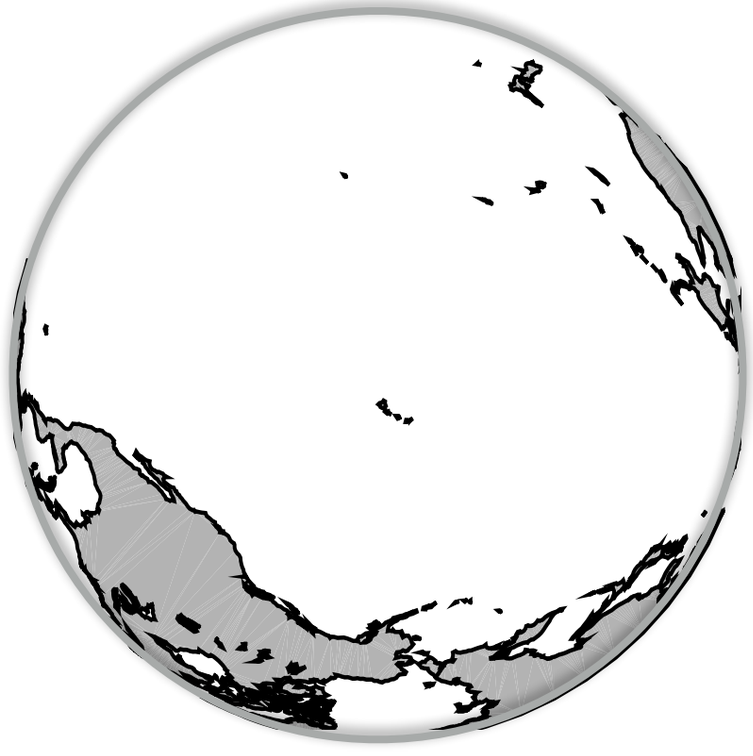
PICES-2017 Annual Meeting

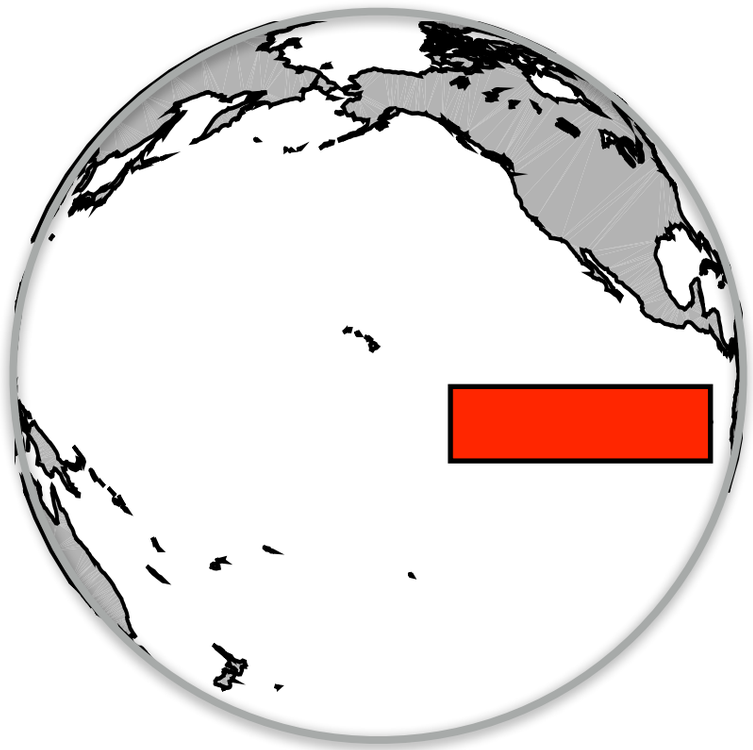
Vladivostok - Sep 29th, 2017

Increasing Pacific decadal variability under greenhouse forcing

Giovanni Liguori
and
Emanuele Di Lorenzo

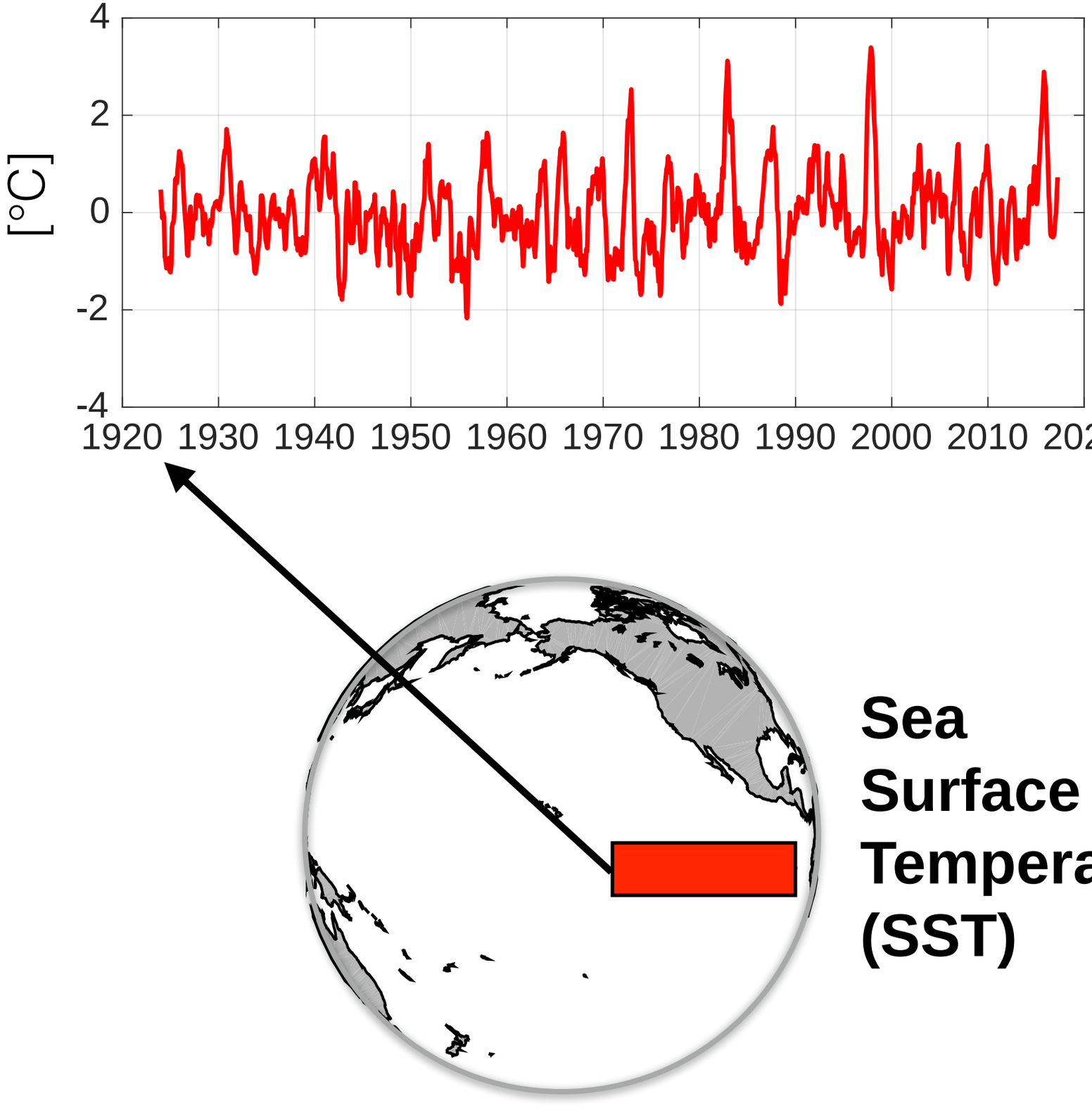
School of Earth & Atmospheric Sciences
Georgia Institute of Technology





Sea Surface Temperature (SST)

Nino3 Index (NOAA SST)



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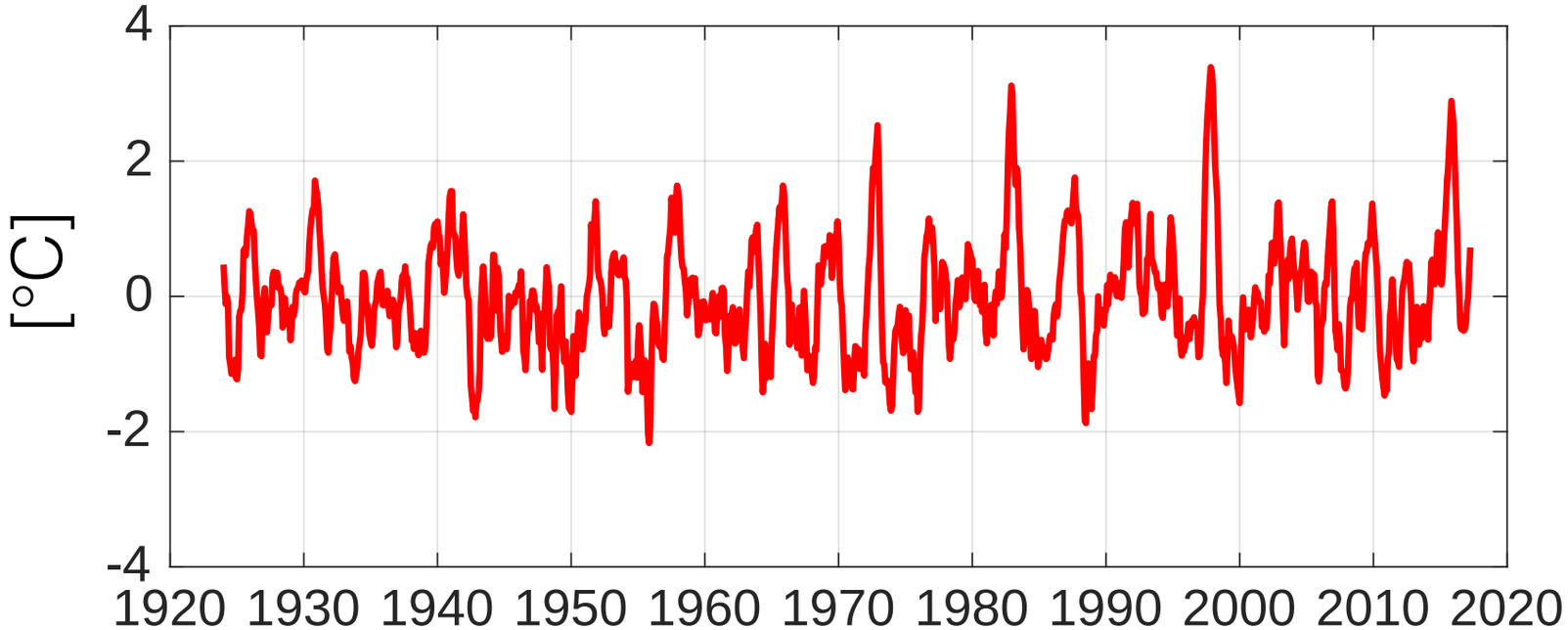
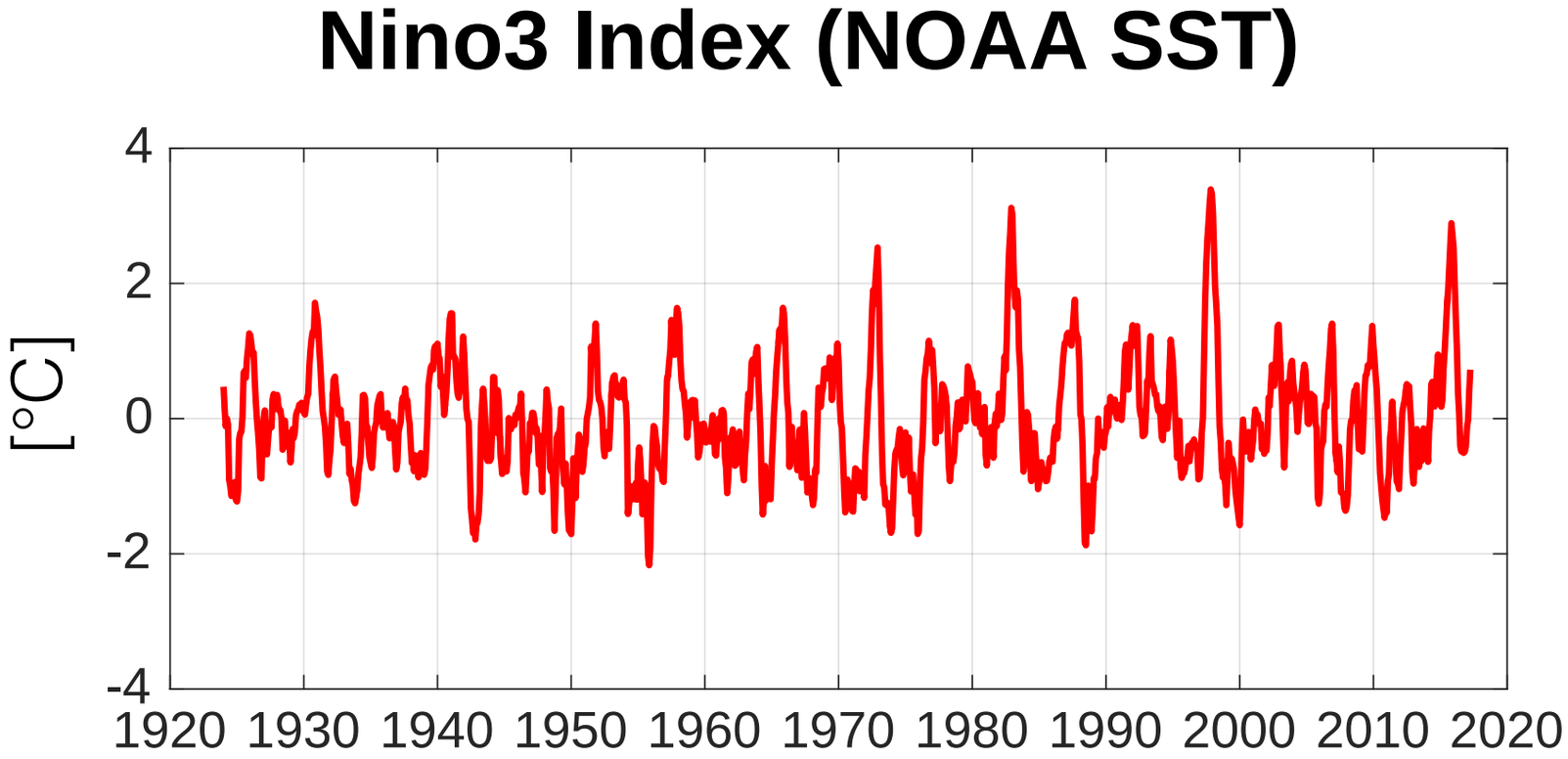
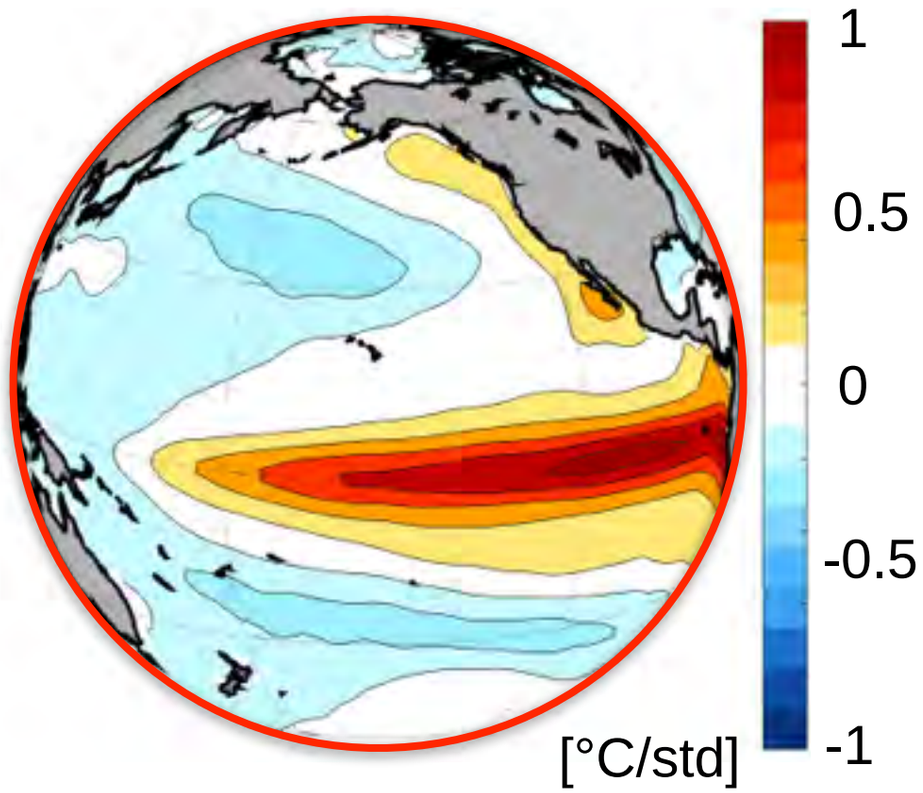




ENSO

Nino3 regressed on NOAA SST



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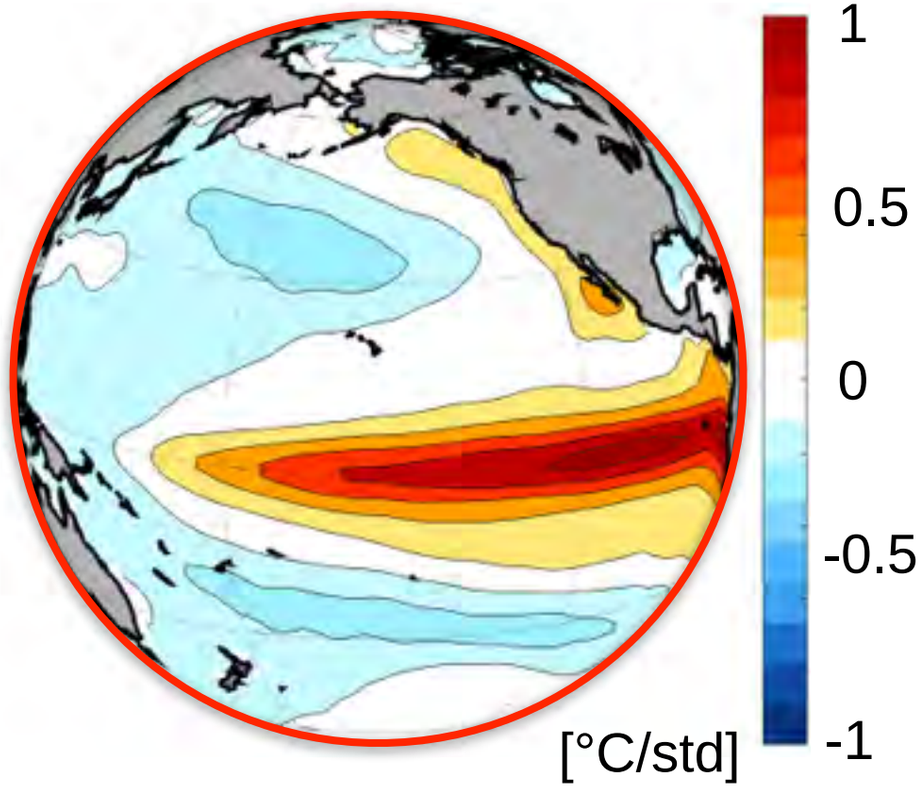

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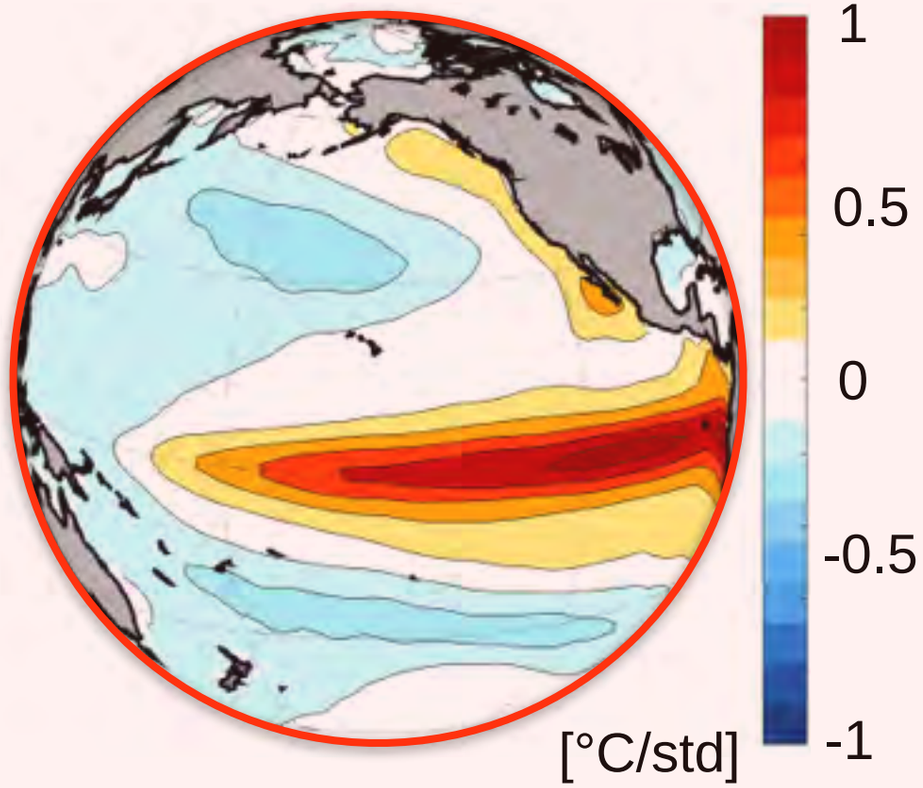

TROPICS

EXTRA-TROPICS

ENSO

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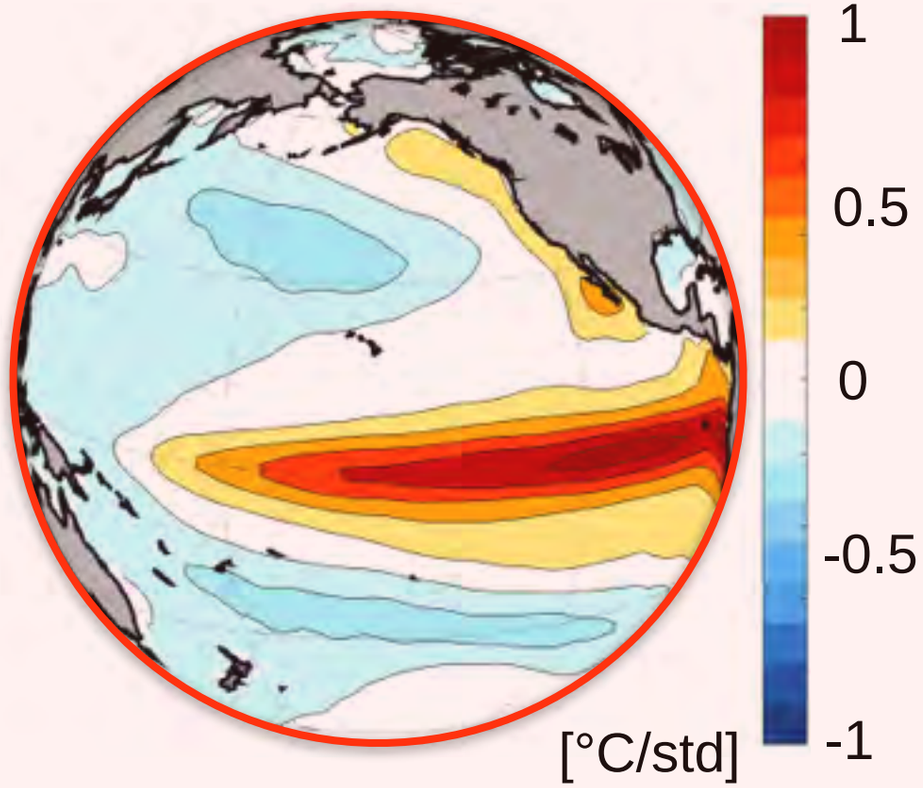

