Nonlinear change in the variability of North Pacific climate: are biological systems responding?

Michael Litzow\textsuperscript{1,2}, William J. Sydeman\textsuperscript{2}, David Schoeman\textsuperscript{3}, Sanae Chiba\textsuperscript{4}, Marisol Garcia-Reyes\textsuperscript{2}, Michael Malick\textsuperscript{5}, Hiroya Sugisaki\textsuperscript{6}, Sarah Ann Thompson\textsuperscript{2}

\textsuperscript{1} University of Tasmania, Hobart, TAS, 7001, Australia. E-mail: malitzow@utas.edu.au
\textsuperscript{2} Farallon Institute for Advanced Ecosystem Research, Petaluma, CA 94952, U.S.A.
\textsuperscript{3} University of the Sunshine Coast, Maroochydore, QLD 4558, Australia
\textsuperscript{4} Research Institute for Global Change, JAMSTEC, Yokohama, Kanagawa, 236-0001, Japan
\textsuperscript{5} Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada
\textsuperscript{6} Fisheries Research Agency, Yokohama, 220-6115, Japan
Motivation

Perception of climate change

The greatest barrier to public recognition of human climate change is probably the natural variability of mean. How can a person discern long-term climate change from the notorious variability of local weather and climate from day to year to year?

This question assumes great practical importance in the need for the public to appreciate the significance of recent global warming. Actions often intended to cause global warming are unlikely to approach what is needed to make the public recognize that human-made climate change is underway and perceive it as an unacceptable phenomenon unless actions are taken to slow the change. A recent survey in the United States (1) found that public opinion about the existence and importance of climate warming depends strongly on their perception of actual climate variations. Early public recognition of climate change is critical. Stabilizing climate with conditions resembling the Holocene, in which civilization developed, can only be achieved if rapid reductions of fossil fuel emissions are made (2).

It was suggested decades ago (3) that by the early 21st century, the informed public should be able to recognize this change in unusually warm seasons had increased. "Climate change," describing the probability of unusually unusually cool seasons, would be sufficiently loaded to be disseminated to the public. Recent high-profile events such as the one in Texas and Oklahoma in the summer of 2011 have raised the question of whether these extreme events are the on-going global warming trend, which has been occurring.
Motivation

Ecological consequences of increasing climate variability

Climate

How does increasing variability in this process...

Climate in year $t$:

$$x_t = 0.7 x_{t-1} + \varepsilon$$

Biology

...affect this process?

Biology in year $t$:

$$y_t = 0.9 x_t + 0.9 y_{t-1} + \varepsilon$$
Motivation

Ecological consequences of increasing climate variability
Goals:

• Test for increasing variability in N. Pacific SST
  – Test for correlates to changing SST variability
• Test for accompanying variability increases in long-term biology observations
Approach (turns out to be important!)

Hansen et al. 2012 PNAS

**Perception of climate change**

*James Hansen*, *Makiko Sato*, and *Reto Ruedy*

*National Aeronautics and Space Administration Goddard Institute for Space Studies*

Approach

• Calculate variability with anomalies from base period:

\[
\left( x - \bar{x}_{1951-1980} \right) / SD_{1951-1980}
\]

Conclusion

Pervasive global increase in surface temperature variability

Huntingford et al. 2013 Nature

**No increase in global temperature variability despite changing regional patterns**

*Chris Huntingford*, *Philip D. Jones*, *Valerie N. Livneh*, *Timothy M. Lenton*, and *Peter M. Cox*

Approach

• Calculate variability without reference to base period

Conclusions

• Variability increase an order of magnitude less than Hansen et al.
• Predict decreasing global variability with global warming
Goal 1: Test for increasing variability

**Basin-scale variability trend**

**Data:**
- HadISST dataset
- 20°-66°N
- 1°×1° grid (4,491 cells)
- 1951-2012
- Weighted mean and variance
- Months including ice removed
- Annual anomalies (detrended data)
Goal 1: Test for increasing variability

Declining basin-scale variability

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**Goal 1:** Test for increasing variability

18% increase

18% decrease

N. Pacific SST variability

Penalized regression splines randomized p < 0.0001

SD (11-yr running window) vs. Year
Goal 1: Test for increasing variability

Spatial pattern in variability trends

% change in SD, 1951–1970 to 1993–2012

%
Goal 1: Test for increasing variability

Spatial pattern in variability trends
Goal 1: Test for increasing variability

Possible correlates of changing variability – change in the mean?

Change in SD (%), 1951-1970 to 1993-2012

\[ r = 0.06 \]

Change in mean (°C), 1951-1970 to 1993-2012
Goal 1: Test for increasing variability

Possible correlates of changing variability – increased importance of the NPGO?

Change in SD (%), 1951-1970 to 1993-2012

NPGO pattern (EOF2 – SSTa)
Goal 1: Test for increasing variability

Possible correlates of changing variability – increased importance of the NPGO?

Change in SD (%), 1951-1970 to 1993-2012

Overall $R^2 = 0.29$
Goal 2: Test for increasing variability

Spatial pattern in variability trends
Goal 2: Test for increasing variability

Connected climatic & biological variability – a first-look hypothesis
Goal 2: Test for increasing variability

**Connected climatic & biological variability – approach**

<table>
<thead>
<tr>
<th>System</th>
<th>Data</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oyashio/Transition</td>
<td>abundance 10 spp. copepod</td>
<td>1960-2002</td>
</tr>
<tr>
<td>S. California Current</td>
<td>abundance - 9 taxa ichthyoplankton, 3 spp. euphausids</td>
<td>1951-2011</td>
</tr>
</tbody>
</table>
Goal 2: Test for increasing biological variability

**Connected climatic & biological variability – approach**

**Analysis**

• Species/taxon as sampling unit

• All groups normalized/detrended

• Multiple imputation to estimate missing values in Bering/GOA

• SD calculated across all groups for 11-yr sliding windows
Goal 2: Test for increasing biological variability

Does biological variability track climatic variability?

$r = 0.64, p' < 0.01$
Goal 2: Test for increasing biological variability

Does biological variability track climatic variability?

- **Bering Sea/Gulf of Alaska**
  - $r = 0.64$, $p' < 0.01$

- **Oyashio/Transition Zone**
  - $r = -0.39$, $p' > 0.5$

- **S. California Current**
  - $r = -0.22$, $p' > 0.5$
Goal 2: Test for increasing biological variability

Does biological variability track climatic variability?

1976/77
Conclusions

• Basin-scale decrease in SST variability
• Great variability in regional variability trends
• No uniform biological response to changing SST variability

Fundamentally regional-scale problems
Our thanks to:
• Tohoku National Fisheries Research Unit for providing Odate zooplankton data
• Rod Towell and Tom Gelatt (NOAA/NMML) for providing Pribilof Is. fur seal data
• CalCOFI for zooplankton/ichthyooplankton data
• CRU/UEA for making HadISST publicly available
• Franz Mueter for providing EOF code
• PICES, UTAS, CSIRO for travel support