Soil Moisture Depletion Experiments to Study

Soil Moisture Teleconnections in the Western United States

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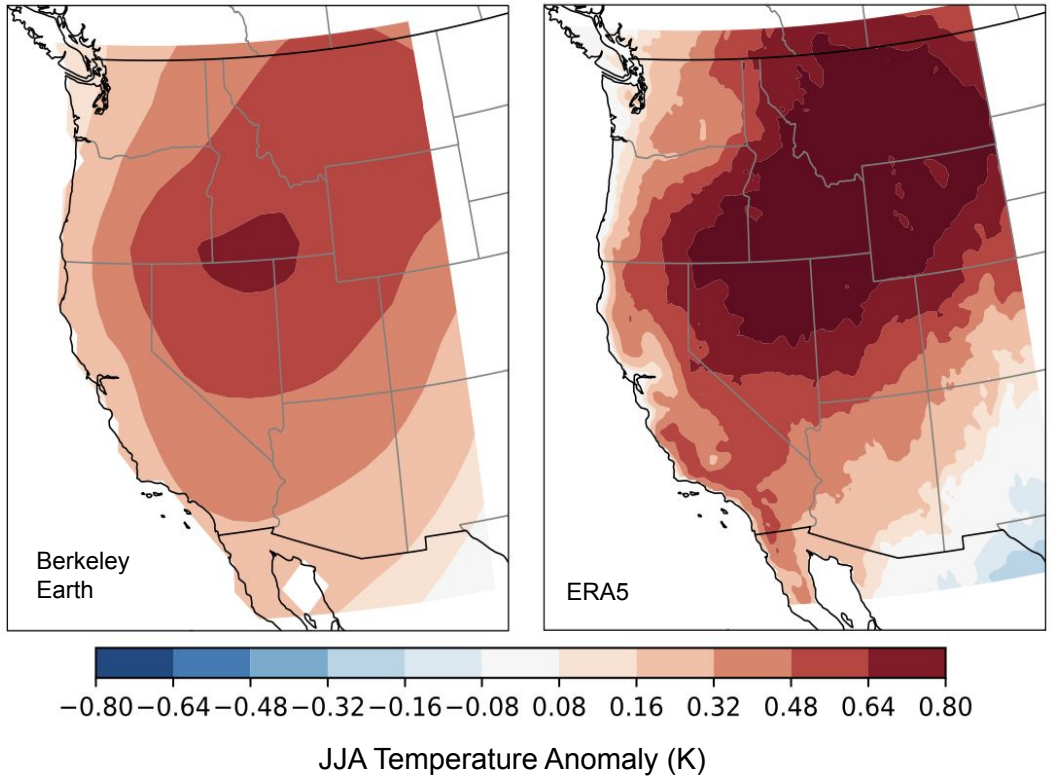
What Characterizes Summertime Climate in the Western United States?

The "Western US Summertime Temperature Pattern" (WUS-STP)

The leading pattern (EOF1) of summertime temperature variability



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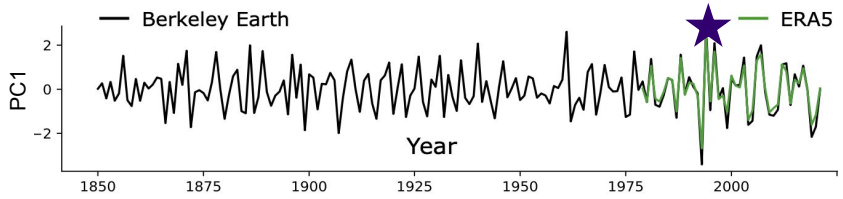

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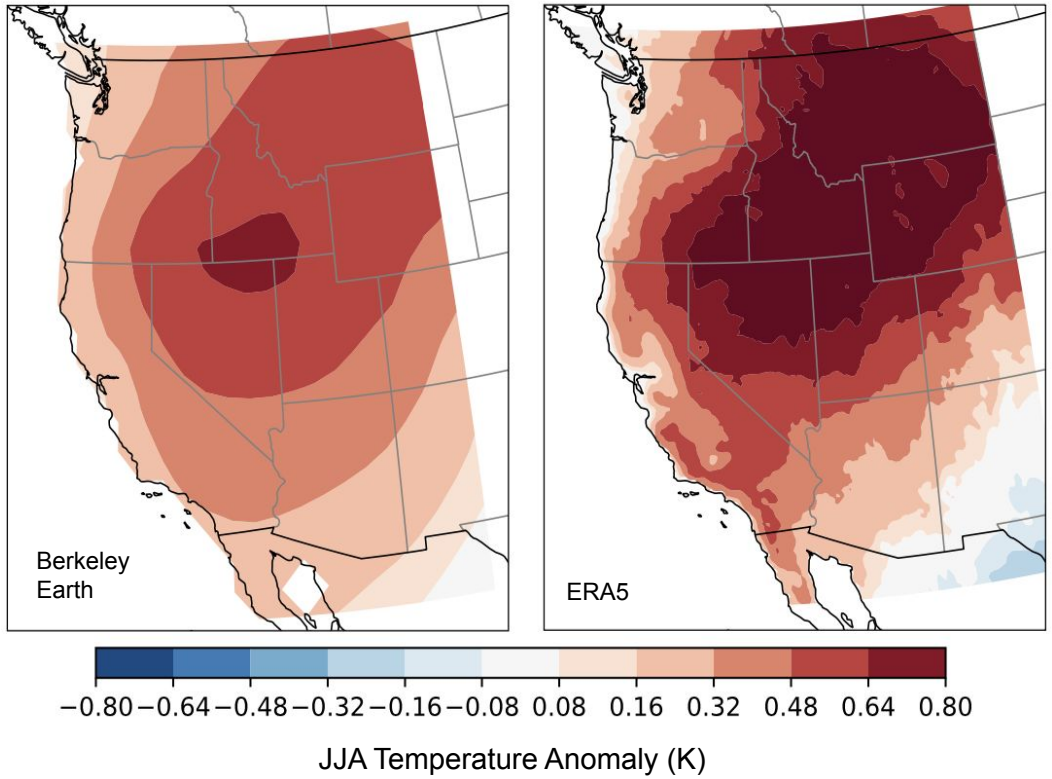

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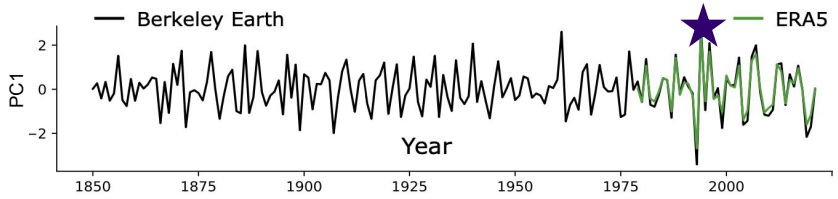

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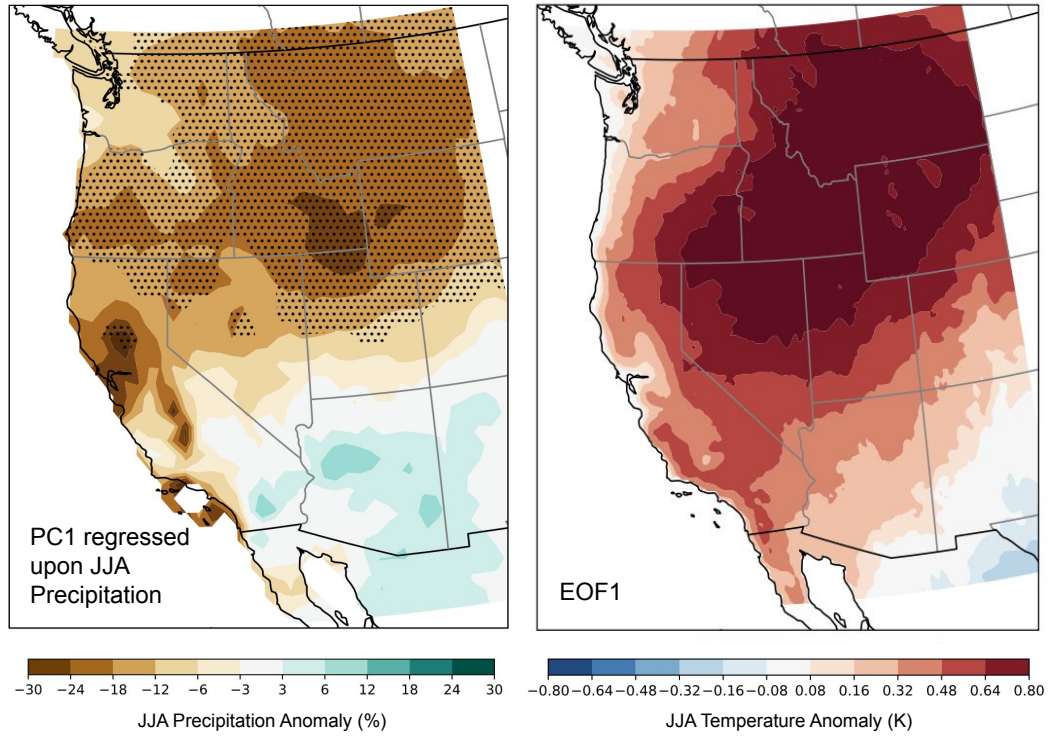

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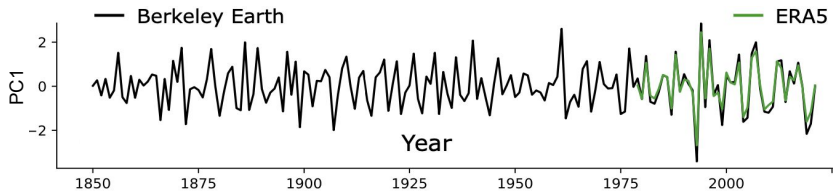

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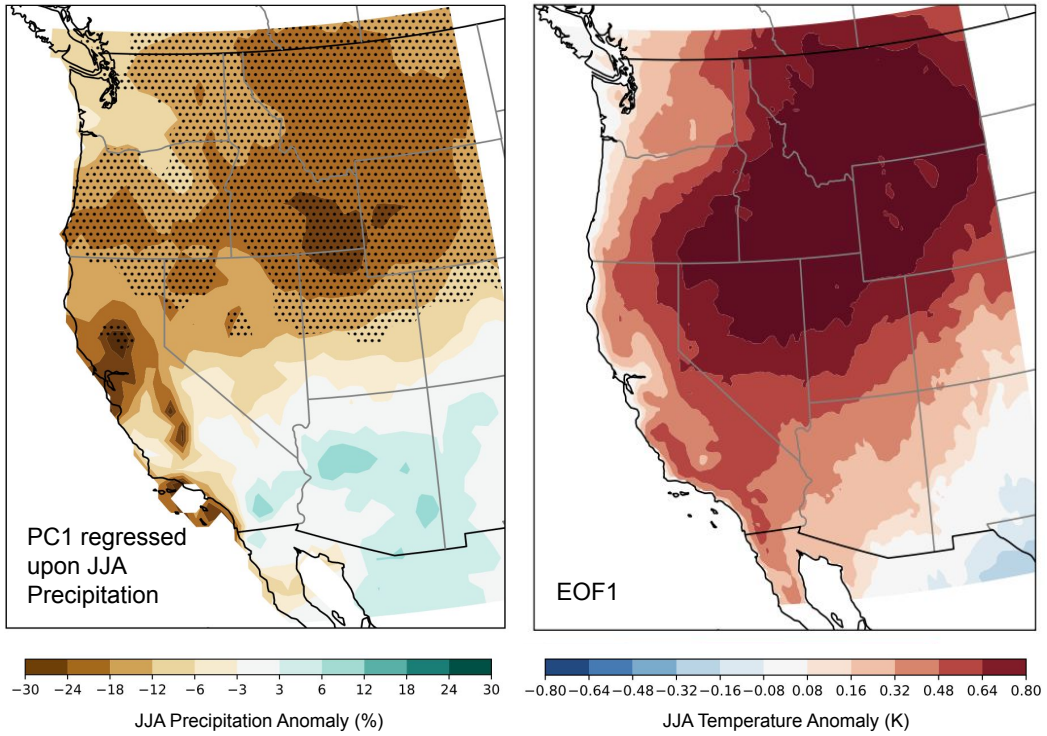

