Ocean-Atmosphere Structure of Pacific Decadal Variability

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Outline

• Another Pacific SST analysis? Why?
• Method, Findings, Evaluation
• ENSO Variability: Canonical & Non-canonical
• Pacific Decadal Variability: Pan-Pacific & North Pacific
• Inter-Basin links and Atlantic Multidecadal Oscillation
• Application (Terrestrial): North American Droughts
• Upper-air and subsurface PDV structure: Preliminary
Another Pacific SST Analysis?

Perhaps, one leading to refined *evolution* descriptions from *contextual* separation of natural variability and the secular trend without any advance filtering (and potential aliasing) of the SST record.

**GOAL:** Obtain robust characterization of *ALL* non-seasonal modes of Pacific SST variability, including trend, from a *single* analysis of *unfiltered* data.
Extended EOF Analysis

- Targets both spatial and temporal recurrence
- No temporal periodicities are imposed
- EEOF differs from EOF only in anomaly definition:
  \[ \psi(x,y,to) \]
  \[ \text{EEOF: [..., \psi(x,y,to-\Delta t), \psi(x,y,to), \psi(x,y,to+\Delta t),...]} \]
- Temporal recurrence analyzed with a 1-year sampling window; 5 staggered seasonal data bands
- Hadley SSTs are analyzed; an all-season, covariance-based analysis
- Pan Pacific analysis domain: 120E-60W; 20S-60N
- EEOFs are rotated
- Mode physicality assessed from analog counts and correlations with biological time series
The SST Principal Components

Nonstationary secular trend

ENSO: 4 modes

Pacific decadal variability: 2 modes
Canonical ENSO

SST regressions
CI=0.1K
Non-Canonical ENSO Variability

SST regressions
CI=0.1K
SST Evolution at the Equator: \textsuperscript{NC}ENSO Impact

SST regressions
CI = 0.1 K

Raw SST regressed on raw Niño3.4 index

Above + BIENNIAL (4 modes)

Before 1976/77 After
Correlation of Standard and Synthetic Nino3.4 SST indices (1900-2002)

- $R_{[\text{STN}, (\text{ENSO}^- + \text{ENSO}^+)]} = 0.84$
- $R_{[\text{STN}, (\text{ENSO}^- + \text{ENSO}^+ + \text{ENSO}^{\text{NC}})]} = 0.92$
- $R_{[\text{STN}, (\text{ENSO}^- + \text{ENSO}^+ + \text{ENSO}^{\text{NC}} + \text{Biennial})]} = 0.95$
Pan-Pacific Decadal Variability

SST Correlations
CI=0.1, beginning at 0.2

Features
- Clockwise development leading to ‘horse-shoe’ Pacific structure
- Quiescent central/eastern Eq. Pacific
- NOT “ENSO-like”
- Strong links to the western Atlantic
- Weak links to the Indian Ocean
- Not the PDO either ($r=0.23$)
- Captures the 1920s climate shift
- Link to the AMO??
PDV-Pan Pacific and the PDO

(a) REEOF PC4: PDV^{pp}, r=0.16, Winter=0.15

Curve: PDO index  Shading: PDV-PP (both smoothed)
North Pacific Decadal Variability

SST Correlations
CI=0.1, beginning at 0.2

Features
• Zonal band in the midlatitude Pacific
• Modest links to the eastern Pacific
• Strong connection to Indian Ocean and the western tropical Pacific
• Captures the 1976/77 climate shift
• PDO correspondence ($r=-0.57$)
PDV-North Pacific and the PDO

Curve: PDO index  Shading: PDV-NP (both smoothed)

(a) REEOF PC6: $PDV^{NP}$, $r = -0.89$, Winter = $-0.90$
Physicality of the PDV Modes

• Biological evidence?

<table>
<thead>
<tr>
<th>Biological time series</th>
<th>PDV\textsuperscript{PP}</th>
<th>PDV\textsuperscript{NP}</th>
<th>PDO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Pacific zooplankton biomass</td>
<td>0.54</td>
<td>0.10</td>
<td></td>
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<td>British Columbia coho salmon catch</td>
<td>−0.42</td>
<td>−0.17</td>
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<td>Gulf of Alaska halibut recruitment</td>
<td>−0.74</td>
<td>0.73</td>
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<td>West Coast mackerel recruitment</td>
<td>−0.73</td>
<td>0.66</td>
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</tbody>
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(Biological time series courtesy of Nate Mantua)
Secular Trend in 20th Century Pacific SSTs

Global SST regressions, CI=0.1K

Features

• Non-stationary trend, with mid-century cooling
• Largest signal off the east coast of Asia and North America
• PC very similar to SAT and ocean heat content trends
• Pervasive warming except in the central equatorial Pacific & off the tip of Greenland
Inter-basin links and the AMO

AMO-Atl: The leading mode of residual Atlantic SST variability
(Residual: Leftover after filtering Atlantic footprints of Pacific SST variability)

Pattern Evolution (SST regressions, CI=0.1K)
The Great Plains
(35-45N; 90-100W; almost a million Km²)

Terrestrial Application
North American Multi-Year Droughts

The 1931 Summer – 1939 Fall
'Dust Bowl' drought

The 1953-1956
1950s drought

The 1982-1986
1980s wet period
Precipitation Reconstruction
CI=0.1 mm/day

Dust Bowl Summer

Dust Bowl Spring

1950s Drought Fall
(Sum recons. FAILED; hypothesis)

1980s Wet Period Fall
PDV-NP
Atmospheric Structure (WINTER)
(1908 – 2002; Preliminary)

- SST correlations: CI=0.1, shaded red/blue when >0.2
- Geop_700 correlations: CI=0.1; contoured in red when >0.2
- 1000 hPa wind regressions, plotted when speed>0.4 m/s
PDV-NP
Subsurface Structure (ALL-season)
(1958 – 2001; Preliminary)

• SST correlations: CI=0.05, shaded red/blue when >0.1

• OHC500 (from SODA1.4.2) correlations: CI=0.07 contoured in red when >0.14
Concluding Remarks

• An evolution-centric analysis provides interesting characterization of PDV, and some insights into its origin

• PDV consists of two modes: North Pacific & Pan Pacific; neither is “ENSO-like”; ENSO\textsuperscript{NC} is the LF ENSO-like mode

• PDV-NP exhibits strong links to the Tropics (IO, WP, EP)

• PDV-PP exhibits interesting links to tropical/subtropical Atlantic; factoring these leads to clarified AMO structure

• Unprecedented extent and efficiency with which multi-year continental droughts are reconstructed is reassuring for the SST analysis scheme: Oceanic droughts – a future target?

• Preliminary analysis of atmospheric and subsurface PDV structure: Trepidations in leaving Terra Firma
Based on


Pacific Meridional Mode vs. Non-canonical ENSO

Chiang and Vimont (2004)
Biennial Variability (3.5%)
Winter Z500 Regressions

ENSO$^-$

ENSO$^+$

ENSONC

PDV$^{PP}$

PDV$^{NP}$

Trend

Biennial
**Trend**

**Trend Mode** (K per unit PC; 10.2%)  **Linear Trend** (K per century)

\[ \Delta PC \approx 3 \text{ units per century} \]