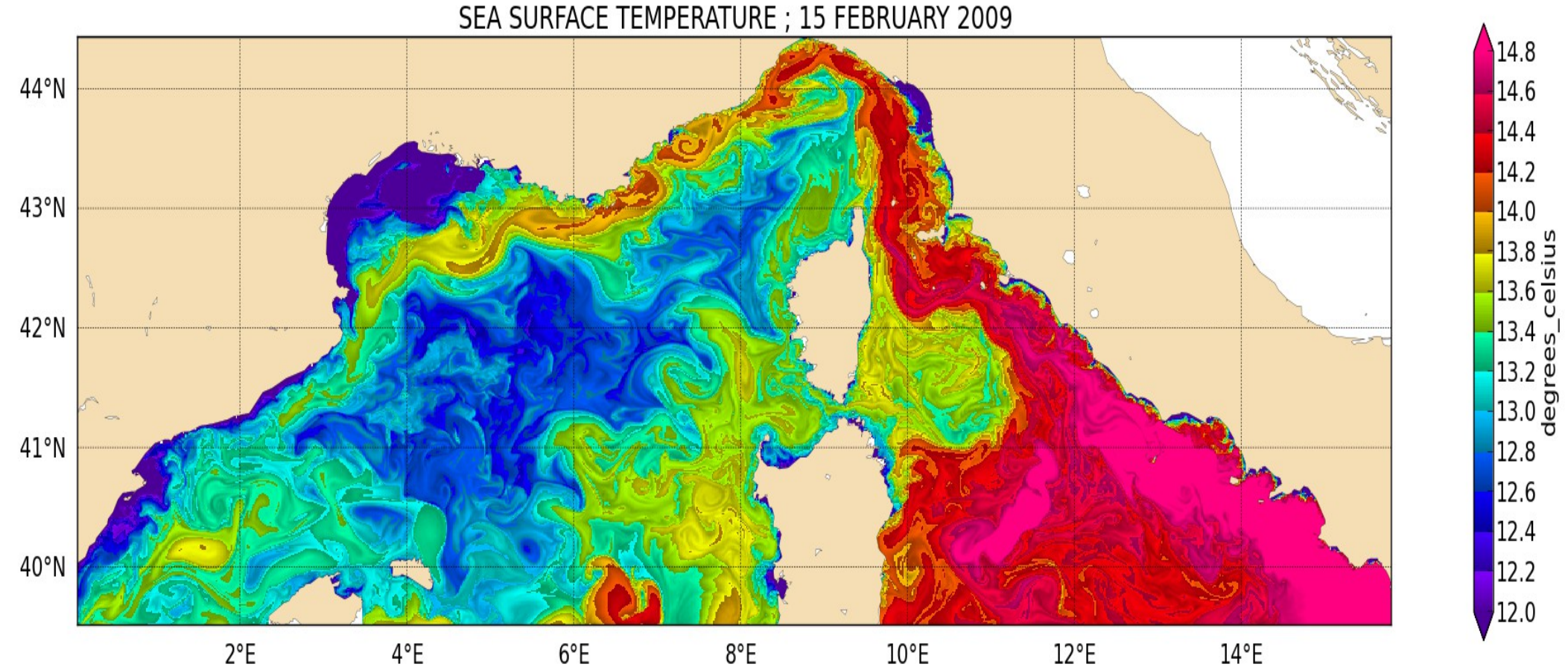
Numerical modelling of the North-Western Mediterranean Sea

Pierre Garreau Valérie Garnier Gaelle Herbert



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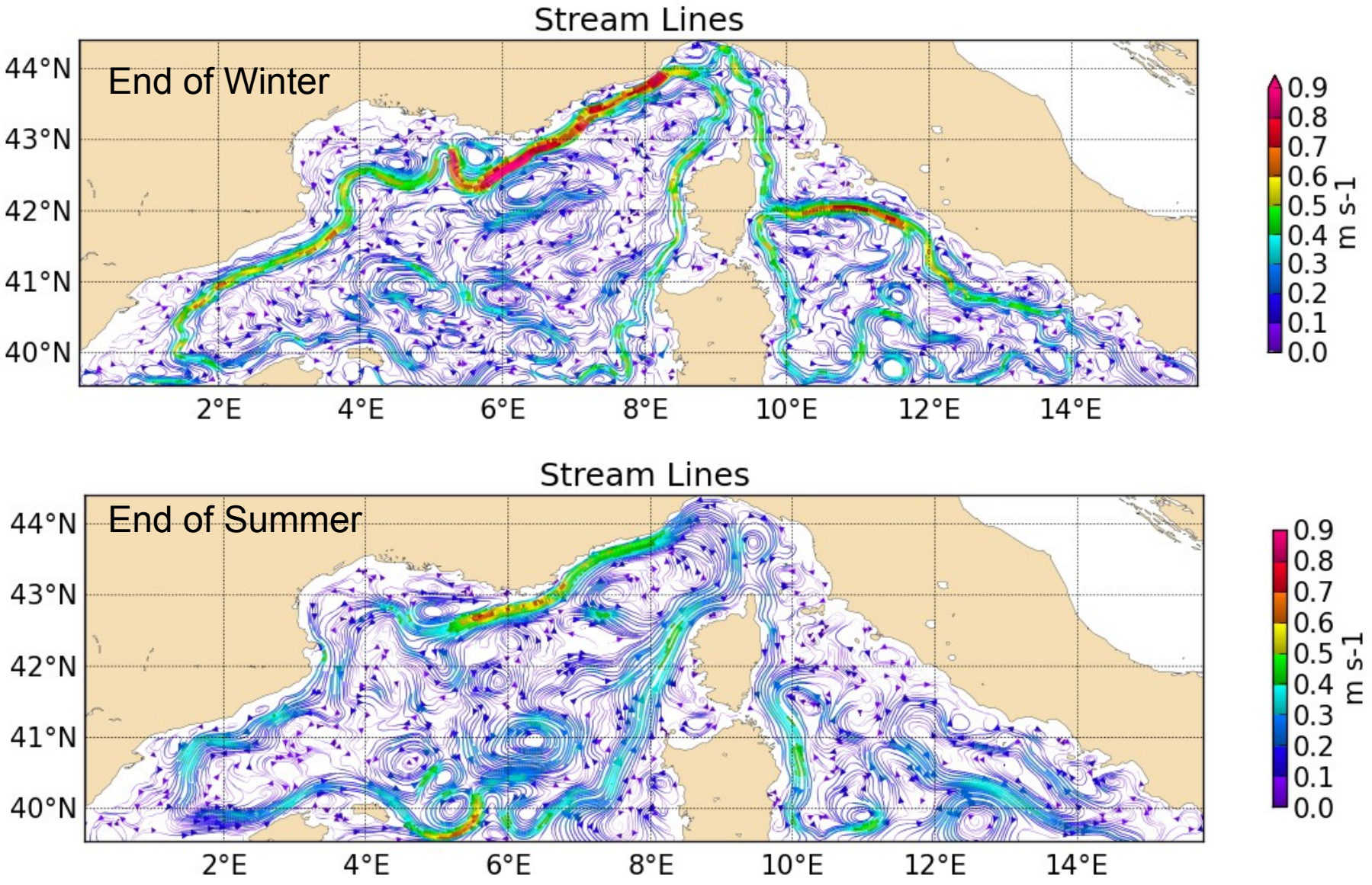
Sub-Surface Circulation snapshots 2009



Outlines

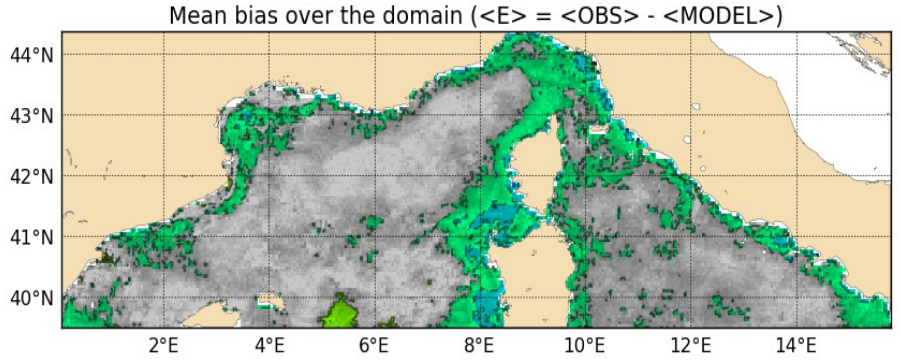
- Presentation of the MENOR configuration
- VACUMM a tools for model exploration and validation
- Validation of the MENOR configuration
- Comparison between OGCM and MENOR
- Dynamic of the N-W Mediterranean Sea inside from a numerical model :
  - The dynamics of Atlantic Water
  - The dynamics of Levantine Intermediate Water (LIW)
  - Dense water formation Western Mediterranean Deep Water (WMDW)
  - Formation of Winter Intermediate Water (WIW)
- Build automatic zoom using Agrif zoom tools

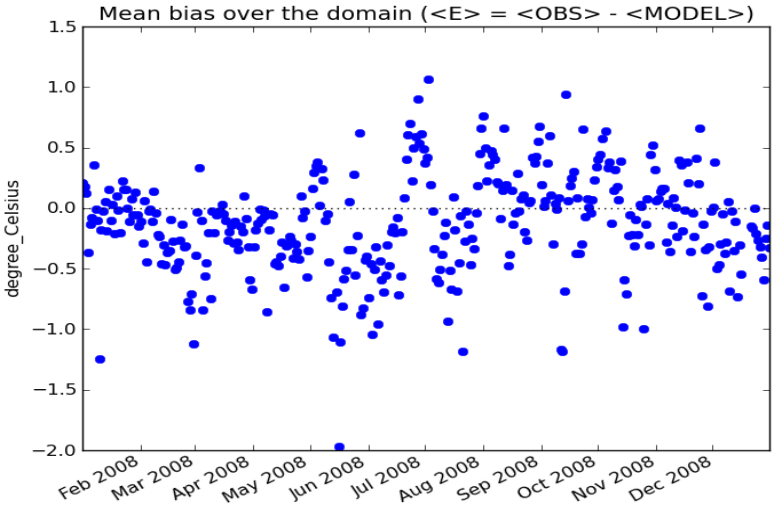
	Caractéristiques la configuration (40 niveau ou 60 niveau)
Domain	0W-16 E ; 39,5-44,5 N
grid	1101x463x40 (or 60) Generalized Sigma Coordinates Résolution 1.2 km
External forcings	Rivers : 9 (mainly the Rhone river) OBC : **NEMOMED12 (southern Boundary)** **ALADIN 12km meteorological forcing** No tide
Schémas	Bulk flux turbulents : **Fairall et al 2003** Advection momentum : Quick (Horizontaly and Vertically) Advection tracer : **Macho3D** (rotation of the treatement of the advection in x-,y-,z-direction) **Fifth order schemes** Presure gradient : Density Jacobian Cubique Spline (Shchepetkin Mc Williams 2003) Viscosity : Smagorinsky formulation Turbulence : **GLS(k-eps)** , z0surf = 1m, z0bottom = 3,5 mm

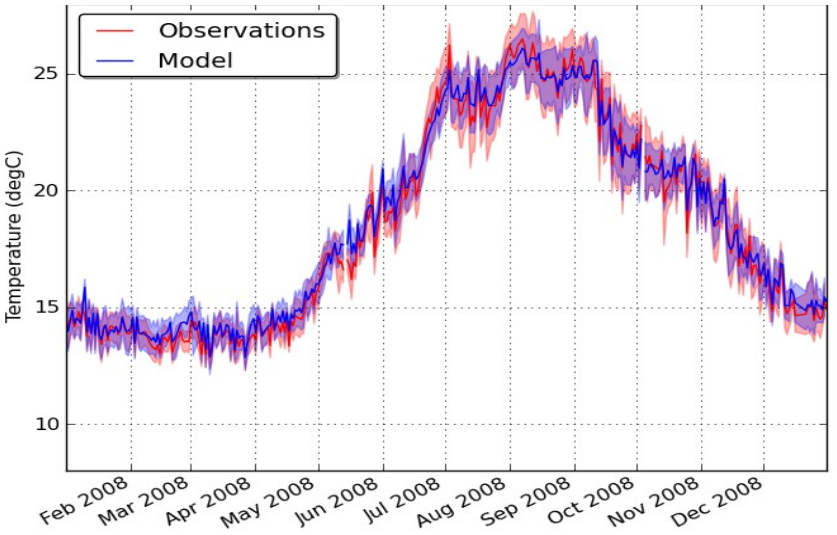
VACUMM – A PYTHON LIBRARY FOR OCEAN SCIENCE
build in collaboration ifremer/Actimar
free-acces / soon in uvcdat package

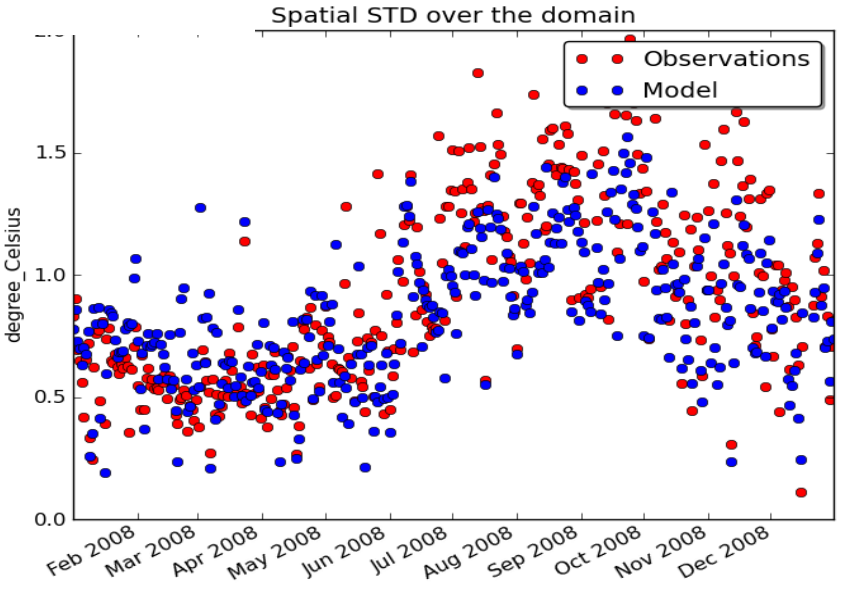
http://www.ifremer.fr/vacumm/
http://www.mercator-ocean.fr/actualites-agenda/newsletter

