PROductivity TOOLs

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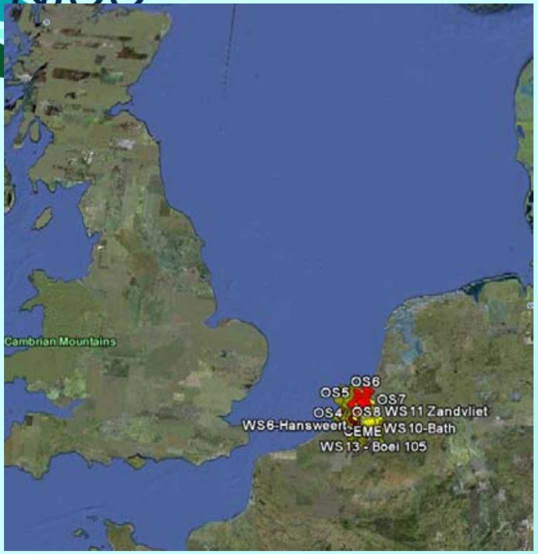
A new and autonomous way to measure water quality parameters and primary production of phytoplankton

Why PROTOOL

- Understanding aquatic ecosystems is not possible to without knowledge of primary production (carrying capacity)
- Biomass (chl*a*) is no good measure of primary production (due to high turnover rates)
- Currently no simple method available to measure phytoplankton primary production, hampering development of long term time series of primary production, certainly by water management agencies
- Application of variable (active) fluorescence techniques can be used to develop a methodology because it is an optical technique

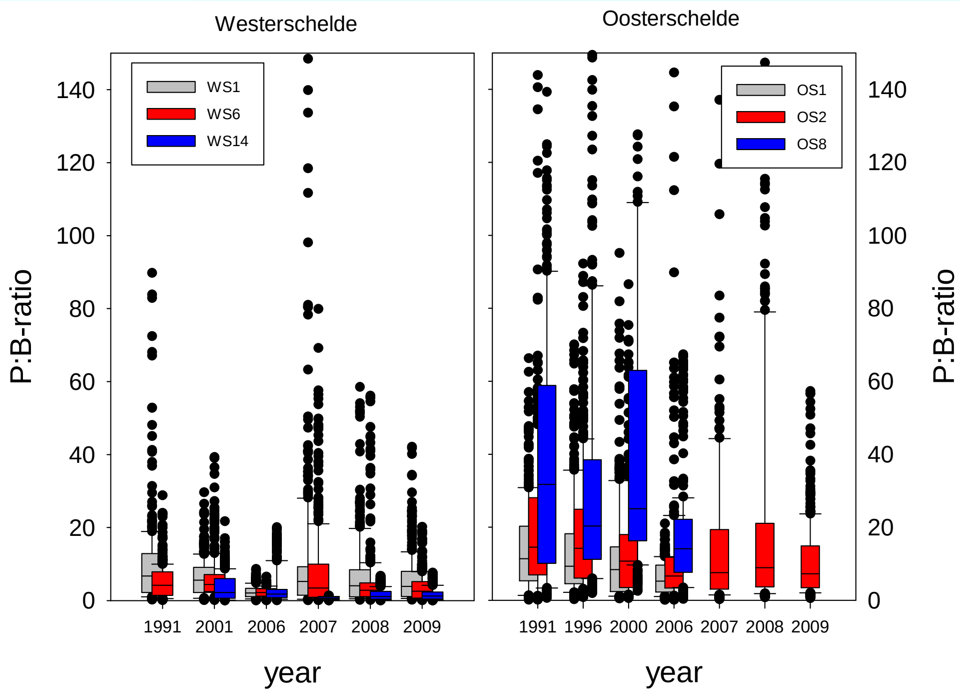
Sampling stations monitoring program

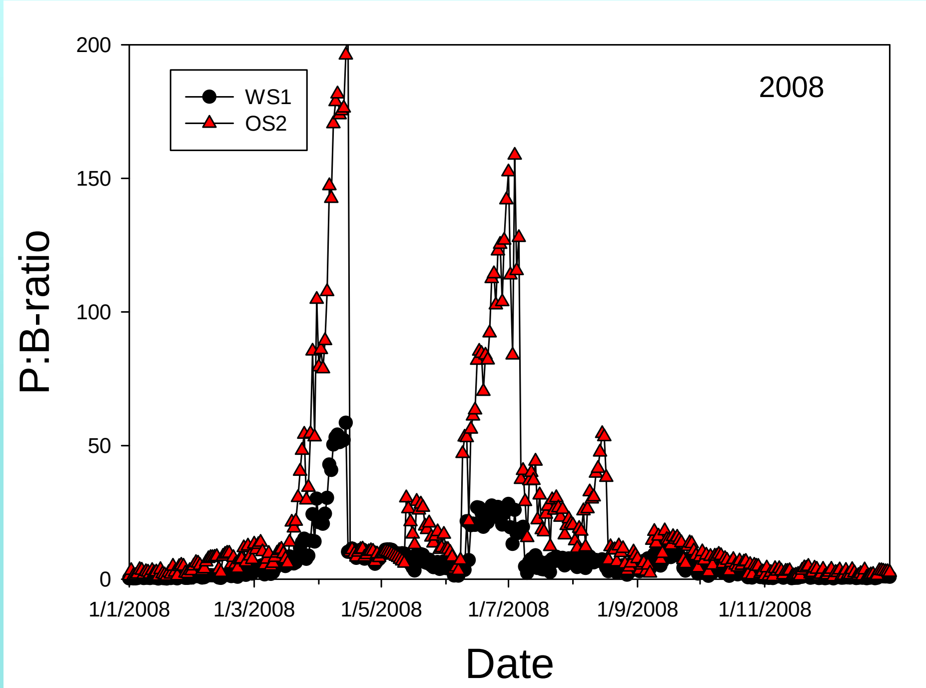


Oosterschelde = Eastern Scheldt

Westerschelde = Western Scheldt

2 estuaries with same climate pattern: P:B (Productivity:Biomass) ratio's





P:B ratios Eastern Scheldt > P:B ratios Western Scheldt (due to more turbidity)

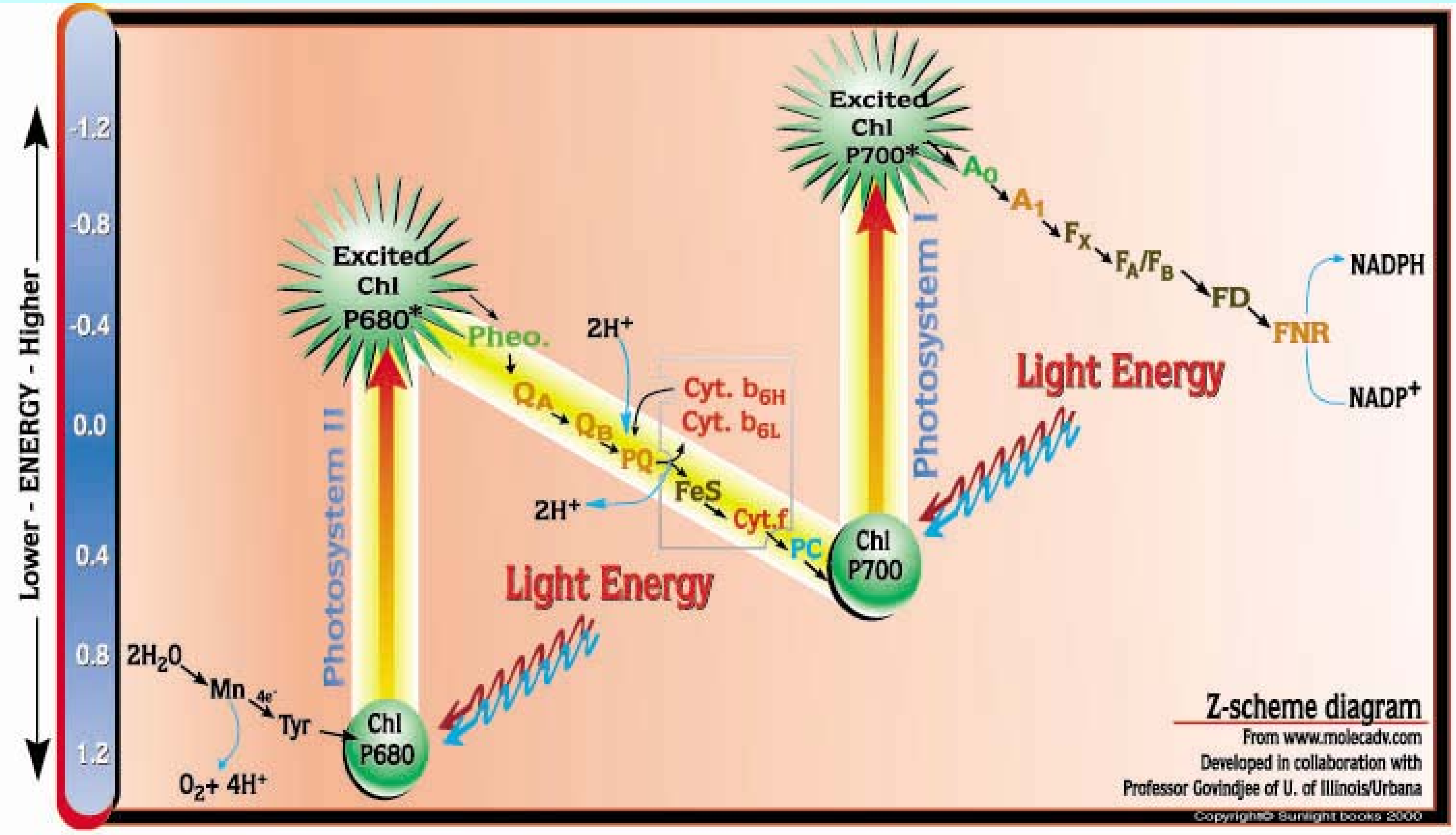
Chlorophyll concentrations no good predictor for primary production and potential

We need:

- **Hardware challenge:**
  - **Automated active fluorometer to measure photosynthetic activity**
  - **Spectral reflectance to obtain WQ parameters (chl*a*, K_d, SPM)**
  - **Absorption to measure phytoplankton absorption in order to quantify the photosynthetic activity (PSICAM)**
- **Software to treat the large datastreams**
- **Scientific challenge: prediction of parameters/drivers to convert photosynthetic ETR into rates of C-fixation (n_{PSII}, a^*_{PSII}, $\frac{molC}{mole^-}$, PQ)**

