Exploring Ocean-driven Multi-year Predictability of Terrestrial Ecosystem Components : A Focus on Wildfires

Jeongeun Yun[1*], June-Yi Lee[1,2*], Yong-Yub Kim[2], Young-Min Yang[3], Alexia Karwat[1], Sun-Seon Lee[2], Jin-Soo Kim[4], Yoshimitsu Chikamoto[5]

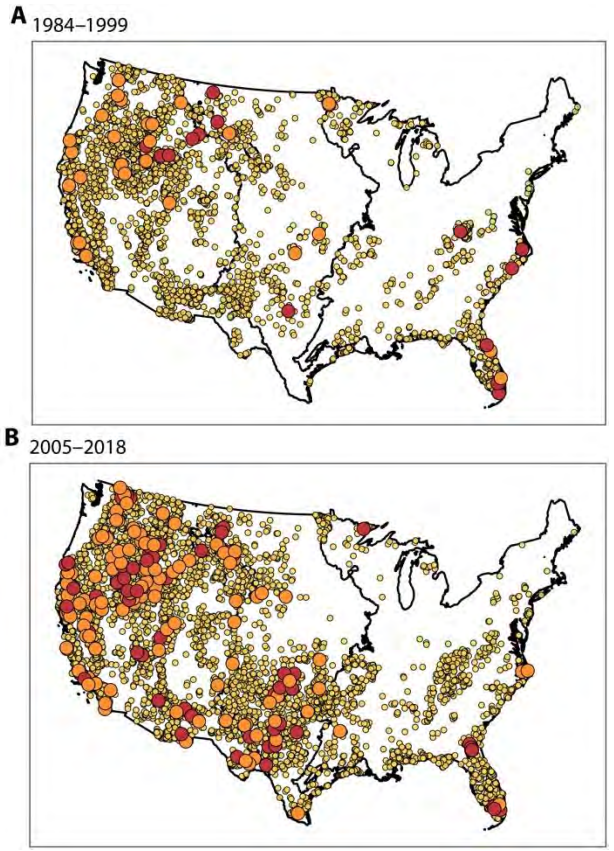
je_yun@pusan.ac.kr

[1]Research Center for Climate Science, Pusan National University, Busan, Republic of Korea
[2]Institute for Masic Science, Center for Climate Physics, Busan, Republic of Korea
[3]School of Civil, Environmental, Resources and Energy Engineering, Jeonbuk National University, Jeonju, Republic of Korea
[4]School of Energy and Environment, City University of Hong Kong, Hong Kong, China
[5]Department of Plant, Soils and Climate, Utah State University, Utah, U.S

Introduction

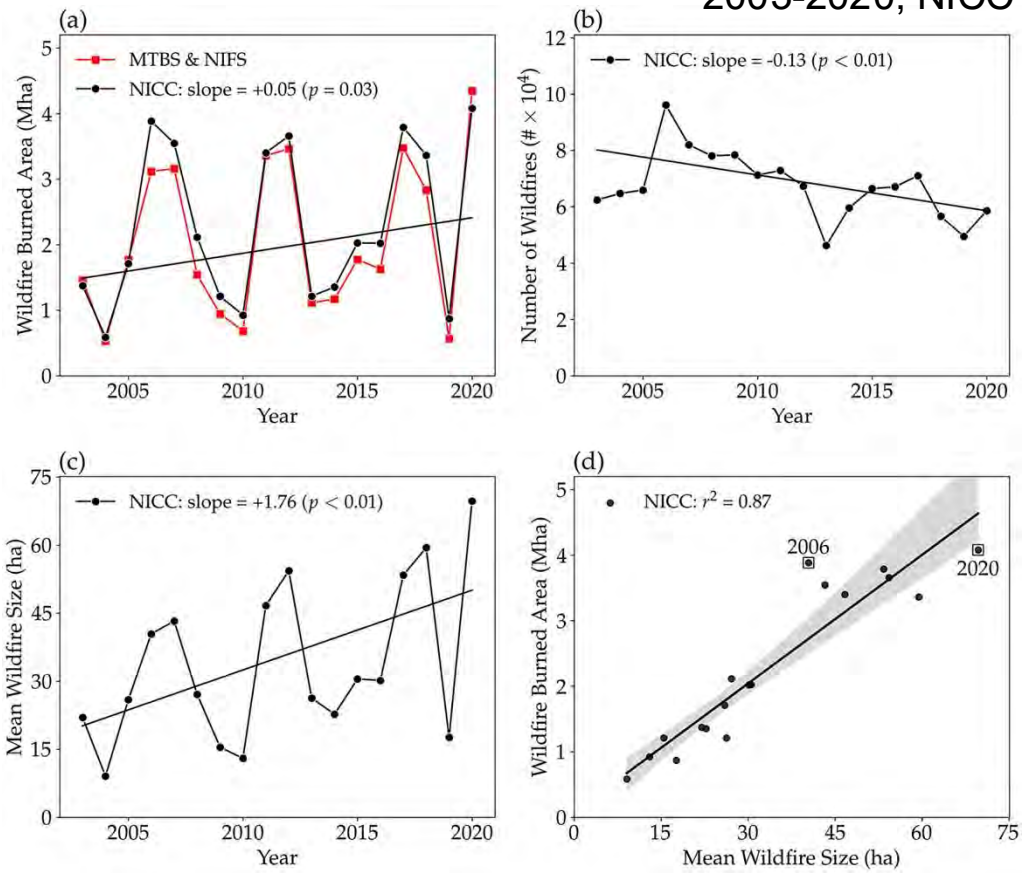
Wildfires in southwestern, USA

- The U.S. Southwest has been increasing **wildfire sizes** and **area burned** in recent decades.
- However, it has not been determined whether these changes have been associated with climatic variability, especially **large-scale ocean-atmosphere interactions**.