TROPICS

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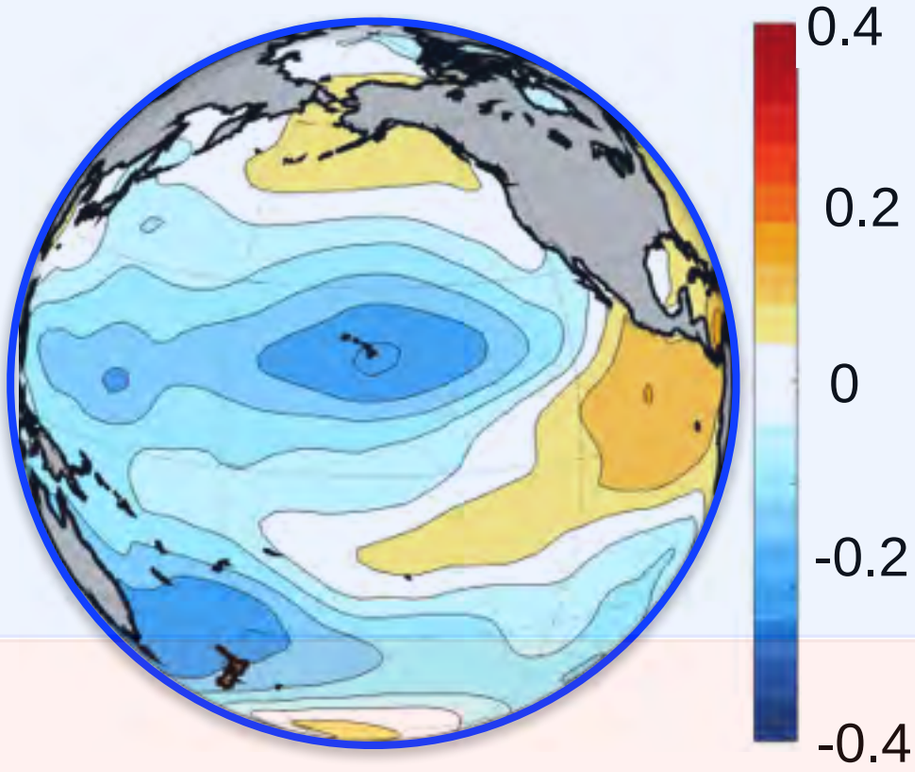
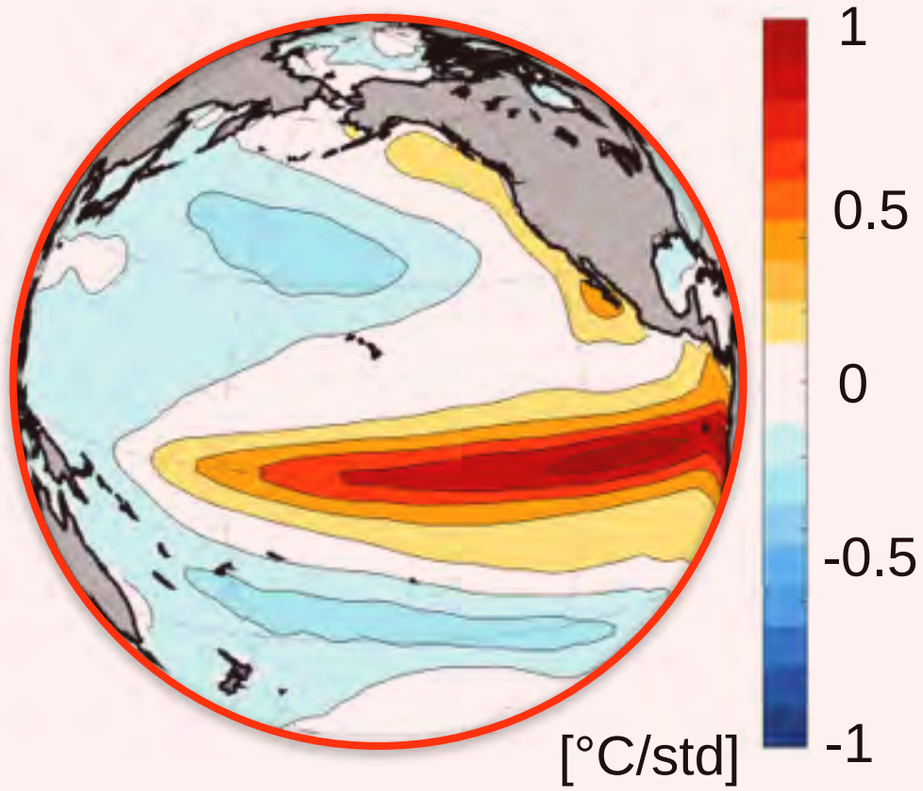


SLP PRECURSOR (1year prior)

Nino3 correlation with NCEP SLP(-1)

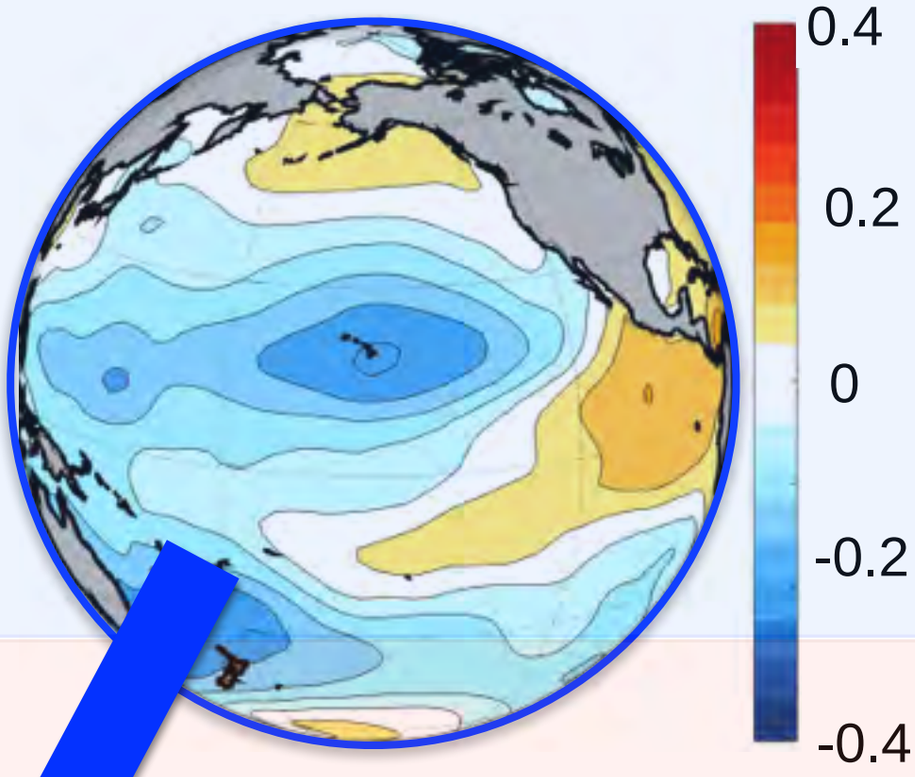
ENSO

Nino3 regressed on NOAA SST



TROPICS

EXTRA-TROPICS



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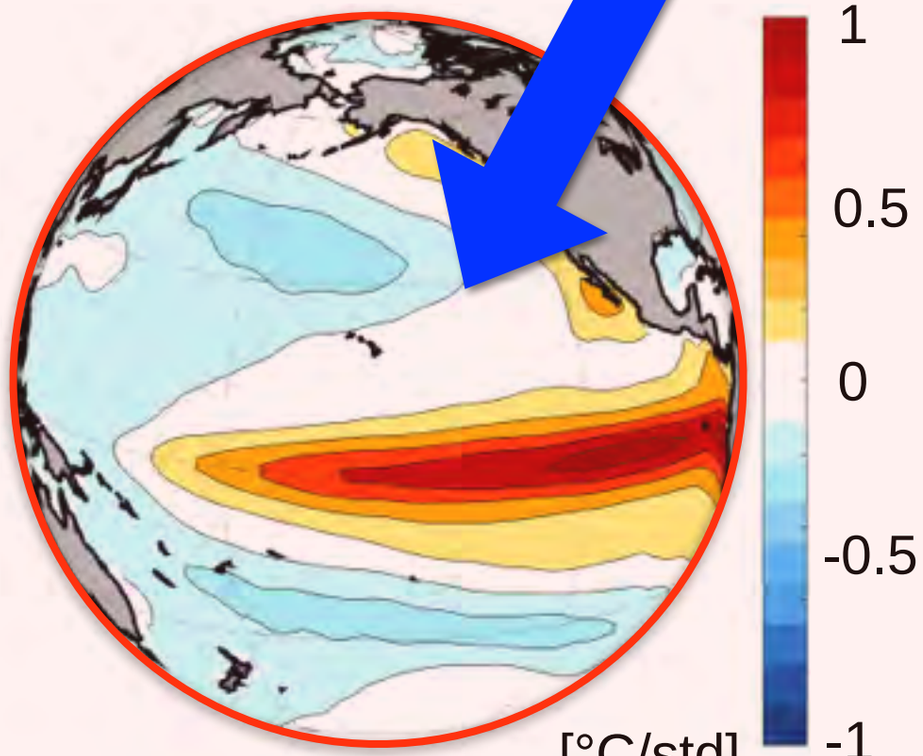
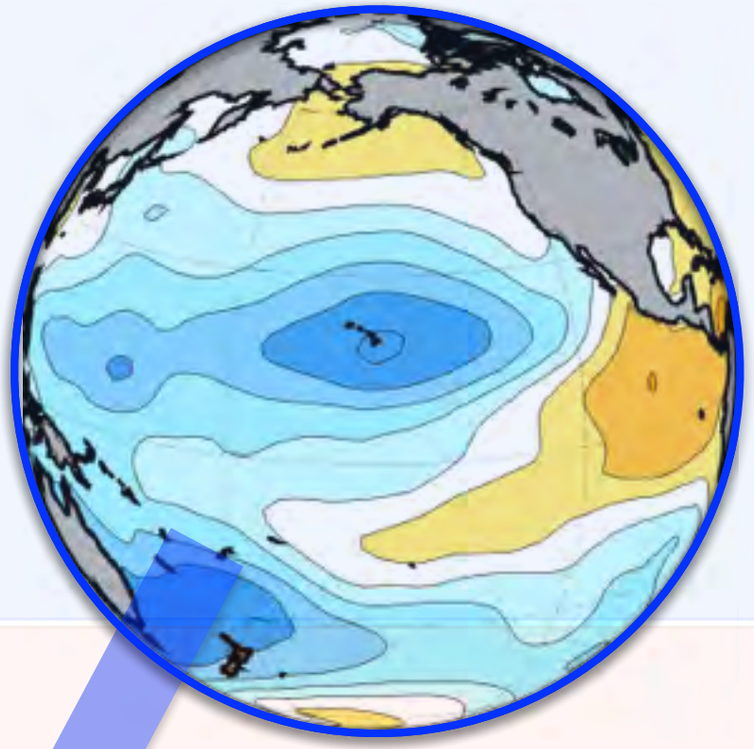


TROPICS

EXTRA-TROPICS

North Pacific Oscillation



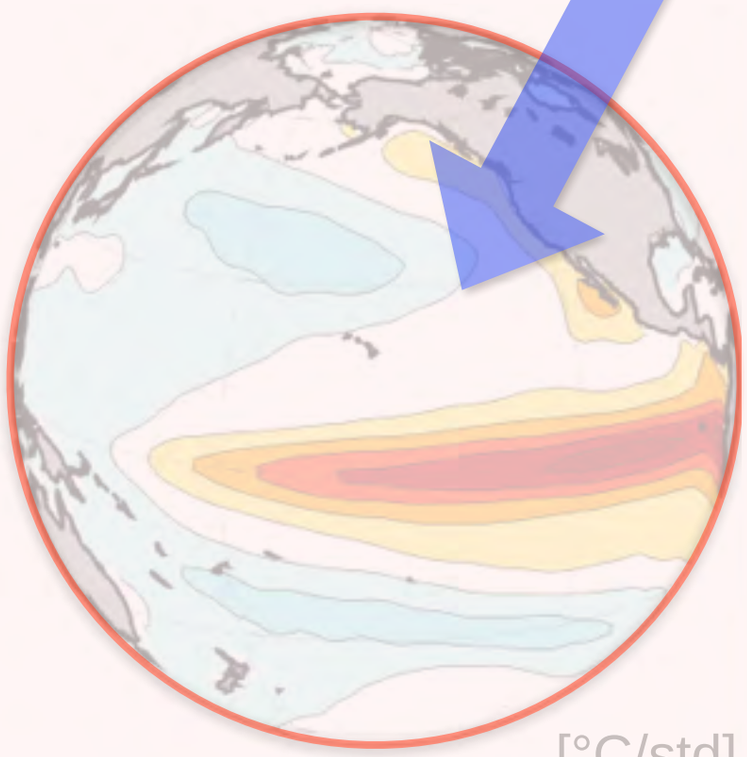
0.4
0.2
0
-0.2
-0.4

SLP PRECURSOR (1year prior)

Nino3 correlation with NCEP SLP(-1)

ENSO

Nino3 regressed on NOAA SST



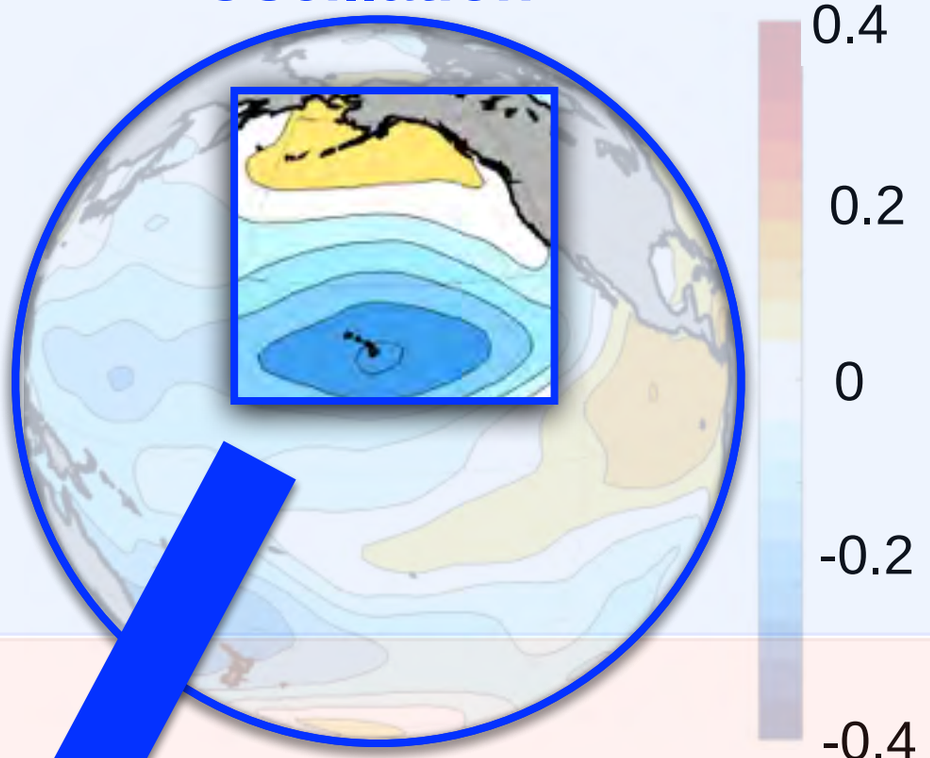
1
0.5
0
-0.5
-1

[°C/std]

TROPICS

EXTRA-TROPICS

North Pacific Oscillation



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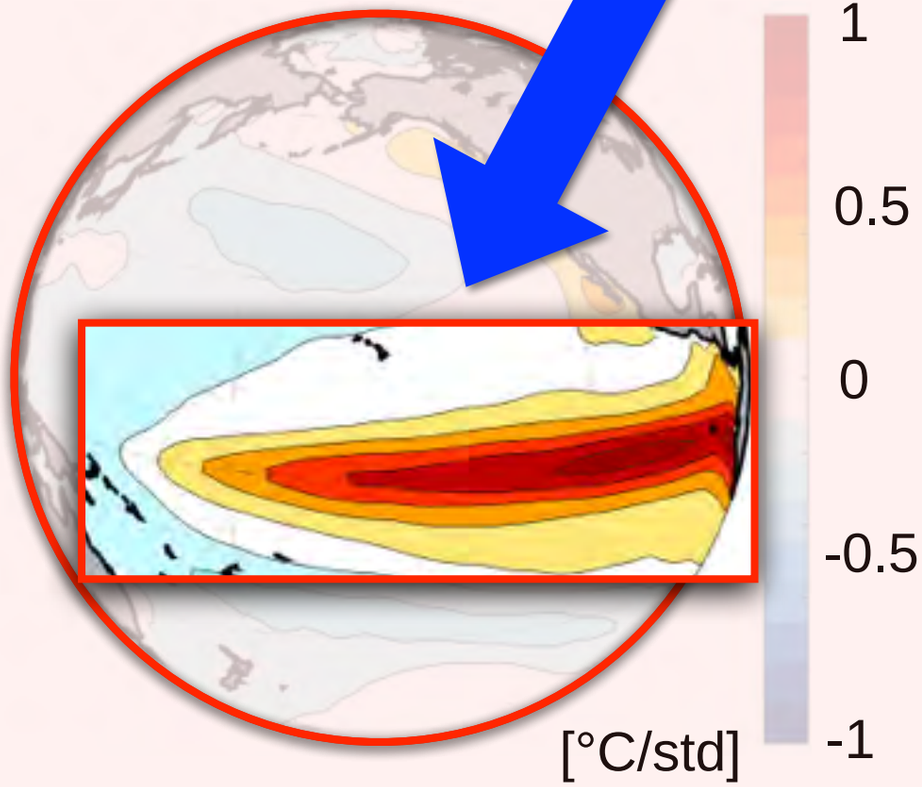
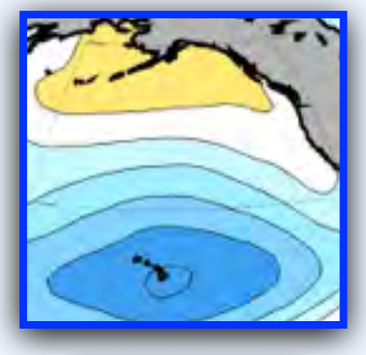


TROPICS

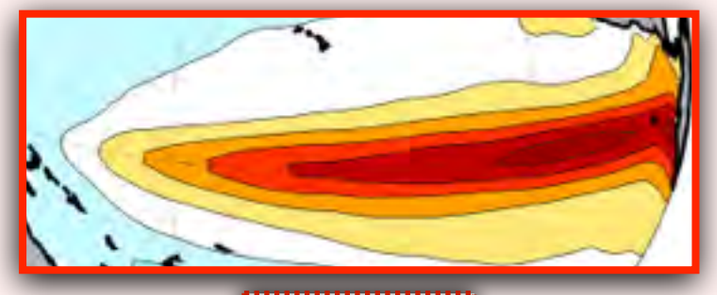
EXTRA-TROPICS

North Pacific Oscillation

ATMOSPHERE



Winter



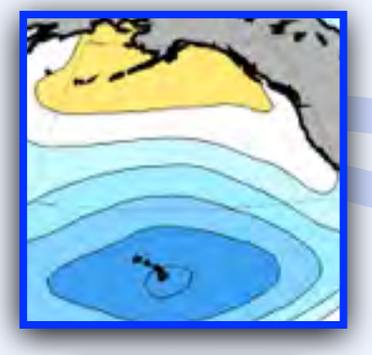
Fall

TROPICS

EXTRA-TROPICS

North Pacific Oscillation

ATMOSPHERE



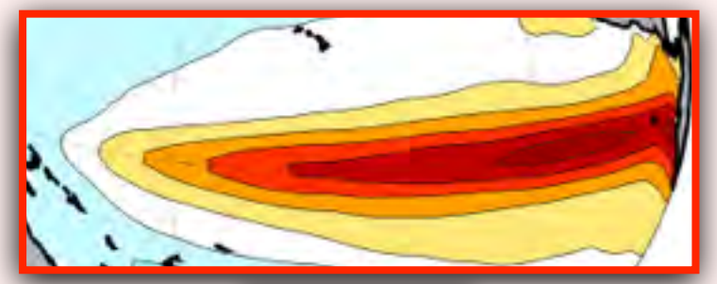
Winter

North Pacific Gyre Oscillation

OCEAN

Meridional Modes

Spring



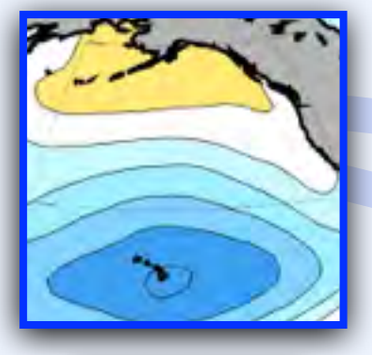
Fall

TROPICS

EXTRA-TROPICS

North Pacific Oscillation

ATMOSPHERE



Winter

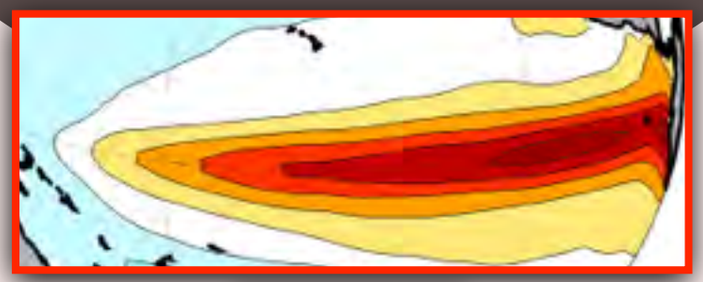
North Pacific Gyre Oscillation

OCEAN

Meridional Modes

Spring

ENSO



Fall

TROPICS

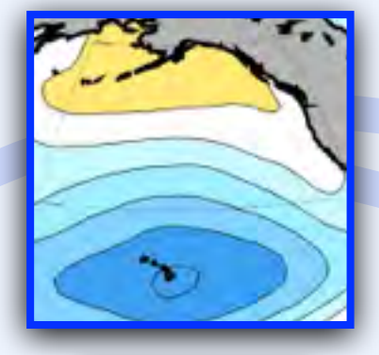
EXTRA-TROPICS

Aleutian Low
ATMOSPHERE

Winter

Pacific Decadal Oscillation
OCEAN

North Pacific Oscillation
ATMOSPHERE

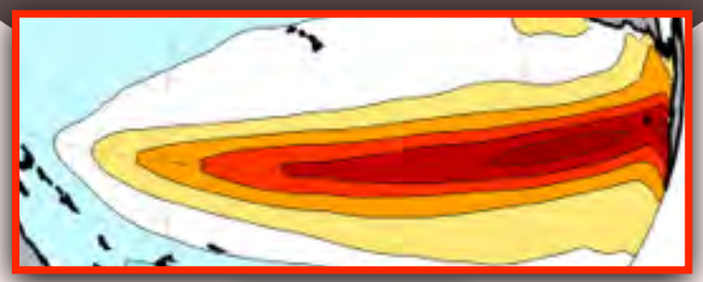


Winter

North Pacific Gyre Oscillation
OCEAN

Extra-tropical Teleconnection

ENSO



Fall

Meridional Modes

Spring

TROPICS

A Null Hypothesis for Pacific Decadal Variability

Red-noise model(AR-1) of PDV

- **Forcing:** Stochastic variability of the NPO
- **Memory:** Evolution of the ocean-atmosphere coupled system from extratropics to tropics and back to extratropics (1–2 years)

[Di Lorenzo, Liguori et al., 2015. GRL]

EXTRA-TROPICS

Aleutian Low

ATMOSPHERE

Winter

Pacific Decadal Oscillation

OCEAN

North Pacific Oscillation

ATMOSPHERE

Winter

North Pacific Gyre Oscillation

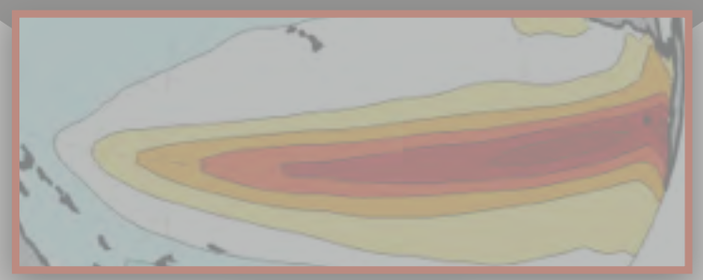
OCEAN

Meridional Modes

Spring

Extra-tropical Teleconnection

ENSO



Fall

TROPICS

Question

Is the Pacific Decadal Variability (**PDV**) increasing under greenhouse forcing?

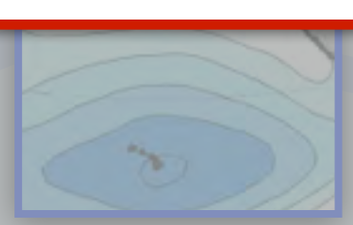
Ex

ATMOSPHERE

Winter

Pacific
Decadal Oscillation

OCEAN



Winter

North Pacific
Gyre Oscillation

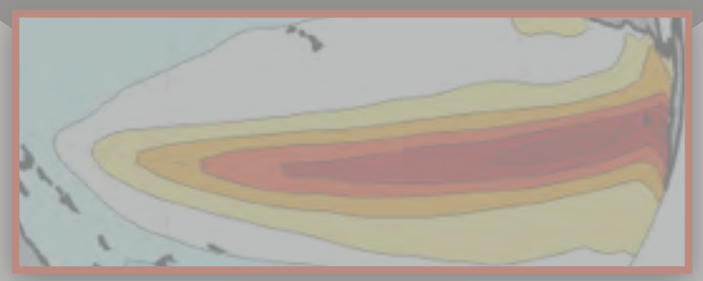
OCEAN

Extra-tropical
Teleconnection

Meridional
Modes

Spring

ENSO



Fall

TROPICS

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Is the Pacific Decadal Variability (**PDV**) increasing under greenhouse forcing?

