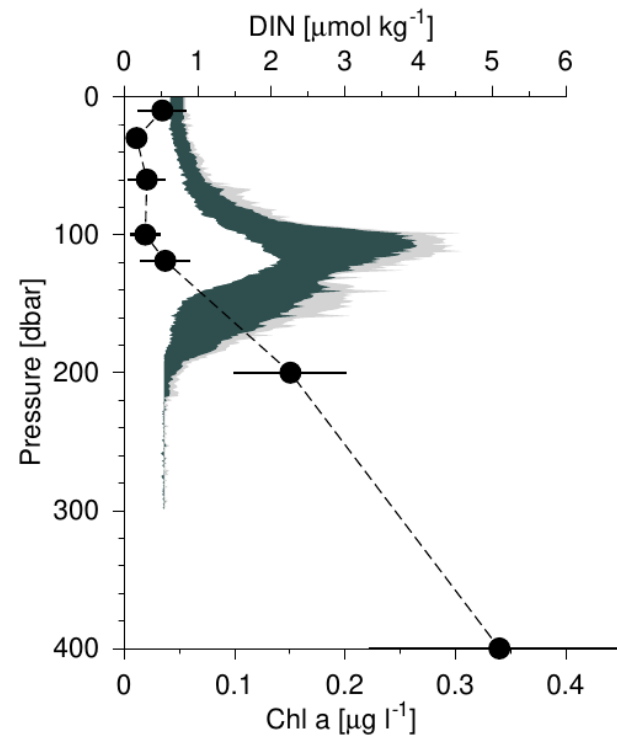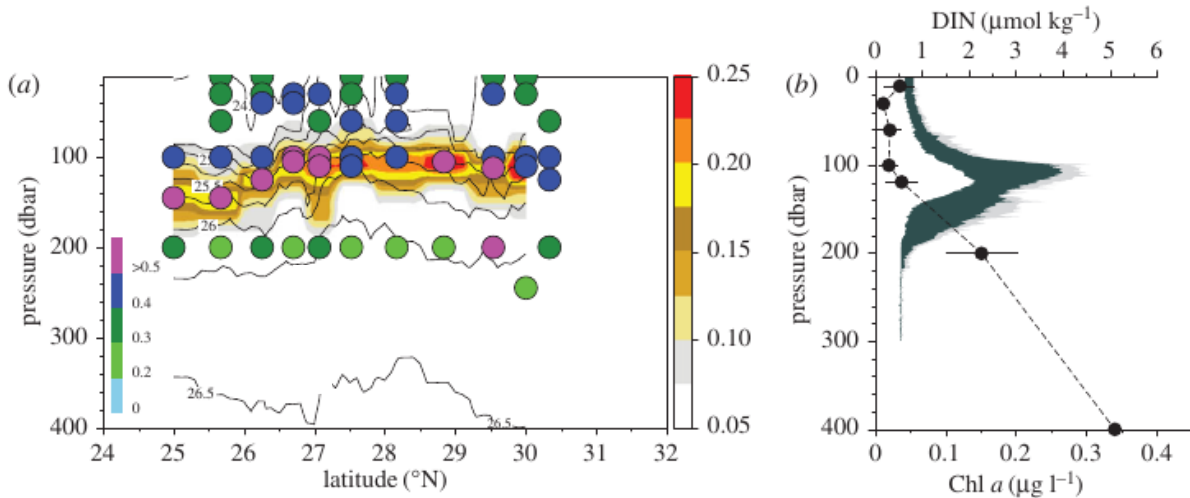# Estimating global PP from space in relation to nutricline depth in the open ocean

