# Primary Productivity from Ocean Color Based on Photosynthetic Quantum Efficiency and Phytoplankton Absorption

---

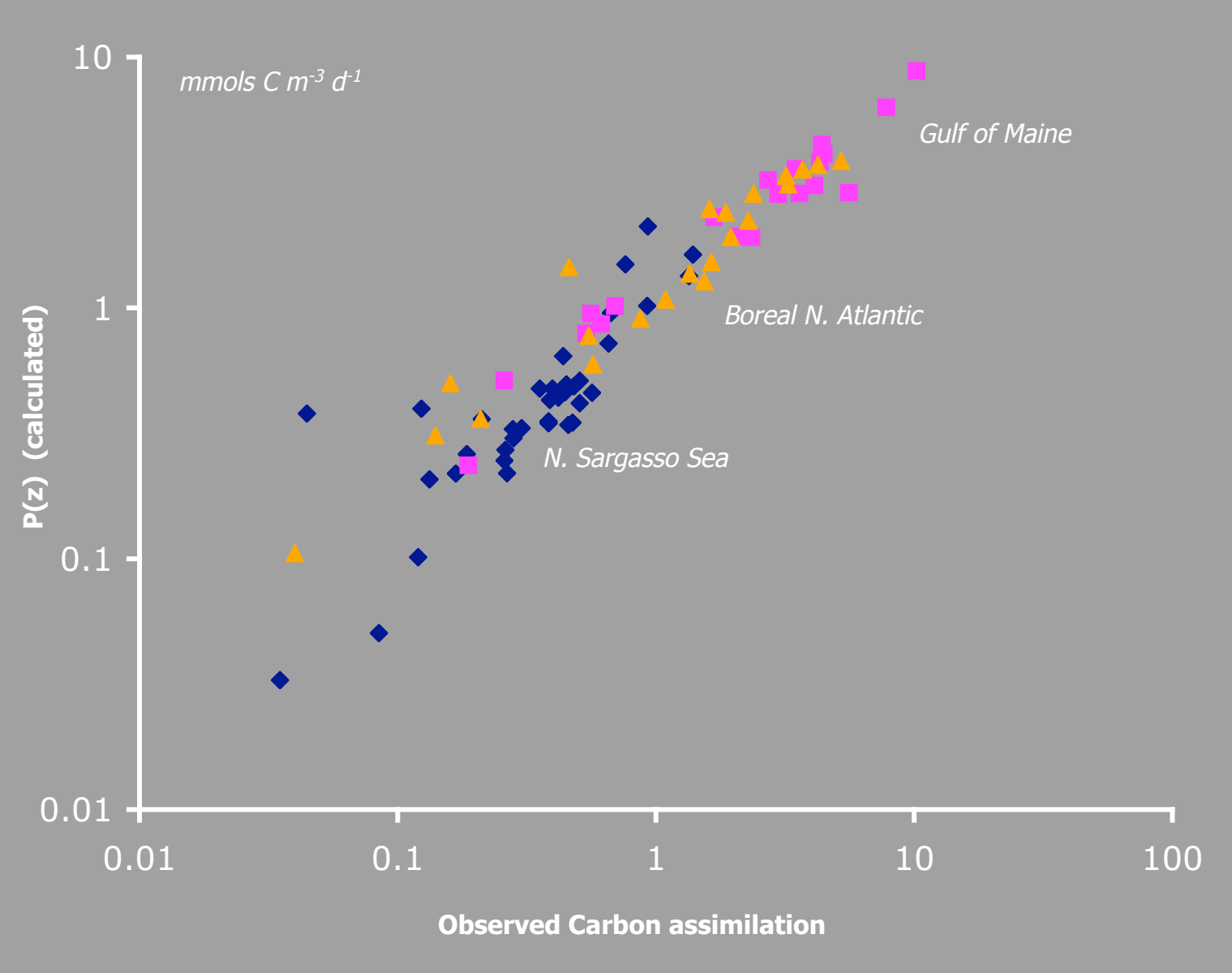
**John Marra**
Lamont-Doherty Earth Observatory of Columbia University

