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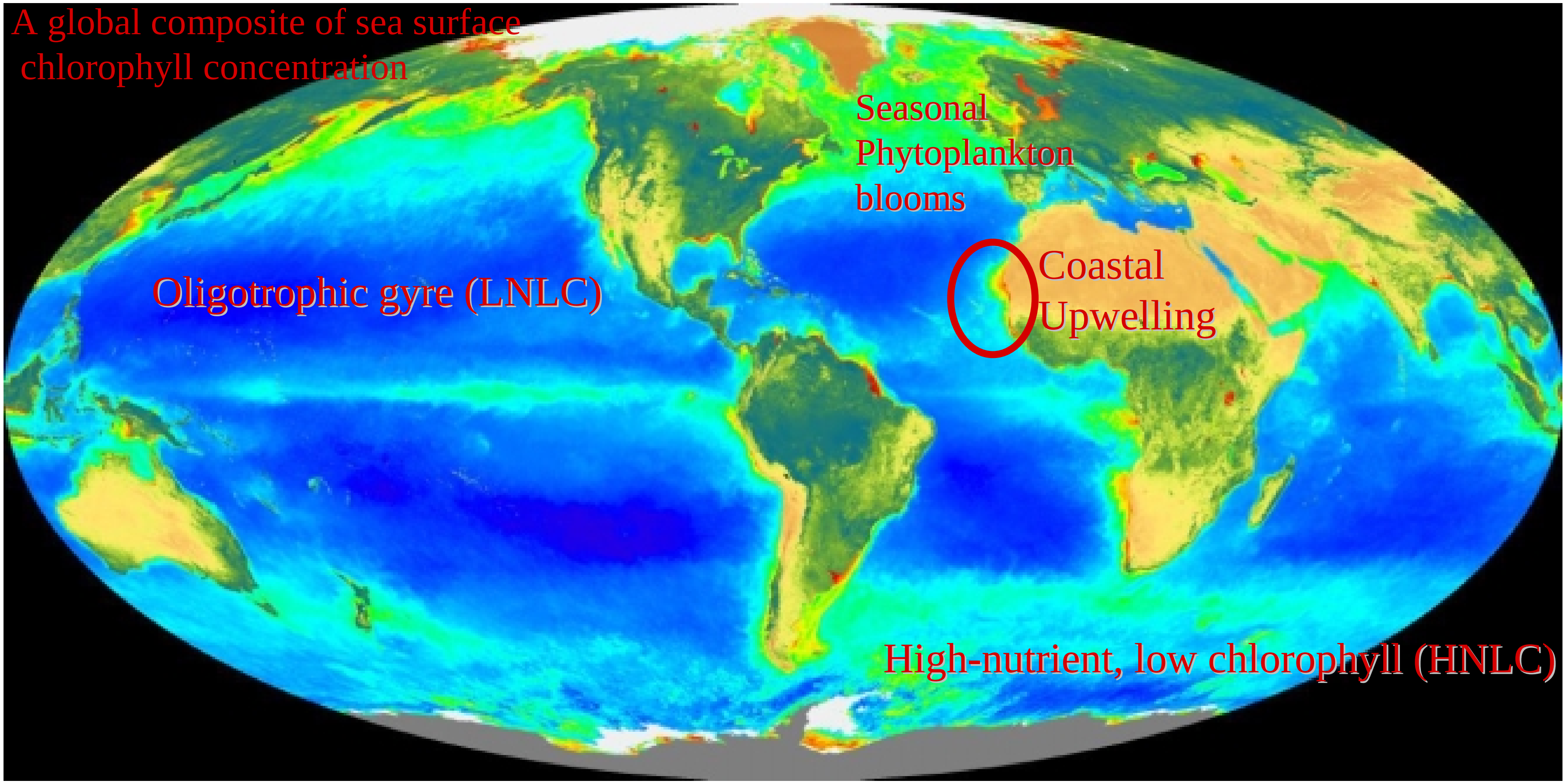
Oceanography

Primary Production in the Ocean



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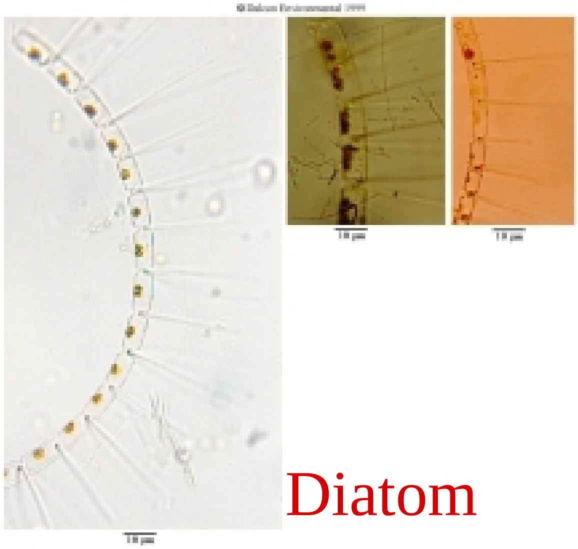
Primary production

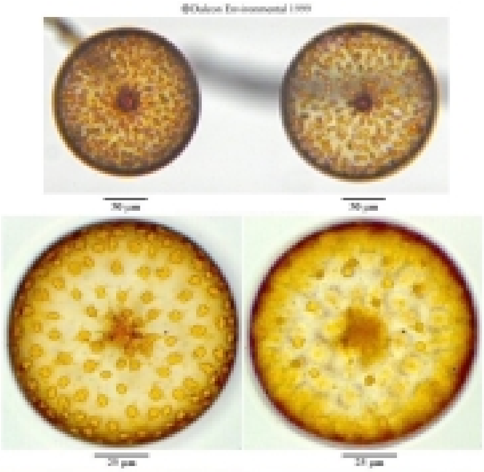
Examples of the larger phytoplankton

Coccolithophorid

Dinoflagellate

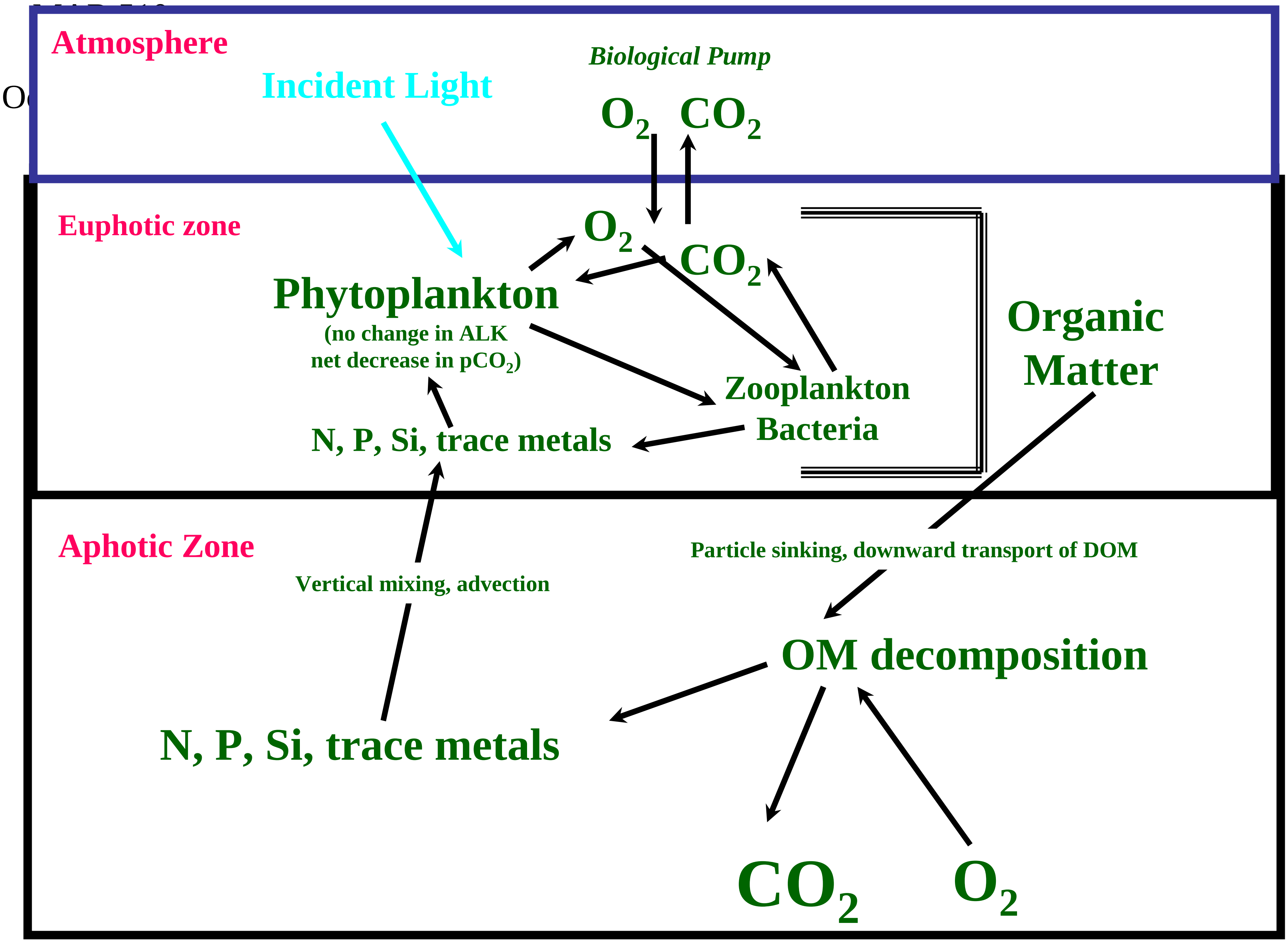


Diatom



Diatom

Oc



Atmosphere

Incident Light

Biological Pump

O_2 CO_2

Euphotic zone

O_2

CO_2

Phytoplankton

(no change in ALK
net decrease in pCO_2)

Zooplankton
Bacteria

Organic
Matter

N, P, Si, trace metals

Aphotic Zone

Vertical mixing, advection

Particle sinking, downward transport of DOM

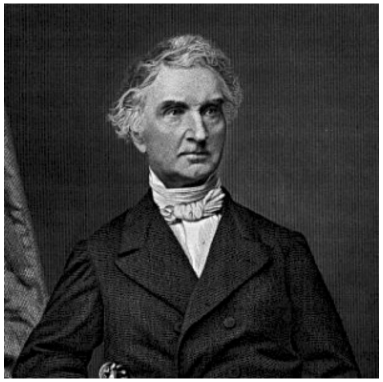
OM decomposition

N, P, Si, trace metals

CO_2 O_2

Law of the Minimum - Liebig's Law

Justus von Liebig, generally credited as the "father of the fertilizer industry", formulated the law of the minimum: if one crop nutrient is missing or deficient, plant growth will be poor, even if the other elements are abundant. Liebig likens the potential of a crop to a barrel with staves of unequal length. The capacity of this barrel is limited by the length of the shortest stave (in this case, phosphorus) and can only be increased by lengthening that stave. When that stave is lengthened, another one becomes the limiting factor.



