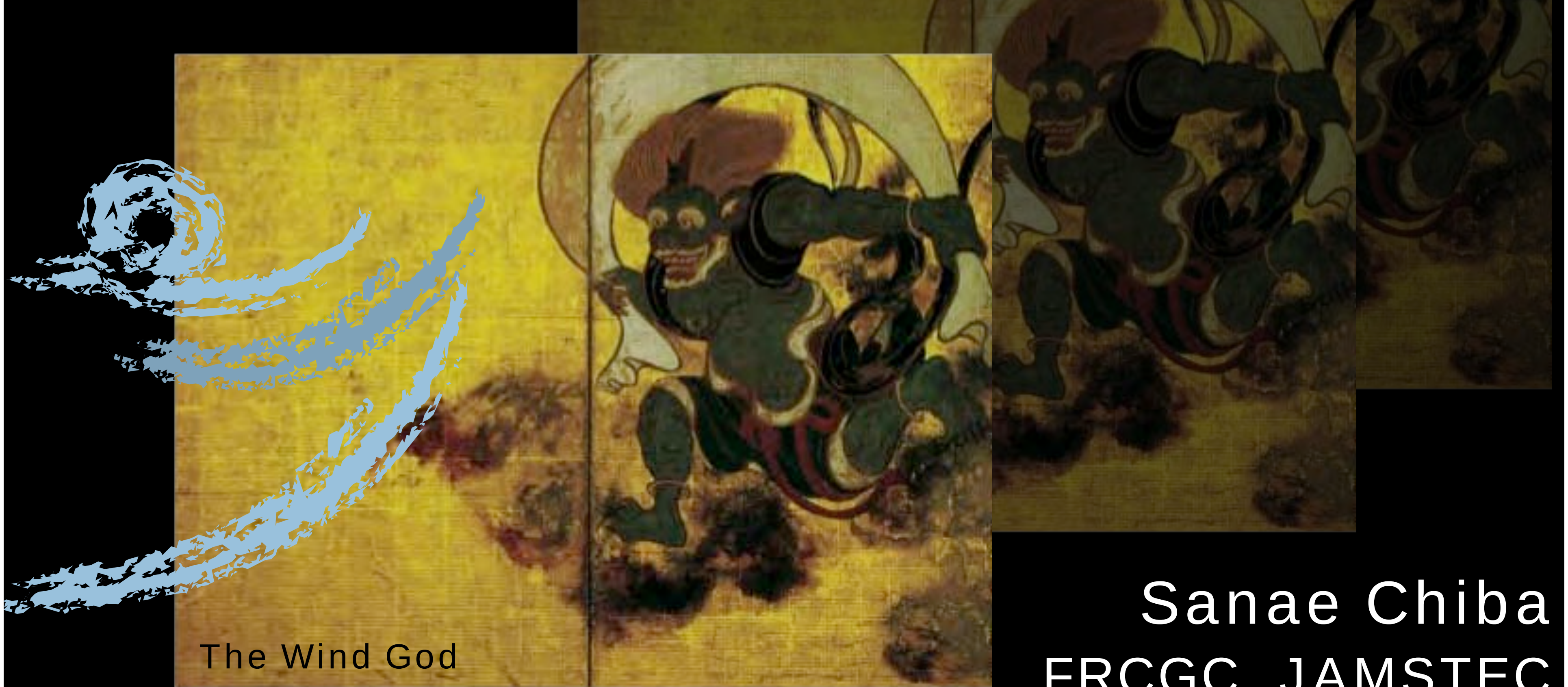
Anyway the wind blows….

From climate to the lower trophic levels in the western North Pacific



The Wind God

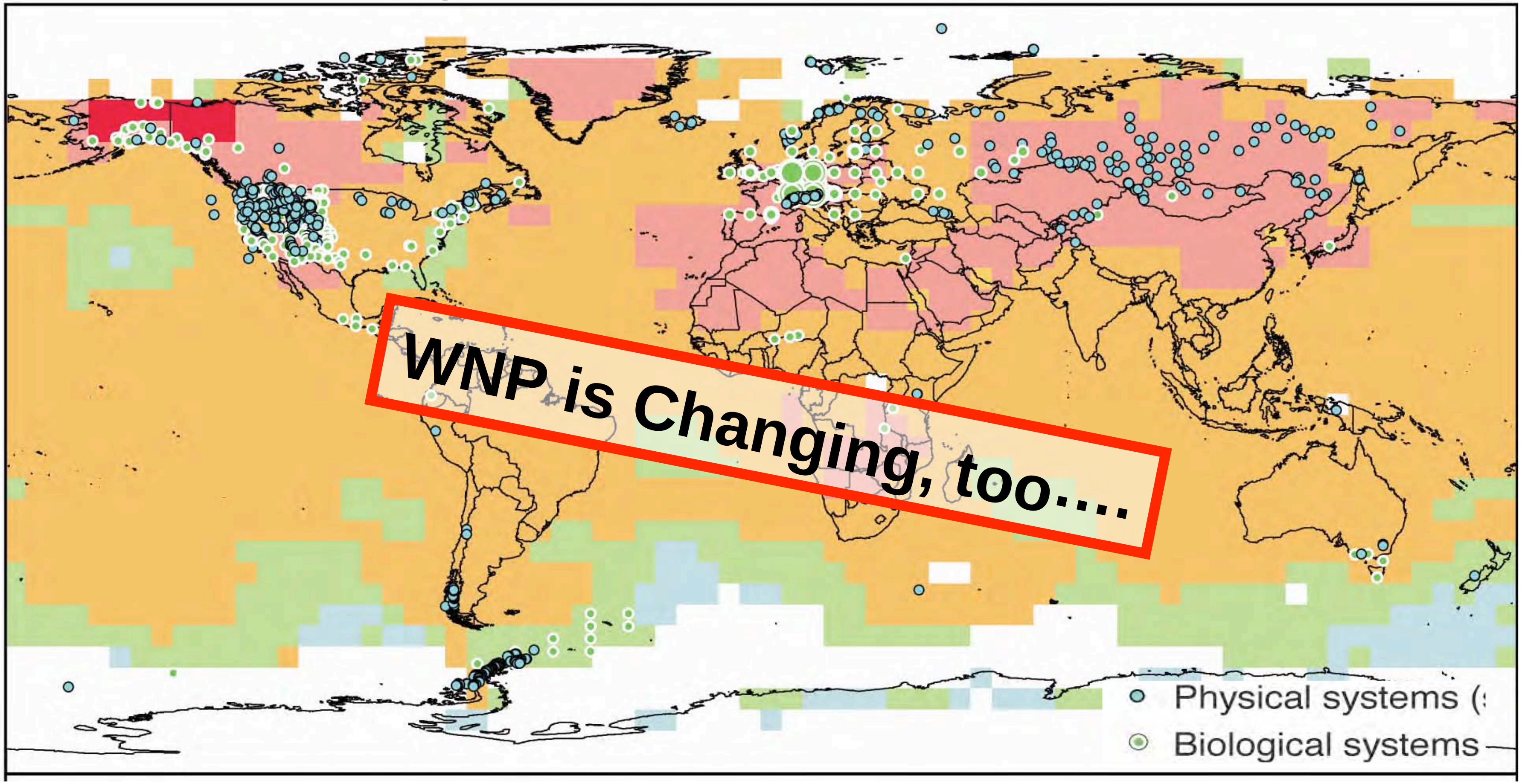
Sanae Chiba

FRCGC, JAMSTEC

and Odate Project Members

International Symposium, Effect of CC on the World Ocean, 2008 Gijon

Observed Changes (IPCC AR4)



Number of significant biological changes

North America 455

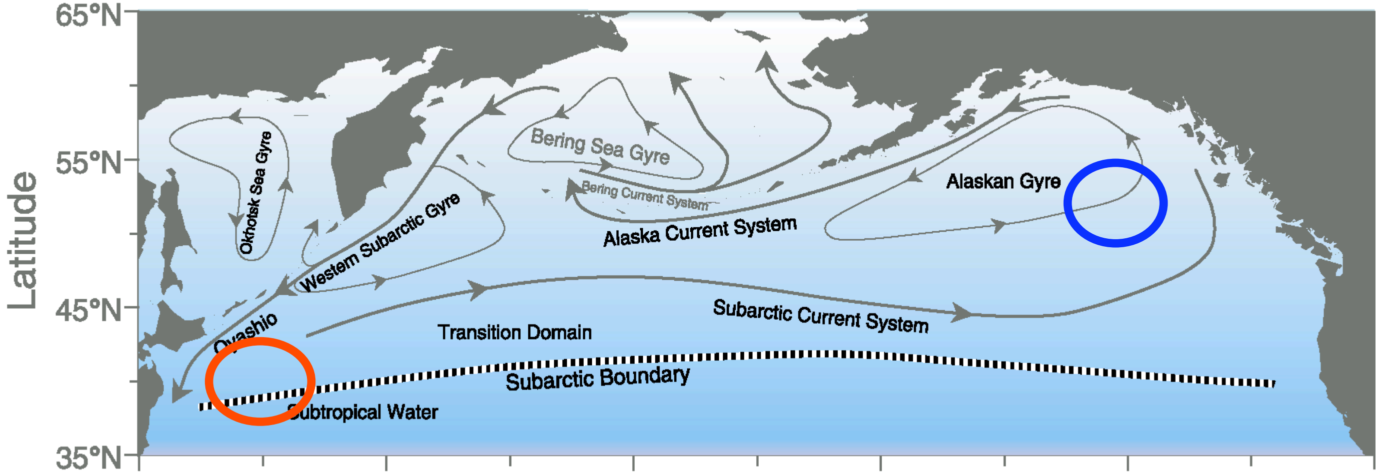
Europe 28115

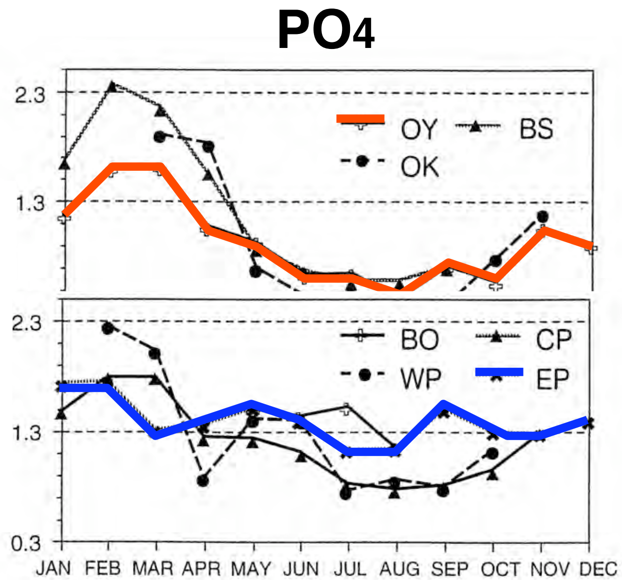
Asia 8

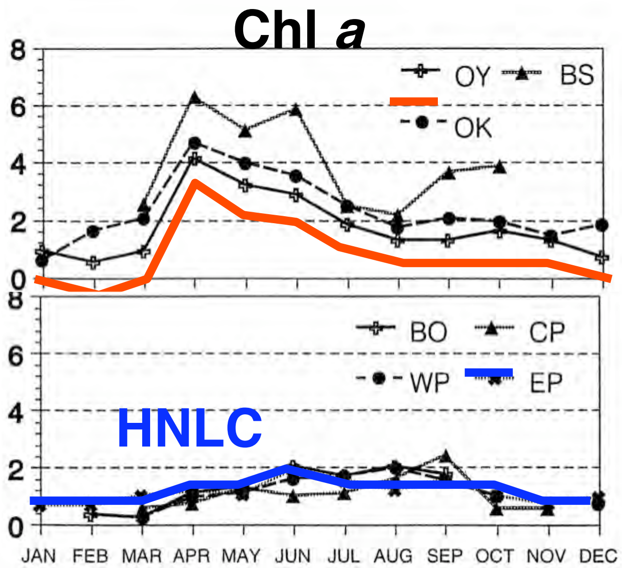
Global Terrestrial 28586

Marine & Fresh Water 85

Target Region: subarctic WNP (Oyashio)







