Mediterranean Sea circulation according to the NEMO-MED model : focus on the North-Western Mediterranean Sea

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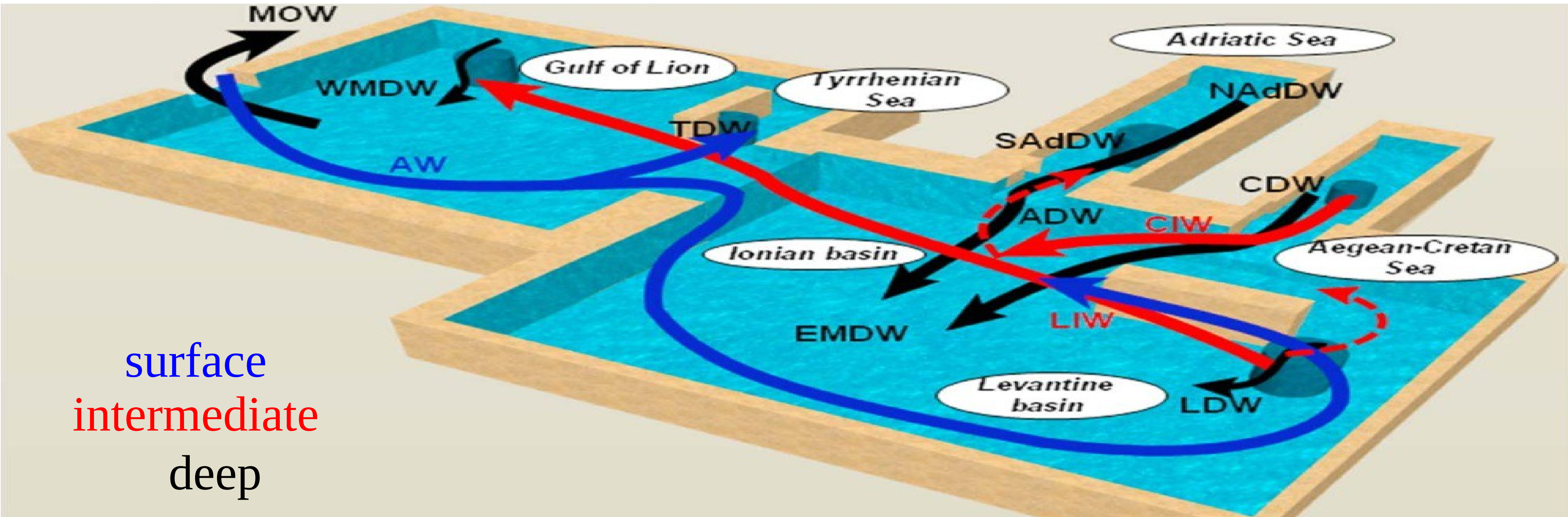
Thermohaline circulation

- AW (surface, warm and relatively fresh) → MW (colder and saltier).

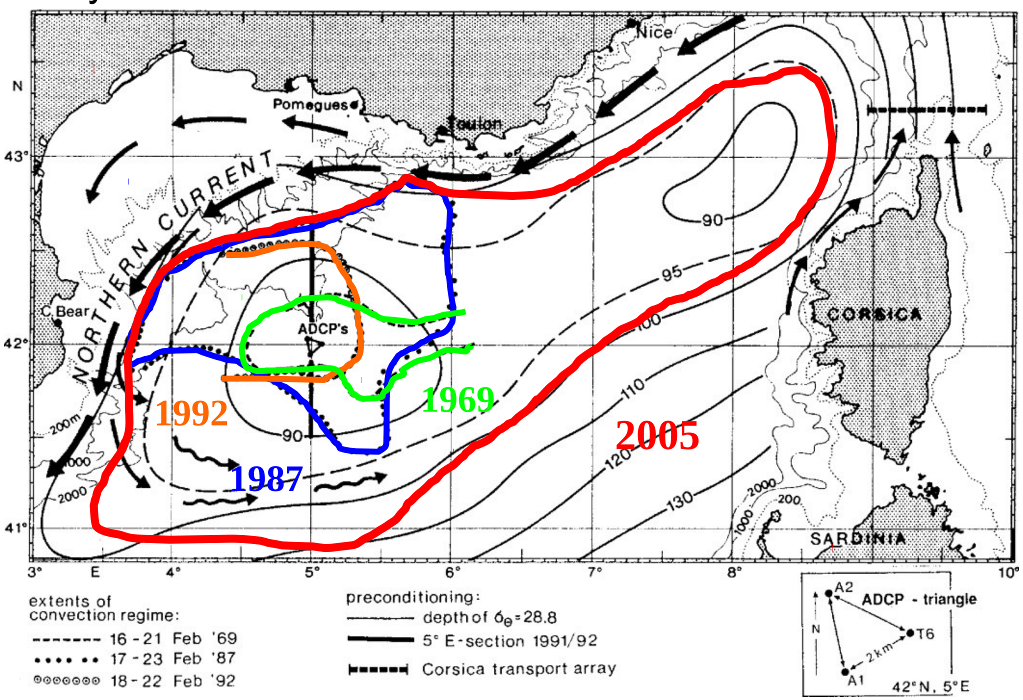


Béranger et al. 2010

- Deep waters :
  - WMDW, *Western Mediterranean Deep Water*
  - EMDW, *Eastern Mediterranean Deep Water*
    (ADW, *Adriatic Deep Water* ; CDW, *Cretan Deep Water*).
- Large interannual variability and extreme deep water formation events.

Golf of Lion deep water formation variability

- Formation rate :
  - 2.4 Sv in 2005 and 2006 (*Schroeder et al. 2008*),
  - observations other years < 1.2 Sv



Marshall & Schott 1999

=> What is the influence of numerical resolution in reproducing deep water convection and exporting newly formed deep water masses ?

The oceanic model and atmospheric forcing

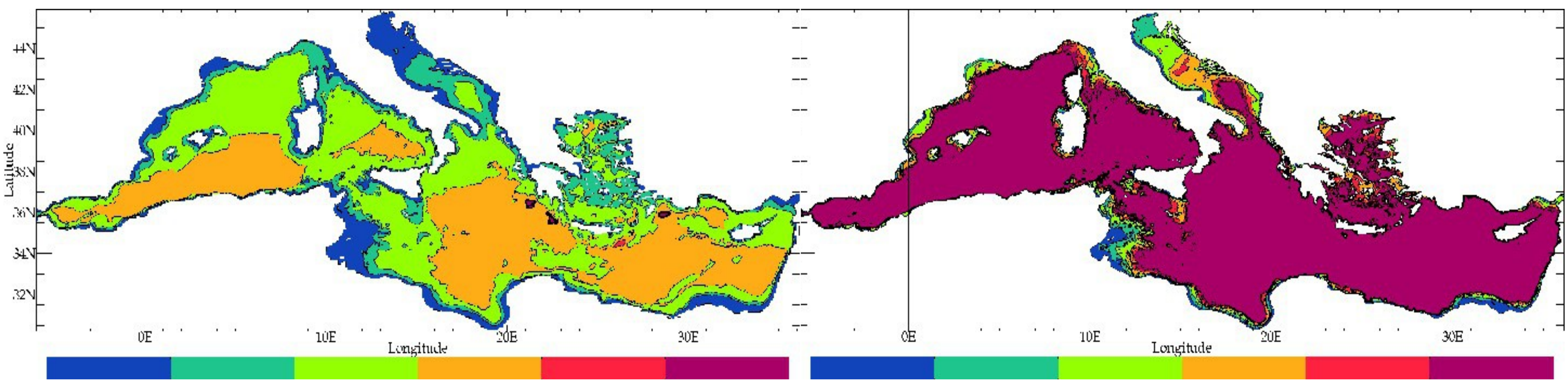
- Oceanic model:
  - NEMO-MED (Lebeaupin-Brossier 2011, Beuvier 2011, Arsouze et al. 2012) based on NEMO official release v3.2
  - Domain: Full Mediterranean bassin (11W-35E) + Gulf of Cadiz as a buffer zone (7.5W)
  - Initial conditions: MEDATLAS (MEDAR-MEDATLAS, 2002), low-pass filtering (window 3yr) around 1998 (Rixen et al. 2005)
- Atmospherical forcing provided by ARPERA (CNRM):
  - Dynamical downscaling (spectral nudging) of ERA40 + ECMWF
  - Small scales: ARPEGE climate model (~50km), (Herrmann and Somot, 2008)
  - Wind stress, heat flux with retroaction term (relaxation toward ERA40 SST) and freshwater flux with correction from previous simulation.
- Oct. 1998 – Dec. 2012 period

=> **4 companion simulations** with same set-up (forcing and initial conditions), but **different vertical / horizontal resolutions**.

Companion simulations : horizontal resolution

- MED12 vs MED36
  - MED12 : 1/12° ; ~6-8km **vs** MED36 : 1/36° ; ~2-3km
  - MED12 : about the size or smaller than deformation radius: eddy resolving in most parts of the bassin
  - MED36 : smaller than deformation radius: eddy resolving

