Operational short-term forecasts of the Mediterranean Sea biogeochemistry

Stefano Salon & OGS-ECHO group

Workshop on Climate change in Mediterranean and Caribbean Seas: Research experiences and new scientific challenges

CIIFEN Headquarters,

Guayaquil, Ecuador, May 8th – 11th 2012

Outline

- Why biogeochemical modelling?
- OGS OPATM-BFM model
- Operational forecast of the biogeochemical state of the Mediterranean Sea
- Achievements
- Conclusions

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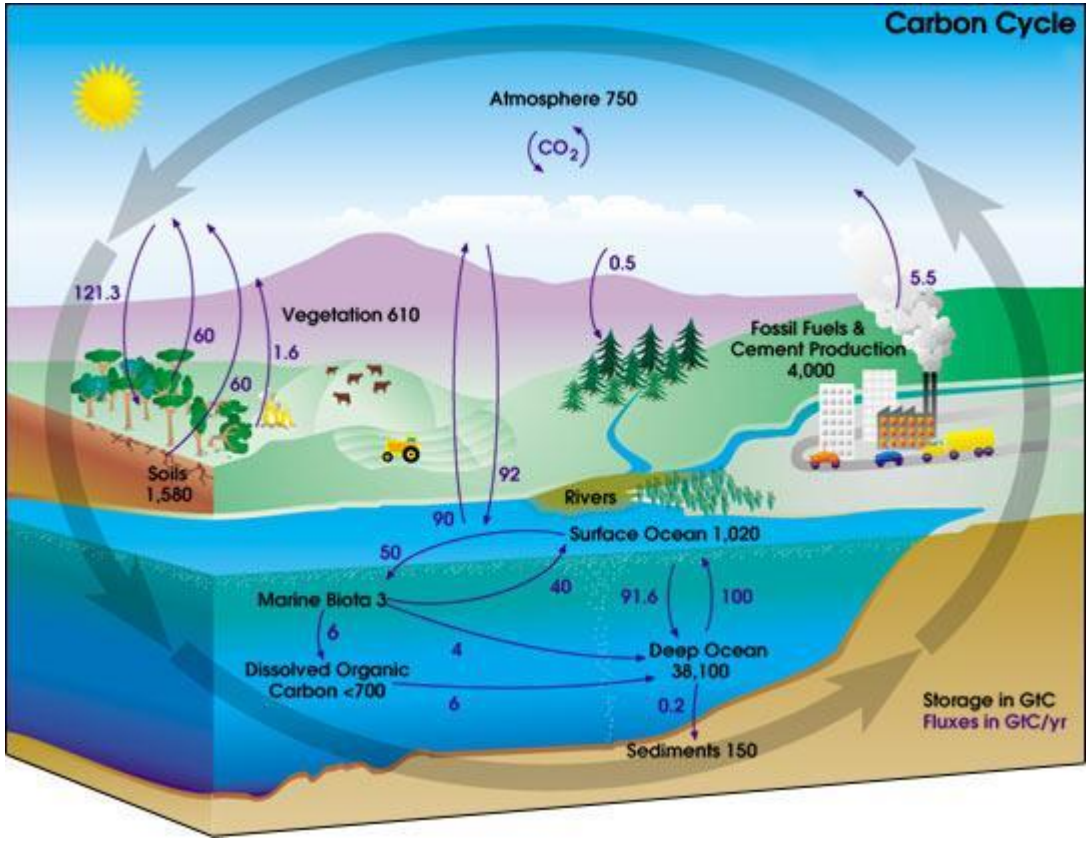
Biogeochemical cycles



BIOGEOCHEMICAL cycles describe the fluxes of one or more elements (**CHEM**) through the different phases inside the biotic (**BIO**) or abiotic (**GEO**) compartments

Uses of marine biogeochemical models

- BGC models are tools for understanding and prediction (as the *ultimate stage* of understanding)

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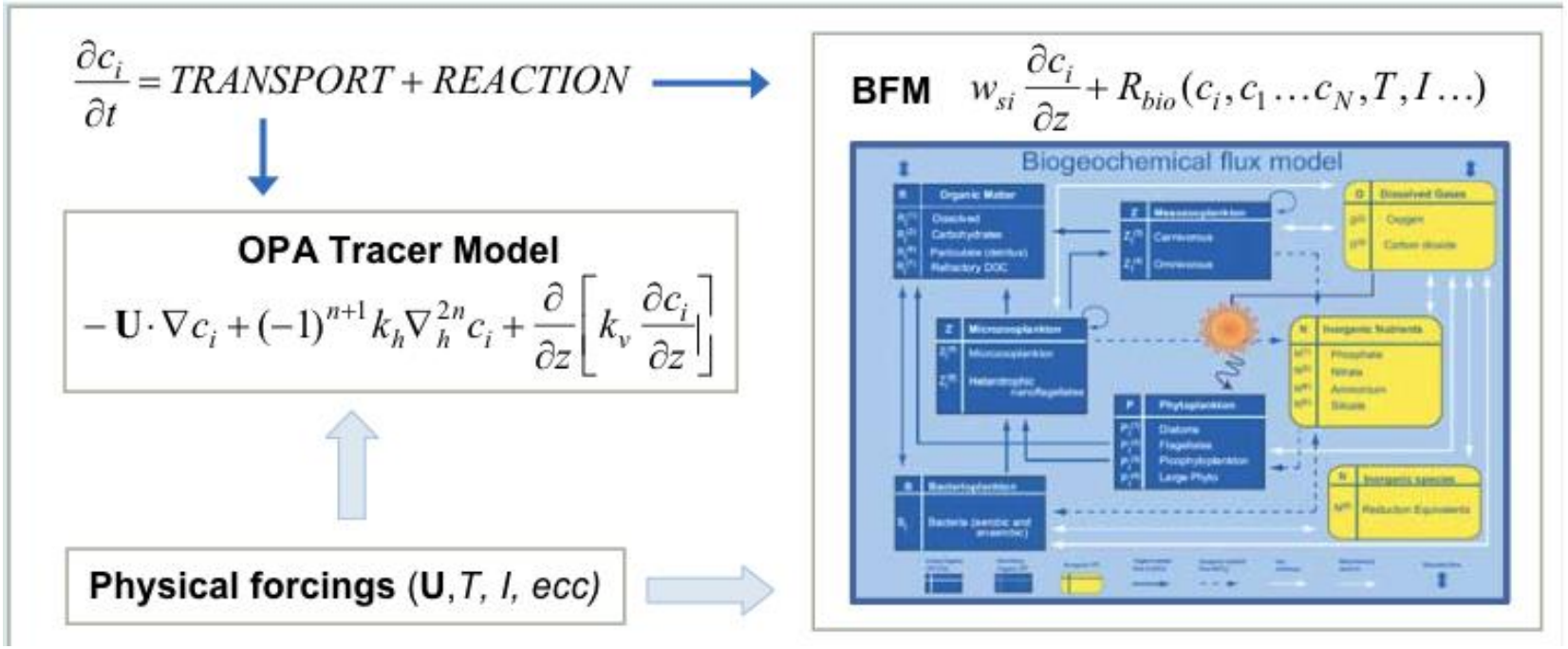
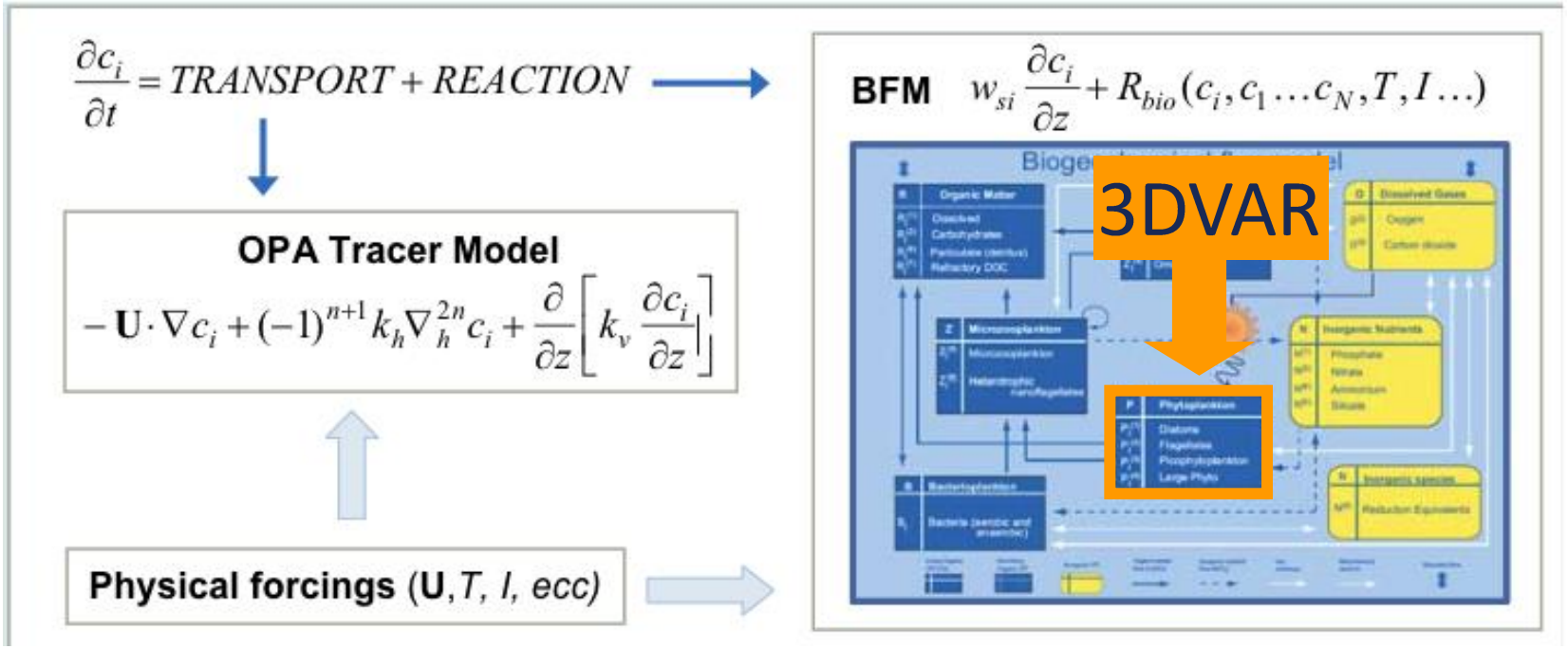
Model configuration: OPATM-BFM scheme



