# Documenting seasonal to decadal variability in Phosphate Content

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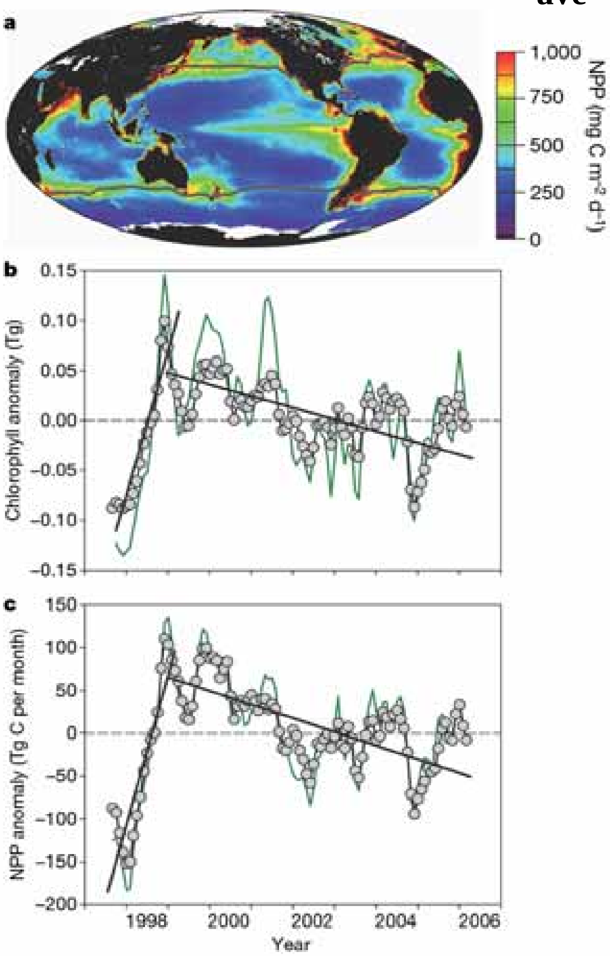
# OUTLINE

- How much $PO_4$?
- $PO_4$ seasonal to decadal variability?
- Role of stratification variability?

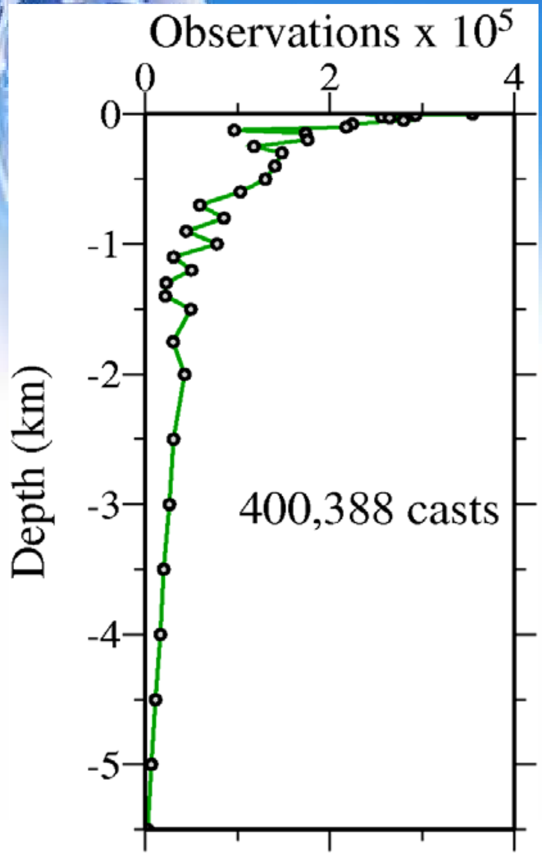
$$\mathbf{DIN = DIN_{ave} + \delta DIN_{sea} + \delta DIN_{LFV}}$$




After Behrenfeld *et al.* 2006

Net Primary Production is regulated by the bio-availability of “nutrients”, in turn largely regulated by physics.

