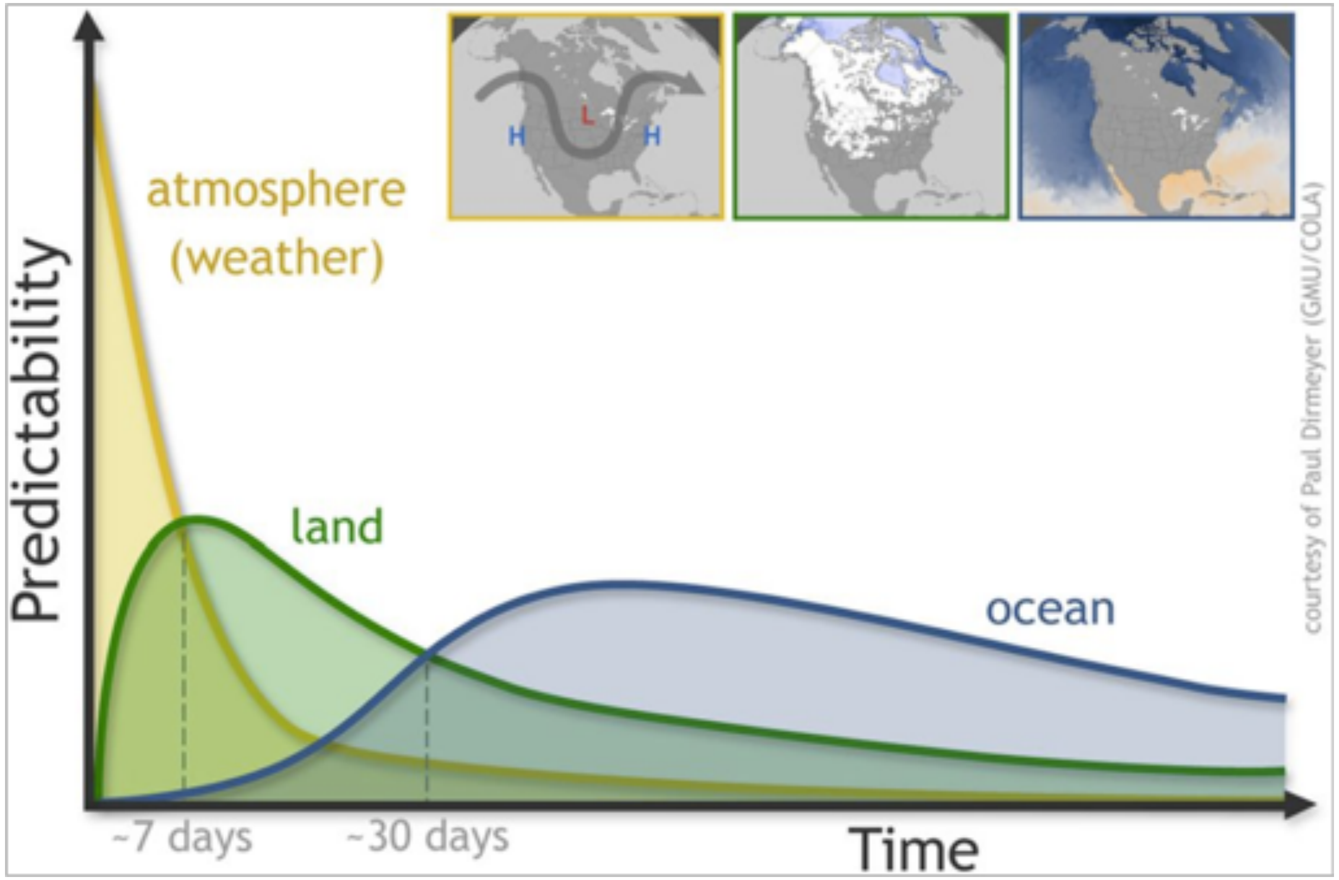
Potential land anomaly effects on hydrologic prediction in the U.S.



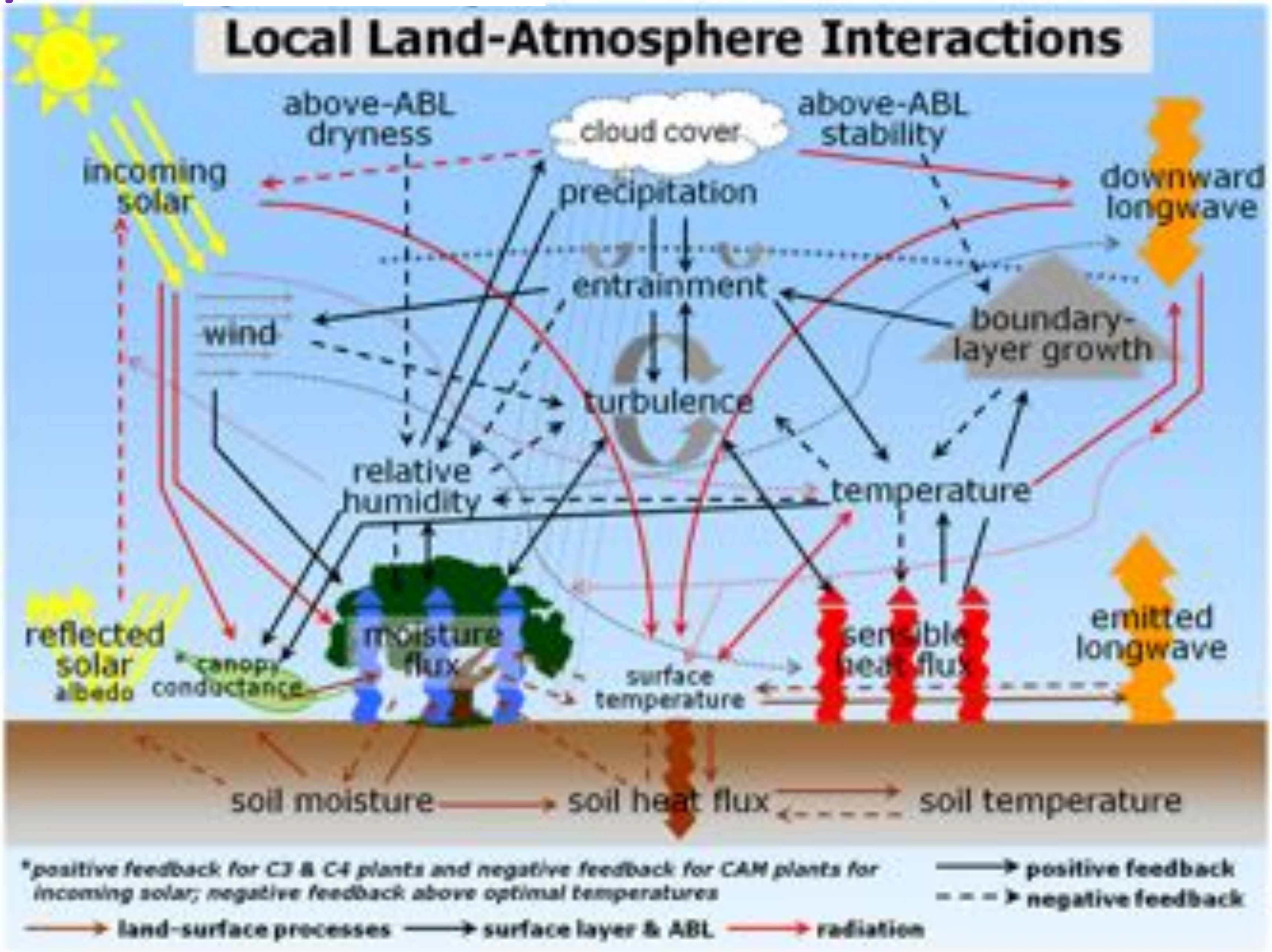
Craig R. Ferguson and David Mocko

Atmospheric Sciences Research Center, University at Albany, State University of New York, Albany, NY, USA

NASA-GSFC, Greenbelt, MD., USA

Fully-coupled system!

Ek complexity

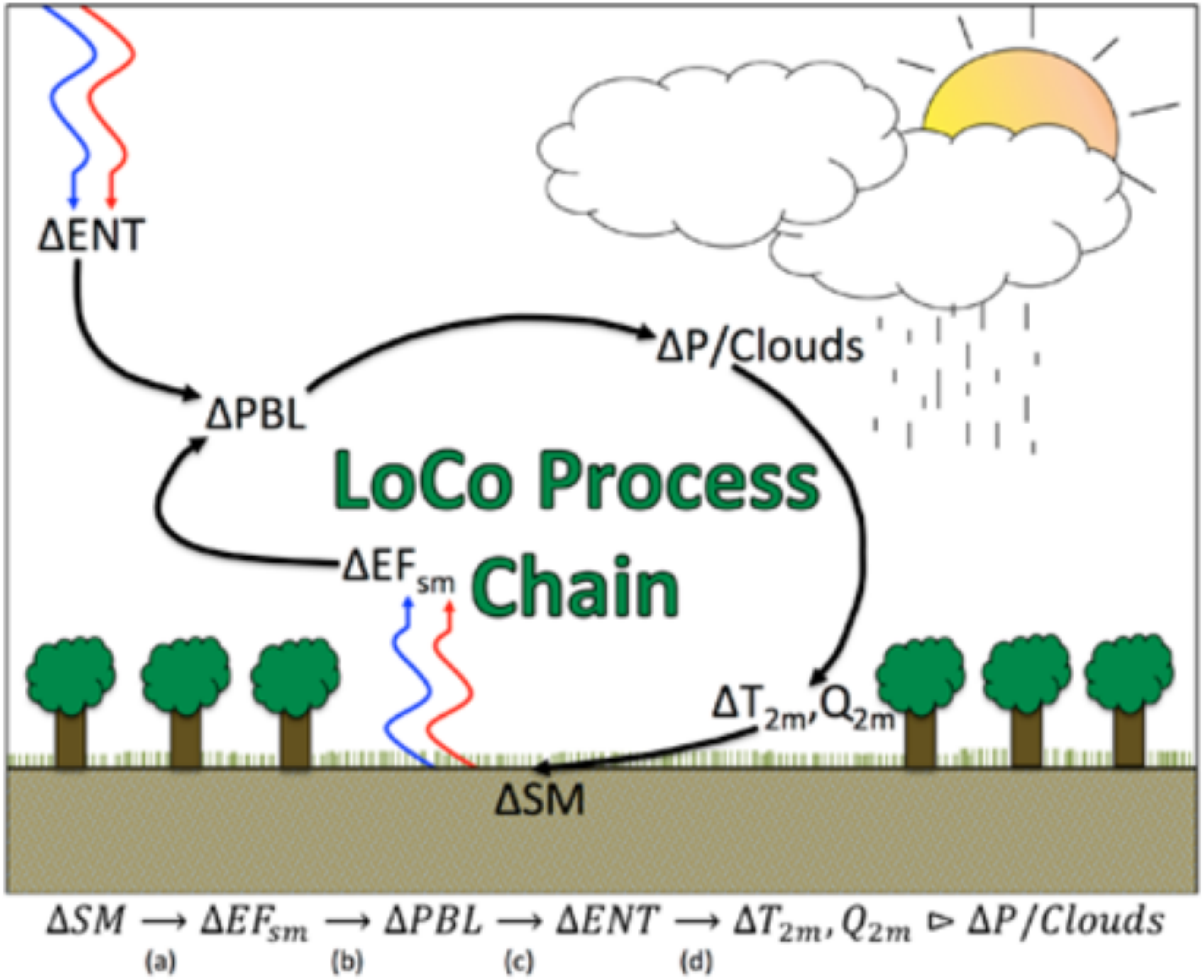


Ek, M. B., and A. A. M. Holtslag, 2004: Influence of Soil Moisture on Boundary Layer Cloud Development. J Hydrometeorol., 5, 86-99.

