

The background of the slide is a composite image. The top half features a bright yellow rectangular area. On the left side of this yellow area, there is a 3D rendering of a satellite in space, with its solar panels extended. The bottom half of the slide shows a blue ocean surface with a yellow autonomous underwater vehicle (glider) floating on it. The glider has a long, slender body, a single wing, and a vertical tail fin.

IMEDEA activities on the use of altimetry and glider data in the Western Mediterranean Sea

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CLS, Space Oceanography Division, Toulouse, FRANCE



- Objectives
- IMEDEA facilities for gliders
- Glider/altimetry missions in the WMed.
 - Balearic Sea
 - Eastern Alboran Sea
- Summary and work in progress

Objectives



- To improve our knowledge on the driving mechanism of the main features in the Balearic sea and the Eastern Alborán area (Western Mediterranean)
- To characterize of North/South exchanges in the Western Mediterranean. The key role of the Balearic channels
- To test the feasibility of the gliders technology usage
- To explore the use and limitations of altimetry data in the coastal area.

Context :

Fronts and mesoscale dynamics: processes, observations and modelling.

Framework

Mersea



Ecoop



Sesame



OST

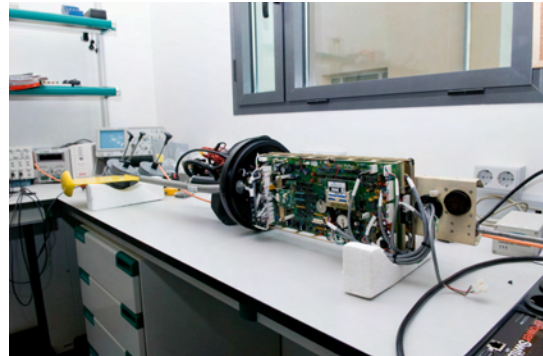


IMEDEA Facilities for glider



We have established new facilities for glider operations:

Electronics
Laboratory



Ballasting
Laboratory



Collaboration:
Search and Rescue
801 Squadron
and local authorities



Missions

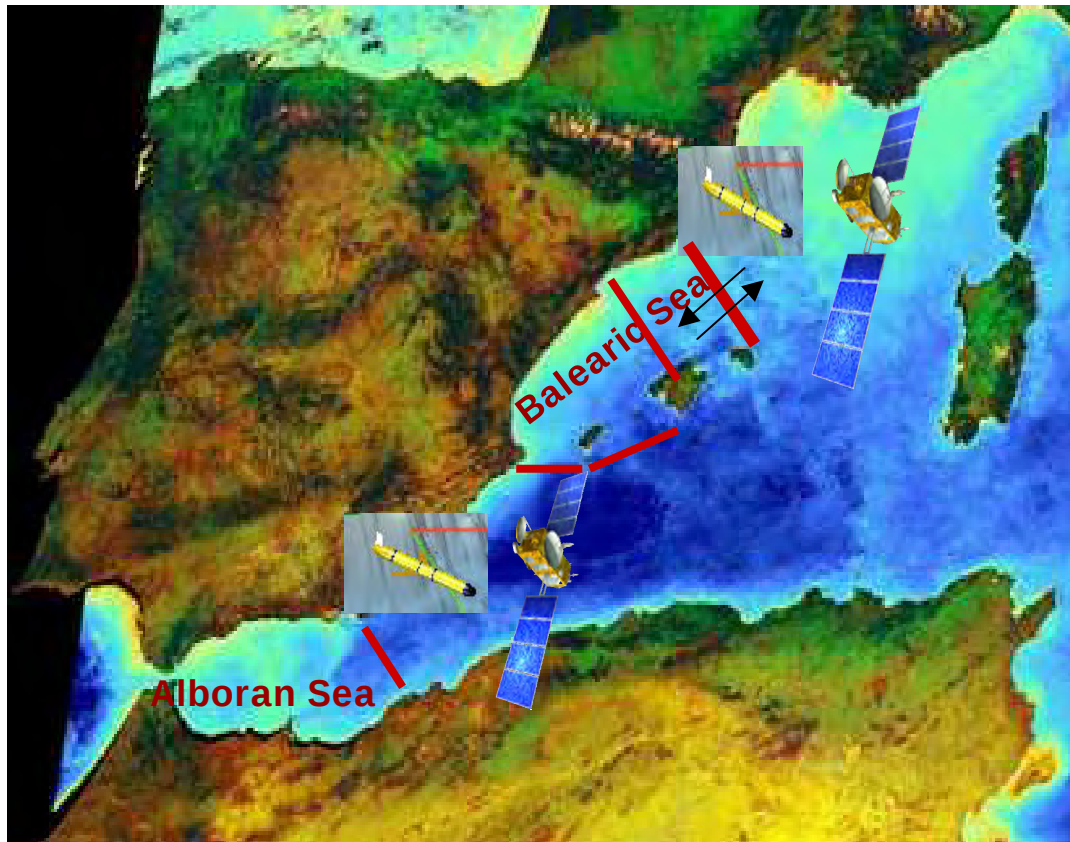


We have carried out **15** glider missions from November 2006 to August 2008 in the Western Mediterranean Sea



5000 full CTD casts
+ oxygen, chlorophyll
turbidity (180 m)

