Land initializations contribute most to the sub-seasonal soil moisture forecast skill in the US

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Motivation

- Can we predict root zone soil moisture anomalies weeks to months in advance?
- Suggestive evidence from potential predictability studies (e.g., Musa, Kumar, et al. 2021)
- Which sources (Atmosphere, Ocean, and Land) contribute the most to soil moisture predictability?

Sub seasonal forecast Experiment (SubX) CESM2
Control + Four sensitivity experiments

	CONTROL	OCN + LND	LND only
ATM			
OCN			
LND			

	ATM only	OCN only	LND only
ATM			
OCN			
LND			

√ - Observation equivalent full field (climatology + anomaly) initialization

× - Climatology-only initialization

Richter et al., in prep.

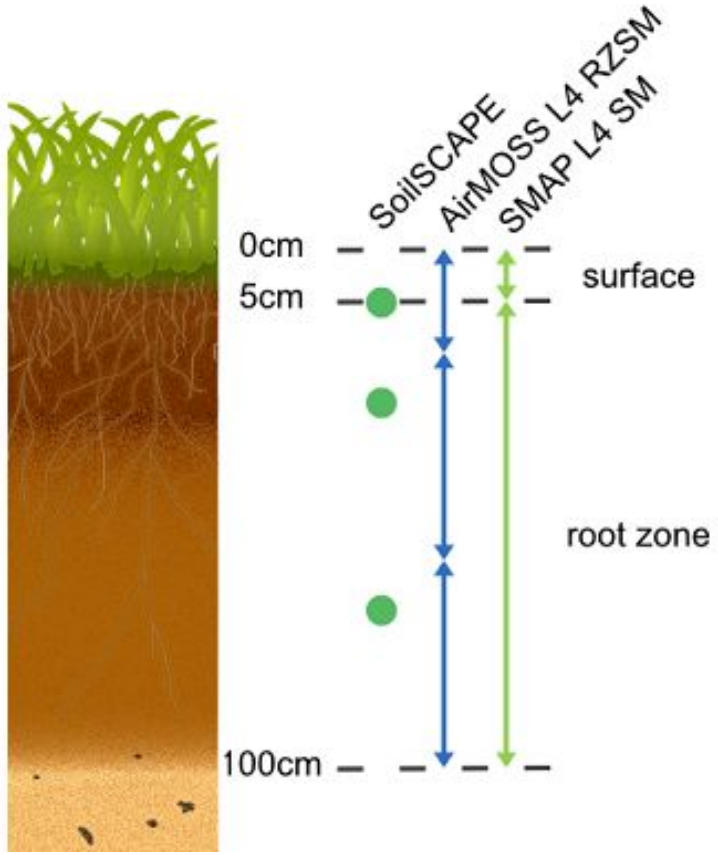
Experiment Details

Method/Period	Details
ATM Initialization	CFSv2 Reanalysis
OCN Initialization	JRA55-do forced ocean and sea ice
LND Initialization	CLM5 with meteorological forcing from CFSv2 reanalysis, and after 700-years spin-up
Reforecast period	1999 to 2021 Every Monday (52 weeks × 23 years)
Ensemble size	11
Real-time forecast	Yes, from April 2021 with an increased ensemble size (21)

Richter et al. (2022), Weather and Forecasting, 37(6), 797-815.

