Changes in character of North Pacific variability and ecosystem implications

by E. Di Lorenzo

Collaborators: J. Furtado, K. Cobb, I. Nurhati

PICES S2 Session, October 2013
Changes in character of **North Pacific variability** and ecosystem implications

**QUESTION:**

What drives the surface ocean variance in the North Pacific?
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What drives the surface ocean variance in the North Pacific?
Oceanic Variability

Atmospheric Variability

Aleutian Low (AL)

North Pacific Oscillation (NPO)

Pacific Decadal Oscillation (PDO)
Aleutian Low (AL)  
North Pacific Oscillation (NPO)  
Pacific Decadal Oscillation (PDO)  
North Pacific Gyre Oscillation (NPGO)  

Atmospheric Variability  
Oceanic Variability
QUESTION:
Why has the North Pacific variance (e.g. NPGO) increased after 1980?
Understand the dynamics of Pacific Ocean variability and the coupling with the tropics

**QUESTION:**
Why has the North Pacific variance (e.g. NPGO) increased after 1980?
Extra-tropics [ Ocean forced by Atmosphere ]

Understand the dynamics of Pacific Ocean variability and the coupling with the tropics

Tropics [ Ocean-Atmosphere Coupled System ]
Model for explaining Pacific decadal dynamics

Extra-tropics [ Ocean forced by Atmosphere ]

Tropics [ Ocean-Atmosphere Coupled System ]
Model for explaining Pacific decadal dynamics

Extra-tropics [ Ocean forced by Atmosphere ]

CPW
Central Pacific Warming
non-Canonical ENSO
(mature)

ENSO
Eastern Pacific
Canonical ENSO
(mature)

Tropics [ Ocean-Atmosphere Coupled System ]
Model for explaining Pacific decadal dynamics

Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
1st extra-tropical mode

Atmosphere
2nd extra-tropical mode

CPW
Central Pacific Warming
*non-Canonical ENSO*
(mature)

ENSO
Eastern Pacific
*Canonical ENSO*
(mature)

Tropics [Ocean-Atmosphere Coupled System]
Model for explaining Pacific decadal dynamics

Extra-tropics [ Ocean forced by Atmosphere ]

Atmosphere
1st
extra-tropical mode

Ocean
1st
extra-tropical mode

Atmosphere
2nd
extra-tropical mode

Ocean
2nd
extra-tropical mode

CPW
Central Pacific Warming
non-Canonical ENSO
(mature)

ENSO
Eastern Pacific
Canonical ENSO
(mature)

Tropics [ Ocean-Atmosphere Coupled System ]
Model for explaining Pacific decadal dynamics

Atmosphere
1st extra-tropical mode

Ocean
1st extra-tropical mode

CPW
Central Pacific Warming
*non-Canonical ENSO*
(mature)

ENSO
Eastern Pacific
*Canonical ENSO*
(mature)

Atmosphere
2nd extra-tropical mode

Ocean
2nd extra-tropical mode
Model for explaining Pacific decadal dynamics

Atmosphere
1st extra-tropical mode

Ocean
1st extra-tropical mode

CPW
Central Pacific Warming
non-Canonical ENSO
(mature)

ENSO
Eastern Pacific
Canonical ENSO
(mature)

Atmosphere
2nd extra-tropical mode

Ocean
2nd extra-tropical mode
Model for explaining Pacific decadal dynamics

ENSO
Eastern Pacific
Canonical ENSO (mature)

AL
Aleutian Low
Trenberth and Hurrell 1995 atmosphere
(winter)

CPW
Central Pacific Warming
non-Canonical ENSO (mature)

Ocean 1st extra-tropical mode

Atmosphere 2nd extra-tropical mode

Ocean 2nd extra-tropical mode
Model for explaining Pacific decadal dynamics

Atmosphere
2nd extra-tropical mode

Ocean
1st extra-tropical mode

1st extra-tropical mode

Ocean
2nd extra-tropical mode

CPW
Central Pacific Warming
non-Canonical ENSO (mature)

ENSOS
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Aleutian Low
Trenberth and Hurrell 1995 atmosphere (winter)