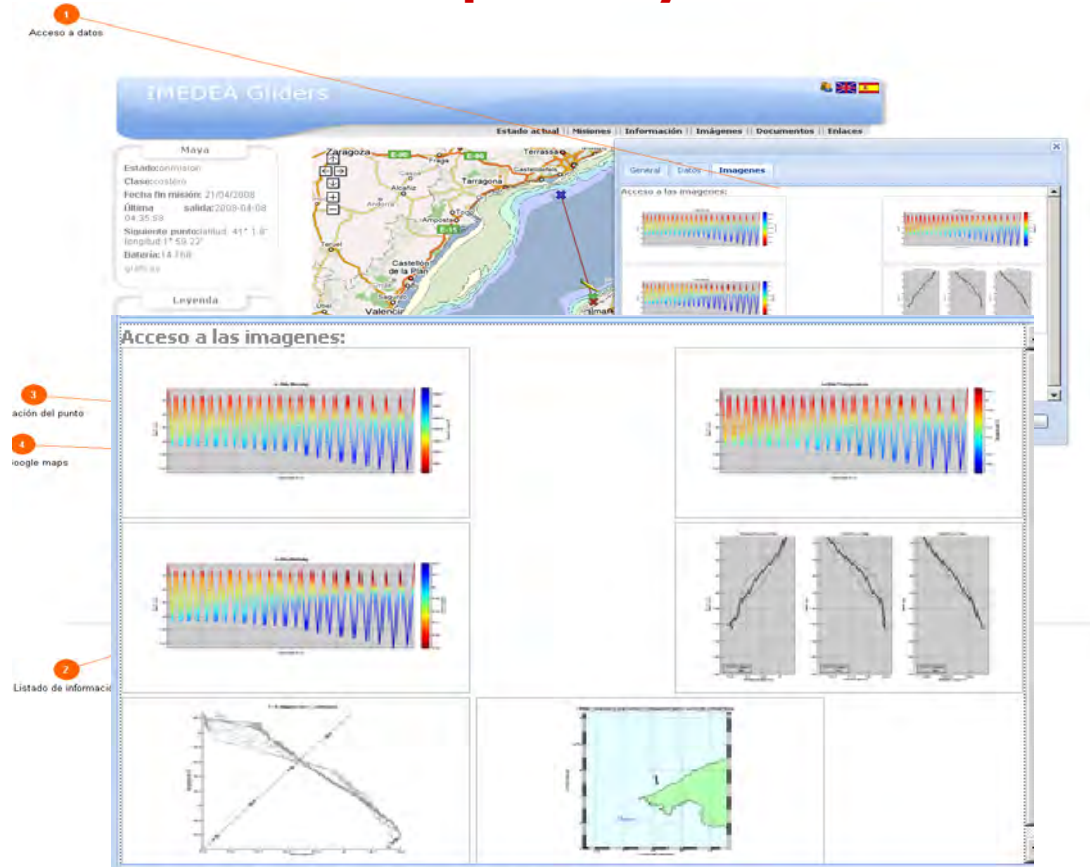
- Sustained glider observations along 773 ENVISAT track (every 70 days)
- Simultaneous sampling (2 gliders) of Balearic channels in collaboration with Ifremer
- Jason Altimeter track from Menorca to mainland
- Eastern Alboran Sea
- Complementary ship cruises
- Specific ship/glider experiment for thermal lag correction



Data management and web



We have developed a system for tracking glider missions in real time:



- Mission definition
- Quality control
- Visualization
- Data transmission to Coriolis
- Data download capability

More details in Garau' talk

<http://www.imedea.uib-csic.es/tmoos/gliders/>

Events with IMEDEA participation



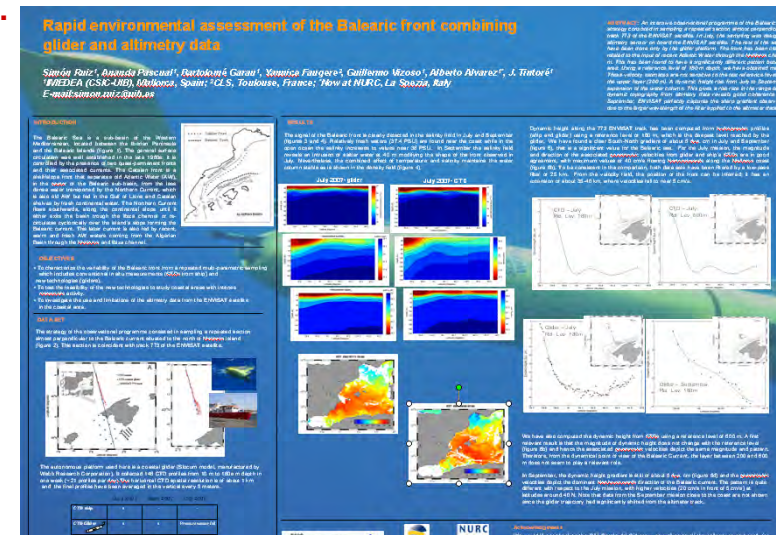
We have organized/co-organized the following events:

- International Glider School 2007 – IMEDEA
- 2nd EGO Workshop 2007 – IMEDEA



We have participated (talks and posters) in the following scientific conferences, meetings, etc:

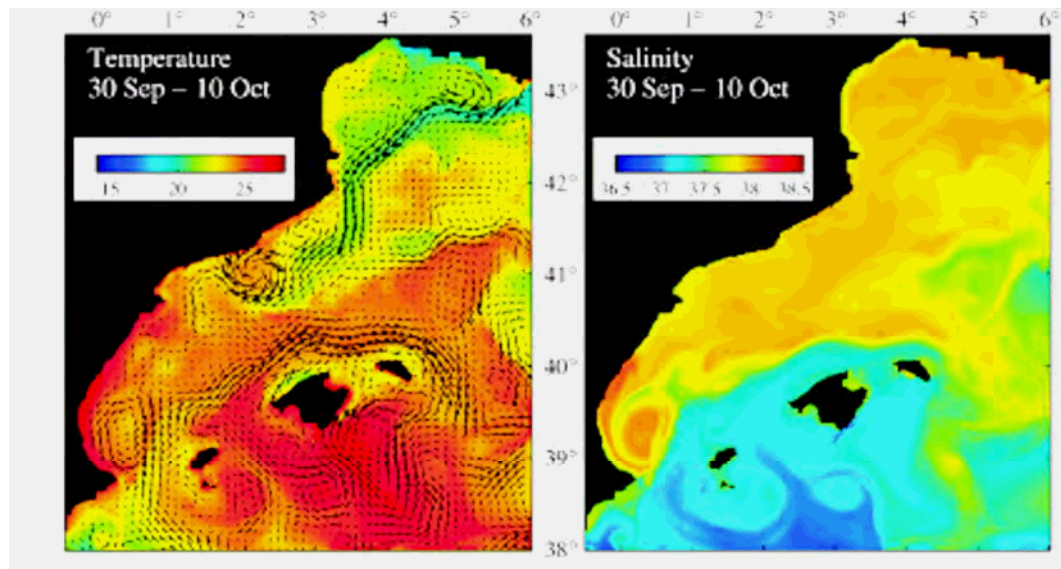
- REA Conference, Sept. 2007, Italy
- EuroGoos 2008, UK
- EGU April 2008, Austria
- OST meeting, June 2008, L.A.,EEUU



