Applying Multiple, Diverse Sources of Soil Moisture to Better Understand Soil Moisture-Precipitation Coupling in the Central United States

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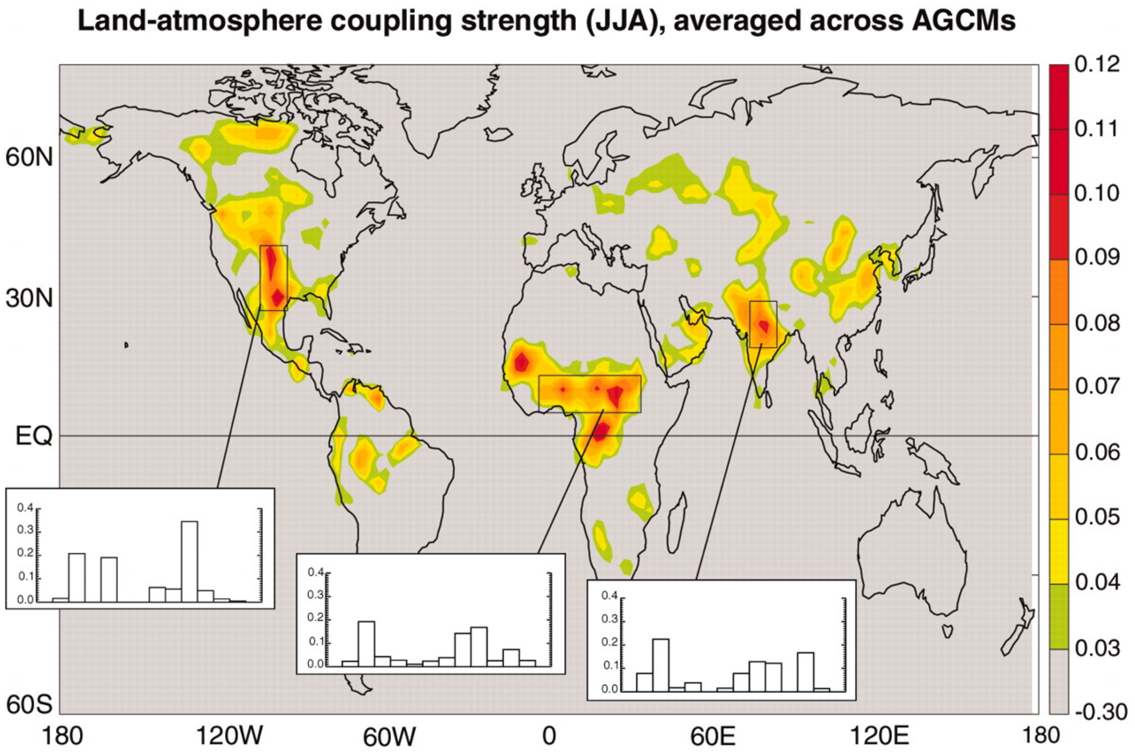
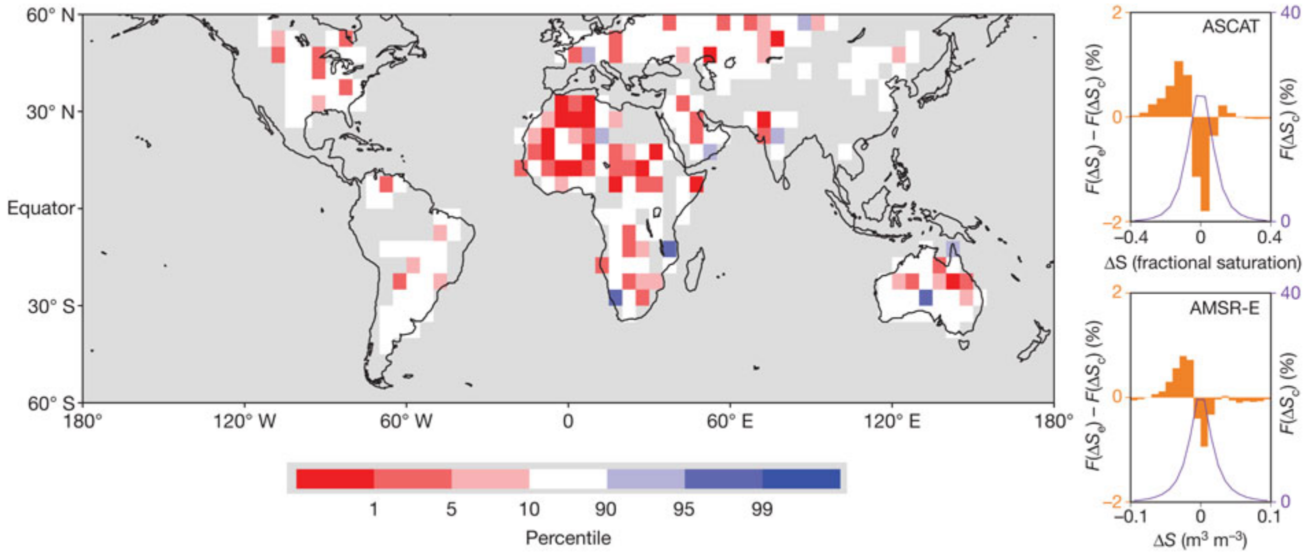
Soil Moisture – Precipitation Coupling