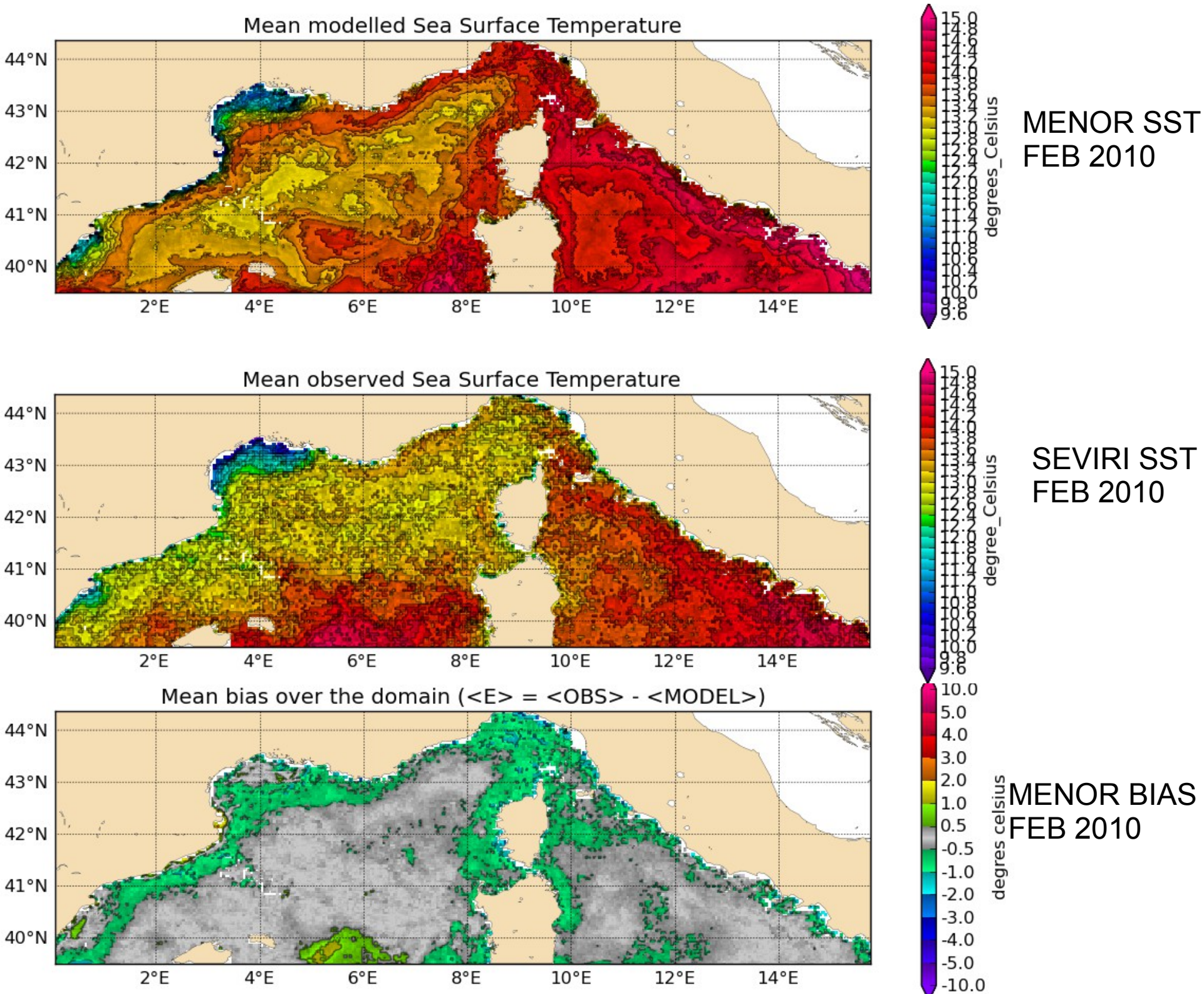
- Comparison modelled SST vs SEVIRI SST



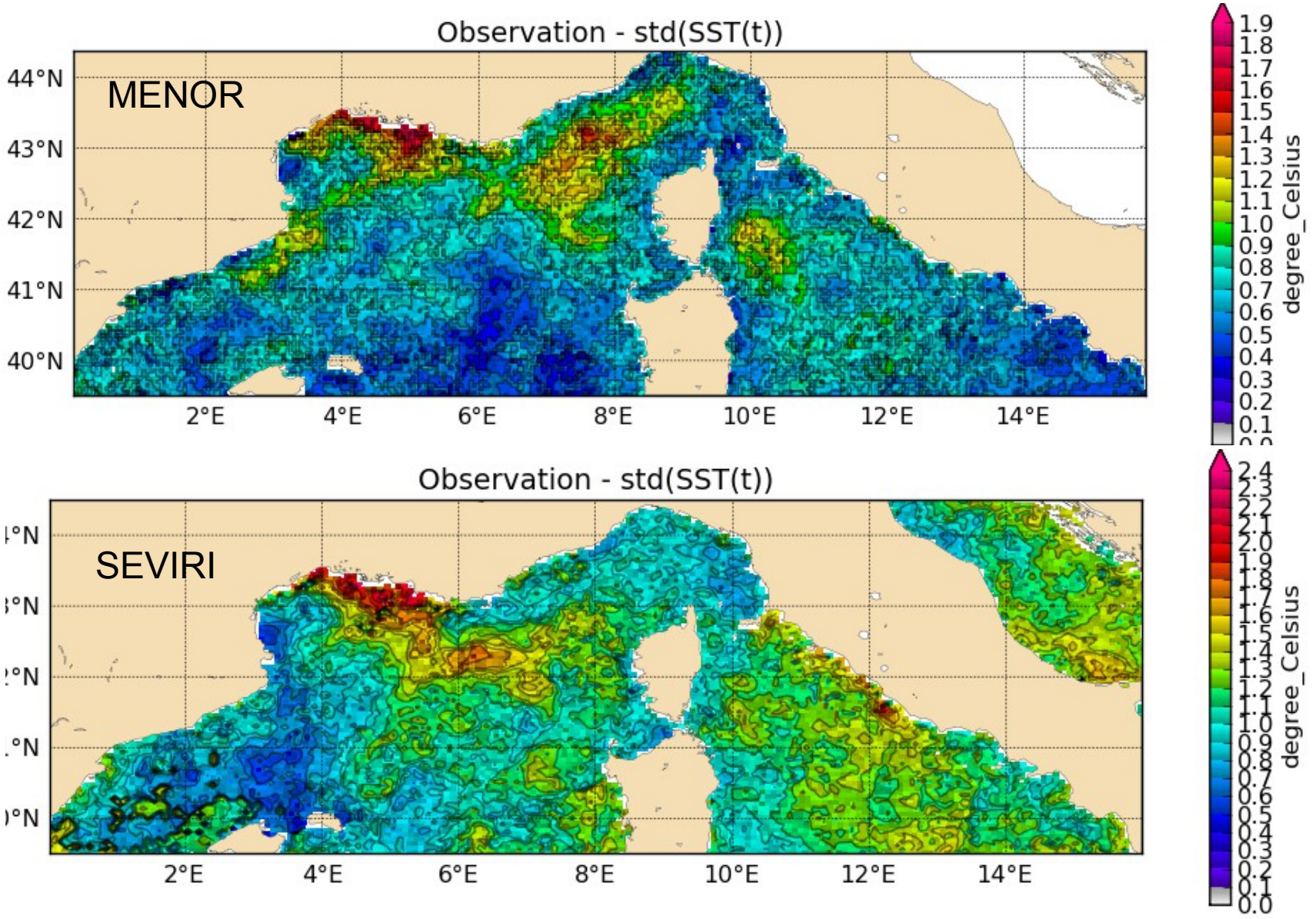




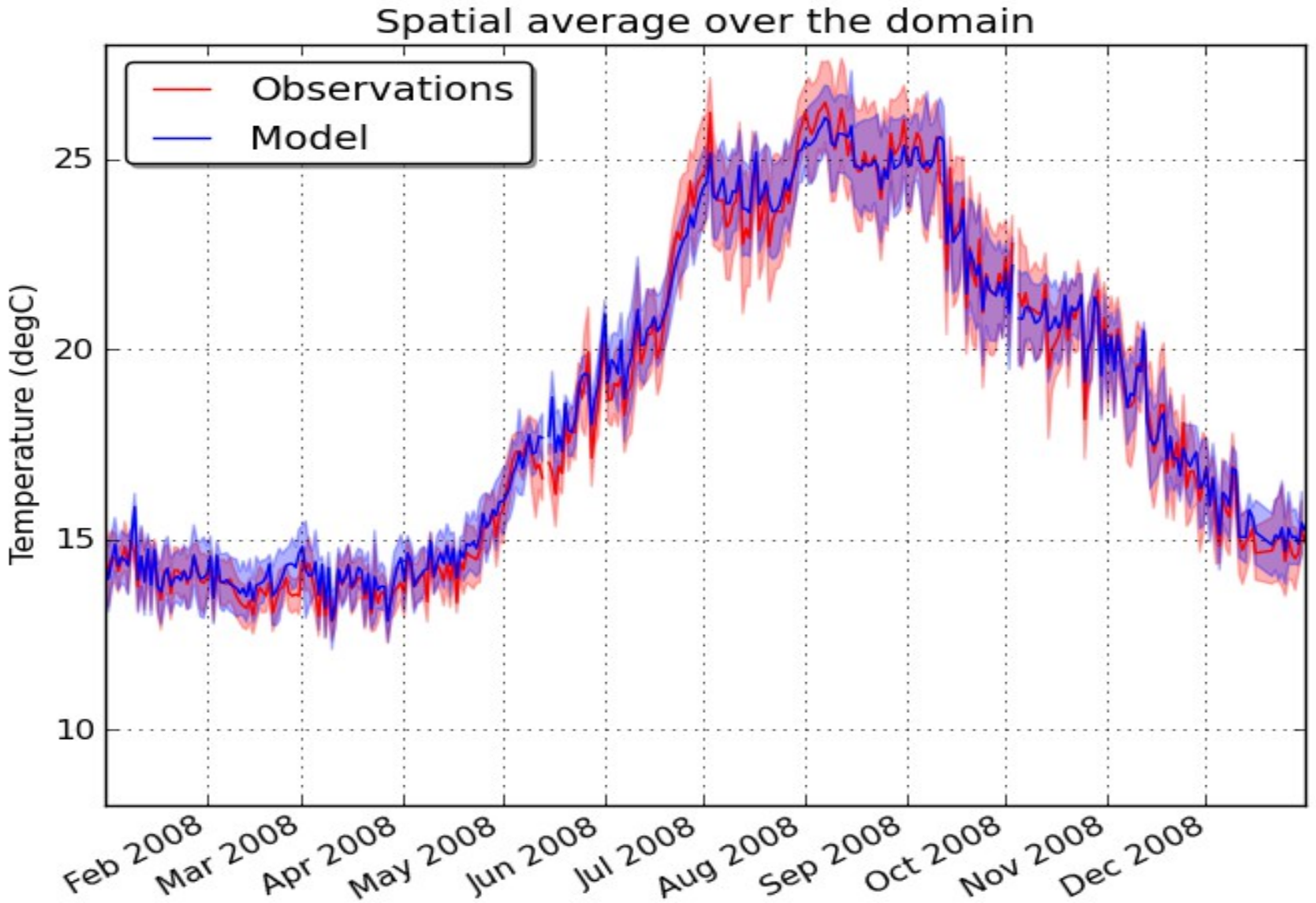



Mean modelled Sea Surface Temperature
44°N
43°N
42°N
41°N
40°N
2°E
4°E
6°E
8°E
10°E
12°E
14°E
degrees_Celsius
MENOR SST
FEB 2010
Mean observed Sea Surface Temperature
degree_Celsius
SEVIRI SST
FEB 2010
Mean bias over the domain (<E> = <OBS> - <MODEL>)
degres celsius
10.0
5.0
4.0
3.0
2.0
1.0
0.5
-0.5
-1.0
-2.0
-3.0
-4.0
-5.0
-10.0
MENOR BIAS
FEB 2010

Temporal STD July 2010



Validation of the SST MENOR 2008



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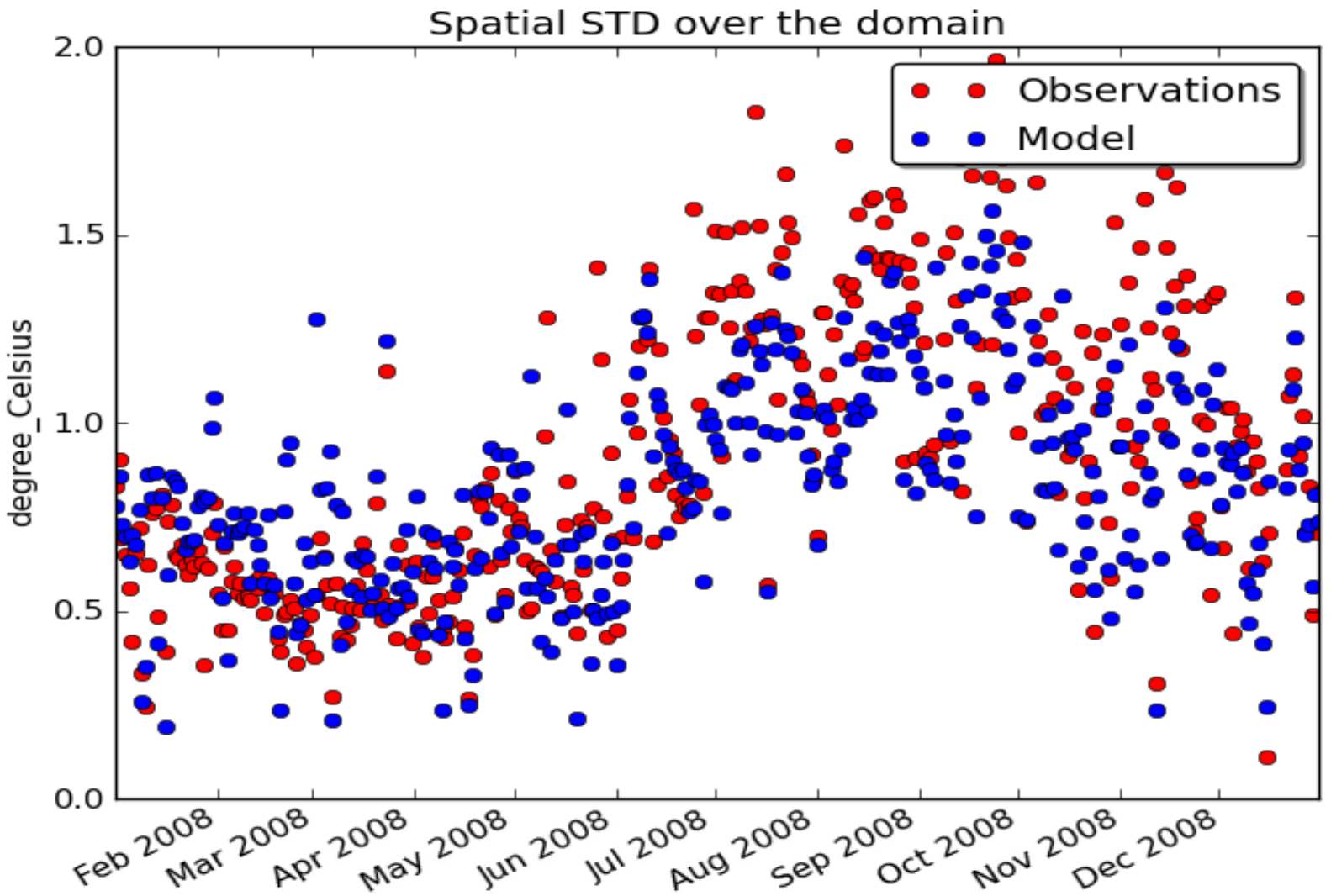
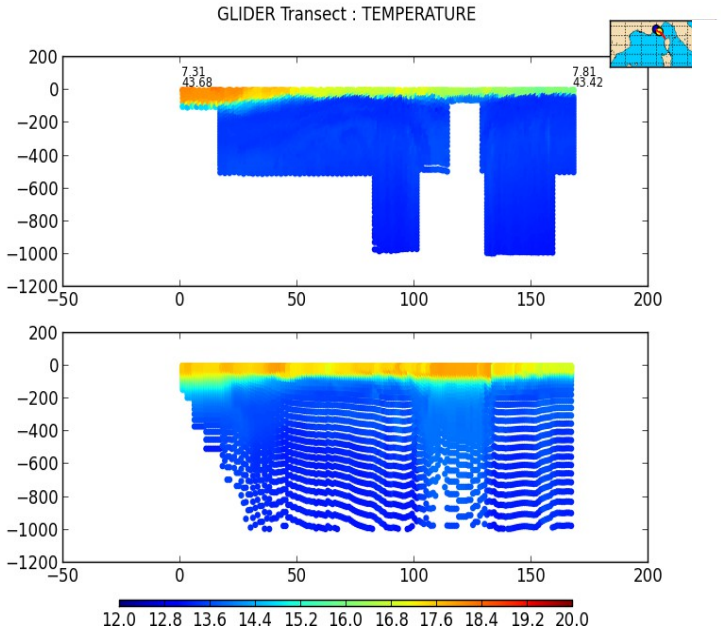
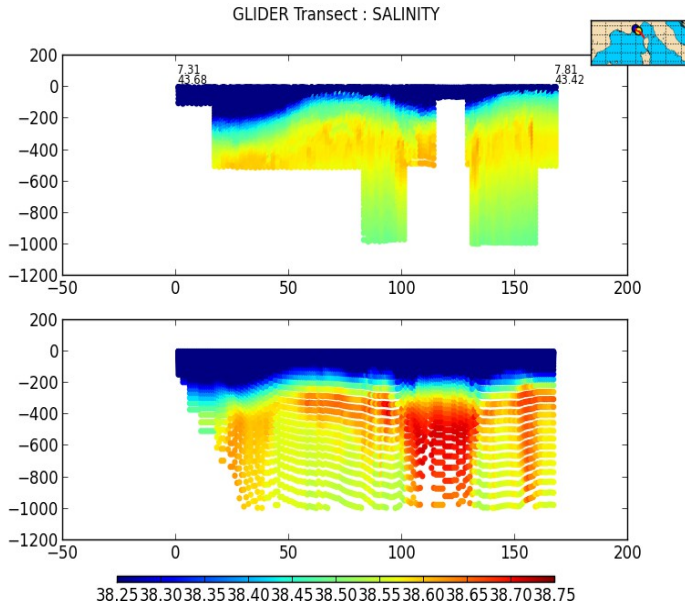
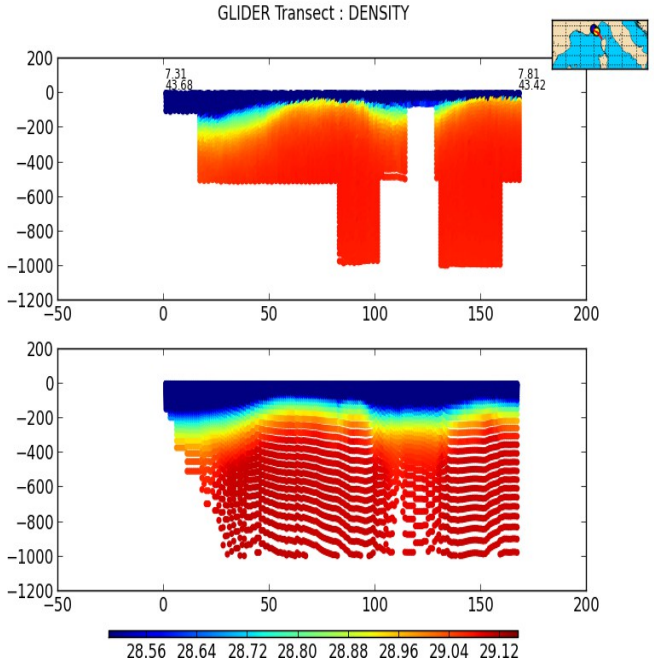


