Study of the seasonal cycle of the biogeochemical processes in the NW Mediterranean sea using a 3D coupled model **Mars3D-Eco3M**.

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B. Thouvenin, P. Garreau, F. Carlotti, B.Espinasse

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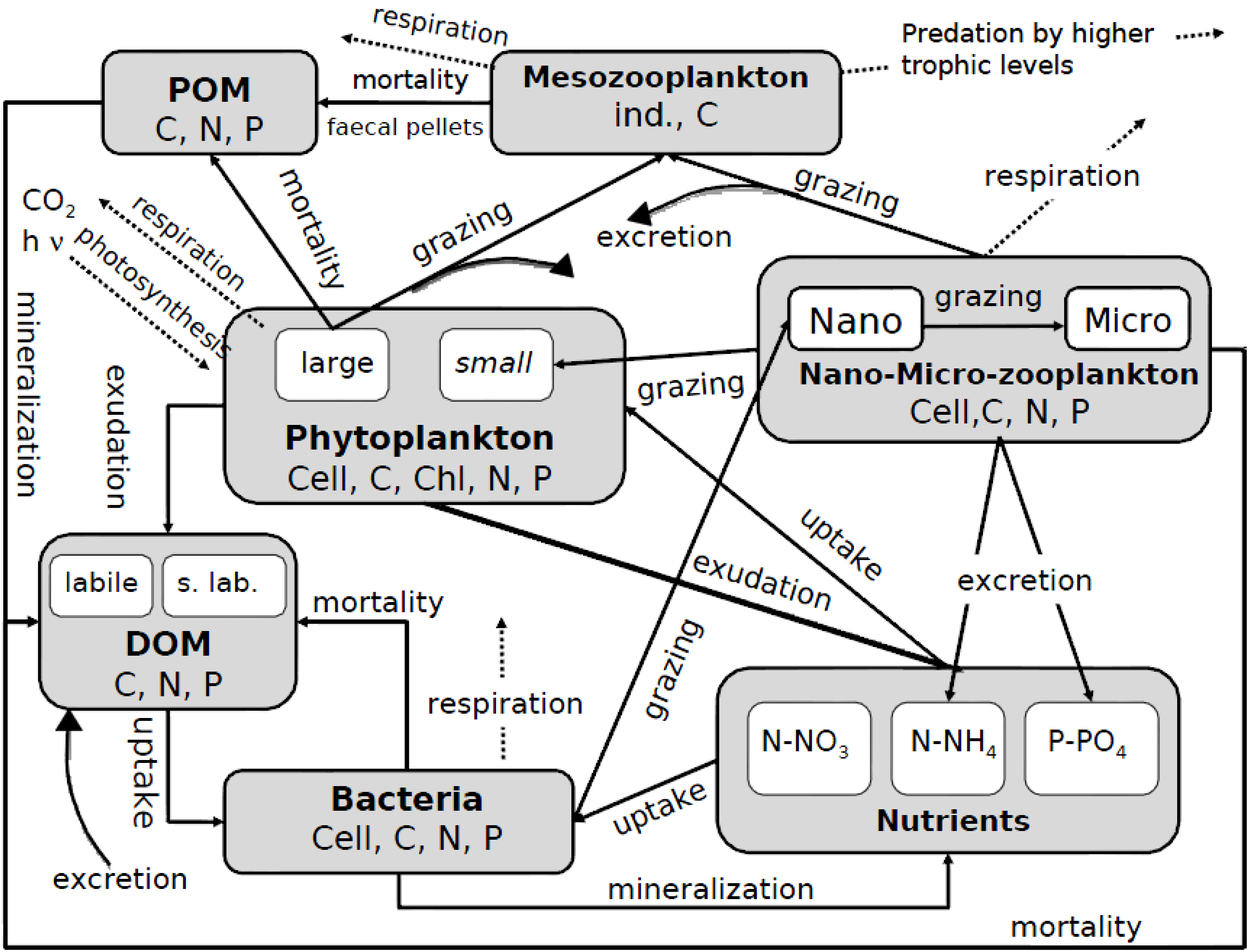
Biogeochemical model : basic schema



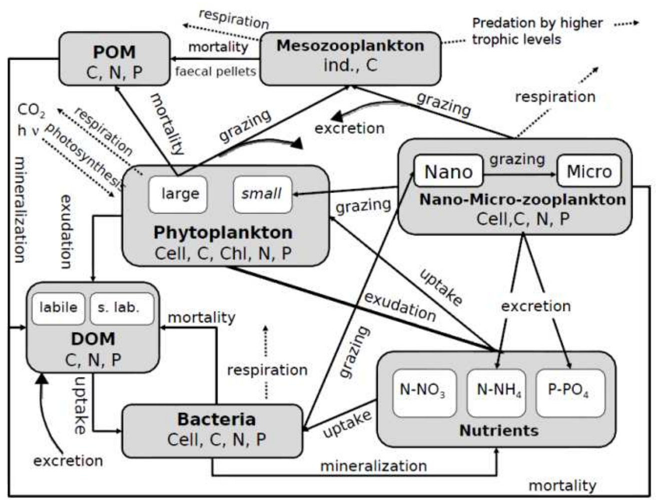
Baklouti et al, in press

Biogeochemical model

- 34 variables including 6 species of organisms :
    - Phytoplankton : Small and Large

      (represent 2 size classes: >5 µm and <5 µm)
    - Bacteries (1 type)
    - Zooplankton : HNF, Ciliates, Copepods

      (represents 3 size classes: nano,micro and mesozooplankton)



- Variable stoichiometry of organisms
- The flux of the different «associated» concentrations is dependent on the «principal» concentration of organism

Interest of such model for the Mediterranean specificities:

- Formulations based on mechanistic processes and already proven in other studies
- Multi-limitation of growth (C and / or N, and / or P following areas)
- Suitable for both oligotrophic areas (open) and eutrophic (coast)
- Allows to study the particular stoichiometry of the Mediterranean

Biogeochemical model

For every variable X of the system (of 34 equations) we have an equation:

$$\frac{dX}{dt} = F_x$$

Where F_x - is a linear combination of functions: growth, nat. mortality, grazing, respiration, primary production, uptake, chlorophyll synthesis, net uptake, mineralization, exudation, remineralization, excretion , etc.

Intracellular content and growth

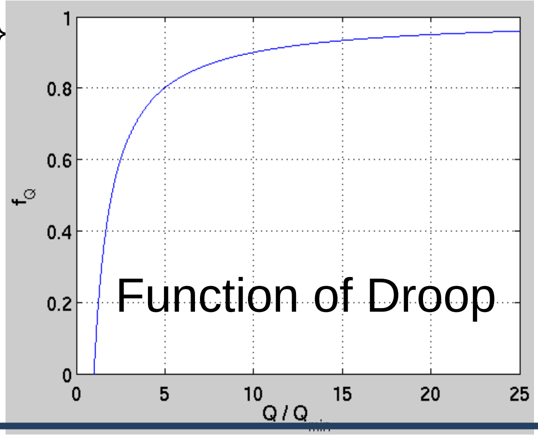
Formula of Droop:

$$\mu = \overline{\mu}_{\max} \cdot \left[1 - \frac{Q_{X_k}^{\min}}{Q_{X_k}} \right]$$

$\overline{\mu}_{\max}$ −Max theoretical growth of organism

$$Q^{X_k} \in \left\{ Q^{C_X}, Q^{N_X}, Q^{P_X} \right\}$$

Q^{X_k} − k content of X



Grazing

formula of Holling II revisited by Kooijman **:**

$$f_{PRED}^{gPREY_i} = \frac{F_i [PREY_i]}{1 + \sum_{k=1}^{n_{PREY}} \frac{F_k}{I_m} [PREY_i]}$$

F − Filtration or attack rate

I_m − Max ingestion rate

Uptake of nutrients

$$f^{upt_X} = V_X^{\max} \cdot \frac{[X]}{[X] + K_X} \cdot \frac{1}{1 + [INH] / K_{INH}}$$

$V_X^{\max}, K_X$ − Model constants

Biogeochemical model

Idea of concentrations in cells/organisms

- Decoupling process of cell division and synthesis of organic carbon

- Use of abundance data that are:
  - More and more numerous (flow cytometry, COGO, Zooscan, ...)
  - Direct (without conversion factors)

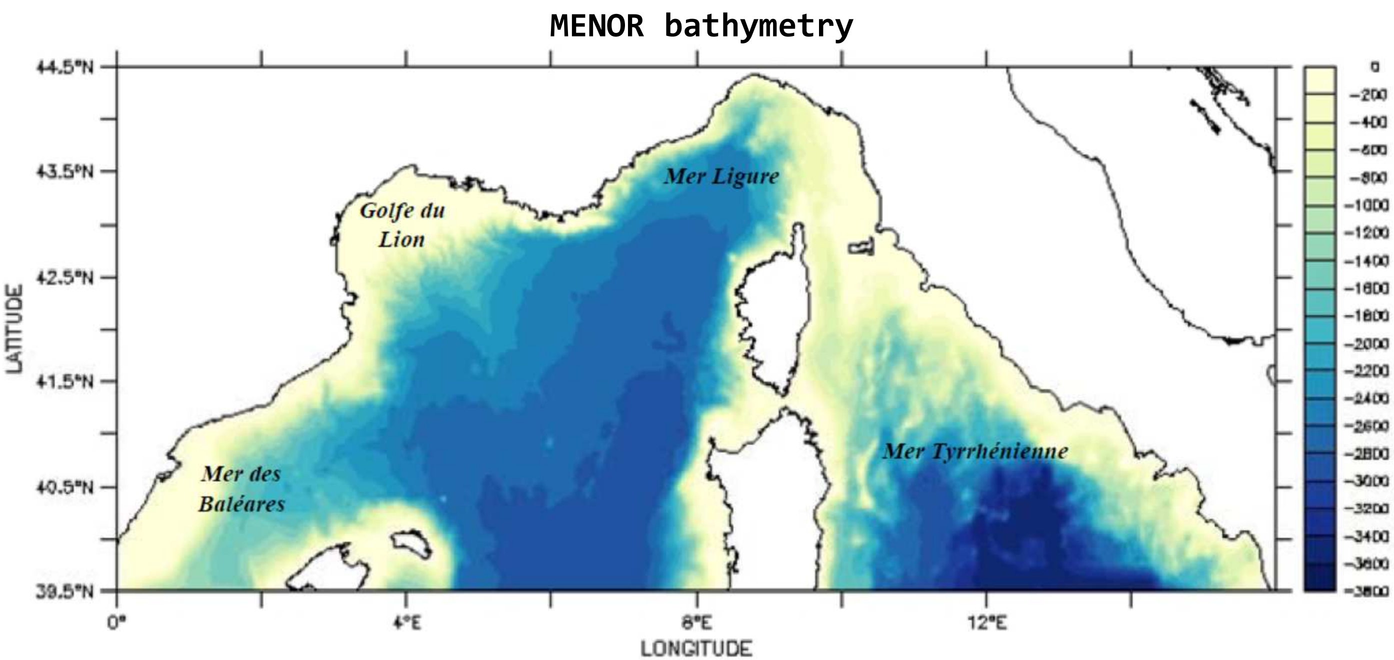
- Using the kinetic parameters of "grazing" expressed in number of prey by predators per unit time (Christaki et al., 2009)

- Advection concentrations associated with those cells (and therefore not independent)

Coupled model **MARS3D-ECO3M**

Characteristics of simulation

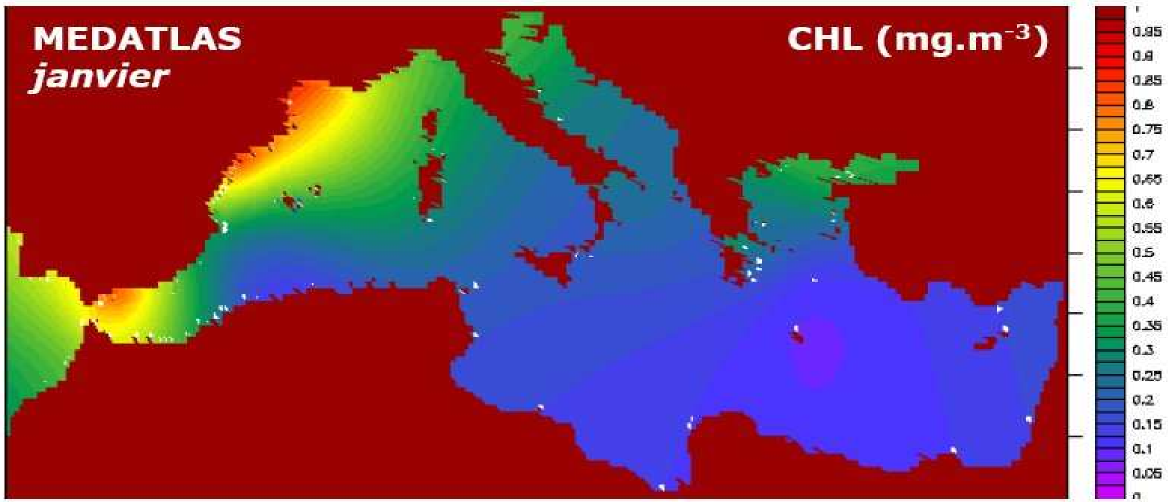
- Used configuration Mars3D: MENOR (Méditerranée Nord-Occidentale)
- 1100*463, 30 sigma layers (resolution : 1,2 km)
- Parallel version on 256 processors with automatic running of jobs for long-term computations (some years)
- Time step :
  - dt_MARS3D : 50 - 75s
  - dt ECO3M : every 31*dt_MARS3D



Initial and boundary conditions

- Initial and boundary conditions are taken from the MEDATLAS database
- **phytoplankton** in division of Chltot (50% small and 50% large) phyto with mean intracellular content
- **bacteries** :
  $BAC_{cell} = 10^{16}$ Chltot
- **zooplancton** :
  $COP_{cell} = 7.10^{4}$ Chltot
  $HNF_{cell} = 10^{13}$ Chltot
  $CIL_{cell} = 3.10^{9}$ Chltot
- **MOD labile** : DOC_L = 2 * Chltot
- **DOC_SL** = 19 * DOC_L
- **POC** = Chltot

Vidussi et al., 2001
Marty et al., 2008
Tanaka, 2009
Christaki et al., 2011
Cauwet (1997)
Avril (2002)
Mari et al. (2001)



Forcing of the model: rivers

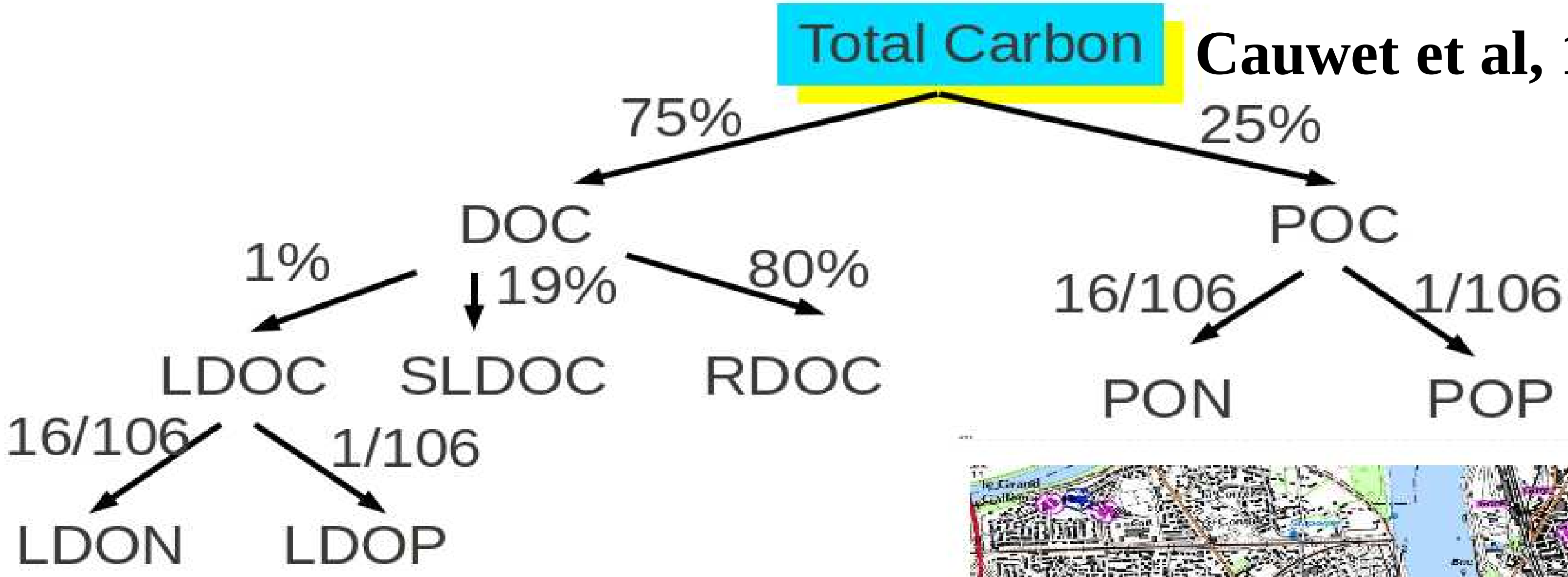
Different tests showed important influence of these rivers (not just of Rhone) on the biogeochemistry