1803-1873

For Phytoplankton

1) Light
2) Macronutrients (N, P)
3) Micronutrients (Fe, Zn)

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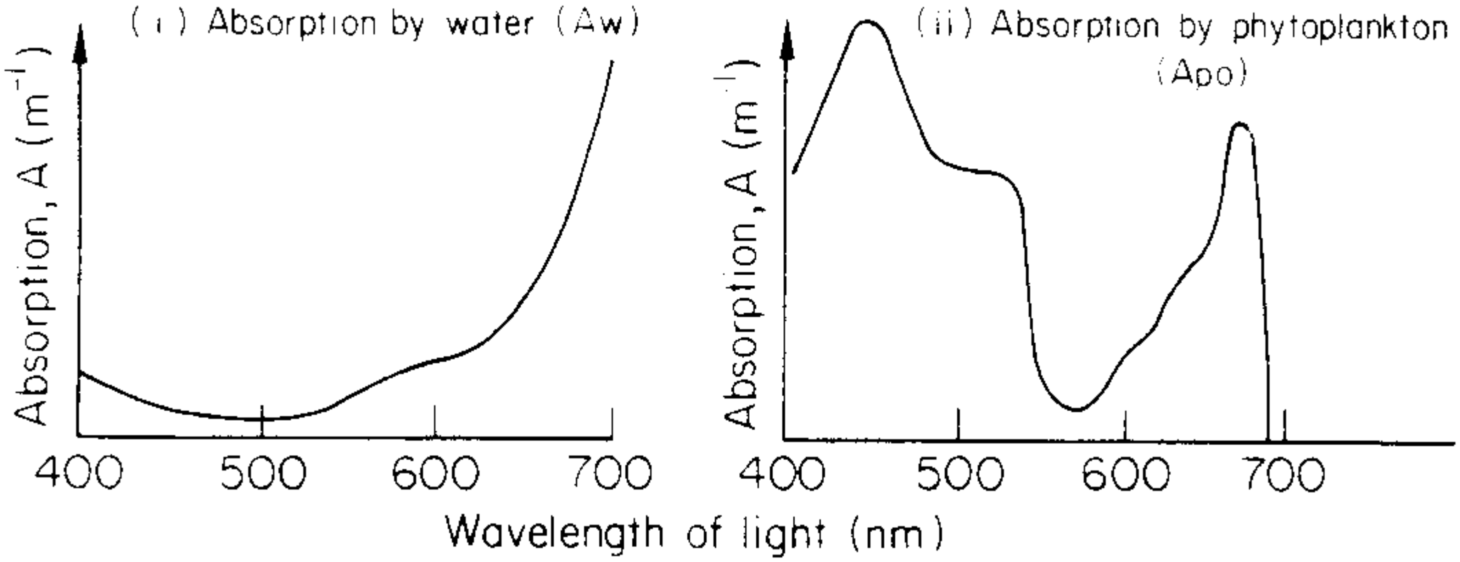
Behavior of Light in the Sea

1)Exponential decrease in intensity with depth (z)

$$I_z = I_0 \text{ x } e^{-kz}$$

2) Preferential absorption in the ‘red-end’ of the spectrum



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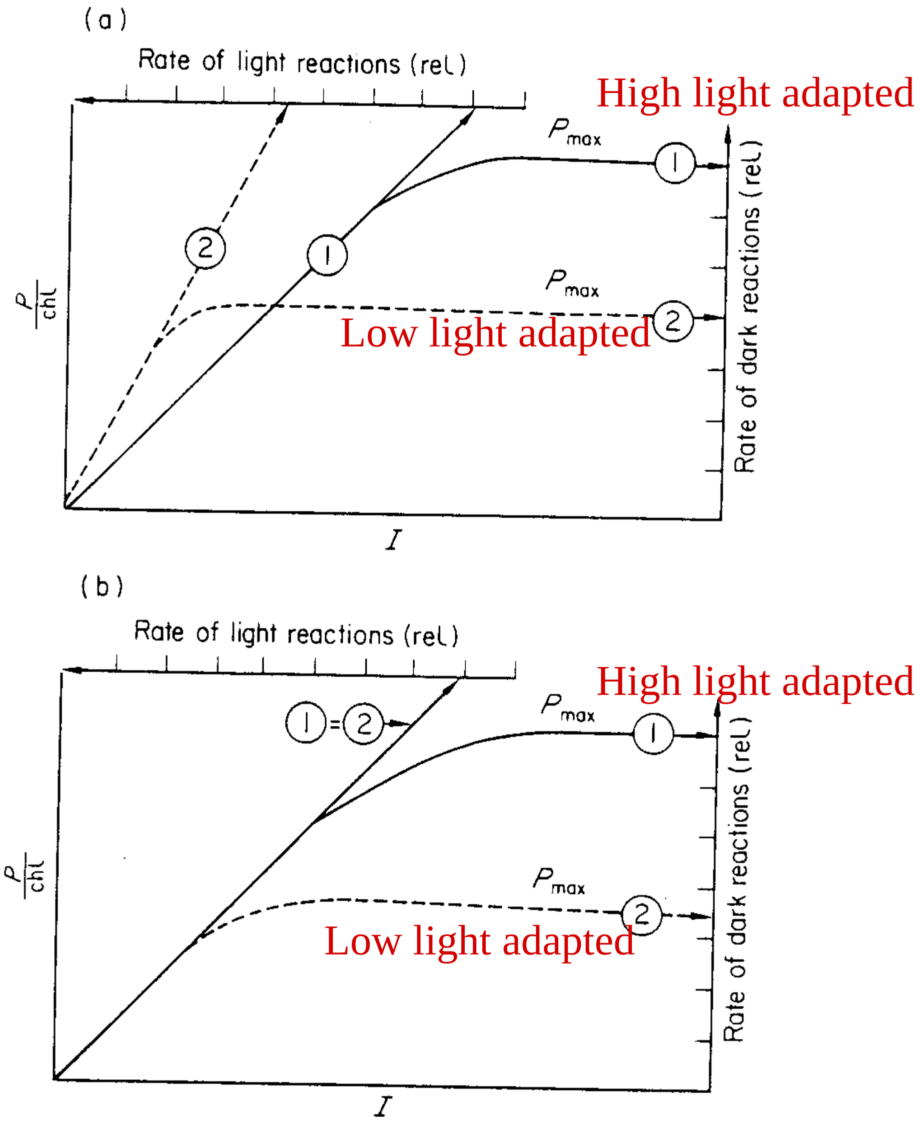
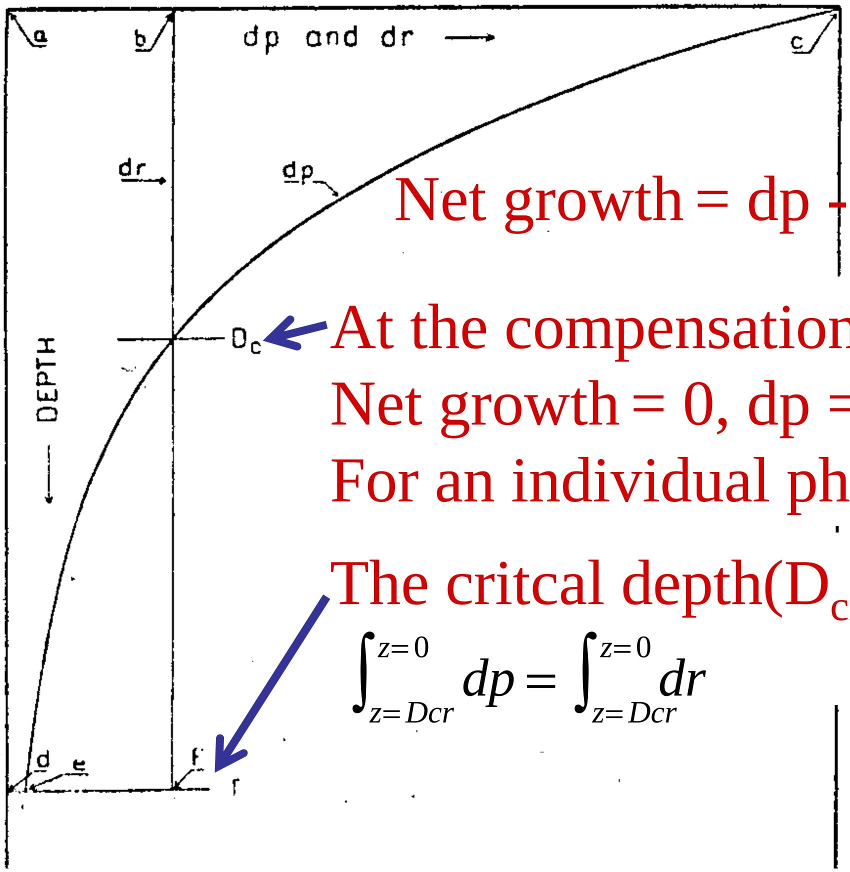


$$P = P_{max} \text{ x } I/(I+k_I)$$

Fig. 3.12. The effects of high and low light conditions on photosynthetic responses in phytoplankton. Population (1) is located at the top of the euphotic zone, population (2) at the bottom. Situation (a) reflects the response of increased chlorophyll content of population (2), that is, the light reaction rate is higher in (2) than (1). Situation (b) reflects the response of the light reactions being equal.

Sverdrup (1952)



Net growth = dp - dr

At the compensation depth (D_c)
Net growth = 0, dp = dr
For an individual phytoplankton cell

The critcal depth(D_{cr}) is defined such that

$$\int_{z=Dcr}^{z=0} dp = \int_{z=Dcr}^{z=0} dr$$

Figure 1. Schematic representation of the variation with depth of the increase of organic matter by photosynthesis, *dp*, and the decrease by respiration, *dr*. Increase and decrease apply to unit volume and unit time.

When the mixed layer depth (mld) < D_{cr}

$\int_{z=mld}^{z=0} dp > \int_{z=mld}^{z=0} dr$, a phyto plankton bloom can occur

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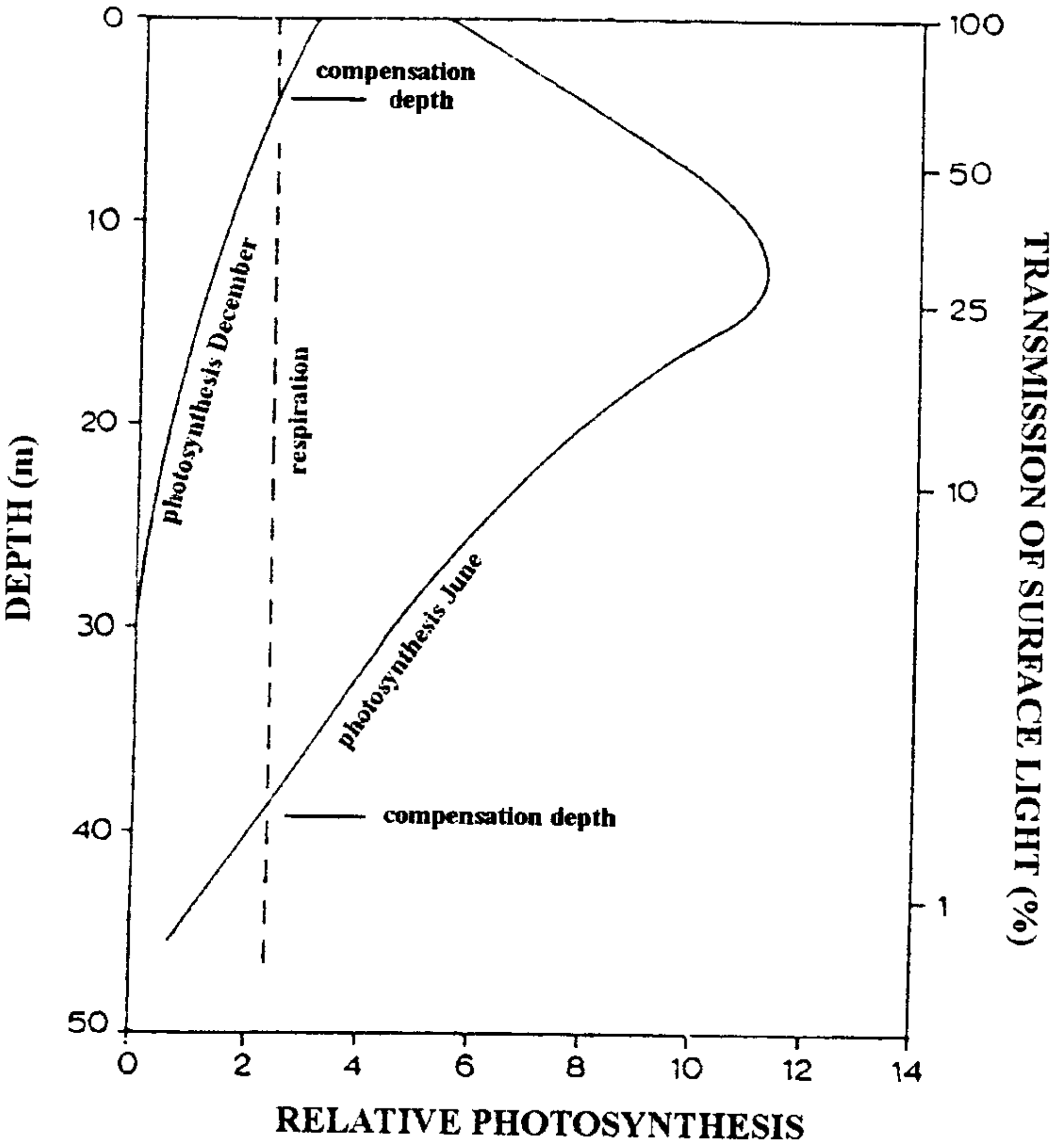

FIGURE 9.7. Integrated daily rate of primary productivity as a function of depth.

