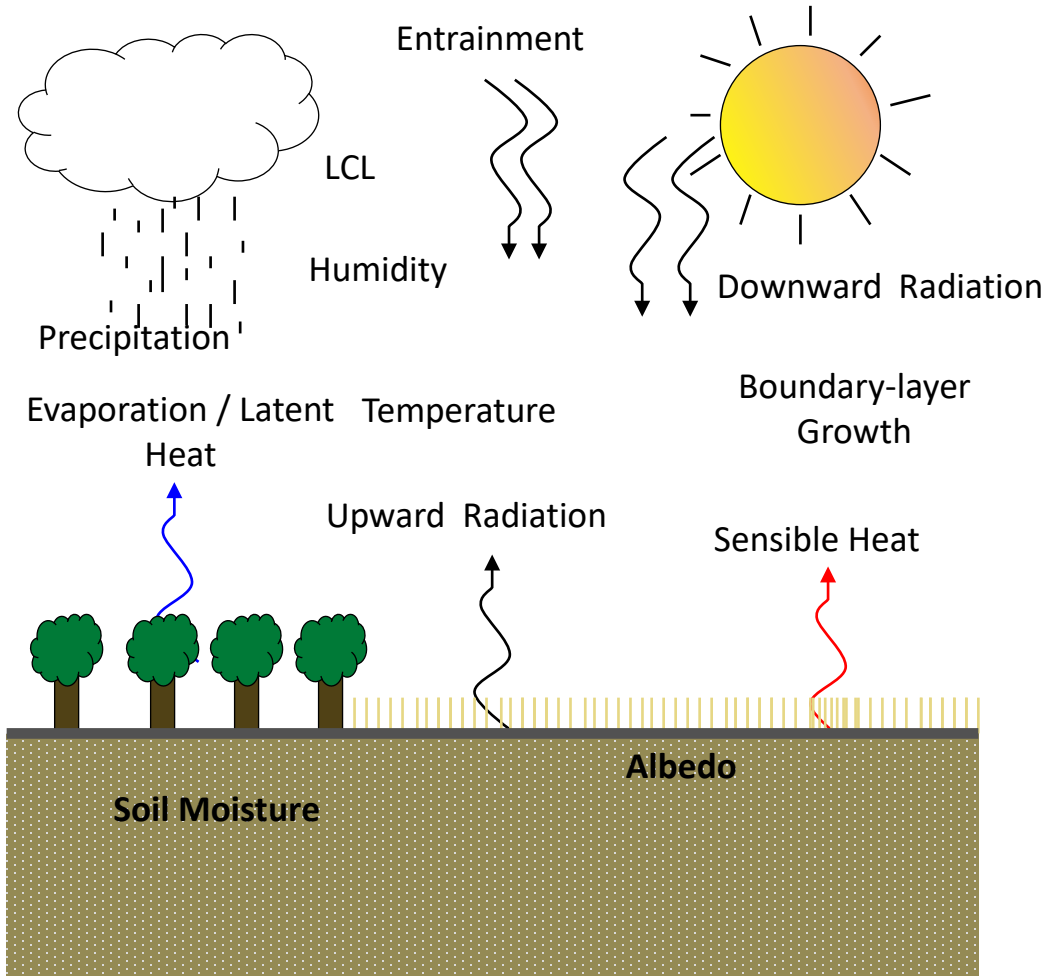
Soil Moisture Driven Land-Atmosphere Interactions and the Connection to Drought

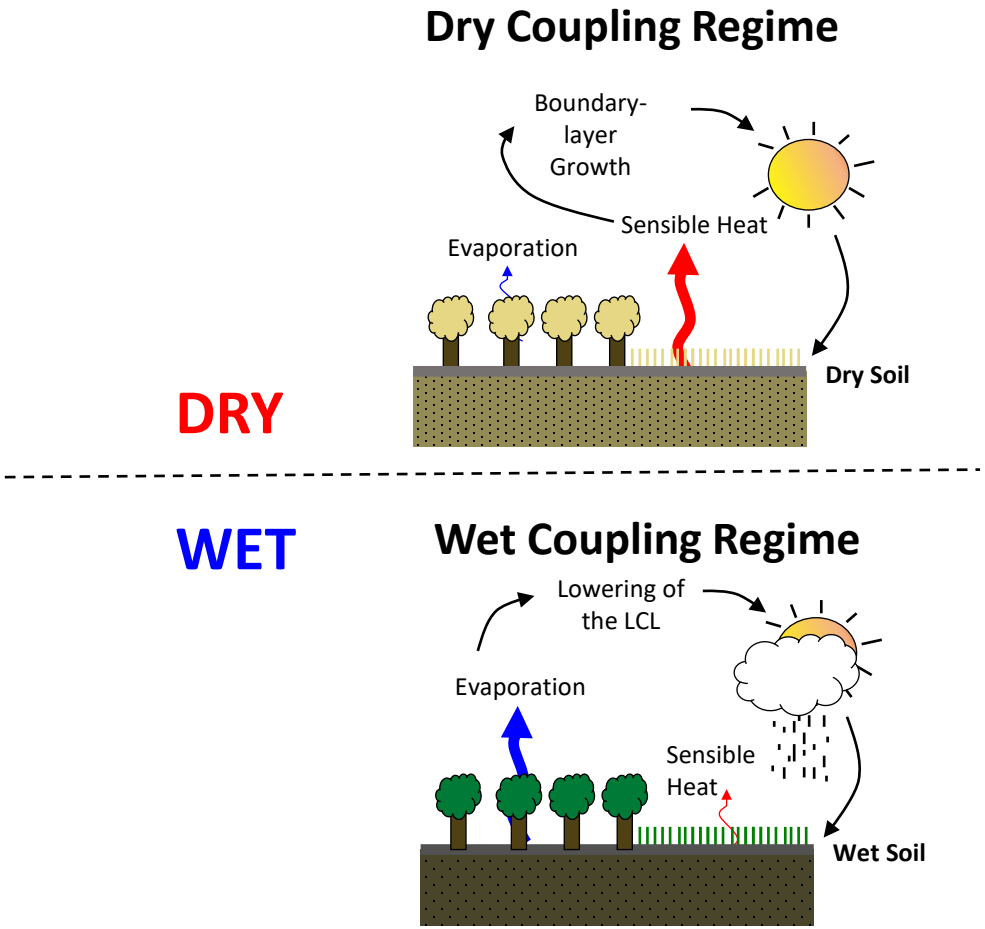
Joshua K. Roundy
Department of Civil, Environmental, and Architectural Engineering
University of Kansas

Monday October 14, 2024

Coordinated Cosmic-Ray Observation System Conference
Lincoln, Nebraska

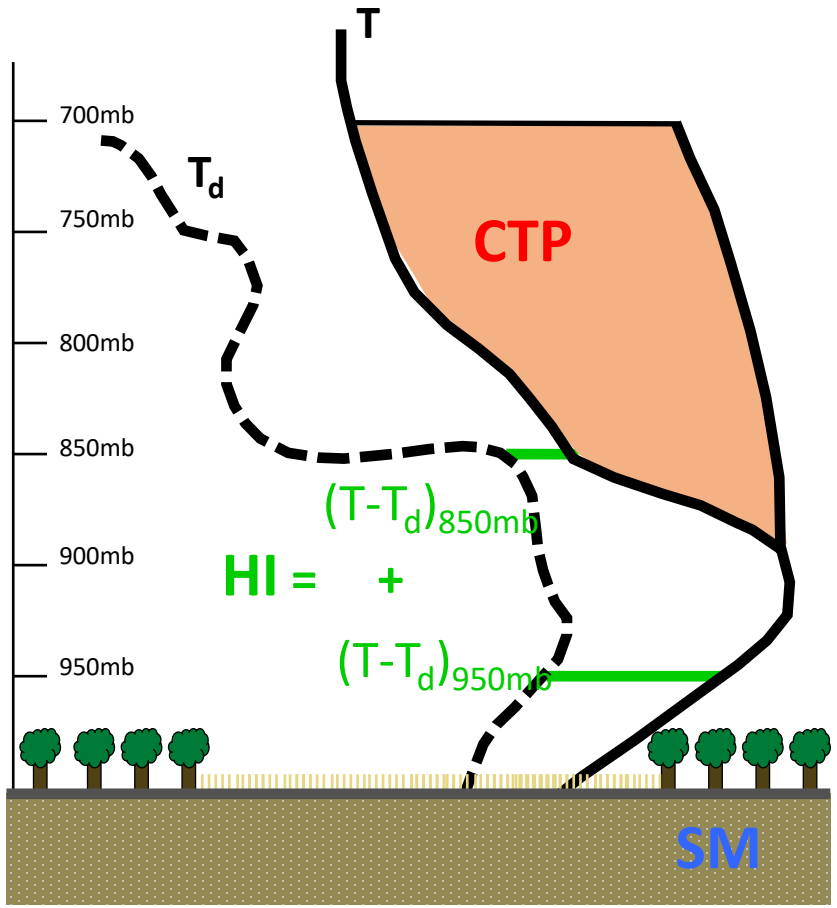
Land Atmosphere Interactions Impact on Extreme Events





