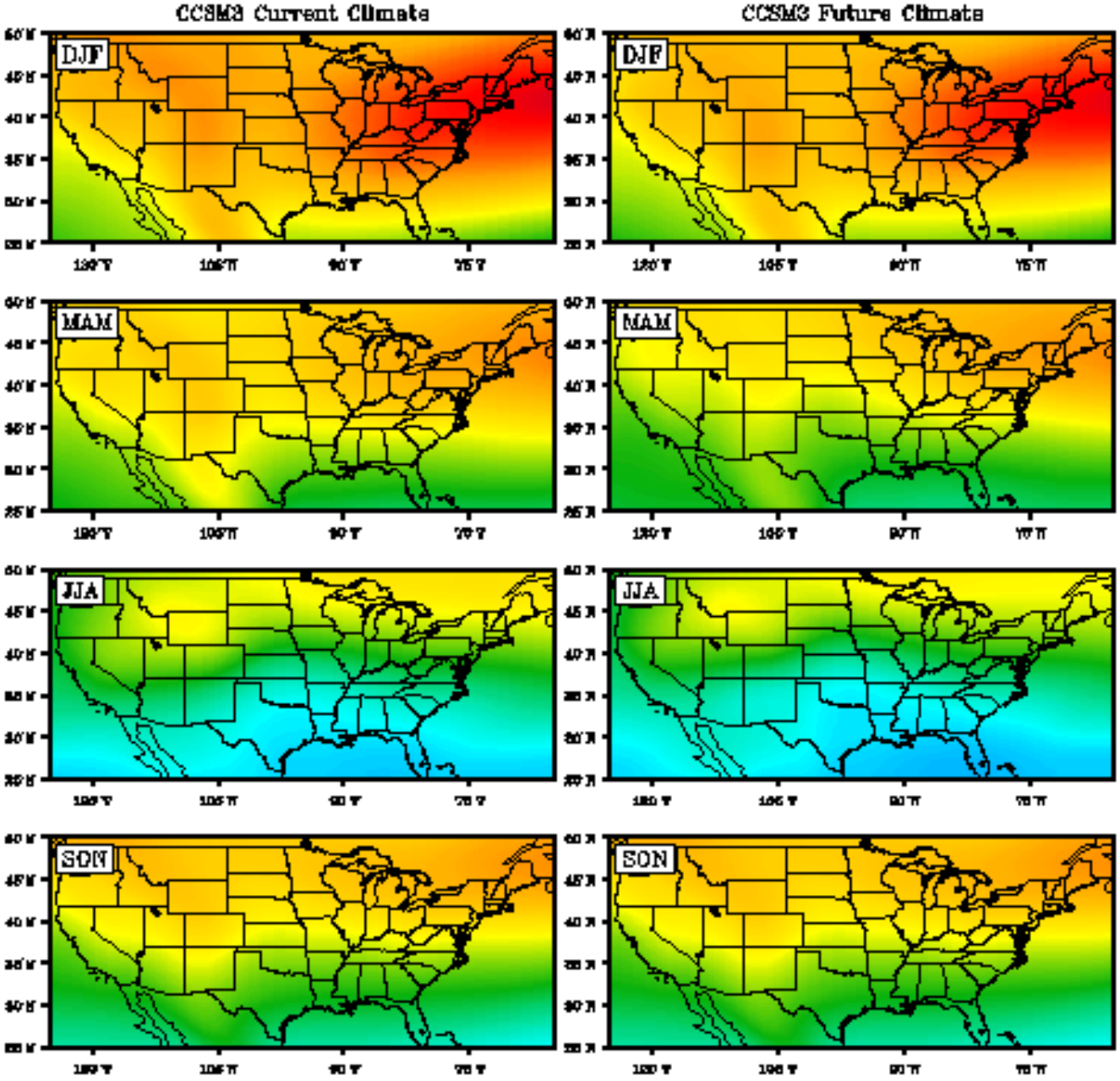
vs.

