CENTRE D'OCÉANOLOGIE DE MARSEILLE
UNIVERSITÉ DE LA MÉDITERRANÉE AIX-MARSEILLE II

A numerical model of the circulation in the NW Mediterranean

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Workshop MEUST
Marseille, 8-9 November 2010

Marsaleix et al., 2008

SYMPHONIE MODEL : *Physics*

Hydrodynamic equations

Momentum conservation

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z} = -\frac{1}{\rho_o}\frac{\partial P}{\partial x}+f\,v-\frac{\partial \overline{u'u'}}{\partial x}-\frac{\partial \overline{u'v'}}{\partial y}-\frac{\partial \overline{u'w'}}{\partial z}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z} = -\frac{1}{\rho_o}\frac{\partial P}{\partial y}-f\,u-\frac{\partial \overline{v'u'}}{\partial x}-\frac{\partial \overline{v'v'}}{\partial y}-\frac{\partial \overline{v'w'}}{\partial z}$$

where

$$P(z)=P_a+g\int_z^{\eta}\rho\cdot dz$$

Hydrostatic approx.

$$\rho=\rho_0(1+\epsilon)$$

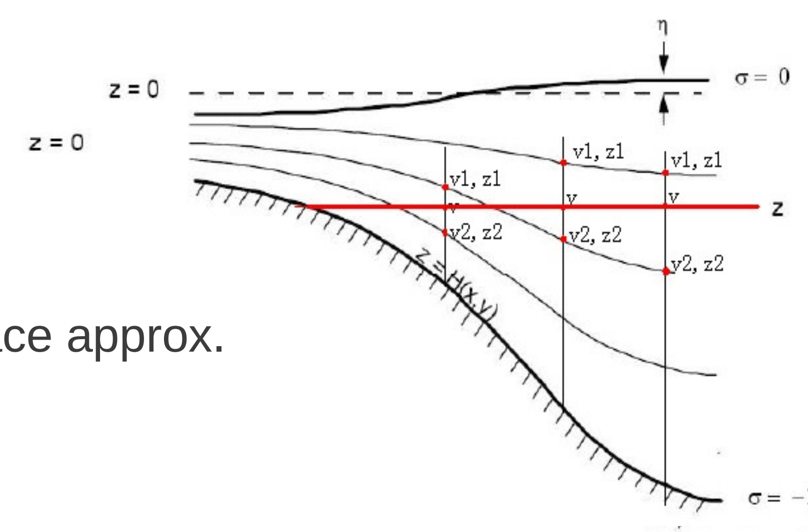
Boussinesq approx.

Mass conservation

$$\frac{\partial \eta}{\partial t}+\frac{\partial (Hu)}{\partial x}+\frac{\partial (Hv)}{\partial y} = 0$$

where $H=h+\eta$

Free surface approx.



SYMPHONIE MODEL : *Physics*

Thermodynamic equations

Temperaure conservation

$$\frac{\partial T}{\partial t}+\vec{v}.\vec{\nabla}T = -\frac{\partial\left(\overline{T'u'}\right)}{\partial x}-\frac{\partial\left(\overline{T'v'}\right)}{\partial y}-\frac{\partial\left(\overline{T'w'}\right)}{\partial z}+\frac{H_c}{\rho_o C_p}\frac{\partial I}{\partial z}$$

Salinity conservation

$$\frac{\partial S}{\partial t}+\vec{v}.\vec{\nabla}S = -\frac{\partial\left(\overline{S'u'}\right)}{\partial x}-\frac{\partial\left(\overline{S'v'}\right)}{\partial y}-\frac{\partial\left(\overline{S'w'}\right)}{\partial z}$$

Equation of State of Seawater

$$\rho=\rho_o\left[1-\alpha\left(T-T_o\right)+\beta\left(S-S_o\right)\right]$$

SYMPHONIE MODEL : *Physics*

Newtonian turbulence closure scheme

$$\overline{u'u'} = -A_x \frac{\partial u}{\partial x} \quad ; \quad \overline{u'v'} = -A_y \frac{\partial u}{\partial y} \quad ; \quad \overline{u'w'} = -A_z \frac{\partial u}{\partial z}$$

Horizontal coeffs

$$\tilde{A}_x = \delta |u| \frac{\Delta x}{2} \quad , \quad \tilde{A}_y = \delta |v| \frac{\Delta y}{2}$$

DX & DX =Grid size

Vertical coeffs

$$A_z = C_Q \, L \, Q^{1/2} \qquad Q = \frac{1}{2}\left(u'^2 + v'^2 + w'^2\right)$$

Turbulent kinetic energy

$$\frac{\partial Q}{\partial t} + \vec{v}.\vec{\nabla} Q = A_Z \left[\left(\frac{\partial u}{\partial z} \right)^2 + \left(\frac{\partial v}{\partial z} \right)^2 \right] + \frac{g}{\rho_0} A_z \frac{\partial \rho}{\partial z} + \frac{\partial}{\partial z} \left(A_Z \frac{\partial Q}{\partial z} \right) + \frac{\partial}{\partial x} \left(A_h \frac{\partial Q}{\partial x} \right) + \frac{\partial}{\partial y} \left(A_h \frac{\partial Q}{\partial y} \right) - \varepsilon$$

$$\varepsilon = \frac{C_\varepsilon \cdot Q^{3/2}}{L_\varepsilon} \qquad L = \min\left(L_{up}, L_{down}\right) \text{ et } L_\varepsilon = \sqrt{L_{up} \cdot L_{down}}$$

SYMPHONIE MODEL : *Physics*

Boundary conditions

surface

$$z=\eta$$

$$A_z\left(\frac{\partial u}{\partial z},\frac{\partial v}{\partial z}\right) = (\tau_{Sx},\tau_{Sy})$$

