Large nutrient variation in the North Pacific Transitional Area

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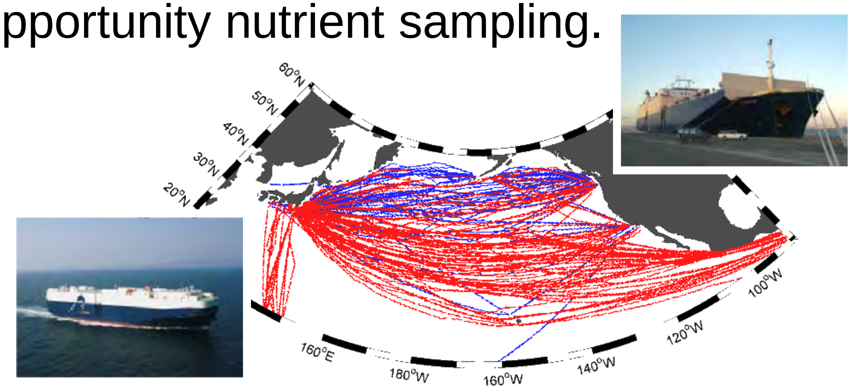
1. Ship-of-opportunity nutrient observation
2. Gridded products
3. Seasnal change & biological production
4. Decadal to long-term variability

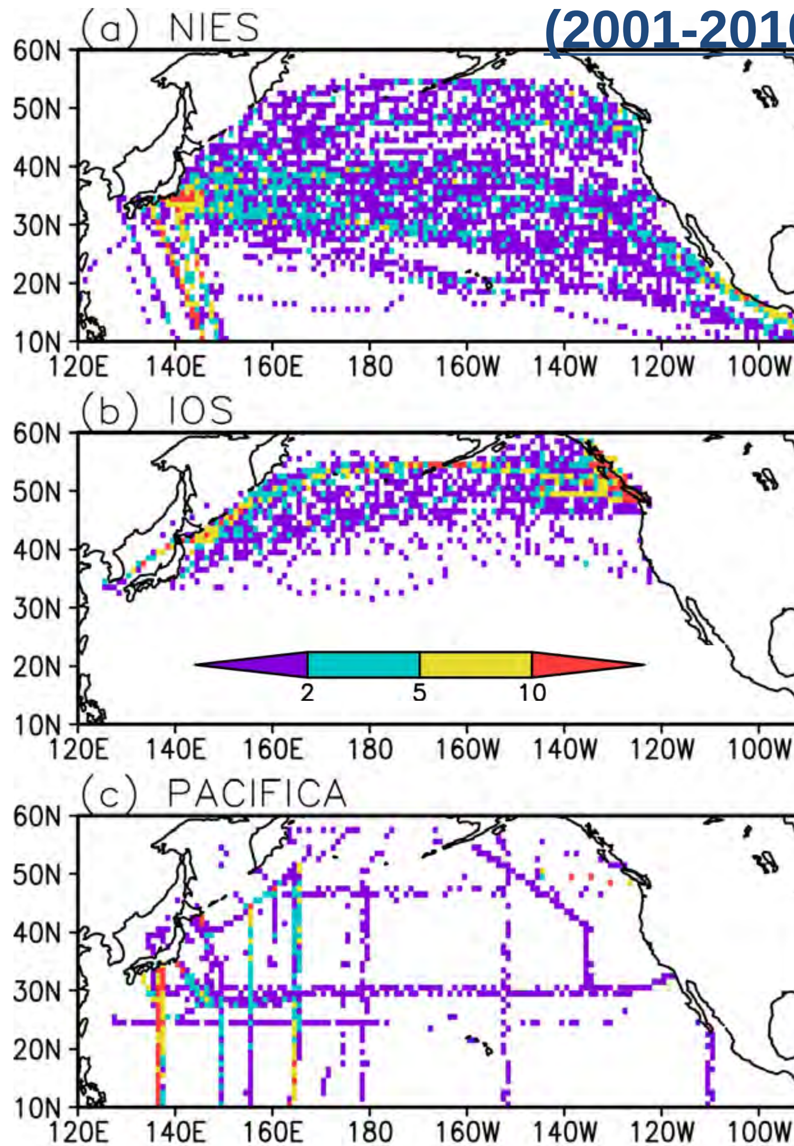
Ship-of-opportunity sampling for nutrients

- IOS and NIES have carried out ship-of-opportunity nutrient sampling.



- Surface water samples were manually collected from the seawater lines installed for pCO_2 observation, routinely at 2 or 3 samples per day.
- Sampled nutrient tubes were stored frozen, then analyzed by colorimetric techniques in the onshore laboratories.
- Ship-of-opportunity nutrient sampling improved data coverage of bottle samplings by the research vessels.

Number of Nutrient Sampling (2001-2010)

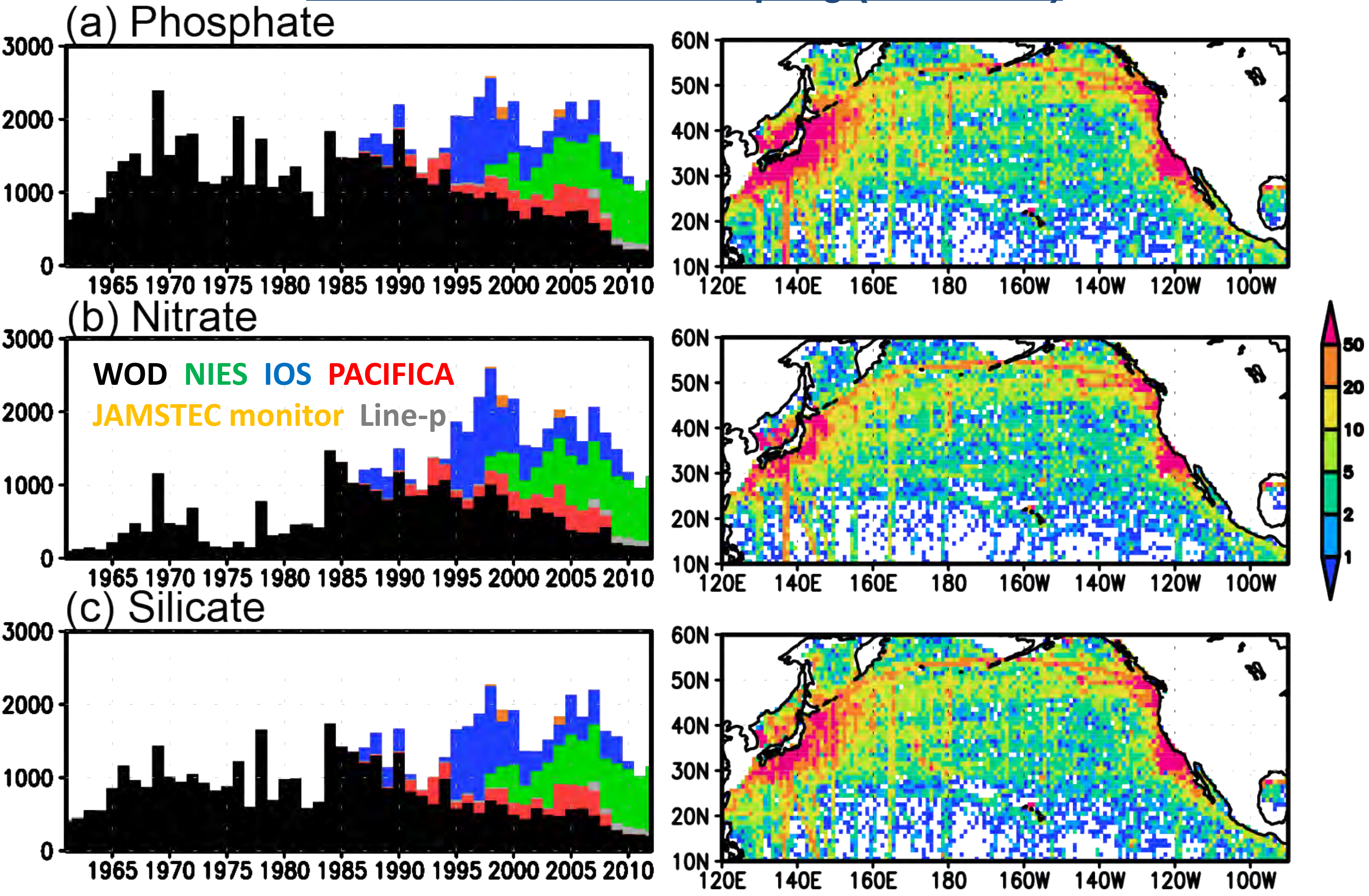


Wong et al. (2002); Whitney (2011); Yasunaka et al. (2014)

