Seasonal to Multi-Year Soil Moisture Drought Forecasting

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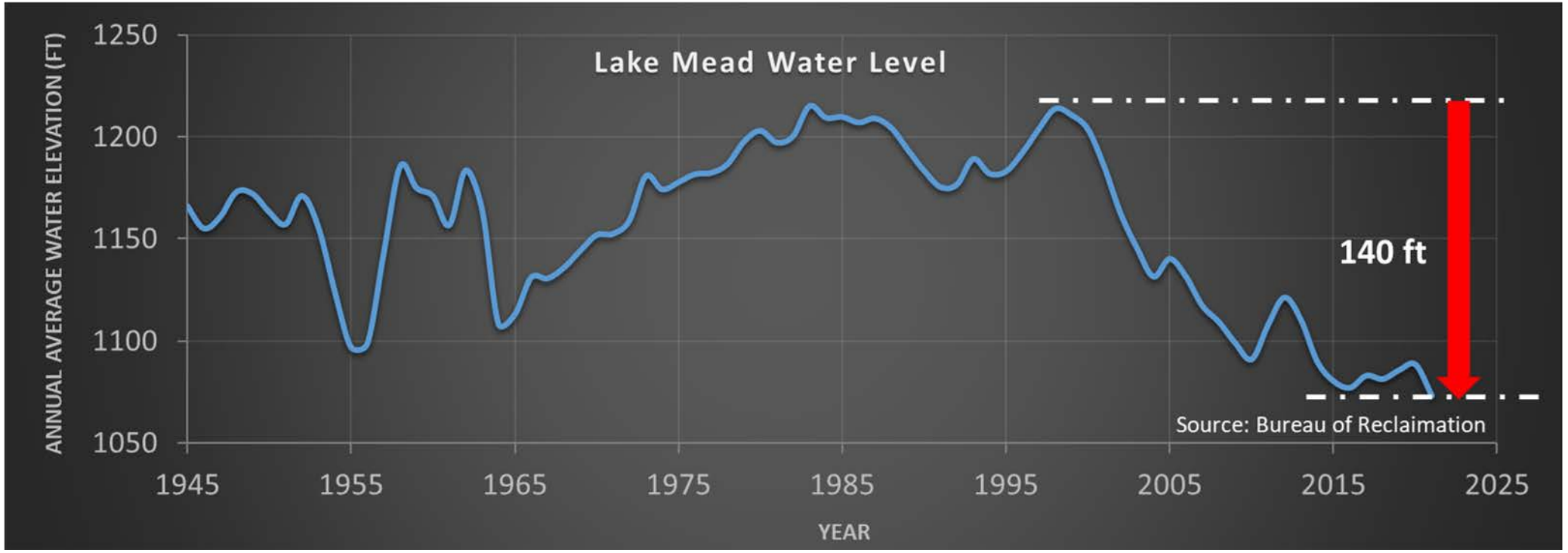
Poster by **Newman, M.**, Potential reemergence of soil moisture anomalies in North America. (Day 2 session in the workshop)

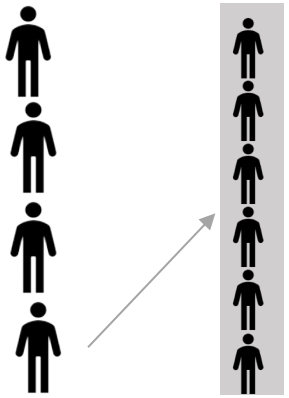
Esit, M., S. Kumar, A. Pandey, D. M. Lawrence, I. Rangwala, and S. Yeager, 2021: Seasonal to multi-year soil moisture drought forecasting. ***npj Climate and Atmospheric Science***, **4,** 16.

Kumar, S., M. Newman, Y. Wang, and B. Livneh, 2019: Potential reemergence of seasonal soil moisture anomalies in North America. ***J Climate***, **32,** 2707-2734.

Kumar, S., and Coauthors, 2020: The GLACE-Hydrology Experiment: Effects of Land-Atmosphere Coupling on Soil Moisture Variability and Predictability. ***J Climate***, **33,** 6511-6529.

