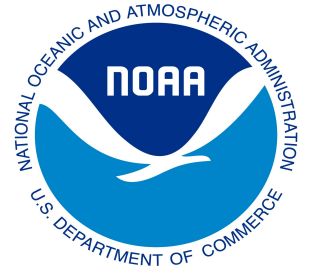# Seasonal predictability of saturation vapor pressure deficit in the western United States

Melissa L. Breeden[1], Andrew Hoell[1], Rochelle Worsnop[1], John Albers[1], Mike Hobbins[1,2], Rachel Robinson[1,2], Daniel Vimont[3]
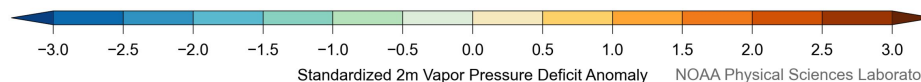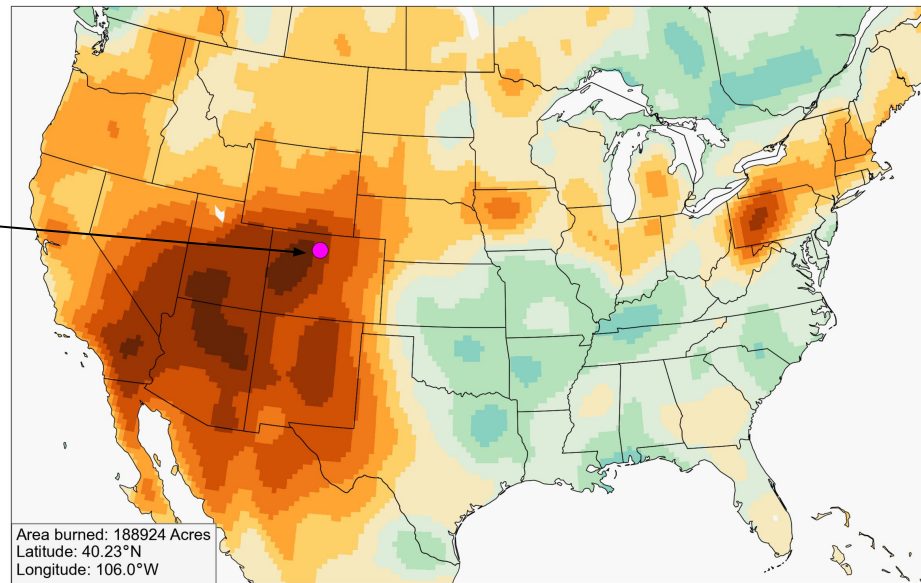
[1]NOAA Physical Sciences Laboratory, Boulder, CO
[2]CIRES CU Boulder, Boulder CO
[3]Dept. Of Atmospheric and Oceanic Sciences, UW-Madison, Madison, WI

ERA5 VPD Anomaly, JAS 2020

East Troublesome Fire

Area burned: 188924 Acres
Latitude: 40.23°N
Longitude: 106.0°W

Standardized 2m Vapor Pressure Deficit Anomaly   NOAA Physical Sciences Laboratory

https://www.psl.noaa.gov/fire_weather/historical/

Saturation vapor pressure deficit (VPD) is highly correlated to area burned by wildfires in western US

$$VPD = e_s(T) - e_a(T_d)$$

Saturation Vapor Pressure: how much moisture the atmosphere could contain
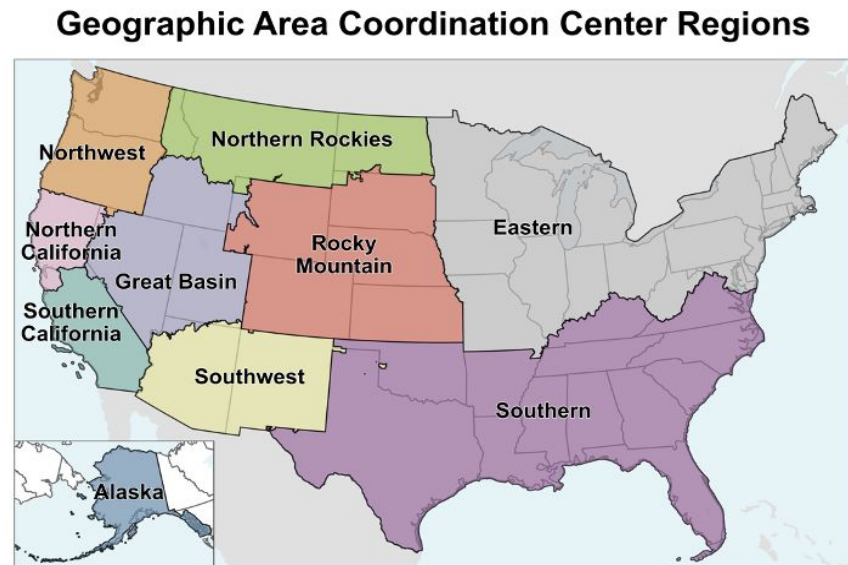
Actual Vapor Pressure: how much moisture is actually present
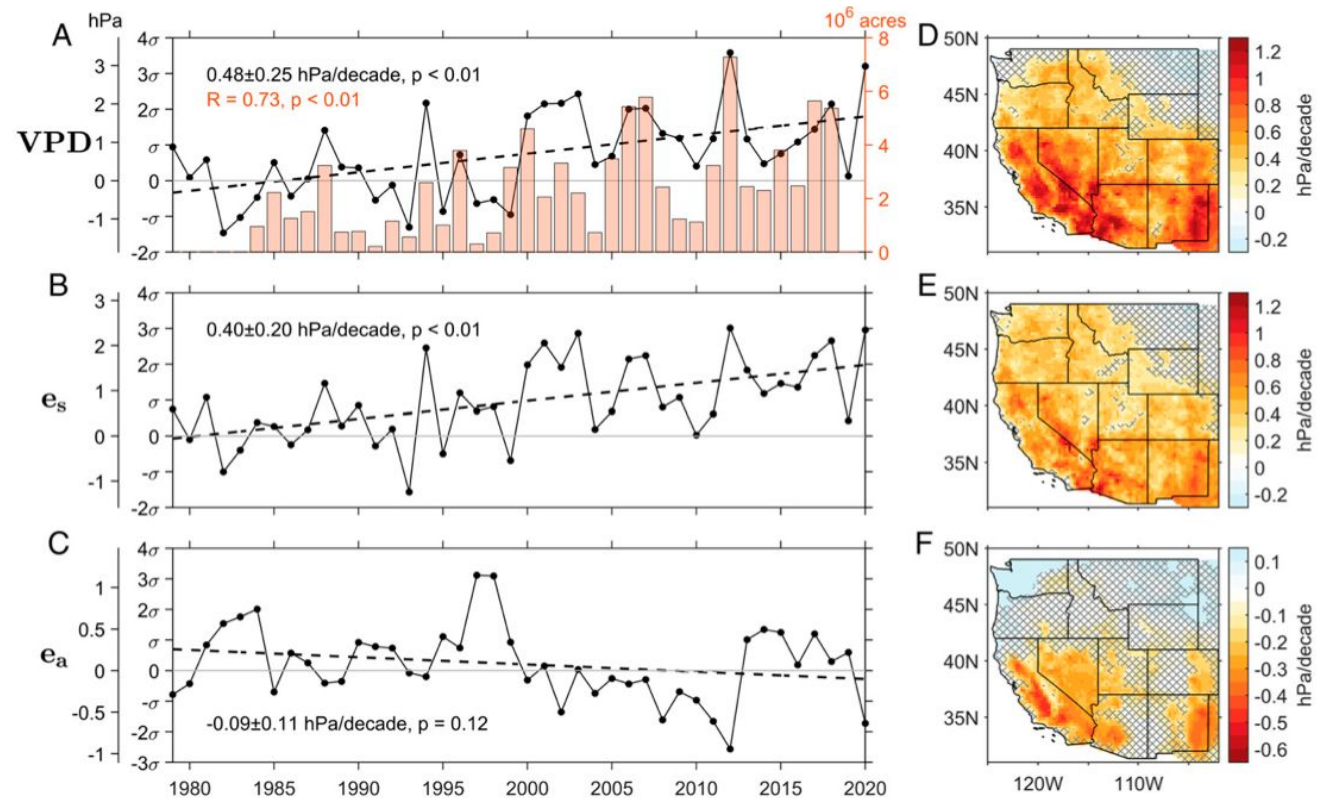
Zhuang et al. PNAS 2018

