Historical context for the atmospheric forcing of record high SSTs in the NE Pacific Arc in 2014-2016

NOAA FISHERIES

SWFSC - FED

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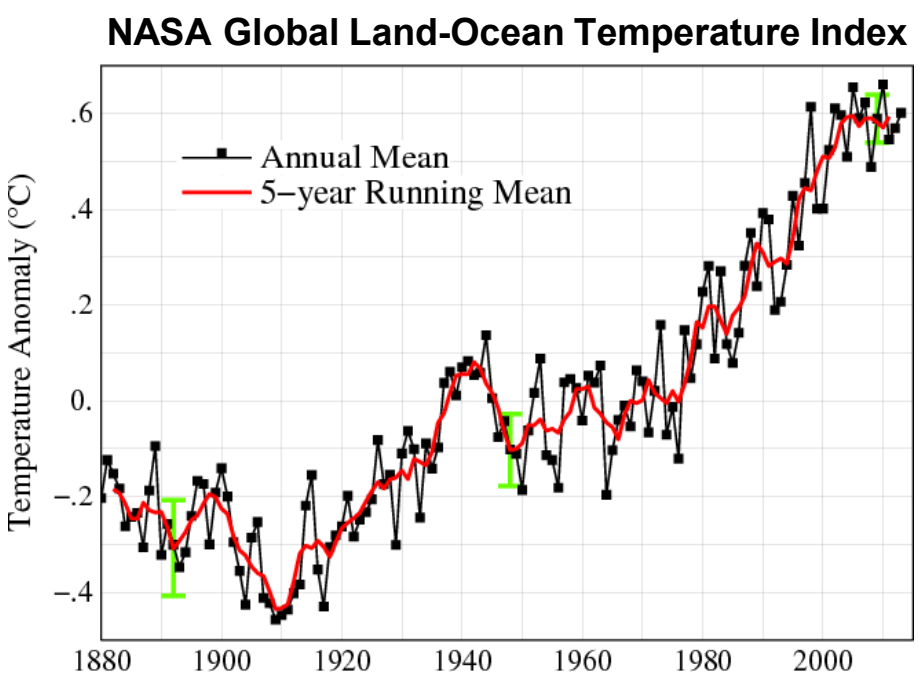
2016 PICES Meeting, San Diego CA

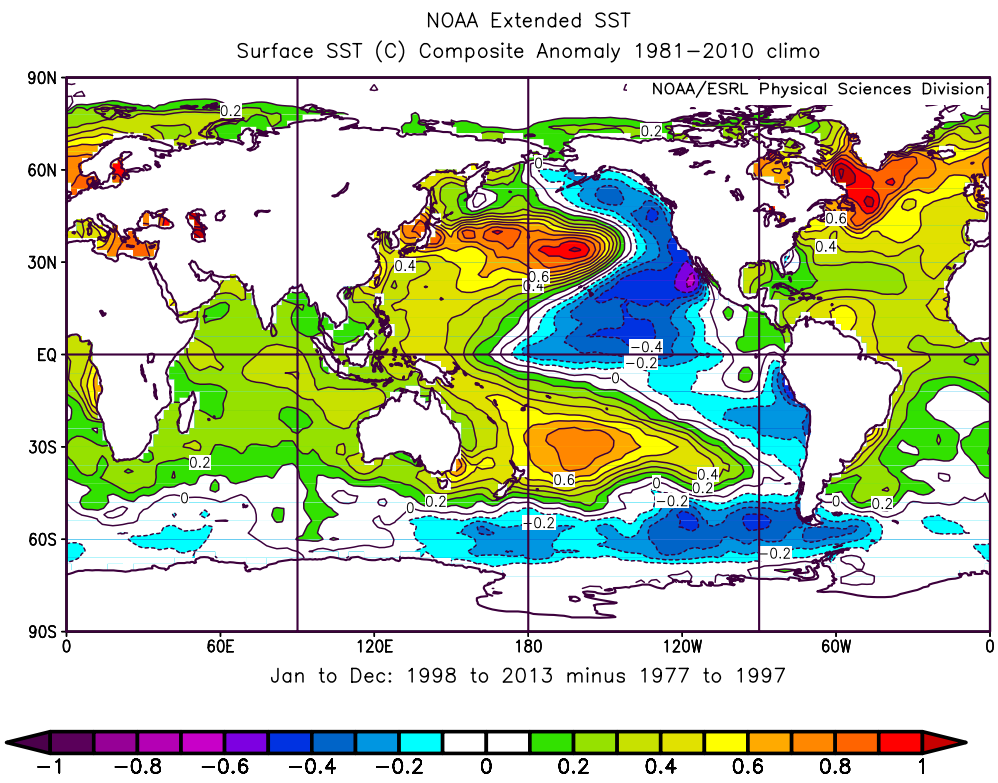
November 10, 2016

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)