# Data sources: World Ocean Database/Atlas 2005

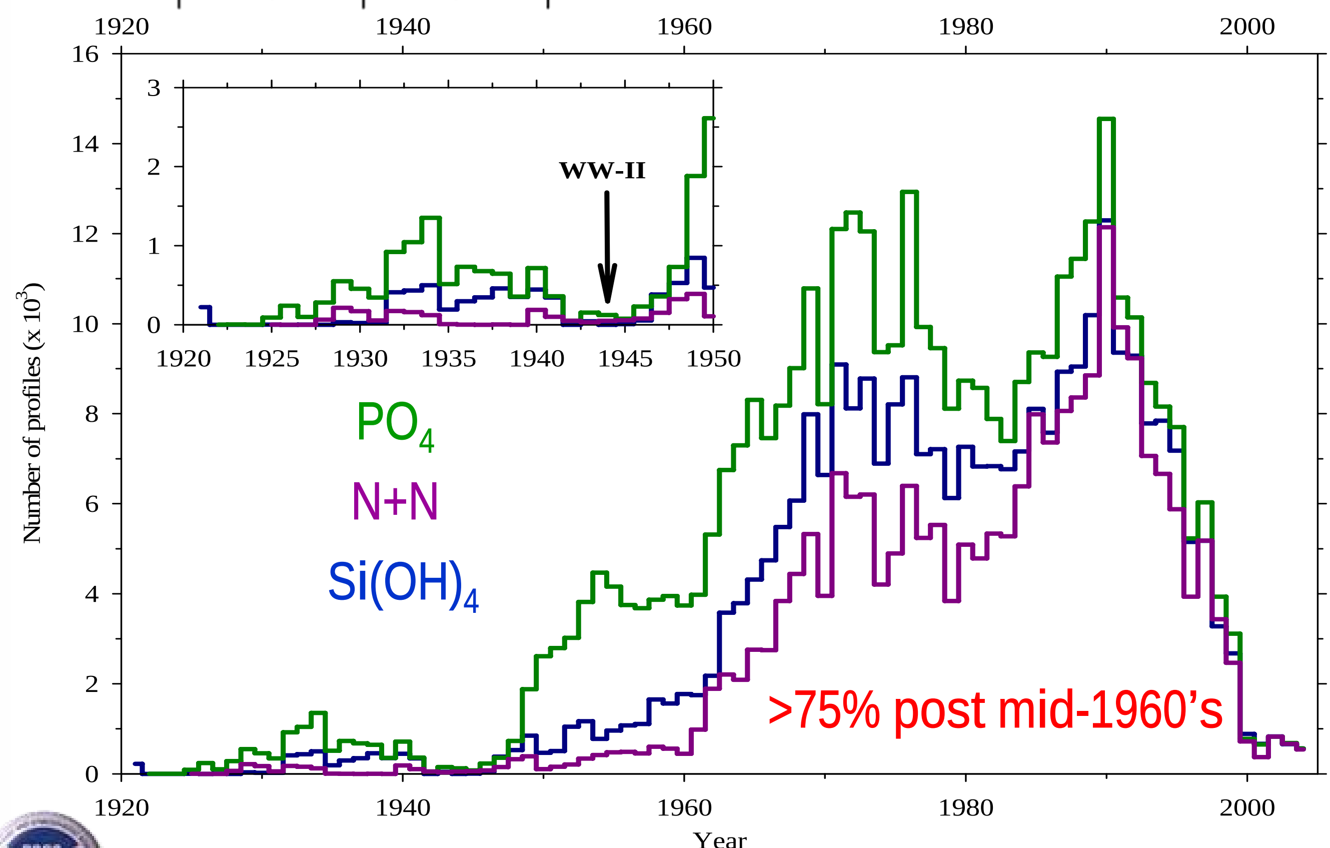



**~$3.6 \times 10^6$ observations**

**~$1.9 \times 10^6$ in the upper 100 m**

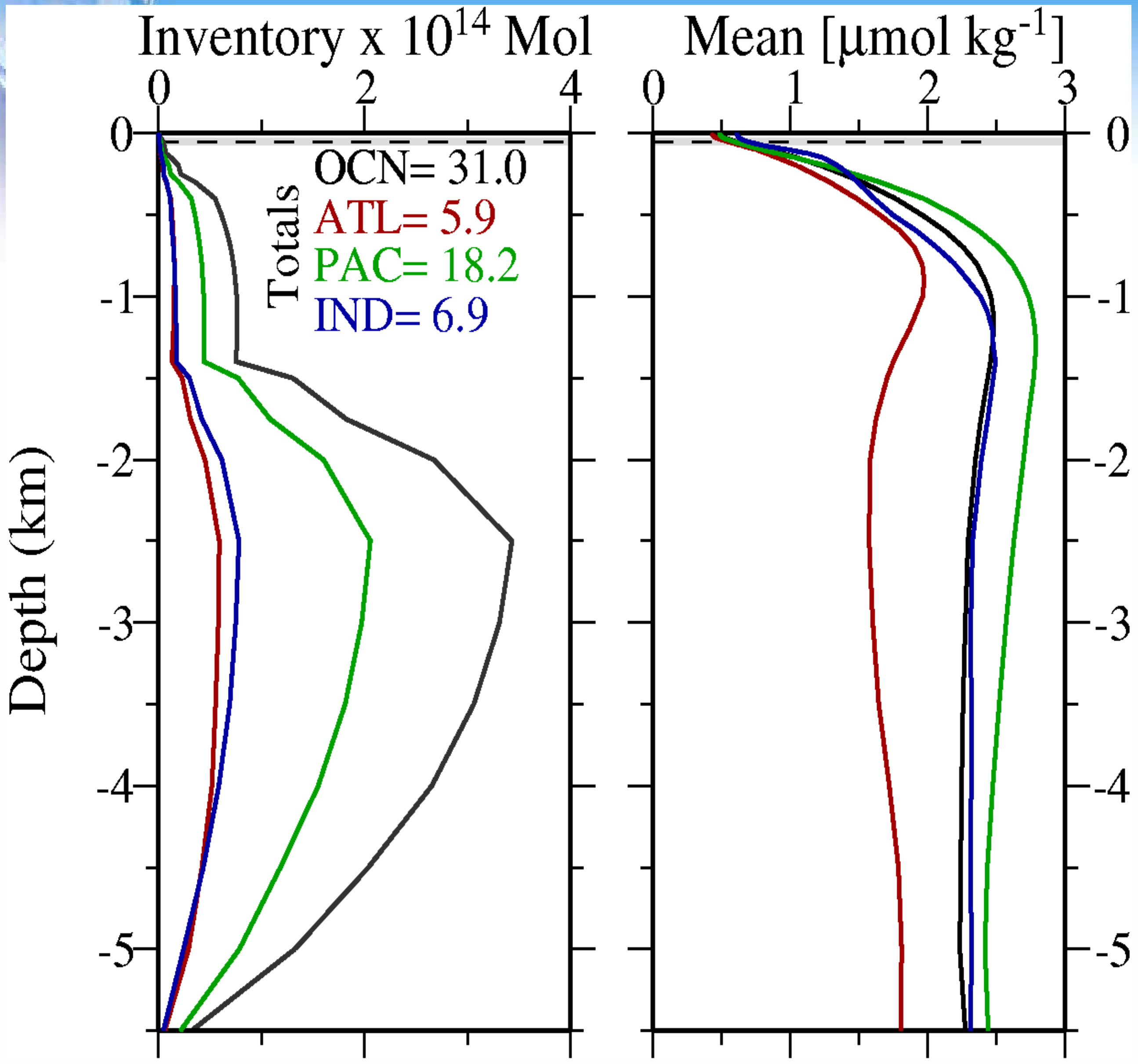
## Issues

- Non-uniform spatial/temporal coverage
- Changes in Instrumentation and techniques over time
- Precision/reproducibility of data and CRM.



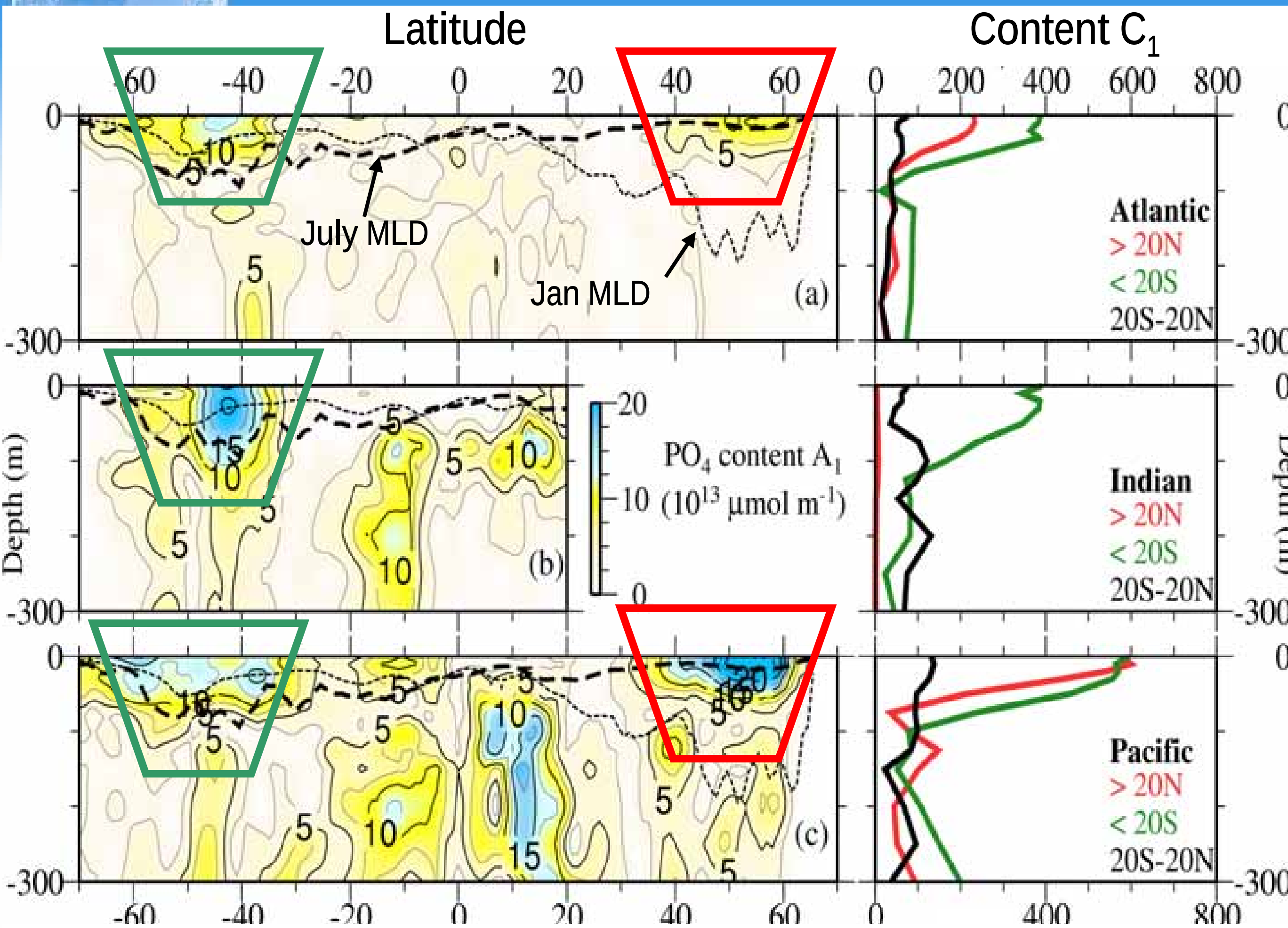
# Climatic Mean Ocean $PO_4$ content

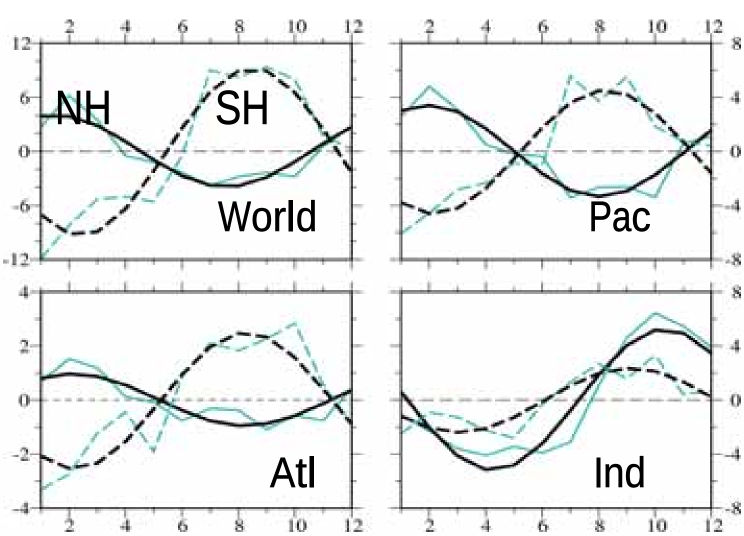
## 70°S-70°N (open ocean)




