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Use of the GlobColour Dataset for Marine Carbon Studies

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Thanks to M. Telszewski, A. Chazottes, L. Bopp, D. Bakker, U. Schuster, A. Watson
+ all teams involved in data collection within EU IP CarboOcean

Introduction

- Ocean is a global sink of atmospheric CO_2
- Strong regional and seasonal variability of this sink (which can be a source) of CO_2
- Global models are used to estimate this sink and to forecast its long-term evolution
- Model validation would benefit from monthly mean maps of the surface pCO_2

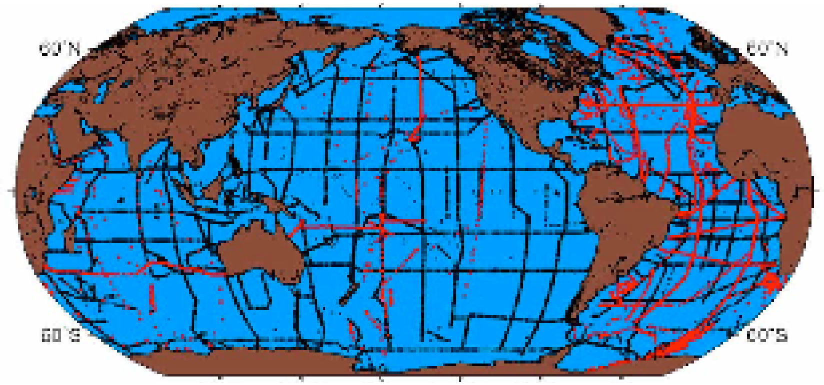
Unfortunately, ocean pCO_2 cannot be measured directly from space !!

Current approaches

- Sparse global network of marine pCO_2 measurements

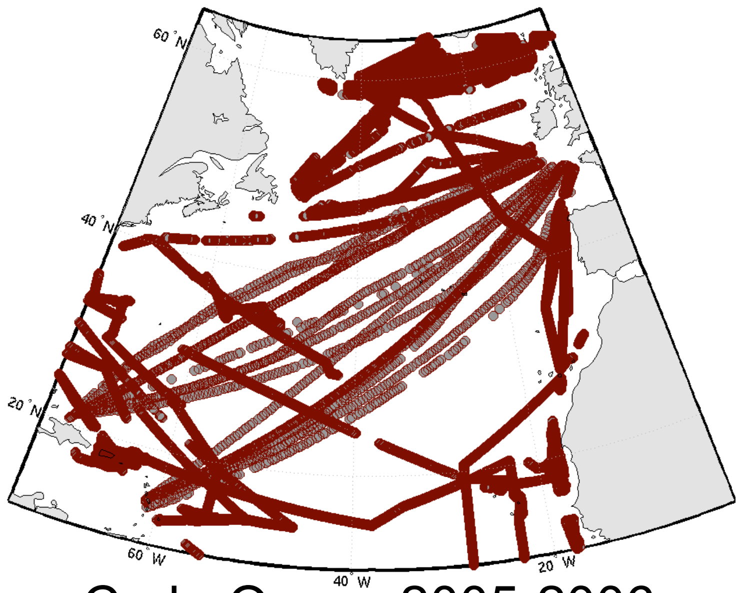
Climatologies are used to validate models

GLODAP 1990-1999



- Dense networks have recently been developed, for example in the North Atlantic

Data assimilation is used to improve models



CarboOcean 2005-2006

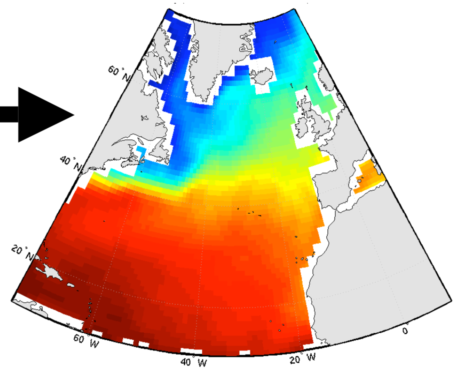
Proposed approach

- Surface ocean pCO_2 depends on thermo-dynamical, biological and vertical mixing effects.
- pCO_2 can be estimated from three parameters (SST,CHL,MLD) that account for these effects (Jamet *et al.*, in press).
- pCO2 maps can be generated using maps of these three parameters obtained from satellite (SST,CHL) and model (MLD).

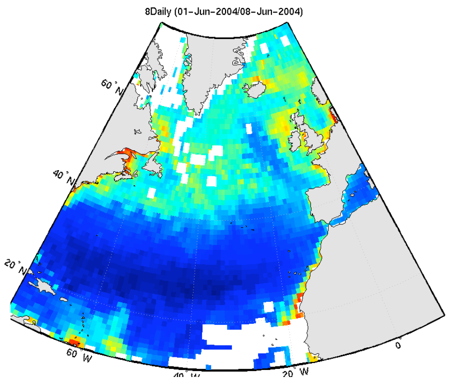
In the framework of the EU CarboOcean IP, we have developed a method based on Neural Networks

The « parameters » dataset

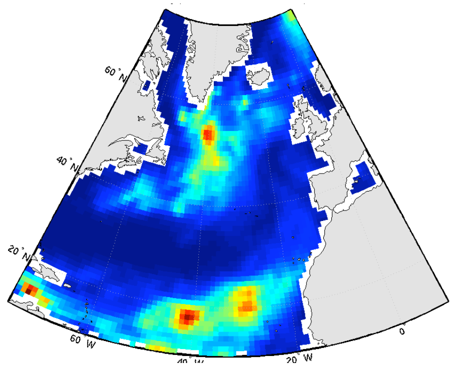
- SST: NCEP/NCAR reanalysis
  http://www.cdc.noaa.gov/cdc/reanalysis/



First week of June 2005



- CHL: NASA MODIS-SEAWIFS merged product.
  http://oceancolor.gsfc.nasa.gov/cgi/level3.pl



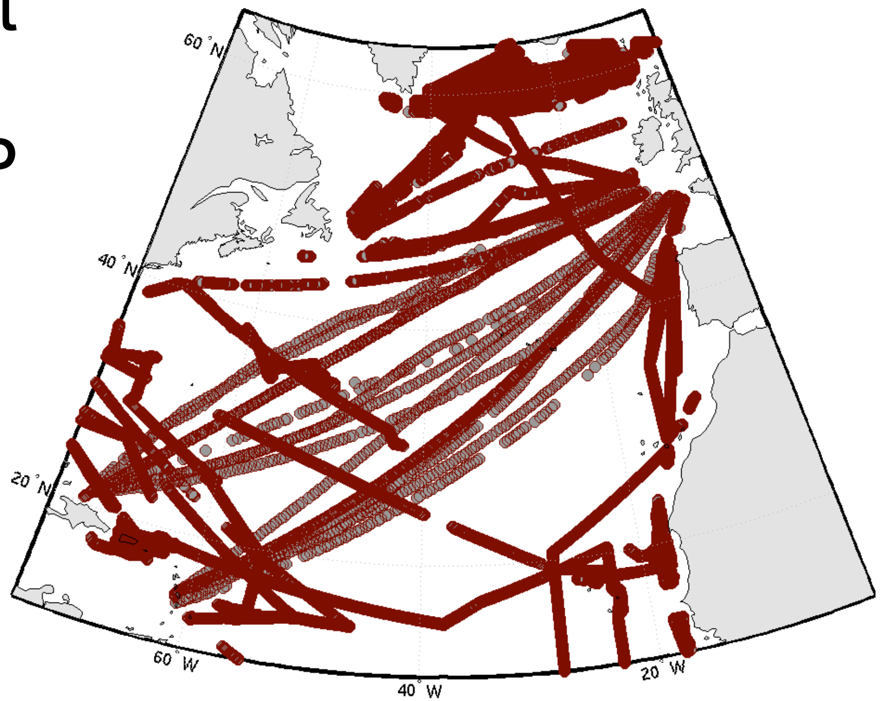
- MLD: FOAM model
  http://www.nerc-essc.ac.uk/godiva/

400000 triplets (SST,CHL,MLD) available for 2005 and 2006 (1°x1° and 8-day).