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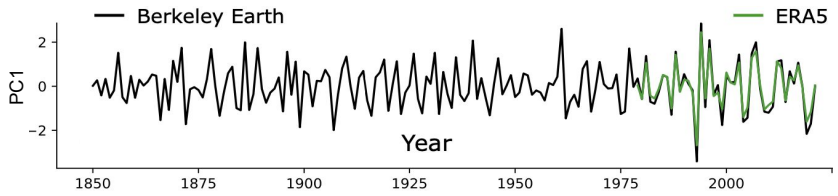

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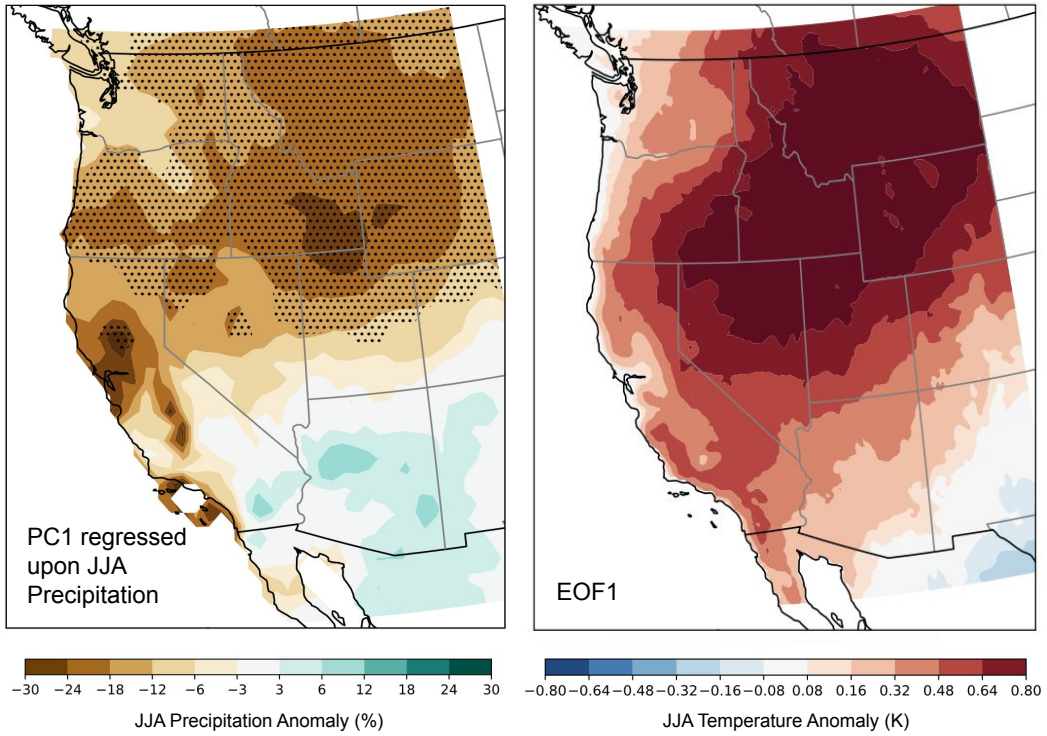
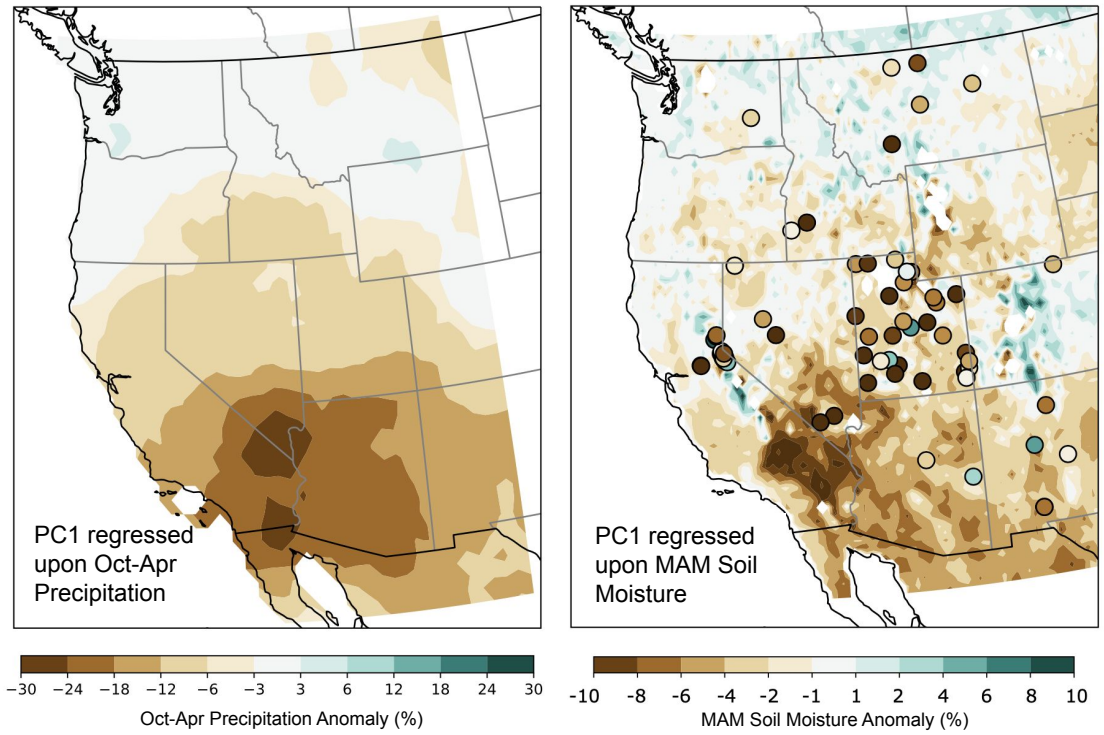
4. Variations in **antecedent hydrological conditions**



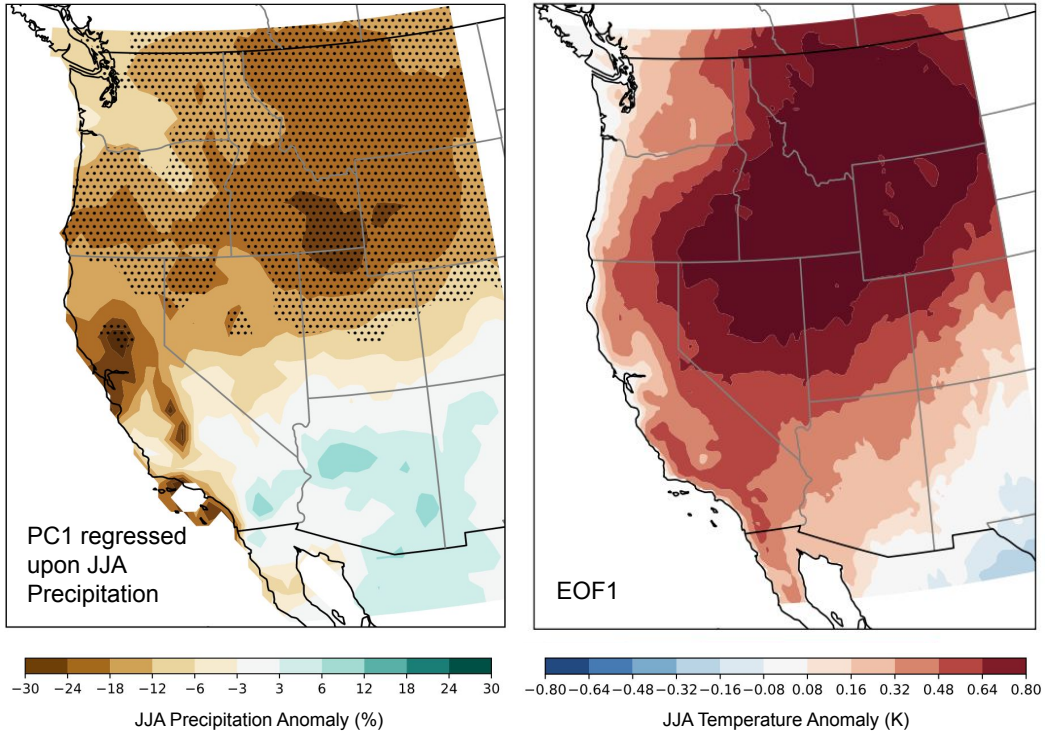
Observed Seasonal Moisture Anomalies Associated with the Summertime Temperature Pattern

Antecedent Hydrological Conditions



Moisture deficits **in the Southwest US** during spring and winter

Summertime Climate



Drought and warming **in the Northwest US** during summer

Seasonal Moisture Anomalies Associated with the Summertime Temperature Pattern in CESM2

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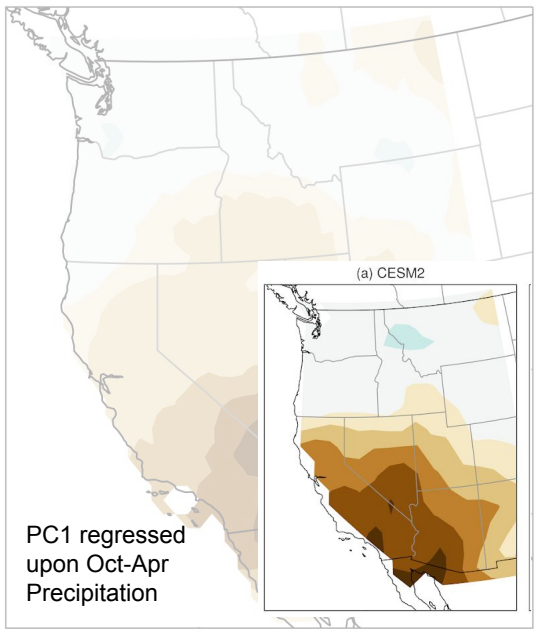

