Current Applications of BFM: An overview

Paolo Lazzari (OGS)
on behalf of the
BFM System Team

BFM Release meeting, Bologna March 19 2013

Outline

✓ BFM coupled with 3D transport equations at different spatial resolutions and different spatial scales: Global (Ocean) → regional (Mediterranean basin) → sub-regional (Adriatic Sea)

✓ Temporal scales: weeks (operational forecast) → multi decadal (climate simulations)

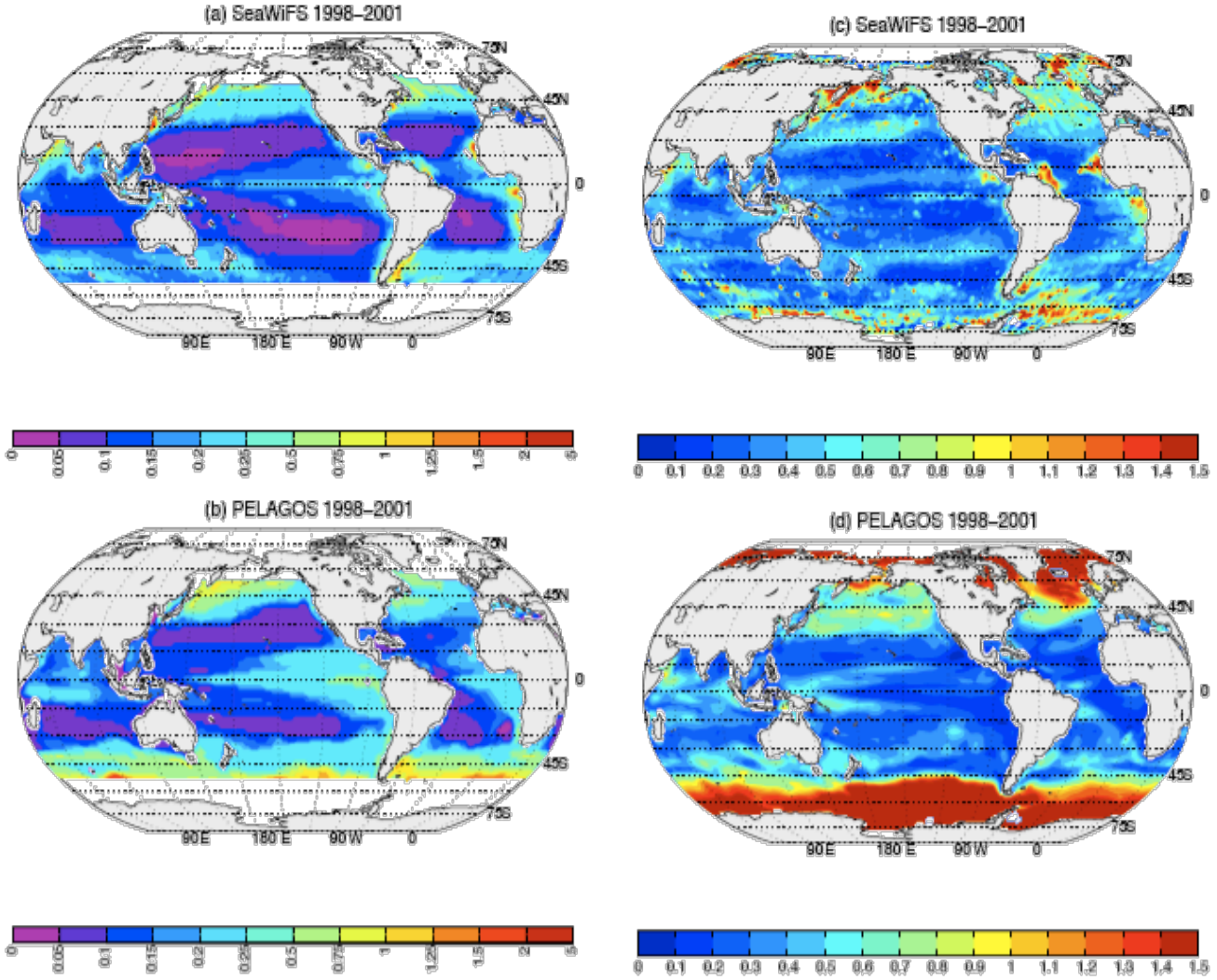
✓ Configurations allow to reconstruct the past and present biogeochemical states (hindcast) and to perform scenario simulations (e.g. IPCC scenarios)

BFM in the Global Ocean

- ✓ BFM coupling with the GCM NEMO at 0.25° and 2°
- ✓ Hindcast simulations of the global ocean biogeochemistry (Vichi et al. 2007a,b; Vichi and Masina, 2009)
- ✓ Biogeochemical cycles in the Earth System under current and future climate conditions with the CMCC Earth System Model (Vichi et al., 2011; Patara et al., 2011; Patara et al., 2012)

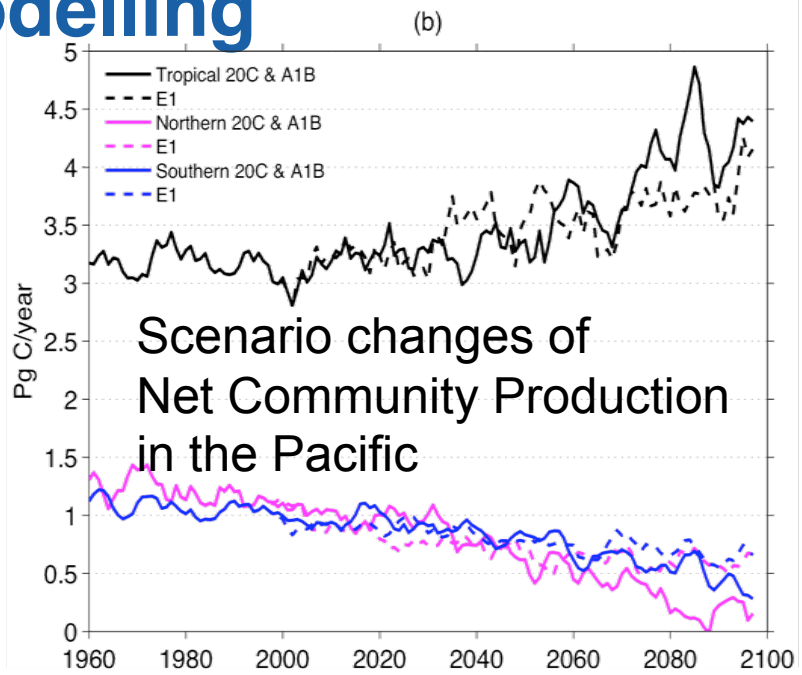
PELAGOS

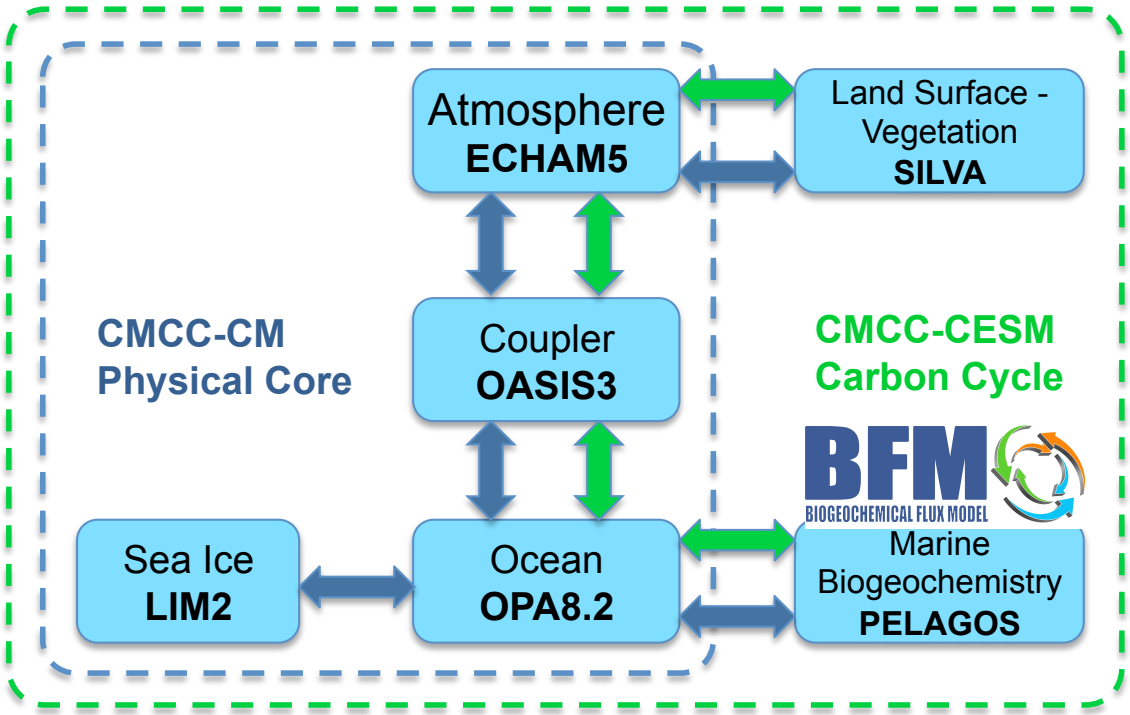
(PELAgic biogeochemistry for Global Ocean Simulations)

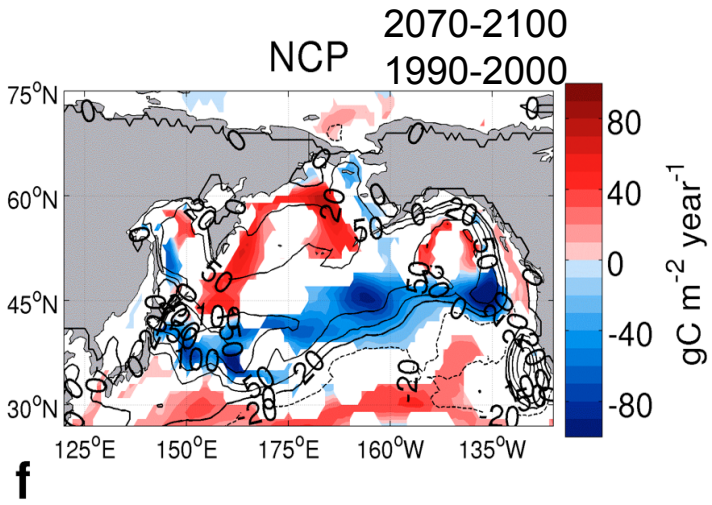


BFM in the Earth System Modelling

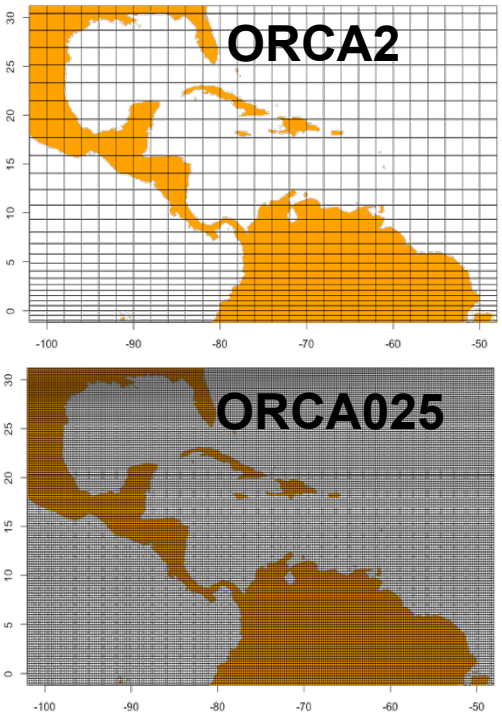
PELAGOS is the marine biogeochemistry component of the CMCC-CESM Carbon Earth System Model
that participated to the Climate Model Intercomparison Project Phase 5 (Cagnazzo et al., 2013)