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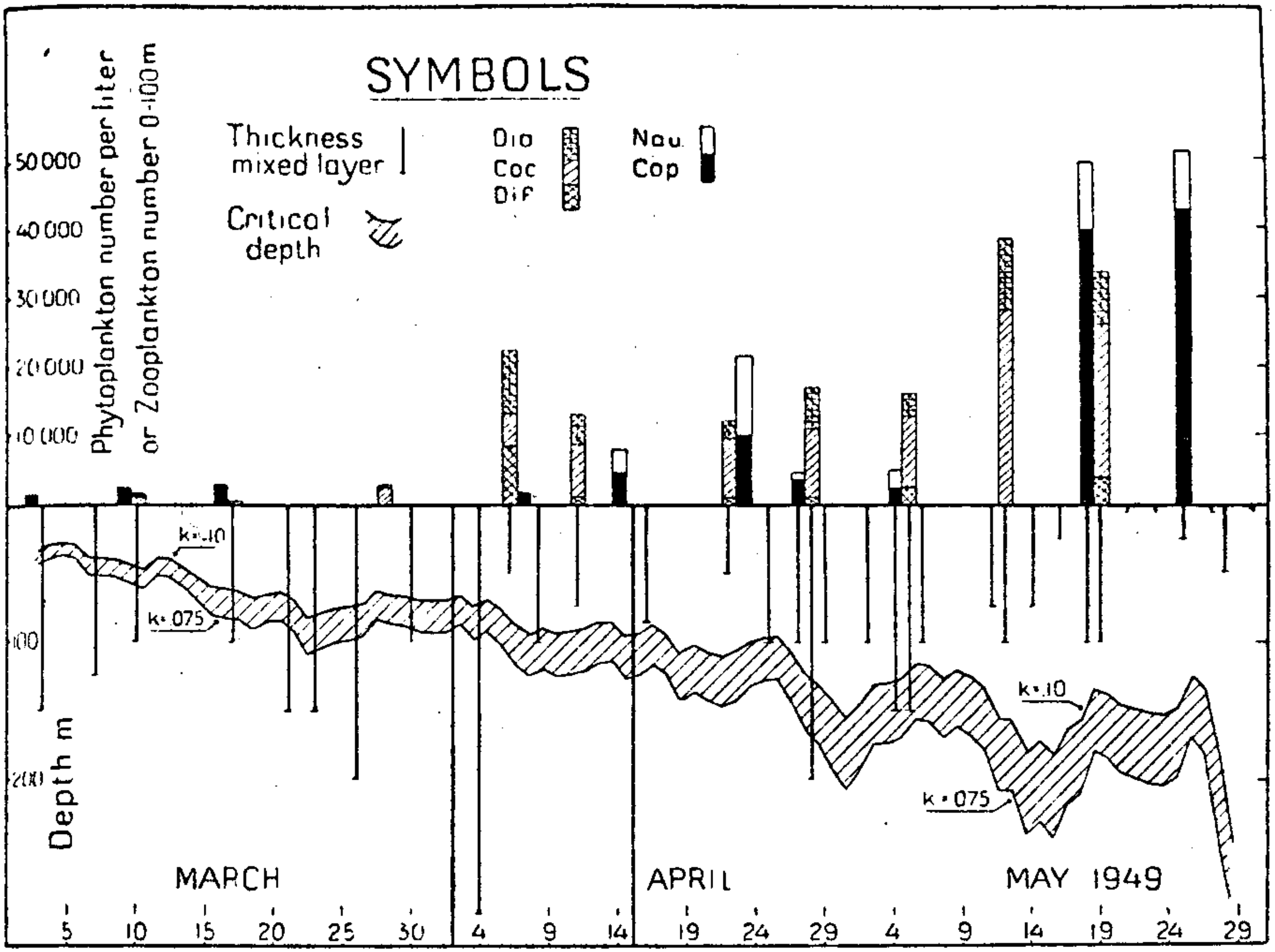

Figure 2. Results of observations at Weather Ship "M" (66°N., 2°E. Gr.). The symbols are explained in the graph, where the following abbreviations have been used:—Dia, Diatomaceae; Coc, Coccolithophoridae; Dif, Dinoflagellatae; Nau, Nauplii; and Cop, Copepods.

Onset of nutrient limitation

Onset of light limitation

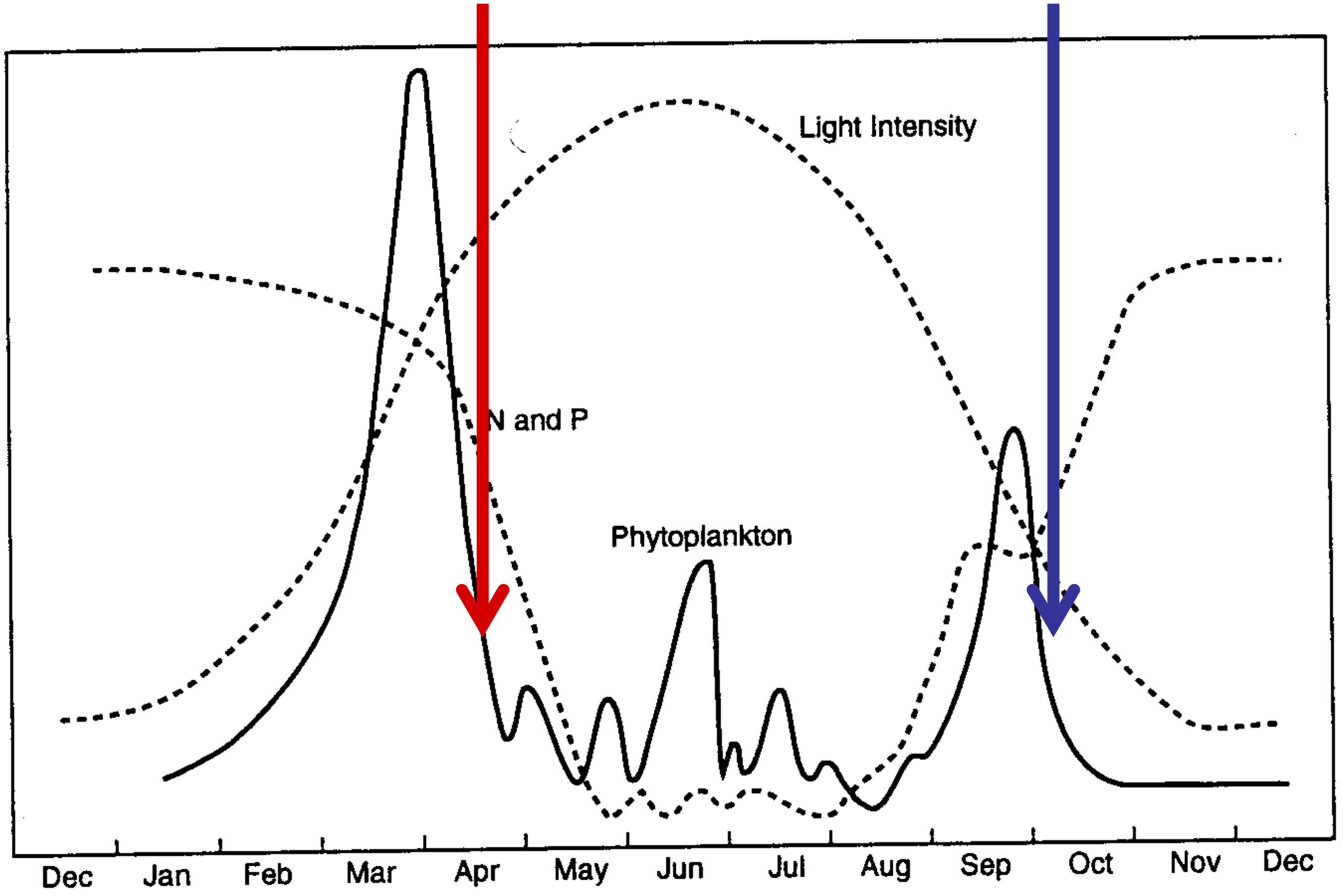

FIGURE 9.6. Seasonal variation of phytoplankton, nutrients, and light in a typical northern temperate sea.

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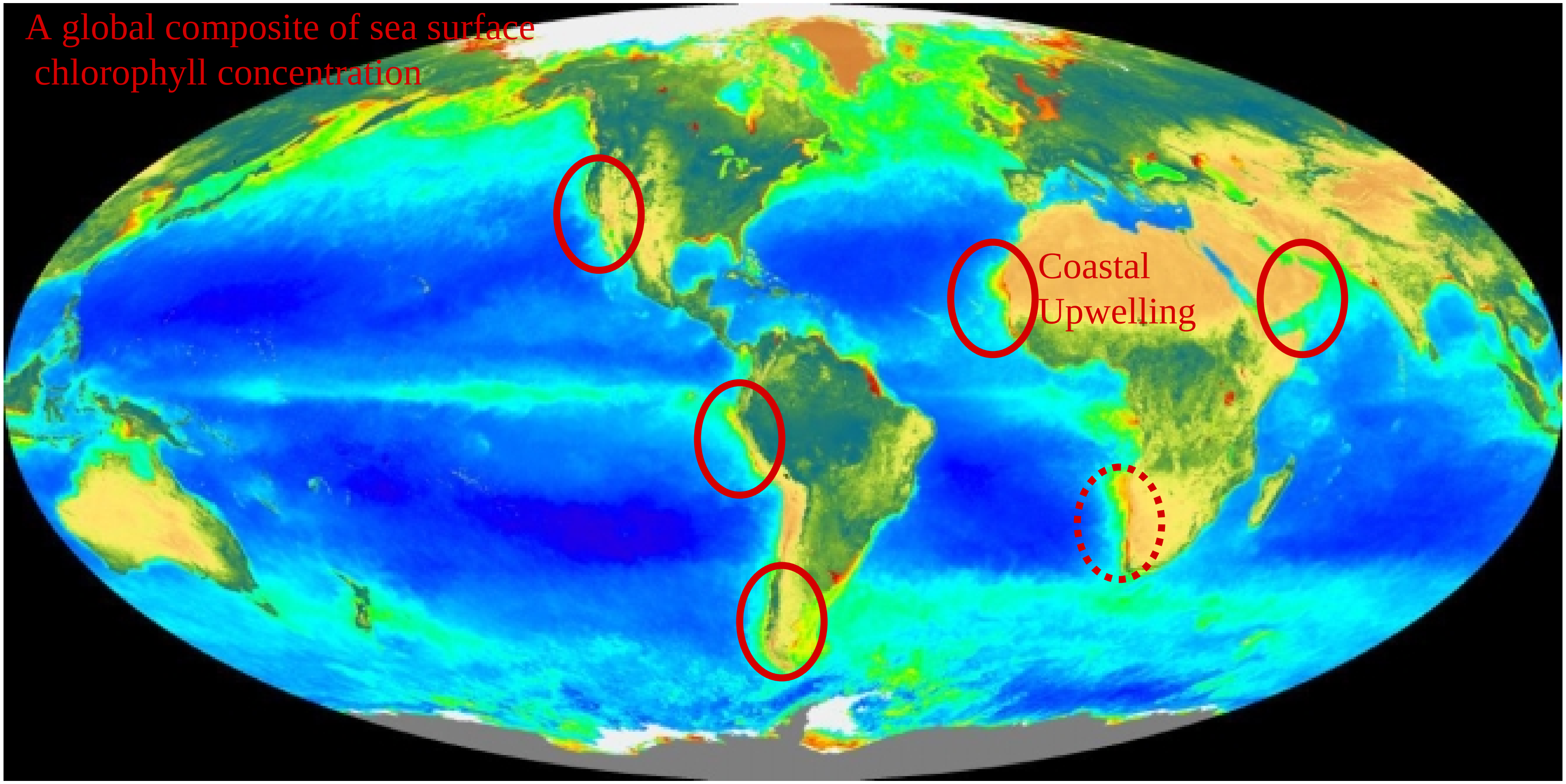
Major Coastal Upwelling Zones



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Primary production

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Herbland &
Le Bouteiller
(1981)
J. Plank. Res.