Current Simulation

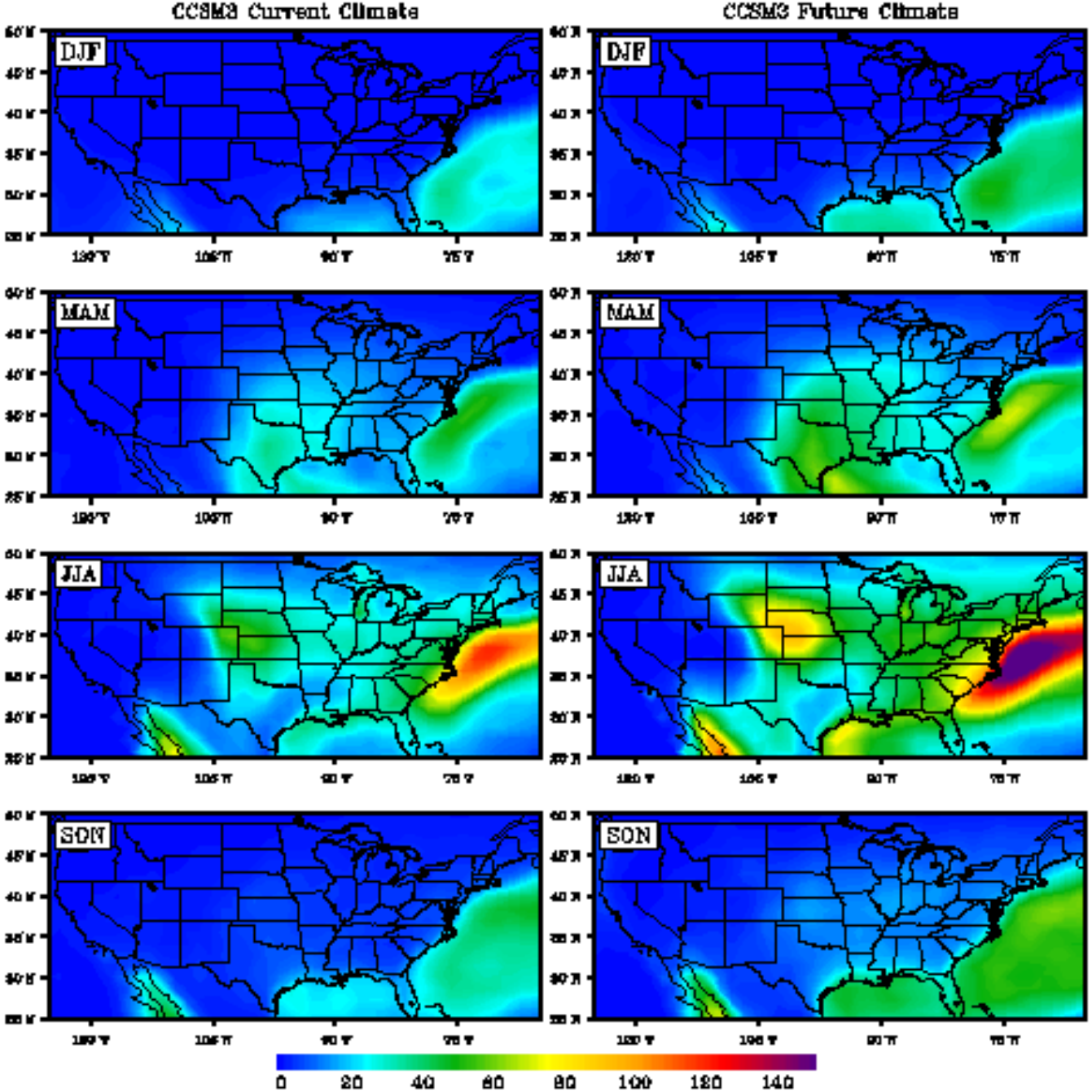
Seasonal Mean CAPE ($J\ kg^{-1}$)



