

# Changes in Climate and Changes in Concepts: Physical-Biological Interplay in the Pacific Ocean Over the PICES Years

Art Miller

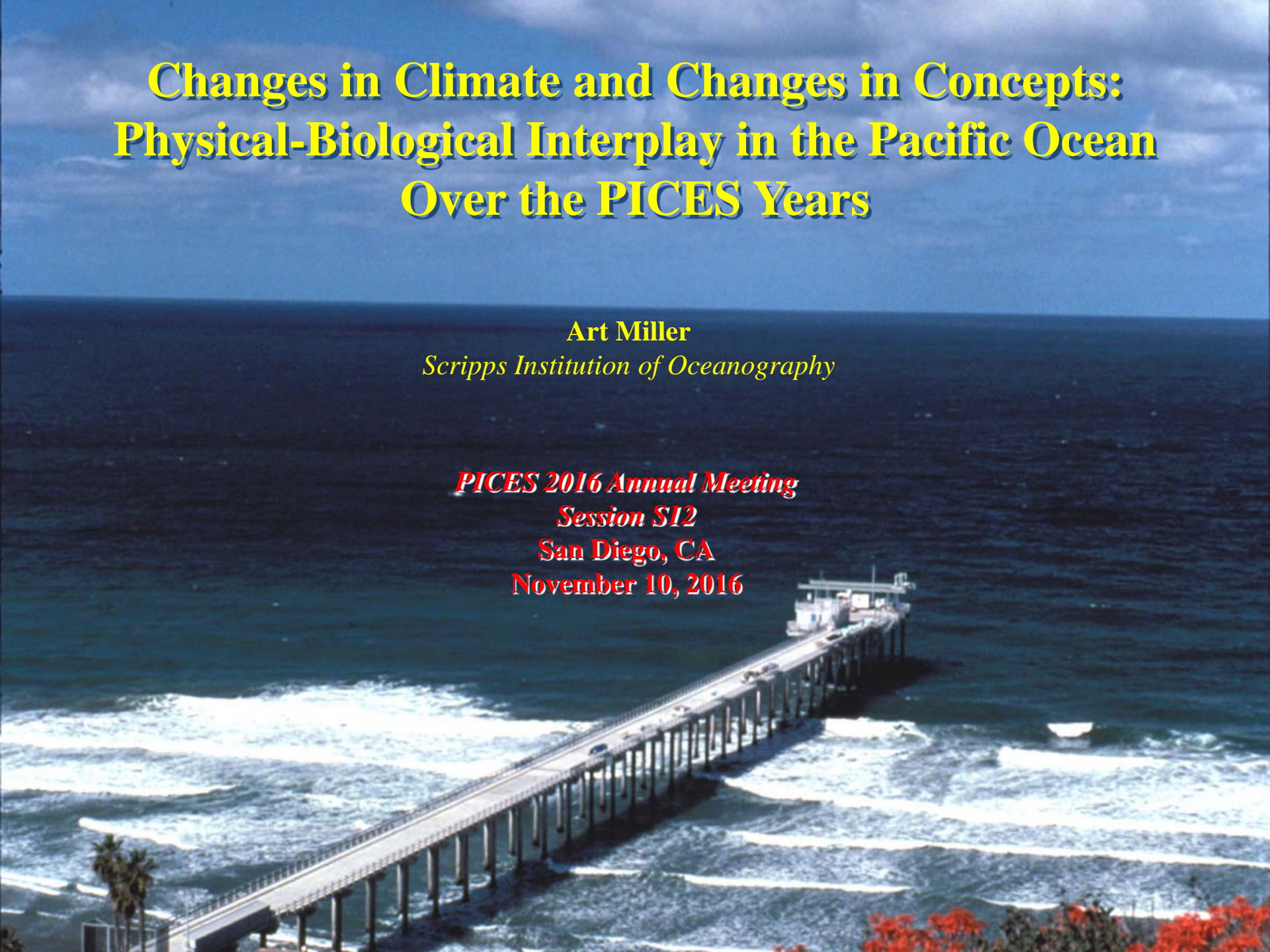
*Scripps Institution of Oceanography*

*PICES 2016 Annual Meeting*

*Session S12*

**San Diego, CA**

**November 10, 2016**



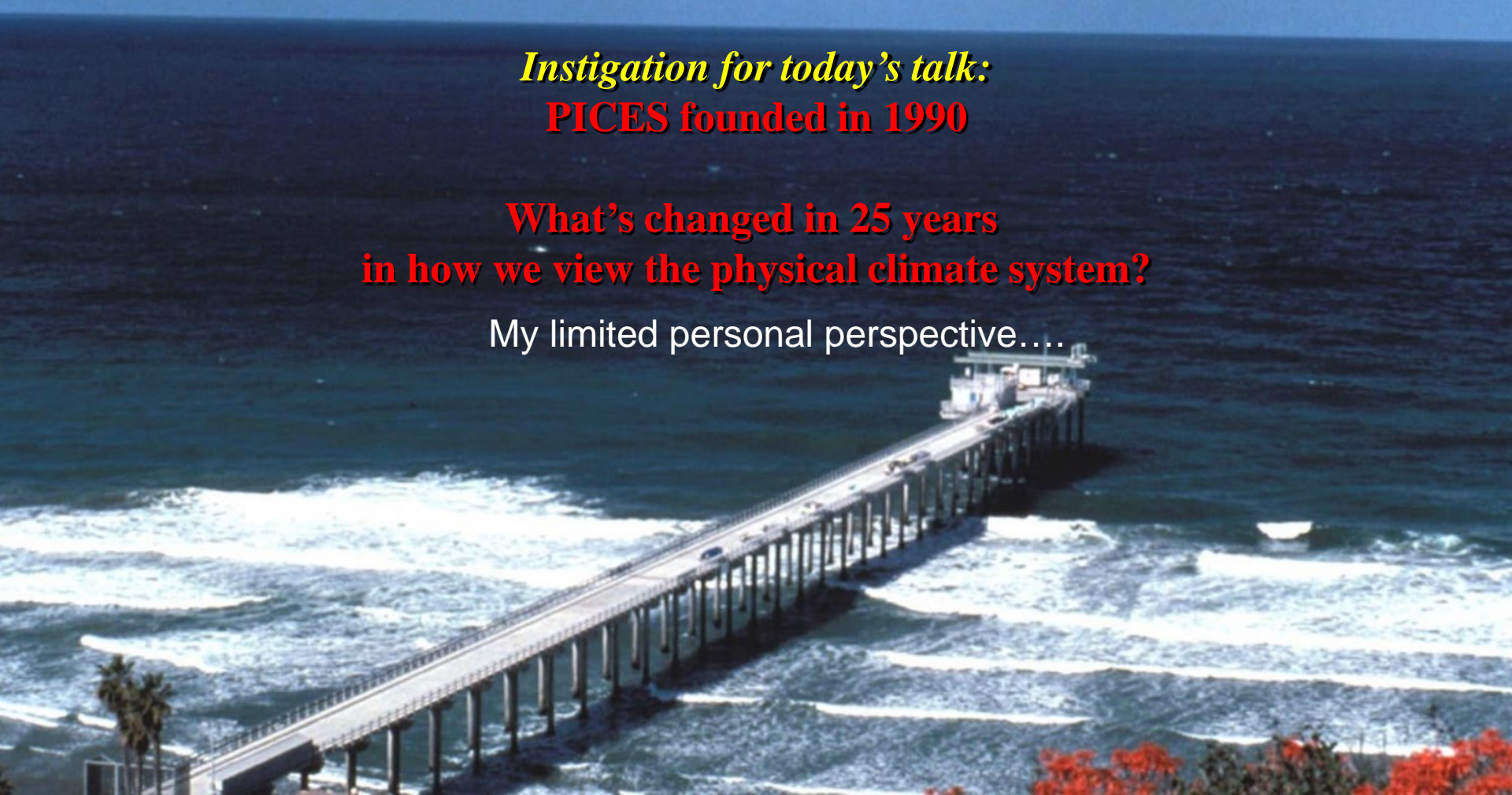


# Changes in Climate and Changes in Concepts: Physical-Biological Interplay in the Pacific Ocean Over the PICES Years

*Instigation for today's talk:*  
**PICES founded in 1990**

**What's changed in 25 years  
in how we view the physical climate system?**

My limited personal perspective....