- **Ideal: combine with ferrybox**

Z-scheme of photosynthesis



Only PSII is fluorescent

Oxidized Q_A is quencher of fluorescence

$\boldsymbol{\Phi_P + \Phi_h + \Phi_f = 1}$

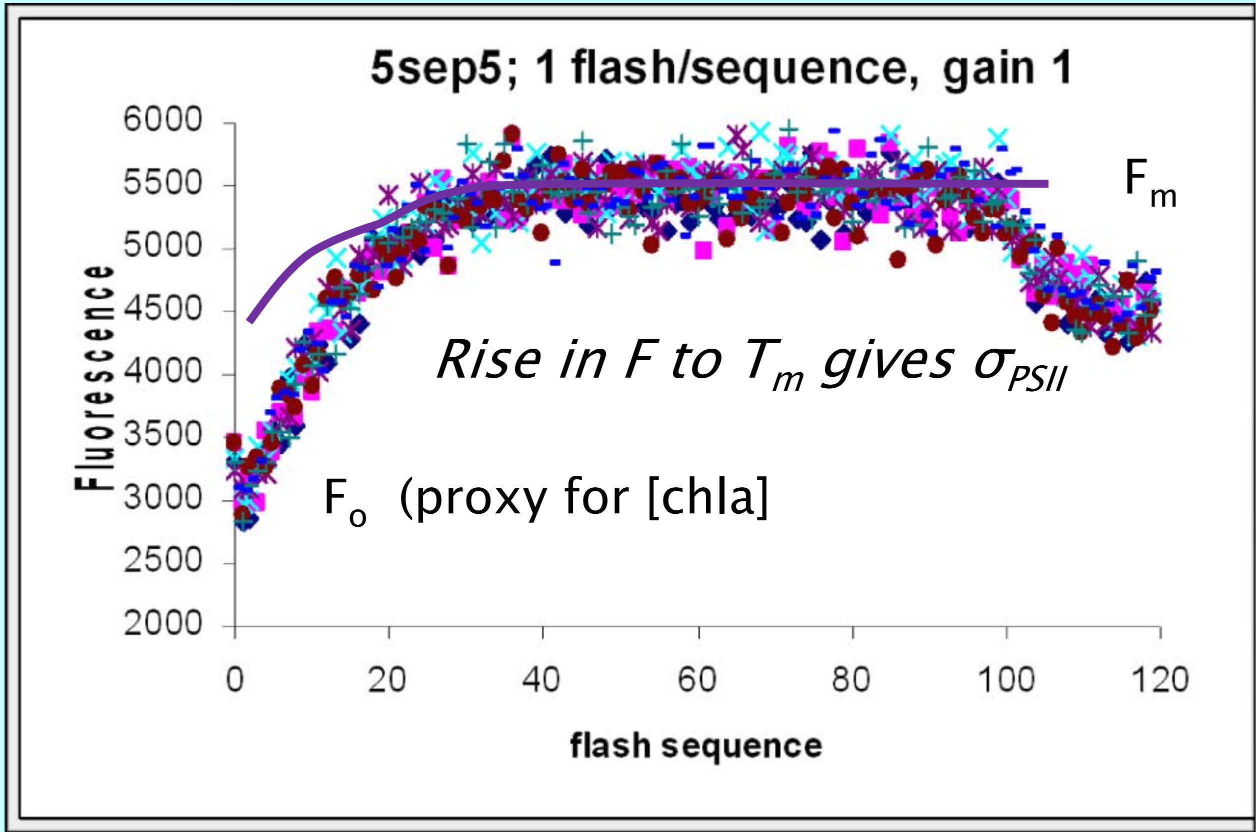
Requirements for PROTOOL

ETR

$$PP = [chla]\int_{0}^{Zp}\int_{sunrise}^{sunset}[E \bullet a^{*}_{PSII} \bullet \Phi_{PSII} \bullet \Phi_{e}]$$

- Fluorometer to measure photosynthetic activity
- R-module to measure [chl], k_d (z_p), E (WP4)
- Absorption unit (PSICAM) to measure a^* (WP3)
- Unknowns:
  - Φ_p (mol C/mol electrons: <≤ 1/QR ≤ 0.25)
  - Relationship a* to a^*_{PSII}
  - Chla distribution with depth (DCM)
  - $a^*_{PSII} = n_{PSII} \cdot \sigma_{PSII}$

Variable fluorescence



Max PSII efficiency

$$F_v / F_m = \frac{F_m - F_0}{F_m}$$

Effective PSII efficiency

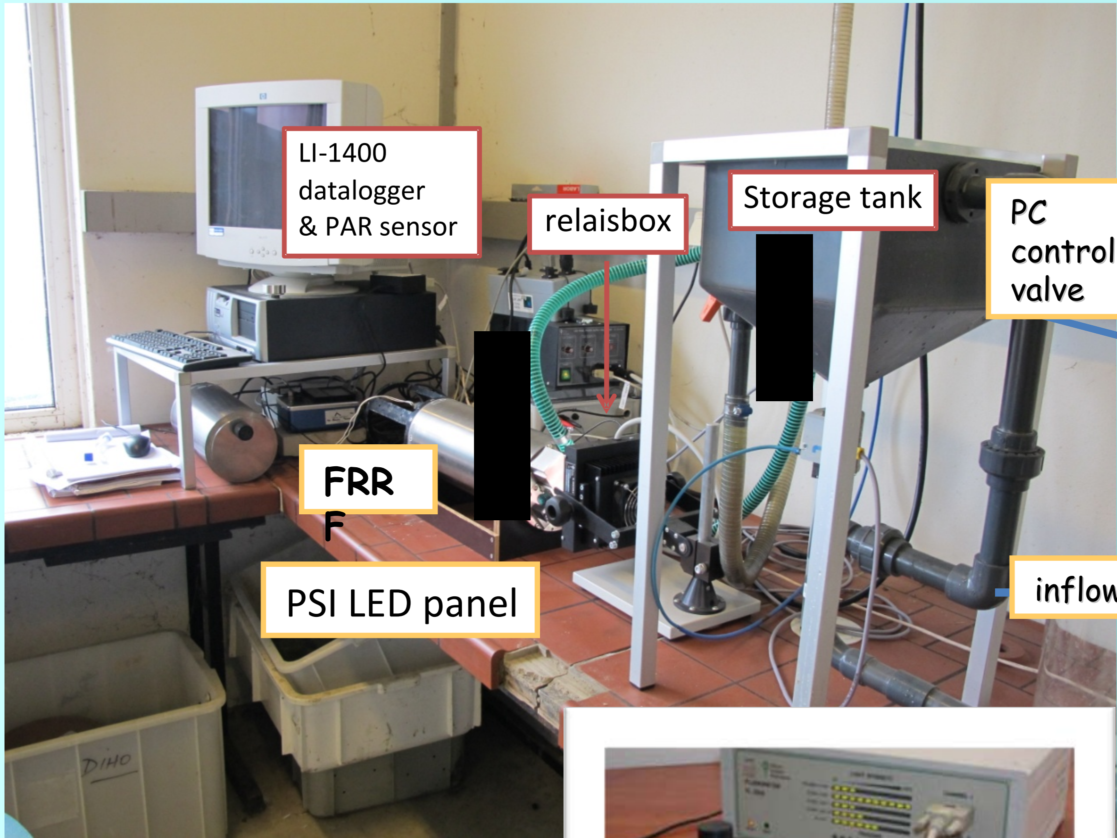
$$\Delta F / F_m = \frac{F_m^{'} - F}{F_m^{'}}$$

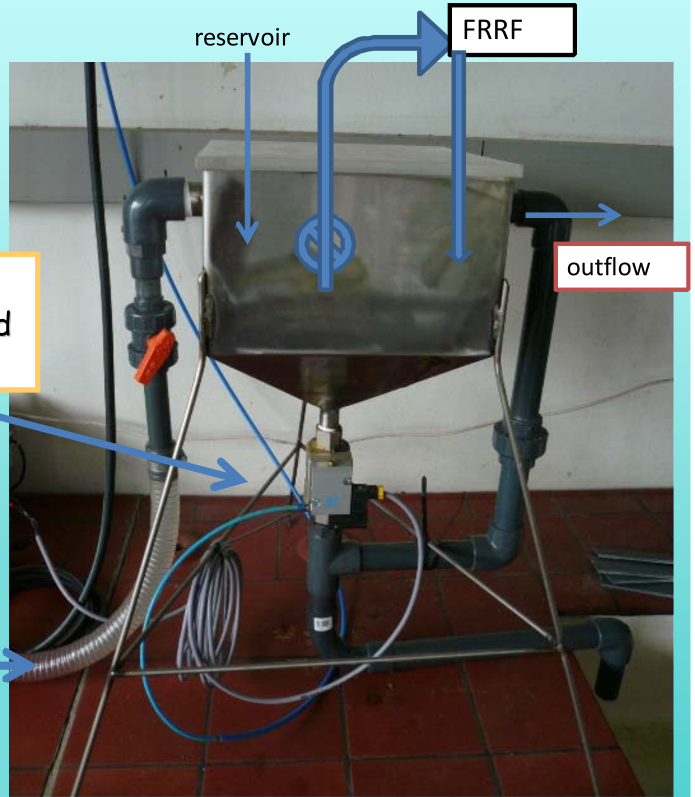
- **F_v/F_m = physiological indicator of condition**
- **PAR x effective PSII efficiency is measure of photosynthetic rate (ETR)**

NIOO

Project Prototype fluorometer for continuous measurements of photosynthesis

similar prototype on ship (smaller!)

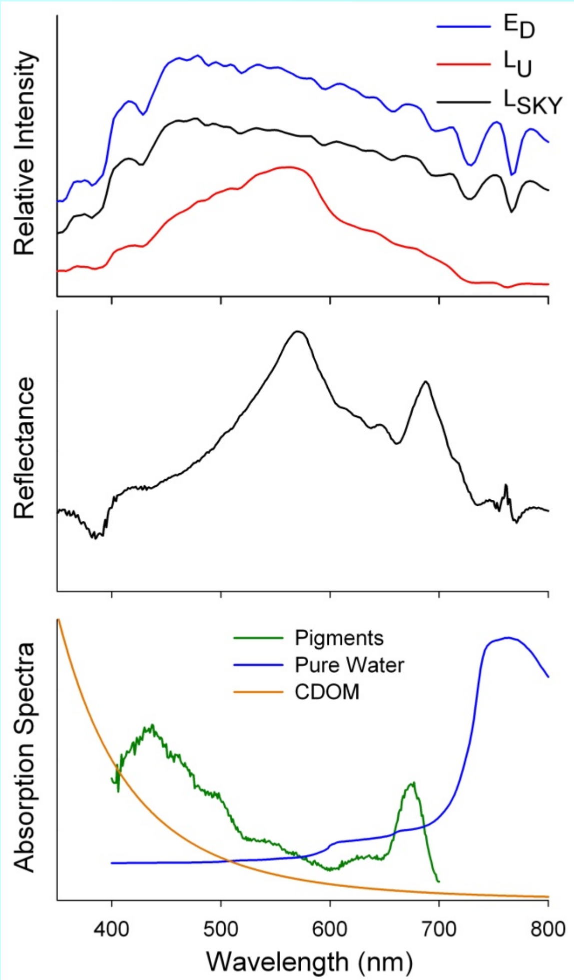


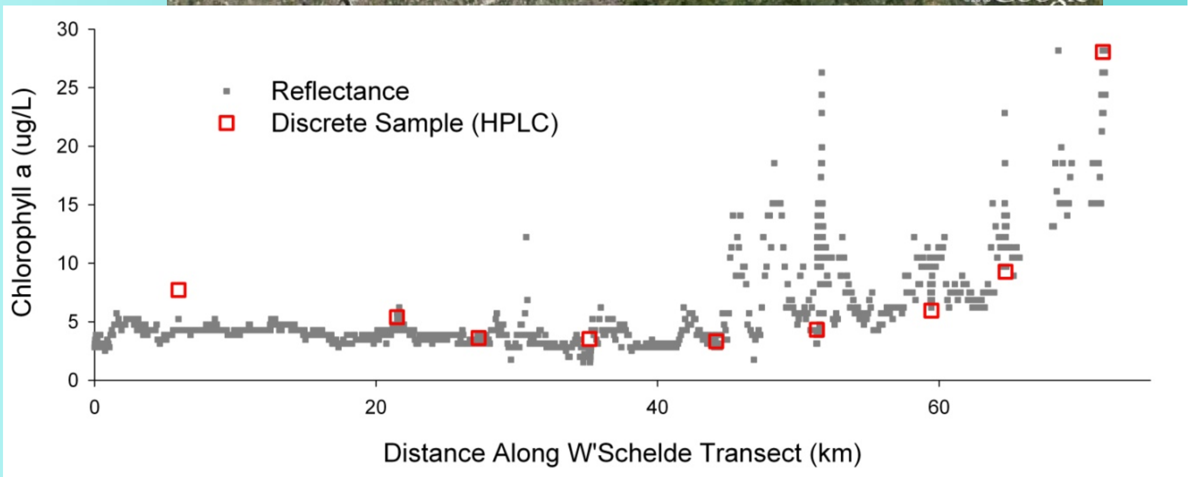


Final product: small fluorometer based on PSI fluorometer FL3500

Project Spectral Reflectance Measurements

High spatial resolution (~100 m) characterization of the optical properties and its driving constituents in European Coastal waters.

