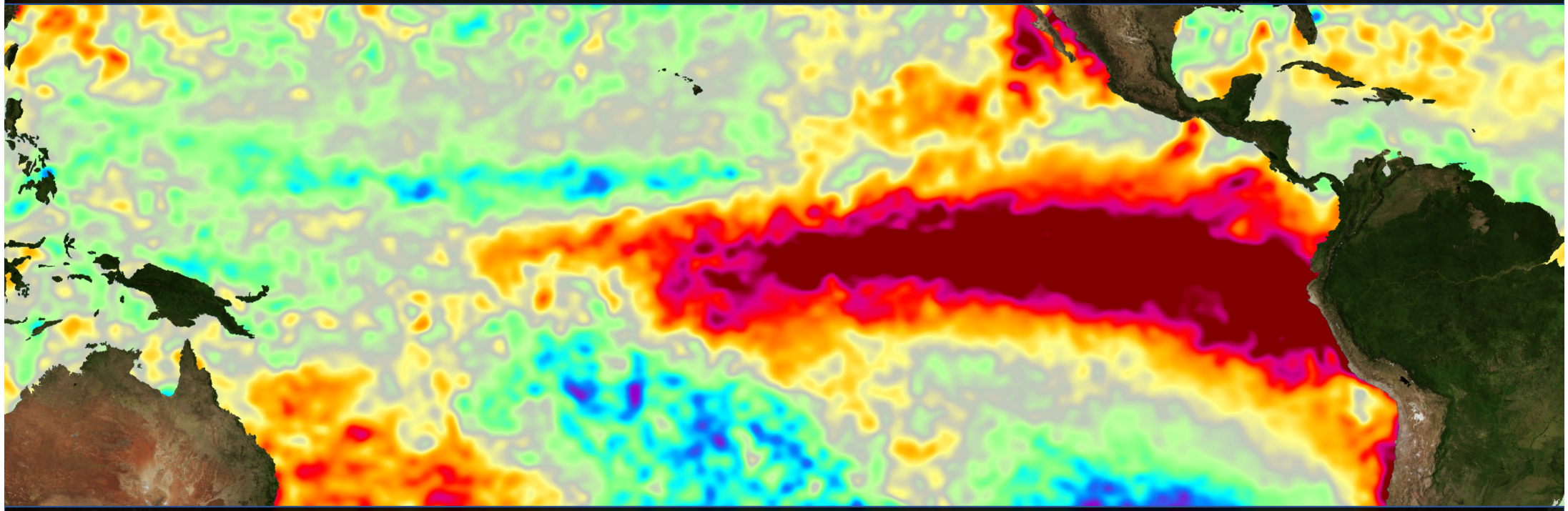
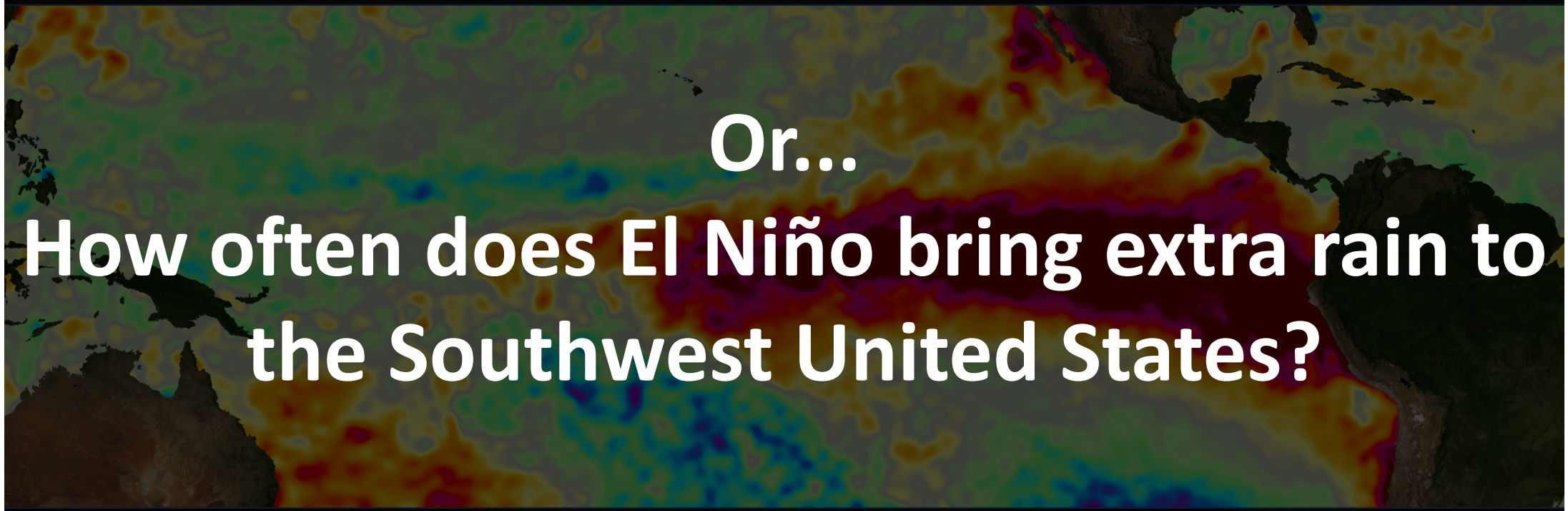
# Intrinsic century-scale variability in tropical Pacific SSTs and their influence on southwestern US hydroclimate



**Colin P. Evans**
**PhD Candidate**
**Department of Earth and Atmospheric Sciences**
**Cornell University, Ithaca, NY, USA**

# Intrinsic century-scale variability in tropical Pacific SSTs and their influence on southwestern US hydroclimate



## Or...

## How often does El Niño bring extra rain to the Southwest United States?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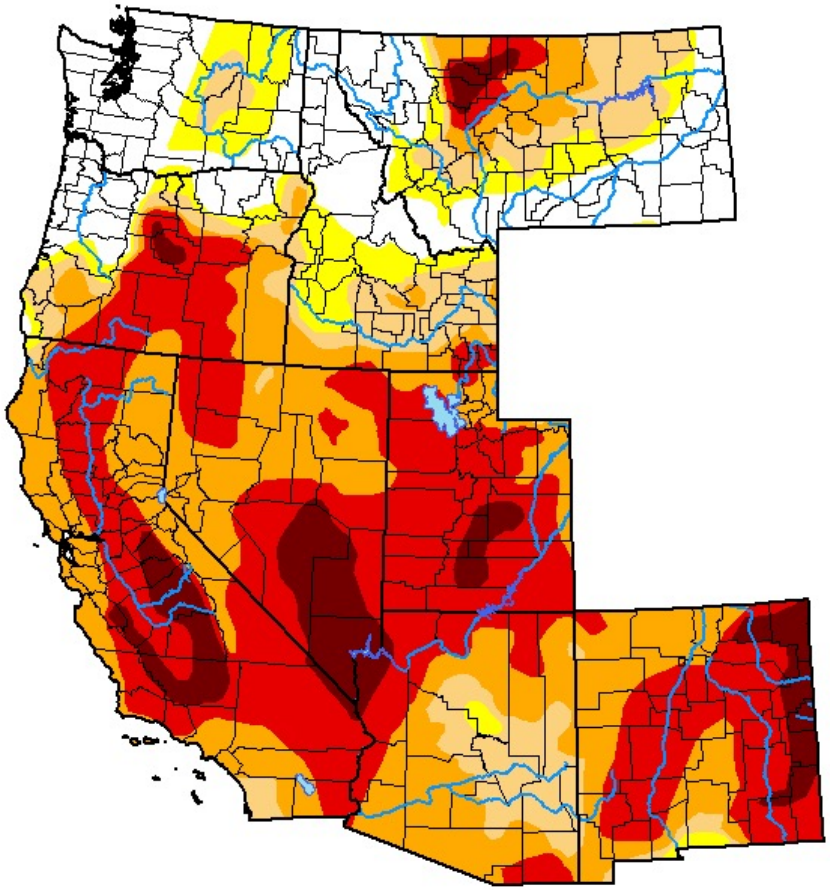
*U.S. Drought Monitor*

# West



**June 28, 2022**

***(Released Thursday, Jun. 30, 2022)***

**Valid 8 a.m. EDT**

*Intensity:*

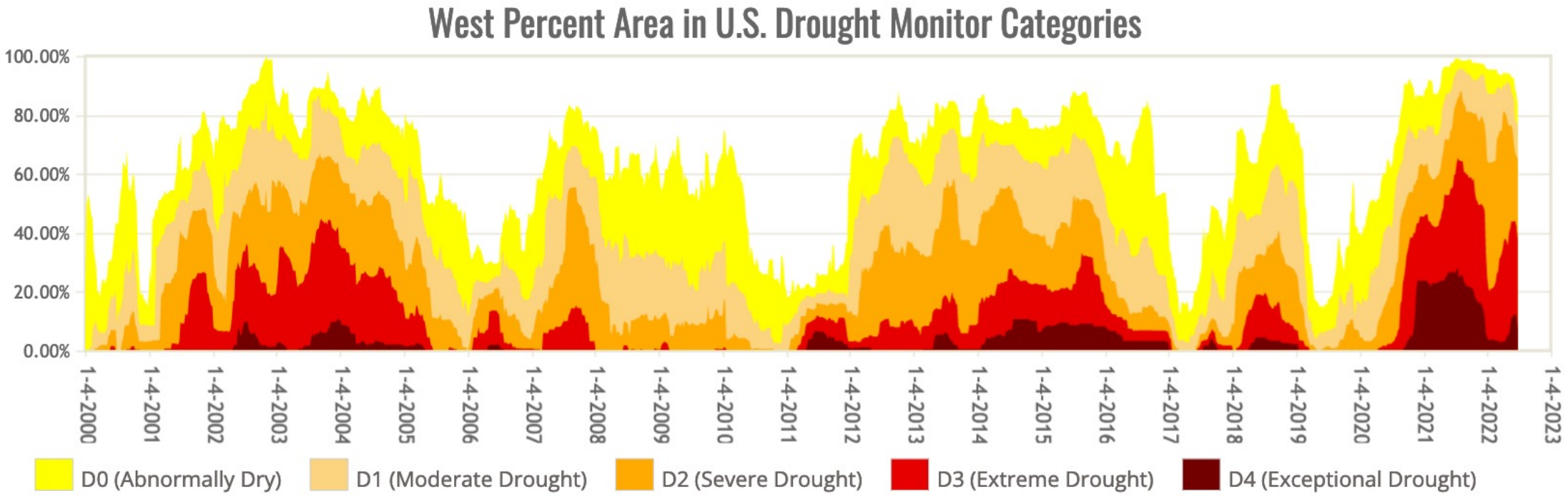
- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

*The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx*

*Author:*

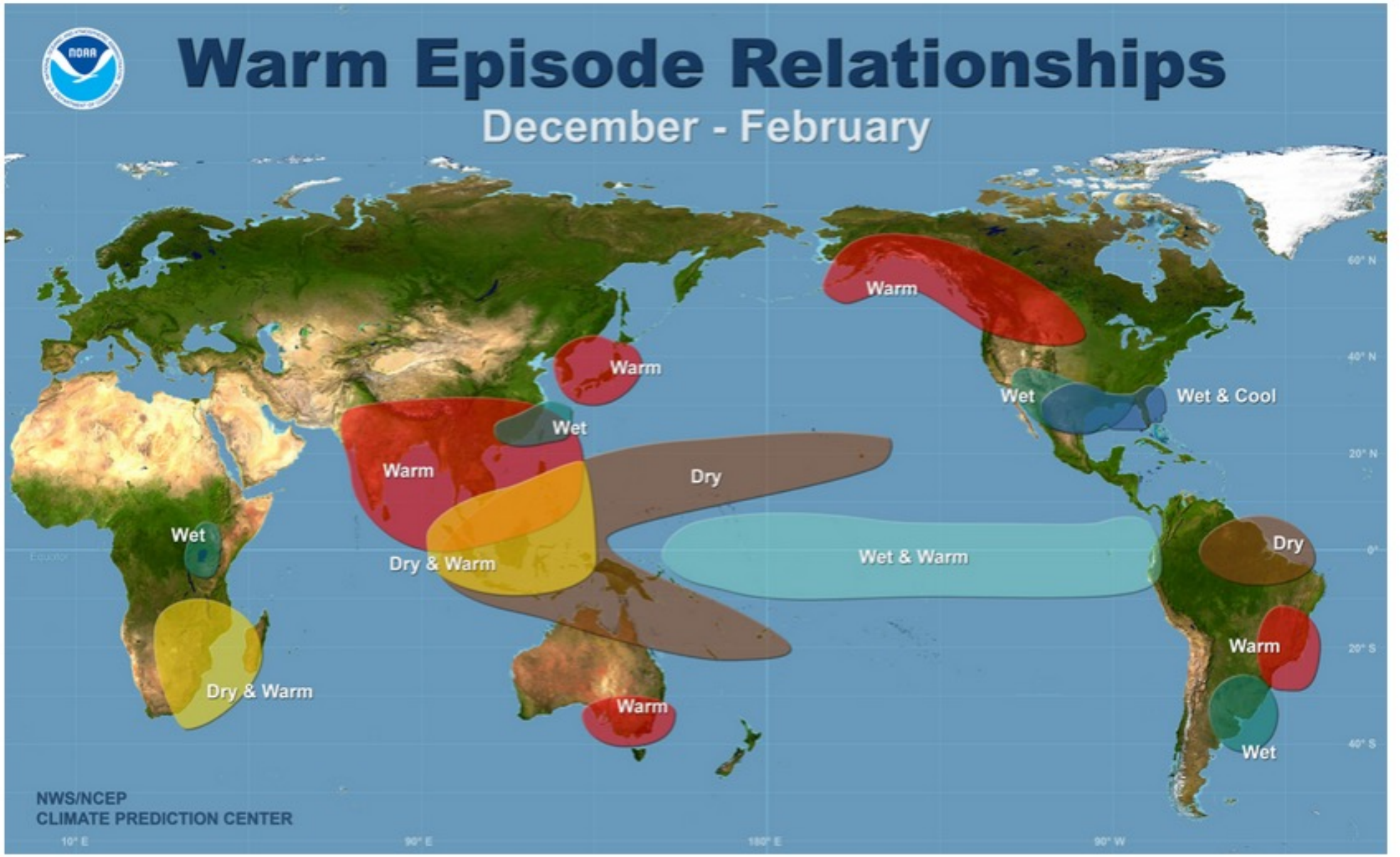
Curtis Riganti
National Drought Mitigation Center