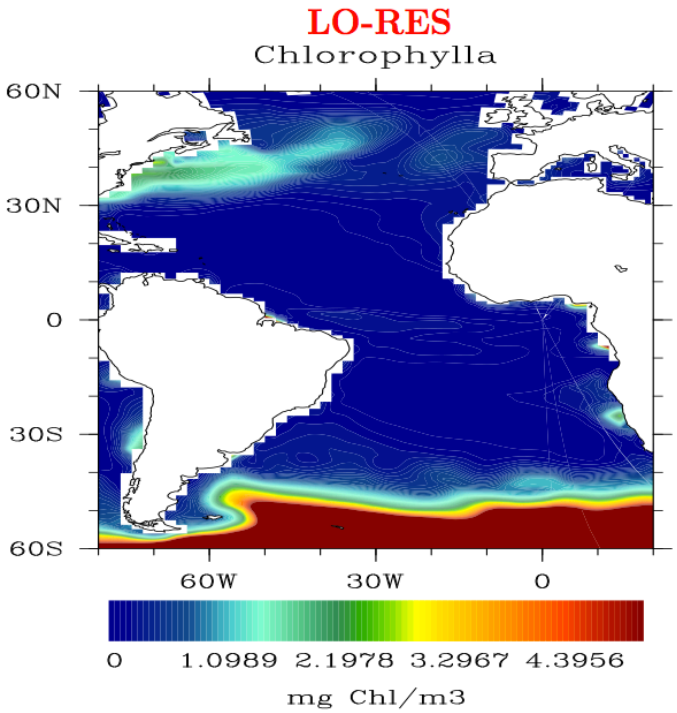


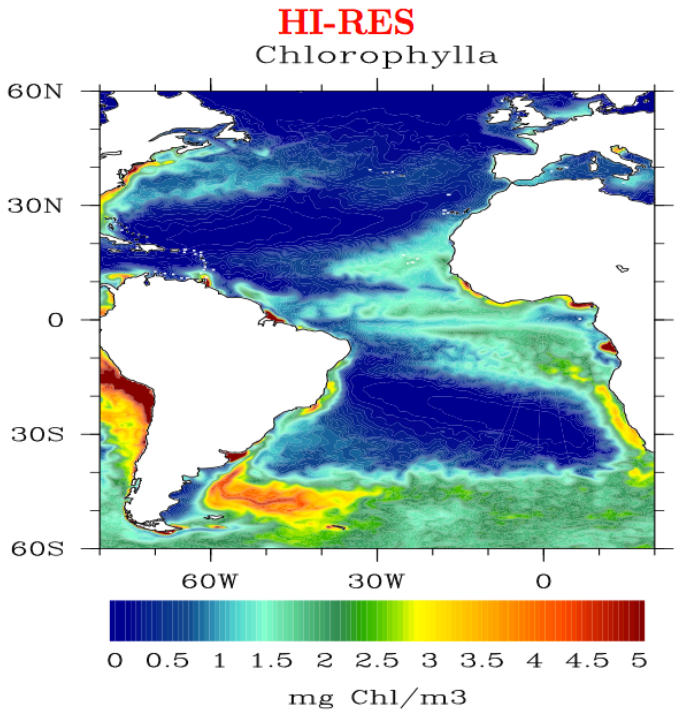




High-resolution simulations with the BFM







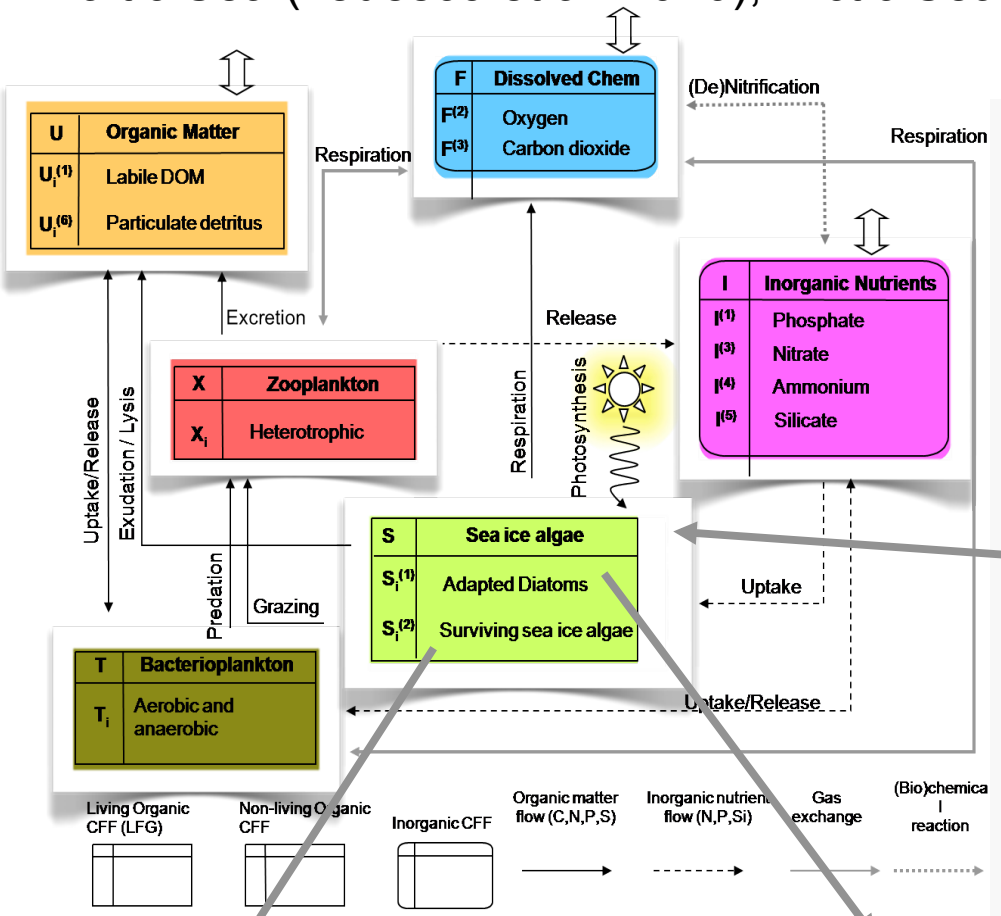
- ✓ Preliminary simulations with high-res ocean model
- ✓ greatly enhances plankton in the equatorial, subtropics and coastal regions
- ✓ whereas it is surpressed in the Southern Ocean

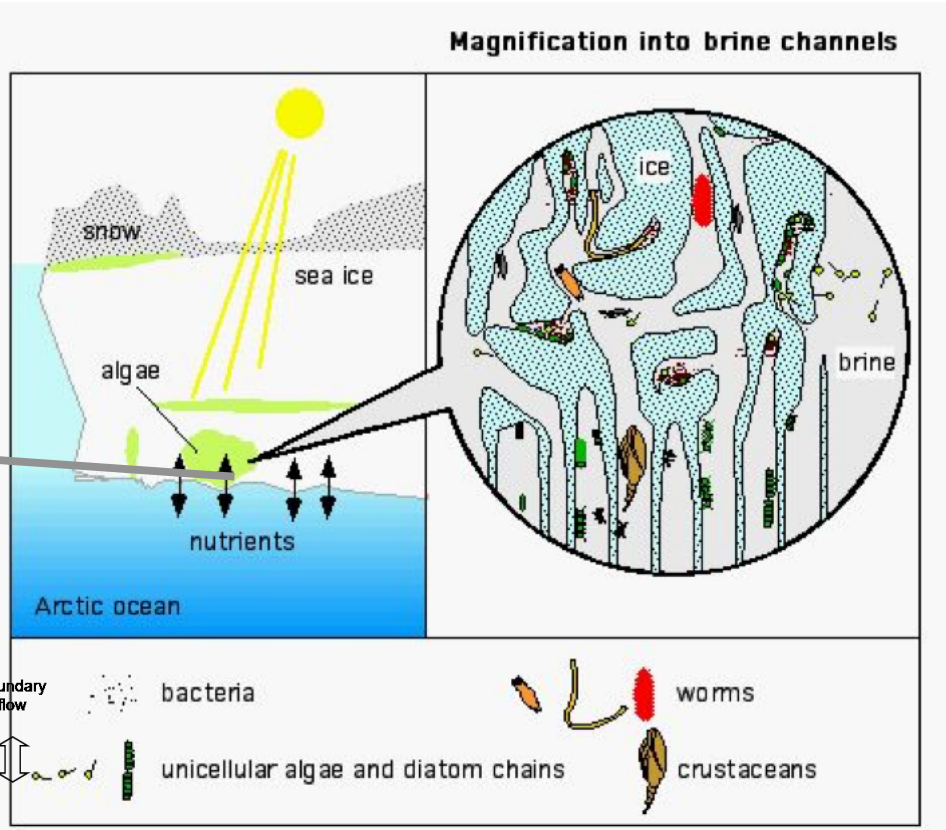
William Mckiver and Andrea Storto (CMCC)

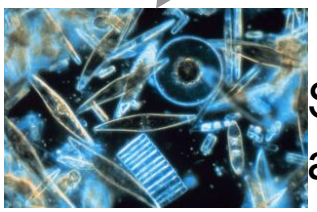
BFM-SI: Biogeochemical Flux Model in Sea Ice

Applications:

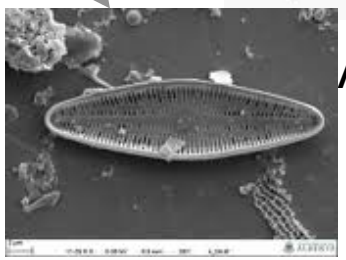
Baltic Sea (Tedesco et al. 2010); Arctic Sea (Tedesco et al. 2010, Tedesco et al., 2012)







