Decadal Modulation of ENSO and the Linkage to Tropical Pacific Decadal Variability

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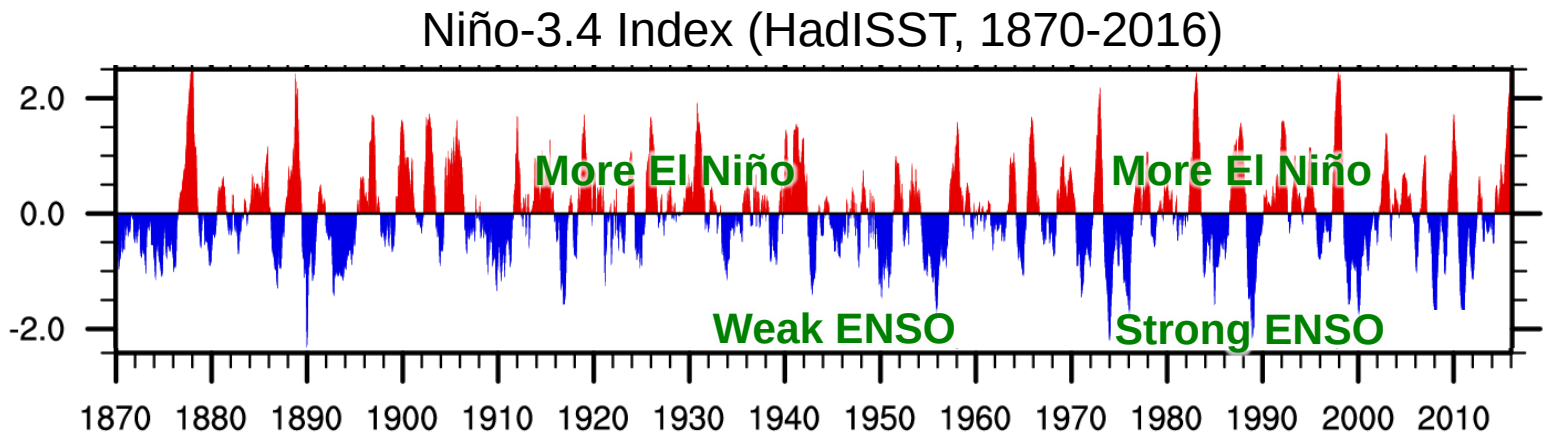
Okumura, Y. M., Sun, T., and Wu, X. (2017). Asymmetric modulation of El Niño and La Niña and the linkage to tropical Pacific decadal variability. J. Climate, 30(12), 4705-4733.

Sun, T., and Okumura, Y. M. (2018). Role of stochastic atmospheric forcing from the South and North Pacific in tropical Pacific decadal variability. J. Climate, submitted.

Sun, T., and Okumura, Y. M. (2018). Impact of stochastically-driven tropical Pacific decadal variability on the El Niño-Southern Oscillation. In preparation.

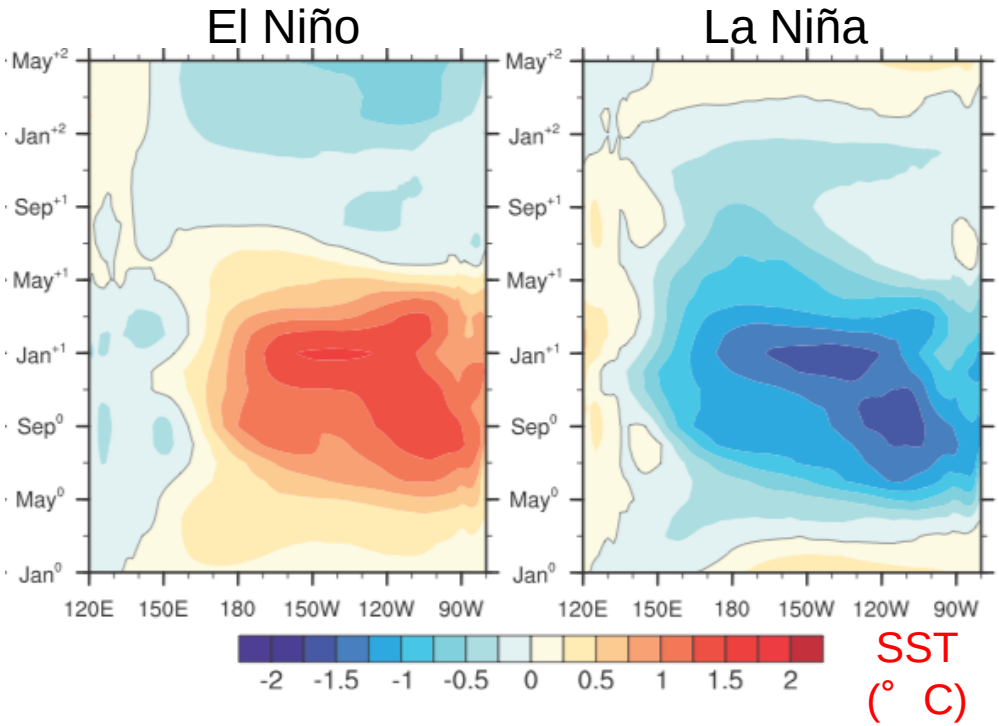
Decadal Modulation of ENSO



What are the fundamental mechanisms of decadal ENSO modulations?

- Does the ENSO modulate with tropical Pacific decadal variability (TPDV)?
  - Do the ENSO properties other than the amplitude modulate?
    - Are the modulations of El Nino and La Nina symmetric?
      - What causes TPDV in the first place?