## Modeling $^{14}$C uptake suggests an algorithm for estimating productivity from space.

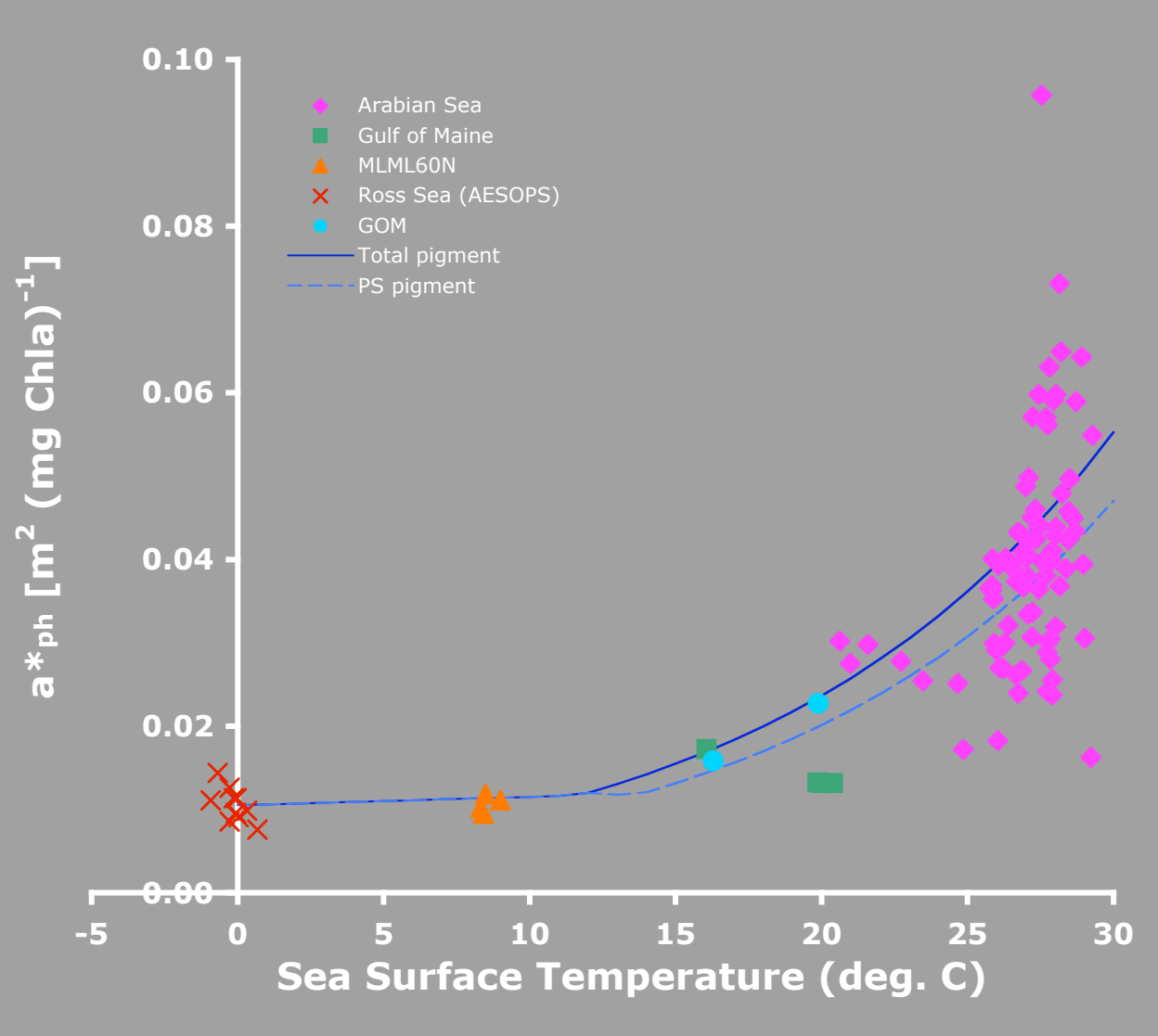
A simple model for photosynthetic production can be written as follows:

$$P(z) = \phi(E) \cdot a^{*}_{ph} \cdot [Chla(z)] \cdot E(z)$$

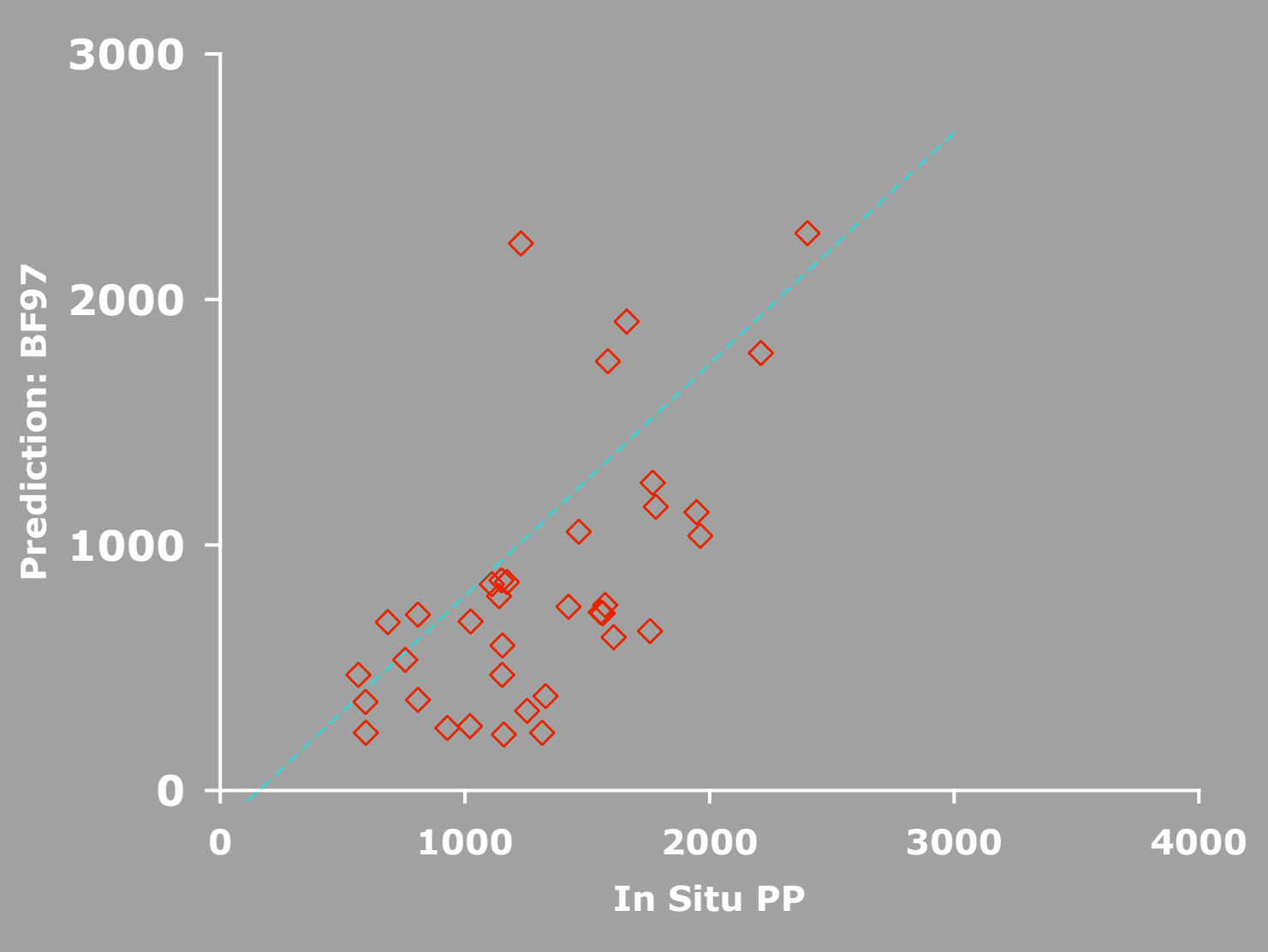
The above equation serves as the basis to calculate productivity from satellite ocean color (chlorophyll-a). It requires two inputs: a maximum for the quantum yield, and a value for the chlorophyll-specific absorption by phytoplankton. (I assume that the function relating quantum yield to irradiance is known.) The figures below represent a first step in understanding the oceanographic variability in these variables.