Research Questions

1. What are sources of seasonal VPD skill in the western US?

2. How do VPD skill, and sources of skill, differ by season and western US subregion?

https://gacc.nifc.gov/

Data and Forecast Model

- Monthly mean JRA55 Reanalysis sea surface temperature (SST), soil moisture (SM) and VPD anomalies calculated with respect to the 1958-2021 monthly climatology

- Two Linear Inverse Models (LIMs; Penland and Sardeshmukh 1995) are trained to forecast VPD using covariance statistics of VPD and predictor variables SST, SM

 - LIMs are used to generate retrospective forecasts and assess VPD skill contributions from modes of variability (such as a long-term trend, ENSO)
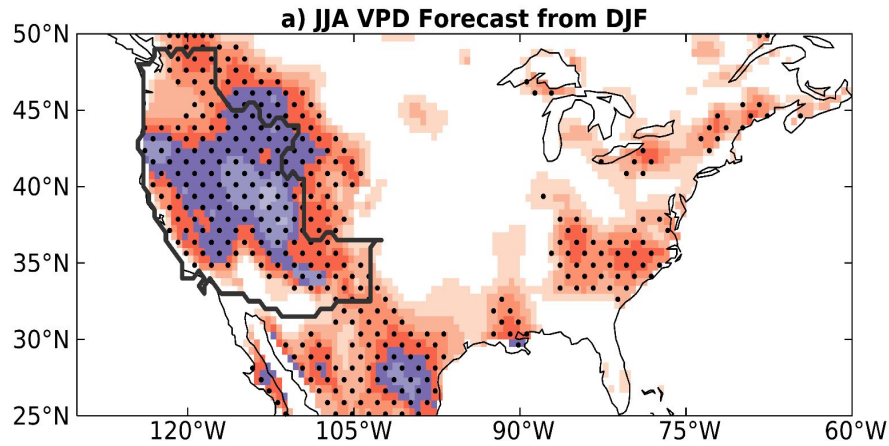
LIM Including the Trend

Variable	Domain
SST	55°S – 55°N, 0-358.75°E
SM	24°N-50°N, 230-300°E
VPD	25°N-50°N, 230-300°E

LIM without the Trend

Variable	Domain
SST	25°S – 55°N, 0-358.75°E
VPD	25°N-50°N, 230-300°E

Seasonal VPD Forecast Skill: Trend Included
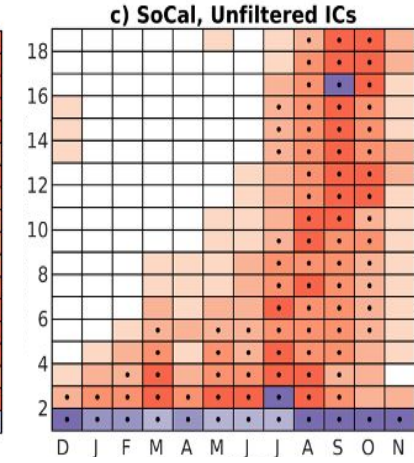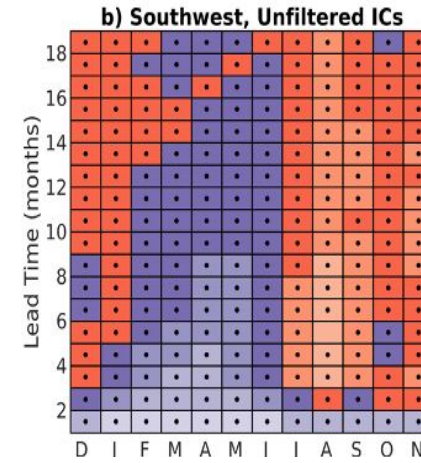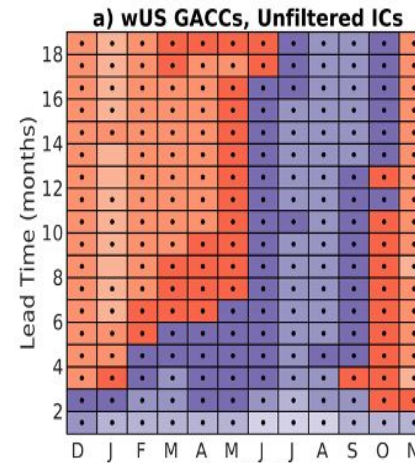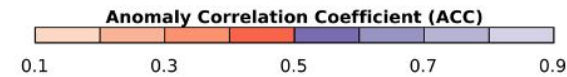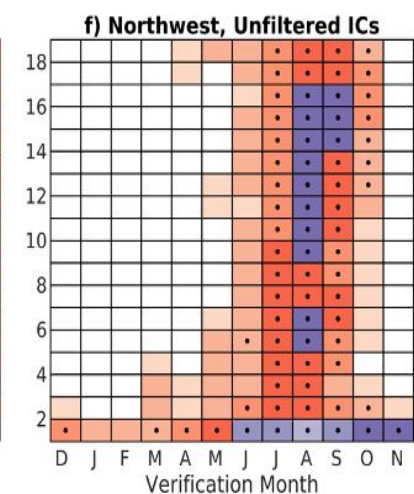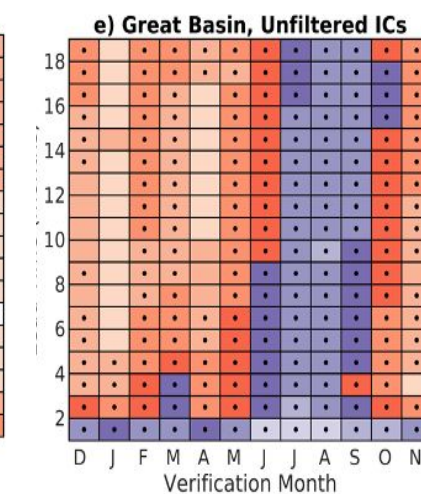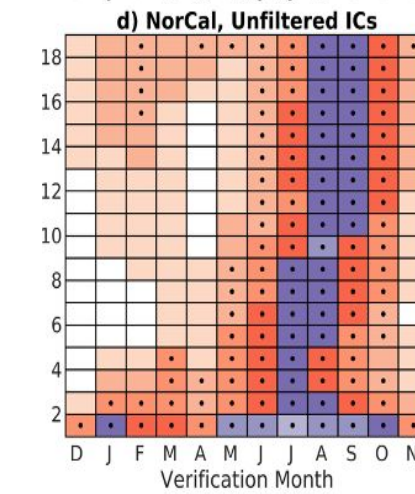
Removing a nonlinear trend

How much VPD skill is associated with the trend?

