Assessing Soil Moisture-Precipitation Interactions using L-Band Remote Sensing

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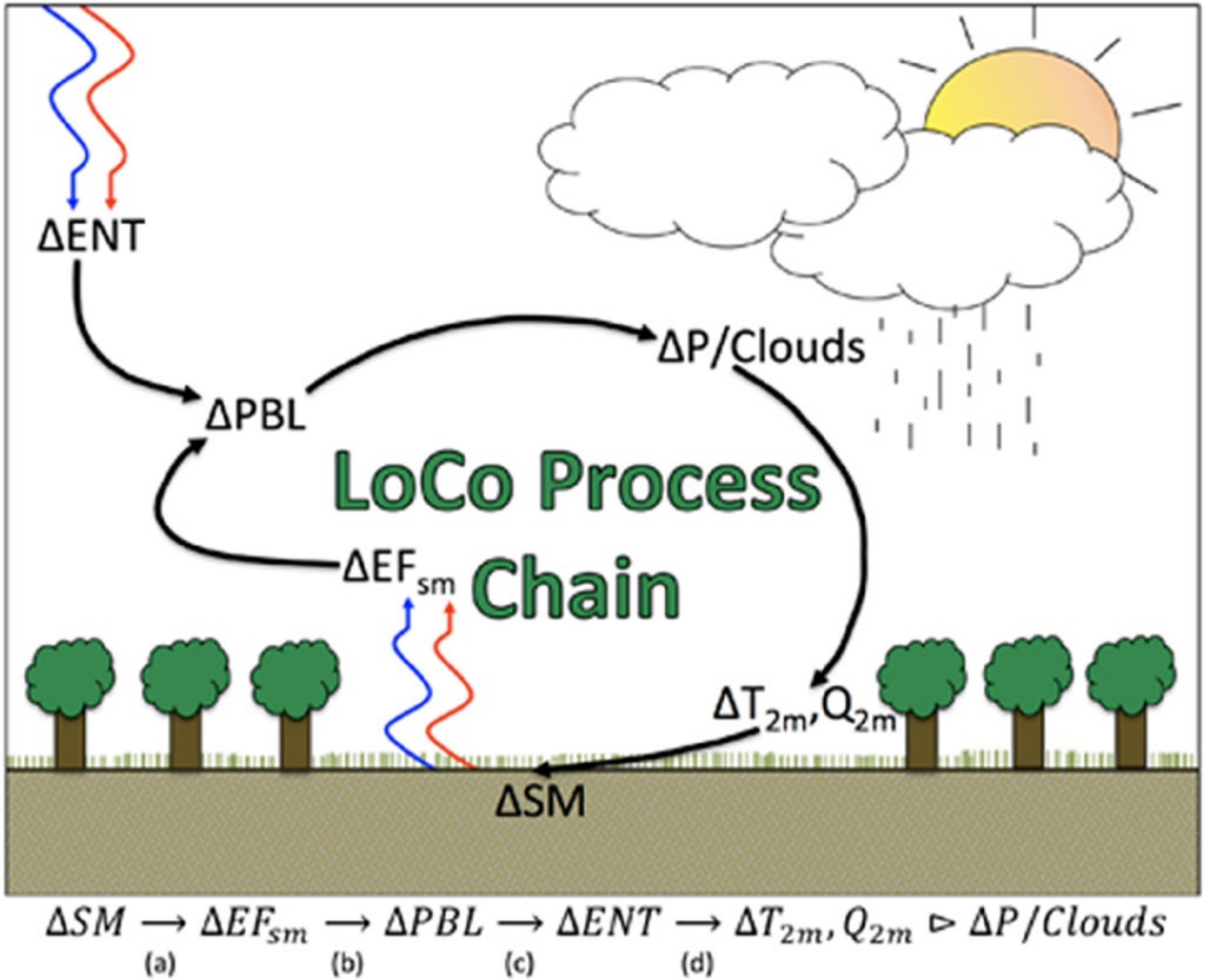
USDA Climate Hubs U.S. DEPARTMENT OF AGRICULTURE

THE OHIO STATE UNIVERSITY

ILLINOIS Illinois State Water Survey PRAIRIE RESEARCH INSTITUTE

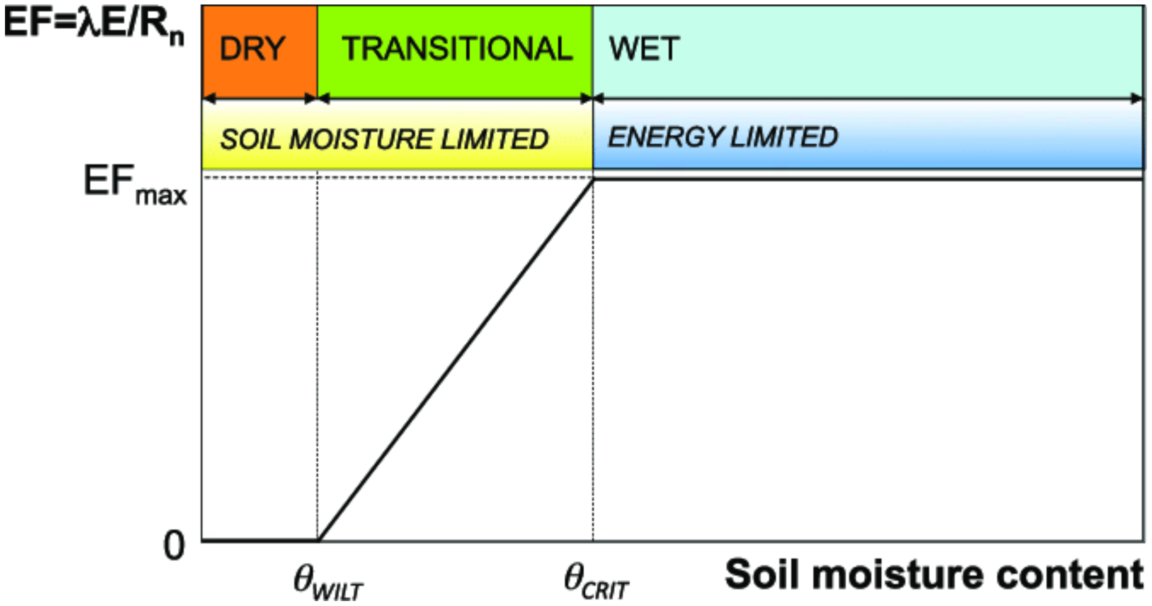
Soil Moisture – Precipitation Coupling



Santanello et al. (2018)

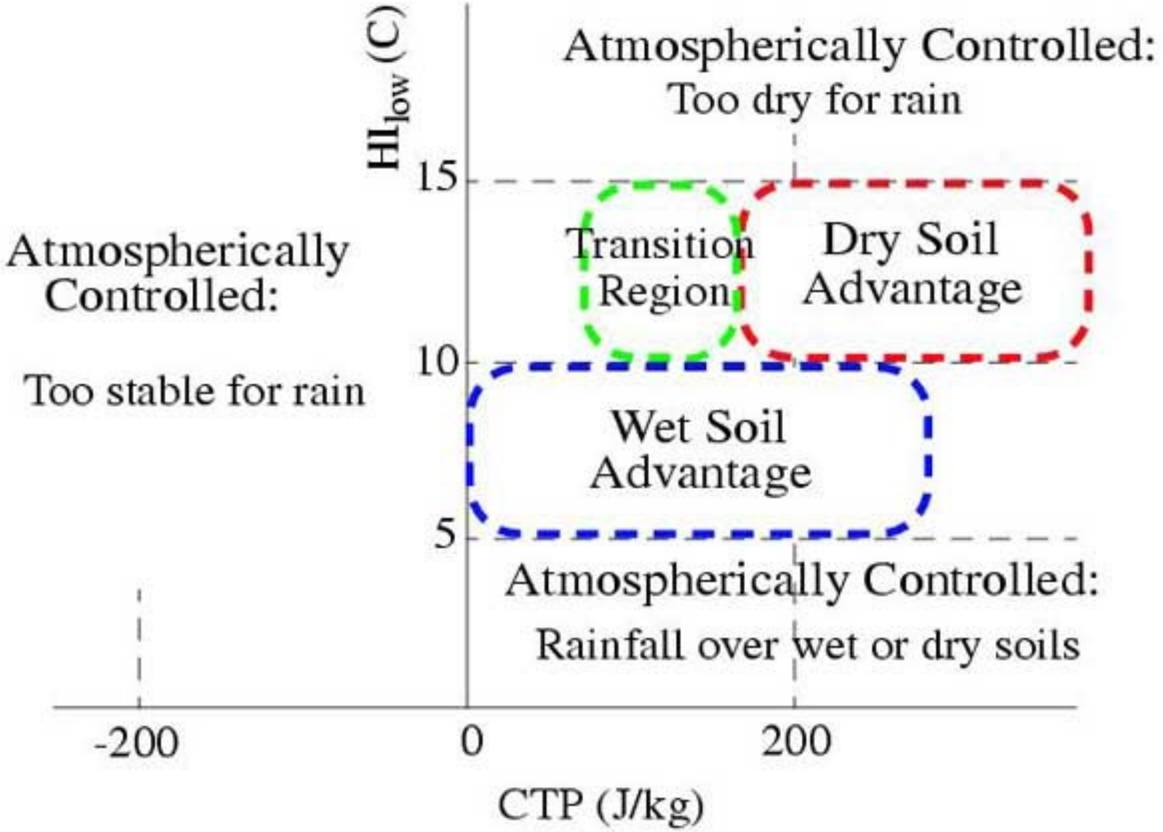
Regimes of Soil Moisture – Precipitation Coupling

