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

SWFSC - FED

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Collaborators: Jim Johnstone, Nick Bond, Megan Cronin, Paul Fiedler, Howard Freeland, and Manu DiLorenzo

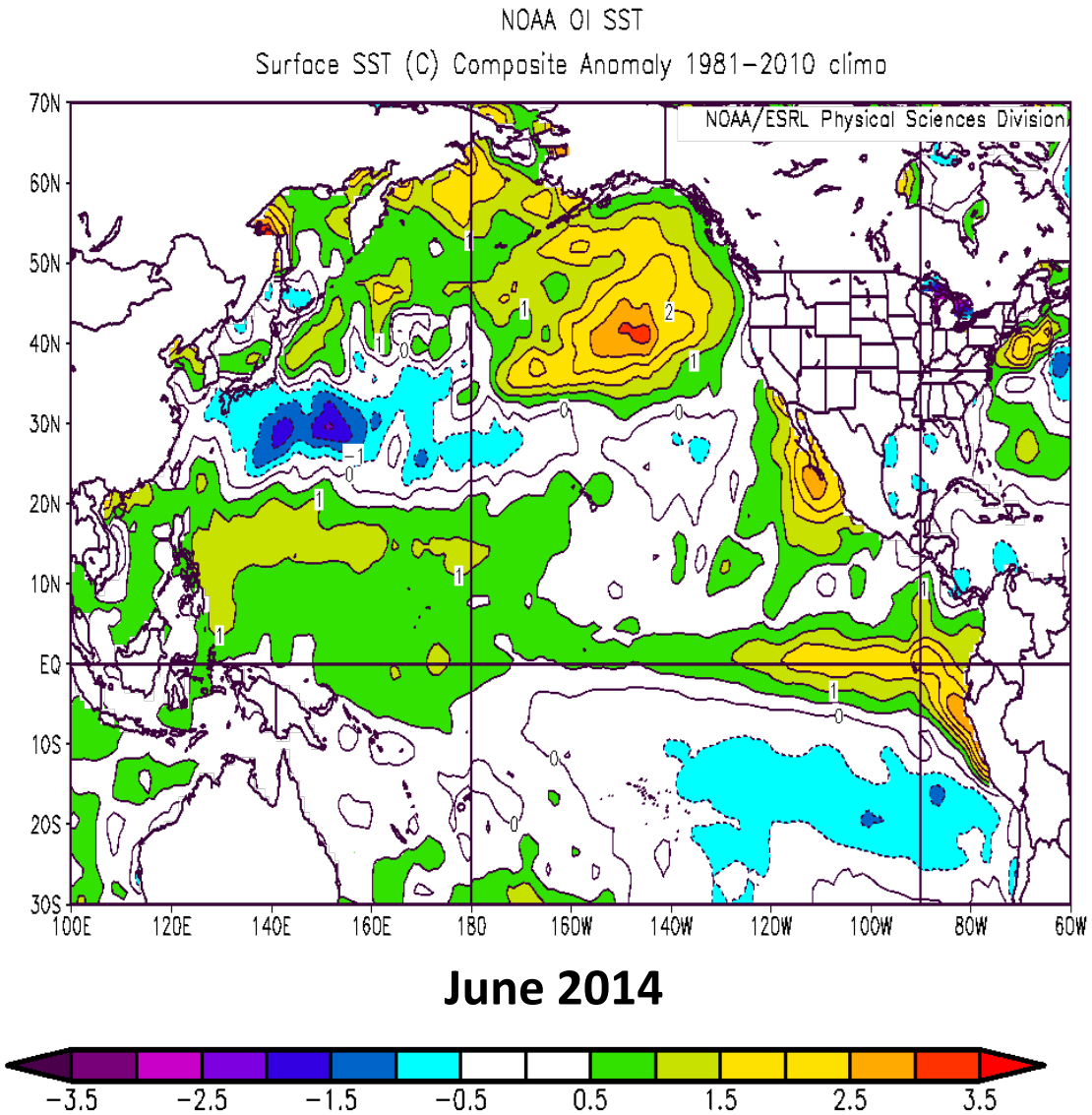
2016 PICES Meeting, San Diego CA
November 10, 2016

- Gulf of Alaska began warming in **Fall 2013**

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

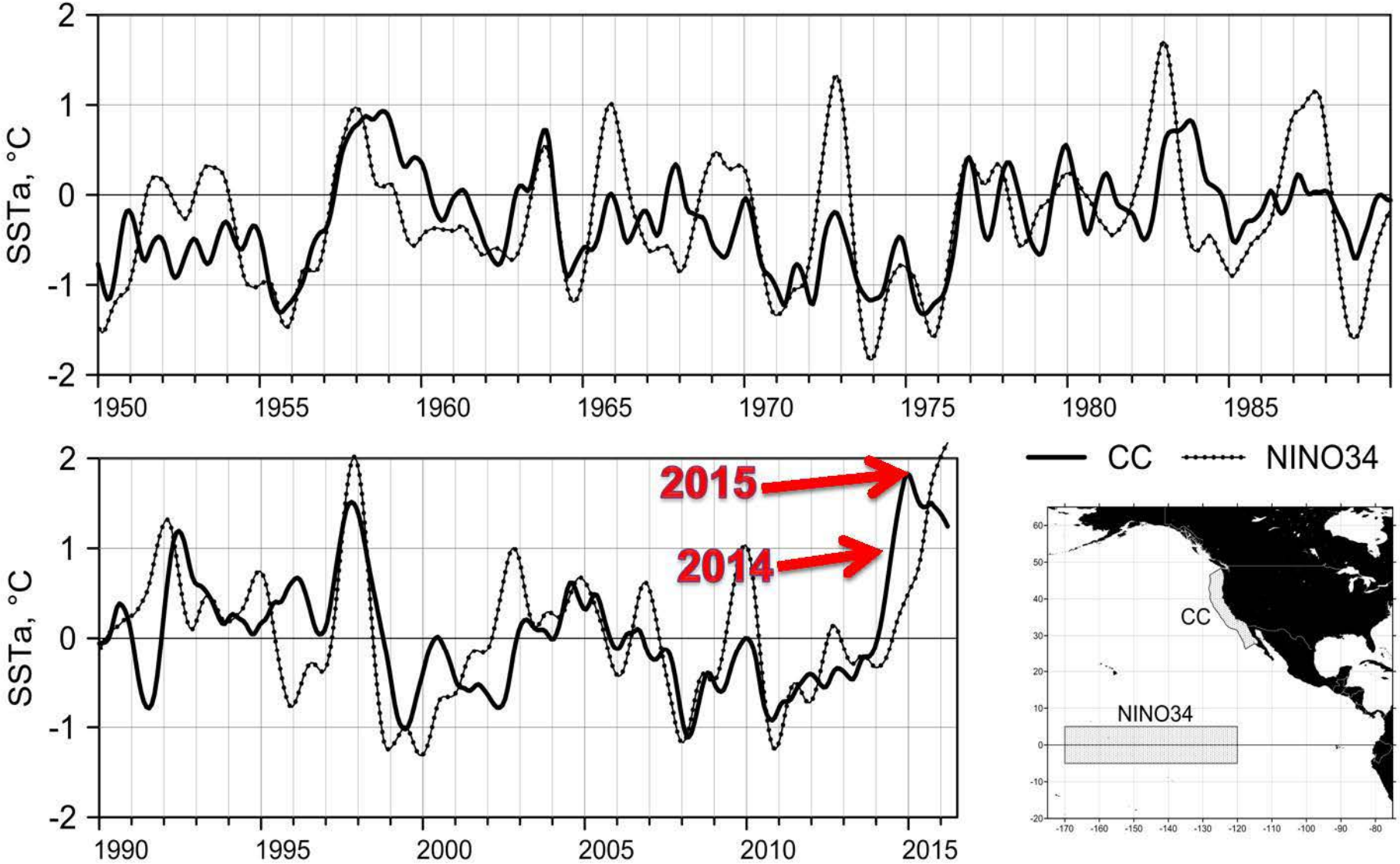
Wide-ranging impacts on Pacific marine life

Sea Surface Temperature Anomaly (relative to 1981-2010)



June 2014

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?