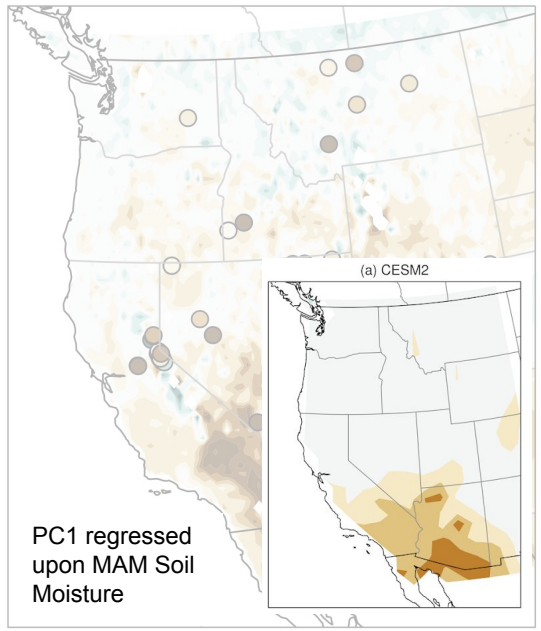

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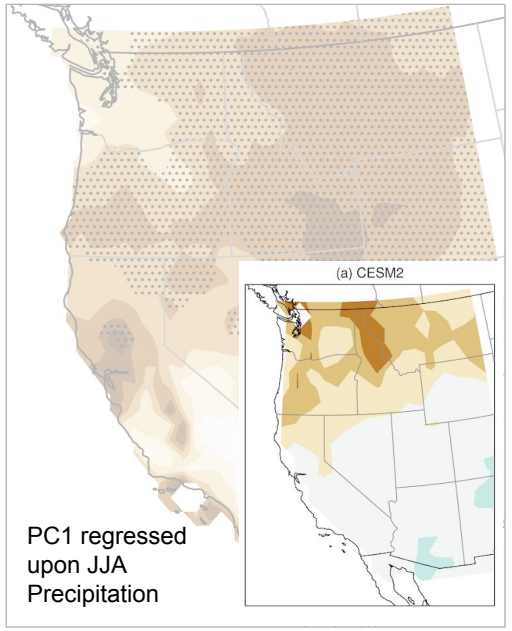

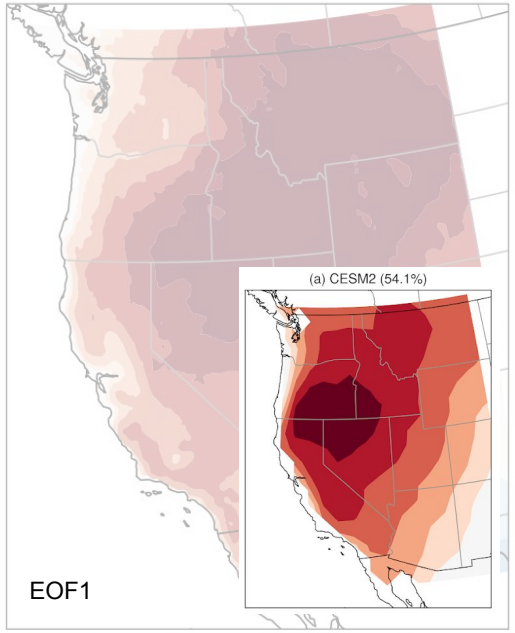

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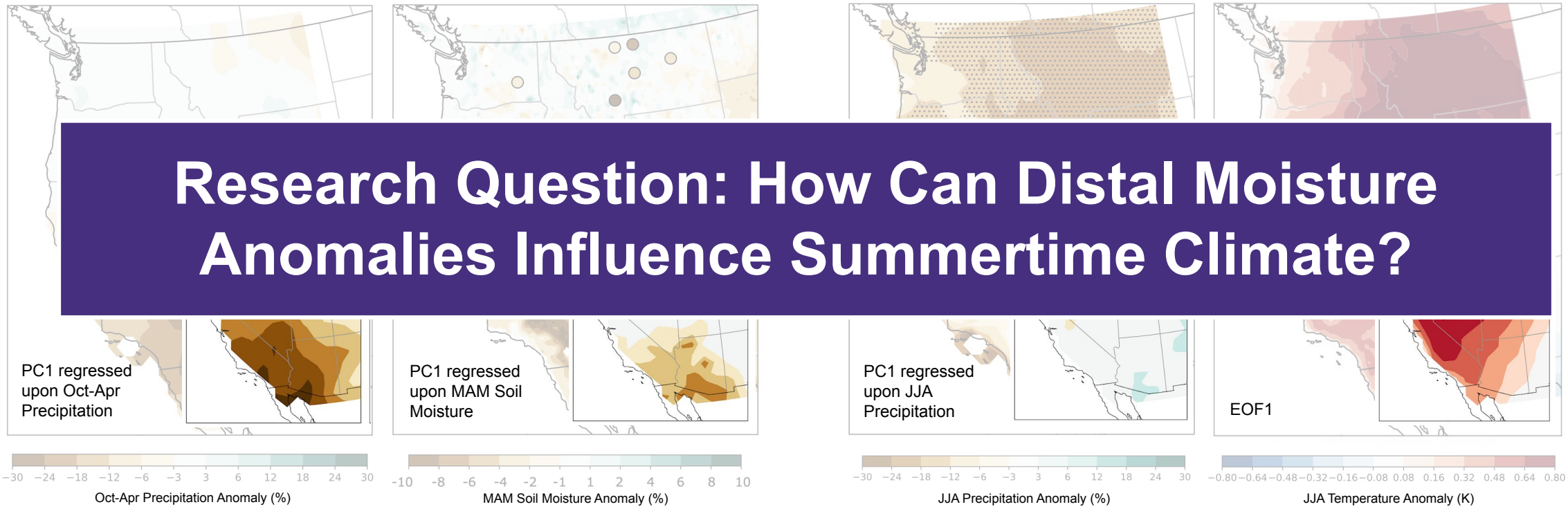

Research Question: How Can Distal Moisture Anomalies Influence Summertime Climate?

Moisture deficits **in the Southwest US** during spring and winter

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Vargas Zeppetello et al. (2024)

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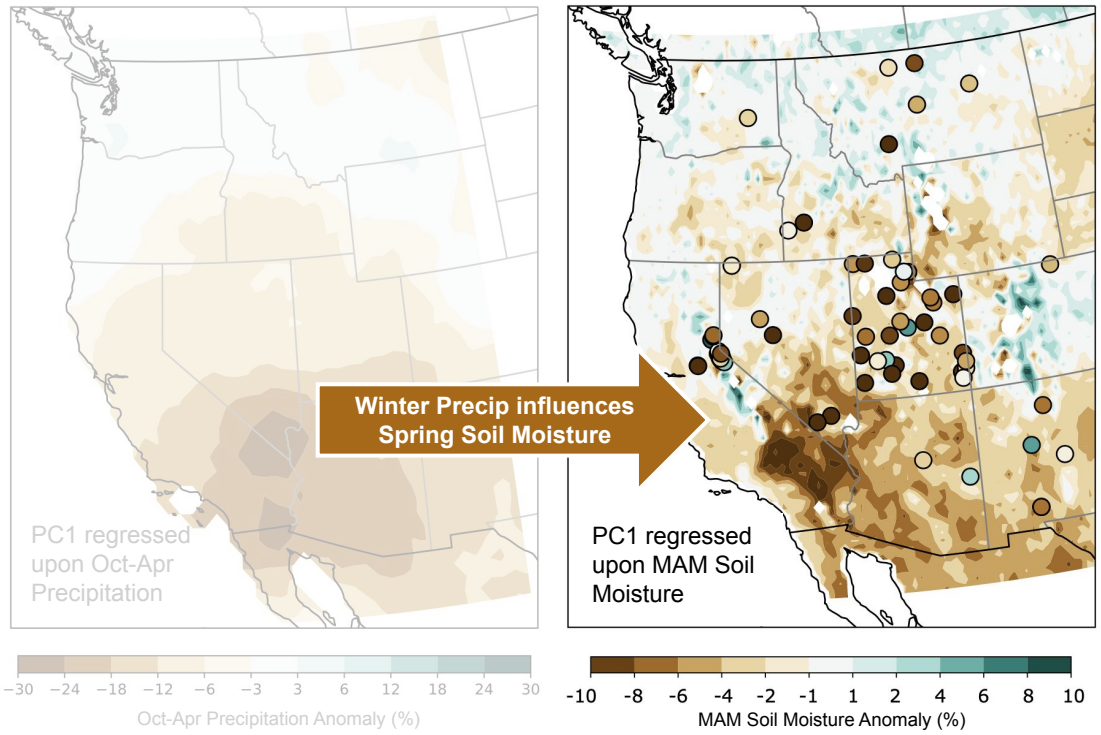

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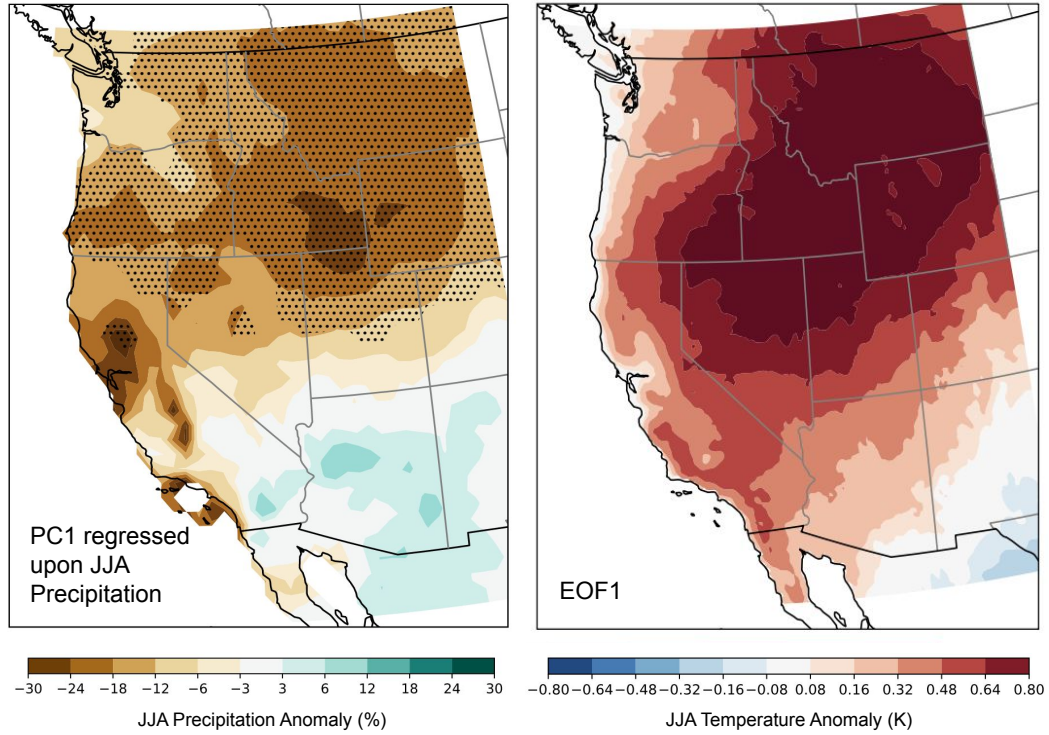

