Predictability of tropical Pacific decadal variability and associated oceanic mechanisms

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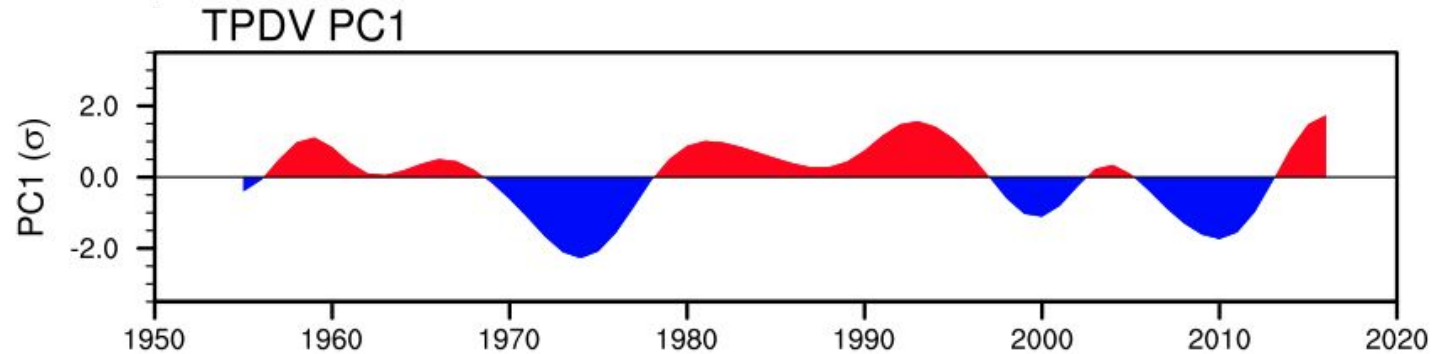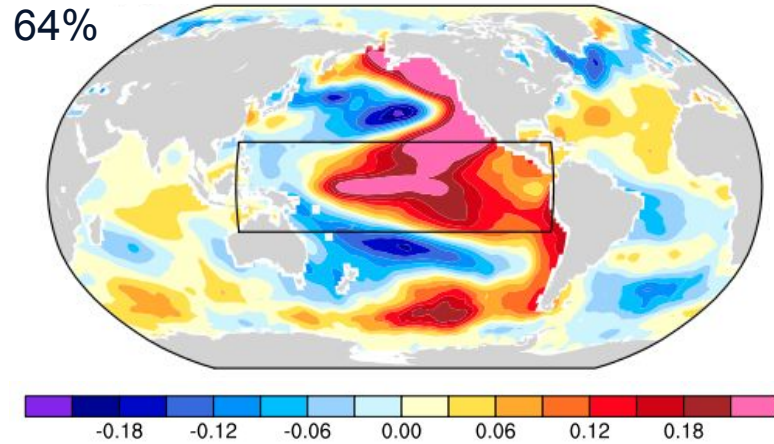*National Center for Atmospheric Research*

ESPWG Meeting
02/22/2023

Leading EOF mode of 10-yr low pass filtered and detrended SST variability in the tropical Pacific


Impacts of TPDV:

○ Modulate global mean temperature ("warming hiatus" during negative TPDV phase)

e.g., Kosaka and Xie 2013; Meehl et al. 2013; England et al. 2014

○ Interact with interannual variability, e.g., El Niño Southern Oscillation (ENSO)

e.g., Gu and Philander 1996; Rodgers et al 2004; Vimont 2005; Okumura et al. 2017