**droughtmonitor.unl.edu**

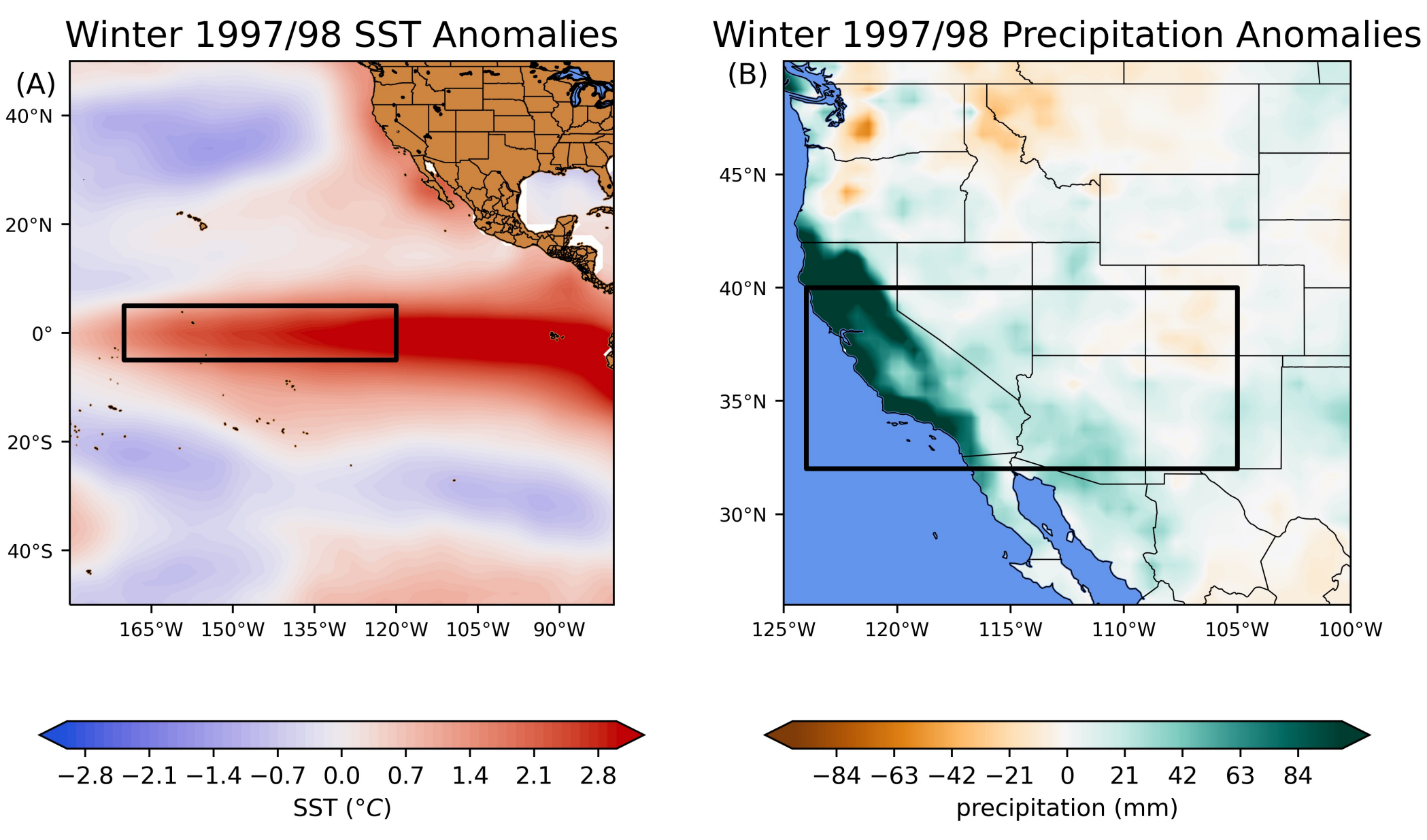

West Percent Area in U.S. Drought Monitor Categories
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
1-4-2000
1-4-2001
1-4-2002
1-4-2003
1-4-2004
1-4-2005
1-4-2006
1-4-2007
1-4-2008
1-4-2009
1-4-2010
1-4-2011
1-4-2012
1-4-2013
1-4-2014
1-4-2015
1-4-2016
1-4-2017
1-4-2018
1-4-2019
1-4-2020
1-4-2021
1-4-2022
1-4-2023
D0 (Abnormally Dry)
D1 (Moderate Drought)
D2 (Severe Drought)
D3 (Extreme Drought)
D4 (Exceptional Drought)

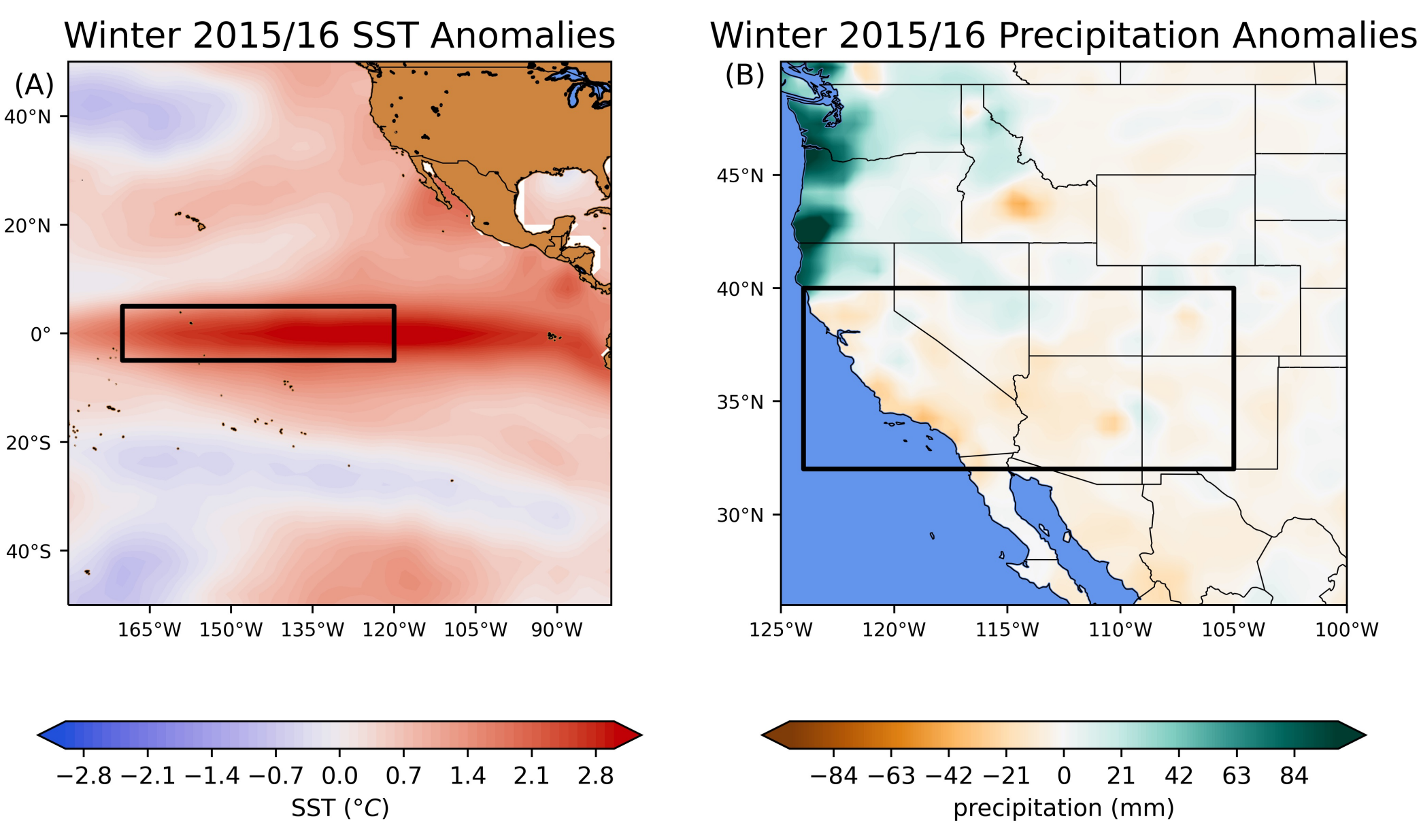
# 25 million people rely on Lake Mead for water

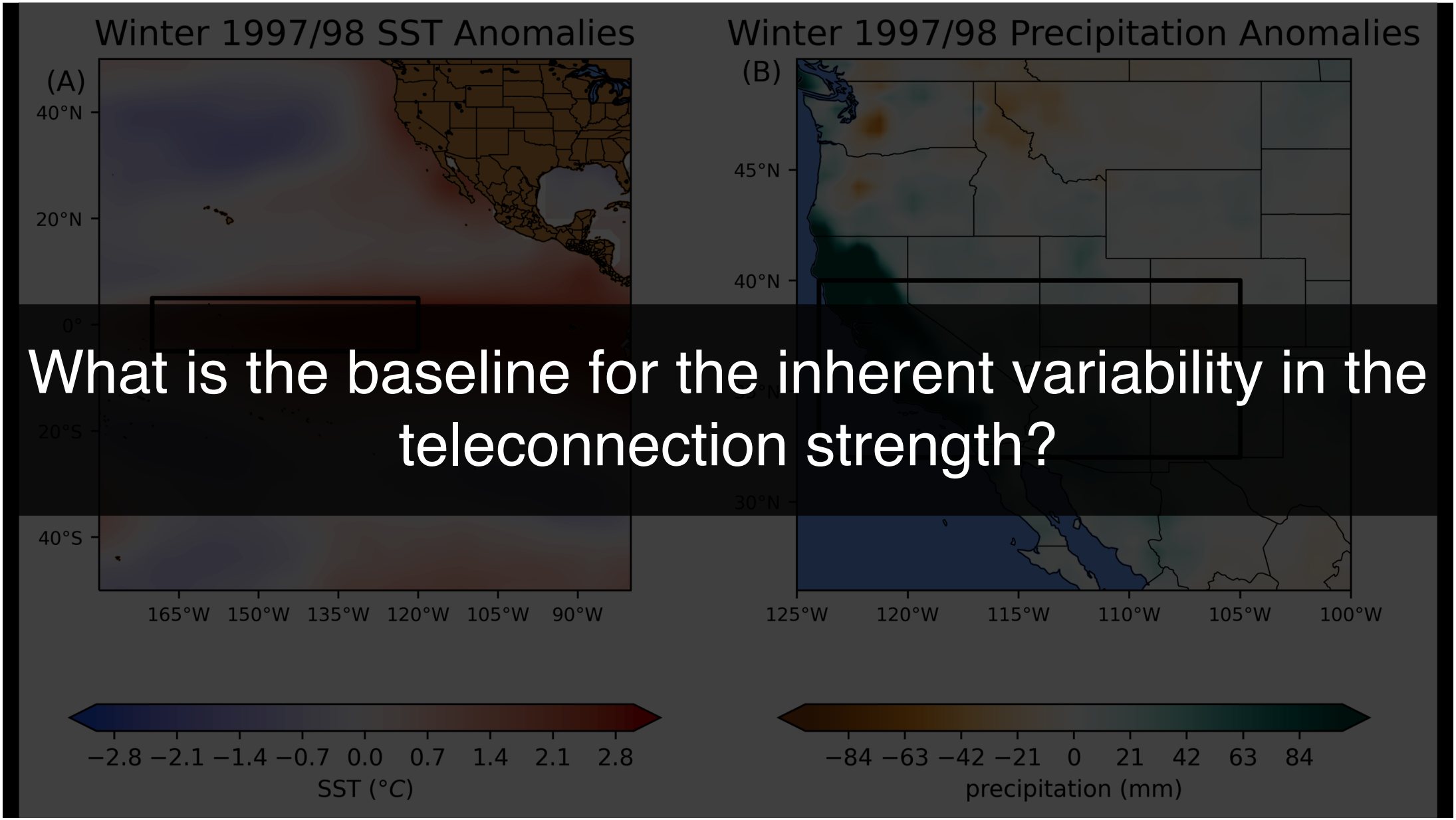

WHY
NO
RENT
CONTROL


Warm Episode Relationships
December - February
Warm
Warm
Wet
Wet & Cool
Wet
Warm
Dry
Wet
Dry & Warm
Wet & Warm
Dry
Warm
Dry & Warm
Warm
Wet
60° N
40° N
20° N
0°
20° S
40° S
NWS/NCEP
CLIMATE PREDICTION CENTER
10° E
90° E
180° E
90° W


Warm
Southwest United States
Wet
Wet & Cool
60° N
40° N
20° N

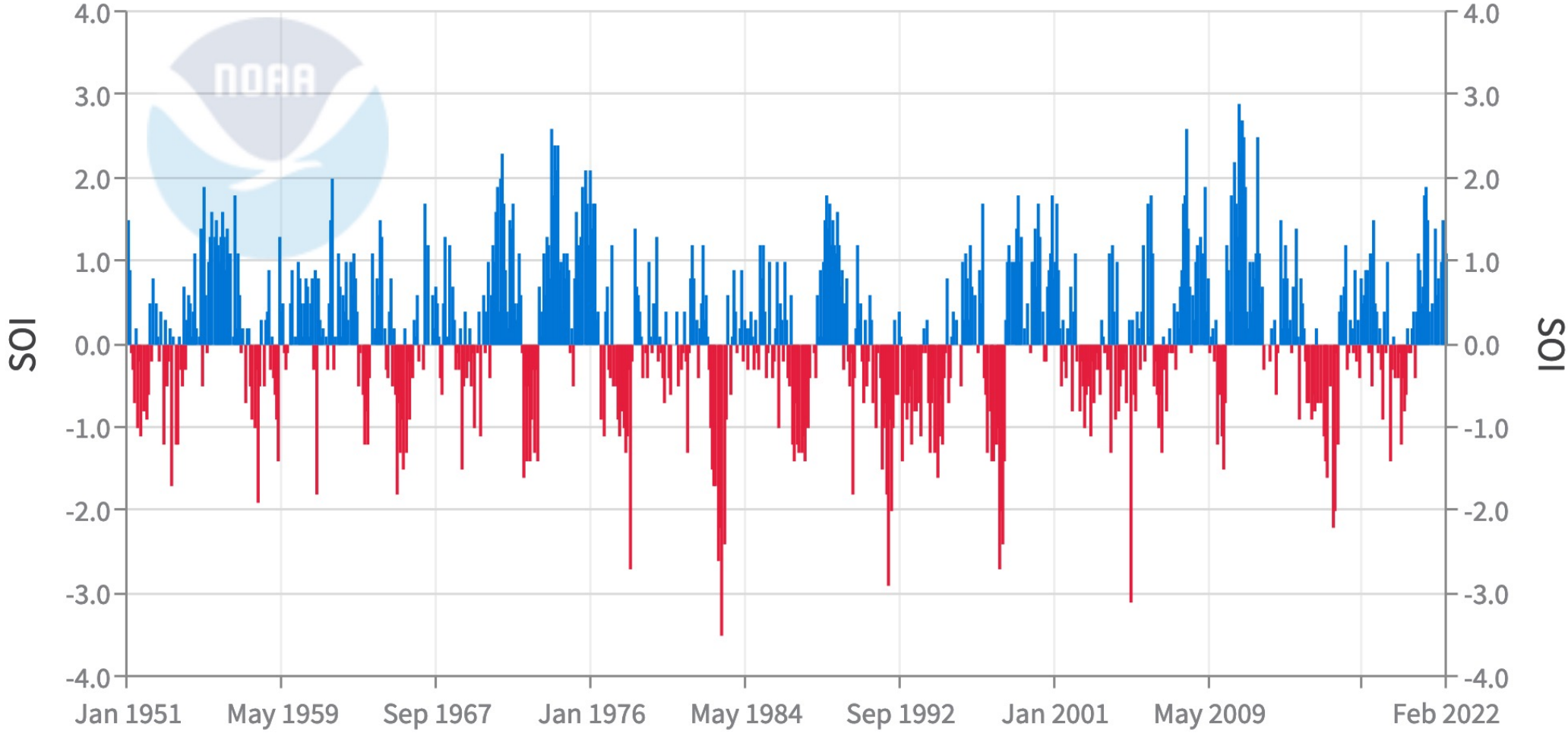

Winter 1997/98 SST Anomalies
(A)
40°N
20°N
0°
20°S
40°S
165°W
150°W
135°W
120°W
105°W
90°W
−2.8 −2.1 −1.4 −0.7 0.0 0.7 1.4 2.1 2.8
SST (°C)
Winter 1997/98 Precipitation Anomalies
(B)
45°N
40°N
35°N
30°N
125°W
120°W
115°W
110°W
105°W
100°W
−84 −63 −42 −21 0 21 42 63 84
precipitation (mm)

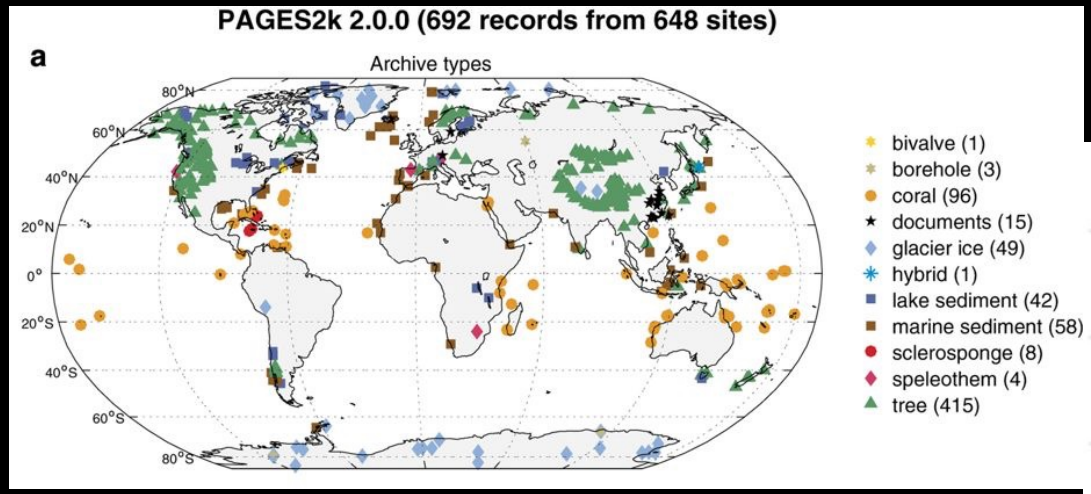

Winter 2015/16 SST Anomalies
(A)
40°N
20°N
0°
20°S
40°S
165°W
150°W
135°W
120°W
105°W
90°W
−2.8 −2.1 −1.4 −0.7 0.0 0.7 1.4 2.1 2.8
SST (°C)
Winter 2015/16 Precipitation Anomalies
(B)
45°N
40°N
35°N
30°N
125°W
120°W
115°W
110°W
105°W
100°W
−84 −63 −42 −21 0 21 42 63 84
precipitation (mm)