- Isolate component of the initial conditions associated with just the trend
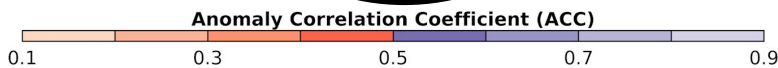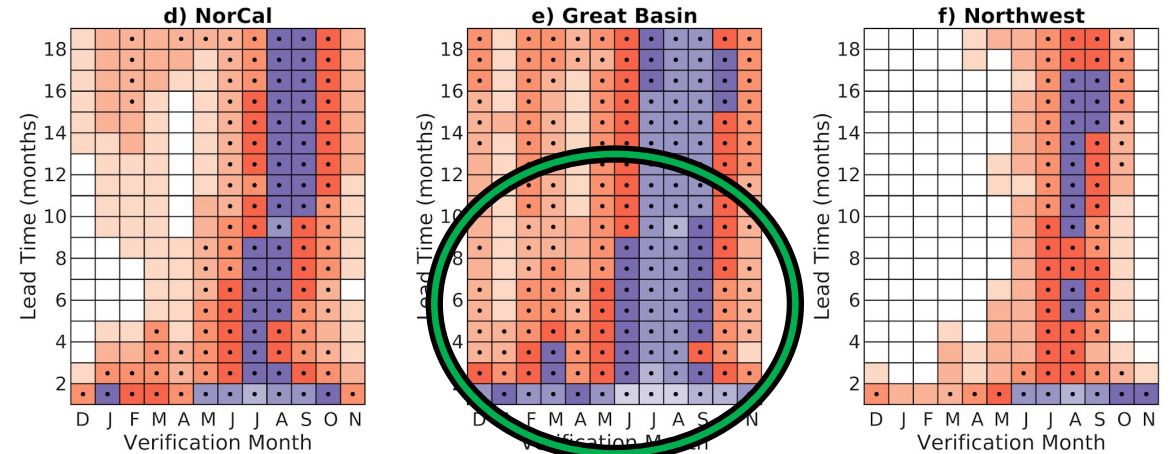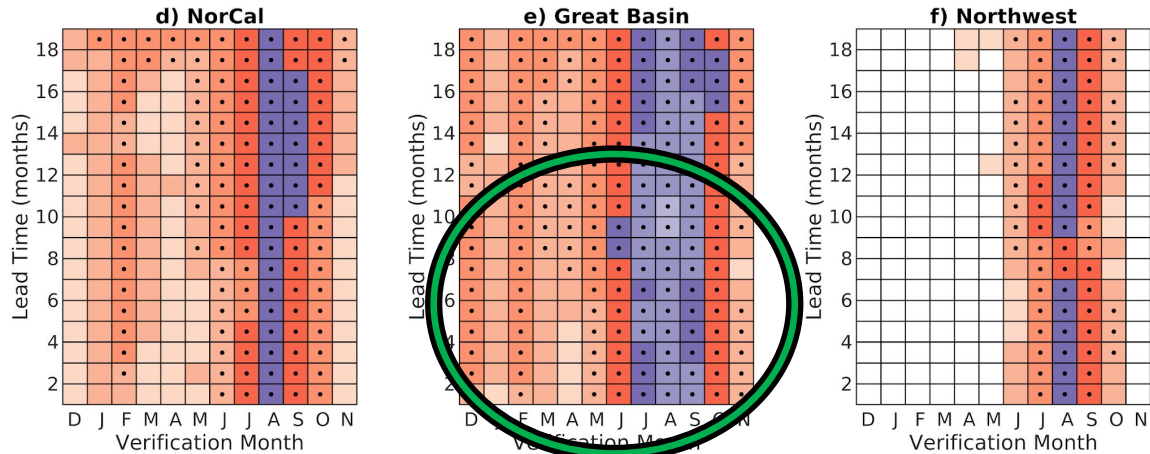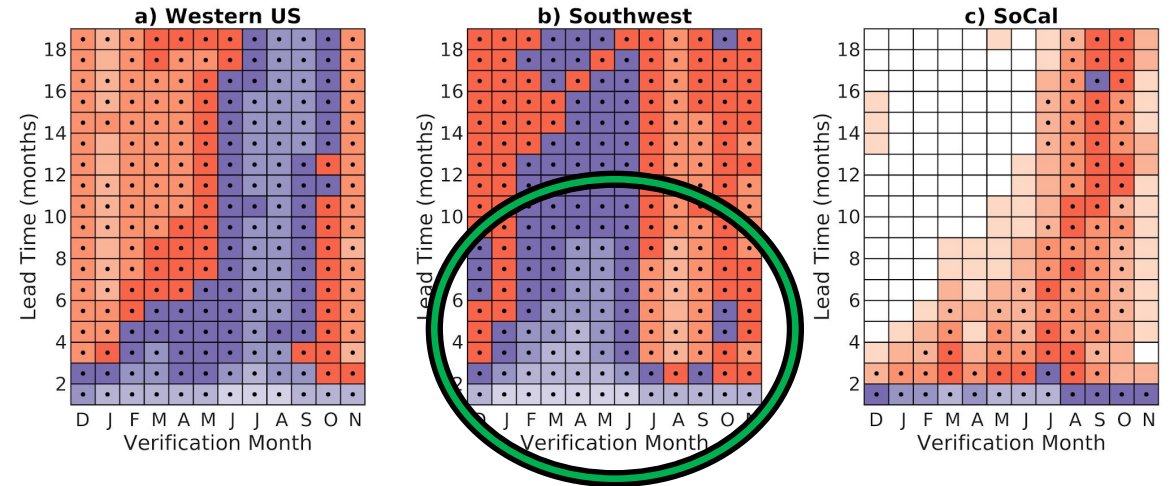