Centric diatoms

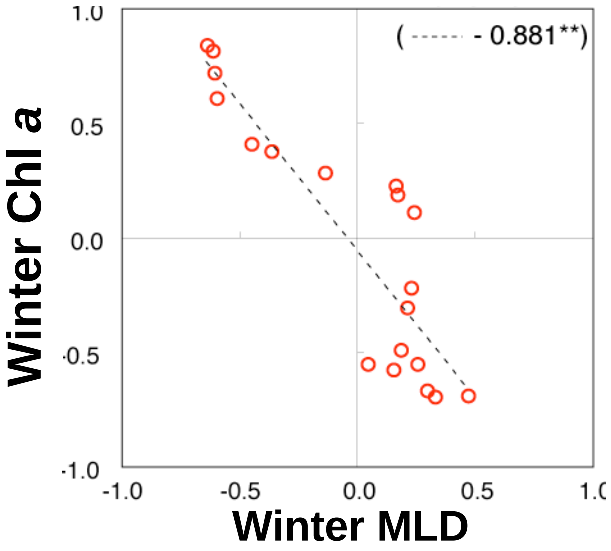
Pennate diatoms

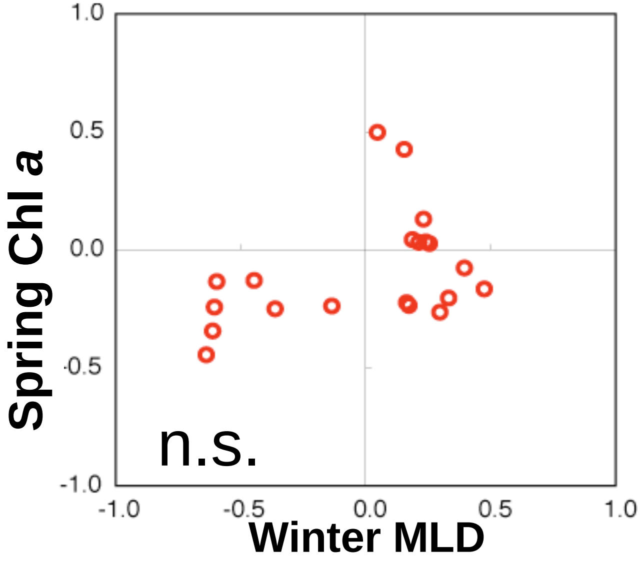
(Tadokoro & Sugimoto, 2000)

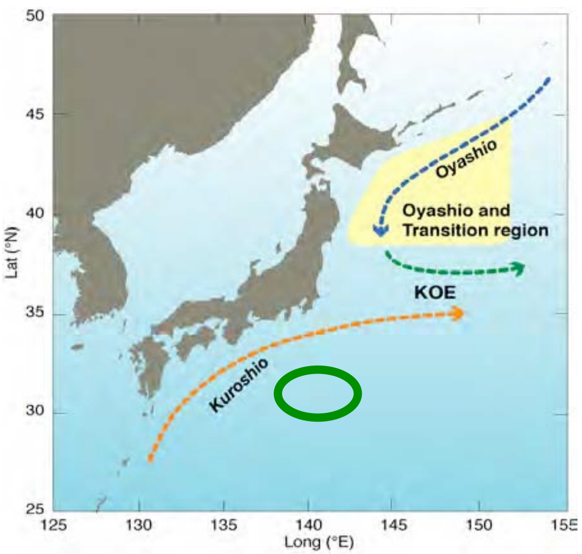
- rich nutrient supply & extensive spring bloom
- strong seasonality

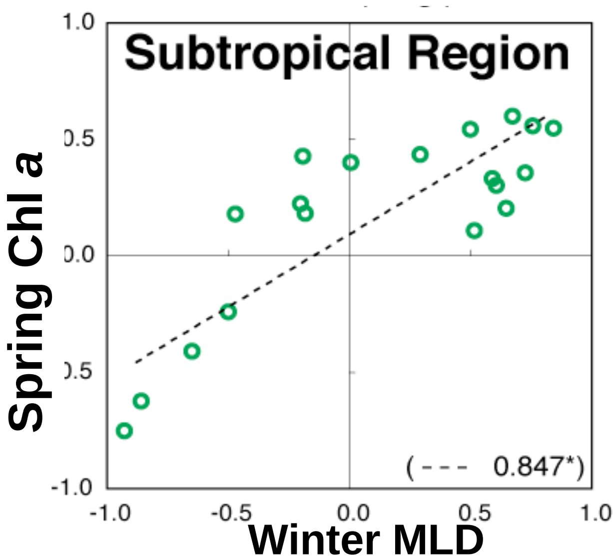
Target Region: subarctic WNP (Oyashio)

Primary Production is limited by Light availability

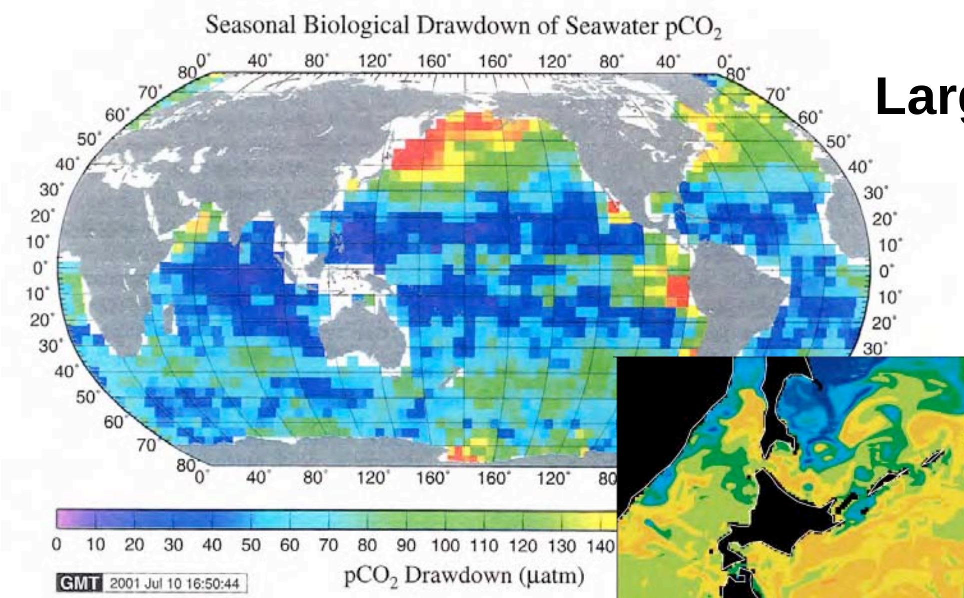






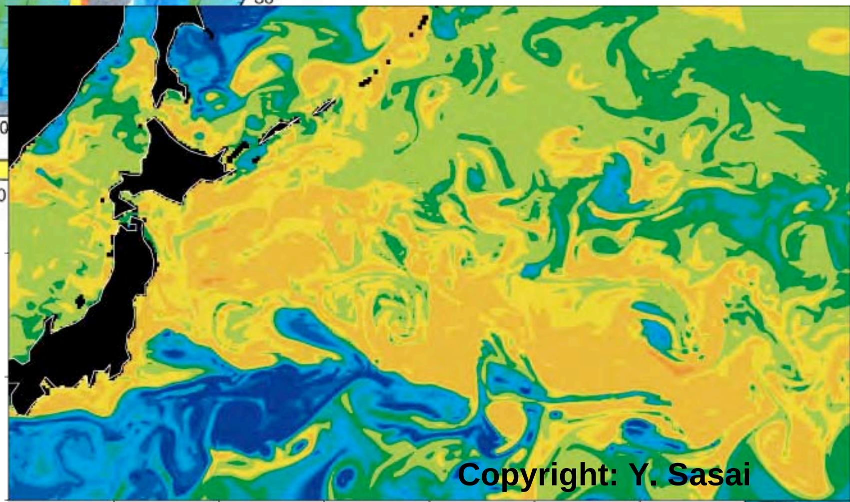


Target Region: subarctic WNP



(Takahashi et al. 2002, DSR II, 49)

Large Biological Drawdown of CO2 ?

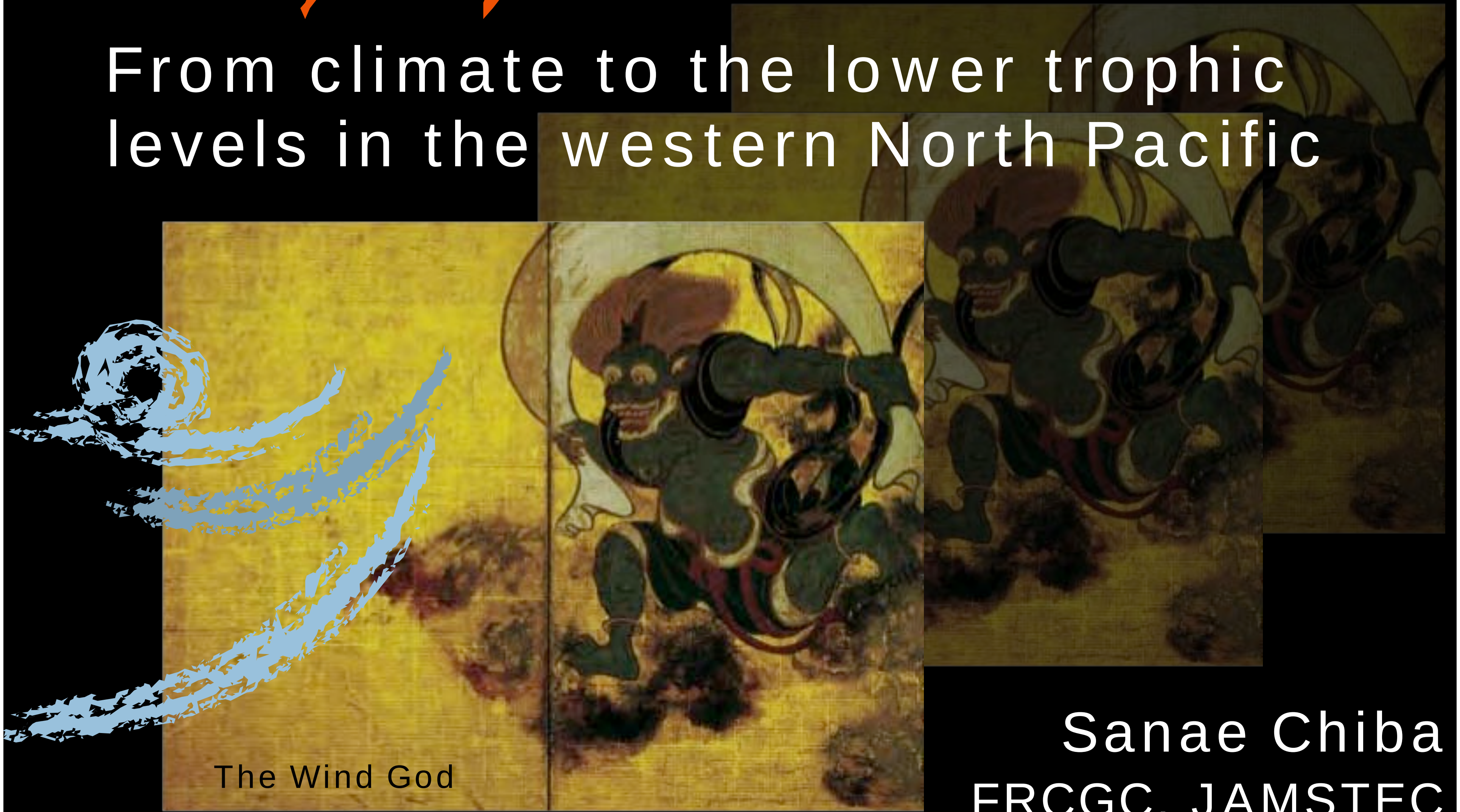


Change in the Future?

Important Fishery Ground ?

Anyway the wind blows....