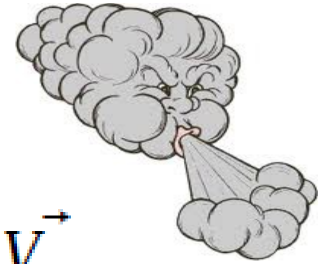
$$Q = \frac{\|\vec{\tau}_S\|}{\rho_0\sqrt{C_\varepsilon \cdot C_k}}$$

$$A_z^T\frac{\partial T}{\partial z} = H_s+H_e+H_l+(1-Tr)H_c$$

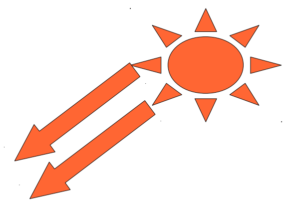
$$A_z^S\frac{\partial S}{\partial z} = (E-P)S$$

Wind stress

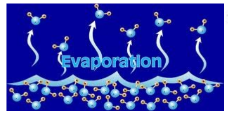
$$\vec{\tau}_s = \rho_{0air}C_v\|\vec{V}_{vent}\|\vec{V}_{vent}$$



Heat fluxes



Salt fluxes



bottom

$$z=-H$$

$$A_z\left(\frac{\partial u}{\partial z},\frac{\partial u}{\partial z}\right)=(\tau_{bx},\tau_{by})$$

$$K=\frac{\|\vec{\tau}_b\|}{\rho_0\sqrt{C_\varepsilon \cdot C_k}}$$

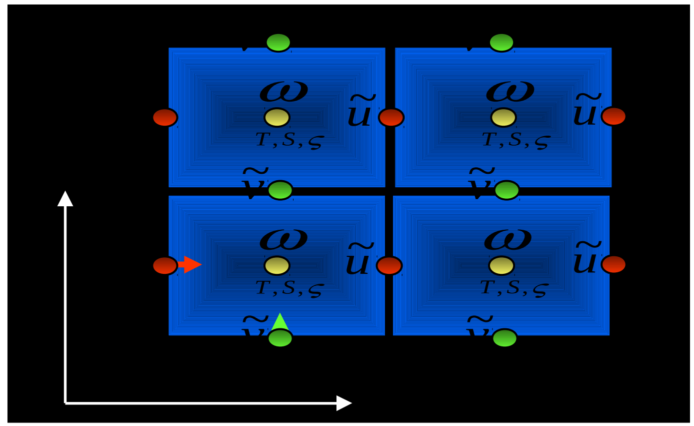
$$\left(\frac{\partial T}{\partial z},\frac{\partial S}{\partial z}\right)=0$$

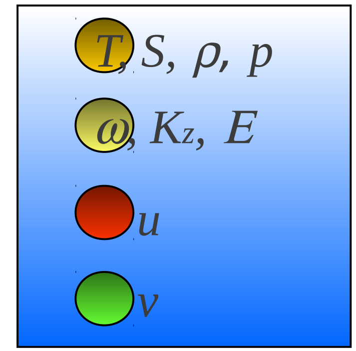
Bottom stress

$$\vec{\tau}_b=\rho_0C_d\|\vec{V}_b\|\vec{V}_b$$

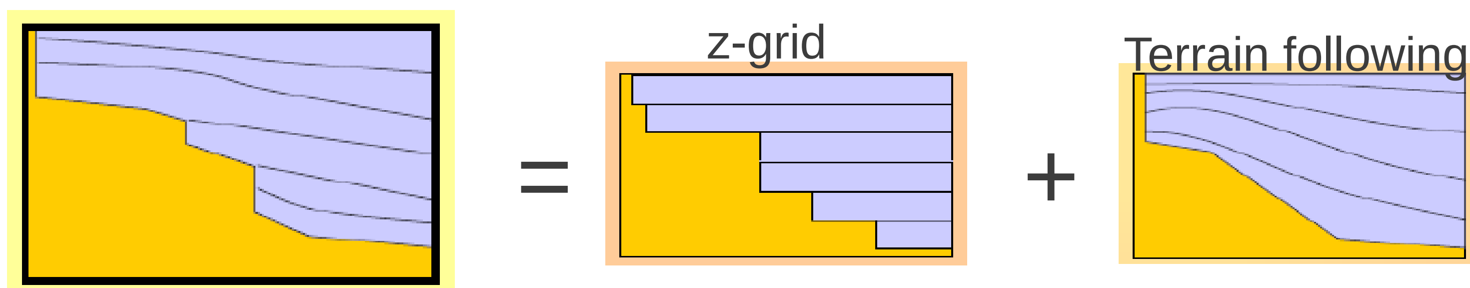
SYMPHONIE MODEL : *Discretization*

Horizontal & vertical staggered grids

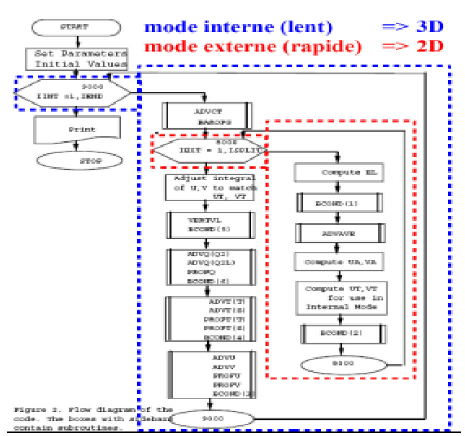




Hybrid vertical grid



Time splitting



2D mode → short DT

3D mode → long DT

for calculation of

η and U_{2D} V_{2D}

U, V, T, S, Q.

SYMPHONIE MODEL : *Literature*

During the last 10 years, the Symphonie has been used widely and successfully by the coastal ocean community.

