

Climatological Annual Cycle of Nutrients

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OUTLINE

- 🌐 **World Ocean Database & Atlas 2005**
- 🌐 **Climatological annual cycle of HPO_4^{2-} , NO_3 , Si(OH)_4 .**
- 🌐 **Remarks on N/P ratios**
- 🌐 **Remarks on thermal stratification variability**



World Ocean Database and Atlas 2005

A global, comprehensive, integrated, quality-controlled database

Release date: May 2006

See Poster W6-2877

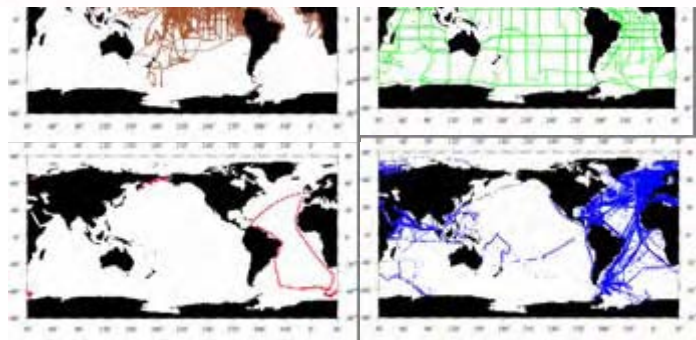
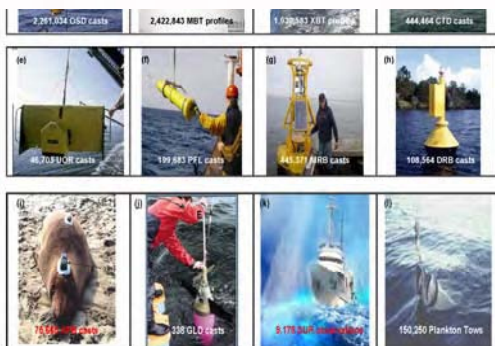
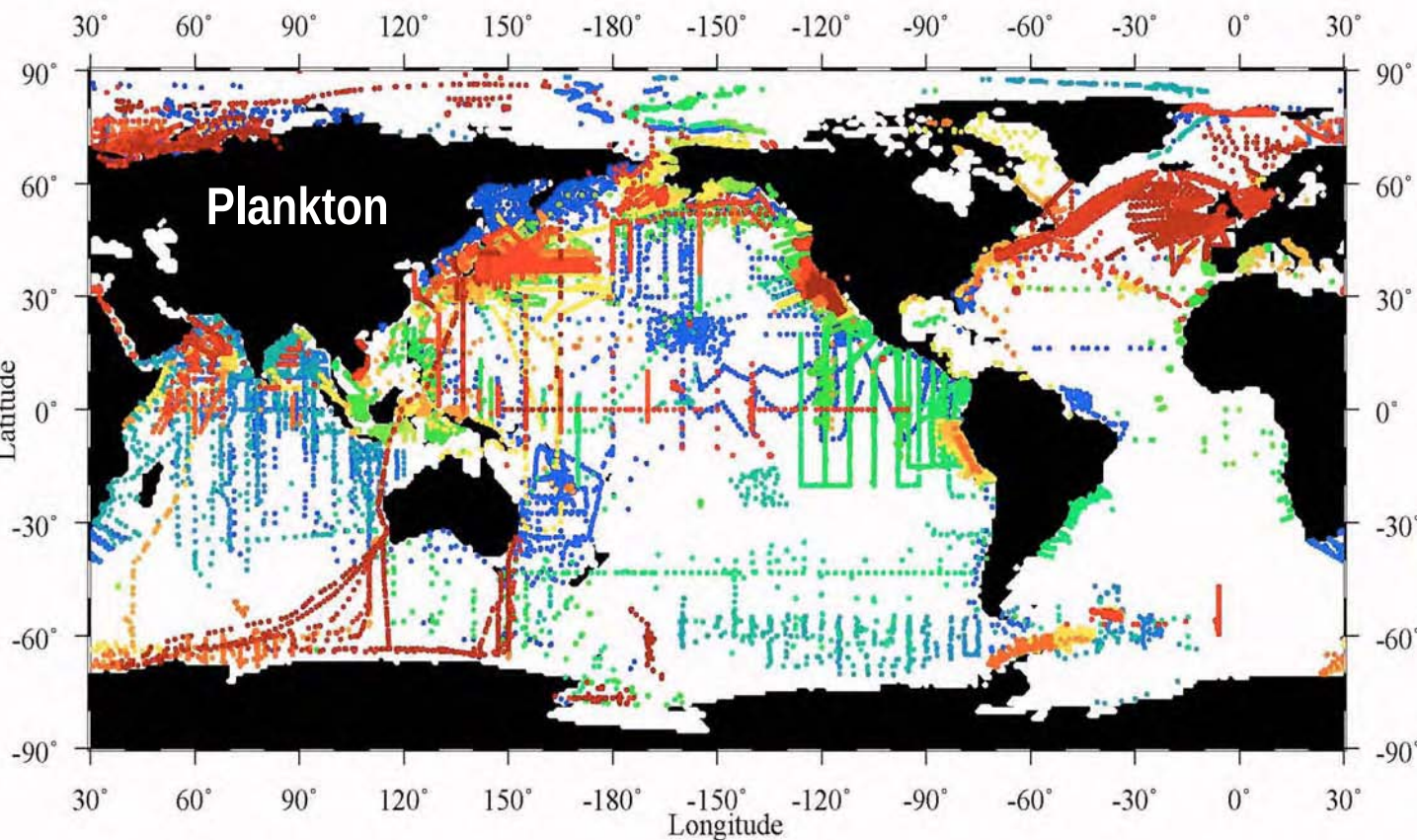
www.nodc.noaa.gov

Geographically- and yearly-sorted subsets, and "user search" (WODSelect)

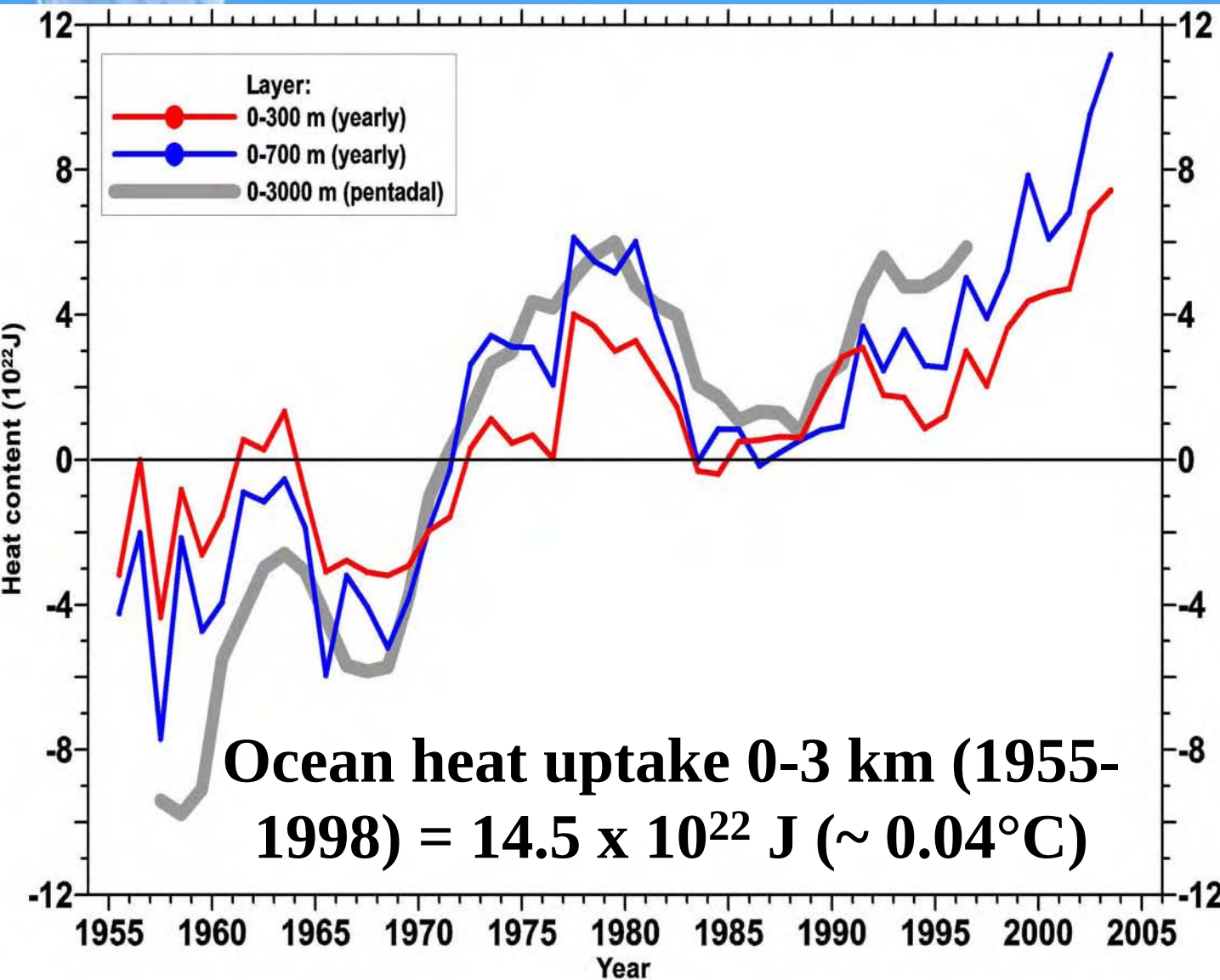
A scientific community contribution towards an instrumental oceanic record

International Sources

Parameter	Number of profiles	Sampled years
Temperature	7,759,262	1772 – 2005
Salinity		
Dissolved		
Phosphate		
Silicate		
Nitrite		
Nitrate	222,328	1925 – 2004

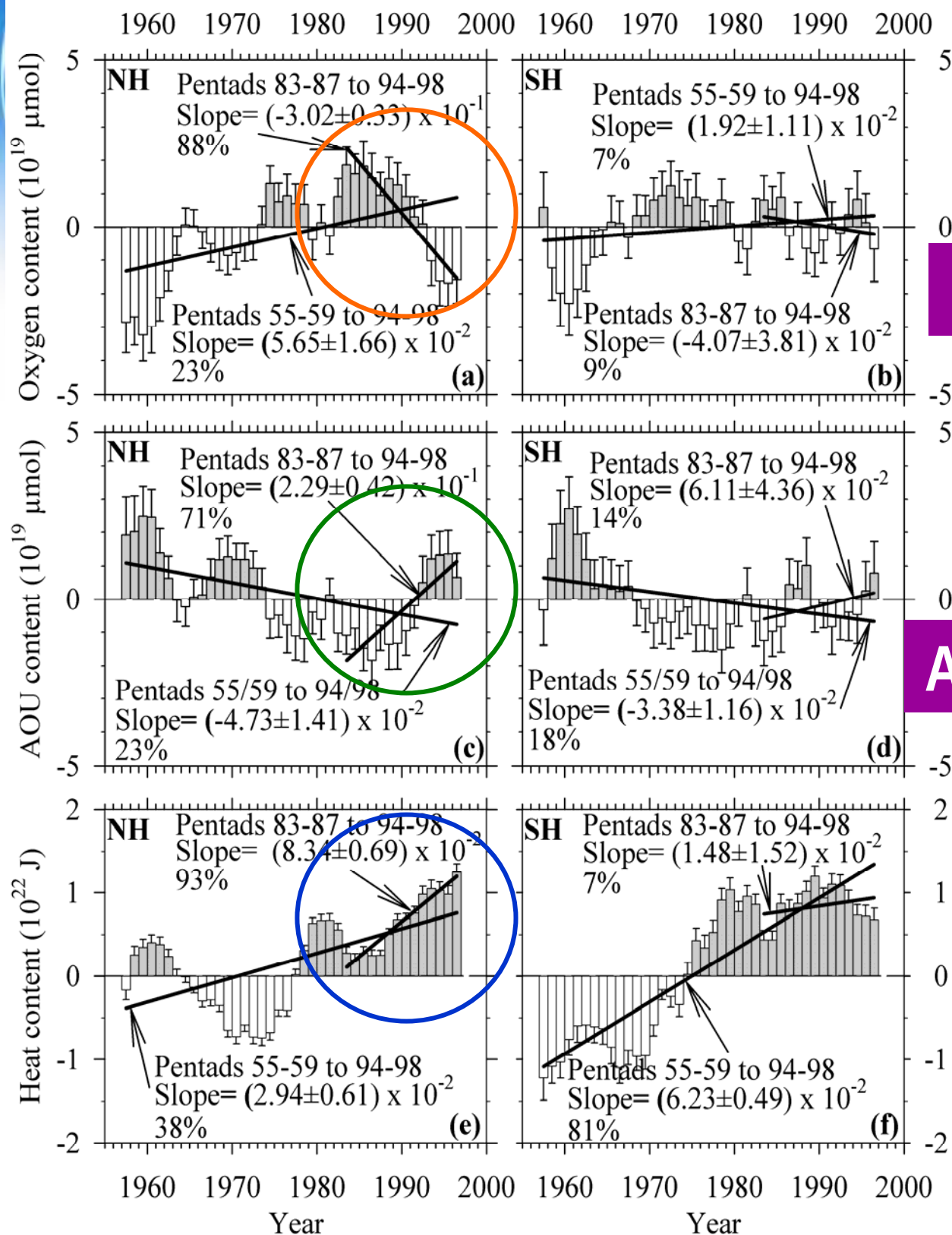


World Ocean Heat Content ($\times 10^{22}$ J)