Impact of soil moisture on precipitation is largest in semi-arid regions, mostly positive (Koster *et al.* 2004)



Afternoon convective precipitation falls preferentially over dry soils, models show opposite (Taylor *et al.* 2012)

Soil Moisture – Precipitation Coupling

Larger Issues

- Both dry- and wet-soil mechanisms exist to initiate convection
- Models tend to wet-soil mechanisms, poor convective schemes

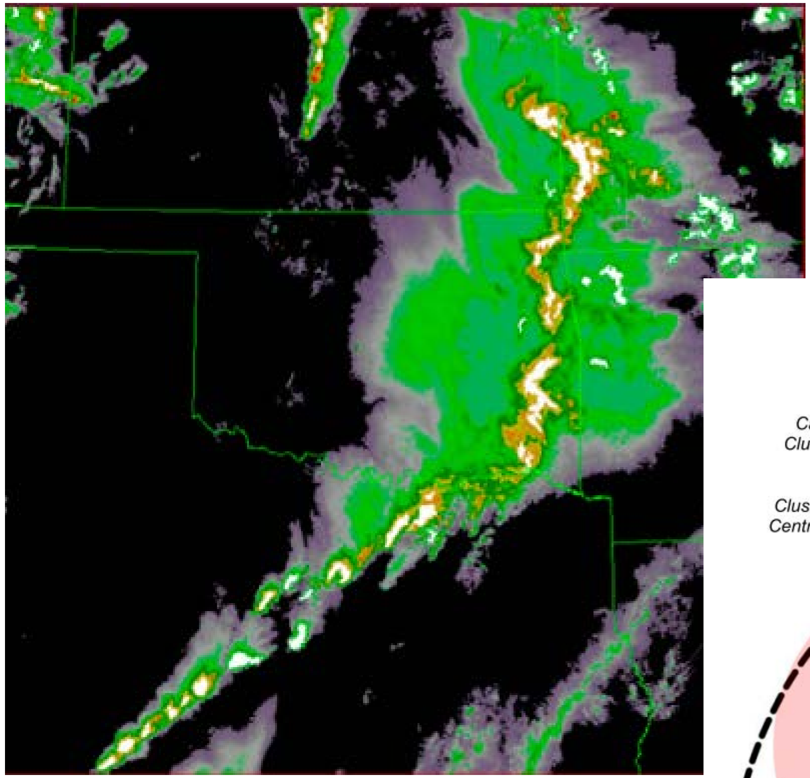
However…

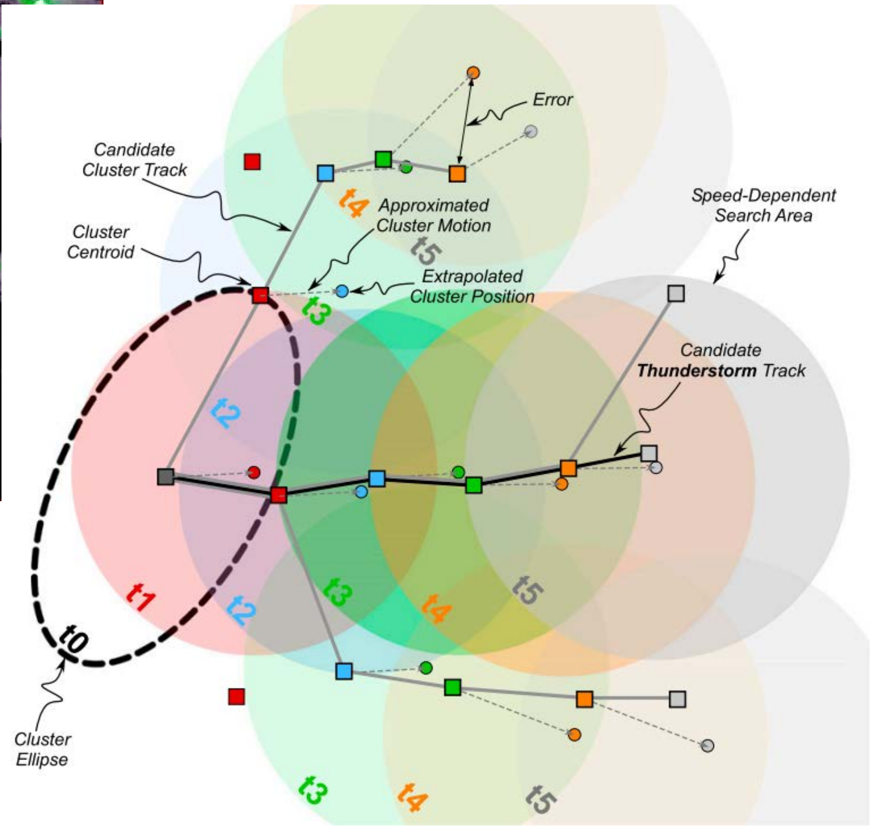
- Majority of observation-driven analyses uses AMSR-E soil moisture
- Previous methods have not adequately addressed the issue of convective forcing (i.e., local vs. synoptic)
- Regions are assumed to exhibit either positive coupling OR negative coupling