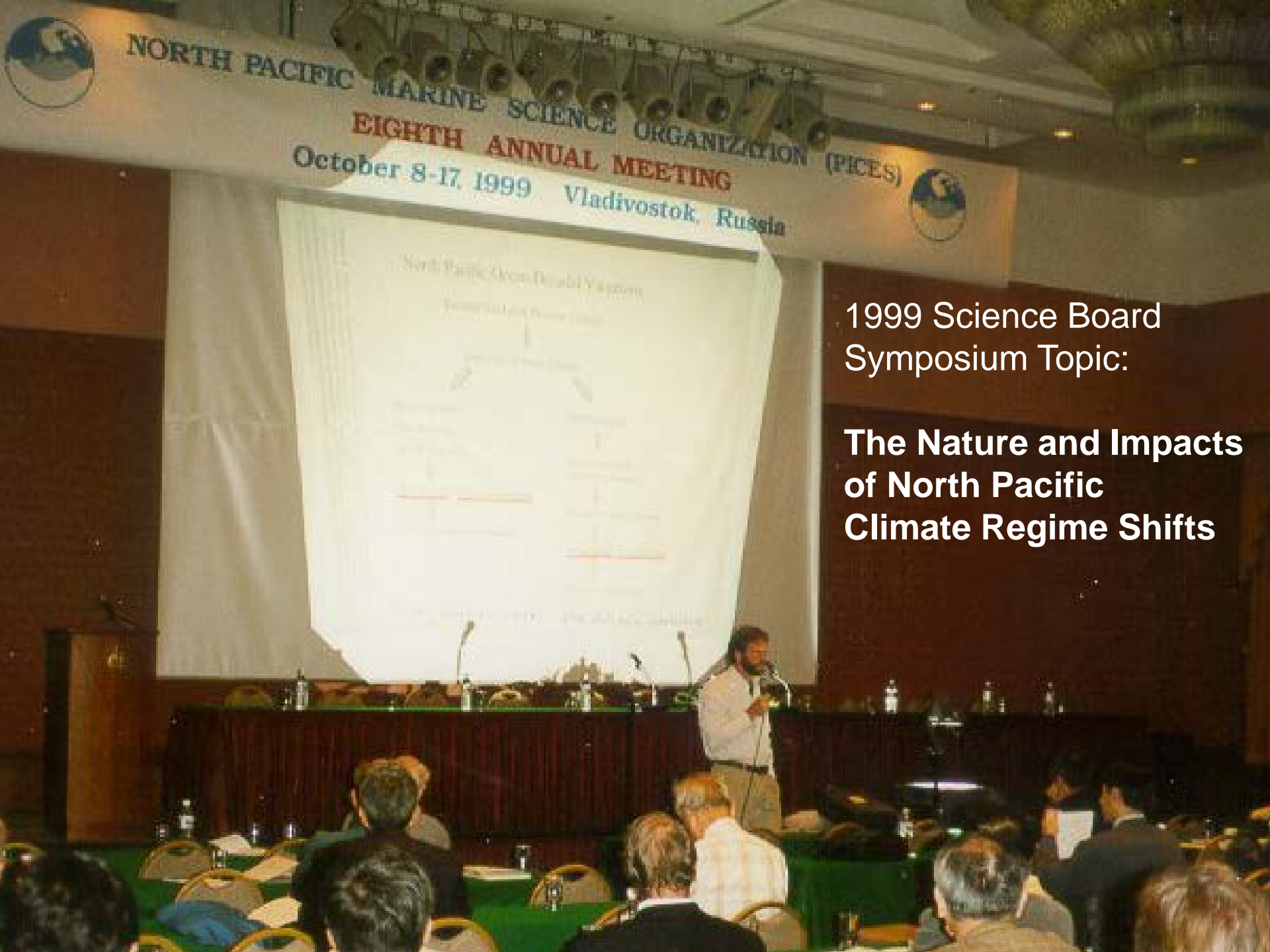




 NORTH PACIFIC MARINE SCIENCE ORGANIZATION (PICES)  
**EIGHTH ANNUAL MEETING**  
October 8-17, 1999 Vladivostok, Russia 



Art's First PICES Talk:  
Science Board  
Symposium  
Keynote Address  
in Vladivostok, 1999  
(Photo by Steve Hare)



 NORTH PACIFIC MARINE SCIENCE ORGANIZATION (PICES)  
**EIGHTH ANNUAL MEETING**  
October 8-17, 1999 Vladivostok, Russia 

1999 Science Board  
Symposium Topic:

**The Nature and Impacts  
of North Pacific  
Climate Regime Shifts**

# The Great Hope

- **Climate regimes: *existence***
- **Climate regimes: *predictability***
- **Climate regimes: *quantify impacts on ecosystem***



Some Theories of Decadal Variability  
of the  
Midlatitude Pacific O-A System

From: Miller 1999  
PICES Talk

- ① Stochastic Atmospheric Forcing  
Hasselmann (1976)  
Frankignoul, Muller + Zorita (1997)  
Barsugli + Battisti (1998)  
Saravanan + McWilliams (1997, 1998)
- ② Atmospheric Teleconnections from Tropics  
Trenberth (1990); Graham (1994)
- ③ Oceanic Teleconnections from Tropics  
Jacobs et al. (1994); Meyers et al. (1997)  
Clarke + Lebedev (1997)
- ④ Midlatitude Ocean - Atmosphere Interaction  
Latif + Barnett (1994); Robertson (1995)  
Jin (1997); Cessi (1998); Münnich et al. (1998)  
Goodman + Marshall (1999); Neelin + Weng (1999)
- ⑤ Tropical - Extratropical Interaction  
Gu + Philander (1996)  
Lysne et al. (1997); McCreary (1998)
- ⑥ Intrinsic Oceanic Variability  
Spall (1996) ....