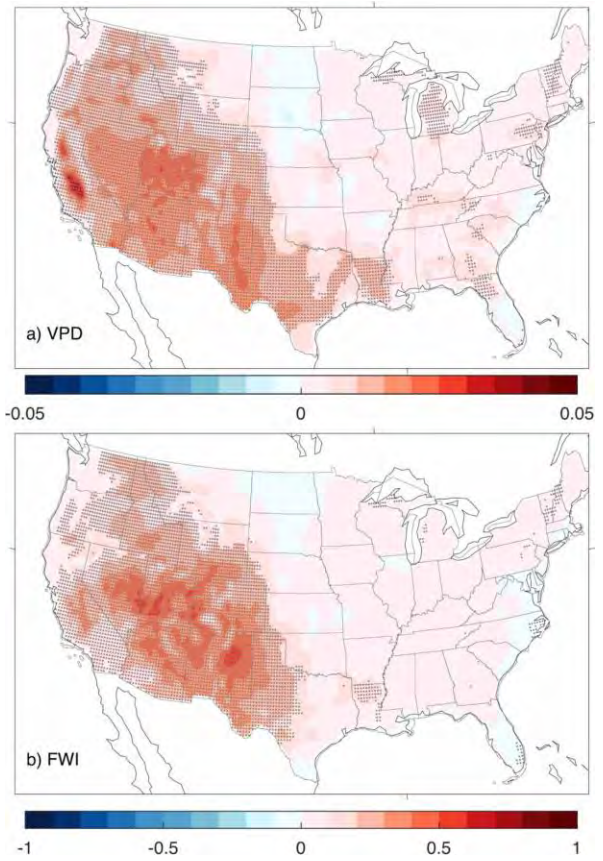
Iglesias et al., 2022

2003-2020, NICC



Freeborn et al., 2022

1980-2020, ERA5



Zhang et al., 2025

Introduction

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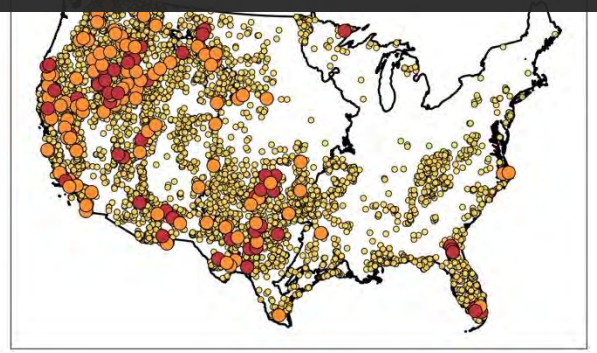
- However, it has not been determined whether these changes have been associated with climatic variability, especially **large-scale ocean-atmosphere interactions**.

Scientific questions

1. **How accurately can Earth system models simulate the spatiotemporal variability of area burned in southwestern U.S.?**
2. **Which climatic and environmental drivers explain the multi-year variability in area burned in the region?**
3. **What are the climate mechanisms linking ocean variability and area burned in the region?**



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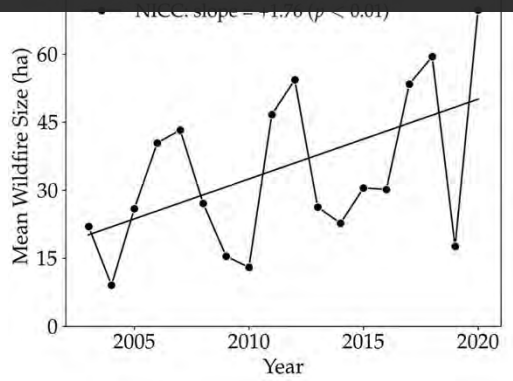

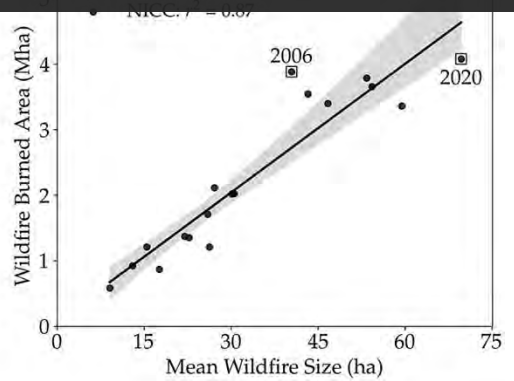

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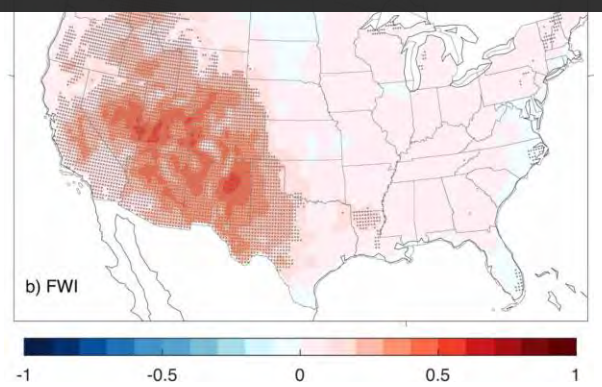
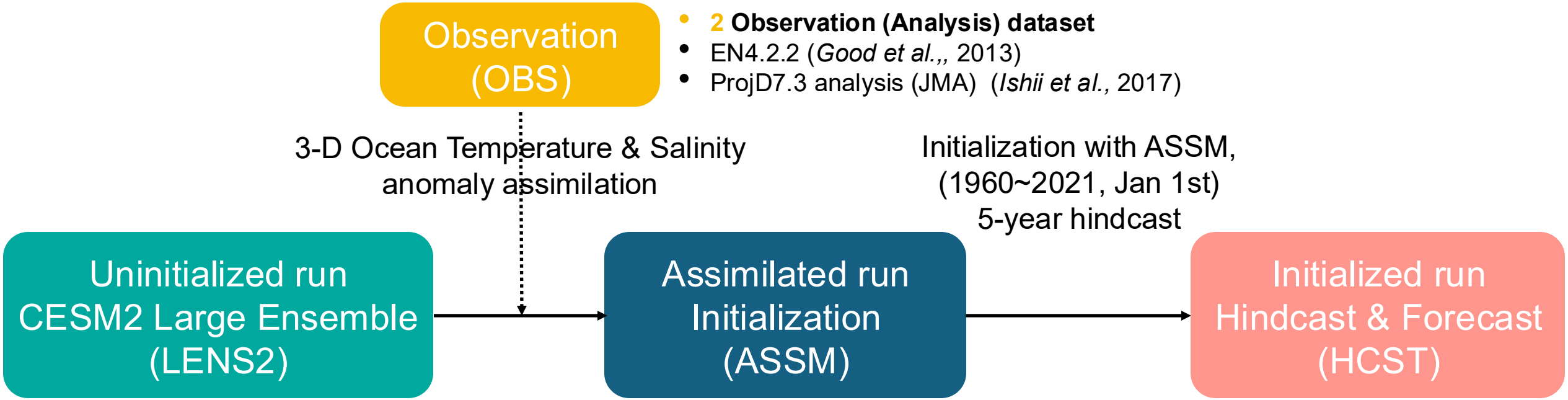


Zhang et al., 2025

Methods

Multi-year Prediction System based on CESM2 (CESM2-MP)



- Total 50 members (Rodgers *et al.,* 2021)
- **10 members for ASSM initial** (1231.011~020)

- **20 (10 * 2) Ensemble members**
  - 10 members for EN4.2.2 (1950 ~ 2021)
  - 10 members for ProjD7.3 (1955 ~ 2021)