Atmosphere
2nd extra-tropical mode
Model for explaining Pacific decadal dynamics

**Atmosphere**
- 2nd extra-tropical mode
- **AL**
  - Aleutian Low
  - *Trenberth and Hurrell 1995*
  - atmosphere
  - *(winter)*

**Ocean**
- 2nd extra-tropical mode
- **PDO**
  - Pacific Decadal Oscillation
  - *Mantua et al. 1997*
  - ocean
  - *(winter)*

**Central Pacific Warming**
- **CPW**
  - *non-Canonical ENSO*
  - *(mature)*

**Eastern Pacific**
- **ENSO**
  - Canonical ENSO
  - *(mature)*

**Eastern Pacific**
- **ENSO**
  - Canonical ENSO
  - *(mature)*
Model for explaining Pacific decadal dynamics

Atmosphere
- Atmosphere 2nd extra-tropical mode
- AL: Aleutian Low (winter)
  - Trenberth and Hurrell 1995
- ENSO: Eastern Pacific
  - Canonical ENSO (mature)
  - Mantua et al. 1997
  - Pacific Decadal Oscillation (PDO)
  - Pacific Decadal Oscillation (PDO)
  - Mantua et al. 1997
  - Ocean "winter"
- Atmospheric Bridge
  - Alexander, 1992; 2002
  - Newman et al., 2003
  - Vimont et al. 2005
  - Schneider and Cornuelle 2005

Ocean
- Ocean 2nd extra-tropical mode
- CPW: Central Pacific Warming
  - non-Canonical ENSO (mature)
Model for explaining Pacific decadal dynamics

**AL**
Aleutian Low
*Trenberth and Hurrell 1995*
*atmosphere*
*(winter)*

**PDO**
Pacific Decadal Oscillation
*Mantua et al. 1997*
*ocean*
*(winter)*

**NPO**
North Pacific Oscillation
*Walker and Bliss, 1932*
*Rogers, 1981*
*atmosphere*
*(winter)*

**CPW**
Central Pacific Warming
*non-Canonical ENSO*
*(mature)*

**ENSO**
Eastern Pacific
* Canonical ENSO
*(mature)*

**Atmospheric Bridge**
*Alexander, 1992; 2002*
*Newman et al., 2003*
*Vimont et al. 2005*
*Schneider and Cornuelle 2005*
Model for explaining Pacific decadal dynamics

- **AL**
  - Aleutian Low
  - Trenberth and Hurrell 1995
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  - Canonical ENSO (mature)

- **NPO**
  - North Pacific Oscillation
  - Walker and Bliss, 1932
  - Rogers, 1981
  - atmosphere (winter)

- **NPGO**
  - North Pacific Gyre Oscillation
  - Di Lorenzo et al. 2008
  - ocean (winter)

**Atmospheric Bridge**
- Alexander, 1992; 2002
- Newman et al., 2003
- Vimont et al. 2005
- Schneider and Cornuelle 2005
Model for explaining Pacific decadal dynamics

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(winter)

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**Atmospheric Bridge**
*Alexander, 1992; 2002*
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*Vimont et al. 2005*
*Schneider and Cornuelle 2005*

**ENS**
Eastern Pacific
*Canonical ENSO (mature)*

Di Lorenzo et al. 2010
Model for explaining Pacific decadal dynamics

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Central Pacific Warming
non-Canonical ENSO (mature)


“CPW becoming more frequent”
Model for explaining Pacific decadal dynamics

**Central Pacific Warming (non-Canonical ENSO)**

*Change in variance significance 97%*

*99% Significance level*

*after 1980*

**CPW**


“CPW becoming more frequent”

**ENSO**

- Eastern Pacific Canonical ENSO (mature)
- Atmospheric Bridge
  - Alexander, 1992; 2002
  - Newman et al., 2003
  - Vimont et al. 2005
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**NPO**

- North Pacific Oscillation
  - Walker and Bliss, 1932
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- North Pacific Gyre Oscillation
  - Di Lorenzo et al. 2008

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  - Mantua et al. 1997
  - Di Lorenzo et al. 2010

**Atmospheric Bridge**

- Atmospheric Bridge
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**CPW**