# Some Mechanisms of Physical Variables Influencing Biology on Decadal Time Scales

From: Miller 1999  
PICES Talk

PHYSICS → Primary Production  
→ Top Level

## TEMPERATURE

SST - fish populations, corals  
zooplankton growth

Thermocline - bottom dwellers on shelf

## SALINITY

- corals

## Mixed Layer Depth

- primary production

## Upwelling

- primary production  
confinement to narrow coast zone  
vs. seaward spreading

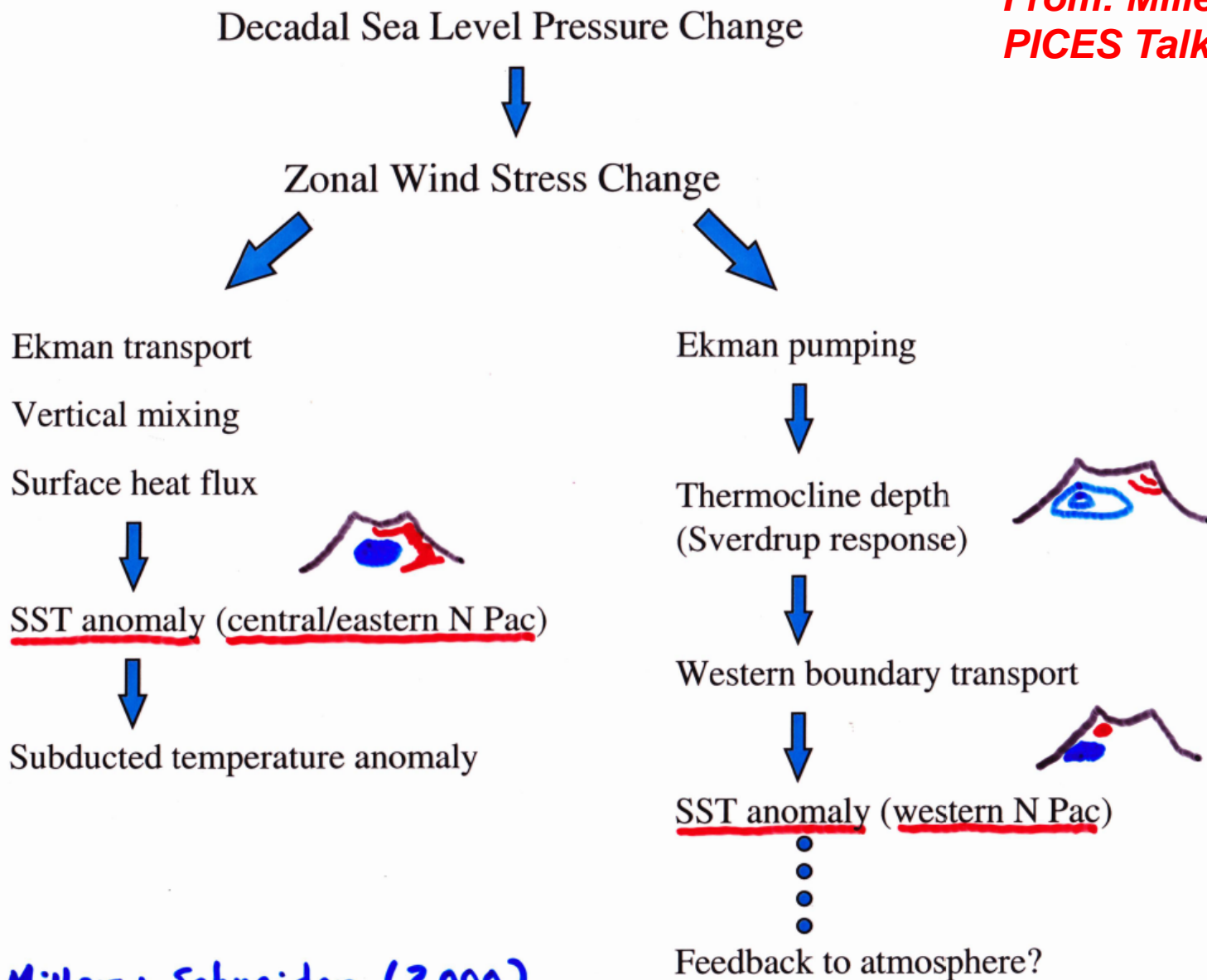
## CURRENTS

- Kuroshio transport of juvenile  
sardines: condensed or expanded  
areal range

-----  
Biological Sampling Uncertainty  
⇒ difficult to constrain theories

# North Pacific Ocean Decadal Variations

*From: Miller 1999  
PICES Talk*



*Miller + Schneider (2000)  
Prog. Oceanogr.*



***Many Other  
Interactions  
Too Hazy  
Too Recall:  
1999 PICES  
Vladivostok***



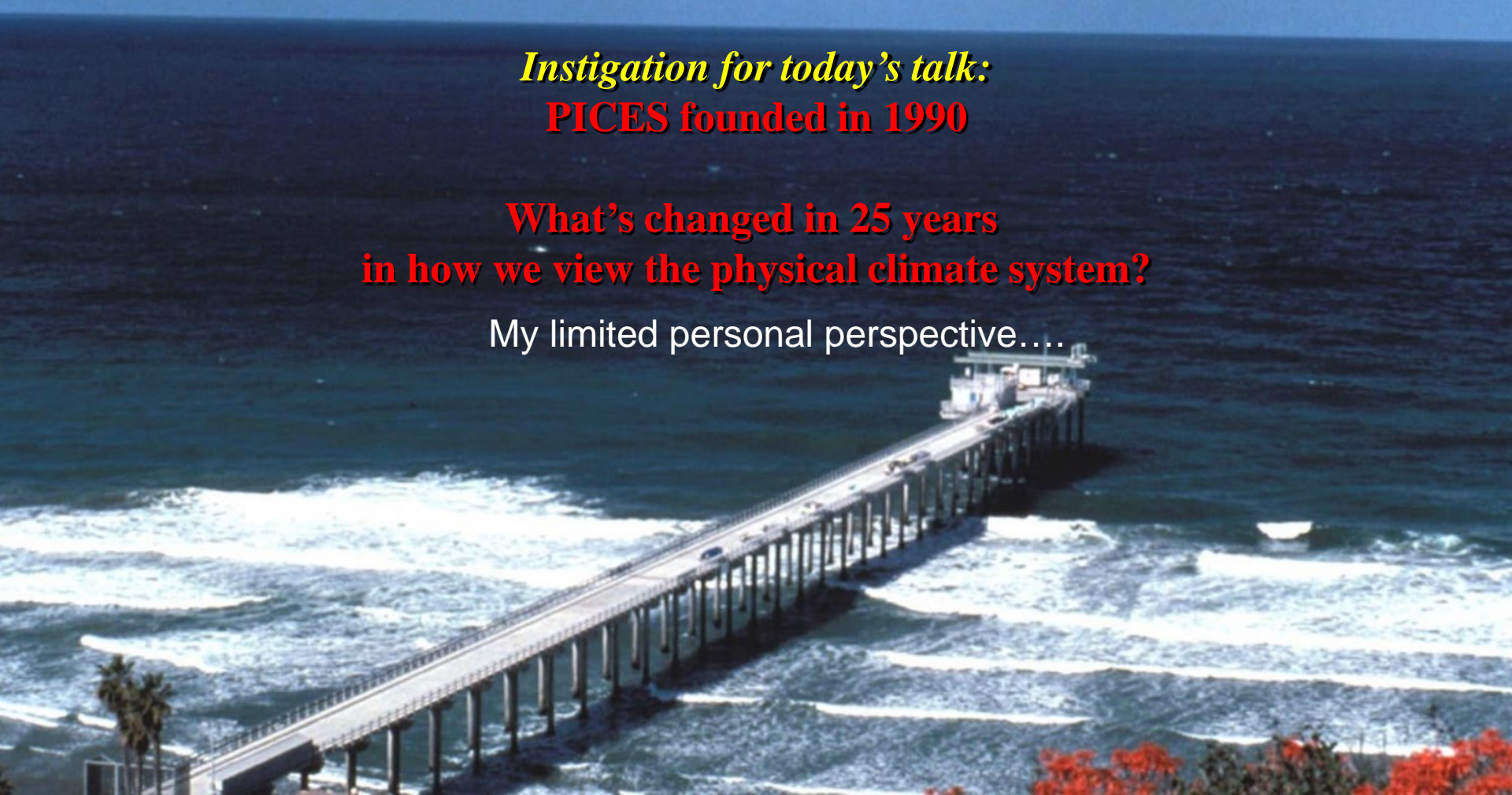


# Changes in Climate and Changes in Concepts: Physical-Biological Interplay in the Pacific Ocean Over the PICES Years

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# The Great Hope: An Update

- **Climate regimes: *existence***

- Physics noise or random superposition

- Pierce (2001), Rudnick and Davis (2003) Hsieh et al. (2005)