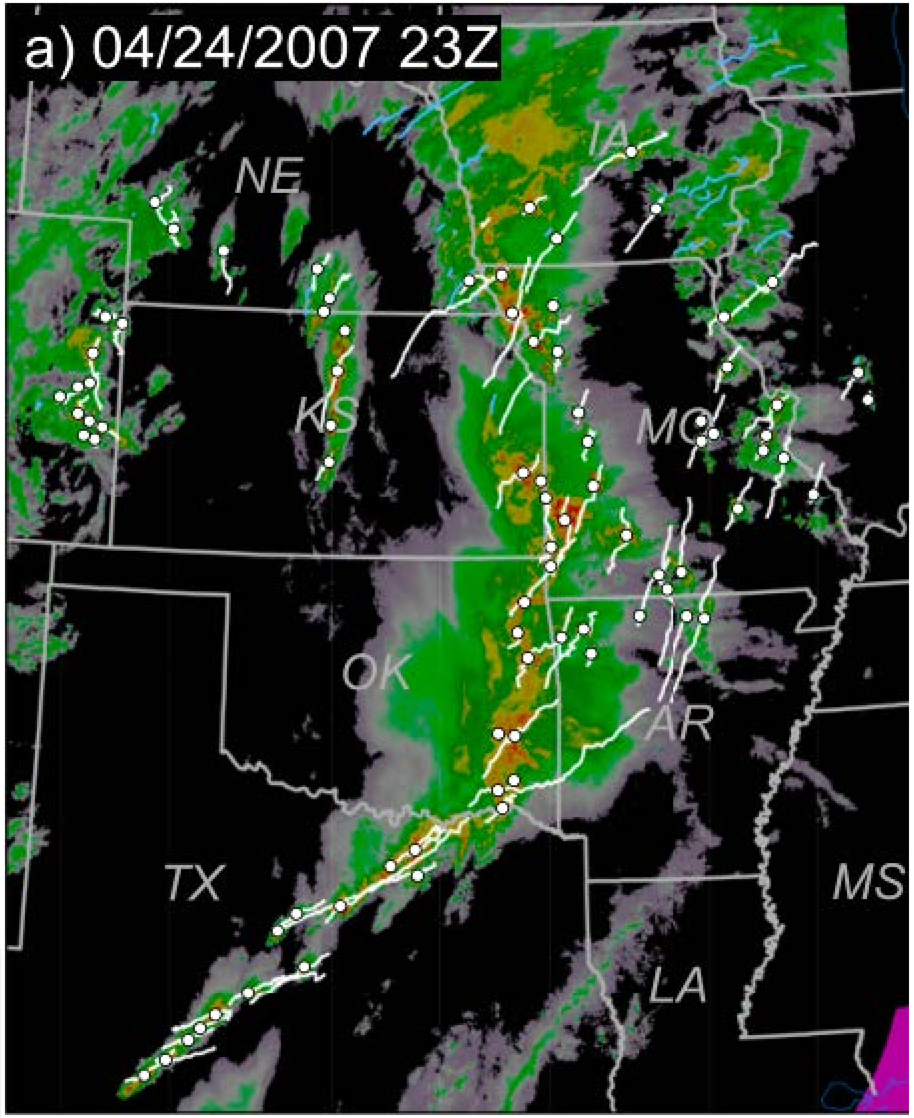
Project Objectives

1) **Evaluate whether deep, moist convection initiation occurs preferentially over wet or dry soils using a variety of soil moisture products (including SMAP)**
2) Evaluate how these preferences (wet/dry) vary over space and time
3) Determine how soil moisture heterogeneity and gradients influence initiation of deep, moist convection

Convective Thunderstorms – ThOR