○ Influence the global hydroclimate and marine ecosystems on decadal timescales

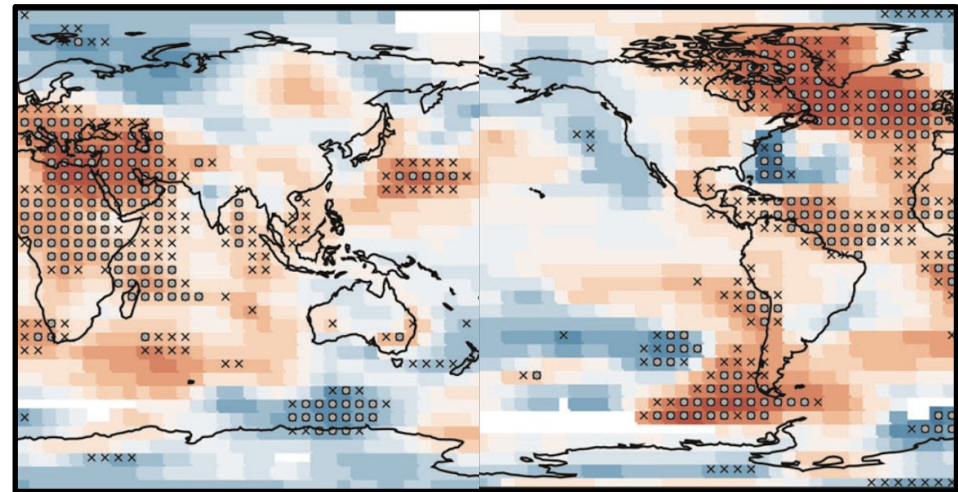*e.g., Alexander et al. 2010; DiLorenzo et al. 2013*

CMIP6 initialized decadal forecasts for near-surface temperature, Forecast Year 2–9

Total correlation skill
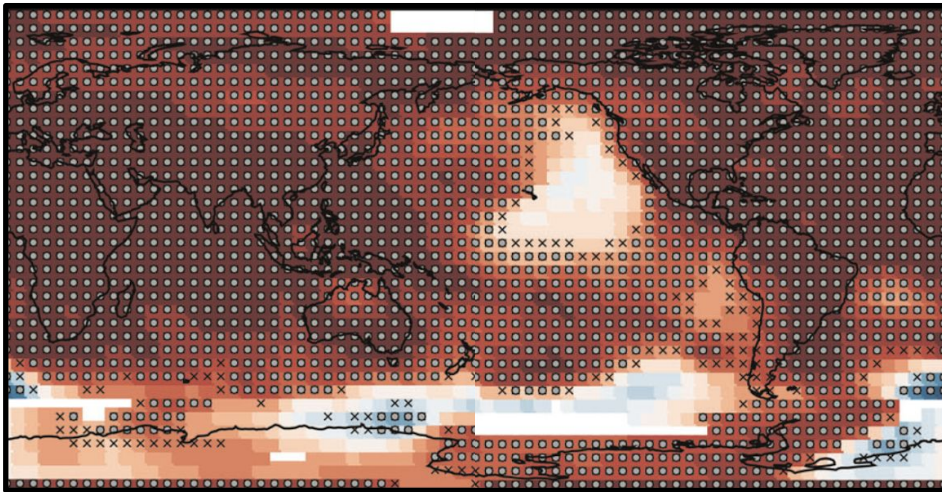
Residual correlation (Impact of initialization)

Smith et al. 2019

o   Why is the decadal prediction skill low in the tropical Pacific?

o   What oceanic processes affect the decadal predictability in the tropical Pacific?

1) CESM1 Decadal Prediction Large Ensemble (DPLE), *Yeager et al. (2018)*

- **Initialized with** 'observed' oceanic and sea ice states on Nov 1st of each year during 1954–2015
- 40 members x 10 years
- **CMIP5 radiative forcing** (Historical & RCP8.5)

2) CESM1 DPLE without historical volcanic forcing (DPLE_NoVolc), *Wu et al. in minor revision*
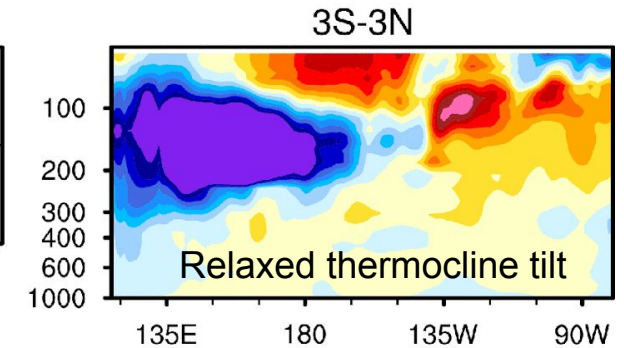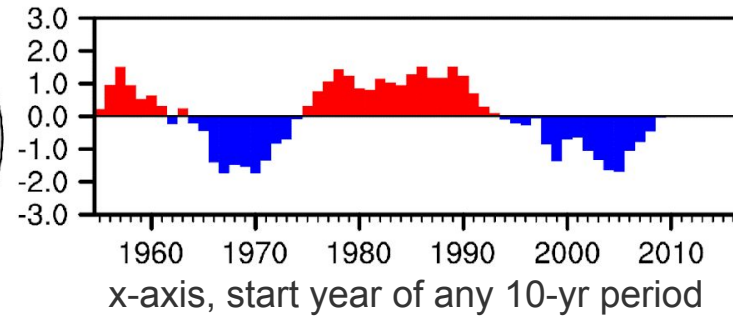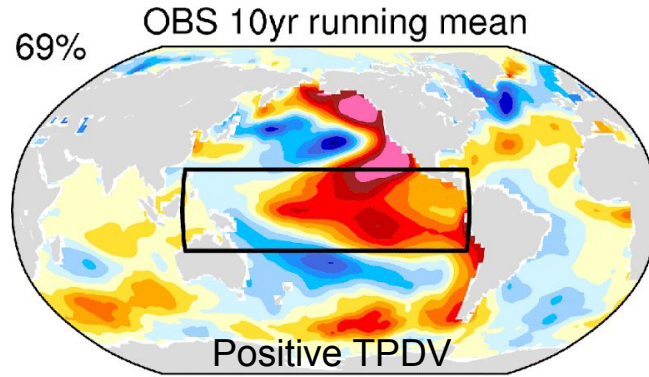
- 10 members