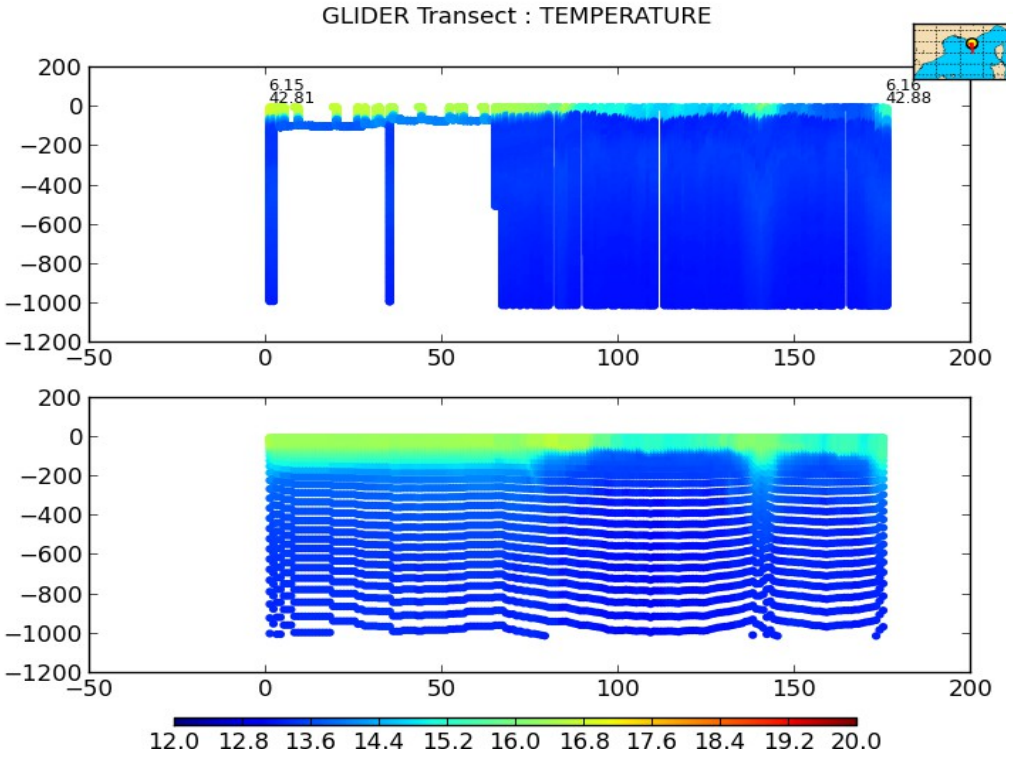
Glider vs Model 2009-11

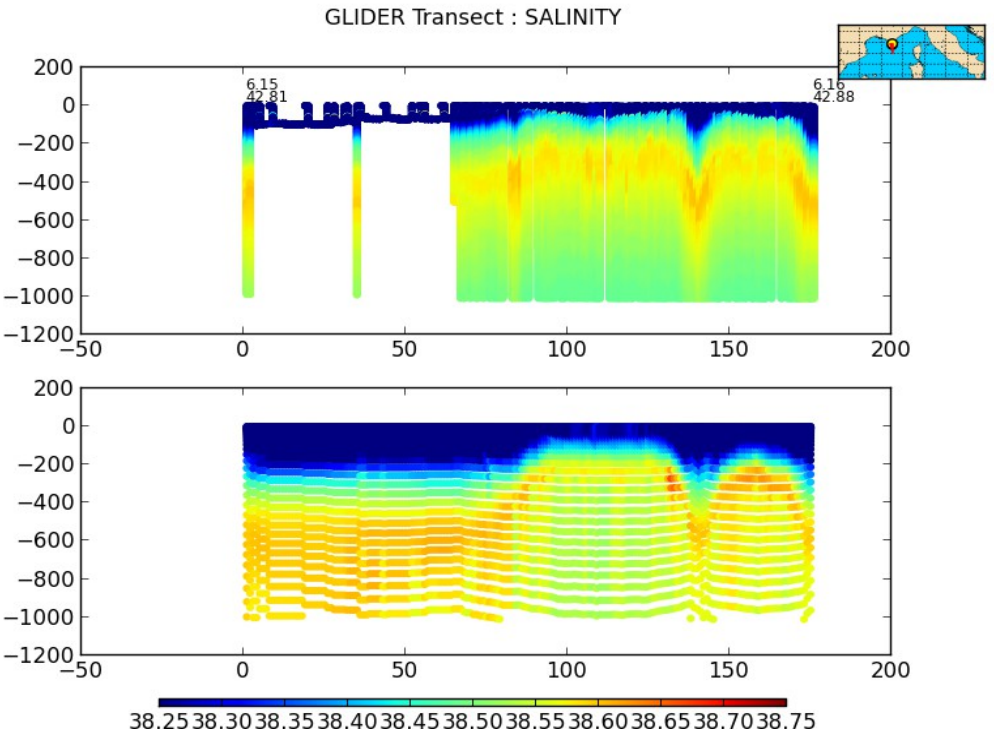






Glider vs Model
2009-12



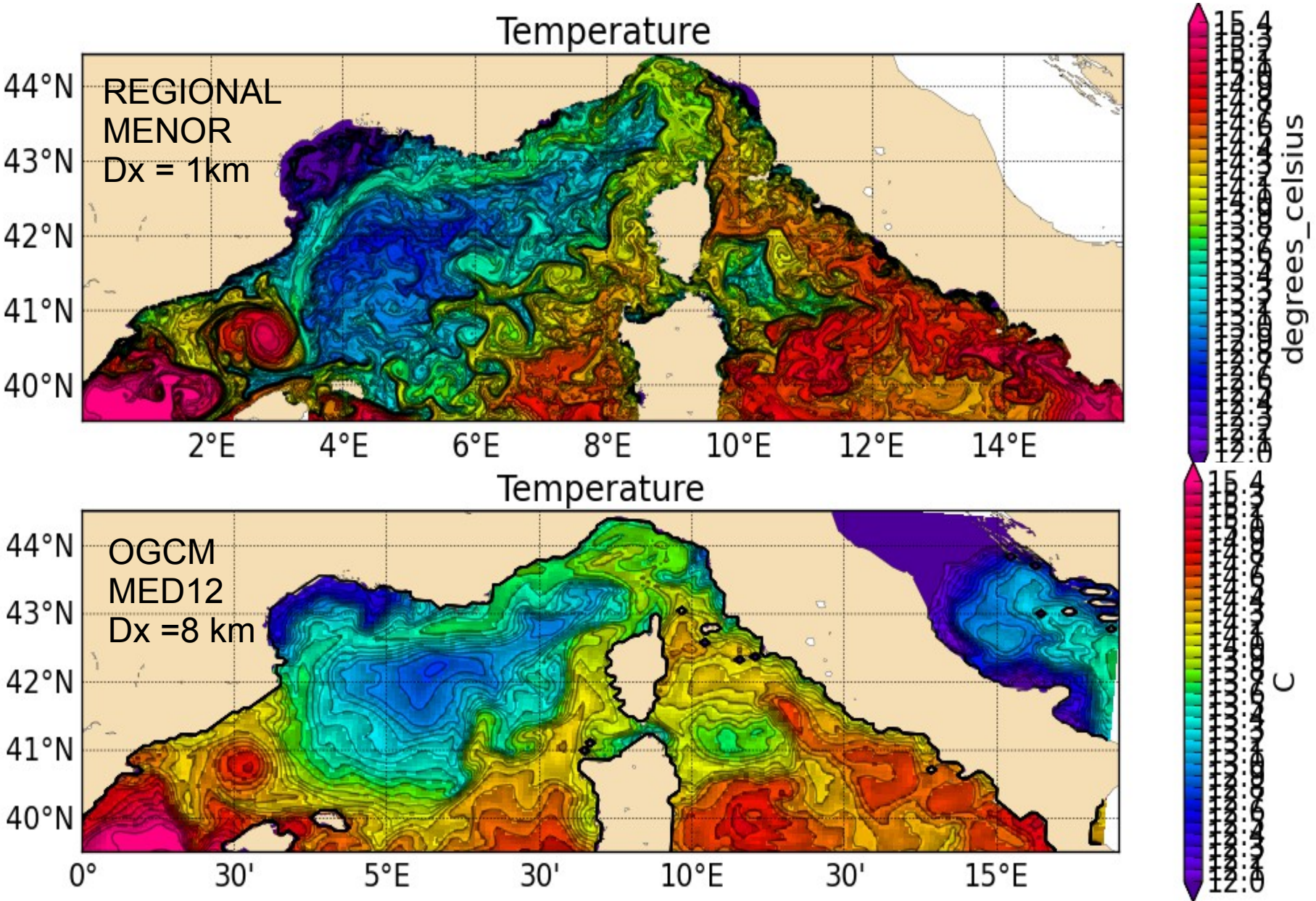


Comparison OGCM / MENOR
2008-2009-2010

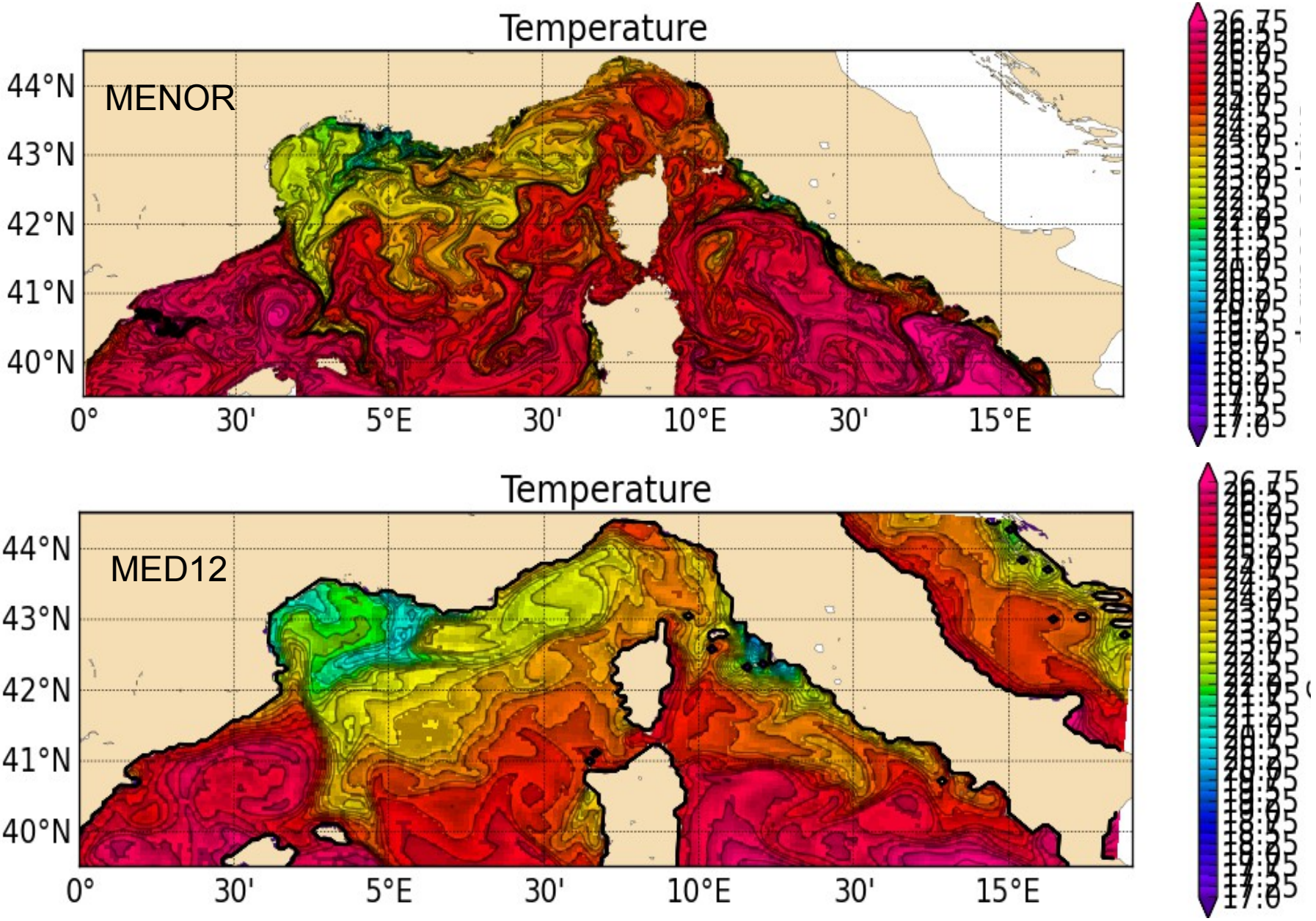
- OGCM (whole mediterranean sea) managed by ENSTA :
  - Nemo code
  - 1/12° horizontal résolution (8km) / 50 z-vertical levels
  - Provides initial and boundary conditions to MENOR

- MENOR (NW mediterranean sea) :
  - Mars3d code
  - 1/64° horizontal résolution (~1.2 km) / 40 (60) generalized sigma coordinates

Snapshots SST 2008-03-01

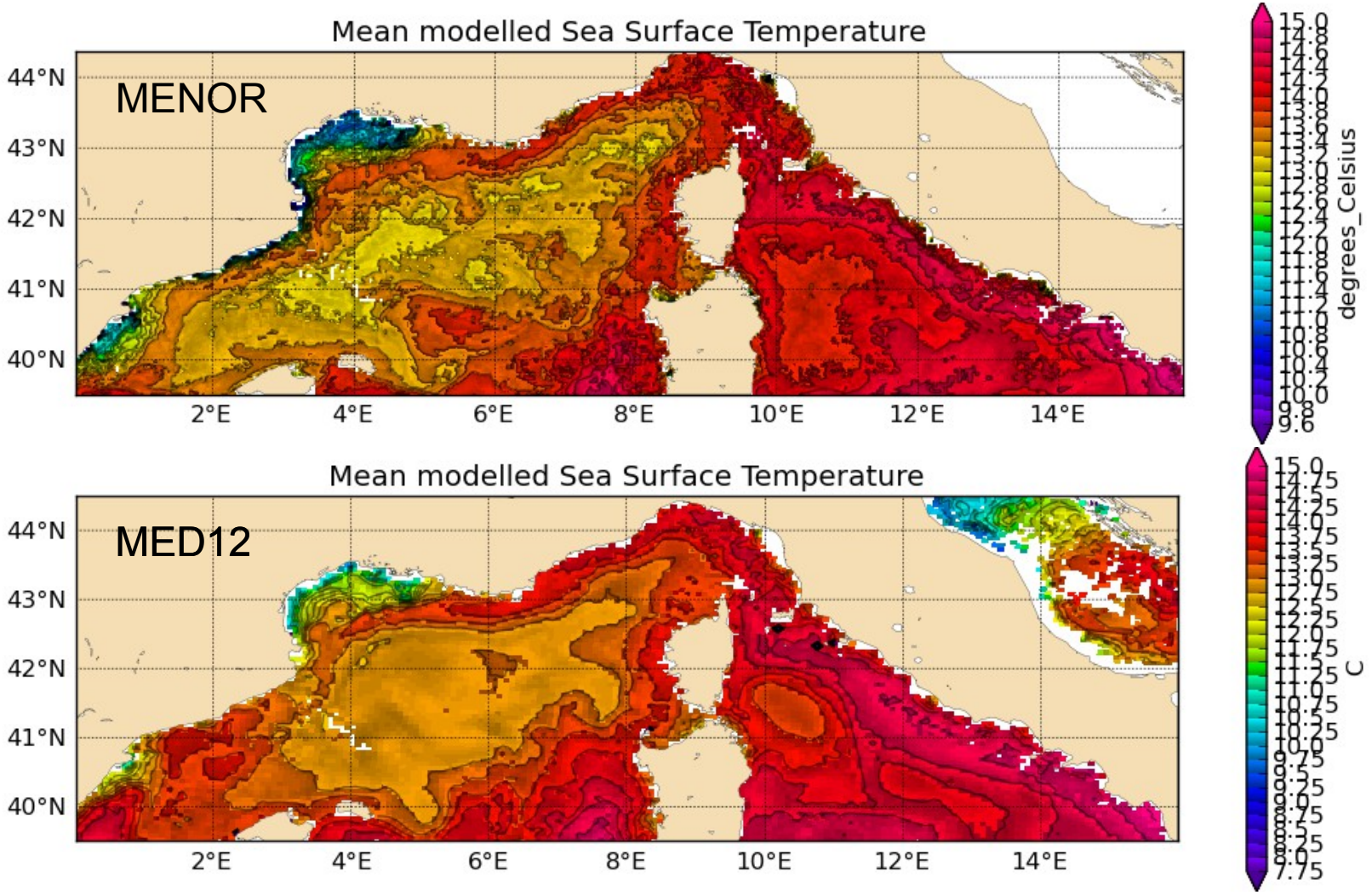


Snapshots 2008-08-31



Comparison MENOR vs MED12

- FEBRUARY 2010



Variability of the circulation : Eddy Kinetic Energy from ssh

Total Kinetic Energy (averaged over 3 months)

$$\overline{TKE}^{\,3\text{months}} = \overline{\frac{g^2}{2f^2}\left[(\eta_x)^2 + (\eta_y)^2\right]}^{\,3\text{months}}$$

Mean Kinetic Energy

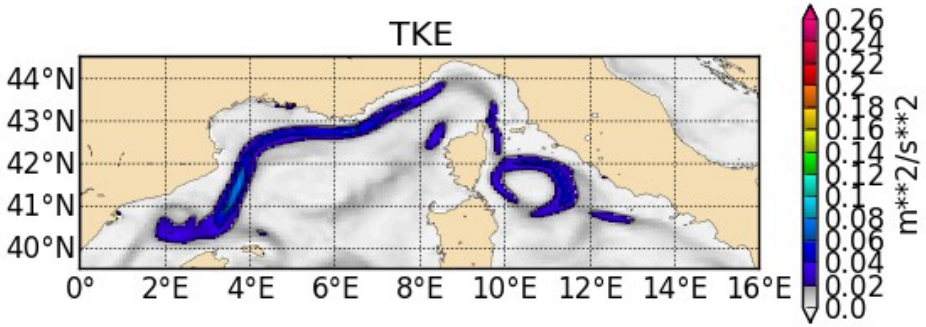
$$MKE = \frac{g^2}{2f^2}\left[(\bar{\eta}_x^{\,3\text{months}})^2 + (\bar{\eta}_y^{\,3\text{months}})^2\right]$$

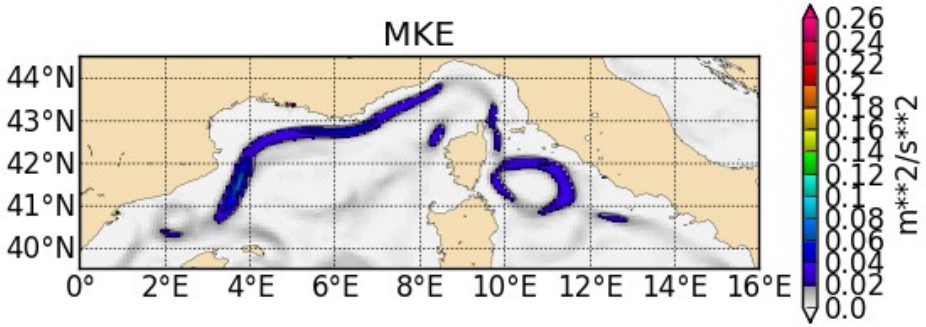
Eddy Kinetic Energy

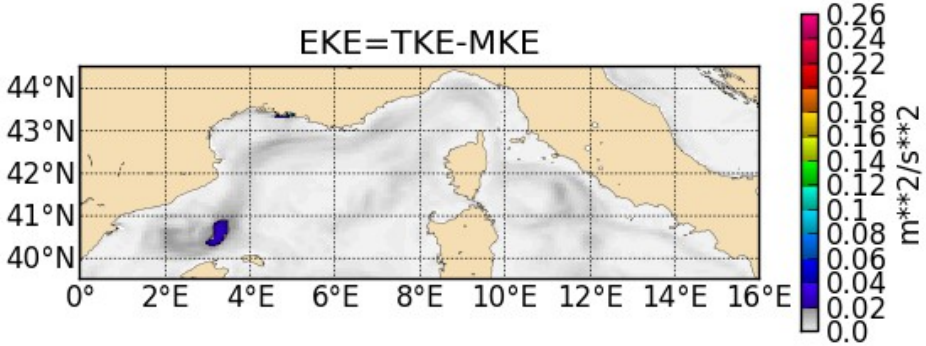
$$\overline{EKE}^{\,3\text{months}} = \overline{TKE}^{\,3\text{months}} - MKE$$