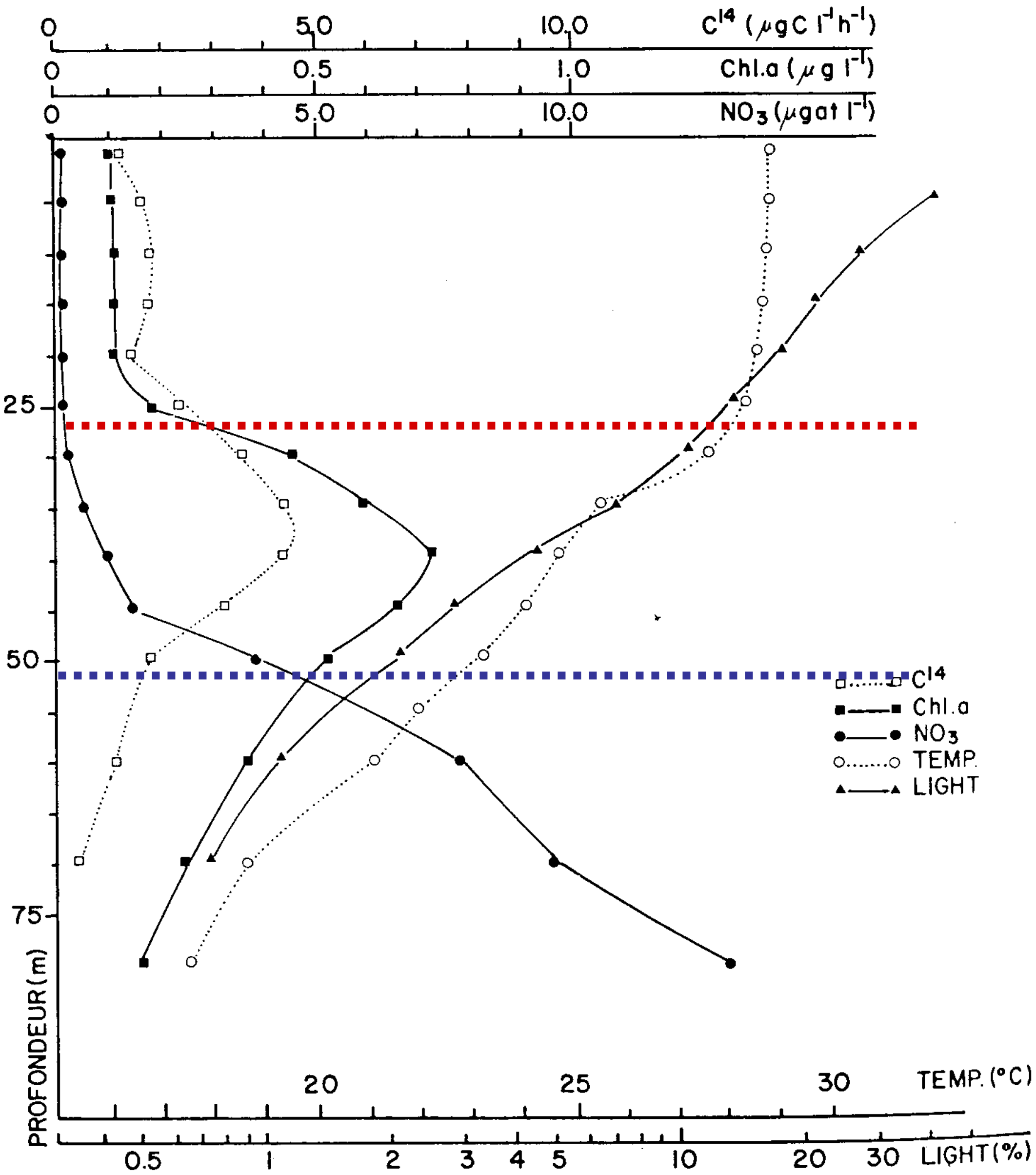

Fig. 2. The mean profiles of temperature, light, nitrate, chlorophyll *a* and $^{14}CO_2$ uptake during a long duration station (14 days) in the Equatorial Atlantic Ocean (0°-4° W). Cruise SOP 1.

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Direction reversed
in southern hemisphere

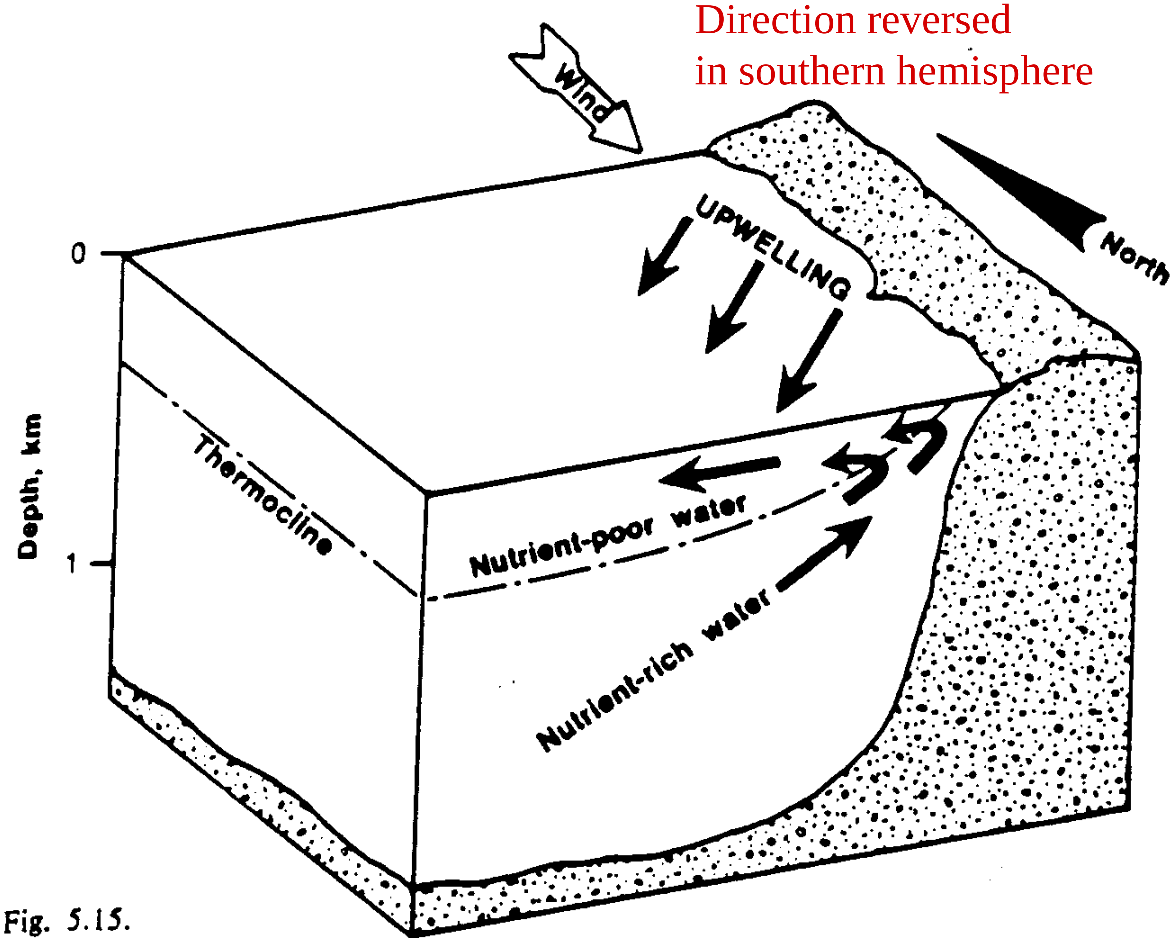

Fig. 5.15.

Primary production

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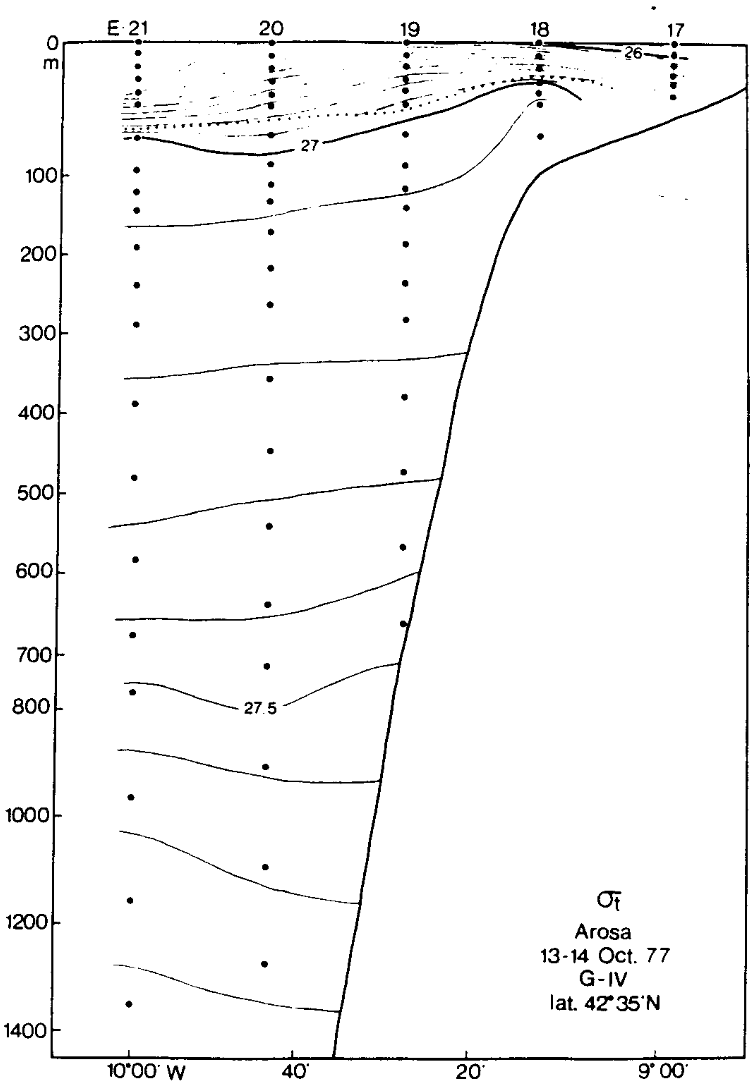


Fig. 10. Vertical distribution of density off Ría of Arosa at latitude 42°33'N, in October. "Galicia IV" cruise.

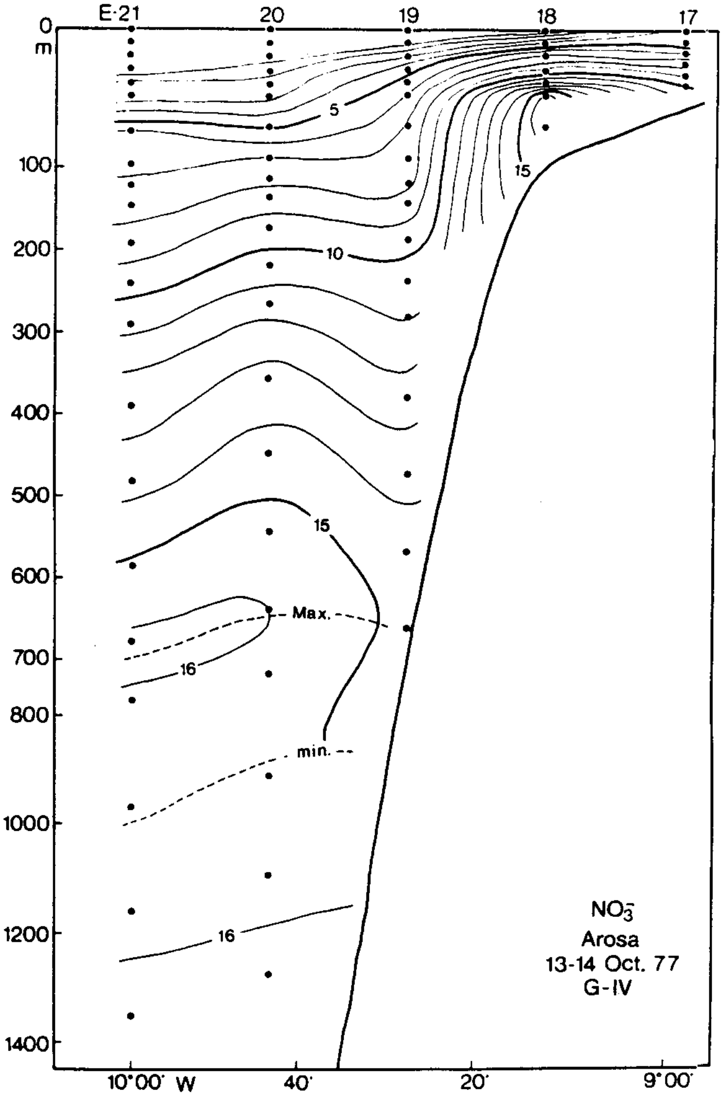
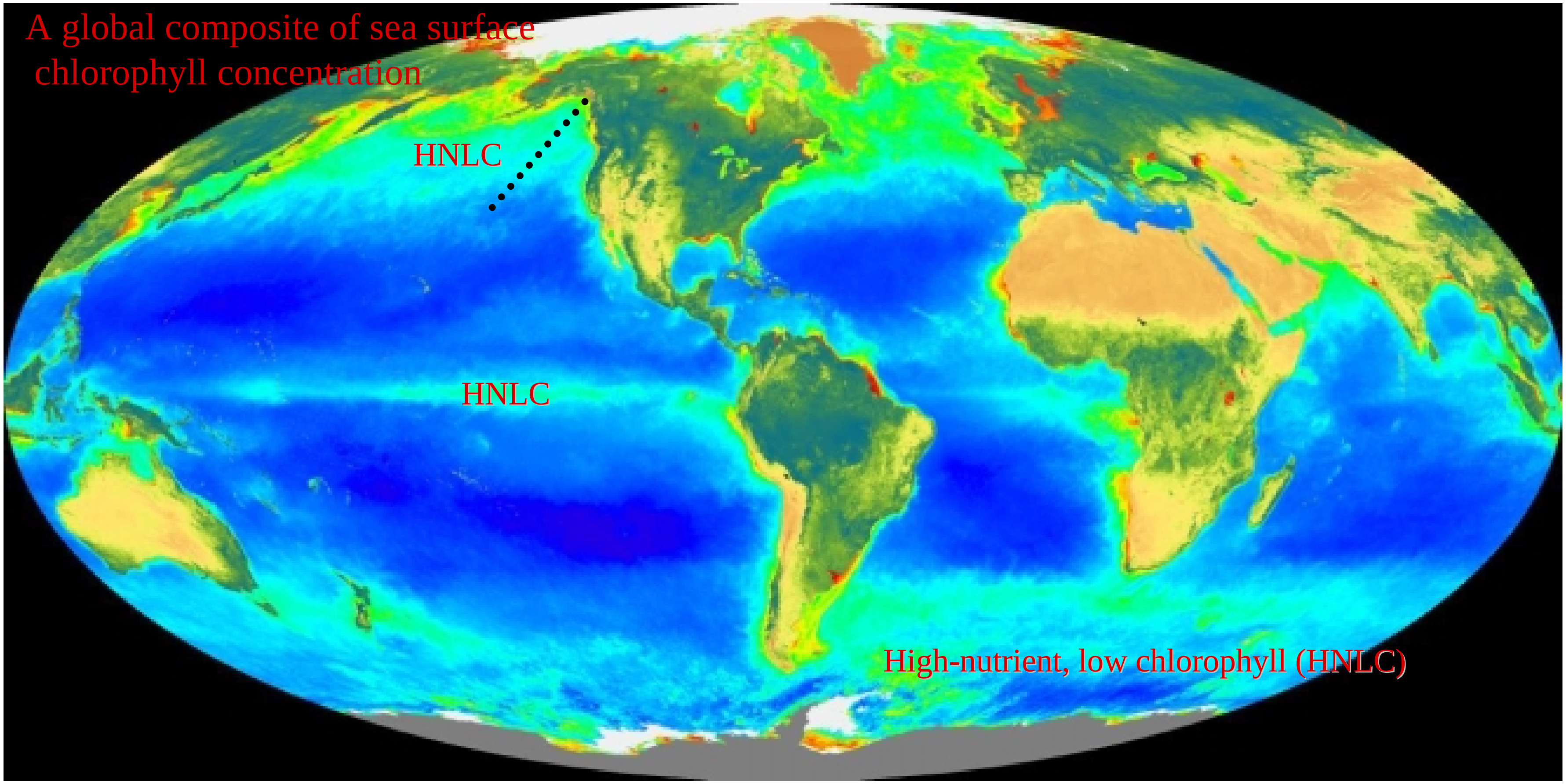