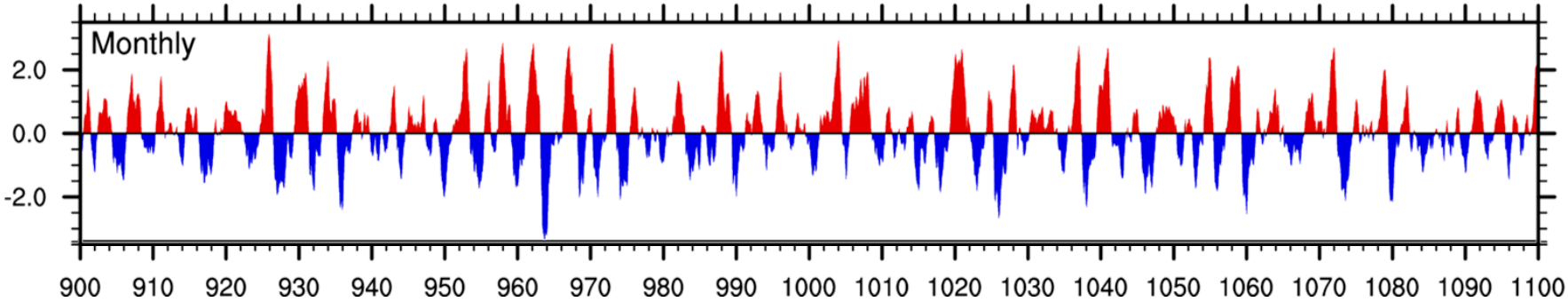
Community Climate System Model Version 4 (CCSM4)



CCSM4
1300-yr PI Control Simulation

- Ocean, atmosphere, land & sea ice models
- 1° resolution
- Preindustrial GHGs
- Variability = Natural

Niño-3.4 Index (Yr 900-1100)

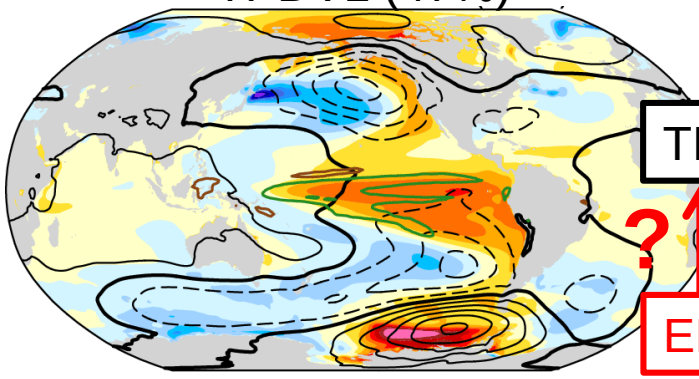


Tropical Pacific Decadal Variability (TPDV)

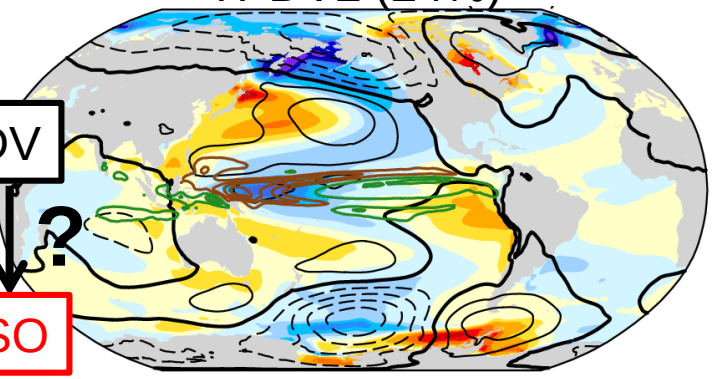
EOF analysis of tropical Pacific SST (>10yr) → Global regressions on PCs

CCSM4
1300-yr run

TPDV1 (47%)



TPDV2 (24%)



TPDV

ENSO

?

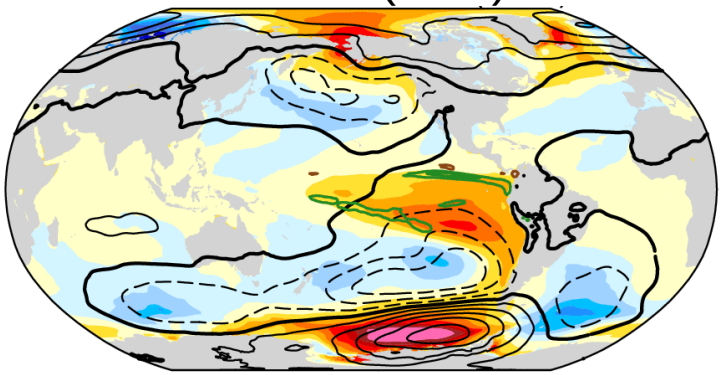
?

Frequency & duration of El Niño

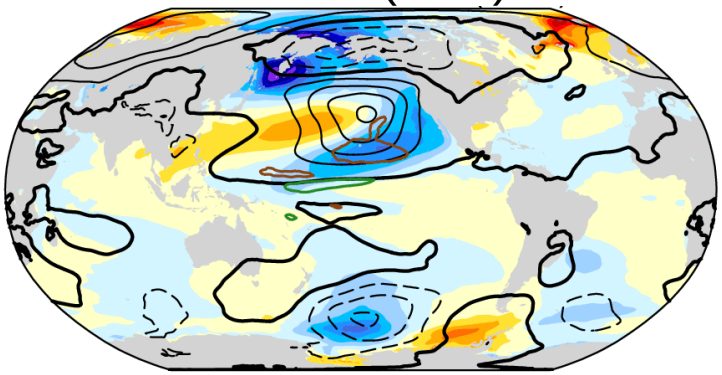
ENSO amplitude & asymmetry

Slab Ocean
500-yr run
(No ENSO)

TPDV1 (38%)



TPDV2 (18%)

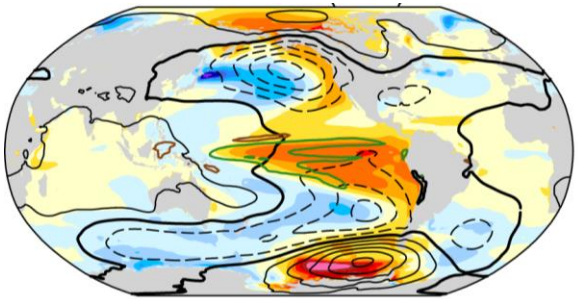


SST (°C)

Contours: SLP (0.1 hPa), Precipitation (0.2 mm/day, WET/DRY)

