

FORECASTING NORTH PACIFIC CLIMATE AND ECOSYSTEM CHANGE: *ADVANCES AND CHALLENGES*

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of Technology



PICES Annual Meeting, Korea 2014


FORECASTING NORTH PACIFIC CLIMATE AND ECOSYSTEM CHANGE: *ADVANCES AND CHALLENGES*

QUESTION:

Which advances in Pacific climate enable ecosystem forecasting ?



NOTICE:

WG27 contributions --> 
minimize use of climate acronyms


ECOSYSTEM CHANGE:
PICES

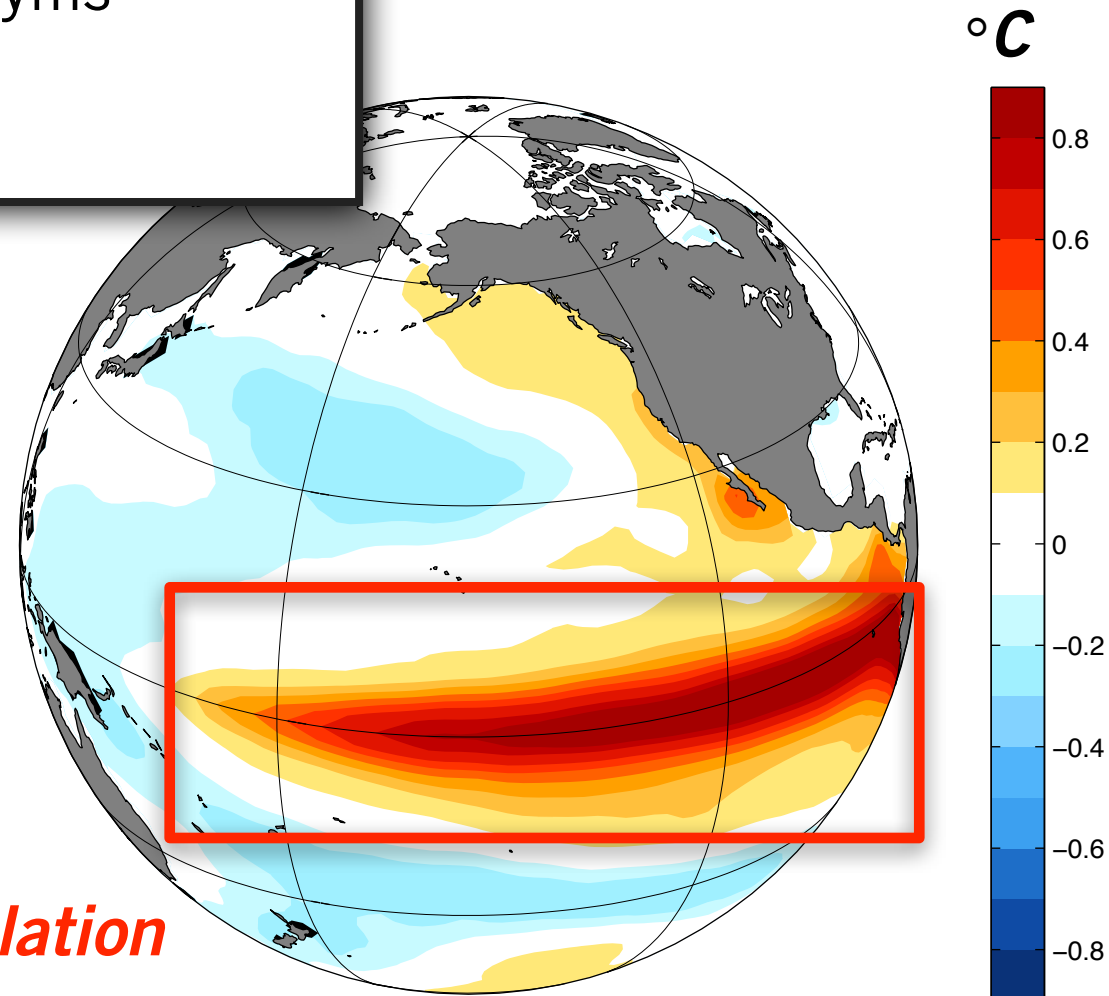
QUESTION:

Which advances in Pacific climate
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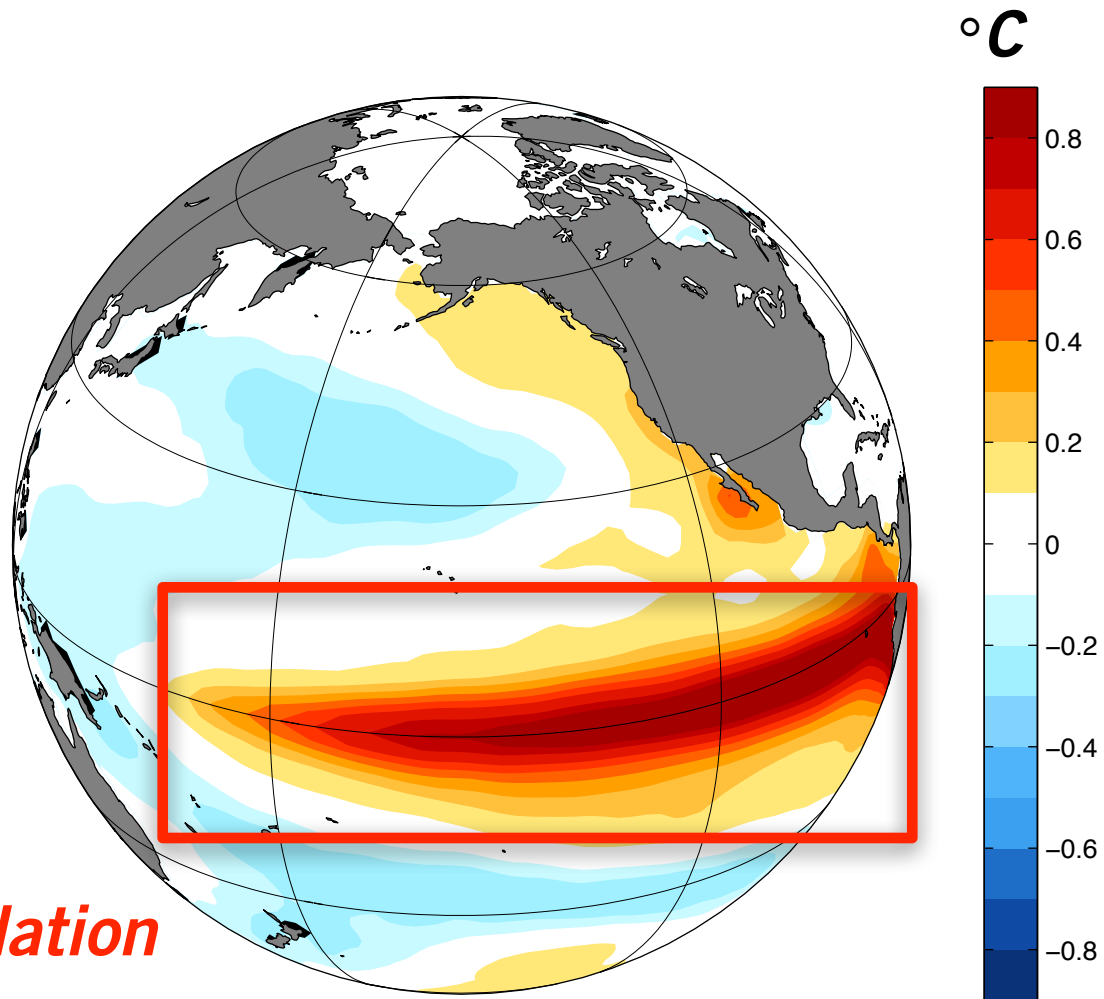
NOTICE:

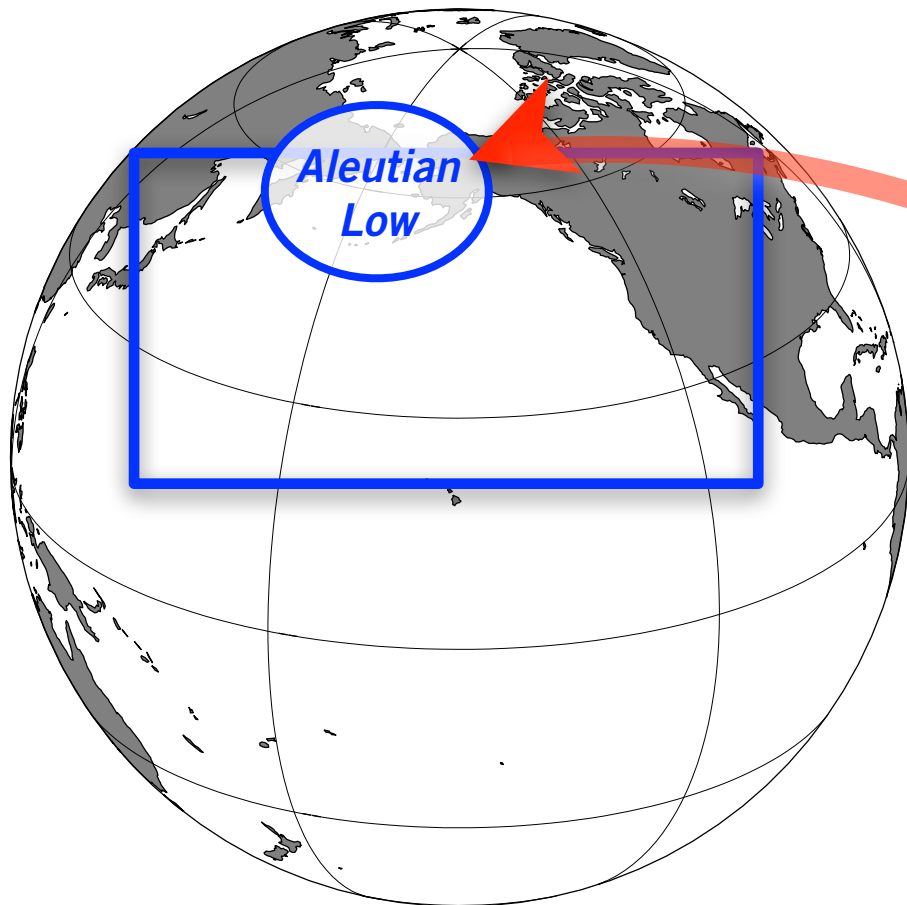
WG27 contributions --> 
minimize use of climate acronyms



El Niño
Southern Oscillation

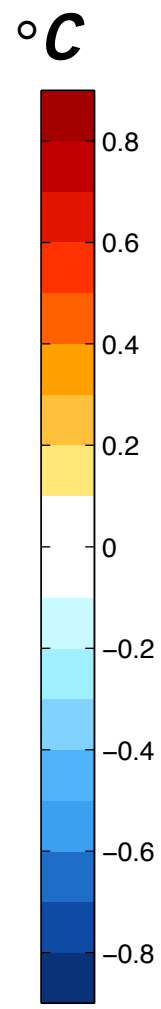
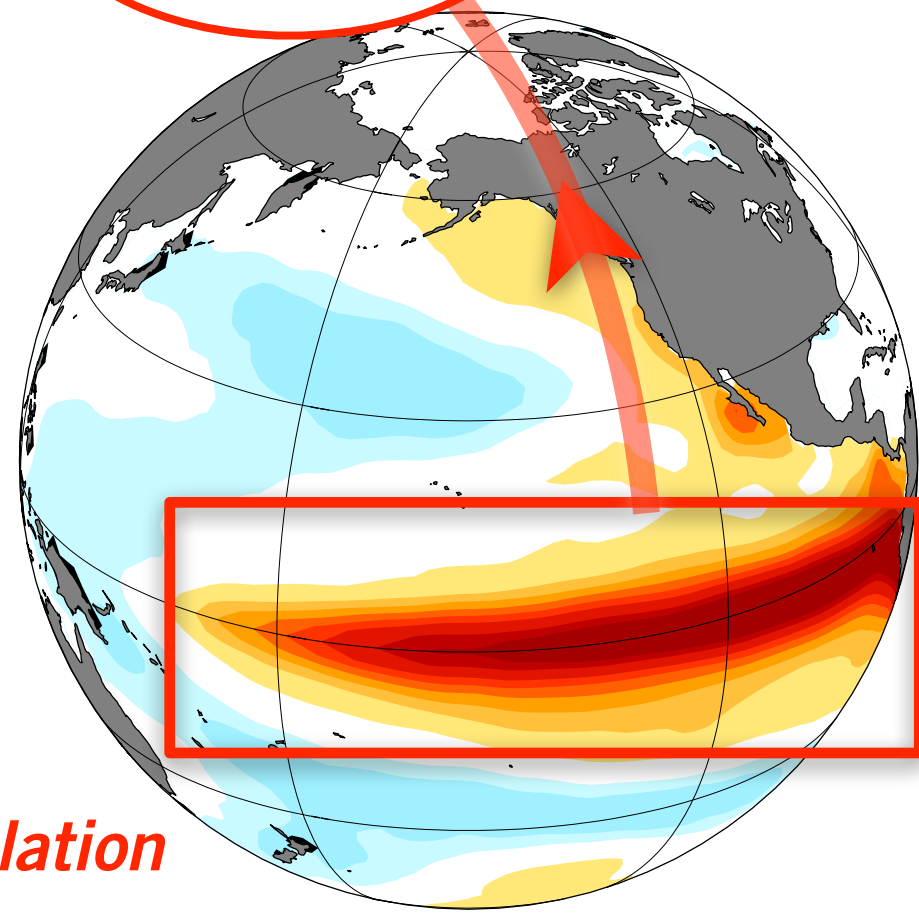
El Niño
Southern Oscillation



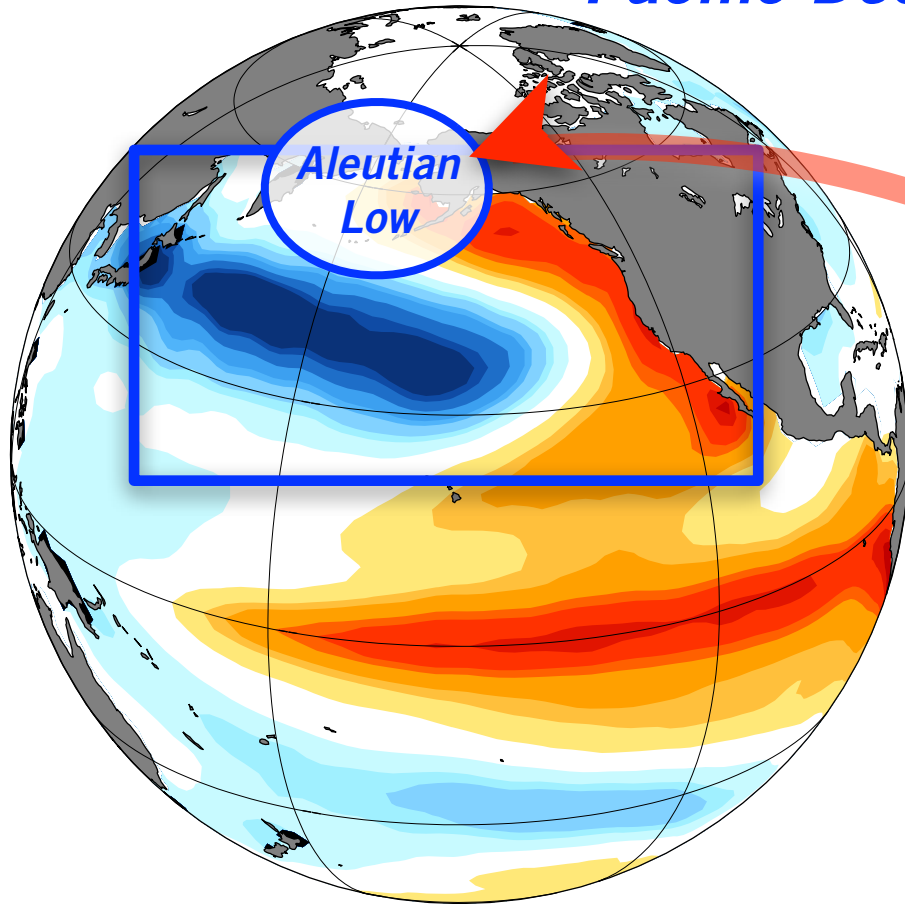


Atmospheric Teleconnections

*El Niño
Southern Oscillation*



Pacific Decadal Oscillation

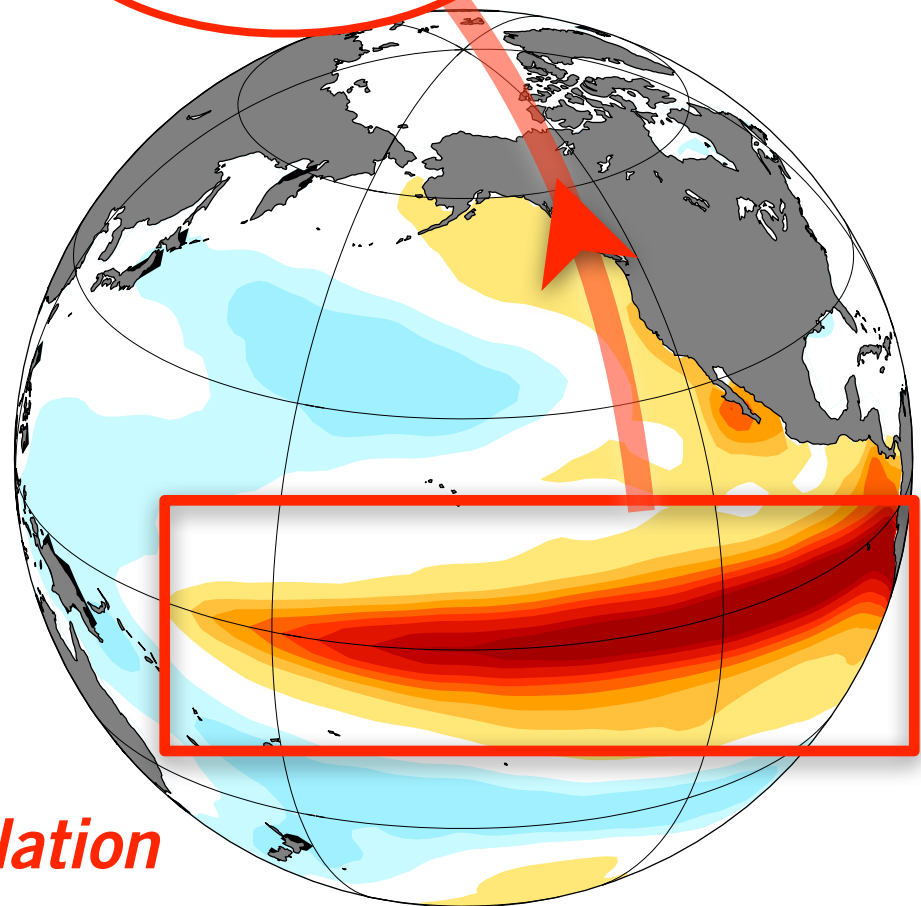


SSTa

Alexander et al. 1992
Newman et al. 2003
Scheider et al., 2007
Chhak et al. 2009

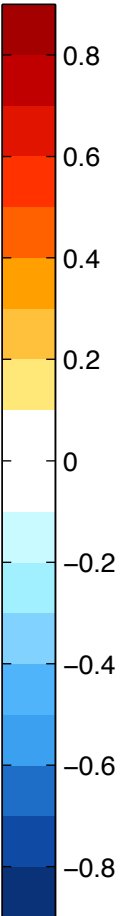


Atmospheric Teleconnections

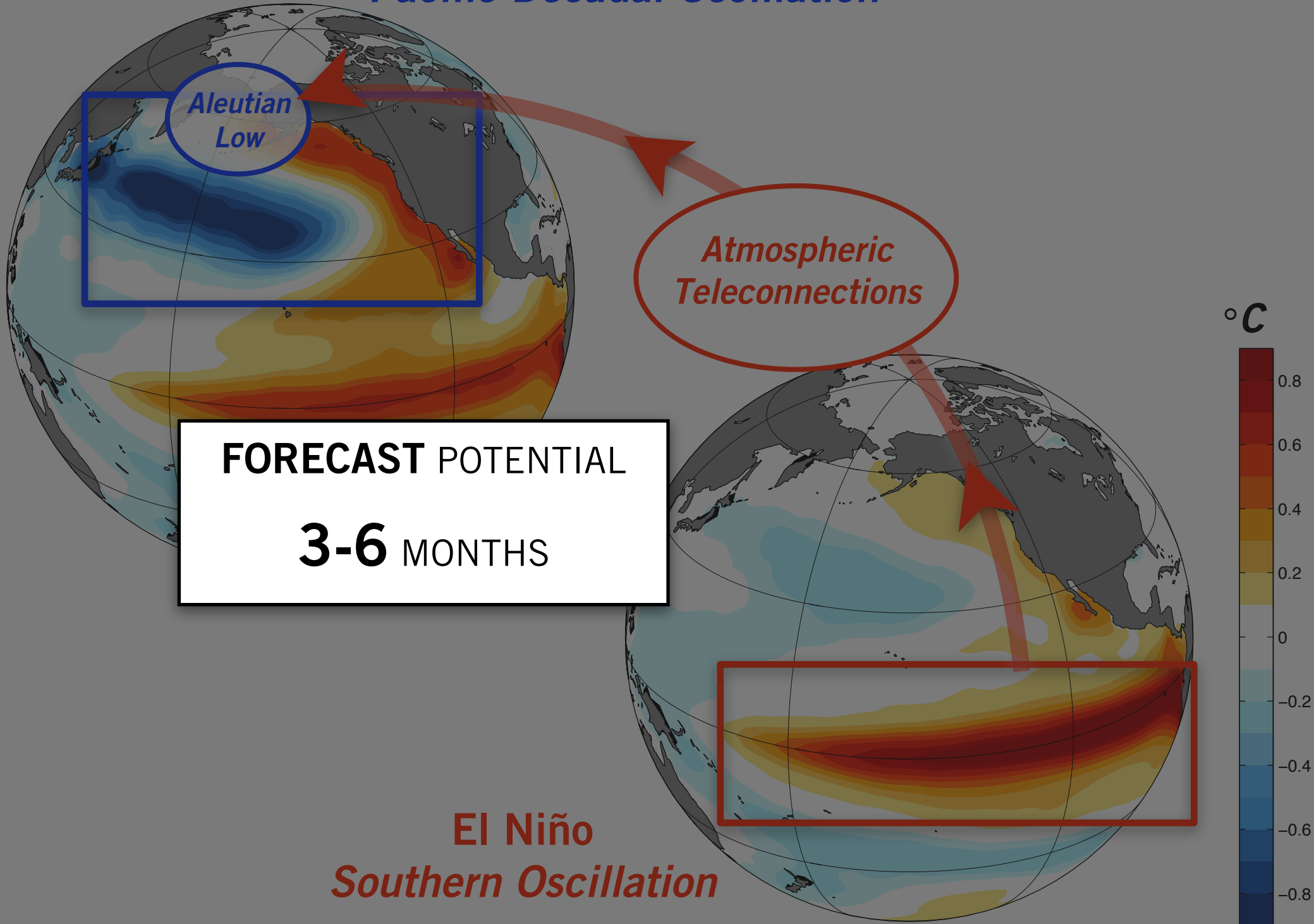


**El Niño
Southern Oscillation**

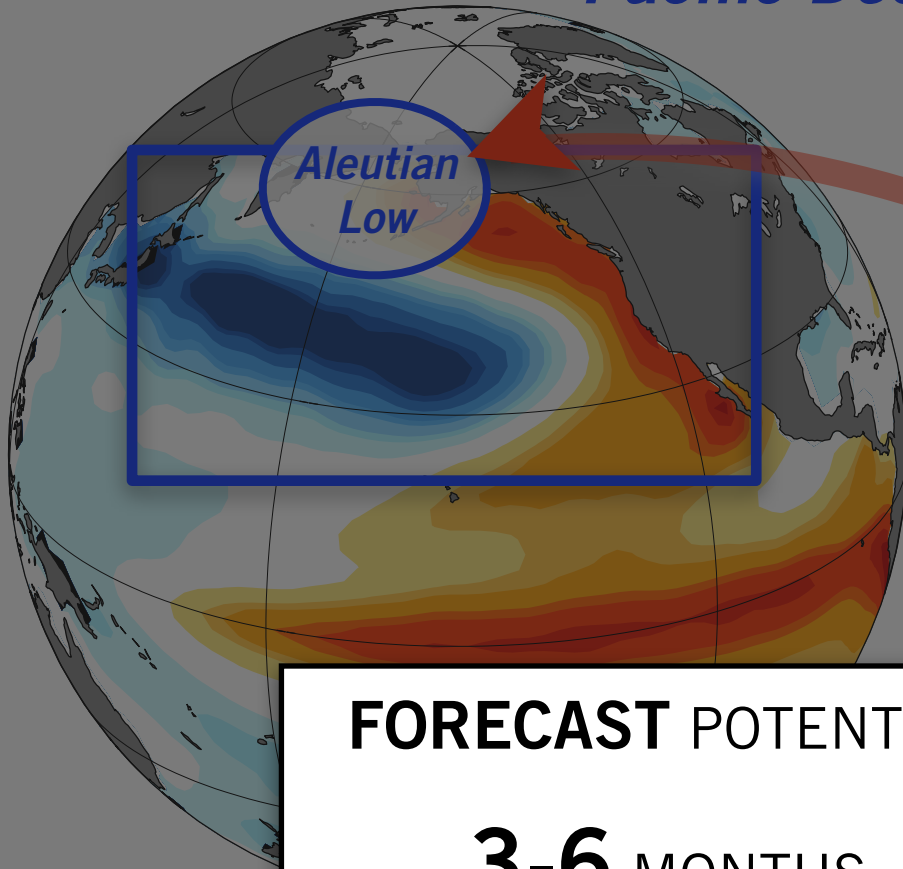
°C



Pacific Decadal Oscillation



Pacific Decadal Oscillation



FORECAST POTENTIAL
3-6 MONTHS

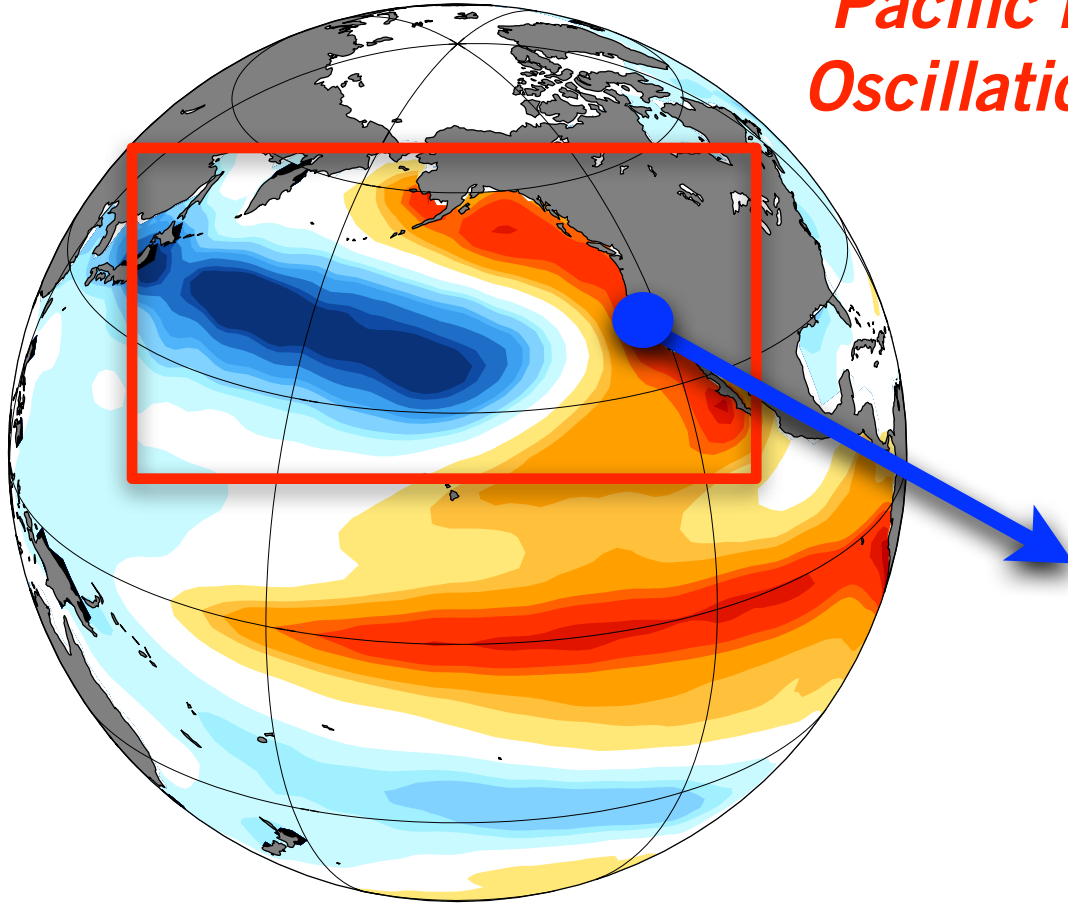
Atmospheric Teleconnections



PDO impacts krills and salmon

*El Niño
Southern Oscillation*

*Pacific Decadal
Oscillation (PDO)*

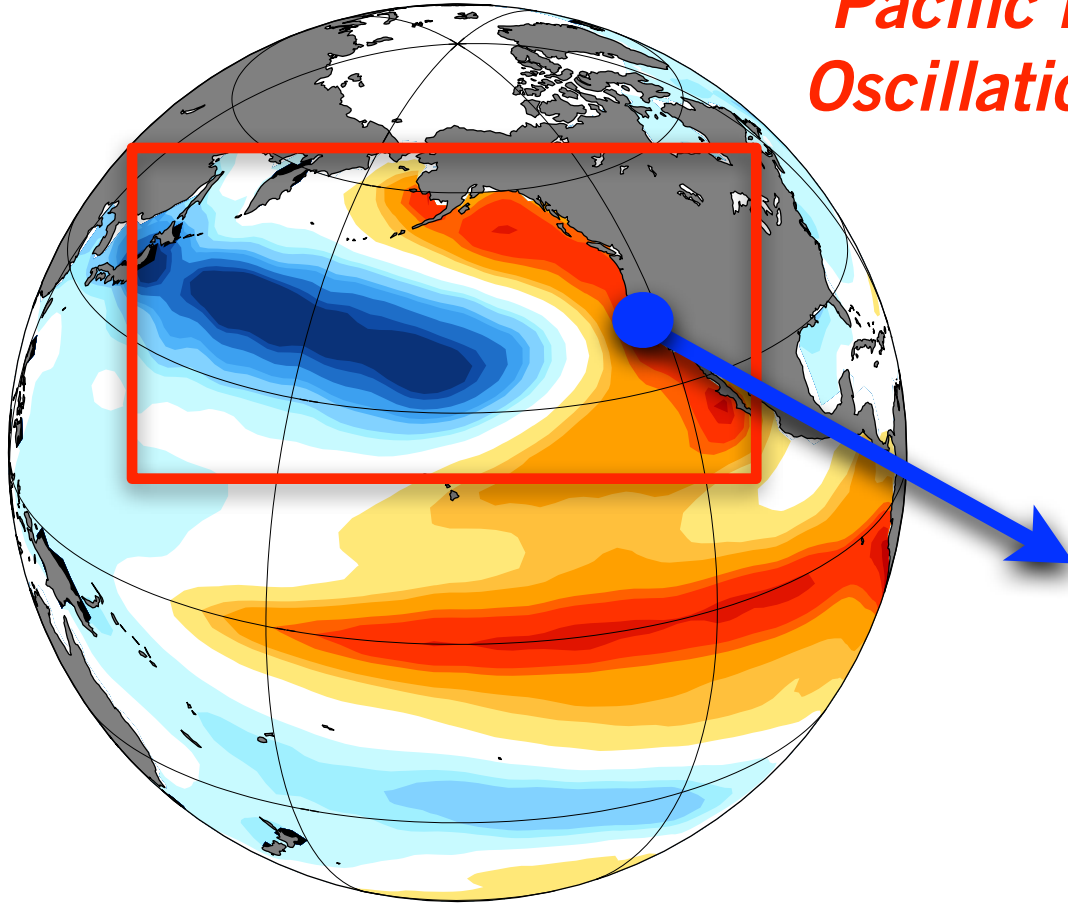


*California Current
Nyctiphanes simplex*

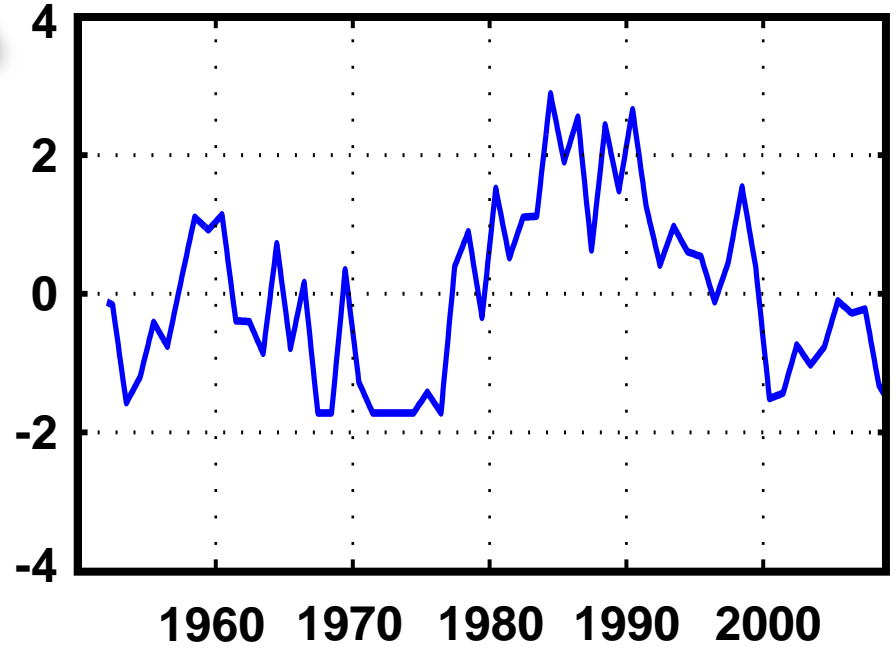


*PDO impacts
krills and salmon*

Pacific Decadal Oscillation (PDO)

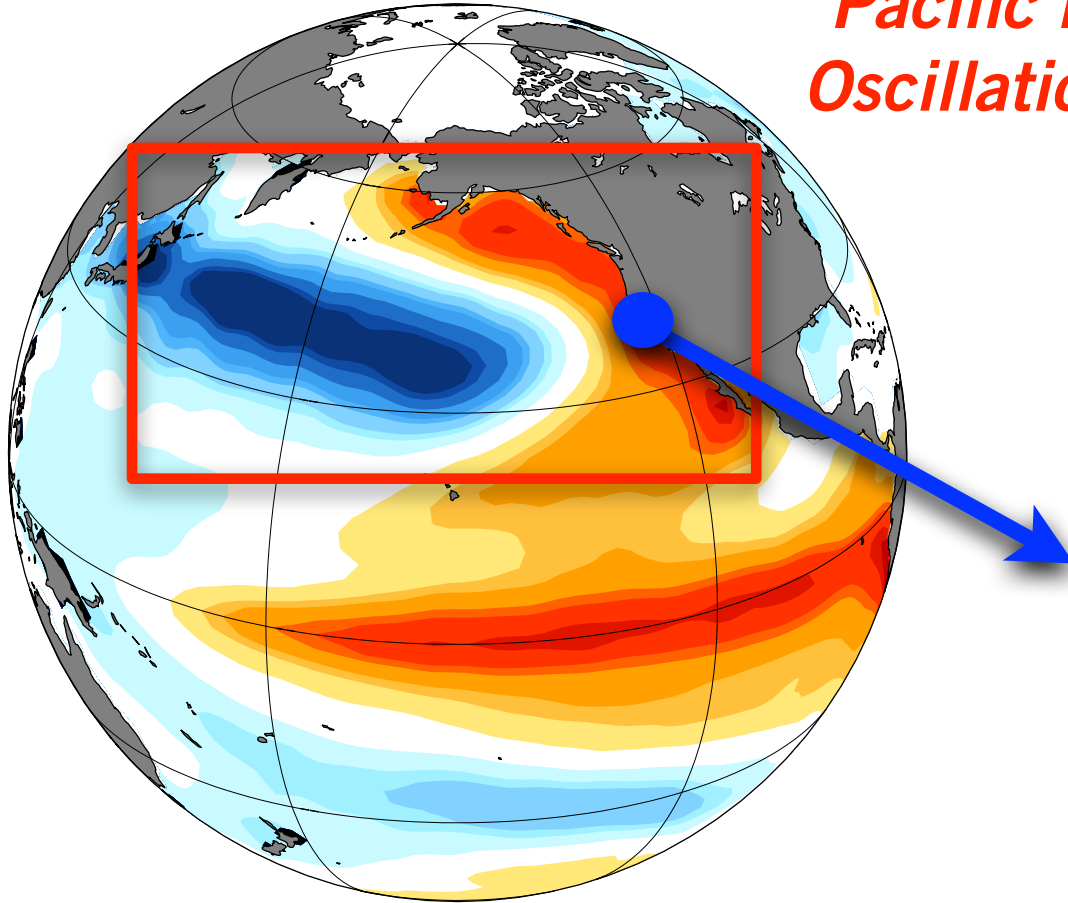


California Current Nyctiphanes simplex

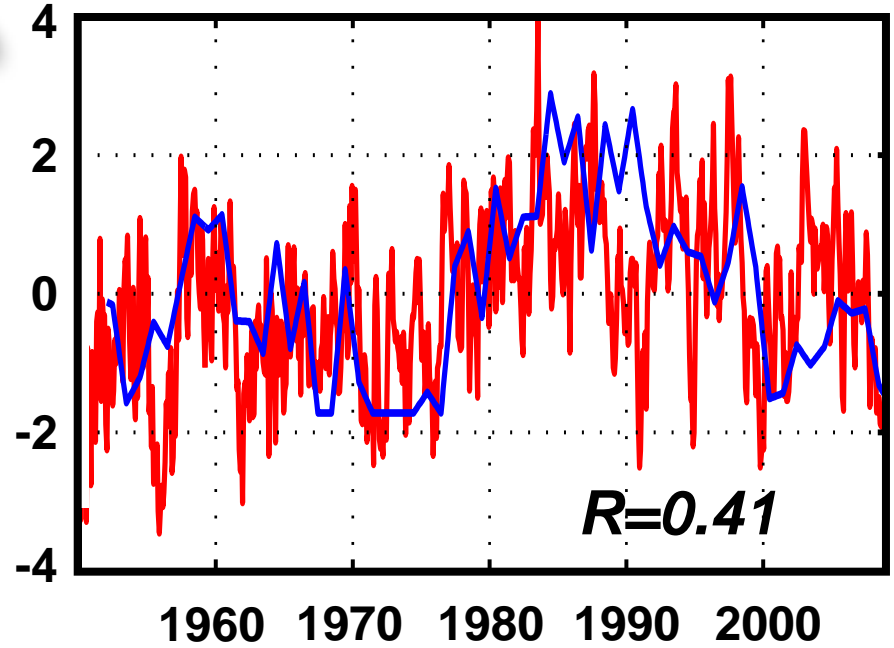


courtesy of Mark Ohman

Pacific Decadal Oscillation (PDO)