- Not much evidence for multiple equilibria

- except perhaps idealized WBC, Kravstov and Ghil (2004)

- **Climate regimes: *predictability***

- Little evidence, except ENSO and global warming

- Doblas-Reyes et al. (2013)

- Rossby wave adjustment => KOE SST

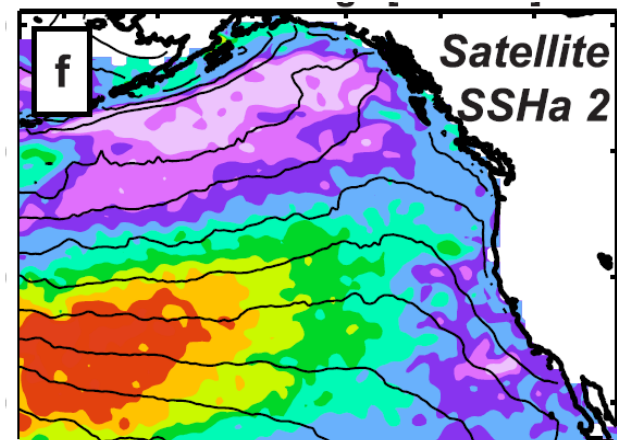
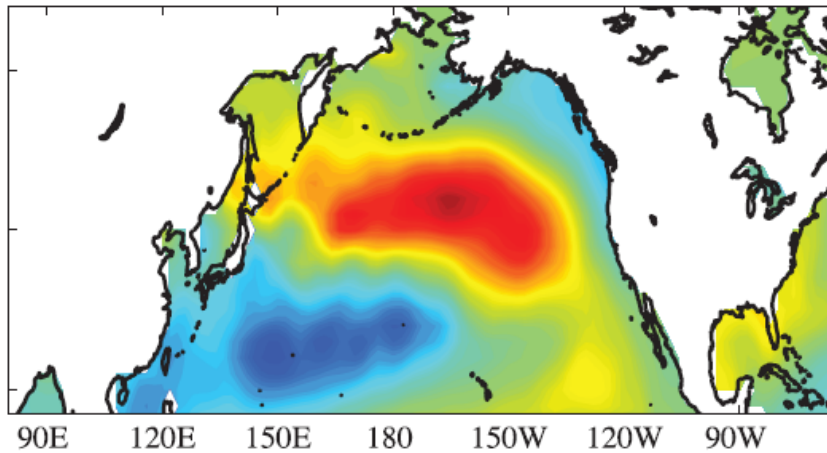
- **Climate regimes: *quantify impacts on ecosystem***

- Too much to catalog here

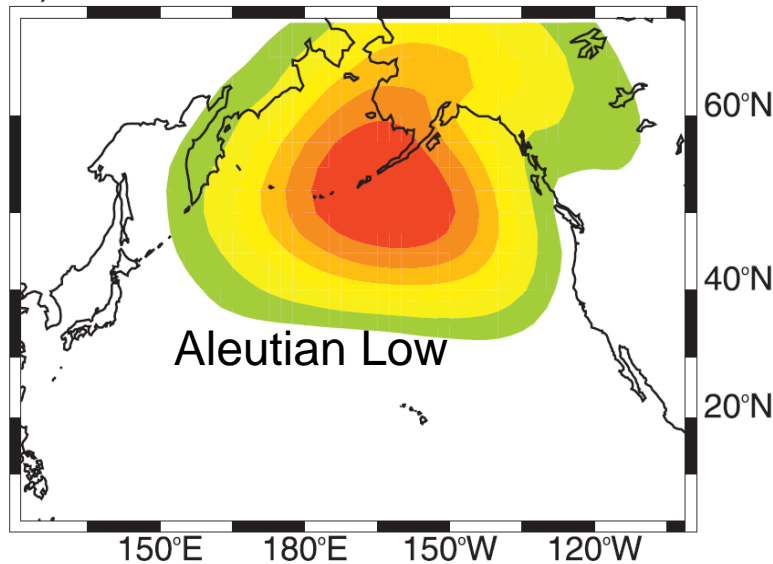


# Changes in perspective of North Pacific climate-ocean physical processes

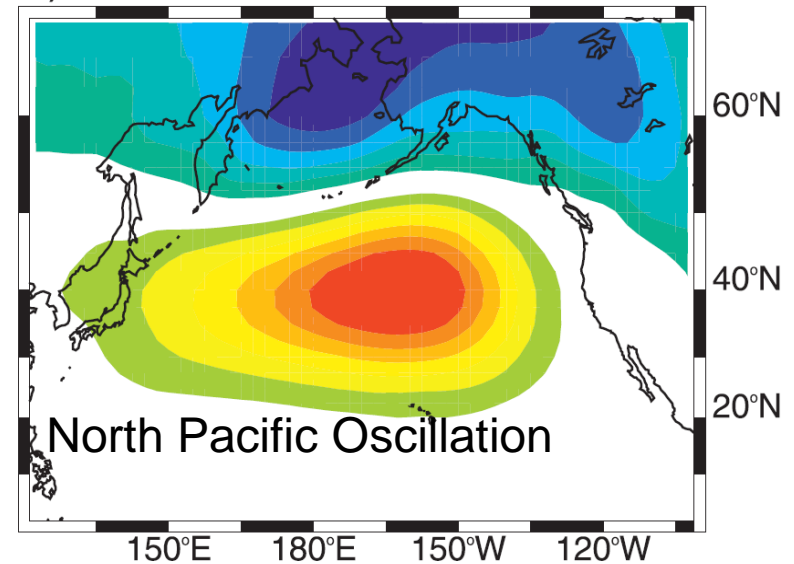
- \* Identification of the North Pacific Gyre Oscillation (NPGO) as an important large-scale controlling feature of upwelling, currents and ecosystem response (Victoria Mode of Bond et al.; Breathing Mode of Cummins et al)
  - Di Lorenzo et al. (2008, 2009)



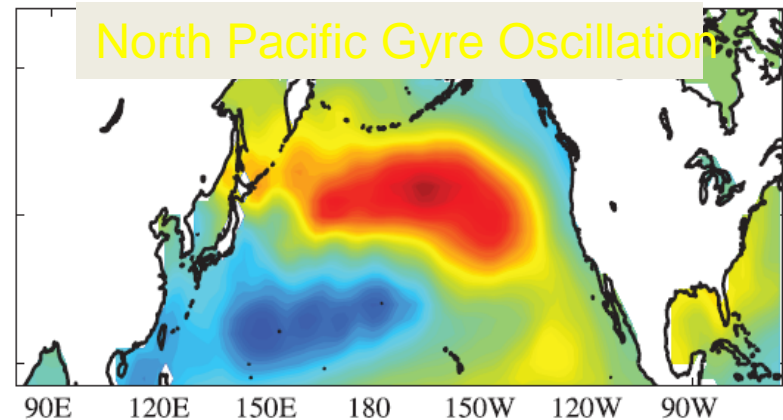
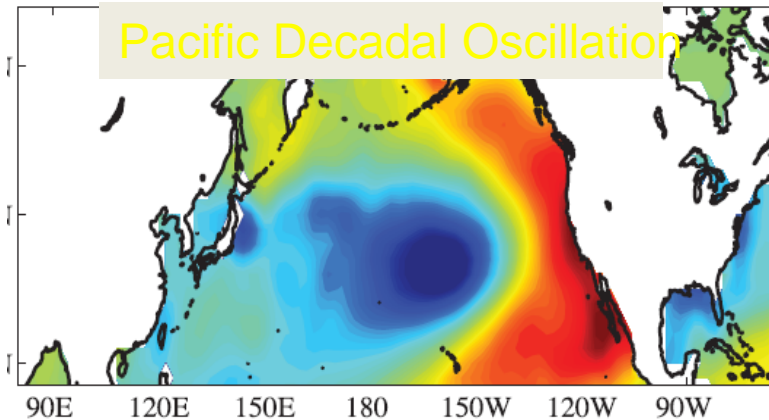
# Parallel Physical Processes and Orthogonal Patterns: PDO/NPGO Driven by 1<sup>st</sup>/2<sup>nd</sup> Atmospheric Pressure Mode