Long-term (1998-present) drought in the US Southwest





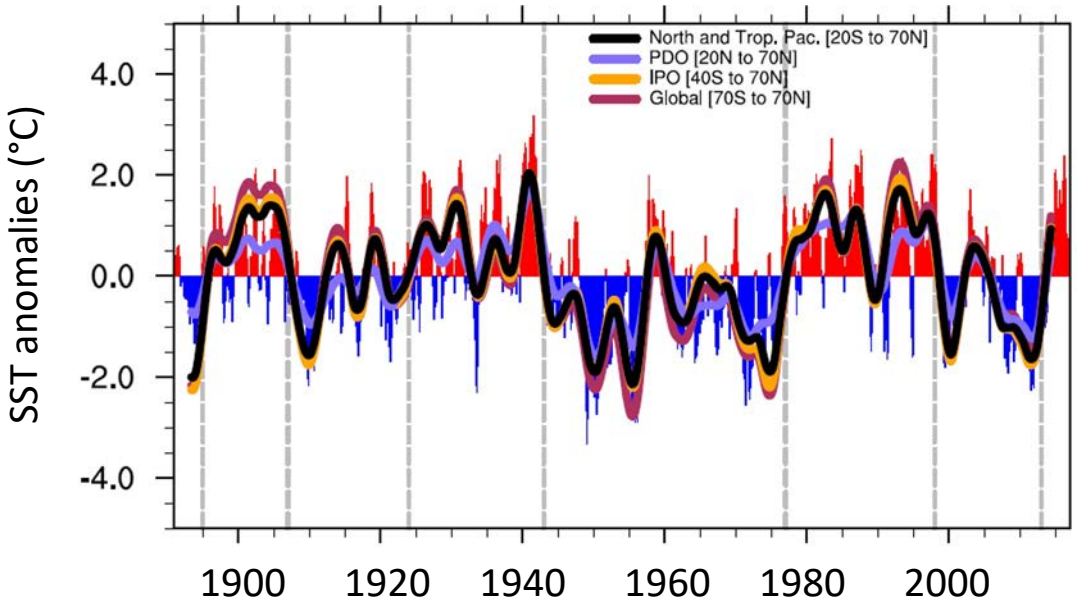
4 X 6 = 24
person height

Annual average water level in Lake Mead at Hoover Dam (Source: Bureau of Reclamation).

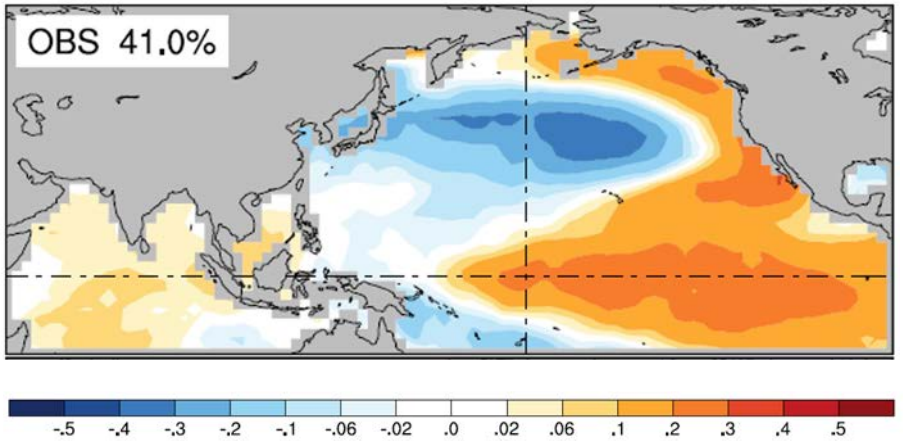
Long-term drought – remote oceanic forcing hypothesis

Long-term hydroclimate variability is remotely forced via atmospheric teleconnections driven by more slowly-varying ocean anomalies in the Pacific