Nutrient sampling at ocean surface

Yasunaka et al. (2016)

Number of Nutrient Sampling (1961-2012)

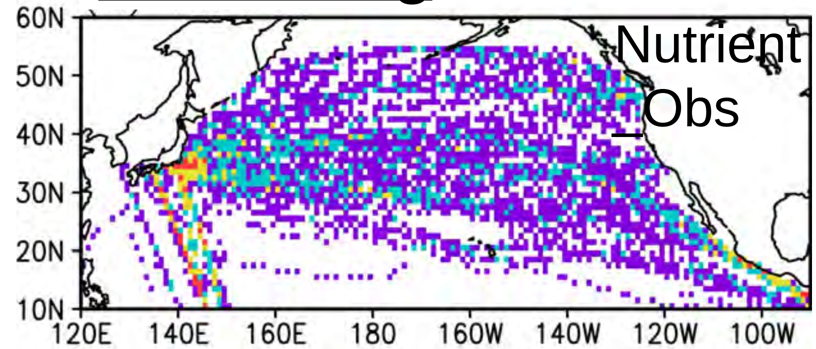


Mapping 1: SOM technique (2001/01–2010/12)

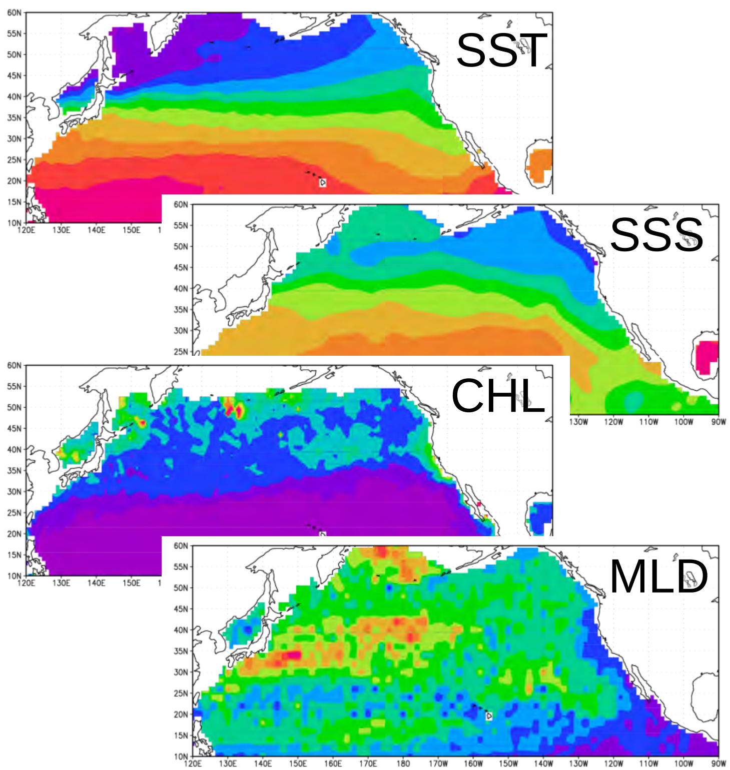
- **Self organizing map (SOM)**

can empirically induce the relationship between parameters without any a-priori assumptions of regression functions and divided areas.

2. Labeling



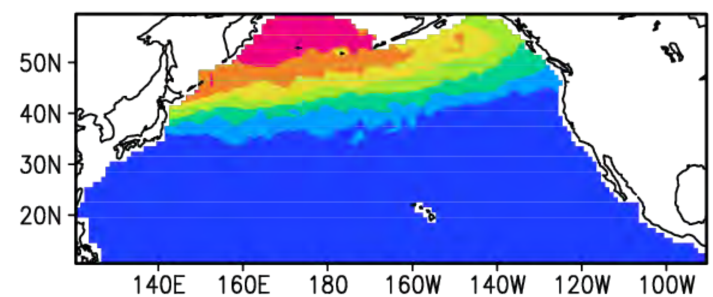
1. Training



SOM

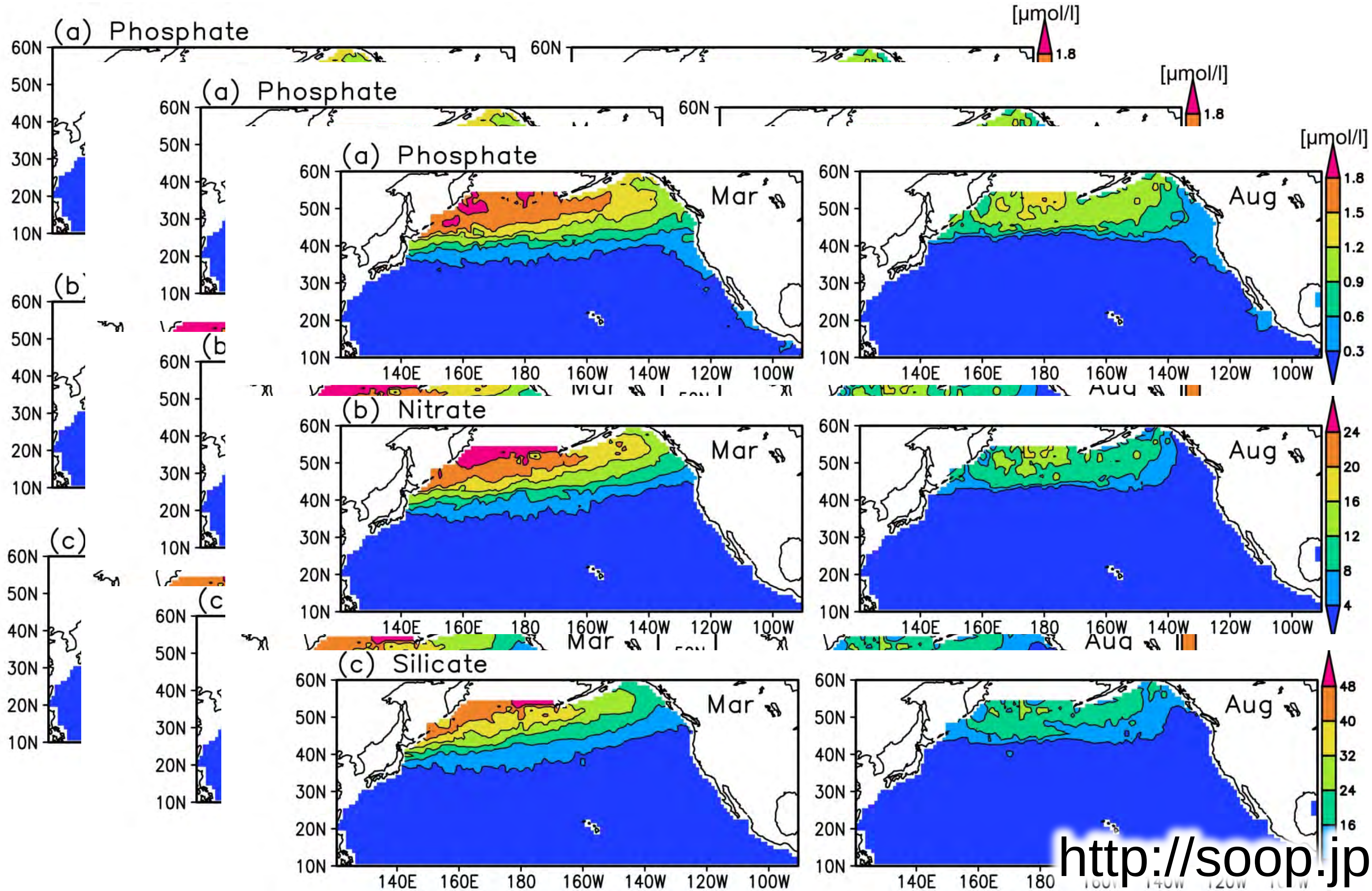
#Neuron	SST	SSS	CHL	MLD	LAT	LON	NO3
1	29.3	34.2	0.06	37.7	15.5	129.4	NaN
		…					
1799	11.4	32.8	0.65	12.6	40.0	159.3	9.5
1800	12.7	32.8	0.61	11.7	46.4	155.8	4.7
		…					

3. Mapping



Mapping 1: SOM technique (2001/01–2010/12)