Levitus *et al.*, 2005

Variability in O₂, AOU, and heat content (0-100 m)



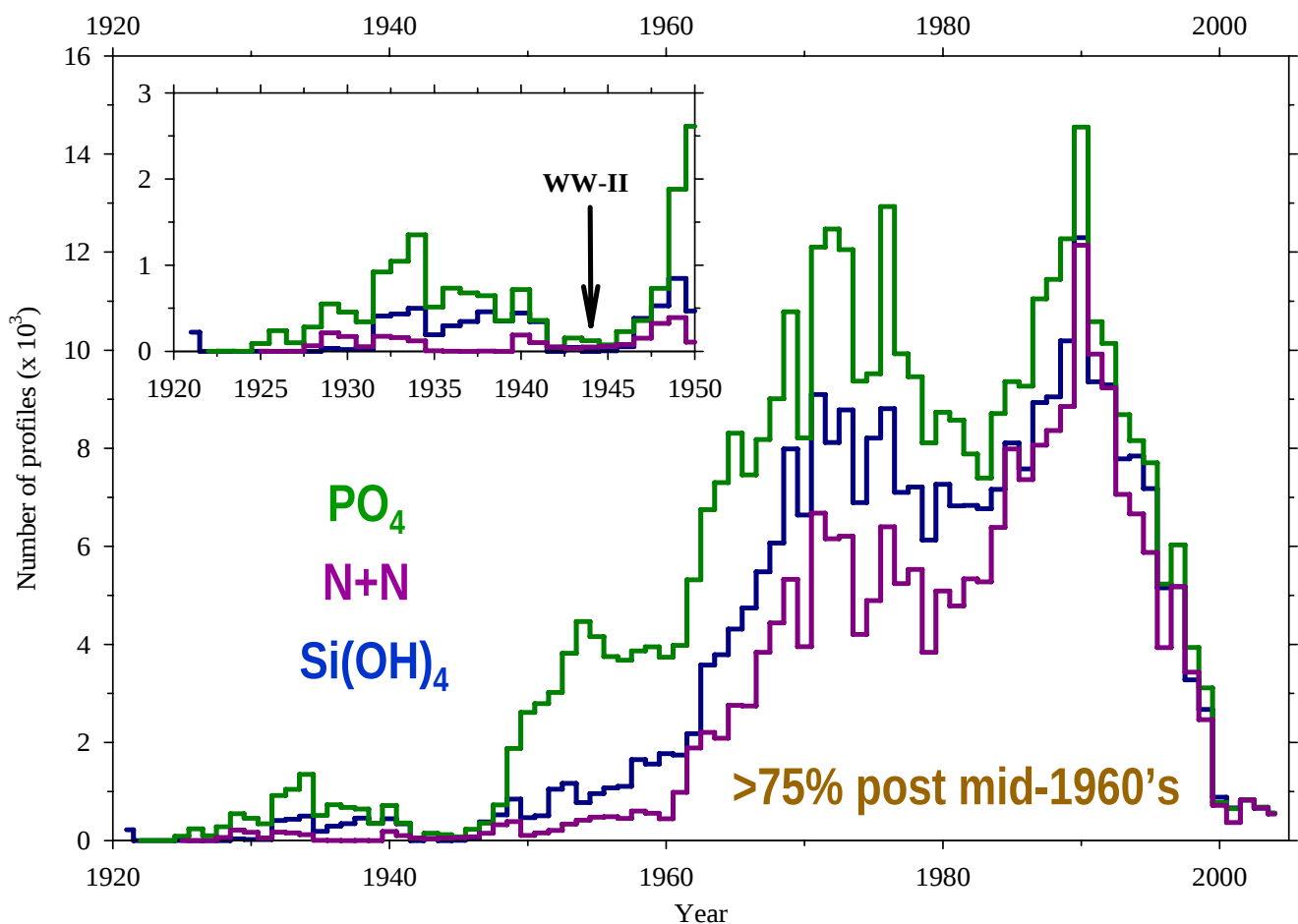
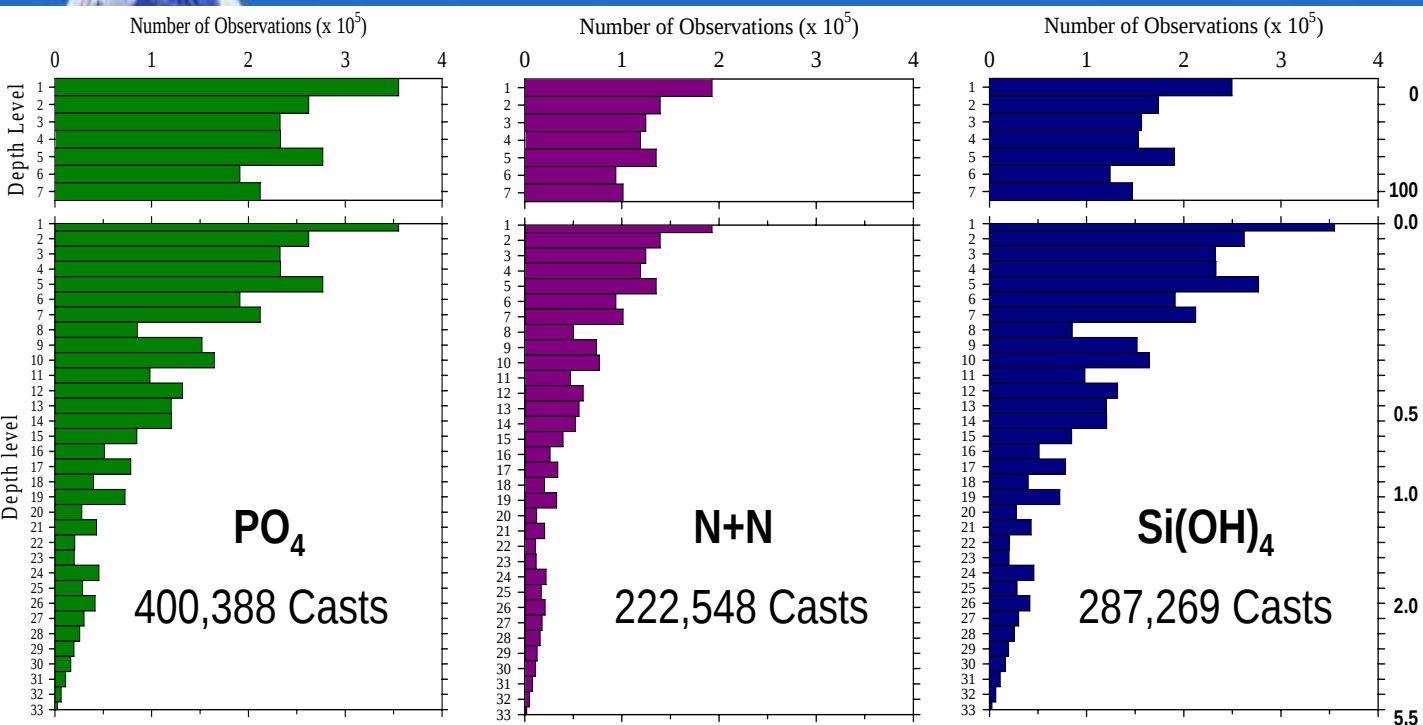
O₂