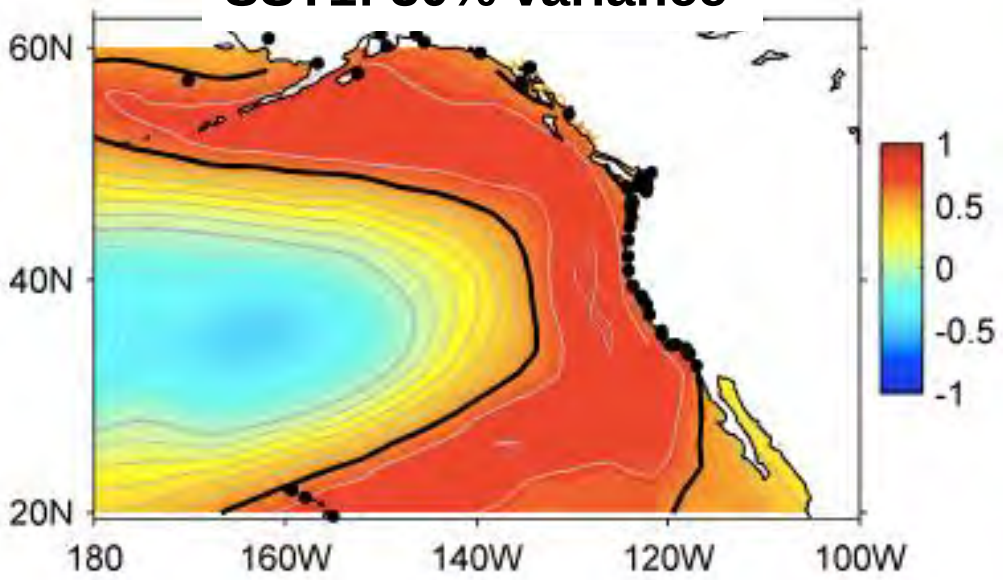


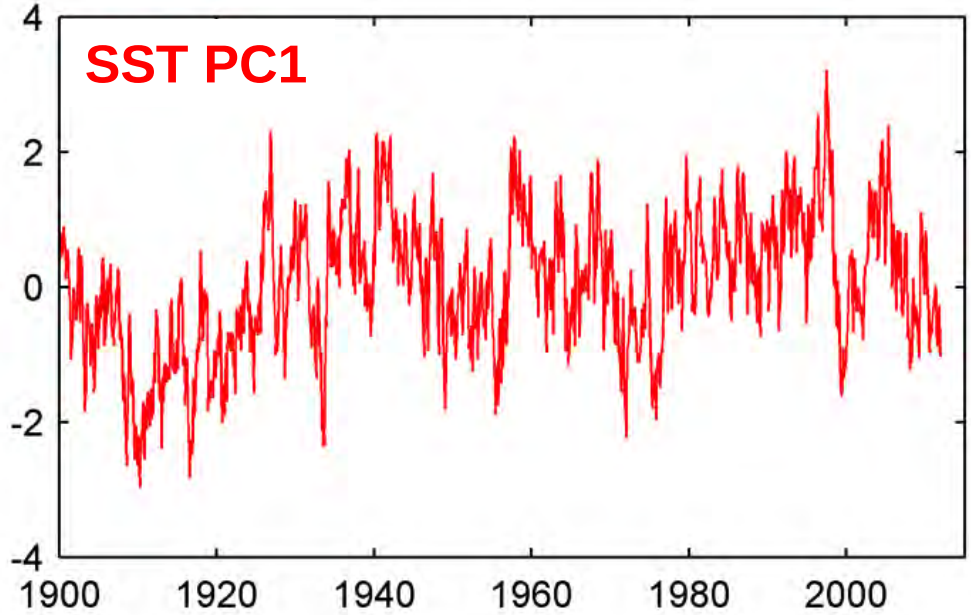


Leading EOFs/PCs of NEP SST and SLP

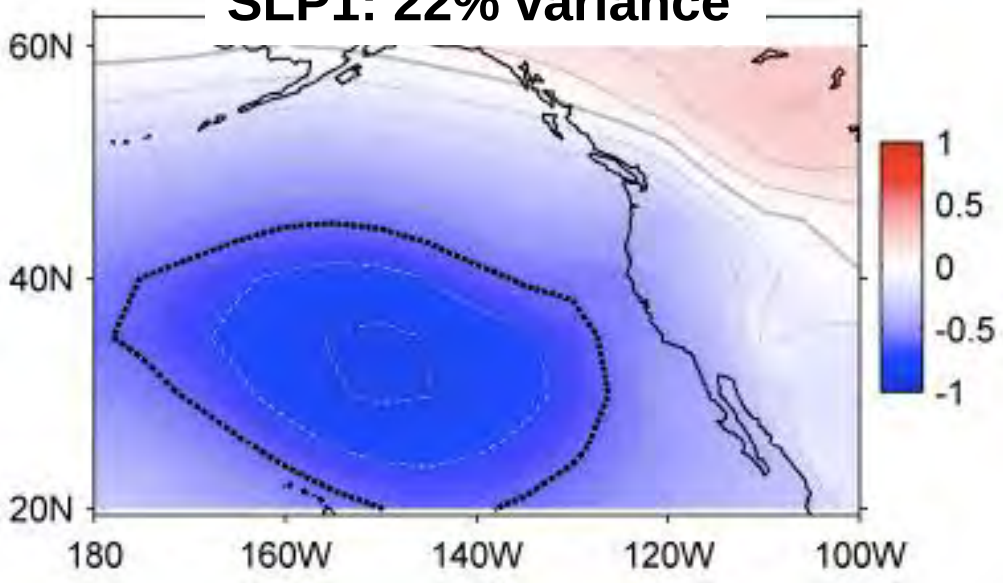
(Johnstone and Mantua, 2014: PNAS)

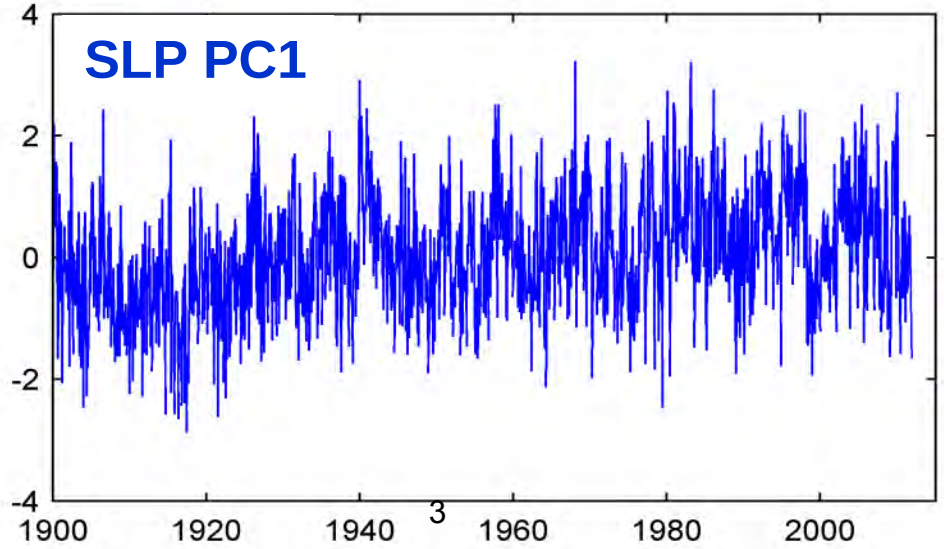
SST1: 30% variance





SLP1: 22% variance





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

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

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

$\alpha = 0.81$ *(persistence term)* $\quad ß = 0.27$ *(SLP perturbation)*

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

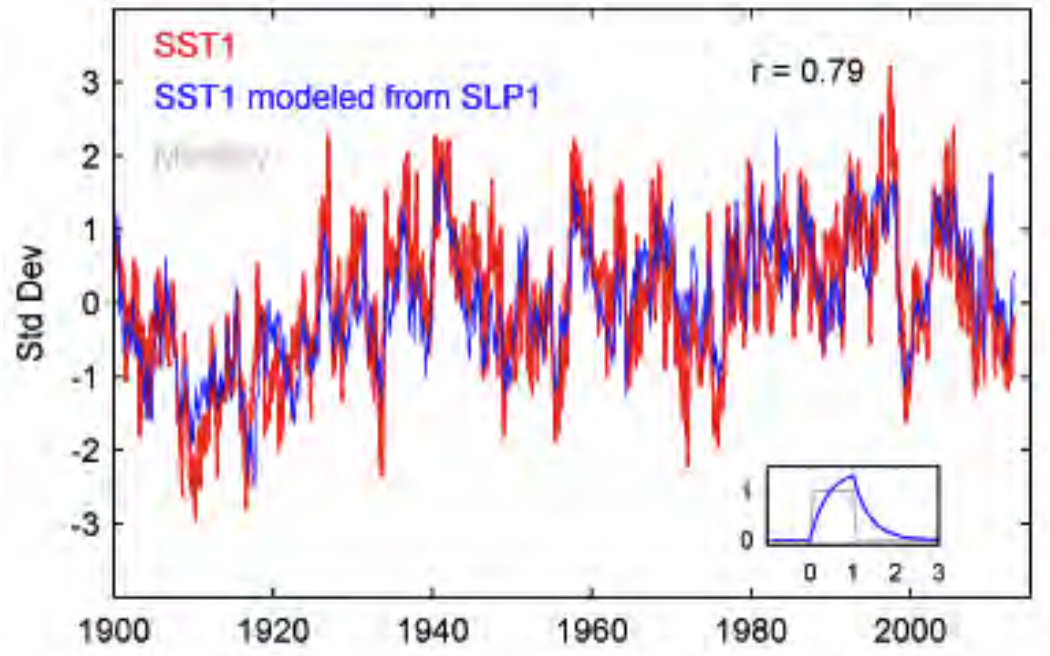
(Johnstone and Mantua, 2014: PNAS)

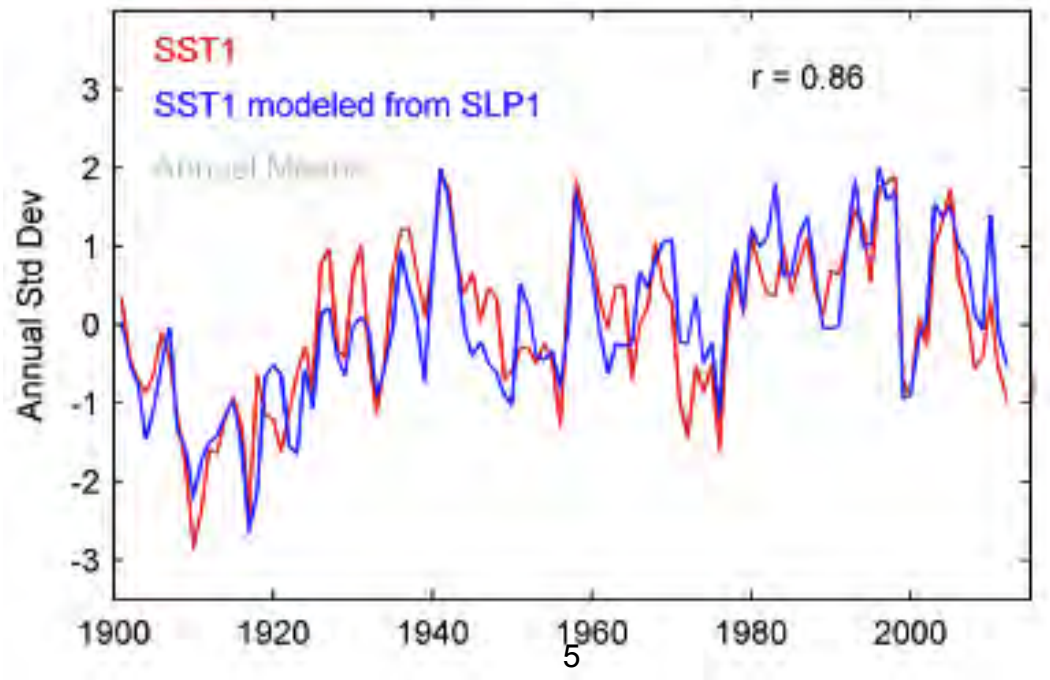
SST1 modeled from SLP1 forcing + persistence