While land-atmosphere coupling plays a role in these events, consistent large-scale forcing is also necessary

CTP-HI are used to classify these regimes

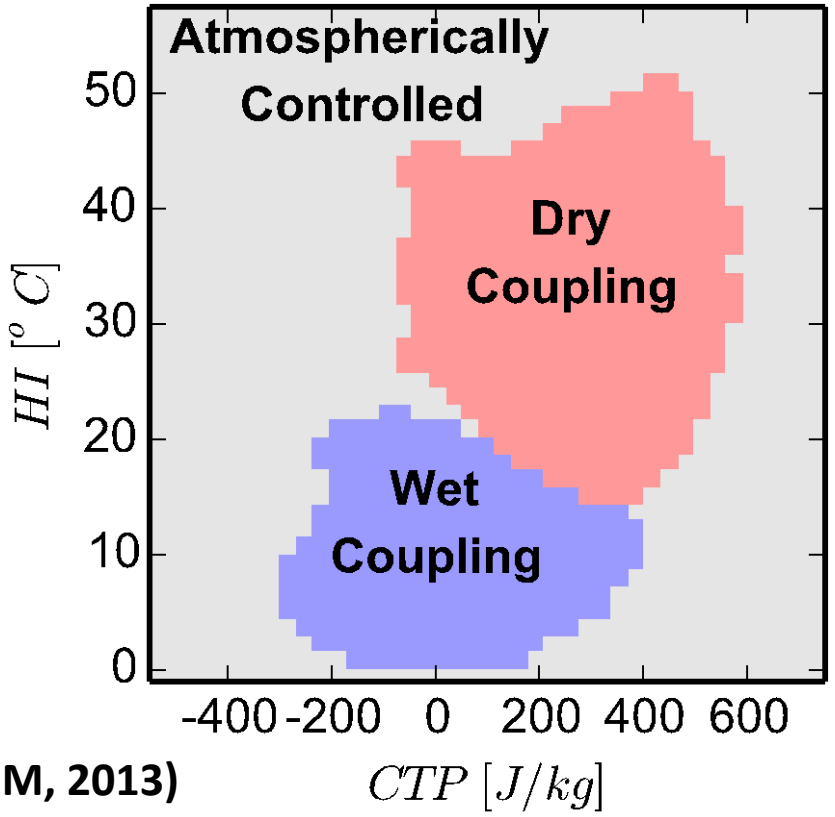


Based on the work of Findell and Eltahir (JHM, 2003).

Once the CTP-HI space is classified, only CTP-HI is needed for daily classification

Historic Sample

CTP-HI Space



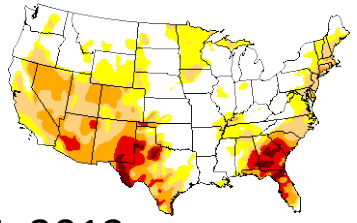
Roundy et al. (JHM, 2013)

$$CDI = \frac{Dry_{Coupling} - Wet_{Coupling}}{Total_{Days}}$$

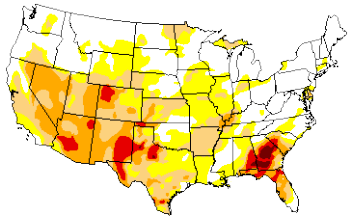
Current Remote Sensing capabilities Provide Insights for Large Scale Droughts