3) CESM1 Large Ensemble (LE), *Kay et al. (2015)*

- 1920-2100, 40 members
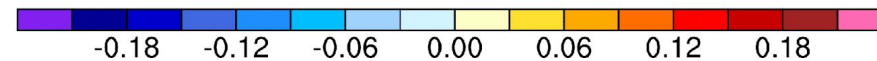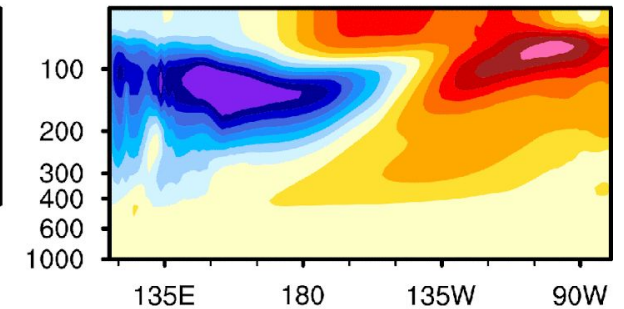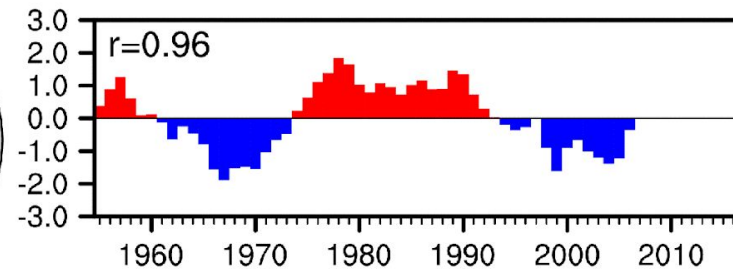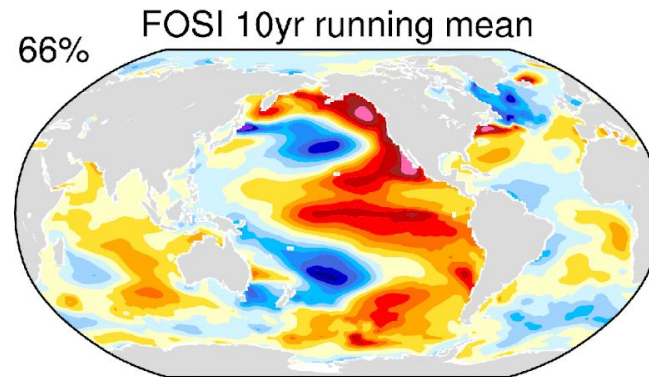- CMIP5 external forcing (including historical volcanic forcing)

Observed TPDV is well captured by the forced ocean simulation

Leading EOF of detrended decadal (10-yr running mean)
SST anomalies in the tropical Pacific

Observation (ERSSTv5 and EN4)

OBS 10yr running mean

69%

Positive TPDV

x-axis, start year of any 10-yr period

3S-3N

Relaxed thermocline tilt

Forced Ocean Sea Ice Simulation (FOSI) with historical atmospheric and surface flux fields