Fully-coupled system!

simplified LoCo form…

ΔSM→ΔEF→ΔLCL→Δclouds/P→ΔSM



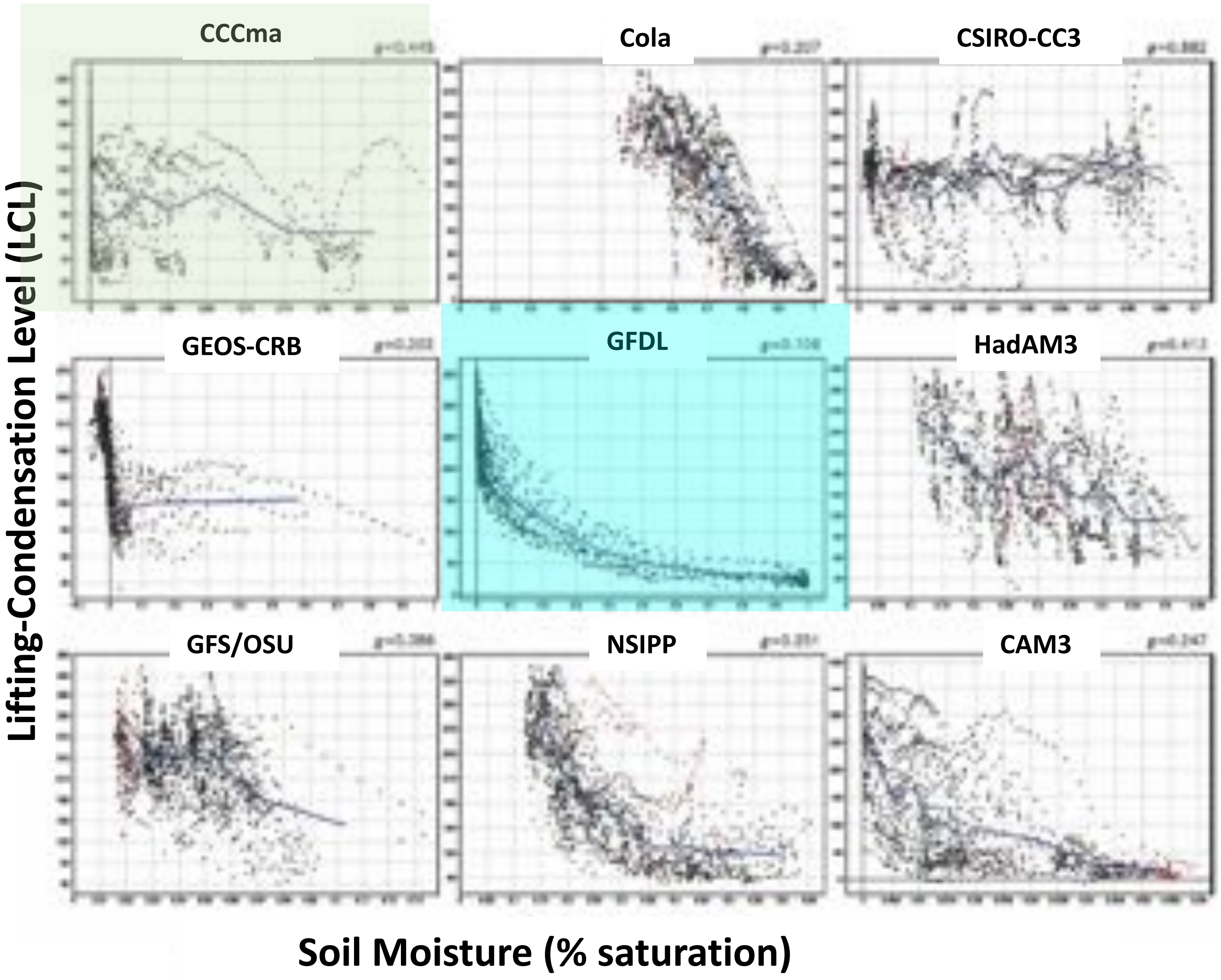
All coupling starts **locally**. The land signal is a necessary but not sufficient pre-requisite for land-atmosphere coupling.

Fully-coupled system!

GLACE-1 results

ΔSM → ΔEF → ΔLCL → Δclouds/P → ΔSM

GLACE-1 revealed exceptional model spread in SM-LCL covariance



Dirmeyer, P. A., R. D. Koster, and Z. C. Guo, 2006: Do global models properly represent the feedback between land and atmosphere? Journal of Hydrometeorology, 7, 1177-1198.

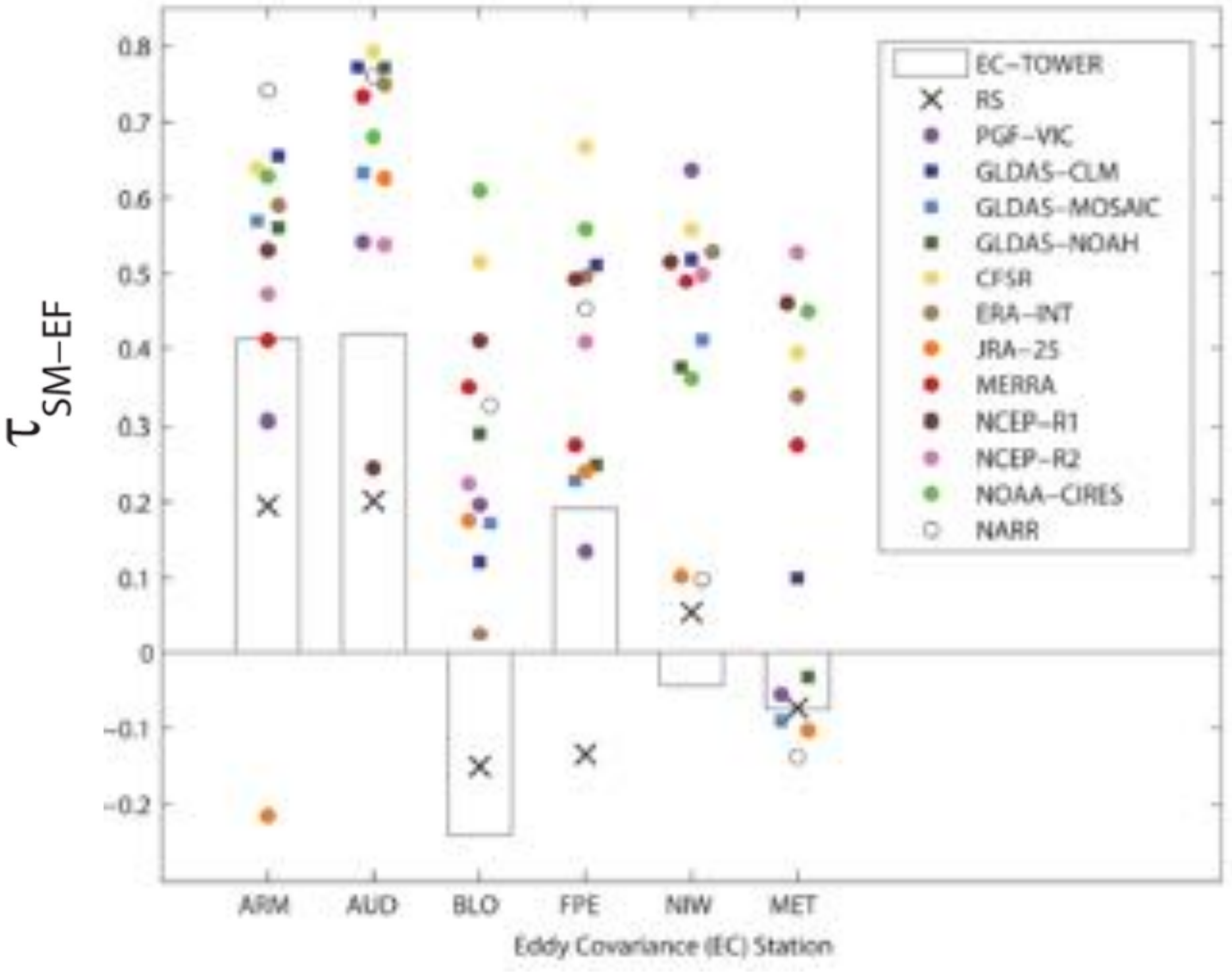
Fully-coupled system!

FLUXNET results

ΔSM→ΔEF→ΔLCL→Δclouds/P→ΔSM

Models are too strongly coupled in SM-EF ‘leg’

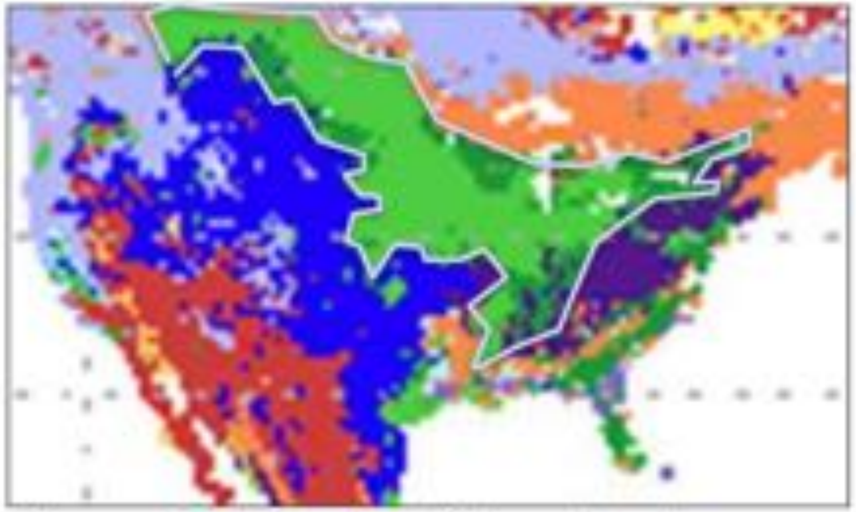
Ferguson, C.R., E.F. Wood, and R.K. Vinukollu (2012), A global inter-comparison of modeled and observed land-atmosphere coupling, J. Hydrometeor., JHM-D-11-0119, 13(3), 749-784, doi:10.1175/JHM-D-11-0119.1.