Metric and Methods

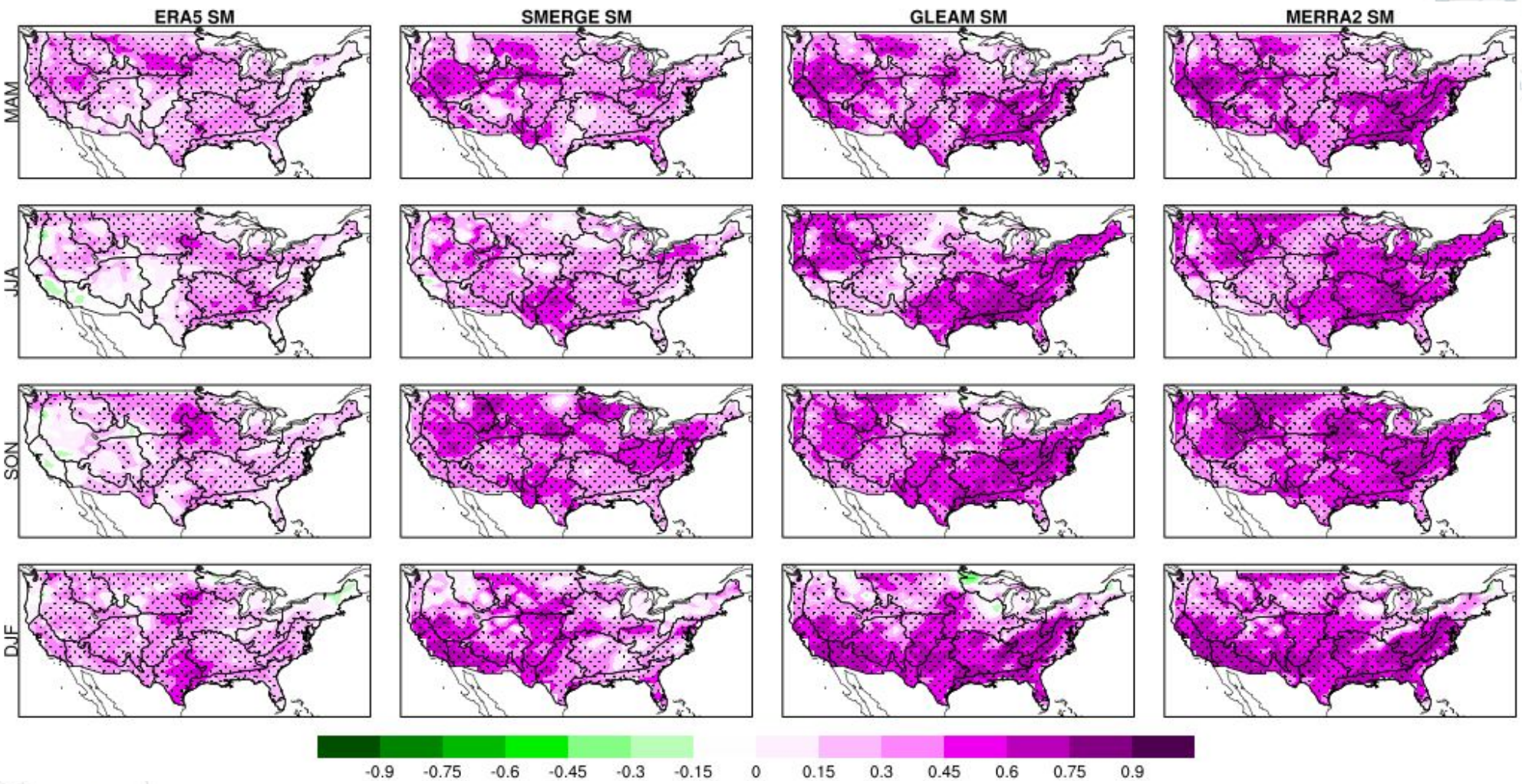
- Root zone soil moisture (0-0.5 m)
- Drift correction – Lead time and forecast initialization time climatology removal (Kumar et al. 2014)
- Observations – Remote sensing and re-analysis-based soil moisture from four sources (ERA5-Land, SMERGE, GLEAM, MEERA2)
- Anomaly correlation for 14-days average forecast (14-day running mean)
- Week 3 to 4 forecast



