Modelling the biological pump

Christoph Völker
Alfred Wegener Institute for Polar and Marine Research,
Bremerhaven, Germany

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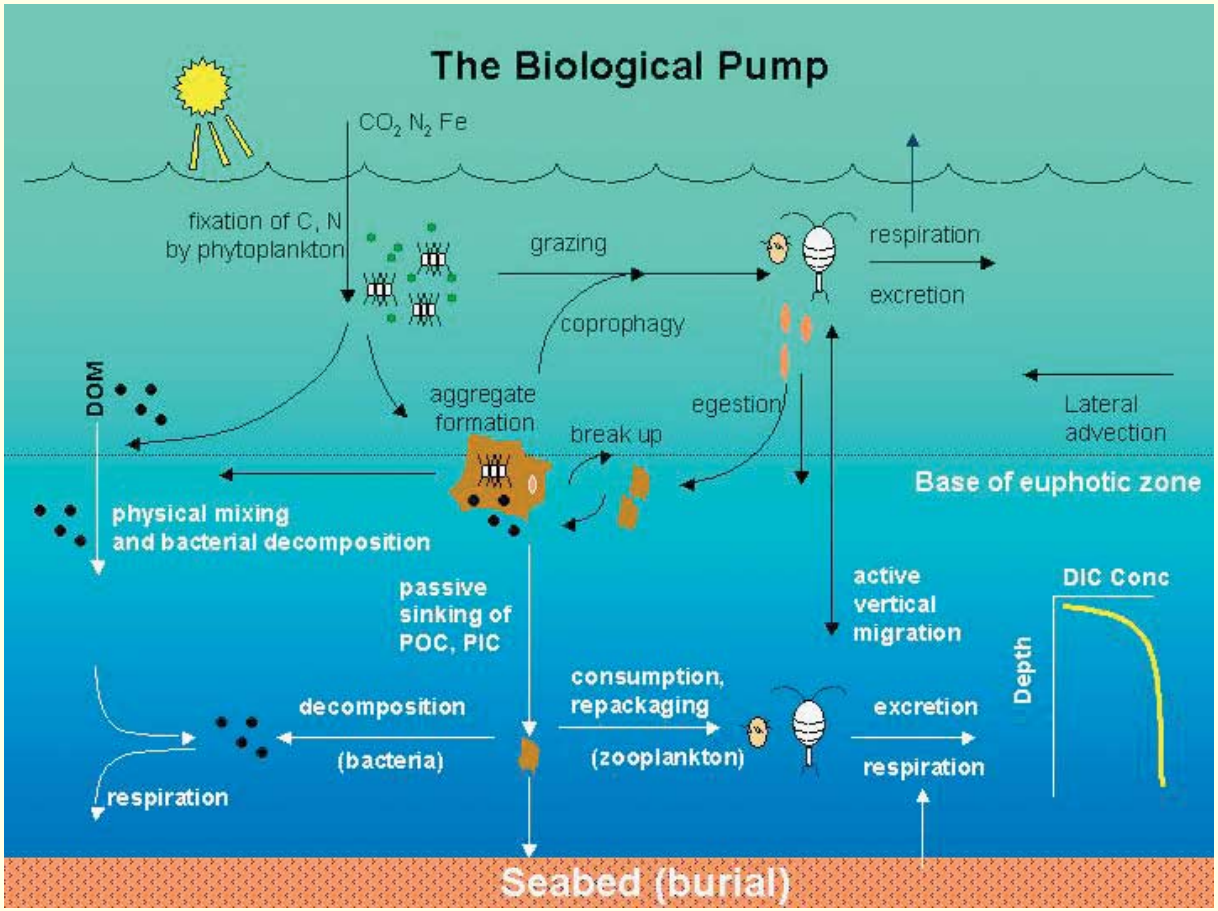
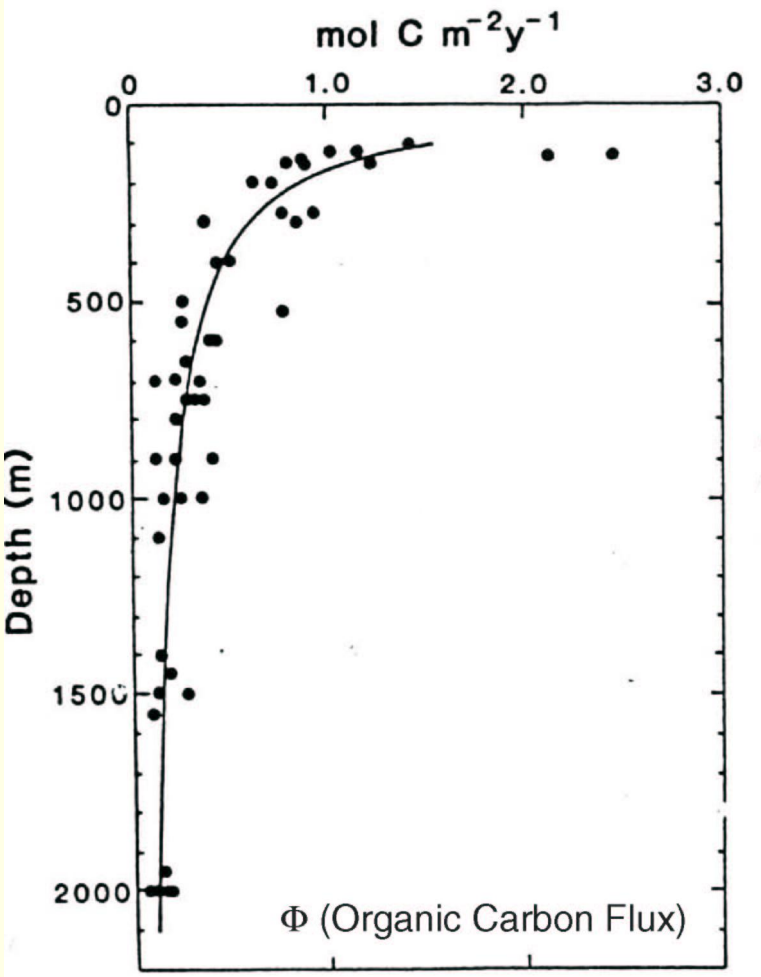
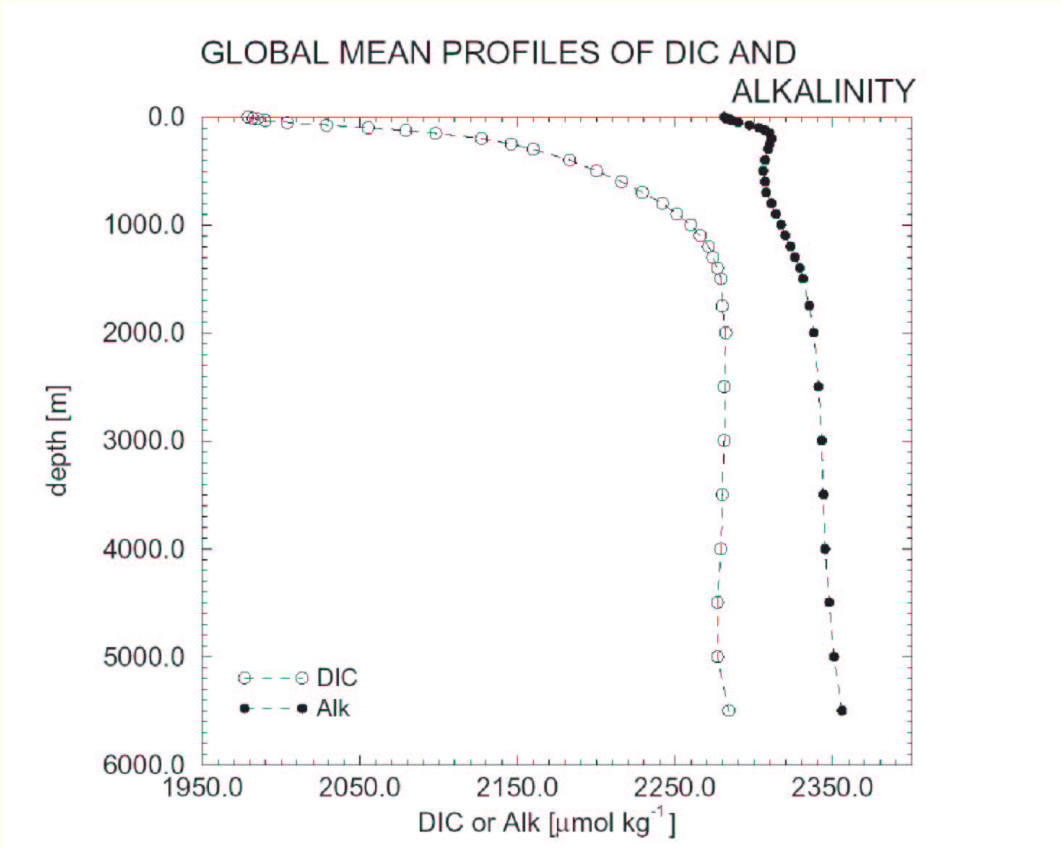