The *in situ* pCO2 dataset

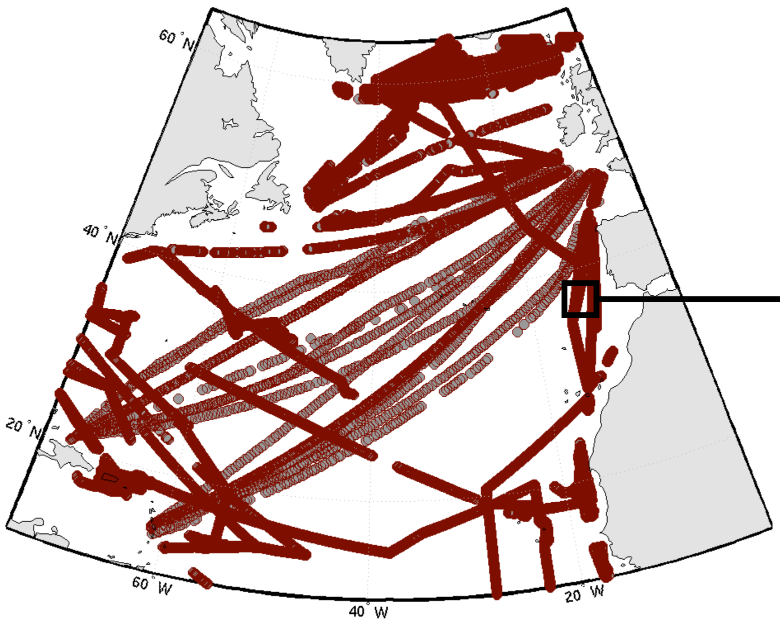
- Measurements of surface pCO2 collected on VOS that regularly cross the North Atlantic, as part of the EU/IP CARBOOCEAN.

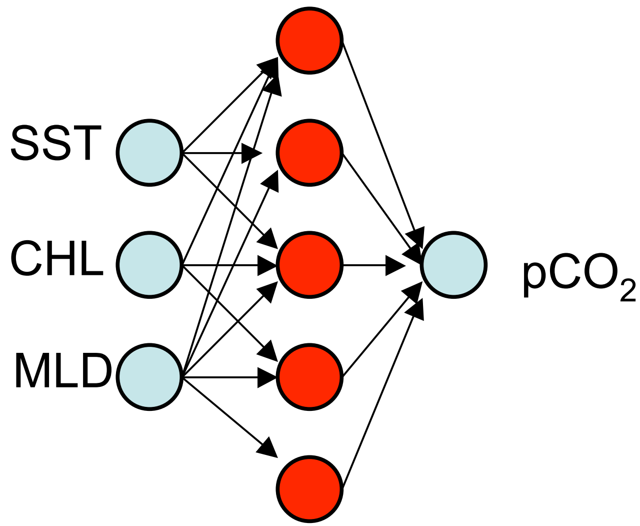
  140000 pCO_2 data for 2005 and 2006, associated with the coincident triplet (SST,CHL,MLD) from the « parameters » dataset.



Multi-Layer Perceptron (*mlp*)

1st step: Supervised learning
(pCO2 data required)





140,000 pCO_2
with their triplets
(SST,CHL,MLD)

The individual weigths of the
hidden neurons are adjusted

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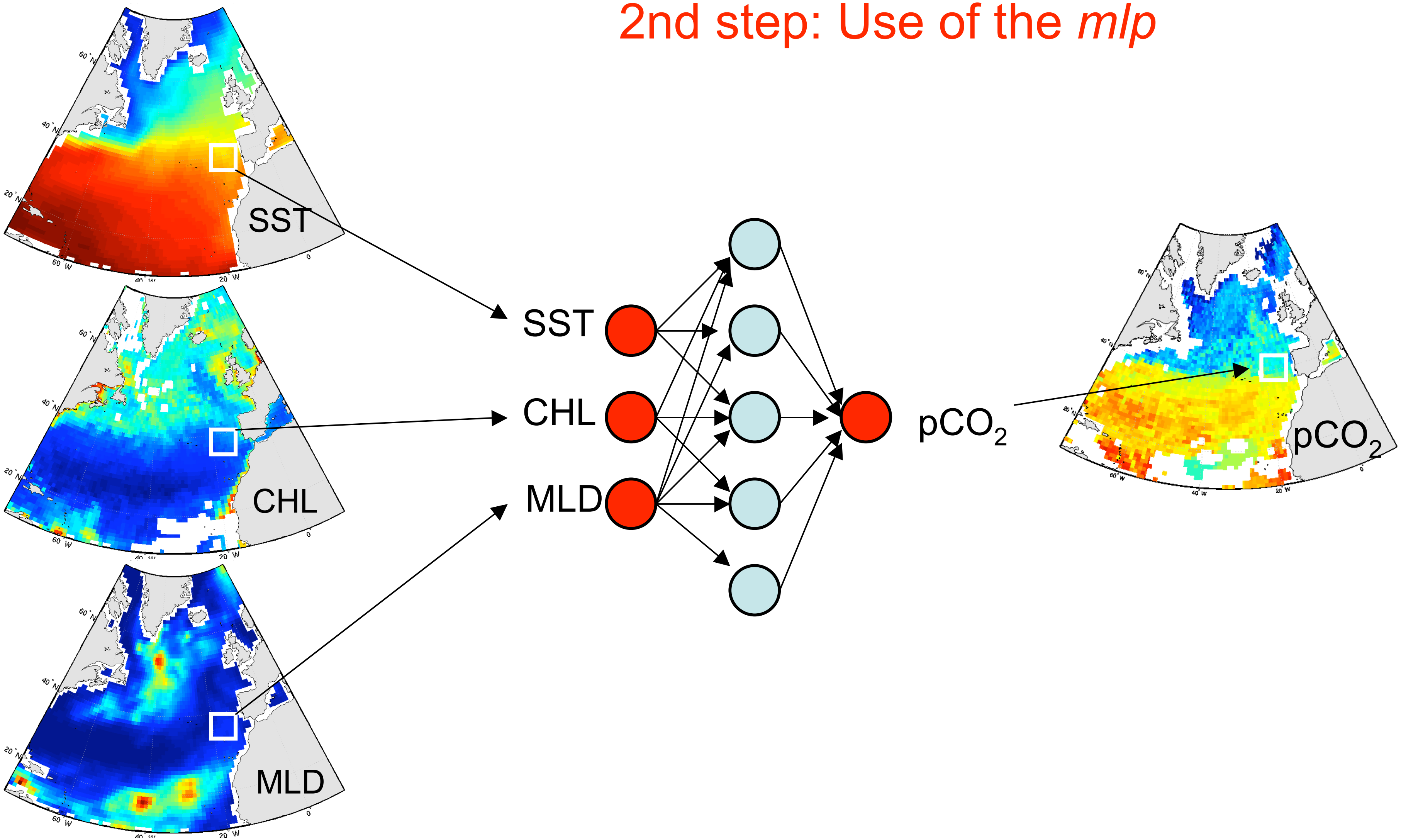
Multi-Layer Perceptron (*mlp*)

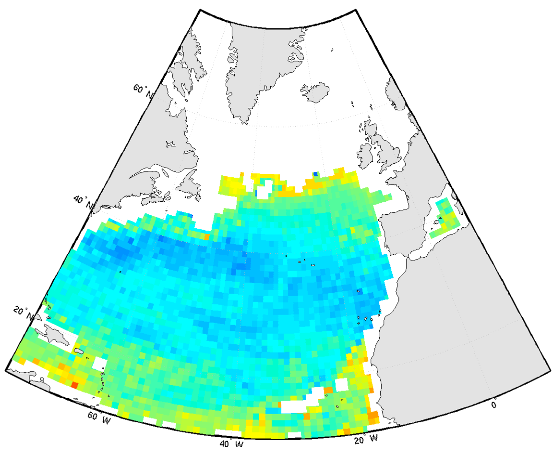
2nd step: Use of the *mlp*



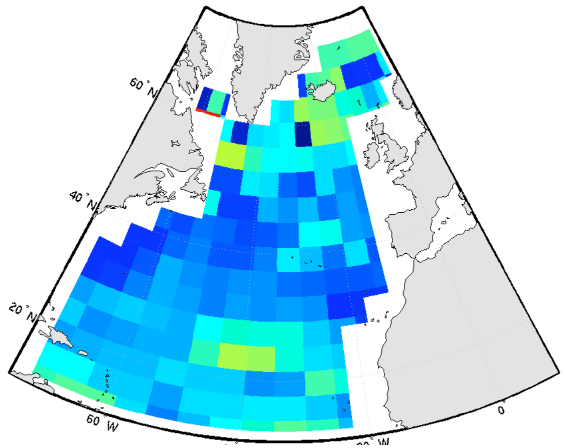
pCO_2 Maps for 2005

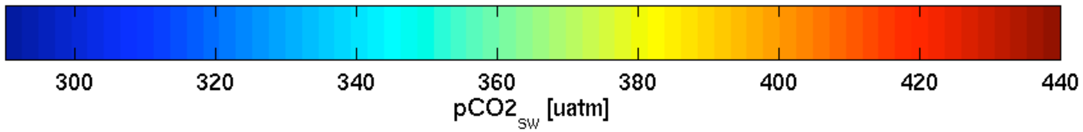
pCO2=*mlp*(SST,CHL,MLD)

