MERCATOR VERT

GREEN MERCATOR

Integration of biogeochemistry and ecology to Mercator Ocean systems: Recent advances and future developments of the Green Mercator initiative.

M. Gehlen (marion.gehlen@lsce.ipsl.fr),

A. El Moussaoui, C. Perruche, E. Dombrowsky,

O. Aumont, P. Brasseur, J. Le Sommer, P. Lehodey

and Green Mercator consortium

Global phytoplankton decline over the past century

Daniel G. Boyce[1], Marlon R. Lewis[2] & Boris Worm[1]

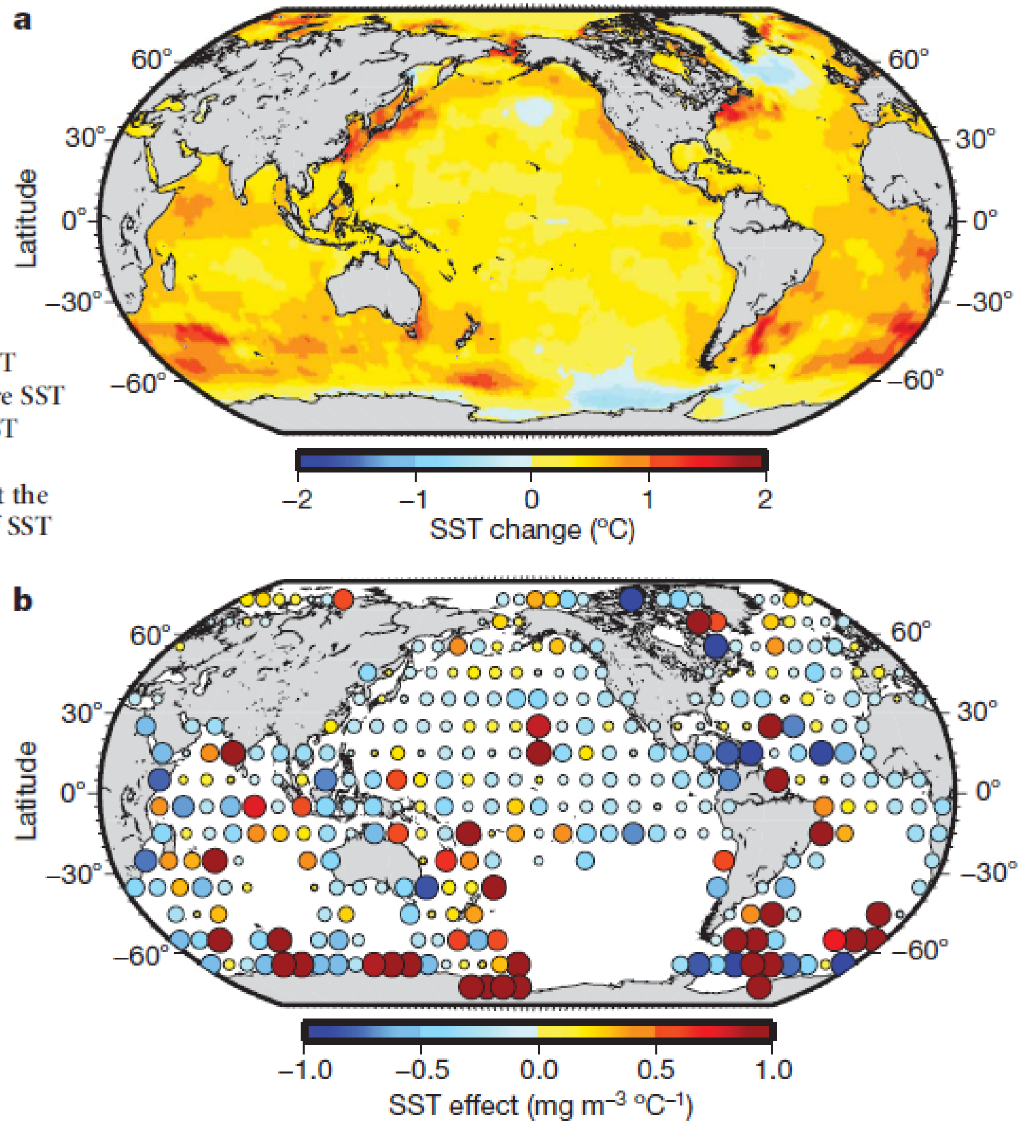


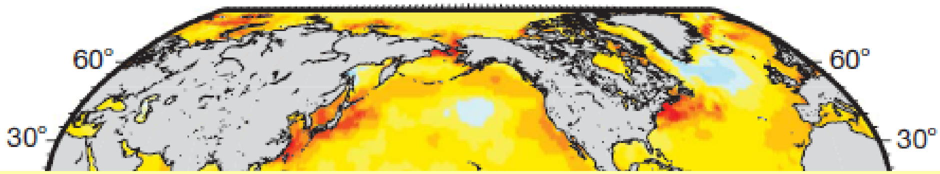
Figure 6 | Physical drivers of phytoplankton trends. **a**, Estimated SST change at 1° resolution from 1899 to 2009. Blue represents cells where SST has declined while yellow and red represent increases. **b**, Effects of SST changes on Chl estimated for each 10° × 10° cell with >10 yr of data (*n* = 205). Size of circles represents the magnitude and colours depict the sign of the standardized SST effect on Chl in each cell. **c**, **d**, Effects of SST

Vol 466|29 July 2010|**doi:10.1038/nature09268**

Global phytoplankton decline over the past century

Daniel G. Boyce[1], Marlon R. Lewis[2] & Boris Worm[1]

a



phytoplankton biomass:

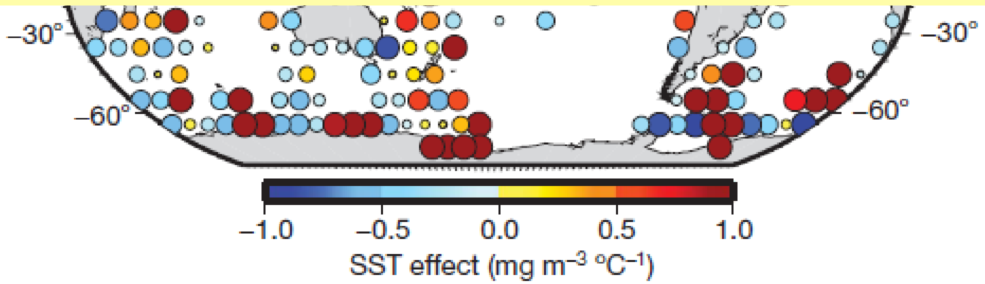
+ global median declines by ~1%/yr

base of food chain => link to *higher trophic levels*

+ large interannual to decadal phytoplankton fluctuations correlated to basin-scale climate indices