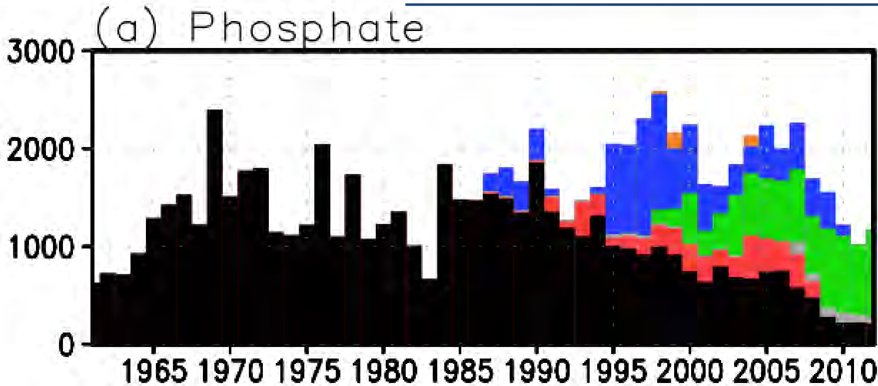
2001/01 ··························· 2010/12

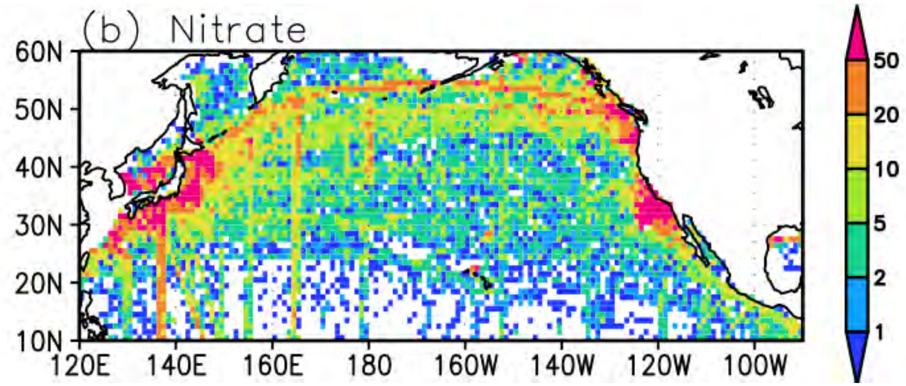


http://soop.jp

Mapping 2: Optimal interpolation (1961/01−2012/12)

Number of Nutrient Sampling (1961-2012)





WOD PACIFICA Line-P
NIES IOS JAMSTEC-monitor

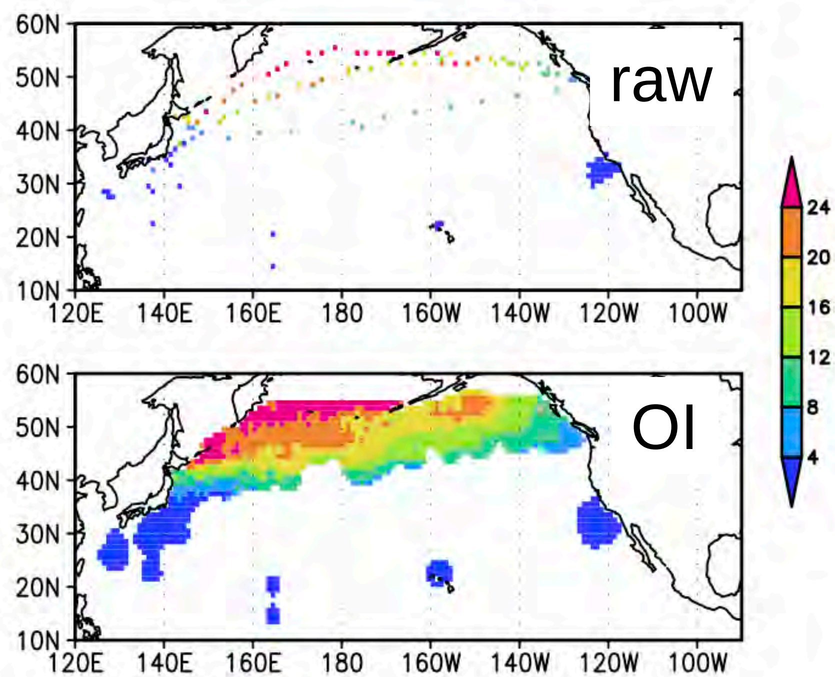
Correlation scale:

- Zonal: 23°
- Meridional: 20°
- Temporal: 3-month

SN ratio: 1.5

Interpolation error $^2 < 0.7$

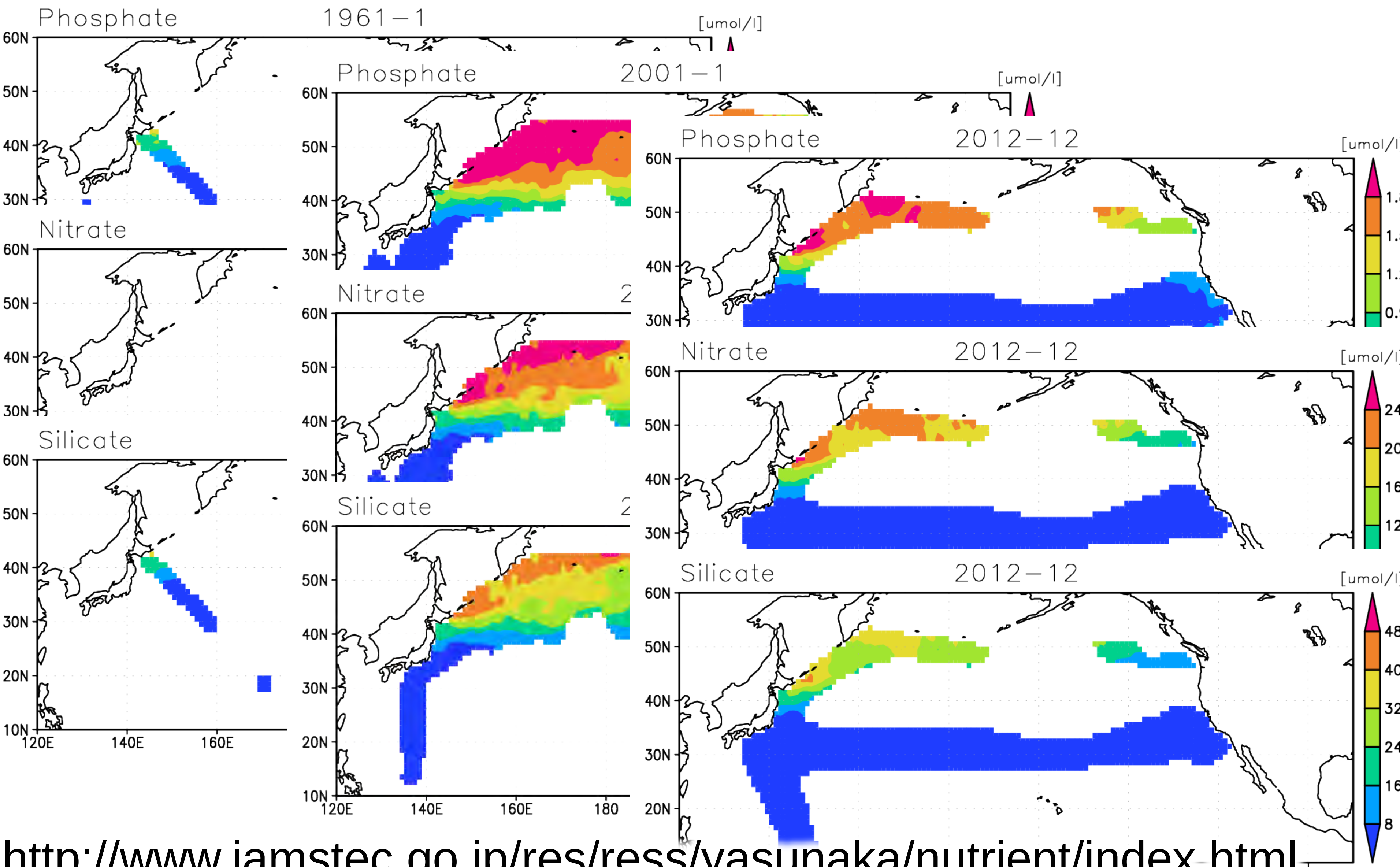
2001/01



Yasunaka et al. (2016)

Mapping 2: Optimal interpolation (1961/01−2012/12)