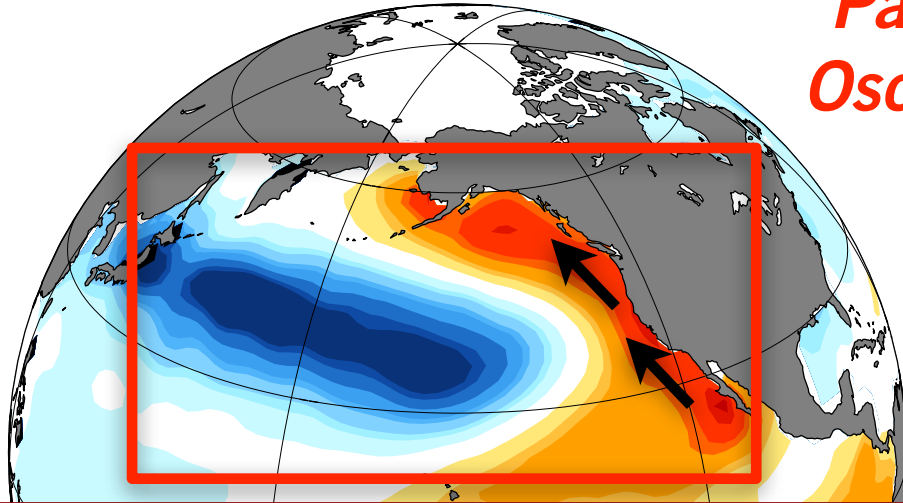


California Current Nyctiphanes simplex



PDO Index

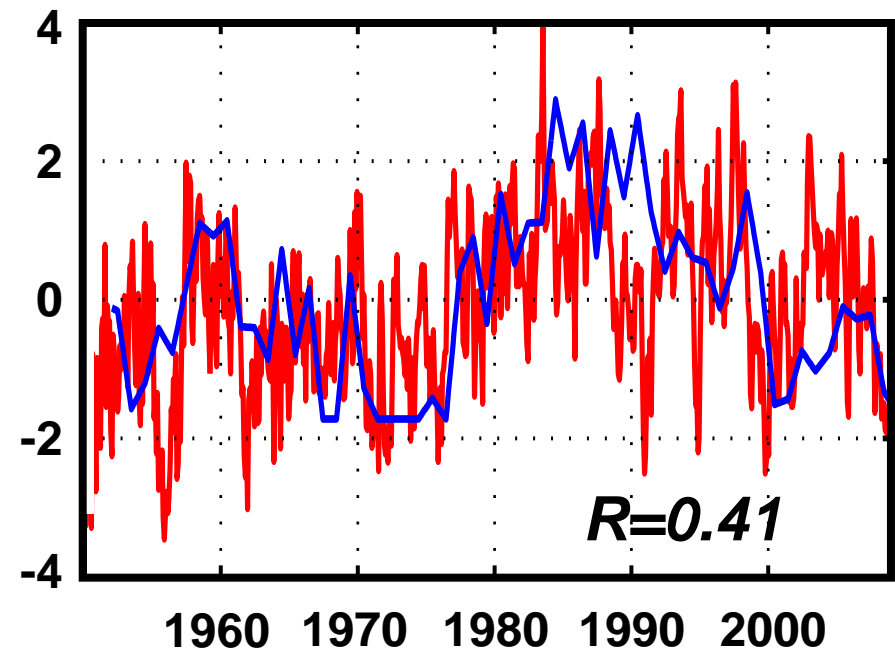
Pacific Decadal Oscillation (PDO)



Bill Peterson Hypothesis:

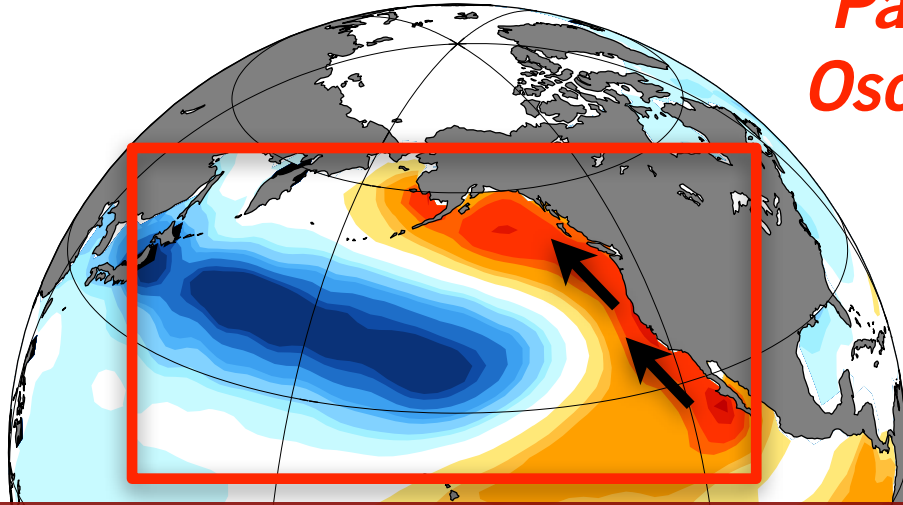
PDO changes the alongshore currents --> Zooplankton

California Current Nyctiphanes simplex



PDO Index

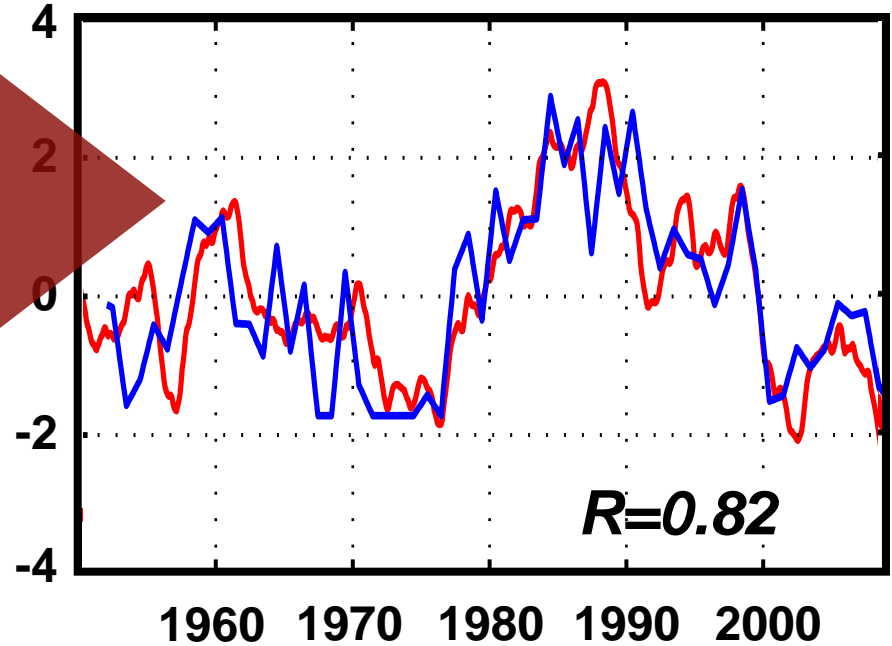
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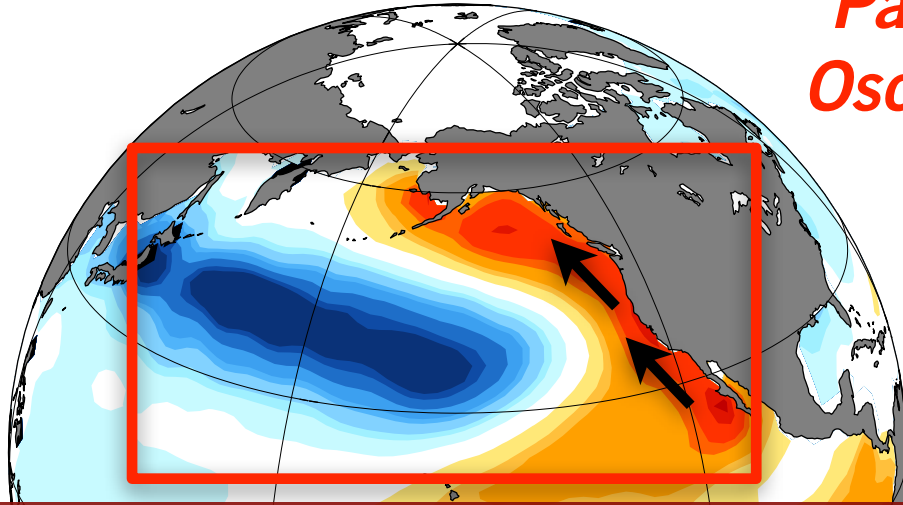
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California Current *Nyctiphanes simplex*



PDO Advection Model

Pacific Decadal Oscillation (PDO)



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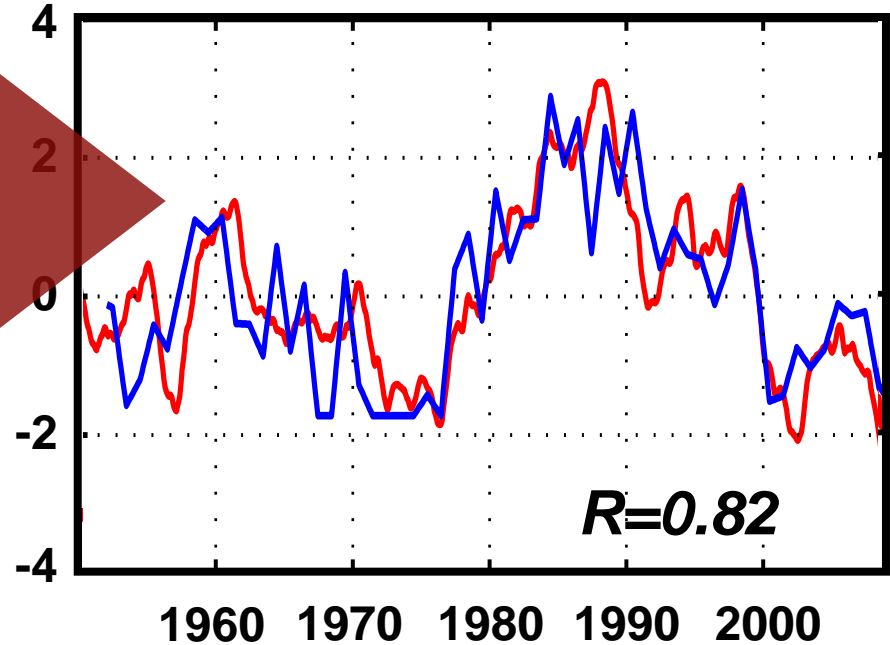
PDO changes the alongshore currents --> Zooplankton

Tested with modeling:

Oregon Shelf, *Keister et al. 2011* 

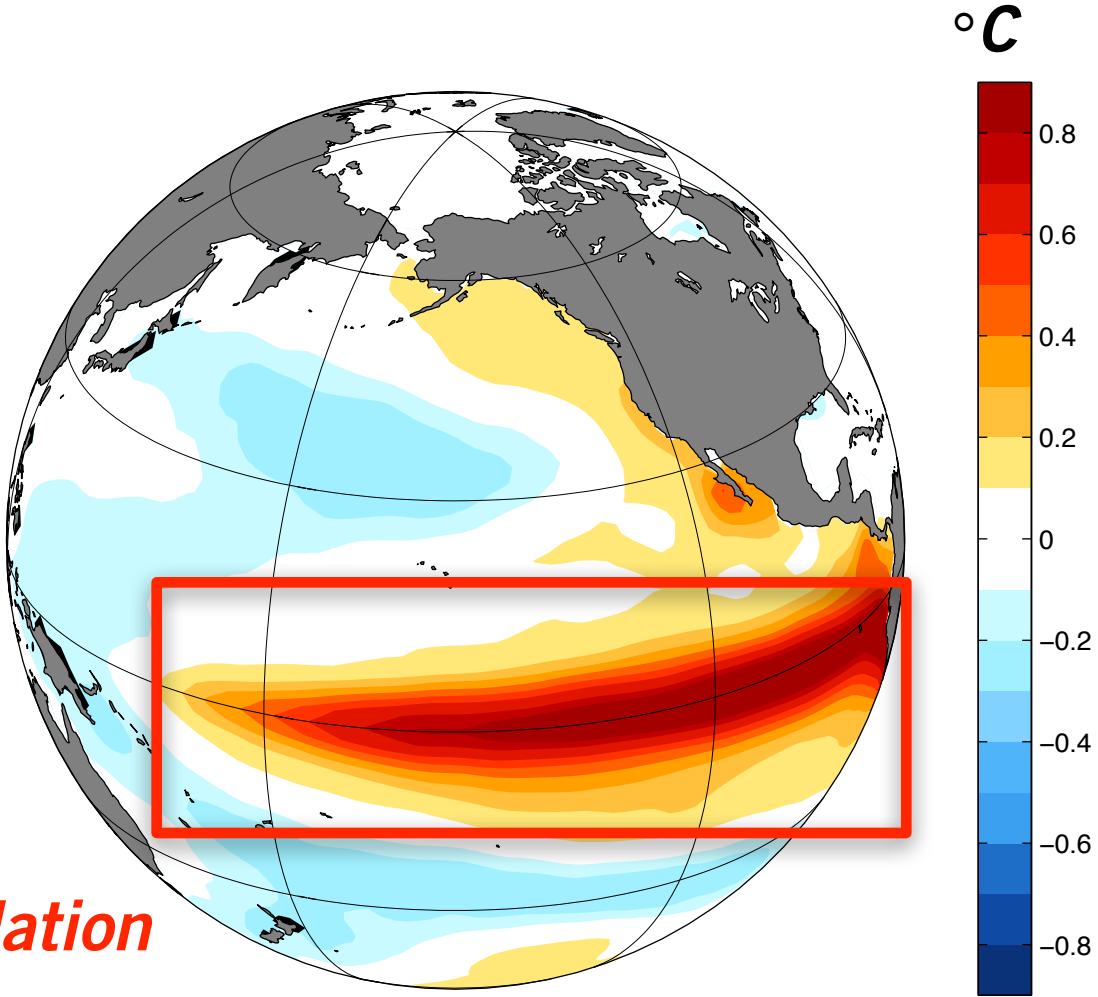
Southern California, *Di Lorenzo et al. 2013* 

California Current *Nyctiphanes simplex*

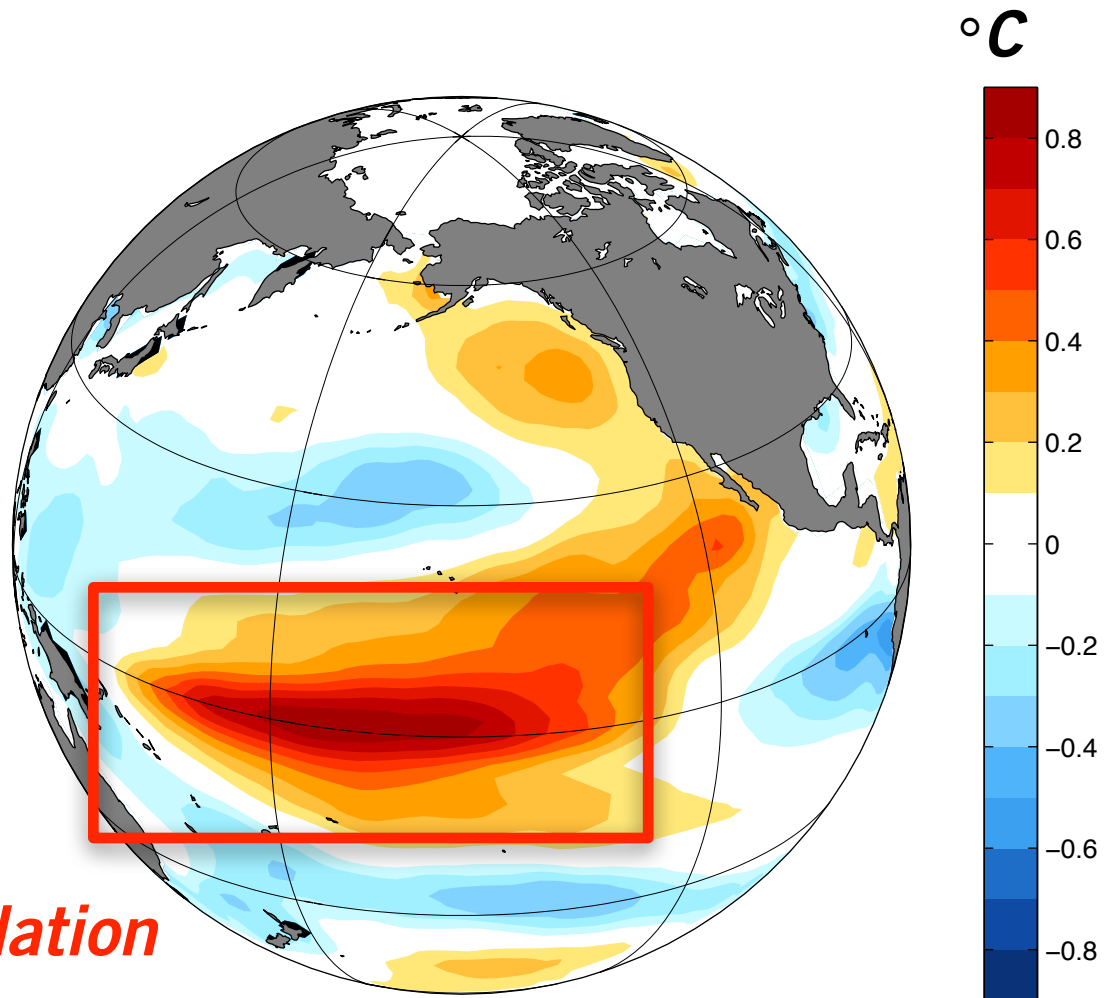


PDO Advection Model

El Niño
Southern Oscillation

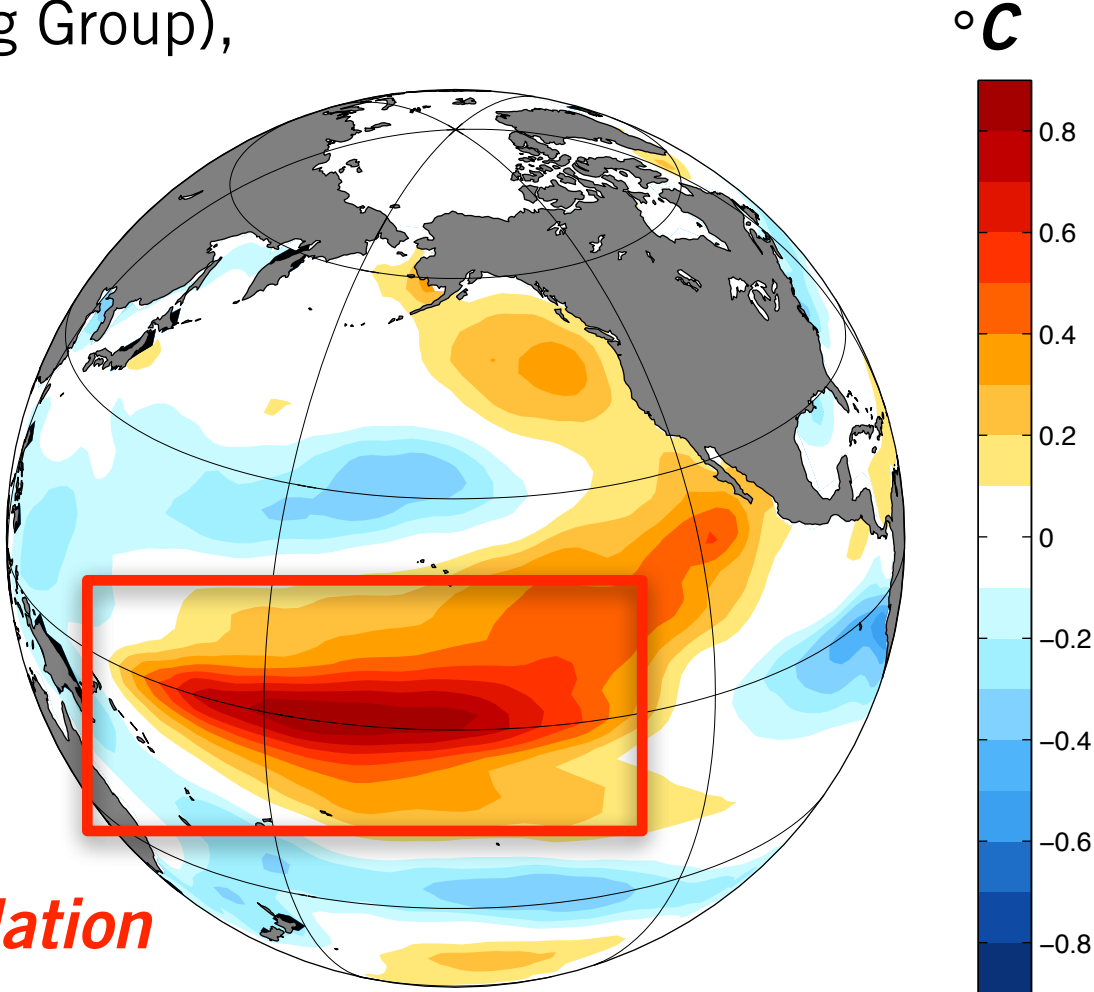


Central Pacific El Niño
Southern Oscillation

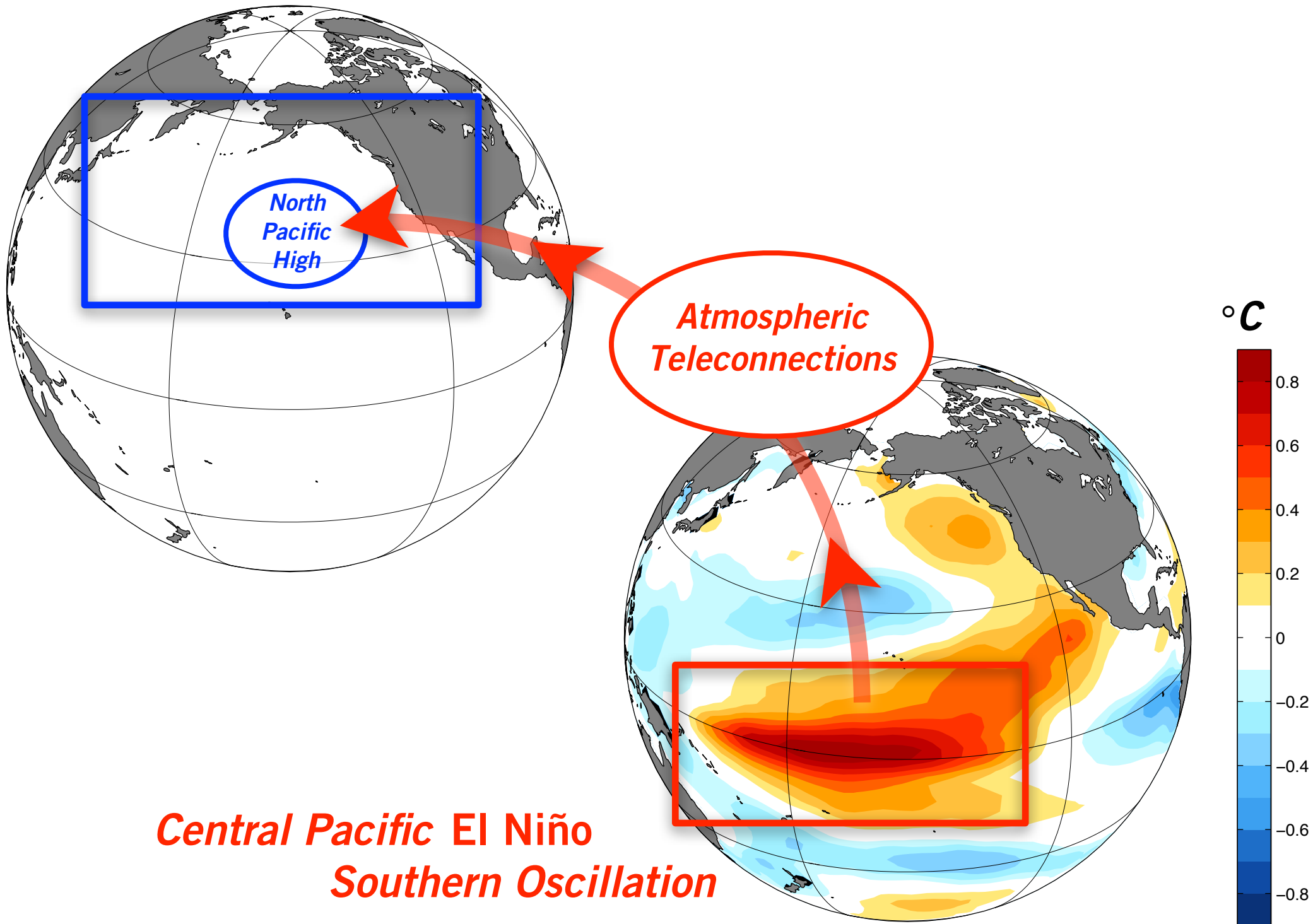


ENSO Diversity (CLIVAR Working Group),

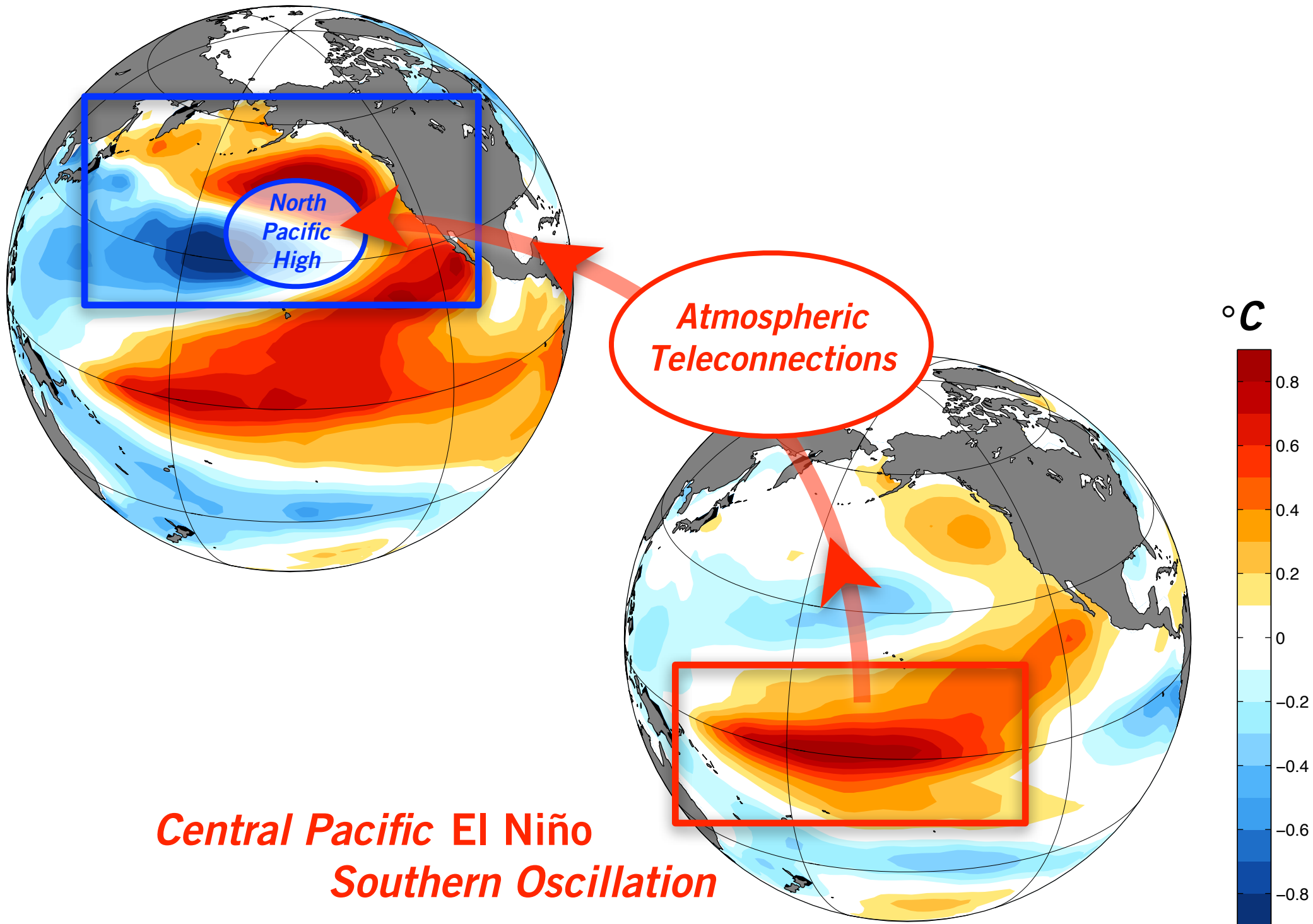
Capotondi et al. 2014 



Central Pacific El Niño
Southern Oscillation

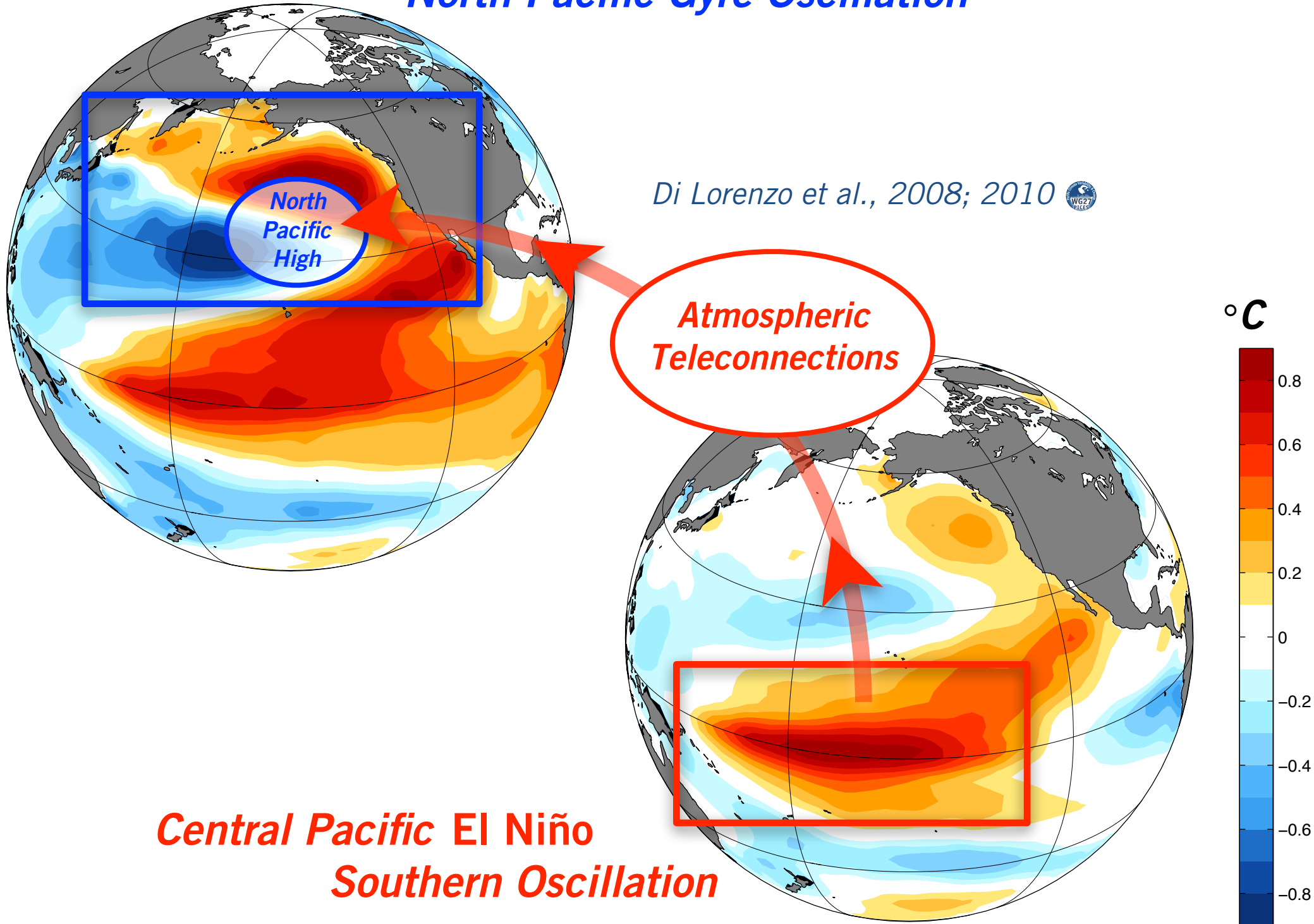


**Central Pacific El Niño
Southern Oscillation**

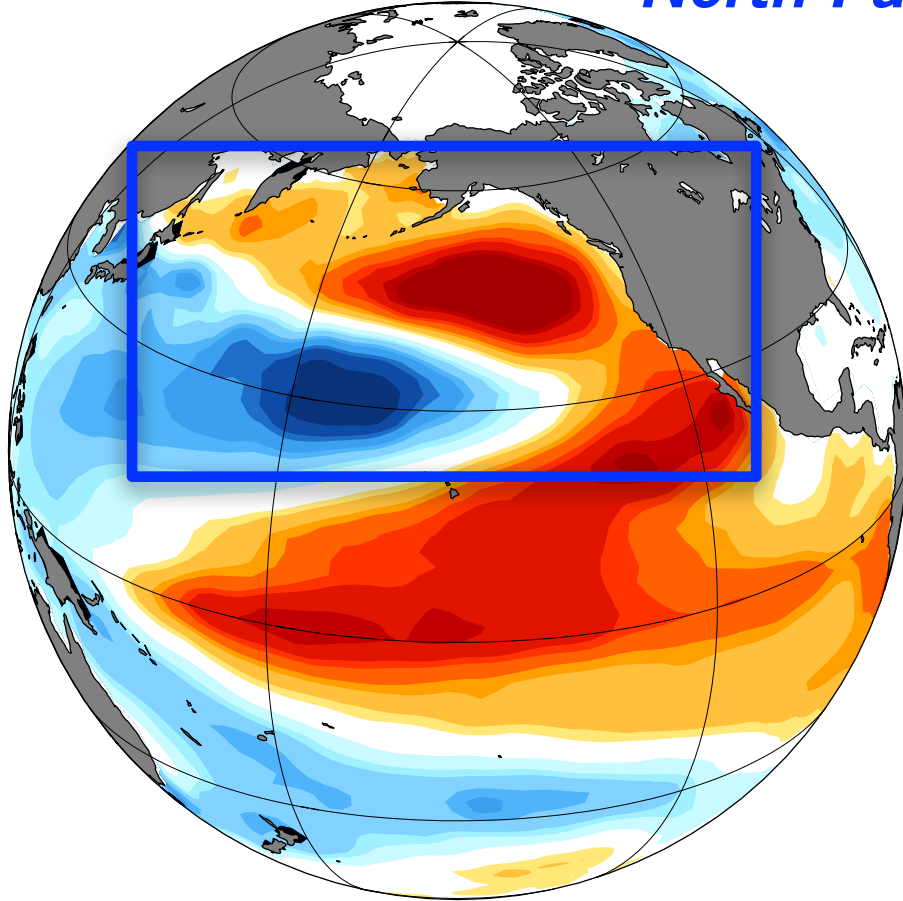


**Central Pacific El Niño
Southern Oscillation**

North Pacific Gyre Oscillation



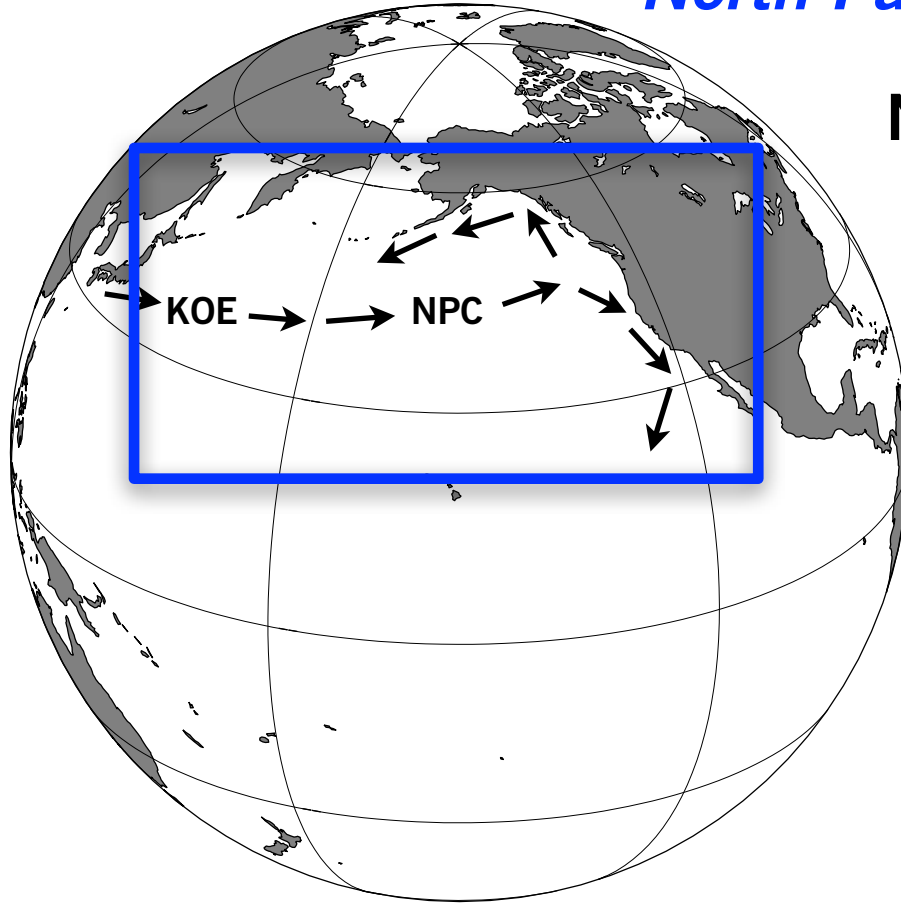
North Pacific Gyre Oscillation



QUESTION:

What is the physical interpretation of the NPGO?

