Documenting seasonal to decadal variability in Phosphate Content

Hernan Garcia, Tim Boyer, Sydney Levitus, Ricardo Locarnini, John Antonov, Daphne Johnson & Alexey Mishonov

NOAA-National Oceanographic Data Center, USA

PICES 16th 10/26-11/5 2007 Victoria, Canada
OUTLINE

How much PO$_4$?
PO$_4$ seasonal to decadal variability?
Role of stratification variability?

$$\text{DIN} = \text{DIN}_{\text{ave}} + \delta \text{DIN}_{\text{sea}} + \delta \text{DIN}_{\text{LFV}}$$

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

After Behrenfeld et al. 2006
Data sources: World Ocean Database/Atlas 2005

~3.6 x 10^6 observations
~1.9 x 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.

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

PO_4
N+N
Si(OH)_4

>75% post mid-1960's
Climatic Mean Ocean PO₄ content

70°S-70°N (open ocean)

Inventory x 10¹⁴ Mol

Mean [μmol kg⁻¹]

Depth (km)

OCN = 31.0
ATL = 5.9
PAC = 18.2
IND = 6.9

(~59% in the Pacific)
Seasonal Signal: Amplitude \((C_1)\) of zonal integral of \(\text{PO}_4\) anomaly \((\times 10^{13} \, \mu \text{mol m}^{-1})\)

\[
PC = A \int_{z_i}^{z_{i+1}} (P_{\text{mon}} - \overline{P_{\text{ann}}})dz
\]

\[
y(t) \approx a_0 + a_1 \sin(\omega t) + a_2 \cos(\omega t) + 0
\]
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 $\sim$0.12 µmol kg$^{-1}$ increase in PO$_4$ to surface waters.
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 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

- MLD$_{av}$ (±SD)
- NH Mean T$_*$ (1996-2000)
- NH Mean PO$_4$ [µmol kg$^{-1}$]
- ΔP/ΔZ [x 10$^{-3}$ µmol kg$^{-1}$/m]
Correlations (0-100m; 0-70°N)

NH Ocean

\[ [\text{PO}_4]_c \sim [\text{O}^*]_c \]

\[ \text{N/P} \sim 5.6 \]

\[ \text{DIN}_{\text{excess}} = (N+N)-16P \]

Bates & Hansell, 2004

\[ \text{DIN}_{\text{excess}} \sim 0.1 \text{ to } 0.3 \mu\text{mol kg}^{-1} \]

[if distributed over the NH 100 m layer]
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