Ratio of Rossby radius over numerical resolution



0 1 2 3 0 1 2 3

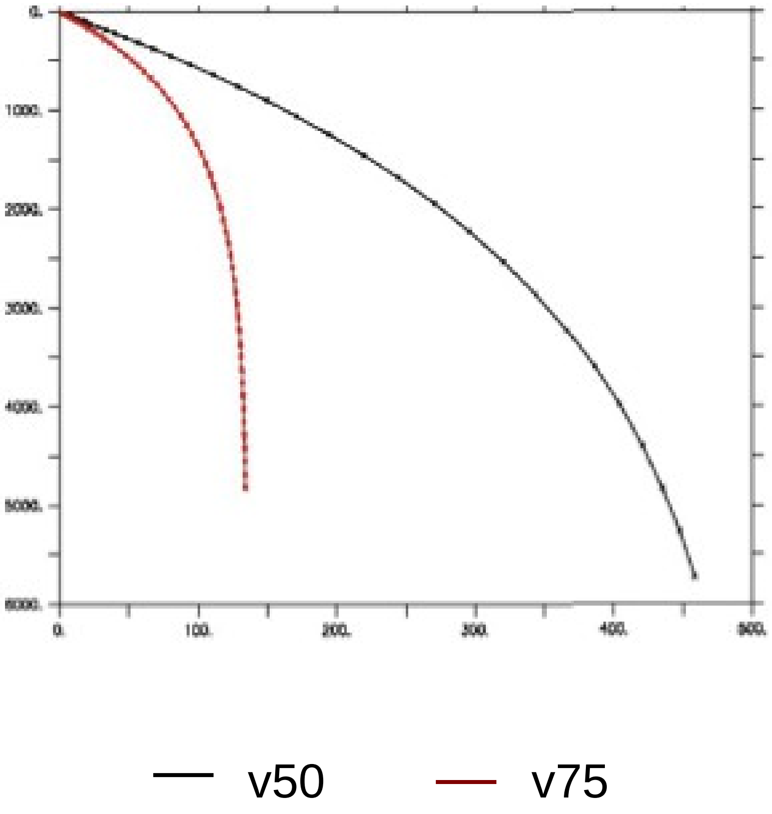
MED12 MED36

Companion simulations : vertical resolution

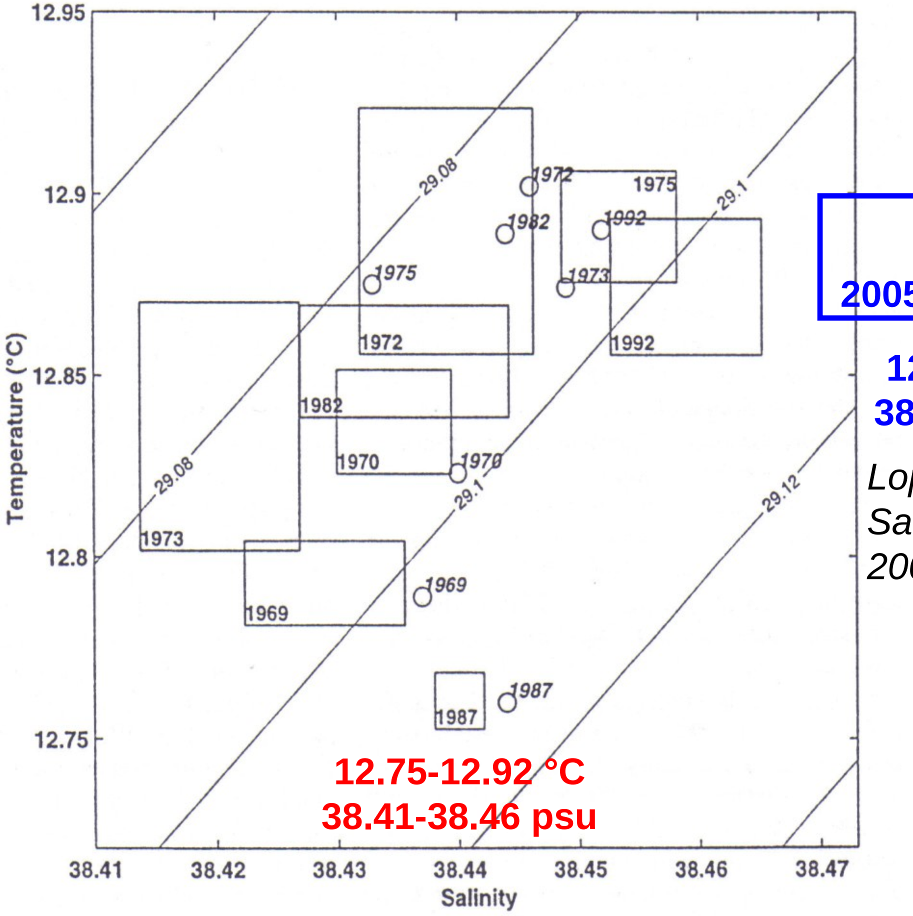
- MED12 vs MED36
  - MED12 : 1/12° ; ~6-8km
  vs
  MED36 : 1/36° ; ~2-3km

- - MED12 : about the size or smaller than deformation radius: eddy permitting
  - MED36 : smaller than deformation radius: eddy resolving

- v50 vs v75



WMDW in 2005 : θ-S characteristics



Mertens & Schott 1998

2005

12.87-12.90 °C
38.47-38.50 psu

Lopez-Jurado et al. 2005 ; Schröder et al. 2006 ; Salat et al. 2006 ; Font et al. 2007 ; Smith et al. 2008

- high θ and S
- Western Mediterranean Transition ?

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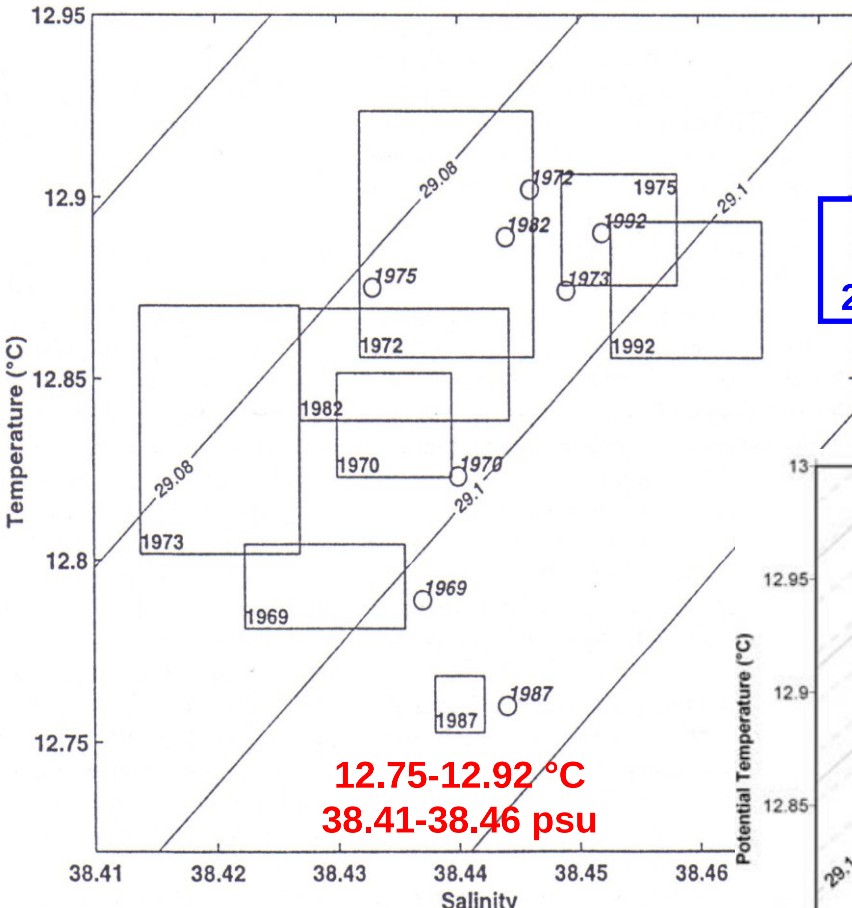

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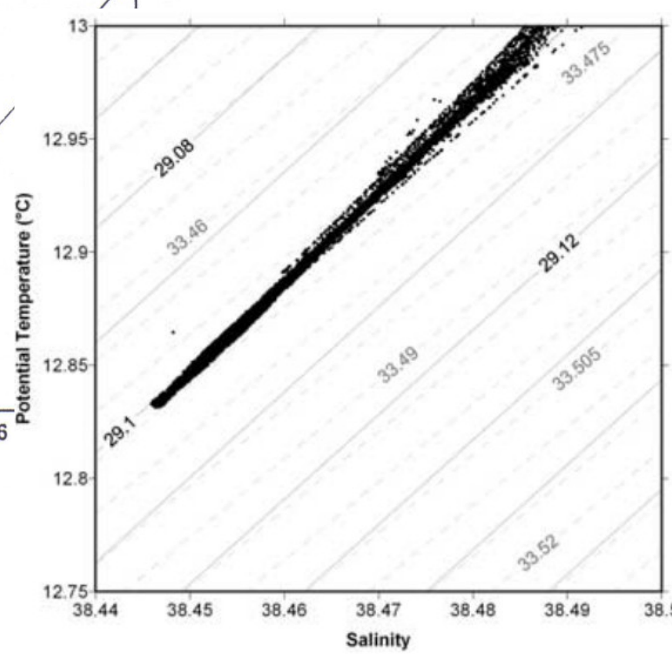
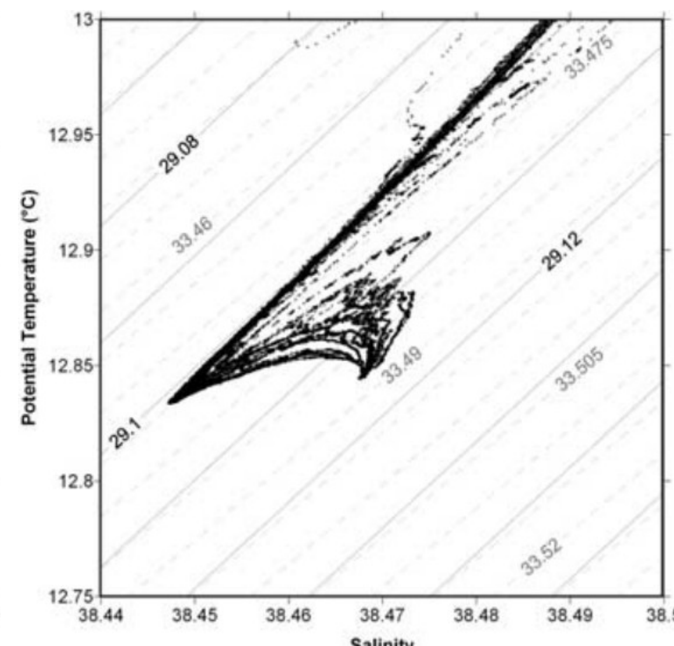