- **20 Ensemble members** (EN4, ProjD)
- **62 Initialized years** (1960 ~ 2021)
- **6200 (62 * 20 * 5) simulation years** (~ 2 PB)

Methods

Data Overview

Observation (OBS)

- **2 Observation (Analysis) dataset**
- EN4.2.2 (*Good et al.,,* 2013)
- ProjD7.3 analysis (JMA) (*Ishii et al.,* 2017)

3-D Ocean Temperature & Salinity anomaly assimilation

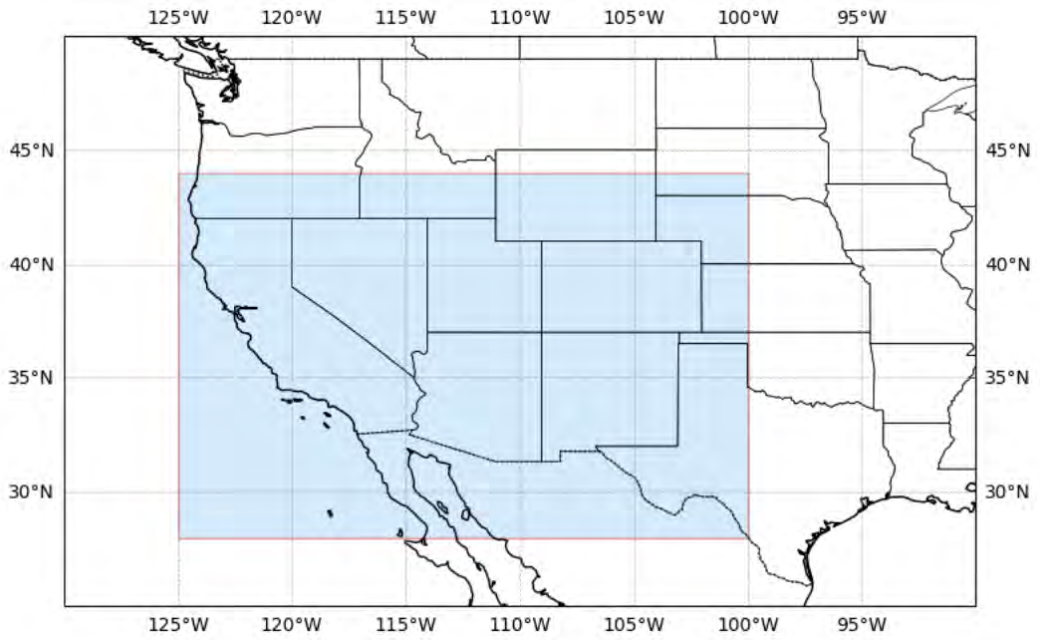
Assimilated run Initialization (ASSM)

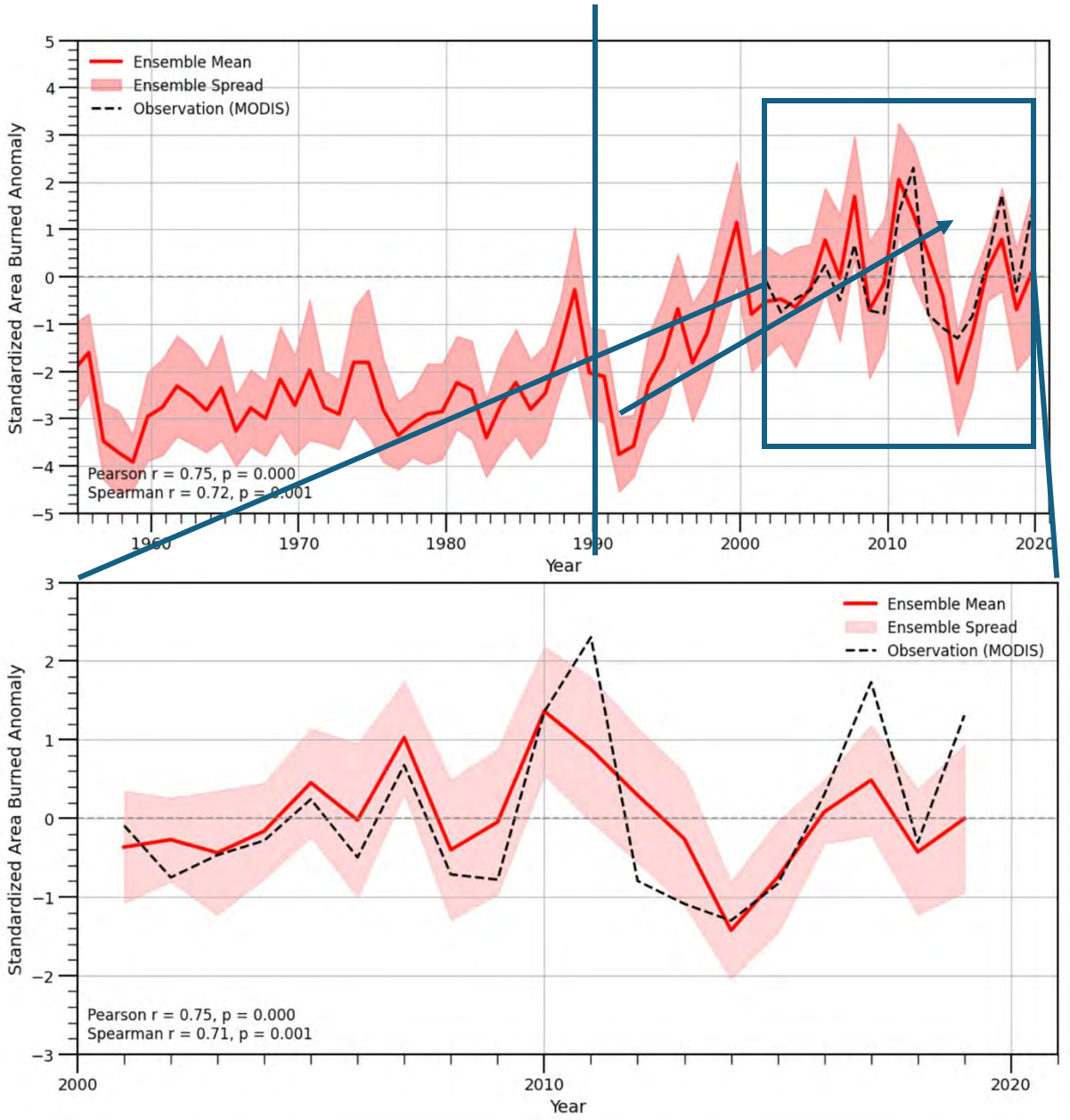
- **20 (10 * 2) Ensemble members**
  - 10 members for EN4.2.2 (1950 ~ 2021)
  - 10 members for ProjD7.3 (1955 ~ 2021)