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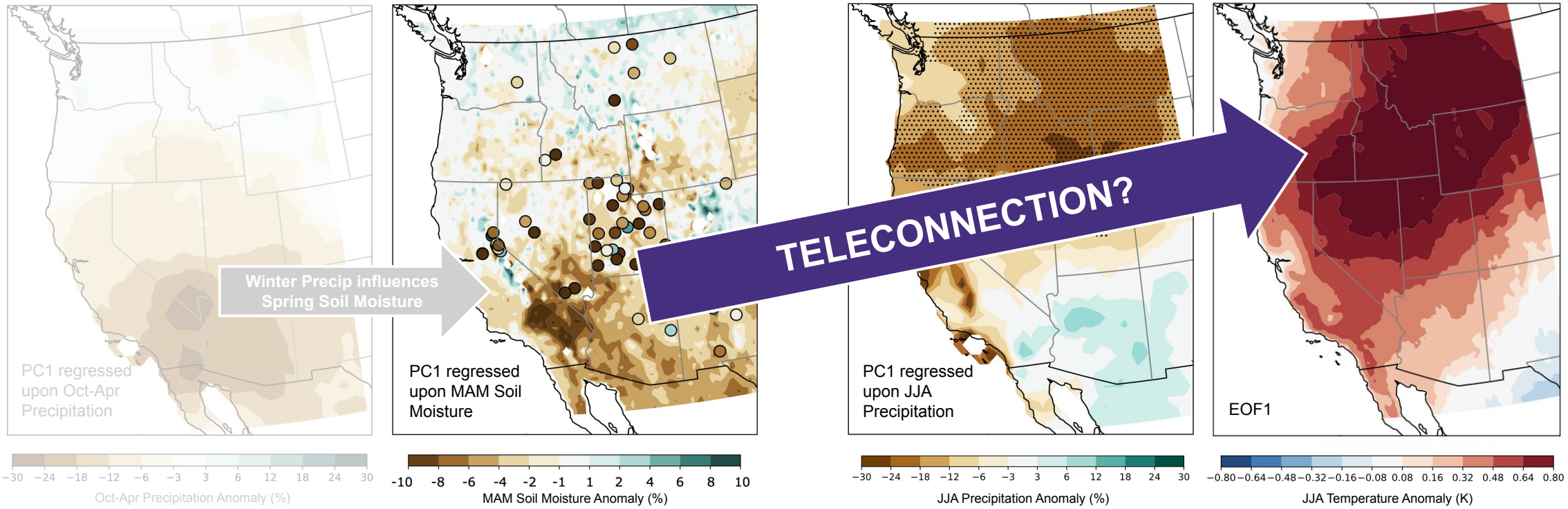

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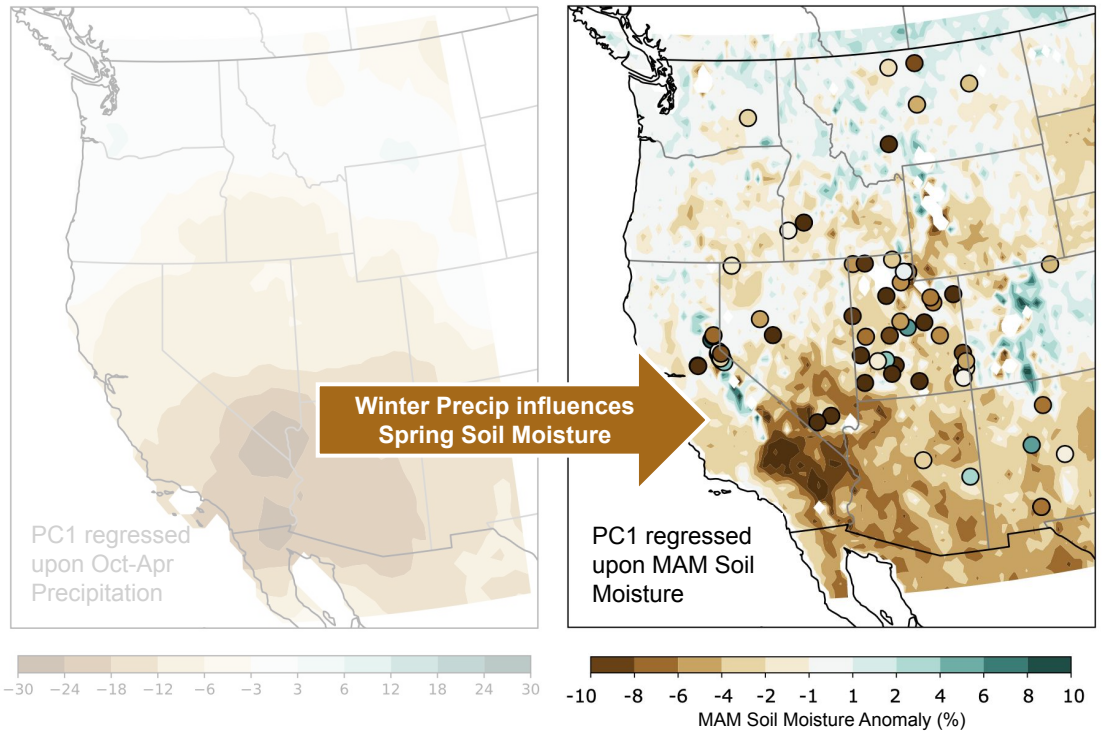

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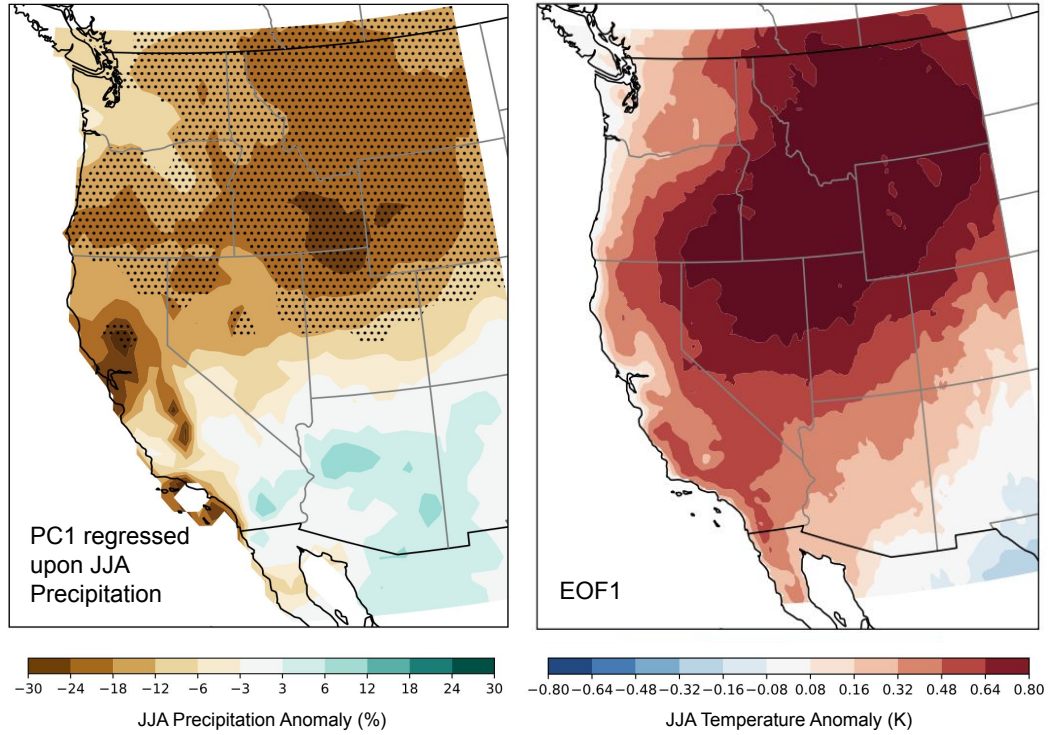

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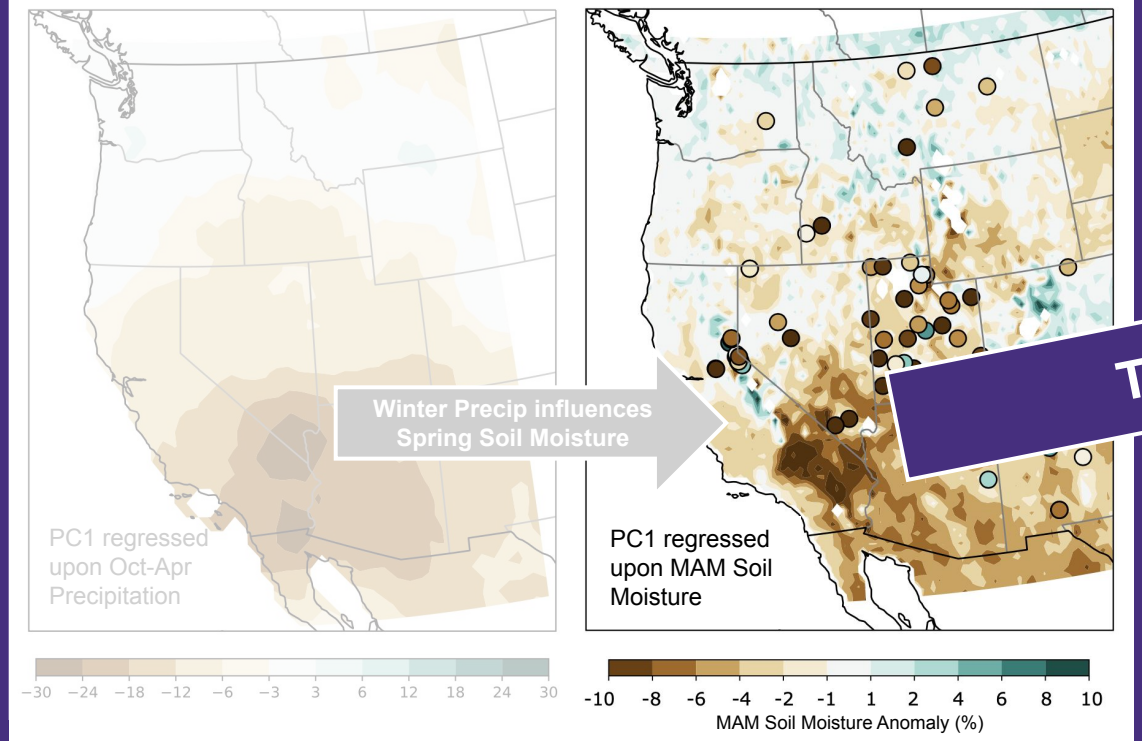