The Biological Pump
CO_2 N_2 Fe
fixation of C, N
by phytoplankton
grazing
respiration
excretion
coprophagy
DOM
aggregate
formation
egestion
Lateral
advection
break up
Base of euphotic zone
physical mixing
and bacterial decomposition
passive
sinking of
POC, PIC
active
vertical
migration
DIC Conc
Depth
consumption,
repackaging
decomposition
(bacteria)
(zooplankton)
excretion
respiration
respiration
Seabed (burial)

Vertical flux of carbon versus depth from sediment traps





results in vertical gradients of dissolved inorganic carbon and alkalinity

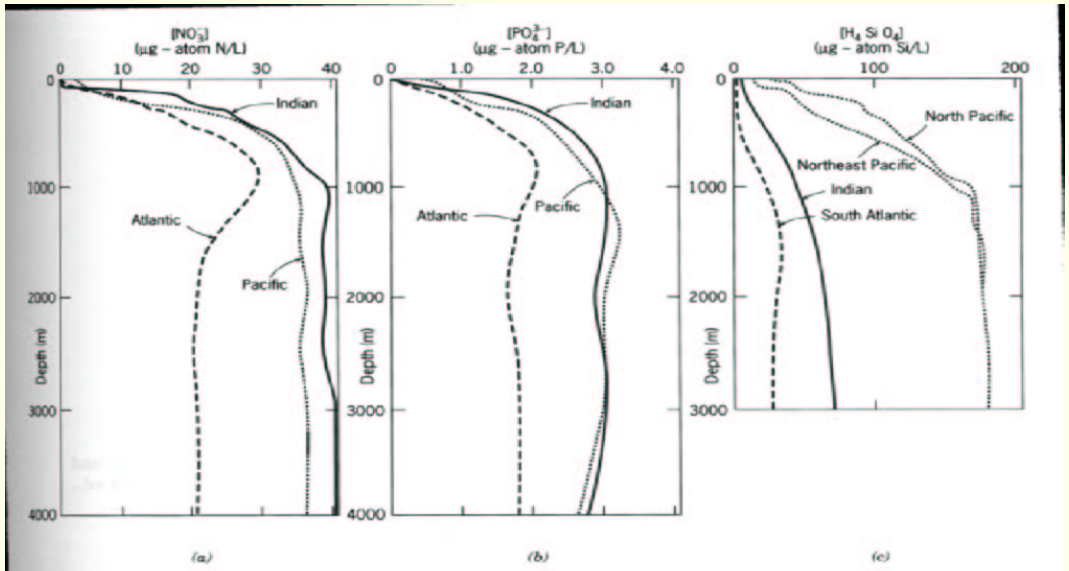


FIGURE 10.1. Vertical distribution of (*a*) nitrate, (*b*) phosphate, and (*c*) dissolved silicon in the Atlantic, Pacific, and Indian oceans. Note that 1 µg-atom/L is equivalent to 1 µ*M*. Thus 1 µg-atom NO_3-N/L is equivalent to 1µmol of dissolved nitrogen (in the form of NO_3^-) per liter of seawater. *Source:* From *The Oceans*, H. U. Sverdrup, M. W. Johnson, and R. H. Fleming, copyright © 1941 by Prentice Hall, Inc., Englewood Cliffs, New Jersey, p. 242. Reprinted by permission. See Sverdrup et al. (1942) for data sources.

vertical gradients also in major nutrients

$$106CO_2 + 16NO_3^- + HPO_4^{2-} + 78H_2O + 18H^+ \Longleftrightarrow C_{106}H_{175}O_{42}N_{16}P + 150\ O_2$$