The NOAA CFSv2 “Quick Fix”: coupling matters!

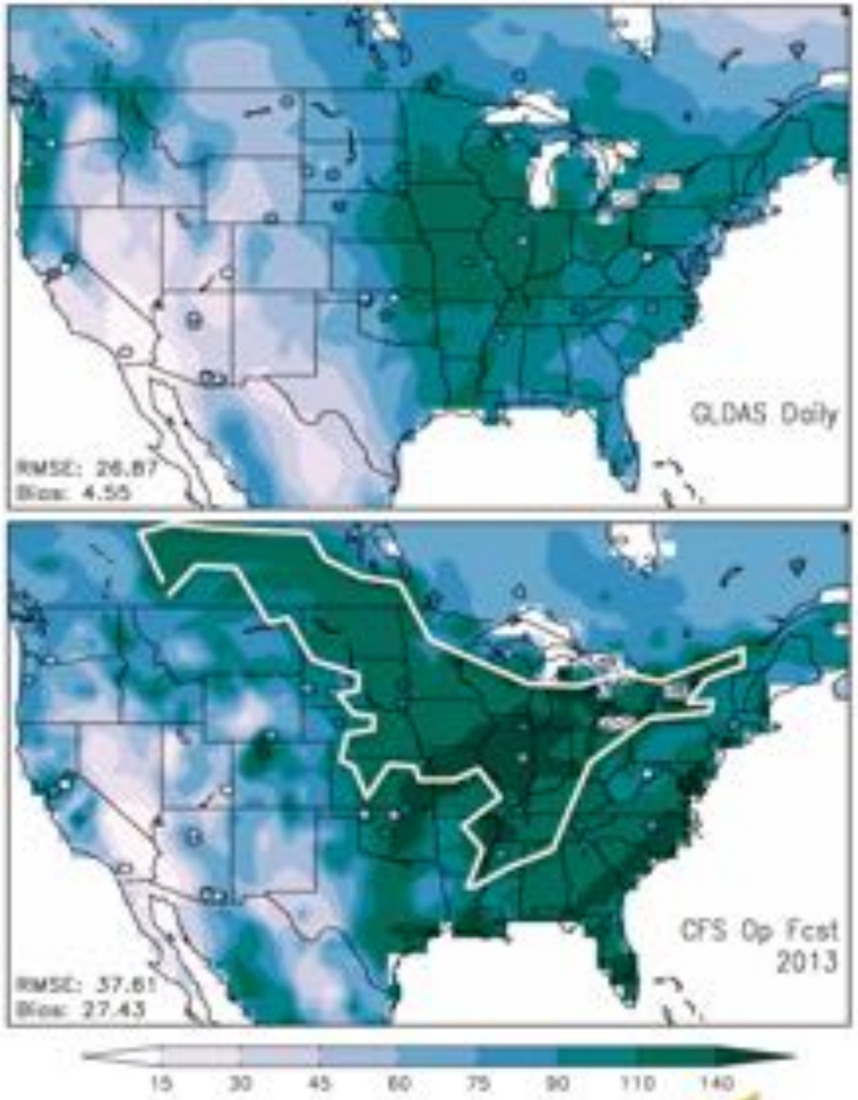
Courtesy Paul Dirmeyer

- To correct warm biases in CFSR, roots for Noah crop vegetation type were extended to all 4 soil layers; it transpires too freely.



Green: Total and partial cropland

Latent Heat Flux **JJA**

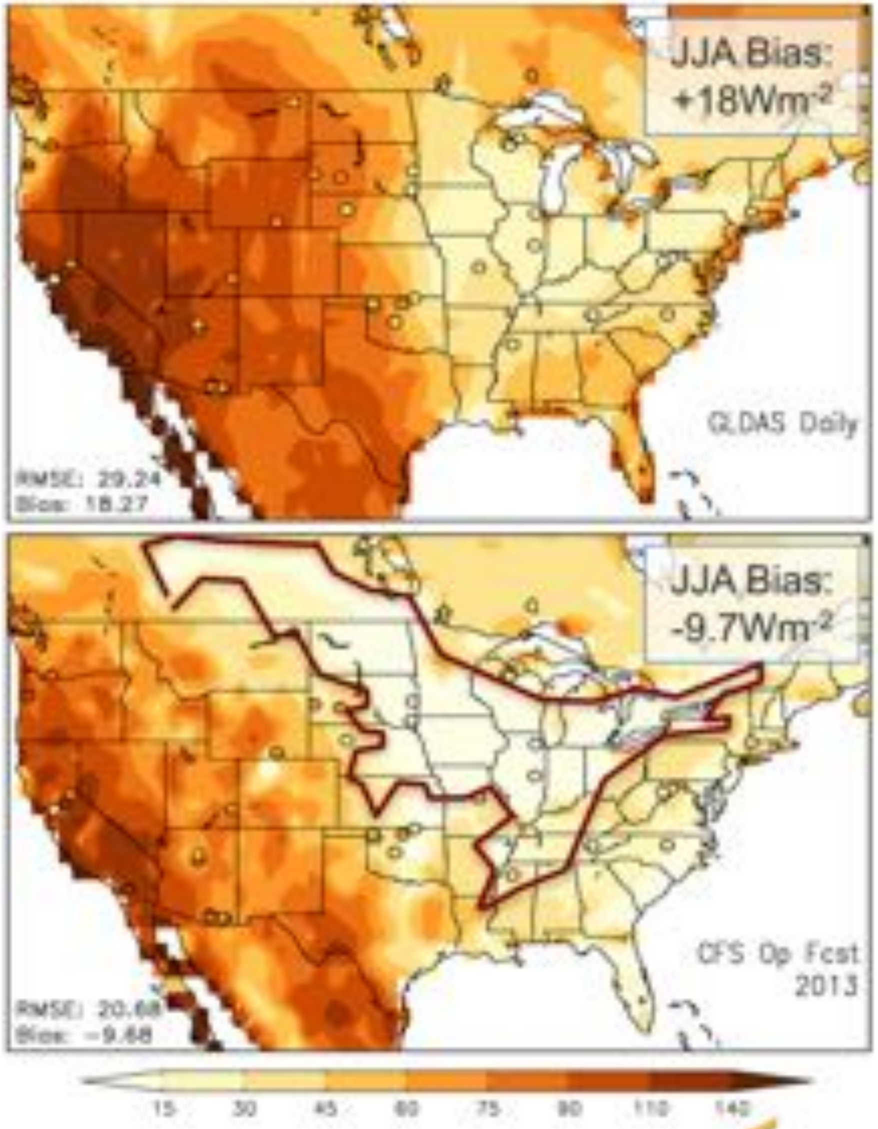


COLA GEORGE MASON UNIVERSITY

The NOAA CFSv2 "Quick Fix": coupling matters!

Sensible heat fluxes

- Essentially zero over much of Midwest in CFS over crop vegetation type.
- This seems to cause problems for boundary layer simulation (essentially there is none)… perpetual fog.
- But hey, the temperature error was reduced! Right result for wrong reason.



Challenges to quantifying land-based predictability

1. Coupled process issue with equifinality and lack of observational constraints
2. Multi-spatiotemporal scale impacts and feedbacks (direct and indirect) amidst low-frequency variability and climate change

Specific physical processes involved:

DYNAMIC VEGETATION

- ocean-forced multi-decadal variability (e.g., ENSO, AMO, PDO)
- land-use/land-cover change
- low-level jets, monsoons, and TCs
- large scale irrigation

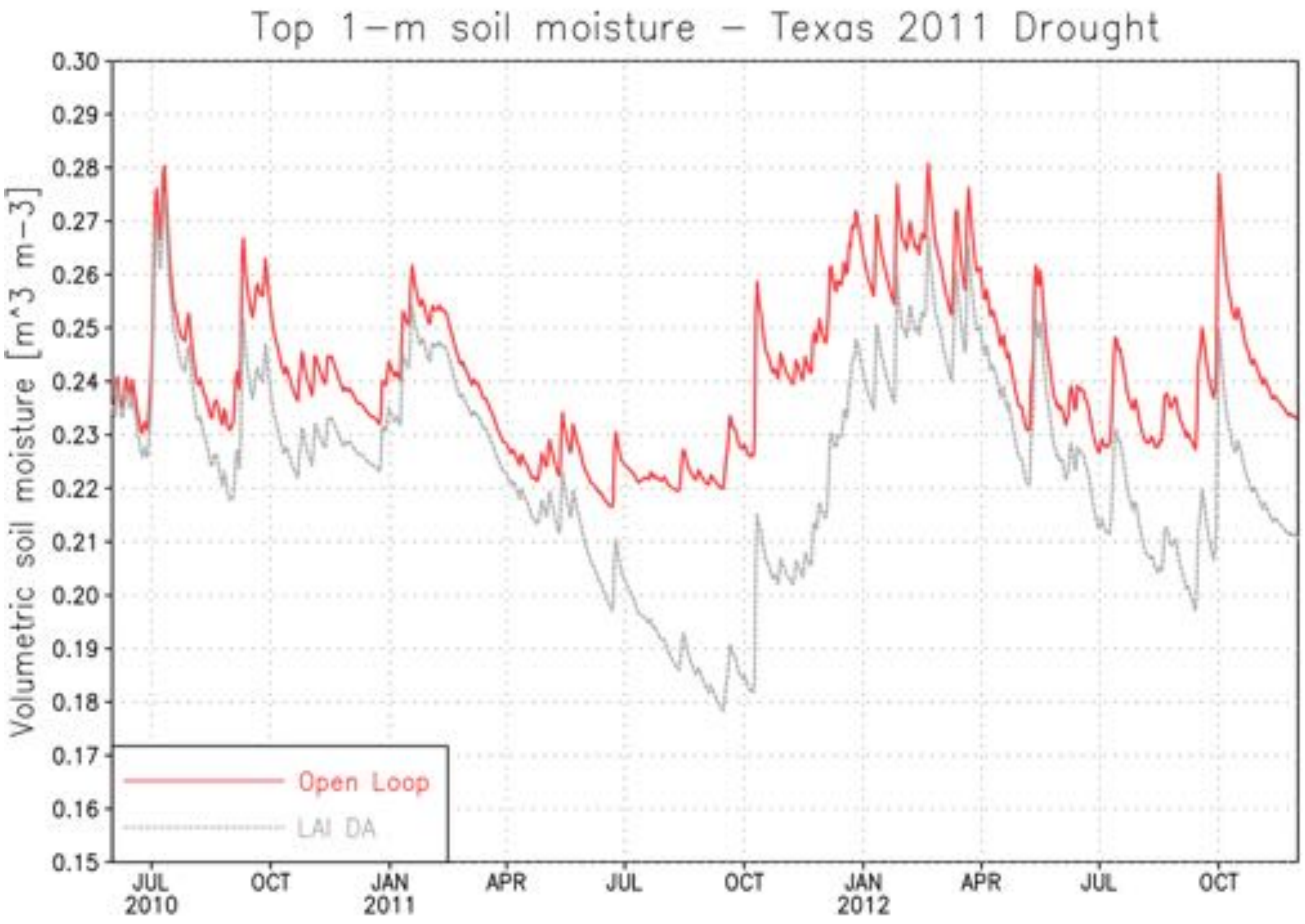
Mid-continental warm/dry bias, diurnal precipitation, etc. (e.g., DOE CAUSES; Rasmussen et al.)