(a) Pacific Climate Variability



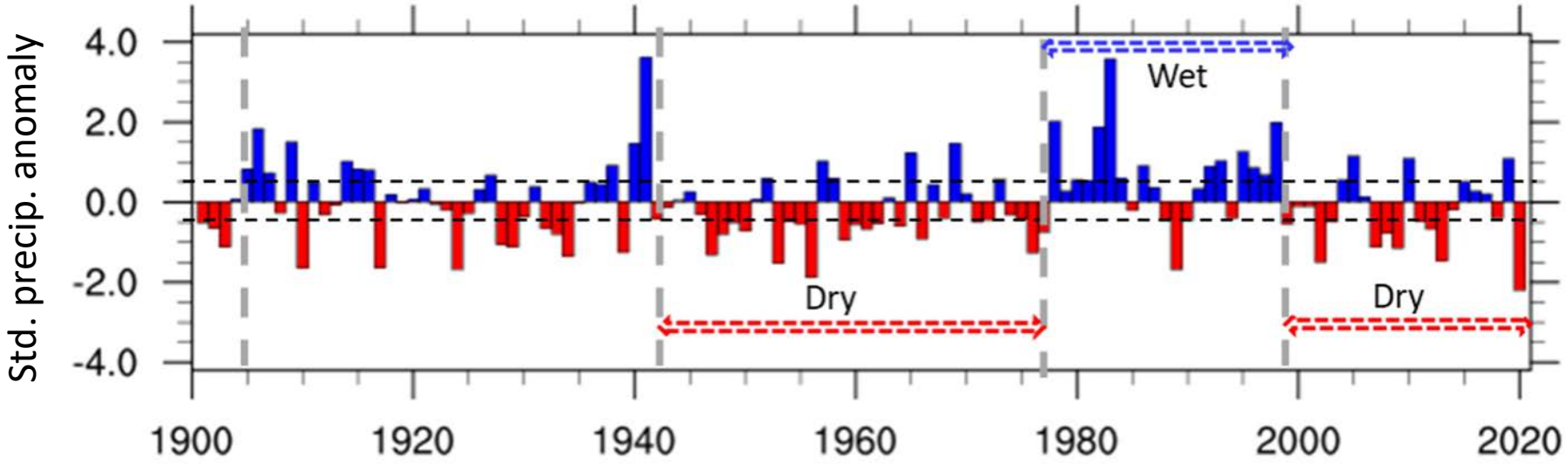
(b) Spatial pattern of EOF1



Kumar and Newman (in prep.)

Long-term drought – land process integration hypothesis

Land processes integrates or *reddens* remote forcing, e.g., ENSO to produce long-term drought

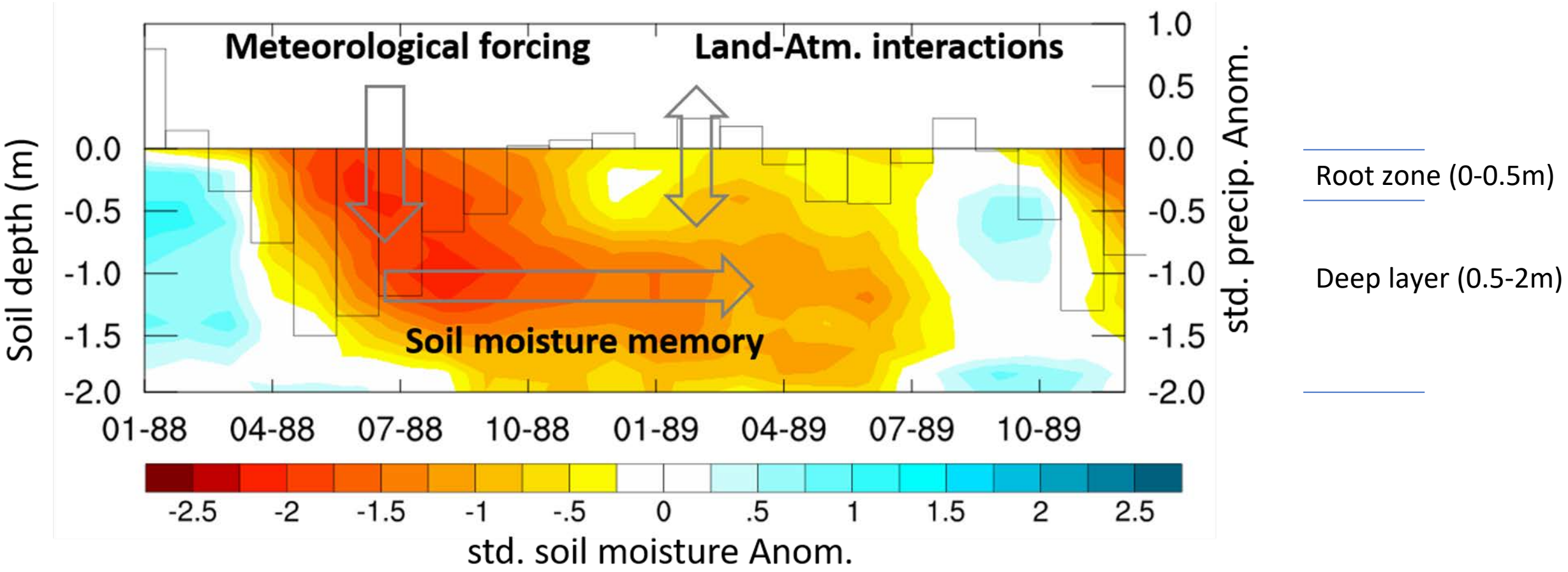


Why?

Standardized annual precipitation anomalies in the U.S, Southwest [31.5 to 42.0N, and 235.6 to 257E]. Data is from Climate Research Unit time series version 4 from 1901 to 2020.

How? What are the implications?

