# The Influence of Land-Surface Conditions on the 2020-21 Western US Drought

## 2024 DOE EESM PI Meeting

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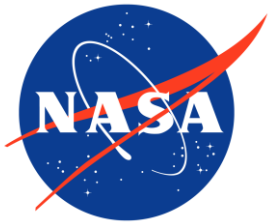
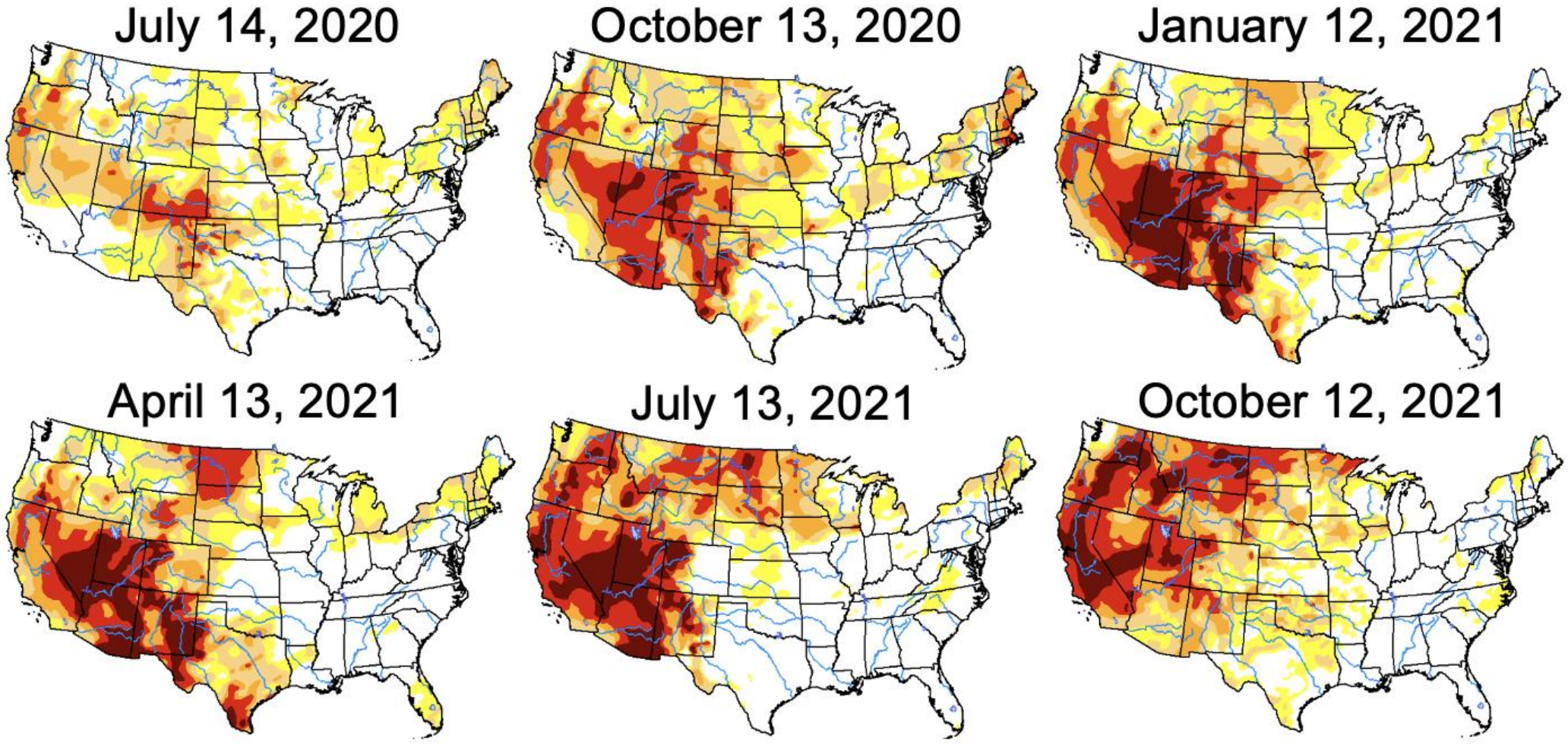
Bethesda, Maryland