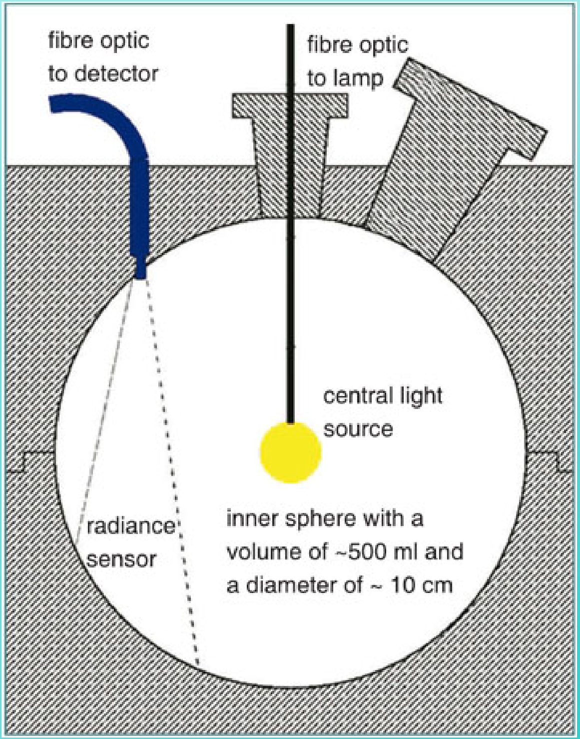




Project absorption meter: PSICAM TriOS-GKSS

- Goal: to obtain algal absorption coefficient in order to compute total light absorbed by algae (necessity to quantify PSII electron transport)

$$a_{total} = a_{water} + a_{CDOM} + a_{SPM} + a_{phyto}$$



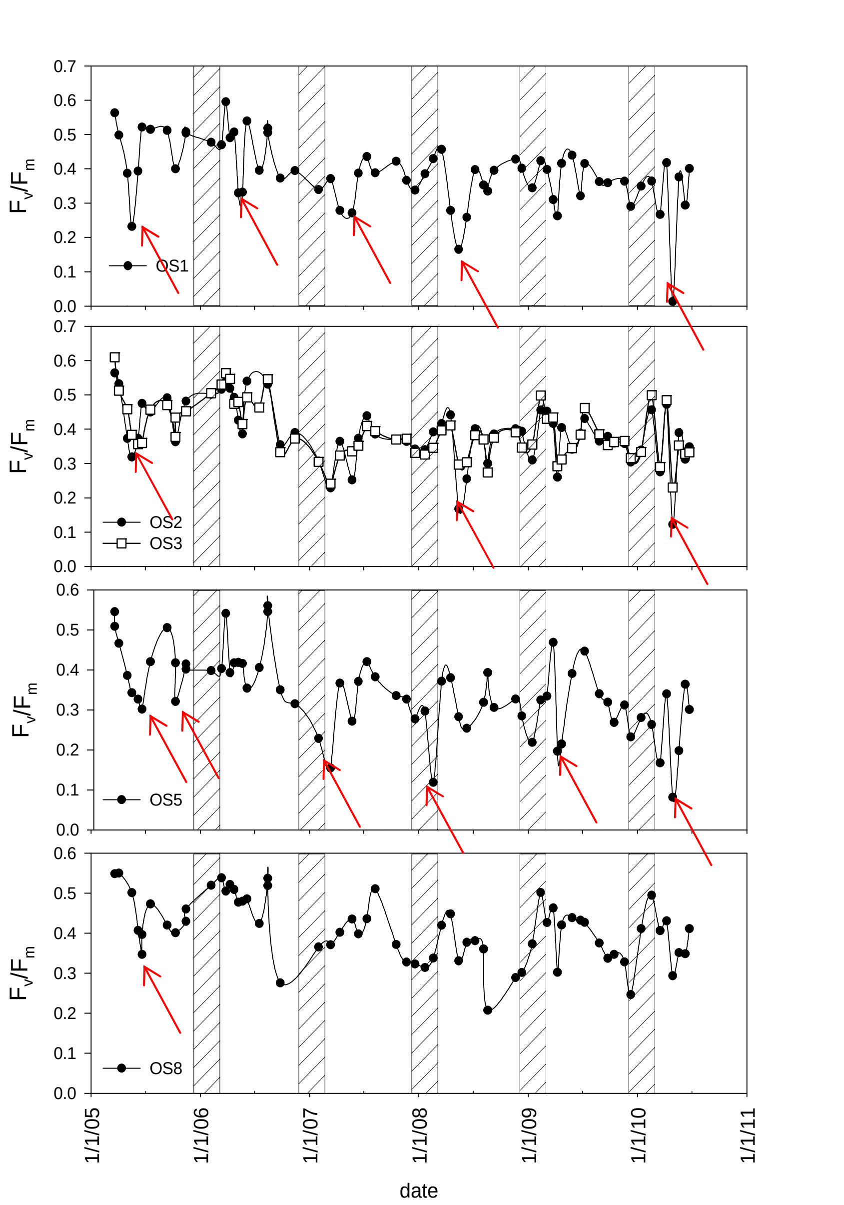
Challenges:

- obtain a_{phyto} from total absorption
- Obtain algal pigment groups
- *Antifouling/cleaning*
- Integration in final PROTOOL module

Test sites

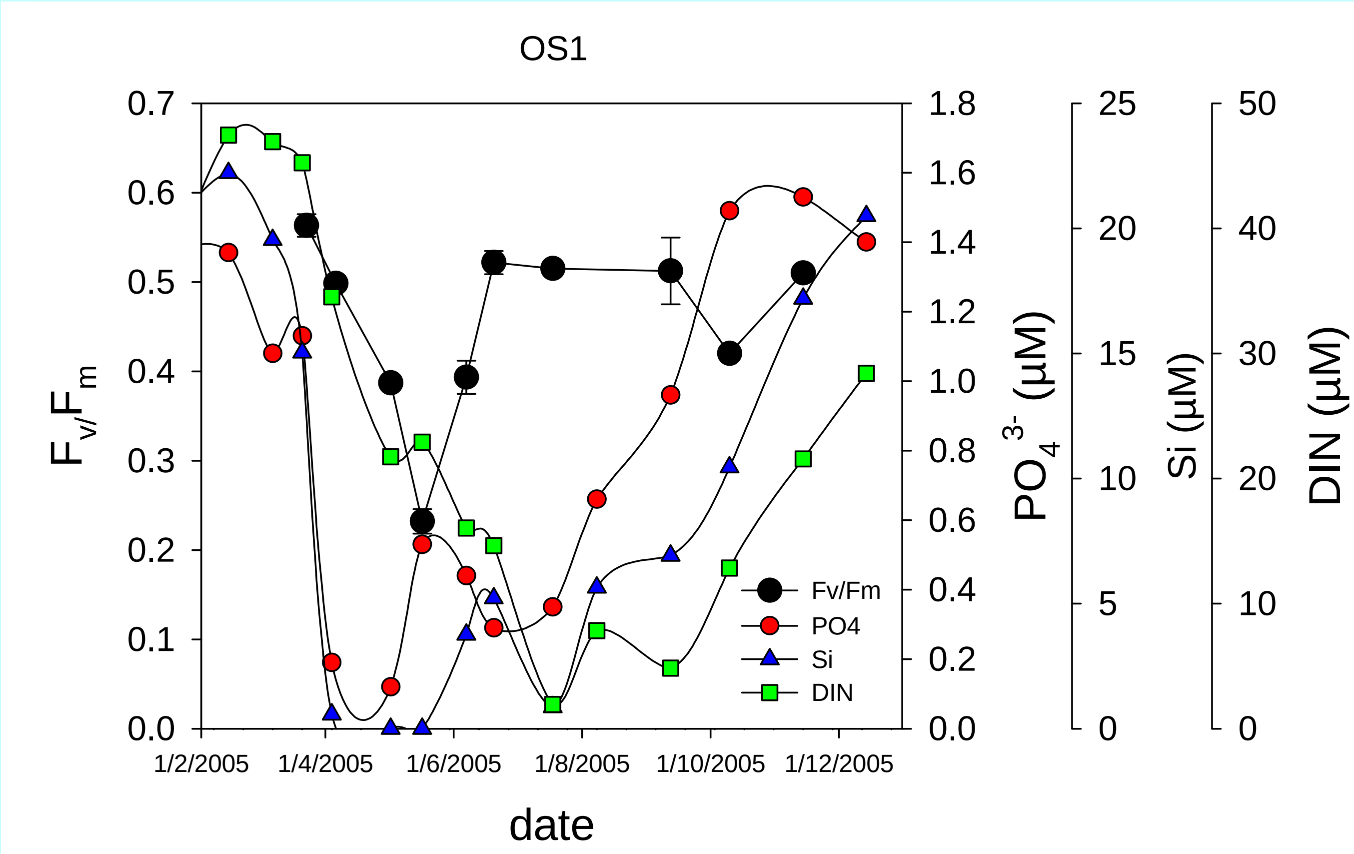
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
© 2011 Cnes/Spot Image
Image © 2011 TerraMetrics
56°16'31.27" N 7°49'13.52" E elev -34 m
©2010 Google
Eye alt 6636.04 km

Results Oosterschelde: change in Fv/Fm due to nutrient limitation?



