Testing Sverdrup’s hypothesis with a profiling float

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The hypothesis: in the sub-polar North Atlantic spring restratification (following winter mixing) is required for phytoplankton biomass to accumulate (have positive net community growth).
Distribution of ARGO floats

3325 Floats
27-Apr-2009

Float profiles every 5 days from 1000m, CTD + $b_{bp}$ and $F_{chl}$
The NA spring bloom (most studied phenomena in Biological Oceanography):
On Conditions for the Vernal Blooming of Phytoplankton.

By

H. U. Sverdrup,
Norsk Polarinstittutt, Oslo.

1953

\[ \frac{\partial P}{\partial t} = (\alpha I - r)P, \quad \alpha, r - \text{const.} \]

Blooming: \( \frac{\partial P}{\partial t} > 0 \).

In the oceans: \( I(z) = I_0 e^{-kz} \)

When phytoplankton are mixed too deep they cannot bloom.
Float results (monthly averages):

First: how do we estimate phytoplankton biomass?

Net growth is positive even when mixing is deepest and light is least.

\[ \mu_{net} \equiv \frac{1}{P} \frac{dP}{dt} \equiv \frac{d \ln P}{dt} \]

\[ \mu_{net}=0.05d^{-1} \rightarrow T_{double}=14 \text{ days} \]

Method: \( F_{chl} \) - red, \( b_{bp} \) - blue
Numerical recipes:

Center difference:

\[ \mu_{\text{net}} = \frac{1}{P} \frac{dP(t_{N+\Delta t/2})}{dt} = \frac{d \ln P(t_{N+\Delta t/2})}{dt} \approx \frac{\ln P(t_{N+1}) - \ln P(t_N)}{\Delta t} \]

→ Have approximately 6 estimates of growth rates per month each year

Uncertainty \equiv \text{standard error of the mean}

Vertical integration: to 300m depth (differences are very small compared to integrating to \text{max}(\text{MLD, Euphotic depth}).
Findings:

We observe values of net growth suggesting grazing rate $\approx$ phytoplankton growth.

Net growth becomes positive near when the light is minimal.

Traditional views of the 'bloom' are biased by focusing on $dP/dt$ rather than $dlnP/dt$.

Sverdrup hypothesis has a simplistic parameterization of the loss term ($-rP$):

$$\frac{\partial P}{\partial t} = (\alpha I - r)P, \quad \alpha, r - \text{const.}$$

At least two additional nonlinear loss rates are currently recognized:

$$- gPZ - \beta P^2$$

When the water is mixed to depth in the winter, both are reduced (dilution).

In addition, phytoplankton respiration has been found to be almost negligible in cold dark conditions.
A vision for the future: the Riley (or NPZ) float

Boss et al., 2008, *EOS*

N: ISUS

P: FL-NTU

Z: LOPC/Gorsky/novel cheap acoutic $b_b$ +PAR & $O_2$

Minimum sensor-suite to constrain ecosystem models.

Our current vision is constrained to be 'bottom-up' by the lack of cheap zooplankton sensors

The age of exploration is not over!
Histograms of estimated $\mu_{Net}$