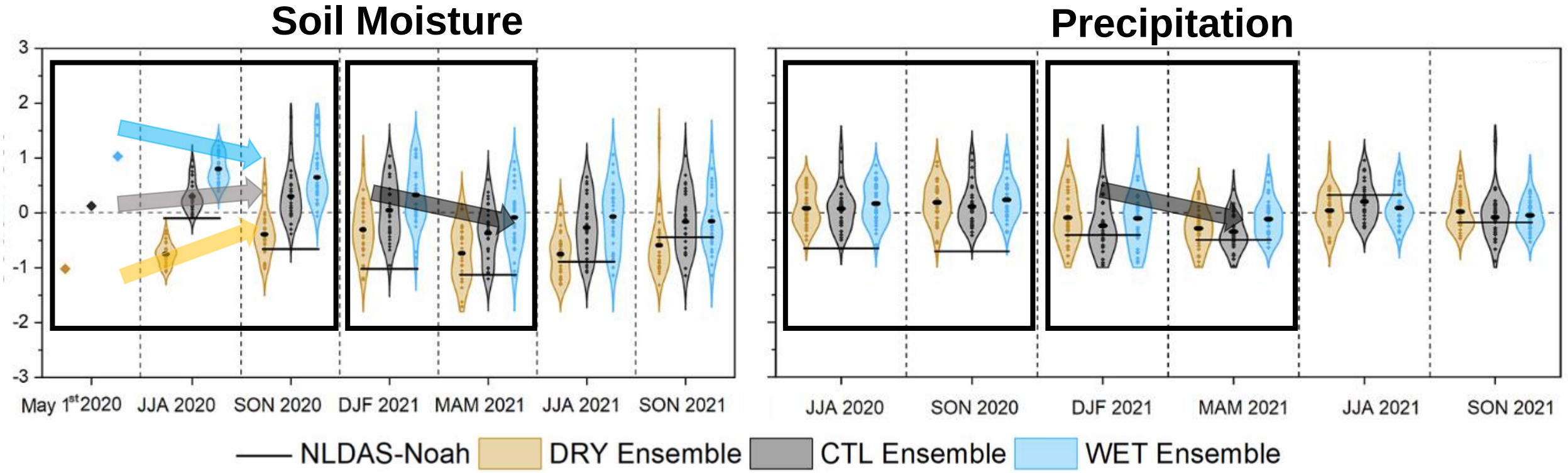


# 2020-21 Western US Drought



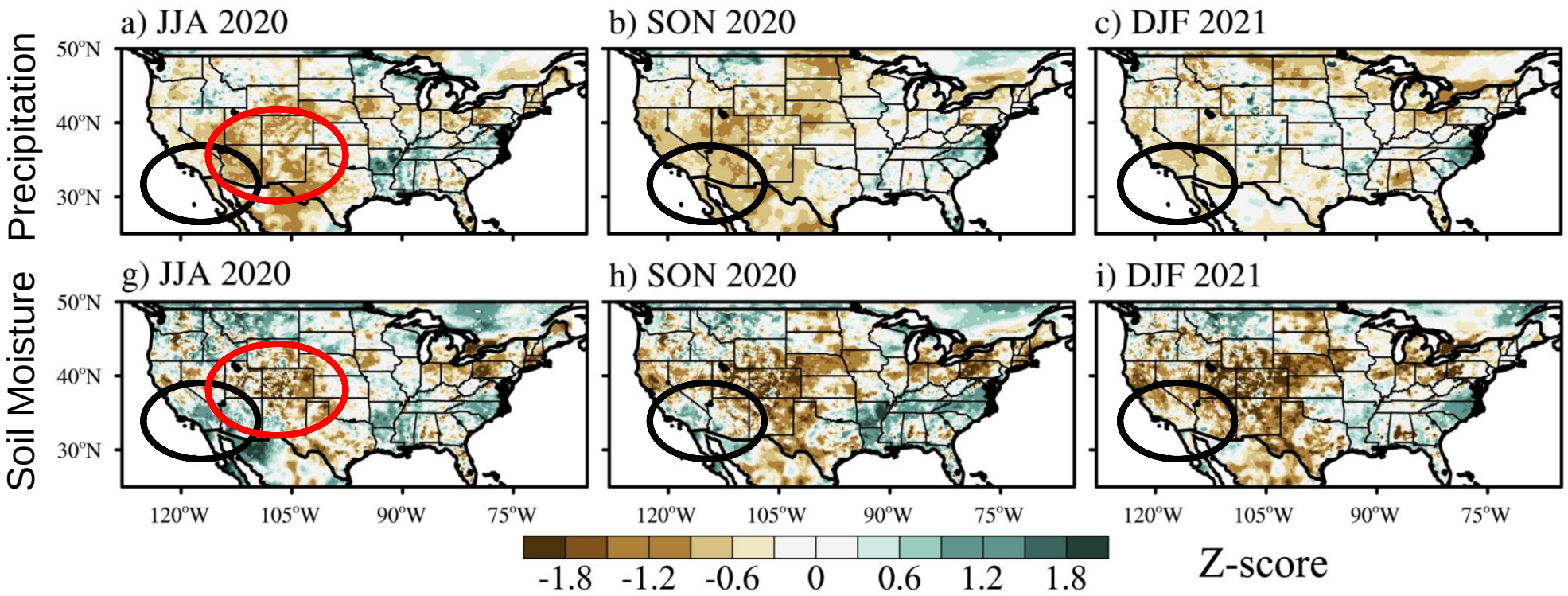

Credit: *US Drought Monitor*

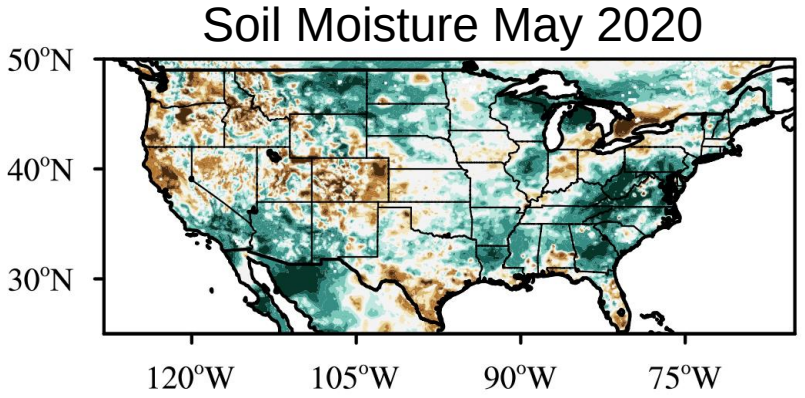
# Simulated Impacts of Initial Soil Moisture




- Wetter soil: delay or even nullify the impact of La Niña-driven meteorological droughts
- Drier soil: more severe, persistent, and impactful soil droughts