- Horiz. Res. = 1/8°
- Vert. Res. = 43/72 levels
- Time Res. = 1800 s
  - 1 year simulated in 4-7 hours
  - Output save 10 days

Model configuration: OPATM-BFM scheme + DA



- Horiz. Res. = 1/8°
- Vert. Res. = 43/72 levels
- Time Res. = 1800 s
  - 1 year simulated in 4-7 hours
  - Output save 10 days

OPATM-BFM main implementations

- **Operational Forecast** (projects: MyOcean 1 & 2, OPEC)

  1. Typical run = 17 days (7 analyses + 10 forecast)

  1. 32 cpu on High Performance Computer (IBM sp6 → PLX)
     → approximatively 2.5 hours of simulation

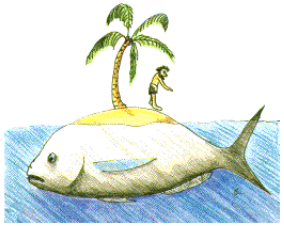
- **Multi-annual climate studies** (projects: VECTOR, SESAME IP, MEDSEA, PERSEUS)

  1. Typical run = 10 years

  1. 32 x 4 cores on High Performance Computer (IBM sp6 → BG/Q)
     → approximatively 5 hours of simulation per 1 year

Model developments: OPATM

- **Strong effort within technological (HPC) development in collaboration with CINECA supercomputer centre (Italy) key element**
- Involved in major HPC projects: PRACE ($21x10^6$ core hours) and ISCRA ($5x10^6$ core hours)
- COUPLING with ECOSIM for End2End approach (PERSEUS and OPEC Projects)
- COUPLING with other OGCMs (MitGCM, ROMS)
- DEVELOPMENT in the FRAMEWORK of the BFM AGREEMENT



MITgcm

ROMS

OPATM-BFM agreement with *in situ* observations

Lazzari et al., Biogeosciences, 9, 2012

Regional average of net primary production climatology presented as annual values and for shorter specific periods.

Values in brackets for annual values indicate seasonal (left hand side) and inter-annual variance (right hand side). Values in brackets for shorter specific periods indicate inter-annual variance.

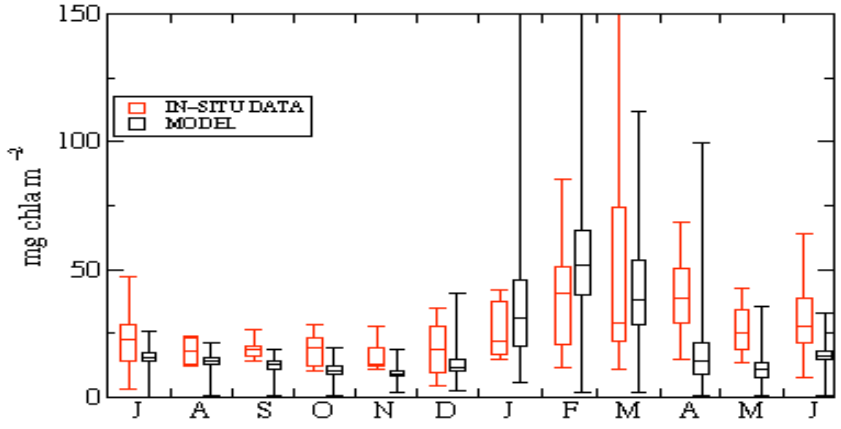
References: (a) Crispi et al. (2002), (b) Allen et al. (2002), (c) Napolitano et al. (2000), (d) Colella (2006), (e) Sournia et al. (1973), (f) Marty and Chiaverini (2002), (g) Boldrin et al. (2002), (h) Moutin and Raimbault (2002), (i) Macìas et al. (2009), (j) Lohrenz et al. (2003), (k) Moran and Estrada (2001), (l) Granata et al. (2004), (m) Bosc et al. (2004), (n) Conan et al. (1998).

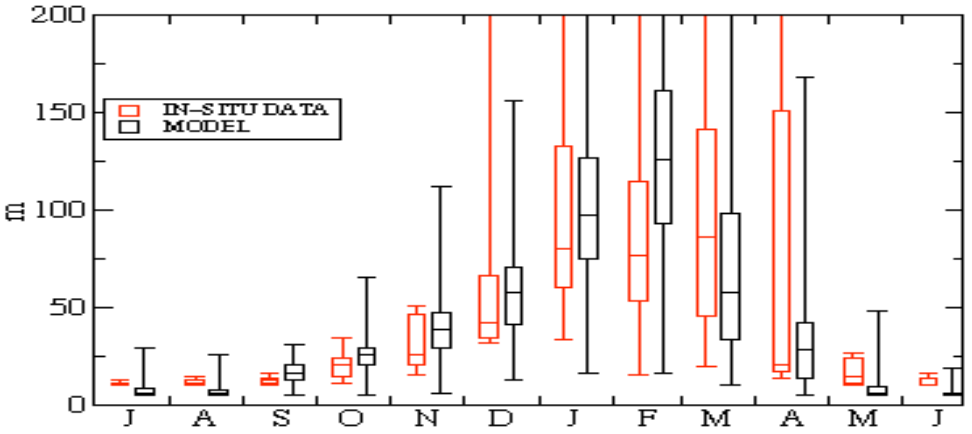
	Climatology/All seasonal cycle ($gC\,m^{-2}\,yr^{-1}$)					Specific periods ($mgC\,m^{-2}\,d^{-1}$)	
	OPATM-BFM REF	Other models	Satellite model[d]	Other satellite models	In situ	OPATM-BFM REF	In situ
Mediterranean (MED)	98 (±82/±5)	–	90 (±48/±3)	135[m]	80–90[e]	–	–
Western basin (WES)	131 (±98/±6)	120[a]	112 (±65/±7)	163[m]	–	430 (±258)	>350[h] (May–Jun)
Eastern basin (EAS)	76 (±60/±5)	56[a]	76 (±20/±2)	121[m]	–	200 (±107)	150–450[h] (May–Jun)
Alboran Sea (ALB)	274 (±155/±11)	24–207[b]	179 (±116/±13)	–	–	545 (±321)	6–644[i] (Nov)
South West Med (SWW)	160 (±89/±8)	24–207[b]	113 (±43/±6)	–	–	570 (±233)	299–1288[j] (May)
South West Med (SWE)	118 (±70/±13)	–	102 (±38/±4)	–	–	447 (±164)	>450[h] (May–Jun)
North West Med (NWM)	116 (±79/±6)	32–273[b]	115 (±67/±8)	–	86–232[f] 140–150[n]	600 (±290)/ 142 (±96)	1000±11[k](Mar)/ 211–249[l](Oct)
Tyrrhenian (TYR)	92 (±63/±5)	–	90 (±35/±7)	–	–	279 (±118)	350–450[h] (May–Jun)
Ionian (ION)	77 (±58/±4)	27–153[b]	79 (±23/±2)	–	62[g]	189 (±99)/ 159 (±68)	150–450[h] (May–Jun)/ 186±65[g] (Aug)
Levantine (LEV)	76 (±61/±5)	97[c]/ 36–158[b]	72 (±21/±2)	–	–	208 (±110)	150–250[h] (May–Jun)

