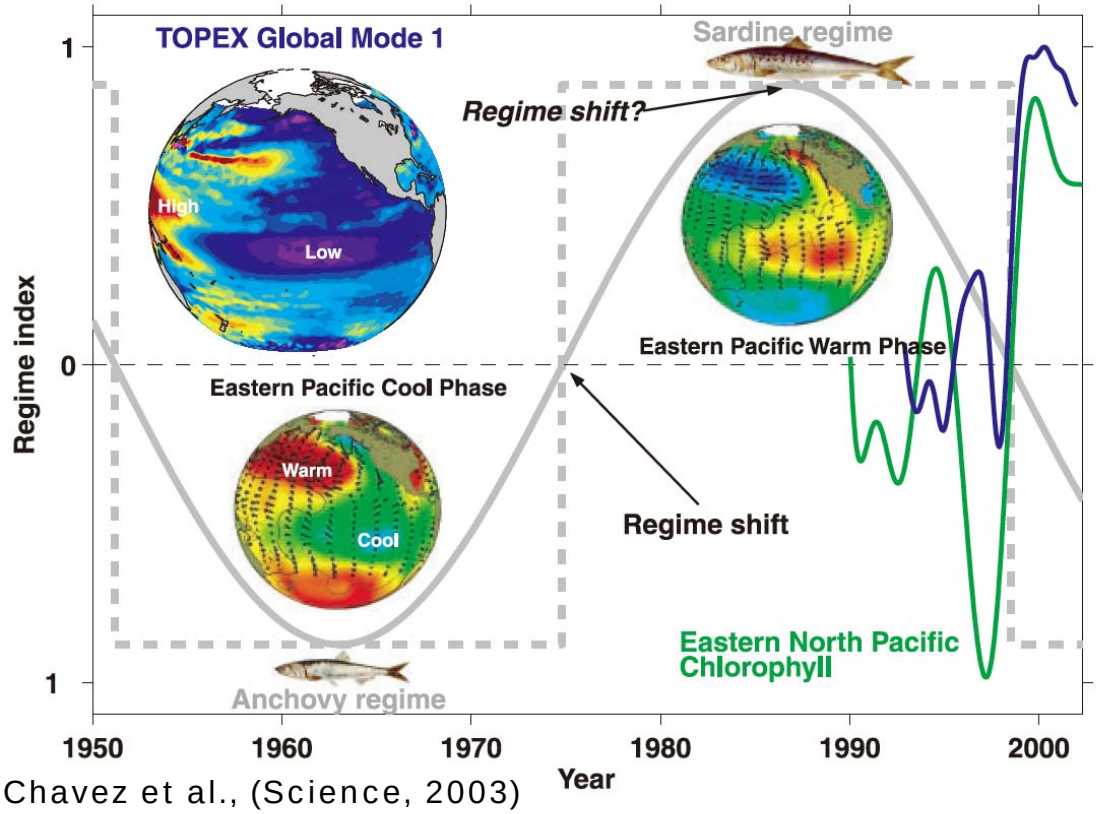
# Geographical comparison of the decadal-scale variations in marine ecosystems in the North Pacific Ocean

**Kazuaki Tadokoro**, Yuji Okazaki, Tsuneo Ono and Hiroya Sugisaki

From early 1990's, the effects of climate change to the marine ecosystem have been actively discussed.

## Possible cause: PDO

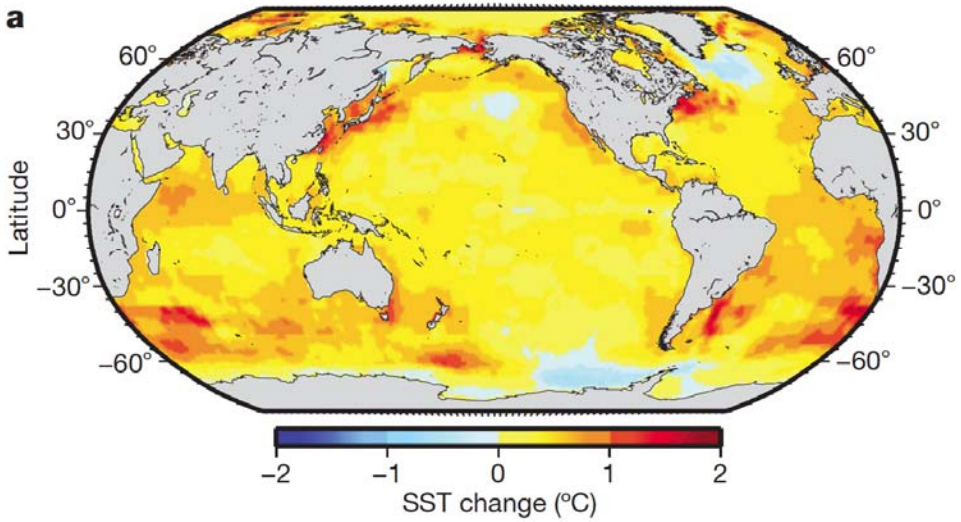


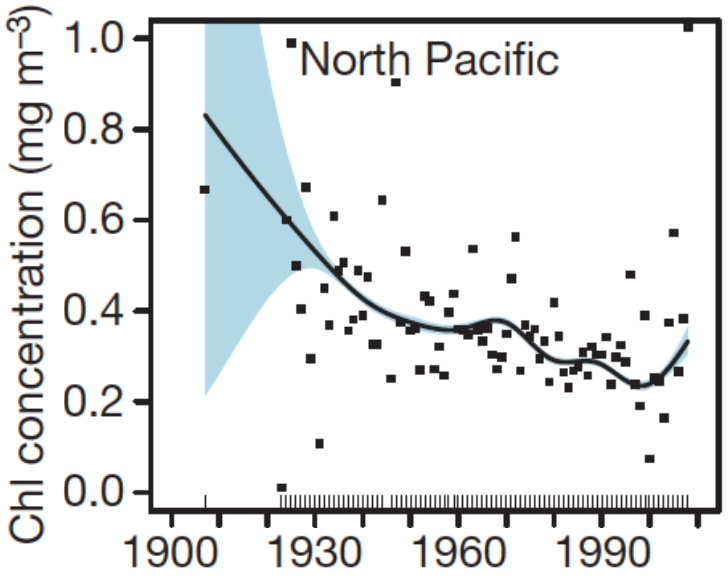

Chavez et al., (Science, 2003)

It is considered that marine ecosystem in the north Pacific was dramatically changed due to relate 1976/77 climatic regime shift.

# Other possible cause: Global warming

Temperature change 1899-2009




Boyce et al., (Nature, 2010)

**Recent study suggested that the increase trend of surface temperature due to Global warming in the world ocean . And the change of marine environment might affect marine ecosystem in the North Pacific.**

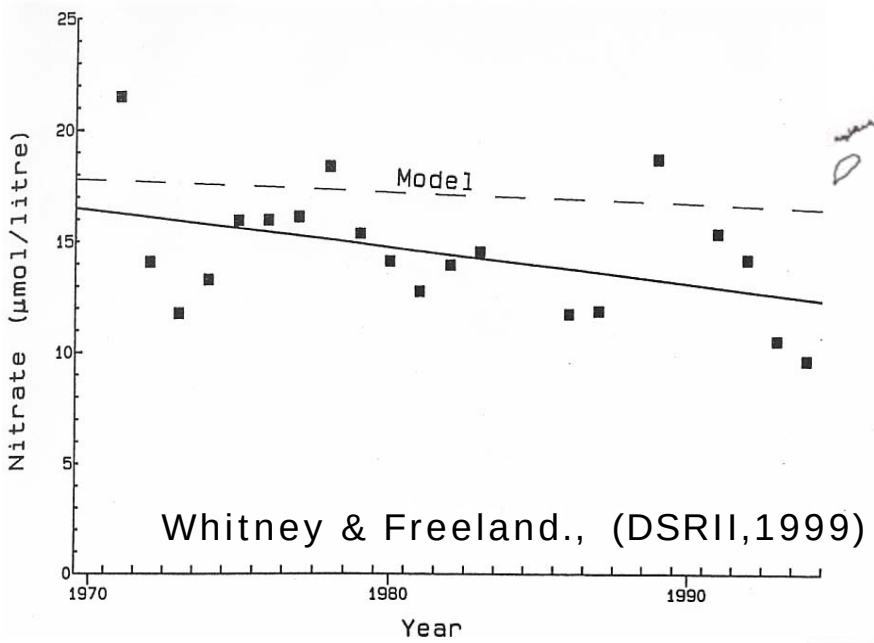

**We will discuss as follows comparing the decadal scale variations of ecosystem among waters.**

**1 Differences in patterns of the variation among waters.**

**2 The effect of the global warming to the ecosystems.**

**3 The effect of the PDO and other natural factor to the ecosystems.**

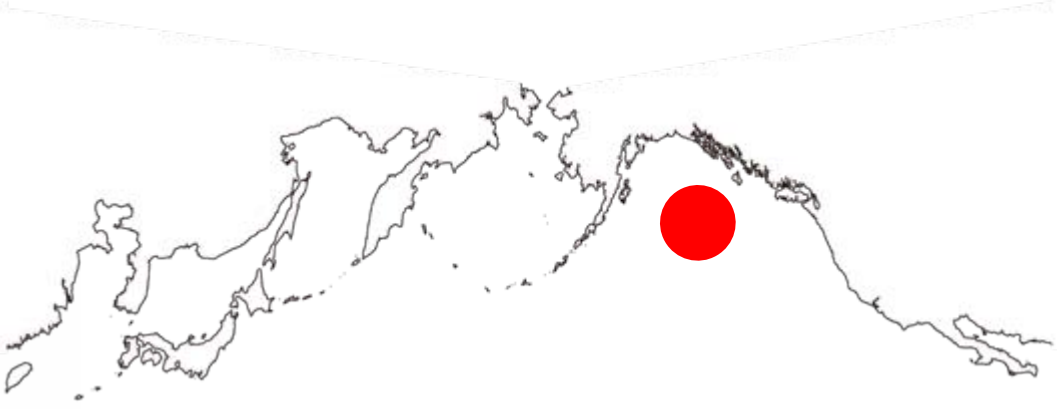
# Gulf of Alaska




Whitney & Freeland., (DSRII,1999)