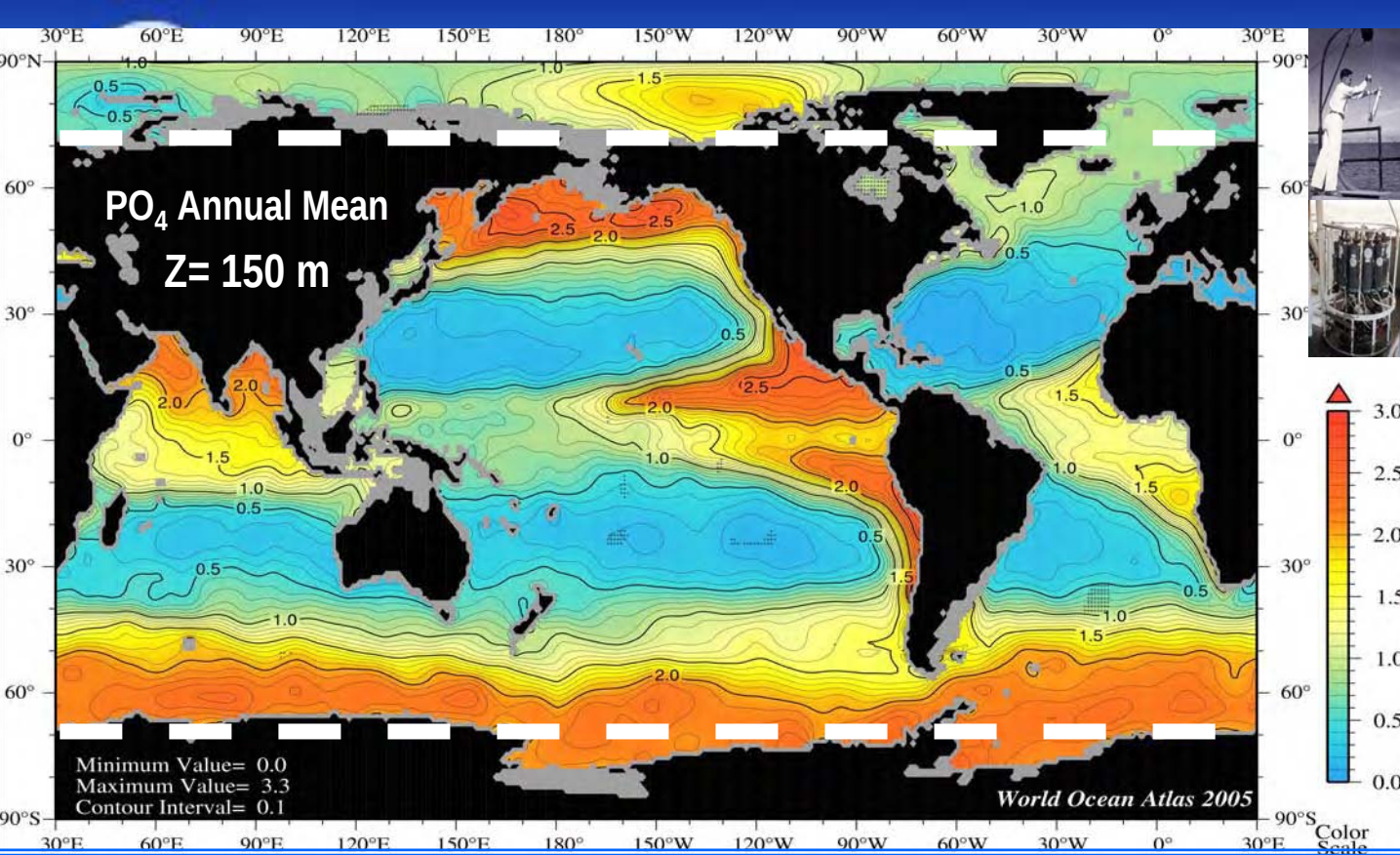
AOU

Q

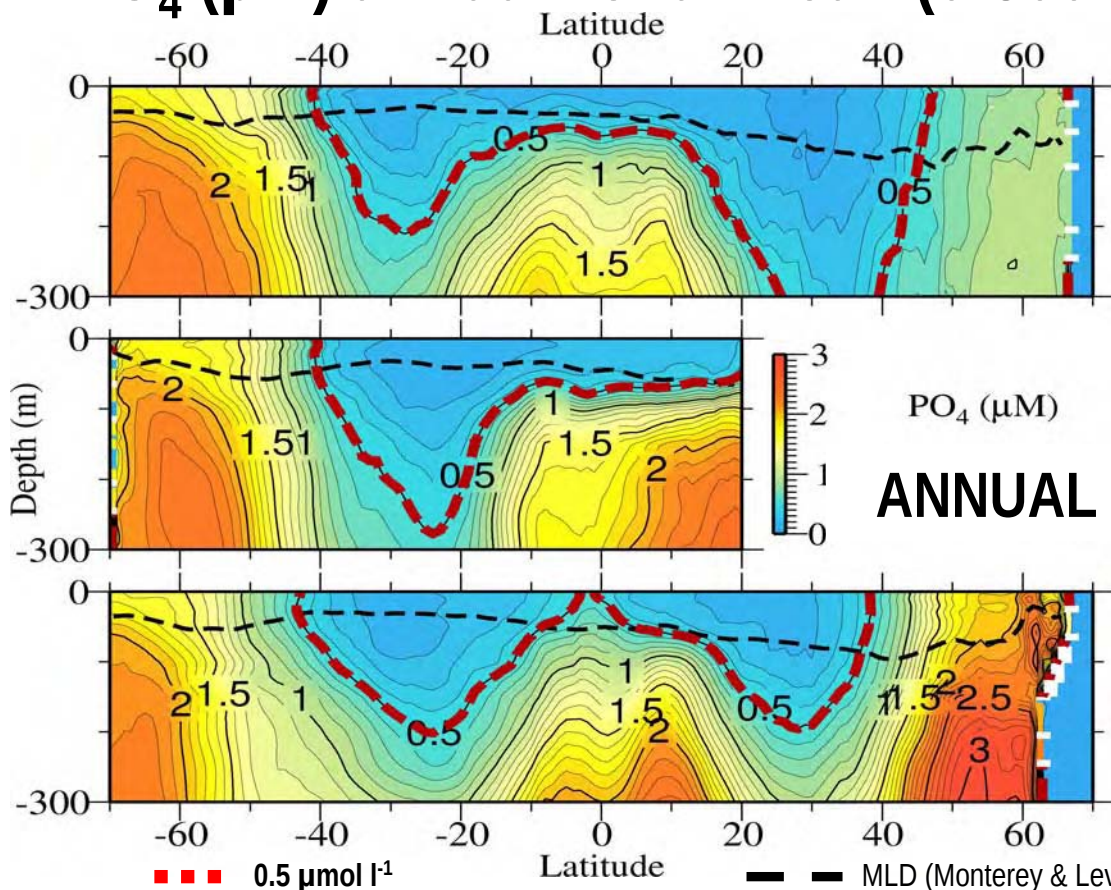
Garcia et al. 2005

World Ocean Database 2005 (Nutrient observations)





PO₄ (μM) annual zonal mean (0-300 m)



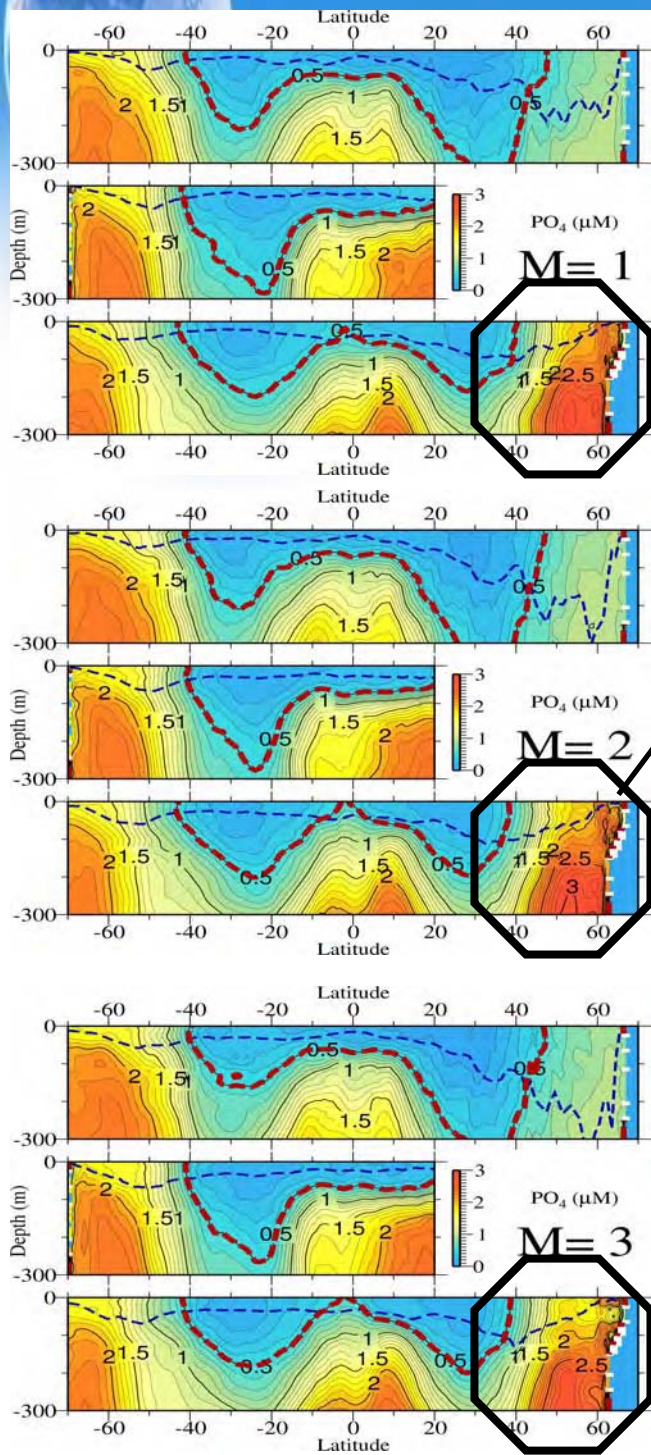
Atlantic

Indian

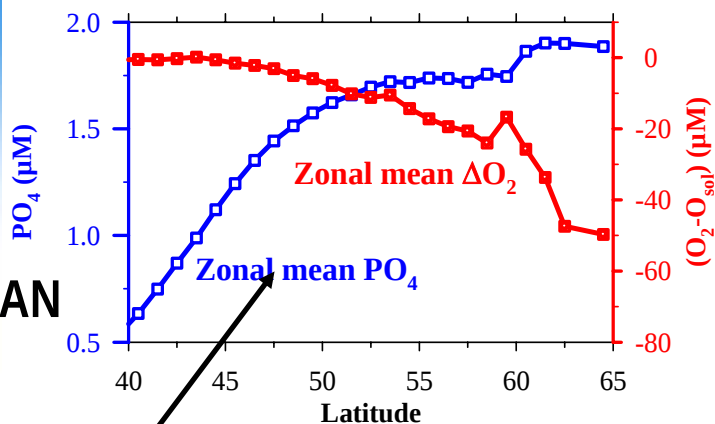
Pacific



North Pacific PO₄ Winter "entrainment"



N. Pacific FEB zonal mean (50 m)



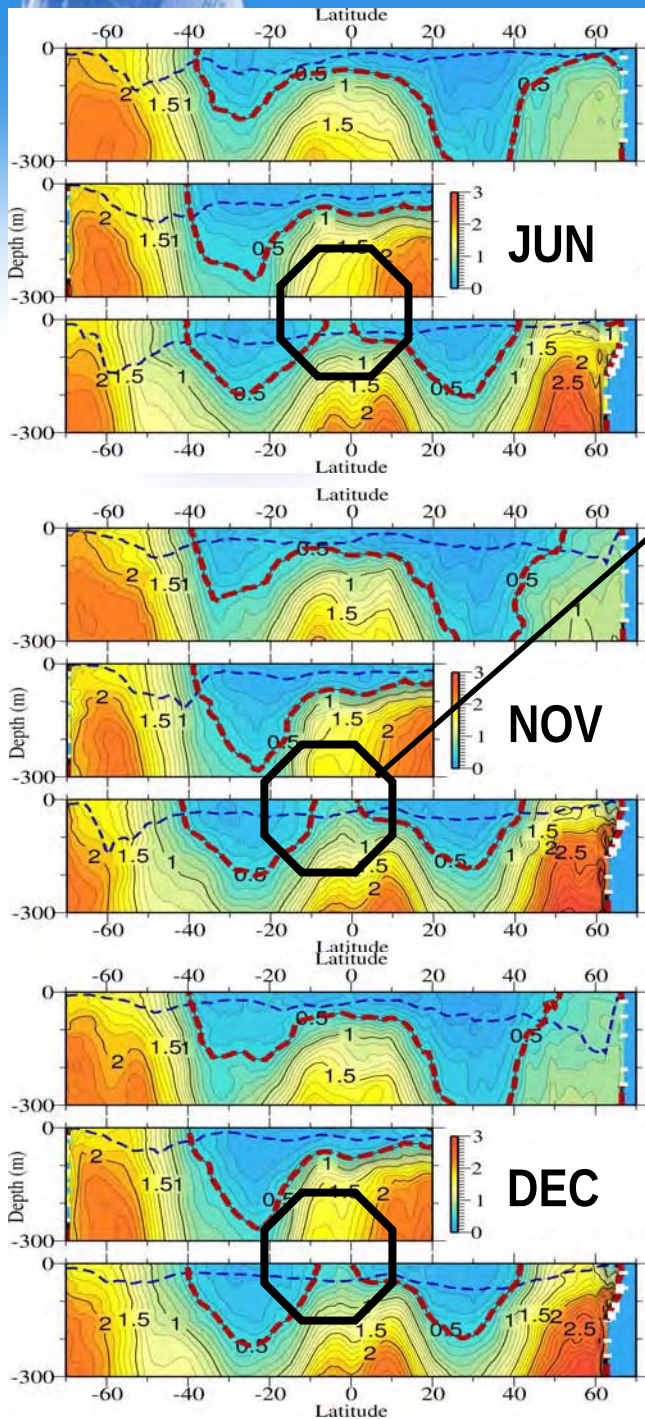
← Atlantic (top)

← Indian (middle)