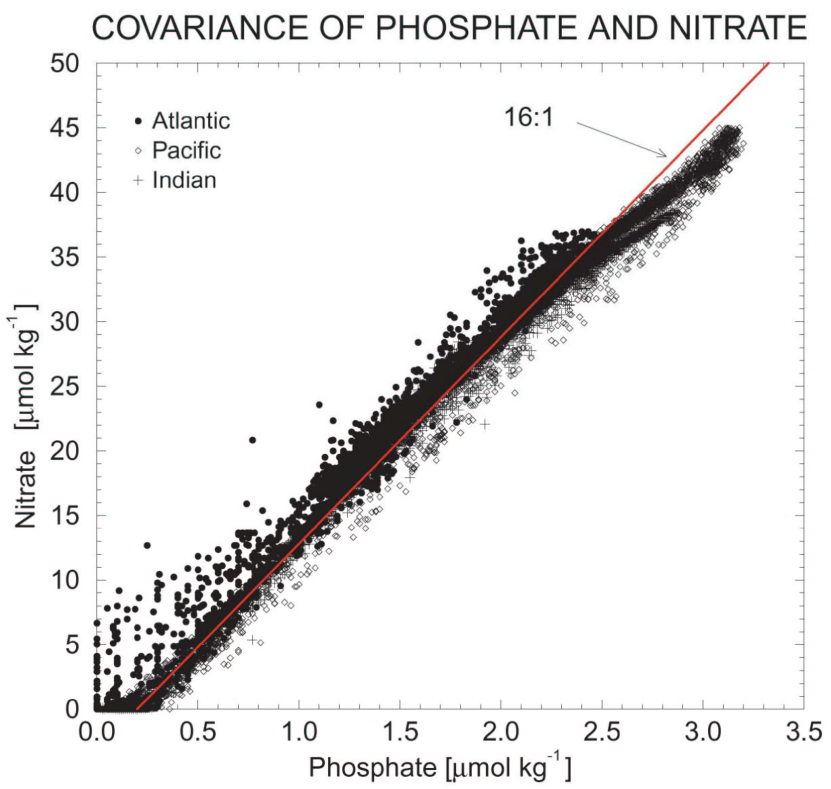
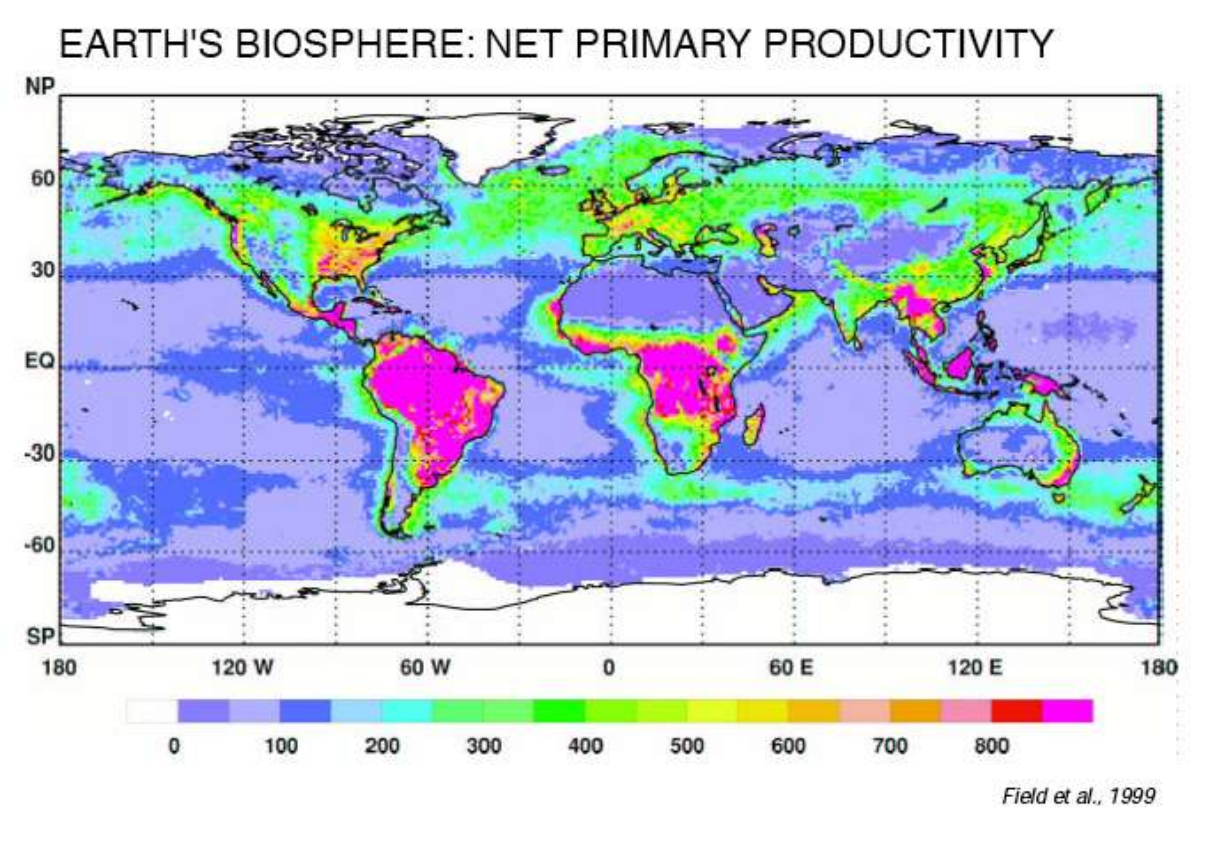