US Drought Monitor

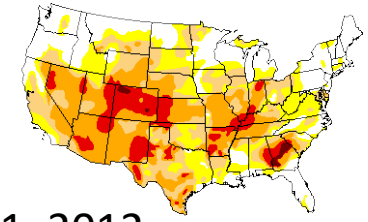
May 8, 2012



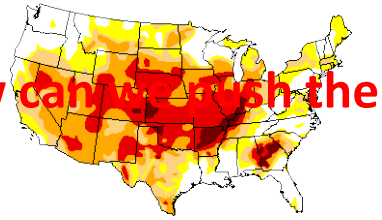
Jun 5, 2012



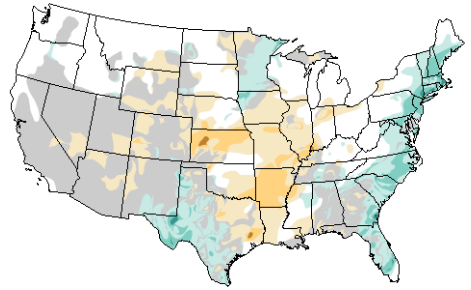
Jul 3, 2012

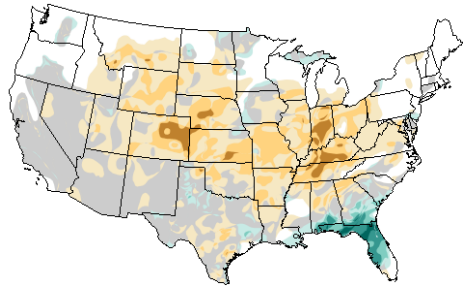


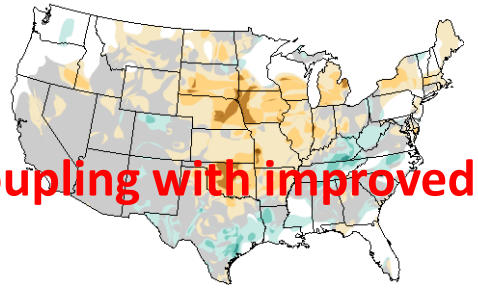
Jul 31, 2012



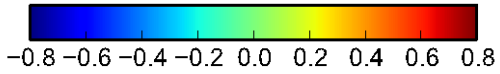
Class Change

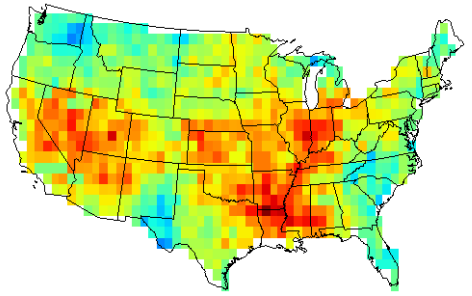


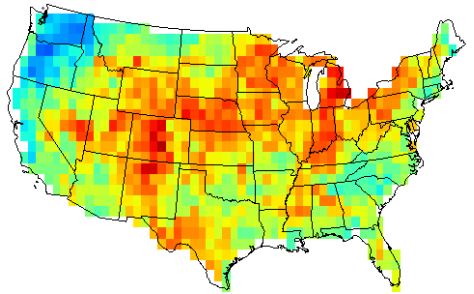


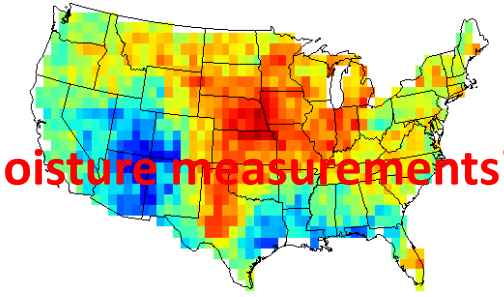


Remote Sensing Coupling Anomalies



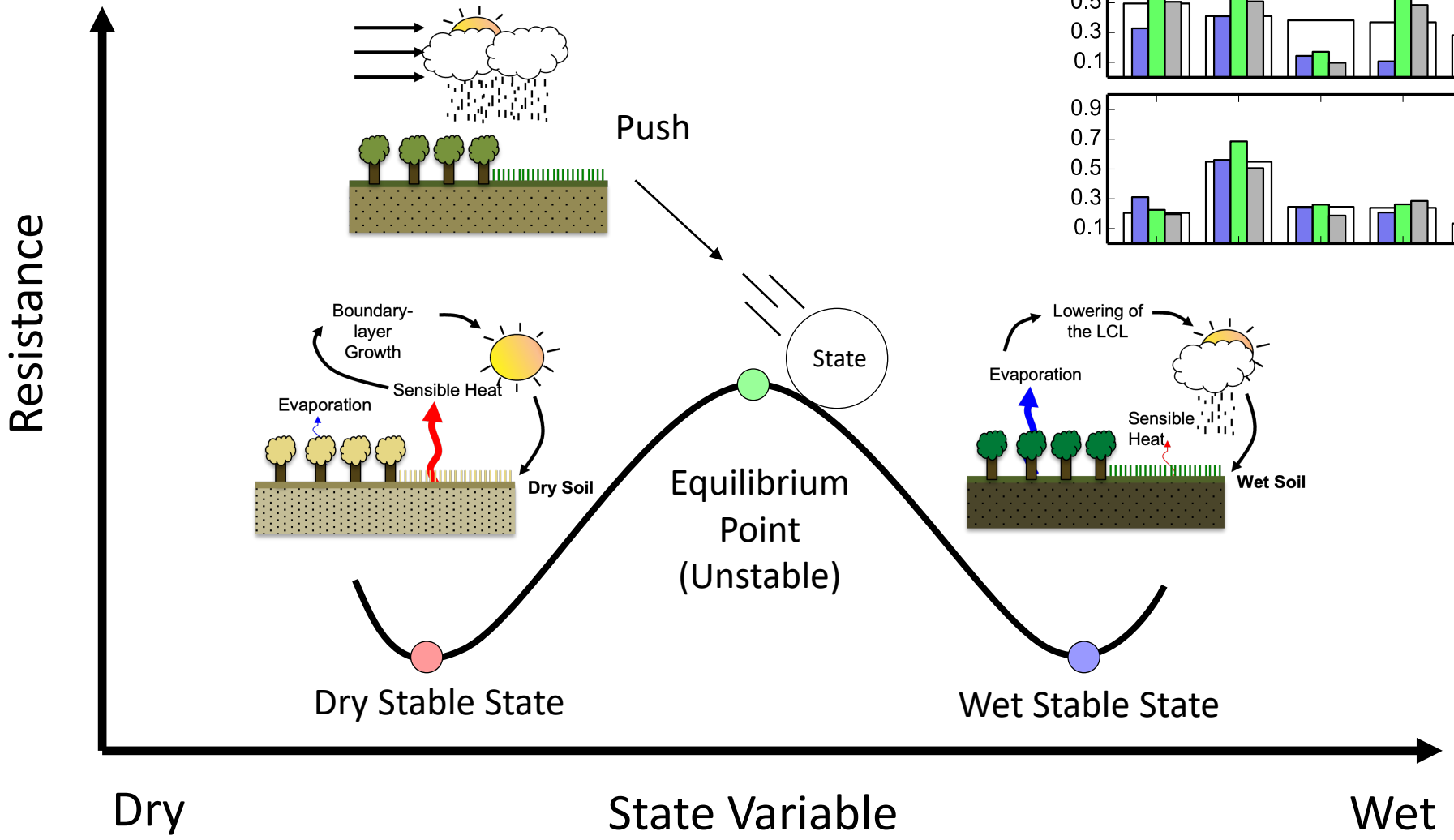


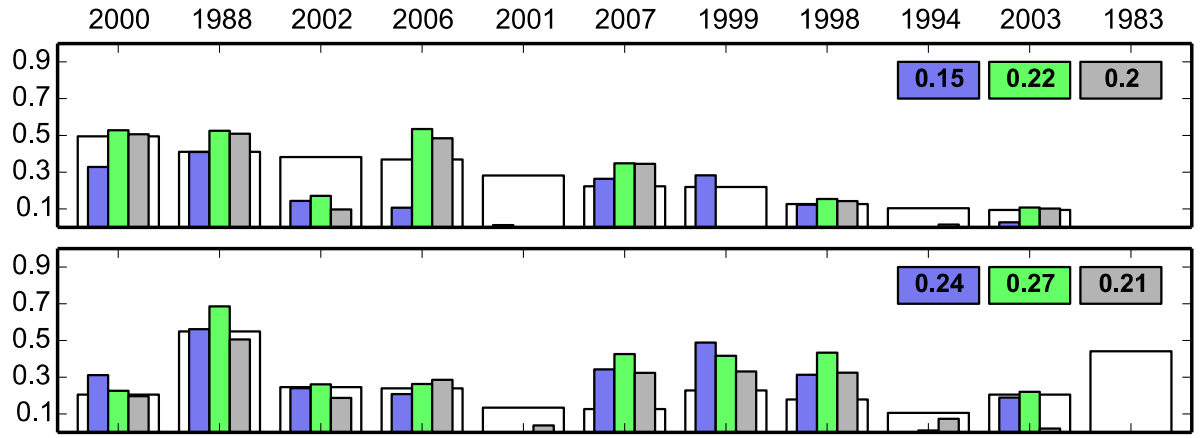




How can we push the science of L-A coupling with improved soil moisture measurements?

This Leads to Stable States which can provide a means for prediction





Roundy and Wood (JHM, 2014)

Observed Area of Drought

Stochastic Model

Hybrid Model

NCEP Climate Model

Soil Moisture is connected to the persistence of Drought

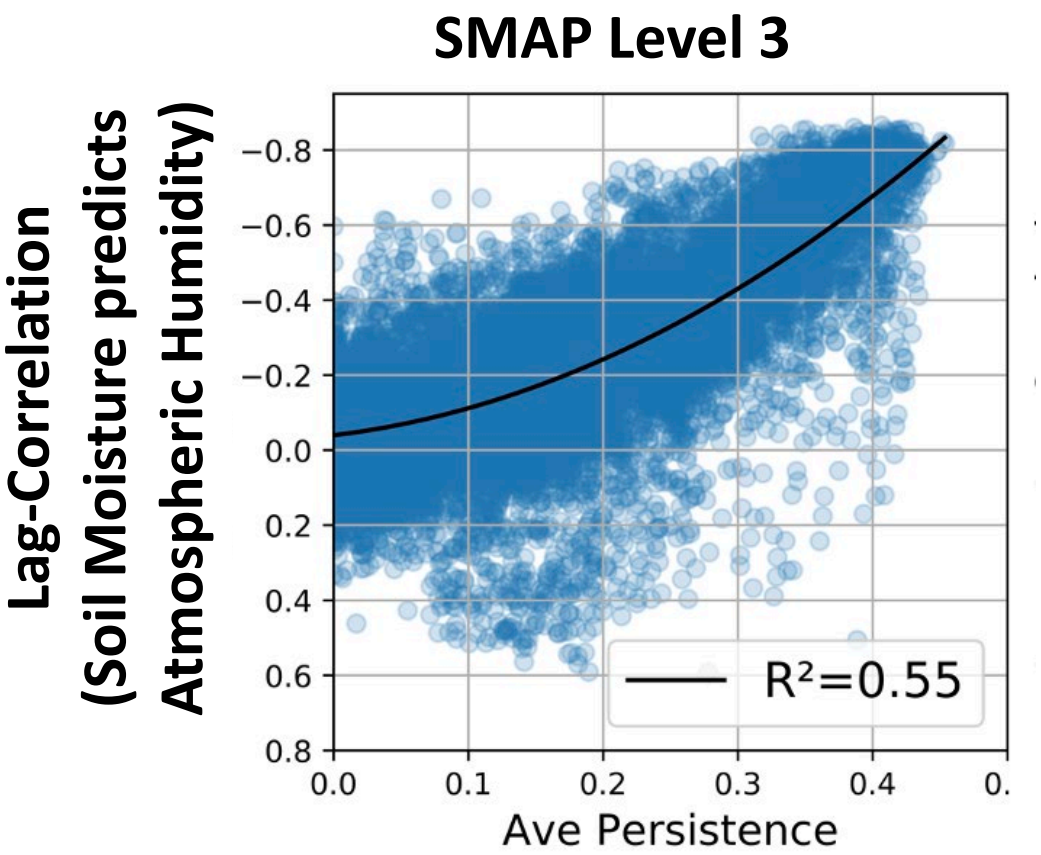
Status: a revised version of this preprint was accepted for the journal HESS and is expected to appear here in due course.