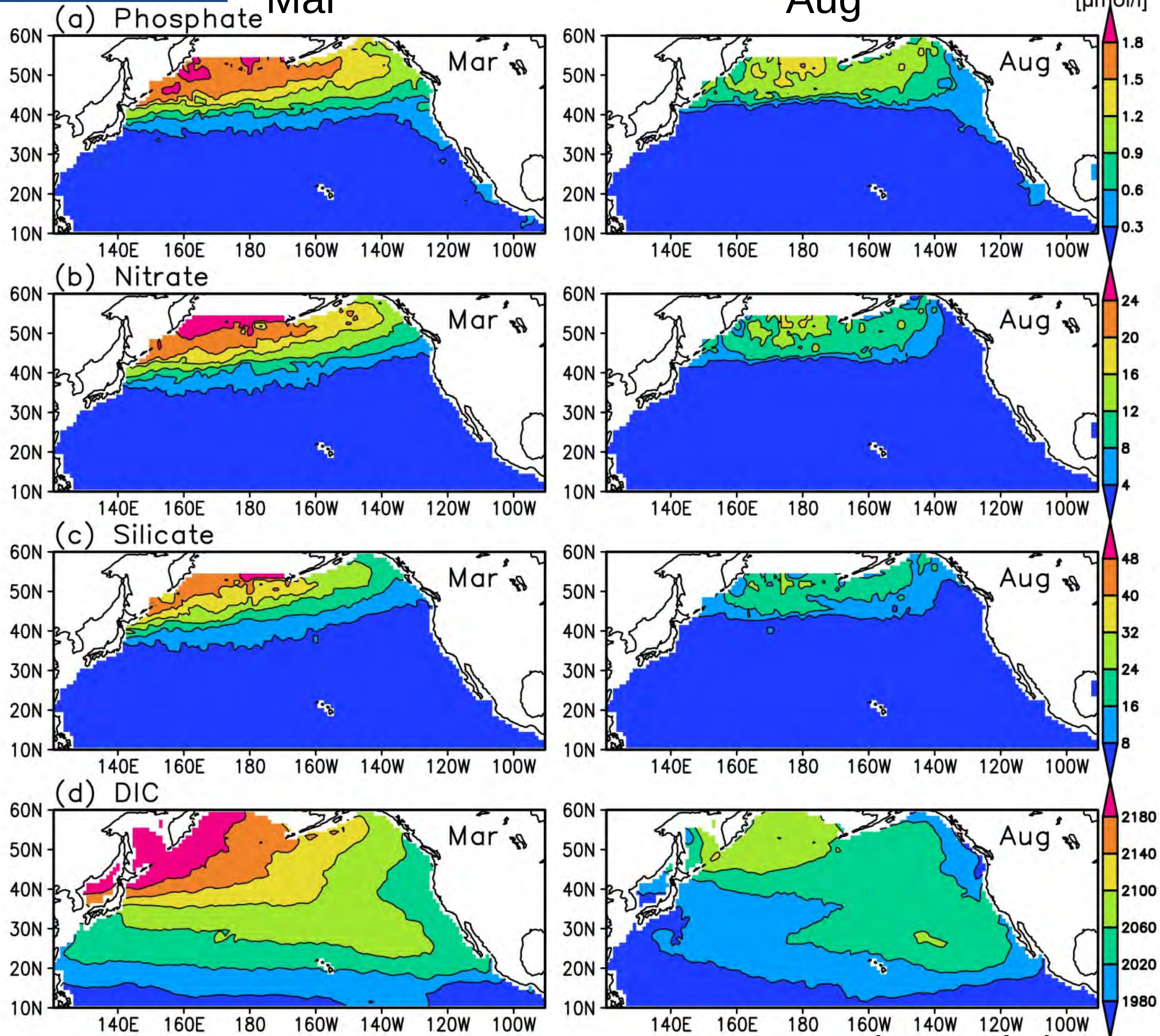
1961/01 ·········· 2012/12



http://www.jamstec.go.jp/res/ress/yasunaka/nutrient/index.html

Seasonal change

Mar Aug



P

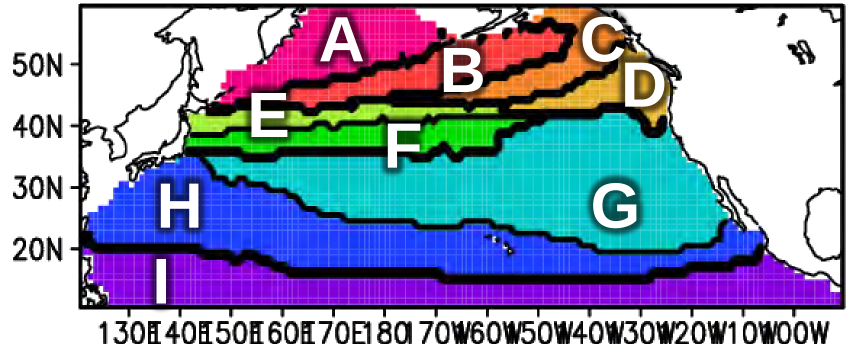
N

Si

DIC

Yasunaka et al. (2013; 2014a)

Seasonal change

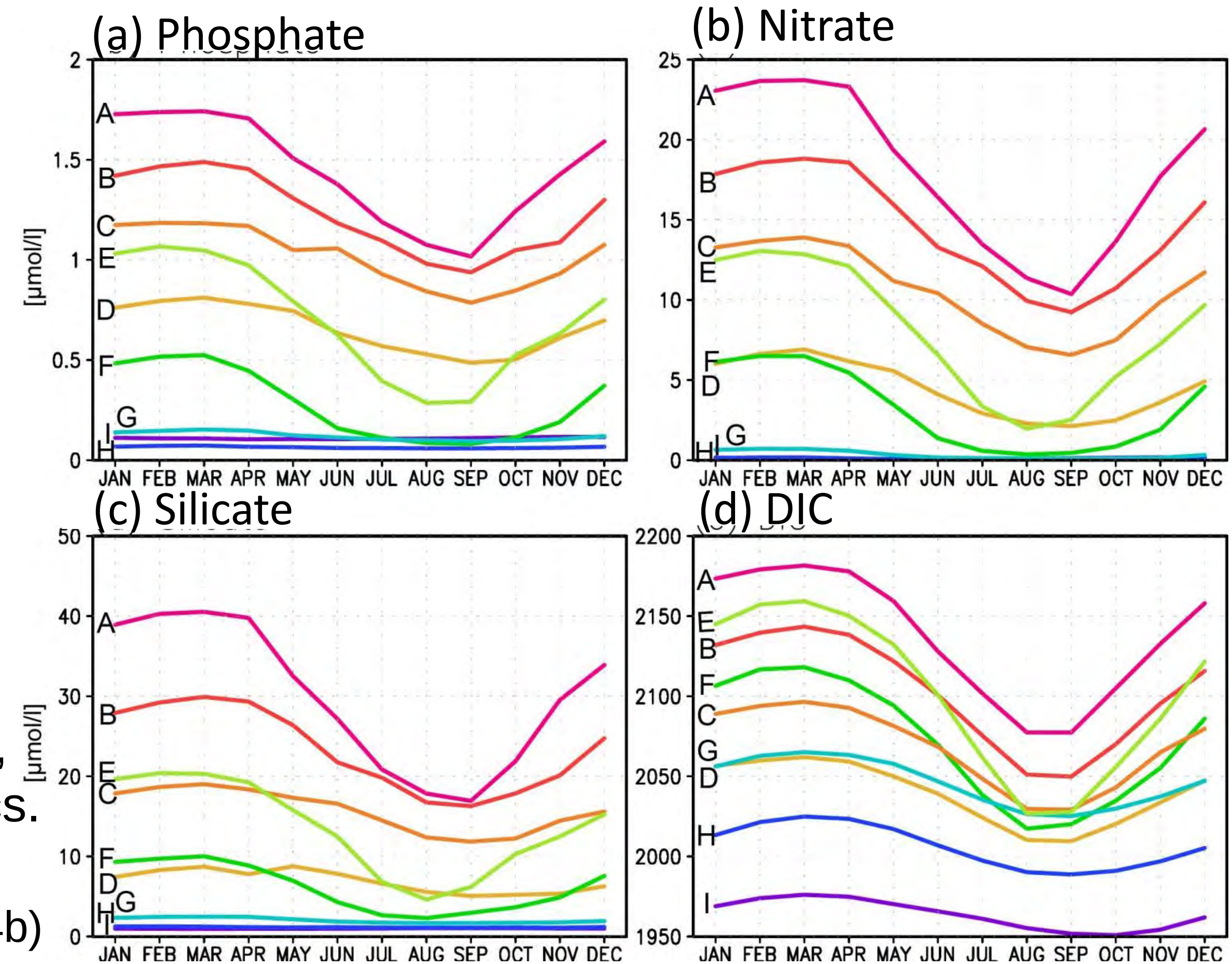


- Climatological seasonal change of P, N, Si and DIC → 9 clusters

Concentrations are
  high in the subarctic,
  low in the subtropics.