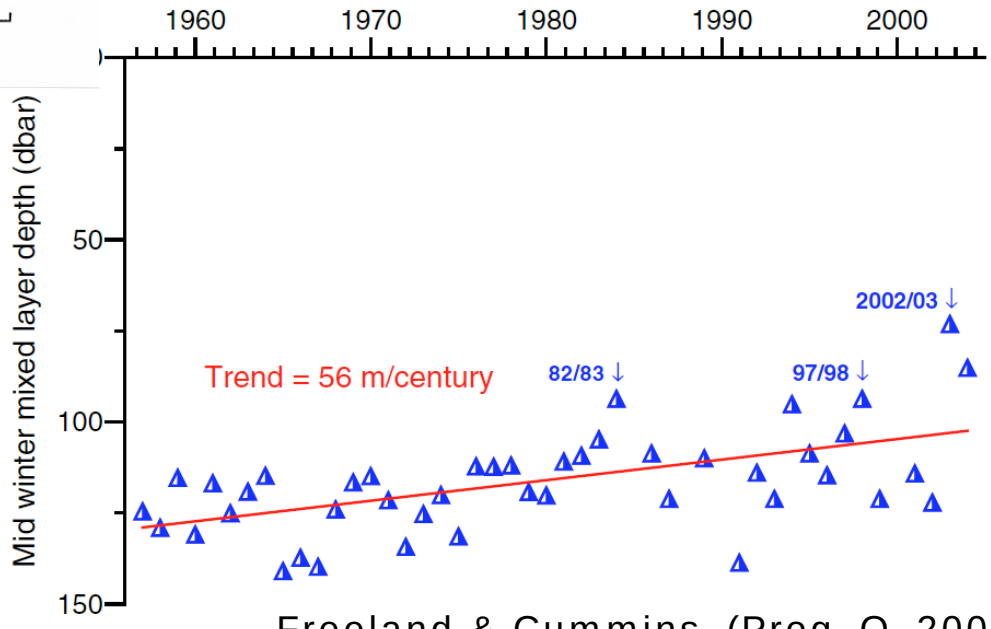
## Winter $NO_3$ in surface layer

Winter $NO_3$ represented decrease trend from 1970s.



Nutrient & MLD

## The max. MLD in the winter

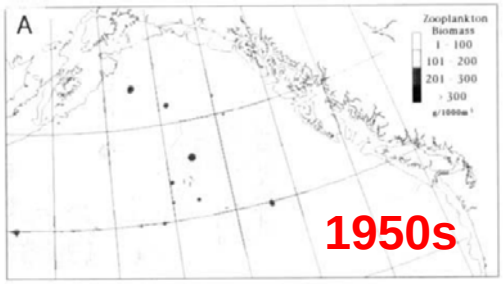


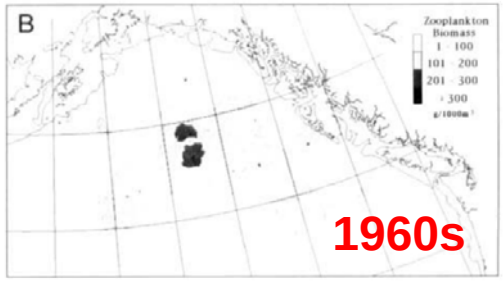

Freeland & Cummins. (Prog. O. 2005)

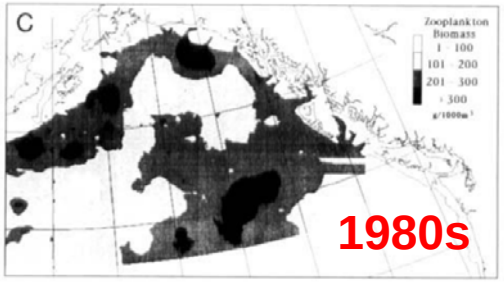
# Gulf of Alaska

Zooplankton

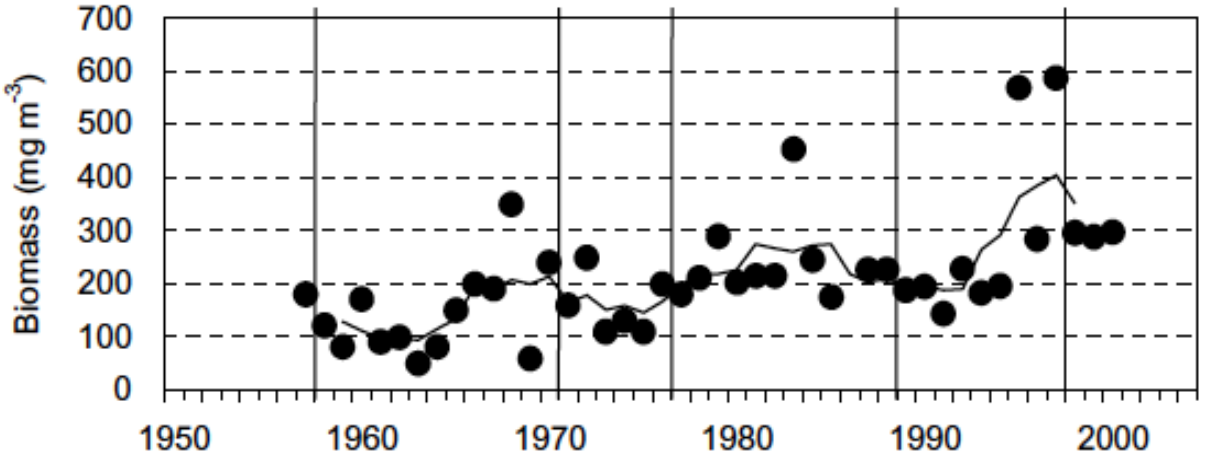
Figure 1. Distribution of zooplankton biomass (g/1000m³) in the Gulf of Alaska for the periods of time (A) 1956–1959, (B) 1960–1962, and (C) 1980–1989.



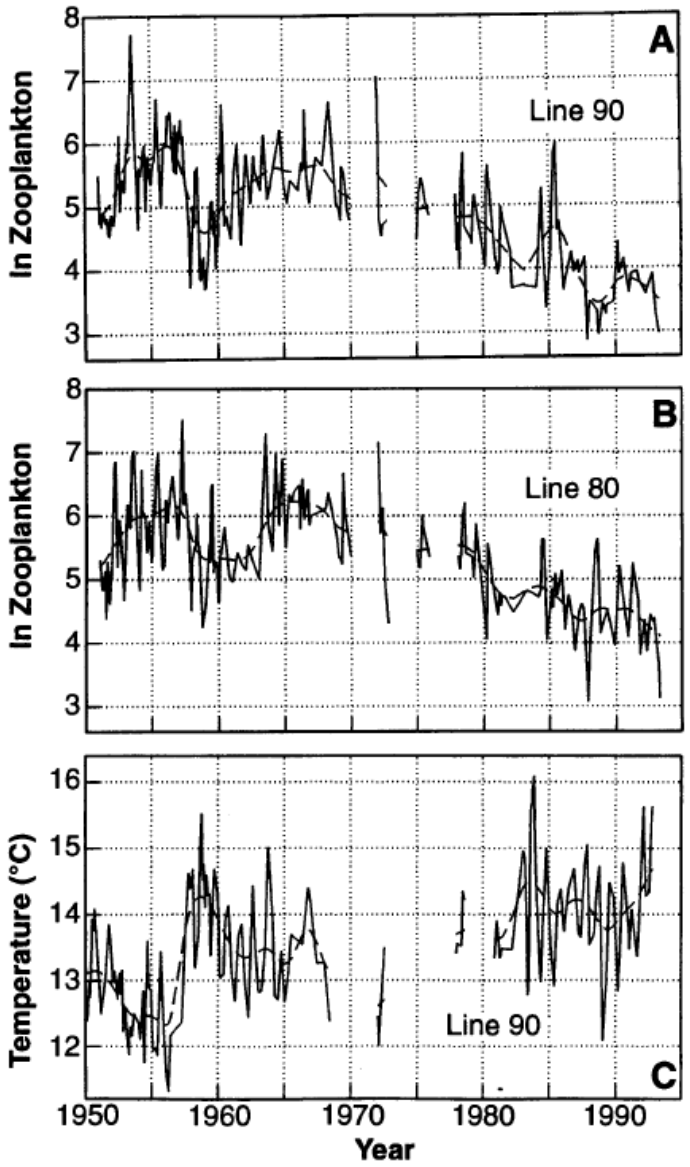

Brodeur & Ware., (FO, 1992)




Yatsu et al., (Prog. O., 2008)

**The biomass had increase trend from 1950s.**

# California Current System



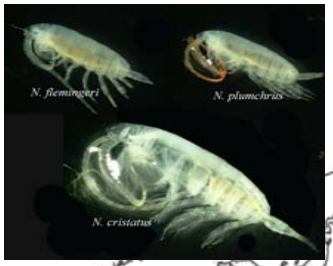

Roemmich & McGowan (Science, 1995)