- Compute new forecasts and evaluate skill
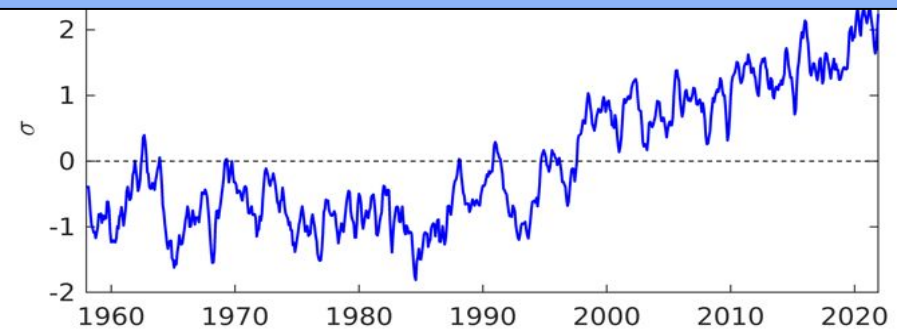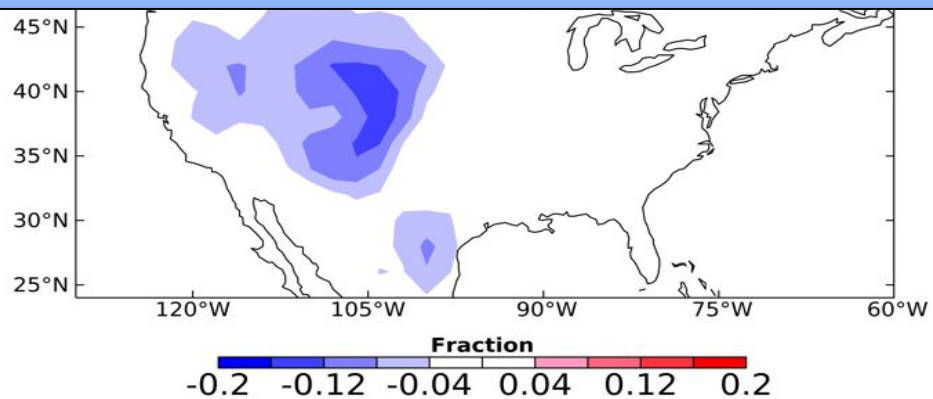
Trend dominates VPD skill at longer lead times
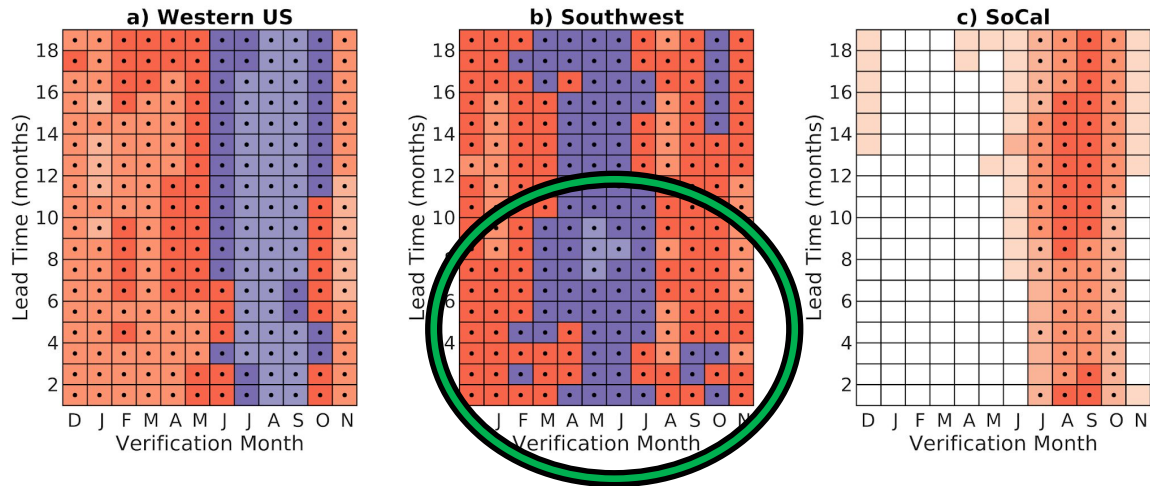
Detrended VPD Skill