Surviving sea ice algae



Adapted Diatoms

BFM in the Med

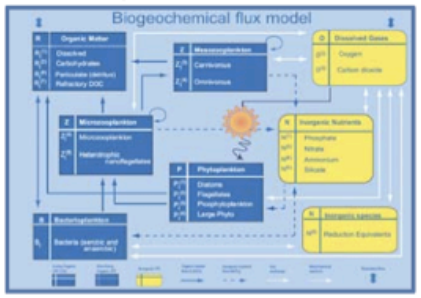
$$\frac{\partial c_i}{\partial t} = TRANSPORT + REACTION$$

OPA Tracer Model

$$-\mathbf{U}\cdot\nabla c_i + (-1)^{n+1} k_h \nabla_h^{2n} c_i + \frac{\partial}{\partial z}\left[k_v \frac{\partial c_i}{\partial z}\right]$$

Physical forcings (**U**,*T, I, ecc*)

BFM $w_{si}\frac{\partial c_i}{\partial z} + R_{bio}(c_i, c_1 \ldots c_N, T, I \ldots)$



Offline approach:

coupling with precomputed physical fields from OGCM

- ✓ Horiz. Res. = 1/8°
- ✓ Vert. Res. = 43/72 levels
- ✓ Time Res. = 1800 s
- ✓ 1 year simulated in 2 hours

Model description and forcings

CIRCULATION MODEL

-OGCM: NEMO (OPA 9) (Madec 2008 http:/www.nemo-ocean.eu Oddo et al. 2009)
-Horizontal Resolution: 1/16 deg ~ 7 Km
-Vertical Resolution: Z-coordinates, 71 levels (partial steps)
-Free run: no relaxation to climatology, full freshwater flux (major rivers), no heat flux correction
-Parallel simulations (on-line)

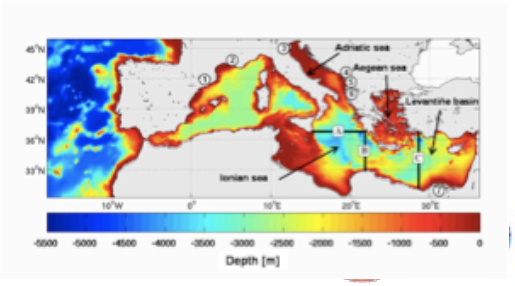
BIOGEOCHEMICAL FLUX MODEL

-BFM: Biological Flux Model (Vichi et al. a,b 2007)
-Carbon based multi-nutrient food web description
-Carbon, Nitrogen, Phosphorus and Silica cycles
-Potential for multiple nutrient co-limitation (Nitrogen, Phosphorus and Silica)

- phytoplancton
- mesozooplancton
- microzooplancton
- bacteria

SET UP

-Physical model settings: ECMWF ERA40 atmospheric forcing functions
-Initial conditions for nutrients and oxygen: annual OA climatologies from SEADATANET project (http://www.seadatanet.org) merged with World Ocean Atlas climatology in the Atlantic box
-Initial conditions for biology: homogeneous guesstimates with vertically-distributed analytical profiles
-Nutrient River input: data from Sesame Project (Ludwig et al. 2009)



Online approach:

Runtime coupling with OGCM (e.g. NEMO)

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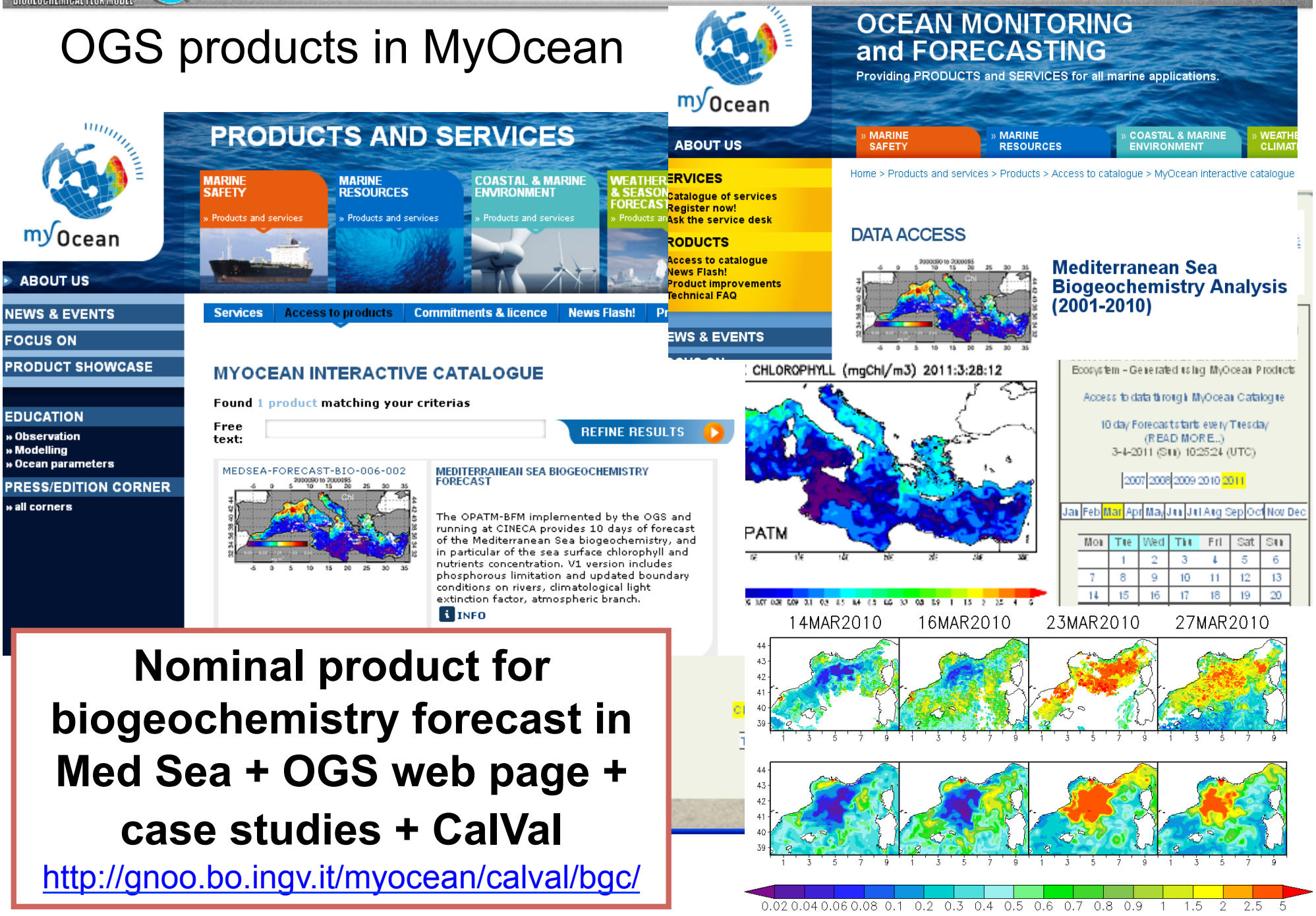
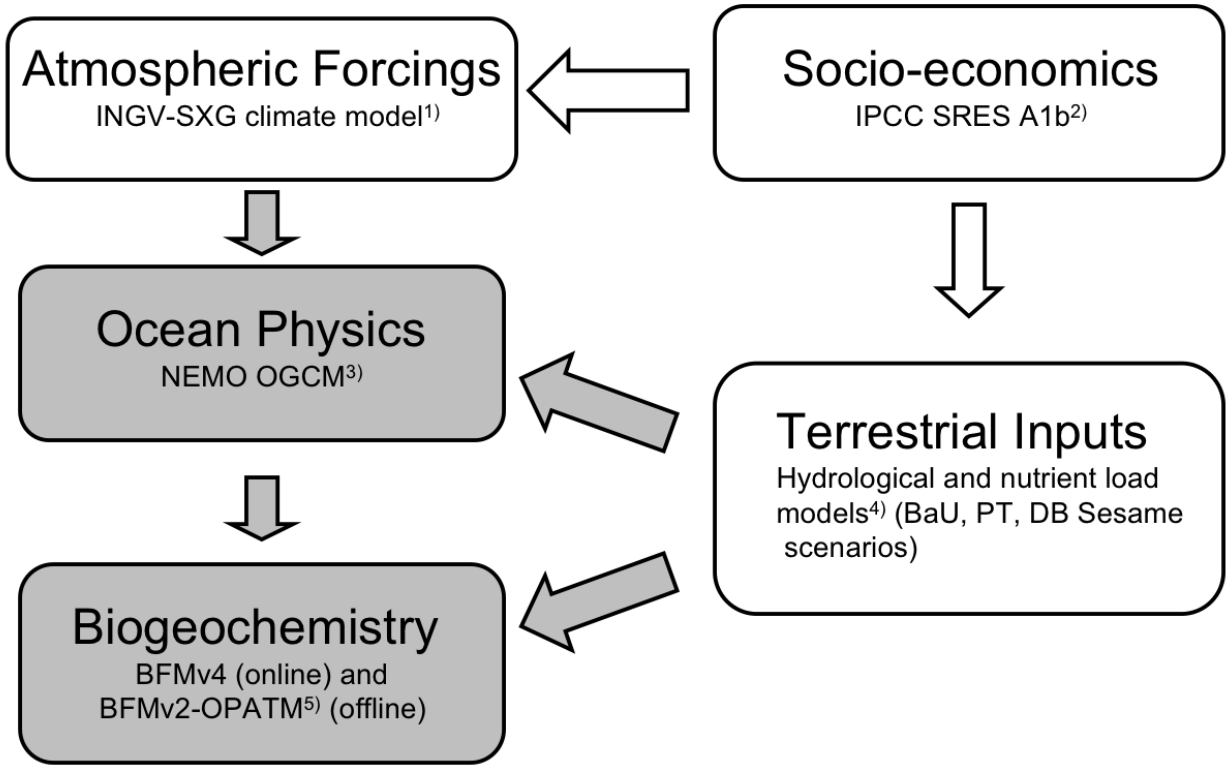
OGS products in MyOcean