Operational Systems



In collaboration with GKSS (Reiner Onken), we are working to incorporate the glider observations into the operational system in the Balearic Sea (data assimilation)

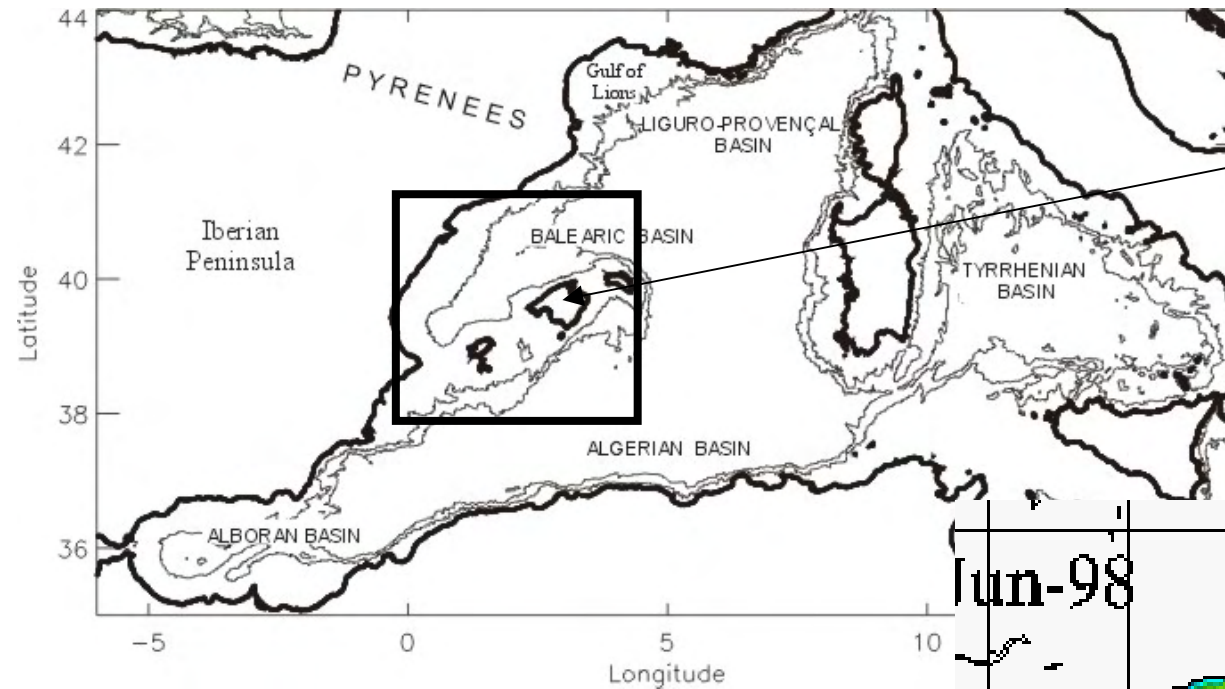


Modelled SST, velocity and salinity in the Balearic Sea (Onken et al., 2008)