Source: NASA EARTHDATA
https://airmoss.ornl.gov/visualize/guide.html

Result 1: Forecast skills are dependent on selected observations

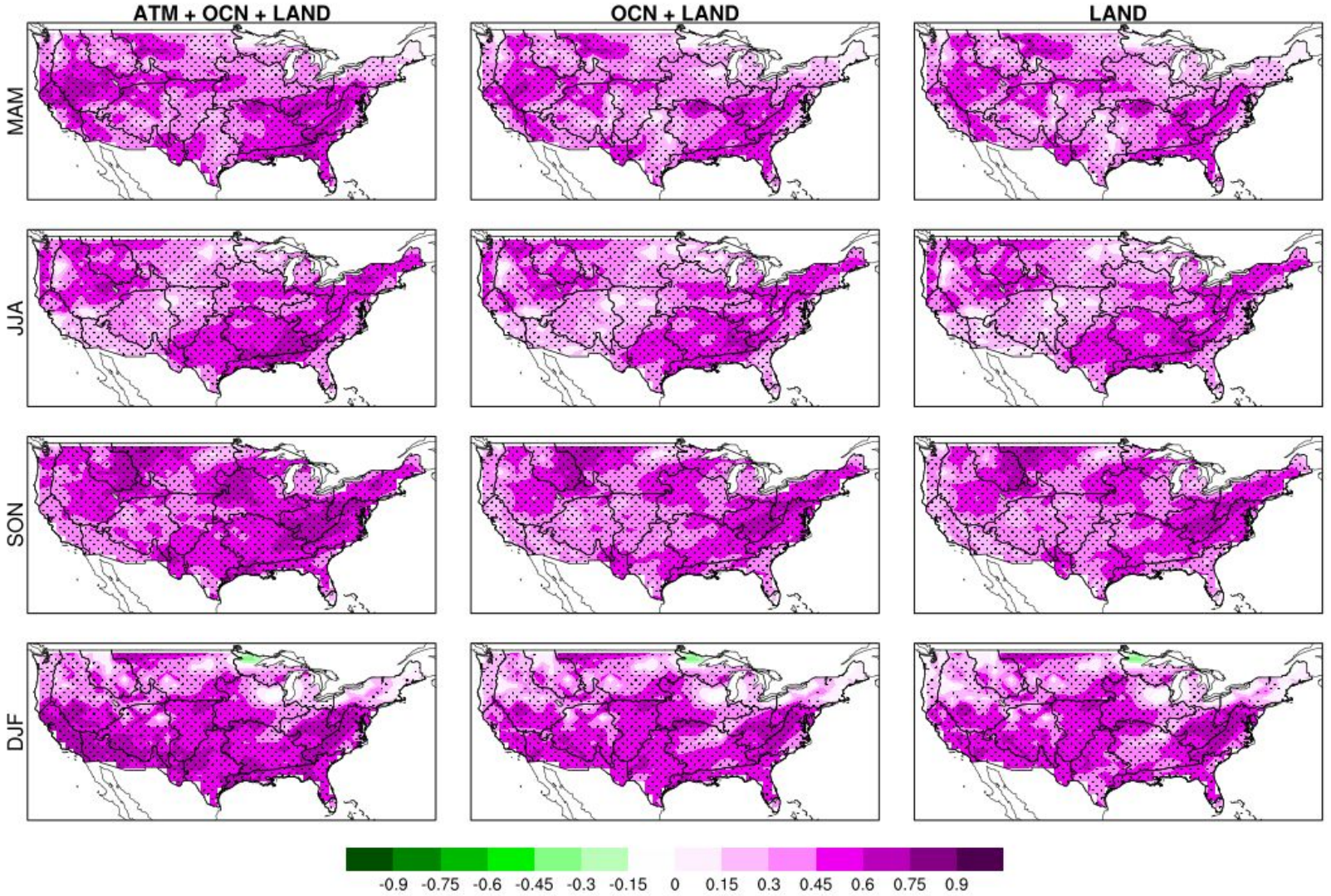
weakest using ERA5, and highest for MEERA2



Week 3 to 4 root zone soil moisture anomaly correlation

Duan et al. (in prep.)