Initial conditions for decadal forecasts

FOSI 10yr running mean

66%

r=0.96

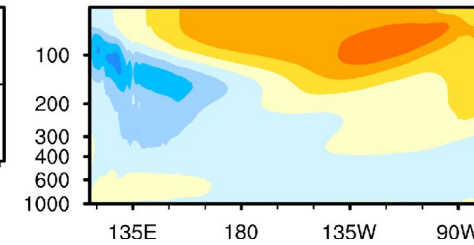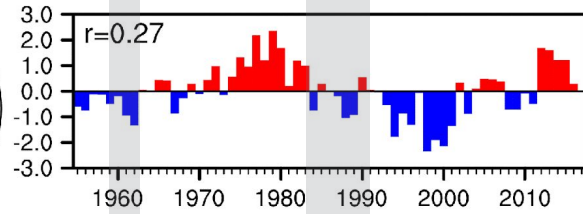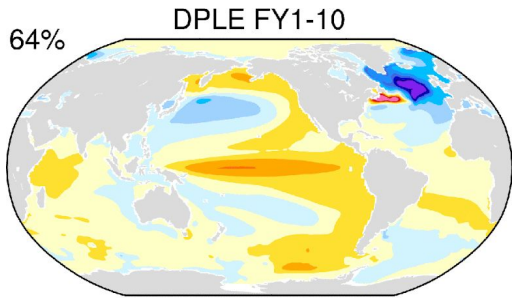-0.18   -0.12   -0.06   0.00   0.06   0.12   0.18

How is TPDV predicted by initialized forecasts and un-initialized simulations?

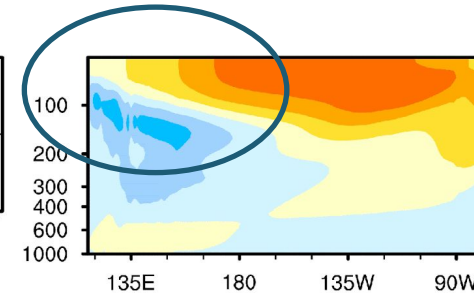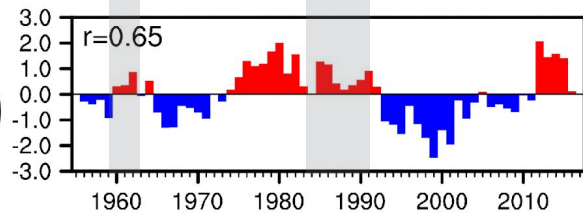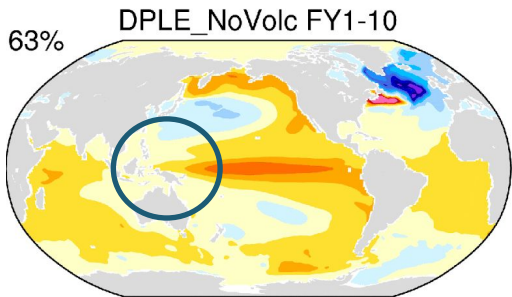**Forced Ocean Sea Ice Simulation (FOSI)** (10-yr running mean)