<u>Observed data:</u>

→ **for the Rhone: runoffs and nutrients**

→ **for the Ebre and Tibre: runoffs, with nutrients of the Rhone**

Cauwet et al, 1996, Redfield

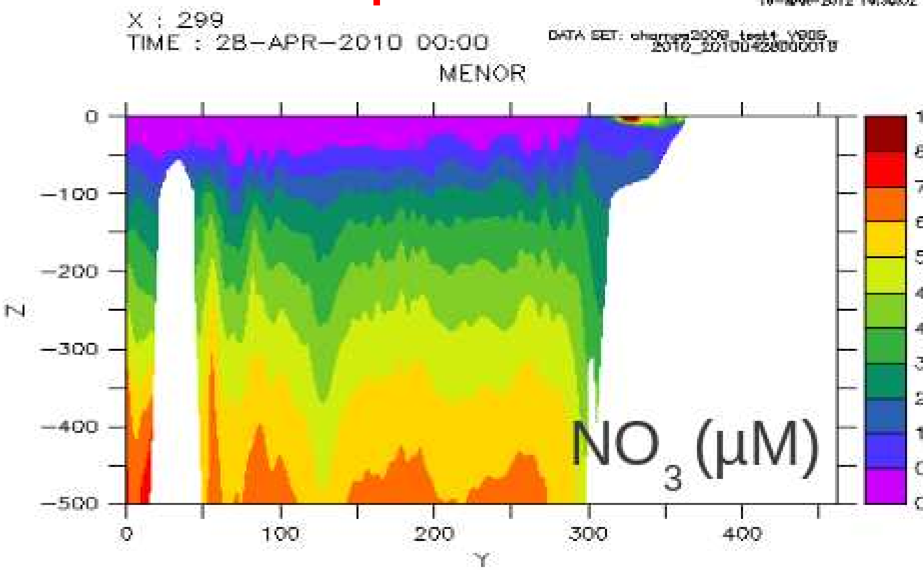


Total Carbon, NO3,NH4,PO4 -

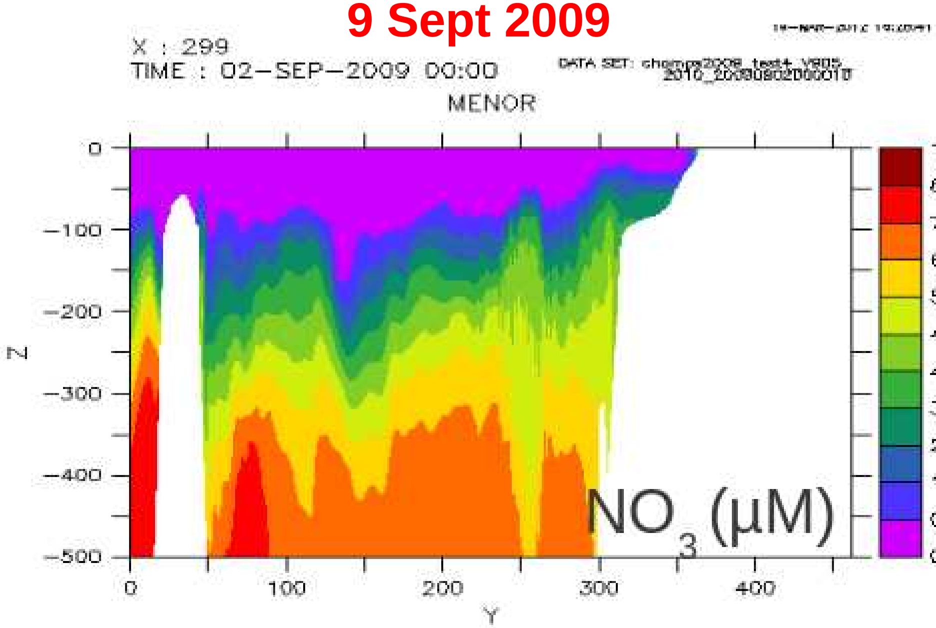
- measured parameters (Rhone; station a Arles <u>**№ 06131550**</u>)

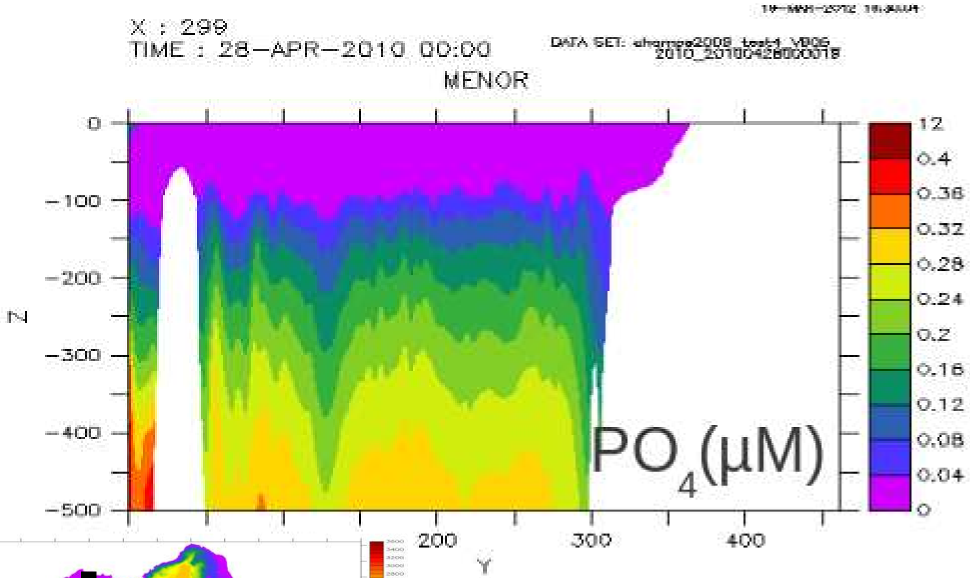
RESULTS: general characteristics

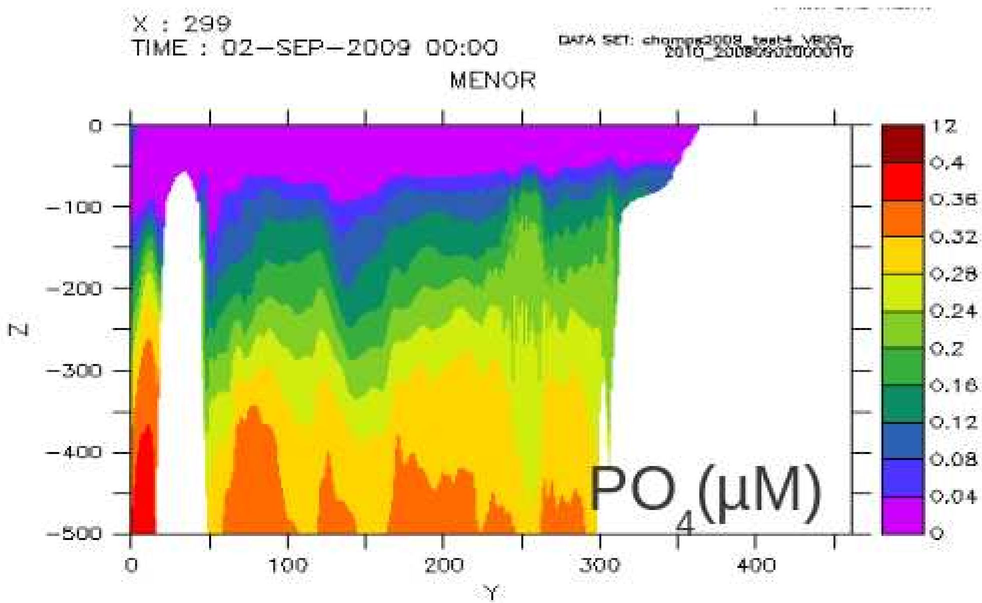
28 April 2010

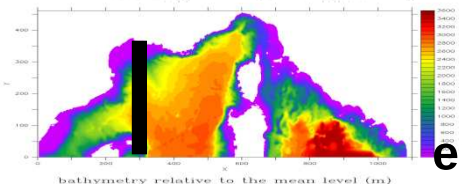


9 Sept 2009





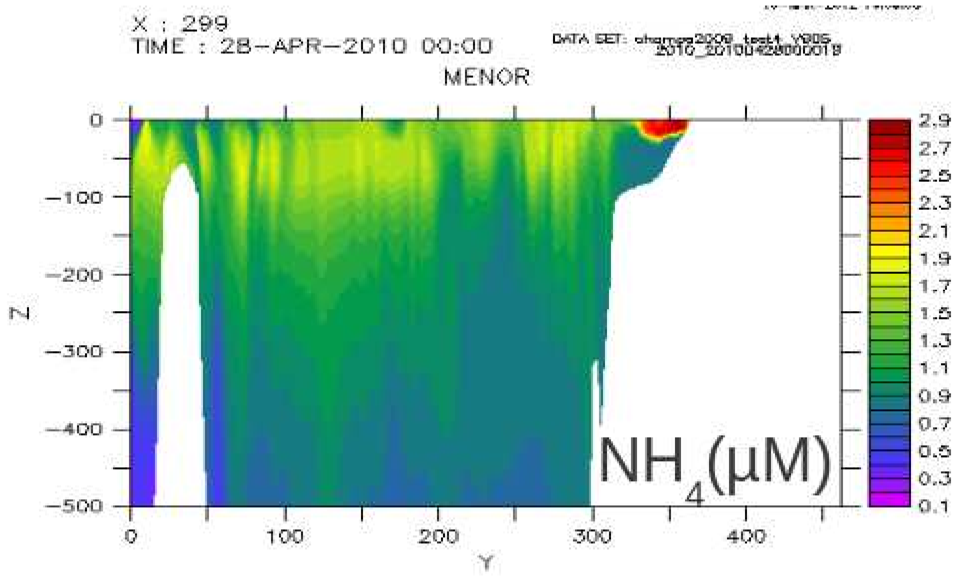


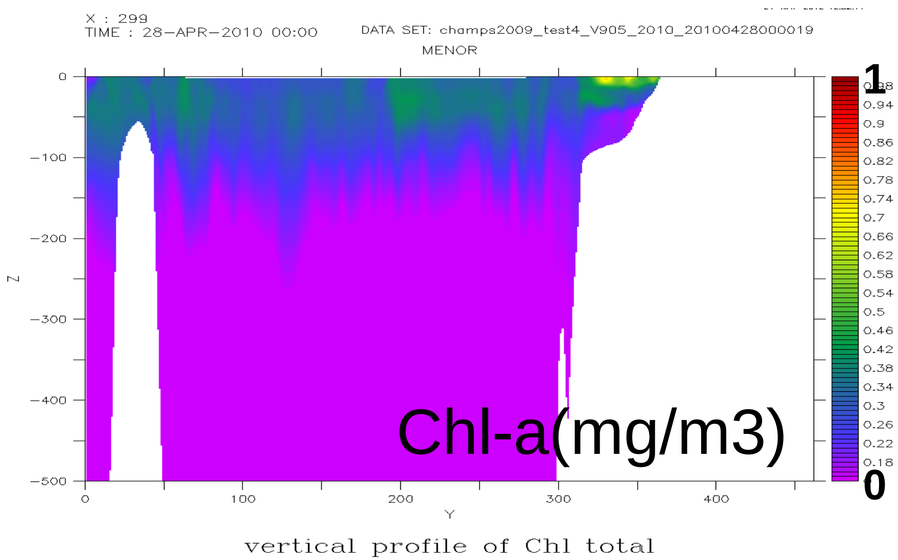


Comparison of two contrast situations:
end of April (bloom) and beginning of September (end of stratified period)

RESULTS: general characteristics

28 April 2010





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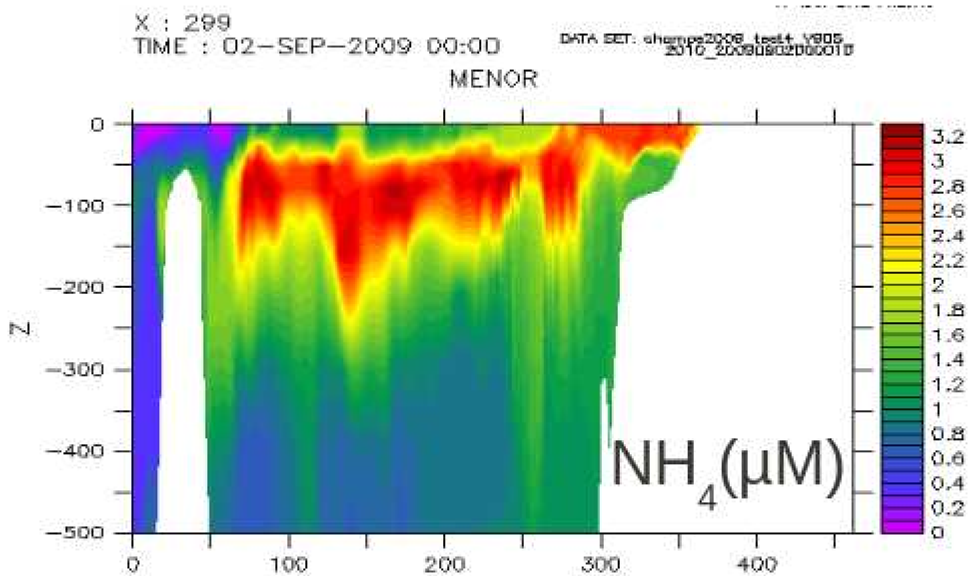
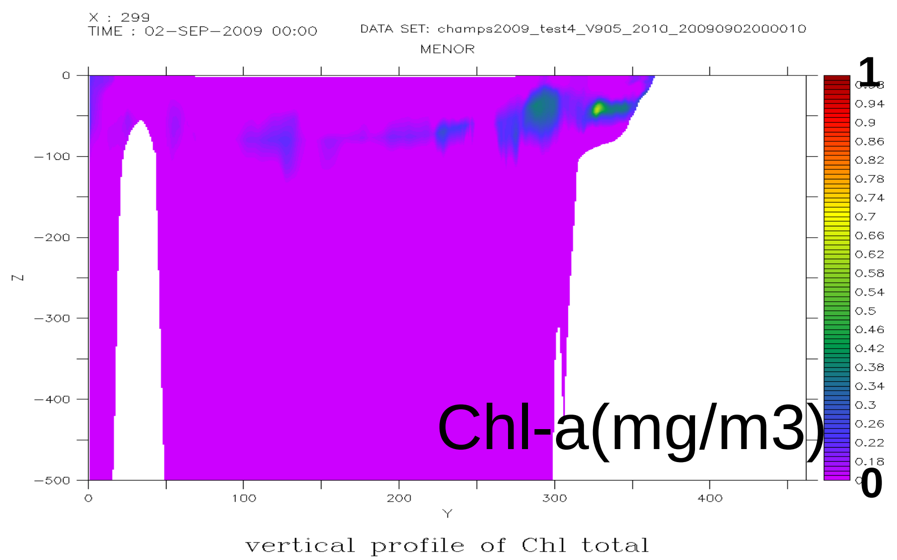
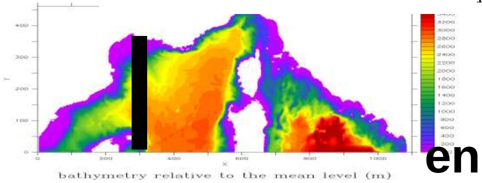


