Variability in the transport and latitude of the North Pacific Current: Consequences for northeastern Pacific ecosystems

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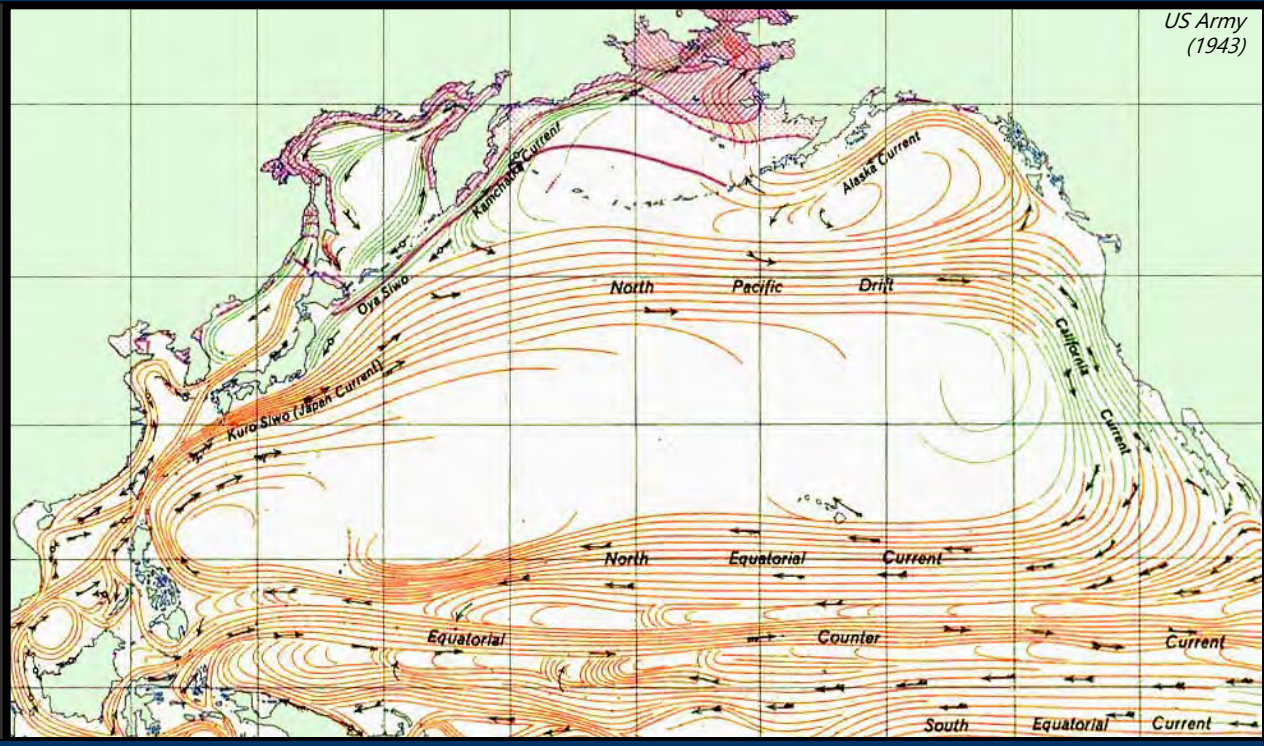
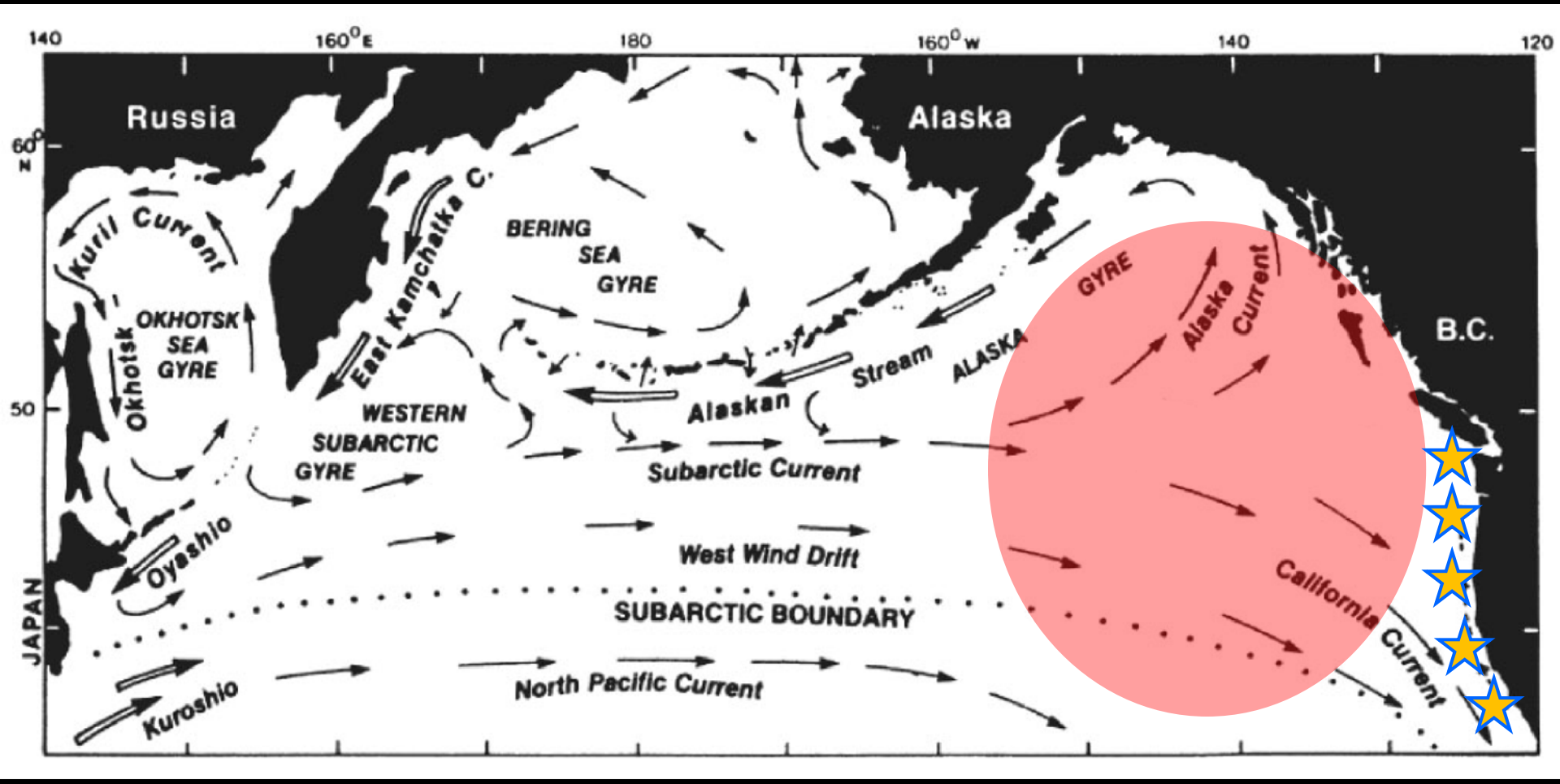


UNIVERSITY OF SOUTH CAROLINA

NOAA

PICES

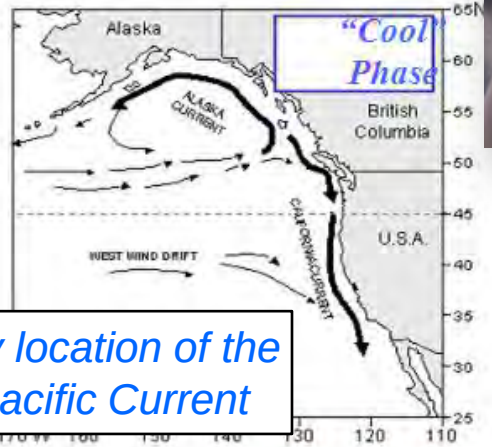

140
160°E
180
160°W
140
120
Russia
Alaska
60°N
50
JAPAN
B.C.
Kuril Current
OKHOTSK SEA GYRE
Okhotsk
East Kamchatka C.
BERING SEA GYRE
WESTERN SUBARCTIC GYRE
Alaskan Stream
ALASKA GYRE
Alaska Current
Subarctic Current
Oyashio
West Wind Drift
SUBARCTIC BOUNDARY
California Current
Kuroshio
North Pacific Current

Bill Peterson's warm-water/cold-water copepod story…

A working mechanistic hypothesis: source waters. . .

Cool Phase →

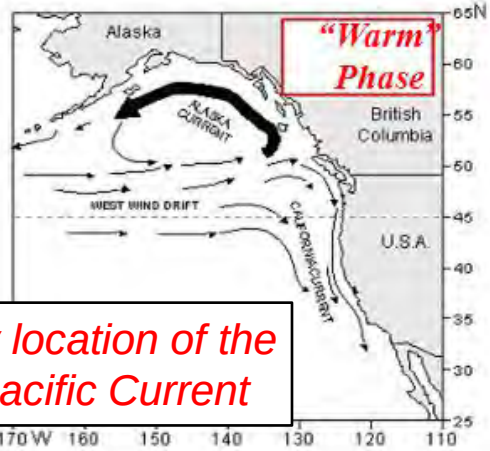
Transport of boreal coastal copepods into NCC from Gulf of Alaska



Southerly location of the North Pacific Current

Warm Phase →

Transport of sub-tropical copepods into NCC from Transition Zone offshore



Northerly location of the North Pacific Current

Verified in Keister et al. 2011 GCB and Bi et al. 2011 GRL

Climate modes; discovery and current understanding

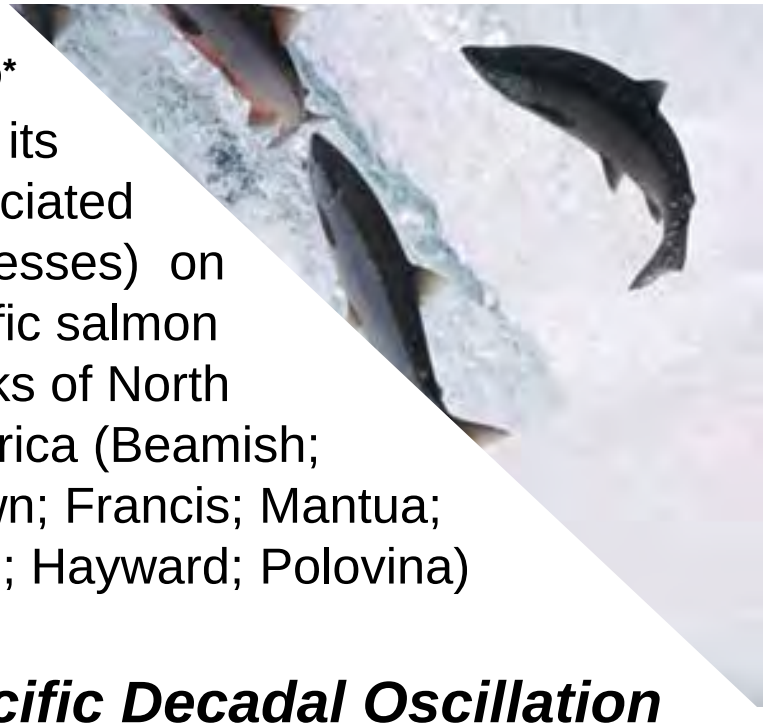
The climate-science community's interest in interannual to interdecadal variability has been motivated by fisheries research in the Pacific.

NPGO* on the salinity and nutrient distributions, its differing impacts on northern and southern portions of the Northeast Pacific, and its influence on ENSO development (Di Lorenzo)

****North Pacific Gyre Oscillation***

ENSO* and its influence on anchovy and sardine of eastern boundary currents (noted since the 1890s; Kawasaki; Lluch-Belda; Schwartzlose)

****El Niño Southern Oscillation***



PDO* (and its associated processes) on Pacific salmon stocks of North America (Beamish; Brown; Francis; Mantua; Hare; Hayward; Polovina)

****Pacific Decadal Oscillation***

A brief overview of what we think we know

The Pacific Decadal Oscillation (PDO) describes the leading principal component of detrended SST anomalies in the North Pacific.

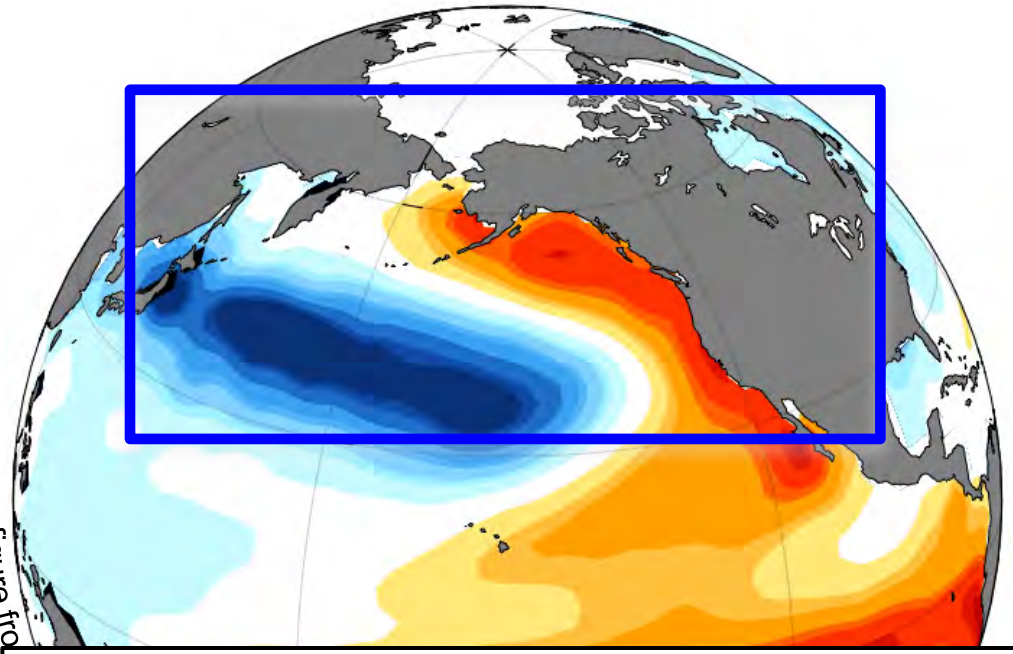
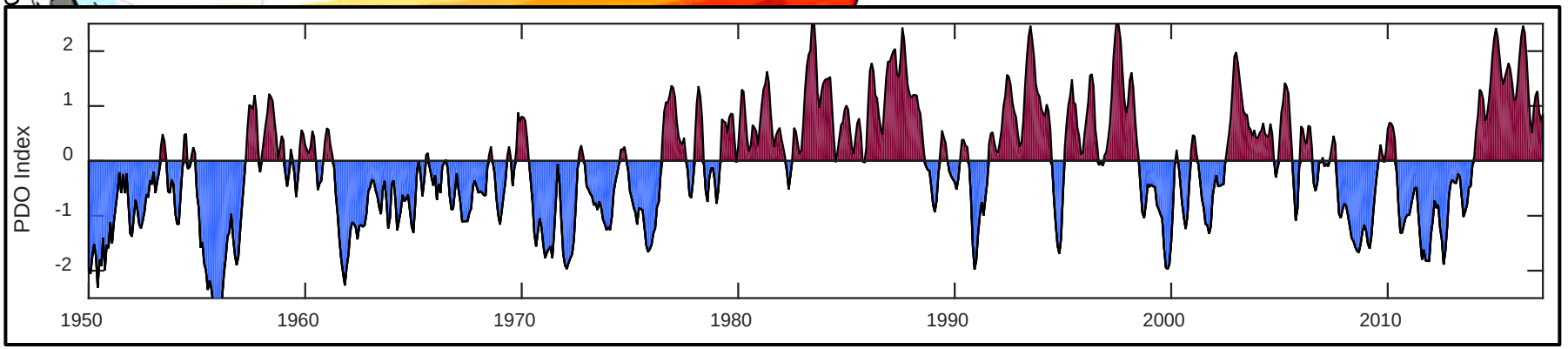
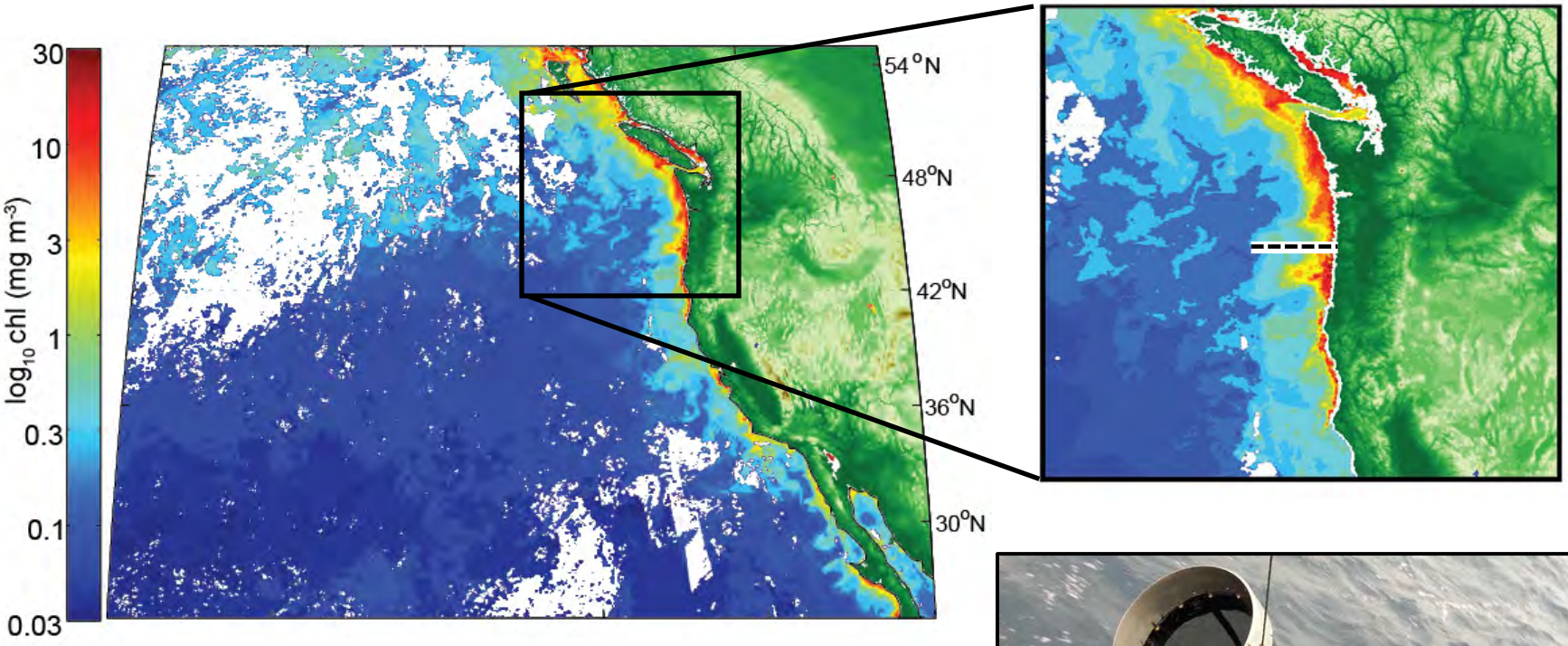