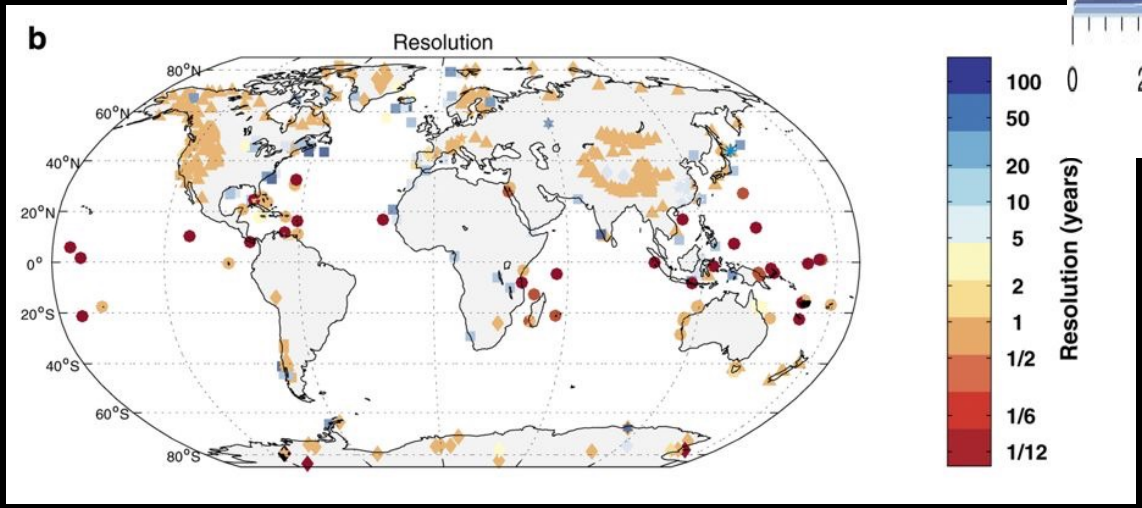


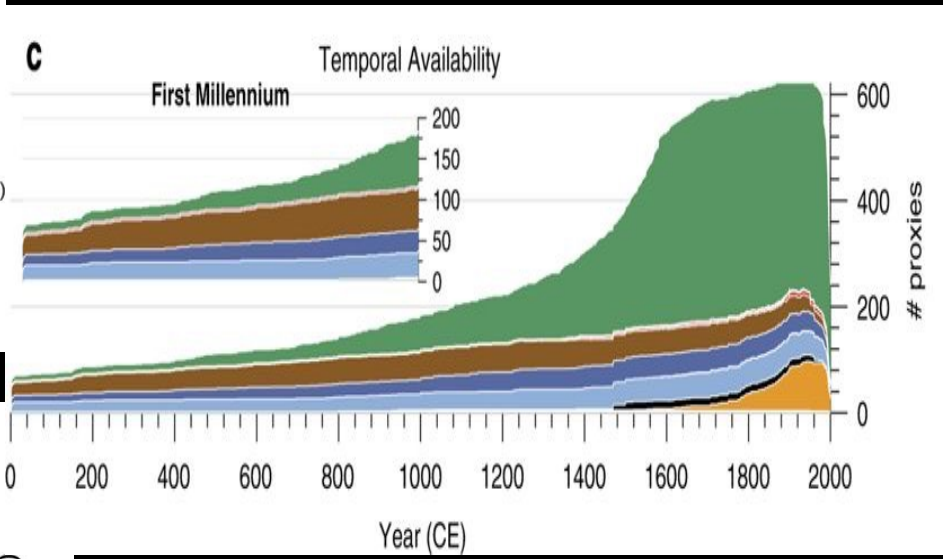

# What is the baseline for the inherent variability in the teleconnection strength?

# Southern Oscillation Index (SOI)

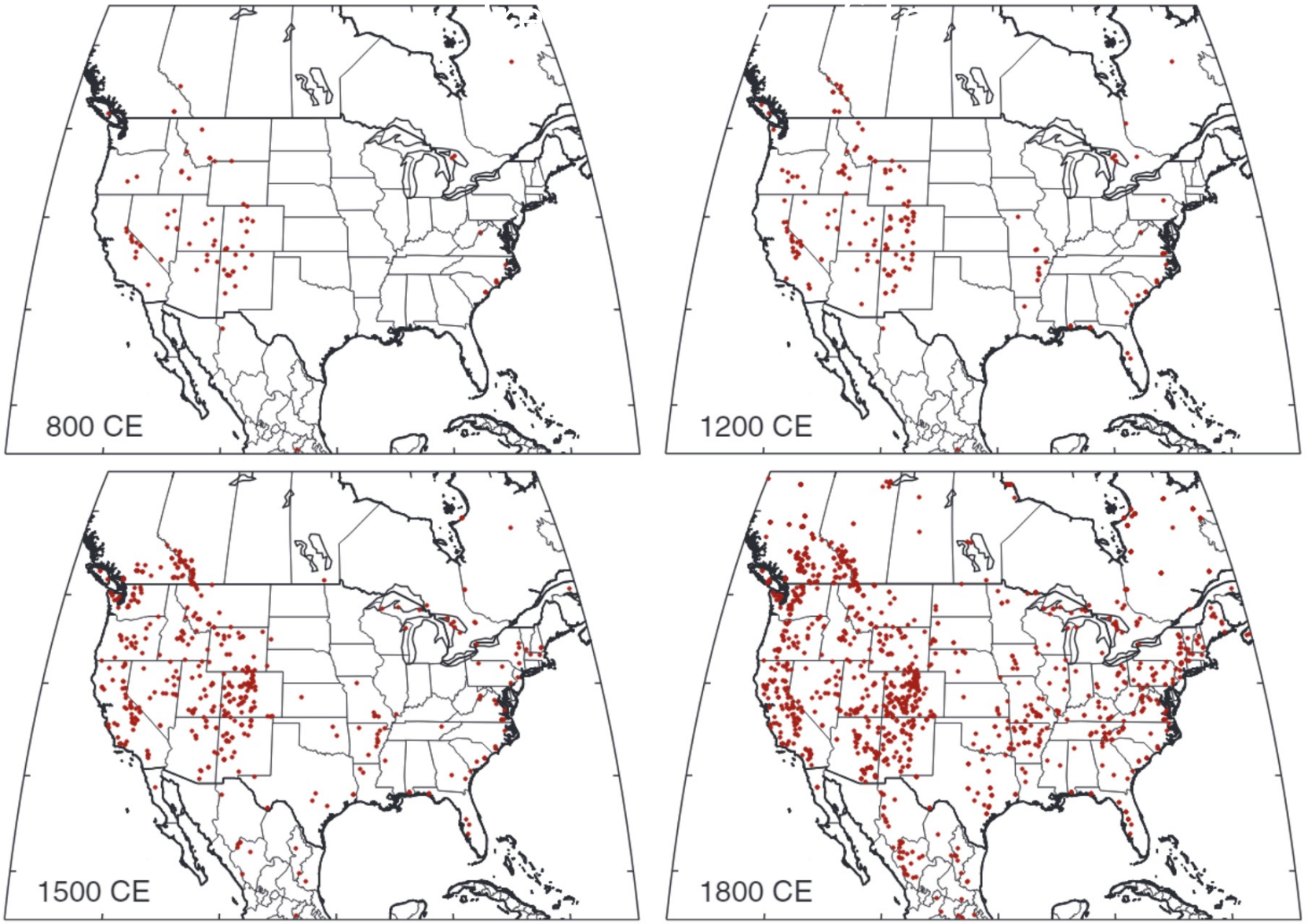




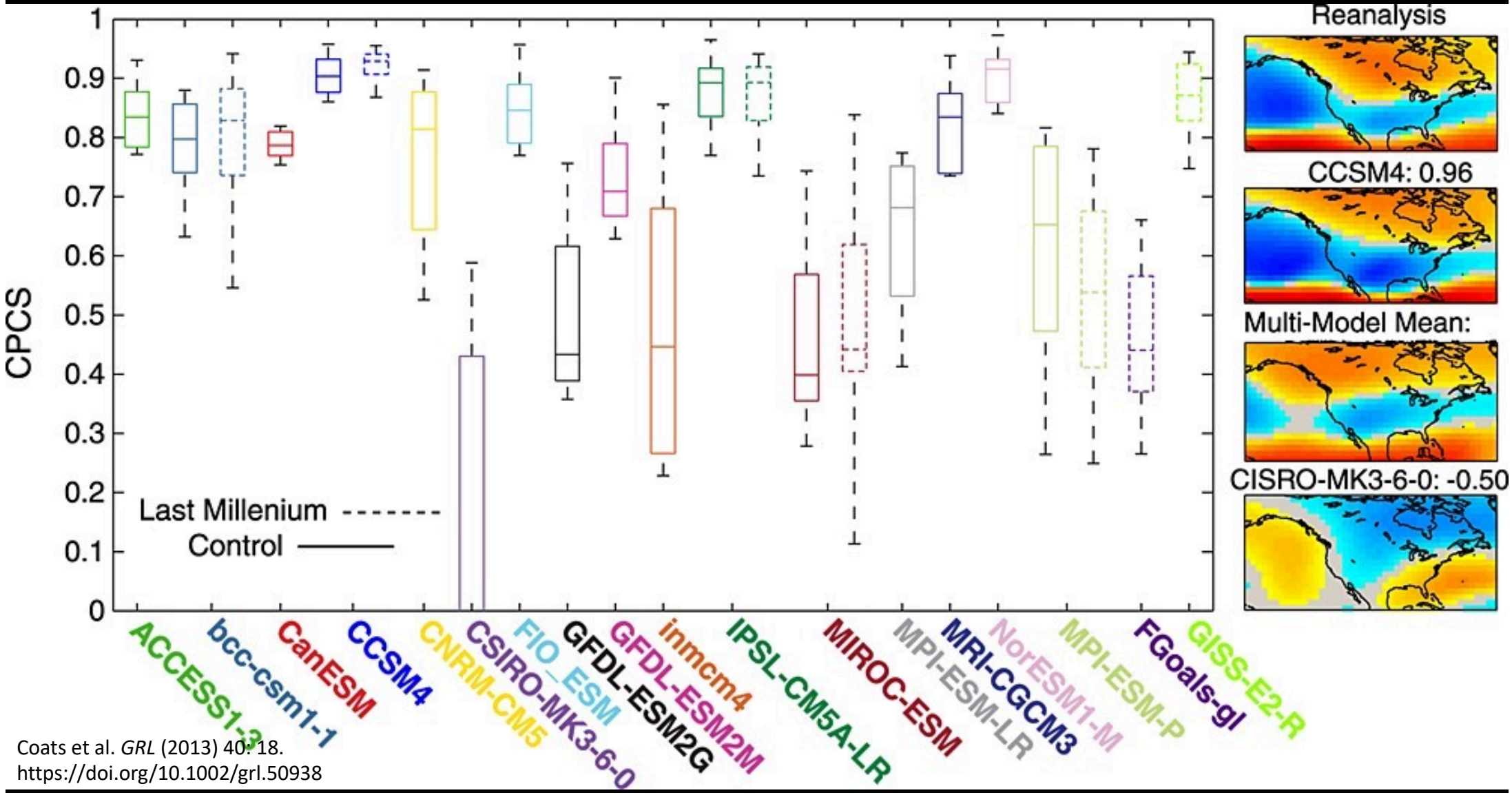




Emile-Geay, J. et al. , Sci. Data. (2017) 4
http://www.nature.com/articles/sdata201788




Cook et al. *WIREs Clim. Change* (2016) 7
https://doi.org/10.1002/wcc.394

# Model-to-model Correlation Variability




Coats et al. *GRL* (2013) 40: 18.
https://doi.org/10.1002/grl.50938

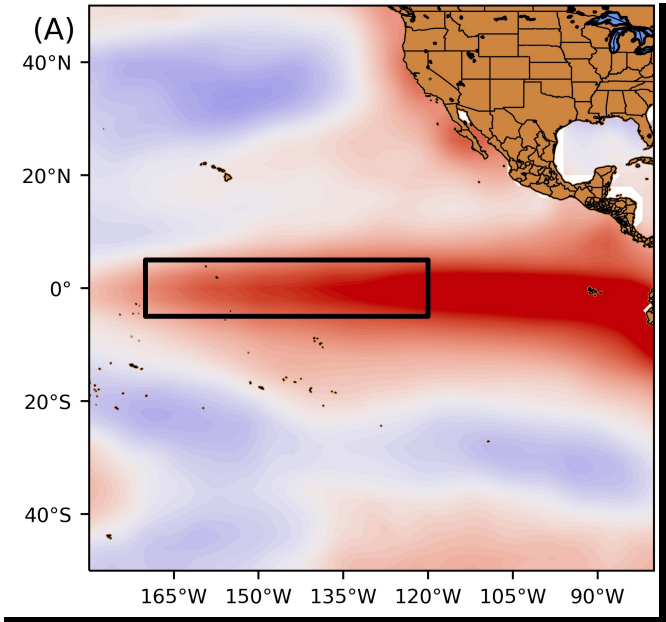
# Linear Inverse Model (LIM)

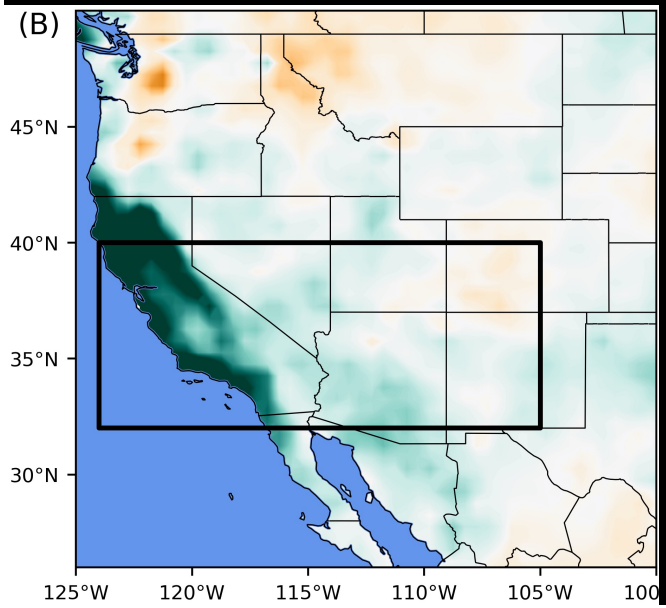
State Vector
(SSTs, PDSI, etc.)