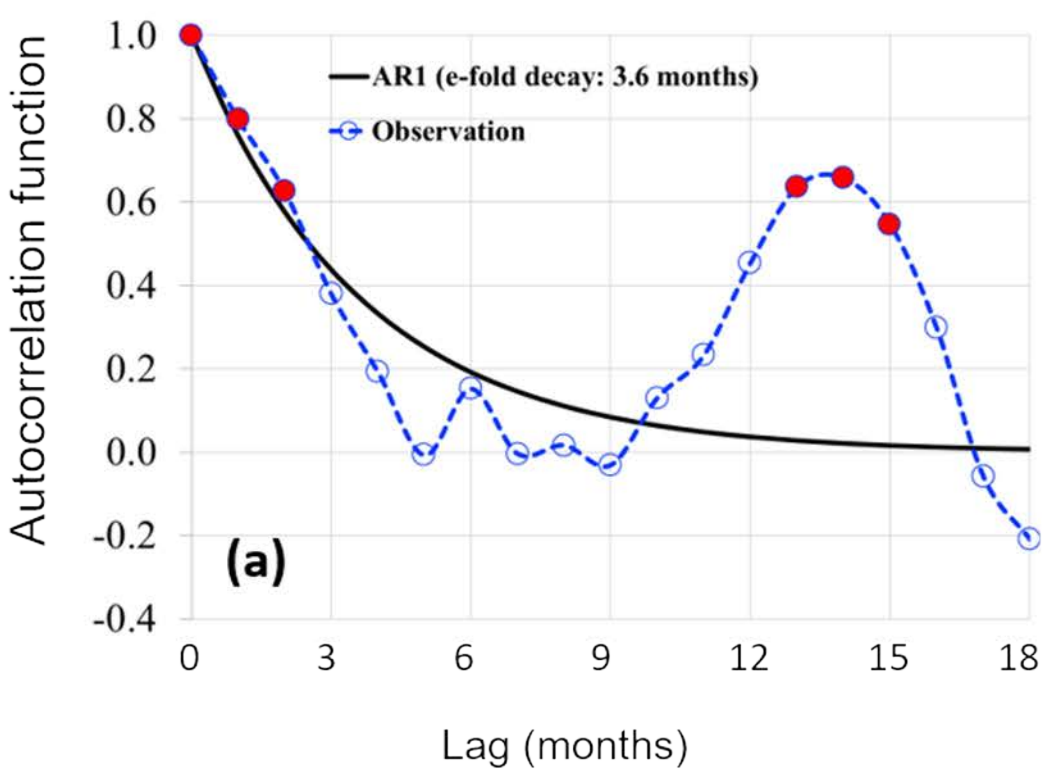
Soil moisture reemergence

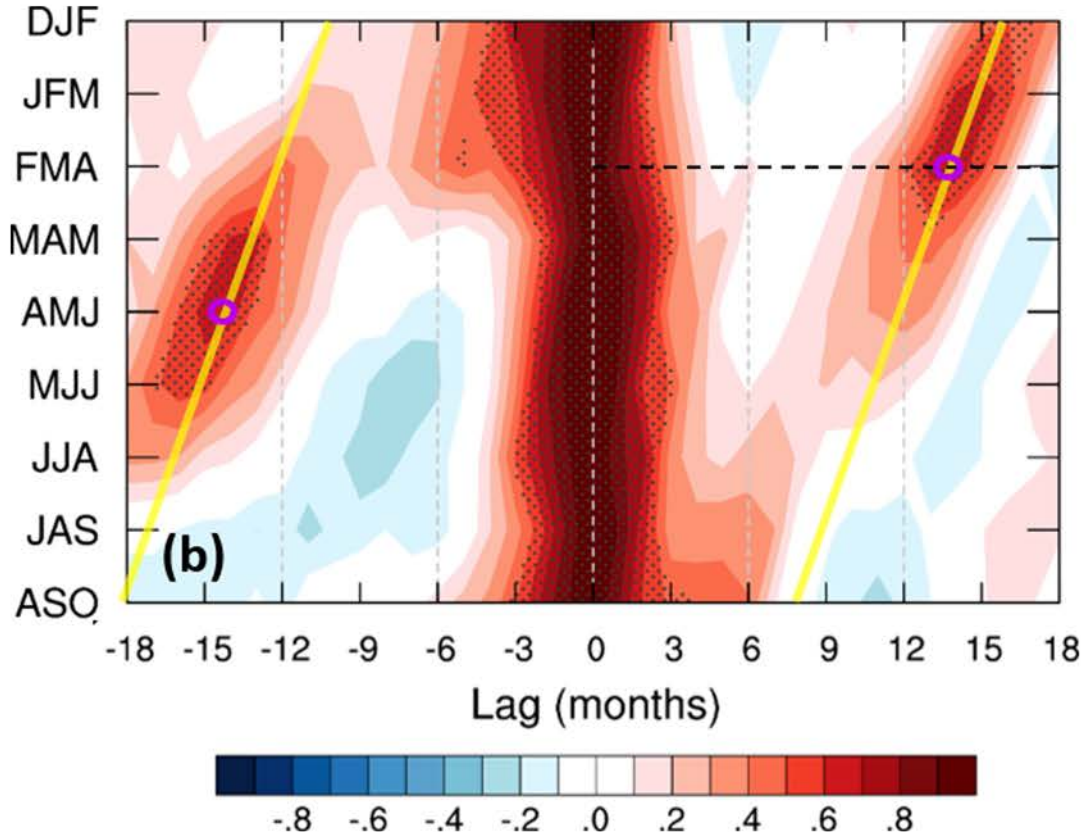


Precipitation (bars) and soil moisture standardized anomalies (color contour) during 1988 drought in Illinois observations

Kumar, Newman et al., 2019 (JCLIM)

Soil moisture reemergence can provide predictability at inter-annual time scale