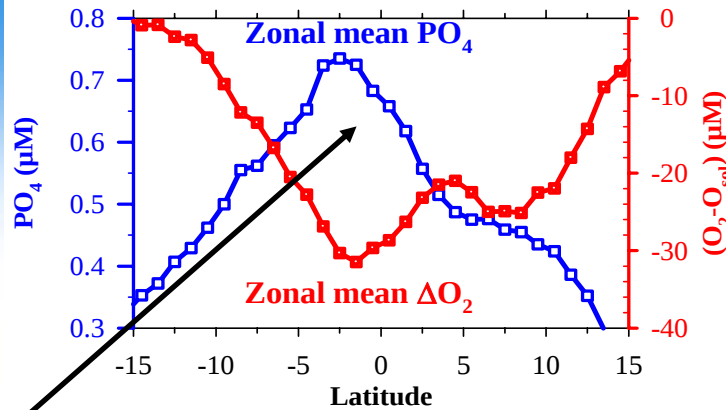
← Pacific (bottom)



Equatorial Pacific PO_4 “entrainment”



Eq. Pacific NOV zonal mean (50 m)



← Atlantic (top)

← Indian (middle)

← Pacific (bottom)

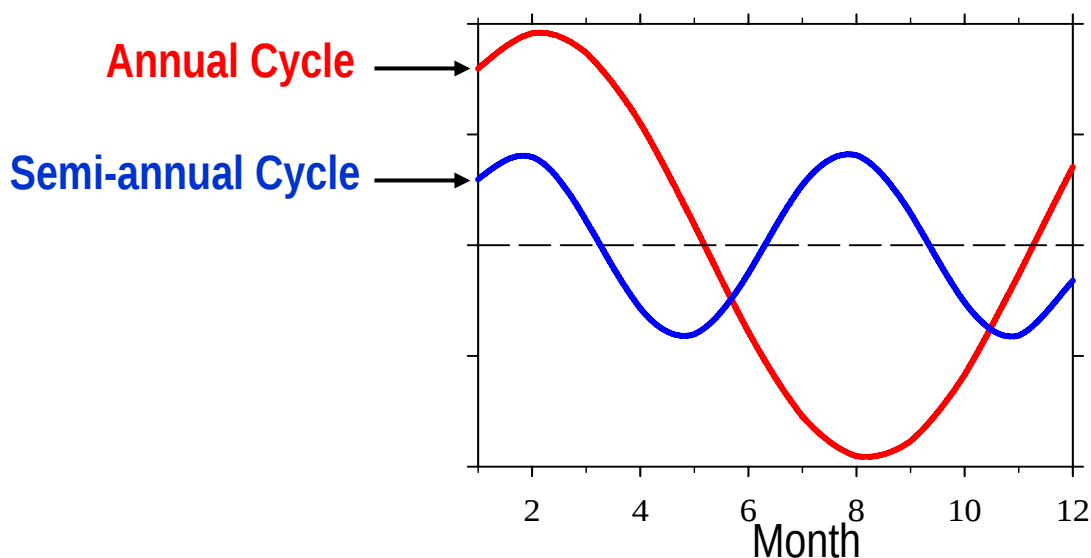


Integrated nutrient content anomaly

$$PC = A \int_{Z_i}^{Z_{i+1}} (P_{\text{mon}} - \overline{P_{\text{ann}}}) dz$$

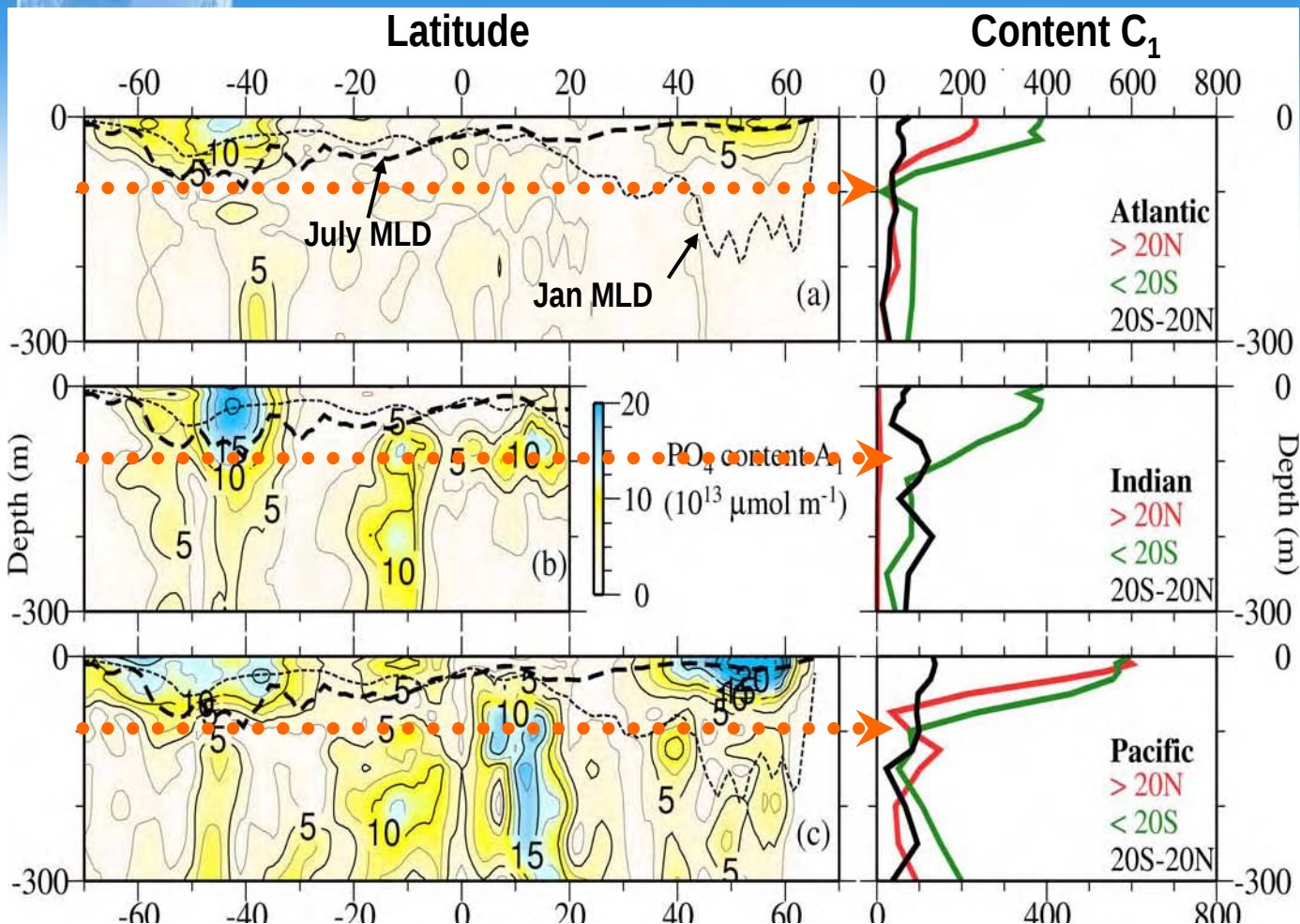
Fourier analysis on nutrient content anomalies

$$y(t) \approx \cancel{a_0^0} + a_1 \sin(\omega t) + a_2 \cos(\omega t) + a_3 \sin(2\omega t) + a_4 \cos(2\omega t) + \dots$$



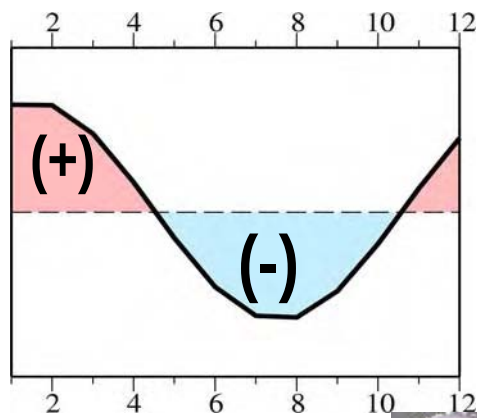
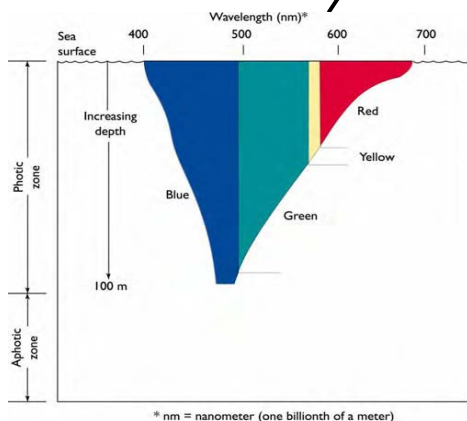


Amplitude (C_1) of zonal integral of PO_4 anomaly ($\times 10^{13} \mu\text{mol/m}$)



$$\text{PC} = A \int_{Z_i}^{Z_{i+1}} (\overline{P_{\text{mon}}} - \overline{P_{\text{ann}}}) dz$$

$$y(t) \approx a_0^0 + a_1 \sin(\omega t) + a_2 \cos(\omega t)$$

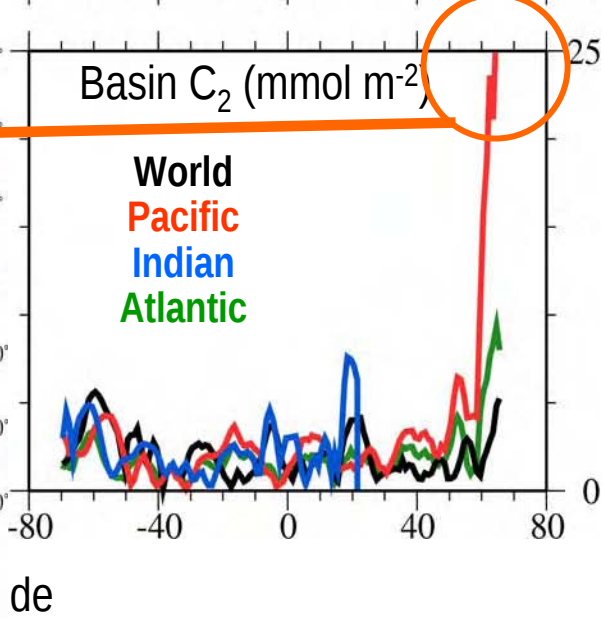
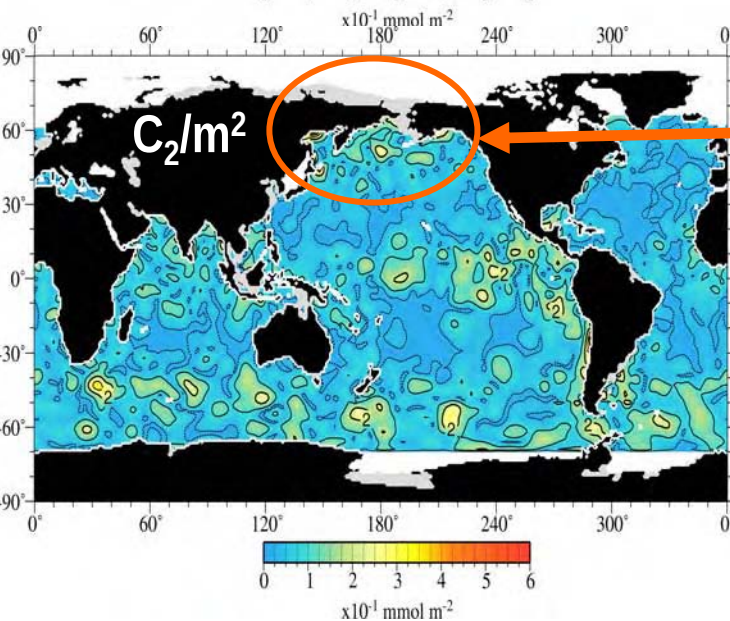
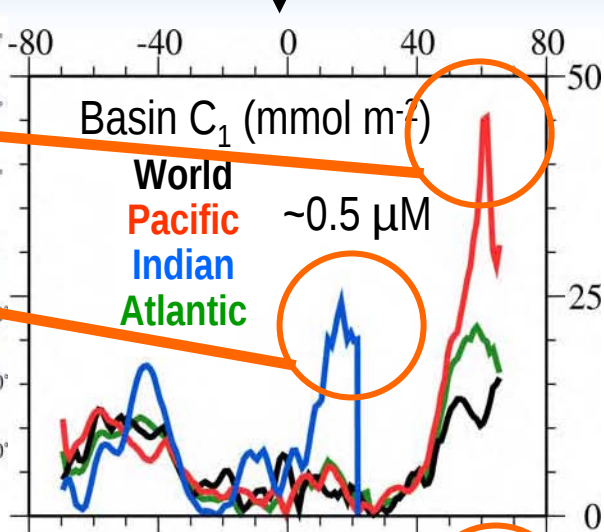
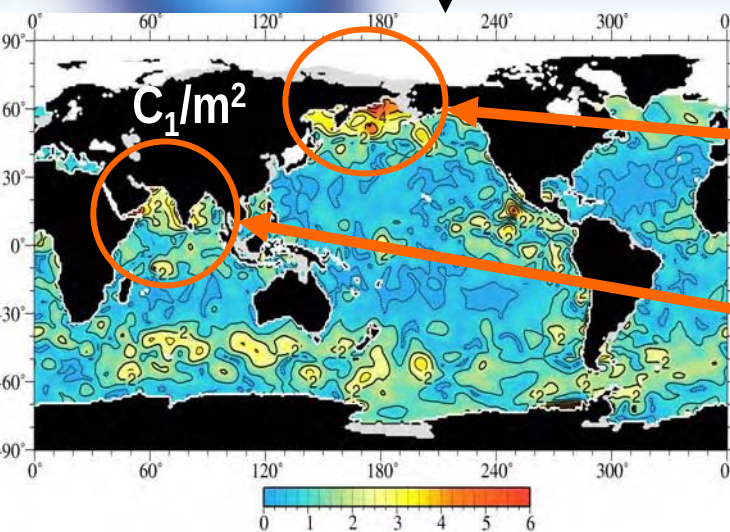




