

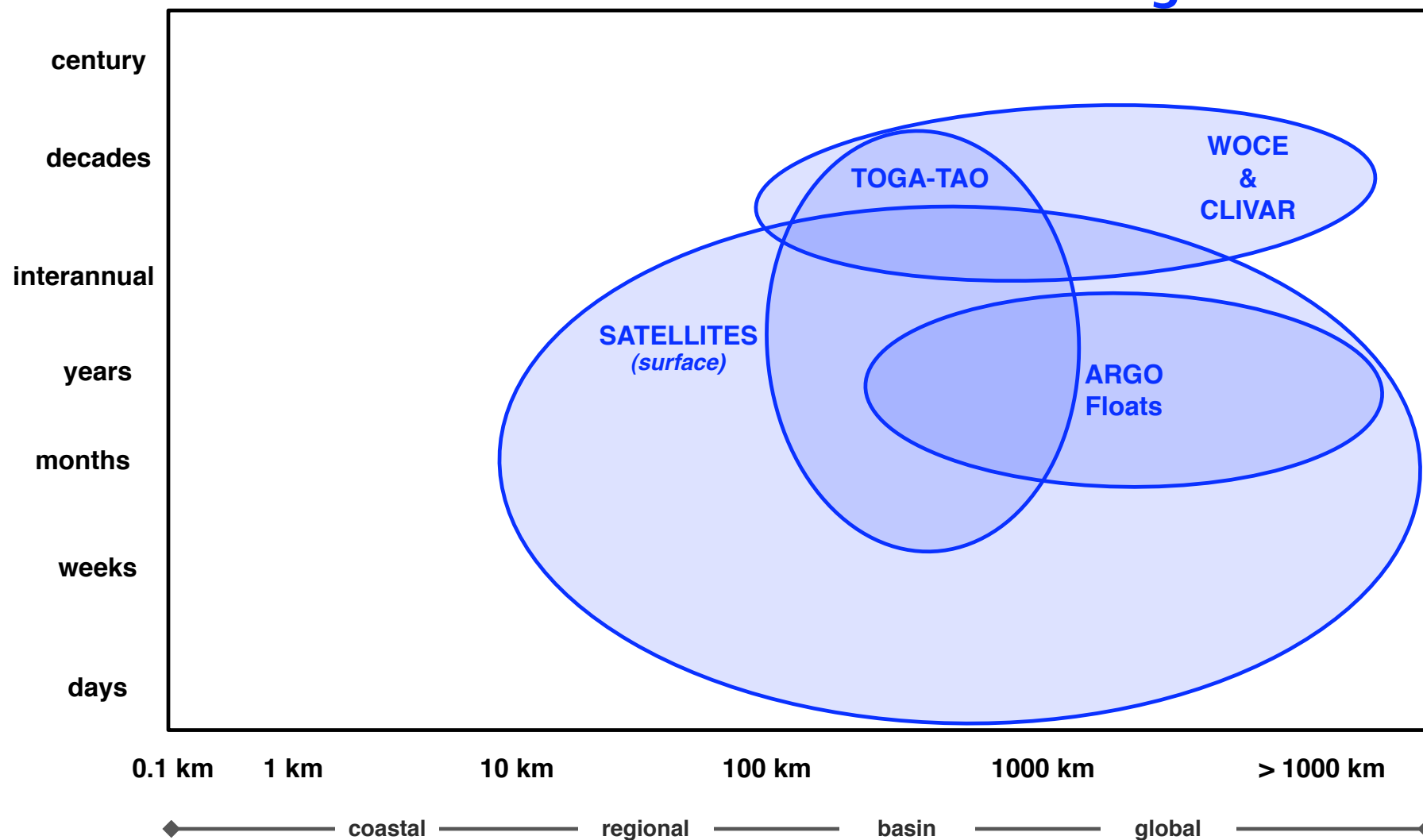
The Pacific Ocean Climate from Regional to Basin Scales

Emanuele Di Lorenzo

Contributors: **K. Chhak, L. Ceballos, V. Combes,**
J. Furtado, T. Kilpatrick,
D. Ionita, C. Saxton, N. Mariani

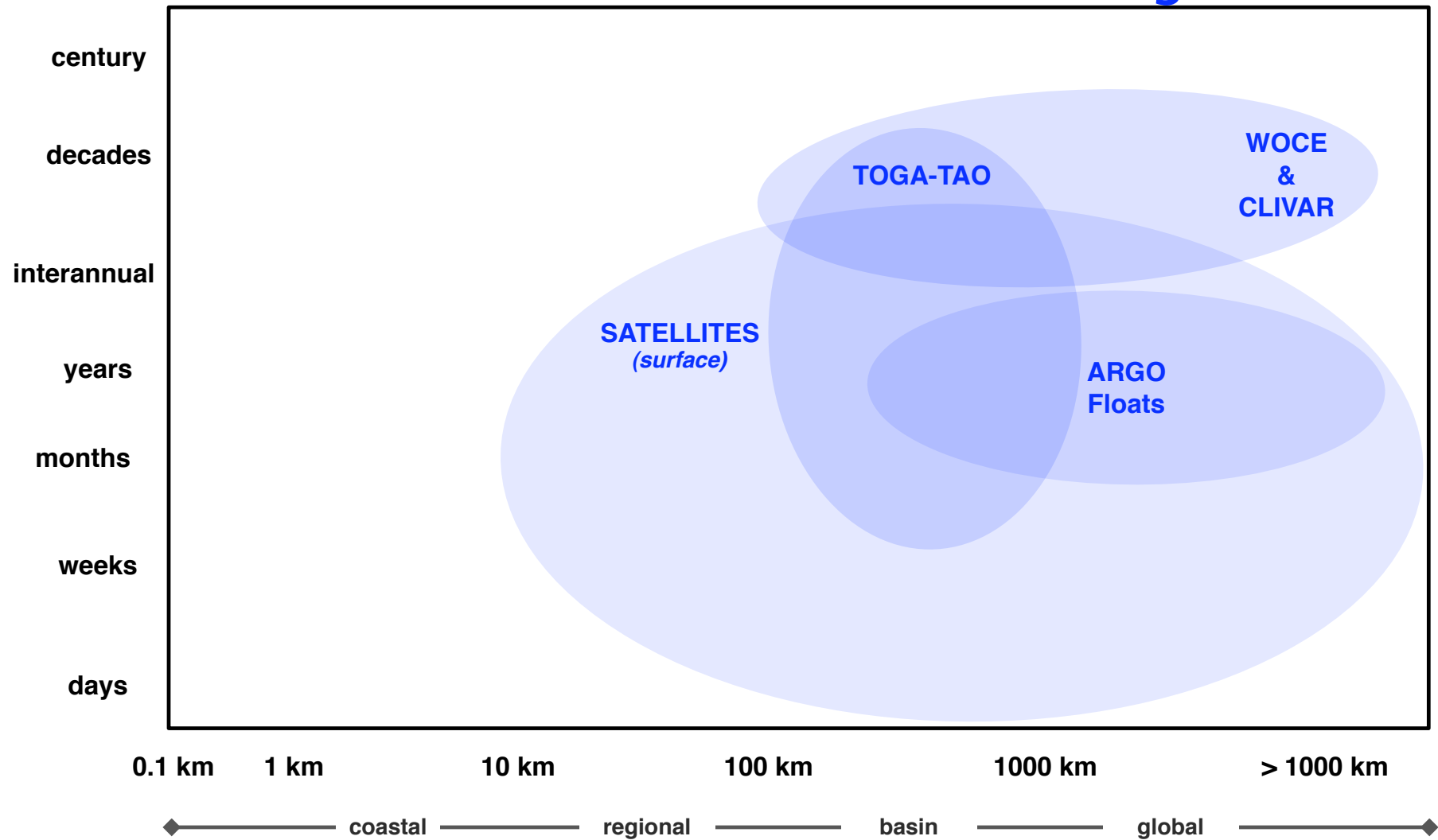


Ocean Observational Programs



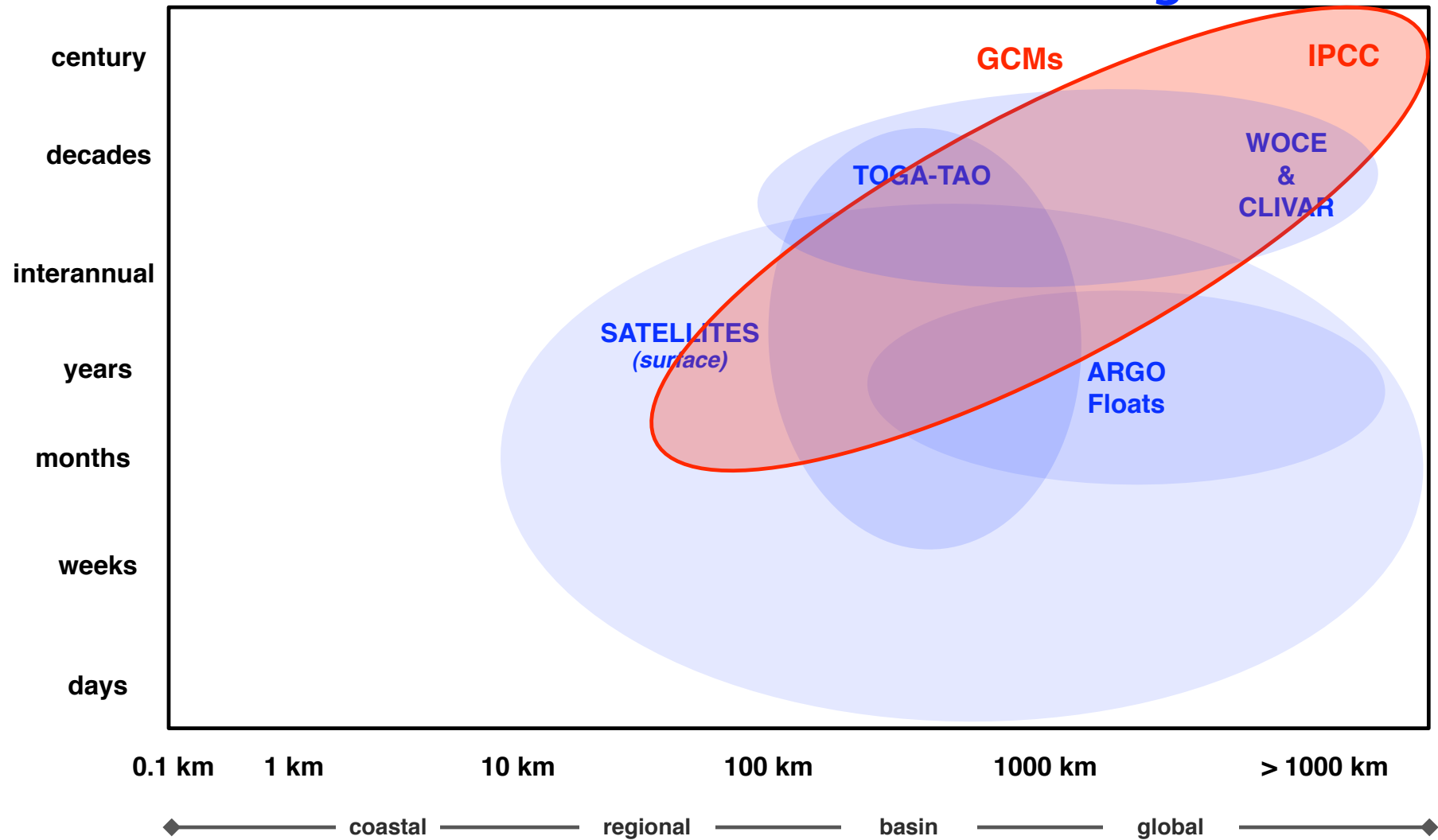
Ocean Modeling

Ocean Observational Programs



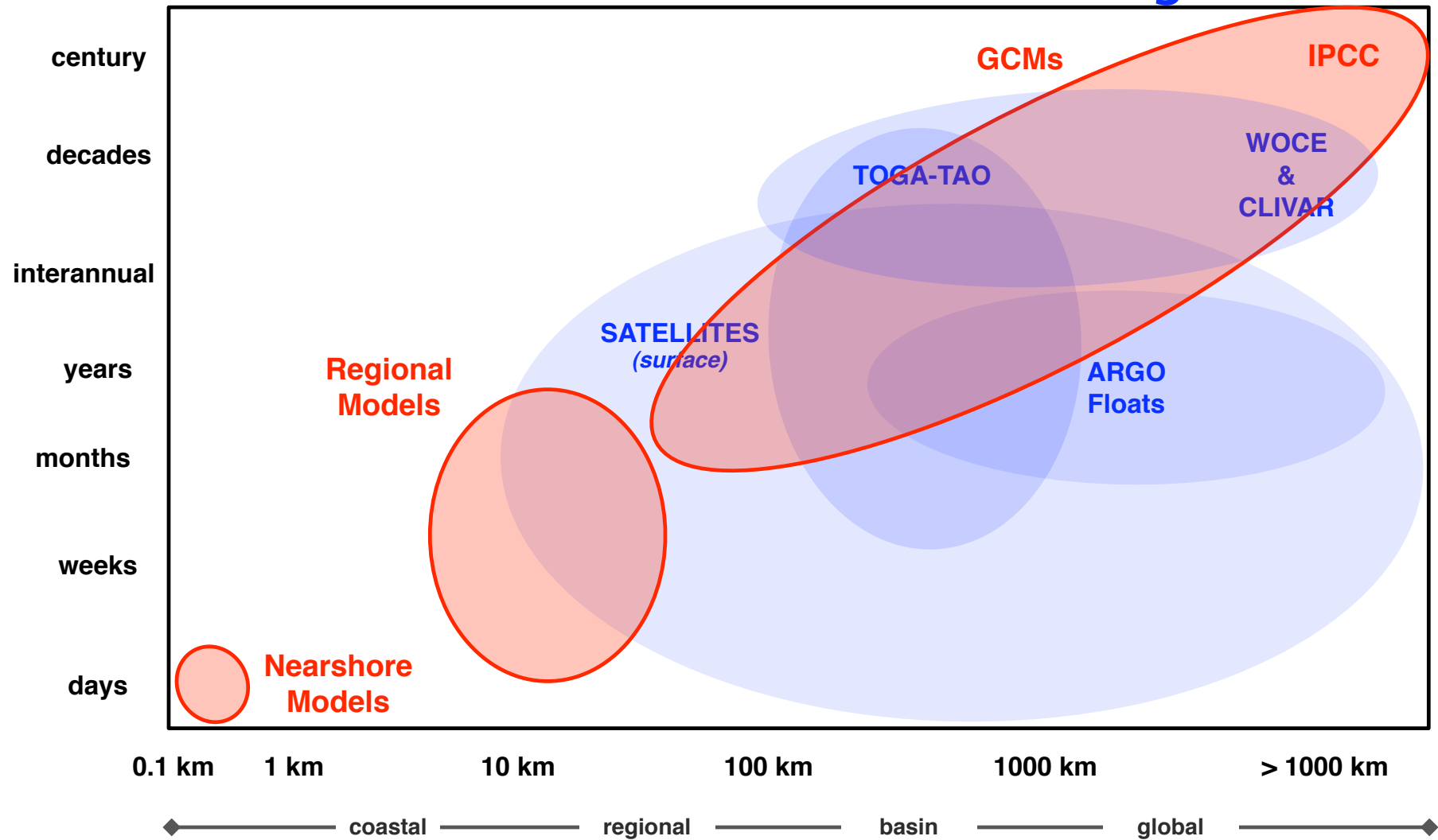
Ocean Modeling

Ocean Observational Programs



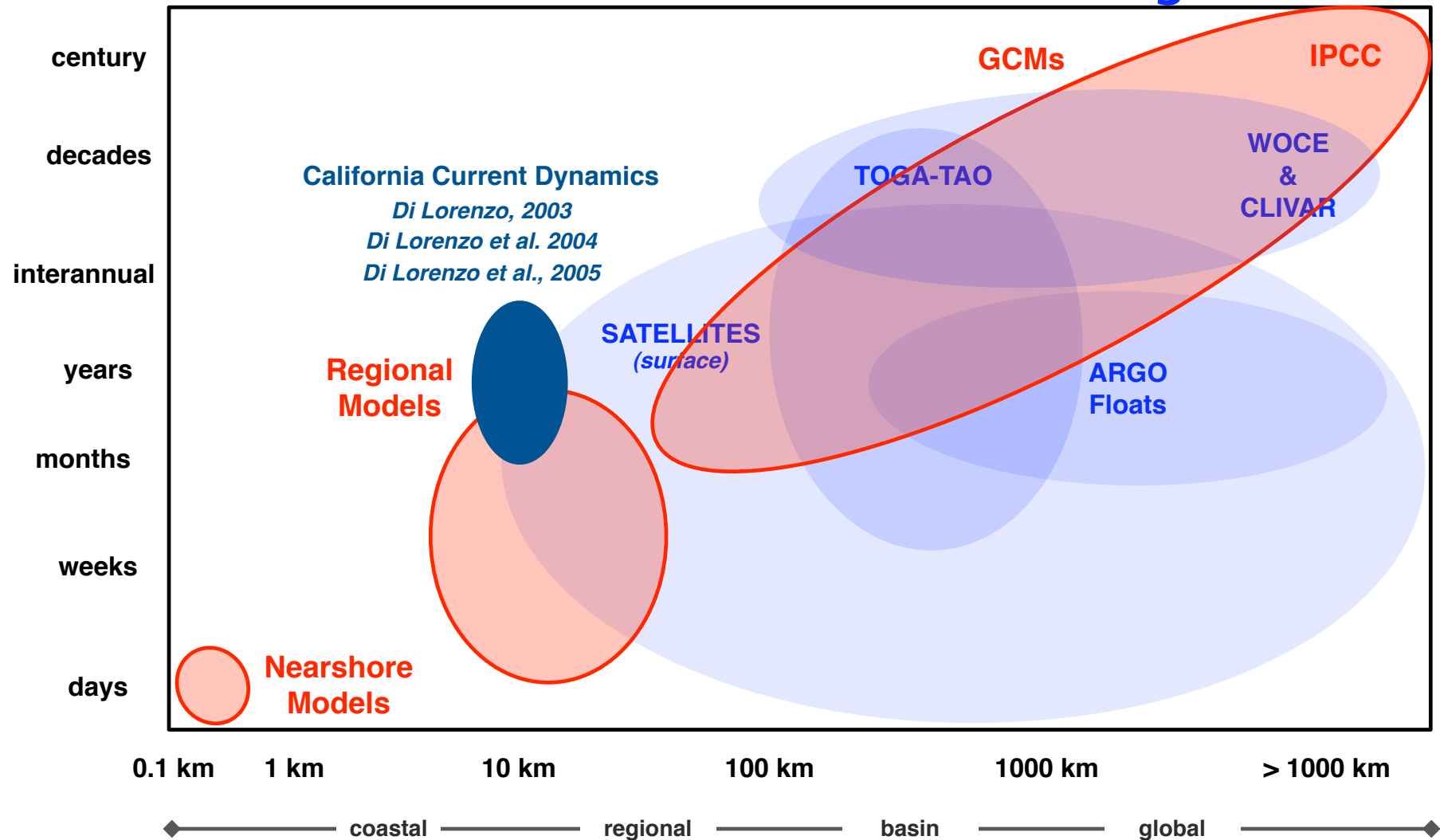
Ocean Modeling

Ocean Observational Programs



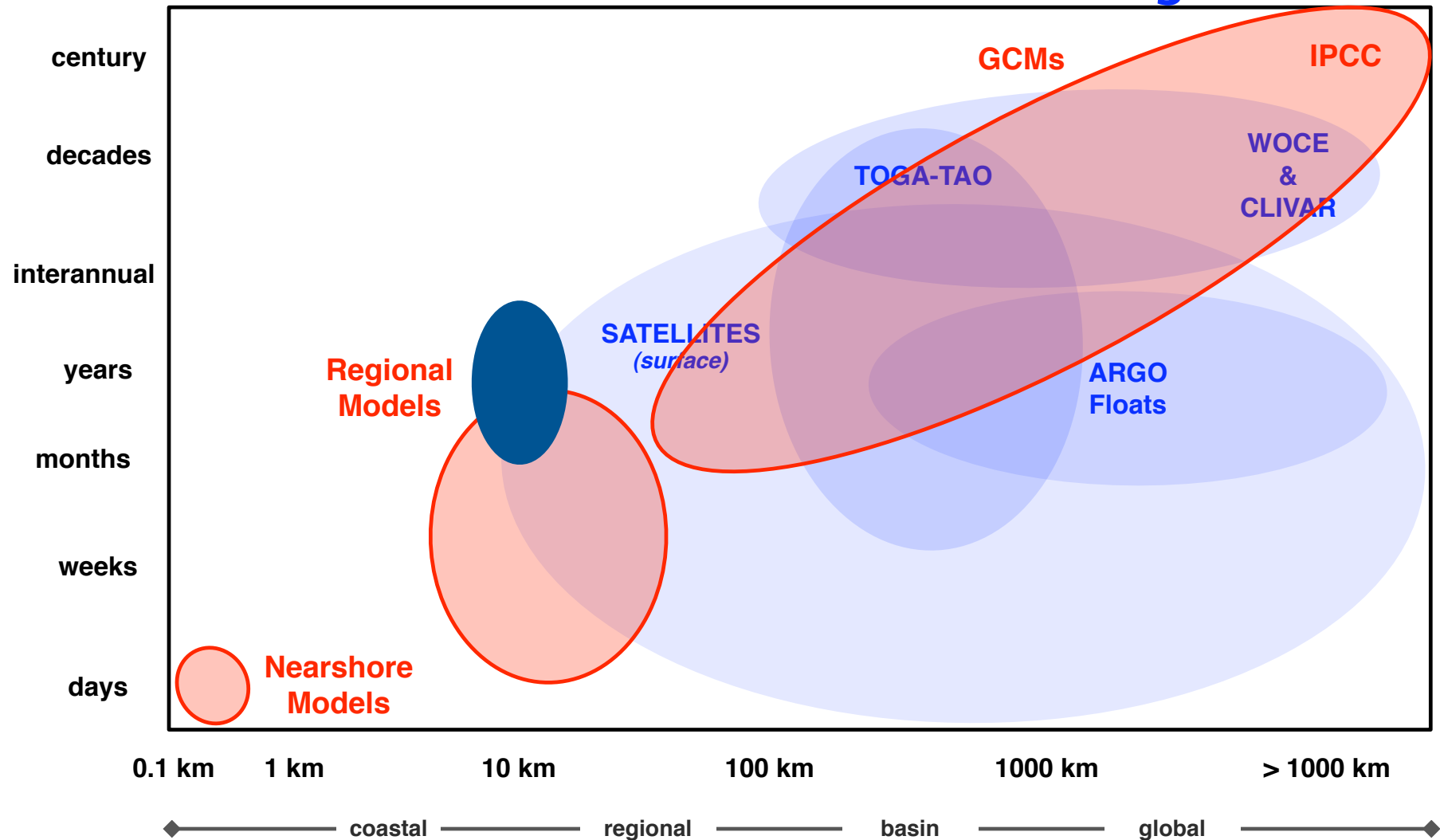
Ocean Modeling

Ocean Observational Programs



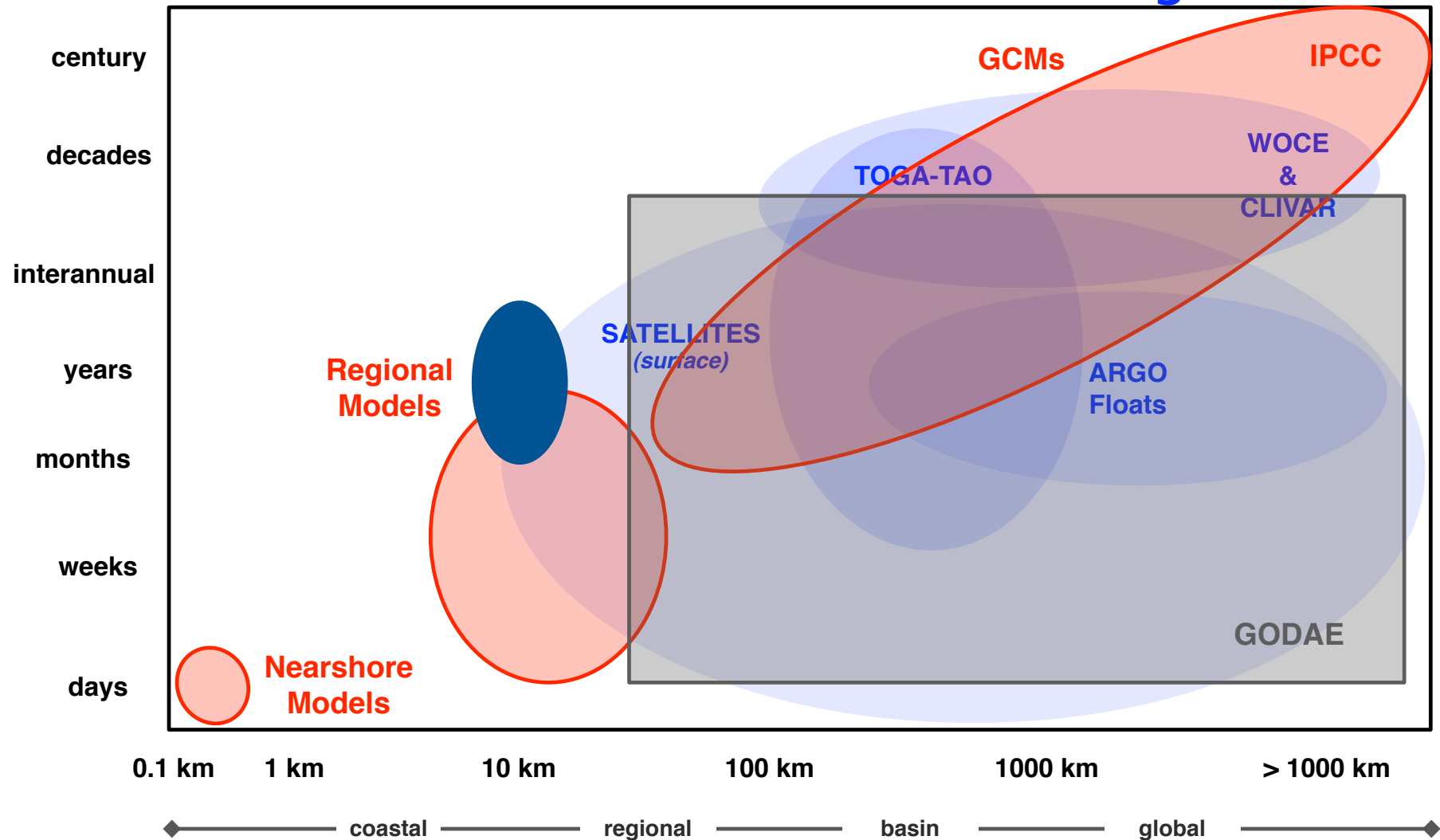
Ocean Modeling + Data Assimilation

Ocean Observational Programs



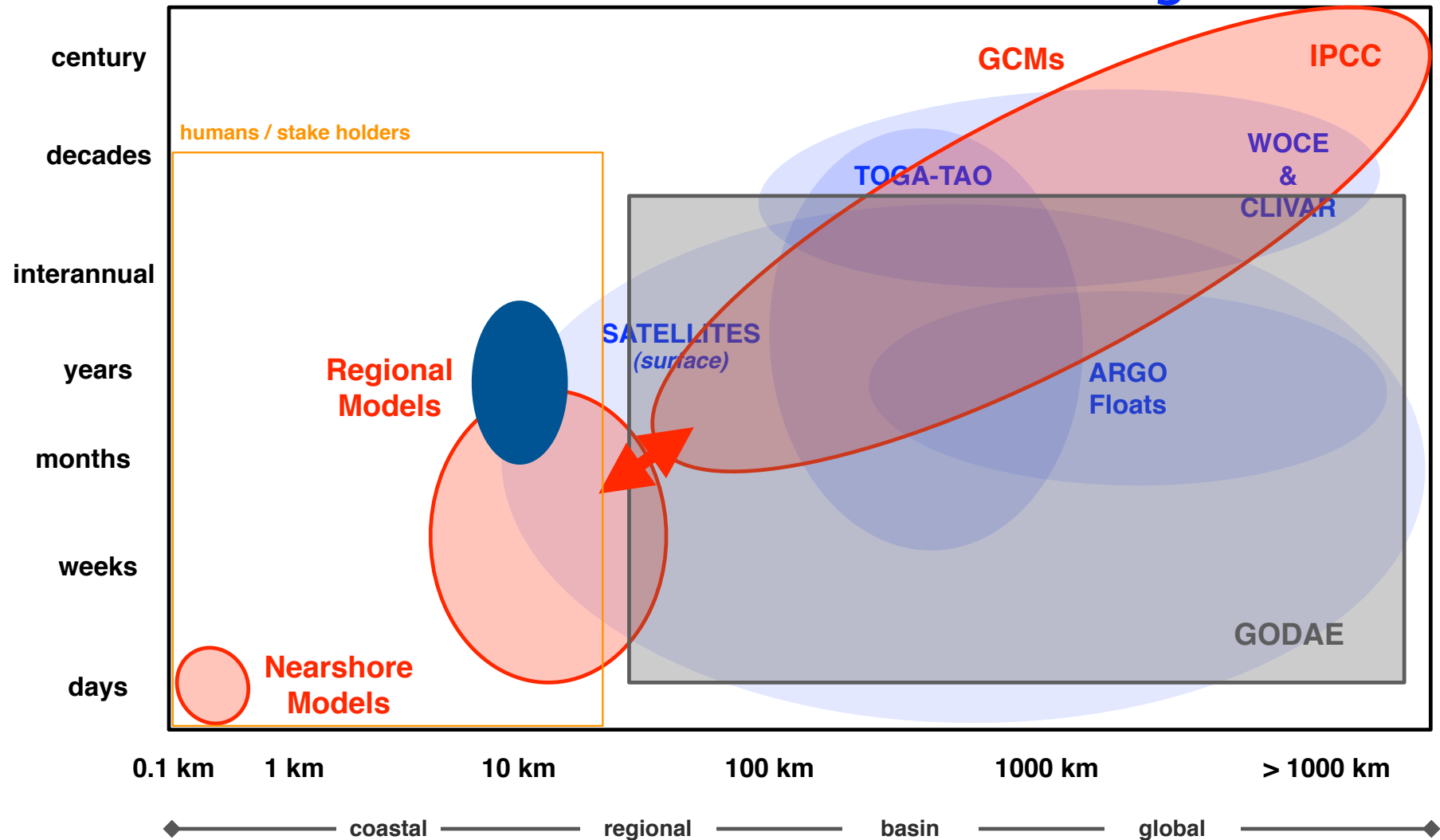
Ocean Modeling + Data Assimilation

Ocean Observational Programs



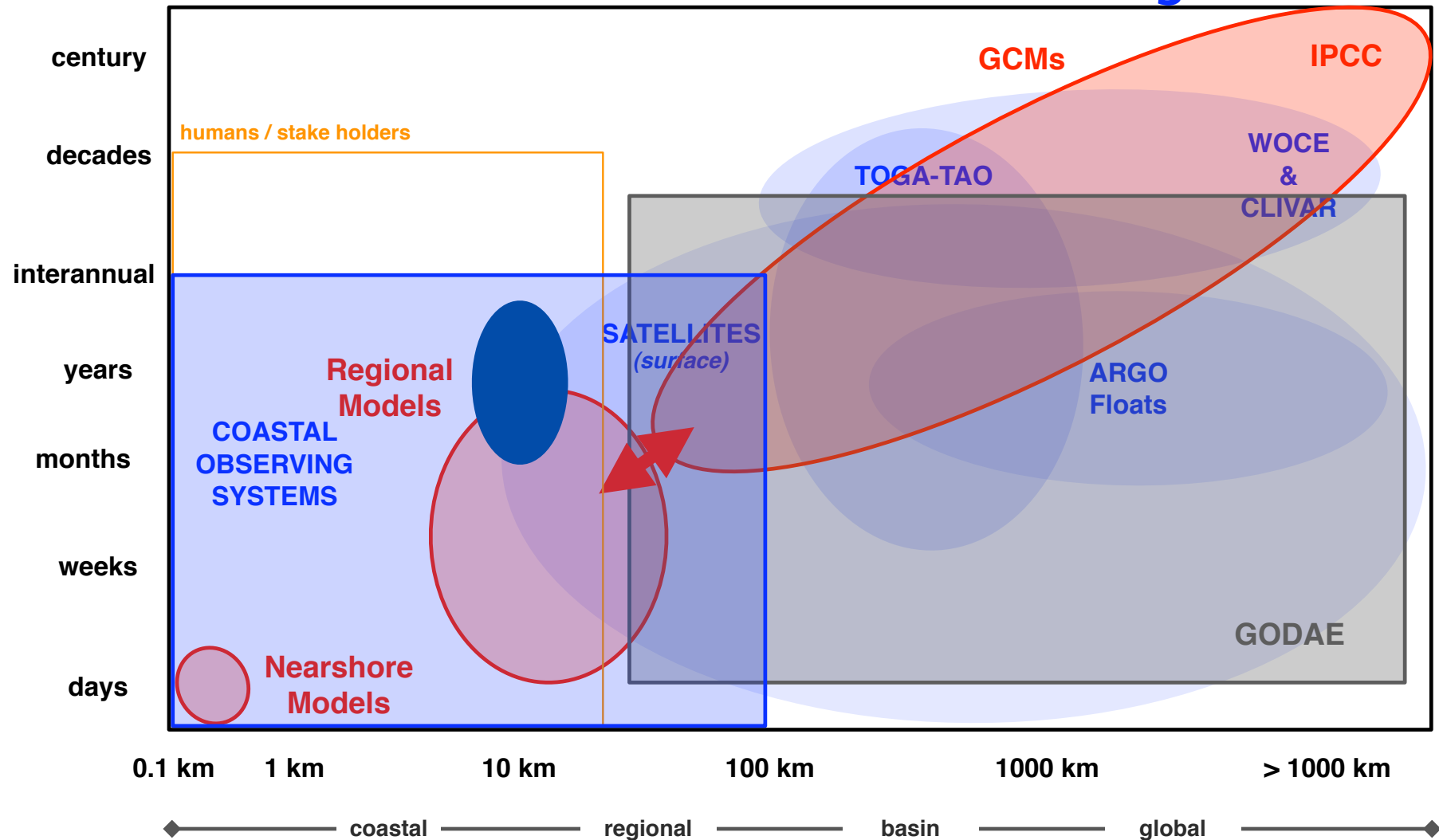
Ocean Modeling + Data Assimilation

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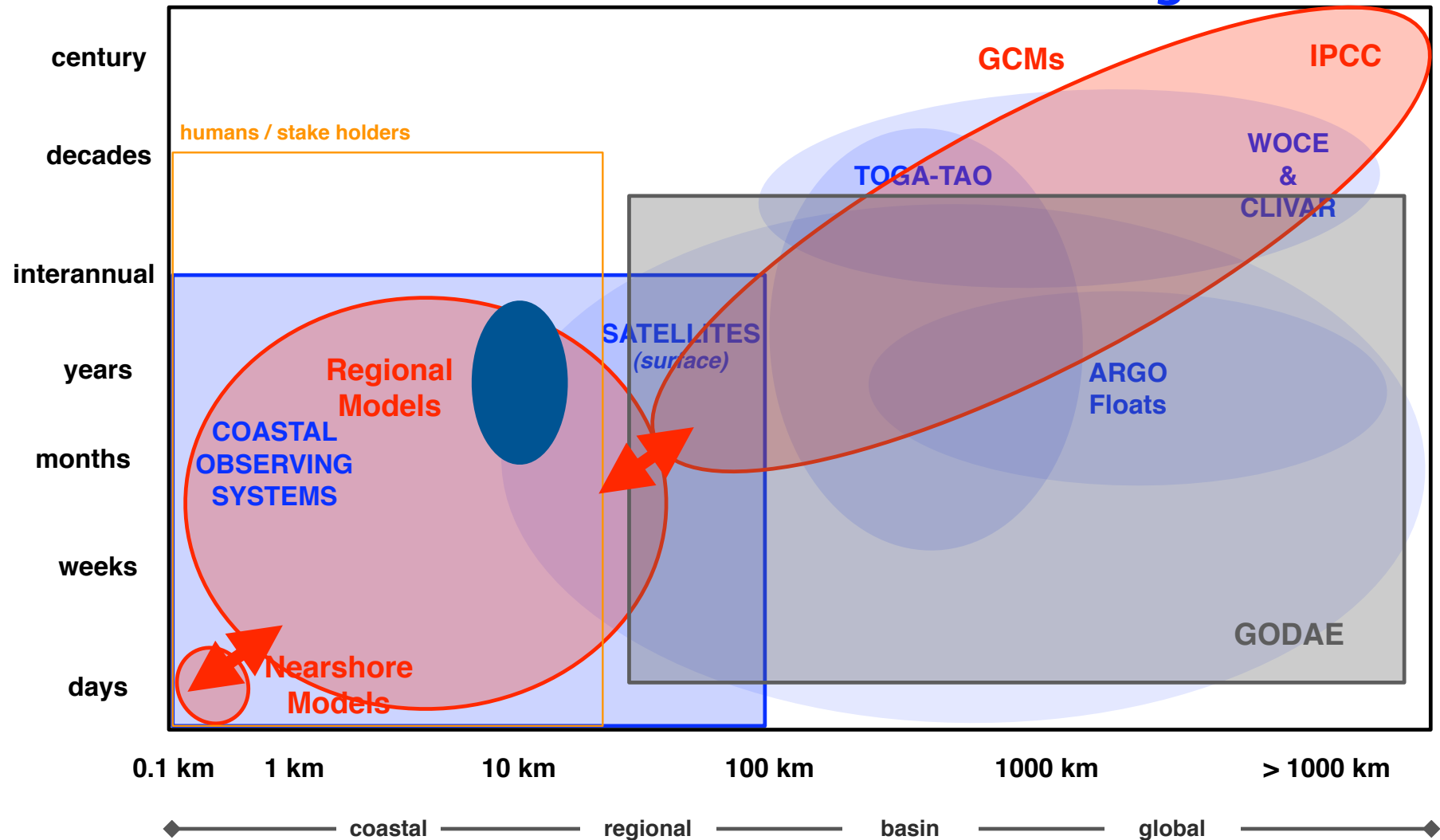
Ocean Modeling + Data Assimilation

Ocean Observational Programs



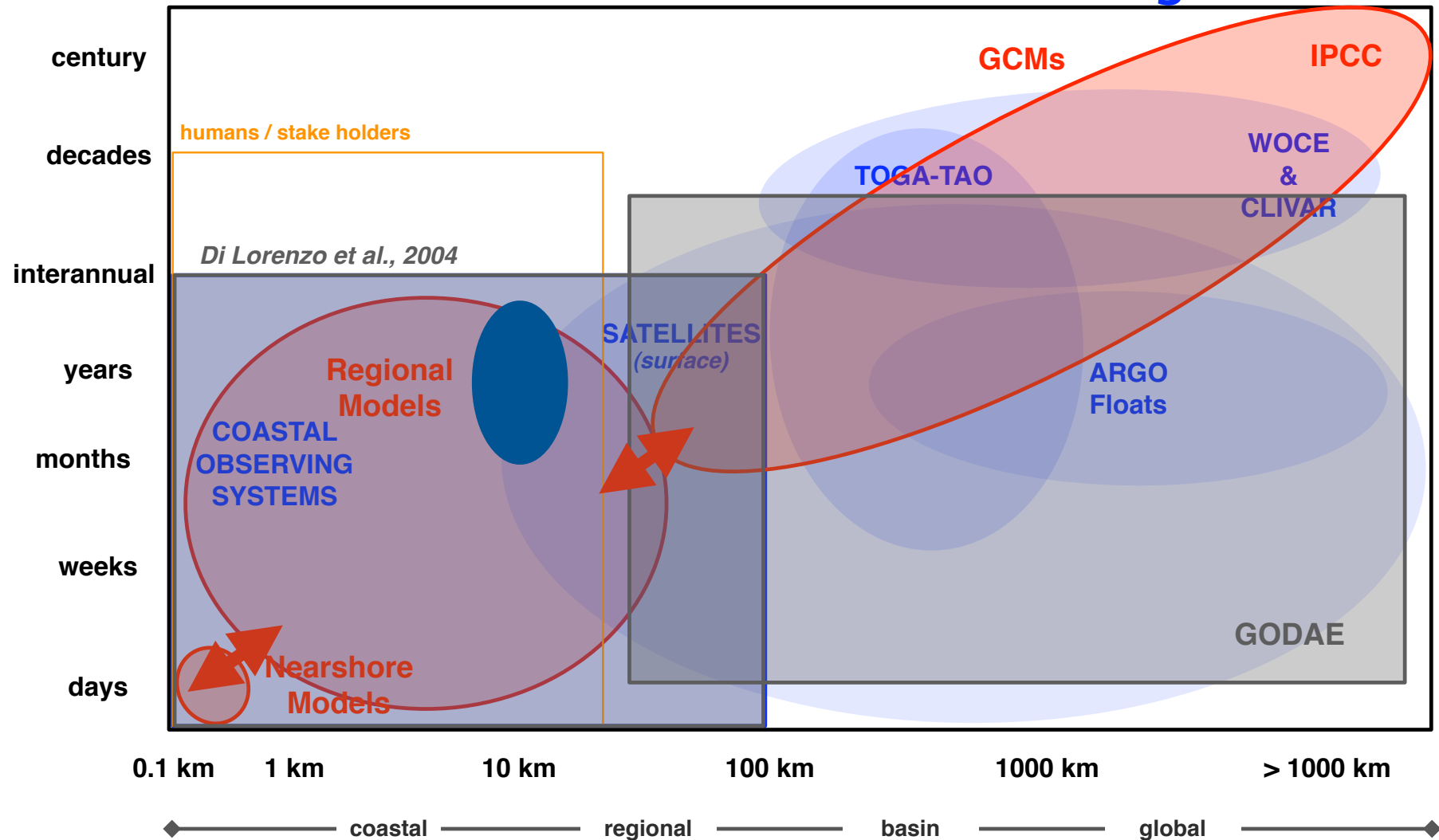
Ocean Modeling + Data Assimilation

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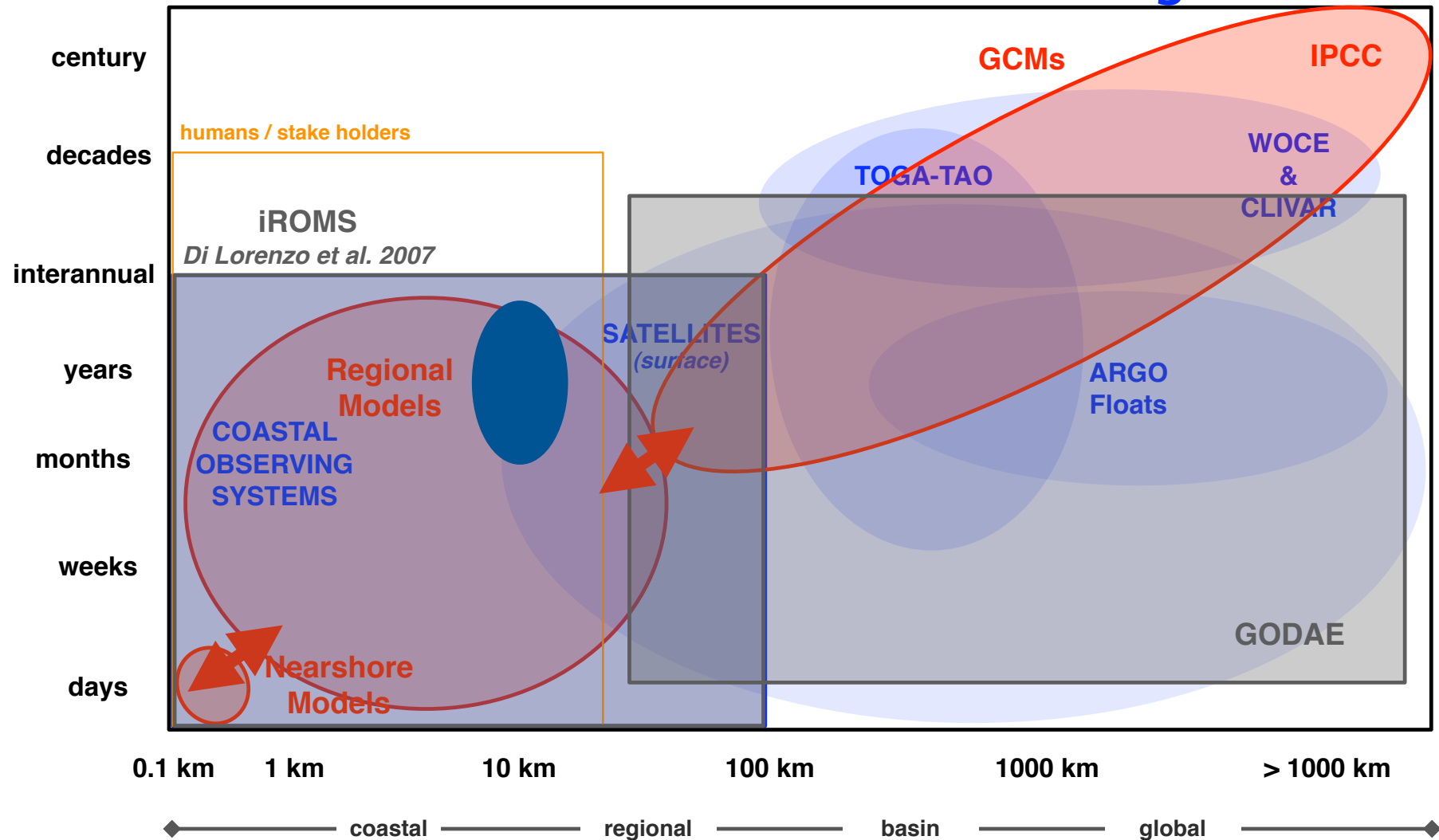
Ocean Modeling + Data Assimilation