Approach

Examine 30-member Community Earth System Model Large Ensemble (**CESM-LE**) from **1920-2100** (RCP8.5 scenario)

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Methodology

Find an **index** that **captures the PDV mechanisms** of the conceptual framework

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An index that capture the **PDV** mechanisms

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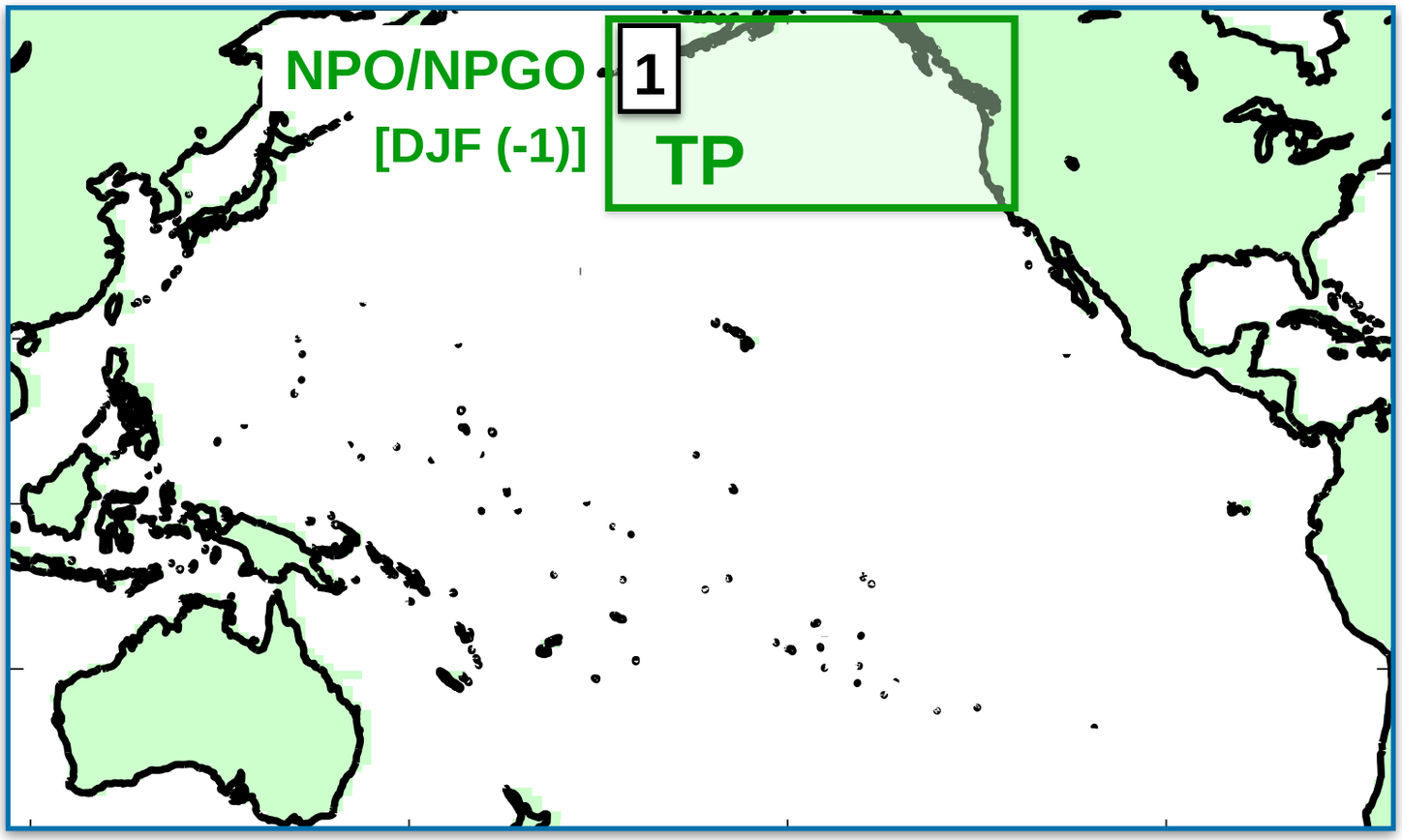
EXTRA-TROPICS

TROPICS

EOF ( )

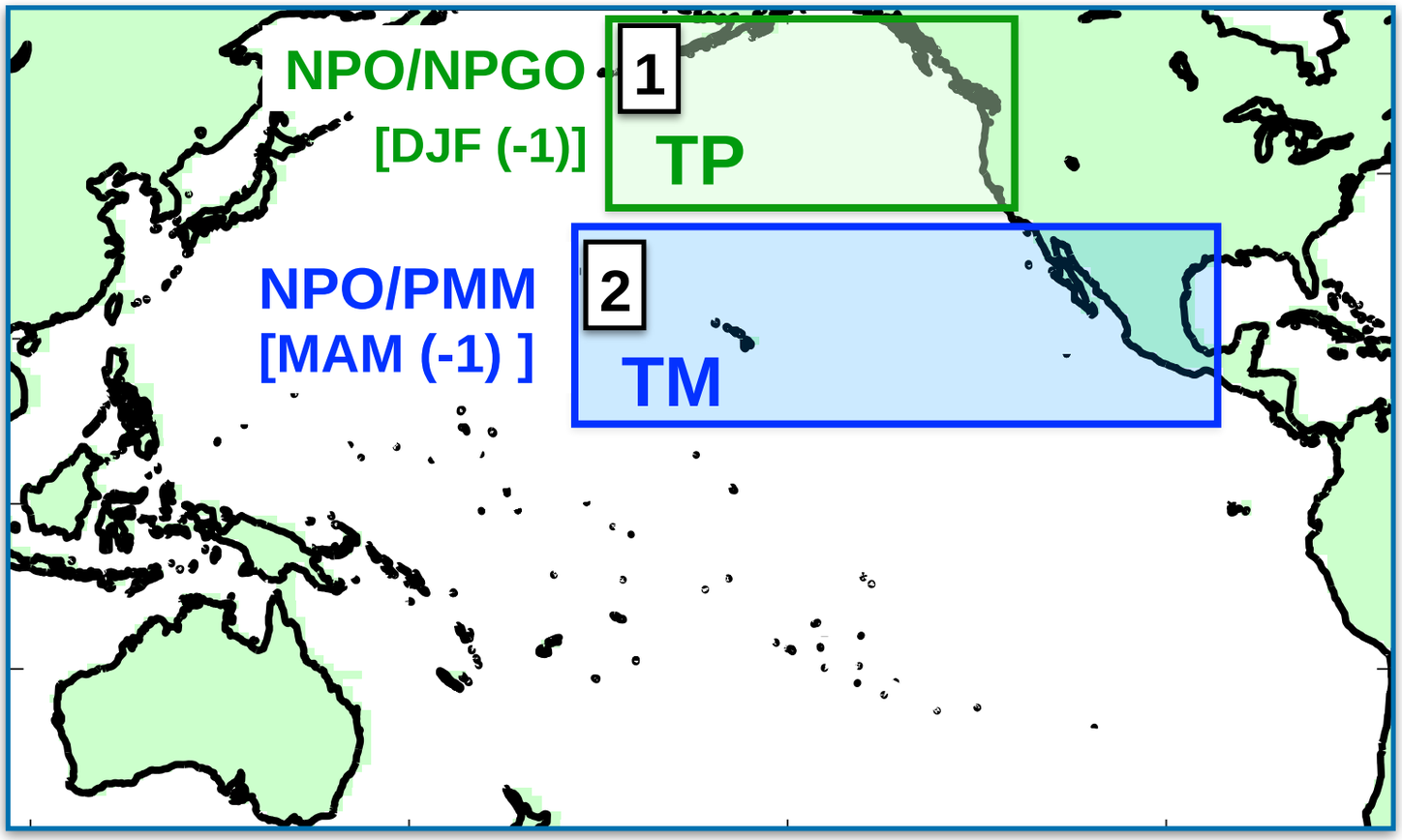
An index that capture the **PDV** mechanisms

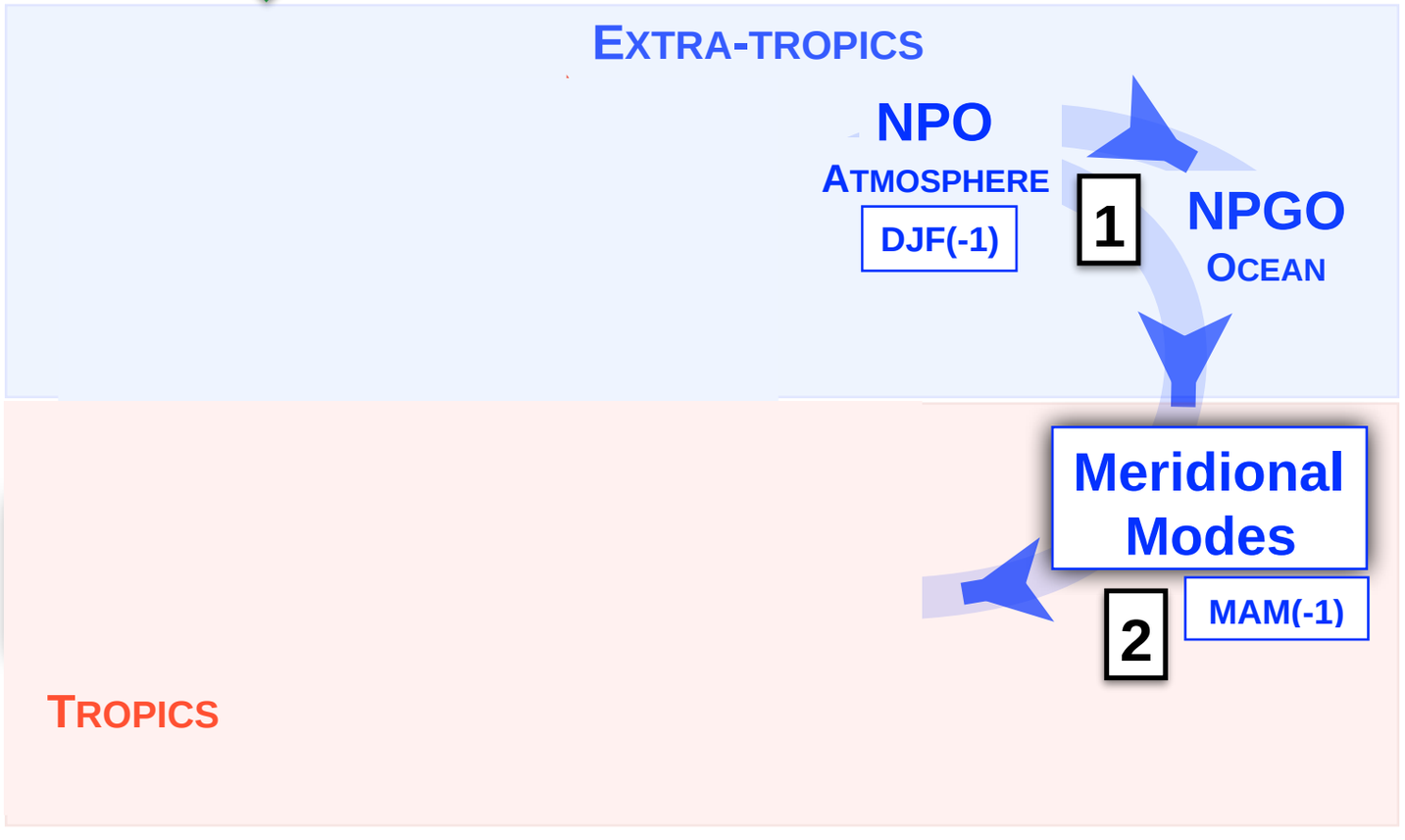


$$EOF\left(\text{SSTa-DJF}_{(-1)}\text{*- in NP}\right)$$

ENSO* signal removed via regression analysis

An index that capture the **PDV** mechanisms





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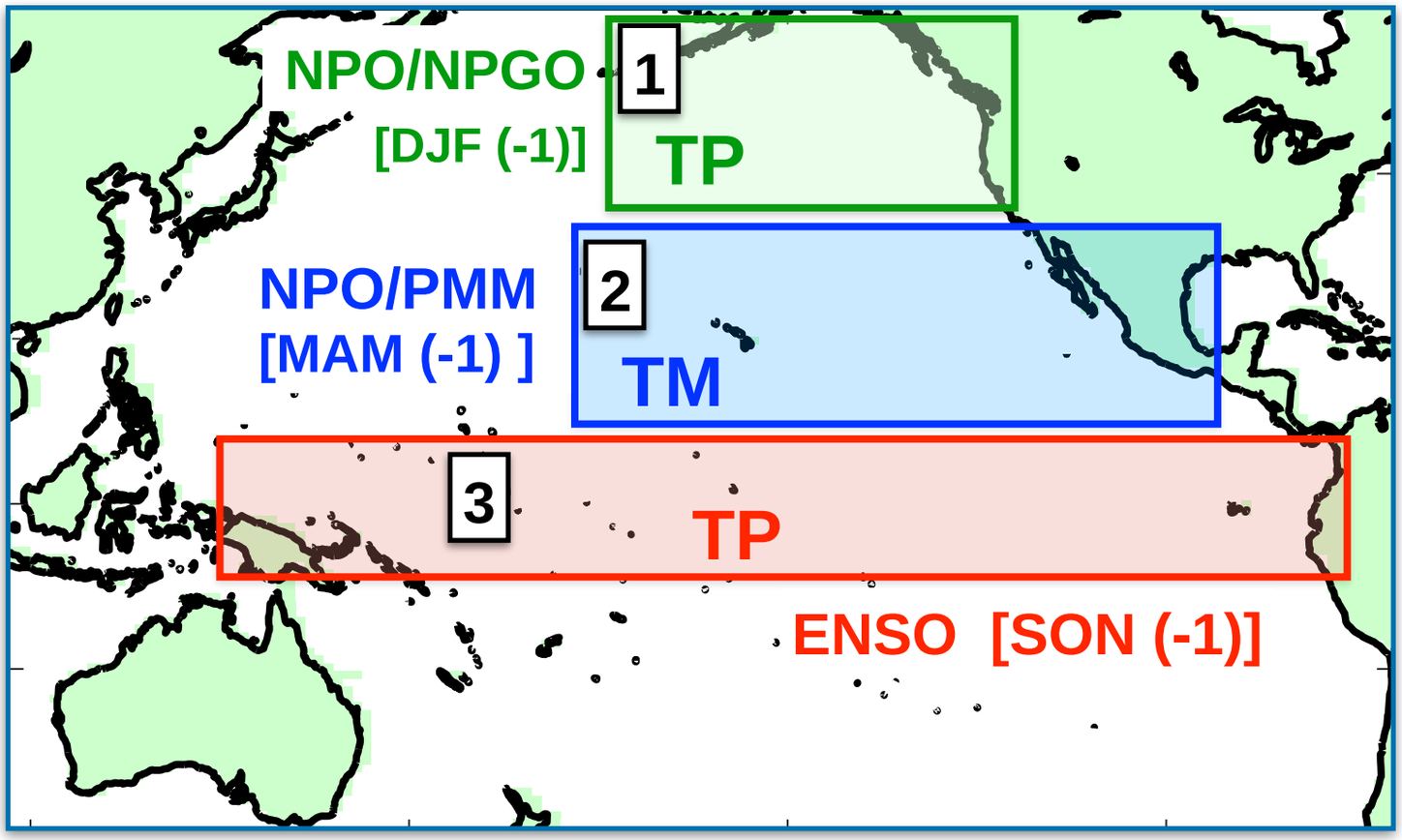

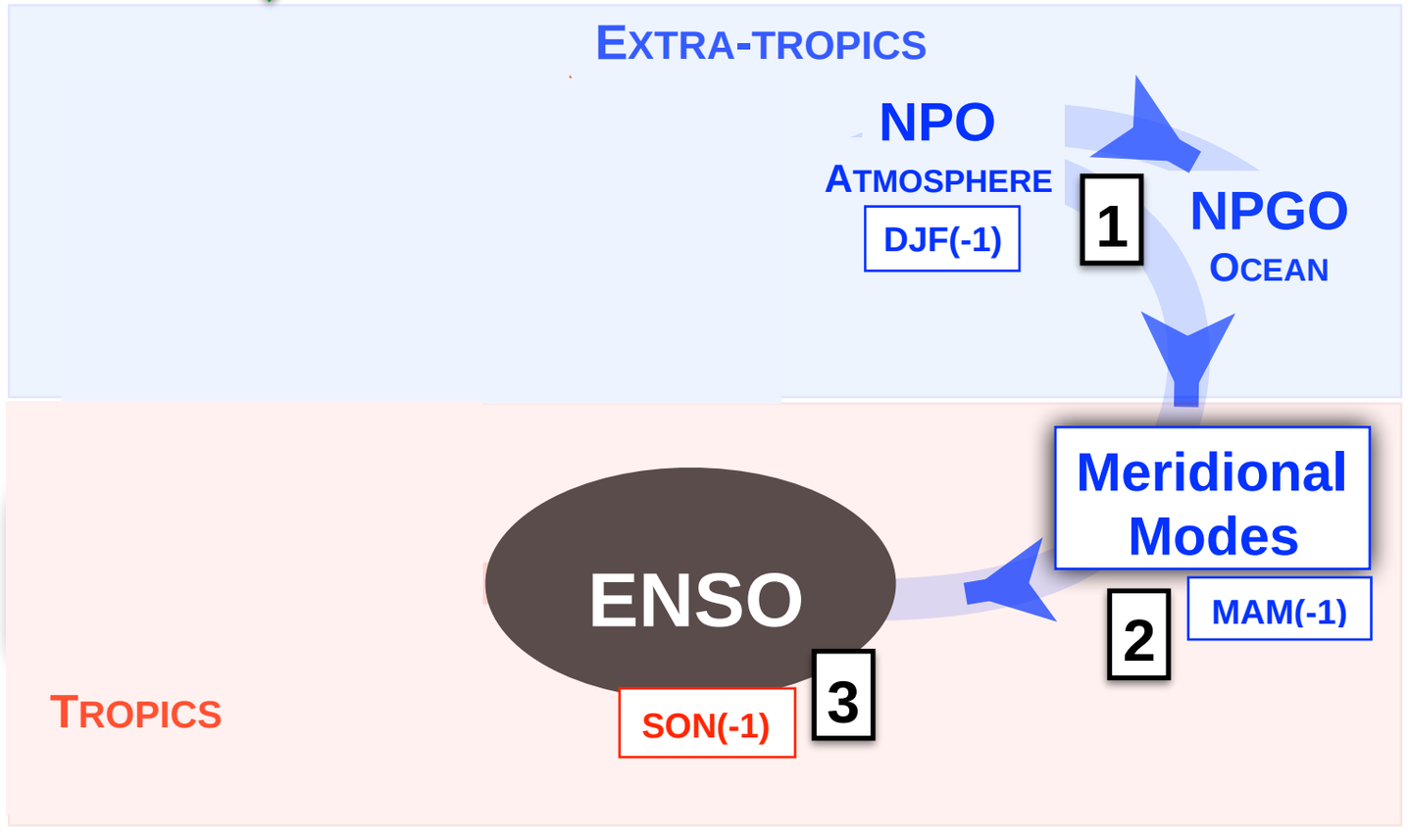

$$\mathbf{EOF}\left(\begin{array}{l}\textbf{SSTa-DJF}_{(-1)}\textbf{*-}\text{ in }\textbf{NP}\\ \textbf{SSTa-MAM}_{(-1)}\textbf{*}\text{ in }\textbf{TM}\\ \textbf{SSTa-SON}_{(-1)}\text{ in }\textbf{TP}\end{array}\right)$$

ENSO* signal removed via regression analysis

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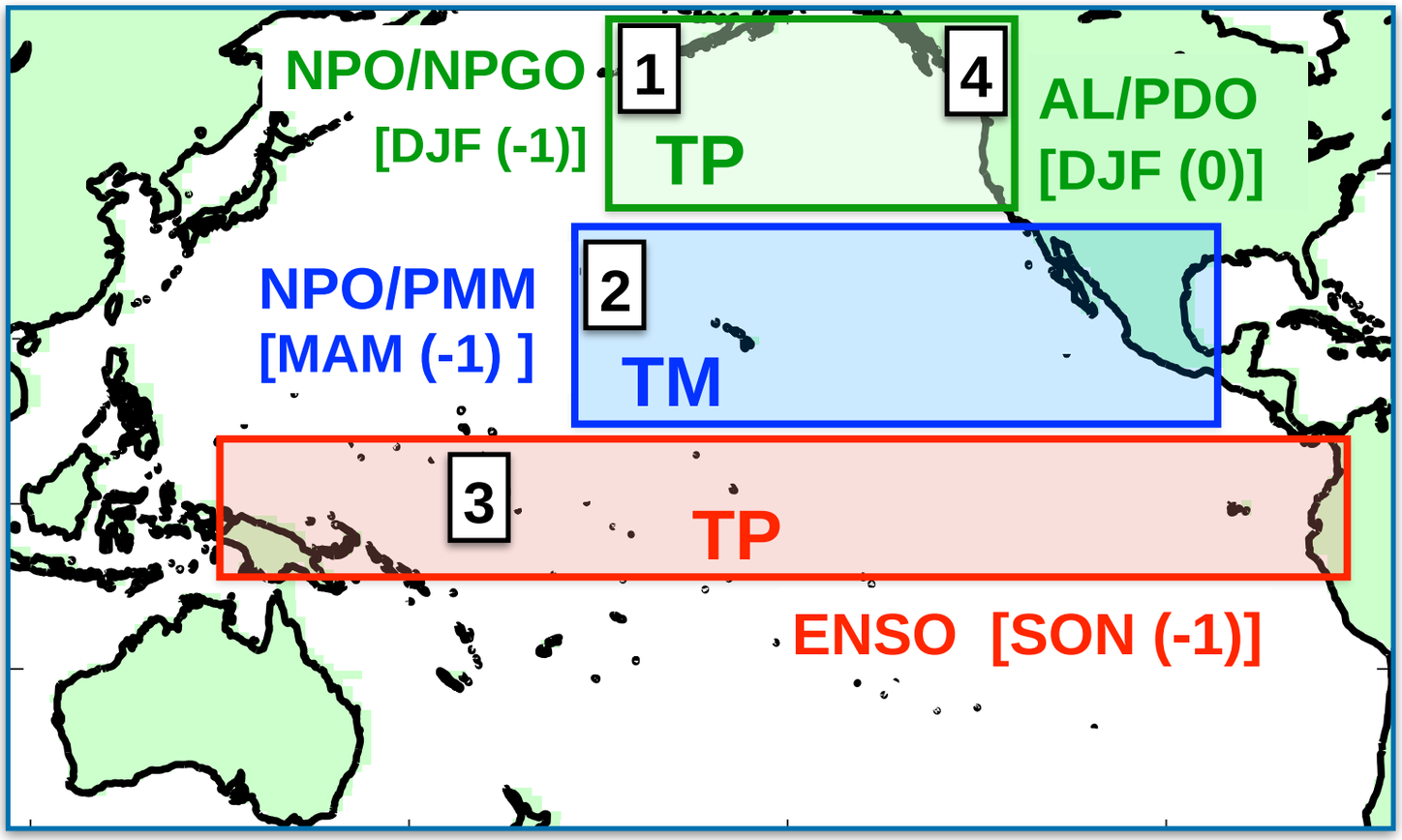