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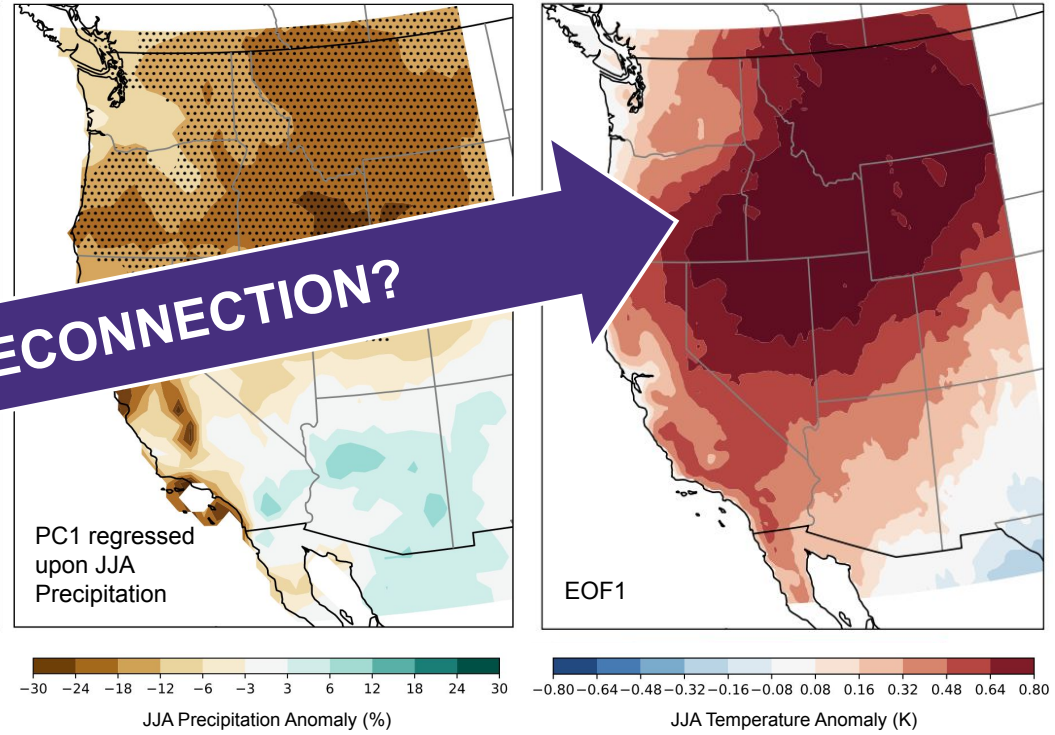

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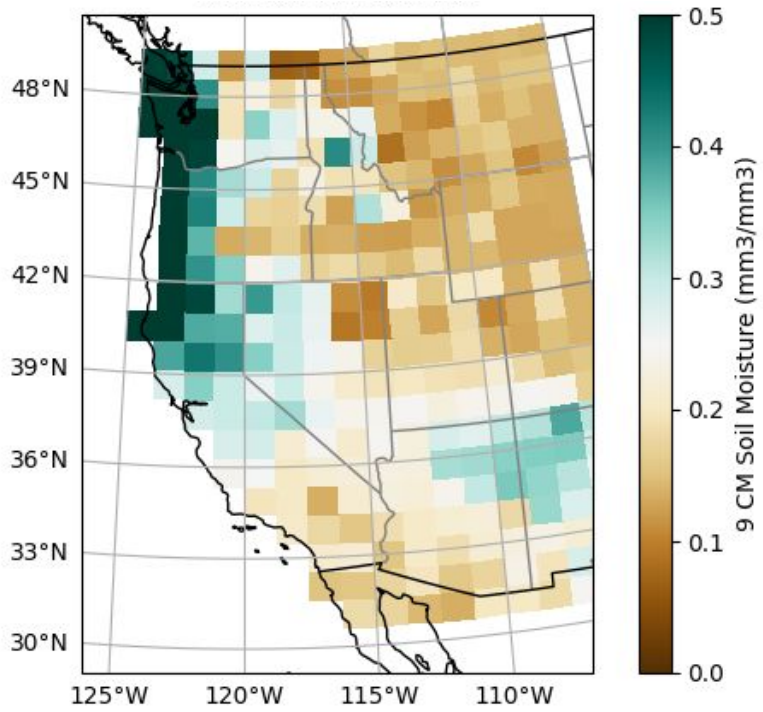
Methods

Soil Moisture Depletion Experiments in CESM2

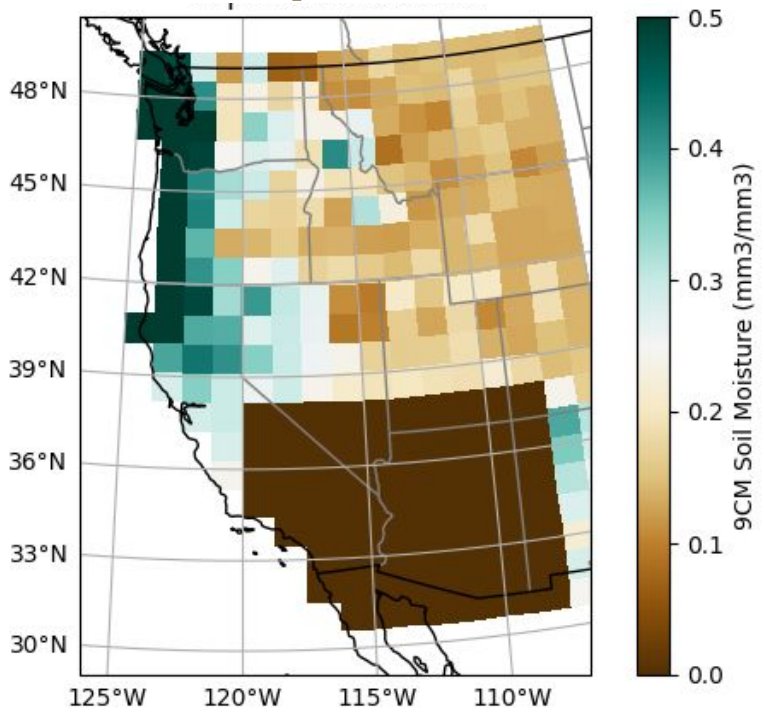
Soil Moisture Depletion Experiments in the Community Earth System Model (CESM2)

March Soil Moisture (Control)



CAM6 | Pre-industrial | Climatological SST

Experiment



H2OSOI_LIQ in top three layers = 0 on March 1st

Sampling Across Internal Variability with a 110-Member Ensemble

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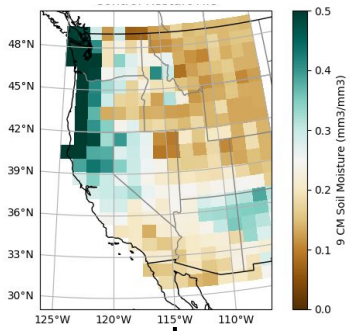
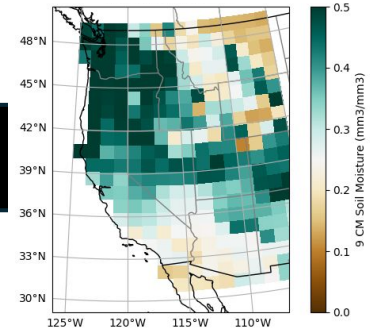
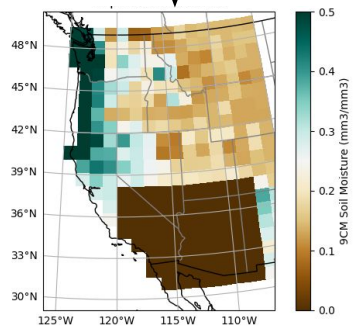


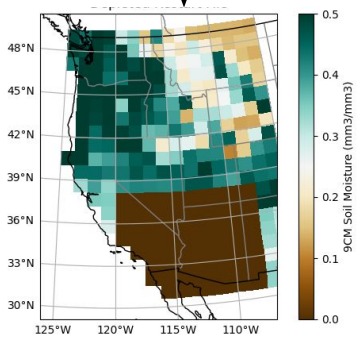
110-Year Control Run



March 1st 0000
Duplicate and deplete restart file



March 1st 0001
Duplicate and deplete restart file



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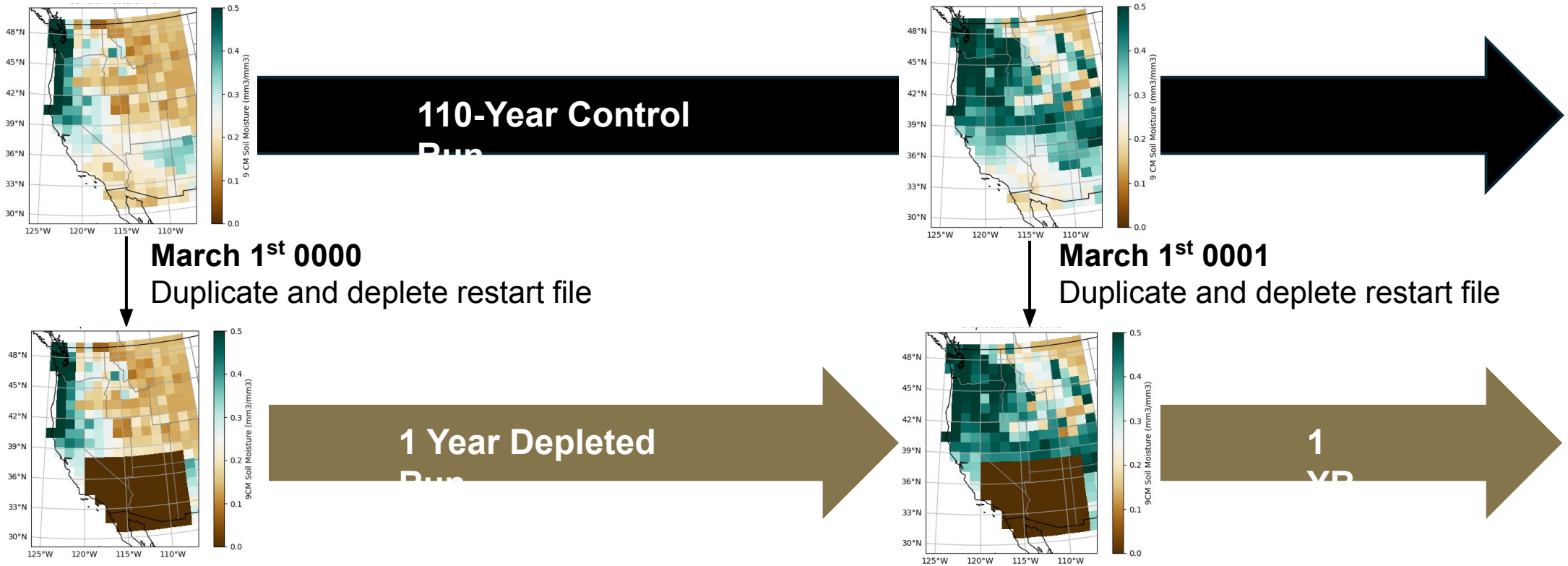
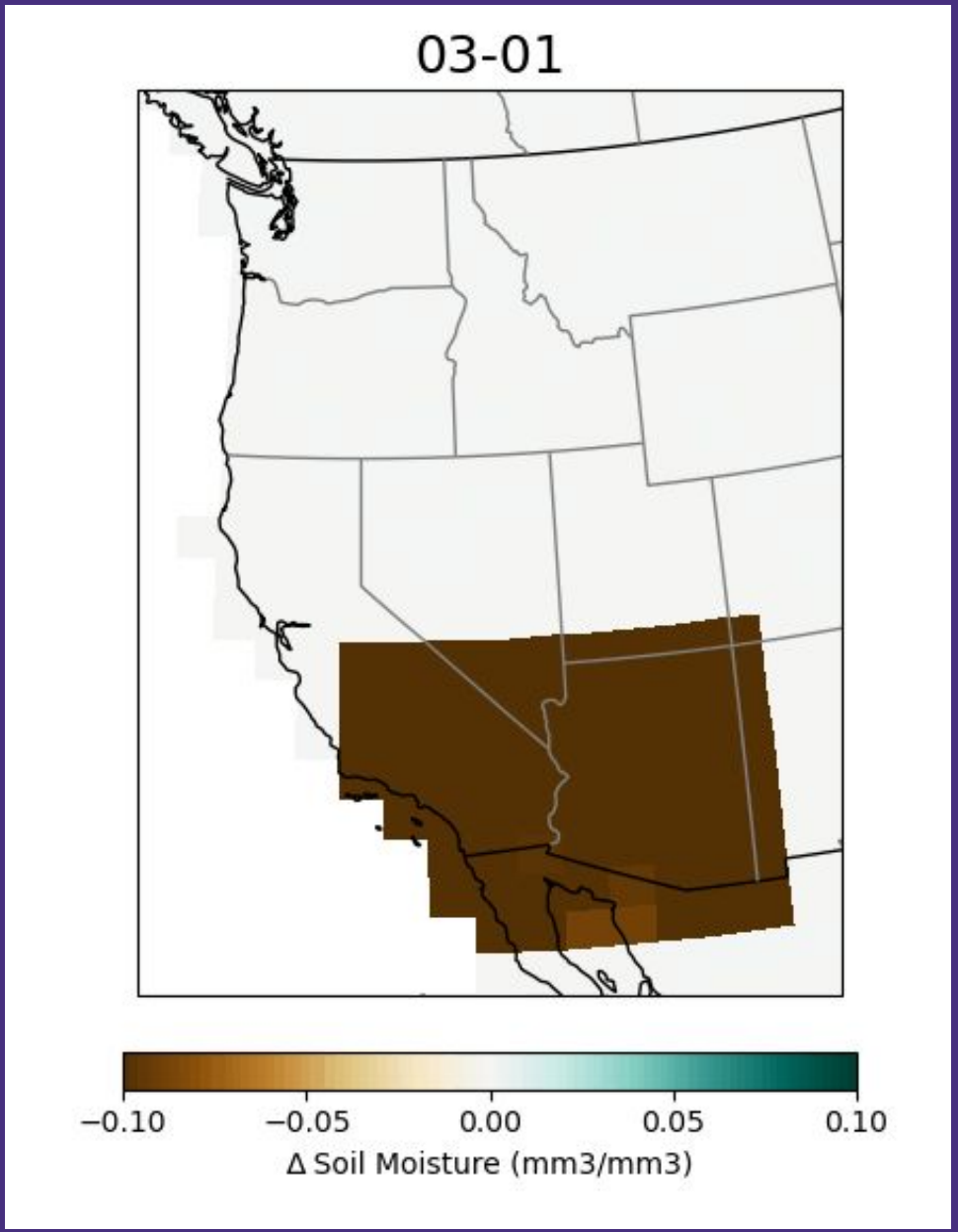