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

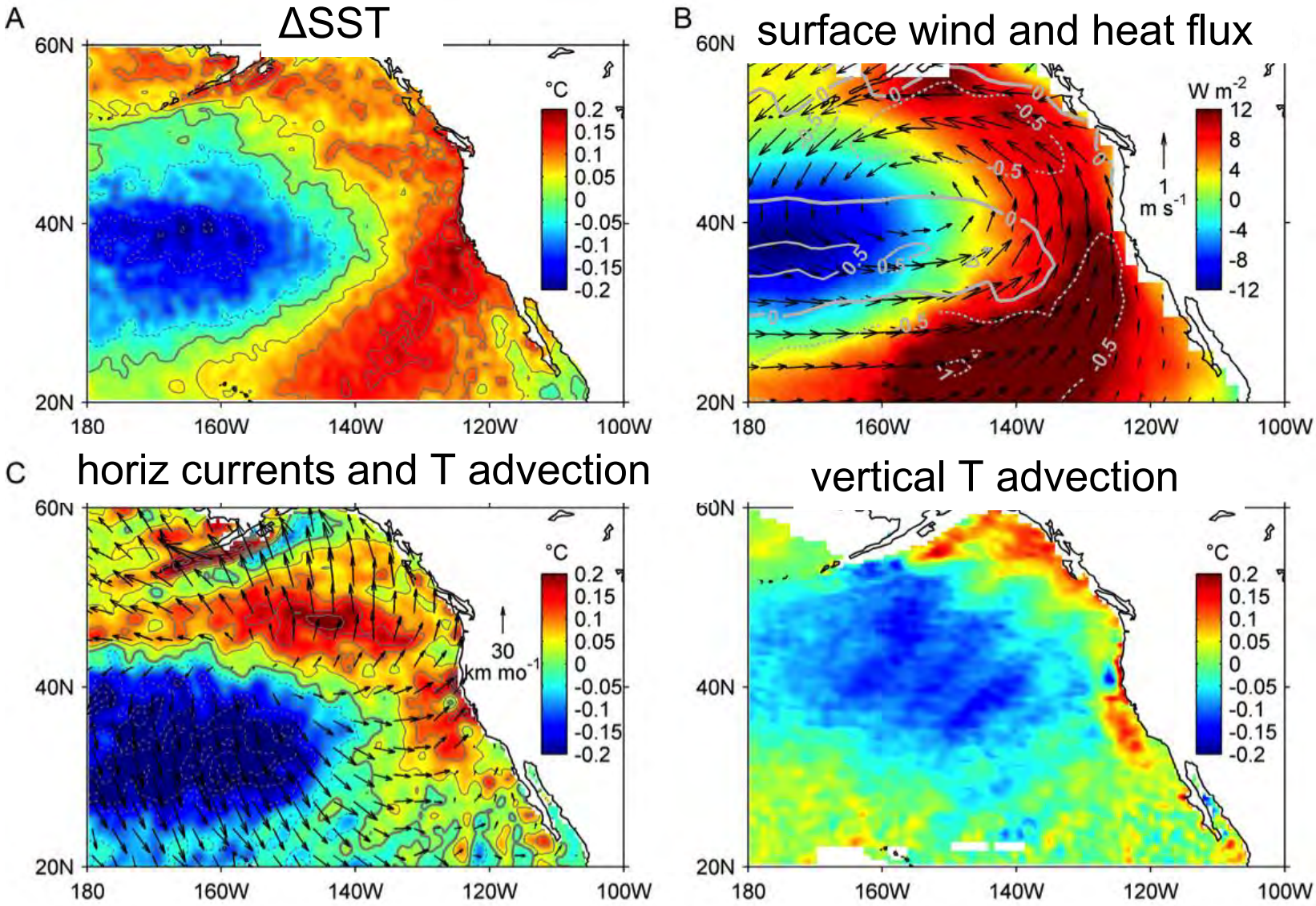
Century long warming trend in the NEP Arc related to trend to lower SLP between Hawaii and the West Coast

(Johnstone and Mantua, 2014: PNAS)





SST tendency and heating terms associated with SLP1 of +1σ



Geophysical Research Letters

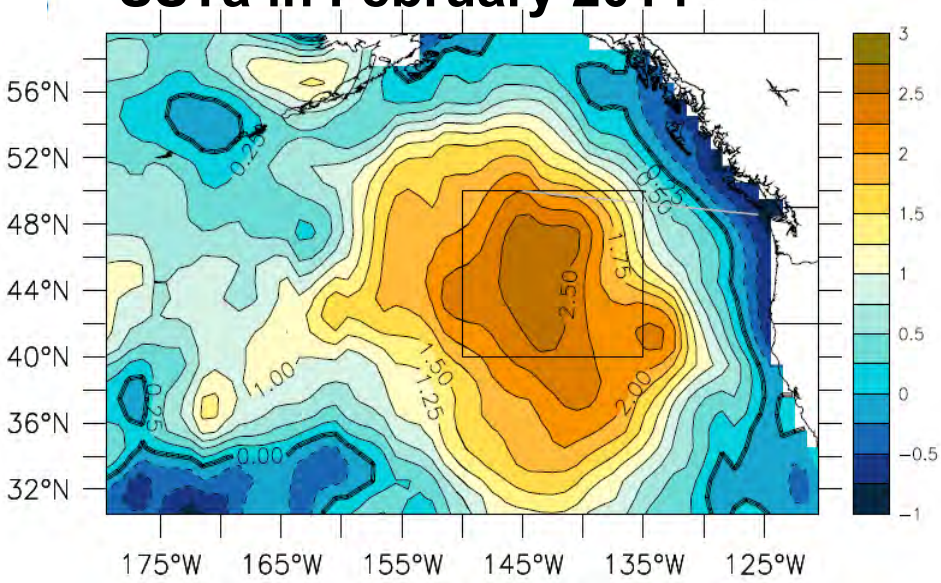
RESEARCH LETTER
10.1002/2015GL063306

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

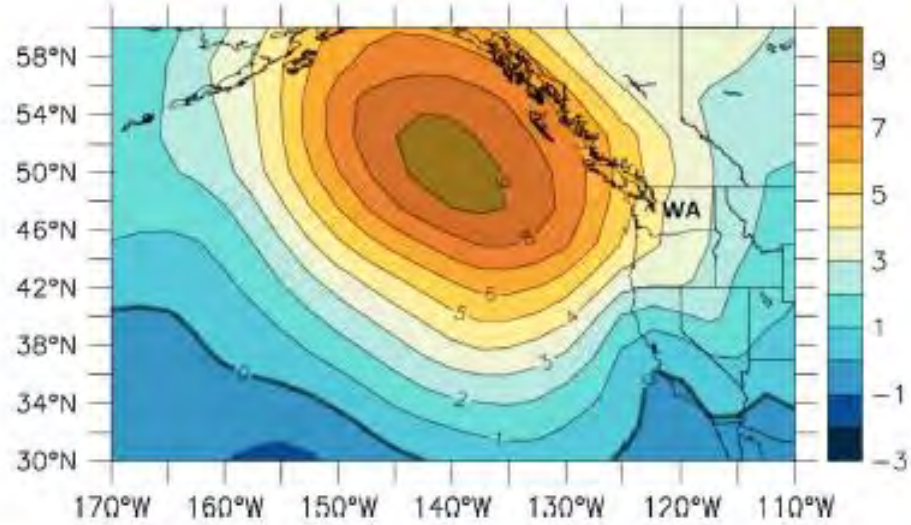
Nicholas A. Bond[1], Meghan F. Cronin[2], Howard Freeland[3], and Nathan Mantua[4]