by Katherine Richardson (Univ. of Copenhagen) and Jørgen Bendtsen (ClimateLab)
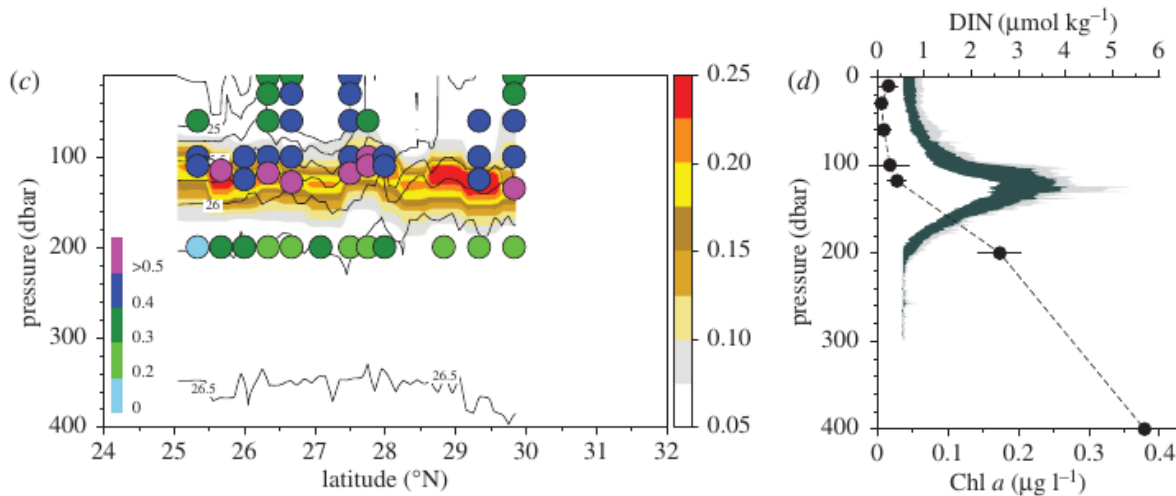
Observations March 2016

Sargasso Sea: 68.5°W

Sargasso Sea: 65.5°W

colors: Chlorophyll a (µg L^{-1})

Bullets: Fv/Fm

Reference
Richardson, K. and Bendtsen, J. (2017) Photosynthetic oxygen production in a warmer ocean: The Sargasso Sea as a case study, Phil. Trans. R. Soc. A, 20160329. https://doi.org/10.1098/rsta.2016.0329.