From climate to the lower trophic levels in the western North Pacific



The Wind God

Sanae Chiba

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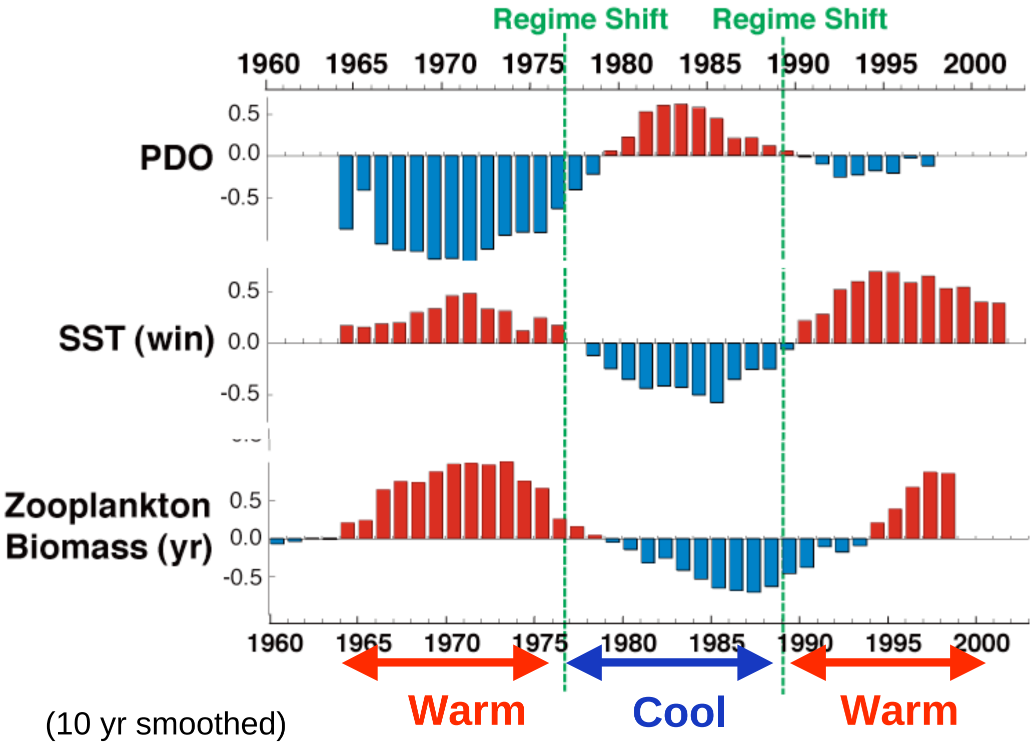
International Symposium, Effect of CC on the World Ocean, 2008 Gijon

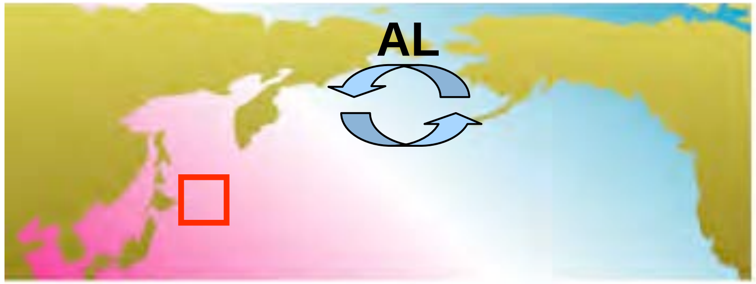
Decadal Changes

Pacific Decadal Oscillation and Western Subarctic NP



(10 yr smoothed)

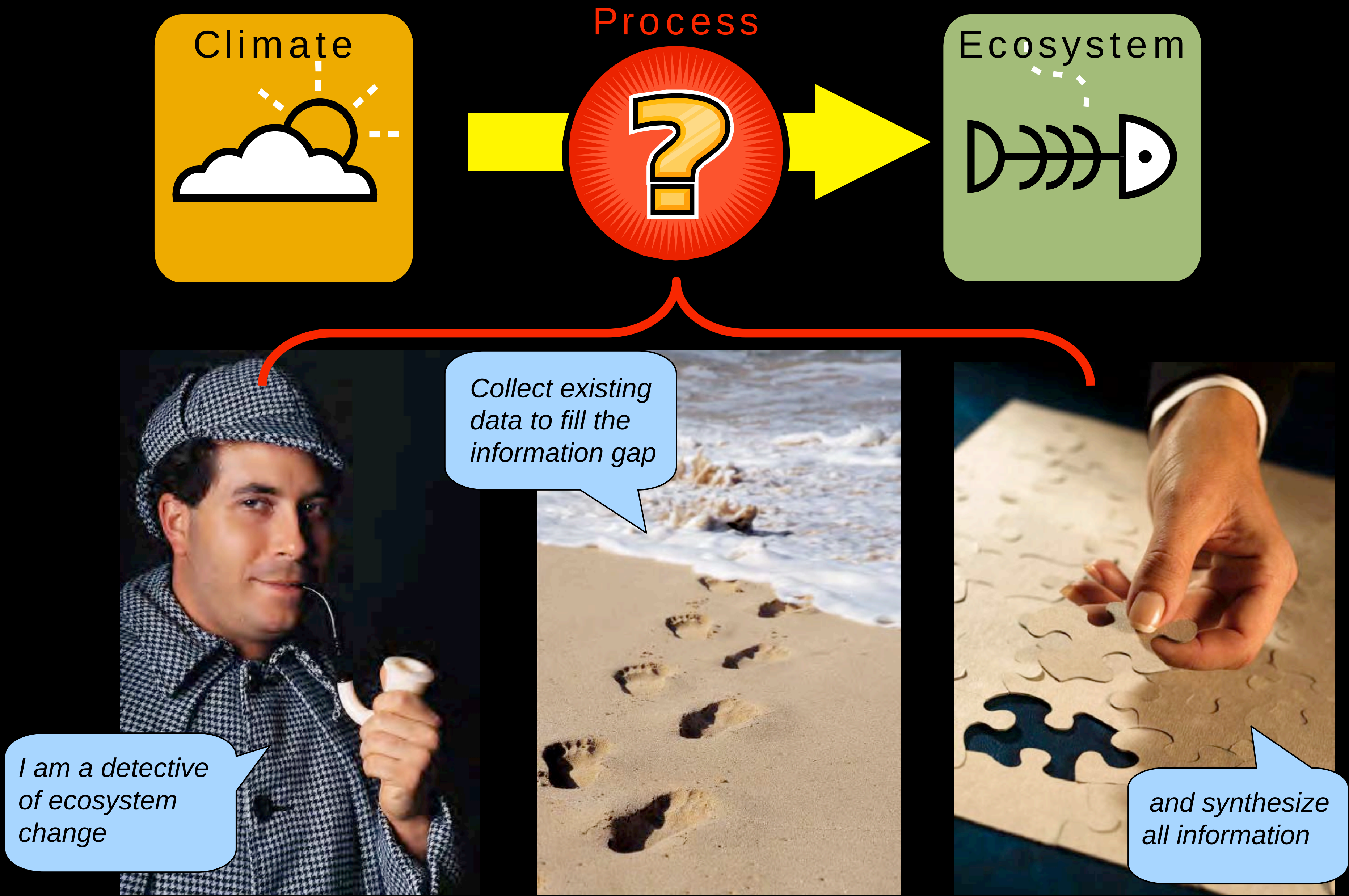
~1975



1976~1987

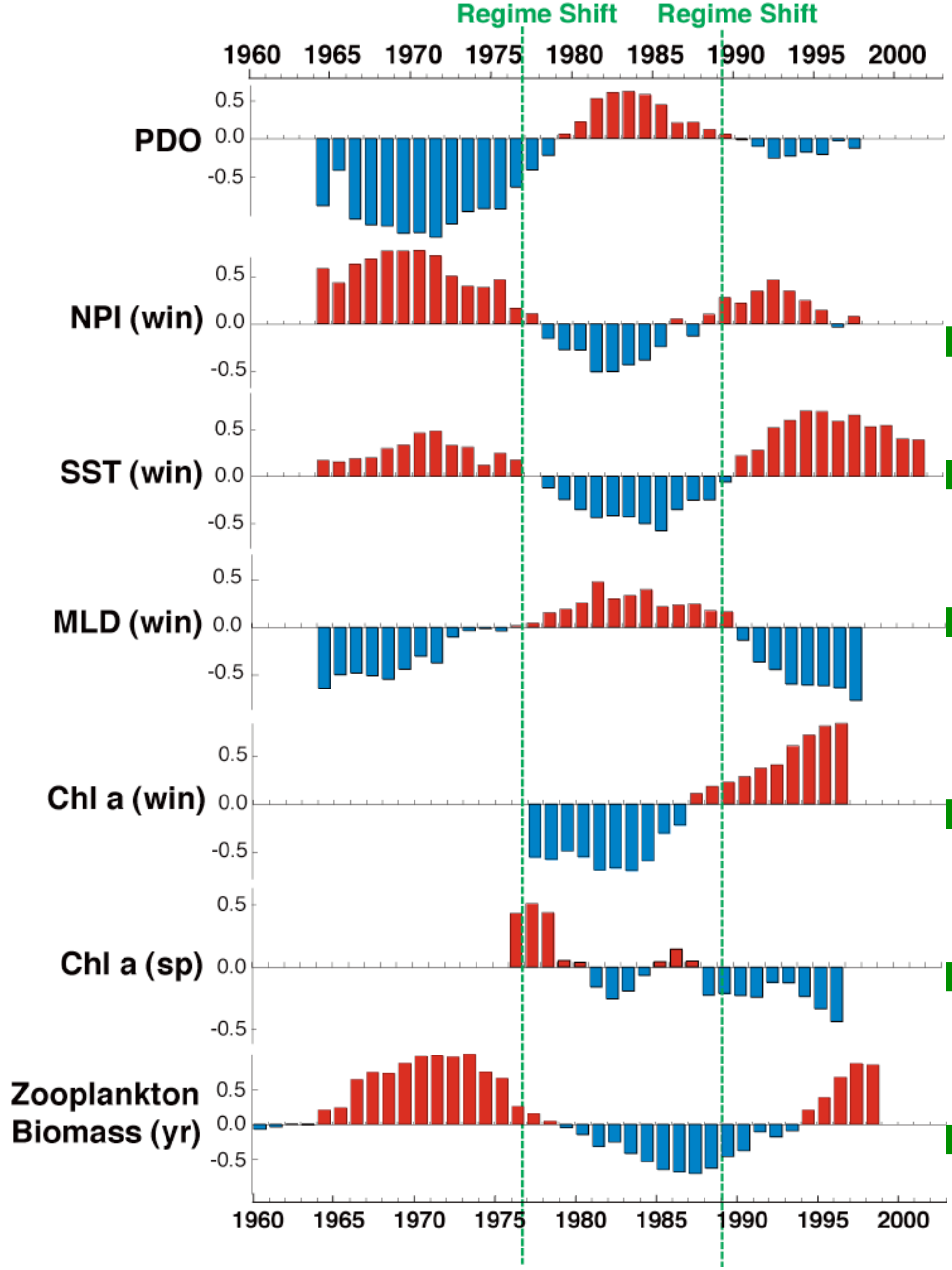
1988~

Retrospective Approach to Find Mechanisms of Changes



Observed Decadal Changes in the western NP

(10 yr smoothed)



"Hypothetical Scenario"
Climatic change altered seasonality of LTL, and PP-ZP link

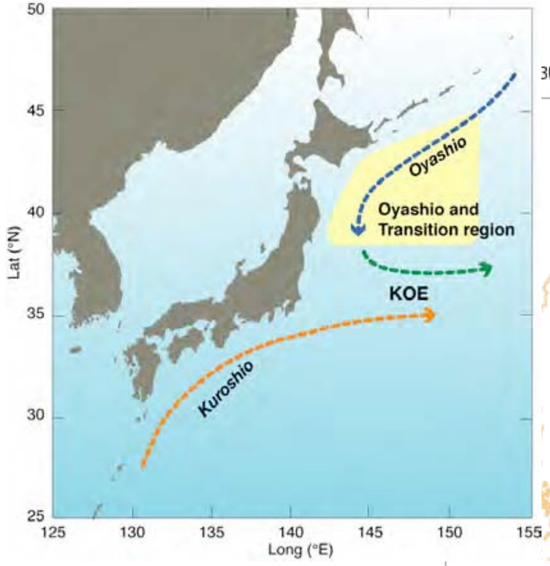
	1976-1880s	1990s
Wind	**Strong**	**Weak**
Temp	**Cool**	**Warm**
Mixing	**Deep**	**Shallow**
(Light	Low	High)
(Nutrient	?	Low)
Winter PP	**Low**	**High**
Spring (and yr) PP	**Low**	**Lower**
ZP	**Low**	**High**