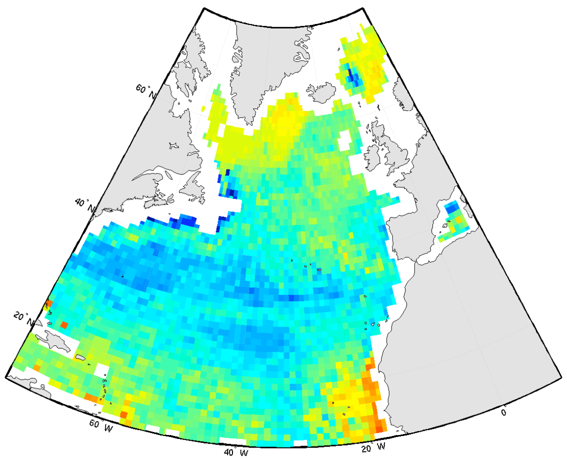
Takahashi et al., 2002



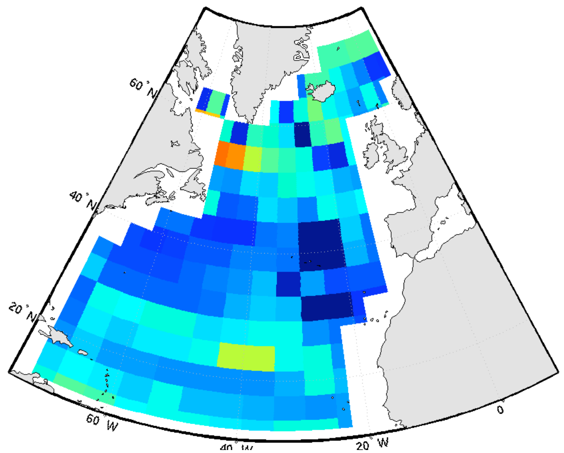
January







March



pCO_2 Maps for 2005

pCO2=*mlp*(SST,CHL,MLD)

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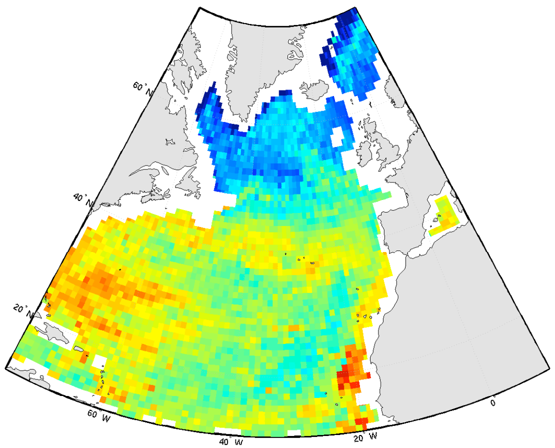
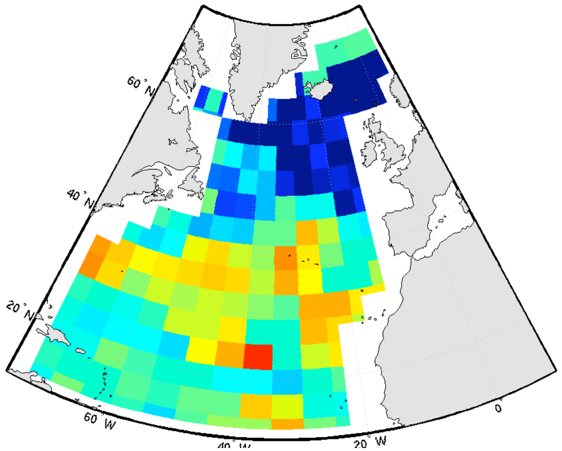
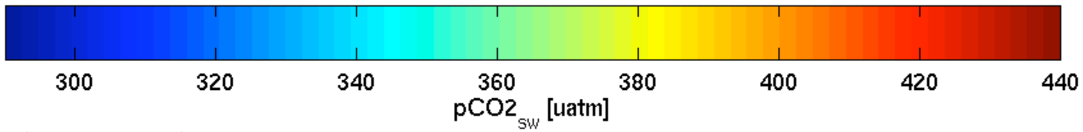
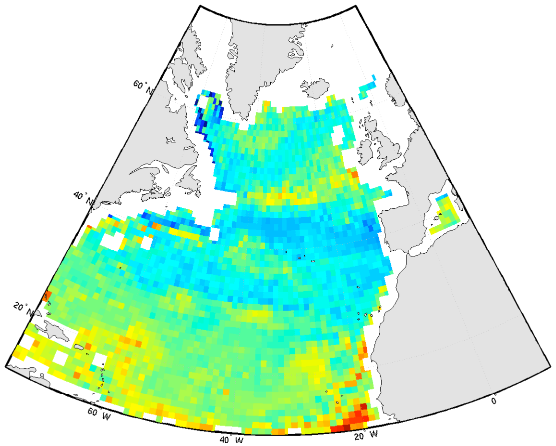


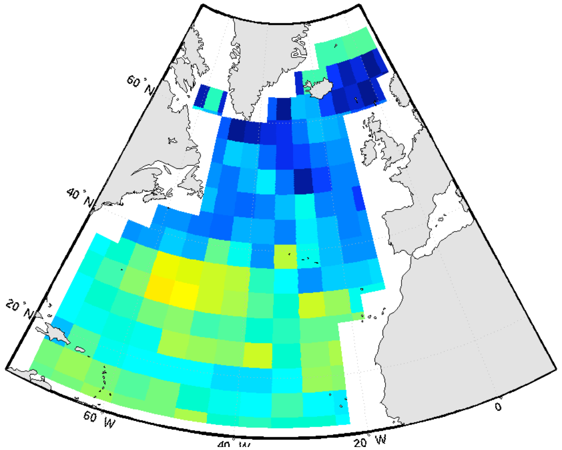


July





October



Perspectives

- Use new satellite products such as the GlobColour dataset to improve the method and to generate global pCO_2 maps.
- A near-real time application could be developed in collaboration with space agencies and operational oceanography centers.

IOCCP aims at organizing a workshop
« Ocean CO2 from Space »
in the first half of 2008.

Global phytoplankton primary production from the GlobColour FPS and the GHRSST data set