+ long-term trends related to increasing temperatures

Figu
char
has
char
(*n* =
sign



Vol 466 | 29 July 2010 | doi:10.1038/nature09268

Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change

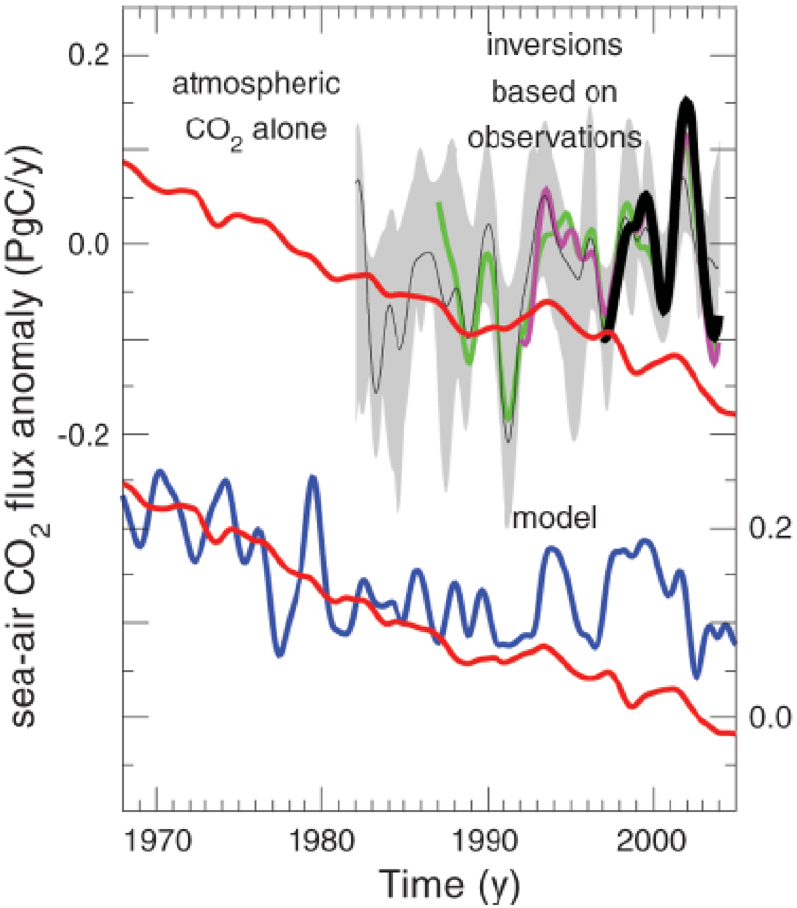


Fig. 2. Sea-air CO_2 flux anomalies in the Southern Ocean (Pg C year^{-1}). The contribution of atmospheric CO_2 alone (top red curve) is calculated based on observed atmospheric CO_2 concentration and a pulse response function that computes the ocean CO_2 uptake as a function of time (*12*, *17*). The estimates based on observations use an inverse model of atmospheric CO_2. Inversions over four time scales are shown starting in 1981 (thin black, 11 sites), 1986 (green, 17 sites), 1991 (purple, 25 sites), and 1996 (thick black, 40 sites). The gray shading encompasses results from all the sensitivity tests using the 11-site inversion. The lower panel shows results from a process model forced by (full red curve) the 1967 constant winds and fluxes and (blue curve) observed daily winds and fluxes from NCEP reanalysis. Sea-air CO_2 fluxes are integrated over 45°S to 90°S. Negative values indicate a flux of CO_2 from the atmosphere to the ocean, or a CO_2 sink

Corinne Le Quéré, *et al.*
Science **316**, 1735 (2007);
DOI: 10.1126/science.1136188

Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change

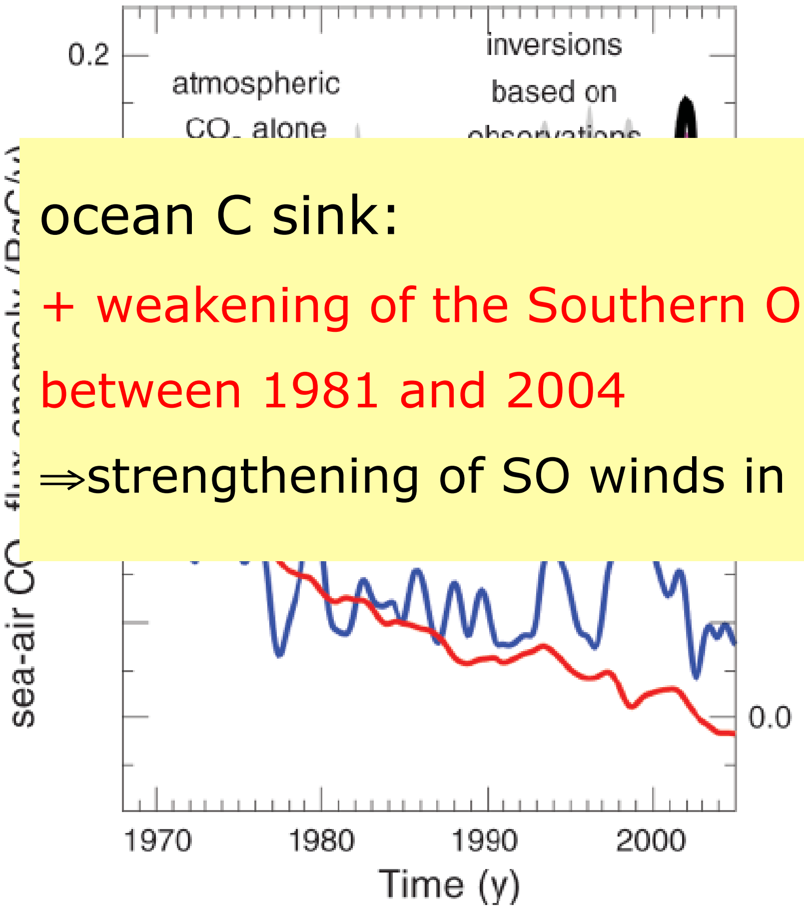


Fig. 2. Sea-air CO_2 flux anomalies in the Southern Ocean (Pg C year^{-1}). The contribution of atmospheric CO_2 alone (top red curve) is calculated based on observed atmospheric CO_2 concentra-

11-site inversion. The lower panel shows results from a process model forced by (full red curve) the 1967 constant winds and fluxes and (blue curve) observed daily winds and fluxes from NCEP re-analysis. Sea-air CO_2 fluxes are integrated over 45°S to 90°S. Negative values indicate a flux of CO_2 from the atmosphere to the ocean, or a CO_2 sink

ocean C sink:

+ weakening of the Southern Ocean sink of CO_2 by 0.08 Pg C/yr between 1981 and 2004

⇒strengthening of SO winds in response to climate change

Corinne Le Quéré, *et al.*
Science **316**, 1735 (2007);
DOI: 10.1126/science.1136188

MERCATOR VERT

GREEN MERCATOR

- Objective:

  building the capacity for monitoring and forecasting ocean biogeochemistry and ecology

- Scientific drivers:

  + Phytoplankton biomass estimation in open oceans
  + Monitoring ocean C uptake and CO_2 air/sea fluxes
  + Marine ecosystem management (fisheries) at seasonal and longer-term time scales
  + Regional downscaling and coastal applications

MERCATOR VERT

GREEN MERCATOR

- Objective:

  building the capacity for monitoring and forecasting ocean biogeochemistry and ecology

- Scientific drivers:

  + Phytoplankton biomass estimation in open oceans
  + Monitoring ocean C uptake and CO_2 air/sea fluxes
  + Marine ecosystem management (fisheries) at seasonal and longer-term time scales
  + Regional downscaling and coastal applications

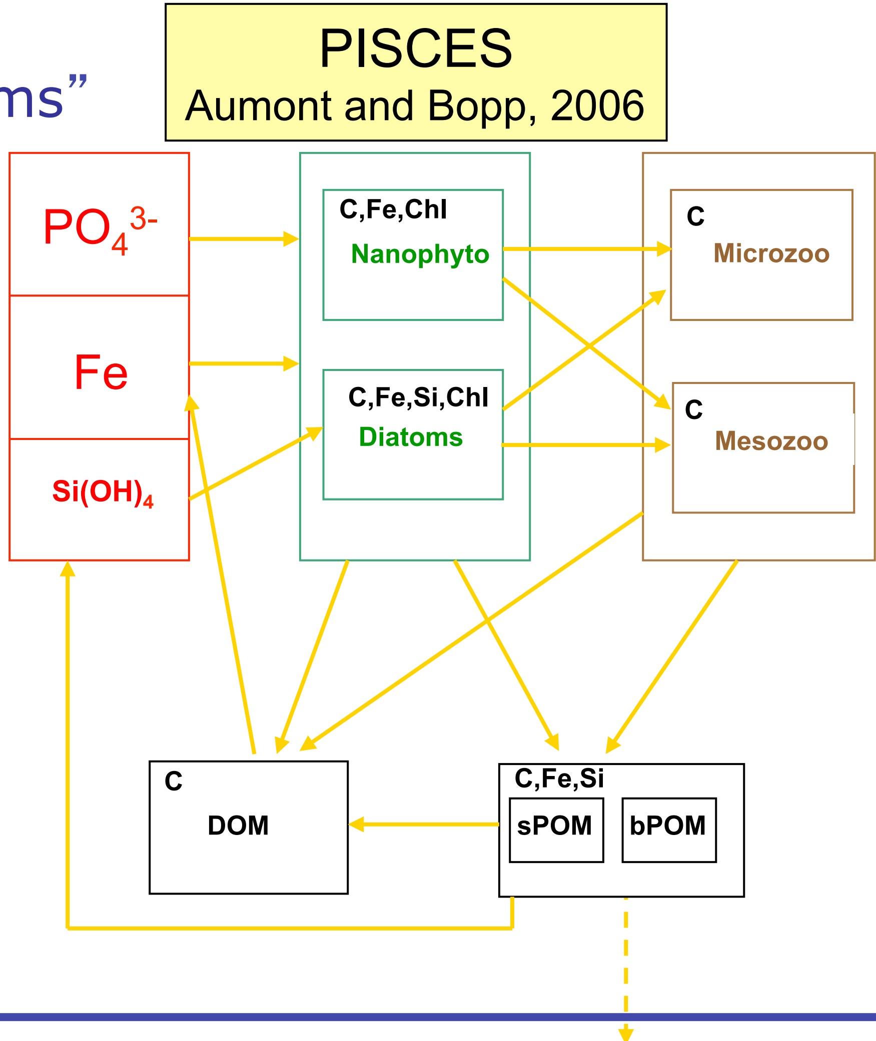
MERCATOR VERT

GREEN MERCATOR

Ingredients of an "integrated systems"