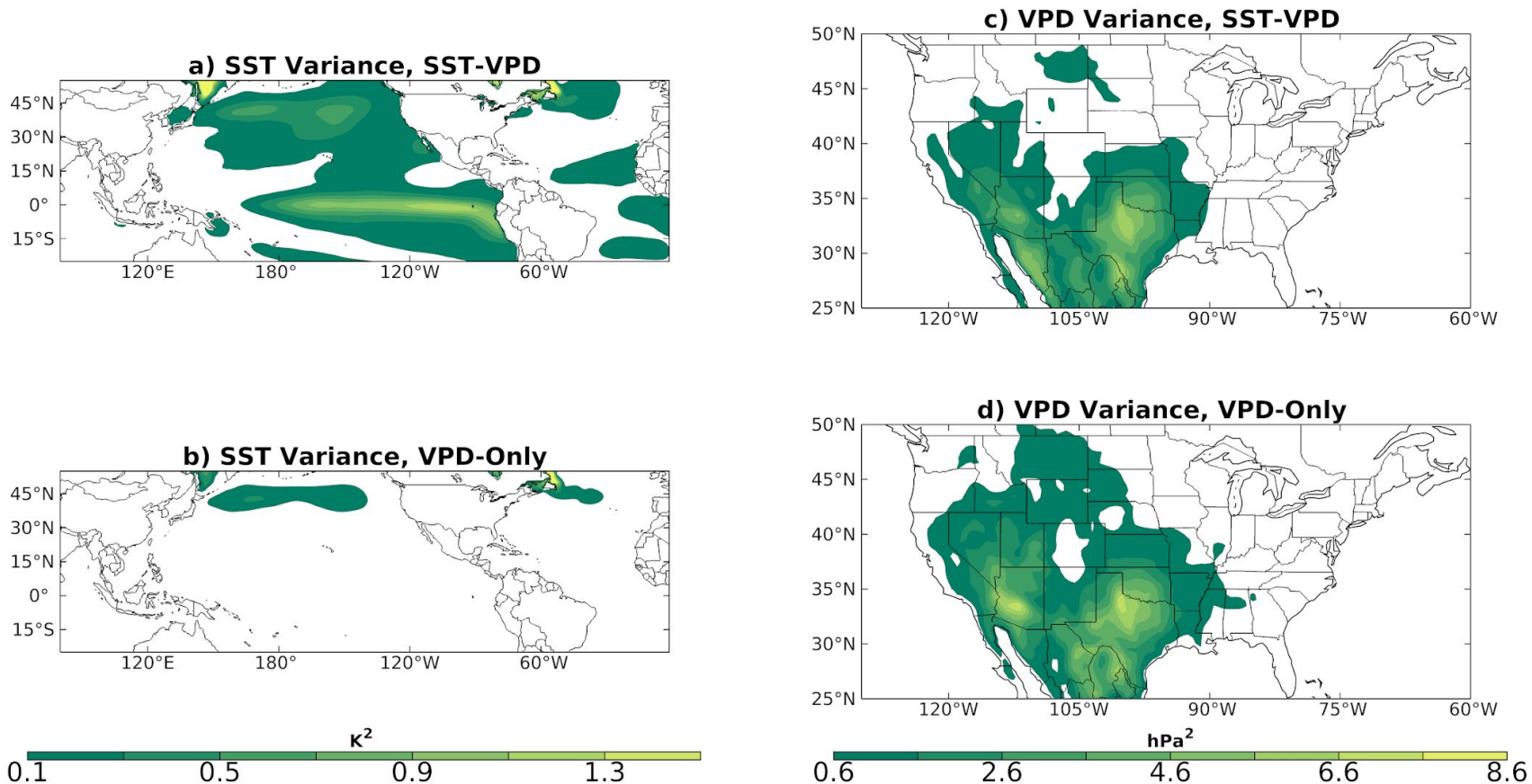## LIM without the Trend

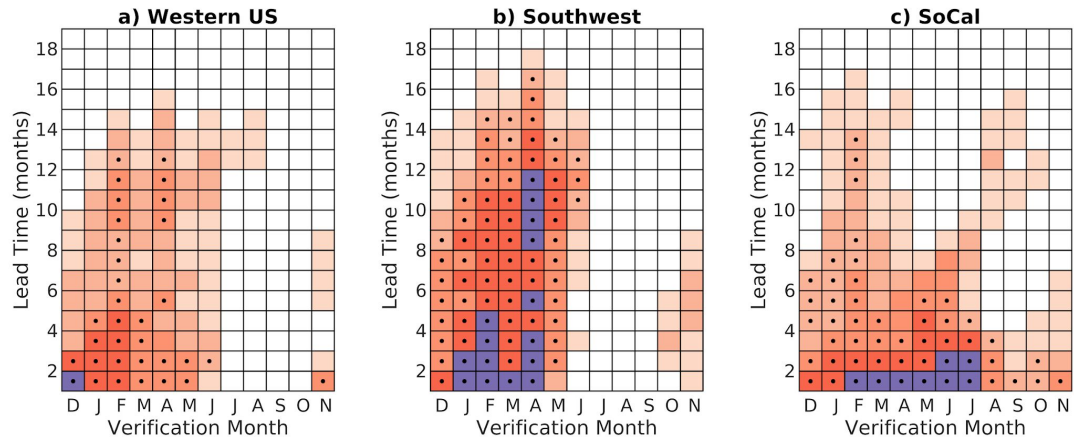| Variable	Domain
SST	25°S – 55°N, 0-358.75°E
VPD	25°N-50°N, 230-300°E
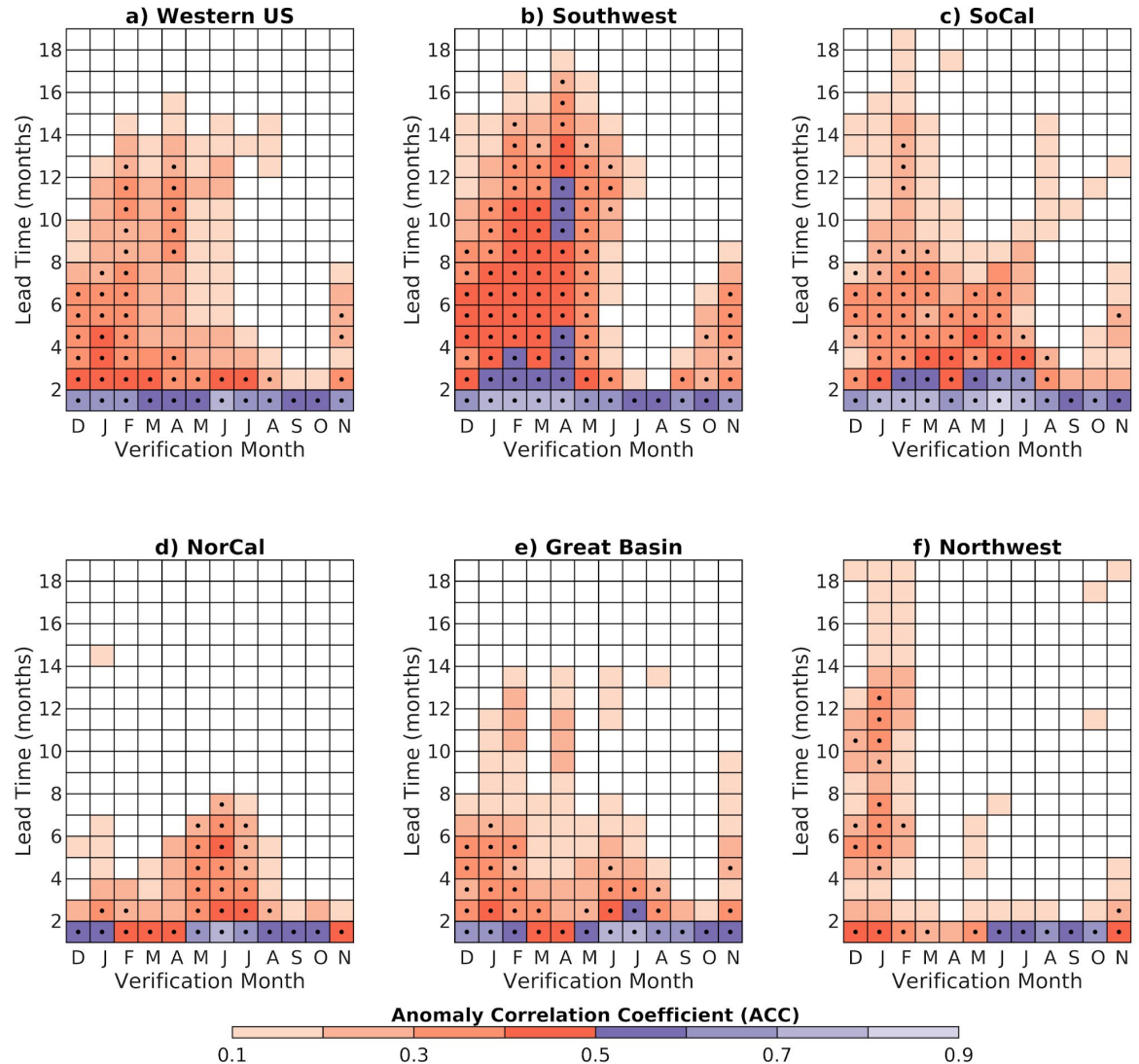
Decomposing Detrended LIM Skill