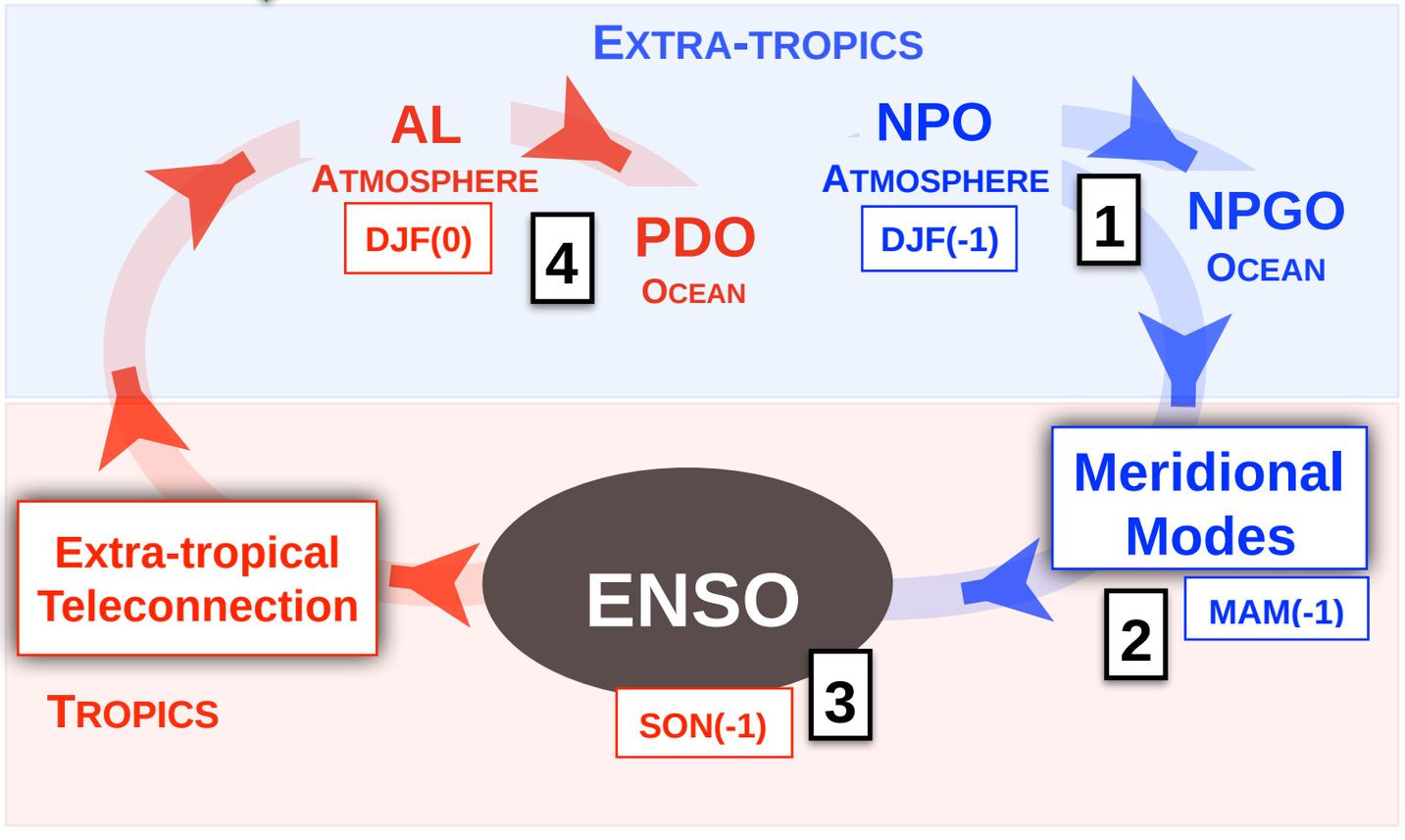

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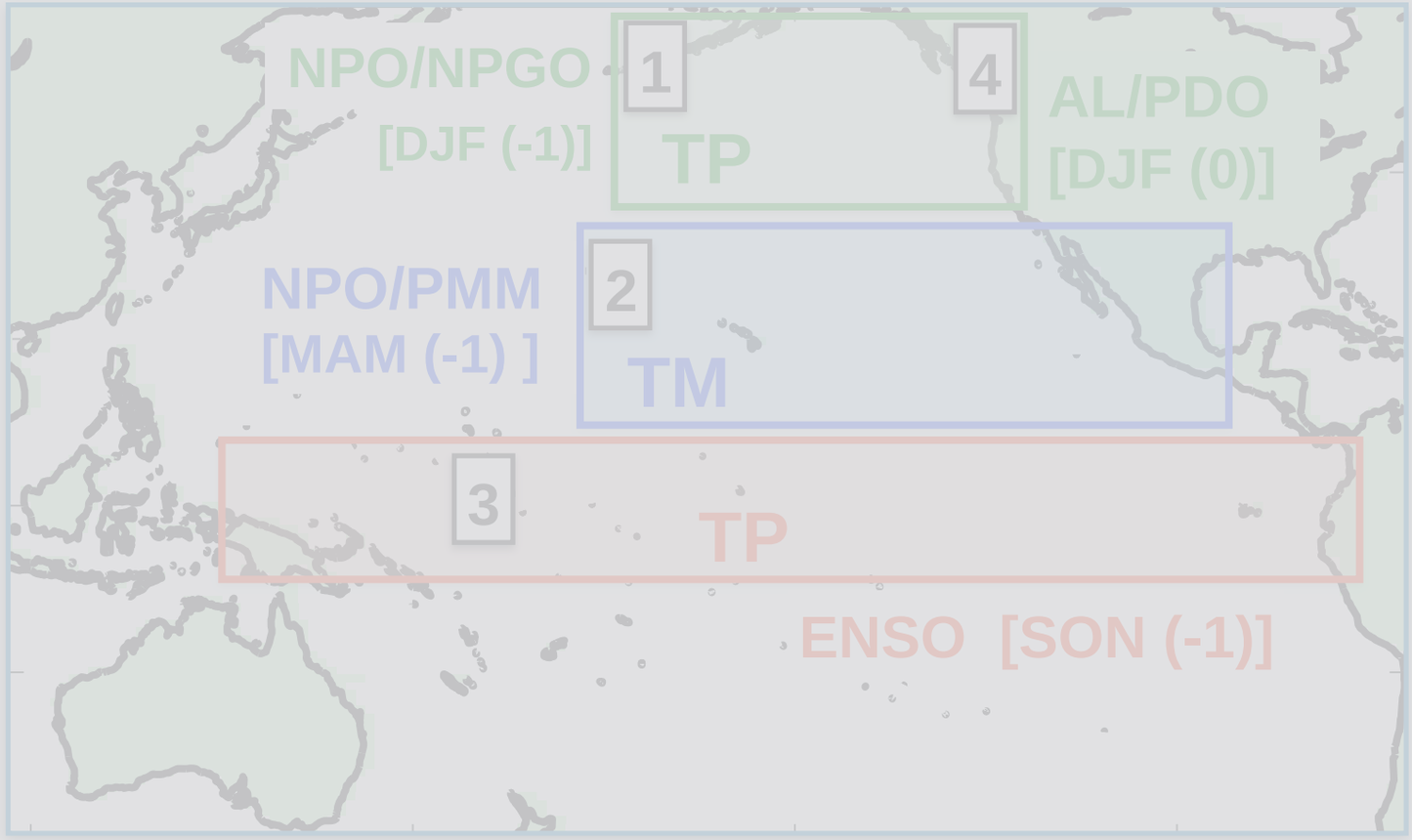
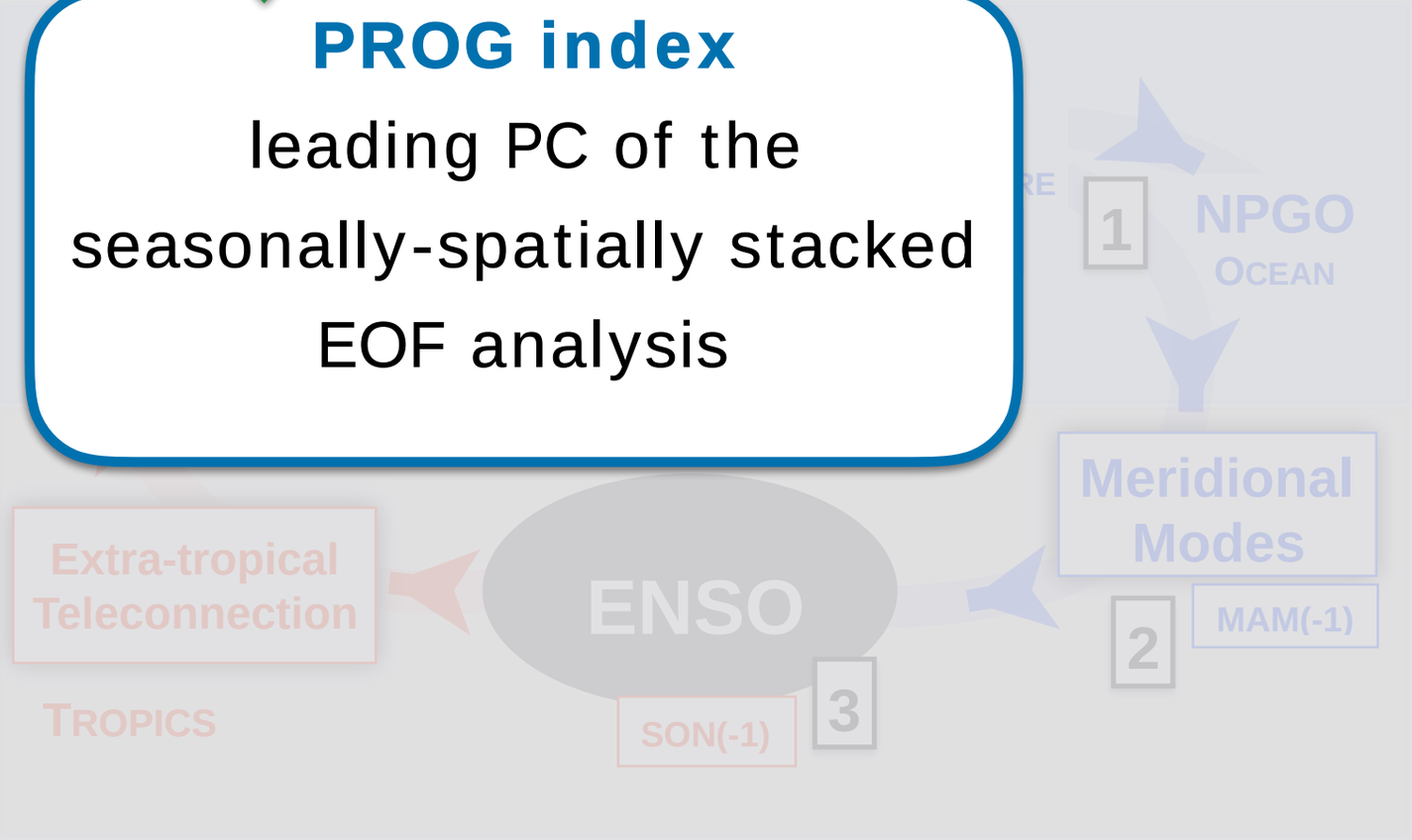
ENSO* signal removed via regression analysis

An index that capture the **PDV** mechanisms



PROG index

leading PC of the seasonally-spatially stacked EOF analysis



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ENSO* signal removed via regression analysis

PROG index

regressed onto

SSTa/SLPa

1950-2014

PROG index

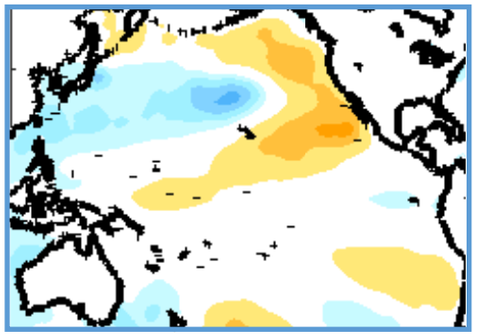
regressed onto

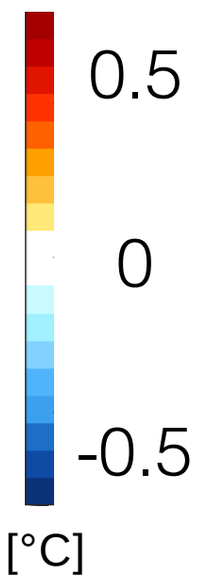
SSTa/SLPa

1950-2014

SST NOOA

DJF (-1)





PROG index

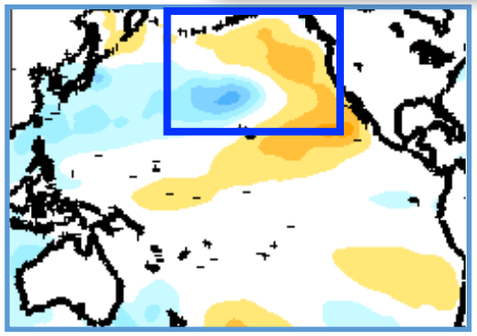
regressed onto

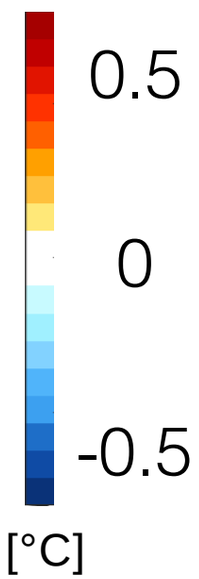
SSTa/SLPa

1950-2014

SST NOOA **NPGO-like**

DJF (-1)





PROG index

regressed onto

SSTa/SLPa

1950-2014

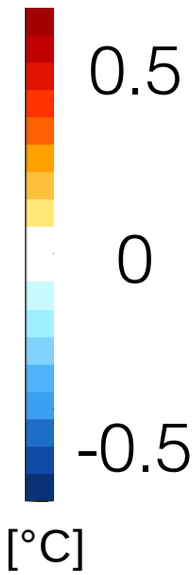
SST NOOA

NPGO-like

DJF (-1)

MAM (-1)

PMM



PROG index

regressed onto

SSTa/SLPa

1950-2014

SST NOOA

NPGO-like

DJF (-1)

MAM (-1)

PMM

JJA (-1)

SON (-1)

ENSO

0.5

0

-0.5

[°C]

PROG index

regressed onto

SSTa/SLPa

1950-2014

SST NOOA

NPGO-like

DJF (-1)

MAM (-1)

PMM

JJA (-1)

SON (-1)

ENSO

DJF (0)

PDO-like

0.5

0

-0.5

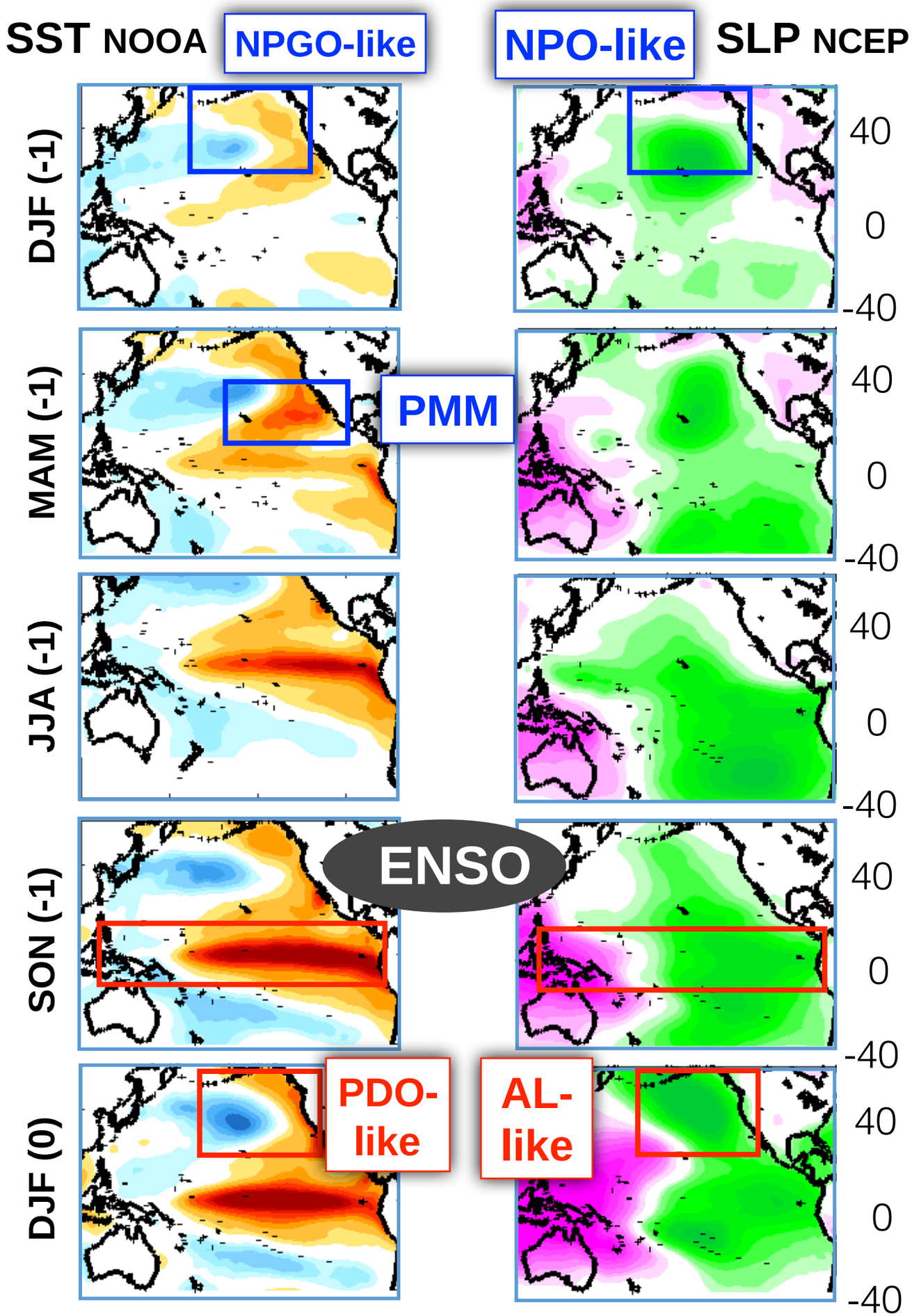
[°C]

PROG index

regressed onto

SSTa/SLPa

1950-2014



PROG index

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SSTa/SLPa

1950-2014

SST NOOA

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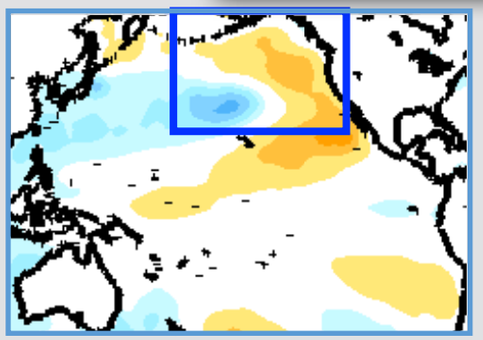
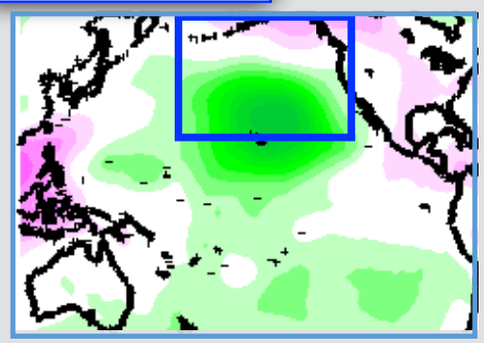
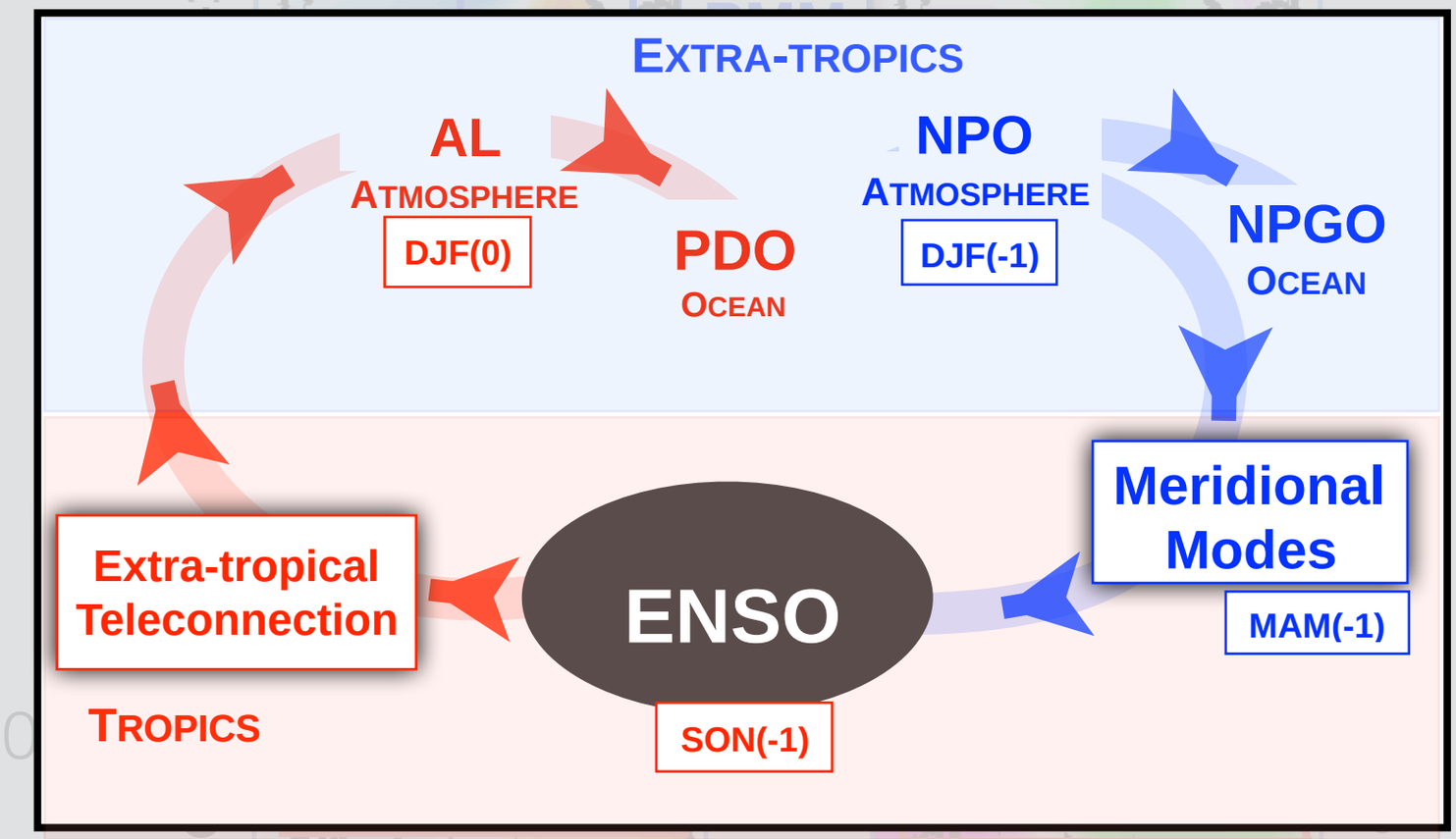
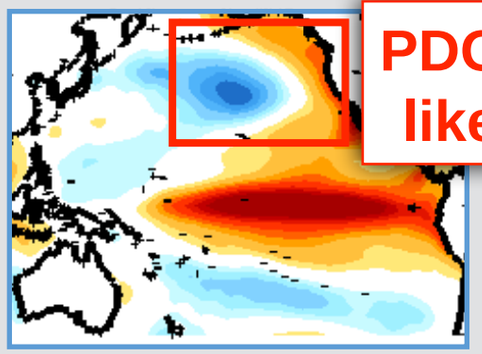


NPO-like

SLP NCEP

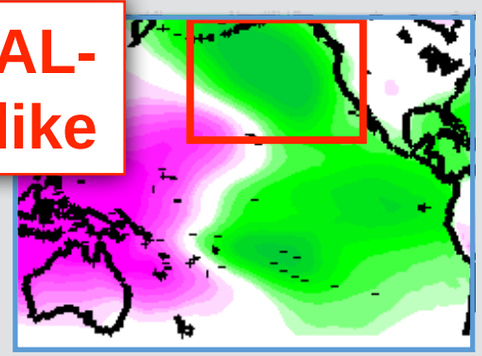






PDO-like

AL-like



DJF (-1)

DJF (0)

40

0

-40

0.5

0

-0.5

[°C]

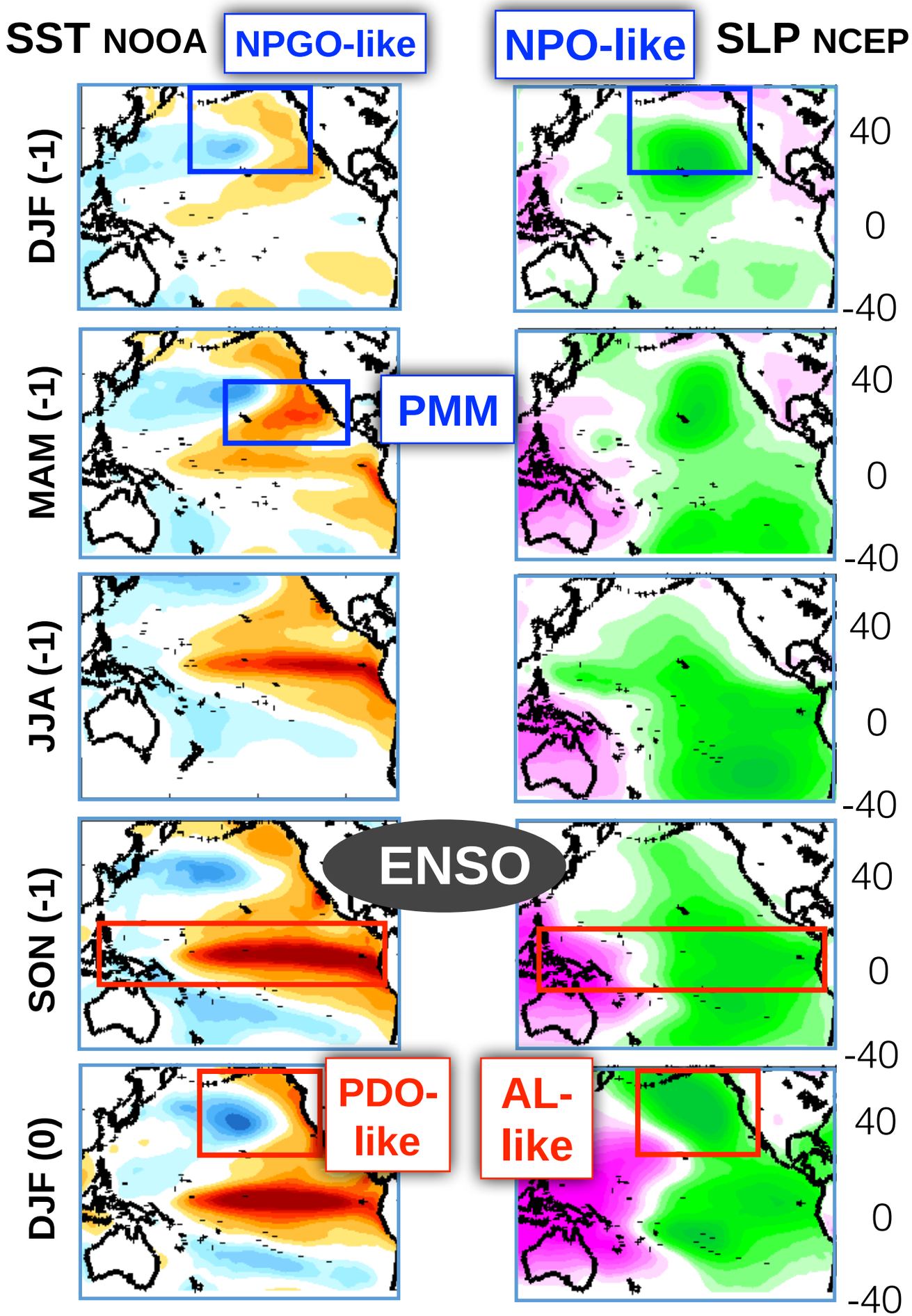
[Corr]

PROG index

regressed onto

SSTa/SLPa

1950-2014



PROG index

regressed onto

SSTa/SLPa

1950-2014

OBS

vs

CESM-LENS

SST NOOA

NPGO-like

DJF (-1)

MAM (-1)

JJA (-1)

SON (-1)

DJF (0)

PDO-like

0.5

0

-0.5

[°C]

PROG index

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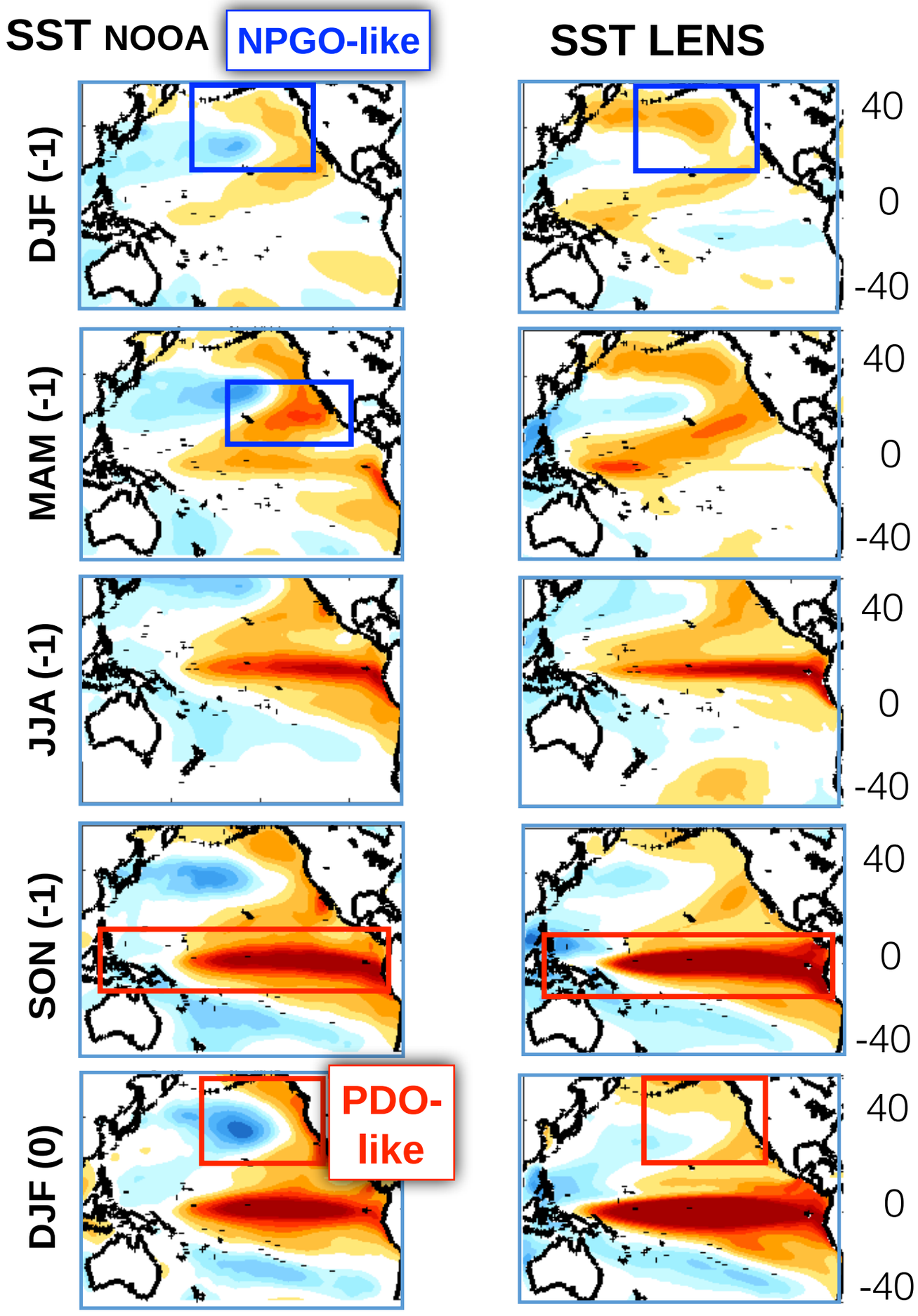

PROG index

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vs

CESM-LENS

SLP NCEP **NPGO-like** **SLP LENS**

DJF (-1)

MAM (-1)

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PDO-like

40

0

-40

0.5

0

-0.5

[Corr]

QUESTION

Is the **PROG index** capturing the PDV?