TPDV1 – Frequency and Duration of El Niño

TPDV1



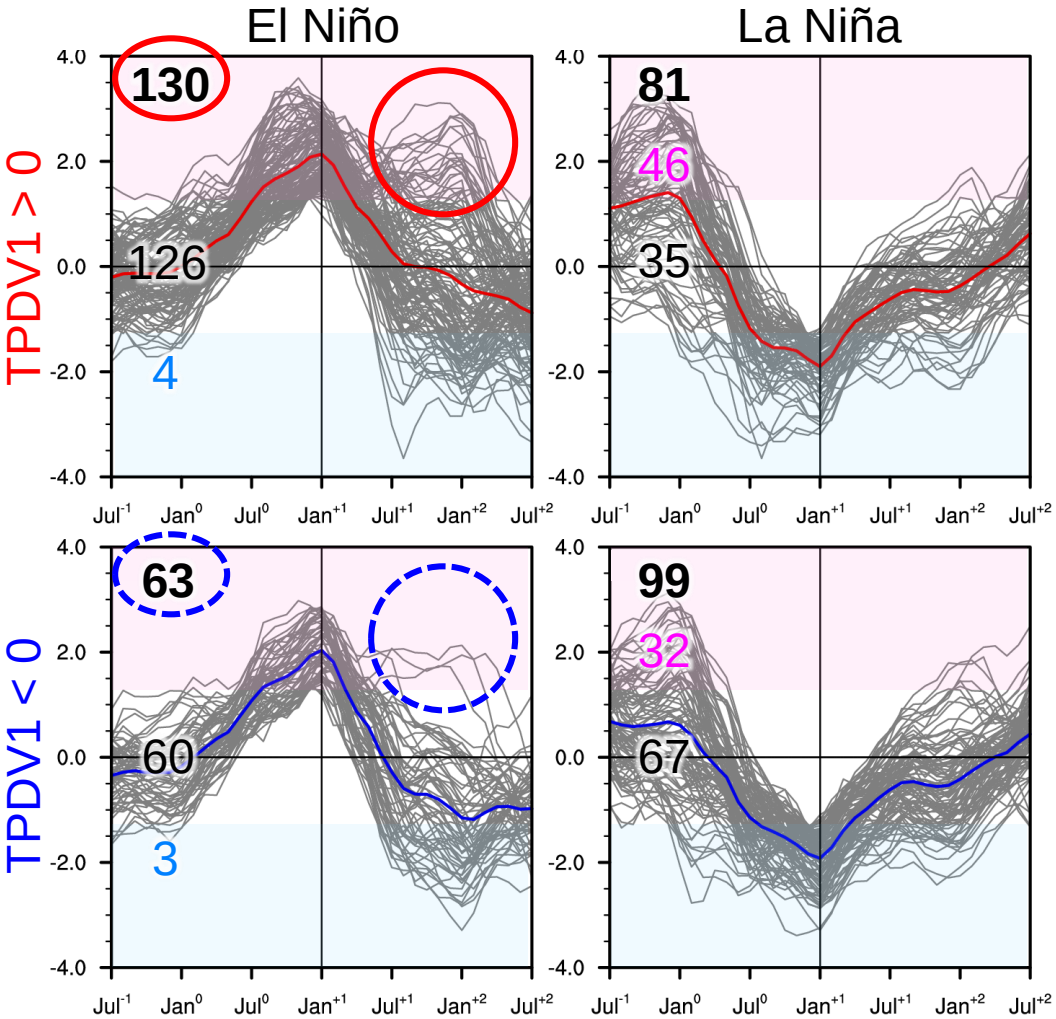
Dec Niño-3.4 SST

>+1σ → El Niño

<−1σ → La Niña

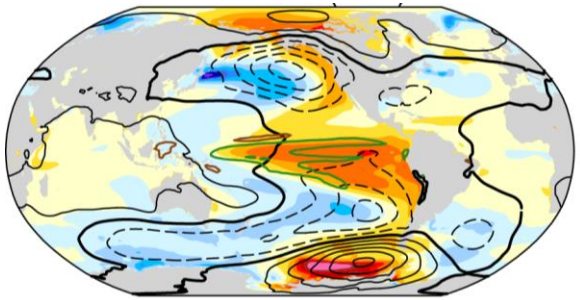
(σ=1.27° C)

Niño-3.4 Index



Role of Interbasin SST Gradient in El Niño Modulation

TPDV1



Relative warmth of the tropical Pacific

↓

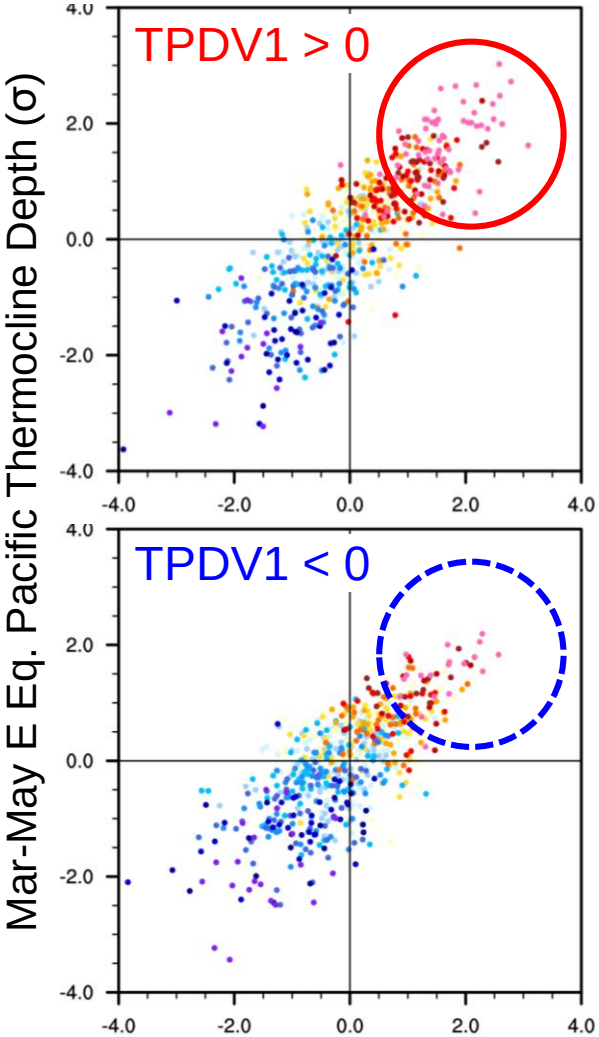
Westerly wind anomalies in W Pacific

↓

Deepening of thermocline in E Pacific

↓

More frequent & persistent El Niño



r(x,y)=0.8

Jan-Mar ∇SSTA* = Pacific − Indian/Atlantic (σ)