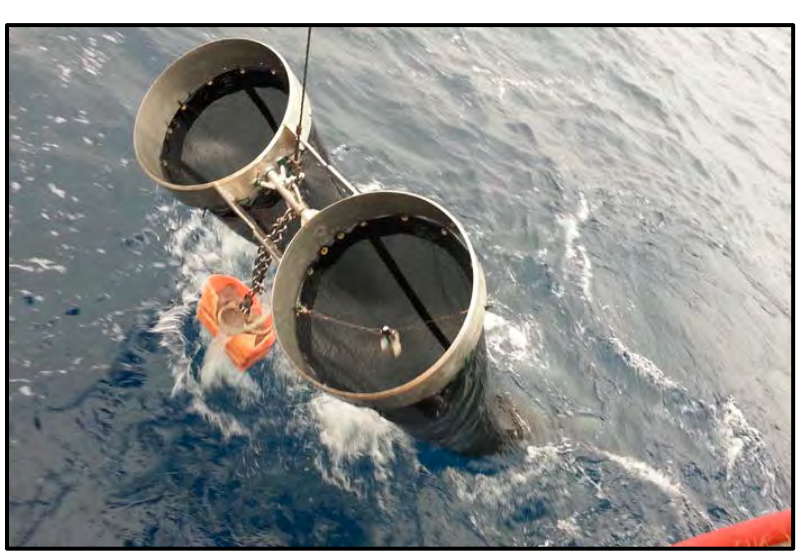
figure fro

Temporal changes in this pattern are associated with strong transitions in the marine ecosystem (as popularized by Mantua *et al.*, 1997).



Variability in copepod assemblages with PDO





Newport Hydrographic Line

- Hydrography, zooplankton, and ichthyoplankton sampling
- Biweekly intervals, 1996-present
- Coast to about 300 km offshore

Variability in copepod assemblages with PDO

Cold-water “northern” taxa	Warm-water “southern” taxa
Pseudocalanus mimus, *Calanus marshallae,* *Acartia longiremis*	*Clausocalanus spp.,* *Ctenocalanus vanus,* *Paracalanus parvus,* *Mesocalanus tenuicornis,* *Calocalanus styliremis*

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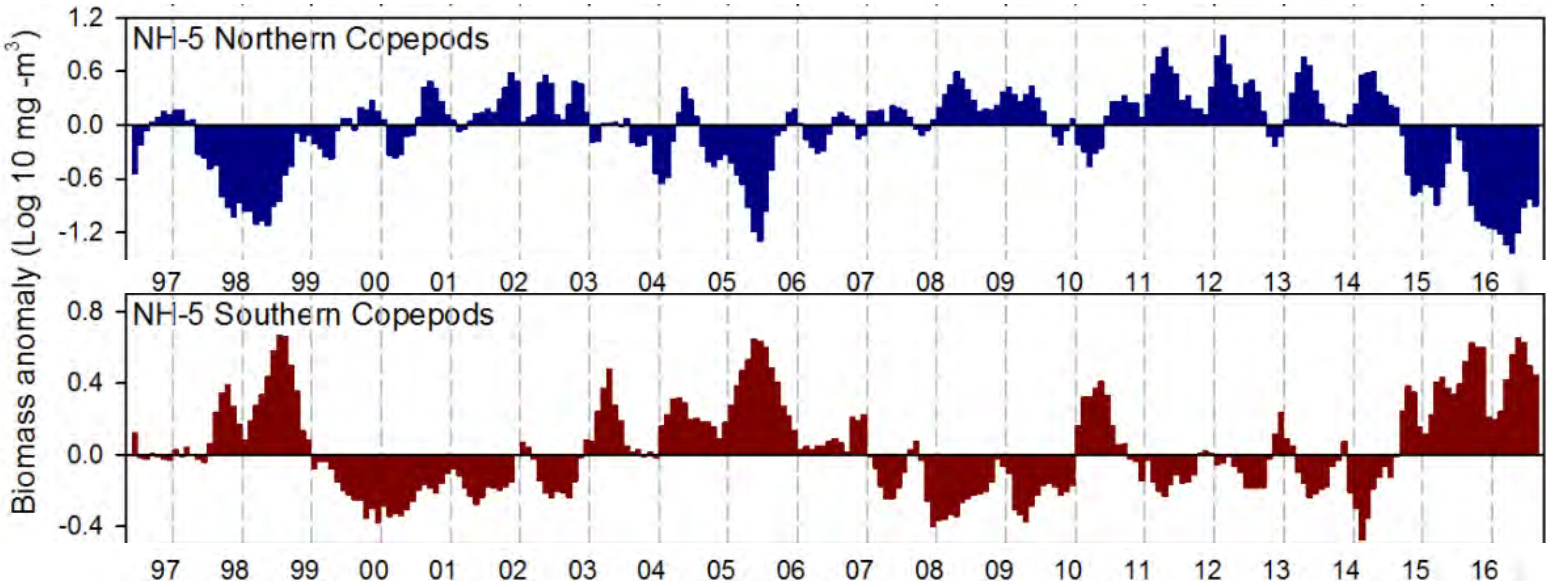

data courtesy of Bill Peterson’s lab at NOAA NWFSC

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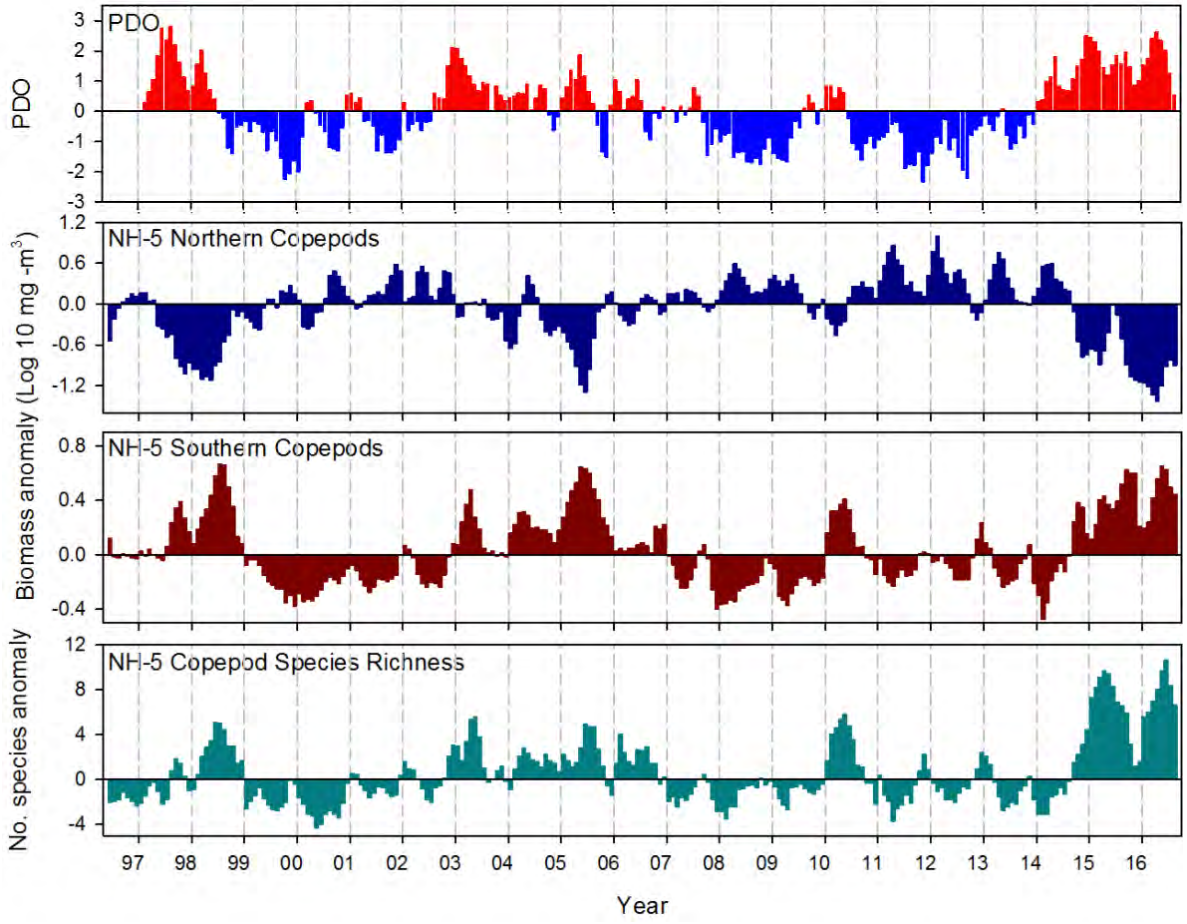