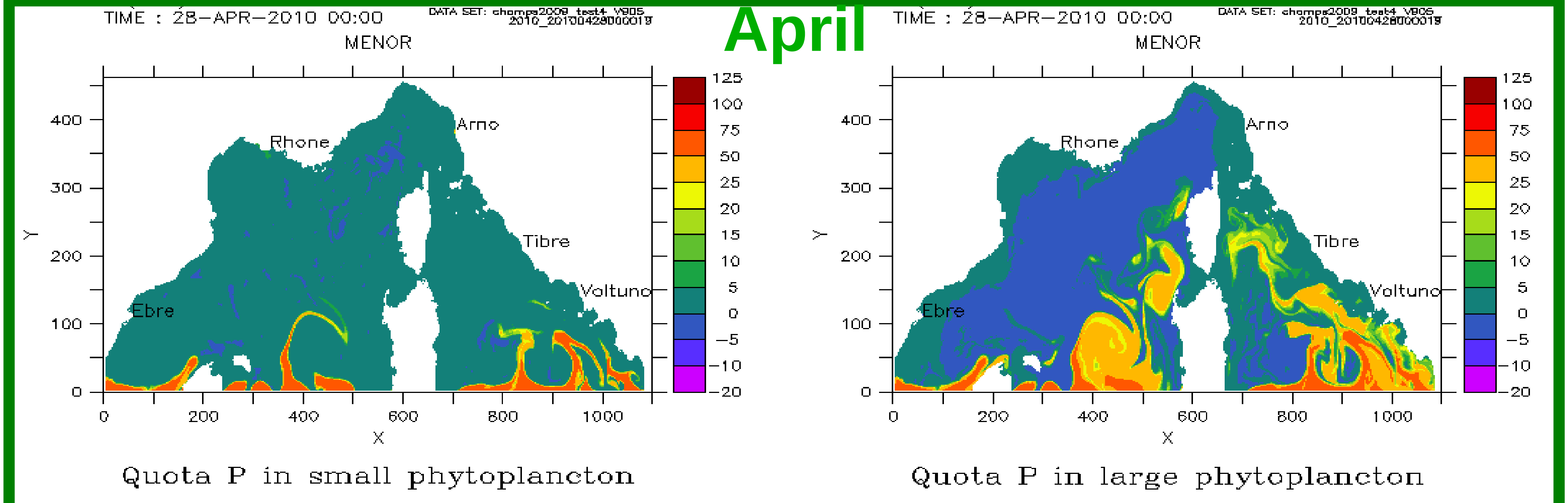




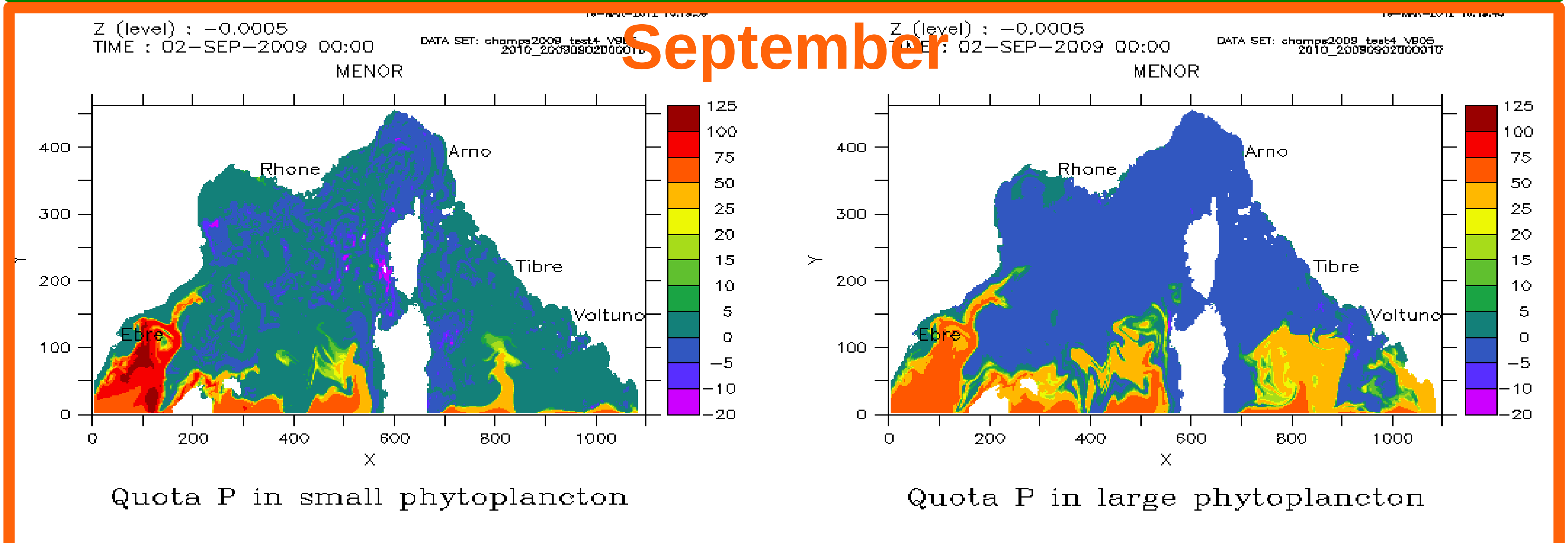
Comparison of two contrast situations:
end of April (bloom) and beginning of September (end of stratified period)