Drives the **PDO** pattern of SST



Drives the **NPGO** pattern of SST



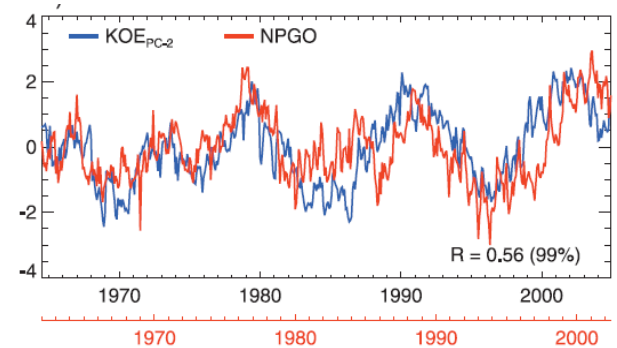
(Ceballos et al., 2009; Furtado et al., 2011)

# Changes in perspective of North Pacific climate-ocean physical processes

- Lagged East-West Cadence** of the PDO and NPGO

with KOE Latitude and Intensity

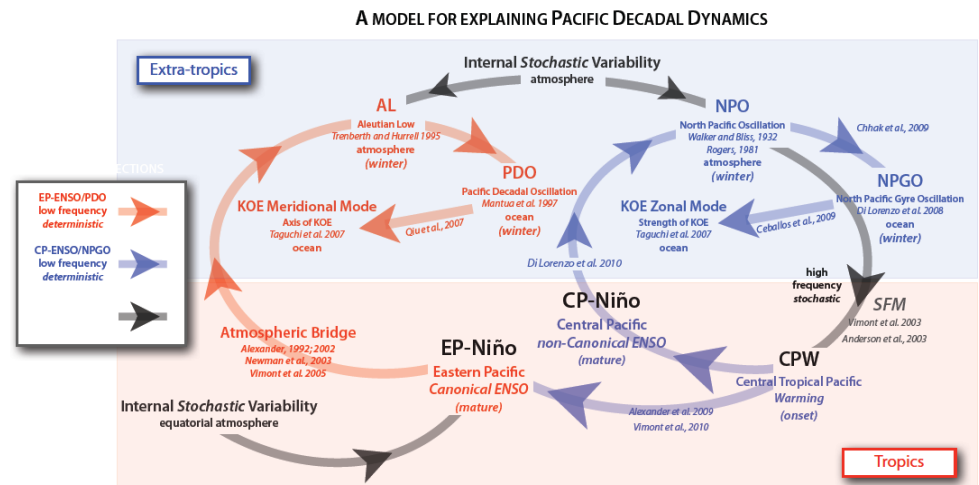
- Taguchi et al. (2007)
- Ceballos et al. (2009)



- Lagged North-South Cadence** of

NPO, NPGO, PMM, CP-ENSO, EP-ENSO, AL, PDO

- Di Lorenzo et al. (2013)

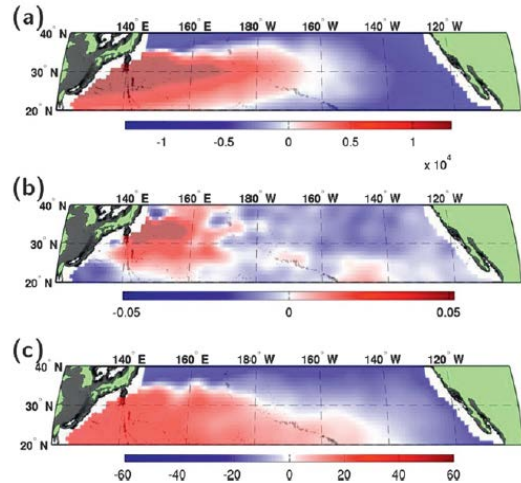




# Changes in perspective of North Pacific climate-ocean physical processes

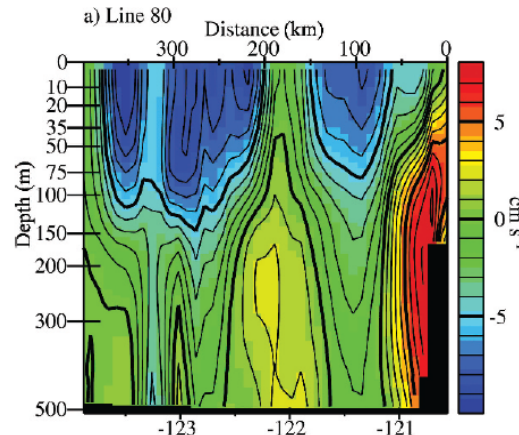
- \* Observations from Argo subsurface T-S coverage yields detailed information on structural changes in gyre scale circulation previously unattainable

- Giglio et al. (2012)



- \* Observations from long-term gliders reveal subsurface changes and patterns, e.g., persistent poleward flows offshore of the CCS undercurrent

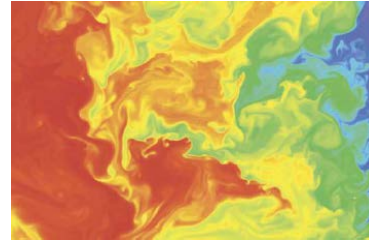
- Davis et al. (2008)



# Changes in perspective of North Pacific climate-ocean physical processes

\* Identification of Submesoscale Eddies as important mixing processes

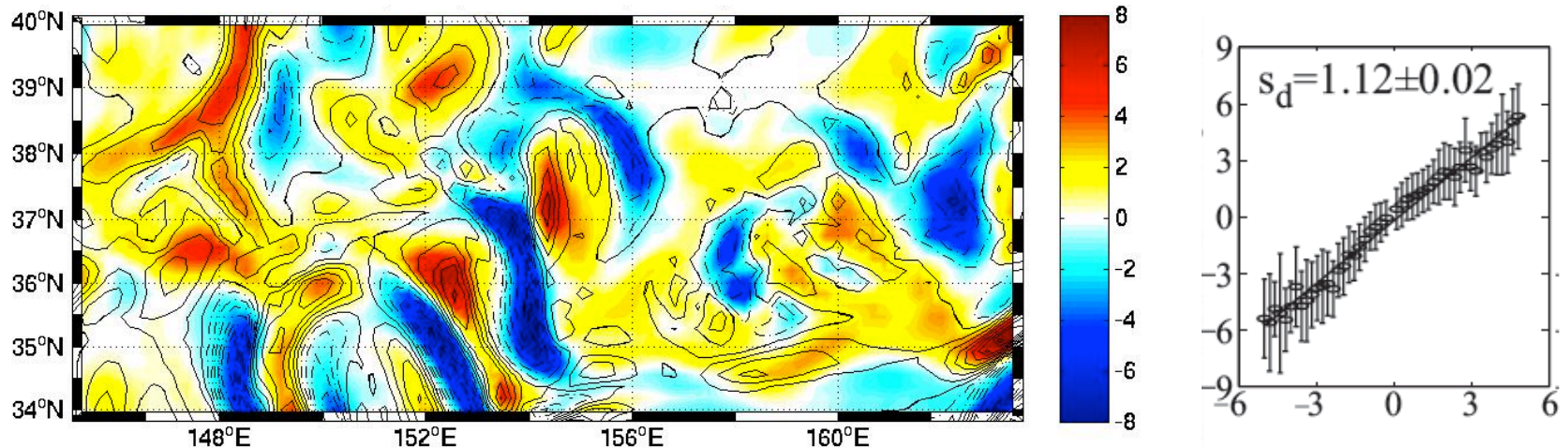
- Capet et al. (2008)
- Bocaletti et al. (2007)
- Fox-Kemper et al. (2009)