David Antoine

Laboratoire d'Océanographie de Villefranche

GlobCOLOUR Project

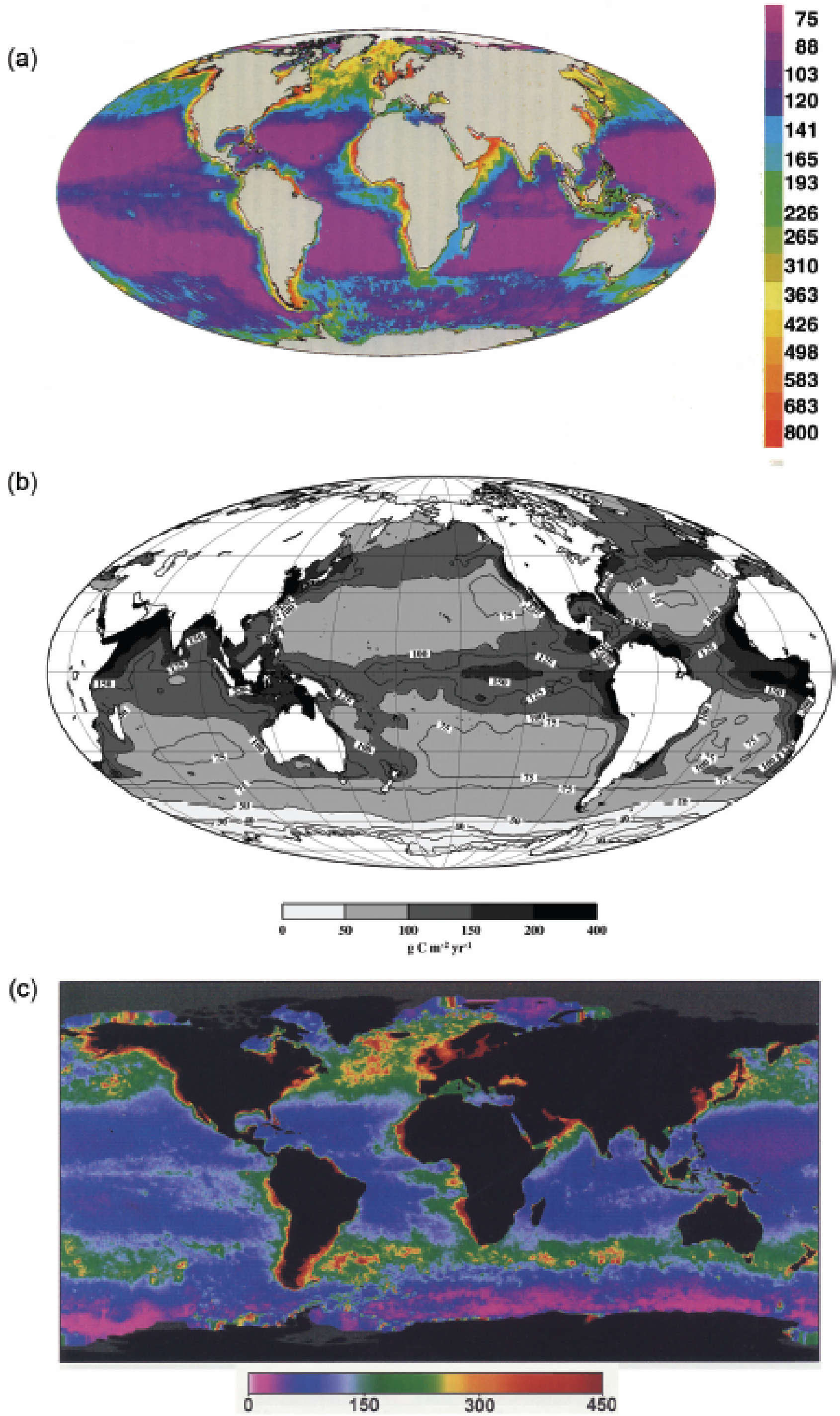
Rationale for this study

-Global PP estimates have not been revised since the 1990’s, when the 3 studies based on the CZCS climatology were published (Longhurst et al., 1995; Behrenfeld and Falkowski, 1997; Antoine et al., 1996).

- Global data sets are now available, covering the past 10 years

- It’s timely to start revising the global value, and, more importantly, to assess the seasonal, interannual and decadal changes in PP.

- The models themselves have not evolved (work in progress, however)



Studies in the 1990's

Longhurst et al., *J. Plank. Res*., 1995;
~50 Gt C per year

Antoine et al., *Global Biogeochem. Cycles*, 1996
~47 Gt C per year

Behrenfeld and Falkowski, *Limnol. Oceanogr*., 1997
~43 Gt C per year

The spectral light-photosynthesis model

(Morel, 1991, Progress in Oceanography, 26, 263-306)

Basic Equation for • LOCAL (z)

• INSTANTANEOUS Photosynthesis (t)

Under • MONOCHROMATIC Irradiance (λ)

$$P(\lambda,z,t) = \frac{dC(\lambda,z,t)}{dt} = E(\lambda,z,t) \quad Chl(z,t) \quad a^{*}(\lambda,z,t) \quad \Phi(\lambda,z,t)$$

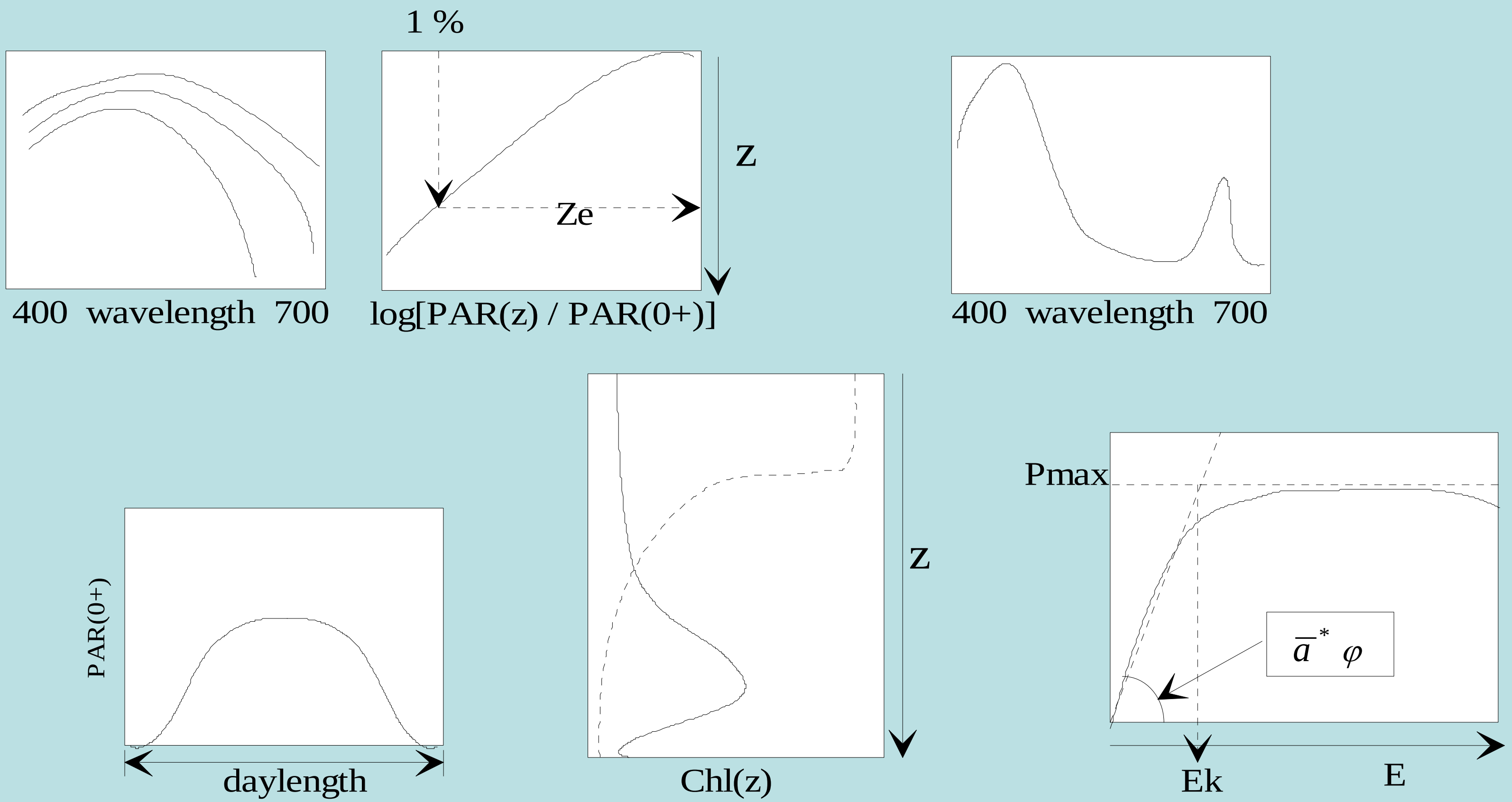
Daily, column-integrated production

$$P = \int^{D} \int_{0}^{Zp} \int_{400}^{700} P(\lambda,z,t)\, d\lambda\, dz\, dt$$

- 400 – 700 nm : Limits for PAR
- Z_p : Depth of the « productive » zone (e.g., 1.5 Z_e)
- D : Day length

Spectral & depth changes of The various parameters

$$P(\lambda,z,t) = \frac{dC(\lambda,z,t)}{dt} = E(\lambda,z,t) \quad Chl(z,t) \quad a^{*}(\lambda,z,t) \quad \Phi(\lambda,z,t)$$



Integrating over the three dimensions (wavelength, depth, time)

$$P = \iiint P(\lambda, z, t)\, d\lambda\, dz\, dt \;=\; \iiint \left[E(\lambda, z, t)\;\; Chl(z, t)\;\; a^*(\lambda, z, t)\;\; \Phi(\lambda, z, t)\right]$$

$$\int_{400}^{700} E(\lambda, 0^+, t)\, d\lambda = PAR(0^+, t)$$

$$\int_{0}^{D} PAR(0^+, t)\, dt = \overline{PAR}(0^+)$$

$$\int_{z=0}^{z=Z_p} Chl(z)\, dz = \langle Chl \rangle_{tot}$$

(t is ignored)

$$\boxed{\psi^* = \frac{P \propto PSR}{\overline{PAR}(0^+)\;\langle Chl \rangle_{tot}}}$$