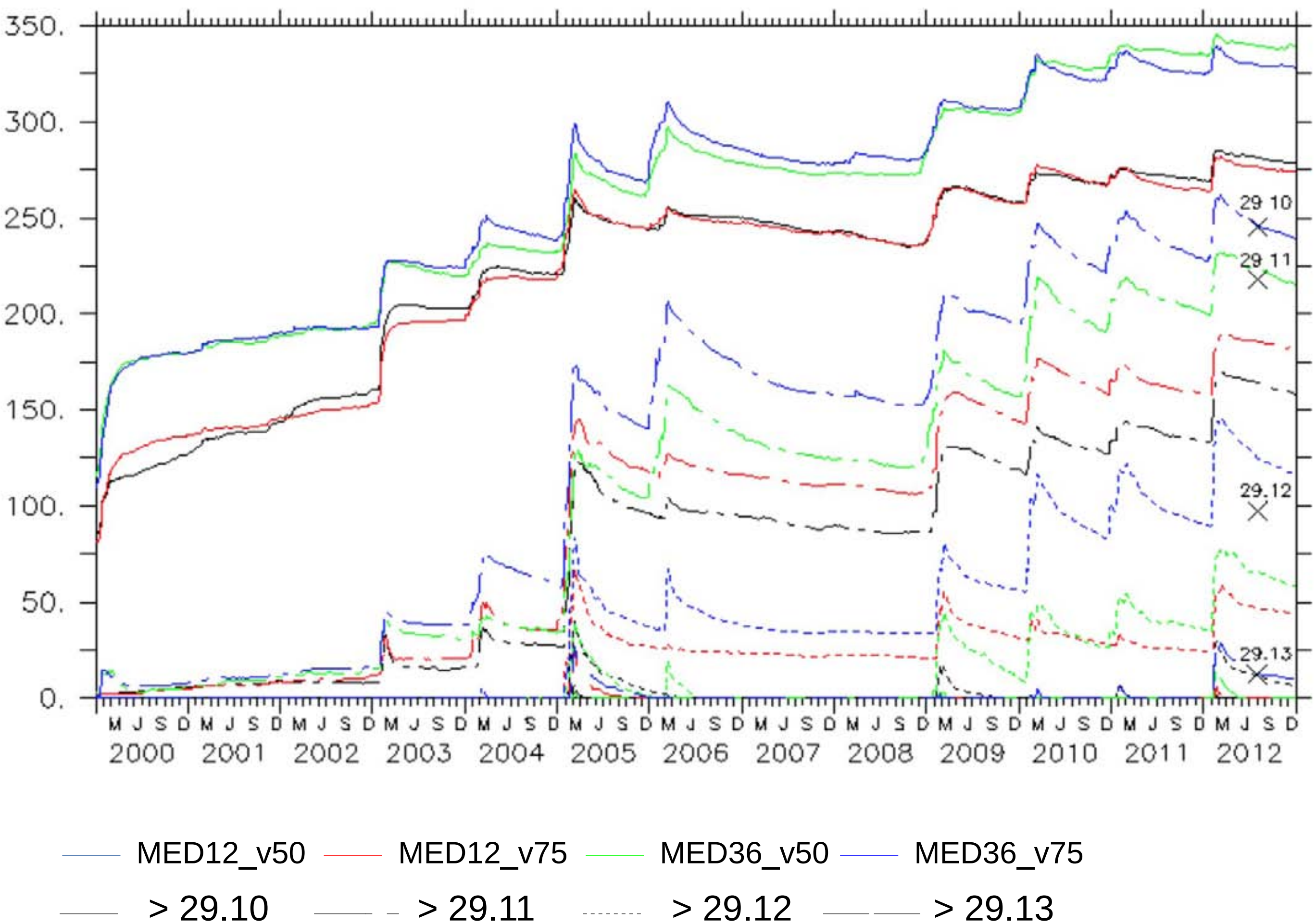
θ-S octobre 2004

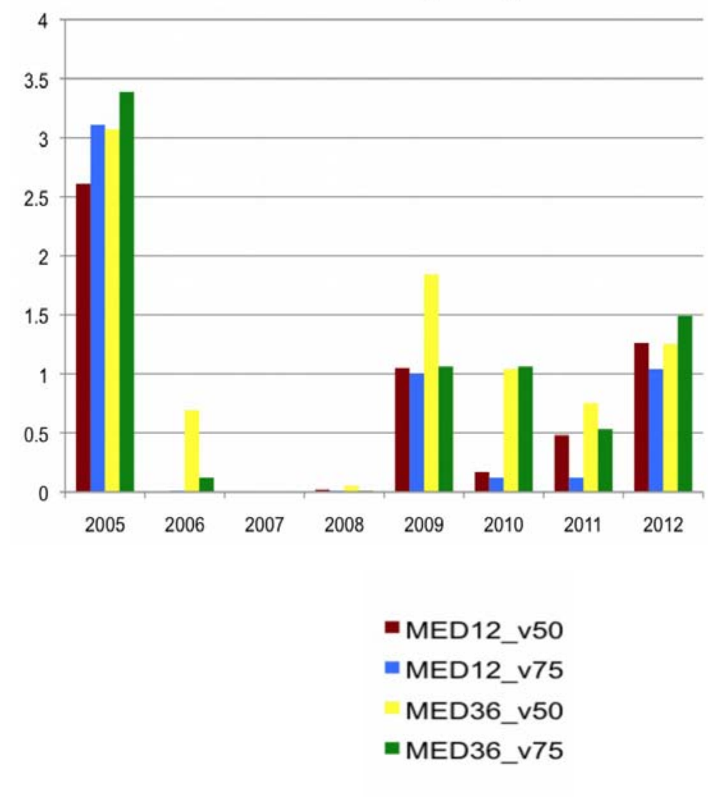


θ-S octobre 2006

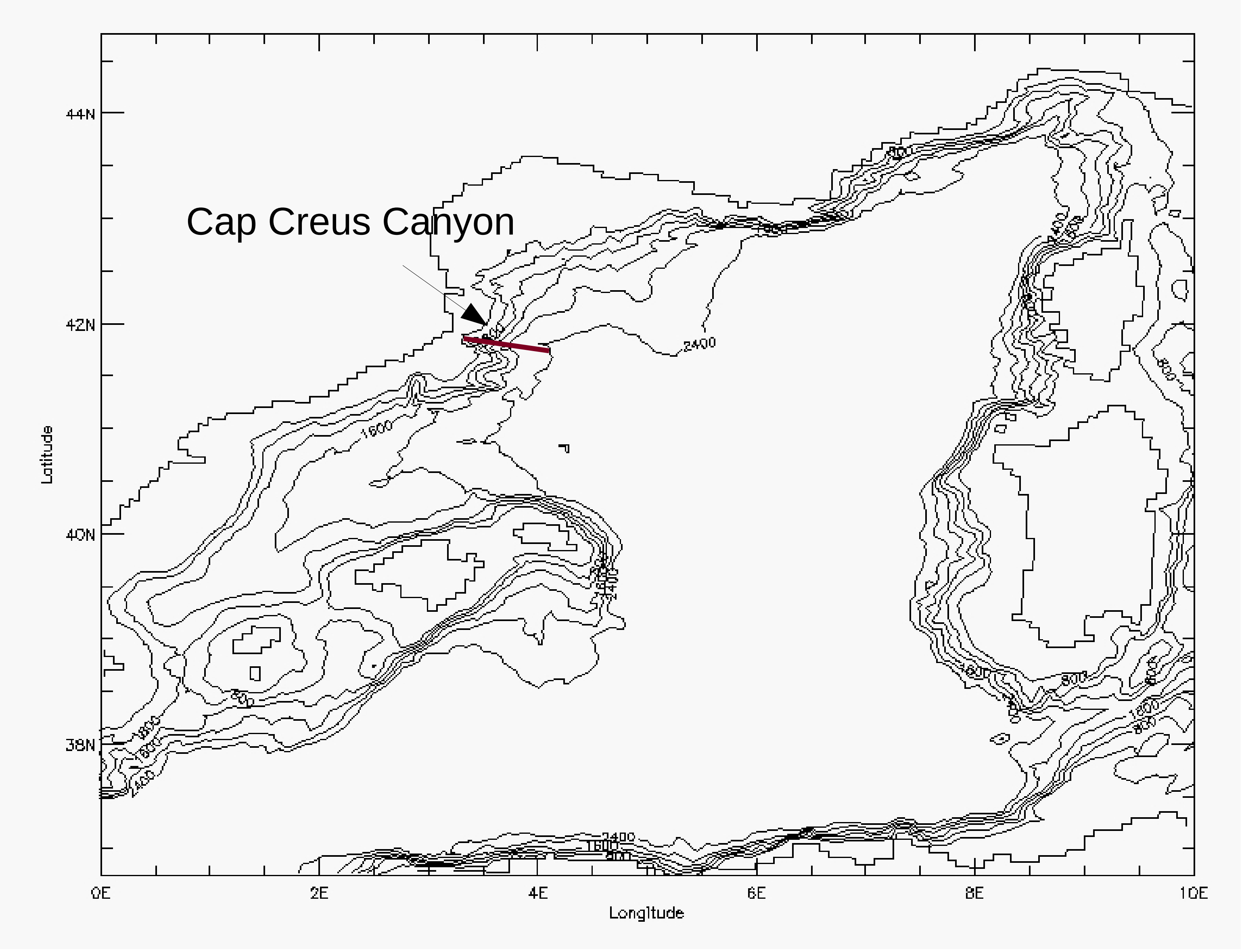
WMDW formation rate

Volume of dense water (10^{12} m^3)