Examples of glider missions

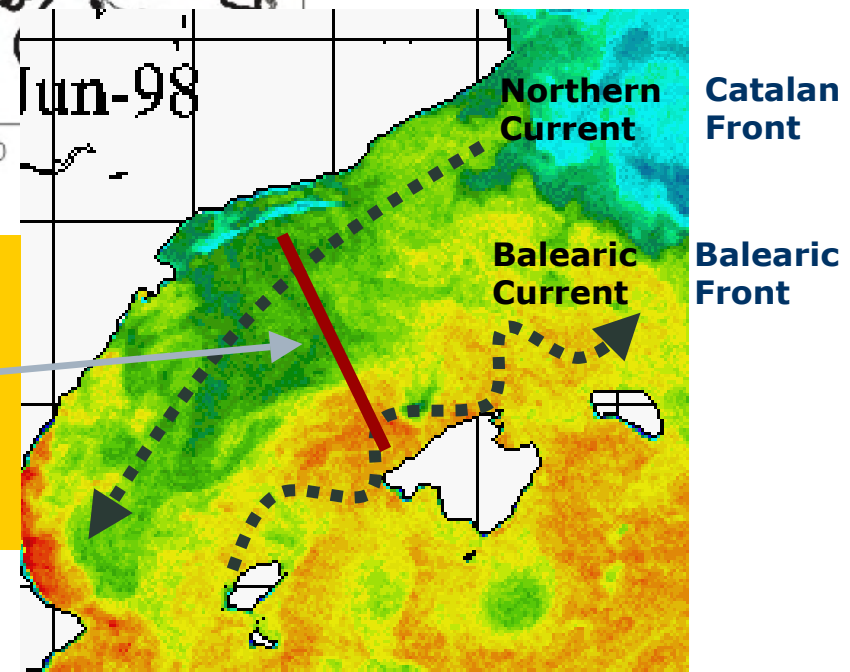
I. The Balearic front

Area of study – I : North Mallorca Island



IMEDEA

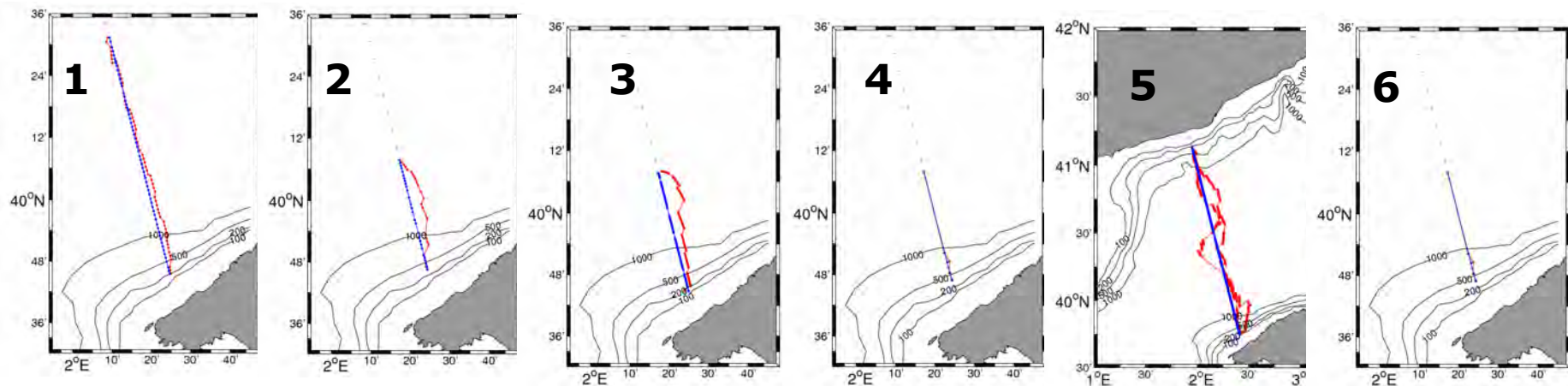
**Sustained observational glider programme:
Missions simultaneous to Envisat passage
along track 773
(perpendicular to the Balearic front)**



Samplings: North Mallorca Island (Balearic front)



N. sampling	Dates	Envisat Cycle	Comments
1	6-13 Jul 2007	59	Complemented with CTD from oceanographic cruise. Z: 0 – 600 m H resolution: 5-12 Km
2	14-17 Sep 2007	61	-
3	23-27 Nov 2007	63	-
4	1-5 Feb 2008	65	Performed with CTD due to a failure of the glider
5	7-23 Apr 2008	67	Catalan coast reached
6	20-24 Jun 2008	69	



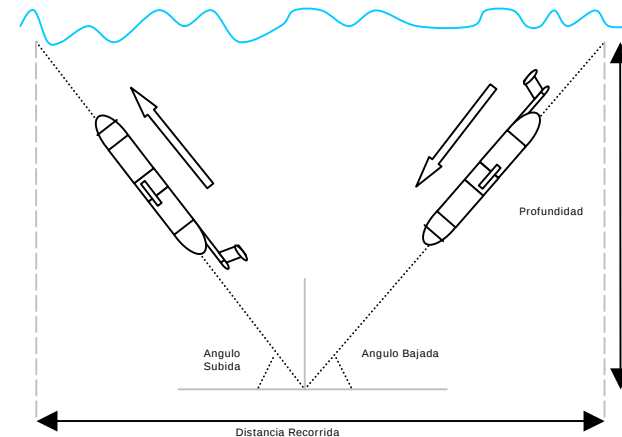
Blue: satellite track - **Red : glider trajectory**

Data Sets



Glider data

- Variables: P, T, S, oxig., chl., turb.
- Vertical extension:
10-180 m
- Horizontal resolution: 1km



Envisat / Jason data

- Along track SLA (AVISO/CLS)
+ MDT (Rio et al.)
- Delayed time product
- Med product
- Horizontal resolution: 7 km



Methodology

Optimal Statistical Interpolation

(Daley, 1991)

- Background: Climatology / polynomial fitting

$$\hat{\phi}_g = \left(\begin{array}{c} C_{11} \\ C_{21} \\ \vdots \\ C_{n1} \end{array} \right) \left(\begin{array}{cccc} \sigma_{11} + \gamma_{11} & C_{12} & \dots & C_{1n} \\ C_{21} & \sigma_{22} + \gamma_{22} & \dots & C_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ C_{n1} & C_{n2} & \dots & \sigma_{nn} + \gamma_{nn} \end{array} \right) \left(\begin{array}{c} \phi_1^o \\ \phi_2^o \\ \vdots \\ \phi_n^o \end{array} \right)$$

Vector de correlaciones entre el punto de mallag y las observaciones

Matriz de correlaciones entre las observaciones

Vector de observaciones

- Correlation Scale: Gaussian model

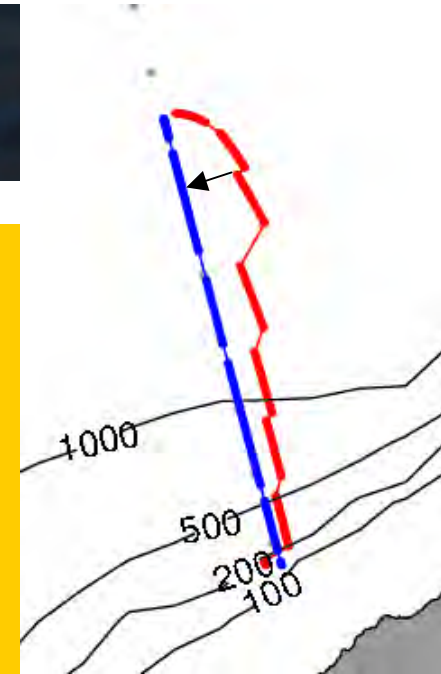
$$R(x) = e^{-\frac{d^2}{2L^2}} \quad L = 15 \text{ km}$$

- Noise-to-signal ratio:

$$\gamma = \frac{\sigma_s^2}{\sigma_n^2} \quad 10^{-5}$$

Direct Projection

- Projection of the glider observation position onto the closest track point.
- Observation values are not modified.
- Along track Lanczos filter (7 km)
- An estimate error is provided by computing rms differences between the values at the original and projected positions using numerical model outputs.