North Pacific Gyre Oscillation



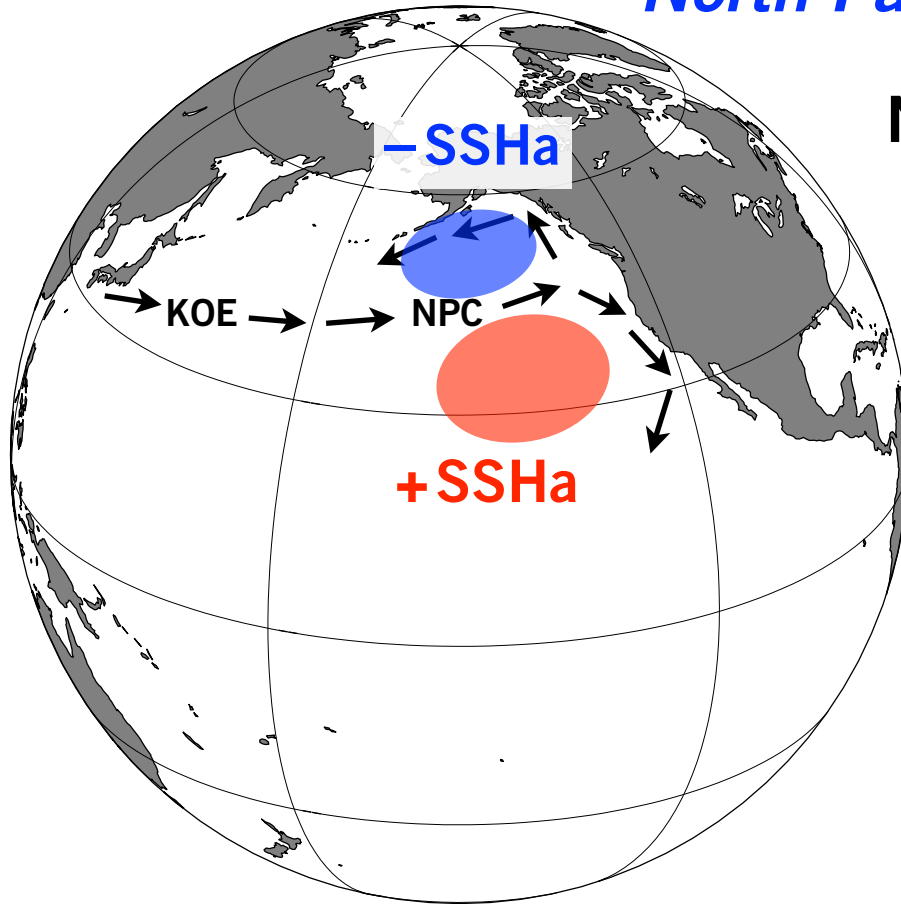
NPC = North Pacific Current

KOE = Kuroshio-Oyashio Extension

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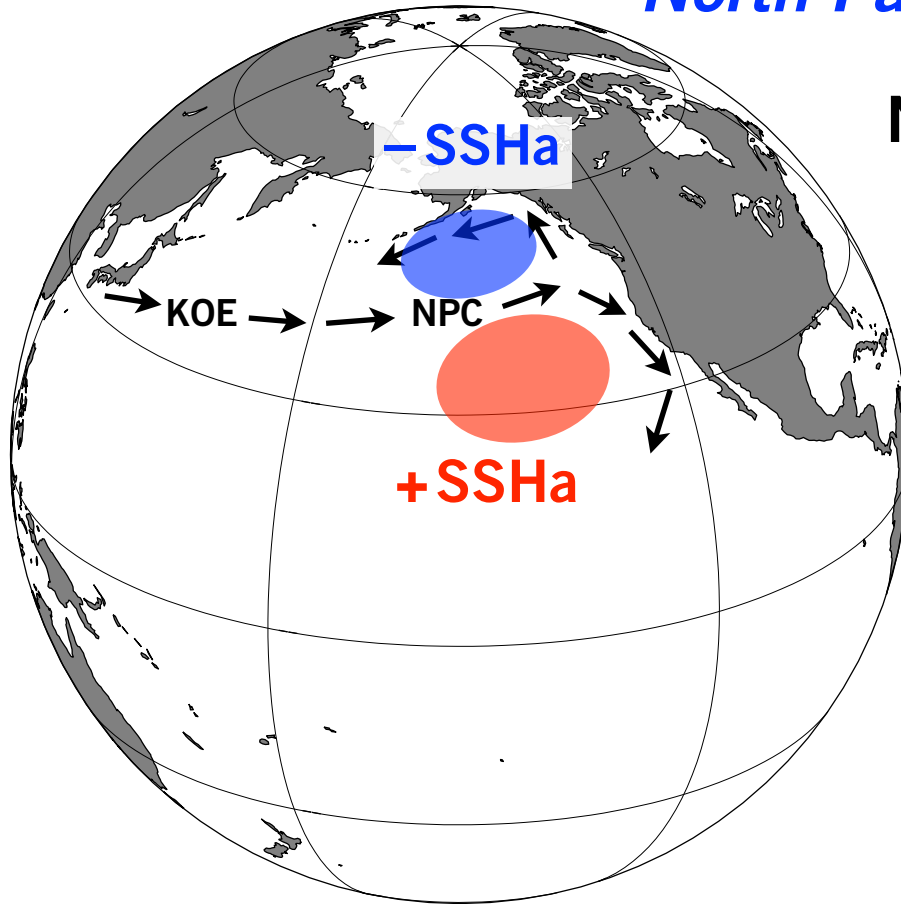
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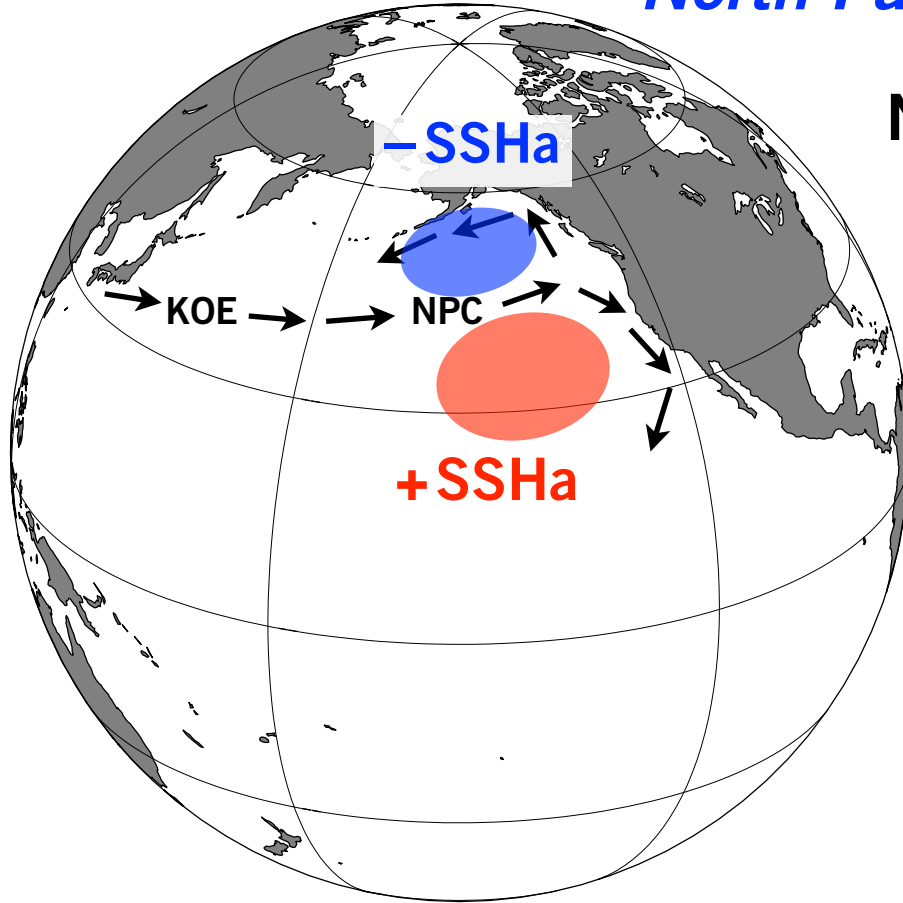


NPC = North Pacific Current

KOE = Kuroshio-Oyashio Extension

... change the strength of the North Pacific Current

North Pacific Gyre Oscillation

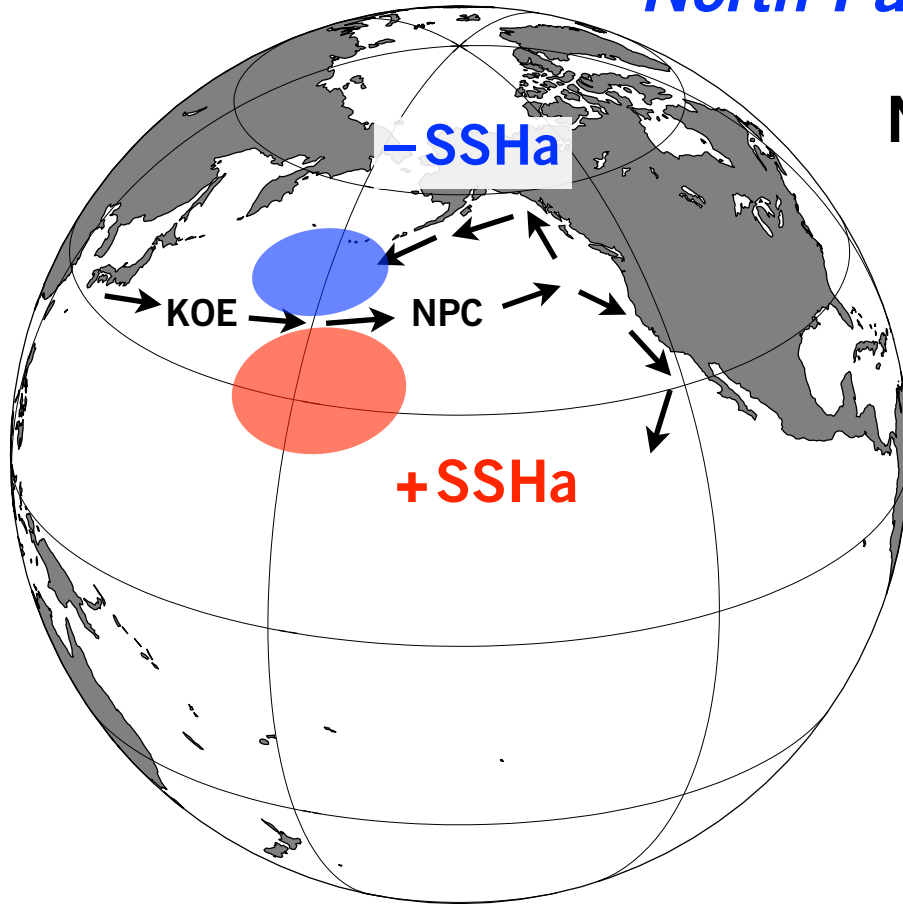


NPC = North Pacific Current

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NPGO Year 0

North Pacific Gyre Oscillation



NPC = North Pacific Current

KOE = Kuroshio-Oyashio Extension

NPGO Year 1.5

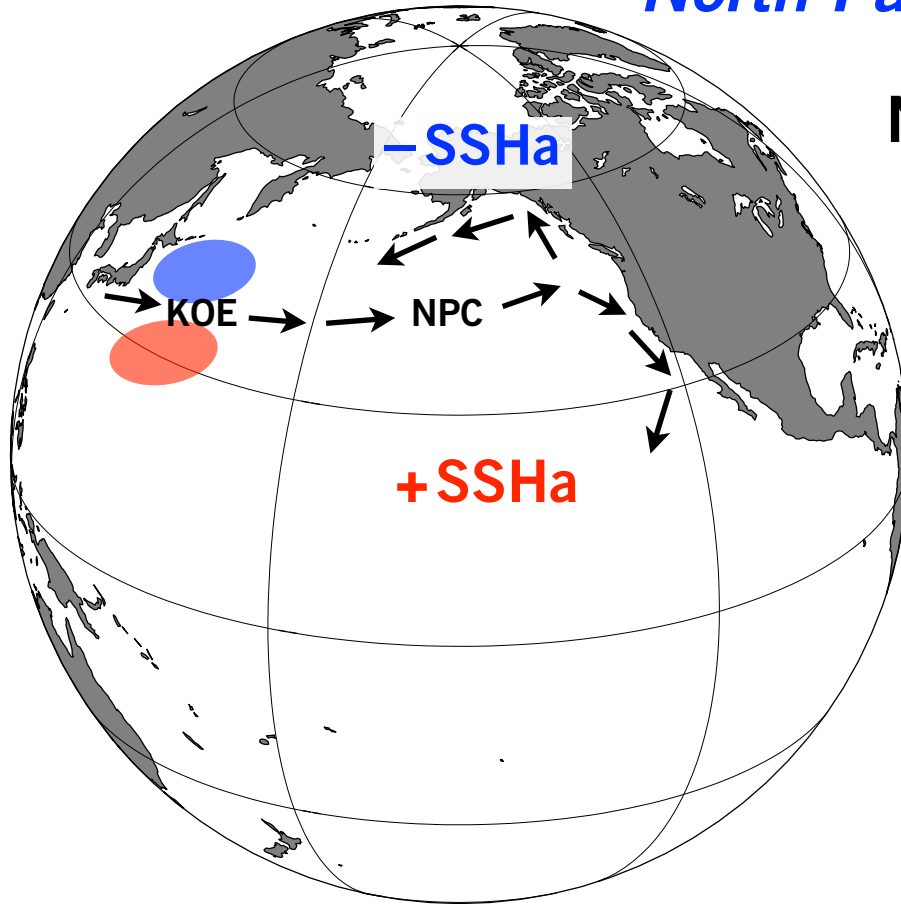
Miller and Schneider, 2001

Qiu et al., 2003

Ceballos et al. 2009



North Pacific Gyre Oscillation



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NPGO Year 3

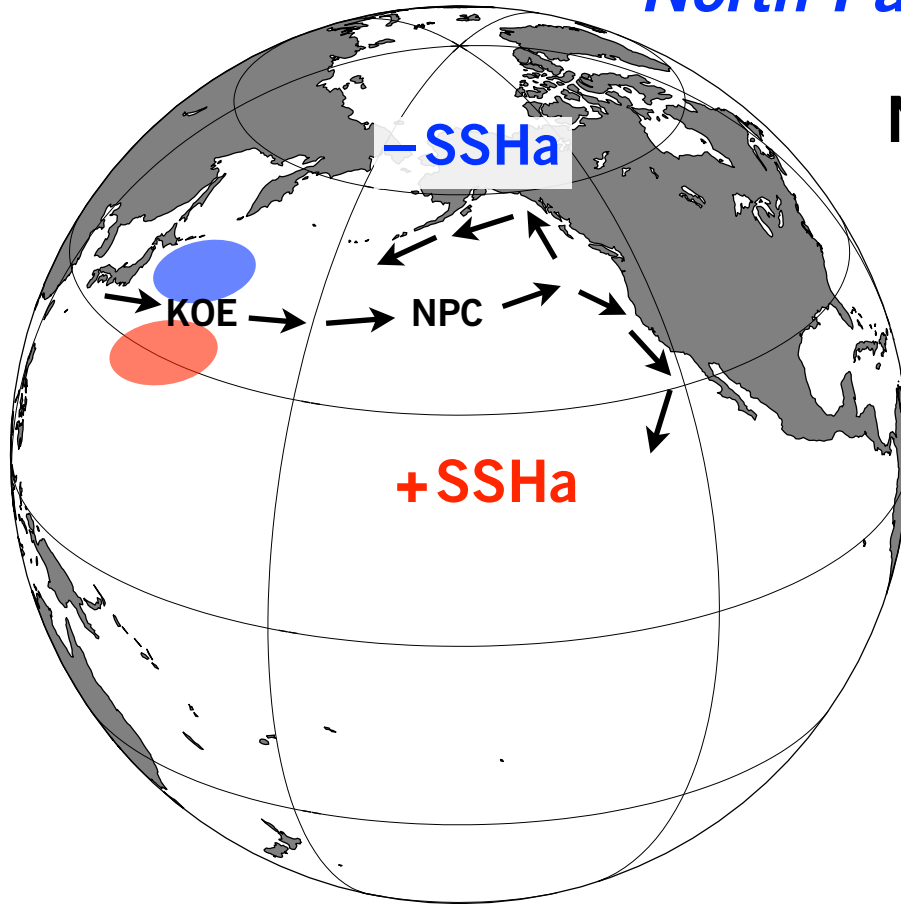
Miller and Schneider, 2001

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North Pacific Gyre Oscillation



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NPGO Year 3

... change the strength of the KOE

Taguchi et al. 2007

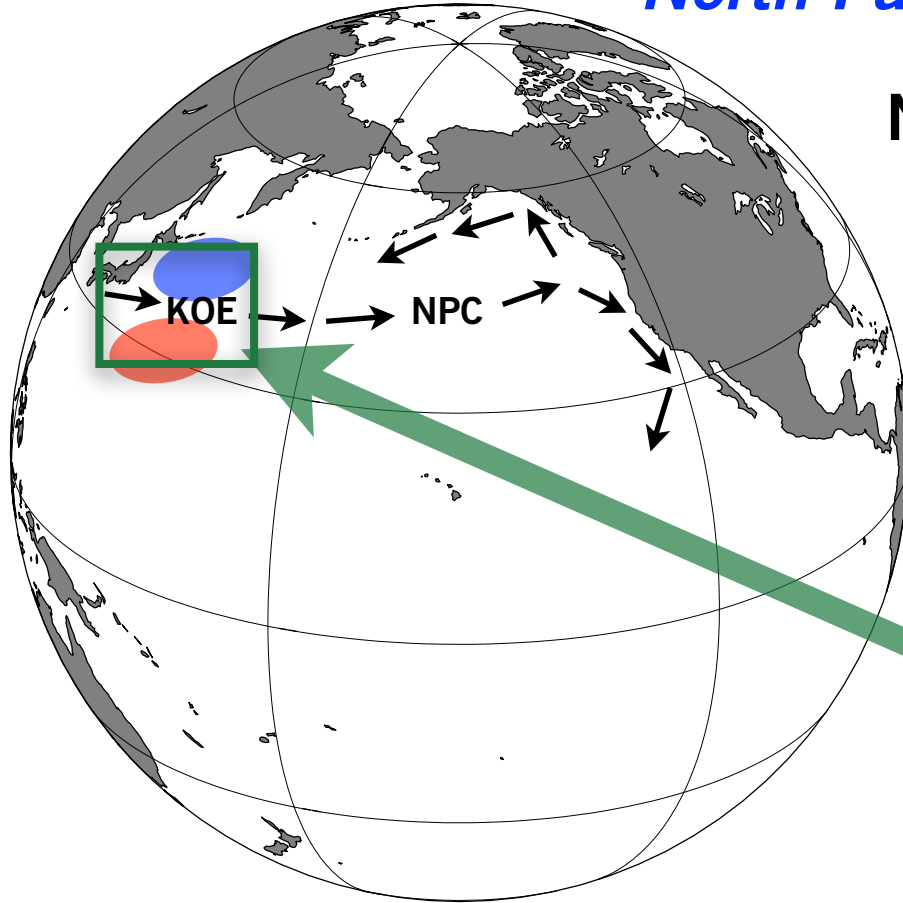


Ceballos et al. 2009



Sasai et al. 2013

North Pacific Gyre Oscillation

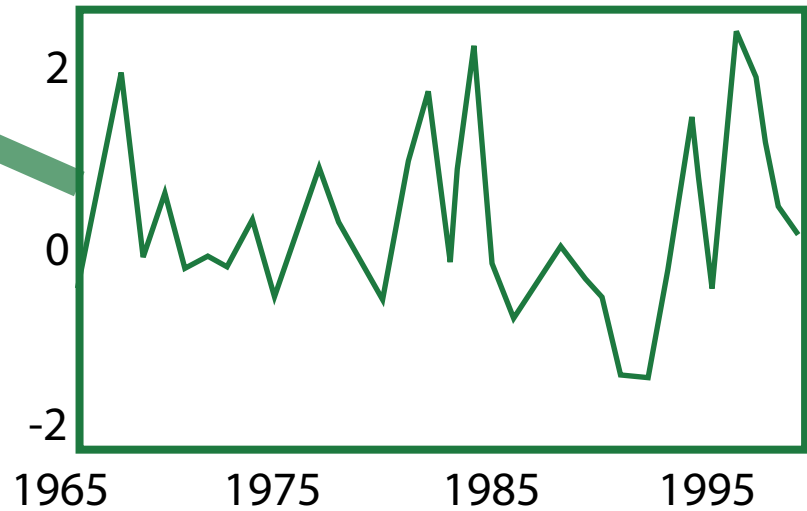


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NPGO Year 3

Zooplankton Index

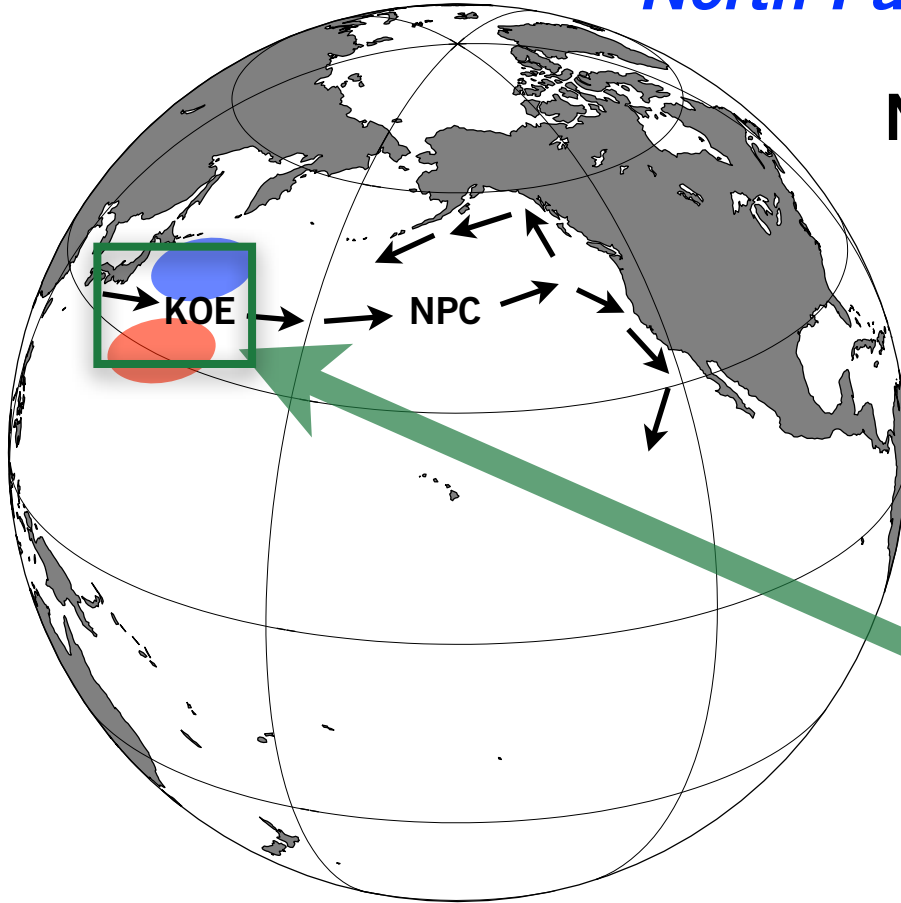


Chiba et al. 2013 

North Pacific Gyre Oscillation

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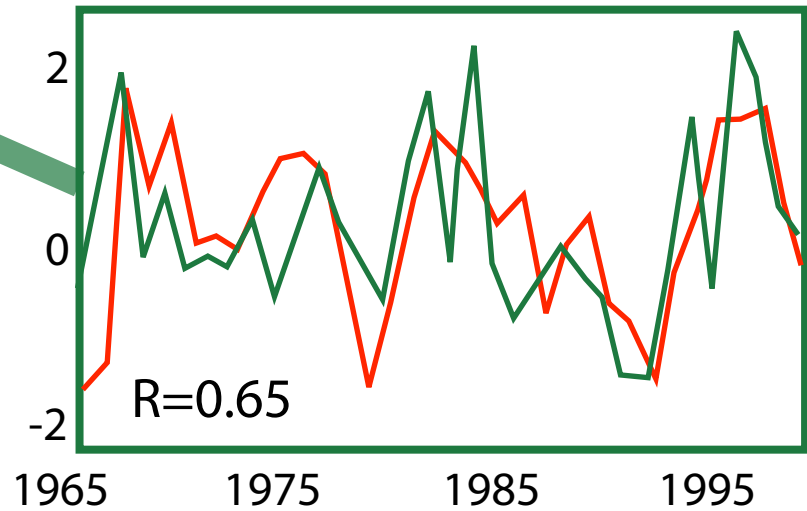
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NPGO Year 3

KOE Transport Index

Zooplankton Index

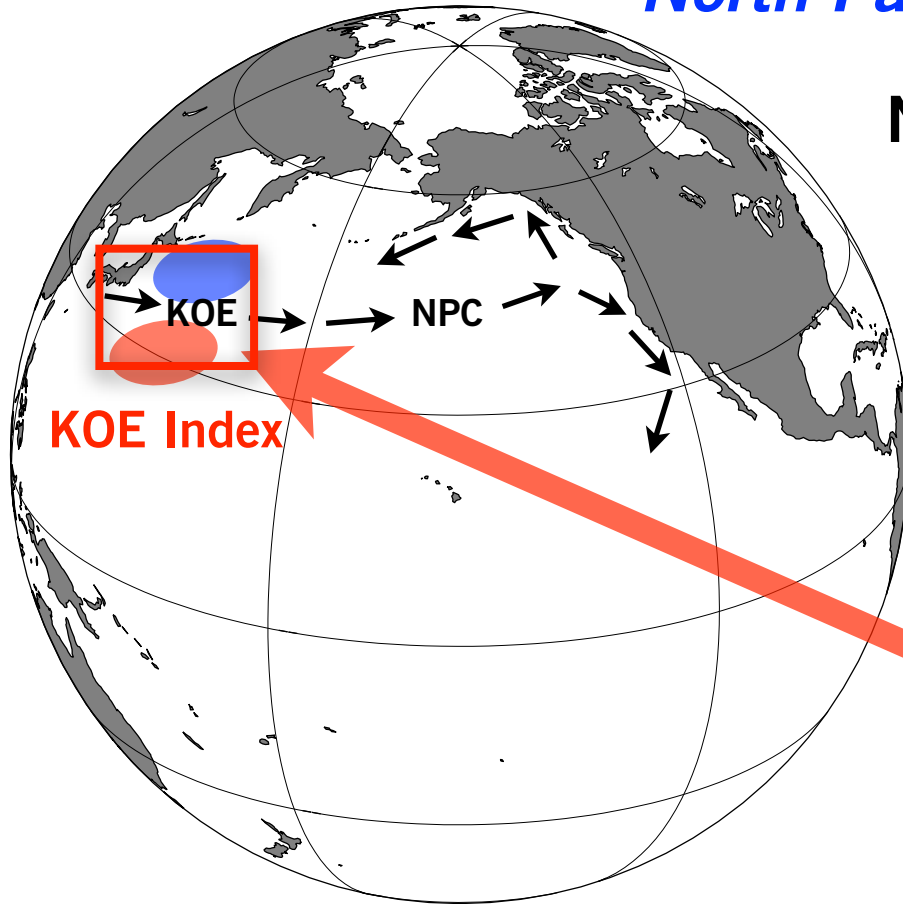


Chiba et al. 2013 

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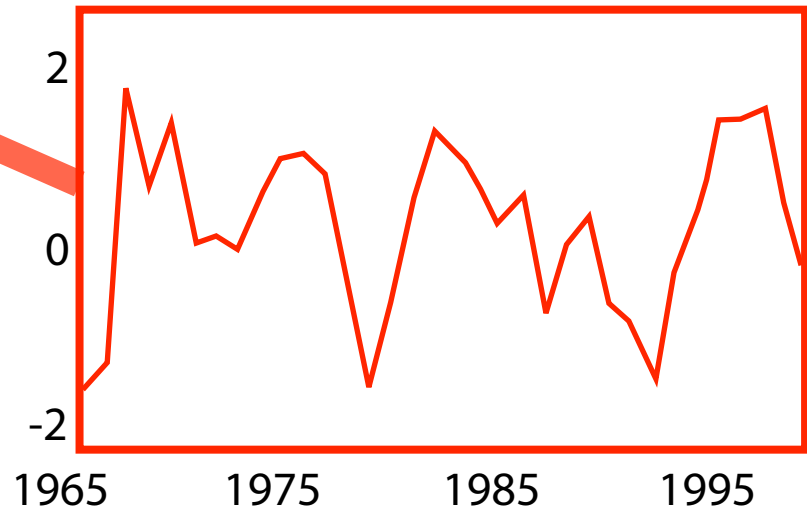
KOE = Kuroshio-Oyashio Extension



KOE Index

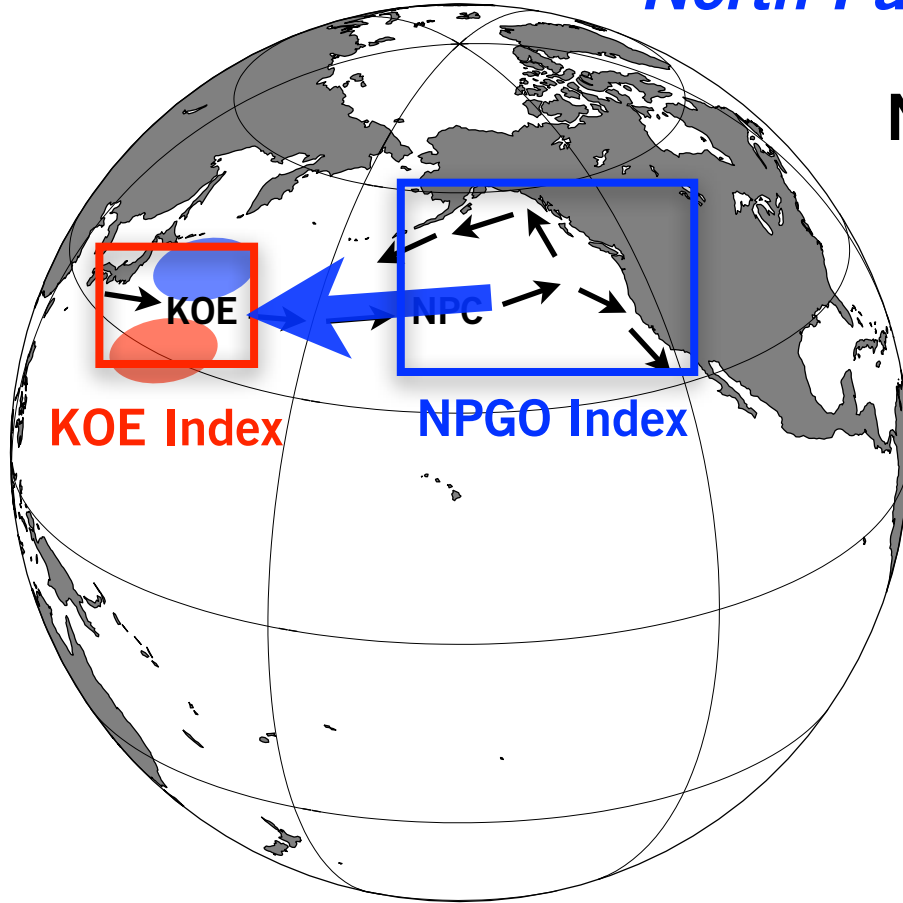
KOE Transport Index

NPGO Year 3



Chiba et al. 2013 

North Pacific Gyre Oscillation

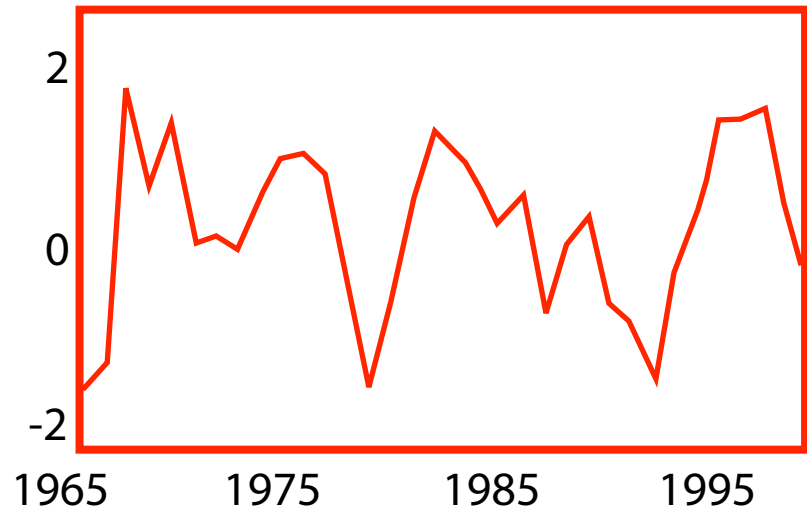


NPGO Year 3

NPC = North Pacific Current

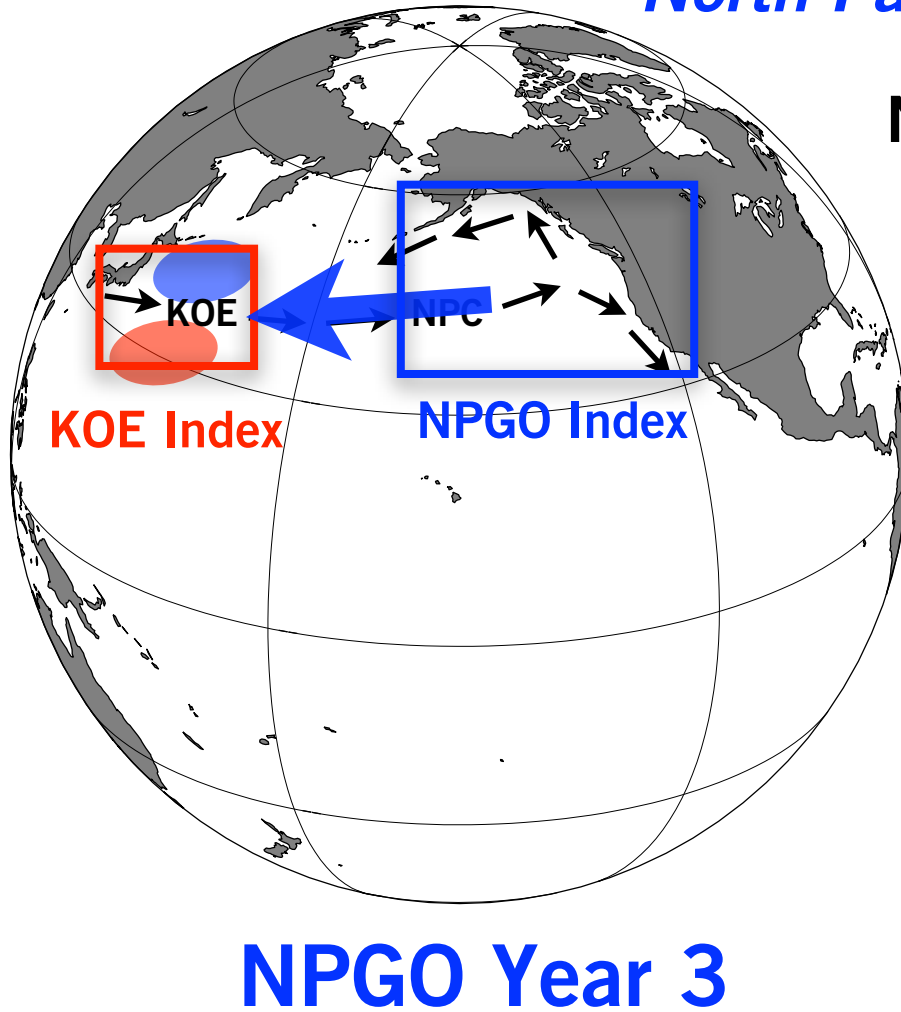
KOE = Kuroshio-Oyashio Extension

KOE Transport Index



Chiba et al. 2013 

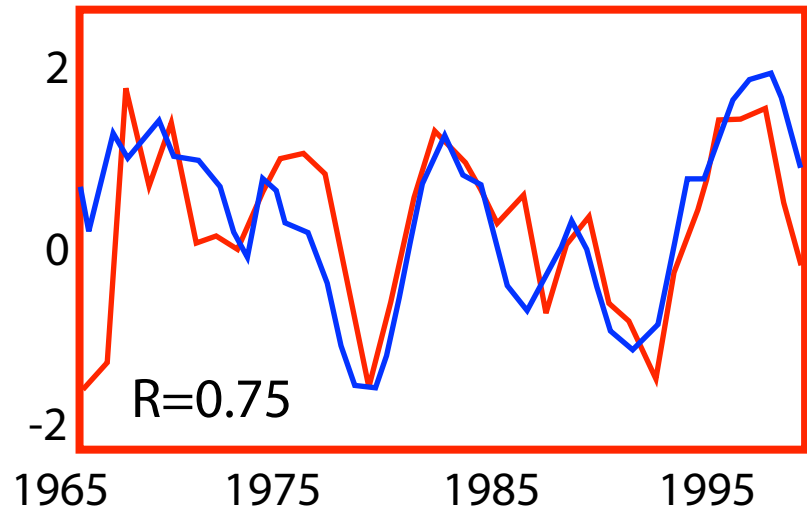
North Pacific Gyre Oscillation



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KOE Transport Index
NPGO Index (3 years prior)