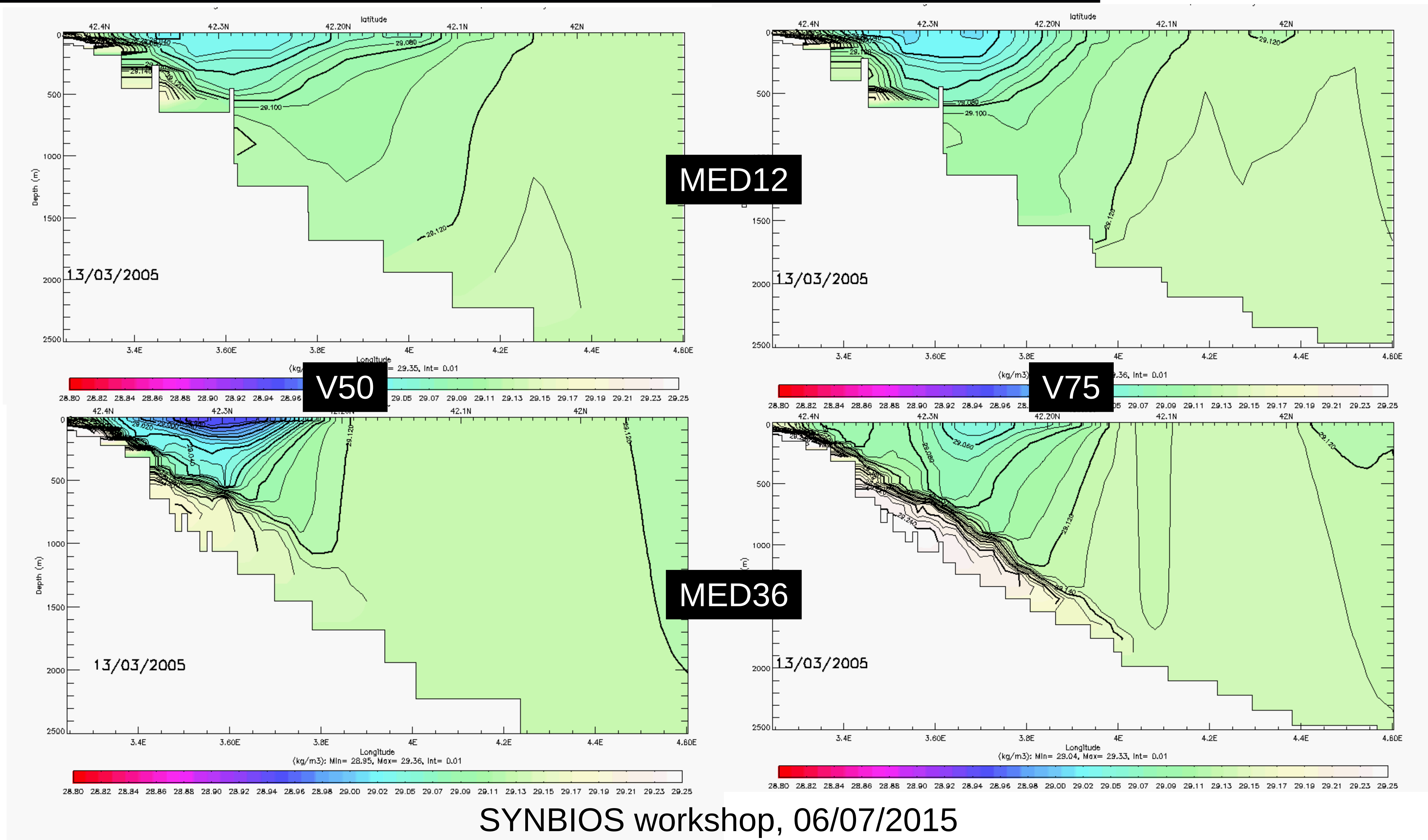




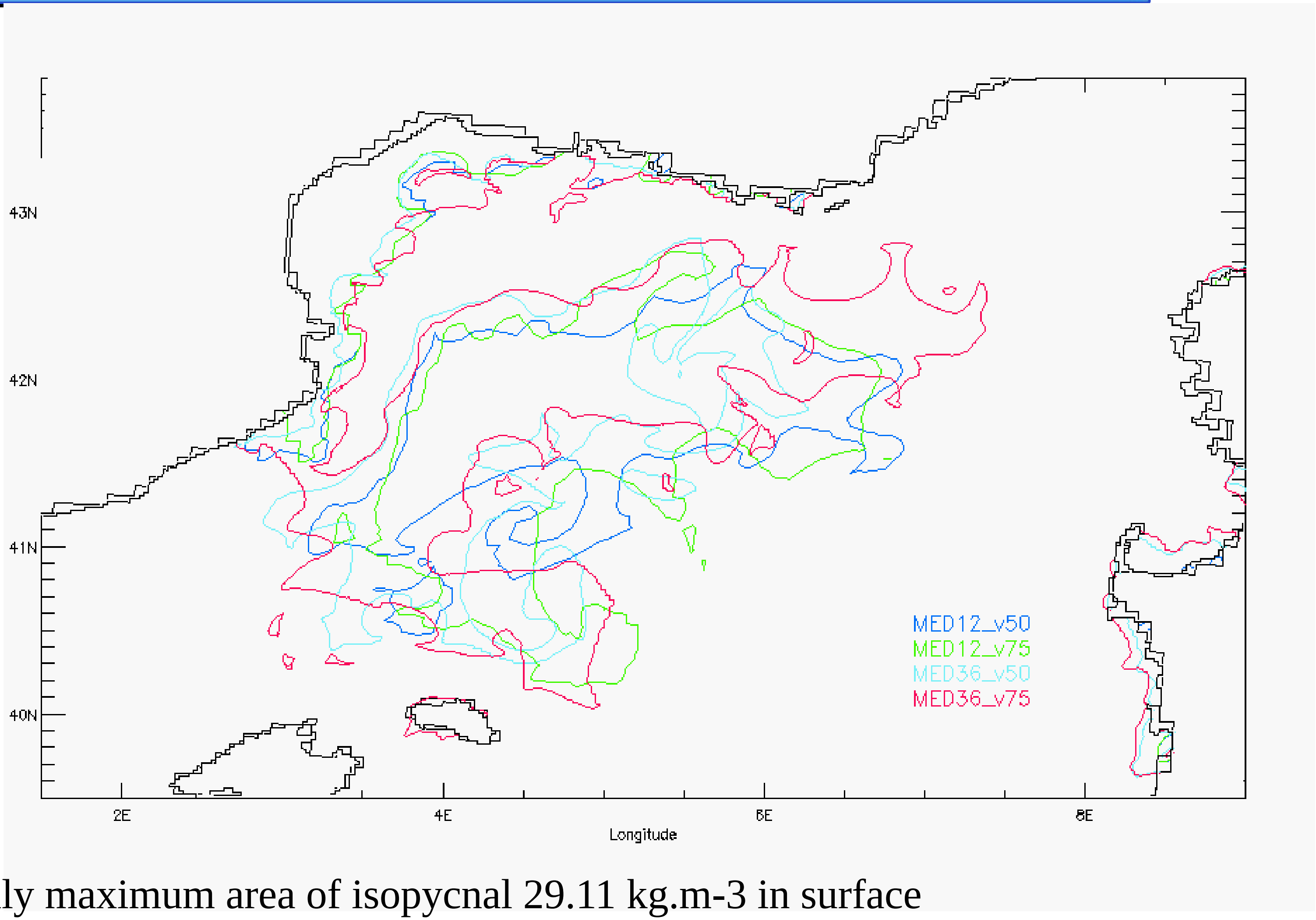
WMDW characteristics : influence of shelf cascading



Reproduction of cascading

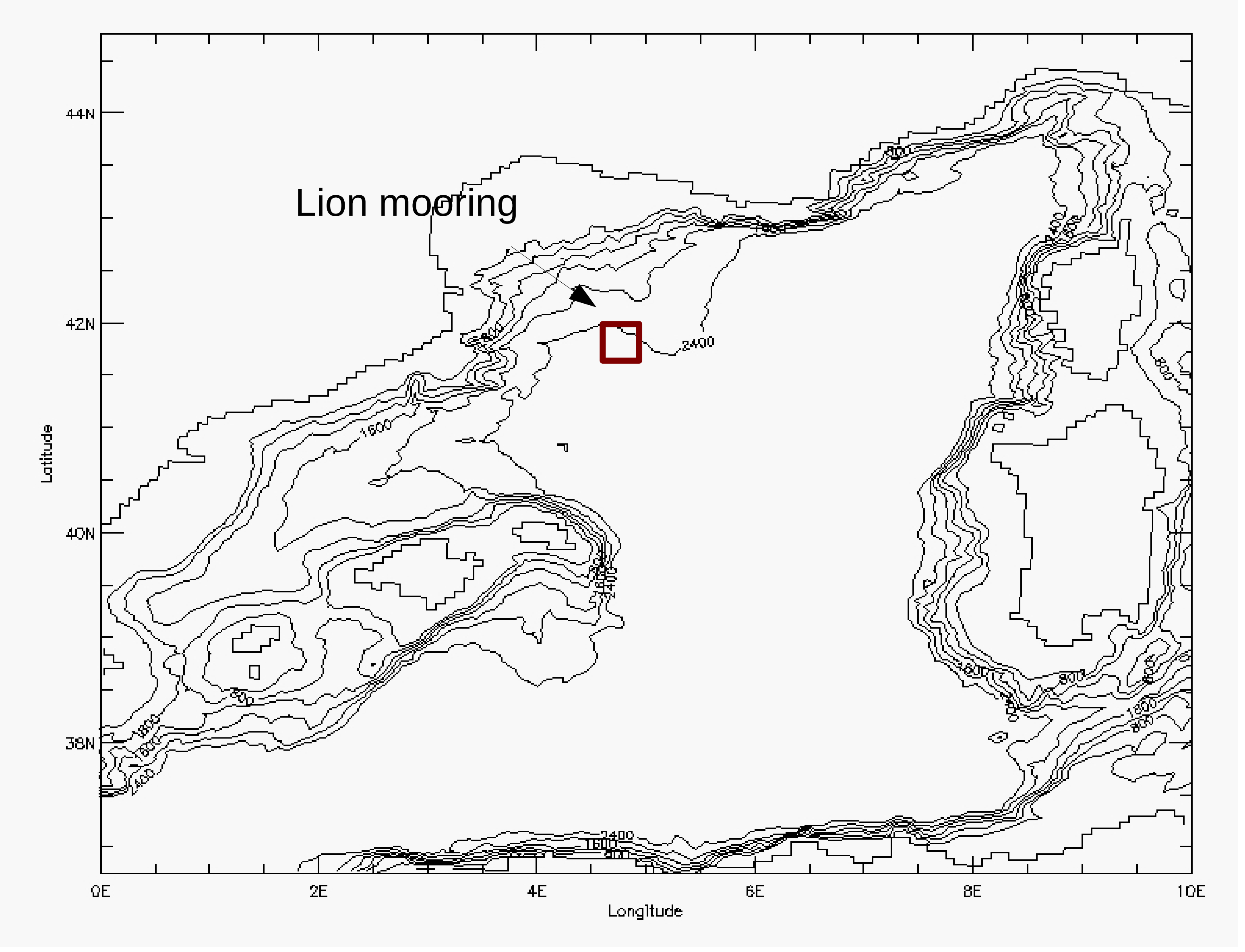


Convection area: 2005



- Daily maximum area of isopycnal 29.11 kg.m-3 in surface
- March 7th 2005 (corresponding for the 4 models)