OBS vs CESM-LENS

SLP NCEP

NPGO-like

SLP LENS

MAM (-1)

JJA (-1)

SON (-1)

DJF (0)

PDO-like

40

0

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[Corr]

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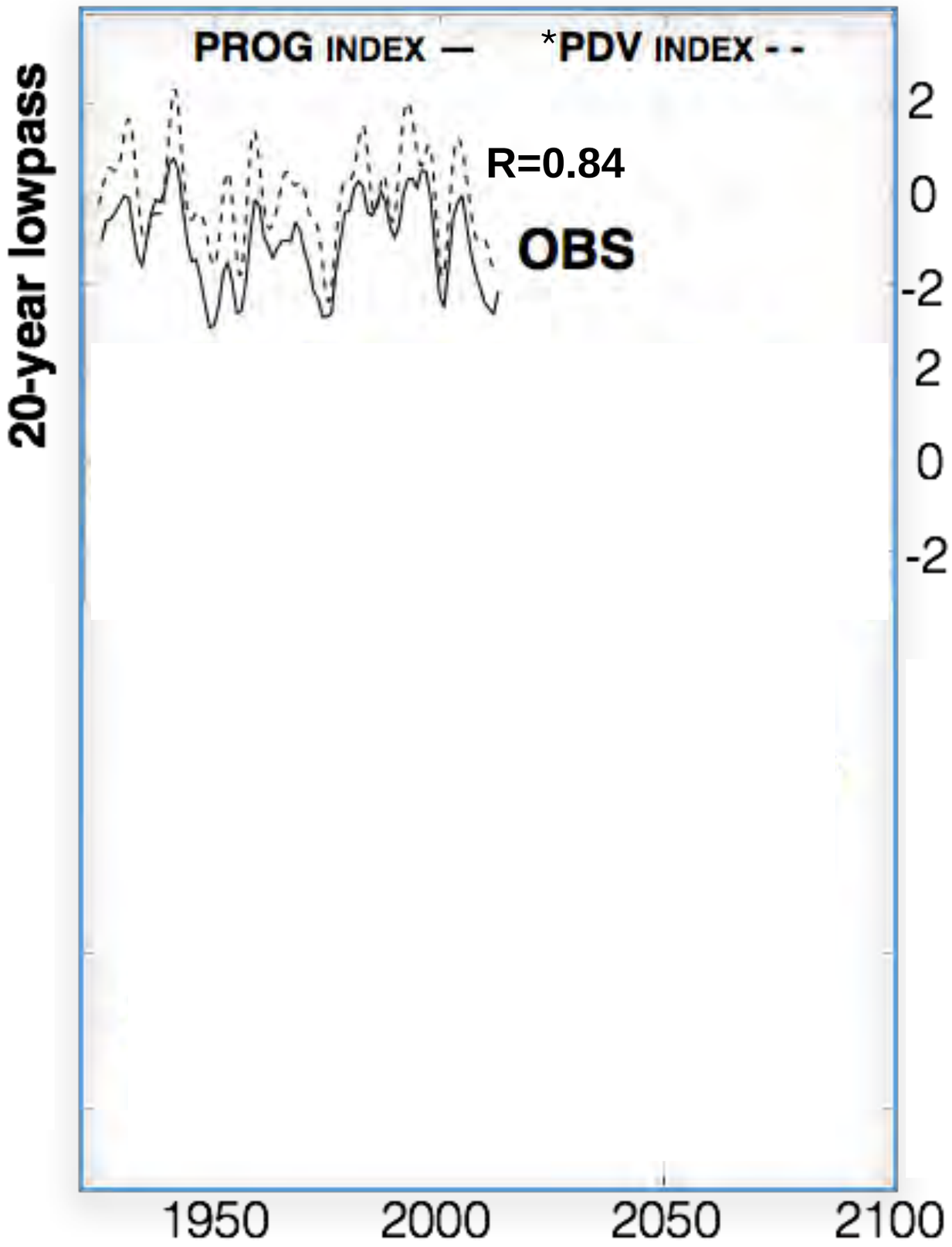

*[Zhang et al., 1997]

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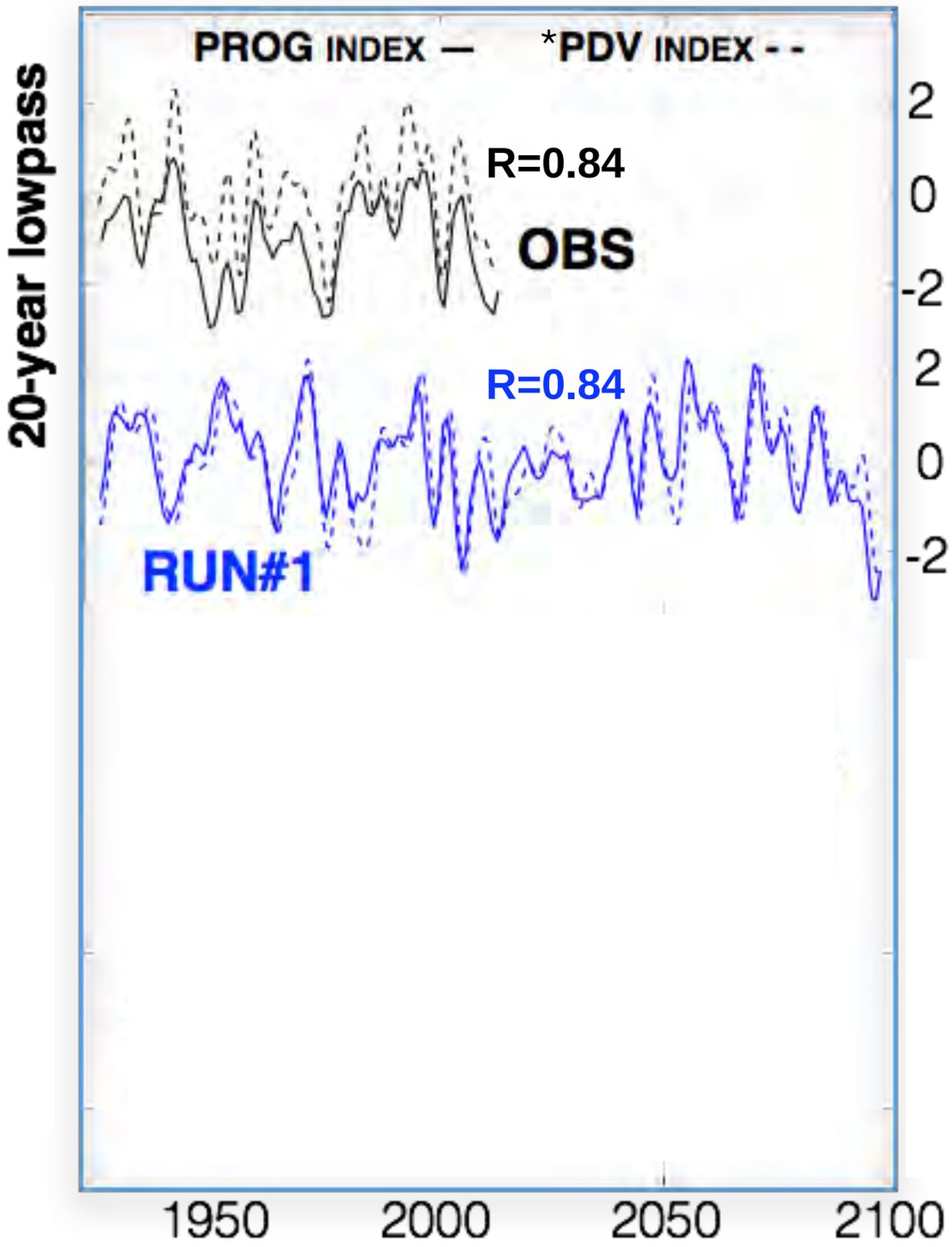

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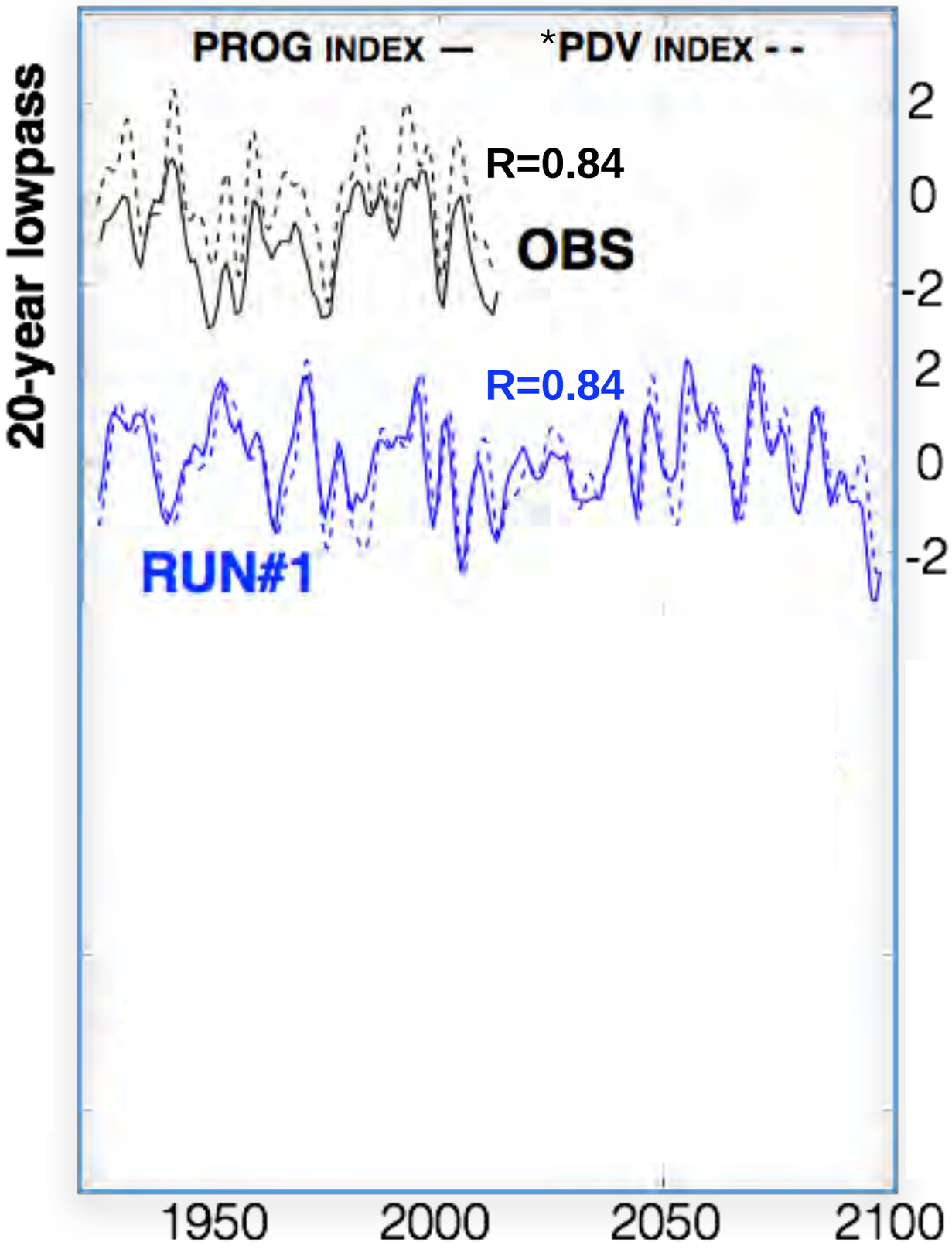


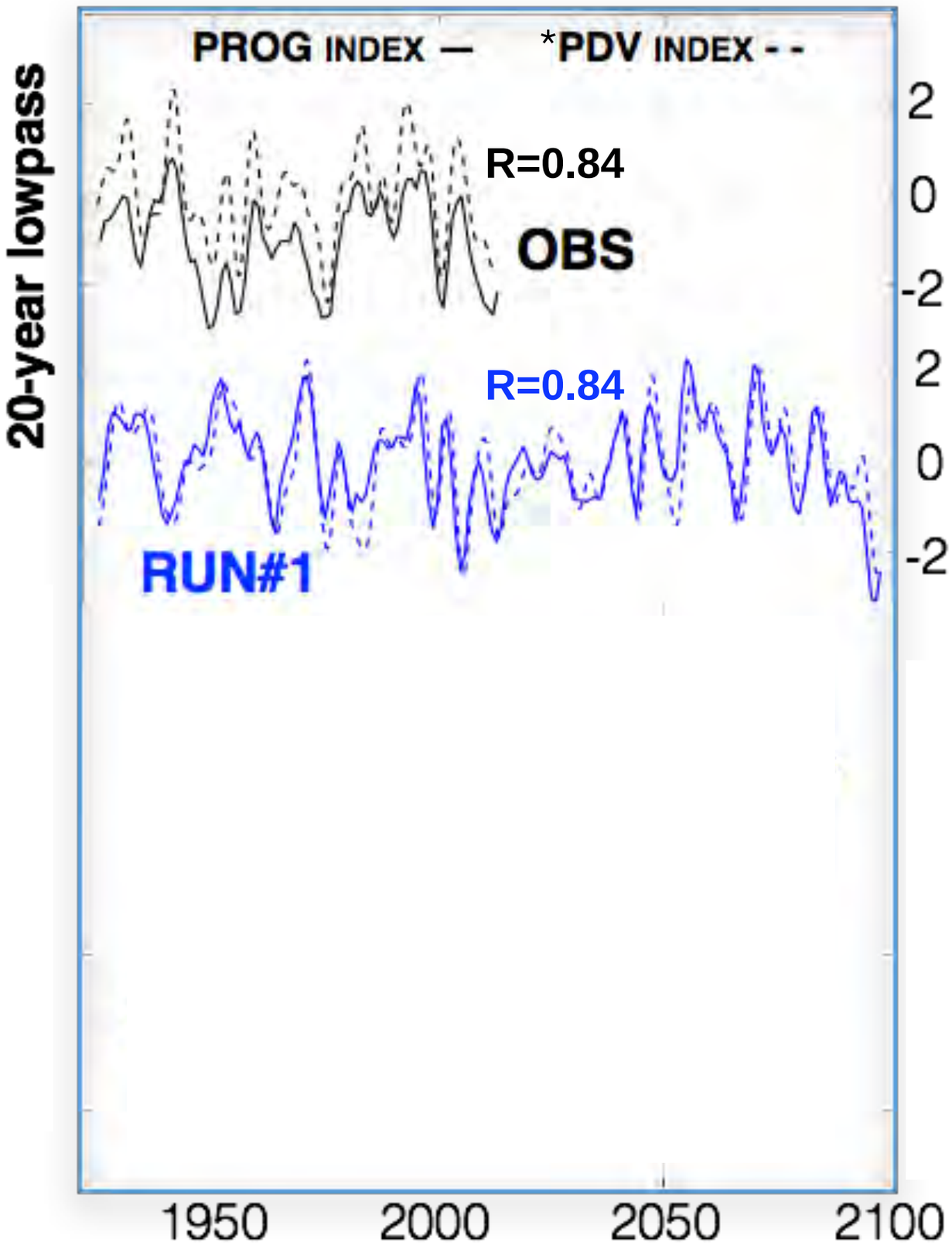
*[Zhang et al., 1997]

QUESTION

Is the **PROG index** capturing the PDV?

QUESTION

Is **PDV** increasing under greenhouse forcing?



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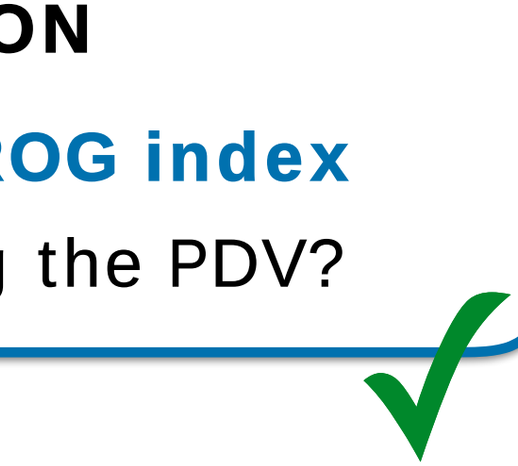

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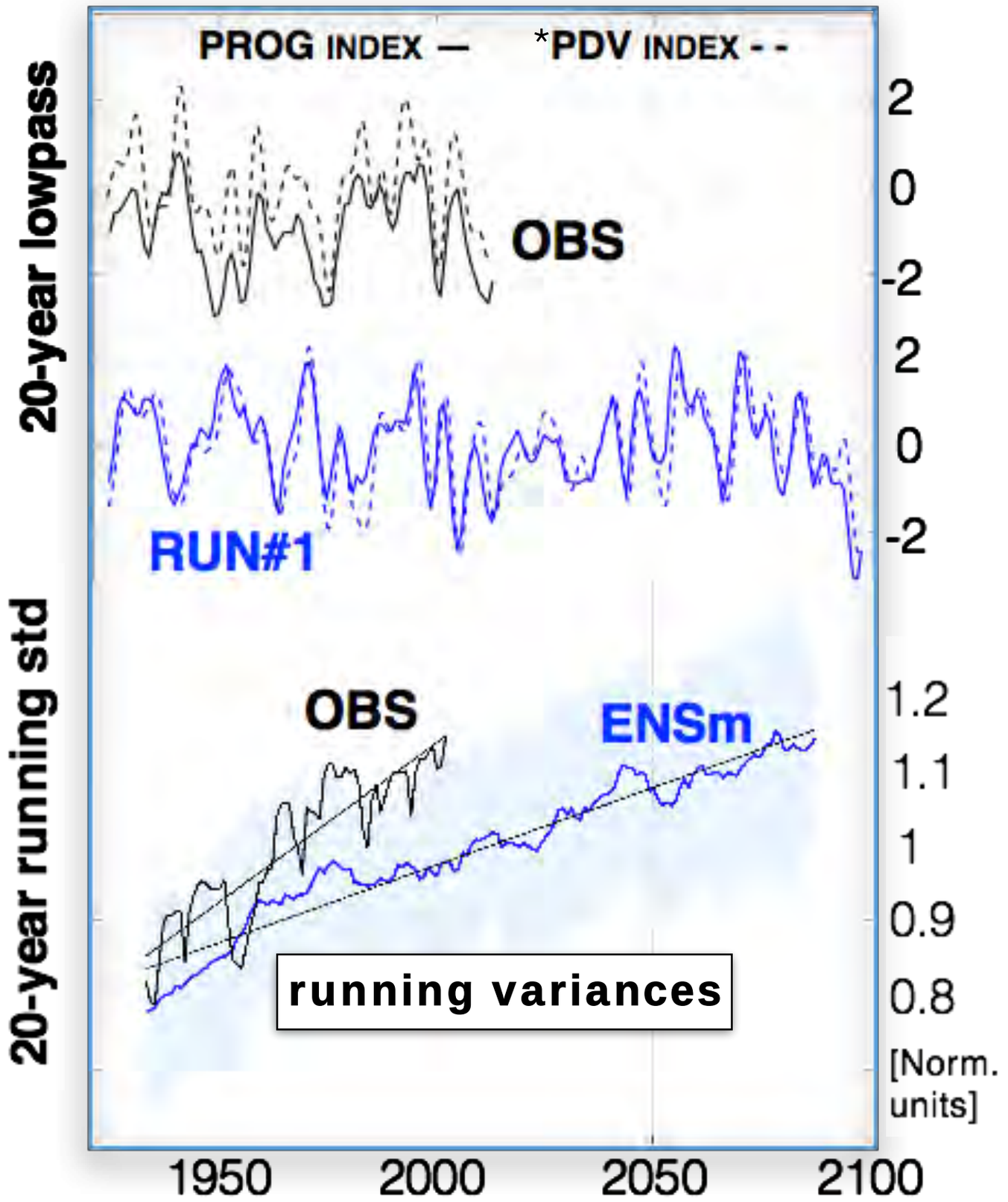

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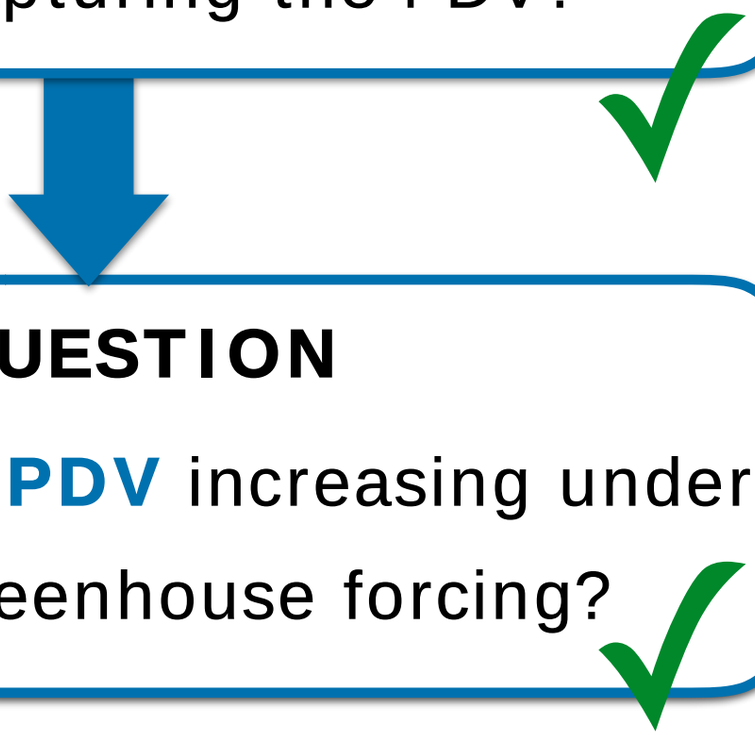

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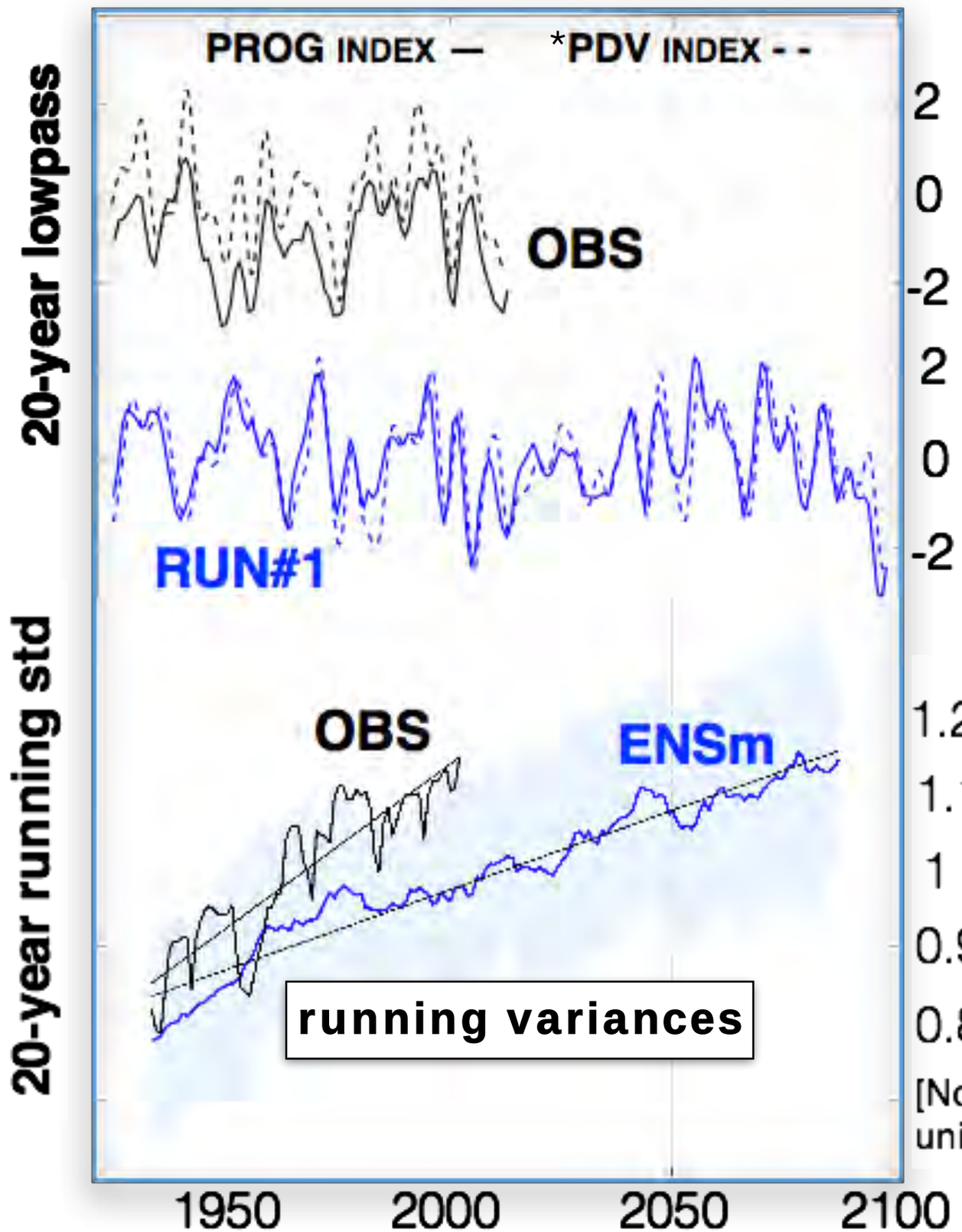