OPATM-BFM validation with *in situ* data (DYFAMED)

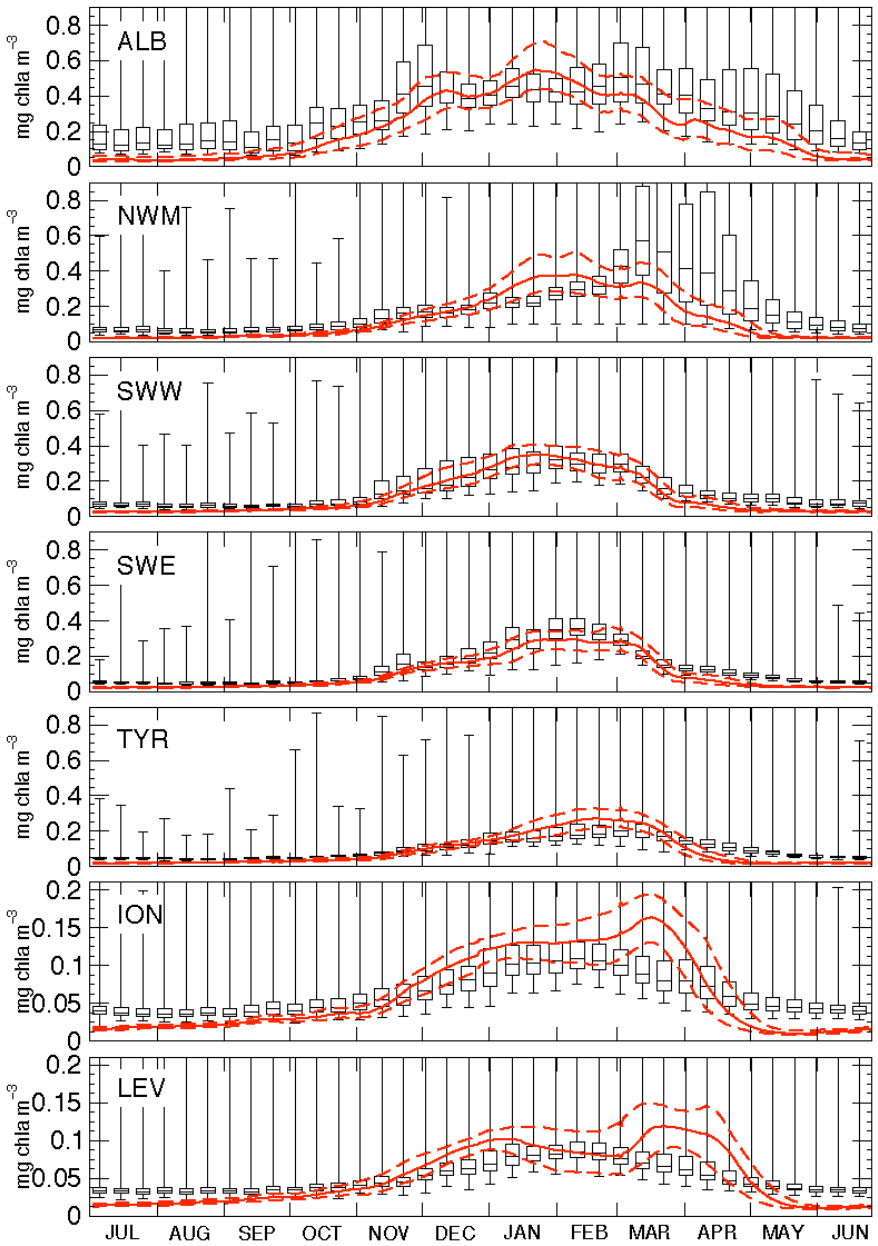
Climatology of chla and MLD from *in situ* data (*sensu* D'Ortenzio et al., 2005)