Ocean Observational Programs



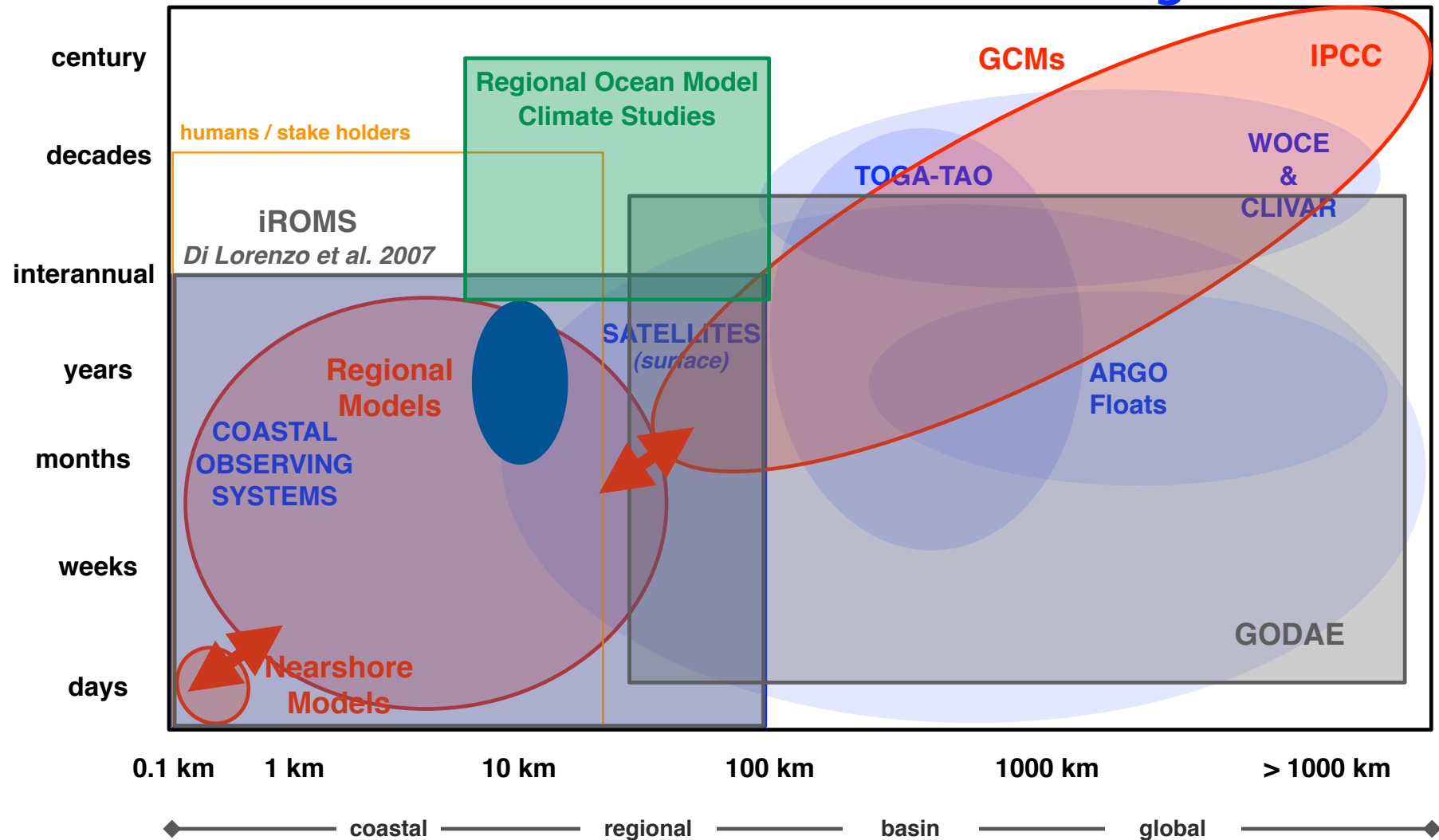
Ocean Modeling + Data Assimilation

Ocean Observational Programs



Ocean Modeling + Data Assimilation

Ocean Observational Programs



Ocean Eddies and Climate

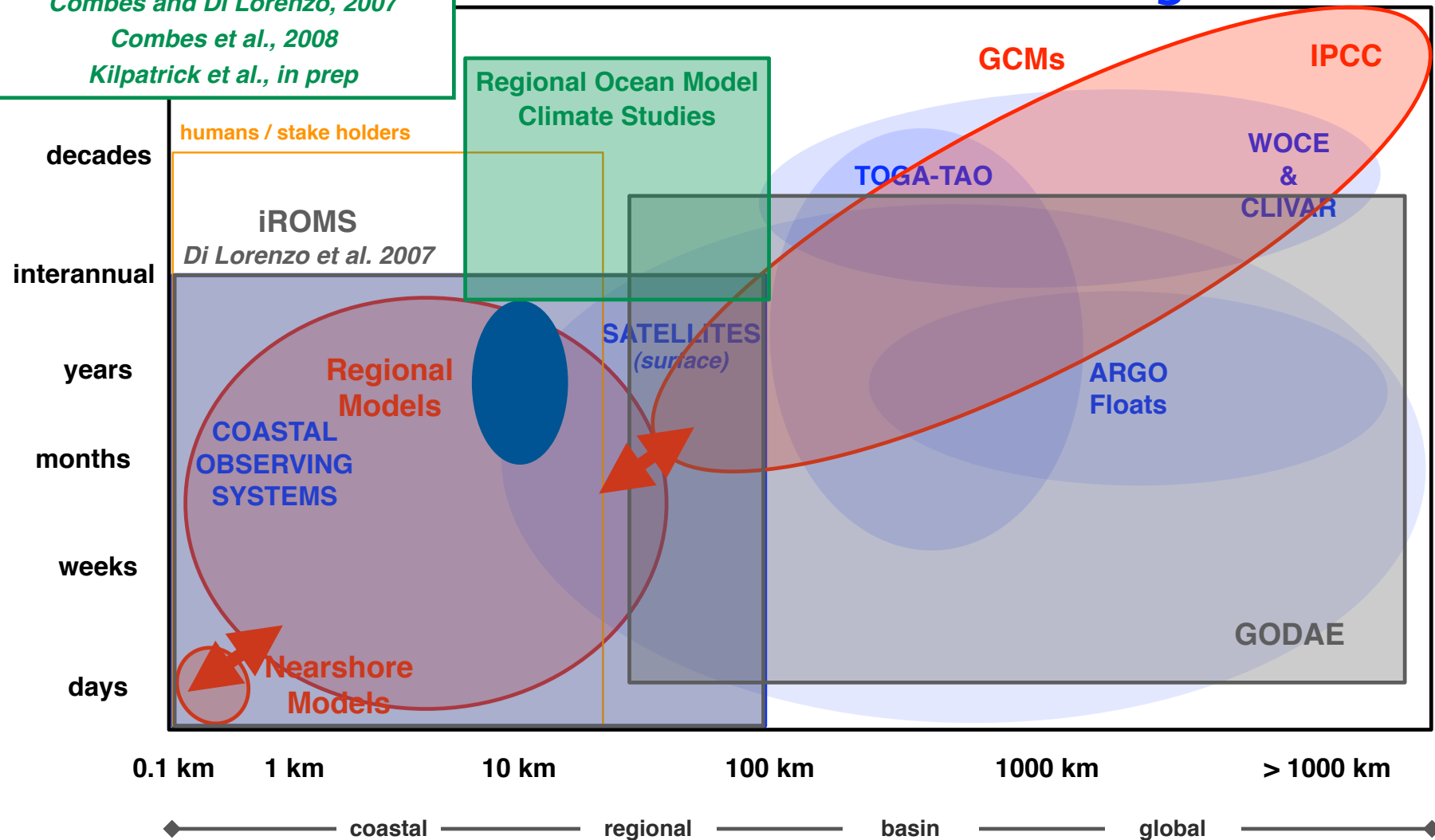
Di Lorenzo et al. 2005

Combes and Di Lorenzo, 2007

Combes et al., 2008

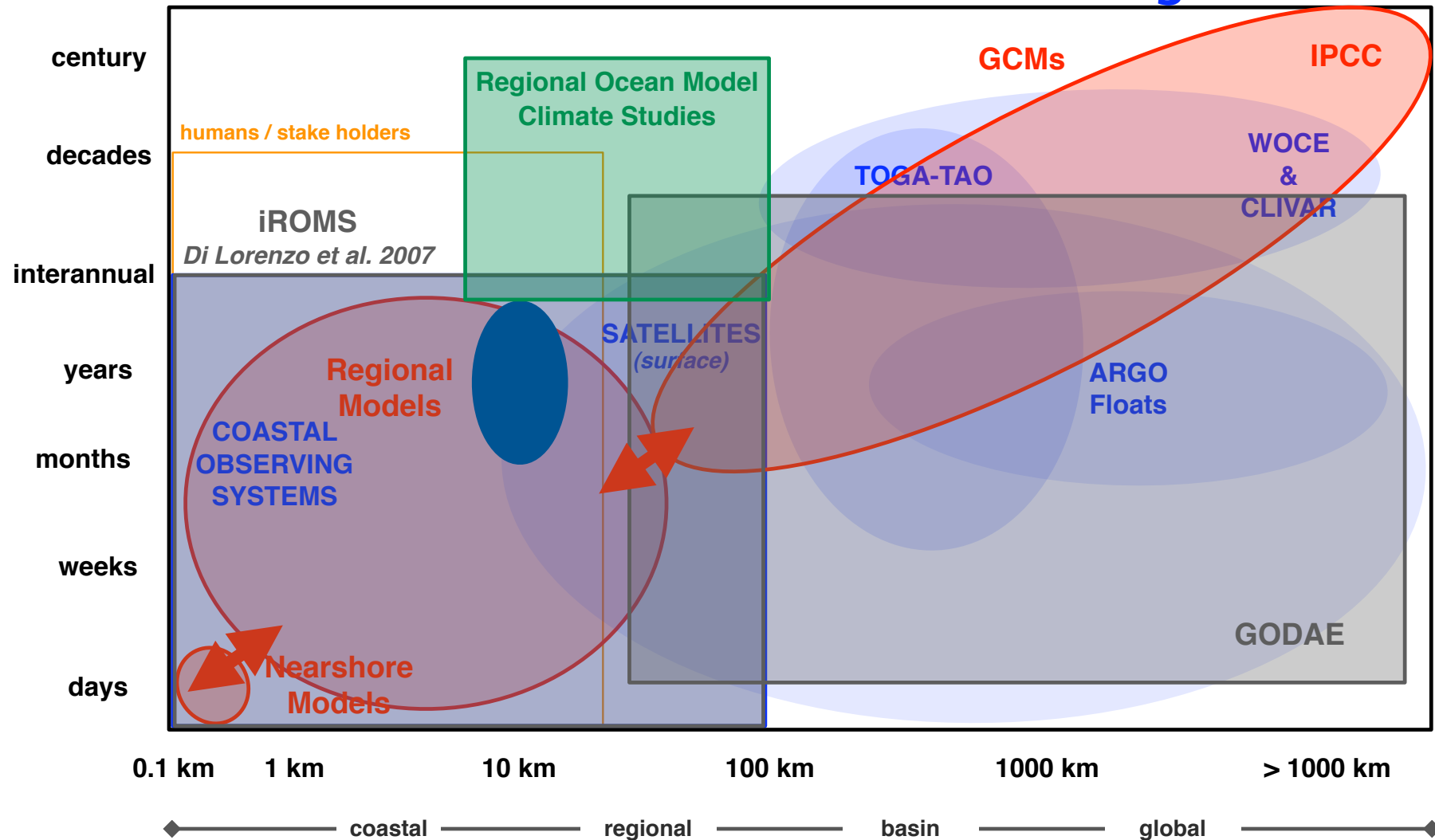
Kilpatrick et al., in prep

Ocean Modeling + Data Assimilation Ocean Observational Programs



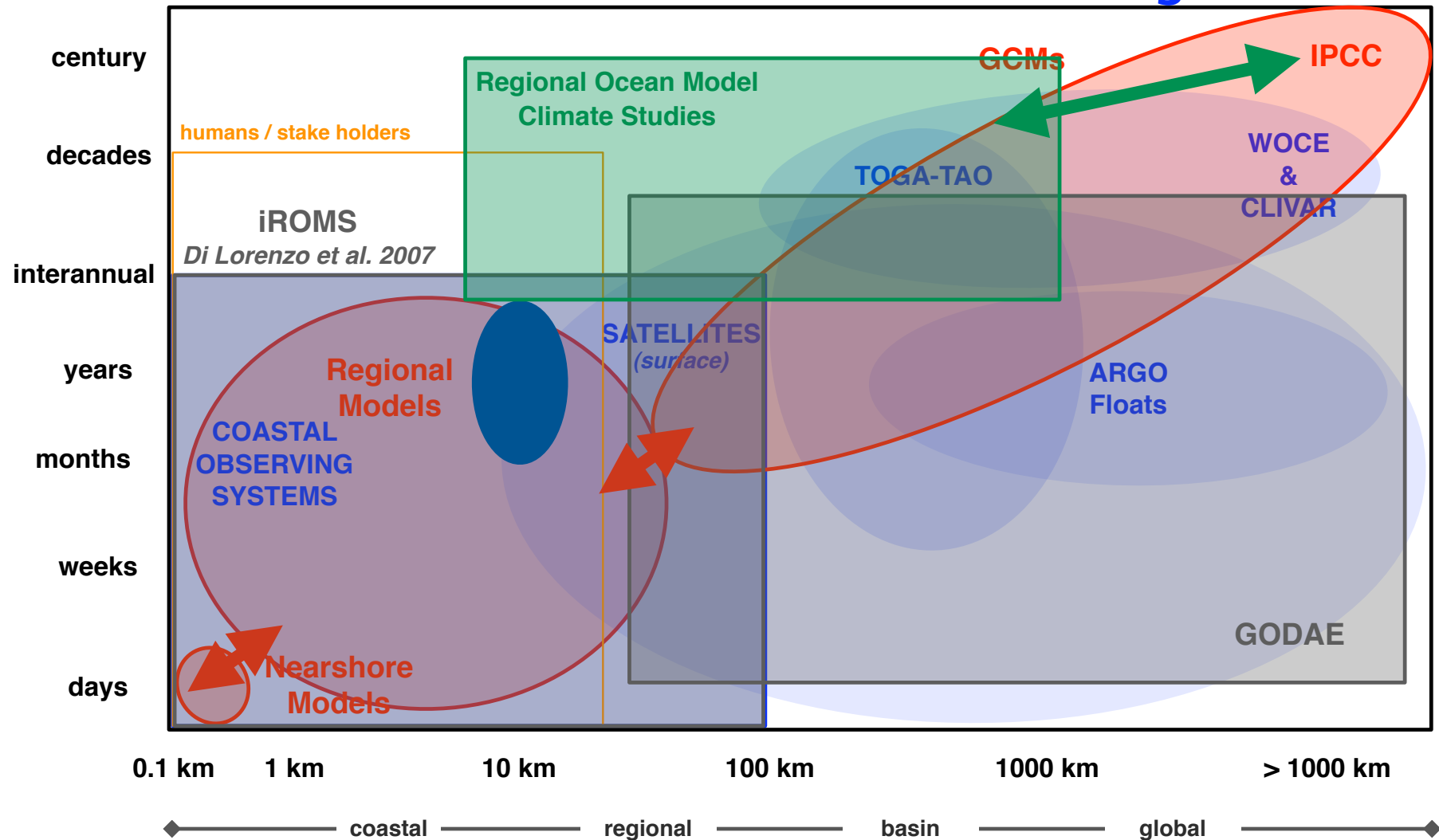
Ocean Modeling + Data Assimilation

Ocean Observational Programs

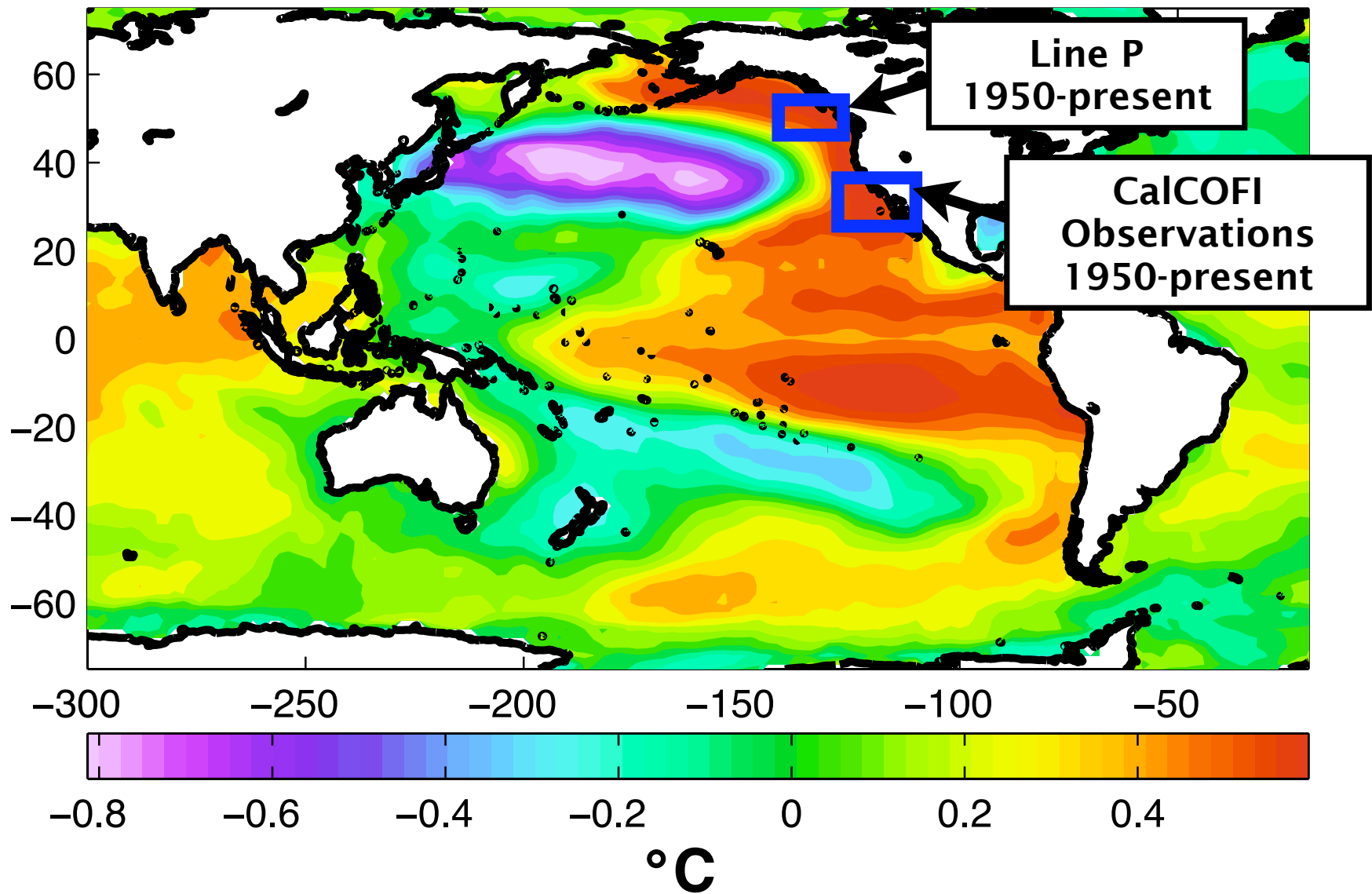


Ocean Modeling + Data Assimilation

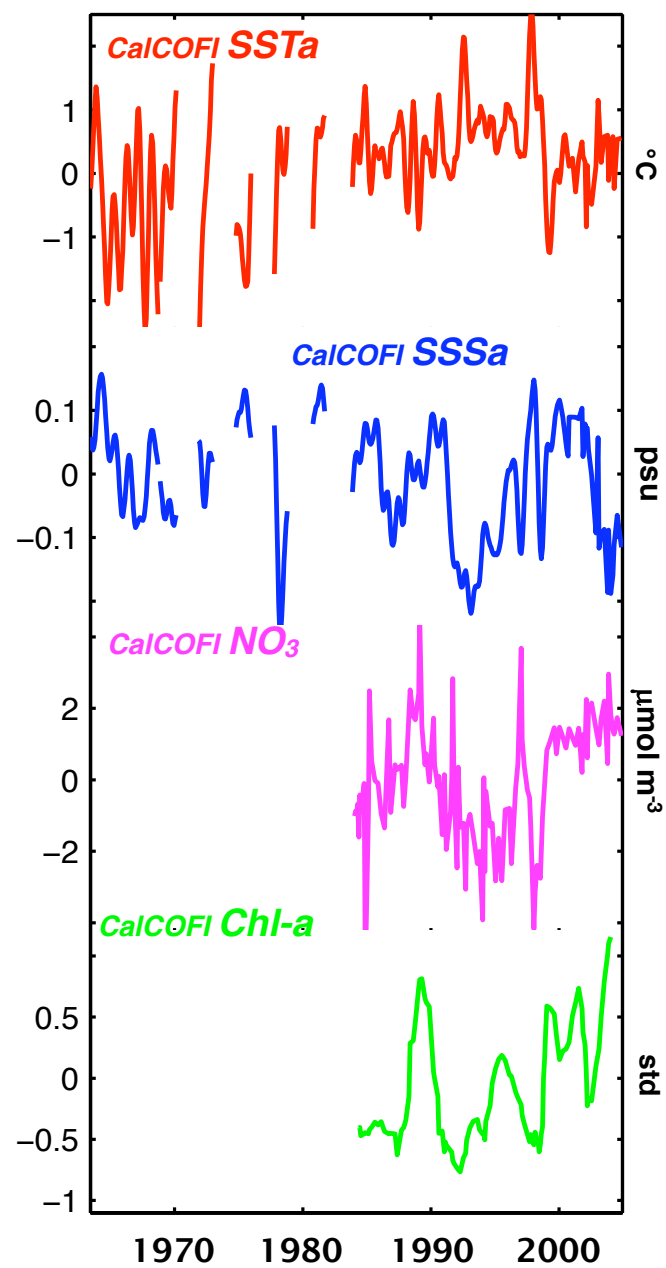
Ocean Observational Programs



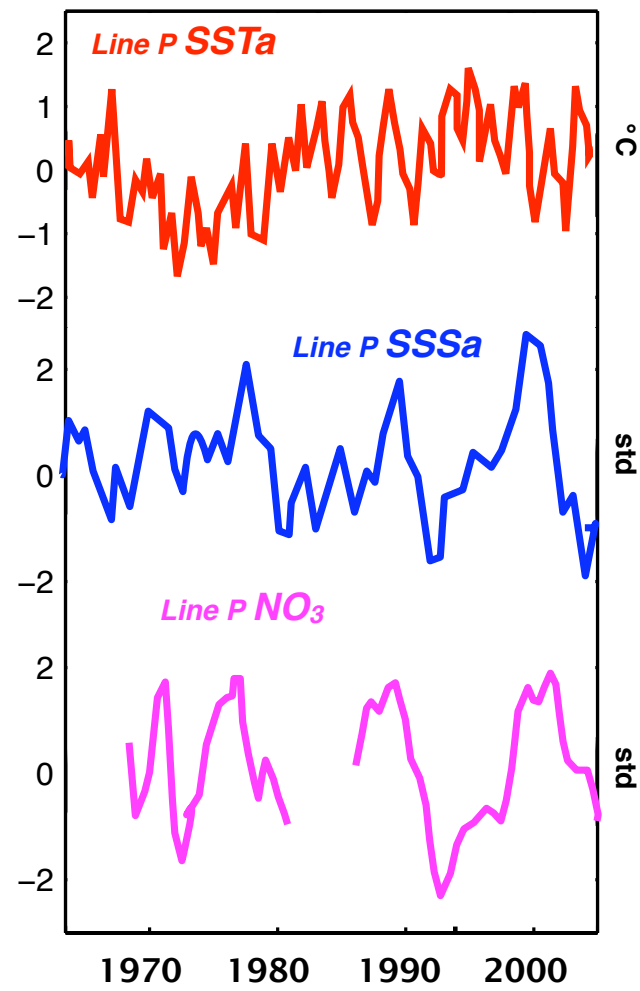
SSTa during Pacific Decadal Oscillation (PDO)



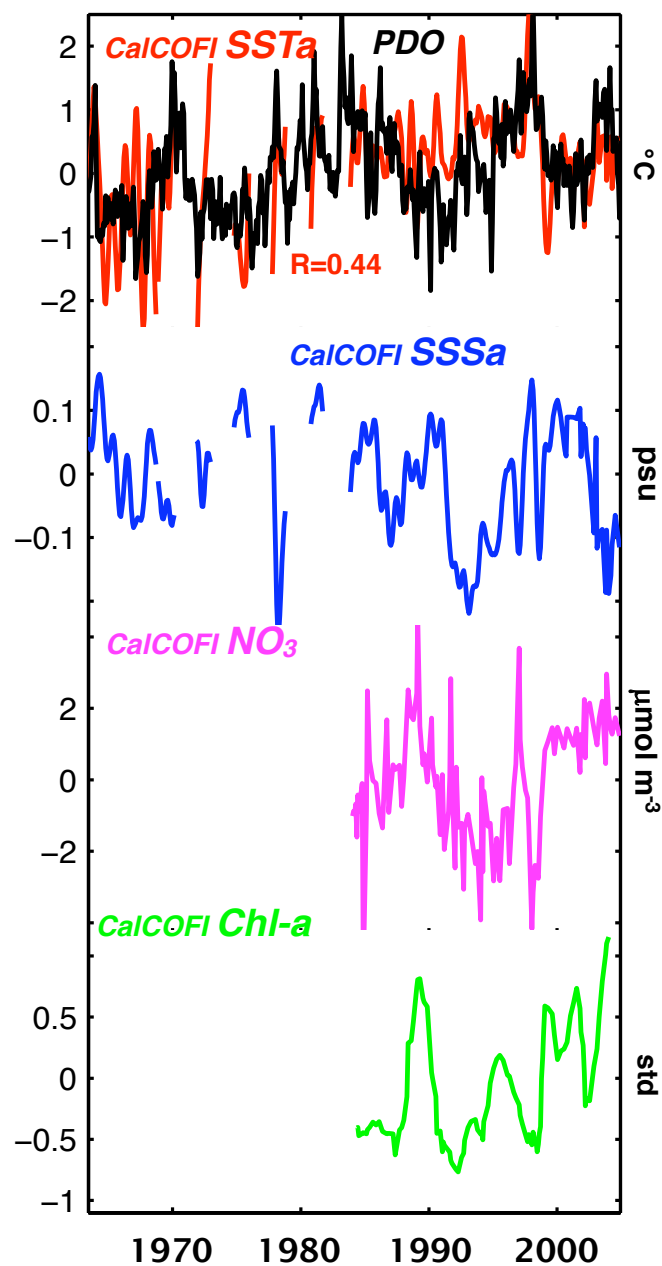
California Current - CalCOFI Observations



Gulf of Alaska - Line P Observations

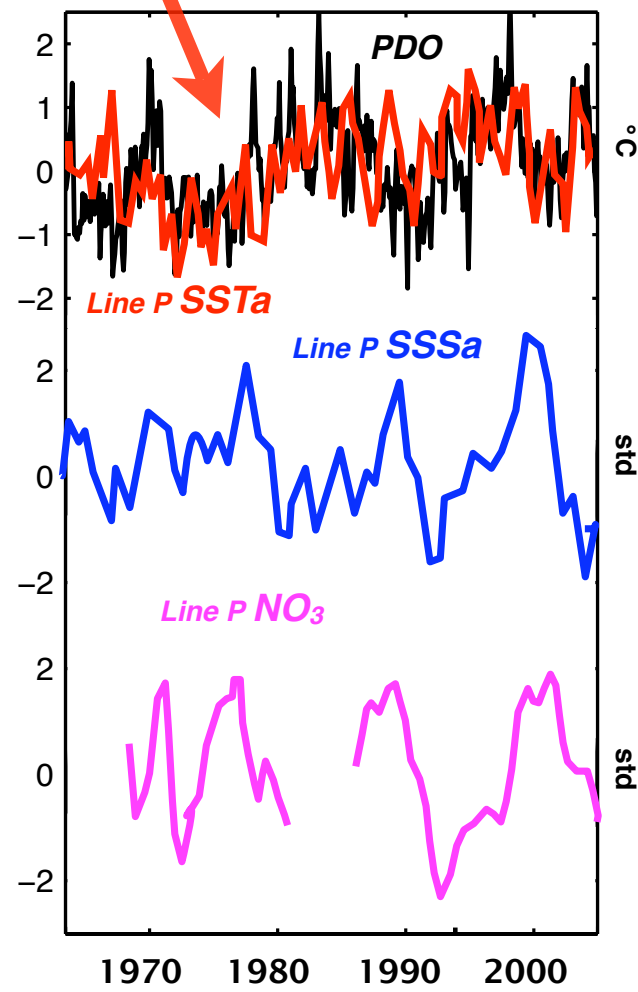


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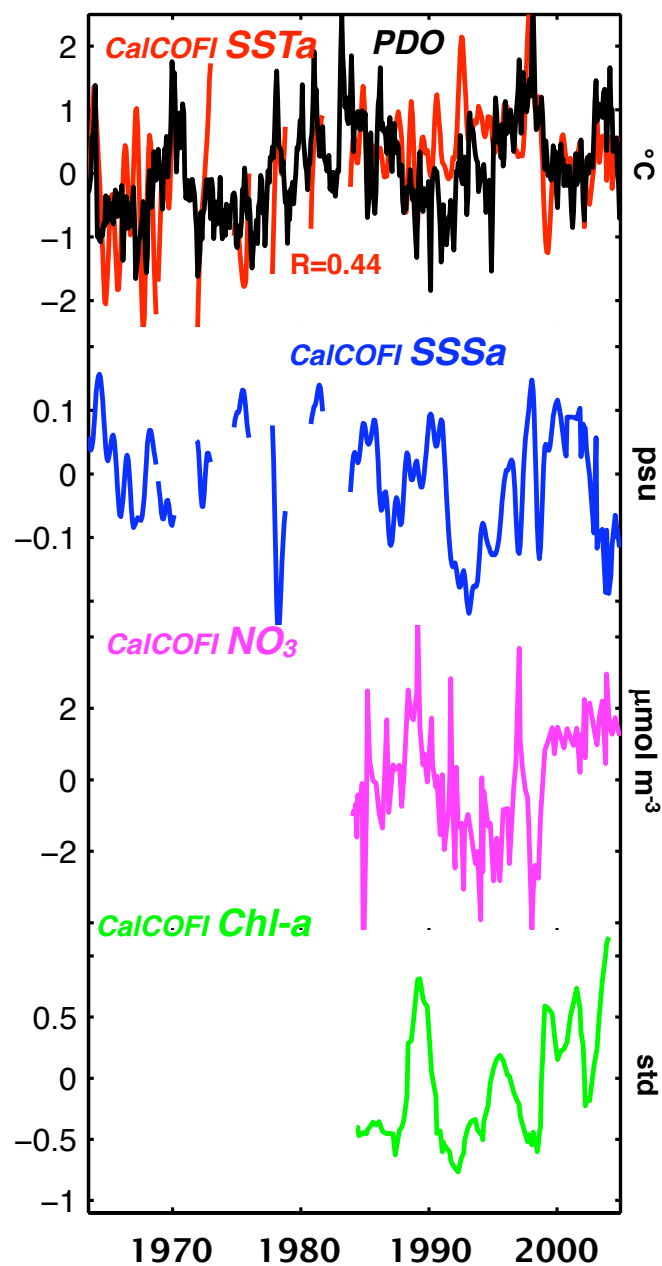


Pacific Decadal Oscillation (PDO)
(Mantua et al., 1997)
EOF1 SSTa

Gulf of Alaska - Line P Observations



California Current - CalCOFI Observations



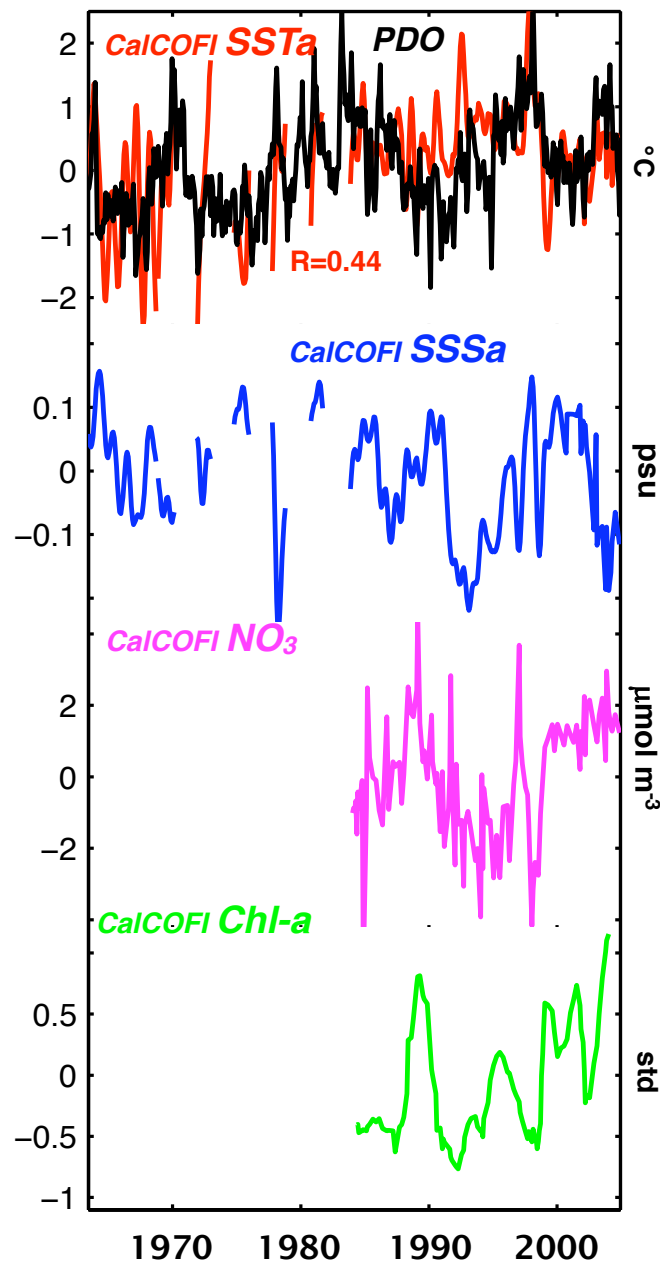
Pacific Decadal Oscillation (PDO)
(Mantua et al., 1997)
EOF1 SSTa

Table 1: Correlations with PDO

	PDO
SSTa	0.44
SSSa	0.06
Chla	0.21
NO_3	0.26
PO_4	0.19
SiO_4	0.31
O_2	0

**Significant
Correlation**

California Current - CalCOFI Observations



Pacific Decadal Oscillation (PDO)
(Mantua et al., 1997)
EOF1 SSTa

Table 1: Correlations with PDO

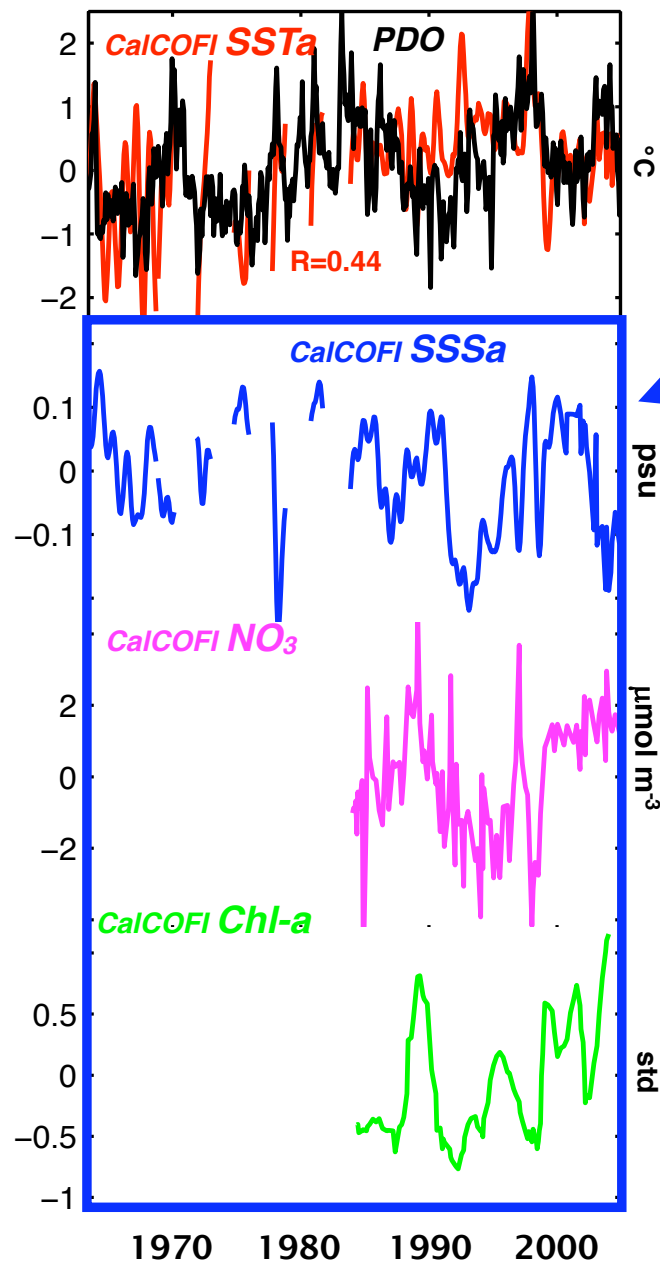
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Correlation**

QUESTION:

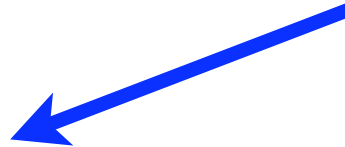
What dynamics control salinity, nutrients upwelling, Chl-a ?

California Current - CalCOFI Observations



Hypothesis

Forced by large-scale wind stress



QUESTION:

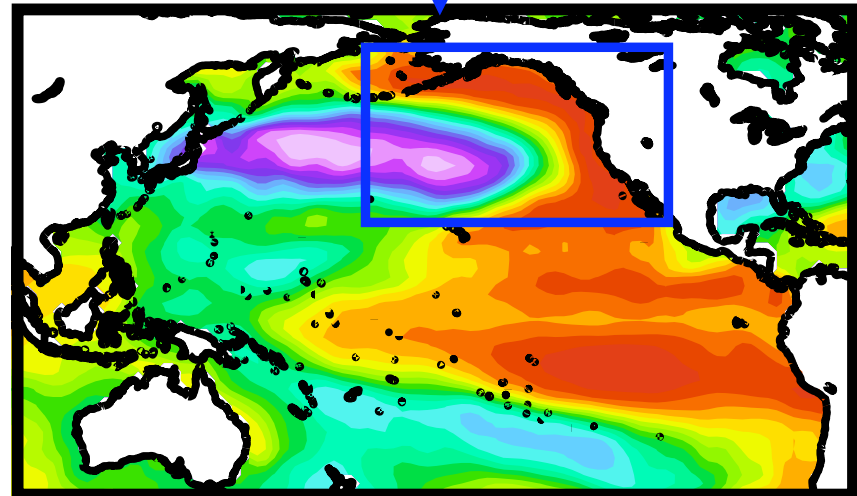
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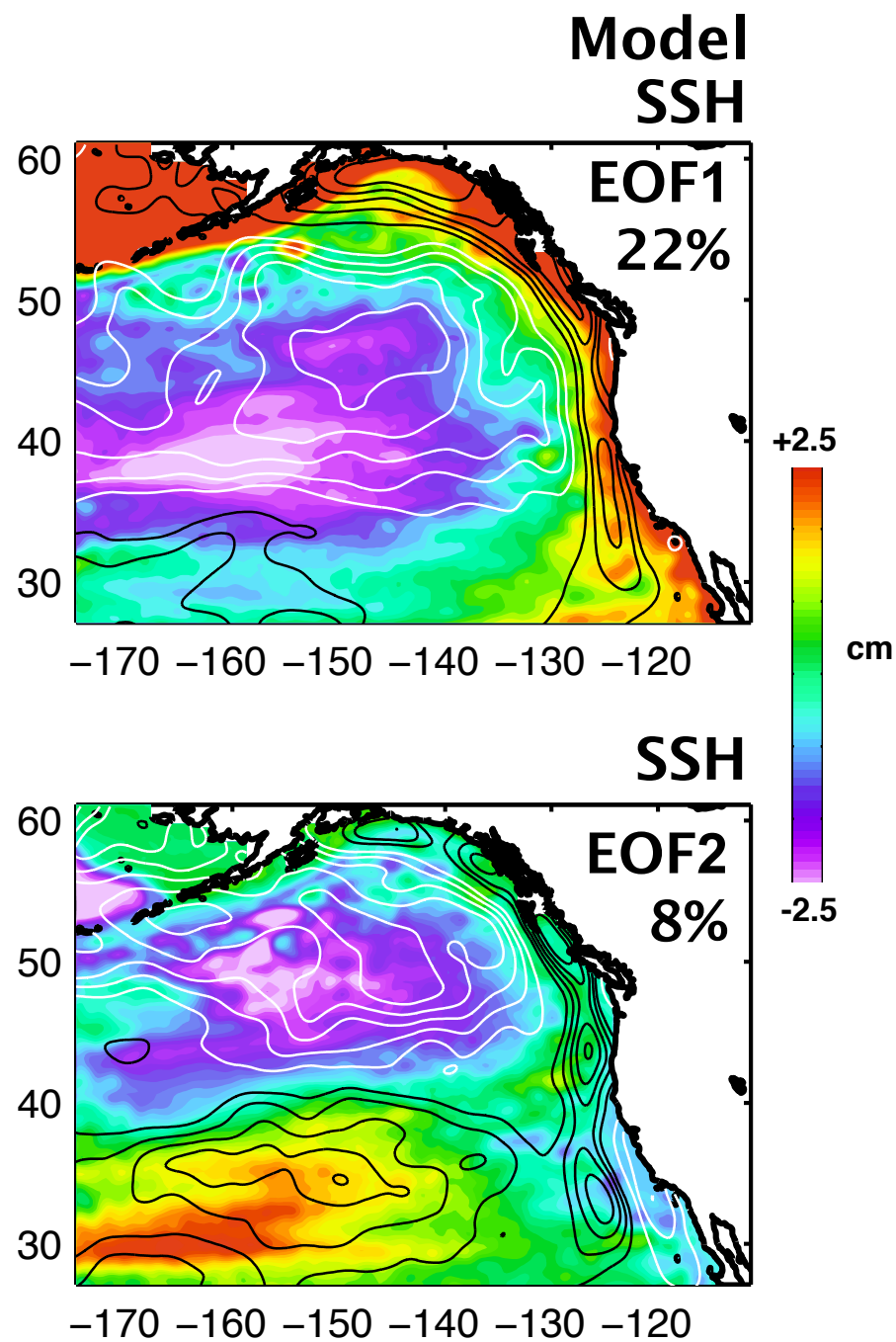
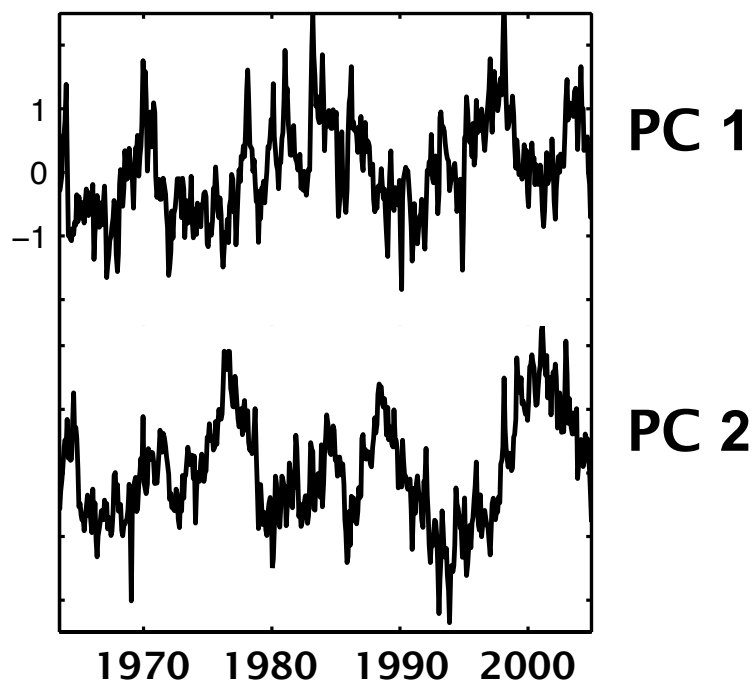
Hypothesis

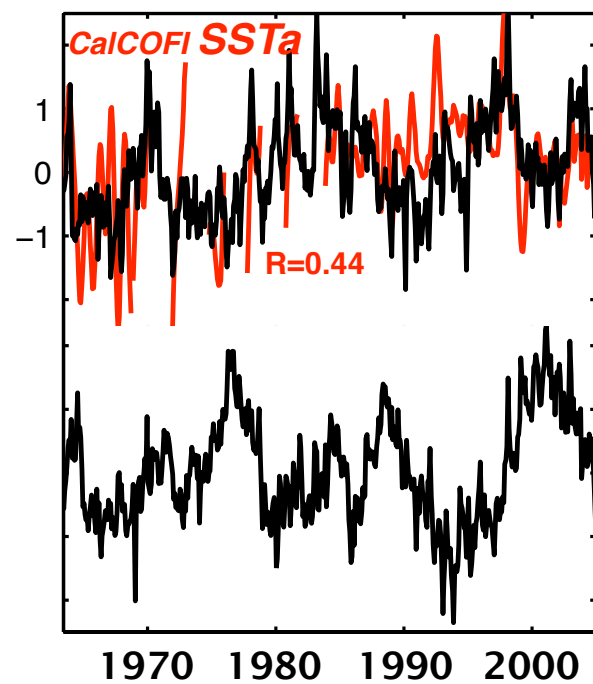
Forced by large-scale
wind stress



Northeast Pacific
ROMS Ocean Model
simulation 1950-2005





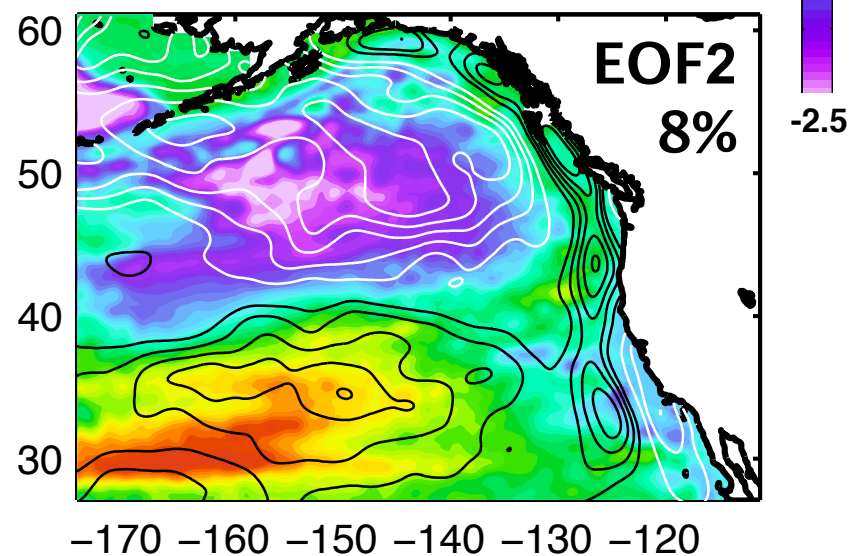
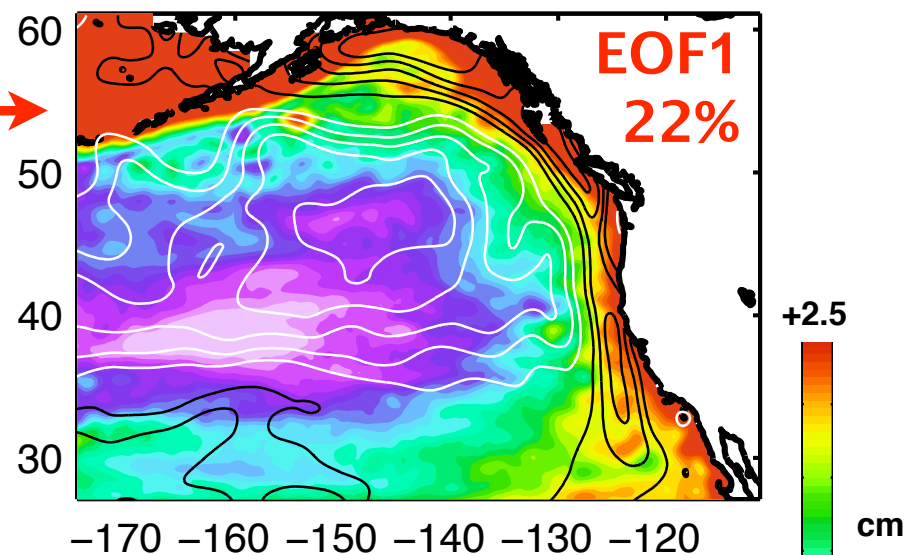


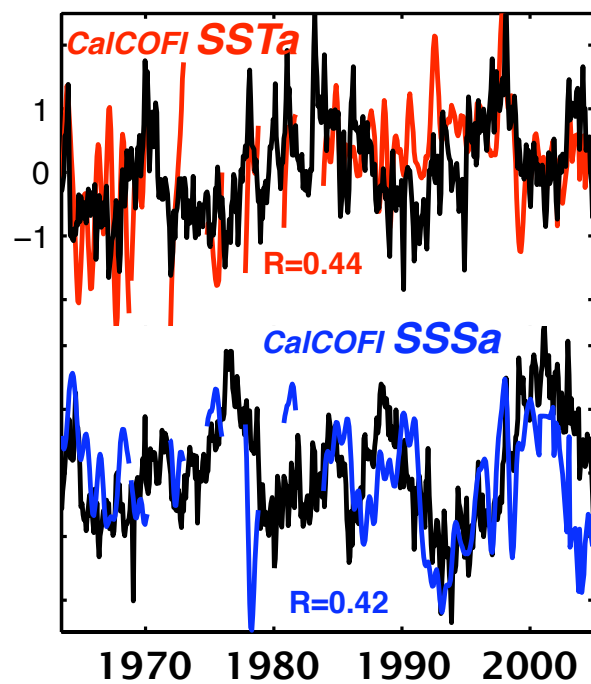
PC 1

PC 2

PDO mode

Model
SSH



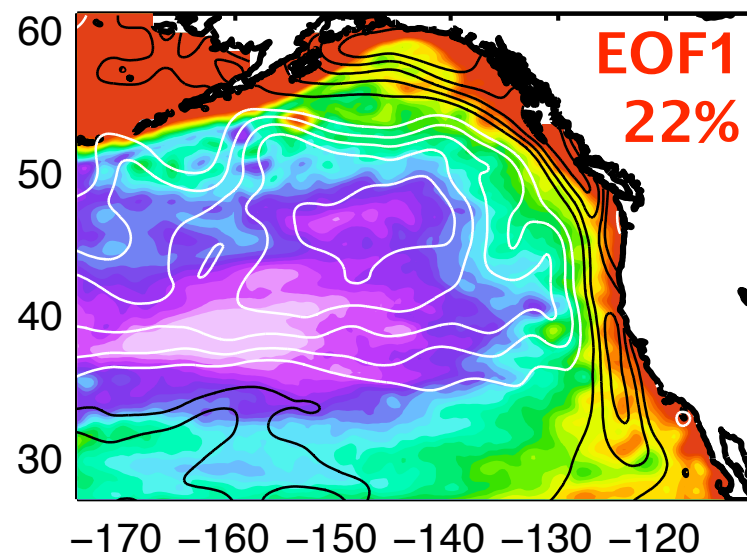


PC 1

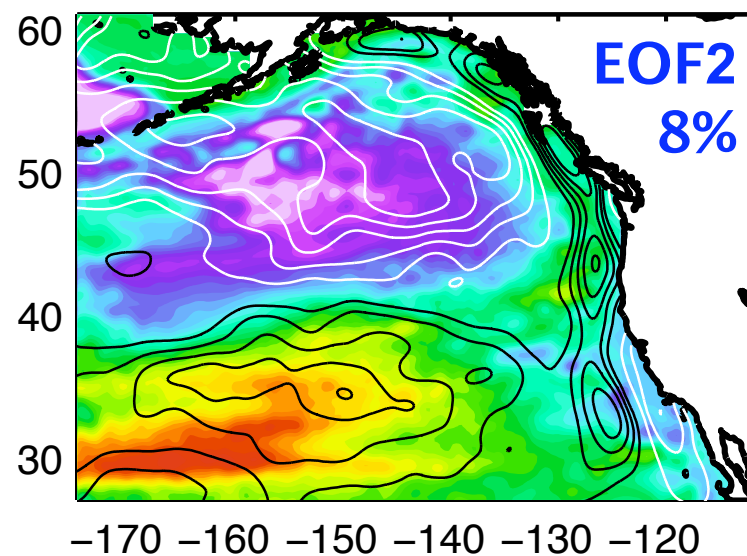
PC 2

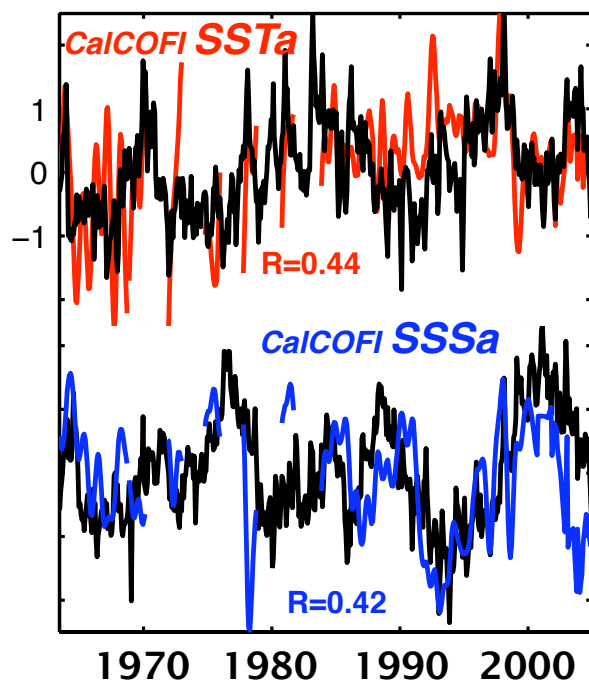
PDO mode

Model
SSH



SSH

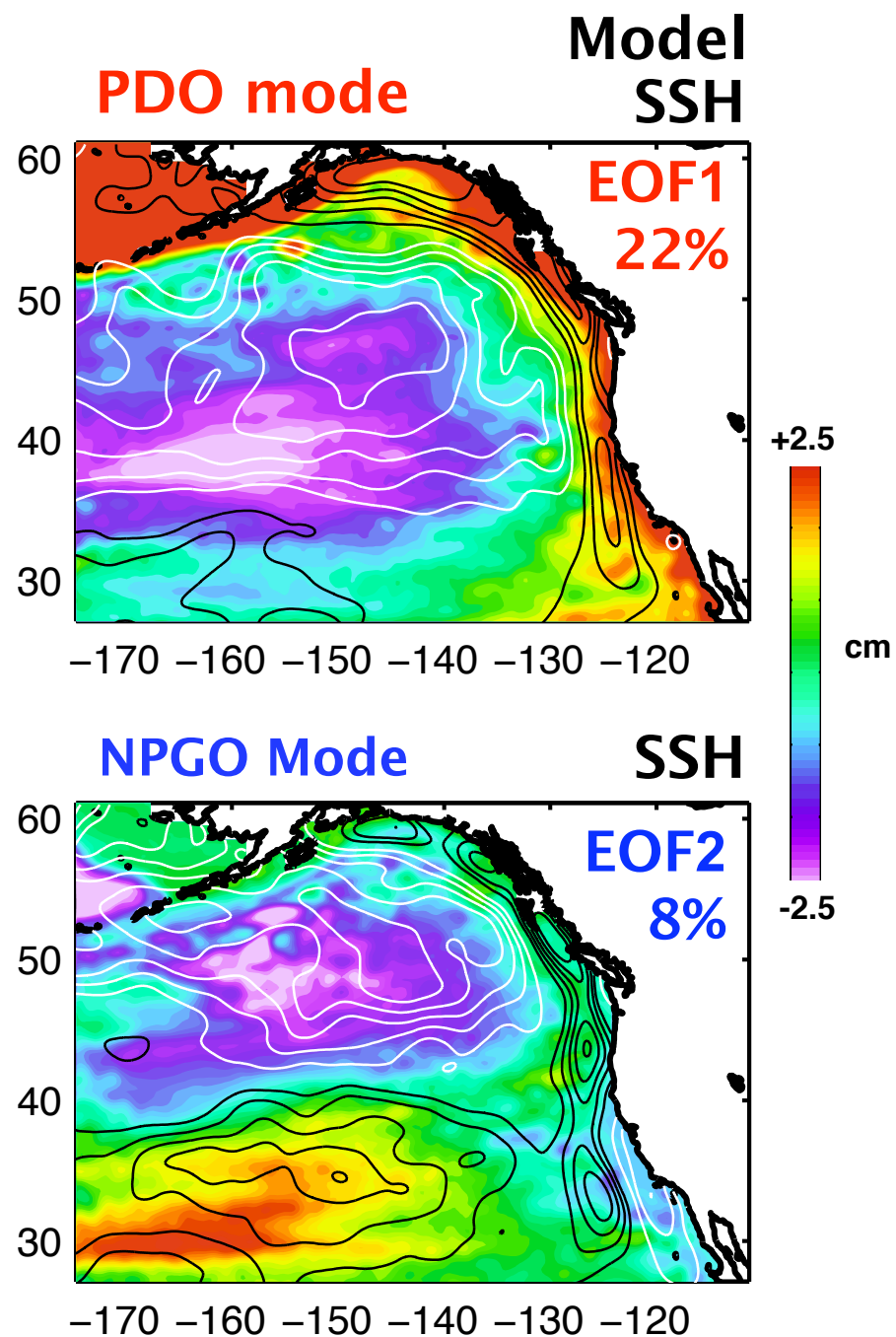


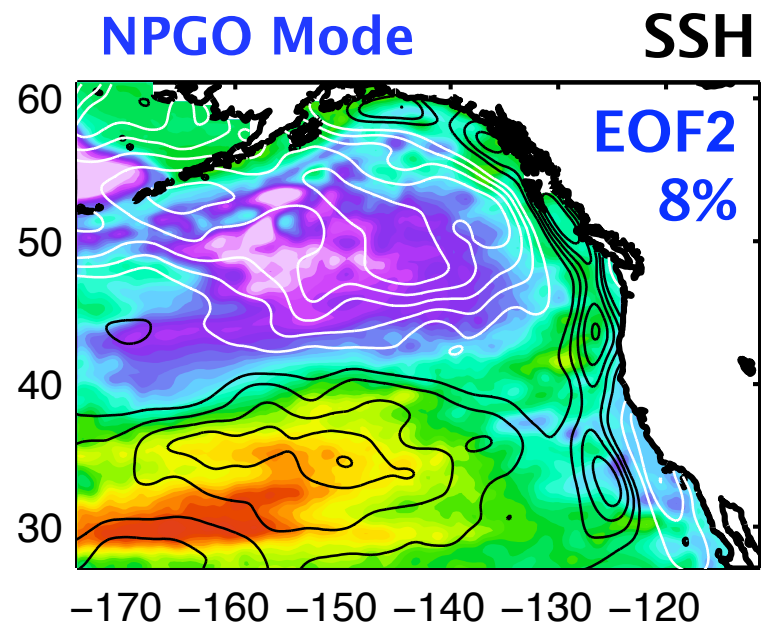
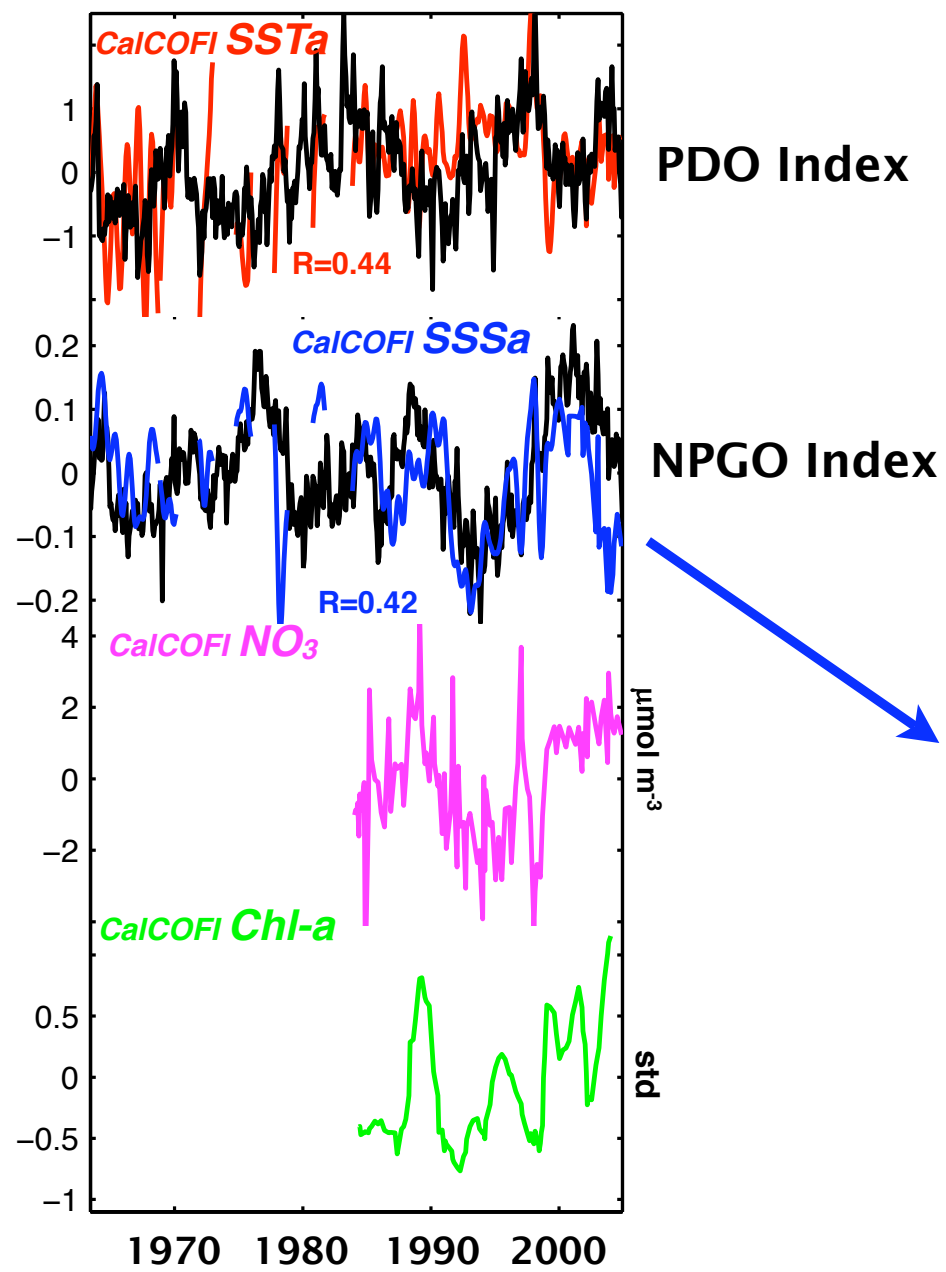


PDO Index

NPGO Index

North Pacific Gyre Oscillation
(NPGO)





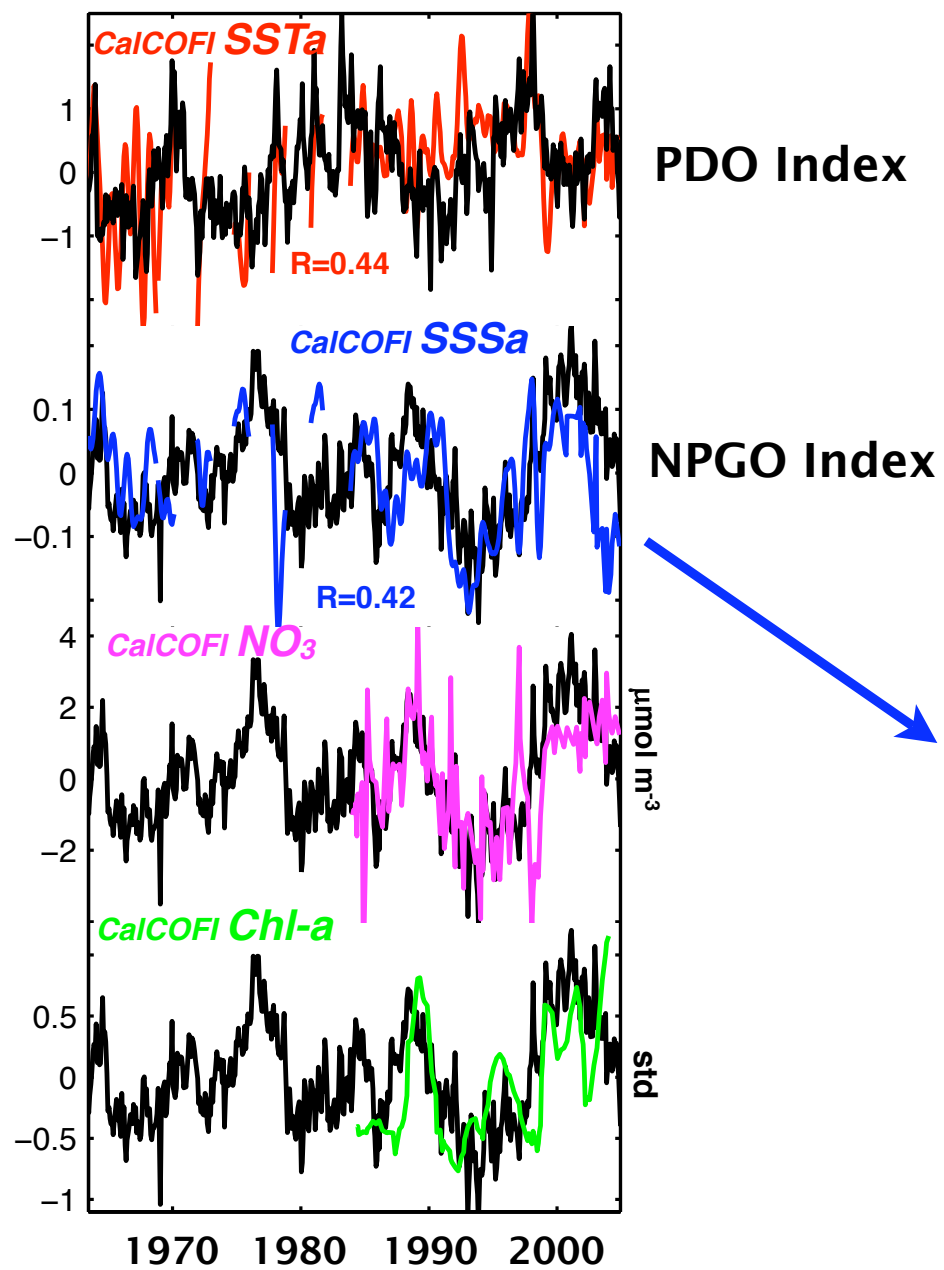
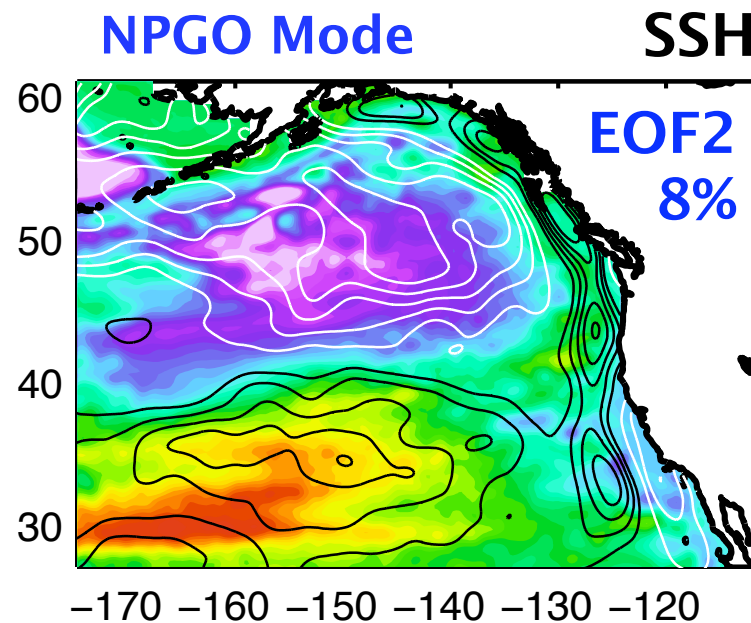


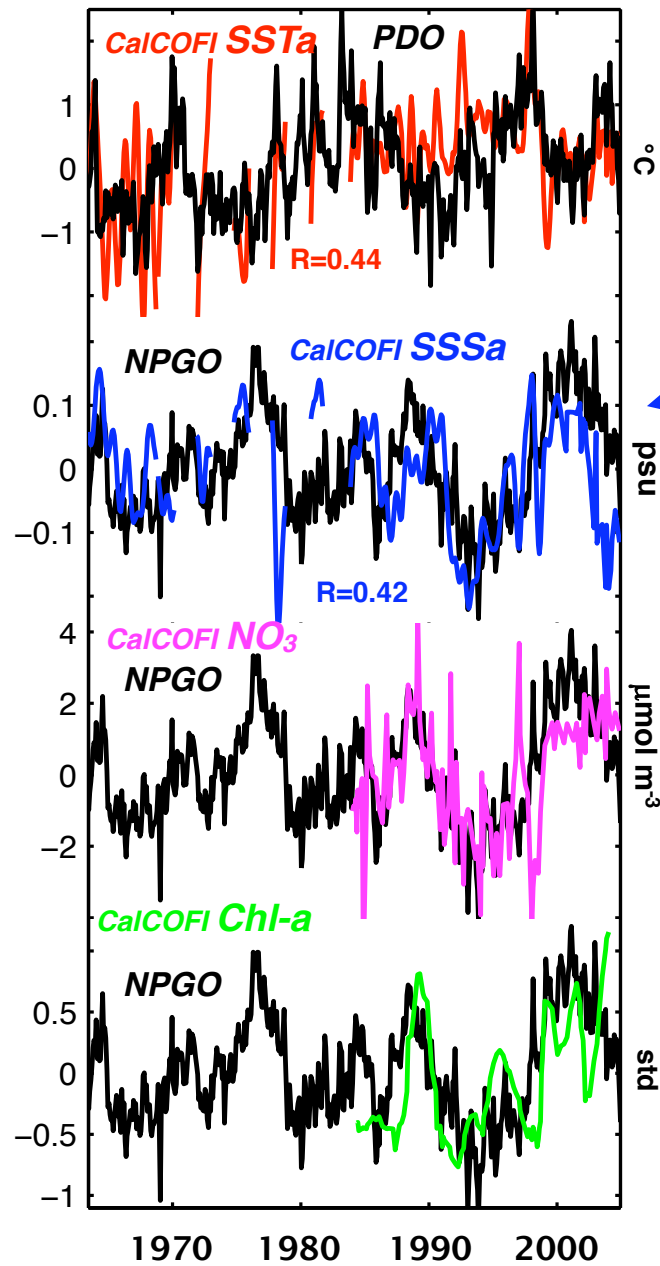
Table 1: Correlations with PDO and NPGO indeces.