Same result for NOAA and Hadley SST

*[Zhang et al., 1997]

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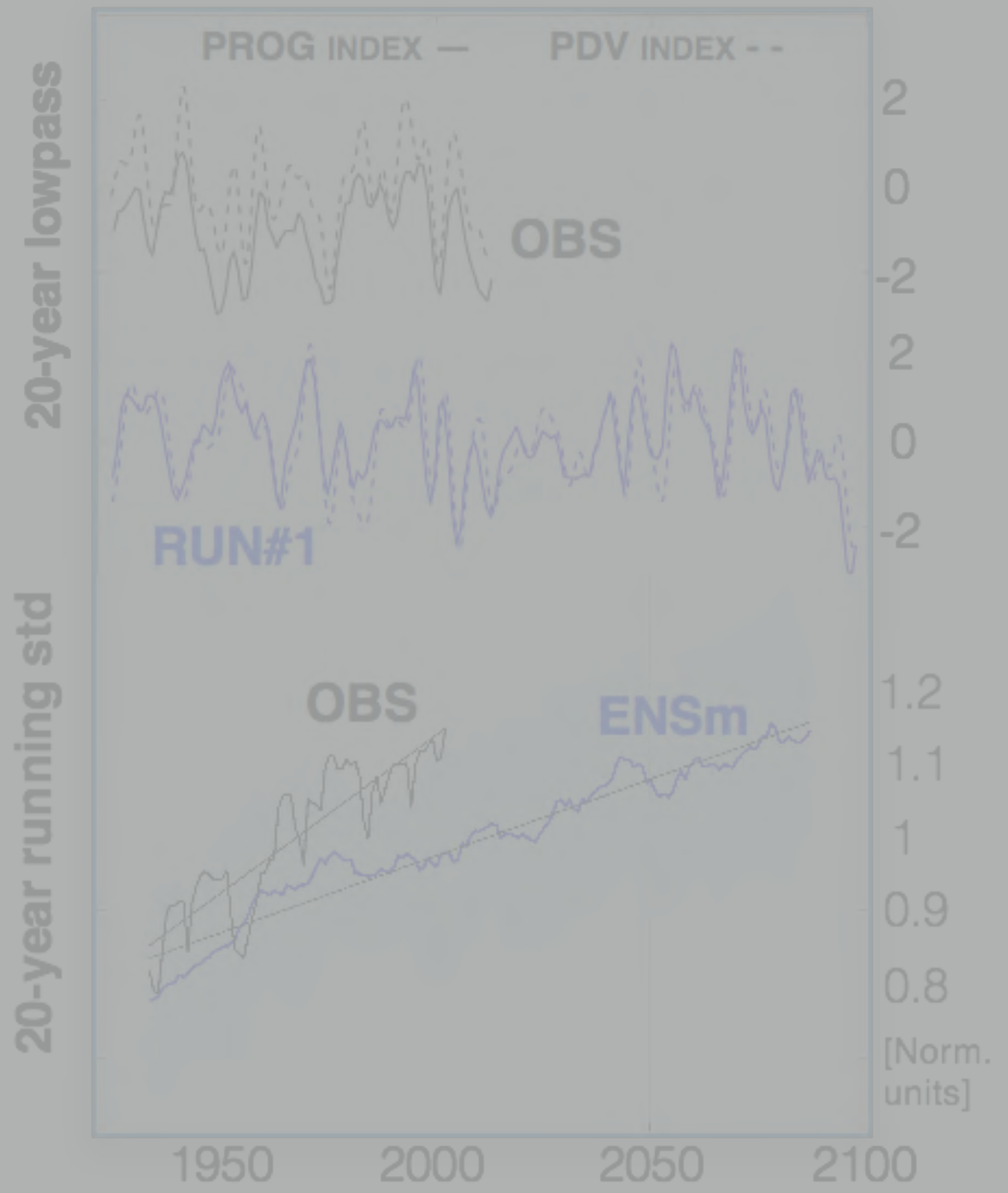

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QUESTION

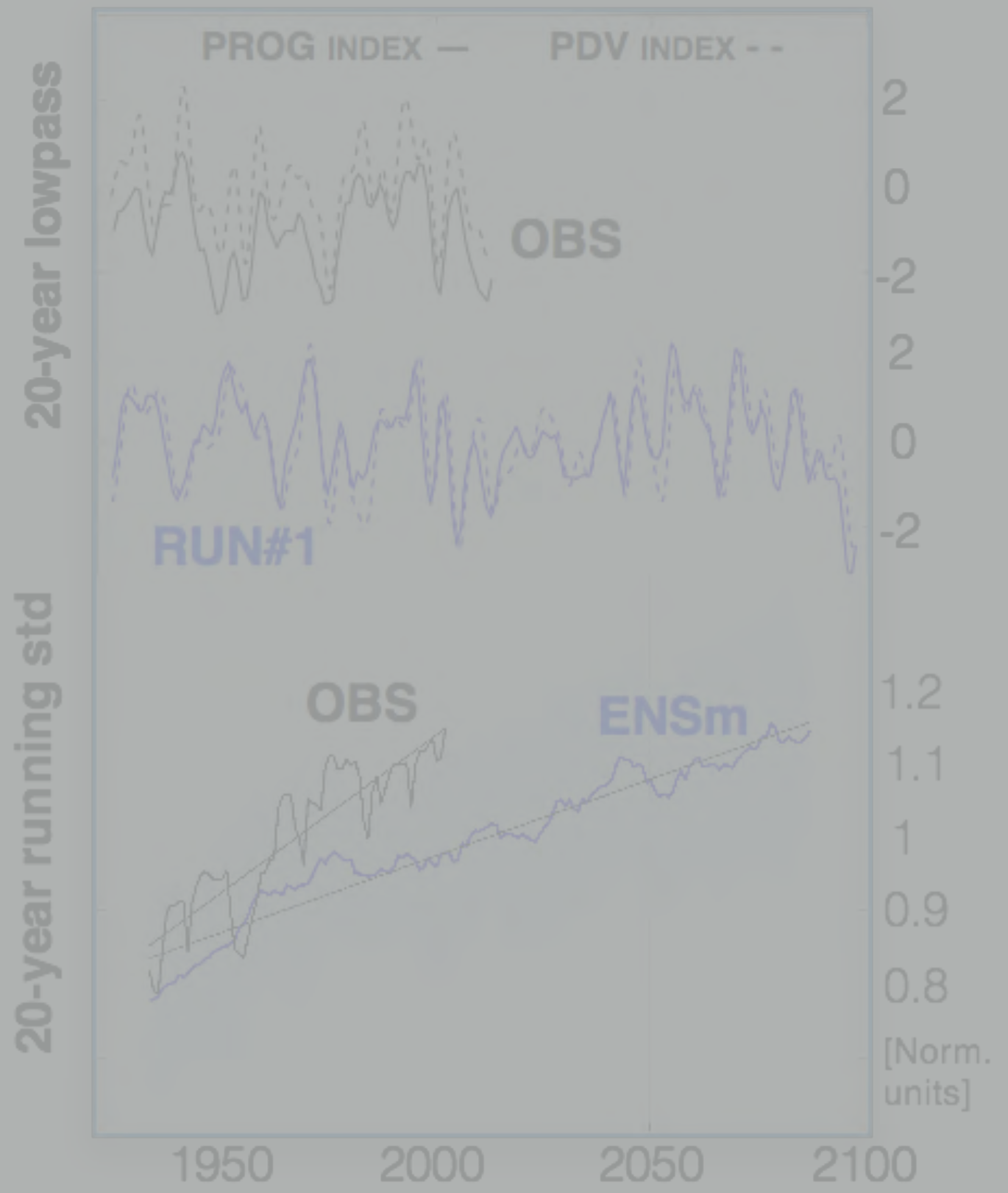
Is the **PROG index** capturing the PDV?

QUESTION

Is **PDV** increasing under greenhouse forcing?

QUESTION

Why is **PDV** variance **increasing**?



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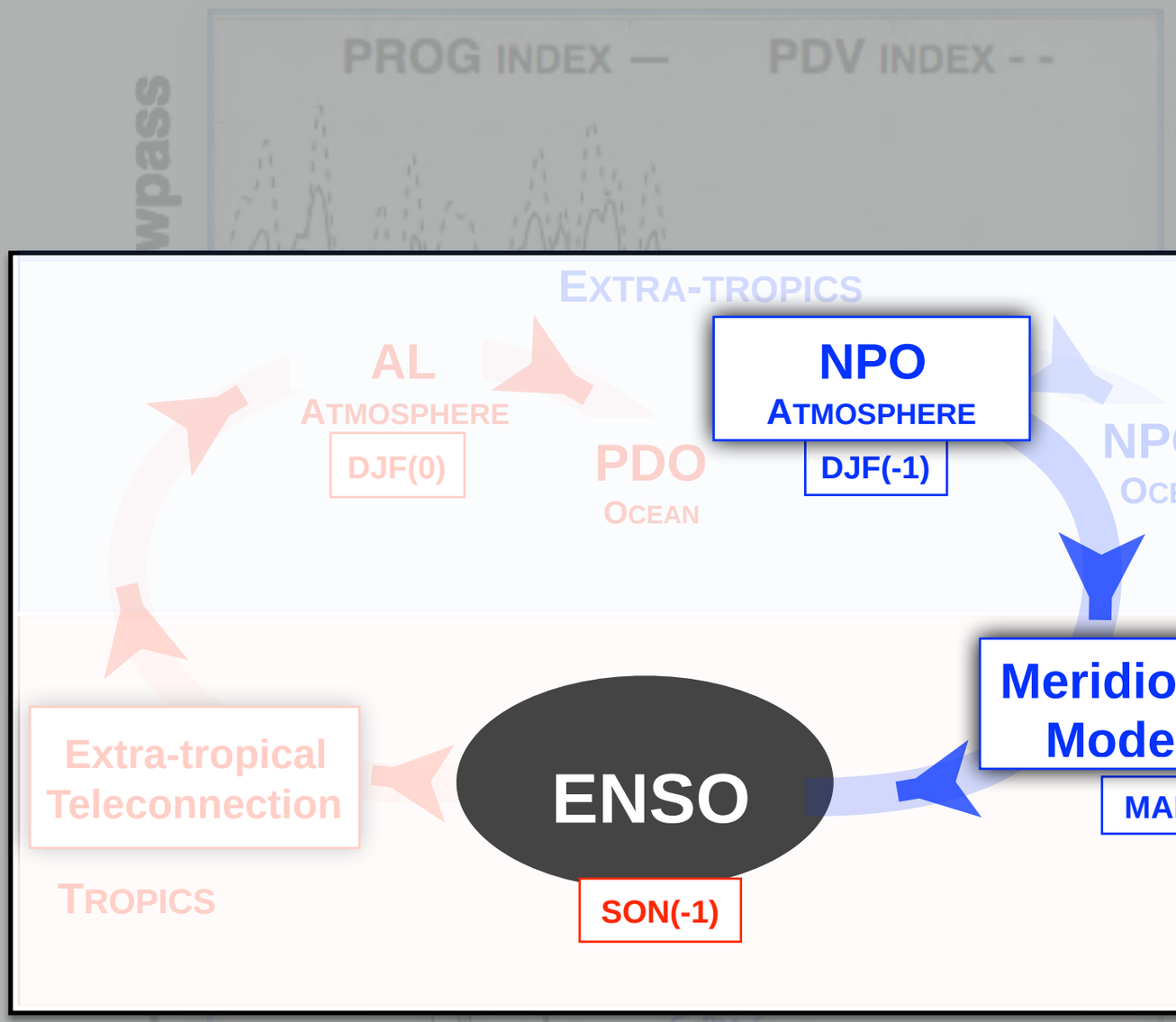

QUESTION

Is **PDV** increasing under greenhouse forcing?

QUESTION

Why is **PDV** variance **increasing**?

HYPOTHESIS

The **PMM**-**ENSO** **relationship** changing under GHG

QUESTION

Is the **PROG index** capturing the PDV?

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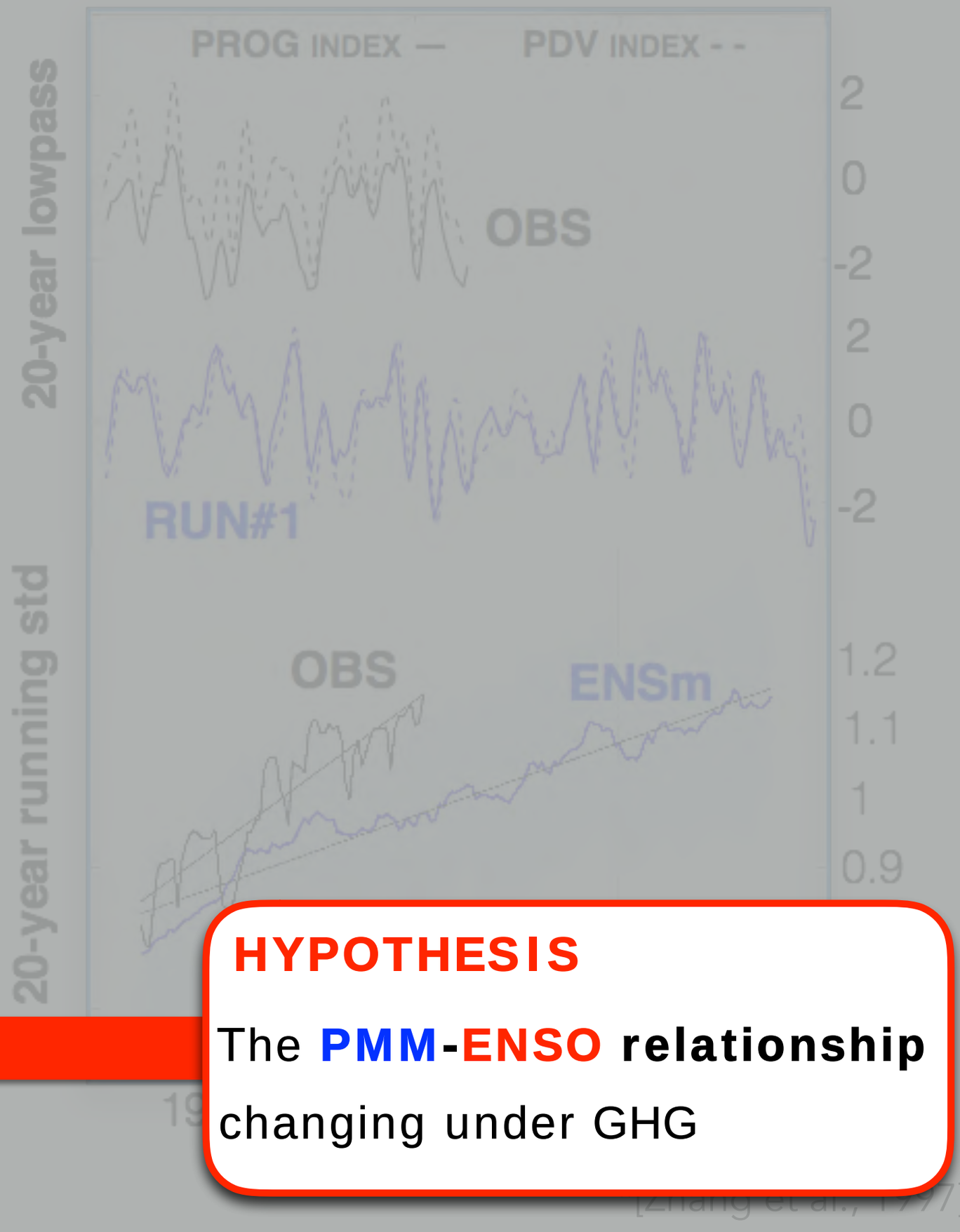
Why is **PDV** variance **increasing**?

HYPOTHESIS

The **PMM**-**ENSO** **relationship** changing under GHG



[Zhang et al., 1997]

HYPOTHESIS

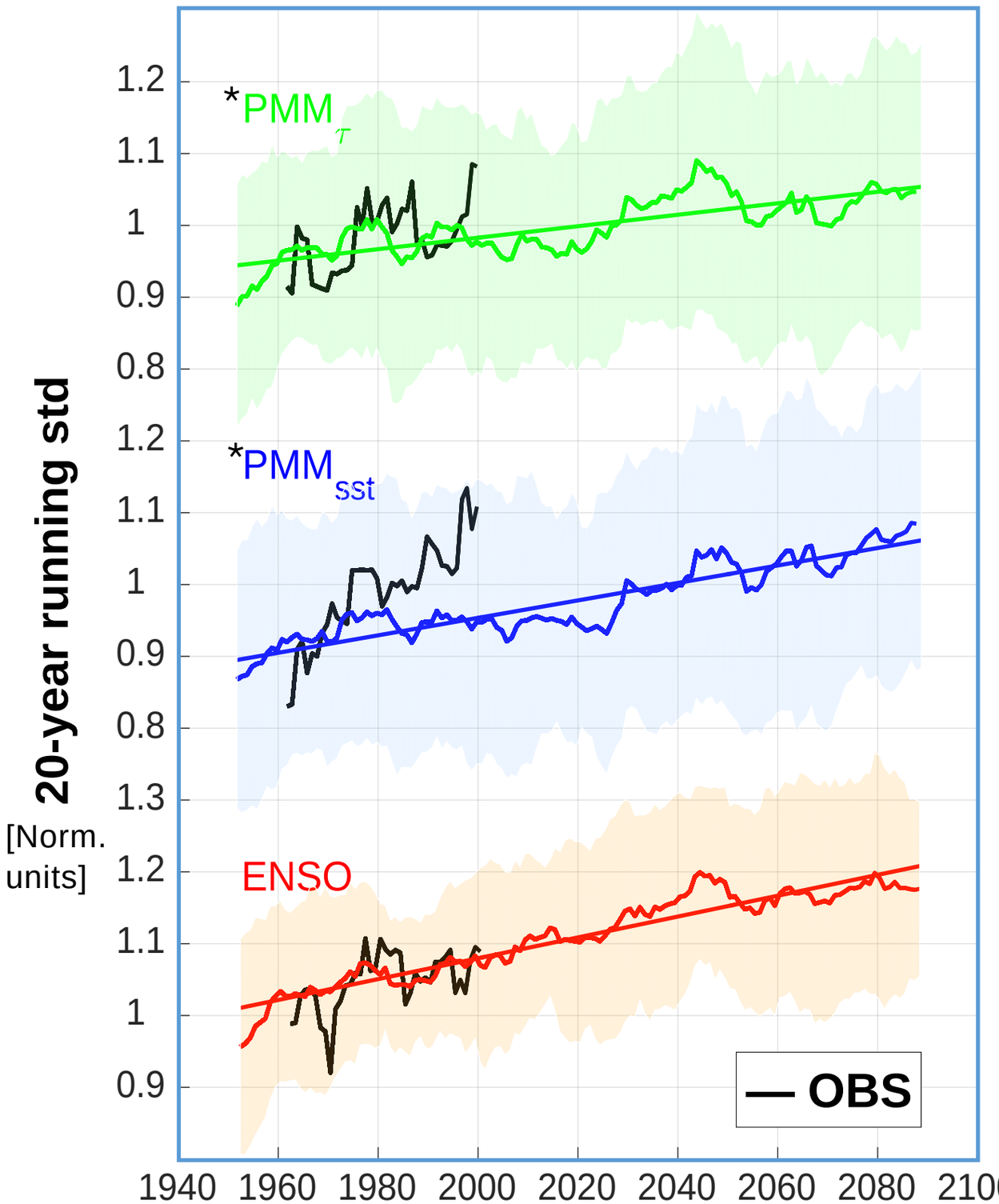
The **PMM-ENSO relationship** changing under GHG

TREND IN THE VARIANCE

HYPOTHESIS

The **PMM-ENSO relationship** changing under GHG

TREND IN THE VARIANCE



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The **PMM**-**ENSO** **relationship** changing under GHG

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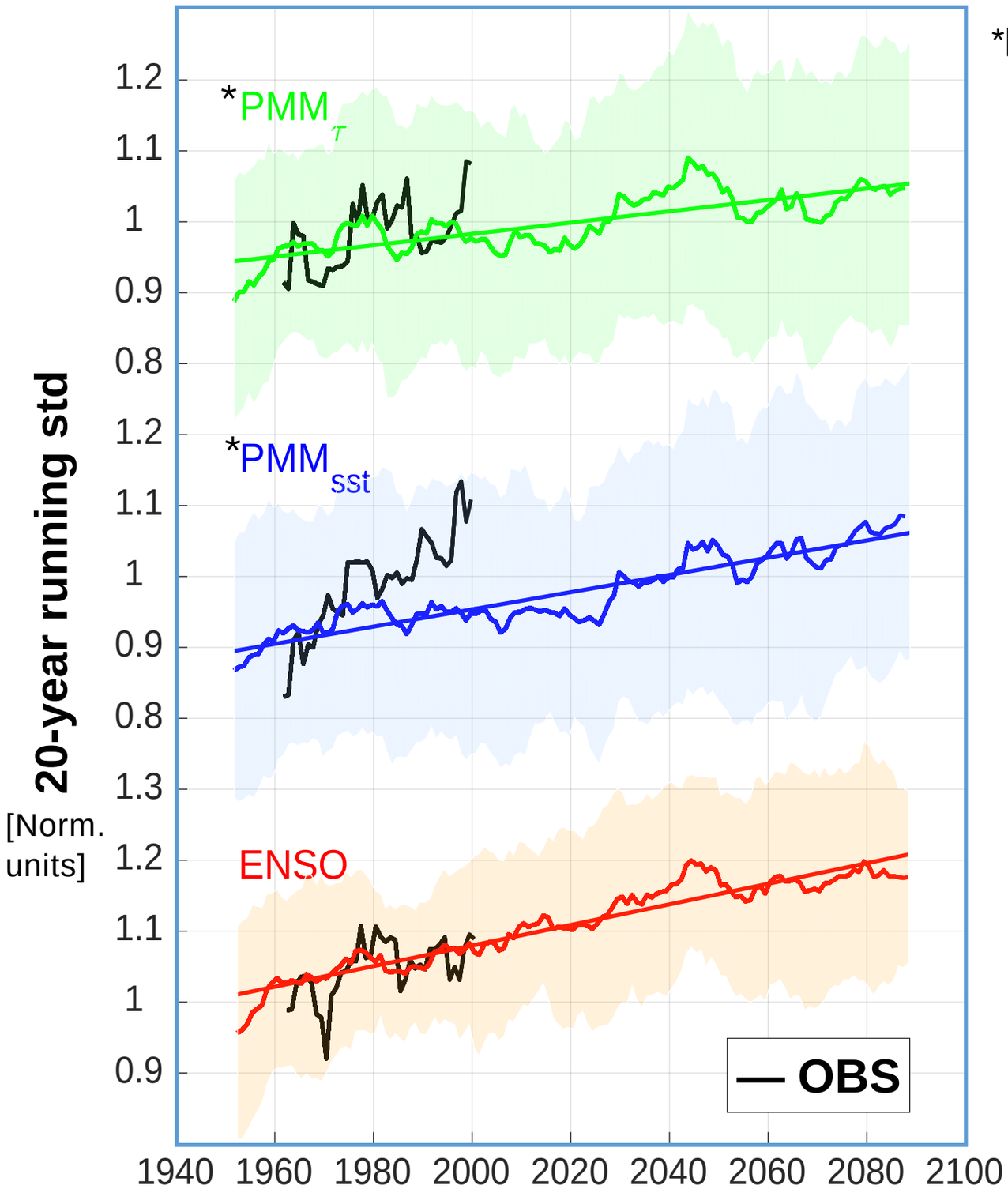