- coupled biogeochemical
  ocean general circulation model

  biogeochemical component
  => PISCES



MERCATOR VERT

GREEN MERCATOR

Ingredients of an “integrated systems”

- coupled biogeochemical ocean general circulation model
- data assimilation to constrain ocean physics and biogeochemistry
- data streams: physical/biogeochemical

MERCATOR VERT

GREEN MERCATOR

- Approach:
  + development of an assimilation system for BGC obs.
  + integration a biogeochemical component to operational Mercator Ocean systems
  + systematic comparison of model output to obs., objective benchmarking of technical choices and new developments

- strong integration with community of scientific users

MERCATOR VERT

GREEN MERCATOR

- Approach:

  + development of an assimilation system for BGC obs.

  + integration a biogeochemical component to operational Mercator Ocean systems

  + systematic comparison of model output to obs., objective benchmarking of technical choices and new developments

- strong integration with community of scientific users

MERCATOR VERT

GREEN MERCATOR

Technical choices

MERCATOR VERT

GREEN MERCATOR

CONFIGURATION of PHYSICAL COMPONENT

NEMO 1.09, ORCA ¼°, 50 vertical layers, LIM2/LIM2_EVP ice model,daily atmospheric forcings: ECMWF operational analysis, CLIO bulk formulation

CONFIGURATION of BIOGEOCHEMICAL COMPONENT

PISCES 2.3, 1° resolution (spatial degradation ¼° to 1°), 2002-2007 (after 3 years of spin-up), offline mode (weekly physical forcing), initial conditions: LEVITUS et GLODAP climatologies

SIMULATIONS

BIOMER_ORCA025_BIO1
PISCES off-line
no assimilation

BIOMER_GLORYS1v1_BIO1
PISCES off-line
assimilation of physical data: T, S, SLA, MSSH
assimilation system: SAM2v, IAU

MERCATOR VERT

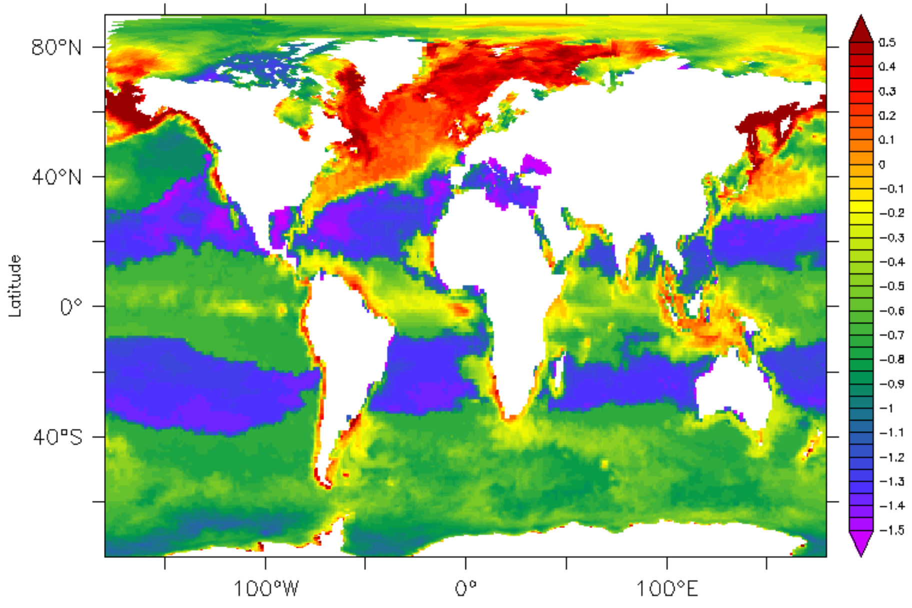
GREEN MERCATOR

Global simulations

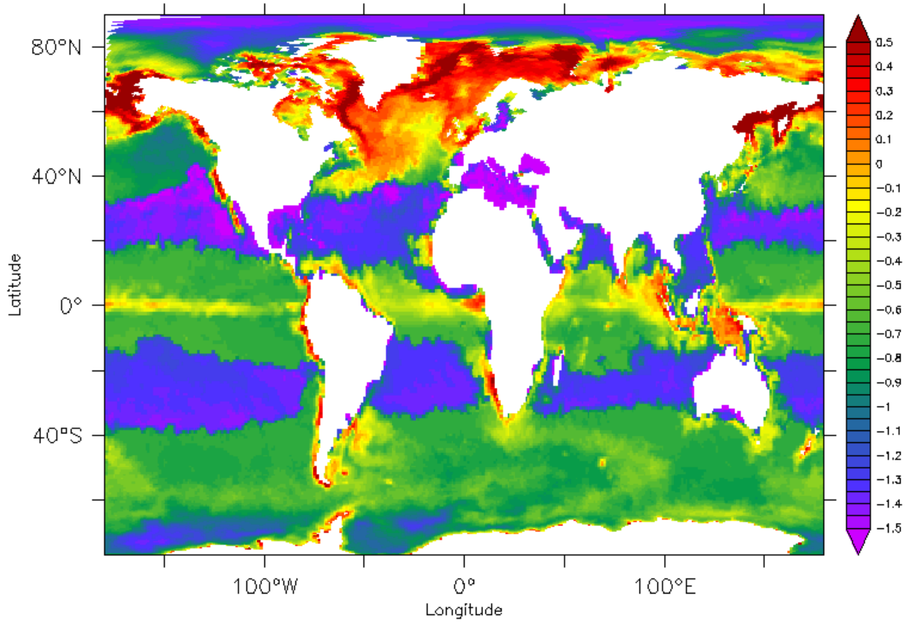
Simulated chlorophyll distributions

May 2002

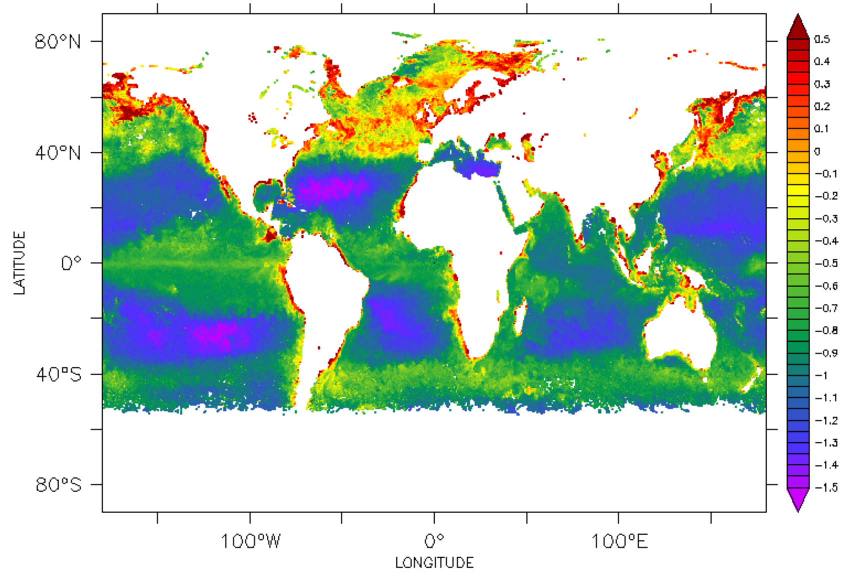
BIOMER_ORCA025_BIO1 (FREE)