Samplings Balearic Front



June 2007

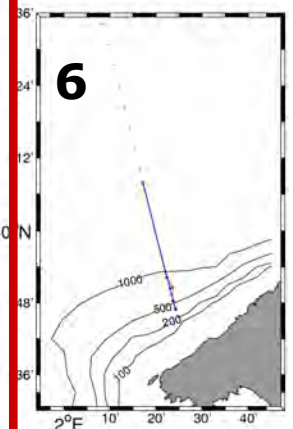
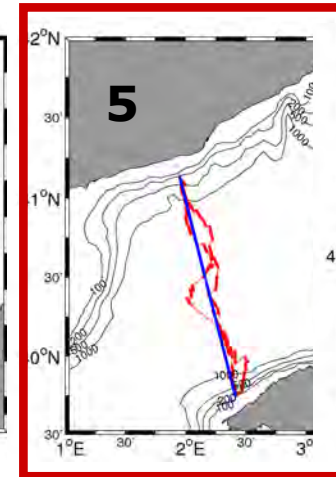
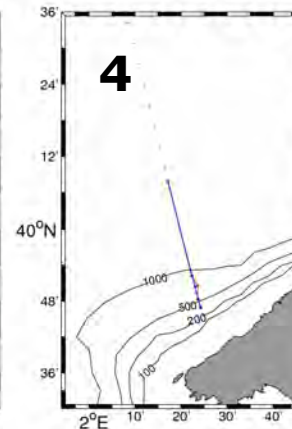
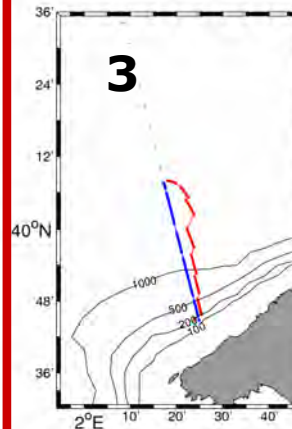
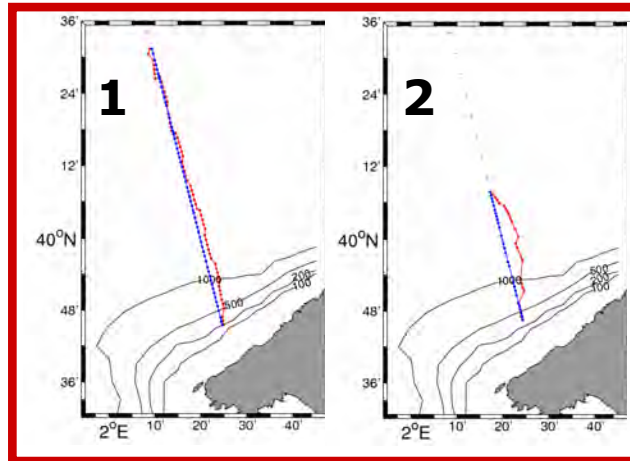
Sept 2007

Nov 2007

Feb 2008

Apr 2008

June 2008



First study: low resolution analysis, comparison to altimetry. Evaluation of coastal altimetry North Mallorca coast

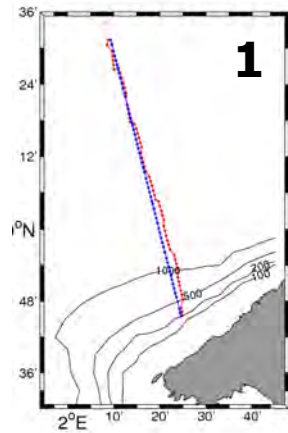
Anomalous anticyclonic eddy in the Balearic Sea
Glider / altimetry / model