P content for the phytoplankton in %

April

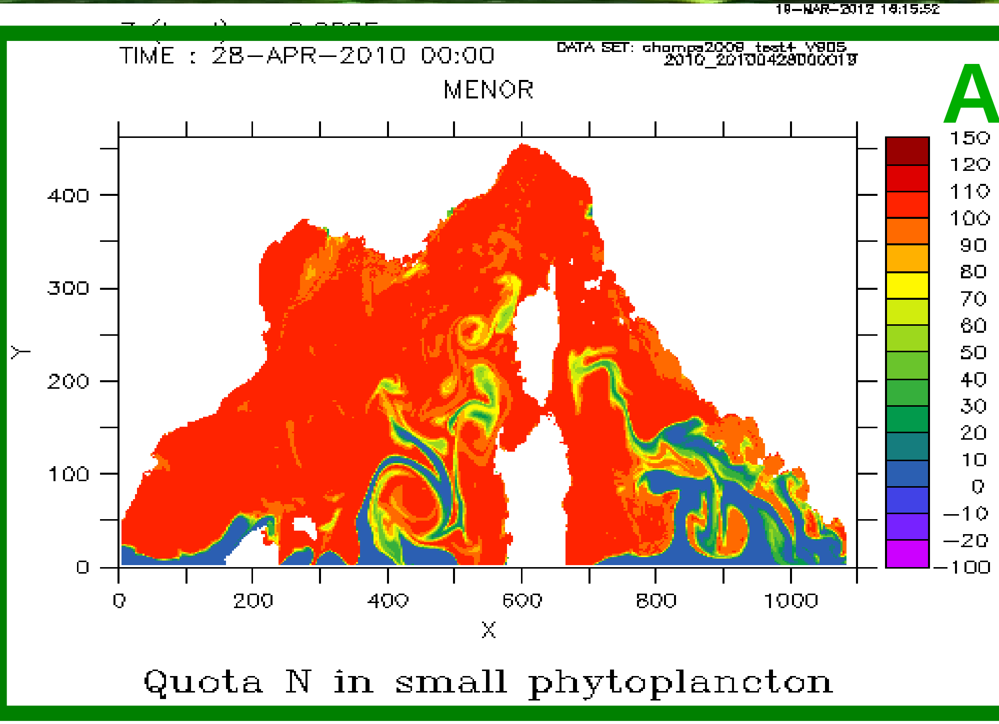


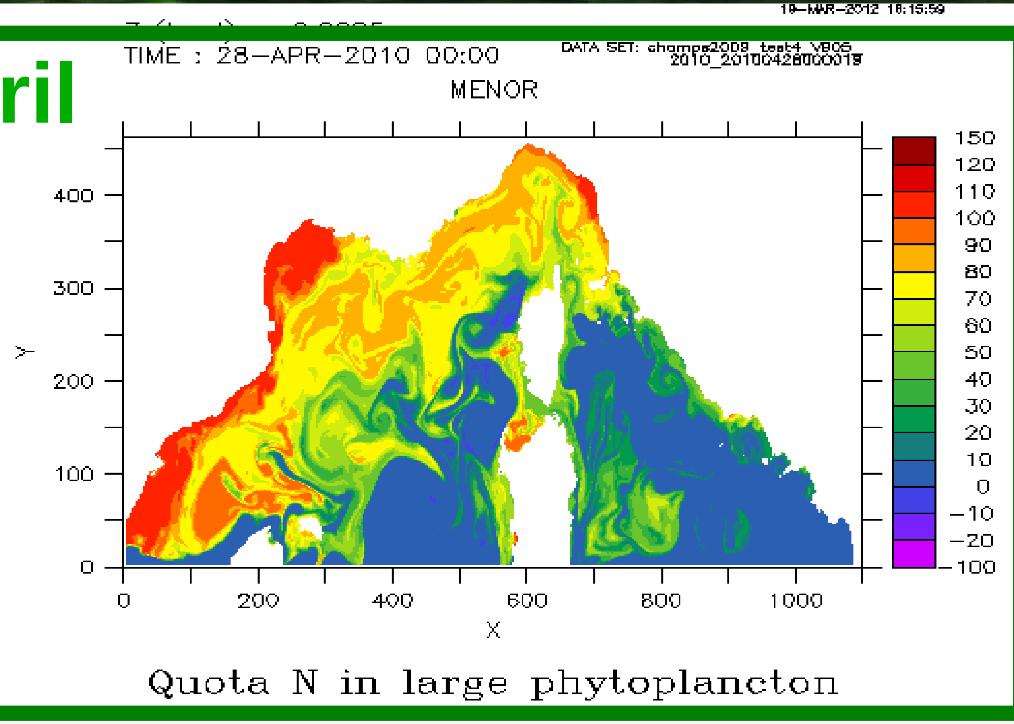
September



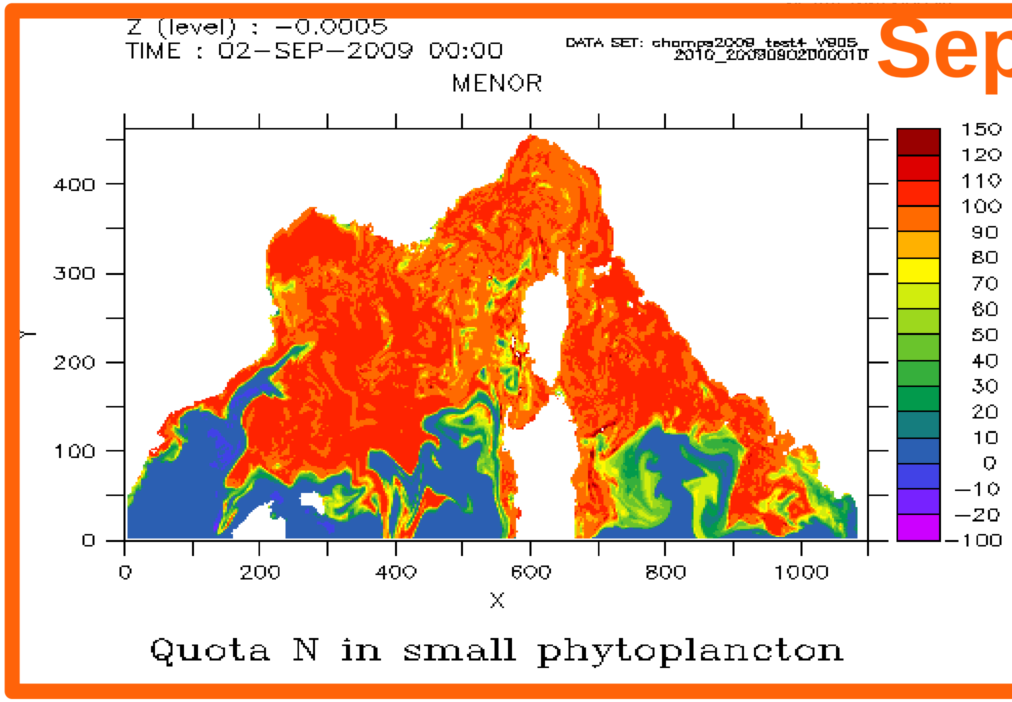
N content for the phytoplankton in %

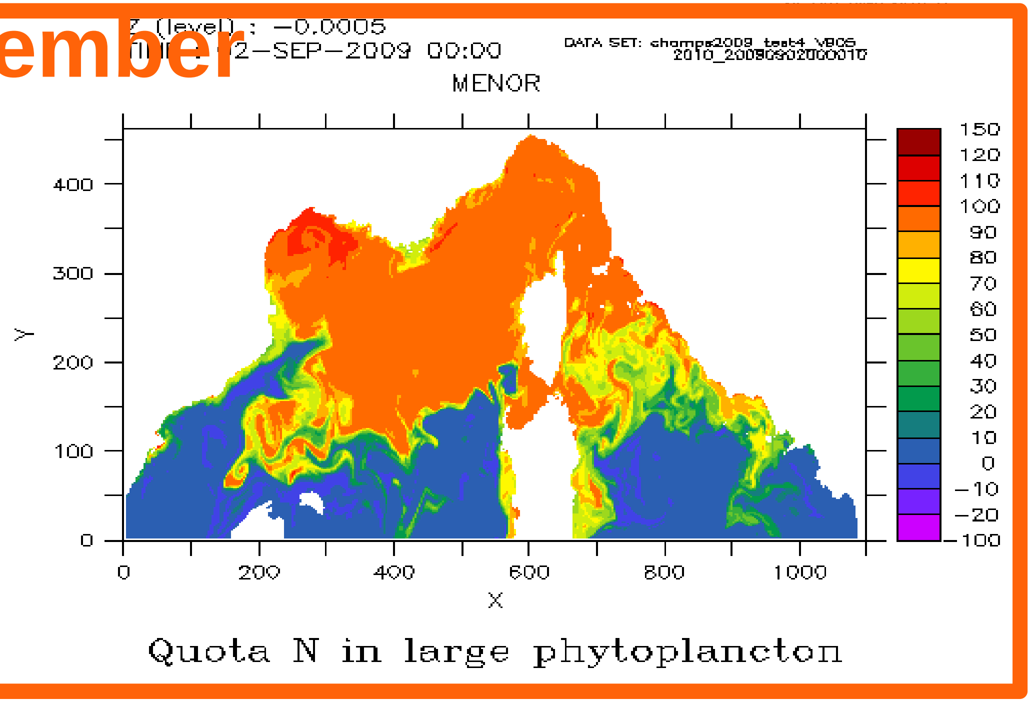
April





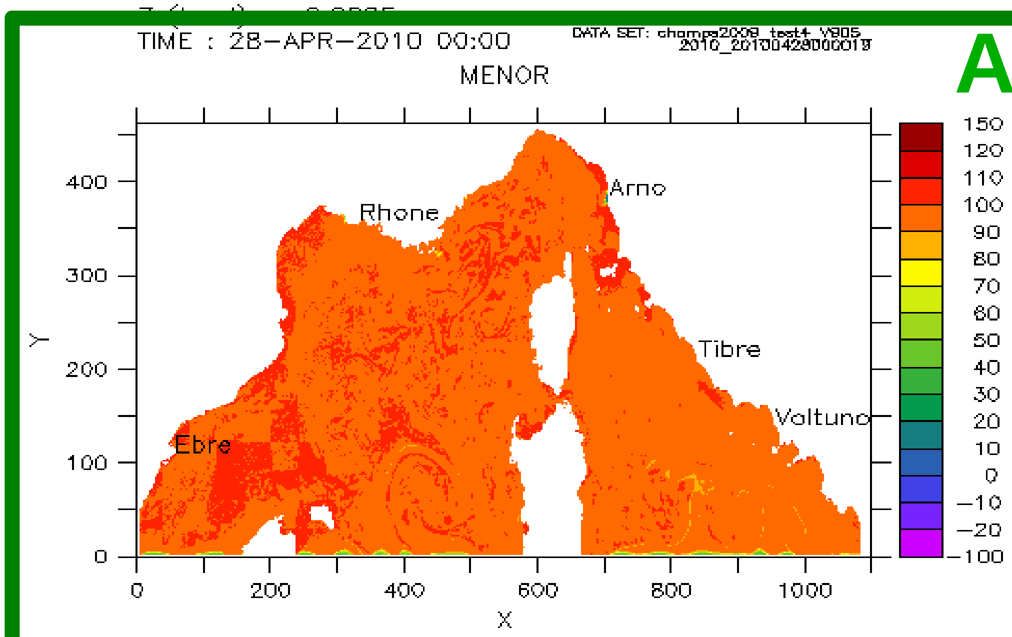
September



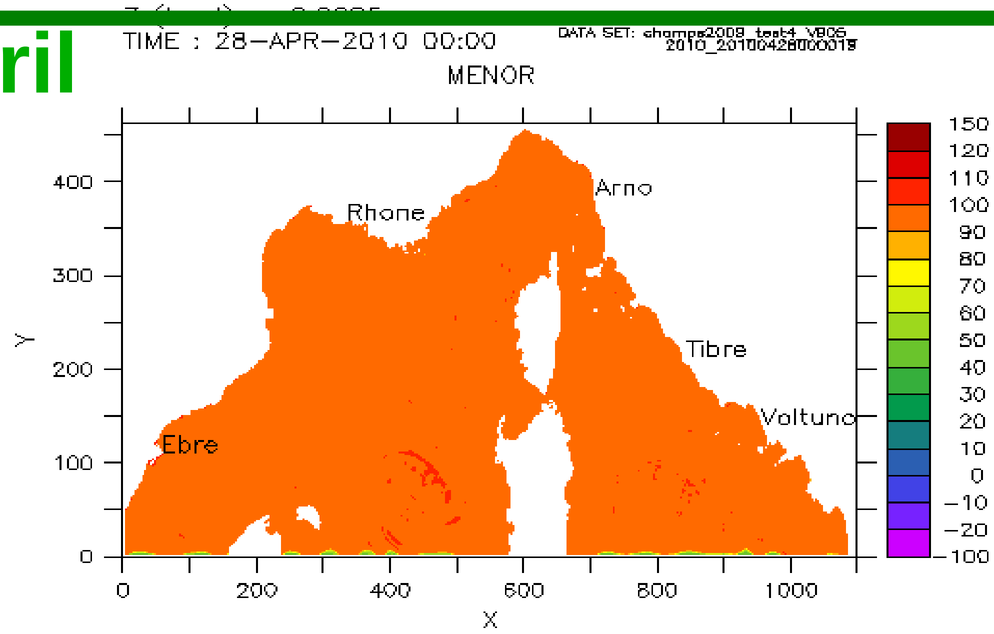


C content for the phytoplankton in %

April

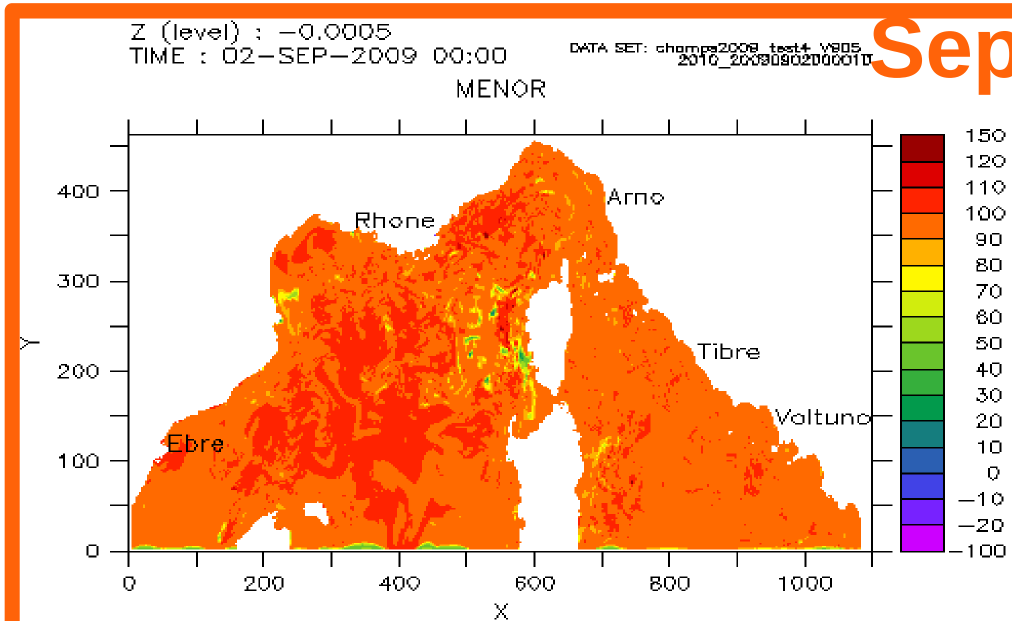


Quota C in small phytoplancton

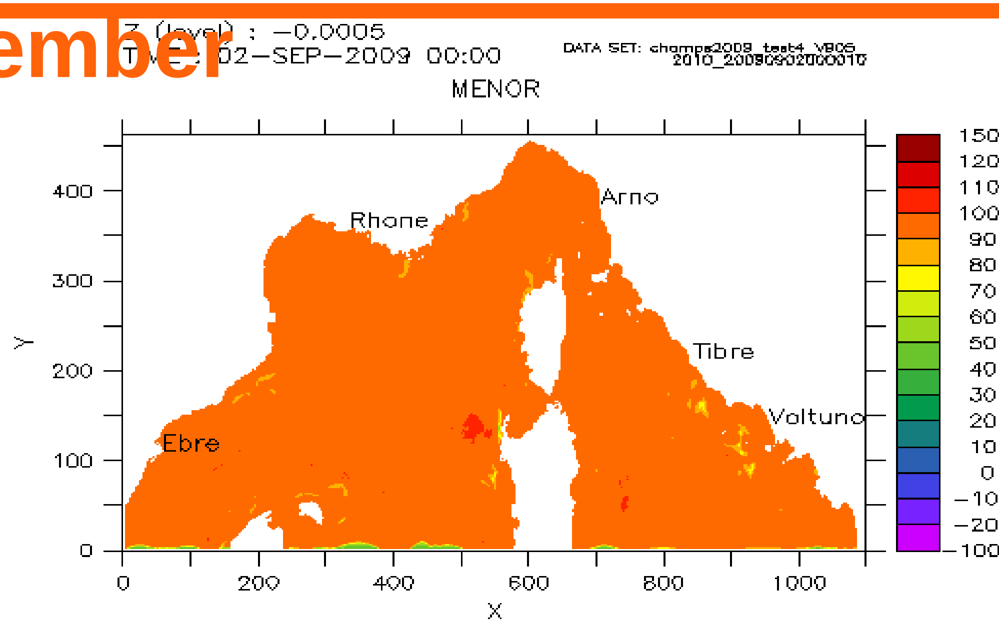


Quota C in large phytoplancton

September

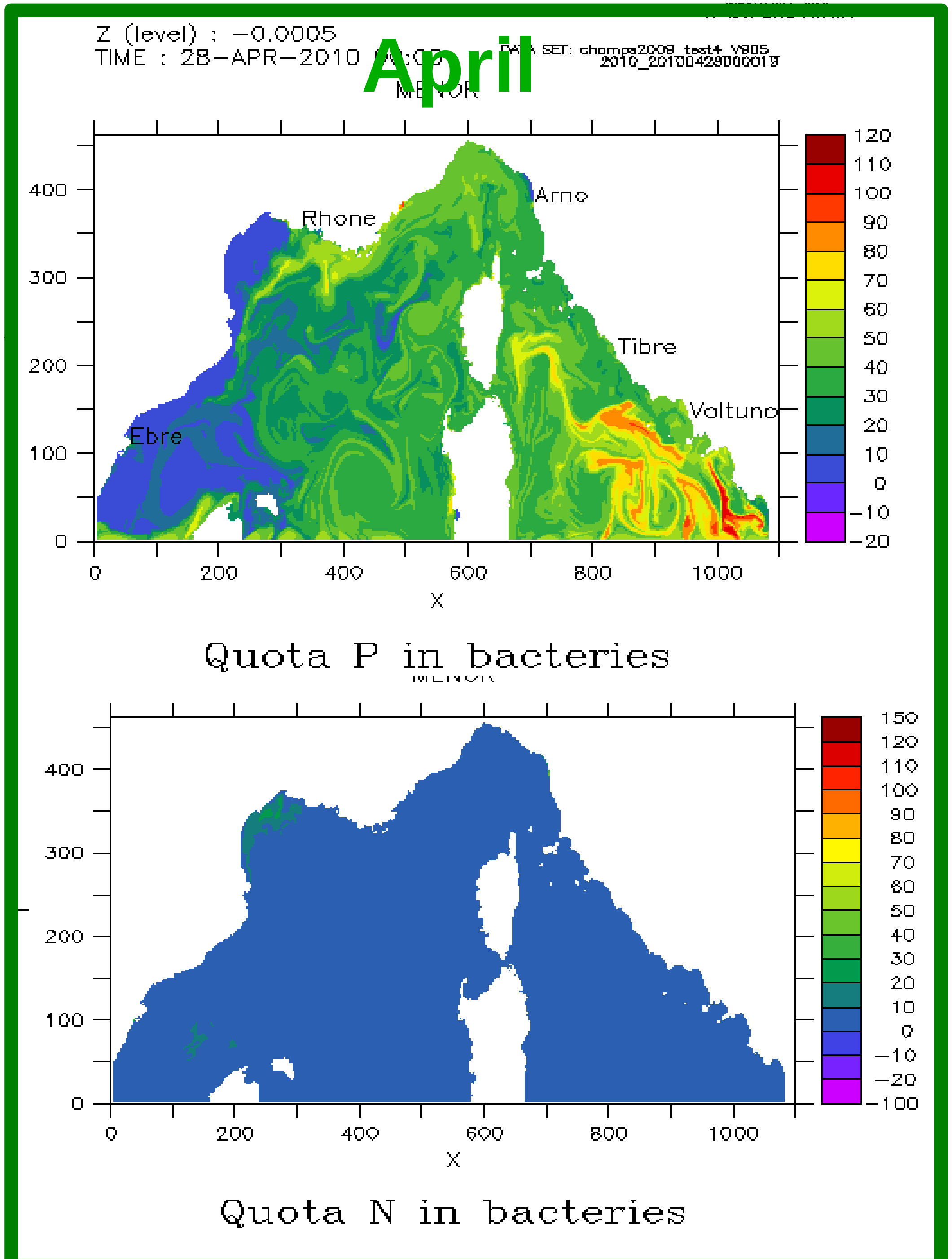


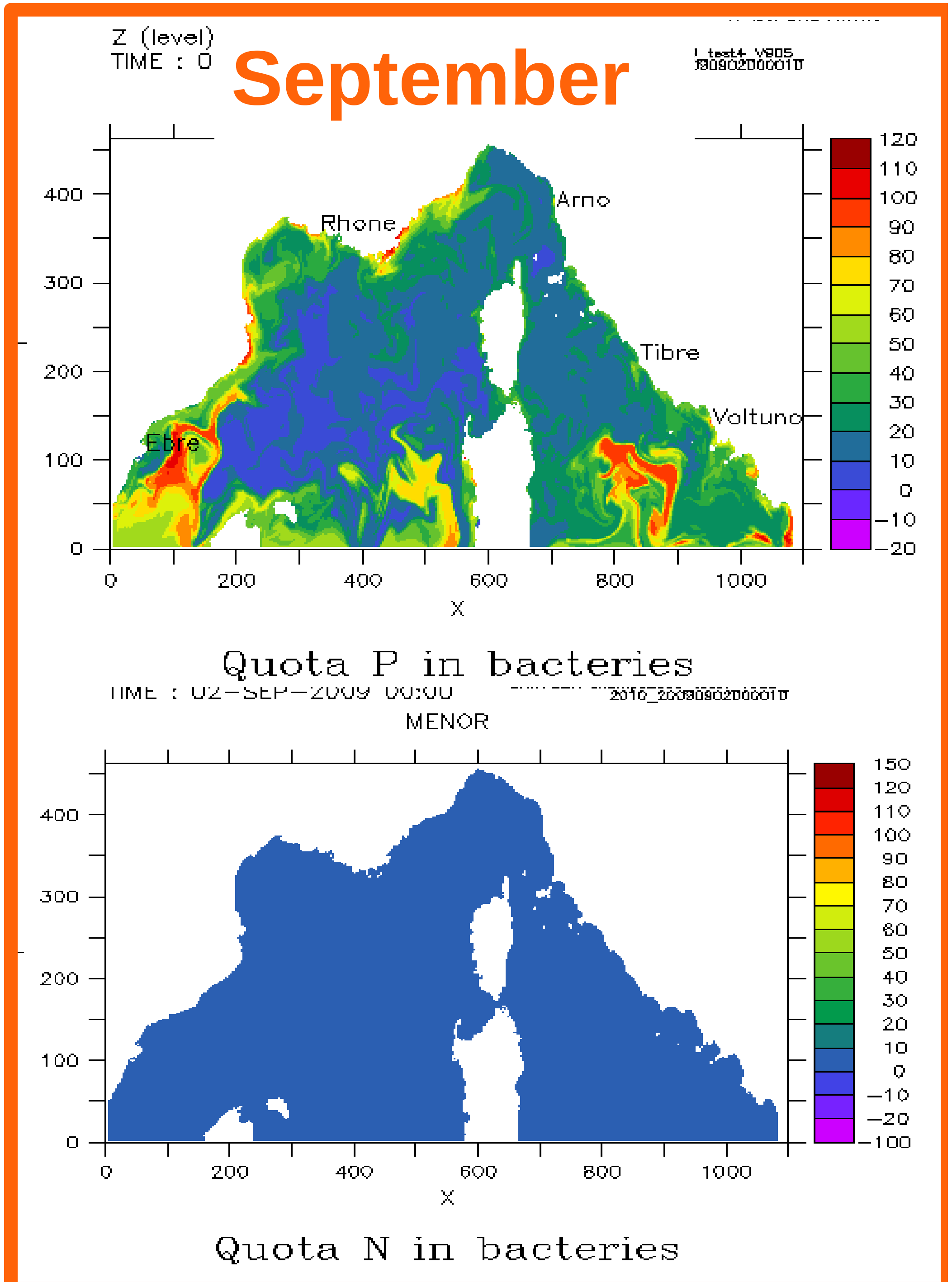
Quota C in small phytoplancton



Quota C in large phytoplancton

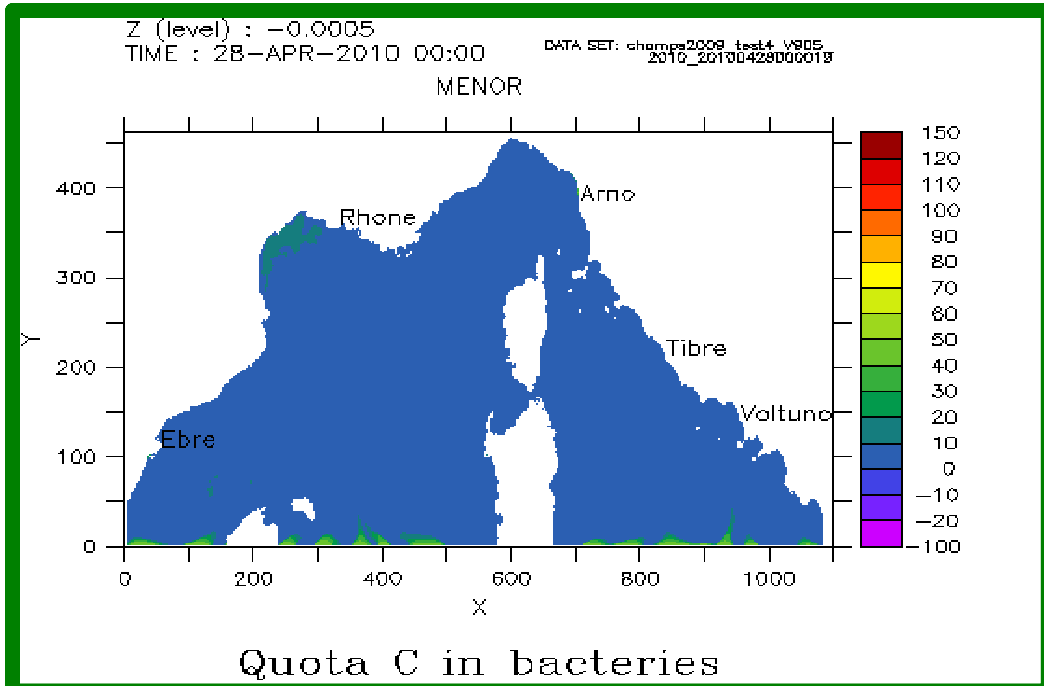