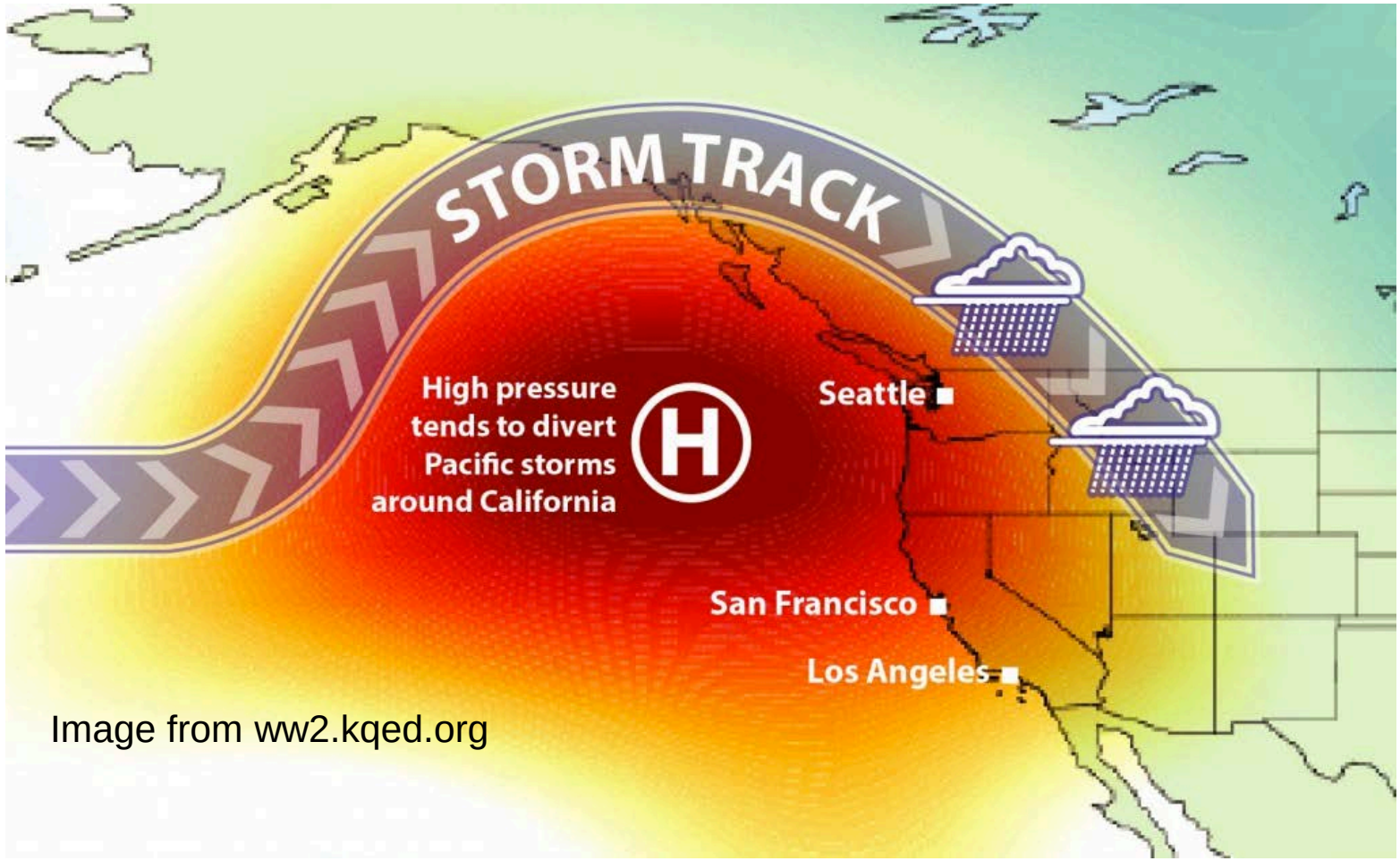


Image from ww2.kqed.org

Geophysical Research Letters

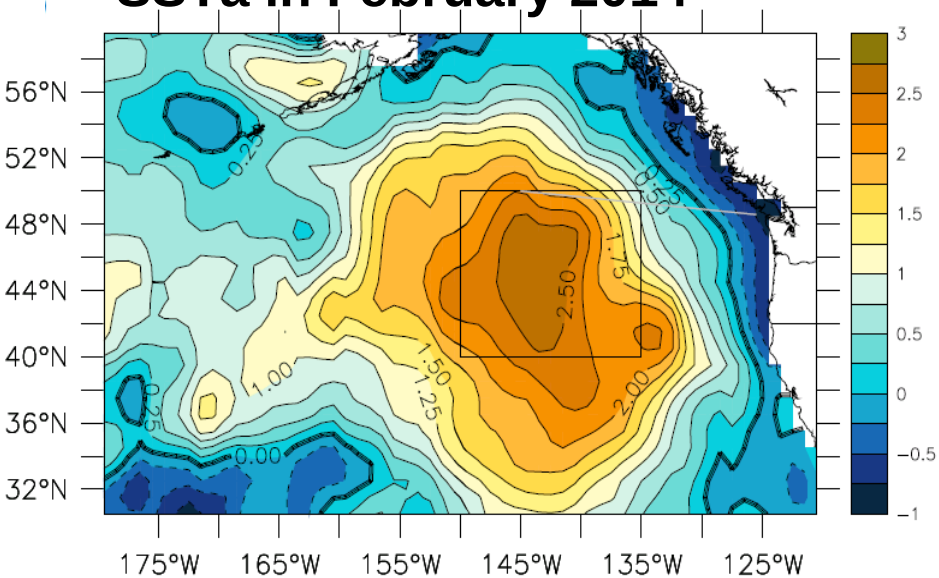
RESEARCH LETTER
10.1002/2015GL063306

Causes and impacts of the 2014 warm anomaly in the NE Pacific

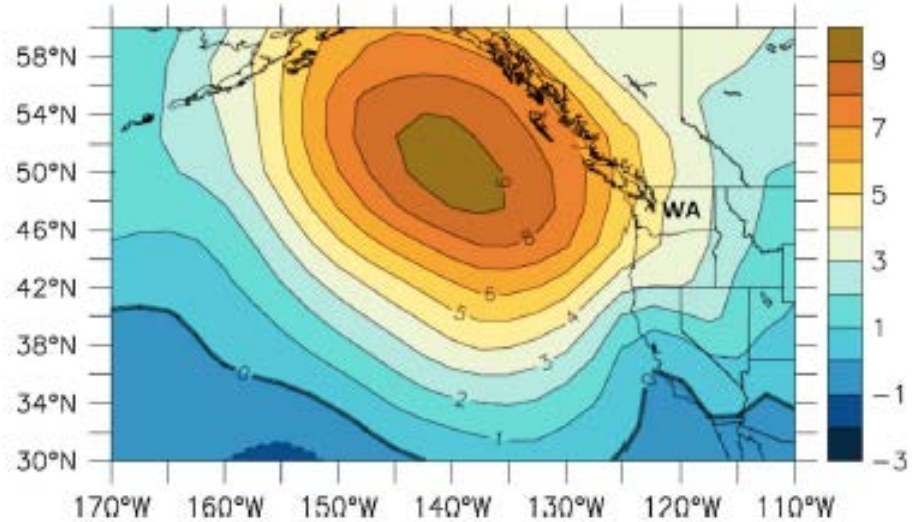
Nicholas A. Bond[1], Meghan F. Cronin[2], Howard Freeland[3], and Nathan Mantua[4]

In winter 2013-14 extreme warm temperature anomalies developed under the influence of an extremely persistent high pressure anomaly in the NEP

SSTa in February 2014

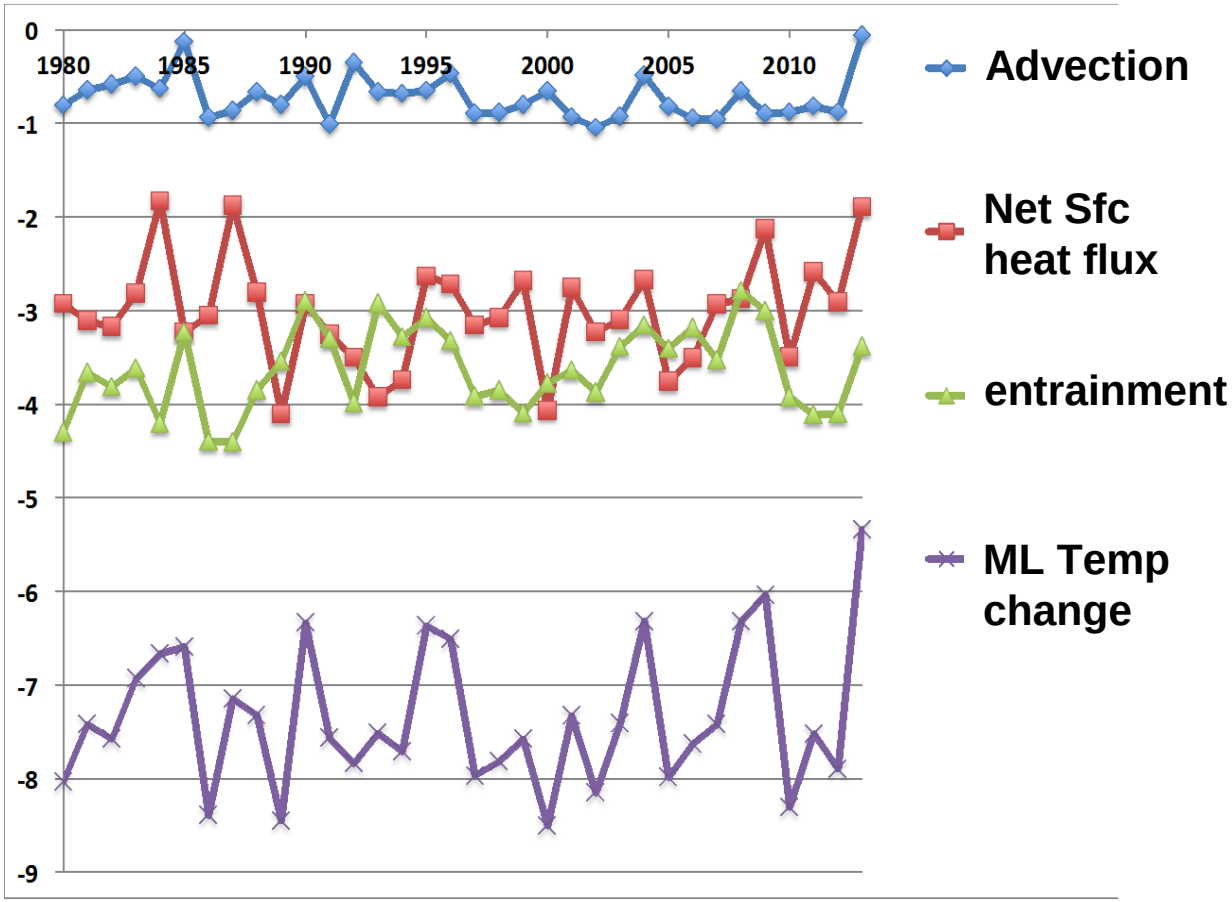


Sea Level Pressure anomalies: Oct 2013-Jan 2014



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
Volume 42, Issue 9, pages 3414-3420, 5 MAY 2015 DOI: 10.1002/2015GL063306
http://onlinelibrary.wiley.com/doi/10.1002/2015GL063306/full#grl52851-fig-0004