Dataset of Observation

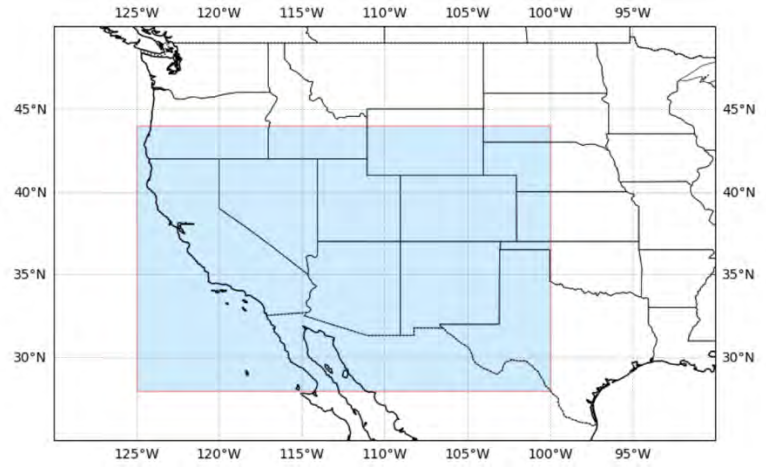
- Area Burned: MODIS (2001~2020)
- Temperature: ERA5 (1955~2020)
- Wind Speed: ERA5 (1960~2020)
- Precipitation: GPCC (1955~2018)
- Relative Humidity: HadISDH (1973~2020)
- Soil Water: NOAA (1955~2019)
- Sea Surface Temperature: ERSST (1955~2020)