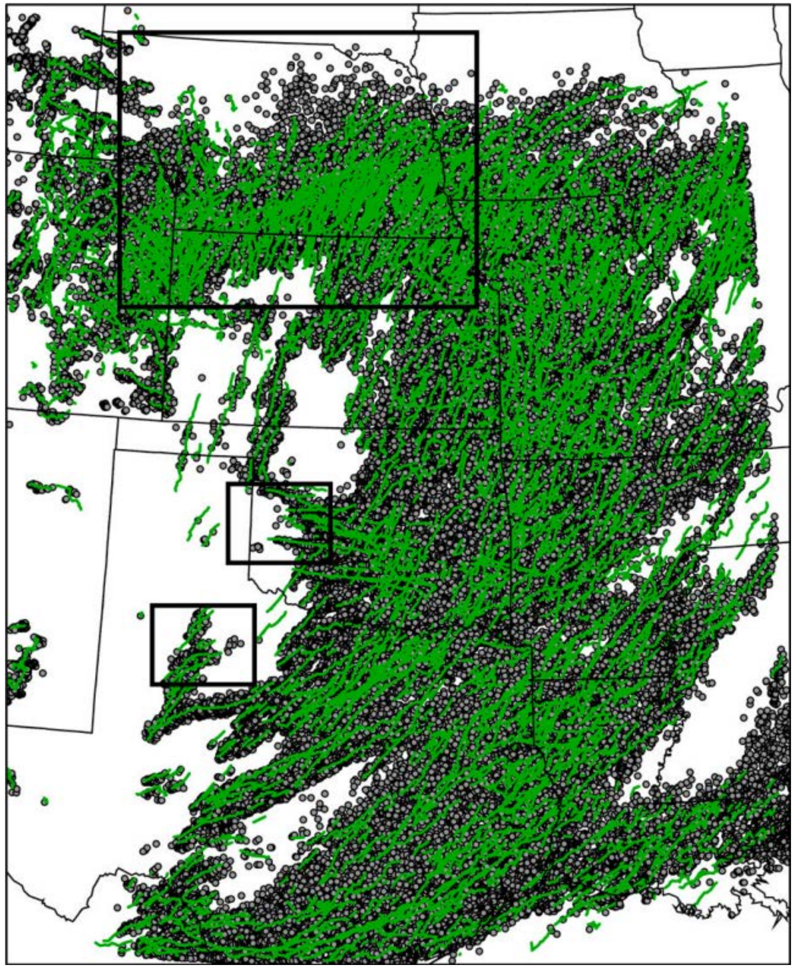


Thunderstorm Observation by Radar (ThOR) algorithm

(Houston *et al.* 2015) *JAS*

Soil Moisture

- **AMSR-E** (L3, C and X bands), 2003 – 2010, 56 km resolution
- **ESA Soil Moisture CCI**, 1992 – 2013, 0.25° resolution
- **TRMM TMI** (L3, X band), 1999 – 2014, 0.25° resolution
- **SMAP** (L3 Passive), 2015 – present, 36 km resolution
- **OK Mesonet** (station within grid cell), 2000 – present