Dec Niño3.4 (σ)

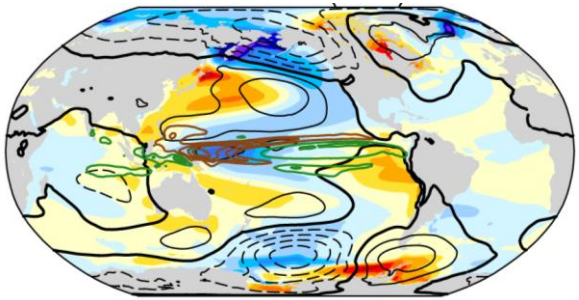
* Regression on Dec(-1) Nino-3.4 index removed

TPDV2 – ENSO Amplitude and Asymmetry

ENSO Amplitude

r = 0.81

TPDV2



Warmer E Pacific
Southward shift of ITCZ

↓

Eastward shift of
El Niño anomalies

↓

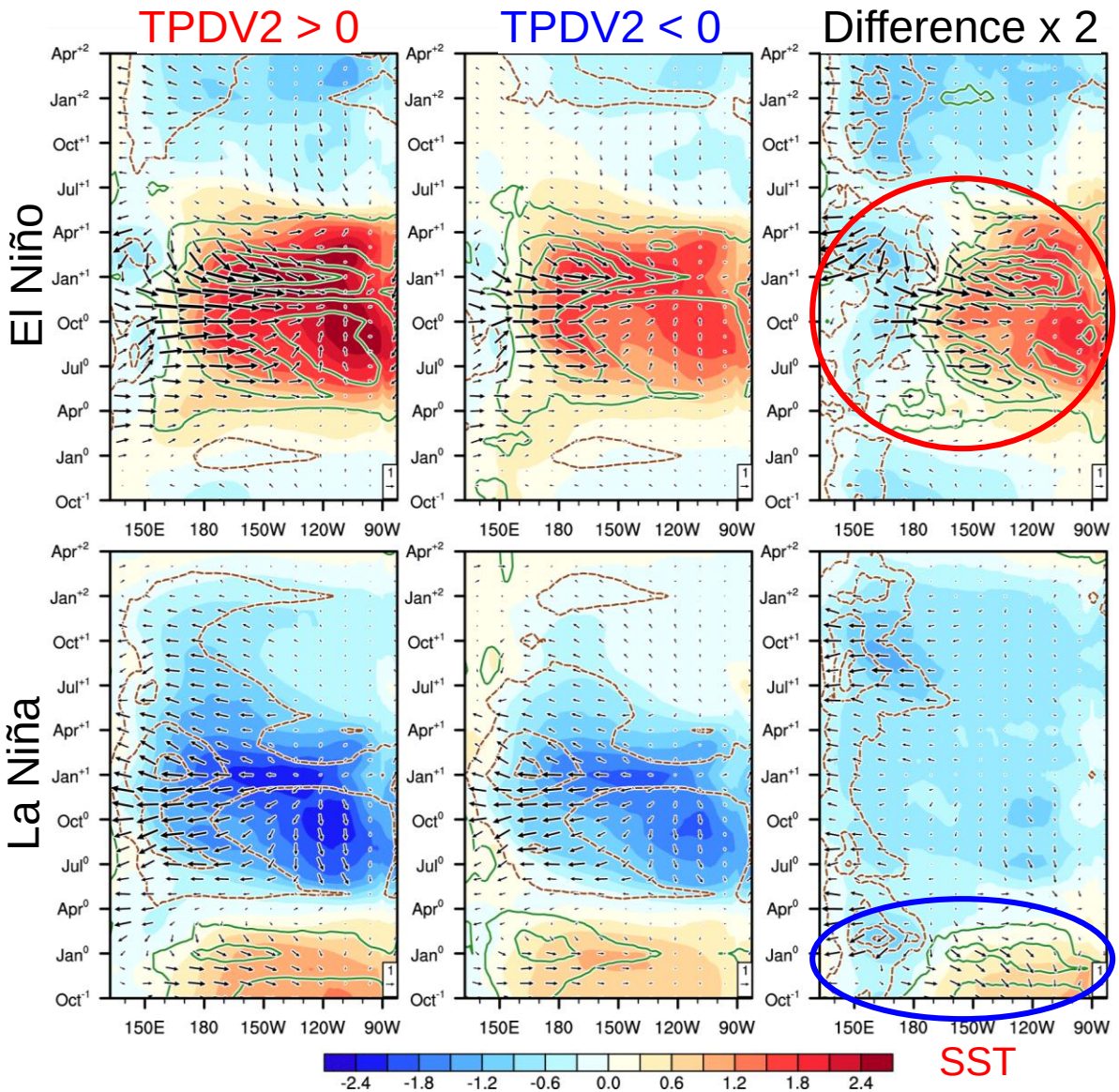
Stronger & shorter El Niño

↓

Stronger & longer La Niña

↓

Stronger ENSO Asymmetry
(pattern & duration)



Surface Winds (m/s), Precipitation (0.2 mm/day, WET/DRY)

Decadal Modulation of ENSO in CCSM4

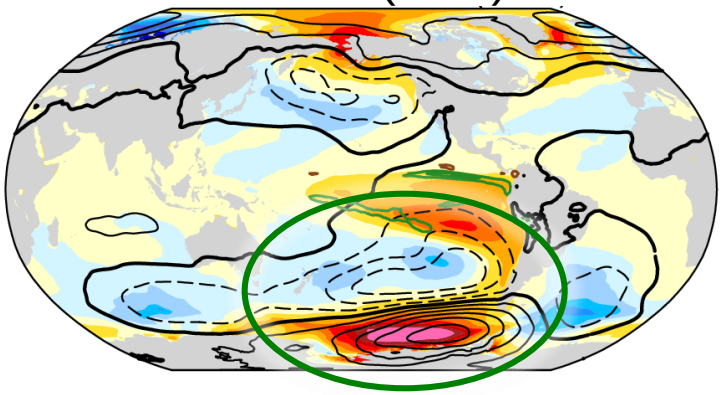
- ✓ ENSO modulates with the two leading modes of TPDV.
- ✓ Various properties of ENSO modulate.
  (Amplitude, frequency, duration and El Nino-La Nina asymmetry)
- ✓ Modulations of El Nino and La Nina are asymmetric.
  (El Nino appears more sensitive to TPDV.)

