Soil moisture-precipitation feedback in the April 2011 drought in the Southern Great Plains

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Water Forum II 10/2012

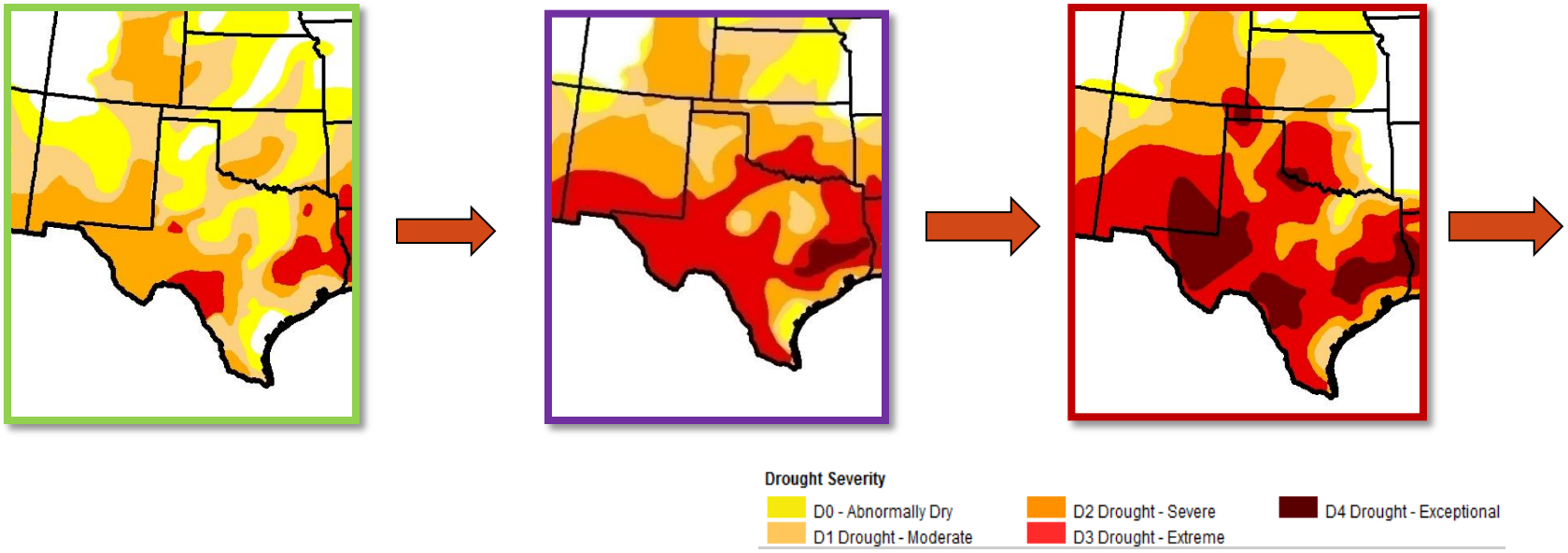
Outline

1. Background
2. Model and experiments
3. Precipitation responses
4. Controlling processes
5. Conclusions

Drought propagation at spring 2011

Drought Severity Index (U.S. Drought Monitor)

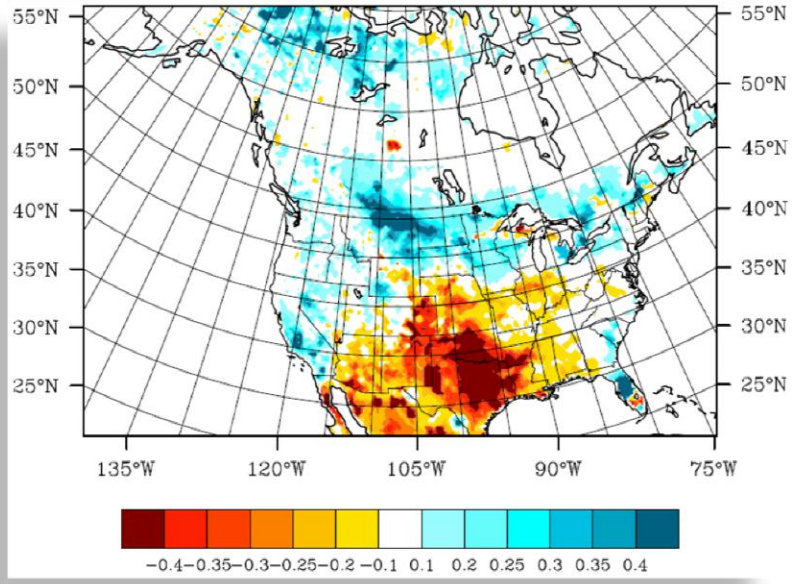
Mar, 1,2011 *Apr, 5* *May, 3*



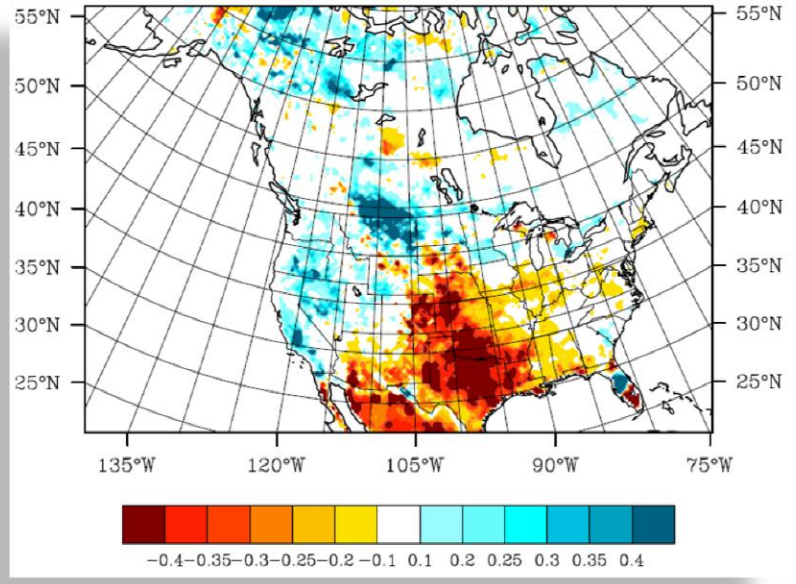
Fast and strong drought development in the Southern Great Plains (SGP) area (especially, April)