Variability of the Balearic front

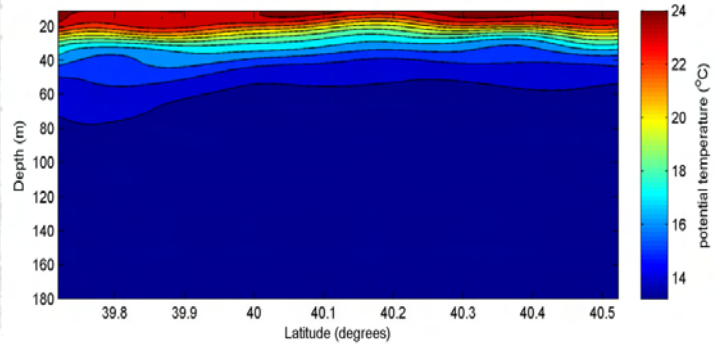
Results: July and September 2007



Glider- July 2007

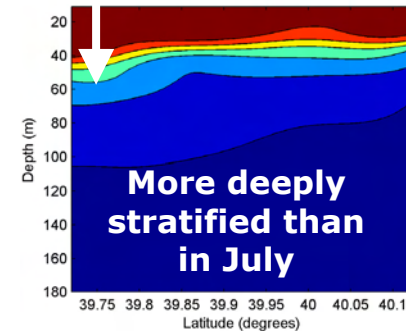


1

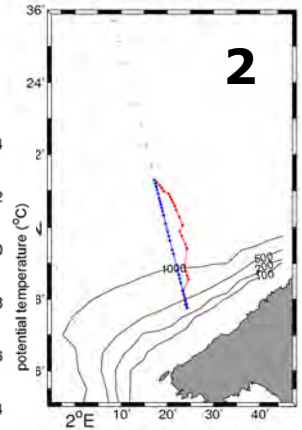


Temp

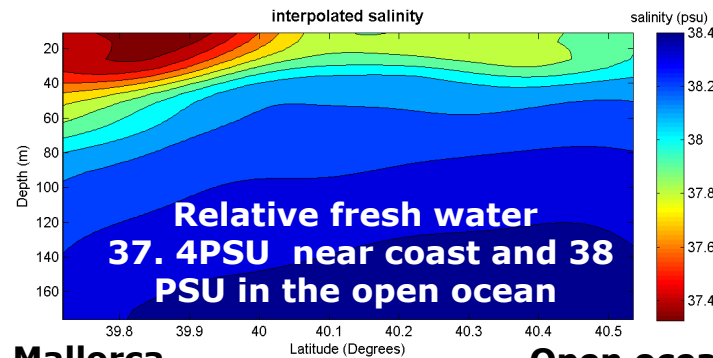
Glider- Sept 2007



More deeply stratified than in July

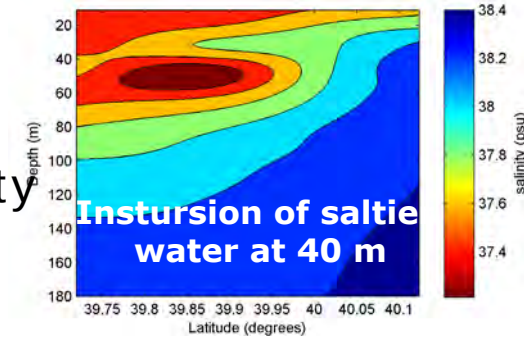


2



Relative fresh water
37.4PSU near coast and 38
PSU in the open ocean

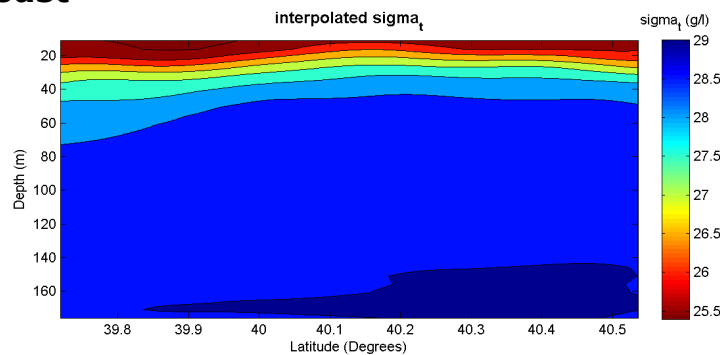
Salinity



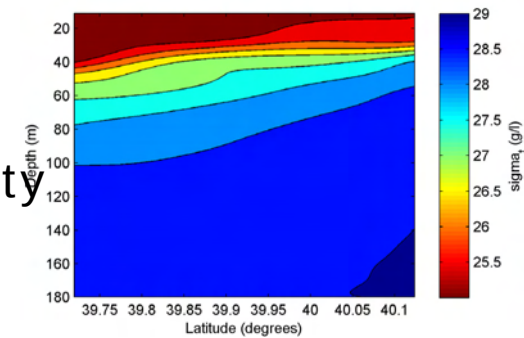
Instursion of saltie
water at 40 m

North Mallorca
coast

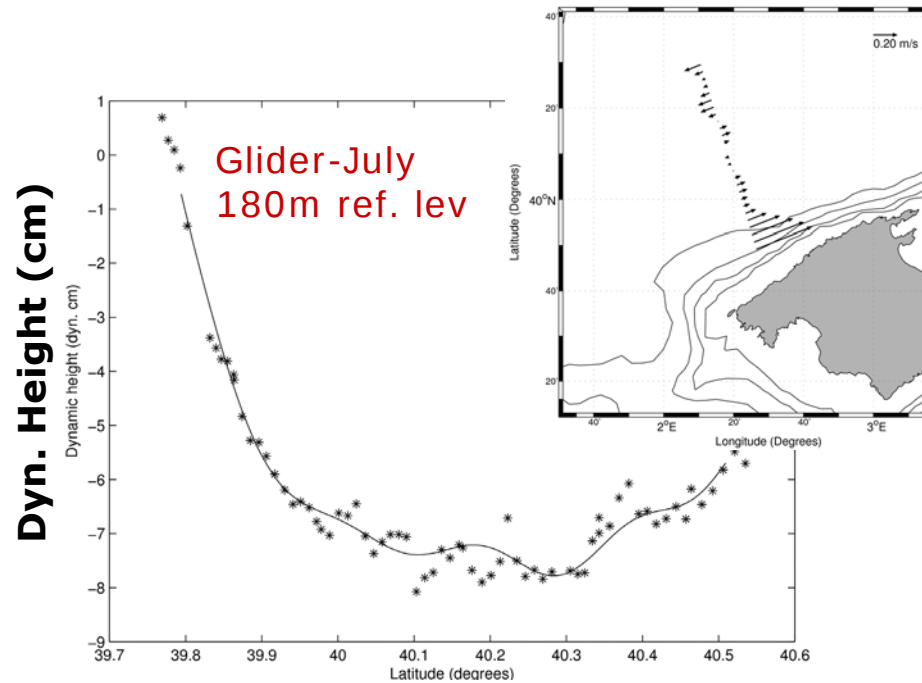
Open ocean



Density

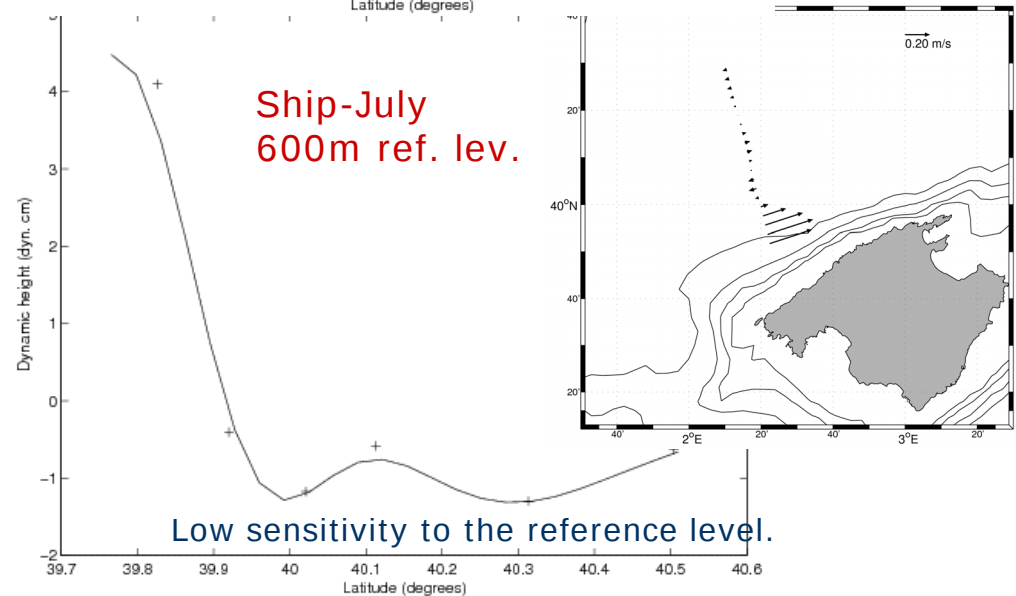
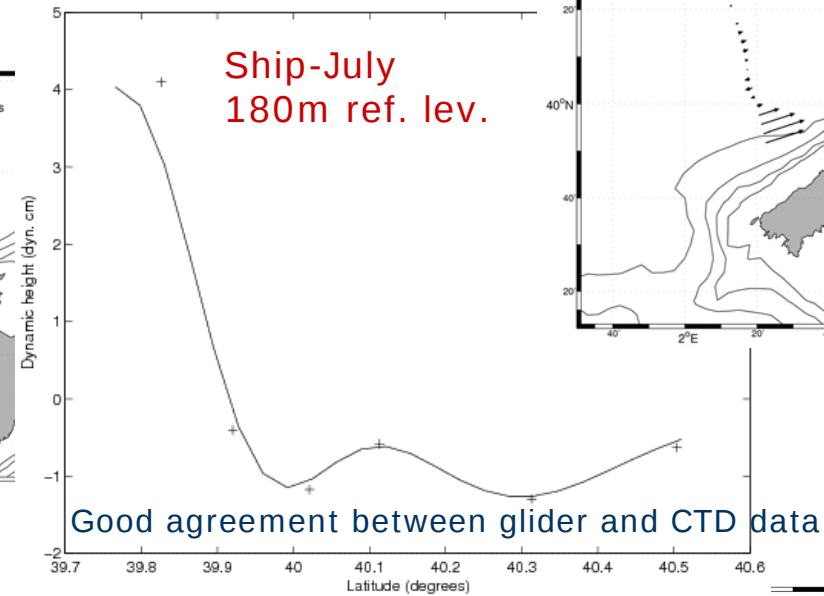