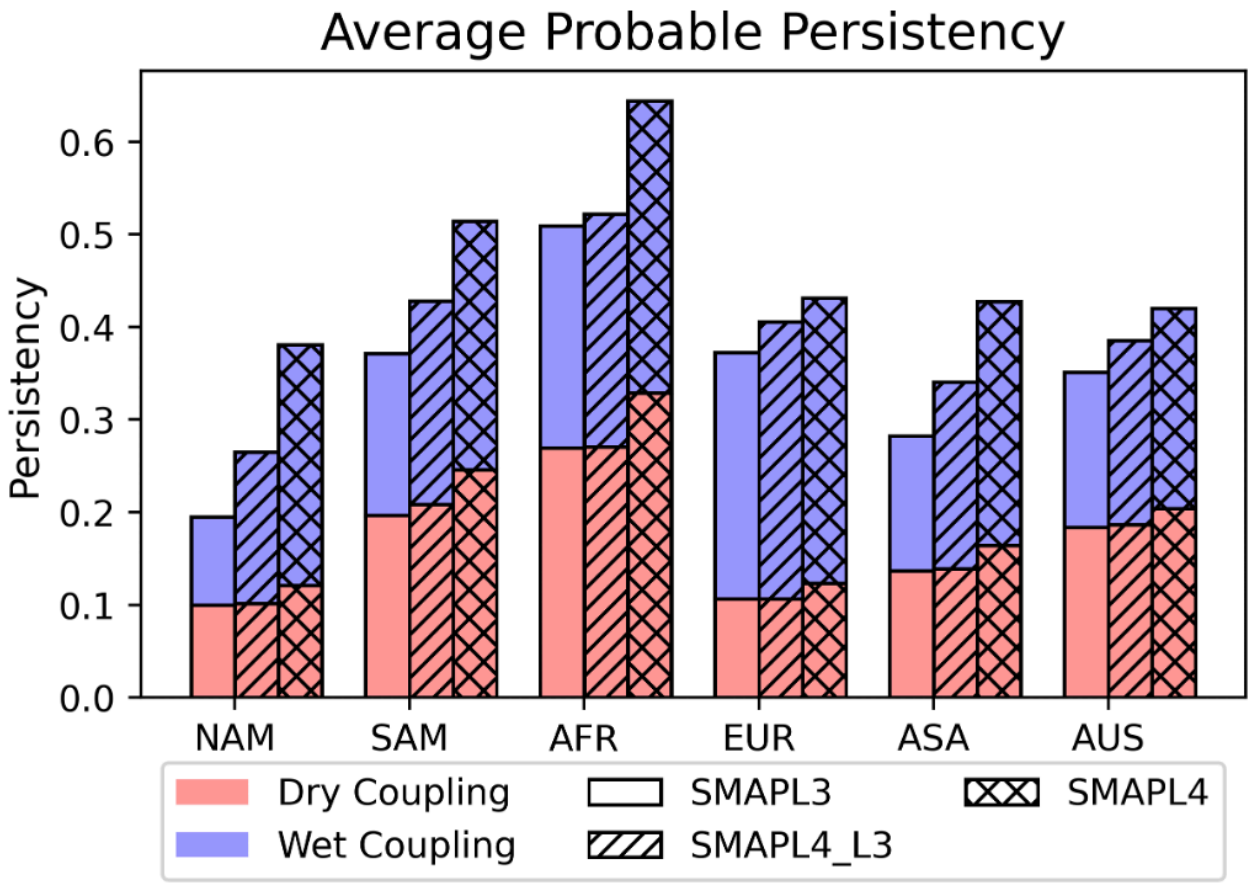
Deducing Land-Atmosphere Coupling Regimes from SMAP Soil Moisture

Payal Makhasana ✉, Joseph Santanello, Patricia Lawston-Parker, and Joshua Roundy

Status: closed

The level of persistency and therefore prediction varies by data set, location, and coupling regime.