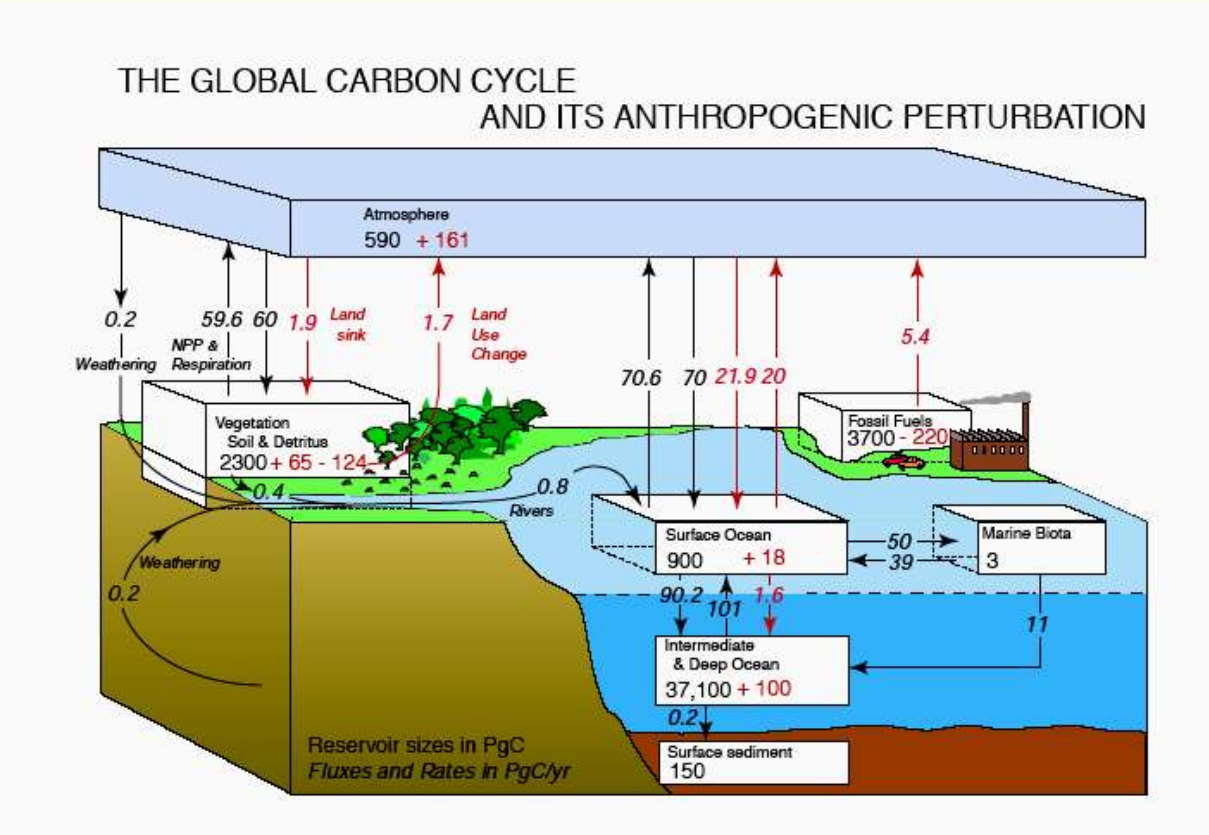
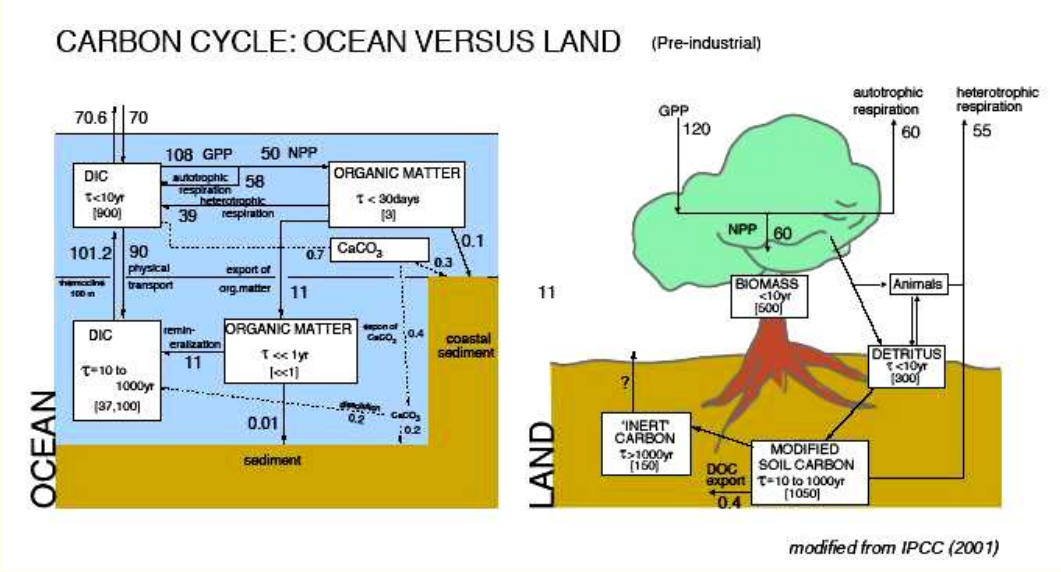