Regimes of surface heat flux partitioning by soil moisture



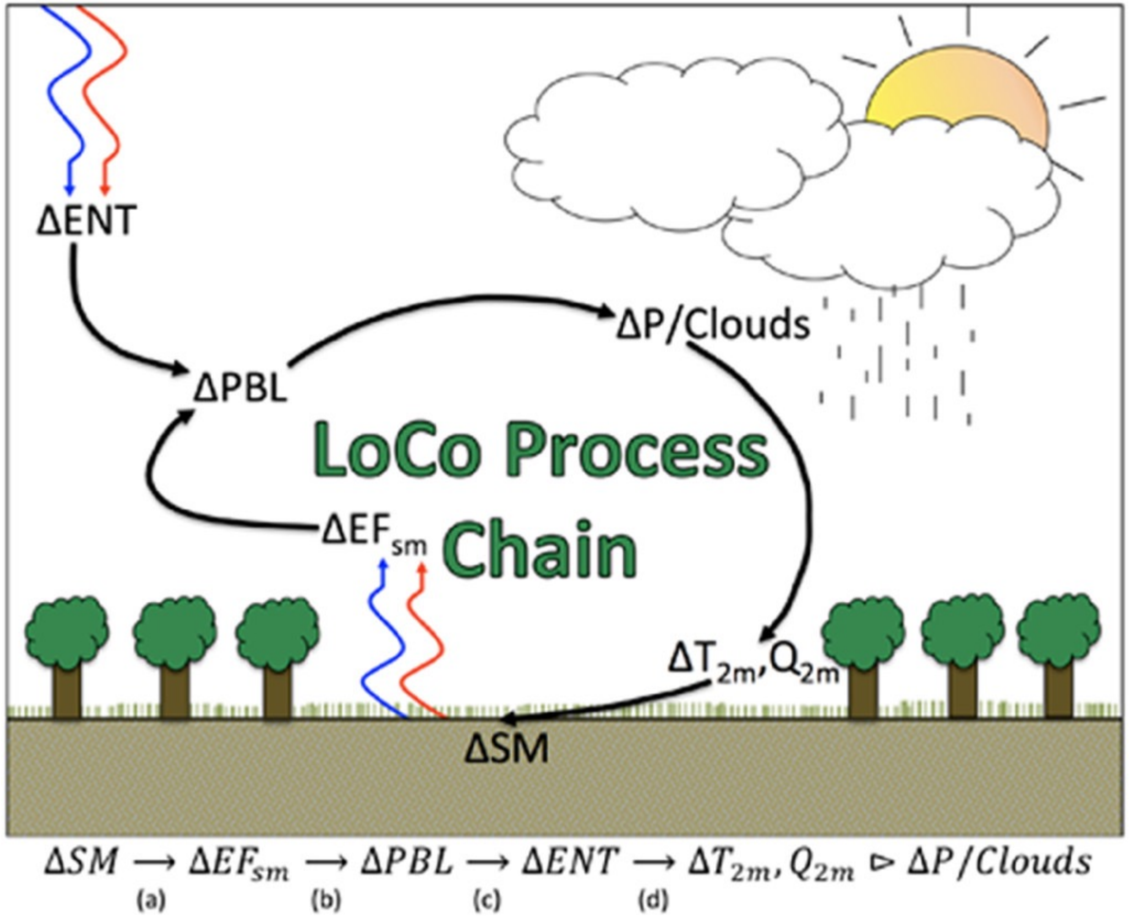
Seneviratne *et al.* (2010)

Regimes of boundary layer "conditioning" to surface-induced convection



Findell *et al.* (2004)