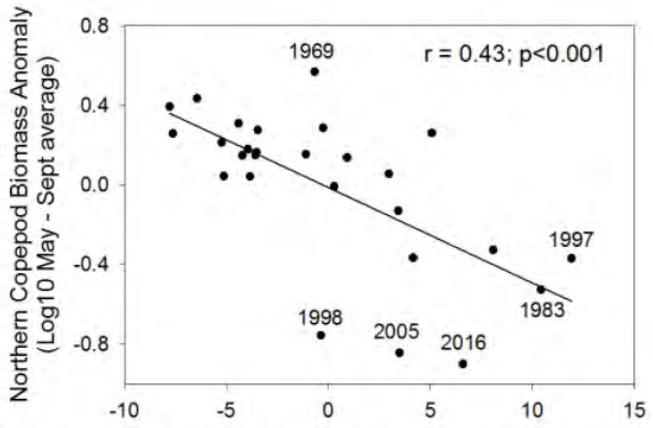

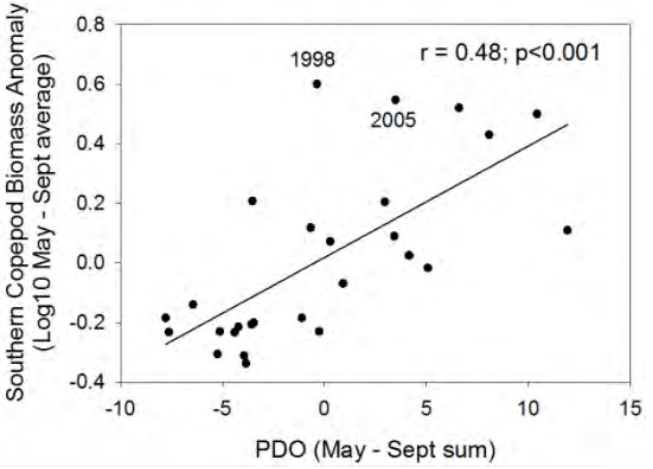

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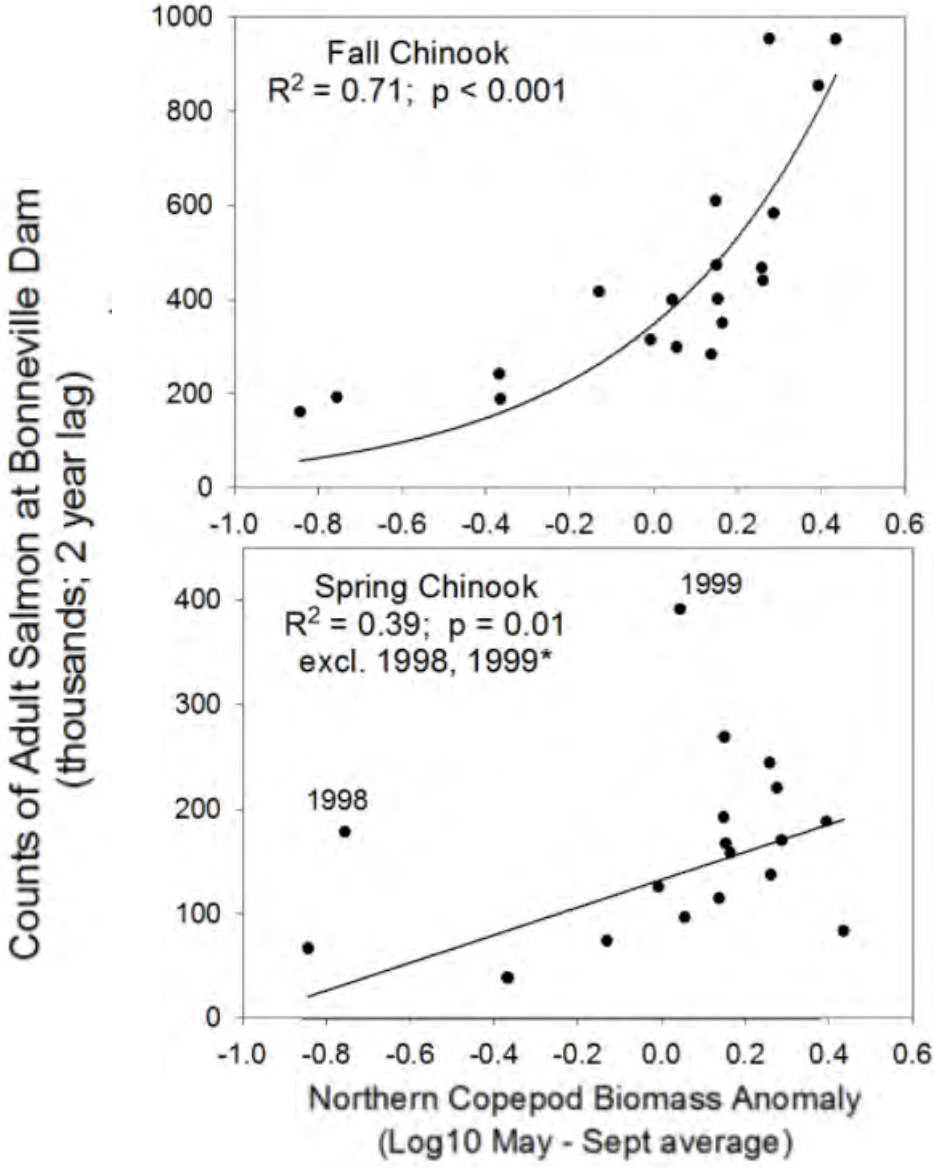
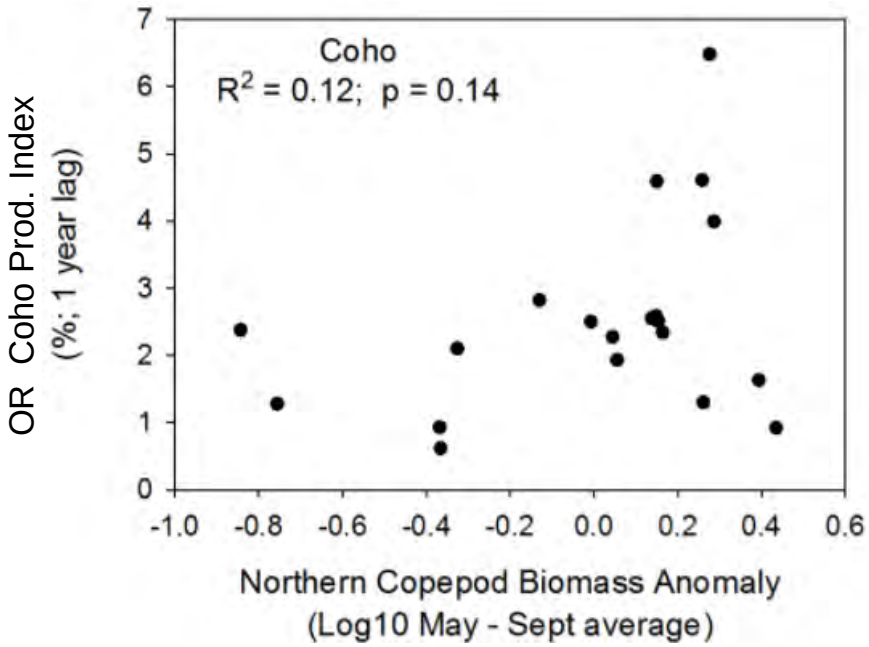
Salmon returns are positively associated with biomass anomalies of cold-water copepods

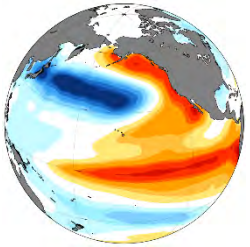




While this sequence of relationships is promising, the relationship between climate processes and the zooplankton remains vague.

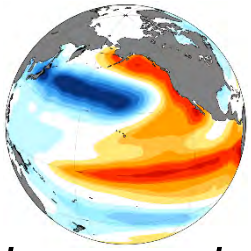
data courtesy of Bill Peterson's lab at NOAA NWFSC

Where does that leave us?



large-scale climate conditions

population characteristics



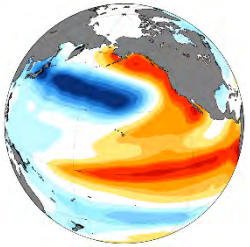
large-scale climate property

influential ecosystem conditions

population characteristics

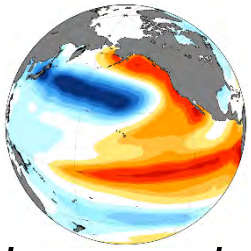
But, there **need not** be a single and/or a temporally invariant process that mediates the relationship between climate and ecological components of the system.

Where does that leave us?



large-scale climate conditions

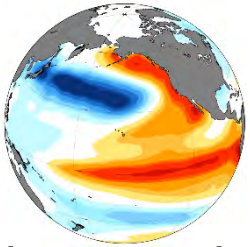
population characteristics



large-scale climate property

influential ecosystem conditions

population characteristics



large-scale climate property

(time variable?)

influential ecosystem conditions

(time variable?)

population characteristics

Strategies for understanding variability in fish populations

We scientists have pursued a number of strategies for describing variability marine fisheries and ecosystems (with varied levels of success).

Manage commercial and recreational fisheries	Use a climate index as a proxy for marine survival	Understand bioenergetics and food-web processes
Wishful thinking, but it can't hurt!	*Aha! It's the _____ ! (e.g. PDO)*	It's complicated…
Variability induced by climate processes is apparently quite influential.	Dynamics of the physical-biological interactions remain vague.	…but careful investigation of specific conditions can perform better than regional climate indices.
	Seems to work (some of the time).	

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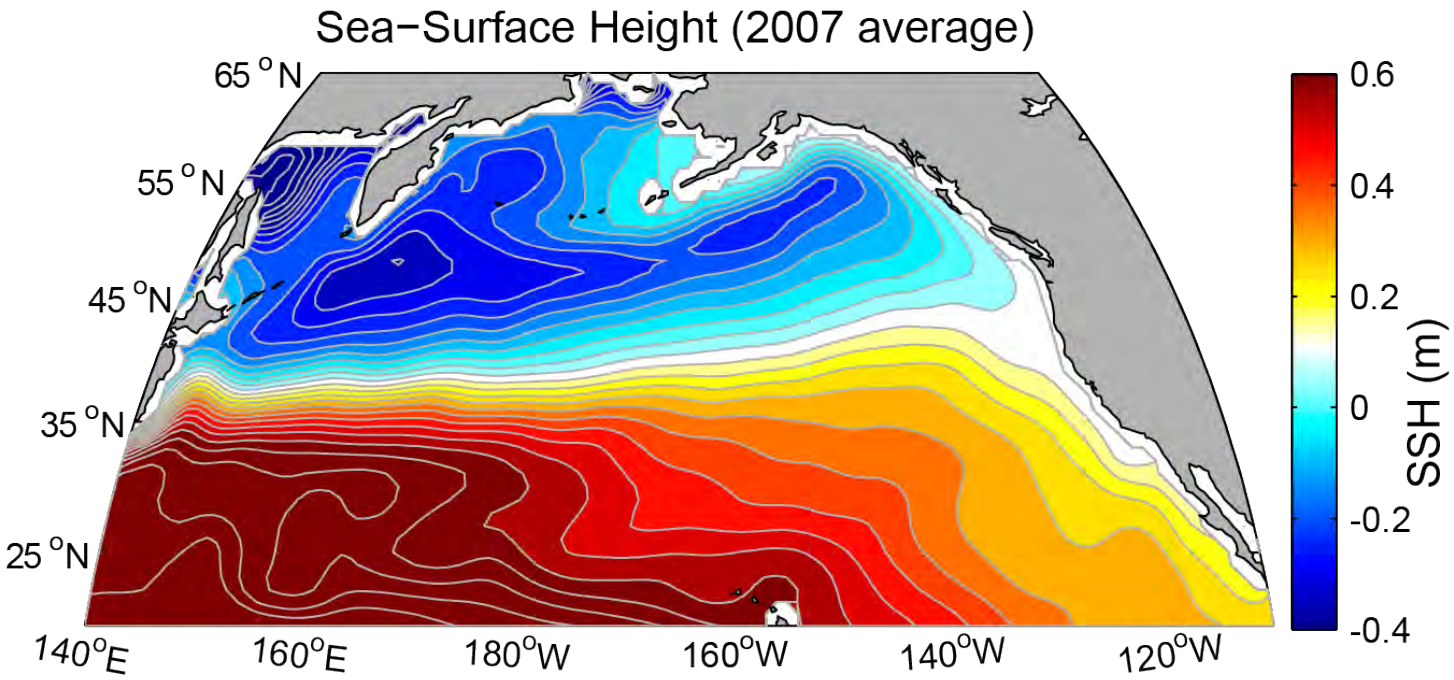
Can we continue to use these empirical, correlative relationships to guide us to real understanding?

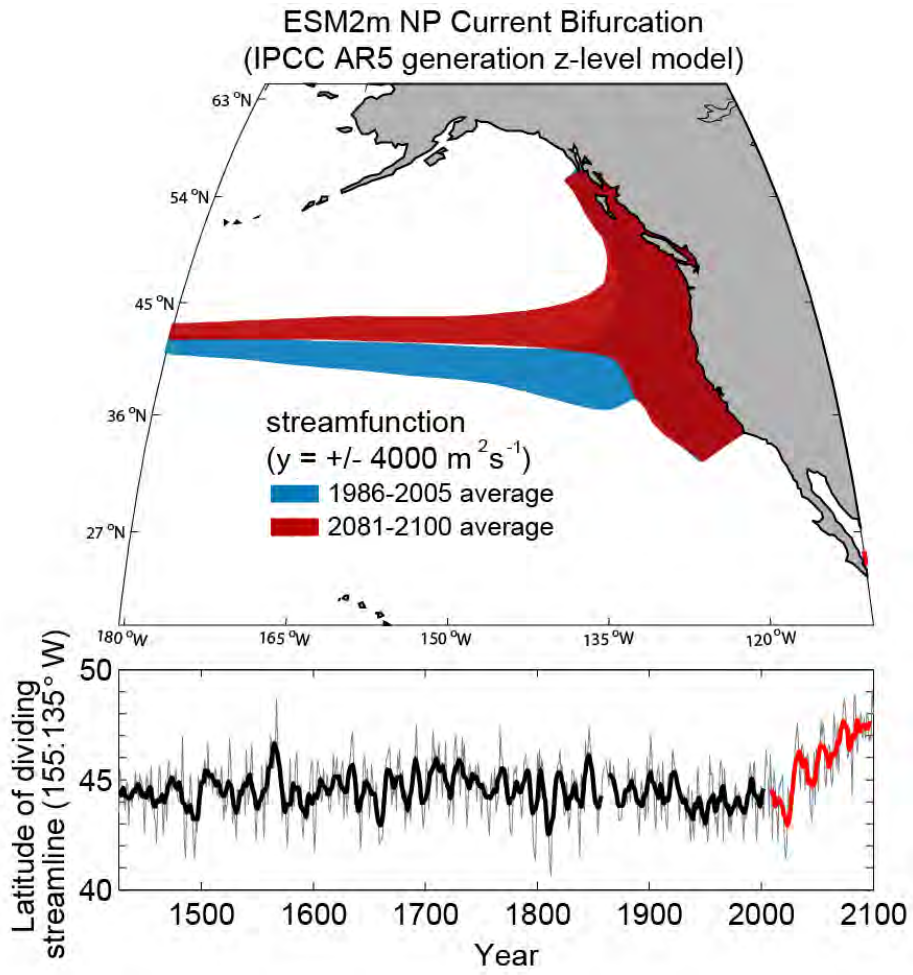
What is attractive about an indicator based on the North Pacific Current?

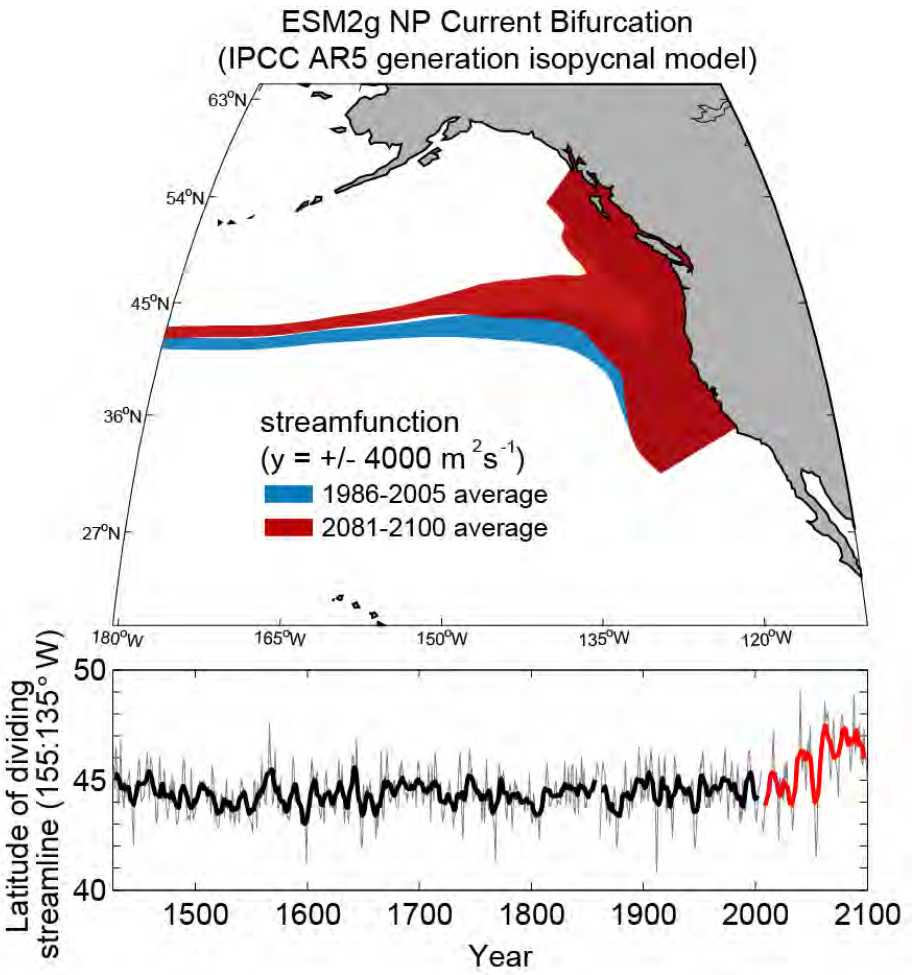
Positioning and intensity of the NPC has received relatively little attention and is perhaps less vague in its relation to ecosystem processes.



What is attractive about an indicator based on the North Pacific Current?

Additionally, a poleward shift in the location of the NPC is one of the more robust projections of IPCC-style global climate models.





Why might we care about the NPC bifurcation?

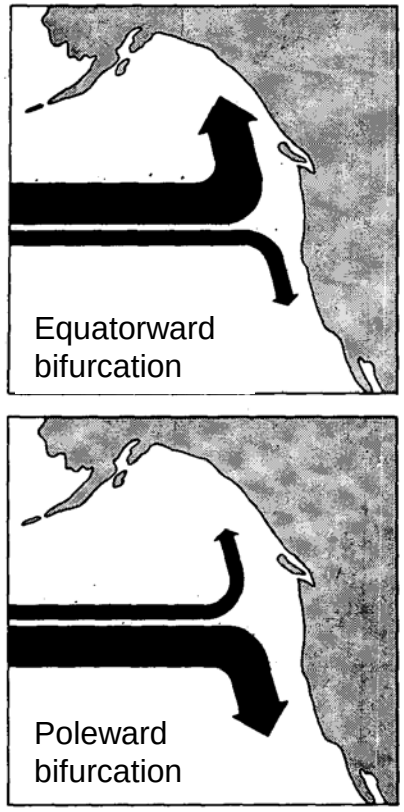
Historical correlations suggest that NPC location is ecologically relevant:

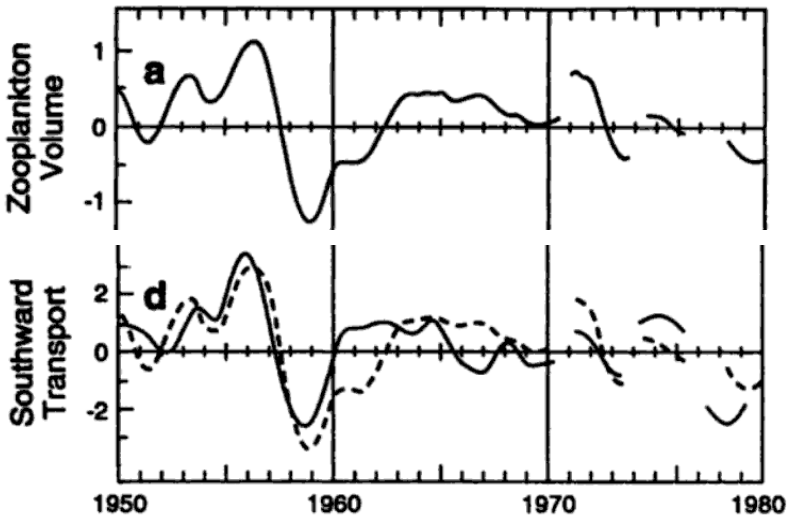
1967 – Wickett. *Journal of the Fisheries Research Board of Canada.* Ekman transport and zooplankton concentration in the North Pacific Ocean.