- **What causes TPDV in the first place?**

Role of Stochastic Atmospheric Forcing from the S Pacific

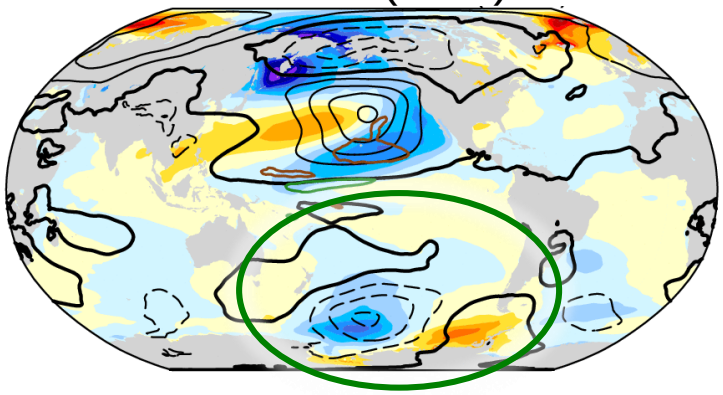
Slab Ocean
500-yr run
(No ENSO)

TPDV1 (38%)



Pacific-South American (PSA)

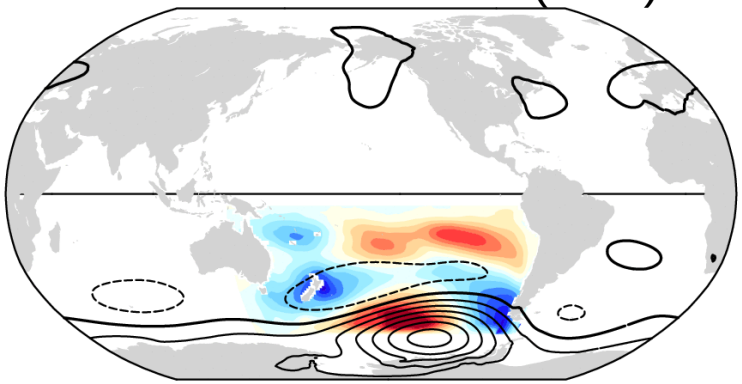
TPDV2 (18%)



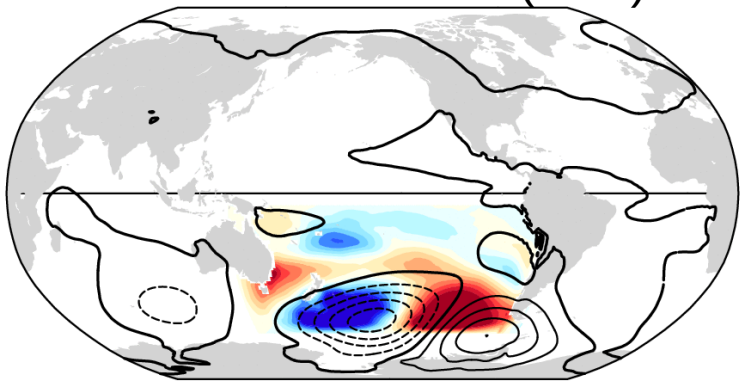
PSA2

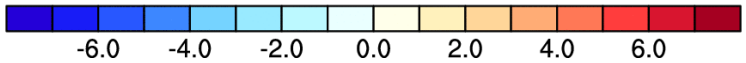
CAM4
300-yr run
(No SST Variability)

S Pacific SLP EOF1 (32%)



S Pacific SLP EOF2 (21%)



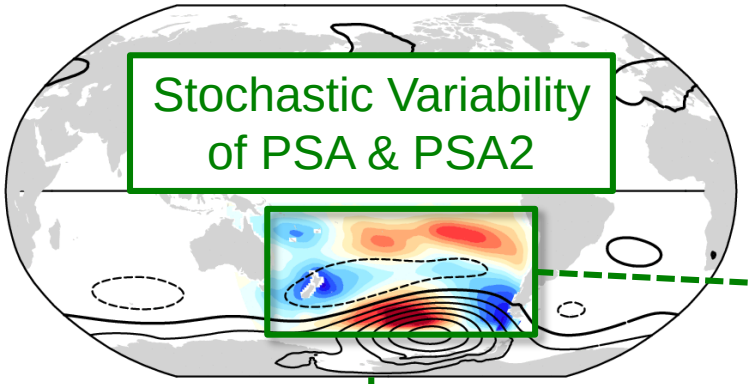


Surface heat flux (W/m^2)

Contours: Sea Level Pressure (1 hPa)

CCSM4 Experiments

Hypothesis



TPDV

ENSO

CCSM4

Atmosphere

PSA & PSA2
heat flux
anomalies
from CAM4

+

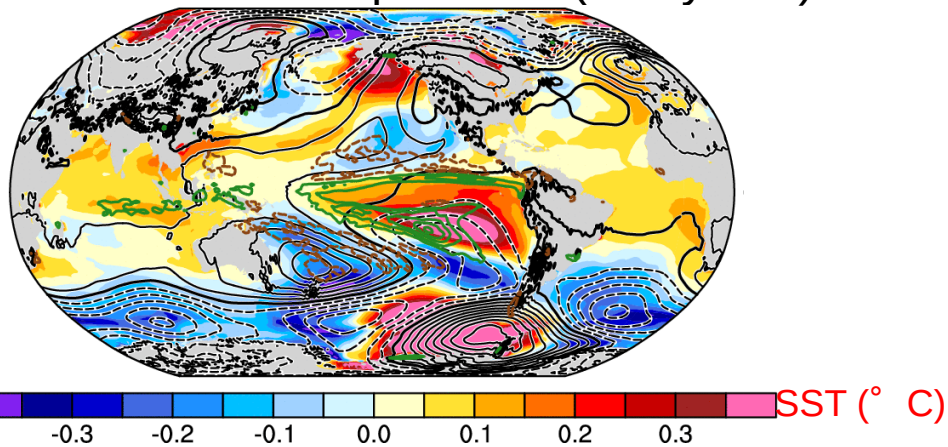
Ocean

Amplitude of heat flux anomalies
is adjusted for decadal variability
and kept constant in time.