Noise vector

$$\frac{d\tilde{\boldsymbol{x}}}{dt} = [\boldsymbol{L}]\tilde{\boldsymbol{x}} + \boldsymbol{\eta}$$

Linear Deterministic Feedback Matrix
(trained on *seasonal* dynamics)




# Observational Datasets

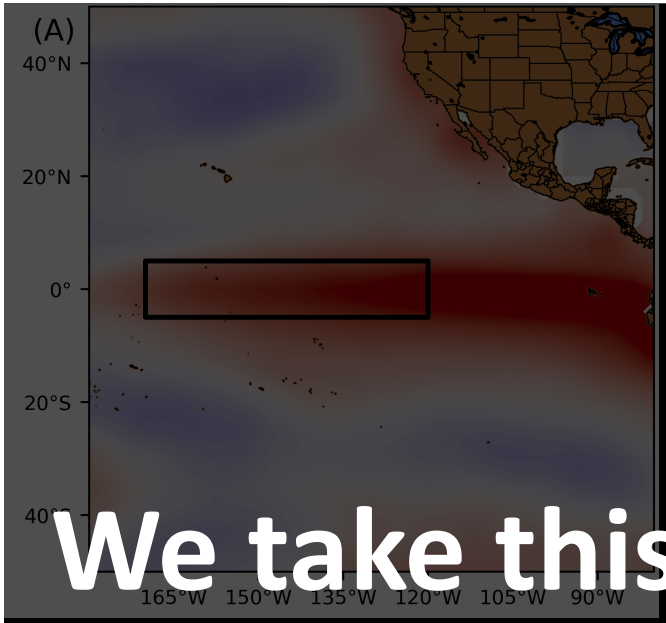
SSTs

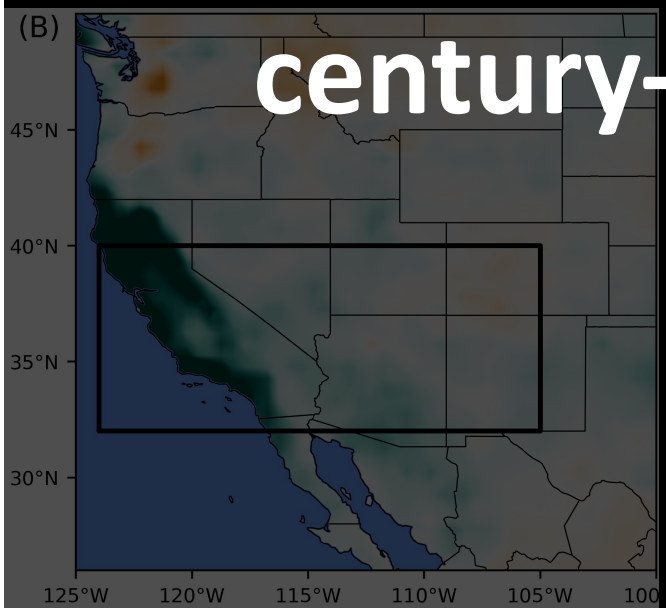
NOAA ERSSTv3b
1948-2008
2°x2° grid
(Smith et al., 2008)

PDSI

Sheffield PDSI
1948-2008
1°x1° grid
(Sheffield et al., 2006)

# Palmer Drought Severity Index?




# Observational Datasets

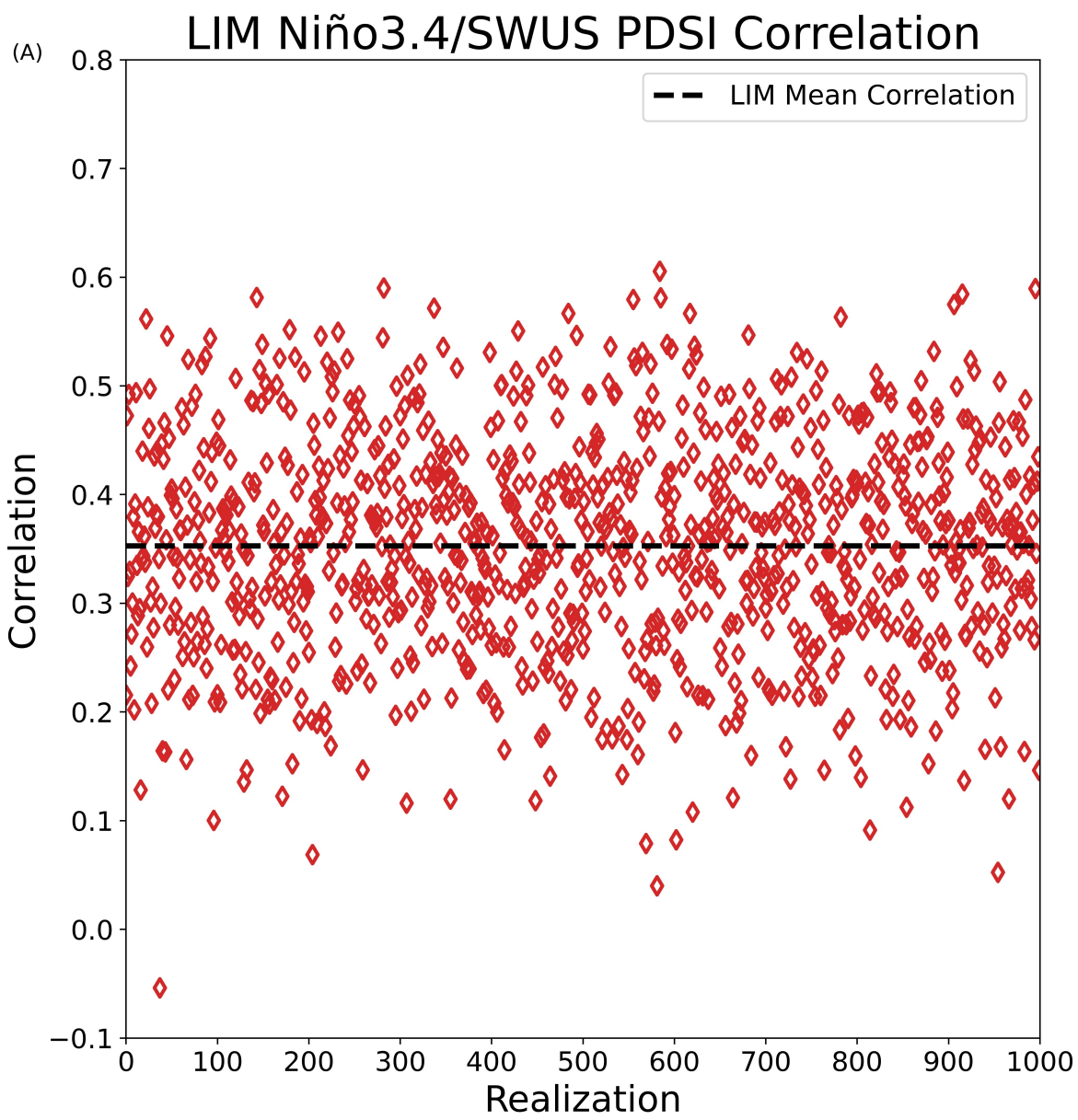
SSTs

NOAA ERSSTv3b
1948-2008
2°x2° grid
(Smith et al., 2008)

**We take this 50-year period and get 1000 century-long monthly time series**

PDSI

Sheffield PDSI
1948-2008
1°x1° grid
(Sheffield et al., 2006)



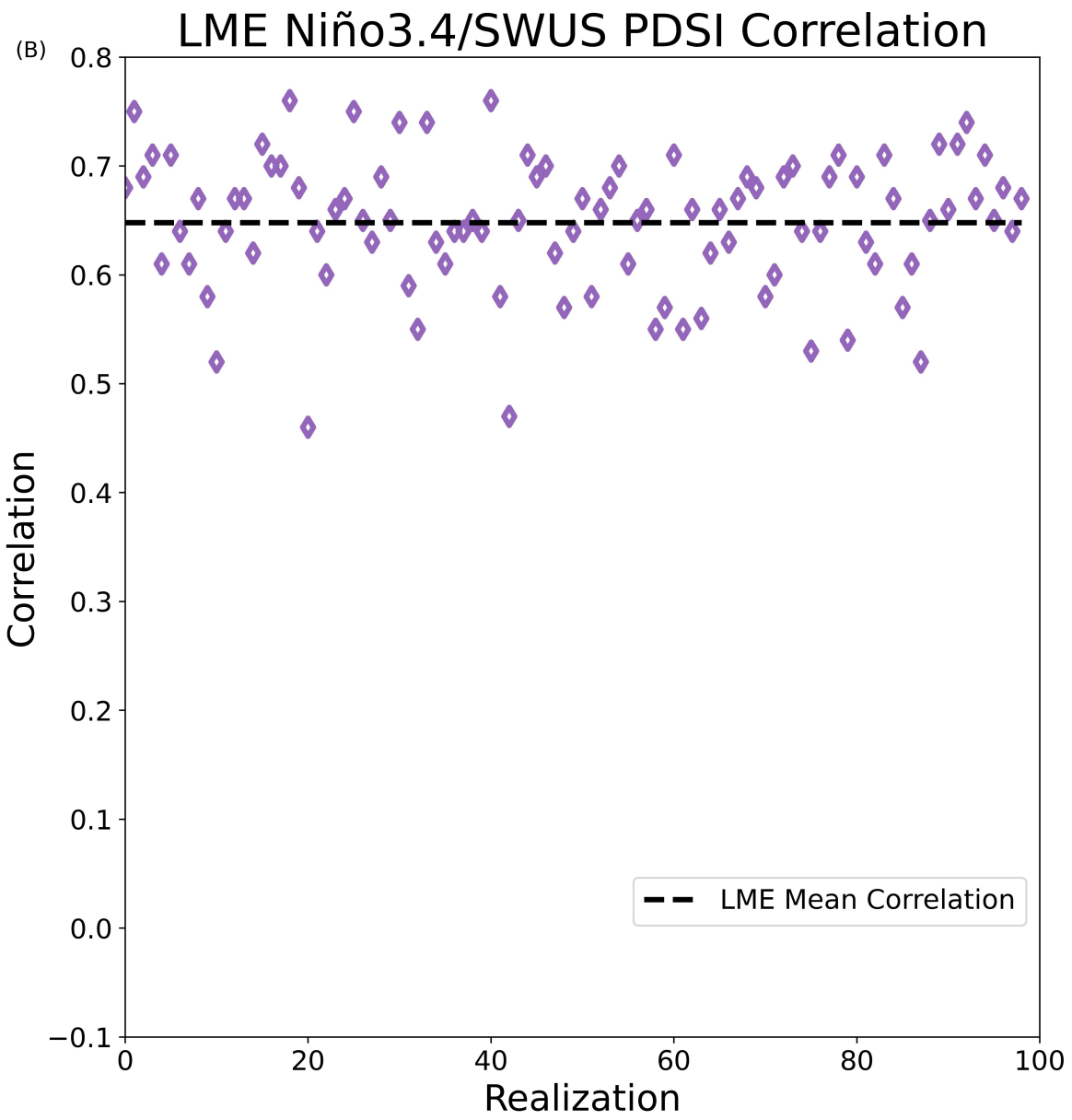

LIM

1000 realizations

Each realization is a century long

Ensemble average = 0.35

# How does this compare to climate models?




LME

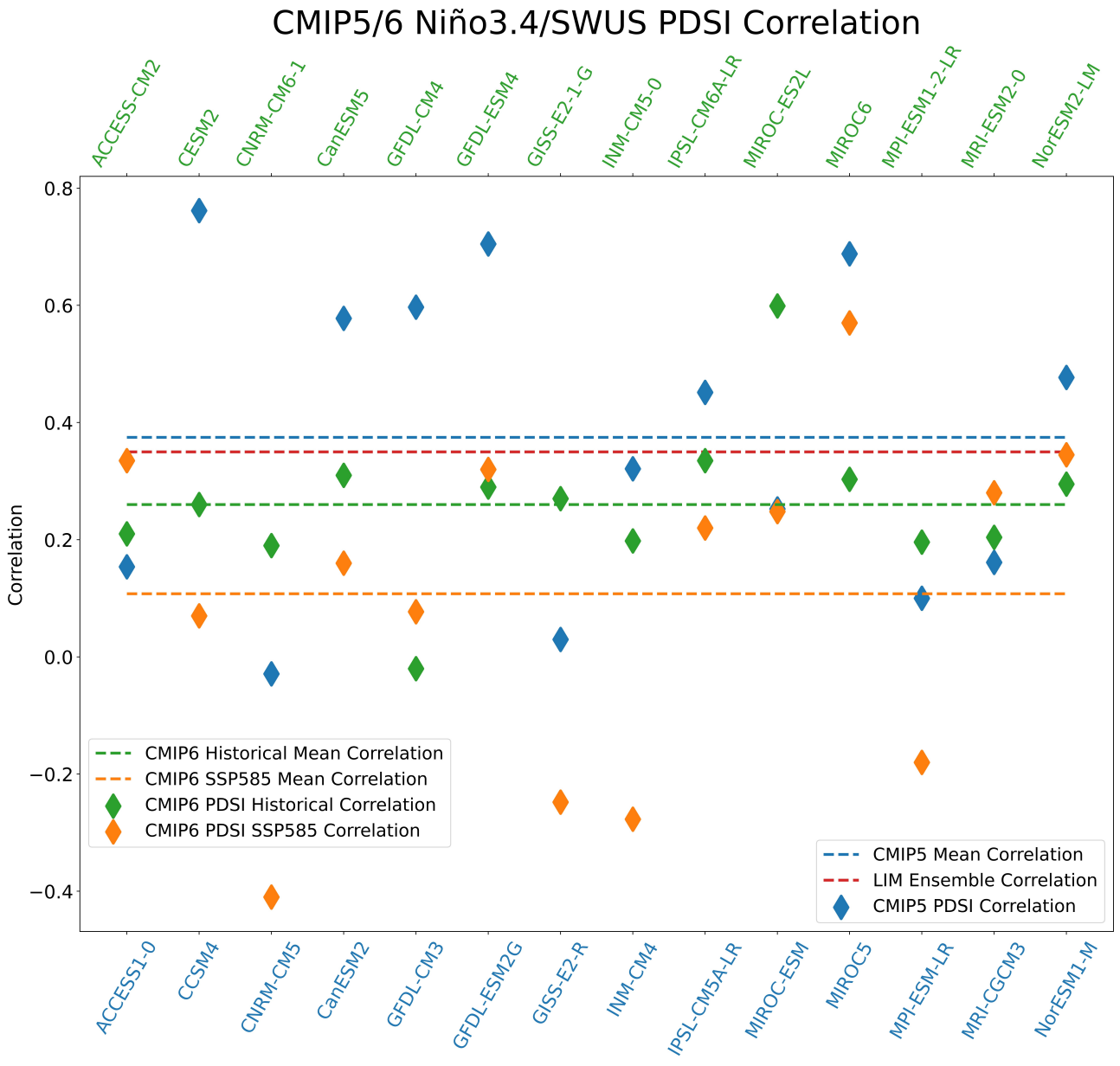
Last Millennium Ensemble

NCAR Paleoclimate Experience (Otto-Bliesner, et al., 2016)

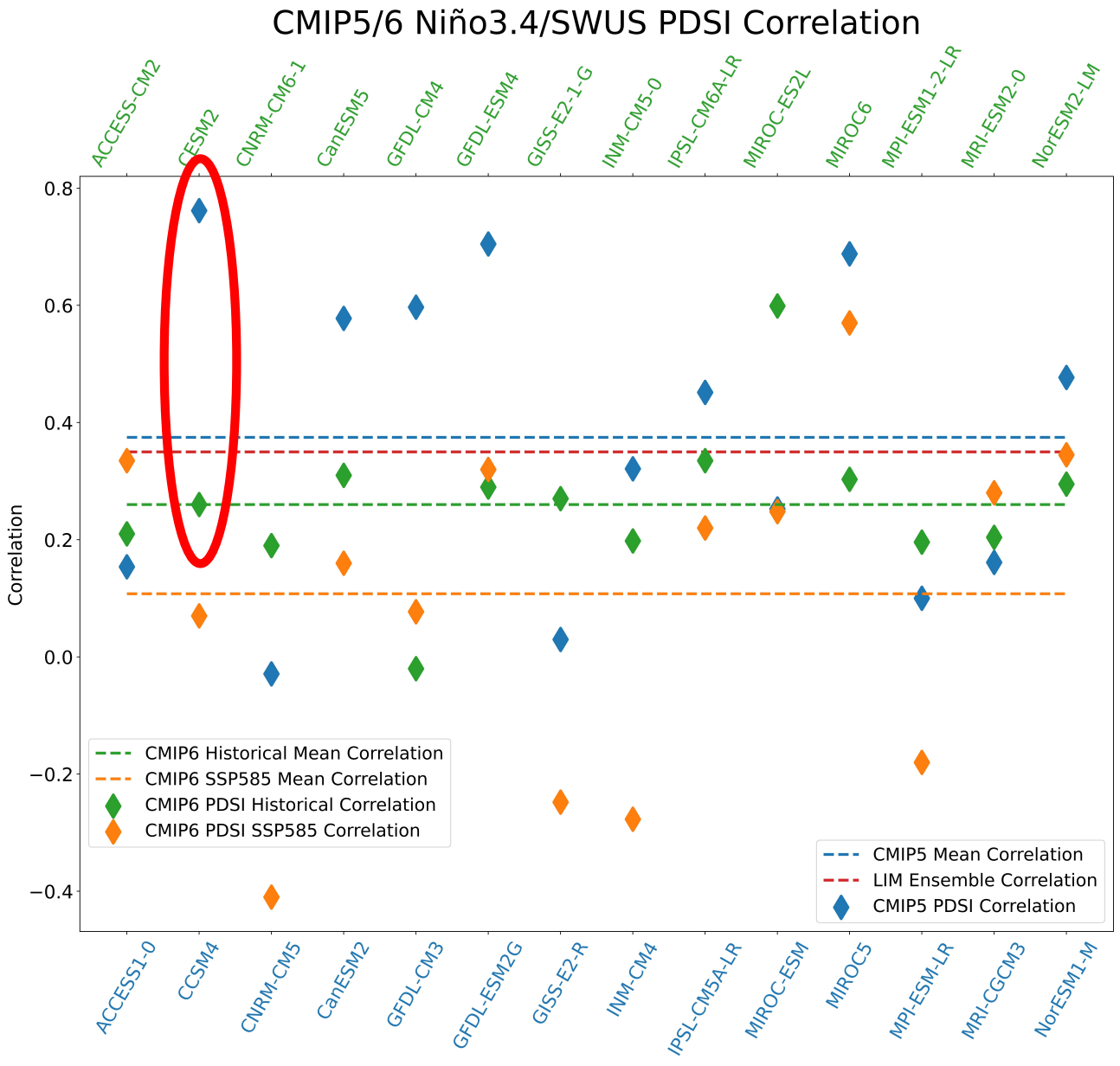
850-2006

- simulates external forcing
- long timescale internal variability
- Mean = 0.65

| Modeling Center | Institute ID | CMIP5 Model | CMIP6 Model |
|---|---|---|---|
| Commonwealth Scientific and Industrial Research Organization | CSIRO-ARCCSS | ACCESS1-0 | ACCESS-CM2 |
| Canadian Centre for Climate Modelling Analysis | CCMA | CanEMS2 | CanESM5 |
| National Center for Atmospheric Research | NCAR | CCSM4 | CESM2 |
| Center National de Recherches Météorologiques/Centre de Recherche et Formation Avancée Calcul Scientifique | CNRM-CERFACS | CNRM-CM5 | CNRM-CM6-1 |
| NOAA Geophysical Fluid Dynamics Laboratory | NOAA GFDL | GFDL-CM3, GFDL-ESM2G | GFDL-CM4, GFDL-ESM4 |
| NASA Goddard Institute for Space Studies | NASA GISS | GISS-E2-R | GISS-E2-1-G |
| Institute for Numerical Mathematics | INM | INM-CM4 | INM-CM5-0 |
| Institute Pierre-Simon Laplace | IPSL | IPSL-CM5A-LR | IPSL-CM6A-LR |
| Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies | MIROC | MIROC-ESM, MIROC-5 | MIROC-ES2L, MIROC6 |
| Max Planck Institute for Meteorology | MPI | MPI-ESM-LR | MPI-ESM1-2-LR |
| Meteorological Research Institute | MRI | MRI-CGCM3 | MRI-ESM2-0 |
| Norwegian Climate Centre | NCC | NorESM1-M | NorESM2-LM |