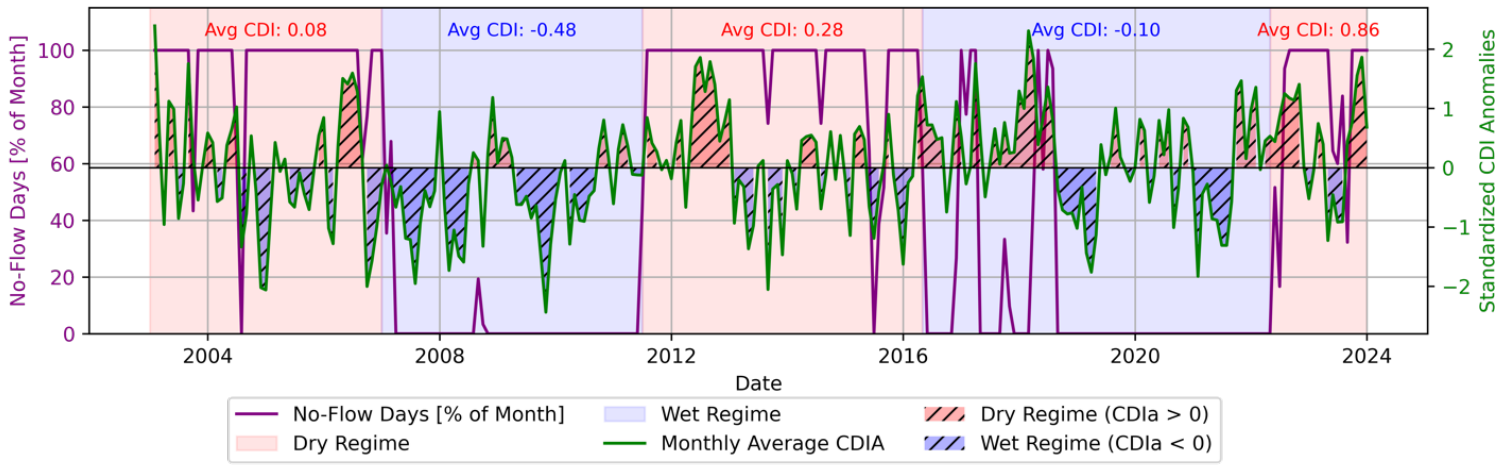


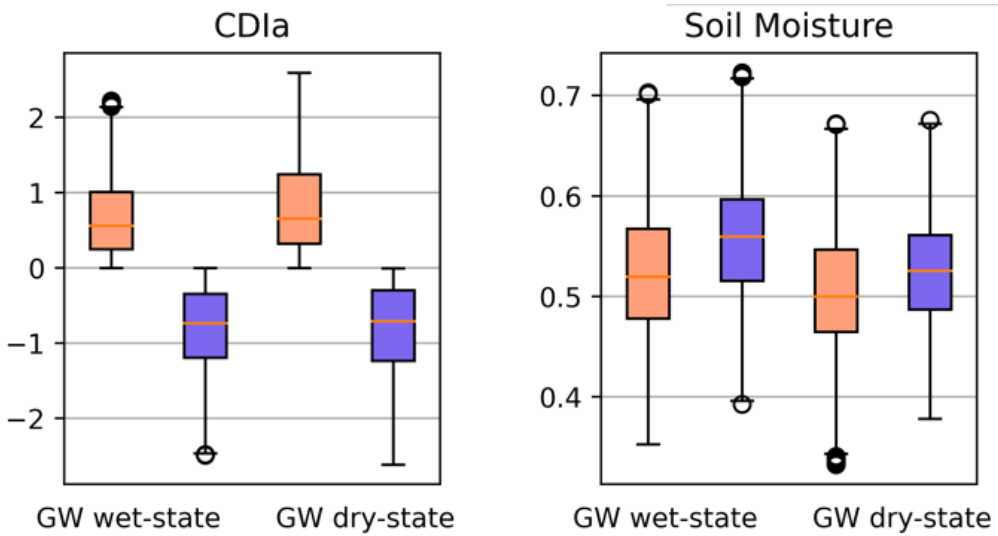


https://doi.org/10.5194/hess-2024-125

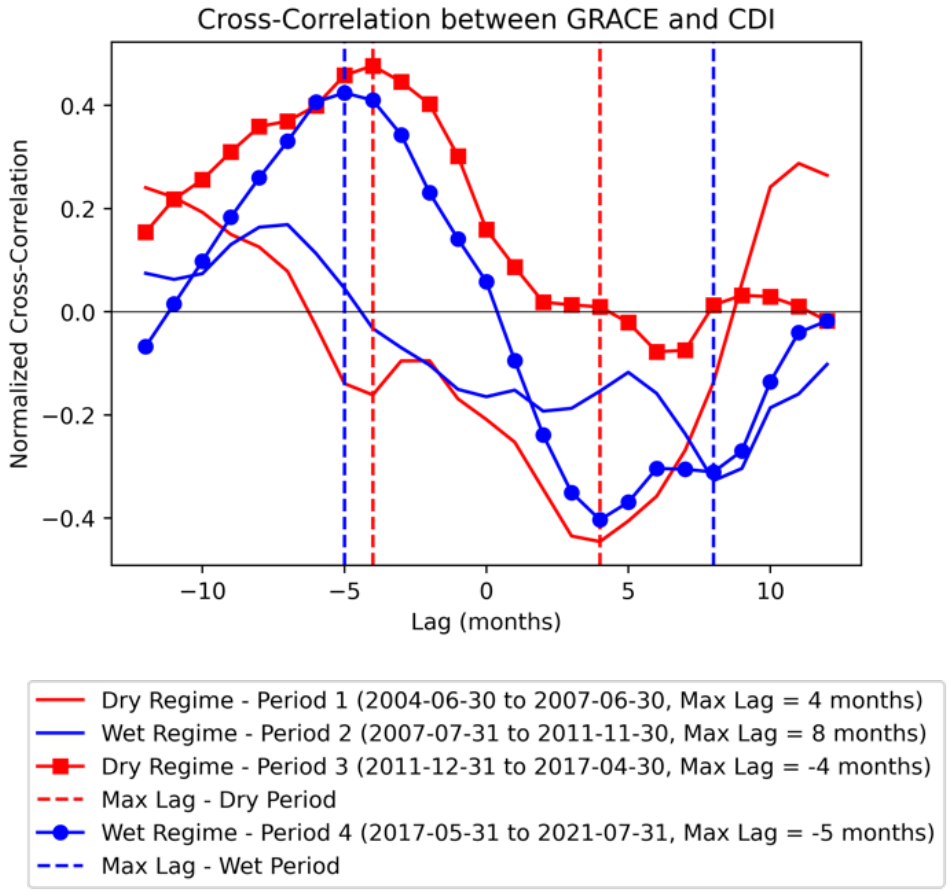
The Groundwater Stable States play a role in the L-A interactions

Western Kansas





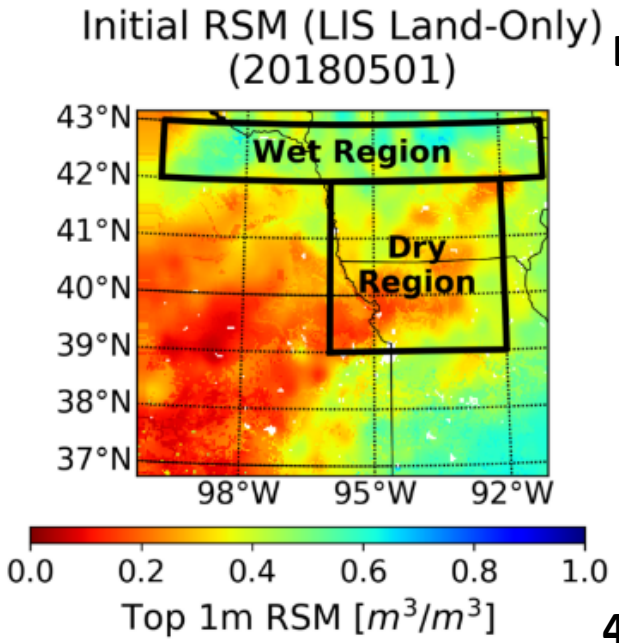
There was a shift in the relationship between CDI and GRACE between 2004-2007 (Dry) and 2007-2011 (Wet)



Makhasana et al. (In preparation)

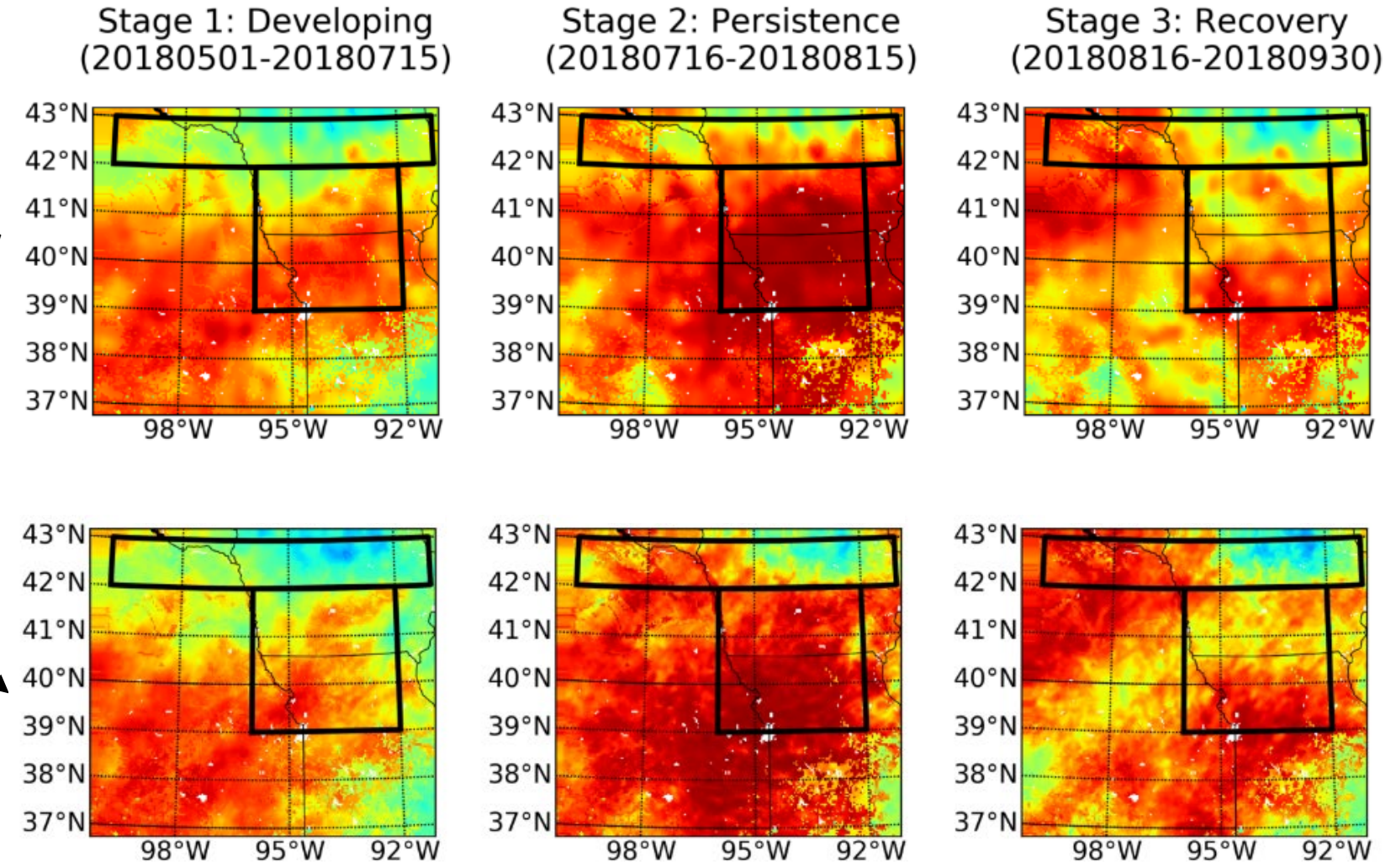
Spatial Heterogeneity of Soil Moisture During the Evolution of droughts