Validation of Area Burned

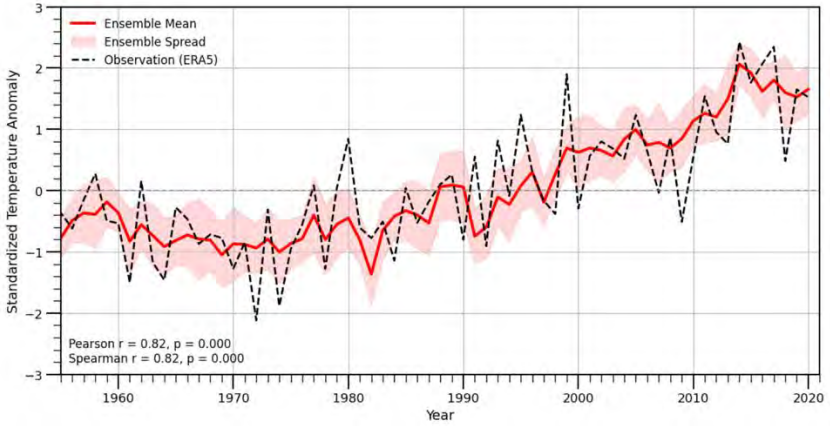




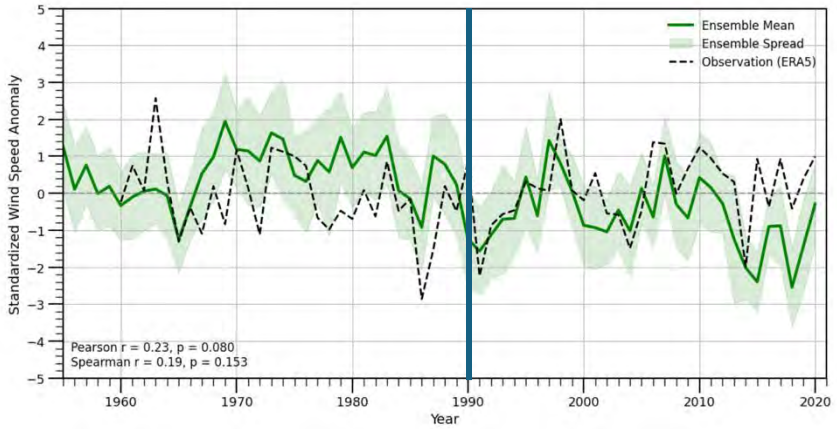
Validation of Environmental Variables



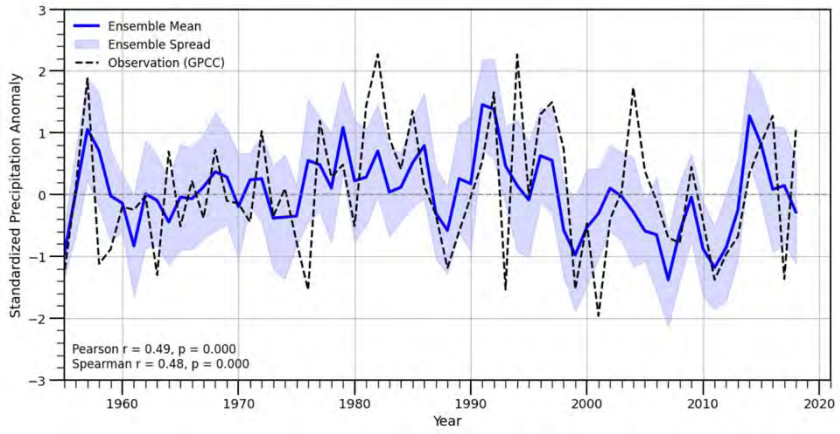
Temperature



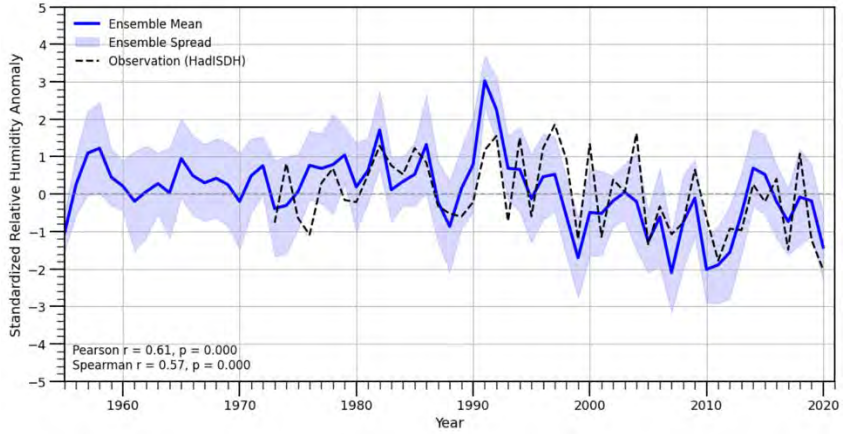
Wind Speed



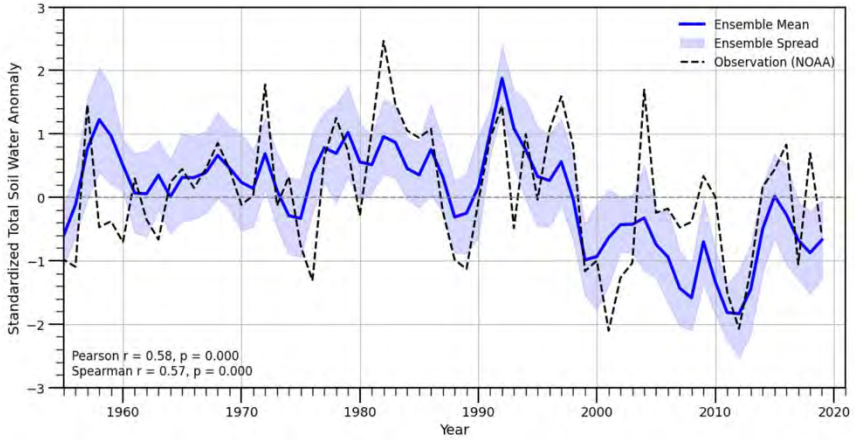
Precipitation



Relative Humidity



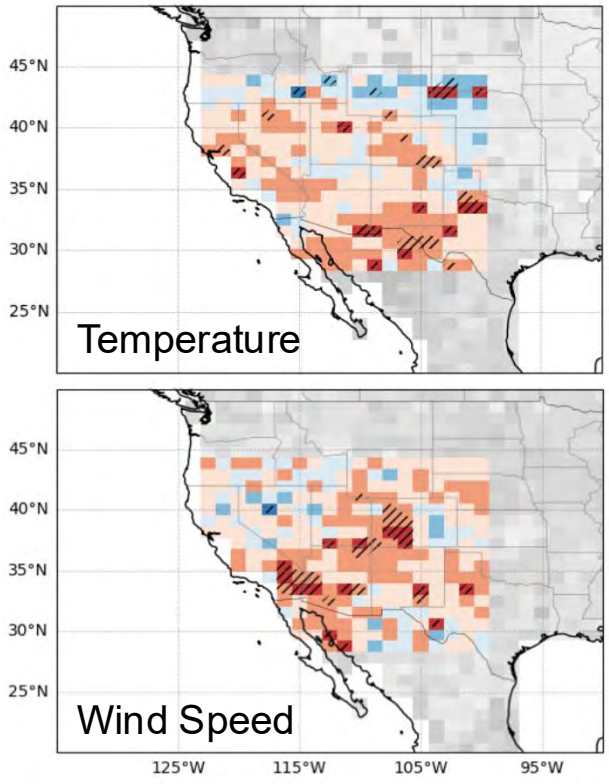
Soil Water

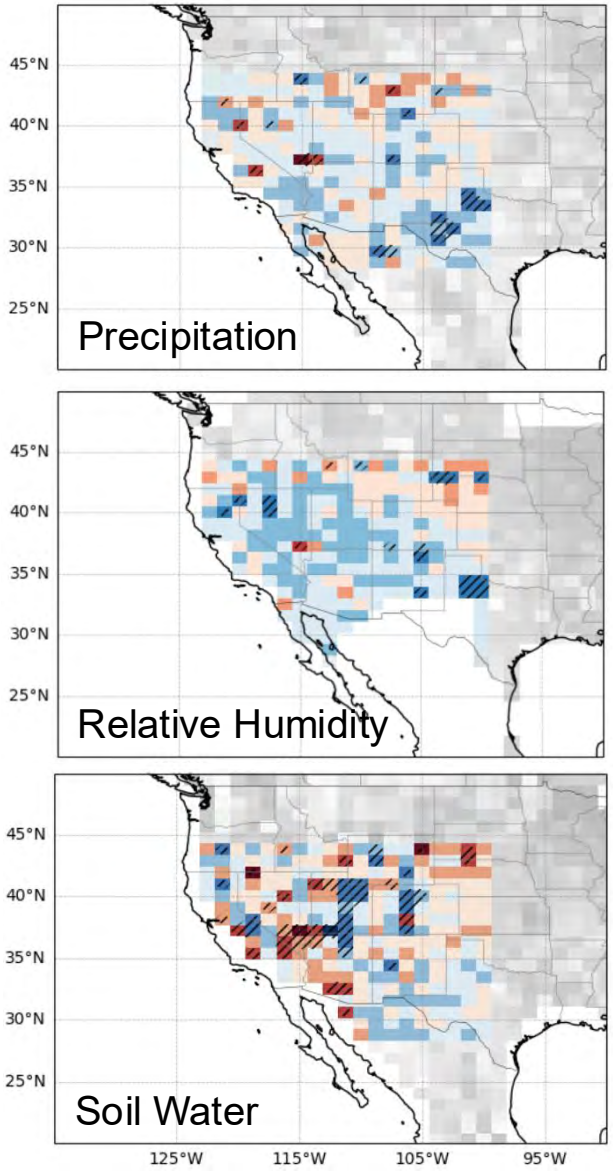


Climate Drivers of Wildfires

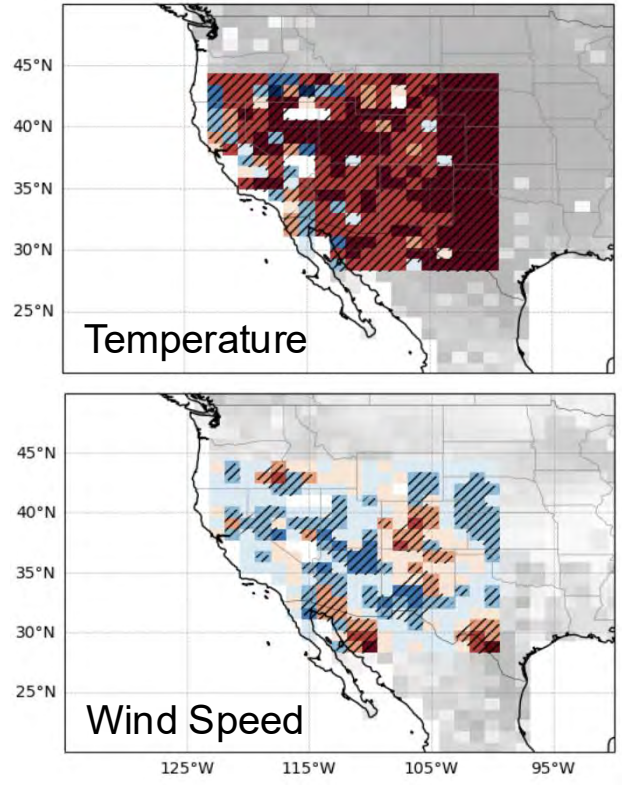
Correlation between Area Burned & Environmental Variables