**Temperature in surface layer had increase trend from 1950s.**

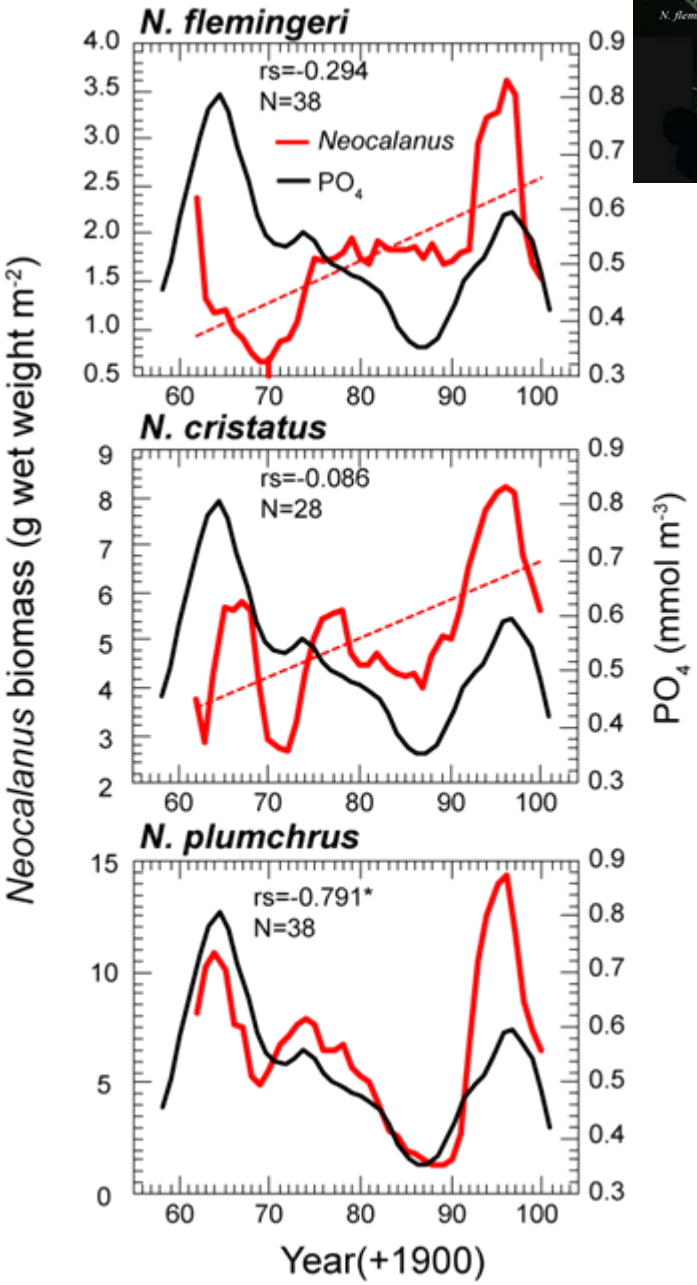
**On the other hand, the zooplankton biomass had decrease trend.**

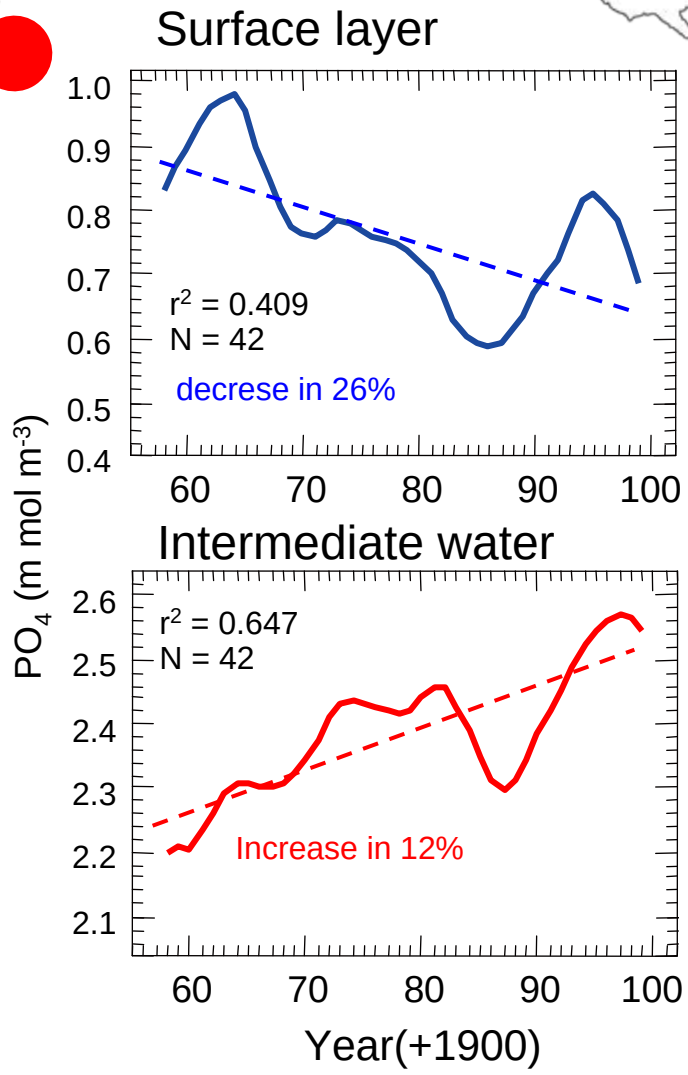
**Weakening of the upwelling due to enhance stratification might decrease the nutrient supply and zooplankton productivity.**