	PDO	NPGO
SSTa	0.44	0.29
SSSa	0.06	0.42
Chla	0.21	0.47
NO ₃	0.26	0.51
PO ₄	0.19	0.35
SiO ₄	0.31	0.53
O ₂	0	-0.50

Significant Correlation



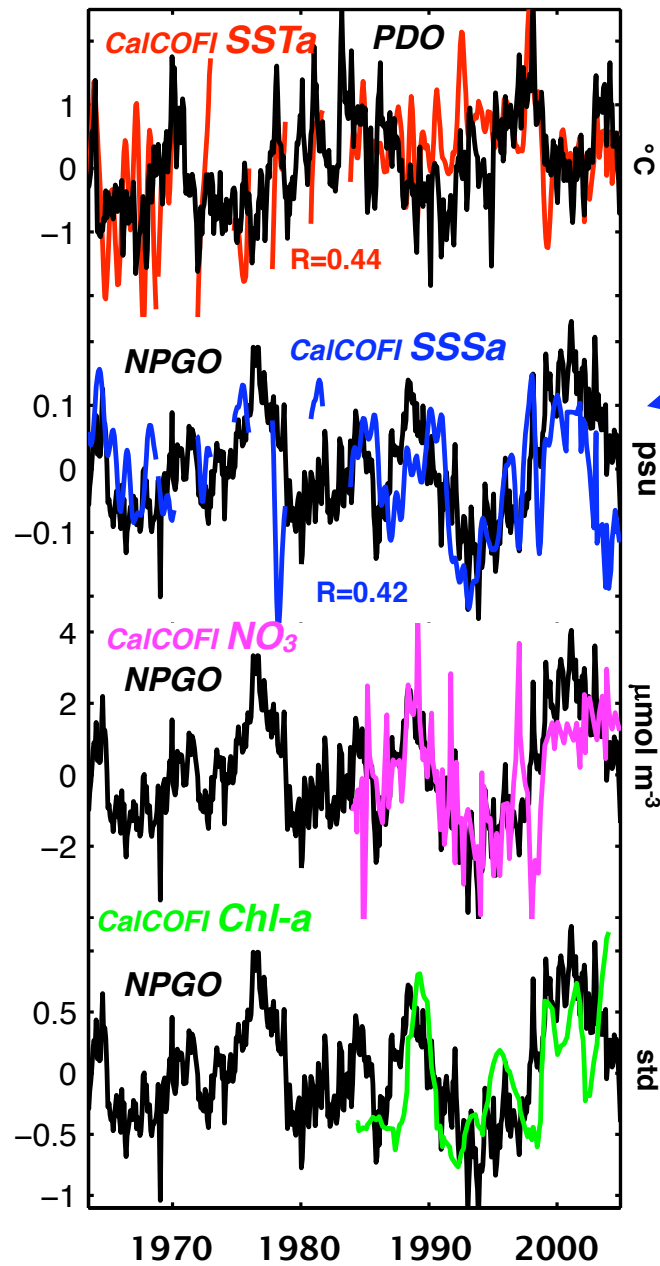
California Current - CalCOFI Observations



Pacific Decadal Oscillation (PDO)
(Mantua et al., 1997)
EOF1 SSTa

North Pacific Gyre Oscillation (NPGO)
(Di Lorenzo et al., 2008)
EOF2 SSHa

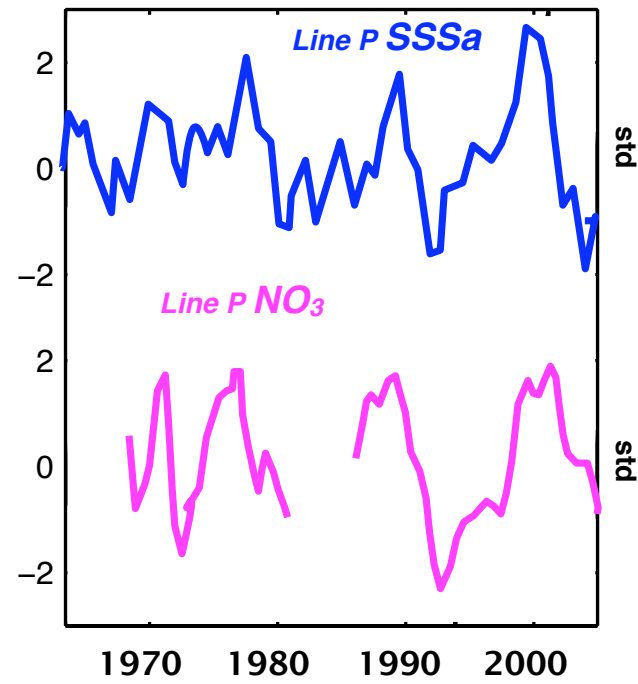
California Current - CalCOFI Observations



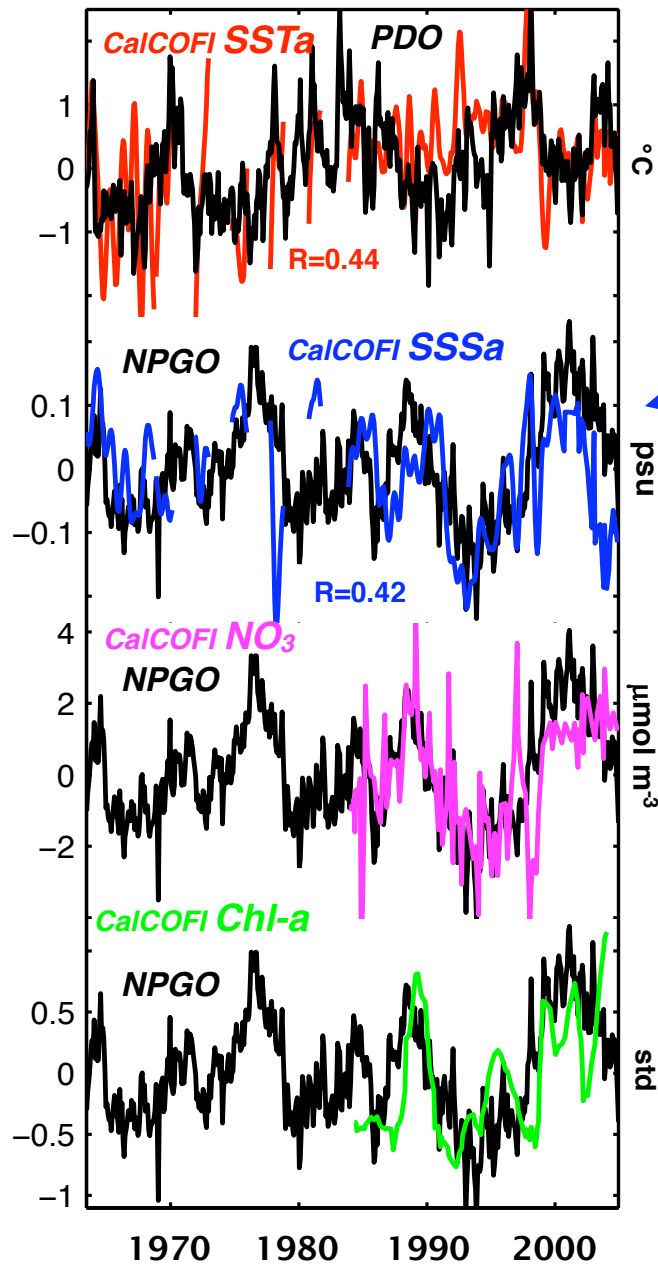
Pacific Decadal Oscillation (PDO)
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North Pacific Gyre Oscillation (NPGO)
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EOF2 SSHa

Gulf of Alaska - Line P Observations



California Current - CalCOFI Observations

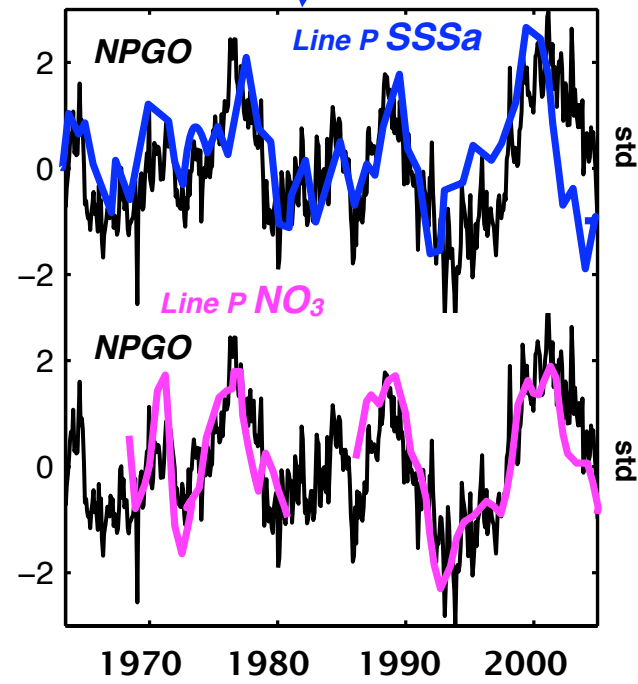


Pacific Decadal Oscillation (PDO)
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EOF1 SSTa

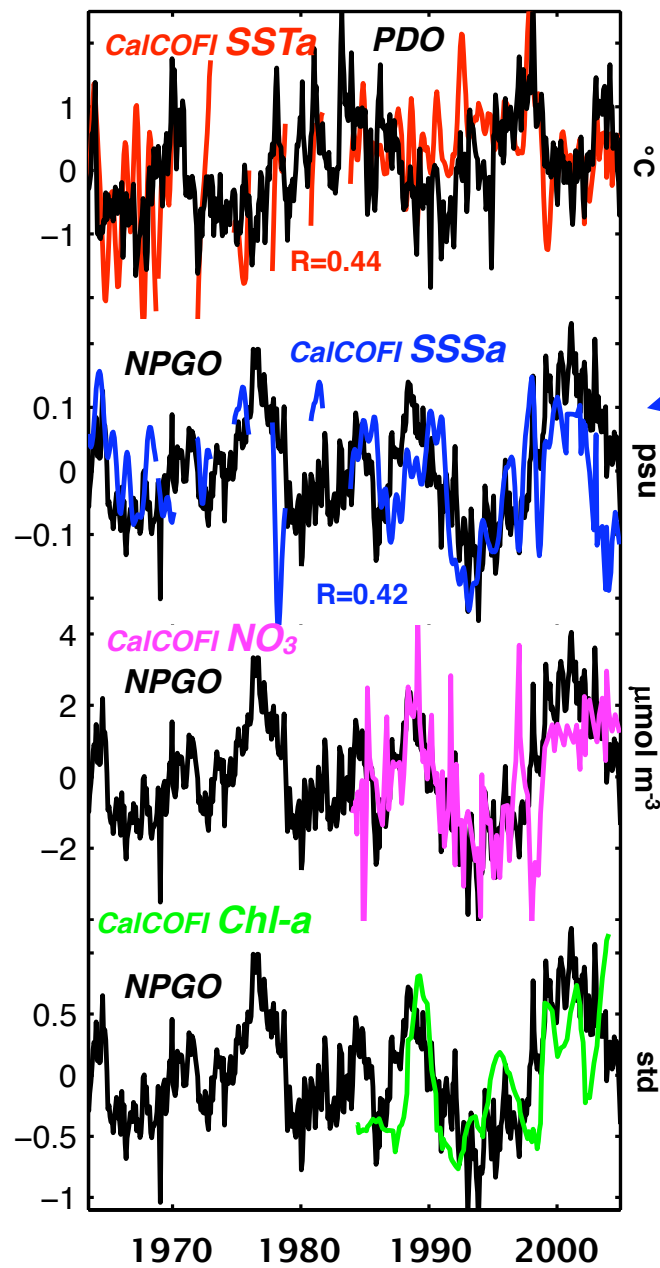
North Pacific Gyre Oscillation (NPGO)
(Di Lorenzo et al., 2008)

EOF2 SSHa

Gulf of Alaska - Line P Observations

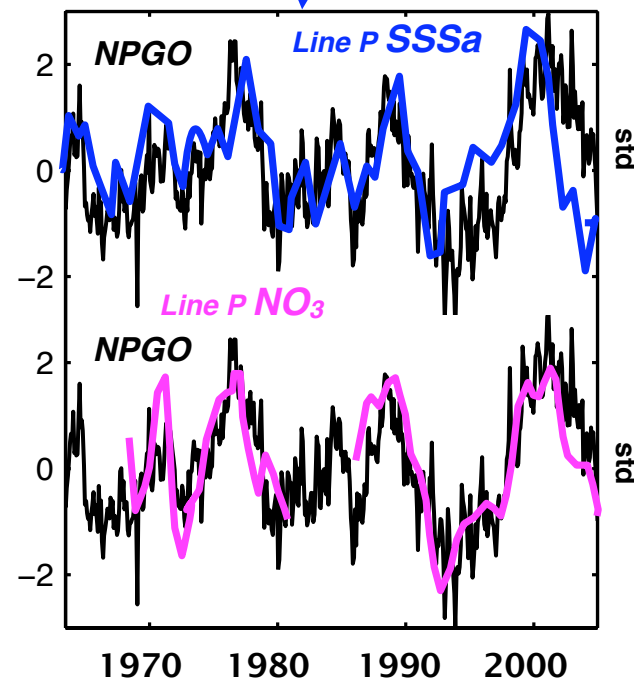


California Current - CalCOFI Observations



The NPGO controls previously unexplained variations of *salinity*, *nutrient upwelling* and *Chl-a* recorded in the Northeast Pacific.

Gulf of Alaska - Line P Observations



QUESTION:

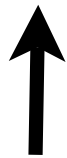
How are coastal upwelling winds in the CCS linked to large-scale forcing?

2 dominant patterns of
atmospheric variability

QUESTION:

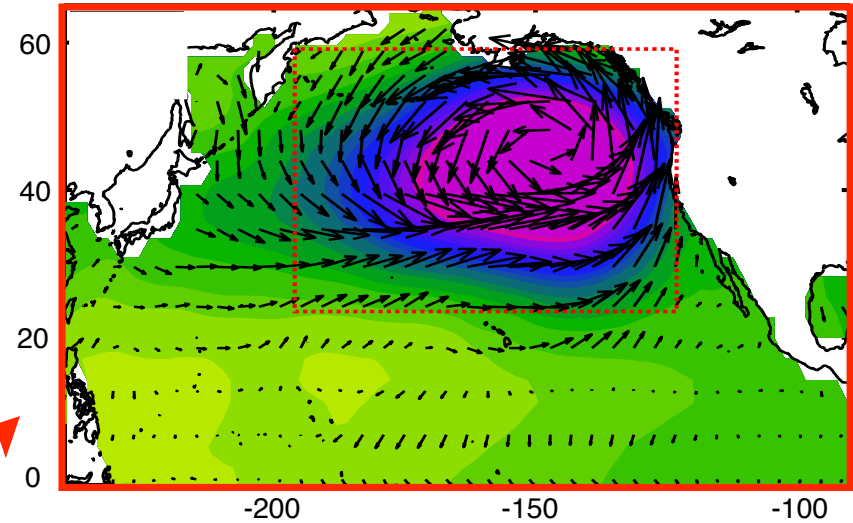
How are coastal upwelling winds in the CCS linked to large-scale forcing?

*Sea Level Pressure
and Wind Stress
Anomalies*



*2 dominant patterns of
atmospheric variability*

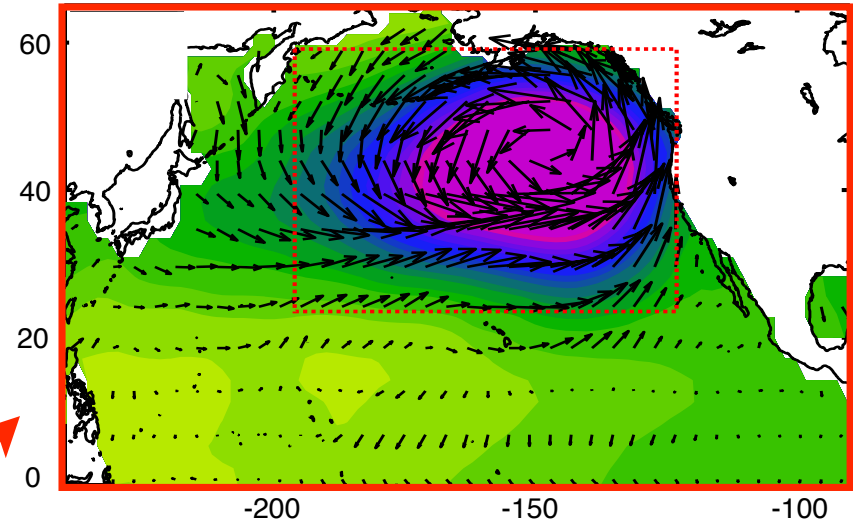
Aleutian Low (EOF1 SLPa)



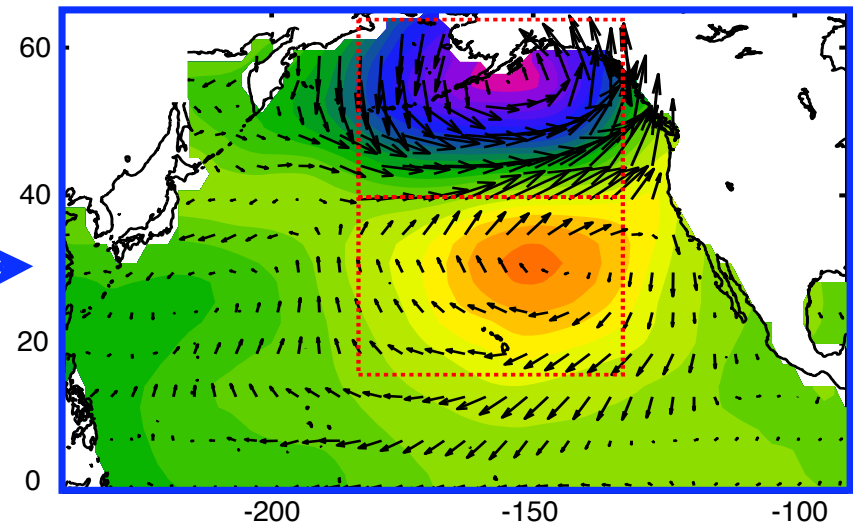
*2 dominant patterns of
atmospheric variability*



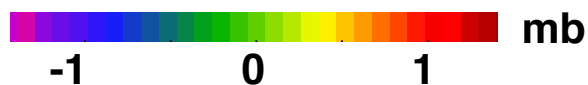
Aleutian Low (EOF1 SLPa)



North Pacific Oscillation (EOF2 SLPa)



*2 dominant patterns of
atmospheric variability*

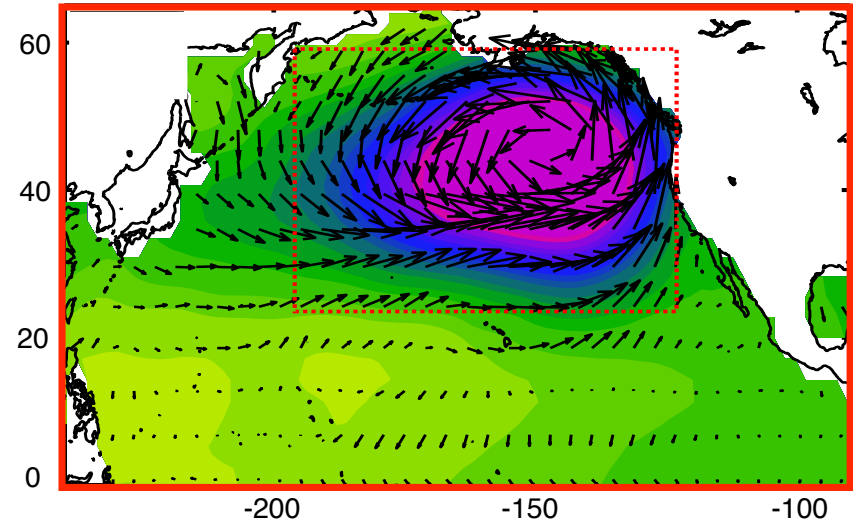


Walker and Bliss, 1932

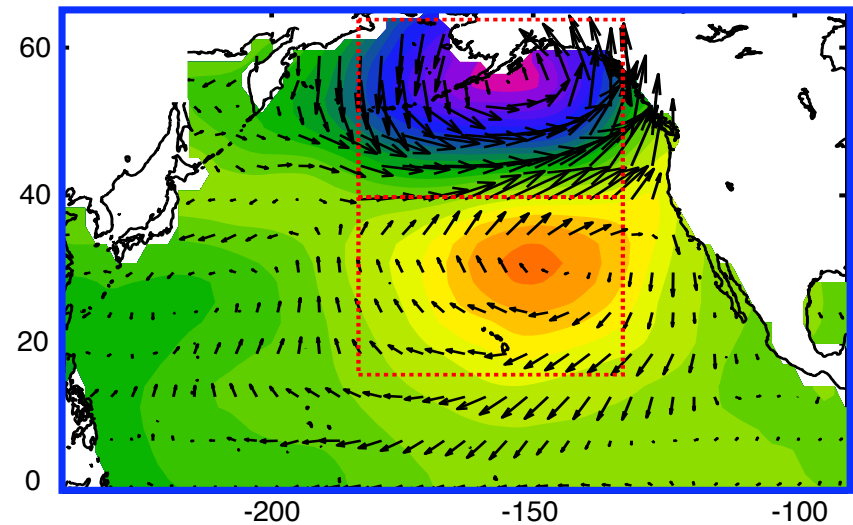
QUESTION:

What is the oceanic footprint of these atmospheric forcings?

Aleutian Low (EOF1 SLPa)



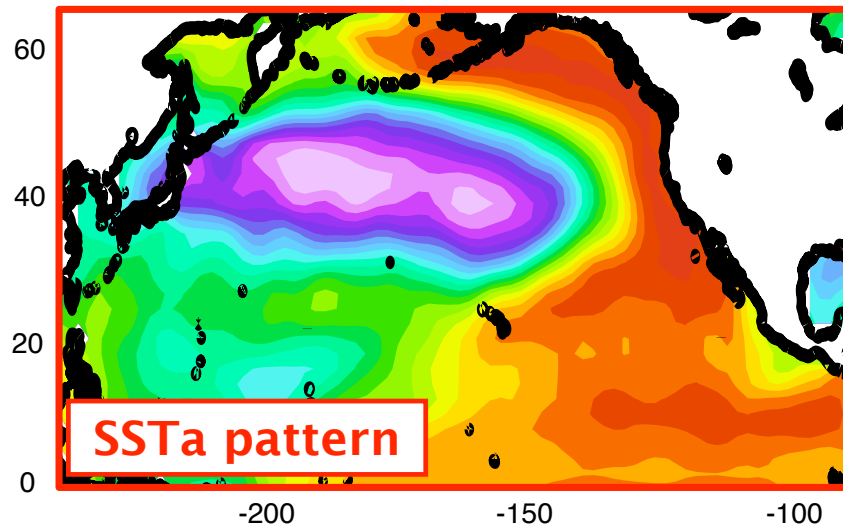
North Pacific Oscillation (EOF2 SLPa)



Walker and Bliss, 1932

PDO

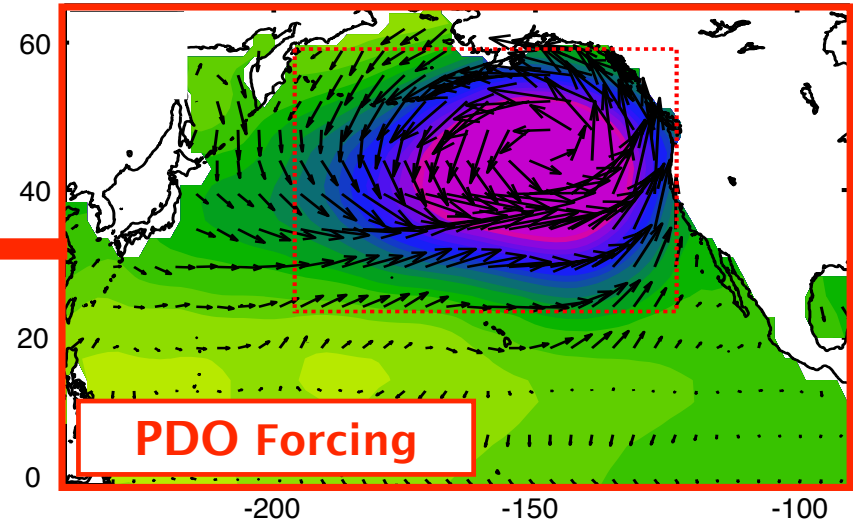
(EOF1 SSTa, SSHa)



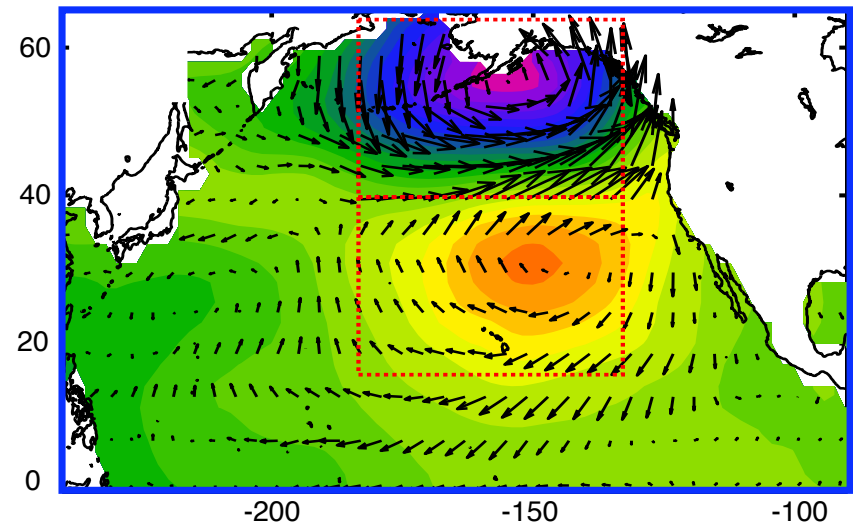
Chhak, Di Lorenzo et al., 2008

Aleutian Low

(EOF1 SLPa)

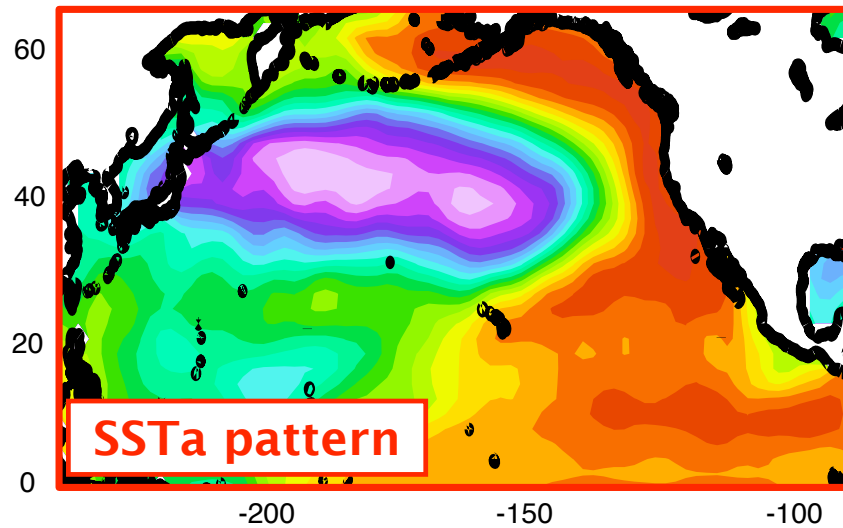


North Pacific Oscillation (EOF2 SLPa)



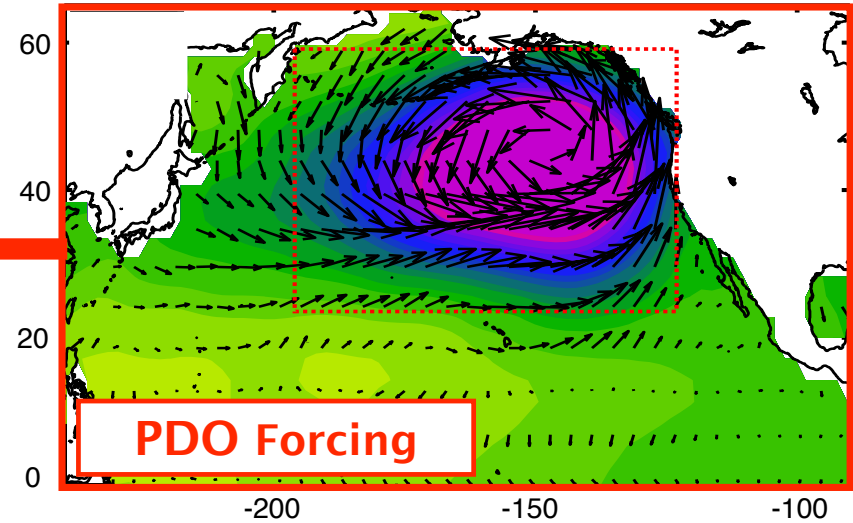
Walker and Bliss, 1932

PDO (EOF1 SSTa, SSHa)

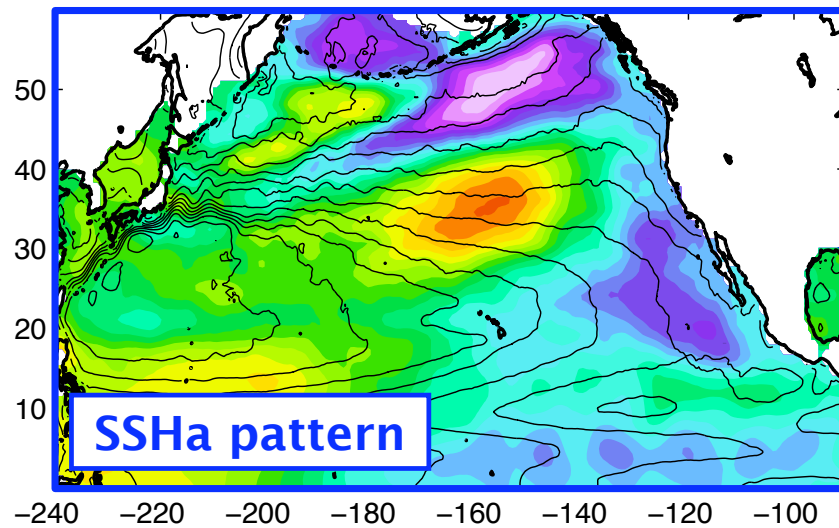


Chhak, Di Lorenzo et al., 2008

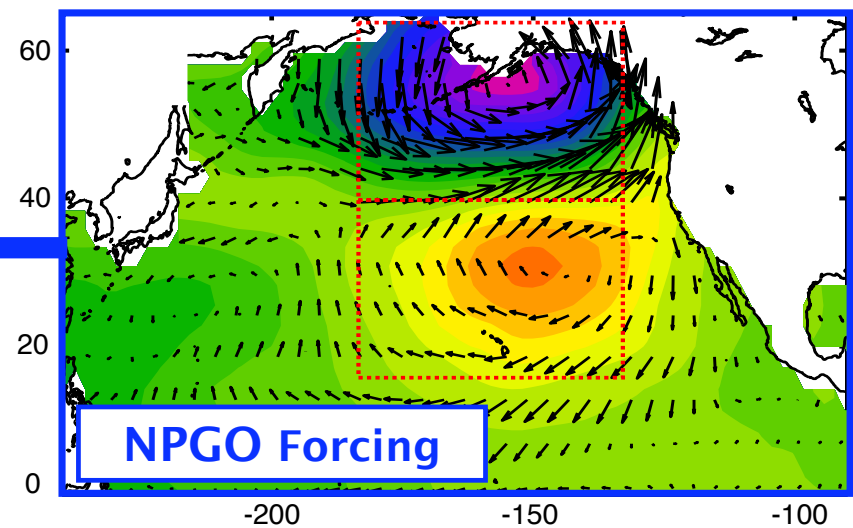
Aleutian Low (EOF1 SLPa)



NPGO (EOF2 SSTa, SSHa)



North Pacific Oscillation (EOF2 SLPa)

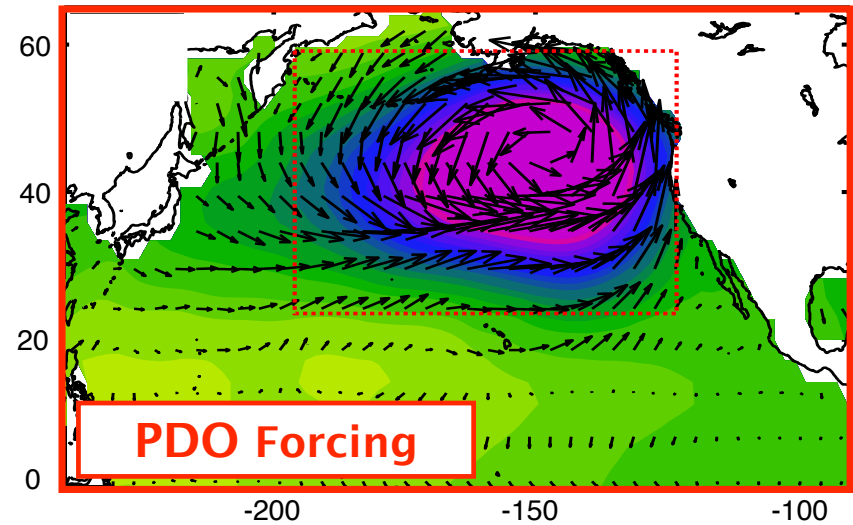


Walker and Bliss, 1932

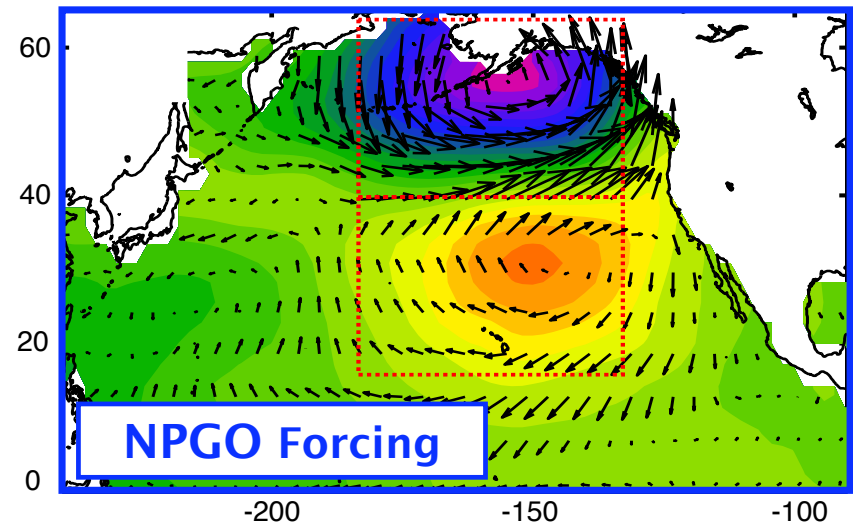
QUESTION:

How do these atmospheric forcing drive coastal upwelling in the CCS?

Aleutian Low (EOF1 SLPa)



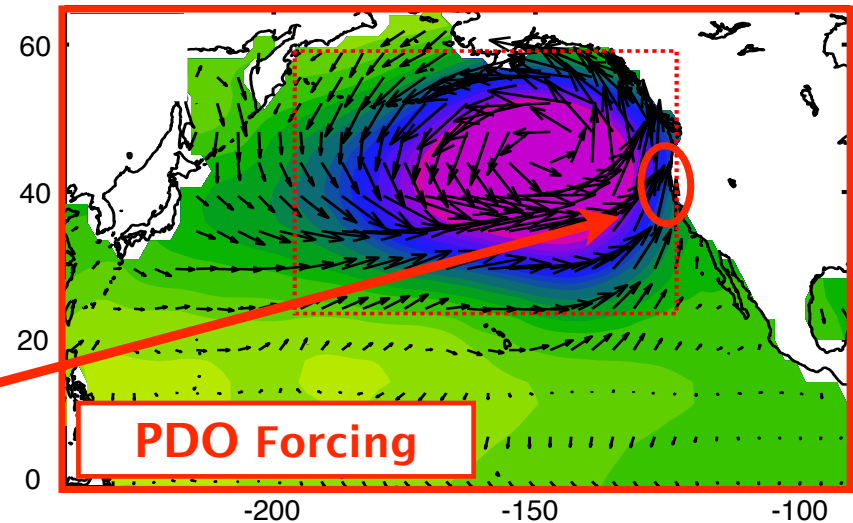
North Pacific Oscillation (EOF2 SLPa)



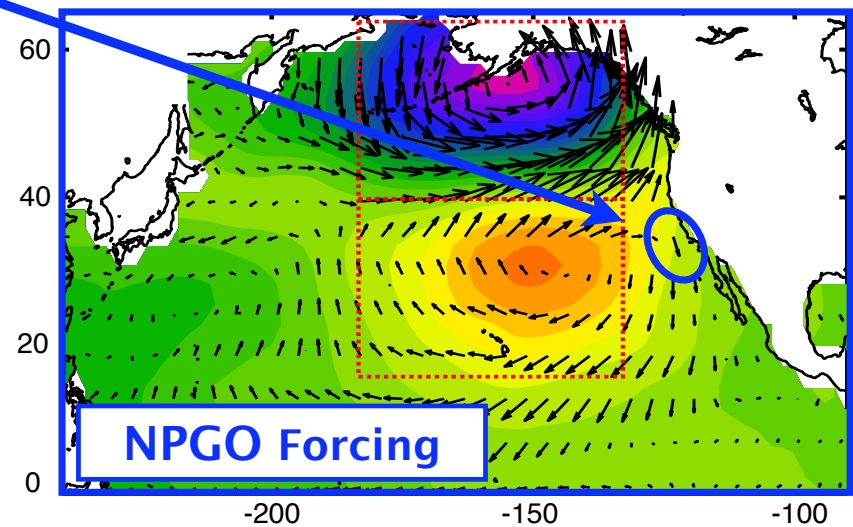
Walker and Bliss, 1932

*different projections on
coastal upwelling*

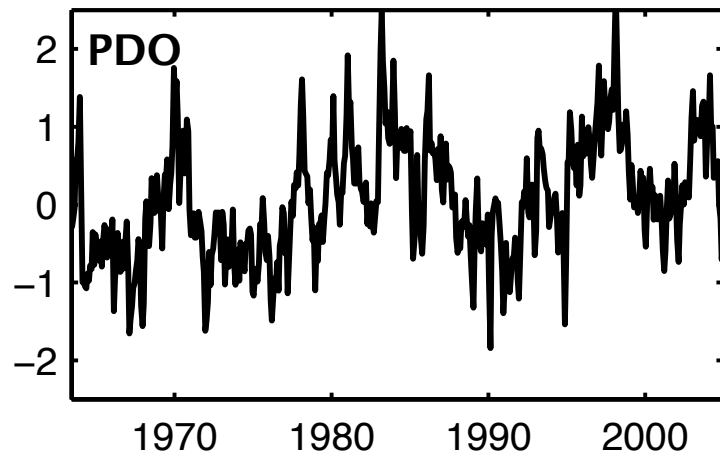
Aleutian Low (EOF1 SLPa)



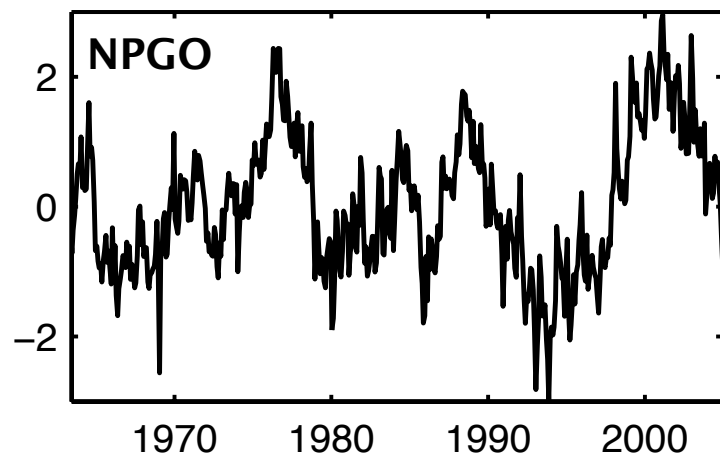
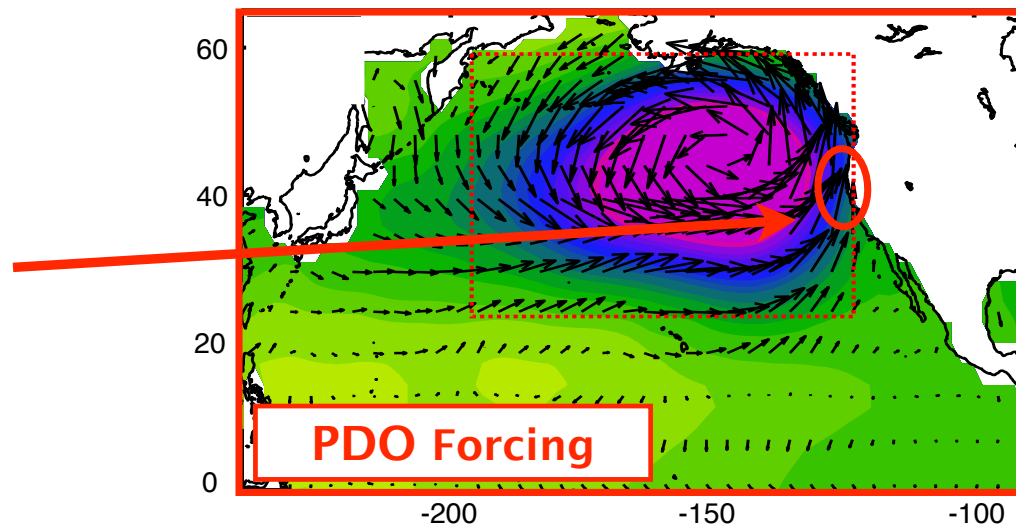
North Pacific Oscillation (EOF2 SLPa)



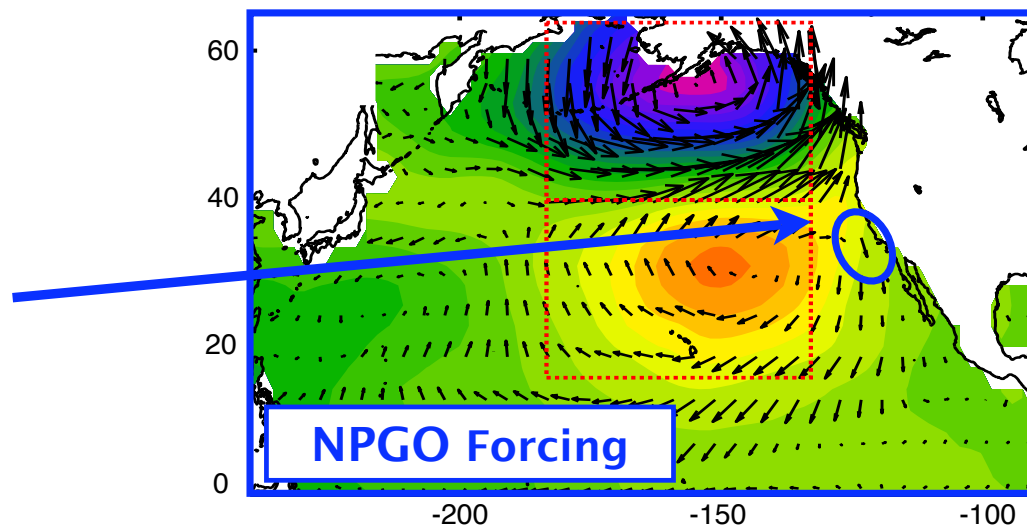
Walker and Bliss, 1932



Aleutian Low (EOF1 SLPa)



North Pacific Oscillation (EOF2 SLPa)

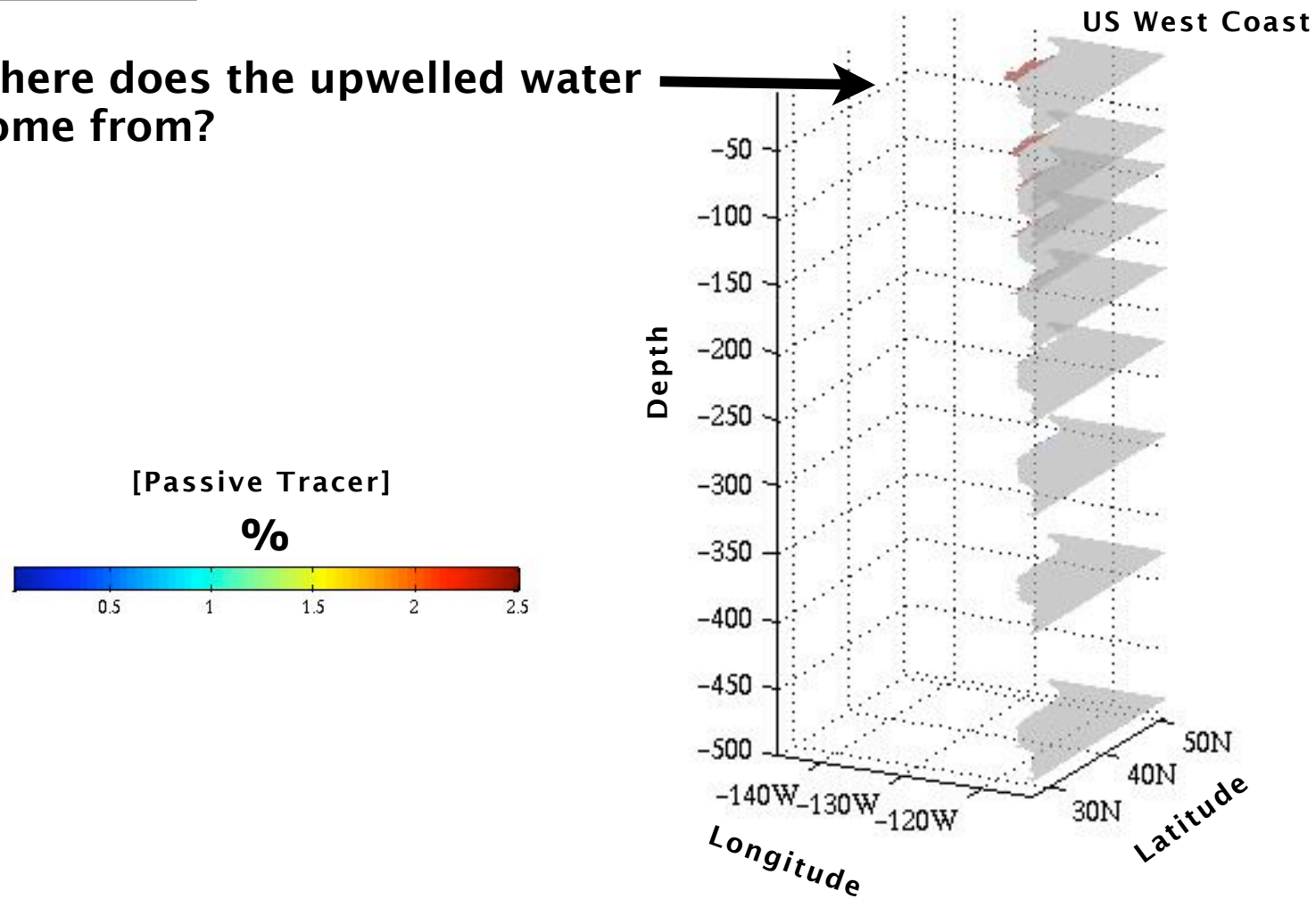


Walker and Bliss, 1932

3D view of Upwelling System

QUESTION:

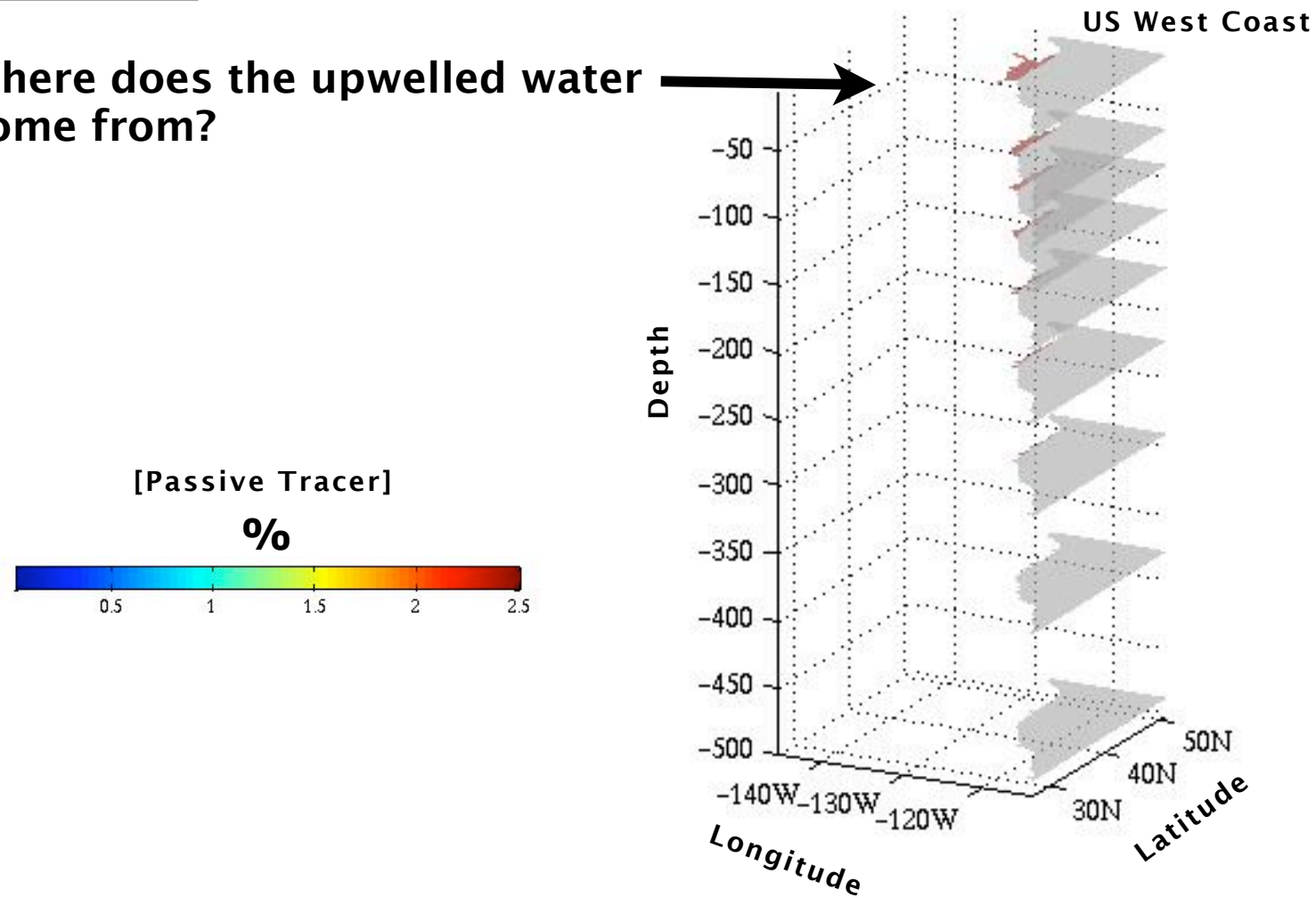
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