- Central Pacific Warming
  - non-Canonical ENSO
  - (mature)


“CPW becoming more frequent”
Model for explaining Pacific decadal dynamics

**ENSO**
- **Eastern Pacific Canonical ENSO (mature)**
- **Trenberth and Hurrell 1995 atmosphere (winter)**
- **Rogers, 1981 atmosphere (winter)**

**PDO**
- **Pacific Decadal Oscillation**
- **Mantua et al. 1997 ocean (winter)**
- **Di Lorenzo et al. 2010 ocean (winter)**

**NPO**
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- **Walker and Bliss, 1932**
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- **Di Lorenzo et al. 2008 ocean (winter)**

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**Atmospheric Bridge**
- **Alexander, 1992; 2002**
- **Newman et al., 2003**
- **Vimont et al. 2005**
- **Schneider and Cornuelle 2005**

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**QUESTION:**
Is this change in variance driven by climate change? *after 1980*

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**CPW**
- **Central Pacific Warming non-Canonical ENSO (mature)**

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Nature, 461, 511-U570.

“CPW becoming more frequent”
Model for explaining Pacific decadal dynamics

**AL**
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atmosphere (winter)

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*non-Canonical ENSO* (mature)

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ocean (winter)

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atmosphere (winter)

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Alexander, 1992; 2002
Newman et al., 2003
Vimont et al. 2005
Schneider and Cornuelle 2005

**QUESTION:**
Is this change in variance driven by climate change?

Journal of Climate, 24, 3294-3308.
Model for explaining Pacific decadal dynamics

Sr/Ca SST Proxy (1880-2000) from Palmyra Atoll


NPO
North Pacific Oscillation
Walker and Bliss, 1932
Rogers, 1981
atmosphere (winter)

NPGO
North Pacific Gyre Oscillation
Di Lorenzo et al. 2008
ocean (winter)

Eastern Pacific
Canonical ENSO (mature)

Vimont et al. 2005
Schneider and Cornuelle 2005

CPW (Non-Canonical ENSO)

Palmyra Atoll coral proxy

Differences in Variance (normalized units)
Model for explaining Pacific decadal dynamics

Sr/Ca SST Proxy (1880-2000) from Palmyra Atoll

R = 0.44

NPGO Index

1900 1920 1940 1960 1980 2000

NPO
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Rogers, 1981
atmosphere (winter)

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ocean (winter)

CPW (Non-Canonical ENSO)

Journal of Climate, 24, 3294-3308.
Model for explaining Pacific decadal dynamics

**Sr/Ca SST Proxy (1880-2000) from Palmyra Atoll**

- **8 year lowpass**
- **R=0.85**

**NPGO Index**

- **NPO**
  - North Pacific Oscillation
  - Walker and Bliss, 1932
  - Rogers, 1981
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- **PDO**
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  - Mantua et al. 1997
  - ocean (winter)
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  - Di Lorenzo et al. 2008
  - ocean (winter)

**CPW (Non-Canonical ENSO)**

- **Nurhati, I.S., Cobb, K.M., Di Lorenzo, E., 2011.**
  - Journal of Climate, 24, 3294-3308.

**Acorus Palmyra Atoll coral proxy (1900-2000)**

- **Vimont et al. 2003**
- **Schneider and Cornuelle 2005**

**Eastern Pacific Canonical ENSO (mature)**
Model for explaining Pacific decadal dynamics

Exploring changes in ENSO variance back to 7000 years ago

Model for explaining Pacific decadal dynamics

Significant increase in ENSO variance in this century compared to last 7,000 years

Can we use IPCC climate model to forecast the changes in North Pacific variance?
Model for explaining Pacific decadal dynamics

AL
Aleutian Low
Trenberth and Hurrell 1995
atmosphere (winter)

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ocean (winter)

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AL
Aleutian Low

PDO
Pacific Decadal Oscillation

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North Pacific Oscillation

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North Pacific Gyre Oscillation

CPW
Central Tropical Pacific Warming
(non-Canonical ENSO
(mature))

ENSO
Canonical ENSO
(mature)

Atmospheric Bridge
Test the AR4 models Pacific decadal dynamics 1800-2000

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Test the AR4 models Pacific decadal dynamics 1800-2000