Observations from the North Sea
Shelf edge area in July 2016

A subsurface chlorophyll a maximum
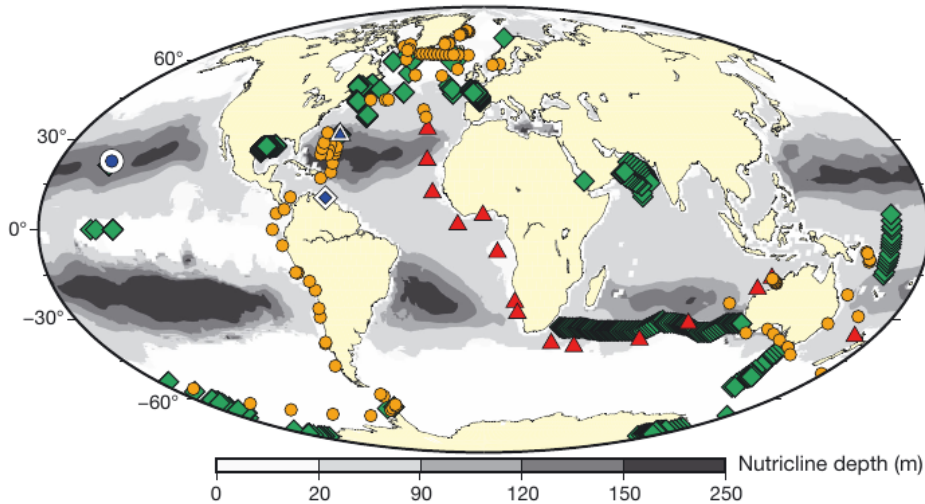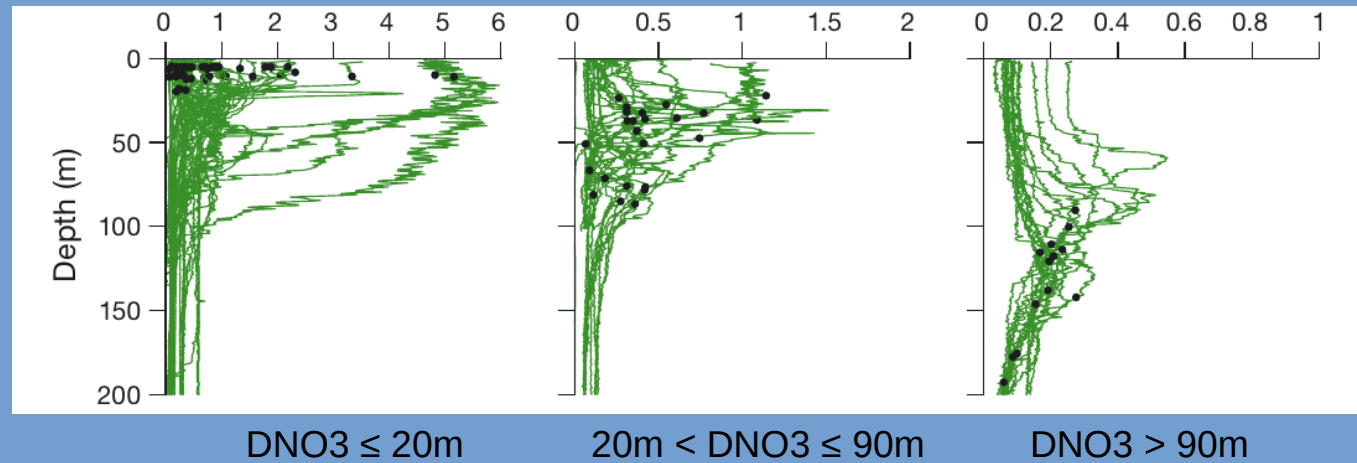is located above the nutricline (red
bullets).
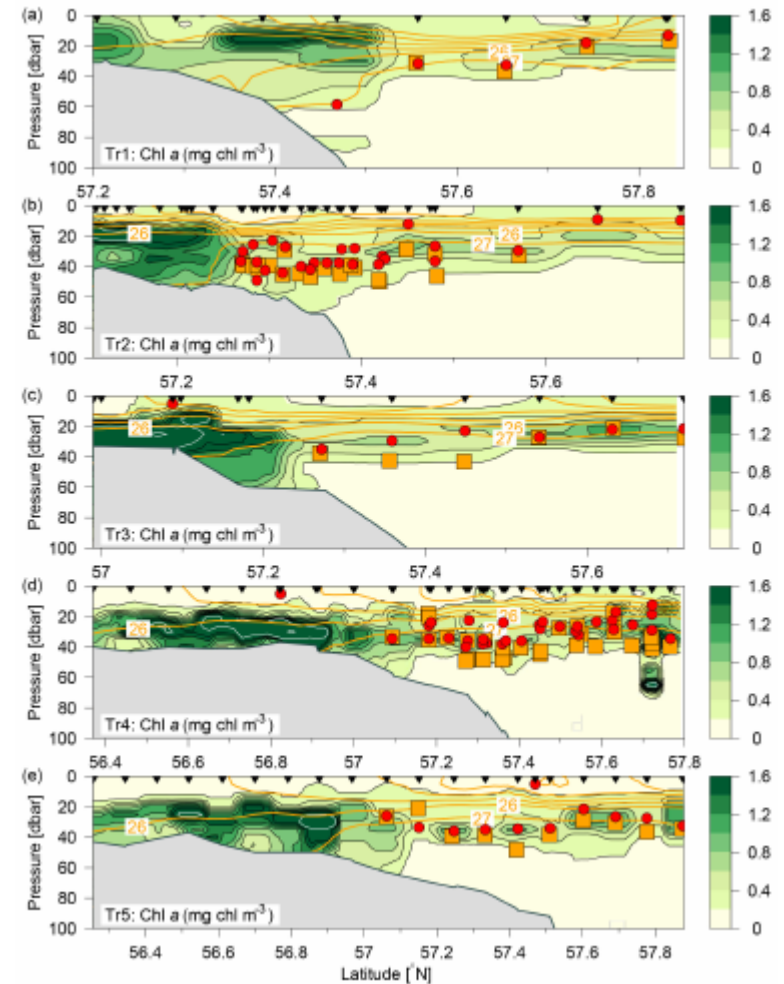
Reference
Bendtsen, J. and Richardson, K. (2018) Turbulence measurements suggest high rates of new production over the shelf edge in the north-eastern North Sea during