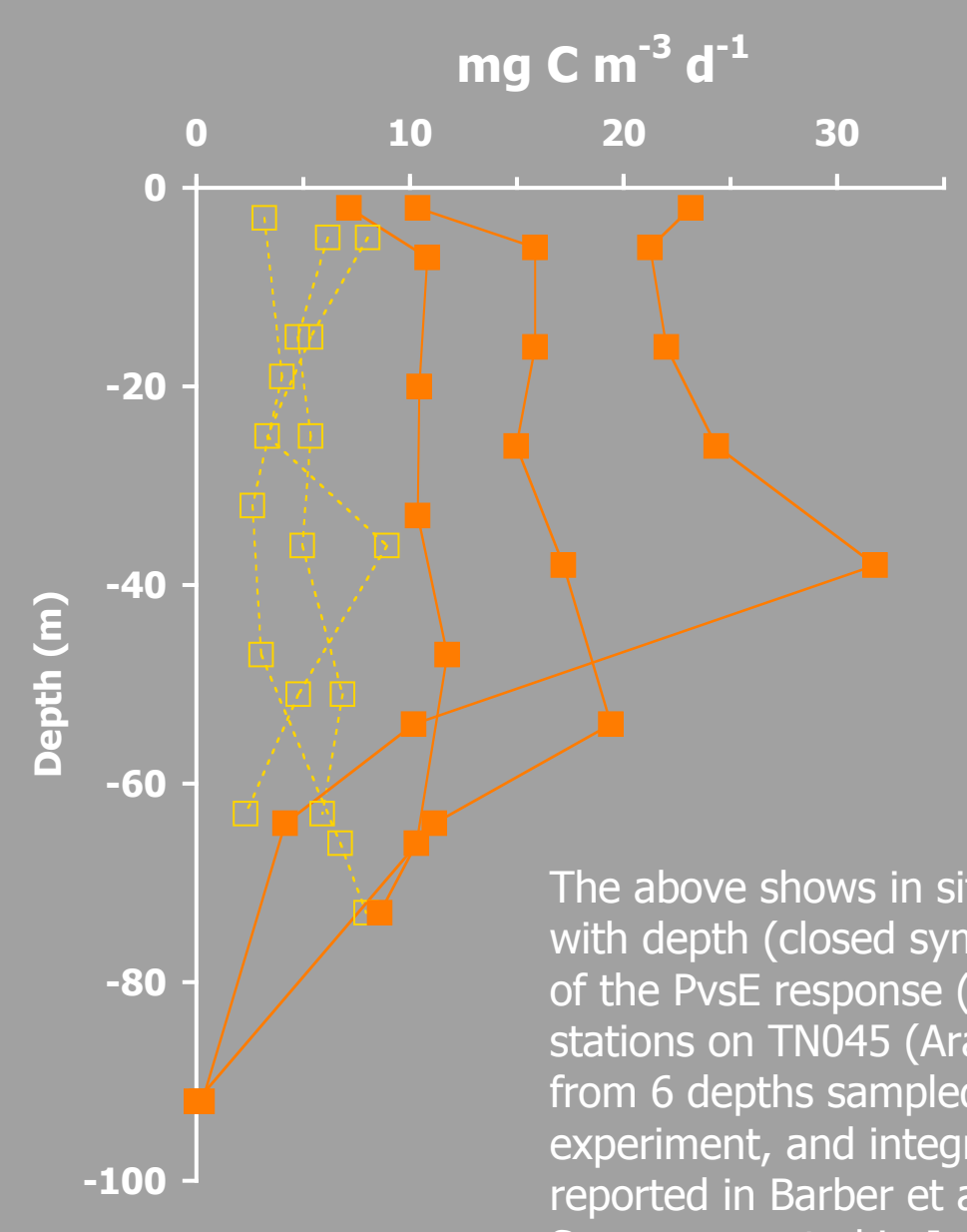
Observed carbon assimilation compared to P(z) from the equation above, and assuming that the maximum quantum yield = 0.06 mol C (mol photons)$^{-1}$. This value, however, does not seem to be appropriate for other environments than the North Atlantic. The maximum quantum yield is observed to be about half this value in the Arabian Sea, and about 25% higher in the Ross Sea and APFZ