Atmospheric Bridge

AL
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Pacific Decadal Oscillation

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North Pacific Oscillation

NPGO
North Pacific Gyre Oscillation

CPW
non-Canonical ENSO (mature)

ENSO
Canonical ENSO (mature)

Furtado et al., 2011
Test the AR4 models Pacific decadal dynamics 1800-2000

Combined EOF analysis of SLP/SST

dominant modes of ocean/atmosphere covariability

Furtado et al., 2011
Test the AR4 models Pacific decadal dynamics 1800-2000

- **AL**: Aleutian Low
- **PDO**: Pacific Decadal Oscillation
- **NPO**: North Pacific Oscillation
- **NPGO**: North Pacific Gyre Oscillation

**Observations**

- **AL**: Atmosphere Sea Level Pressure
- **PDO**: Ocean Sea Surface Temperature

**Ocean/Atmosphere Combined EOF Mode 1**

*Furtado et al., 2011*
Test the AR4 models Pacific decadal dynamics 1800-2000

Al
Aleutian Low

PDO
Pacific Decadal Oscillation

NPO
North Pacific Oscillation

NPGO
North Pacific Gyre Oscillation

Observations

AR4 Models (Ensemble Mean)

Ocean/Atmosphere Combined EOF Mode 1

Furtado et al., 2011
Test the AR4 models Pacific decadal dynamics 1800-2000

- **ENSO**
  - Canonical ENSO (mature)
  - Central Tropical Pacific Warming (onset)

- **Observations**
  - **NPO**
    - North Pacific Oscillation
  - **PDO**
    - Pacific Decadal Oscillation
  - **NPGO**
    - North Pacific Gyre Oscillation

- **Maps**
  - Atmosphere Sea Level Pressure
  - Ocean Sea Surface Temperature

- **Ocean/Atmosphere Combined EOF Mode 2**

*Furtado et al., 2011*
Test the AR4 models Pacific decadal dynamics 1800-2000

- **AL**: Aleutian Low
- **NPO**: North Pacific Oscillation
- **NPGO**: North Pacific Gyre Oscillation
- **PDO**: Pacific Decadal Oscillation

**Observations**

- **NPO**
- **NPGO**

**AR4 Models (Ensemble Mean)**

- **Atmosphere Sea Level Pressure**
- **Ocean Sea Surface Temperature**

**Ocean/Atmosphere Combined EOF Mode 2**

*Furtado et al., 2011*
Test the AR4 models Pacific decadal dynamics 1800-2000

Atmospheric Bridge

AL
Aleutian Low

PDO
Pacific Decadal Oscillation

NPO
North Pacific Oscillation

NPGO
North Pacific Gyre Oscillation

ENSO
Canonical ENSO
(mature)

CPW
non-Canonical ENSO
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Furtado et al., 2011
Test the AR4 models Pacific decadal dynamics 1800-2000

Atmospheric Bridge

NPGO
North Pacific Gyre Oscillation

NPO
North Pacific Oscillation

CPW
non-Canonical ENSO
(mature)

ENSO
Canonical ENSO
(mature)

PDO
Pacific Decadal Oscillation

AL
Aleutian Low
Test the AR4 models Pacific decadal dynamics 1800-2000

CP El Niño pattern emerges as 2nd mode
Tropics [12S 12N]

Ocean/Atmosphere Combined EOF Mode 2

Furtado et al., 2011
Test the AR4 models Pacific decadal dynamics 1800-2000

Furtado et al., 2011
Test the AR4 models Pacific decadal dynamics 1800-2000

Ocean/Atmosphere Combined EOF Mode 2

Furtado et al., 2011
IPCC climate model AR-4 do not consistently reproduce the decadal dynamics of the Pacific, the structure and variability of ENSO and its teleconnections.

Furtado et al., 2011
ASSUME:
The North Pacific variance is increasing in response to greenhouse forcing
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ASSUME: The North Pacific variance is increasing in response to greenhouse forcing.
Model for explaining Pacific decadal dynamics

### Ecosystem Variability

**ASSUME:** The North Pacific variance is increasing in response to greenhouse forcing.