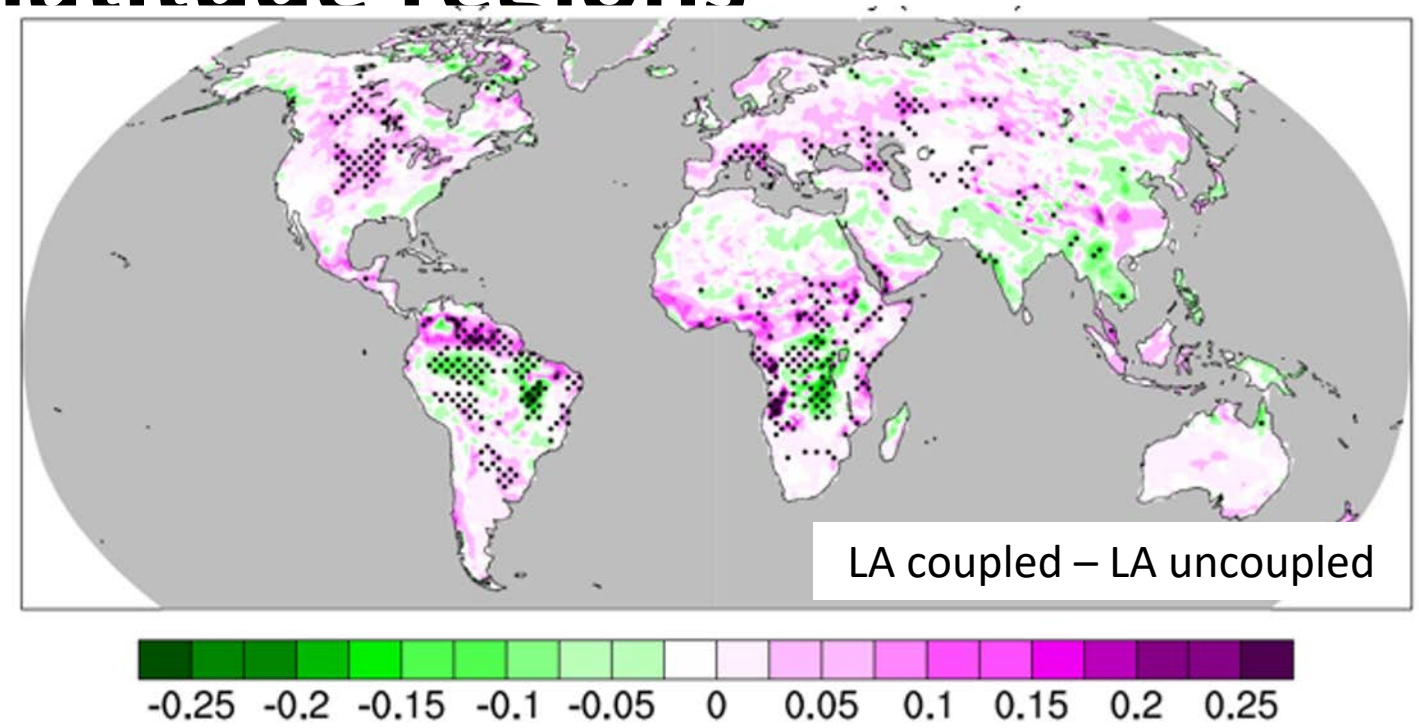




Root zone (0-0.5m) soil moisture anomaly correlations in Illinois Climate Network observations

Kumar, Newman et al., 2019 (JCLIM)

Land-Atmosphere (LA) coupling feedback increases soil moisture memory in the mid-latitude regions