P and N contents for the bacteries in %

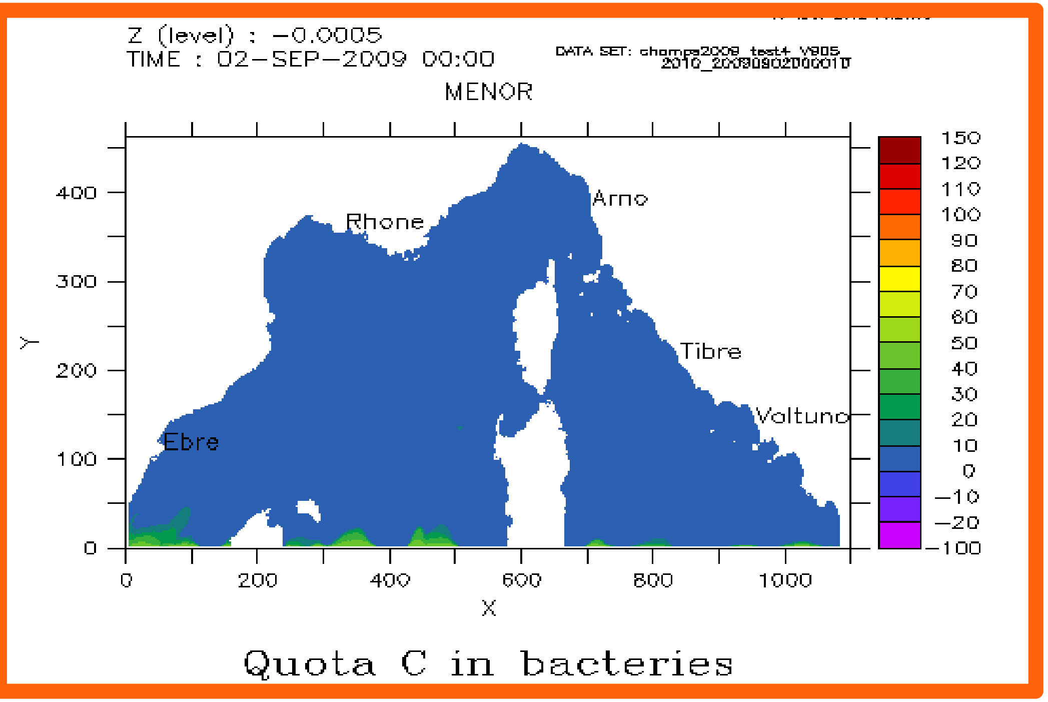




C content for the bacteries in %

April **September**





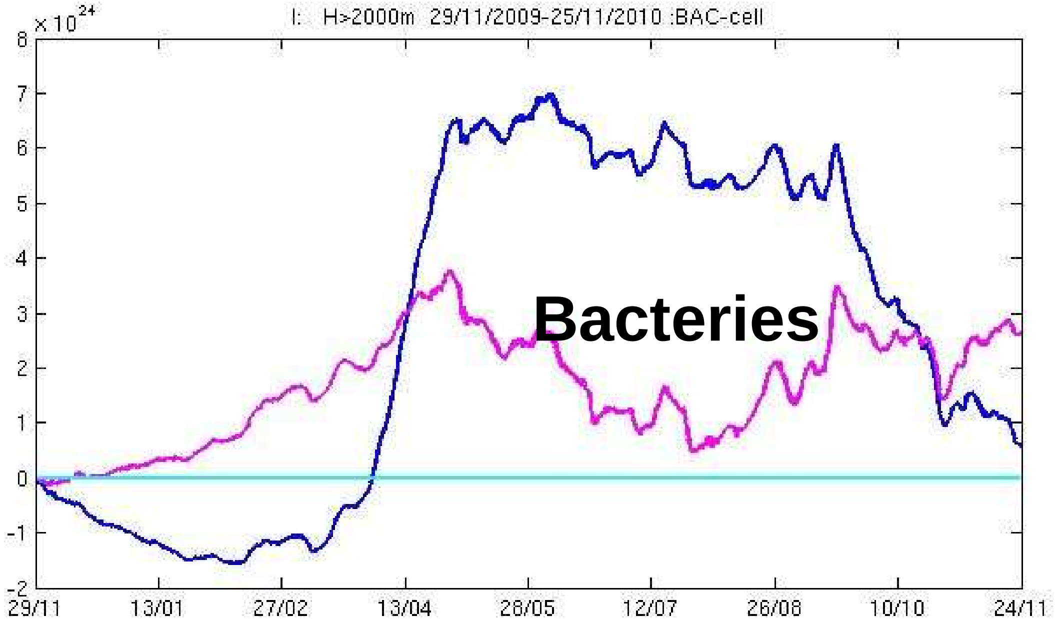
Conclusion :

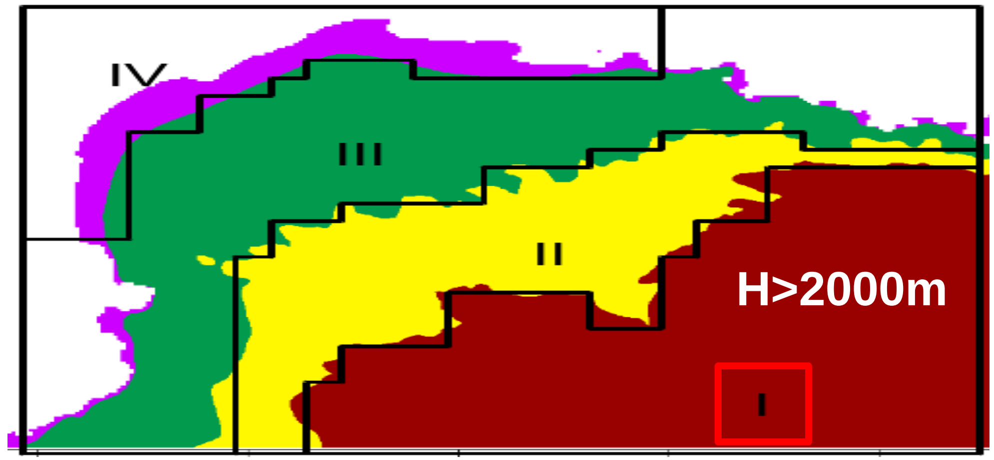
- Bacteries co-limited in N and C

- Phytoplankton limited in P; what coherent with other studies in MENOR (Romero et al, 2011, Diaz et al, 2001, Thingstad et al; 1993, etc.)

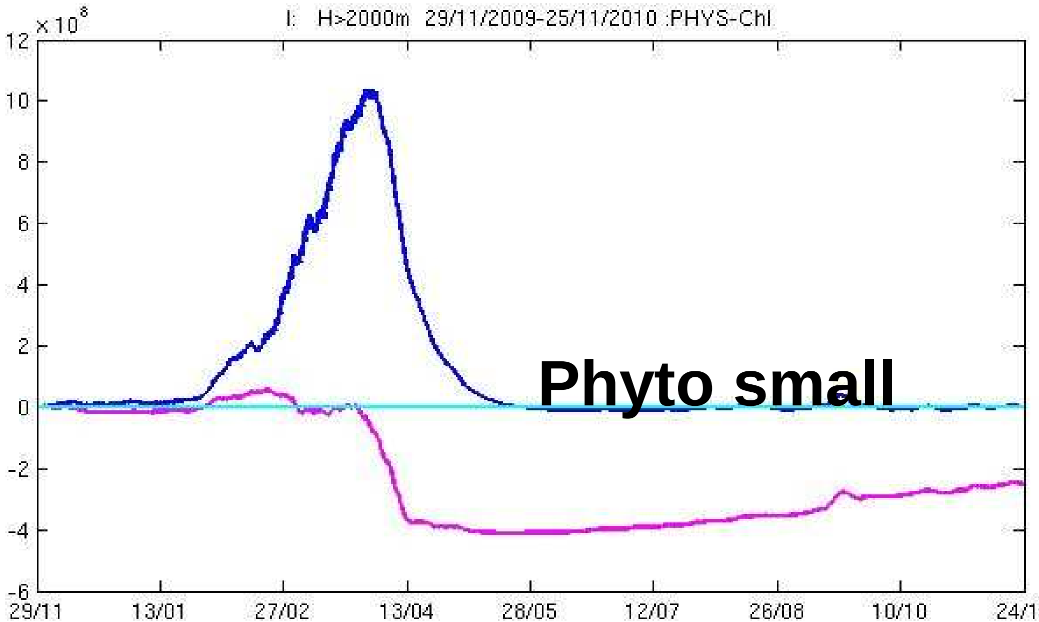
- In all cases : limitations are more marked in the end of summer

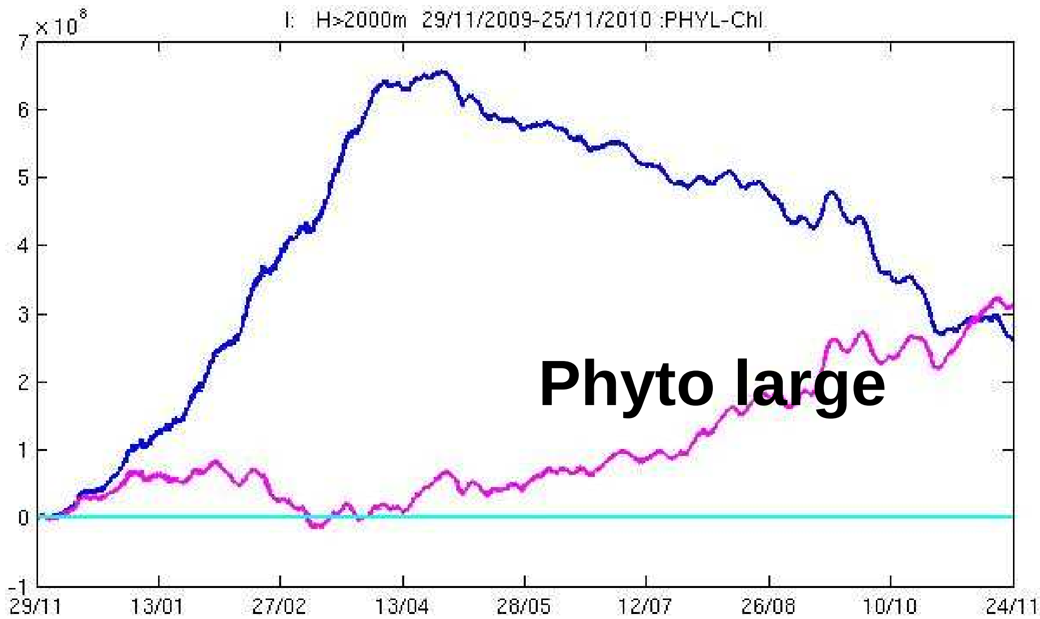
Time evolution of the variable's stock
29/11/2009-29/11/2010



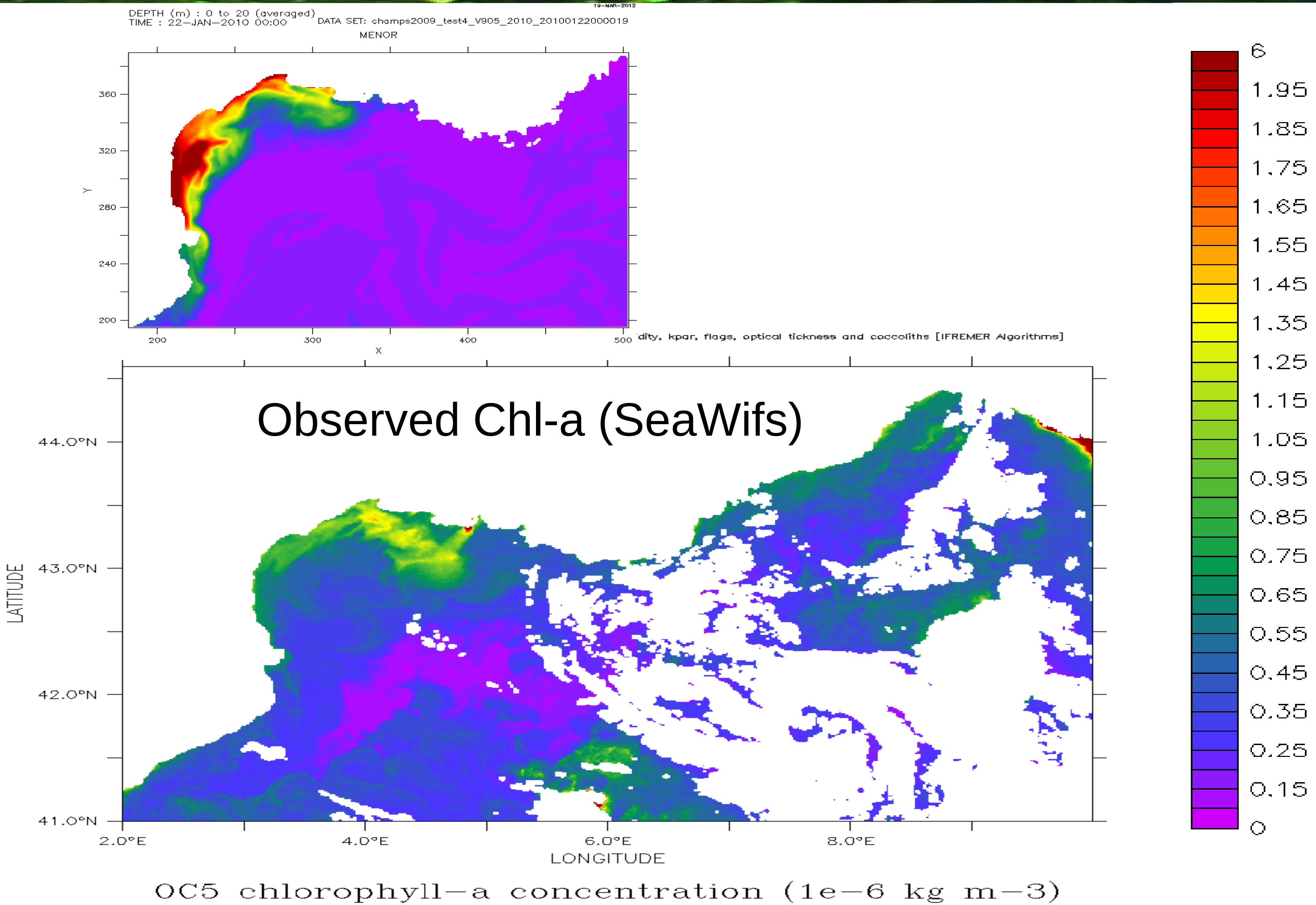


Blue line – variable stock inside (mass)
Rose line – coming/outcoming flux by bondaries