Evans et al., *in prep*

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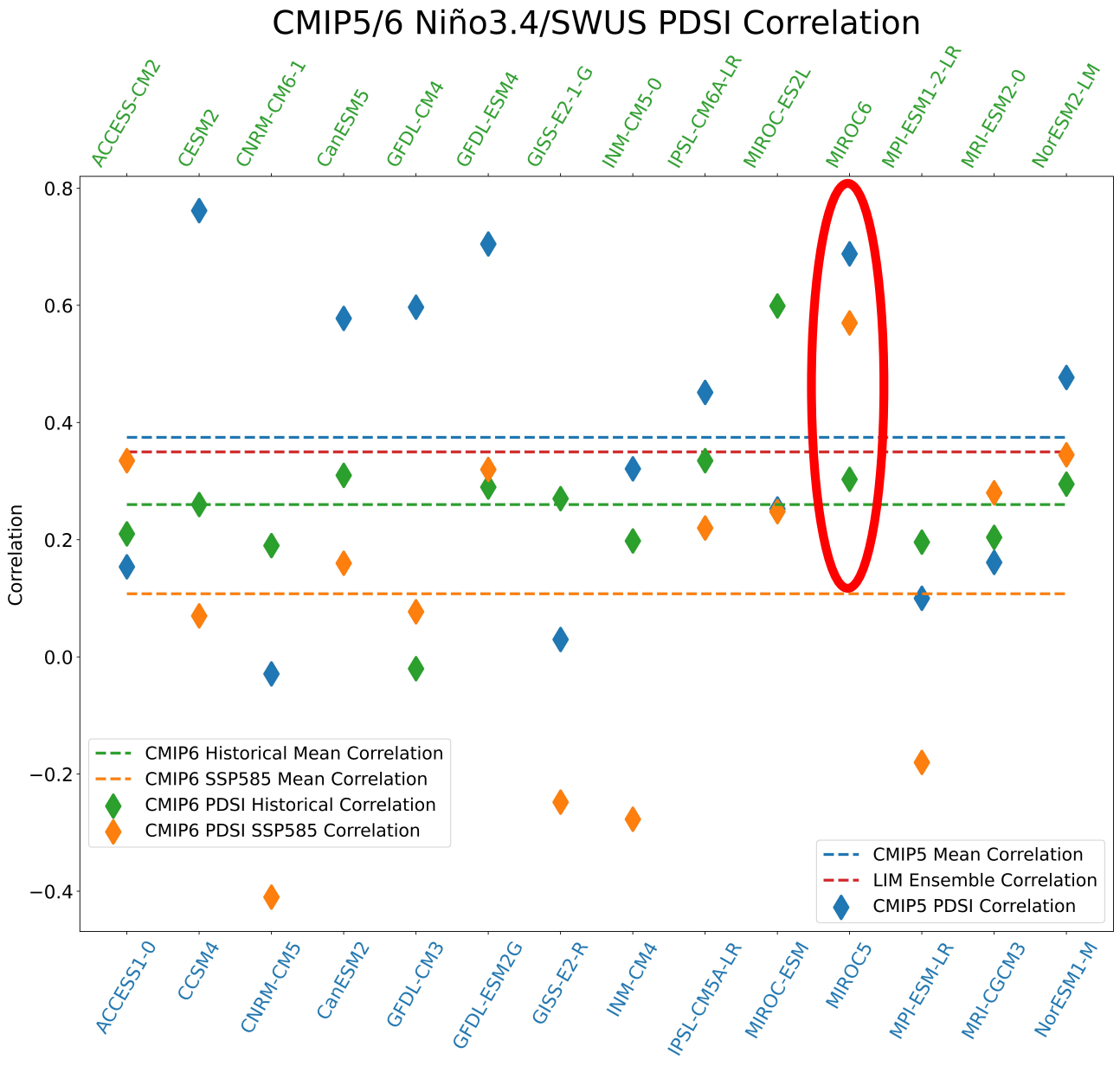


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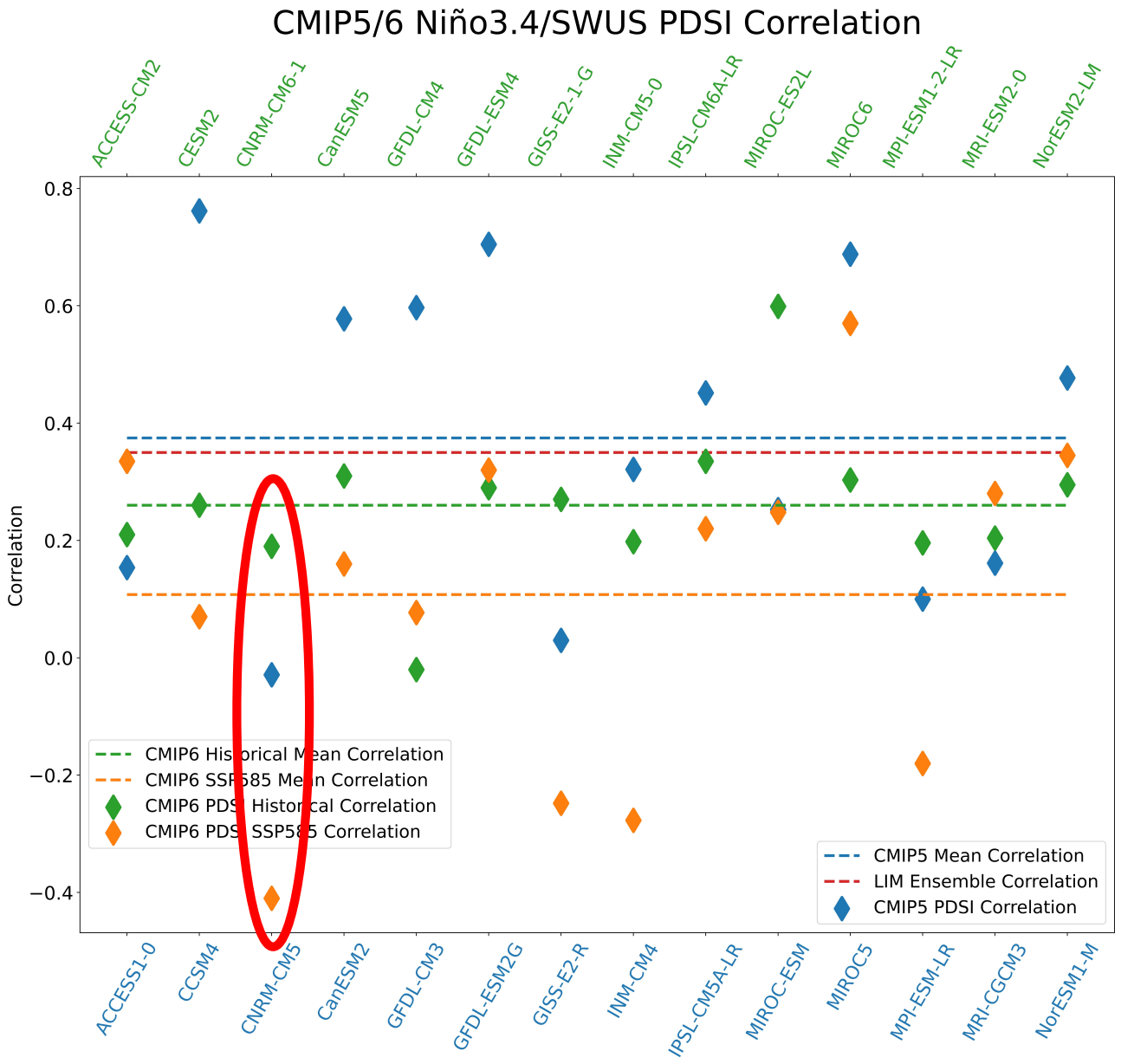


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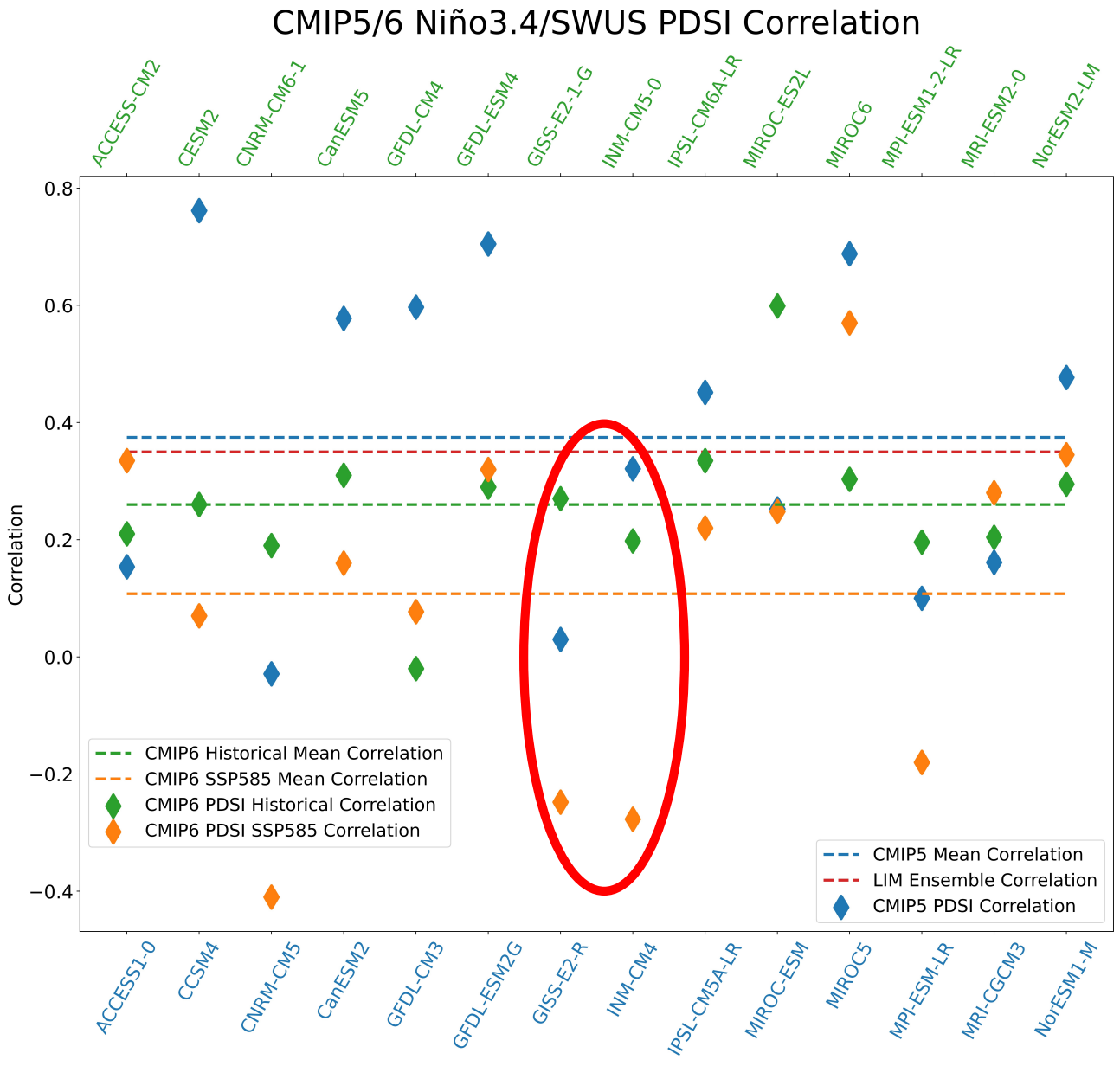


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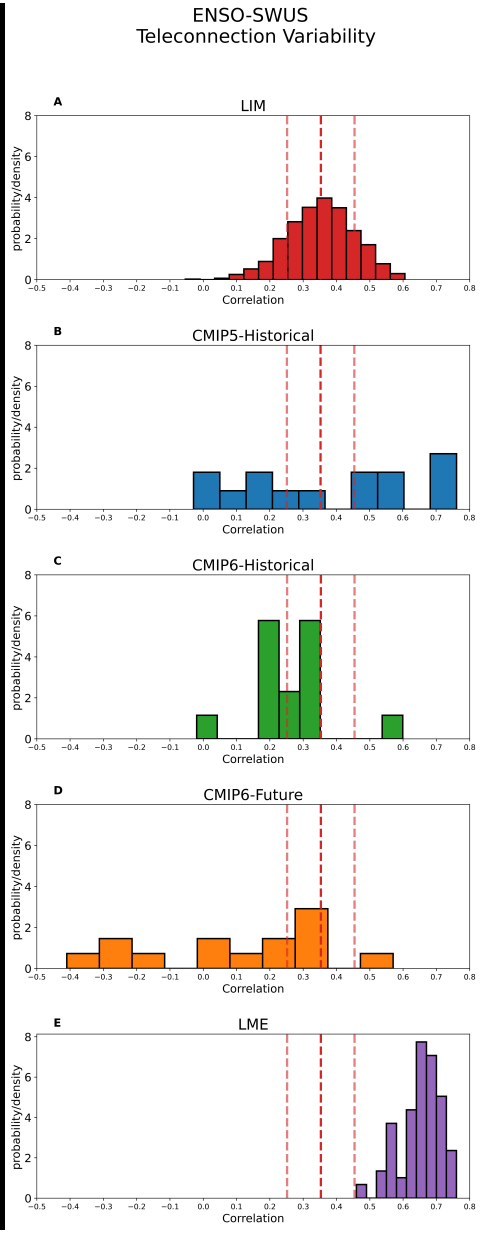