nature climate change

ARTICLES

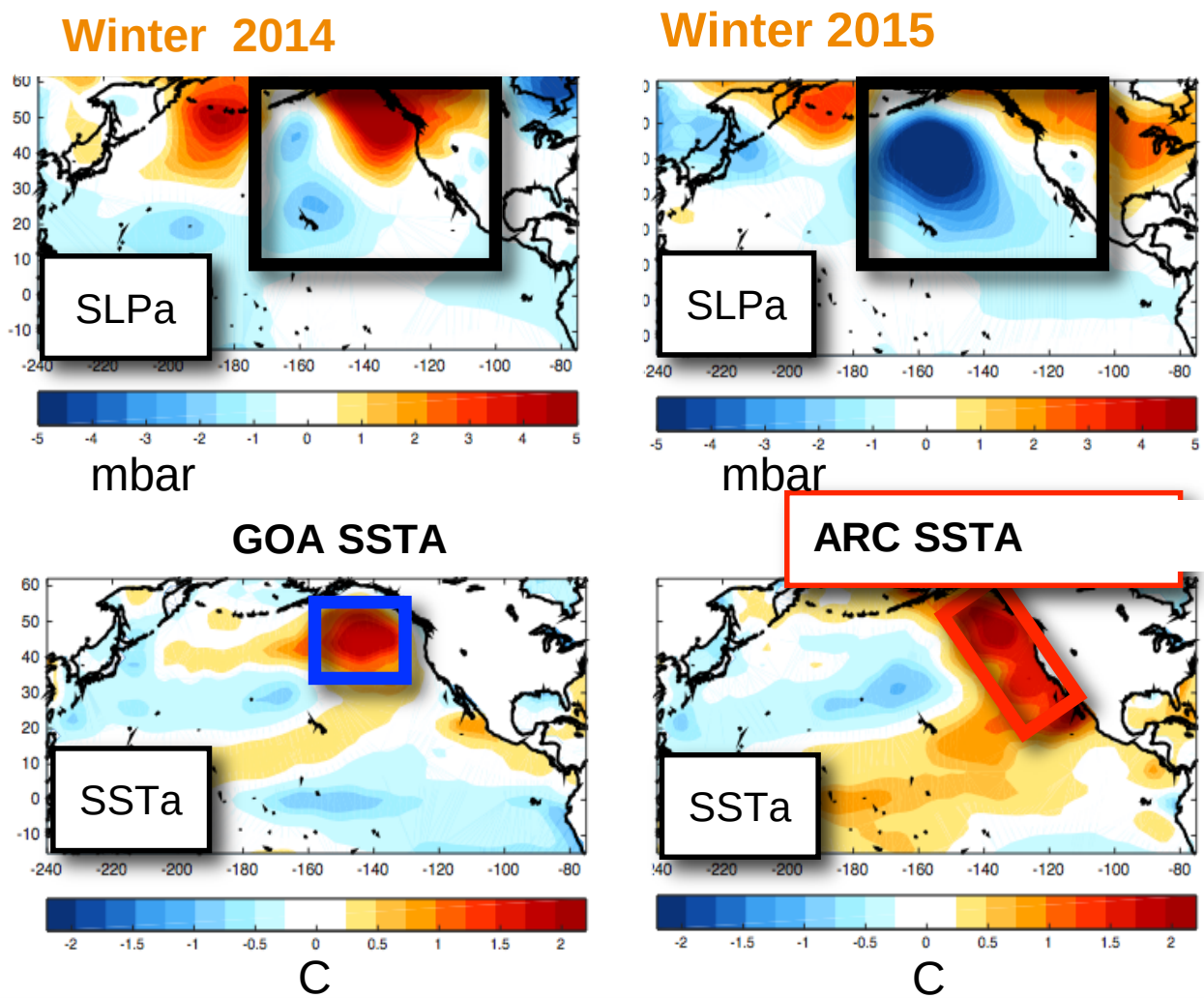
PUBLISHED ONLINE: 11 JULY 2016 | DOI: 10.1038/NCLIMATE3082

Multi-year persistence of the 2014/15 North Pacific marine heatwave

Emanuele Di Lorenzo[1*] and Nathan Mantua[2]

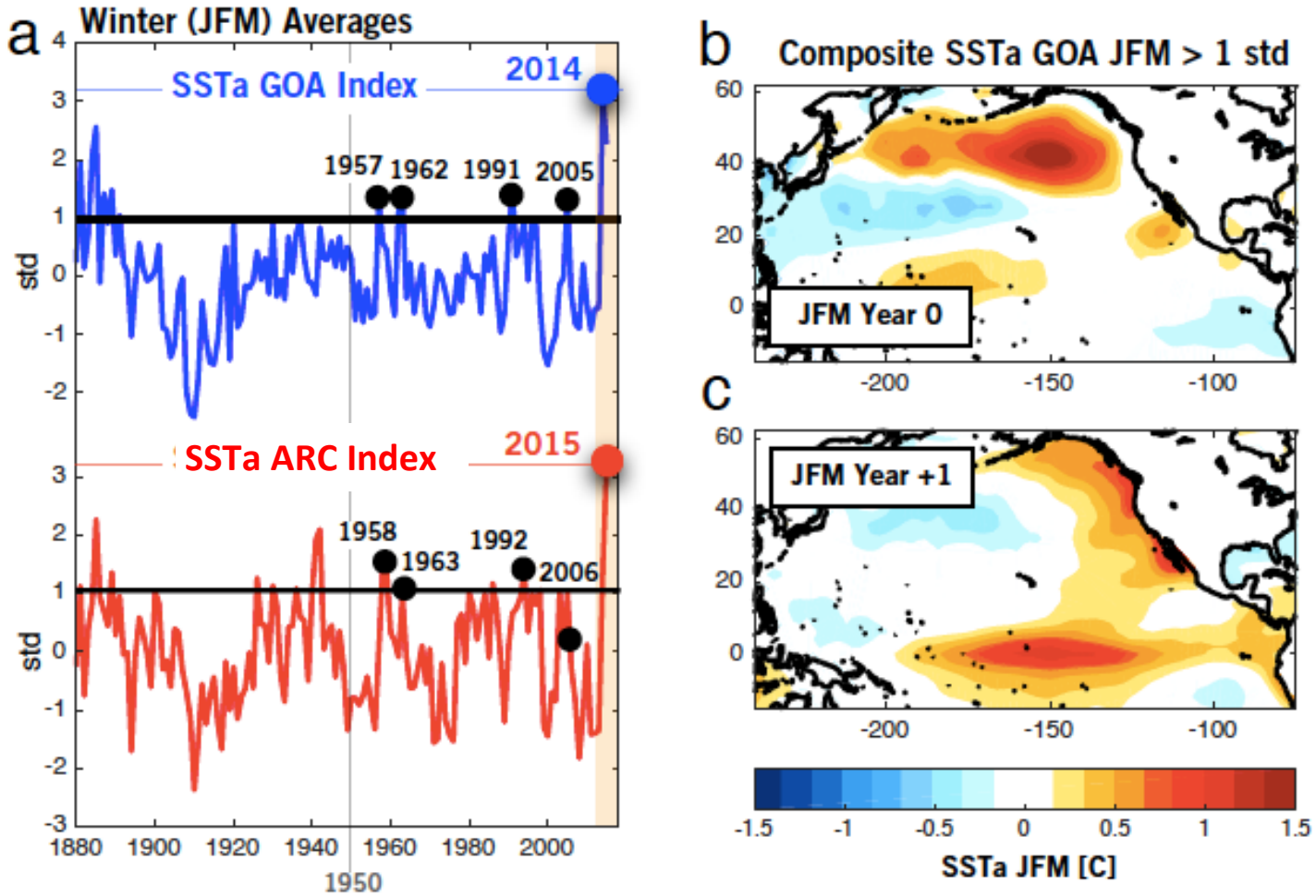
- Winter (JFM) 2014 warm blob evolved into an ARC-like warming pattern fall 14/winter 15

- The associated persistent SLP anomalies in the Northeast Pacific also changed



GOA warming followed by “ARC” pattern warming has happened before: 1957-58, 1962-63, and 1991-92