Soil moisture anomaly (Apr, 1st)

0-10 cm



10-40 cm

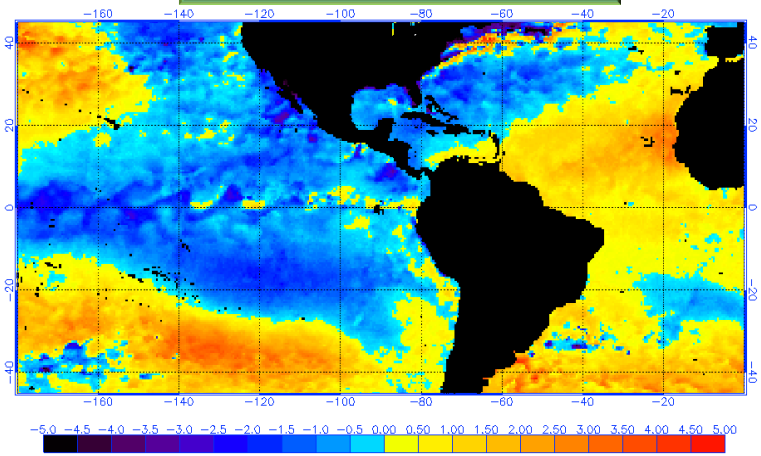


from NARR (relative anomaly)

What could be the role played by the soil moisture anomaly in the April precipitation deficit ?

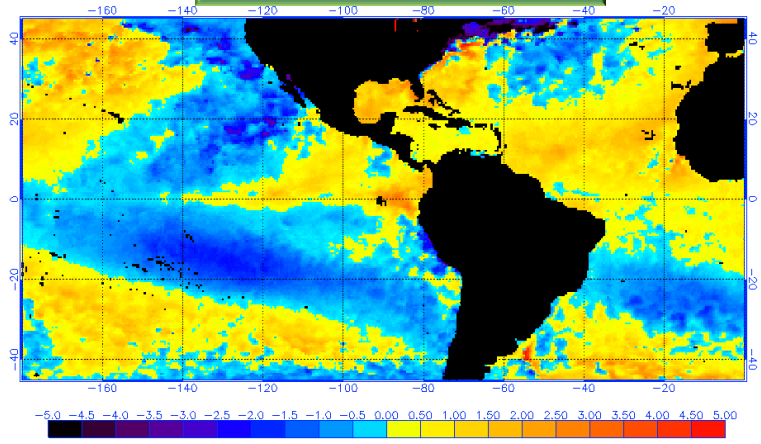
Tropical SST anomaly

Jan, 6, 2011



La Niña signal was much weaker in April, although the circulation patterns resembled those (winter) under its peak impacts

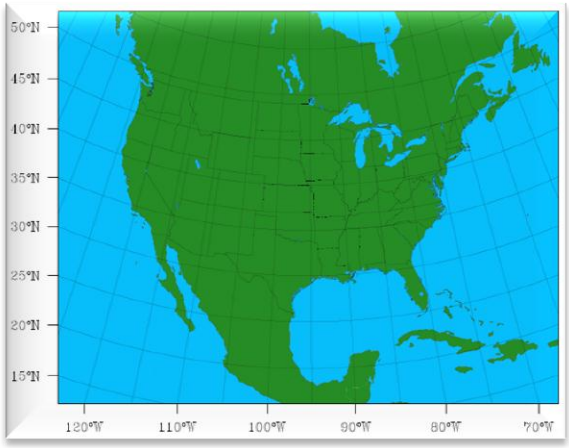
Apr, 18, 2011

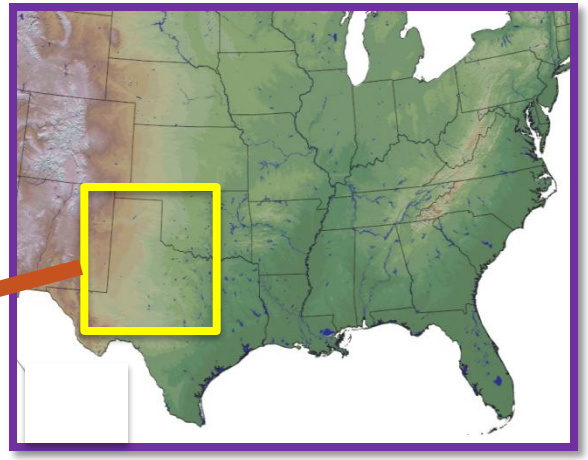


Other processes could have impacts on the drought (e.g., soil moisture)

Model and experiments

- The Weather Research and Forecasting Model (WRF)
- North American domain
- One month simulation (April 2011)
- Wet run establishes a wet soil moisture anomaly for the Southern Great Plains area
- Ensemble simulations in both CTL and WET experiments