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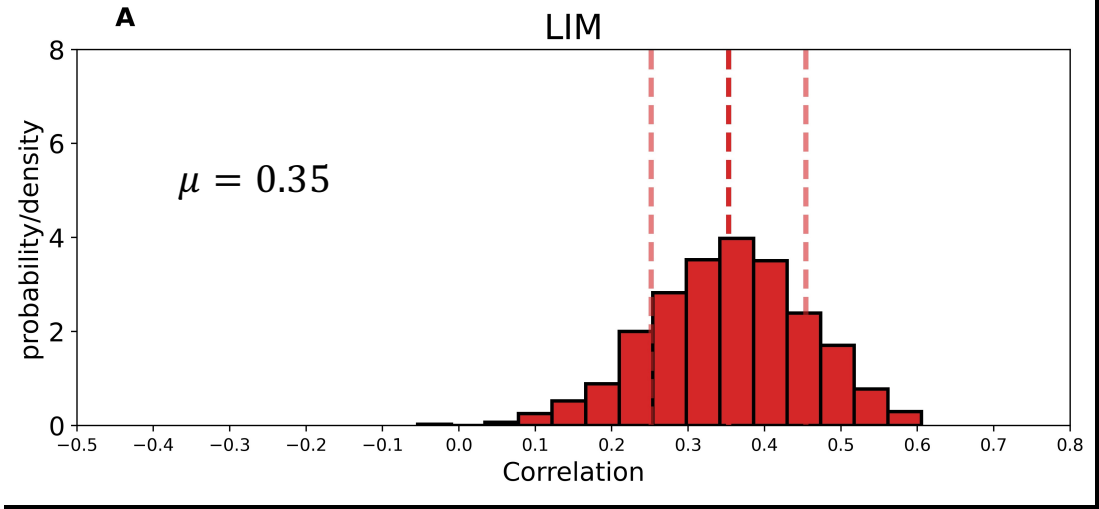
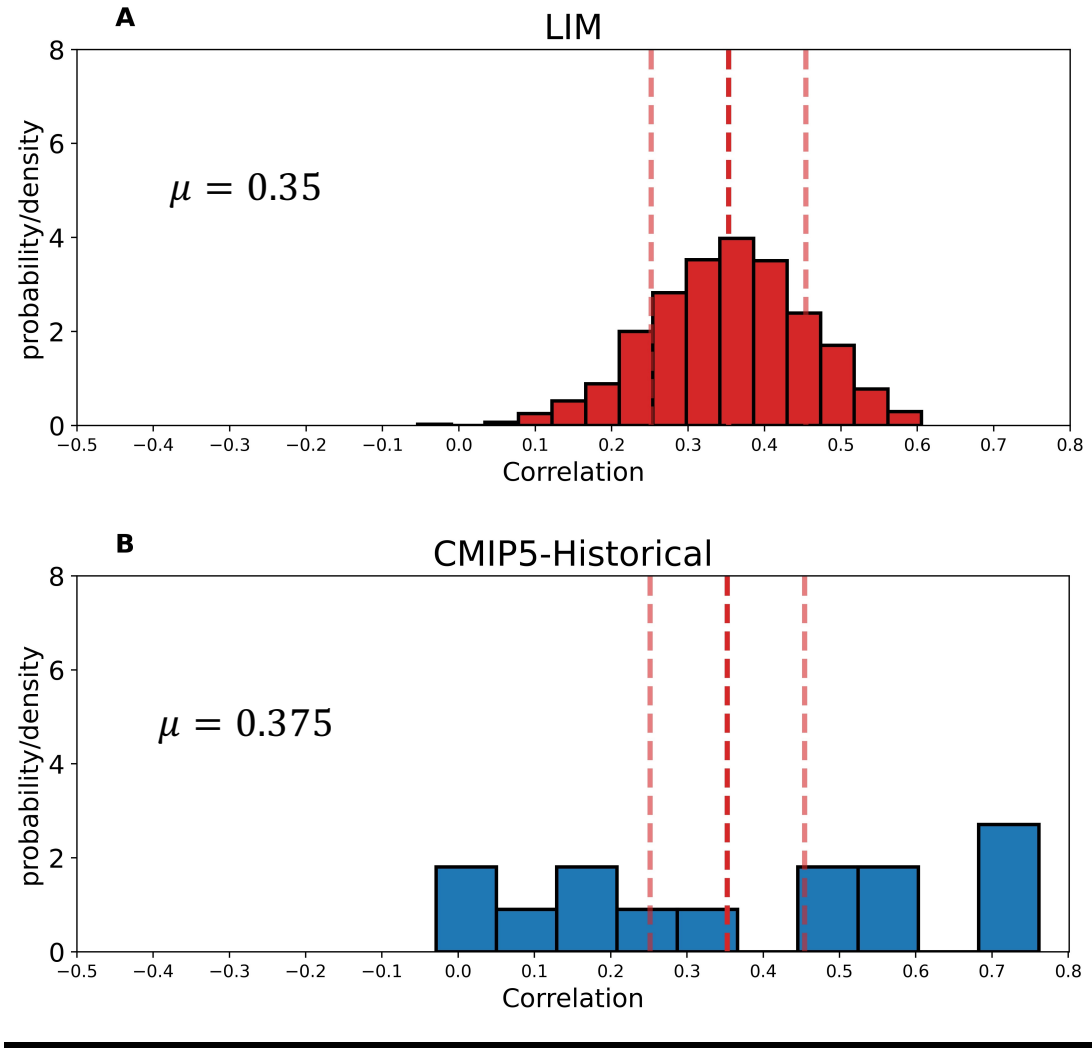
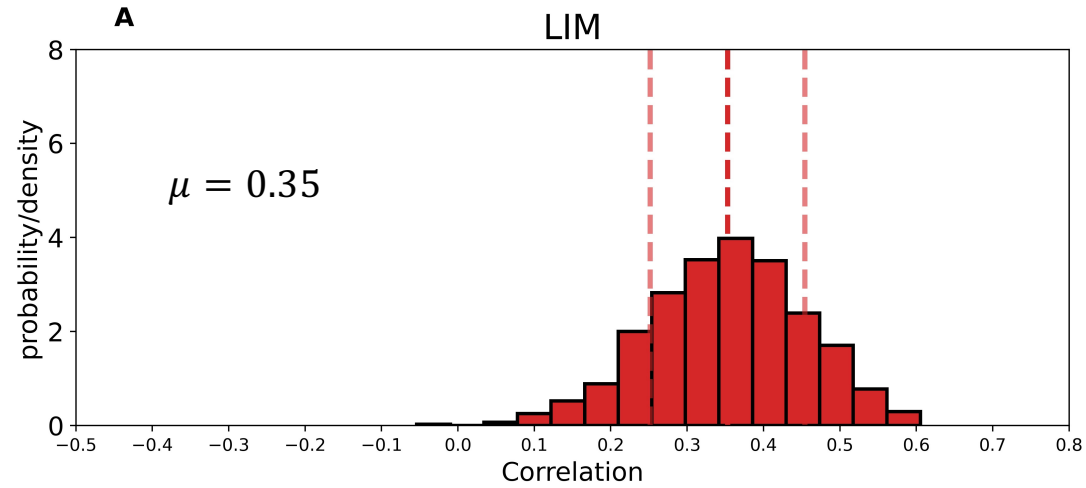
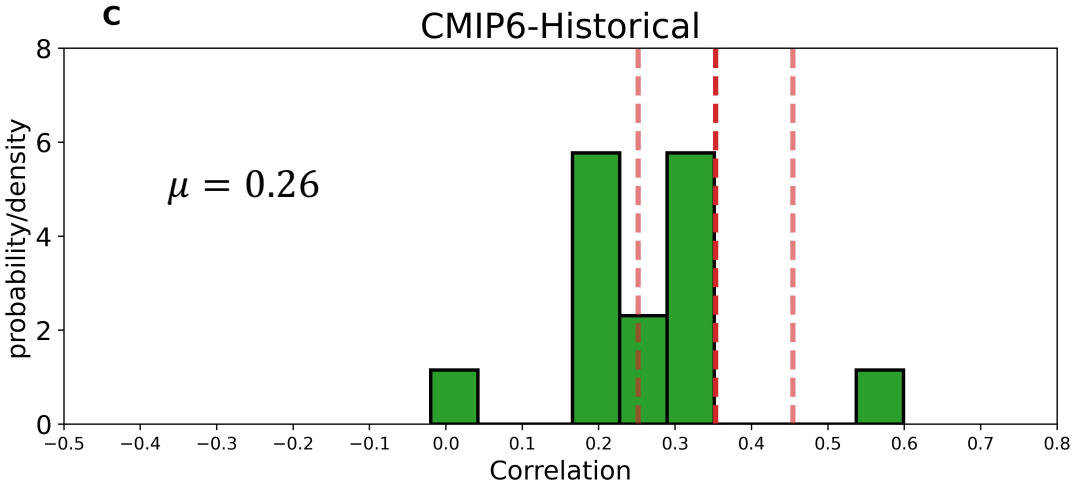


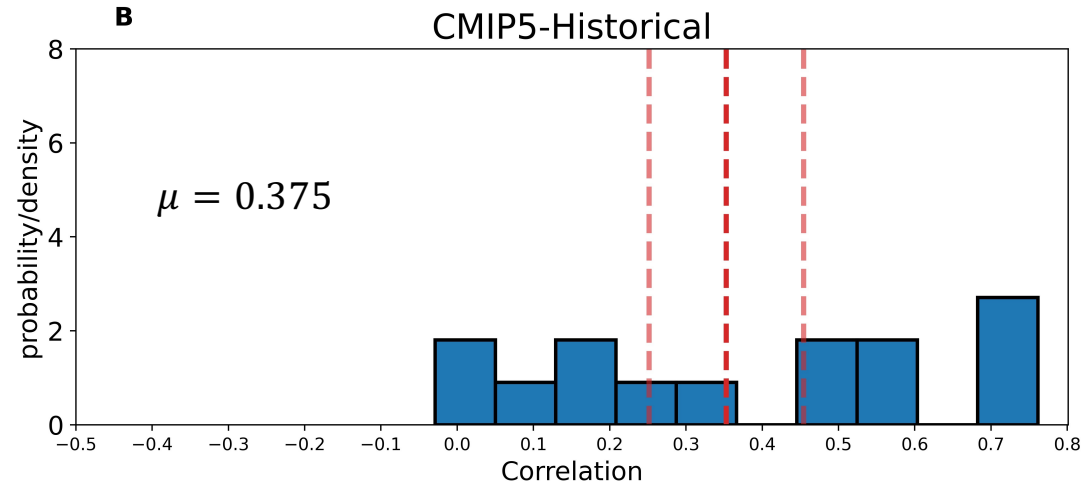

Evans et al., *in prep*




Evans et al., *in prep*

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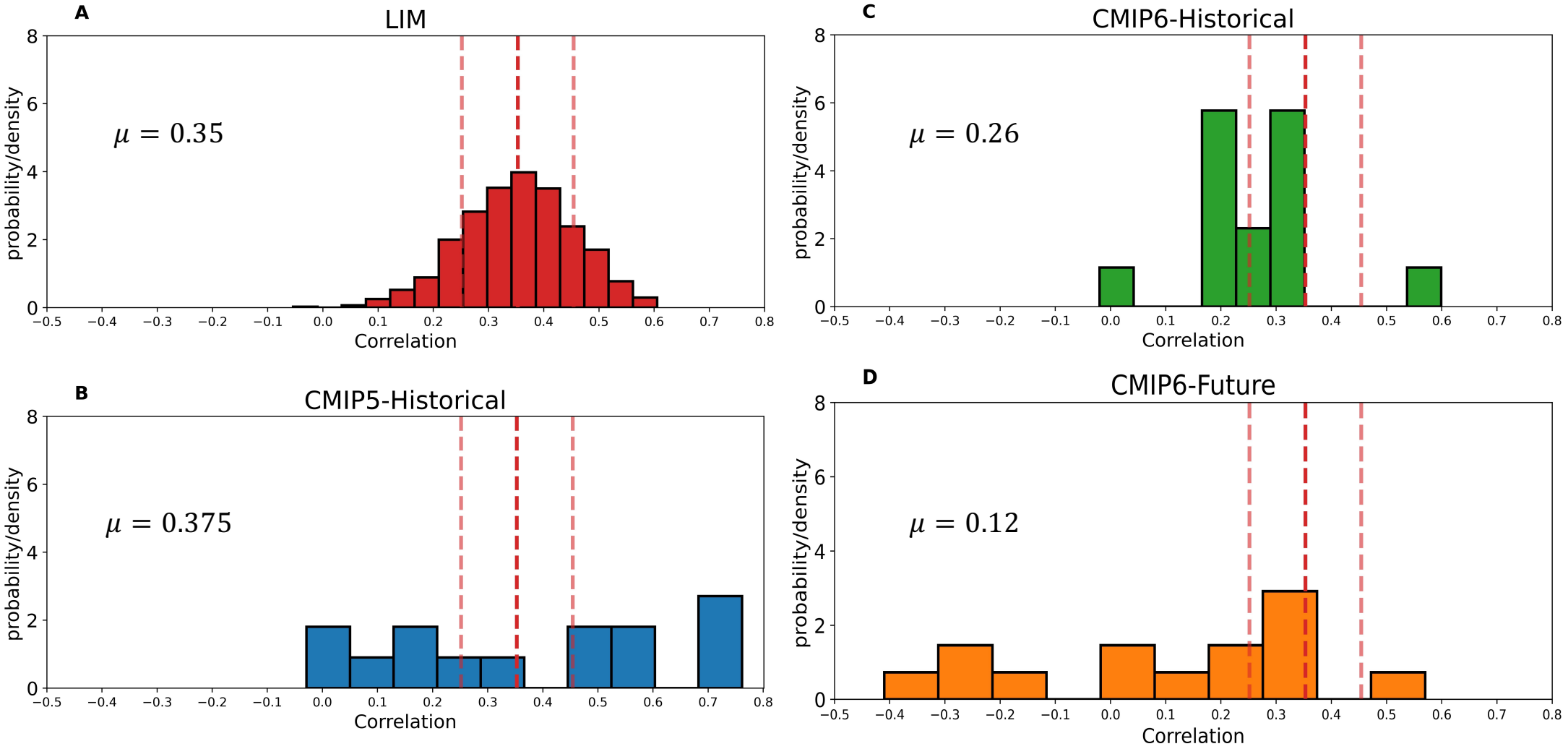


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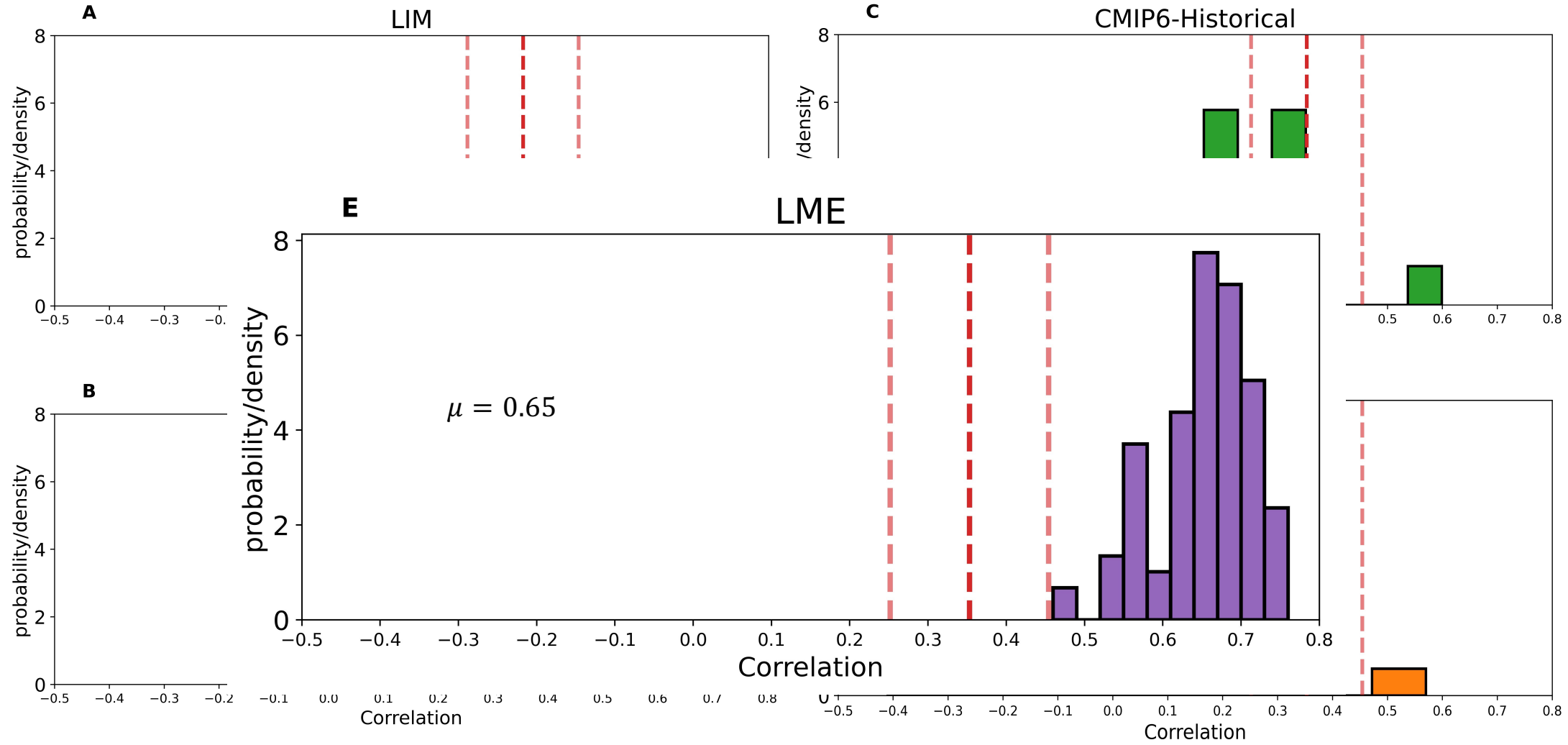