Eddy Kinetic Energy from ssh
Jan-Feb-Mar 2009

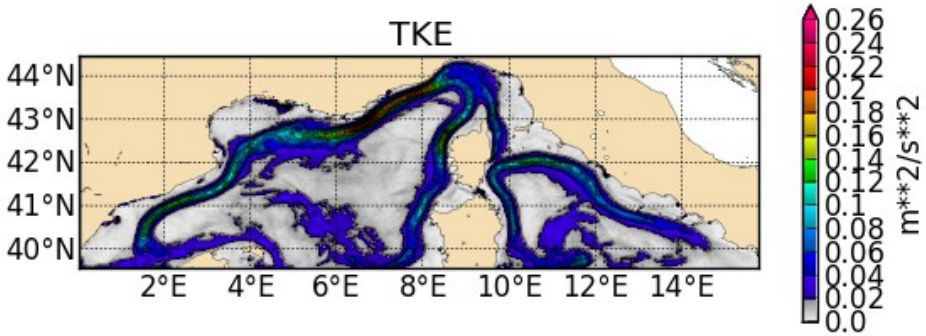
MED12-OGCM 1/12

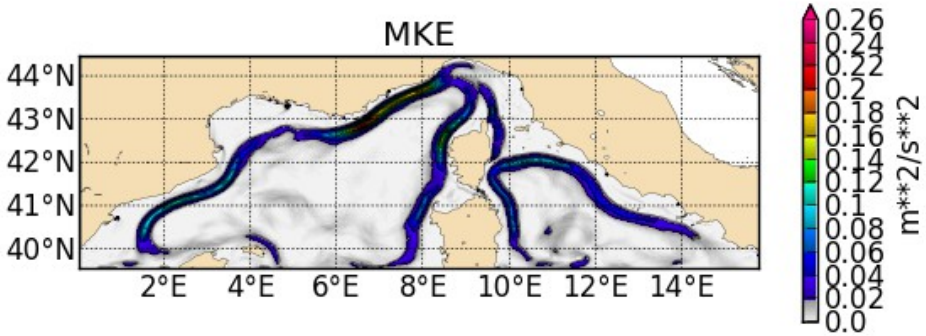


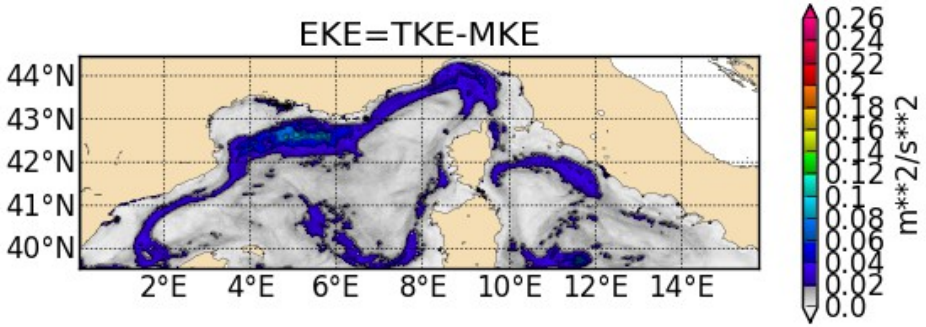




MENOR – REGIONAL 1/64

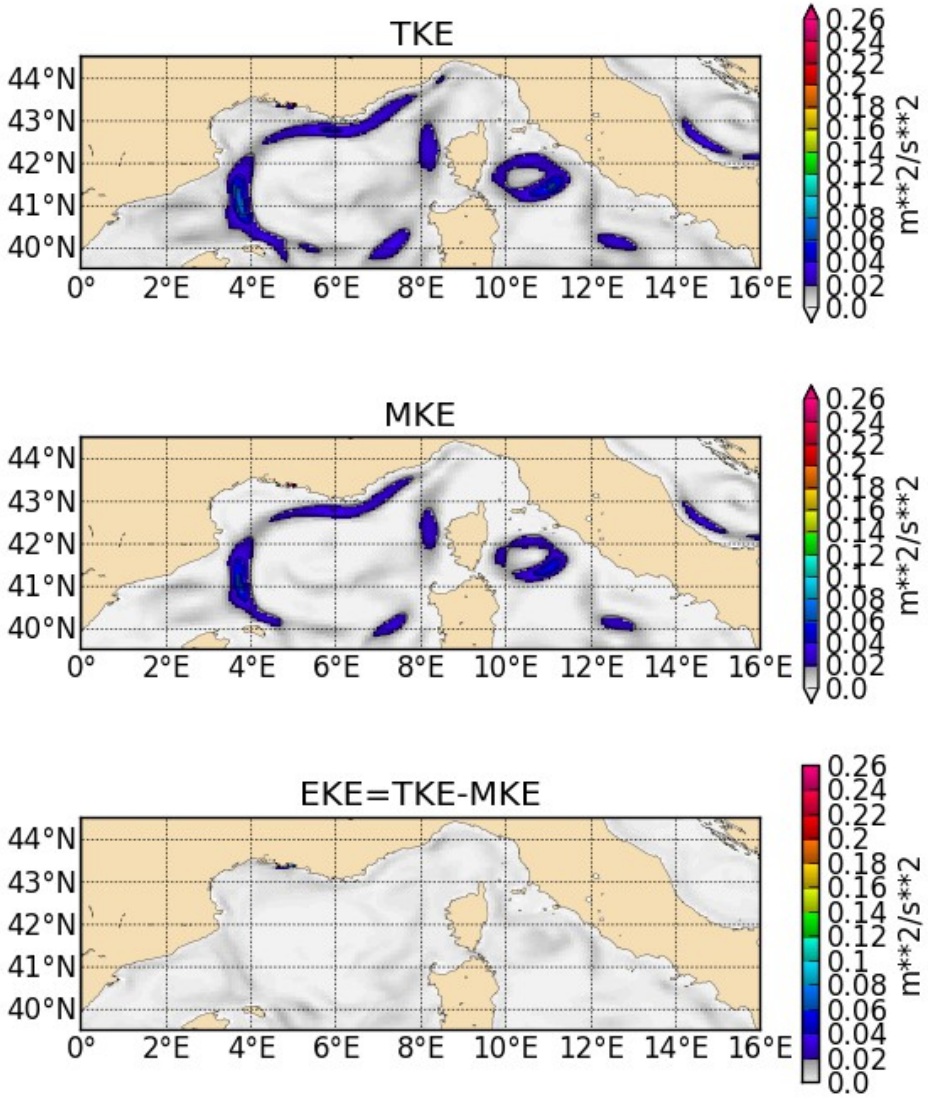




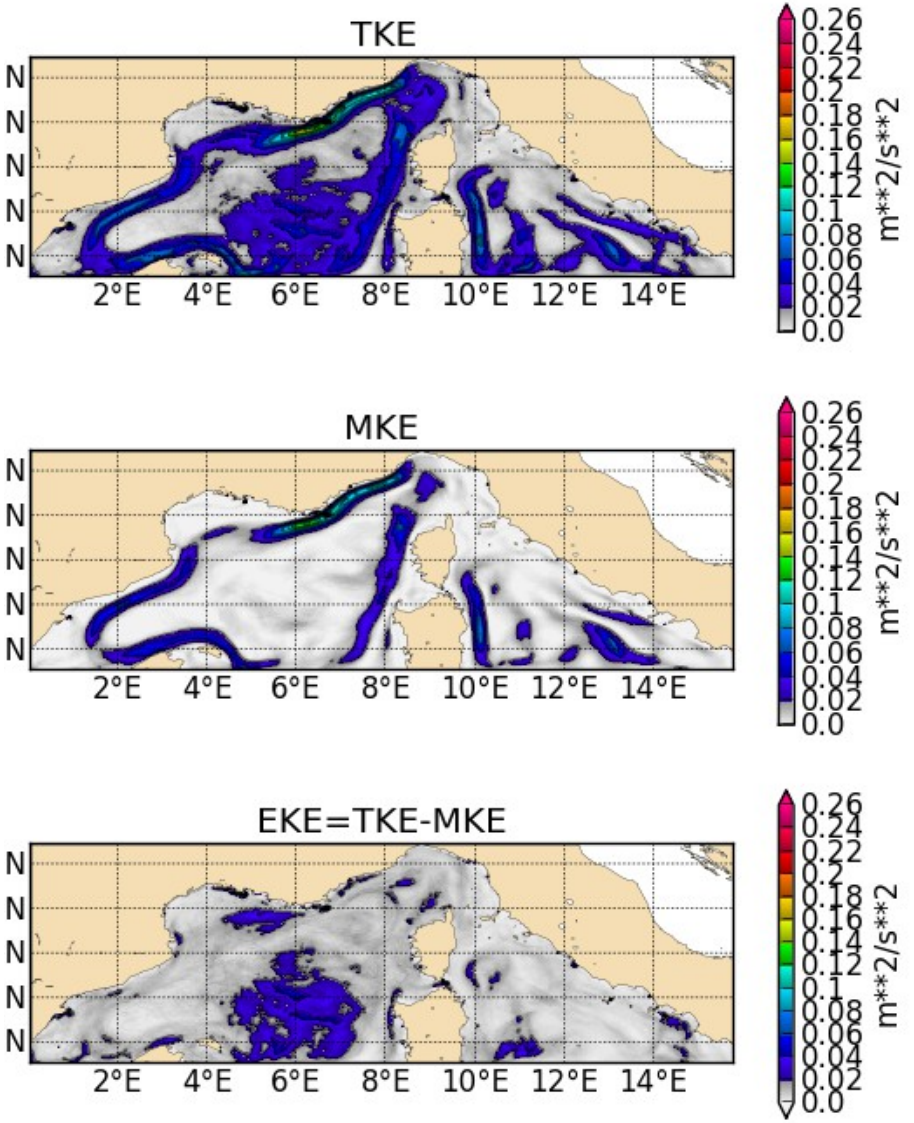


Eddy Kinetic Energy Diagnostic
Sep-Oct-nov 2009

MED12-OGCM 1/12



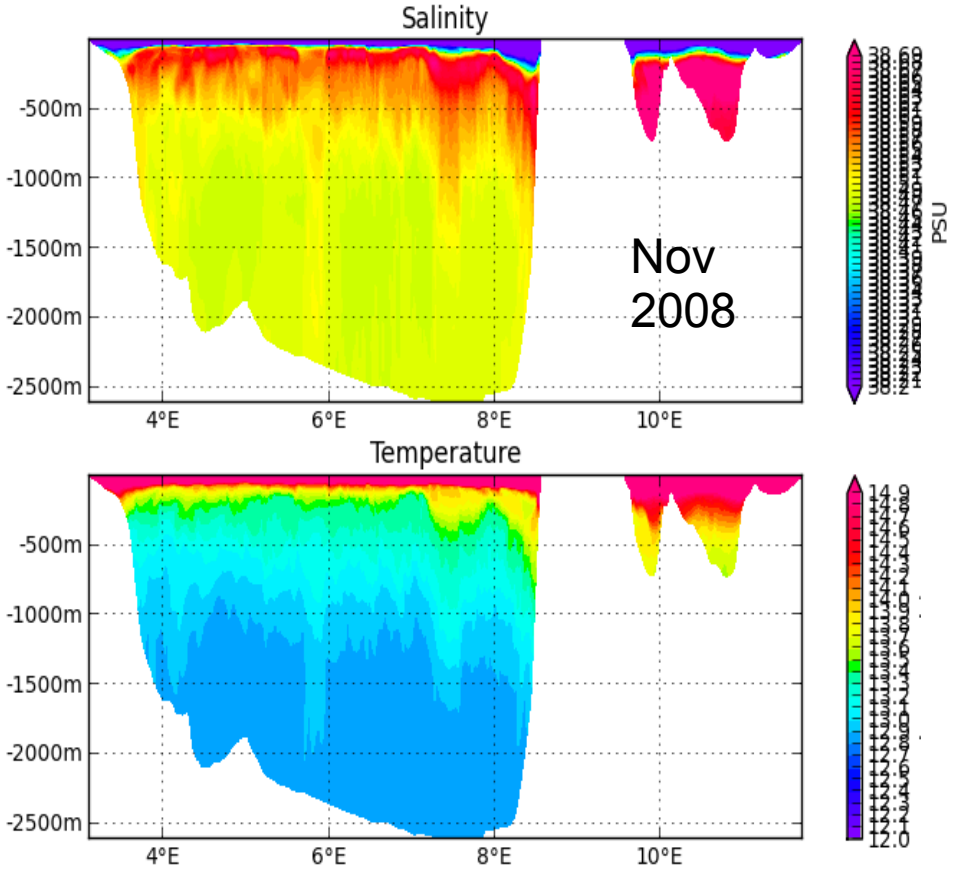
MENOR – REGIONAL 1/64



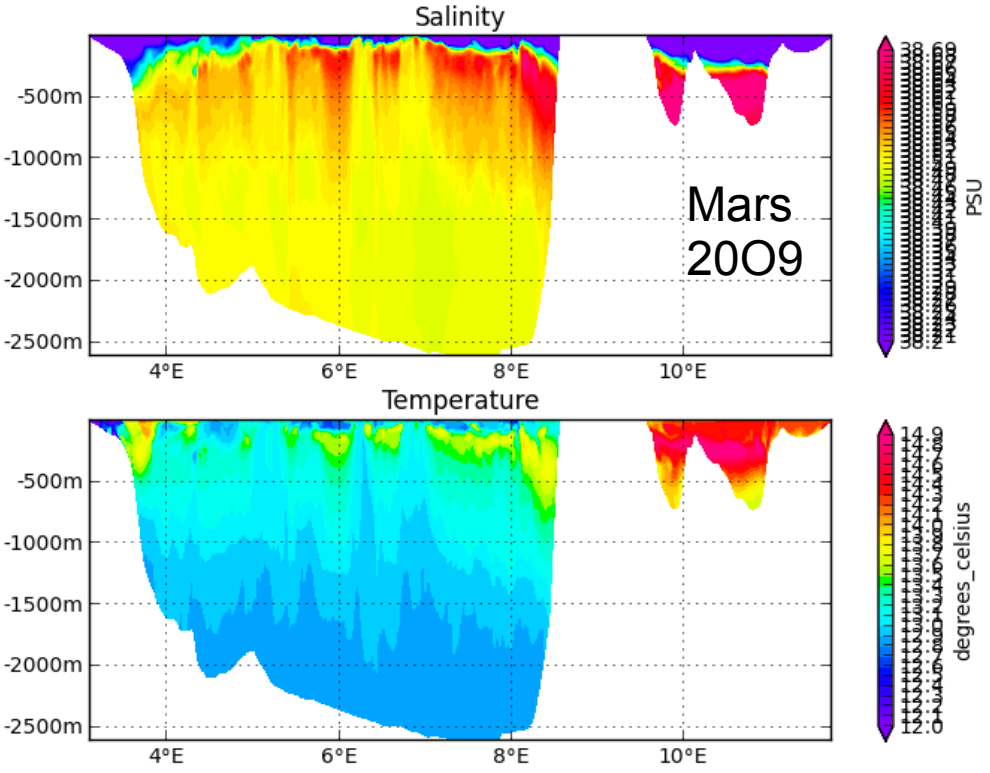
Dynamic of the Levantine Intermediate Water

- Levantine Intermediate Water (LIW) is « salted » « warm » water mass comming from Levantine (oriental) basin ; flowing into North-Western Mediterranean basin along Sardinia and through Corsica strait.
- LIW stays between 300:800 m depth
- LIW is essential for the dynamics of the « Northern gyre »

Dynamic of levantine water (LIW)
Cross Section at 42.0° N

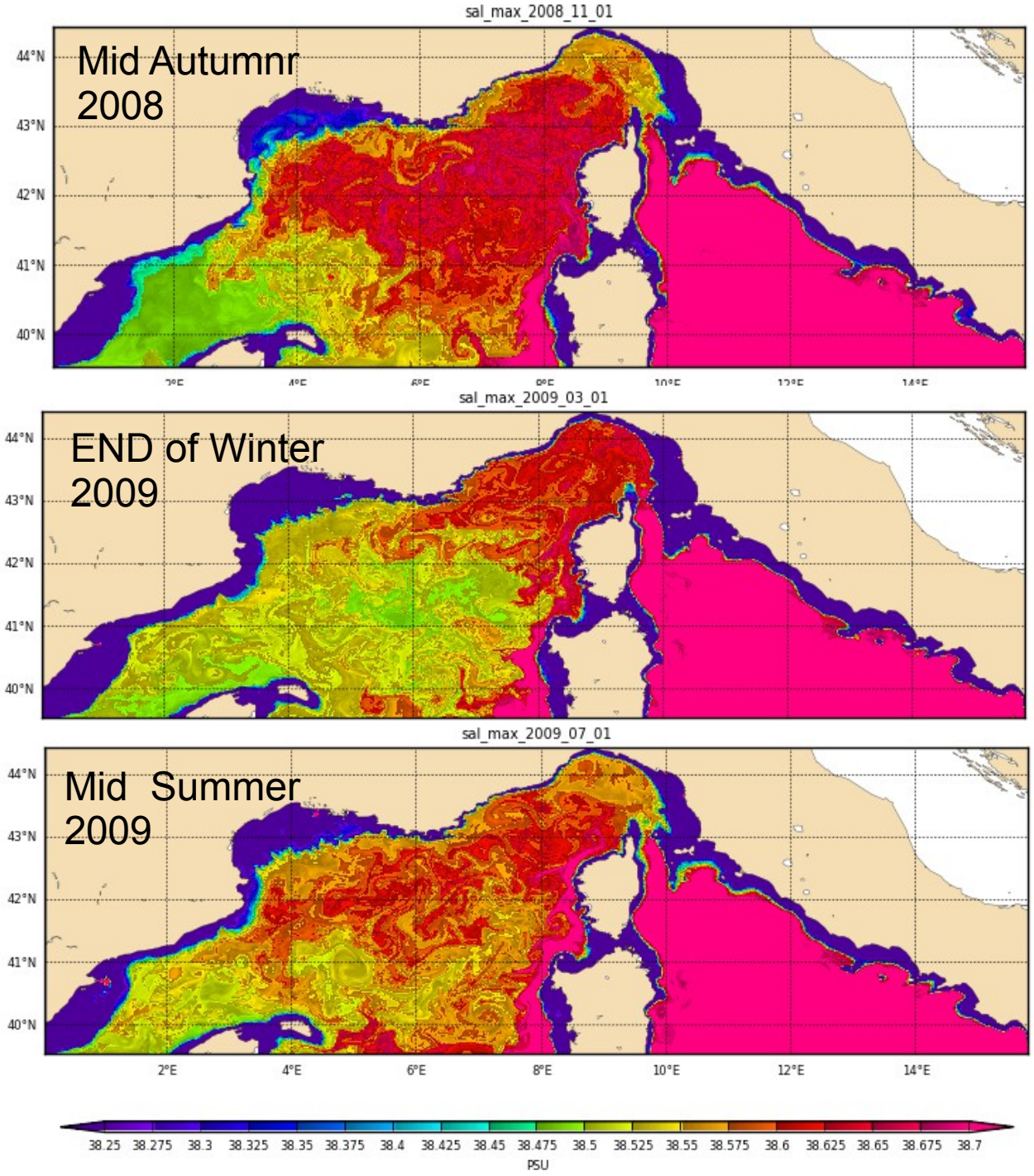


LIW characteristics :
- min_sal=38.48 ; max_sal=38.86
  min_temp=13.2 ; max_temp=14.2
- -depth (300 :800)



Dynamic of Levantine Intermediate Water

Maximum of salinity between 0:800m

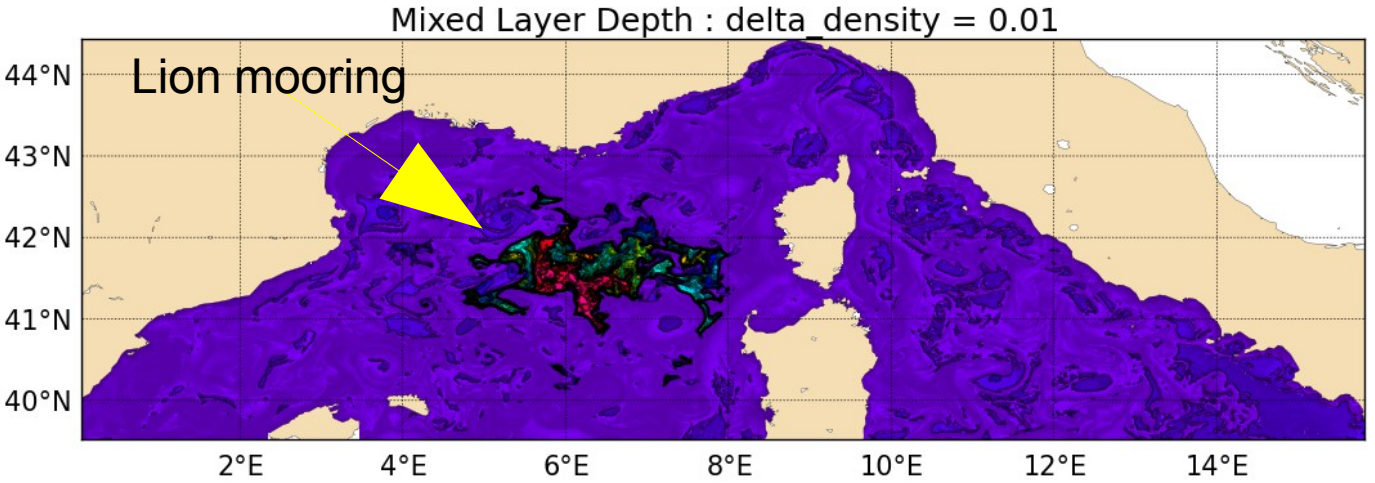


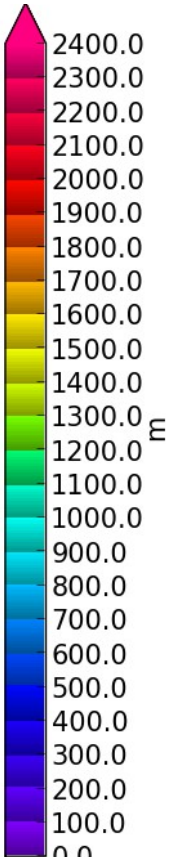
Levantine water is present on the main part of the basin

Levantine water disappears from the central part of the basin du to vertical mixing