**(~59% in the Pacific)**

# Seasonal Signal: Amplitude ($C_1$) of zonal integral of $PO_4$ anomaly (x $10^{13}$ μmol $m^{-1}$)



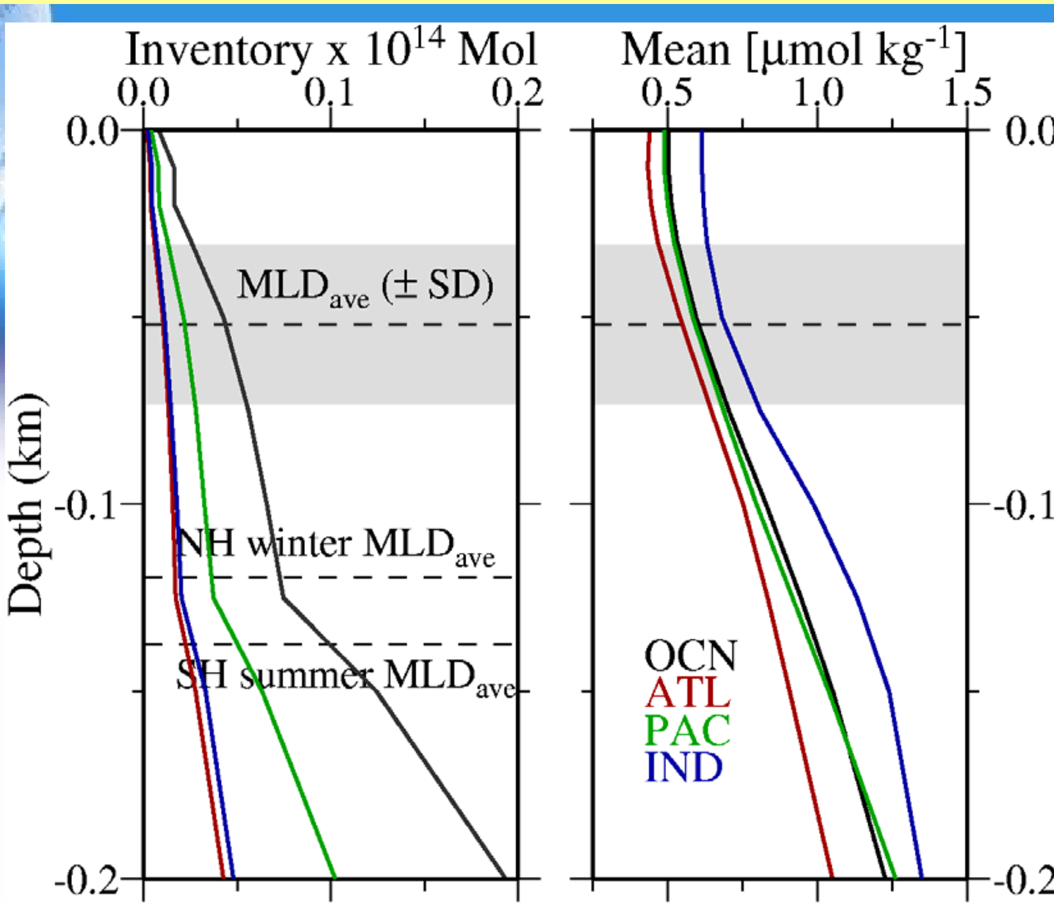

$$PC = A \int_{z_i}^{z_{i+1}} (\mathbf{P}_{mon} - \overline{\mathbf{P}_{ann}})dz$$

Ind

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

0

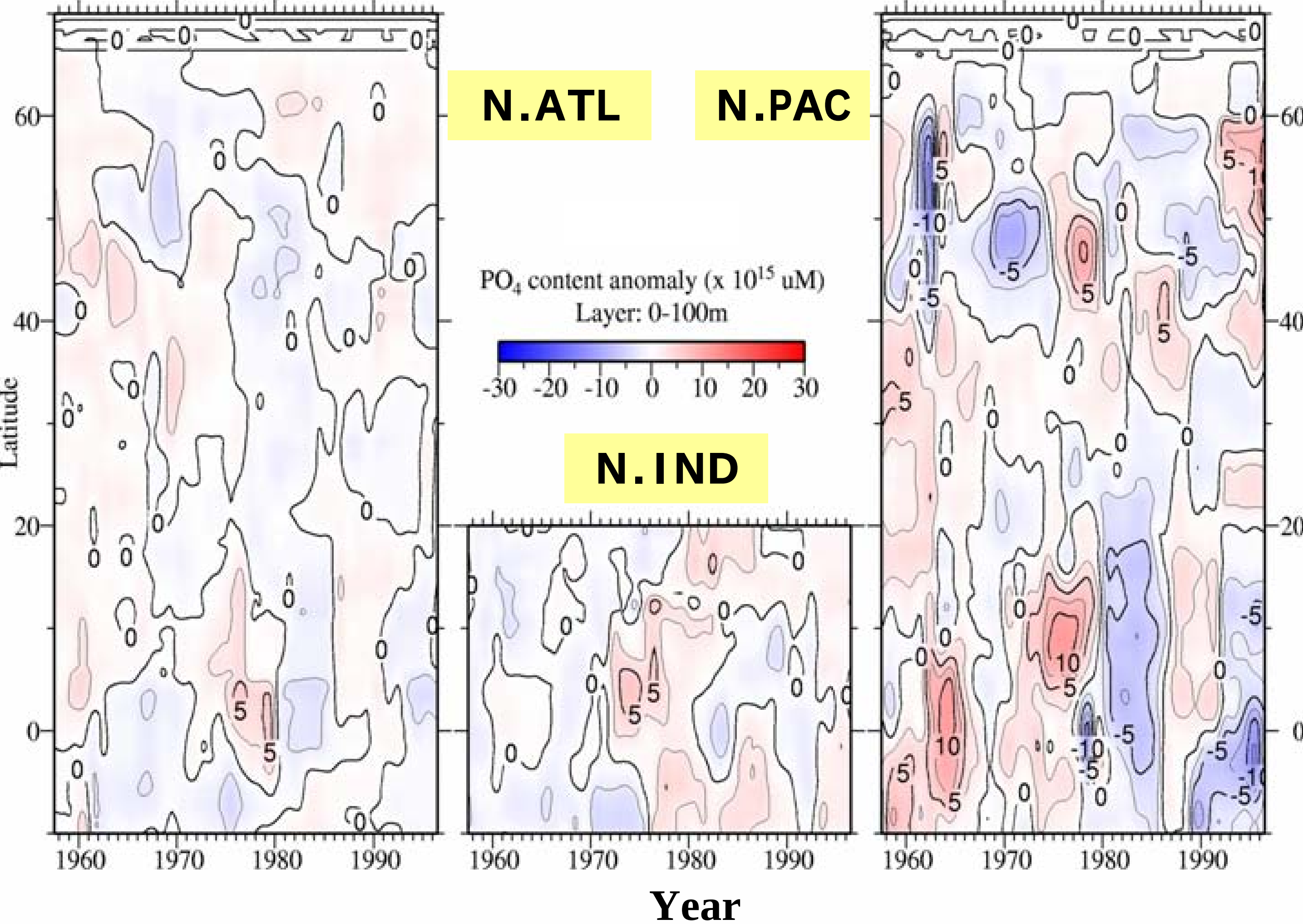
# Decadal Signal: Upper-ocean $PO_4$ content