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

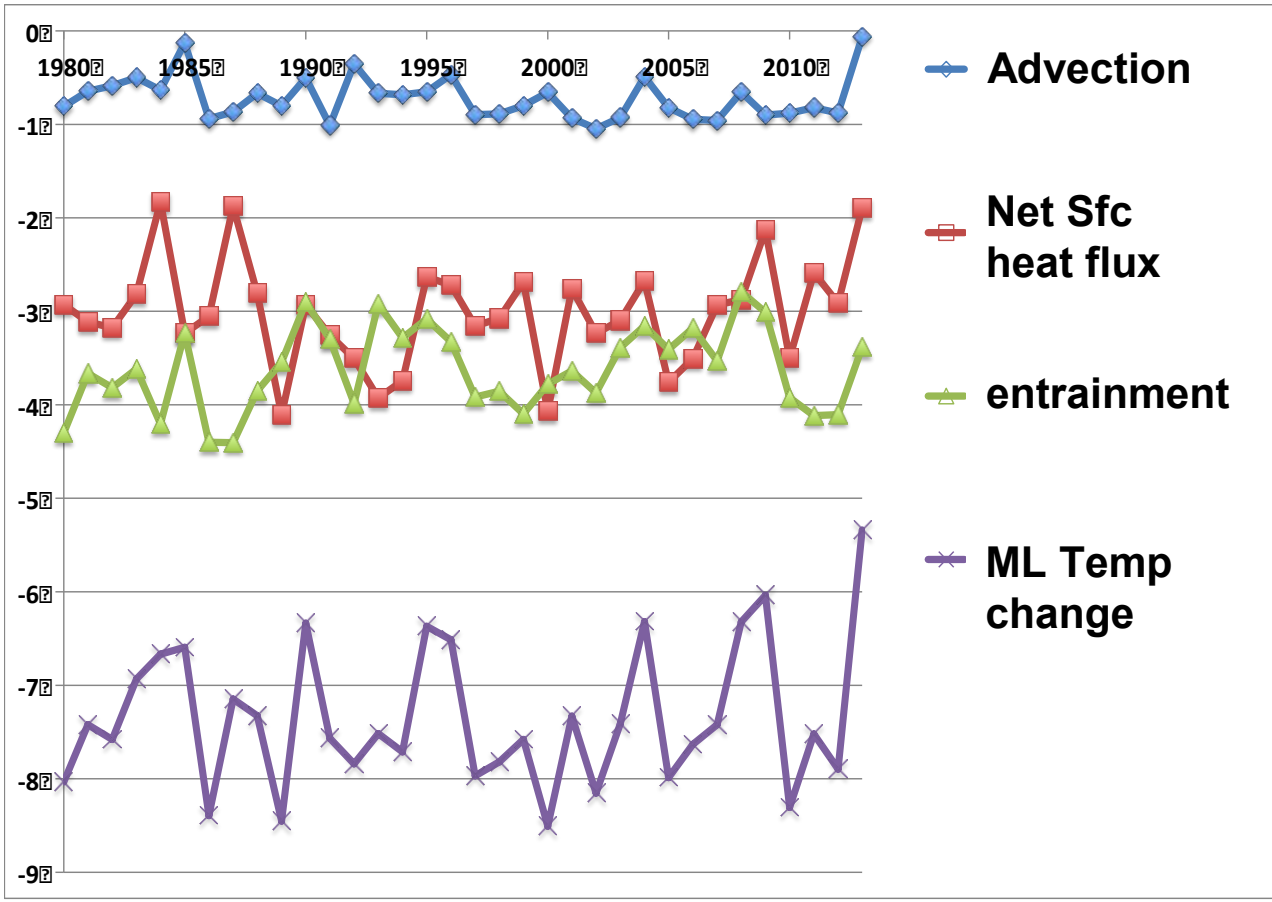


Sea Level Pressure anomalies: Oct 2013-Jan 2014



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



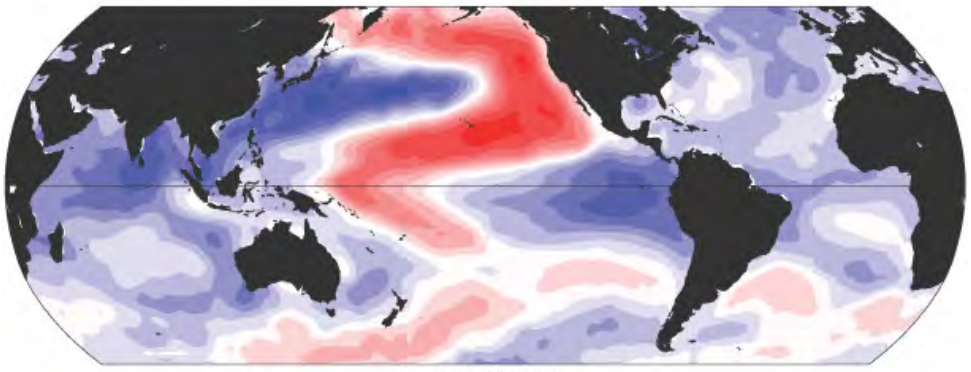
Bond et al; Geophysical Research Letters
Volume 42, Issue 9, pages 3414-3420, 5 MAY 2015 DOI: 10.1002/2015GL063306
http://onlinelibrary.wiley.com/doi/10.1002/2015GL063306/full#grl52851-fig-0004

What Caused the warm Blob in 2013/14?

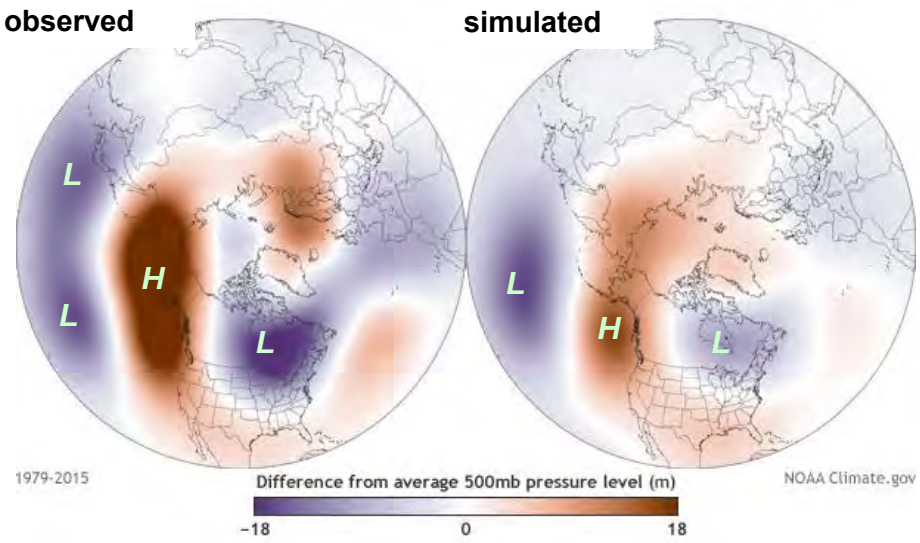
- The proximate cause: persistent ridge of high pressure – and the lack of stormy weather and strong winds (Bond et al. 2015, GRL)

- 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

nature climate change

ARTICLES

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

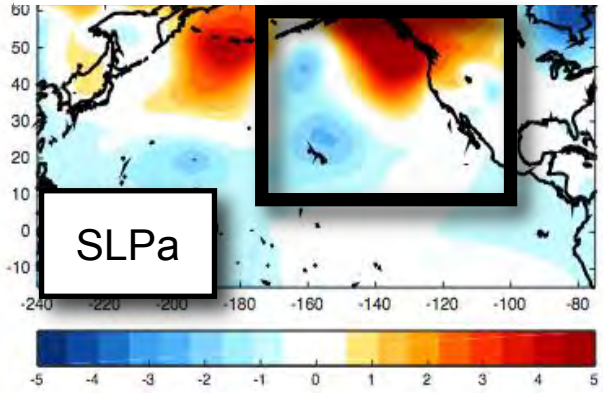
Multi-year persistence of the 2014/15 North Pacific marine heatwave