WMDW characteristics and propagation



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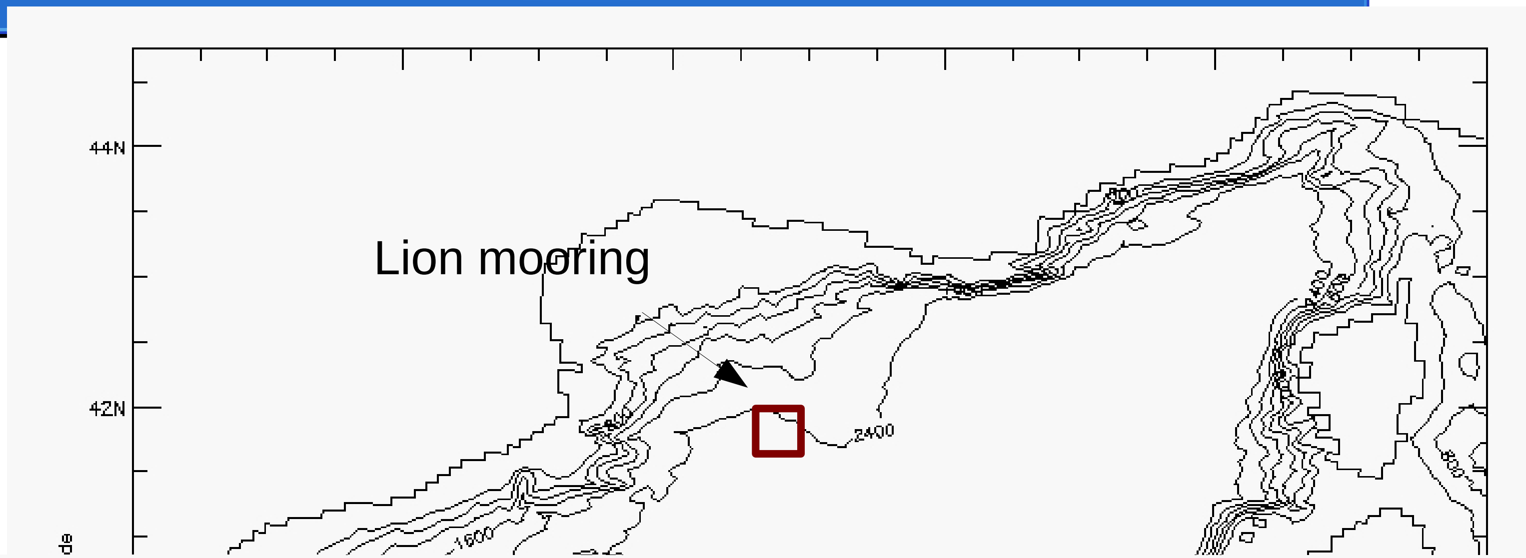
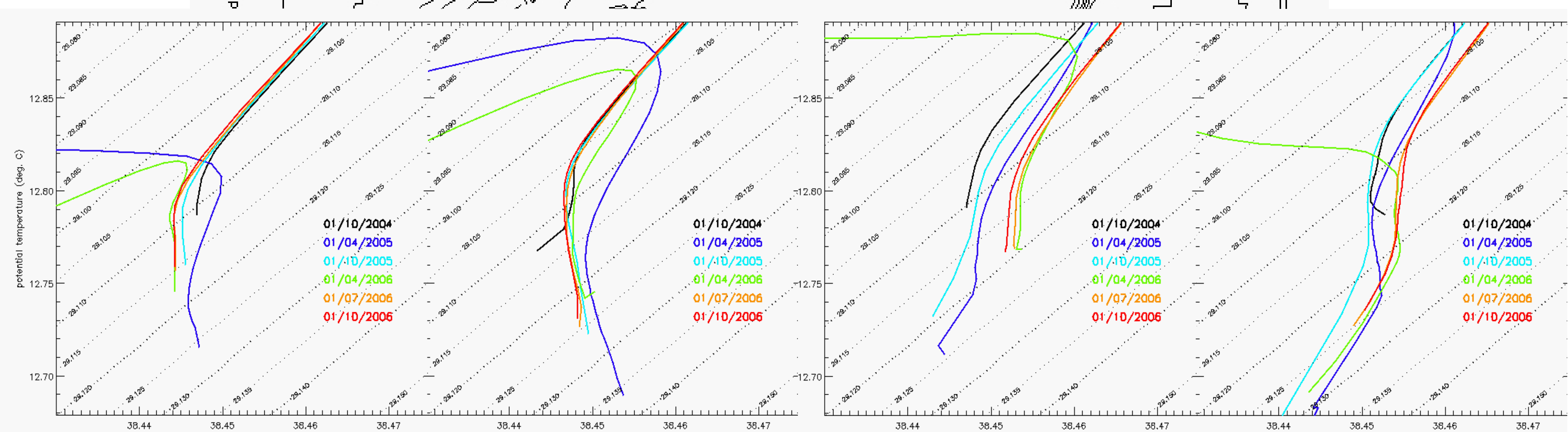
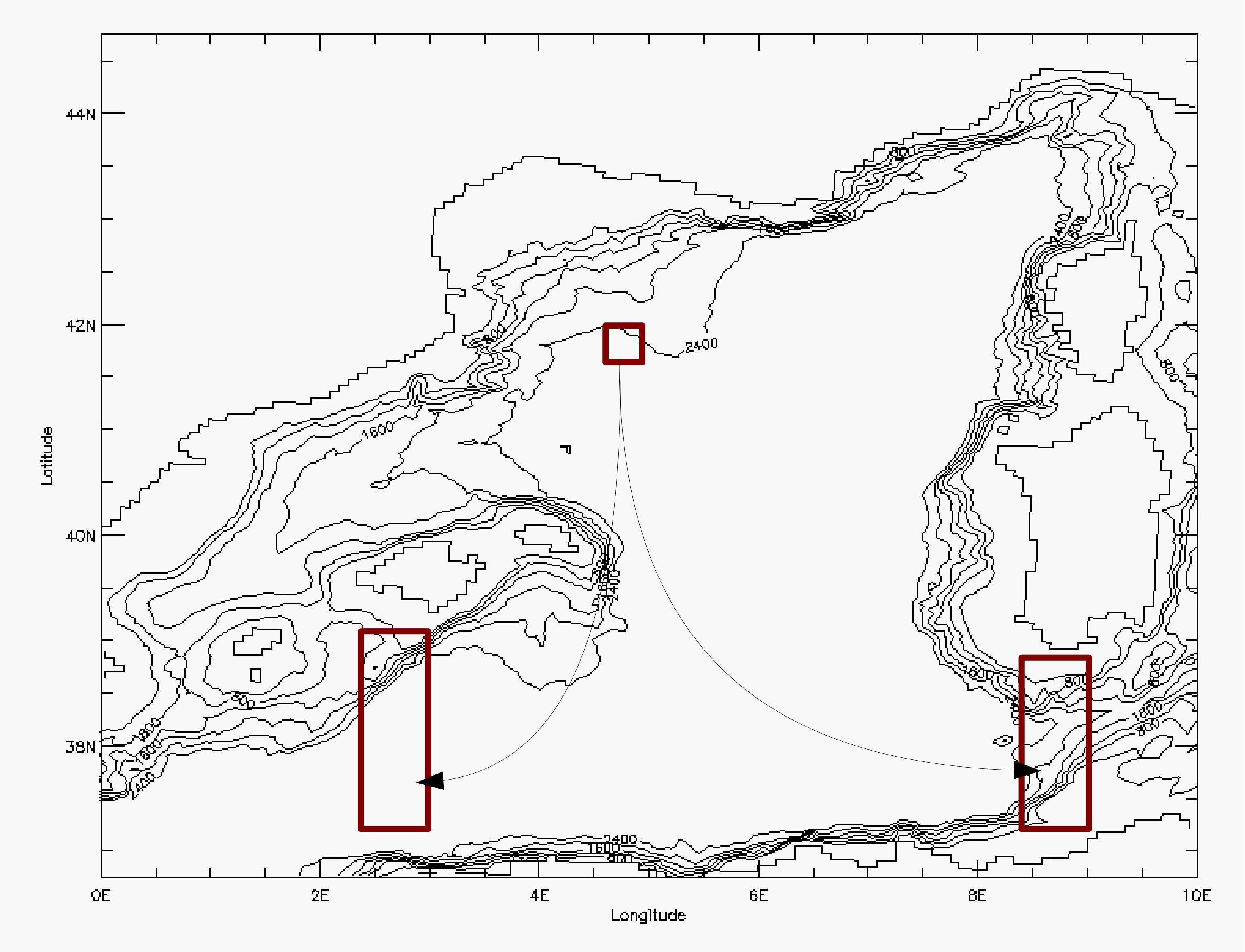