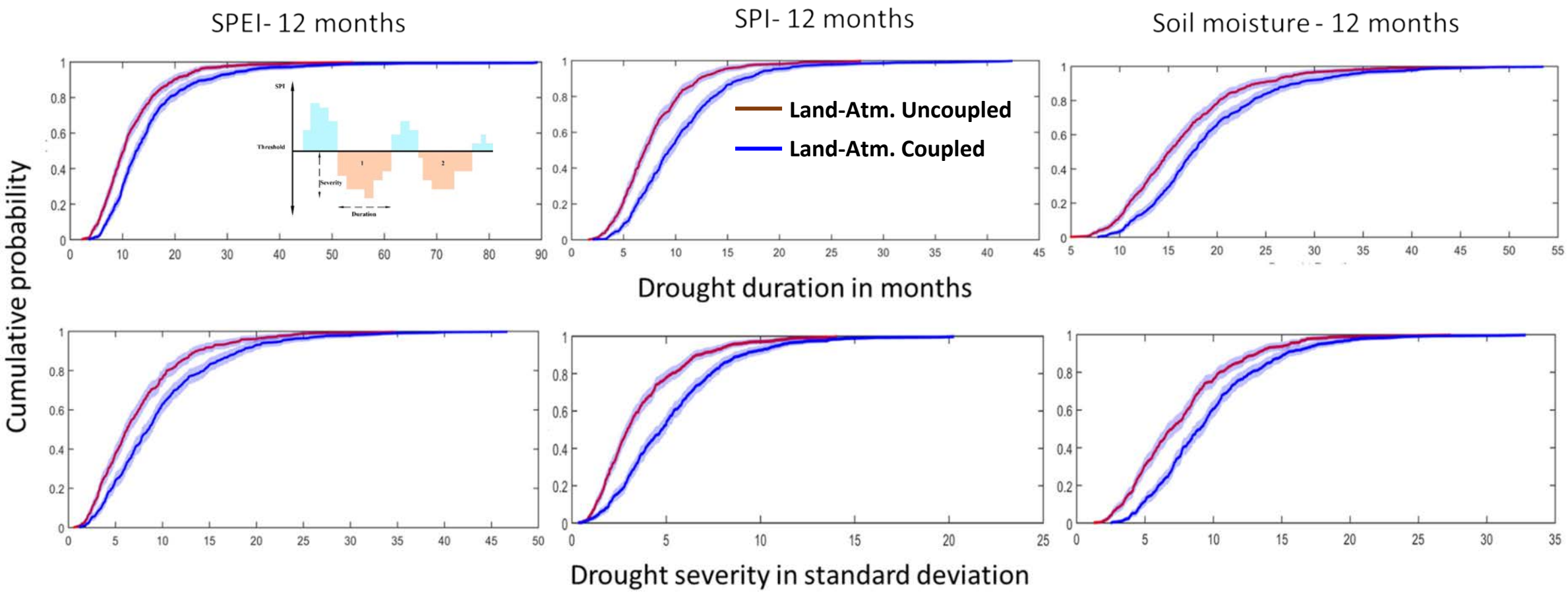


A first-order effect: ***land-atmosphere coupling decreases the humidity gradient between the land and the atmosphere.*** Therefore, it decreases the water flow rate between land and atmosphere; and increases the memory.

Root zone (0-0.5m) soil moisture lag1 autocorrelation difference between LA coupled and uncoupled experiment (ensemble size = 10)

Kumar et al., 2020 (JCLIM)