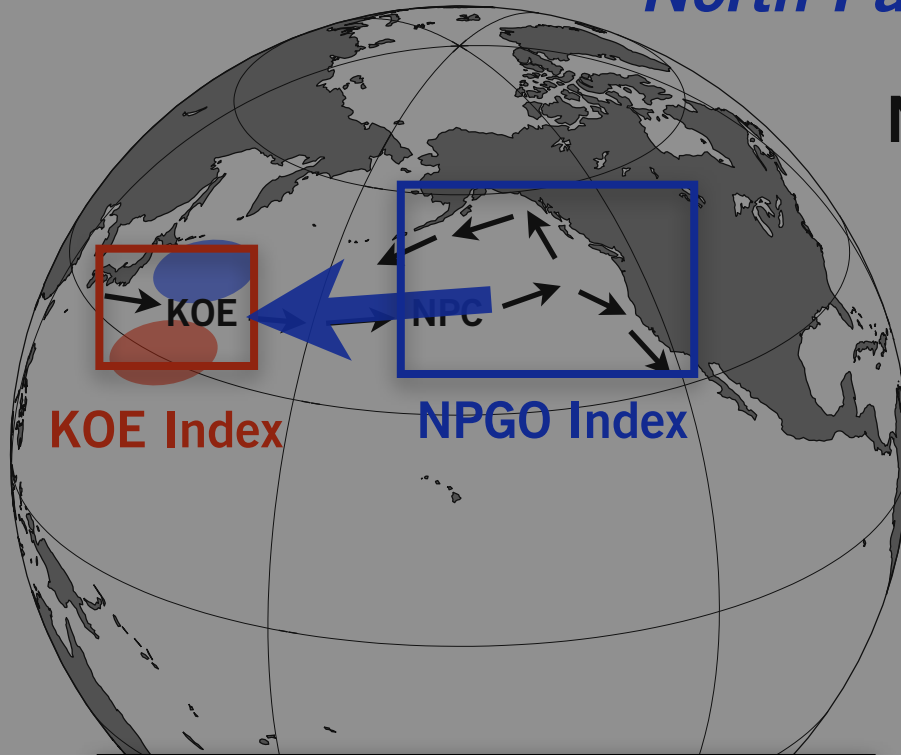
Chiba et al. 2013



Ceballos et al. 2009



North Pacific Gyre Oscillation



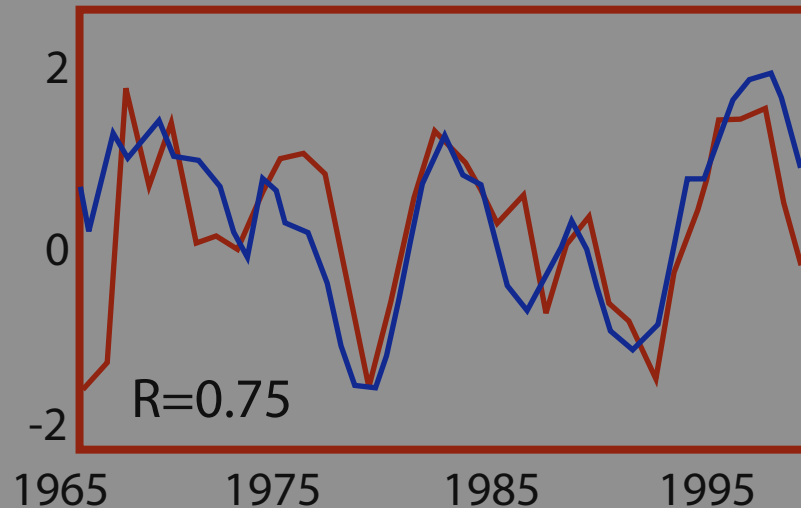
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FORECAST POTENTIAL

~3 YEARS

KOE Transport Index
NPGO Index (3 years prior)



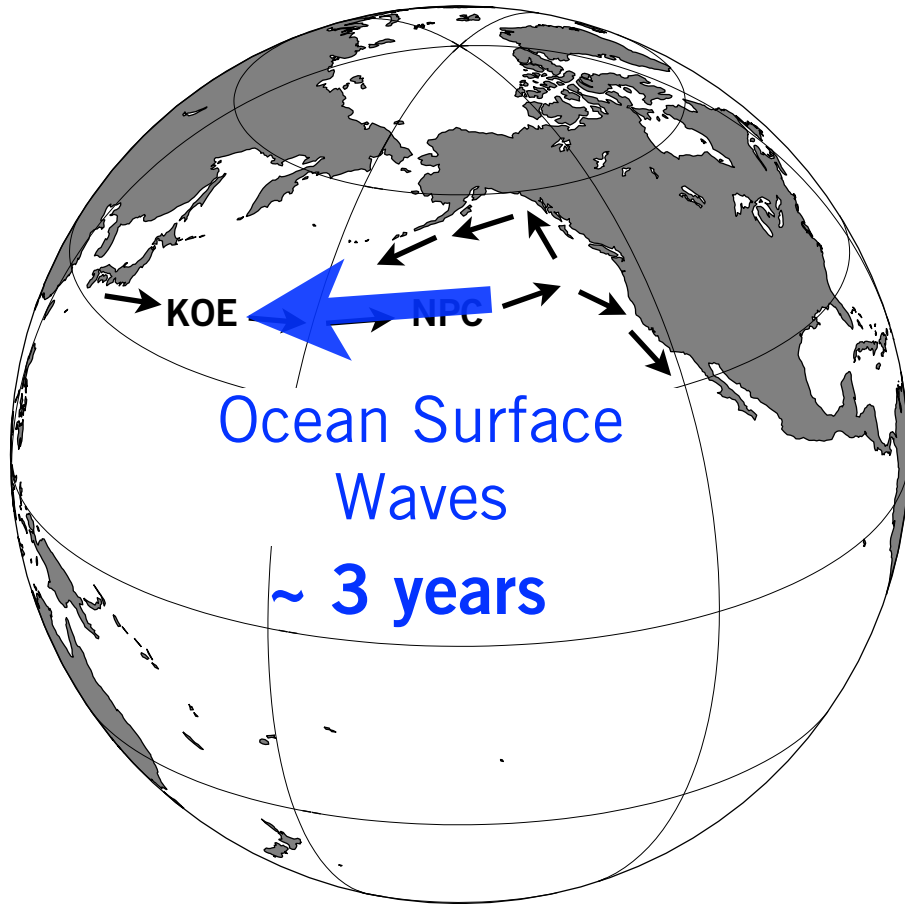
Chiba et al. 2013



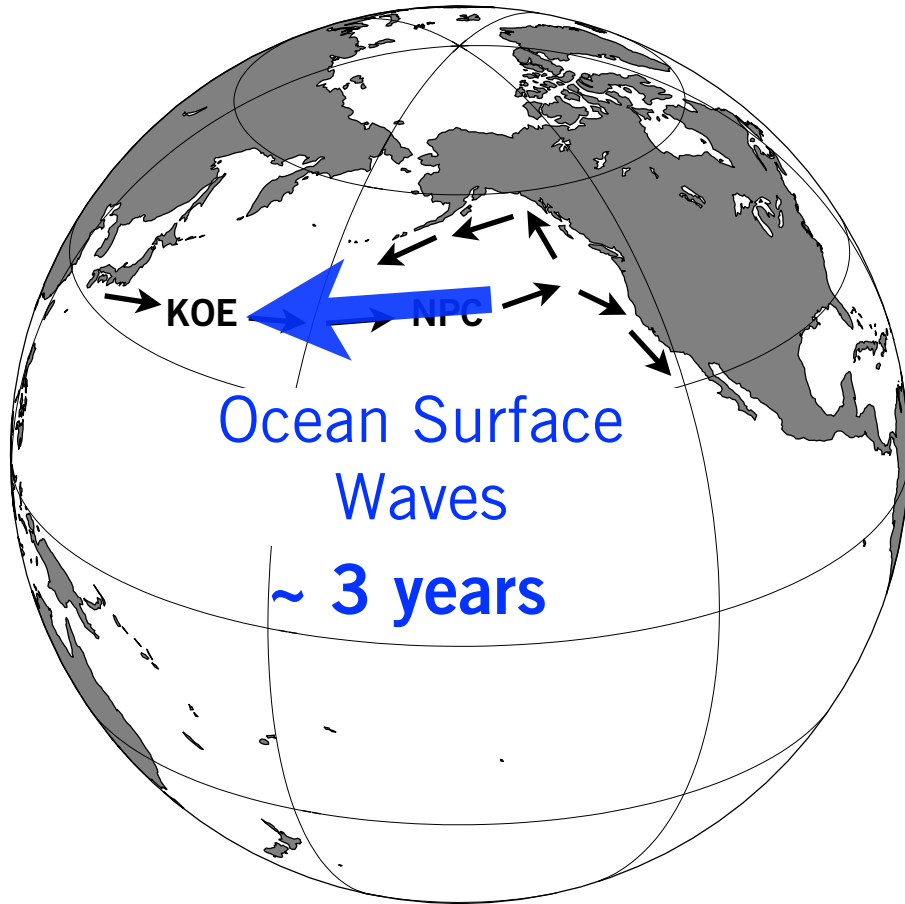
Ceballos et al. 2009



OCEAN SURFACE

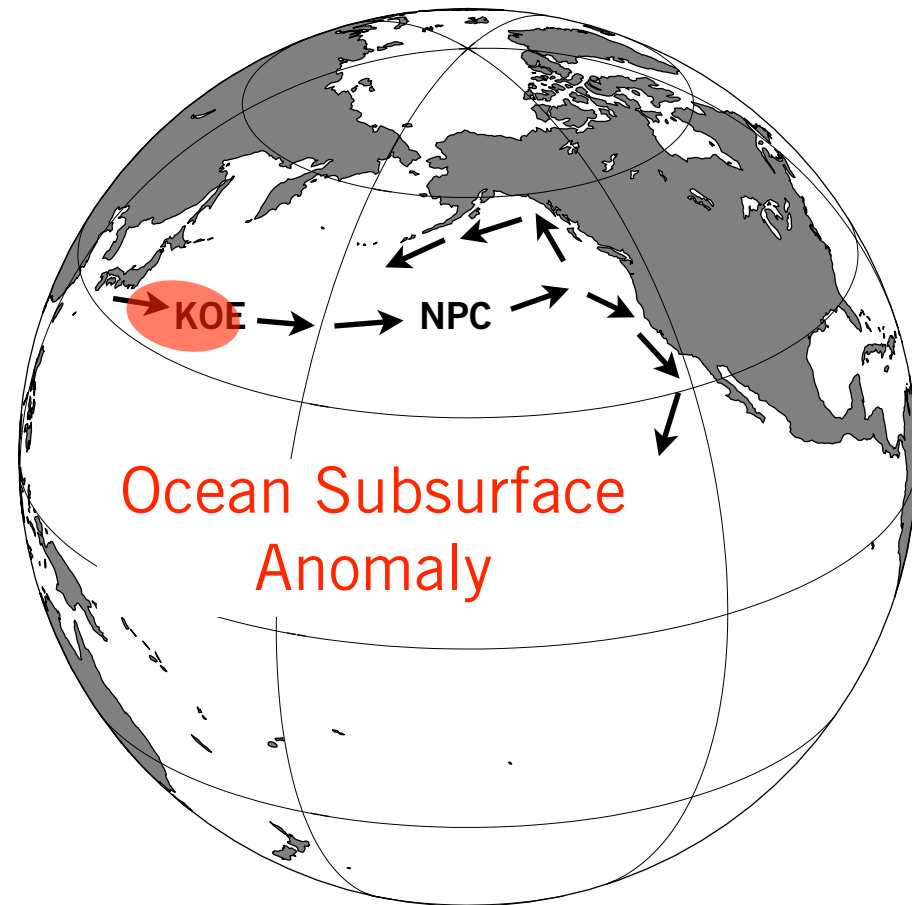


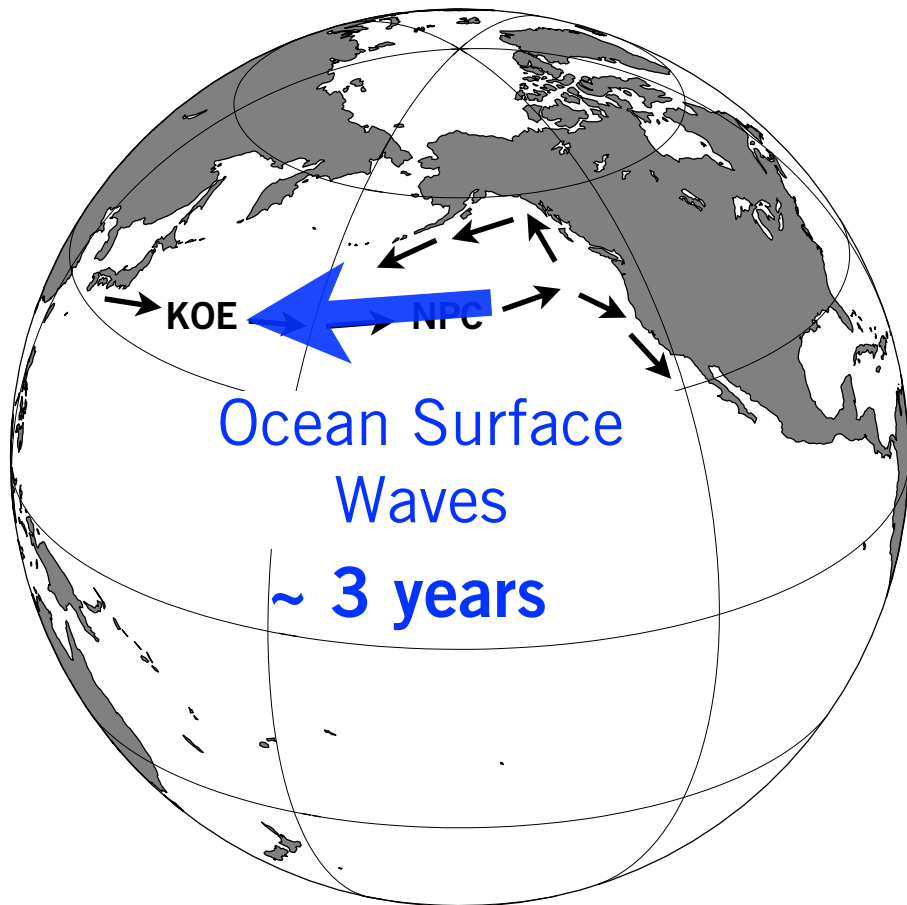
OCEAN SURFACE



Taguchi et al. 2014 

OCEAN SUBSURFACE

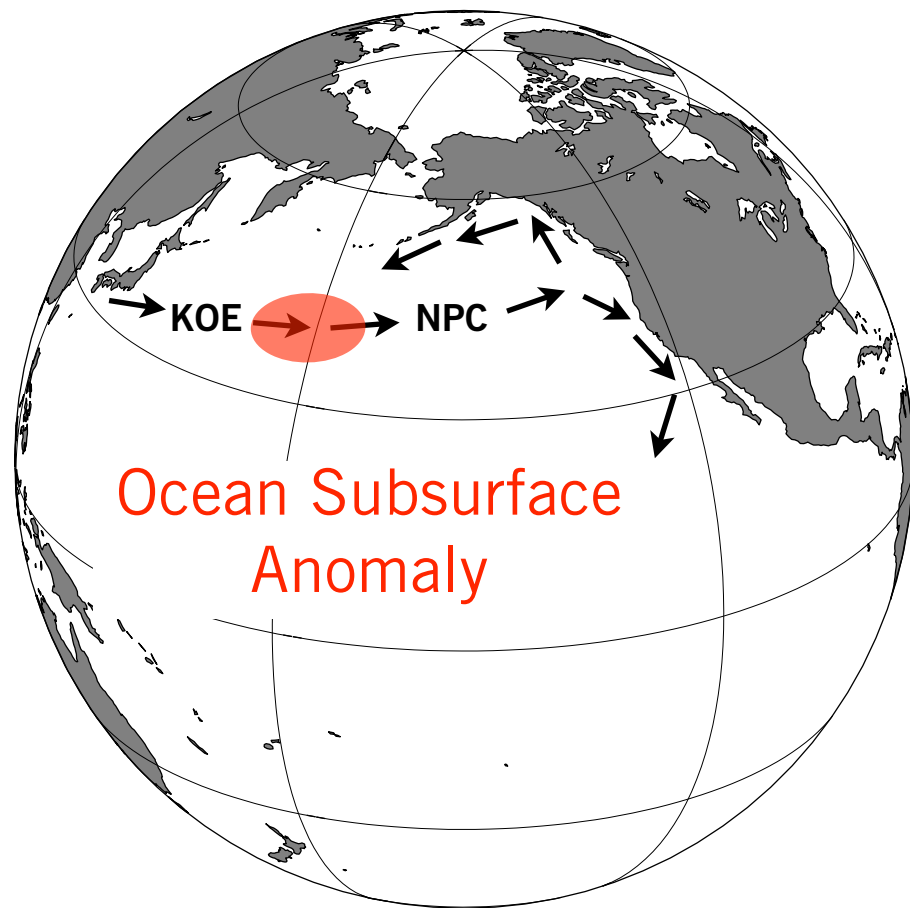




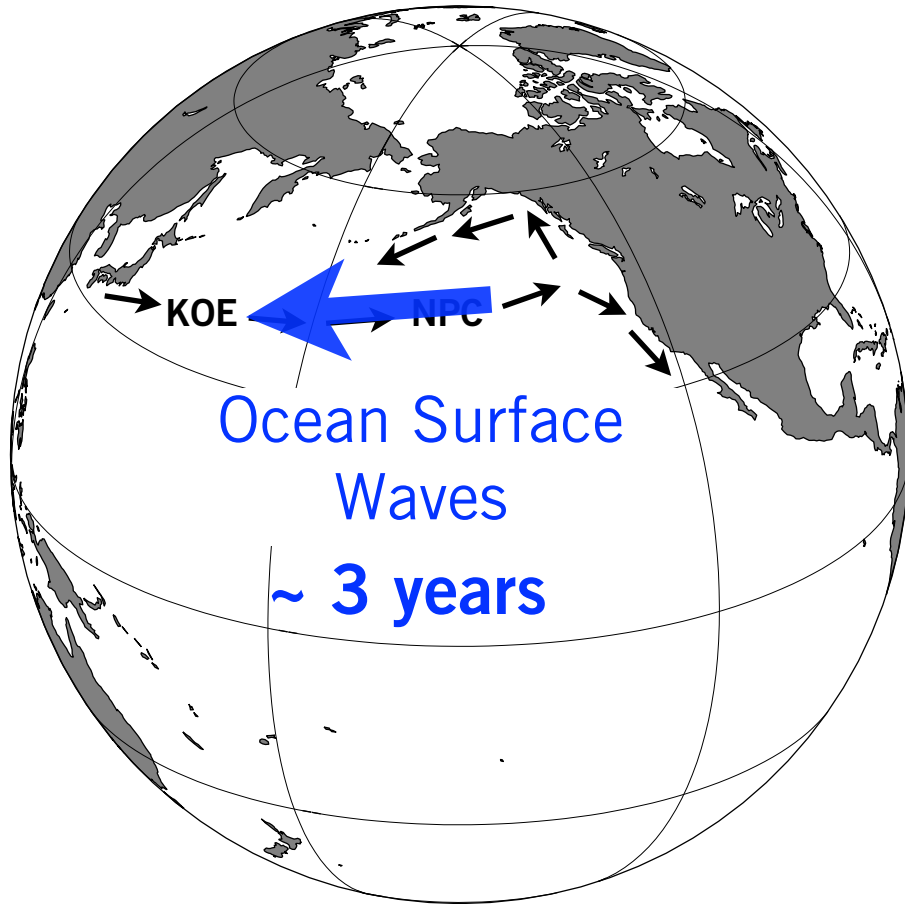
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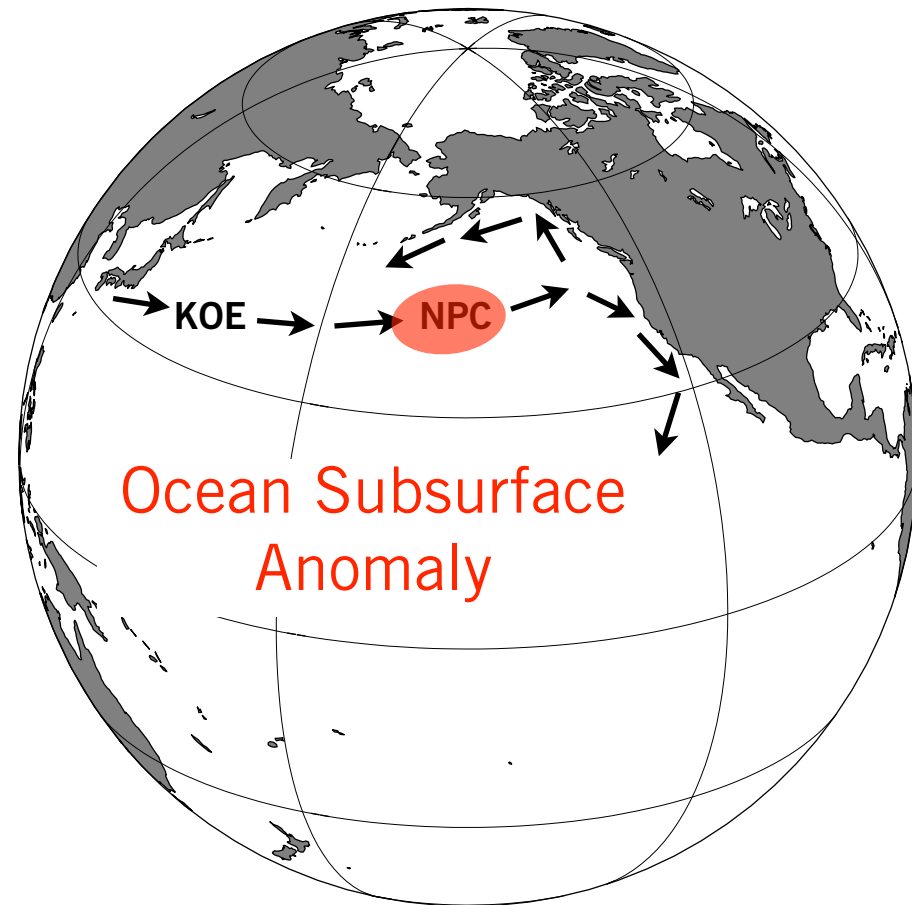


OCEAN SURFACE

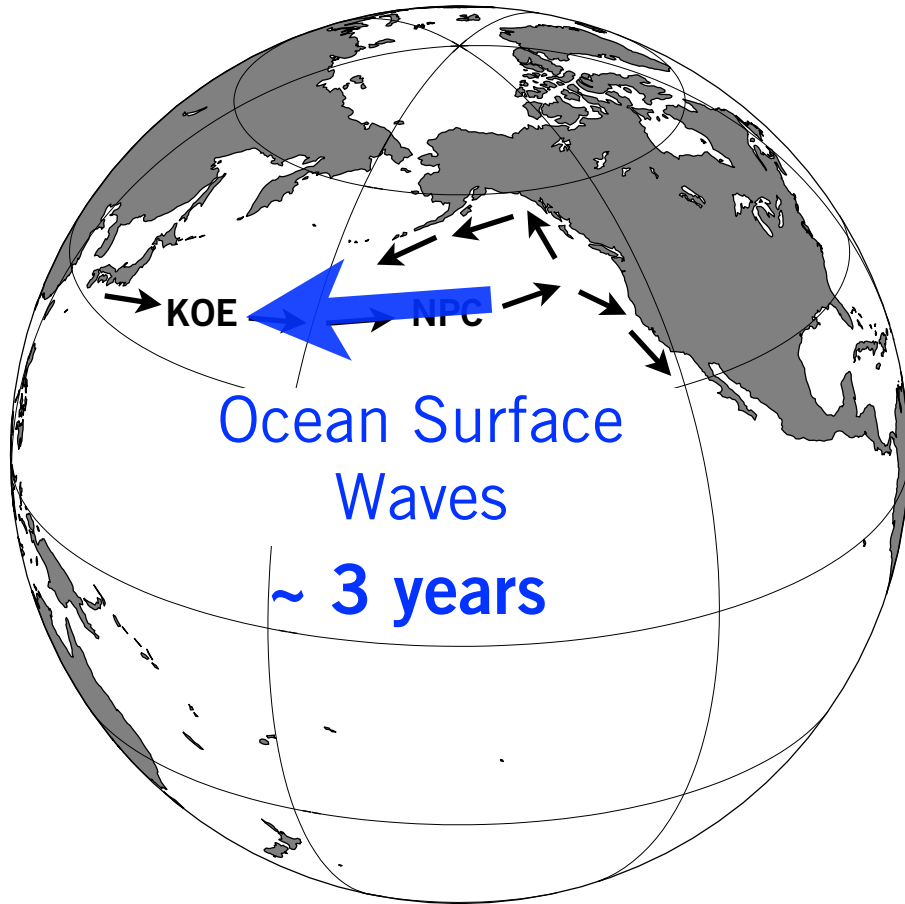


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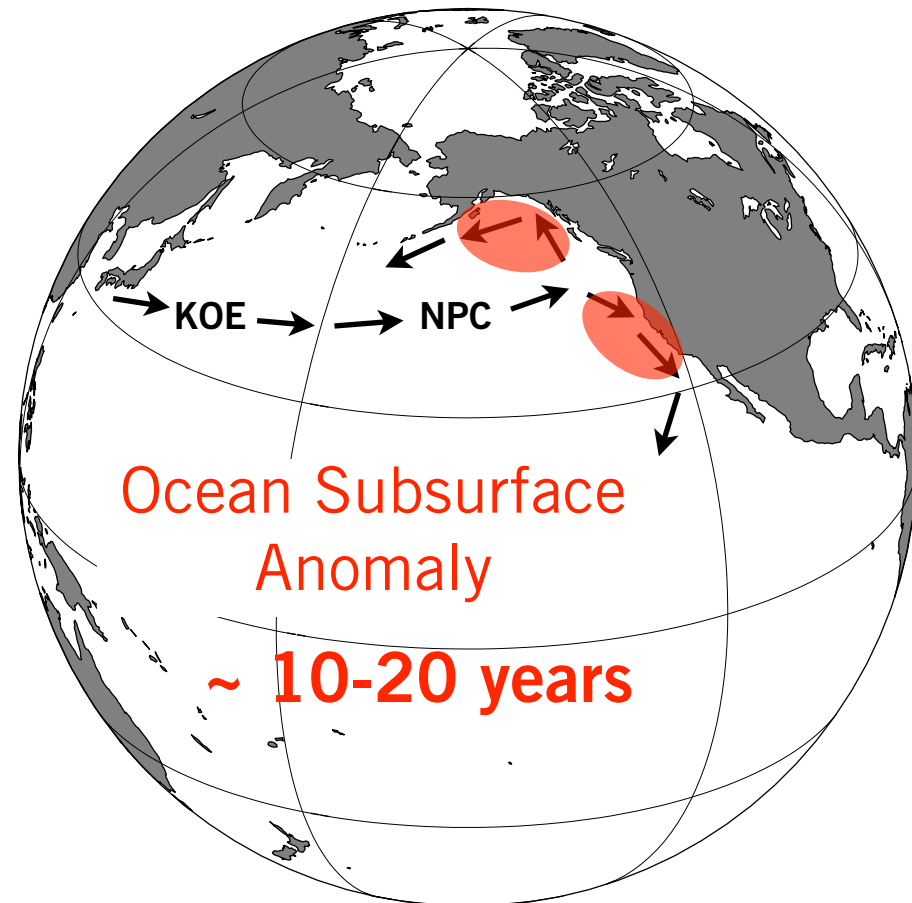


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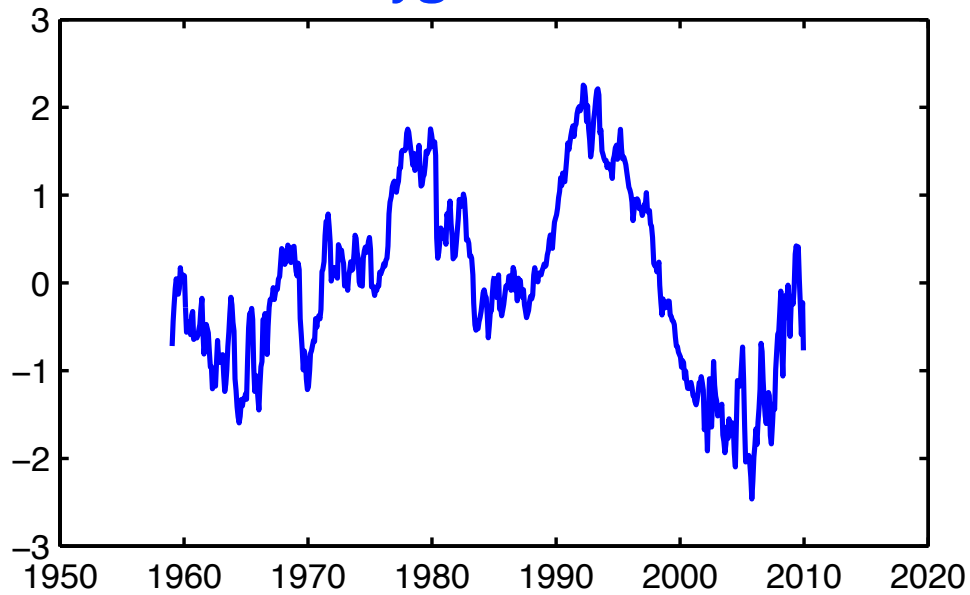


Taguchi et al. 2014 

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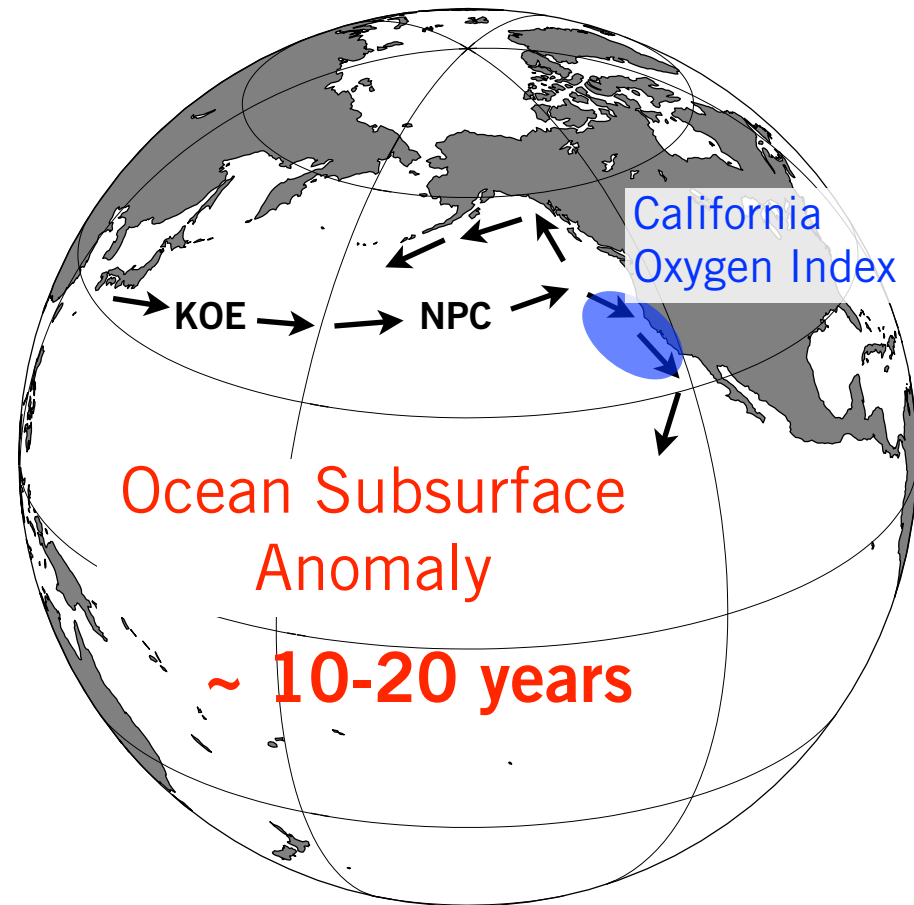