# Oyashio



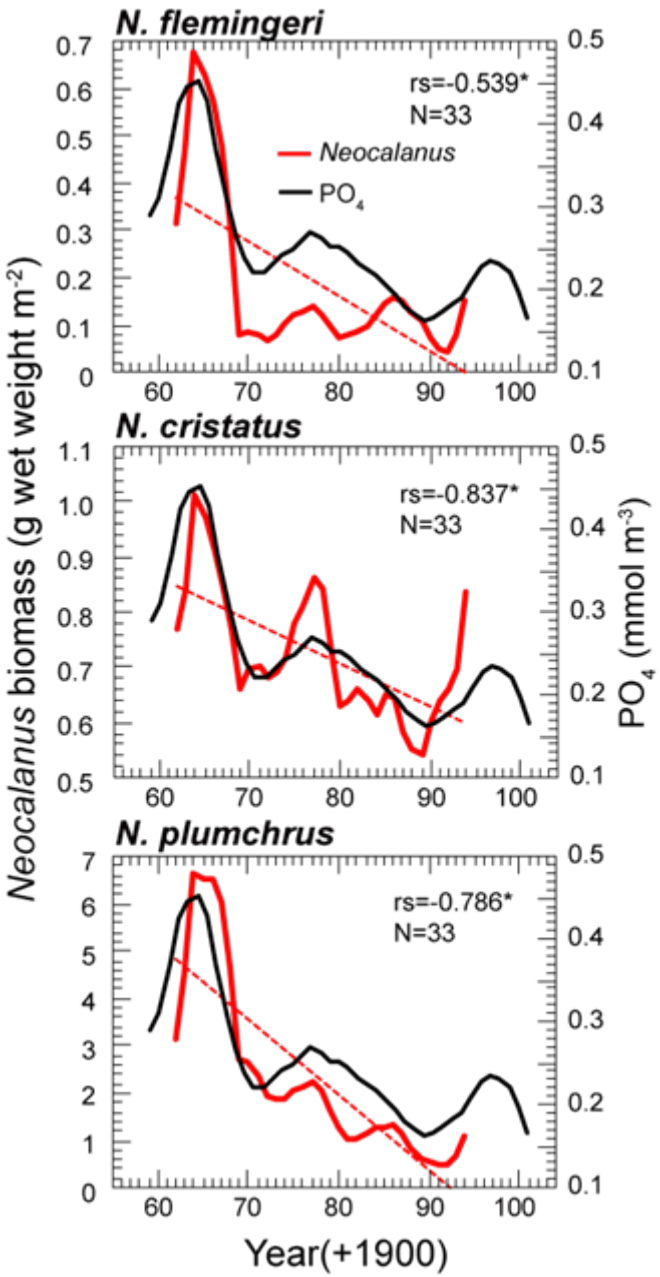


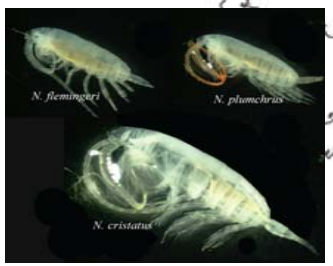



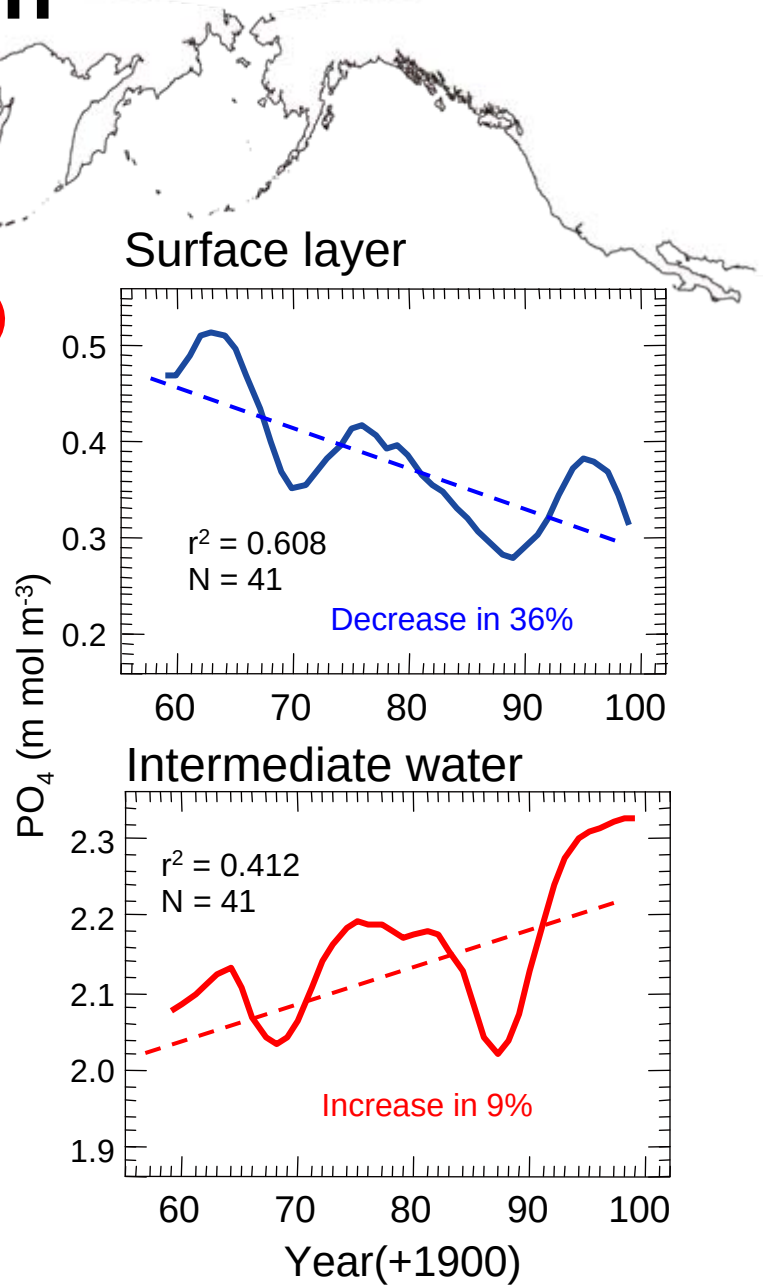




**Tadokoro et al., (GRL, 2009)**

# Kuroshio-Oyashio Transition



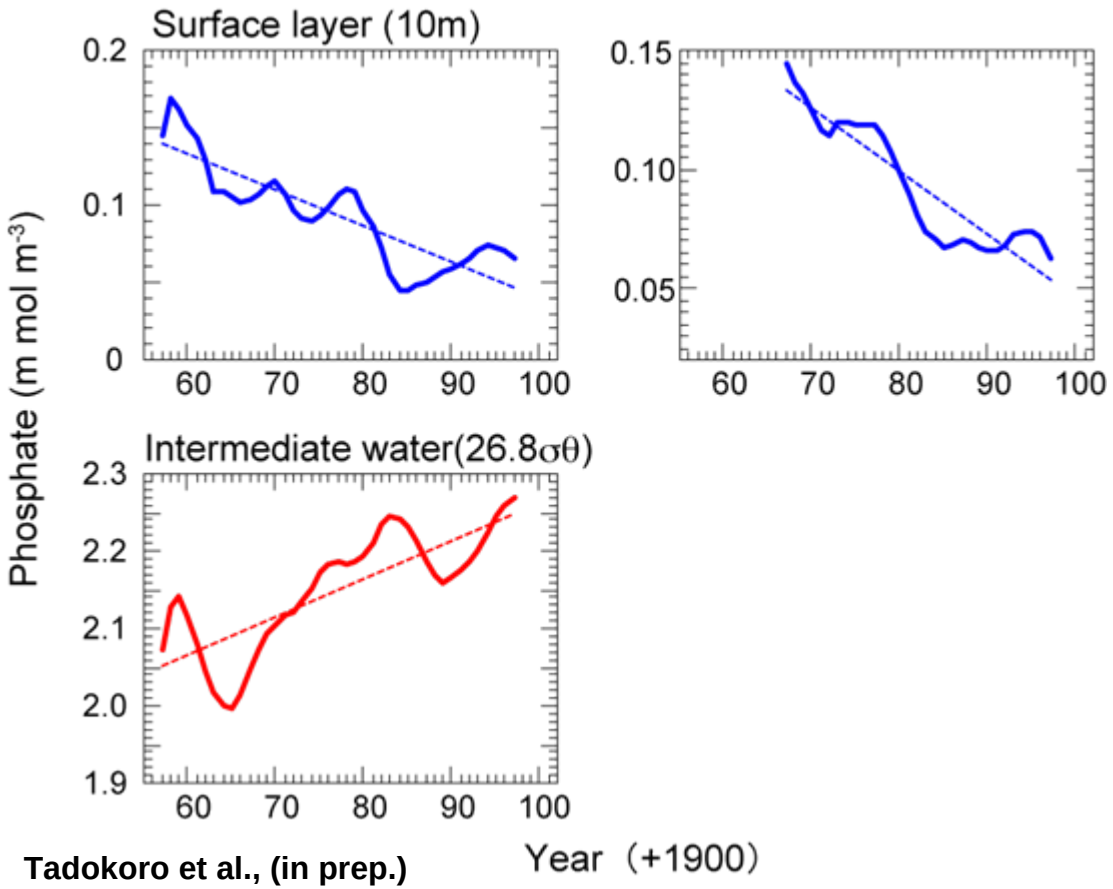



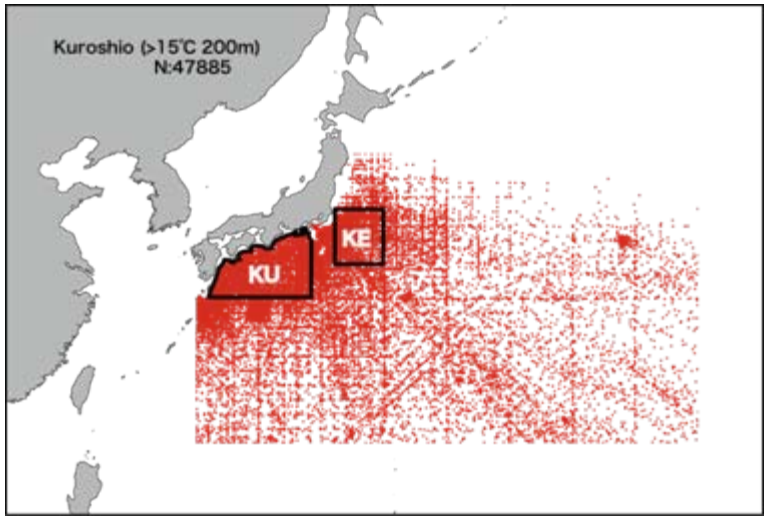

Tadokoro et al., (GRL, 2009)

# Kuroshio & its extension

Kuroshio

Extension




Tadokoro et al., (in prep.)