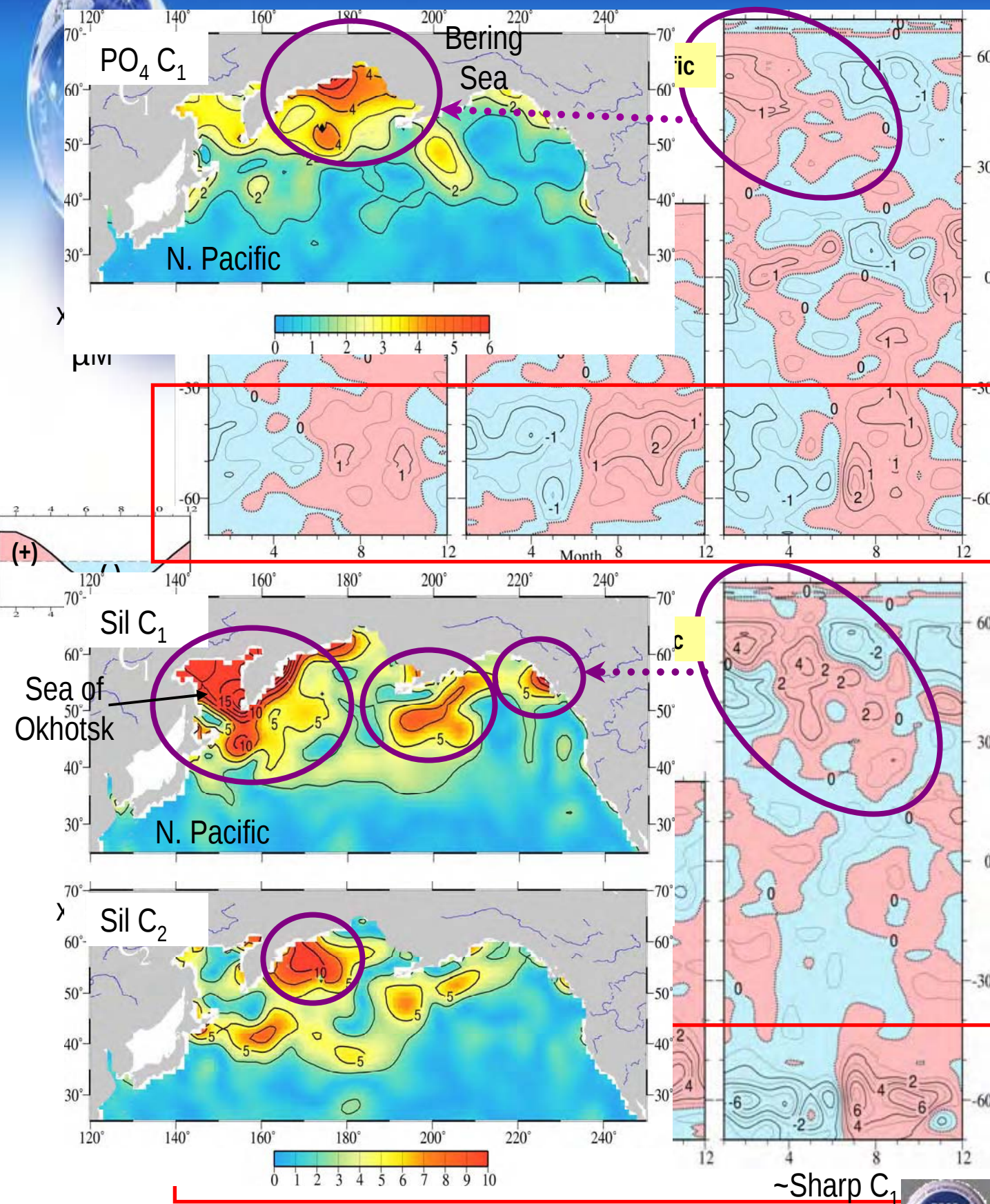
PO₄ anomaly basin integral 0-100m (C₁ and C₂)

Amplitude

Amplitude/m²



Integrated monthly content anomaly 0-100 m



~Sharp C_1



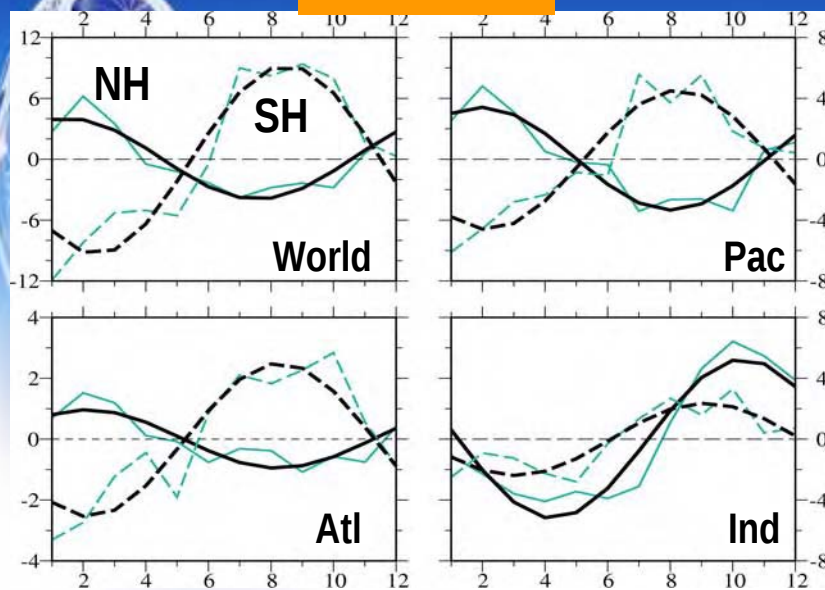
Month

Basin content
($\times 10^{16}$ μmol)