Never before as extreme as 2014-15

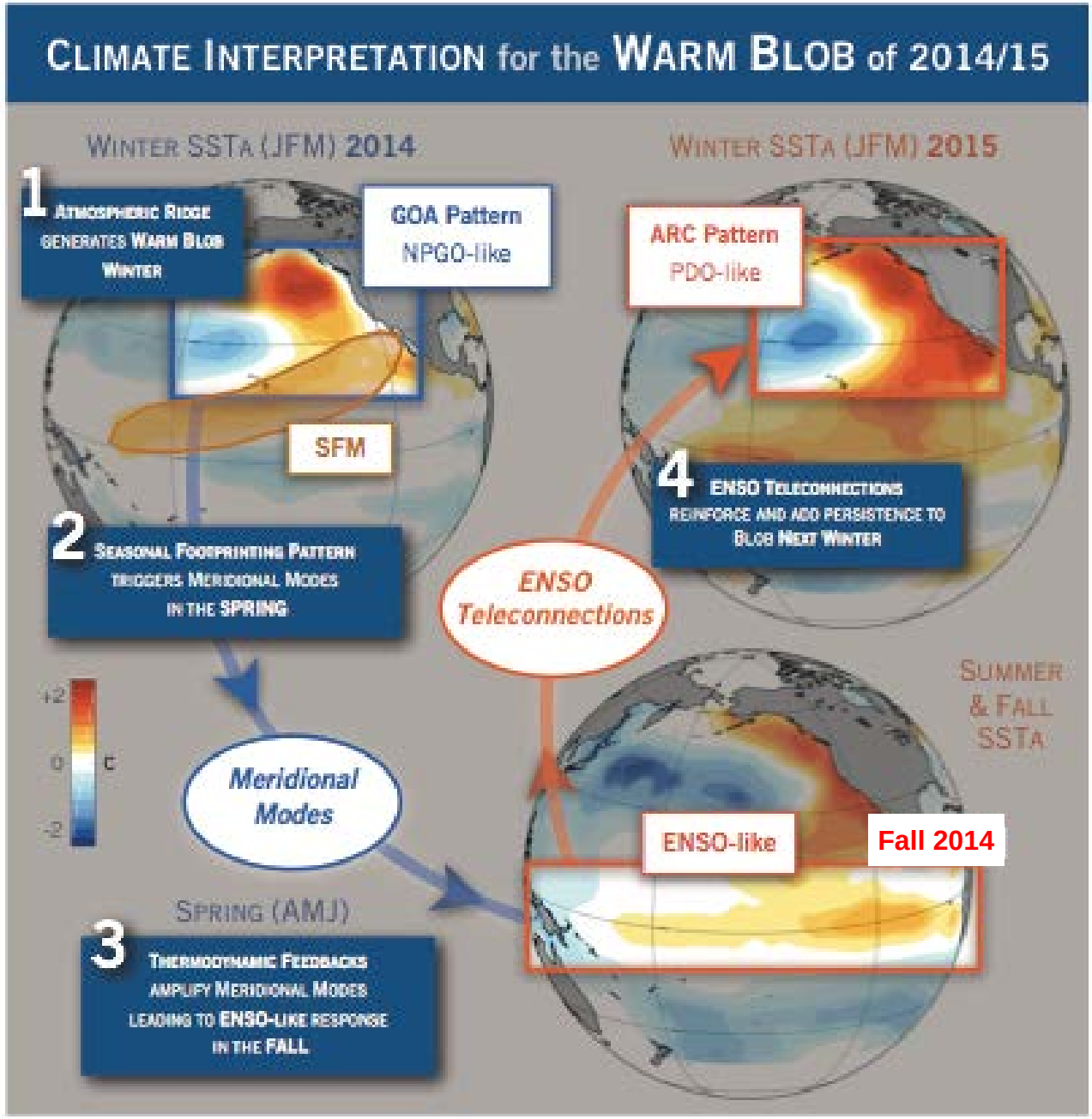


Figures from Di Lorenzo and Mantua (2016): Nature Climate Change

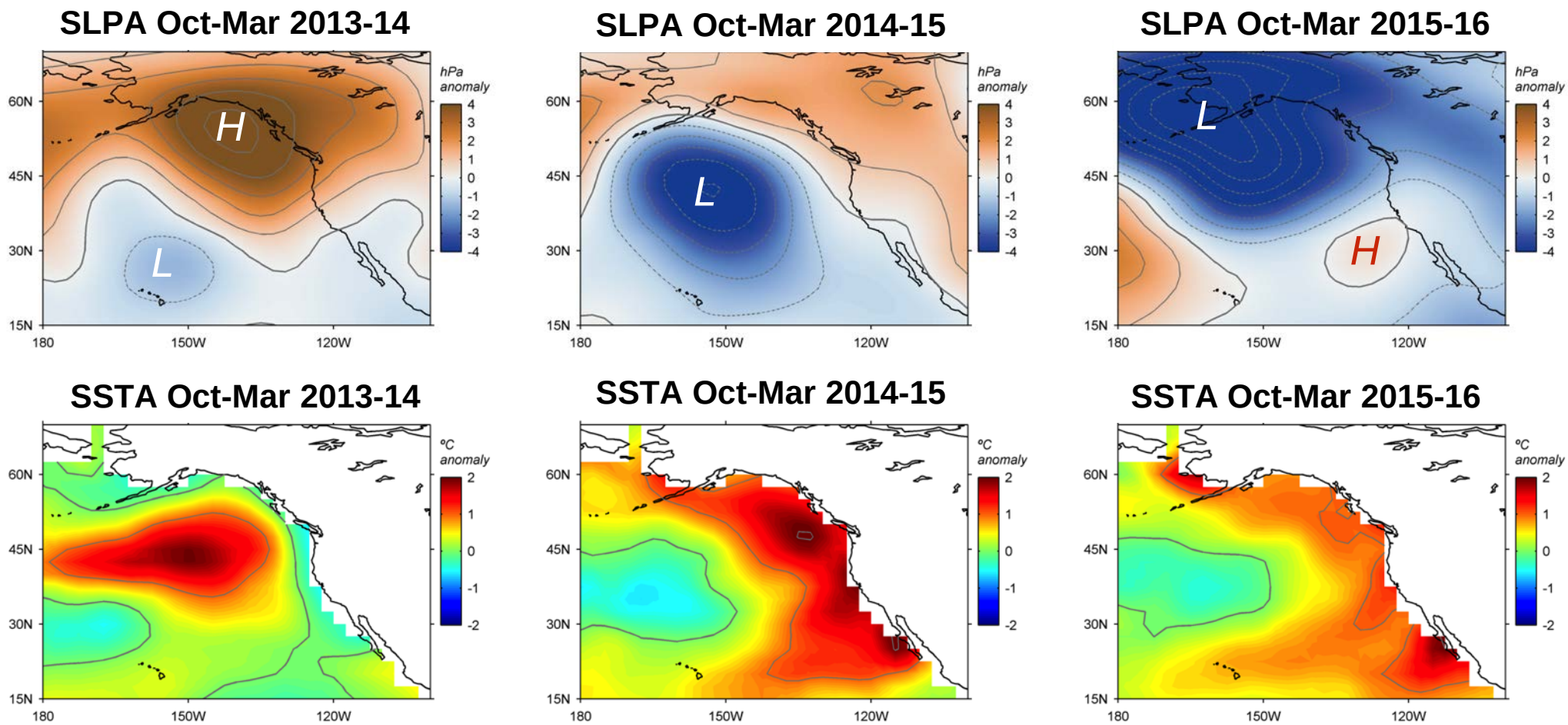
Persistence and evolution of SST/SLP anomalies involved well-known extratropical-tropical-extratropical teleconnections

- 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)




EL NIÑO
THE BLOB
©8/15
DUGINSKI

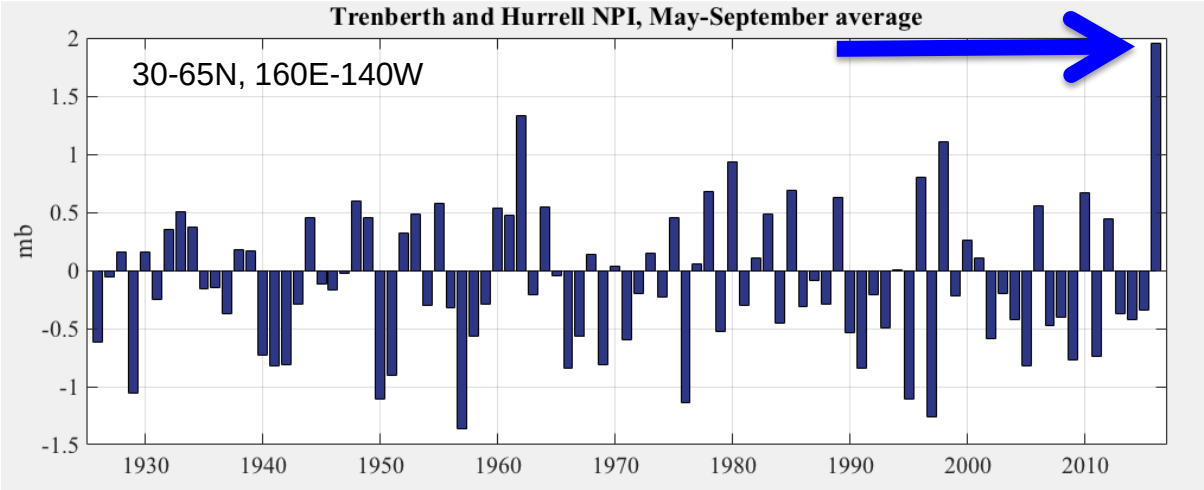


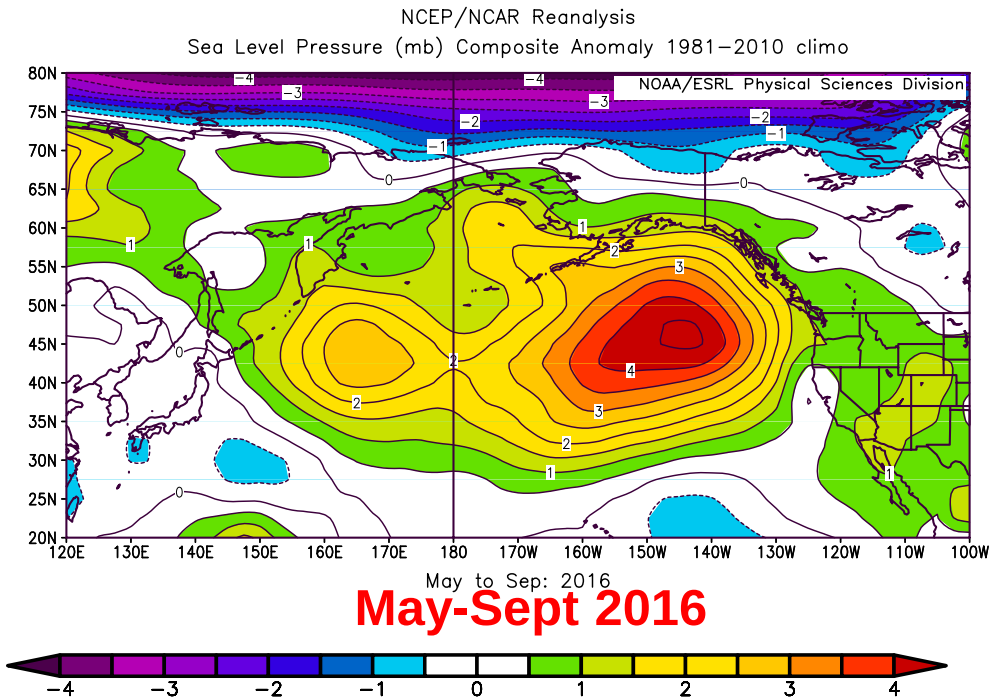
Extreme El Niño of 2015-16 came with North Pacific atmospheric forcing that largely maintained the warm SSTs in the NE Pacific

Summer 2016

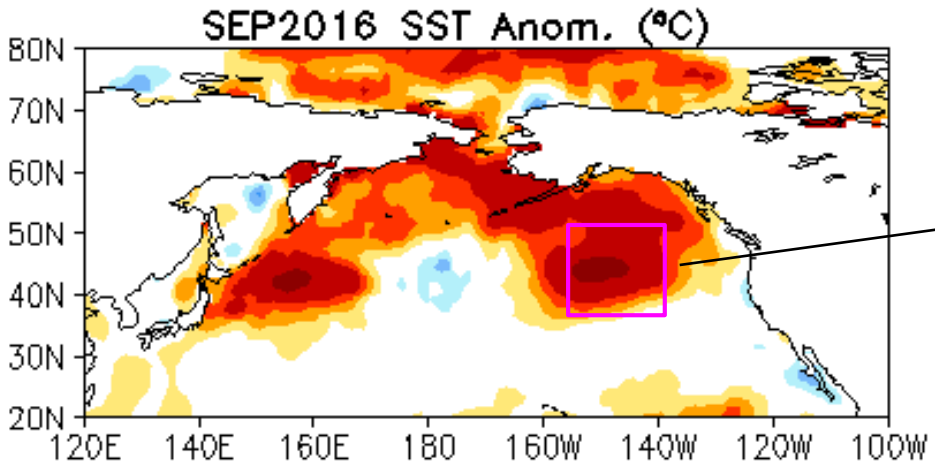
A period of extraordinary atmospheric conditions followed the end of the El Niño winter … record high sea level pressure anomalies over the N. Pacific from May-September 2016