summer. Biogeosciences, 15, 7315–7332. https://doi.org/10.5194/bg-15-7315-2018

Chlorophyll a (mg/l)

in 3 nutricline intervals (DNO3)

DNO3 ≤ 20m   20m < DNO3 ≤ 90m   DNO3 > 90m

Global data:

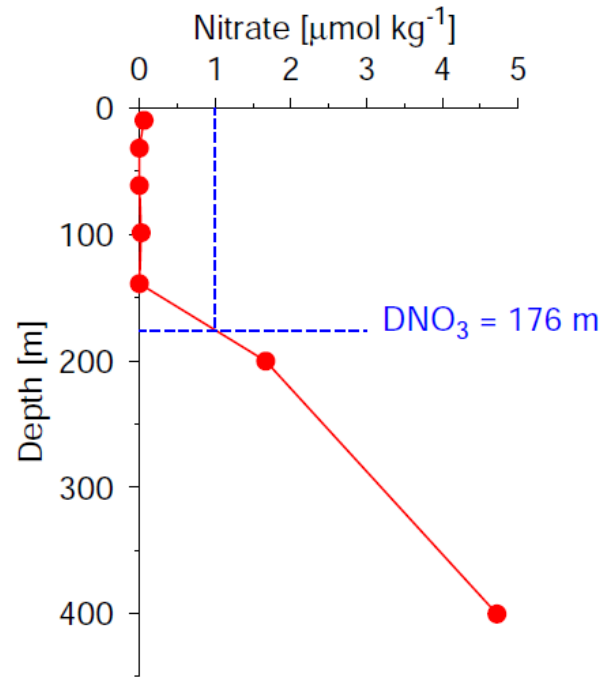Observations, including Galathea 3
(Yellow bullets and red triangles)

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46.
https://doi.org/10.3354/meps12960

How do we find Nutricline depth ?