Fig. 11. Vertical distribution of nitrate along the same section shown in Fig. 10.

Primary production

Martin et al. Fe studies in subarctic N. Pacific



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Primary production

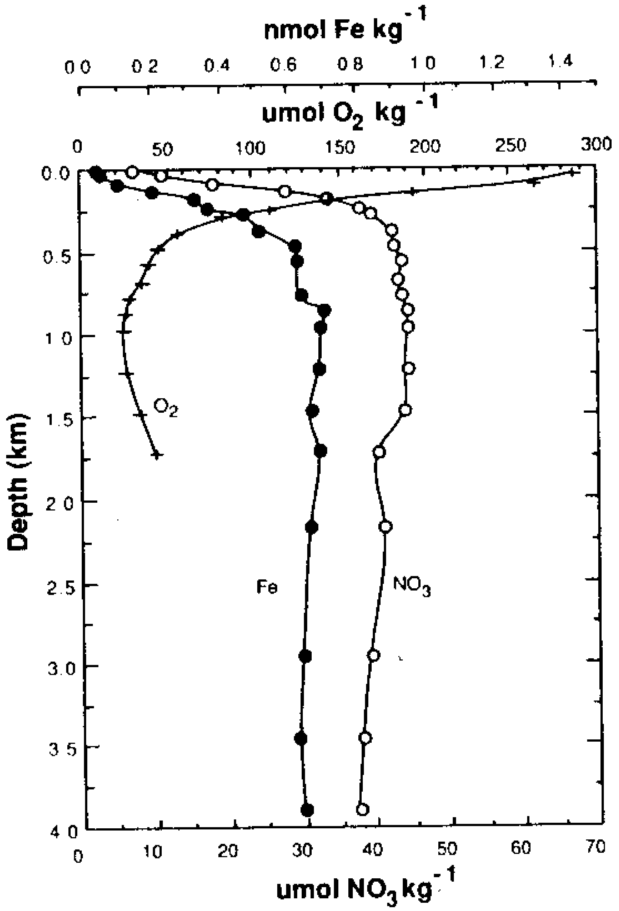

Fig. 4. Vertical distribution of dissolved Fe at Sta. T-7 ("Papa") together with oxygen and nitrate; data from Appendix Table A4.

Fe/NO_3^- ratio

Martin et al. (1989) Deep-Sea Res.

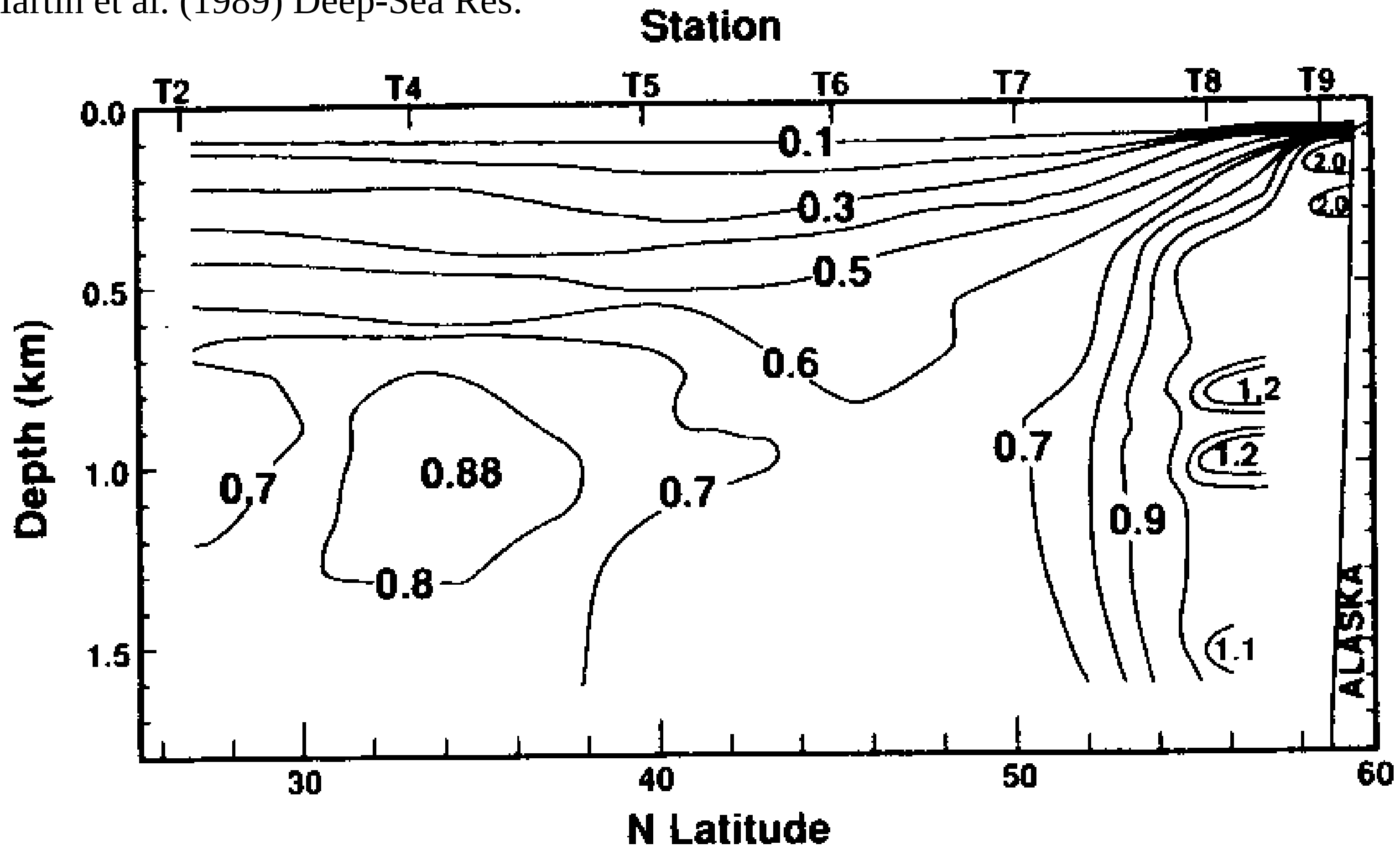

Fig. 7. A dissolved Fe section; station locations are shown in Fig. 1.

MAR 510 Chemical Oceanograph

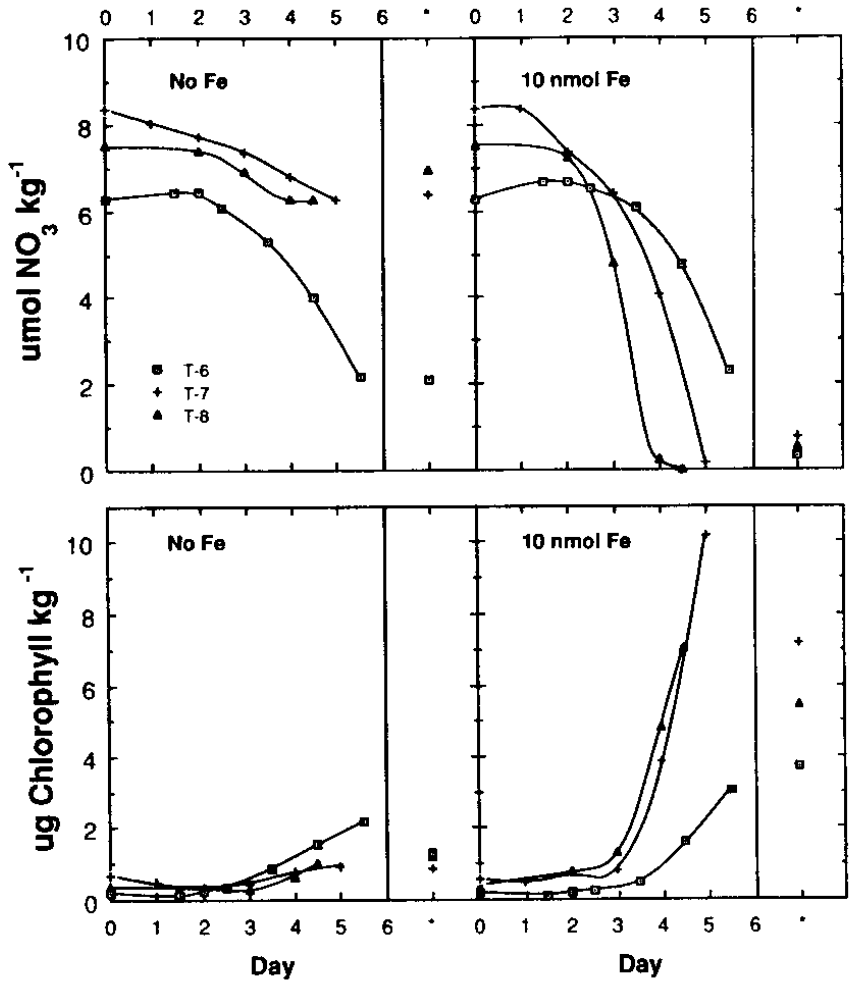

Fig. 12. Chlorophyll and NO_3 levels vs experimental day at Stas T-6, T-7 and T-8. Data for second sets of replicates measured only at the end of the experiment are in the boxes marked with an *. Stas T-6 and T-7 data are not shown for day 6 since growth had stopped, as evidenced by decreases in chlorophyll levels (Appendix Tables A8 and A9).

Primary production

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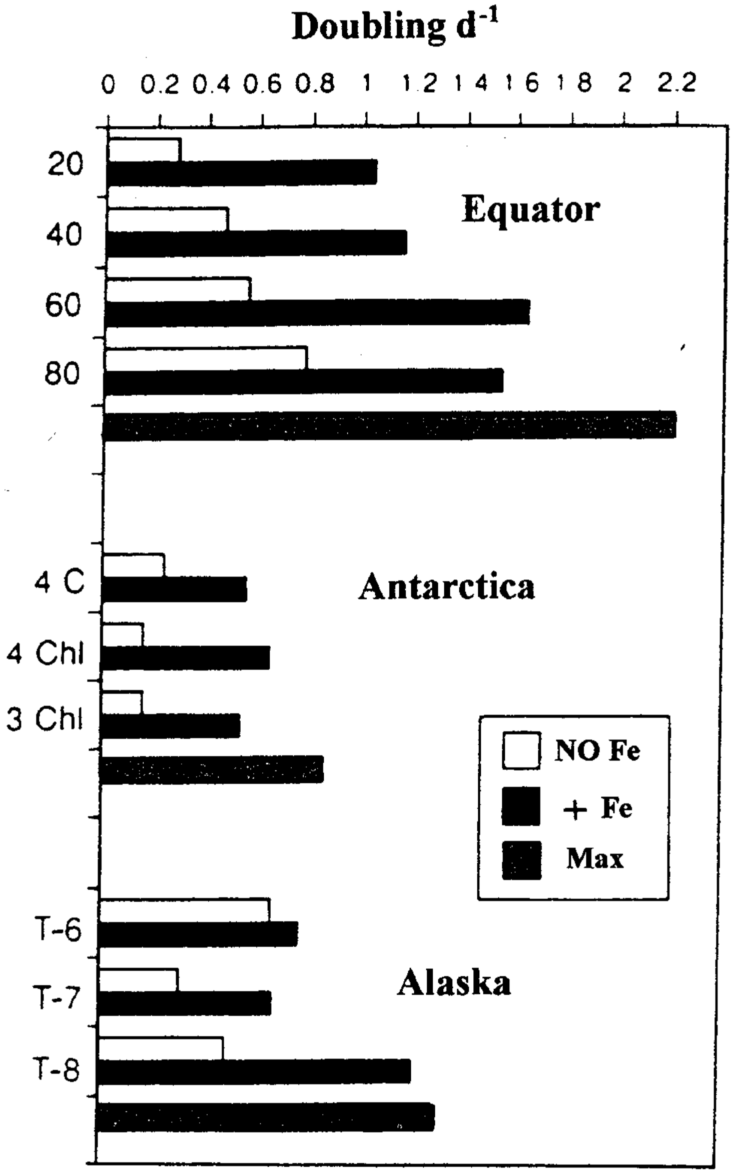

FIGURE 9.16. The effect of the additions of Fe on the doubling times of the growth of phytoplankton in the North Pacific, Equatorial Pacific, and South Pacific.