2018 Drought Kansas-Missouri-Nebraska, Iowa



LIS Land-Only NLDAS2

4km NU-WRF Coupled Run



Zhang et al. (in preparation)

Spatial Heterogeneity of Soil Moisture is Connected with Mesoscale Circulation

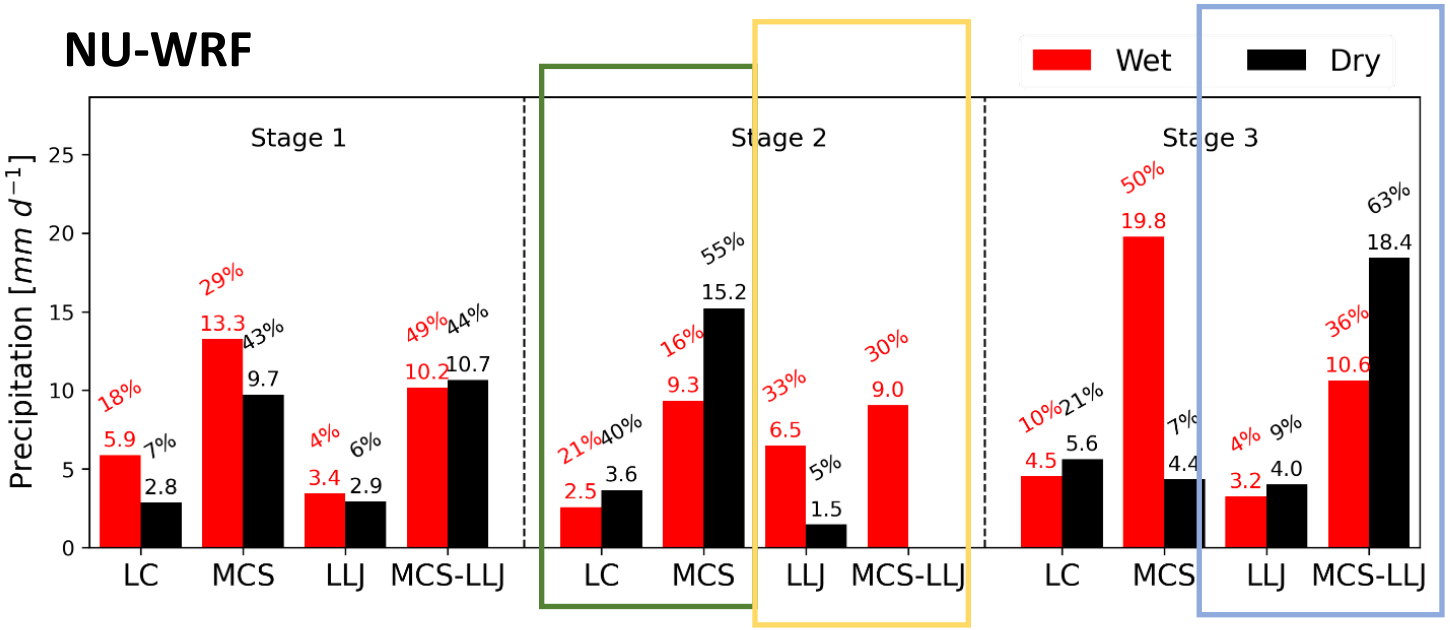
LC – Local Feedbacks

MCS – Mesoscale Convective System

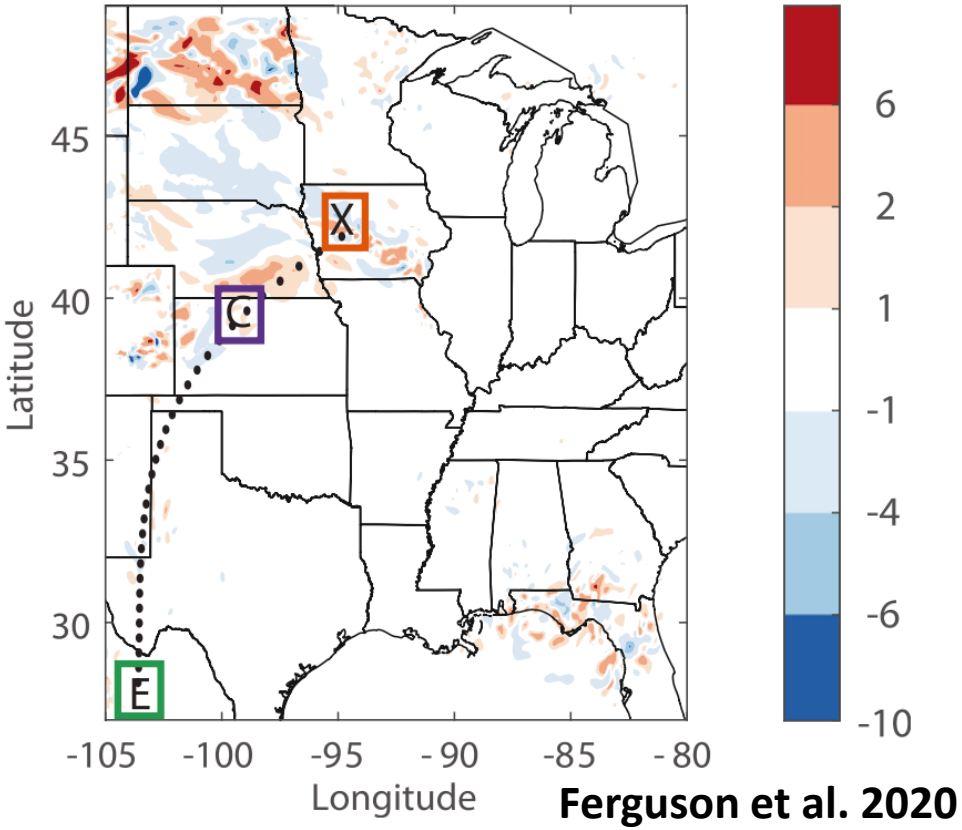
LLJ – Low Level Jet

MCS-LLJ – Both MCS and LLJ

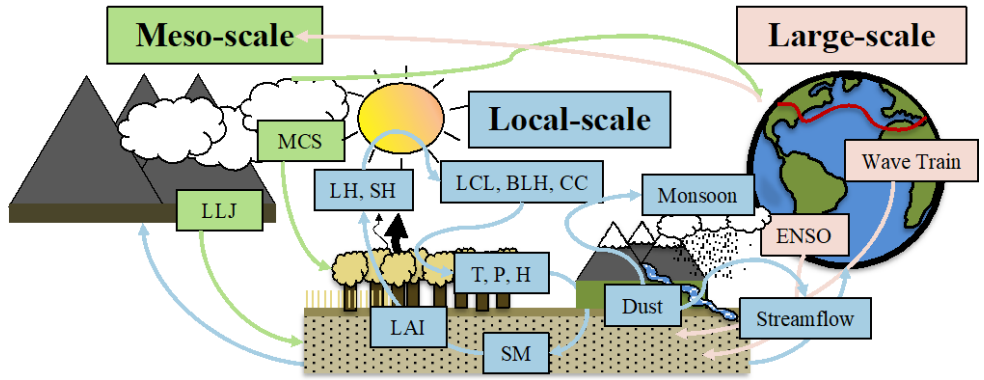
NU-WRF



Zhang et al. (in preparation)



Ferguson et al. 2020



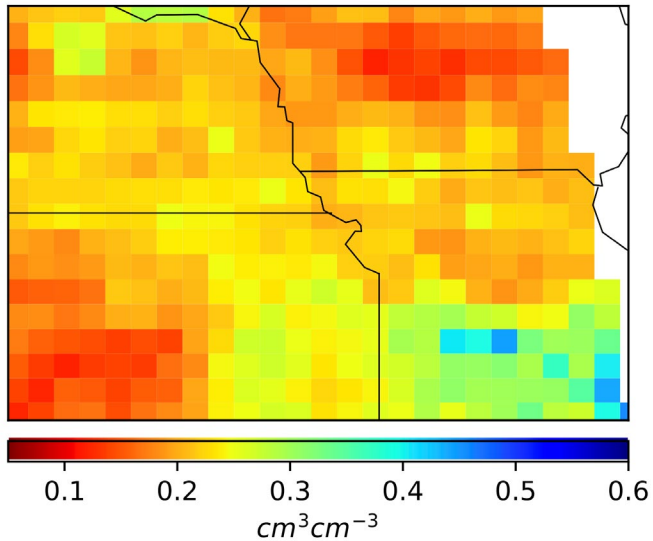
Hires Soil Moisture Measurements is Needed for Understanding Extreme Events