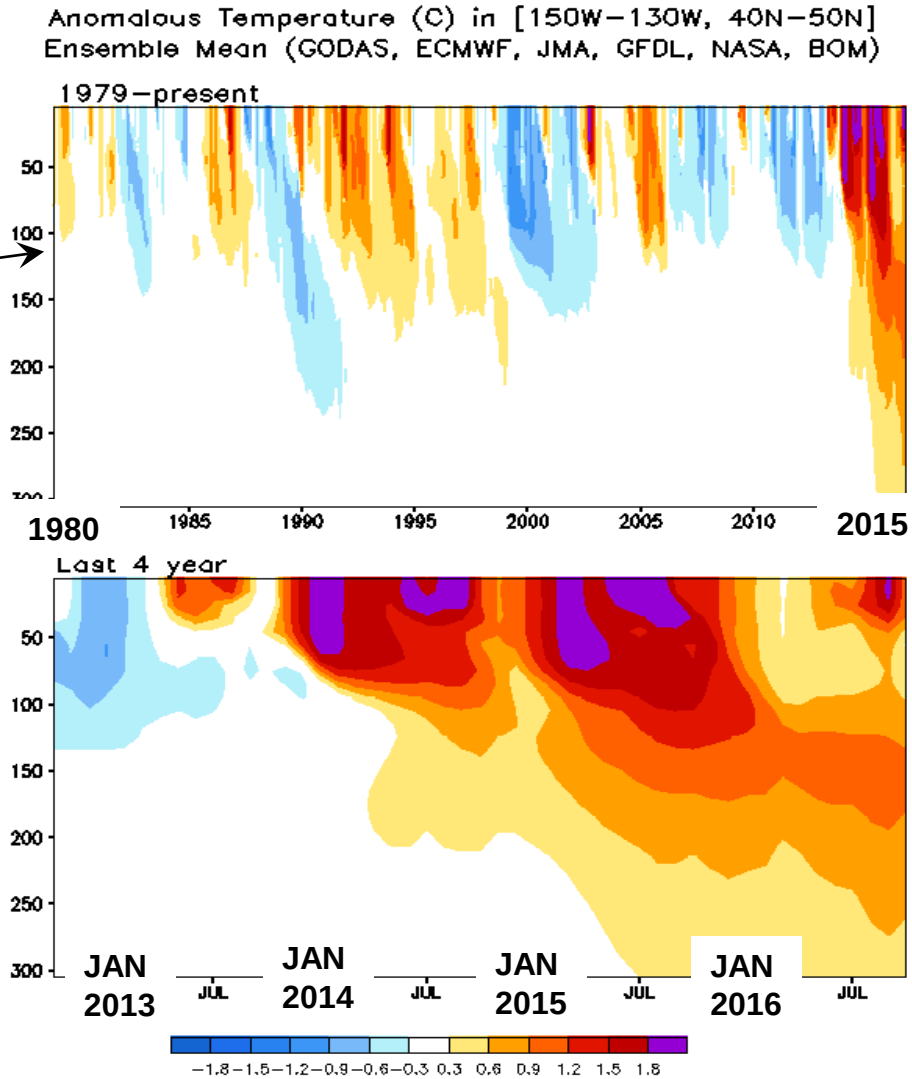
What happens after 5 months of fair weather across the N. Pacific and Bering Sea???





The blob makes a comeback!
SSTA - September 2016

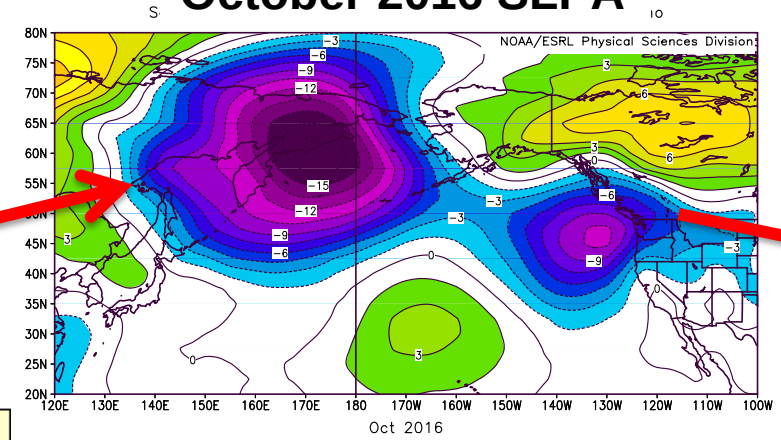




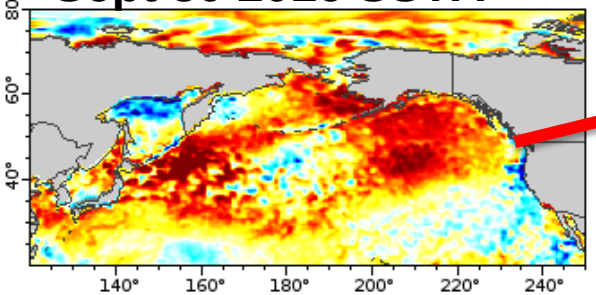
Rapid growth of near-surface warm anomalies beginning in June

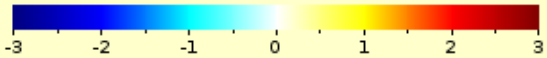
http://www.cpc.ncep.noaa.gov/products/GODAS/

October 2016 SLPA

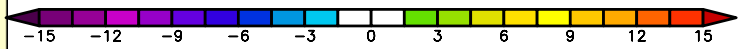


Sept 30 2016 SSTA

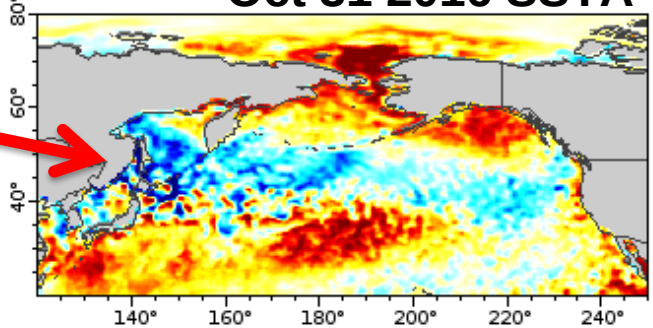


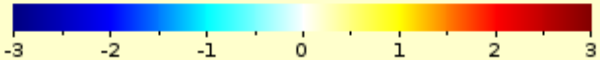


Daily Sea Surface Temperature Anomalies (degree_C)
SST, Daily Optimum Interpolation (OI), AVHRR Only, Version 2, Final+Preliminary
(2016-09-30T00:00:00Z, Altitude=0.0 m)
Data courtesy of NOAA NCDC



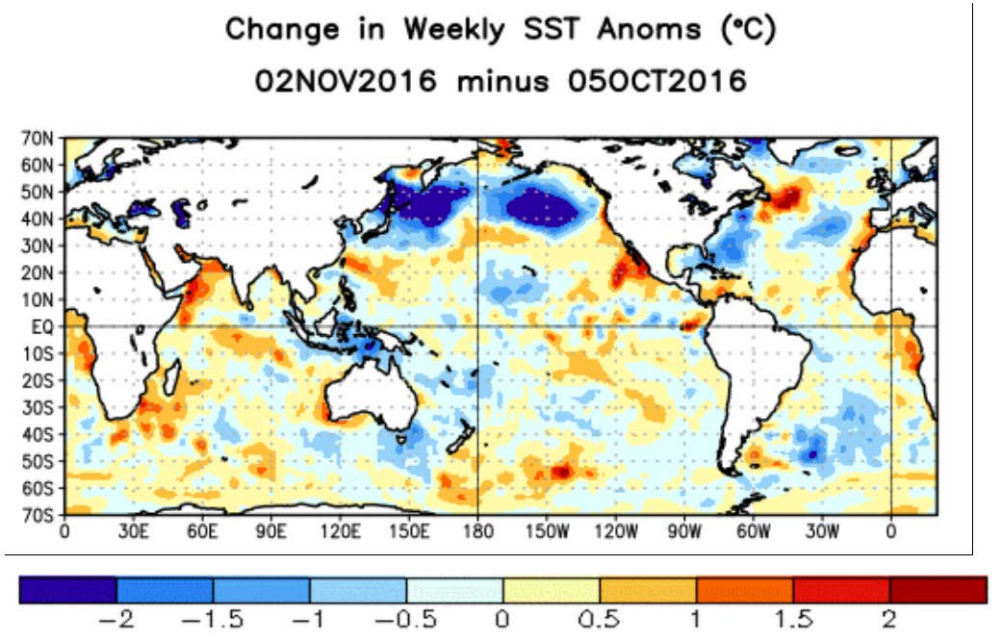
Oct 31 2016 SSTA





Daily Sea Surface Temperature Anomalies (degree_C)
SST, Daily Optimum Interpolation (OI), AVHRR Only, Version 2, Final+Preliminary
(2016-10-31T00:00:00Z, Altitude=0.0 m)
Data courtesy of NOAA NCDC

October takes a bite out of the Blob



A climate timeline for California's salmon

2012	2013	2014	2015	2016
Year 1 CA drought, carryover storage in reservoirs	Year 2 CA drought, some carryover storage	Year 3 CA drought, record heat	West Coast "snow drought" and record high temperatures	near average precip and snowpack but an early melt
Cold productive NE Pacific	Cold productive NE Pacific	NE Pacific in transition from good to bad ocean conditions	Record warm temperatures in NE Pacific; many signs of stress on "subarctic" species off the West Coast	A still warm unproductive NE Pacific? Pockets of nearshore productivity
BY 2012 chinook	Smolt migration	Ocean year 2	Ocean year 3, majority maturing	
	BY 2013 chinook	Smolt migration	Ocean year 2	Ocean year 3, majority maturing
		BY2014 chinook	Smolt migration	Ocean Year 2

Summary and Discussion

- Many SST records broken in 2014-2016 – Blob origination region (2014), NE Pacific ARC and CCS (2015), eastern Bering Sea (2016)
- 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?)