California Oxygen Index Today

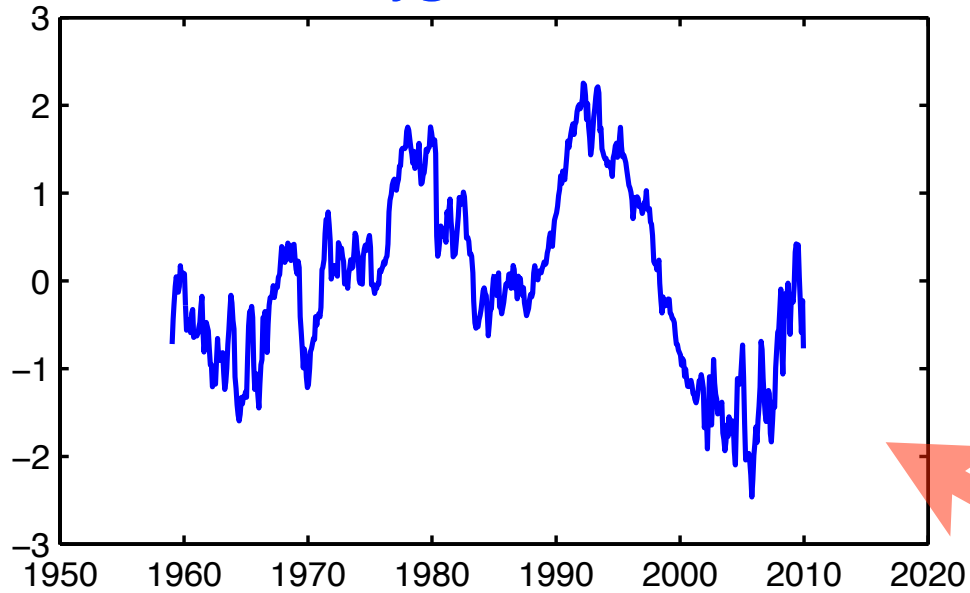


Pozo-Buil et al. 2014 

OCEAN SUBSURFACE

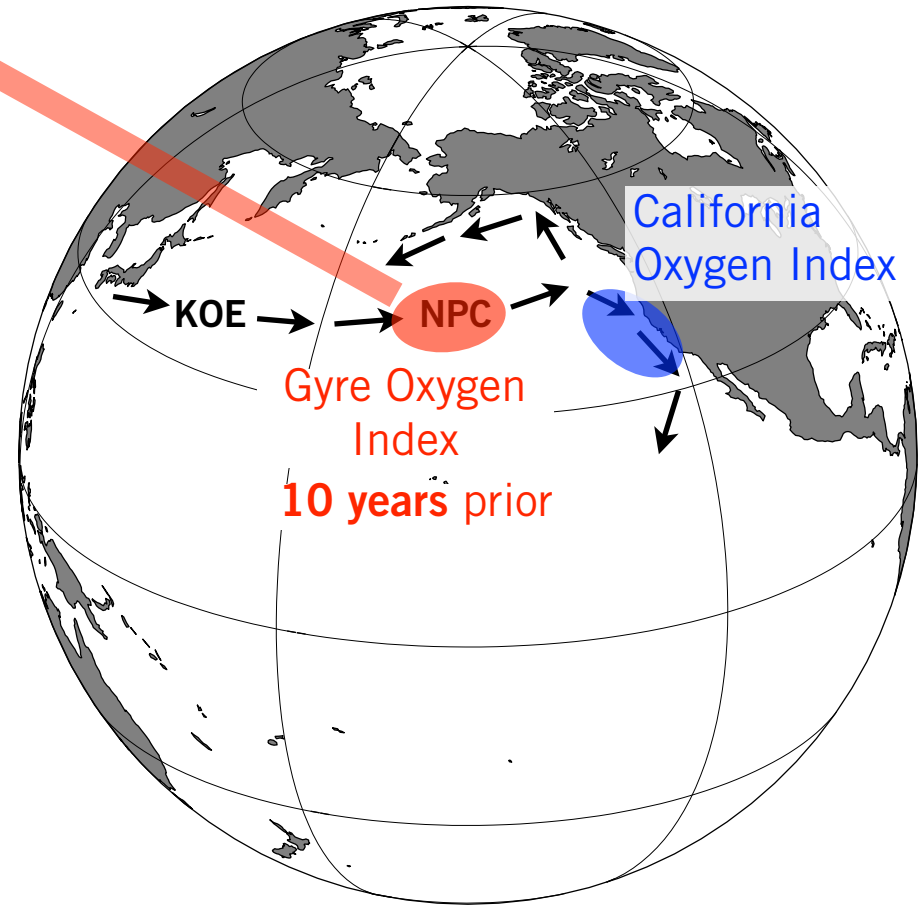


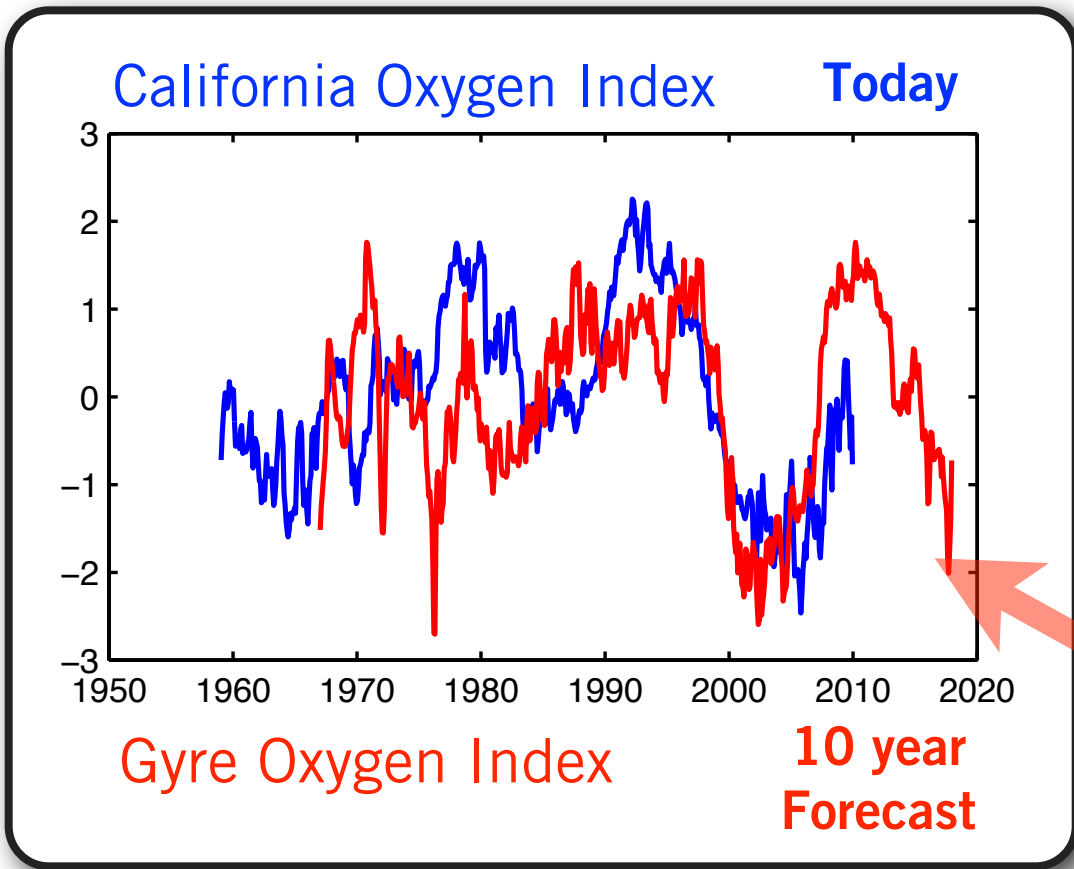
California Oxygen Index Today



Pozo-Buil et al. 2014 

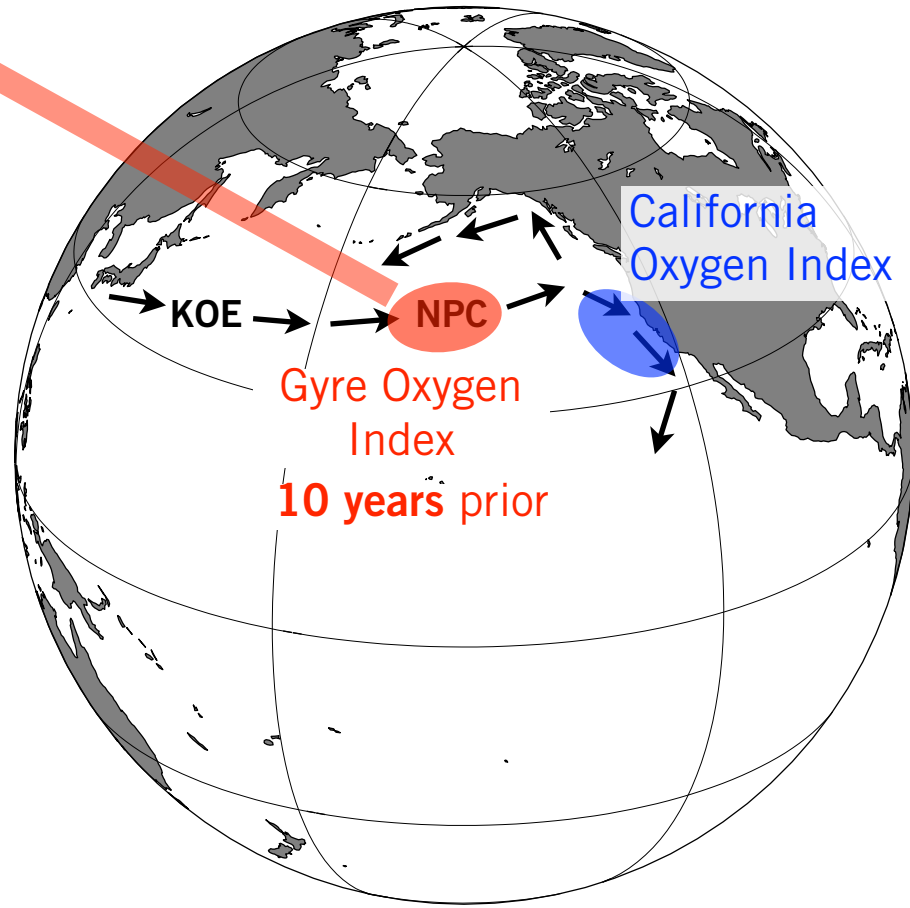
OCEAN SUBSURFACE

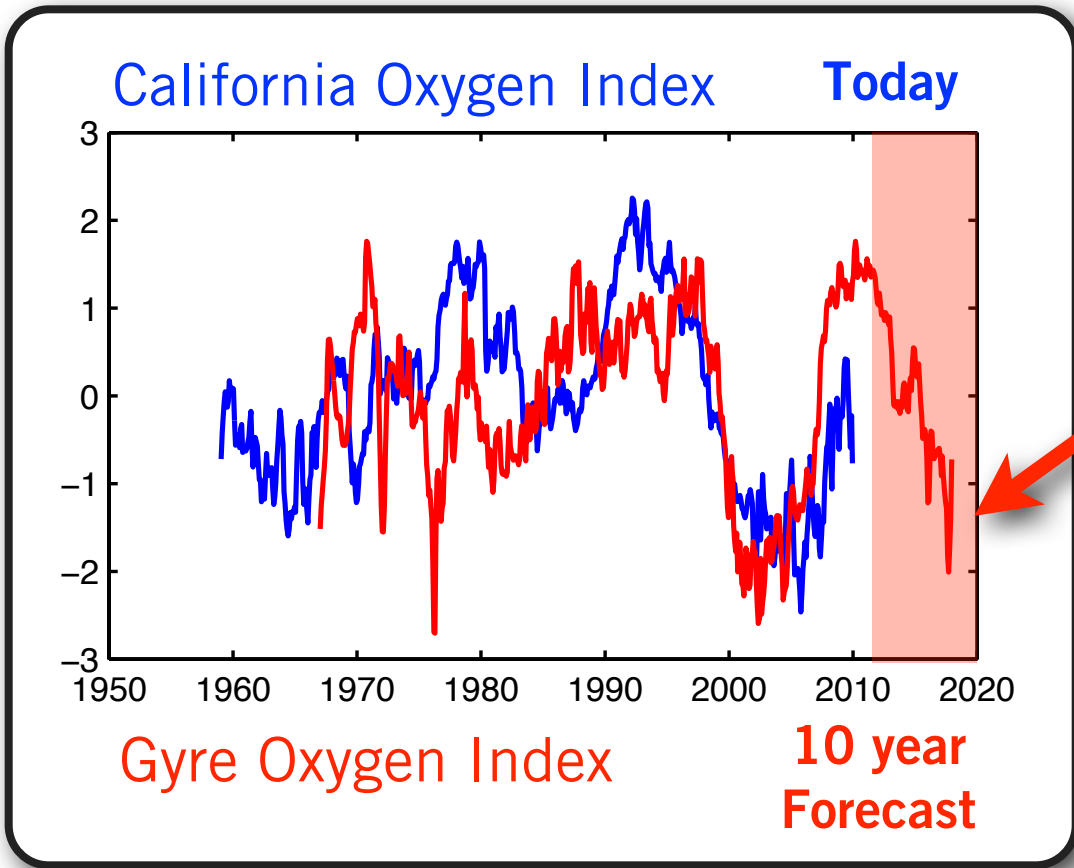




Pozo-Buil et al. 2014 

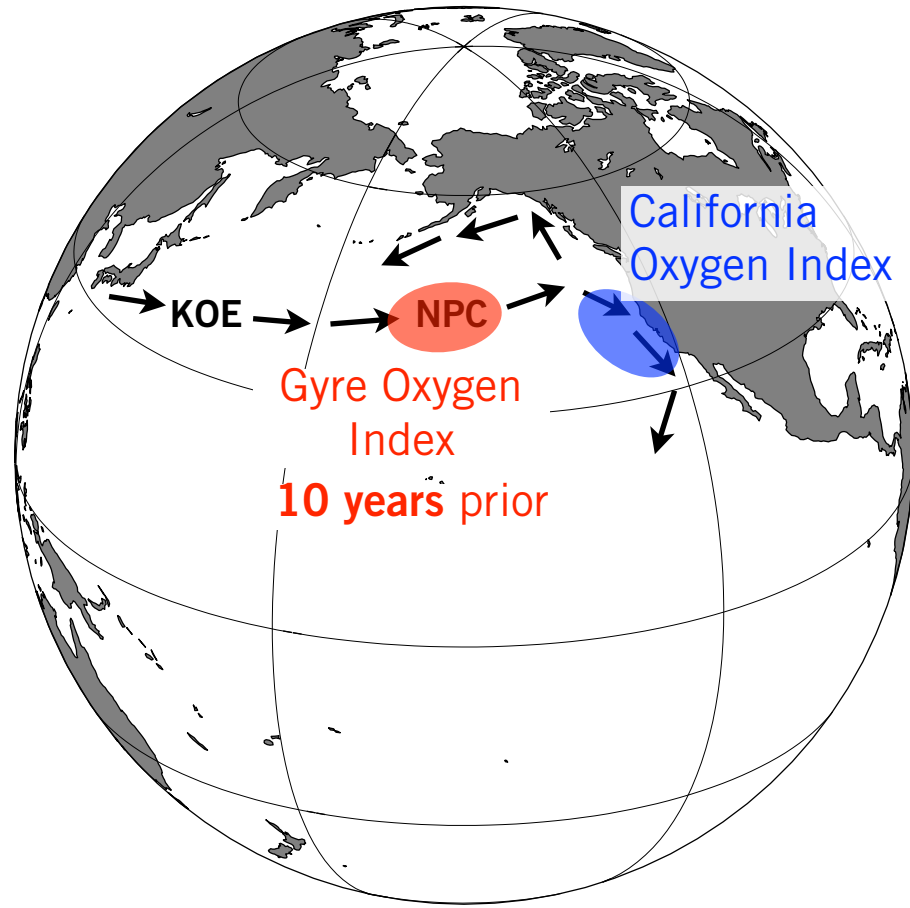
OCEAN SUBSURFACE



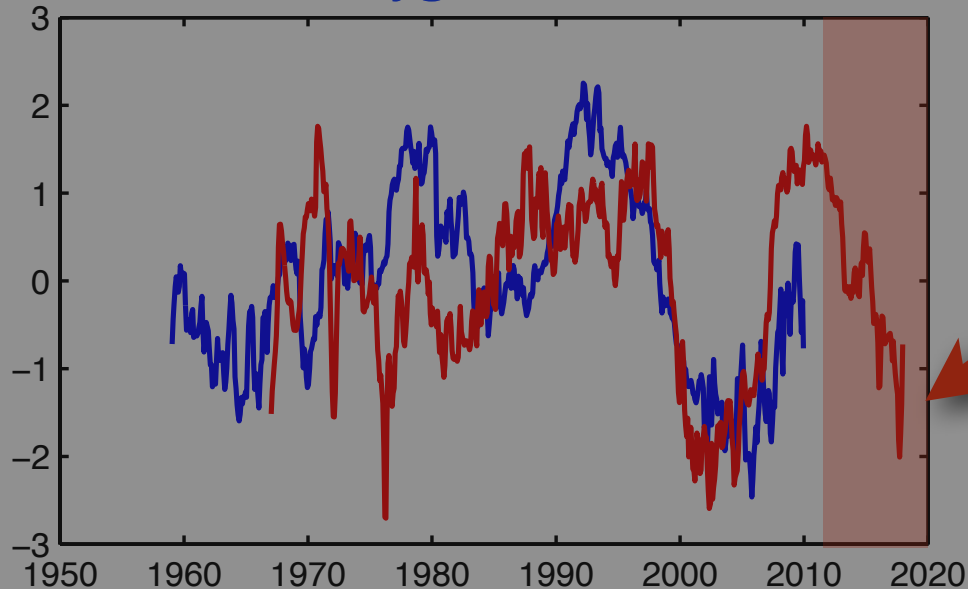


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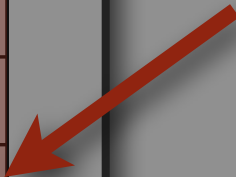
OCEAN SUBSURFACE



California Oxygen Index Today



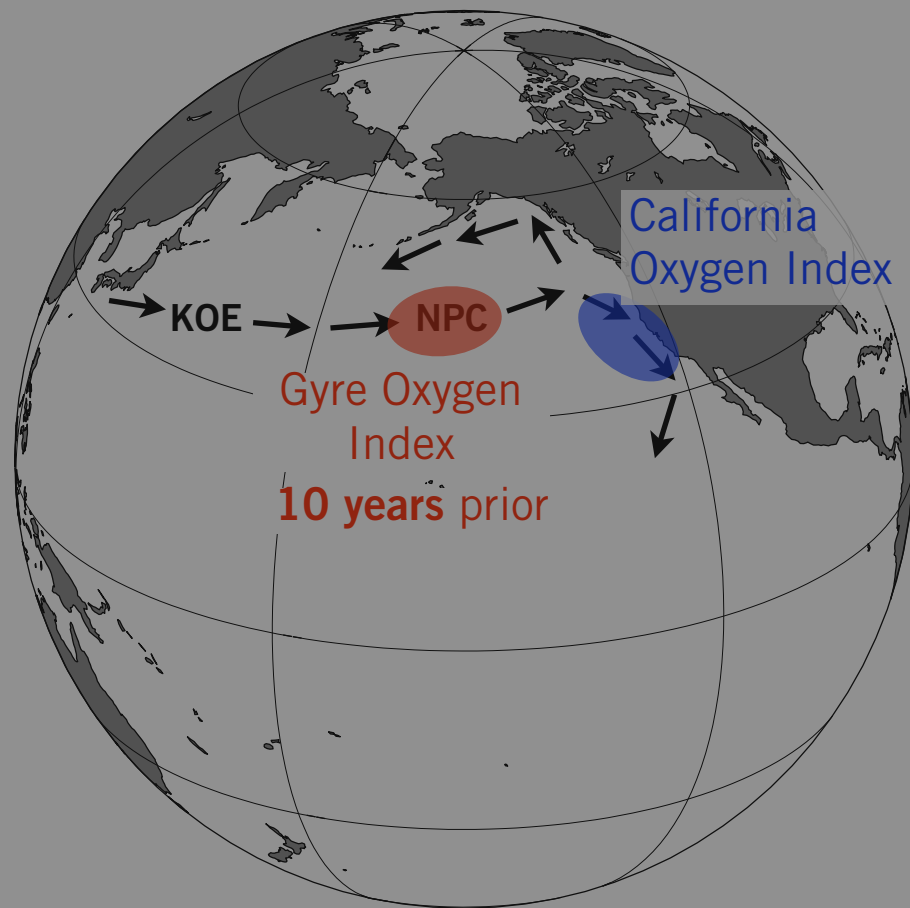
towards another period of strong hypoxia?



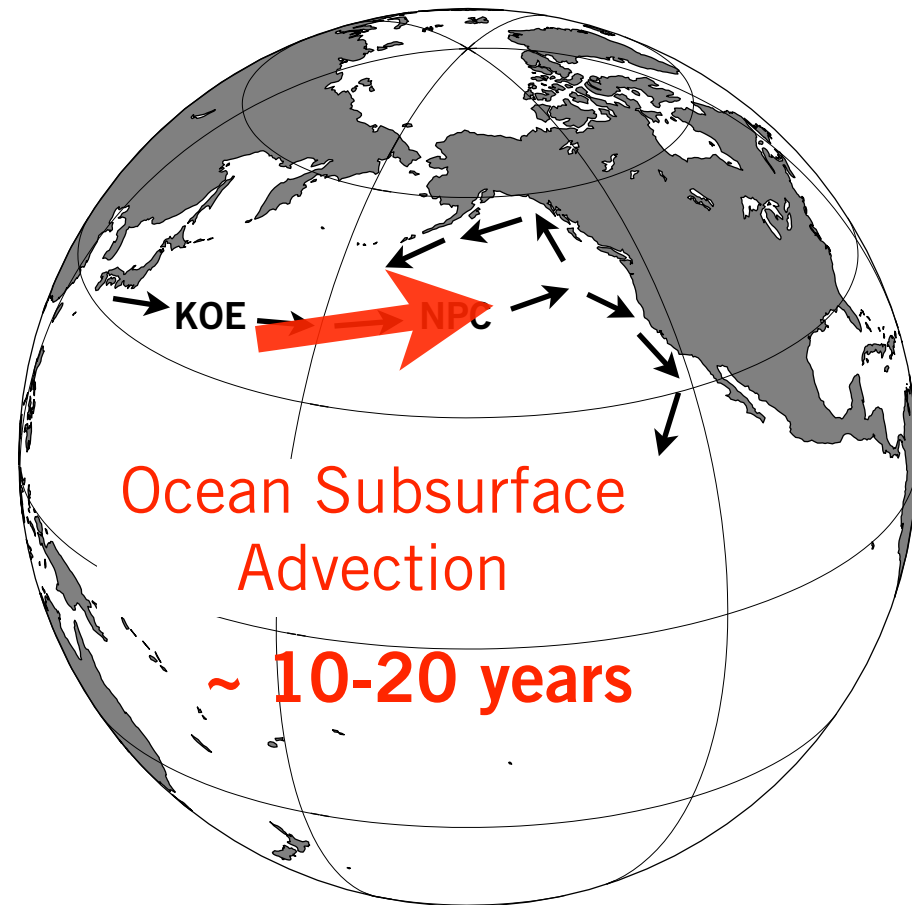
Gyre Oxygen Index 10 year forecast

FORECAST POTENTIAL
~10 YEARS

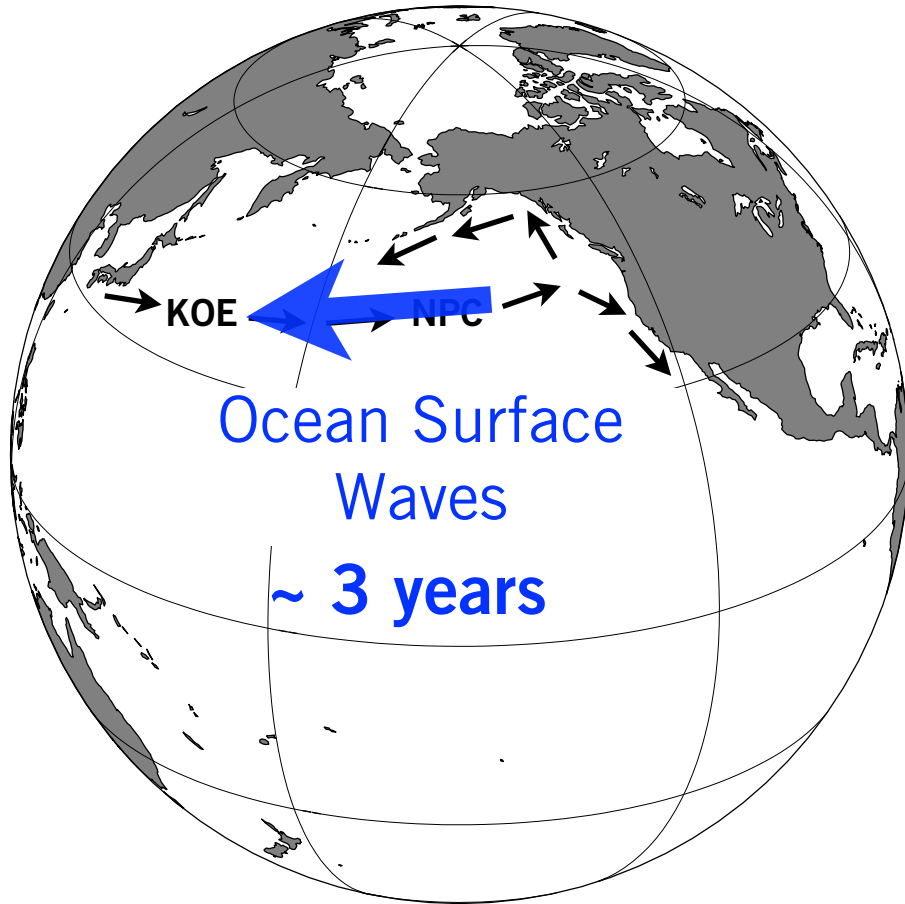
OCEAN SUBSURFACE



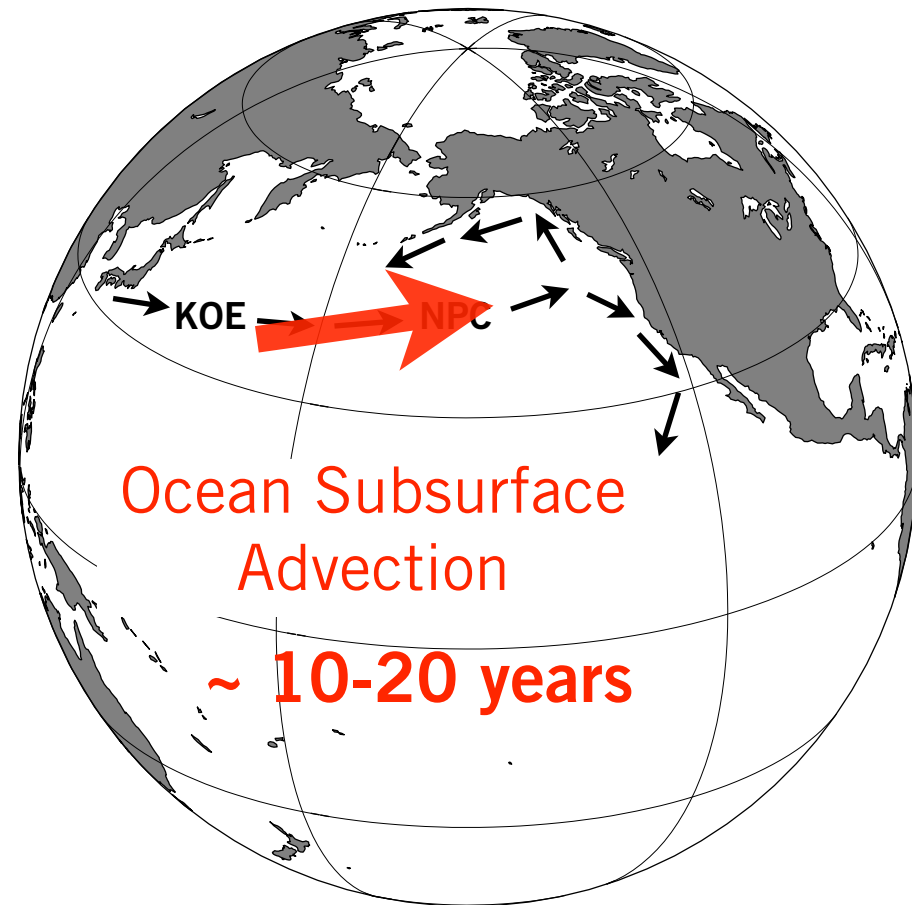
OCEAN SUBSURFACE



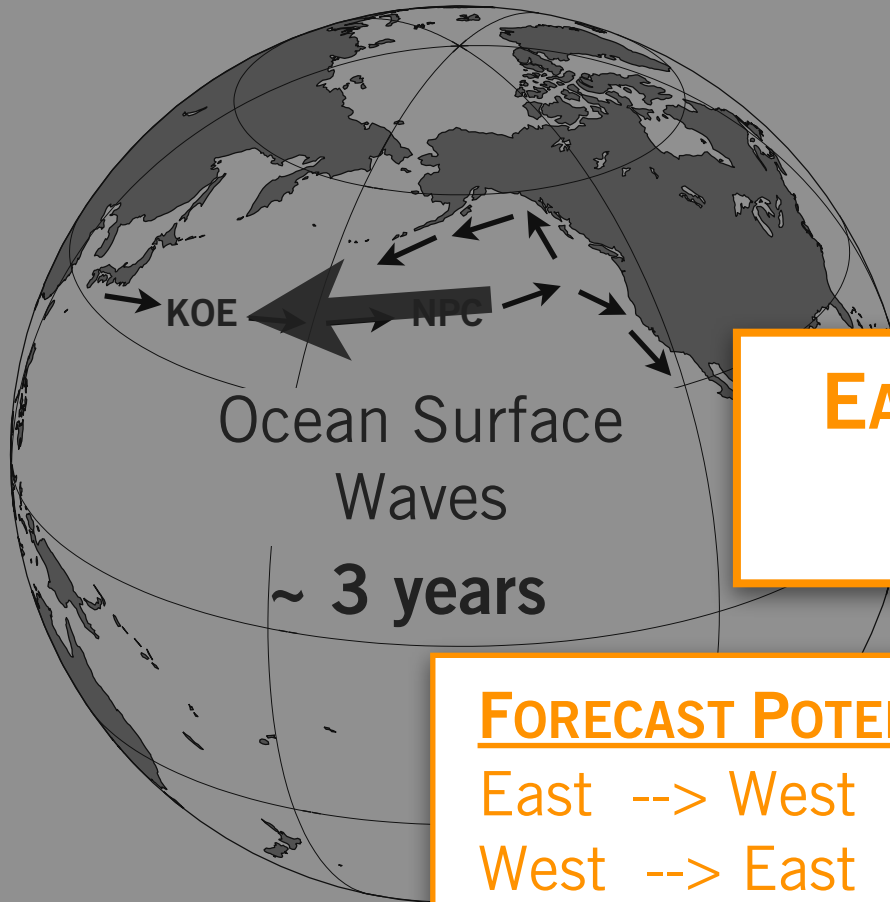
OCEAN SURFACE



OCEAN SUBSURFACE



OCEAN SURFACE



EASTERN & WESTERN BOUNDARY CLIMATE CONNECTION

FORECAST POTENTIAL

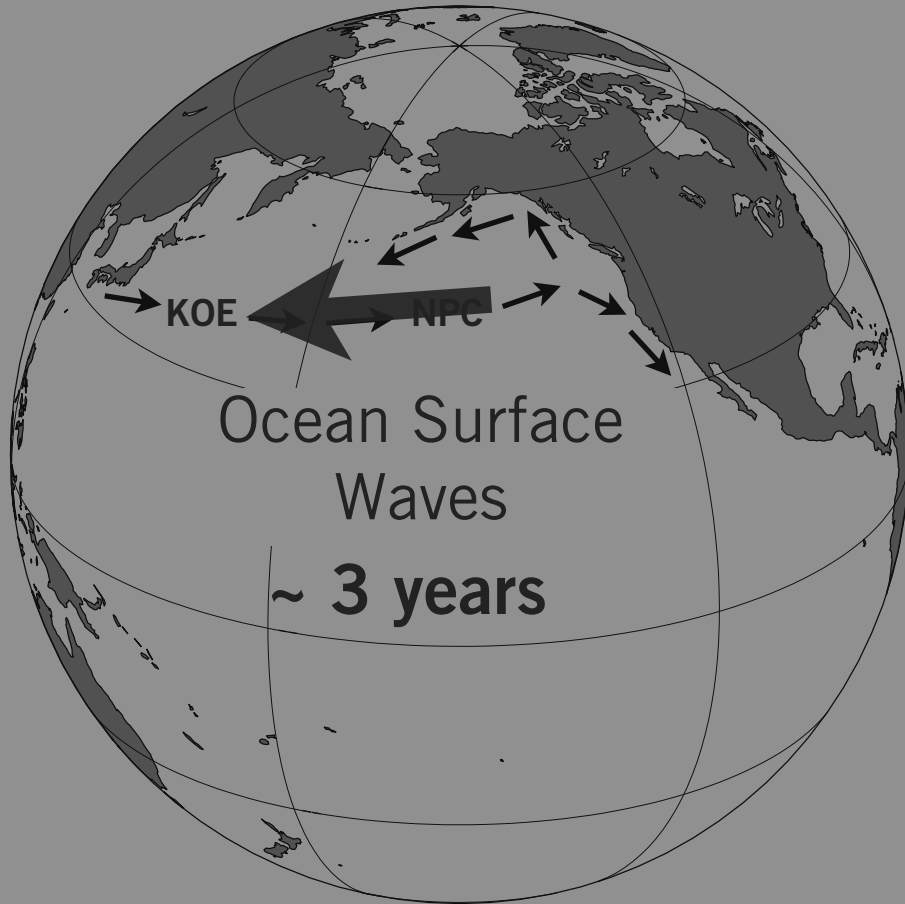
East --> West ~3 years

West --> East ~10 years

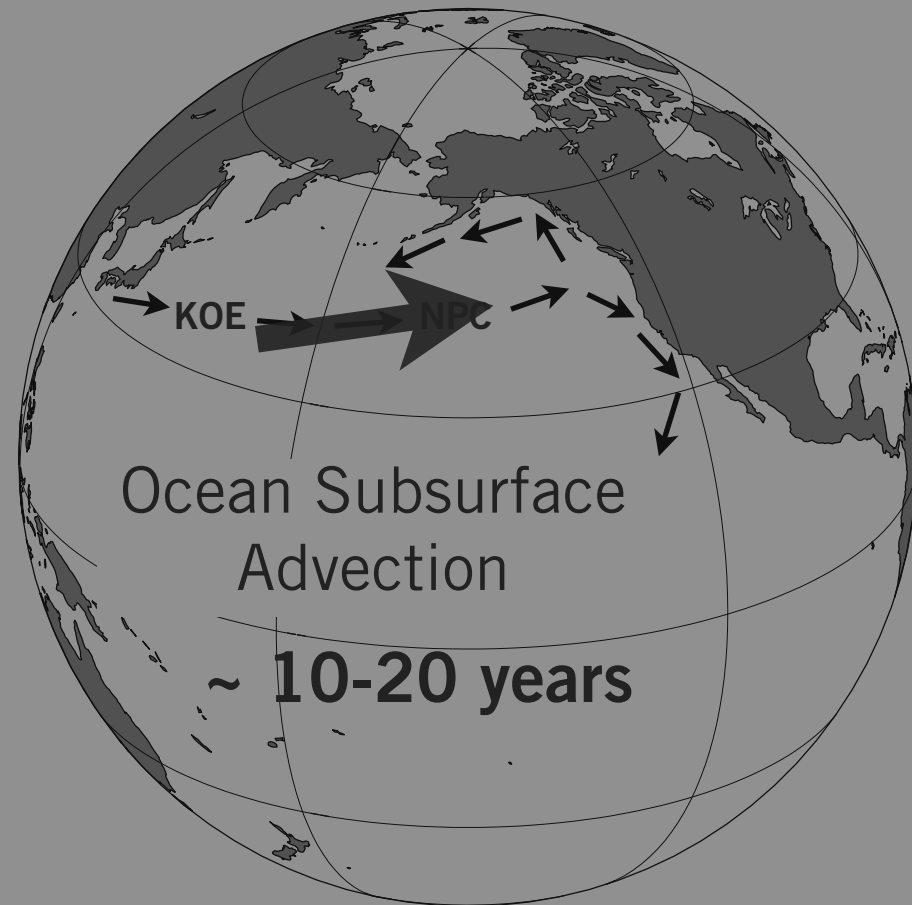


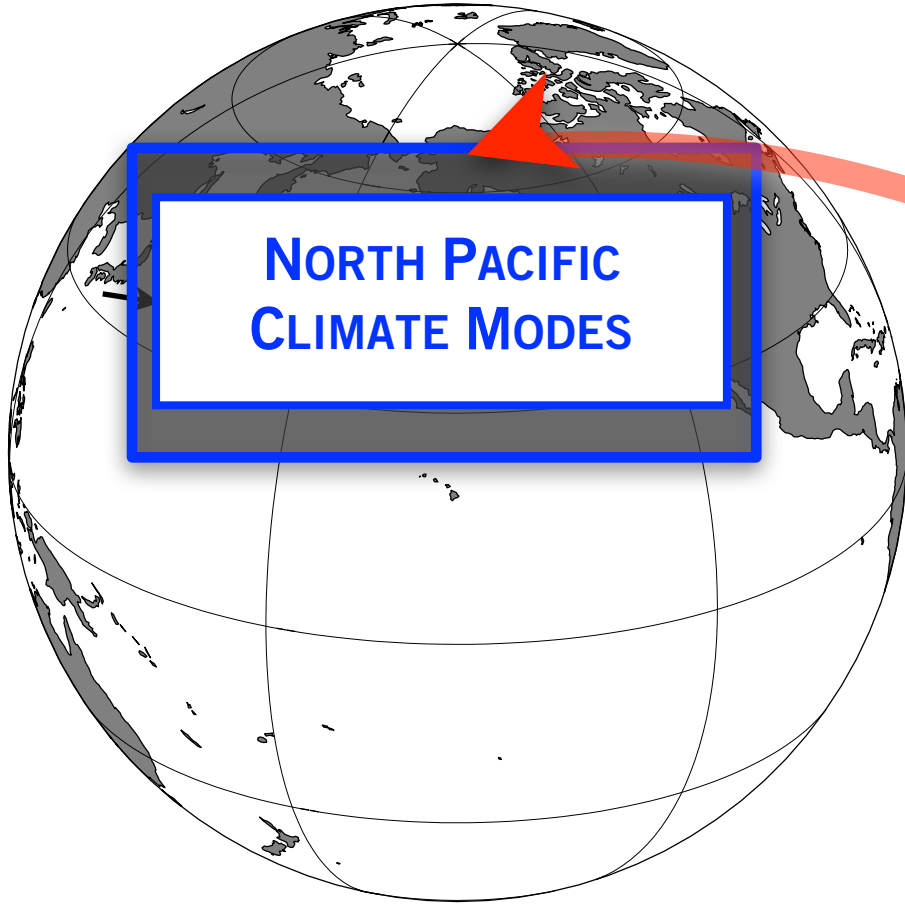
OCEAN SUBSURFACE

OCEAN SURFACE



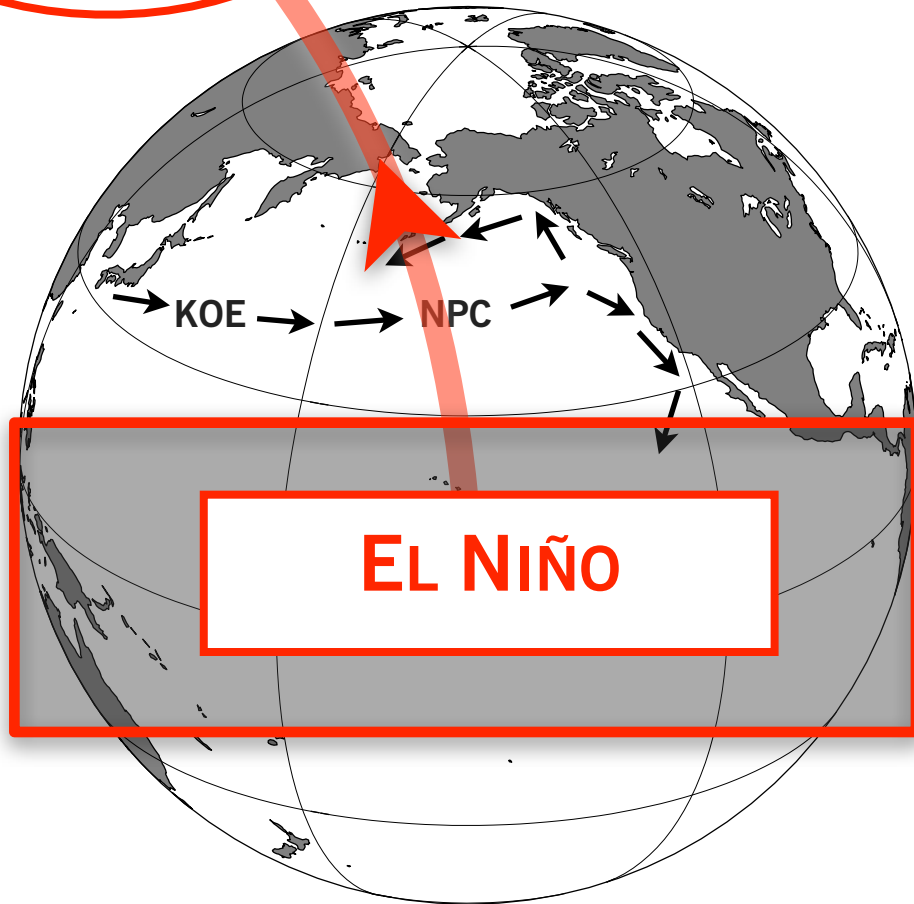
TROPICS & NORTH PACIFIC CLIMATE CONNECTION