Defined where
$NO_3^- = 1$ µmol kg^{-1}

Nitrate [µmol kg^{-1}]

DNO$_3$ = 176 m

Data from Galathea 3
Sargasso Sea
64 °N, 25° 25' W

DCM vs nutricline

DCM (m) vs DNO3 (m)

Plotting all our data from Galathea3 and subarctic cruises

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46.
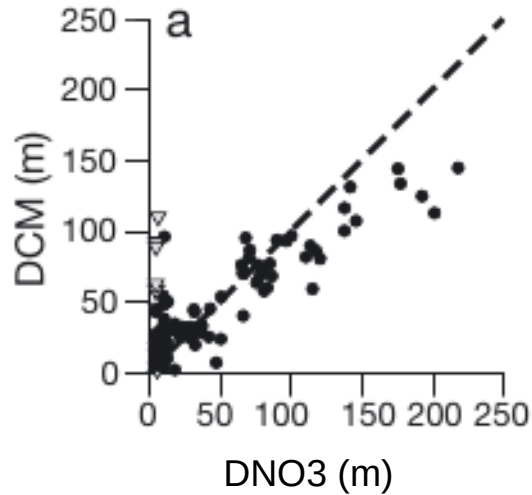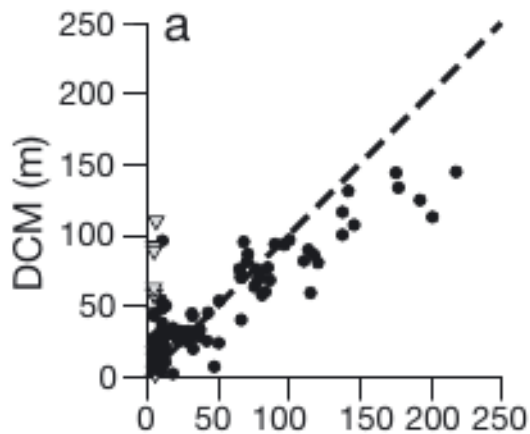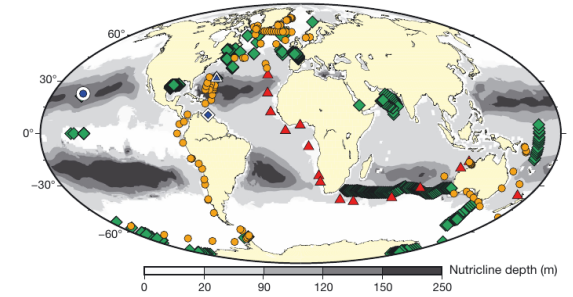https://doi.org/10.3354/meps12960

DCM vs nutricline

Galathea 3 & subarctic cruises

Timeseries stations
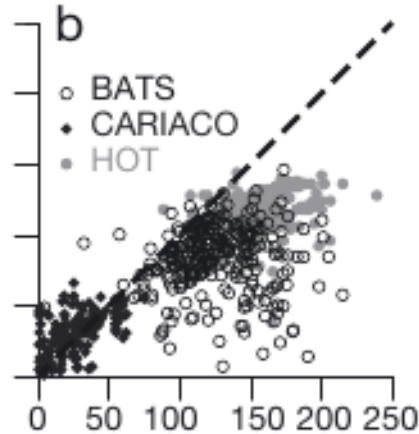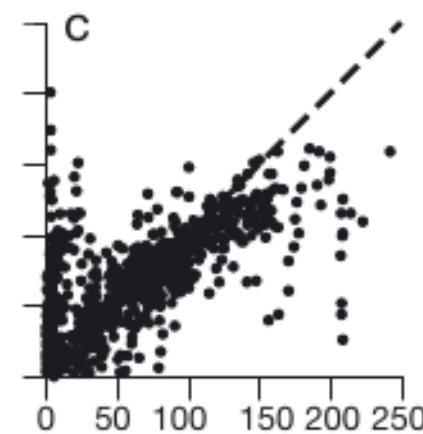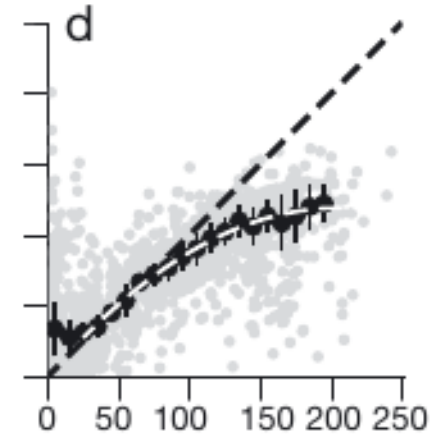
World Ocean Data