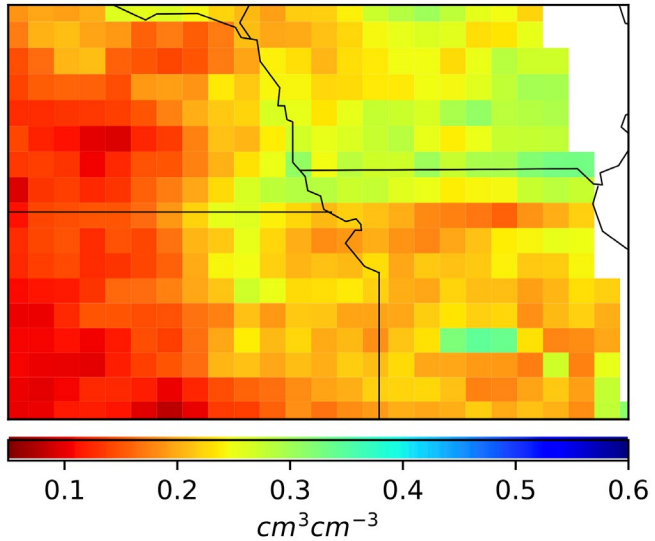
- Heterogeneity of Soil moisture is important for understanding the evolution of extreme events
- Heterogeneity is important to untangling the feedbacks between the local and mesoscale

SMAP Soil Moisture May 1, 2018

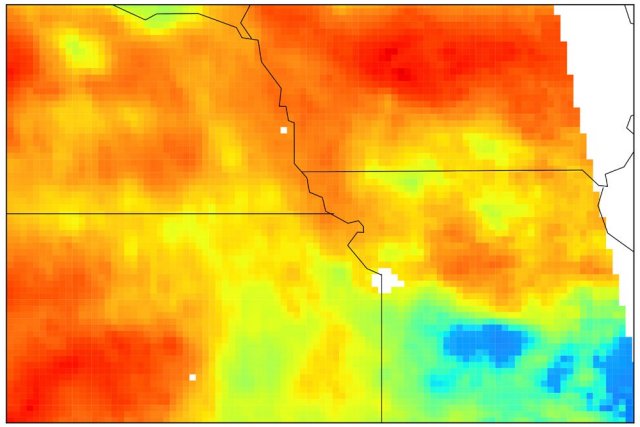
SMAP Soil Moisture Sep 30, 2018

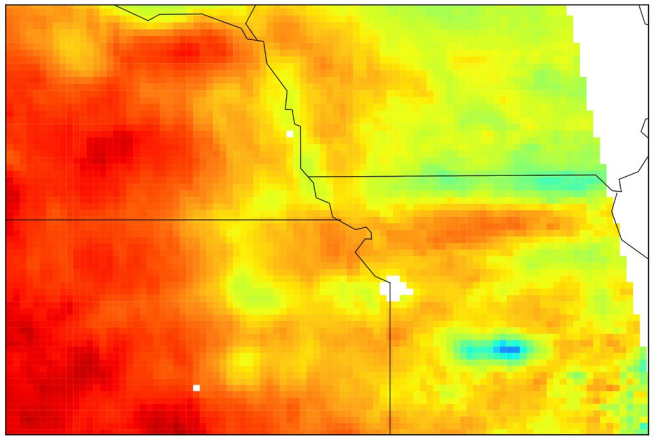
36 km





9 km





Hires Soil Moisture Measurements is Needed for Understanding Human Impacts

Lawston-Parker et al. 2023, HESS

- Even a small percentage of irrigation can cause large changes in soil moisture, fluxes, and PBLH
- Different irrigation maps create a different spatial signature of irrigation and downstream impacts
- The spread in evaporative fraction (EF) is different across irrigated runs even though the spatial averages are similar
- Some ‘tiles’ reach critical moisture and PBL thresholds that allow for PBL feedbacks that are not well represented by the ‘gridcell' average value