# Kuroshio, Subtropical & Tropical

Surface layer

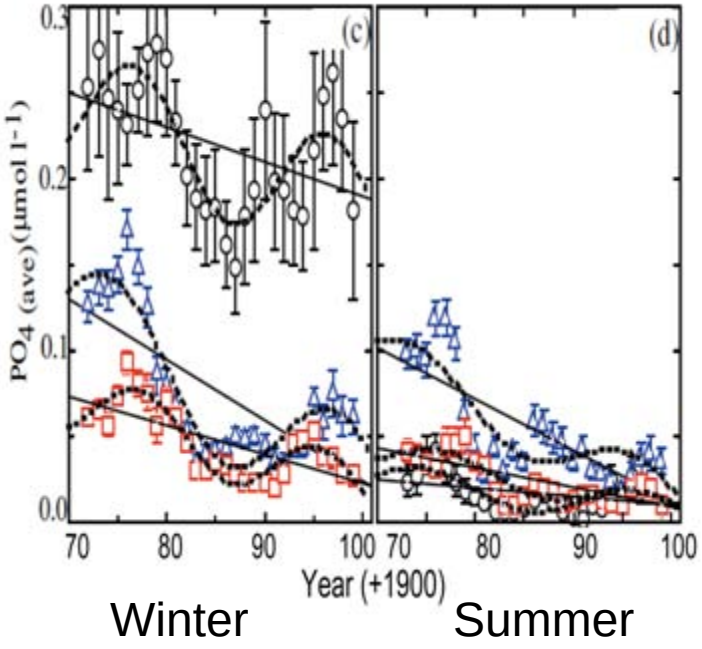
Kurhoshio

Subtropical

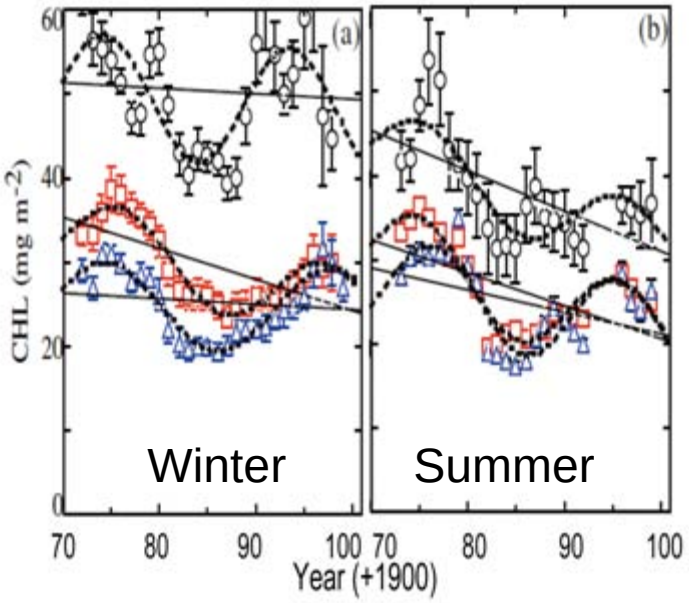
Tropical

$PO_4$

Chl-a



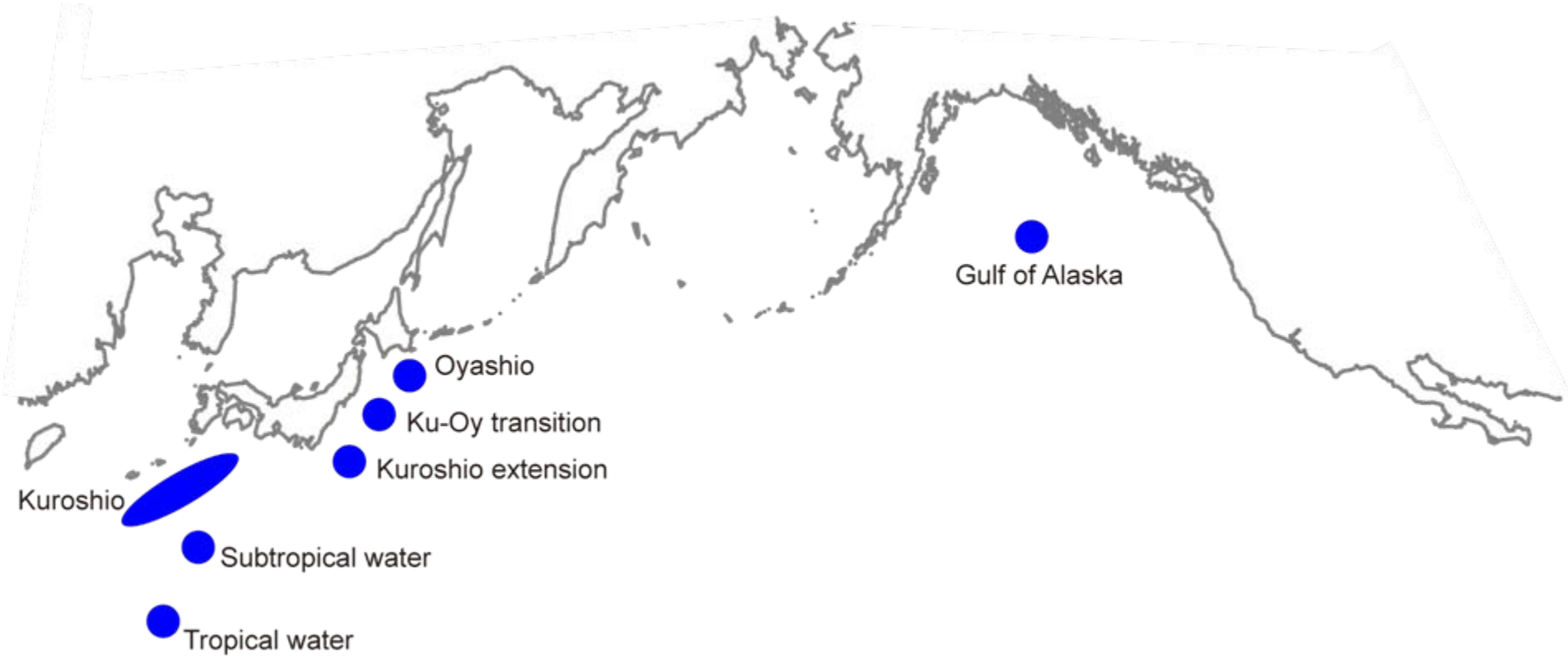

Winter Summer




Watanabe et al., (GRL. 2005)

# Trend

# Decrease trends of nutrient in the NP




Decrease trends of nutrient in upper layer were observed in the broad areas in the North Pacific. This imply decreasing of the water exchange betwee subsurface and surface layer.

# Change of environmental conditions from 1950s

## Temperature

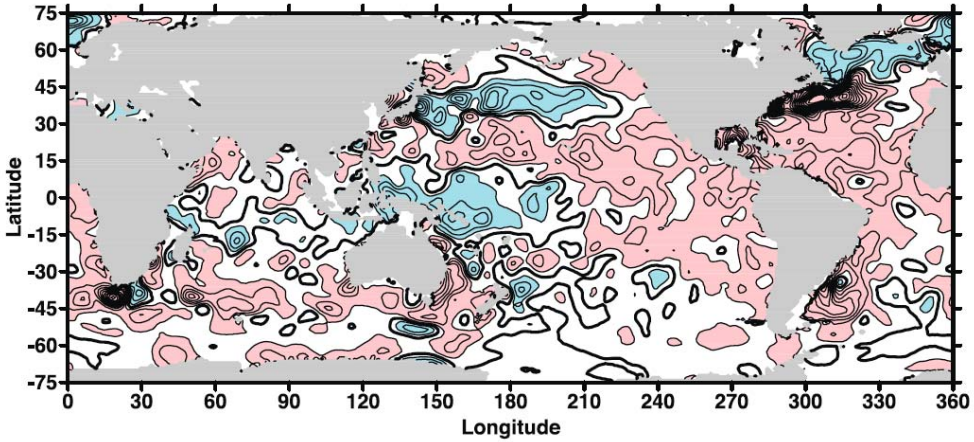
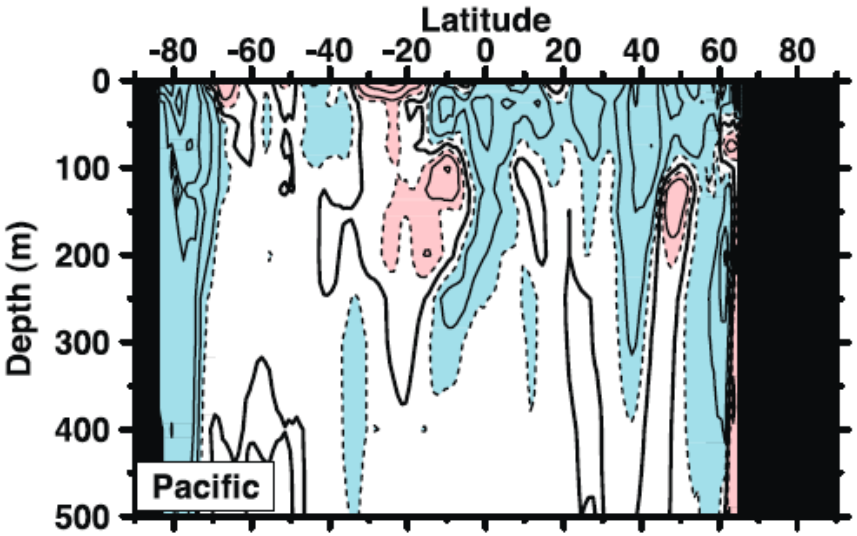



Figure 5.2. *Linear trends (1955–2003) of change in ocean heat content per unit surface area (W m$^{-2}$) for the 0 to 700 m layer, based on the work of Levitus et al. (2005a). The linear trend is computed at each grid point using a least squares fit to the time series at each grid point. The contour interval is 0.25 W m$^{-2}$. Red shading indicates values equal to or greater than 0.25 W m$^{-2}$ and blue shading indicates values equal to or less than –0.25 W m$^{-2}$.*