FOSI 10yr running mean — 66% — r=0.96
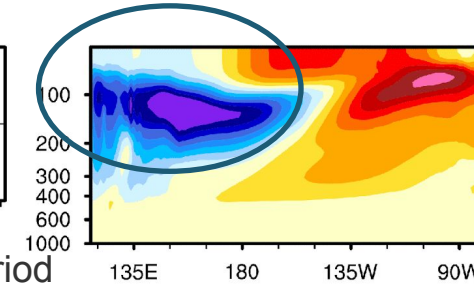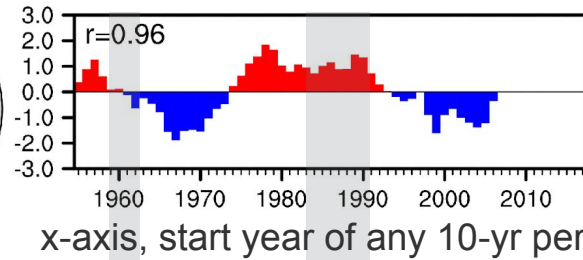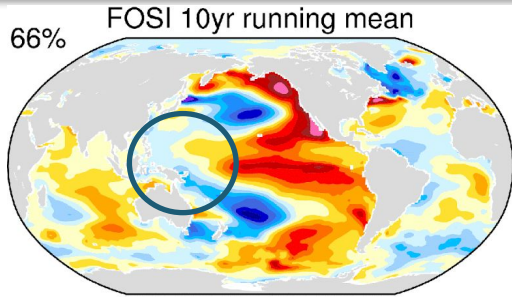
DPLE (Forecast Year 1-10)
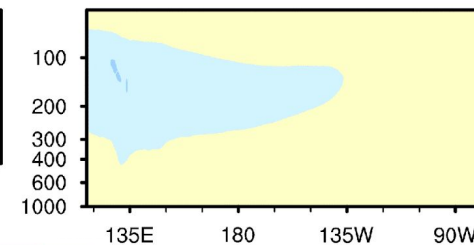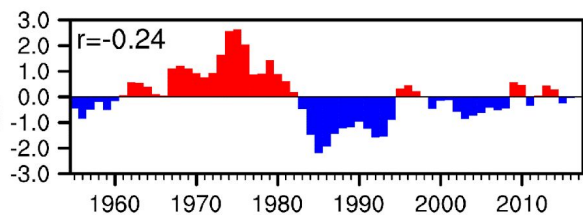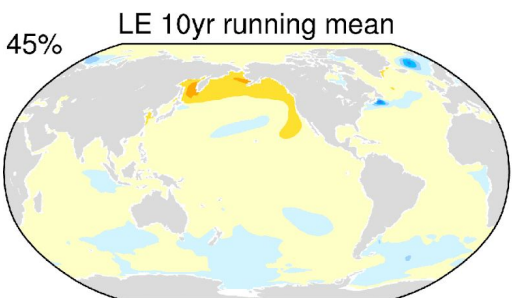
DPLE FY1-10 — 64% — r=0.27

Volcanic forcing degrades prediction skill of TPDV *(Wu et al. in minor revision)*

DPLE_NoVolc (Forecast Year 1-10)

DPLE_NoVolc FY1-10 — 63% — r=0.65

DPLE_NoVolc show high skill in predicting TPDV

Large Ensemble (10-yr running mean)

LE 10yr running mean — 45% — r=-0.24

Uninitialized simulations cannot capture TPDV
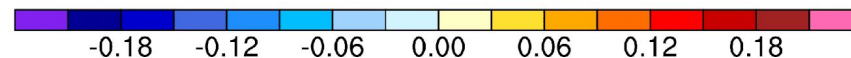
x-axis, start year of any 10-yr period

-0.18 -0.12 -0.06 0.00 0.06 0.12 0.18

Correlation maps with Eq. Pacific SST index in Forecast Year 1-10, 1955–2016

SST

Ocean temperature (3°S–3°N)