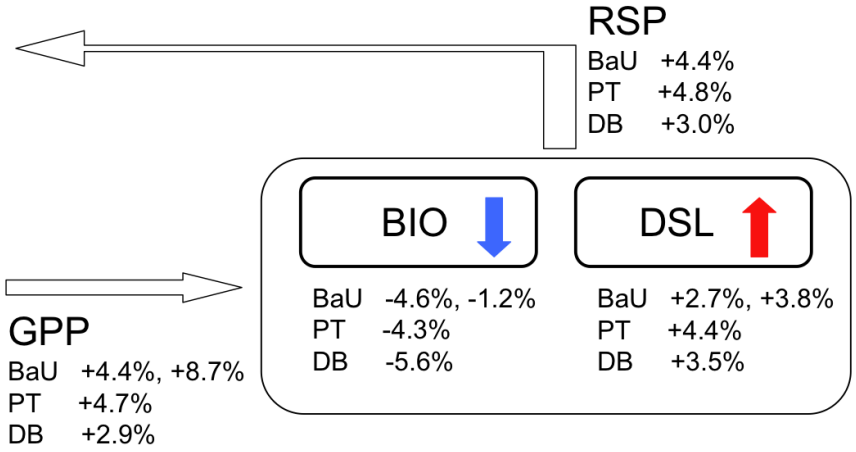
Nominal product for biogeochemistry forecast in Med Sea + OGS web page + case studies + CalVal

http://gnoo.bo.ingv.it/myocean/calval/bgc/



1) Gualdi et al. (2008); 2) Nakicenovic and Swart (2000); 3) Oddo et al (2009); 4) Ludwig et al. (2010); 5) Lazzari et al. (2012)

- ✓ **Increase of carbon rates both production (GPP) and community respiration (RSP)**
- ✓ **Increase of dissolved semi-labile carbon**
- ✓ **Reduction in biomass**



MEDITERRANEAN BASIN

	20C	A1B-BaU	A1B-PT	A1B-DB
GPP	0.66	0.044	0.047	0.029
RSP	0.65	0.044	0.048	0.030
NPP	0.36	0.032	0.036	0.015
NCP	0.01	-0.001	-0.033	-0.064
DSL	0.96	0.038	0.044	0.035
BIO	4.12	-0.046	-0.043	-0.056

WESTERN BASIN

	20C	A1B-BaU	A1B-PT	A1B-DB
GPP	0.81	0.023	0.017	0.011
RSP	0.80	0.023	0.016	0.013
NPP	0.46	0.009	0.001	-0.006
NCP	0.01	0.050	0.019	-0.002
DSL	1.02	0.030	0.027	0.025
BIO	4.97	-0.070	-0.074	-0.076

EASTERN BASIN

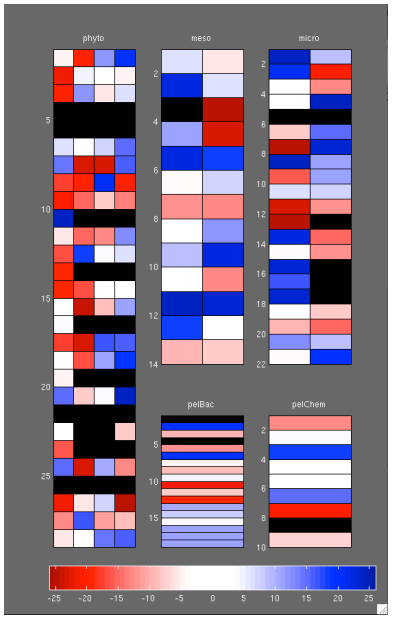
	20C	A1B-BaU	A1B-PT	A1B-DB
GPP	0.58	0.061	0.073	0.044
RSP	0.56	0.063	0.076	0.046
NPP	0.30	0.053	0.067	0.034
NCP	0.01	-0.035	-0.068	-0.104
DSL	0.93	0.045	0.056	0.042
BIO	3.63	-0.027	-0.018	-0.039

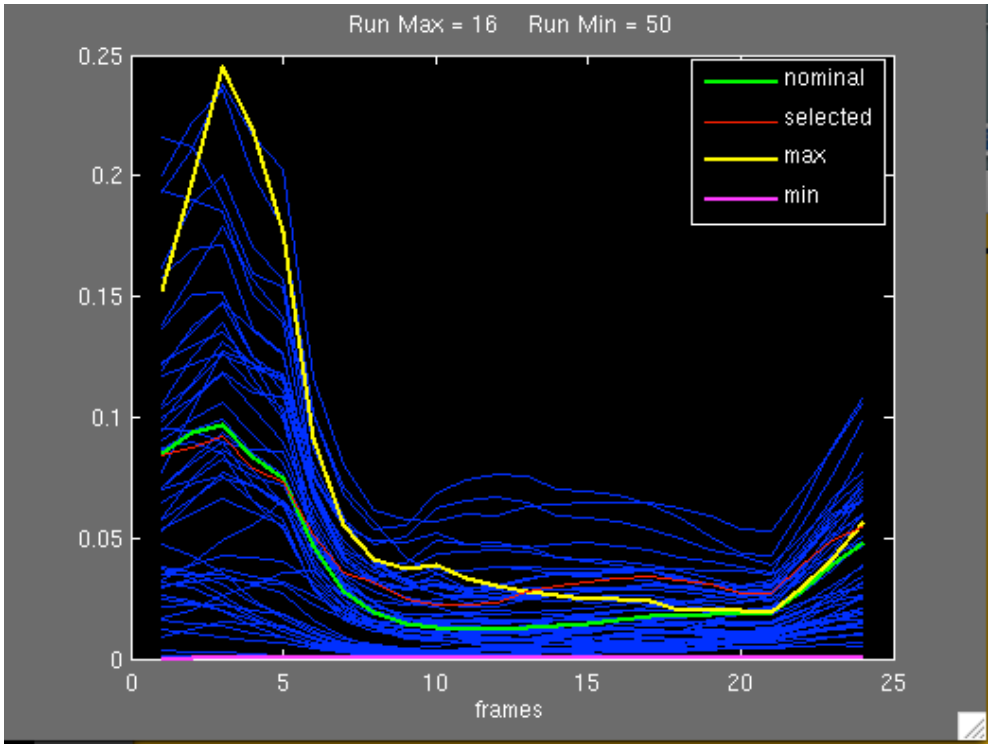
BFM
BIOGEOCHEMICAL FLUX MODEL

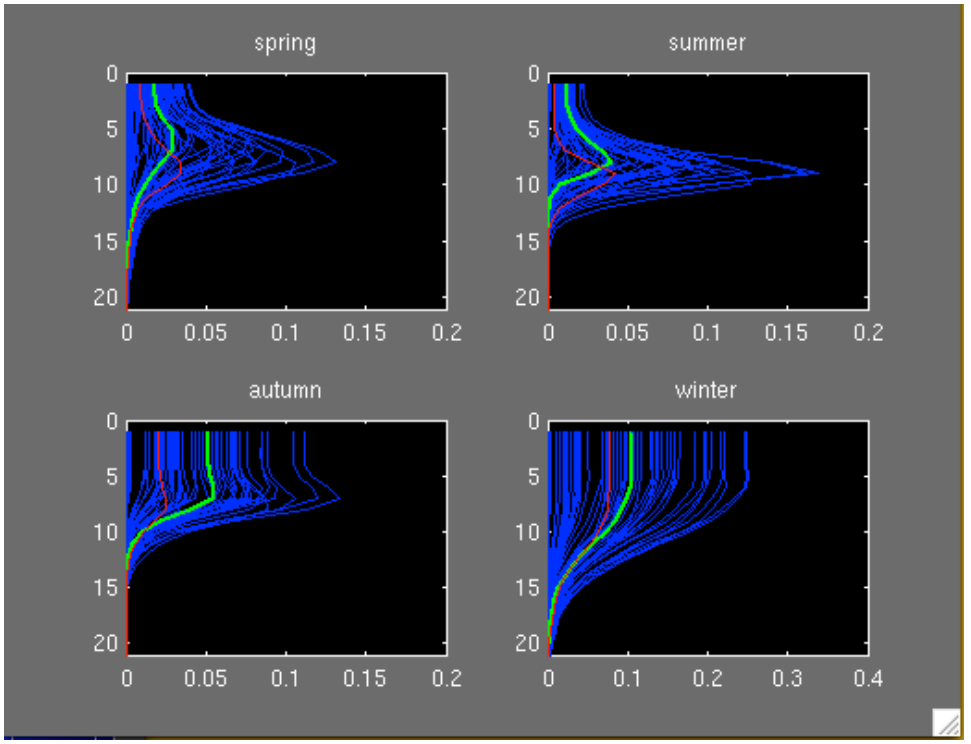
PRACE
PARTNERSHIP FOR ADVANCED COMPUTING IN EUROPE

Impact of OPATM-BFM parameters uncertainty on model results, 3D global sensitivity analysis on Mediterranean scale

GSENSMED TIER-0 project awarded by PRACE with > 20 M core hours

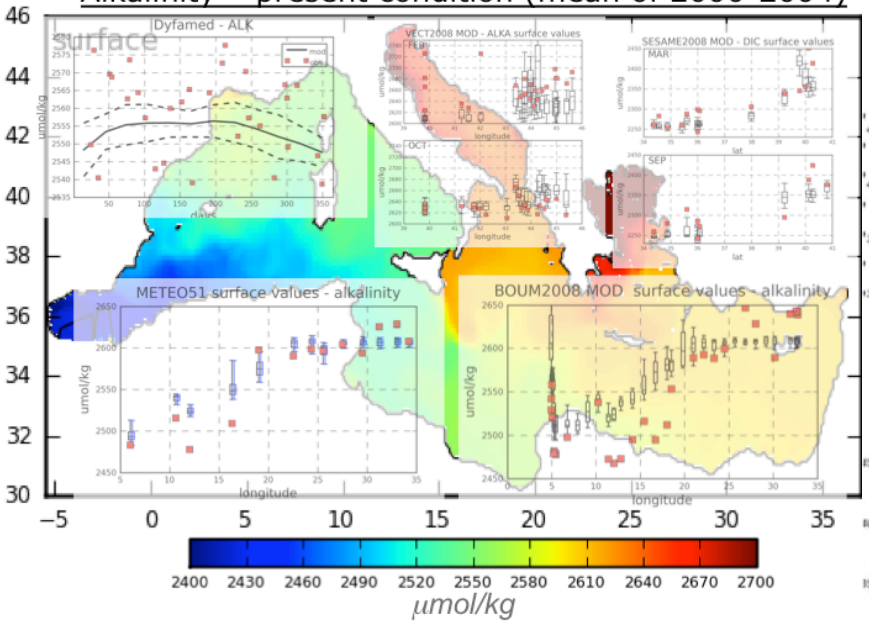






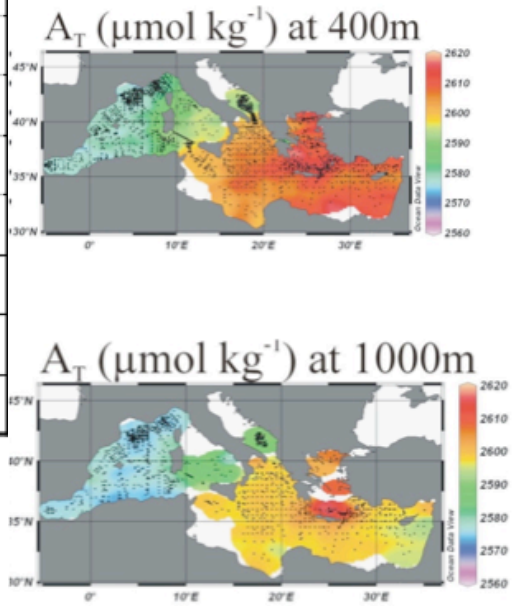
Carbonate system dynamics BFM

Alkalinity – present condition (mean of 2000-2004)