\* Recognition that frontal-scale SST variations impact the surface fluxes

(heat, momentum) and consequently alter the local ABL and eddy statistics

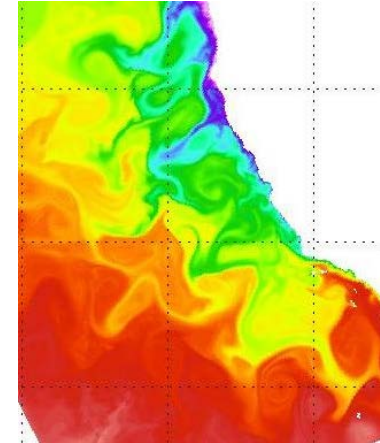
- Obs: Chelton (1999), Xie (1999), Liu (2000) --- Models: Seo et al. (2007)



# Changes in perspective of North Pacific climate-ocean physical processes

\*New Ocean Modeling capabilities, finely resolved and over decadal timescales, reveal forced response, intrinsic variations

- OFES (JAMSTEC)
- Marchesiello et al. (2003)
- Di Lorenzo et al. (2005)
- Centurioni et al. (2008)

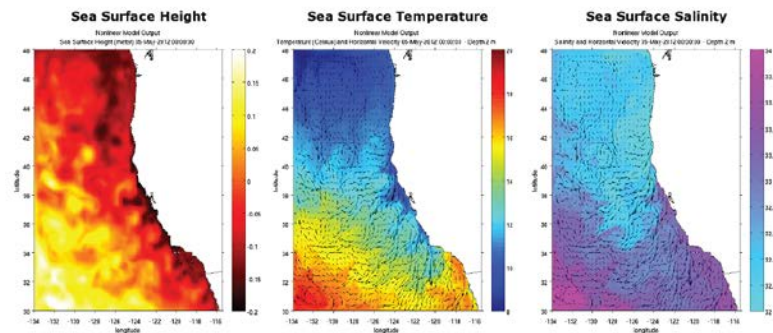


\*Long-term Data Assimilation projects, strong or weak constraints, allow evaluation of space-time structures to diagnose possible processes found in short-term data compared with those found in long-term climate model runs

- SODA; Carton and Giese
- Moore et al. (2011)
- Broquet et al. (2009)

...including near-real time fits

UCSC California Current Ocean Modeling and Data Assimilation

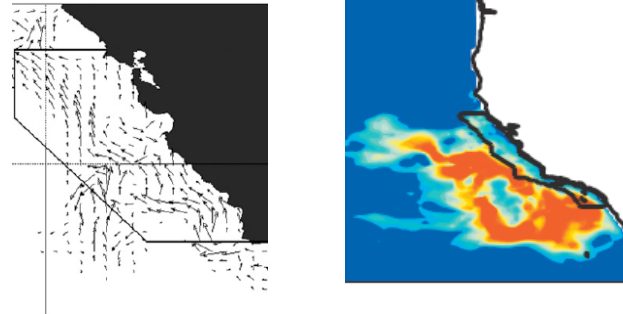




# Changes in perspective of North Pacific climate-ocean physical processes

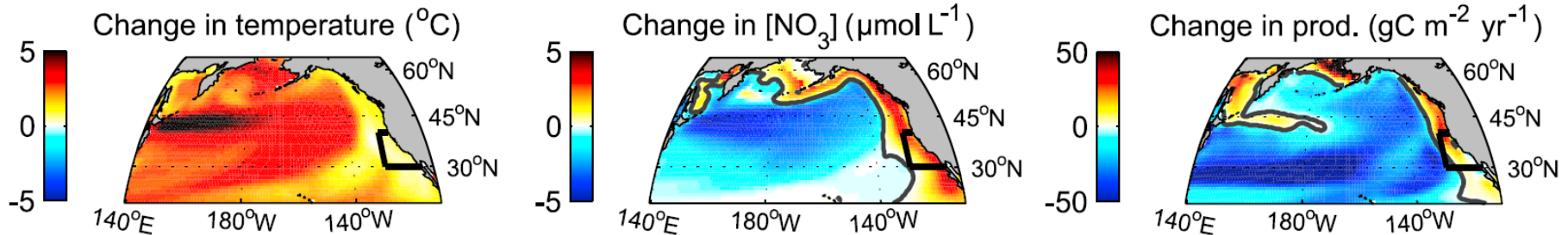
\* New computational diagnostic tools (Generalized Stability Analysis, tangent linear and adjoint models) provide metrics of sensitivity to forcing and explanations of upwelling source water changes

- Moore et al. (2004, 2011)
- Chhak and Di Lorenzo (2007)



\* Long earth system model runs, including GHG-forcing and intrinsic variability, allow separation of forced from natural variability to isolate processes of physical-biological interactions

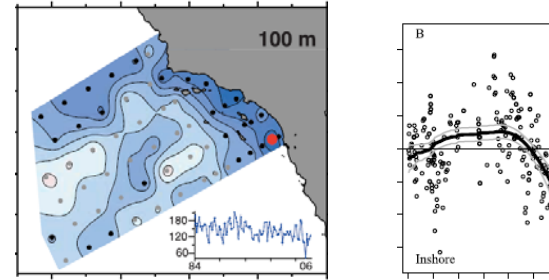
- Rykaczewski and Dunne (2010)



# Changes in perspective of North Pacific climate-ocean biological processes

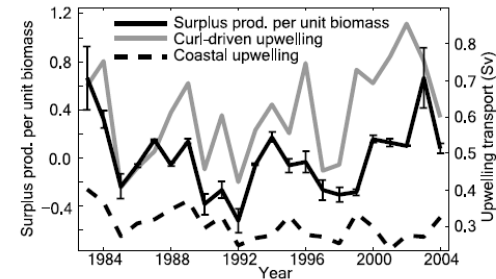
\* Long-term decreases in dissolved oxygen below the thermocline threaten numerous species

- Bograd et al. (2008)
- McClatchie et al. (2010)