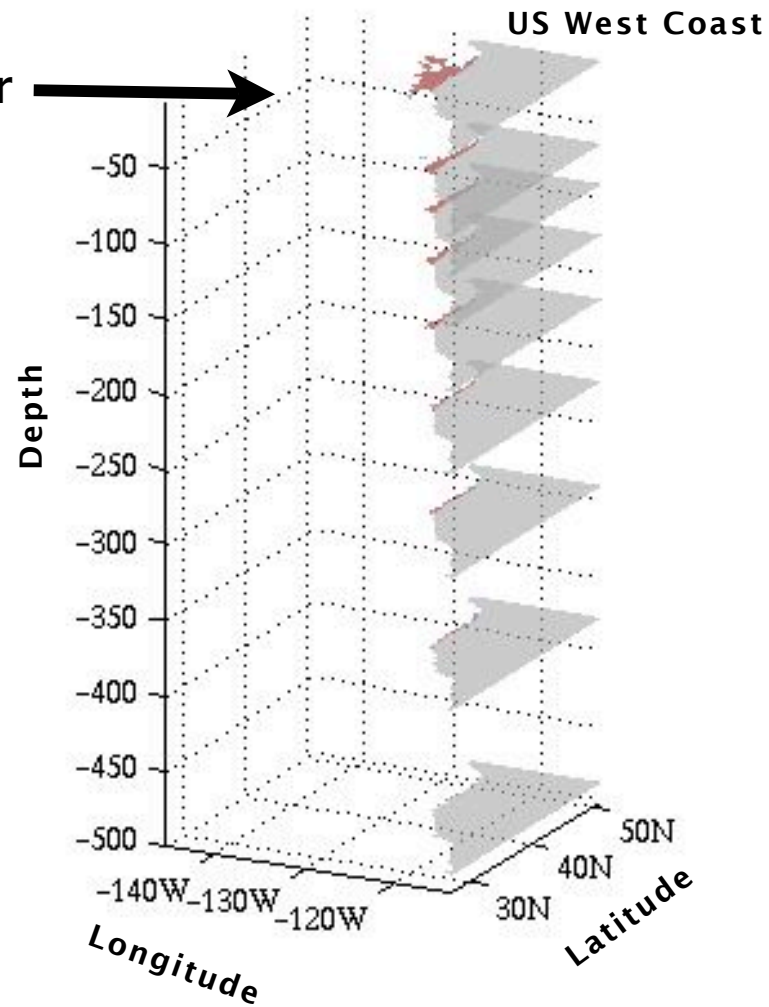
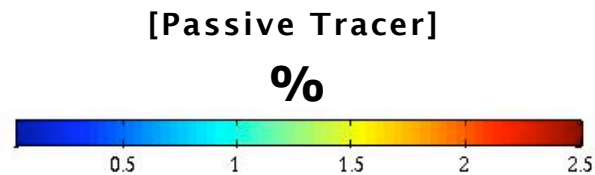
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3D view of Upwelling System

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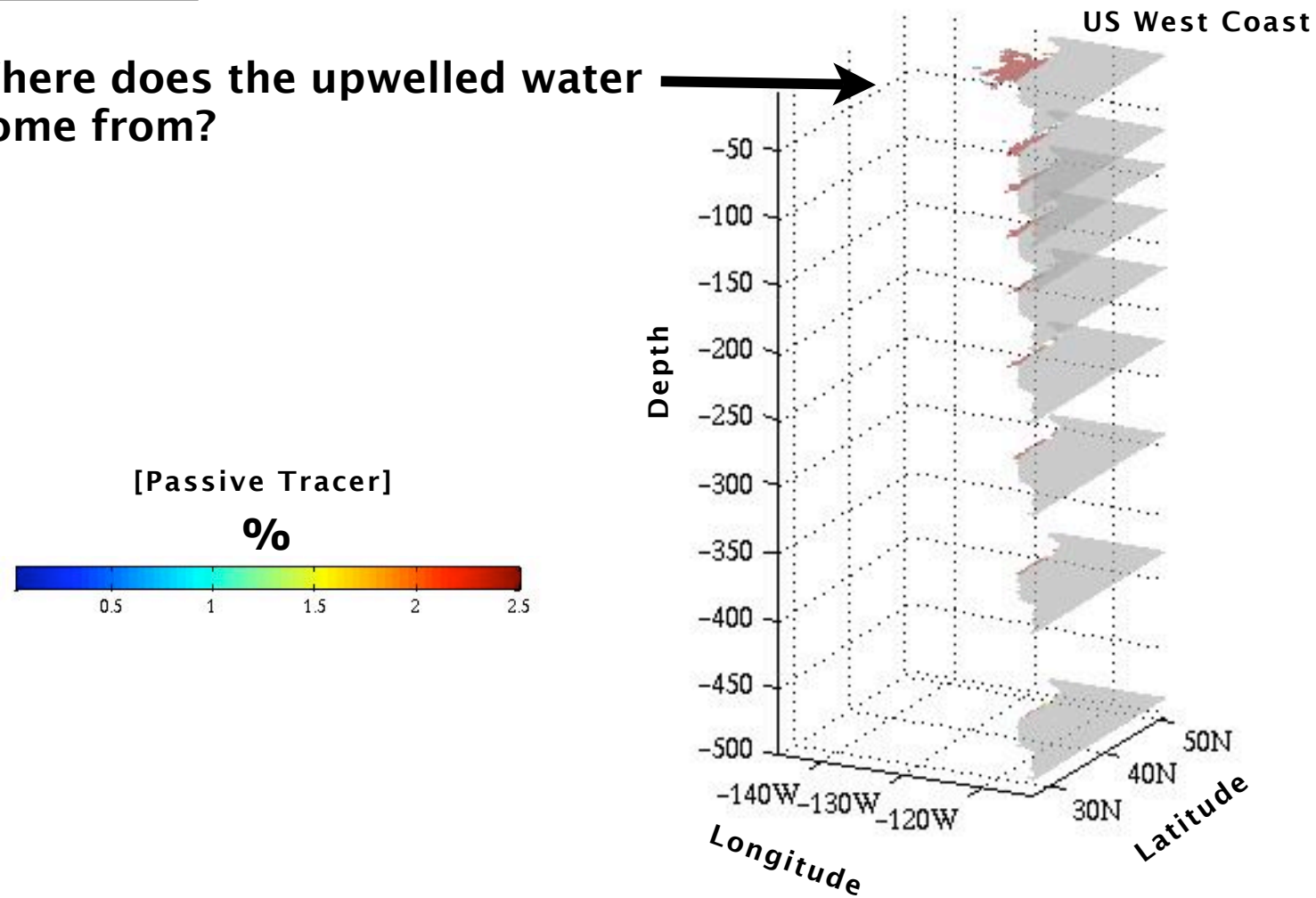
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3D view of Upwelling System

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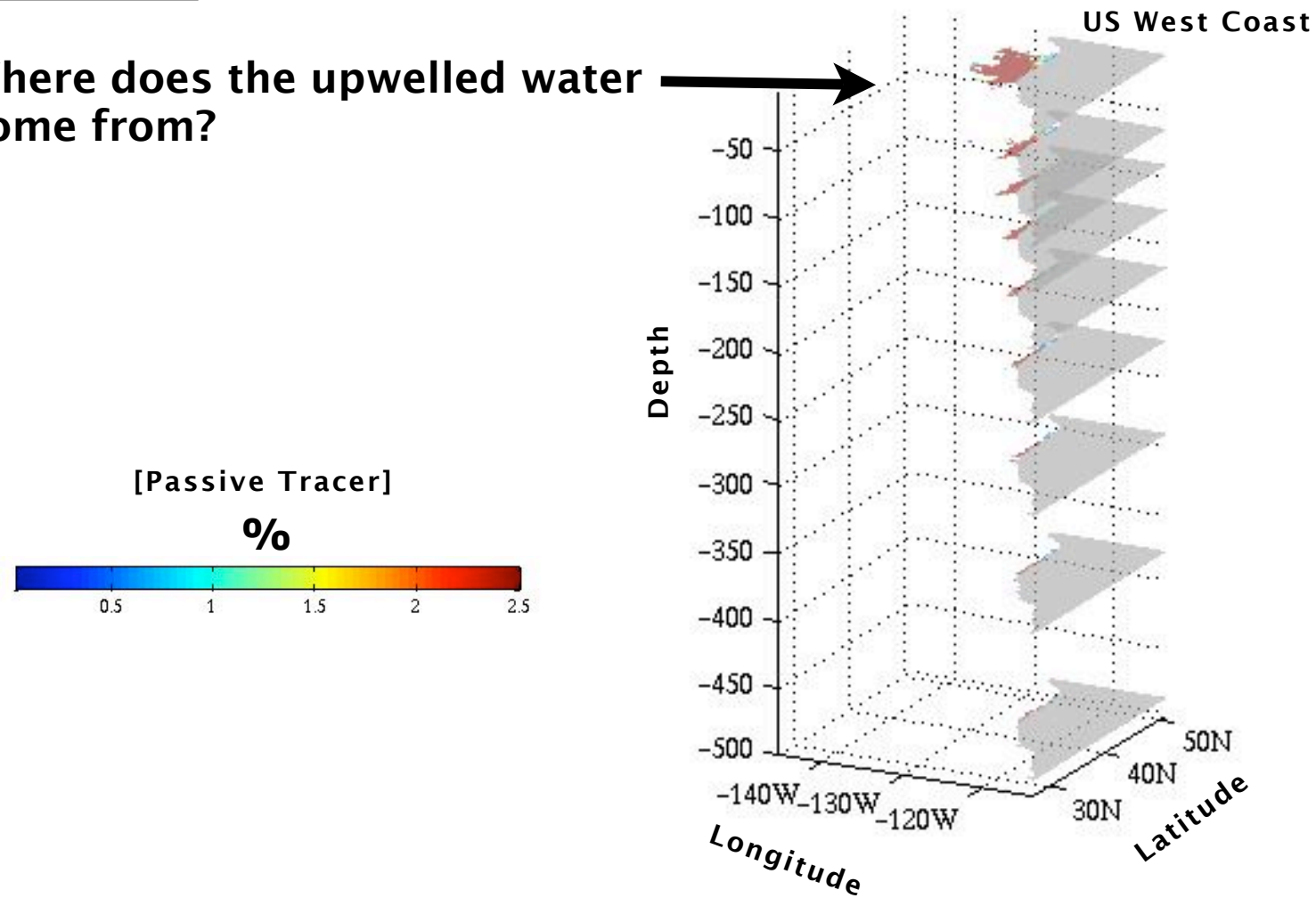
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3D view of Upwelling System

QUESTION:

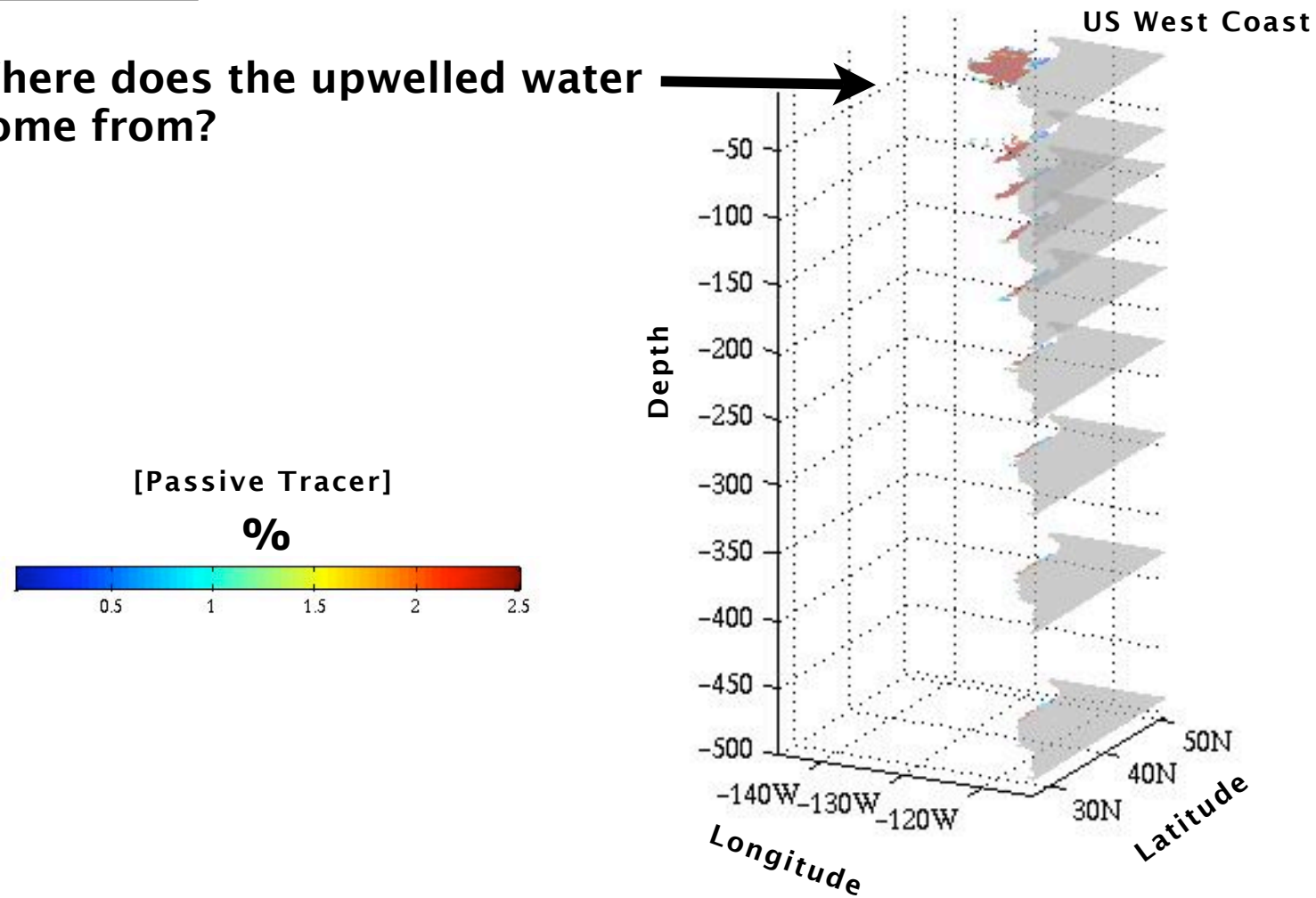
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

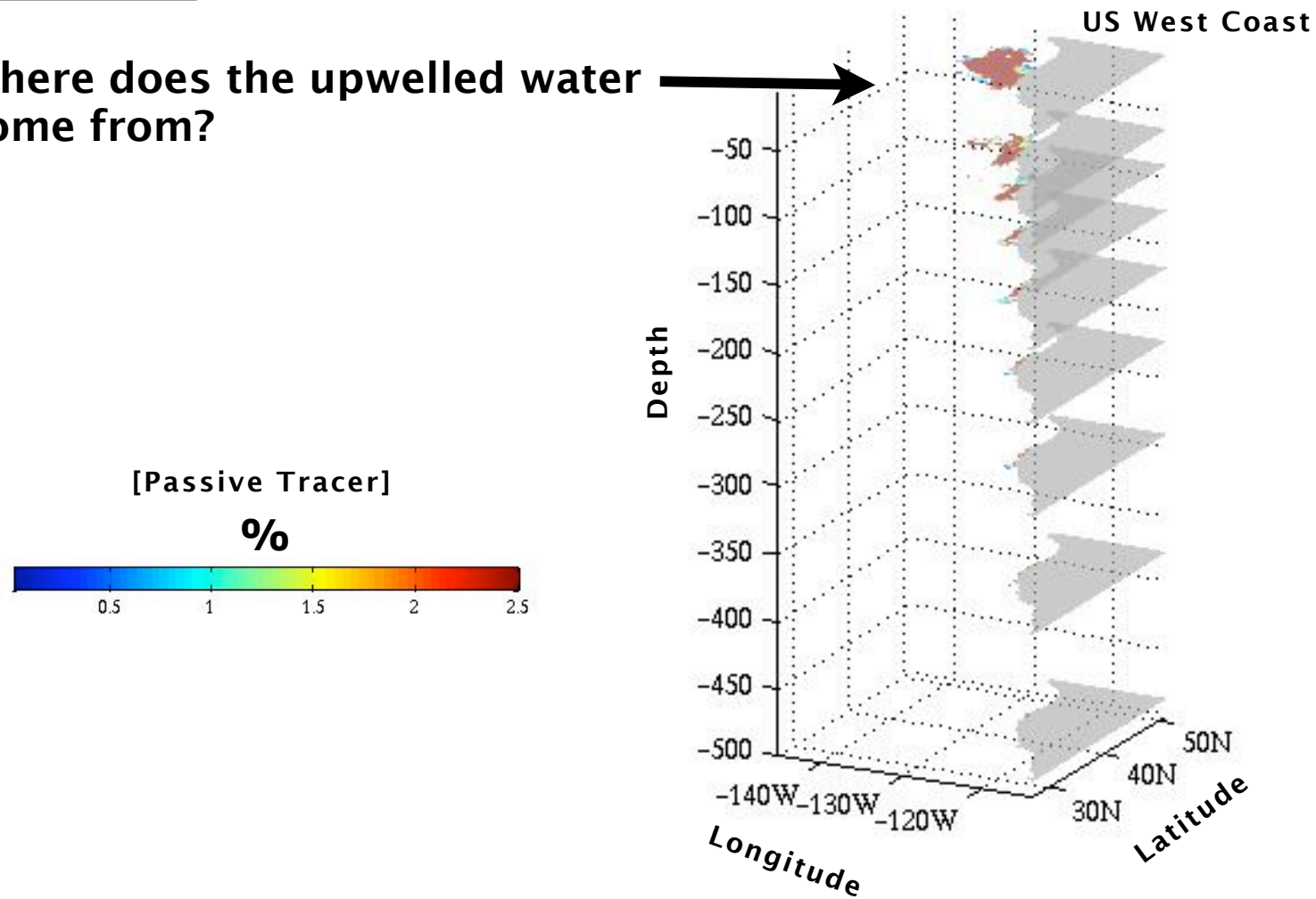
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3D view of Upwelling System

QUESTION:

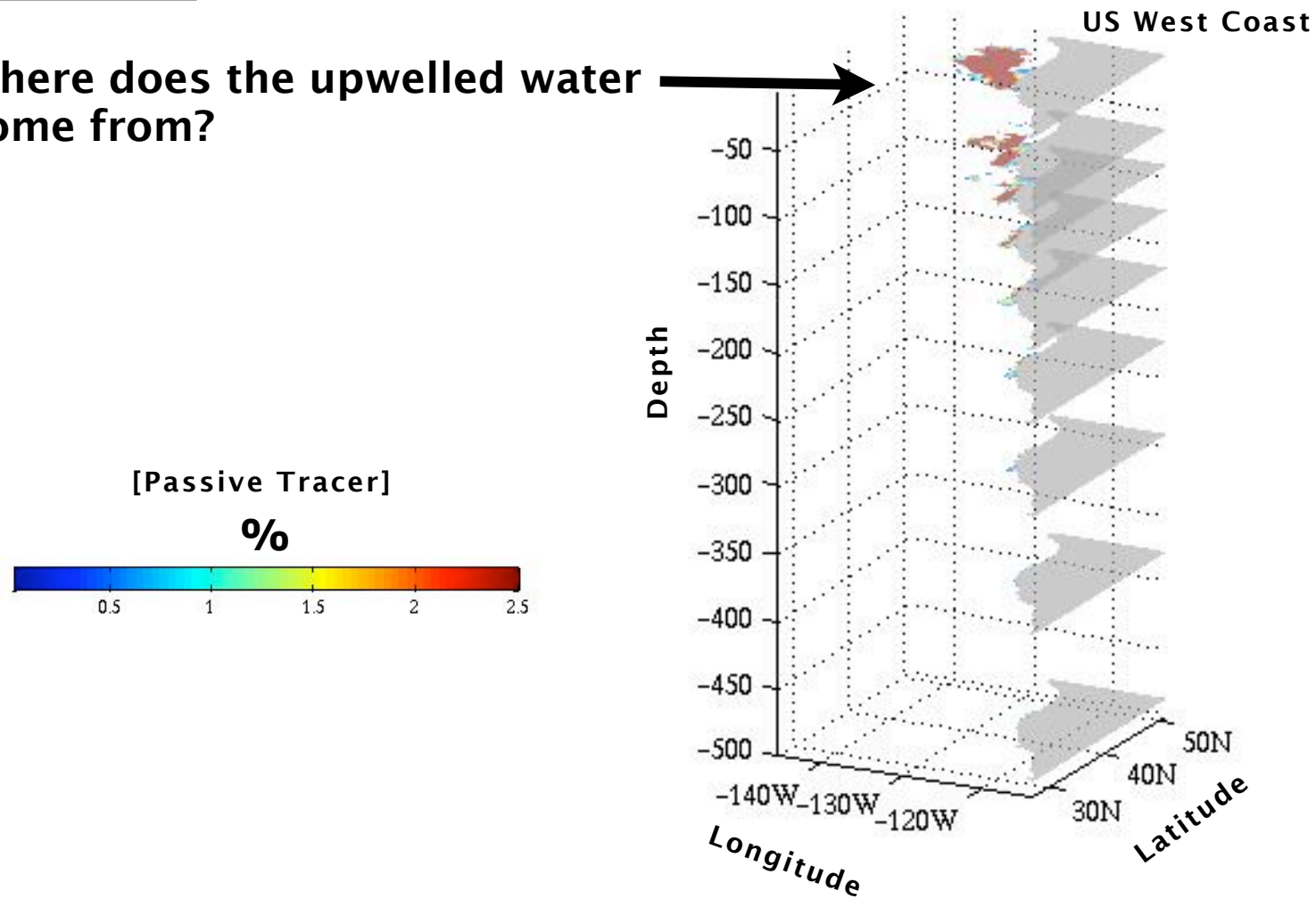
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3D view of Upwelling System

QUESTION:

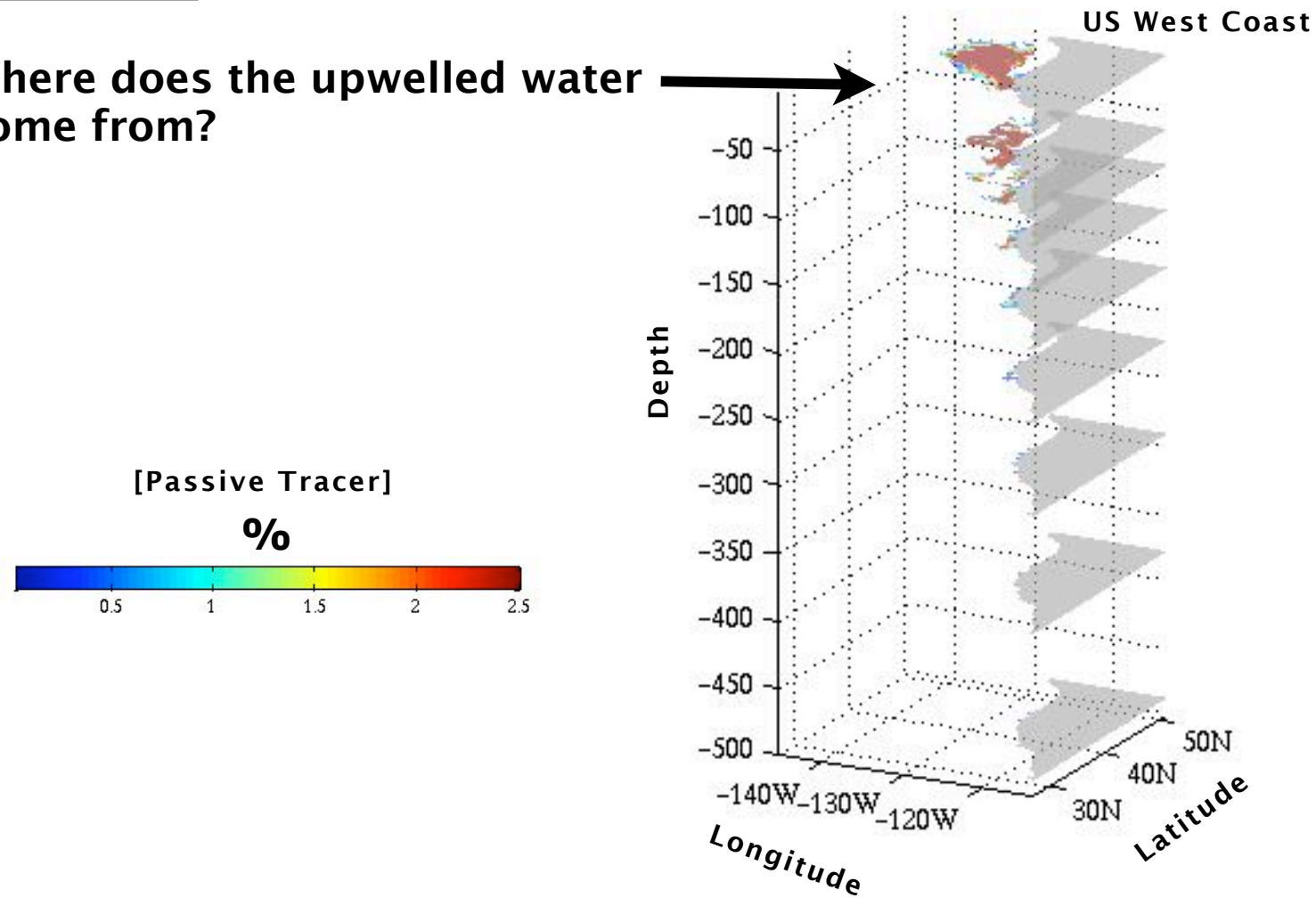
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

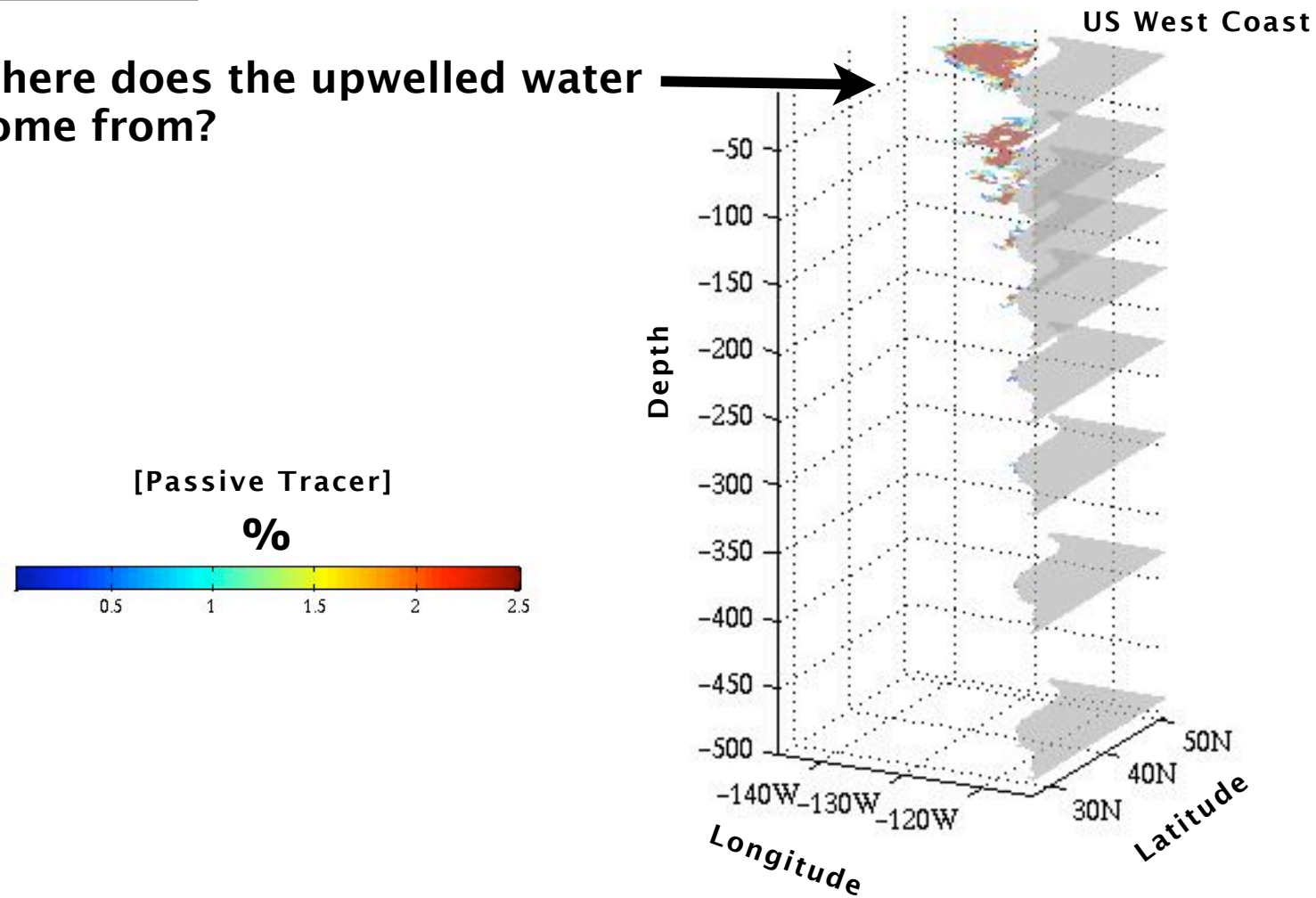
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

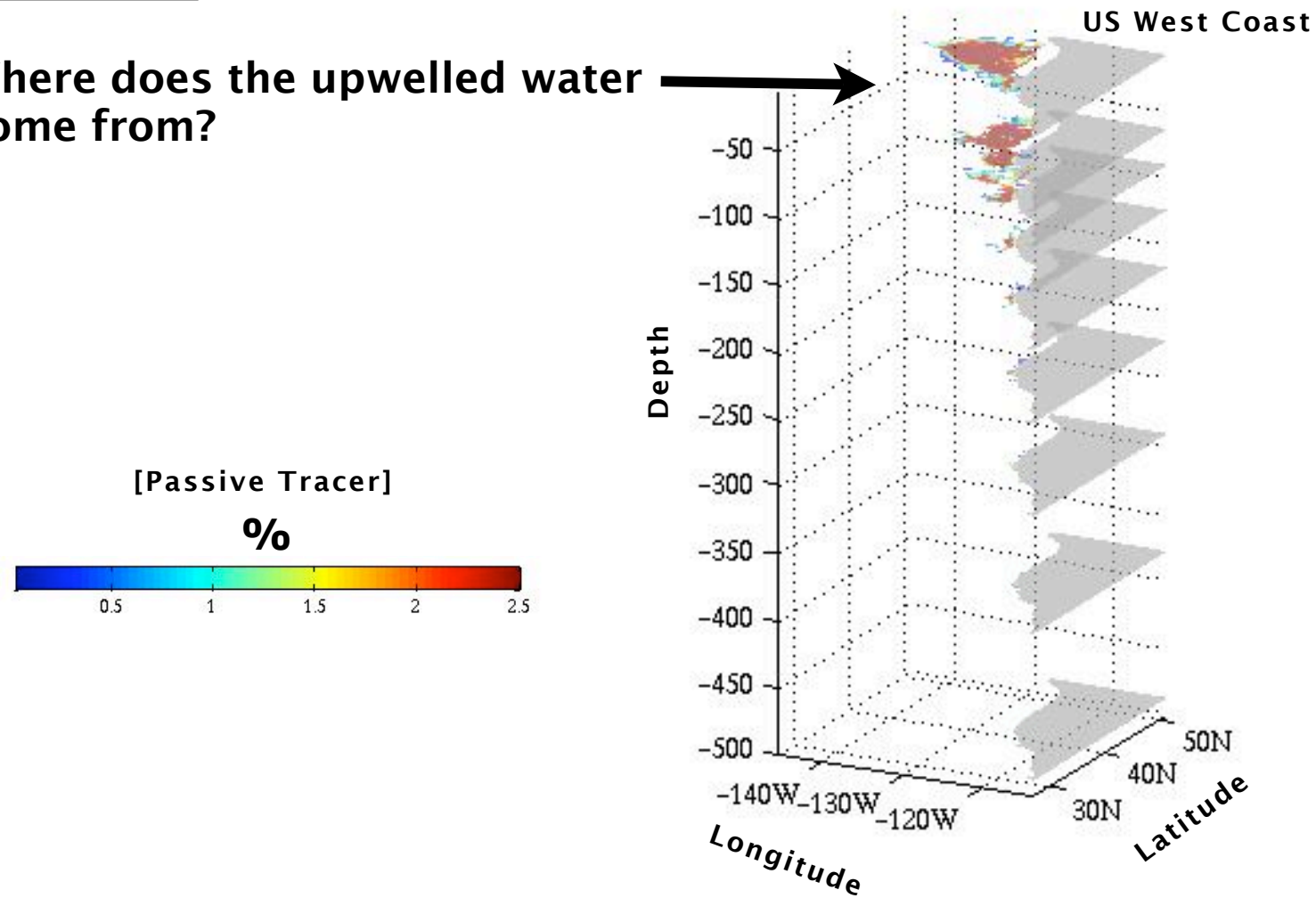
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

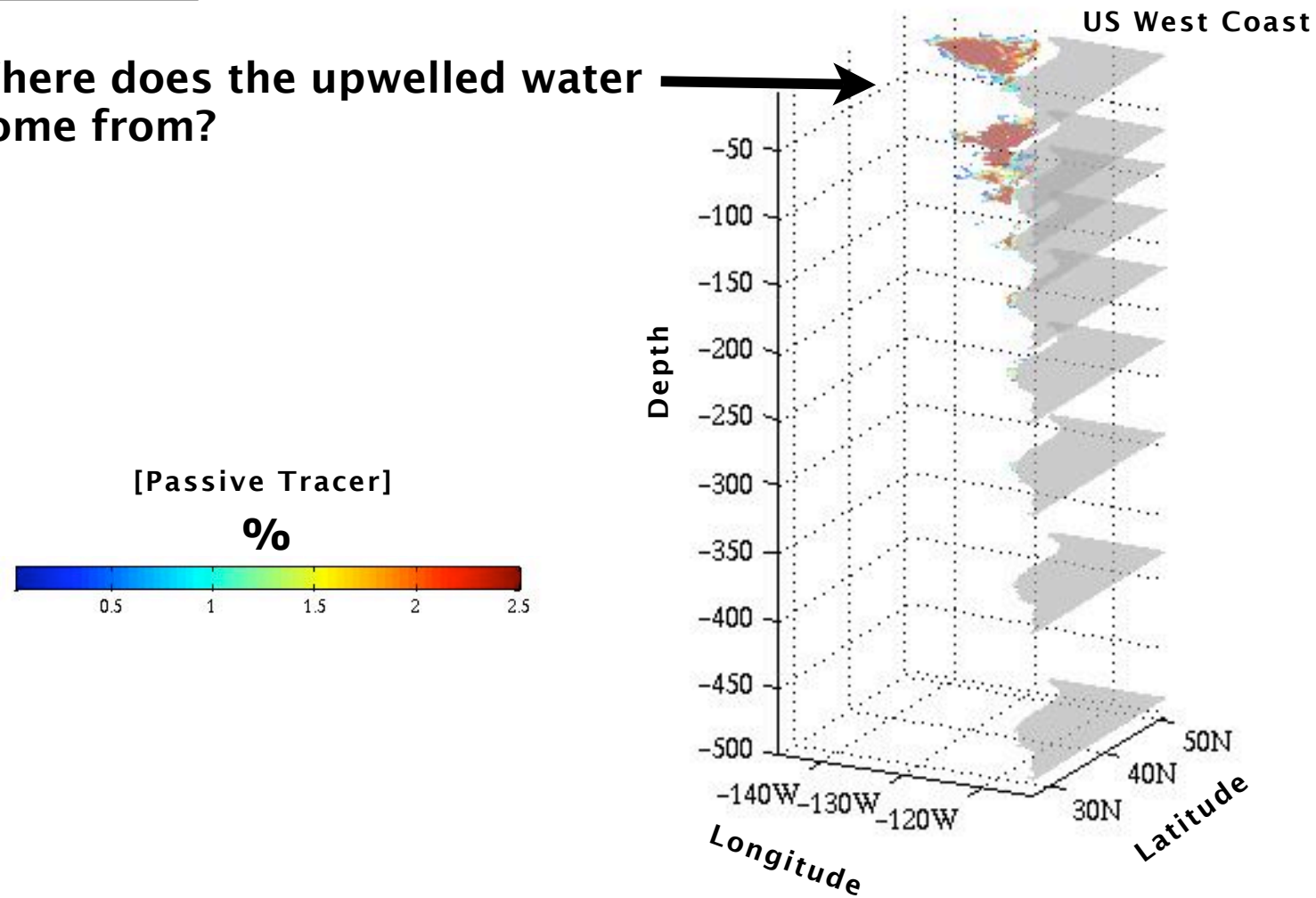
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3D view of Upwelling System

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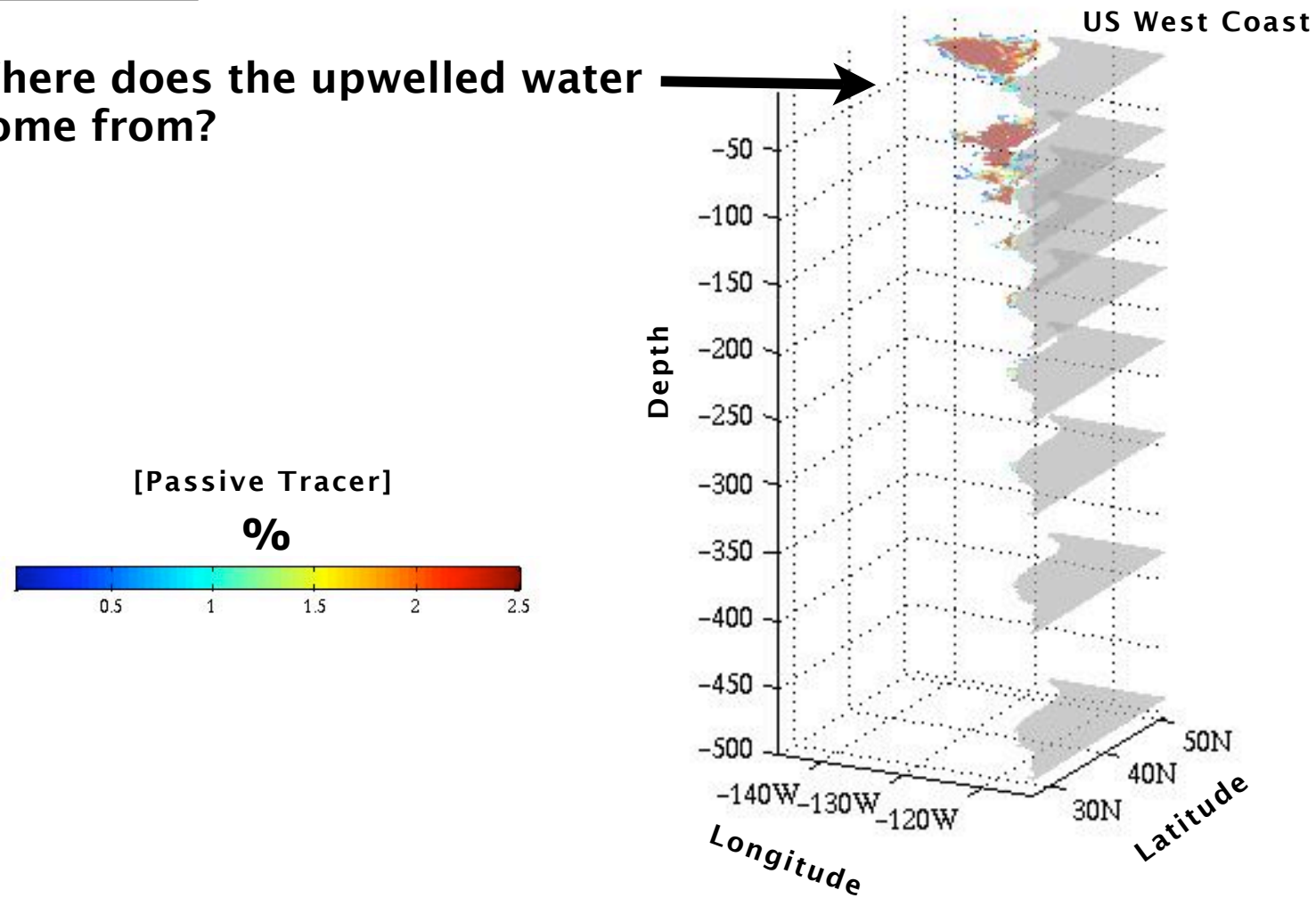
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3D view of Upwelling System

QUESTION:

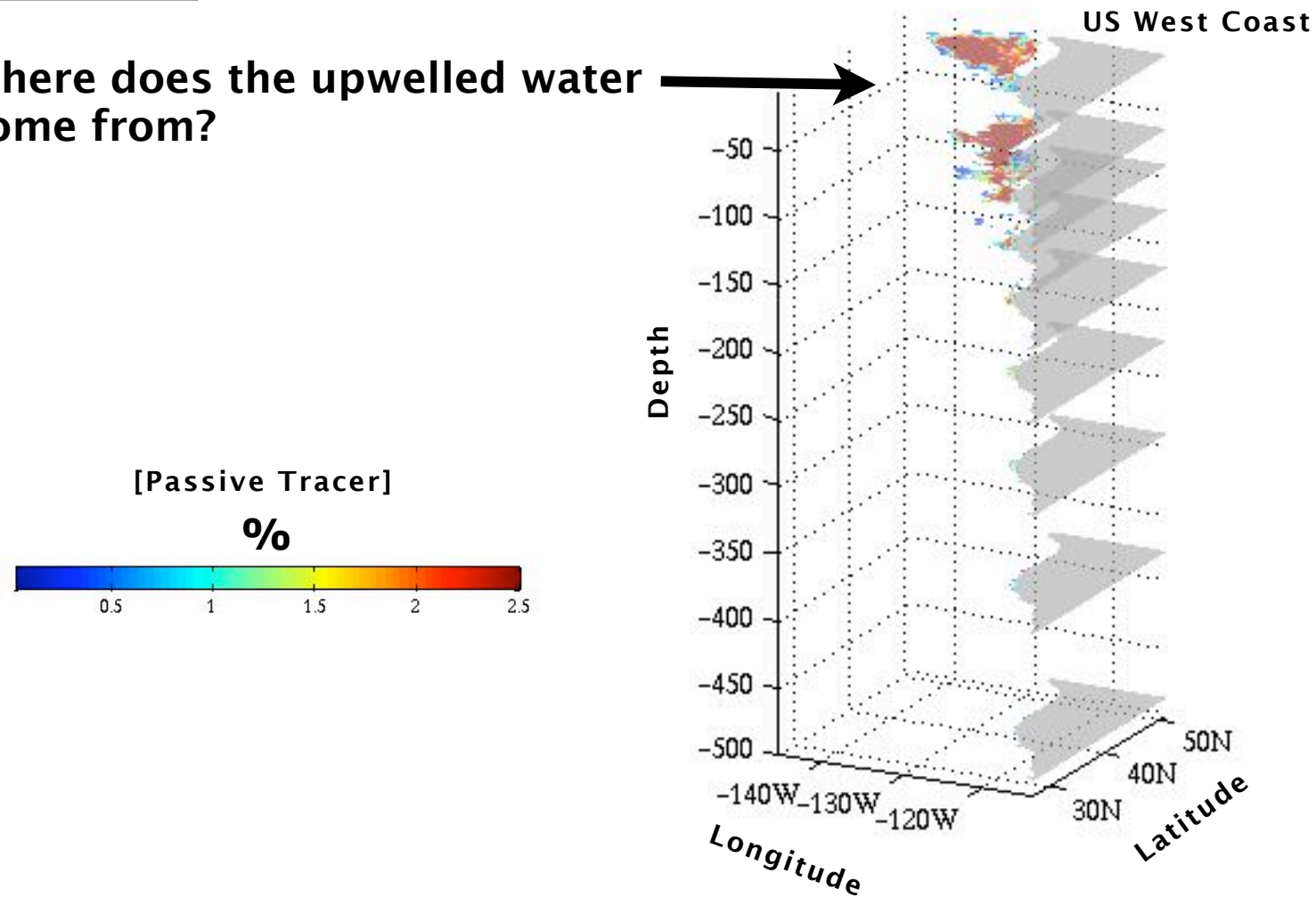
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

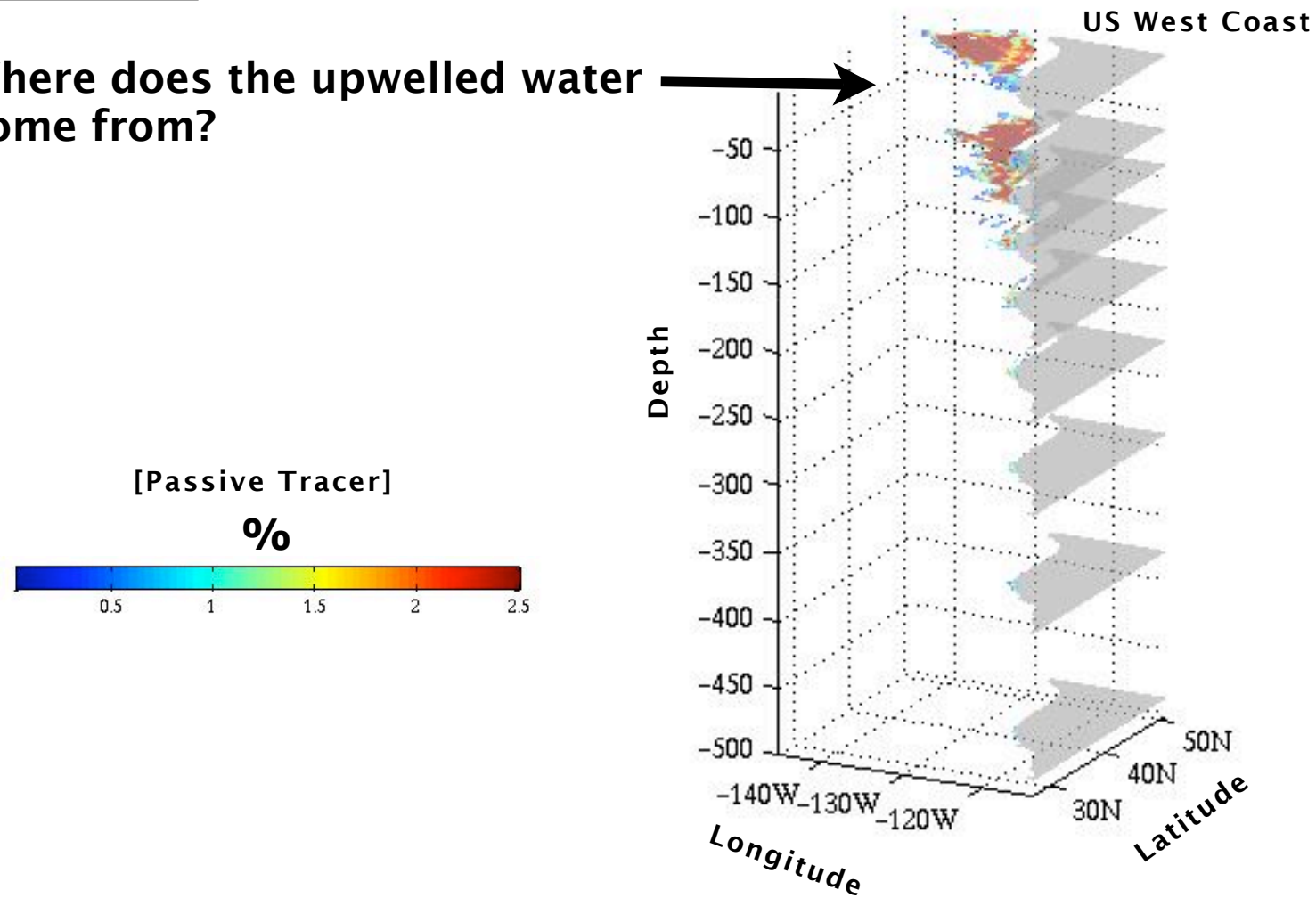
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3D view of Upwelling System

QUESTION:

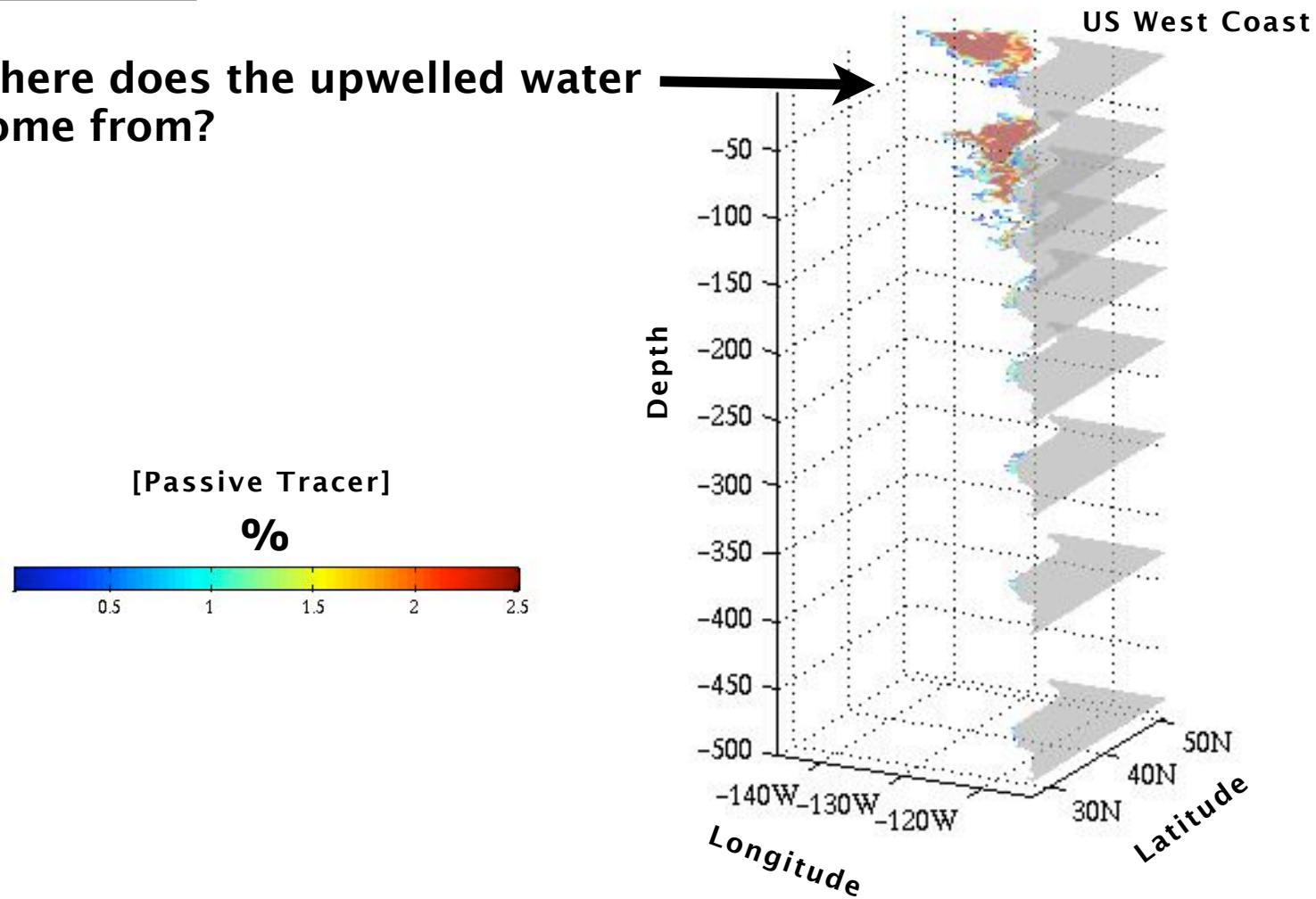
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

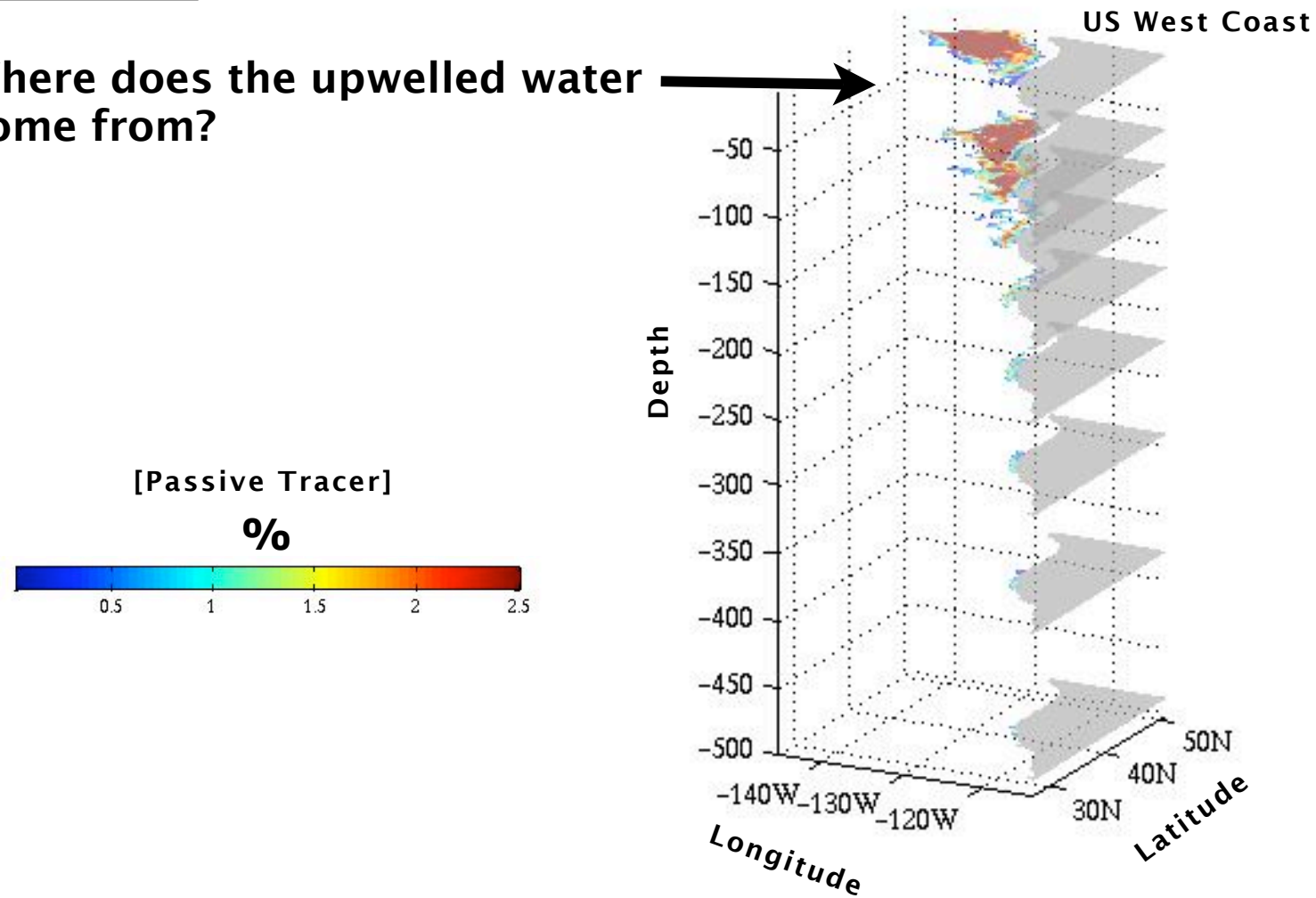
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