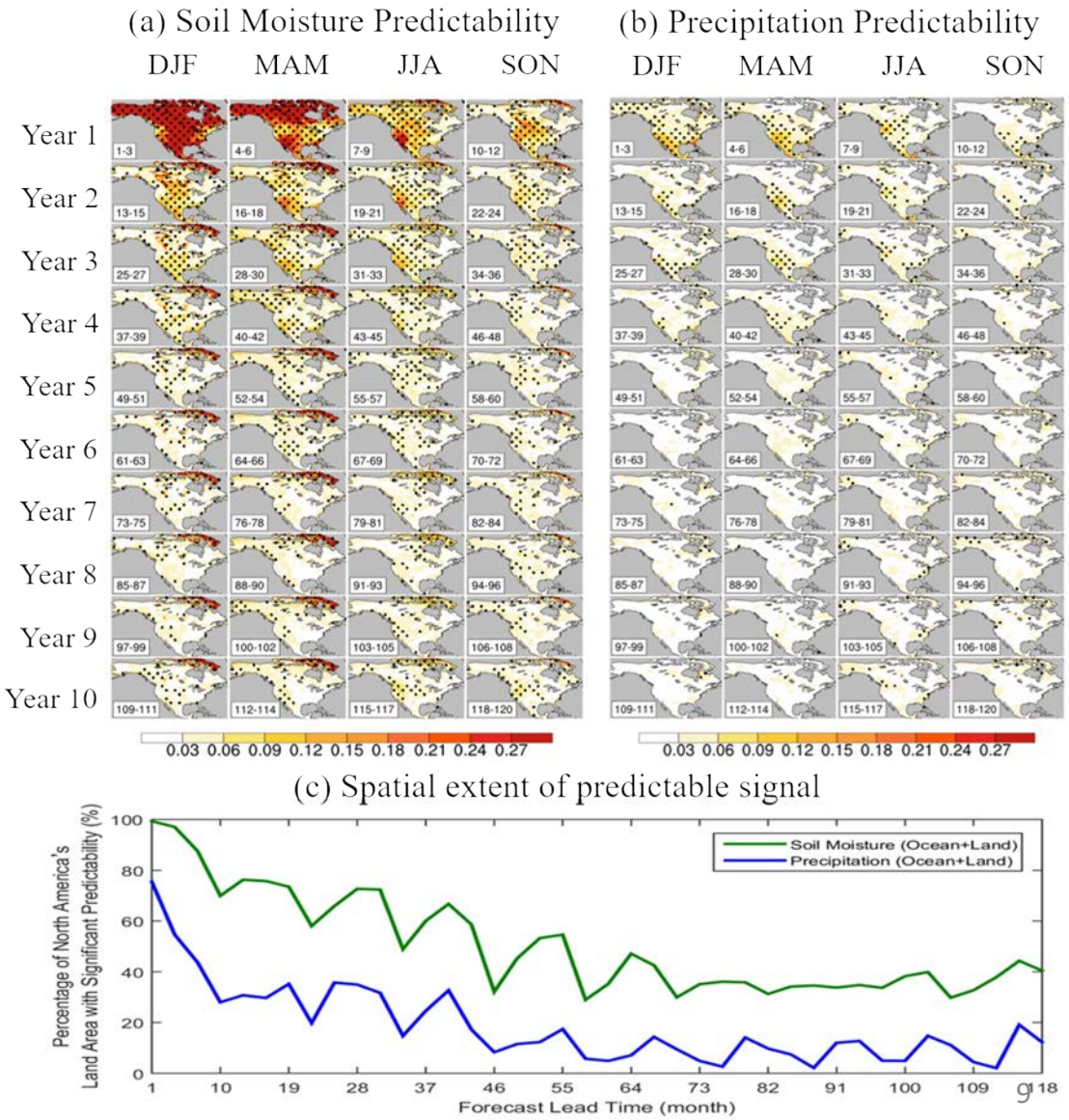
Land-Atmosphere (LA) coupling feedback can make longer and more severe drought in the Great Plains



Esit and Kumar (in prep.)

Soil moisture predictability in the latest generation of climate and earth system model

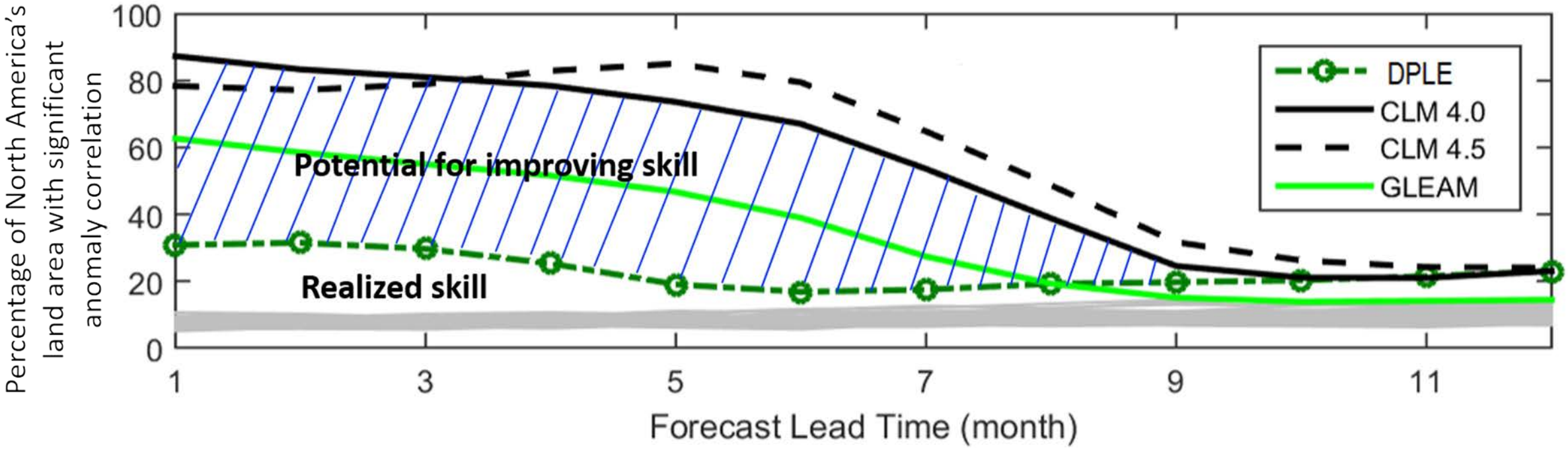
- CESM Decadal Prediction Large Ensemble (DPLE) (Yeager et al., 2018)
- Signal-to-noise ratio metric
- Spatial extent where statistically significant signals are found in North America
- The spatial extent of the statistically significant signal is <u>three times greater for soil moisture than for precipitation</u>.