Forecast Year 1-10

↑ precedes

Nov 0 Initial state

**Nov 0 Initial state
10-yr high pass filtered**

**Nov 0 Initial state
10-yr low pass filtered**

Isopycnal depth deepening in the equatorial and off-equatorial western Pacific precedes TPDV warming, indicative of the Rossby wave reflection mechanism.
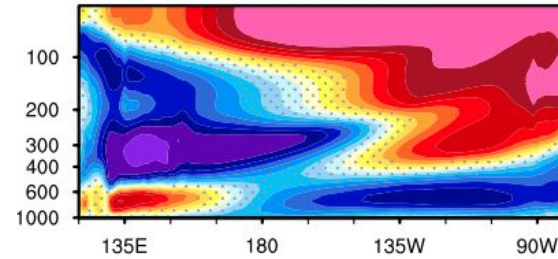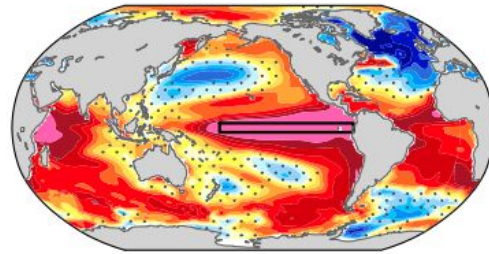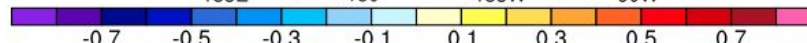
Isopycnal depth (σ_θ = 25.5 kg m^{-3})
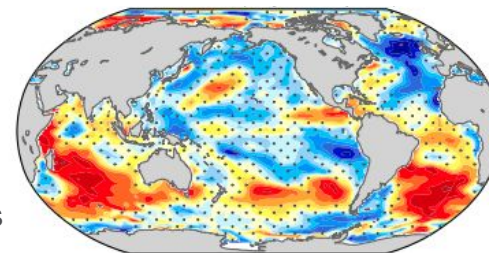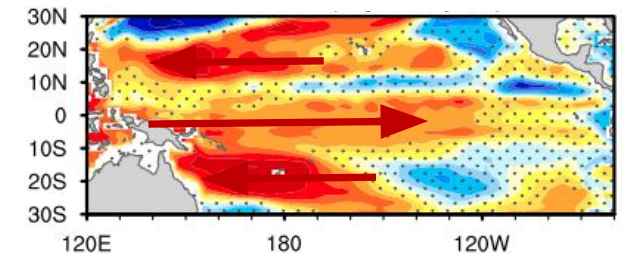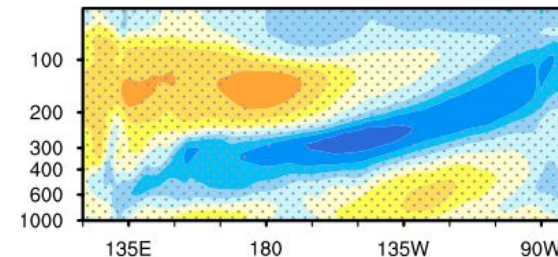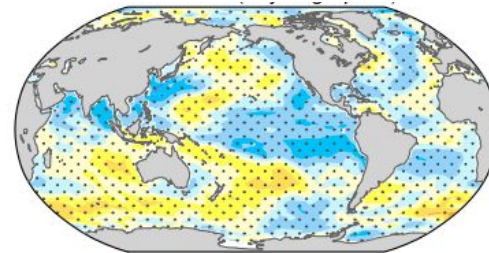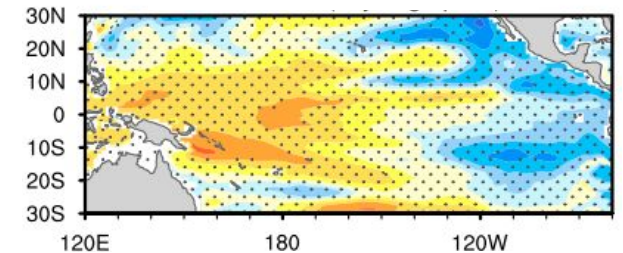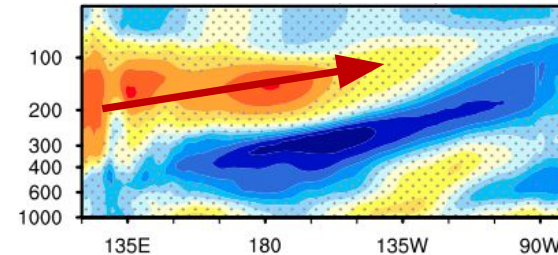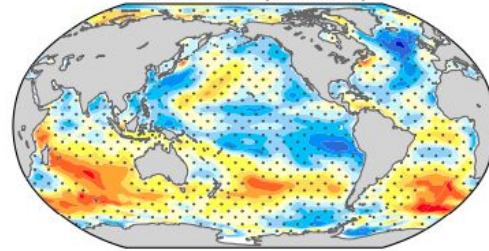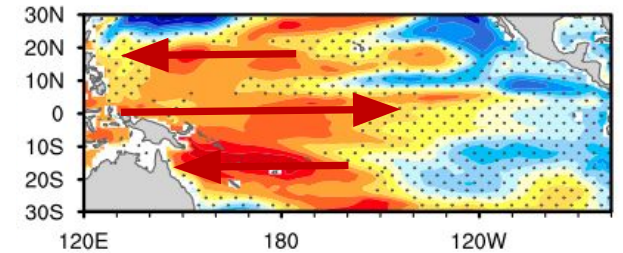
*Stippling indicates insignificant values 90% confidence level based on t test.