1982 – Chelton and Davis. *Journal of Physical Oceanography*. Monthly mean sea-level variability along the west coast of North America.

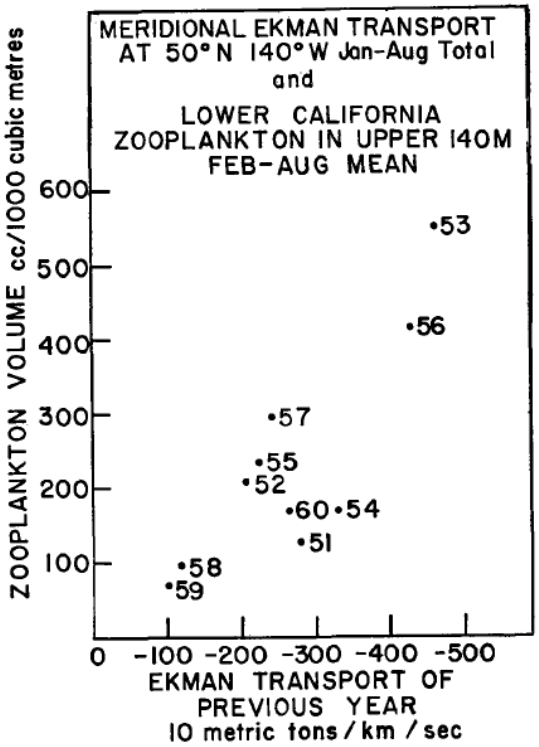
1982 – Chelton, Bernal, and McGowan. *Journal of Marine Research*. Large-scale physical and biological interaction in the California Current.

Poleward bifurcation ⟶ more zooplankton





Chelton and Davis (1982); Chelton *et al*., (1982).



Wickett (1967).

<u>The mechanism of this relationship is not clear.</u>

But the suggested reason is:

When the bifurcation is further north, there is an increased transport of “enriched” subarctic waters to the south.

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Summary – A ***poleward*** shift in the bifurcation (or in the latitude of westerly winds) tends to increase zooplankton volume off California.

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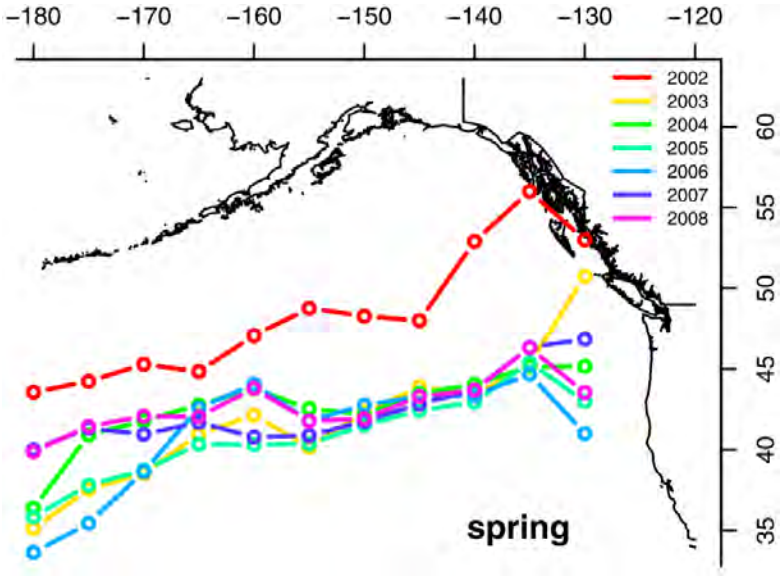
⋮

2011 – 

Poleward bifurcation → *more zooplankton more birds more fish*



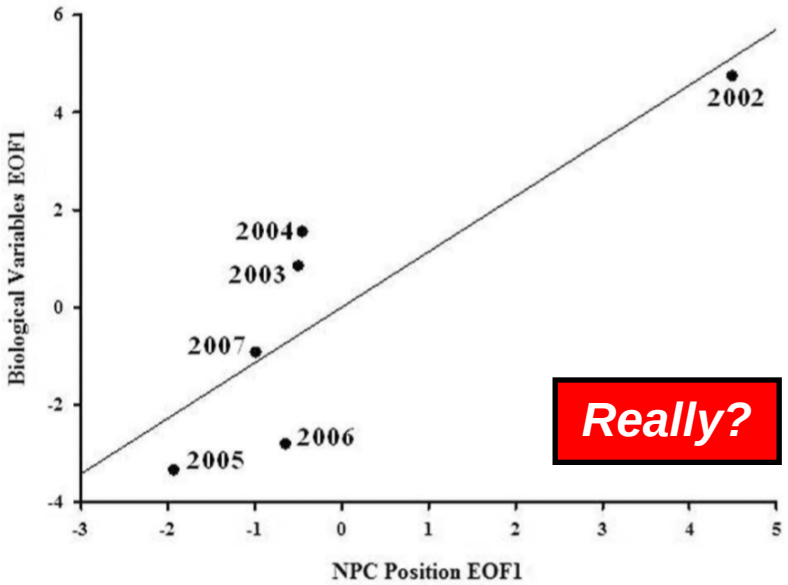


Table 1. Biological Data Sets, Showing Sampling Location, Interval, and Length of Each Time Series

Biological Data Set	Location	Sampling Interval	Time Series Length
Northern Copepod Abundance	Central Oregon	Biweekly	1996–2009
Copepod Species Richness	Central Oregon	Biweekly	1996–2009
T. spinifera Abundance	Northern California	Annual	2002–2007
T. spinifera Biomass	British Columbia	Annual	1991–2007
E. pacifica Abundance	Northern California	Annual	2002–2007
E. pacifica Biomass	British Columbia	Annual	1991–2007
Juvenile Rockfish Abundance	Northern California	Annual	1983–2007
Auklet Productivity	Northern California	Annual	1971–2007
Auklet Phenology	Northern California	Annual	1972–2006
Murre Productivity	Northern California	Annual	1972–2007
Murre Phenology	Northern California	Annual	1972–2006
Coho Marine Survival	Oregon	Annual	1970–2007
Chinook – Sacramento River	California	Annual	1983–2009
Chinook – Russian River	California	Annual	2000–2009

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⋮

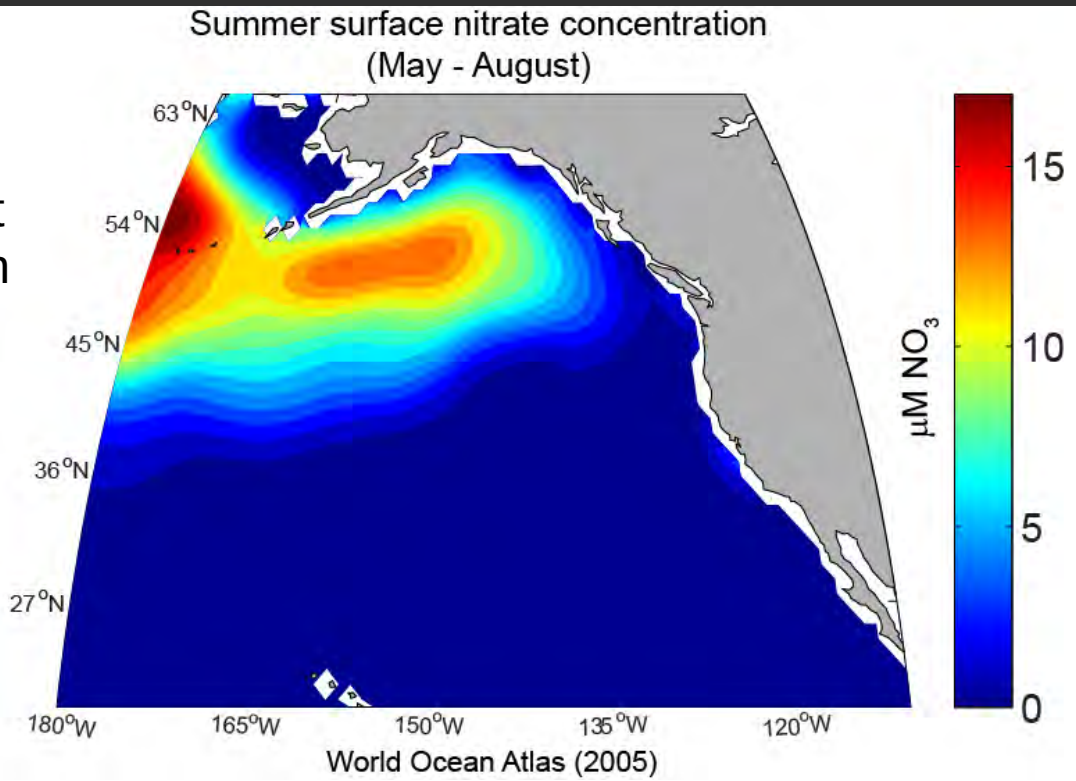
2011 – Sydeman, Thompson, Field, Peterson, Tanasichuk, Freeland, Bograd, and Rykaczewski. *Geophysical Research Letters*. Does positioning of the North Pacific Current affect downstream ecosystem productivity?

2017 – Malick, Cox, Mueter, Dorner, and Peterman. *Fisheries Oceanography*. Effects of the North Pacific Current on the productivity of 163 Pacific salmon stocks.

Suggested mechanism:

Increased transport of "rich" northern waters to the south

Assume that this large-scale, latitudinal gradient in surface nitrate concentration is constant and decoupled from the position of the currents.



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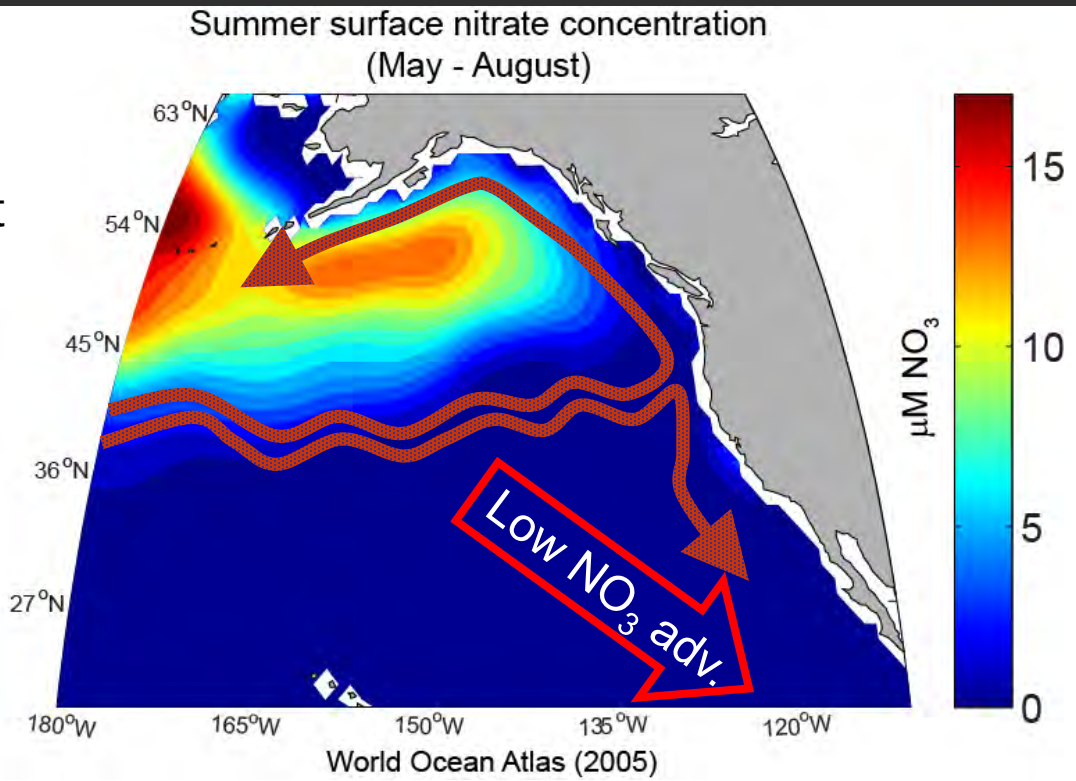
A more **southerly** location of the current would transport **oligotrophic** waters along the coast.



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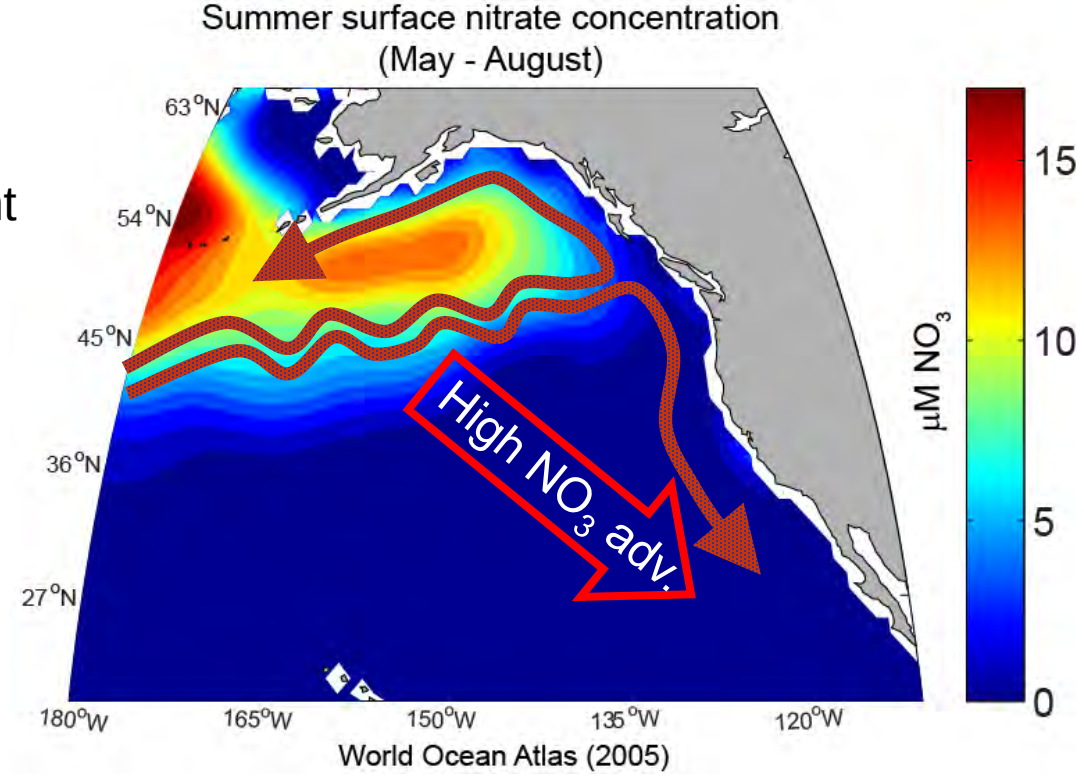
A more **southerly** location of the current would transport **oligotrophic** waters along the coast.

A more **northerly** location of the current would transport **eutrophic** waters to the coast.

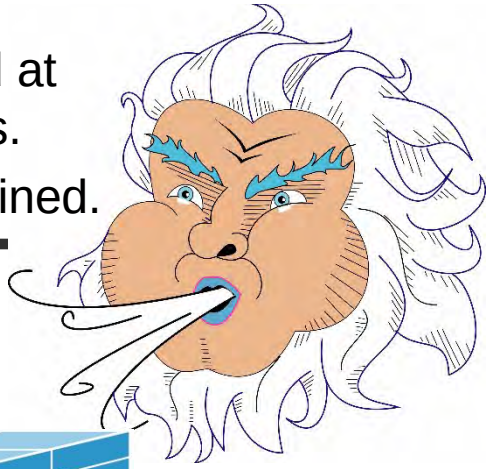


Is this really how it works? Can this mechanism be tested?