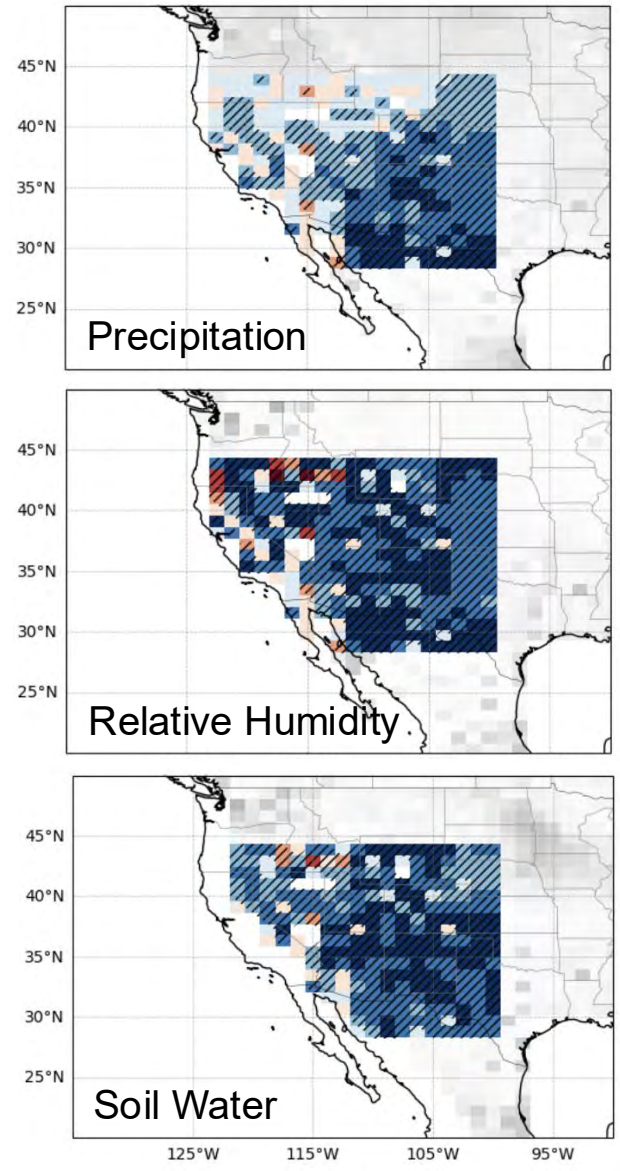
Observation





Assimilation

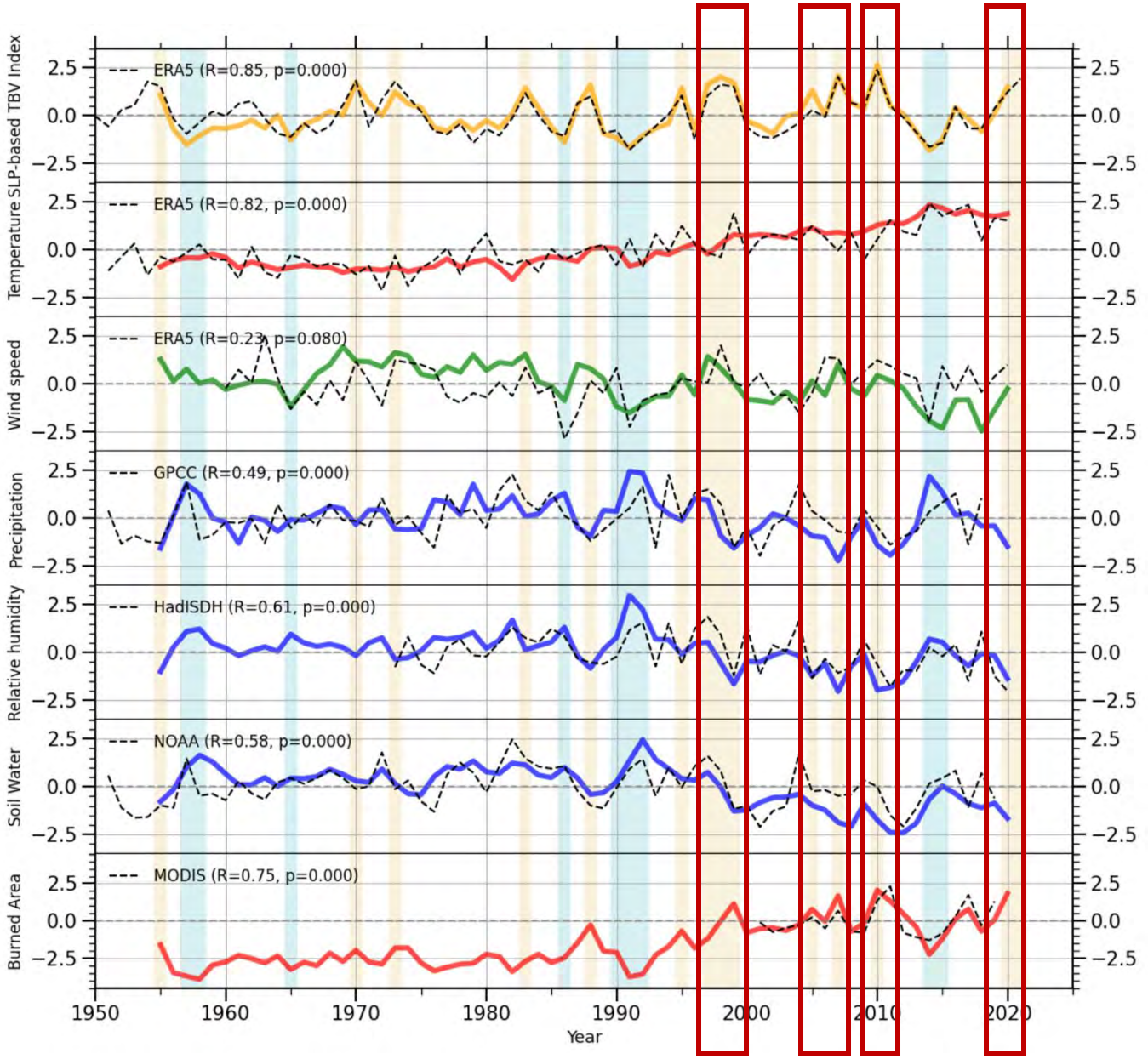




Ocean-Land Teleconnections

TBV(Trans Basin Variability): Sea level pressure anomaly difference between the central tropical Pacific (180-150W) and the tropical Atlantic-Indian Ocean (40W-60E), averaged over 15S-15N

- **Periods of strong TBV signals** are consistently followed by climate anomalies.
- **Multi-year co-variability** between oceanic TBV and regional climate **controls fire activity** in the U.S. Southwest.
- **Ocean-atmosphere variability** can precondition the regional environment for **fire-prone condition**.