Regional initialization experiments: a case study for 1999-2008

Decadal SST anomalies
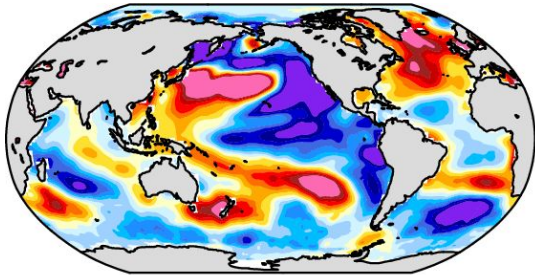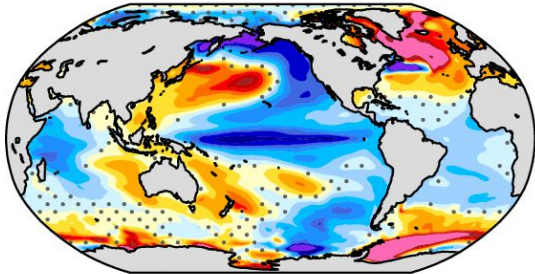1999 – 2008

Observation

DPLE_NoVolc (Initialized 1998 Nov)

Initial SST anomalies
Nov 1998

Observation
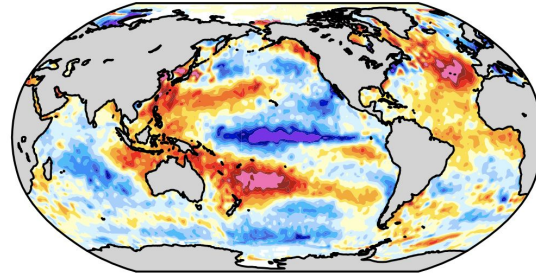
Forced Ocean and Sea Ice
Simulation (FOSI)
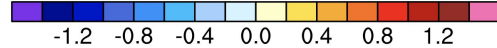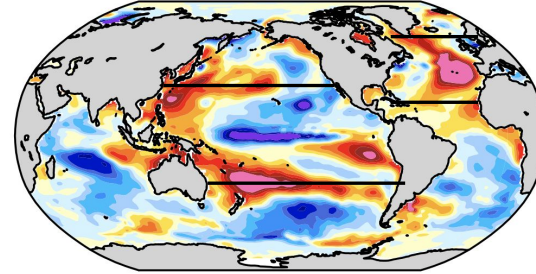
1) **FOSI Climatology Initialization (Control)**

2) Climatology everywhere
+ **Tropical Pacific Initialization** (30°S-30°N)
full-depth ocean temperature & salinity anomalies
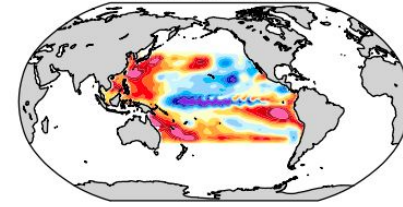
3) Climatology everywhere
+ **North Atlantic Initialization** (20°N-60°N)
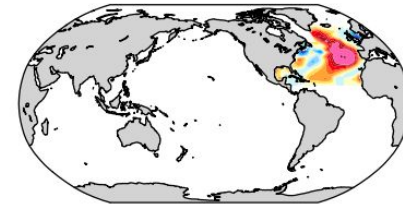
4) Climatology everywhere
+ **Southern Hemisphere Ocean Initialization**

+ external forcing during 1999-2008, 10 members

Remove 1) from 2), 3), 4) and DPLE_NoVolc
to calculate forecast anomalies.

SST anomalies during 1999–2008

Observation

FULL Initialization (DPLE_NoVolc)

TPAC Initialization

NATL Initialization

SH Initialization

TPAC Initialization is important to the prediction of equatorial Pacific decadal cooling.

NATL initialization does not generate significant tropical Pacific SST anomalies.