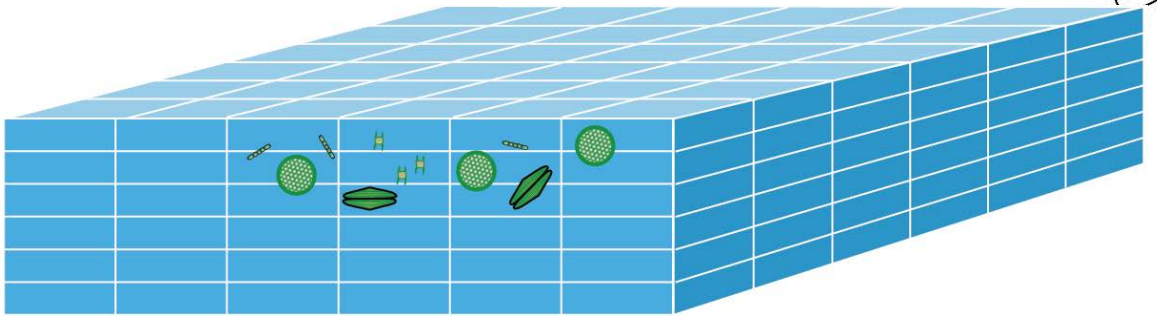
Does the position of the current affect nutrient transport along the coast?

Method

1. Position of the North Pacific Current was examined in an ocean model coupled to a biogeochemistry model, forced at the surface by observed (gridded) atmospheric conditions.
2. Coherent anomalies in nutrient transport were then examined.



Atmosphere: **CORE v2** (Common Ocean-Ice Reference Experiment; Griffies *et al.*, 2009)

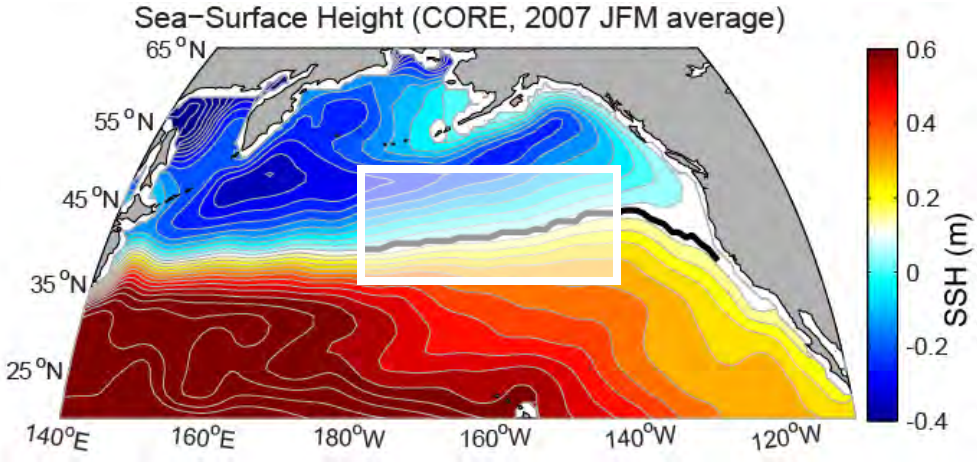


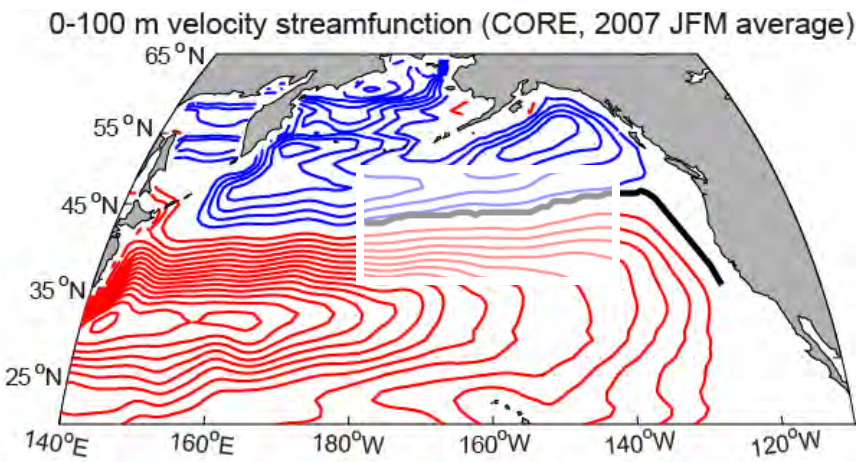
Ocean: NOAA-GFDL **MOM 4.1** (Modular Ocean Model; Pacanowski and Griffies, 1999)

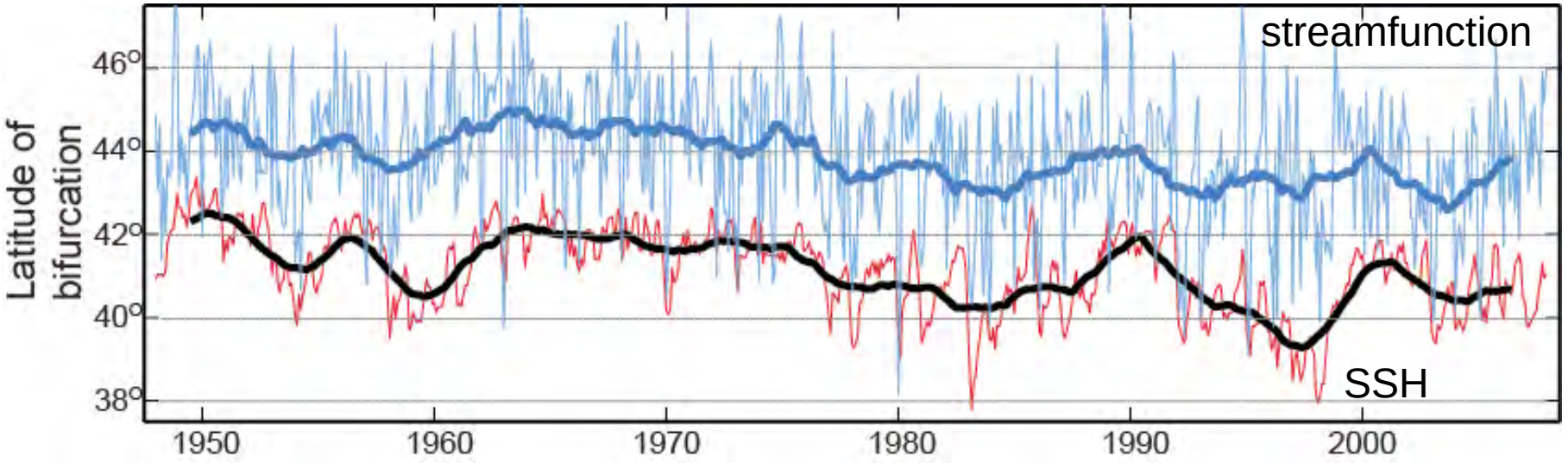
Biology: NOAA-GFDL **TOPAZ** (Tracers of phytoplankton with Allometric Zooplankton) which includes N, P, Si and Fe cycles and three phytoplankton classes (Dunne *et al.*, 2007).

NP Current position:

SSH and streamfunction methods give similar estimates







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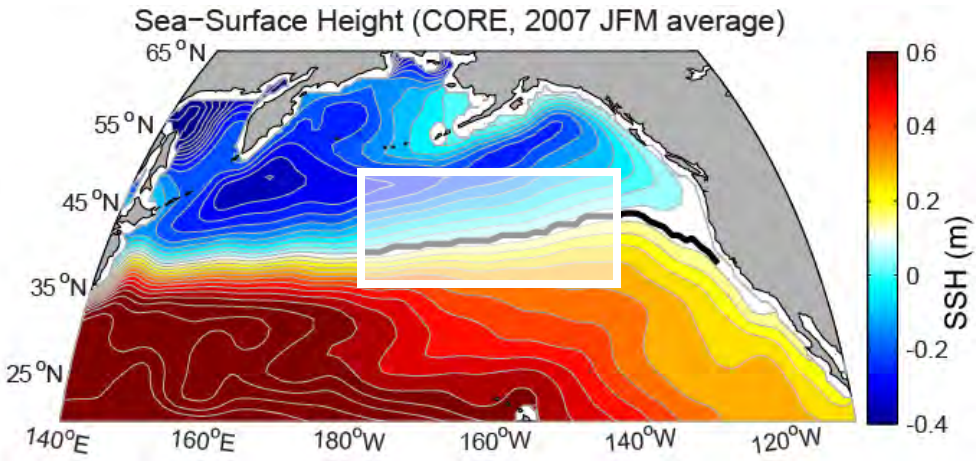
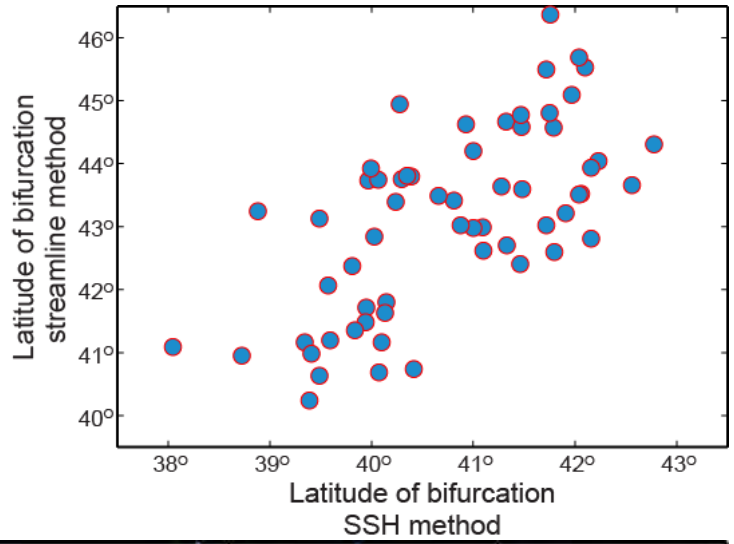
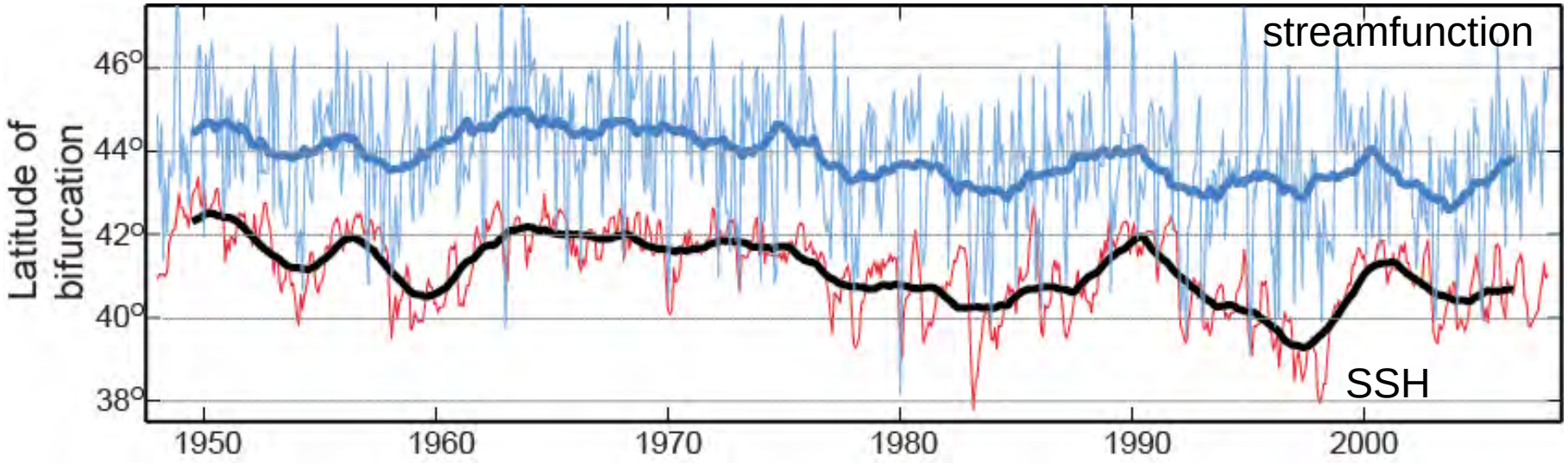
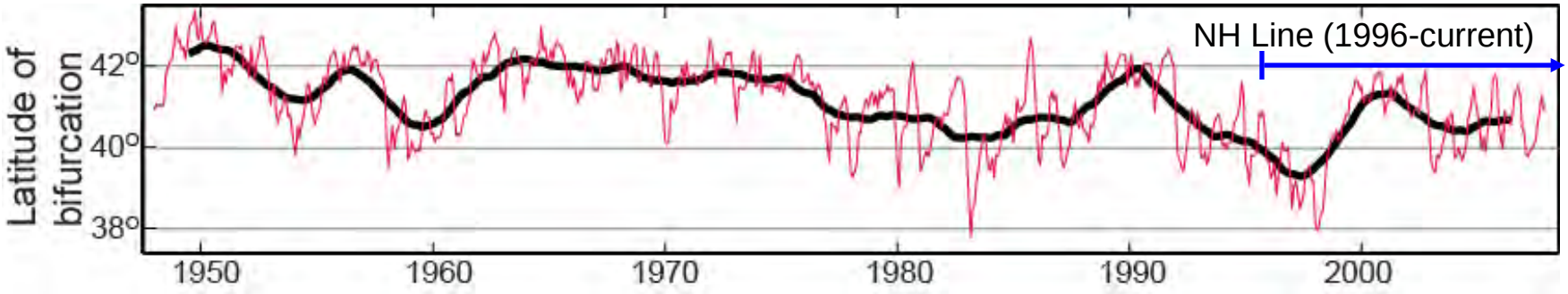


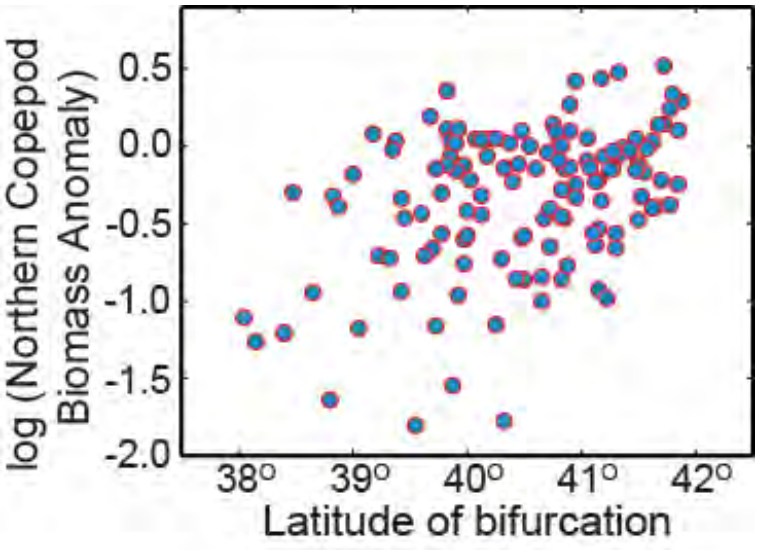


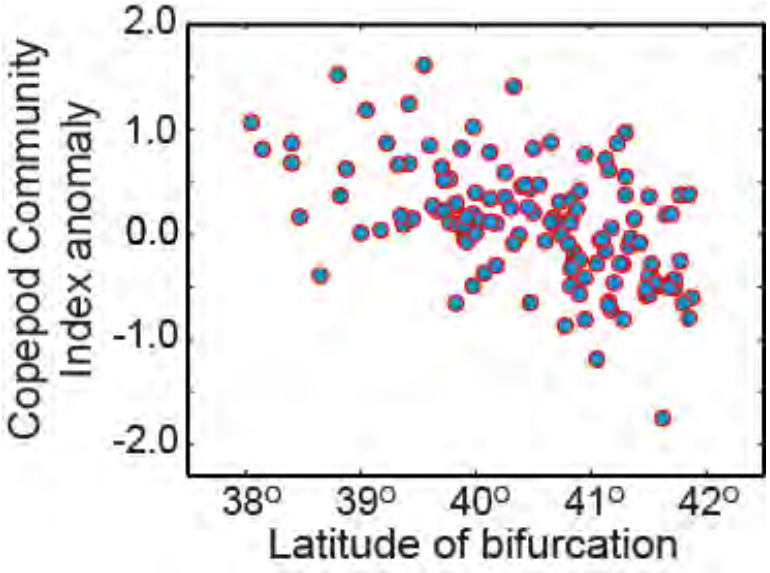


Northerly position correlates with NH Line zoopl.