All data and fit

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46.
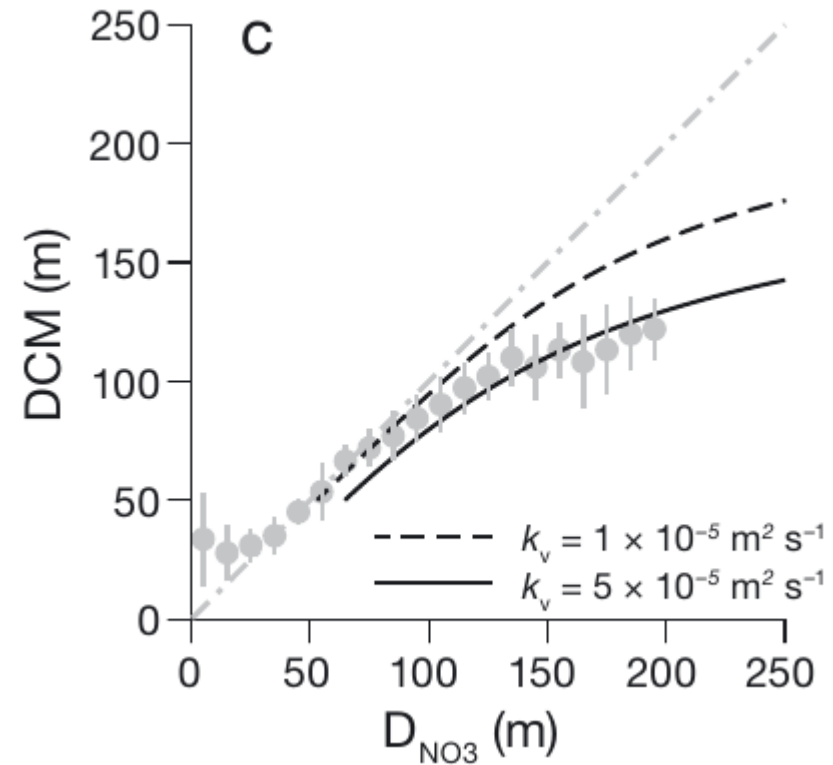https://doi.org/10.3354/meps12960

A simple balance: light vs nutrients

Assuming:

- Observed light field and chlorophyll a

- A balance between export of organic carbon and vertical nutrient fluxes:
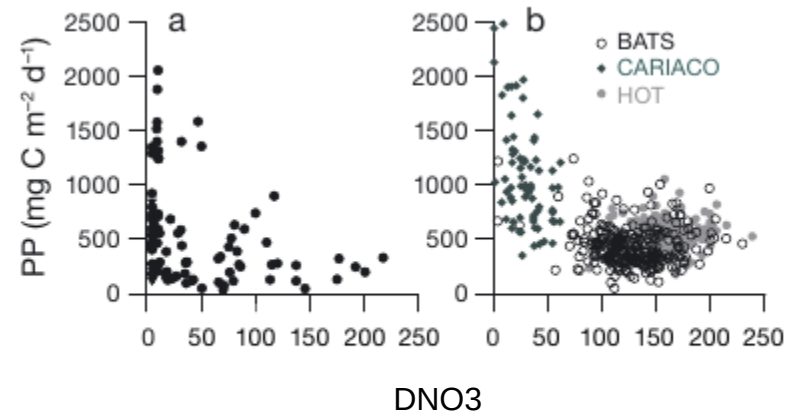
  export = vertical nutrient flux

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46.
https://doi.org/10.3354/meps12960

PP vs DNO3

Total PP

PP in the upper 10 m divided
by the total PP:

*The fraction of PP decrease
when DNO3 increase*
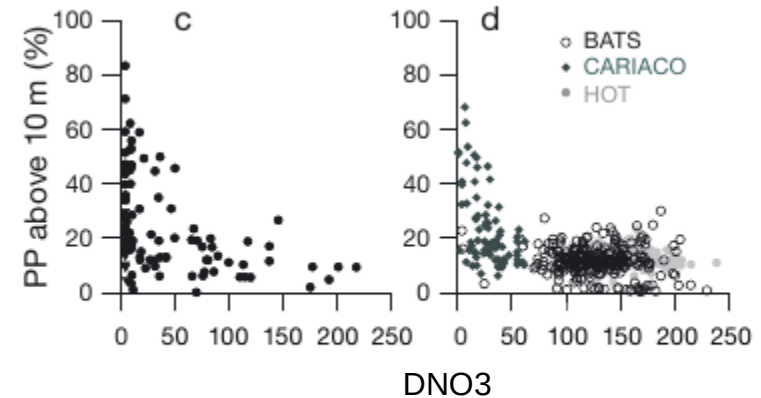
Empirical PP model

DNO3: < 20 m: PP(0-10m) = 31% of total PP

DNO3: 20-90m: PP(0-10m) = 19% of total PP

DNO3 > 90 m: PP(0-10m) = 10.7% of total PP

DNO3

VPP-model: total PP is estimated from PP(0-10m)

PP(0-10m) = fraction of PP

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46.
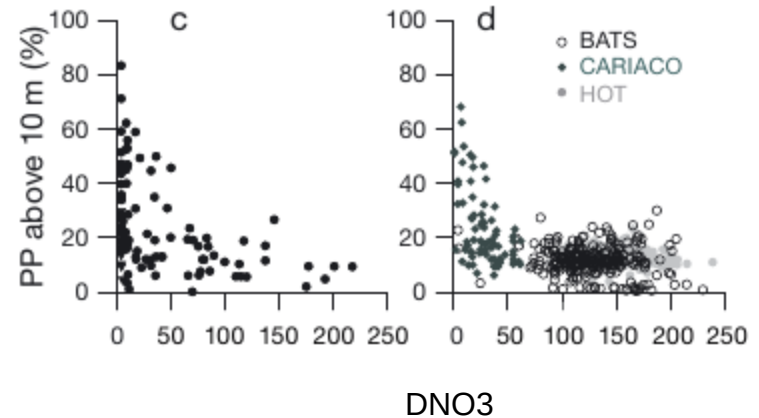https://doi.org/10.3354/meps12960

VPP-model

The production in the upper 10 m is a fraction (γ) of total PP,

where γ is a function of nutricline depth: PP$_{10m}$ = γ(DNO3) PP

$$PP_{10\,m} = \int\limits_{0}^{24\,h} \int\limits_{-10\,m}^{0} P_{max}^{B}\, chl\,(z)\left(1 - \exp\left(-PAR\,(t,z)\frac{\alpha^{B}}{P_{max}^{B}}\right)\right)dz\,dt$$

Satellite data of:

chl, PAR, Kd, SST

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46. https://doi.org/10.3354/meps12960
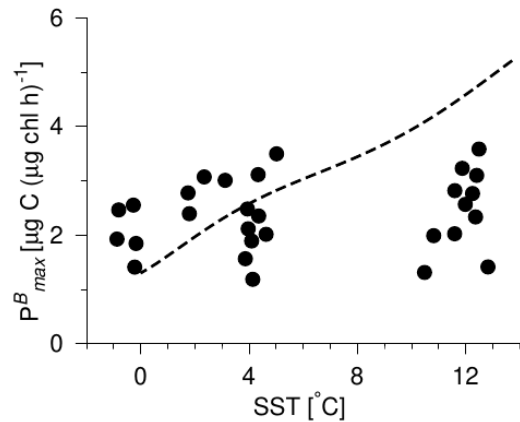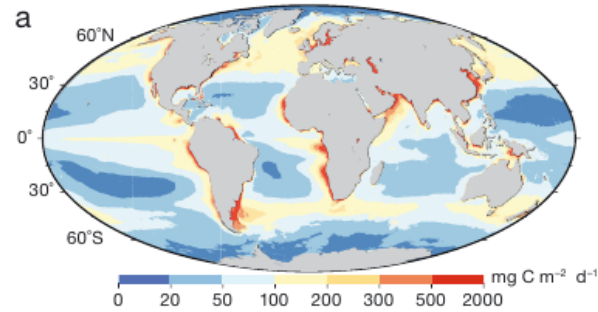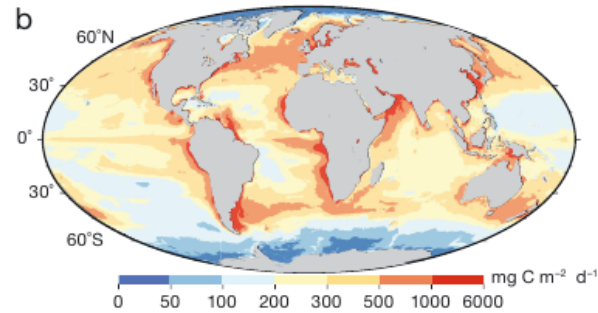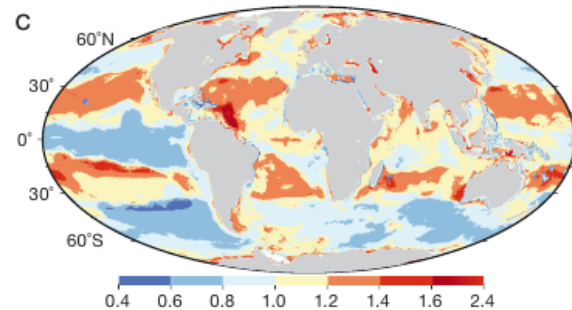
Average PP