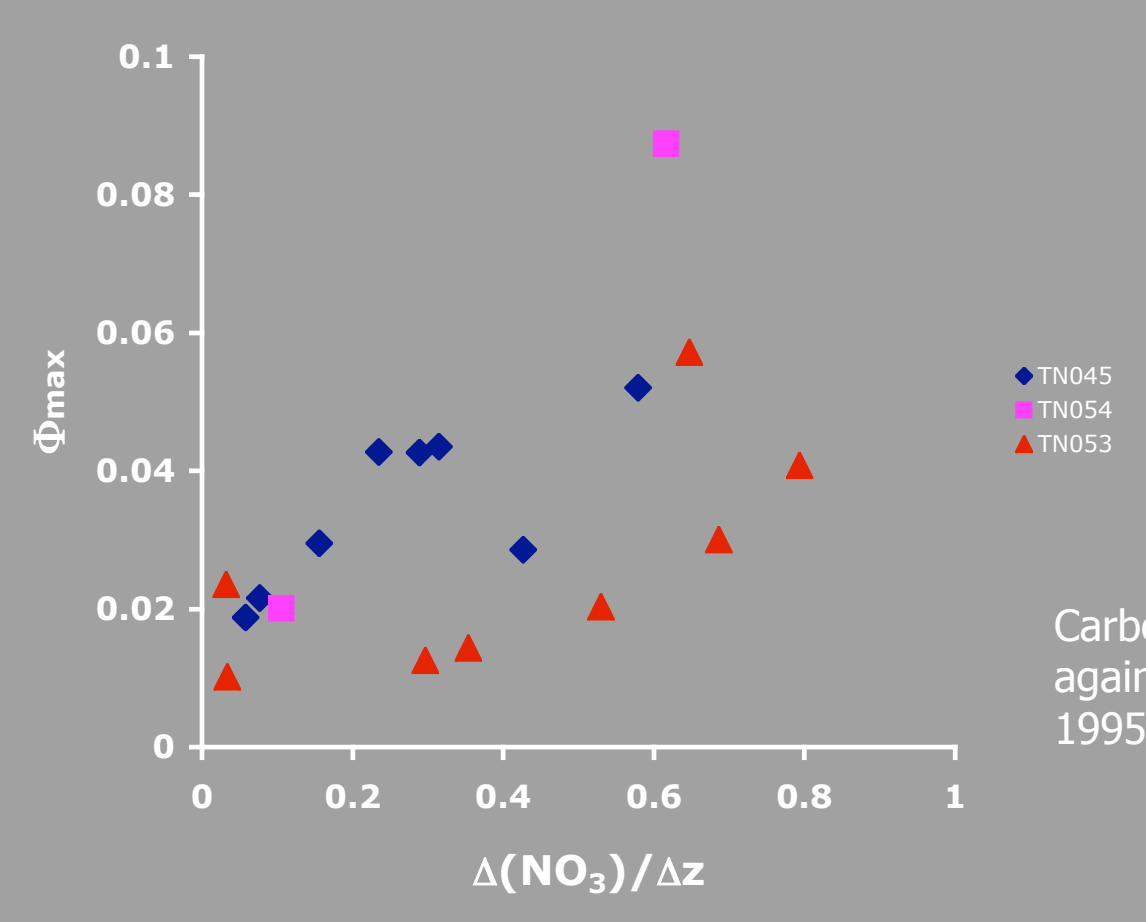
Surface temperatures are an approximation for phytoplankton community structure (high SST -> stability -> small cells ->high $a^{*}_{ph}$). Also, SST can be observed from space. The above relationship is provisional, and complicated, for example, by low latitude upwelling (see Marra et al., 2003). In future, we plan to look at SST variability around the climatological seasonal cycle for individual regions.