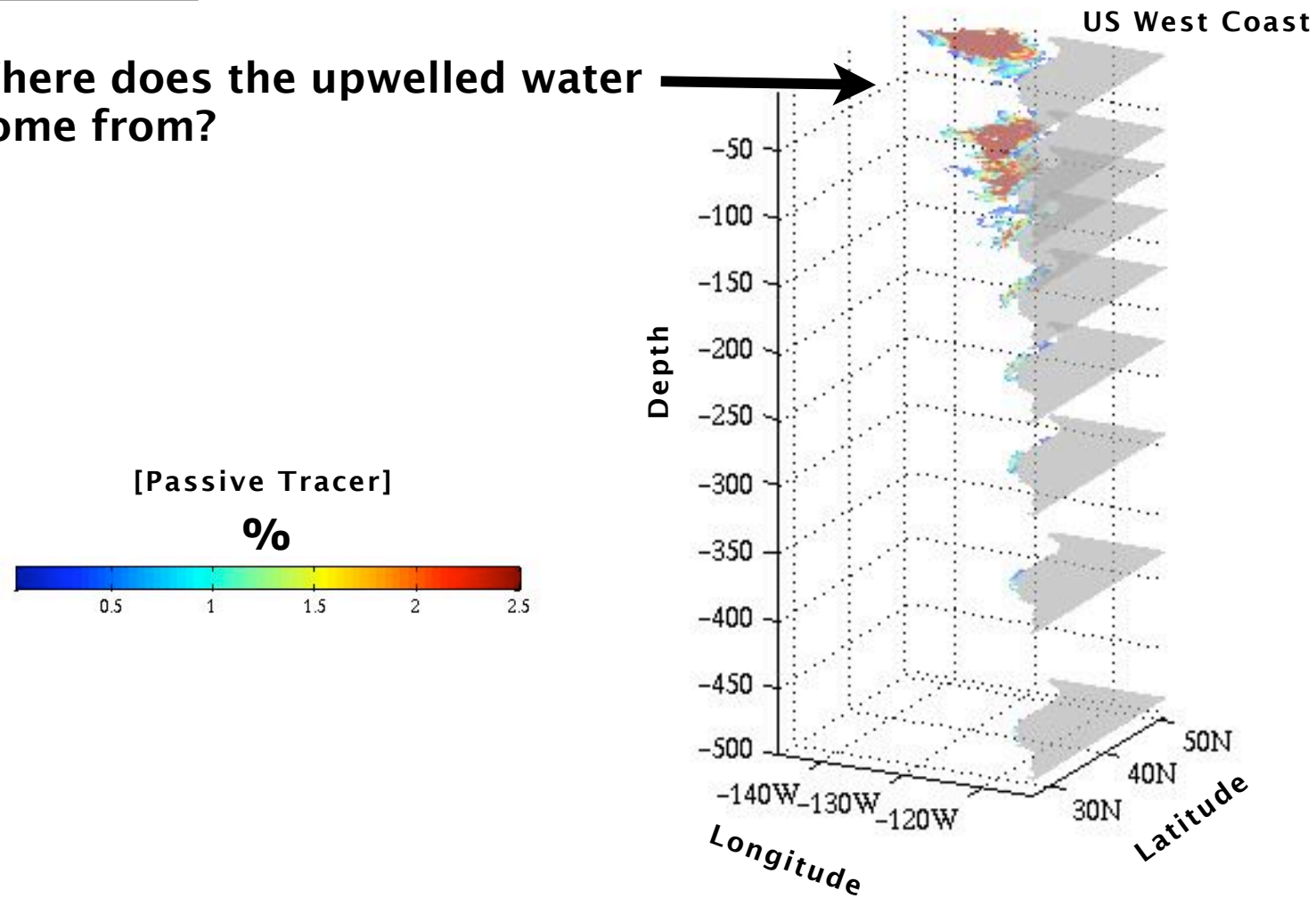
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

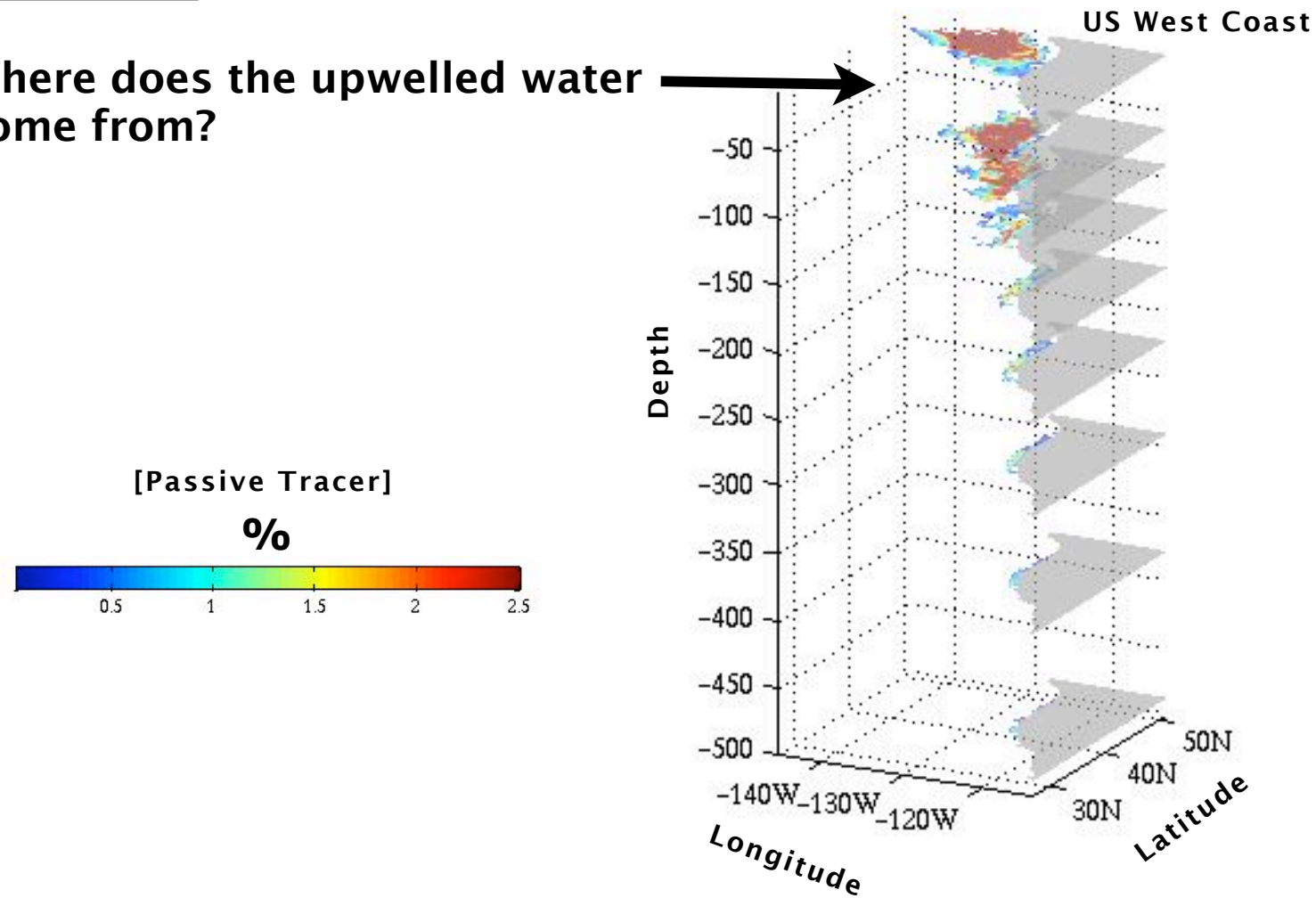
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

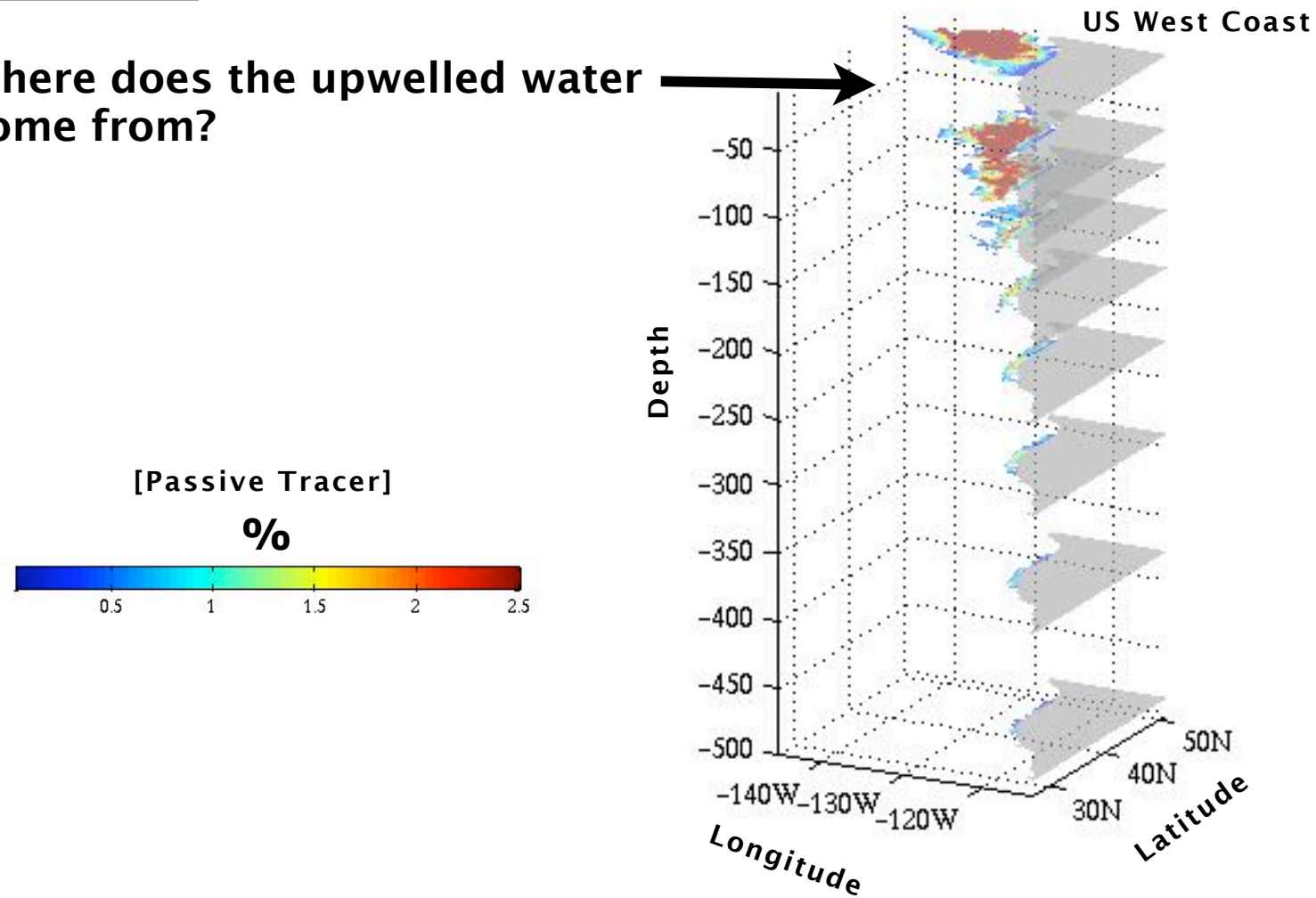
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3D view of Upwelling System

QUESTION:

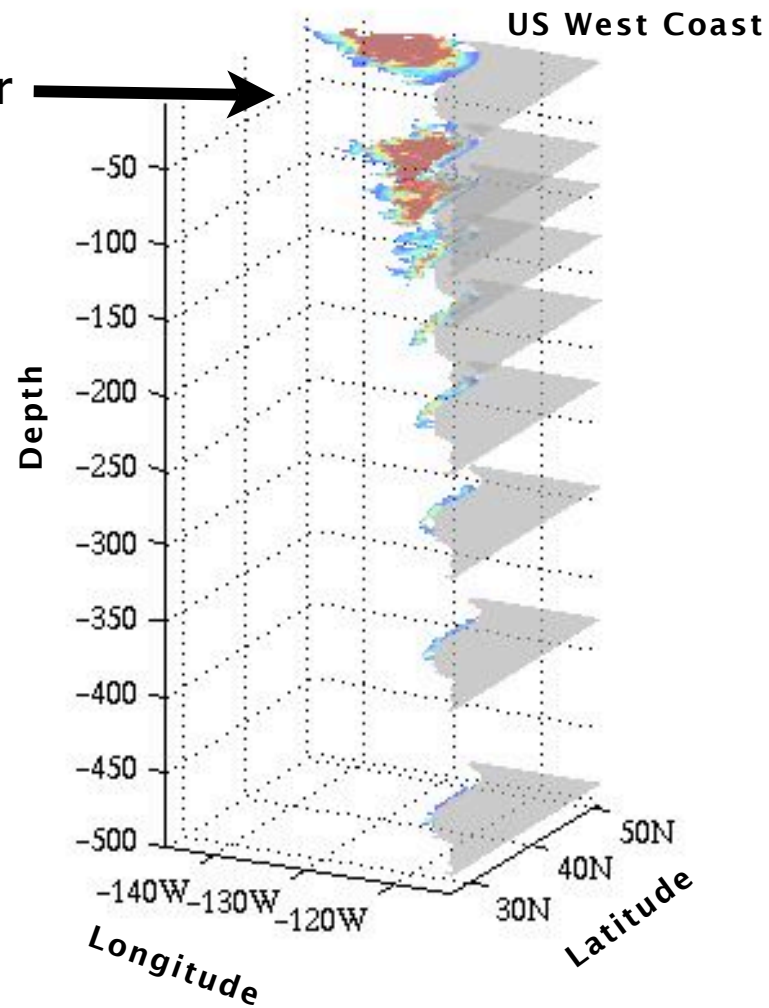
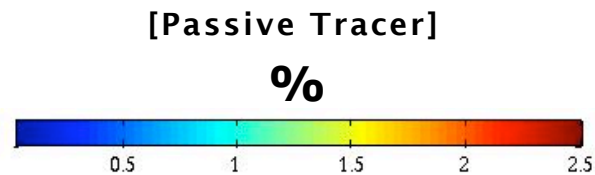
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

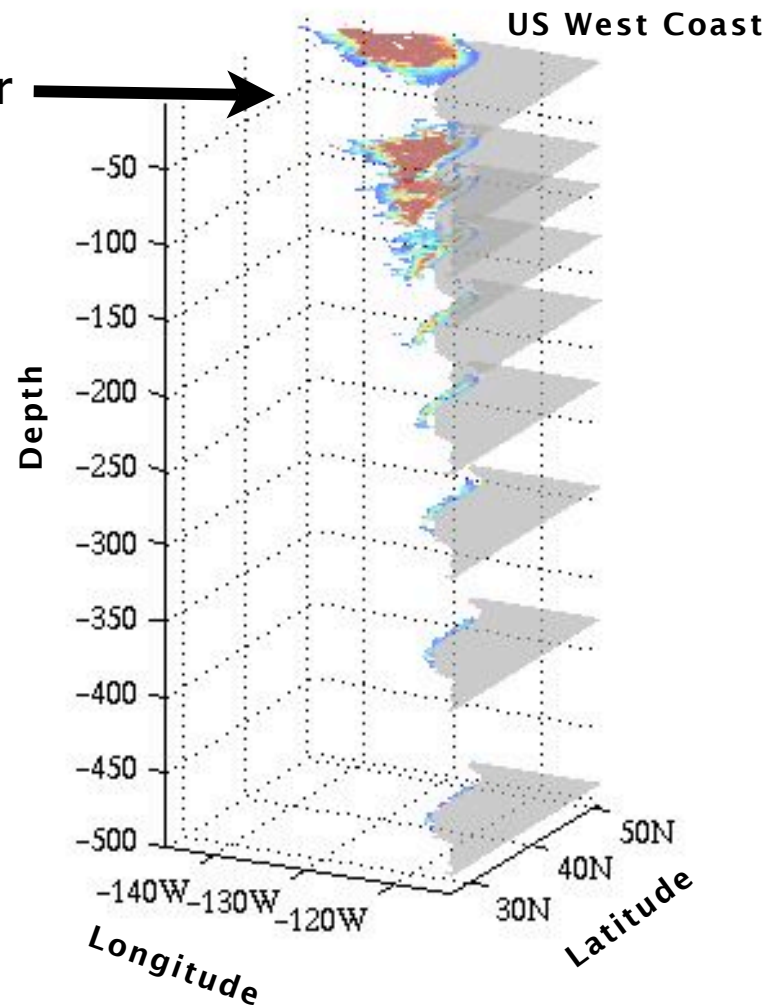
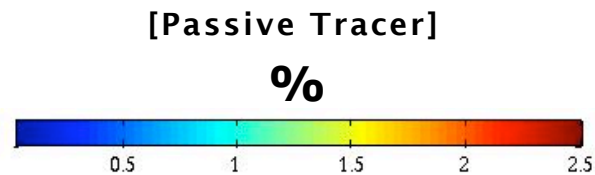
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3D view of Upwelling System

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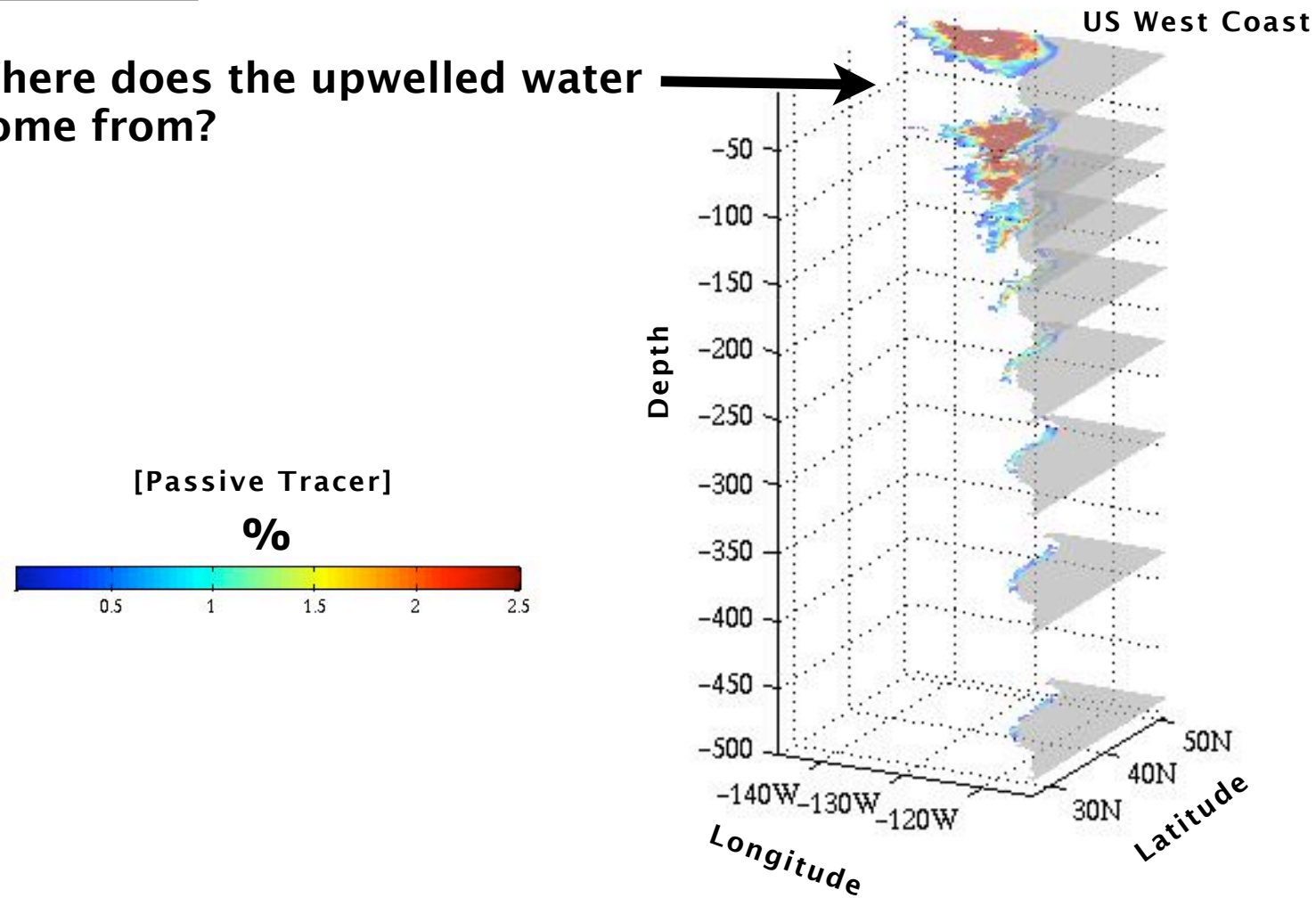
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

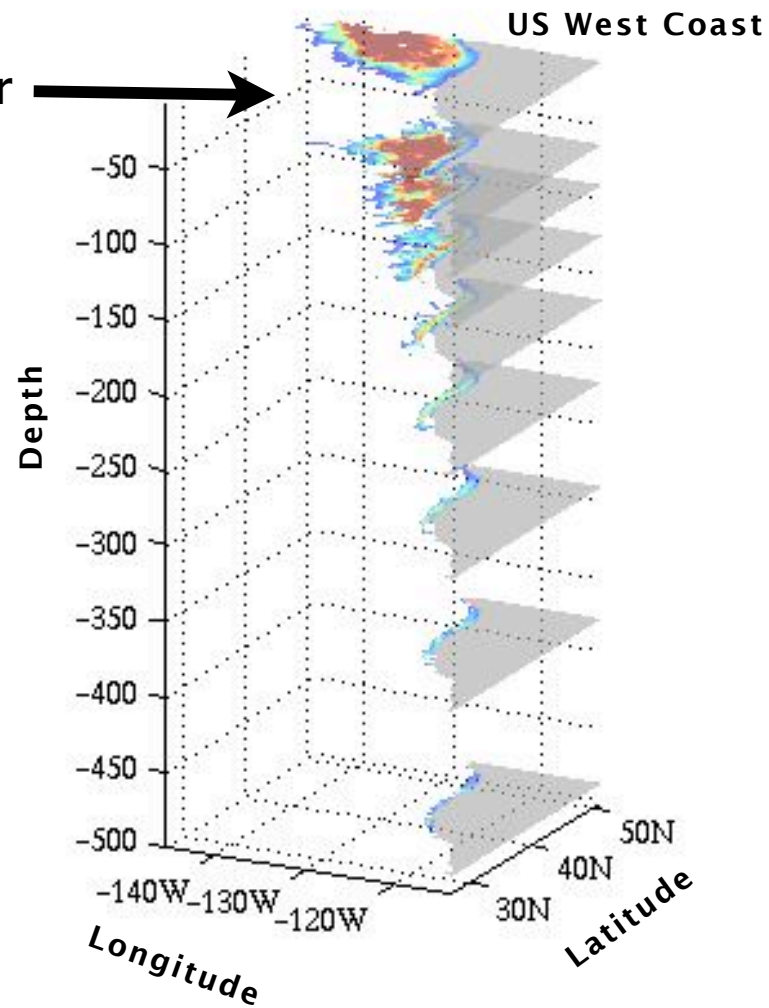
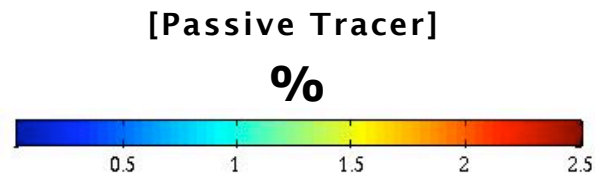
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3D view of Upwelling System

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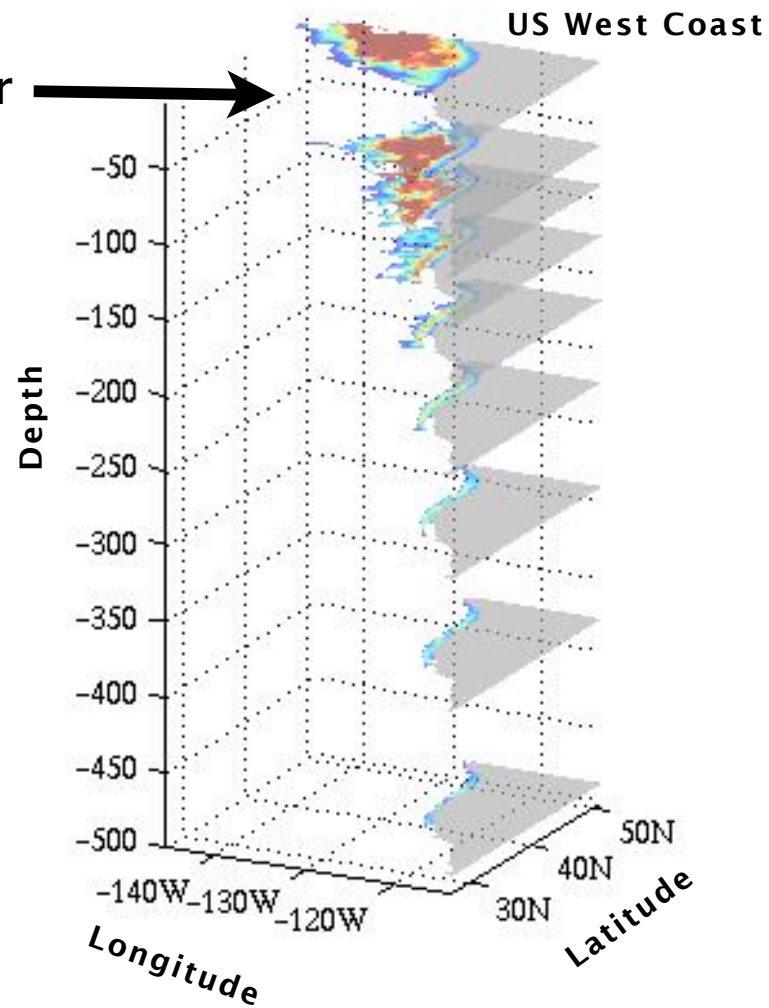
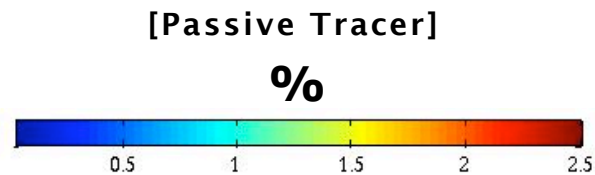
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3D view of Upwelling System

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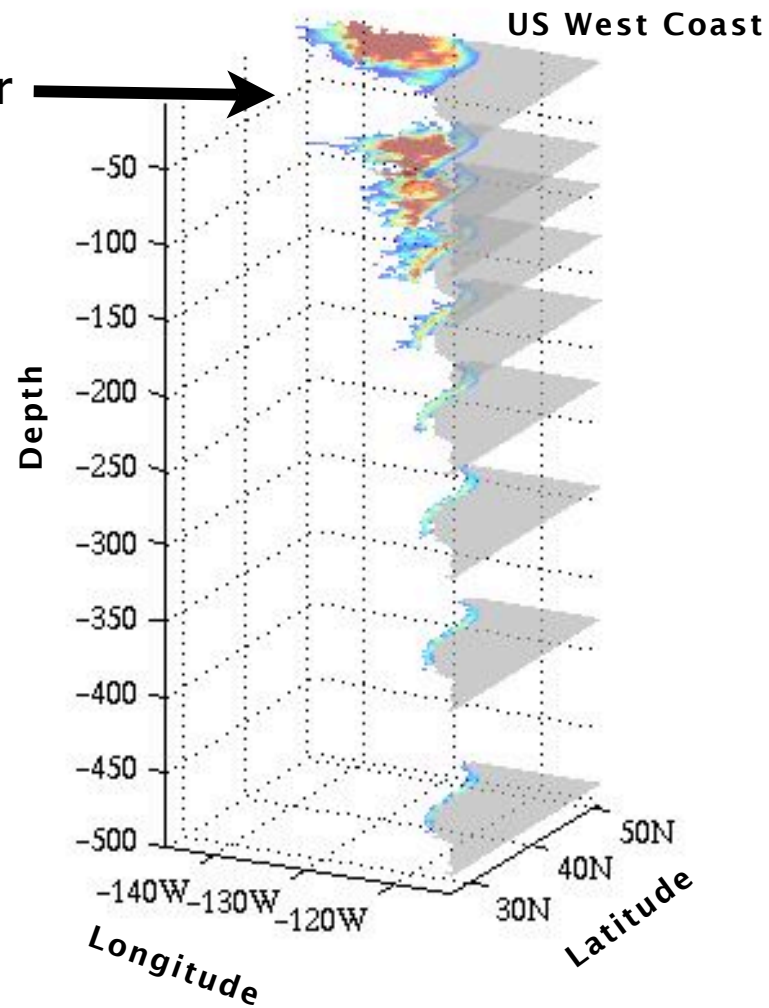
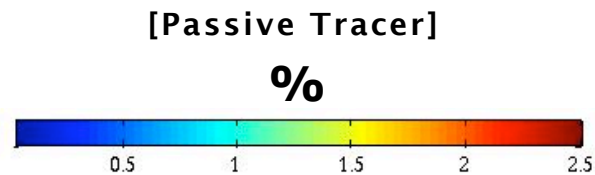
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

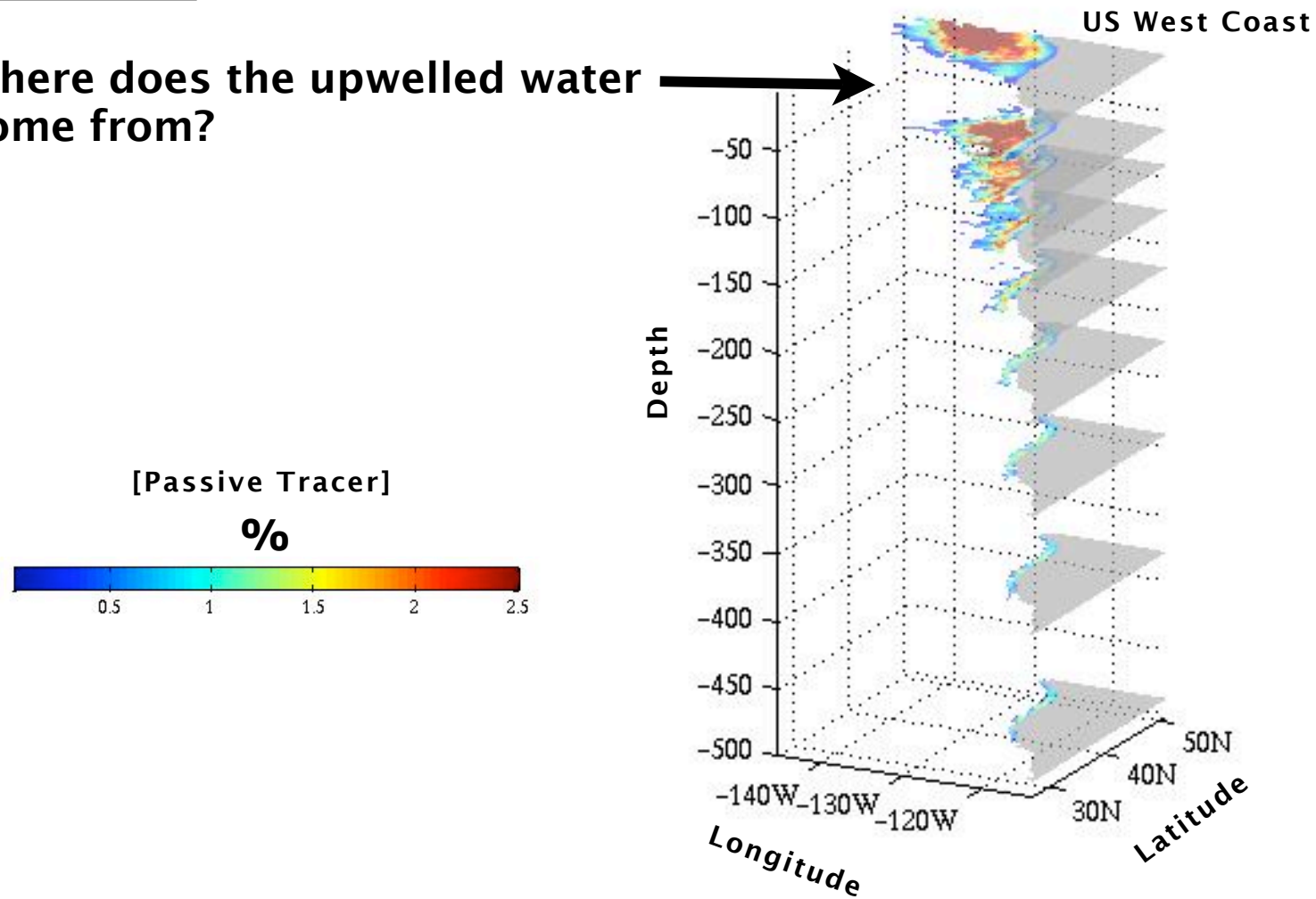
Where does the upwelled water come from?



3D view of Upwelling System

QUESTION:

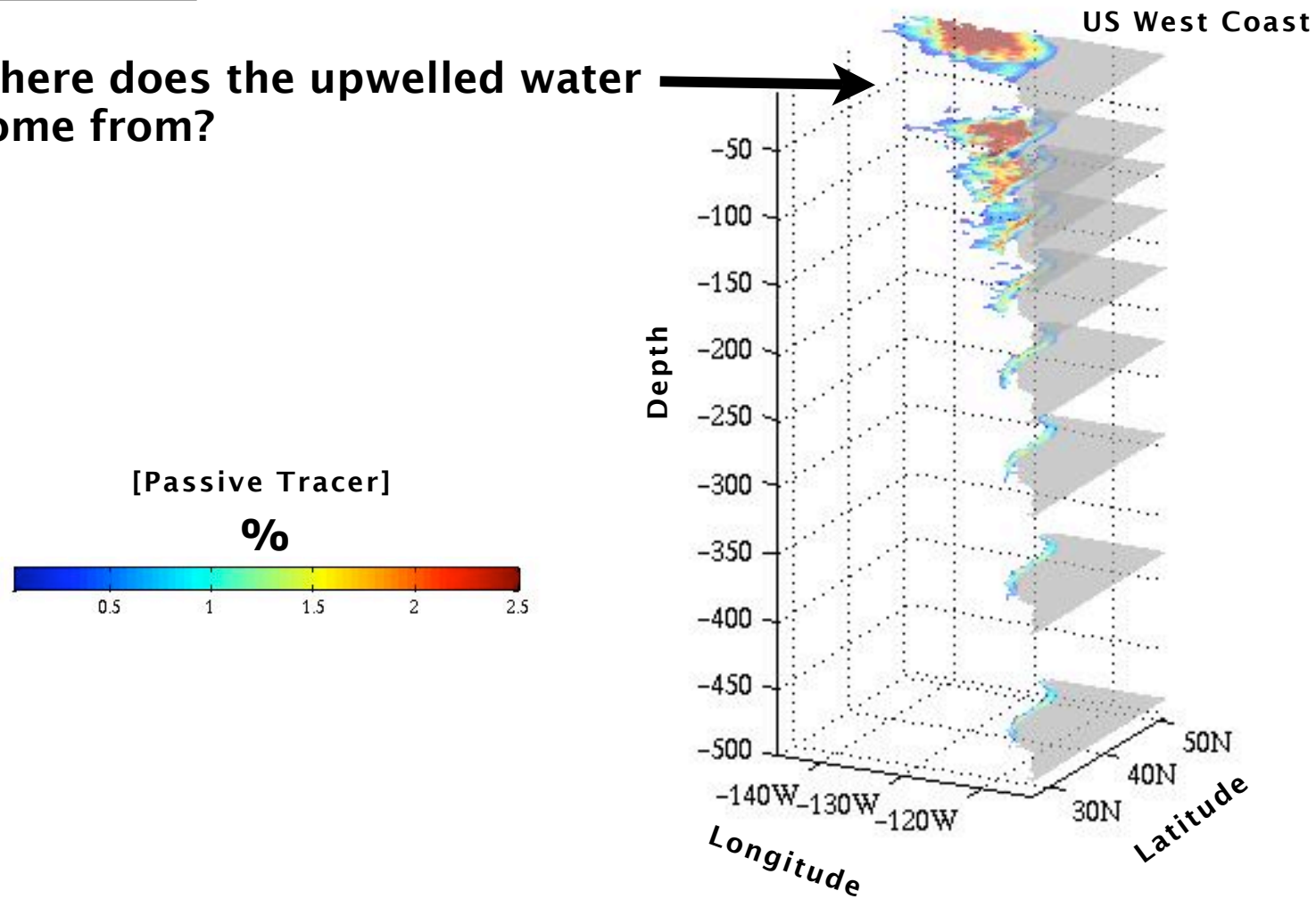
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3D view of Upwelling System

QUESTION:

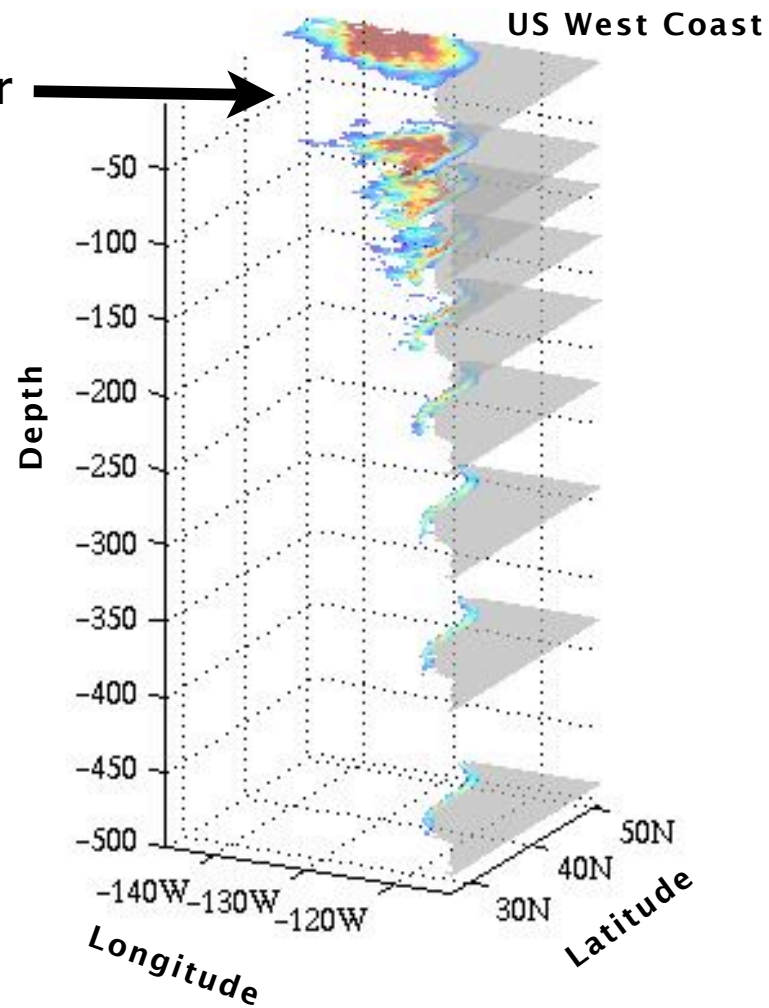
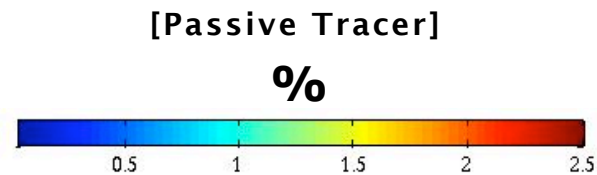
Where does the upwelled water come from?



3D view of Upwelling System

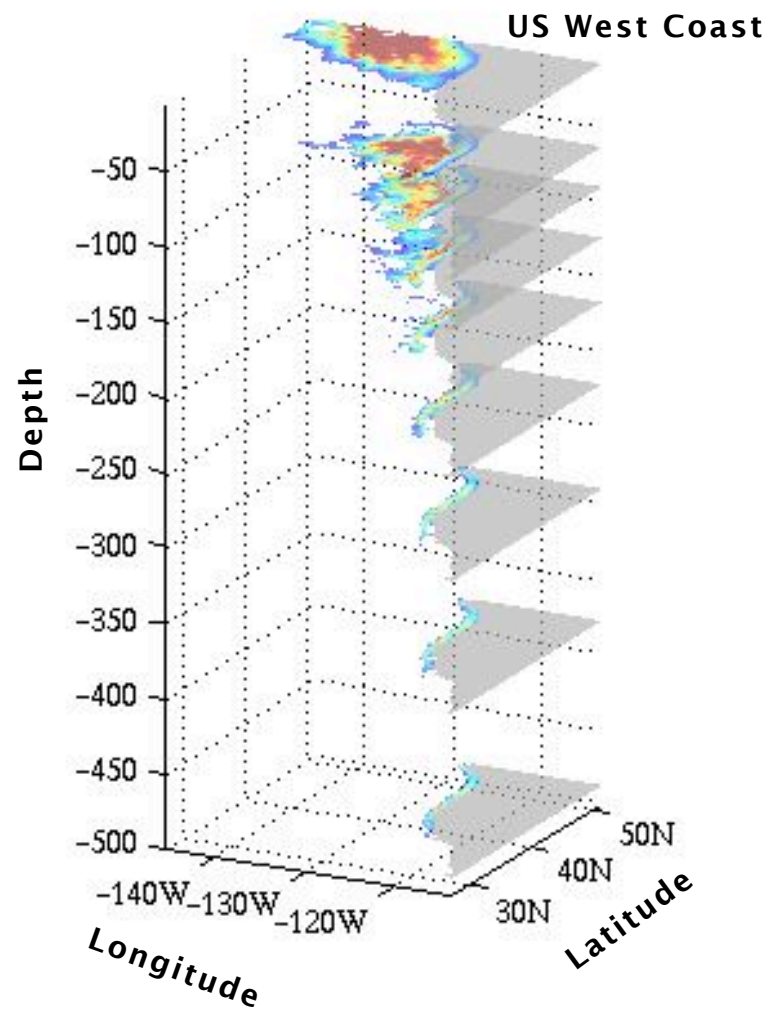
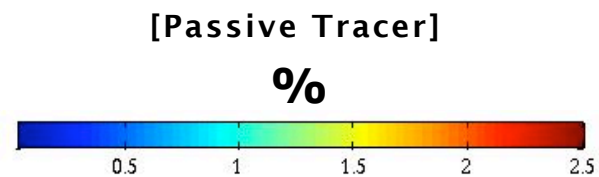
QUESTION:

Where does the upwelled water come from?



end of movie

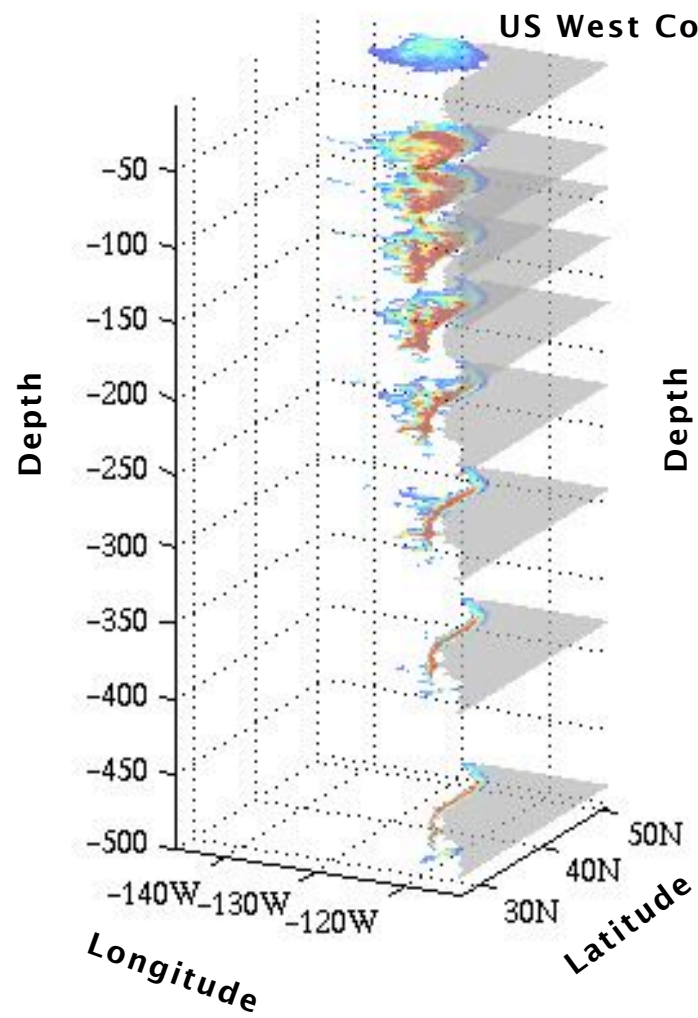
shallow upwelling cell



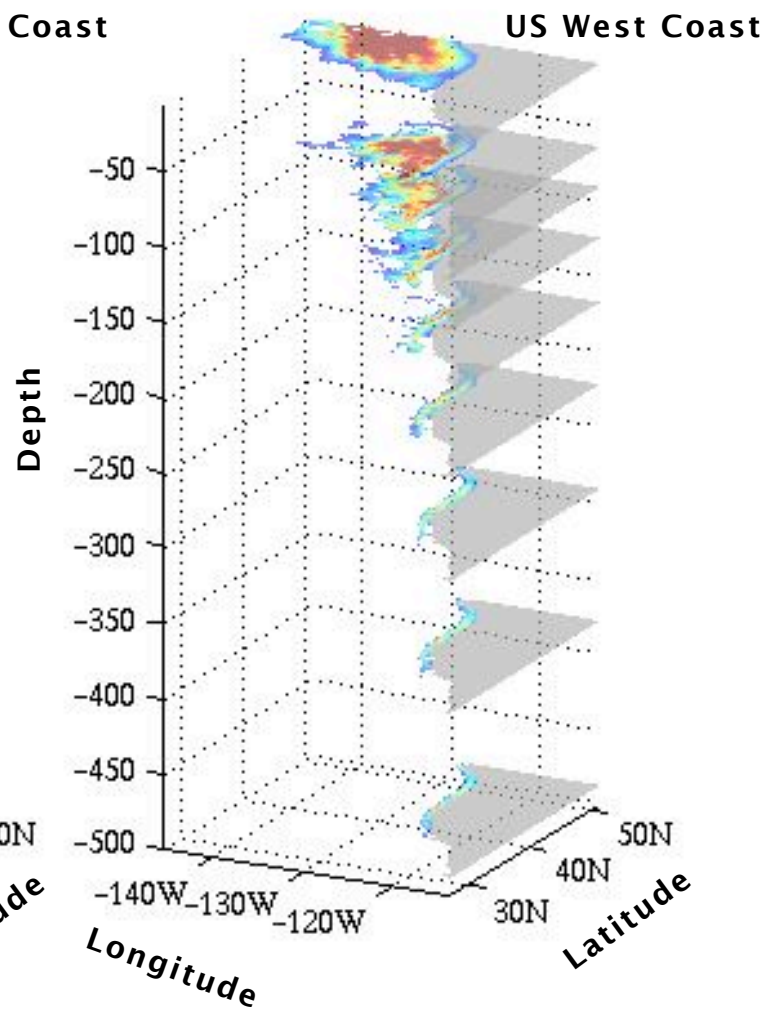
Decadal variations in the
California Current upwelling cells.