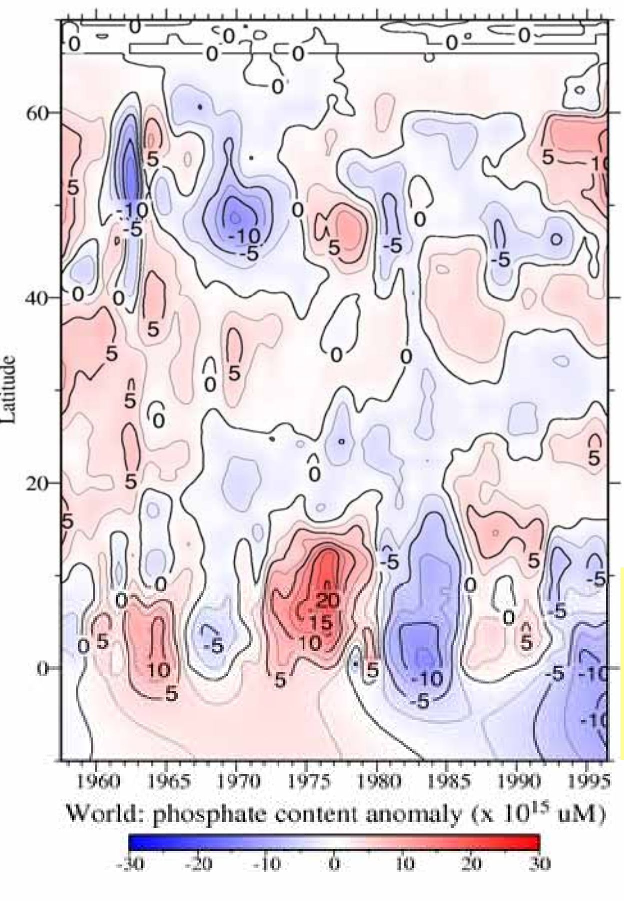



**Simple case (relative to a stationary $PO_4$-cline) :**

Deepening or weakening of "thermocline (as *proxy*)" nominally results in the mixing of more nutrient-rich deeper waters into the generally more depleted surface waters.

*e.g.*, a transient 20 m deepening of depth of mixing in the N. Pacific implies a nominal ~0.12 µmol kg$^{-1}$ increase in $PO_4$ to surface waters.



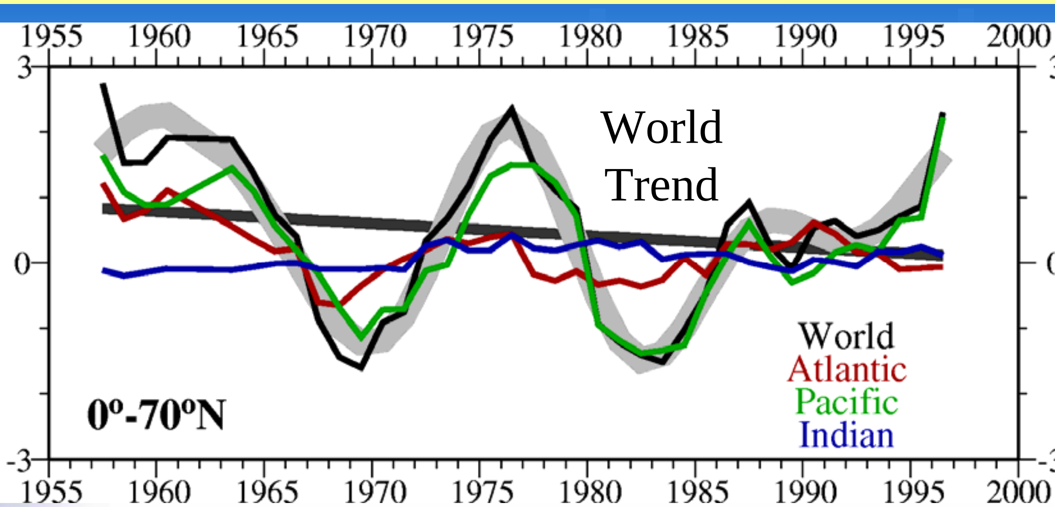

**NH World Ocean**

## Decadal $\Sigma PO_4$ content (0-100 m)

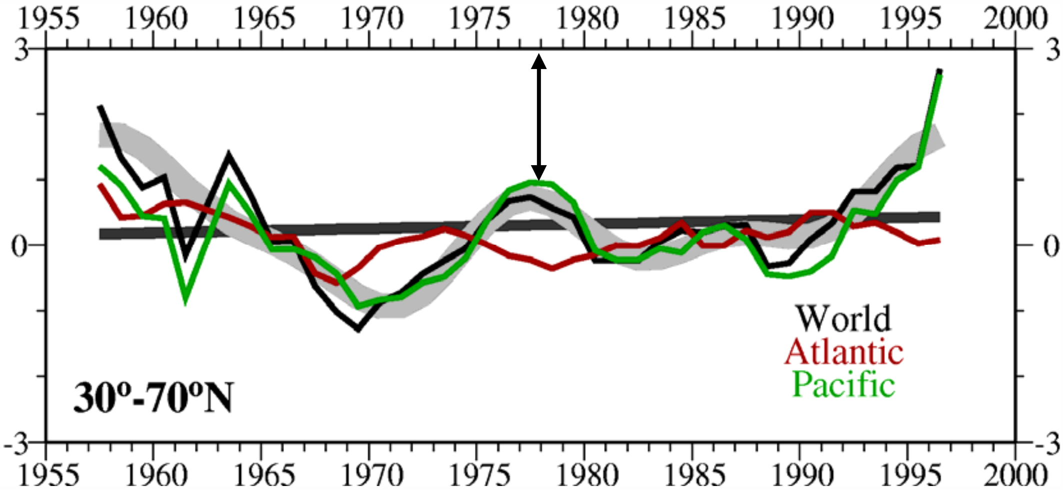
- High/low latitude phasing
- Lat bands of changes
- Pacific dominates ocean signal