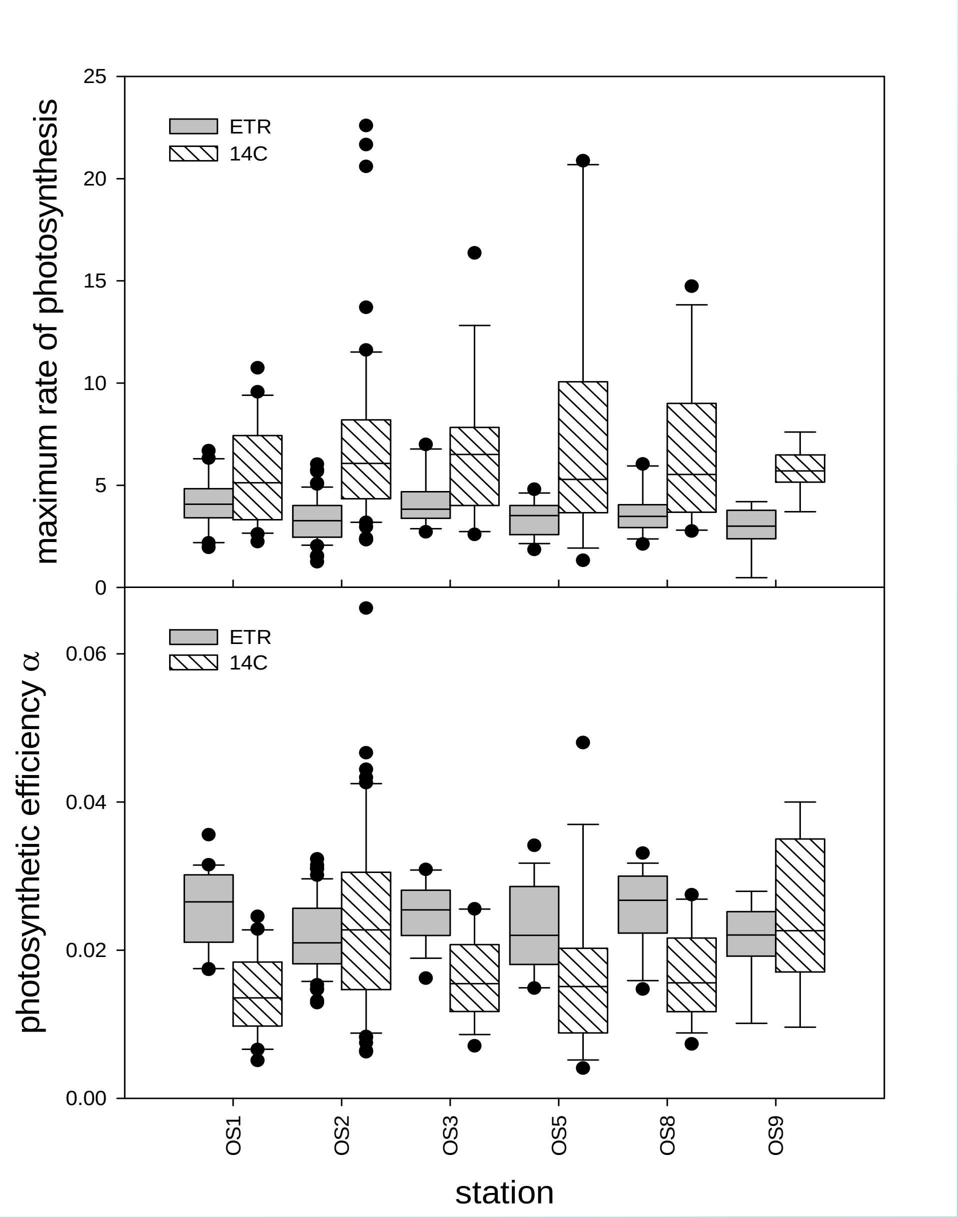
- Fv/Fm drops to low values in spring (especially in OS1, OS2 and OS3)
- OS5 & OS8 erratic pattern (long residence times with own dynamics)
- Interannual variation in pattern

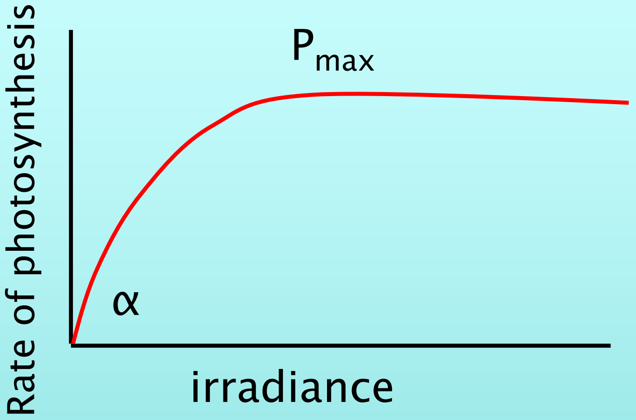
Results Oosterschelde: change in Fv/Fm due to nutrient limitation?



- Fv/Fm follows drop in PO4 and Si (but with a delay of 2- 4 weeks)
- DIN not limiting (continuous to decrease when Fv/Fm recovers)
- N:P > 16, P:Si < 16, thus P-limitation of P-Si co-limitation for diatoms

Photosynthetic parameters



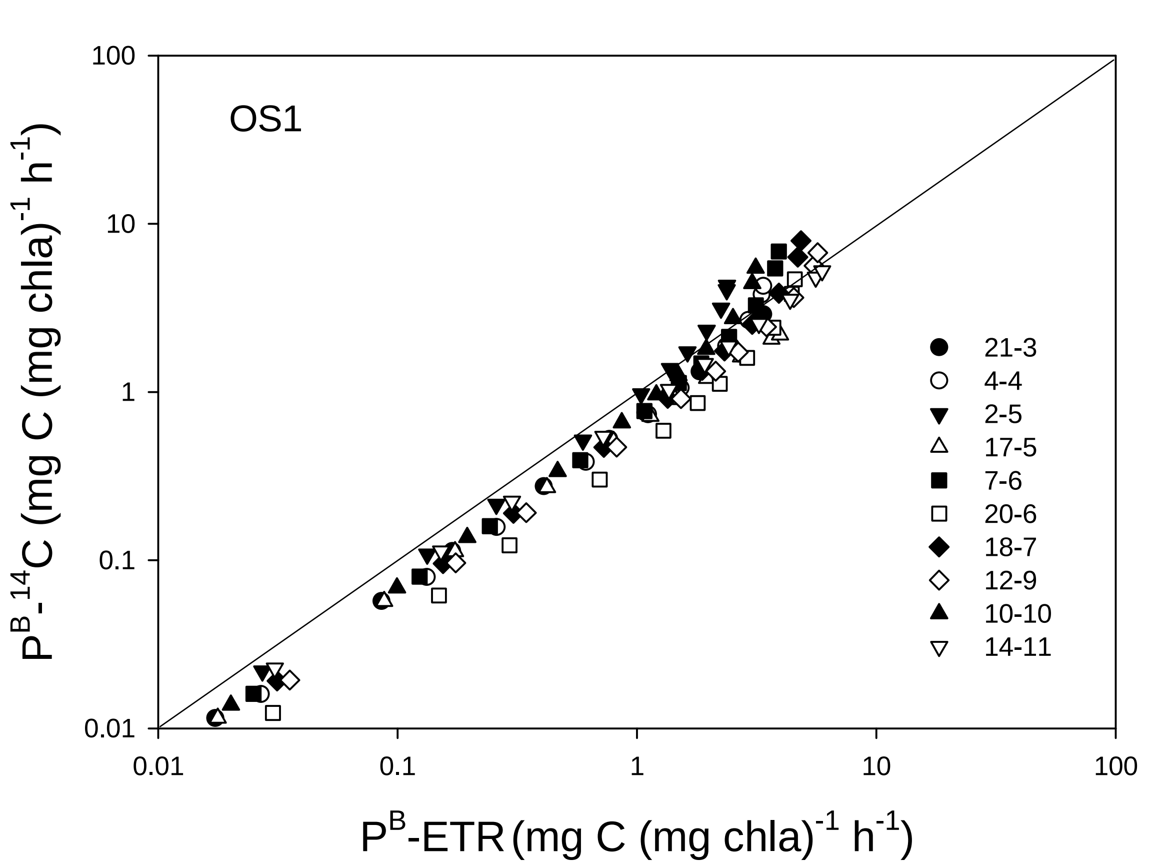


Using a-priori parameters:

QR = 4, 500 chl/PSII

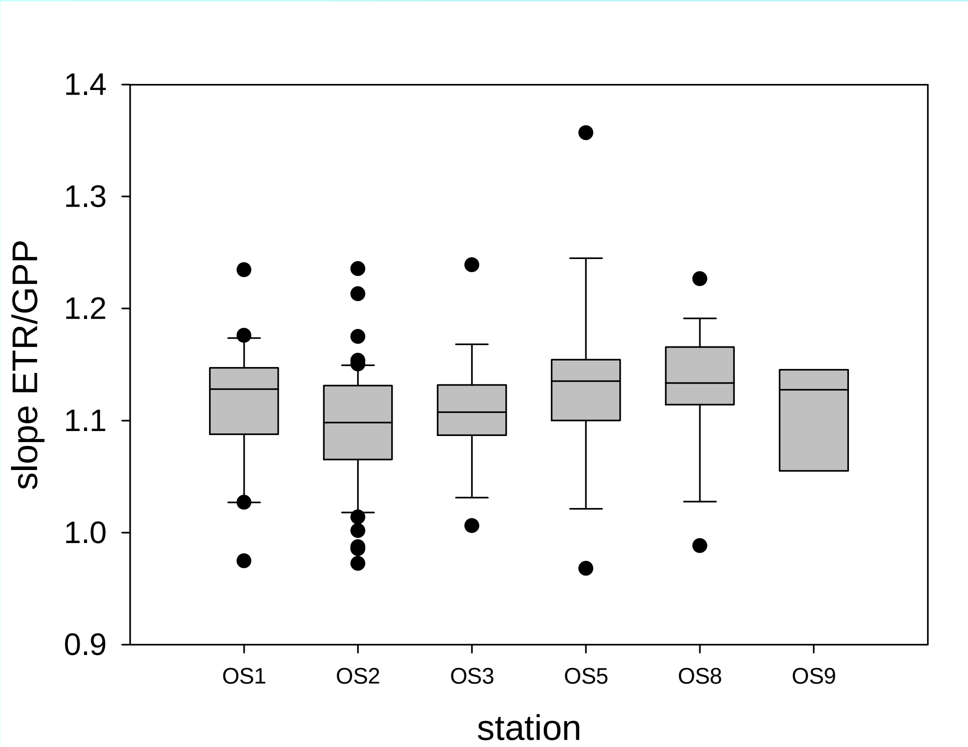
- P_{max} FRRF < P_{max} ^{14}C
- α FRRF > α ^{14}C

Relationship ETR – C-fixation along a light gradient (vector from 0-750 µmol Q m^{-2} s^{-1})



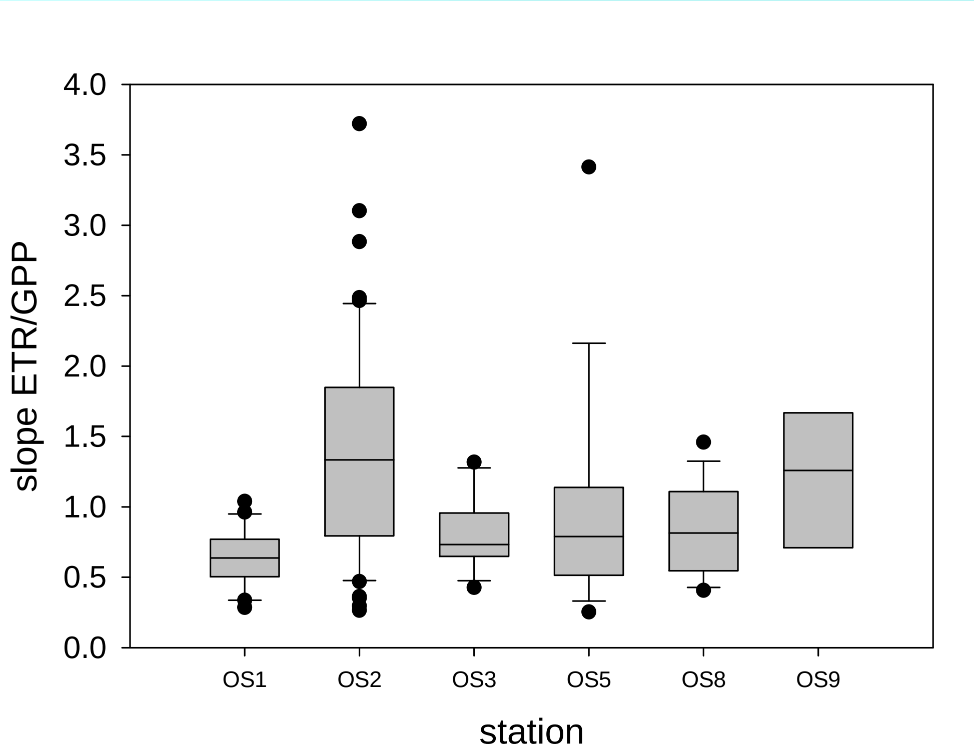
- Linear at low-mid light to non-linear at high light.
- Slope gives average conversion factor (factor to correct a-priori assumptions of n_{PSII} and mol C/e^-)