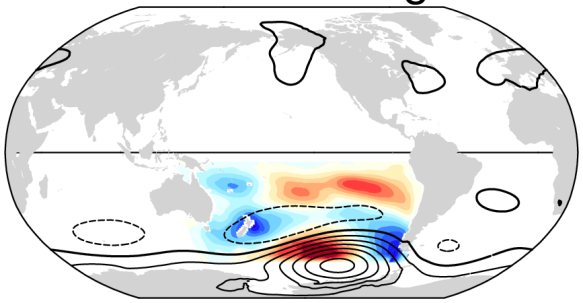
100 yr x 3 members
for each of PSA and PSA2 forcing

Mean State and ENSO Changes in the **PSA** Experiments

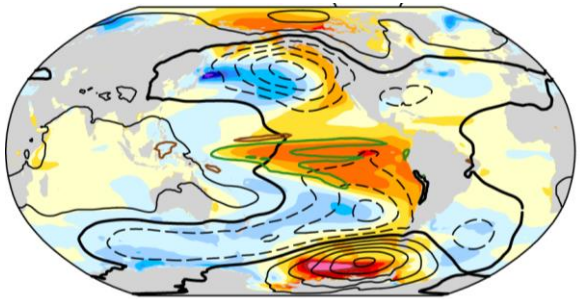
Slab Ocean PSA Experiment (100 yr x 1)