# Decadal $\Sigma PO_4$ content ($\times 10^{17}$ µmol; 0-100 m)

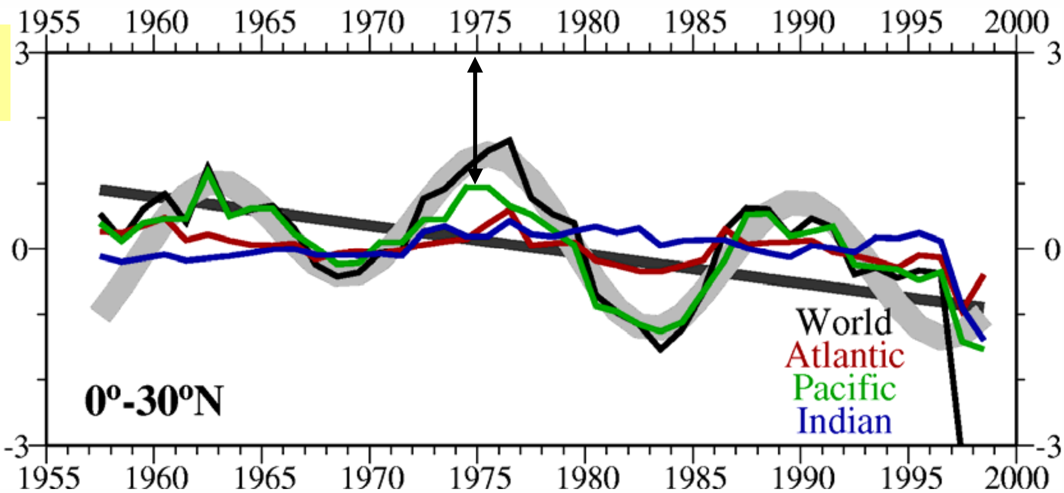
**NH**




**Extra-tropical**

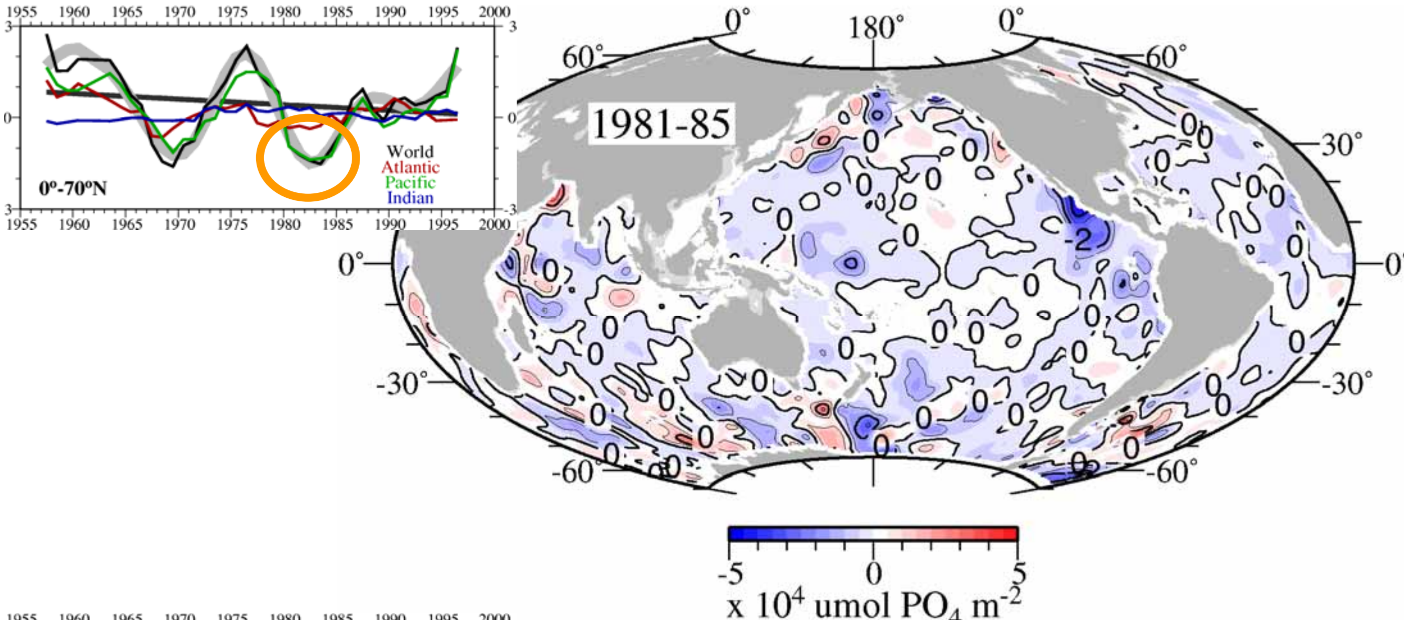


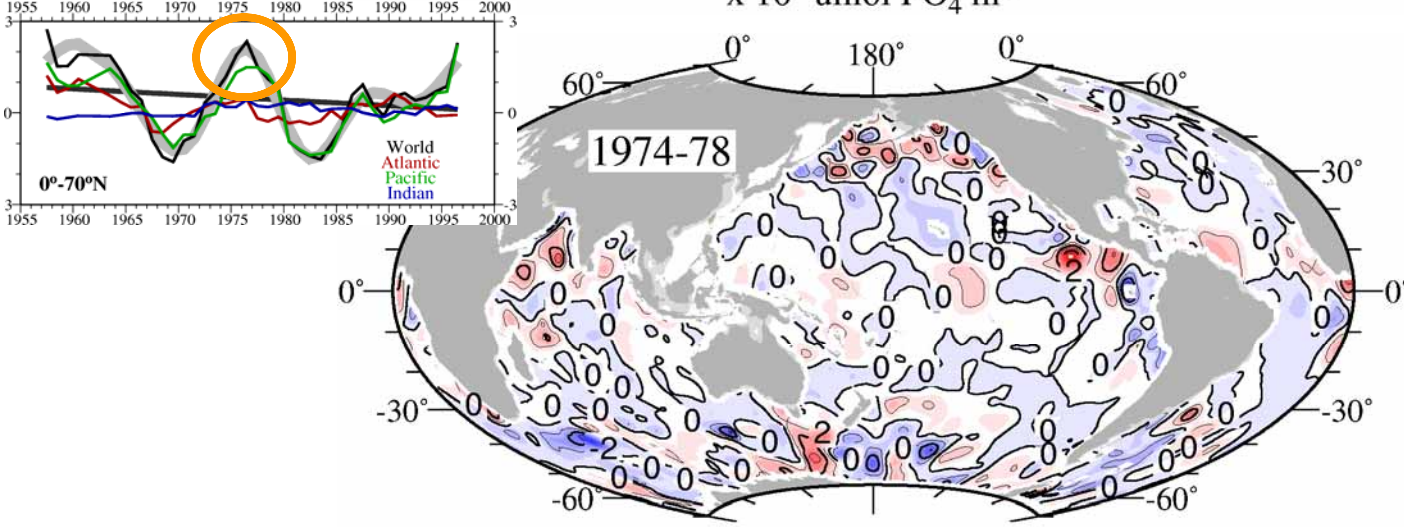

**Tropical**

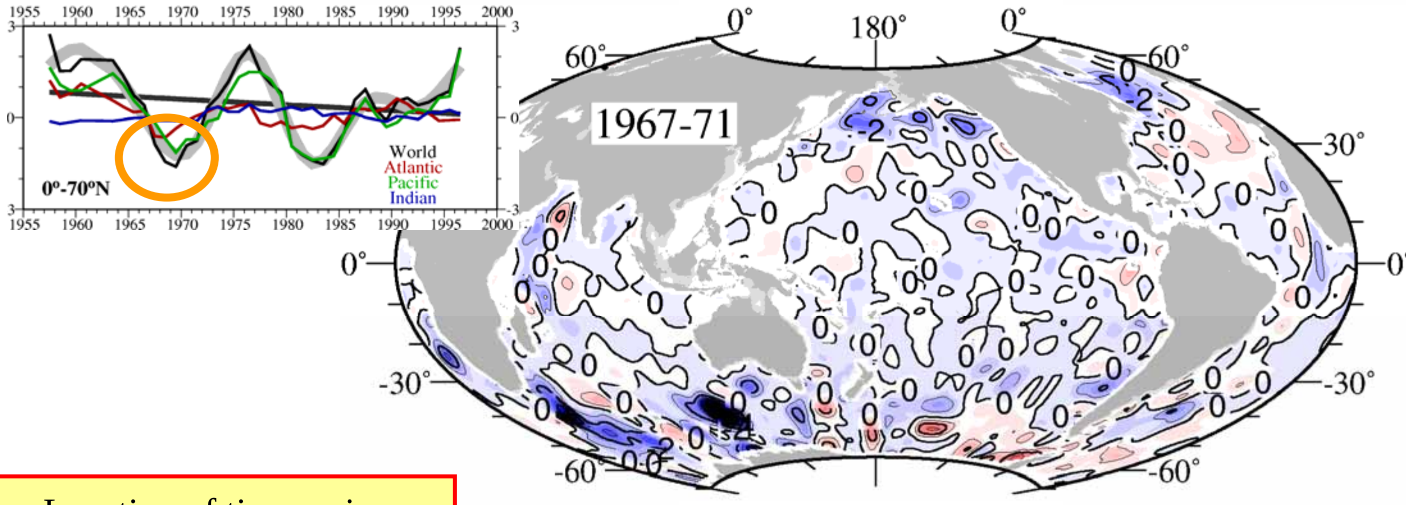



**Year**

# Decadal $\Sigma PO_4$ content anomaly (0-100 m)



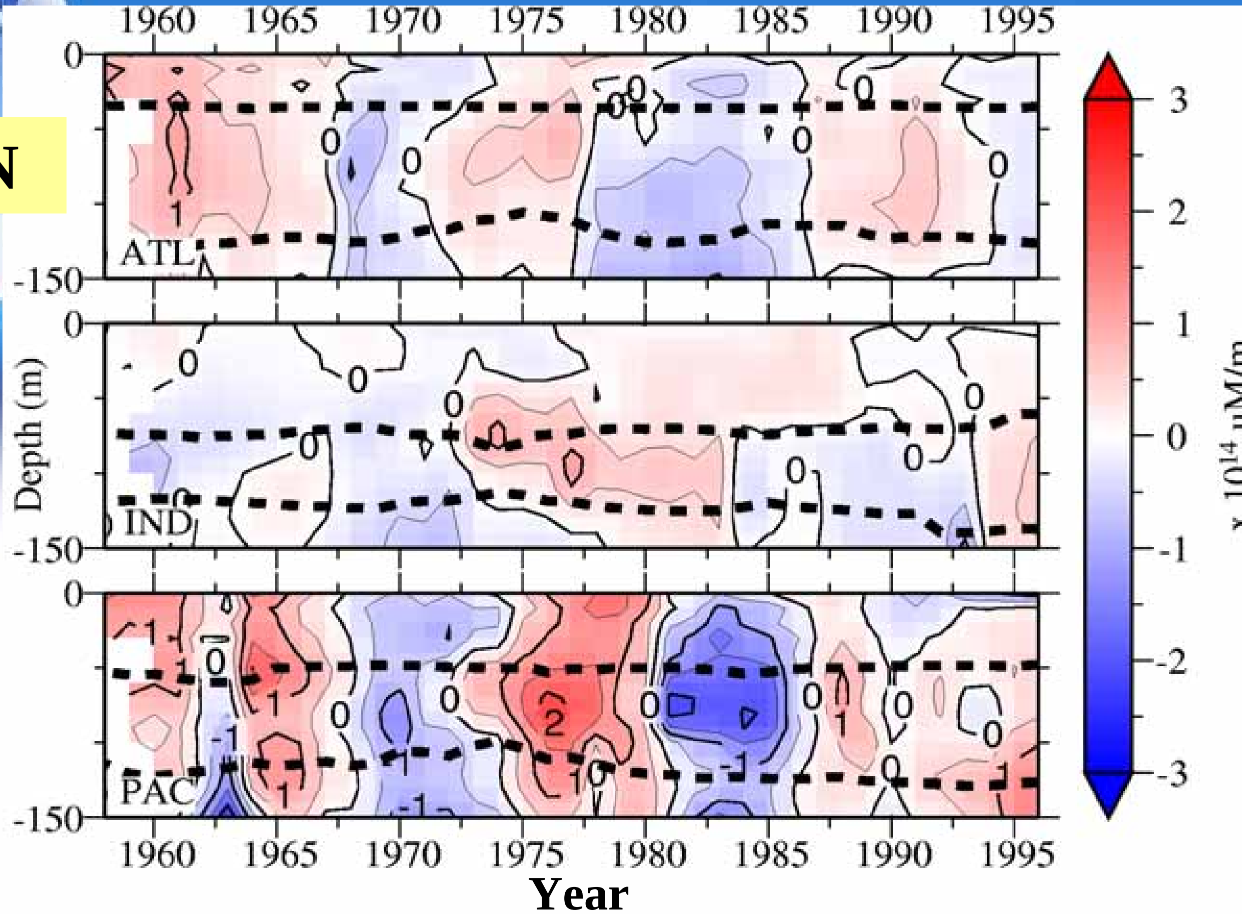



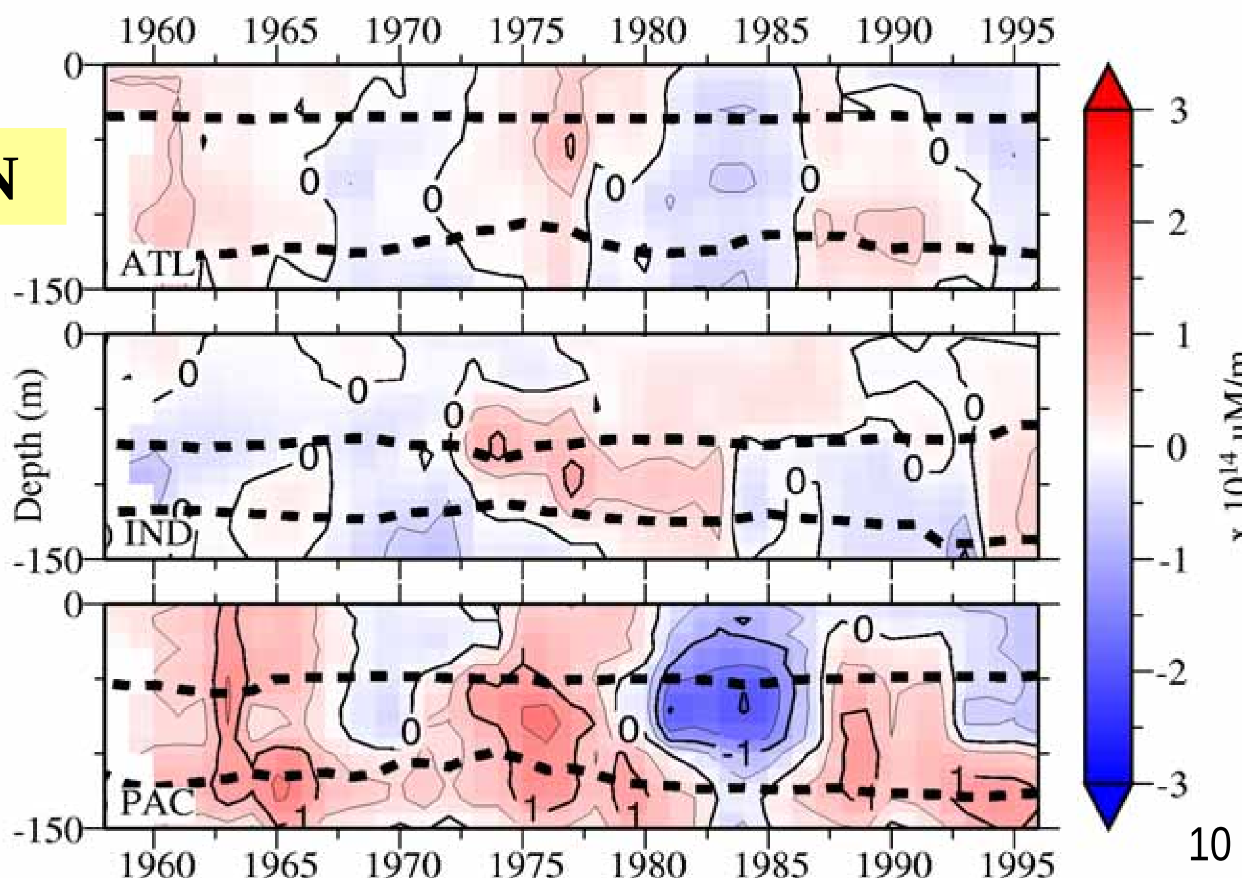