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

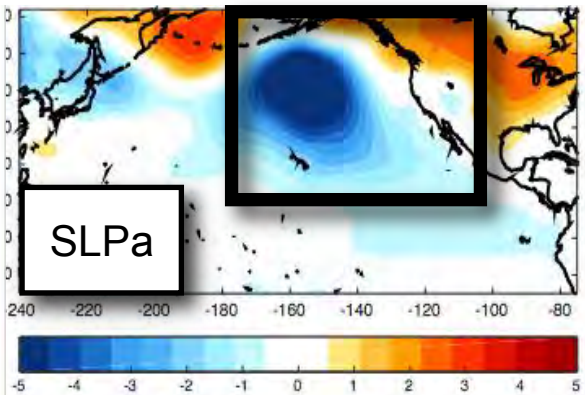
- Winter (JFM) 2014 warm blob evolved into an ARC-like warming pattern fall 14/winter 15

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

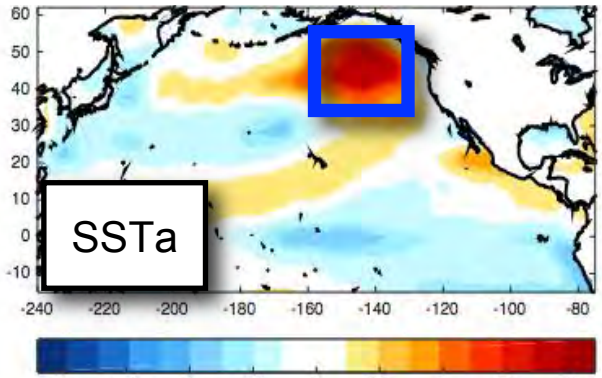
Winter 2014



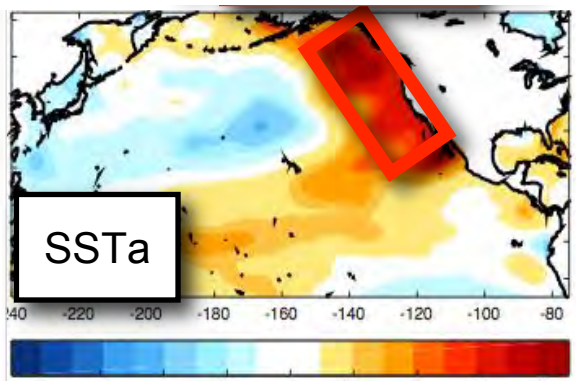
Winter 2015



GOA SSTA



ARC SSTA



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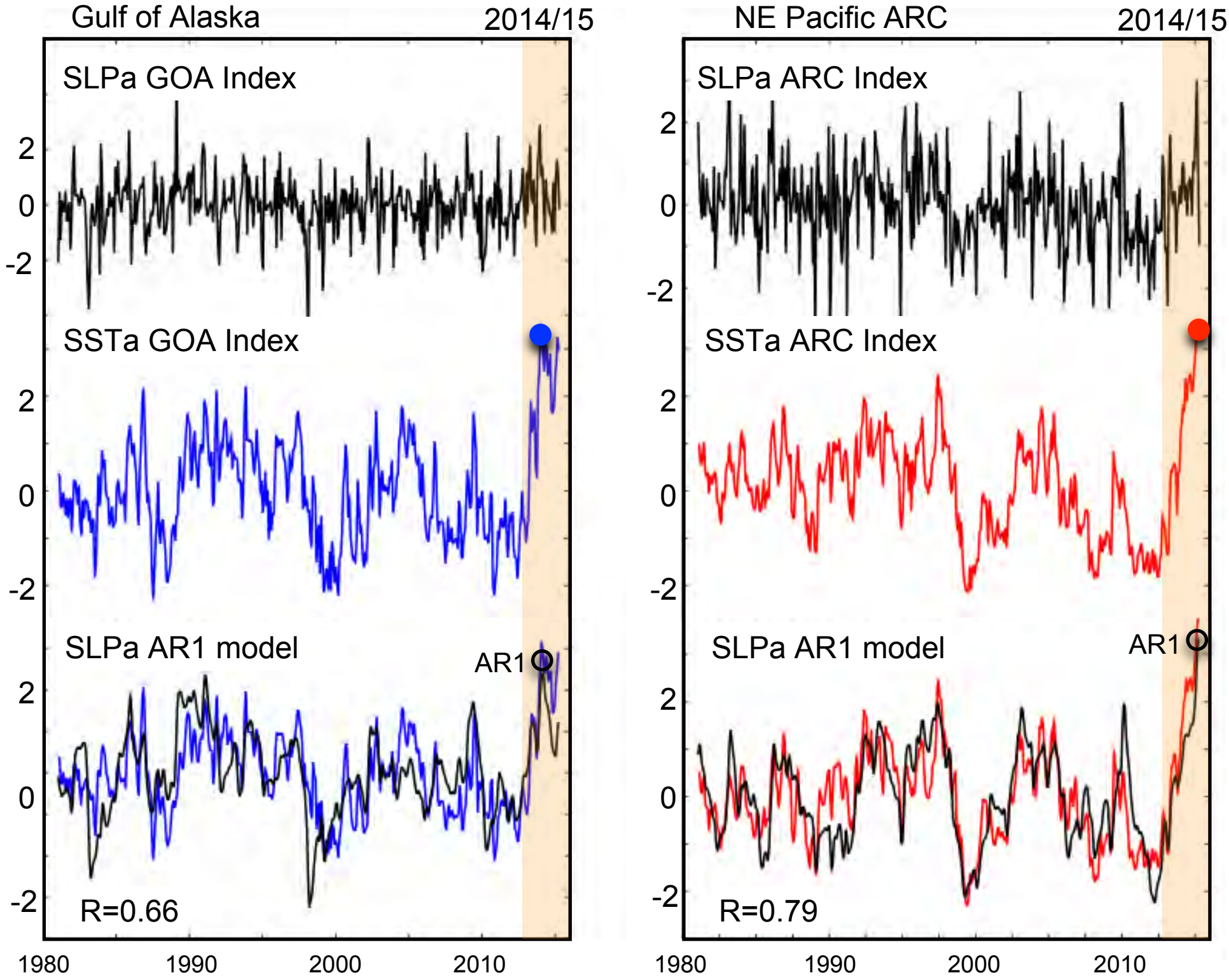
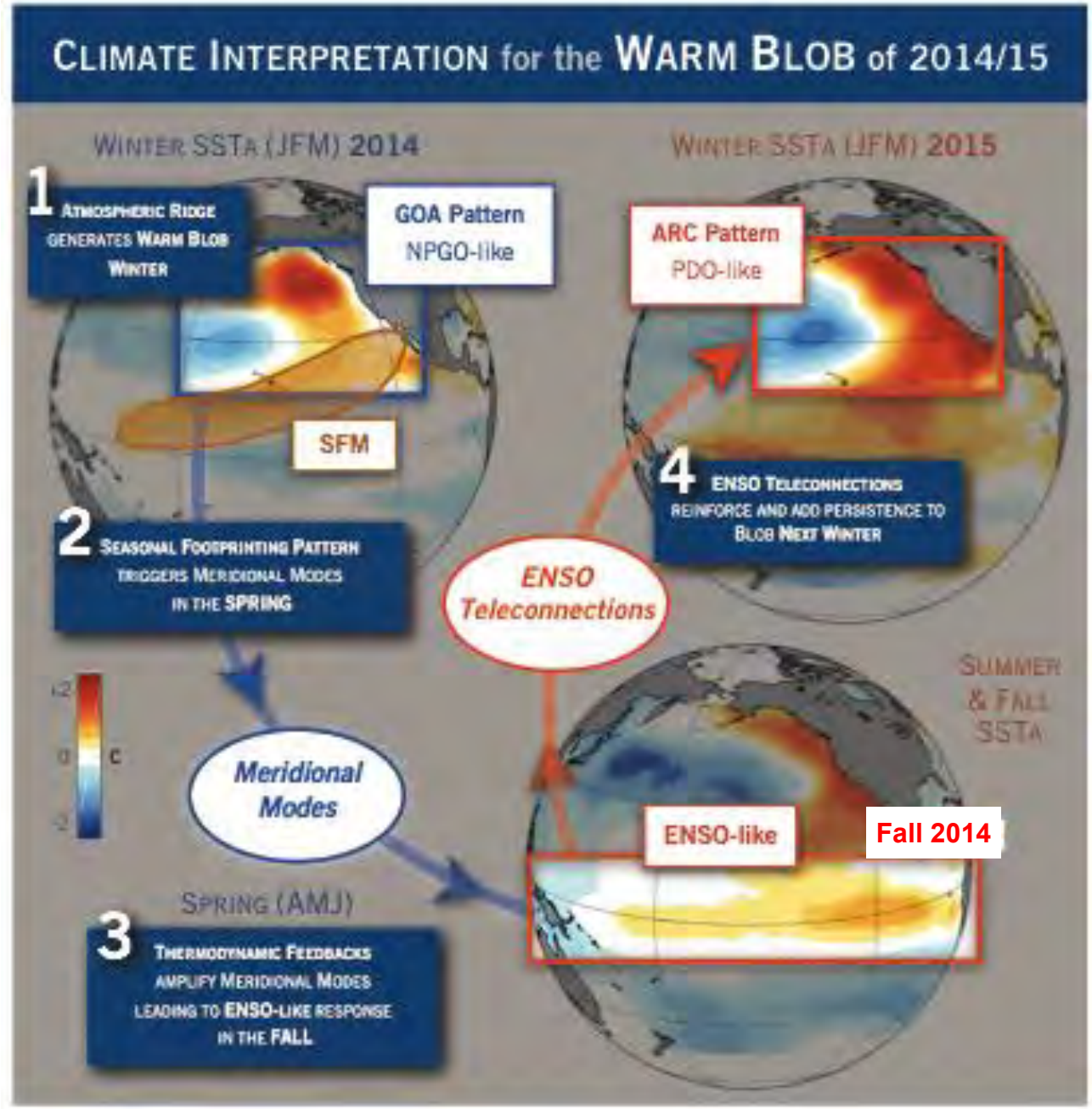