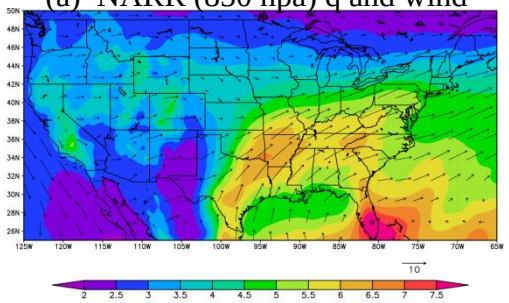
SGP soil moisture anomaly

WRF evaluation-circulation

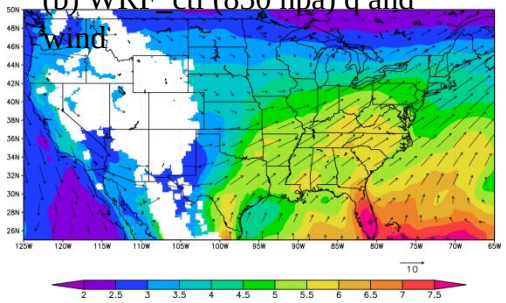
NARR

Ctl run

(a) NARR (850 hpa) q and wind

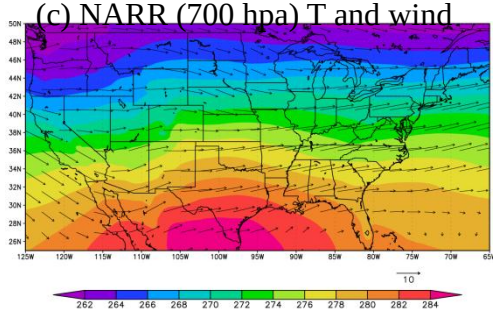


(b) WRF_ctl (850 hpa) q and wind

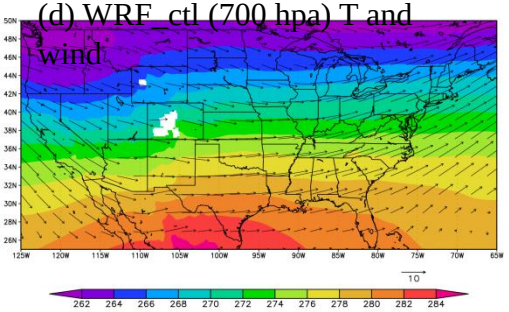


q, wind (850 hpa)

(c) NARR (700 hpa) T and wind

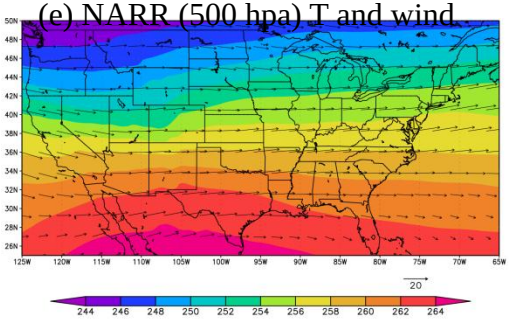


(d) WRF_ctl (700 hpa) T and wind

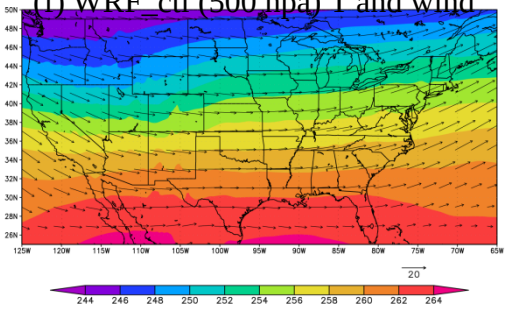


T, wind (700 hpa)

(e) NARR (500 hpa) T and wind



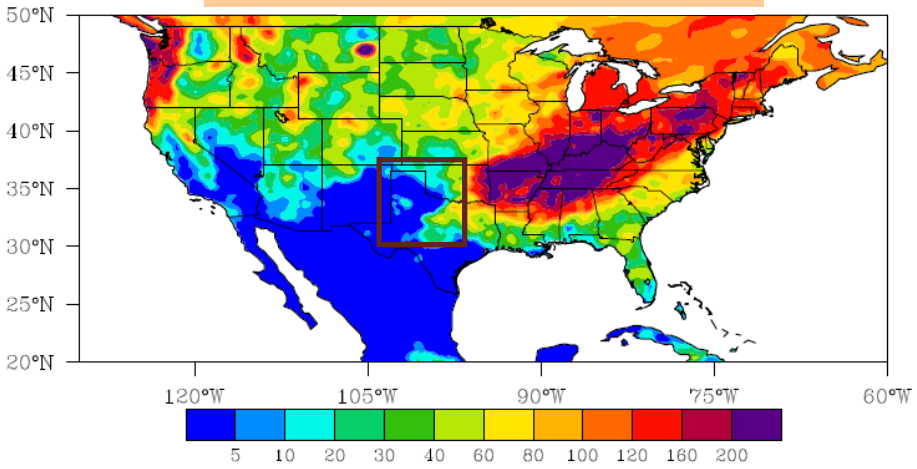
(f) WRF_ctl (500 hpa) T and wind



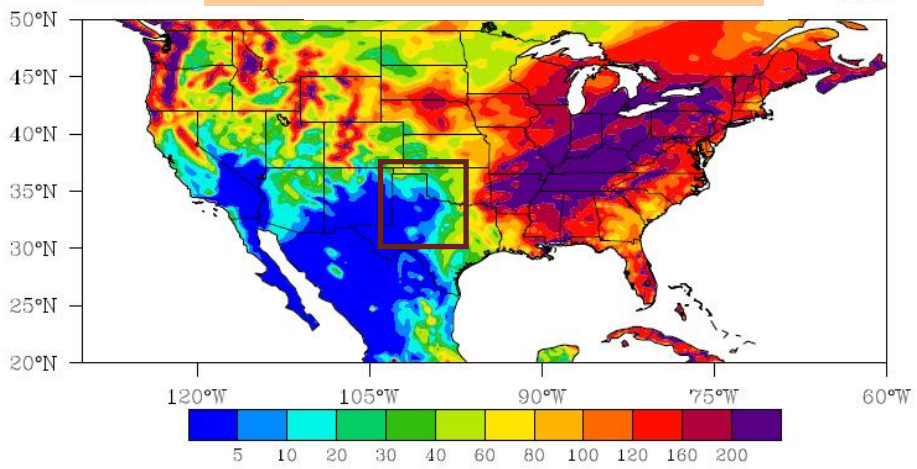
T, wind (500 hpa)