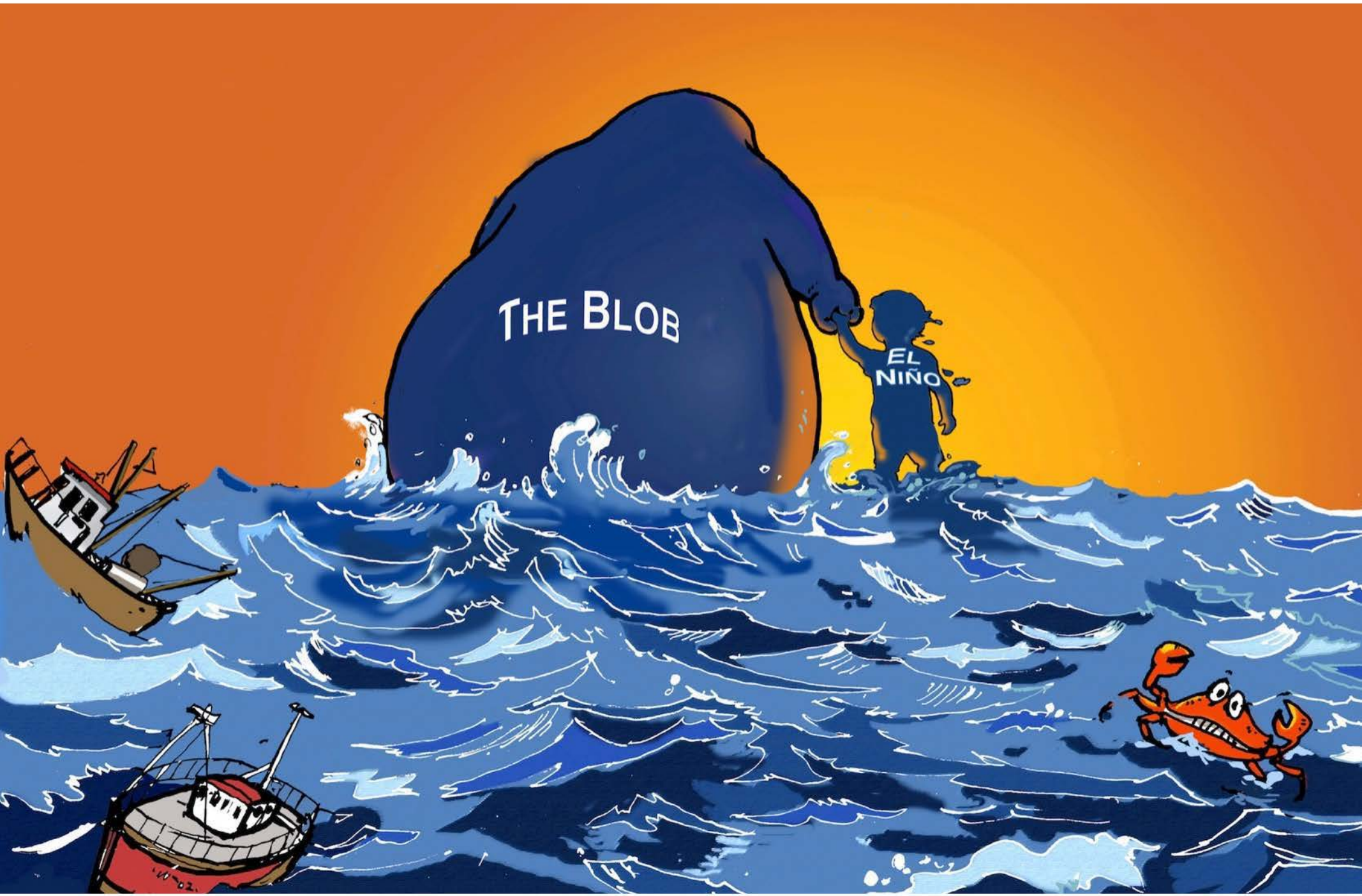
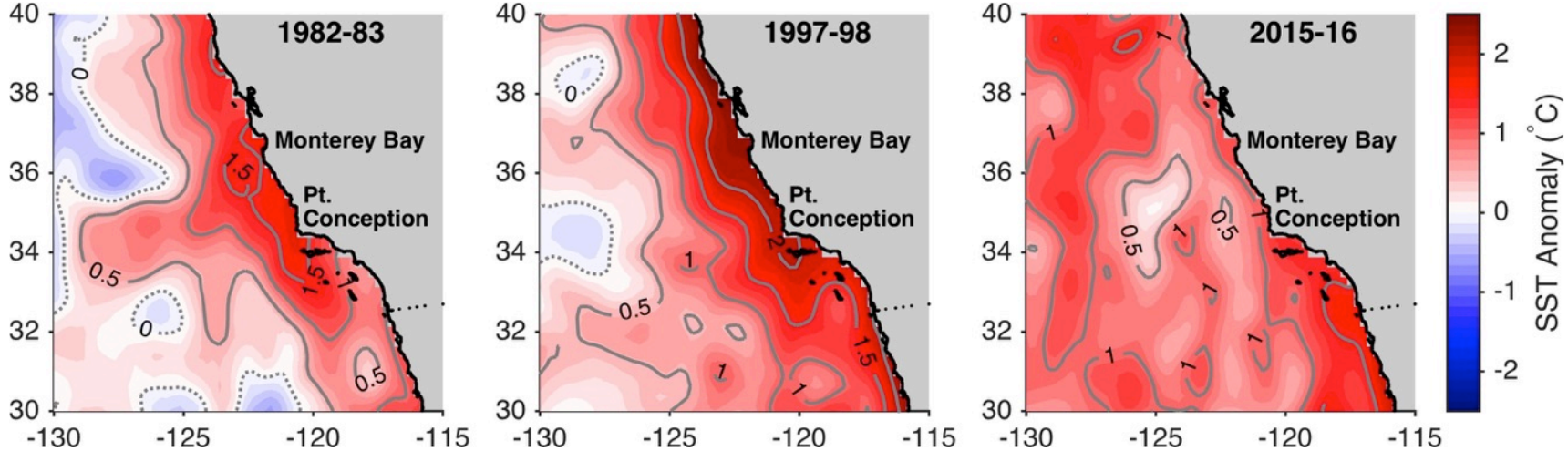
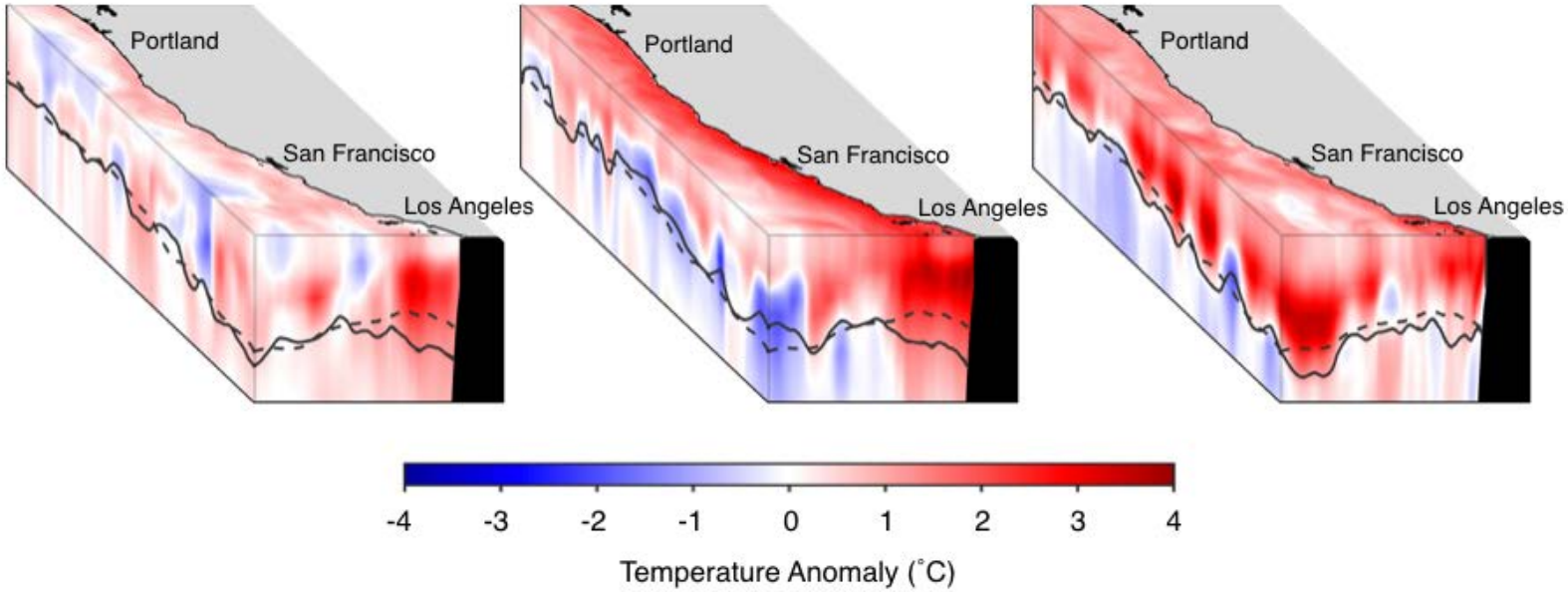


Figure from Mike Jacox, NOAA/SWFSC

OBSERVED DEC-FEB SST ANOMALIES (OISST)



MODELED DEC-FEB UPPER OCEAN TEMPERATURE ANOMALIES



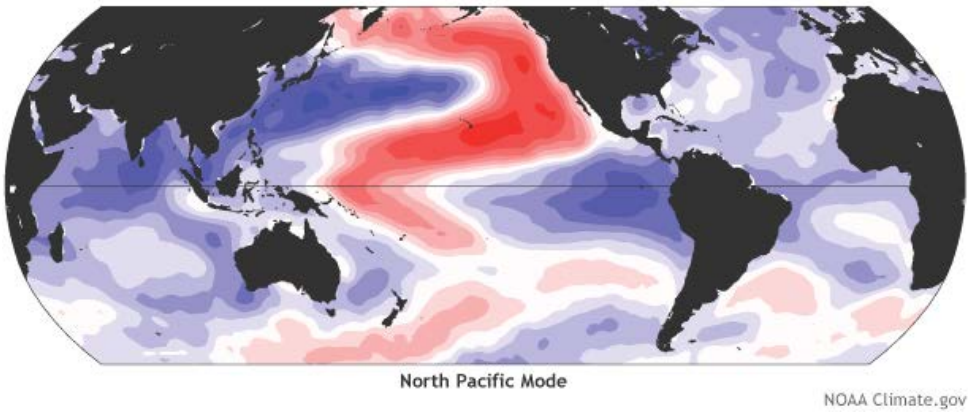
Jacox et al. 2016: GRL

What Caused the warm Blob in 2013/14?

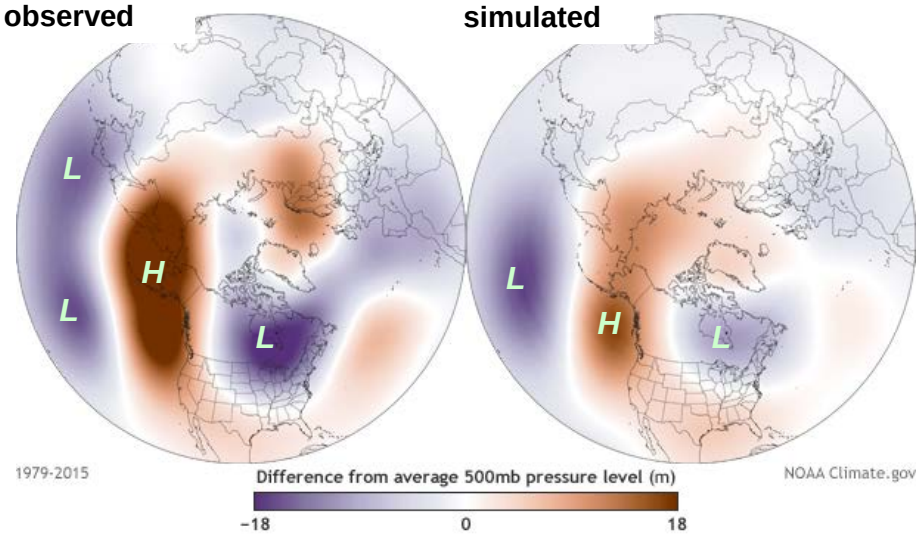
- The proximate cause: persistent ridge of high pressure – and the lack of stormy weather and strong winds (Bond et al. 2015, GRL)