- We use the LIM to split VPD anomalies into a group associated with SSTs, 'SST-VPD', and a group with *only* VPD anomalies, 'VPD-only'
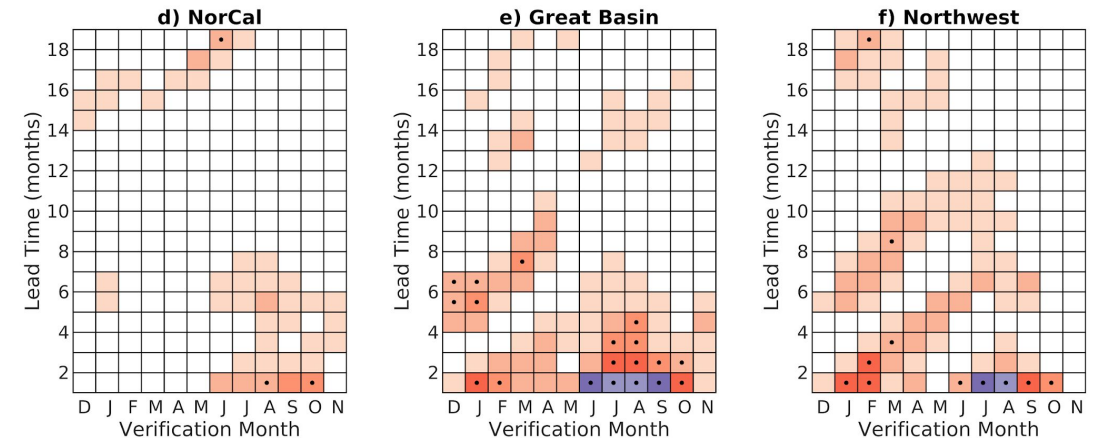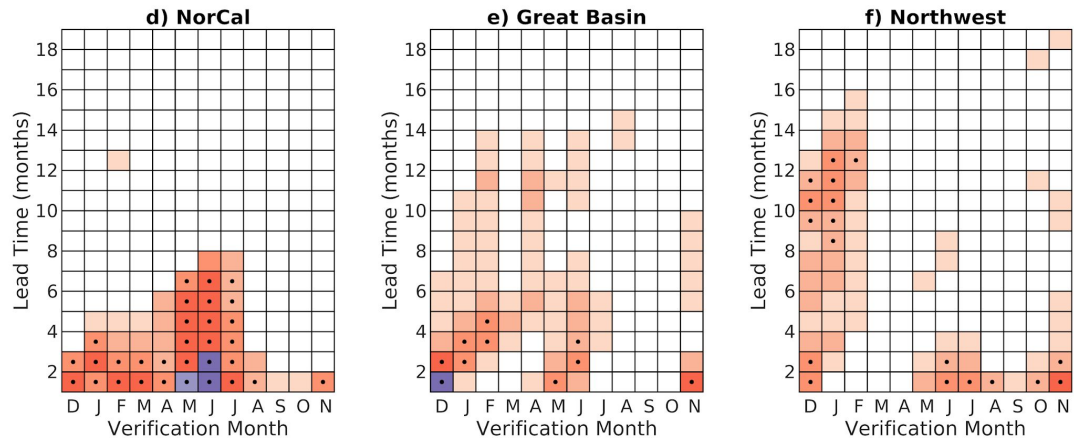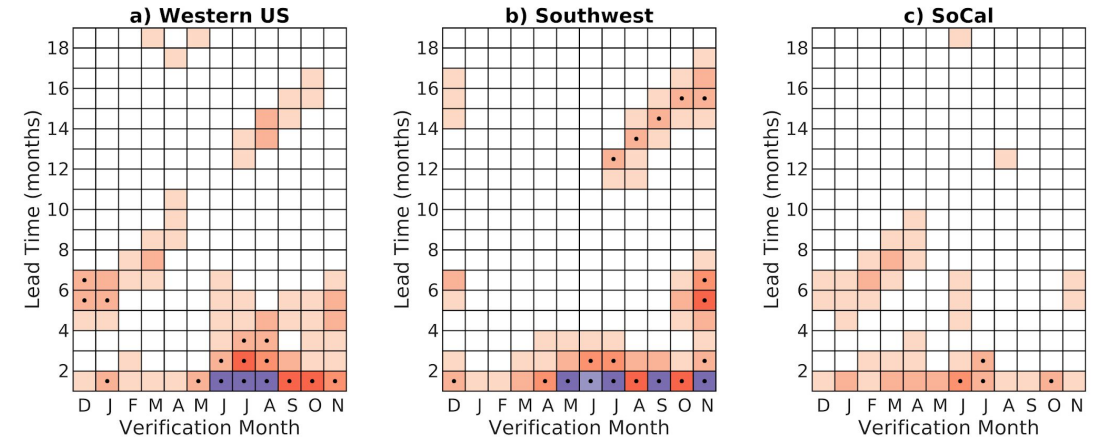

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VPD skill from SST-VPD and VPD-only modes differs in timing and amplitude
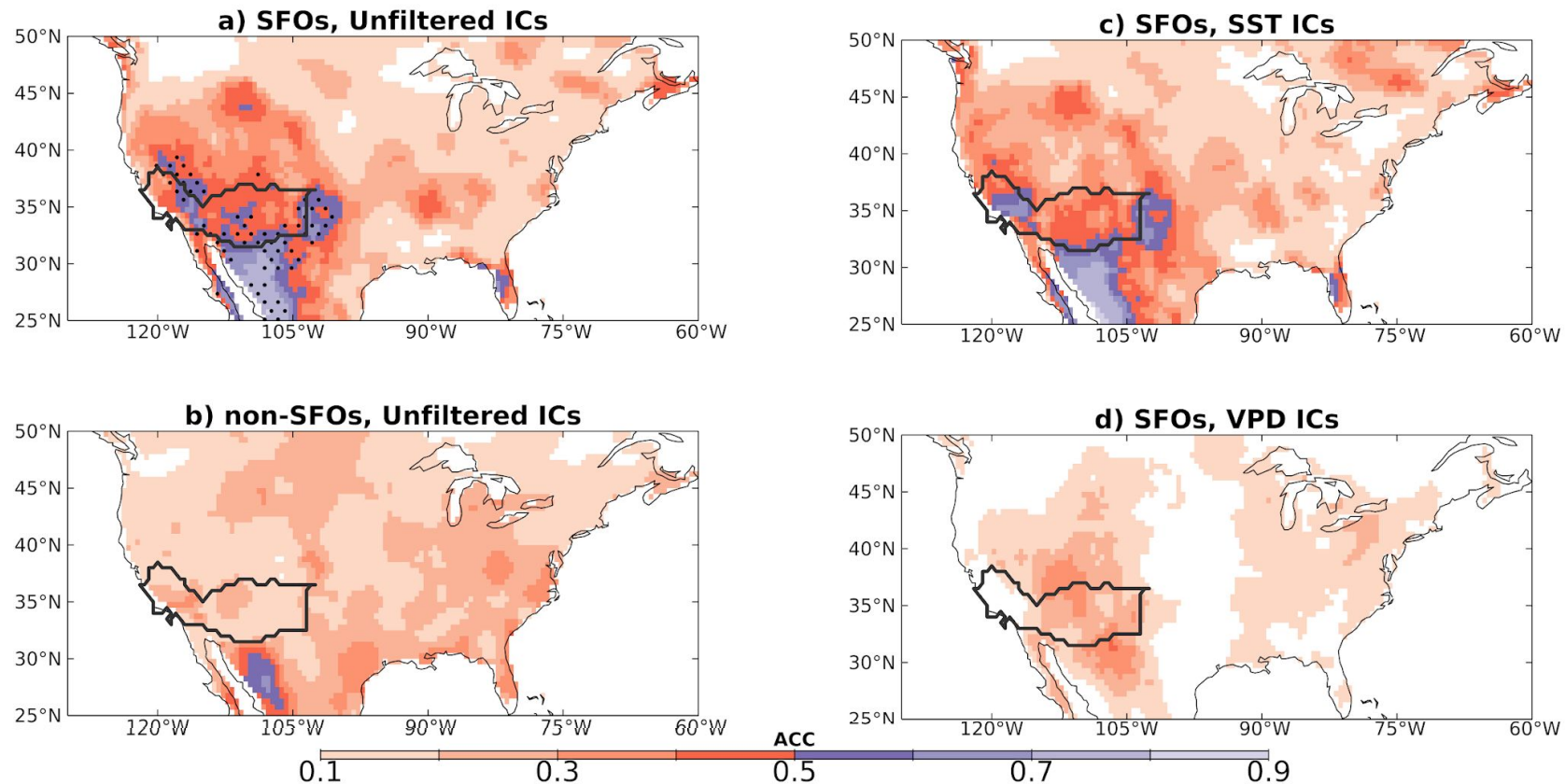