Soil Moisture – Precipitation Coupling

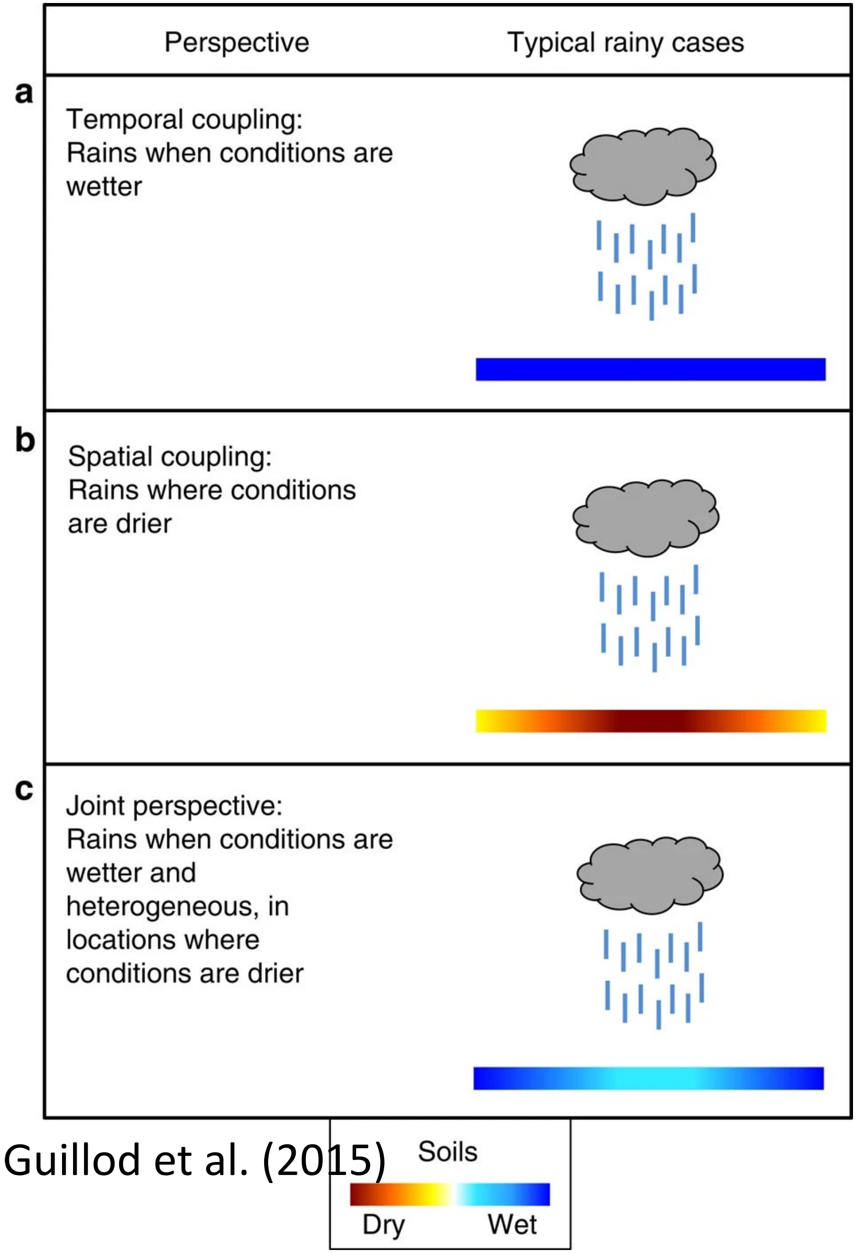


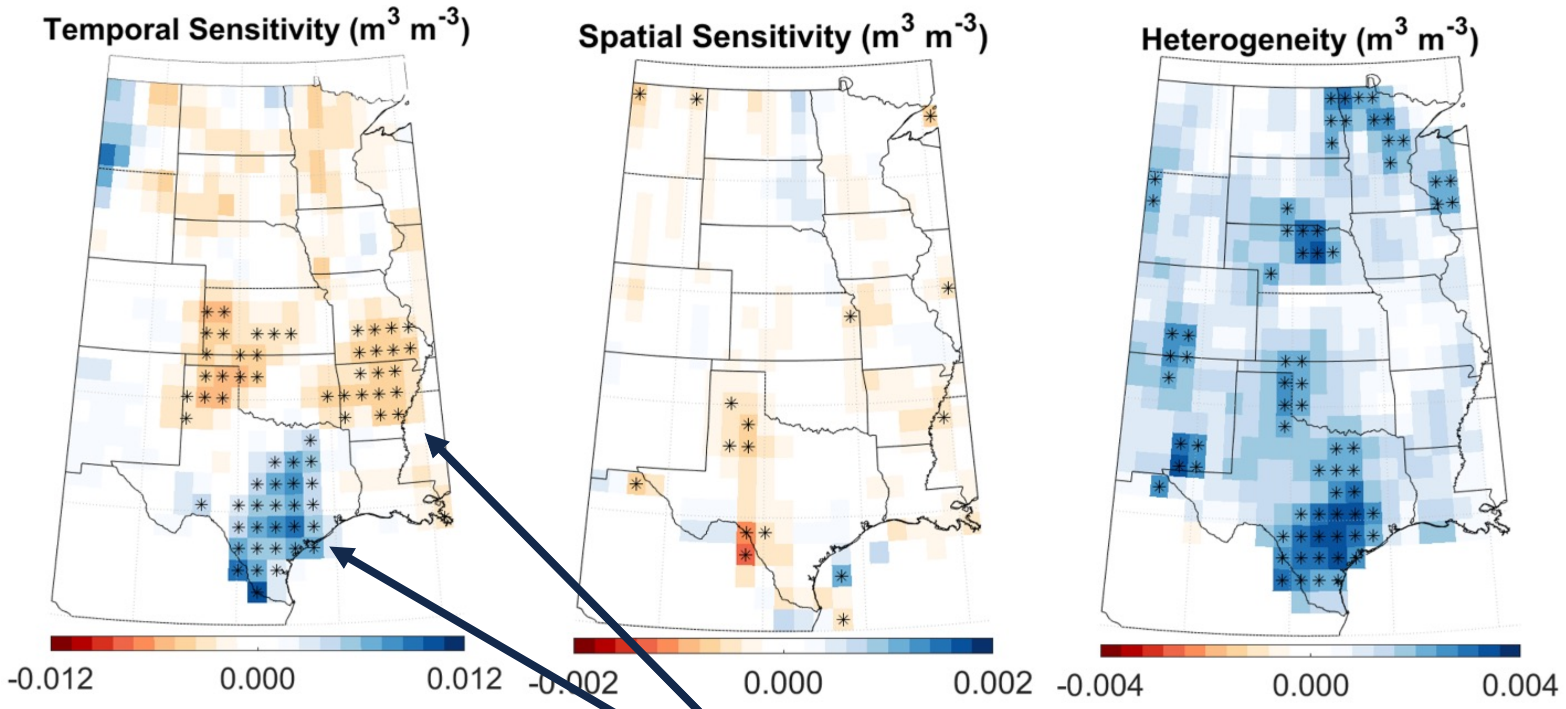
Santanello et al. (2018)

<u>Confounding Factors</u>

- Paucity of high-quality observations
- Difficulty establishing causality
- Dataset dependency
- Spatial scale

Quantifying Feedbacks: One Number to Rule Them All



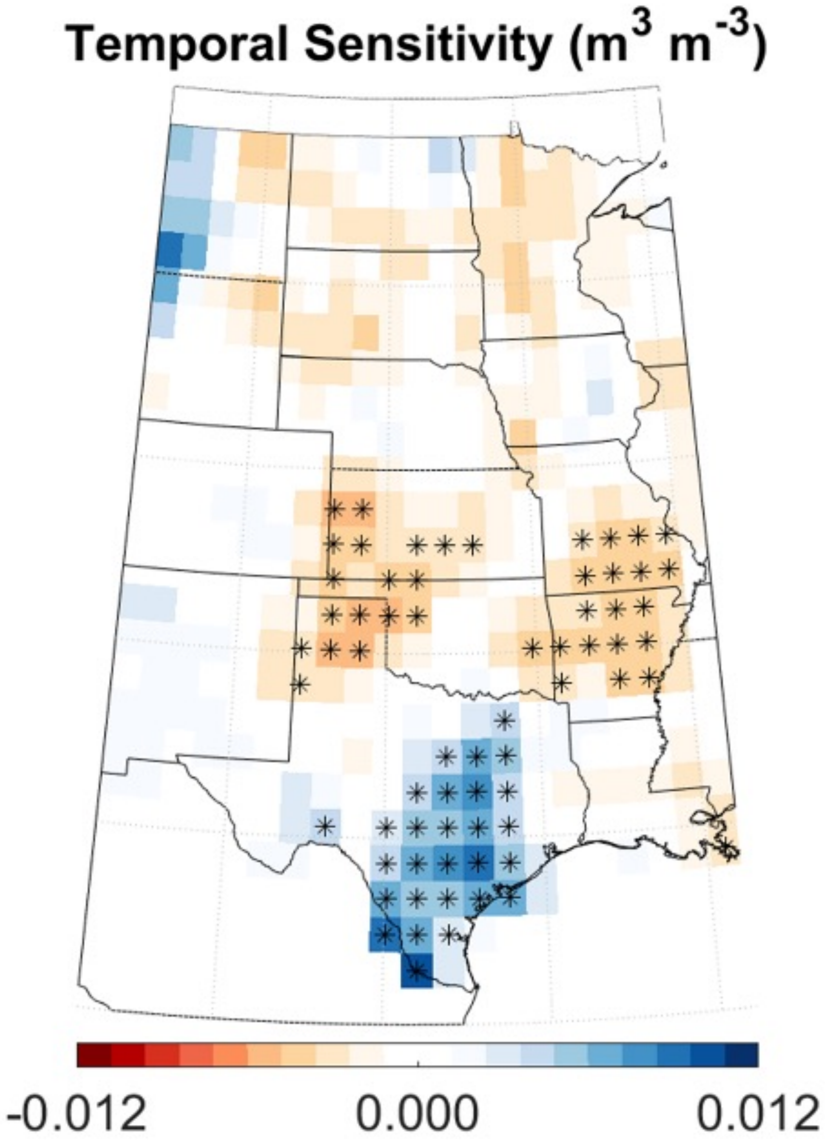


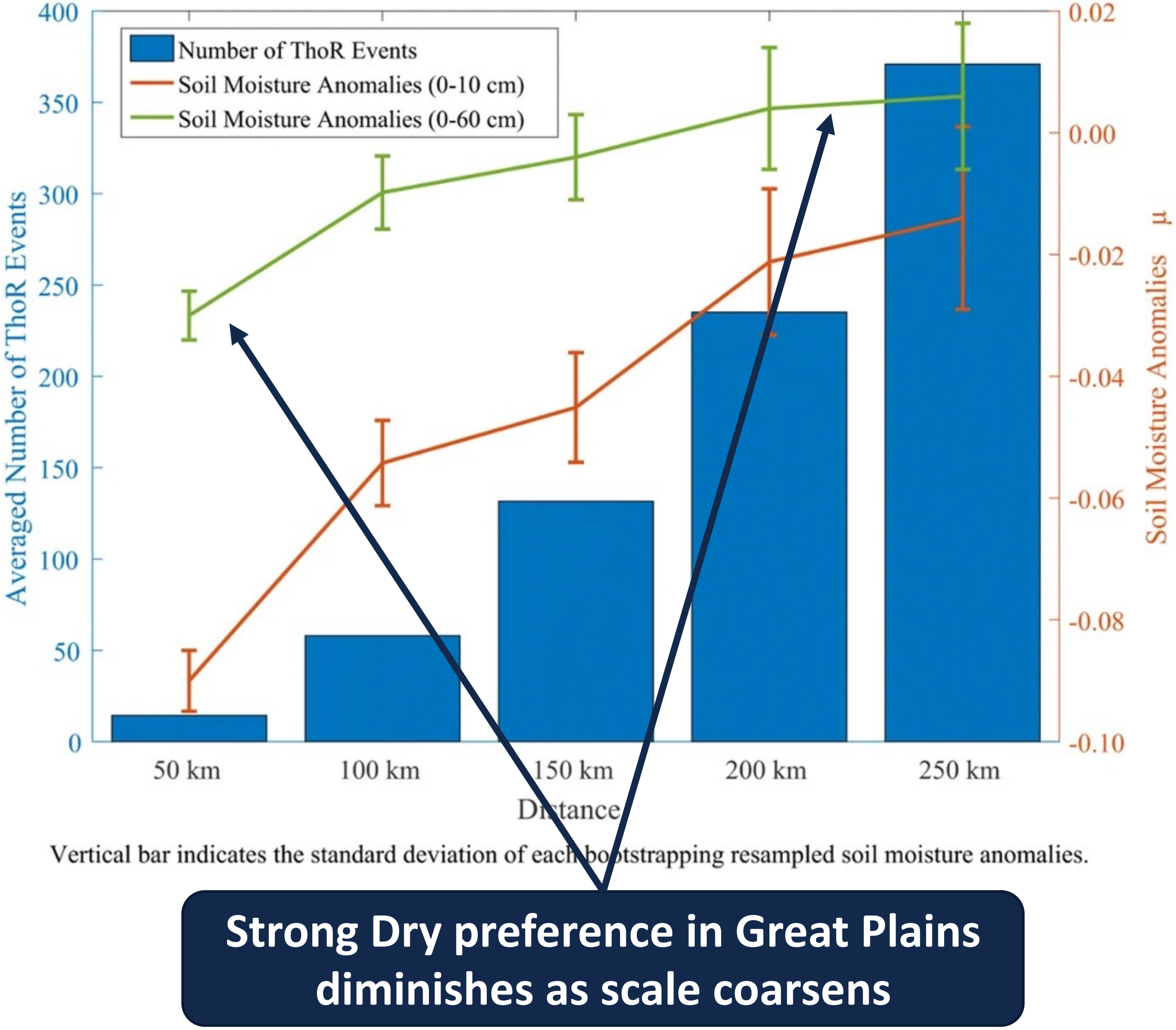
Significant preference for Wet soil coupling in Texas and Dry soil coupling farther north