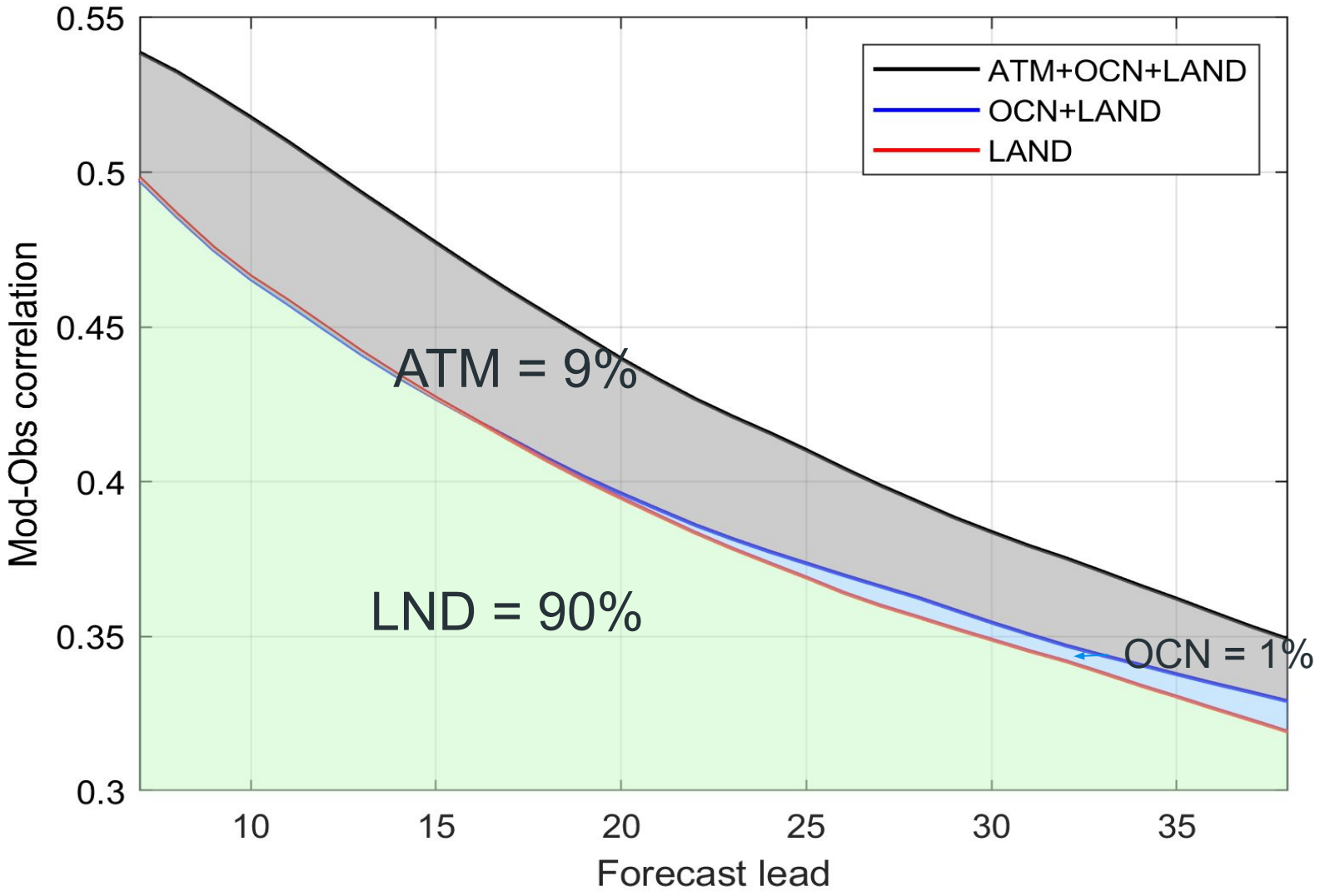
Result 2: One source removal experiment shows the highest contribution from the LND



Week 3 to 4 root zone soil moisture anomaly correlation

Duan et al. (in prep.)

Ninety percent of total predictability is coming from the LND initialization in an agriculturally dominated ecoregion (Eco # 6)