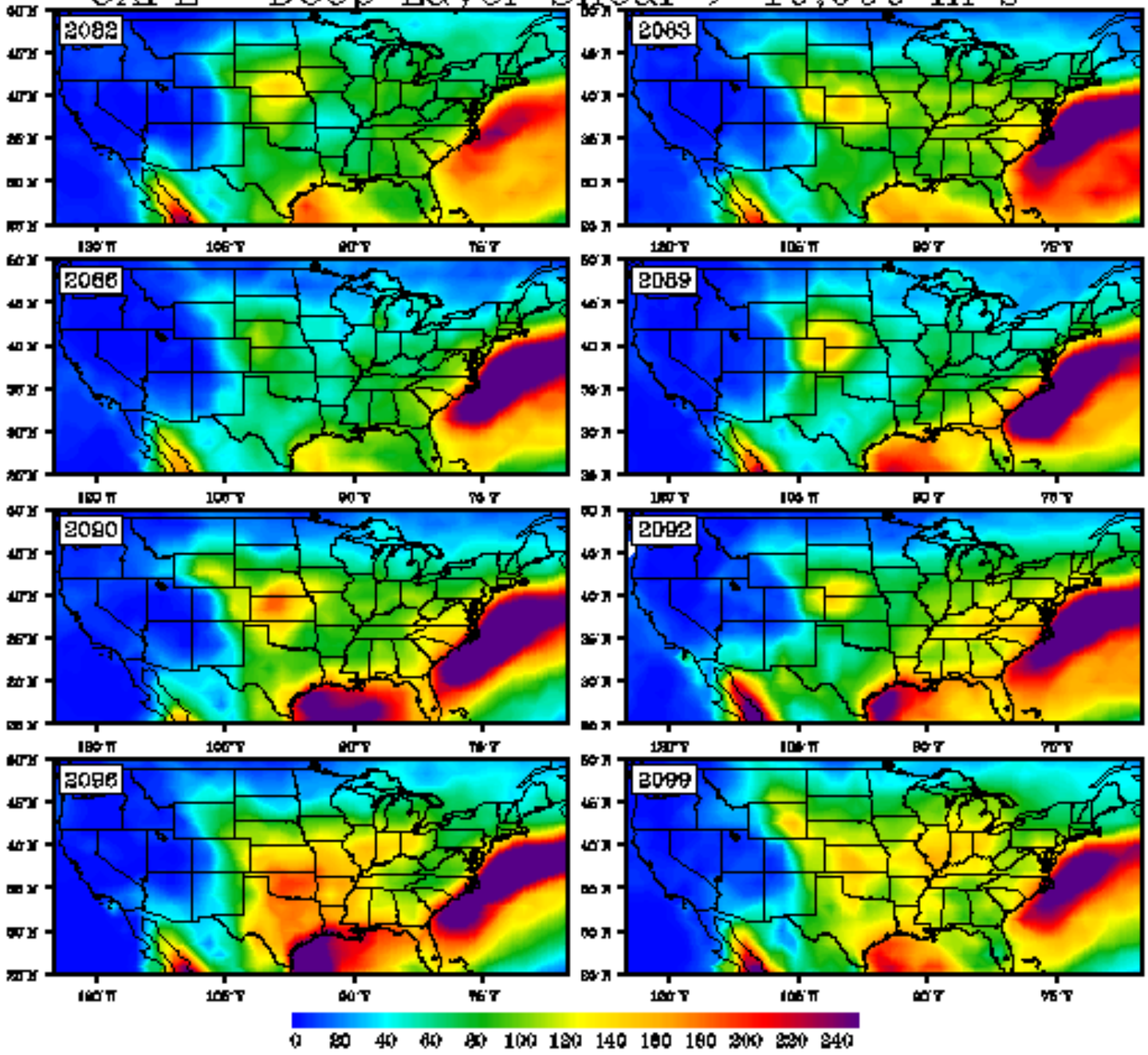
Seasonal 0–6km Mean Shear



Mean Number of Favorable Severe Environments Per Season



Number of 6 Hour Periods
CAPE * Deep Layer Shear > 10,000 m^3s^{-3}



Conclusions

- In future climate simulations substantial increases in mean CAPE occur over much of the US
- Small decreases in deep layer wind shear
- Annual frequency of SWE occurrence increases, particularly over the eastern US

Caveats

- One model (with possible coupling problem)
- One convective scheme (which destroys CAPE too fast)
- One emission scenario

Future Work

- Look at several other emission scenarios
- Examine more GCMs (GFDL, CAM3.5, etc)
- Nest mesoscale models into GCMs to provide higher resolution
- Investigate the “initiation” problem