what do global climate models say about increasing variance in the california current upwelling ecosystem

marisol garcía-reyes
farallon institute for advanced ecosystem research

william sydeman, ryan rykaczewski, allison wiener, isaac schroeder & steven bograd
referred to as the central tropical Pacific warming (El Nin˜o (Kug et al., 2009), drives the dominant decadal scale fluctuations of the NPGO (Di Lorenzo et al., 2010), implying that a large fraction of the interannual and decadal power of the CCS originates from the tropical Pacific.

Superimposed on the variability driven by the large-scale climate fluctuations, local wind variability along the eastern boundary has been demonstrated to excite coastally trapped waves, which propagate into the CCS from the south, affecting the coastal variability (Battisti and Hickey, 1984).

Primary productivity
Seasonal variability of primary production in the CCS can be divided into three periods, based on prevailing wind patterns.

Figure 3.
Generalized regional variations in physical and biological processes within the CCS. The boundaries between regions are only approximate and vary over time (from Agostini, 2005).
Increasing variance in North Pacific climate relates to unprecedented ecosystem variability off California

WILLIAM J. SYDEMAN*, JARROD A. SANTORA*, SARAH ANN THOMPSON*, BALDO MARINOVIC† and EMANUELE DI LORENZO‡
ecosystem sensitivity to winter upwelling variability

garcía-reyes et al., 2013

garcía-reyes et al., 2013
choosing the indicators
climate indicators driving ecosystem variability

• upwelling: winds and temperature

• winter time
and its peaks and troughs occurring 1–2 months later in the year increasing over the period (component varied in the opposite manner, with its amplitude the year over the length of the record (Figure 2d). The semi-annual component has changed as well, (2.5 mb in 1950) is twice as large as in the early 1990s (1.2 mb in 1992). The phase of the annual component has changed as well, (Figure 1). Maps of 1948–2000 mean sea level pressure over the summer (June–August). Data are reanalysis products from the National Centers for Environmental Prediction. Locations of the Aleutian Low (50\°N, 180\°W) and North Pacific High (30\°N, 135\°W) Sea Level Pressure Time Series, 1948–2000. Variability at semi-annual frequencies is particularly highly correlated between these pressure centers, with the highest correlation at latitudes of 45\°N–55\°N, and 170\°W–160\°W (Table 2). The correlations are significant for the annual, semi-annual, and full seasonal components when the NPH lags the Siberian High by one month. Variance Ratios (% of Seasonal Total) of the Seasonal Components for the Northern Hemisphere for the period 1977–2000 (Table 1), there has been a substantial trend to a relatively doubled seasonal amplitude. Since the late 1980s, in fact, the amplitude of both the annual and semi-annual components has increased substantially since the mid-1970s, resulting in a nearly quadrupled seasonal amplitude. The magnitude of this seasonal modulation are obvious. The maxima of the annual and semi-annual components occur nearly in September (Figure 2c). Interannual to decadal scale fluctuations in the spring during the early part of the record (Figure 2e). Thus, the spring seasonal phase of the NPH, with the spring peak occurring in February–March during the 1950s, in May through most of the 1980s, and in April during the 1990s (Figure 3b). An earlier spring peak in the 1990s relative to the 1980s has also been recently observed in the Bering Sea [2001], Table 1), there has been a substantial trend to a relatively higher semi-annual amplitude. Since the late 1980s, in fact, the semi-annual component has been the dominant seasonal frequency band in the seasonal cycle. This is a deeper wintertime low after 1976 (Figure 1c). The entire structure of the seasonal cycle has changed in the NPH, with the semi-annual component deepening (fills) the low by 5–7 mb during December–February (March–June), while the upwelling winds driver
winter upwelling and the NPH

Correlation SLP-V (Dec-Feb)

Longitude vs UI

Latitude vs UI

Area vs UI

Maximum pressure vs UI

Schroeder et al., 2013
climate indicators driving ecosystem variability

- upwelling: winds and temperature

- winter time
climate indicators driving ecosystem variability

• upwelling: winds and temperature

• winter time
climate indicators driving ecosystem variability

• upwelling: winds and temperature
  • sea level pressure

• winter time

• spatial and temporal scales adequate for the use of global climate models
change in variance

past

future

García-Reyes & Sydeman. 2012, PICES

Macias et al. 2012
mechanism for increased variance unknown

- natural Pacific climate oscillations
- anthropogenic climate change
- regional changes
how to test a change in variance

- long time series, with enough temporal resolution

<table>
<thead>
<tr>
<th>Past</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>regional models</td>
<td>local processes</td>
</tr>
<tr>
<td>global models</td>
<td>large scale ones are prescribed</td>
</tr>
<tr>
<td></td>
<td>global change &amp; large scale processes</td>
</tr>
<tr>
<td></td>
<td>no local processes</td>
</tr>
</tbody>
</table>
mechanism for increased variance unknown

• natural pacific climate oscillations
• anthropogenic climate change
• regional changes