A comparison of measured, areal, in situ primary production (mg C m$^{-2}$ d$^{-1}$) from the Arabian Sea, with that predicted by the algorithm of Behrenfeld and Falkowski (1997). The line is the linear regression ($r^2 = 0.48$). The standard error is ±350 mg C m$^{-2}$ d$^{-1}$. A more thorough study needs to be done to investigate the biases noted here.



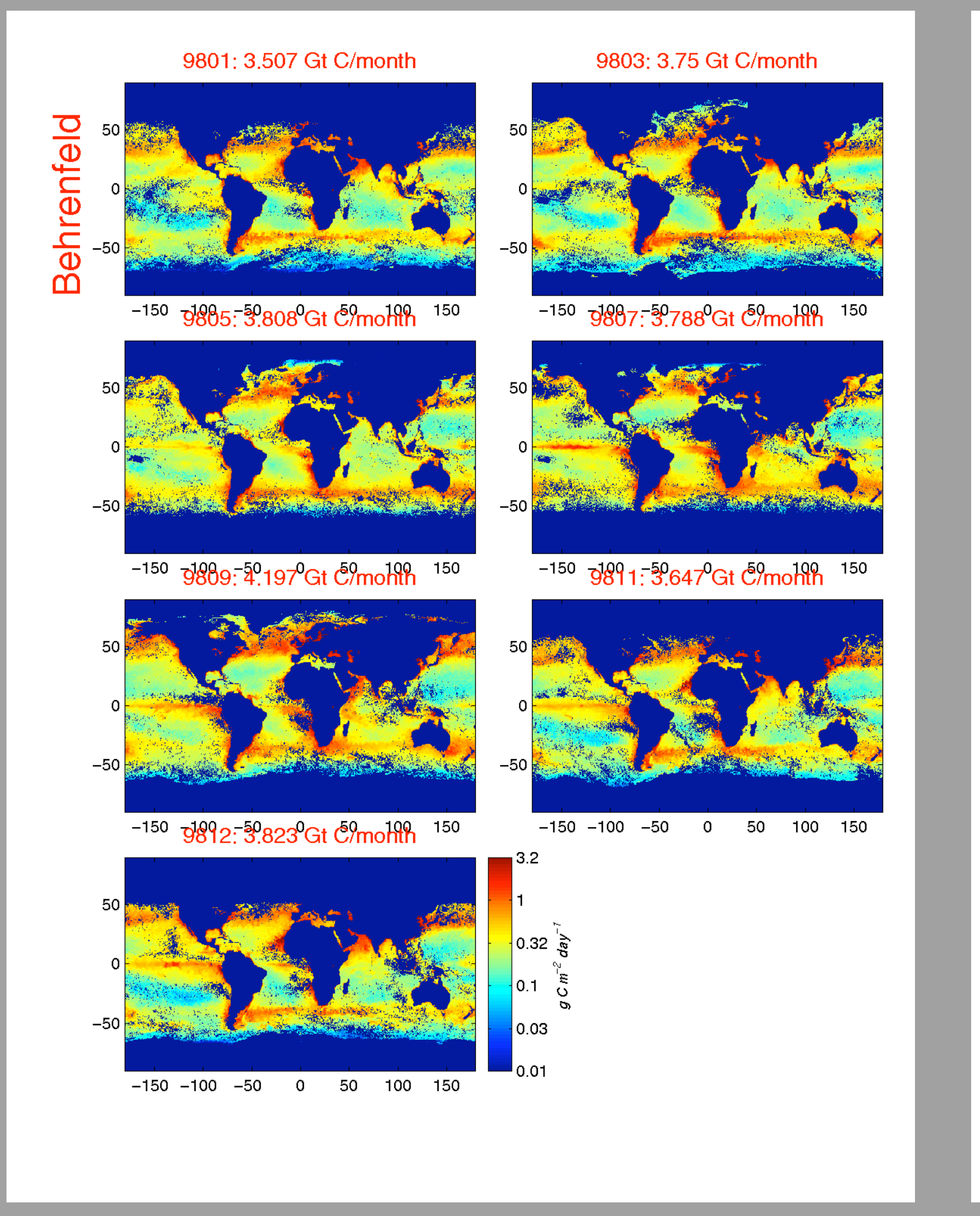
The above shows in situ primary production (ISPP) from with depth (closed symbols), and that calculated by means of the PvsE response (open symbols). The data are from 3 stations on TN045 (Arabian Sea Process 2). PvsE curves from 6 depths sampled at noon of the day of the experiment, and integrated over time. ISPP data are reported in Barber et al. (2001). PvsE data from the Arabian Sea are reported in Johnson et al. (2002). These data are limited. We need a more extensive set of comparisons to find out if the bias noted here is real, and if so, what are the causes.