ψ^* LUT (2 LUTs : uniform or non-uniform Chl distributions)

- Date
- Latitude
- Cloudiness
- Temperature
- Chl

ψ^* : $m^2\,(gChl)^{-1}$

Photosynthesis cross section per unit of areal chlorophyll

Berthon and Morel (1992), *Limnology and Oceanography*, 37, 781-796

Antoine and Morel (1996), *Global Biogeochemical Cycles*, 10, 43-55

GLOBCOLOUR

The integral, "satellite version" of the model

$$\boxed{P \propto PSR = \langle Chl \rangle_{tot} \; \overline{PAR}(0^+)\, \psi^*}$$

For given $\overline{PAR}(0^+)$ and temperature distributions :

- ♦ $\langle Chl \rangle_{tot}$ is the first determinant, to the extent that

  → ψ^* is only weakly dependent on Chl ←

  (mainly depends on T° and $\overline{PAR}(0^+)$)

- ♦ $\langle Chl \rangle_{tot}$ roughly varies as $\sqrt{Chl_{sat}}$, so does P (approximately)

- ♦ While Chl_{sat} spans about 3 orders of magnitude,

  $\langle Chl \rangle_{tot}$ and P span about 1.5 orders of magnitude

Data sets, 1998-2006

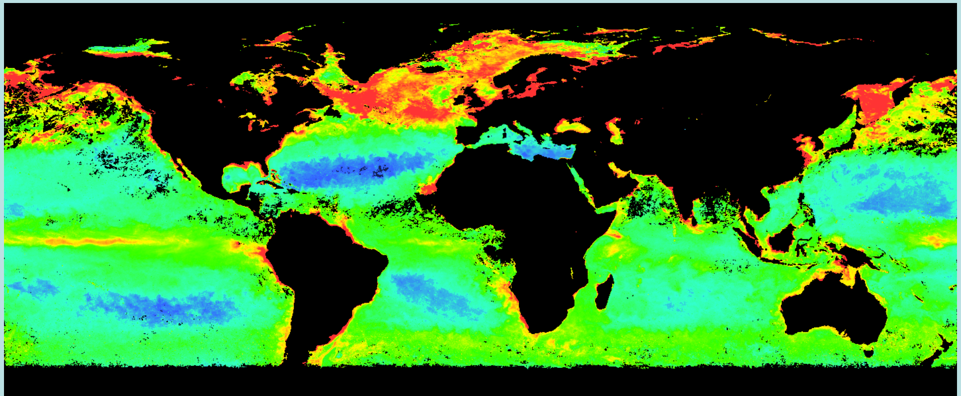
Chl → GlobCOLOUR FPS (GSM & AVW). ¼ degree

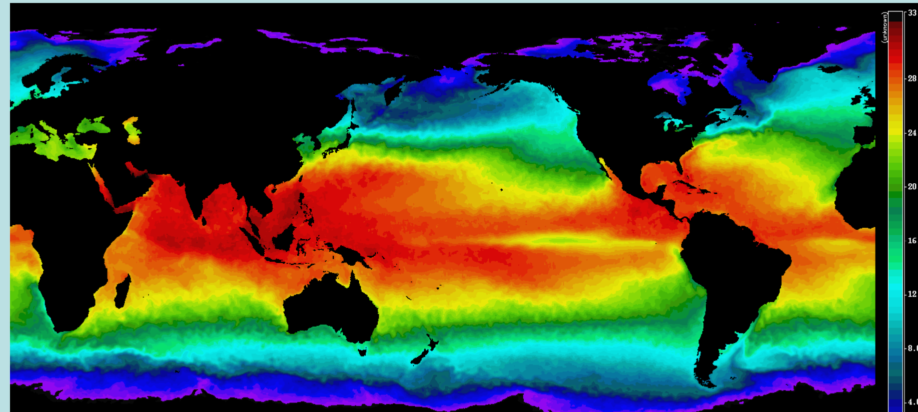
SST → GHRSST-PP, daily global, ¼ degree

PAR → SeaWiFS monthly PAR product, $\frac{1}{12}$ degree

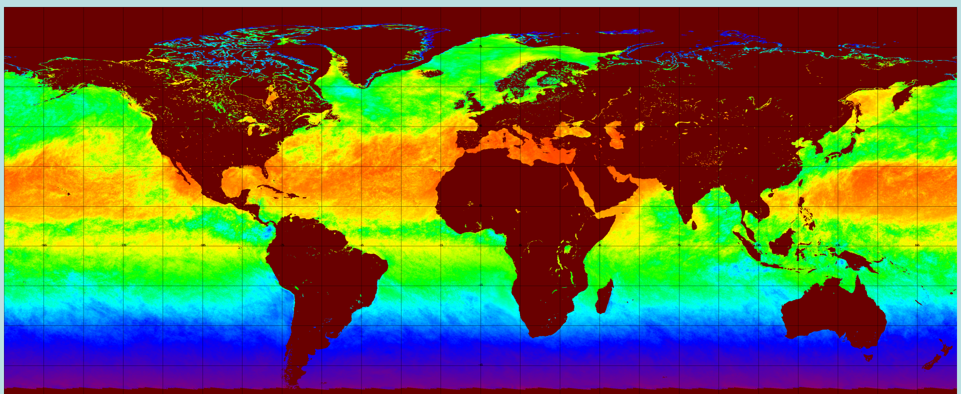
Mixed-layer depth (climatology) → De Boyer Montégut et al. (2002)