GCM models
IPCC AR5
(CMIP5)
**IPCC AR5 - CMIP5**

- 38 models output, 21 “different” models
- RCP8.5
- period: 2006-2095

### Modeling Center (or Group) | Institute ID | Model Name
--- | --- | ---
Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Meteorology (BOM), Australia | CSIRO-BOM | ACCESS1.0
 |  | ACCESS1.3
Beijing Climate Center, China Meteorological Administration | BCC | BCC-CSM1.1
 |  | BCC-CSM1.1(m)
Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research) | INPE | BESM OA 2.3
College of Global Change and Earth System Science, Beijing Normal University | GCESS | BNU-ESM
Canadian Centre for Climate Modelling and Analysis | CCCMA | CanESM2
 |  | CanCM4
 |  | CanAM4
University of Miami - RSMAS | RSMAS | CCSM4(RSMAS)*
National Center for Atmospheric Research | NCAR | CCSM4
Community Earth System Model Contributors | NSF-DOE-NCAR | CESM1(BGC)
 |  | CESM1(CAM5)
 |  | CESM1(CAM5.1,FV2)
 |  | CESM1(FASTCHEM)
 |  | CESM1(WACCM)
Center for Ocean-Land-Atmosphere Studies and National Centers for Environmental Prediction | COLA and NCEP | CFSv2-2011
Centro Euro-Mediterraneo per I Cambiamenti Climatici | CMCC | CMCC-CESM
 |  | CMCC-CM
 |  | CMCC-CMS
Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancée en Calcul Scientifique | CNRM-CERFACS | CNRM-CM5
 |  | CNRM-CM5-2
Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence | CSIRO-QCCCE | CSIRO-Mk3.6.0
EC-EARTH consortium | EC-EARTH | EC-EARTH
LASY, Institute of Atmospheric Physics, Chinese Academy of Sciences and CESS, Tsinghua University | LASG-CESS | FGOALS-g2

### Models Output
- Output from highlighted models is available for unrestricted use.
- Output from others may only be used for non-commercial research and educational purposes.

CMIP5 models resolution
Dec-Feb

Schroeder et al. 2013

Apr-Aug
not all models are made equal
not all models are made equal

best representation of the NPH
2nd-round models
The highest correlation among variables is between the monthly average of sea level pressure at a coastal tide gauge and the maximum sea level pressure within the 1020 hPa contour and the weighted center of the 1020 hPa contour. The maximum sea level pressure and its amplitude (in cm) are strongly correlated with the normalized upwelling index (NUI) at all eight locations. The maximum sea level pressure explains 38.0%, 51.3%, and 54.3% of the overall variance, respectively, for latitude, longitude, and position coordinates.

While the seasonal signals are relevant, correlations among these variables occur between January and May. So, when the NPH is strong in January, it is likely to lead to enhanced upwelling. This correlation is strongest in February and March.

When the seasonal signals are removed, all variables correlate with the maximum sea level pressure at coastal tide gauges. The maximum sea level pressure correlates negatively with longitude, especially during winter. Thus, the NPH center tends to be farther offshore or farther to the west. The NPH center can be located as far south as 23 degrees south or as far north as 36 degrees north, have higher maximum pressure, and a larger area (1020 km²) such that the NPH center tends to be farther offshore (1570 km) or farther to the west. The seasonal cycle of the four position terms is stronger in January, and those of latitude, longitude, and position coordinates are stronger in February and March.

The latitude of the maximum sea level pressure and the maximum sea level pressure correlate significantly with the monthly average of the normalized upwelling index (NUI), sea level from coastal tide gauges, and sea surface temperature over the course of the year. However, the strongest correlation from January into early spring. So, when the NPH is strong in January, it is likely to lead to enhanced upwelling.
Maximum SLP over NPH region
Maximum SLP over NPH region
Difference Maximum and Minimum SLP
Models ensemble
Difference Maximum and Minimum SLP Models ensemble

\[ -0.1 \text{hPa/decade} \]
Difference Maximum and Minimum SLP Models ensemble

-0.1 hPa/decade
Latitude of Maximum SLP

SLP Climatology

Summer

Winter
We associate the position and amplitude of the NPH (anomalies) with pulses in upwelling in January. Time series of upper-trophic biological productivity were then collected near this latitude. We interpret the NPH location and strength is lowest during the summer and shifts northwestward through the spring and summer. The position and amplitude of the NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological

The NPH is of the lowest amplitude (low NPI values indicate a more intense winter, February) NPH was compared to winter values of the Multivariate ENSO Index (MEI) as sea ice and SST data set. To put the central region into context Hadley Centre. We used the grid point located closest to the shore over the study region. To assess linkages with the broader Pacific basin, the North Pacific Index (NPI) was calculated for all UI locations mentioned above, the daily UI between January 1 and March 1 each year. The pCUI, or pre-conditioning cumulative upwelling index, is calculated by averaging the SLP over the 300 hPa isobar. Position of the NPH for a given year; color denoted the area of the 1020 hPa contour. The black contour is the climatological
no change in SLP variability
how well models represent variability & its change?

no change in SLP variability

IPCC Climate Models Future Projections

Indices of Climate Forcing relevant to specific Ecosystems

Ecosystem response to Climate

Dynamics

Climate Variability & Change

Mechanisms
how well models represent variability & its change?

no change in SLP variability

IPCC Climate Models Future Projections

temperature?

SLP <=> winds?

Indices of Climate Forcing relevant to specific Ecosystems

Ecosystem response to Climate

Dynamics

Climate Variability & Change

Mechanisms
how well models represent variability & its change?

no change in SLP variability

IPCC Climate Models Future Projections

temperature?

SLP <=> winds?

- is lack of change or models’ skill?
- match with observed increasing variability in winds?
- ensemble method appropriate?