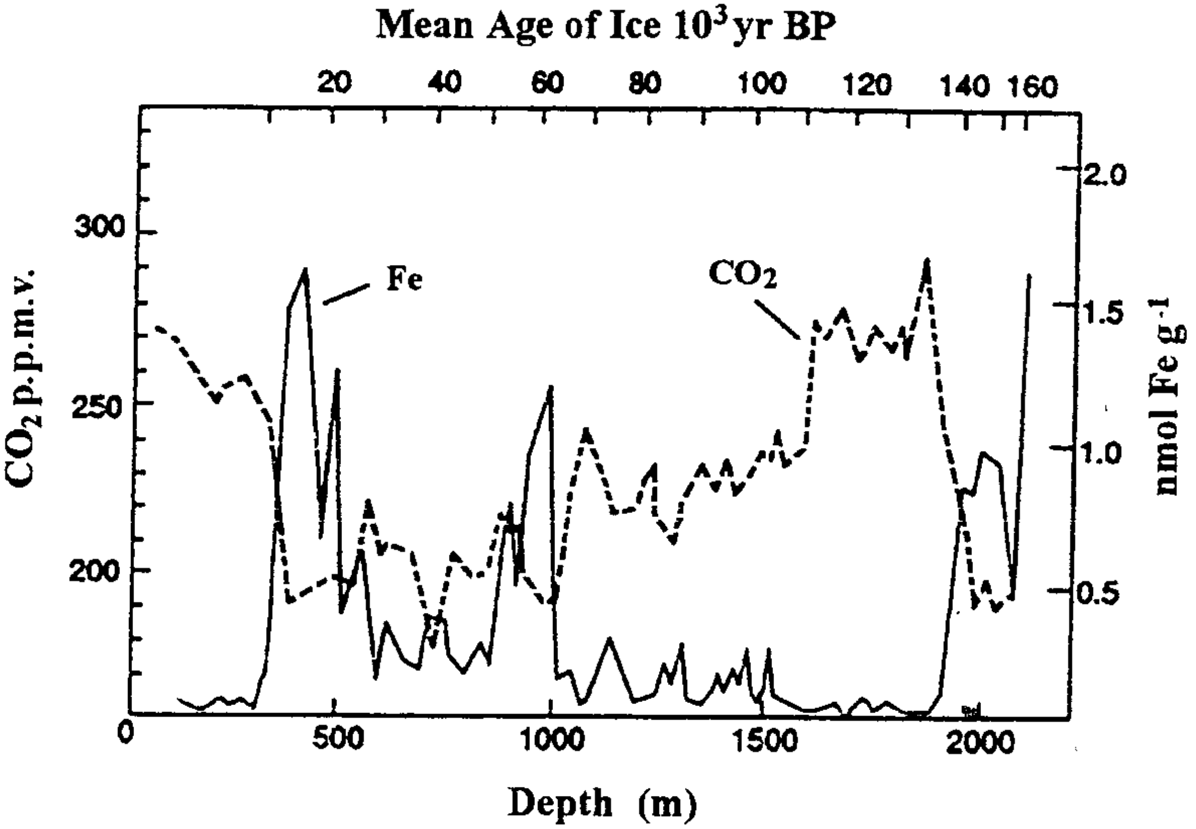

FIGURE 9.17. The historical record of atmospheric CO_2, dust deposition, and nonseasalt aerosols.

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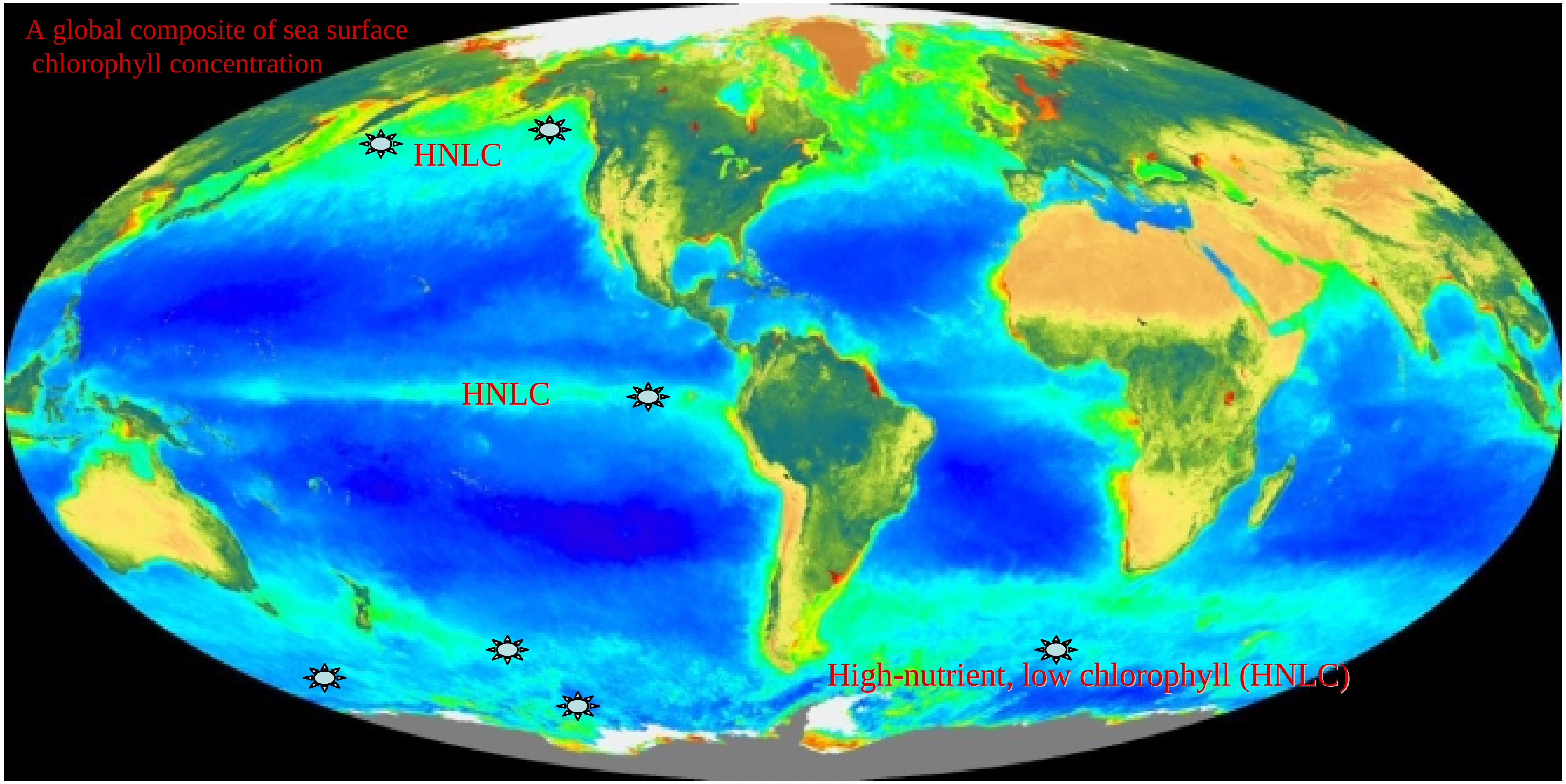
Large-Scale Fe Fertilization Experiments



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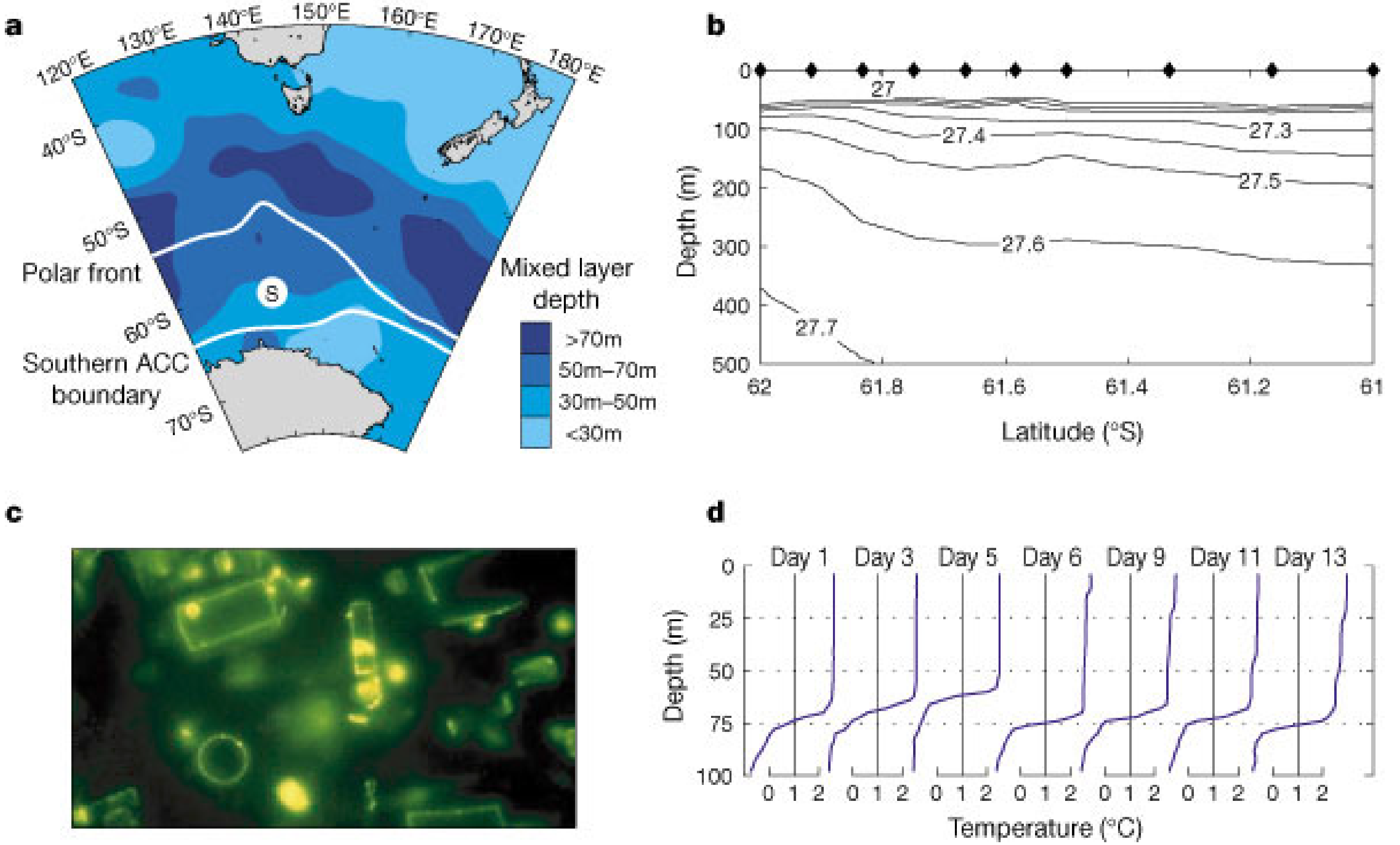
Primary production

Boyd, P. W., et al. (2000) A mesoscale phytoplankton bloom in the polar Southern Ocean stimulated by iron fertilization. *Nature* 407: 695 - 702.