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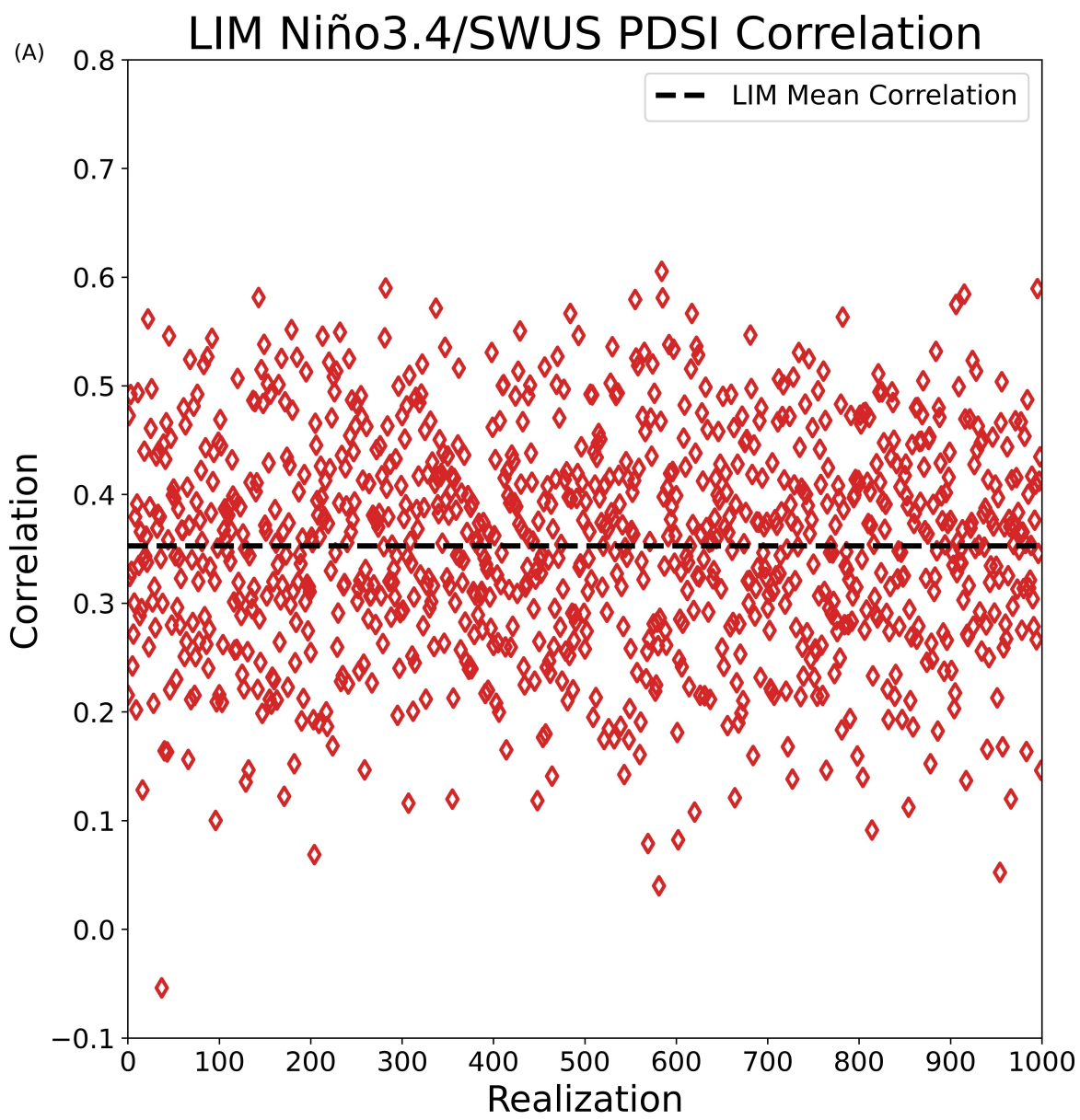
(A)
LIM Niño3.4/SWUS PDSI Correlation
LIM Mean Correlation
Correlation
Realization
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
0
100
200
300
400
500
600
700
800
900
1000

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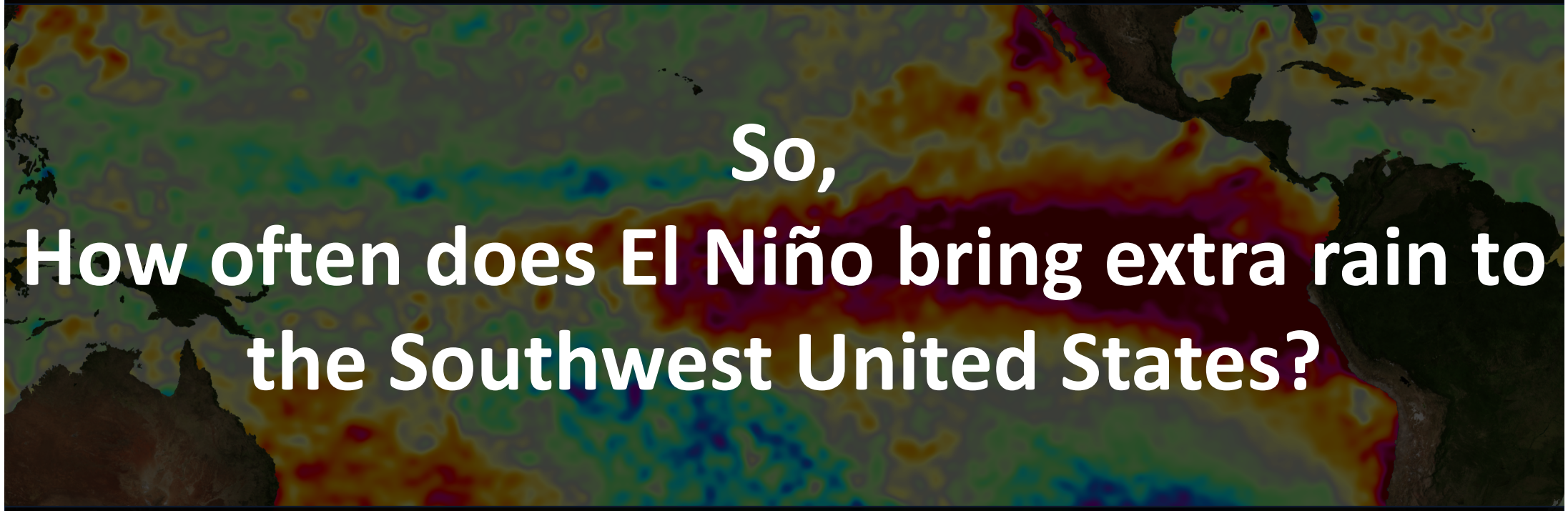


## So,
## How often does El Niño bring extra rain to the Southwest United States?

Colin P. Evans*, Toby R. Ault, Sloan Coats, Carlos M. Carrillo, Xiaolu, Li, Marc J. Alessi, Dimitris A. Herrera, and Brandon N. Benton

Intrinsic century-scale variability in tropical Pacific SSTs and their influence on southwestern US hydroclimate

**So,**

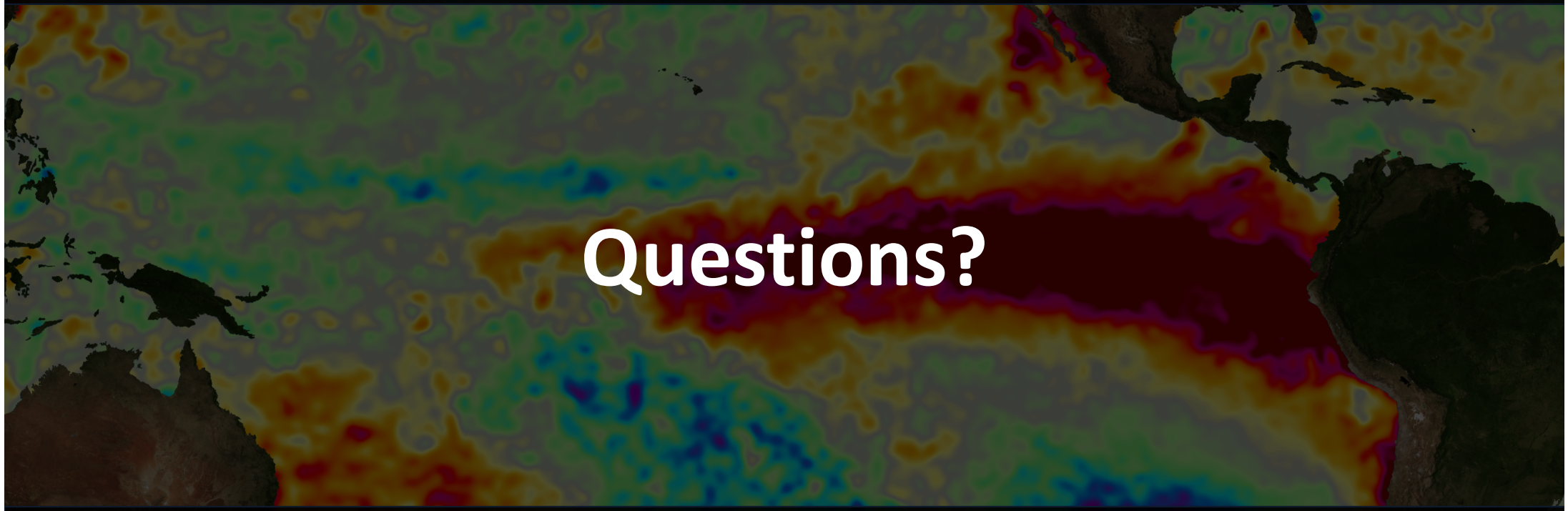
**How often does El Niño bring extra rain to the Southwest United States?**

**About 30% of the time…ish**

**And also, maybe never?**

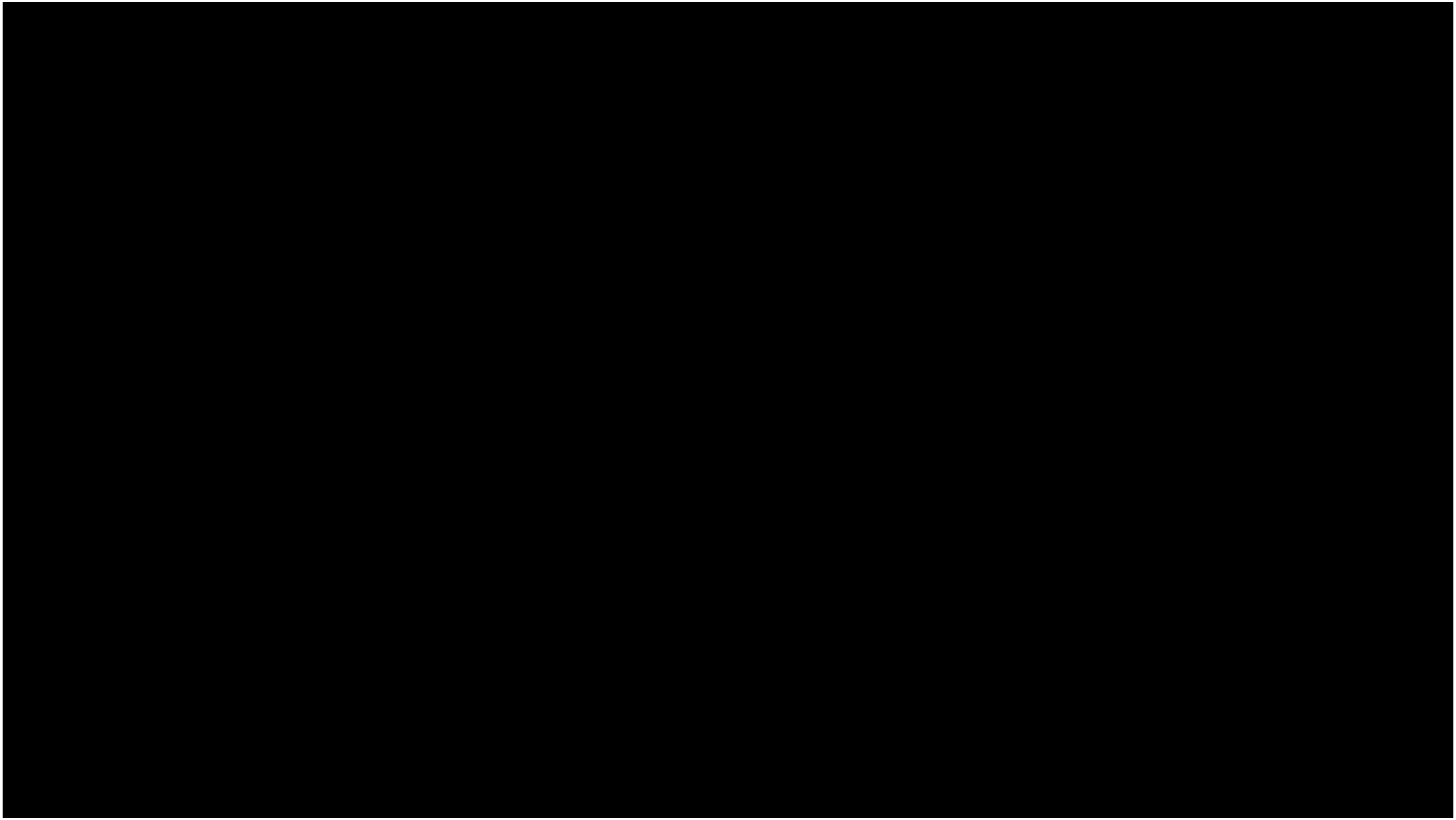
Colin P. Evans*, Toby R. Ault, Sloan Coats, Carlos M. Carrillo, Xiaolu, Li, Marc J. Alessi, Dimitris A. Herrera, and Brandon N. Benton

# Intrinsic century-scale variability in tropical Pacific SSTs and their influence on southwestern US hydroclimate



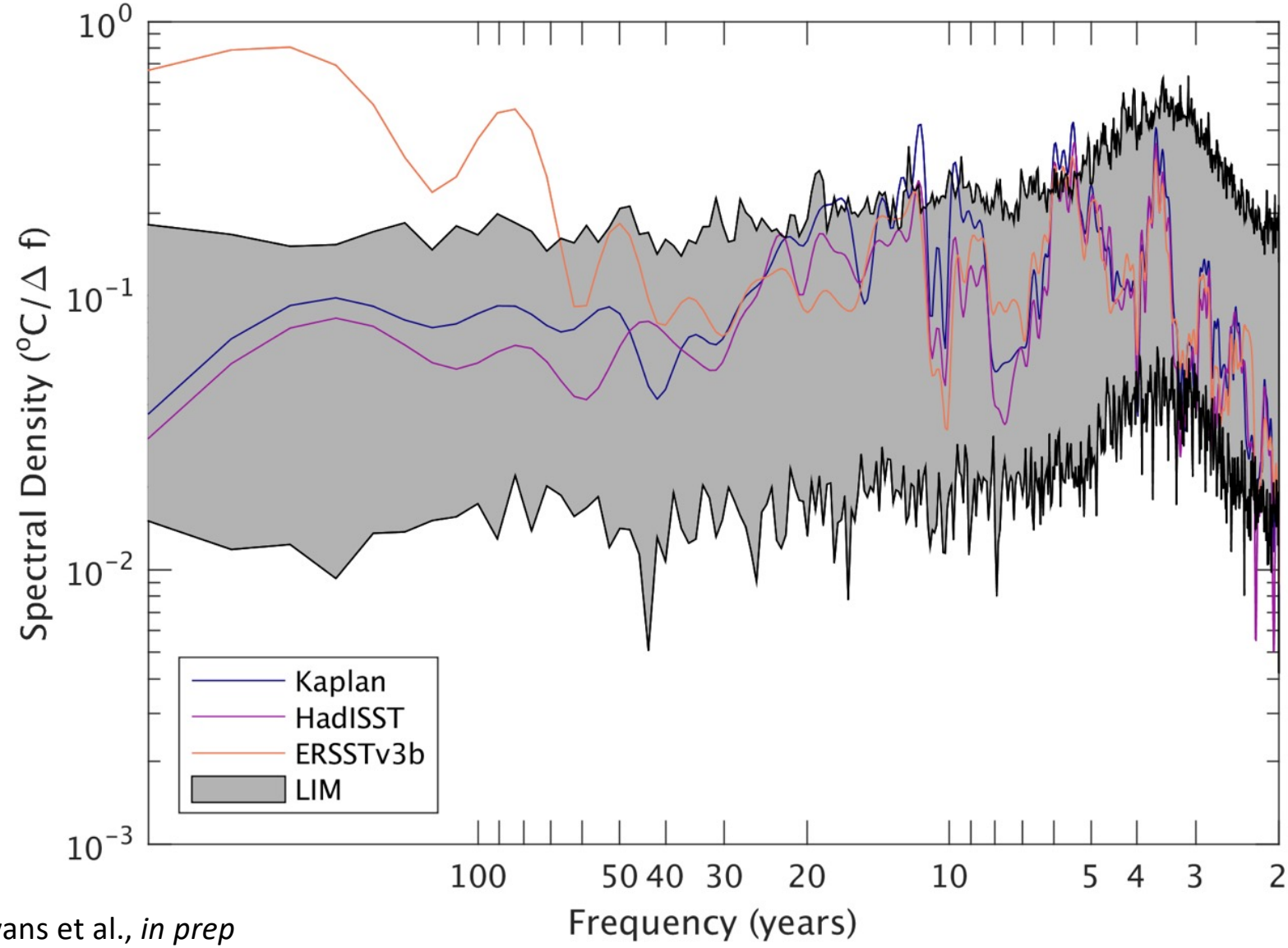
## Questions?