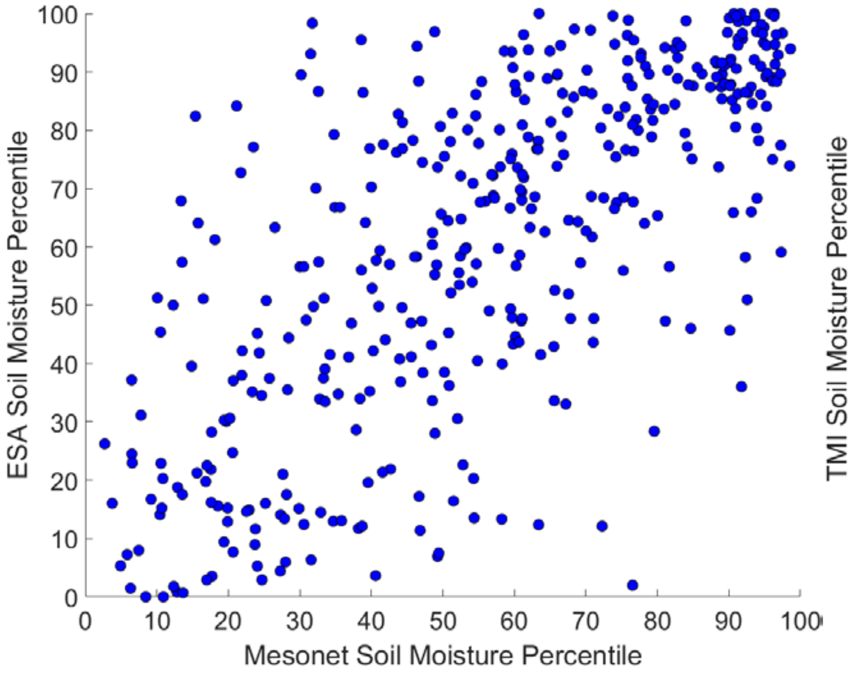


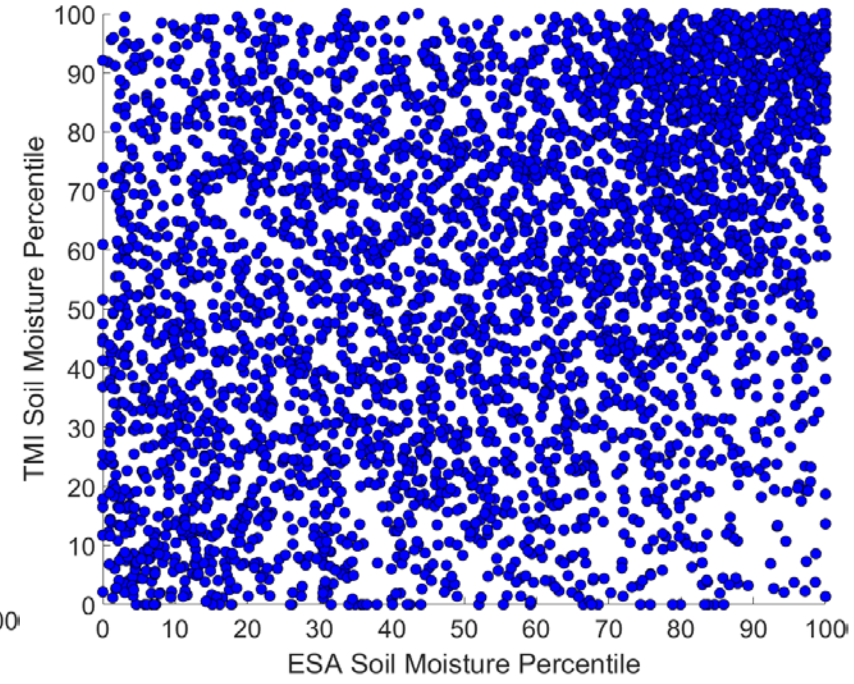
ThOR events in 2007.