Ocean-Land Teleconnections

SVD between Area Burned & SST

- **SVD Time Coefficient:** temporal evolution of the co-variability pattern
  Positive: spatial pattern + Negative: spatial pattern −
- **TBV-related ocean variability** modulates **co-evolving temporal patterns of SST and area burned** in the U.S. Southwest.

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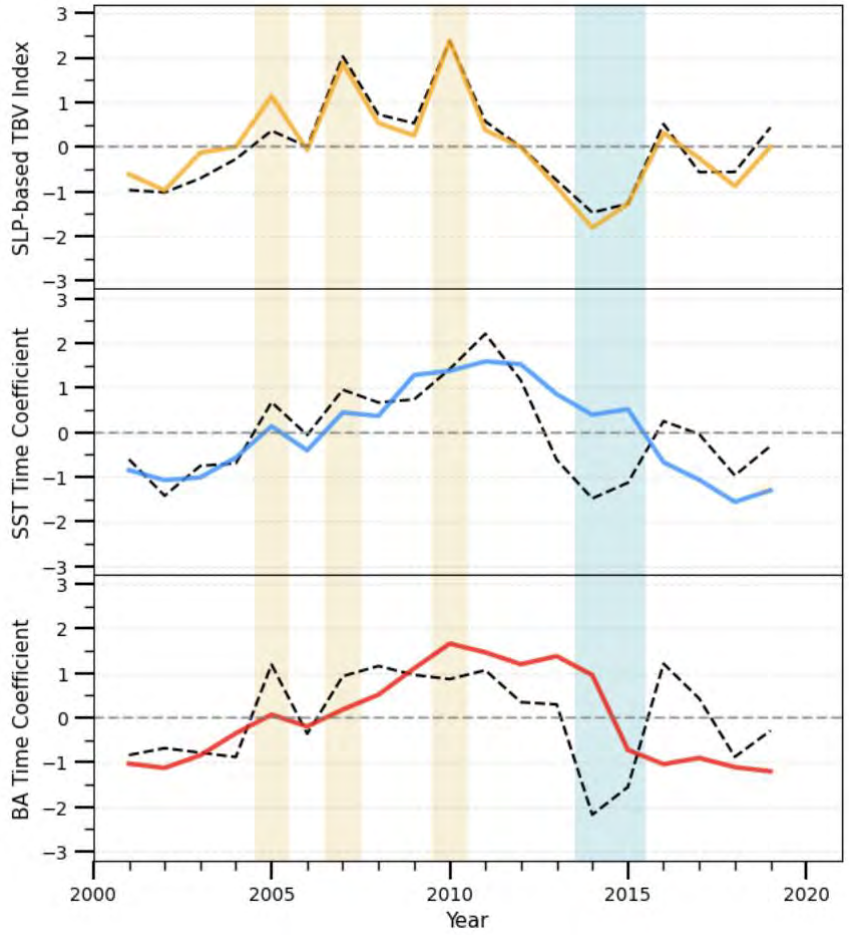
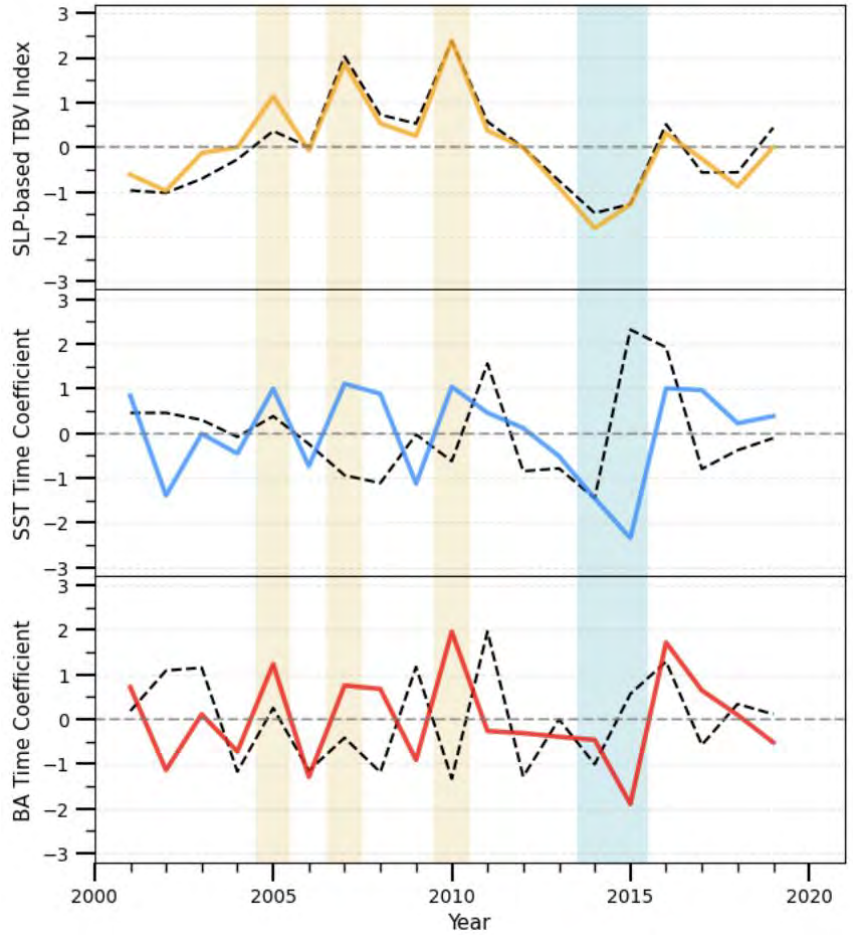
SVD 1st Mode