Guillod et al. (2015)

Quantifying Feedbacks: Sensitivity to Spatial Resolution

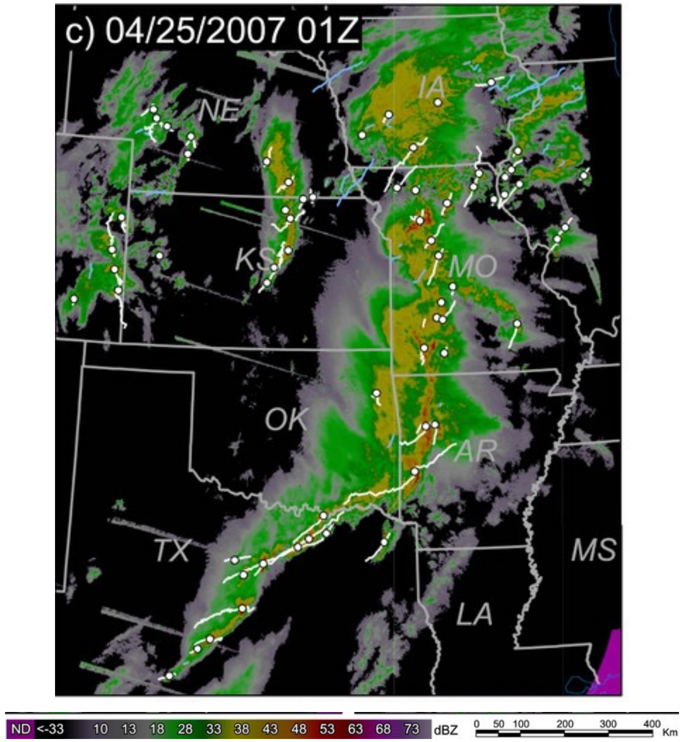
Yuan *et al.* (2020)





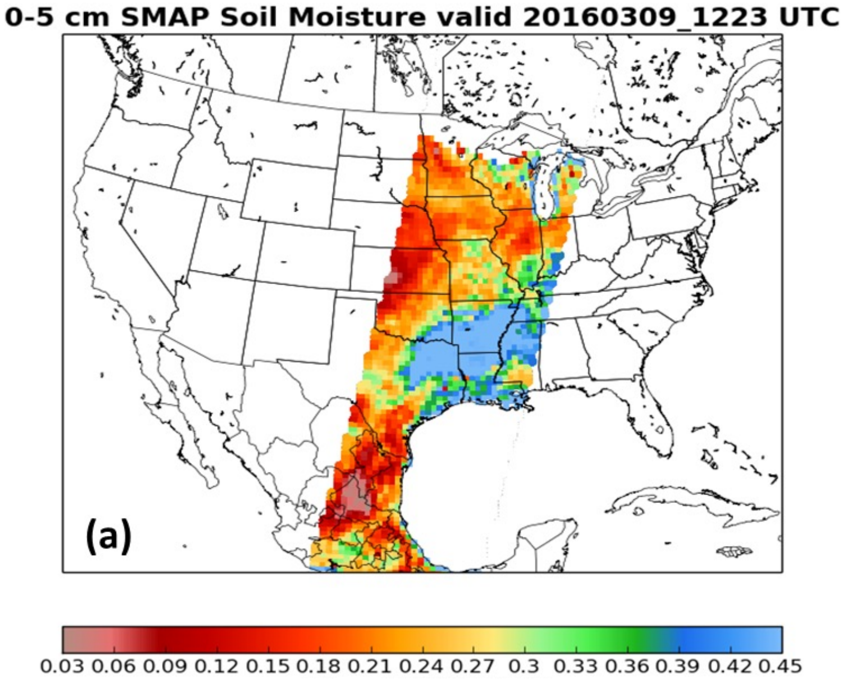
Using Multiple Lines of Evidence to Disentangle Feedbacks

Convection Initiation Thunderstorm Observation by Radar (ThOR)



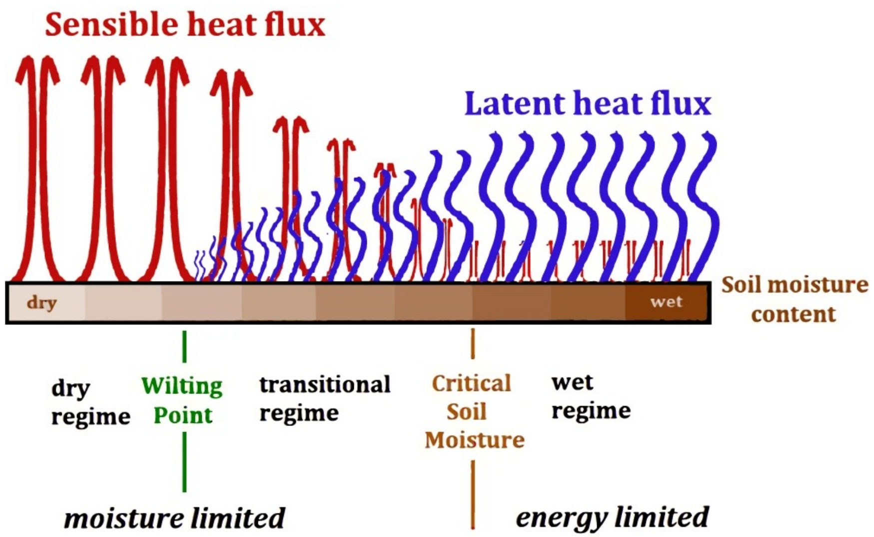
Houston *et al.* (2015)

Soil Moisture from L-band sensors, offline LSMs, *in situ*



Case (2020)