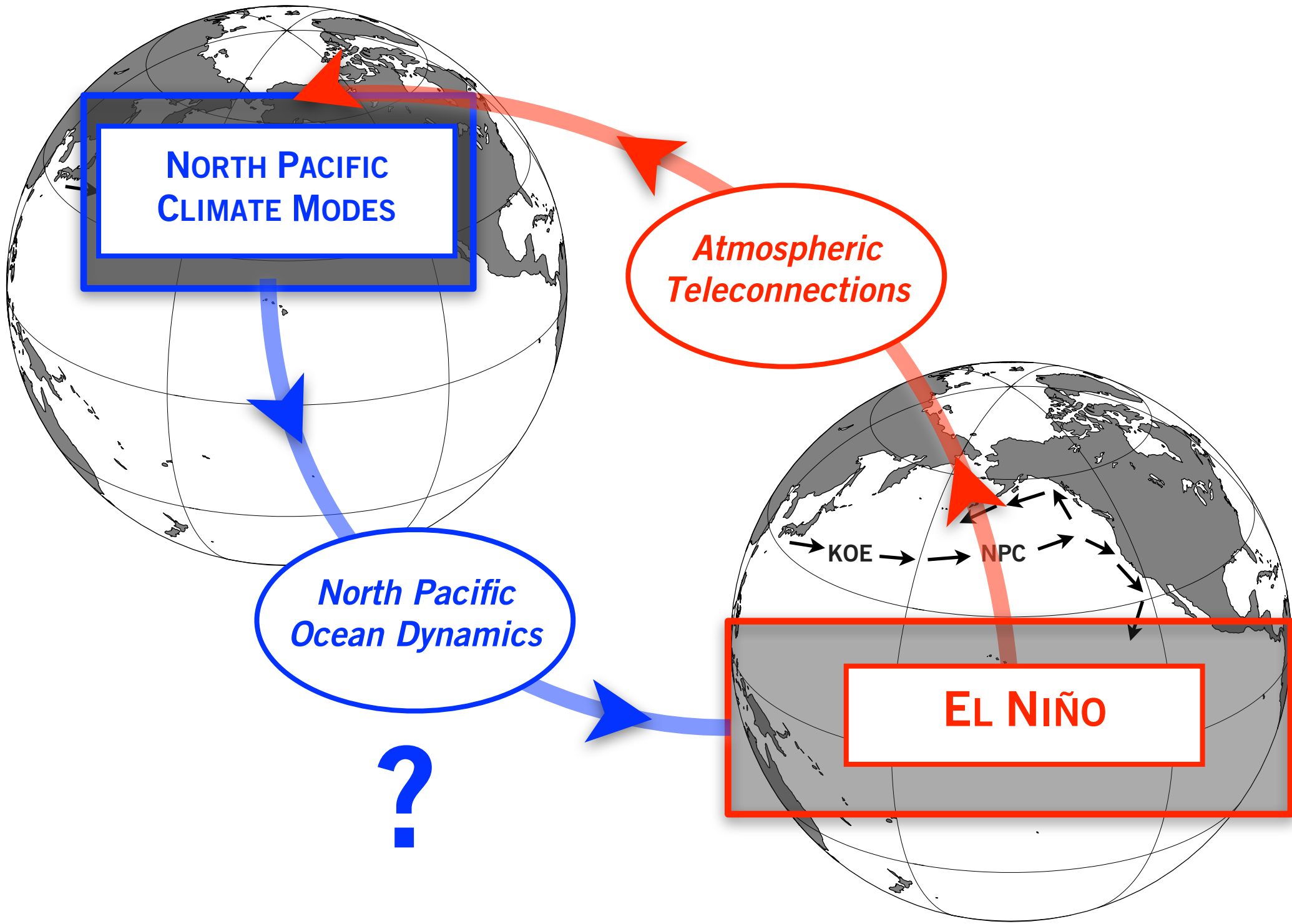
**NORTH PACIFIC
CLIMATE MODES**

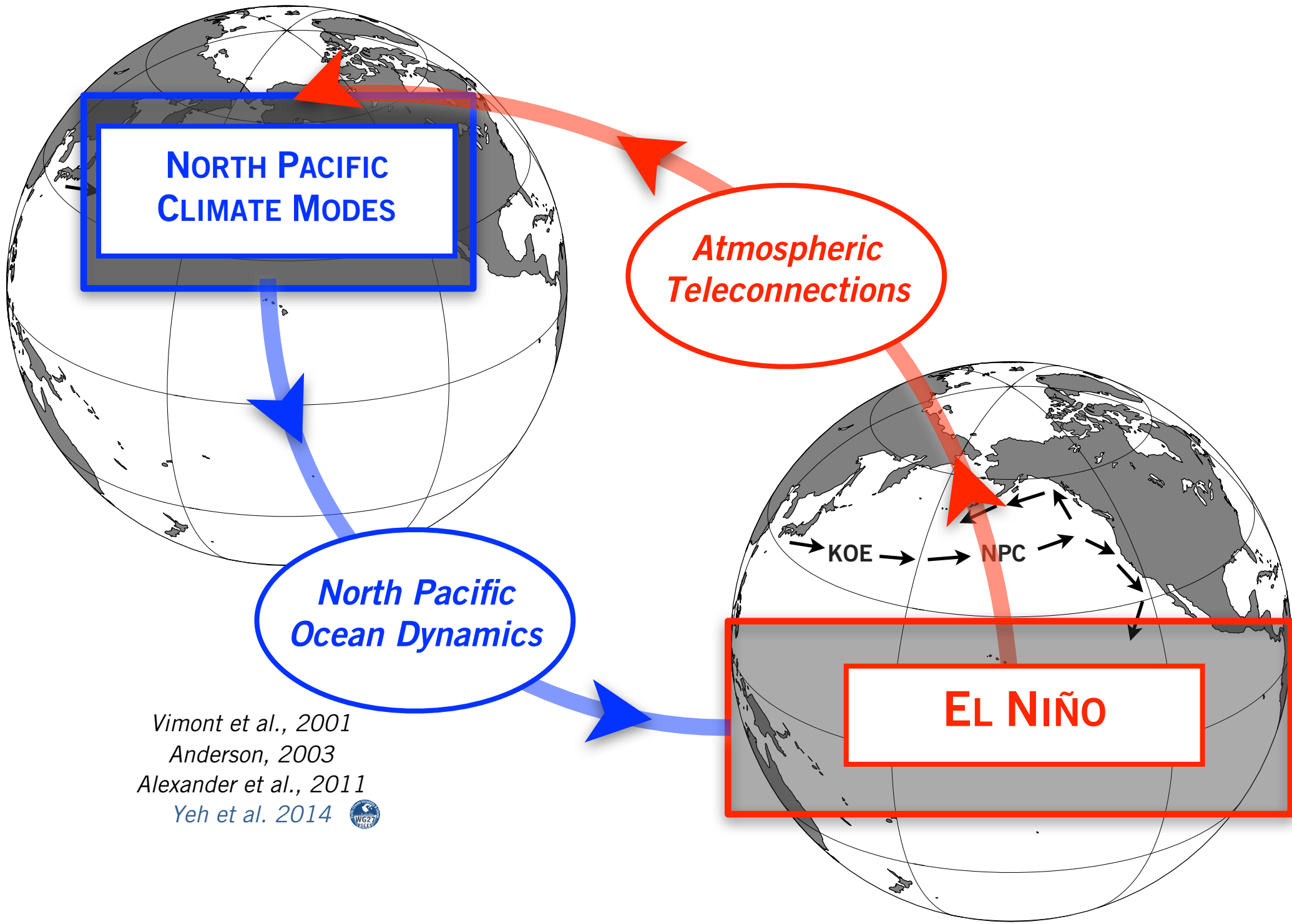
*Atmospheric
Teleconnections*



EL NIÑO

**TROPICS & NORTH PACIFIC
CLIMATE CONNECTION**





**NORTH PACIFIC
CLIMATE MODES**

*Atmospheric
Teleconnections*

*North Pacific
Ocean Dynamics*

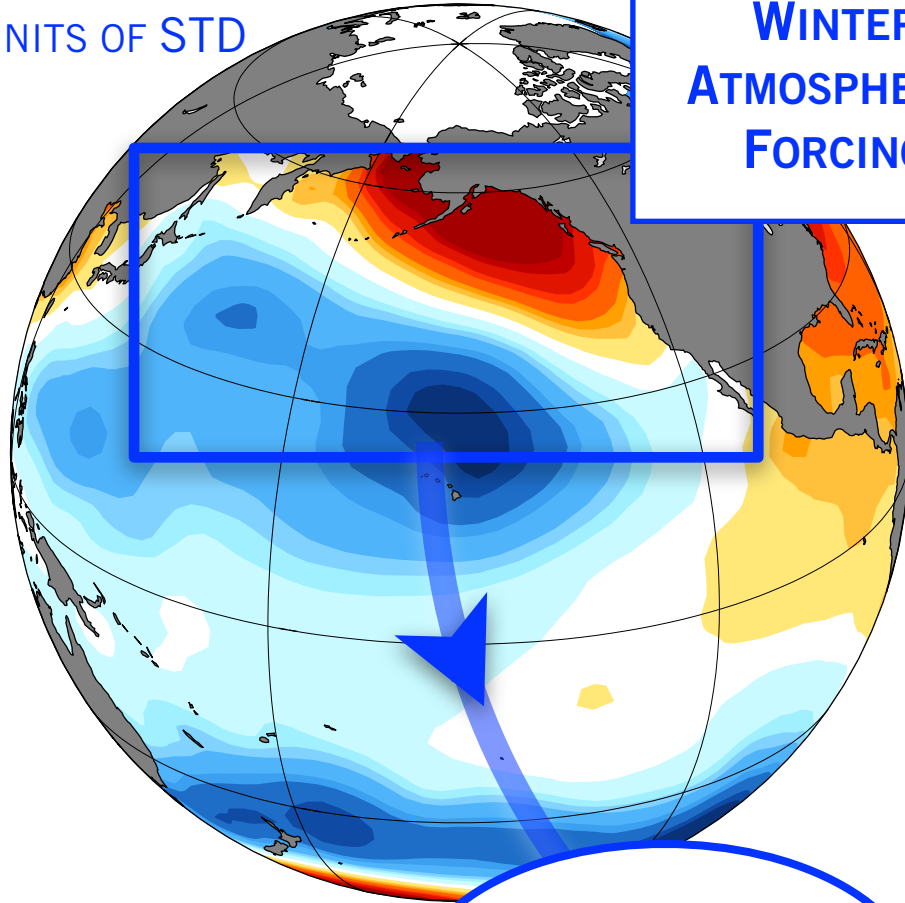
EL NIÑO

Vimont et al., 2001
Anderson, 2003
Alexander et al., 2011
Yeh et al. 2014



SLPA
UNITS OF STD

**WINTER
ATMOSPHERIC
FORCING**

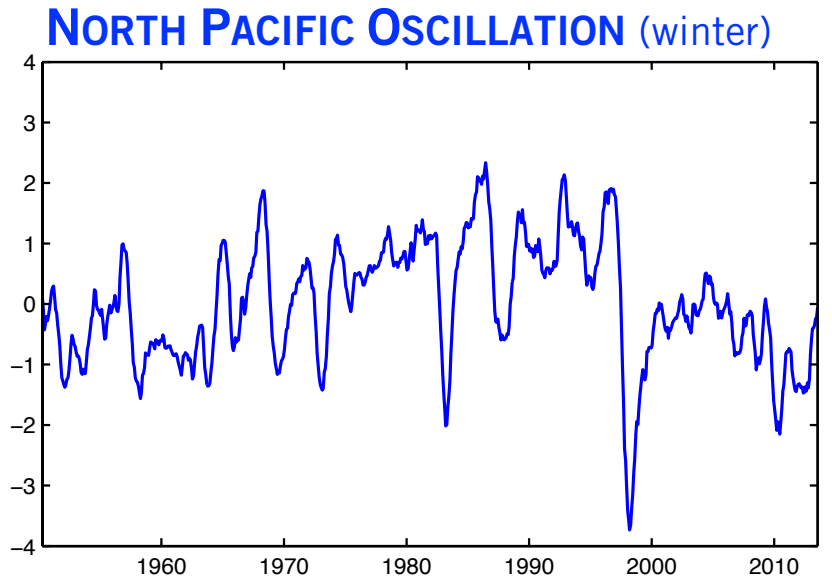
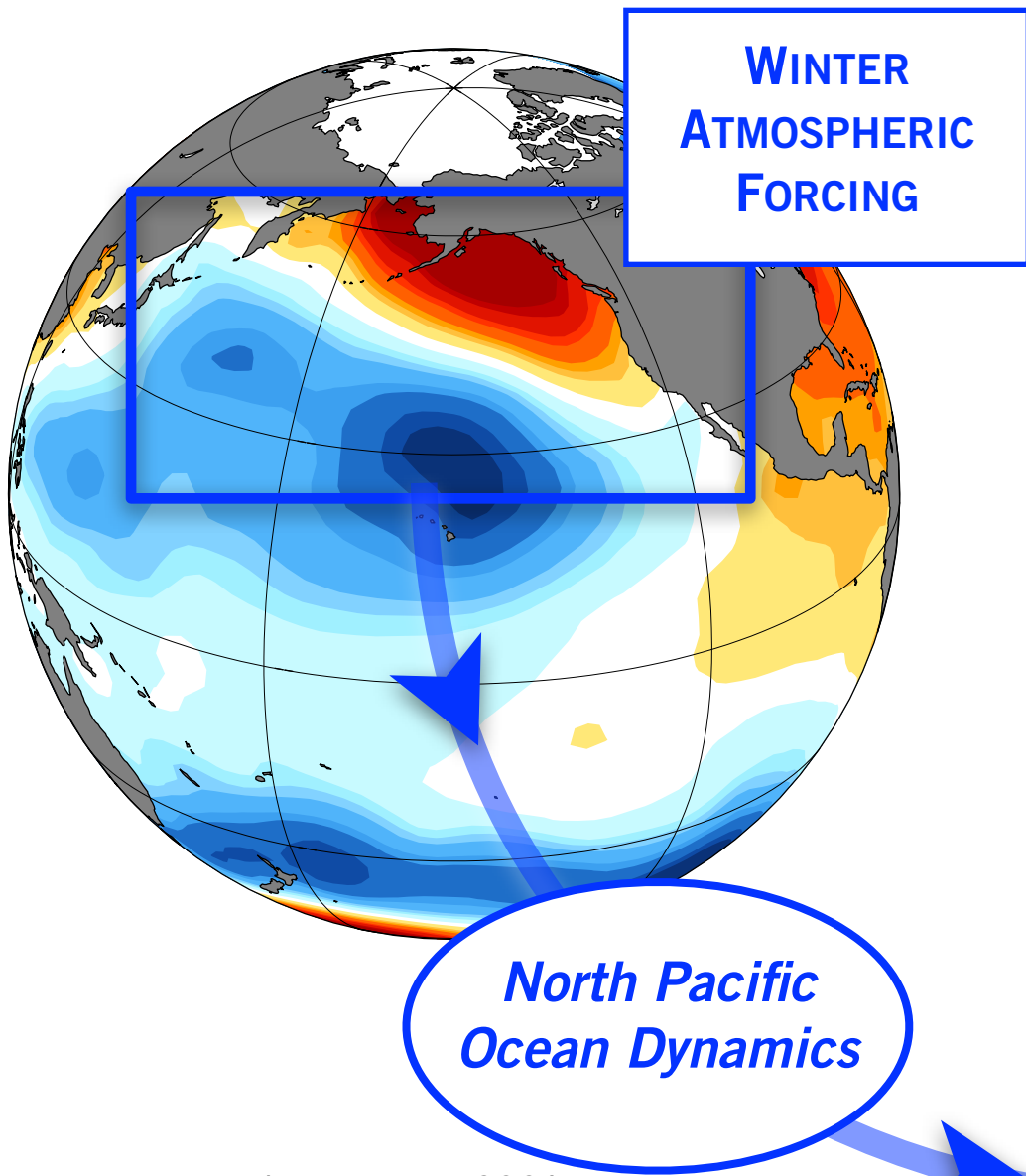


**North Pacific
Ocean Dynamics**


Vimont et al., 2001
Anderson, 2003
Alexander et al., 2011
Yeh et al. 2014

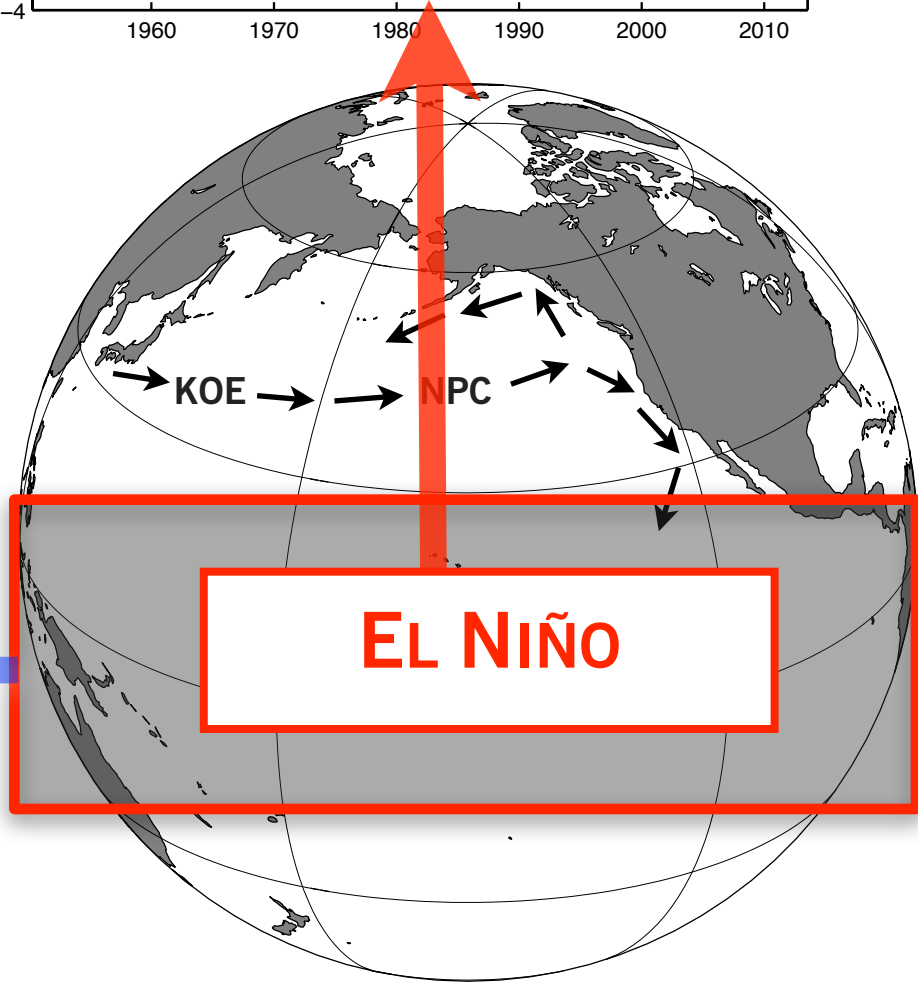
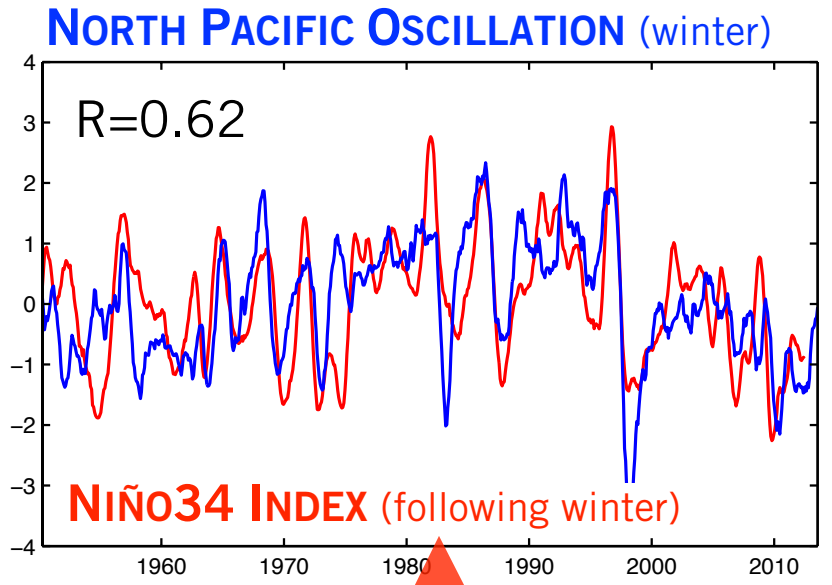
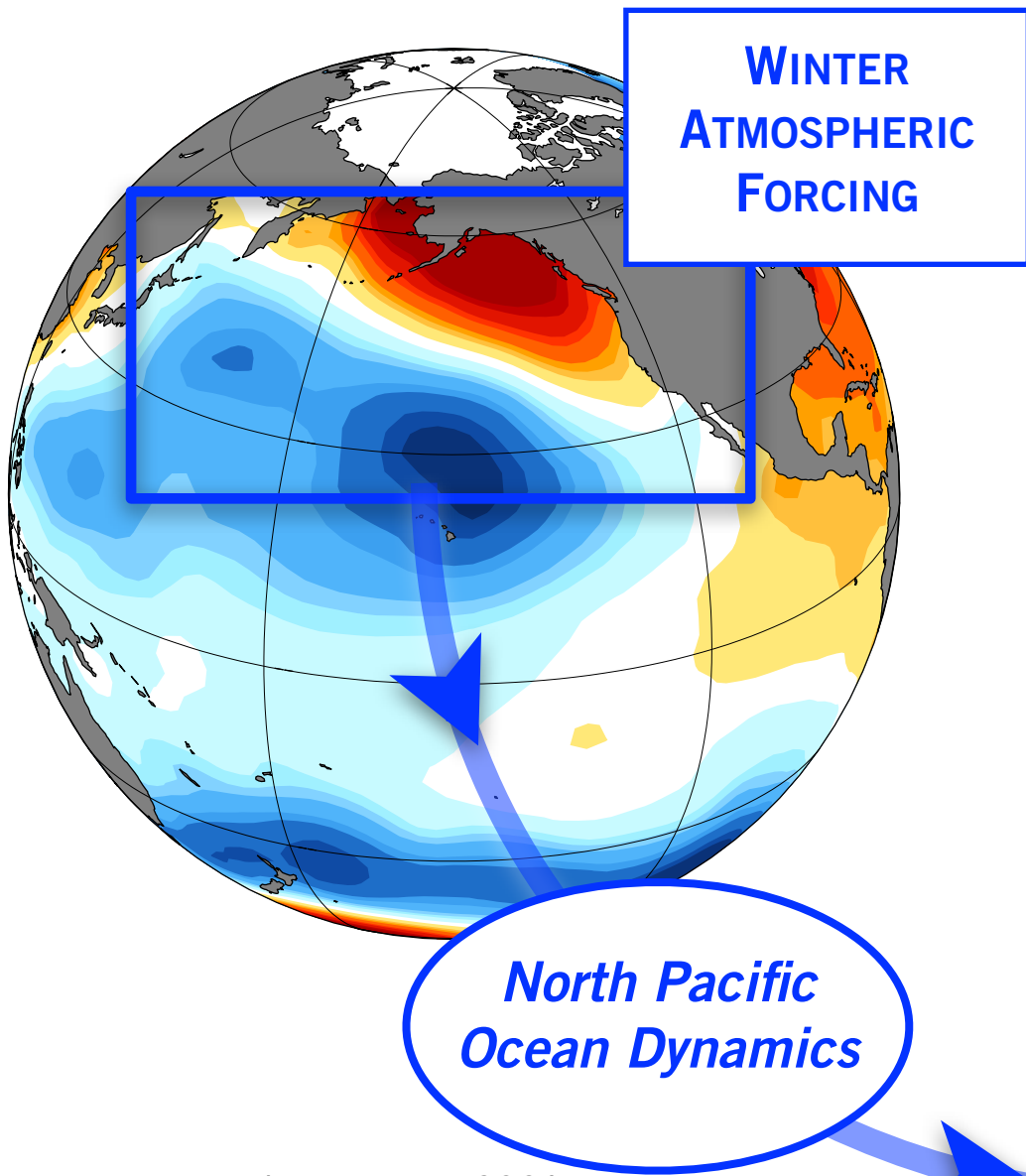


EL NIÑO




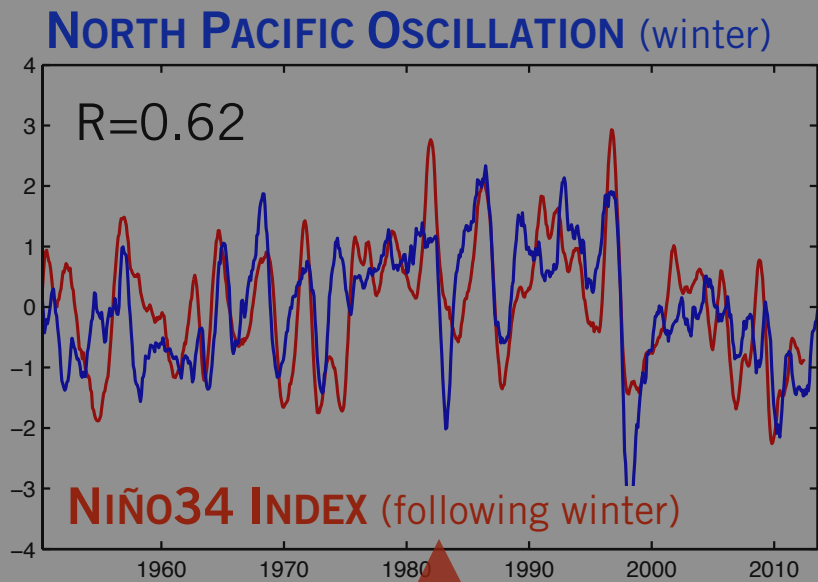
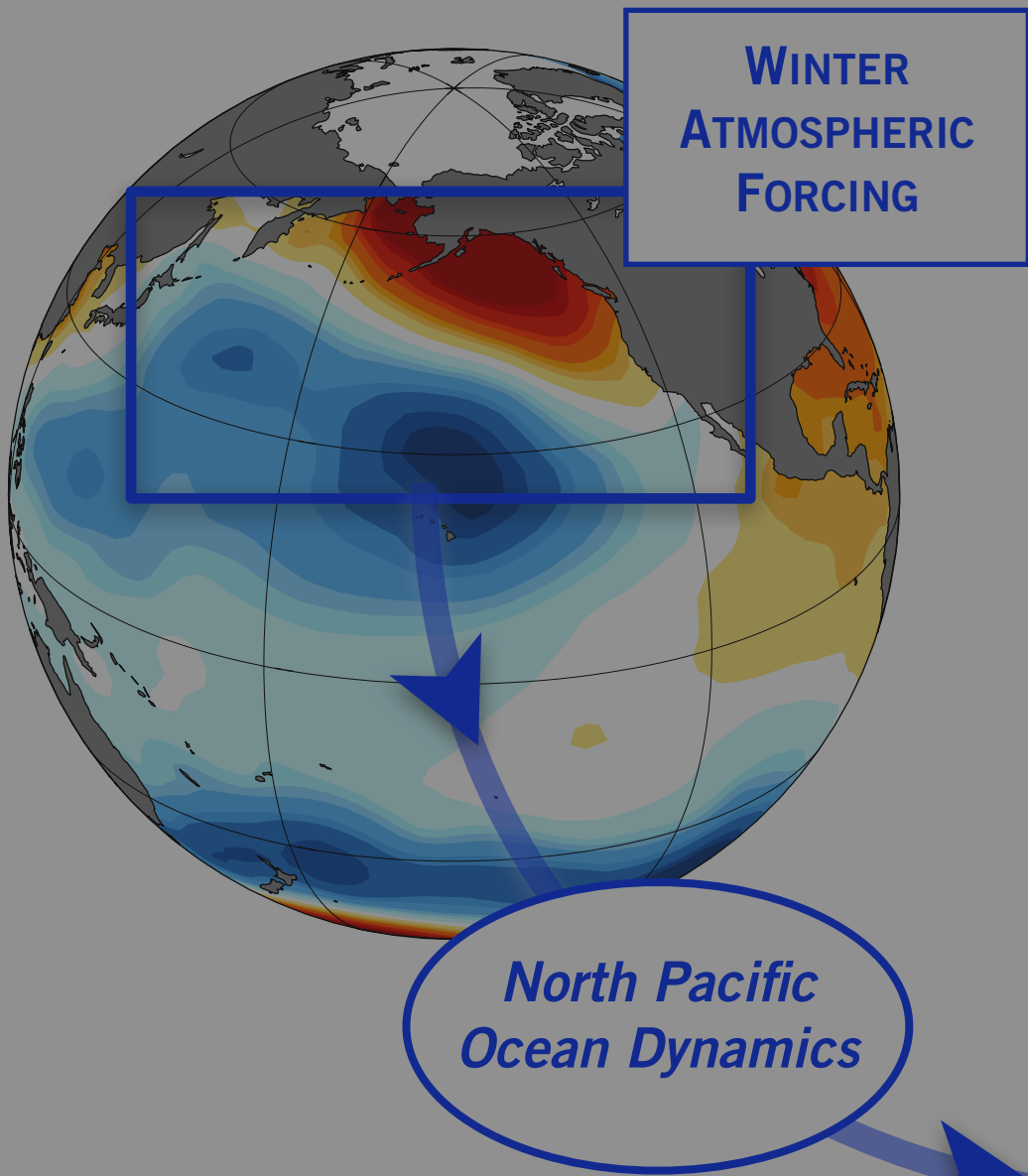
Vimont et al., 2001
Anderson, 2003
Alexander et al., 2011
Yeh et al. 2014





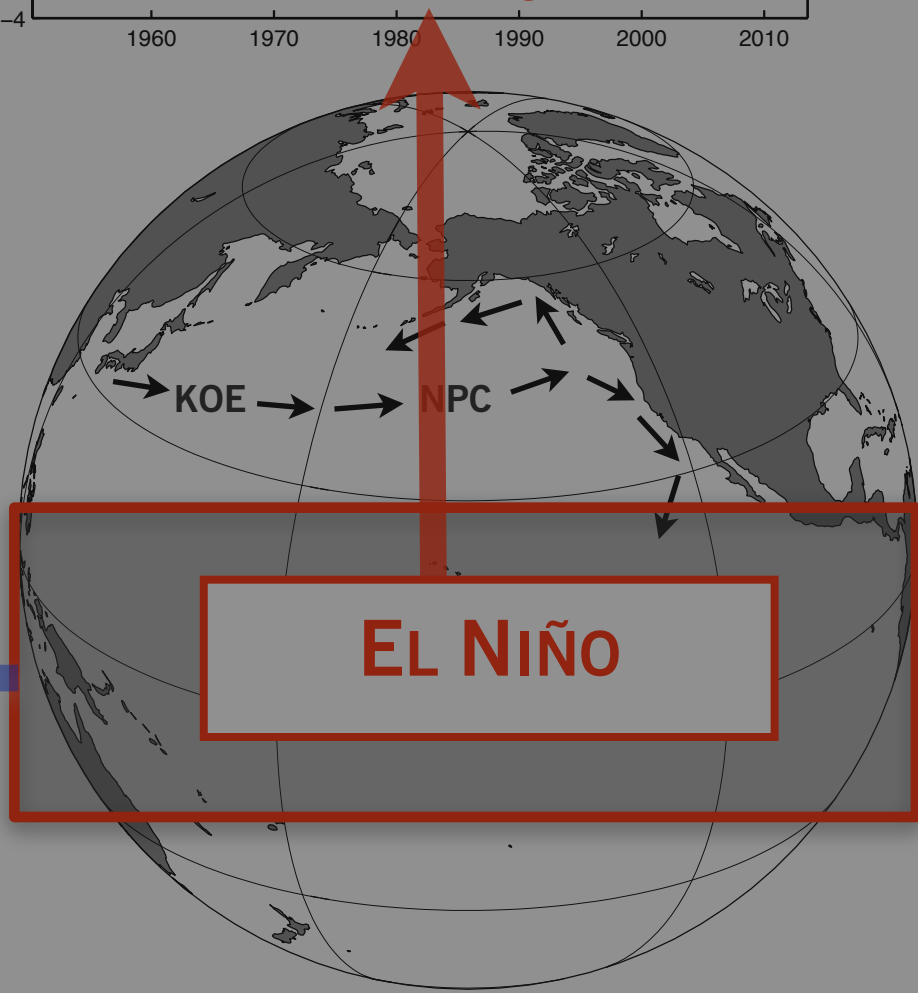
Vimont et al., 2001
Anderson, 2003
Alexander et al., 2011
Yeh et al. 2014