PP(0-10m)

VPP

VPP/VGPM

Results:

~25% of PP in the upper 10m

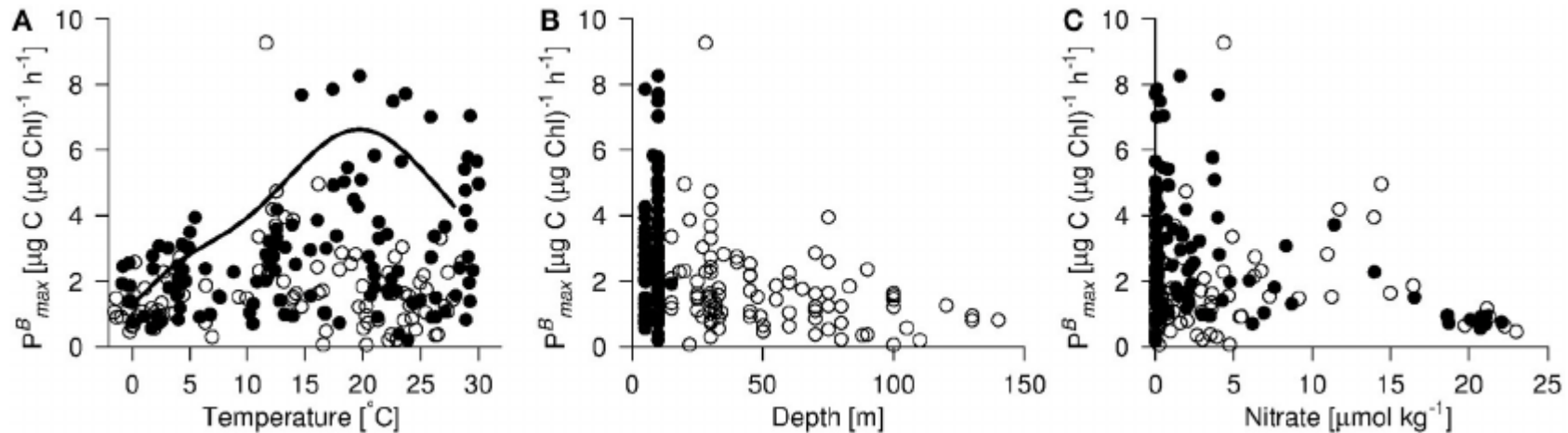Oligotrophic areas more productive

Total PP~49 Pg C/yr

Reference
Richardson, K., and Bendtsen, J. (2019) Vertical distribution of phytoplankton and primary production in relation to nutricline depth in the open ocean, Mar. Ecol. Prog. Ser., 620, 33–46.
https://doi.org/10.3354/meps12960
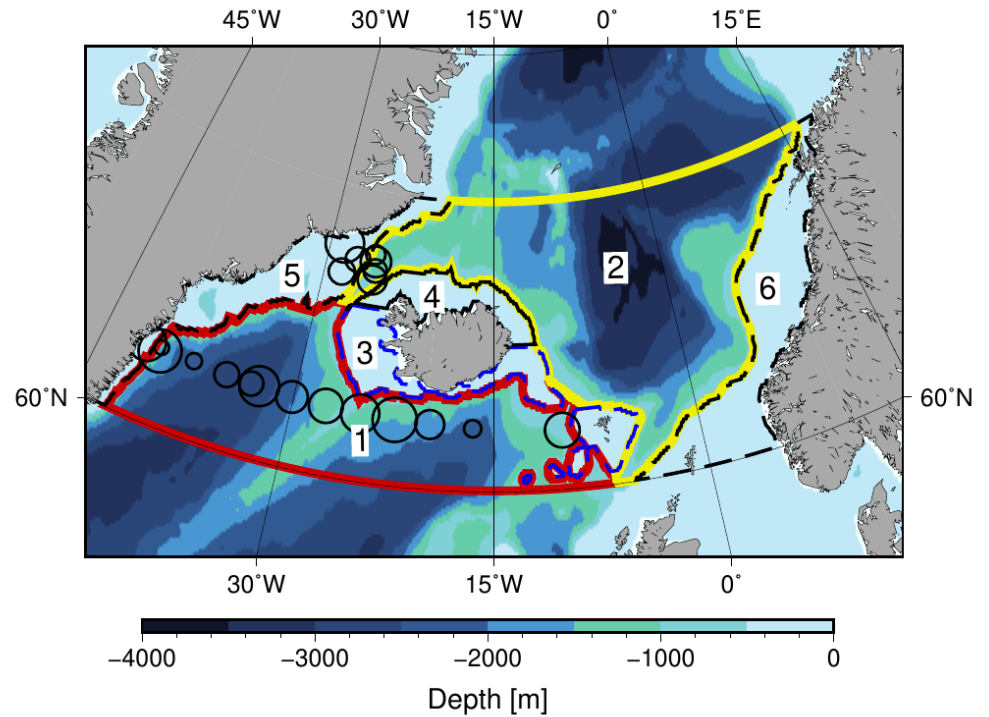
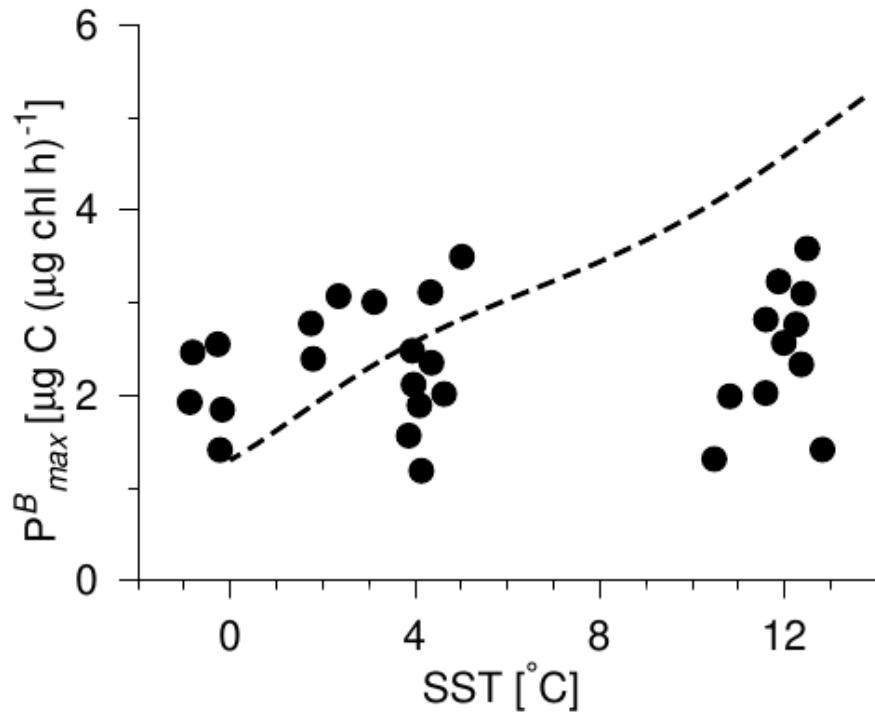# P$^B_{max}$ vs T, depth & nitrate

Bullets: The upper 10 m

Open circles: DCM

Reference
Richardson, K., Bendtsen, J., Kragh, T., Mousing, E.A. (2016). Constraining the distribution of photosynthetic parameters in the global ocean, Frontiers in Marine Science, 3, 269. https://doi.org/10.3389/fmars.2016.00269

P$^B_{max}$ in the northern NA

Reference
Richardson, K., and Bendtsen, J. (2021). Distinct seasonal primary production patterns in the sub-polar gyre and surrounding seas. Front. Mar. Sci. 8:785685. https://doi.org/10.3389/fmars.2021.785685

Summary & knowledge gabs

Summary

- subsurface PP is a significant fraction of total PP

- only ~25% in the surface layer (0-10m)

- Nutricline depth may improve estimates of PP

- Relatively large variation in photosynthetic parameters

Knowledge gaps

- photosynthetic parameters

- distribution of nutrients