Dynamic height and Vg: July and September 2007

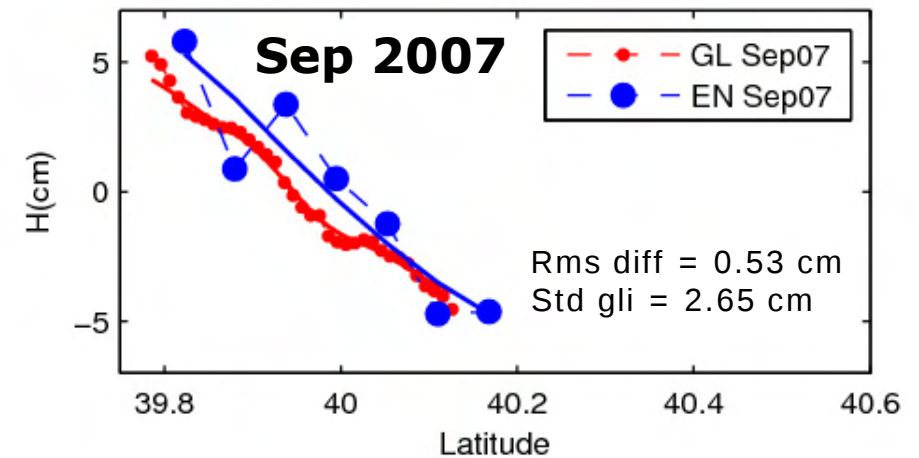
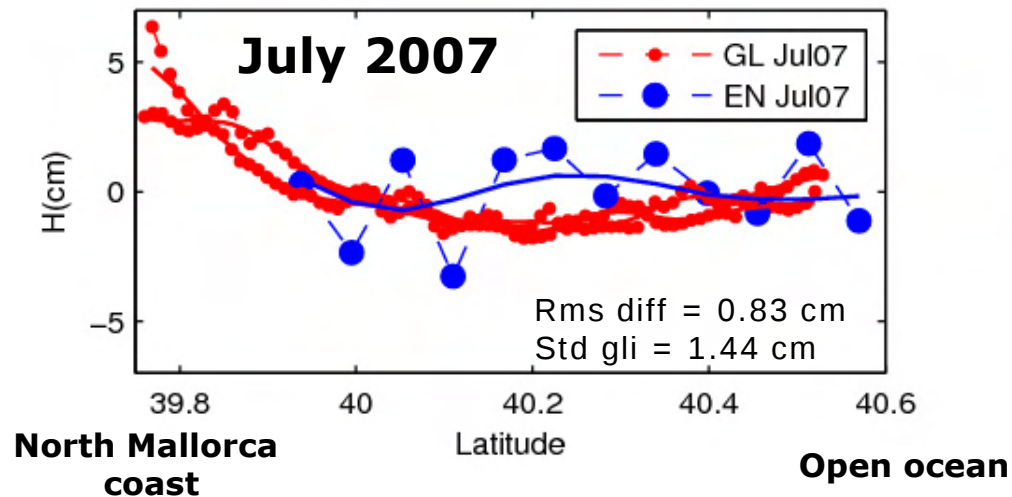


North Mallorca coast **LATITUDE** **Open ocean**

- Detection of the Balearic front.
- Maximum CTD velocities of 40 cm/s flowing northeastwards.



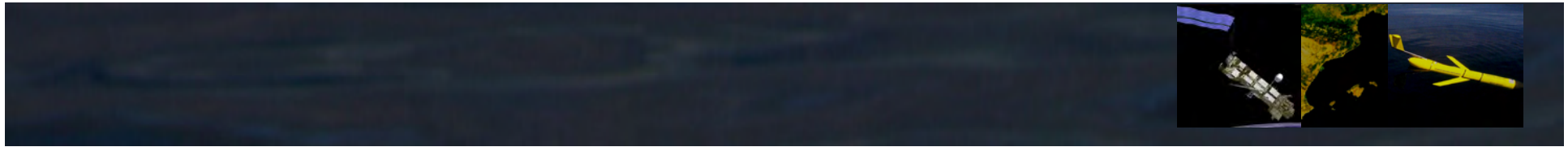
Glider vs altimetry: July and September 2007



Altimetry:

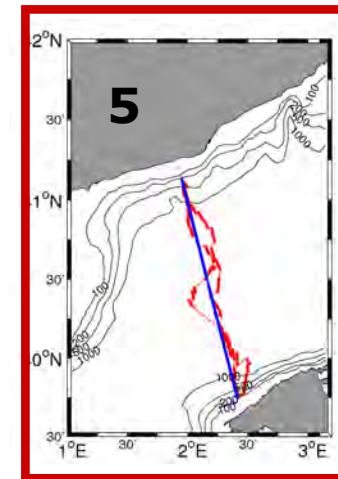
-July: Almost no signature of the front – Envisat did not provide data for the closest points to the coast.