MED12v50 MED12v75 MED36v50 MED36v75

WMDW characteristics and propagation



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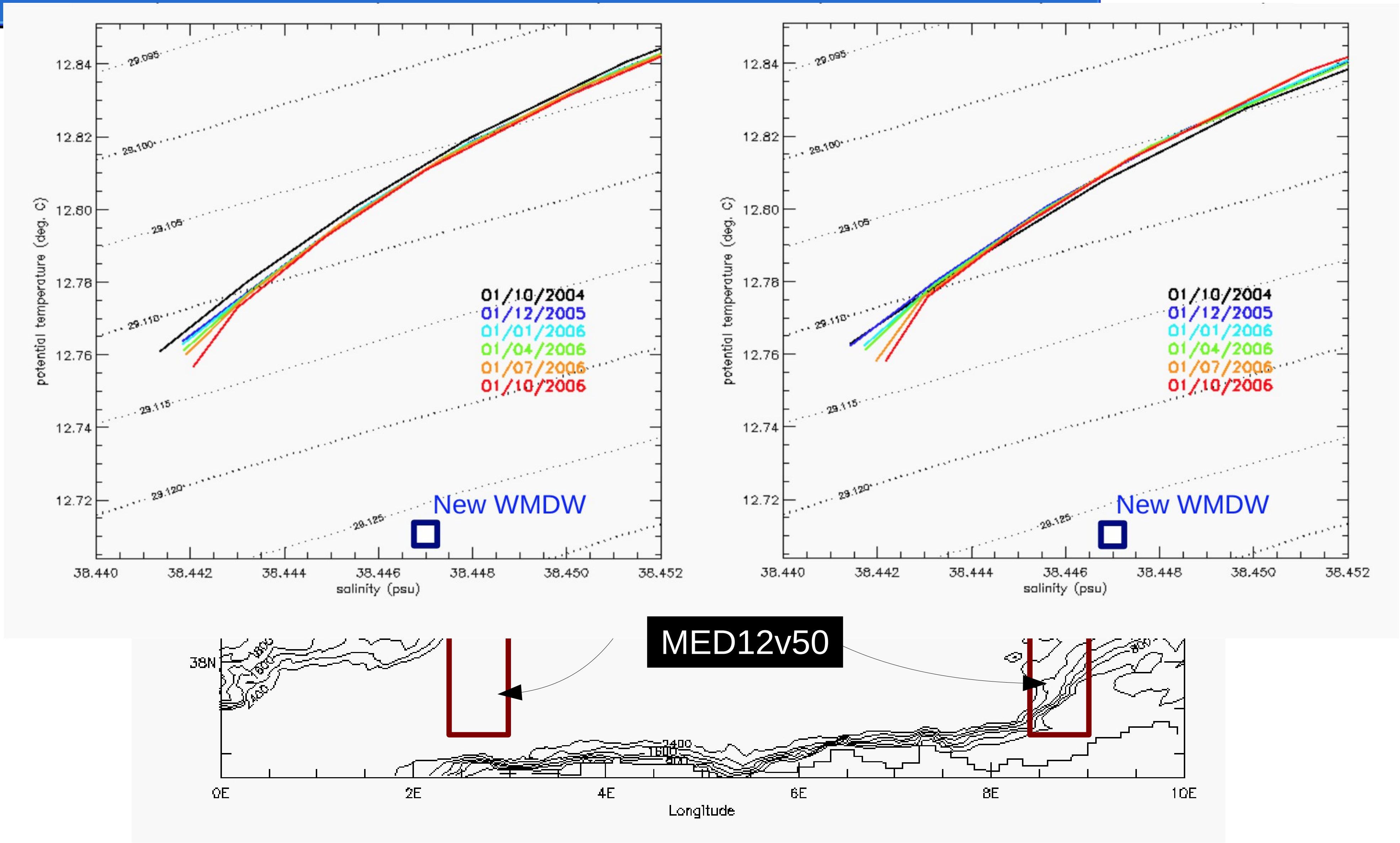
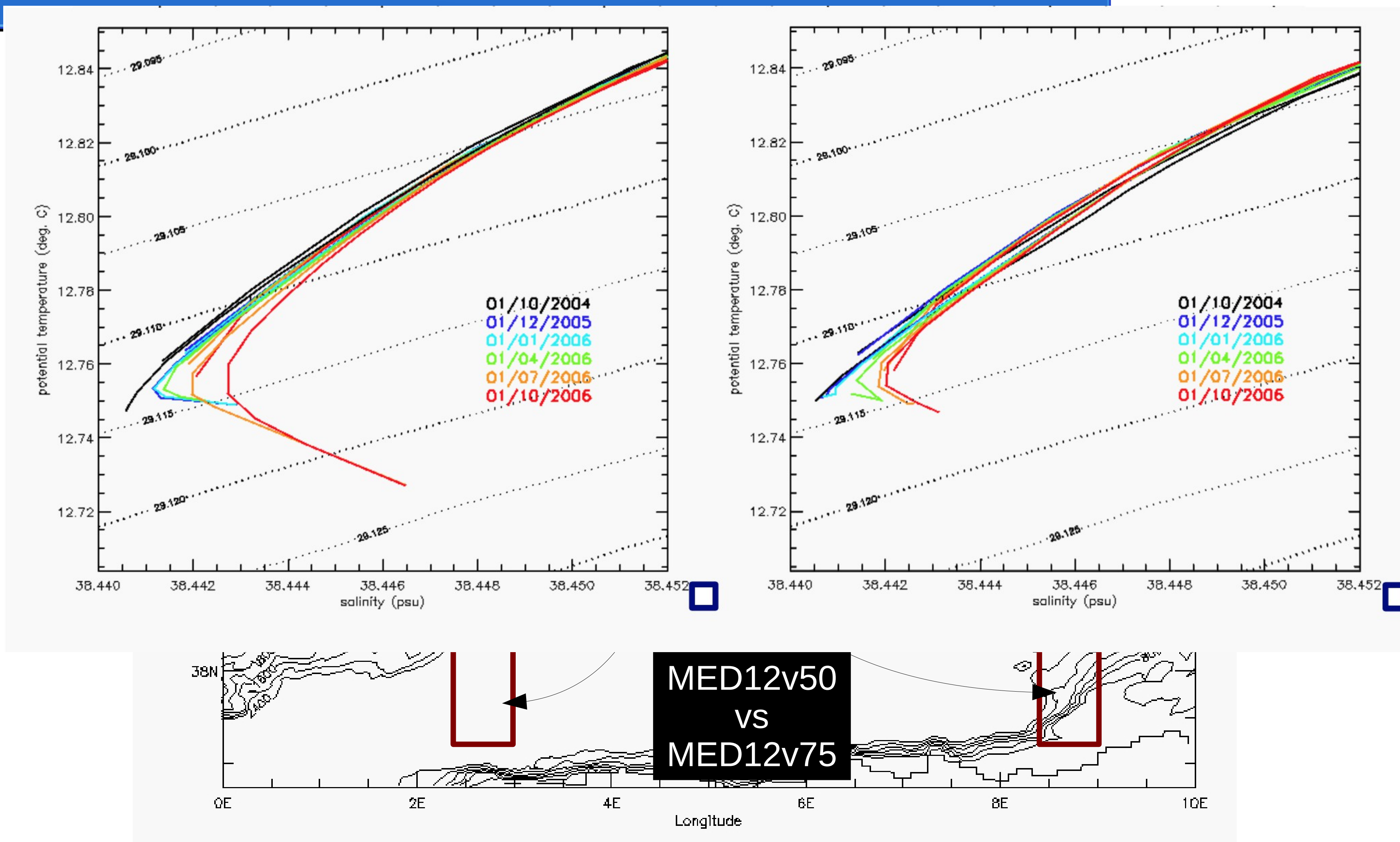
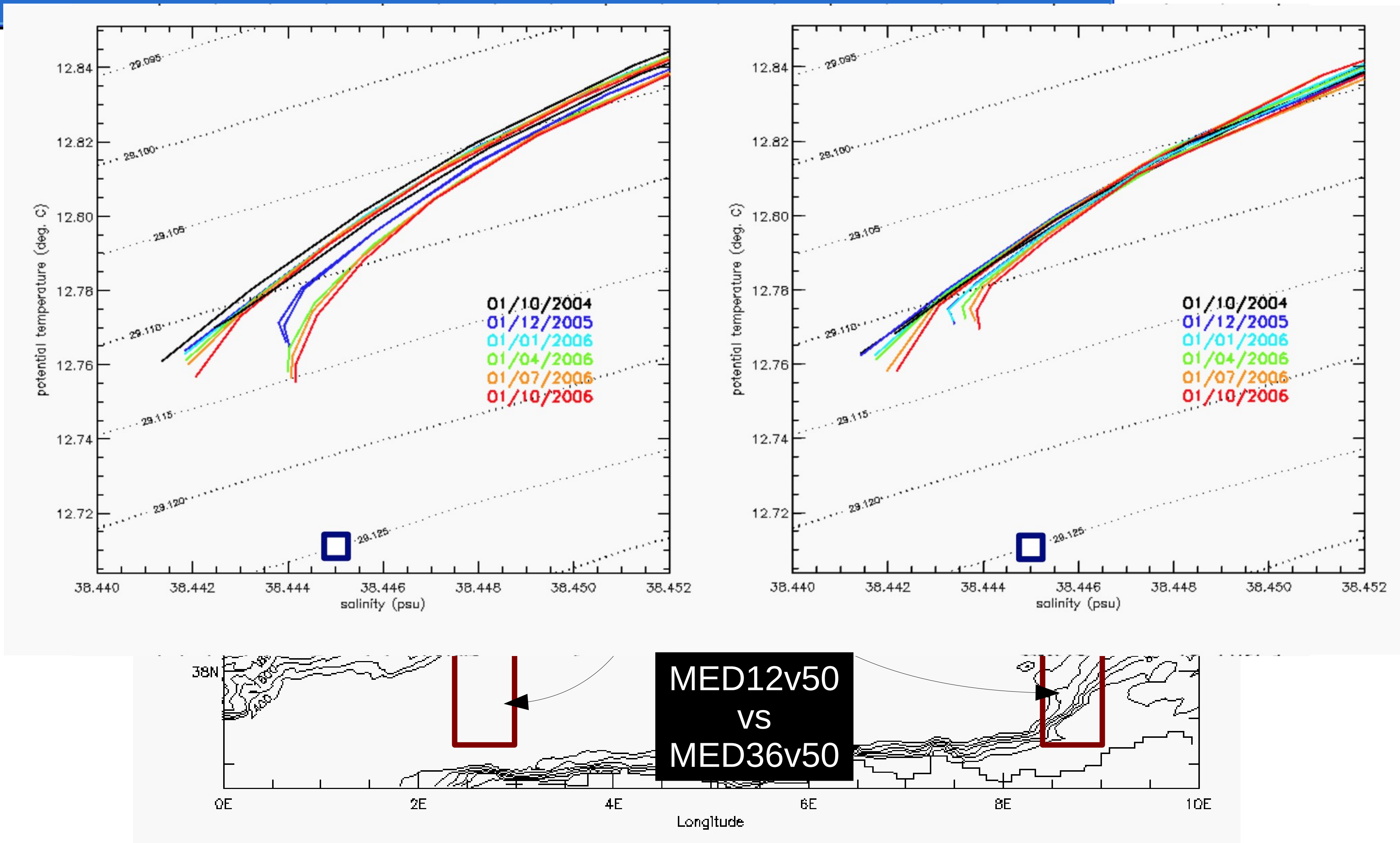


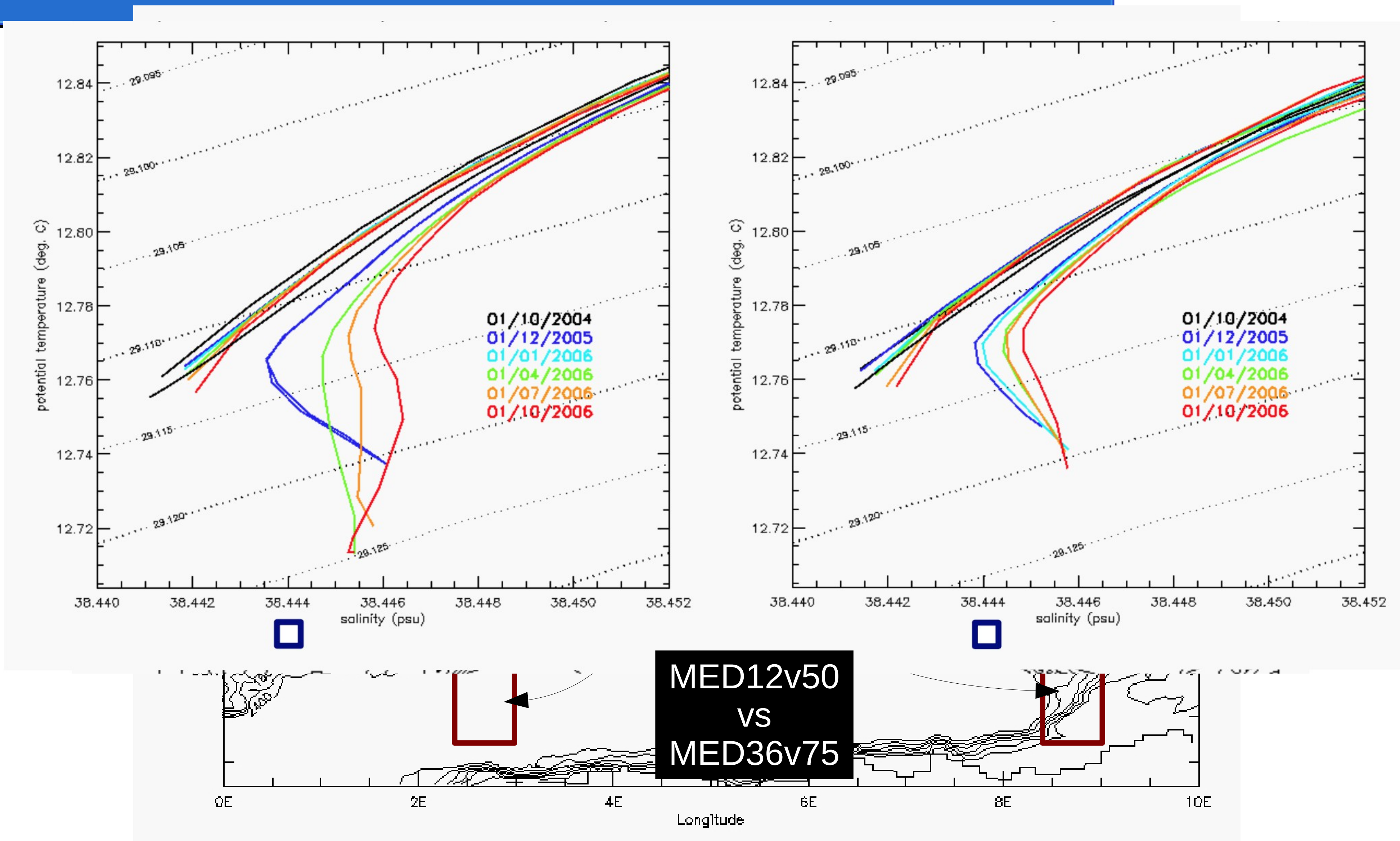
WMDW characteristics and propagation



WMDW characteristics and propagation



WMDW characteristics and propagation



WMDW spreading

Conclusions

- Same temporality for all 4 companion models
- Before the WMT, in 2004, old WMDW Sal. and T. characteristics (density 29.10-29.11) in good agreement with observations
- Important contribution of cool and fresh shelf water cascading through the Cap Creus Canyon (~ 10 % of newly formed dense water) at high resolution
- Up to 5.8 Sv of WMDW formed for the years 2005-2006 (simulation MED36_v75)
- MED36 models generate more WMDW, especially after 2005
- Good reproduction of WMDW fast transport southward via eddies in v75 models (especialy MED36_v75)
- Importance of sub-mesoscale structures in deep water formation and transport ?