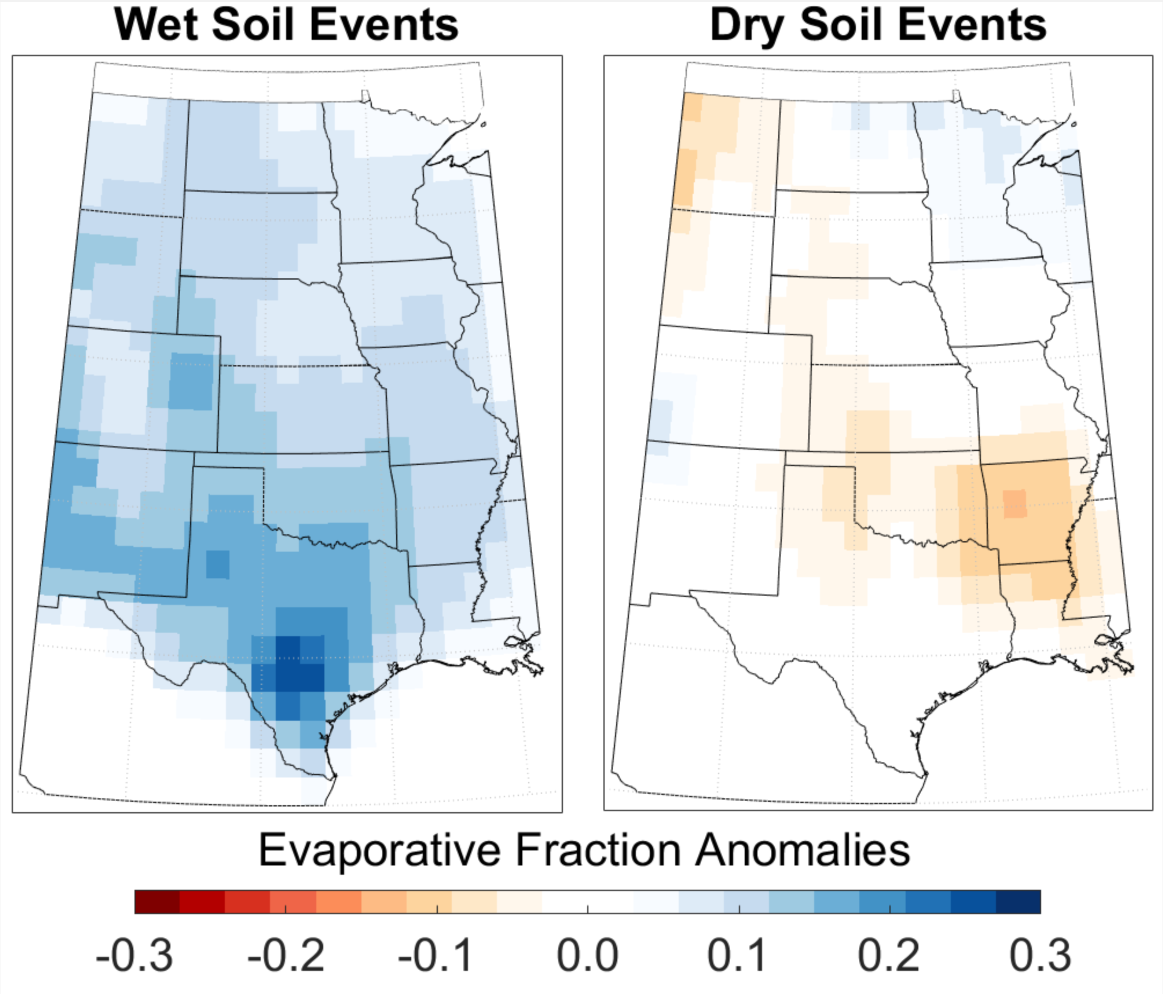
Evaporative Fraction & PBL/LCL Heights from observations and reanalysis



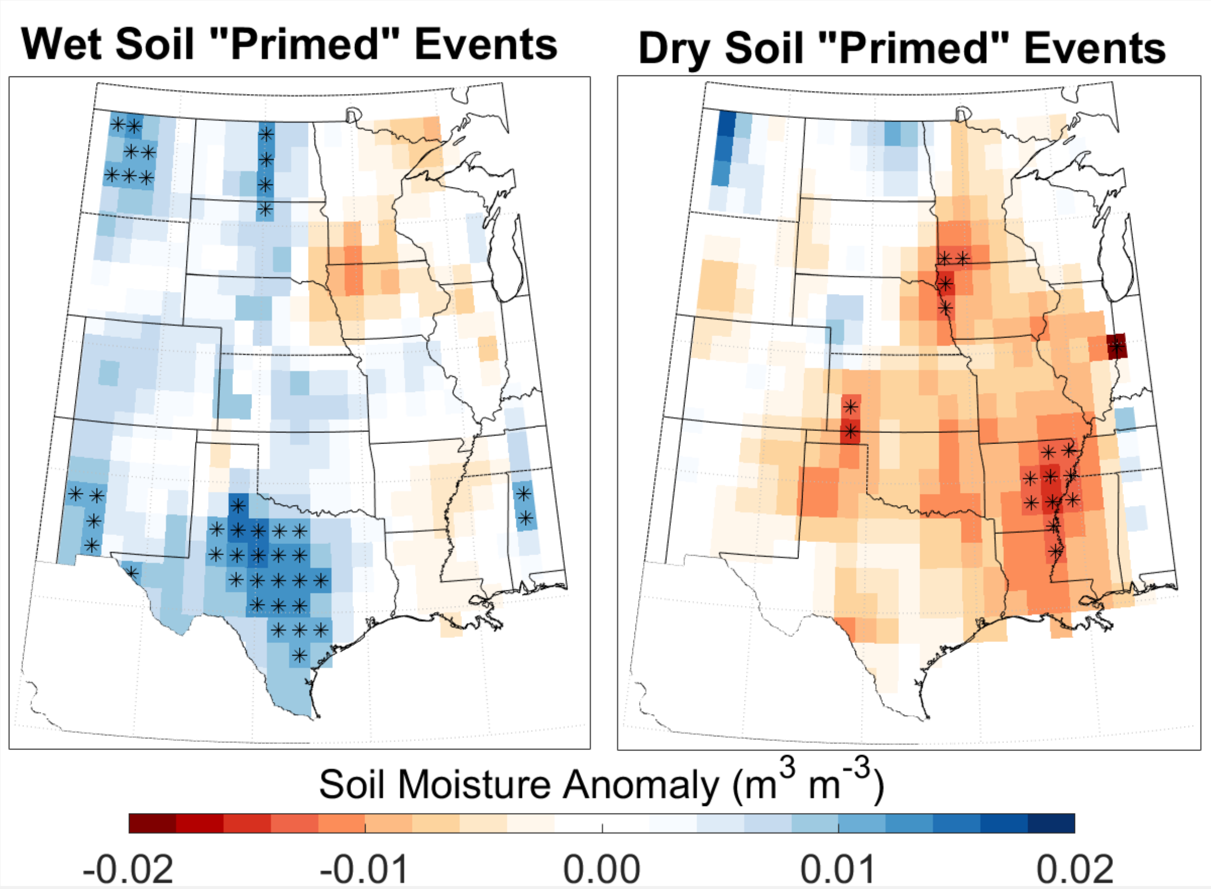
Hsu & Dirmeyer (2023)

Disentangling the LoCo Process Chain – Soil to Boundary Layer

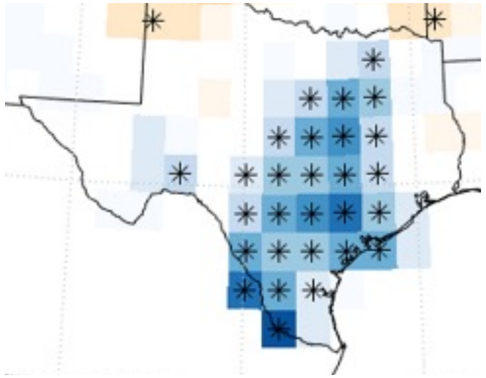
Surface Heat Flux Response to Soil Moisture