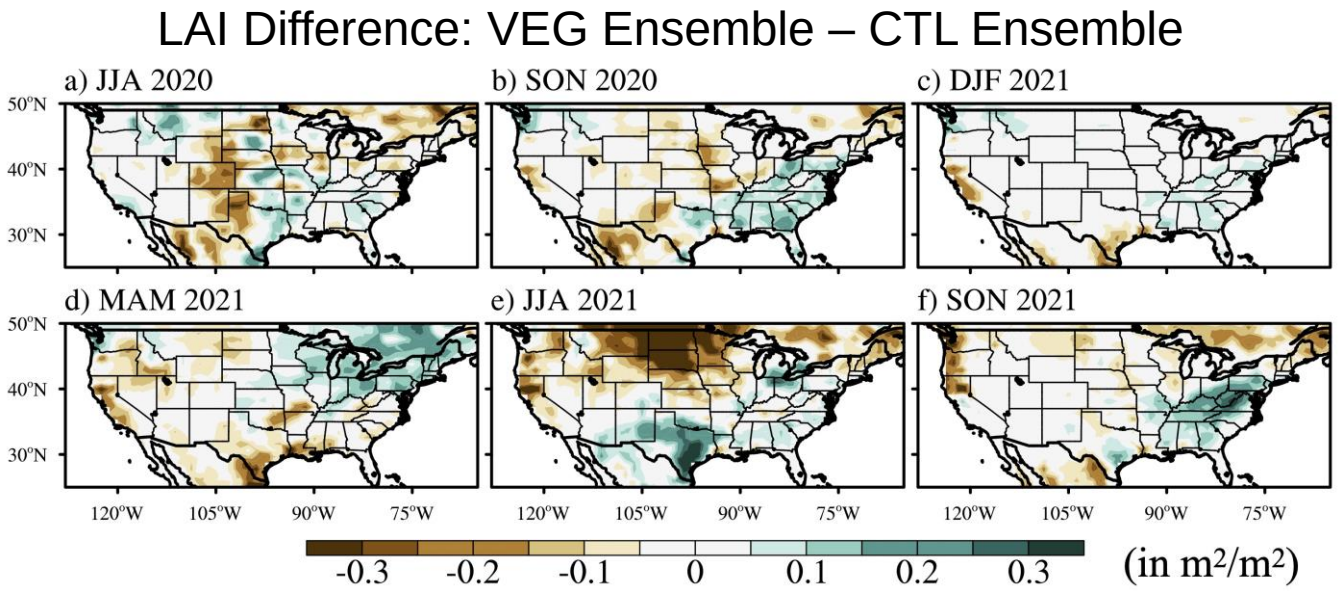
# Observational Evidence for Soil Moisture Impact