Anomalies Averaged Across the 110-Member Ensemble

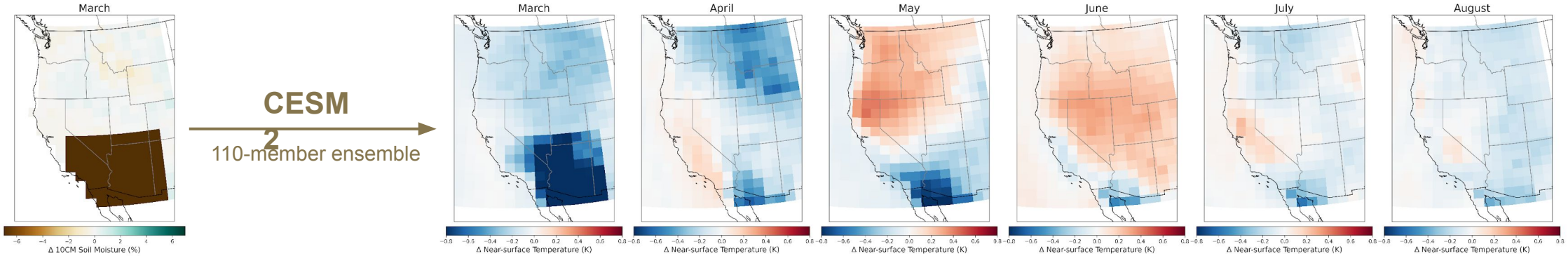
Our results are **not** dependent on:

- Initial conditions
- Internal variability
- SST coupling

Results

Anomalies Averaged Across the 110-Member Ensemble

Near-Surface Temperature Response to March Soil Moisture Depletion



Depleting surface soil moisture over the Southwest US at the start of March leads to:

1. **Cooling in March** over the Southwest US
2. **Warming in May-June** across the Northwest US

1. Increased Albedo Due to Surface Drying Explains March Cooling Response

Cooling in March over the Southwest US is consistent with:

- Decreases in net downwelling surface shortwave
- Little change in cloud fraction
- Increased surface albedo*

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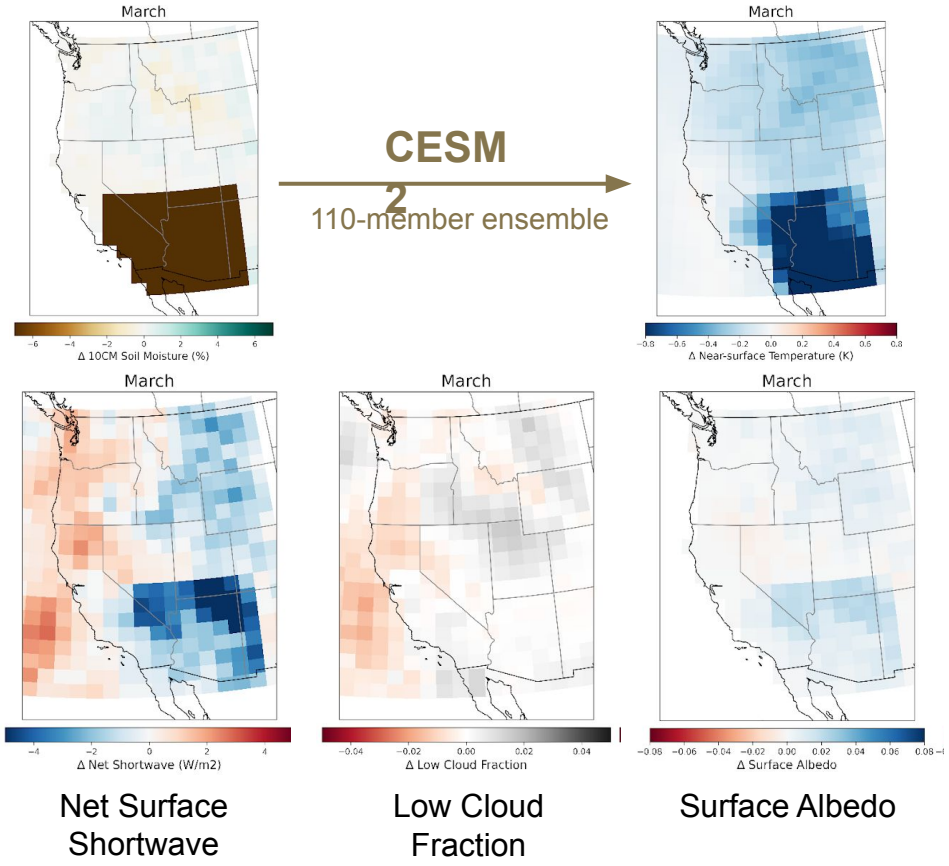

Net Surface Shortwave | Low Cloud Fraction | Surface Albedo

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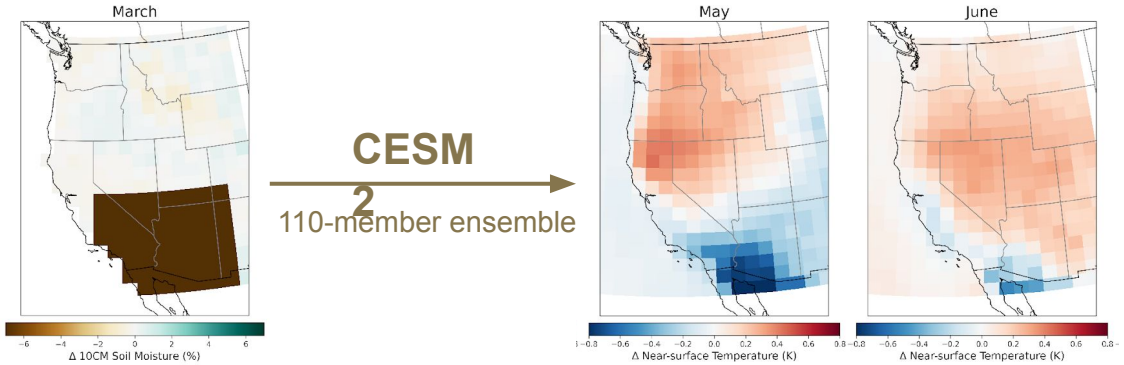
** Saturated soil appears darker than dry soil*

2. Large-Scale Circulation Changes Explain May-June Warming



Warming in May-June across the Northwest US is consistent with:

- Observed summertime temperature pattern
- Increased net downwelling shortwave
- Decreases in low cloud frac.
- Decreases in large-scale precipitation and humidity
- Circumglobal circulation changes

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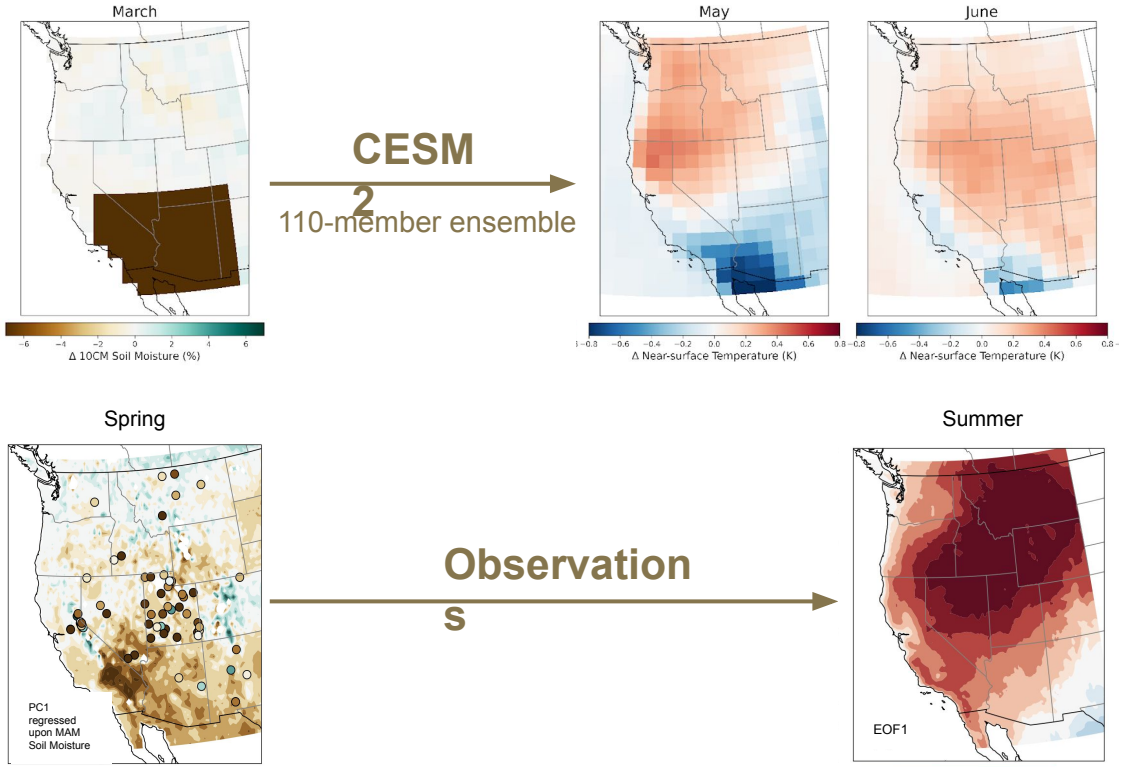