WRF evaluation-April Precipitation

Obs Apr precp



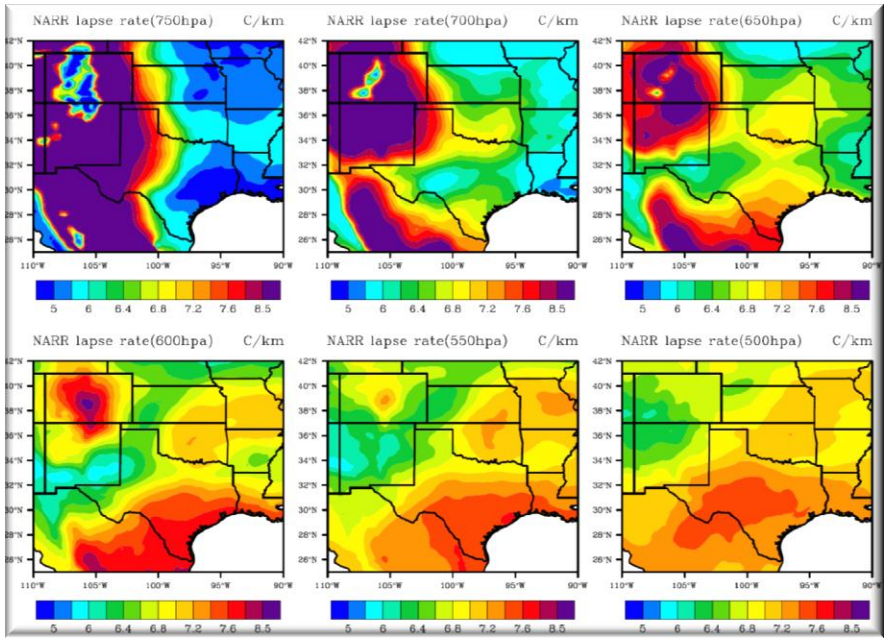
WRF CTL Apr precp



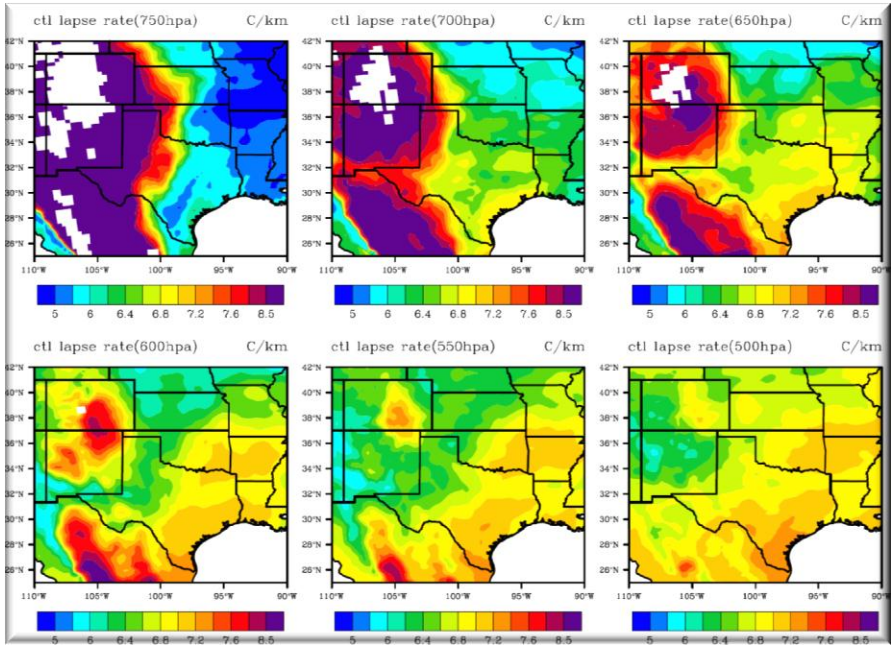
Model and observation agree well in the SGP area

WRF evaluation-lapse rate

NARR



Ctl run

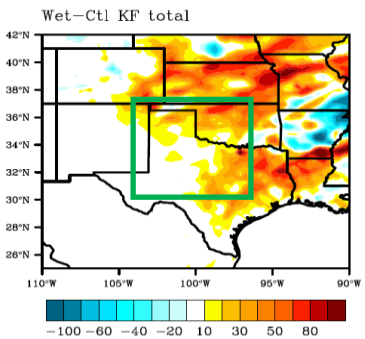


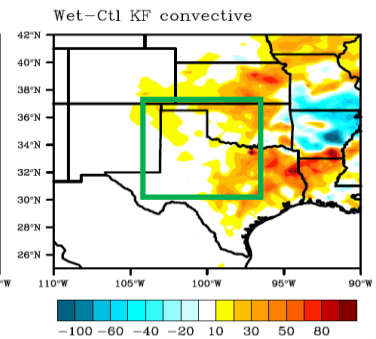
at 750, 700, 650, 600, 550, 500 hpa

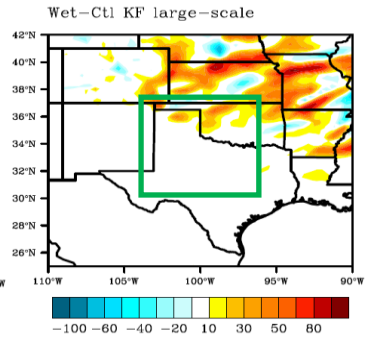
Precp response (WET – CTL)