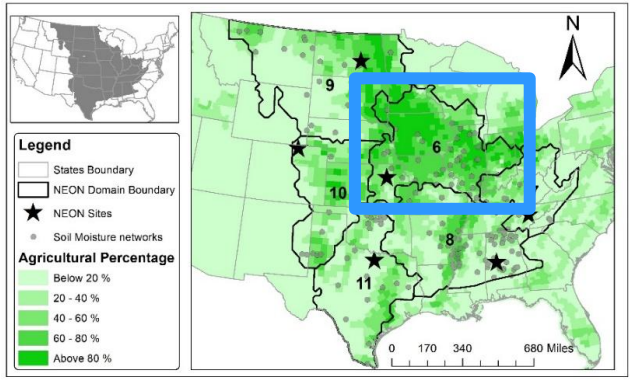
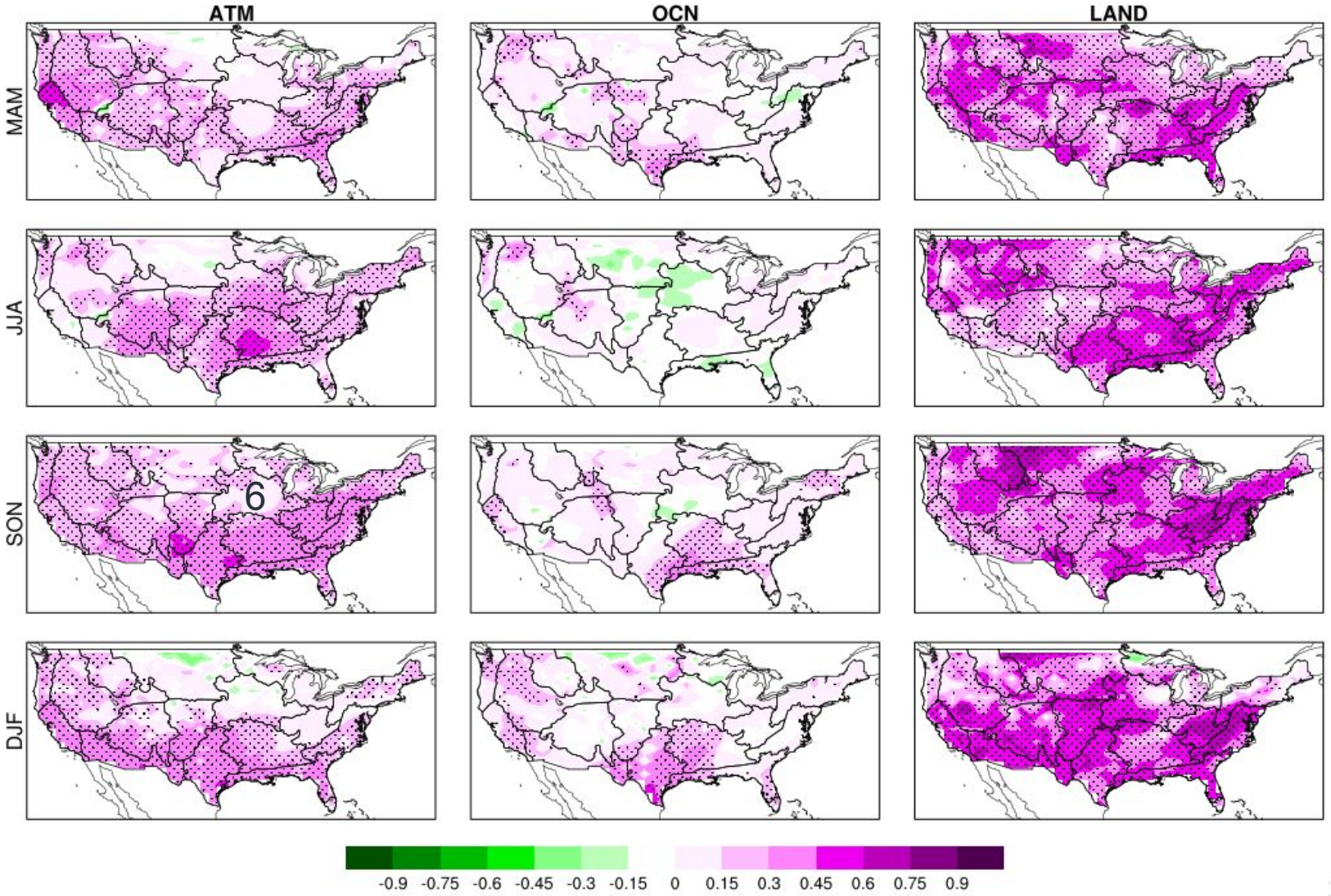


Figure credit: Thomas Kavoo (Auburn U.)

Duan et al. (in prep.)

Result 3: One source-only SubX experiment confirms the highest contribution from the LND source