**Increase trend of temperature was reported in the Gulf of Alaska.**

## Salinity



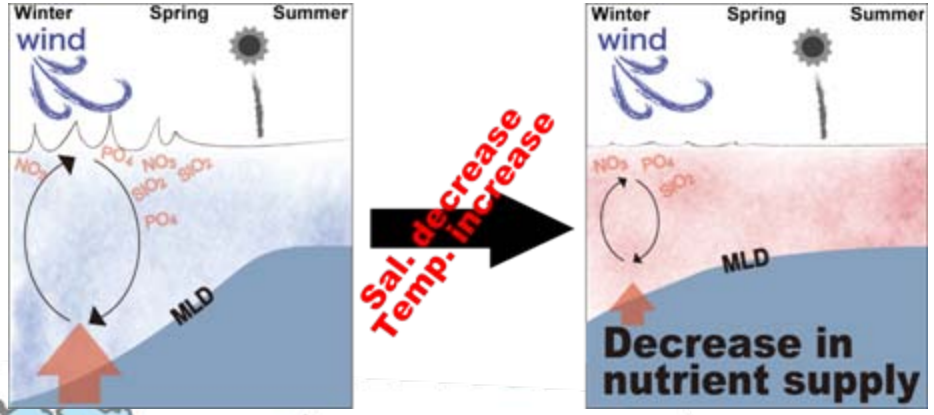

**IPCC AR4 (2008)**

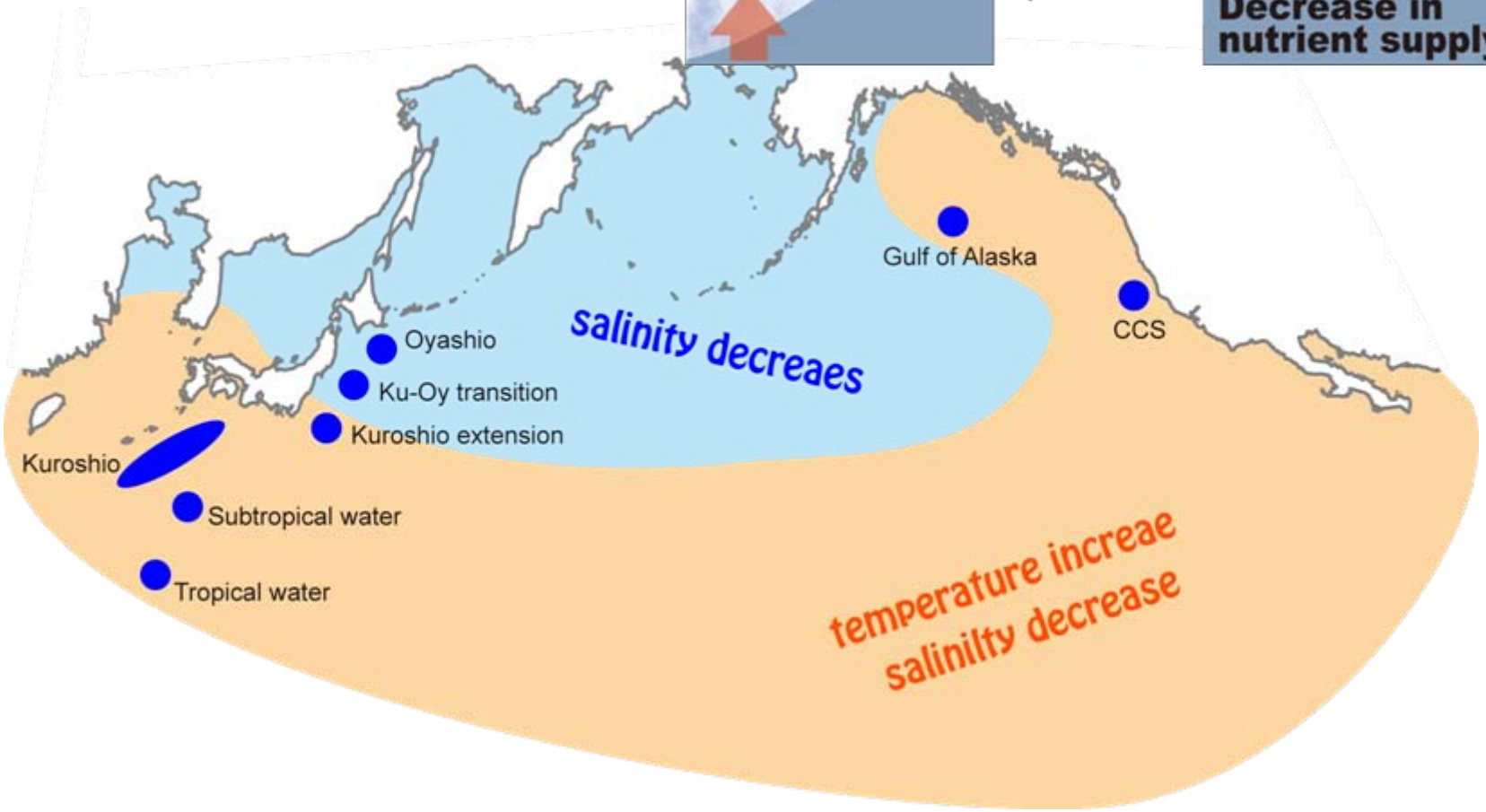
**Decrease trend of salinity was reported in the North Pacific.**

# Schematic of the decrease in Nutrients

**Possible process**

**Enhancement of stratification due to change in salinity and temperature diminished water exchange between subsurfae and surface layer.**



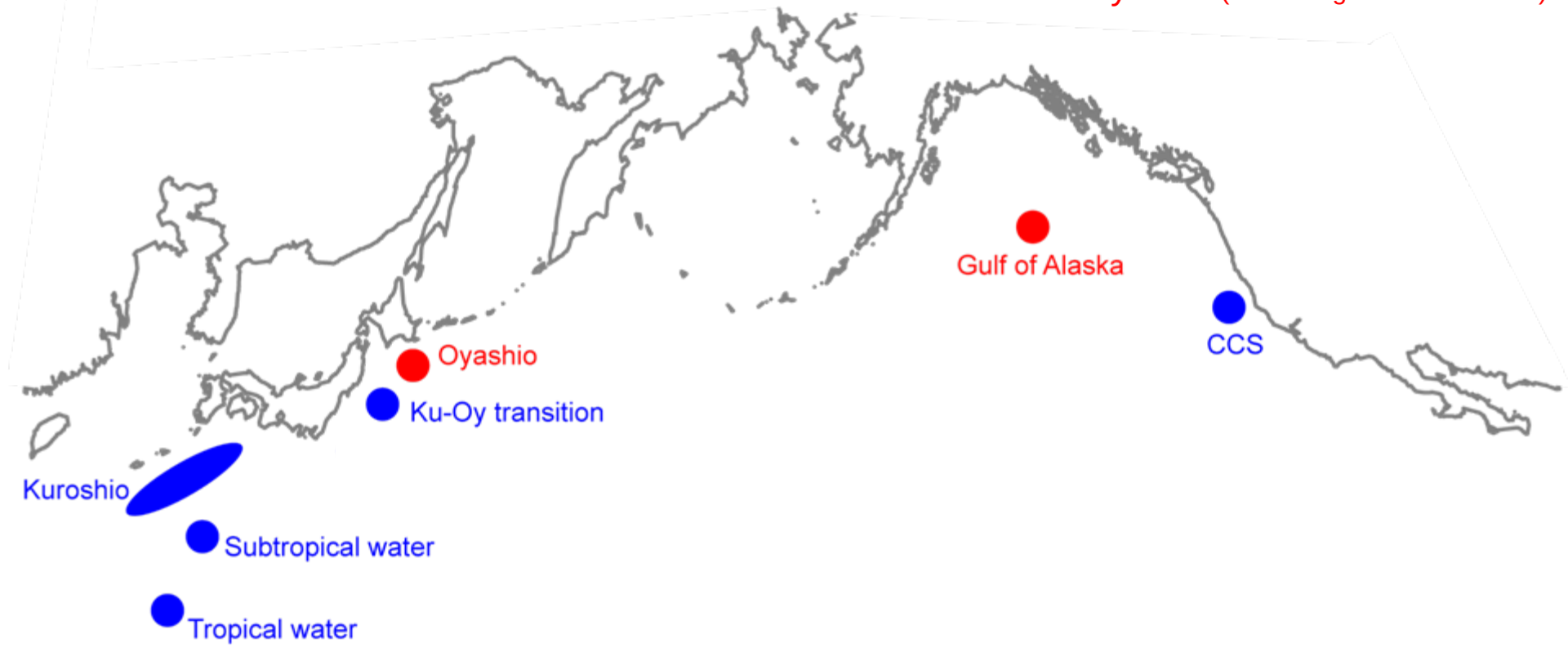
# Trends of plankton biomass

## Decrease

CCS, Ku-OY transition,
Kuroshio, Subtoropical, Tripical

## Increase

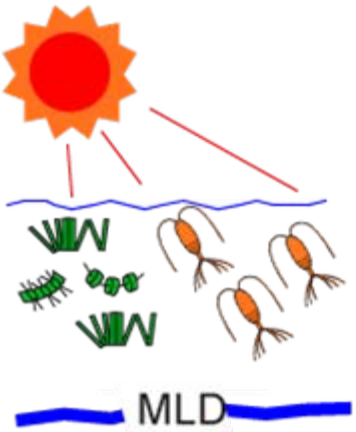
Gulf of Alaska
Oyashio (N. flemingeri & N. cristatus)



# Two effects of stratification enhancement

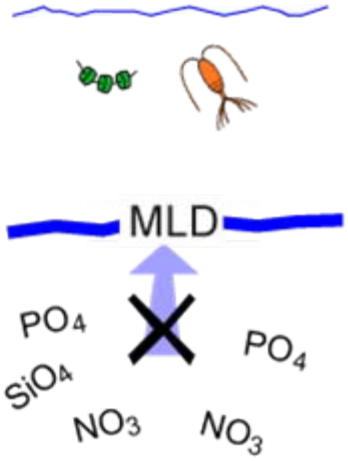
Light limiting

Increase in irradiance availability




Nutrient limiting

Decrese in Nutrients




Productivity:

Increase

Decrease

# Decrease

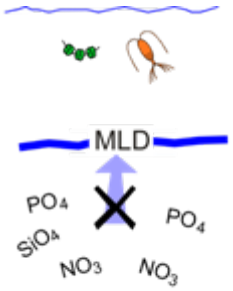
CCS, Ku-OY transition,
Kuroshio, Subtoropical, Tripical

# Increase

Gulf of Alaska
Oyashio (N. flemingeri & N. cristatus)

Limiting factor

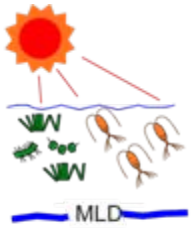
## Nutrients?