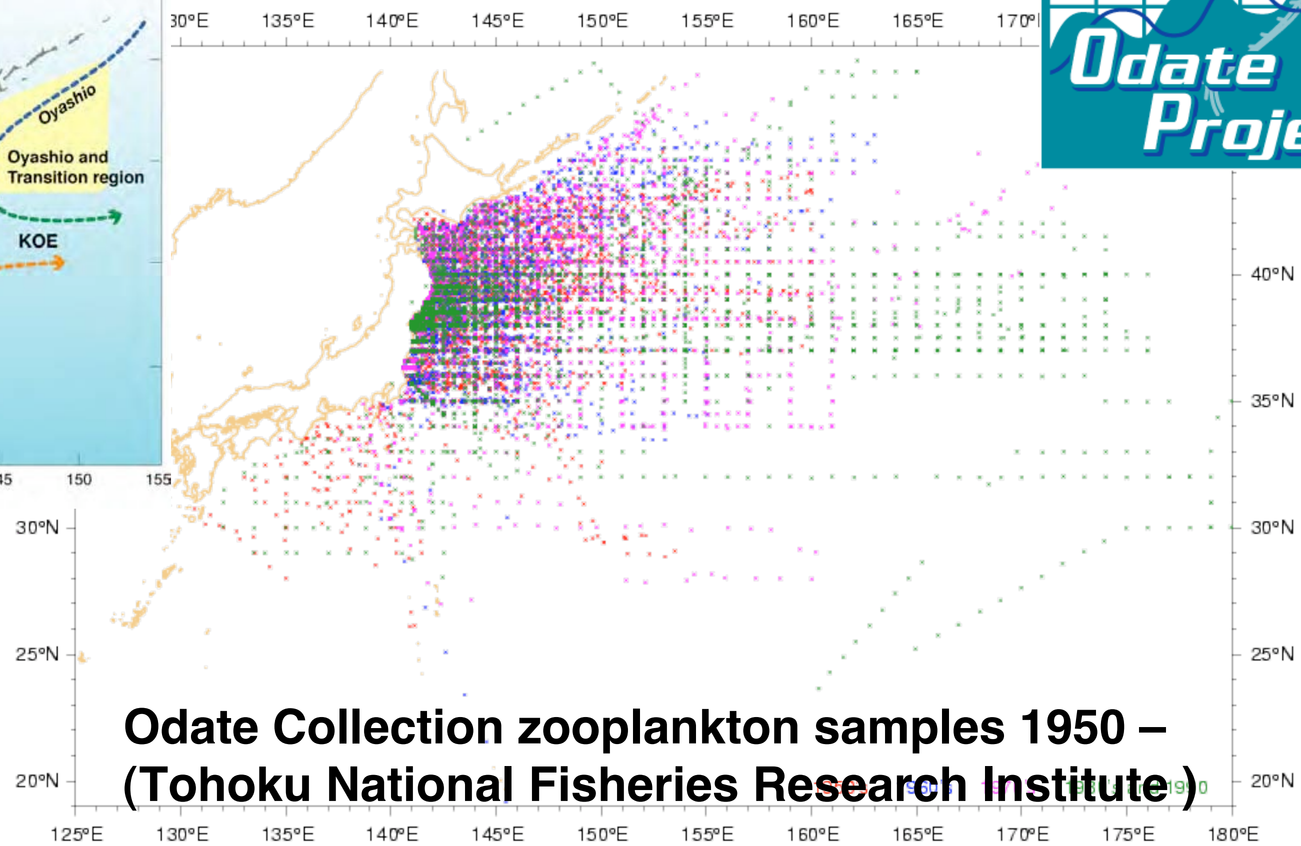
+ – ? + ?

Need evidence to support the hypothesis….

*Historically collected and preserved zooplankton specimens can be used as **FINGERPRINT** of mechanisms of **Ecosystem Responses** to the **Past Environmental Changes***

The Odate Collection





Odate Collection zooplankton samples 1950 – (Tohoku National Fisheries Research Institute)

Dr. Kazuko Odate, the originator of the Odate Collection
(PICES Press, 16(1), 2008)

- Original Odate Collection data set: wet weight of total c.a.20000 samples
- NORPAC net tow (0-150 m, mesh: 330 um)
- FY2003- Species level analysis of the selected c.a. 3000 samples
- Target: Copepods

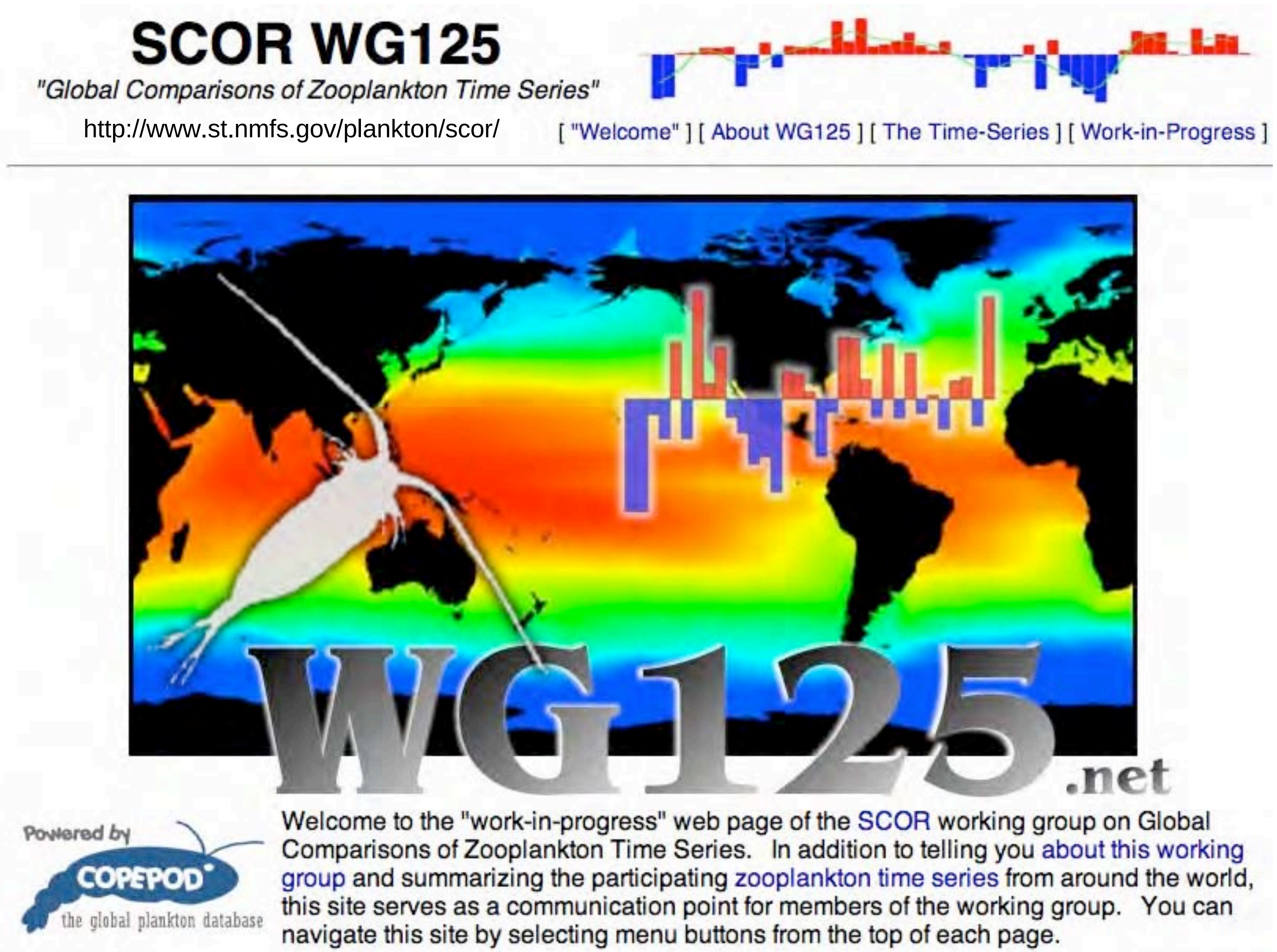
Detailed Analysis on The Odate Collection

Taxonomic breakdown, Seasonal breakdown

Monthly based data for 1960-2000 on:

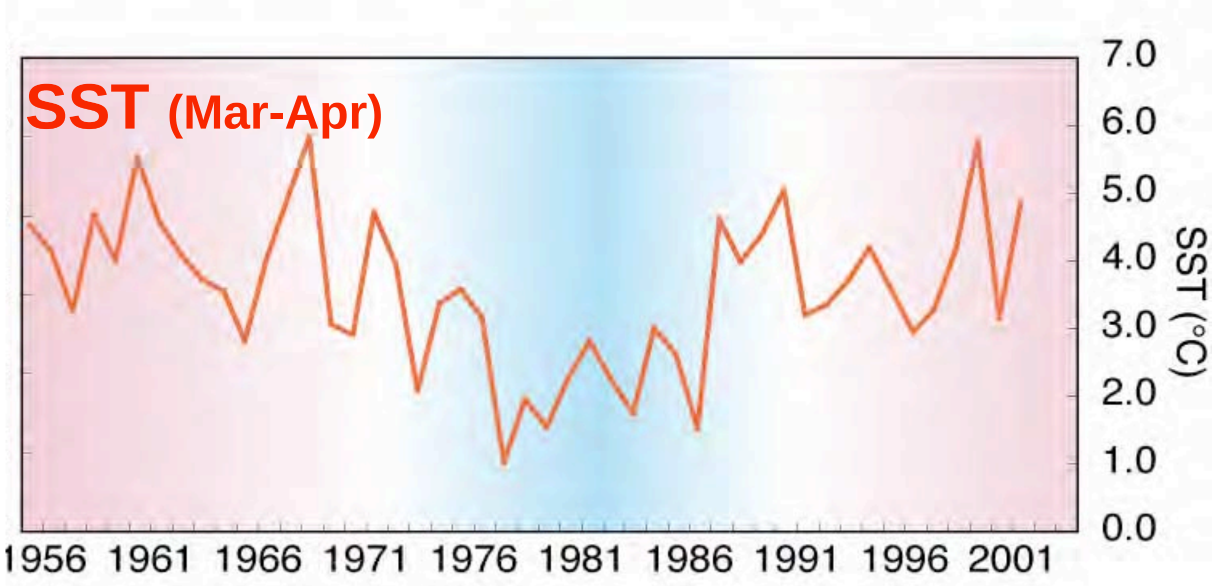
Data	What to analyze	What to examine
Species composition (based on abundance)	Cluster analysis (R-mode & Q-mode) Warm-Cold water species composition Large species composition	Phenology Biogeographical shift
	Diversity	Diversity
Major species 3 *Neocalanus* spp. *Eucalanus bungii*	Developmental stage composition (CI-CV)	Phenology Biogeographical shift
	Body length of CV Nitrogen stable isotope ratio	Food availability & T Population change Bottom-up control

Workshop 1: Zooplankton and climate: response modes and linkages among regions, regimes, and trophic levels (May 18)

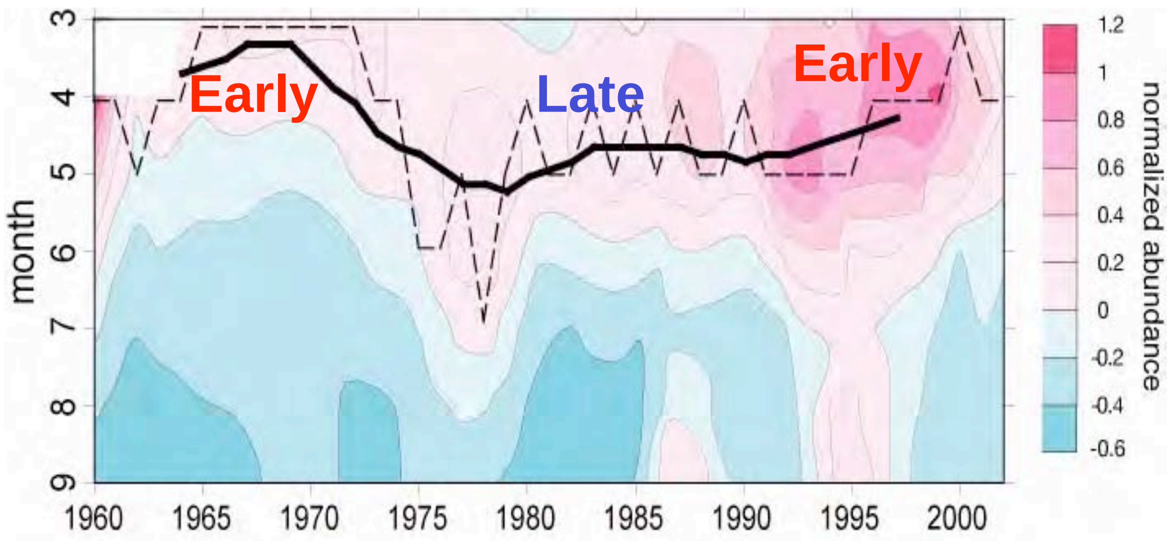


See Presentation, David Mackas, et al., S4.1 1645~
and Posters also…

Zooplankton Phenology in WNP



Yr-month abundance of Spring Copepod Community



(Chiba et al 2006 GCB)

Direct influence of T change?