Total precp | Convective | Large-scale

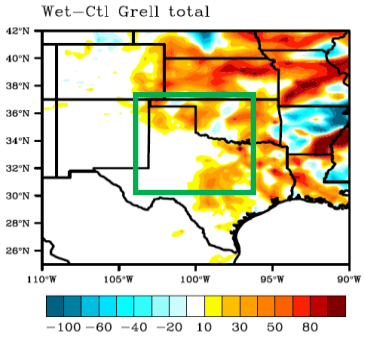
KF

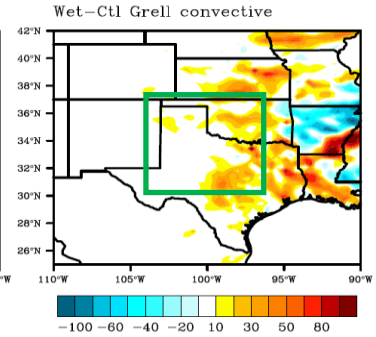


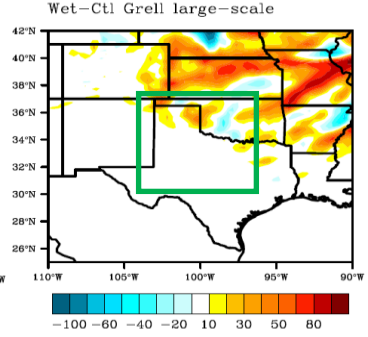




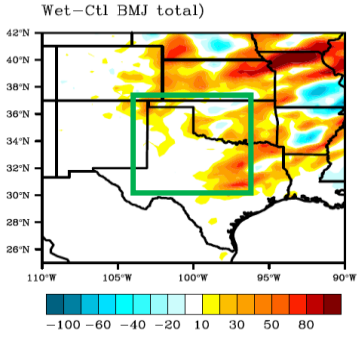
Grell

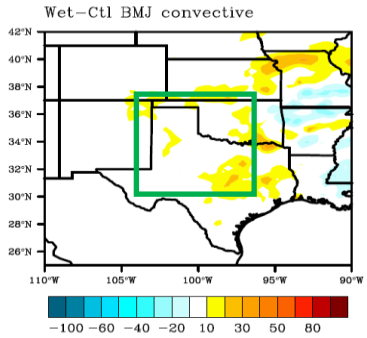


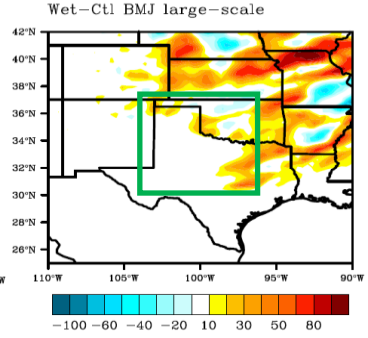




BMJ







Higher precp (lower) sensitivity to wet soil at eastern (western) side;