Primary production

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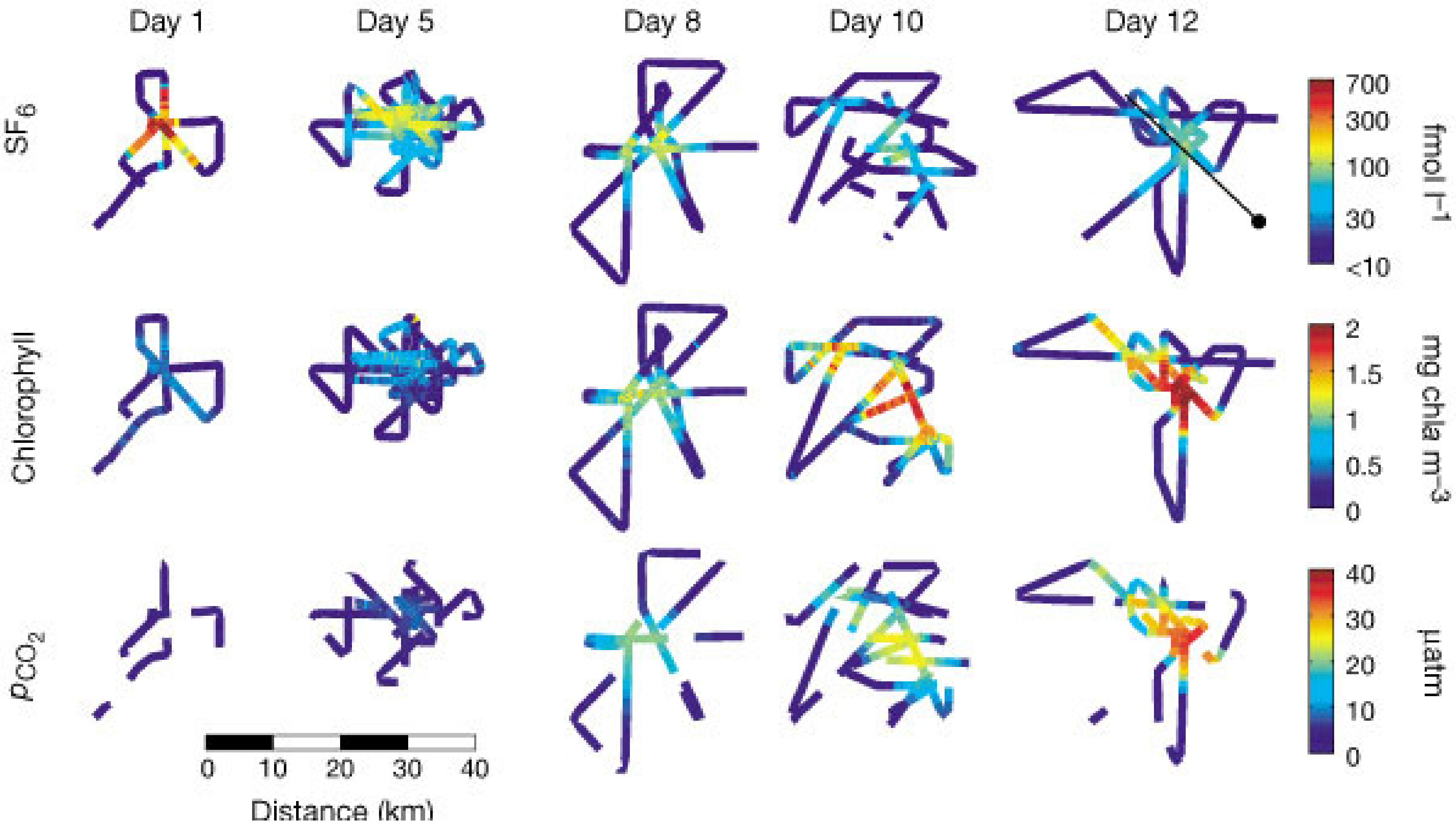

Primary production

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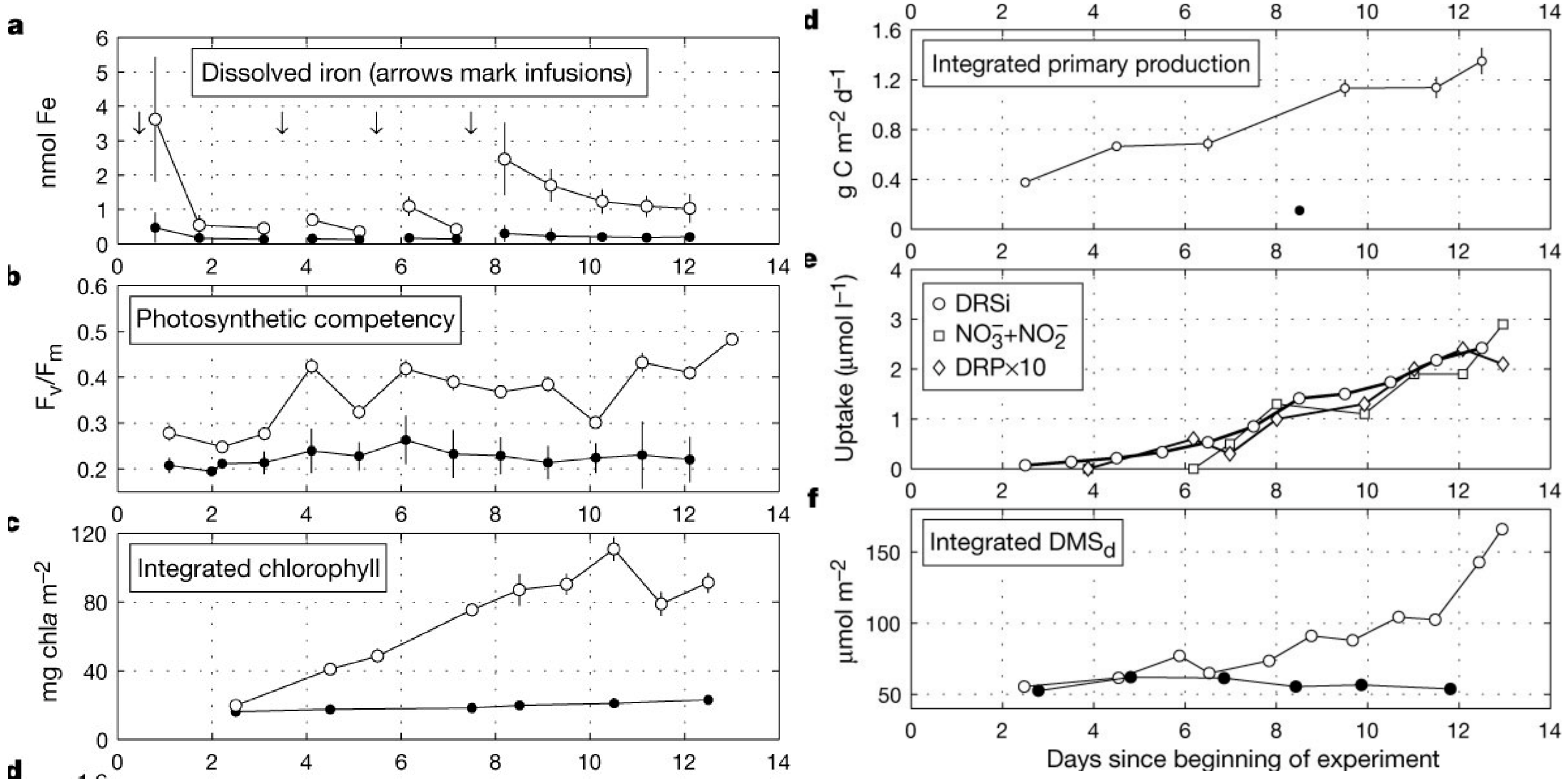
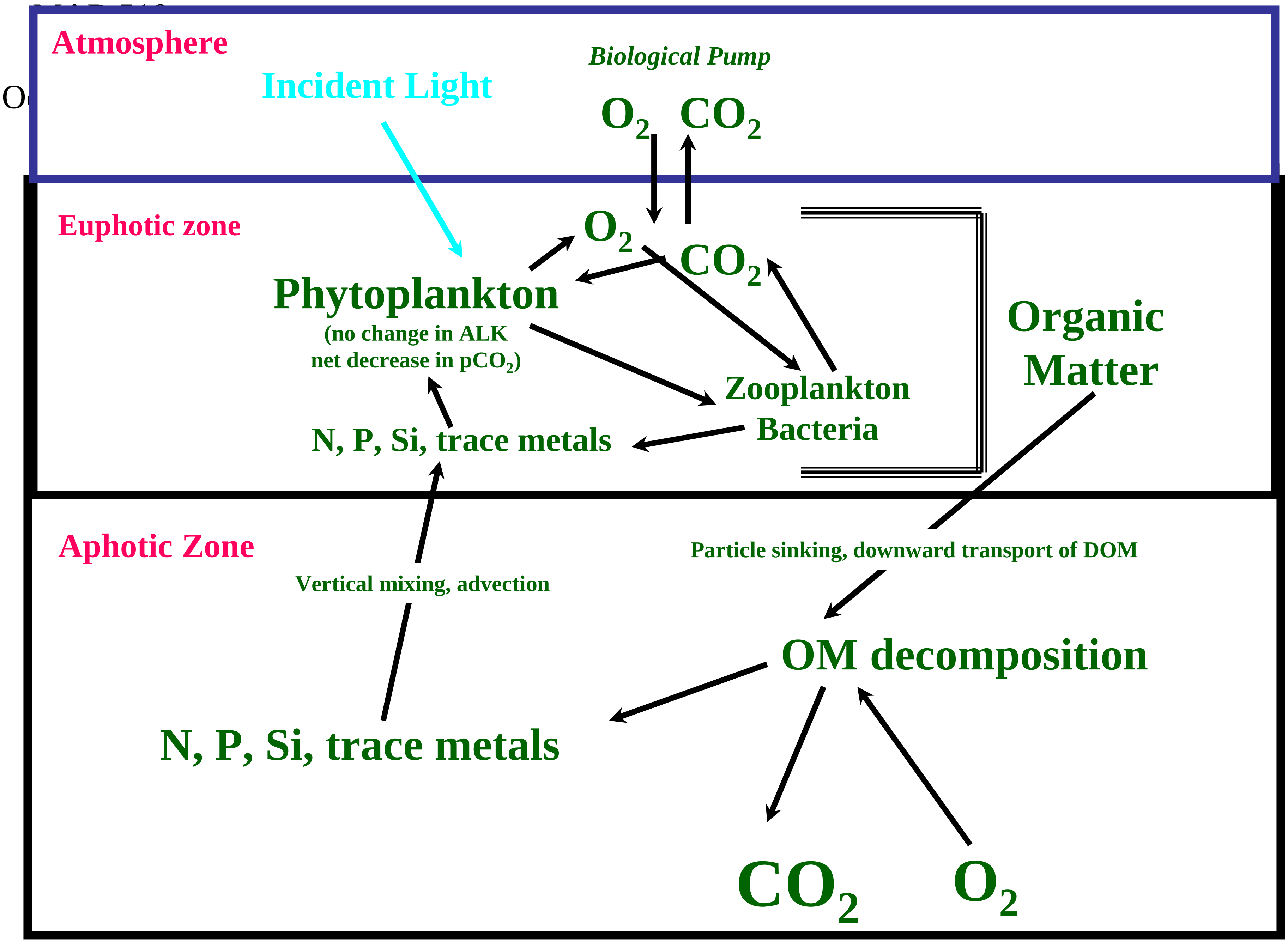


Primary production



Atmosphere

Incident Light

Biological Pump

O_2 CO_2

Euphotic zone

O_2

CO_2

Phytoplankton

(no change in ALK
net decrease in pCO_2)

Zooplankton
Bacteria

Organic
Matter

N, P, Si, trace metals

Aphotic Zone

Vertical mixing, advection

Particle sinking, downward transport of DOM

OM decomposition

N, P, Si, trace metals

CO_2 O_2

From W. Deuser

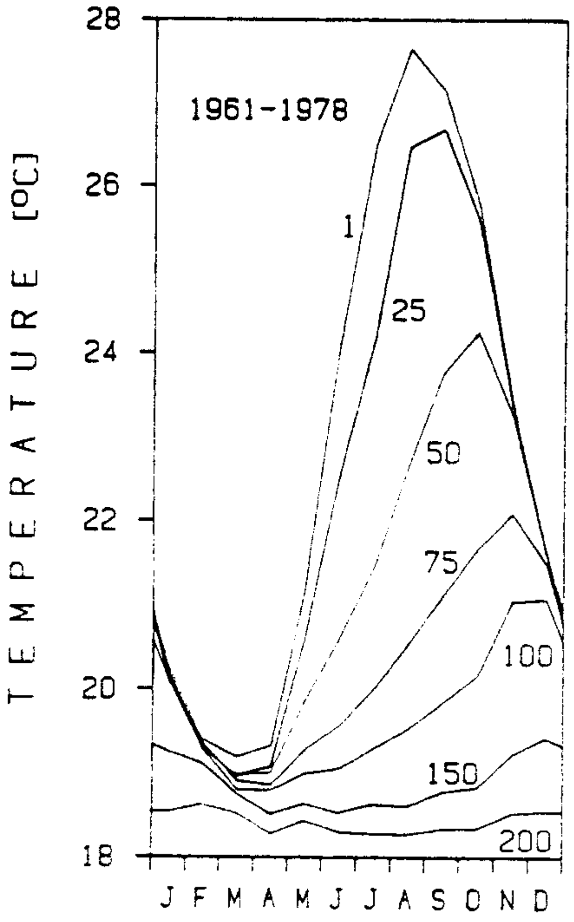


Fig. 1: Mean annual temperature variation in top 200 m at Station 'S' off Bermuda