Decrese in Nutrients

Limiting factor

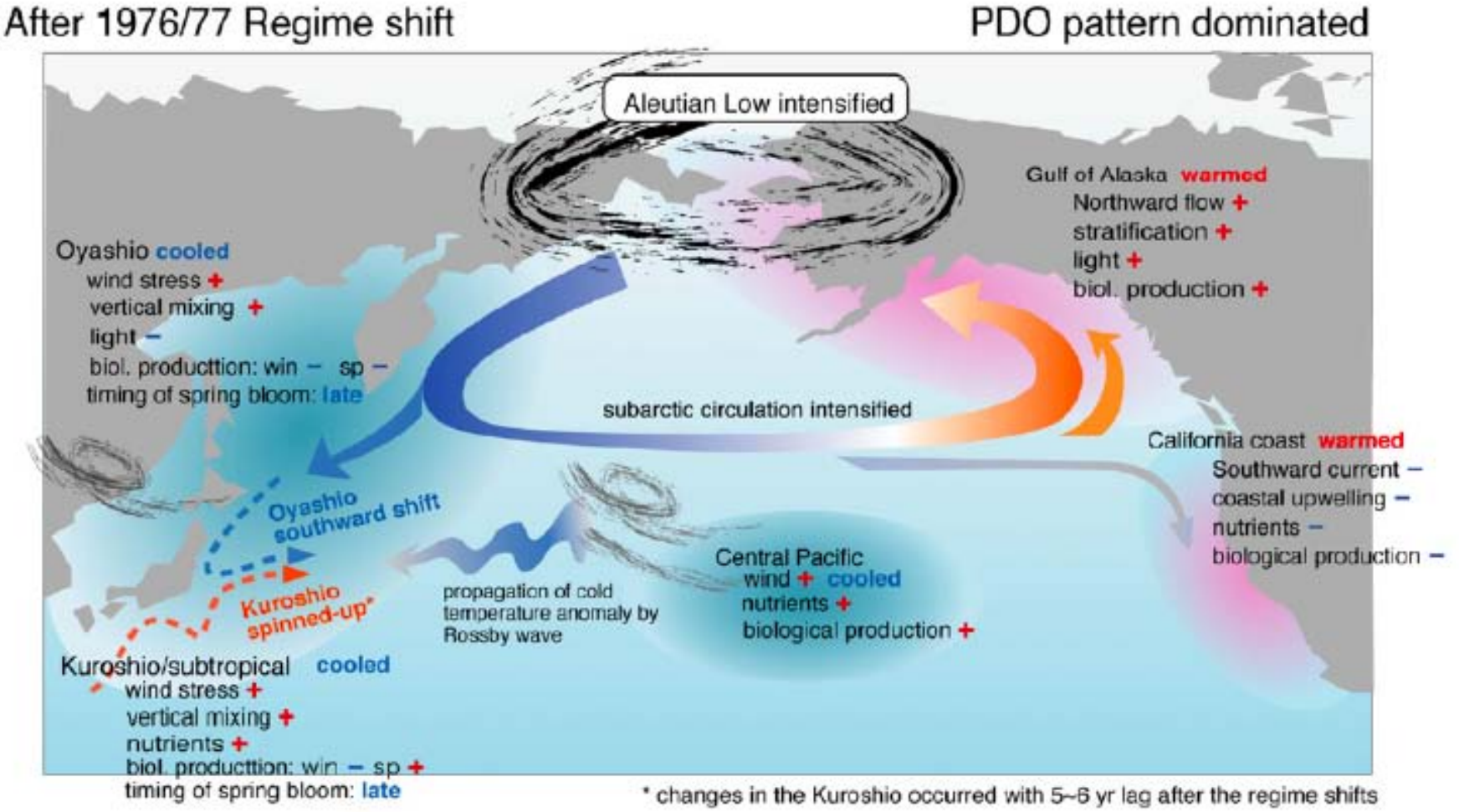
## Light ?




Increase in light availability

# Fluctuation

# Possible effects of PDO




Yatsu et al., (Prog. O.2008)

# Possible effects of PDO

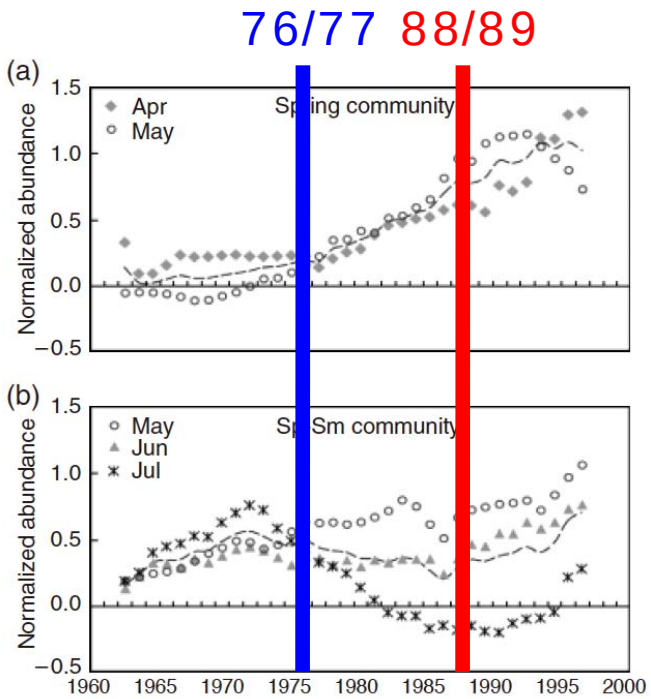




**Fig. 6** Time series of the normalized abundance of each copepod community group (10-year running mean). Only data for the months of high abundance are plotted: the spring community in April and May; the spring–summer community from May to July. The broken line indicates the mean of the plotted monthly time series.

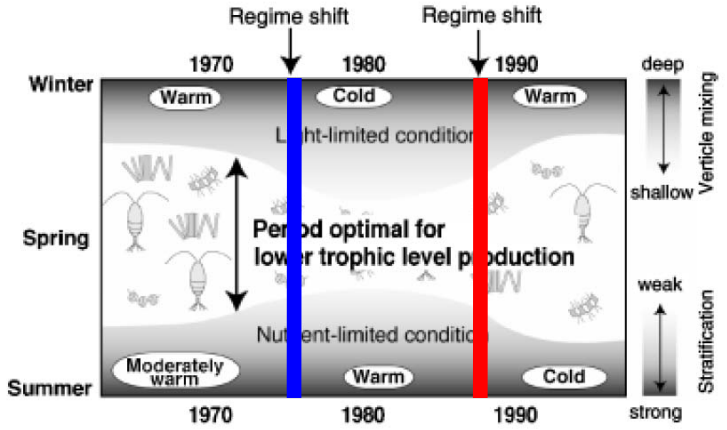
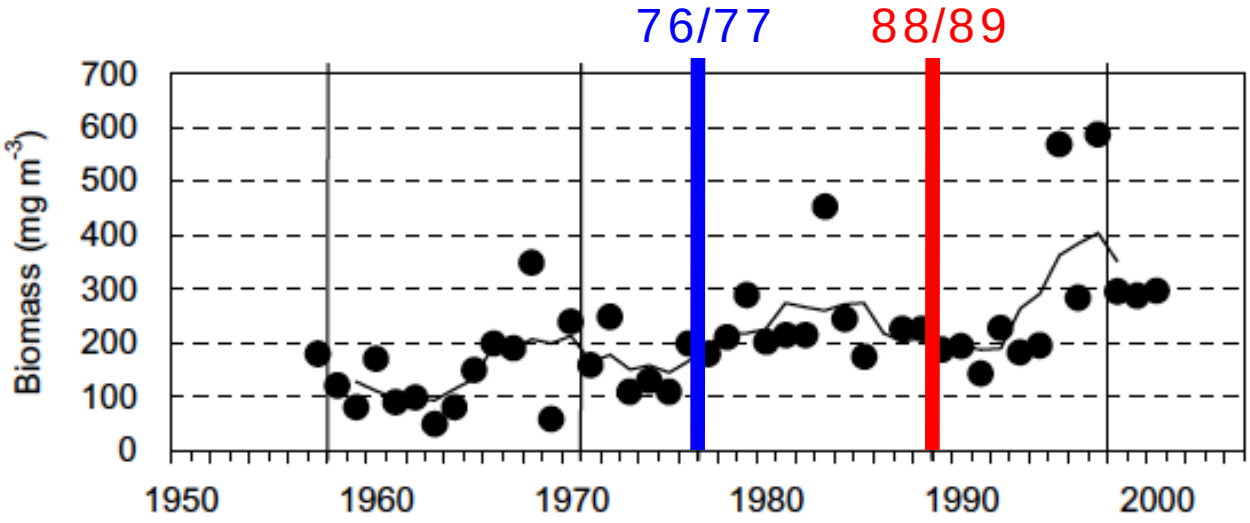



**Fig. 10** Hypothetical diagram of mechanisms of decadal variation in the phenology of the lower trophic level in the western North Pacific (see text for details).