COVARIANCE OF PHOSPHATE AND NITRATE
Atlantic
Pacific
Indian
16:1
Nitrate [µmol kg-1]
Phosphate [µmol kg-1]
0
5
10
15
20
25
30
35
40
45
50
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

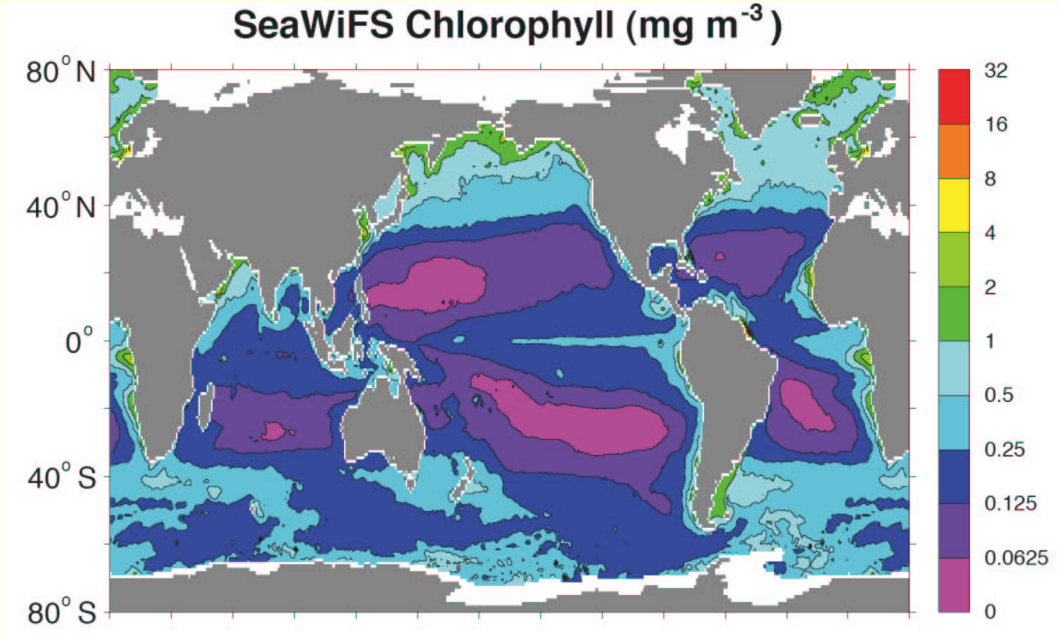
Figure 4.1.10


EARTH'S BIOSPHERE: NET PRIMARY PRODUCTIVITY
NP
60
30
EQ
-30
-60
SP
180
120 W
60 W
0
60 E
120 E
180
0
100
200
300
400
500
600
700
800
Field et al., 1999


THE GLOBAL CARBON CYCLE
AND ITS ANTHROPOGENIC PERTURBATION
Atmosphere
590 + 161
0.2
Weathering
59.6 60
NPP & Respiration
1.9
Land sink
1.7
Land Use Change
70.6 70 21.9 20
5.4
Vegetation
Soil & Detritus
2300 + 65 - 124
0.4
0.8
Rivers
Fossil Fuels
3700 - 220
Surface Ocean
900 + 18
50
39
Marine Biota
3
Weathering
0.2
90.2
101
1.6
11
Intermediate
& Deep Ocean
37,100 + 100
0.2
Surface sediment
150
Reservoir sizes in PgC
Fluxes and Rates in PgC/yr