SST-VPD Modes

VPD-only Modes

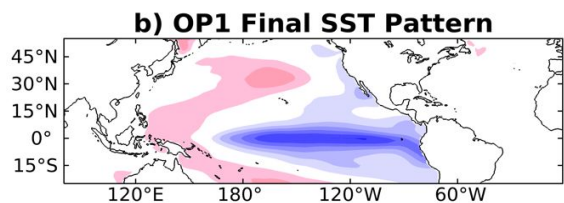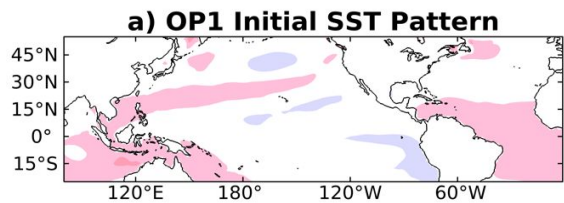# Seasonal Forecasts of Opportunity (SFOs)

- Sort forecasts based on their signal-to-noise ratio and resultant *expected skill*
(Sardeshmukh et al. 2000; Albers and Newman 2019, 2021)

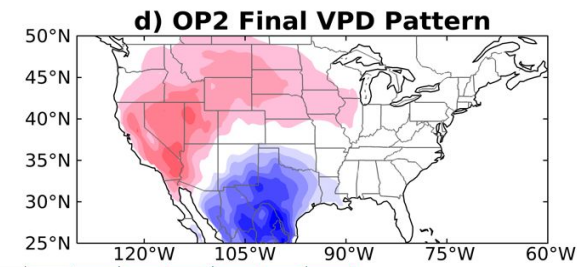- SFOs defined as forecasts with the top 15% of expected skill values
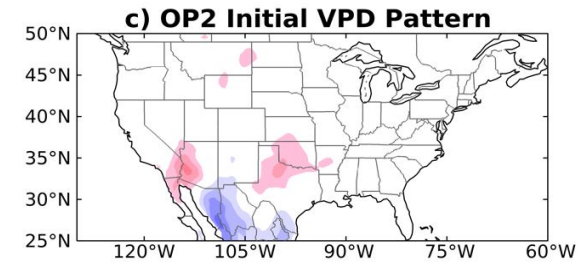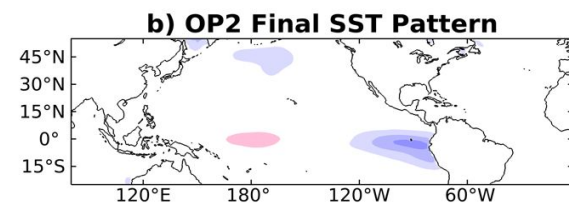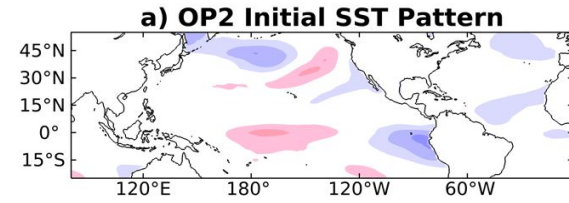

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Patterns associated with forecasts of opportunity include ENSO

- Optimal patterns (OPs) maximize system growth over a specified growth period
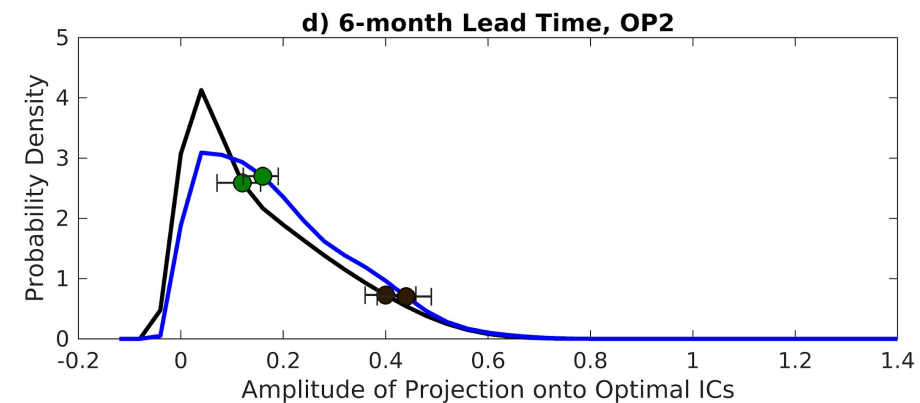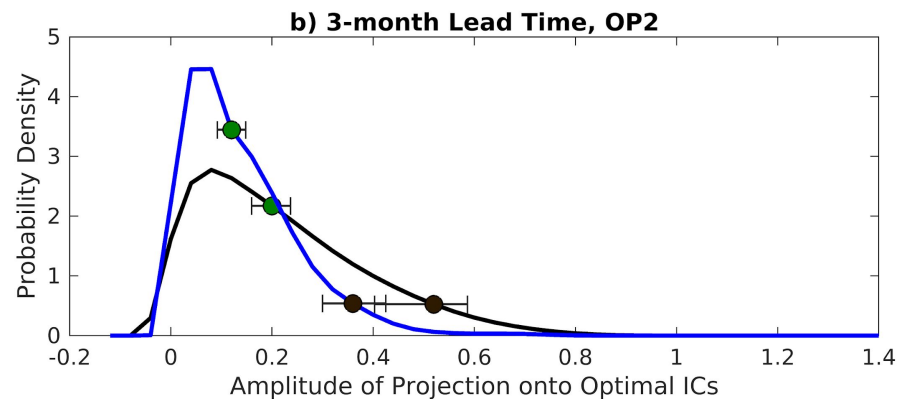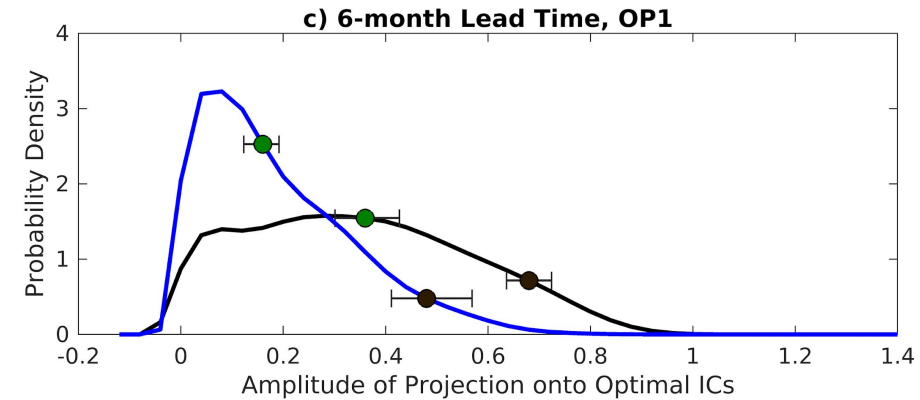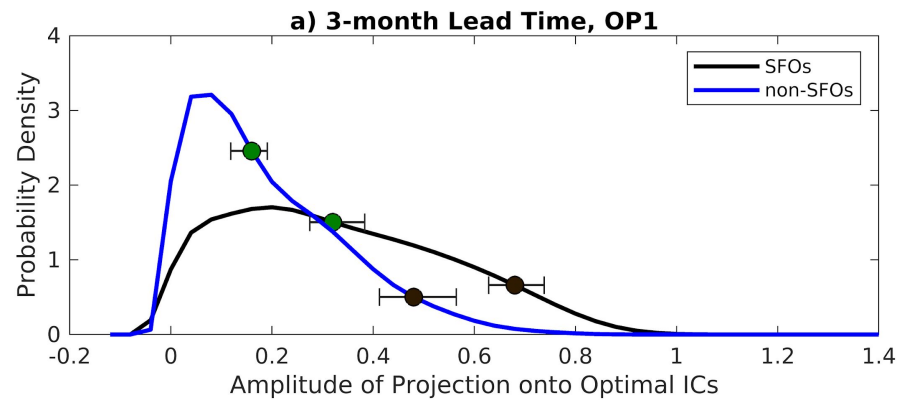
7-month growth period
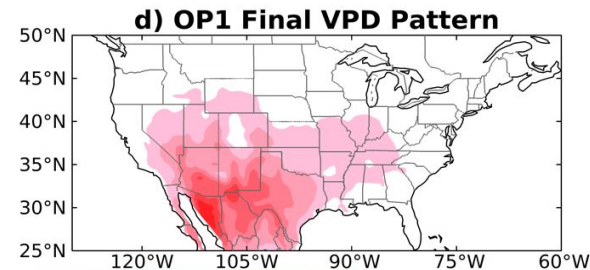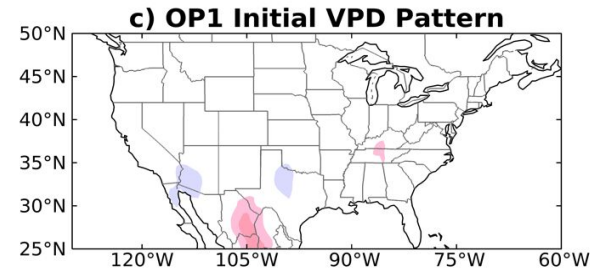
3-month growth period