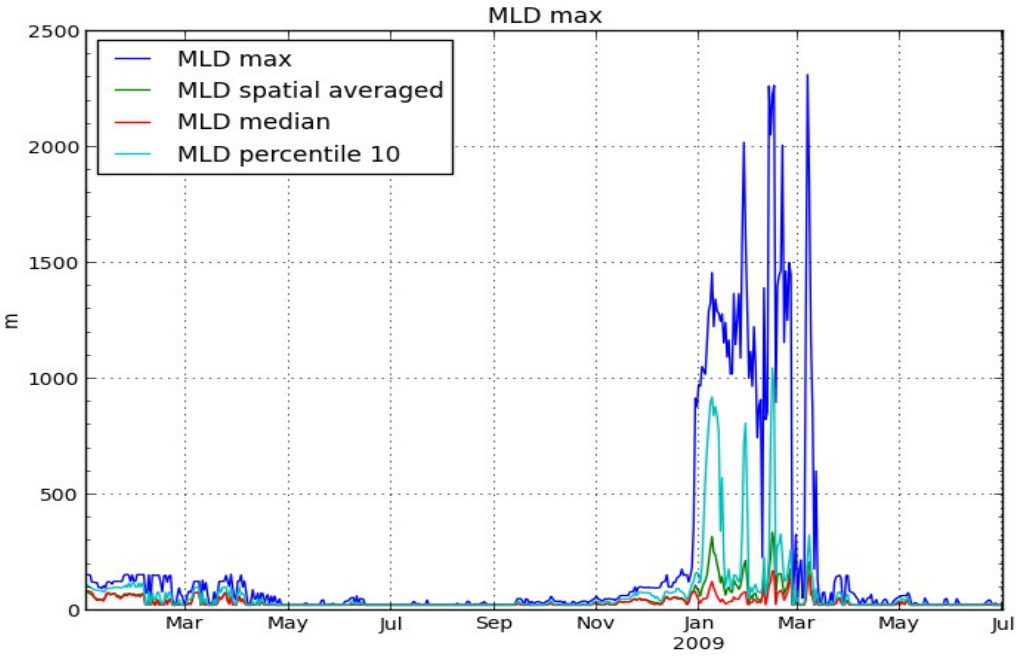
Levantine water is flowing back in the central part of the basin Note the advection along Sardinia

Dynamic of Levantine Intermediate Water
Mixed layer Depth





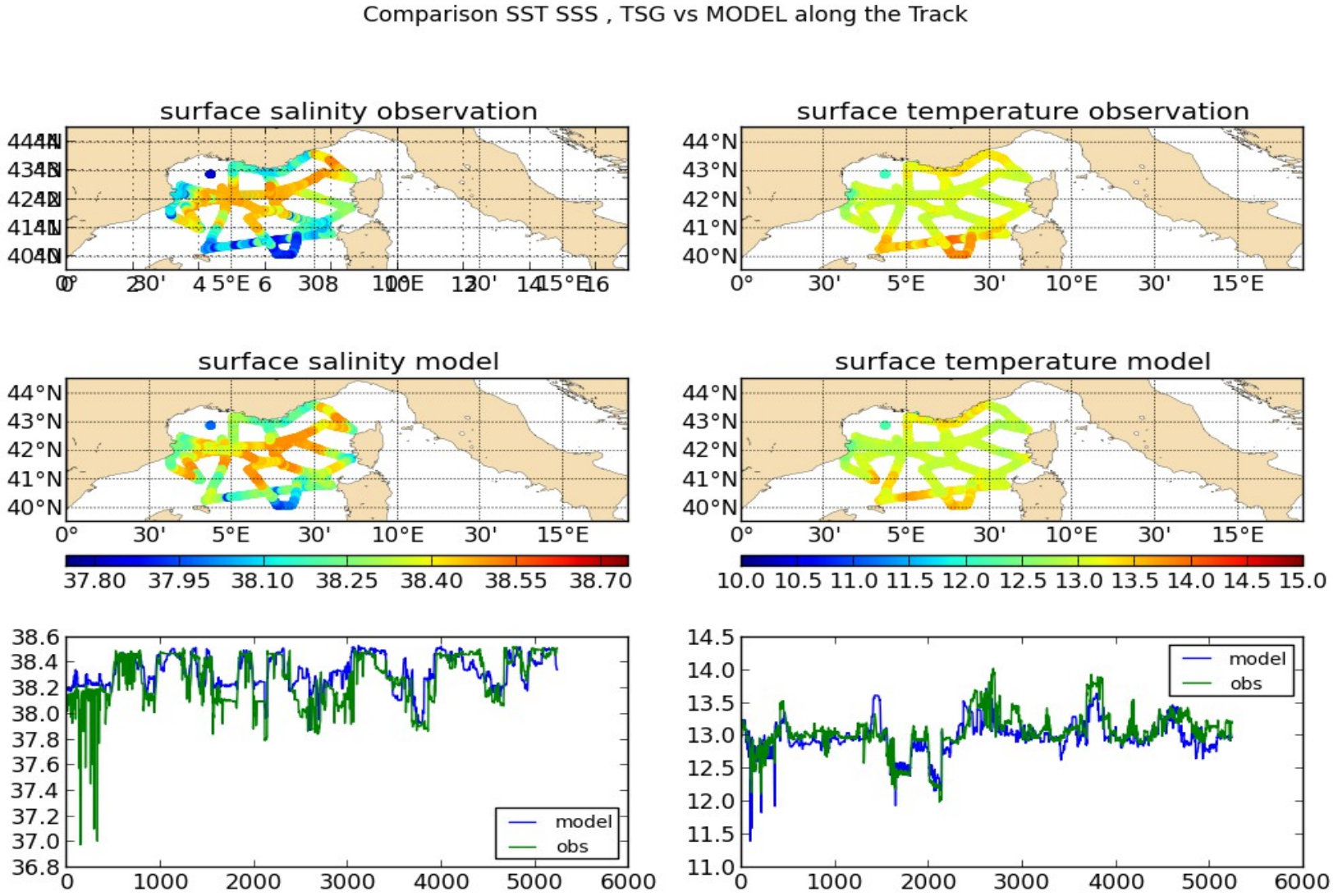
Mixed Layer
Depth 50 km
Around Lion Buoy



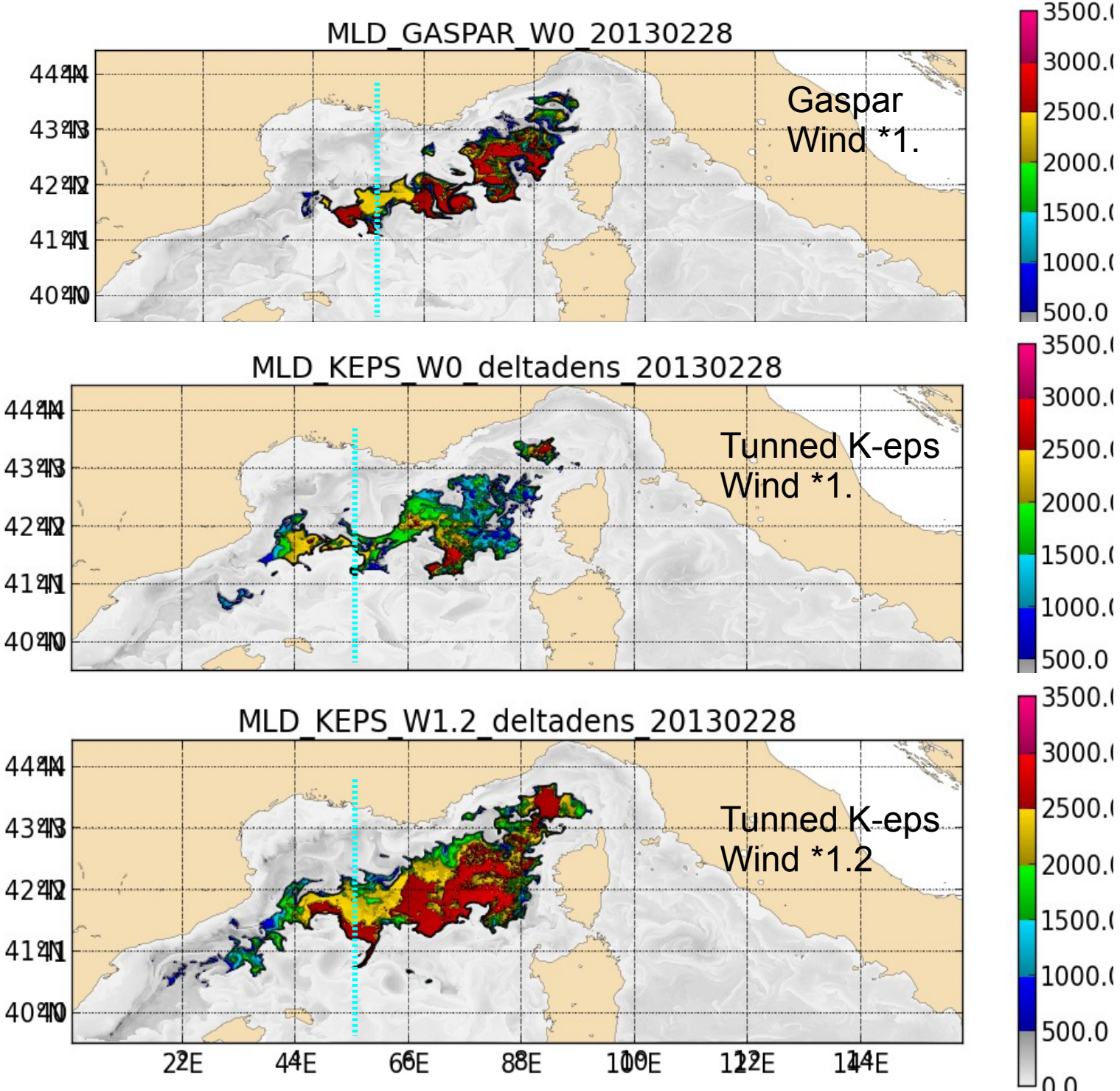
Modelling the dense water formation « Hymex Experiment » winter 2012/2013

- Hymex is an (inter)national experiment about the water cycle in the Mediterranean sea focusing in feb-march 2013 on dense water formation (http://www.hymex.org)
- Prescribed initial and boundary conditions form Mercator global model
- Atmospheric forcing : Arpege-HR from french Met-Office (hourly /10km resolution)
- Comparison of vertical diffusion models : Gaspard (1 equation) vs k-eps (2 equations)
- In the k-eps the minimum of dissipation rate coefficient (eps) has been tunned in order to save the Levantine Water subsurface layer. min(eps) is increased just below the Levantine mater masses in order to inhibates the mixing with the bottom layer.

Comparison SSS and SST (Tsg) vs model during Hymex experiment feb-march 2013

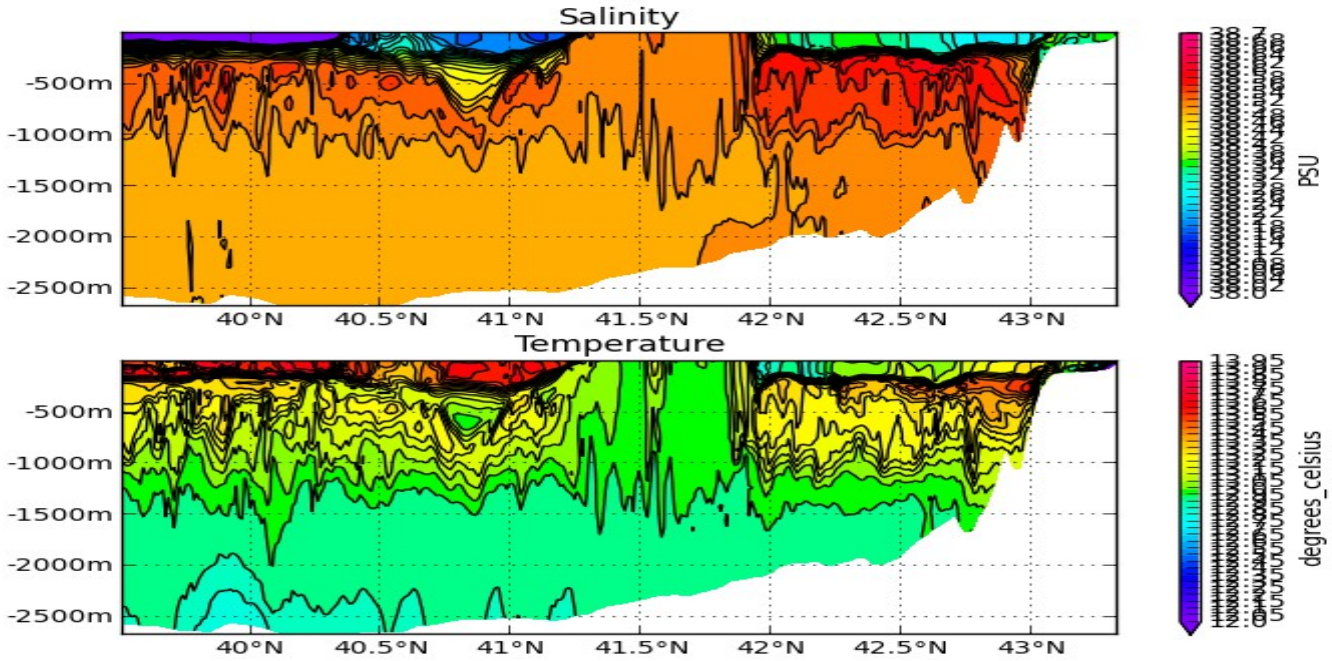


Mixed Layer Depth defined as deltadens < 0.01

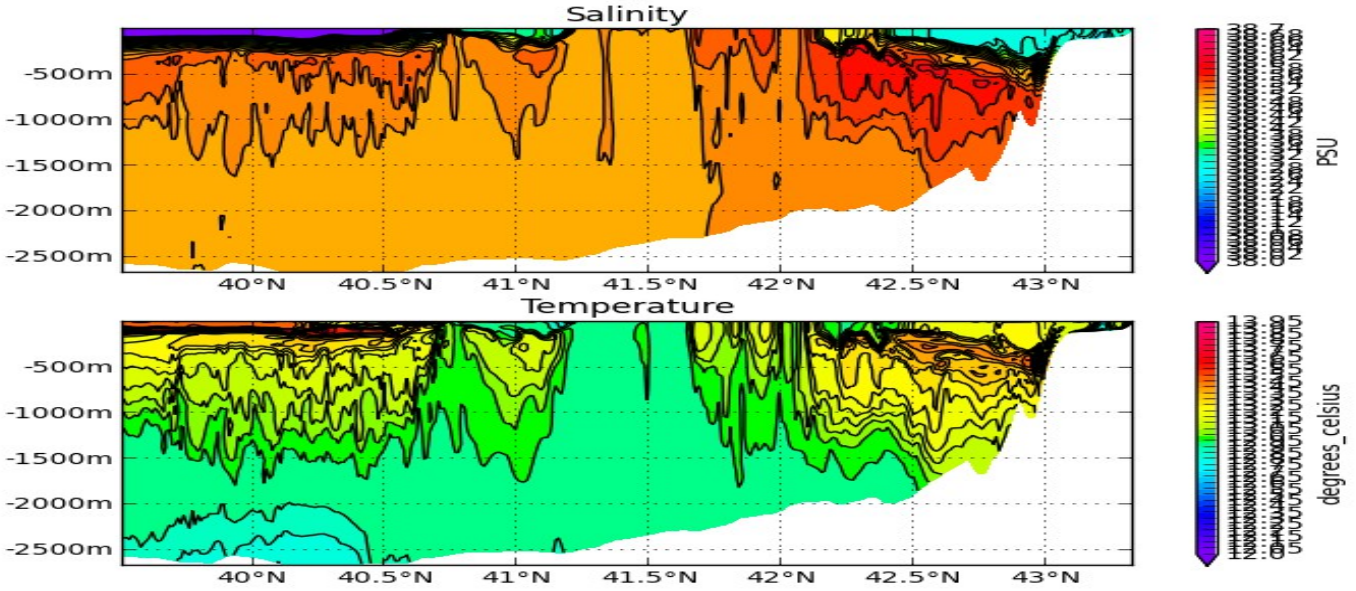


Transect 5.0°E 2013-02-15 /20130228
Tunned K-eps model

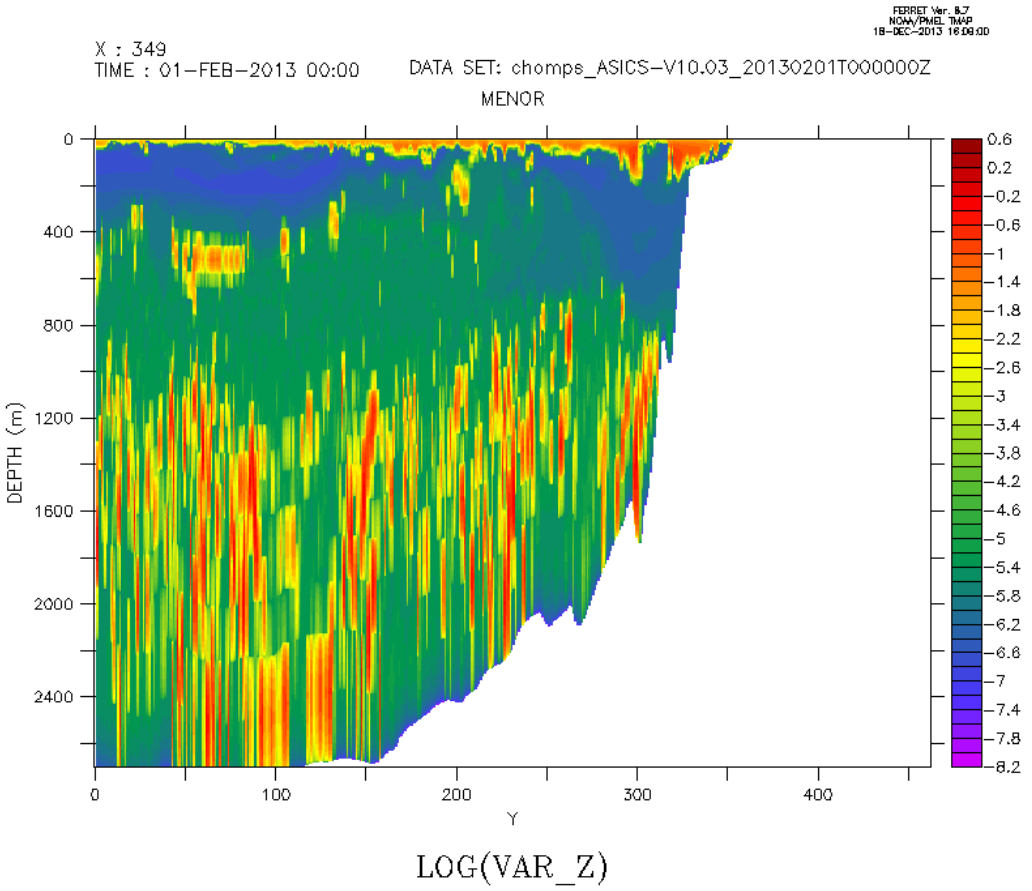
2013-02-15
Just before
deep
convection
event