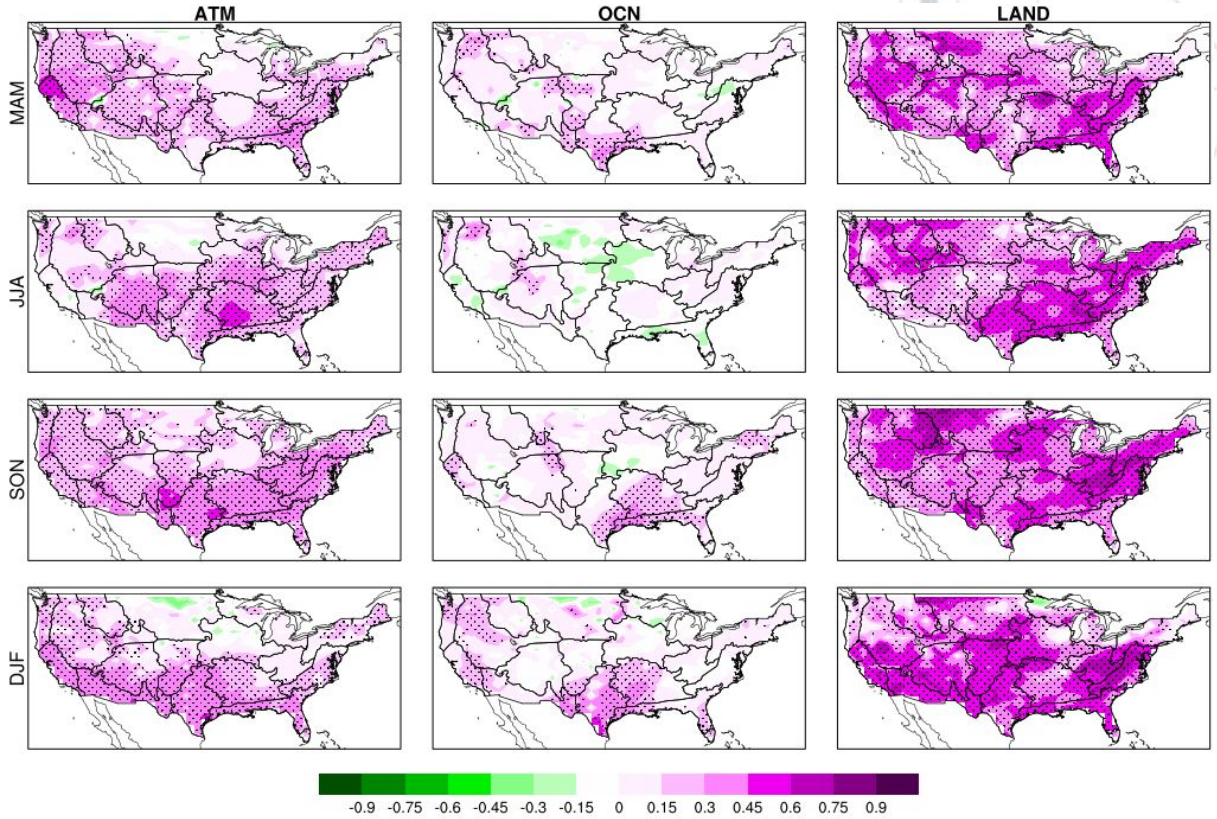
Week 3 to 4 root zone soil moisture anomaly correlation

Duan et al. (in prep.)