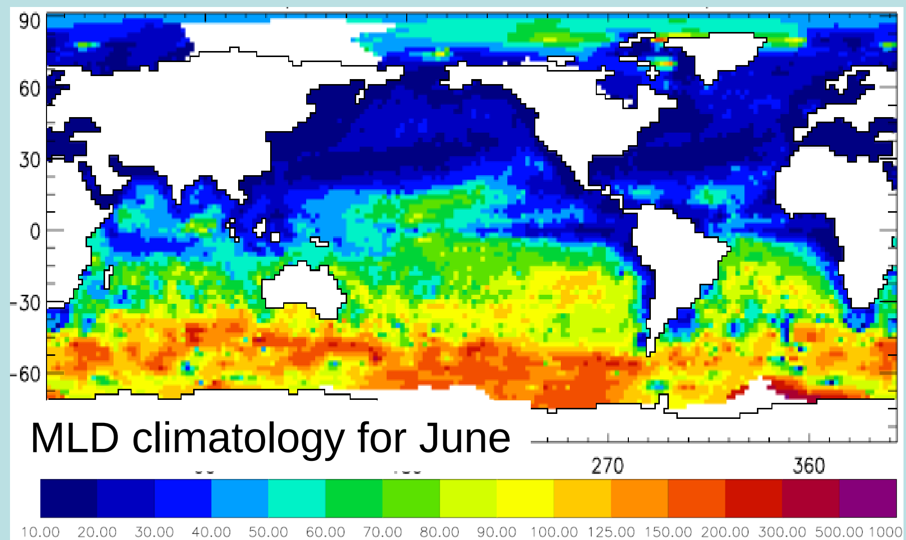
Input data sets: examples for June 1998


GlobCOLOUR Chl (GSM) monthly composite

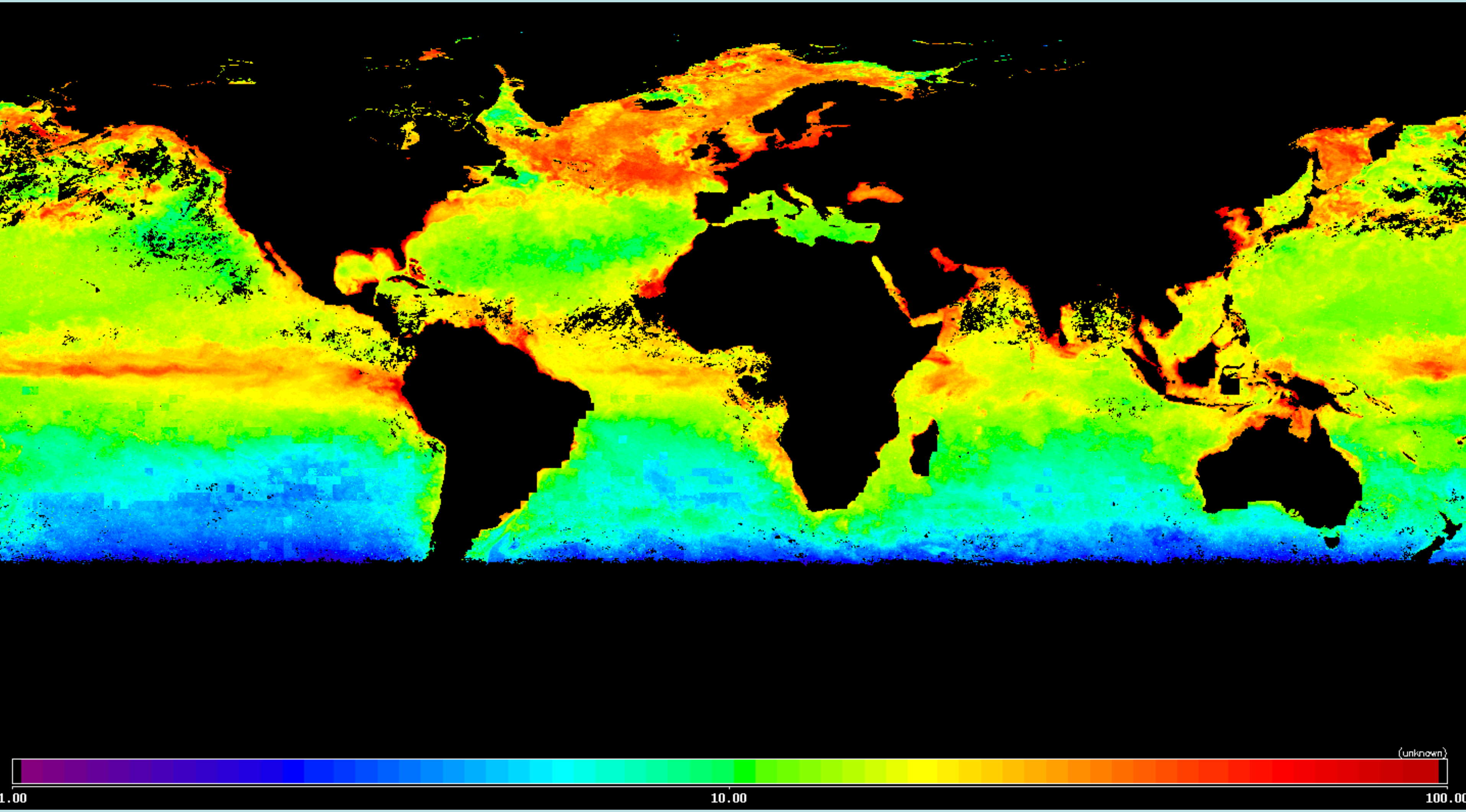


GHRSST monthly composite


SeaWiFS PAR monthly composite

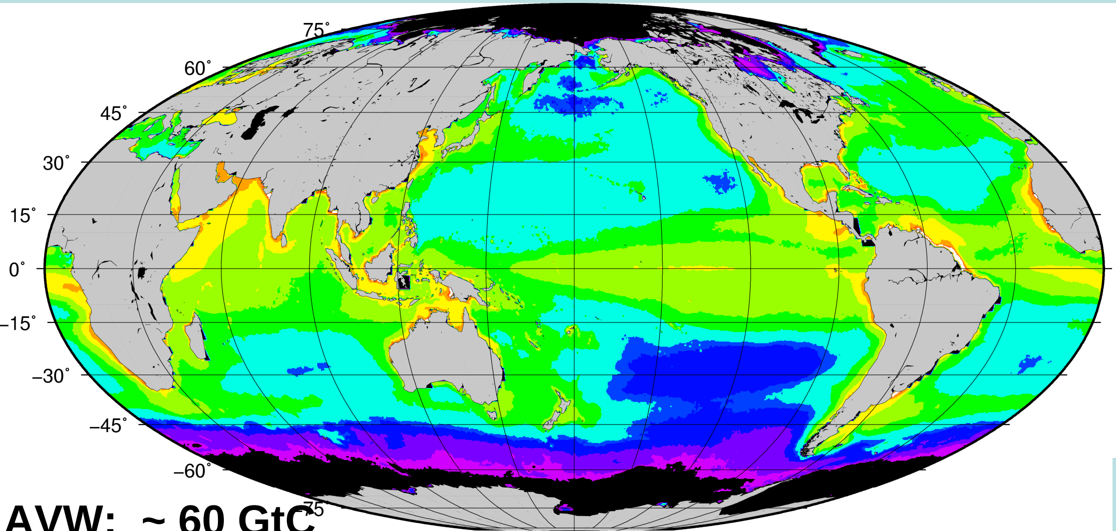


MLD climatology for June

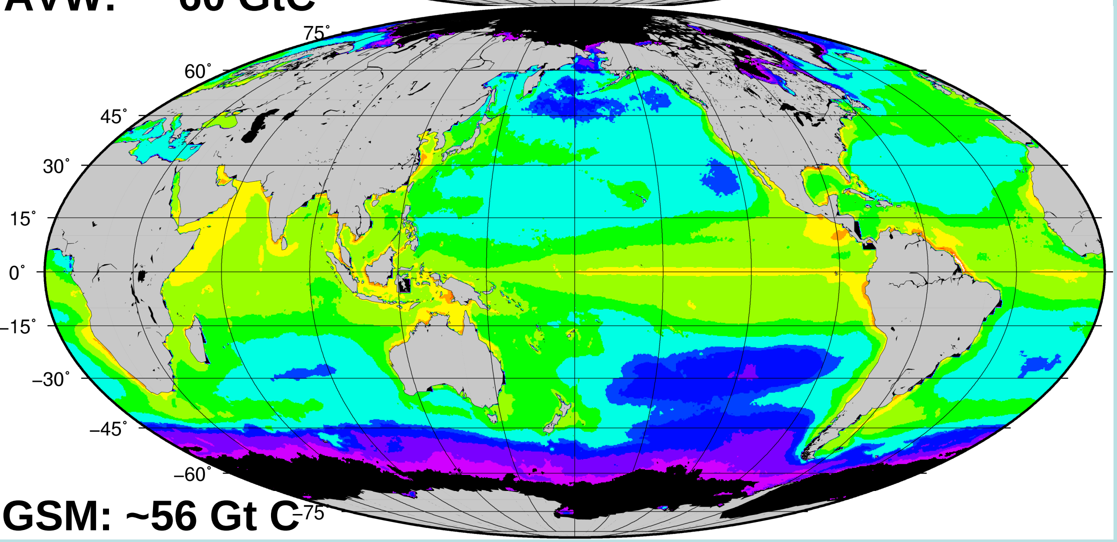


Resulting global PP : 4.2 Gt C (54 for the year 1998)

Results: average PP 1998-2006



AVW: ~ 60 GtC



GSM: ~56 Gt C

Table 2. Global annual phytoplankton primary production (Pg C yr^{-1}) calculated with the vertically generalized production model (VGPM), Laboratoire de Physique et Chimie Marines (LPCM) model (Antoine et al. 1996), Bedford production model (BPM) (Longhurst et al. 1995), and the Eppley and Peterson (1979) compilation (E&P). Annual production is also shown for the five major ocean basins defined by Antoine et al. (1996) (percentages of total production indicated in parentheses), as well as three trophic categories for the VGPM and LPCM models (subpolar plus global in brackets).