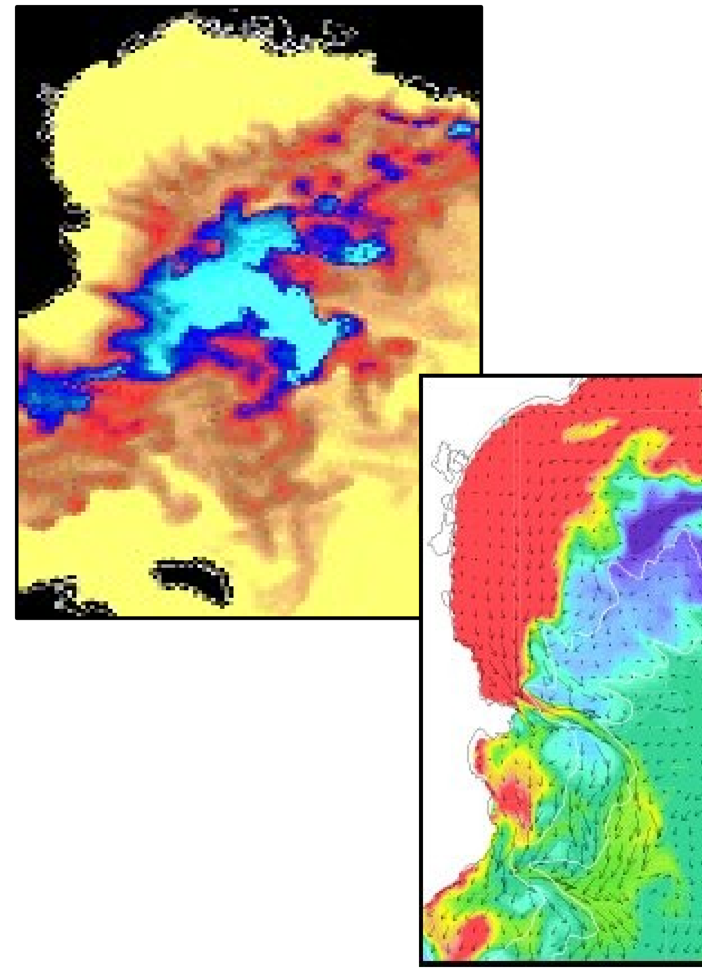
The realistic simulations of this model have contributed to the study of:

(i) *the wind-induced circulations in the GoL*
Auclair et al., 2003; Estournel et al., 2003; Petrenko et al.,2005, 2008;

(ii) *the intrusion of the NC onto the continental shelf*
Auclair et al., 2001; Gatti, 2008;

(iii) *dense-water formation and cascading phenomena over the continental shelf*
Dufau-Julliand et al., 2004; Herrmann and Somot, 2008; Herrmann et al., 2008; Ulses et al., 2008a,b ;

(iv) *the Rhône river plume circulation*
Marsaleix, 1998; Estournel, 2001.



since 2007 : INSU community model

http://sirocco.omp.obs-mip.fr/eng/home/Home.htm

SYMPHONIE @ COM

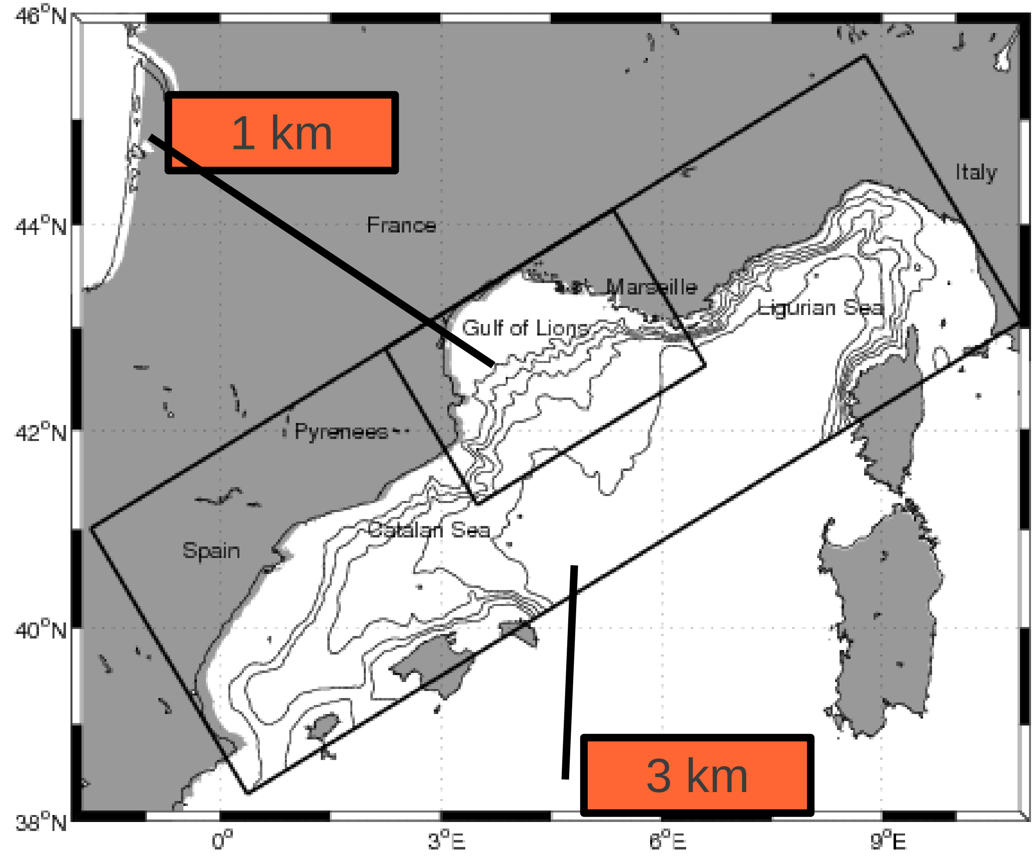
NW Mediterranean implementation

Grid res. horizontal: 3km x 3km & 1km x 1km
One – Way Nesting
vertical: 40 layers