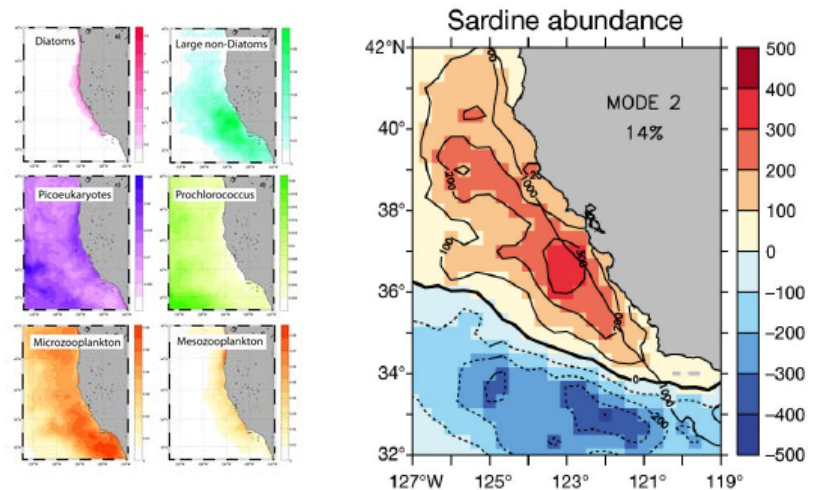
\* Recognition that offshore open-ocean Ekman pumping can be as important coastal upwelling in fluxing nutrients to the photic zone

- Rykaczewski and Checkley (2008)



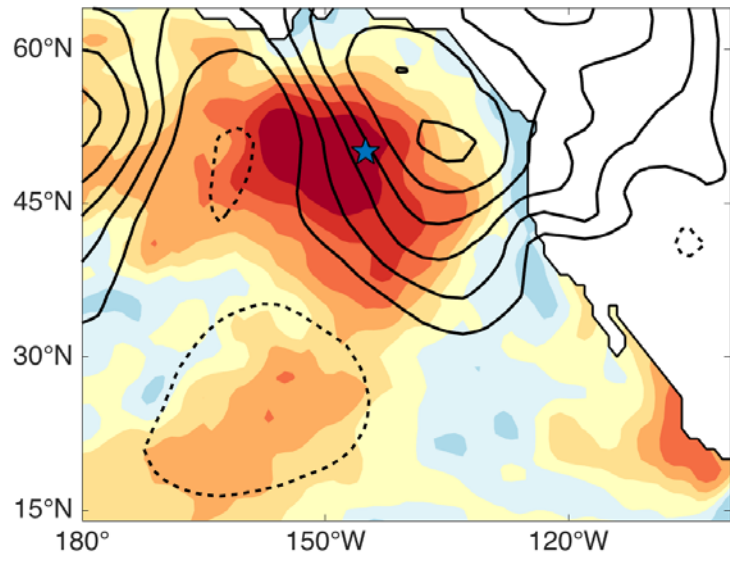
\* New ecosystem modeling capabilities, finely resolved and over decadal timescales, reveal ecosystem response

- Gruber et al. (2010)
- Goebel et al. (2010)
- Hermann et al. (2013)
- Fiechter et al. (2015)