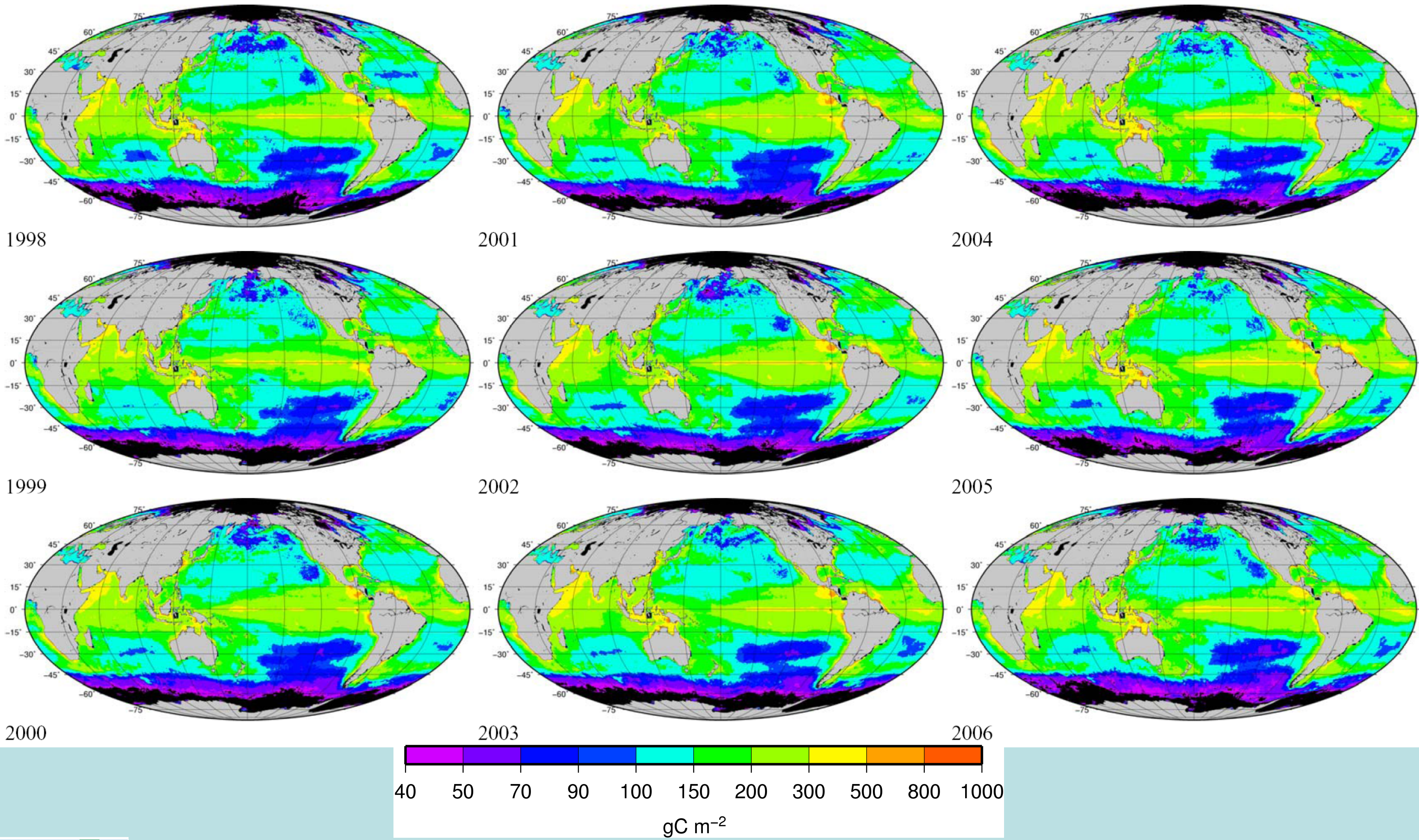
	VGPM	LPCM*	BPM†	E&P‡
Global total	43.5	46.9	$50.2^{[illegible]}_{44.7}$	27.1
Pacific	16.7(38.3)	20.0(42.7)	$19.4^{[illegible]}_{17.4}$(38.6)	9.1(33.7)
Atlantic§	11.9(27.5)	11.3(24.0)	$13.7^{11.7}_{10.8}$(27.3)	8.6(31.6)
Indian	6.2(14.2)	8.1(17.3)	$6.5^{[illegible]}_{6.0}$(13.0)	6.0(22.0)
Arctic	0.4(0.9)	0.6(1.3)	1.4(2.8)	0.1(0.5)
Antarctic	8.3(19.1)	6.9(14.7)	9.2(18.3)	3.3(12.2)
Oligotrophic	10.3[10.5]‖	16.2		
Mesotrophic	22.0[26.4]‖	22.5		
Eutrophic	3.6[6.6]‖	2.5		

Previous results (from Behrenfeld and Falkowski, 1997)

Average global value from more than 20 models, using SeaWiFS data for the year 1998, is of about 50 Gt C (56 with our model). See Carr et al., 2006

Results: interannual variability

Annual PP for the 9 years of the time series



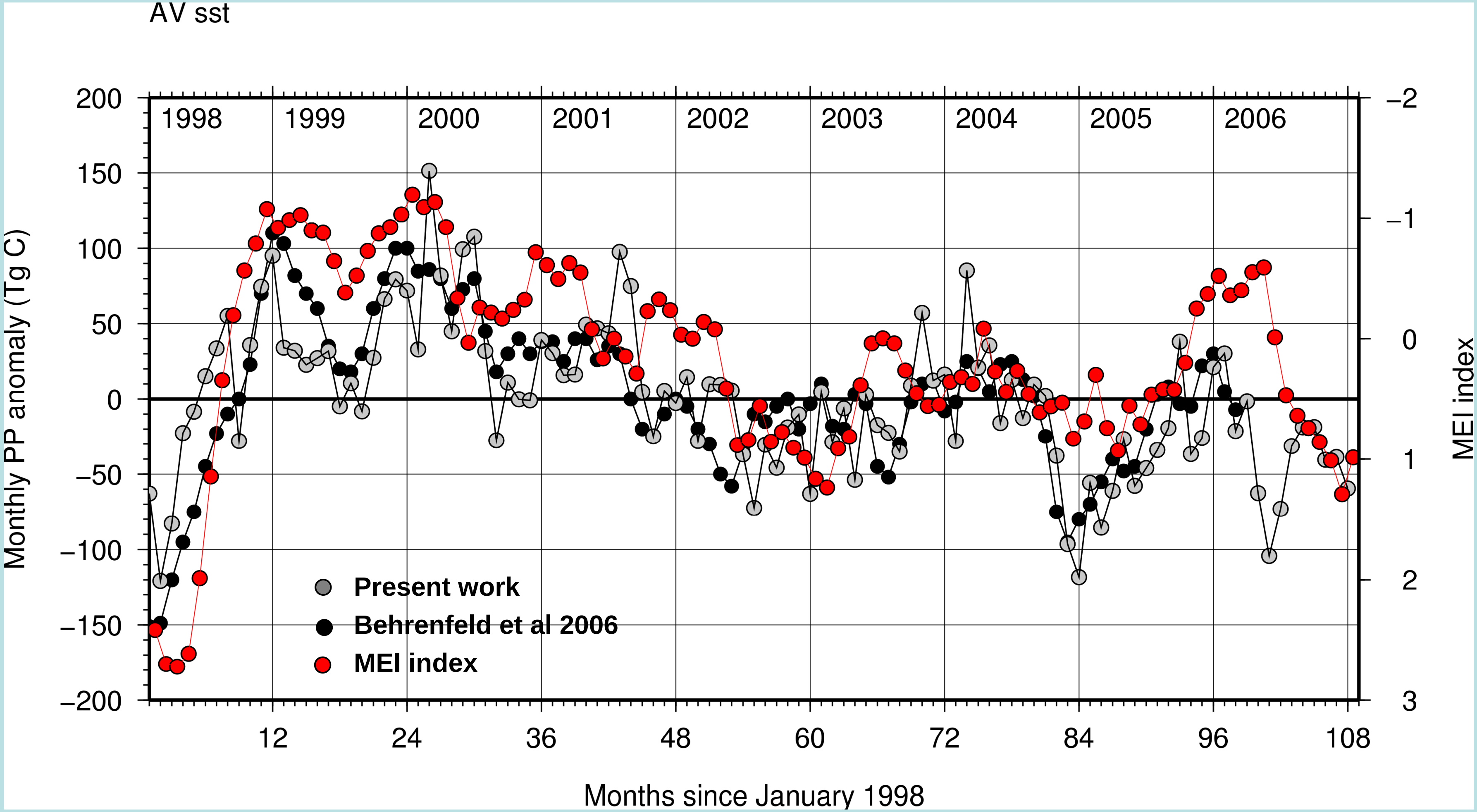
Results: interannual variability

	Global PP (GtC/year)	
Year	AVW	GSM
1998	58.95	54.25
1999	59.69	54.91
2000	59.77	54.97
2001	59.52	54.72
2002	59.98	56.60
2003	61.21	58.99
2004	61.30	58.86
2005	60.88	57.98
2006	60.99	57.14
Average	60.25	56.49
Stdev	0.85	1.85