Gulf of Alaska
2014/15
SLPa GOA Index
SSTa GOA Index
SLPa AR1 model
AR1
R=0.66
NE Pacific ARC
2014/15
SLPa ARC Index
SSTa ARC Index
SLPa AR1 model
AR1
R=0.79
2
0
-2
1980
1990
2000
2010

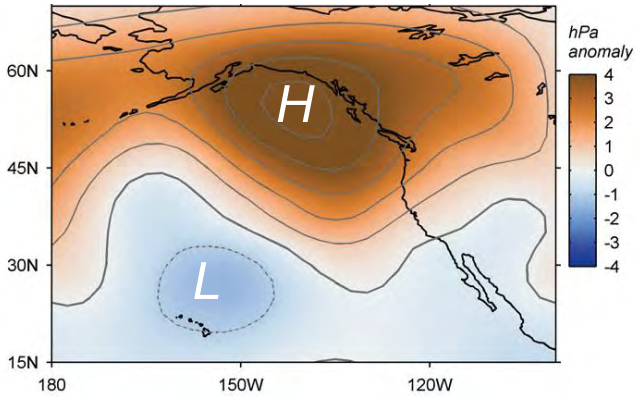
Persistence and evolution of SST/SLP anomalies involved well-known extratropical-tropical-extratropical teleconnections

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

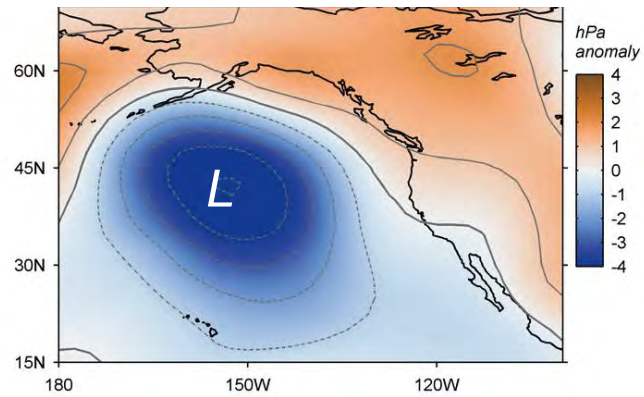
DiLorenzo, Liguori, Mantua 2016: US CLIVAR Variations (Spring)