Wetter soil leads to equivalent ET increase at eastern and western SGP

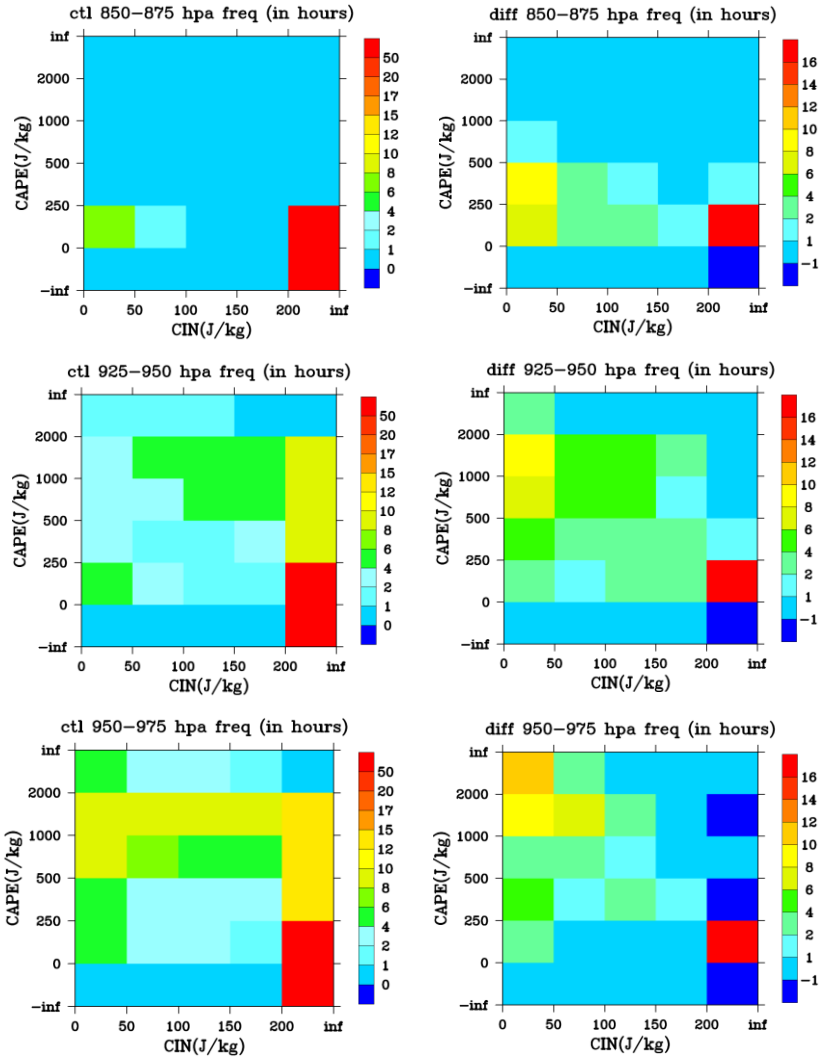
Joint pdf of CAPE and CIN

CTL

WET-CTL

Limit moisture convection

Favor moisture convection

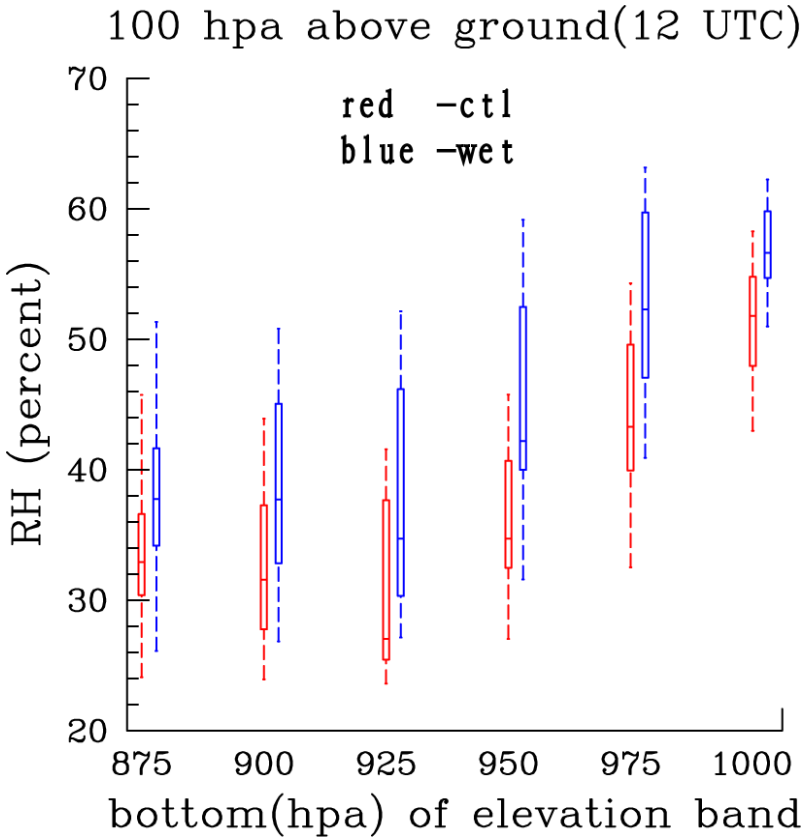


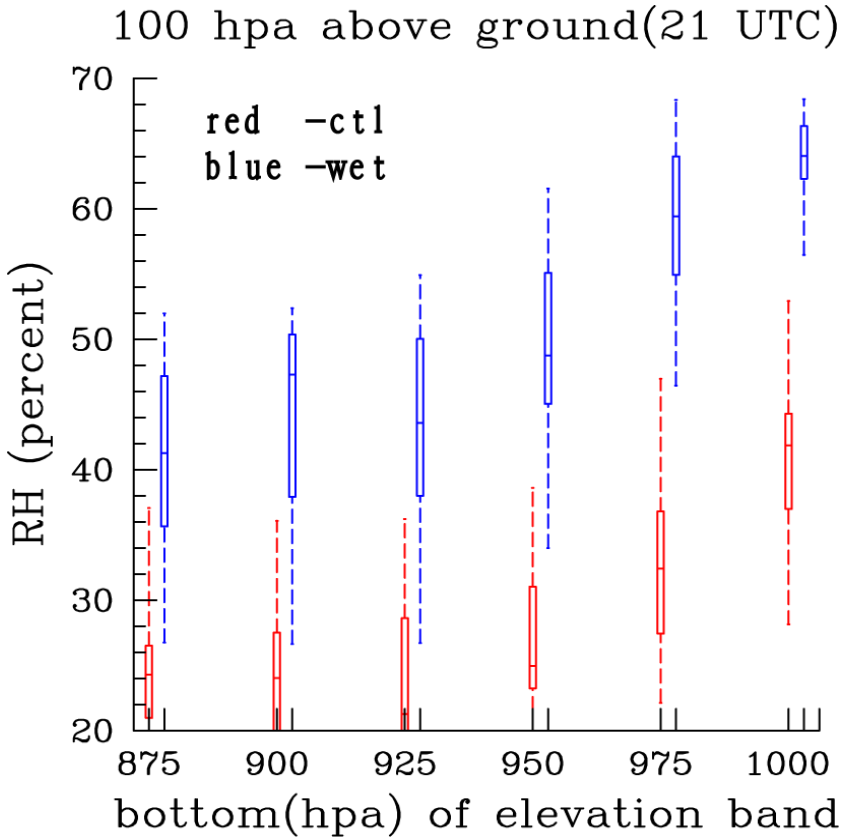