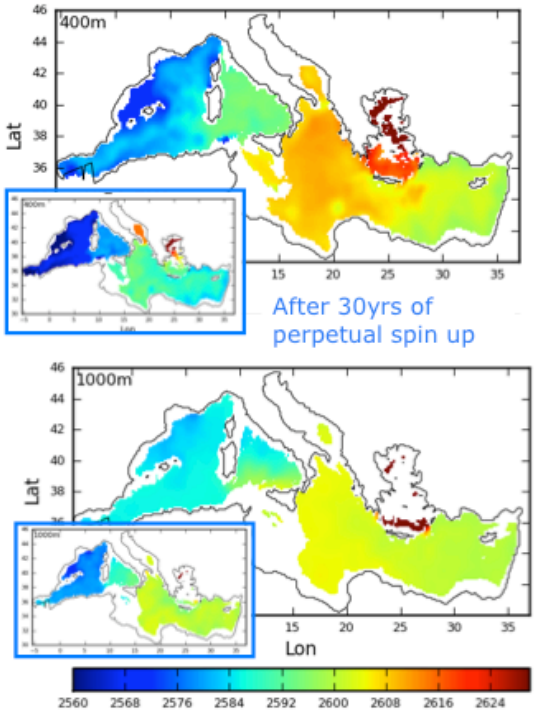


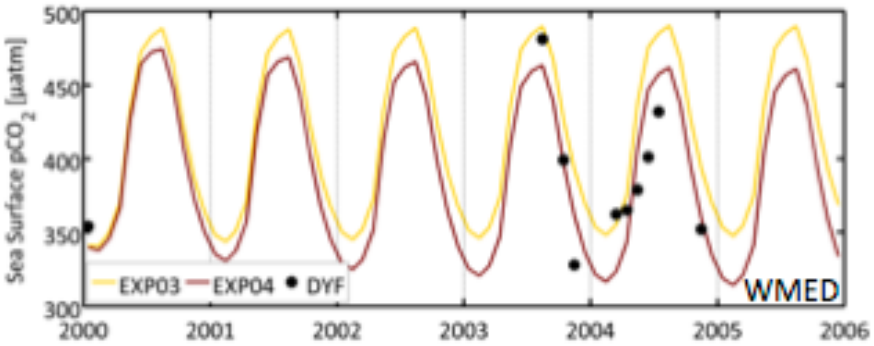
Alkalinity – present condition (mean of 2000-2004)

MedSea Deliverable 2.2



OPATM-BFM





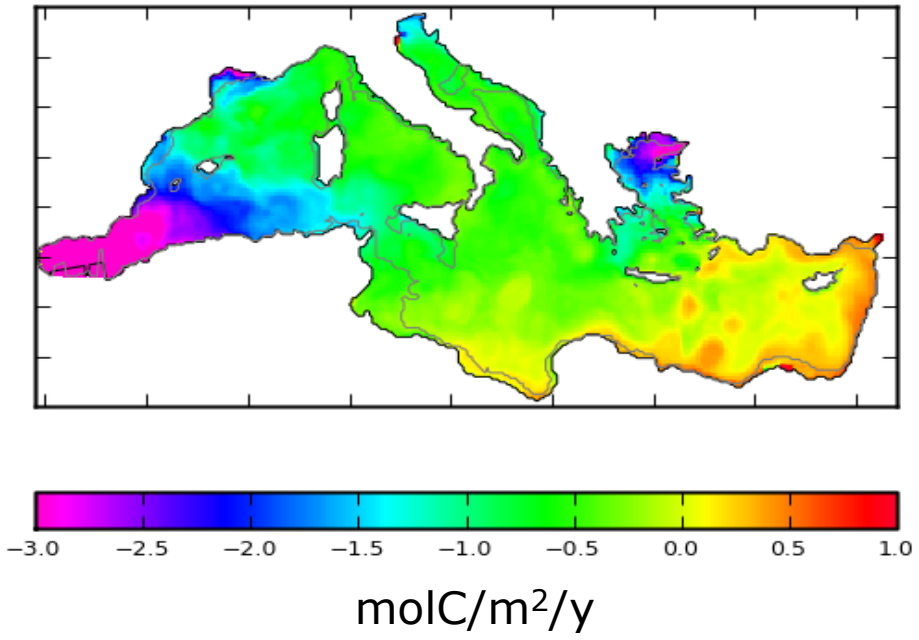
Time series of simulated ocean pCO2 in the Western Med and DYFAMED
Tomas Lovato CMCC

MedSeA
MEDITERRANEAN SEA ACIDIFICATION IN A CHANGING CLIMATE

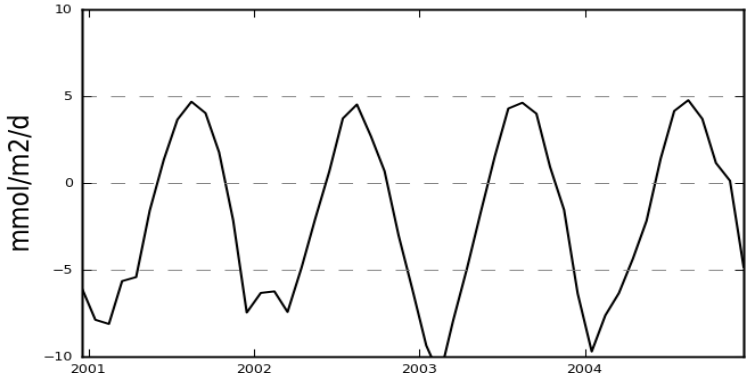
Models simulate the mean state and seasonal variability of the carbonate system in the Mediterranean

CO2 flux at air-sea interface

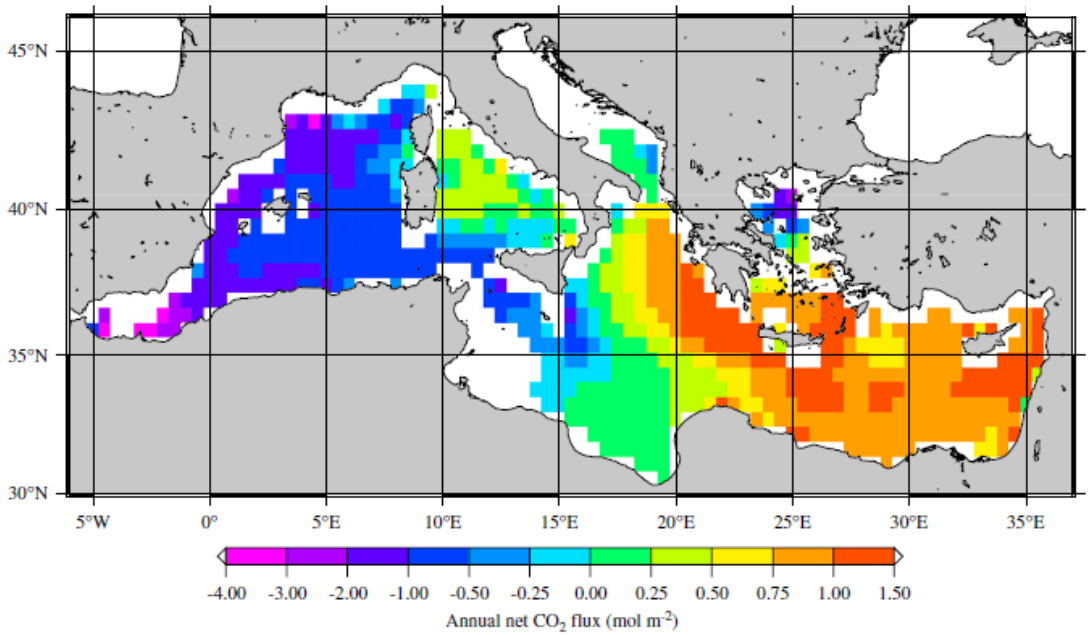
OPATM-BFM



OPATM-BFM: sink of 1.6 x 10^{12} mole per year



D'Ortenzio et al., 2009



Copin-Montegut, 1993: sink of 0.35-1.85 x 10^{12} mole per year

D'Ortenzio et al., 2008: sink of 0.02 x 10^{12} mole per year

MedSeA
MEDITERRANEAN SEA ACIDIFICATION IN A CHANGING CLIMATE

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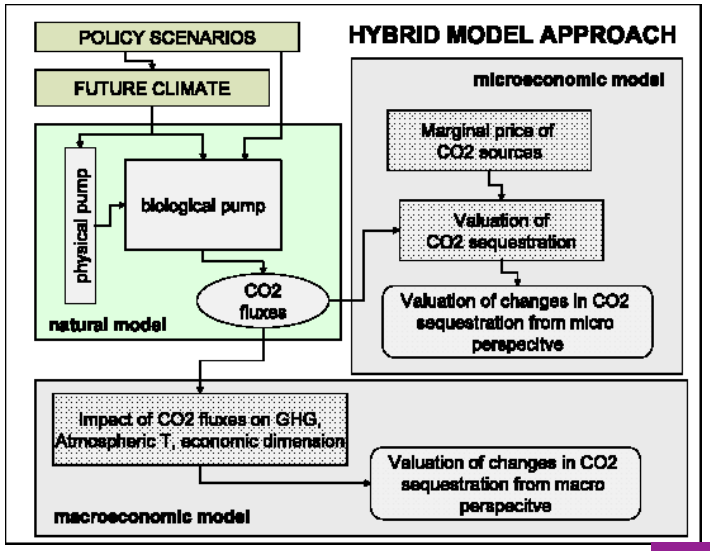
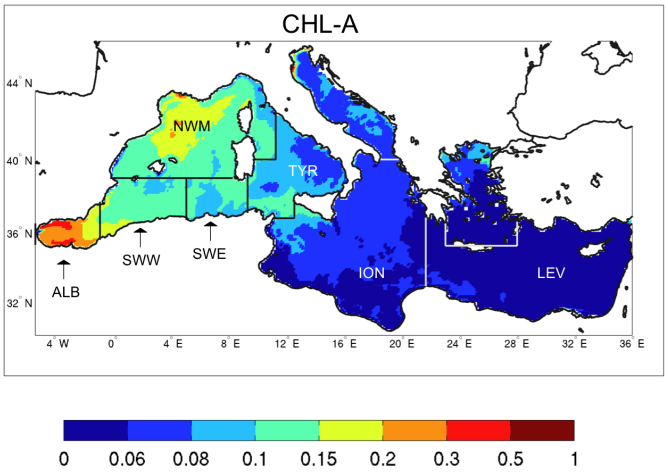
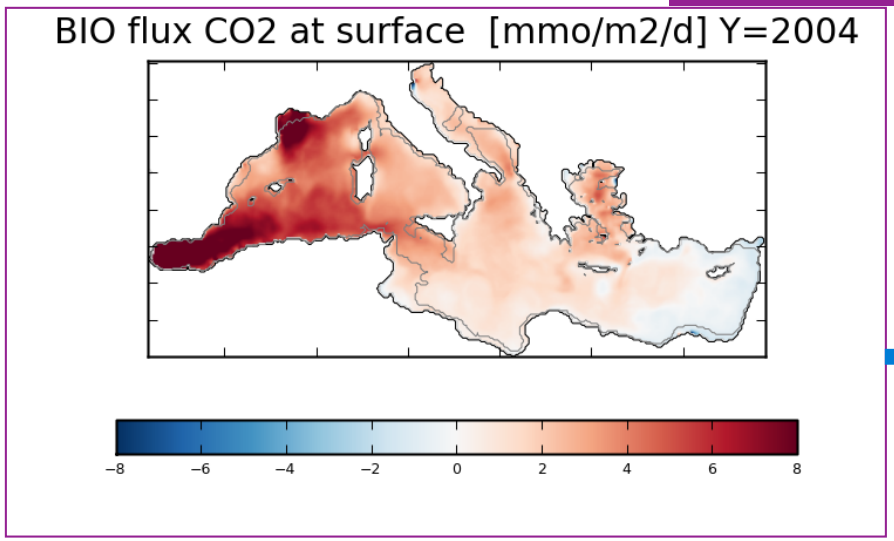
BFM
BIOGEOCHEMICAL FLUX MODEL