Current analysis from 2005 – 2007, focus on May – September, afternoon precipitation events

Event-to-Event Correspondence

- Considerable inter-dataset differences in SM percentiles
- Better correspondence between ESA and Mesonet





Correlation	ESA	TMI
TMI	0.34	
AMSR-E	0.30	0.35

Correlation	ESA	TMI	AMSR-E
TMI	0.40		
AMSR-E	0.41	0.44	
Mesonet	0.72	0.45	0.42

Soil moisture percentile correlation tables with (left) all events ($n > 9500$) and (right) Oklahoma events ($n > 400$)

Event-to-Event Correspondence

- TMI is wetter than ESA, AMSR-E
- Wet/dry: percent differences are all > 50%

% Wet Agreement	ESA	TMI
TMI	71%	
AMSR-E	63%	61%

% Dry Agreement	ESA	TMI
TMI	54%	
AMSR-E	59%	65%

Difference	ESA – TMI	TMI – AMSR-E	ESA – AMSR-E
	-0.030	0.070	0.005

Event-to-Event Correspondence

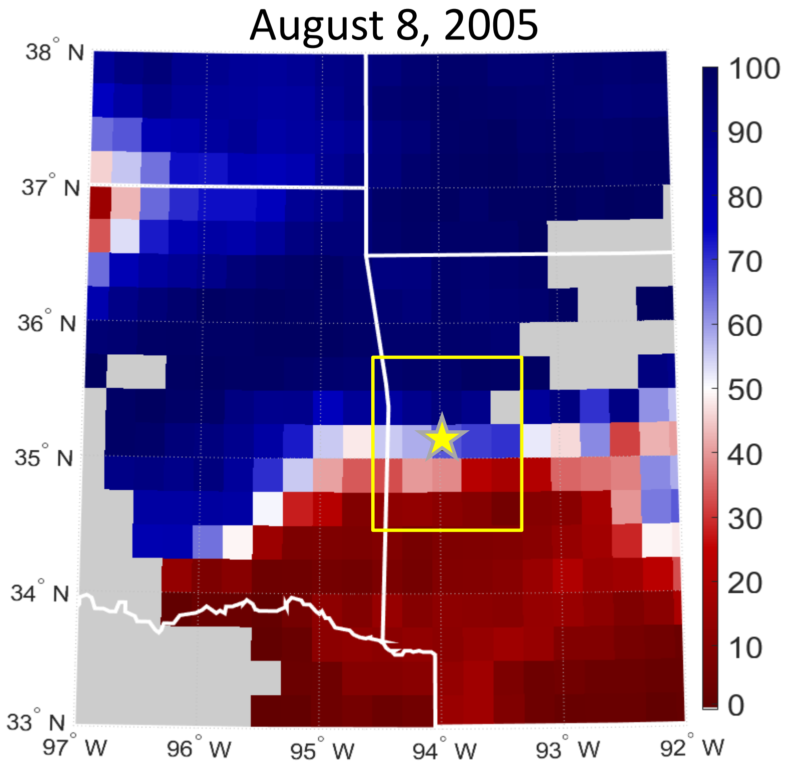
- All products show better wet event agreement with Mesonet
- ESA has highest overall agreement (73%) and fewest large errors, AMSR-E has lowest bias