**Chiba et al., (GCB2006)**

# Possible effects of PDO

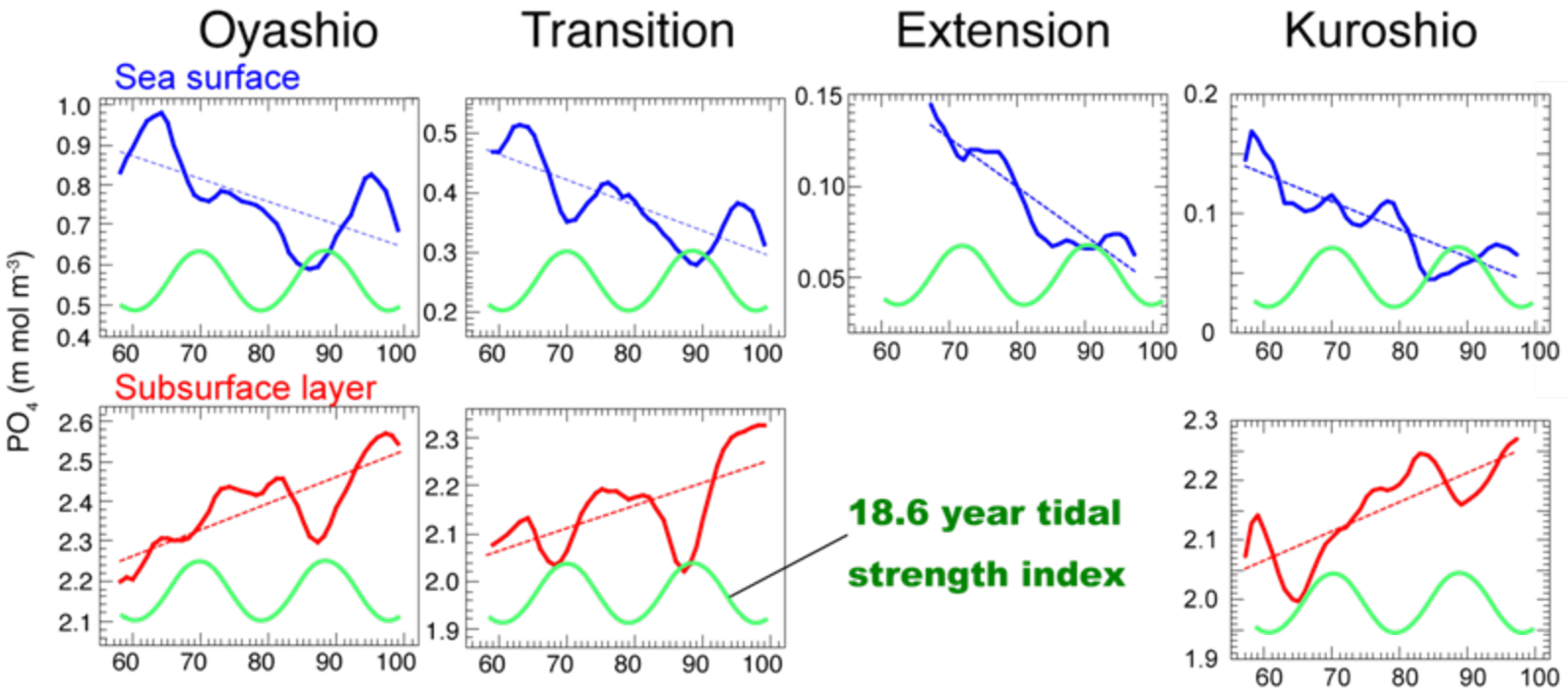

**Yatsu et al., (Prog. O.2008)**

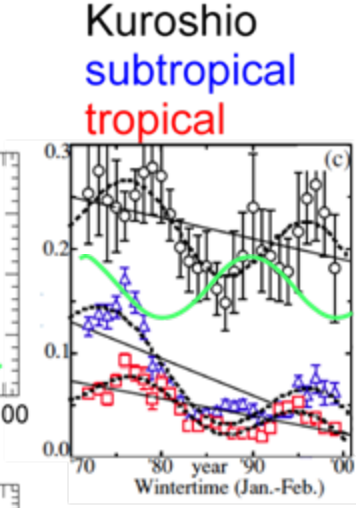
The biomass increased after the 76/77 regime shift, and decreased after 88/89. However, it increased in late 1960s and after mid 90s. Therefore the fluctuation of biomass did not fully correspond with PDO throughout the study period.

# Effect of 18.6 yr. tide oscillation

**Fluctuation components had similar pattern in the all study sites of the western North Pacific.**


**Fluctuation components had significant negative correlation with 18.6 year cycle of tide strength index.**



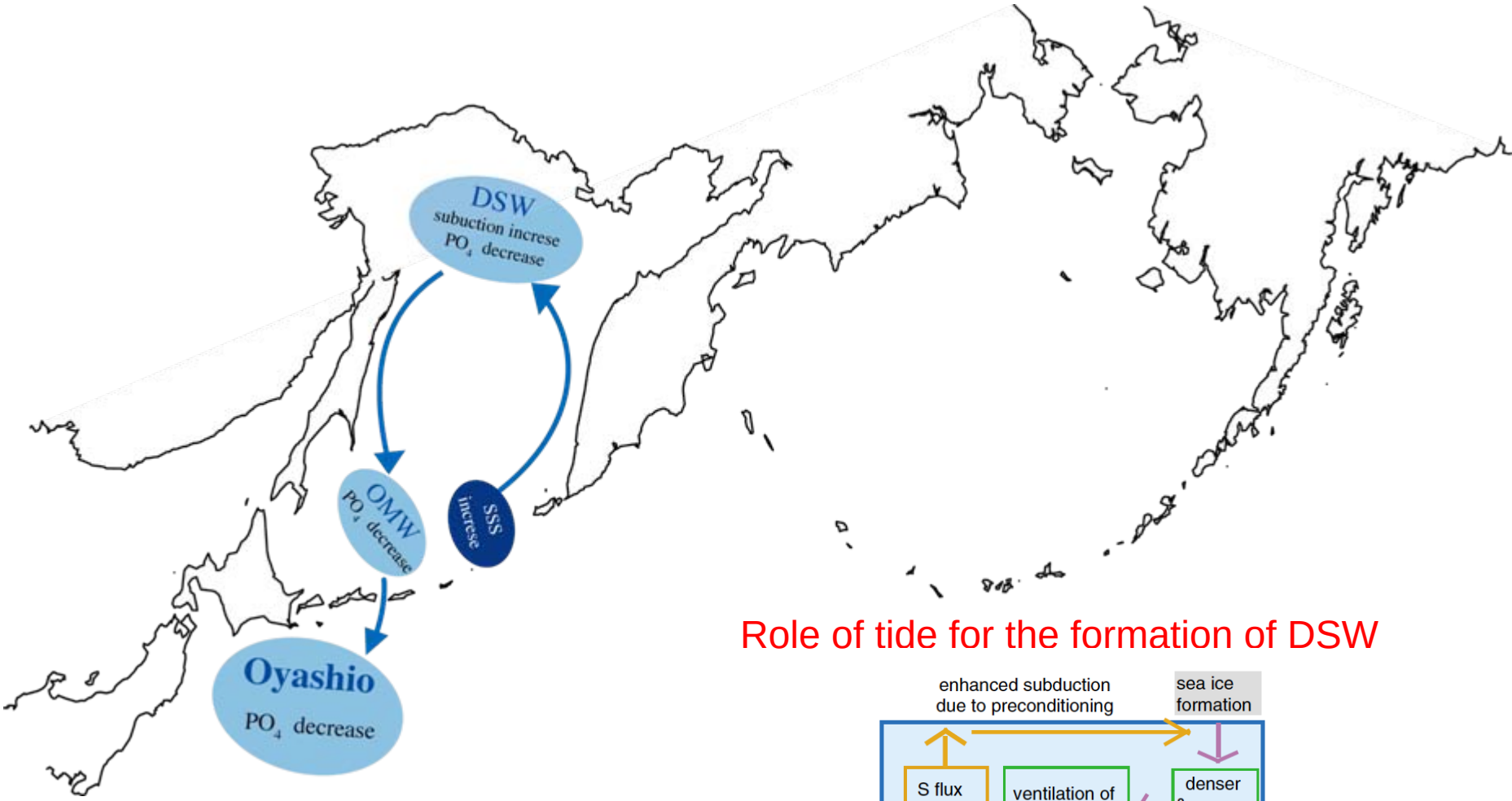




Watanabe et al., (JO, 2005)

Tadokoro et al., (GRL, 2009)

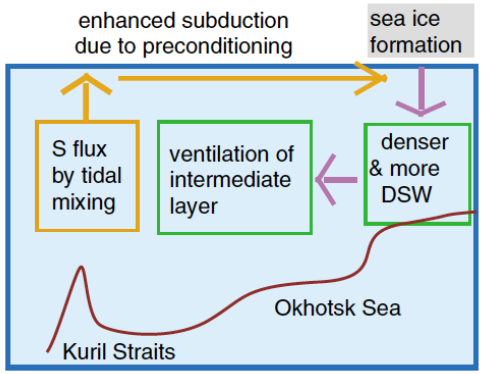
Tadokoro et al., (in prep.)

# Schematic of effect of 18.6 yr. cycle of tide to $PO_4$




Osafuene & Yasuda (JGR, 2006)

Role of tide for the formation of DSW




Nakamura et al., (DSR1, 2006)

# Summary

## Possible effect of Global Warming

Decrease trend in nutrients were observed in the broad areas of the North Pacific. Stratification enhancement due to change in temperature and salinity might relate the trend.

Decrease trend of plankton biomass were observed in the western North Pacific except with Oyashio and in the Gulf of Alaska . It might relate decrease in nutrient supply.

Increase trend of plankton biomass were appeared in the Gulf of Alaska and Oyashio (N. flemingeri & N. cristatus). Increase in irradiance availability might relate to the trend.

# Summary

## Possible effect of natural climatic Oscillation

PDO might related the decadal scale fluctuation of the plankton biomass in the Oyashio waters. In the Gulf of Alaska, timing of increase and decrease in biomass corresponded with 76/77 and 88/89 regime shift. However, PDO could not fully explain the fluctuation.

18.6 yr. cycle of the tide strength might relate the fluctuation of the plankton productivity in the broad area of the western North Pacific due to affect the nutrient supply.