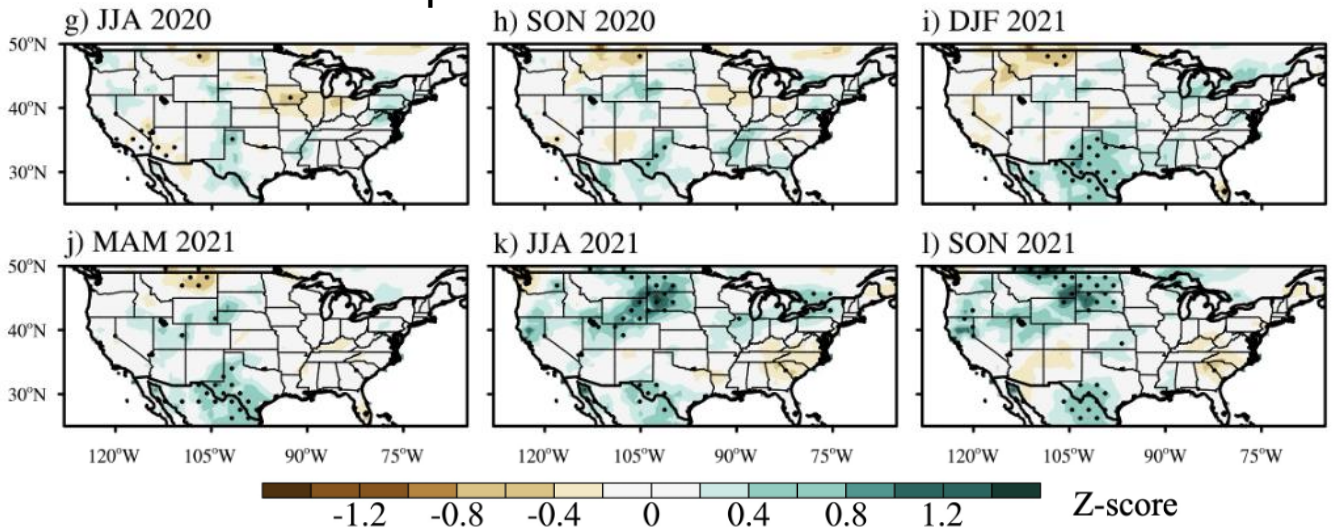


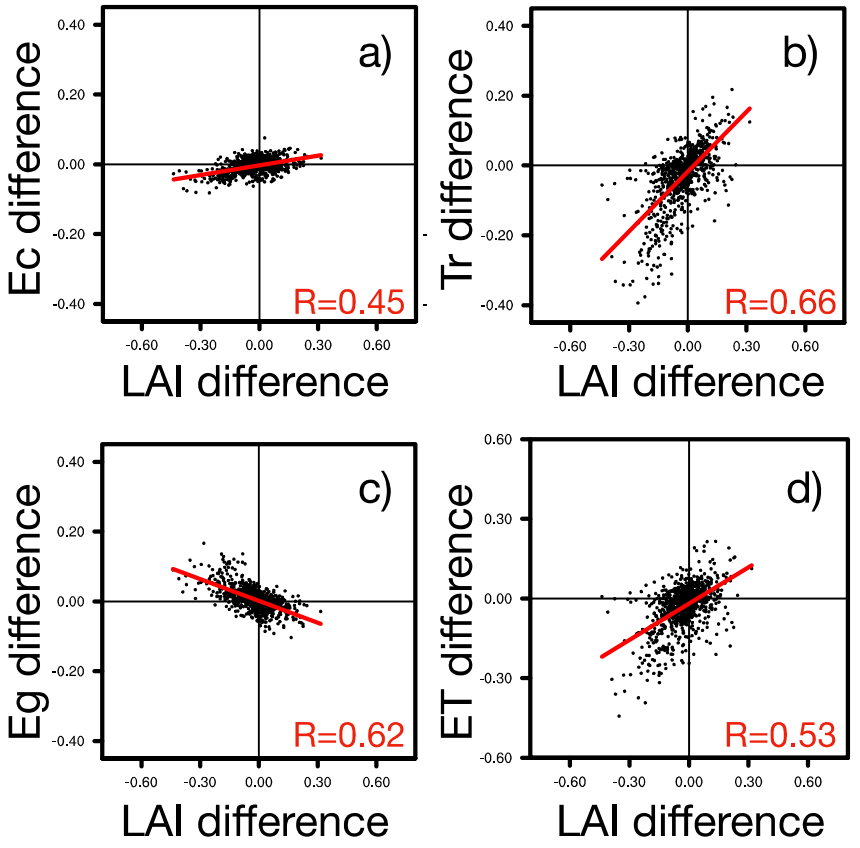




- Southern California: did not emerge until DJF 2021
- Northern California, Nevada, Texas, and the Four Corner states: initiated as early as JJA 2020

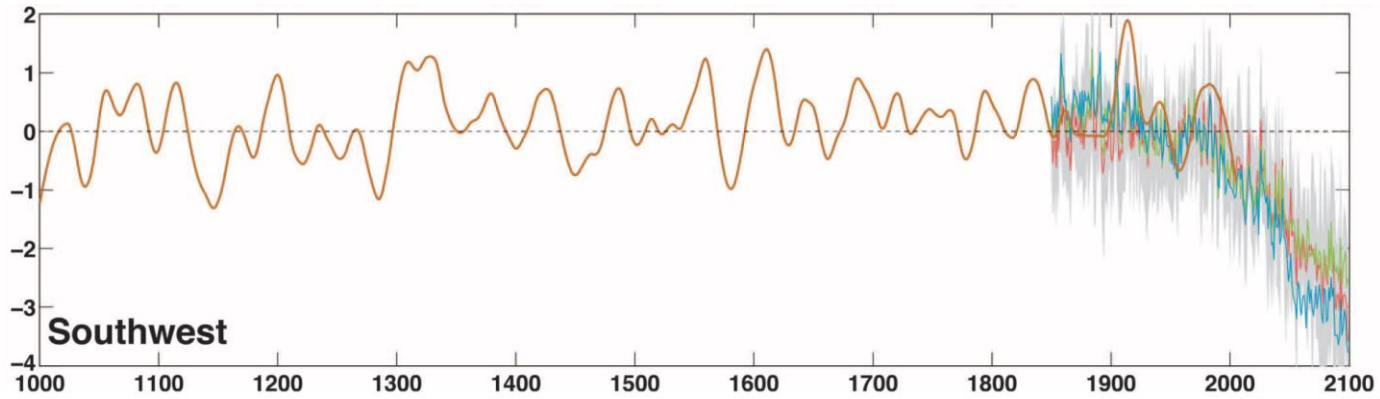
# Simulated Impacts of Vegetation Variations



