Increasing Pacific decadal variability under greenhouse forcing

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and
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Sea Surface Temperature (SST)
Nino3 Index (NOAA SST)
Nino3 Index (NOAA SST)
Nino3 Index (NOAA SST)

ENSO

Nino3 regressed on NOAA SST
ENSO

Nino3 regressed on NOAA SST

[°C/std]

-1
-0.5
0
0.5
1
TROPICS

Nino3 regressed on NOAA SST

ENSO

[Temperature anomaly map in °C/standard deviation]
TROPICS

EXTRA-TROPICS

ENSO

Nino3 regressed on NOAA SST

[Temperature anomaly in °C/standard deviation]
Nino3 regressed on NOAA SST

Nino3 correlation with NCEP SLP(-1)

SLP Precursor (1 year prior)
ENSO

Nino3 regressed on NOAA SST

TROPICS

SLP PRECURSOR (1 year prior)

Nino3 correlation with NCEP SLP(-1)

[T°C/ std]
Nino3 regressed on NOAA SST

ENSO

North Pacific Oscillation

SLP PRECURSOR (1 year prior)
Nino3 correlation with NCEP SLP(-1)

TROPICS

EXTRA-TROPICS
**ENSO**

Nino3 regressed on NOAA SST

**TROPICS**

SLP PRECURSOR (1 year prior)

Nino3 correlation with NCEP SLP(-1)

North Pacific Oscillation

**EXTRA-TROPICS**

[°C/std]
North Pacific Oscillation
ATMOSPHERE

North Pacific Gyre Oscillation
OCEAN

Meridional Modes

EXTRA-TROPICS

TROPICS

Winter

Spring

Fall
Extra-tropical Teleconnection

North Pacific Gyre Oscillation

Pacific Decadal Oscillation

Aleutian Low

Winter

Fall

Spring

Meridional Modes

ENSO

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]
**Question**

Is the Pacific Decadal Variability (PDV) increasing under greenhouse forcing?
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**Approach**
Examine 30-member Community Earth System Model Large Ensemble (CESM-LE) from 1920-2100 (RCP8.5 scenario)
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Is the Pacific Decadal Variability (PDV) increasing under greenhouse forcing?

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

**Methodology**
Find an index that captures the PDV mechanisms of the conceptual framework
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ENSO* signal removed via regression analysis.
An index that captures the **PDV** mechanisms

**EOF**

- SSTa-DJF\((-1)\)^*- in NP
- SSTa-MAM\((-1)\)^*- in TM

ENSO* signal removed via regression analysis
An index that captures the PDV mechanisms

EOF

SSTa-DJF(-1)* in NP
SSTa-MAM(-1)* in TM
SSTa-SON(-1) in TP

ENSO* signal removed via regression analysis
An index that captures the PDV mechanisms

EOF (extra-tropical teleconnection)

1. SSTa-DJF(-1)* in NP
2. SSTa-MAM(-1)* in TM
3. SSTa-SON(-1) in TP
4. SSTa-DJF(0) in NP

ENSO* signal removed via regression analysis
An index that captures the PDV mechanisms

**PROG index**
leading PC of the seasonally-spatially stacked EOF analysis

ENSO* signal removed via regression analysis
PROG index regressed onto SSTa/SLPa 1950-2014
PROG index regressed onto SSTa/SLPa

1950-2014
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1950-2014

[SST NOAA NPGO-like]

DJF (-1)

[°C]

[PROG index regressed onto SSTa/SLPa]

1950-2014

[SST NOAA NPGO-like]

DJF (-1)

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PROG index regressed onto SSTa/SLPa

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SST NOAA

NPGO-like

PMM

ENSO

[°C]

DJF (-1)

MAM (-1)

JJA (-1)

SON (-1)

1950-2014
PROG index regressed onto SSTa/SLPa

1950-2014
**PROG index regressed onto SSTa/SLPa**

1950-2014
1950-2014

DJF (-1)

MAM (-1)

JJA (-1)

SON (-1)

DJF (0)

PMM

ENSO

NPGO-like

NPO-like

SLP NCEP

PROG index regressed onto SSTa/SLPa

1950-2014

Extra-tropical Teleconnection

ENSO

PDO-like

AL-like

NPGO-like

NPO-like

PDO

Ocean

NPGO

Ocean

Meridional Modes

Montreal

SON (-1)

TROPICS

PDO

AL

MAM (-1)

ATMOSPHERE

ATMOSPHERE

DJF (-1)

DJF (0)

Extra-tropical Teleconnection

ENSO

PDO-like

AL-like

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NPO-like

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TROPICS
PROG index regressed onto SSTa/SLPa

1950-2014
PROG index regressed onto SSTa/SLPa

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OBS vs CESM-LENS

SST NOAA

NPGO-like

PDO-like

DJF (-1)

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OBS vs CESM-LENS

SST NOOA

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PDO-like

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PROG index regressed onto SSTa/SLPa

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OBS vs CESM-LENS

SLP NCEP NPGO-like

SLP LENS

PDO-like
**QUESTION**

Is the **PROG index** capturing the PDV?
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*Zhang et al., 1997*
QUESTION

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*[Zhang et al., 1997]*
QUESTION

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

✓

*[Zhang et al., 1997]*
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QUESTION
Is PDV increasing under greenhouse forcing?