BIOMER_GLORYS1V1_BIO1 w ASSIMILATION



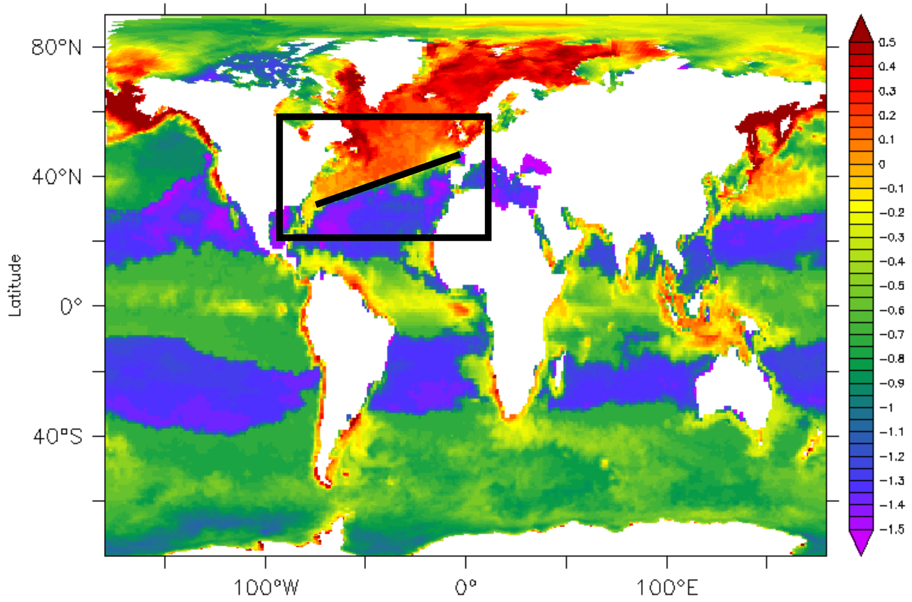
Observations GLOBCOLOUR



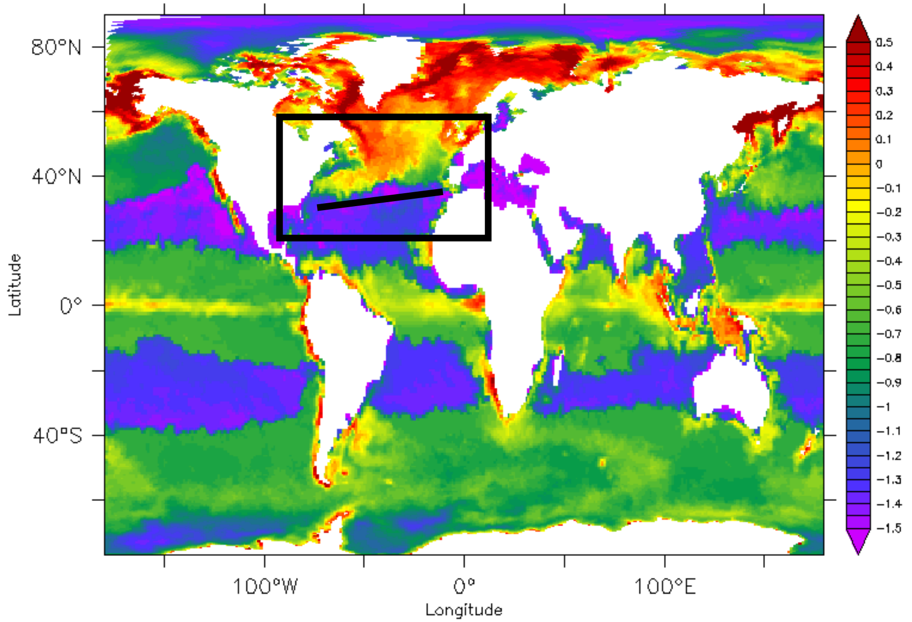
Log(chla)

Perruche et al. – Mercator Océan

BIOMER_ORCA025_BIO1 (FREE)



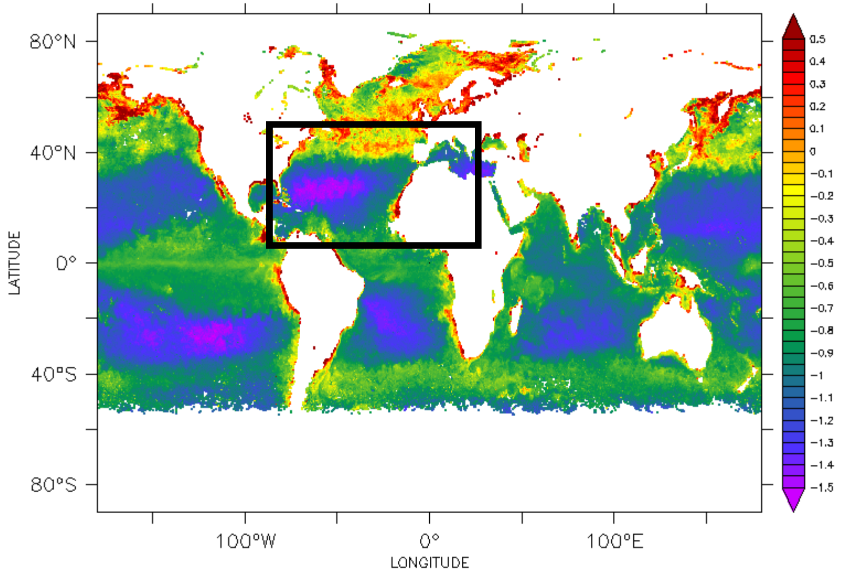
BIOMER_GLORYS1V1_BIO1 w ASSIMILATION



Simulated chlorophyll distributions

May 2002

Observations GLOBCOLOUR



Log(chla)

Perruche et al. – Mercator Océan

MERCATOR VERT

GREEN MERCATOR

Data assimilation:

+ PISCES 1D

+ basin scale application

MERCATOR VERT

GREEN MERCATOR

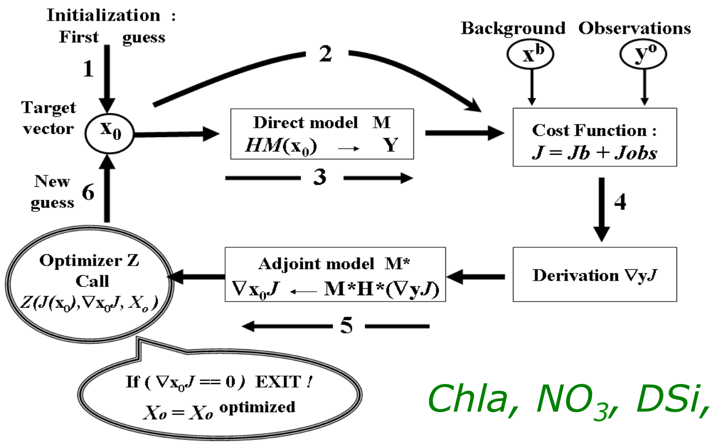
Data assimilation:

+ PISCES 1D

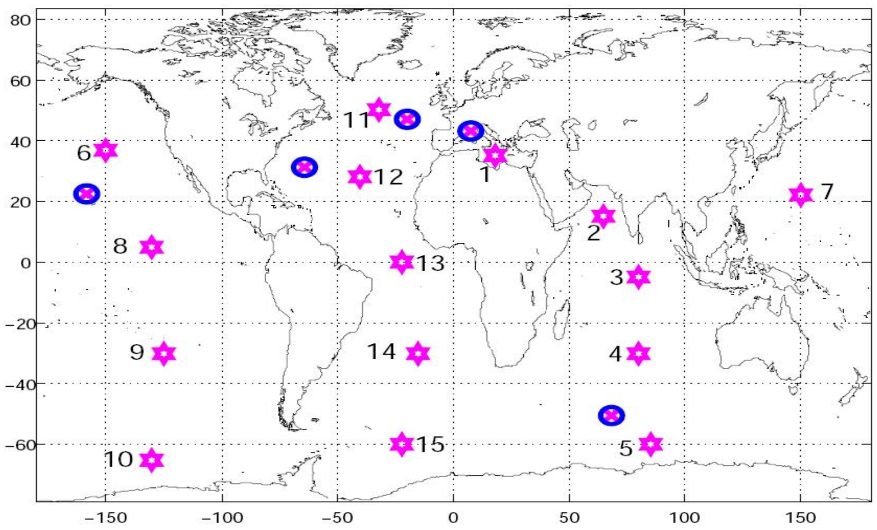
+ basin scale application

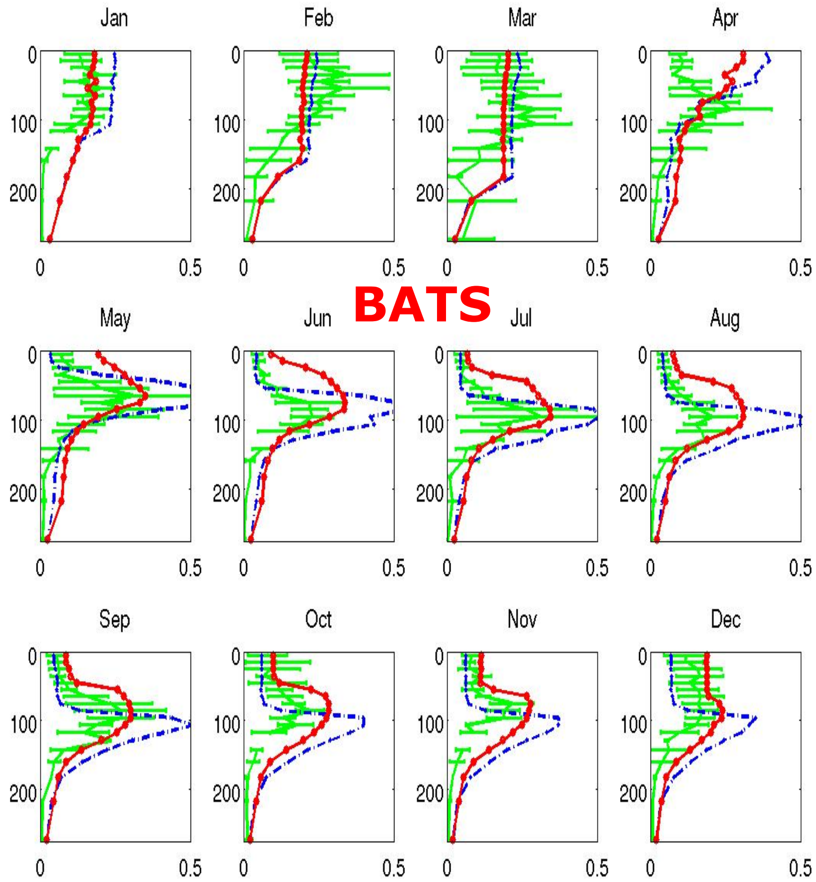
Optimization of biogeochemical model PISCES: improved parameters via variational assimilation of *in situ* data at 5 time-series stations.