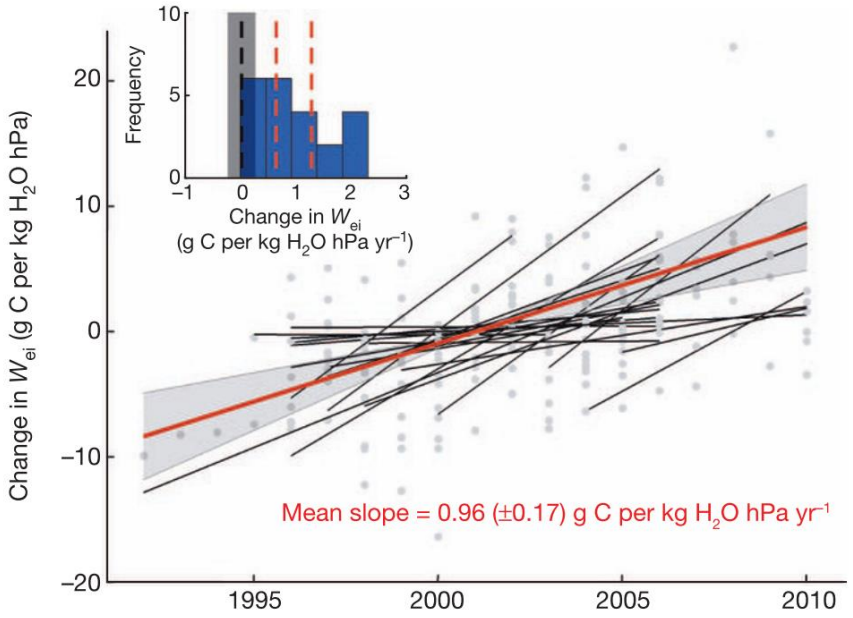



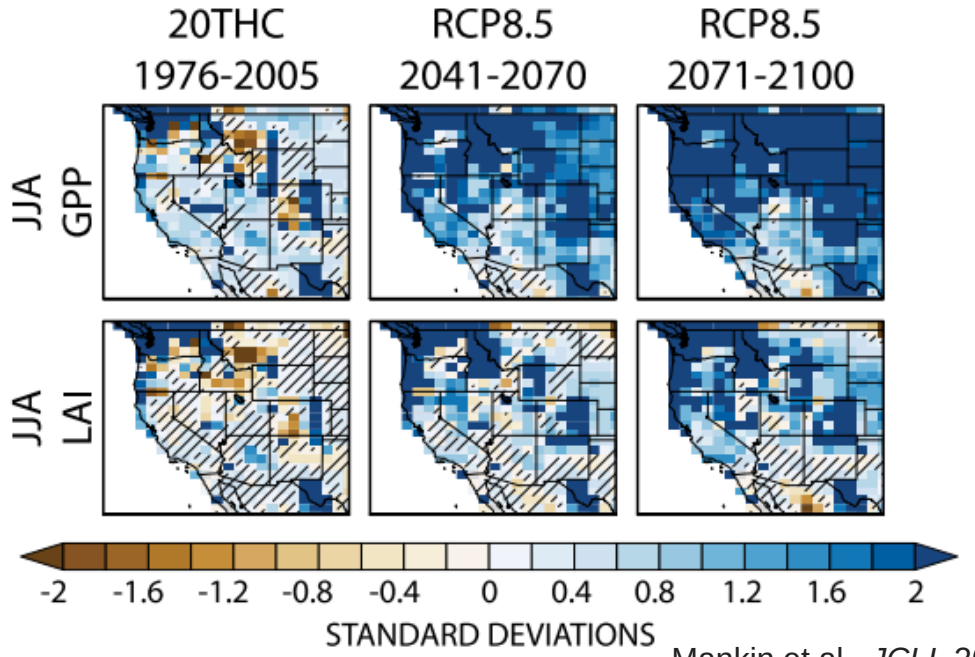
# Drier and Greener Western US in the Future