Patterns associated with forecasts of opportunity include ENSO

- OP1 and OP2 associated with 3-month SFOs, only OP1 with 6-month SFOs

Conclusions and More Information

- Seasonal VPD skill is associated with a nonlinear warming trend and SST variability, which contribute to skill mainly during the warm and cool seasons, respectively.

- Breeden, M. L., Hoell, A., Worsnop, R. P., Albers, J. R., Hobbins, M. T., Robinson, R. M., and Vimont, D. J.: Seasonal Predictability of Vapor Pressure Deficit in the western United States, submitted to *Weather and Climate Dynamics*
  preprint:
  https://egusphere.copernicus.org/preprints/2025/egusphere-2025-115/

- Realtime VPD forecasts!

- Contact Info: Melissa Breeden, NOAA PSL
  melissa.breeden@noaa.gov

- This work was funded by NOAA grant: NA230AR40501861

Experimental Seasonal Vapor Pressure Deficit Guidance
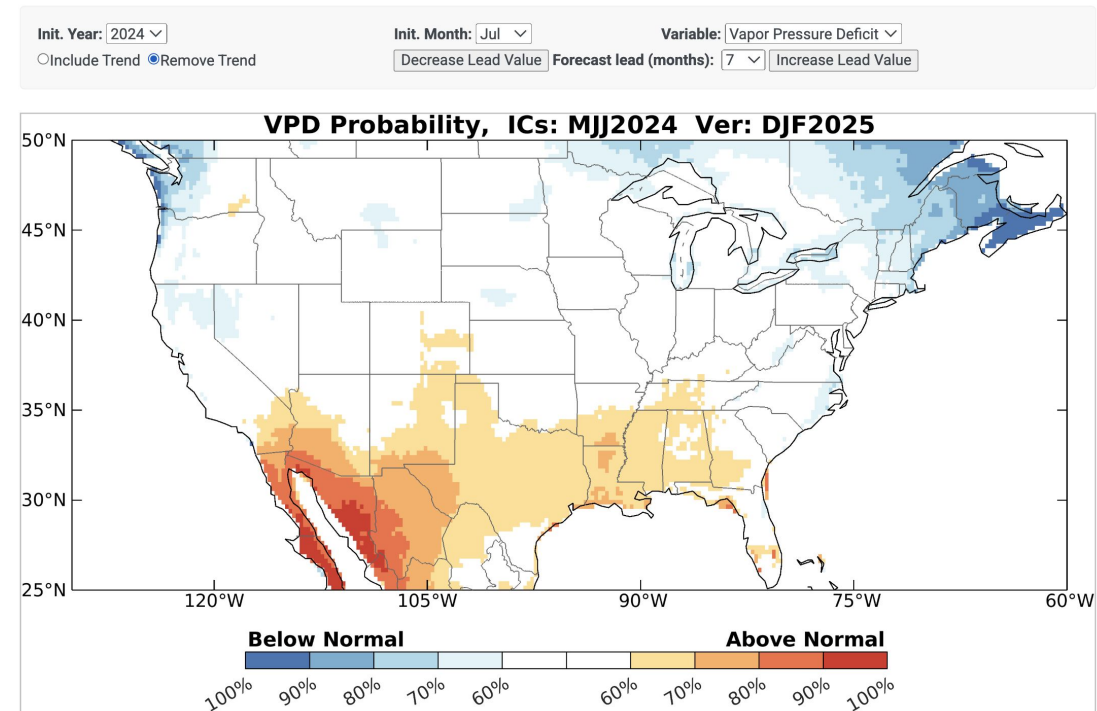
https://www.psl.noaa.gov/forecasts/seasonal_vpd/

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Linear Inverse Model (LIM)

For state vector $\mathbf{x} = \{VPD, SM, SST\}$,

All from JRA55 reanalysis

$$\frac{d\mathbf{X}}{dt} = \mathbf{Lx} + F_S$$

Evolution of system

Slow, predictable

Fast, rapidly decorrelating, unpredictable

Dynamic Operator: $\mathbf{L} = log(\mathbb{C}\tau * inv(\mathbb{C}_0))/\tau$

LIM Forecast: $x(t) = x(0) * exp(Lt) = x(0)G(t)$

Penland and Sardeshmukh 1995