Conclusion and Implication

1. LAND initializations contribute **most** (90%) to the soil moisture forecast skill at the sub-seasonal time scale.

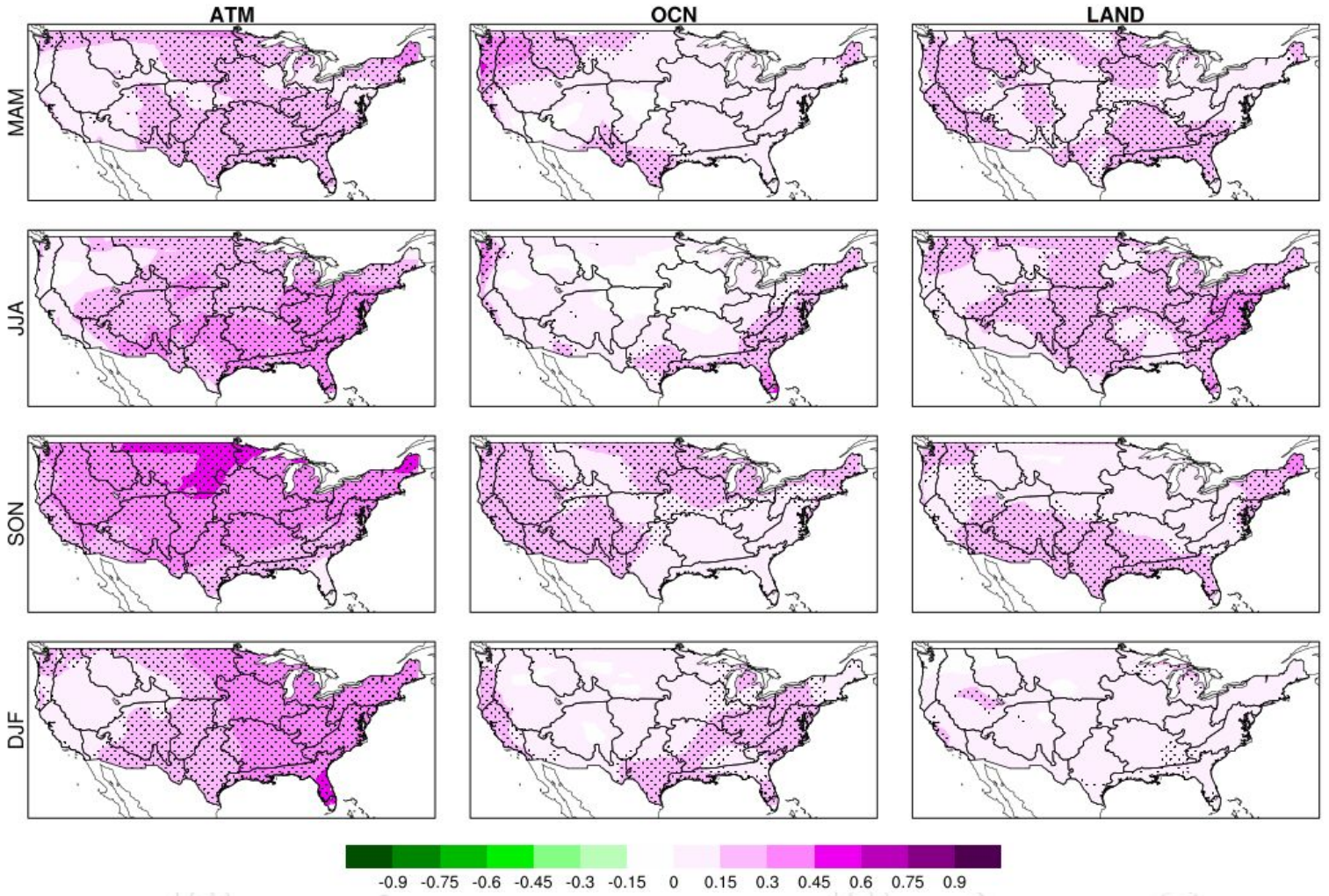
2. Implications – Observationally constrained **LAND initialization is necessary** for improving forecast skills in agricultural applications



Week 3 to 4 root zone soil moisture anomaly correlation

Duan et al. (in prep.)

Additional slide
Reconciling the previous results
ATM contributes most to the near-surface air temperature SubX forecast