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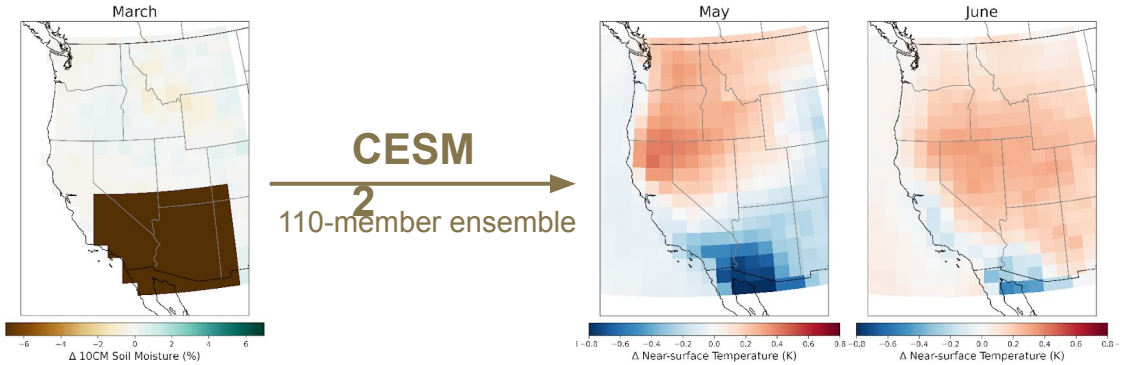

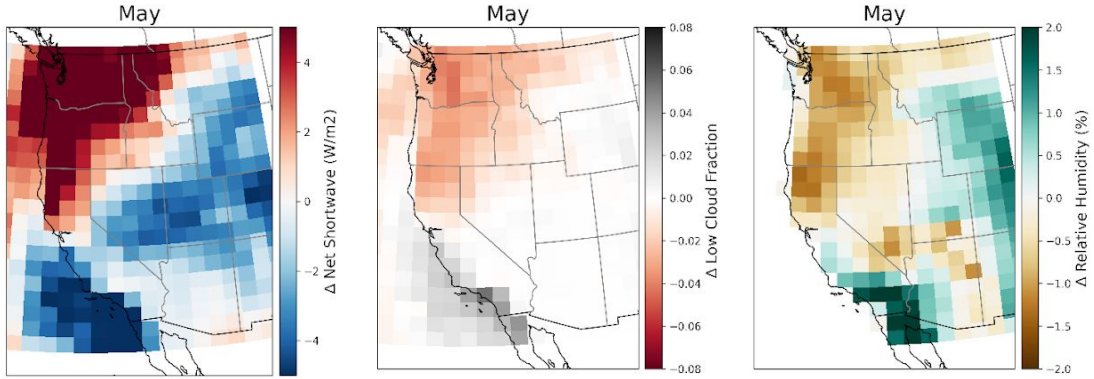

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Low Cloud Fraction

Low-Level Relative Humidity

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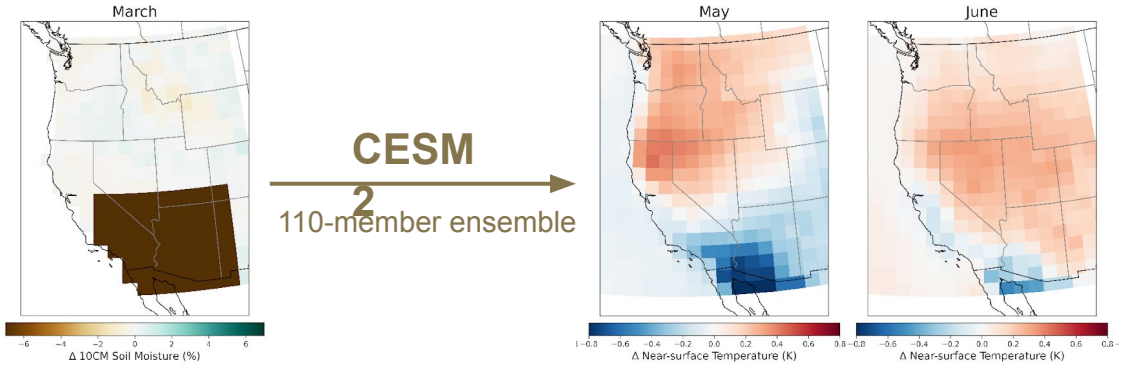

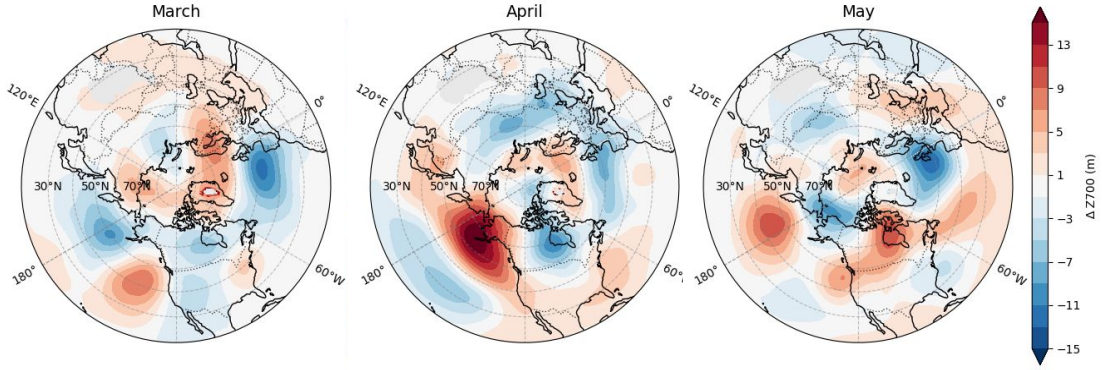

700 mb Geopotential Height

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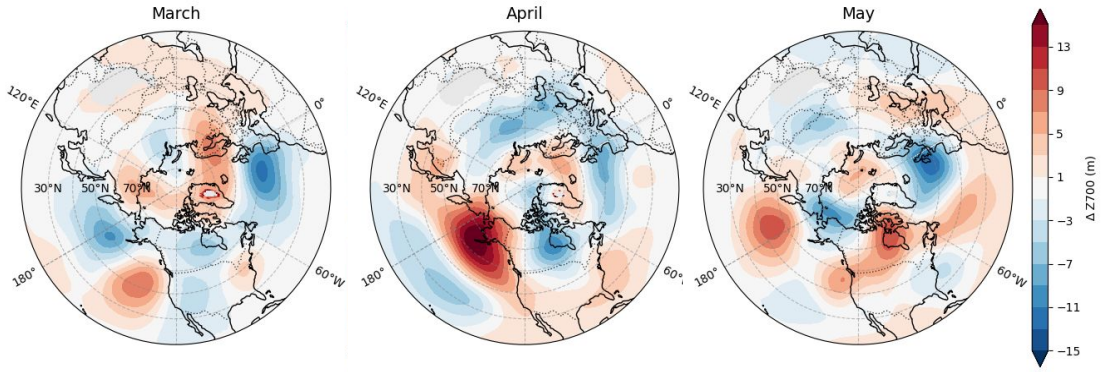
Large-Scale Circulation Changes

Daytime heating over dry surface excites **quasi-stationary wave anomalies along the waveguide** (Branstator 1990; Koster et al. 2016; Teng et al. 2019)



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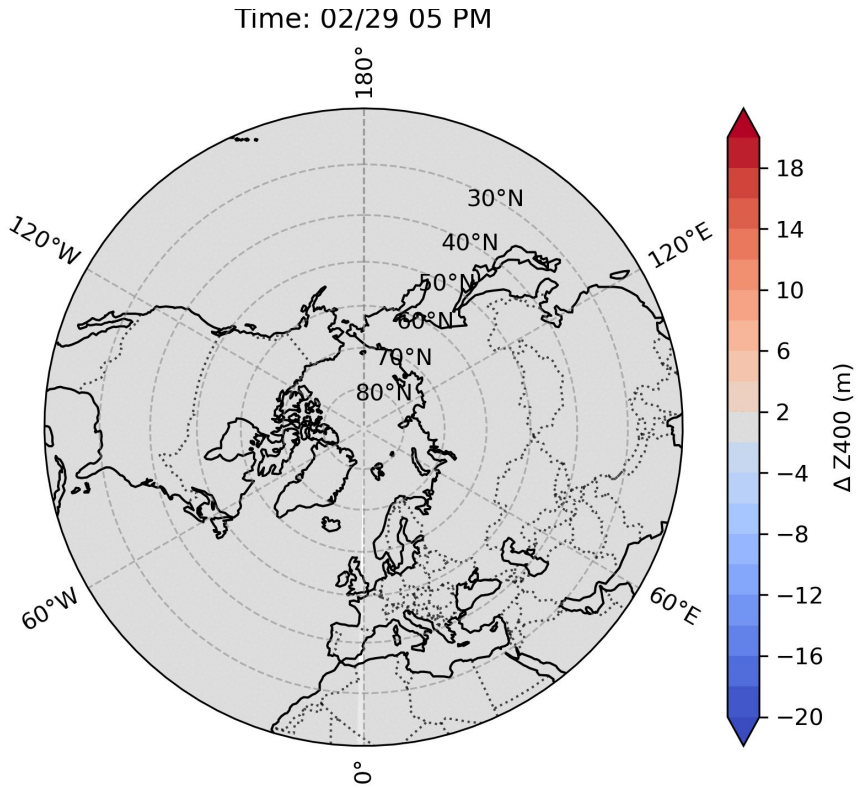

- **Circumglobal circulation changes**

Large-Scale Circulation Changes Driven by Diabatic Heating over Depleted Southwest