MLD controlling mechanism for winter chla accumulation



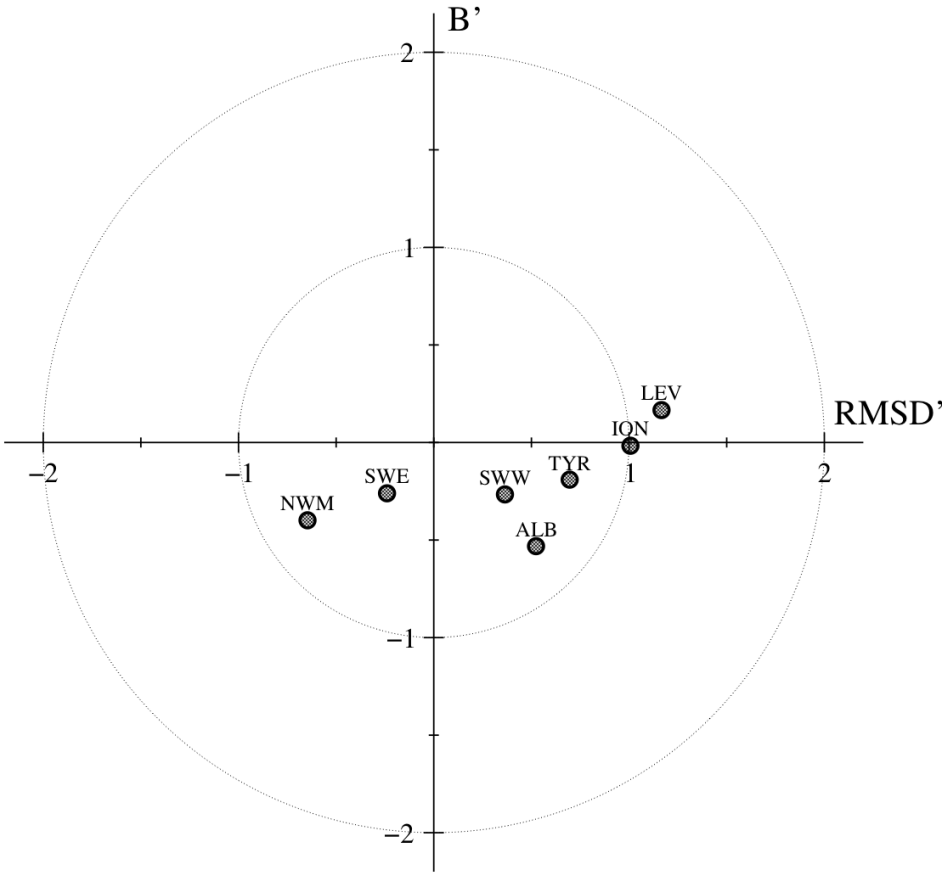


OPATM-BFM temporal variability of chl vs SeaWiFS



Seasonal cycle 1999-2004

Target Diagram

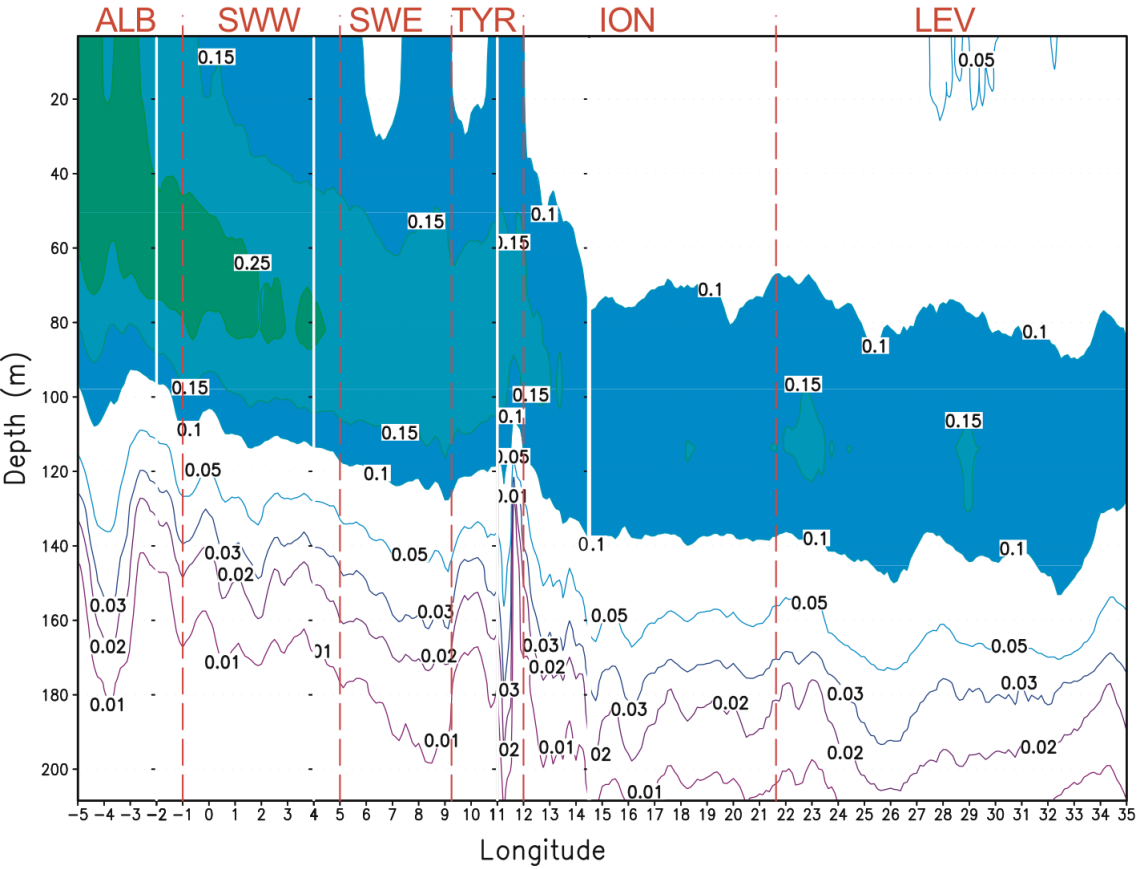


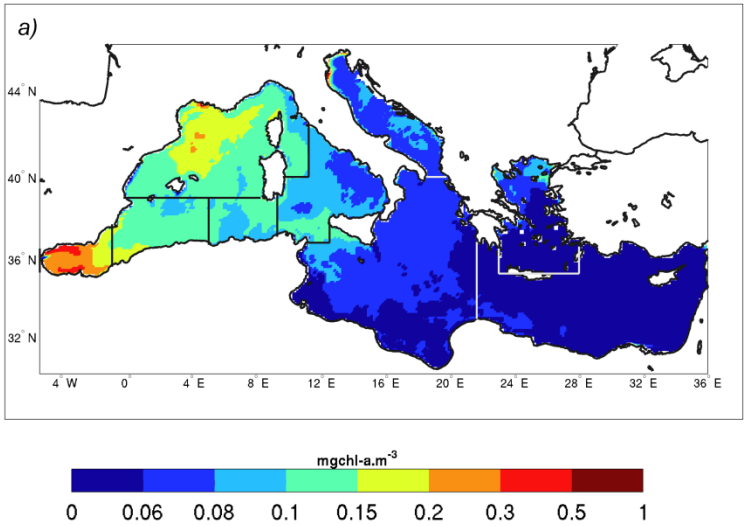
Lazzari et al., Biogeosciences, 9, 2012

OPATM-BFM spatial variability of chl

Declining Deep Chlorophyll Maximum eastward

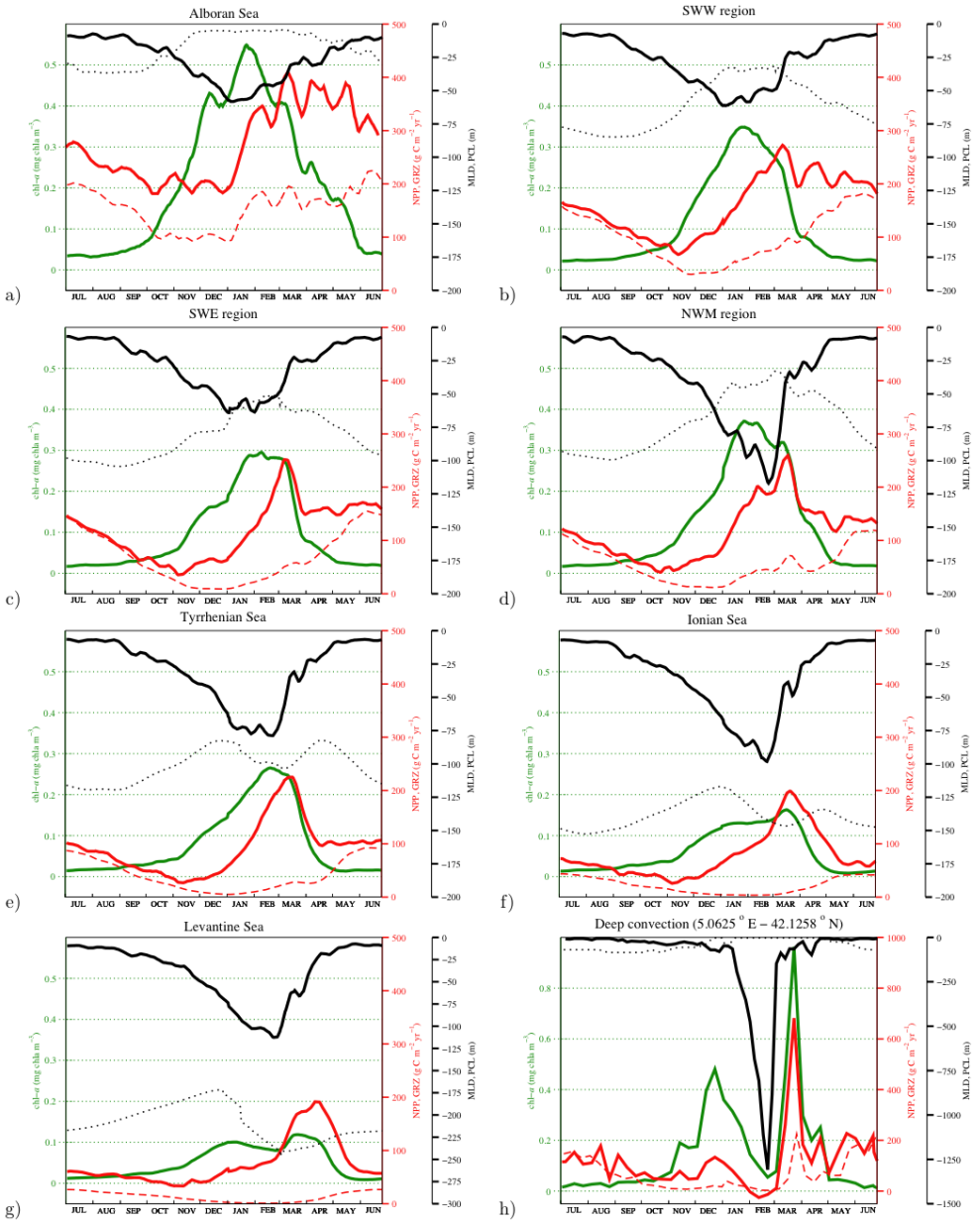
Well-known East-West Chlorophyll gradient