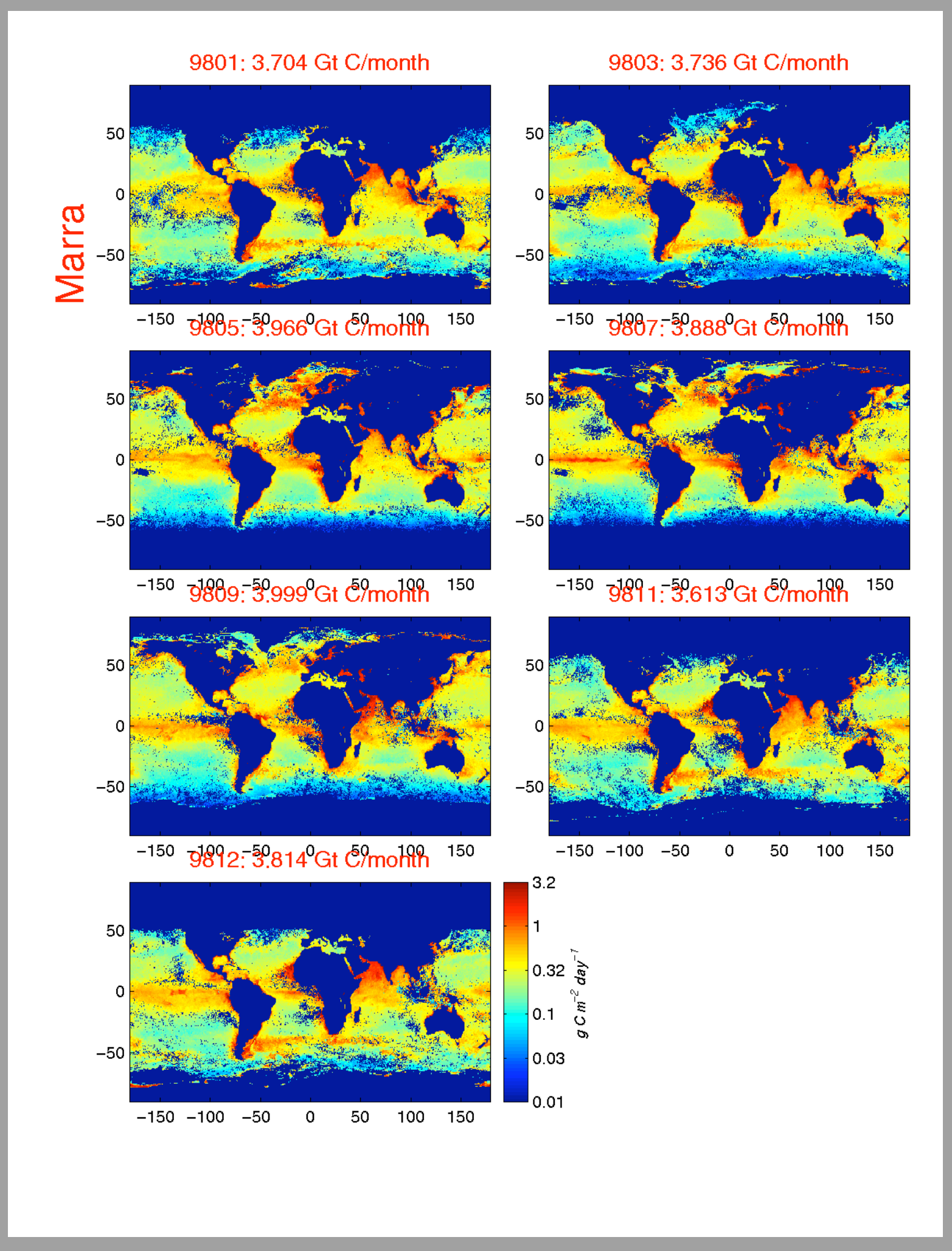
Carbon-based maximum quantum yield plotted against the nitrate gradient for the Arabian Sea in 1995.