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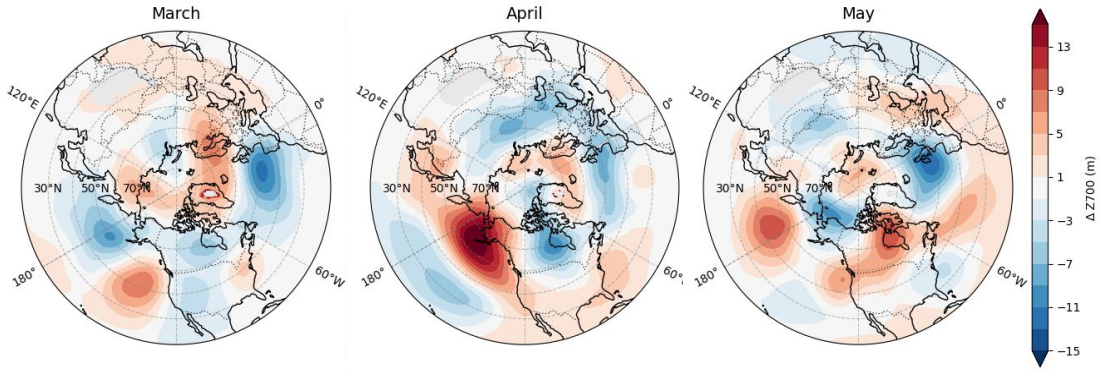

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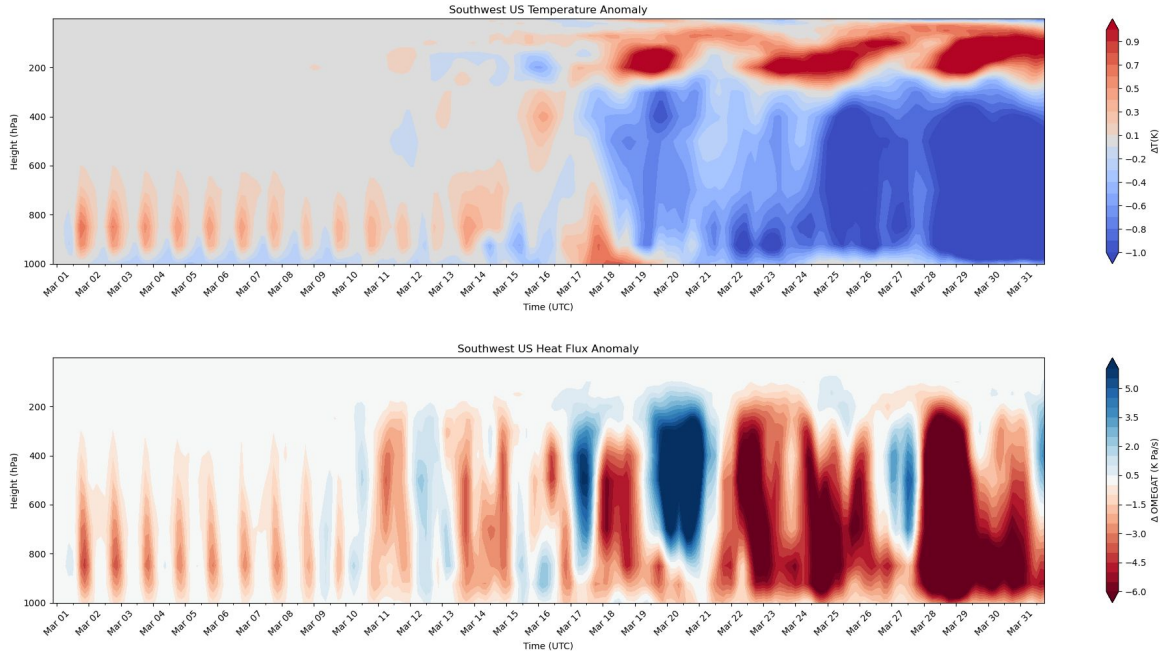
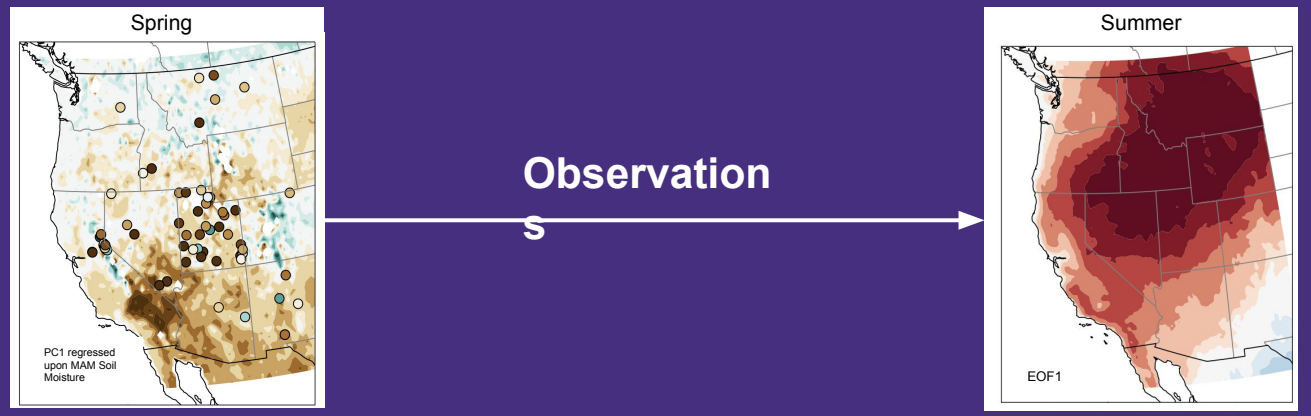
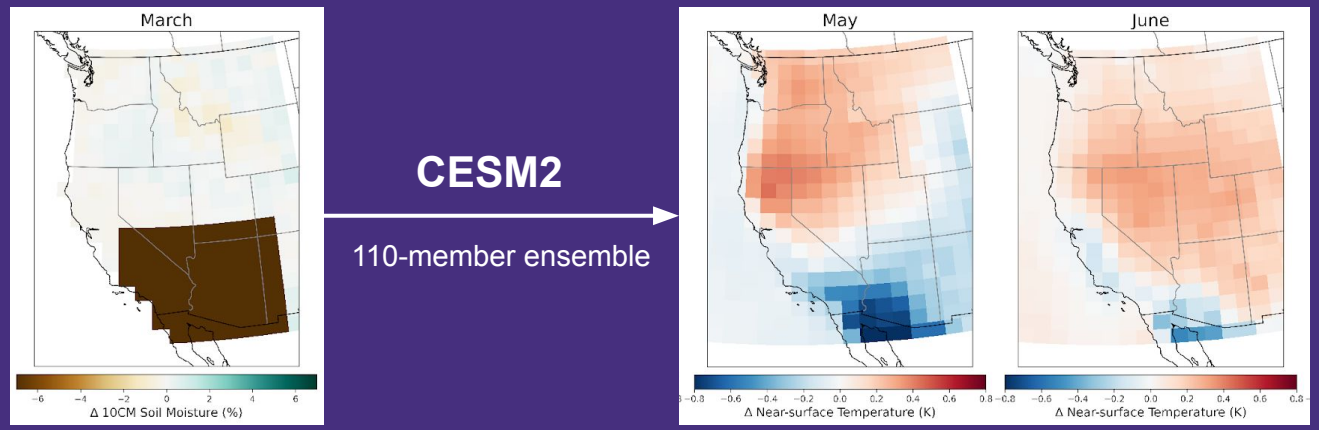


March 3-hrly temperature (top) and vertical heating rate (bottom) by pressure level, averaged over the Southwest US.

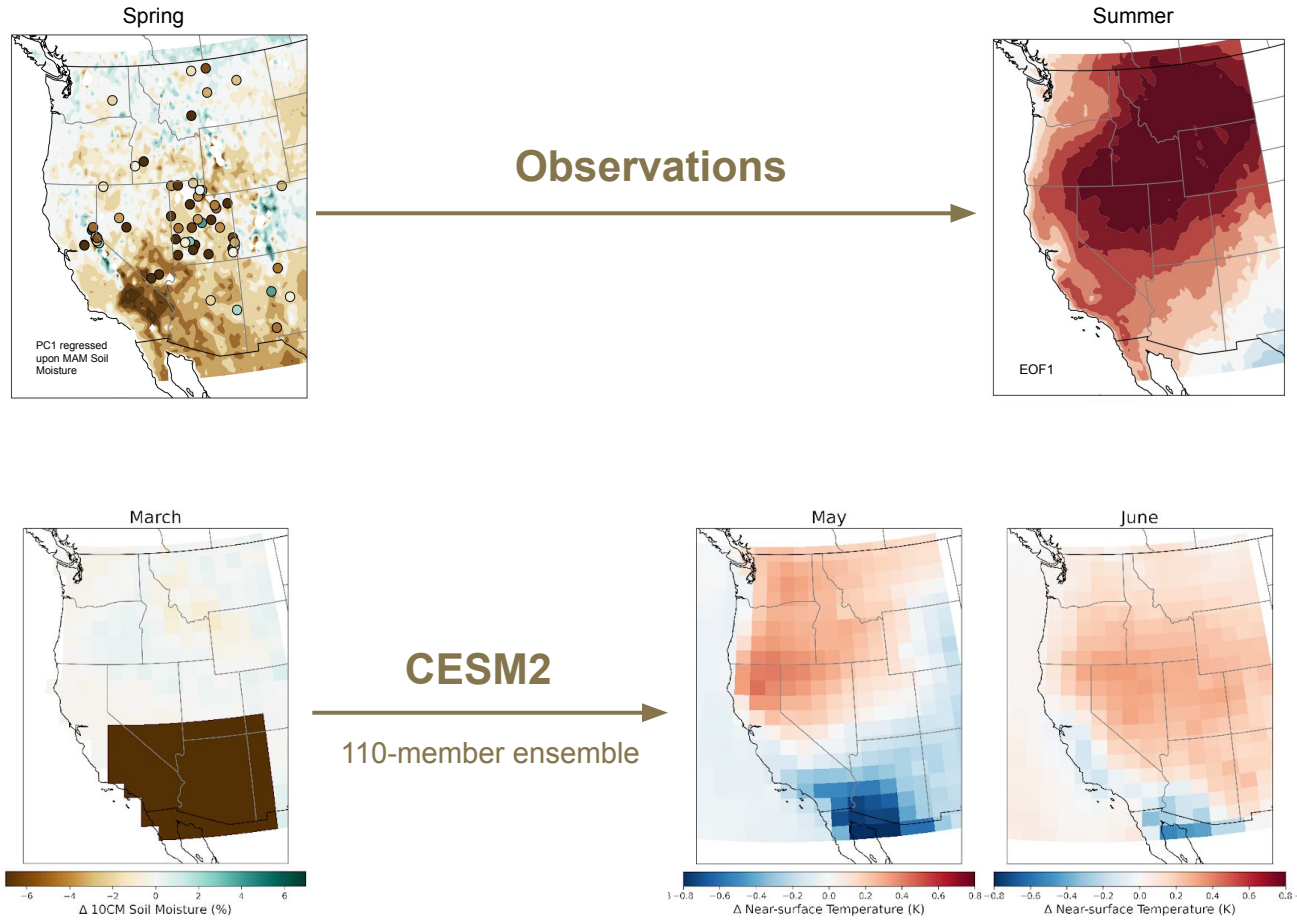
Conclusion





Summary

- Springtime soil moisture deficit ***drives*** distal summertime warming in CESM2 and observations
- Response is independent of atmospheric and SST variability
- Soil moisture anomalies affect surface albedo (local) and circulation (circumglobal)



Implications

- Predictability on seasonal time scales
- Large-scale teleconnections modulated by soil moisture

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