Data Length Requirements for Observational Estimates of Land-Atmosphere Coupling Strength. (Findell et al., 2015)

Proving a robust change/trend in precipitation requires large ensembles (e.g., Deser et al. 2013)

Advancing Hydrometeorological-Hydroclimatic-Ecohydrological Process Understanding and Predictions, NSF workshop/white paper (Dirmeyer et al., 2014).

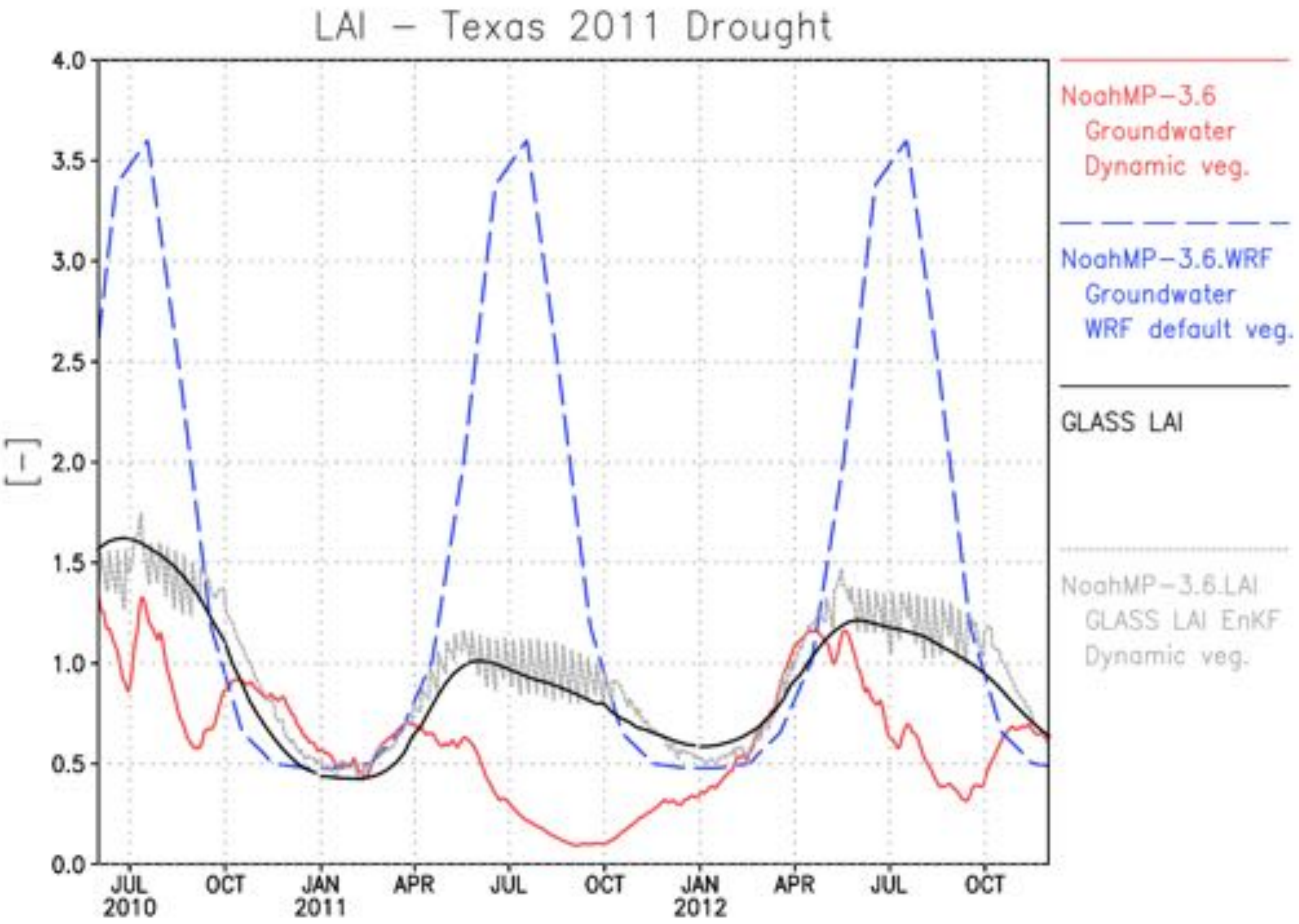
LAI Data Assimilation (Mocko)



The dynamic vegetation Open Loop run (without LAI data assimilation) has a low LAI, which greatly reduces the transpiration. This reduction, in turn, does not remove soil moisture from the root zone. The soil moisture is not anomalously dry during this drought.

When assimilating LAI, transpiration increases, and soil moisture is lower, improving the signal of drought.

LAI Data Assimilation (Mocko)



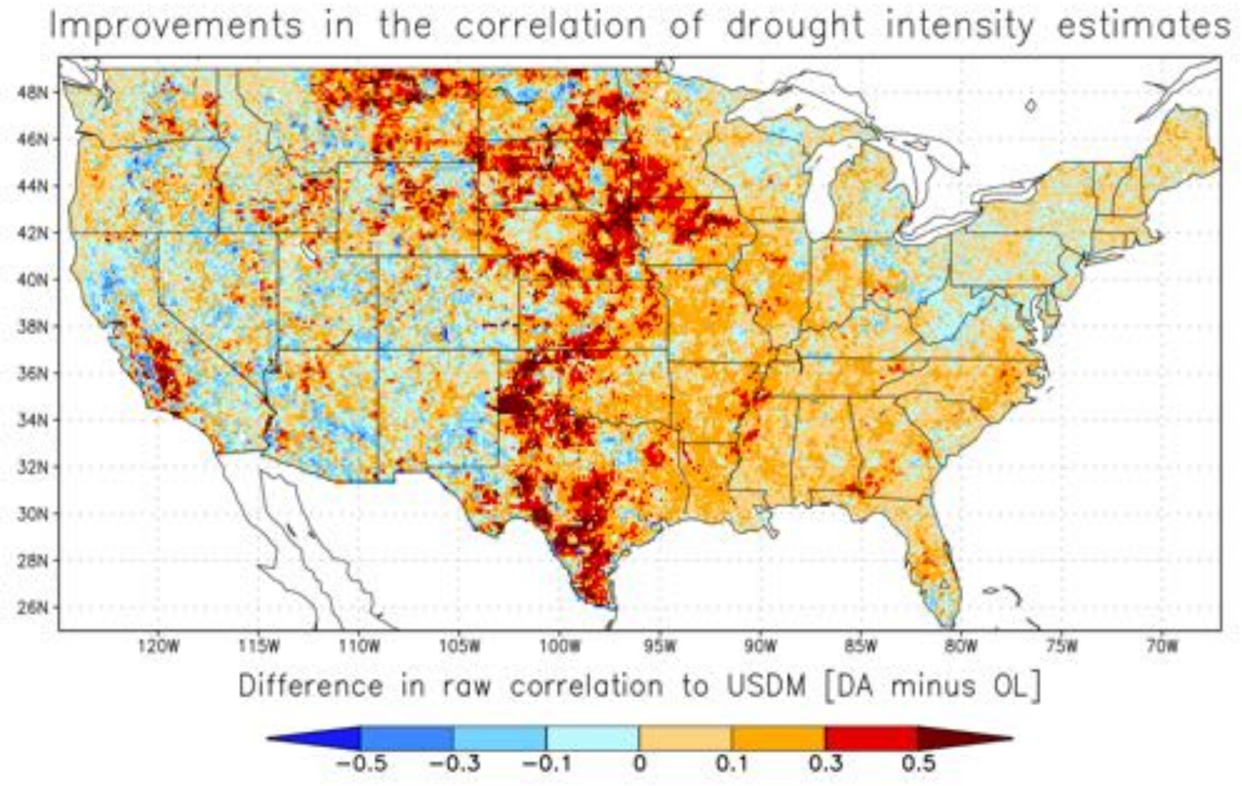
Default vegetation is a climatological LAI that is the same every year, and much higher than measured by GLASS, particularly in the 2011 drought year.

Dynamic vegetation, however, has a much lower LAI than from GLASS for the 2011 drought year.