% Wet Agreement	ESA	TMI	AMSR-E
Mesonet	80%	78%	72%

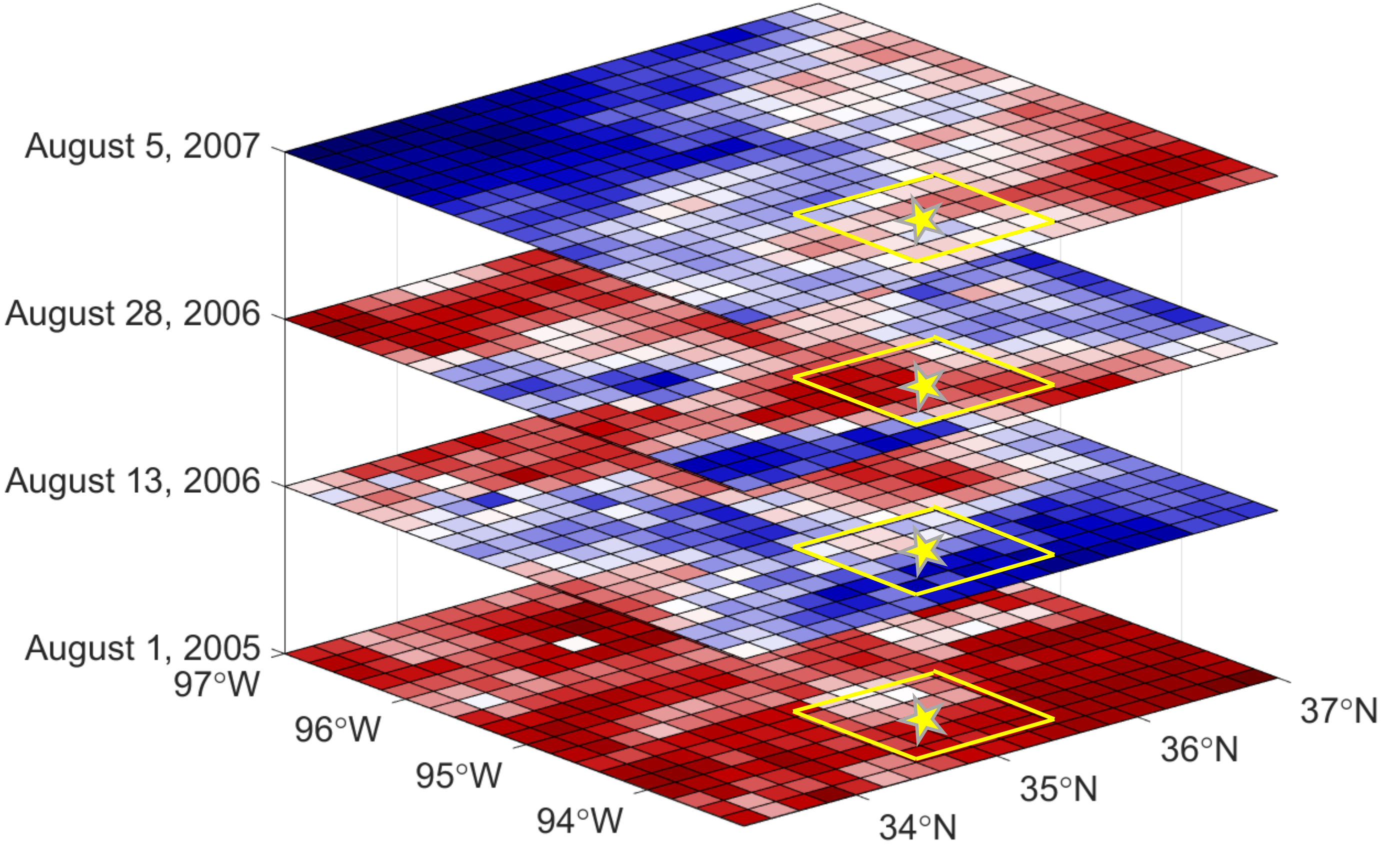
% Dry Agreement	ESA	TMI	AMSR-E
Mesonet	67%	56%	59%