Esit, Kumar et al., 2021 (NPJ Climate Sci.)

Have we reached the upper limit of the forecast skill? Answer - NO

Root zone soil moisture anomaly correlation with the initial condition total soil moisture



Effects of land initialization on soil moisture forecasts in the decadal prediction system (DPLE) with that of the observational estimates from CLM4.0, CLM4.5, and GLEAM.

Gray lines are random land initial conditions

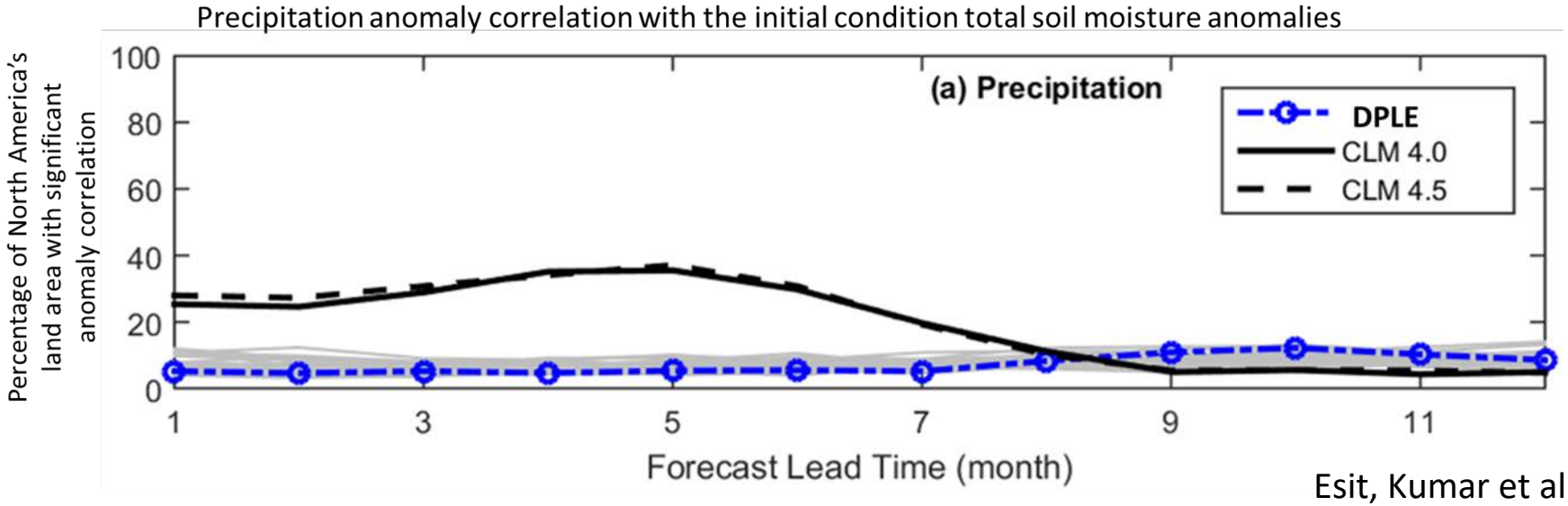
Esit, Kumar et al., 2021 (NPJ Climate Sci.)

Summary

1. Land processes and its interactions with the atmosphere, e.g., soil moisture memory and reemergence can improve drought forecasts at seasonal to muti-year time scales

1. Land-Atmosphere coupling feedback is under-represented in the latest climate and earth system prediction system

1. Measurements of land surface memory reservoir, e.g., deep layer soil moisture (0.5 to 2m) are needed to constrain long-term drought processes in climate models.



Esit, Kumar et al., 2021 (NPJ Climate Sci.)