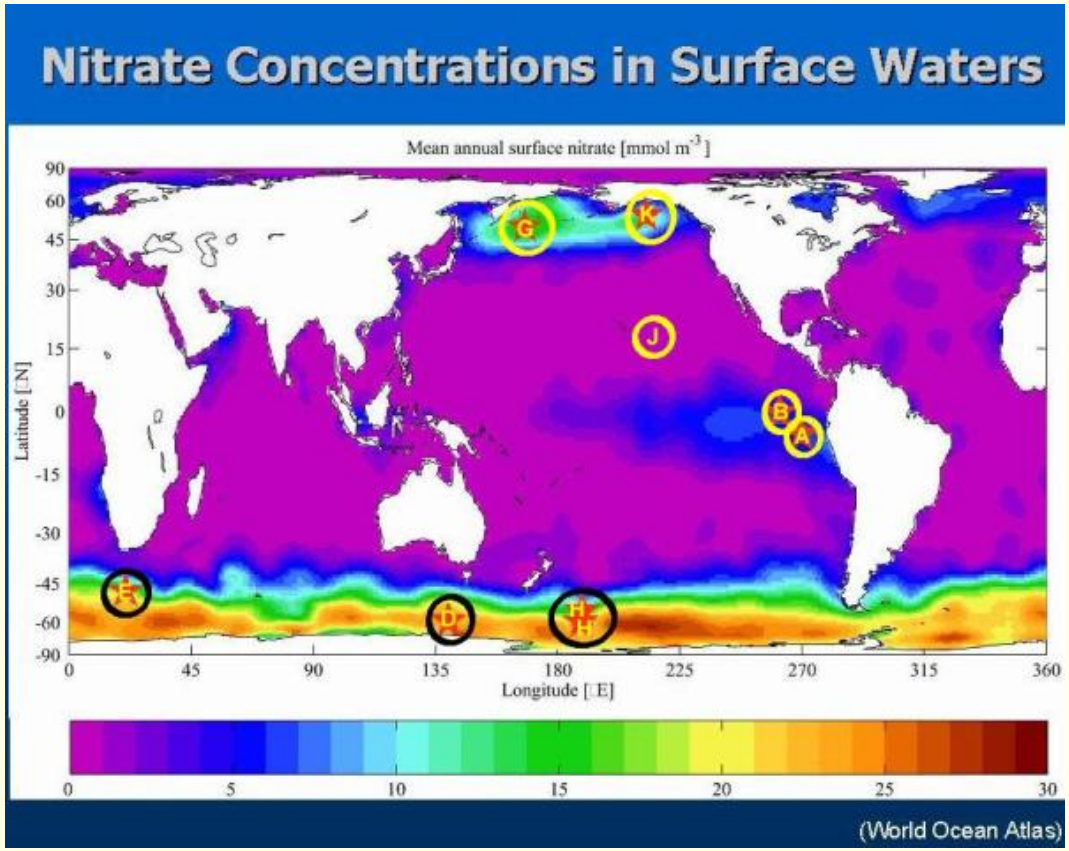
modified from IPCC (2001)



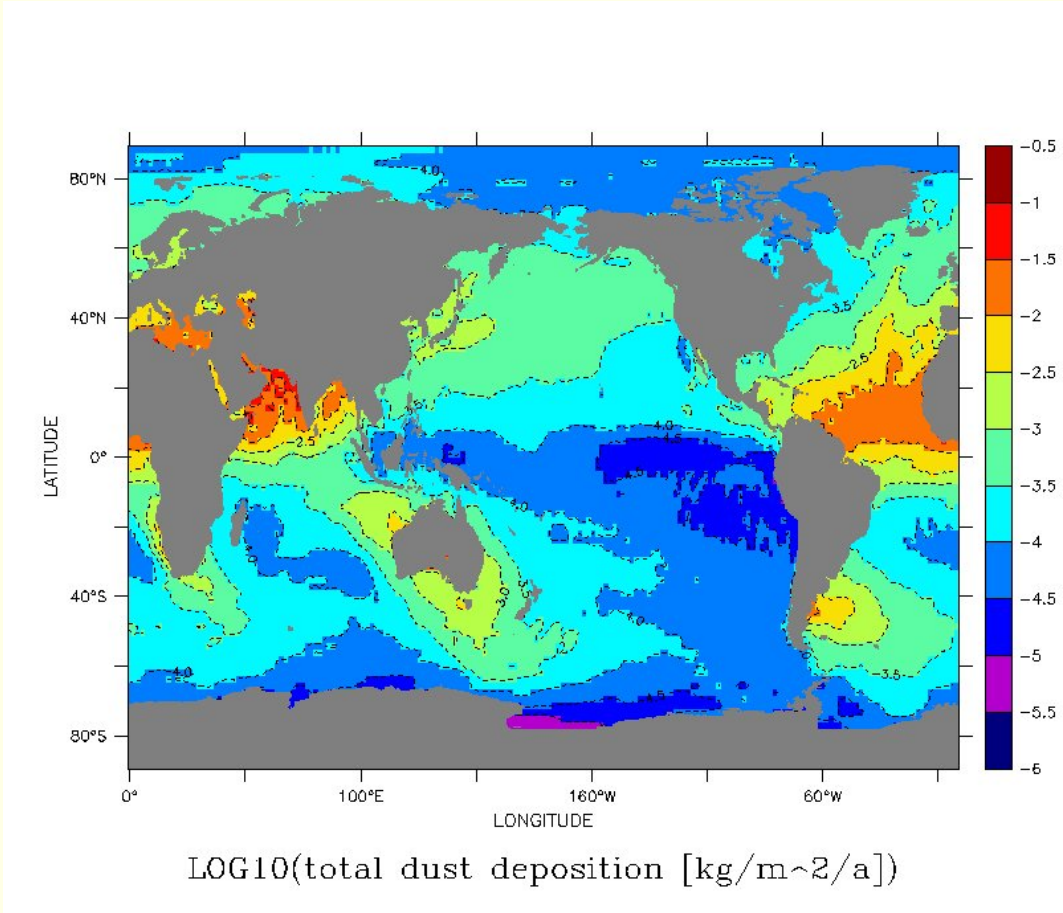
Chlorophyll is not evenly distributed: large oceanic deserts in the subtropical gyres

What controls distribution of primary productivity?