Western SGP

Central SGP

Eastern SGP

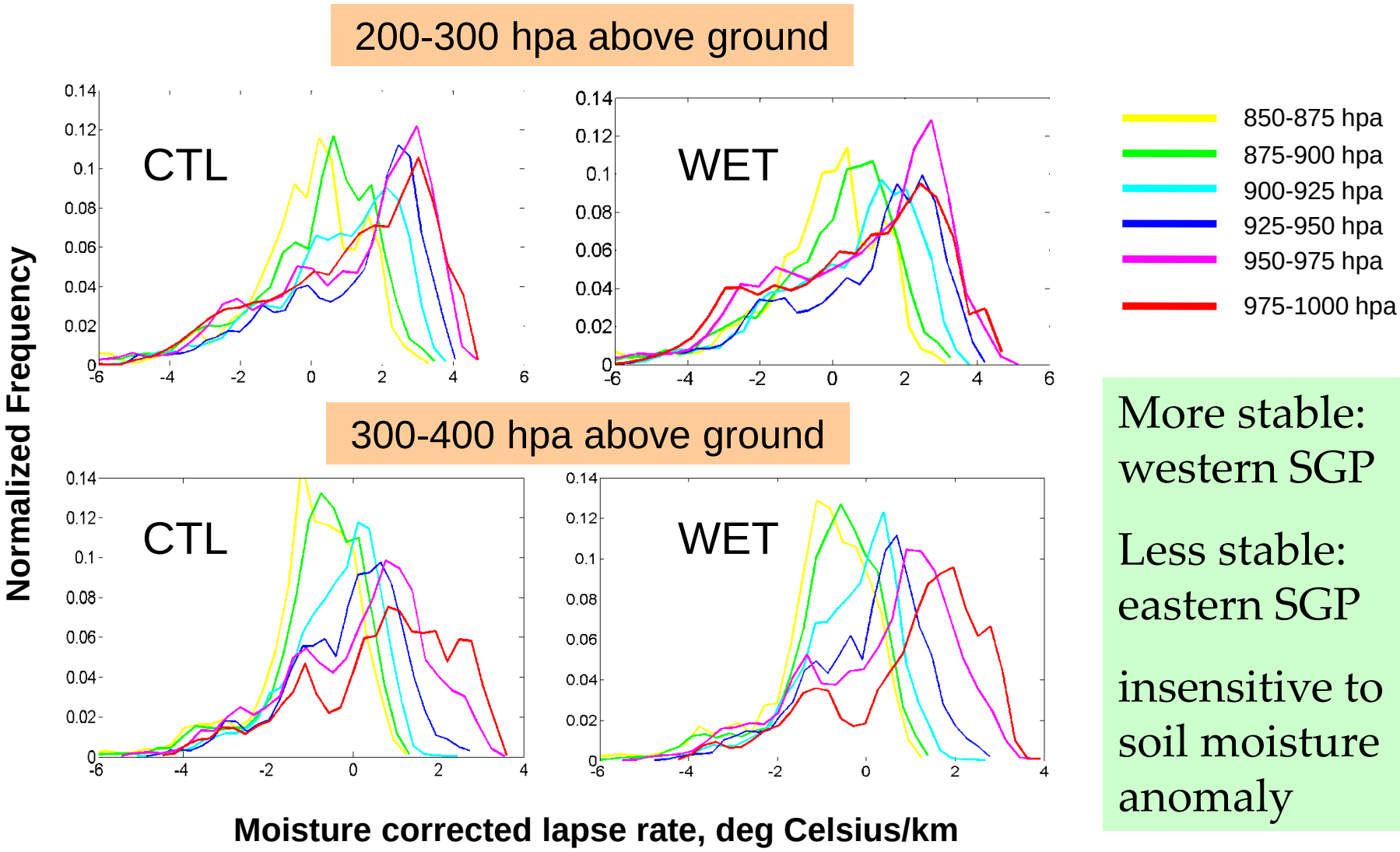
Lower troposphere RH





Wetter soil increases RH at both western and eastern SGP because of increased ET, but RH is still very low at the western SGP that reduce moisture convection