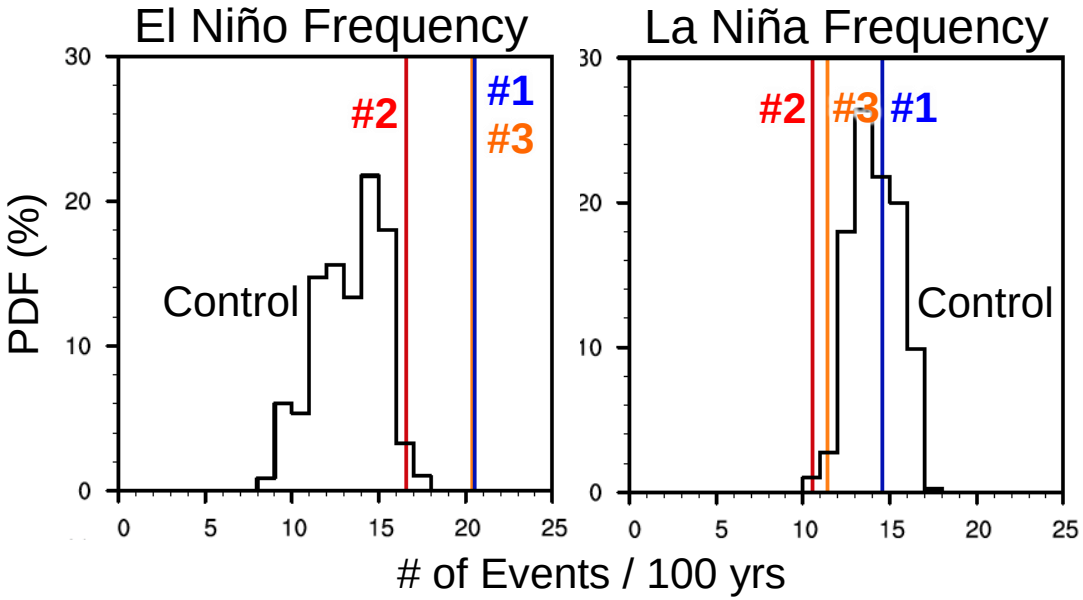


PSA Forcing



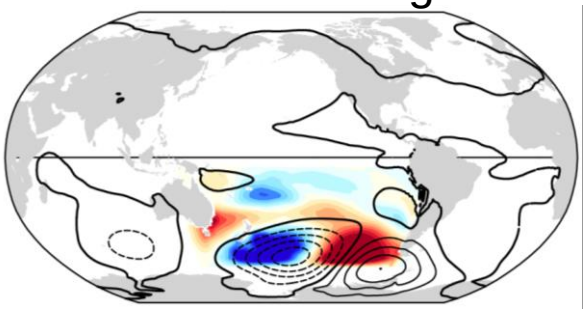
TPDV1



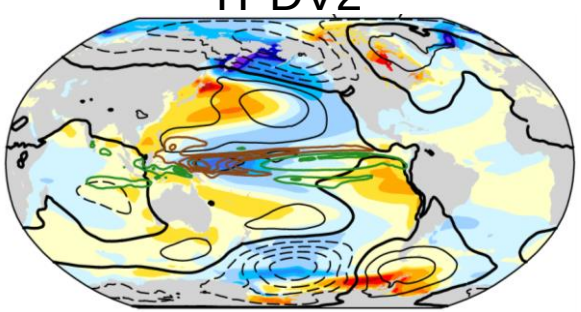


Mean State and ENSO Changes in the **PSA2** Experiments

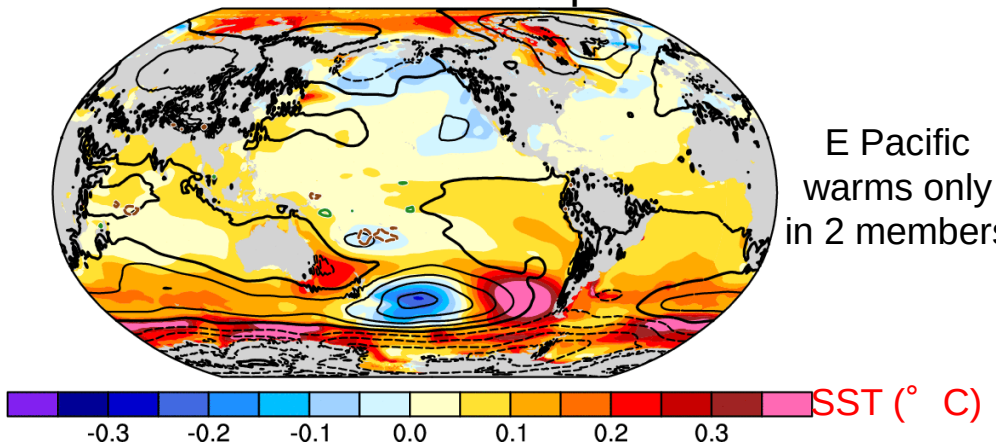
PSA2 Forcing



TPDV2



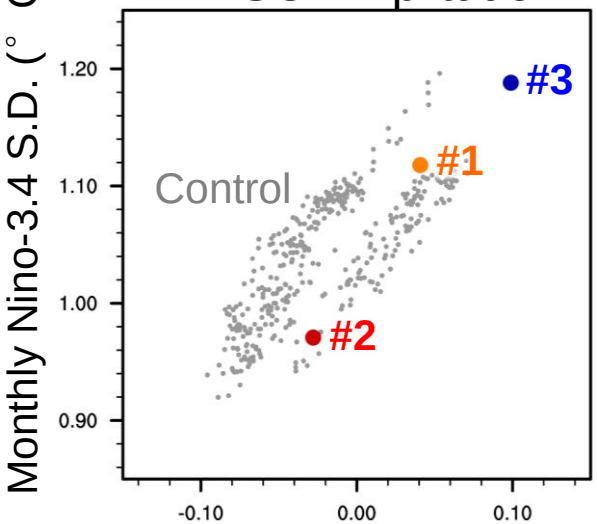
Ensemble Mean Response



E Pacific warms only in 2 members

SLP (0.1 hPa), Precipitation (0.2 mm/day, WET/DRY)

ENSO Amplitude



∇(Mean SSTA) = E − W Pacific (° C)