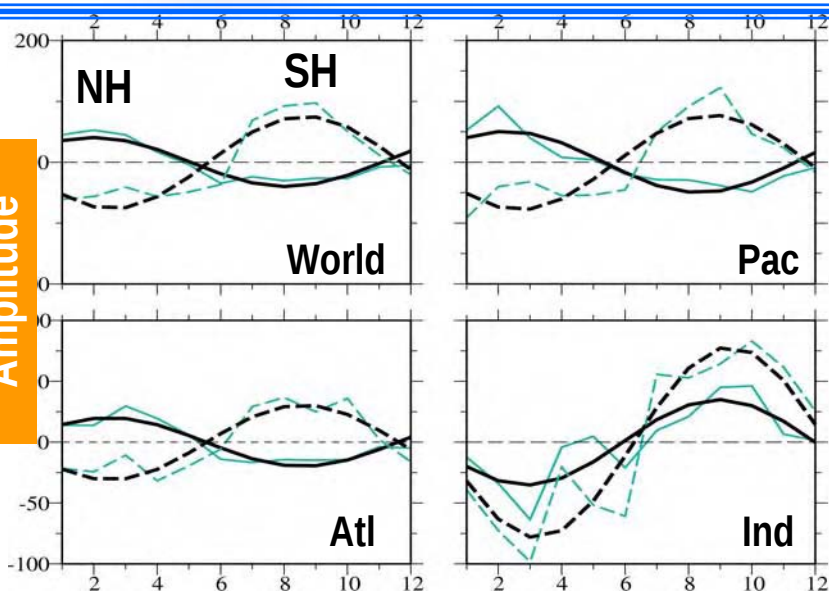
observed C_1

PO_4

77-92%

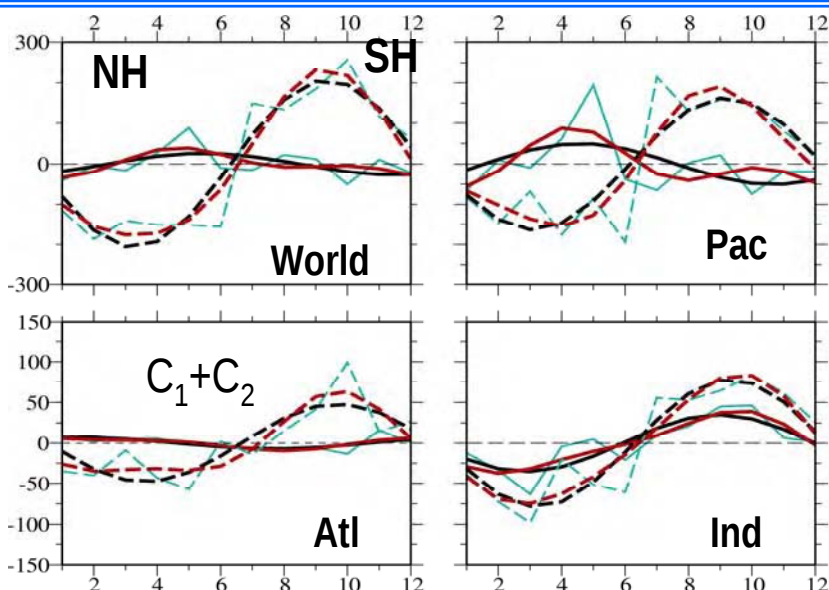


Amplitude



NO_3

76-94%



Si(OH)_4

Lat	% C_1	% C_2
$>0^\circ$	26-70	6-18
$30-70^\circ$	44-88	14-15

$C_1 + C_2$





Relation between nutrient cycles (C_1 phasing) 0-100 m

Southern Hemisphere

Northern Hemisphere

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11 12

P

SH World

NH World

NO_3
 PO_4

S. Pacific

N. Pacific

PO_4
 NO_3

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11 12

Month

Relative Scale



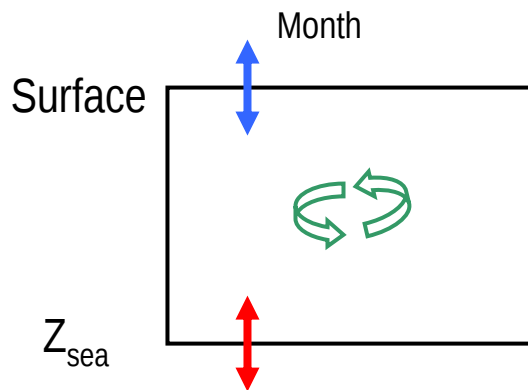
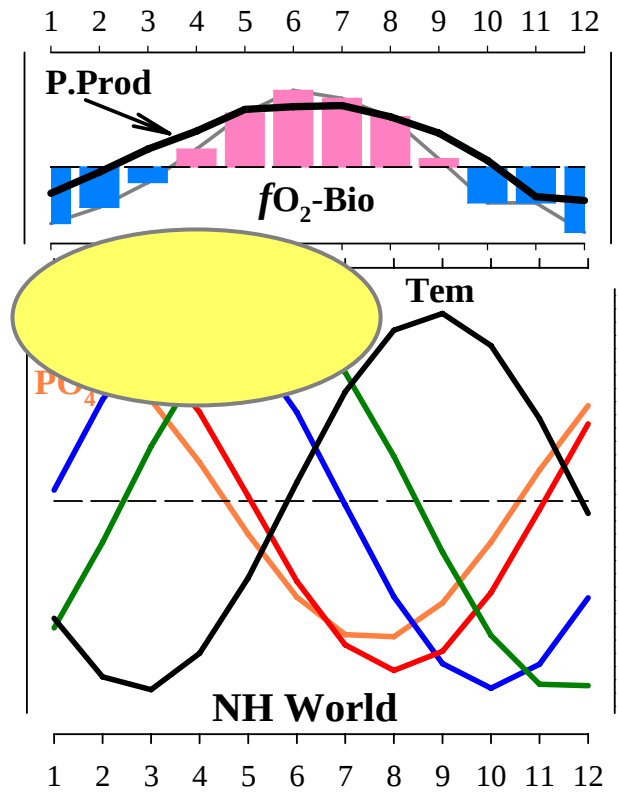
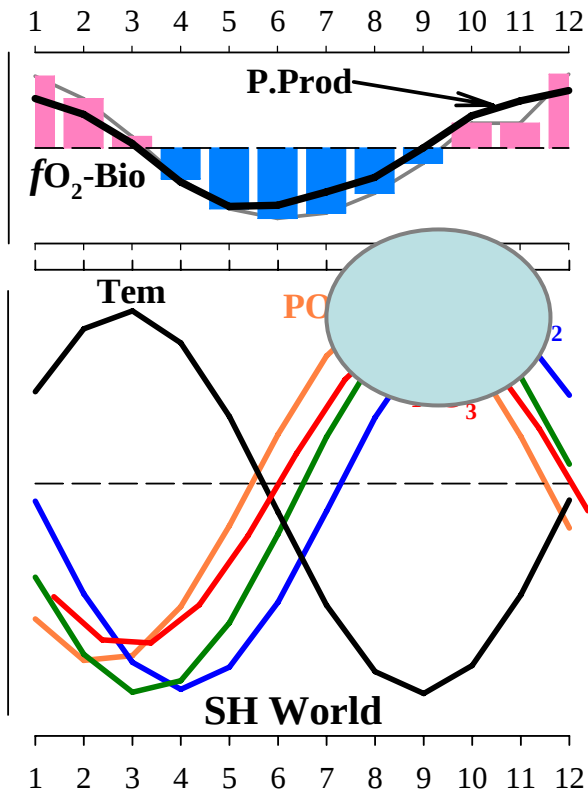


Ultimately...relation between cycles?

Southern Hemisphere

Northern Hemisphere

Relative Scale



Air-sea O_2 flux: Garcia and Keeling (2001)
P. Prod: CZCS (Antoine et al. 1996)



Biological Pump

Nutrient Utilization



Sun

Air-sea



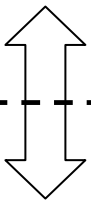
Summer



Low

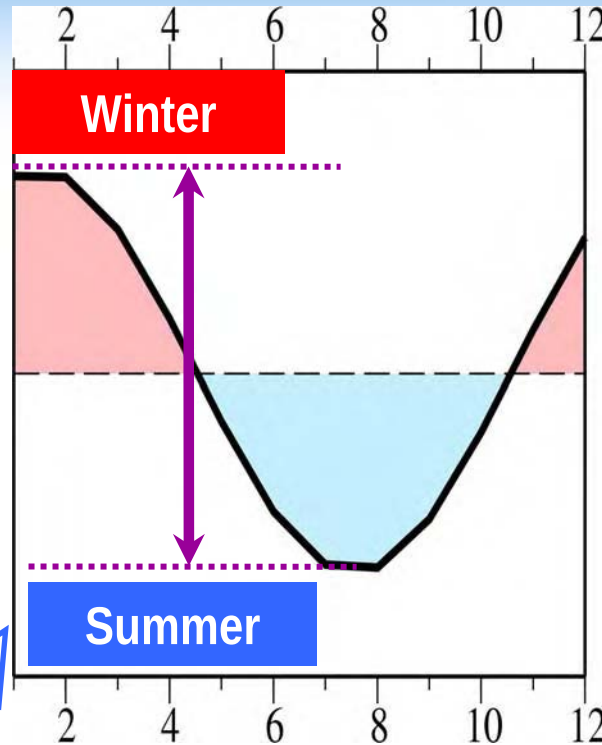
Nutrients/Carbon

Winter



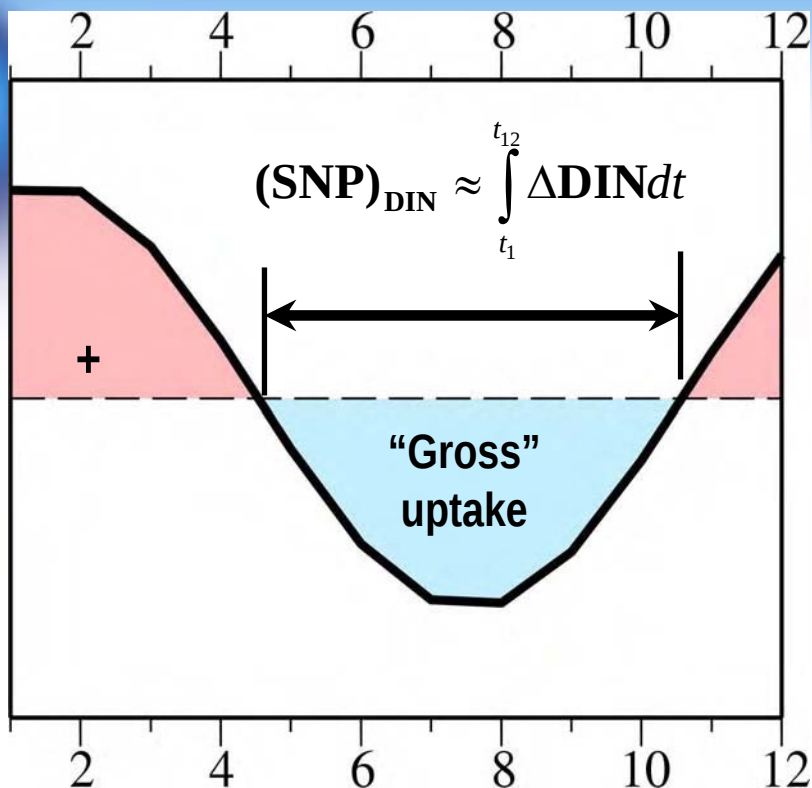
Mixed
layer

High
Nutrients/Carbon





Seasonal Nutrient Production (SNP)

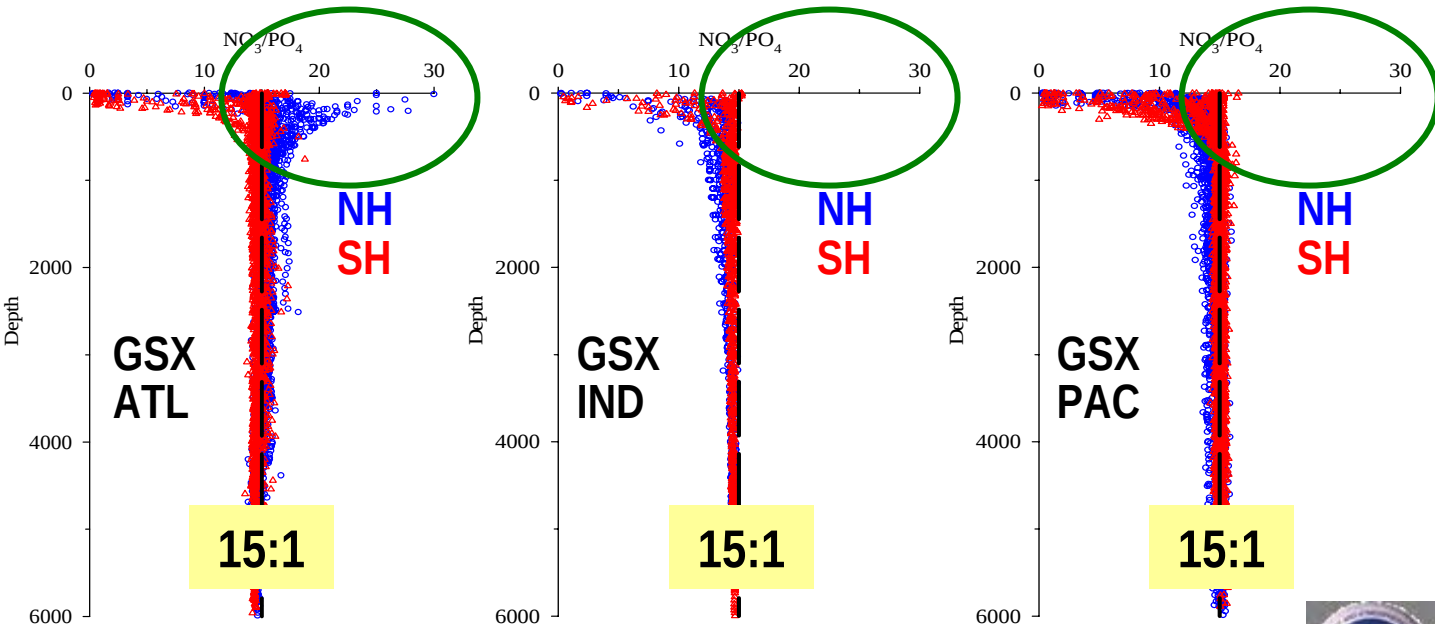
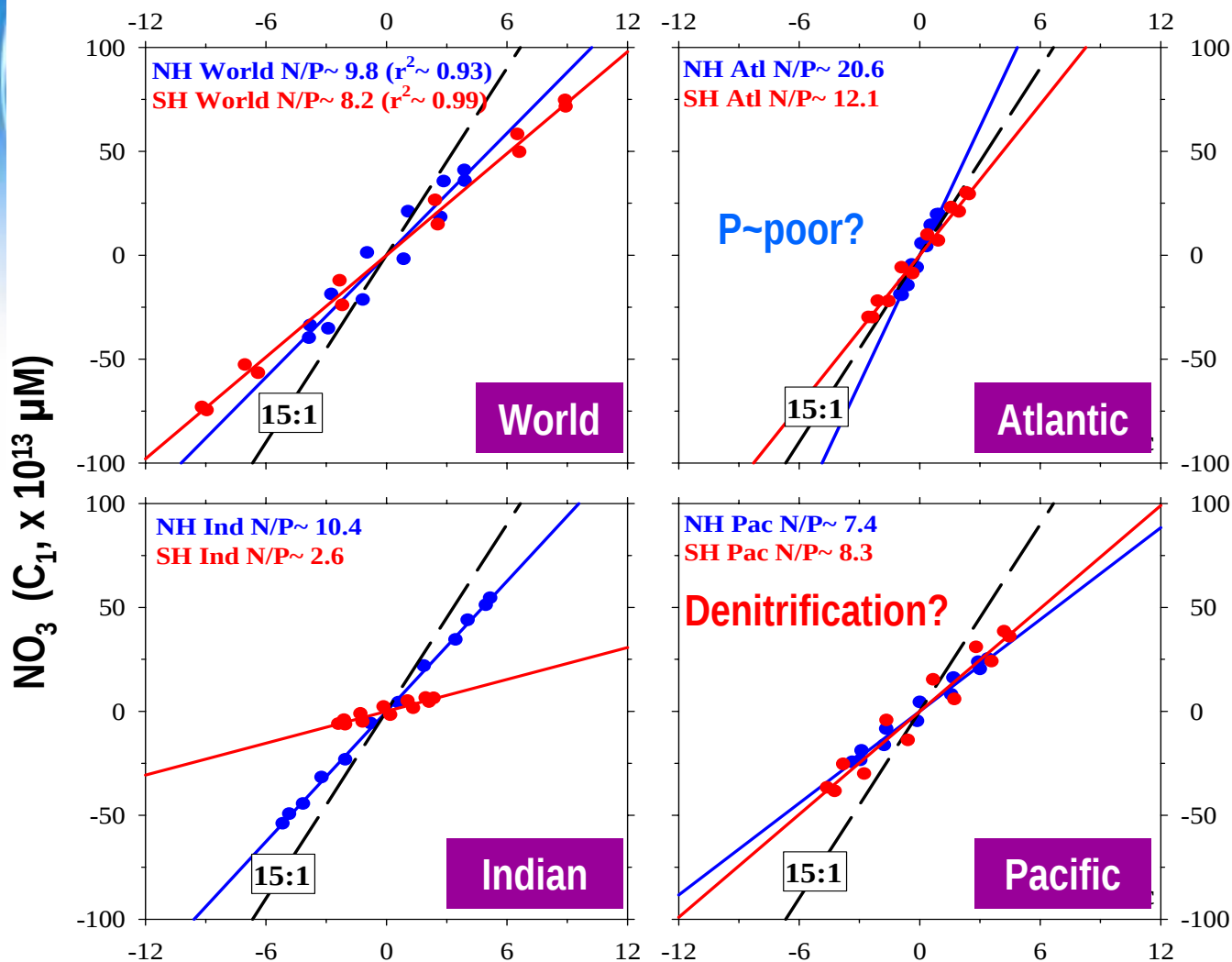