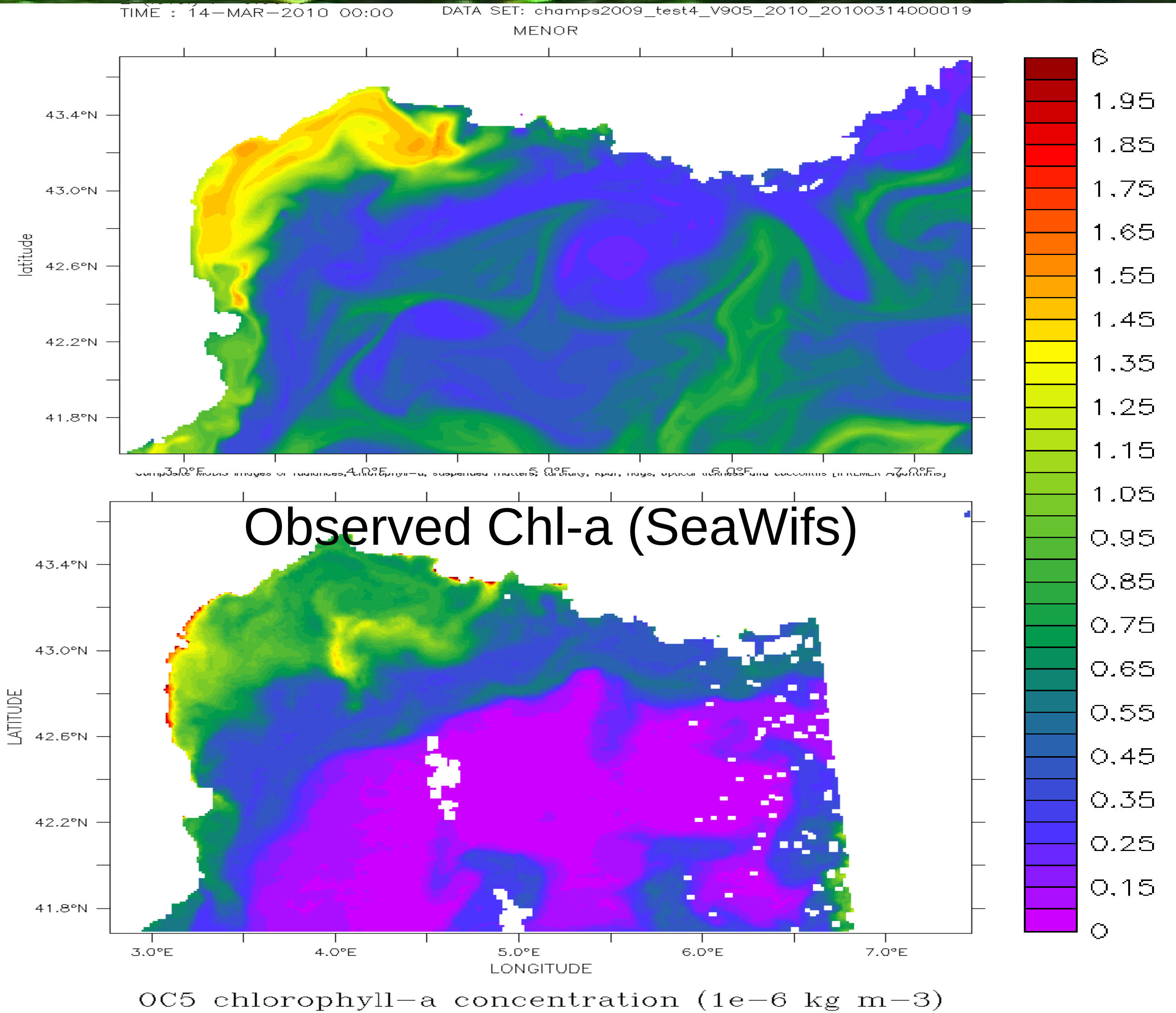




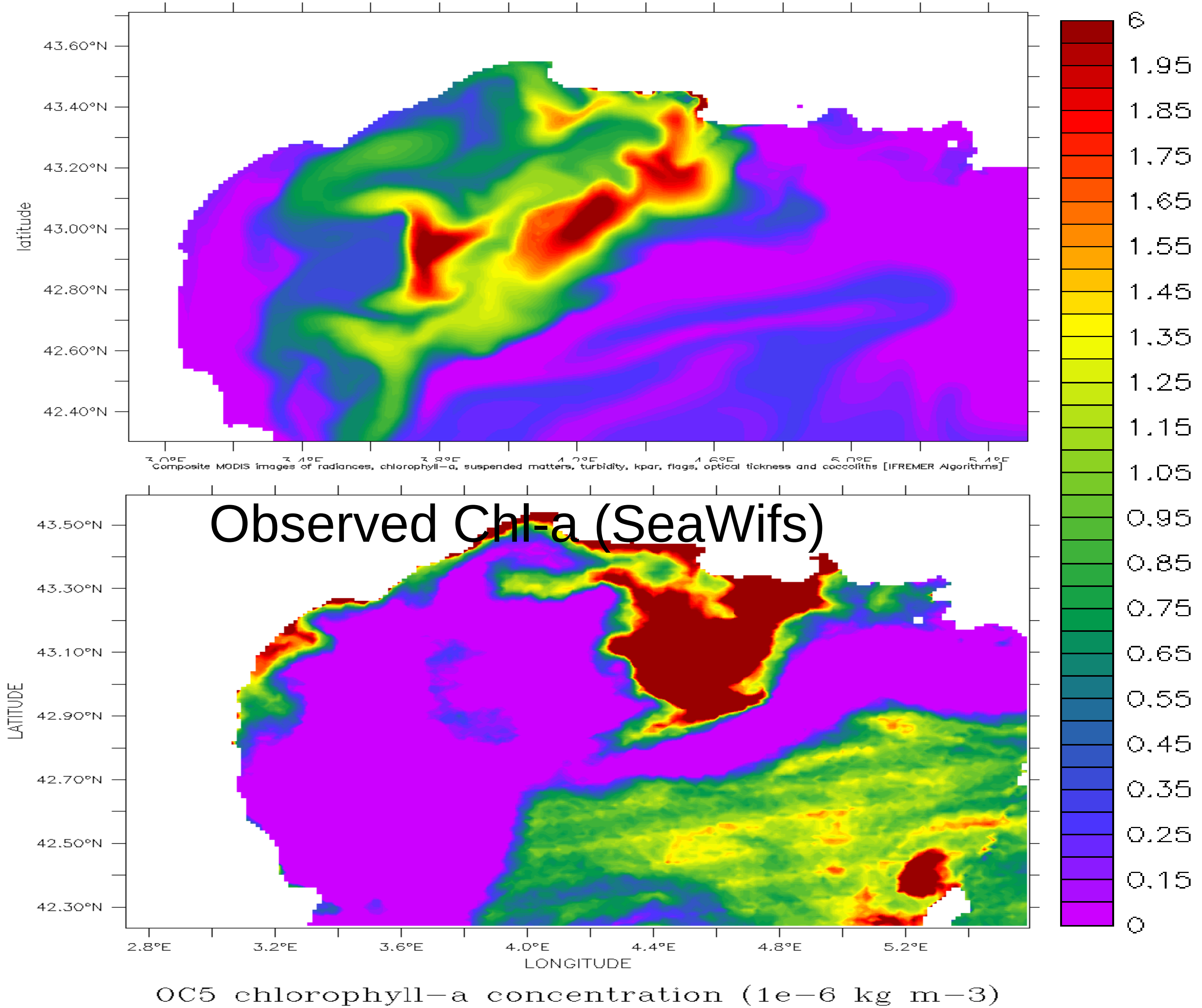
Comparison of Chl-a with satelite data 22/01/2010



Comparison of Chl-a with satelite data 15/03/2010

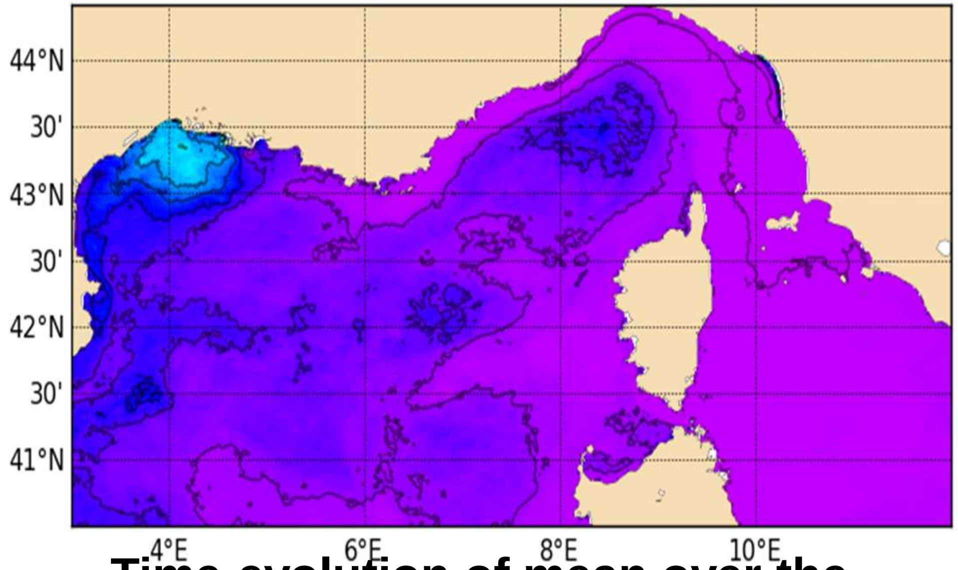


Comparison of Chl-a with satelite data 28/04/2010

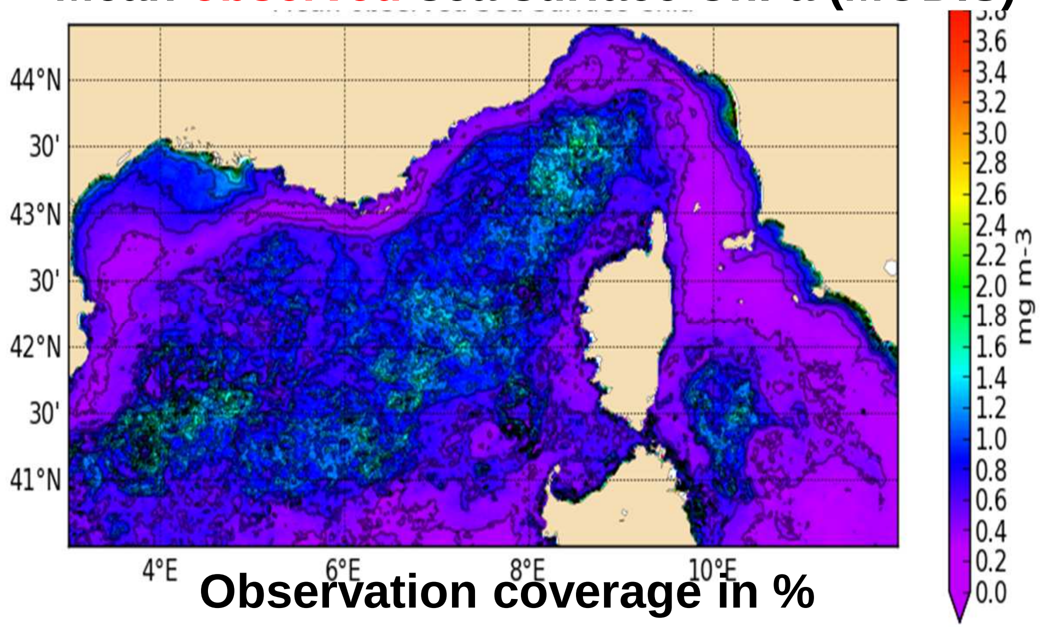


Comparison and analysys of mean over 3 months (Feb-Apr,2010) sea surface Chl-a (P. Garreau)

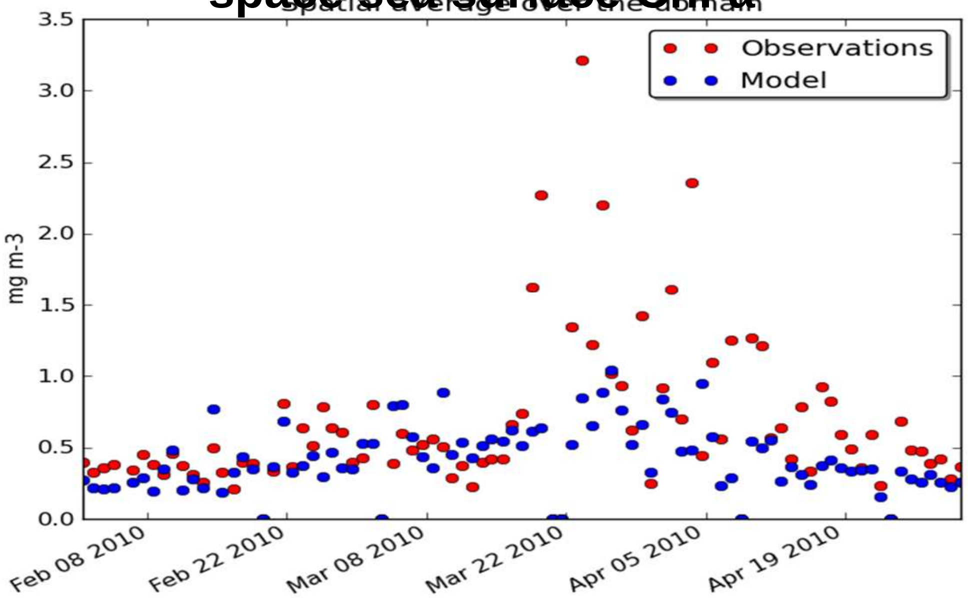
Mean modelled sea surface Chl-a



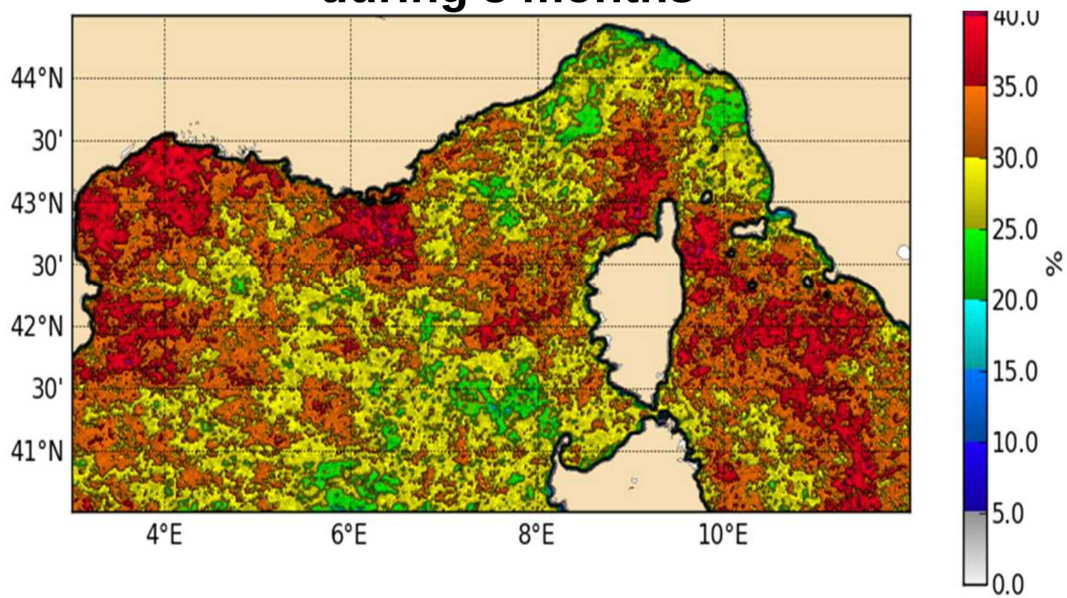
Mean observed sea surface Chl-a (MODIS)