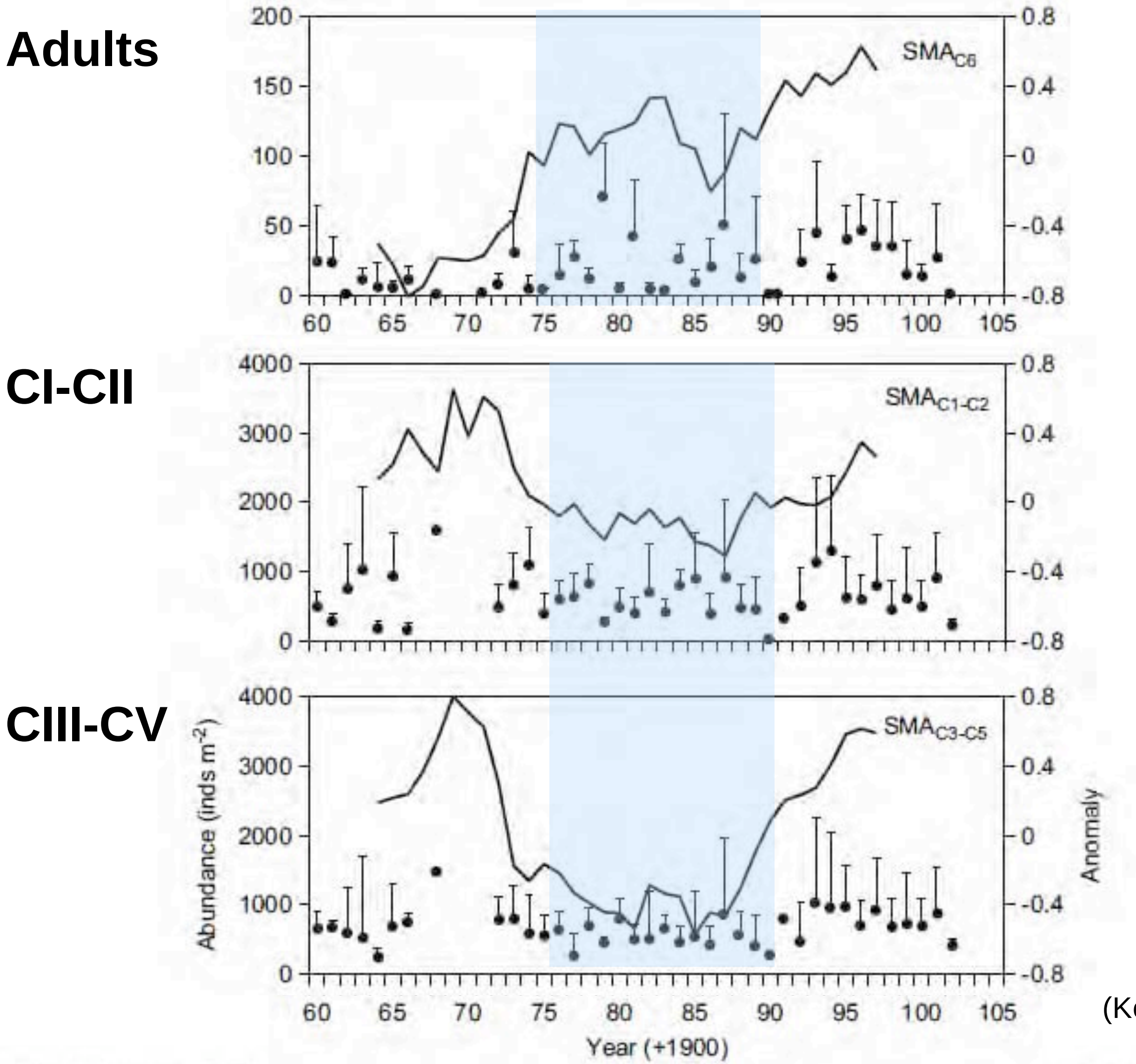
Unlikely…

Phytoplankton availability?

Likely…

Zooplankton Phenology in WNP

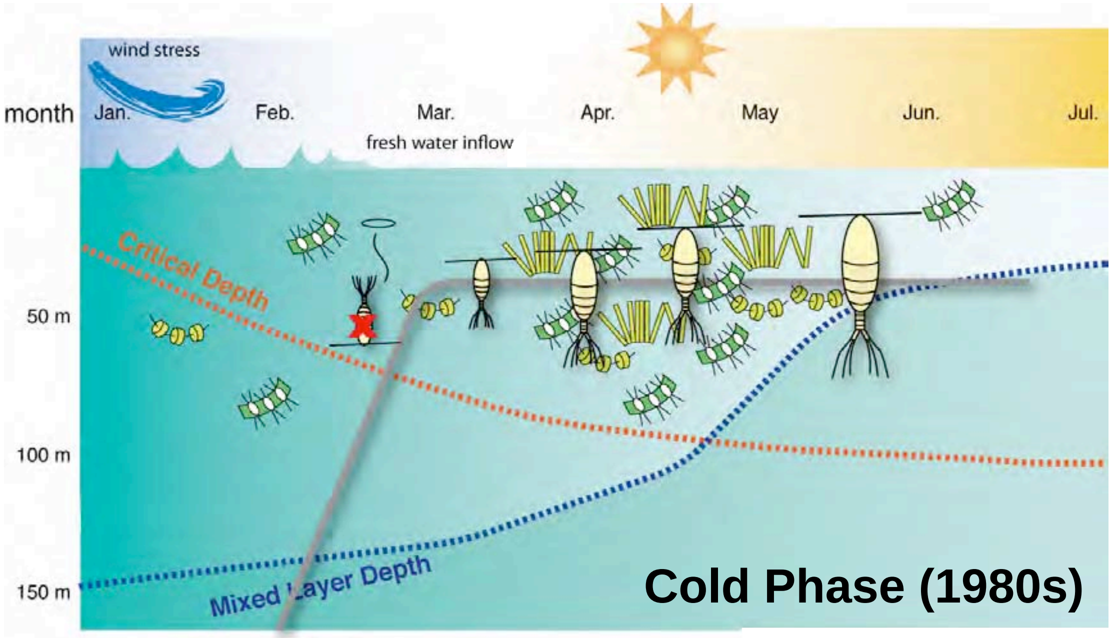
Abundance of *Eucalanus bungii*

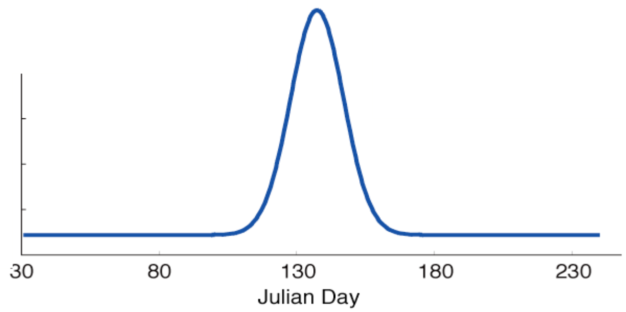


(Kobari et al, 2007 DSRII)

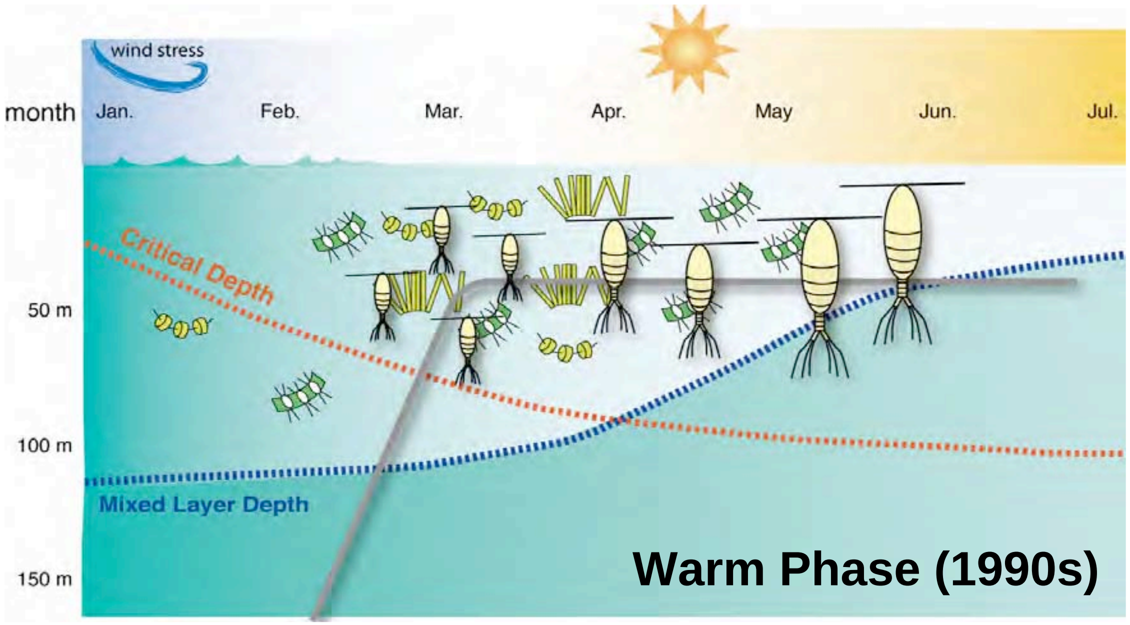
Fig. 5. Interannual variations in spring–summer mean abundance (solid circles: animals m^{-2}) of copepodite stage 1–2 (SMA$_{C1-C2}$), 3–5 (SMA$_{C3-C5}$) and adult (SMA$_{C6}$) for *Eucalanus bungii*. The 10-year running mean of its standardized anomalies is indicated by solid line. Bars show 95% confident intervals.

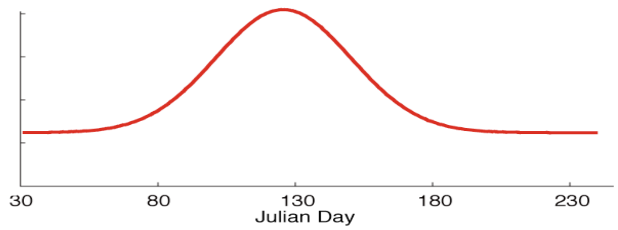
Zooplankton Phenology in WNP: Mechanisms





Extensive? but short spring bloom



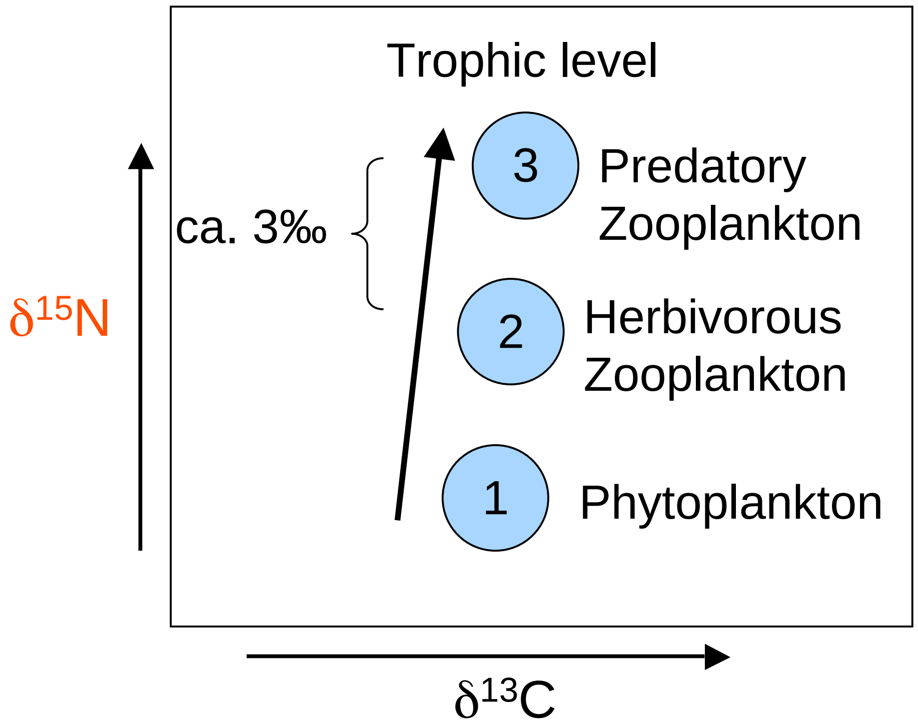


Moderate but longer spring bloom

Match-mismatch bw/ PP-ZP

Stable Isotope Analysis: Bottom-up or Top-down

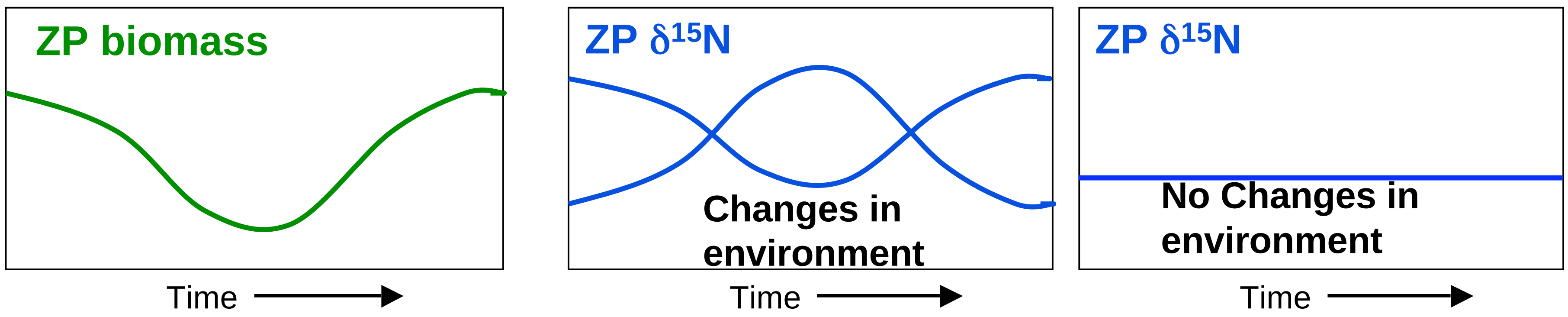
What stable Isotope ratio of zooplankton implies….