Issues:

- Regenerated production
- Denitrification, DOP/DON
- Steady new production=export
- Dissolution
- Mixing...

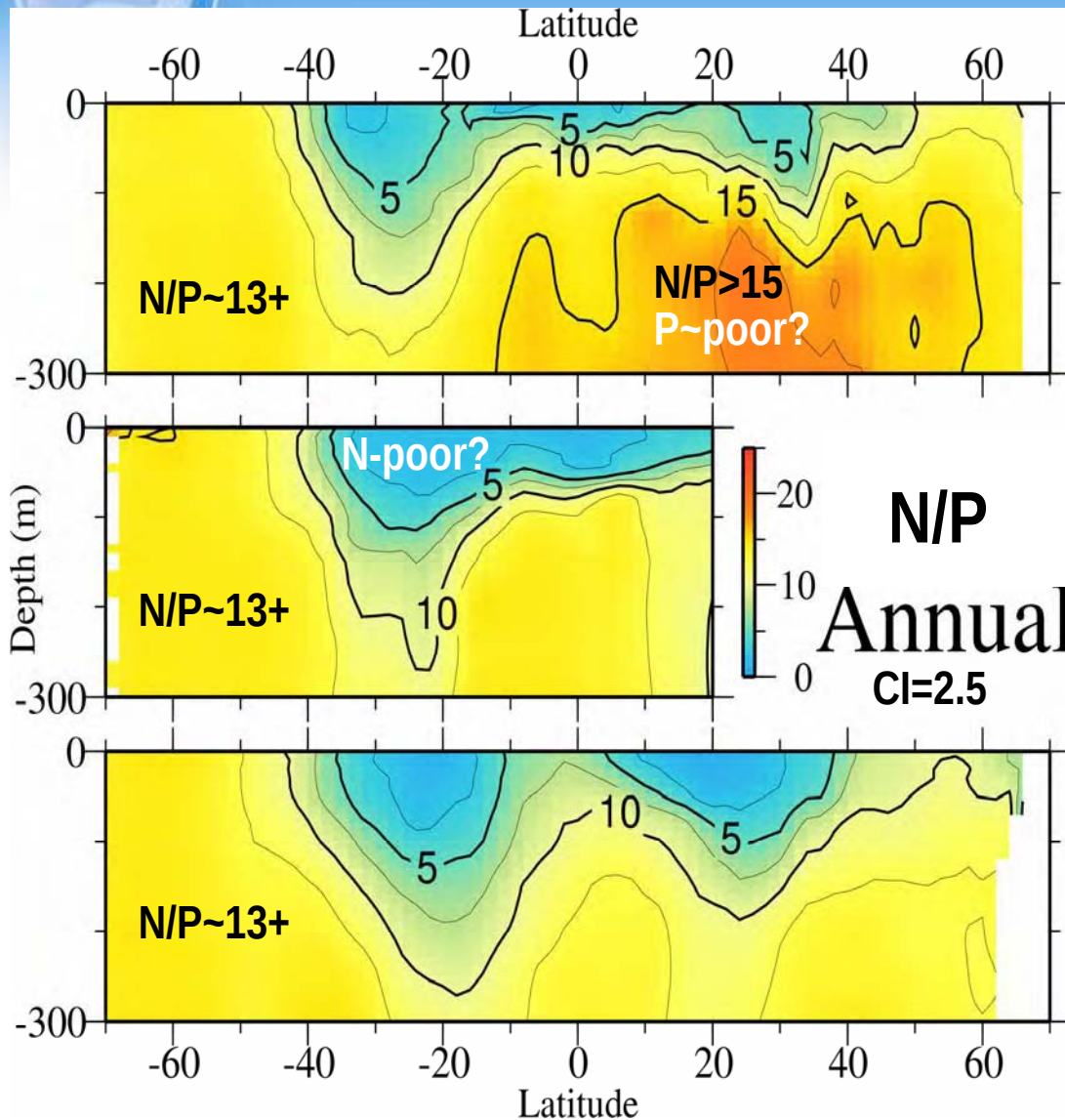


Climatological N/P ratios (C_1) sub-RKR for 0-100 m?





Climatological N/P ratios of zonal annual mean (0-300m)



Atlantic

Indian

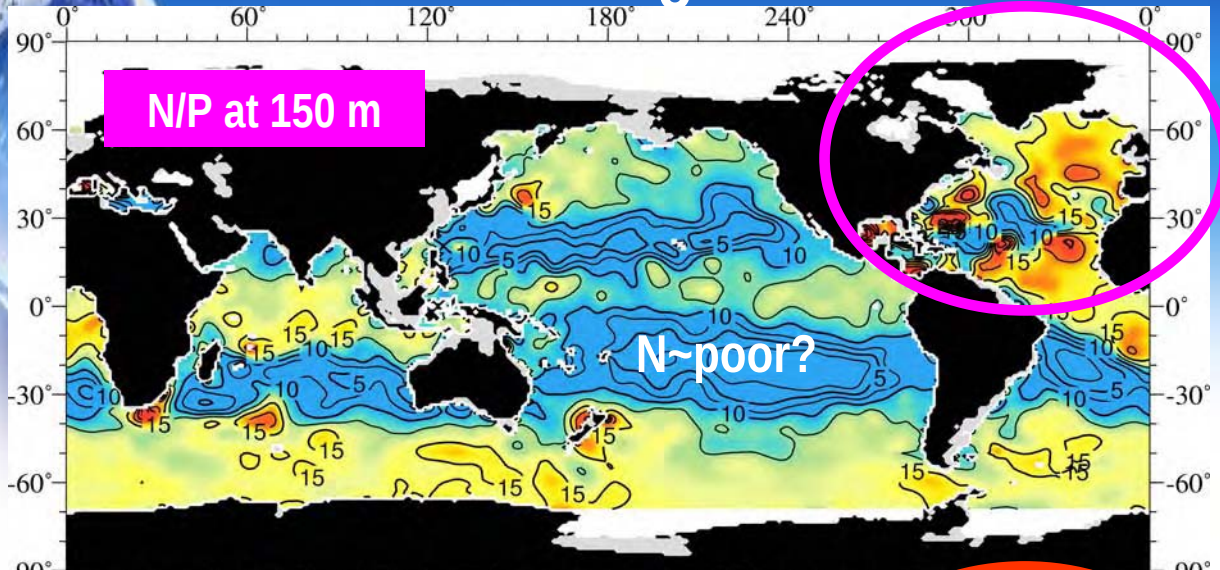
Pacific

Near-surface waters (0-100 m):

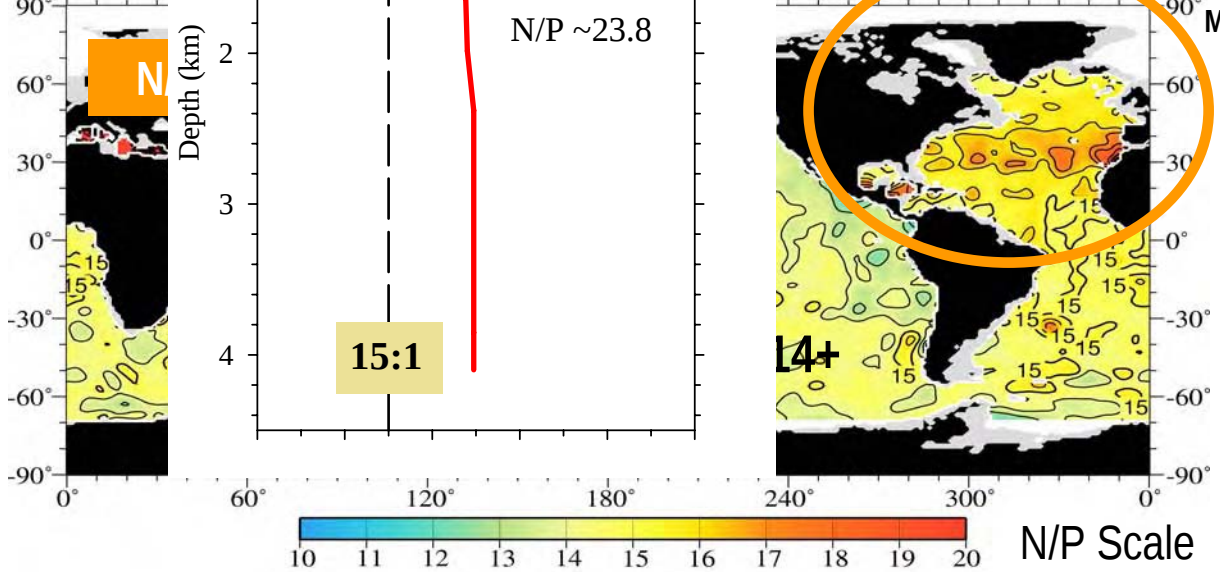
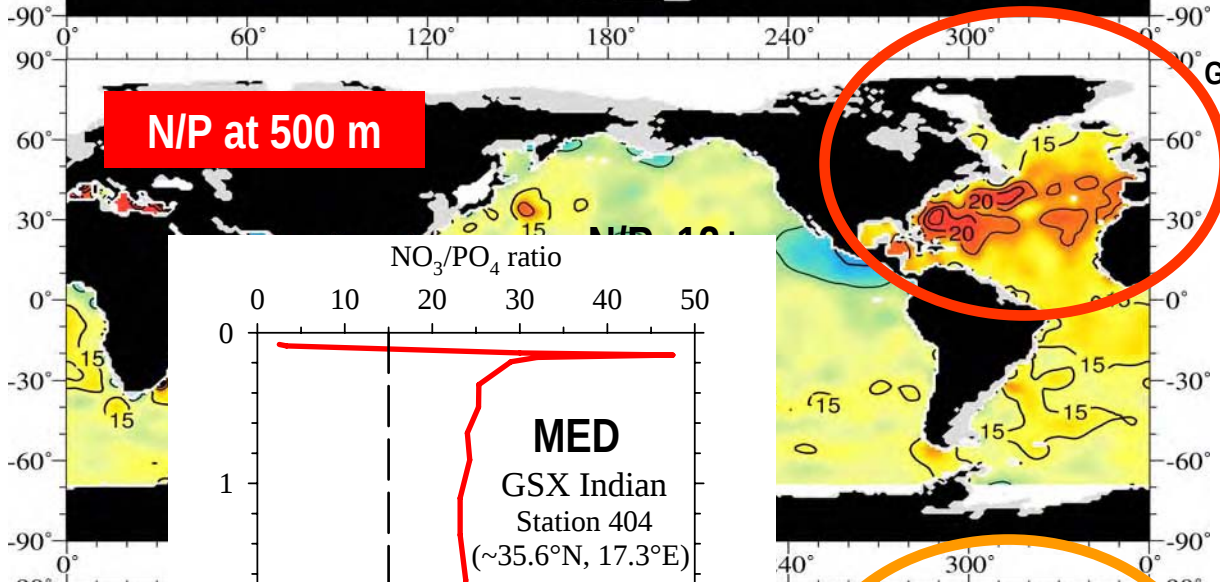
N/P sub-RKR 15:1 (*i.e.*, gyres)?