Max: Mar
Min: Aug-Oct

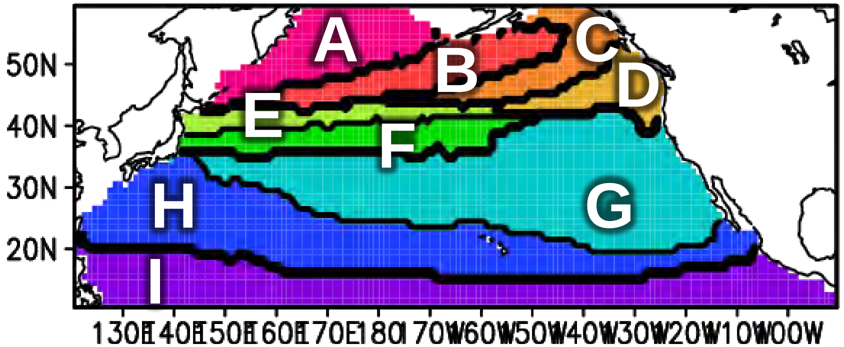
Amplitudes are
  large in the subarctic,
  small in the subtropics.



Yasunaka et al. (2014b)

Seasonal drawdown

Mar-Aug



*1: Large drawdown

*2: Nutrient drawdown ~ 0
DIC drawdown > 0

*3: Nitrogen fixation

*4: Diatom

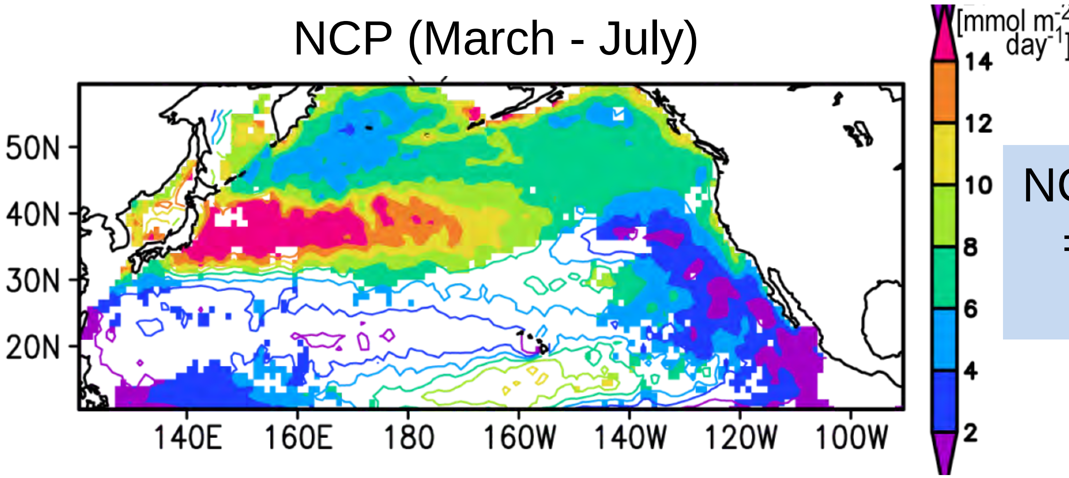
*5: Labile DOP/DIP using microbes

	ΔnP	ΔnN	ΔnSi	ΔnC		ΔnN/ ΔnP	ΔnSi/ ΔnP		ΔnC/ ΔnP	
A	0.70	12.98	23.85	84.2	*1	18.5	34.1	*4	120.0	
B	0.53	9.36	13.90	78.8		17.7	26.0		148.7	
C	0.40	7.28	7.02	55.6		18.2	17.6		139.0	
D	0.30	4.96	3.34	41.0		16.5	11.1		136.0	
E	0.79	11.31	16.30	113.8	*1	14.3	20.6		144.1	
F	0.45	6.28	7.88	90.1		14.0 *3	17.5		200.2	*5
G	-	-	-	30.4		-	-		-	
H	-	-	-	27.9	*2	-	-		-	
I	-	-	-	16.7		-	-		-	

Relation to biological production

- Net Community Production (NCP)

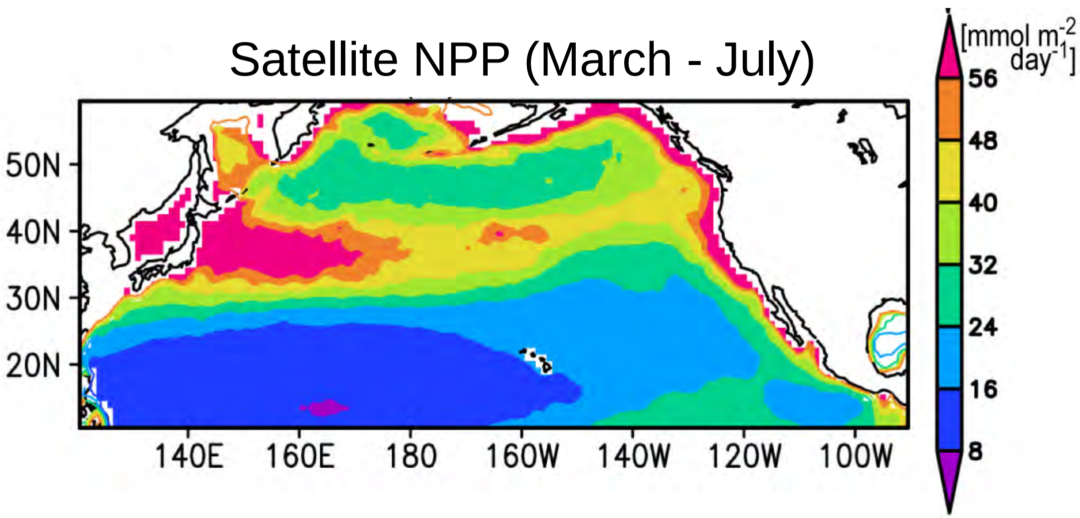
NCP (March - July)



NCP[m – m+1]
= MLD[m+1] * (nDIC[m] – nDIC[m+1])
– (Flux[m] + Flux[m+1])/2

by Lee (2001)

Satellite NPP (March - July)



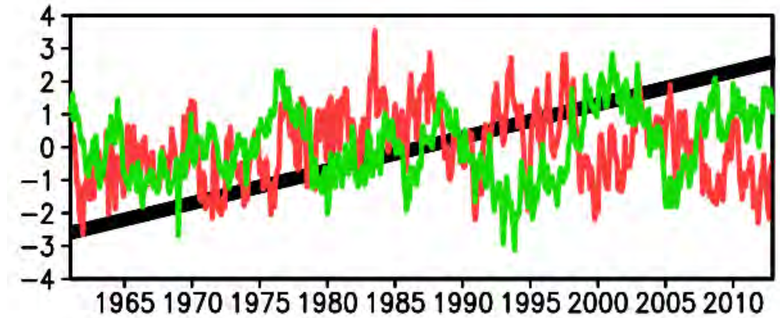
- NCP ~ 20-30% of NPP

Yasunaka et al. (2013)