Results: interannual variability

Analysis of: Behrenfeld et al., *Nature*, vol 444, 2006

SeaWiFS 9-year global record coupled with indicators of the ocean physical state



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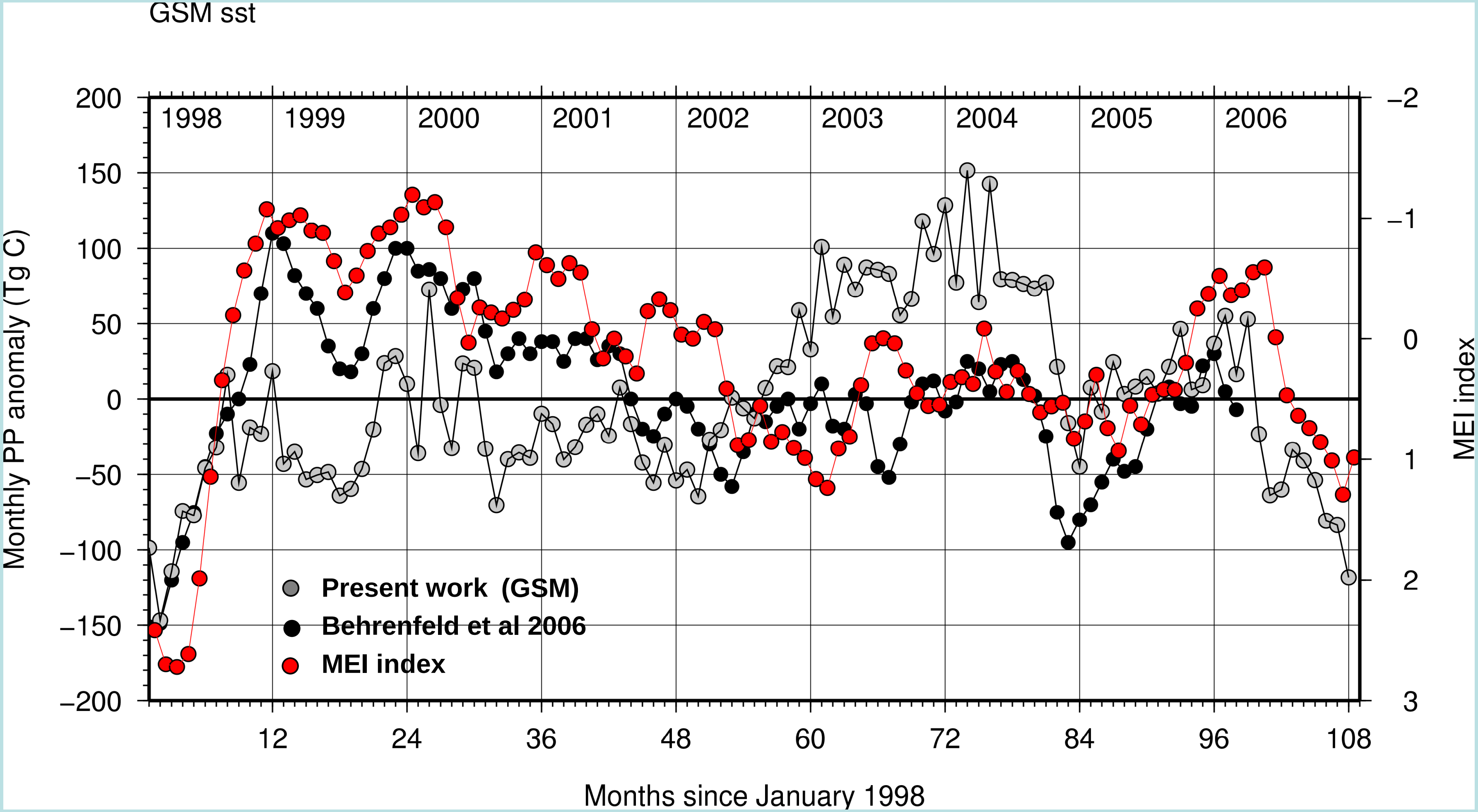


Conclusions

- Thanks to the new existing data sets (GlobColour & GHRSST), global PP and its inter-annual changes can be assessed up to the decadal scale

- Improvements are, however, still needed, in order for the decadal analyses to be worth of trust; this is not due to the merging process, but to remaining uncertainties in the calibration of the various ocean color sensors, to algorithmic differences, and to the “frozen” parameters of the model

Perspectives

Besides the improvement of the input CHL data sets (i.e., calibration & algorithmic issues), the next step is to improve the primary production modeling itself, which includes:

- Representation of the vertical Chl profile

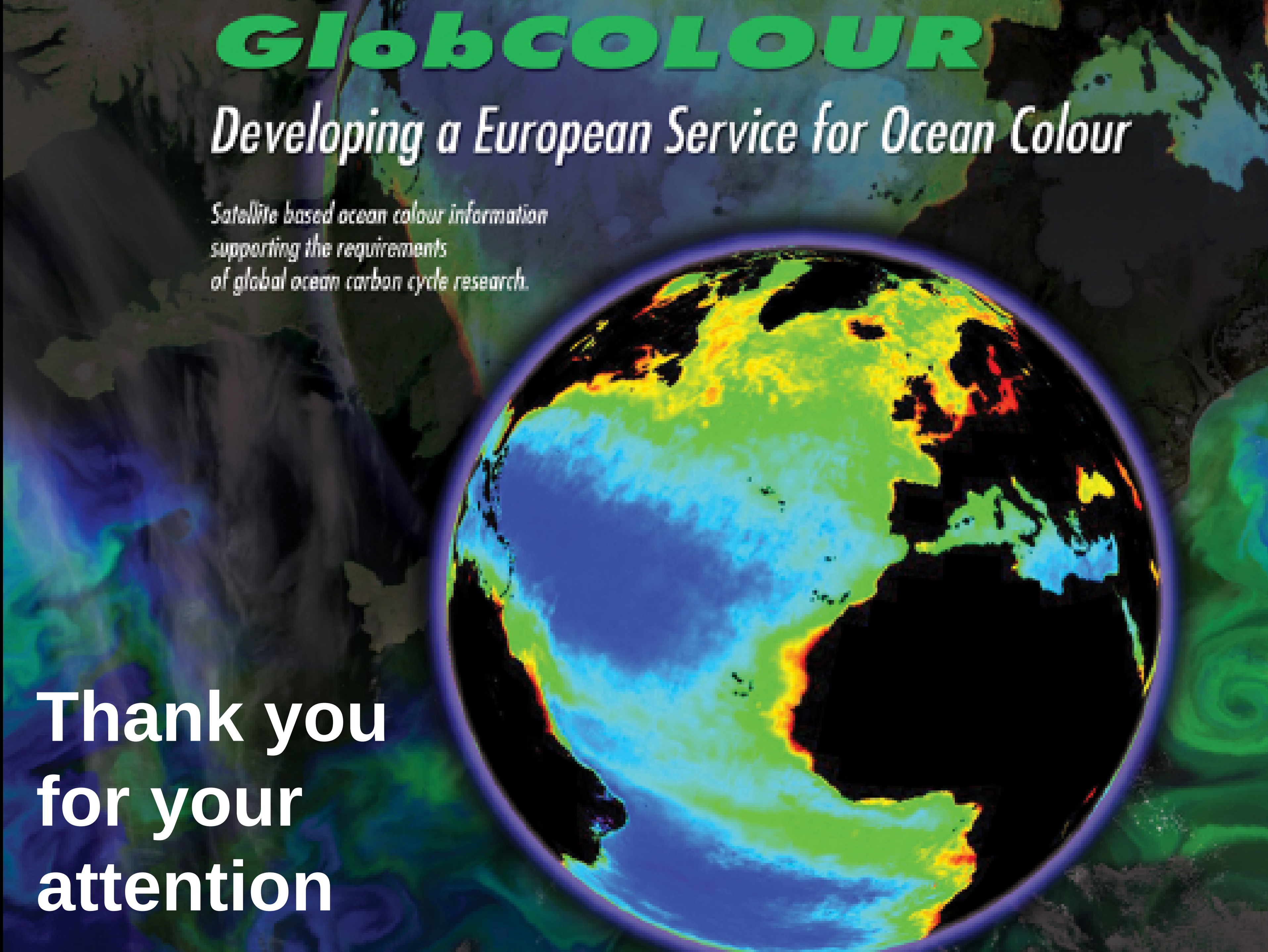
- Parameterization of P^B_{max}

- Temperature dependence of the maximum rate

- Effect of nutrients and average irradiance level on the maximum rate

- Dependence on PFTs ??

A lot has been done in the past decade. New knowledge has to be integrated now in a new generation of models



Thank you for your attention