N. Atlantic P-sink and N. Pacific N-sink?

N/P climatological ratios



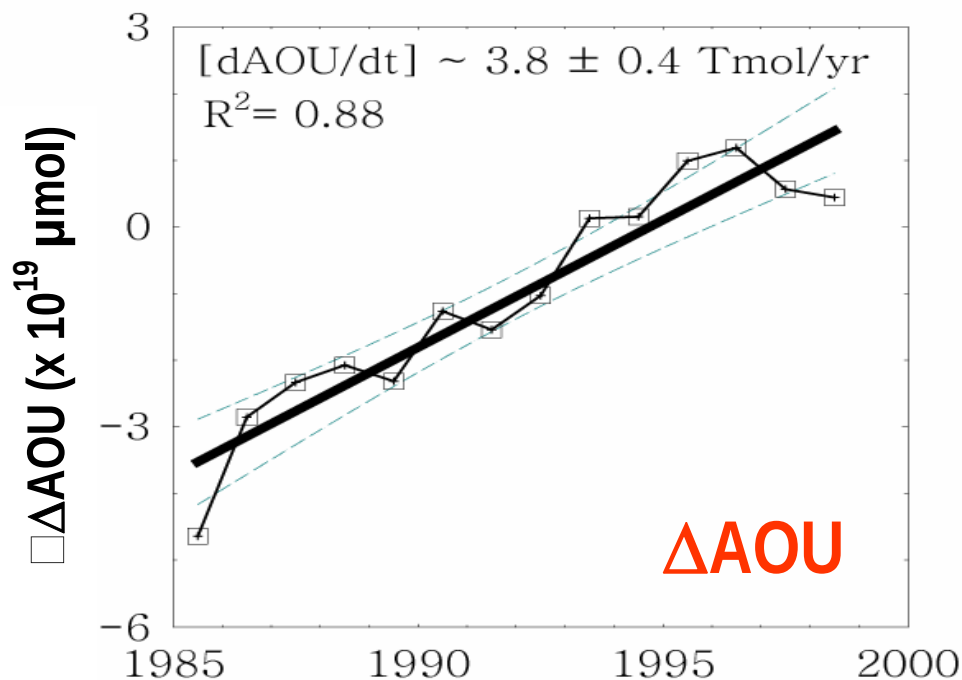
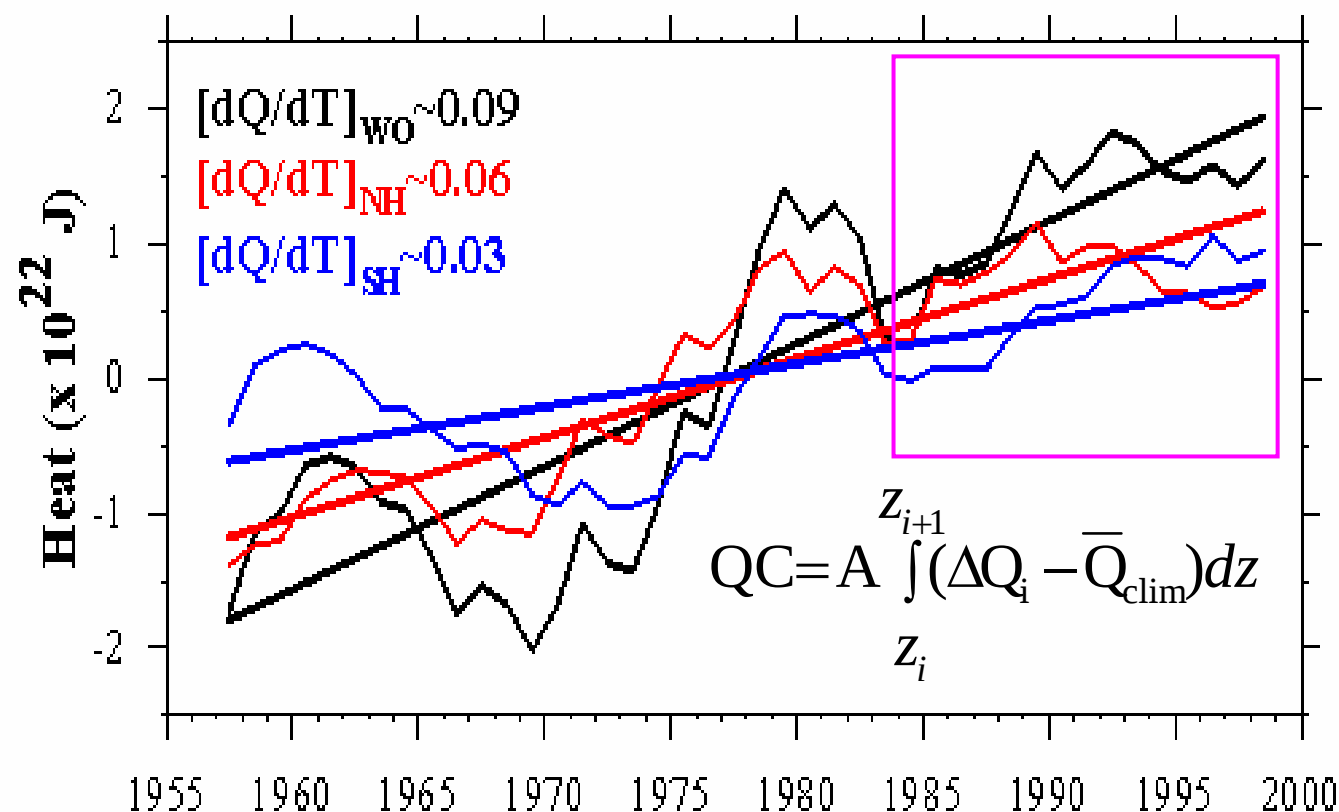
??



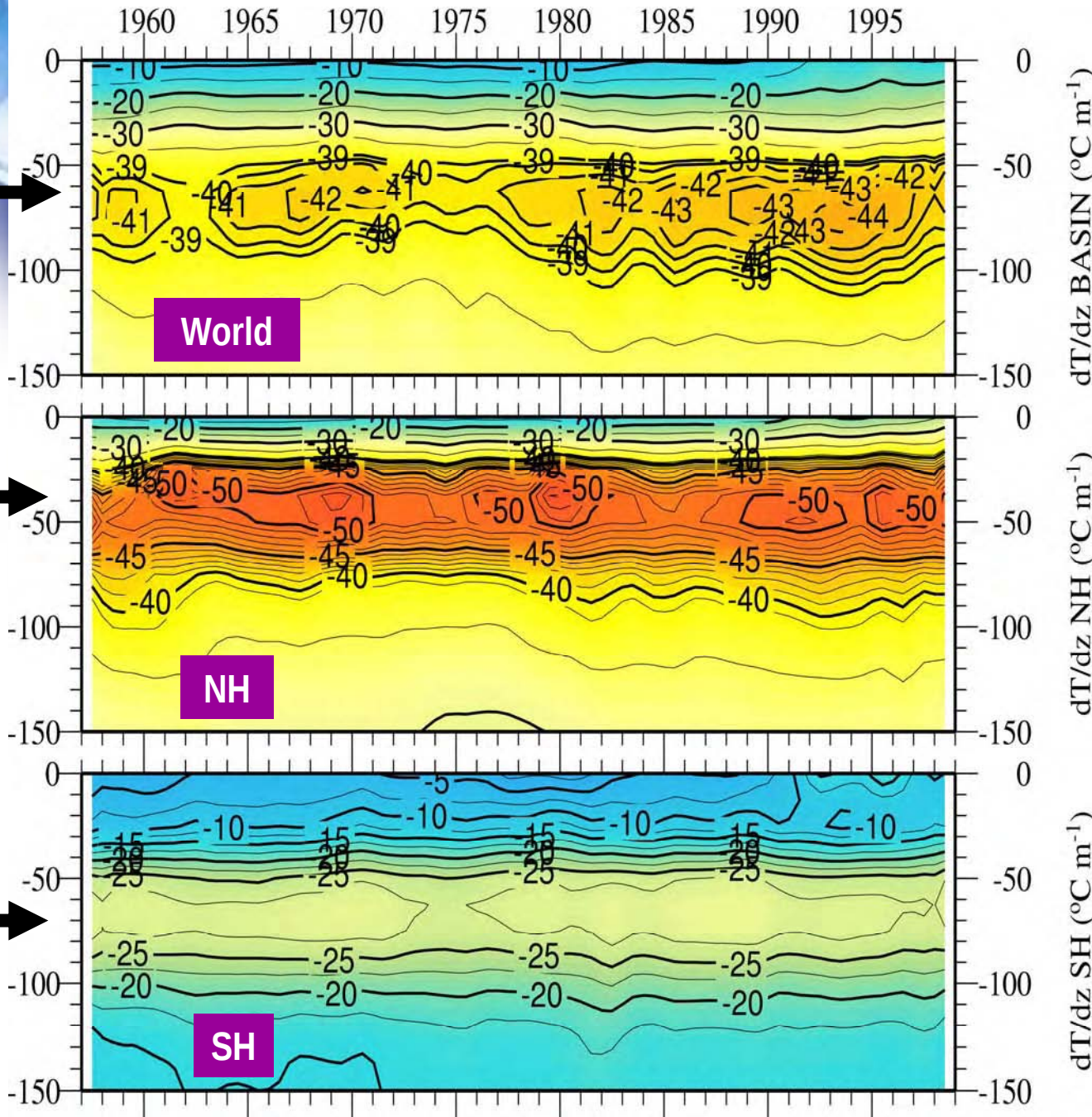
MED/GS?

Heat content variability (0-100m; 70°S-70°N)?

WOA01 Linear trends on heat content (0-100 m)



Vertical stratification variability (C/m)



$$d(T_i + \bar{T})/dz$$

Summary

- 🌐 WOD05 and WOA05 are available (free).
- 🌐 Surface nutrient amplitude largest ~75 m (extra-tropics ~40°-60° band); large sub-surface equatorial Pacific seasonality.
- 🌐 First-order nutrient cycle: 2 harmonics (C_1 & C_2). Amplitudes are significant. Integral provides gross nutrient uptake.
- 🌐 Preformed N/P ratios are sub-RKR except in the N. Atlantic. N. Pacific appears N-poor near surface in the RKR sense (implication to C/N)
- 🌐 Net effect of vertical stratification variability (T, S) on vertical fluxes?

Thank you!