Conversion factors using vector 0-750 $\mu mol\ Q\ m^{-2}\ s^{-1}$



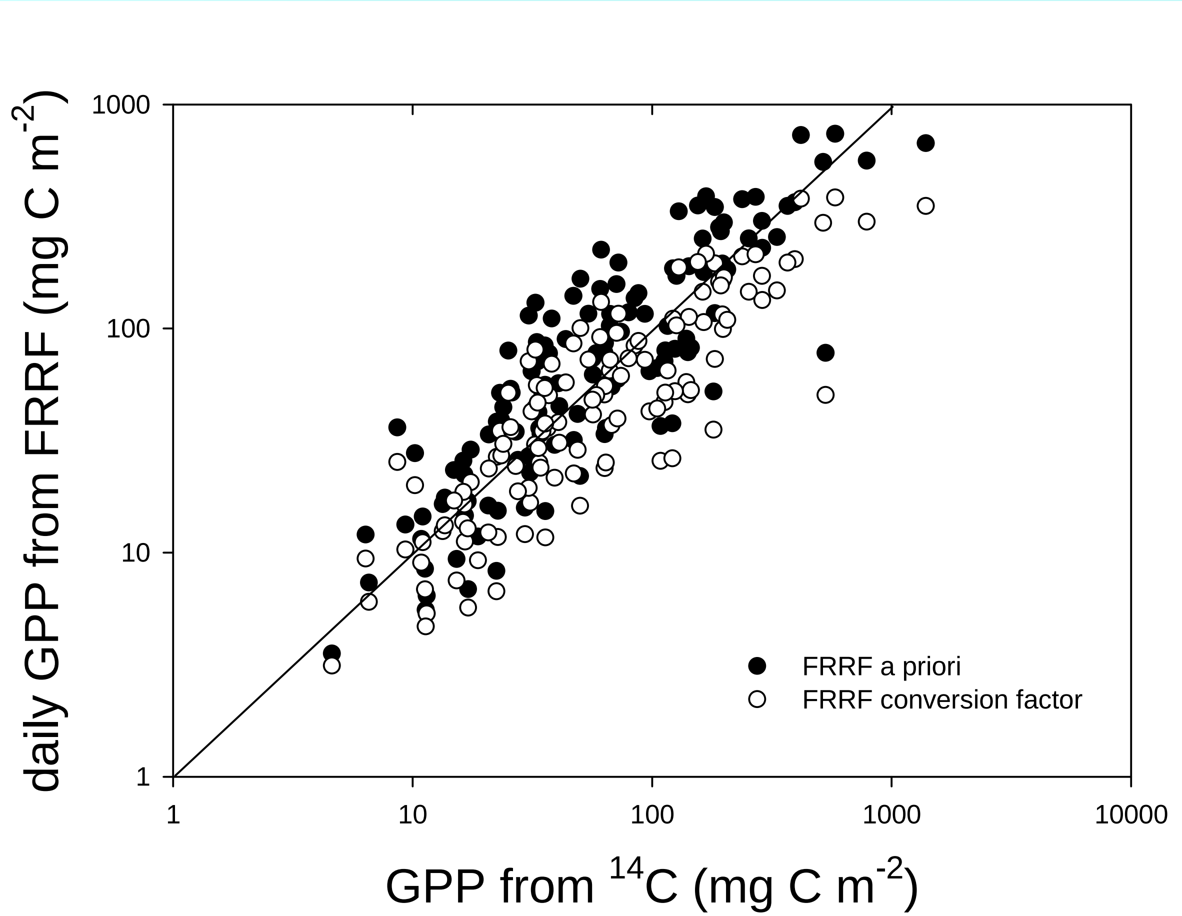
- *Average conversion factors similar for all stations*
- FRRF overestimates *C*-fixation in general 10-15%

Is it correct to use a limited vector?: approach 2: vector with 50 irradiance values from surface to bottom photic zone (0.5 % Eo)

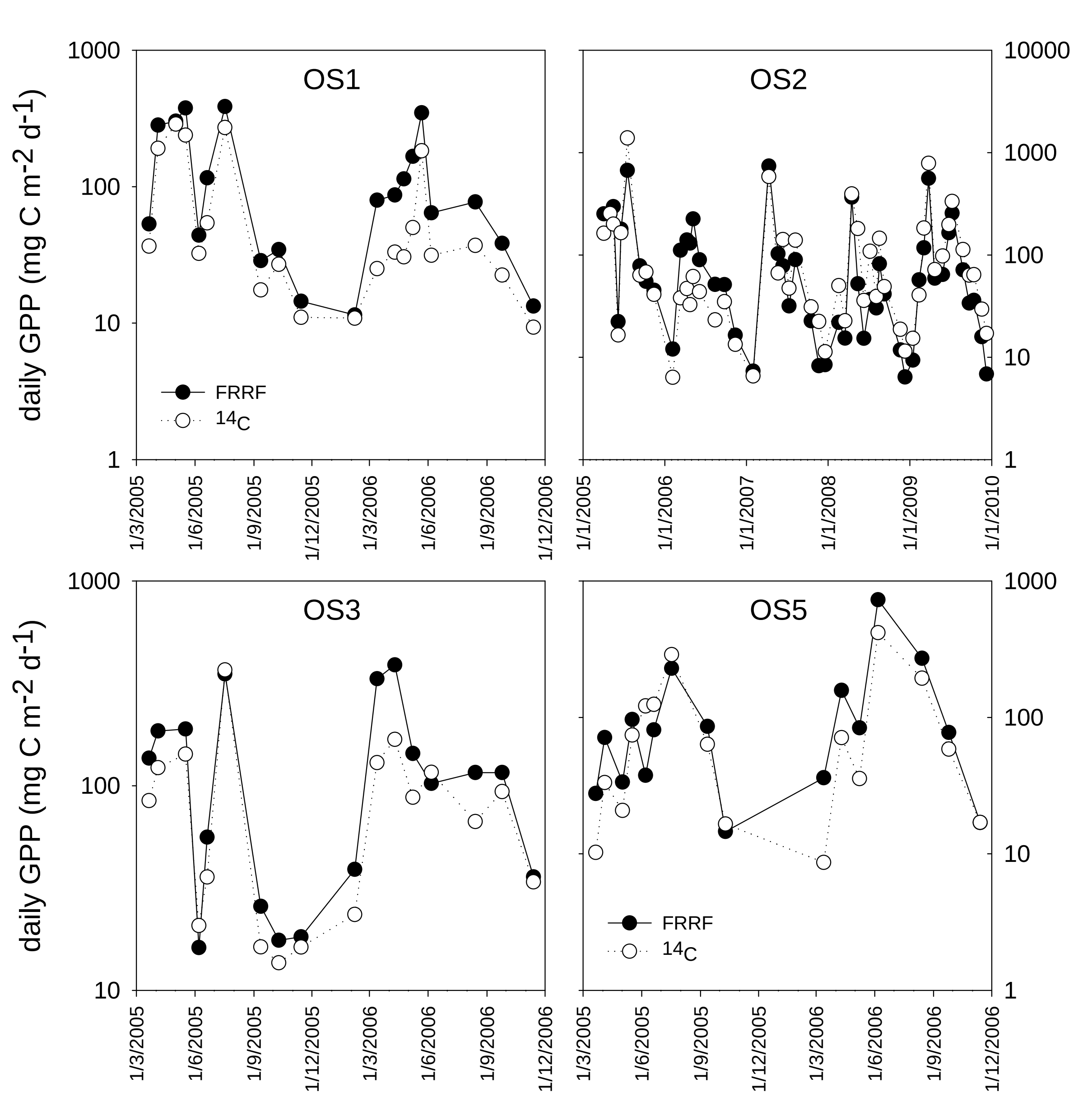


- This approach causes more variability in the slopes (n=2 for all stations except OS2: 5 years, OS9 1 year).
- More influenced by non-linearity at higher irradiances

Daily primary production



- **With a-priori assumptions; ETR > 14C**
- **With conversion factor: ETR< 14C**