- 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)

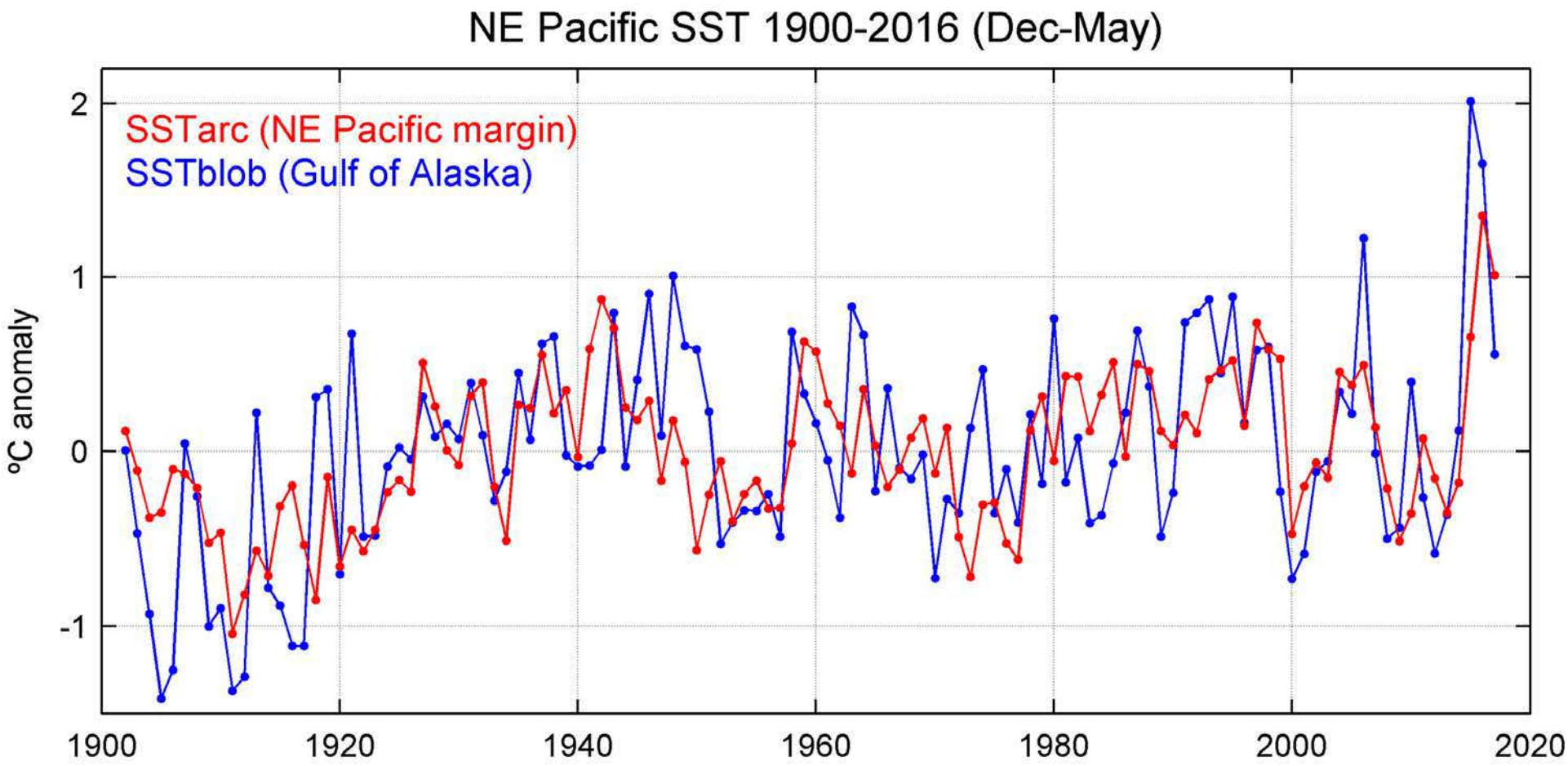
"North Pacific mode" SSTA pattern

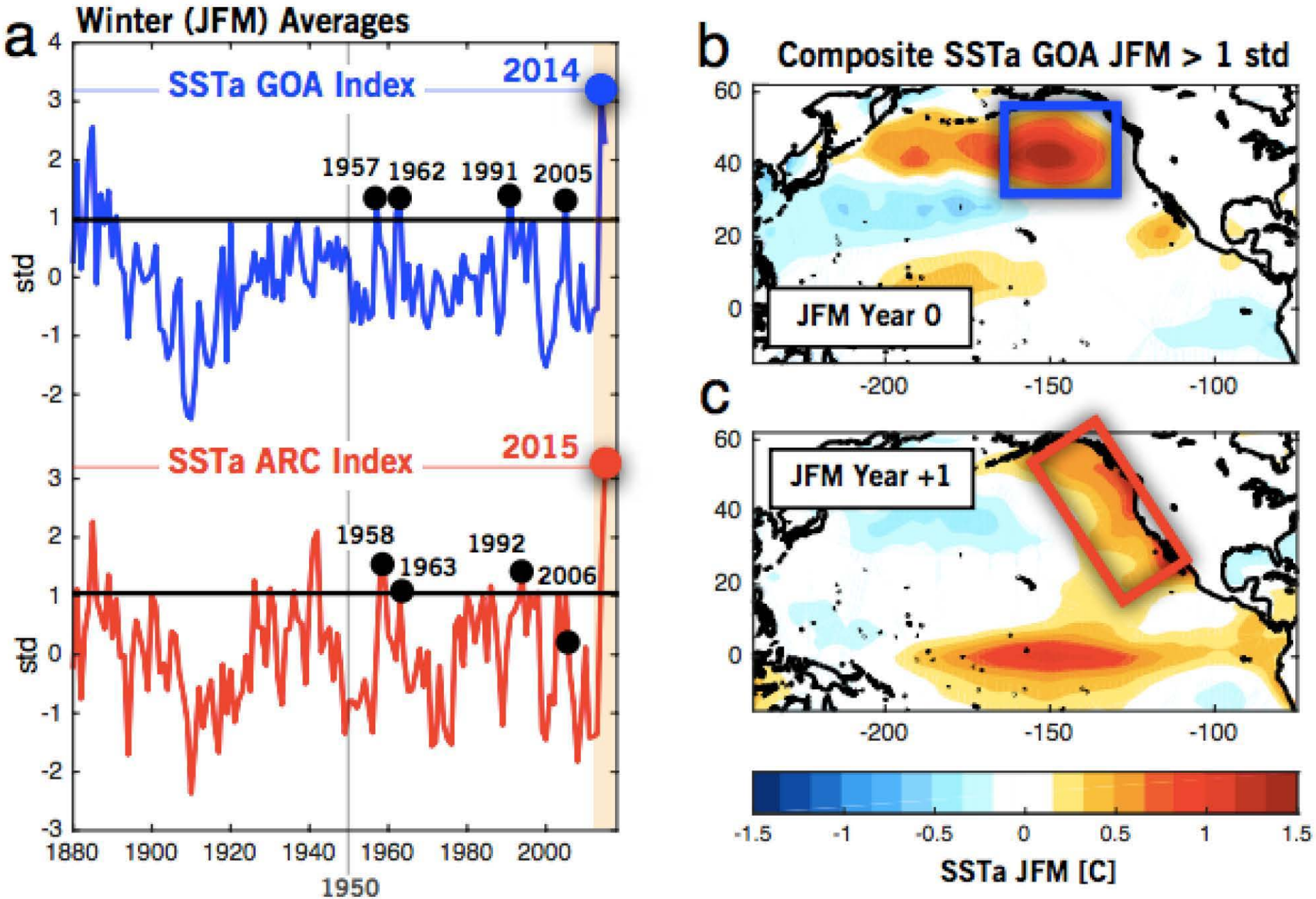


500mb ht. anomalies associated with NPM SSTA



Images from: https://www.climate.gov/news-features/blogs/enso/tropics-prime-suspect-behind-warm-cold-split-over-north-america-during


NE Pacific SST 1900-2016 (Dec-May)
SSTarc (NE Pacific margin)
SSTblob (Gulf of Alaska)
ºC anomaly
2
1
0
-1
1900
1920
1940
1960
1980
2000
2020

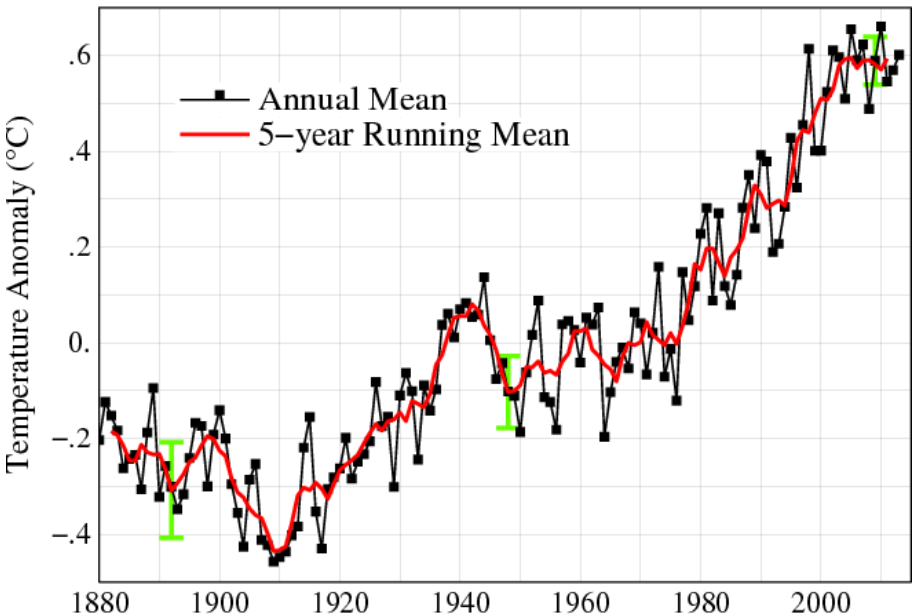

a
Winter (JFM) Averages
SSTa GOA Index
2014
1957
1962
1991
2005
std
SSTa ARC Index
2015
1958
1963
1992
2006
std
1880
1900
1920
1940
1960
1980
2000
1950
b
Composite SSTa GOA JFM > 1 std
JFM Year 0
c
JFM Year +1
SSTa JFM [C]