Chhak and Di Lorenzo, 2007

deep upwelling cell

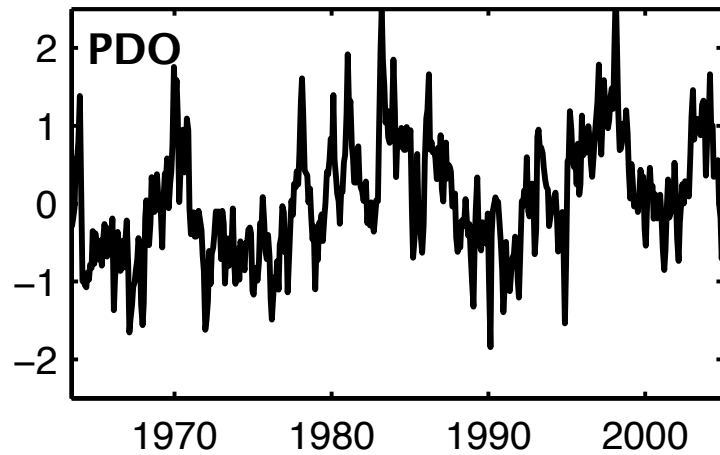


shallow upwelling cell

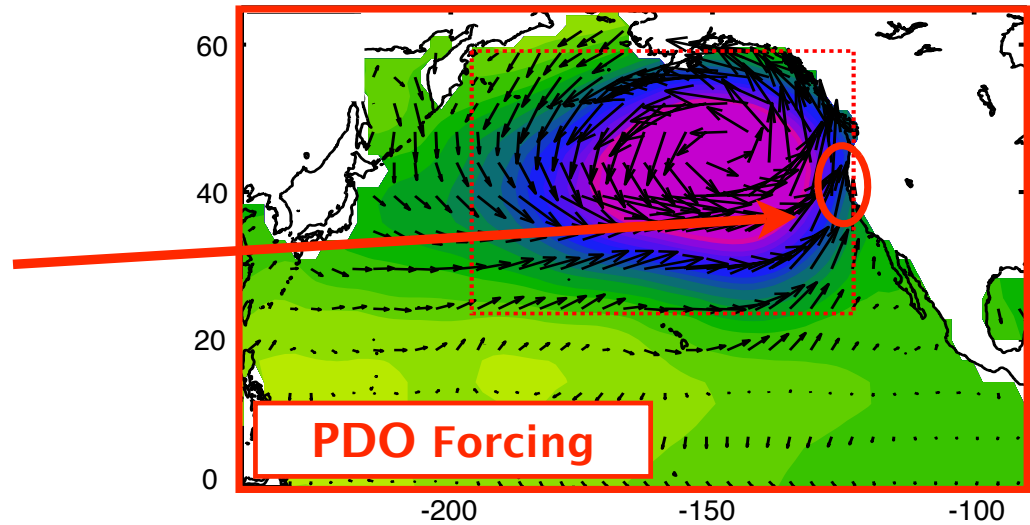


Chhak and Di Lorenzo, 2007

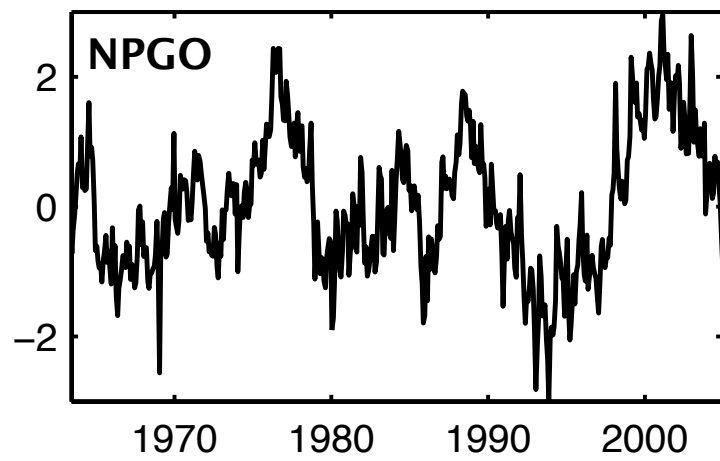
**Coastal Upwelling
depth index (38N-48N)**



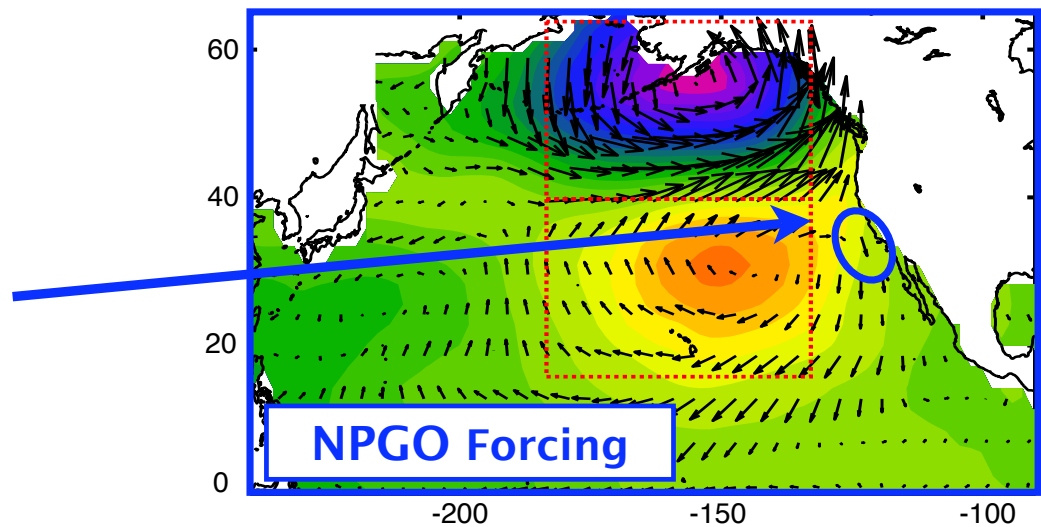
Aleutian Low (EOF1 SLPa)



**Coastal Upwelling
depth index (30N-38N)**

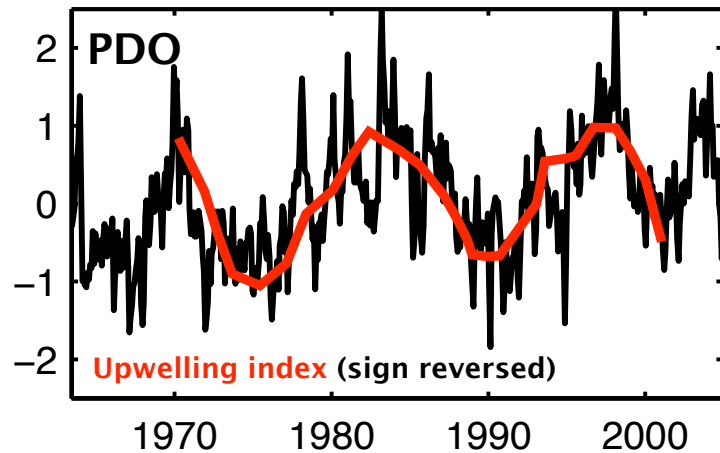


North Pacific Oscillation (EOF2 SLPa)



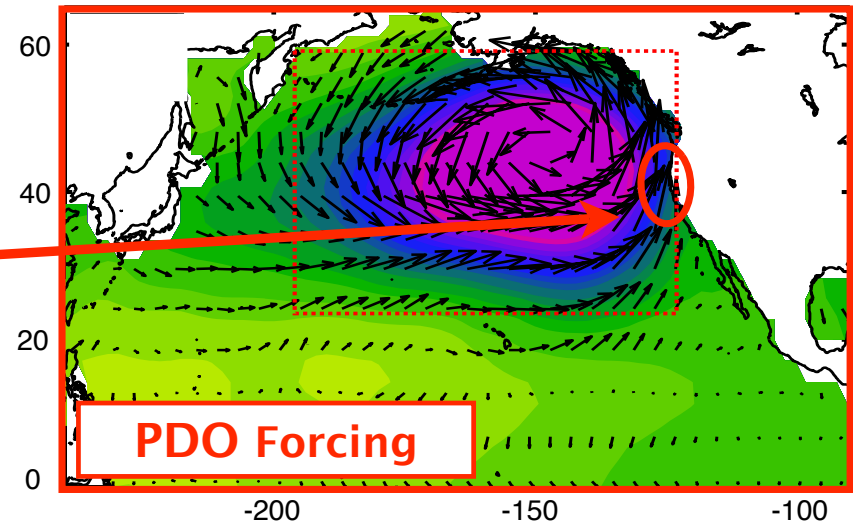
Walker and Bliss, 1932

Coastal Upwelling depth index (38N-48N)

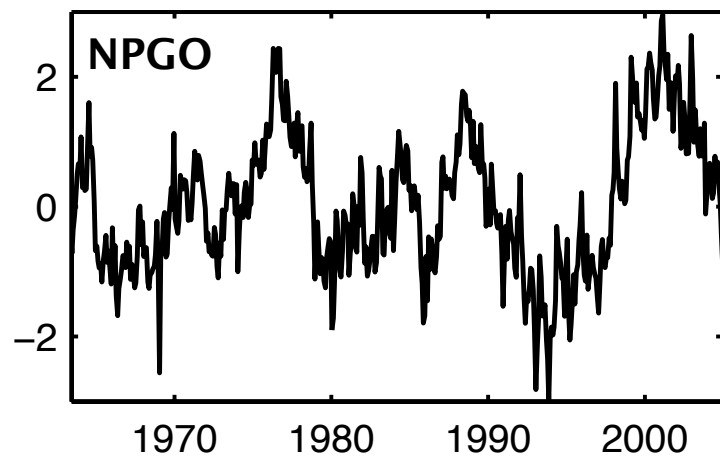


Chhak and Di Lorenzo, 2007

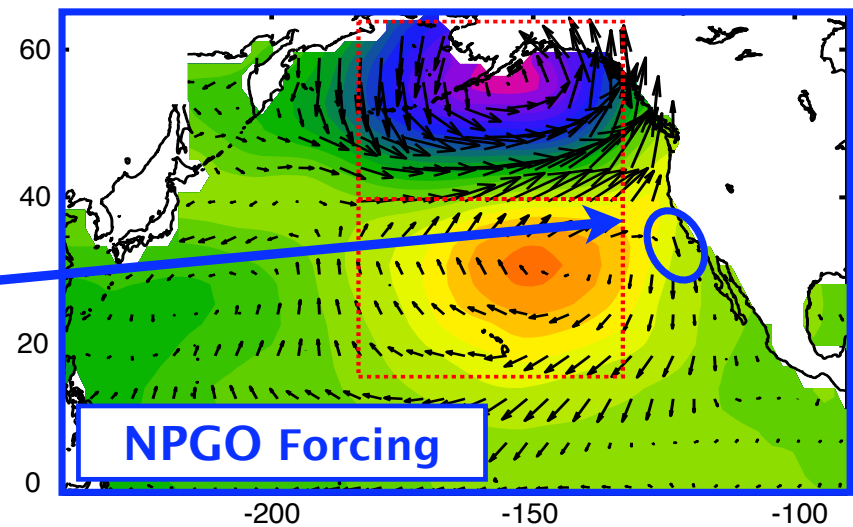
Aleutian Low (EOF1 SLPa)



Coastal Upwelling depth index (30N-38N)

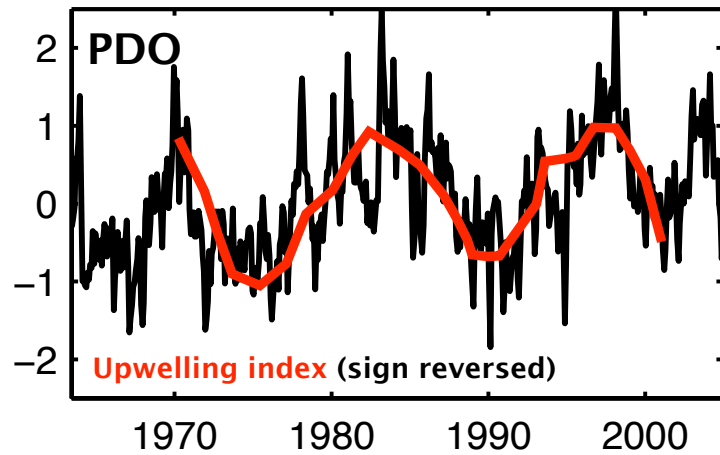


North Pacific Oscillation (EOF2 SLPa)



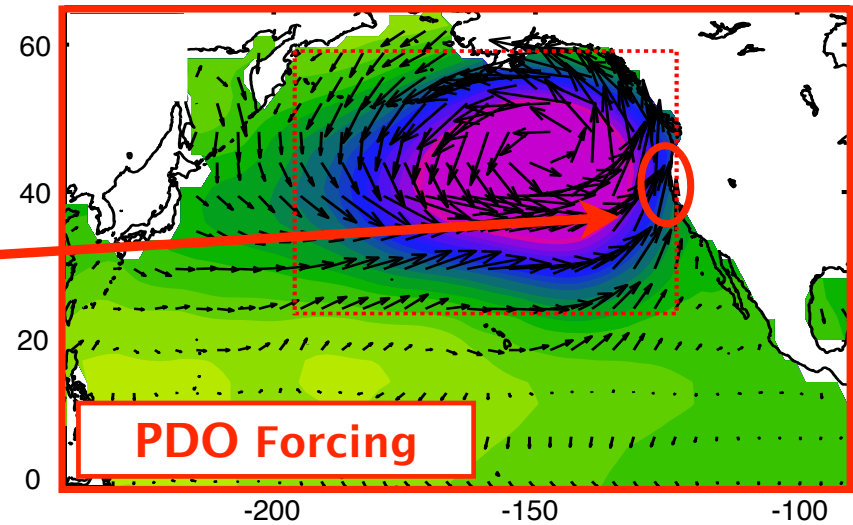
Walker and Bliss, 1932

Coastal Upwelling depth index (38N-48N)

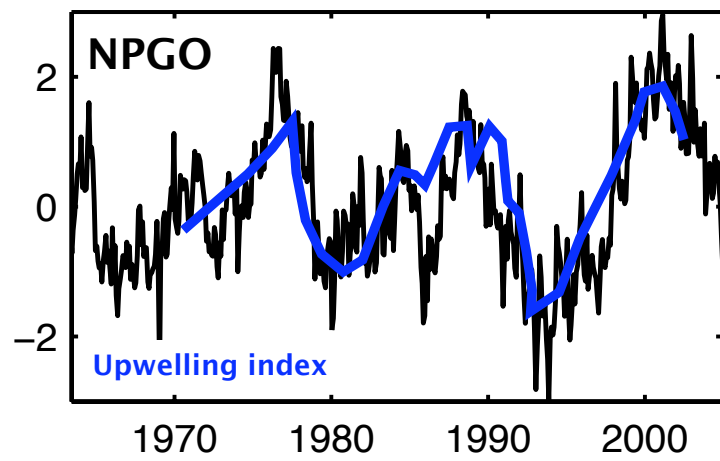


Chhak and Di Lorenzo, 2007

Aleutian Low (EOF1 SLPa)

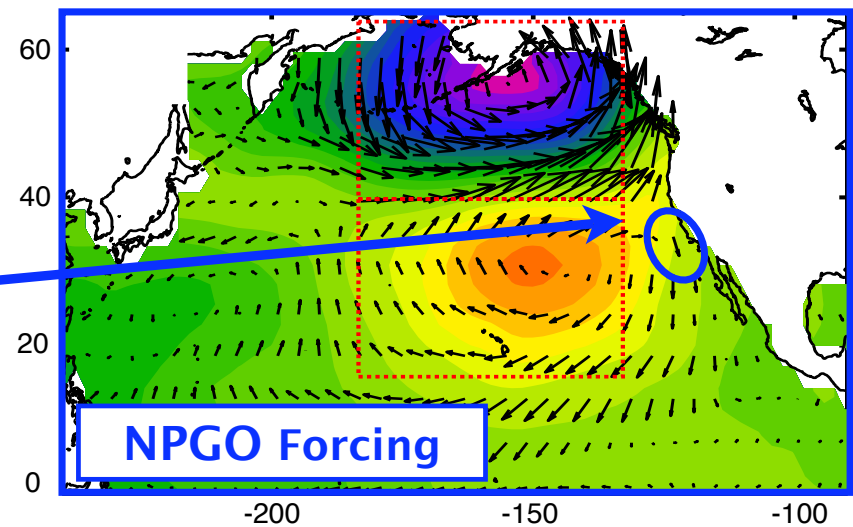


Coastal Upwelling depth index (30N-38N)



Di Lorenzo et al., 2008

North Pacific Oscillation (EOF2 SLPa)

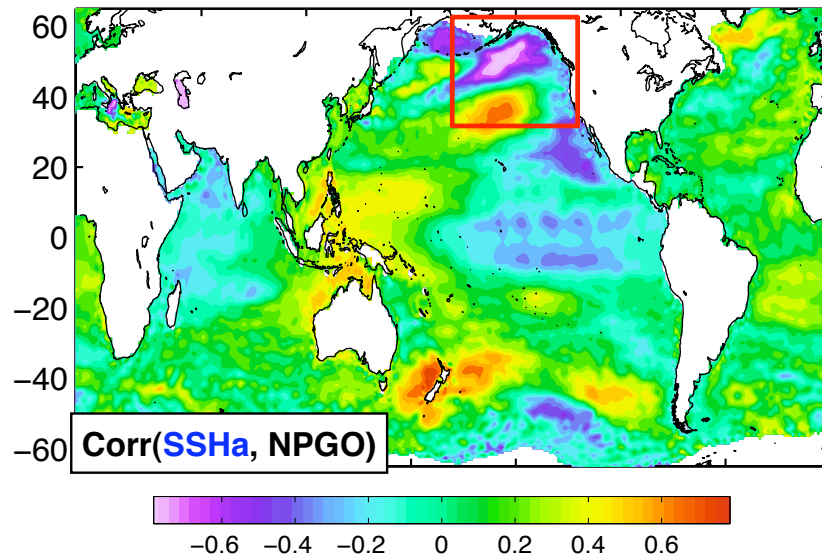


Walker and Bliss, 1932

QUESTION:

Is the NPGO a global-scale pattern?

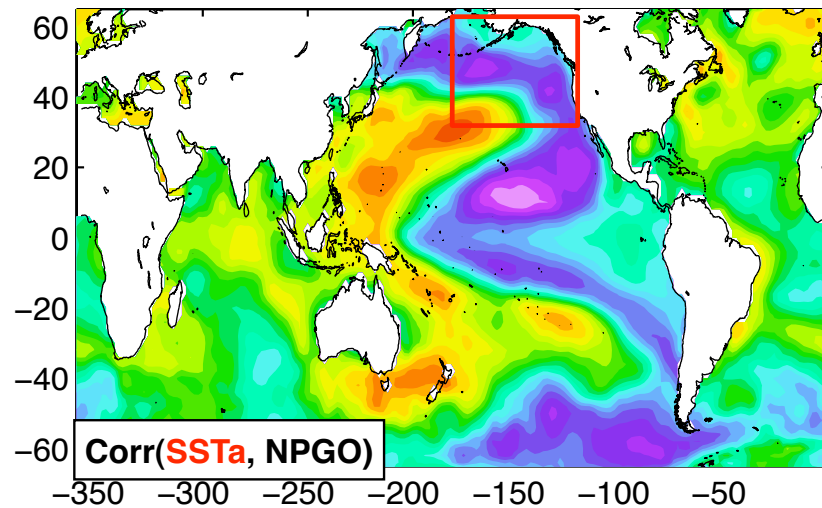
NPGO pattern in Satellite SSHa



QUESTION:

Is the NPGO a global-scale pattern?

NPGO pattern in Global SSTa

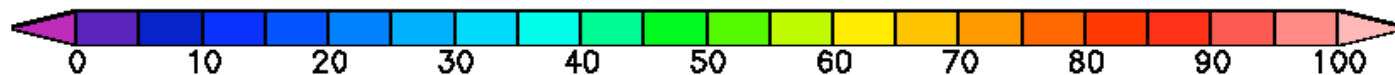
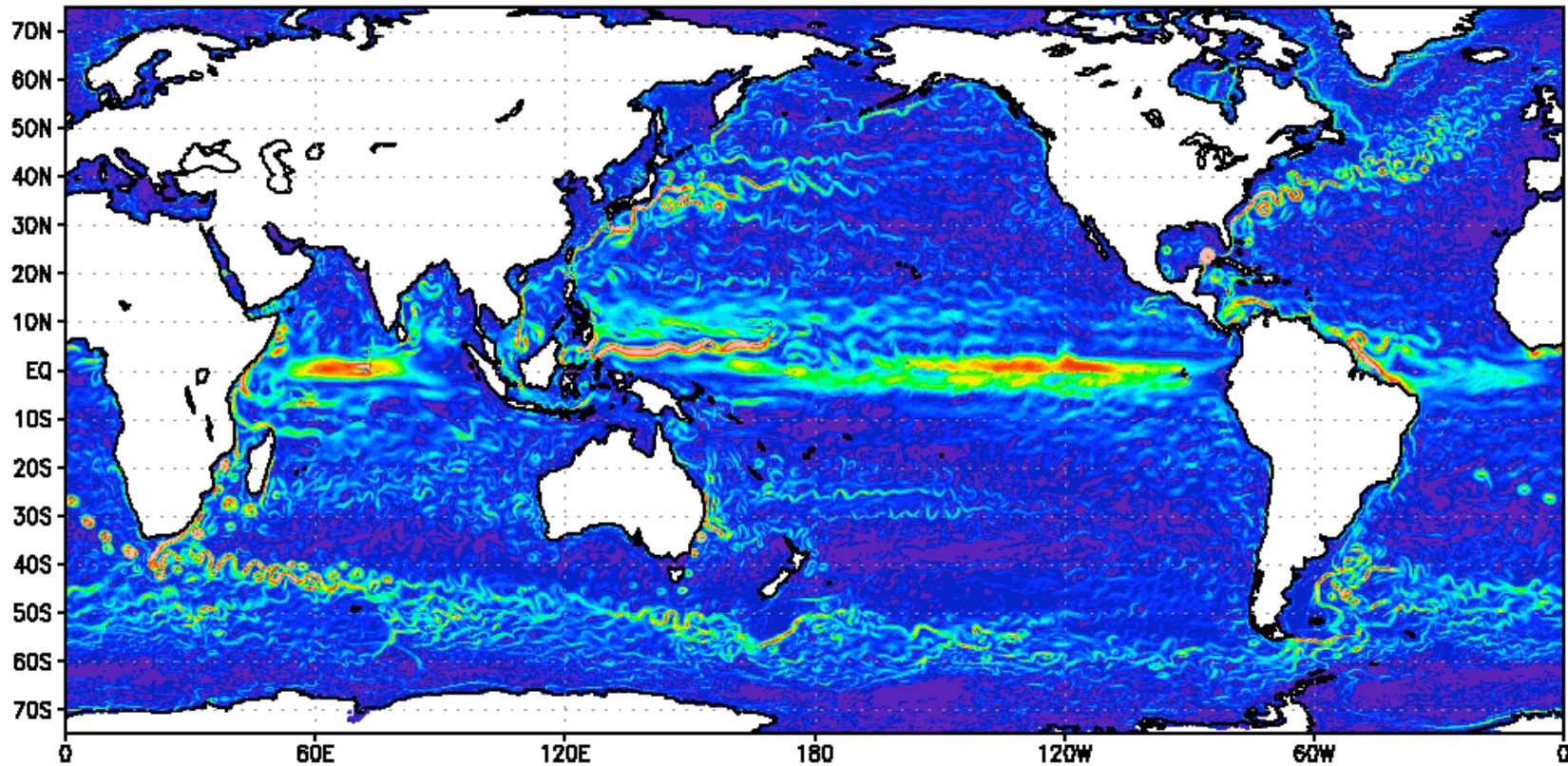


Earth Simulator Ocean General Circulation Model

10 km resolution 1950-2007

Surface Ocean Currents

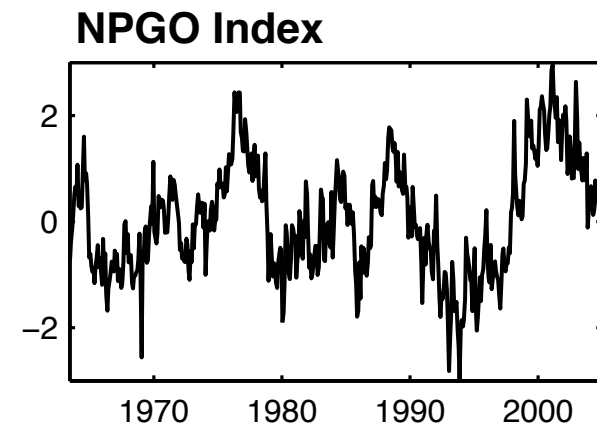
OFES Model



(C)ESC/JAMSTEC

QUESTION:

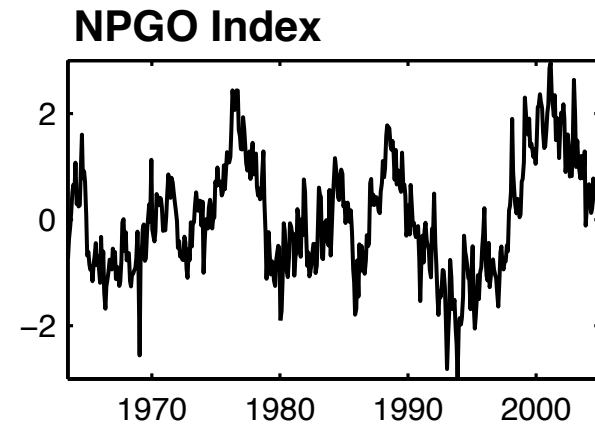
Does OFES capture the NPGO?



QUESTION:

Does OFES capture the NPGO?

Correlation
<NPGO index, **OFES SSHa**>

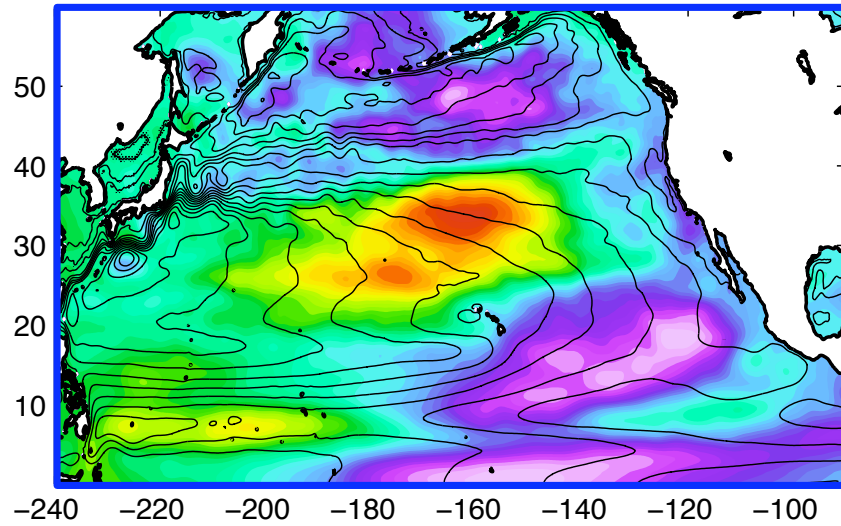


QUESTION:

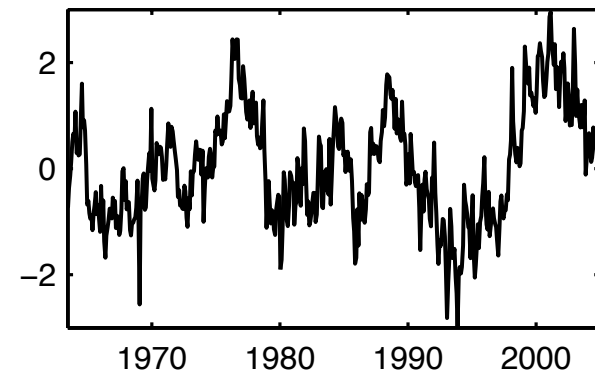
Does OFES capture the NPGO?

Correlation
<NPGO index, **Satellite SSHa**>

NPGO pattern in OFES



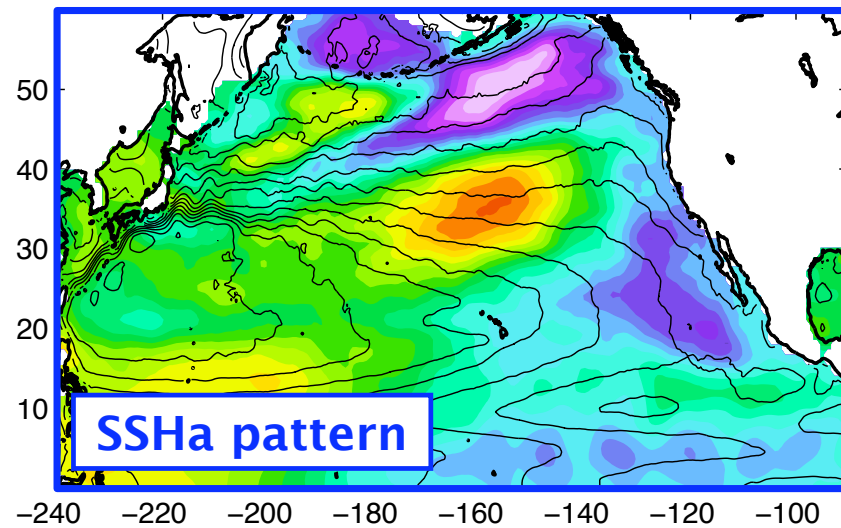
NPGO Index



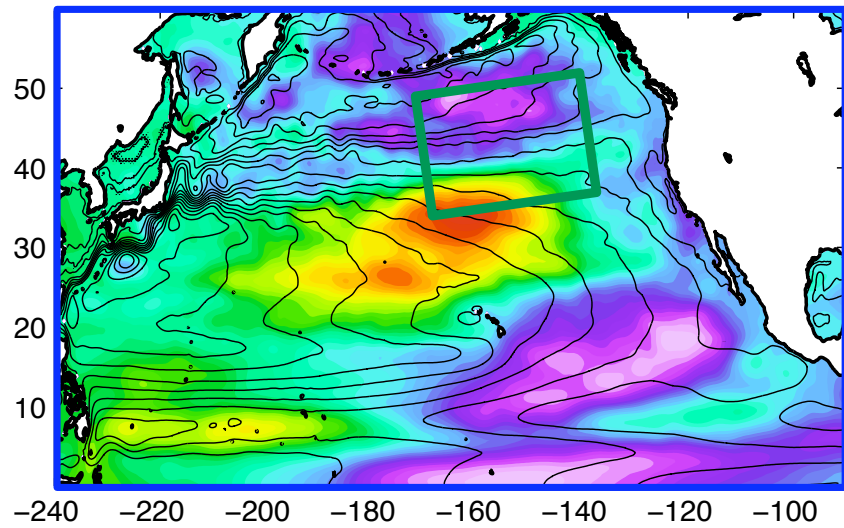
QUESTION:

Does OFES capture the NPGO?

NPGO pattern in Satellite

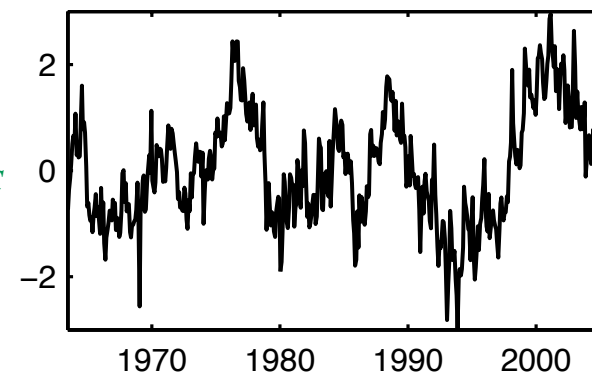


NPGO pattern in OFES

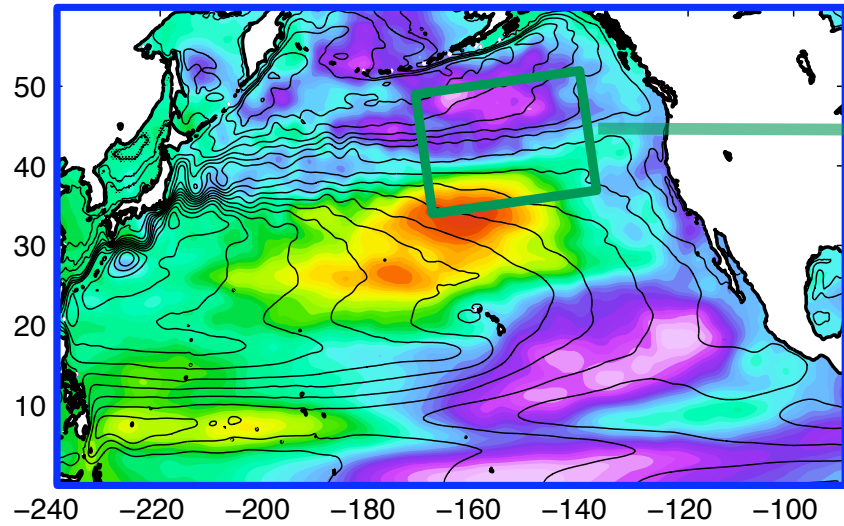


$$\left. \frac{\partial SSH}{\partial y} \right|_{NPC}$$

NPGO Index



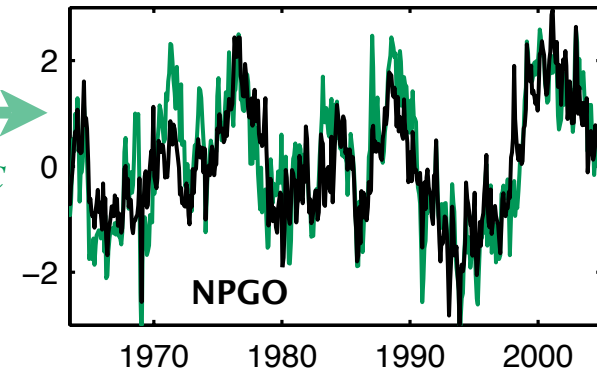
NPGO pattern in OFES



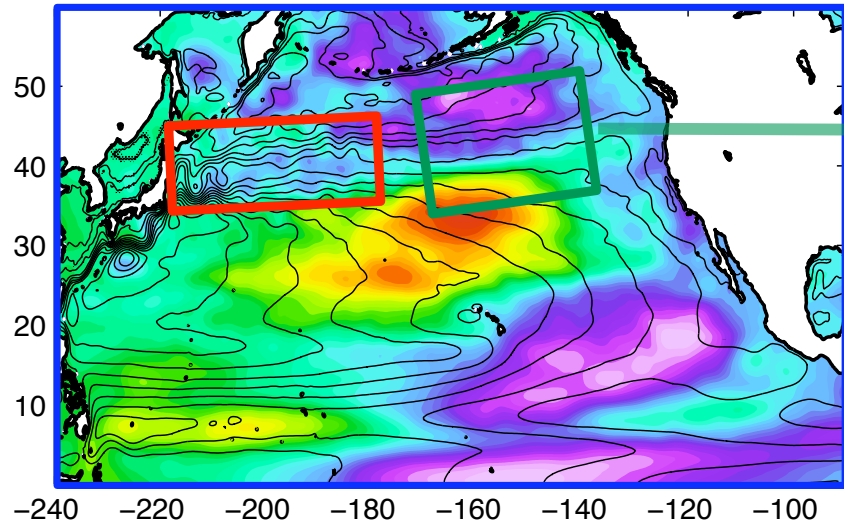
$$\left. \frac{\partial SSH}{\partial y} \right|_{NPC}$$



Strength of North Pacific Current



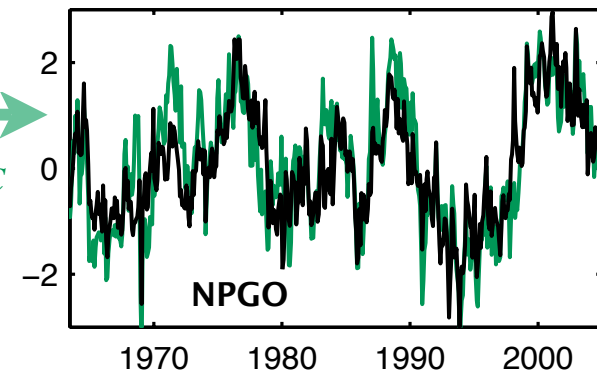
NPGO pattern in OFES



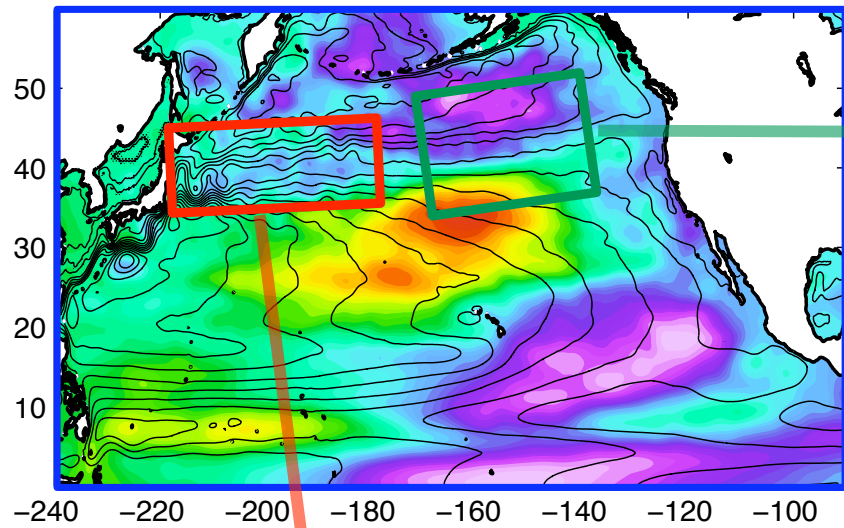
$$\left. \frac{\partial SSH}{\partial y} \right|_{NPC}$$



Strength of North Pacific Current

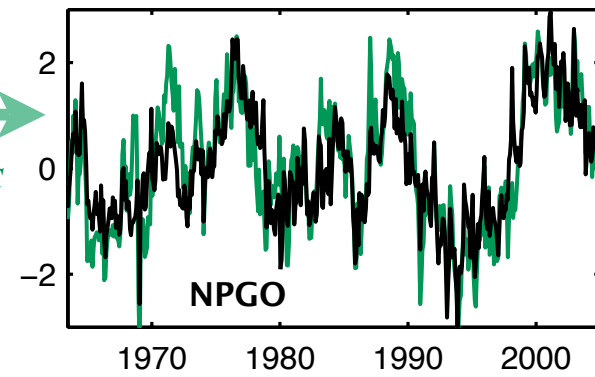


NPGO pattern in OFES



$$\left. \frac{\partial SSH}{\partial y} \right|_{NPC}$$

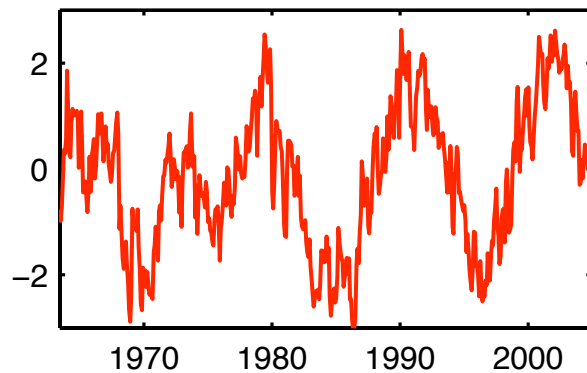
Strength of North Pacific Current



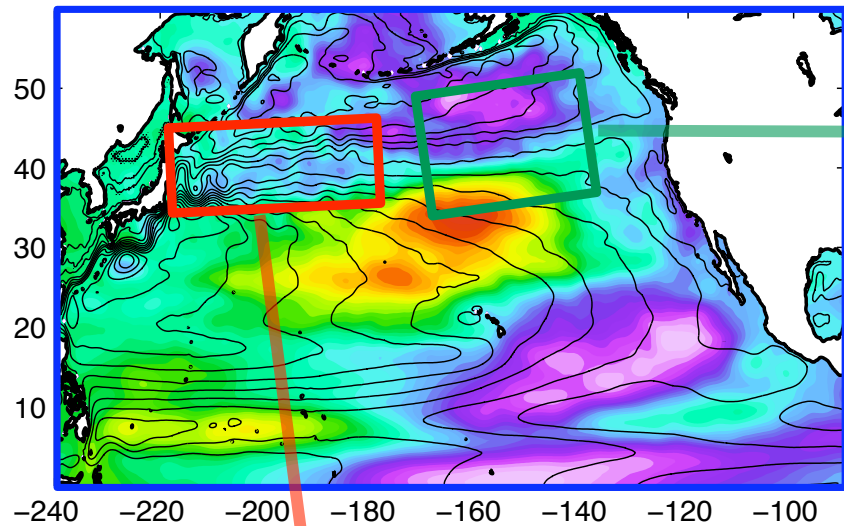
$$\left. \frac{\partial SSH}{\partial y} \right|_{KOE}$$

Taghuci et al. 2007

Strength of Kuroshio-Oyashio Extension

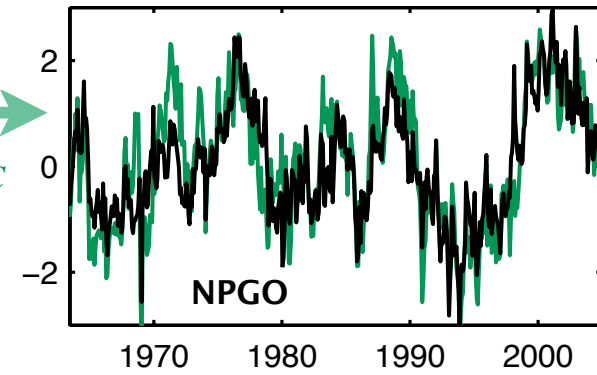


NPGO pattern in OFES



$$\left. \frac{\partial SSH}{\partial y} \right|_{NPC}$$

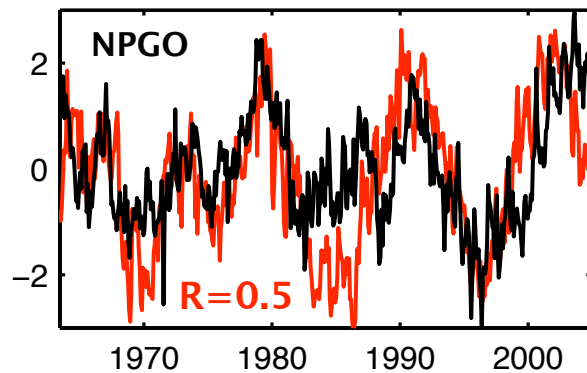
Strength of North Pacific Current



$$\left. \frac{\partial SSH}{\partial y} \right|_{KOE}$$

Taghuci et al. 2007

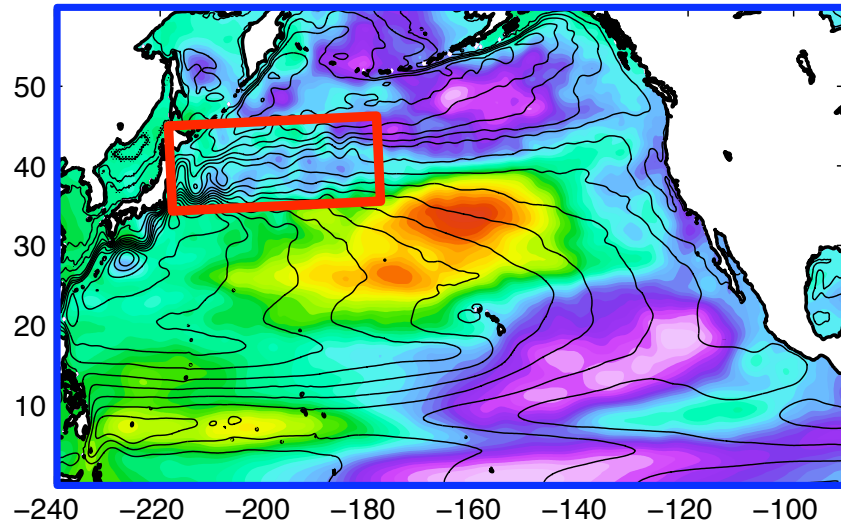
Strength of Kuroshio-Oyashio Extension



3 years later

Ceballos et al., 2008

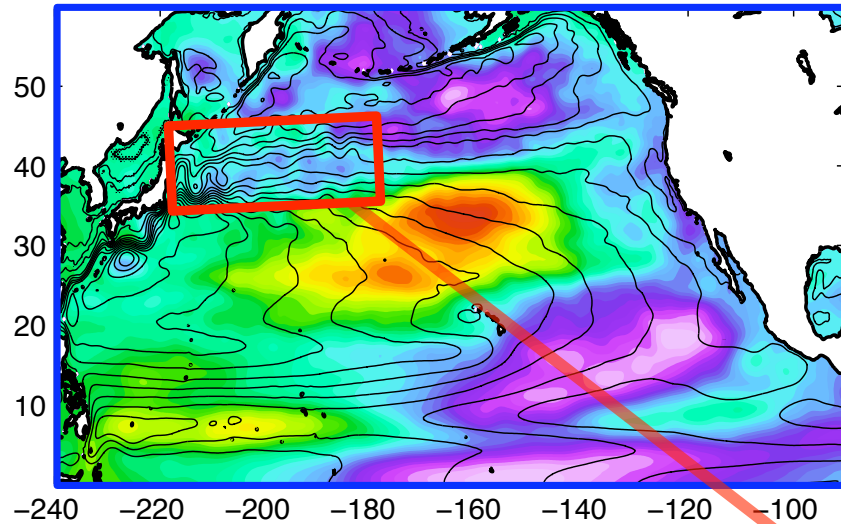
NPGO pattern in OFES



QUESTION:

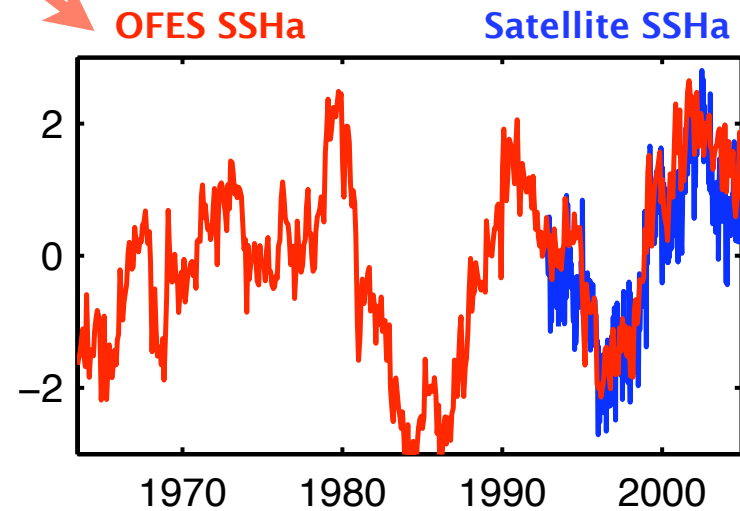
Do Rossby wave propagate the NPGO information in the KOE?

NPGO pattern in OFES

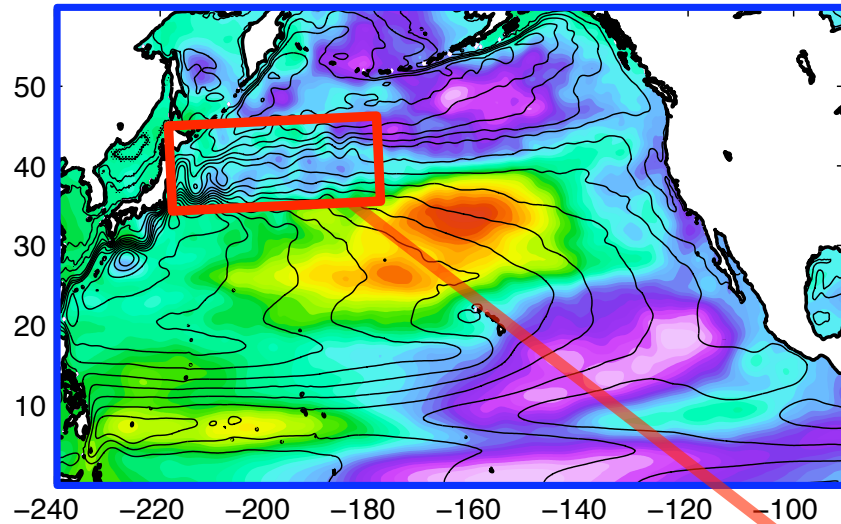


QUESTION:

Do Rossby wave propagate the NPGO information in the KOE?



NPGO pattern in OFES



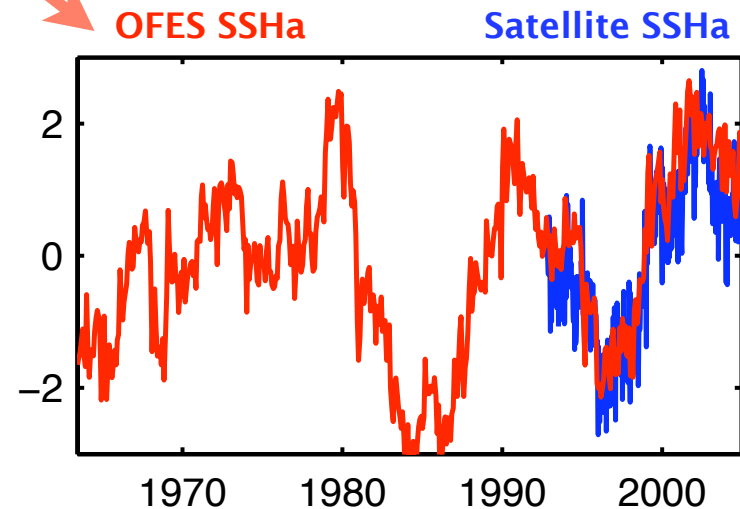
QUESTION:

Do Rossby wave propagate the NPGO information in the KOE?

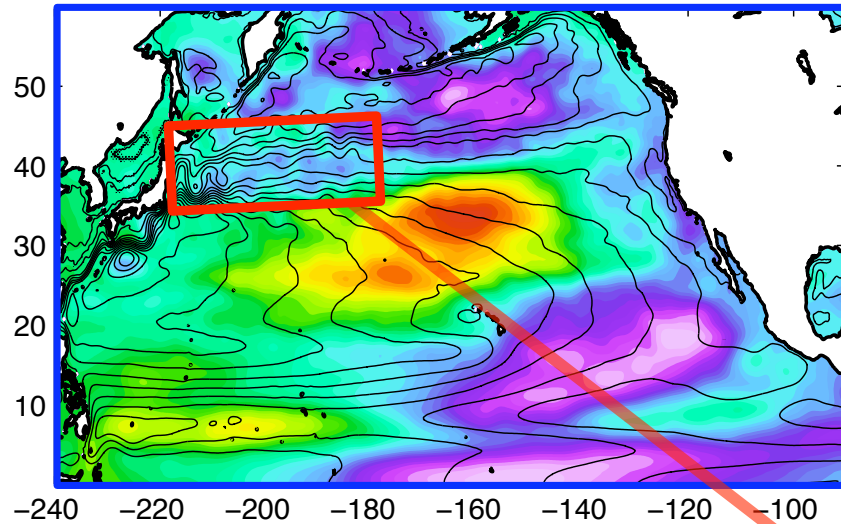
Linear Rossby Wave Model

$$\frac{\partial h}{\partial t} - c_R \frac{\partial h}{\partial x} = - \frac{g' \text{curl} \tau}{\rho_o g f}$$

Qiu et al. 2007



NPGO pattern in OFES



QUESTION:

Do Rossby wave propagate the NPGO information in the KOE?

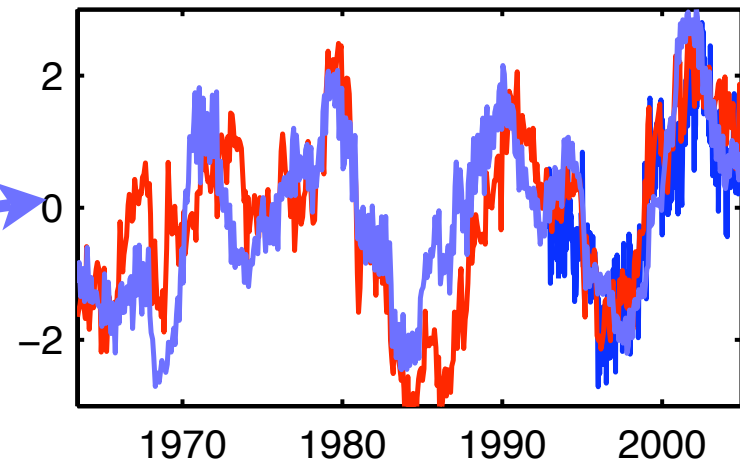
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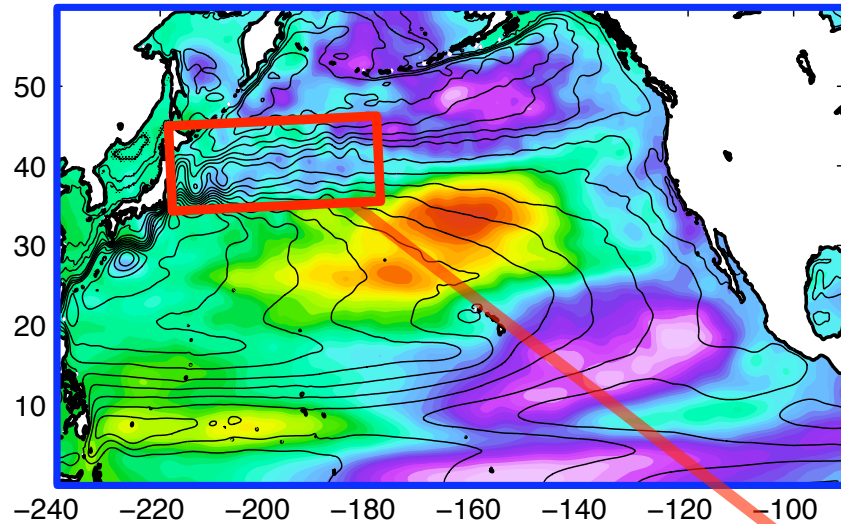
Qiu et al. 2007

OFES SSHa

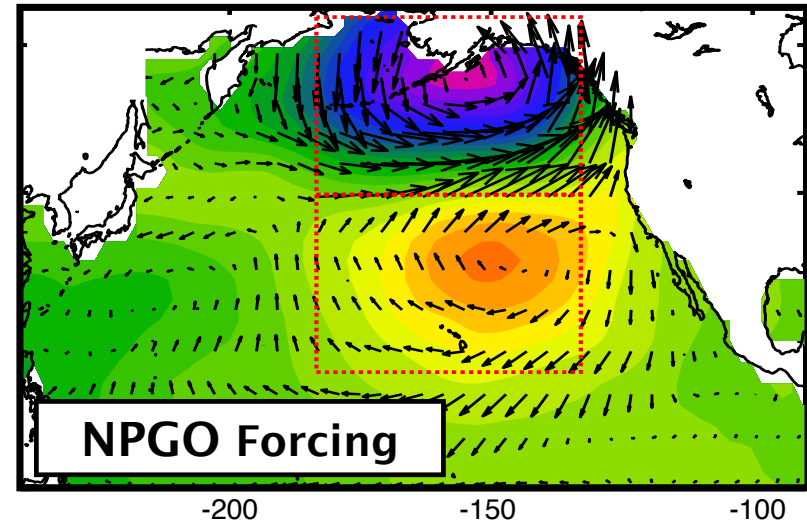
Linear Rossby
Wave Model
Satellite SSHa



NPGO pattern in OFES



North Pacific Oscillation (EOF2 SLPa)



Linear Rossby Wave Model

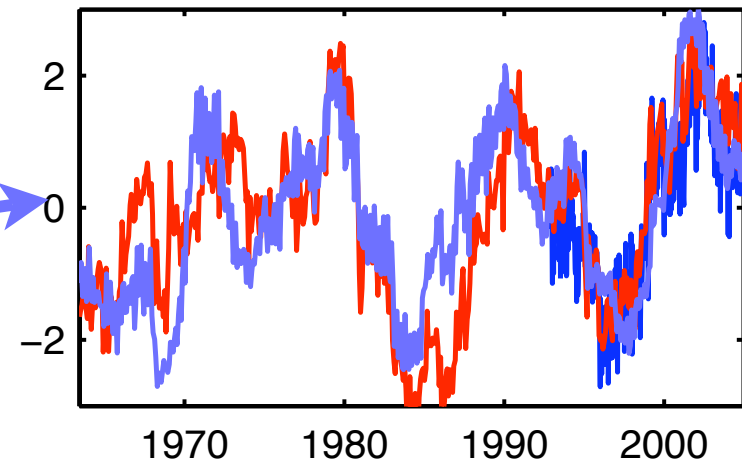
$$\frac{\partial h}{\partial t} - c_R \frac{\partial h}{\partial x} = - \frac{g' \text{curl} \tau}{\rho_o g f}$$

Qiu et al. 2007

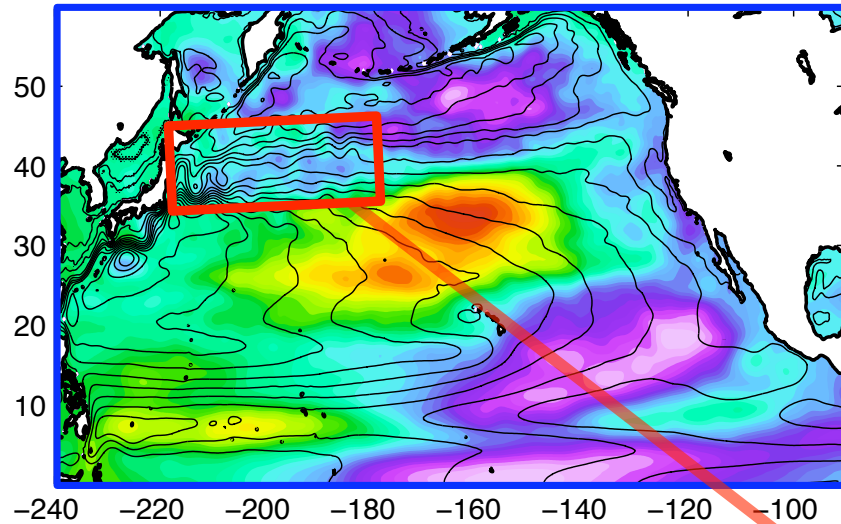
OFES SSHa

Linear Rossby
Wave Model

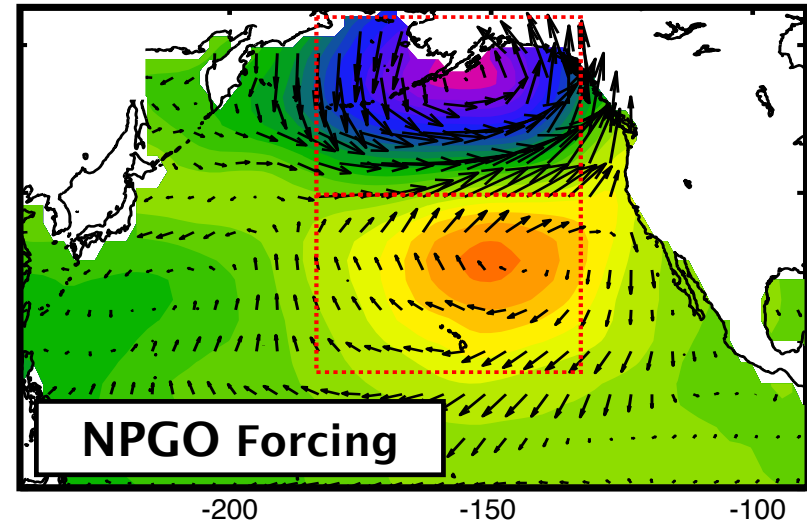
Satellite SSHa



NPGO pattern in OFES



North Pacific Oscillation (EOF2 SLPa)



Linear Rossby Wave Model forced by NPO

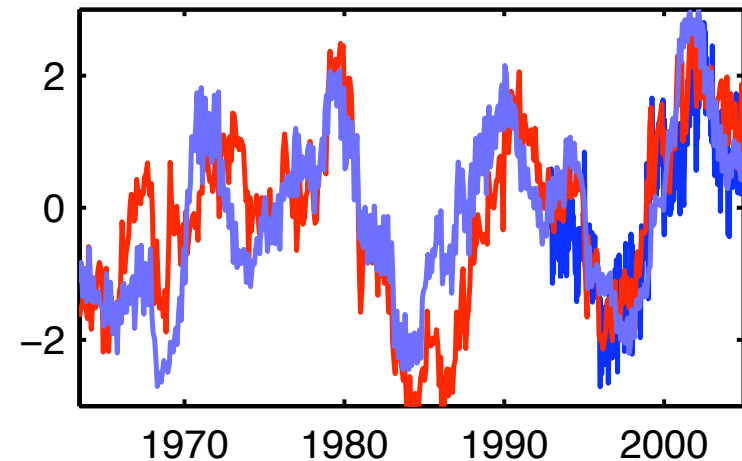
$$\frac{\partial h}{\partial t} - c_R \frac{\partial h}{\partial x} = - \frac{g' \text{curl} \tau_{NPO}}{\rho_o g f}$$

Ceballos et al., 2008

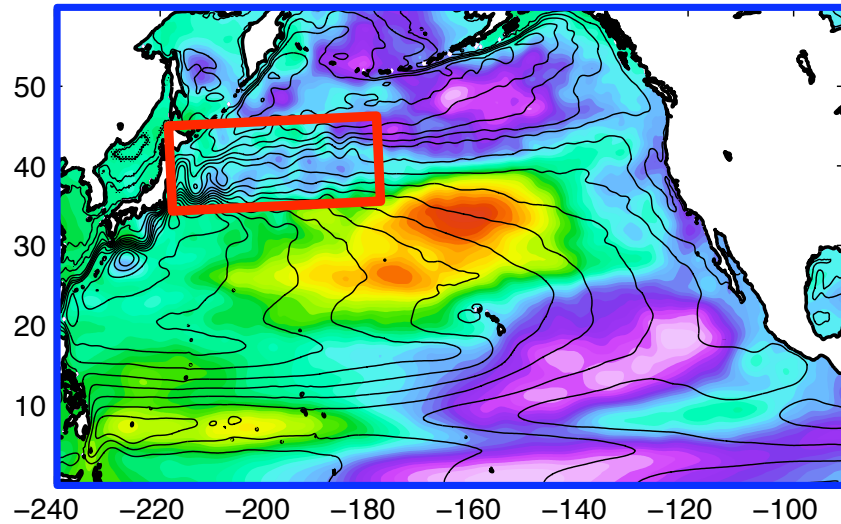
OFES SSHa

Linear Rossby
Wave Model

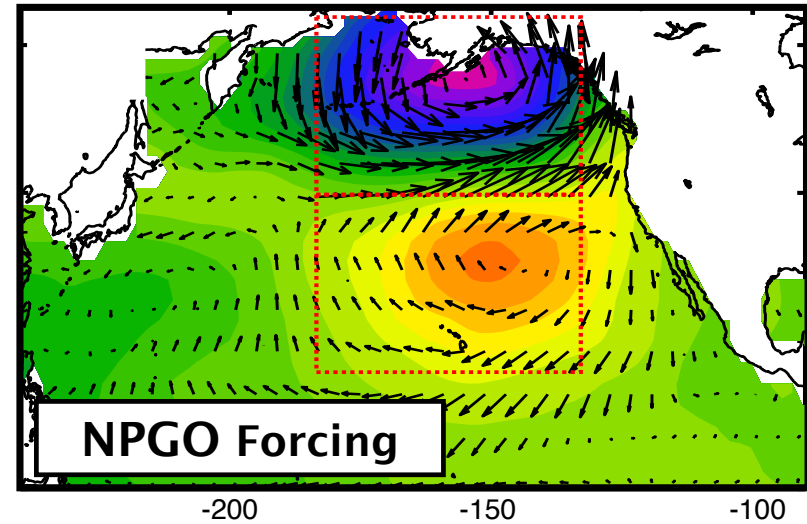
Satellite SSHa



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North Pacific Oscillation (EOF2 SLPa)