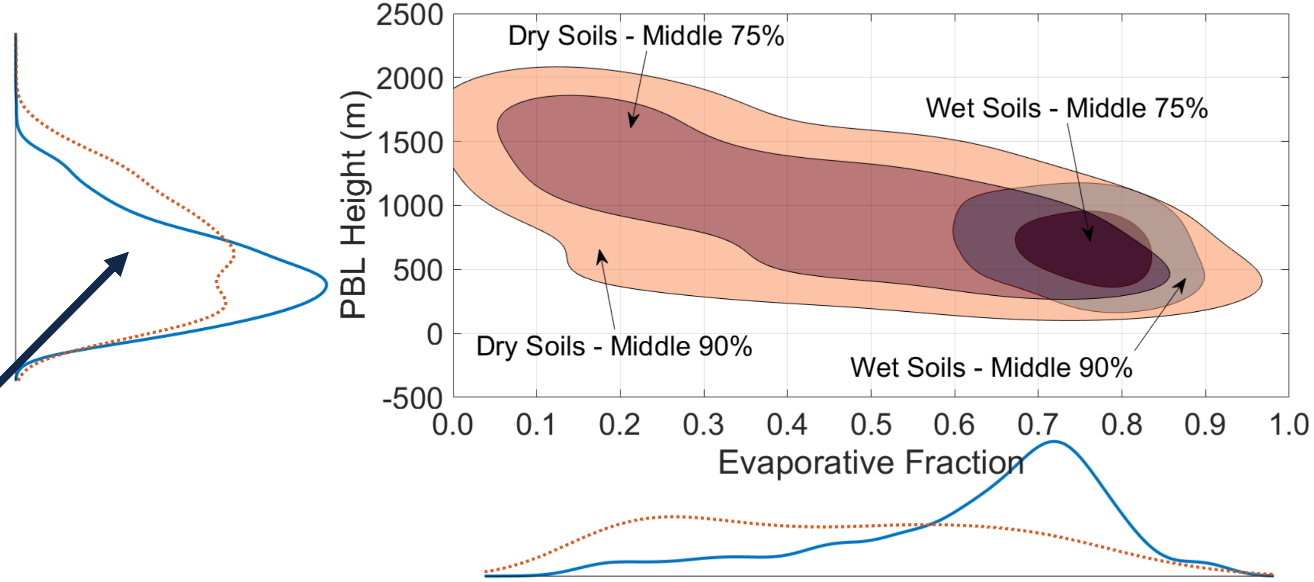


Boundary Layer “Conditioning” to Land-Forced Convection

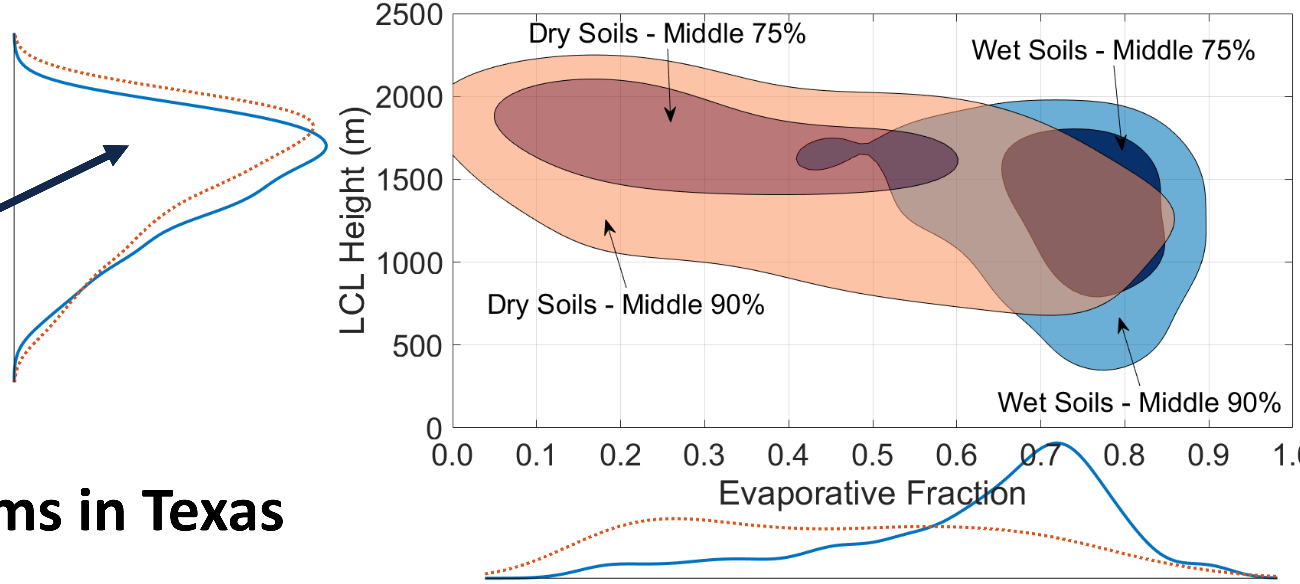


Disentangling the LoCo Process Chain – Boundary Layer Response





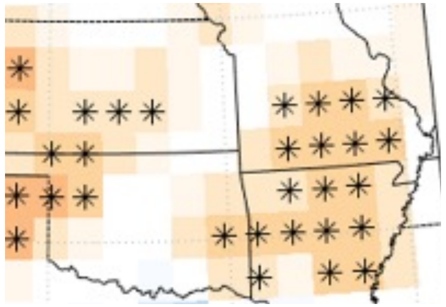
Stronger afternoon PBL growth over dry soils than wet soils

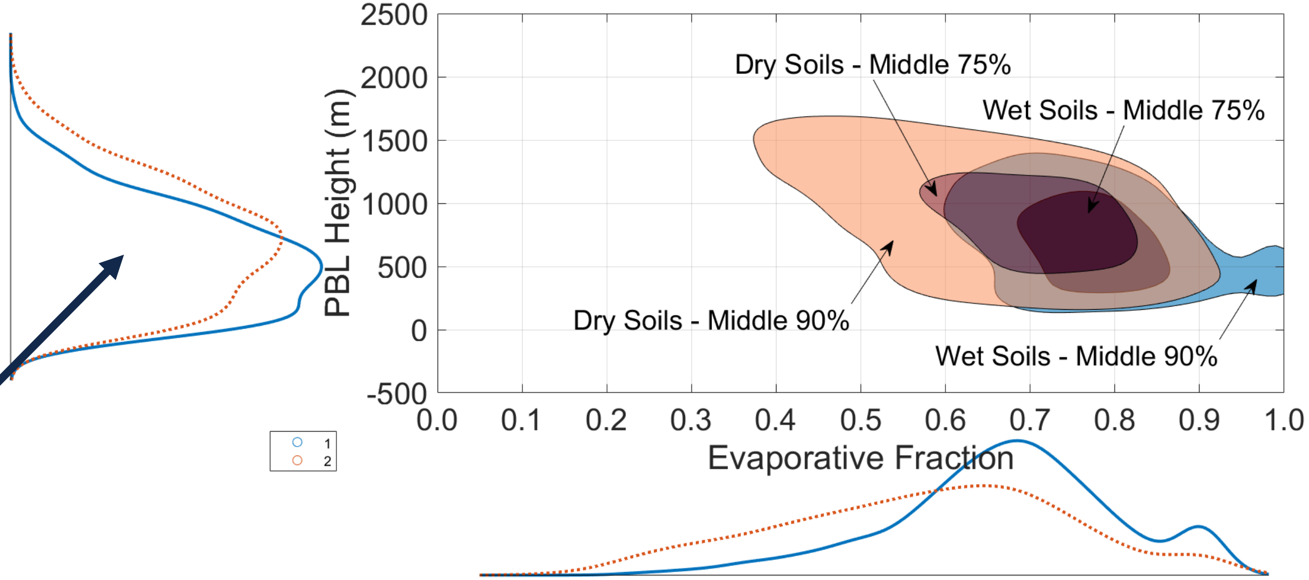


Weaker LCL response, but lower levels over wet soils than dry soils

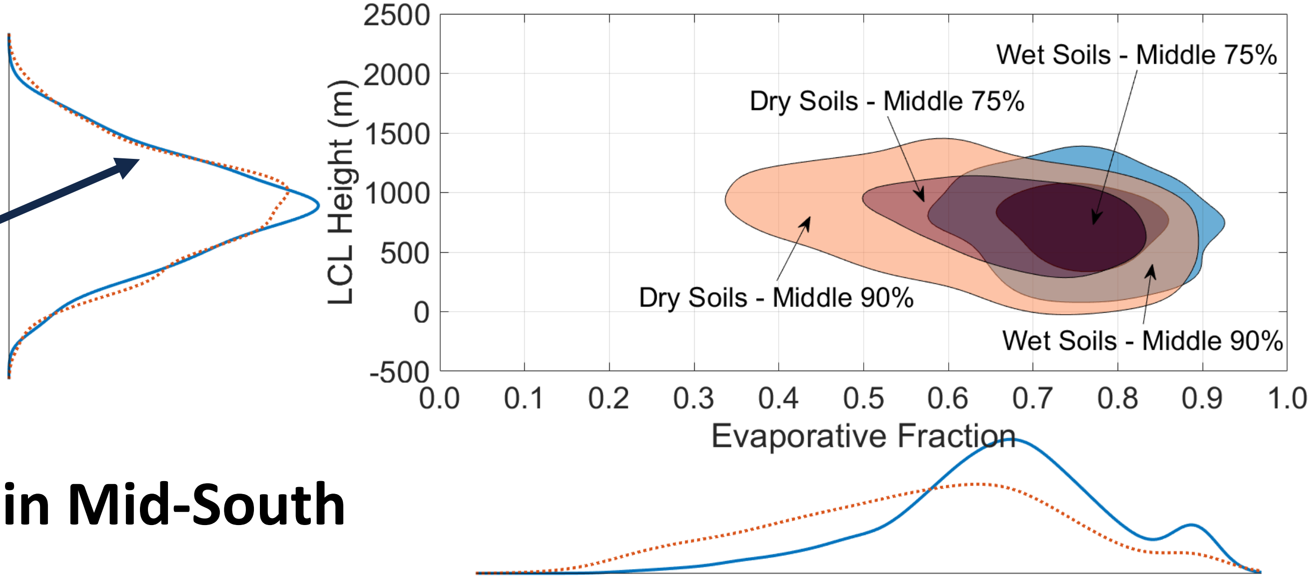
Consistent Wet Soil Feedback Mechanisms in Texas