Open Boundary conditions : MFS
(Mediterranean ocean Forcasting System)
http://gnoo.bo.ingv.it/mfs/

Atmospheric forcing : MétéoFrance
Aladin model, high spatial (0.1º x 0.1º) and temporal (3 h) resolution
http://www.cnrm.meteo.fr/aladin/

River Input : Compagnie du Rhône & Directions Départementales de l'Équipement
Daily fluxes of Rhône, Hérault, Aude and Orb



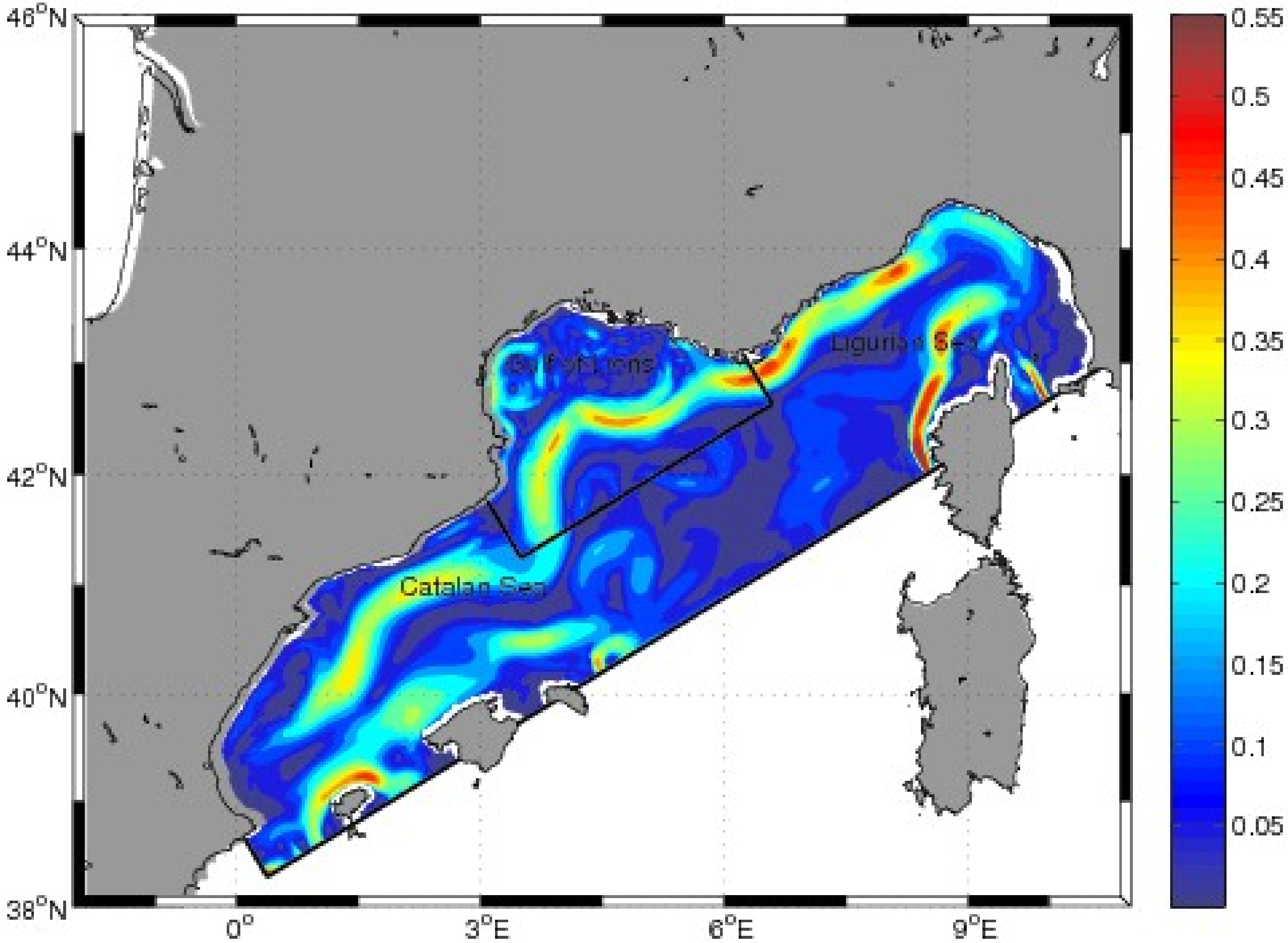
Dataset : 2001-present, 1-day averaged data of current, elevation, T, S.