OPATM-BFM spatial-temporal variability of BGC state

- **PRIMARY PRODUCERS SEASONAL CYCLE**
- **LOWER TROPHIC LEVELS**
- **INORGANIC NUTRIENTS**
- **SYSTEM CARRYING CAPACITY**
- **CARBON FLUXES**



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Operational forecast of biogeochemical state of Med Sea

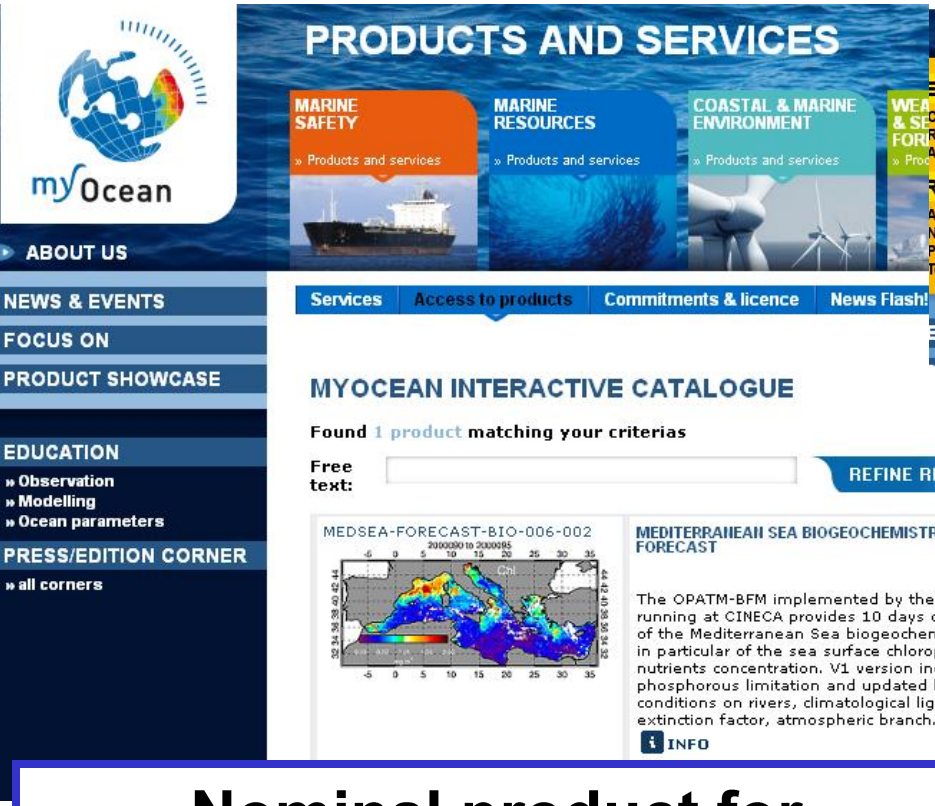
- 2006-2009 **MERSEA-IP** FP6 project: 1st pre-operational automatic chain for weekly 10-day forecasts of the Med biogeochemistry (chl, nutrients) delivered via OGS website
- 2009-2012 **MyOcean** FP7 project: fully operational twice/week 10-day forecast integrated in the pan_EU MyO infrastructure BGC products delivered via web catalogue + Data Assimilation
- 2012-2014 **MyOcean 2** FP7 project: development of DA + refinement 1/8° 1/16° + 10 yrs re-analysis + CalVal activity to support MSFD directions (Good Environmental Status)
- 2012-2014 **OPEC** FP7 project: towards regional Operational Ecology and Marine Ecosystem Forecasting (LTL ↔ HTL)

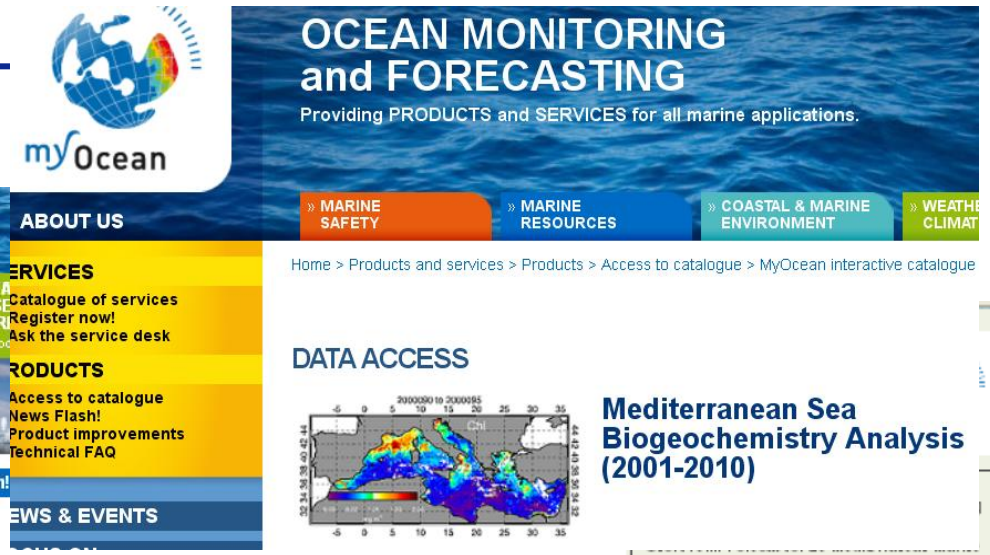
- **Numerical tool**: OPATM-BFM 3D parallel model off-line physics-biogeochemistry coupled, forced by physical fields provided by MFS-INGV OGCM and with surface chlorophyll assimilated from GOS-ISAC-CNR satellite data

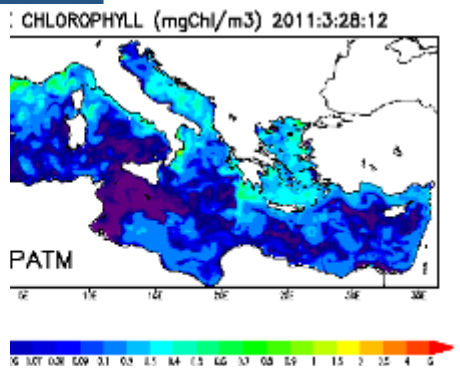
OGS in MyOcean project

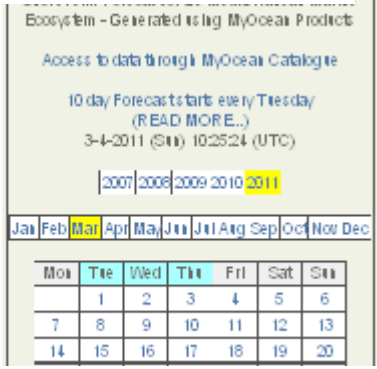
- fully operational + 3DVAR assimilation scheme of surface chl
- biogeochemical 10-day forecasts released on Wed and Sat
- **nominal products** = daily averaged 3D concentrations at 1/8° of chl, nutrients (nitrates and phosphates), oxygen, PP, phytoplankton biomass + 10yrs simulation (2001-2010)
- OPATM-BFM model embedded in the automatic operational chain implemented at CINECA e-infrastructure involving OGS, CINECA, INGV (forcings) and GOS-ISAC-CNR (chl satellite obs.)
  - **CINECA upstream** = downloading of INGV physical forcing fields, data interpolation
  - **CINECA stream** = production (parallel)
  - **CINECA downstream** = products dissemination MyOcean web catalogue
  - **OGS downstream** = local archive (whole output – 51vars), surface chl from model and satellite non-parametric statistics for NRT comparison