*Zhang et al., 1997*
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Is **PDV** increasing under greenhouse forcing? ✓

*[Zhang et al., 1997]*
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QUESTION
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Same result for NOAA and Hadley SST

*[Zhang et al., 1997]*
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QUESTION
Why is PDV variance increasing?

*Zhang et al., 1997*
**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
QUESTION
Is the PROG index capturing the PDV?

✓

QUESTION
Is PDV increasing under greenhouse forcing?

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Why is PDV variance increasing?

HYPOTHESIS
The PMM-ENSO relationship changing under GHG
HYPOTHESIS

The PMM-ENSO relationship changing under GHG
TREND IN THE VARIANCE

HYPOTHESIS
The PMM-ENSO relationship changing under GHG
HYPOTHESIS

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

![Graph showing trends in PMM-ENSO variance](image)

**HYPOTHESIS**

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

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

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**COUPLING**

between PMM and ENSO

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**TREND IN THE VARIANCE**

20-year running std

[Norm. units]

*Chang et al., 2007*
The PMM-ENSO relationship is changing under GHG.

**HYPOTHESIS**

**COUPLING between PMM and ENSO**

**TREND IN THE VARIANCE**

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

**Correlation**

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

**Niño34 Index (NDJ)**

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

**20% increase**

**CEM Run #**

- **hist**
- **rcp**
- **OBS**
**HYPOTHESIS**

The PMM-ENSO relationship is changing under GHG.

**COUPLING between PMM and ENSO**

**TREND IN THE VARIANCE**

The correlation between Spring PMM and Winter Niño34 is increasing.

**Correlation between Spring PMM and Winter Niño34**

<table>
<thead>
<tr>
<th>Member</th>
<th>Correlation TP-PMM τ index: 1920-1970 vs 2050-2100</th>
<th>Percentage Increase</th>
</tr>
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<tr>
<td>12345</td>
<td>0.42</td>
<td>~20%</td>
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<tr>
<td>6789</td>
<td>0.51</td>
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</table>

**Periods**

- Period 1920-1960
- Period 2060-2100

**Graphical Representation**

- **R** = 0.42 for period 1920-1960
- **R** = 0.51 for period 2060-2100

**~20% increase**
PMM/ENSO **variance** and **coupling** are **increasing** in both OBS and CESM-LENS
PMM/ENSO **variance** and **coupling** are increasing in both OBS and CESM-LENS

**HYP:** Under GHG forcing the thermodynamical coupling increase

\[
WESp \approx \left. \frac{\partial \text{Heat Flux}}{\partial \text{Wind Speed}} \right|_{\text{LENS}}
\]
PMM/ENSO **variance** and **coupling** are **increasing** in both OBS and CESM-LENS

HYP: Under GHG forcing the thermodynamical coupling increase

\[
WESp \approx \frac{\partial \text{Heat Flux}}{\partial \text{Wind Speed}}
\]

![Graph showing the trend of PMM/ENSO variance and coupling over time, with OBS and LENS data, and a quadratic fit.](image-url)
Ok, Nice!
But why should PICES be interested in this?

HYP: Under GHG forcing the thermodynamical coupling increase

\[ WESp \approx \frac{\partial \text{Heat Flux}}{\partial \text{Wind Speed}} \]

OBS

LENS

PMMSST (20-YR RUNNING STD)
Ok, Nice!
But why should PICES be interested in this?

HYP: Under GHG forcing the thermodynamical coupling increase

Increased variance of the PDV may result in an **increase** in the decadal **variability of fishery stocks**
Ok, Nice!
But why should PICES be interested in this?

HYP: Under GHG forcing the thermodynamical coupling increase

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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![Graph showing survival rate data stations](image)

![Map of data stations](image)
**CASE STUDY**

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

Correlation climate modes and survival rate time series

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<td>-0.01</td>
<td>-0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>1 - 38</td>
<td>0.10</td>
<td>-0.23</td>
<td>0.00</td>
<td>-0.07</td>
<td>0.00</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

Correlation climate modes and survival rate time series
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