Simultaneous optimization of 45 out of a total of 60 param



Chla, NO_3, DSi, POC

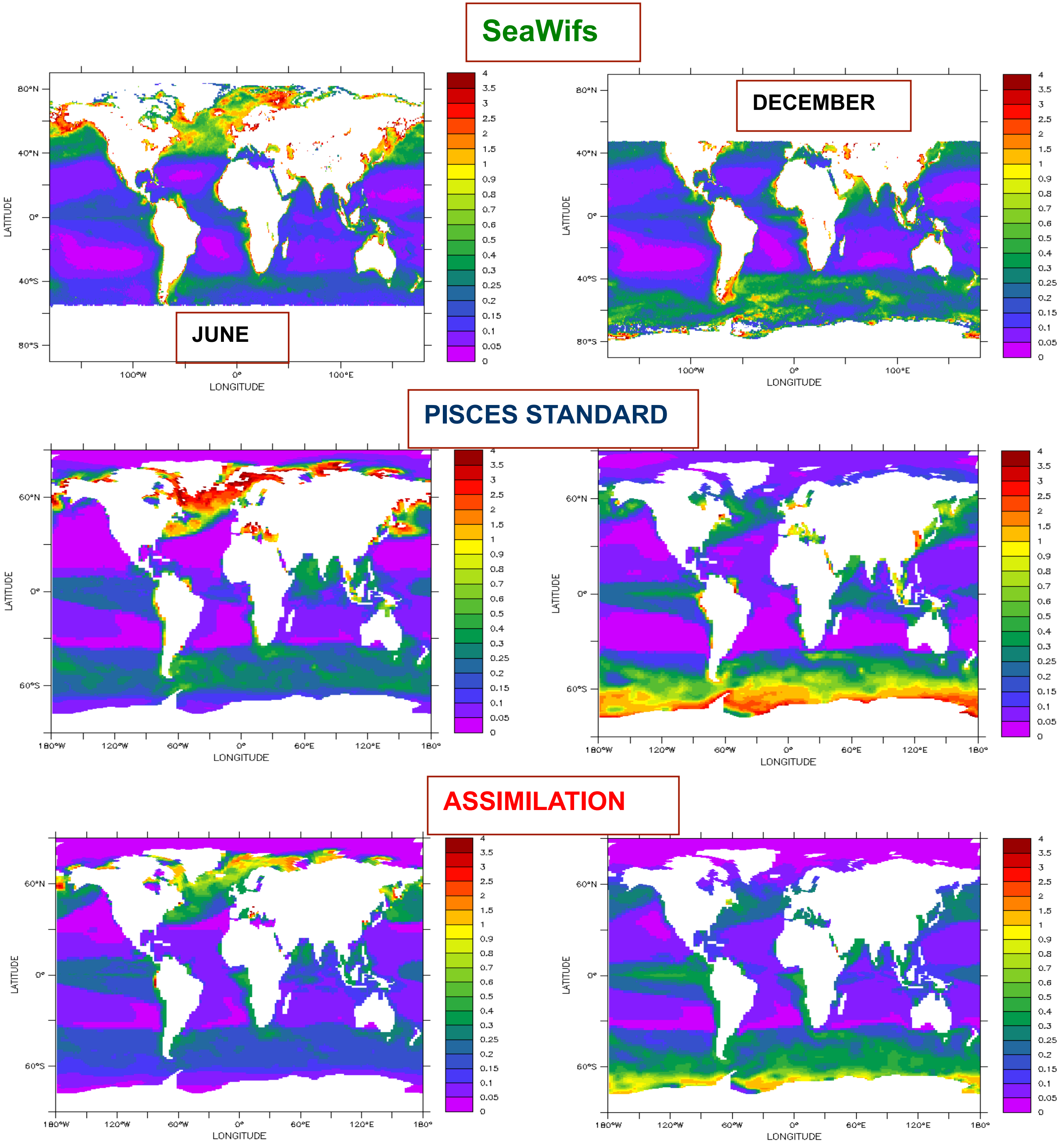




data +/- STD
model prior to optimization
optimized model output

Kane et al., JGR, accepted

ORCA2 - PISCES



Kane et al., LSCE

MERCATOR VERT

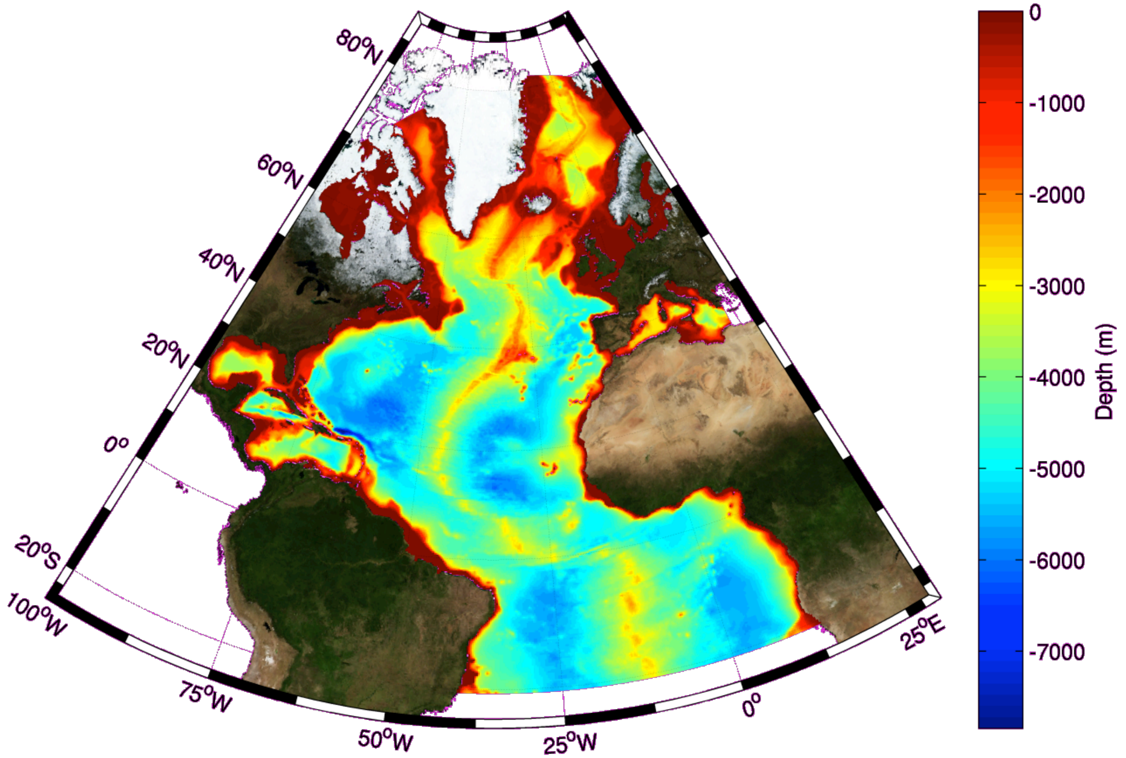
GREEN MERCATOR

Data assimilation:

+ PISCES 1D

+ basin scale application

model configuration



physical model

NEMO

NATL025

forcings: ECMWF

U,V :10 m } 6h
T,H :2 m }

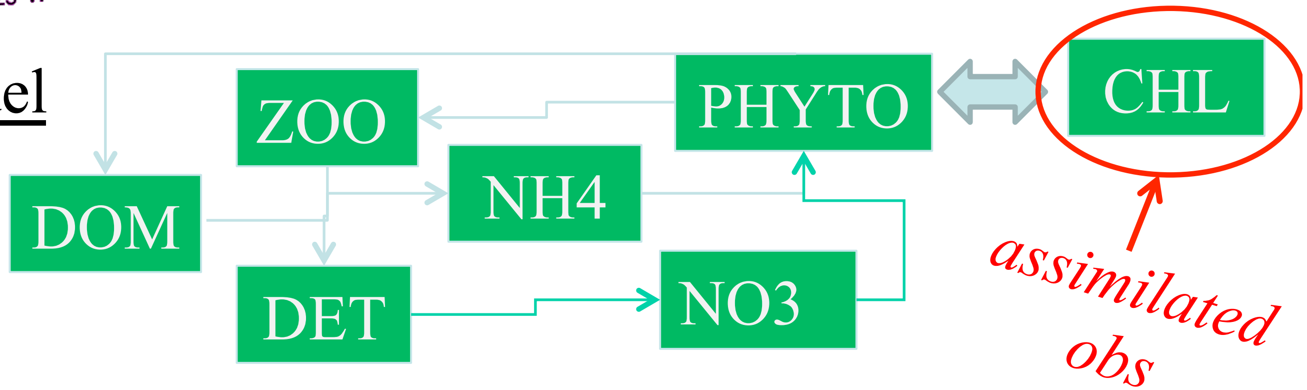
Precipitation } mois

Radiation } 24h

biogeochemical model

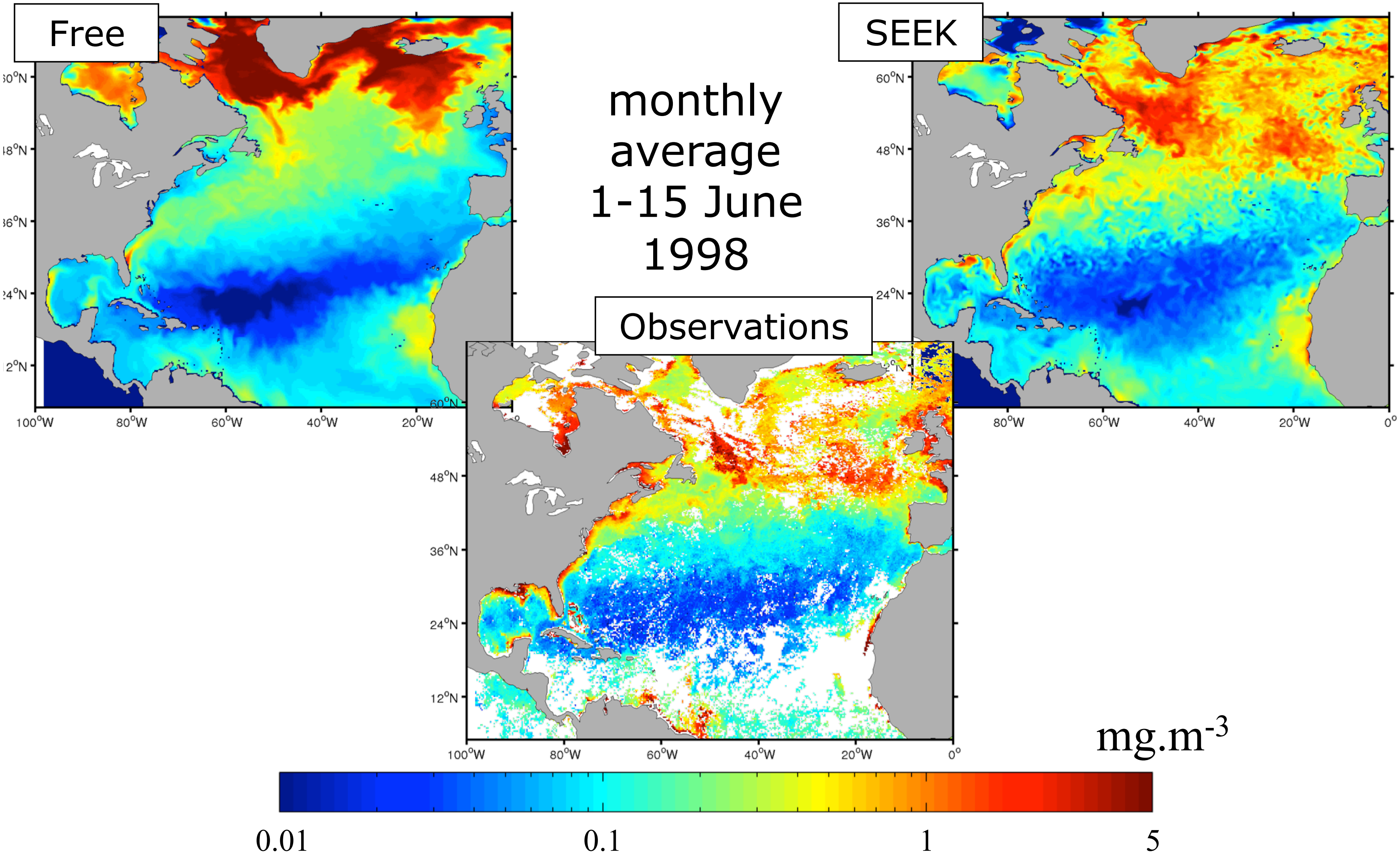
LOBSTER

N cycle



Fontana et al.

chlorophyll bloom



Fontana et al.