Location of time series stations? A-Line, P-line, HOT, BATS

# Basin $\Sigma PO_4$ content anomaly: Variability

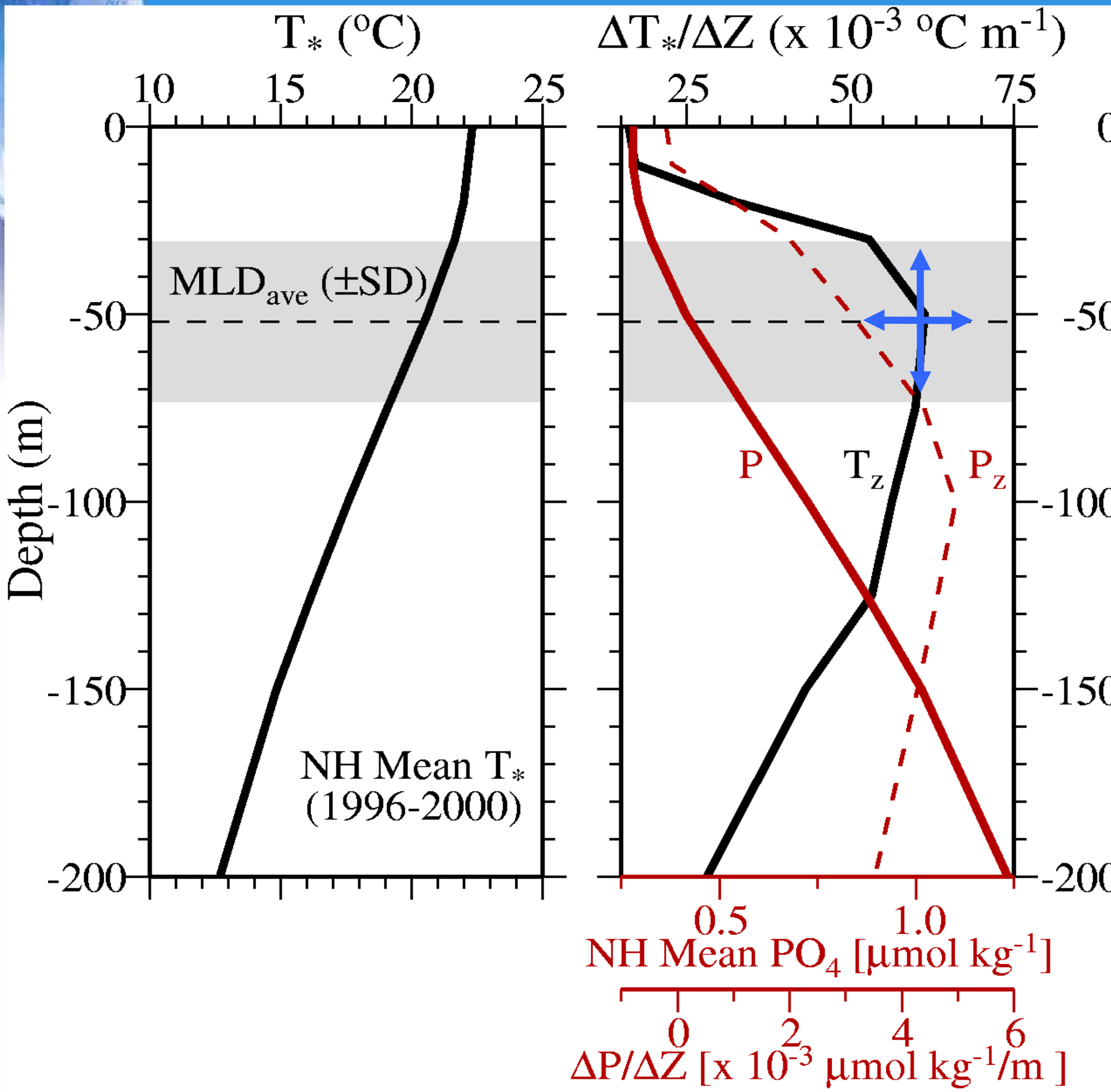
**0-70°N**

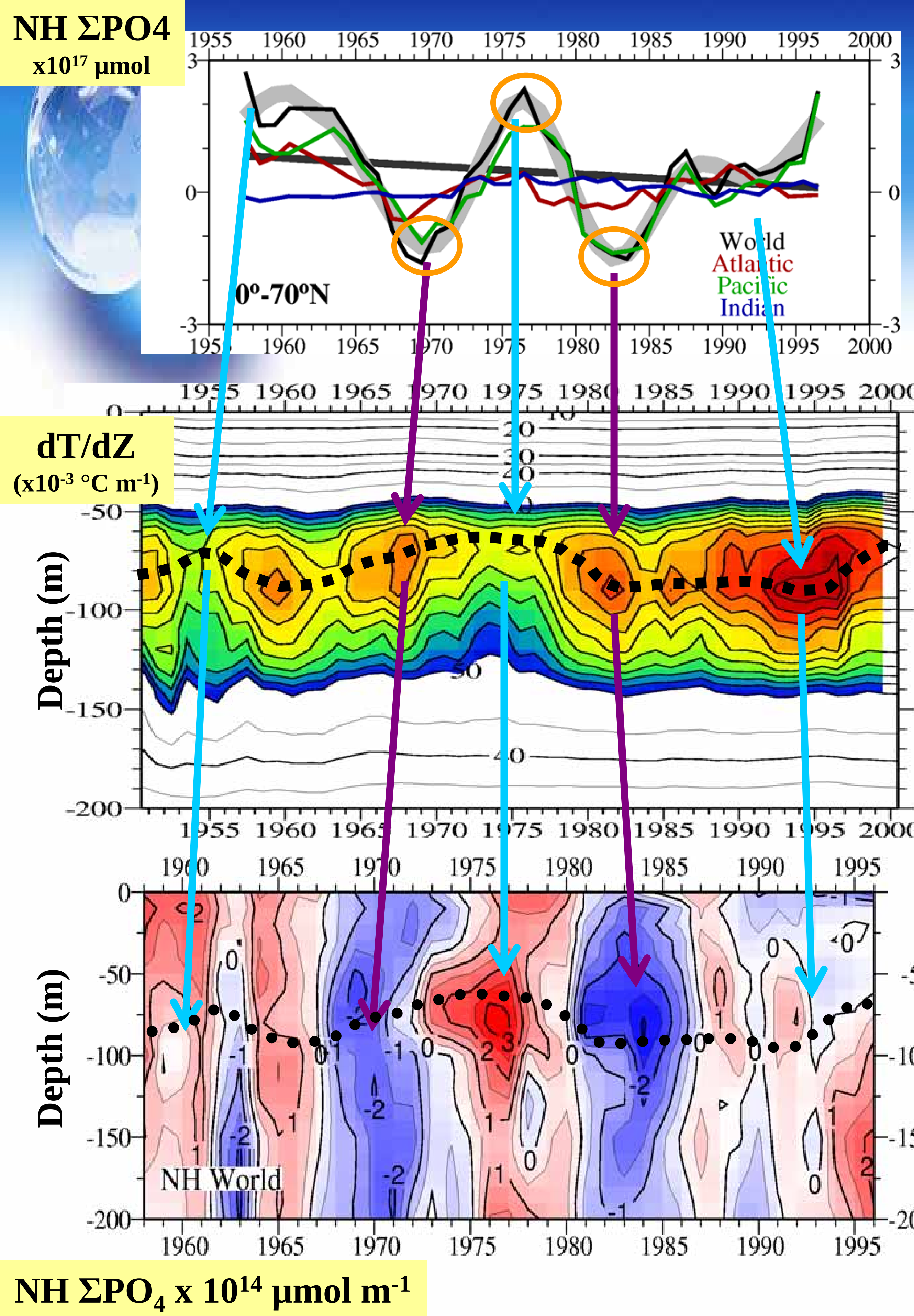



**0-30°N**



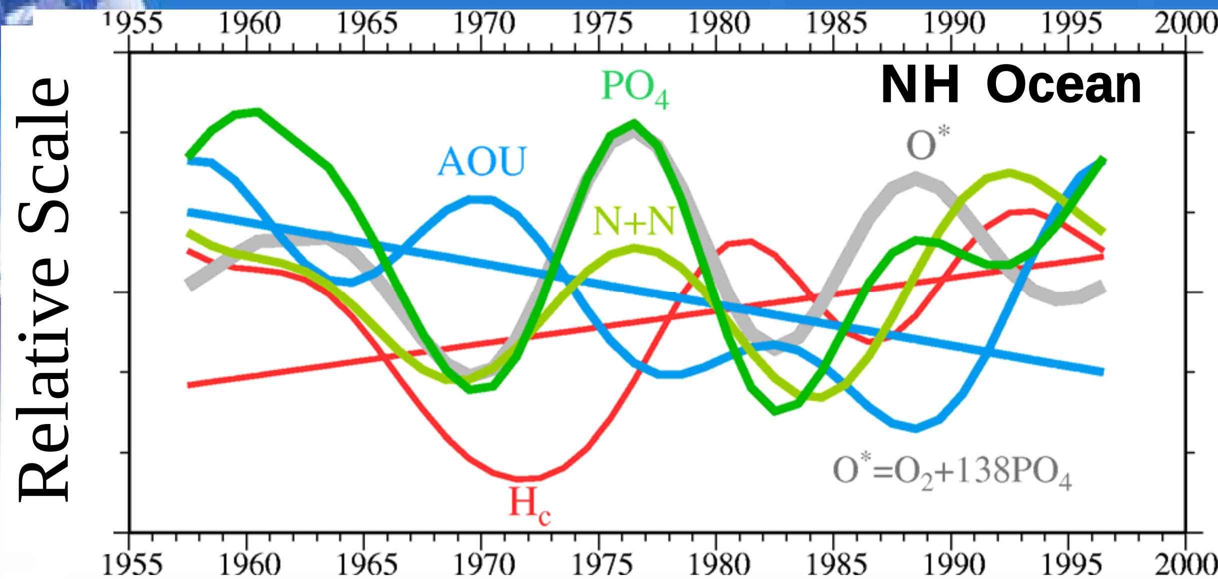
# Role of stratification variability

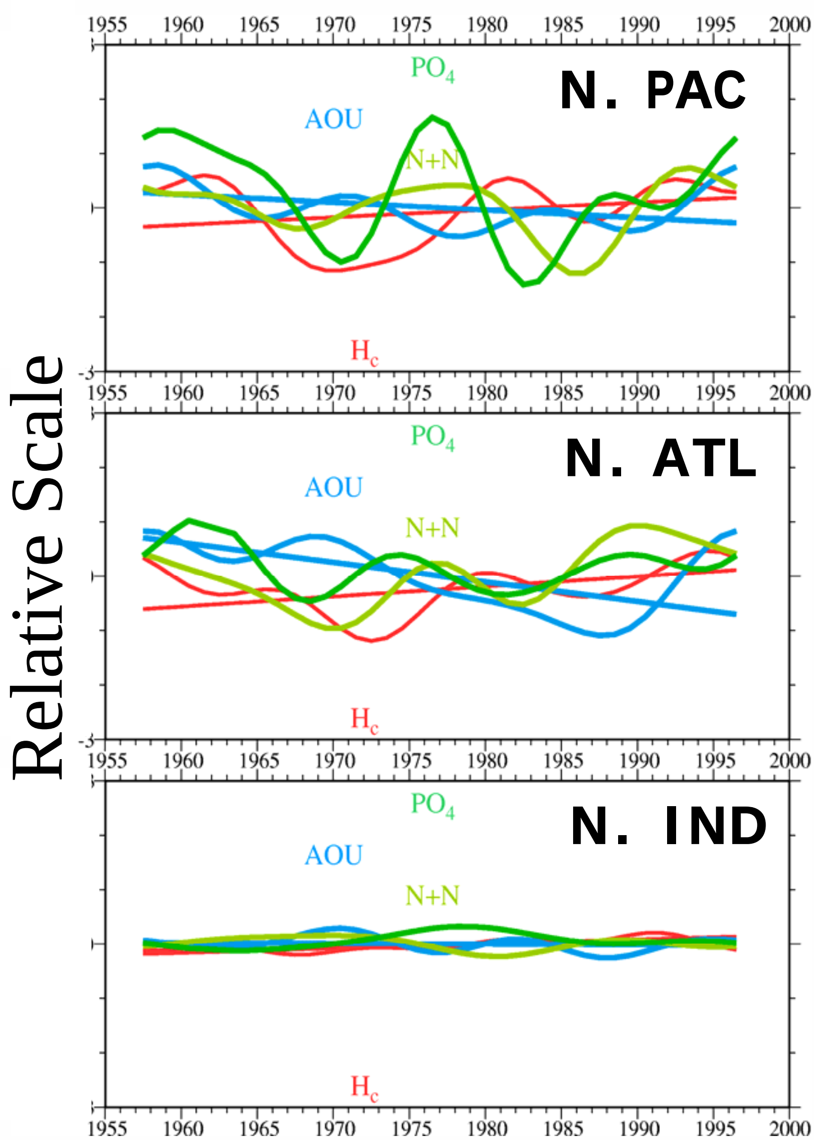




NH ΣPO4
x10^17 μmol
0°-70°N
World
Atlantic
Pacific
Indian
dT/dZ
(x10^-3 °C m^-1)
Depth (m)
Depth (m)
NH World
NH ΣPO4 x 10^14 μmol m^-1