netCDF

Network Common Data Format, free, self-describing, machine-independent

http://www.unidata.ucar.edu/software/netcdf/

SYMPHONIE @ COM



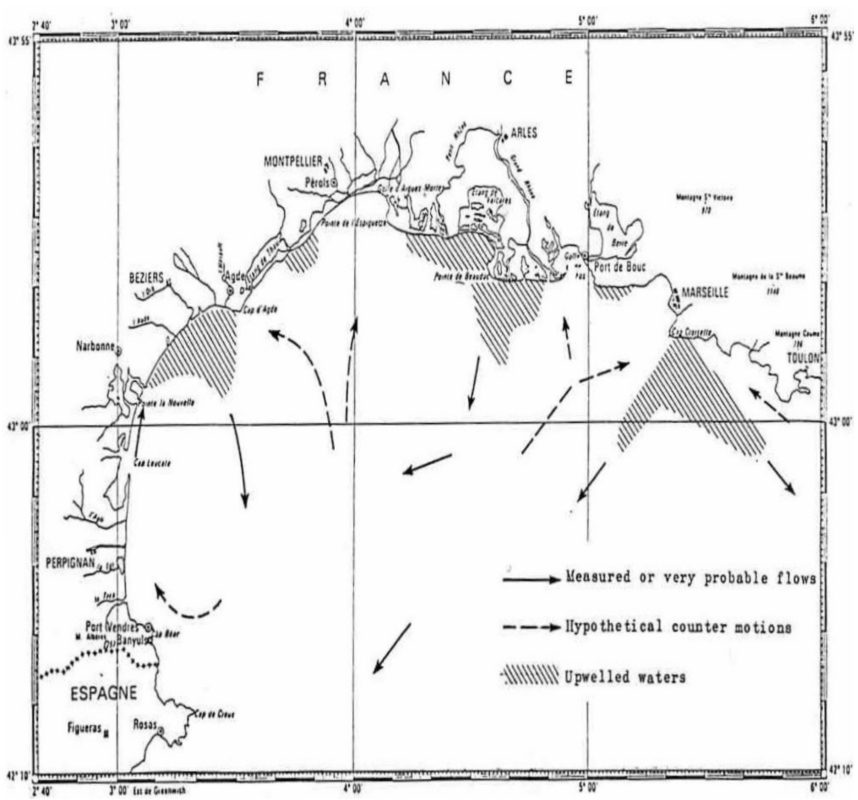
Horizontal slice of the modeled speed intensity on July 25, 2001 at 20-m. The simulations reproduce the major features in the GoL: the NC, eddies and filaments.

Hu et al., 2009

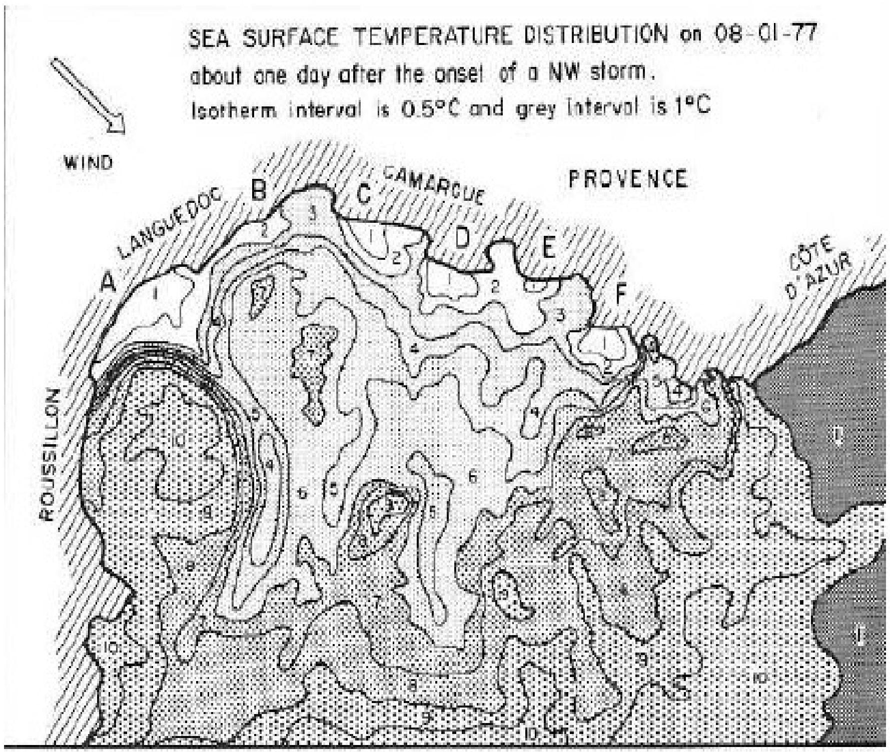
SYMPHONIE @ COM

LATEX (Lagrangian Transport Experiment)

Study of mesoscale eddies in the western Gulf of Lion



From Millot [1979], with a sketch of wind-induced circulation at the surface drawn coherently with infrared and in situ data.



From Millot [1982], showing the infrared thermography obtained on the August 1, 1977 at about 09 00 TU

LATEX (Lagrangian Transport Experiment)

Study of mesoscale eddies in the western Gulf of Lion

THE NUMERICAL MODEL

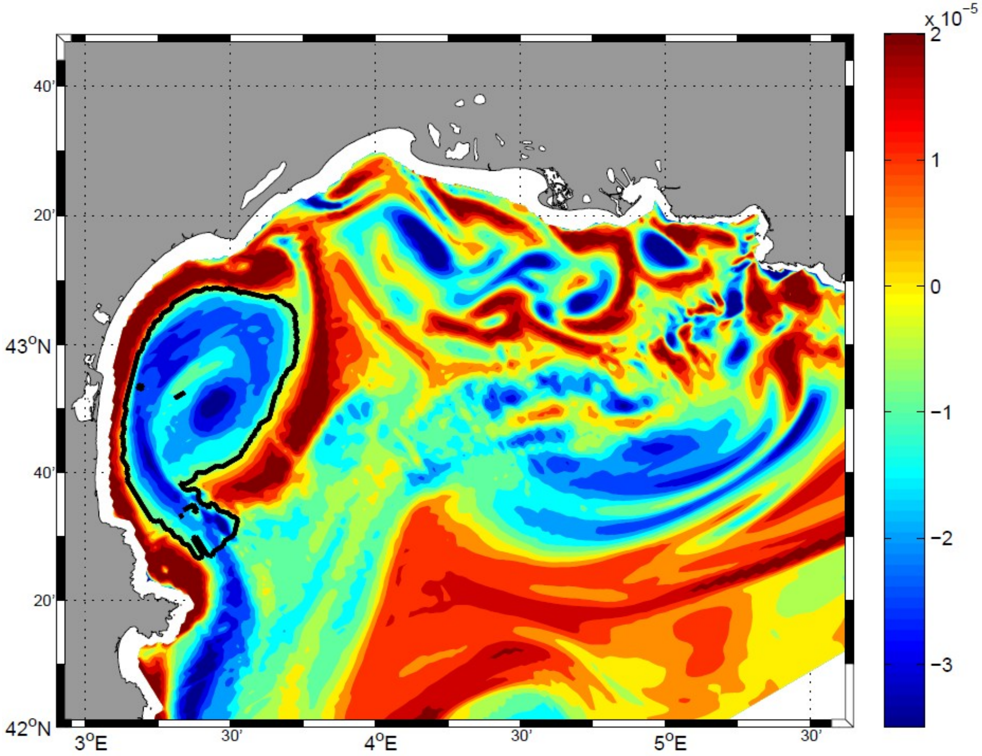
"in silico" truth
helps in cruise planifications
tests different hypotheses