Time-evolution of mean over the space sea surface Chl-a

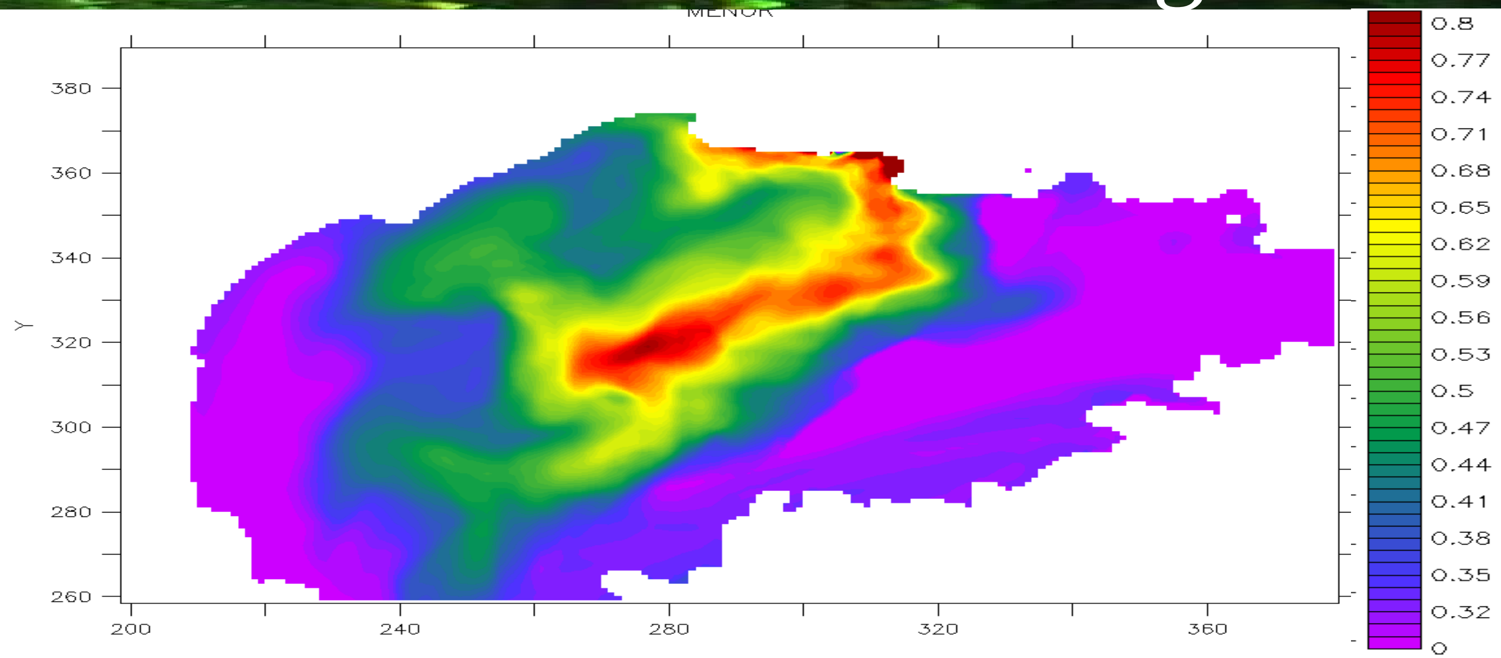


Observation coverage in % during 3 months

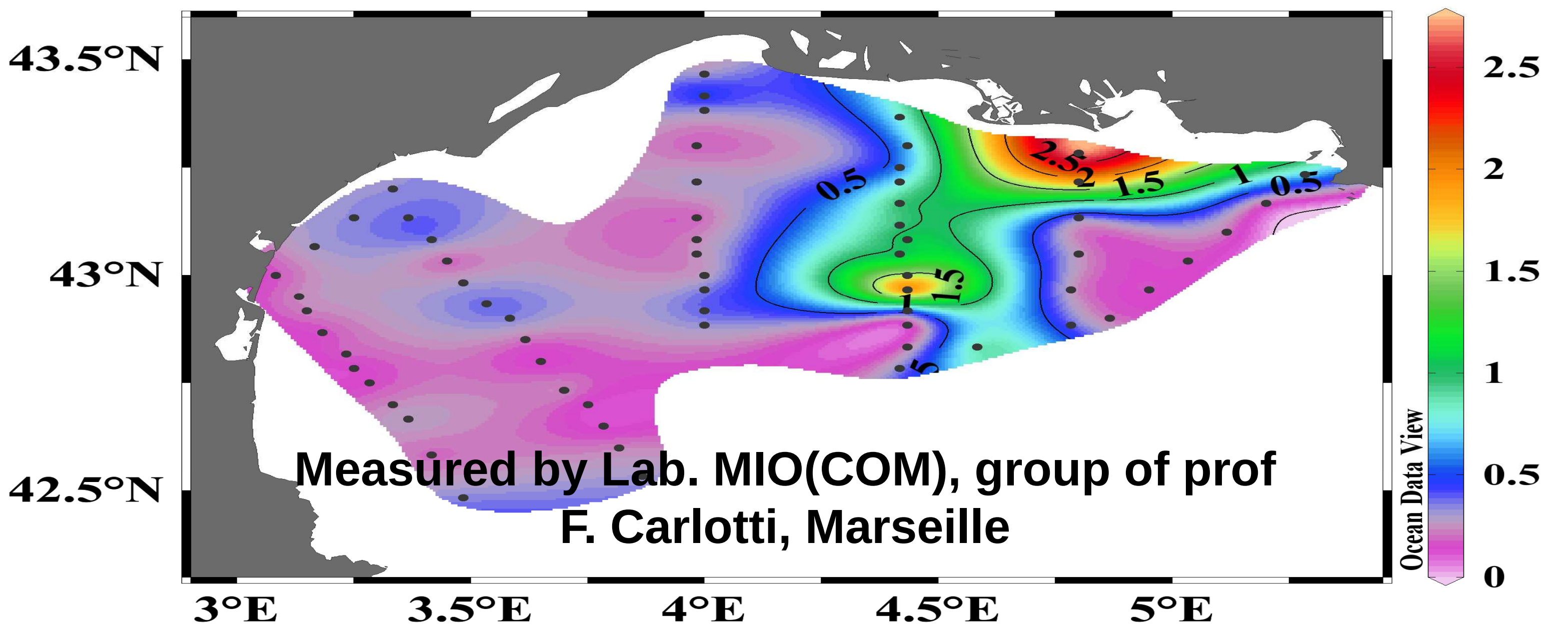


ATTENTION: minimal error of the processed images of MODIS ~ 0.5 mg / l

Measurement COSTEAU4 (26 April-1 Mai 2010) Sea surface Chl-a in mg/m3

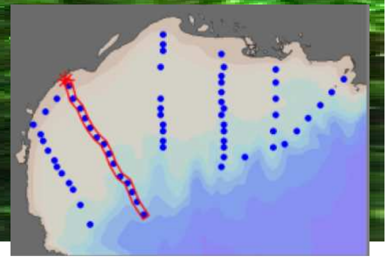


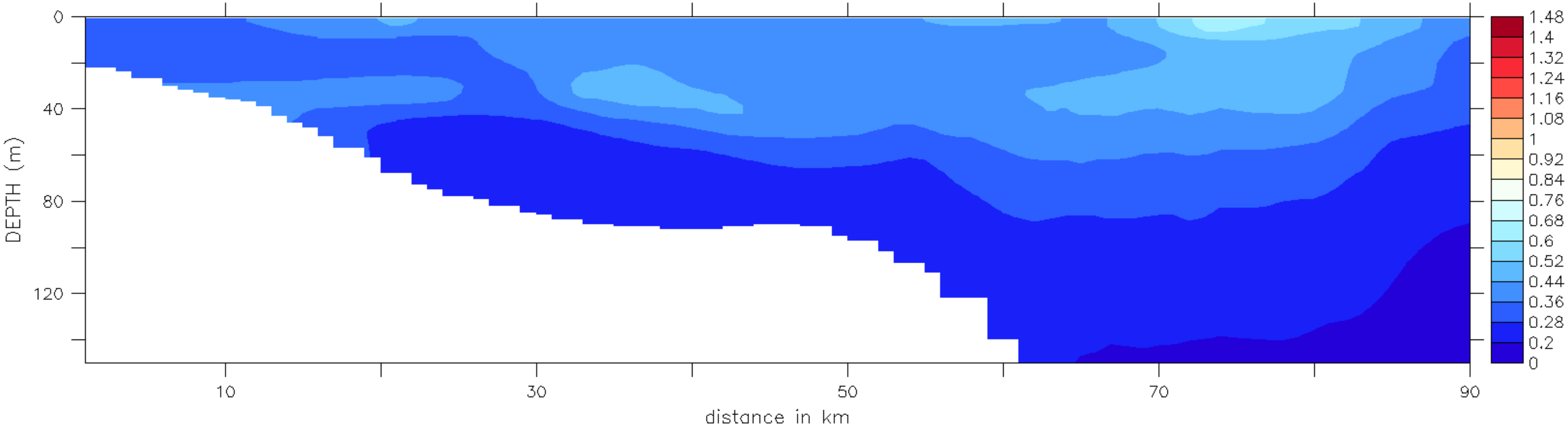
Chla_Vert @ DEPTH [M]=first



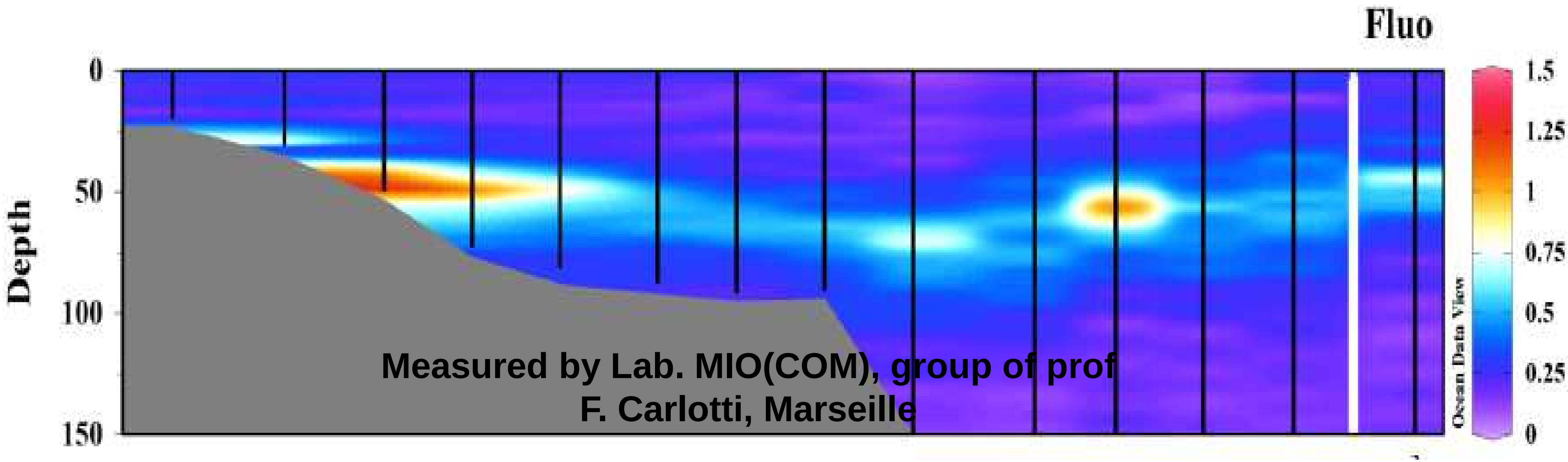
Measured by Lab. MIO(COM), group of prof F. Carlotti, Marseille

COSTEAU4
27/04/2010 transection B

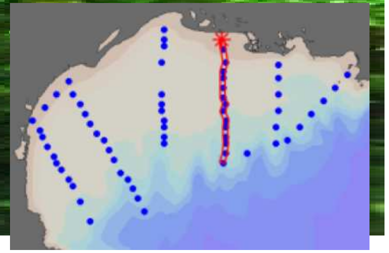


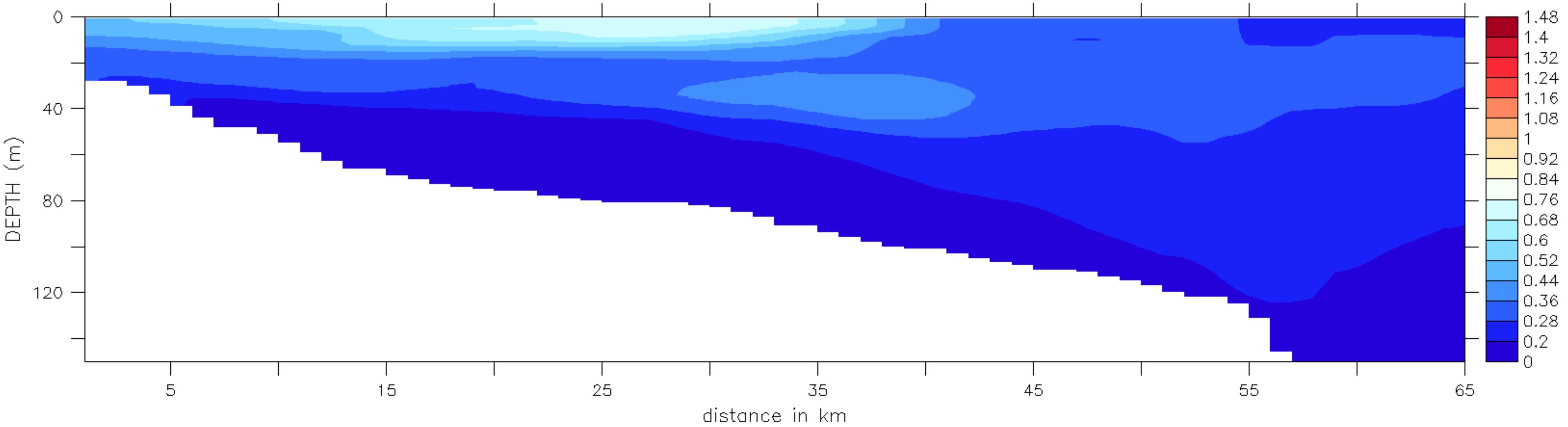


'Chl-a in the transection B' (mg/m3)