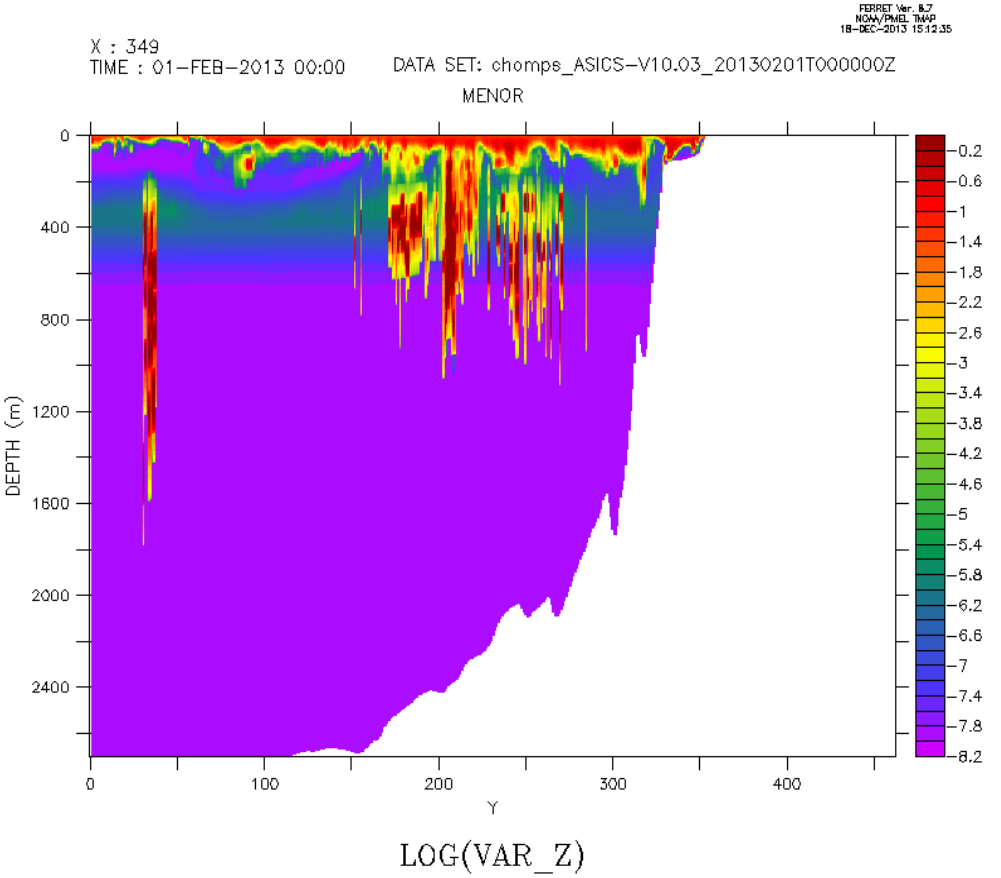


2013-02-28
Just after
deep
convection
event

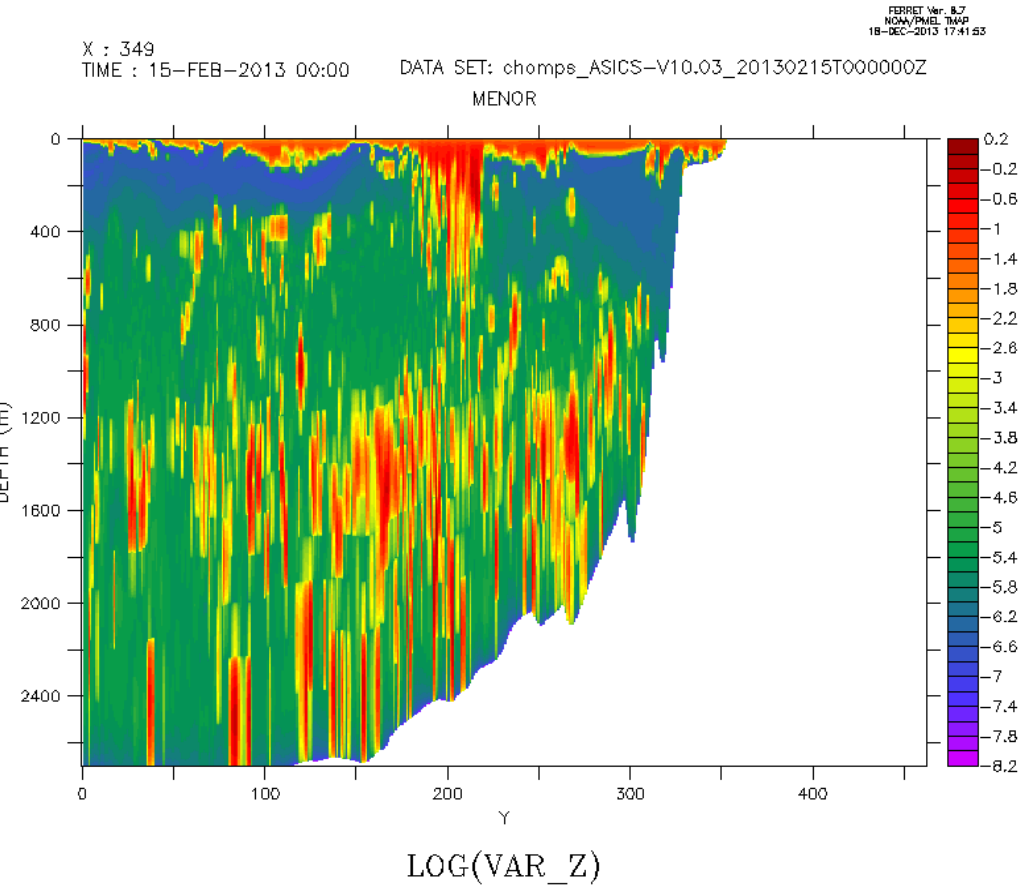


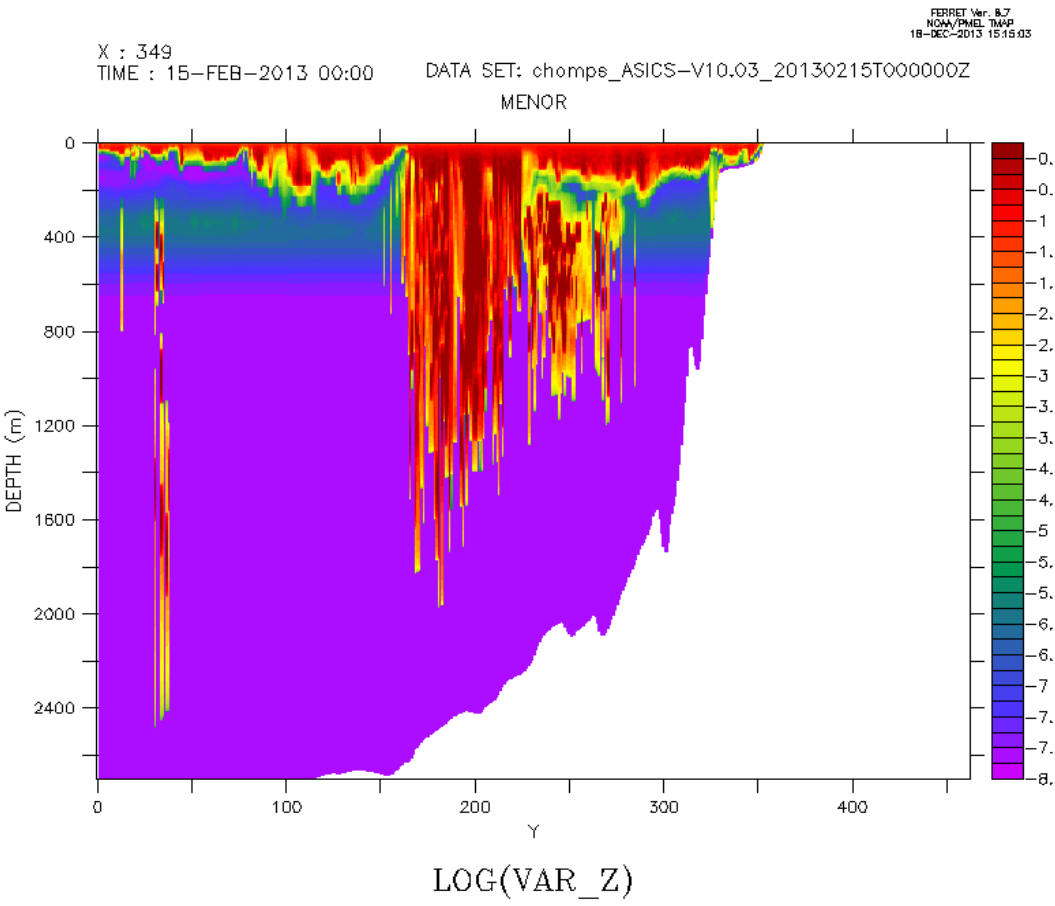
Transect log(kz) 2013-01-15
GASPAR vs tunned K-eps