Colin P. Evans*, Toby R. Ault, Sloan Coats, Carlos M. Carrillo, Xiaolu, Li, Marc J. Alessi, Dimitris A. Herrera, and Brandon N. Benton

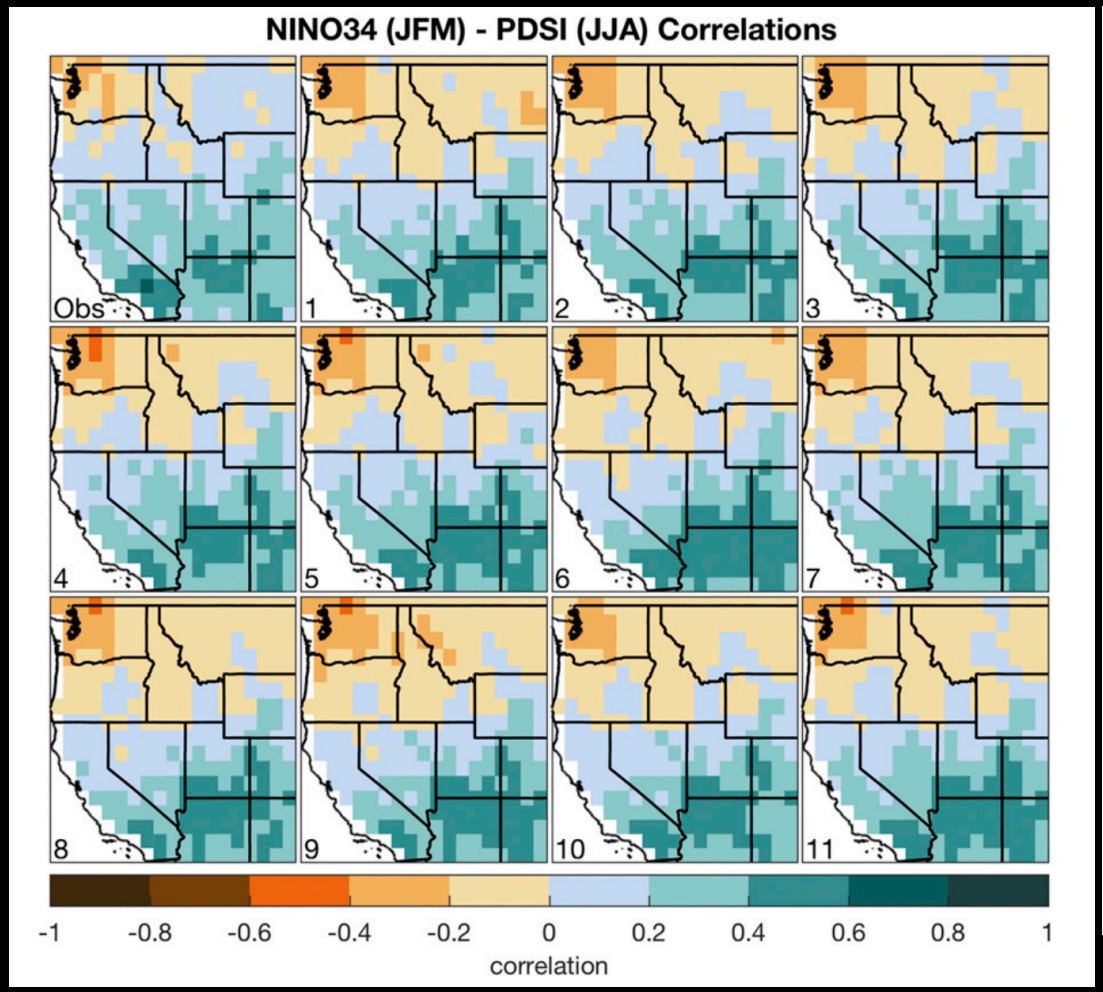


# We need the LIM to:

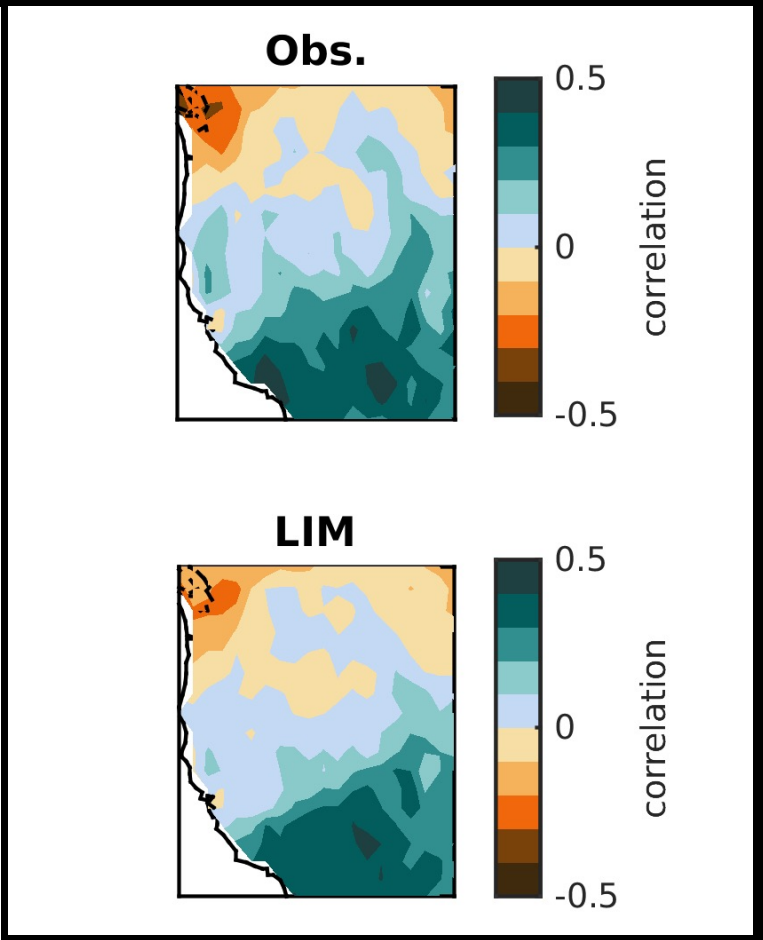
- Capture ENSO Variability: ☐
- Capture teleconnection correlation pattern: ☐
- Capture tropical Pacific SST and WUS PDSI variance: ☐



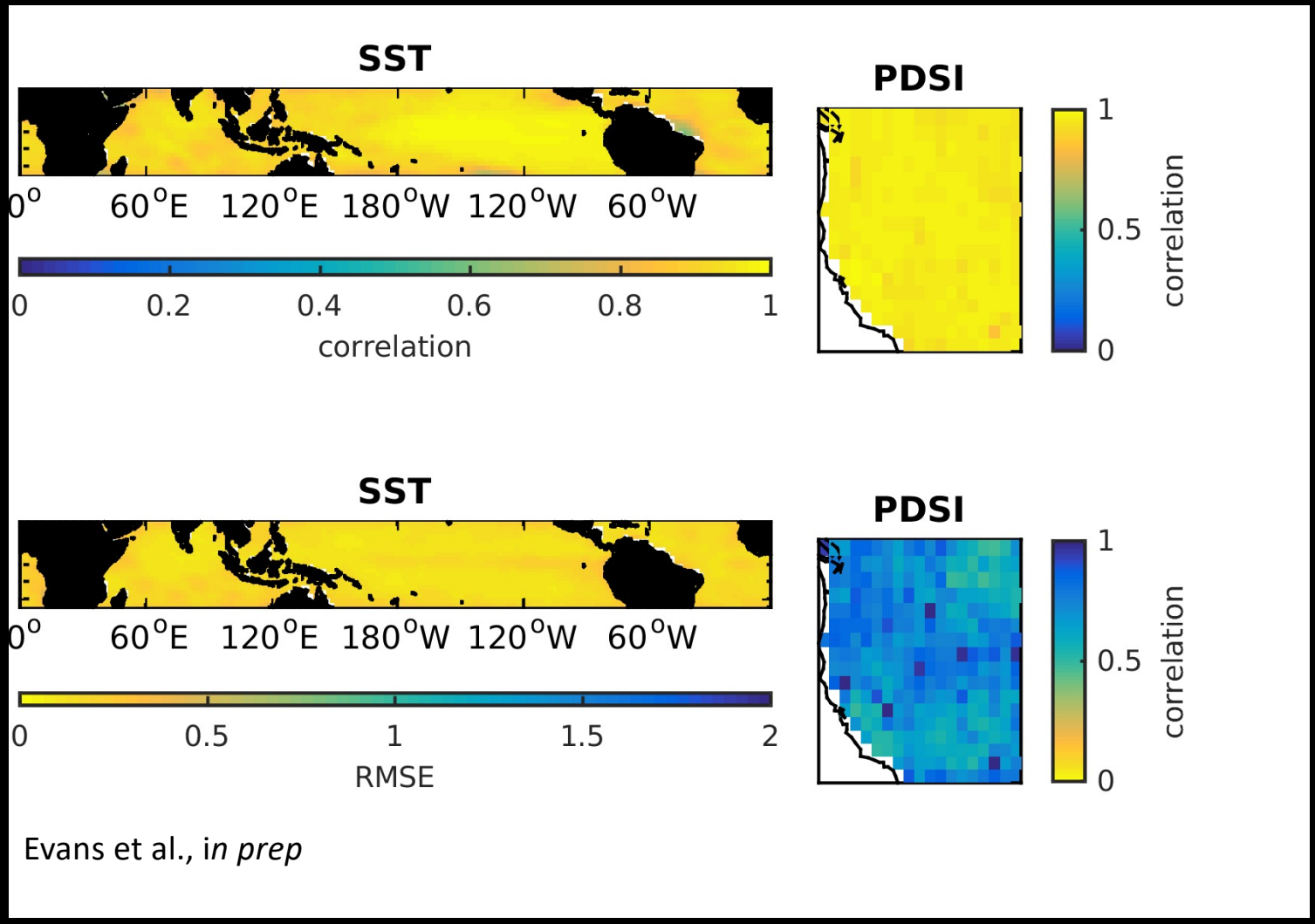

Evans et al., *in prep*




Ault et al. *J .Clim. (*2018) 31
DOI: 10.1175/JCLI-D-17-0154.1



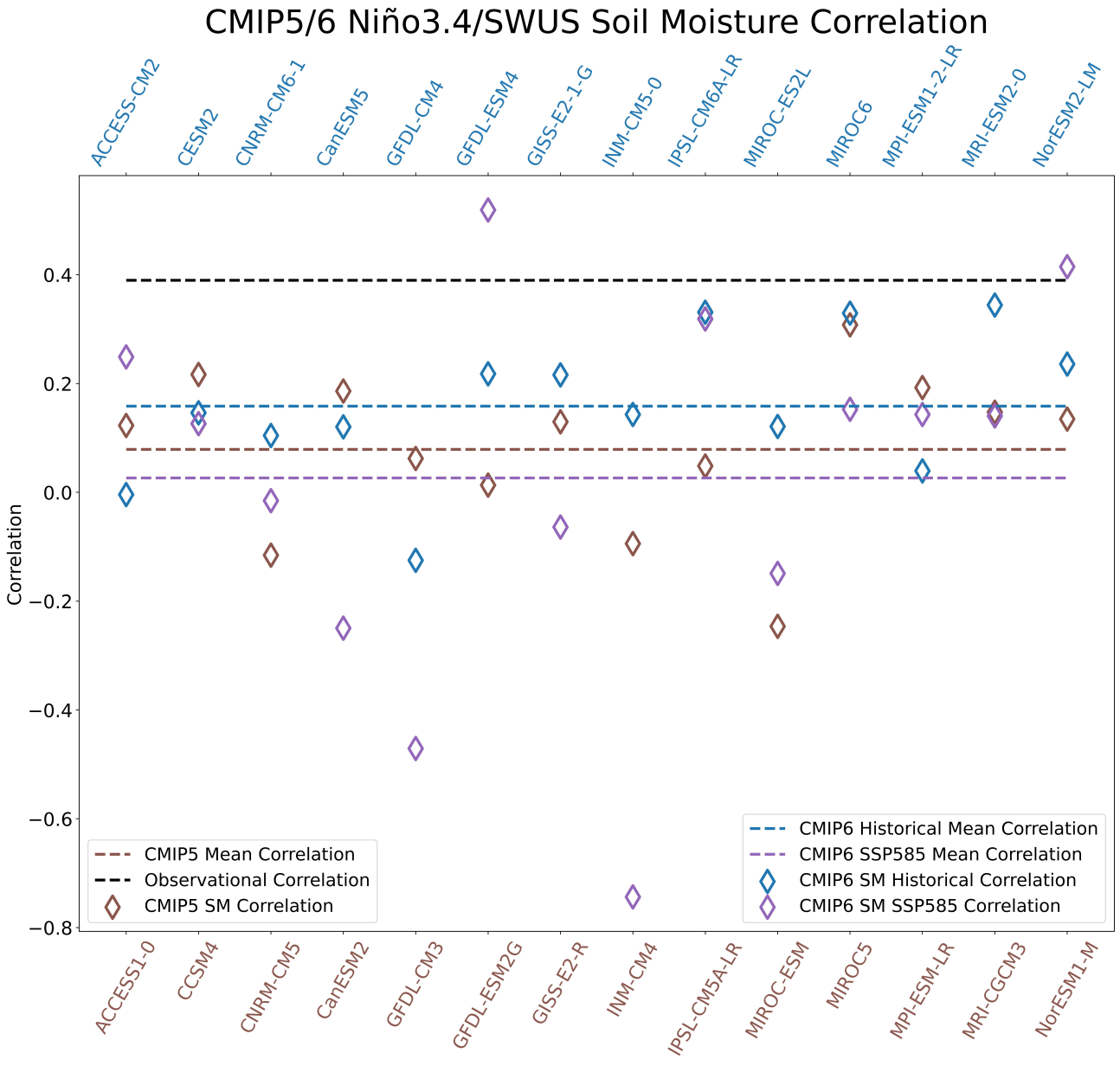

Evans et al., *in prep*




Evans et al., i*n prep*

# We need the LIM to:

- Capture ENSO Variability: 
- Capture teleconnection correlation pattern: 
- Capture tropical Pacific SST and WUS PDSI variance: 


CMIP5/6 Niño3.4/SWUS Soil Moisture Correlation
ACCESS-CM2
CESM2
CNRM-CM6-1
CanESM5
GFDL-CM4
GFDL-ESM4
GISS-E2-1-G
INM-CM5-0
IPSL-CM6A-LR
MIROC-ES2L
MIROC6
MPI-ESM1-2-LR
MRI-ESM2-0
NorESM2-LM
Correlation
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
CMIP5 Mean Correlation
Observational Correlation
CMIP5 SM Correlation
CMIP6 Historical Mean Correlation
CMIP6 SSP585 Mean Correlation
CMIP6 SM Historical Correlation
CMIP6 SM SSP585 Correlation
ACCESS1-0
CCSM4
CNRM-CM5
CanESM2
GFDL-CM3
GFDL-ESM2G
GISS-E2-R
INM-CM4
IPSL-CM5A-LR
MIROC-ESM
MIROC5
MPI-ESM-LR
MRI-CGCM3
NorESM1-M