Difference	ESA	TMI	AMSR-E
Mesonet	-0.042	-0.060	0.004

Soil Moisture Spatial Variation



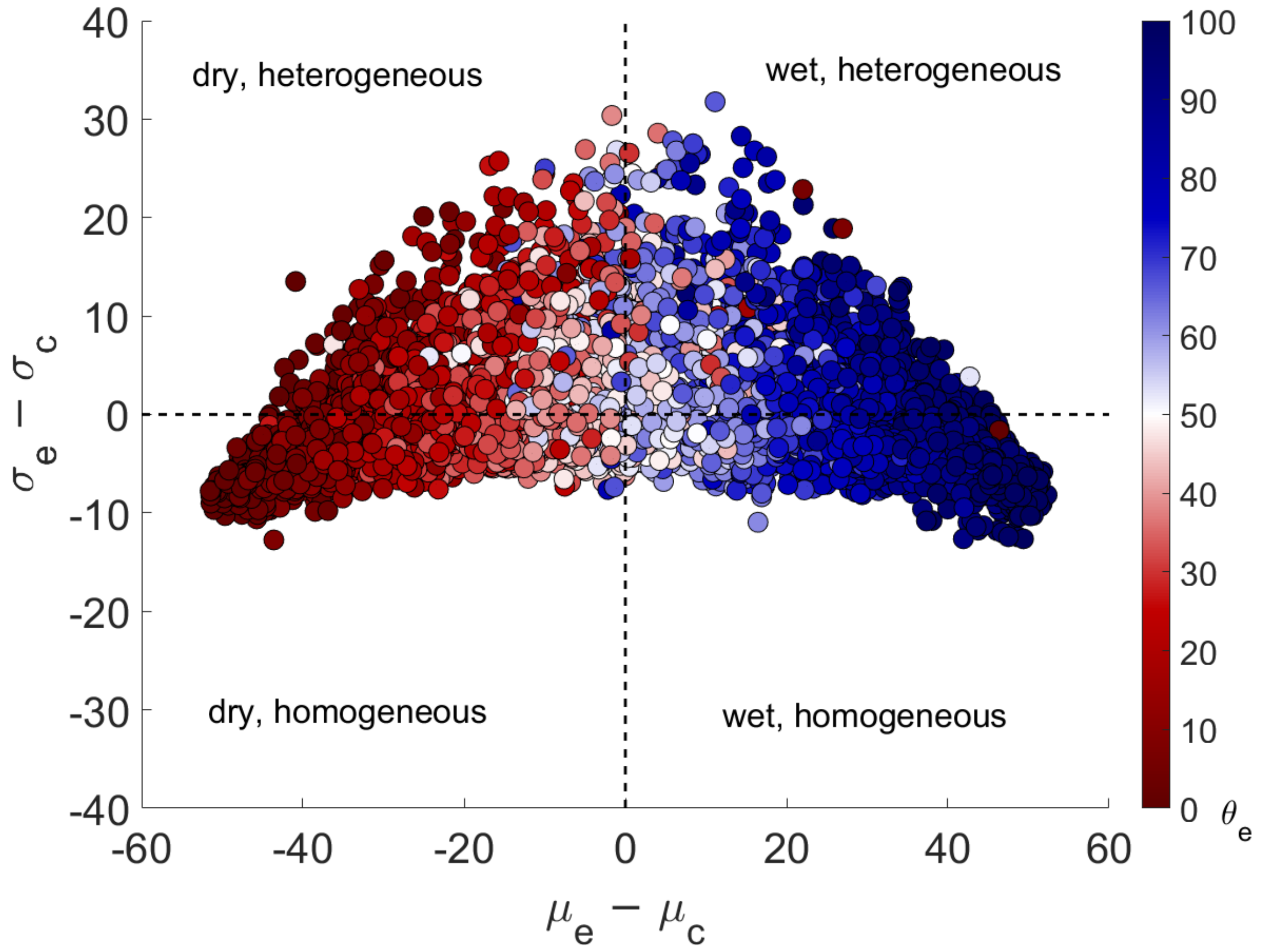
Find soil moisture percentile underlying ThOR event initialization (θ_e). Compute 5° × 5° region mean soil moisture (μ_e) and standard deviation (σ_e).



Compute climatological soil moisture mean (μ_c) and standard deviation (σ_c) of 5° × 5° region. Climatology based on all days of the calendar month in which the event occurred.

Soil Moisture Spatial Variation

- Relative homogeneity increases with relative wetness/dryness
- Absolute wetness/dryness of soil moisture underlying ThOR events related to the relative wetness/dryness of the region



ESA soil moisture (θ_e) underlying ThOR events plotted in dual region-mean (μ_e), region-variability space (σ_e). μ_e and σ_e are standardized by their respective climatological means.

Summary

- Hundreds of thousands of convective storm events in the central U.S., 2005 – present
- Remote sensing soil moisture intercomparison:
  - Decent correspondence between datasets (r ~ 0.3 – 0.5, % agreement ~ 50% - 80%)
  - TRMM TMI shows wet preference (bias?)
  - ESA closest matches nearest Mesonet station
  - Suggests wet/dry preference could be somewhat dataset-dependent
- Soil moisture spatial patterns:
  - Climatologically, events tend to occur over dry (wet) soils when the surrounding region is dry (wet)
  - Events tended to occur over drier (wetter) soils when the surrounding region was dry (wet), more heterogeneous

Next Steps, Challenges

- Getting more data
- Separating weakly-forced events (hopefully automated)
- Finalizing framework for assessing soil moisture spatial patterns/gradients
  - Incorporating storm movement, surface and upper-atmosphere winds
- Quantitatively determining dataset dependency of wet/dry preferences
  - Replicating past studies