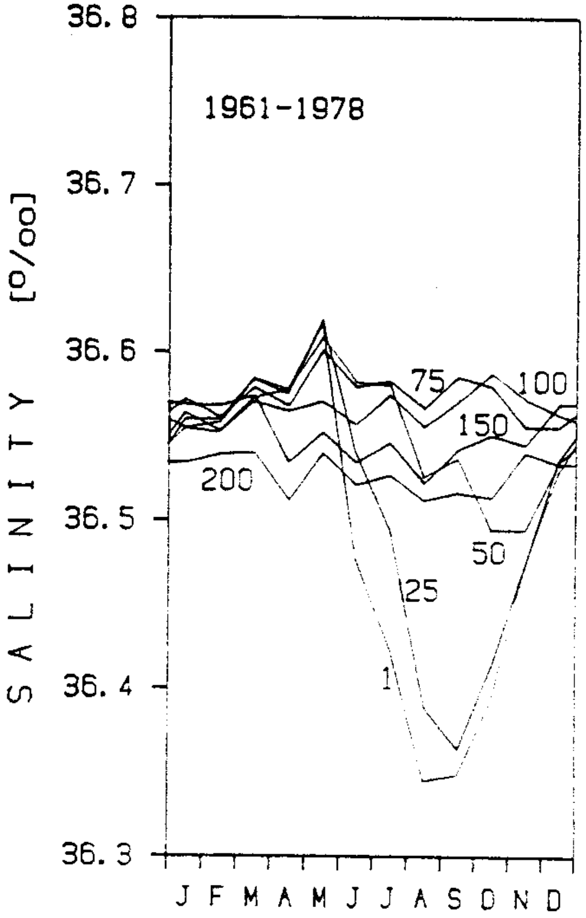


Fig. 2: Mean annual salinity variation in top 200 m at Station 'S' off Bermuda

From W. Deuser

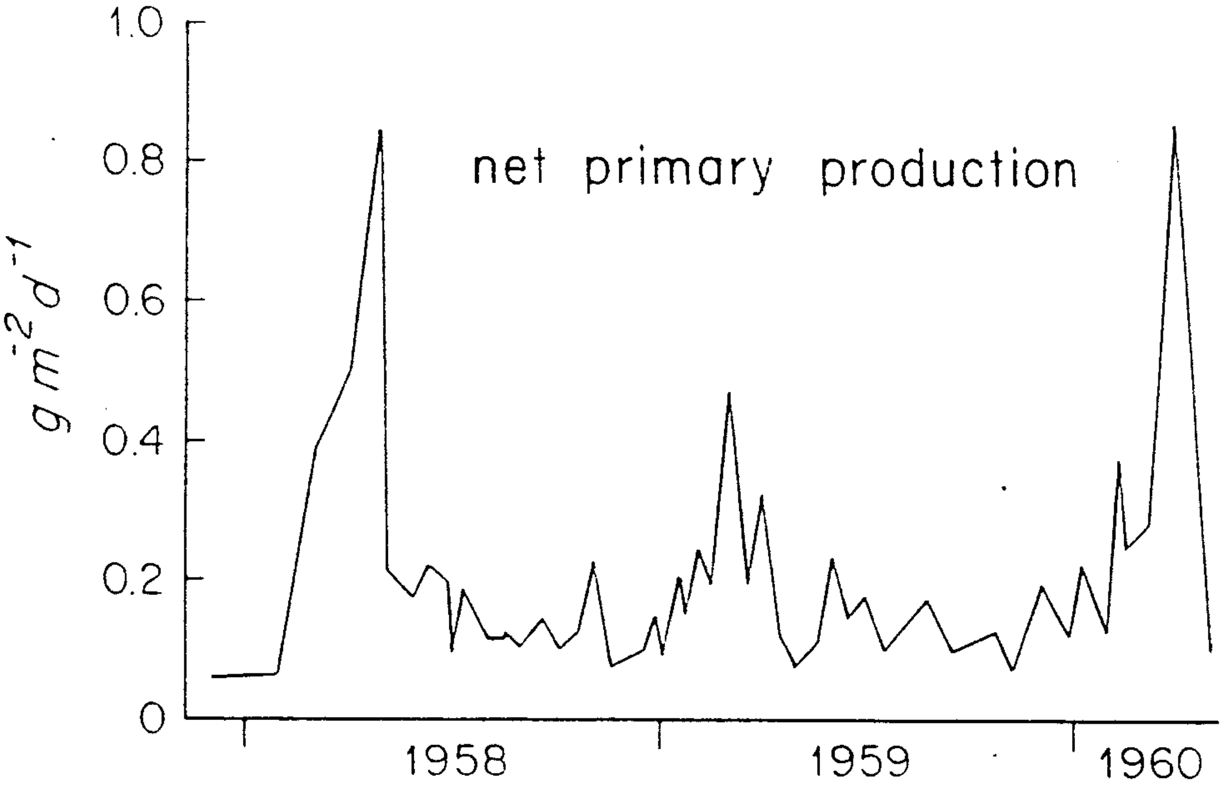
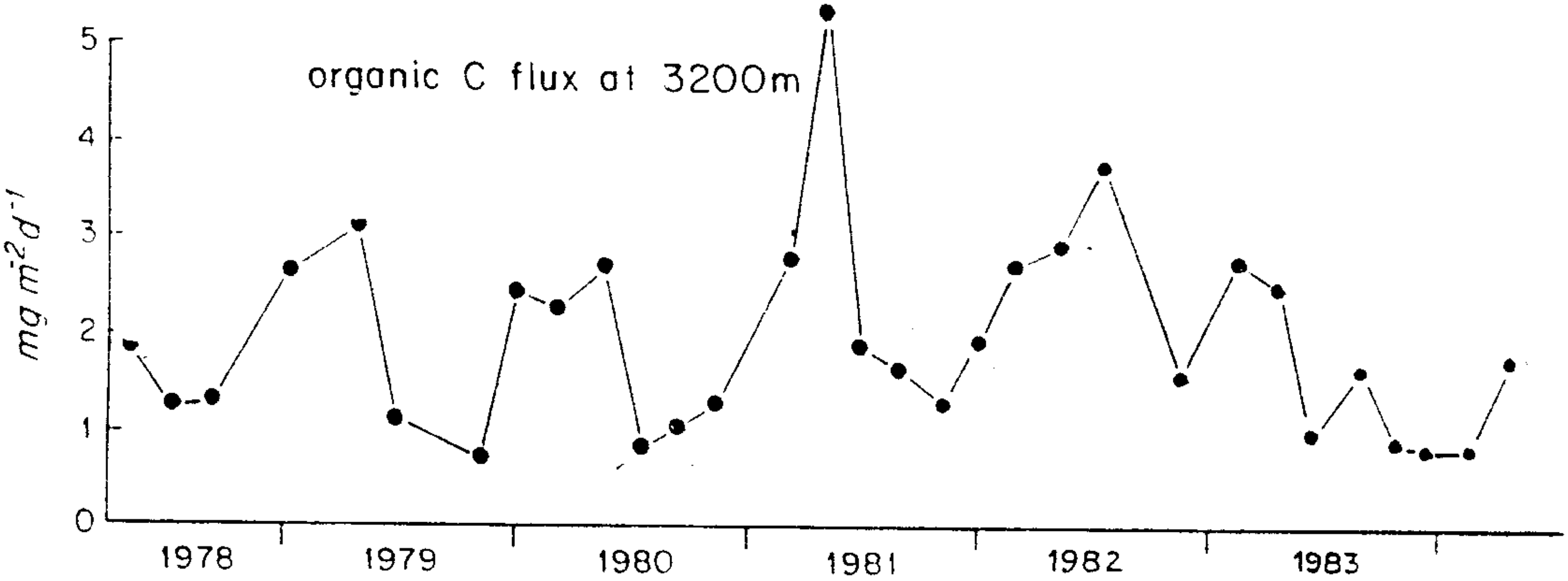


Fig. 3: Variations in net carbon assimilation at Station 'S' (Menzel and Ryther, 1961)



Six-year record of variations in deep-water organic-carbon flux southeast of Bermuda

Primary production

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Alldredge and Silver (1988) Prog. Oceanogr.

Particle Dynamics of Marine Snow

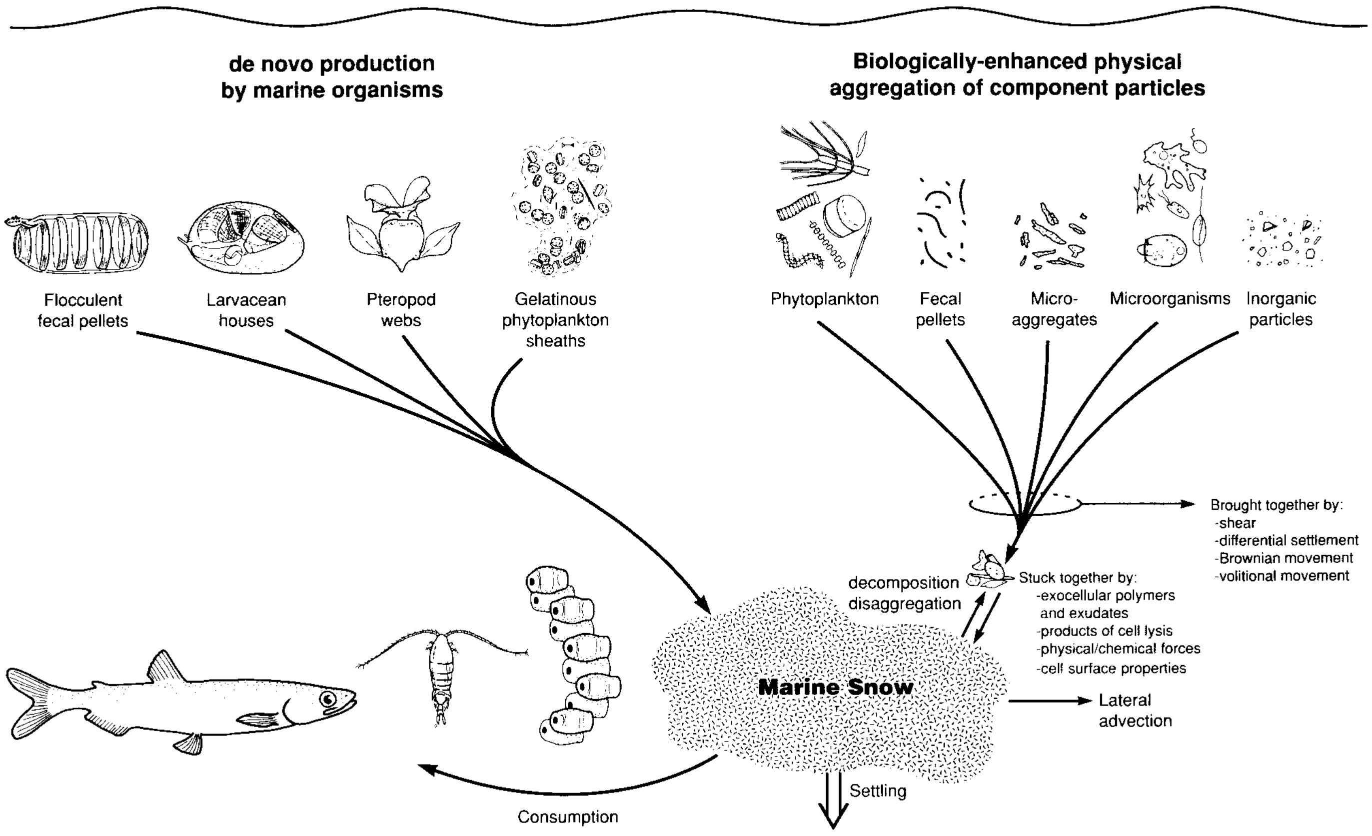

FIG.5. Major processes by which marine snow is produced, broken down and lost from the pelagic zone. Marine snow is produced by two major pathways. First, marine plankton produce marine snow aggregates *de novo* as mucus webs, houses, sheaths, and flocculent fecal pellets. Second, smaller component particles, including phytoplankton, fecal pellets, microaggregates, bacteria and inorganic particles, collide together via physical processes and become stuck together, facilitated by biological "glues". Snow is broken down or lost by processes of decomposition, disaggregation, consumption, lateral advection and settlement.