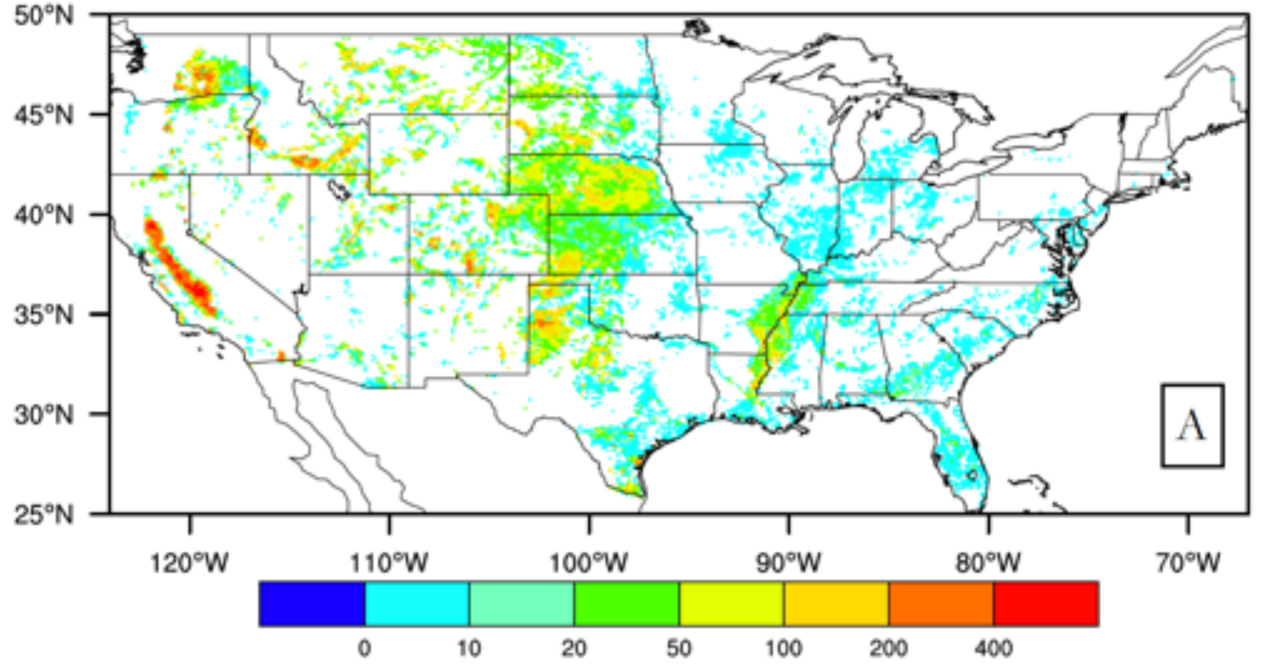
LAI DA is much closer to the GLASS LAI, which is an 8-day product, and the LAI simulated by Noah-MP can drift during these 8-days.

This figure is a Texas state average.

LAI Data Assimilation (Mocko)



Average annual irrigated water use (mm year-1) from NCA-LDAS (Kumar et al., JHM, early online release)



Irrigated area in NCA-LDAS is determined by MODIS. Areas with both high irrigated amounts and improvements in the raw correlation of soil moisture percentiles against USDM from LAI data assimilation include:

- California central valley
- Nebraska
- Lower Mississippi river
- Texas (in particular, northwest Texas – we will look closer at this region for the 2011 drought case)

Challenges to quantifying land-based predictability

1. Coupled process issue with equifinality and lack of observational constraints

2. Multi-spatiotemporal scale impacts and feedbacks (direct and indirect) amidst low-frequency variability and climate change

Mid-continental warm/dry bias, diurnal precipitation, etc. (e.g., DOE CAUSES; Rasmussen et al.)

Data Length Requirements for Observational Estimates of Land-Atmosphere Coupling Strength. (Findell et al., 2015)

Specific physical processes involved:

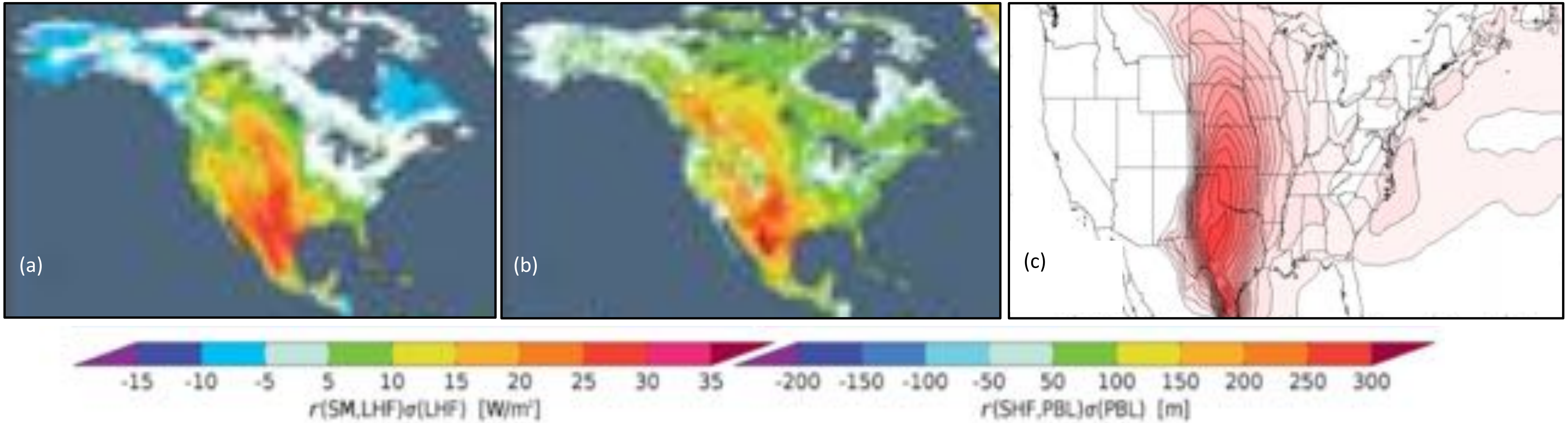
- dynamic vegetation
- resolved convection, MCSs
- rainfall/runoff
- groundwater/baseflow
- atm. circulation (e.g., polar and sub-tropical jets)
- ocean-forced multi-decadal variability (e.g., ENSO, AMO, PDO)
-
-
- large scale irrigation

Low-level jets

Proving a robust change/trend in precipitation requires large ensembles (e.g., Deser et al. 2013)

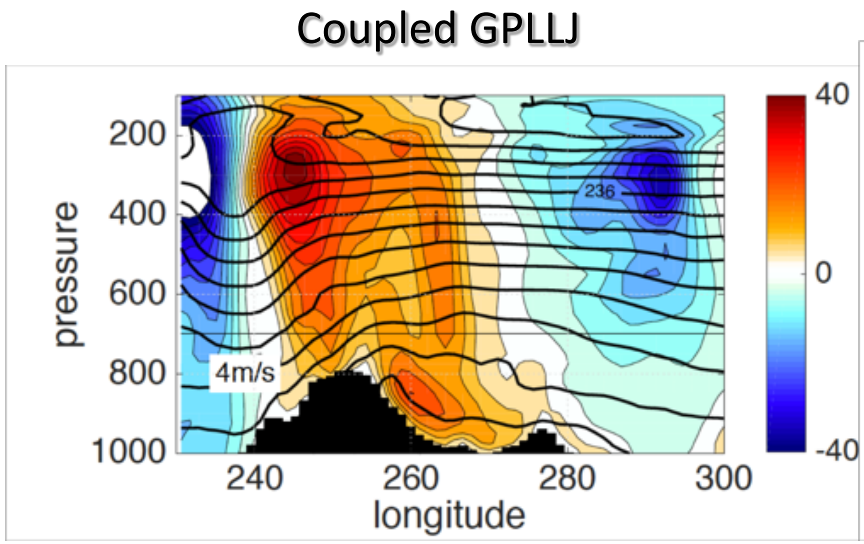
Advancing Hydrometeorological-Hydroclimatic-Ecohydrological Process Understanding and Predictions, NSF workshop/white paper (Dirmeyer et al., 2014).

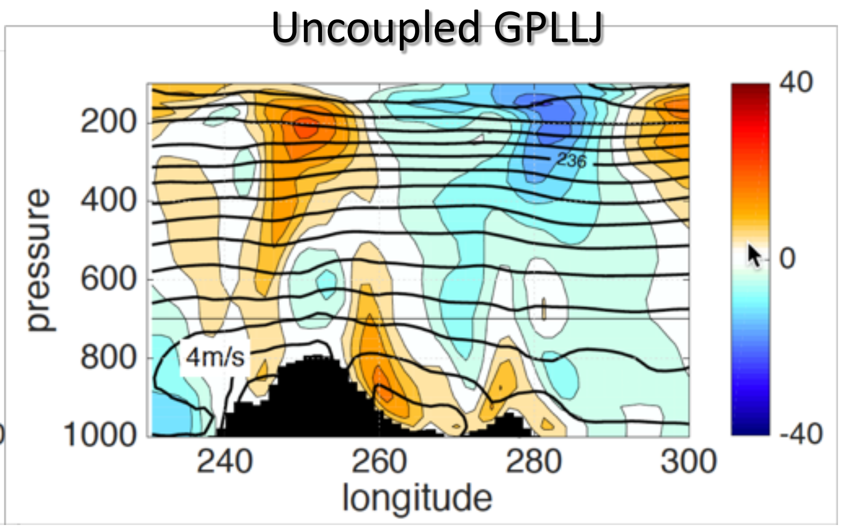
Local-remote support for land-atmosphere interactions (Ferguson)

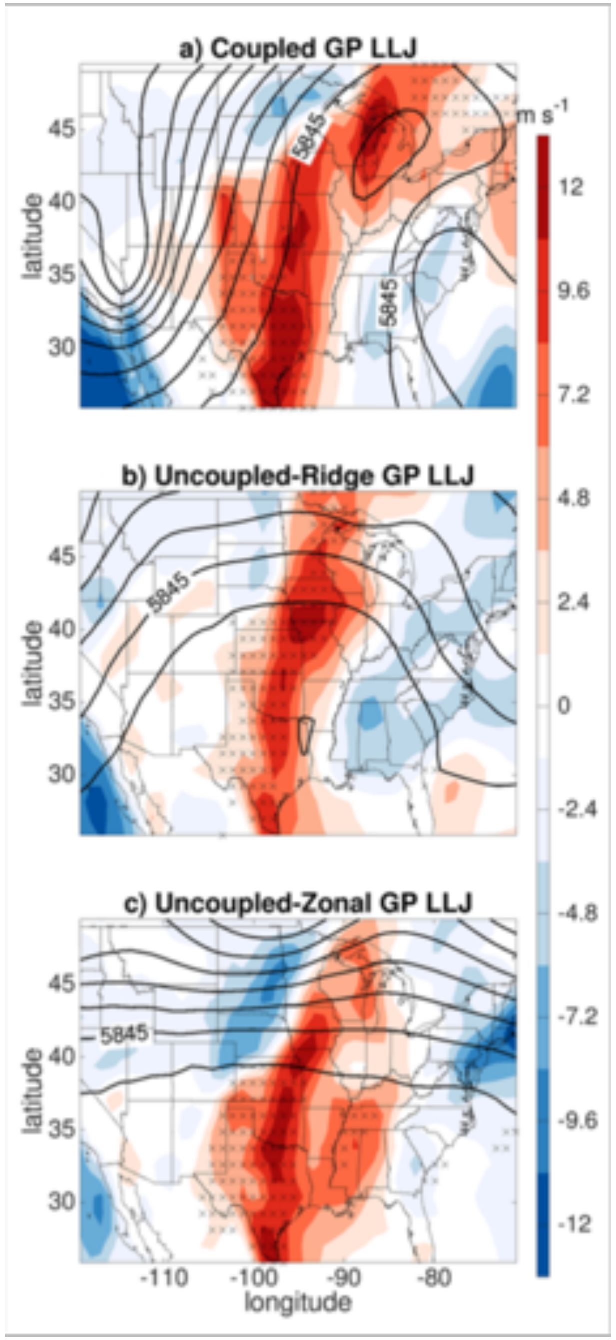


(a) Terrestrial and (b) atmospheric coupling indices based on the two-legged coupling metric of **Dirmeyer** (2011), outlined in Section 4.3.2 for JJA: SM is soil moisture, LHF is latent heat flux, SHF is sensible heat flux, and PBL is height of the planetary boundary layer. Positive values indicate coupling, and insignificant correlations are masked. Adapted from Dirmeyer et al. (2012, their Fig. 8).(c) Based on 125km CERA20C, the percentage of days in May-September 1901-2010 with uncoupled LLJs. The contour interval is 1.25% and ranges from 0 to 25% (**Burrows et al., 2018**).