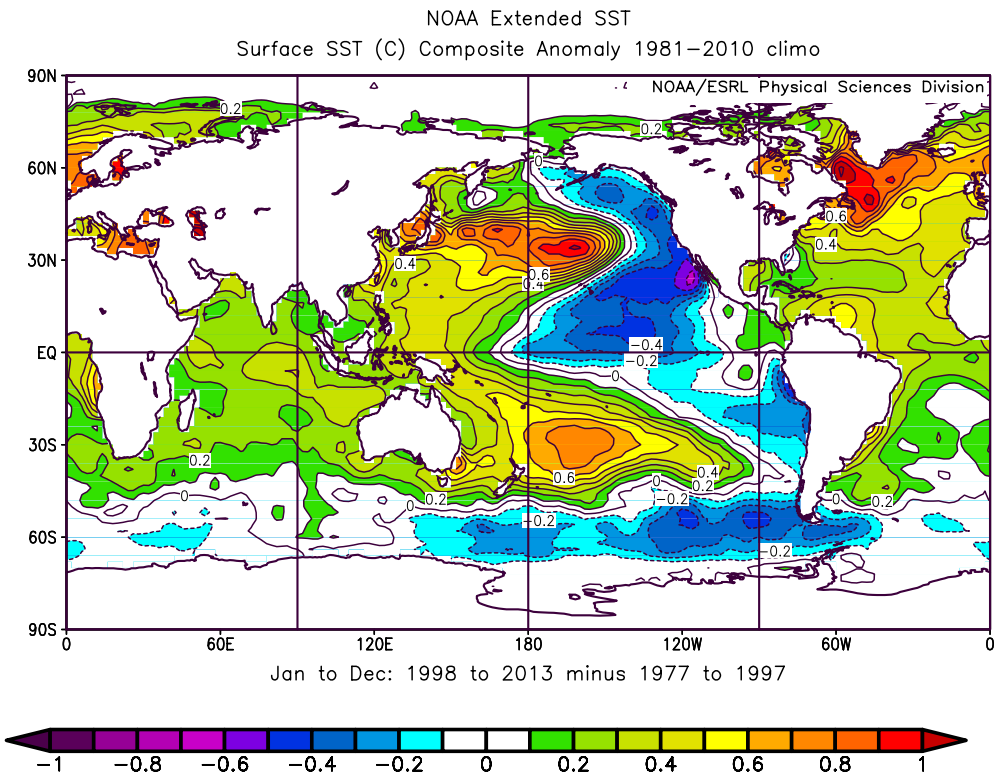
Atmospheric controls on northeast Pacific temperature variability and change, 1900–2012

Johnstone and Mantua, PNAS, 2014, DOI: 10.1073/pnas.1318371111

Global warming, but Eastern Pacific cooling:
(1998-2013) – (1977-1997)

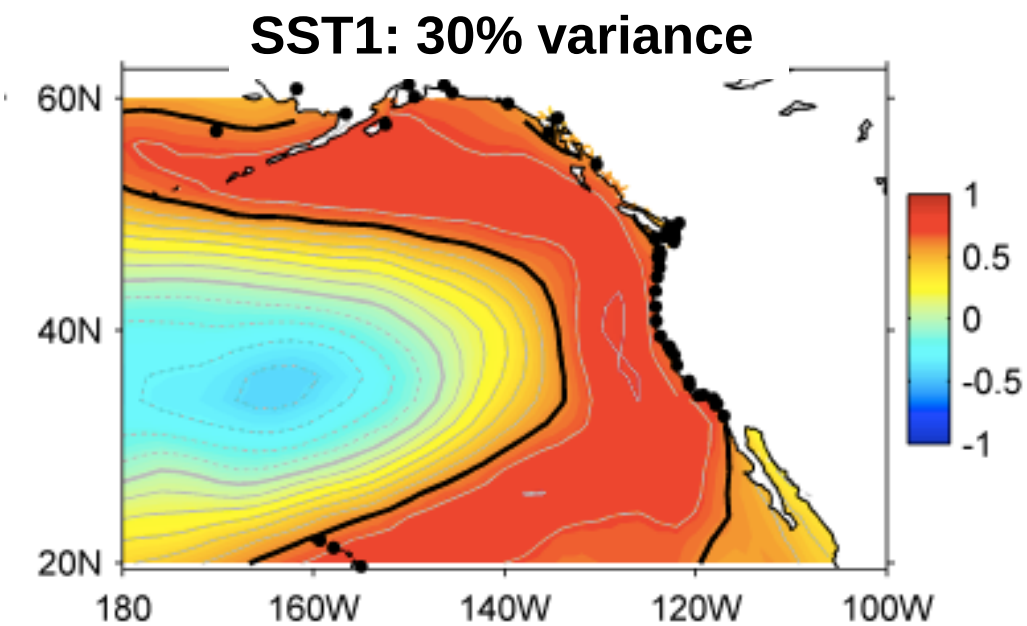
NASA Global Land-Ocean Temperature Index

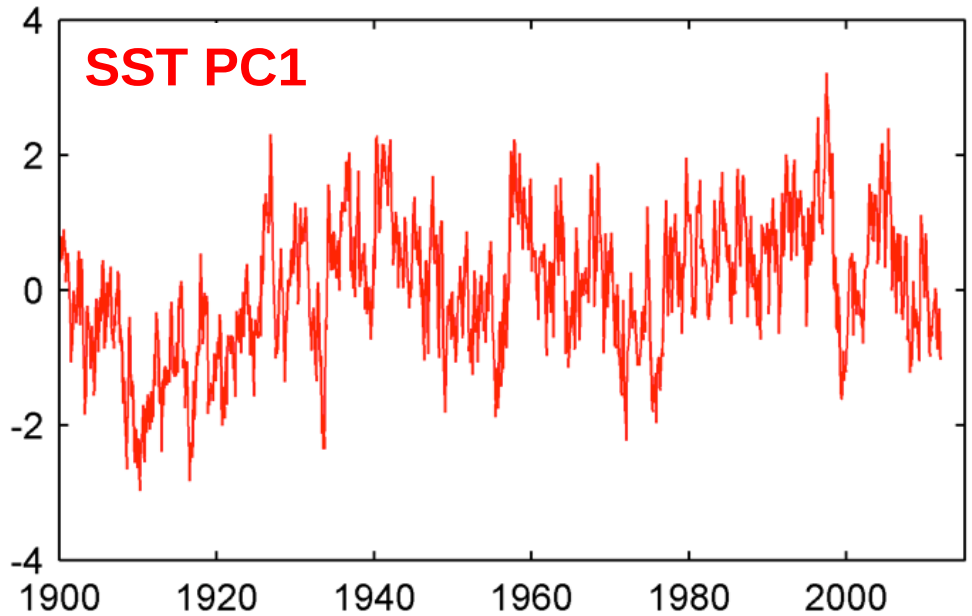


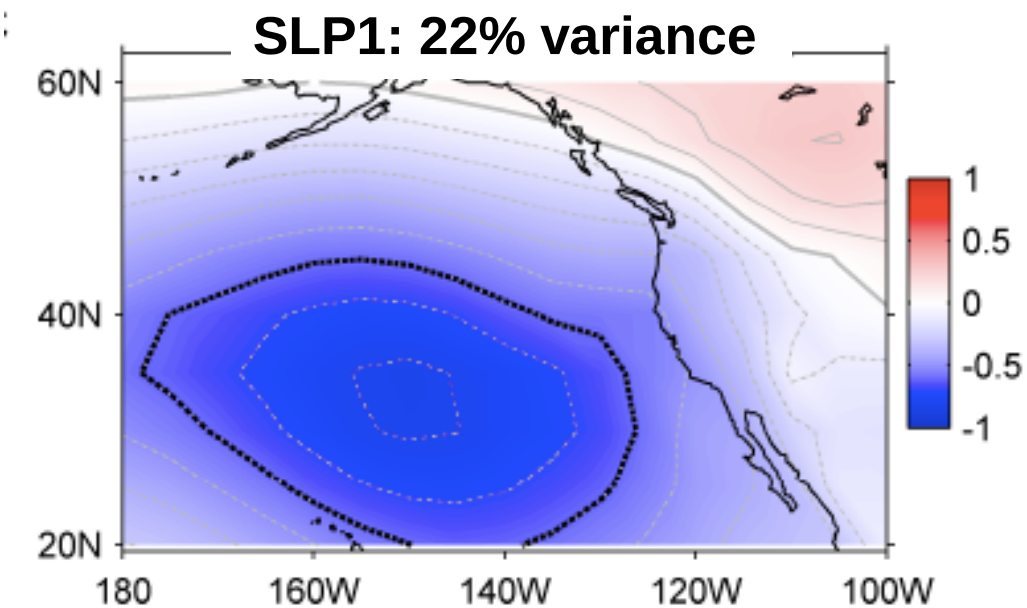


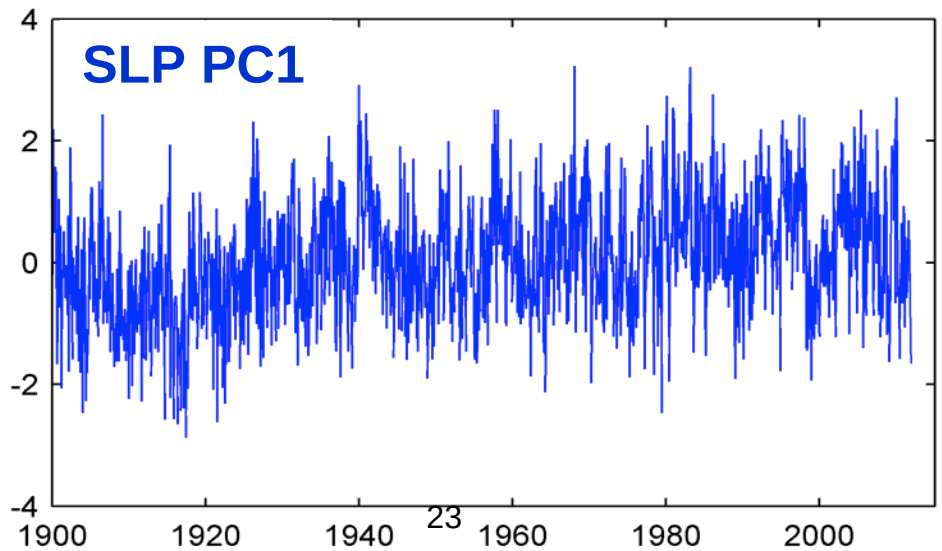
Leading EOFs/PCs of NEP SST and SLP

(Johnstone and Mantua, 2014: PNAS)









Relate variations in SLP and SST patterns with a Stochastic Climate Model

$$SST_t = \alpha\, SST_{t-1} + ß SLP_t + \varepsilon_t$$

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

$\alpha = 0.81$ *(persistence term)* $ß = 0.27$ *(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 <u>lower</u> SLP between Hawaii and the West Coast

(Johnstone and Mantua, 2014: PNAS)