Cook, Ault & Smerdon, *Sci. Adv.,* 2015




Keenan et al., *Nature,* 2013




Mankin et al., *JCLI,* 2017

- Enhanced plant WUE due to the partial closure of leaf stomata in response to higher $CO_2$
- Accelerate the transition from meteorological to soil droughts, leading to more rapid, severe, and persistent soil droughts in the future

# Grand Challenges in Understanding and Simulating Vegetation Impact on Extremes

**1) Lack of long-term reliable observational records:**

- Satellite observations: Since the 1980s; Unreliable in cloudy and aerosol-heavy areas
- In-situ observations: Sparse distribution; No data in hard-to-access regions (e.g., Amazon)

**2) Insufficient detailed representation of sub-grid and grid level processes:**

- Absence of species-specific responses due to the use of aggregated PFTs
- Lack of representation of vegetation competition within grid cells
- Simplified soil-vegetation interactions (e.g., root dynamics, nutrient cycling)
- Difficulty in accurately capturing microclimate variations

**3) Uncertainties in future projections of vegetation:**

- Future socio-economic developments ($CO_2$ levels and Land-use practices)
- Decadal oceanic variability (PDO and AMO)
- Vegetation adaptations
- Nutrient limitations

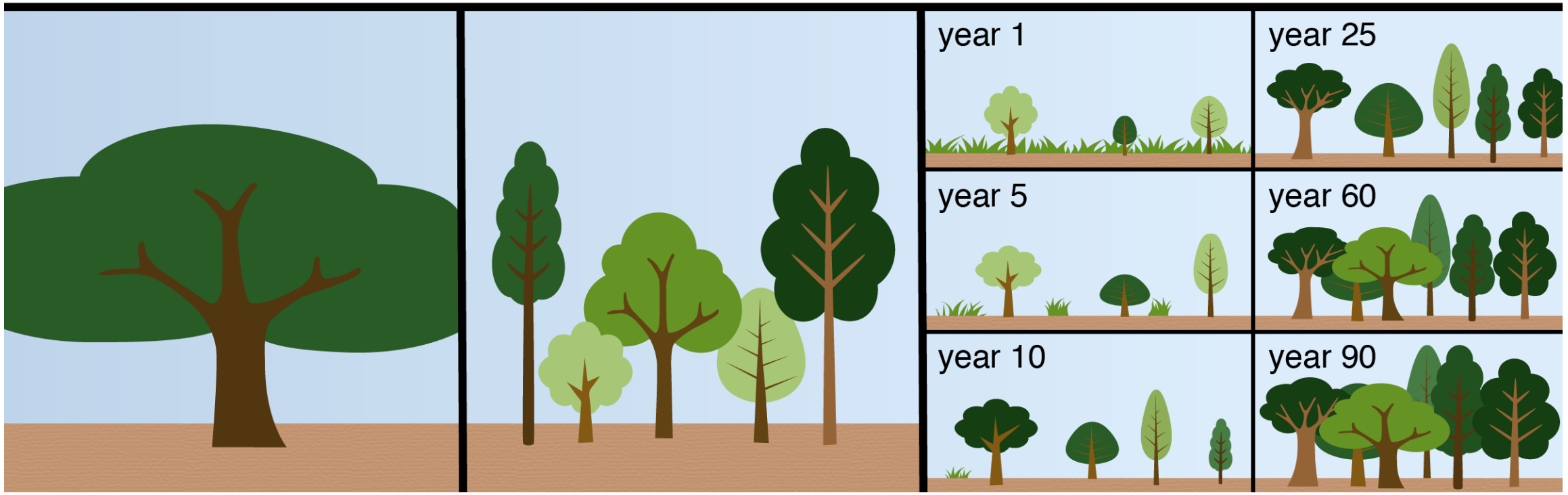
# The Current and Unique Strengths of DOE