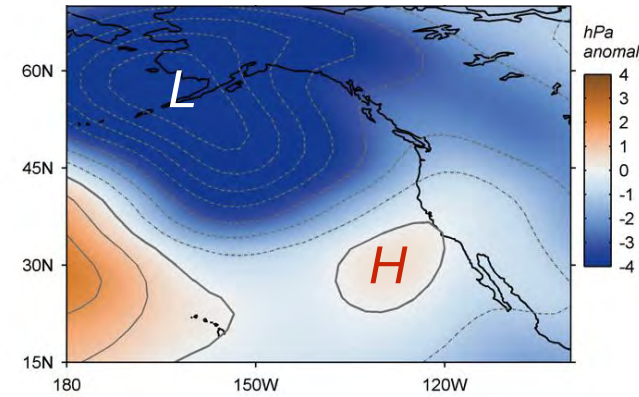
SLPA Oct-Mar 2013-14



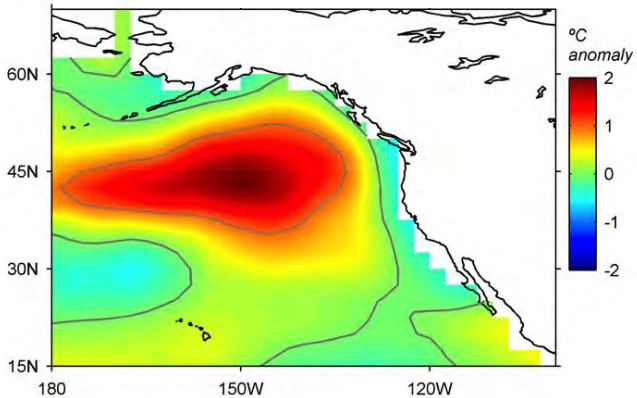
SLPA Oct-Mar 2014-15



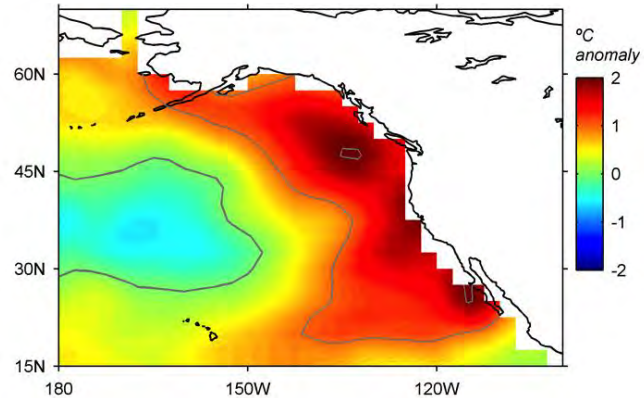
SLPA Oct-Mar 2015-16



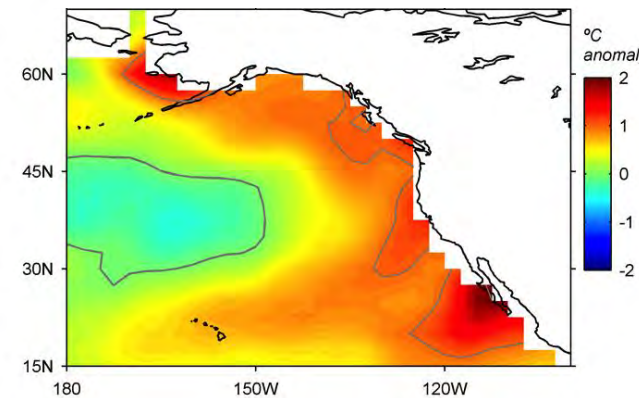
SSTA Oct-Mar 2013-14

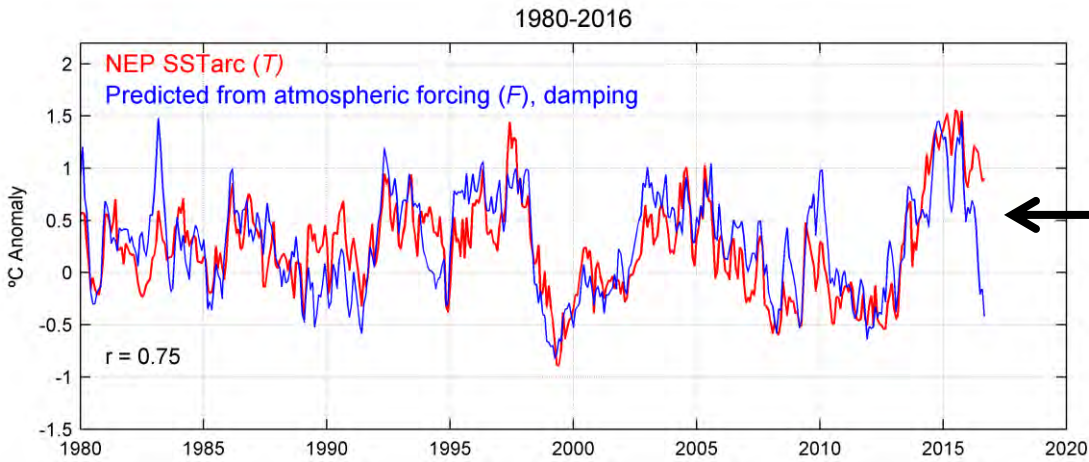


SSTA Oct-Mar 2014-15



SSTA Oct-Mar 2015-16



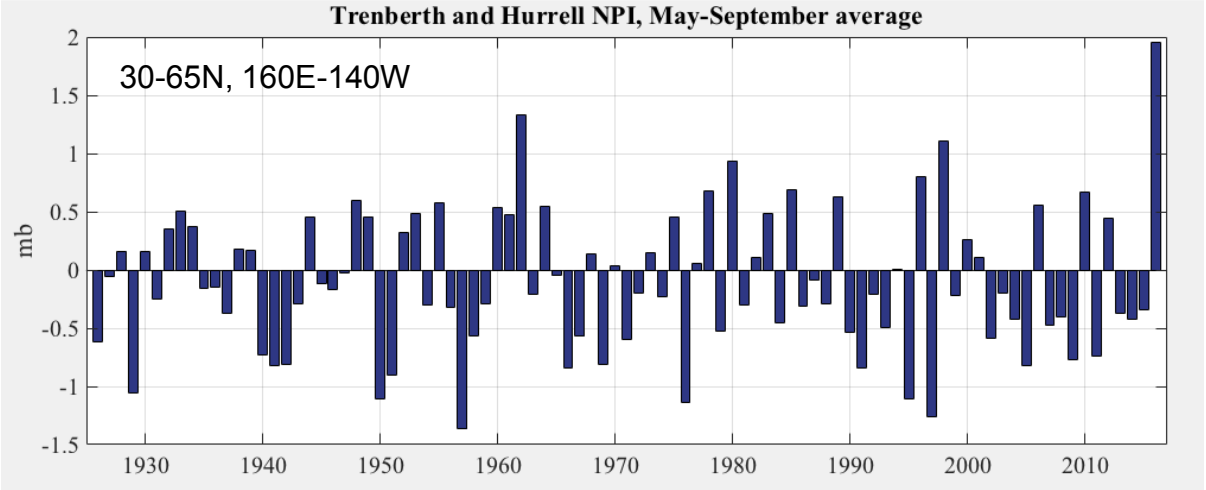


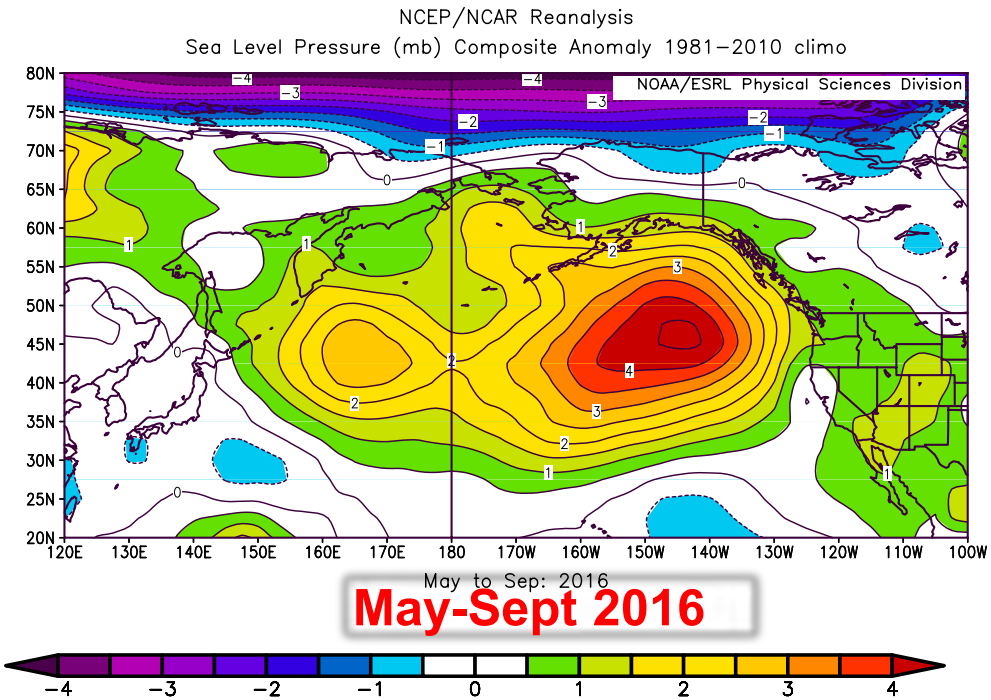
SLP-forced AR1 model for ARC SST pattern generally does a good job matching observations, but not in 2016

Summer 2016

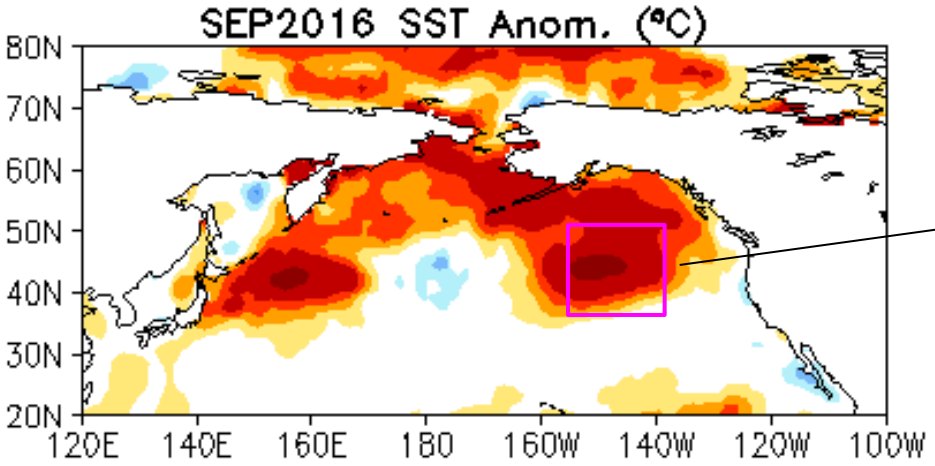
A period of extraordinary atmospheric conditions followed the end of the El Niño winter … record high sea level pressure anomalies over the N. Pacific from May-September 2016