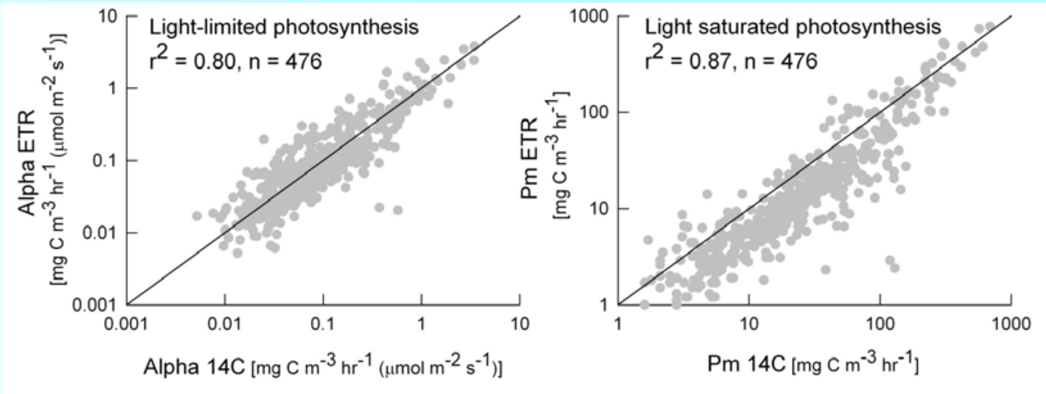


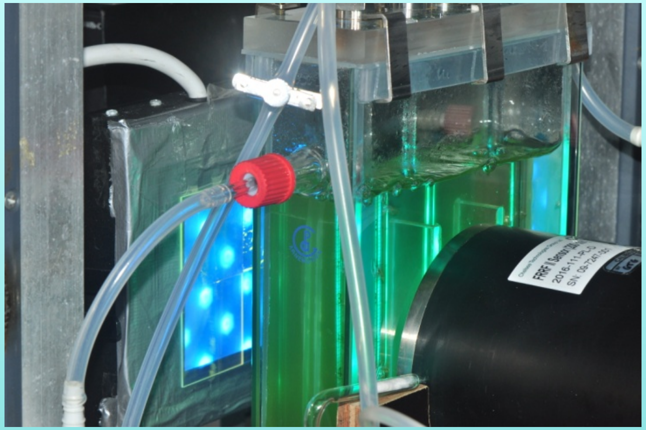
Annual pattern in GPP

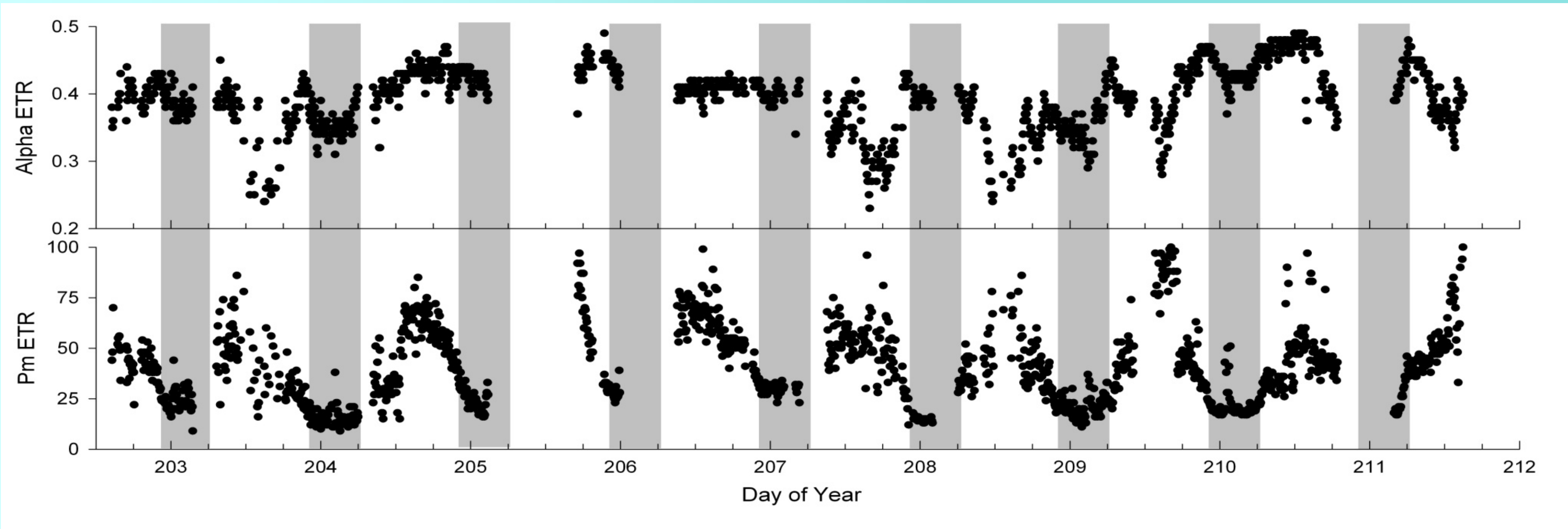
- No conversion factors
- Match in general quite good

Photosynthetic ETR in flow through mode

The combination of active fluorometry and a programmable LED panel allows us to characterize light-dependent changes in photosynthetic electron transport rates in European Coastal waters.







What is needed for the future:

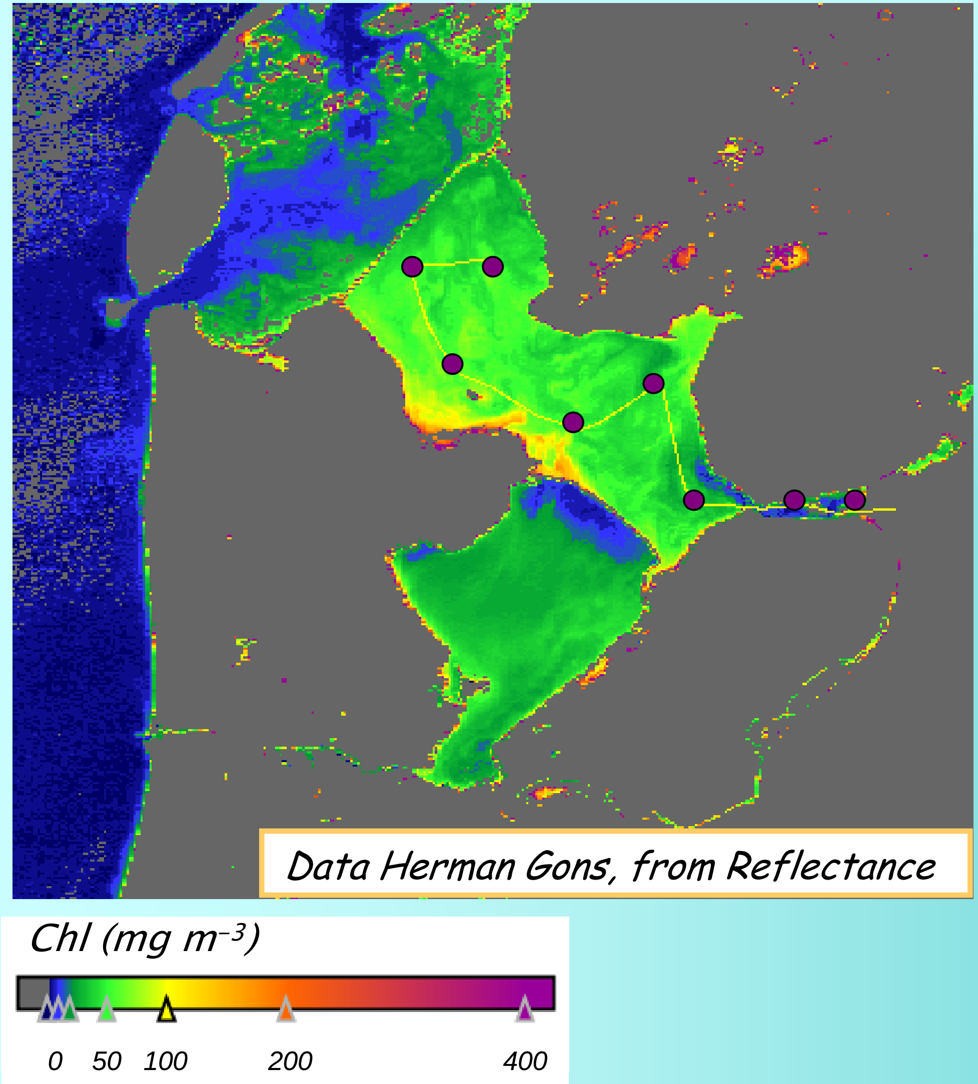
- More platforms (SOOPs)
- Combination with ferrybox routes
- Possibility for calibration (use of ^{13}C?)
- Software to treat data
- Implementation in ongoing programs (including RS) to give PROTOOL approach a firm footing
- Tools to automate measurements of phytoplankton absorption (PSICAM, to give a* and IOPs for RS)
- Possibility to predict conversion factors
  - n_{PSII} (progress at Essex)
  - Electron yield (mol O_2 (or CO_2) per mol electrons produced (< 0.25 = QR > 4
  - PQ (O_2/CO_2)

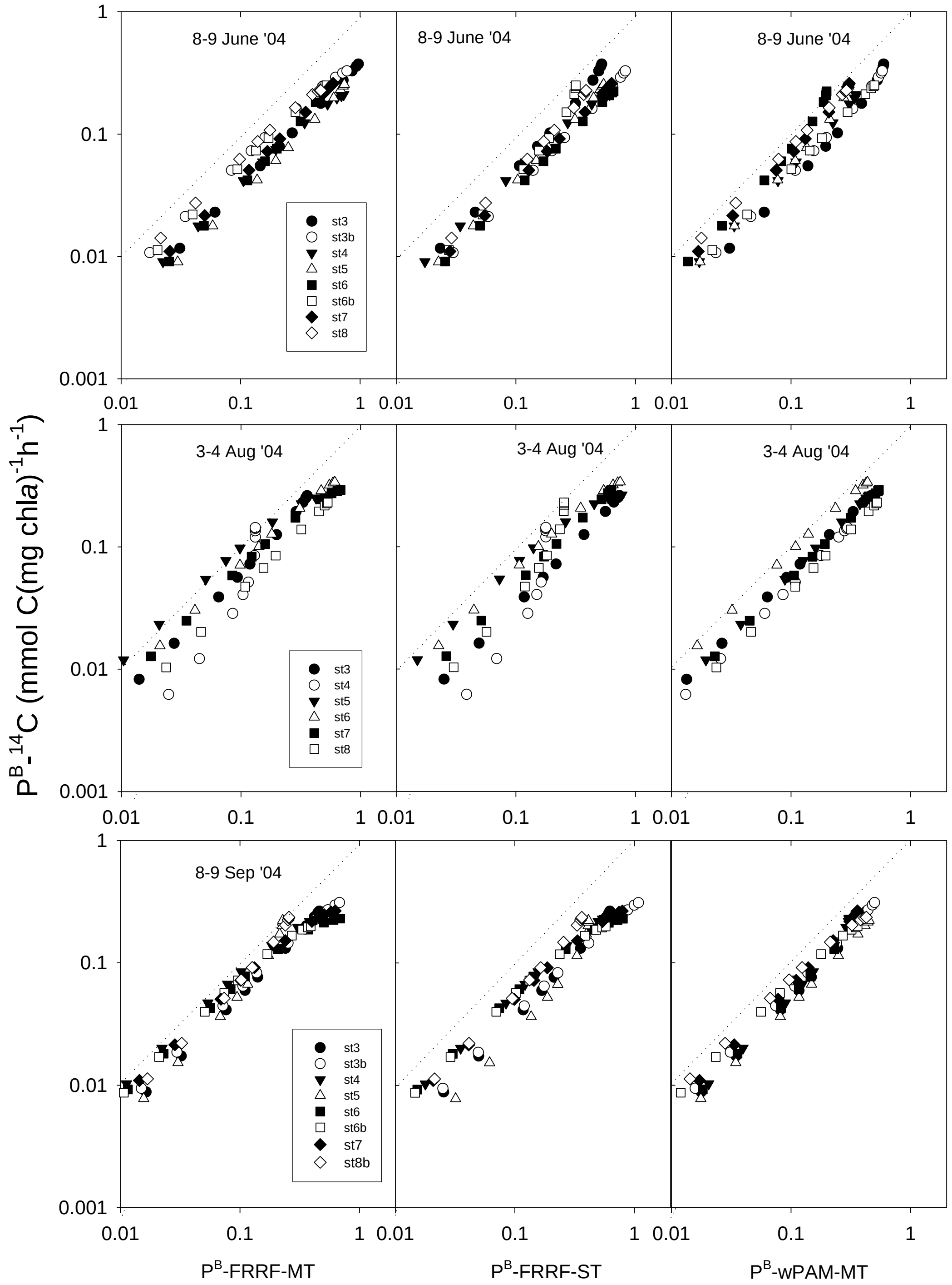
Thank you for listening

I like to Acknowledge

- EU-FP7 for funding
- PROTOOL partners
- Rodney Forster, Stefan Simis, Dave Suggett, Ondrej Prasil, Rudiger Rottgers, Denise Smythe-Wright, PSI, TriOS and many others
- My co-authors Greg Silsbe and Jan Peene
- People from our analytical lab and crew of RV Luctor