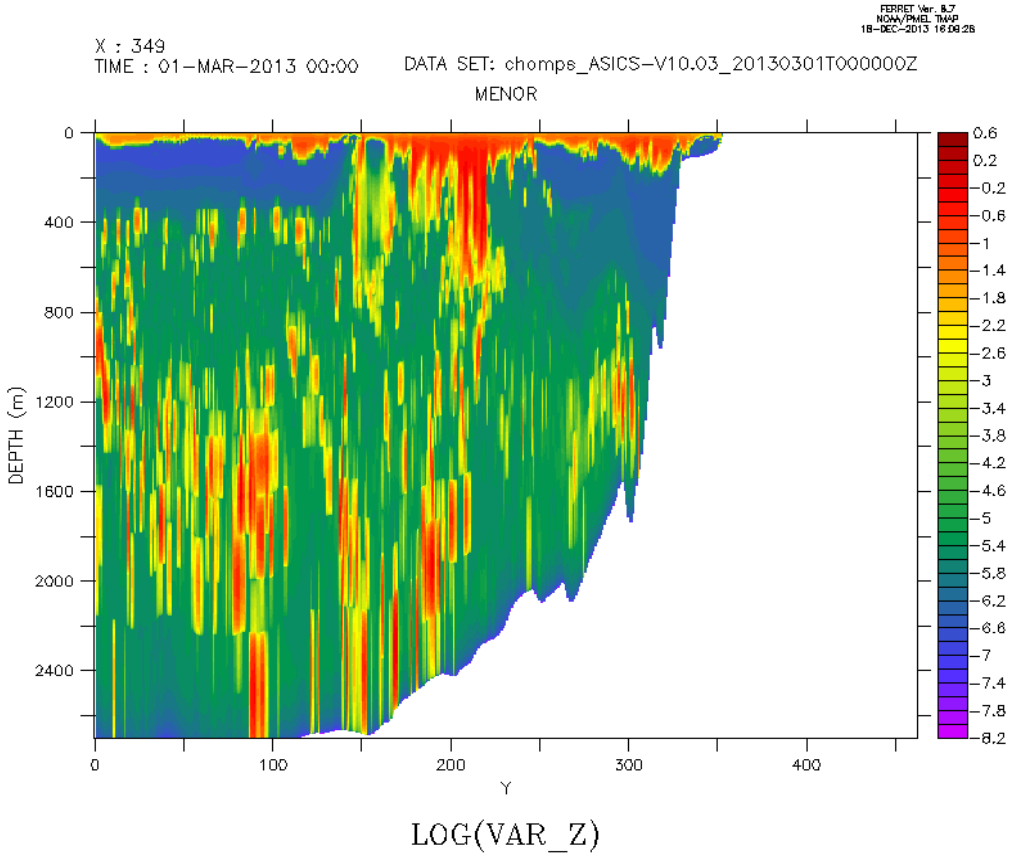


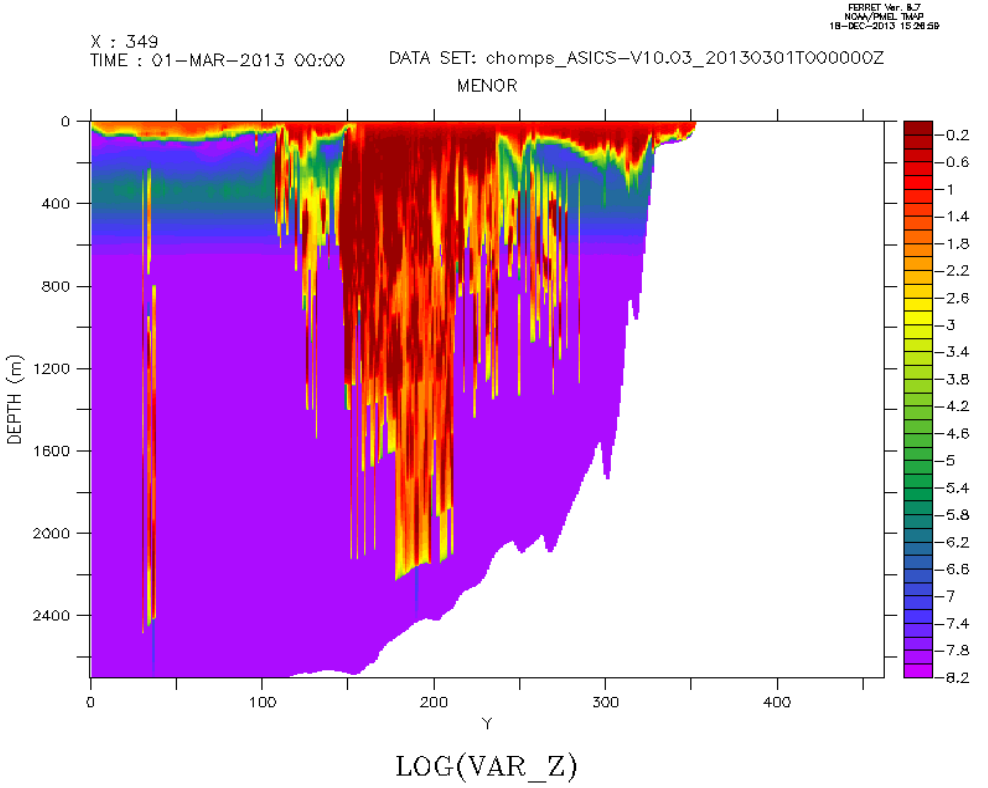
Transect kz 2013-02-15



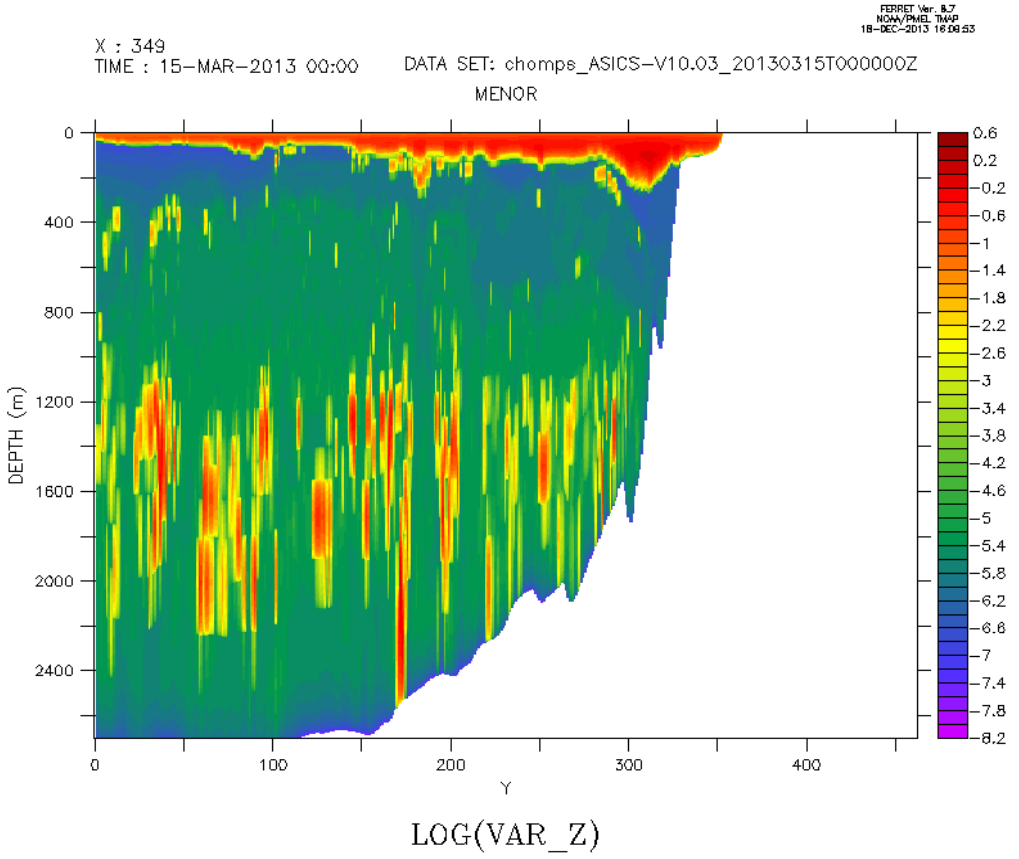


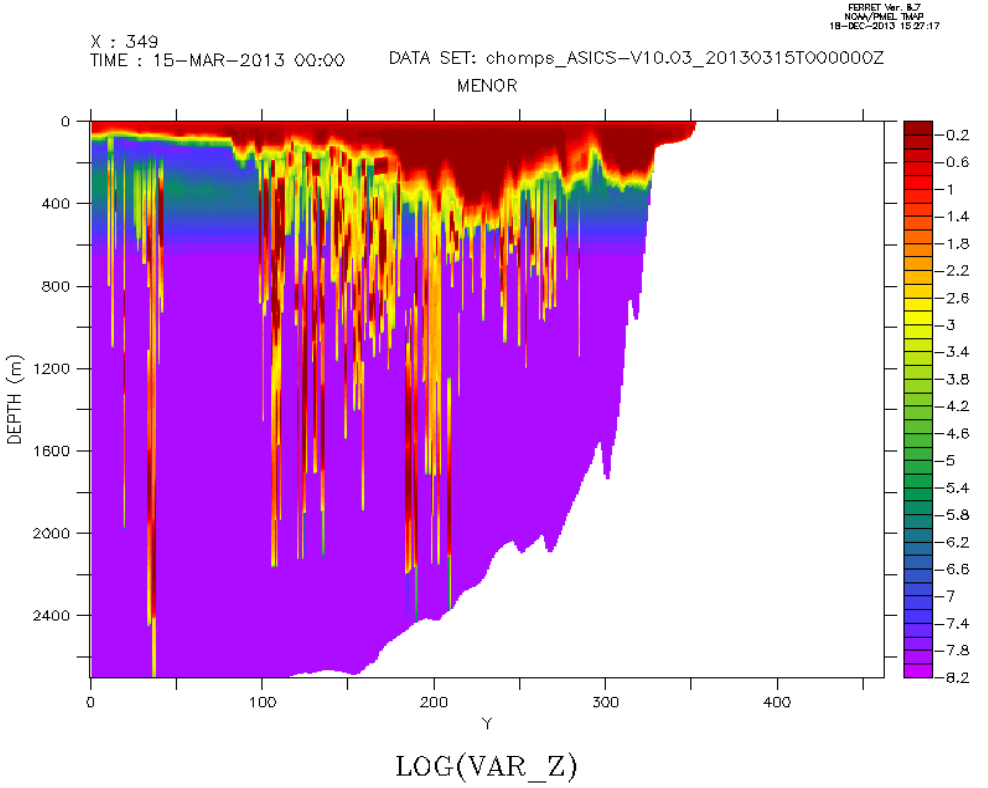
Transect log(kz) 2023-03-01



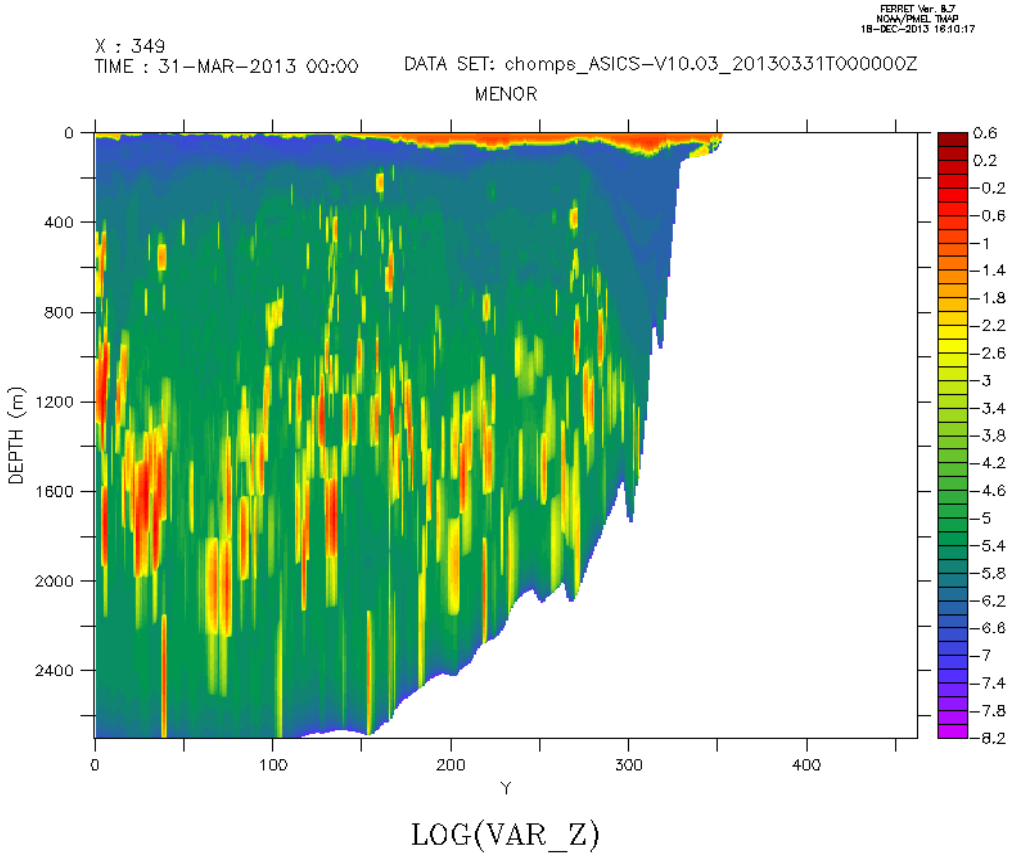


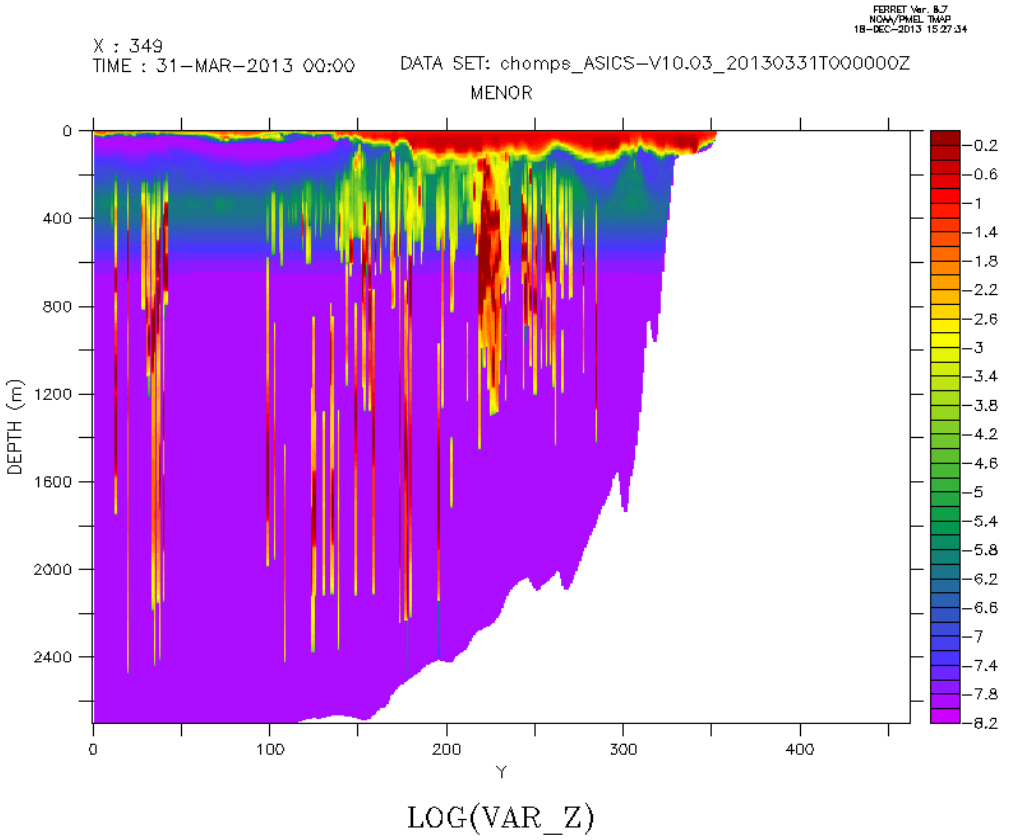
Transect log(kz) 2023-03-15





Transect log(kz) 2023-03-31



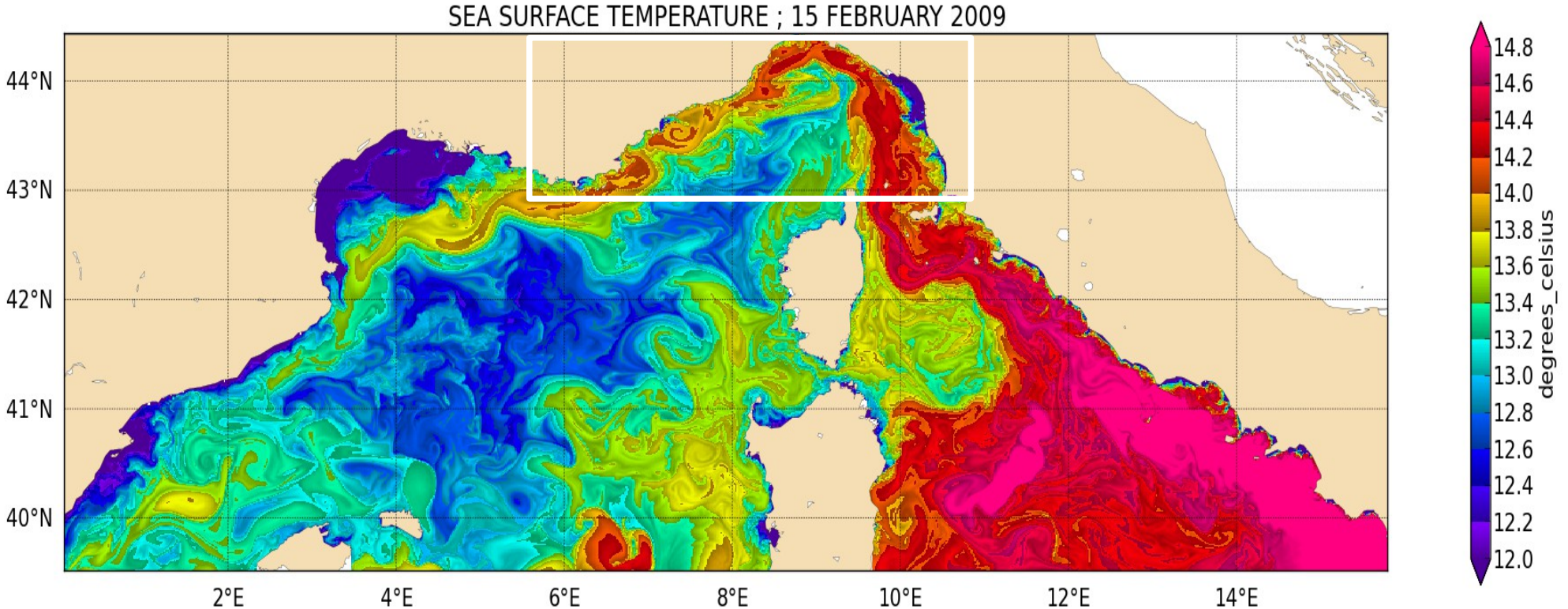


Conclusion :

- Direct measurement of turbulence and estimation of kz is needed.
- Deep convection is mainly simulated by vertical mixing (its is probably mot the main process)
- k-eps model need to be tunned to trigger the mixing at the correct date
- add in k-eps model the horizontal advection and diffusion of k and eps

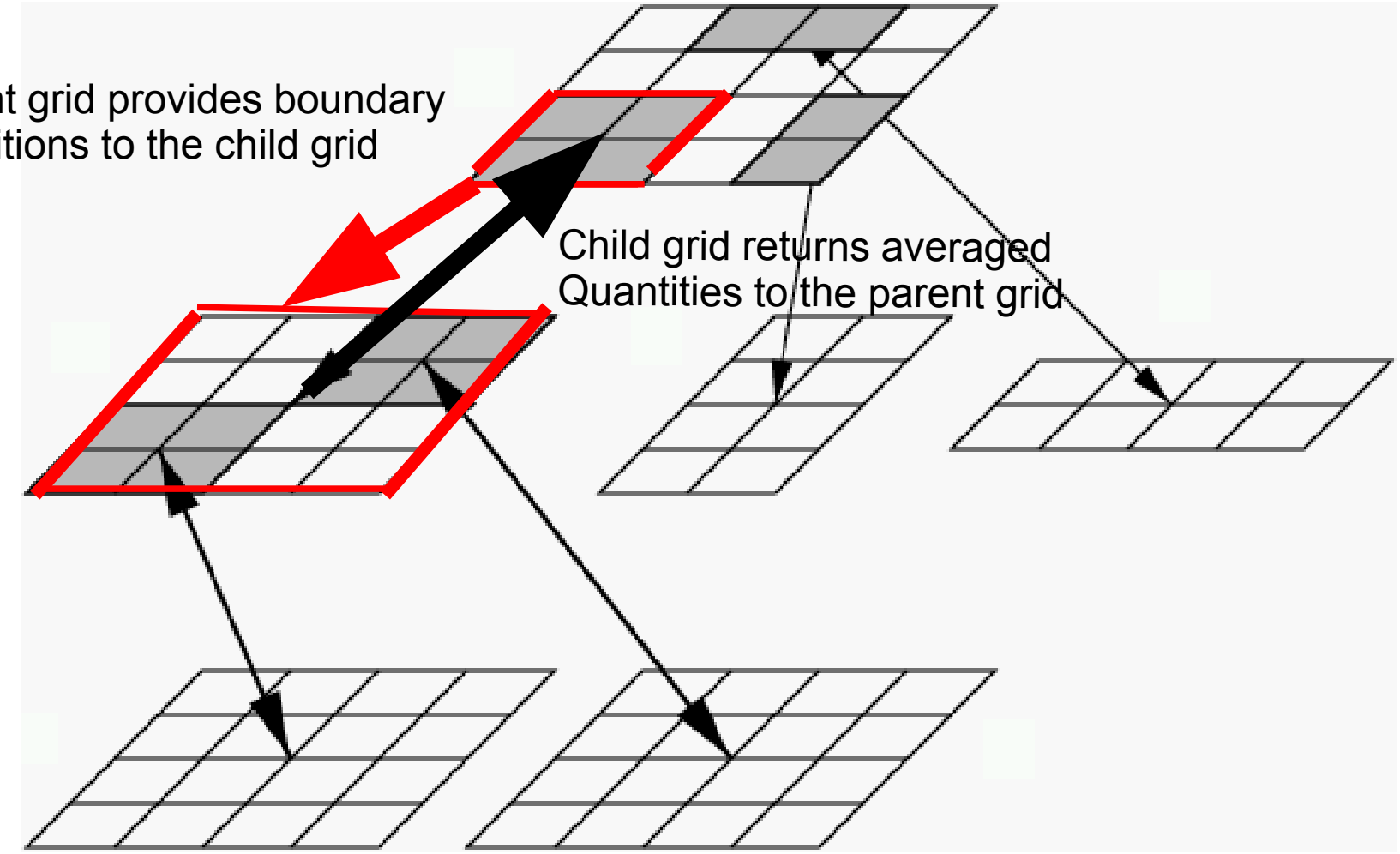
Eddies and Winter Intermediate Water
Use of Agrif tools for zooms

- Implementation of a zoom in the Ligurian sea
  - Same vertical résolution
  - Horizontal grid size ratio is 1/3



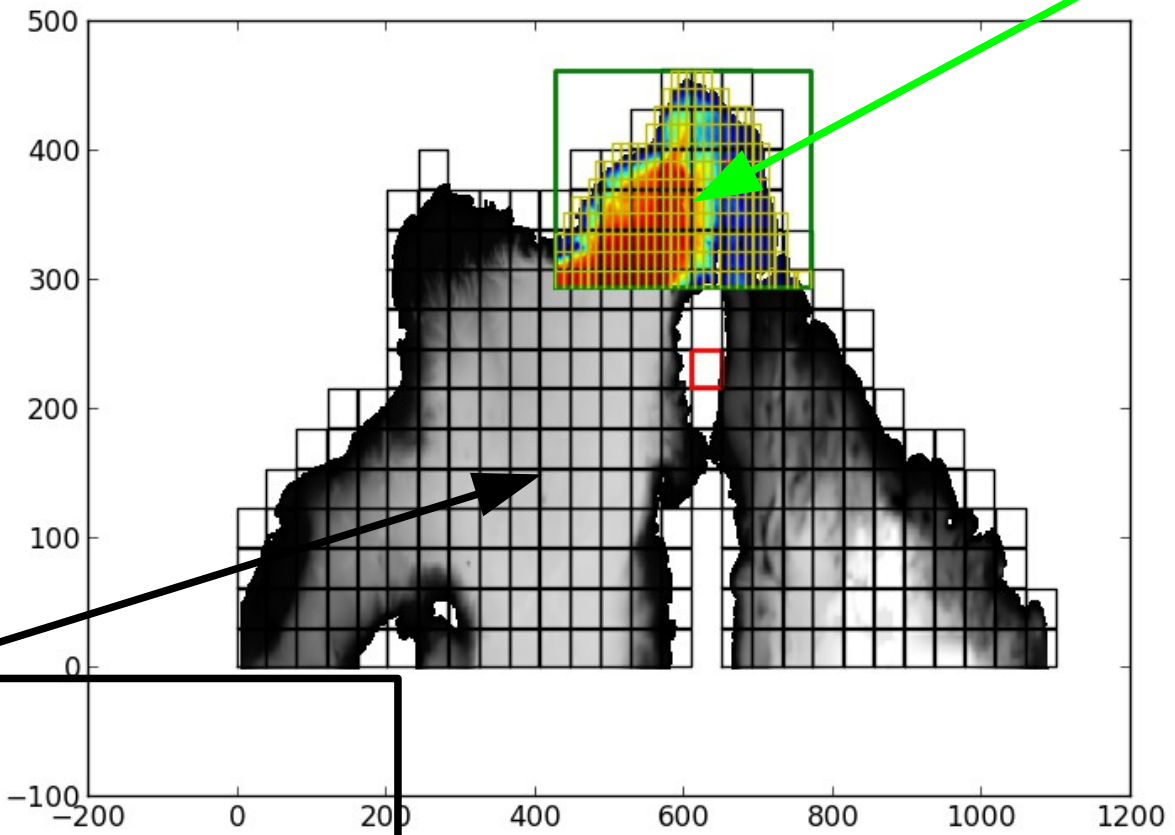
Building an « Agrif » Zoom

http://www-ljk.imag.fr/MOISE/AGRIF/applications/labra.html
- Takes advantage of the pointer facilities in fortran90.
- rewrites partially and automatically the code.
- manages the exchanges between root grid and child grids
- Already available on NEMO/ROMS/HYCOM and MARS3D



Design of the MENOR and LIGURE configurations

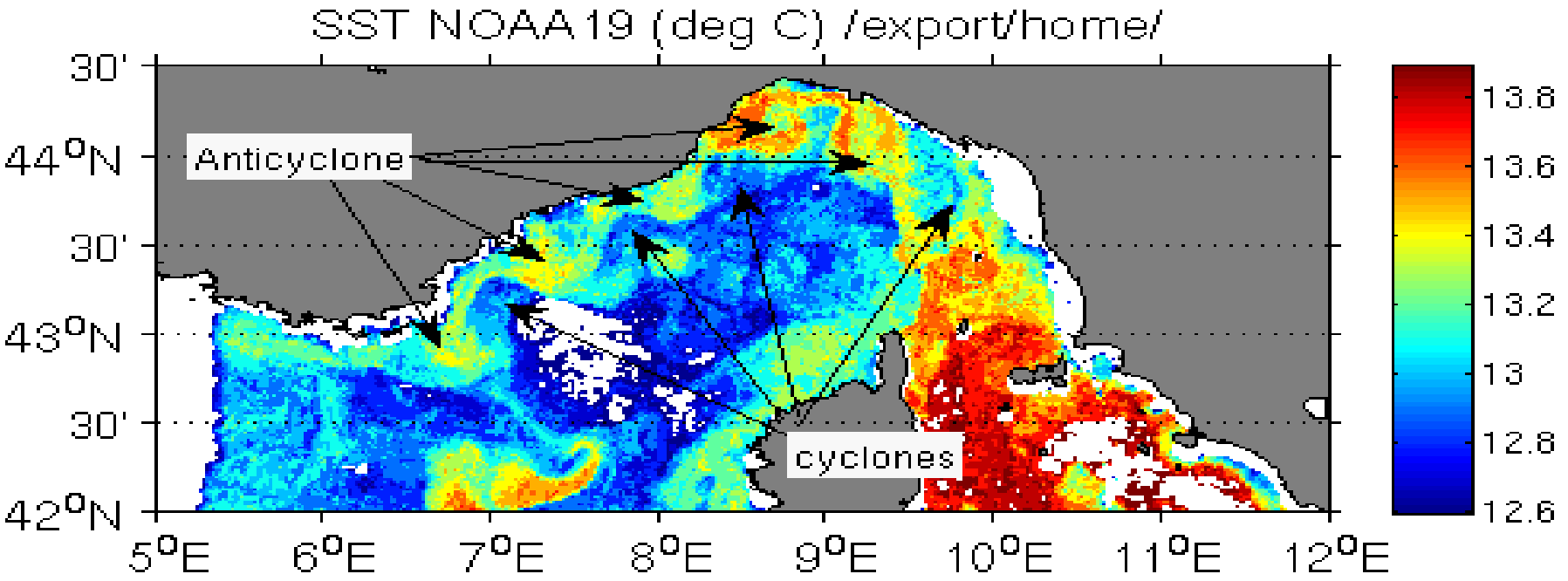
LIGURE ZOOM configuration
- resolution dx = 400m
- grid size : 1300x450
- 256 mpi ranks
- returns u,v,ssh,salt,temperature on the whole comonn domain to the rood grid using conservative integration



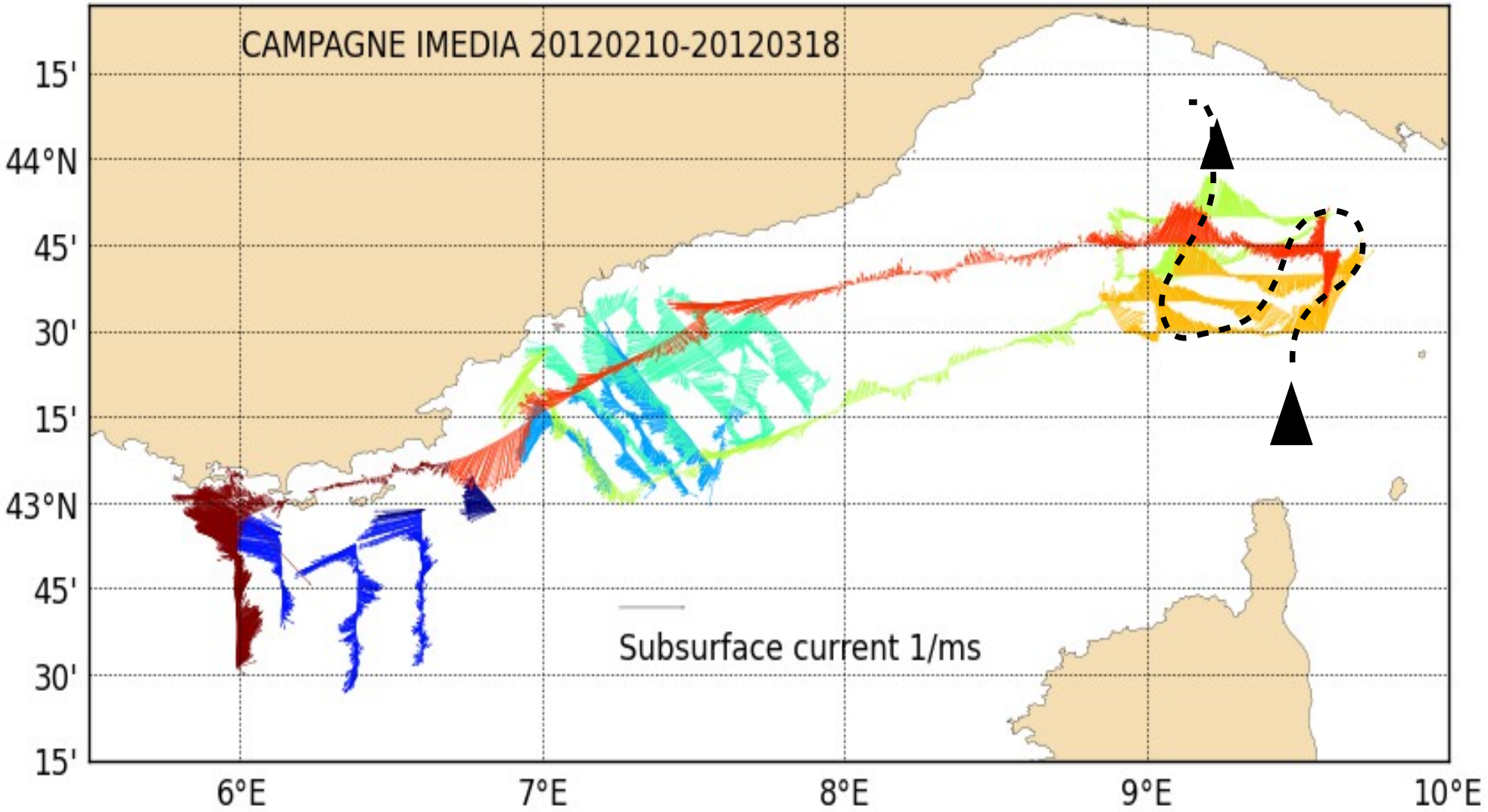
- MENOR configuration
- resolution dx = 1.2 km
- grid size 1100 x 462
- 256 mpi ranks
- Provides boundary conditions to the sub-domain.