Pdf of the atmospheric stability



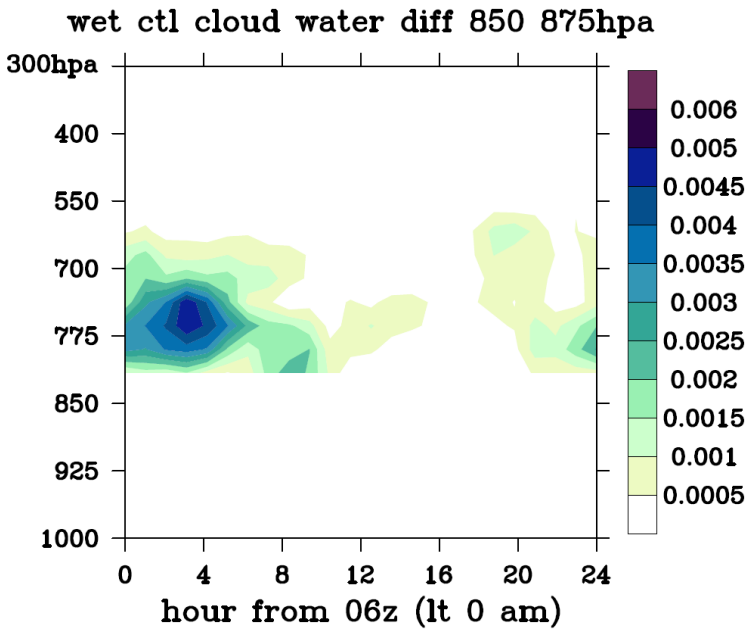
More stable: western SGP

Less stable: eastern SGP

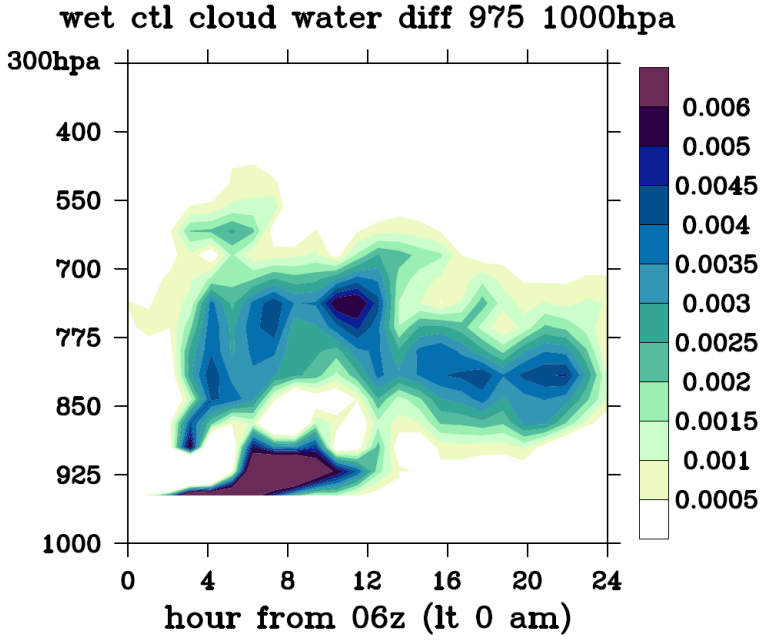
insensitive to soil moisture anomaly

cloud water content response

Western SGP (wet – ctl)



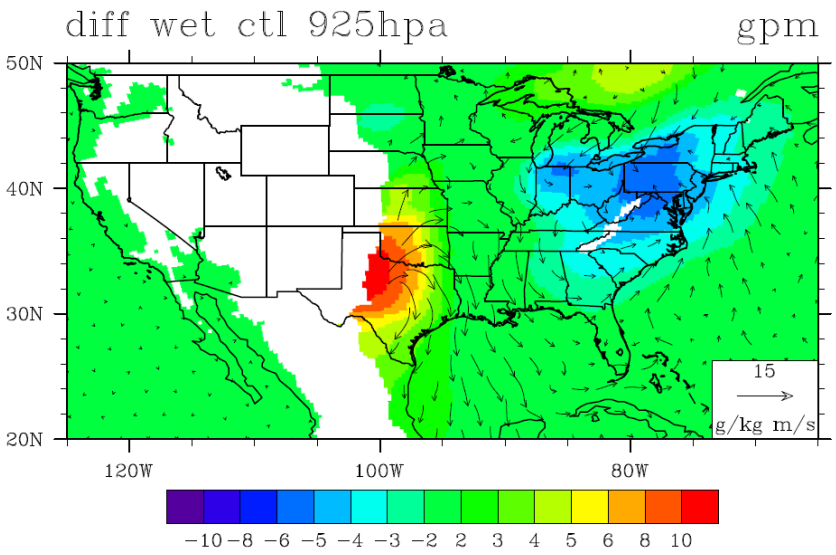
Eastern SGP (wet –ctl)



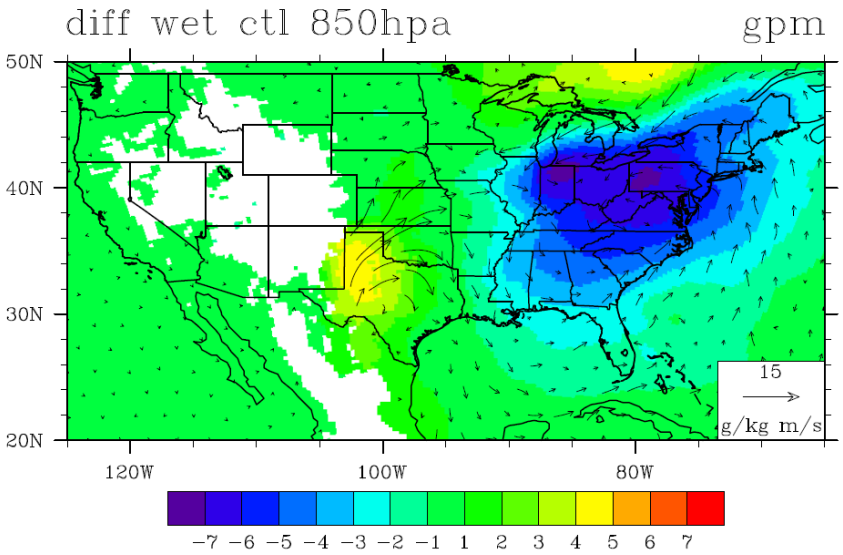
Stronger increase of moisture convection from wet soil at the eastern SGP, especially for the day-time

Moisture flux and GPH responses

925 hpa (wet – ctl)



850 hpa (wet – ctl)



Wet soil brought an increased GPH, and a moisture outflux anomaly at the western and central SGP (because of a stronger cooling effect at the western area)

Summary

1. The precipitation at the eastern SGP is much more sensitive to a local wet soil moisture anomaly;

2. The dry soil played an important role in the eastern SGP to shaping local drought condition;

3. The spatial difference of soil moisture-precipitation coupling is largely driven by convective features of the area, especially the low-level moisture availability and stability profile at different levels; circulation response help reinforce the spatial difference of feedback strength.

Future work

1. Soil moisture and other observational datasets to evaluate the model represented feedback strength;

2. The role played by vegetation in the drought development;

3. Interaction between the unsaturated soil/groundwater and their role in the drought development.