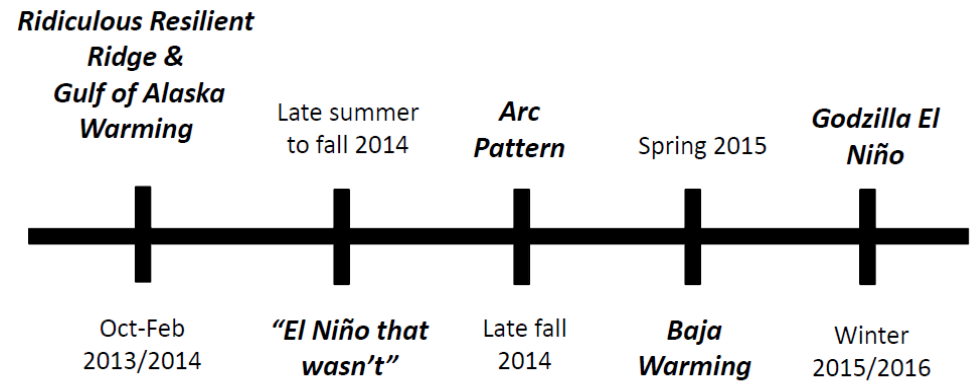




## The Blob

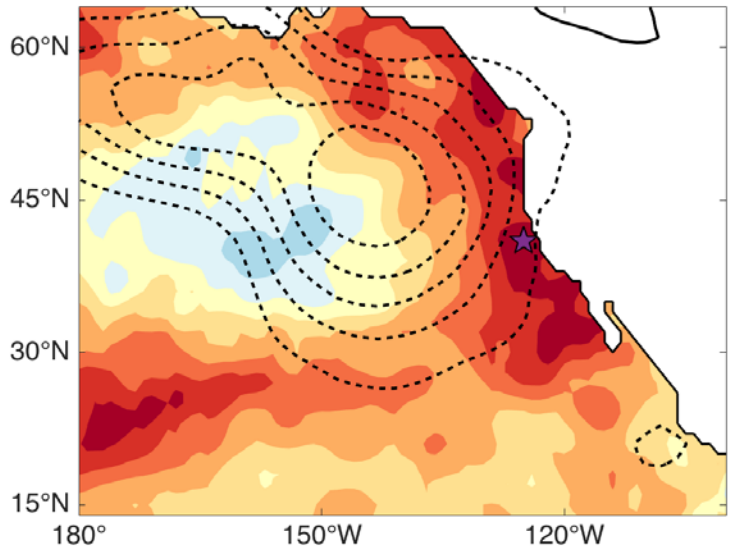


# A Series of Extreme

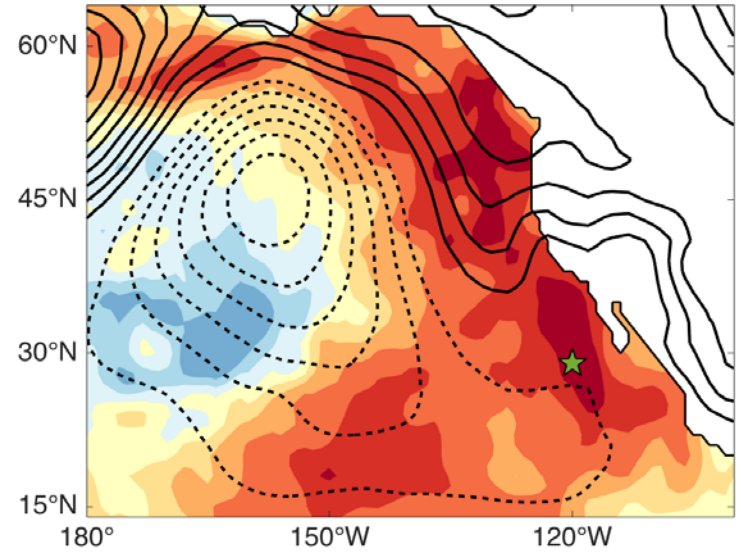


Amaya et al., 2016

## Arc Pattern



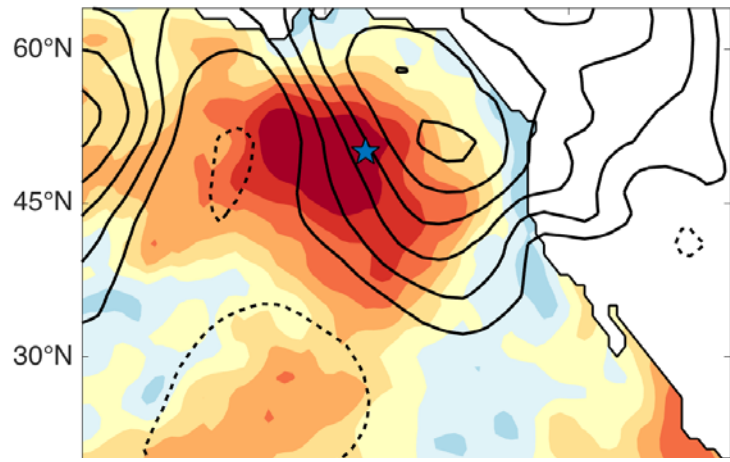
## Baja Pattern



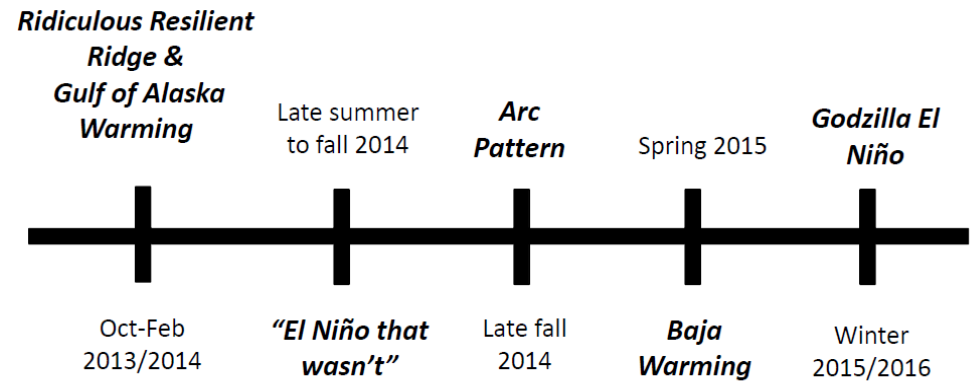




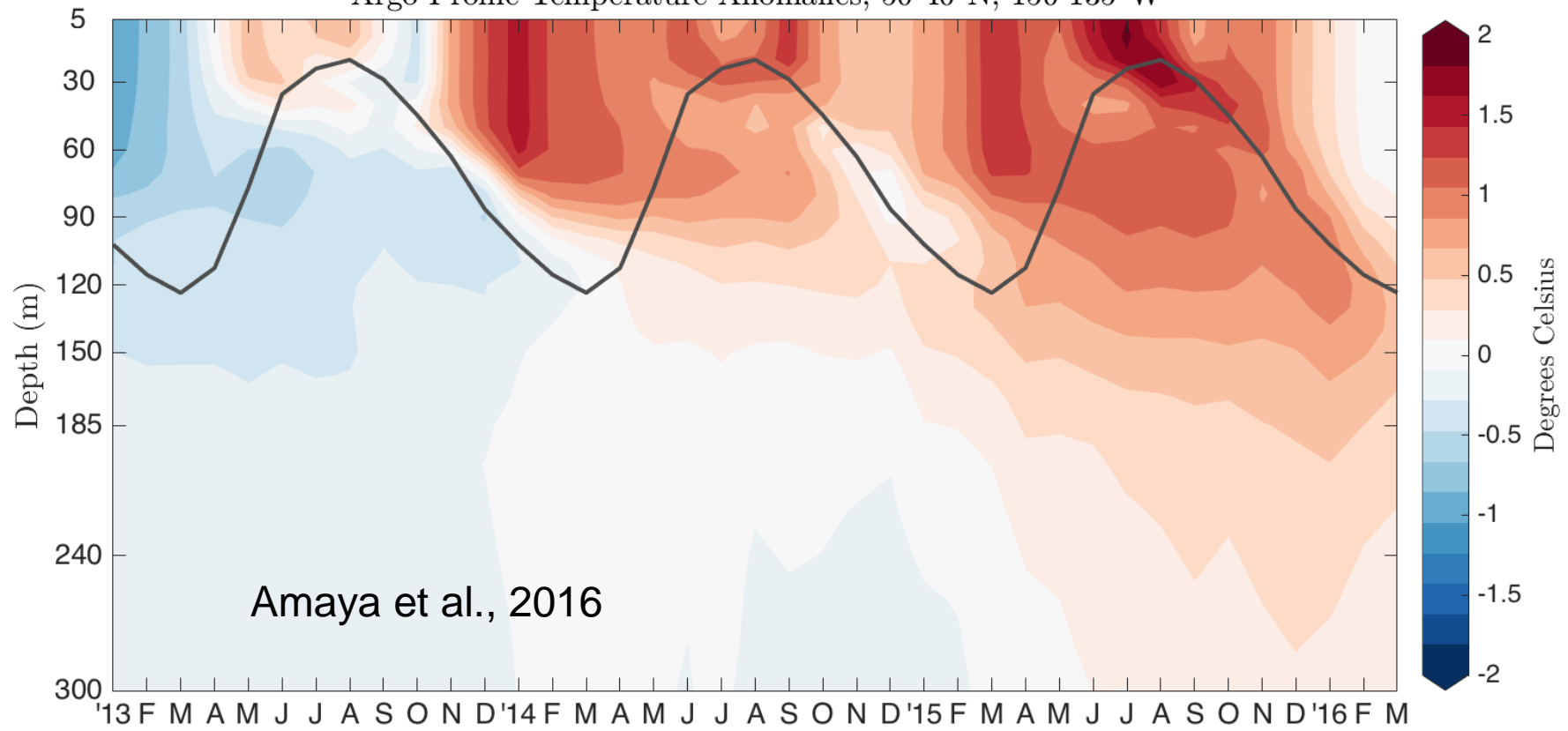
# The Blob



# A Series of Extreme



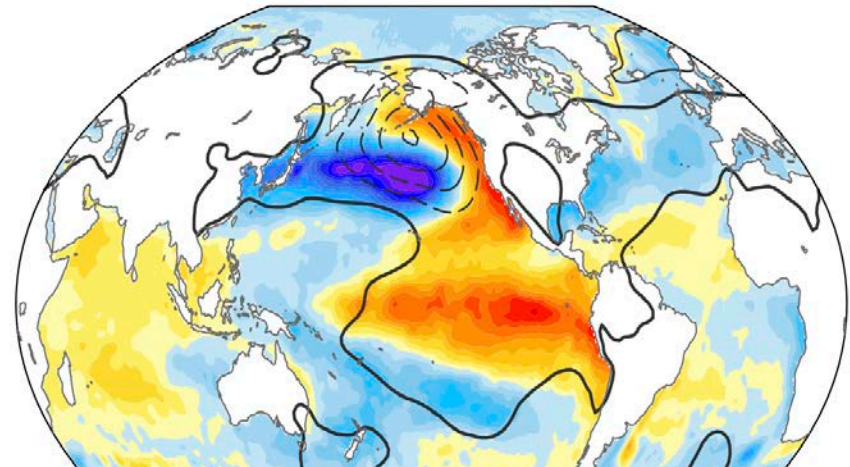
Argo Profile Temperature Anomalies, 50-40°N, 150-135°W



# PDO ----- Revisited

- The PDO is **not a physical mode** but rather is the **sum of several physical processes**
  - North Pacific SST *integrates* effects of extratropical weather noise and particularly of ENSO (“reddened ENSO”)
  - Re-emergence brings back anomalies in succeeding winters (no summer/fall PDO)
  - KOE variations provide more persistent SST anomalies and perhaps much of the predictable atmospheric response
- Need to differentiate **PDO-forced** signal from **PDO-correlated** signal (for impacts and reconstructions)

- Newman et al. (2016)



# ***1999 PICES Vladivostok ----- Revisited***

***Many Other  
Interactions  
Too Hazy  
Too Recall!***





**2007 PICES Victoria ----- Revisited**



**Sempre Famiglia**



**Art Miller**  
***Scripps Institution of Oceanography***  
***University of California, San Diego***  
***La Jolla, CA***

***PICES 2016 Annual Meeting***  
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**Thanks!**