Climate Variability and Change: GP LLJ



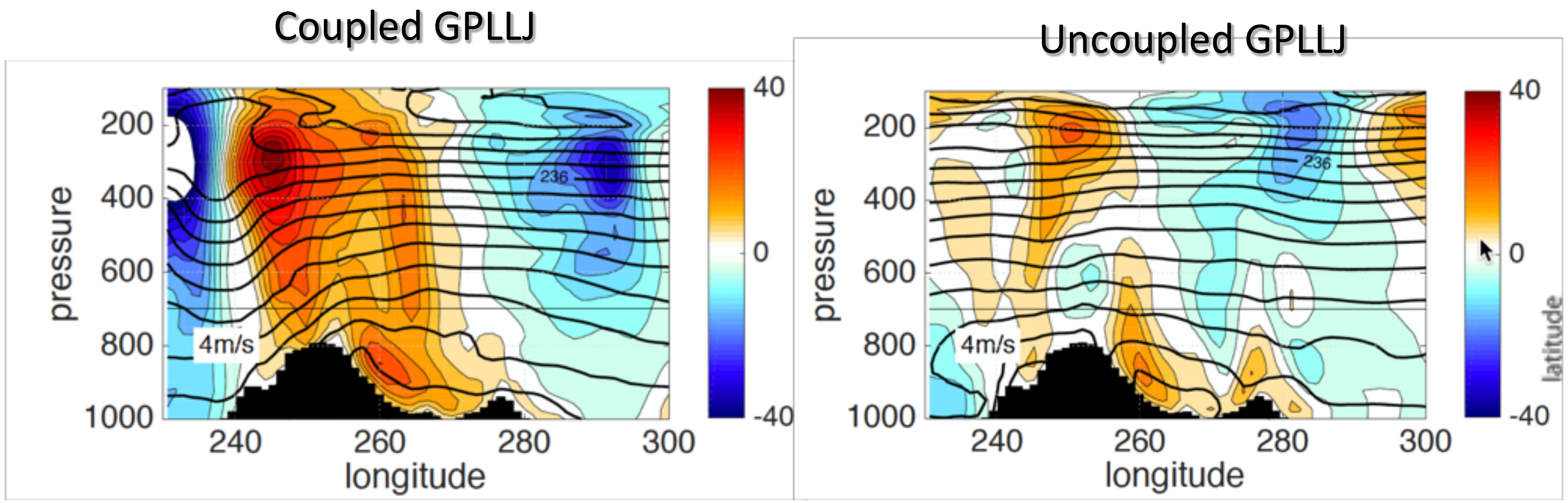


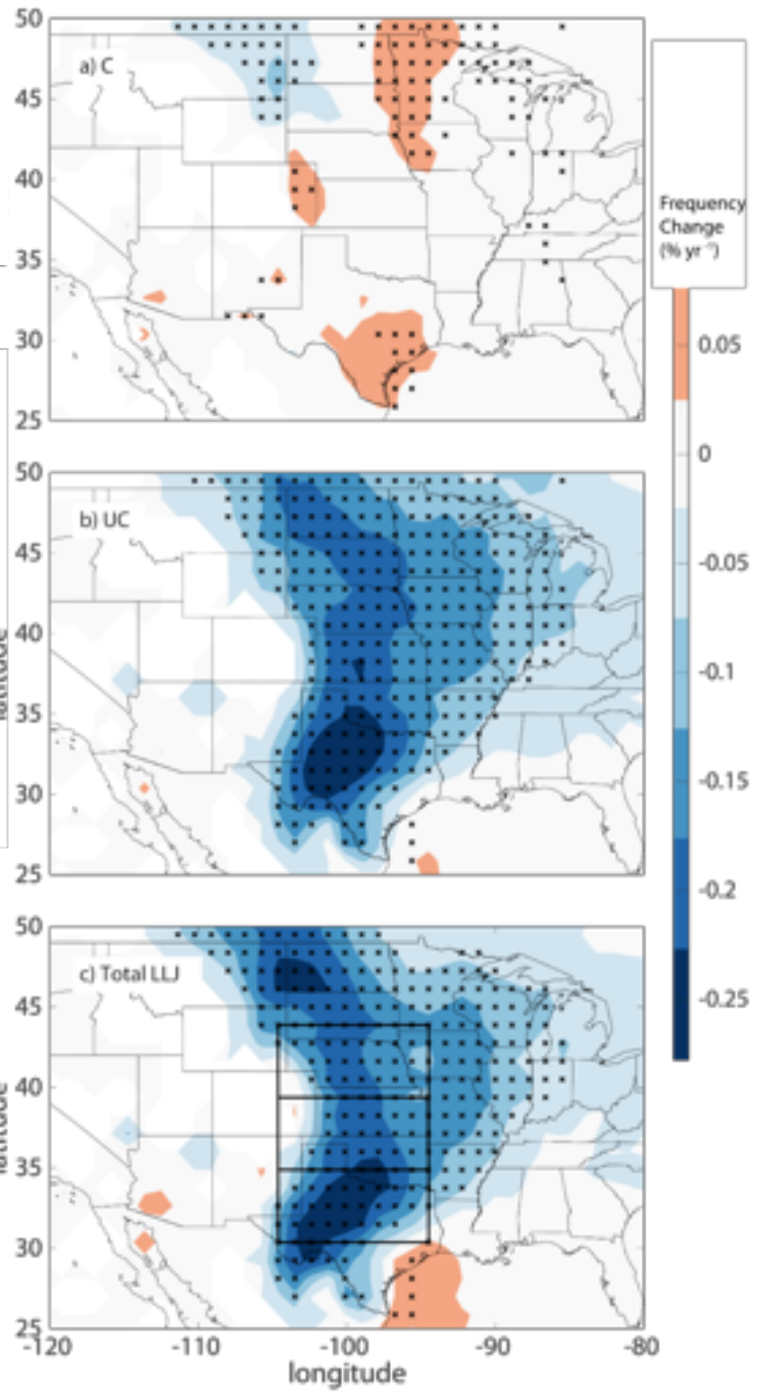


Cyclone/coupled LLJs will be situated within the warm conveyor belt sector of an approaching frontal system, positioned between a trough to the west and a ridge to the east (**Burrows et al., in-prep**)

Climate Variability and Change: GP LLJ

CERA-20C
1901-2010
Frequency change
(%/yr; right)

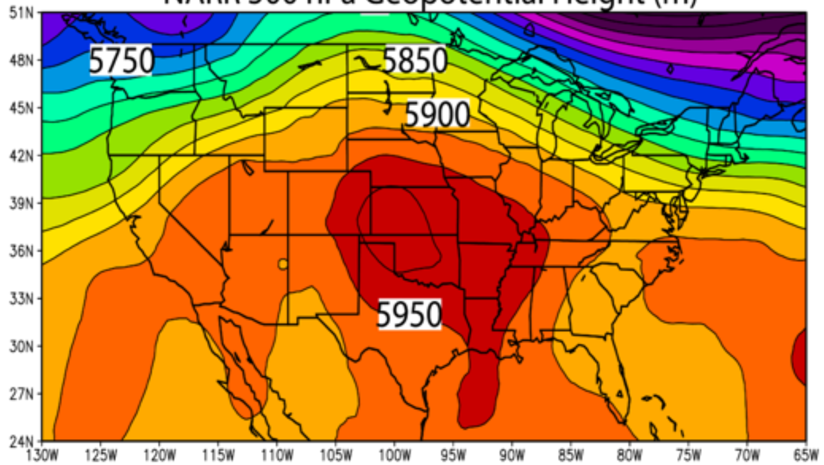




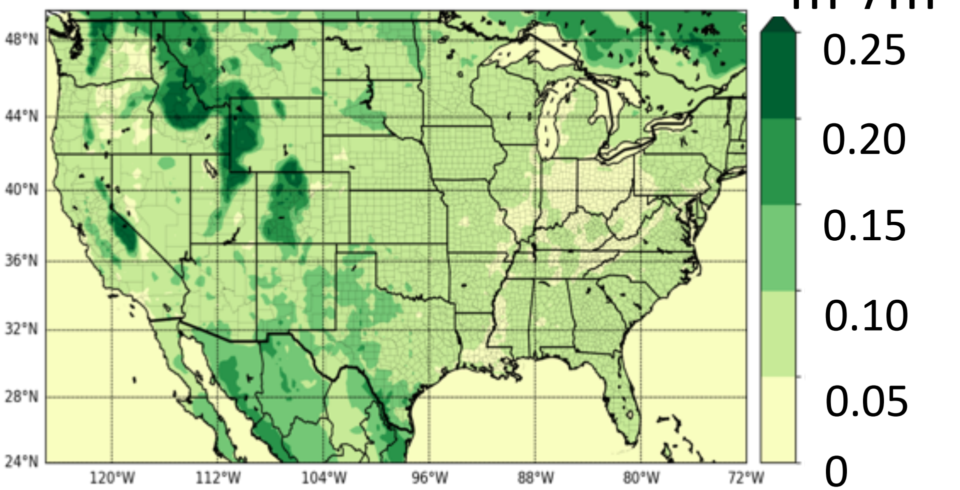
Cyclone/coupled LLJs will be situated within the warm conveyor belt sector of an approaching frontal system, positioned between a trough to the west and a ridge to the east (**Burrows et al., in-prep**)