Hybrid model approach BFM





Biogeochemical model results



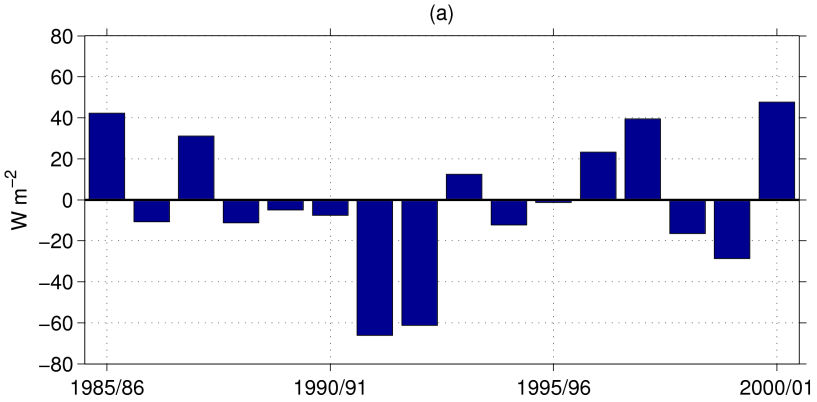
Impacts on target species

Hybrid model results

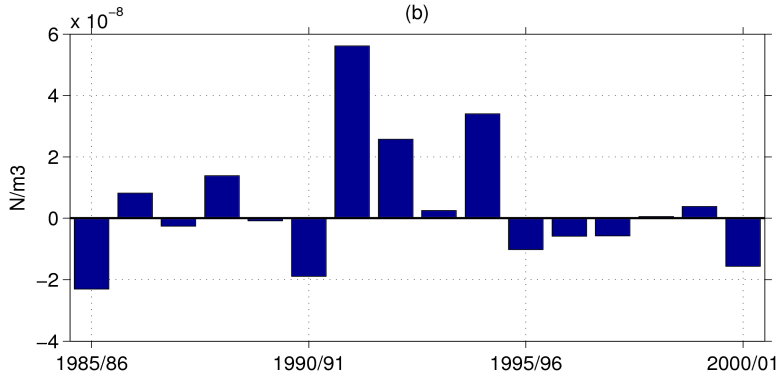
Carbon Sequestration estimate-SCC and Med Carbon sequestration value

A transient event 1990-1995
Mattia et al., 2013

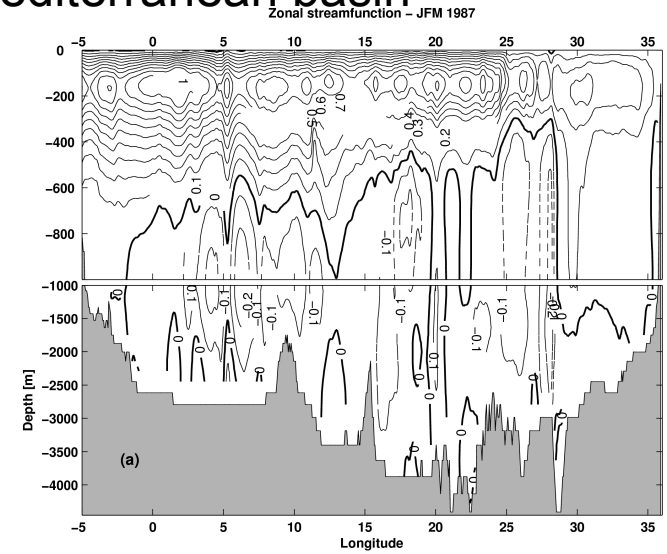
Anomaly of the mean winter (NDJF)
net surface heat flux over the Aegean sea



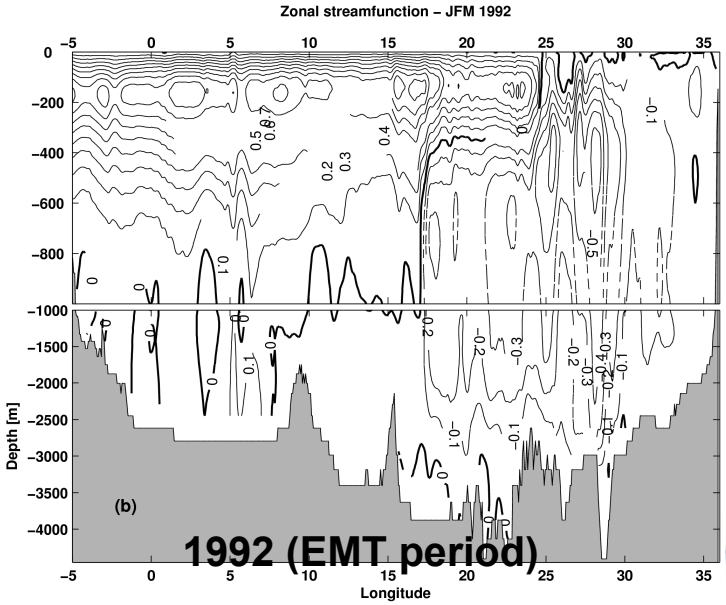
Anomaly of the mean winter (NDJF)
wind stress curl in the Eastern Mediterranean



Mean winter (JFM) zonal streamfunction for the Mediterranean basin

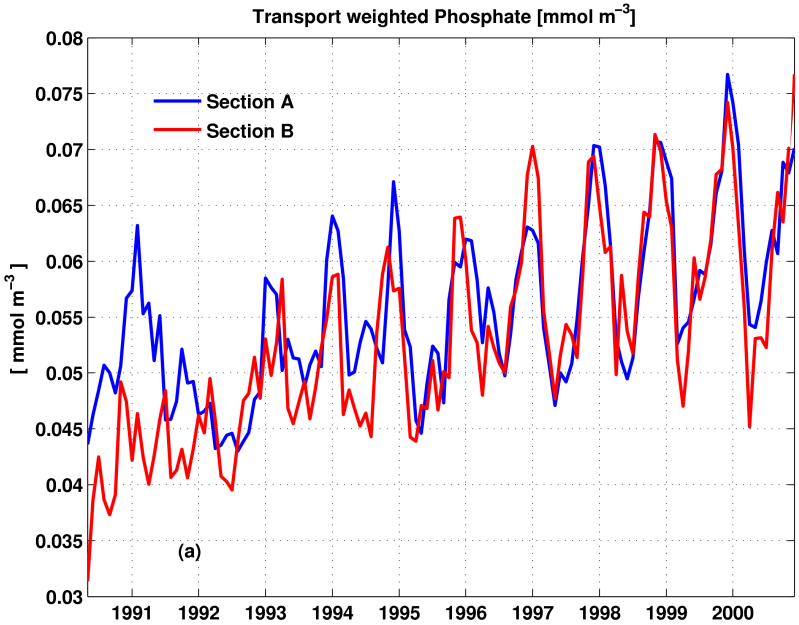


1987 (PRE EMT period)

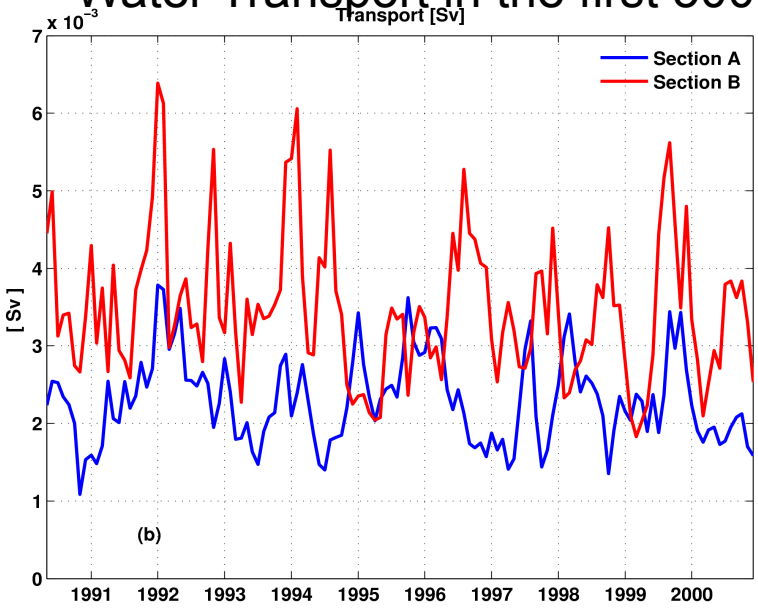


1992 (EMT period)