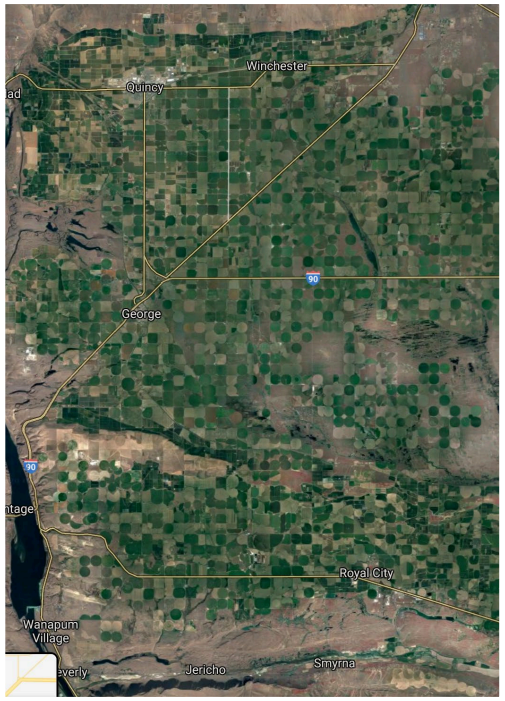
Example for Central Washington

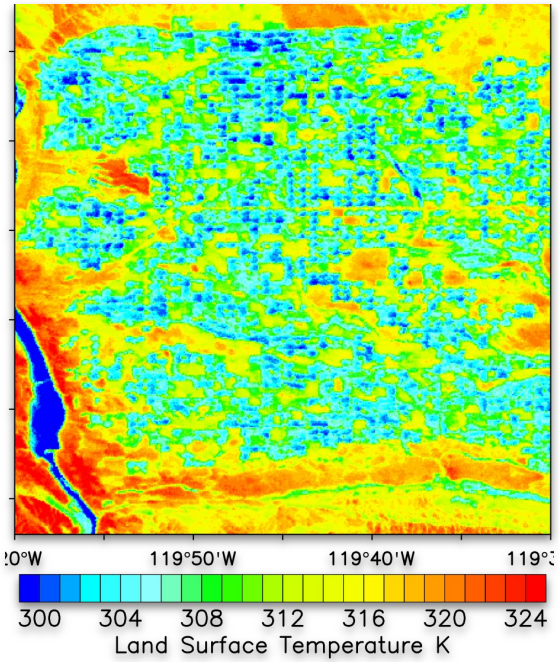
ECOSTRESS LST

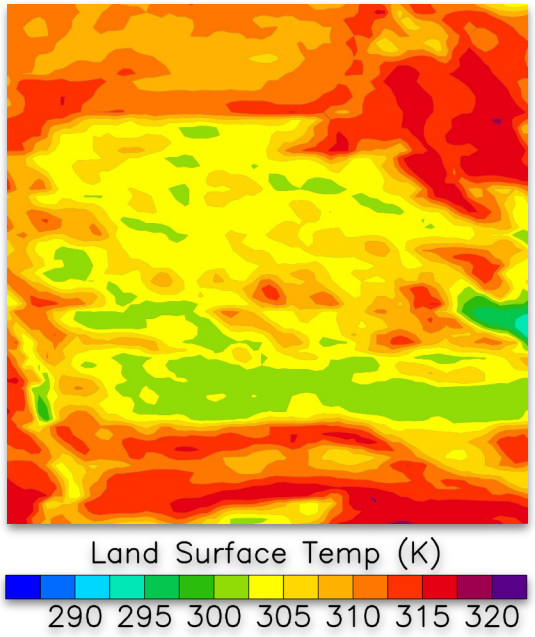
MODIS LST

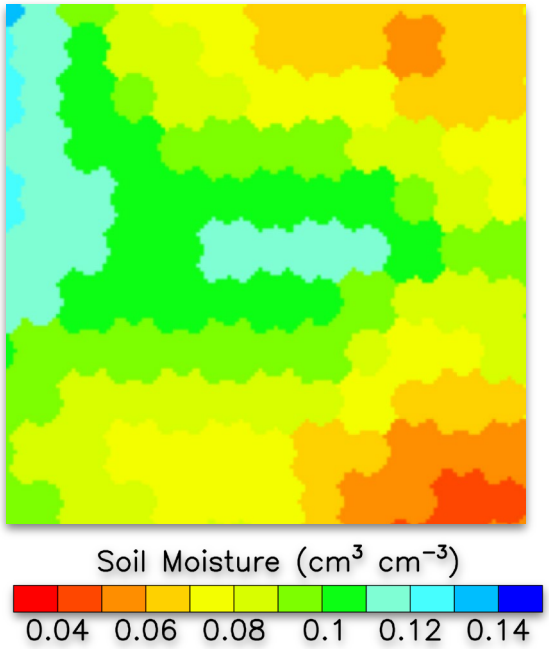
SMAP SM

~ 50 km









~ 40 km

70 m

1 km

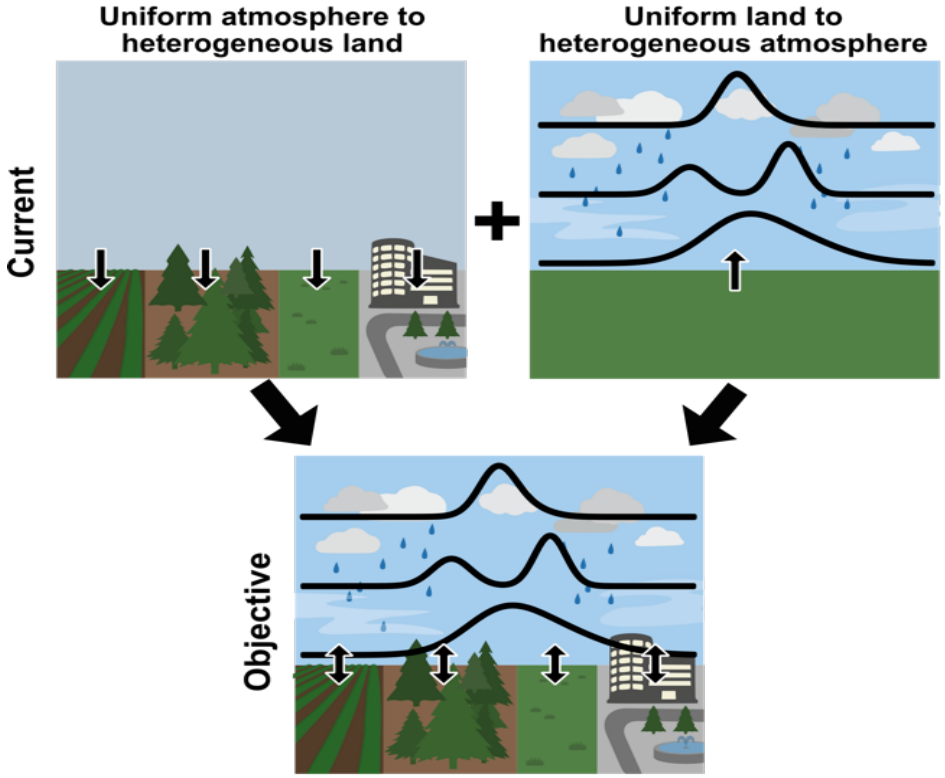
9 km

Hires Soil Moisture Measurements is Needed for Forecast Models

Physical Models

Getting these feedbacks correct in physical models is important for future forecasts

- We need hires observations of soil moisture to scrutinize physically based models

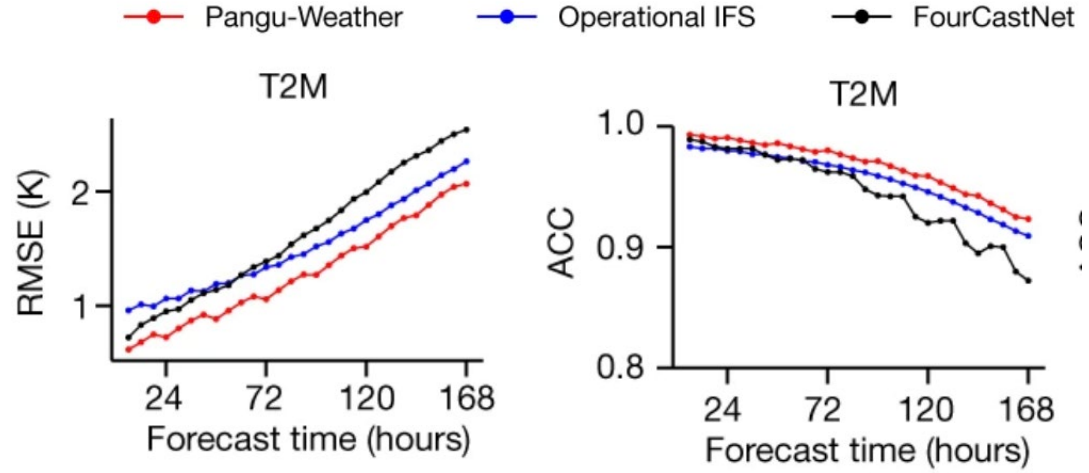


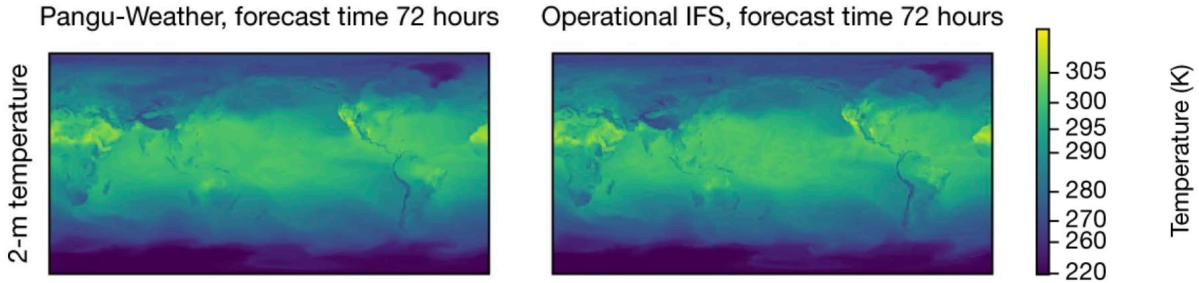
NOAA CPT: Coupling of Land and Atmosphere Subgrid Parameterizations (CLASP), Lead PI: Nate Chaney

ML/AI Models

The future of extreme event forecasting lies in ML/AI

- We need hires observations of soil moisture to train and run ML/AI models.





Bi et al. 2023, Nature

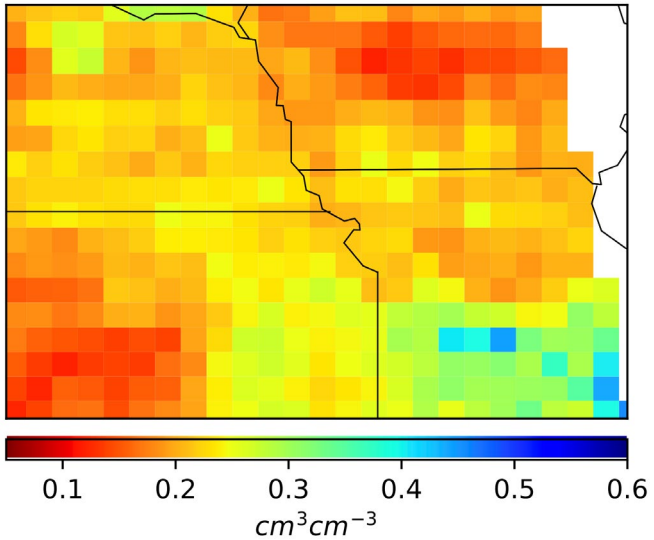
Summary and Conclusions

Higher resolution soil moisture measurements will push the science of L-A coupling for:

- **Extreme Event Evolution**
- **Human Impacts**
- **Forecast Models**

This is due to the heterogeneity of soil moisture and land-atmosphere feedbacks that occur at different scales (local, meso)

36 km



9 km