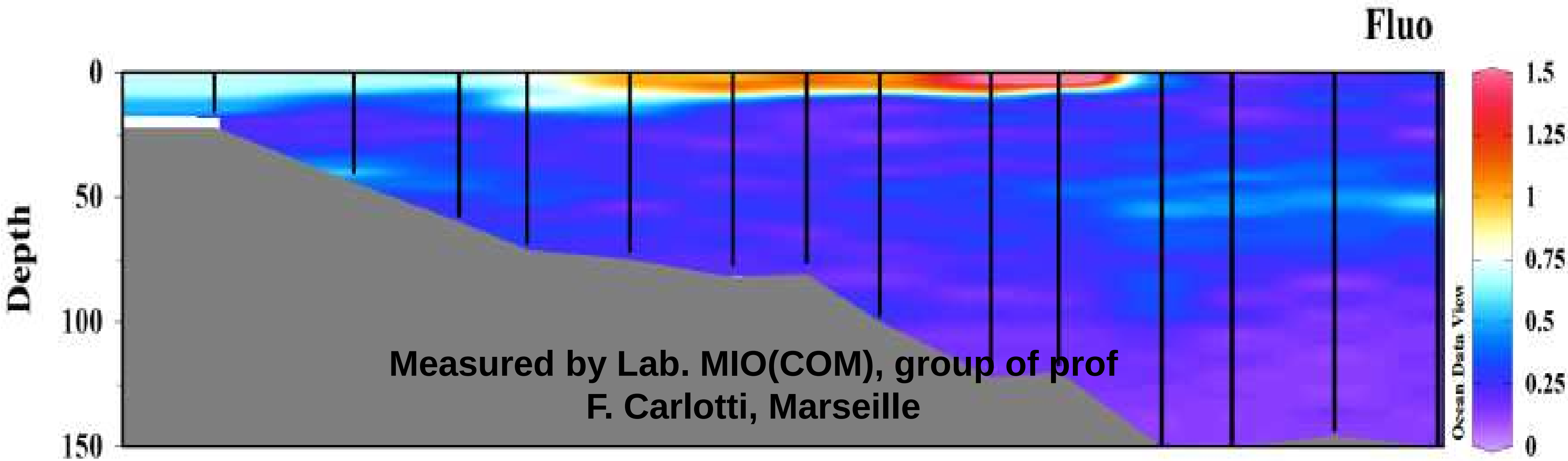


COSTEAU4
29/04/2010 transection D



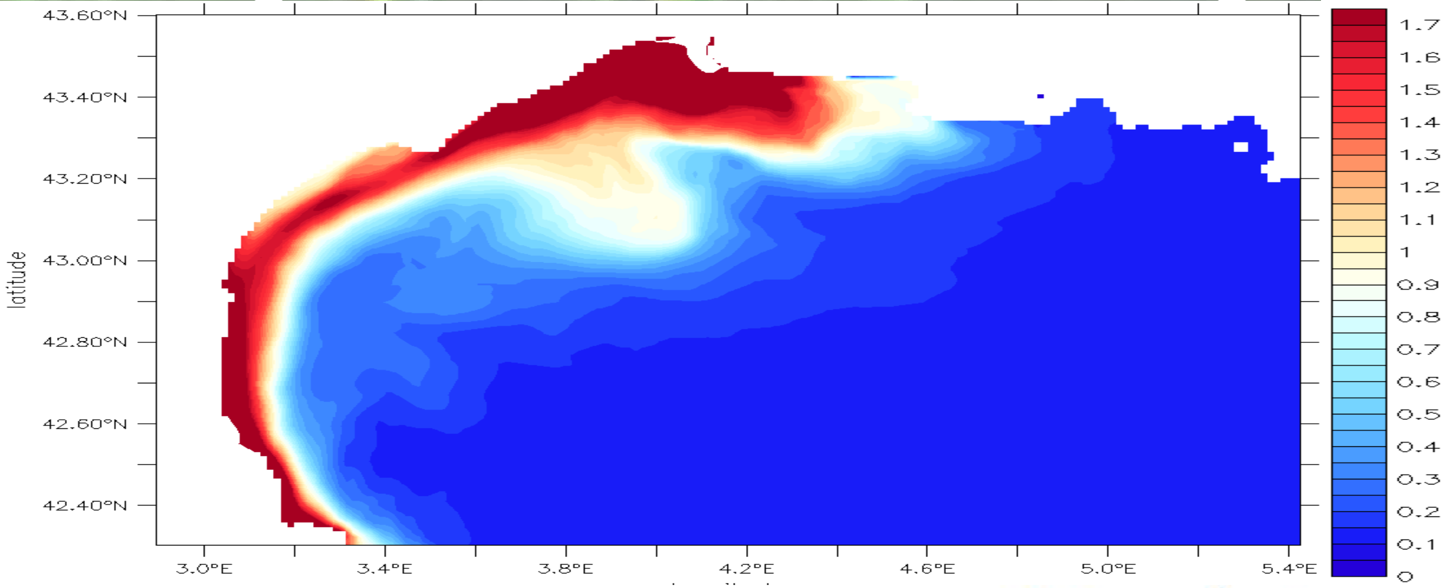


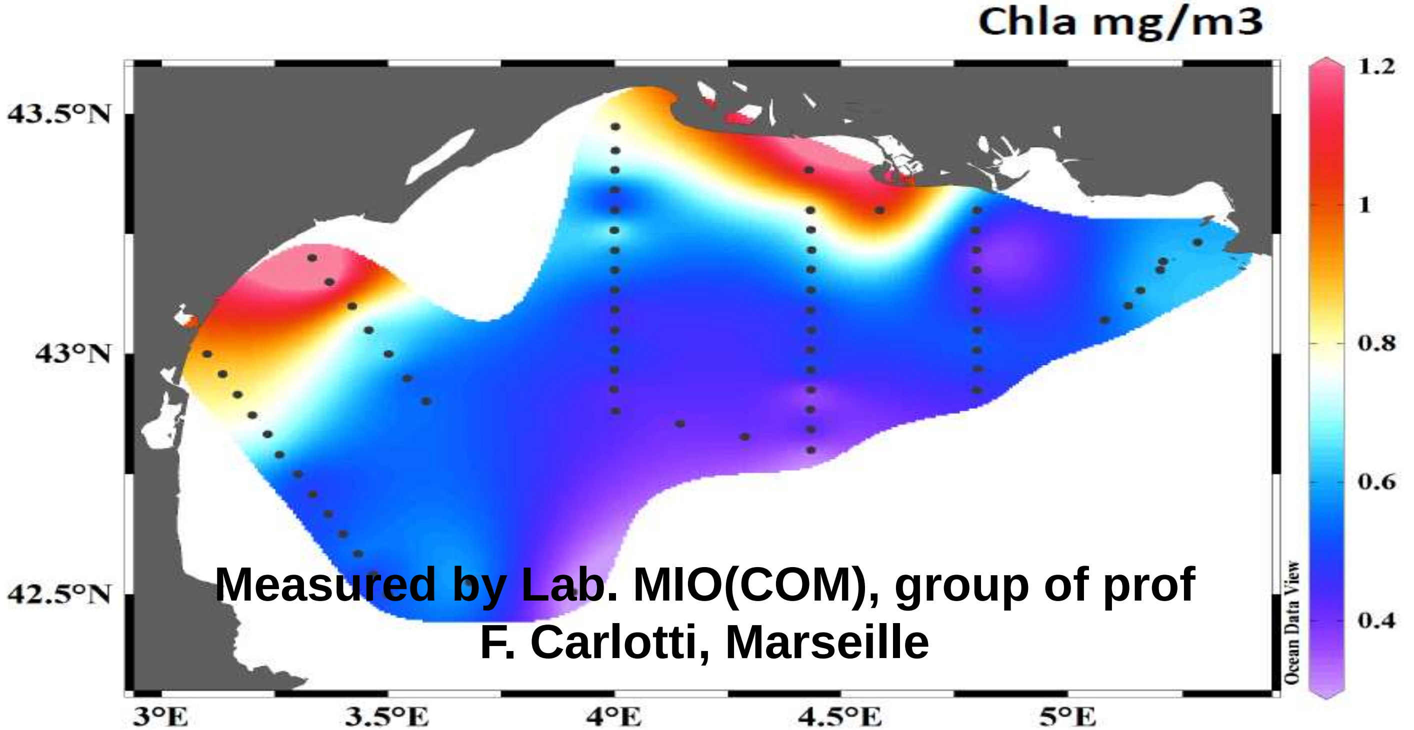
'Chl–a in the transection D' (mg/m3)



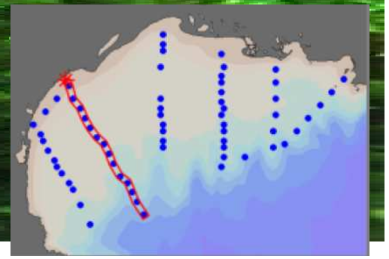
Measured by Lab. MIO(COM), group of prof F. Carlotti, Marseille

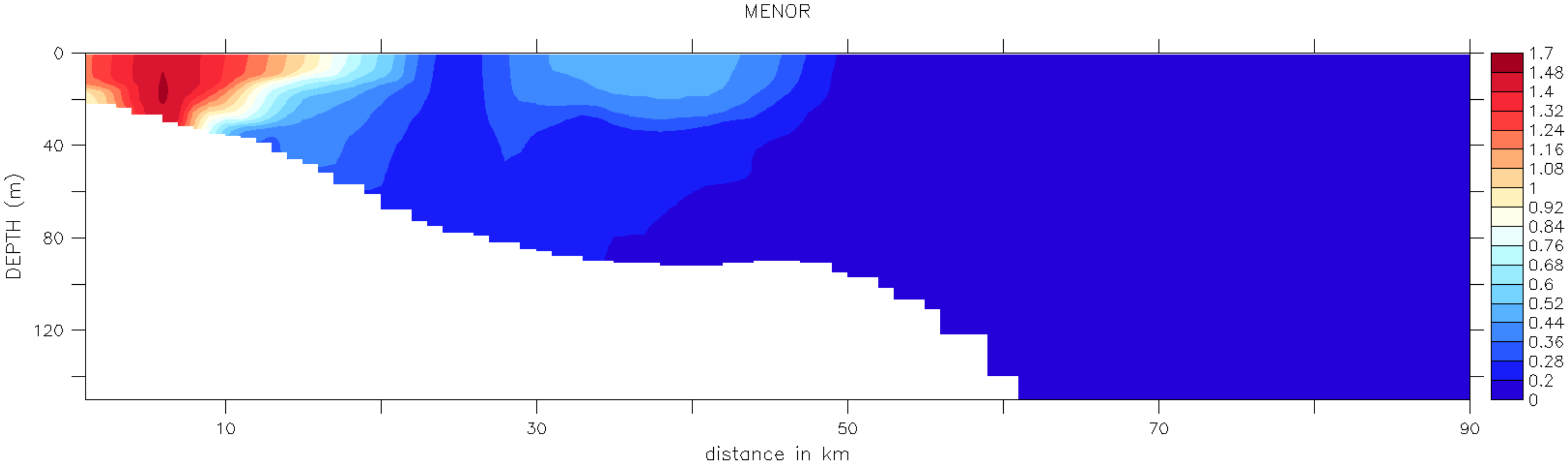
Measurement COSTEAU6(23 Jan-27 Jan 2011) Average in 100m Chl-a in mg/m3



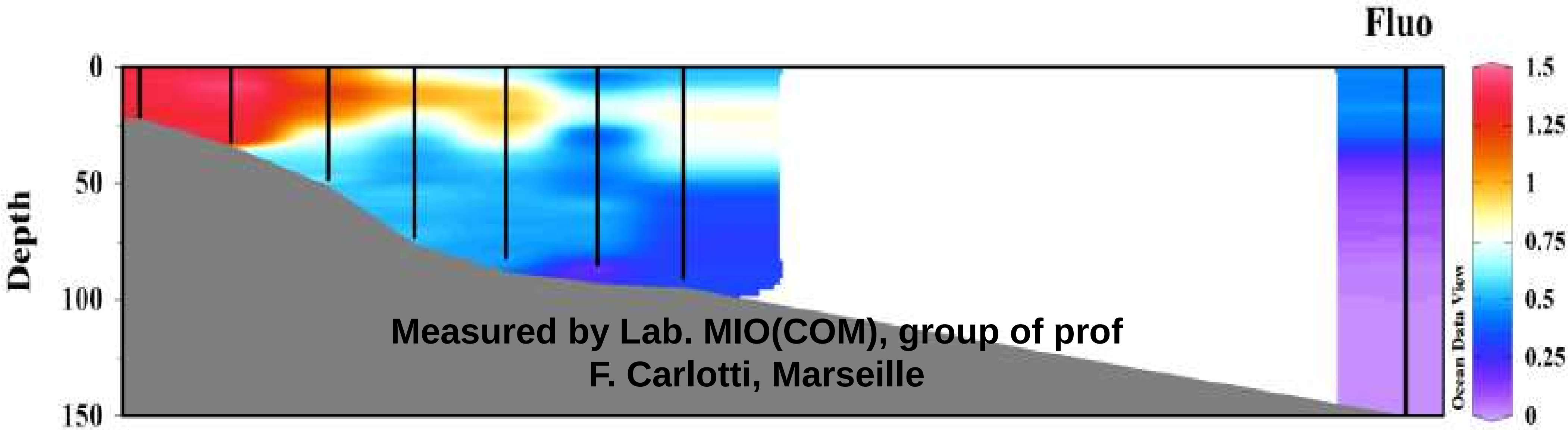


COSTEAU 6
24/01/2011 transection B



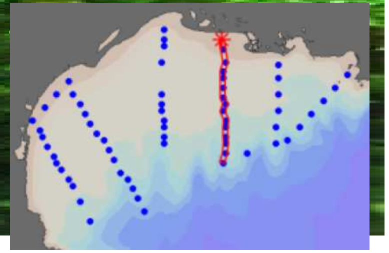


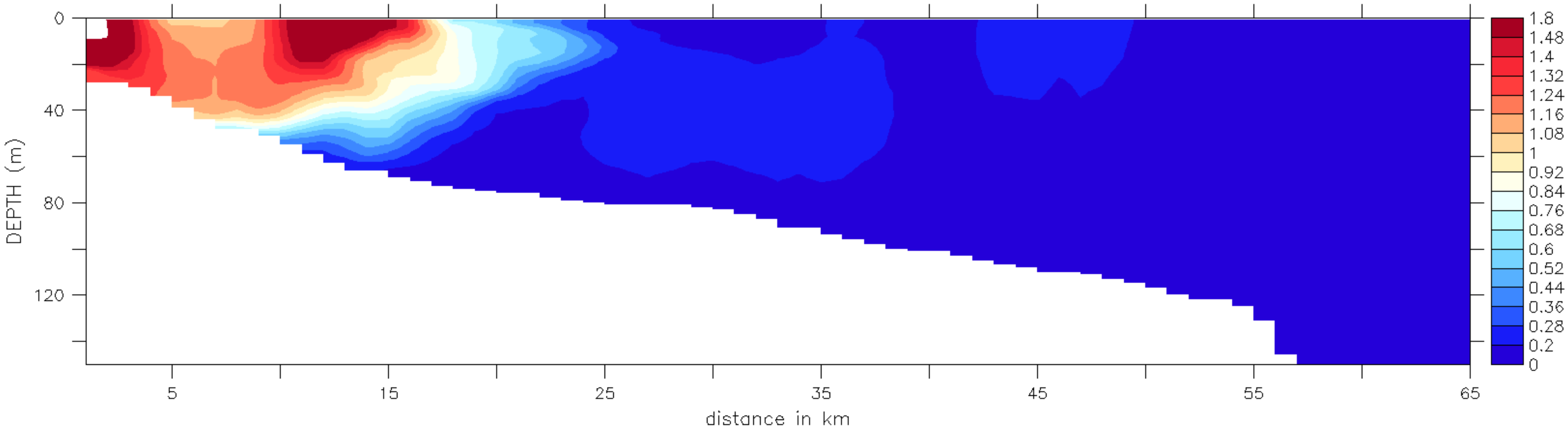
'Chl–a in the transection B' (mg/m3)



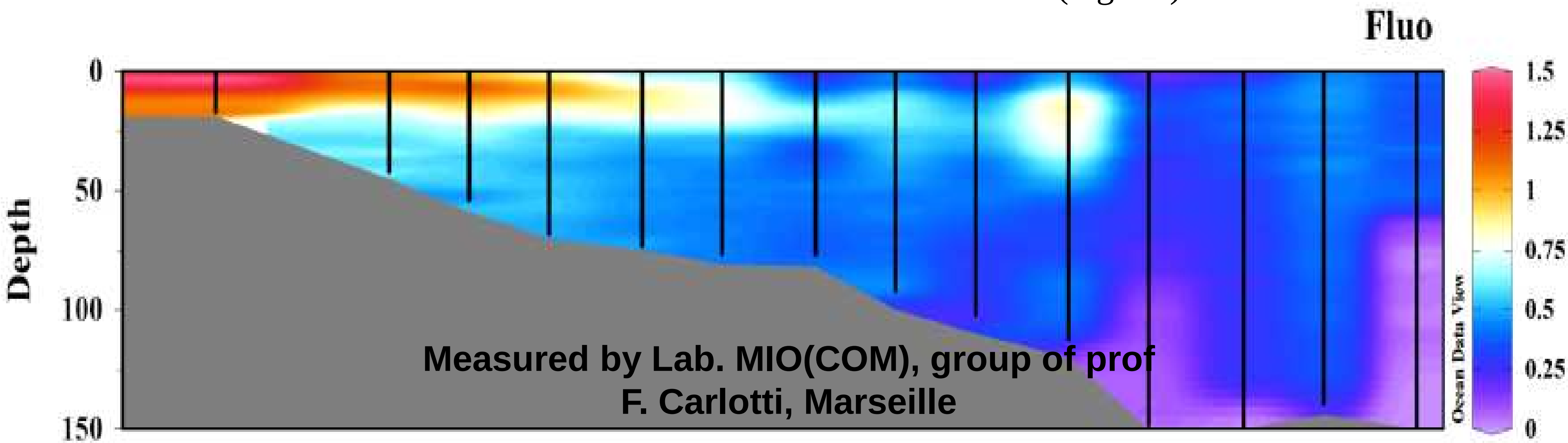
Measured by Lab. MIO(COM), group of prof F. Carlotti, Marseille

COSTEAU 6
26/01/2011 treansection D





'Chl–a in the transection D' (mg/m3)



Conclusions and perspectives

Conclusions

- model reproduces the **principal characteristics of the biogeochemistry of the Mediterranean** in comparison with measured and observed data;

- allow to compute the **dynamics of organisms and nutrients**, to analyze a complex mechanism of its interactions and its limitations for two contrast situations: bloom period with well-mixed waters and stratified period;

- Intensity of the bloom off not always coherent with images sat (attention to errors of the processed images ~ 0.5 mg / l).

Perspectives

- To continue model calibration tests for its improvement;

- Coupling biogeochemical processes with contamination module in the scale of the Golf of Lion.