Eddies in North Current and Winter Intermediate Water Formation (IMEDIA Cruise)

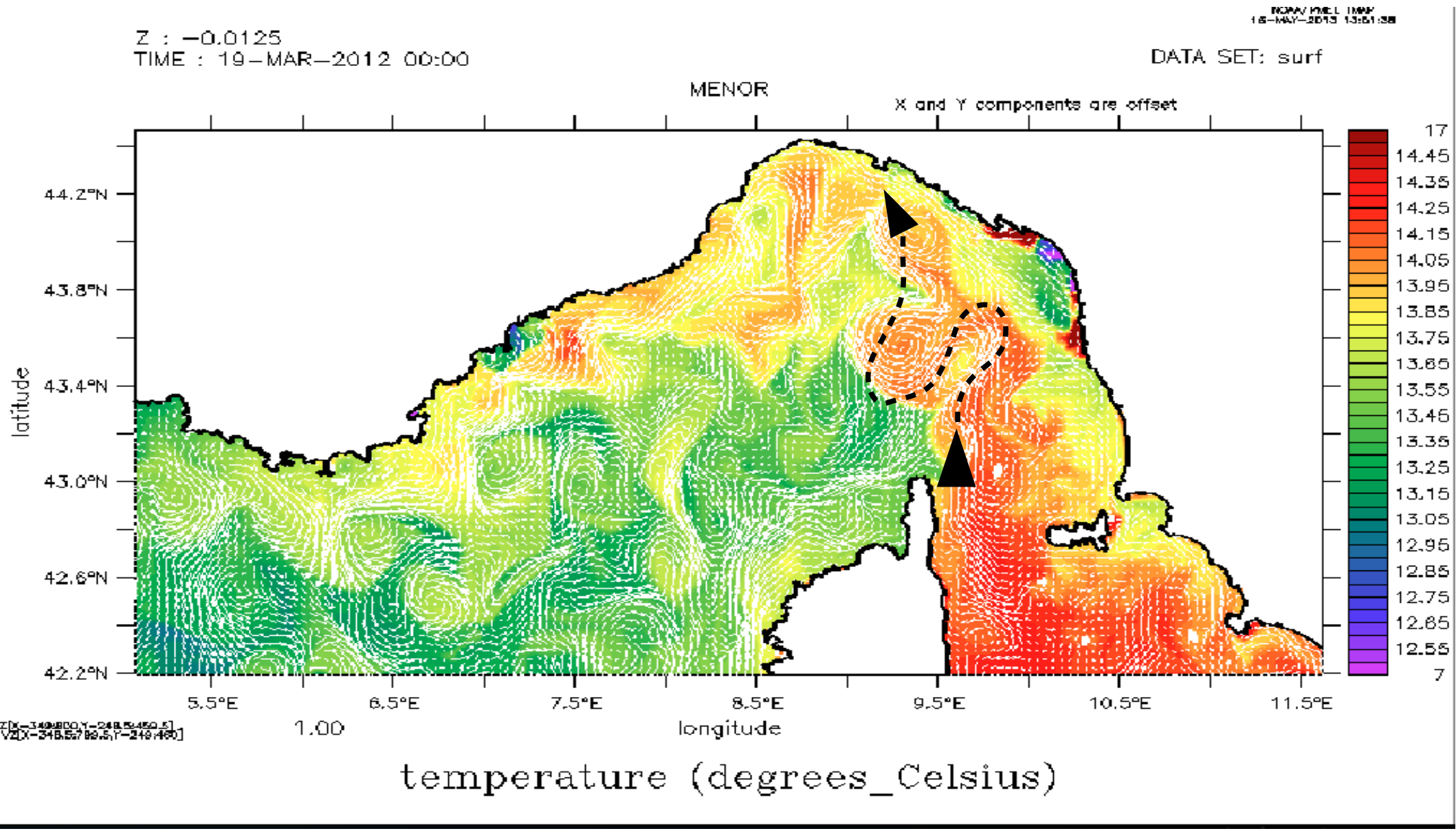
- WIW is cold water found under the thermocline generated during winter
- WIW is surface cooled water diving under the North Current



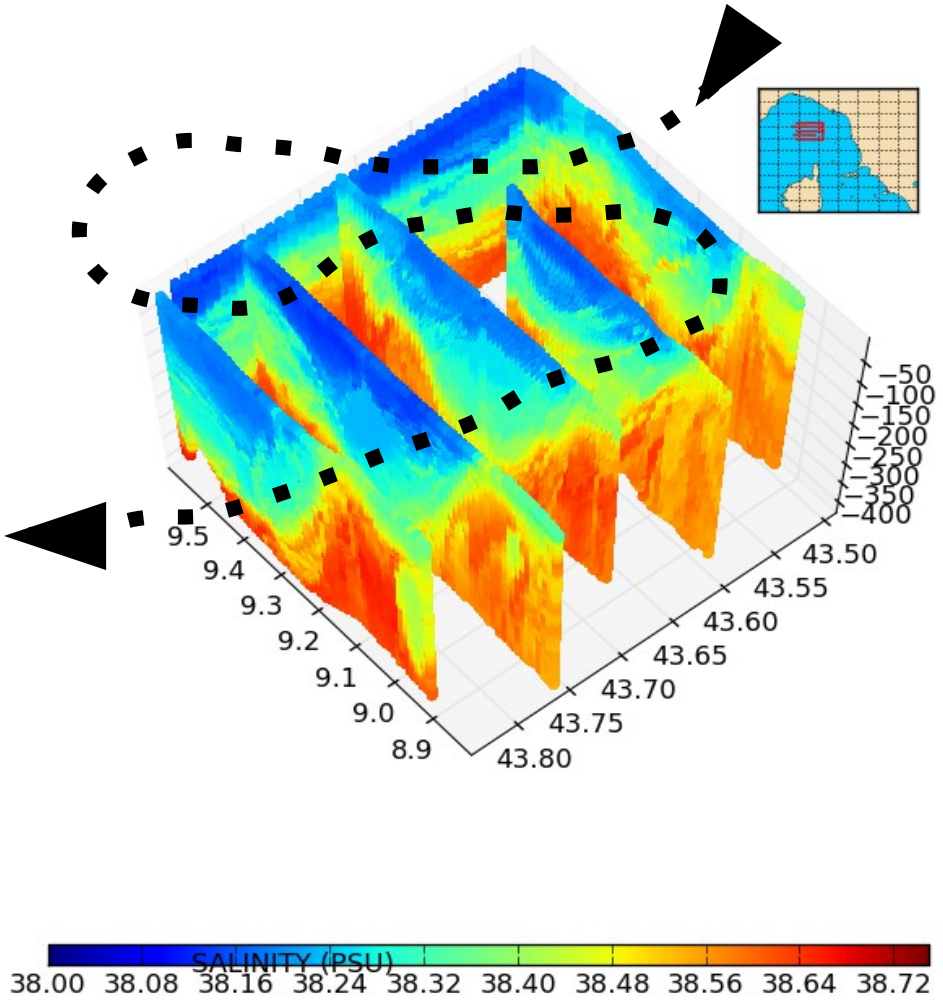
Imedia Cruise experiment

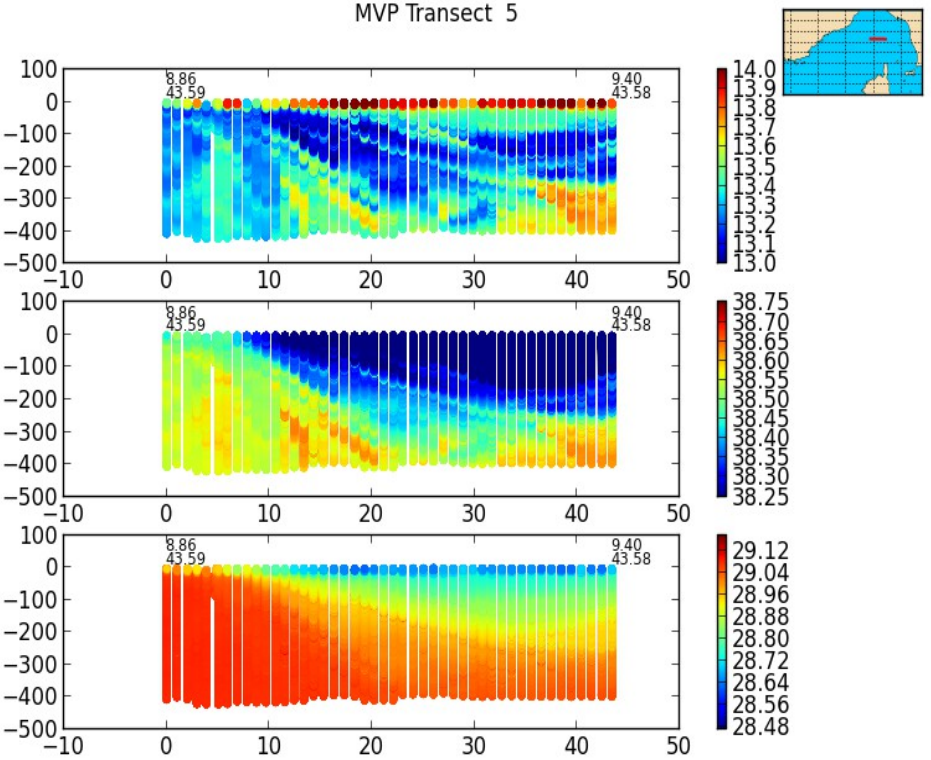


Imedia Cruise experiment

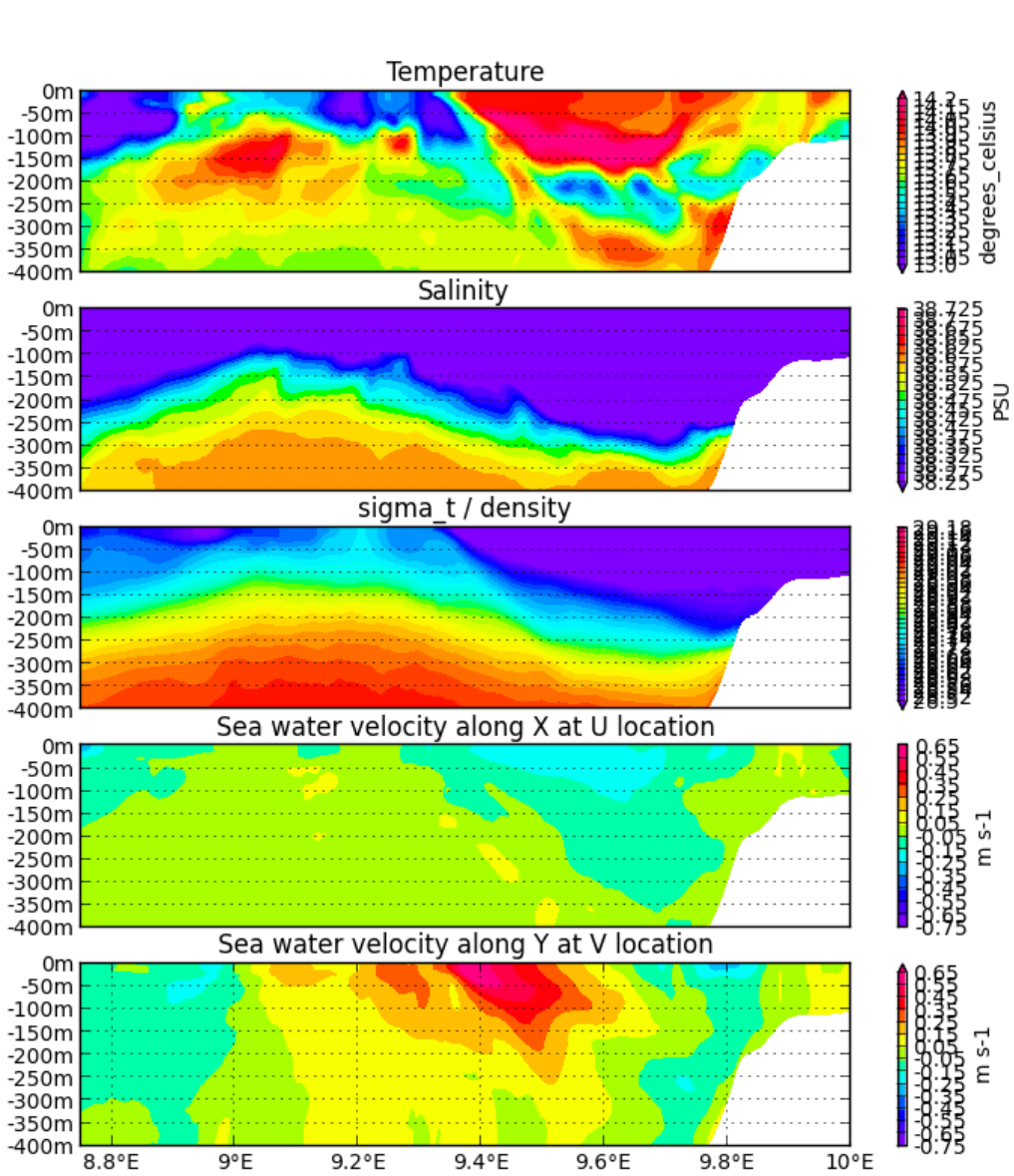


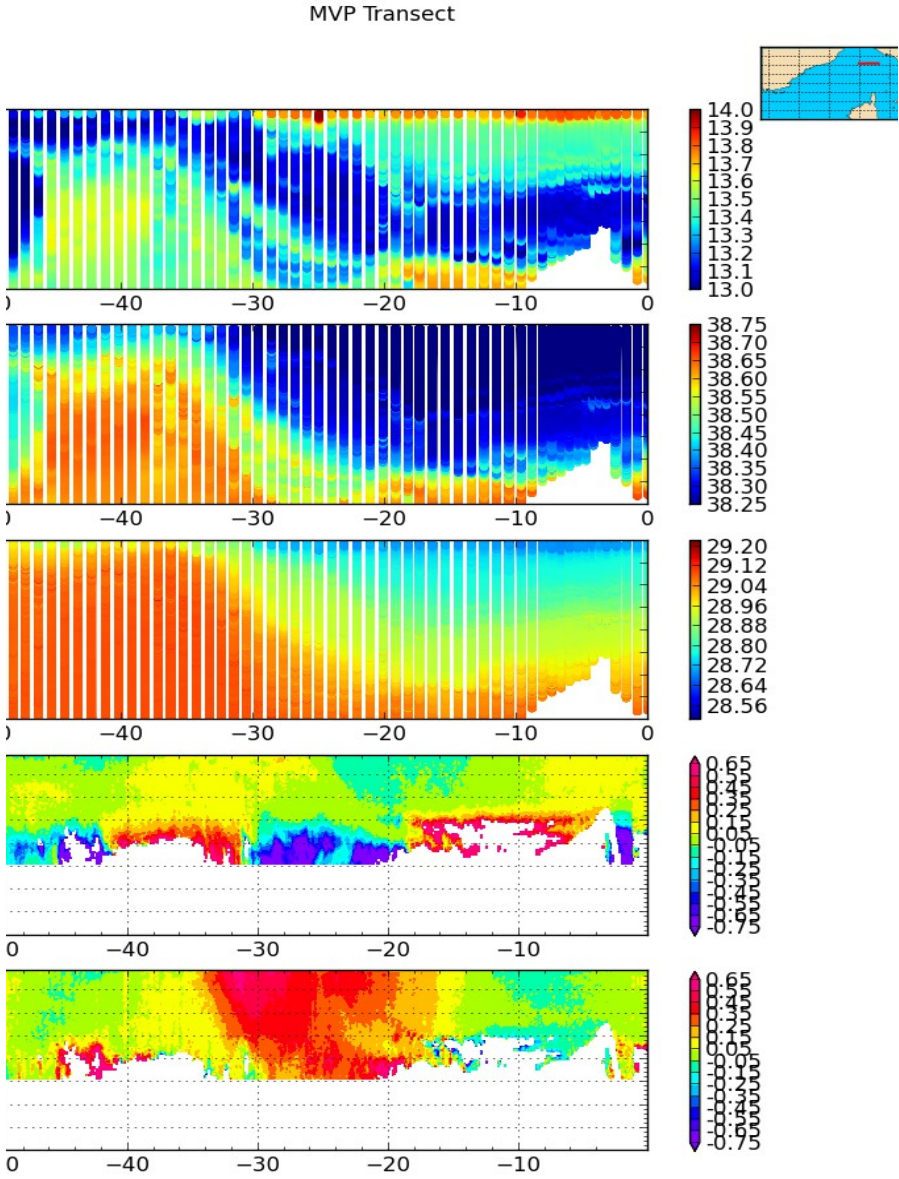
Inside from an anticyclonic eddy using Marine Vessel Profiler





Inside from an anticyclonic eddy using Numerical modelling





Current Application for MENOR Configurations

- *MENOR-CLIMCARE (30 sigma levels)*
  - *Regionalisation of climate change*
- *MENOR-ECO3M (30 sigma levels)*
  - *Ecosystem modelling (cooperation with Marseille University)*
- MENOR-PREVIMER (60 sigma levels)
  - Operational Oceanography (Previmer)
  - Spectral nudging
- MENOR-SIMED (40 sigma levels) 2008-2010
  - Comparison with OGCM
- MENOR-ASICS/HYMEX (60 sigma levels)
  - Deep Water convection 2012/2013
- MENOR-AGRIF_ZOOM (40 sigma level)
  - Investigate mesoscale and sub mesoscale processes

- Thank you for your attention