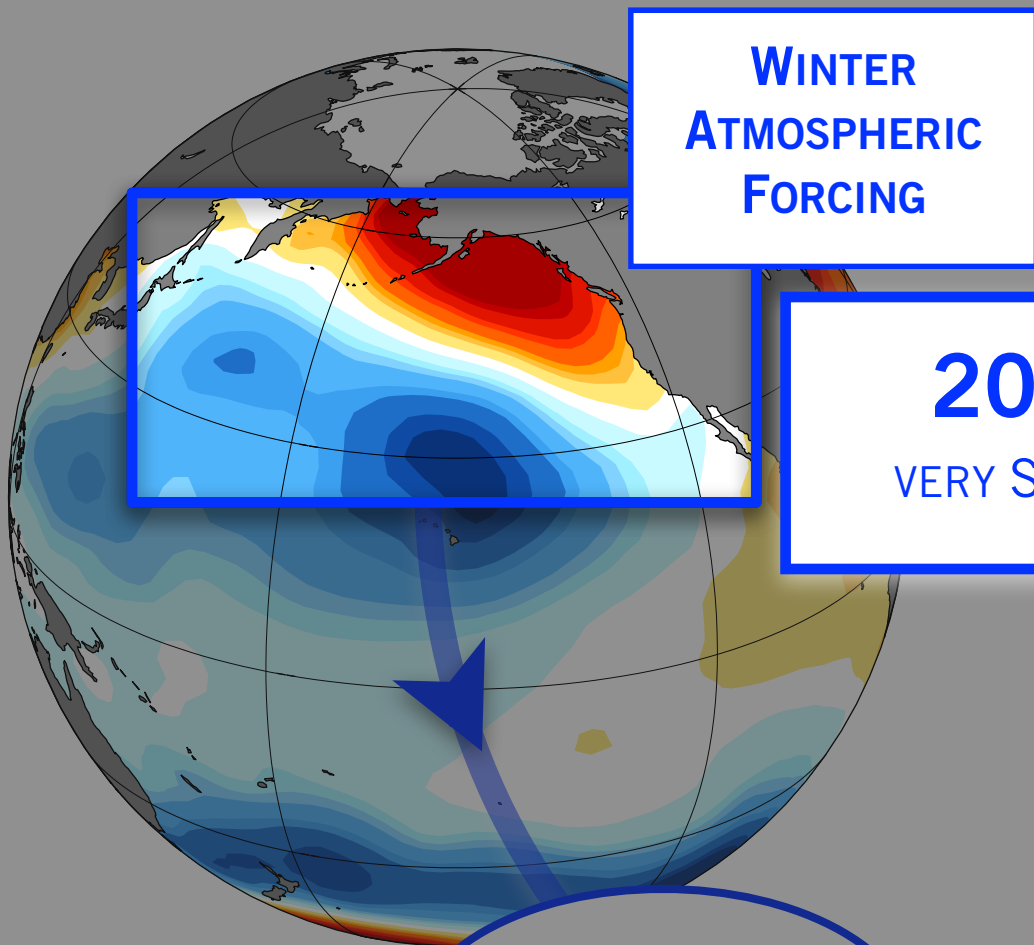




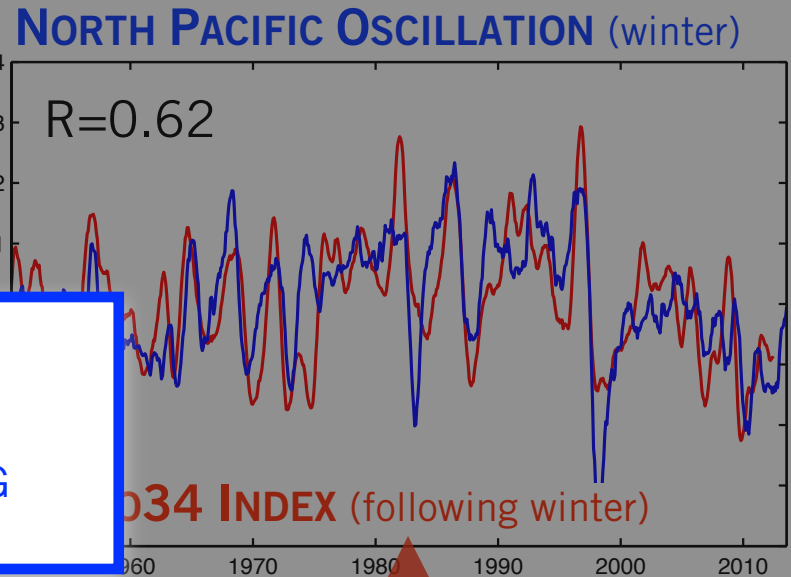
FORECAST POTENTIAL

~1 YEARS



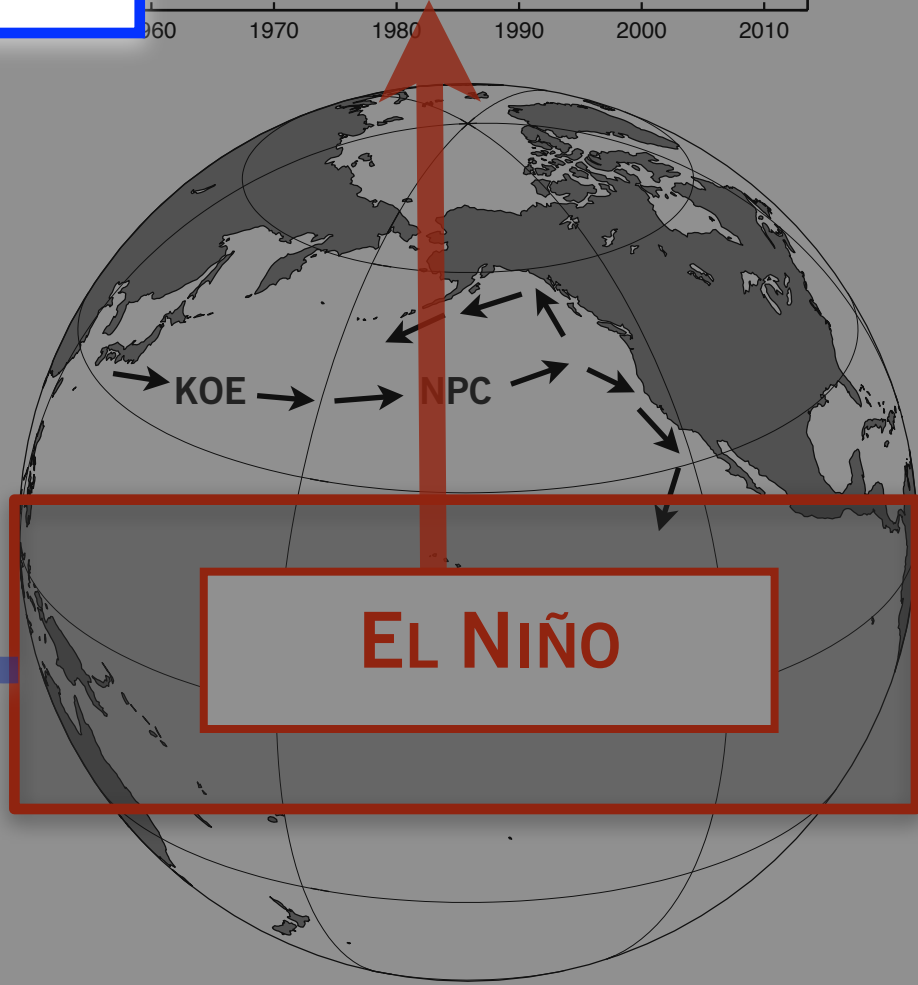


2014
VERY STRONG



*North Pacific
Ocean Dynamics*

FORECAST POTENTIAL
~1 YEARS





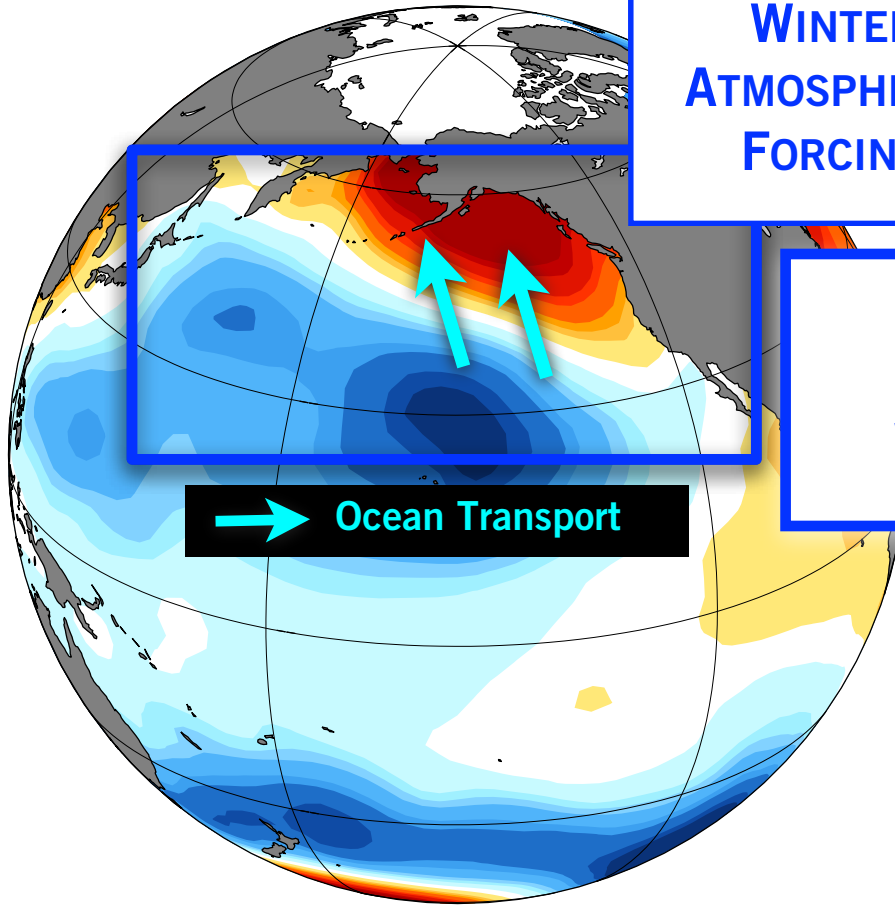
**WINTER
ATMOSPHERIC
FORCING**

2014
VERY STRONG

**WINTER
ATMOSPHERIC
FORCING**

2014
VERY STRONG

→ Ocean Transport



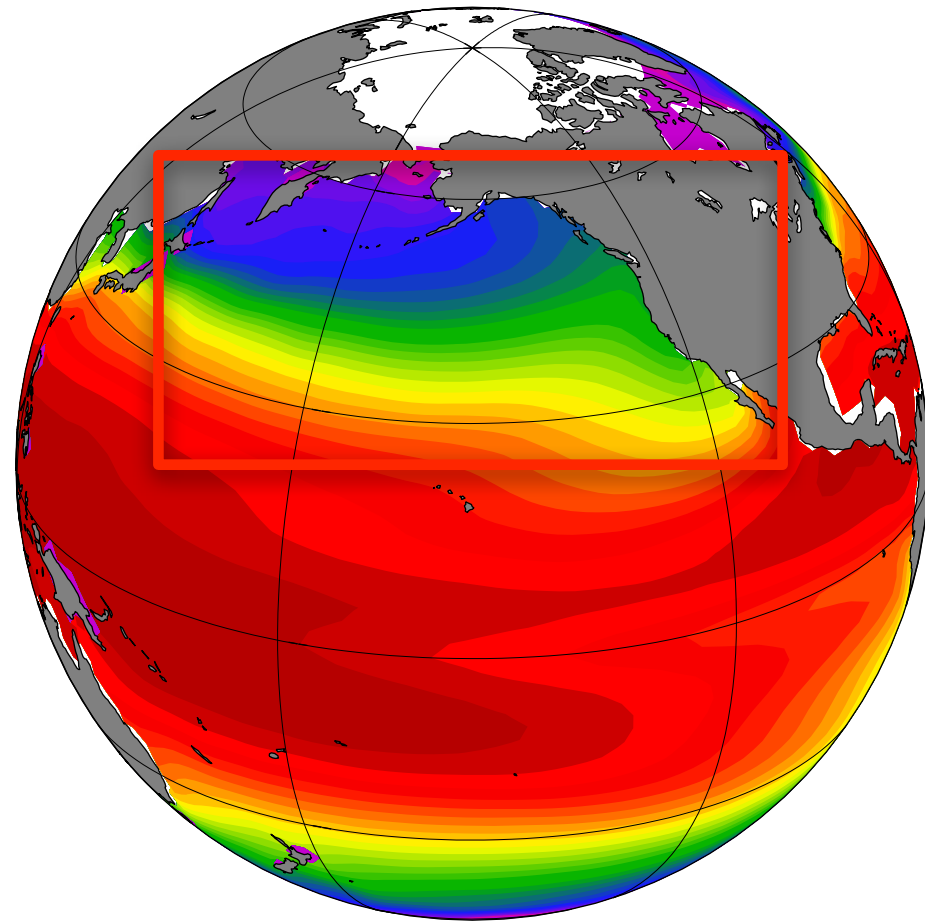
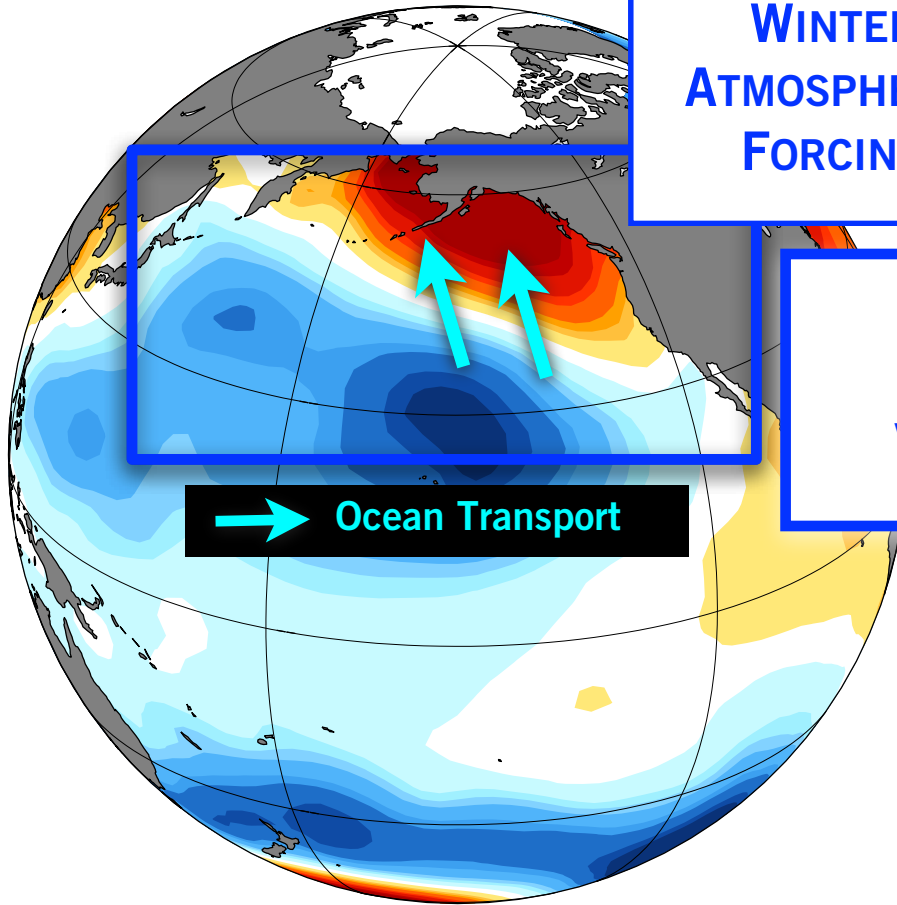
**WINTER
ATMOSPHERIC
FORCING**

2014

VERY STRONG

→ Ocean Transport

MEAN SST



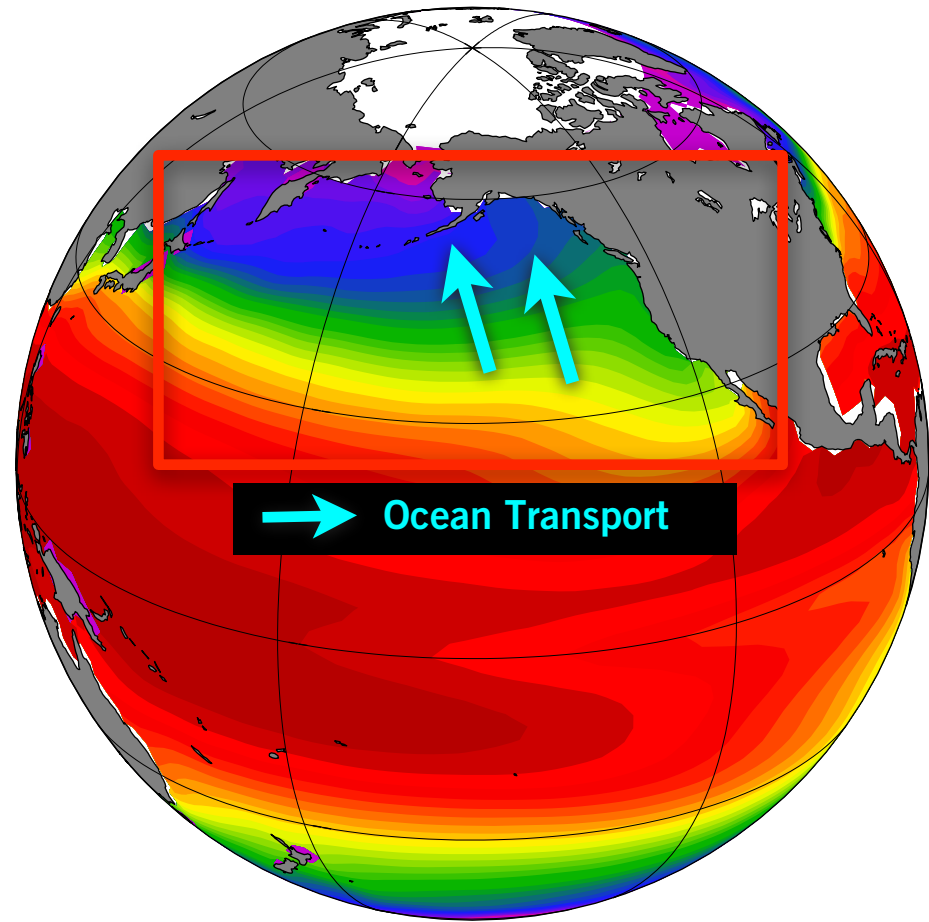
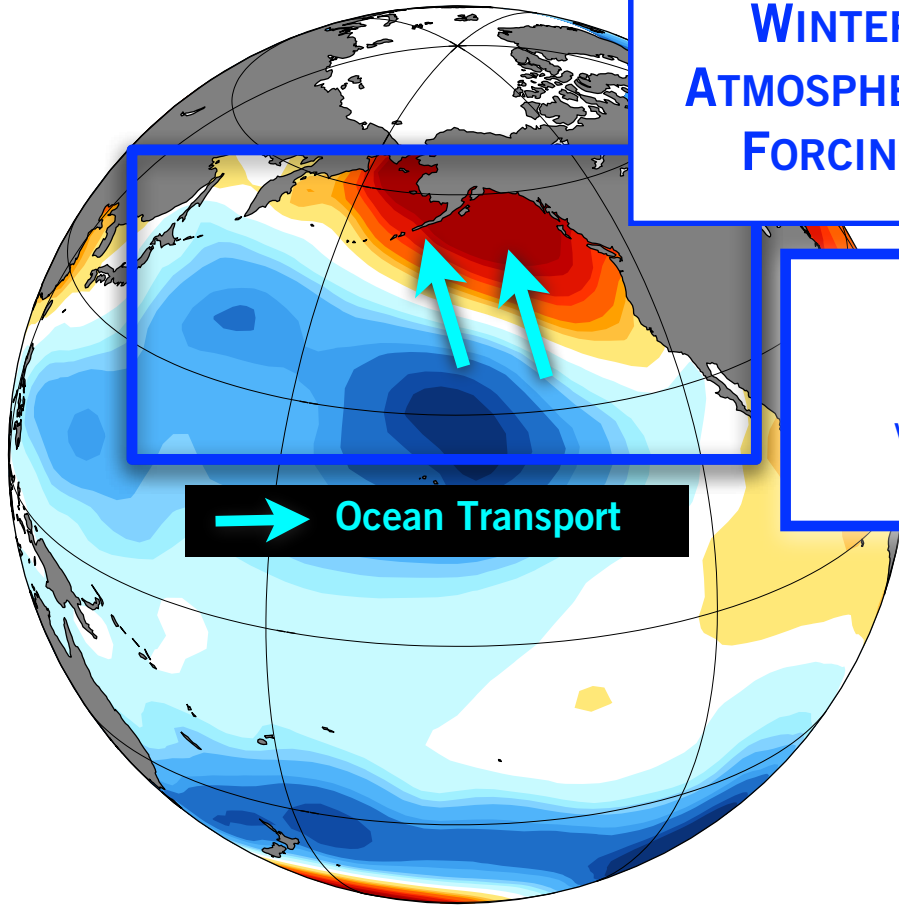
WINTER
ATMOSPHERIC
FORCING