SM Anomaly—LLJ interactions

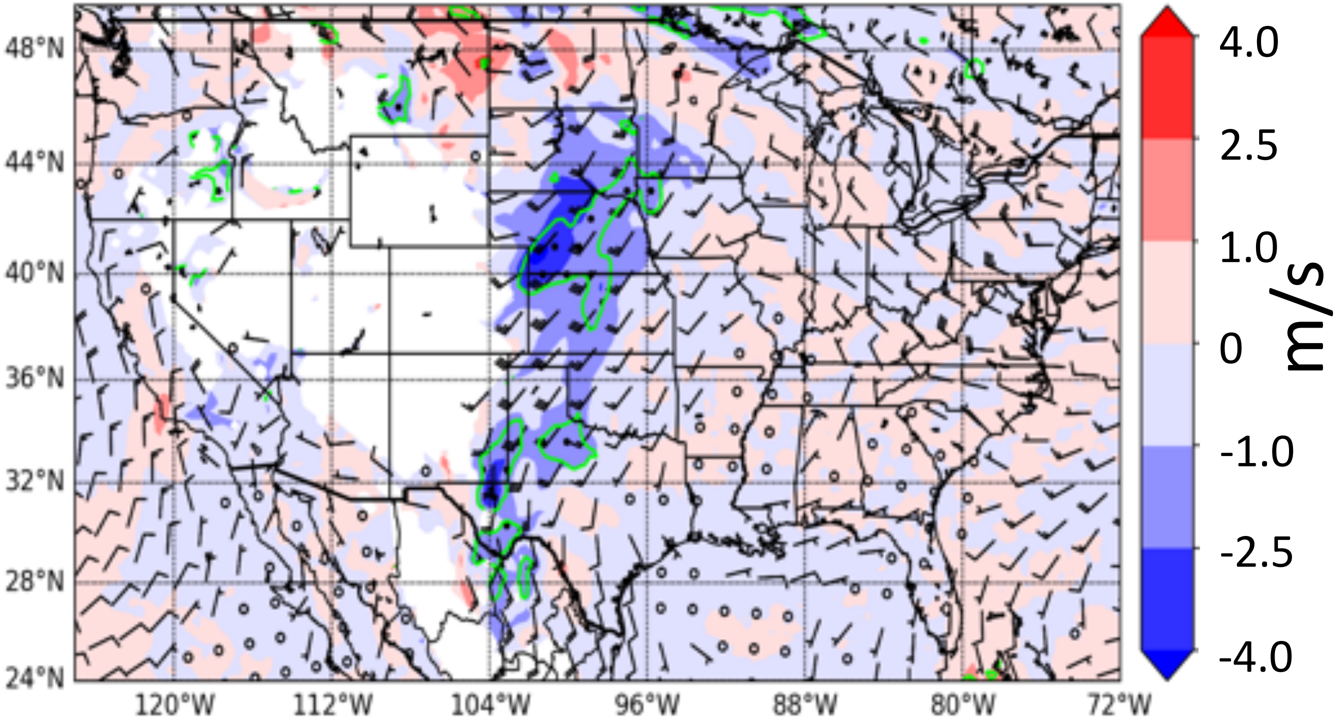
06z July 21, 2017
NARR 500 hPa Geopotential Height (m)



Soil Moisture Perturbation:
0-10cm p95-minus-p05



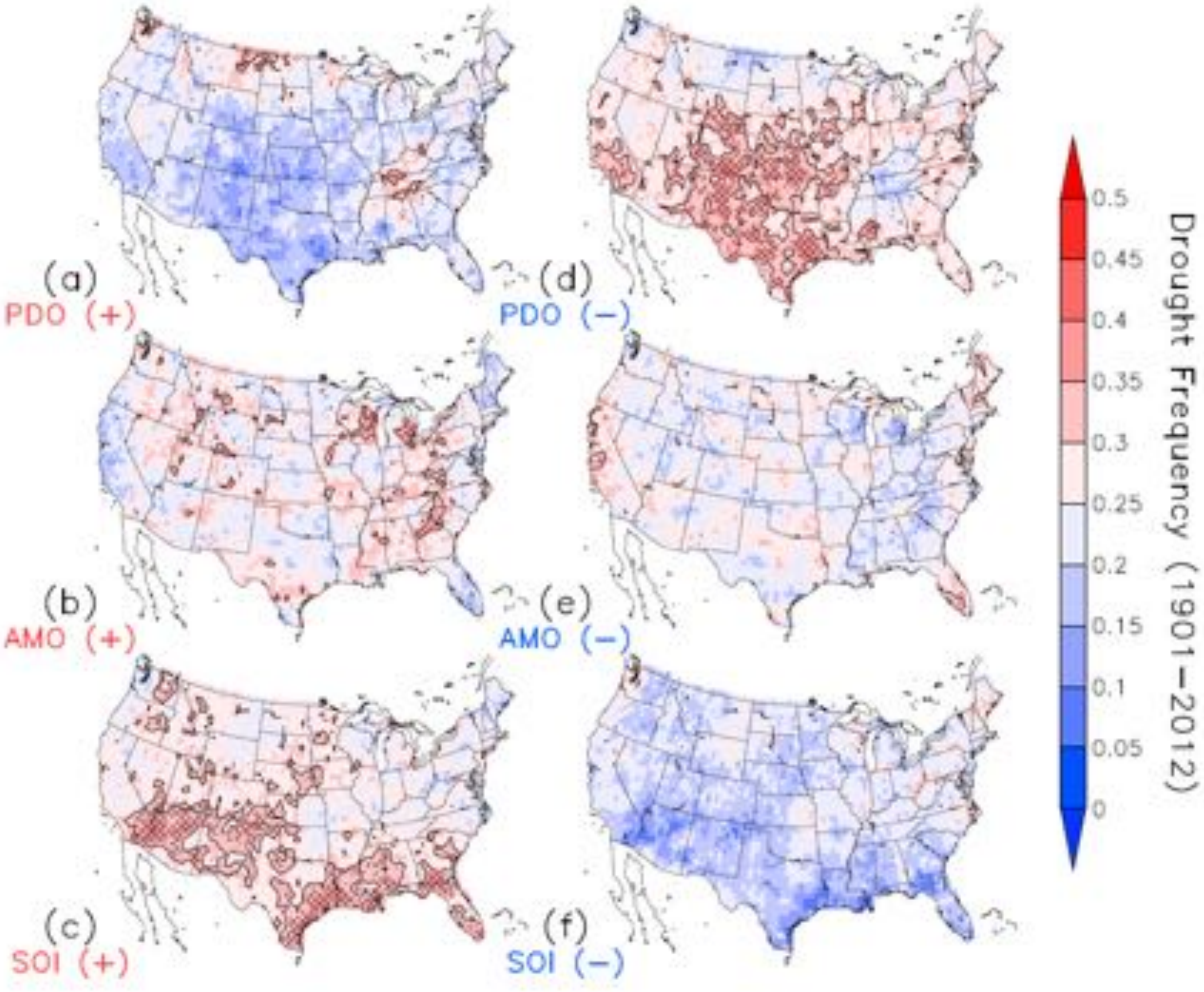
850 hPa Ensemble Mean Wind Difference @ 06 UTC
(p95-minus-p05)



850hPa windspeed impacts at tail and nose of jet are significant, as well as CAPE, CIN, and 0-1km wind shear (**Campbell et al., in-prep**)

Future Work: GPLLJ under low-frequency ocean-forced variability

Annual drought frequency map during each phase of ((a) + and (d) -) PDO, ((b) + and (e) -) AMO, and ((c) + and (f) -) ENSO. Contour lines and hatched areas represent the grid cells at PTV = 90% and 95%, respectively, from each conditional posterior distribution for drought frequency during 1901–2012.; cited from Figure 3, **Kam et al. (2014)**



Upcoming AGU Posters

Ferguson et al., **Monday 13:40-18:00, Hall A-C, H13H-1836:** Clarifying the role of soil moisture on low-level jet dynamics and the impact of SMAP data assimilation on forecast skill.

Mocko et al., **Thursday 13:40-18:00, Hall A-C, H43G-2526:** Improvements to drought estimation through assimilation of remotely-sensed vegetation data in the Noah-MP land-surface model.

Extra slides

What is GEWEX doing related to ILSTSS2S?

1. GLASS (Global Land-Atmosphere System Study)

- CMIP6-LS3MIP (Land Surface, Snow and Soil moisture MIP; van den Hurk; Seneviratne)
- Local Coupling (LoCo; Santanello)
- Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project (PLUMBER) (Best and Abramowitz)
- Diurnal land/atmosphere coupling experiment (DICE) (Lock and Best)
- LIAISE (land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment; Best and Boone)

2. GHP (GEWEX Hydroclimatology Panel)

- RHPs(Regional Hydroclimate Projects): US, TPE, Pannonian Basin, HYMEX
- CCs (Cross-cuts): Evapotranspiration, Water Management

3. GDAP (GEWEX Data and Assessments Panel)

- Landflux
- Soil moisture
- Irrigation?