Decomposing the LoCo Process Chain – Boundary Layer Response





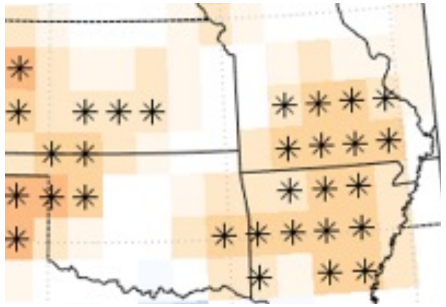
Same stronger afternoon PBL growth over dry soils

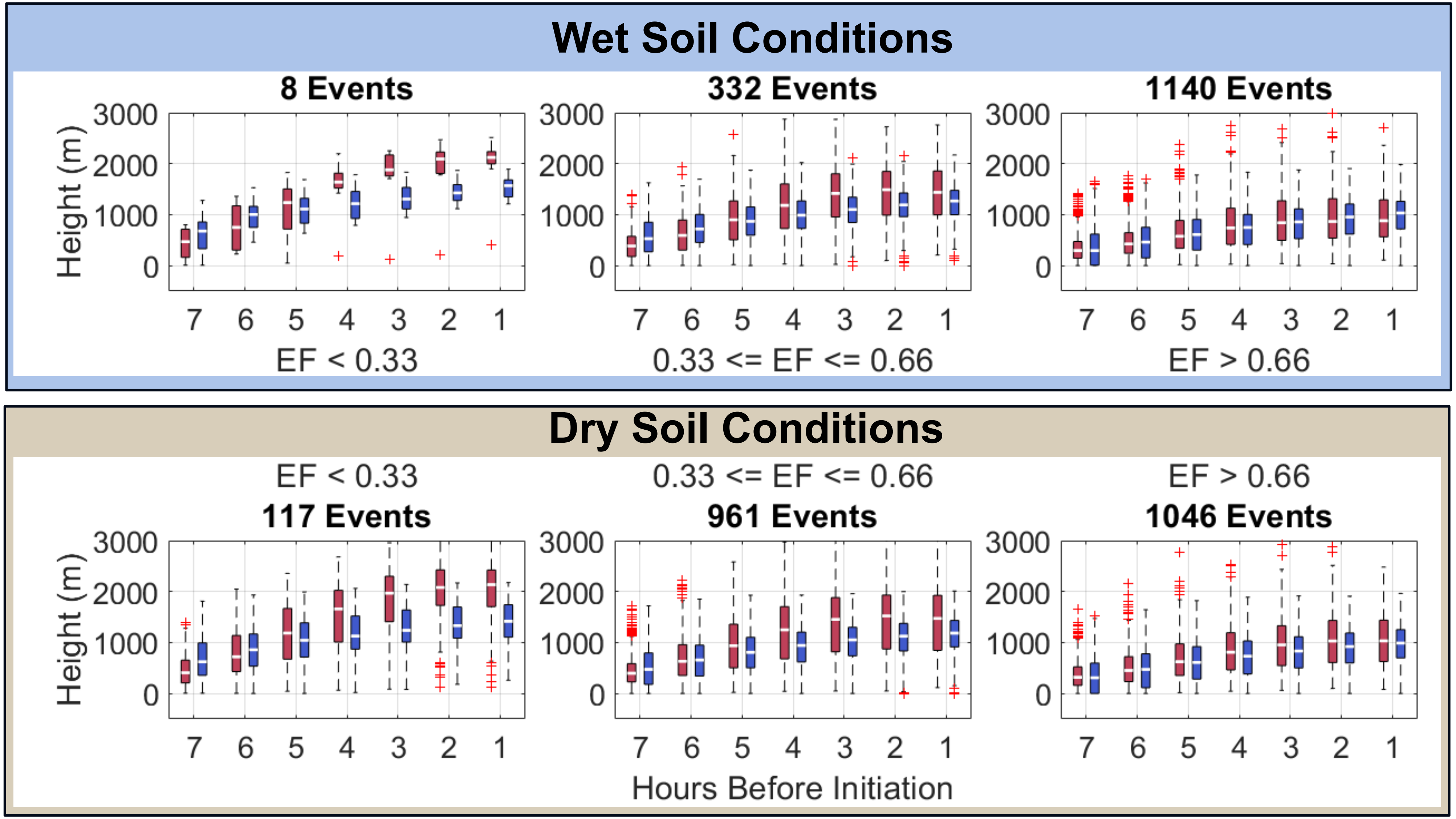


No difference in LCL response to soil moisture in the Mid-South region

Consistent Dry Soil Feedback Mechanisms in Mid-South

Decomposing the LoCo Process Chain – Boundary Layer Response



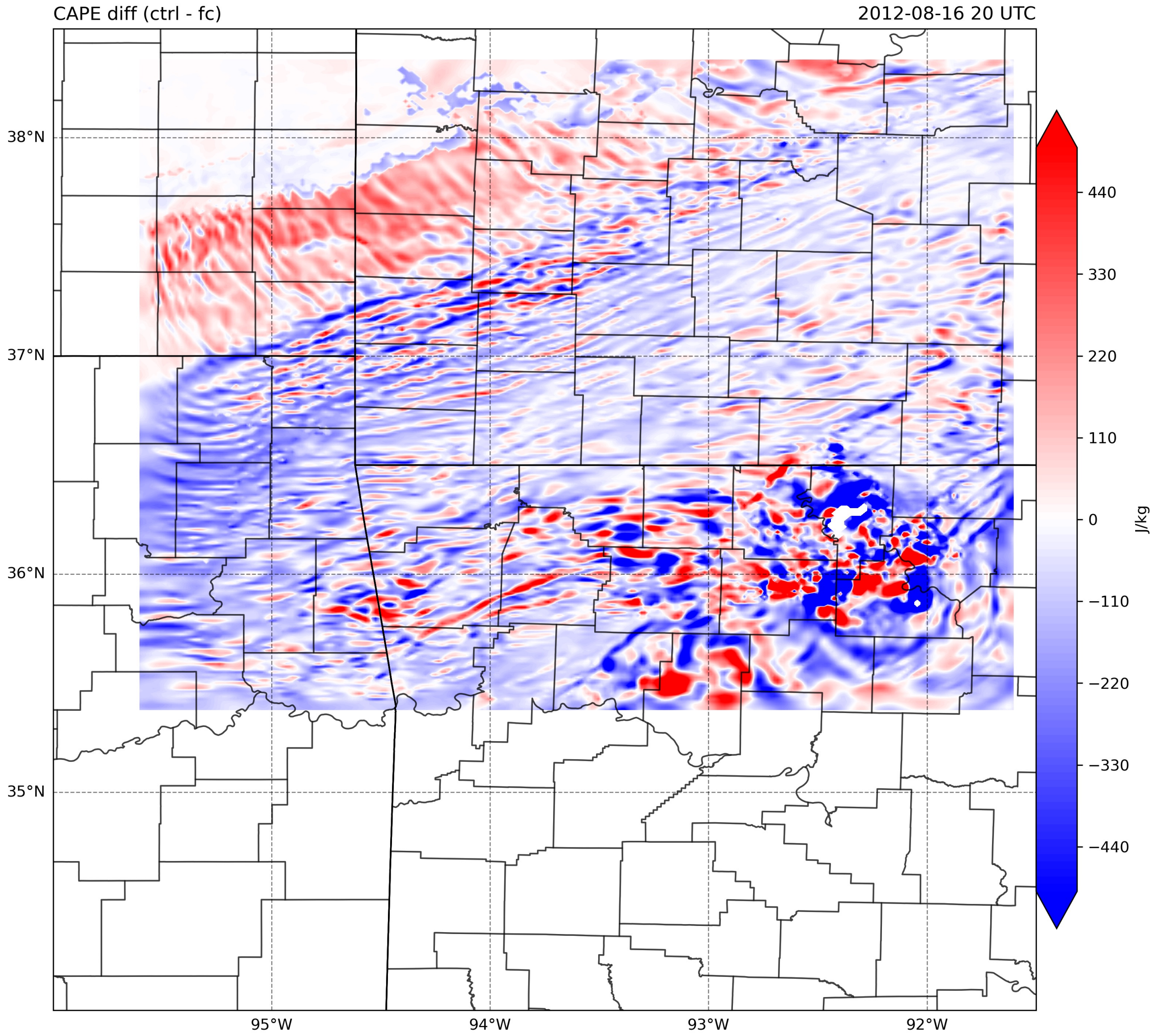


Surface heat flux is sensitive to soil moisture, but it modulates atmosphere response