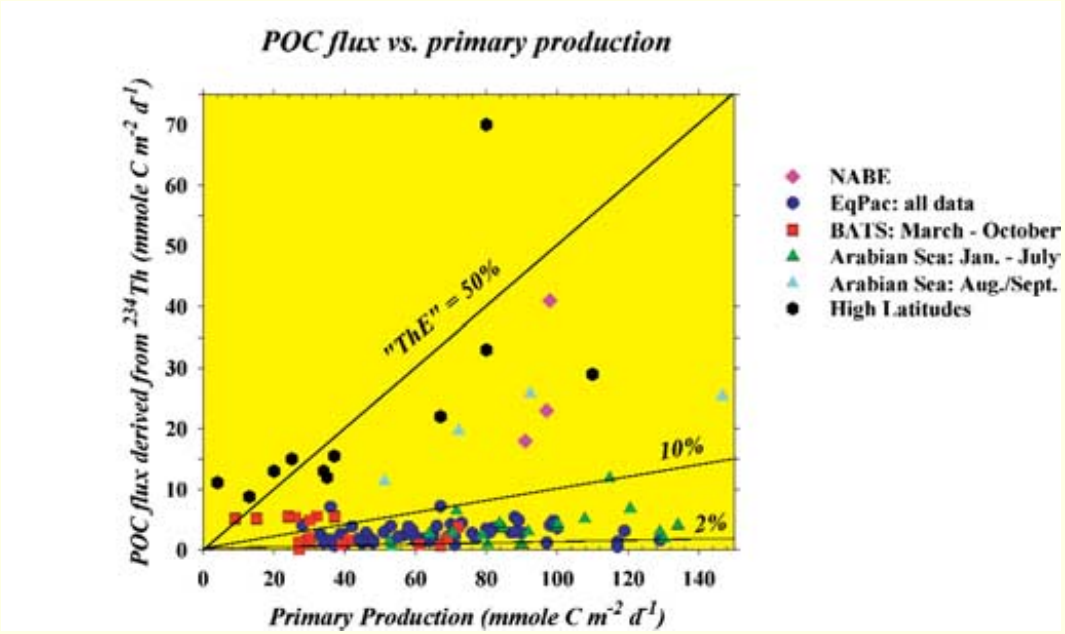
- Nutrients: mainly available where upwelling or deep mixing brings up nutrient-rich deep water
- Light: At the surface of the ocean (euphotic zone)
- Iron and other micronutrients
- Grazing



There are large areas in the world ocean, where nitrate is available, yet not much chlorophyll is found. Why?



the main source of iron: dust deposition (logarithmic)



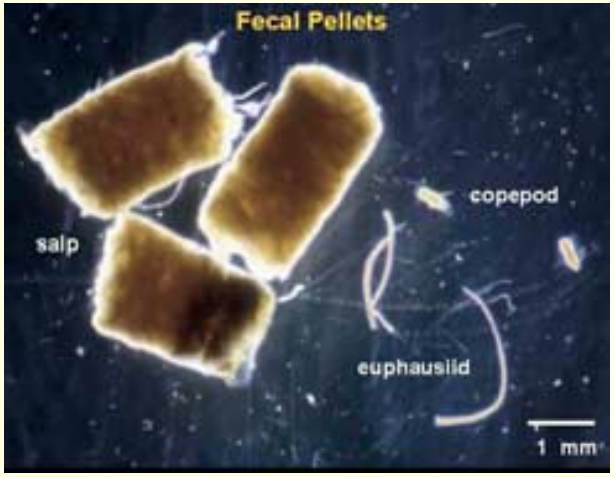
Only very little of the biomass produced in the euphotic zone sinks into the deep ocean

What happens with the biomass produced by photosynthesis?

- Most gets eaten by heterotrophs, such as copepods, but also heterotrophic unicellular plankton
- There is some production of dissolved organic carbon
- Viral lysis
- ...

What happens with the rest that escapes being eaten?

- It sinks
- The larger the particle is, the faster it sinks
- Fecal pellets and aggregates are the ones most likely to sink deep

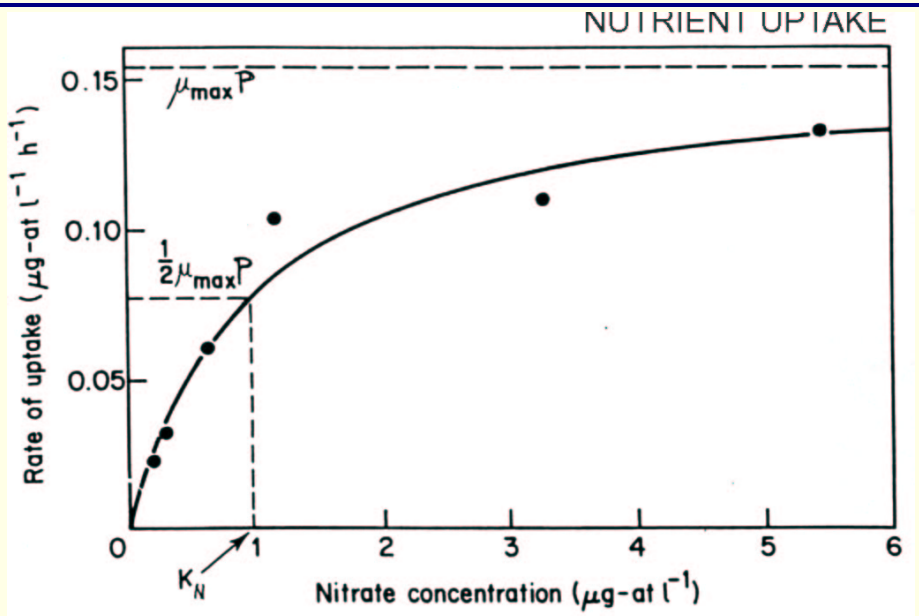


Modelling the biological pumps is necessary e.g. if we want to study influence of climate on them.