4. CLIVAR/GEWEX Monsoons Panel

Considering minimum model output needs from ILSTSS2S

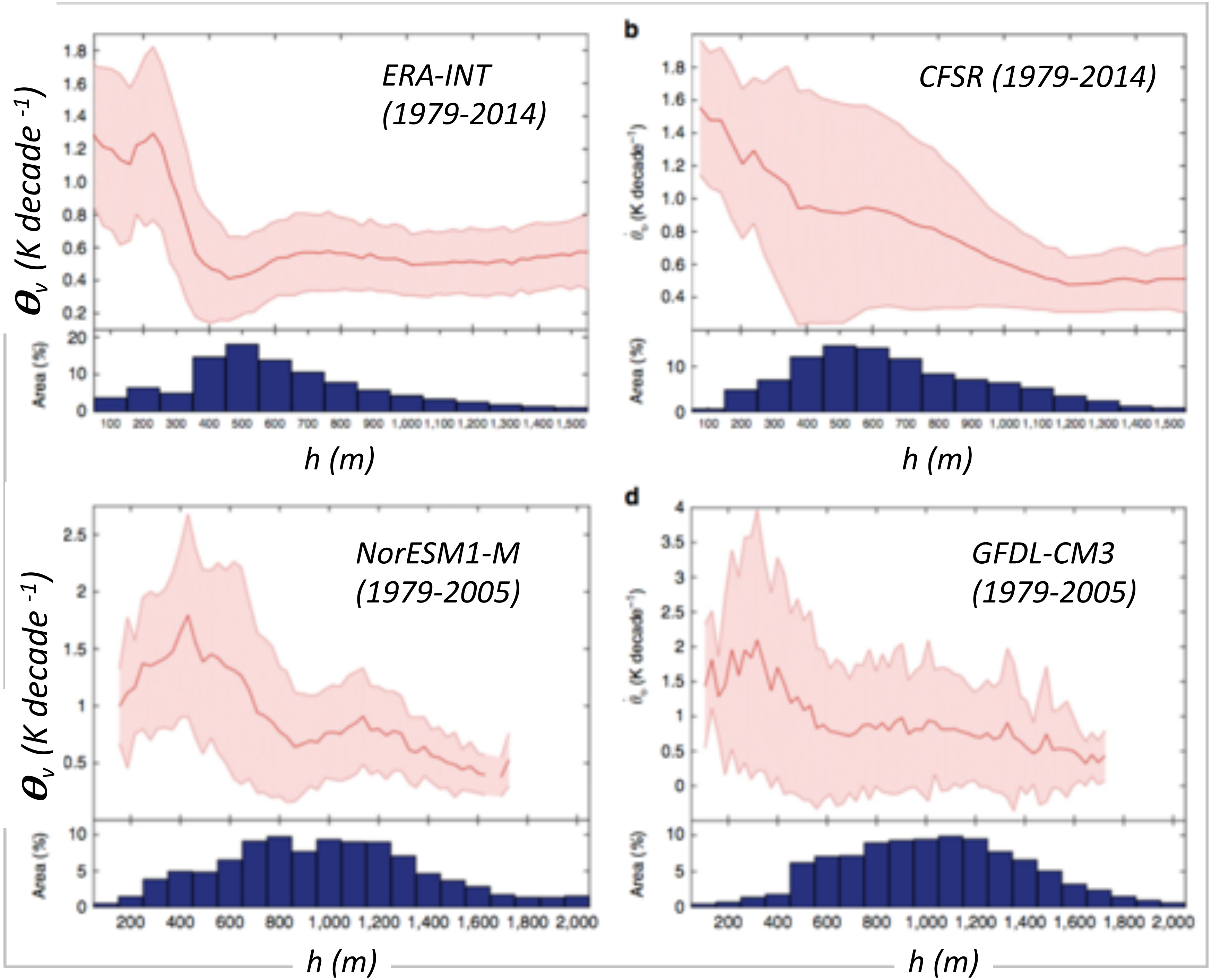
- sub-daily (1- or 3-hourly), 50km or finer: 3D Ta, q, u- and v-winds; PBLh, P, LH, SH, z500, SM
- weekly GVF, LAI
- static: landcover, soil texture, depth to GW
- multi-model!

e.g. , Danco and Martin (2017) found that only 3 CMIP models provided 3-hourly wind profiles to study the sensitivity of LLJs to ENSO.

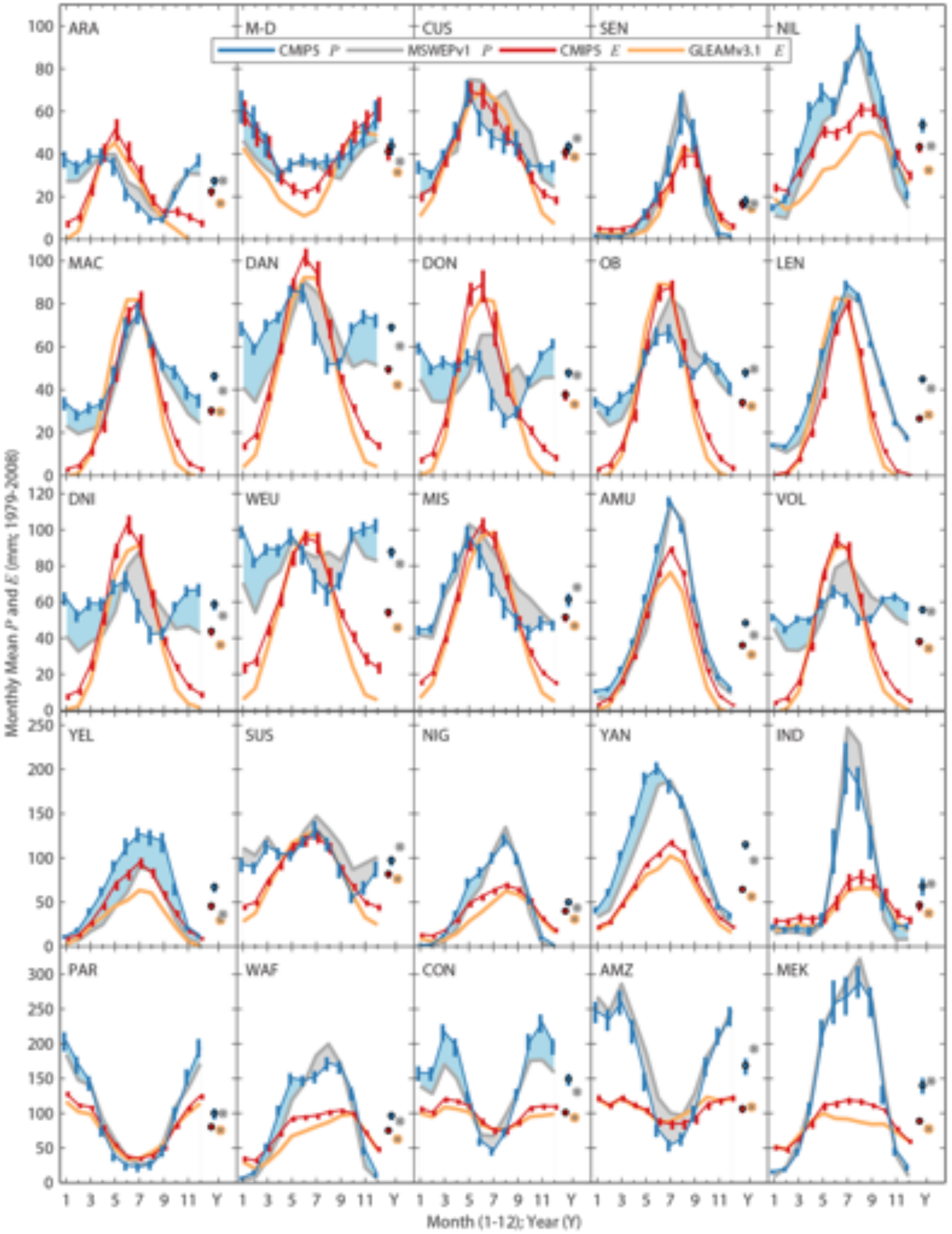
PBLh and model sensitivity

Projected warming rates vary by PBLh

(*Davy and Esau,* 2016)



CMIP-5 P and E biases exceed the multi-model spread



Regional CMIP5 AMIP 1979-2008 monthly (lines) and annual (filled circles) mean *P* and *E* relative to 1979-2008 MSWEPv1.0 *P* and 1980-2009 GLEAMv3.1 *E*. Vertical bars constitute the 95% bootstrap confidence intervals on the CMIP5 AMIP ensemble mean. Light blue and gray fill areas highlight months for which the CMIP5 AMIP ensemble mean is higher or lower than the observational counterpart, respectively. Twenty-nine models comprise both the CMIP5 AMIP *P* and *E* ensembles (see Table S1). (**Ferguson et al., 2018**)

LSM uncertainty and calibration

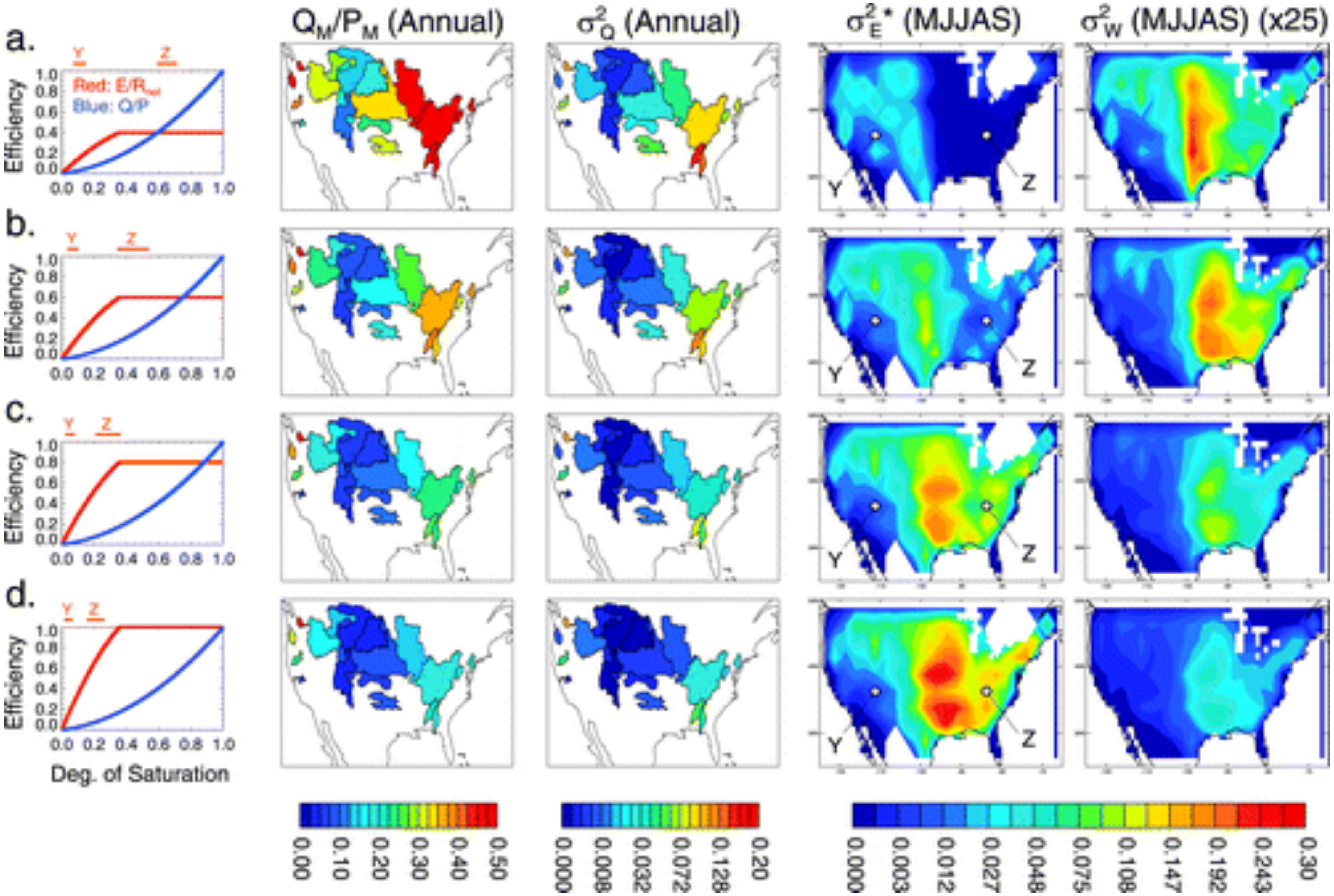


Fig. 4 Impact of the "height" of the λE/Rn relationship on hydrological means and variability from (Koster and Mahanama, 2012).