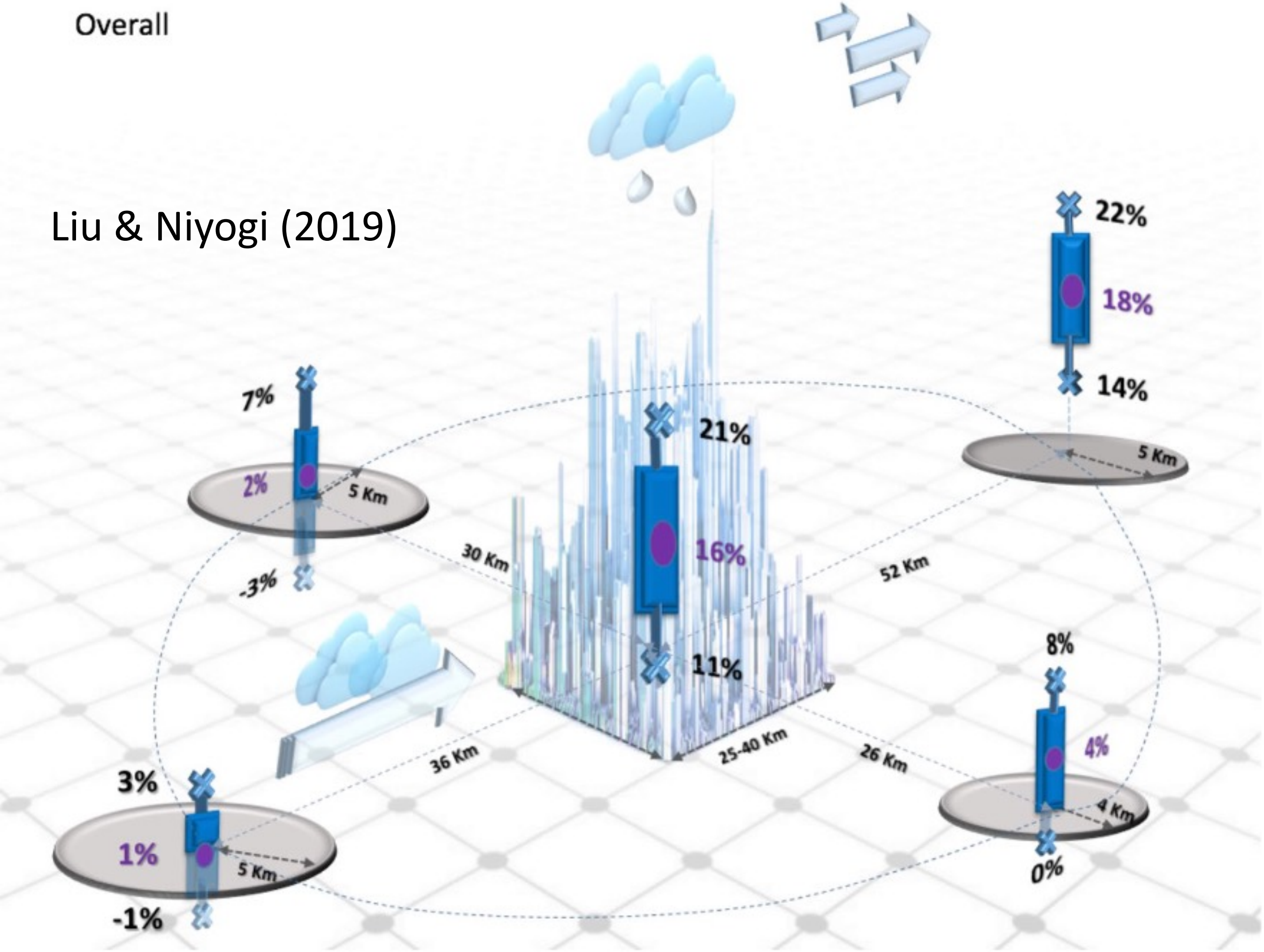
Next Step – Moving to WRF World

- Experimental (soil moisture) WRF runs with homogenously wet or dry soils
- Realistic soil moisture WRF runs with SMAP
- High-res runs with enhanced SMAP & NISAR
- Assessing differential response in surface heat flux, boundary layer, and precipitation

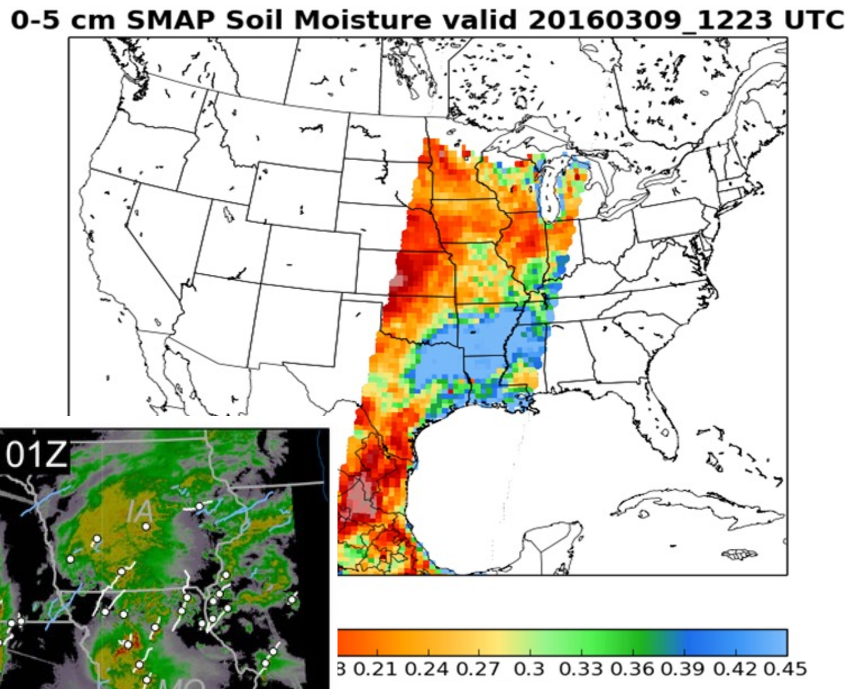
Simulation	Soil Moisture
CTRL	MERRA-2
WET	Field Capacity
DRY	Wilting Point
SMAP	Bias-corrected with SMAP
NISAR	Bias-corrected with NISAR

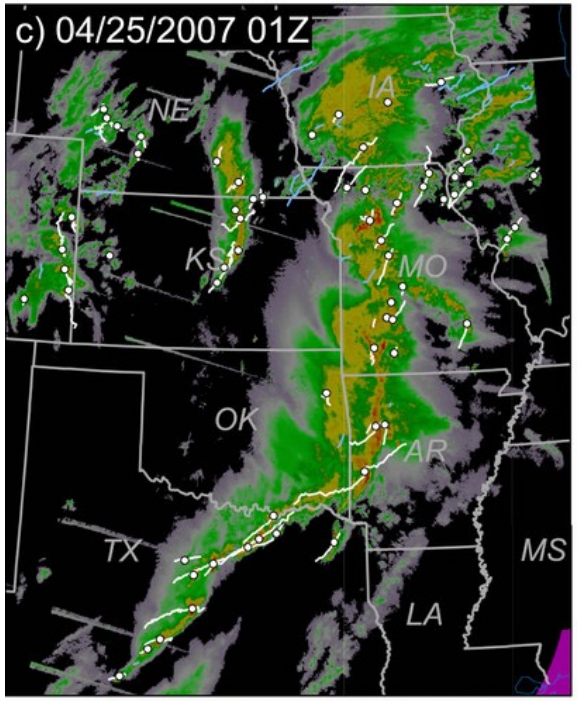


Next, Next Step – Precipitation Intensity



Liu & Niyogi (2019)





Better characterizing soil moisture & how it impacts rainfall intensity across the United States

Summary

- SMAP and other L-band platforms have helped significantly advance land-atmosphere interaction measurement and understanding, but results are highly sensitive to spatial resolution (possibly different mechanisms when moving from synoptic- to meso-scale)
- Likely "wet soil" and "dry soil" processes occur in many climates, but signal may be obscured by relatively coarse spatial scale and lack of consistent observations
- Finer scale soil moisture patterns and heterogeneity are important contributors to atmospheric response and precipitation outcomes – 10 km soil moisture can help fingerprint those connections and how they cross scales
- Evidence of improved storm modeling with better soil moisture representation and initialization – opportunity for L-band data assimilation
- Role of L-A interactions in heavy rainfall modification – opportunity to improve operational predication and impact warning

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