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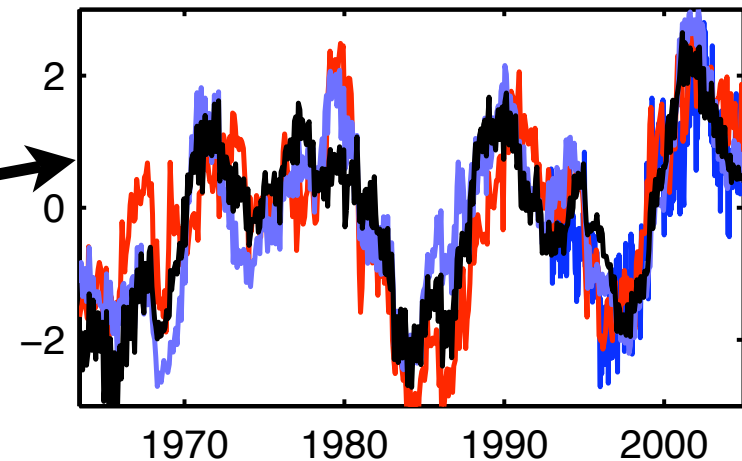
Ceballos et al., 2008

NPO
Linear Rossby
Wave Model

Linear Rossby
Wave Model

OFES SSHa

Satellite SSHa



EXTRA-TROPICS

NPGO

North Pacific Gyre Oscillation

Di Lorenzo et al. 2008

ocean

NPO

North Pacific Oscillation

Walker and Bliss, 1932

atmosphere

EXTRA-TROPICS

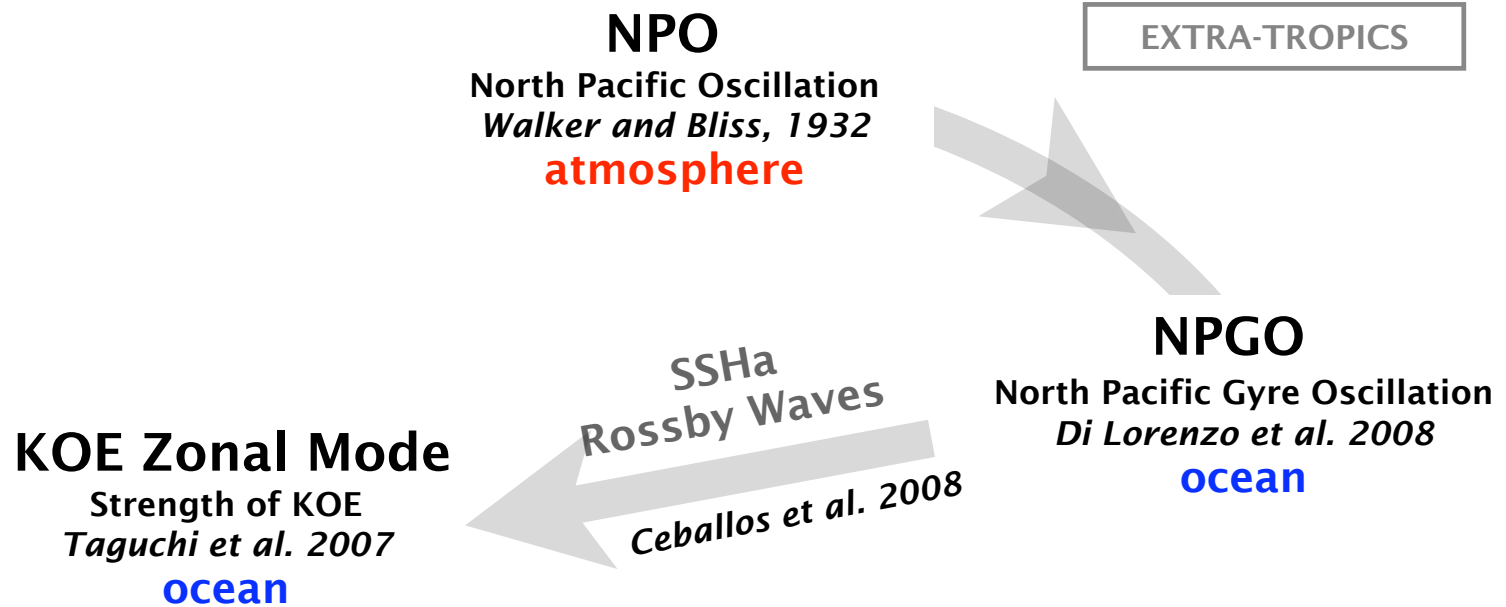


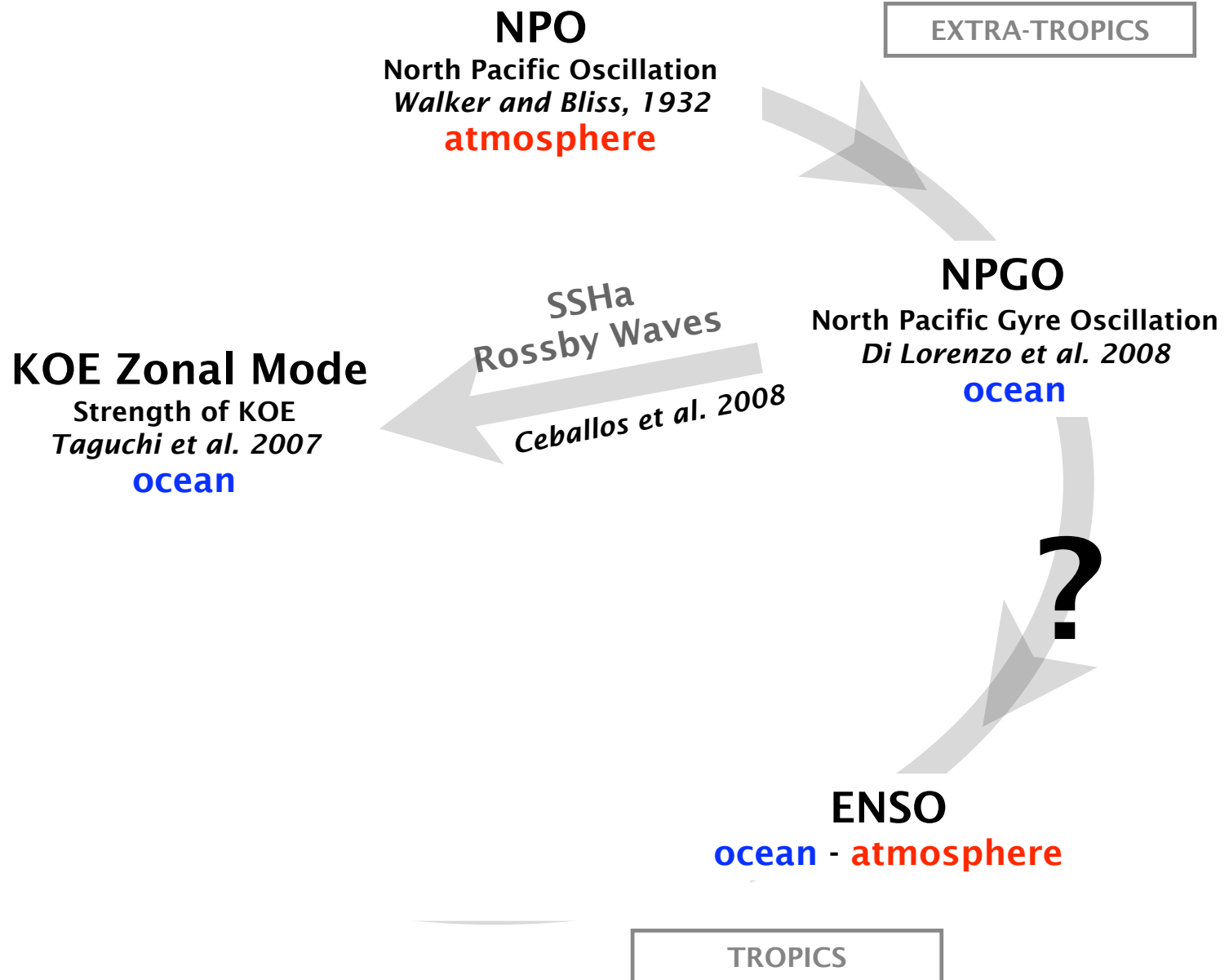
NPGO

North Pacific Gyre Oscillation

Di Lorenzo et al. 2008a

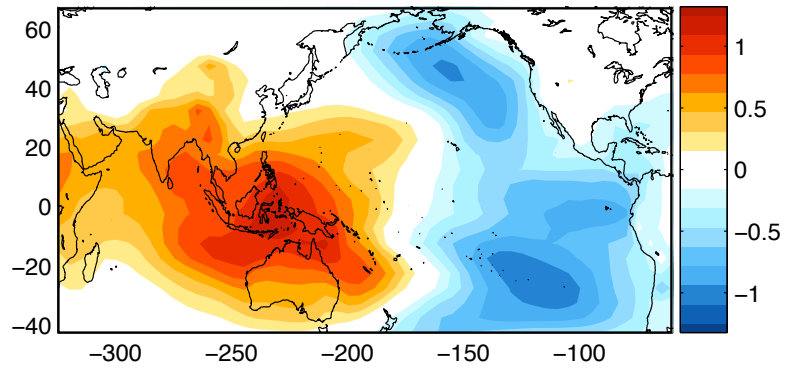
ocean



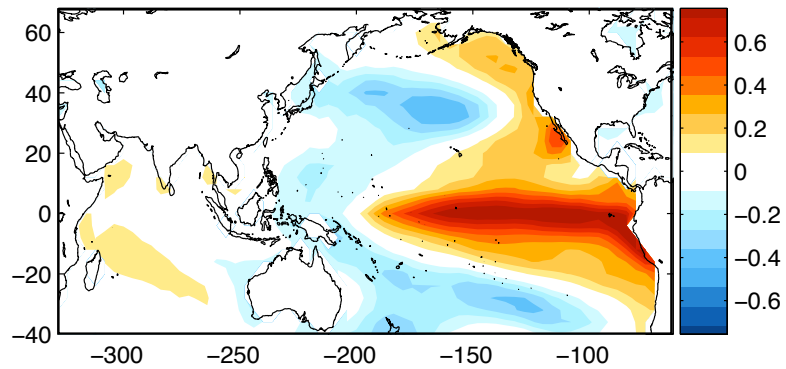


Combined EOF
SLPa/SSTa
over the Pacific Ocean

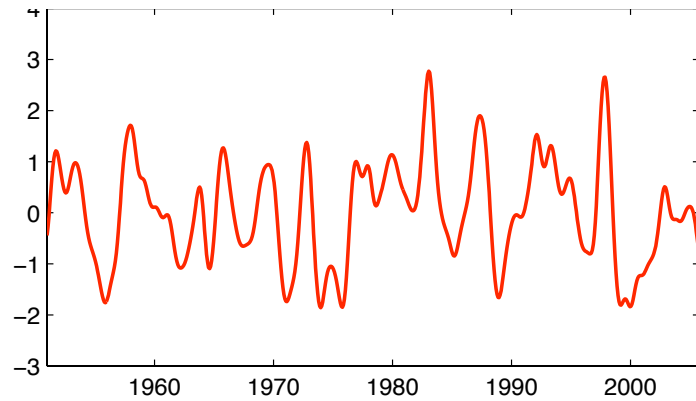
SLPa combined EOF 1



SSTa combined EOF 1

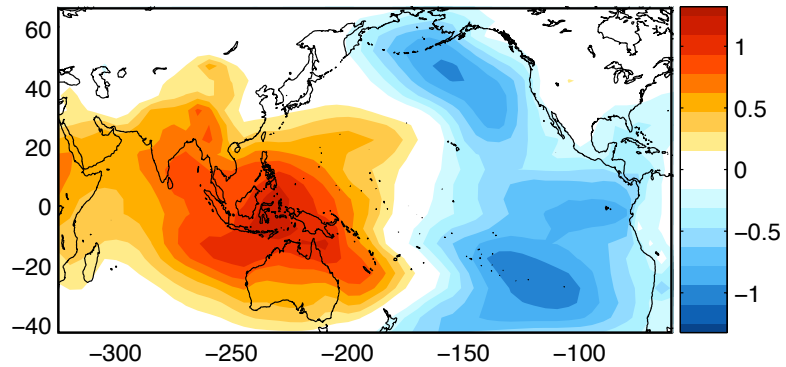


PC 1

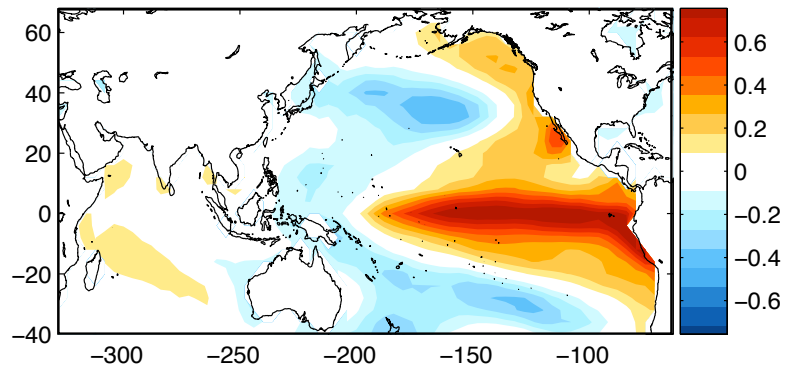


Combined EOF 1 SLPa/SSTa

SLPa combined EOF 1

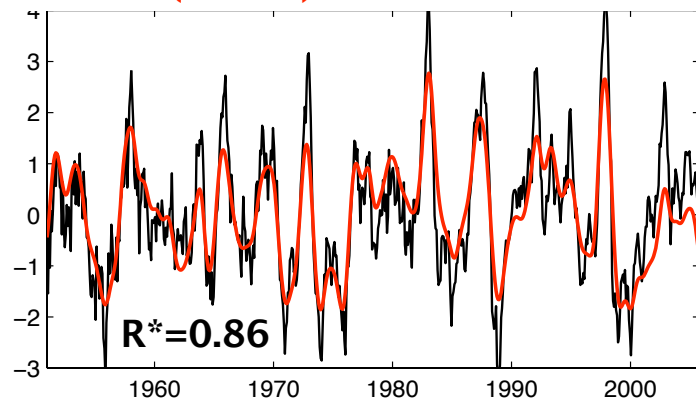


SSTa combined EOF 1



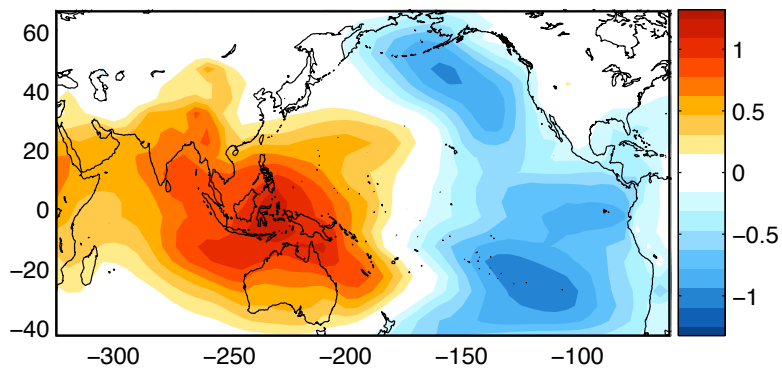
PC 1 (ENSO)

NINO 3.4 index

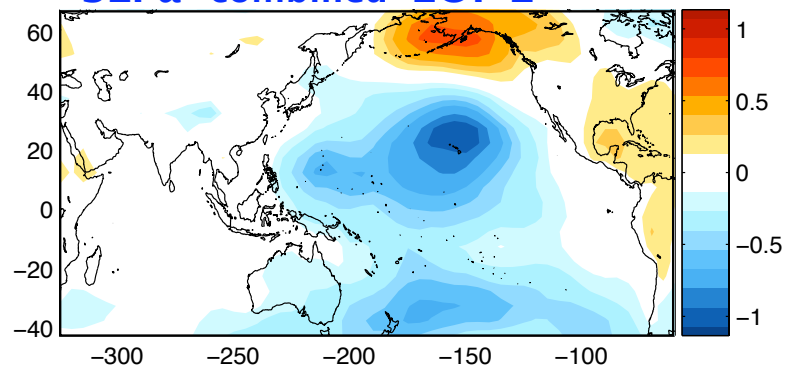


Combined EOF 1 SLPa/SSTa

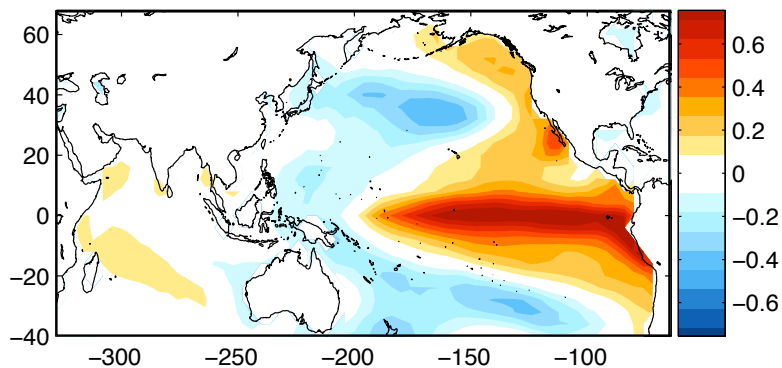
SLPa combined EOF 1



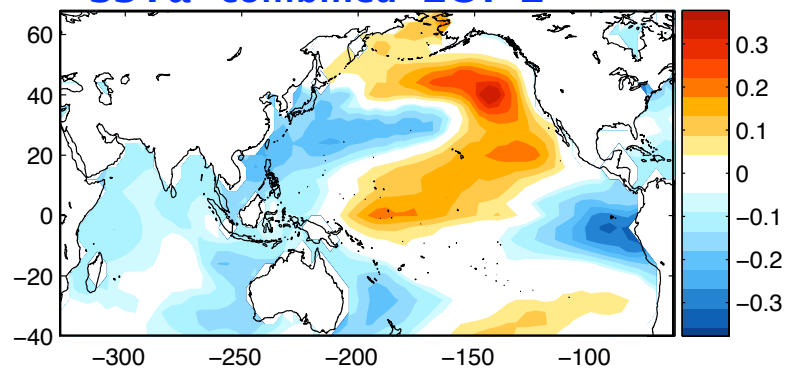
SLPa combined EOF 2



SSTa combined EOF 1

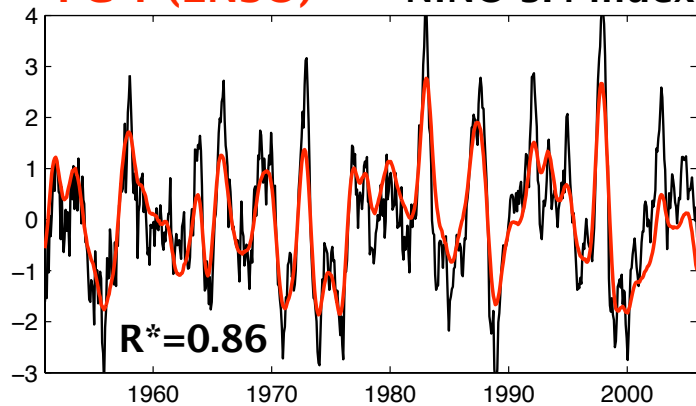


SSTa combined EOF 2

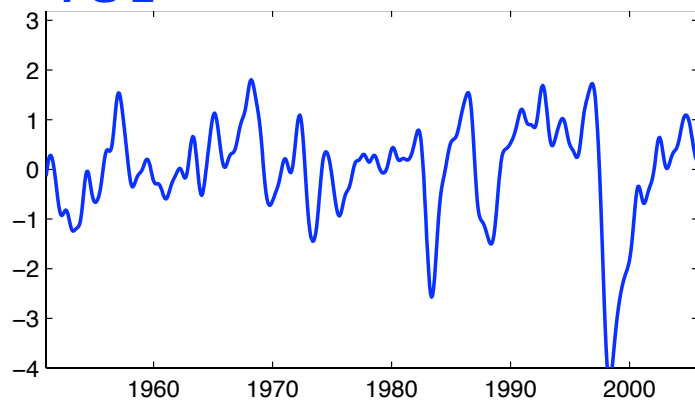


PC 1 (ENSO)

NINO 3.4 index

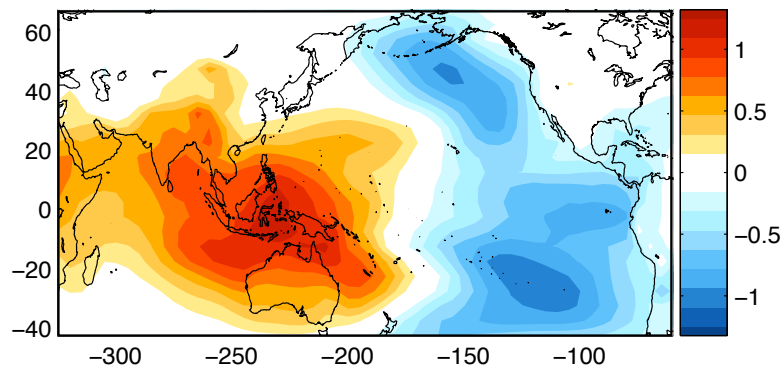


PC 2

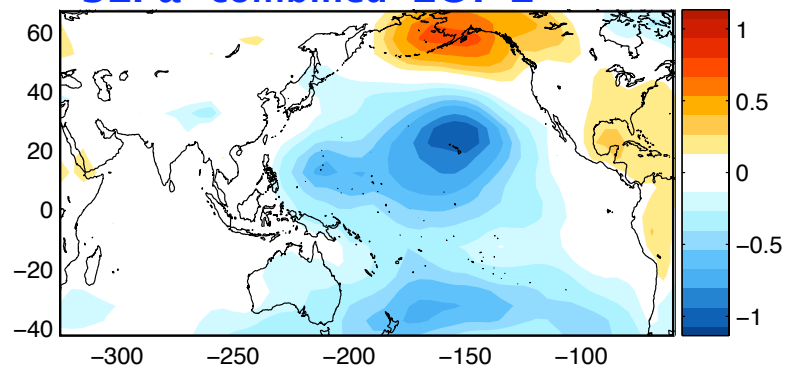


Di Lorenzo et al., in prep.

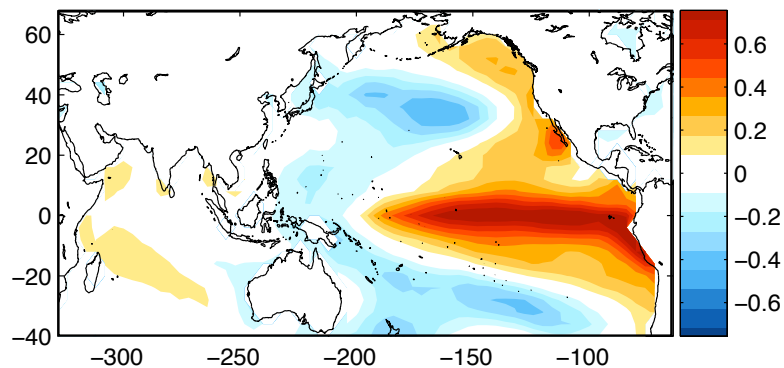
SLPa combined EOF 1



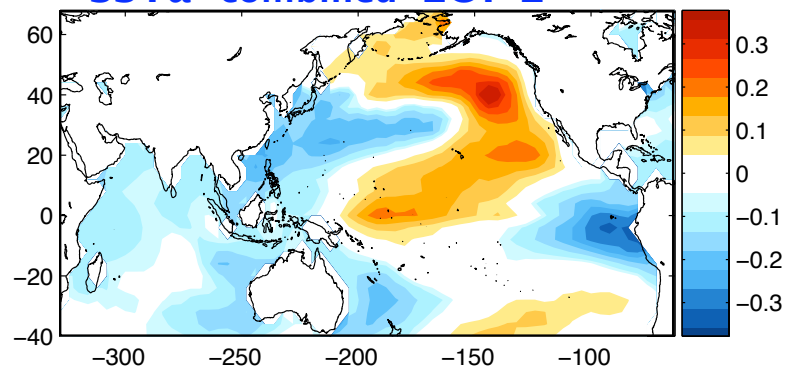
SLPa combined EOF 2



SSTa combined EOF 1

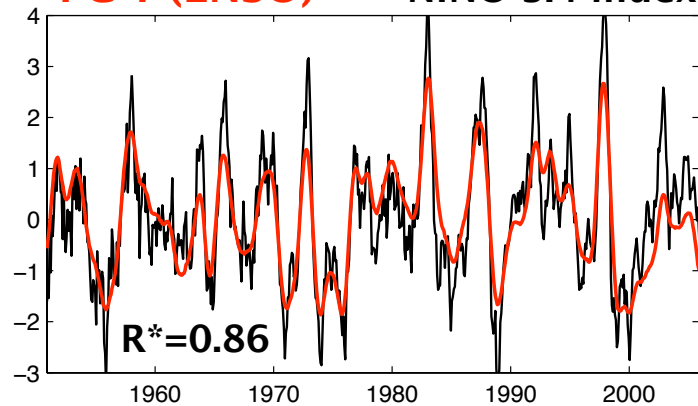


SSTa combined EOF 2



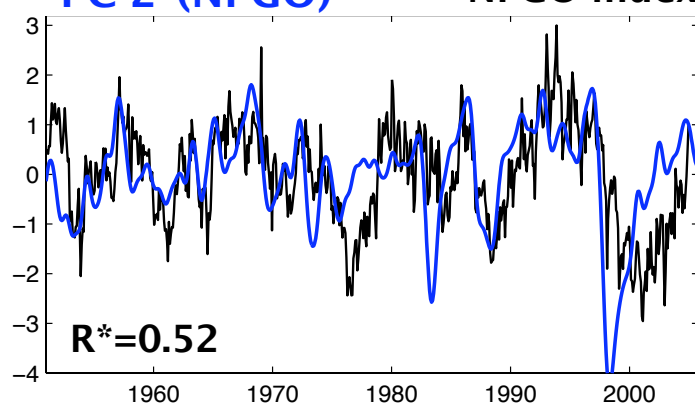
PC 1 (ENSO)

NINO 3.4 index



PC 2 (NPGO)

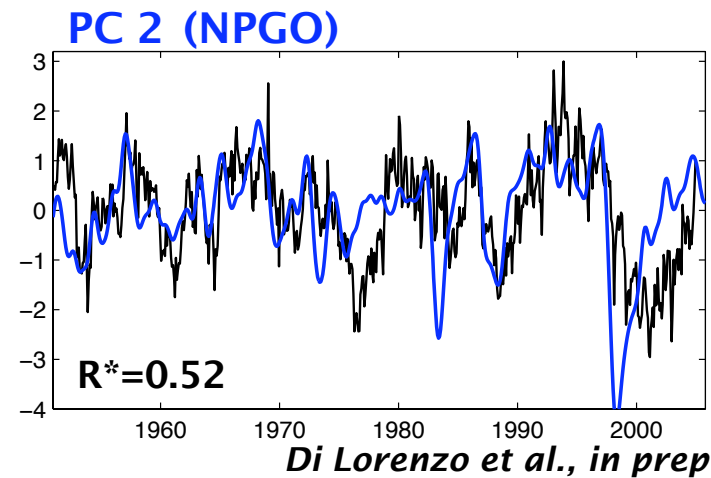
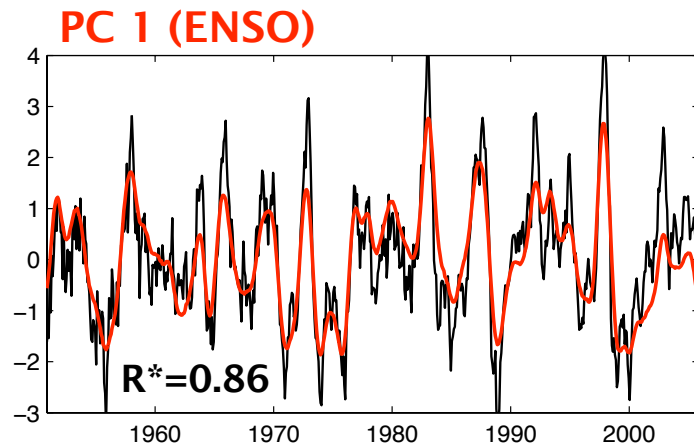
NPGO index



Di Lorenzo et al., in prep.

QUESTION:

Is there a relationship between
ENSO and **NPGO** mode?

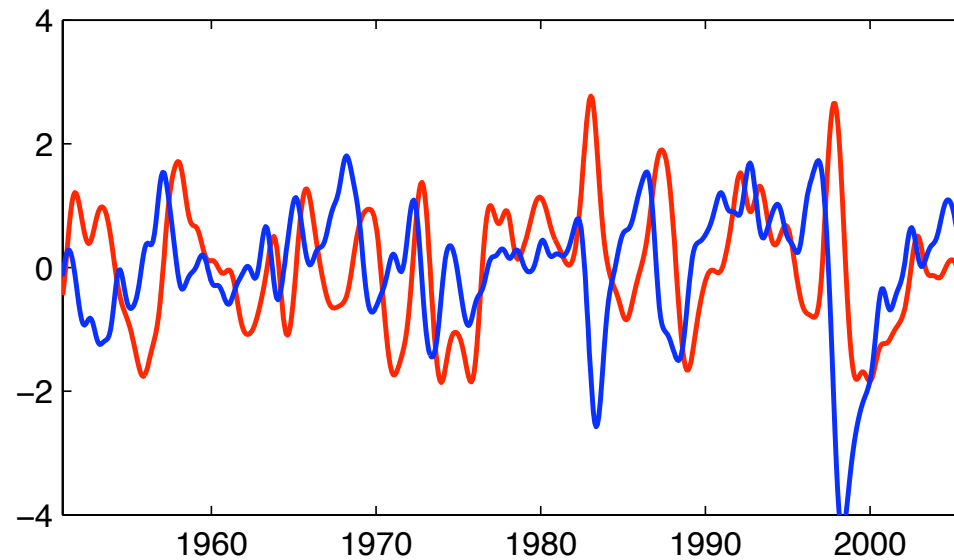


QUESTION:

Is there a relationship between
ENSO and **NPGO** mode?

PC 1 (ENSO)

PC 2 (NPGO)



Di Lorenzo et al., in prep.

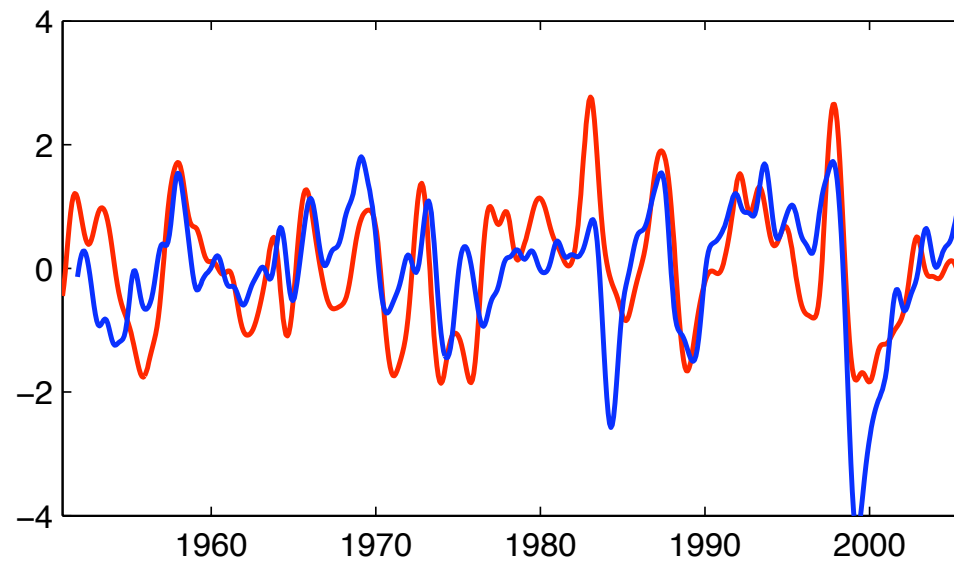
QUESTION:

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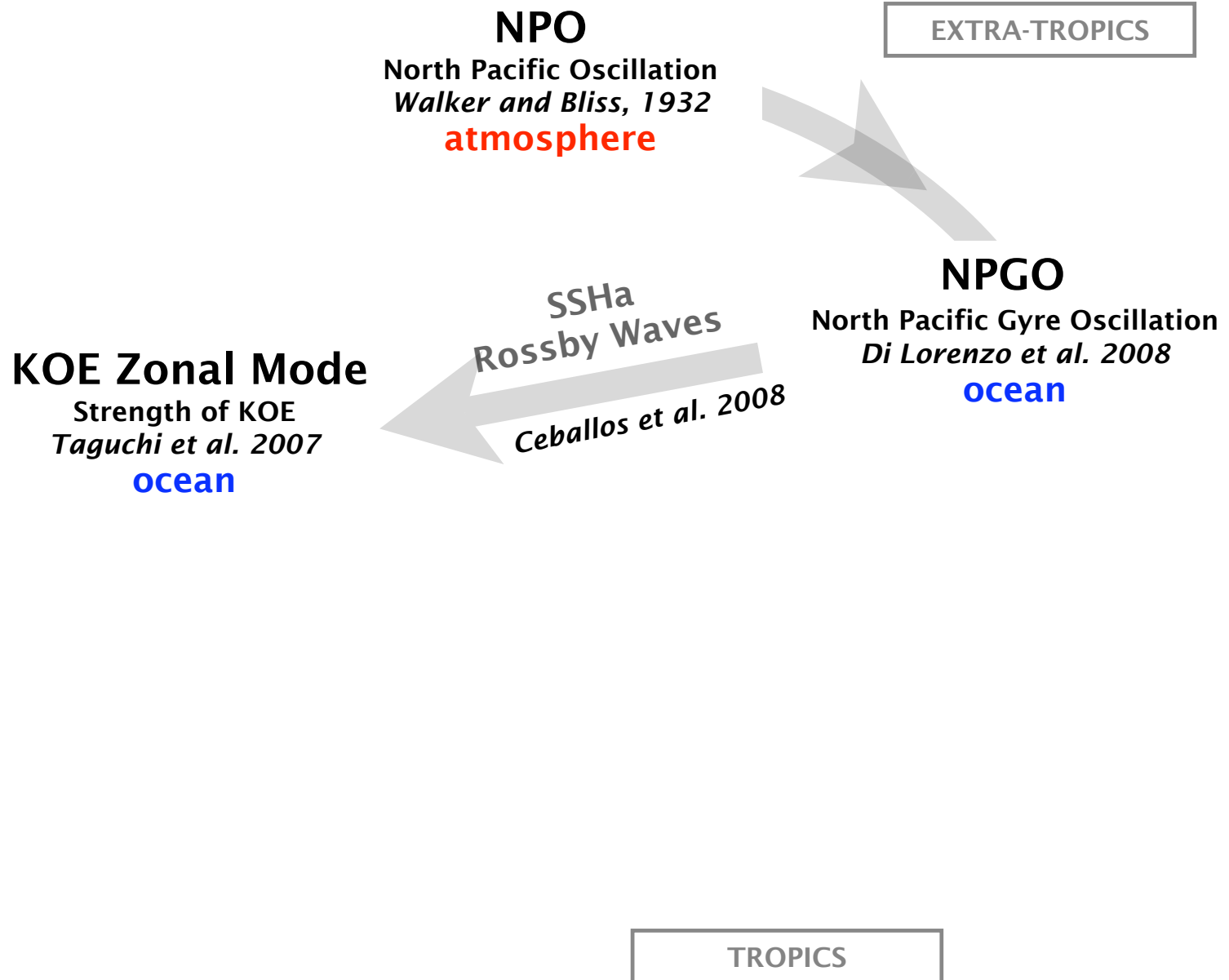
PC 1 (ENSO)

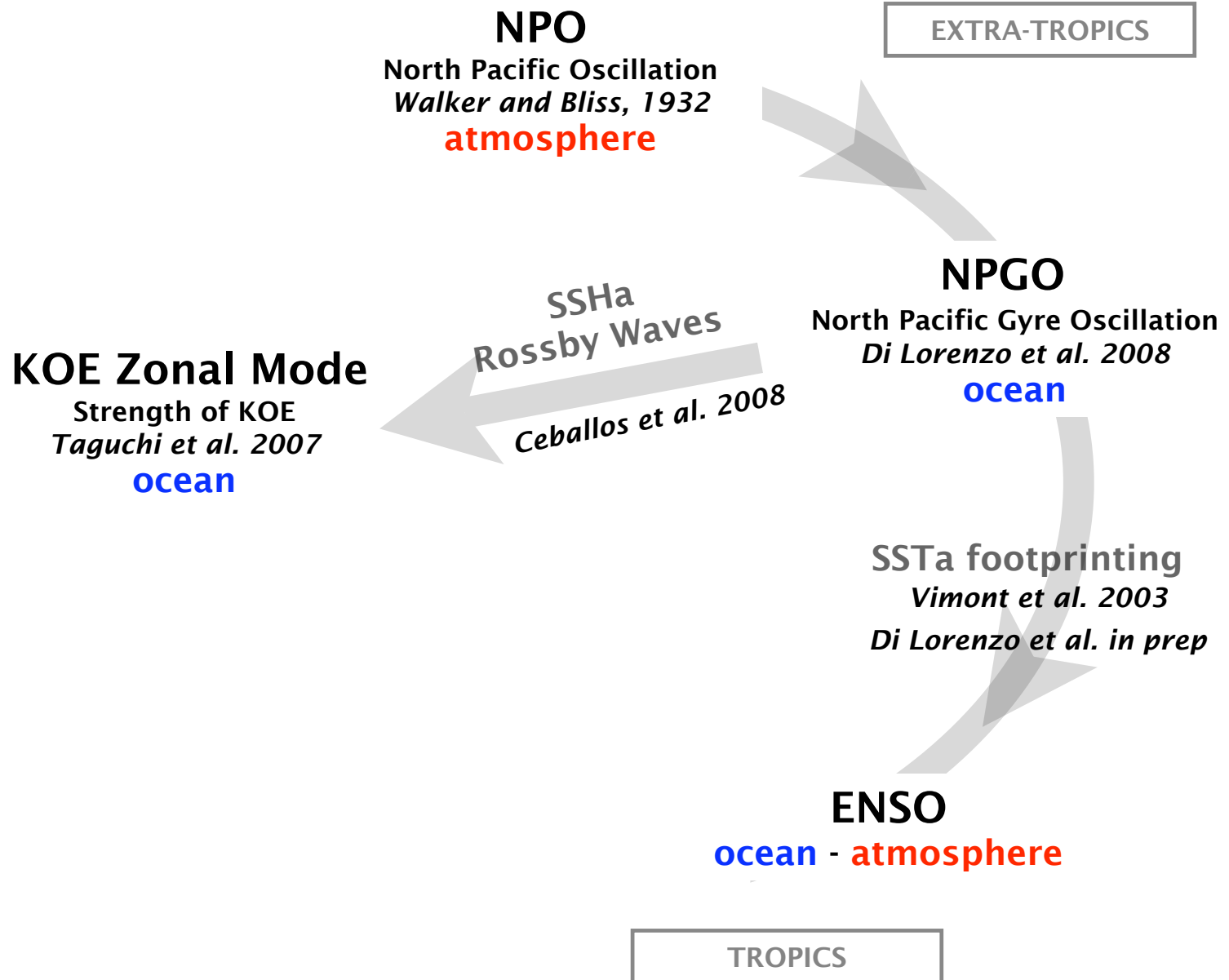
PC 2 (NPGO) lead by ~10 months

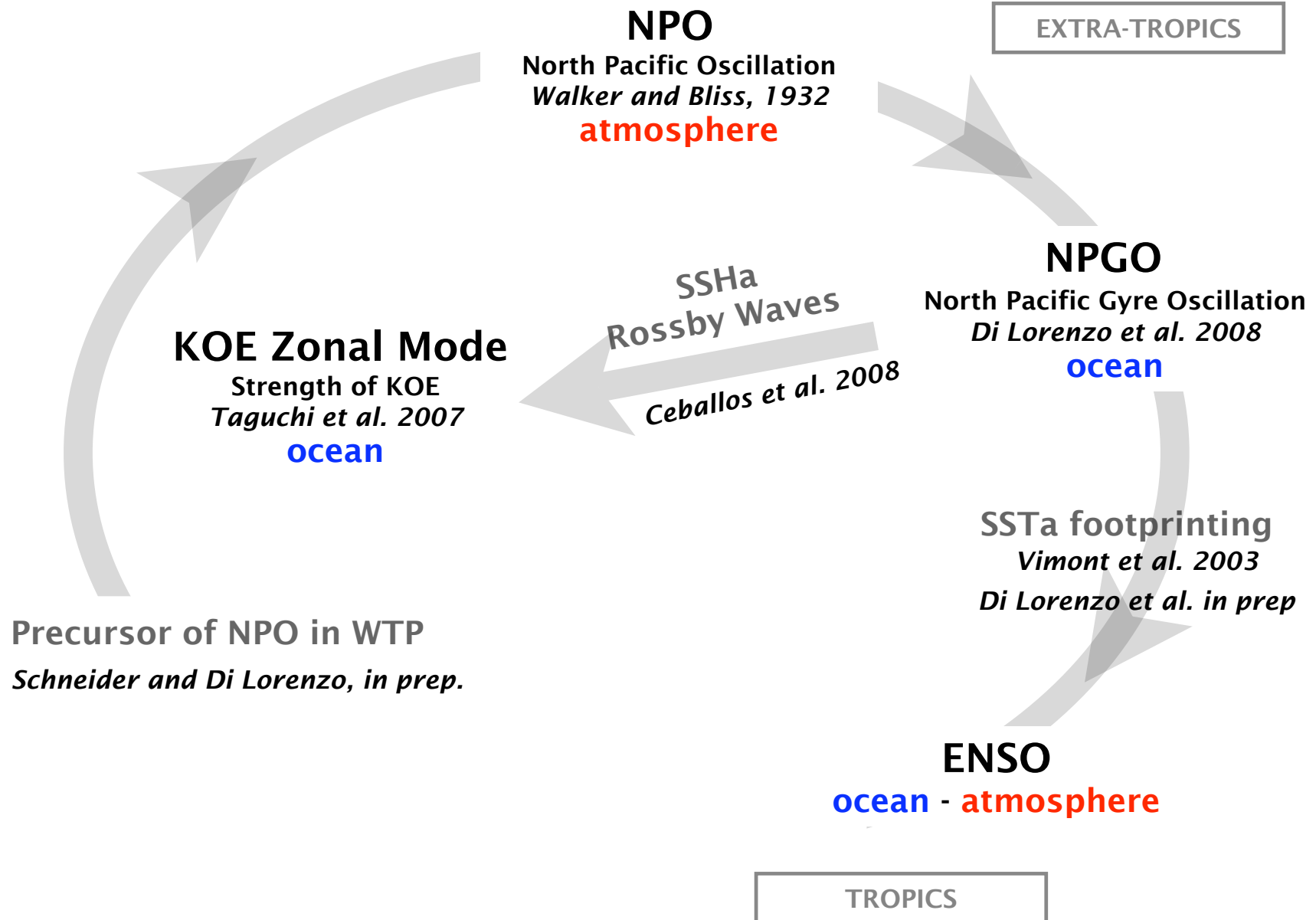
$R^*=0.64$



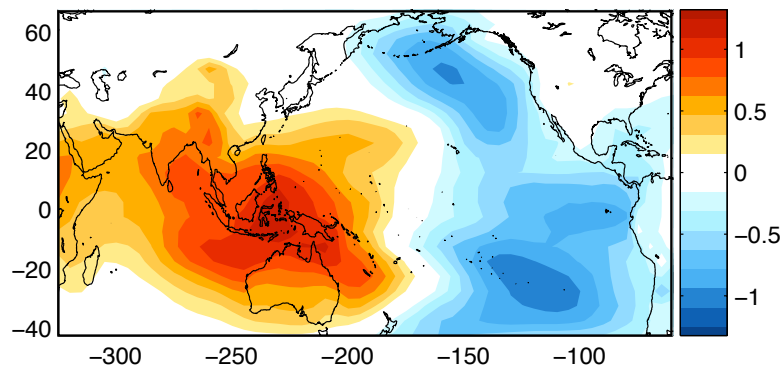
Di Lorenzo et al., in prep.



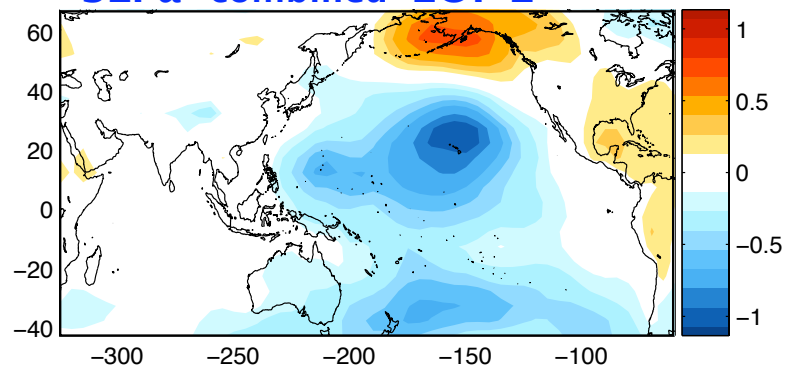




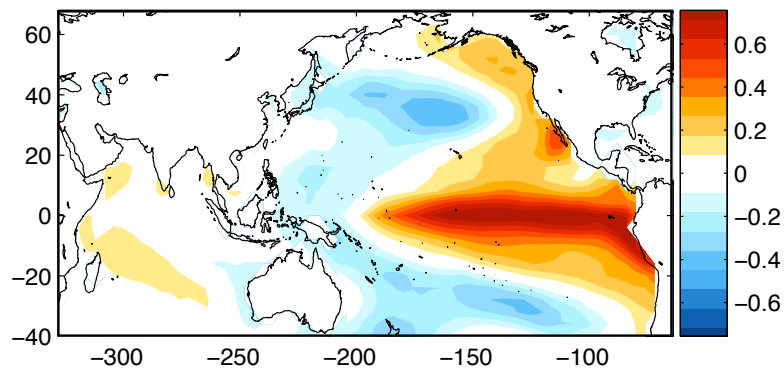
SLPa combined EOF 1



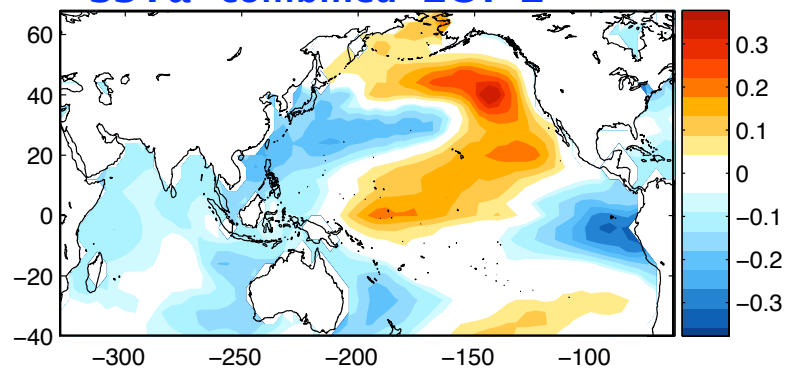
SLPa combined EOF 2



SSTa combined EOF 1

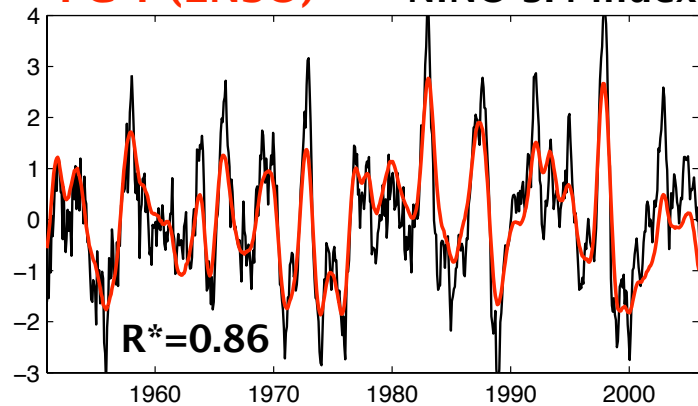


SSTa combined EOF 2



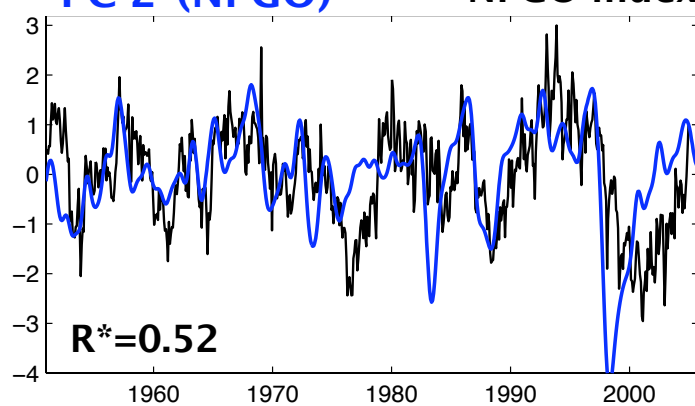
PC 1 (ENSO)

NINO 3.4 index



PC 2 (NPGO)

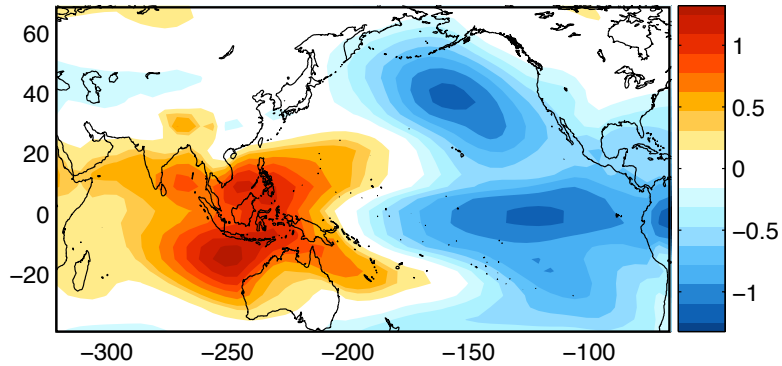
NPGO index



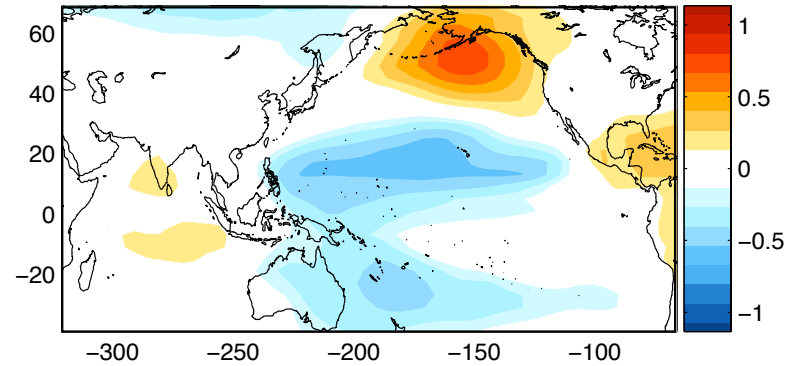
Di Lorenzo et al., in prep.

GFDL 2.0 Climate Model (IPCC)

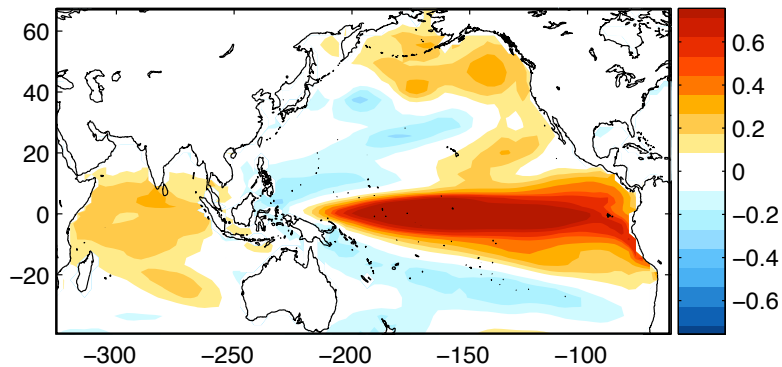
SLPa combined EOF 1



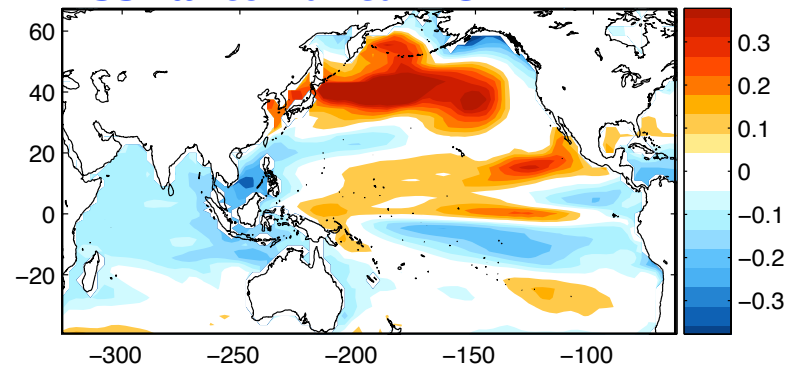
SLPa combined EOF 2



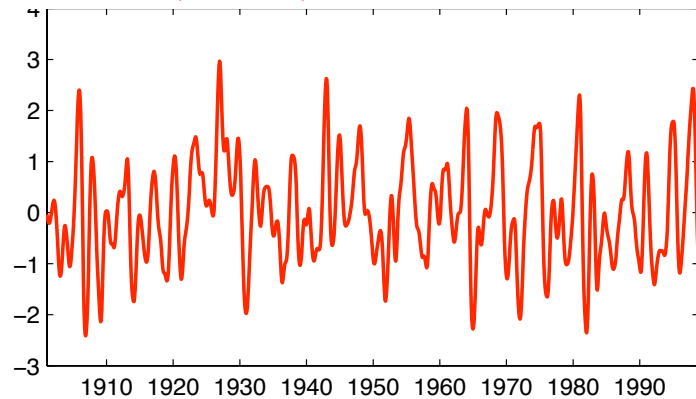
SSTa combined EOF 1



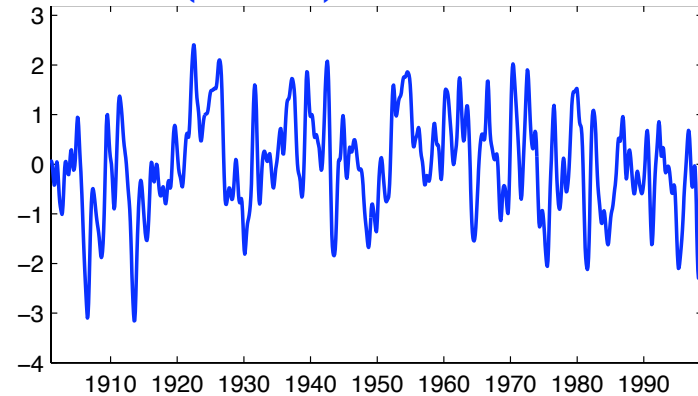
SSTa combined EOF 2



PC 1 (ENSO)



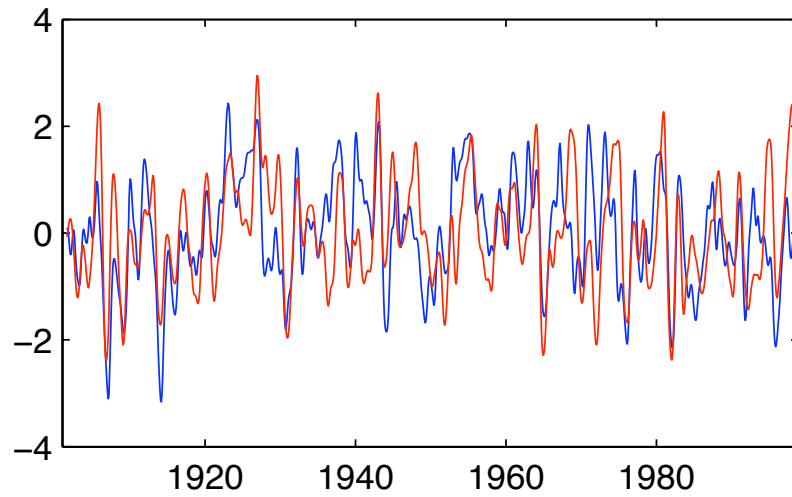
PC 2 (NPGO)



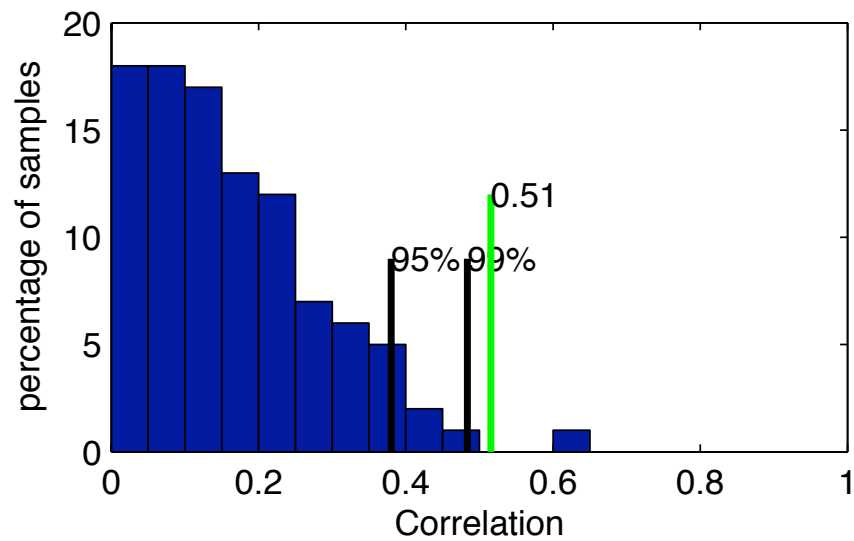
Furtado and Di Lorenzo, in prep.