2014
VERY STRONG

→ Ocean Transport

MEAN SST

→ Ocean Transport



**WINTER
ATMOSPHERIC
FORCING**

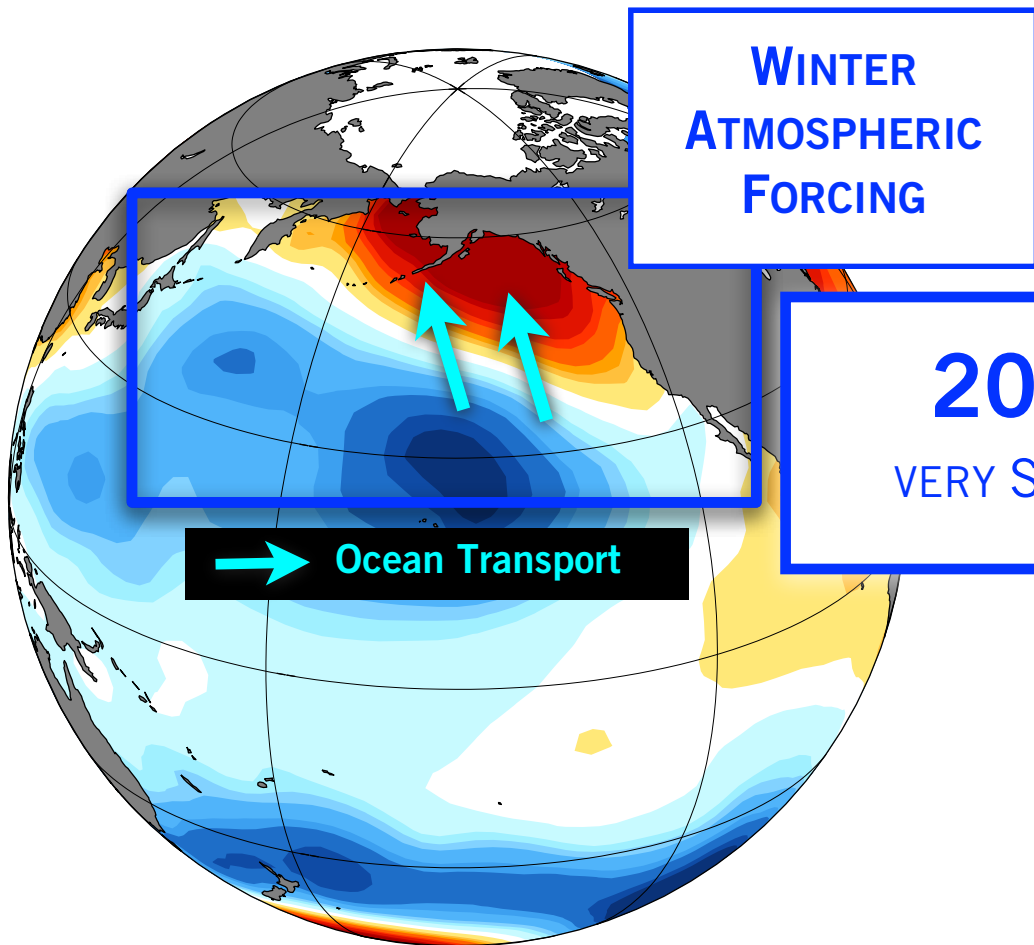
2014
VERY STRONG

→ Ocean Transport

**2014 SST
ANOMALY**

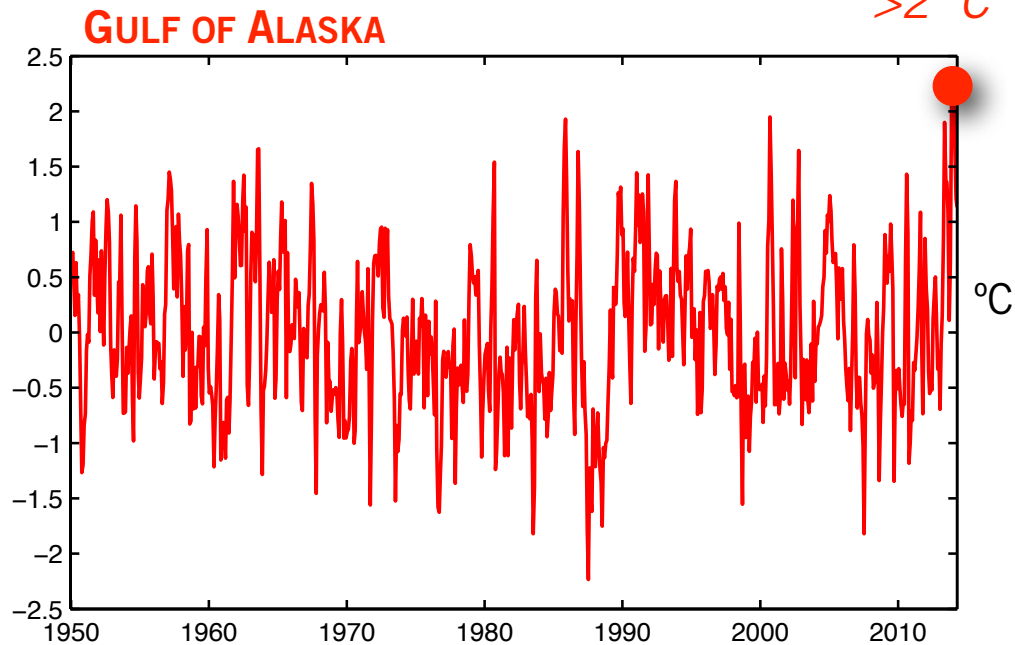
→ Ocean Transport

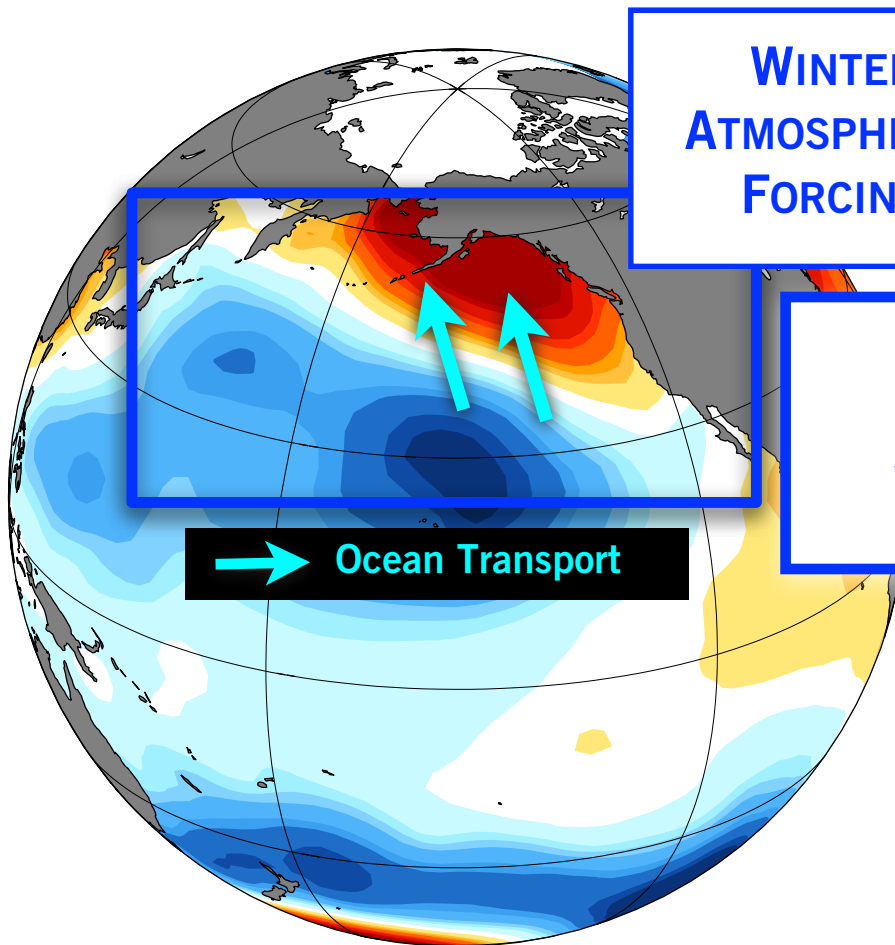




**2014 SST
ANOMALY**

*Winter 2014
>2 °C*



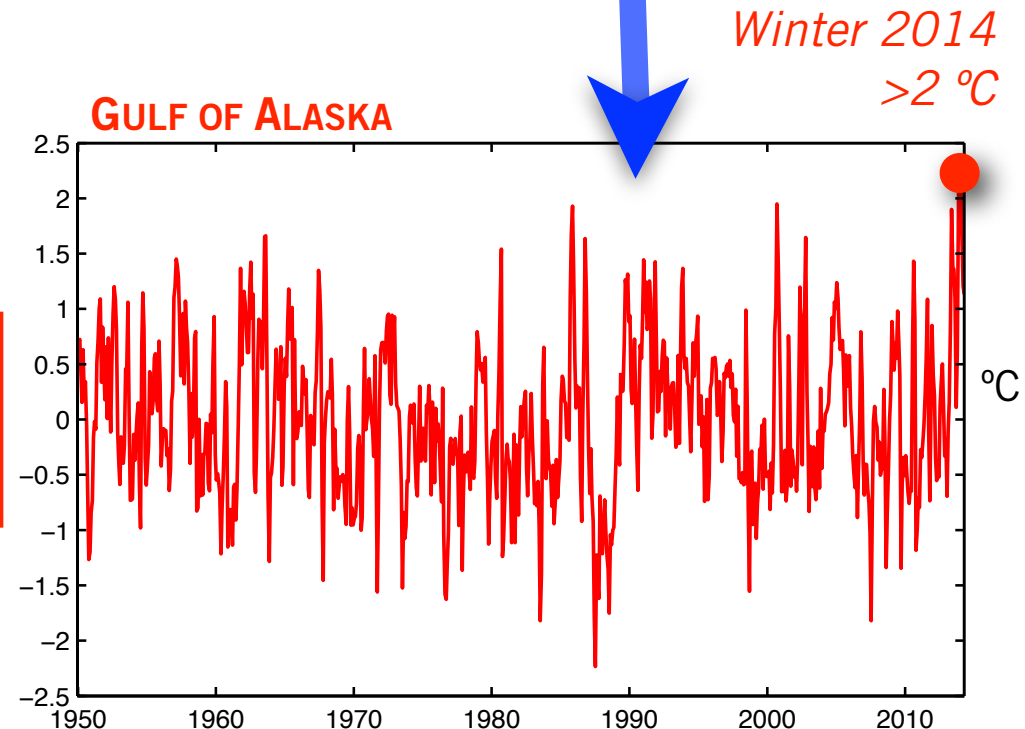


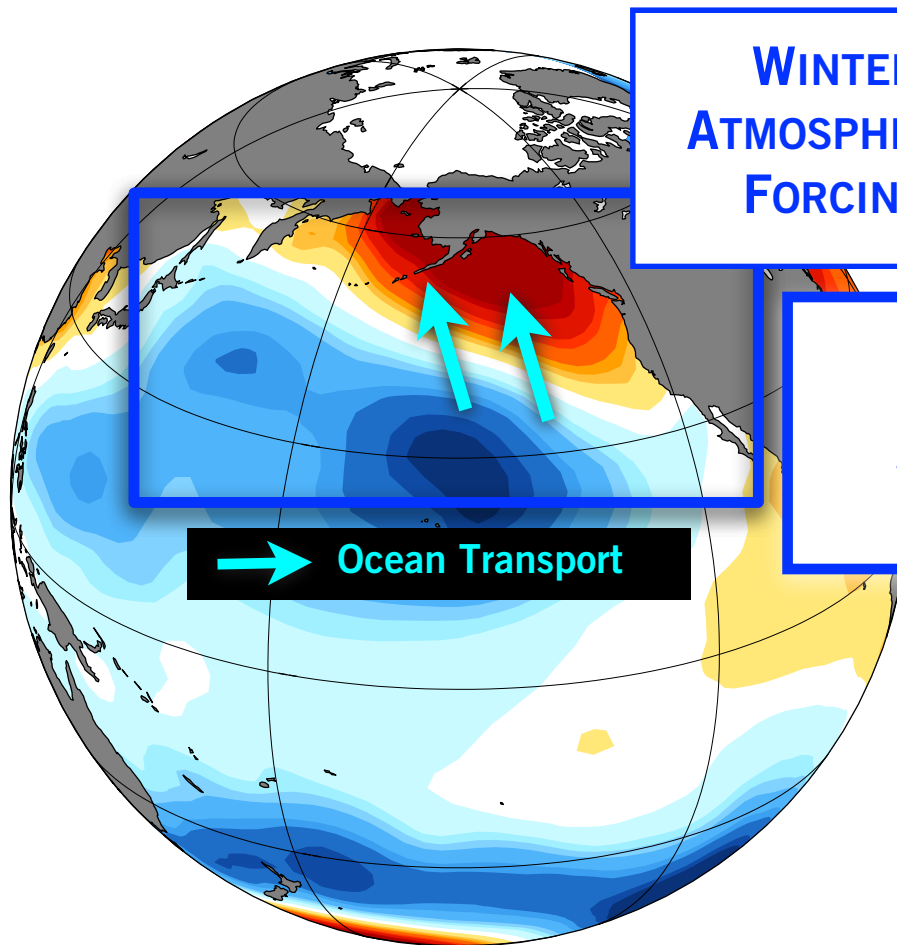
**WINTER
ATMOSPHERIC
FORCING**

**2014
VERY STRONG**

**SIMPLE EKMAN
MODEL**

**2014 SST
ANOMALY**



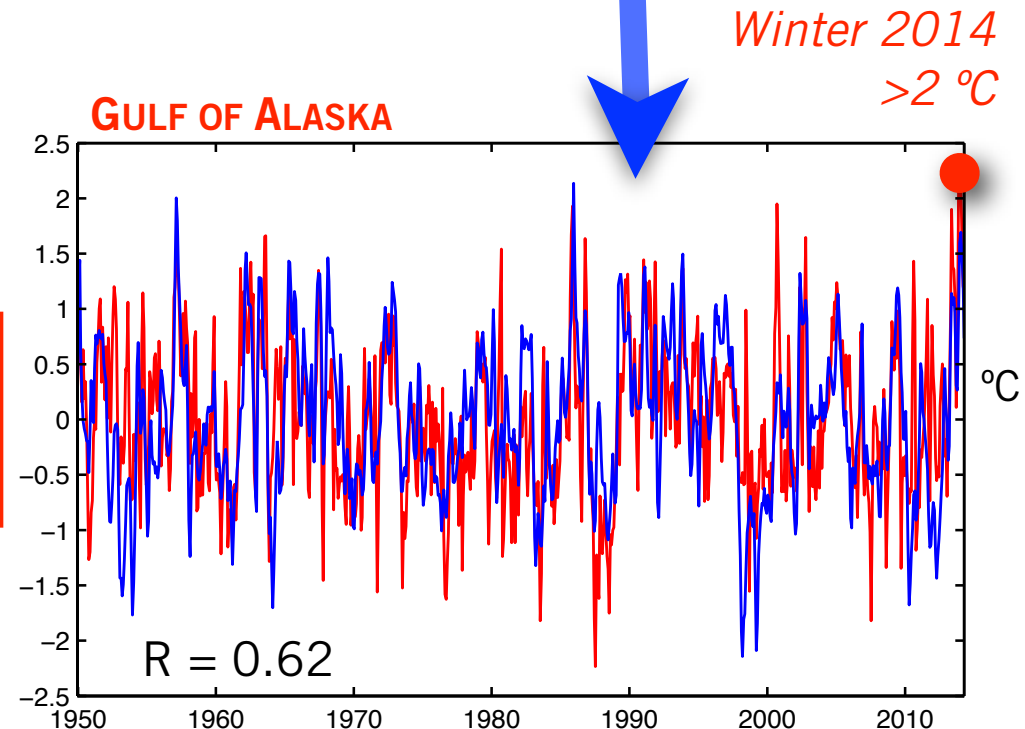


**WINTER
ATMOSPHERIC
FORCING**

**2014
VERY STRONG**

**SIMPLE EKMAN
MODEL**

**2014 SST
ANOMALY**





**WINTER
ATMOSPHERIC
FORCING**

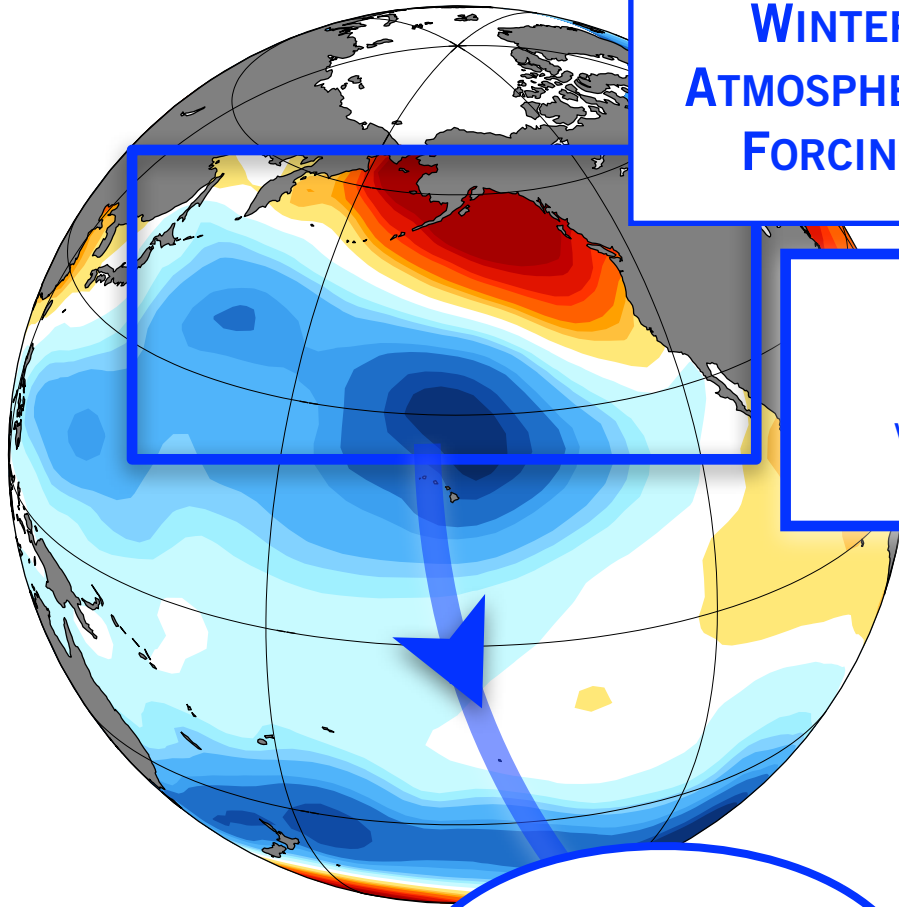
2014
VERY STRONG

**WINTER
ATMOSPHERIC
FORCING**

2014
VERY STRONG

*North Pacific
Ocean Dynamics*

EL NIÑO

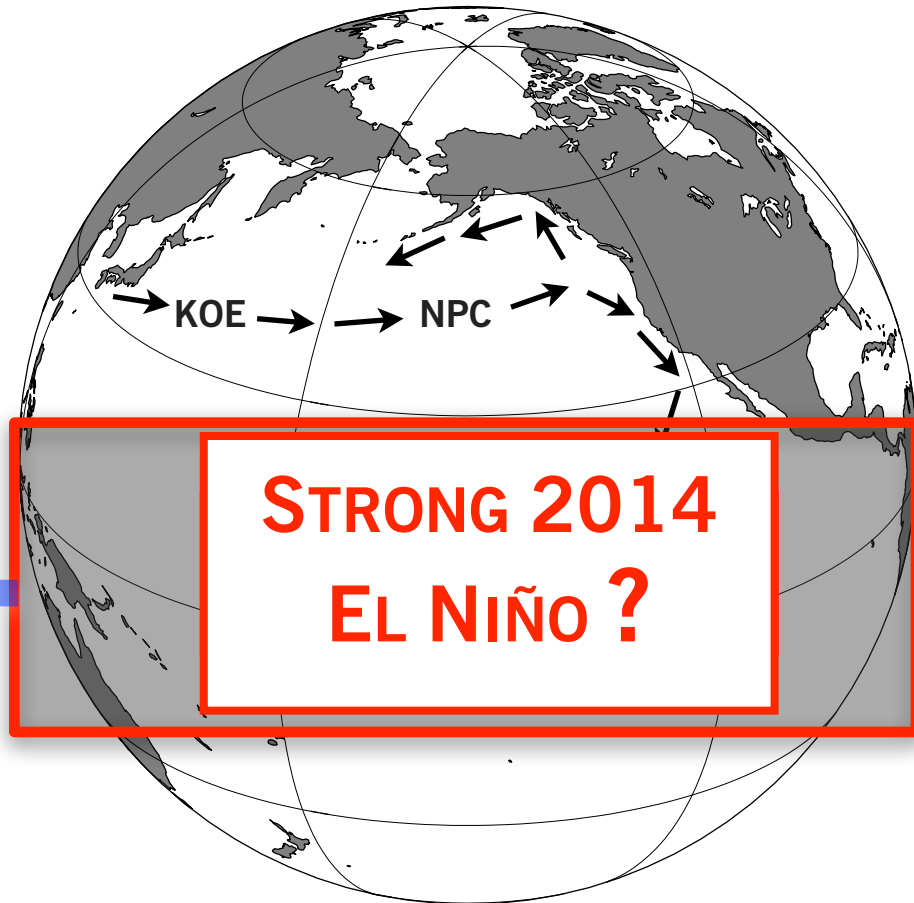
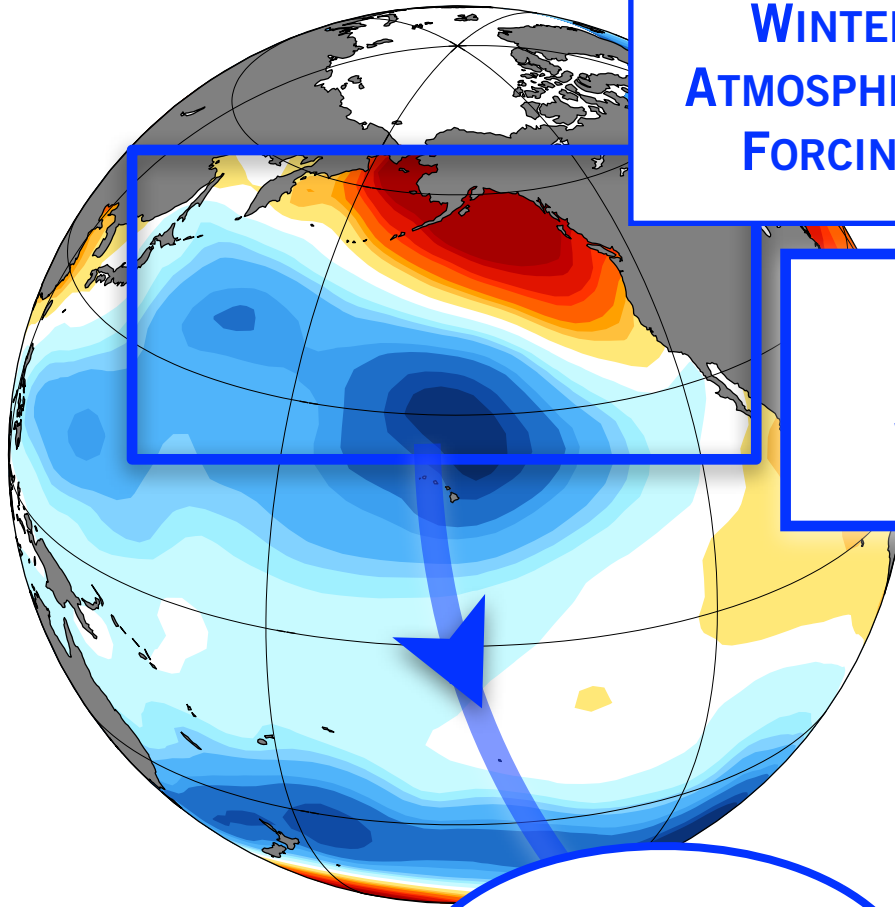


**WINTER
ATMOSPHERIC
FORCING**

2014
VERY STRONG

*North Pacific
Ocean Dynamics*

**STRONG 2014
EL NIÑO ?**



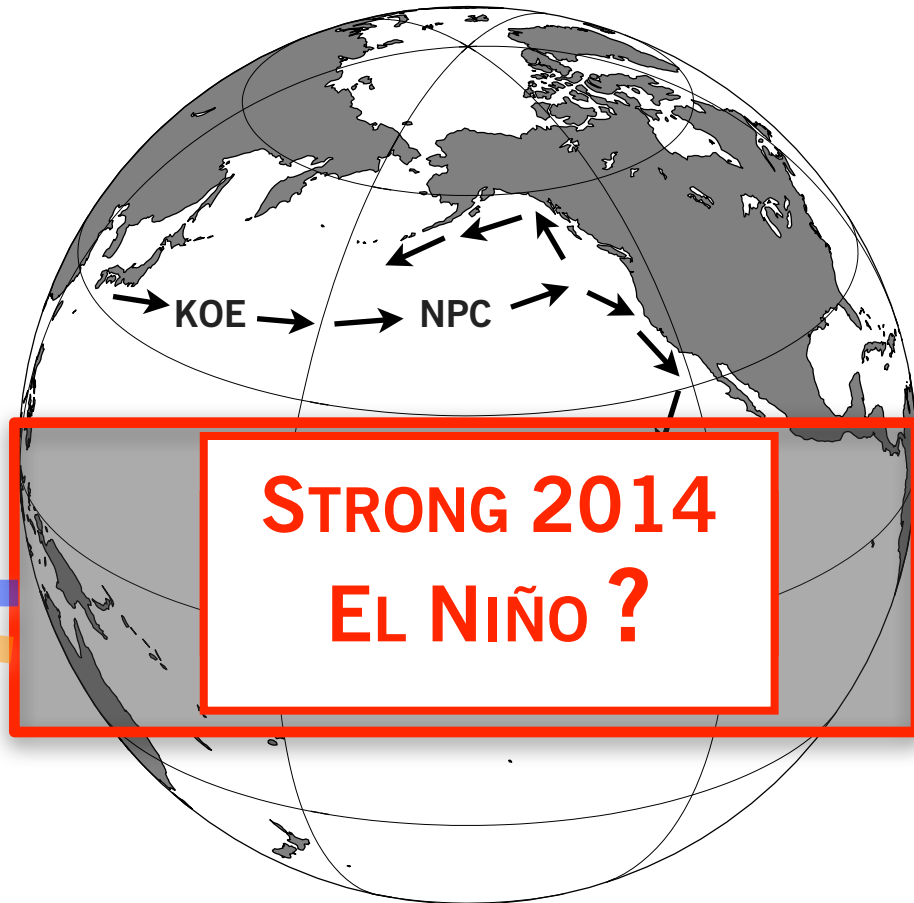
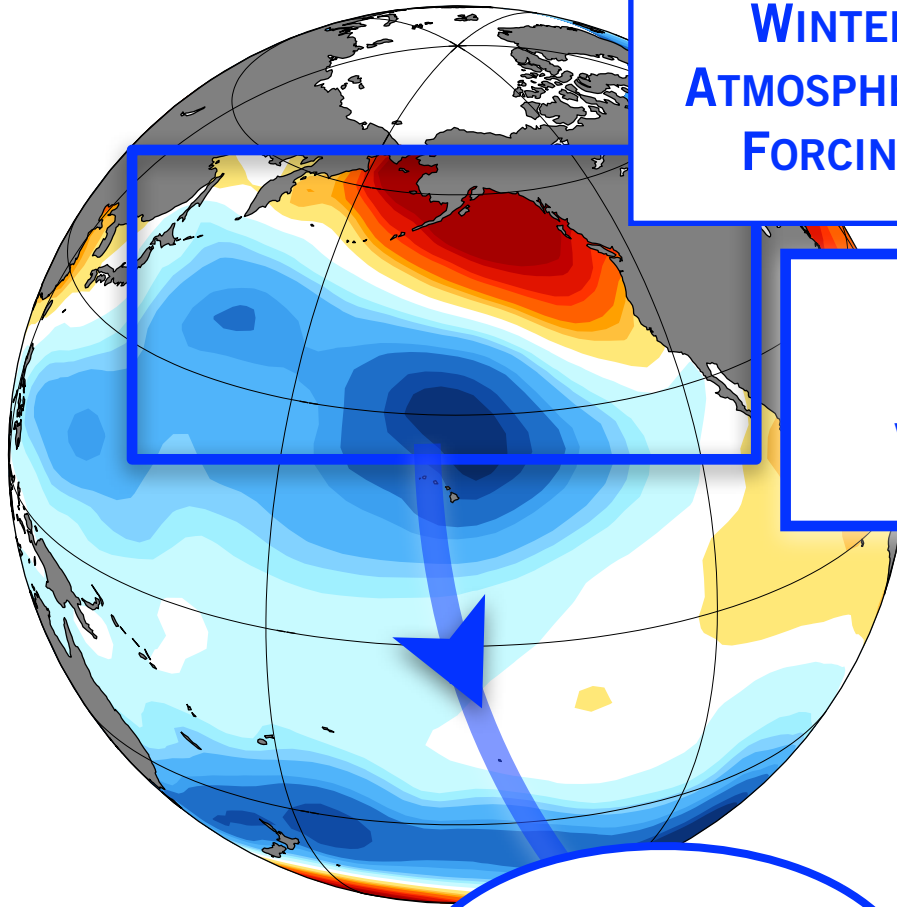
**WINTER
ATMOSPHERIC
FORCING**

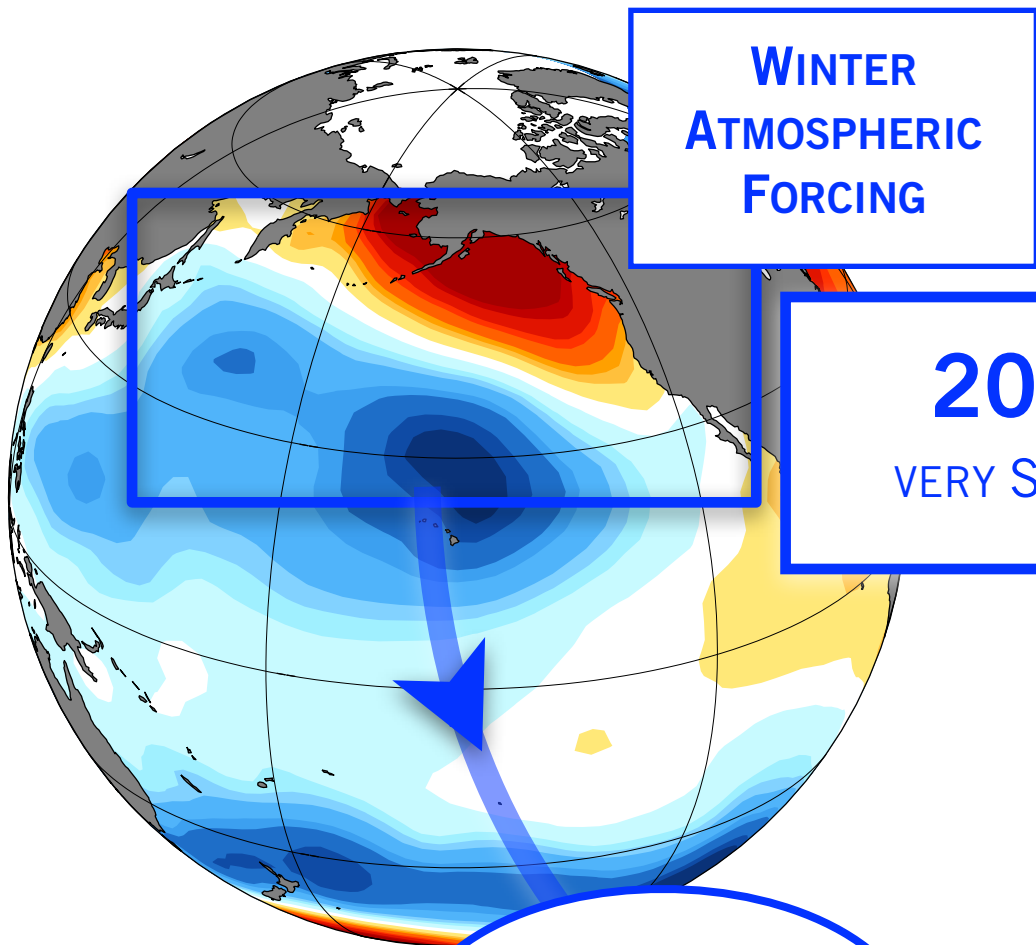
2014
VERY STRONG

*North Pacific
Ocean Dynamics*

*Tropical
Westerly Wind
Bursts*

**STRONG 2014
EL NIÑO ?**

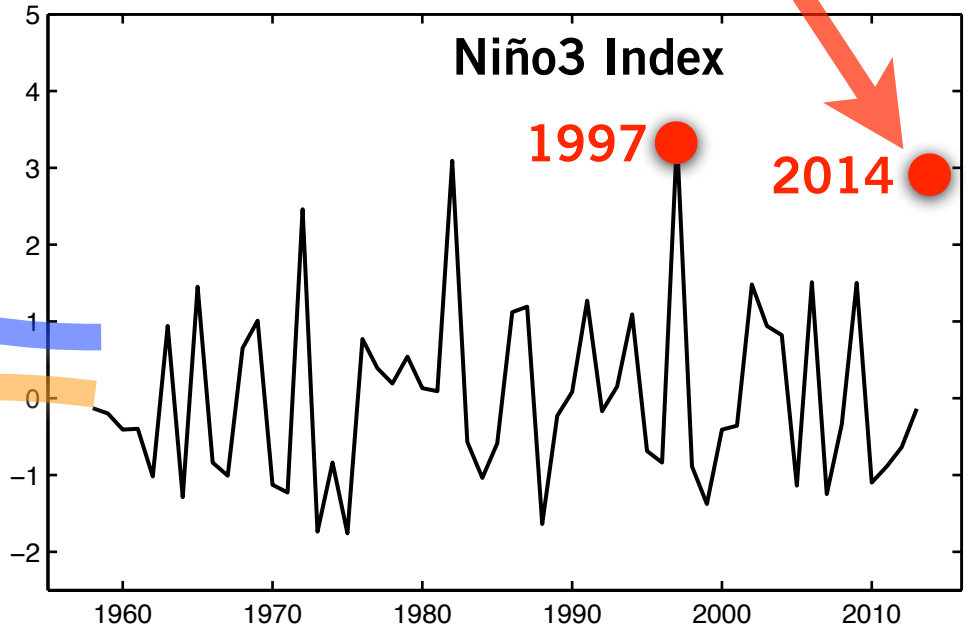




*North Pacific
Ocean Dynamics*

*Tropical
Westerly Wind
Bursts*

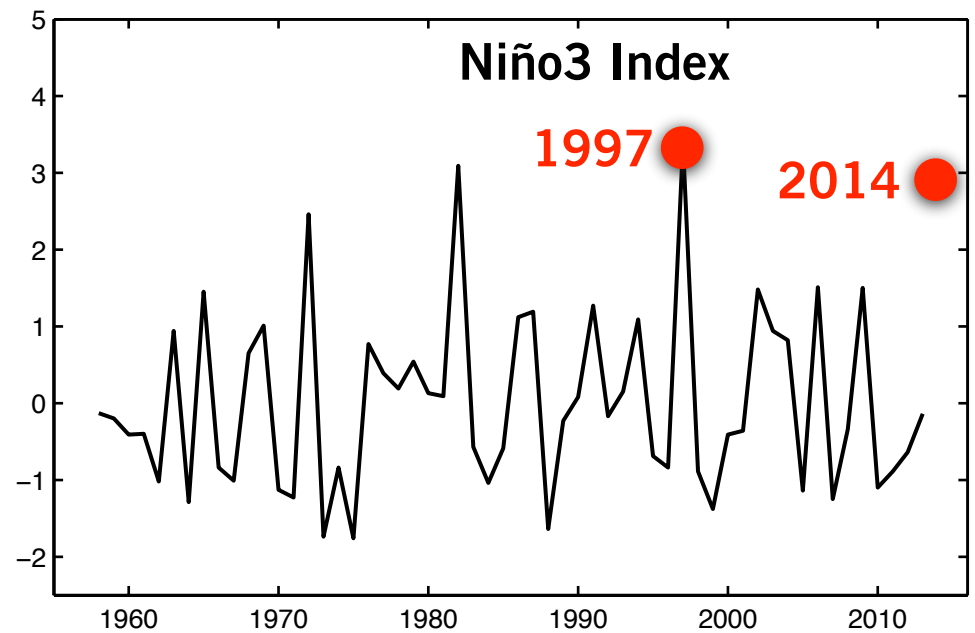
STRONG 2014 EL NIÑO ?



ENSO
FORECAST
MODEL

*North Pacific
Ocean Dynamics*

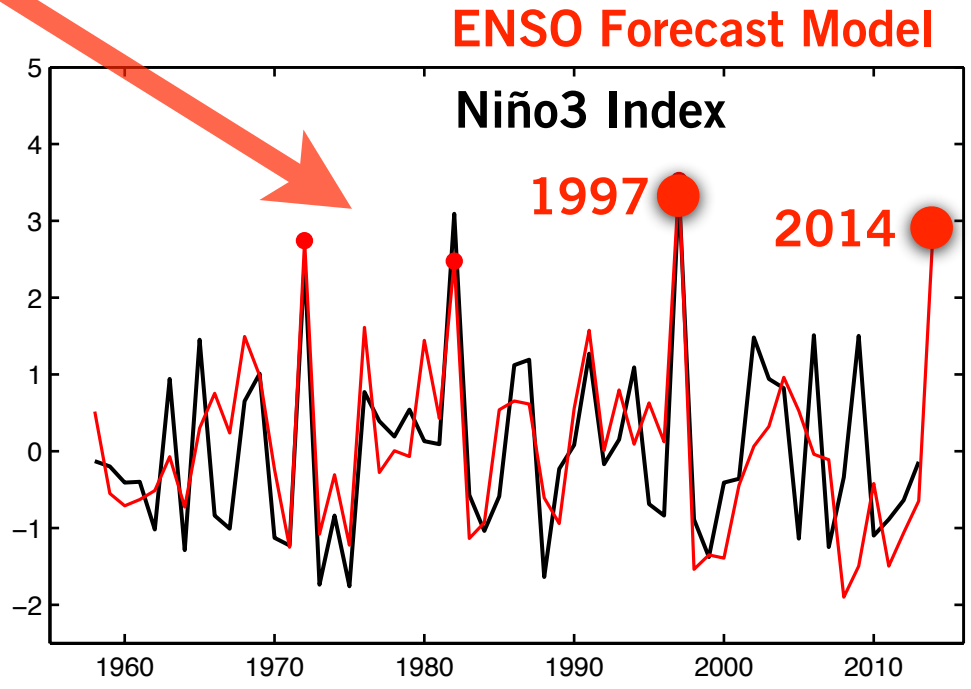
*Tropical
Westerly Wind
Bursts*



ENSO
FORECAST
MODEL

*North Pacific
Ocean Dynamics*

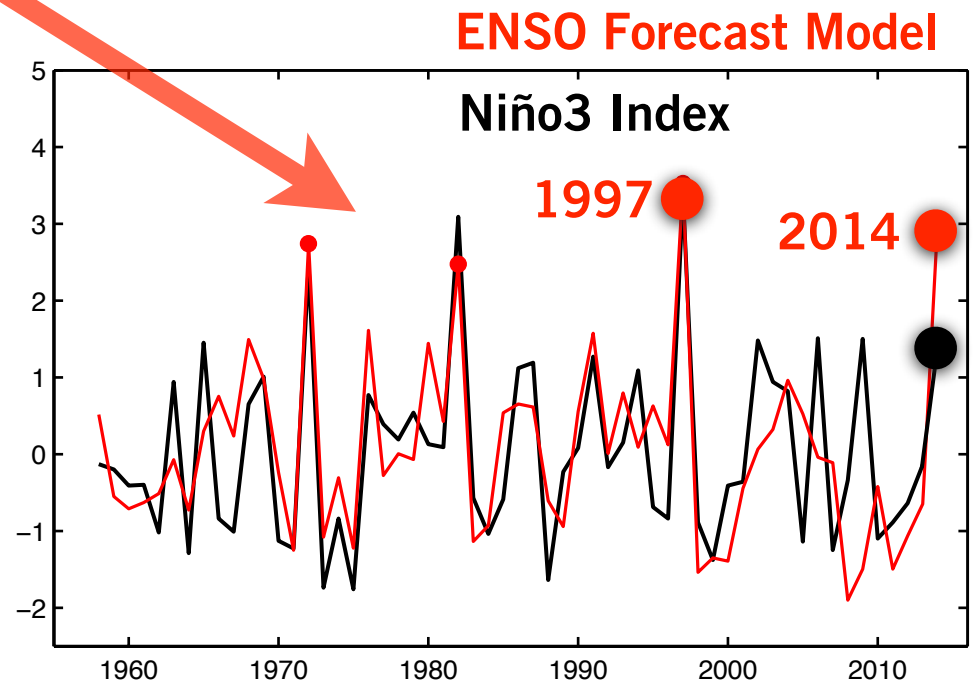
*Tropical
Westerly Wind
Bursts*



ENSO
FORECAST
MODEL

*North Pacific
Ocean Dynamics*

*Tropical
Westerly Wind
Bursts*



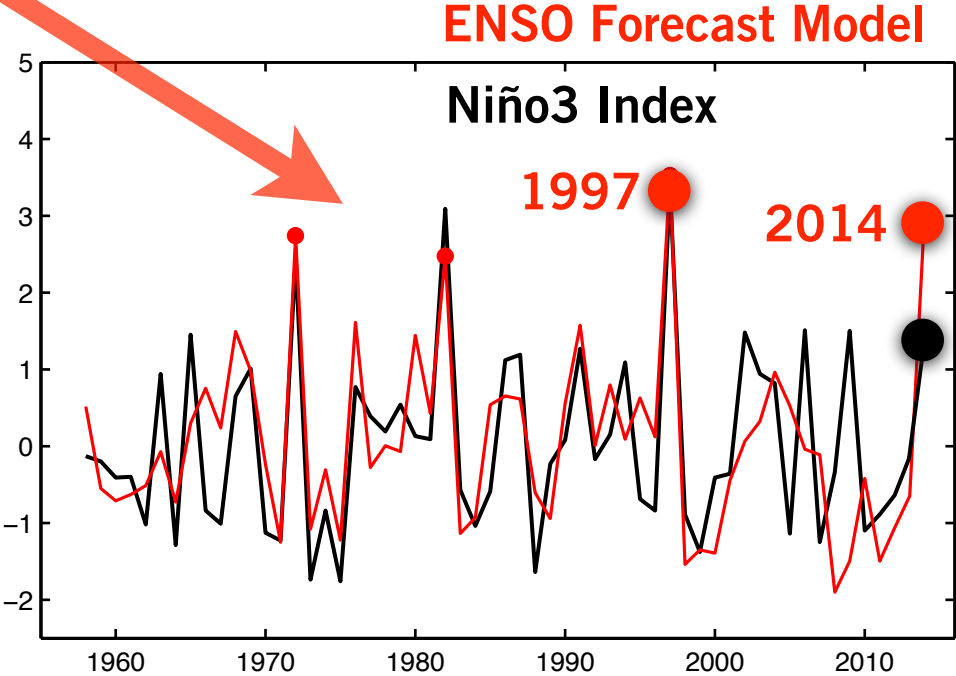
Di Lorenzo, Newman, et al. 2014 

Why did the prediction fail ?

ENSO
FORECAST
MODEL

North Pacific
Ocean Dynamics

Tropical
Westerly Wind
Bursts



Paper rejected in Nature



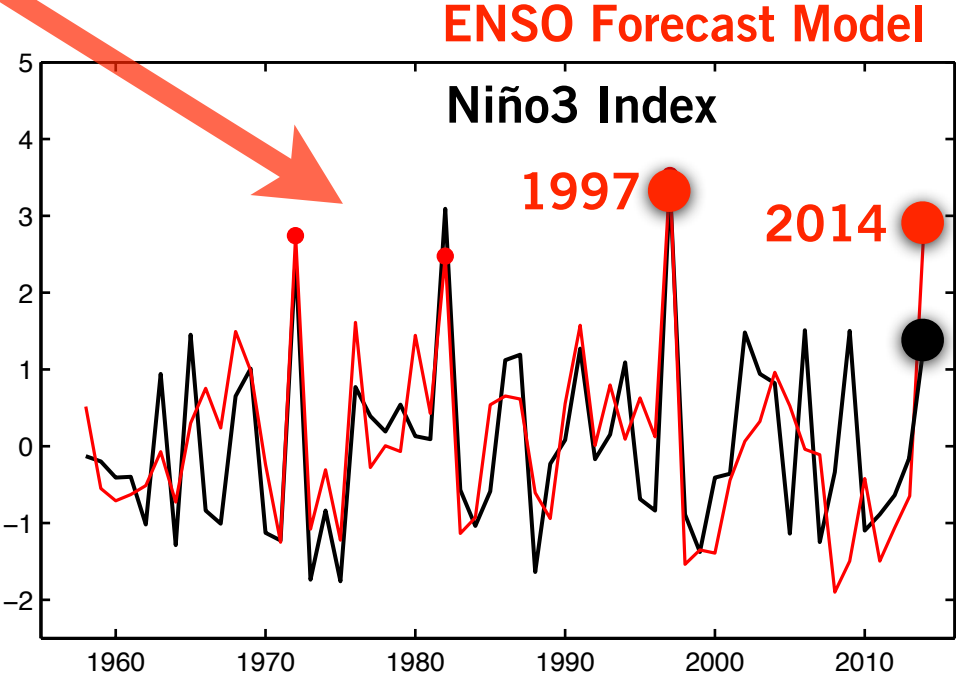
~~Di Lorenzo, Newman, et al. 2014~~ 

Why did the prediction fail ?

ENSO
FORECAST
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North Pacific
Ocean Dynamics

Tropical
Westerly Wind
Bursts

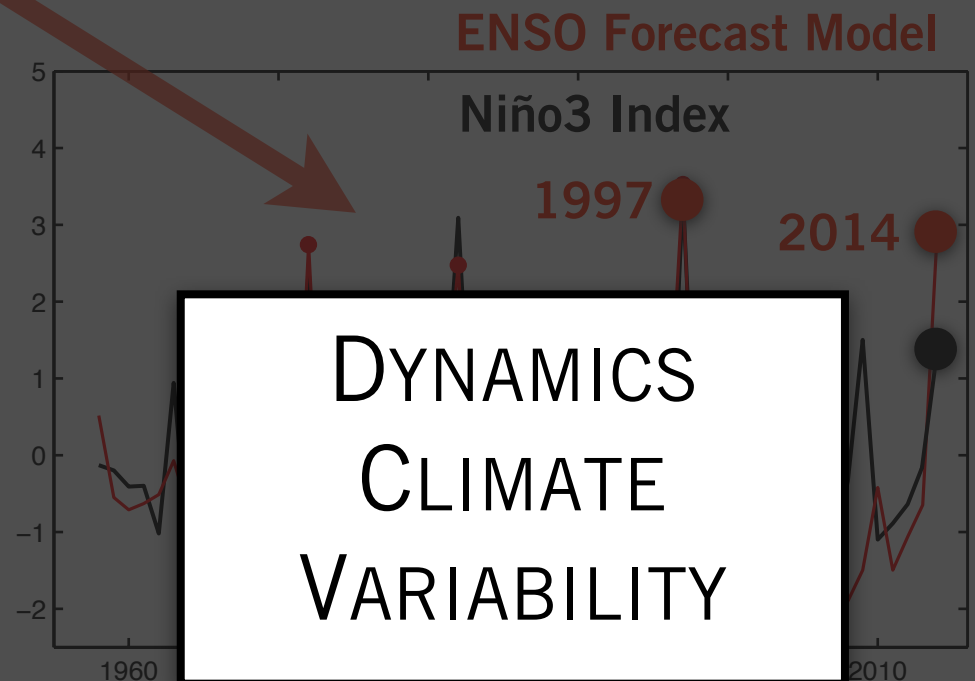


Why did the prediction fail ?

ENSO
FORECAST
MODEL

*North Pacific
Ocean Dynamics*

*Tropical
Westerly Wind
Bursts*



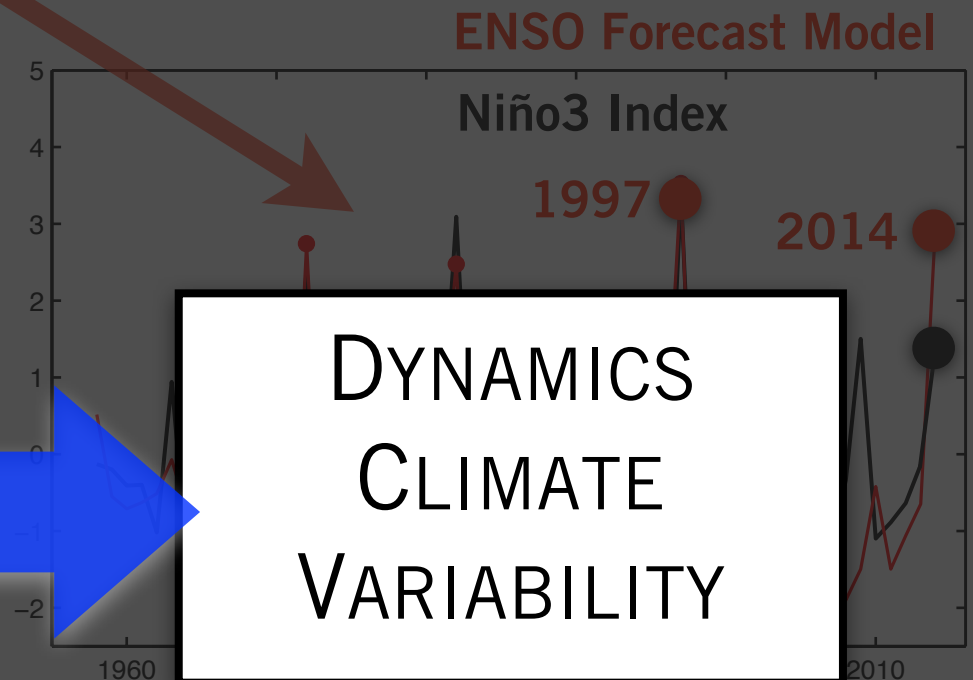
Why did the prediction fail ?

ENSO
FORECAST
MODEL

*North Pacific
Ocean Dynamics*

MEAN CLIMATE
STATE

DYNAMICS
CLIMATE
VARIABILITY



CHALLENGES

MEAN CLIMATE
STATE



DYNAMICS
CLIMATE
VARIABILITY

ADVANCES IN FORECASTING CLIMATE & ECOSYSTEMS

CHALLENGES

MEAN CLIMATE
STATE



DYNAMICS
CLIMATE
VARIABILITY

ADVANCES IN FORECASTING CLIMATE & ECOSYSTEMS

EASTERN & WESTERN BOUNDARY
CLIMATE CONNECTION

TROPICS & NORTH PACIFIC
CLIMATE CONNECTION

CHALLENGES

MEAN CLIMATE
STATE



DYNAMICS
CLIMATE
VARIABILITY

ADVANCES IN FORECASTING CLIMATE & ECOSYSTEMS

EASTERN & WESTERN BOUNDARY
CLIMATE CONNECTION

~3-10 years
FORECAST POTENTIAL

TROPICS & NORTH PACIFIC
CLIMATE CONNECTION

~1 years
FORECAST POTENTIAL

CHALLENGES

MEAN CLIMATE
STATE



DYNAMICS
CLIMATE
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CHALLENGES

MEAN CLIMATE
STATE



DYNAMICS
CLIMATE
VARIABILITY

ADVANCES IN FORECASTING CLIMATE & ECOSYSTEMS

EASTERN & WESTERN BOUNDARY CLIMATE CONNECTION

~3-10 years

Di Lorenzo, E., Combes, V., Keister, J.E., Strub, T.P., Thomas, A.C., Franks, P.J.S., Ohman, M.D., Furtado, J., Bracco, A., Bograd, S.J., Peterson, W.T., Schwing, F.B., Chiba, S., Taguchi, B., Hormazabal, S., Parada, C., 2013.

Synthesis of Pacific Ocean climate and ecosystem dynamics

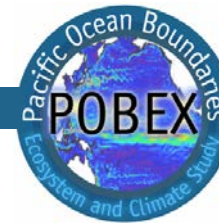
Oceanography, Vol. 26 (4).

MEAN CLIMATE STATE



Topic 8: New Dynamics

Synthesis of Pacific Ocean Climate & Ecosystem Variability



BY EMANUELE DI LORENZO, VINCENT COMBES, JULIE KEISTER, TED STRUB, ANDREW THOMAS, PETER J.S. FRANKS, ANNALISA BRACCO,

STEVEN BOGRAD, WILLIAM PETERSON, FRANK SCHWING, SANA CHIBA, BUNMEI TAGUCHI, SAMUEL HORMAZABAL AND CAROLINA PARADA