example: Lake IJssel

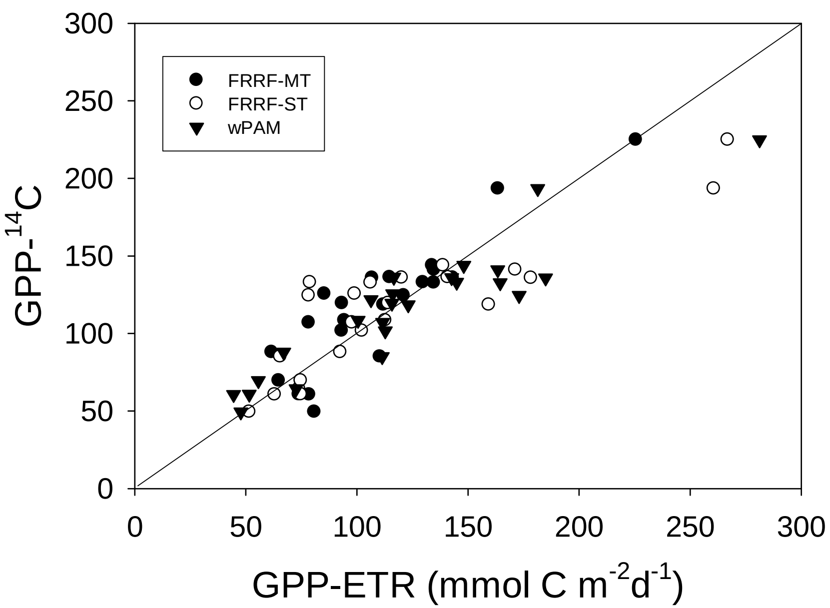




$GPP = P^B \times slope$

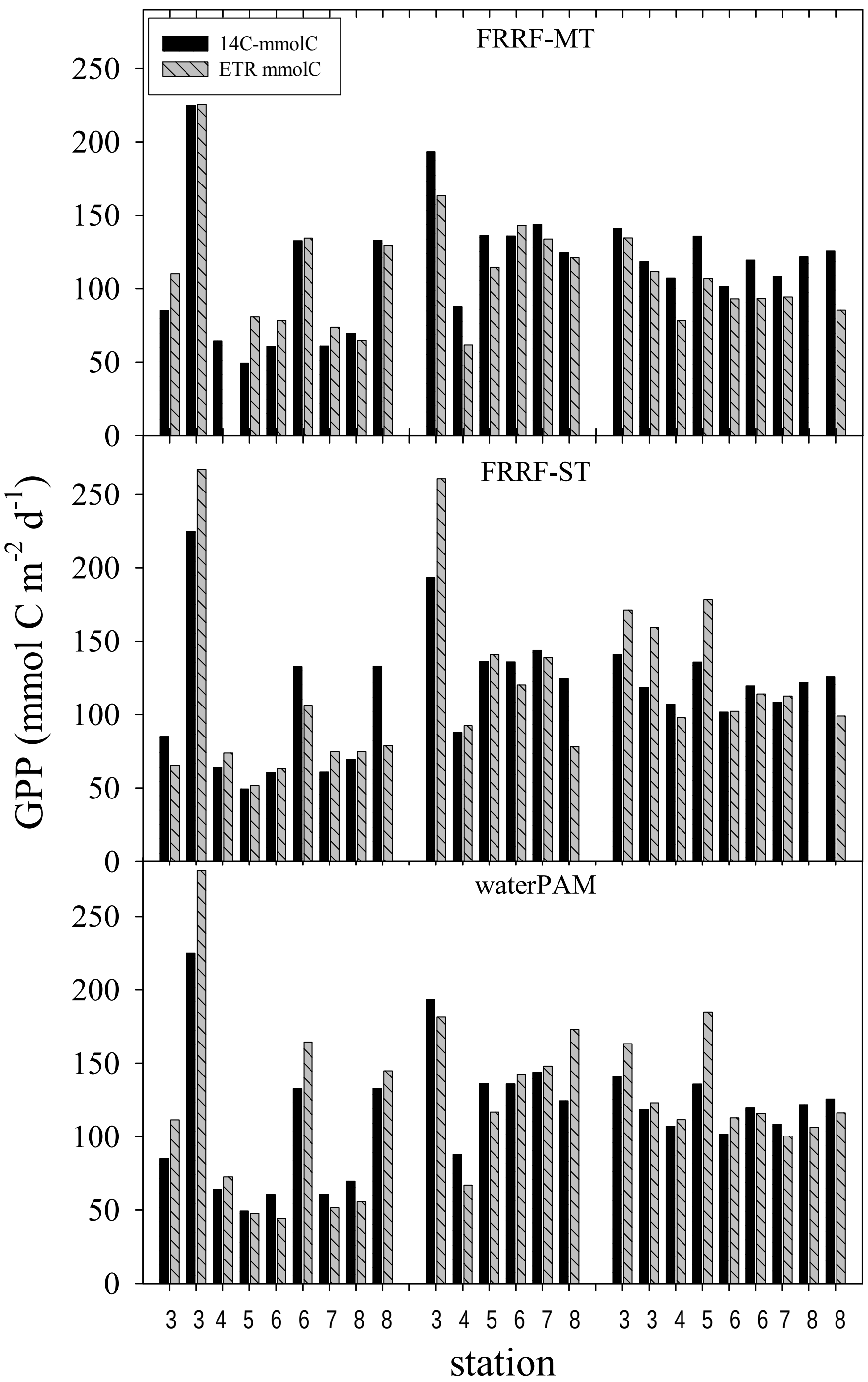
FRRF-MT	0.53±0.125
FRRF-ST	0.45±0.111
wPAM	0.63±0.115

a* measured, a^*_{PSII} = 50% a*



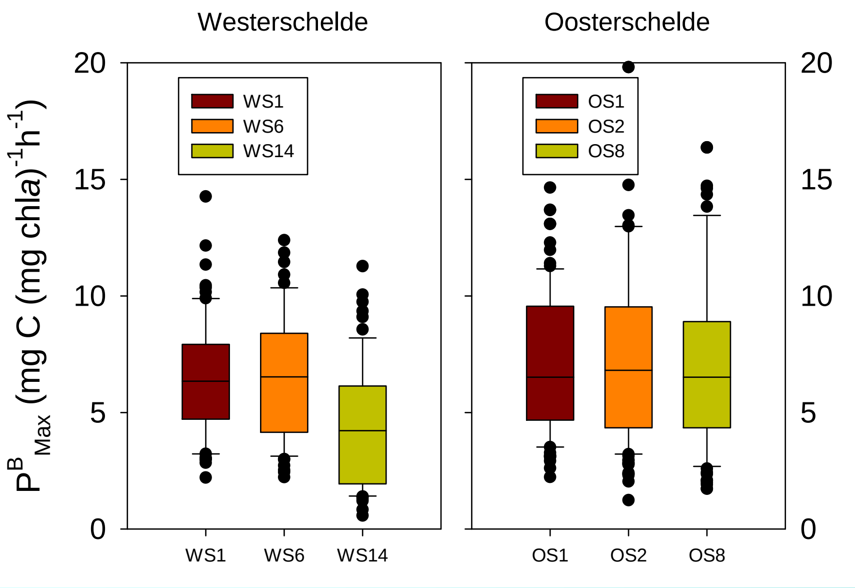
Daily primary production in Lake Ijssel

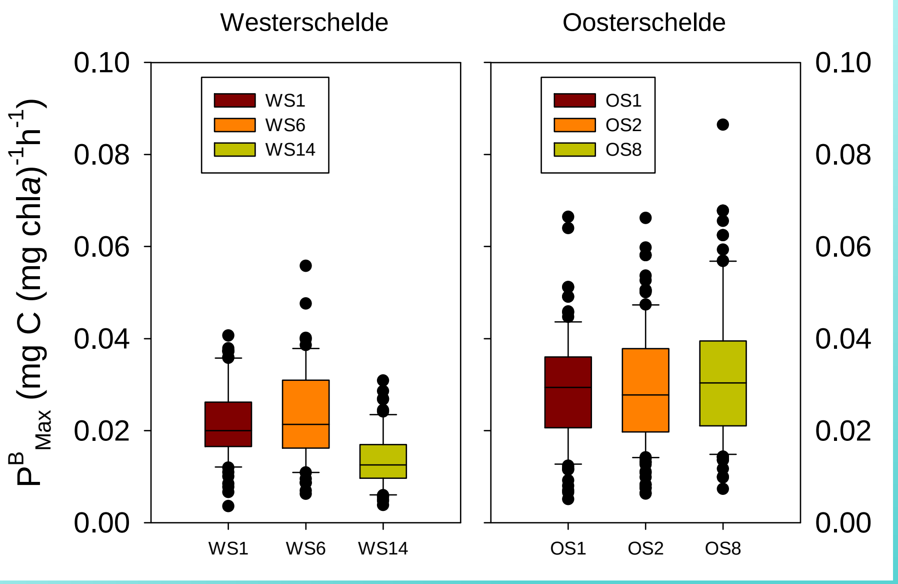
- Improvement realized by measuring quantum efficiency of C-fixation, allowing calculation of Φ_e (mol C/mol e^-)



Photosynthetic parameters

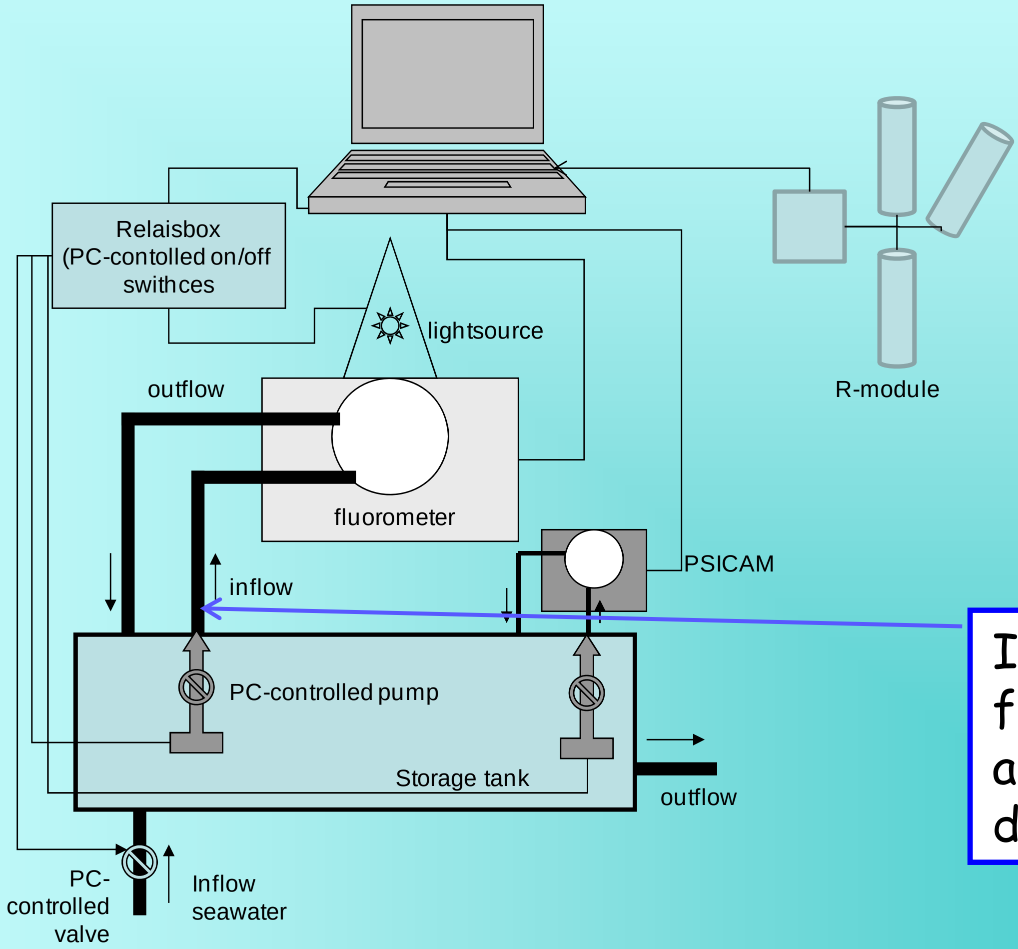
Slightly higher P^b_{max} and α^B in Oosterschelde





Back to presentation

End product Sub Project 2



Inflow water ferrybox after debubbling?