# Correlations (0-100m; 0-70°N)




$[PO_4]_c \sim [O^*]_c$

N/P ~ 5.6

$DIN_{excess}$= (N+N)-16P

Bates & Hansell, 2004

$DIN_{excess}$~ 0.1 to 0.3 µmol kg$^{-1}$

[if distributed over the NH 100 m layer]

# Summary (Surface NH)

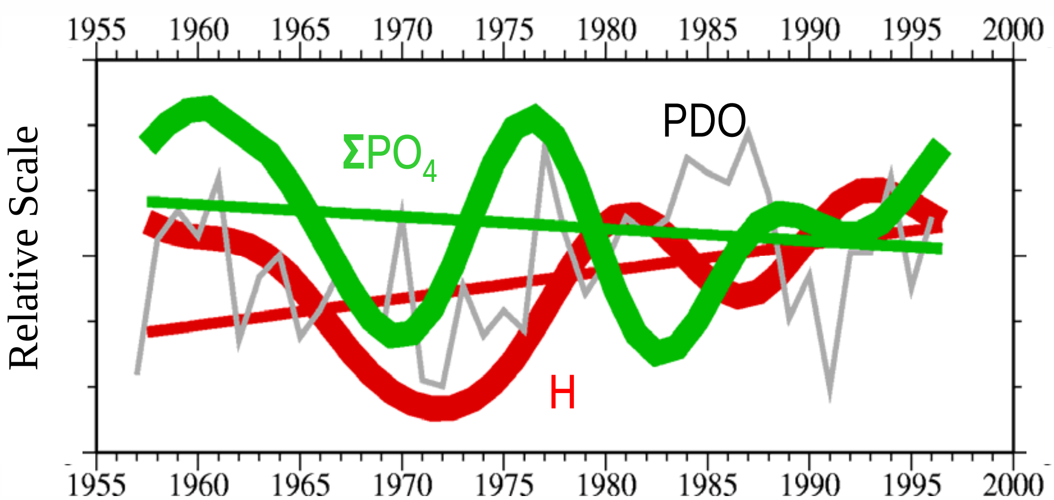
1. Peak-to-peak [$PO_4$] ocean seasonal (~0.5 μmol $kg^{-1}$) to decadal (~0.04 μmol $kg^{-1}$) variability (Pacific dominates).

2. $PO_4$ low-frequency variability non-linearly related to transient stratification (depth, strength, and persistence; ~75 to 120 m depth layer).

3. Nutrient LFV overlooked as a mechanism ("excess nutrients") that potentially affects Net New Production (up to ~ 0.3 Pg C; assuming 1P:106C Redfield Ratio).

4. **Challenge:** Nutrient content trends super-imposed on large decadal-scale changes (relation to PDO?).

**A model approach needed**




January PDO: North Pacific Ocean, poleward of 20°N (Mantua *et al.*,1997).