δ15N
Proxy of trophic level
= switch of feeding strategy
== phytoplankton abundance
=== nutrients availability

But be careful in the N-limited environment (increase), and existence of N^2 fixation phytoplankton (decrease).

Bottom-up control? **Top-down control?**

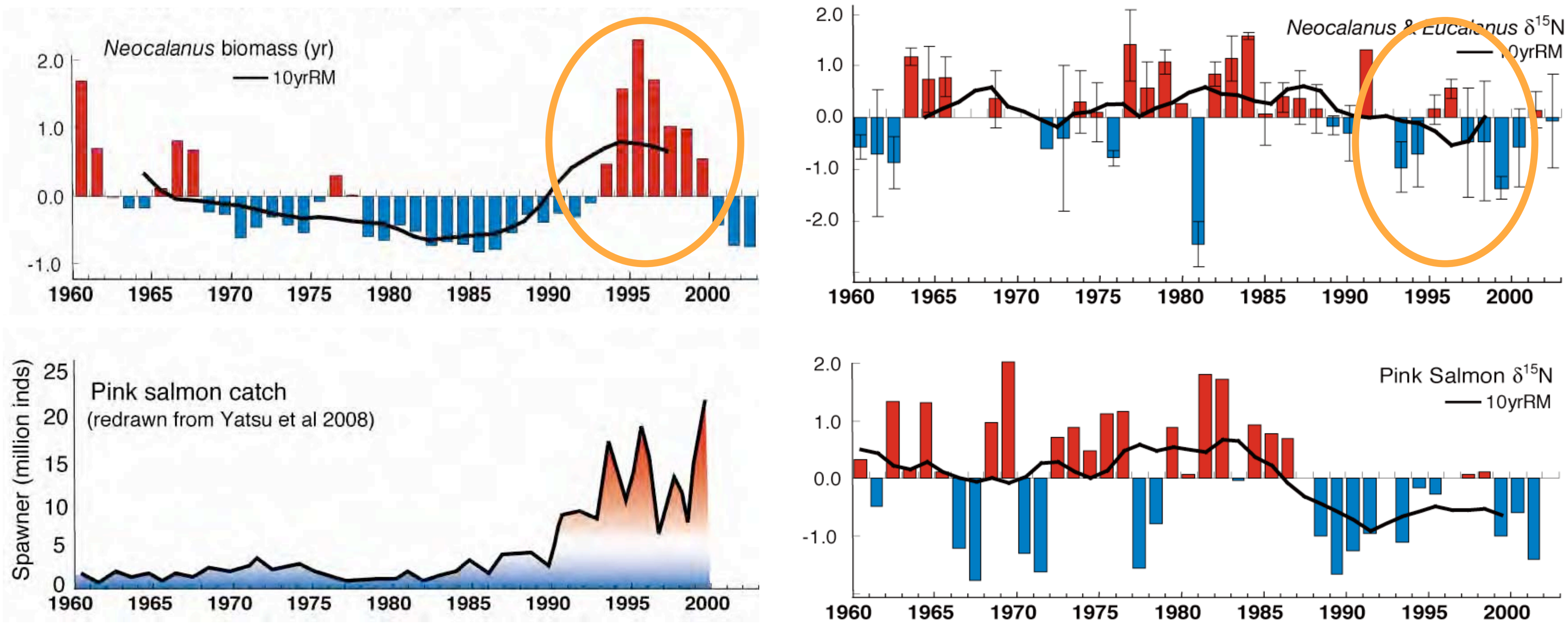


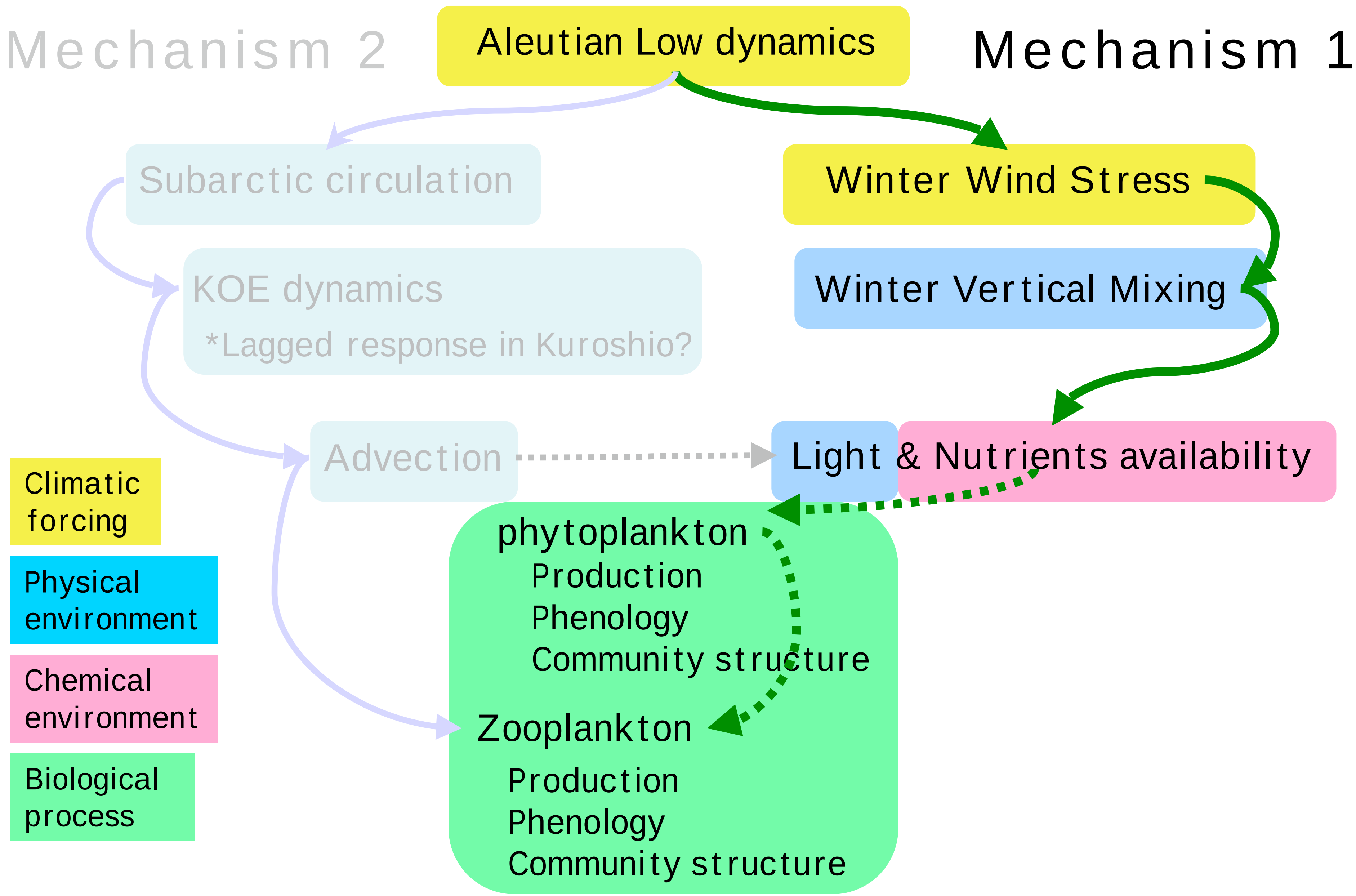
Stable Isotope Analysis: Bottom-up control

Time-series δ^{15}N of *Neocalanus*

Low δ^{15}N and high biomass during the 1990s indicates that phytoplankton availability was favorable for Neocalanus production