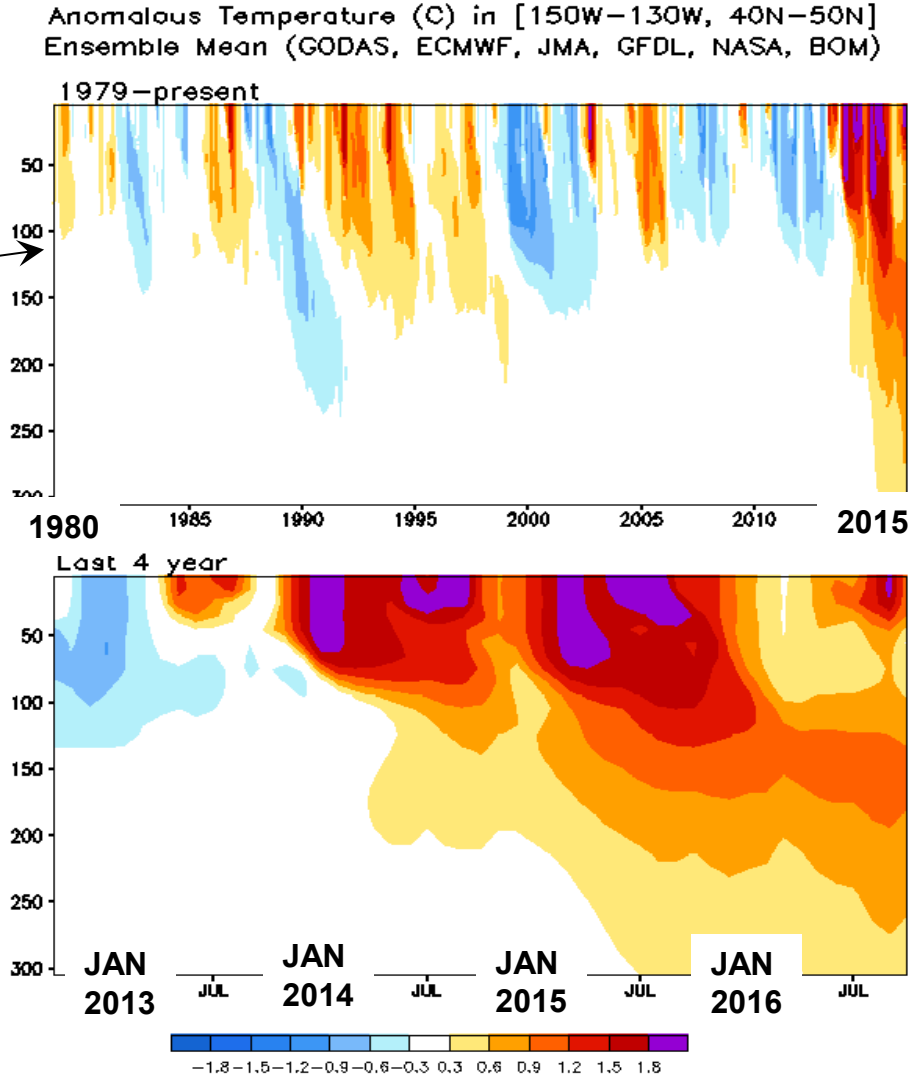
What happens after 5 months of fair weather across the N. Pacific and Bering Sea???





The blob makes a comeback!
SSTA - September 2016

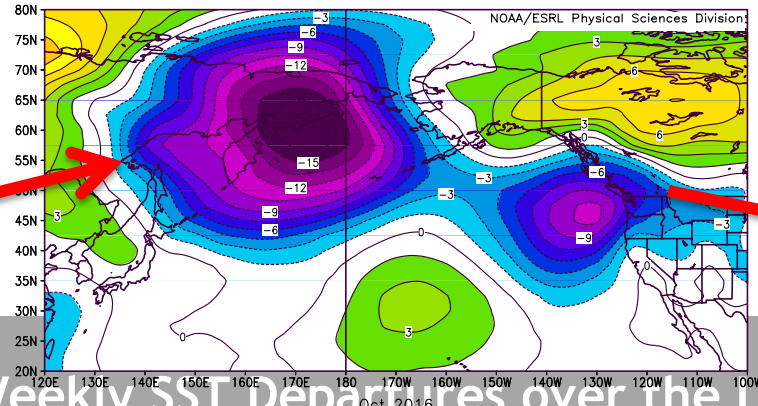




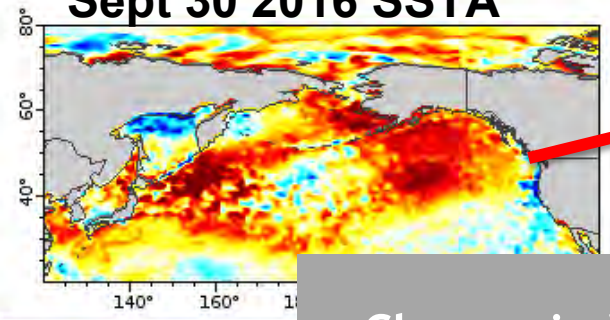
Rapid growth of near-surface warm anomalies beginning in June

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

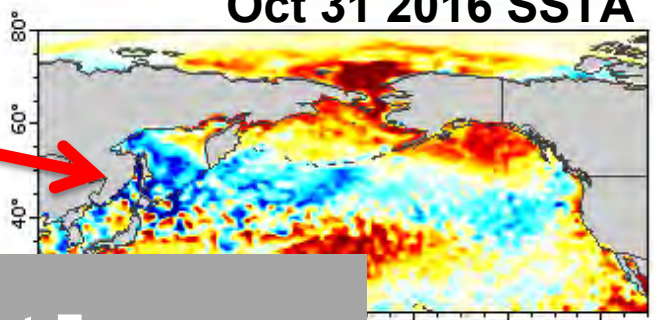
October 2016 SLPA



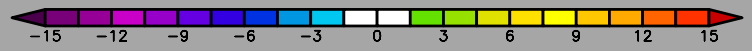
Sept 30 2016 SSTA



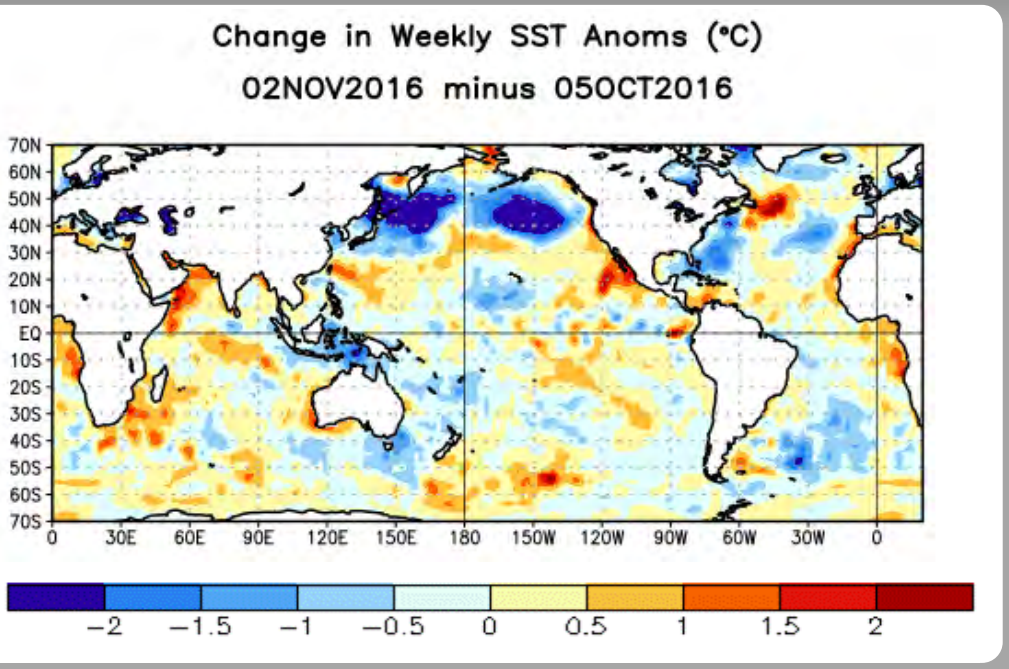
Oct 31 2016 SSTA



Change in Weekly SST Departures over the Last Four Weeks



During the last four weeks, small regions of equatorial SST anomalies increased or decreased across the central and eastern Pacific.



Summary and Discussion

- The cool PDO period of 1998-2013 seems like a distant memory
- Many SST records broken in 2014-2016 – Blob origination region (2014), NE Pacific ARC (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 – in this case, expressed through increased variance in natural modes