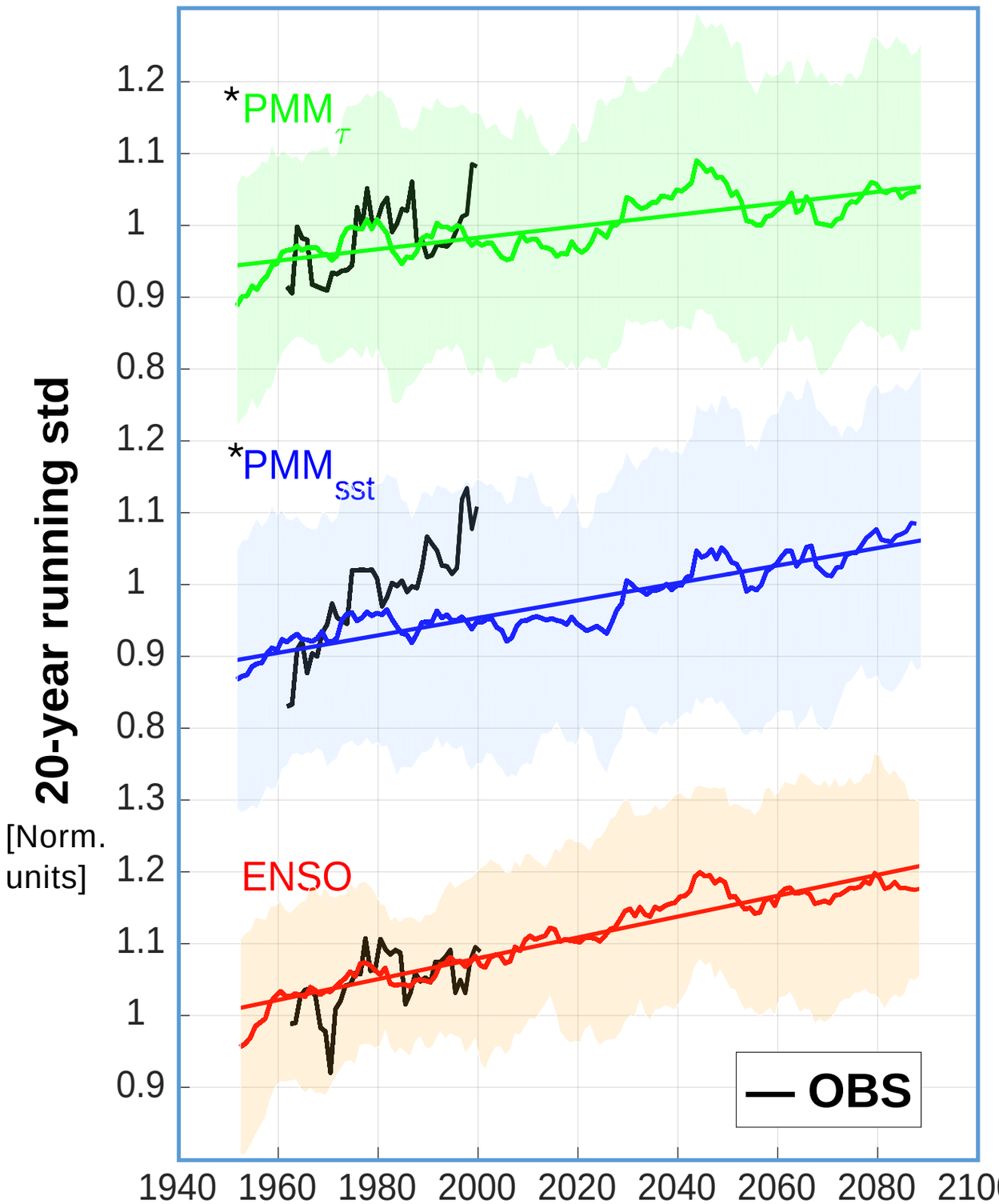
*[Chang et al., 2007]

- Both ENSO and PMM show **significant trend**
- Both in model and observations the trend in PMMsst is larger than PMMtau **consistent with the AR1-type** amplification

HYPOTHESIS

The **PMM-ENSO relationship** changing under GHG

TREND IN THE VARIANCE



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HYPOTHESIS

The **PMM**-**ENSO** **relationship** changing under GHG

TREND IN THE VARIANCE

COUPLING
between PMM and ENSO

*[Chang et al., 2007]

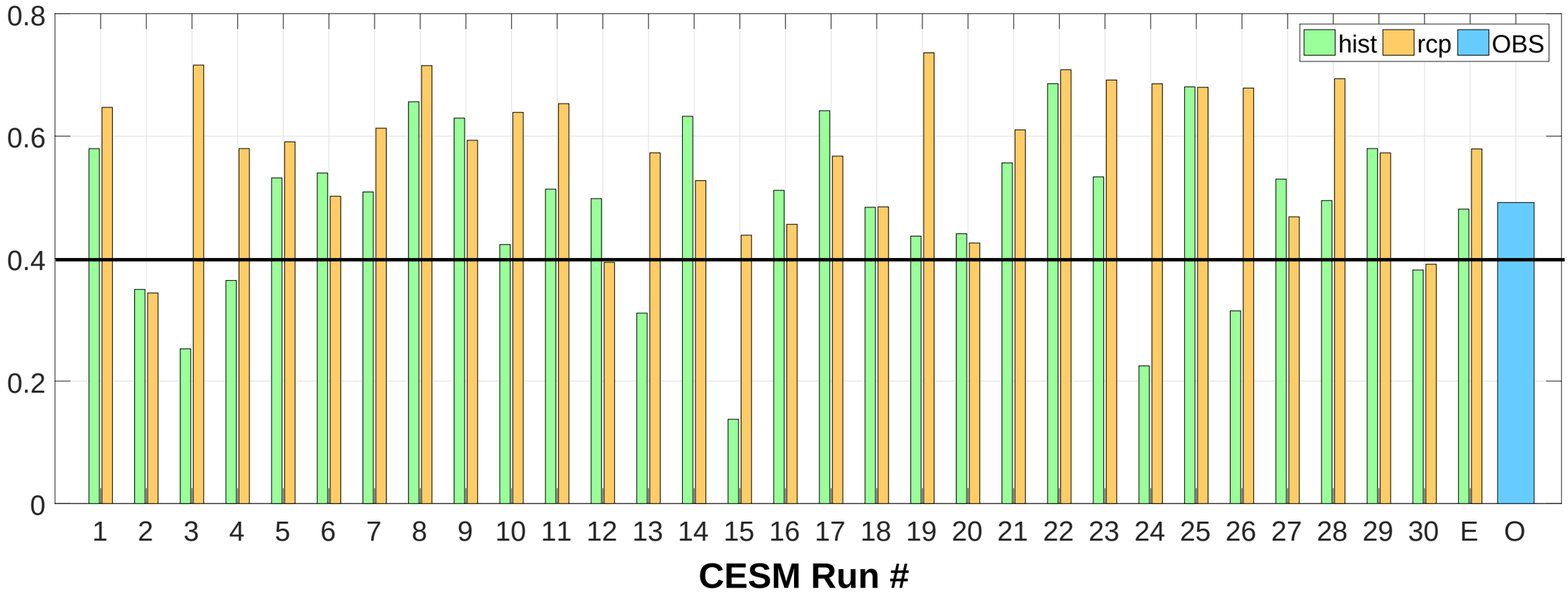
HYPOTHESIS

The **PMM-ENSO relationship** changing under GHG

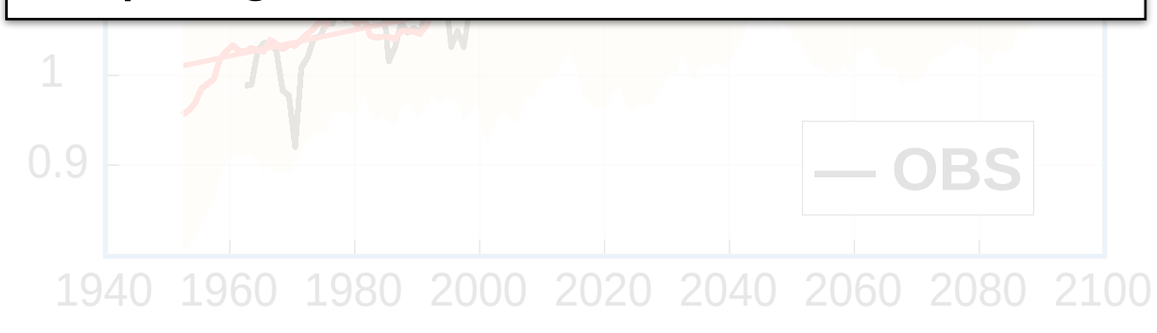
TREND IN THE VARIANCE

COUPLING
between PMM and ENSO

Correlation **period 1920-1960** **period 2060-2100**



Correlation between
Spring **PMM** and Winter **Niño34**



HYPOTHESIS

The **PMM-ENSO relationship**

changing under GHG

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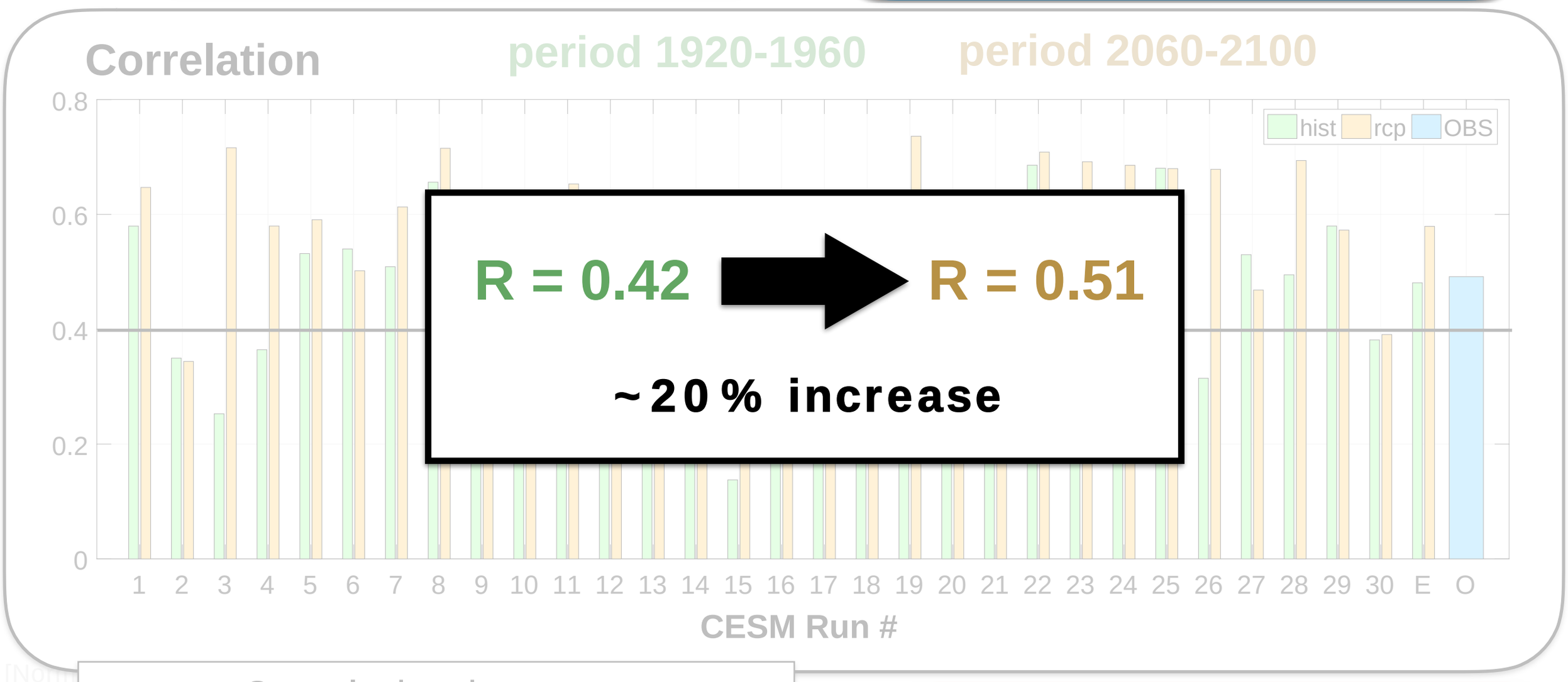

Correlation between
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HYPOTHESIS

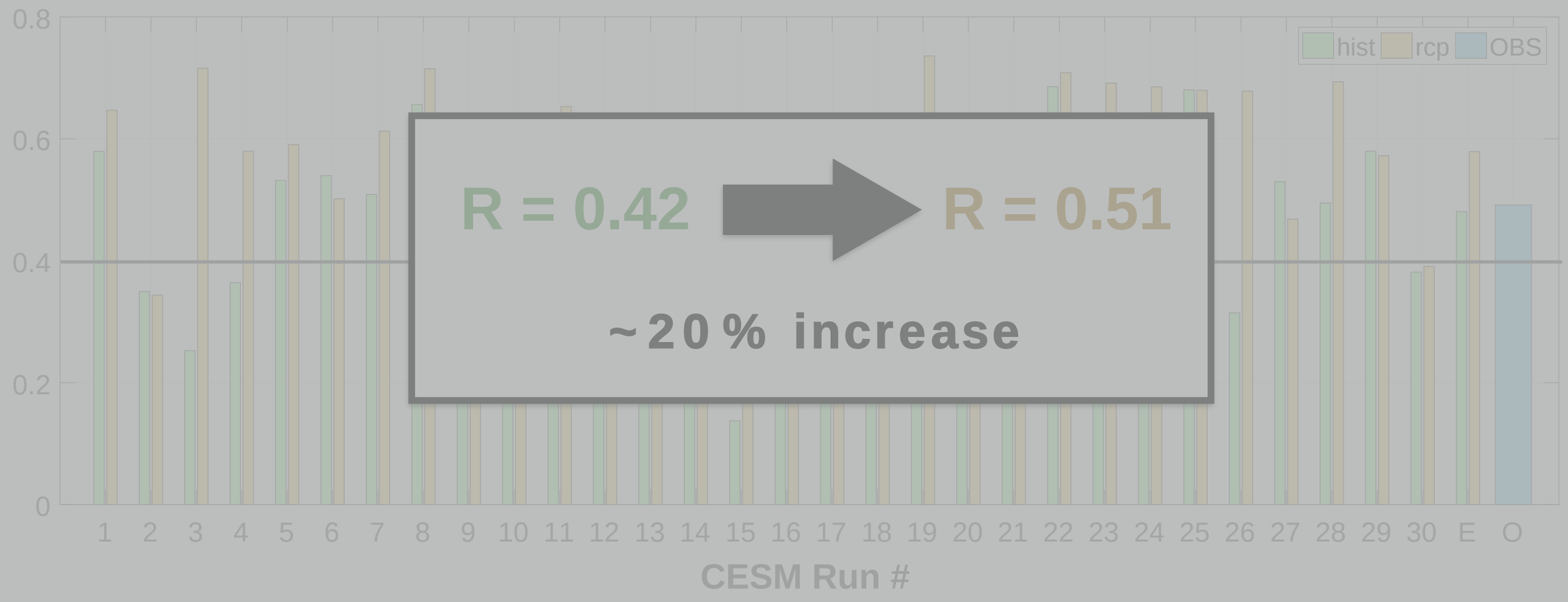
The **PMM-ENSO relationship** changing under GHG

PMM/ENSO **variance** and **coupling** are **increasing** in both OBS and CESM-LENS

Correlation

period 1920-1960

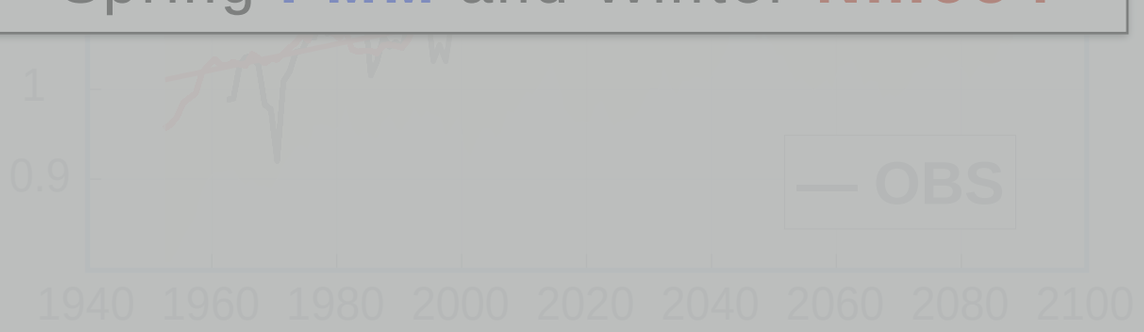
period 2060-2100



R = 0.42 → R = 0.51

~20% increase

Correlation between
Spring **PMM** and Winter **Niño34**



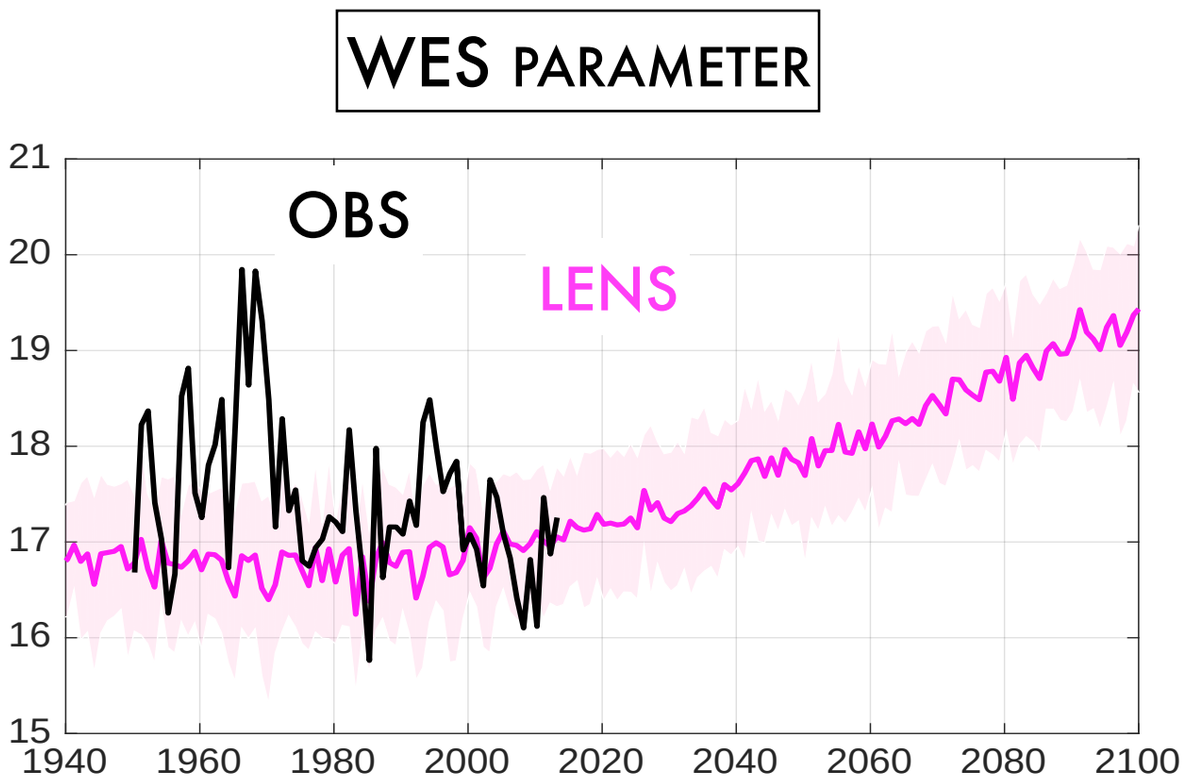
HYPOTHESIS

The **PMM/ENSO relationship** changing under GHG

PMM/ENSO **variance** and **coupling** are **increasing** in both OBS and CESM-LENS

HYP: Under GHG forcing the thermodynamical coupling increase

$$WESp \approx \left| \frac{\partial Heat\ Flux}{\partial Wind\ Speed} \right|$$



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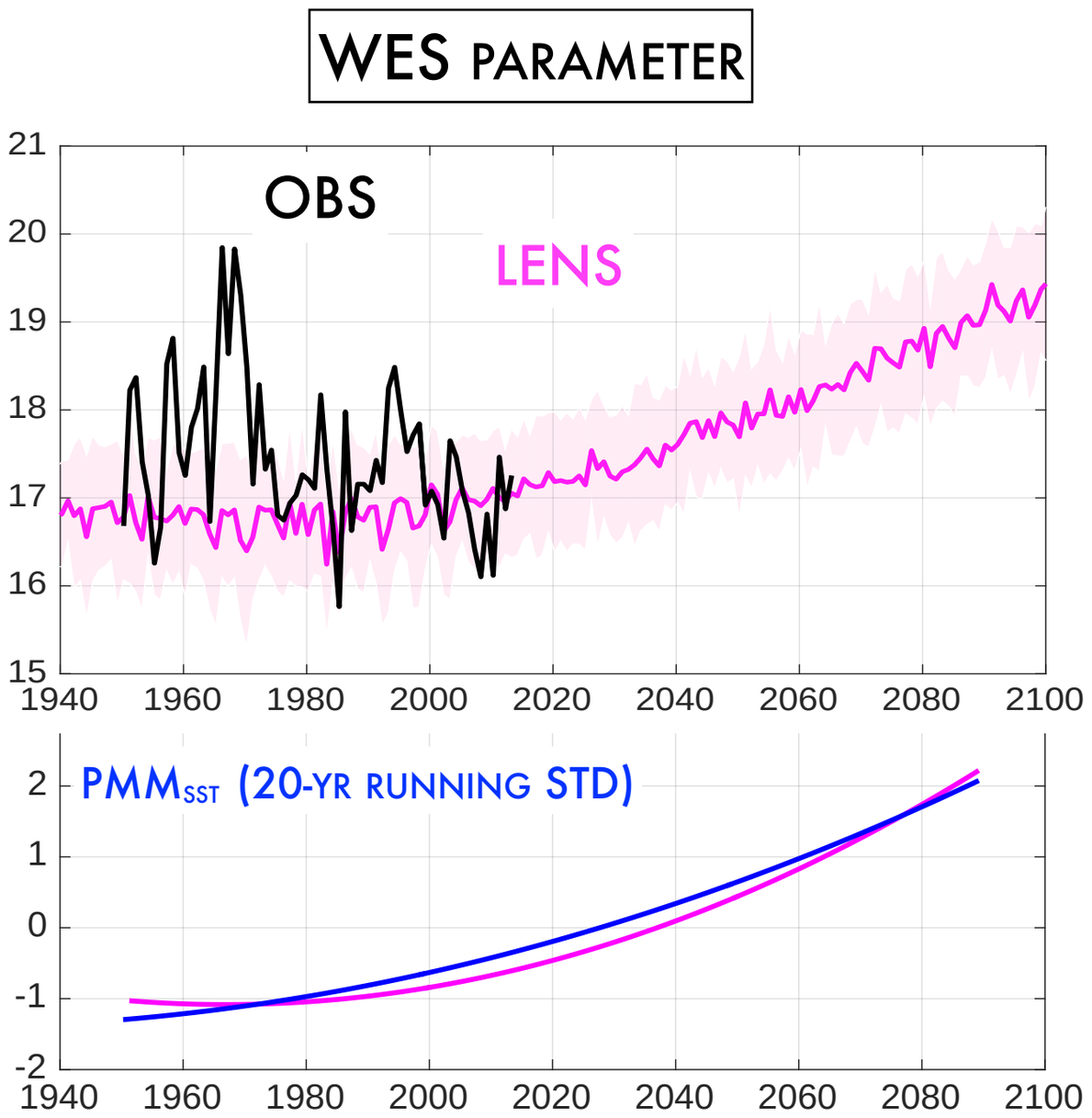

Ok, Nice!

But why should PICES be interested in this?

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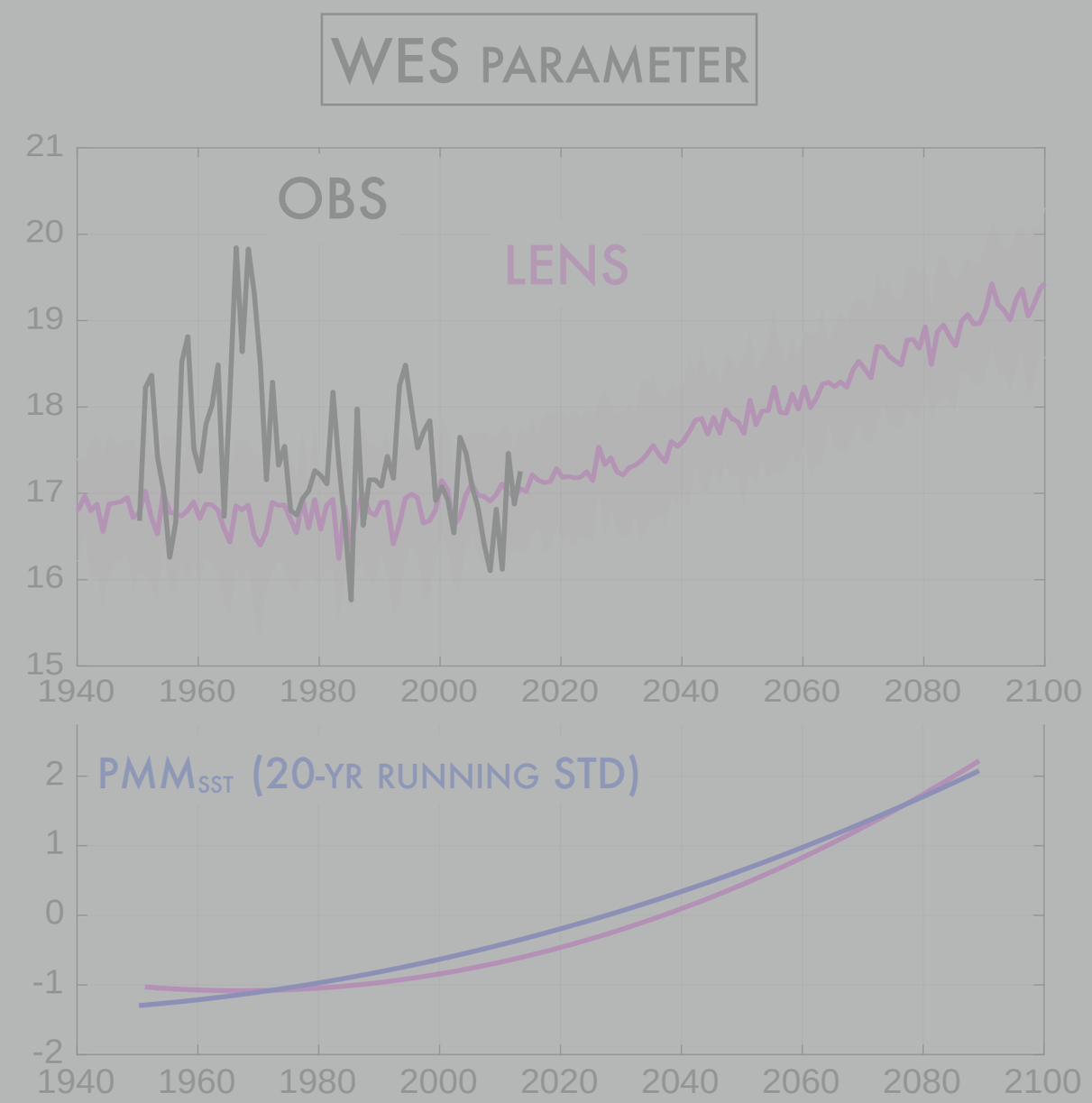