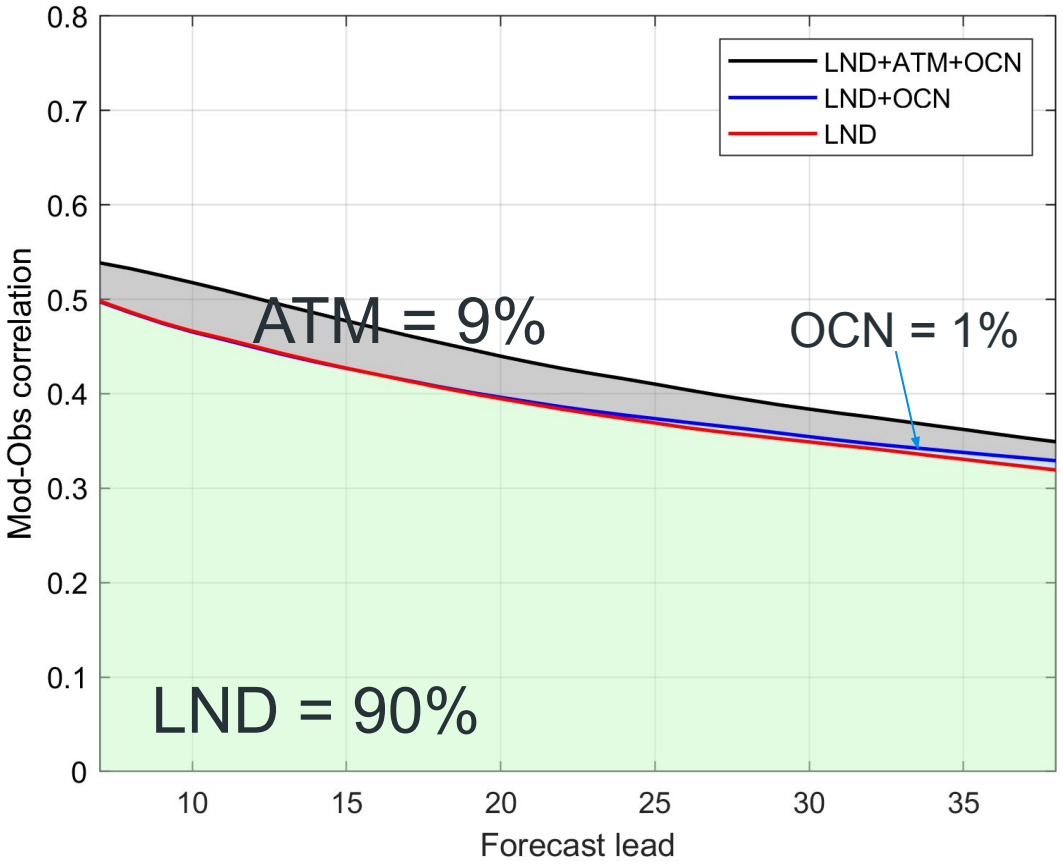


Week 3 to 4 near-surface temperature anomaly correlation

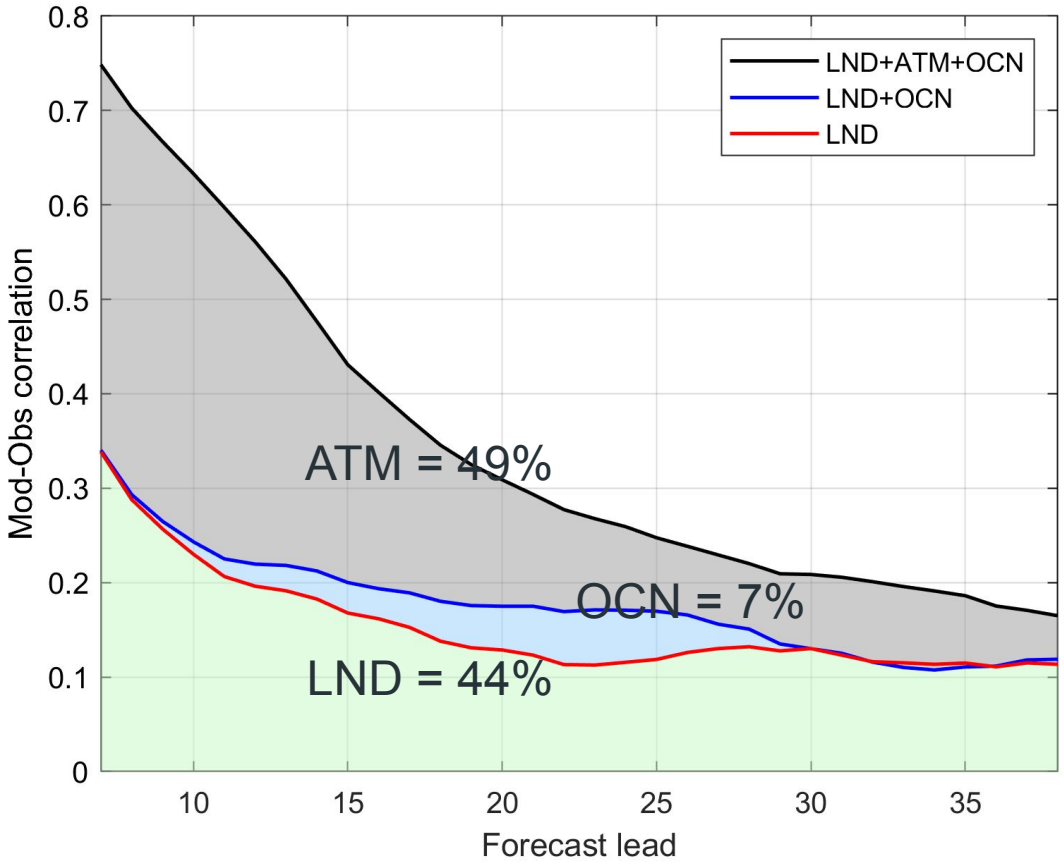
Duan et al. (in prep.)

Comparison of the predictability sources between soil moisture and surface temperature in agricultural region (Eco # 6)

Soil Moisture



2-m air temperature



Duan et al. (in prep.)

Extra slide: Correlation of CAM6 week 1-2 surface temperature