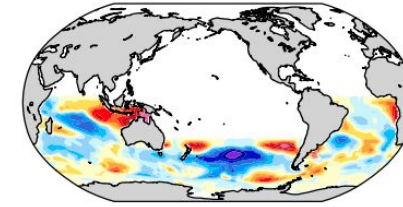Southern Hemisphere Ocean initialization generates tropical Pacific warming.
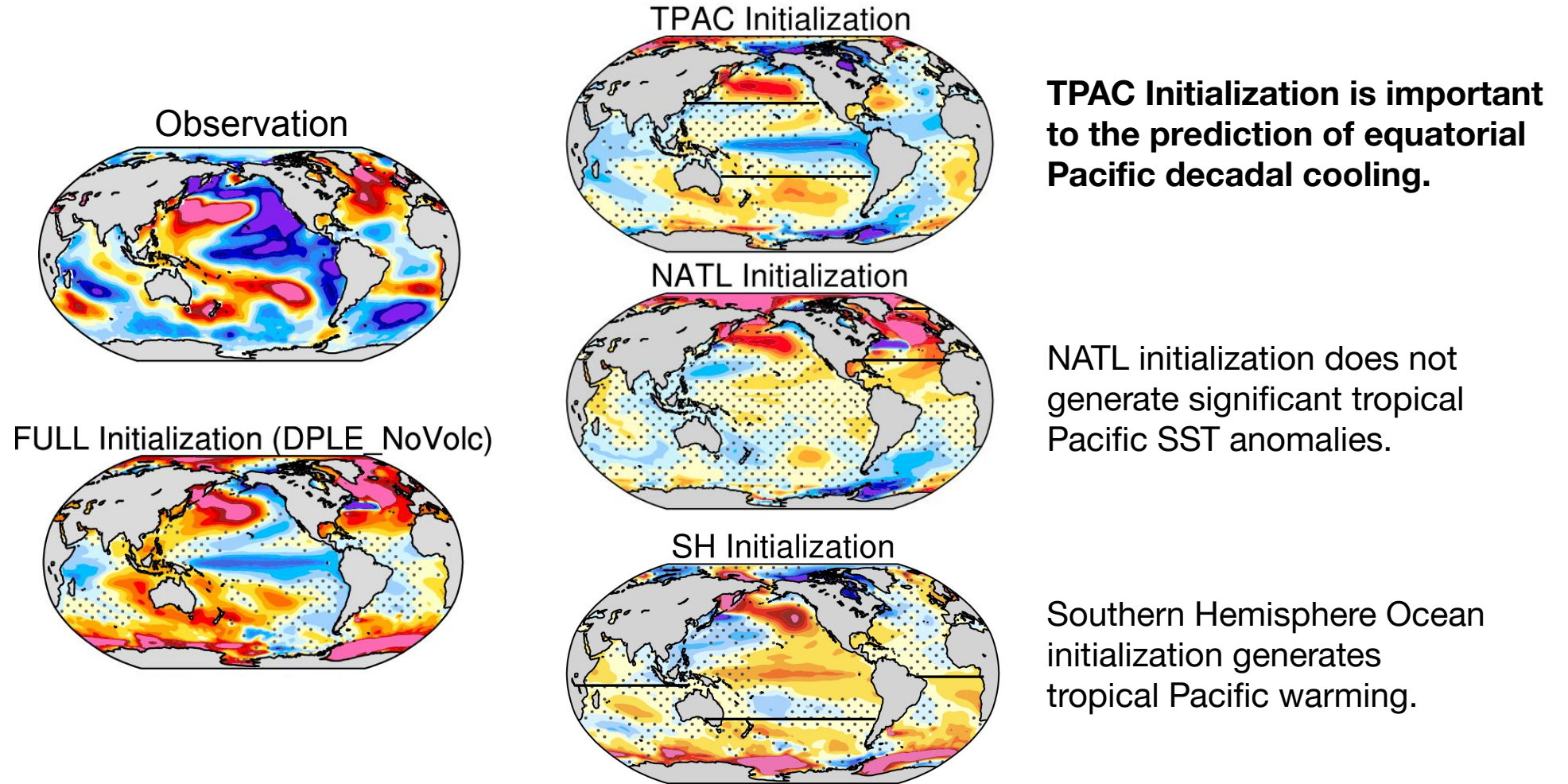
*Stippling indicates **insignificant** composite values at 90% confidence level based on bootstrap method against ensemble members.

-0.30 -0.20 -0.10 0.00 0.10 0.20 0.30   (°C)

Summary

o Predictability of TPDV SST anomalies arises from low-frequency subsurface ocean temperature anomalies, particularly the isopycnal depth (σ_θ= 25.5 kg m-3) anomalies in the western tropical Pacific and associated Rossby wave reflection.

o We also explored other mechanisms for TPDV (not shown in this presentation): The Pacific subtropical-tropical cell lags and amplifies TPDV SST anomalies, while the spiciness advection from the subtropical Pacific tends to damp TPDV SST anomalies.

o Regional initialization experiments suggest that the initialization of the tropical Pacific plays a key role in TPDV predictability.

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