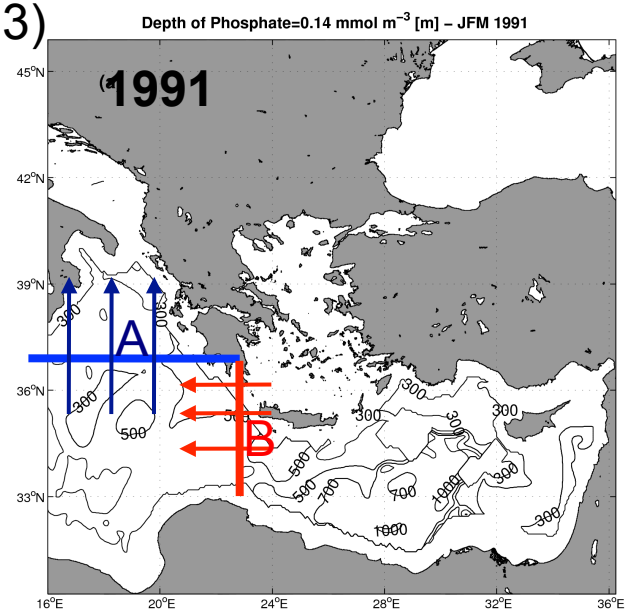
Transport-weighted PO_4 in the first 500 m

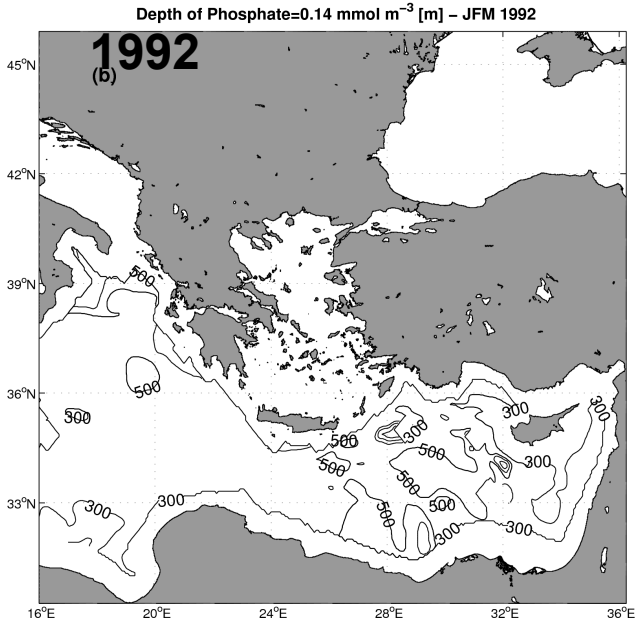


Water Transport in the first 500 m



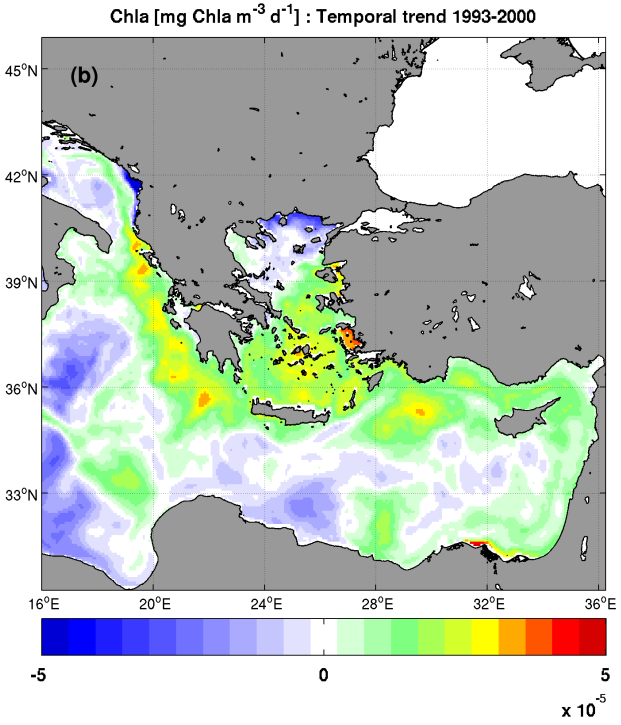
Depth of isosurface (PO_4 =0.14 mmol/m3)





Model response to the physical forcings

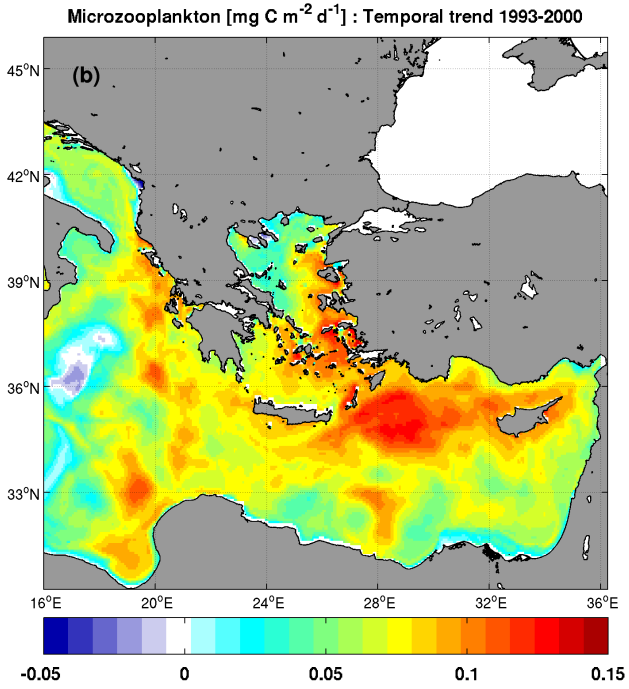
Linear temporal trends and over the period 1993-2000

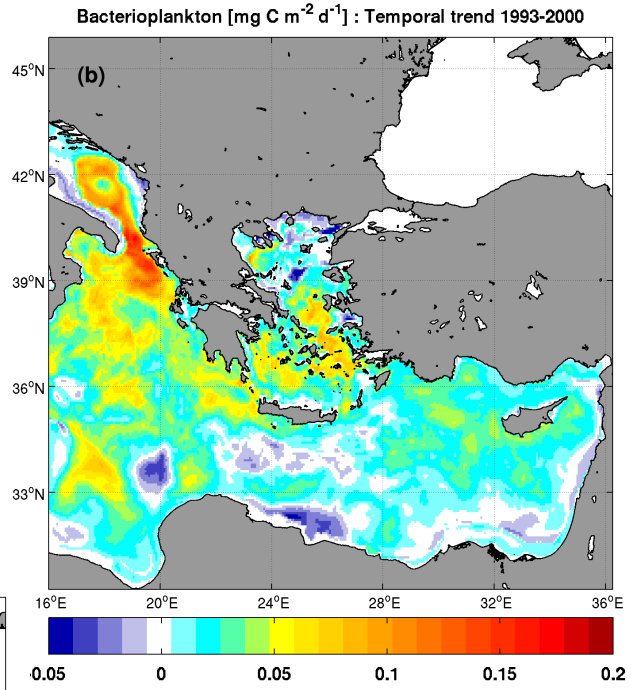


Chla (mg Chla m^3/d)

Microzooplankton

(mg C m^2/d)





Bacterioplankton

(mg C m^2/d)

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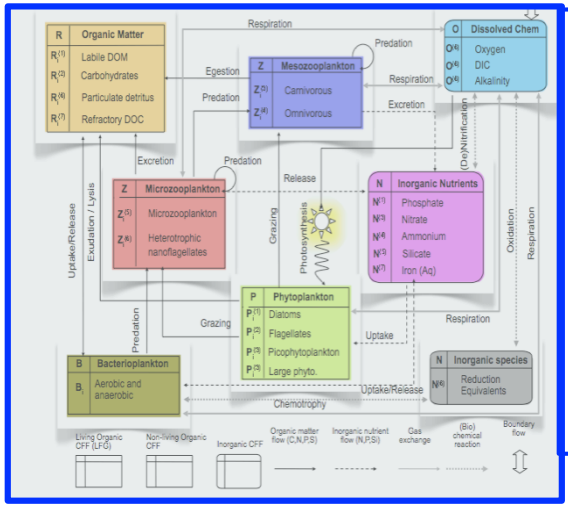
OGS

BFM in the Adriatic Sea

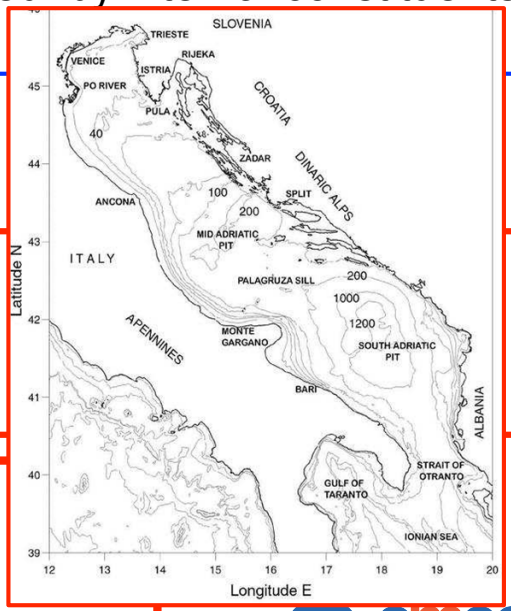
POM (Princeton Ocean Model) – BFM (Biogeochemical Flux Model)



physiological and population processes of lower trophic levels (LTL)

3 main trophic groups:Primary producers, predators, decomposers (standard organism)

functional group biomass defined by internal constituents (C, N, P, Si)



Horizontal resolution: 2 kms, 27 sigma vert. levels.
Nesting with Mediterranean OGCM

<u>Ecosystem response to climate scale drivers.</u>
<u>Ecosystem response to direct anthropogenic drivers.</u>

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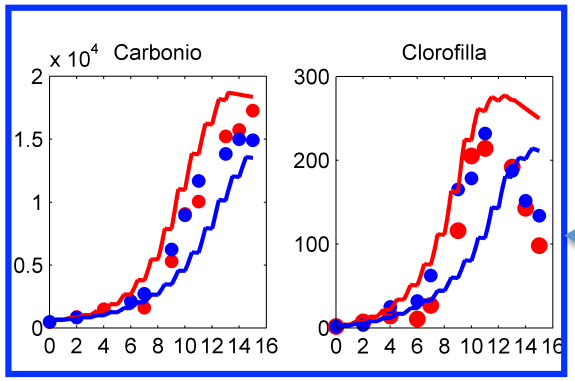
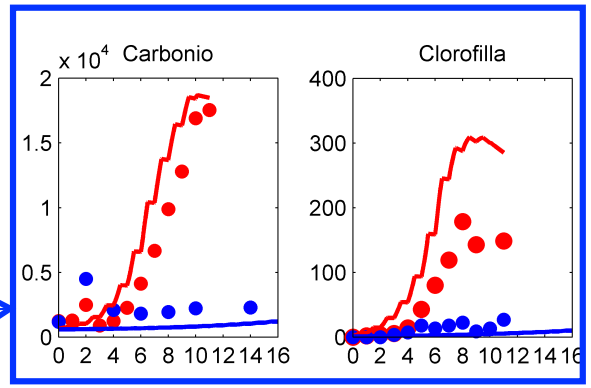
Phytoplankton laboratory cultures exposed to organic pollutants (herbicide). Development and test of appropriate model parameterisation.