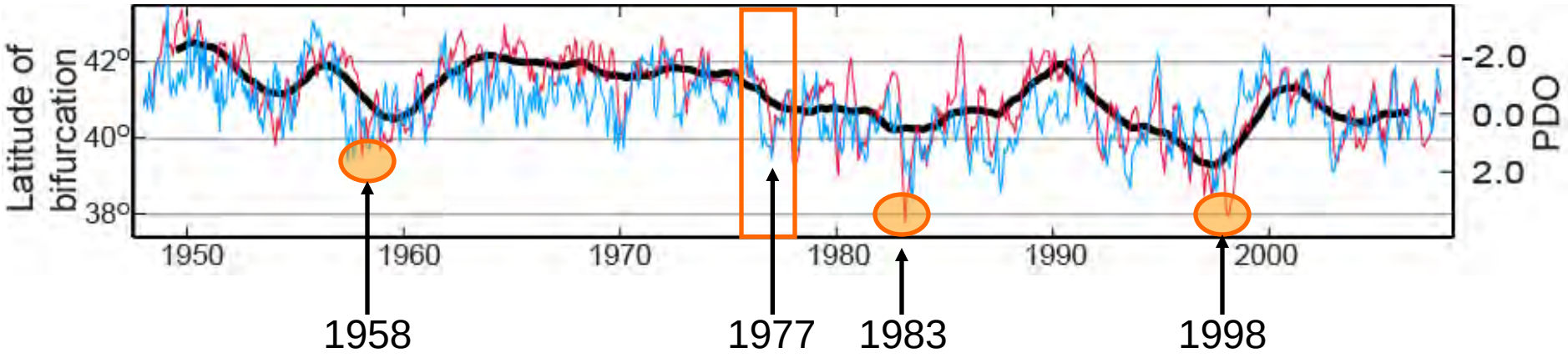


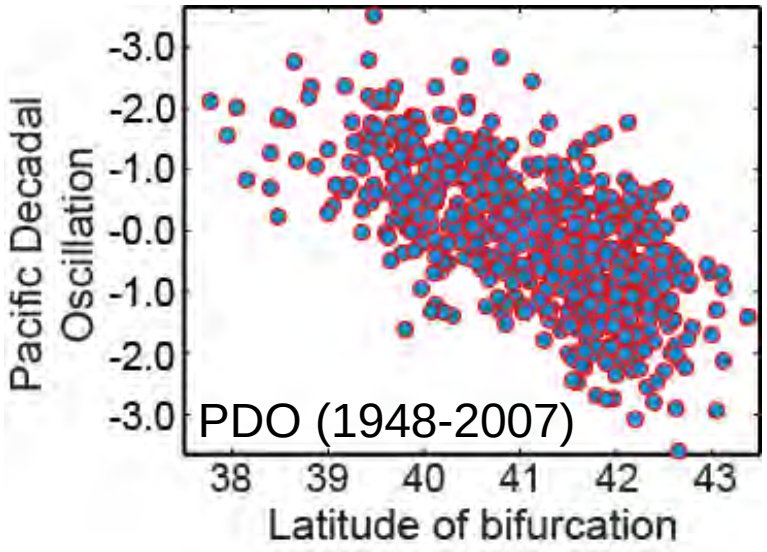
NH Line copepods: A more **northerly** bifurcation is correlated with higher abundance of **"cold-water," lipid-rich copepods** and low species diversity.





Current position related to large-scale climate





Latitudinal position of the North Pacific Current and its bifurcation appears to be another dynamic related to the PDO.

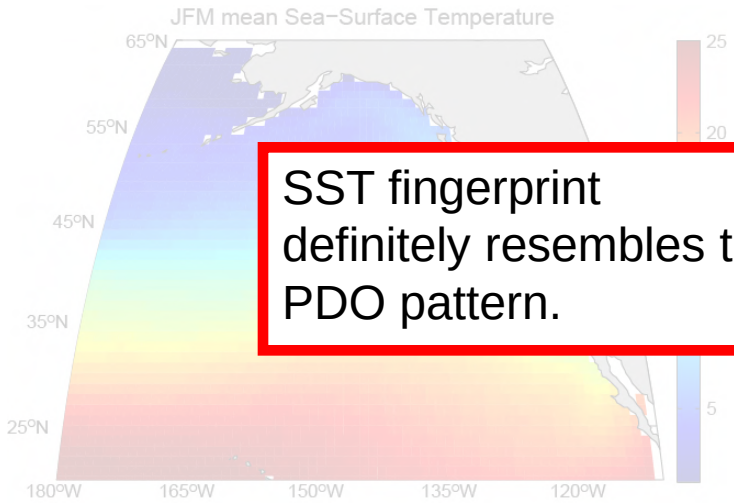
Remaining questions:

- Does the related SST fingerprint support this PDO relationship?
- What are the related anomalies of nutrient transport?

SST and NO_3 variability correlated with position

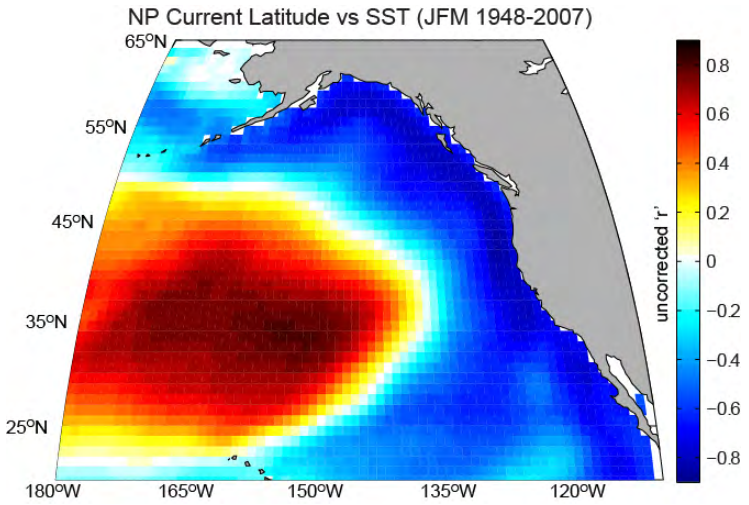
SST:

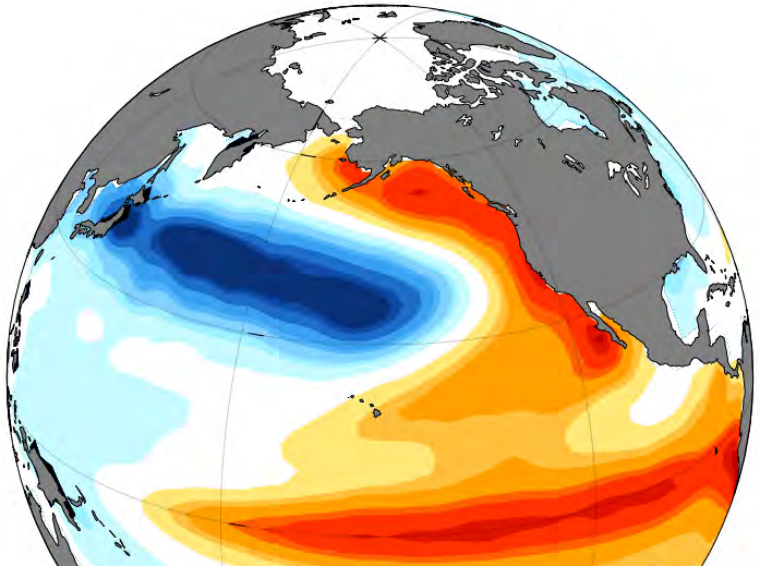
mean:



SST fingerprint definitely resembles the PDO pattern.

correlation with NPC latitude:

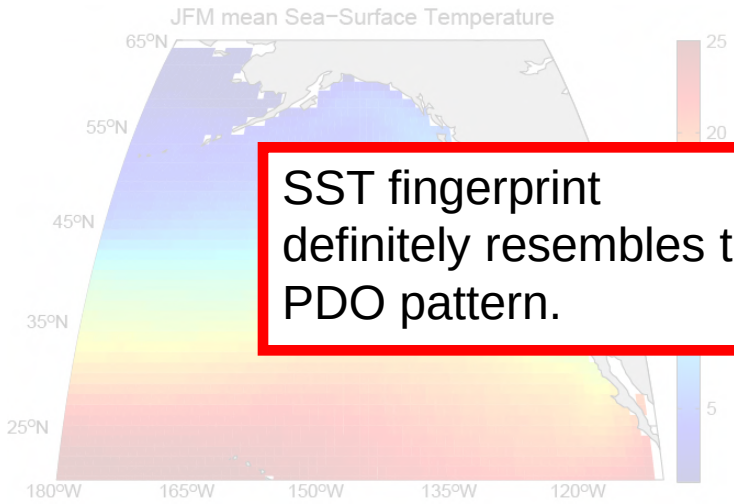




SST and NO_3 variability correlated with position

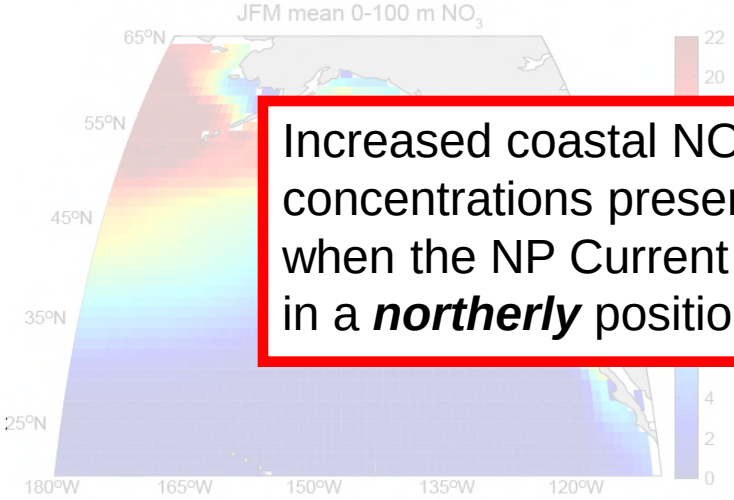
mean:

SST:



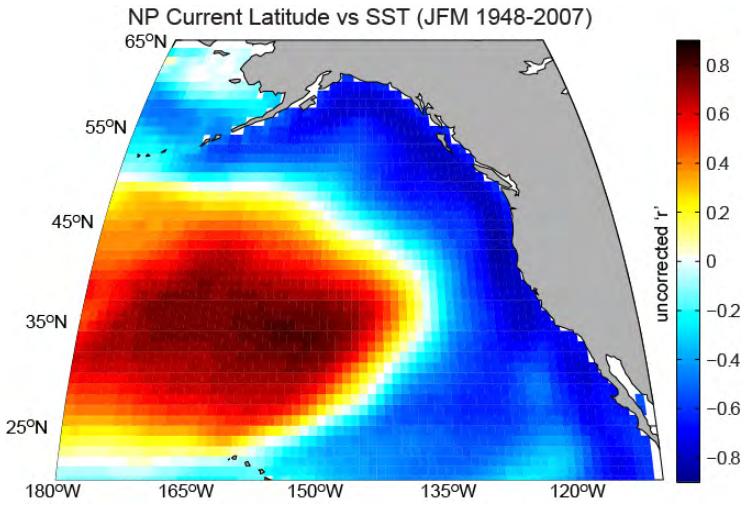
SST fingerprint definitely resembles the PDO pattern.

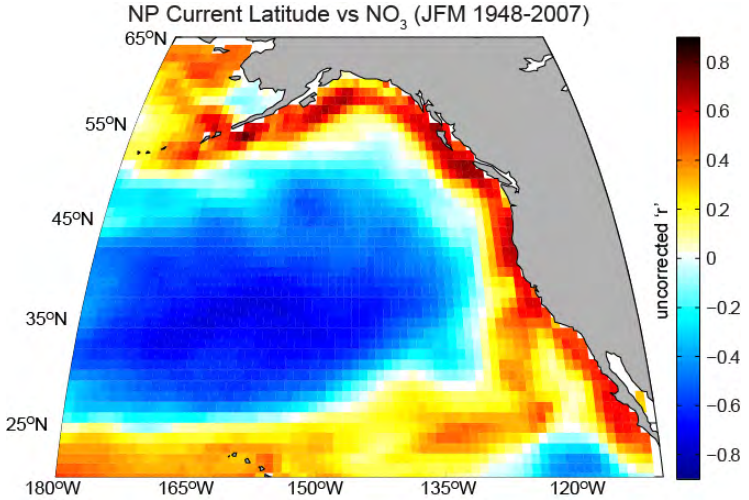
NO_3:



Increased coastal NO_3 concentrations present when the NP Current is in a ***northerly*** position.

correlation with current latitude:

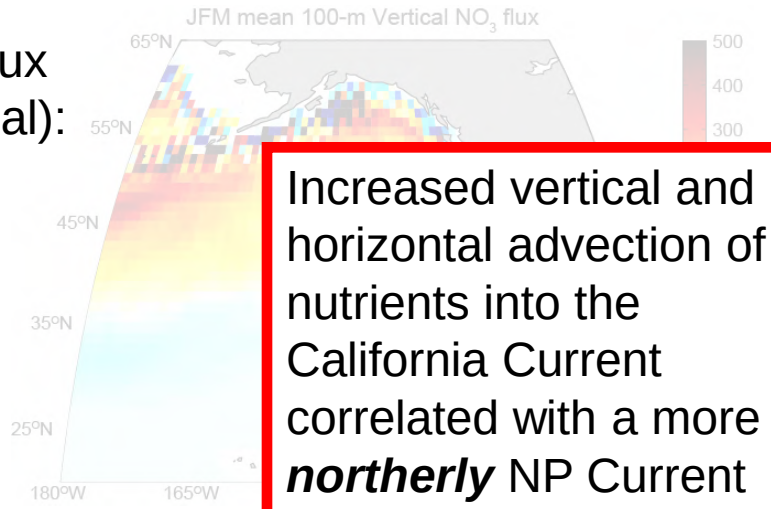




NO_3 transports also correlated with position

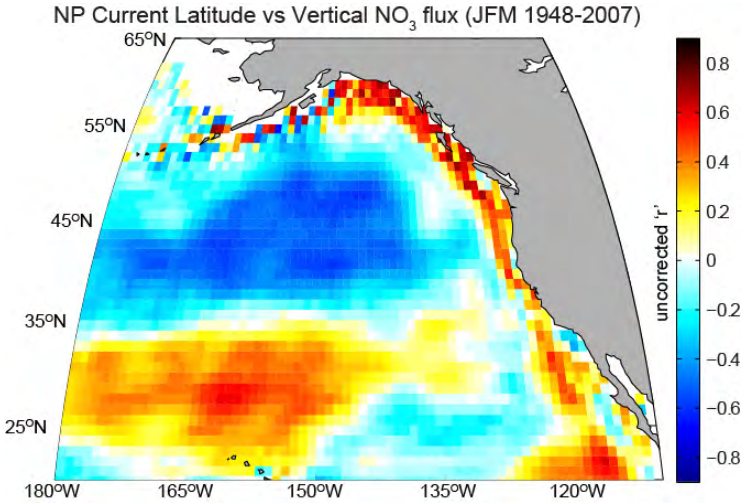
mean:

NO_3 flux (vertical):