## The Functionally Assembled Terrestrial Ecosystem Simulator (FATES)

**ELM**
"Big-Leaf" vegetation

**FATES**
Demographic vegetation

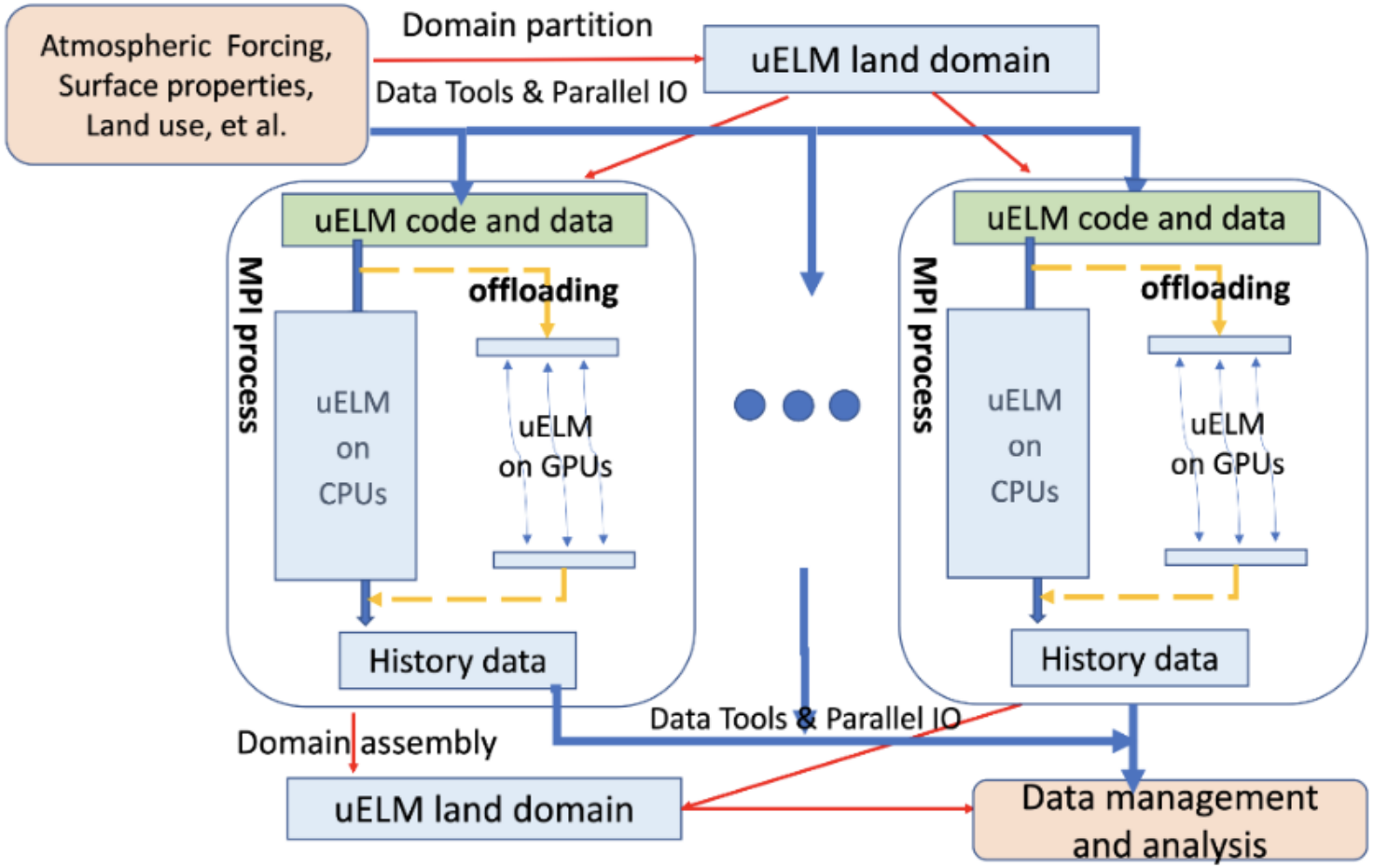
**ELM – FATES**
Patch and Cohort Dynamics




Credits: Jennifer Holm, LBNL

# THE CURRENT AND UNIQUE STRENGTHS OF DOE

## Ultrahigh Resolution ELM via GPUs




Wang et al., *CiSE,* 2022
E3SM Land Team, E3SM tutorial, 2024

# More Information

## Funded by RGMA Program: The Role of Vegetation in Past and Future Global Hydroclimatic Change

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