THE OCEANOGRAPHIC CRUISES

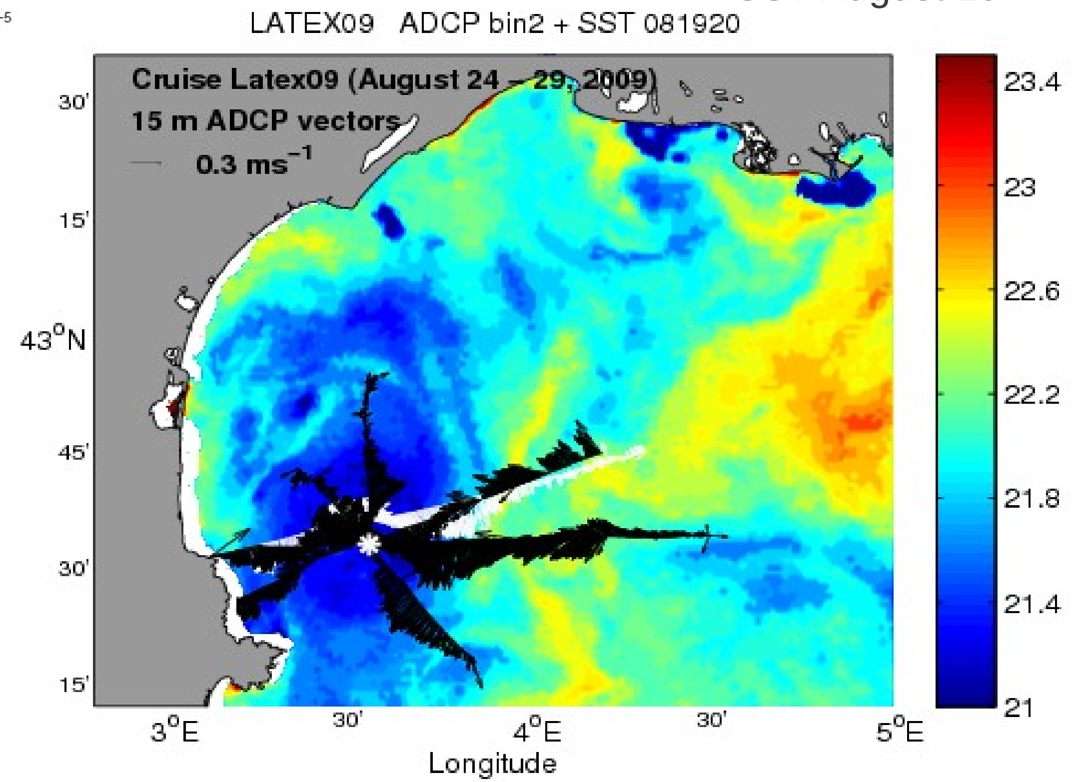
"in situ" truth
new information
validate interpretation

(Partial!) understanding of phenomena
New questions

July 2001
Relative vorticity
(Symphonie 1 km)