Conversion factors (WP9)
UESSEX

- Overview of empirical conversion factors (stored in database (WP11)
- Conversion factors from laboratory studies and controlled field work
- Relationships between conversion factors and other relevant environmental parameters and bio-optical parameters and a method to predict them!! (database, GIS etc)
- Method to evaluate effect of Deep Chlorophyll Maximum (DCM)

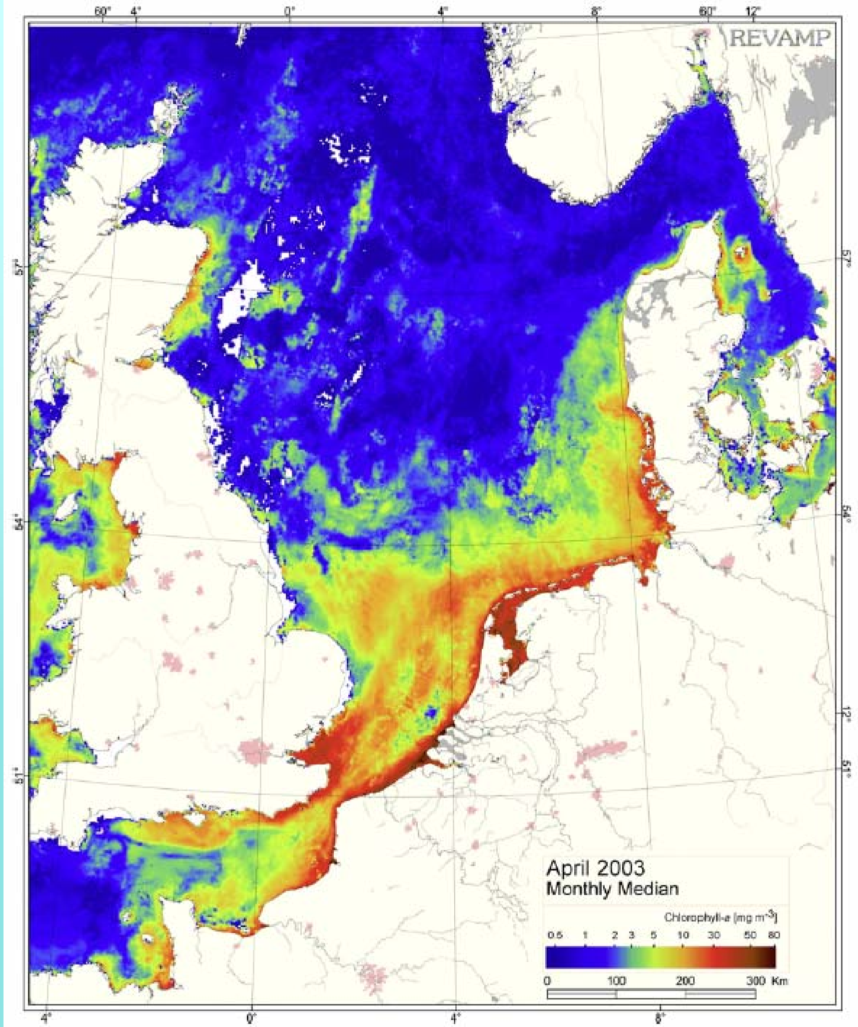
Greg Silsbe, Post-Doctoral Researcher
Marine Microbiology
Jan-2010 to Sep-2012

Funding: EU-PROTOOL Project
PE: Dr. Jacco Kromkamp, NIOO-CEME
8 Project Partners in UK, CZ, FI, DE

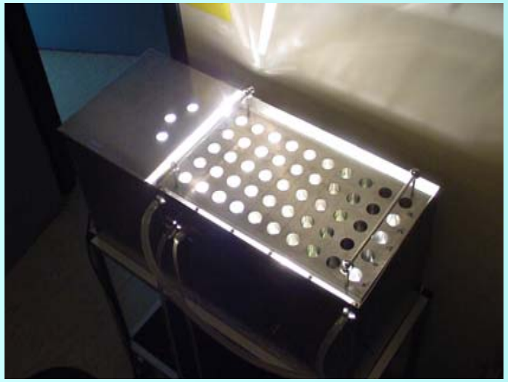
Project Scope: 'Develop an autonomous platform to measure phytoplankton production and its constituents in European Coastal Waters.'

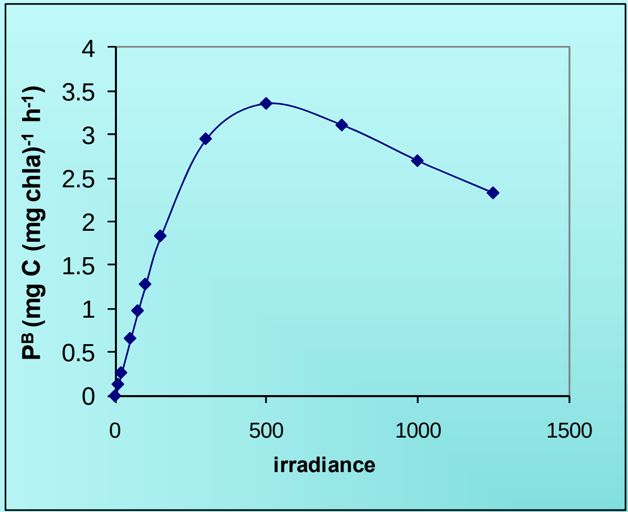
Applied Objective: Installation of the platform on ships of opportunity (e.g. ferries and container ships) as a cost-effective measure to enhance water quality monitoring programs.

Research Objective: Elucidate

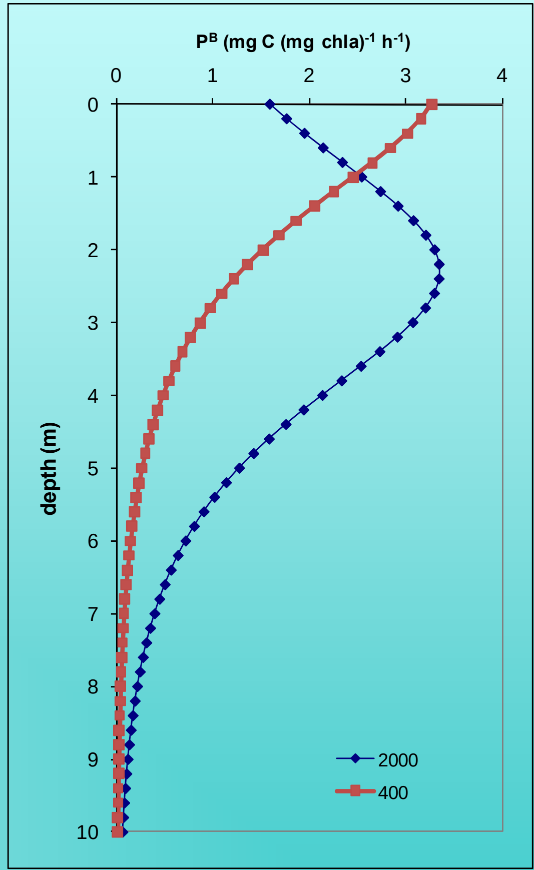


Source: Van der Woerd and Pasterkamp. 2008. Remote Sensing of Environment 112 (1795).



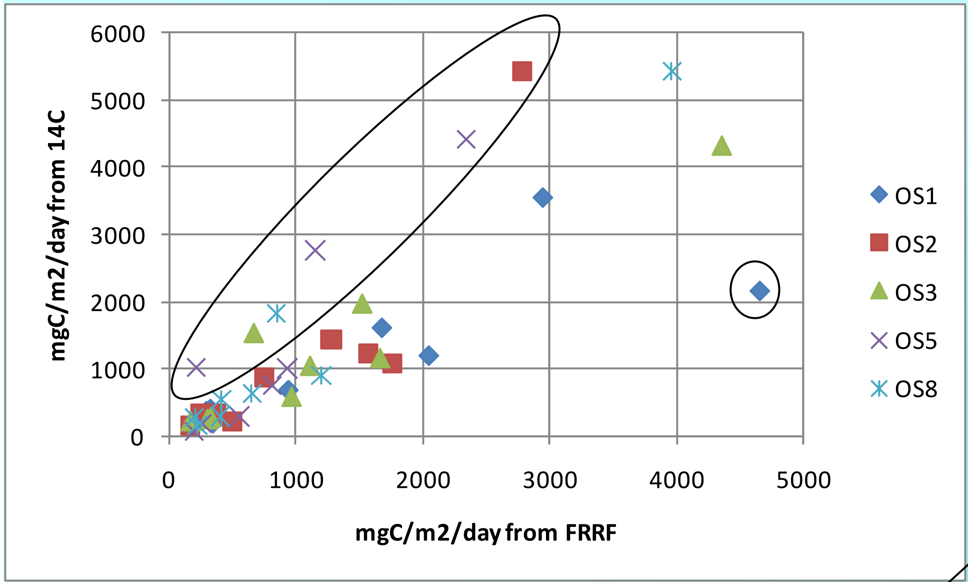


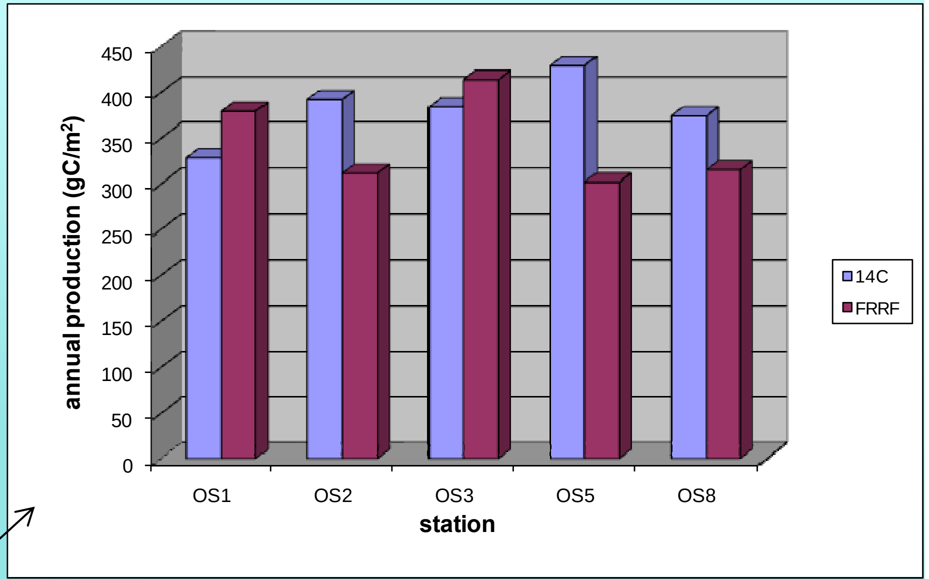
P^B (mg C (mg chla)$^{-1}$ h^{-1})
irradiance
0
0.5
1
1.5
2
2.5
3
3.5
4
0
500
1000
1500



P^B (mg C (mg chla)$^{-1}$ h^{-1})
0
1
2
3
4
depth (m)
0
1
2
3
4
5
6
7
8
9
10
2000
400

Some results Eastern Scheldt
1 empirical conversion factor!





14C=1.036•FRRF, r^2=0.90
Outliers:
14C=1.993•FRRF, r^2=0.95