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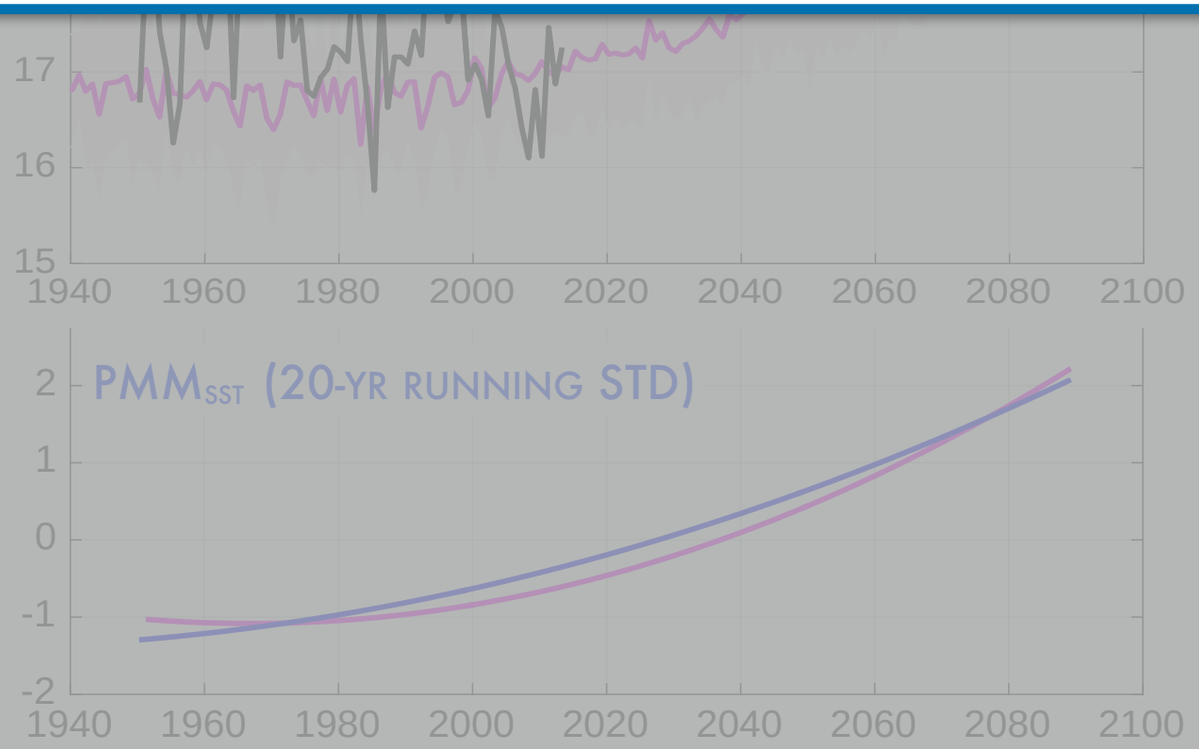
WES PARAMETER

Increased variance of the PDV may result in an **increase** in the decadal **variability of fishery stocks**



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WES PARAMETER

Increased variance of the PDV may result in an **increase** in the decadal **variability of fishery stocks**

ONGOING AND FUTURE WORK

1. **Identify** the relationship between Pacific climate modes and fishery stocks in the historical records
2. **Project** changes in fishery stocks variability using climate projections of Pacific climate modes

*CASE STUDY

Large scale
Pacific climate modes
and
salmon (Sockeye)
survival rate

* In collaboration with Eric Hertz (Univ. Victoria)

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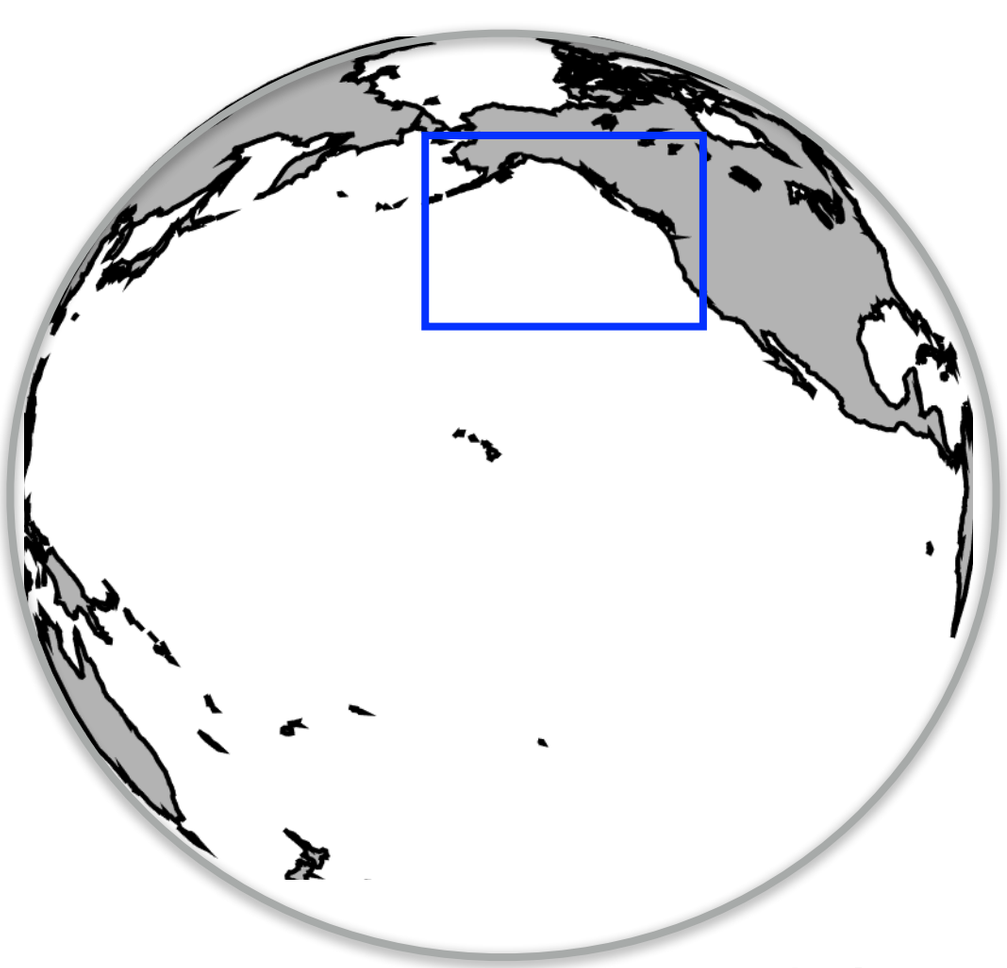

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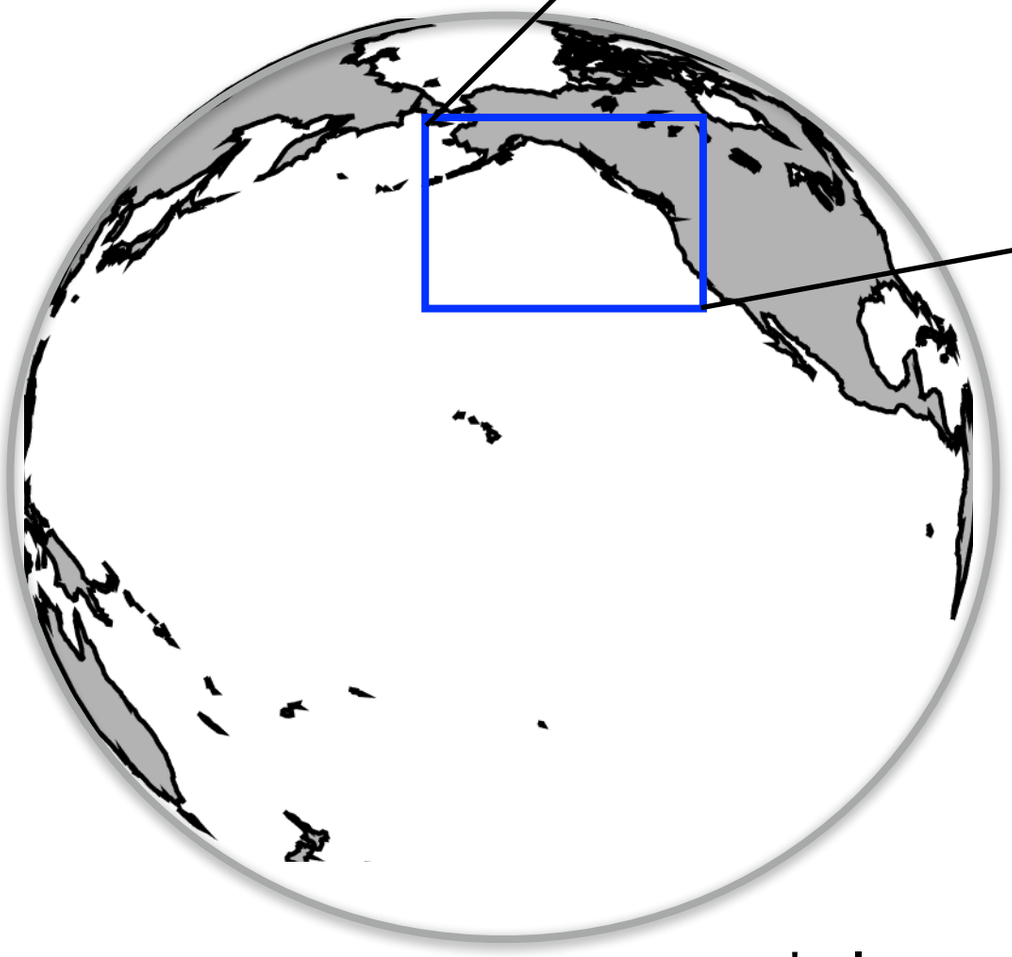

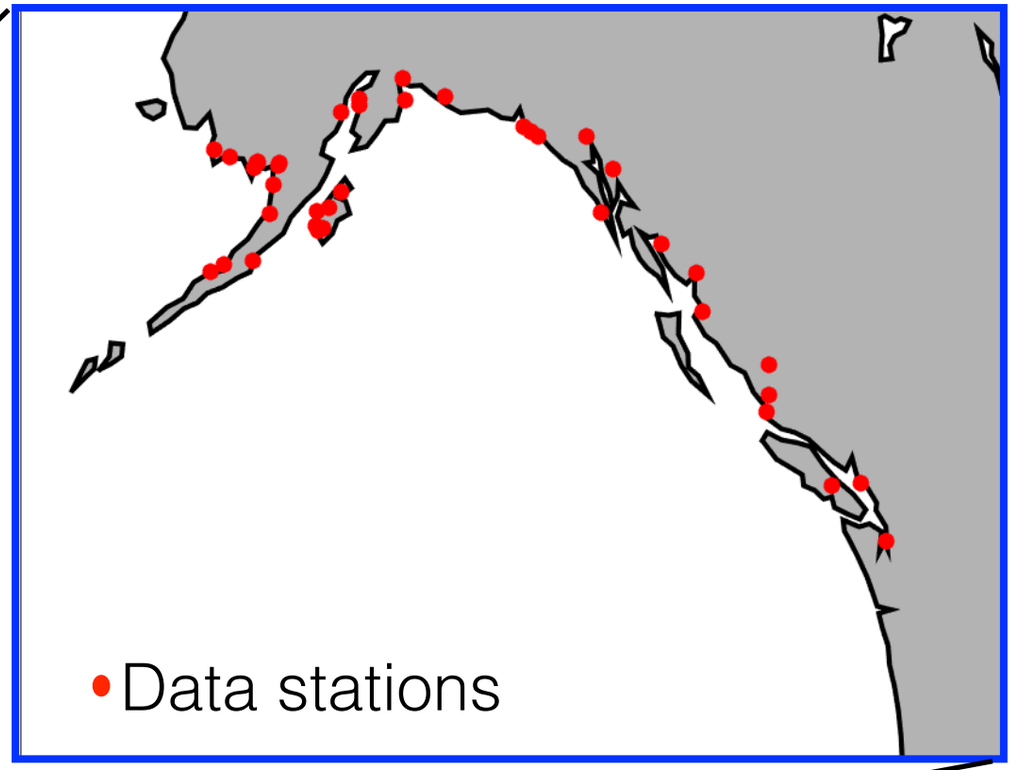

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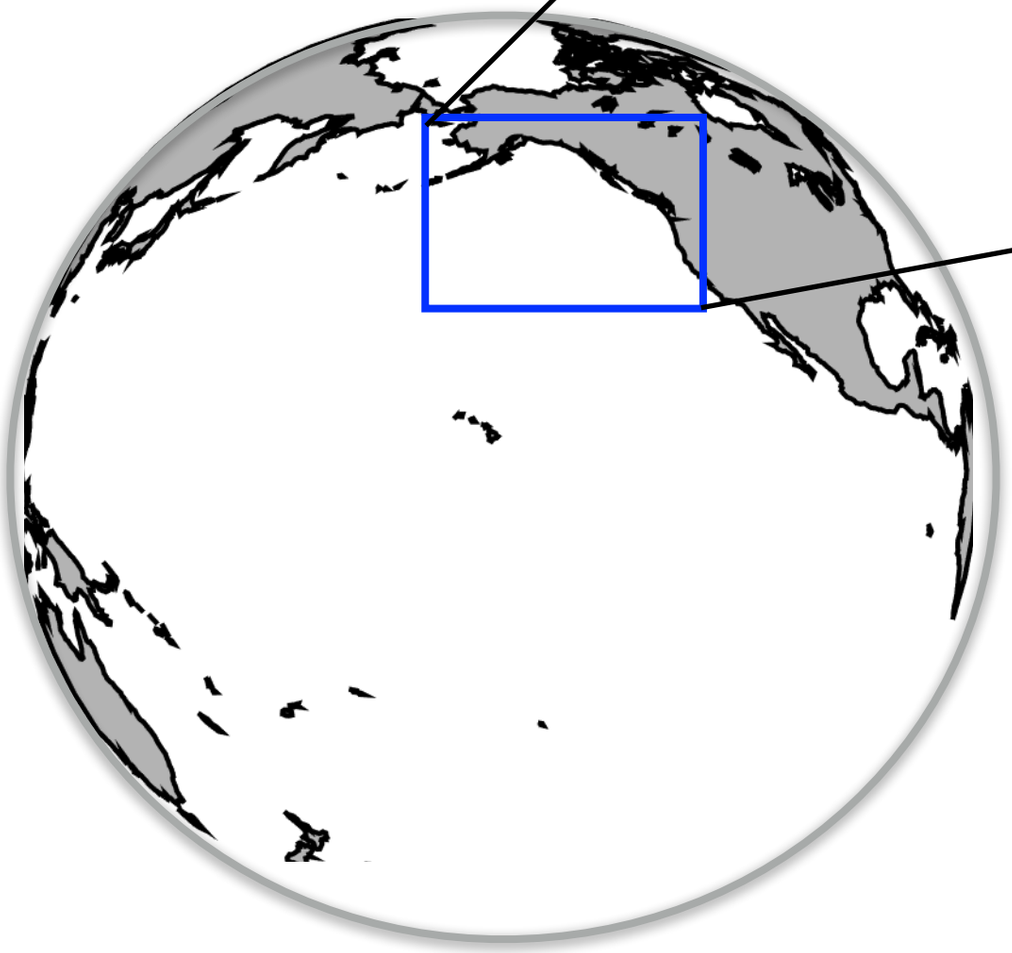

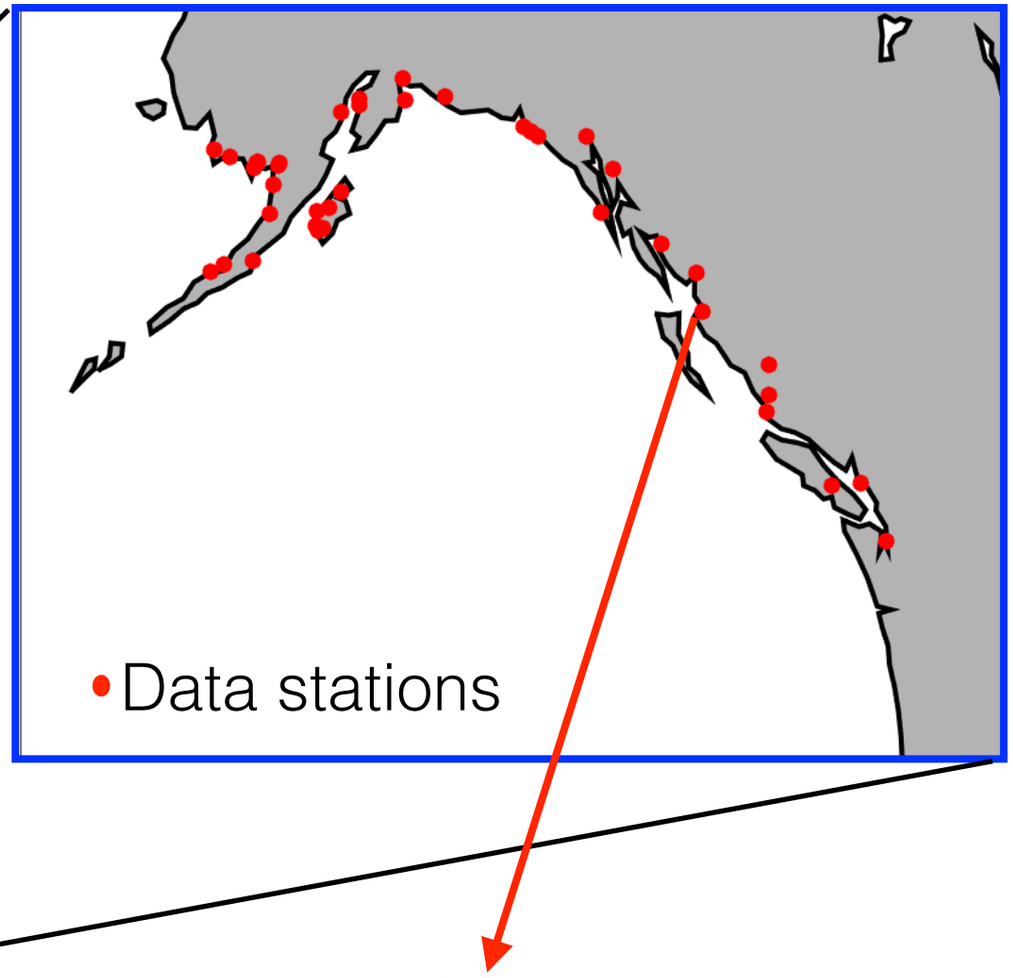

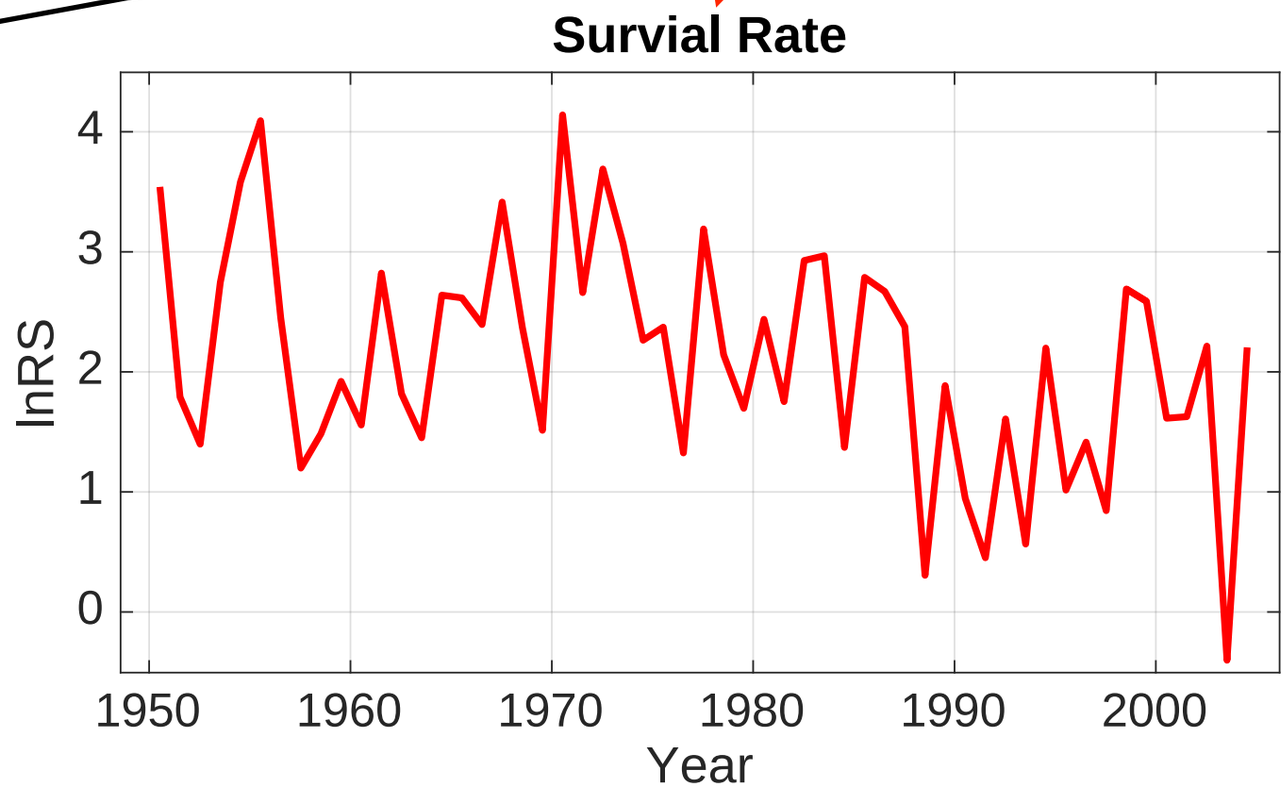

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Large scale
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Correlation
climate modes
and survival rate
time series

	PDO	NPGO	sPMM	wCTI	wN1+2	wN3
24 - 35	-0.21	0.66	0.60	-0.21	-0.09	-0.14
23 - 35	0.19	0.46	0.23	0.05	0.15	0.12
22 - 25	-0.09	0.00	0.22	-0.23	0.04	-0.18
21 - 25	-0.04	-0.04	0.18	-0.24	0.00	-0.20
20 - 62	-0.42	-0.15	0.17	-0.07	-0.01	-0.12
19 - 62	0.15	-0.30	-0.26	0.02	-0.07	0.03
18 - 62	-0.12	0.08	0.15	-0.09	-0.14	-0.06
17 - 62	0.05	0.57	0.40	-0.14	-0.08	-0.06
16 - 62	-0.32	0.06	0.26	-0.05	0.00	-0.07
15 - 62	0.13	-0.22	-0.18	0.01	-0.06	0.04
14 - 62	0.01	0.01	0.02	0.00	0.02	0.01
13 - 62	-0.35	-0.14	0.24	-0.18	-0.05	-0.18
12 - 62	0.39	-0.58	-0.74	0.34	0.12	0.24
11 - 62	0.02	-0.26	-0.22	0.02	-0.03	0.03
10 - 62	-0.01	-0.14	-0.08	-0.02	-0.09	-0.00
9 - 62	-0.23	0.26	0.33	-0.05	0.03	-0.05
8 - 62	-0.51	0.15	0.46	-0.30	-0.09	-0.28
7 - 62	-0.14	0.28	0.14	-0.09	-0.07	-0.13
6 - 62	-0.01	-0.13	-0.14	-0.02	-0.03	-0.02
5 - 62	0.00	0.27	0.10	-0.08	-0.19	-0.05
4 - 62	0.13	-0.38	-0.39	0.06	-0.04	0.04
3 - 62	0.01	-0.36	-0.24	0.02	-0.11	0.01
2 - 62	0.14	-0.12	-0.20	-0.01	-0.06	0.01
1 - 38	0.10	-0.23	0.00	-0.07	0.00	-0.02

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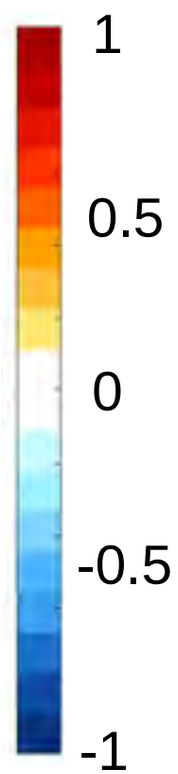

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20 - 62	-0.42	-0.15	0.17	-0.07	-0.01	-0.12
19 - 62	0.15	-0.30	-0.26	0.02	-0.07	0.03
18 - 62	-0.12	0.08	0.15	-0.09	-0.14	-0.06
17 - 62	0.05	0.57	0.40	-0.14	-0.08	-0.06
16 - 62	-0.32	0.06	0.26	-0.05	0.00	-0.07
15 - 62	0.13	-0.22	-0.18	0.01	-0.06	0.04
14 - 62	0.01	0.01	0.02	0.00	0.02	0.01
13 - 62	-0.35	-0.14	0.24	-0.18	-0.05	-0.18
12 - 62	0.39	-0.58	-0.74	0.34	0.12	0.24
11 - 62	0.02	-0.26	-0.22	0.02	-0.03	0.03
10 - 62	-0.01	-0.14	-0.08	-0.02	-0.09	-0.00
9 - 62	-0.23	0.26	0.33	-0.05	0.03	-0.05
8 - 62	-0.51	0.15	0.46	-0.30	-0.09	-0.28
7 - 62	-0.14	0.28	0.14	-0.09	-0.07	-0.13
6 - 62	-0.01	-0.13	-0.14	-0.02	-0.03	-0.02
5 - 62	0.00	0.27	0.10	-0.08	-0.19	-0.05
4 - 62	0.13	-0.38	-0.39	0.06	-0.04	0.04
3 - 62	0.01	-0.36	-0.24	0.02	-0.11	0.01
2 - 62	0.14	-0.12	-0.20	-0.01	-0.06	0.01
1 - 38	0.10	-0.23	0.00	-0.07	0.00	-0.02

SUMMARY

- The **PDV is increasing** (PROG index variance) in OBS and in GHG forced simulations.
- This increase in PDV is **linked to changes in the PMM-ENSO relationship.** Increase in variance and coupling.
- In the model this changes are associated with and increase in the **thermodynamical coupling (WES).**
- **ONGOING and FUTURE WORK:** Assess the significance of this study in Salmon survival rate along the North East Pacific coast.


Russky Island