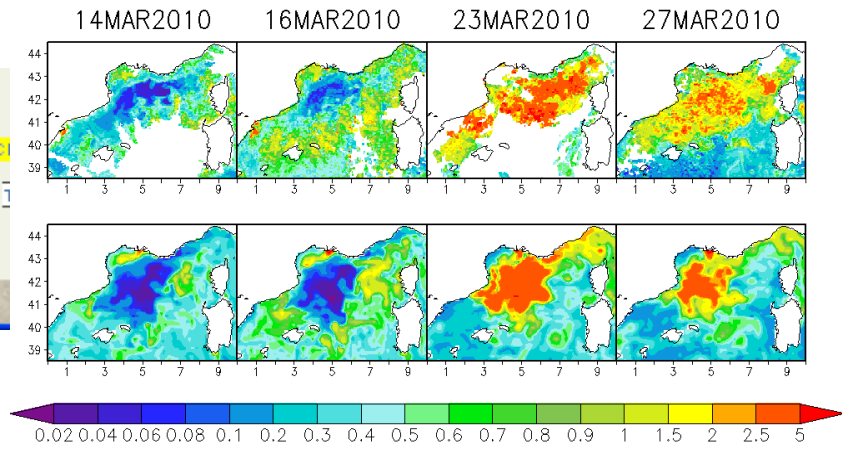
OGS products in MyOcean











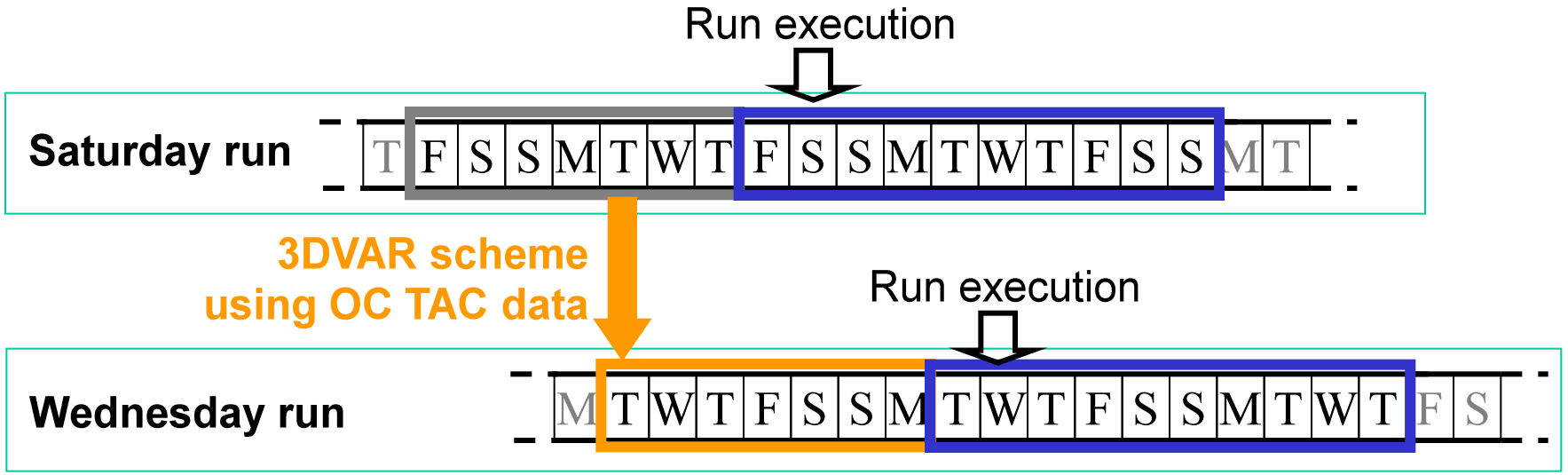
Nominal product for biogeochemistry forecast in Med Sea + OGS web page + case studies + CalVal

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

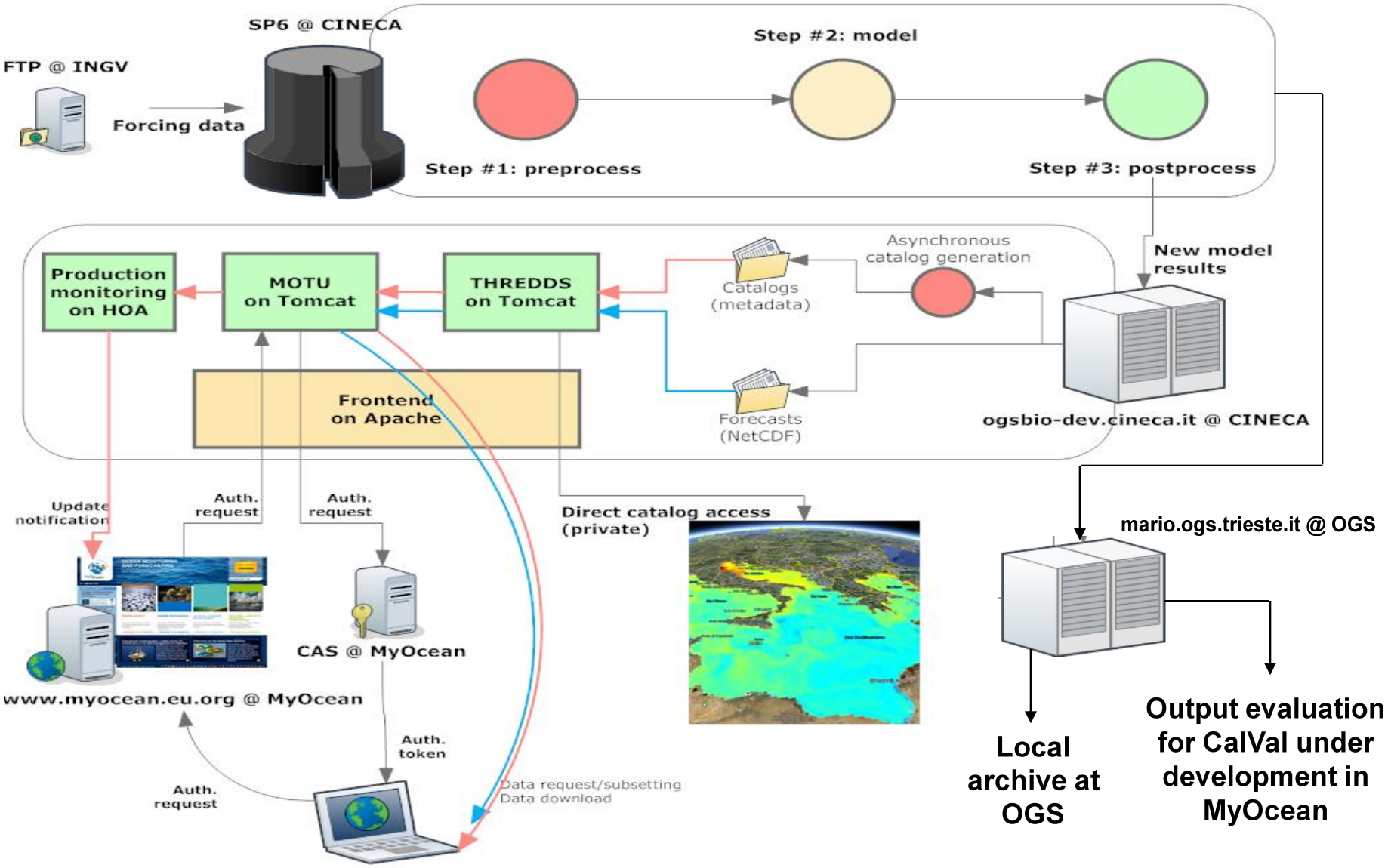
Layout of the operational chain

- on Saturday at 12:00
  - 7 days of hindcast (using INGV analysis)
  - 10 days of forecast (using INGV forecast)