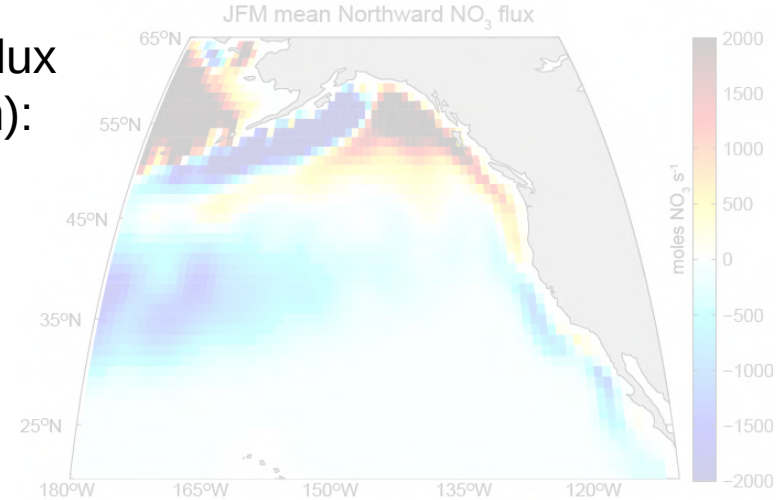


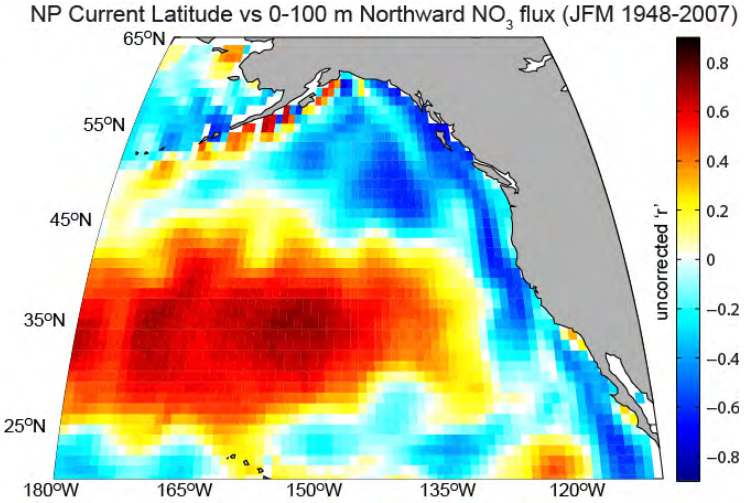
Increased vertical and horizontal advection of nutrients into the California Current correlated with a more ***northerly*** NP Current position.

correlation with current latitude:



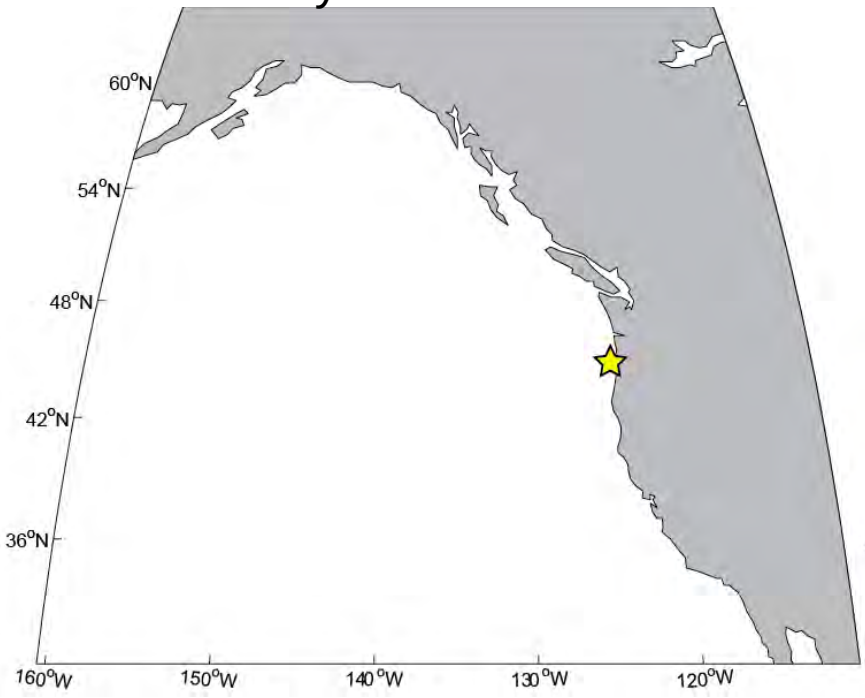
NO_3 flux (north):



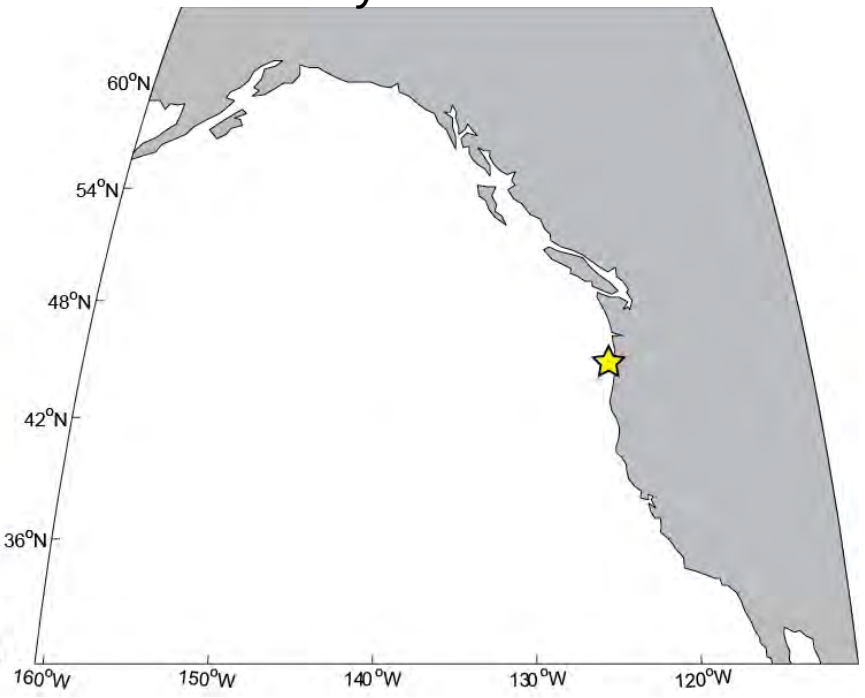


Incorporating position into the conceptual 'PDO model'

More northerly current & bifurcation

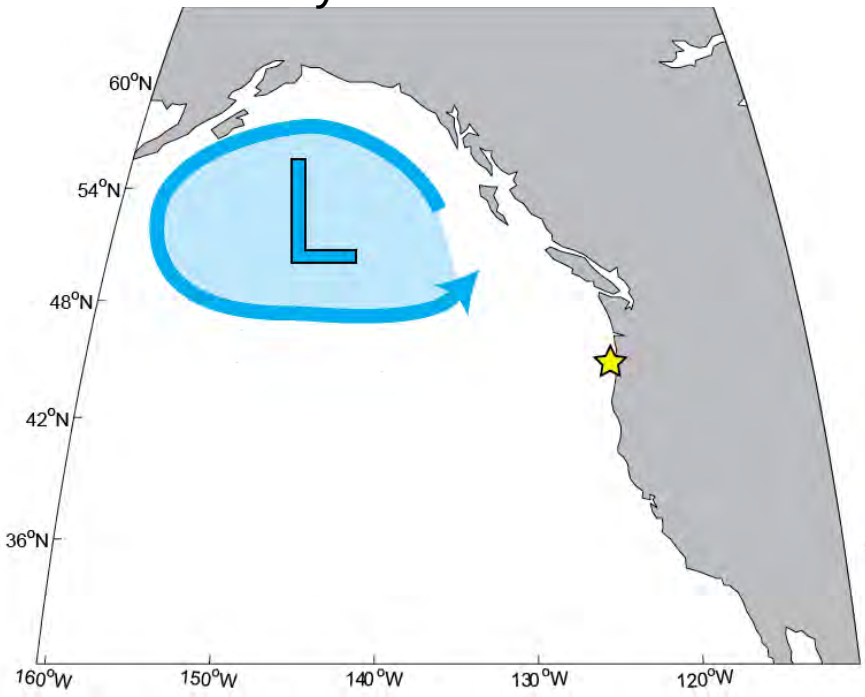


More southerly current & bifurcation

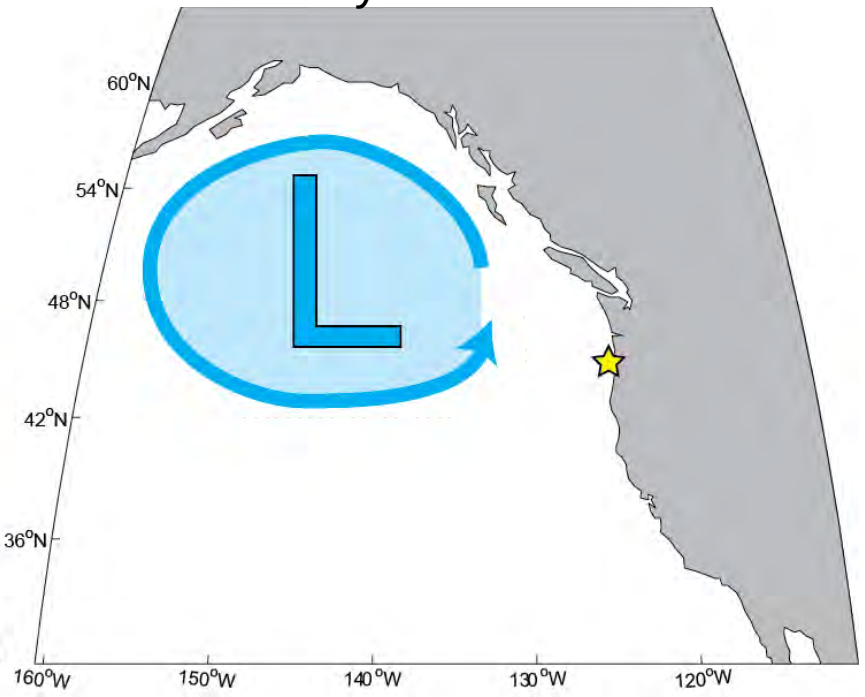


Incorporating position into the conceptual 'PDO model'

More northerly current & bifurcation



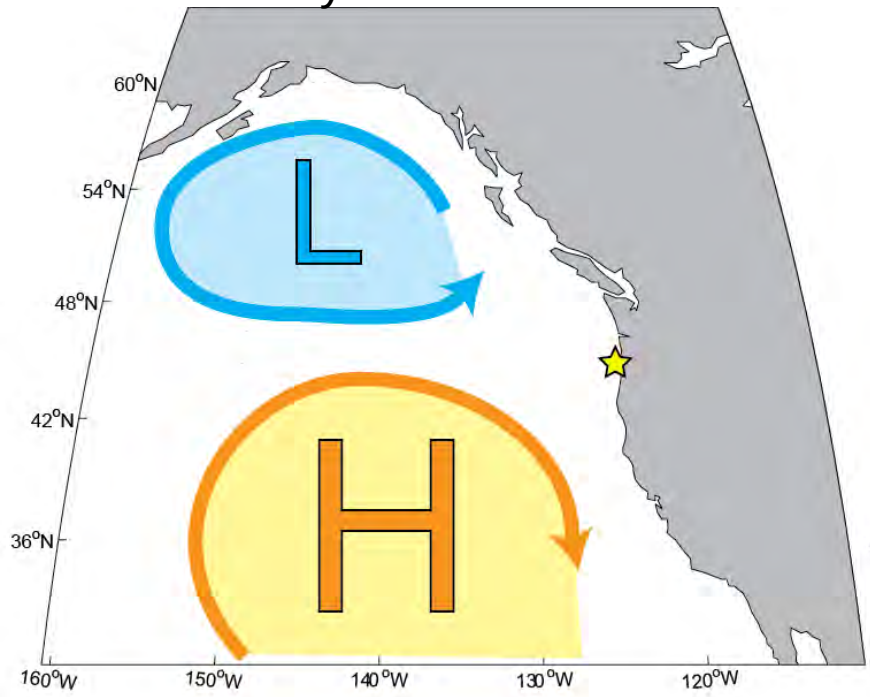
More southerly current & bifurcation



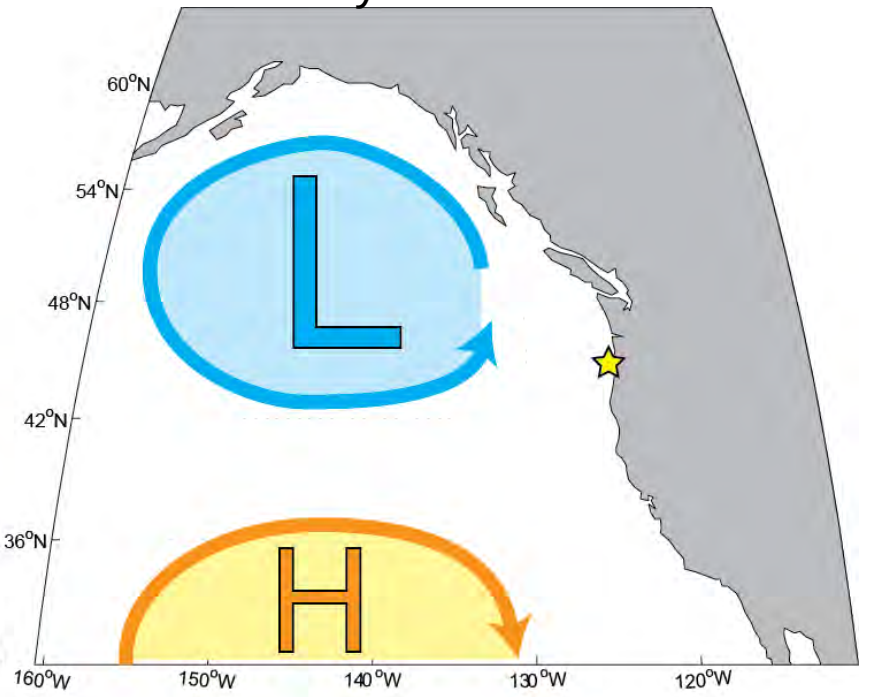
PDO phase:	*negative*	*positive*
Aleutian Low:	weak	strong

Incorporating position into the conceptual 'PDO model'

More northerly current & bifurcation



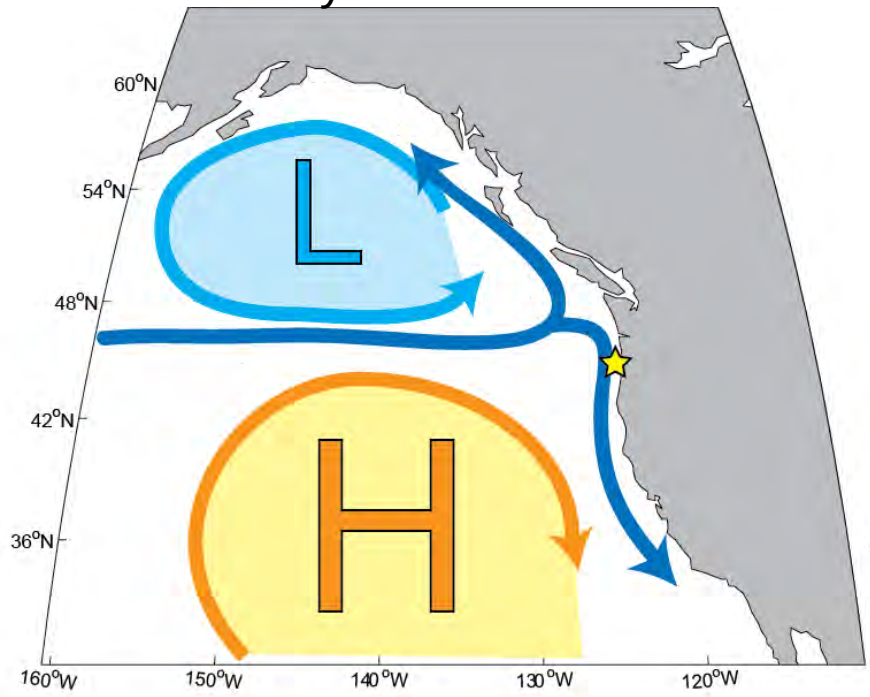
More southerly current & bifurcation



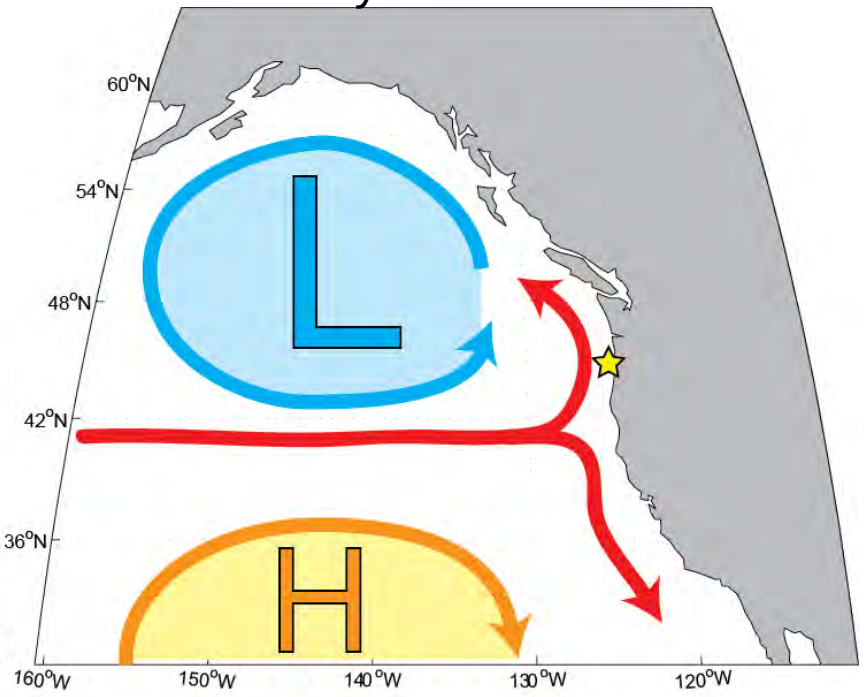
PDO phase:	*negative*	*positive*
Aleutian Low:	weak	strong
Pacific High:	north	south