MERCATOR VERT

GREEN MERCATOR

Contribution of operational oceanography to ocean C cycle research:

- improved estimates of chlorophyll fields
  - \+ assessment of ocean biogeochemical state
  - \+ forcing of models of higher trophic levels
- improved estimates of surface ocean pCO_2
  - \+ assessment of evolution and variability of ocean C sink
  - \+ provide boundary conditions for atmospheric inversion studies

link to EU C cycle projects: e.g. CARBOCHANGE FP7, COCOS, RECCAP (international)

MERCATOR VERT

GREEN MERCATOR

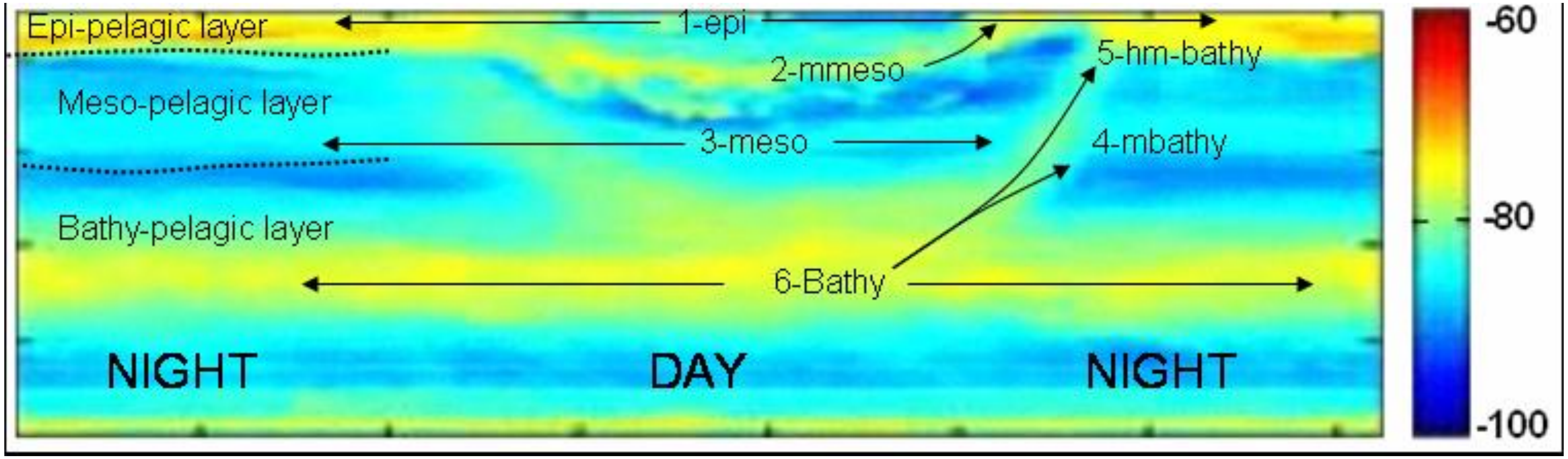
Higher trophic levels

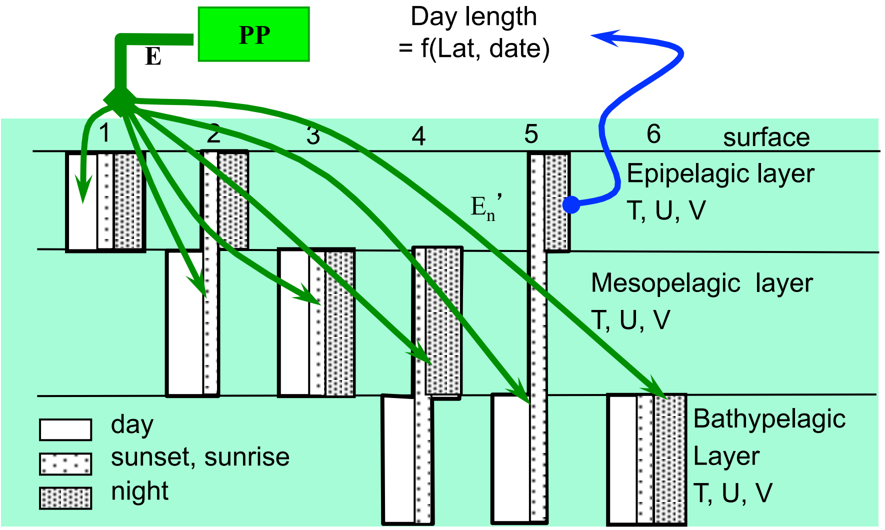
MLT model

Bridging the gap from ocean models to population dynamics of large marine predators: A model of mid-trophic functional groups

Lehodey et al., Progress Oceanography, 2010

Mar-ECO station North Atlantic, (IMR, Bergen Norway) showing acoustic detection of micronekton



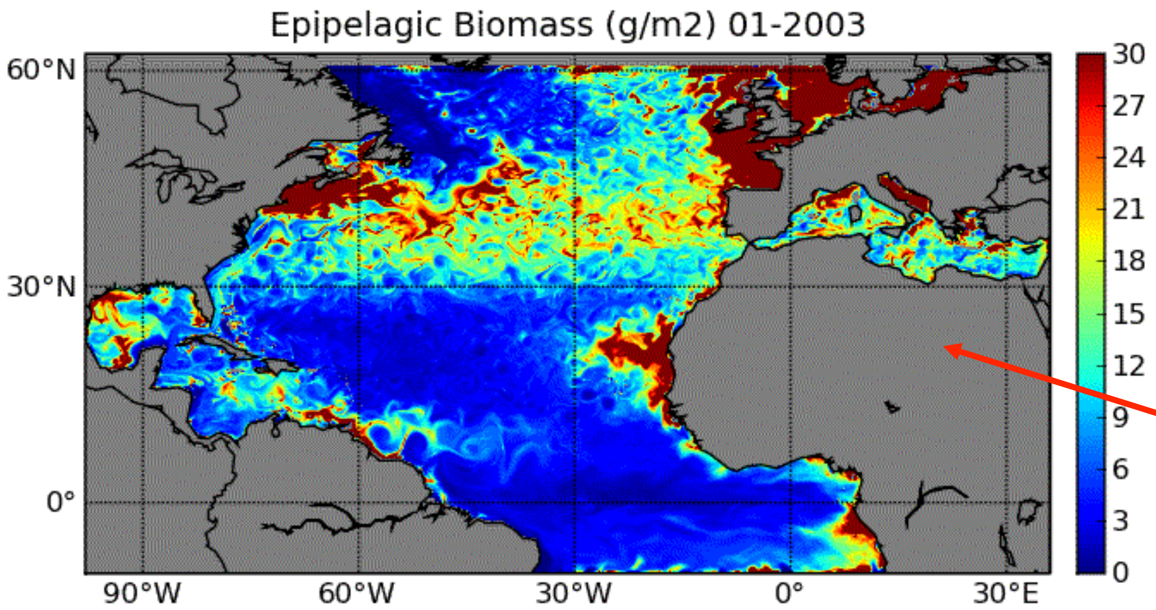


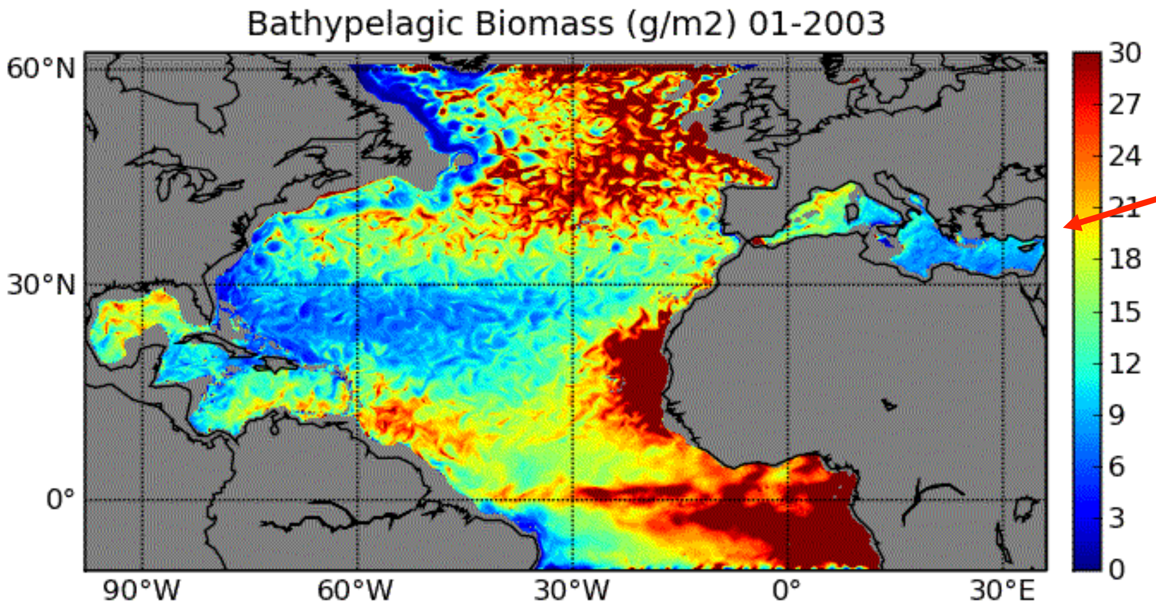
A model of micronekton (small prey organisms)

The MODEL: 6 functional groups in 3 vertical layers. Three components exhibit diel vertical migrations, transferring energy from surface to deep layers.