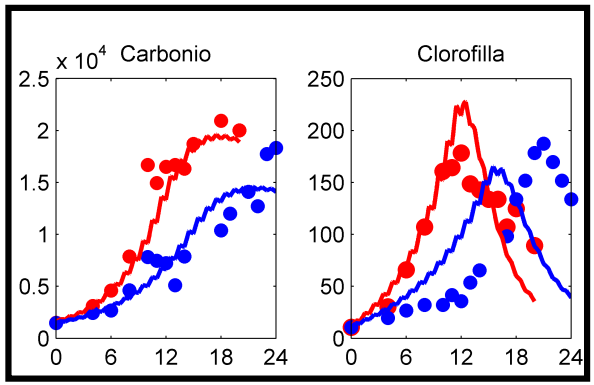
S. Marinoi

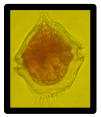
15°C
Terb. 10µg/L

20°C
Terb. 30µg/L



Model control
Model Herb.
Data Control
Data Herb.



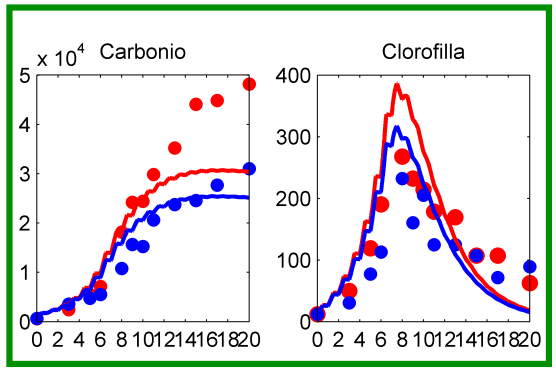


G. Spinifera

20°C
Terb. 5µg/L

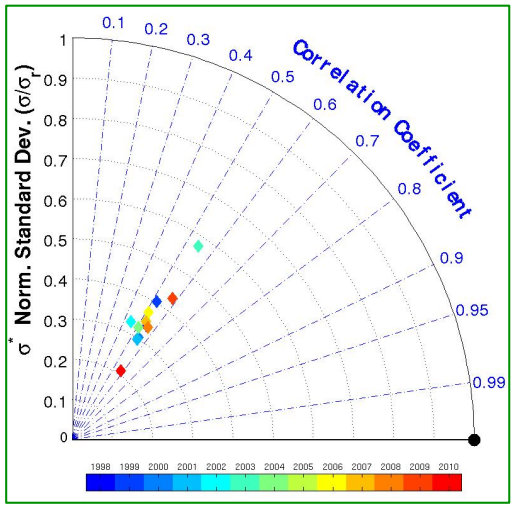
P.Minimum

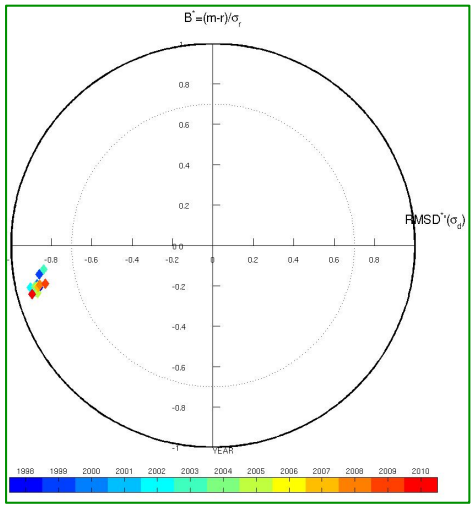
20°C
Terb. 30µg/L



Hindcast: Validation against SeaWifs surface pigments (1998-2010) for the Adriatic Sea

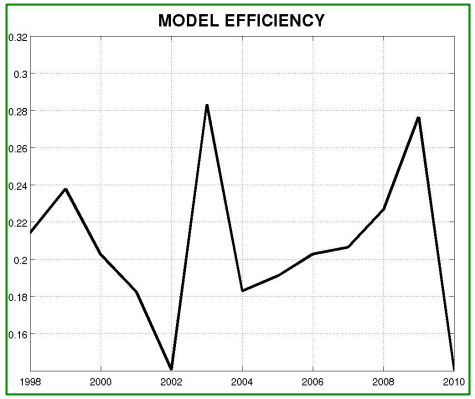
Marine Ecosystem Evolution in a Changing Environment

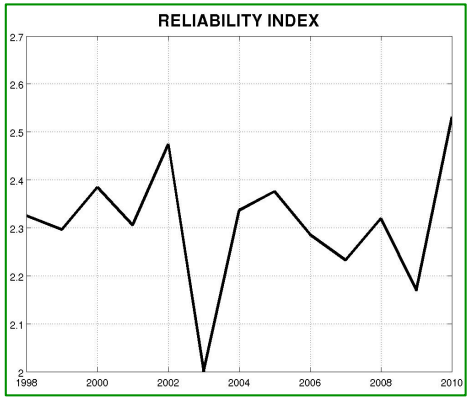


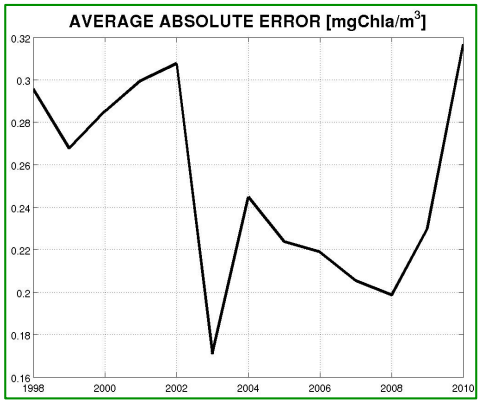


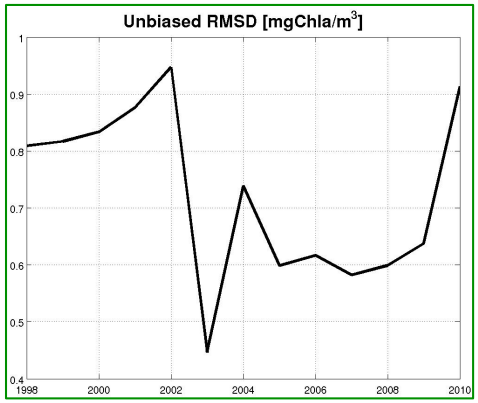
ANNUAL AVERAGES

Validation by means of objective statistical indicators









cmcc Centro euro-Mediterraneo sui Cambiamenti Climatici

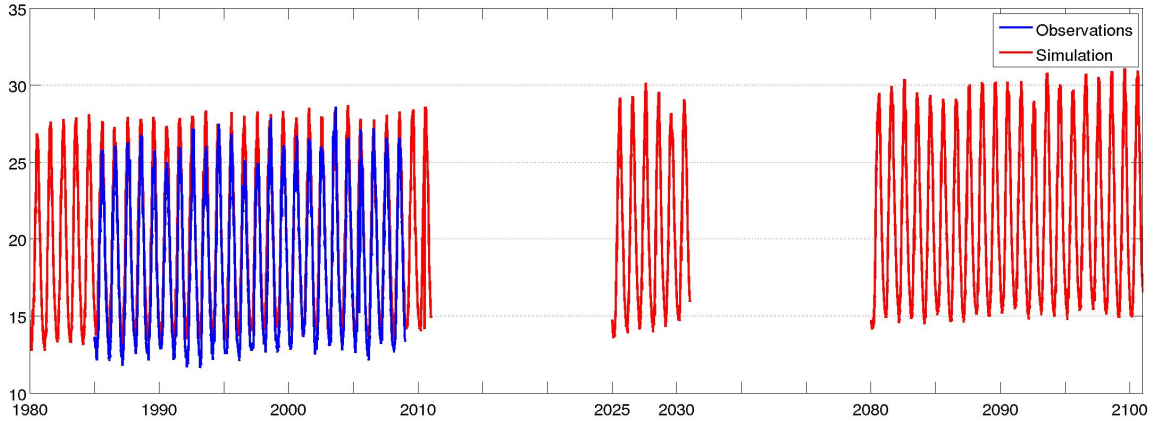
OGS

BFM
BIOGEOCHEMICAL FLUX MODEL

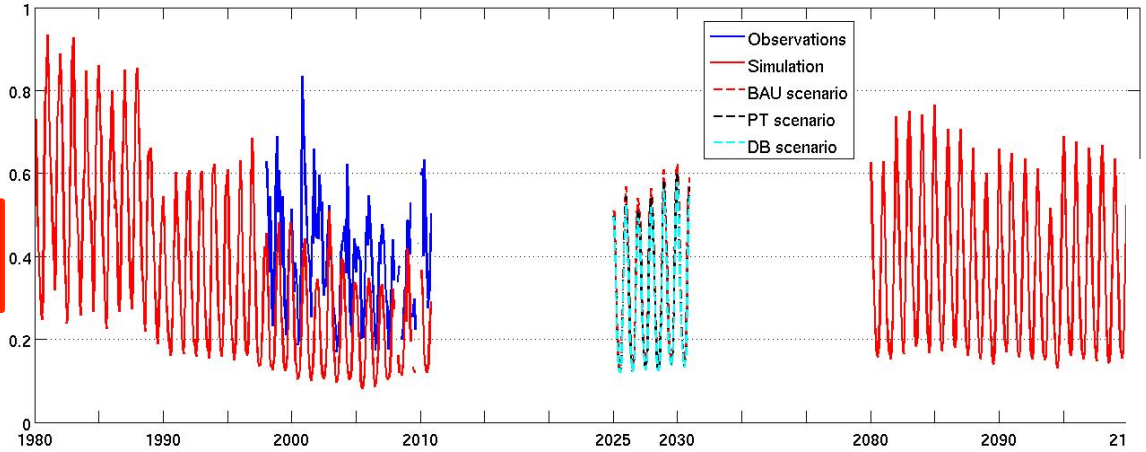
MEECE
Marine Ecosystem Evolution in a Changing Environment

Time Slices Considered: (1980-2010), (2025-2030), (2080-2100)

SST



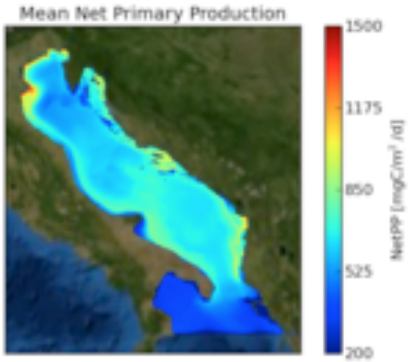
Surf. Chl-a



LTL runs:

30 years hindcast
20 years end 21st Century scenario.

Scenarios for:
Land based nutrient Inputs.
Herbicide



Thank you for the attention!