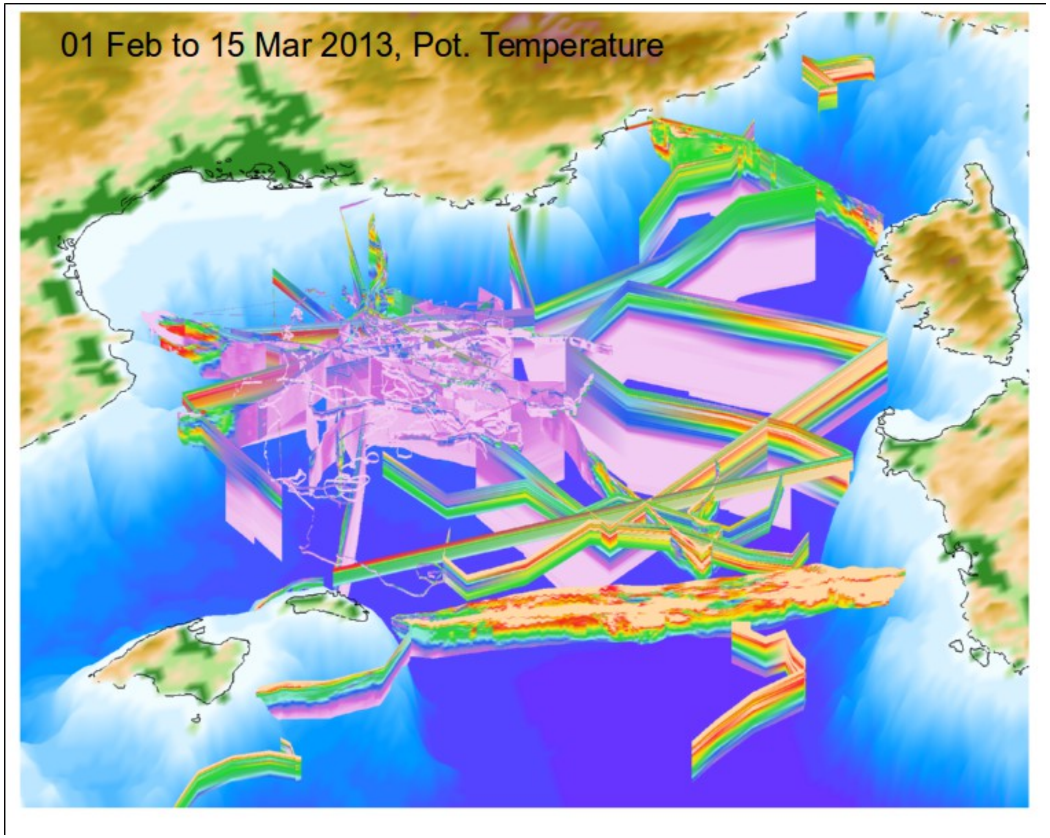
HyMeX SOP2

- 1st Feb 2013-15th Mar 2013
- Observation of deep convection event in the Gulf of Lion : deepening of the Mixed Layer Depth, convection process, restratification, export.

- Extensive network of observations
- 5 gliders deployed

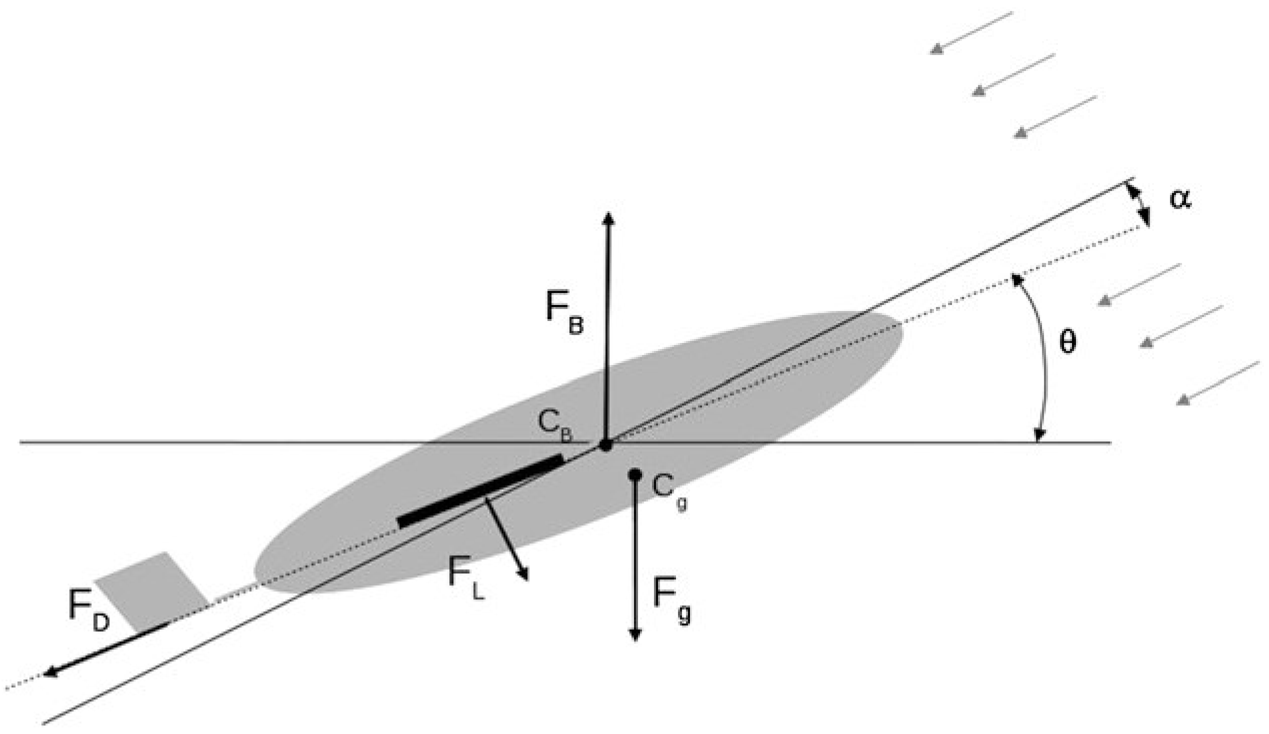
- Is this view representative of the 3-D state of the ocean during SOP2 ?
  - Does it provide a good estimate of the convection area ?
  - Does the glider sampling strategy capture all the scales associated with the processes happening during deep convection ?

=> try to answer this question in a modeling framework



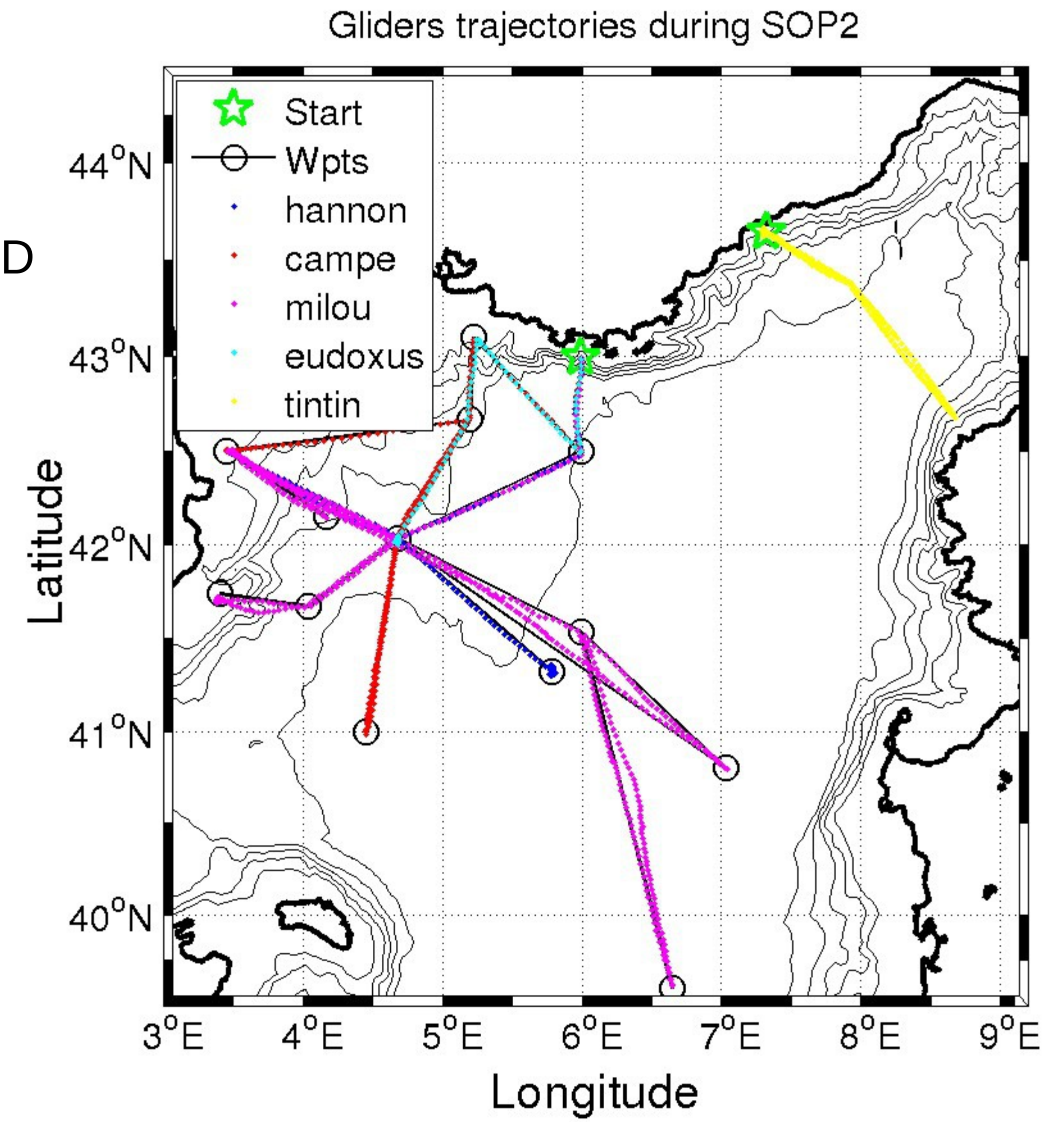
SIGLID

- GLIDer flight SImulator : implemented in the offline tracer module of the NEMO model (L'Hévéder et al., 2013)
- Setting up parameters describing glider fleet (weight, pitch angle, volume change, etc...) and missions (list of waypoints)
- Models gliders' flights submitted to currents, buoyancy changes (defined by environment variables T & S) provided by the model