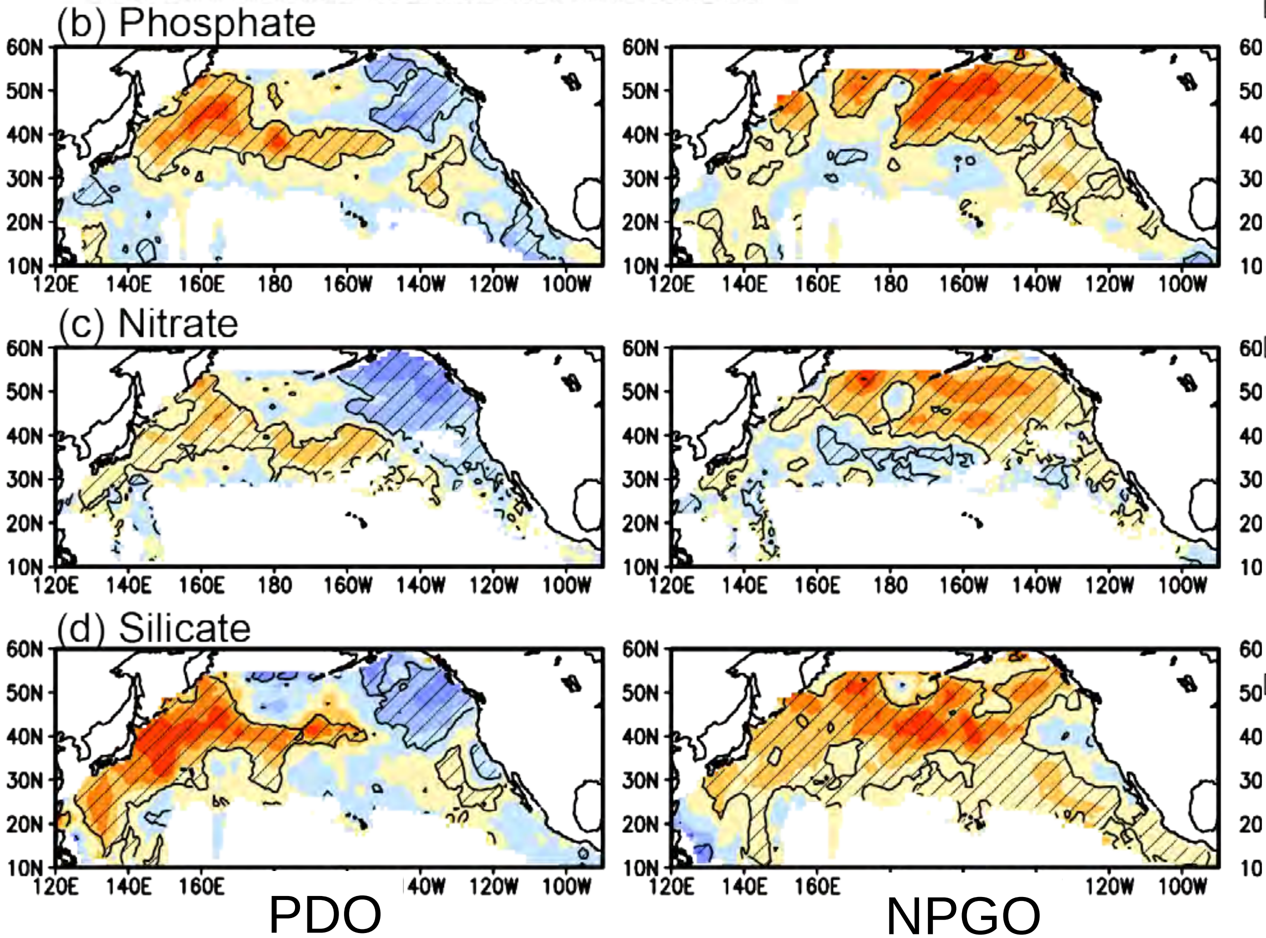
Decadal & long-term variability

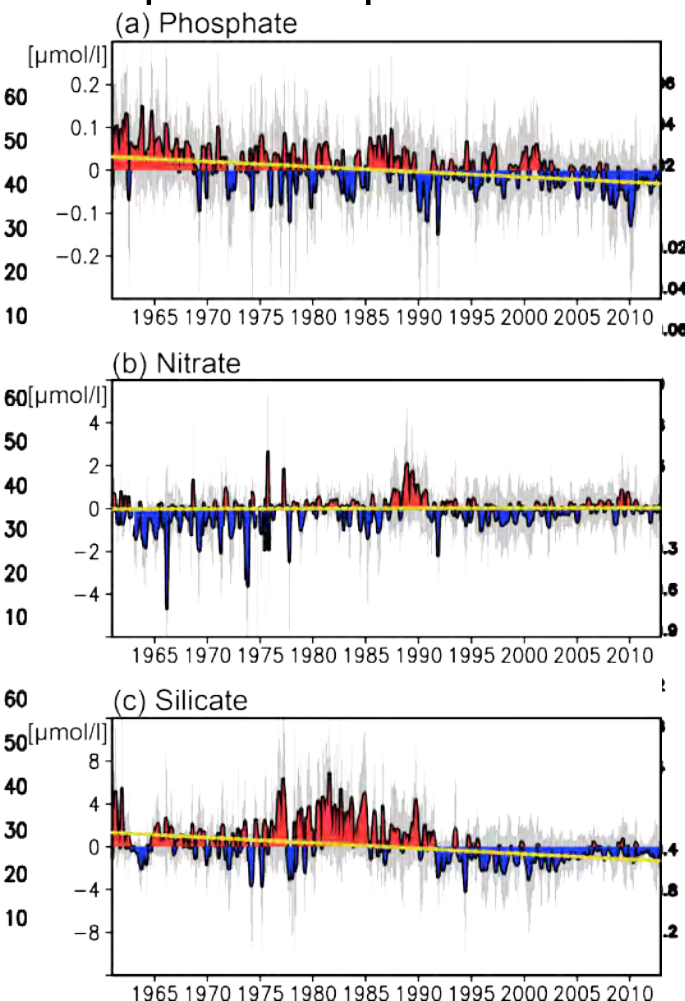
Yasunaka et al. (2016)

(a) PDO index / NPGO index / Trend



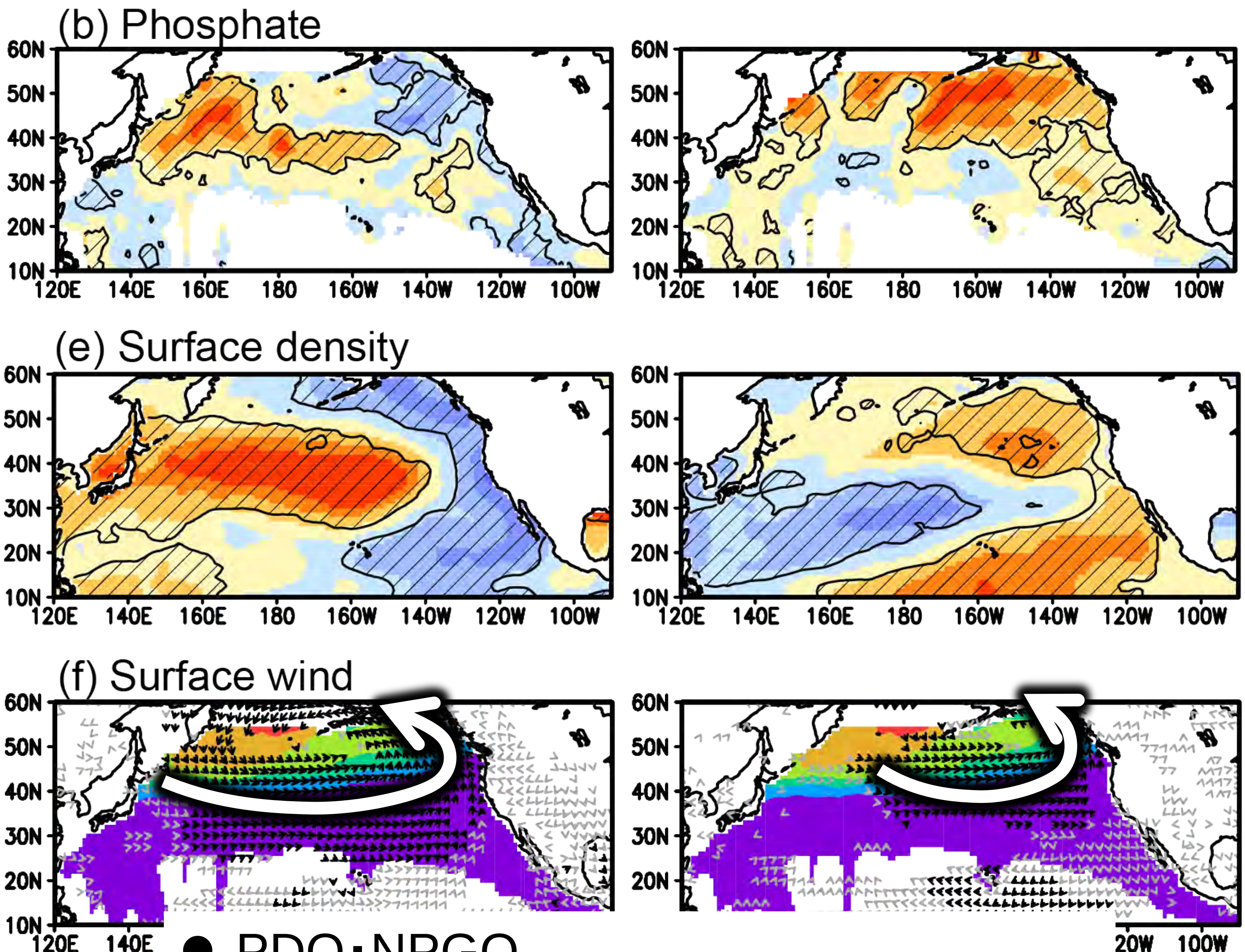
- PDO･NPGO
  ← Entrainment + Ekman advection
- Trend (P･Si) ← Shallowing MLD
- Trend (N)
  ← MLD + Atmospheric deposition？