The source of energy is the primary production PP.

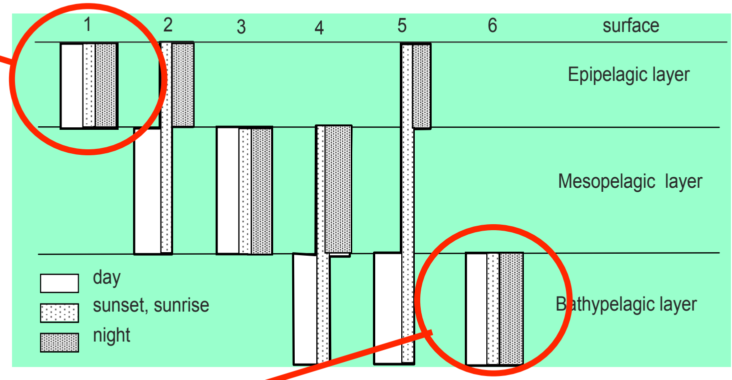
Simulation of Mid Trophic Levels





1/12th deg x 6 day

Physical fields from MERCATOR
(http://www.mercator-ocean.fr/)
+
Satellite derived Primary production

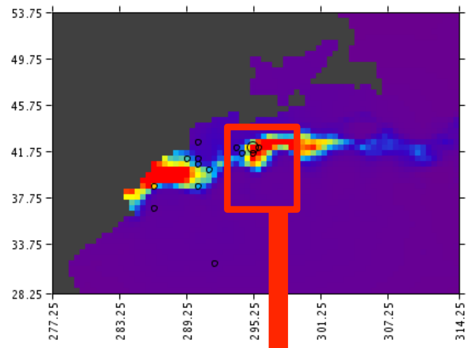


Lehodey et al. CLS

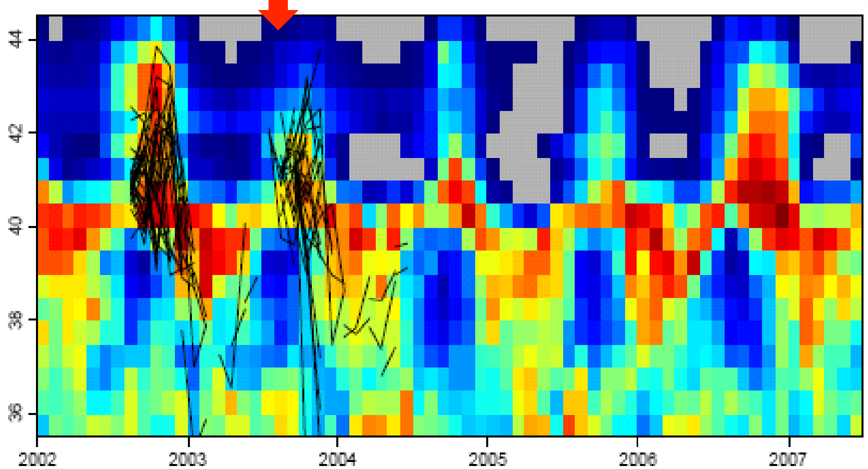
Animal tracking: identification of foraging habitat and movement

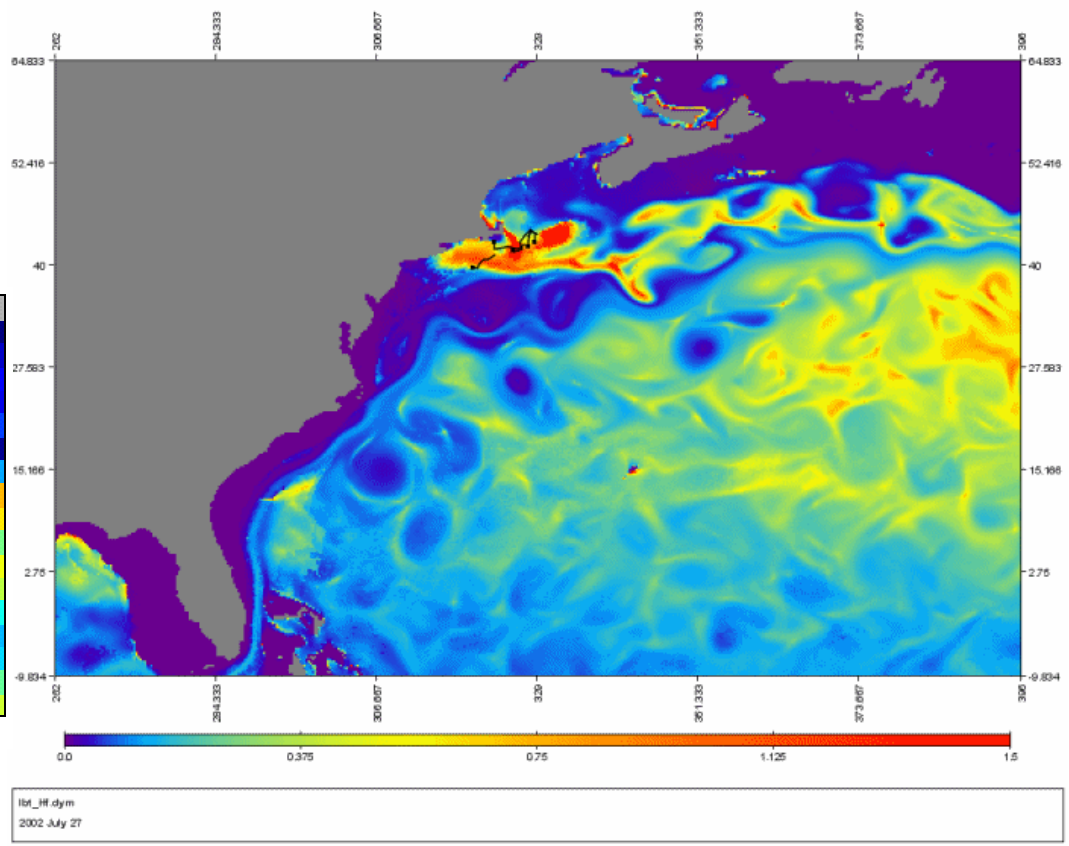
Parameter estimation of habitat driven spatial dynamics of Atlantic bluefin tuna with tagging data

Project funded by the Large Pelagic Research Center, USA



latitude-time plot of habitat index in the box (67W-71W; 35N-44N) estimated from tagging data. Black lines show Atlantic bluefin tag position trajectories.





Lehodey et al. CLS

MERCATOR VERT

GREEN MERCATOR

Contribution of operational oceanography to monitoring of ecosystems and fishery ressources:

- improved estimates of ocean physical (T, SAL, mesoscale …) and biogeochemical environment (chlorophyll, oxygen, pH …)

  + habitat definition: foraging, spawning …

  + management of ressources: science-based management of fisheries (long-term)

  link to projects: e.g. EUROBASINS FP7, IMBER …

MERCATOR VERT

GREEN MERCATOR

Outlook Green Mercator phase II:

data assimilation:

+ develop the prototype of an assimilative system that will provide hindcasts of the biogeochemical state of the N Atlantic ocean during the period 1998-2008

MERCATOR VERT

GREEN MERCATOR

Outlook:

future simulations:

+ global biogeochemical off-line simulations over the last 2 decades (1989-2009, core era interim 3h)

1 - forced with NEMO: OPA-3.1 – PISCES-3.2, 75 vertical levels, 1° and ¼° horizontal resolution

2 - forced with the reanalysis GLORYS2V1: OPA-3.1 – PISCES-3.2, 75 vertical levels, 1° and ¼° resolution

MERCATOR VERT

GREEN MERCATOR

Outlook:

applications:

+ provide improved boundary conditions for regional scale studies: e.g. PREVIMER inititiave
+ C source and sink assessment
+ monitoring of marine ressources