Gliders deployment

Gliders trajectories simulated with SIGLID with NEMO_MED36 simulation



Variographic analysis

- Variogram : function describing the degree of spatial dependence of a spatial random field

- Variogram and covariance express the same dependance of two measurements spaced by intervals of distance *h :*

  $$\gamma(h) = 1/2\ Var\ (Z(s) - Z(s + h))$$

  where *s* is is the position of a measurement *Z*

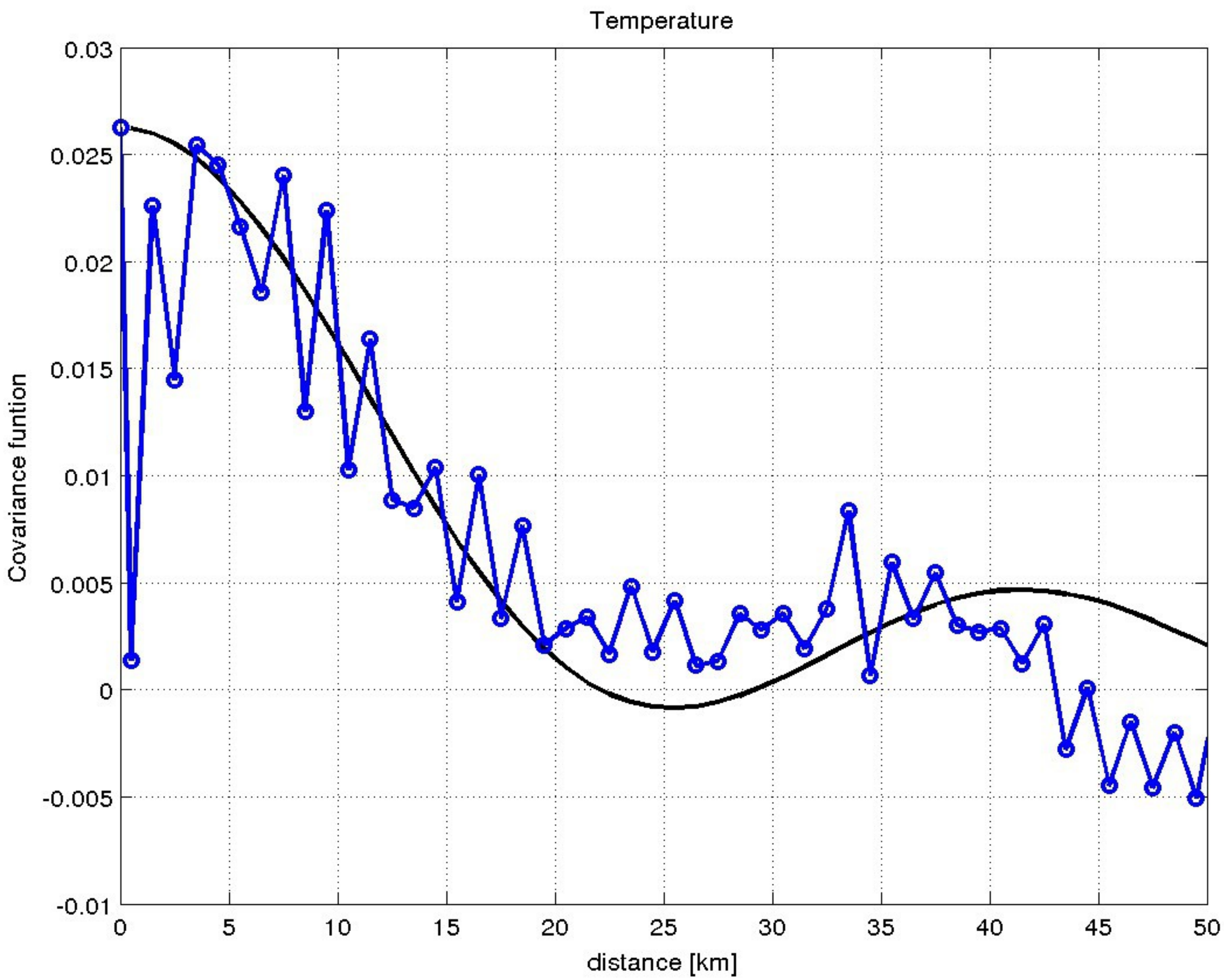
- Field measured : temperature at 450m (hydrographic core of the LIW) in the GoL domain : view the 'fingerprint' of convection area (salty and warm waters of LIW vs cold waters recently convected waters)
- Limit over a 50km window (~1 day for a glider)

- Is the variogram obtained from the gliders data coherent compared to the one from the « real » ocean ? i.e. do the scales of observed coherent structures with the gliders representative of all the structures in the ocean ?

SIGLID variogram

- Covariance function approximated by the sum of 2 functions (positive definite)

- Sum of a cardinal sinus function and a gaussian function



- First characteristic scale : **~7-10 km** (small eddies)

- Second characteristic scale : **~25-30 km** (big eddies / large scale waves / convection zone characteristic extent)

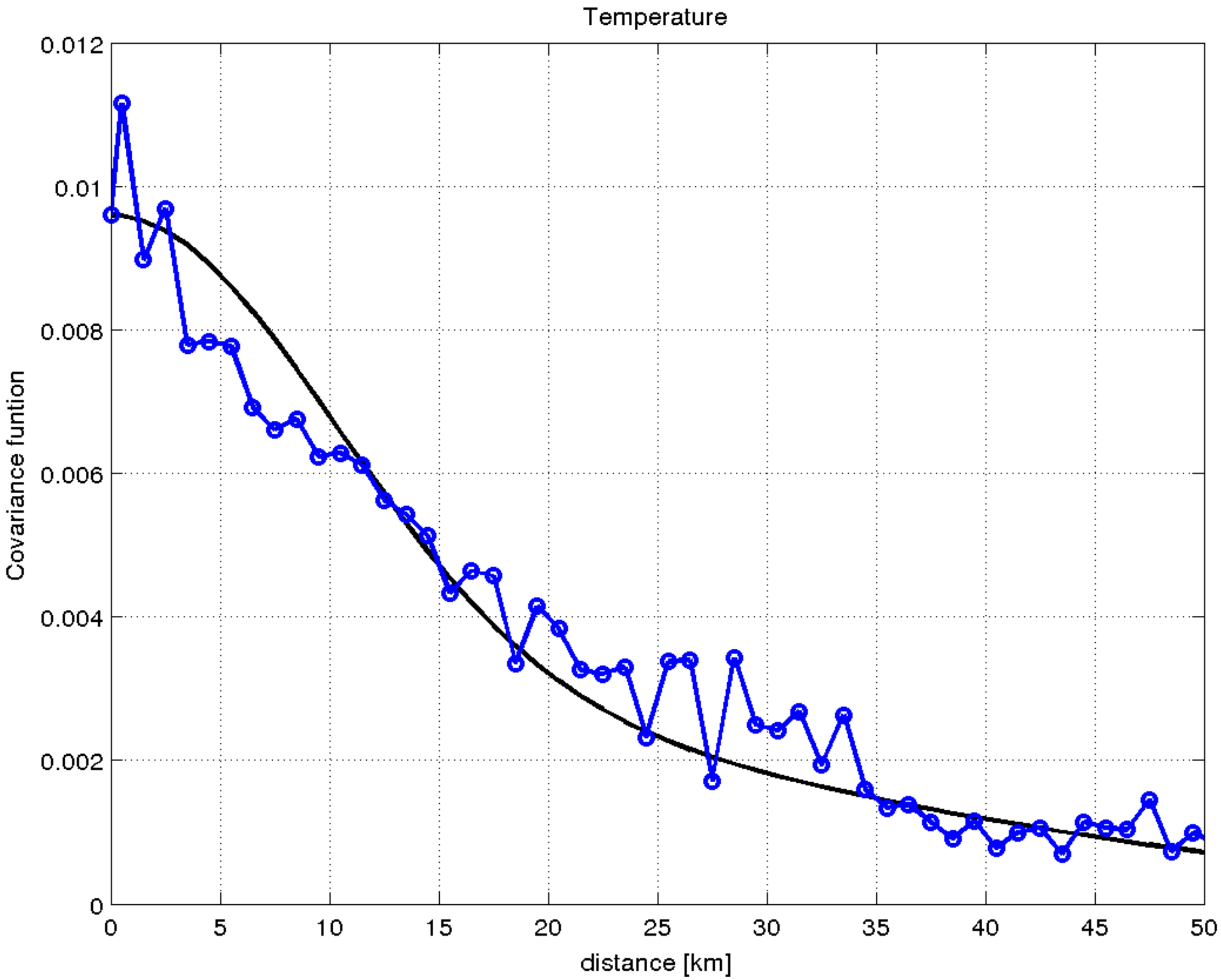
Gliders variogram

- All gliders data assimilated

- First characteristic scale : **~10 km**

- Second characteristic scale : **~30-35 km**

- Same characteristic scale as for the glider simulator...



- Covariance function here approximated by the sum of 2 gaussian functions

Outline and perspectives

- Only preliminary results so far…

- Variogram can be used as a tool to apprehend characteristic scales captured by data and models
- Approximately the same characteristic scales captured by the the model, the gliders in the model, and the gliders deployed : ~8-10 and ~25-30 km

- SIGLID numerical glider simulator :
  - Main uses :

  - apprehend the representativity of data
  - to establish deployment strategies (number of gliders, spatial coverture, timing of deployments, etc...) to capture main features of determined process studies
  - systematicaly in a forcast mode to make day to day adjustments to gliders deployments and waypoints determination when on field campaign
  - Can be used with biogeochemistry simulations
  - Make it easy to implement in other models and configurations