Decadal & long-term variability

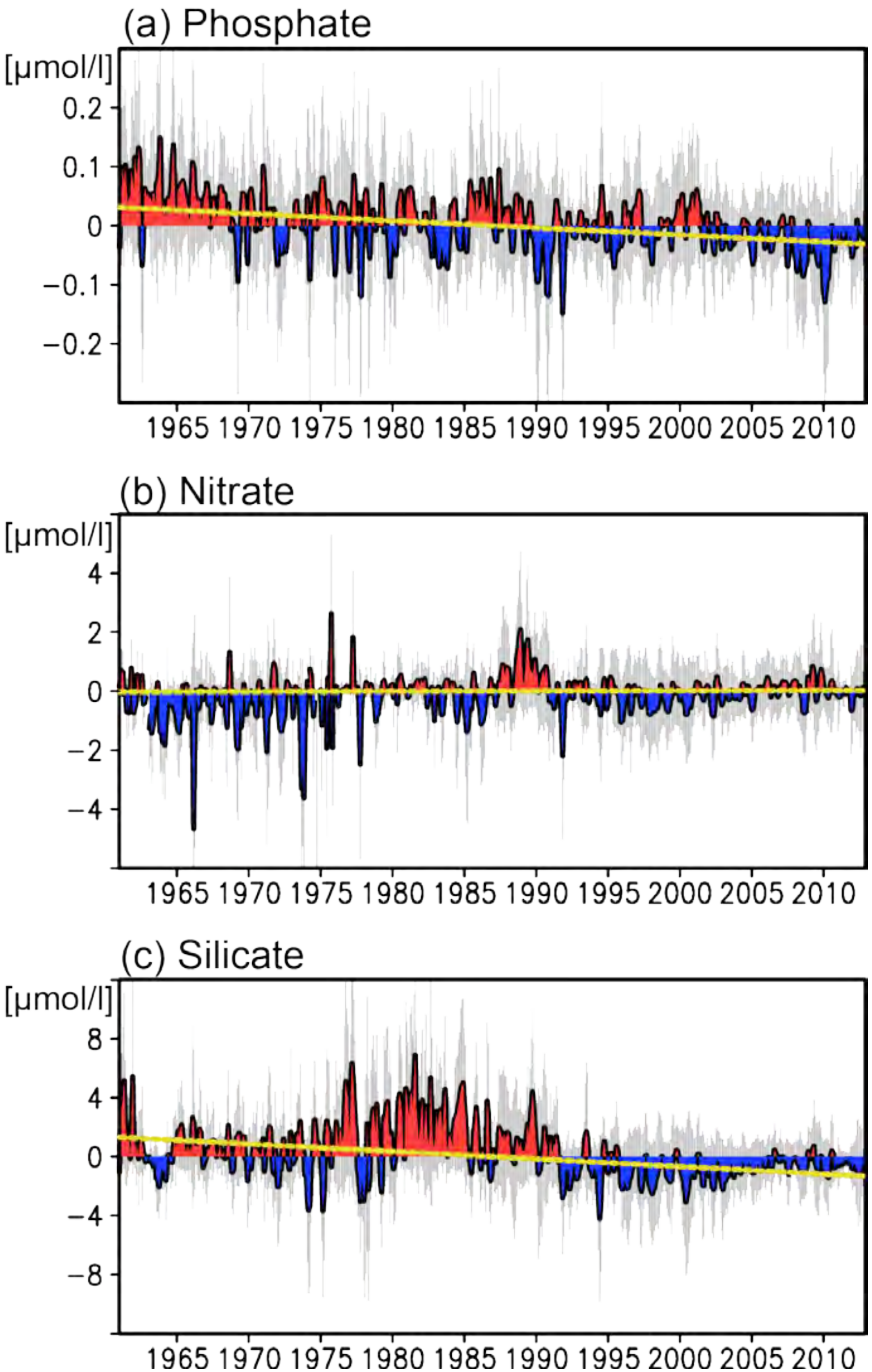
Yasunaka et al. (2016)



● PDO・NPGO

← Entrainment + Ekman advection

Long-term trend



P: −0.012 ±0.005 μmol/l/dec
N: −0.001 ±0.013 μmol/l/dec
Si: −0.38 ±0.13 μmol/l/dec

Global warming
→ Shallowing mixed layer
→ Reduction of entrained nutrient

Observed trend
P: −0.012 ±0.005 μmol/l/dec
N: −0.001 ±0.013 μmol/l/dec
Si: −0.38 ±0.13 μmol/l/dec

Entrainment effect
P: −0.014 ±0.006 μmol/l/dec
N: −0.19 ±0.09 μmol/l/dec
Si: −0.45 ±0.21 μmol/l/dec

P and Si trend ← shallowing MLD

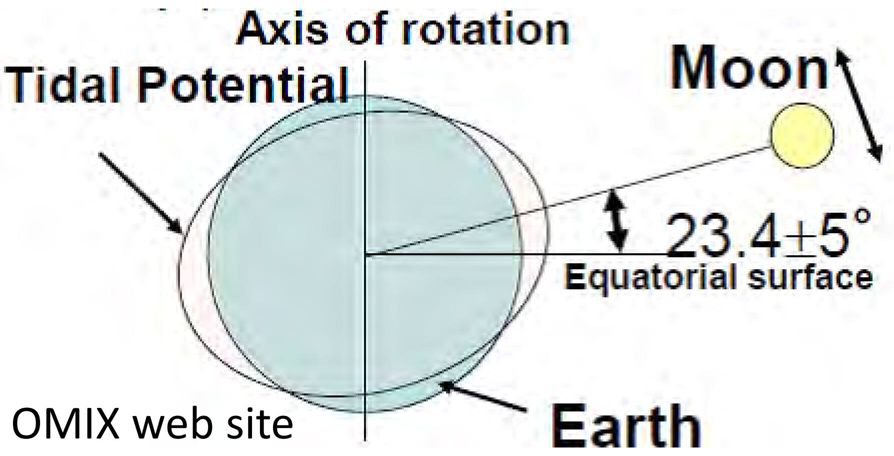
- Global anthropogenic N depositions：
  54 TgN/yr (Duce et al. 2008 and references therein)

→ If it is uniformly distributed in the upper 500 m of the ocean,
it increases the N concentration by 0.2 μmol/l/dec.