## Model Comparison for SeaWiFS, 1998

### VGPM



### Marra



## Research Plan, 2004-2005

1. Refine the relationship between $a^{*}_{ph}$ and SST. I plan to add to the database, extending further the geographical range. On another track, I will focus on the data in the Arabian Sea since we have a fairly complete seasonal cycle, and the data are spatially extensive. Since the temperature range is limited, I will examine the use of an SST anomaly, or normalize the SST data to a climatological seasonal cycle.
2. Create a relationship that allows a spatio-temporal extrapolation of $\phi_{max}$ using in situ data. Again, we will use the Arabian Sea as a test case for determining the environmental effects on $\phi_{max}$. I will look for relationships among mixed layer depth, nitrate gradients, and SST in elaborating a relationship.
3. Test the use of PvsE parameters in calculating areal photosynthesis. PvsE parameters form the basis of one means to model primary productivity from space. However, whether these can be used to predict in situ productivity has not been tested comprehensively. As shown in the graph to the left, a preliminary look shows wide disagreement. We need to find out if the disagreement is general, and whether there exists a means to bring the two results into agreement.
4. Investigate the use of water-leaving radiances, instead of Chl-a, as a means to model productivity from space. Both VGPM and methods based on PvsE require the use of satellite chlorophyll, a derived product of ocean color. Satellite chlorophyll has its own kind of errors, and the idea here is that it might be advantageous to rely instead on water-leaving radiances ($L_w$'s). The disadvantage is that we need to account more accurately for CDOM and other components that affect ocean color.

John Marra
Lamont-Doherty Earth Observatory
61 Route 9W
Palisades, NY 10964 USA
Marra@ldeo.columbia.edu
Tel:  1-845-365-8891
Fax: 1-845-365-8150