LATEX 2009
ADCP August 24 – 28
SST August 19



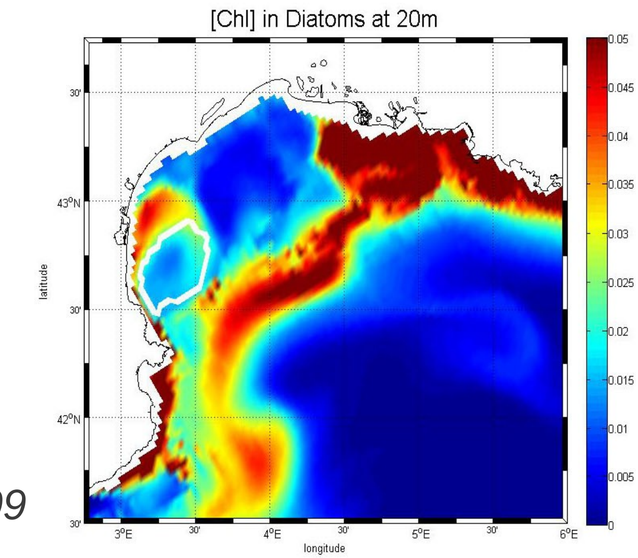
SYMPHONIE @ COM

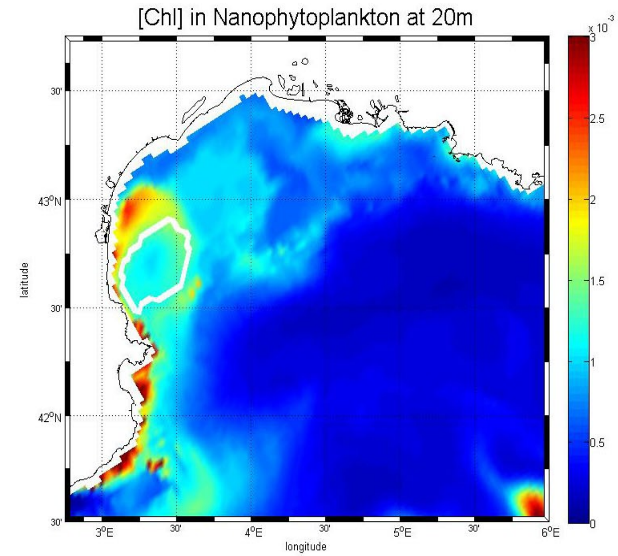
Physics-biogeochemistry coupling

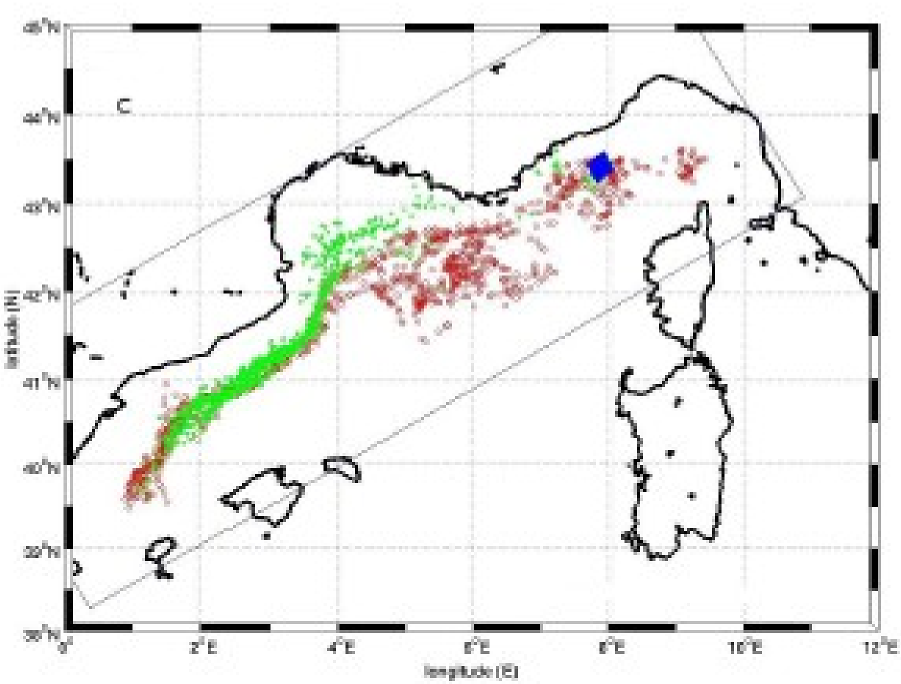
Cross-shelf matter exchanges due to mesoscale eddies

Chlorophyll from diatoms and nanophytoplankton (mg Chl/m3) as predicted by the Symphonie-Eco3M-NWMED model at 20m in the Gulf of Lion on August 1 2001,

Campbell et al,, 2009







Zooplankton distribution

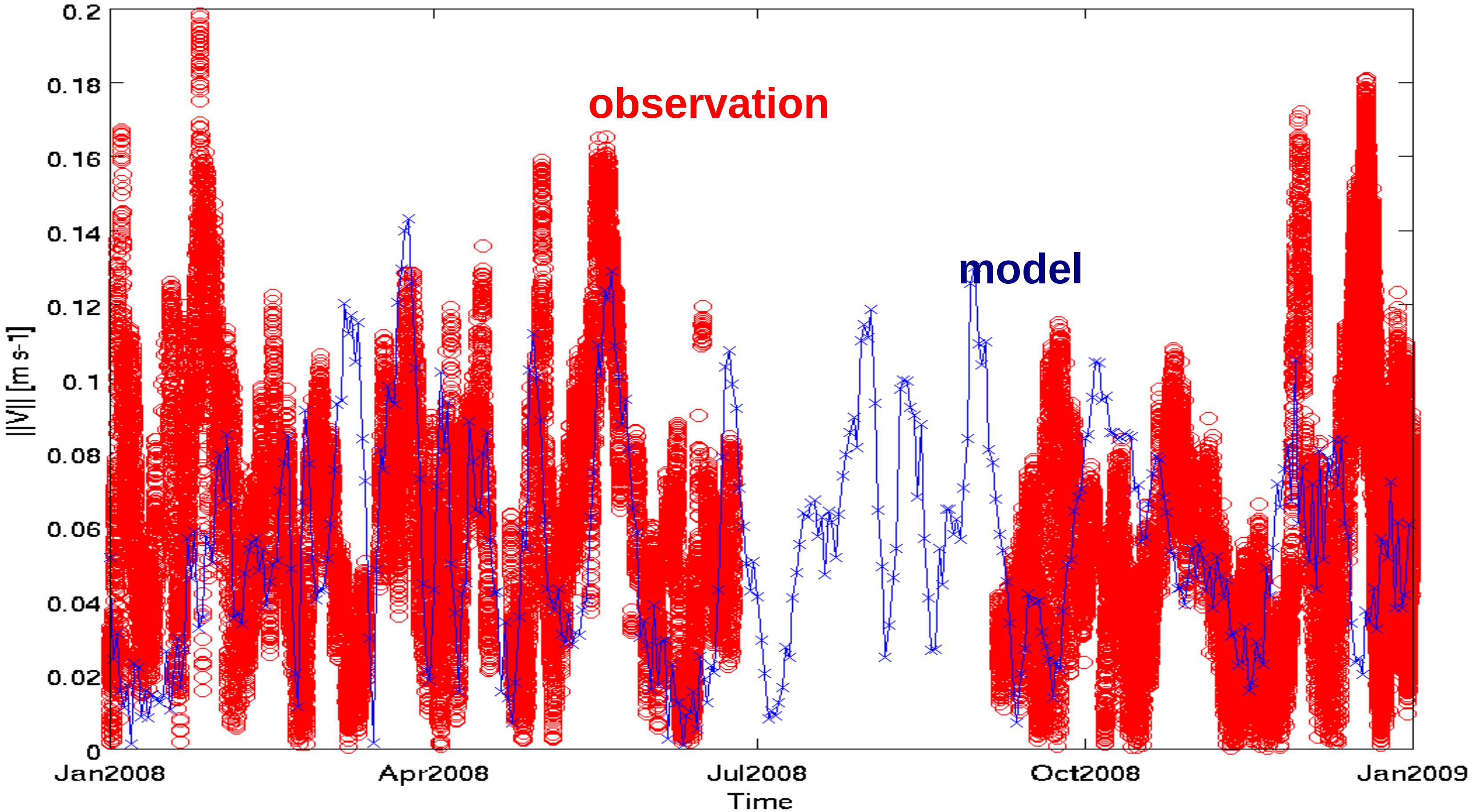
Final distribution patterns of particles released around the DYFAMED station (blue square) with DVM in August 2001.
Empty red circles represent final positions of particles released at 5m; full green lozenges represent nal positions of particles released at 100m.