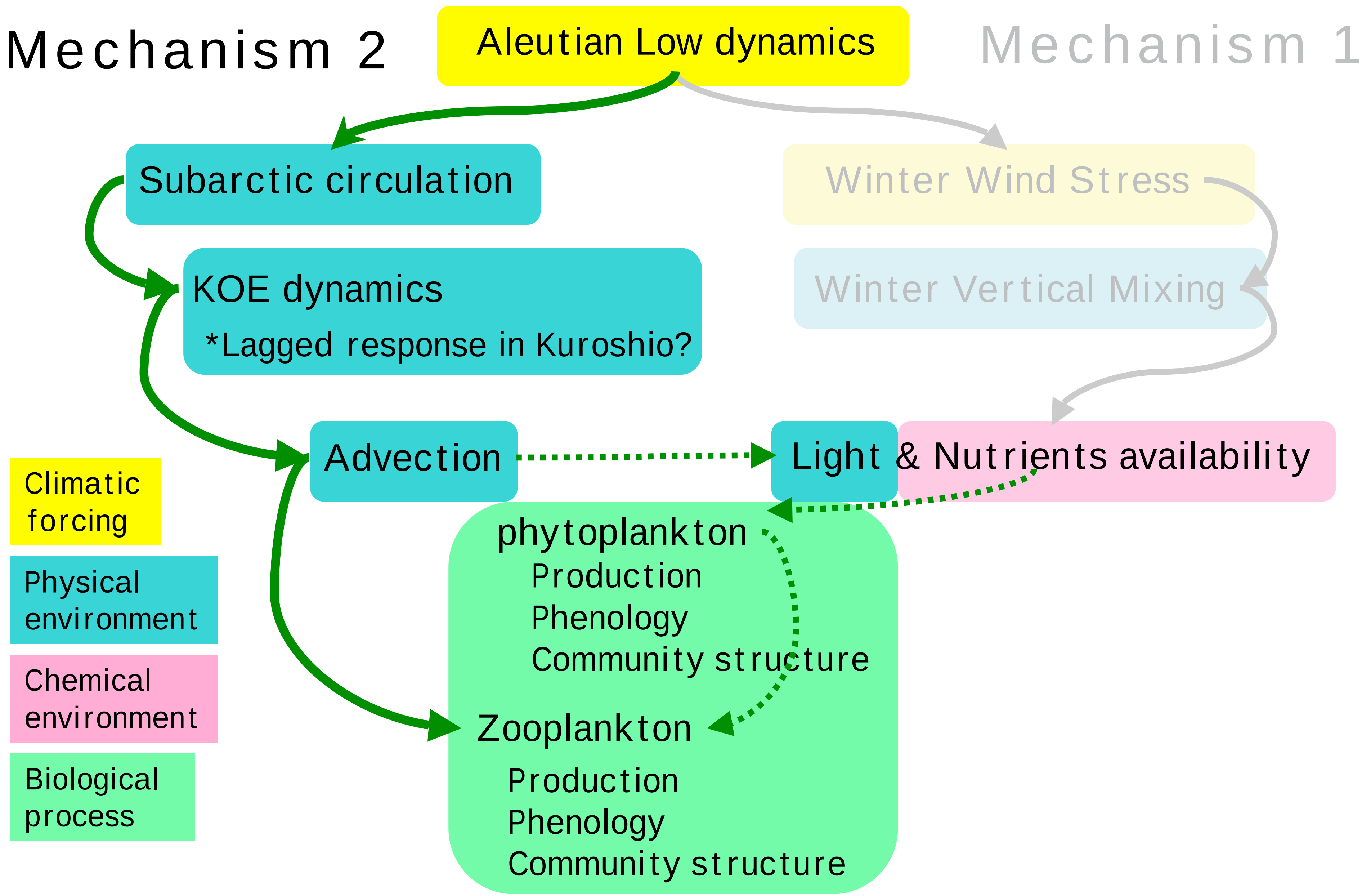
And Pink salmon





Conceptual Model for WNP Ecosystem Changes

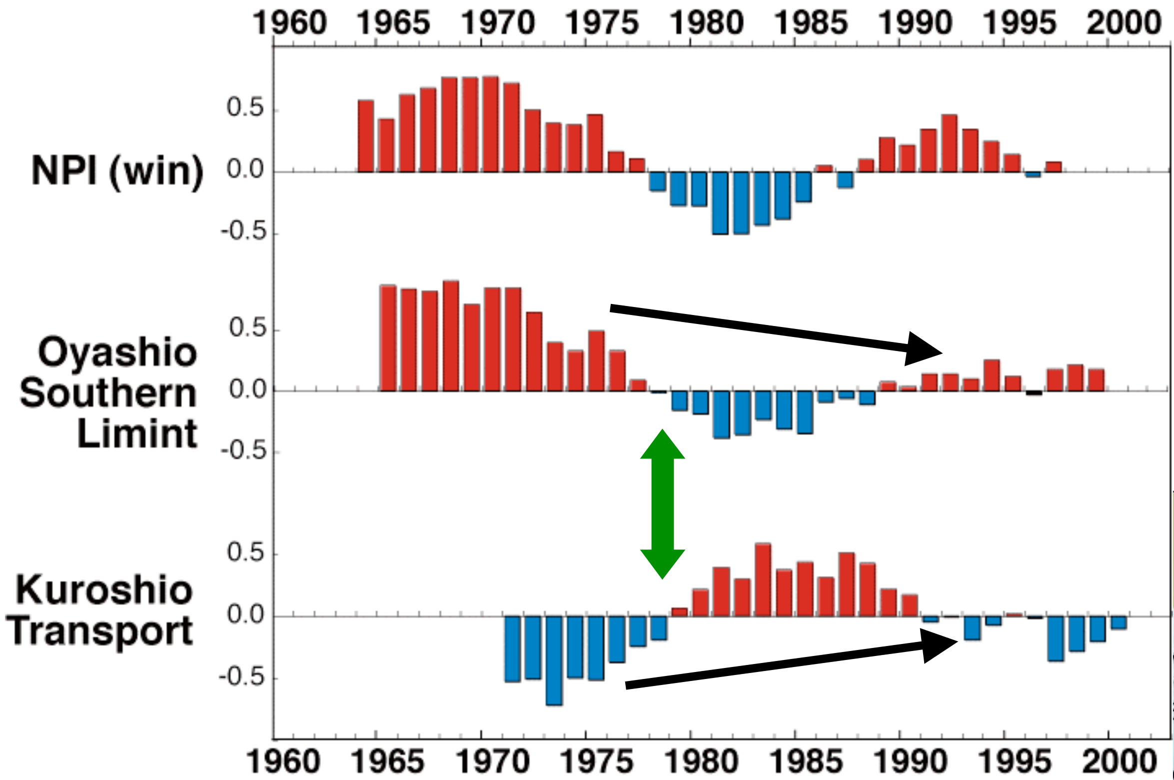
from climate to plankton



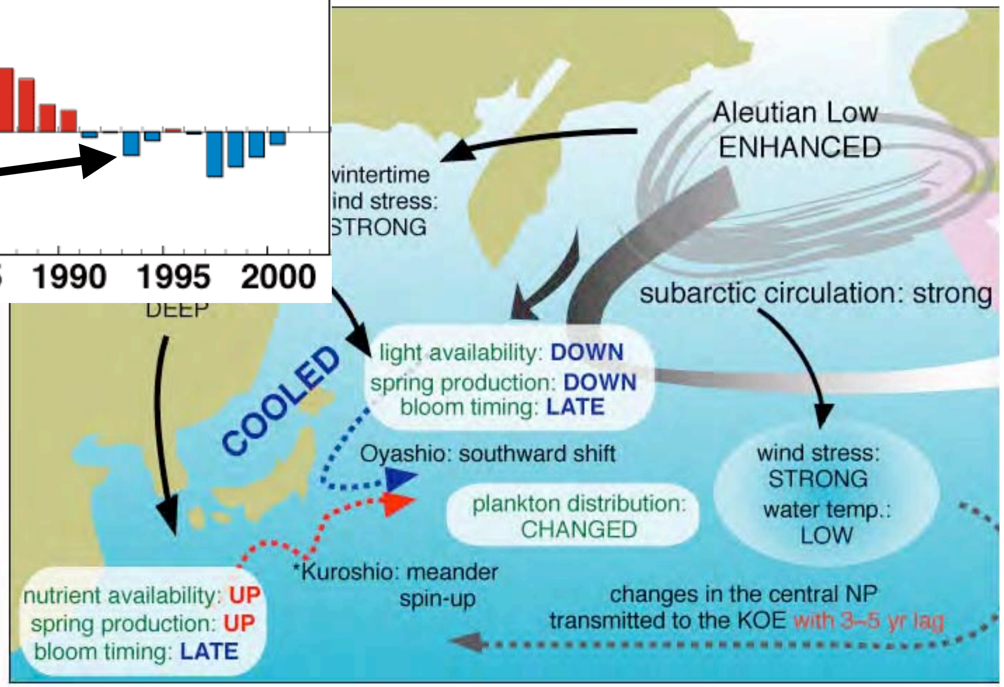
Conceptual Model for WNP Ecosystem Changes