PC 1 (ENSO)

PC 2 (NPGO) lead by ~10 months

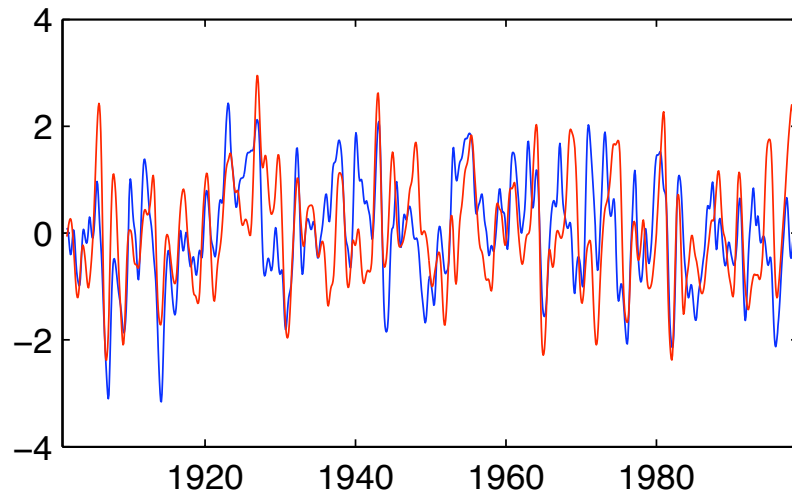


Probability distribution of correlation coefficient

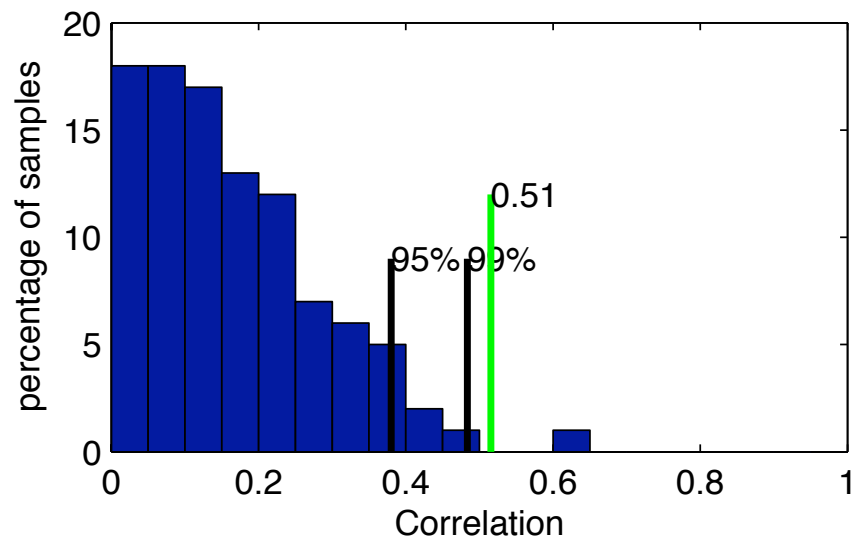


PC 1 (ENSO)

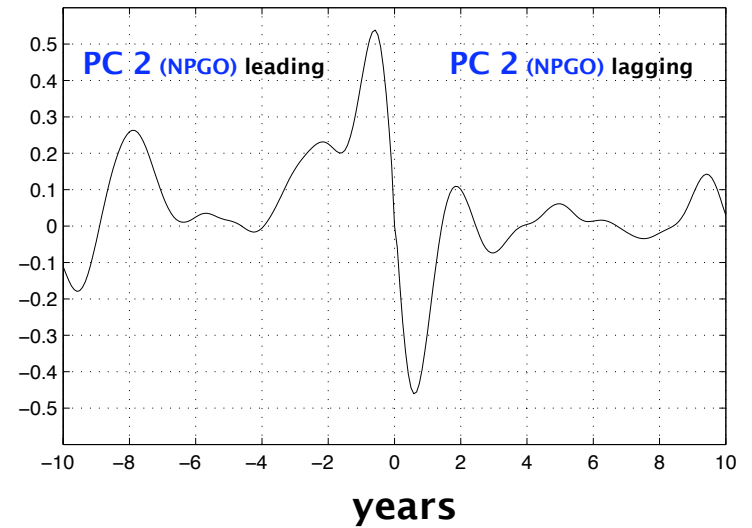
PC 2 (NPGO) lead by ~10 months

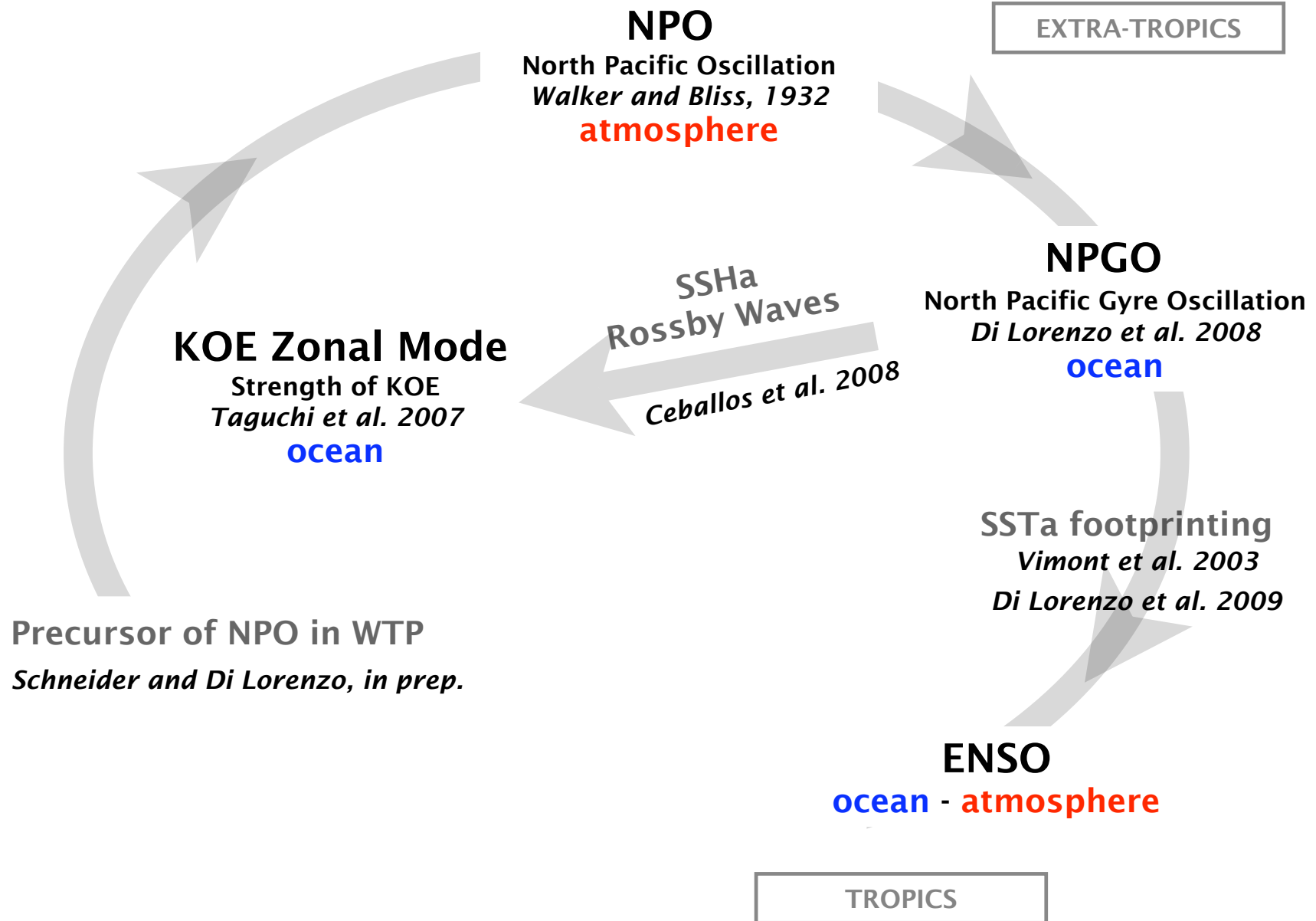


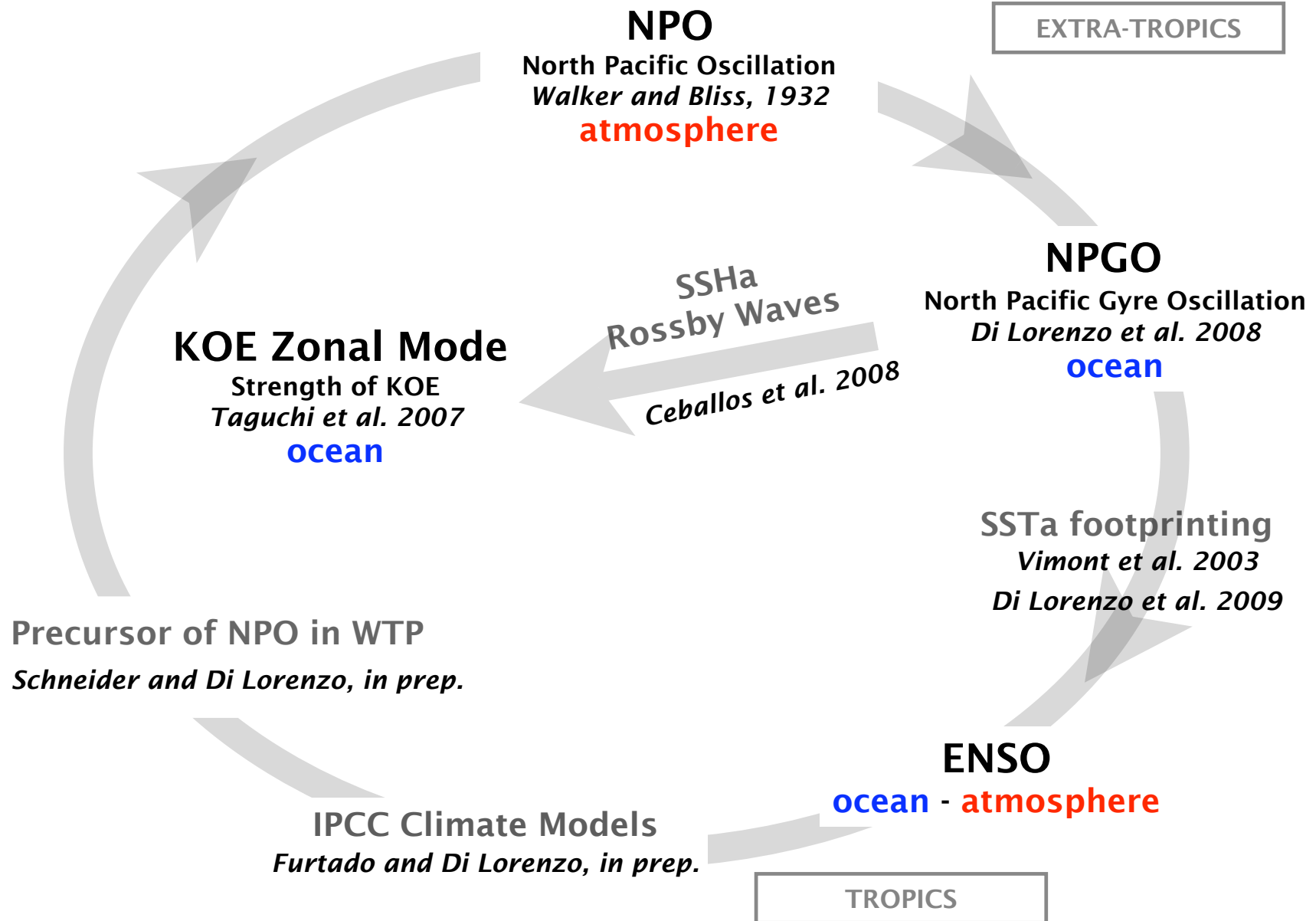
Probability distribution of correlation coefficient



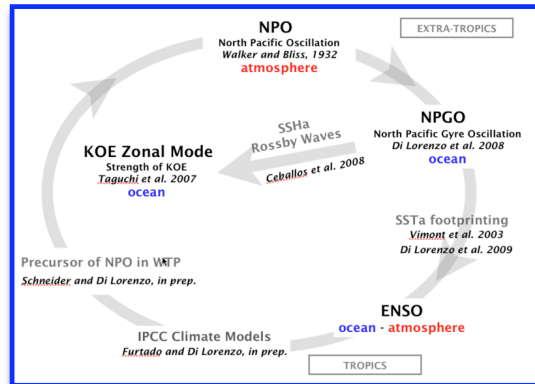
Lead/Lag correlations PC 1 vs. PC 2



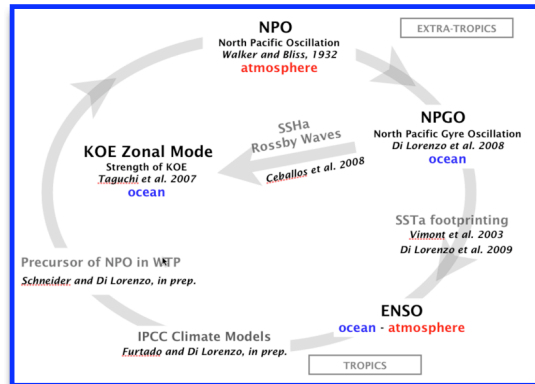




Pacific Climate Framework



Pacific Climate Framework



Emanuele Di Lorenzo - Pacific Ocean Boundary Ecosystems - www.Pacific-Ecosystems-Climate.Org

<http://www.pacific-ecosystems-climate.org/>

TibetMed - ...nd research - **NU Fotran / GCC** - The G95 project - VI - Figuring ren...epreciation - Bandwith Test - Holy Day Ma...Atlanta, GA

Pacific Ocean Boundary Ecosystems

<http://Pacific-Ecosystems-Climate.Org>

Home | Background | Research Results | Docs | Data Access | Images & Videos | Publications

NSF-GLOBEC Pan-regional Synthesis:
Pacific Ocean Boundary Ecosystems:
response to natural and anthropogenic climate forcing

PIs: E. Di Lorenzo, J. C. Furtado, A. Bracco, J. Keister, P.T. Strub, A. Thomas, P.J.S. Franks
NOAA Co-PIs: S. Bograd, W. Peterson, R. Mendelssohn, F. Schwing
Japanese Collaborators: S. Chiba, Y. Sasai, H. Sasaki, M. Nonaka, B. Taguchi, A. Ishida
South American Collaborators: O. Pizarro, R. Escibano, J. Rutllant, V. Montecino
Canadian Collaborators: D. Mackas, M. Foreman, A. Pena, W. Crawford

Project Goal - [POBE-Project-Summary.pdf]

Using US and international observational datasets combined with physical and biological models, this project investigates the mechanisms of climate-related variability in three Pacific boundary ecosystems: Gulf of Alaska (GOA) and California Current System (CCS) referred to as the Northeast Pacific (NEP), the Humboldt or Peru-Chile Current System (PCCS), and the Kuroshio-Oyashio Extension (KOE) region.

1 Large-scale climate mode in the PHYSICS
NPGO pattern in Global SSTa

Corr(SSTa, NPGO)

-0.6 -0.4 -0.2 0 0.2 0.4 0.6

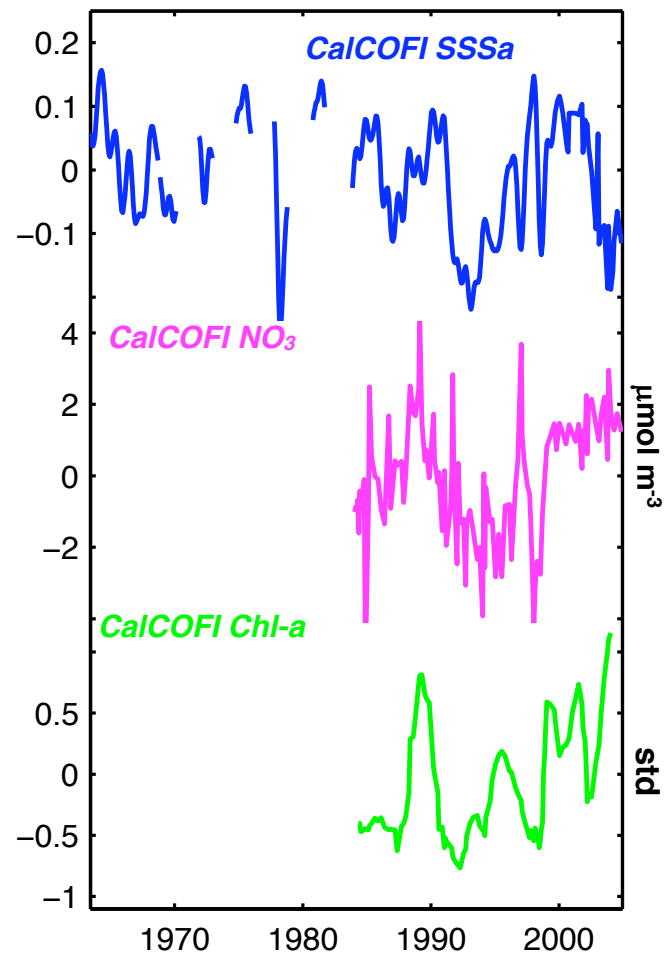
2 ECOSYSTEM footprint along Pacific Boundaries
NPGO pattern in SeaWiFS CHL-a

Pacific Ocean Ecosystem Boundary Study Regions

Corr(CHL-a, NPGO)

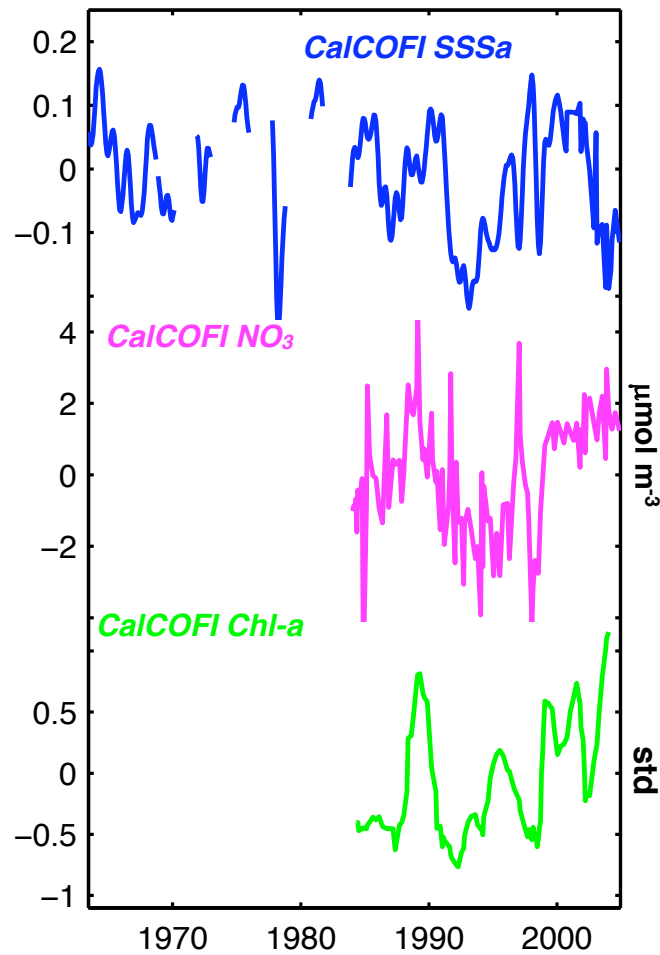
-0.6 -0.4 -0.2 0 0.2 0.4 0.6

END



QUESTION:

How does NPGO affect locally the Southern California Current?



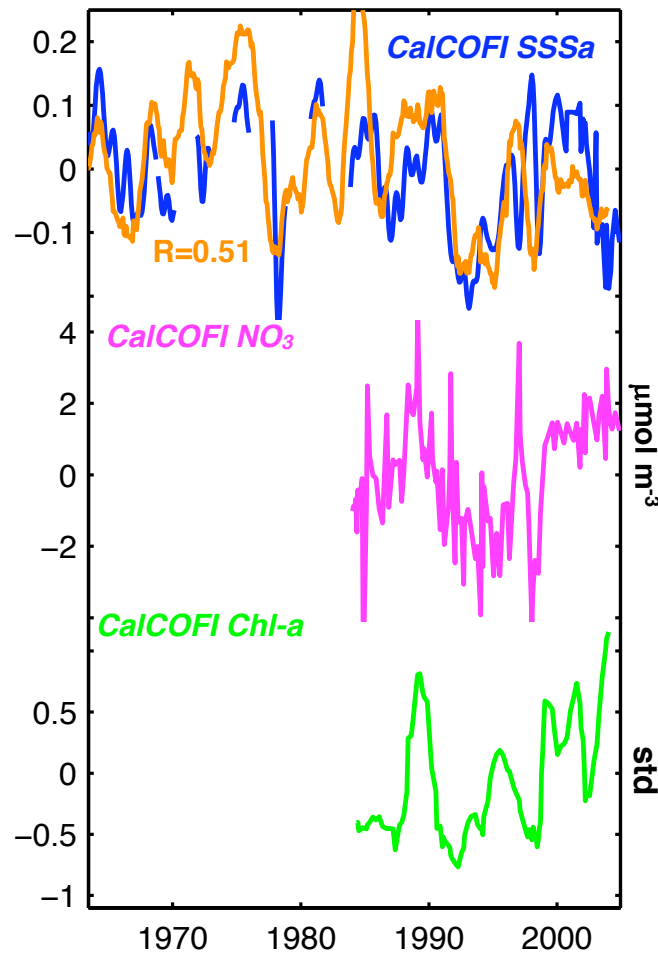
QUESTION:

How does NPGO affect locally the Southern California Current?

hypothesis:

Atmospheric forcing associated with NPGO modulates upwelling

Alongshore Wind Stress in CCS



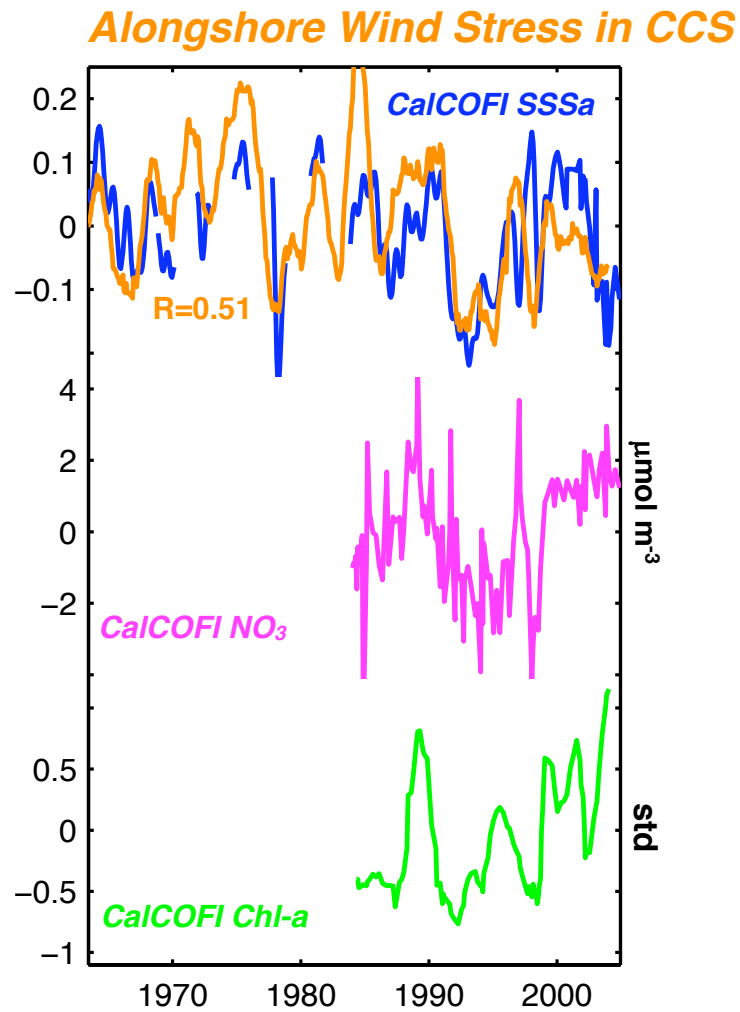
QUESTION:

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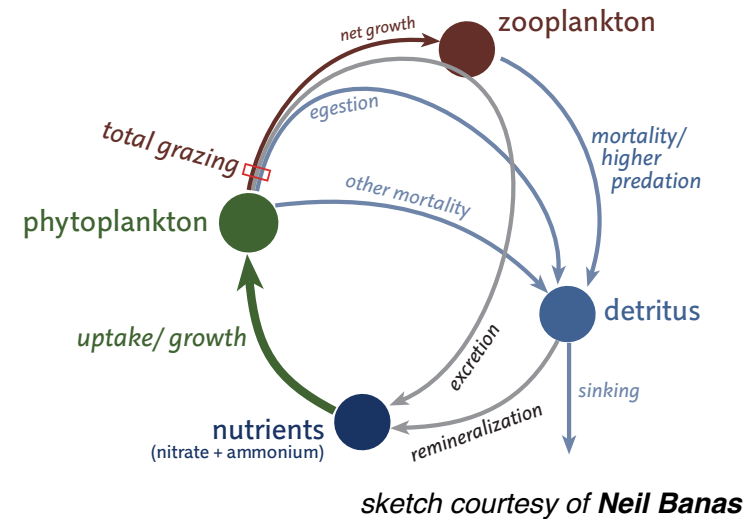
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Atmospheric forcing associated with NPGO modulates upwelling

Testing the Upwelling Hypothesis



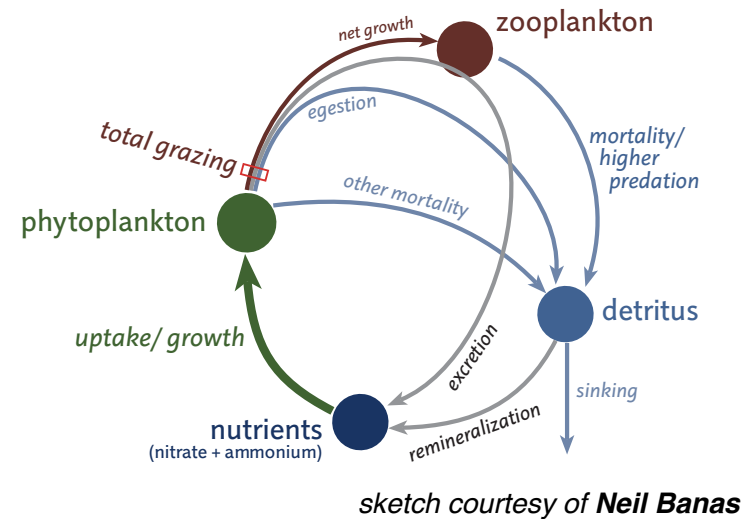
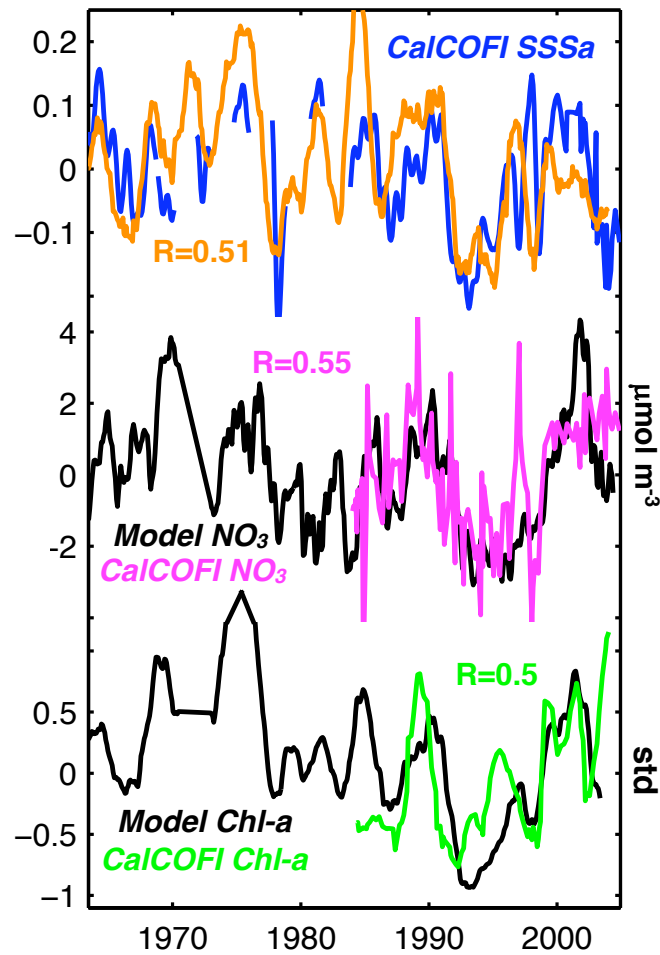
NPZD “simplistic” model



Testing the Upwelling Hypothesis

NPZD “simplistic” model

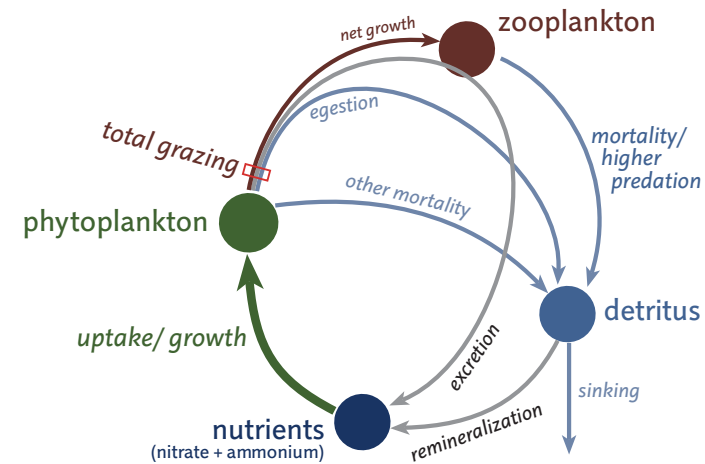
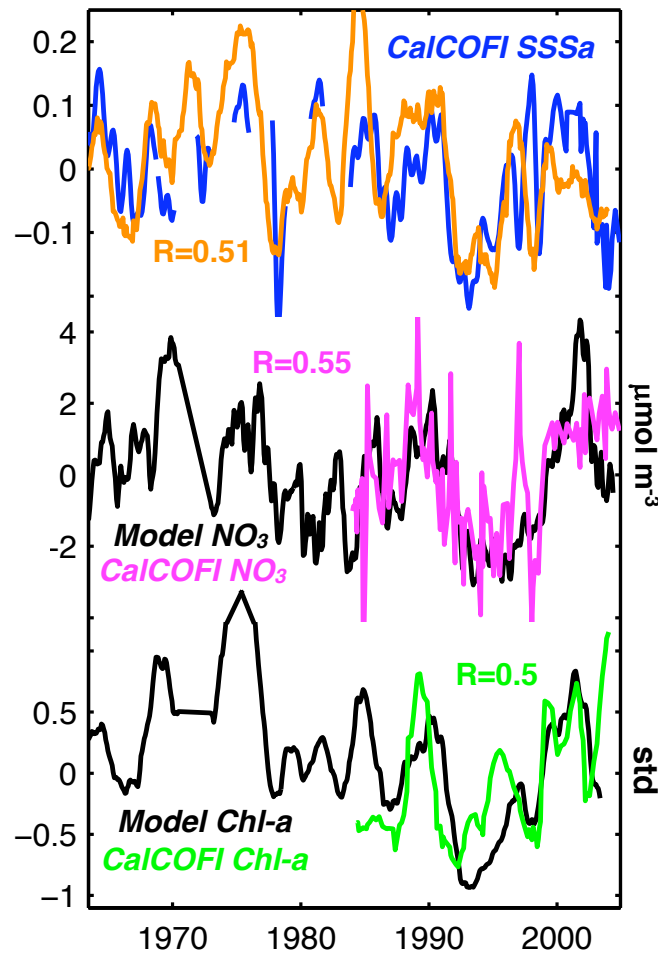
Alongshore Wind Stress in CCS



Testing the Upwelling Hypothesis

NPZD “simplistic” model

Alongshore Wind Stress in CCS



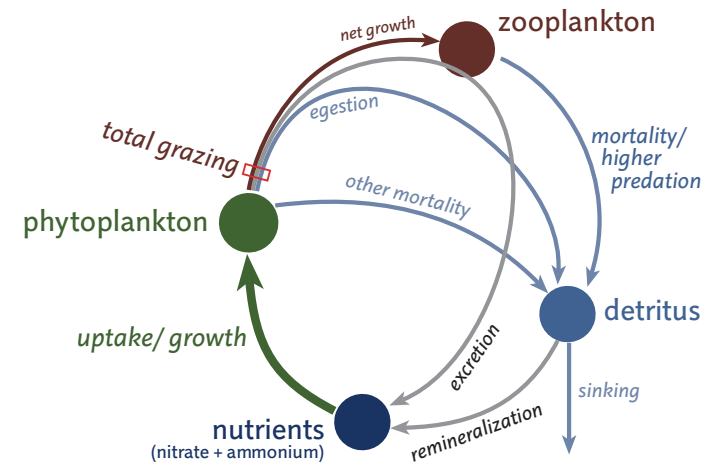
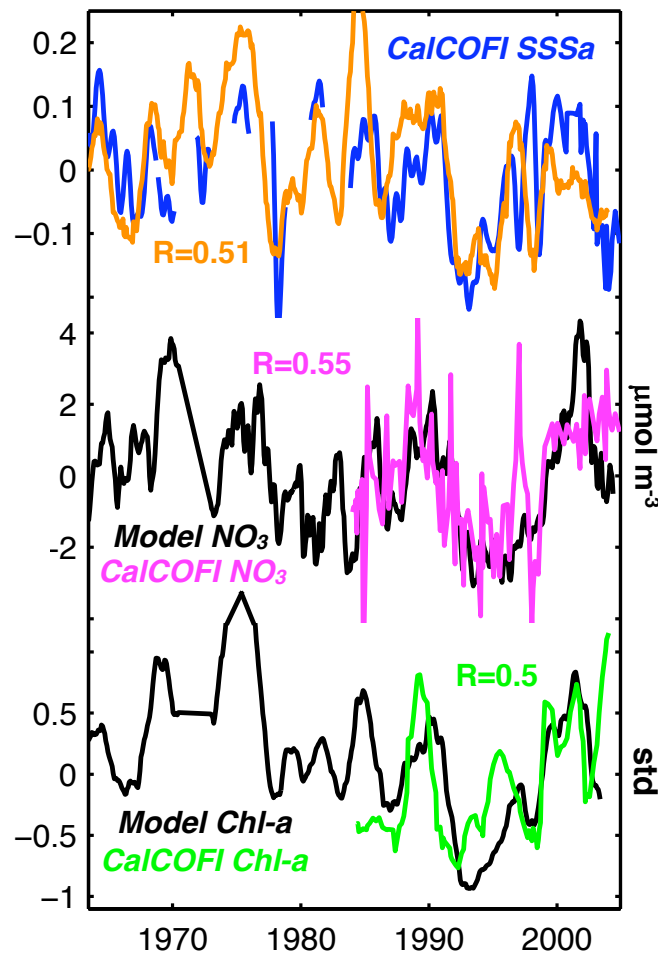
sketch courtesy of **Neil Banas**

Fluctuations in lower ecosystem levels are consistent with bottom-up forcing

Testing the Upwelling Hypothesis

NPZD “simplistic” model

Alongshore Wind Stress in CCS



sketch courtesy of Neil Banas

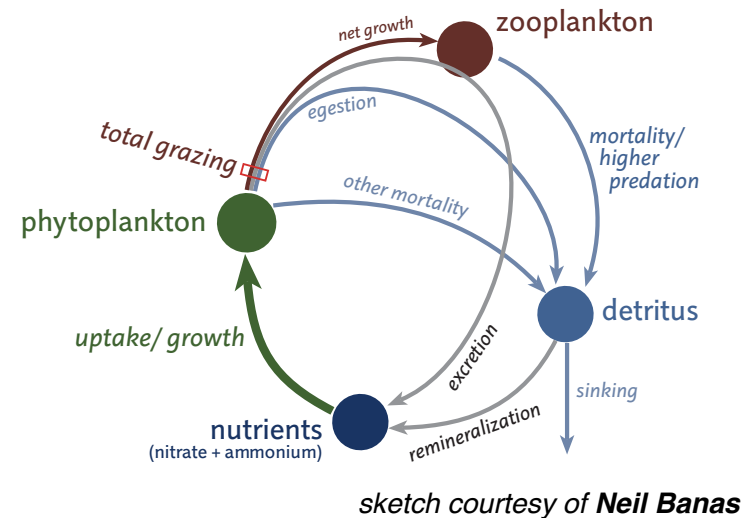
Fluctuations in lower ecosystem levels are consistent with bottom-up forcing



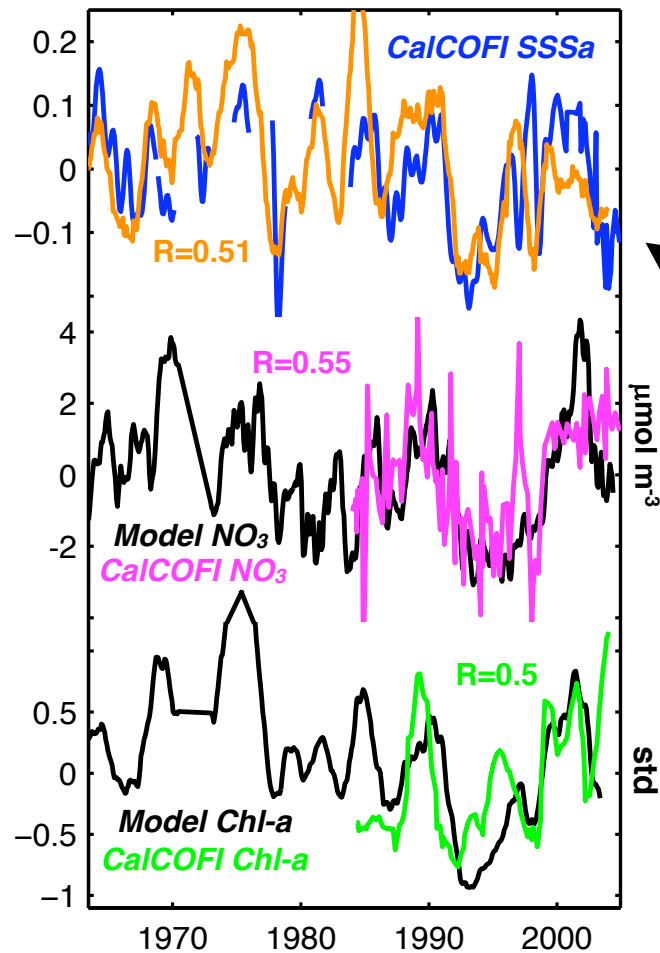
Rykaczewski and Checkley, 2008:
changes in upwelling drive changes in fish

Testing the Upwelling Hypothesis

NPZD “simplistic” model

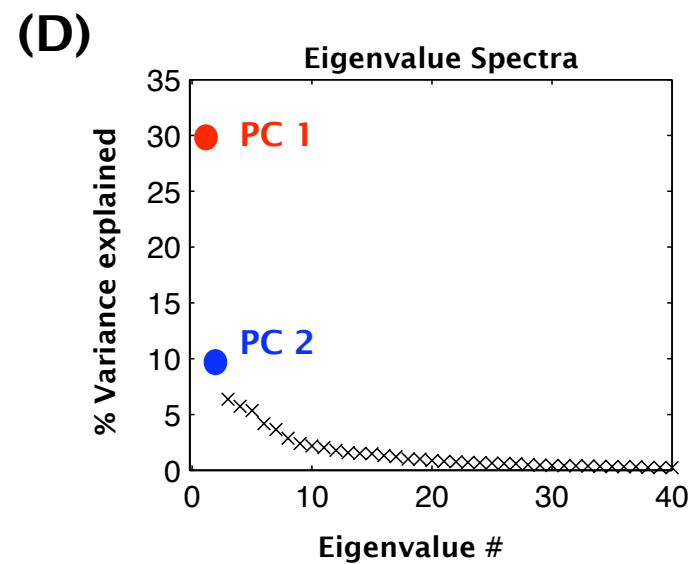
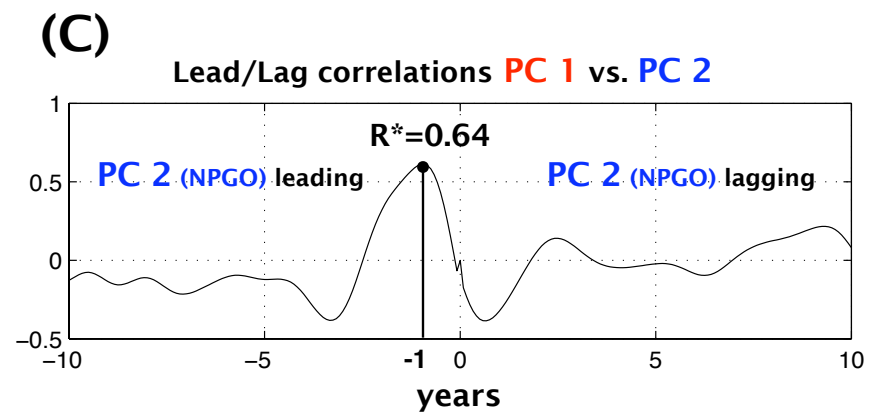
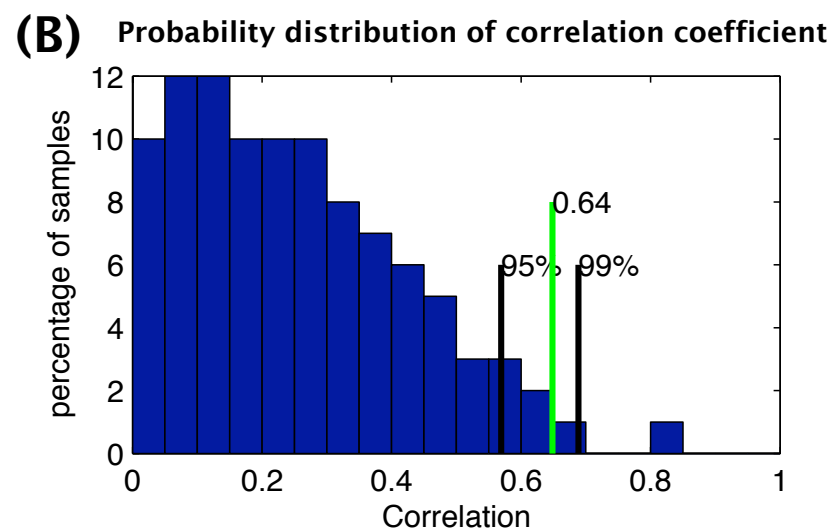
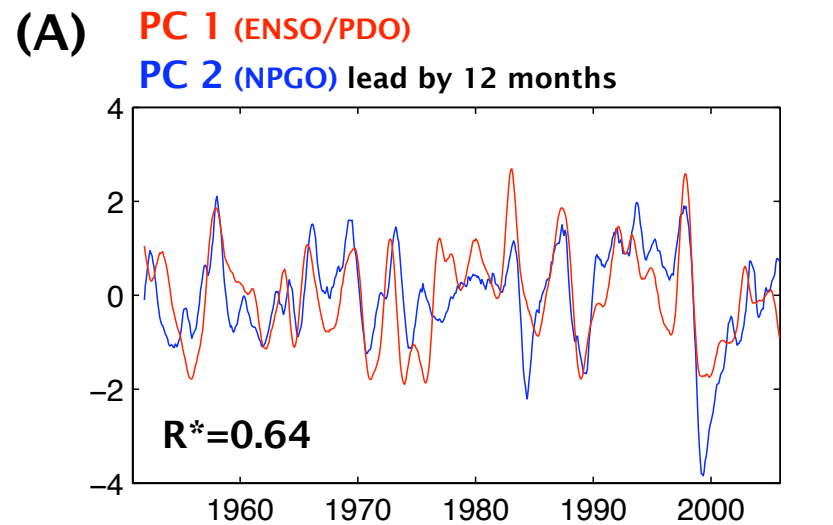


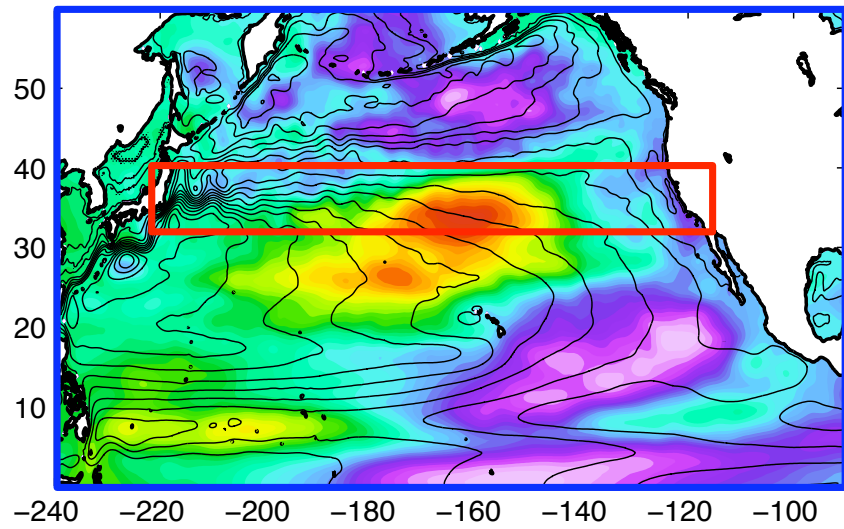
Alongshore Wind Stress in CCS



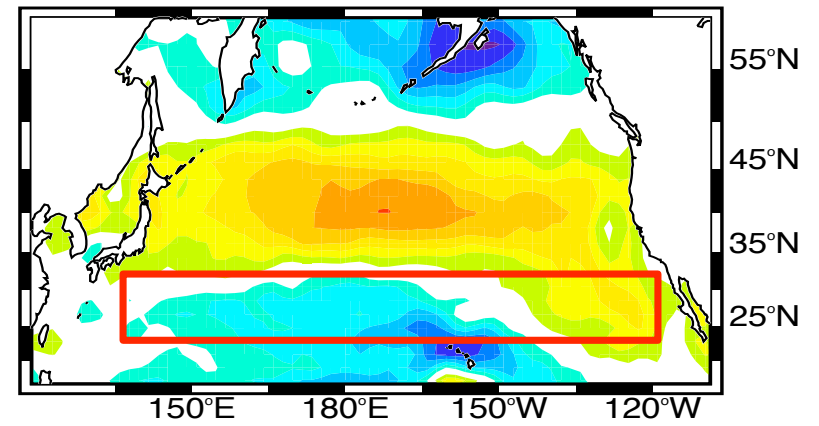
QUESTION:

How are coastal upwelling winds in the CCS linked to large-scale forcing?

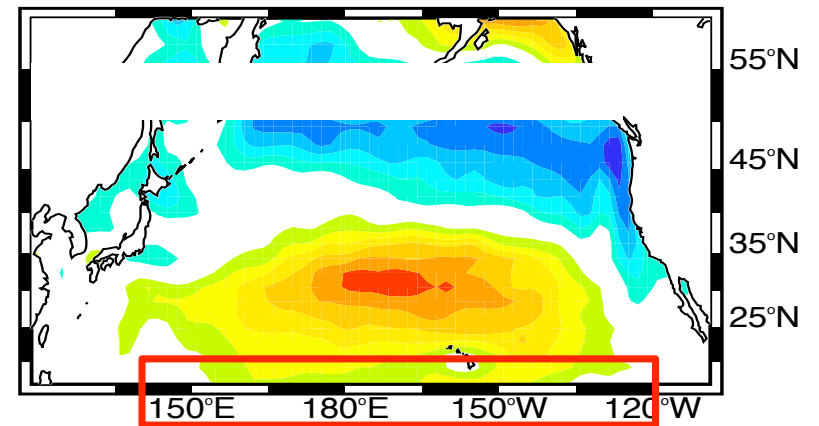




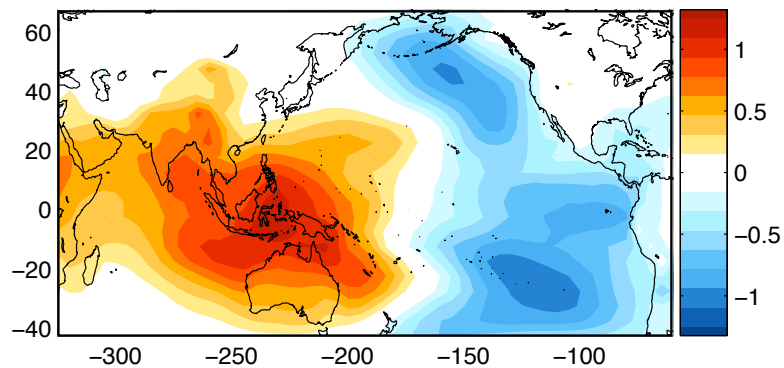
$\text{curl} \vec{\tau}_{NPO}$



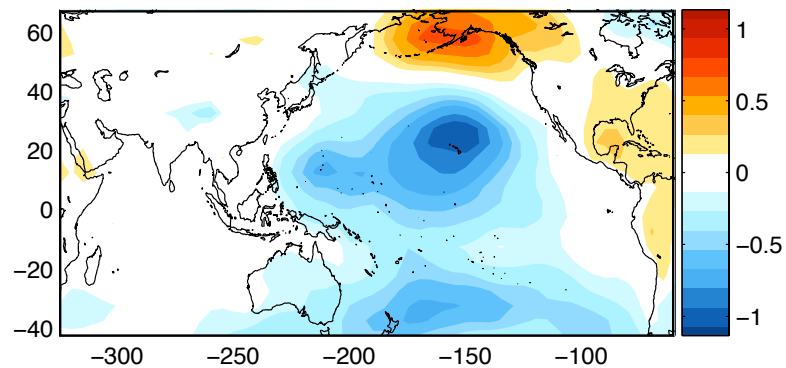
d) Correlation WSC-SLP_{PC-1}



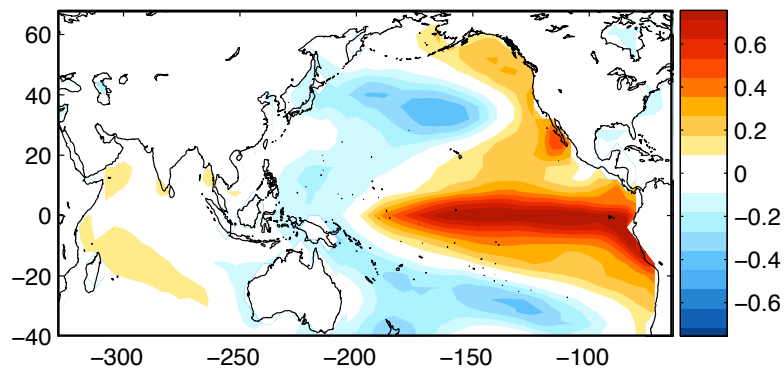
SLPa combined EOF 1



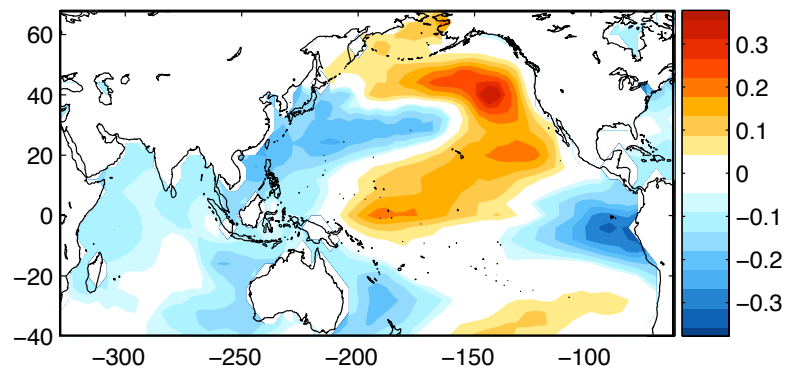
SLPa combined EOF 2



SSTa combined EOF 1

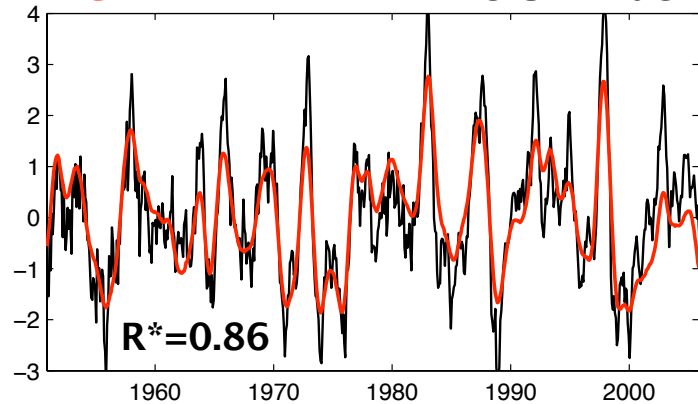


SSTa combined EOF 2



PC 1

NINO 3.4 index



PC 2

NPGO index

