Multi-Year Persistence of the 2014–15-16 West Coast Marine Heat Wave

Nate Mantua
Southwest Fisheries Science Center
Santa Cruz, CA

Collaborators: Jim Johnstone, Nick Bond, Megan Cronin, Paul Fiedler, Howard Freeland, and Manu DiLorenzo
• Gulf of Alaska began warming in Fall 2013

• Baja and So. California near-shore from June 2014 – August 2016

Wide-ranging impacts on Pacific marine life
California Current Sea Surface Temperature Anomaly (relative to 1981-2010)

Fiedler and Mantua, in prep
Ridiculously Resilient Ridge(s) are to blame!

- A few “ridge patterns” kept storms away and temperatures high in CA
- What caused the atmosphere to get stuck like this?

*Unusual warm-west cool-east temperatures in the tropical Pacific? The warm Arctic and reduced sea ice cover? The warmth of the northeast Pacific Ocean? A combination of these factors?*
In winter 2013-14 extreme warm temperature anomalies developed under the influence of an extremely persistent high pressure anomaly in the NEP.
Mechanisms “warming” the Blob

- Blob region September to February mixed-layer temperature changes from the NCEP GODAS
- Weak wind stress and wind stress curl reduced entrainment, reduced net surface heat fluxes, and reduced advective cooling all combined to create extreme warm anomalies in fall/winter 2013-14

Bond et al: Geophysical Research Letters
Multi-year persistence of the 2014/15 North Pacific marine heatwave

Emanuele Di Lorenzo and Nathan Mantua

- Winter (JFM) 2014 warm blob evolved into an ARC-like warming pattern fall 14/winter 15
- The associated persistent SLP anomalies in the Northeast Pacific also changed

Never before as extreme as 2014-15

Figures from Di Lorenzo and Mantua (2016): Nature Climate Change
Persistence and evolution of SST/SLP anomalies involved well-known extratropical-tropical-extratropical teleconnections

- However, only about half the magnitude of the Arc SST anomaly could be related to tropical-origin forcing

DiLorenzo, Liguori, Mantua 2016: US CLIVAR Variations (Spring)
Extreme El Niño of 2015-16 came with North Pacific atmospheric forcing that largely maintained the warm SSTs in the NE Pacific.
Summer 2016

A period of extraordinary atmospheric conditions followed the end of the El Niño winter ... record high sea level pressure anomalies over the N. Pacific from May-September 2016

What happens after 5 months of fair weather across the N. Pacific and Bering Sea???
The blob makes a comeback!
SSTA - September 2016

Rapid growth of near-surface warm anomalies beginning in June

http://www.cpc.ncep.noaa.gov/products/GODAS/
October takes a bite out of the Blob
<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1 CA drought, carryover storage in reservoirs</td>
<td>Year 2 CA drought, some carryover storage</td>
<td>Year 3 CA drought, record heat</td>
<td>West Coast “snow drought” and record high temperatures</td>
<td>near average precip and snowpack but an early melt</td>
</tr>
<tr>
<td></td>
<td>Cold productive NE Pacific</td>
<td>Cold productive NE Pacific</td>
<td>NE Pacific in transition from good to bad ocean conditions</td>
<td>Record warm temperatures in NE Pacific; many signs of stress on “subarctic” species off the West Coast</td>
<td>A still warm unproductive NE Pacific? Pockets of nearshore productivity</td>
</tr>
<tr>
<td>BY 2012 chinook</td>
<td>Smolt migration</td>
<td>Ocean year 2</td>
<td>Ocean year 3, majority maturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BY 2013 chinook</td>
<td>Smolt migration</td>
<td>Ocean year 2</td>
<td>Ocean year 3, majority maturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BY 2014 chinook</td>
<td>Smolt migration</td>
<td>Ocean year 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary and Discussion

• A small number of persistent atmospheric forcing patterns have been associated with different SSTa extremes
• Climate change is here and now – for 2014-2016 expressed through extreme amplitude in natural modes
• Underlying causes still under investigation (Natural? Anthropogenic?)
OBSERVED DEC-FEB SST ANOMALIES (OISST)

MODELED DEC-FEB UPPER OCEAN TEMPERATURE ANOMALIES

Jacox et al. 2016: GRL
What Caused the warm Blob in 2013/14?

- The proximate cause: persistent ridge of high pressure – and the lack of stormy weather and strong winds (Bond et al. 2015, GRL)

- Forcings: **warm SSTA in the far western tropical Pacific** and **cold SSTA in the eastern tropical Pacific** (Wang et al. 2014, Hartmann 2015; Lee et al 2015; Seager et al 2014); **reduced Arctic/subarctic sea ice** (Lee et al. 2015, Kug et al. 2015), and **the warm blob** itself (Lee et al. 2015)


NASA Global Land-Ocean Temperature Index

NOAA Extended SST
Surface SST (°C) Composite Anomaly 1981–2010 climo

Leading EOFs/PCs of NEP SST and SLP

(Johnstone and Mantua, 2014: PNAS)

SST1: 30% variance

SLP1: 22% variance
Relate variations in SLP and SST patterns with a Stochastic Climate Model

\[ SST_t = \alpha \, SST_{t-1} + \beta \, SLP_t + \varepsilon_t \]

Coefficients first from lag-1 autoregression of SST
Slight adjustments guided by sensitivity experiments

\[ \alpha = 0.81 \ (\text{persistence term}) \quad \beta = 0.27 \ (\text{SLP perturbation}) \]

\[ SST_t = 0.81 \, SST_{t-1} + 0.27 \, SLP_t + \varepsilon_t \]

(Johnstone and Mantua, 2014: PNAS)
SST1 modeled from SLP1 forcing + persistence

The simple stochastic climate model does about equally well reproducing observed monthly and annual mean variations in SST1

Century long warming trend in the NEP Arc related to trend to lower SLP between Hawaii and the West Coast

(Johnstone and Mantua, 2014: PNAS)