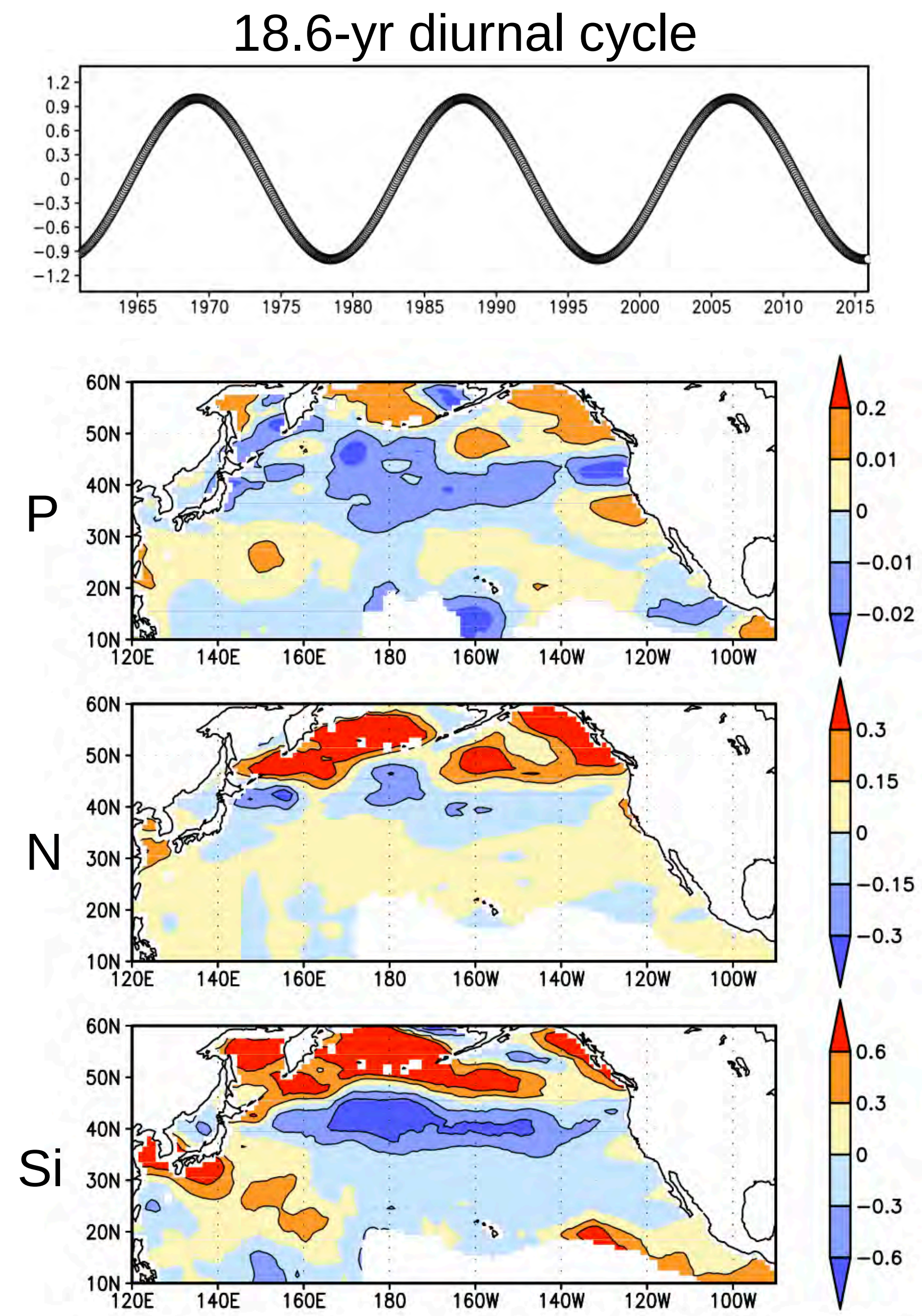
N trend ← shallowing MLD + anthropogenic N depositions

18.6-yrear cycle

Moon orbit changes the inclination with the 18.6-yr, which generates the 18.6-yr modulation of tidal mixing.



OMIX web site



Positive response

around Aleutian and Kuril Islands

<- high nutrient water to the surface

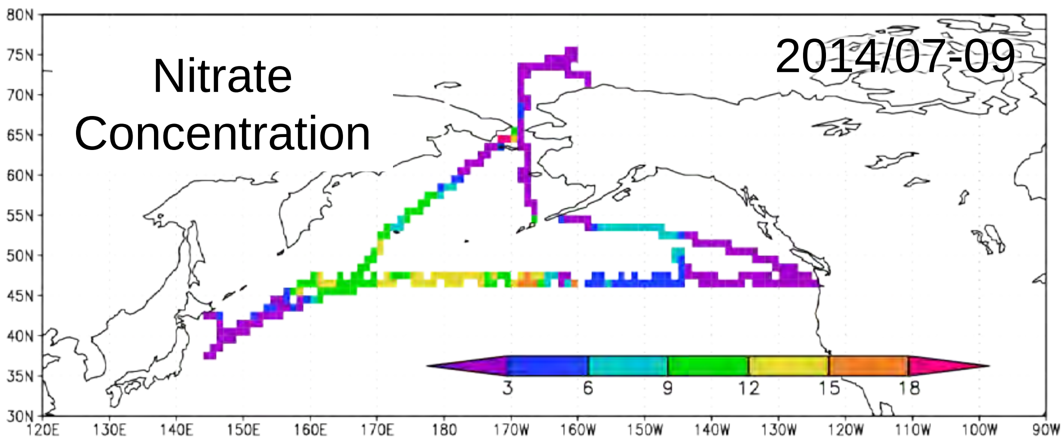
<- strong vertical mixing

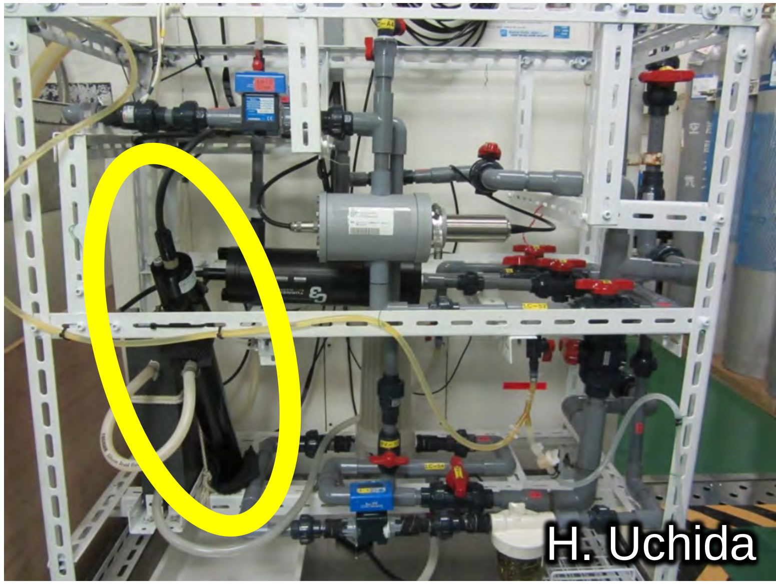
<- strong 18.6-yr oscillation of tidal energy dissipation rate

Other observations

● Nitrate continuous observation by optical sensor

JAMSTEC R/V Mirai 2014-

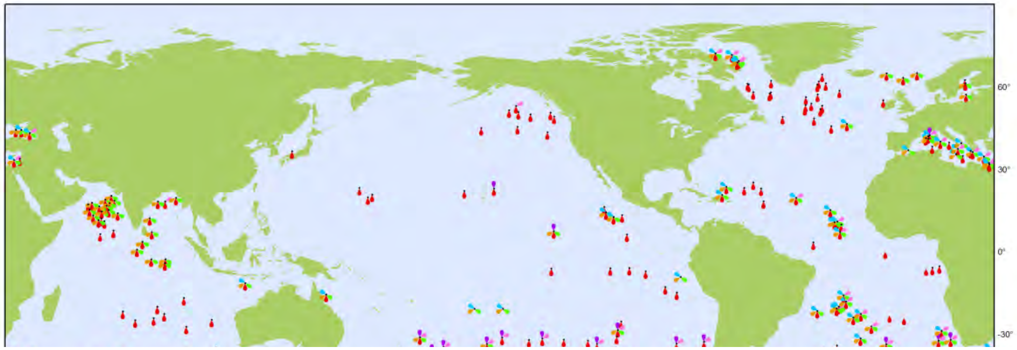




● Biogeochemical Argo

biogeochemical Argo

2018/03



I hope various observations are continued, and data are archived in a user-friendly form.

Summary

- SOOP observations improved data coverage of the traditional datasets (i.e. bottle sampling by the research vessels).
- Nutrient data accumulation enable us to understand large-scale variability of nutrients.
- Large seasonal drawdown and decadal-scale variation were found in the North Pacific Transitional Area.
- Continued observations and data archiving are desired.

References:

Yasunaka et al. (2016) Long-term variability of surface nutrient concentrations in the North Pacific, GRL 43, 3389-3397.

Yasunaka et al. (2014a) Mapping of sea surface nutrients in the North Pacific: basin-wide distribution and seasonal to interannual variability, JGR 119, 7756-7771.

Yasunaka et al. (2014b) North Pacific dissolved inorganic carbon variations related to the Pacific Decadal Oscillation, GRL 41,1005-1011.

Yasunaka et al. (2013) Monthly maps of sea surface dissolved inorganic carbon in the North Pacific: basin-wide distribution and seasonal variation, JGR 118, 3843-3850.

Estimate of entrainment reduction

1. Obtain ρ data from T and S data from Ishii and Kimoto (2009).
2. Convert the surface ρ-trend into a long-term trend of MLD by using the climatological ρ-profiles during summer at the climatological MLD in winter. → 2.3 ± 0.9 m decade^{-1}
3. Assuming that annual new production is constant (c), determine the winter nutrient concentration at year i+1 (n^{i+1}_w) from the winter nutrient concentration at year i (n^i_w), the winter mixed layer depth (h^{i+1}_w), and summer euphotic zone depth (h_s):

$$n^{i+1}_w = \{(n^i_w - c)\, h_a + [a + b\,(h_a + h^{i+1}_w)/2](h^{i+1}_w - h_a)\}/h^{i+1}_w$$

by Freeland et al. (1997).

4. Integrate this equation over 52 years.