- on Wednesday at 12:00
  - 7 days of analysis (using INGV analysis and biogeochemical analysis, ICs via DA based on GOS-ISAC-CNR satellite chl)
  - 10 days of forecast (using INGV forecast)



System Chart of OGS products within MIS-GW



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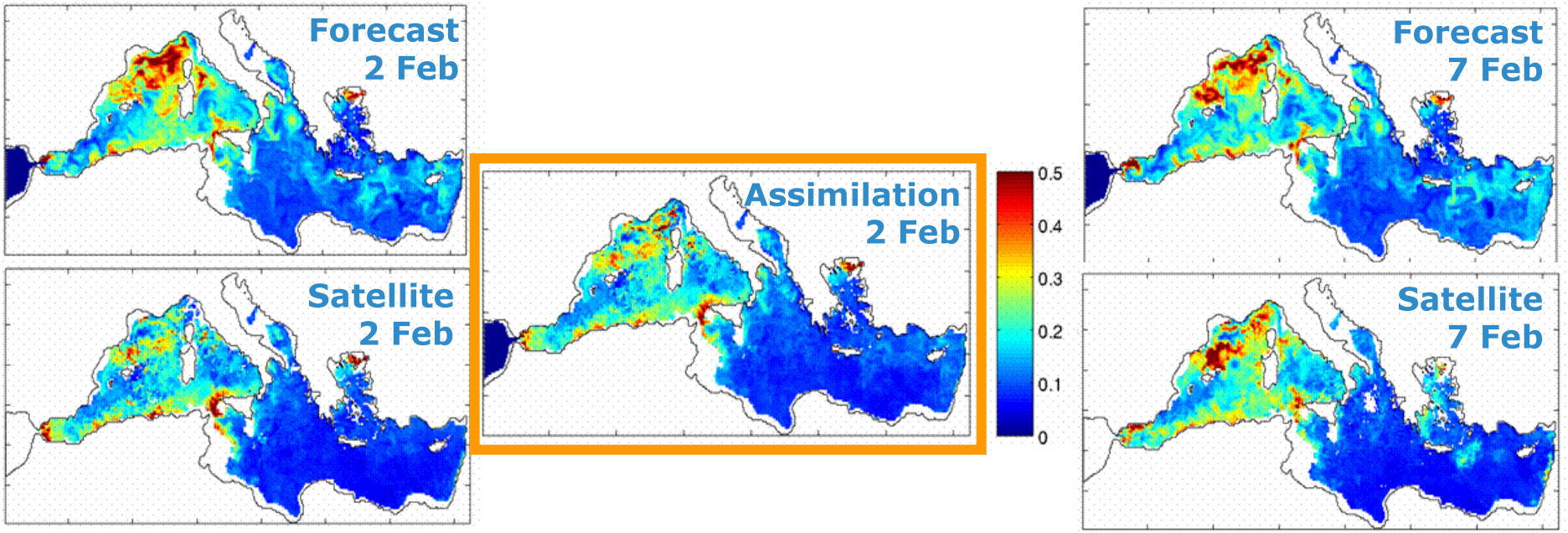
Results of Data Assimilation

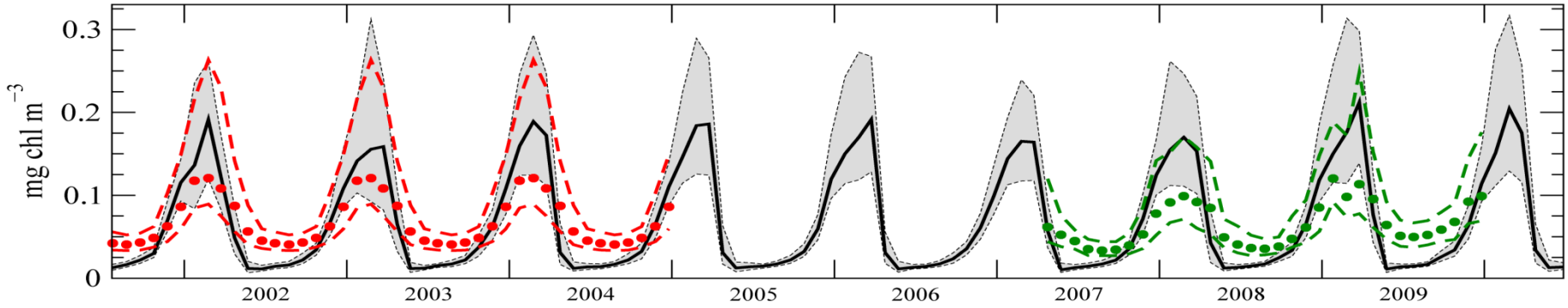
- **DA scheme is based on 3DVAR (Dobricic & Pinardi, 2008)**
- **The DA postpones the start of the bloom in NWM, then model correctly reproduces the bloom in the next 5-day-period forecast**
- **New forecasts show a better consistency with short term evolution of satellite observations (timing and location of local blooms)**
- **Elongation of results temporal series will drive the MyO2 forecast system improvements**



Results of 10yrs re-analysis

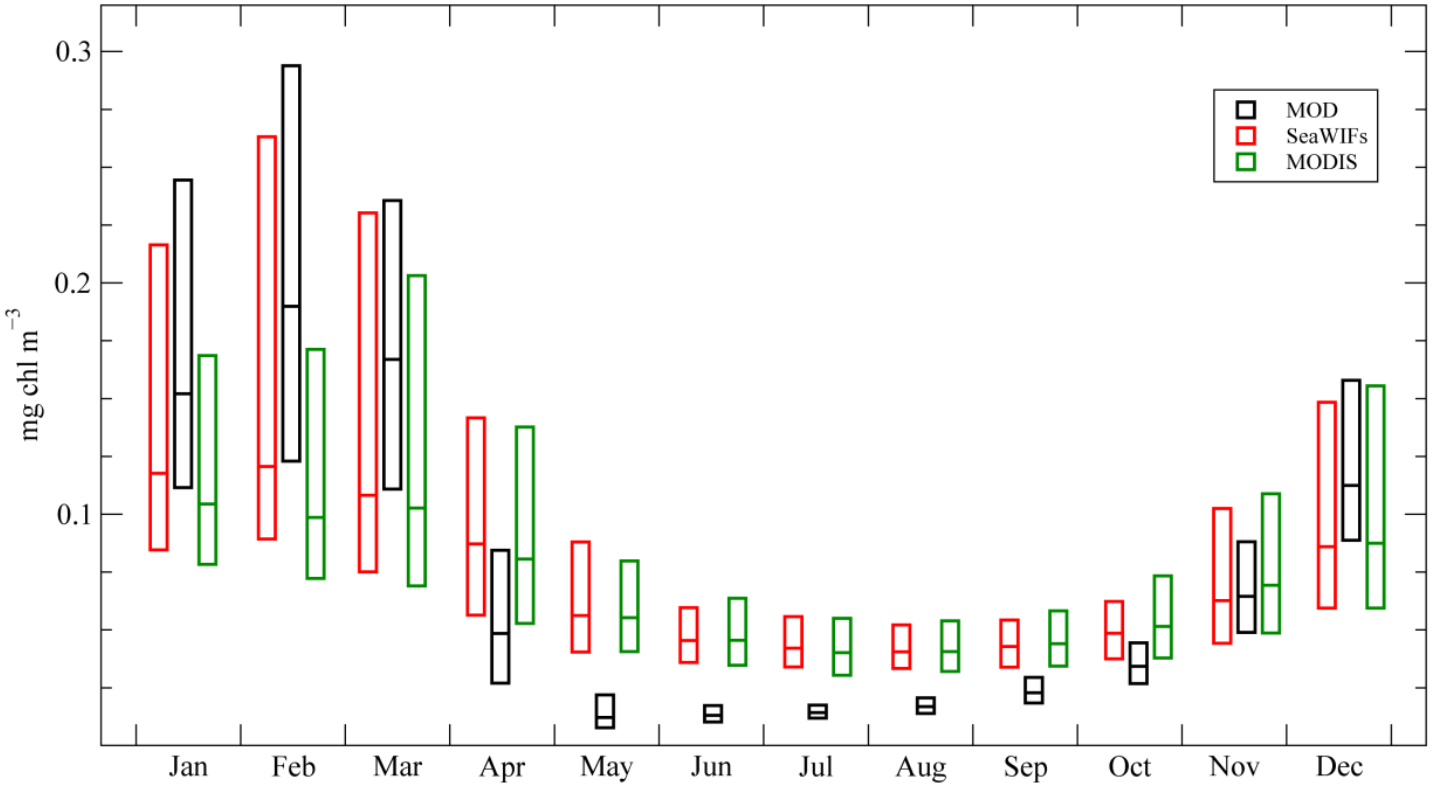
- **Period 2001-2010**
- **Physical forcings**
  Analysis of the operational chain of Med_MFC-Currents model managed by INGV (daily means)
- **Boundary Conditions**
  Climatological (Atmospheric + Terrestrial Inputs)
- **Light Extinction coefficient**
  SeaWiFS dataset
- **Initial fields**
  Uniform value for sub-basins (Medar-MedAtlas)
- **Mesh**
  72 levels, 1/8° resolution