Qiu et al., 2010

Preliminary comparaison with Antares ADCP raw data

Lat=42.48N Lon= 6.10E depth=-2398m

Year = 2008 Model resolution = 3km Variable = Current intensity



Encouraging !!!

Possible future work :

- comparaison with treated data (u,v, T, S) for all available years (in collaboration with S. Martini,C. Tamburini, D. Nerini).

- help in interpretation of observations :

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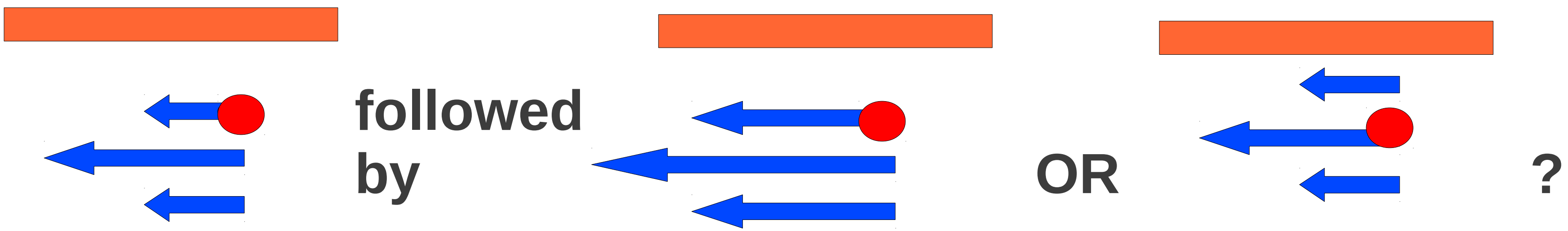

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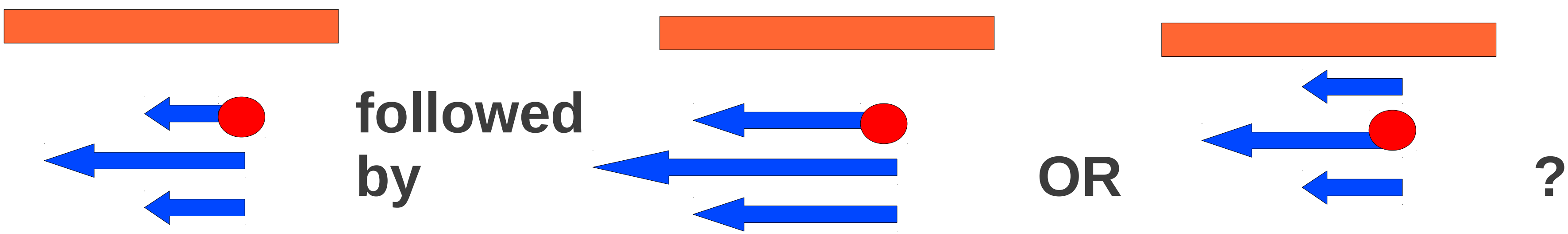

Open questions and scientific themes :

Is SYMPHONIE modelling correctly the ocean bottom layer ?

How intense is NW Med deep water circulation ?

How act the Physics and Biogeochemistry coupling in the deep ocean ?

The model information can help for future observations planning and/or support fund-raising...

Thank you
for your attention !

Title
A numerical model of the circulation in the NW Mediterranean.

Authors
A.M.Doglioli, A.A.Petrenko, Z.Hu, M.Kersalé, F.Nencioli, I.Dekeyser, C.Estournel, P.Marsaleix

Abstract
We present a costal, high-resolution, one-way-nested thermo-hydrodynamical model of the NW Mediterranean, based on the code SYMPHONIE (Marsaleix et al, 2008).
The model provides the three velocity components, the free surface elevation, and the temperature and salinity fields.
It solves the Reynolds-averaged Navier-Stokes equations, using the hydrostatic and Boussinesq approximation, and the equations of the mass and tracers' conservation. The turbulence closure is achieved through a prognostic equation for the turbulent kinetic energy and a diagnostic equation for the mixing and dissipation length scales.
A generalized vertical coordinate and a staggered horizontal grid are used. Computation costs are limited thanks to a time splitting technique
that allow to compute the vertical shear of velocity and the three depth-averaged components separately with appropriate time steps.
Radiation conditions combined to restoring terms to the large-scale circulation (Mediterranean Forecasting System data) are applied at the open boundaries, and bulk formulas are used for the meteorological forcing (Météo-France data).
A ten-year simulation (2001-2009) is available at COM. The model data are proposed for a comparison with the ANTARES observations in order to both validate the model, in particular in the deep layers, and to use its information for future observations planning.