How can one model primary productivity? Usually as equation for growth

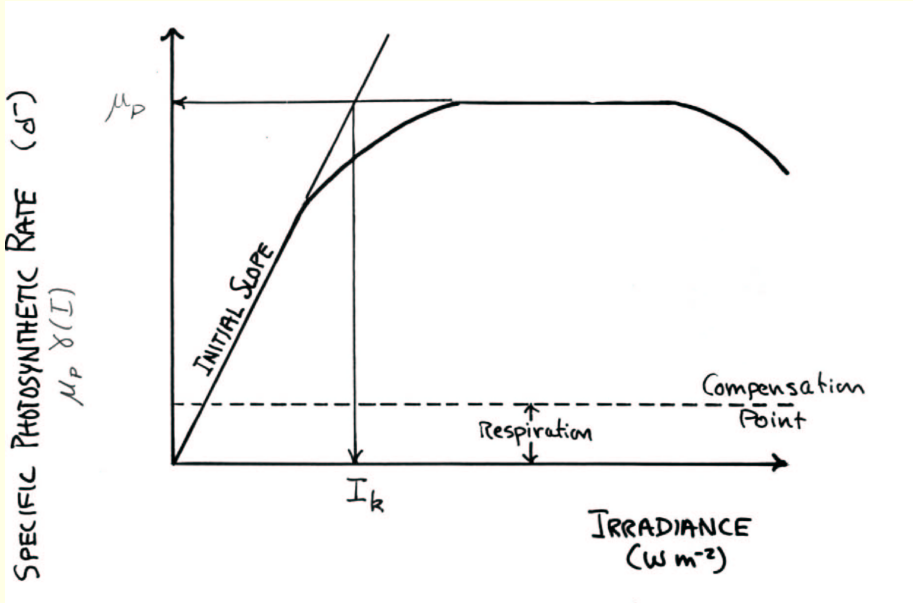
$$\frac{d}{dt}P = \mu P \tag{1}$$

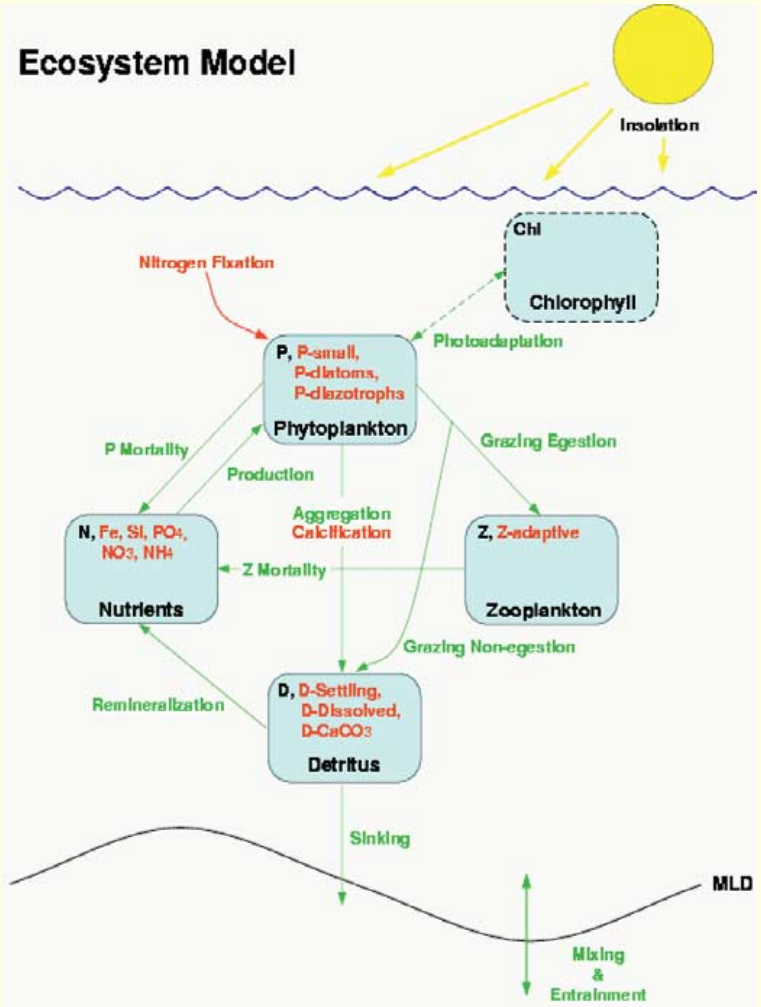
Where the growth rate μ depends on nutrients and light.



Nutrient dependency of growth: Usually a Michaelis-Menten formulation is adopted

$$\mu = \mu_{max} \frac{N}{K_N + N} \tag{2}$$


SPECIFIC PHOTOSYNTHETIC RATE (d⁻¹)
$\mu_p \gamma(I)$
μ_p
INITIAL SLOPE
Compensation Point
Respiration
I_k
IRRADIANCE (W m⁻²)


Ecosystem Model
Insolation
Chl
Chlorophyll
Nitrogen Fixation
Photoadaptation
P, P-small, P-diatoms, P-diazotrophs
Phytoplankton
P Mortality
Production
Grazing Egestion
Aggregation
Calcification
N, Fe, Si, PO4, NO3, NH4
Nutrients
Z Mortality
Z, Z-adaptive
Zooplankton
Grazing Non-egestion
Remineralization
D, D-Settling, D-Dissolved, D-CaCO3
Detritus
Sinking
MLD
Mixing
&
Entrainment