Results of 10yrs re-analysis



- Post-analysis run (**10 years**) concluded: 1st example of decadal simulation of Mediterranean Sea biogeochemistry
- Decadal cycle of spatially aggregated surface chlorophyll concentration for the Mediterranean Sea
  - Model monthly medians **(black line)**
  - SeaWIFs annual climatology median **(red dots)**
  - MODIS monthly medians **(green dots)**
  - The 25th and 75th percentiles are also plotted

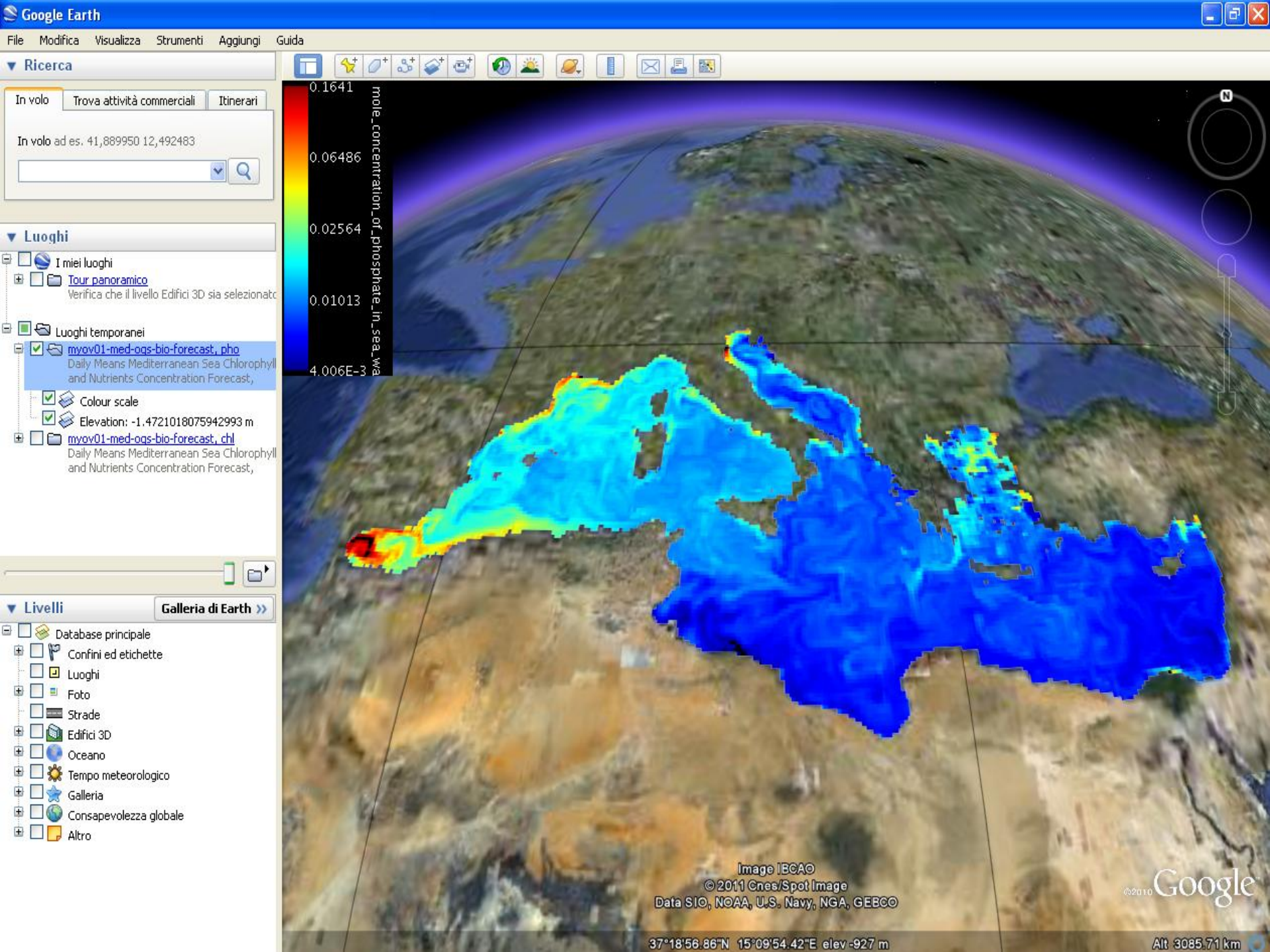
Results of 10yrs re-analysis



Yearly climatological surface chl concentration for the Mediterranean Sea

Box (with median, 25th and 75th percentiles)

The seasonal cycle is correctly reproduced, as well as the gradient between eastern and western Mediterranean, with the latter known to have higher concentration than the former.


Google Earth
File Modifica Visualizza Strumenti Aggiungi Guida
Ricerca
In volo
Trova attività commerciali
Itinerari
In volo ad es. 41,889950 12,492483
Luoghi
I miei luoghi
Tour panoramico
Verifica che il livello Edifici 3D sia selezionato
Luoghi temporanei
myov01-med-ogs-bio-forecast, pho
Daily Means Mediterranean Sea Chlorophyll and Nutrients Concentration Forecast,
Colour scale
Elevation: -1.4721018075942993 m
myov01-med-ogs-bio-forecast, chl
Daily Means Mediterranean Sea Chlorophyll and Nutrients Concentration Forecast,
Livelli
Galleria di Earth
Database principale
Confini ed etichette
Luoghi
Foto
Strade
Edifici 3D
Oceano
Tempo meteorologico
Galleria
Consapevolezza globale
Altro
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0.02564
0.01013
4.006E-3
mole_concentration_of_phosphate_in_sea_wa
N
Image IBCAO
© 2011 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
©2010 Google
37°18'56.86"N 15°09'54.42"E elev -927 m
Alt 3085.71 km

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Conclusions *and* ongoing steps

- **OPATM-BFM model** as a general system to simulate biogeochemistry at different temporal/spatial scales ⇒ *reasonable and not trivial* effort to be applied at regional scales
- **MyO**:
  - fully operational forecast of Med Sea biogeochemistry, integrated in the pan_EU MyO infrastructure
  - data assimilation of surface chl and nominal products in catalogue (6 operational variables + 10 years run)
  - tools developed in R&D activities are now operatively ready for NRT comparison with GOS-ISAC-CNR satellite estimates ⇒ validation website
- **MyO2**:
  - development of DA + upgrade model 1/8° → 1/16°
  - 10 yrs run MyO evaluation + new 10 yrs re-analysis
- **Ongoing R&D**:
  - coupling with ECOSIM, with other OGCMs, development in framework of BFM consortium + HPC developments
  - daily 3DVAR re-initialization during analysis, daily chl sat data
- **OPEC**: pre-operational assessment of “ecosystem services” following MSFD on Lower and Higher Trophic Levels

Many Thanks for your kind attention

References:

http://www.myocean.eu/

http://www.marineopec.eu/

http://poseidon.ogs.trieste.it/cgi-bin/opaopech/myocean