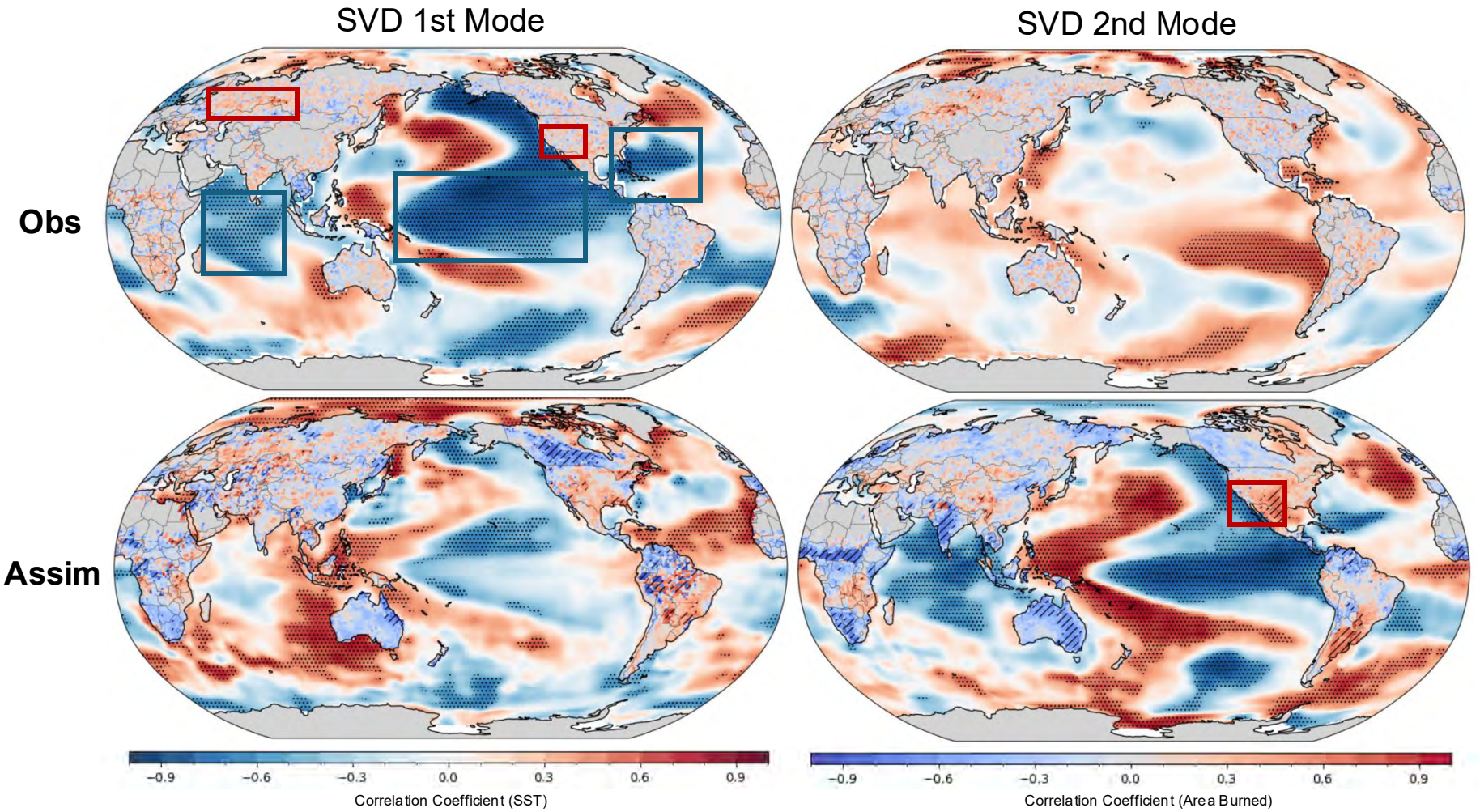


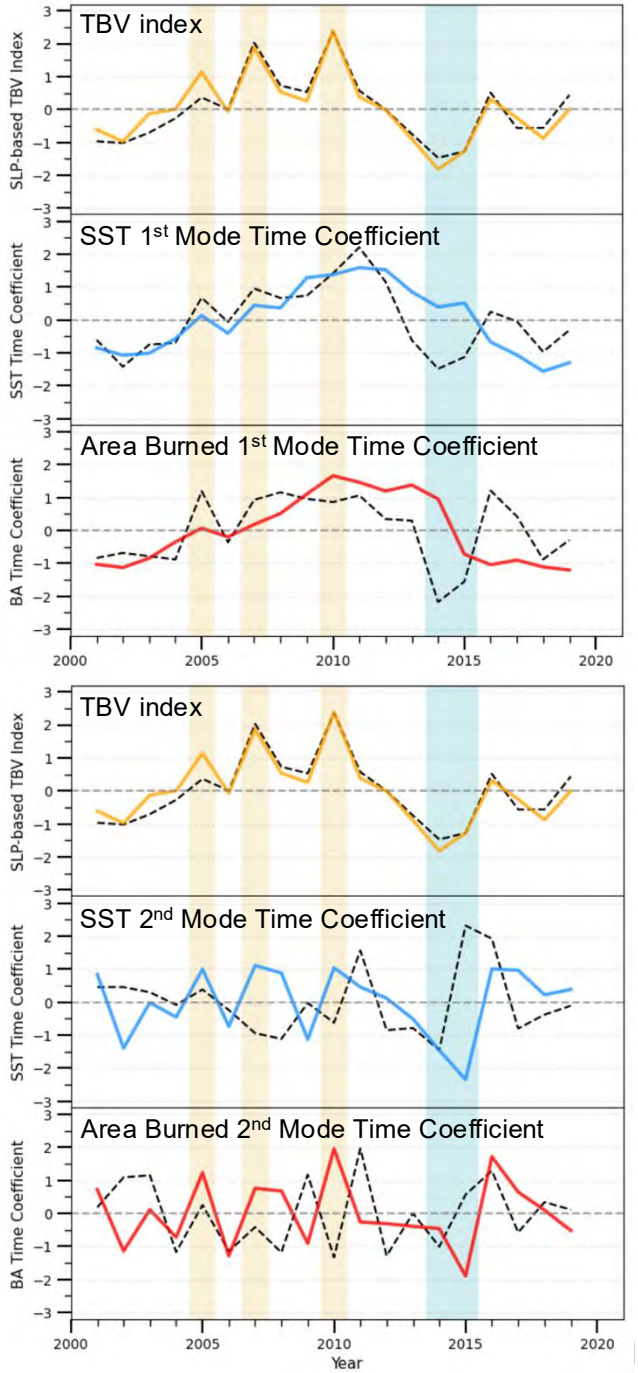
SVD 2nd Mode

Ocean-Land Teleconnections

SVD between Area Burned & SST

- Correlation between anomalies of each grid and SVD Time Coefficient (temporal evolution of the co-variability pattern)
  Red: when time coefficient +, value of grid + Blue: when time coefficient +, value of grid −
- Global SST variability drives co-evolving patterns with area burned.





Take Home Messages

- **Assimilation-based Earth system simulations effectively capture observed wildfire-climate relationships**, highlighting their utility for understanding and anticipating complex land-atmosphere interactions.

- **Global SST, especially TBV-related patterns, are strongly linked to environmental drivers and burned area**, suggesting a potentially important role for tropical ocean variability in shaping fire-prone conditions.

- **Ocean variability can provide potential multi-year predictability of wildfires in the U.S. Southwest**, offering a valuable window for early warning and adaptive fire management strategies.

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[1]Research Center for Climate Science, Pusan National University, Busan, Republic of Korea
[2]Institute for Masic Science, Center for Climate Physics, Busan, Republic of Korea
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