Incorporating position into the conceptual 'PDO model'

More northerly current & bifurcation



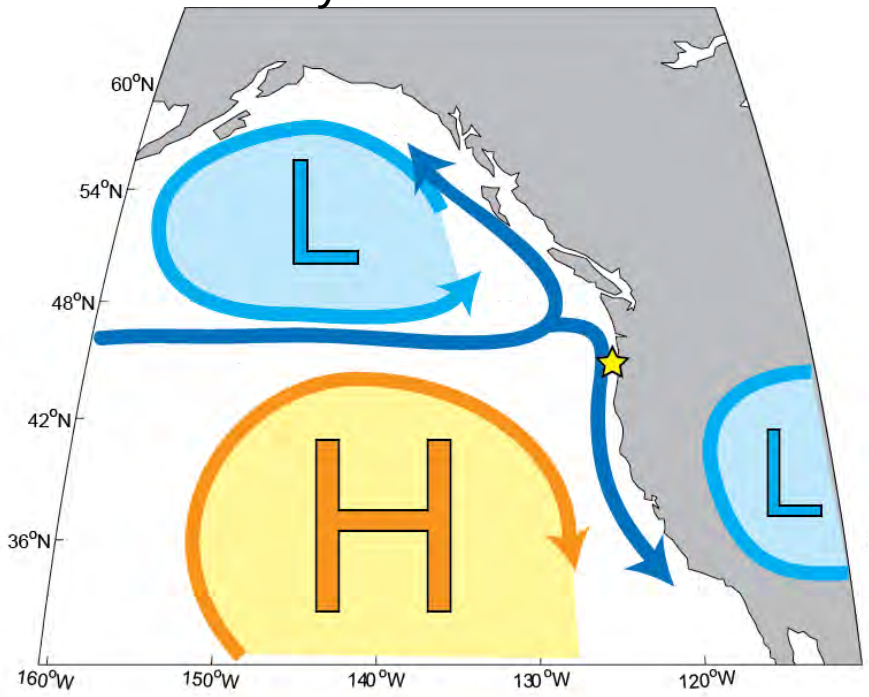
More southerly current & bifurcation



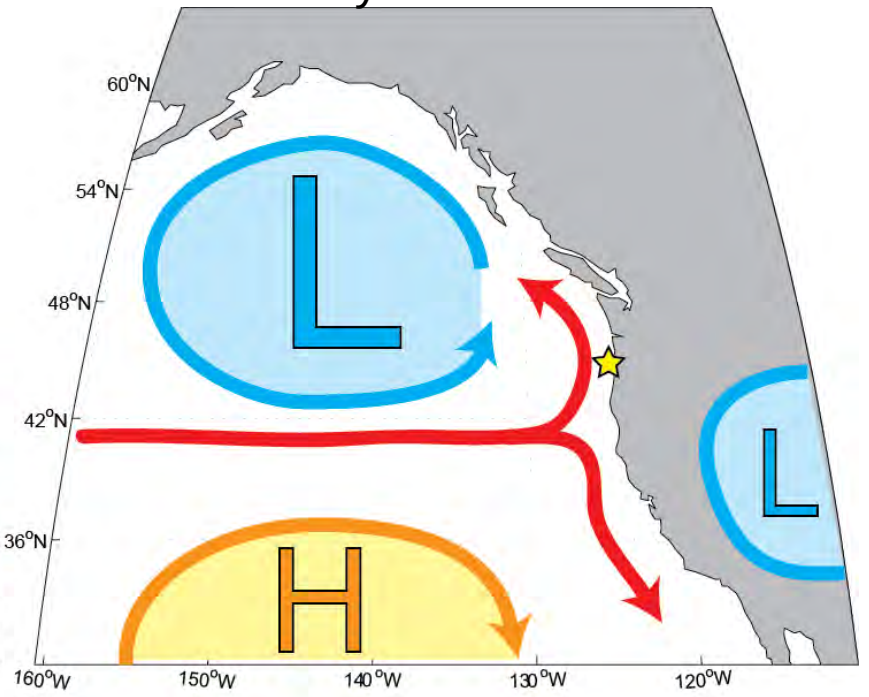
PDO phase:	*negative*	*positive*
Aleutian Low:	weak	strong
Pacific High:	north	south
NP Current, CC:	north, strong	south, weak

Incorporating position into the conceptual 'PDO model'

More northerly current & bifurcation



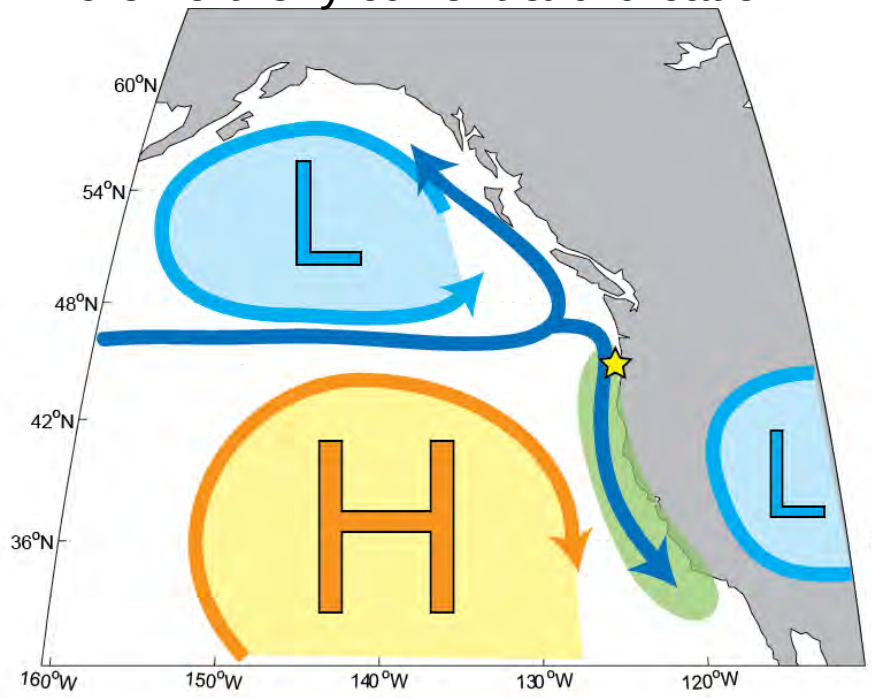
More southerly current & bifurcation



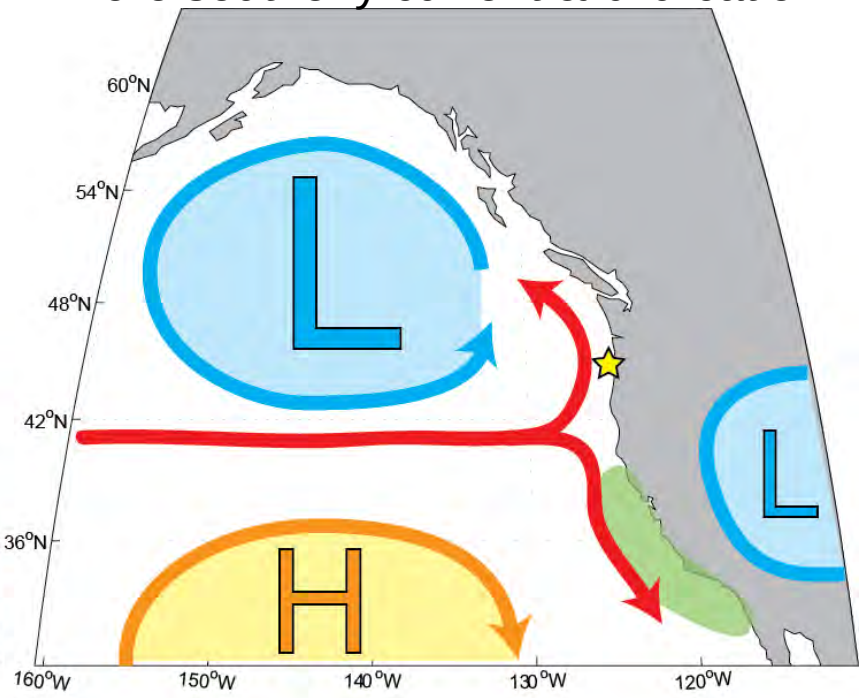
PDO phase:	*negative*	*positive*
Aleutian Low:	weak	strong
Pacific High:	north	south
NP Current, CC:	north, strong	south, weak
Coastal Upwelling:	strong/extends poleward	weak/restricted to south

Incorporating position into the conceptual 'PDO model'

More northerly current & bifurcation



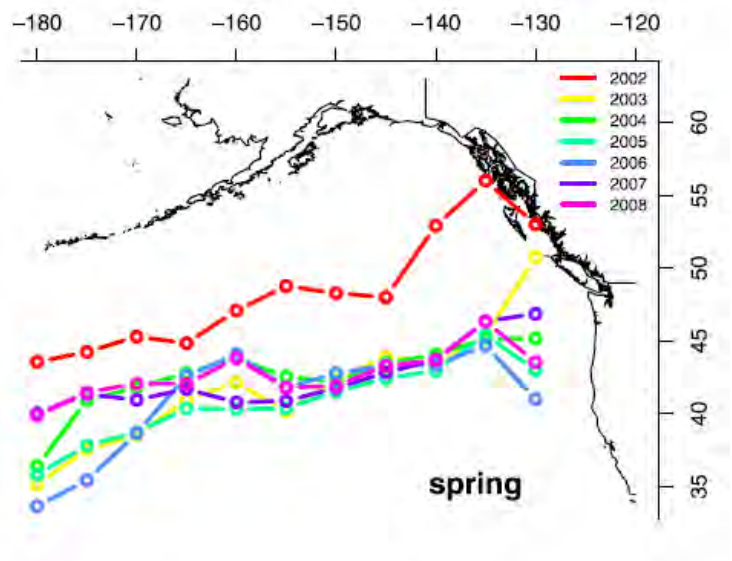
More southerly current & bifurcation



PDO phase:	*negative*	*positive*
Aleutian Low:	weak	strong
Pacific High:	north	south
NP Current, CC:	north, strong	south, weak
Coastal Upwelling:	strong/extends poleward	weak/restricted to south
Bio. Productivity:	high	low

Final thoughts…

Q: Does positioning of the North Pacific Current affect downstream ecosystem productivity?



A: In terms of nutrient supply and primary production.:

Position of the current is certainly *correlated* with “downstream” production.

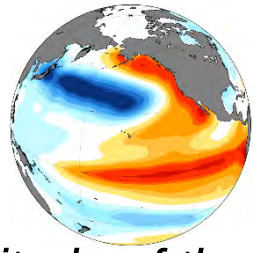
I don’t find this different than the suite of dynamics that have long been associated with the PDO and the strength of the Aleutian Low, *e.g.* changes in:

coastal upwelling and wind stress
strength of the California Current equatorward transport

However—Meso/macro zooplankton, with a longer residence time, may be more influenced by horizontal transport than vertical transport or local production.

Where does that leave us?

Intensity and position of the Aleutian Low



Latitude of the North Pacific Current

?

(time variable?)

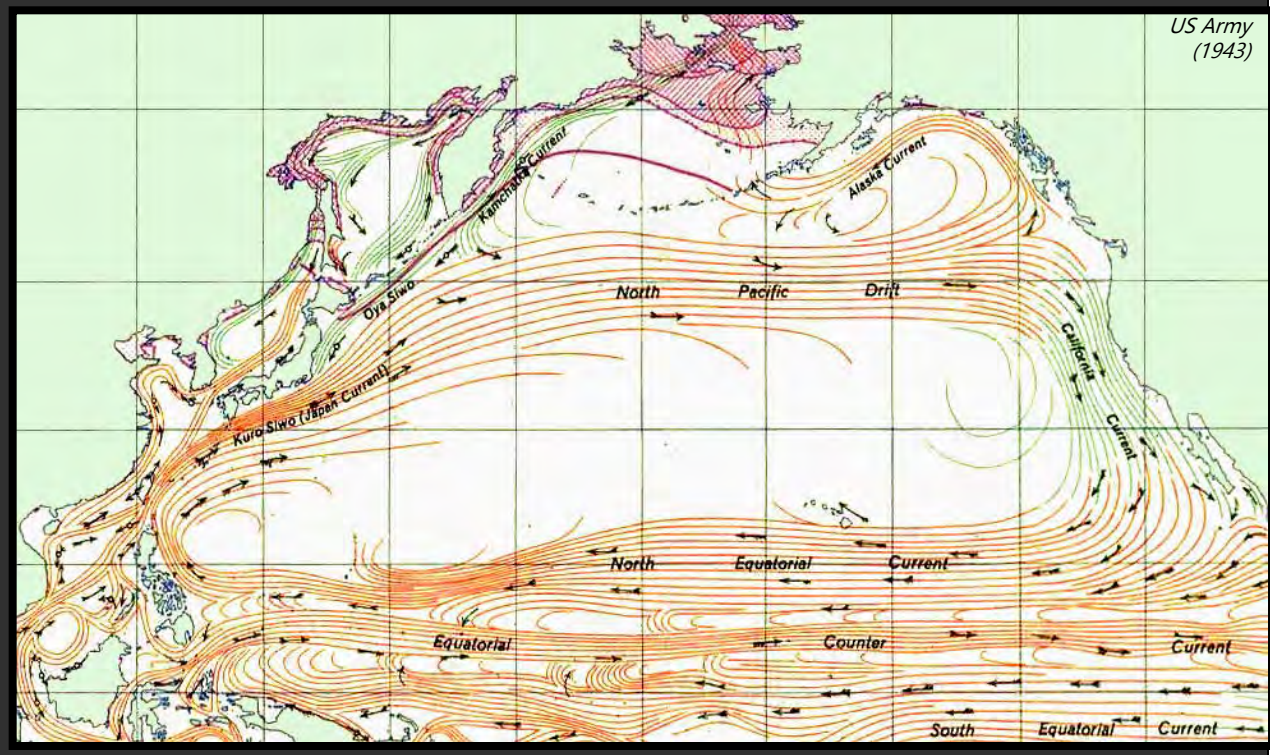
influential ecosystem conditions

(time variable?)

population characteristics

Thanks!

Ryan Rykaczewski
University of South Carolina
ryk@sc.edu



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