Summary

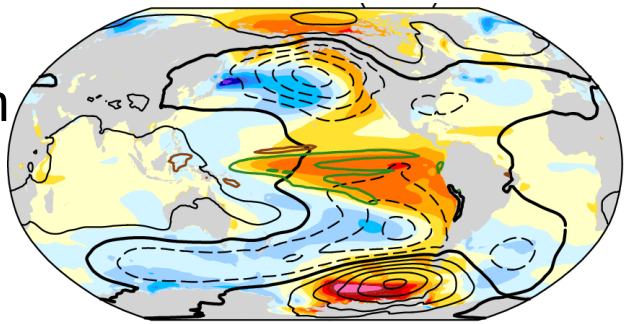
Frequency & Duration of El Nino

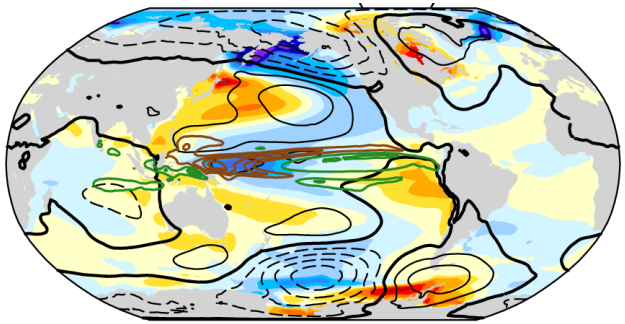
ENSO Amplitude & Asymmetry

TPDV1

TPDV2

Interbasin SST Gradient





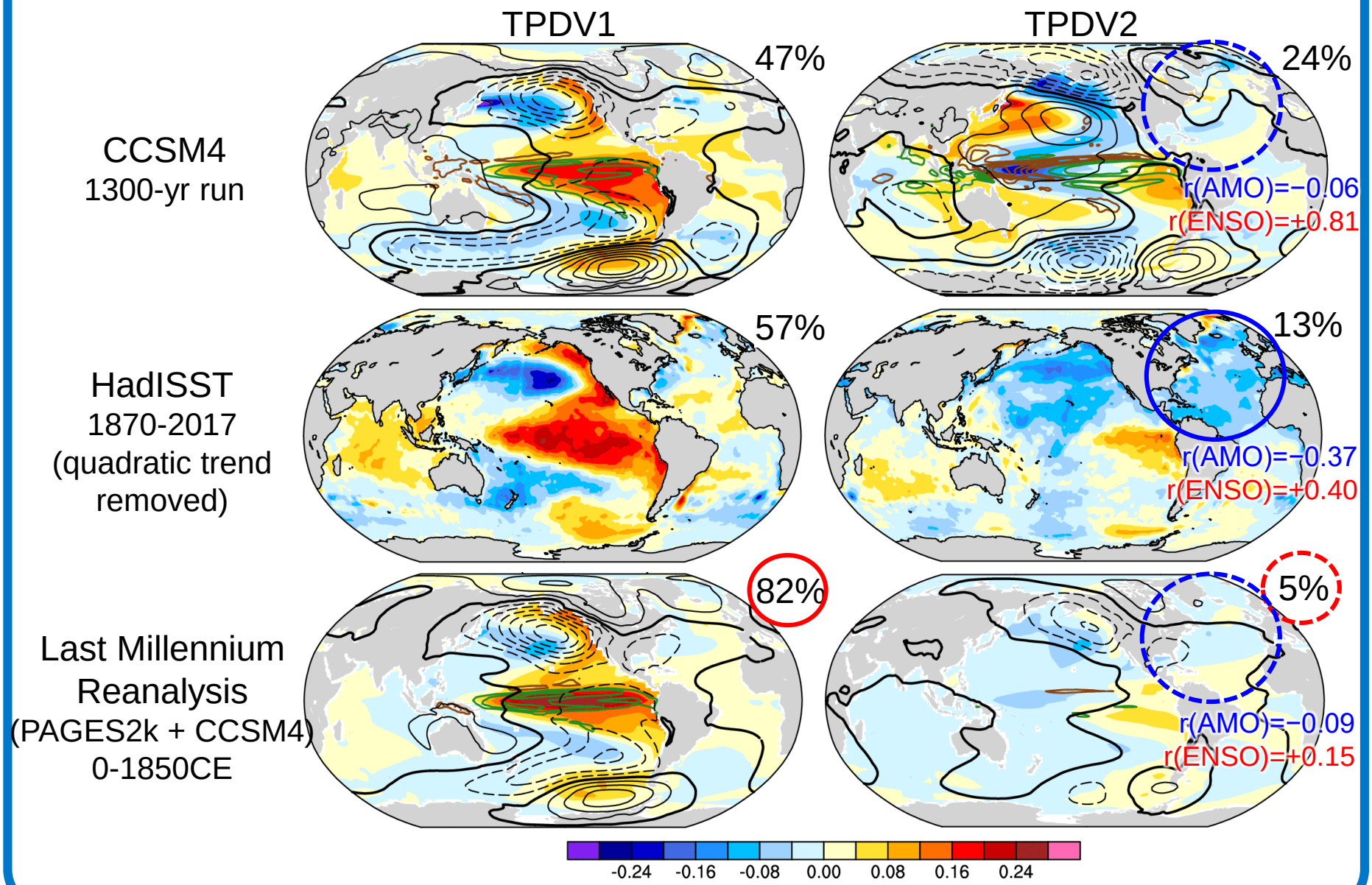
Zonal SST Gradient

Stochastic PSA variability

Stochastic PSA2 variability

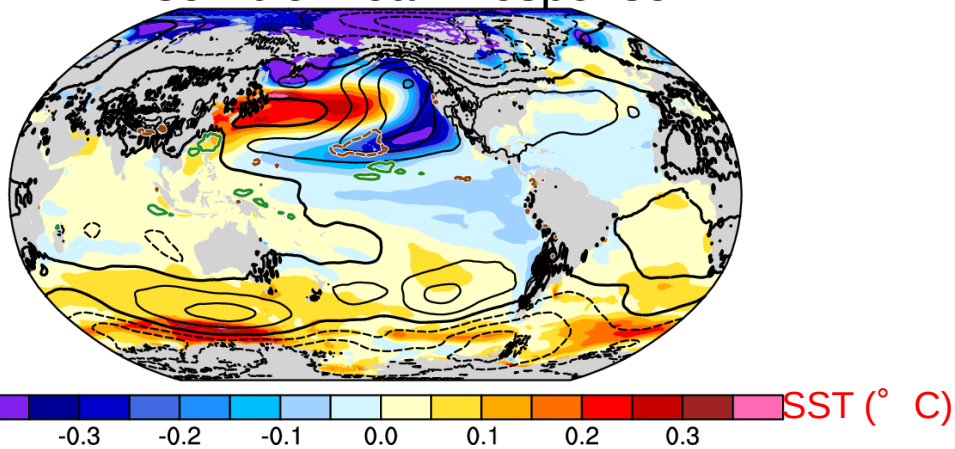
Additional Slides

TPDV in CCSM4 vs Observations



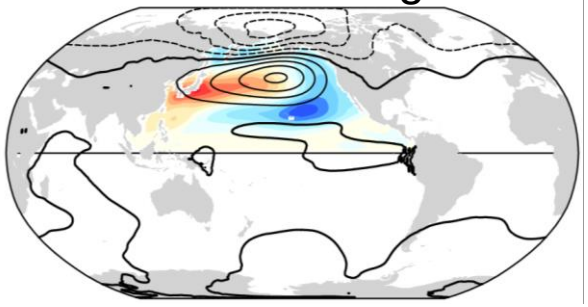
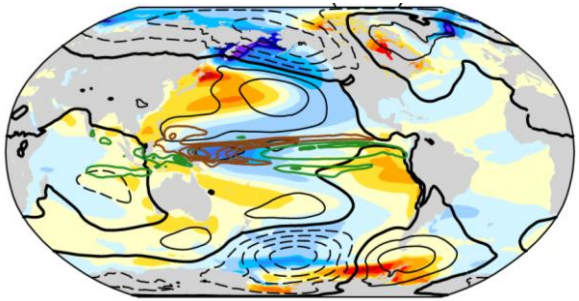
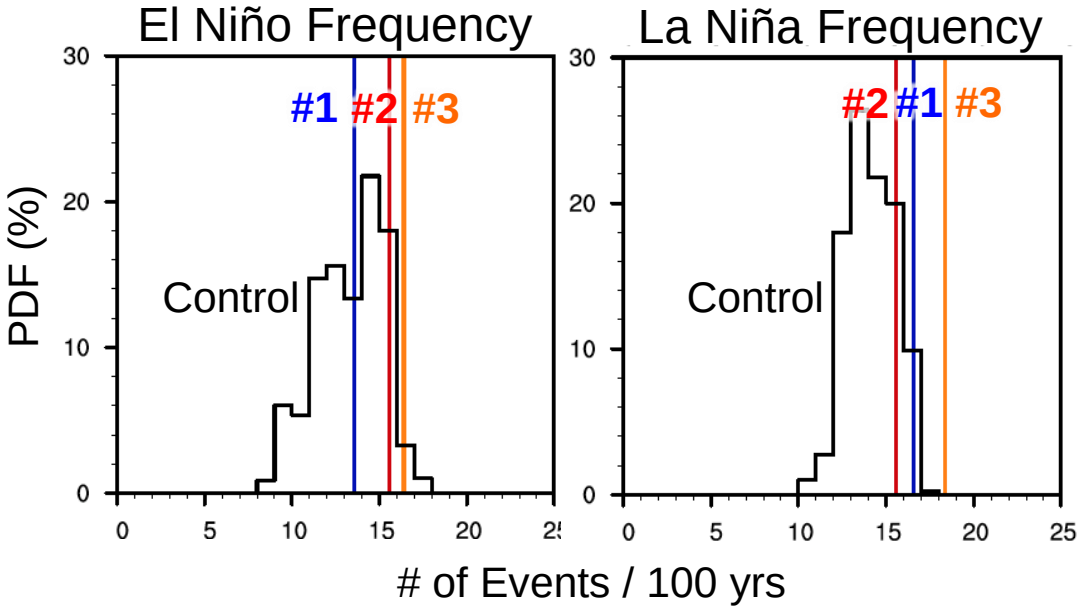
Mean State and ENSO Changes in the **NPO** Experiments

Ensemble Mean Response



SLP (0.1 hPa), Precipitation (0.2 mm/day, WET/DRY)

NPO Forcing



TPDV2