from climate to plankton

Aleutian Low & Kuroshio-Oyashio Dynamics

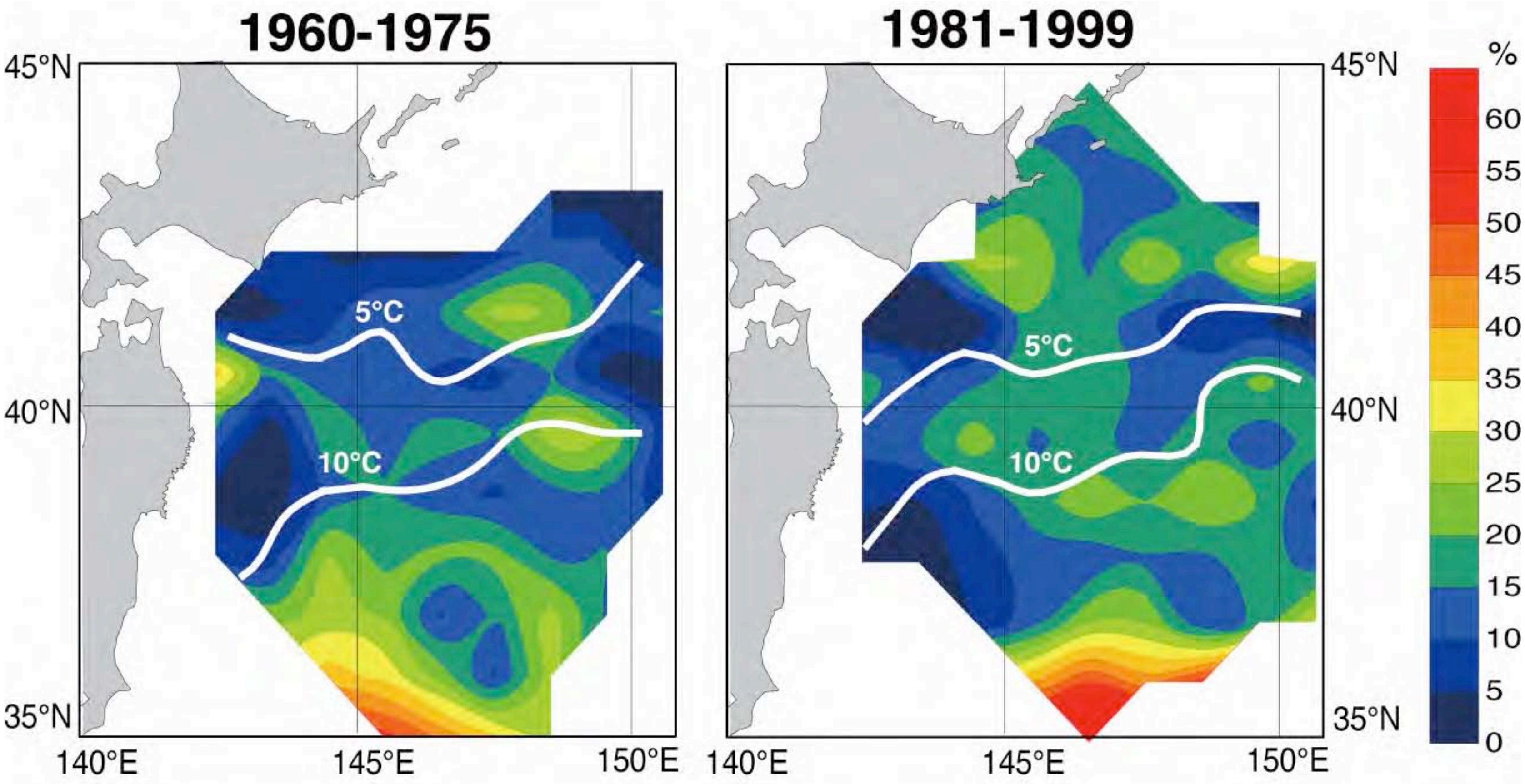


10 ry smoothed



Marked change in 1976-1980
Trend though the early 2000s

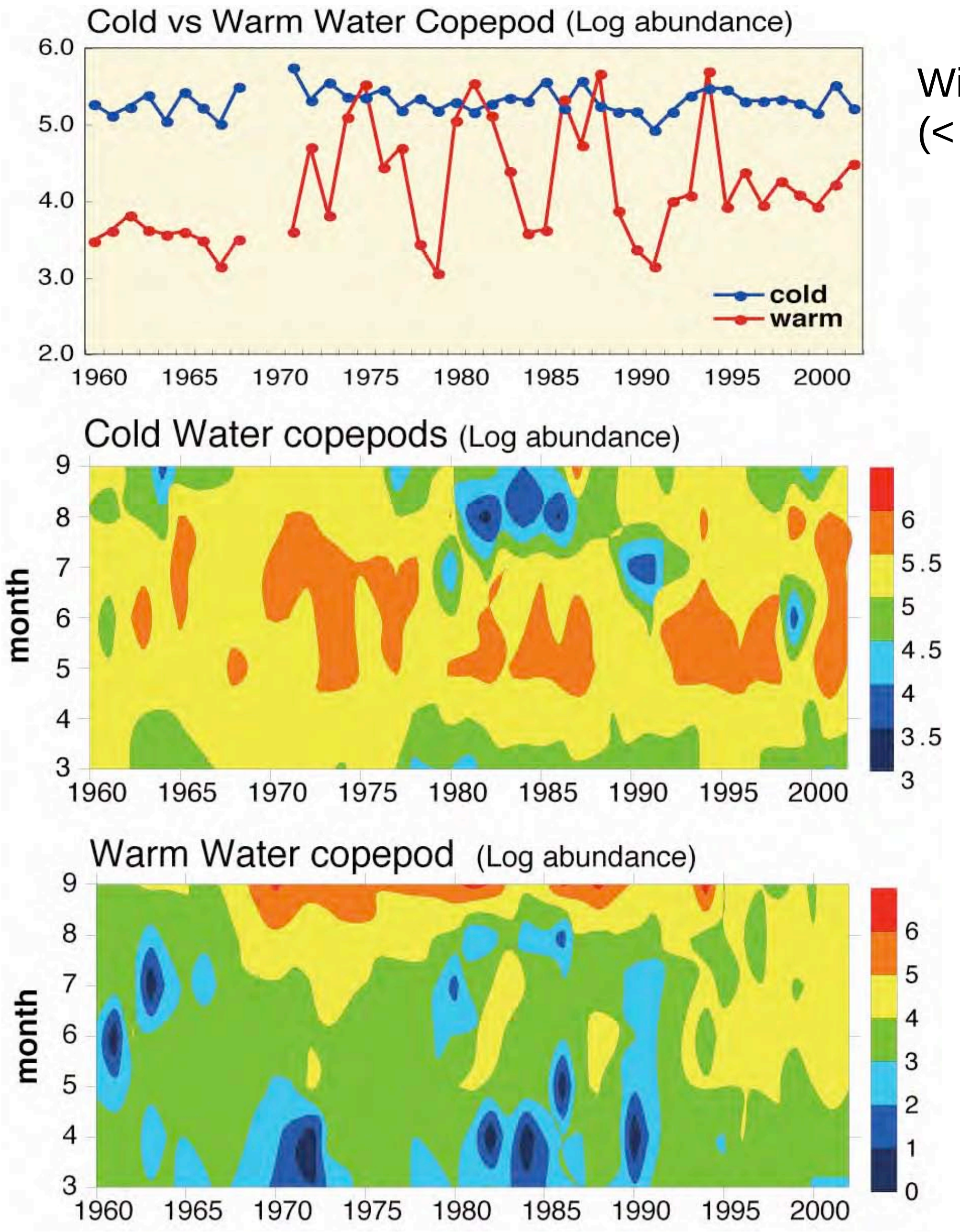
Biogeographical Shift of Zooplankton



temperature: at 100 m

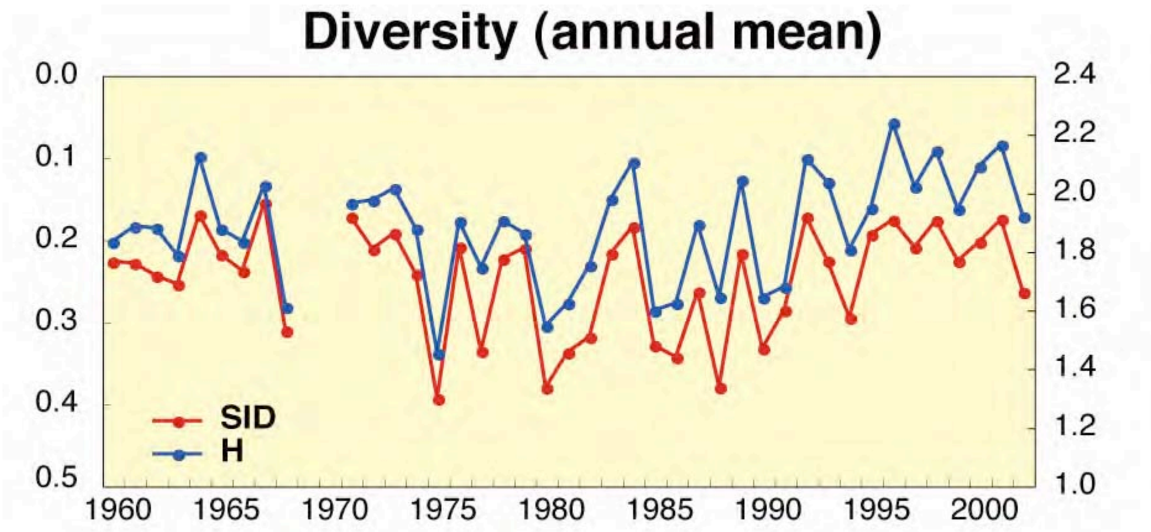
Occurrence of Warm Water copepod species before & after the Regime Shift

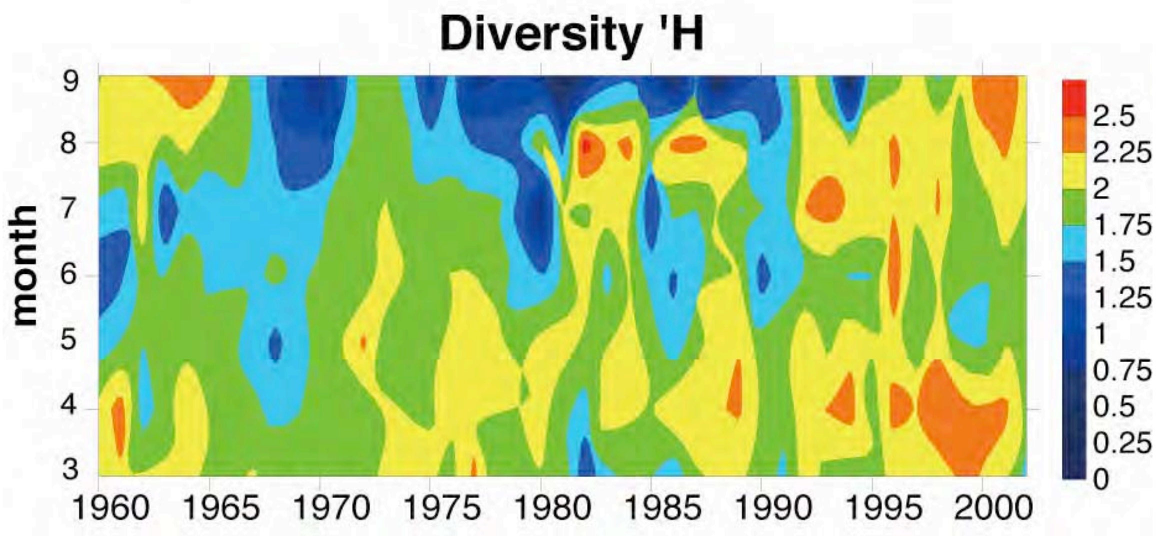
Biogeographical Shift of Zooplankton: Seasonality



Within the Oyashio domain
(< 5C at 100m)

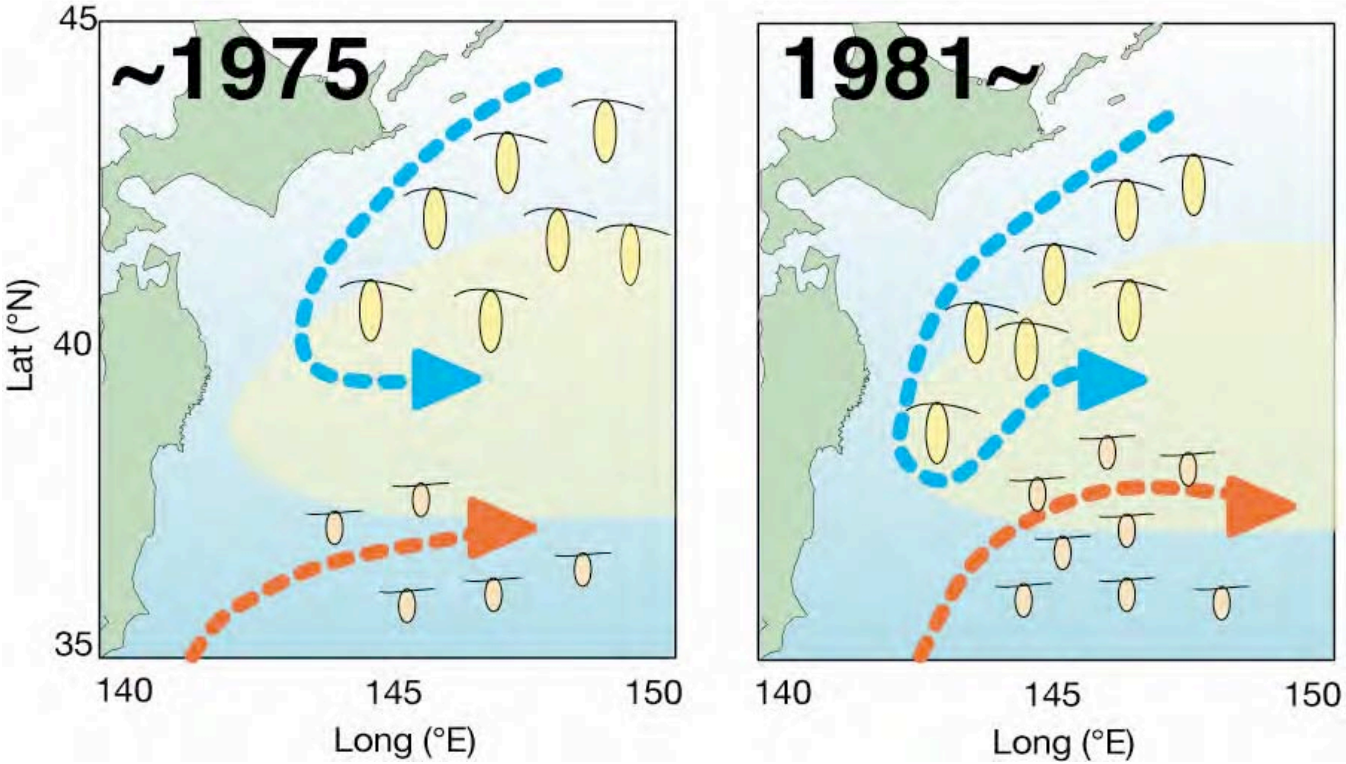
Biogeographical Shift of Zooplankton: Diversity





Within the Oyashio domain
(< 5C at 100m)

Biogeographical Shift of Zooplankton: Diversity



Caused spatial match-mismatch with higher trophic levels?

Conclusion

Yes, wind does matter….

Zooplankton time-series can tell the mechanisms of ecosystem changes

For prediction of ecosystem responses to future climate changes, need to consider two processes driven by atmospheric forcing:

- **Wind driven mixing**
- **Current dynamics**
- **Seasonality of both of above**

Summary of the Observed Changes and Prediction

	Present Cool Phase	Present Warm Phase	Future Warmer World
Temperature	Low	High	
AL dynamics	Strong	Weak	
Winter wind stress	Strong	Weak	
Winter mixing	Deep	Shallow	
Nutrients	More	Less	
Light	Less	More	
Oyashio	Spin-up Southward shift	-	
Kuroshio	Spin-up More meandering Northward shift	-	
Limiting factor for PP	Light		
Bloom timing	Late	Early	
Winter PP	Low	High	
Annual PP	-	Low?	
Annual ZP biomass	Low	High	
ZP Diversity	Low	High	

Kuroshio will spin up in the warmer world

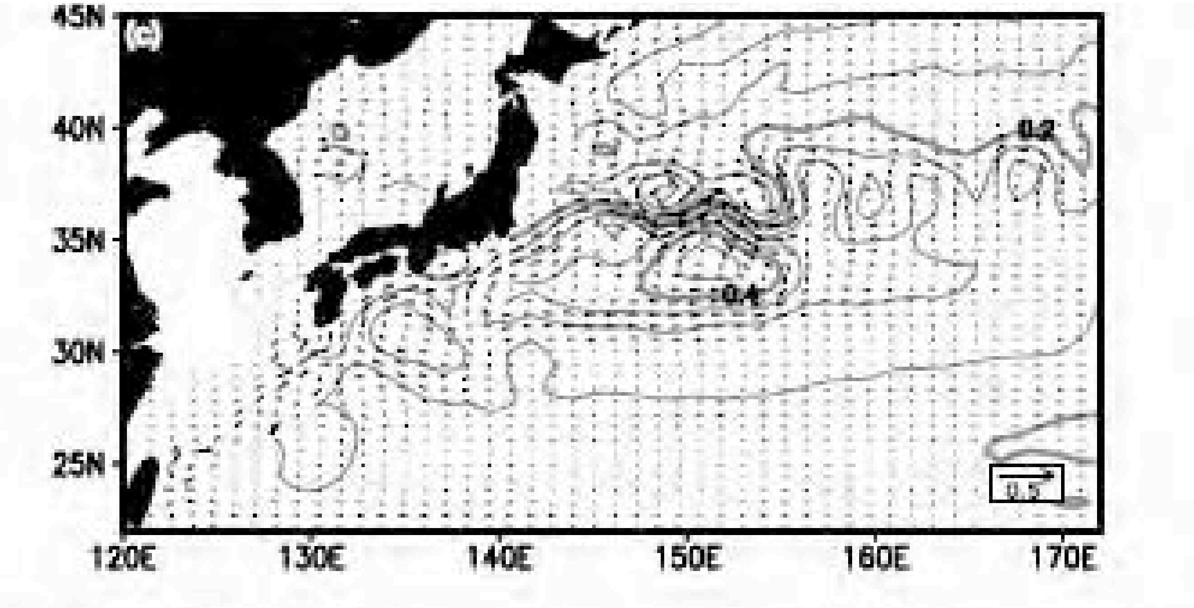


Figure 1. Long-term mean current velocities at 100-m depth (vectors, unit: m s^{-1}) and dynamic sea surface height (contours, unit: m) relative to 2048-m depth in (a) the control-run, (b) the CO_2-run, and (c) their difference of those between the CO_2-run and the control-run (former minus latter). Contour intervals are 0.2 m in (a) and (b), and 0.05 m in (c).

- Sakamoto et al, 2005, GRL

Summary of the Observed Changes and Prediction

	Present Cool Phase	Present Warm Phase	Future Warmer World
Temperature	Low	High	Higher
AL dynamics	Strong	Weak	Stronger ?
Winter wind stress	Strong	Weak	Stronger ?
Winter mixing	Deep	Shallow	?
Nutrients	More	Less	?
Light	Less	More	?
Oyashio	Spin-up Southward shift	-	Spin-up?
Kuroshio	Spin-up More meandering Northward shift	-	Spin-up More meandering (Sakamoto et al 2005 GRL)
Limiting factor for PP	Light		Nutrients?
Bloom timing	Late	Early	Eariler ?
Winter PP	Low	High	?
Annual PP	-	Low?	Decrease ?
Annual ZP biomass	Low	High	?
ZP Diversity	Low	High	?

See the presentation of…

Session 4.1 1630- Taketo Hashioka et al.

Impacts of global warming on lower-trophic level ecosystem projected by a 3-D high-resolution ecosystem model => predict future phenological changes in the WNP

Thank you

ODATE PROJECT MEMBERS

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This project could not be possible without

Dr. Toshiro Saino
Dr. Hiroshi Ito
and (of course…)
Dr. Kazuko Odate