-September: Relatively sharp gradient of about 5 cm in only 20km -> 25 cm/s northeastwards.



Anomalous anticyclonic eddy

Apr 2008

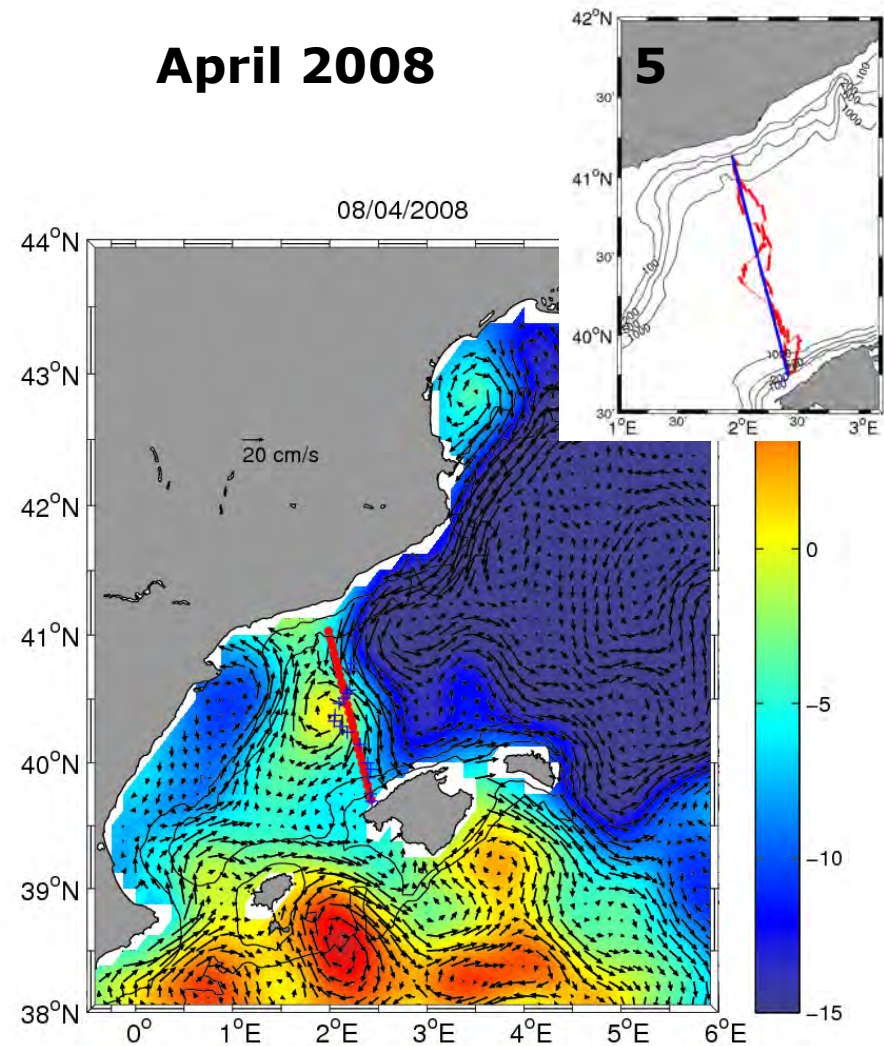
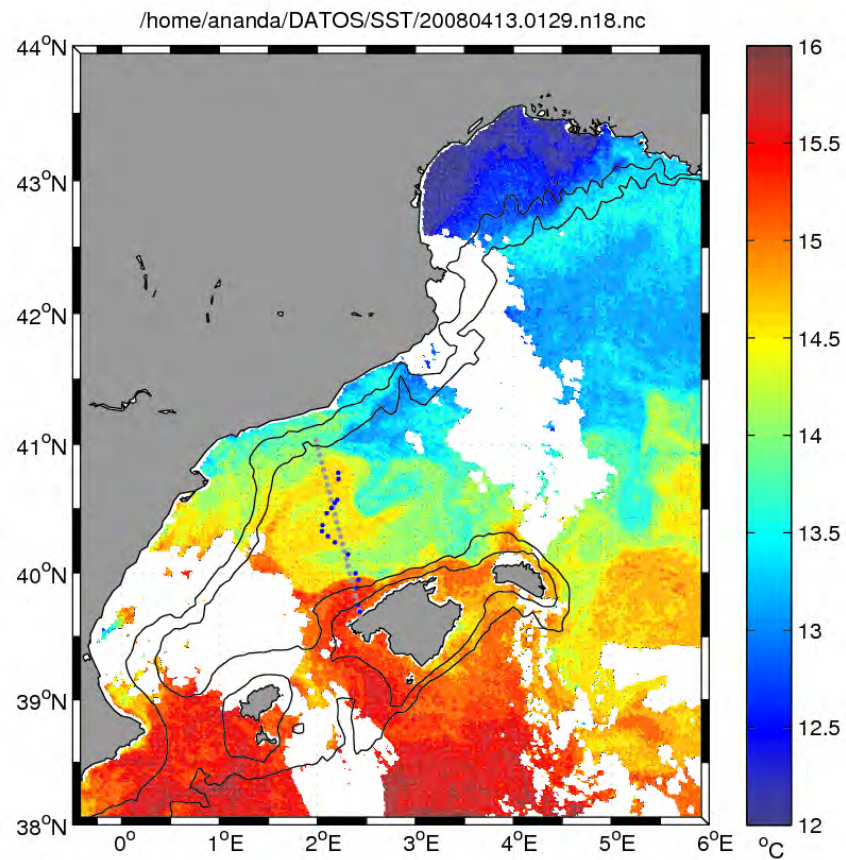


**Anomalous
anticyclonic eddy in
the Balearic Sea**
**Glider / altimetry /
model**

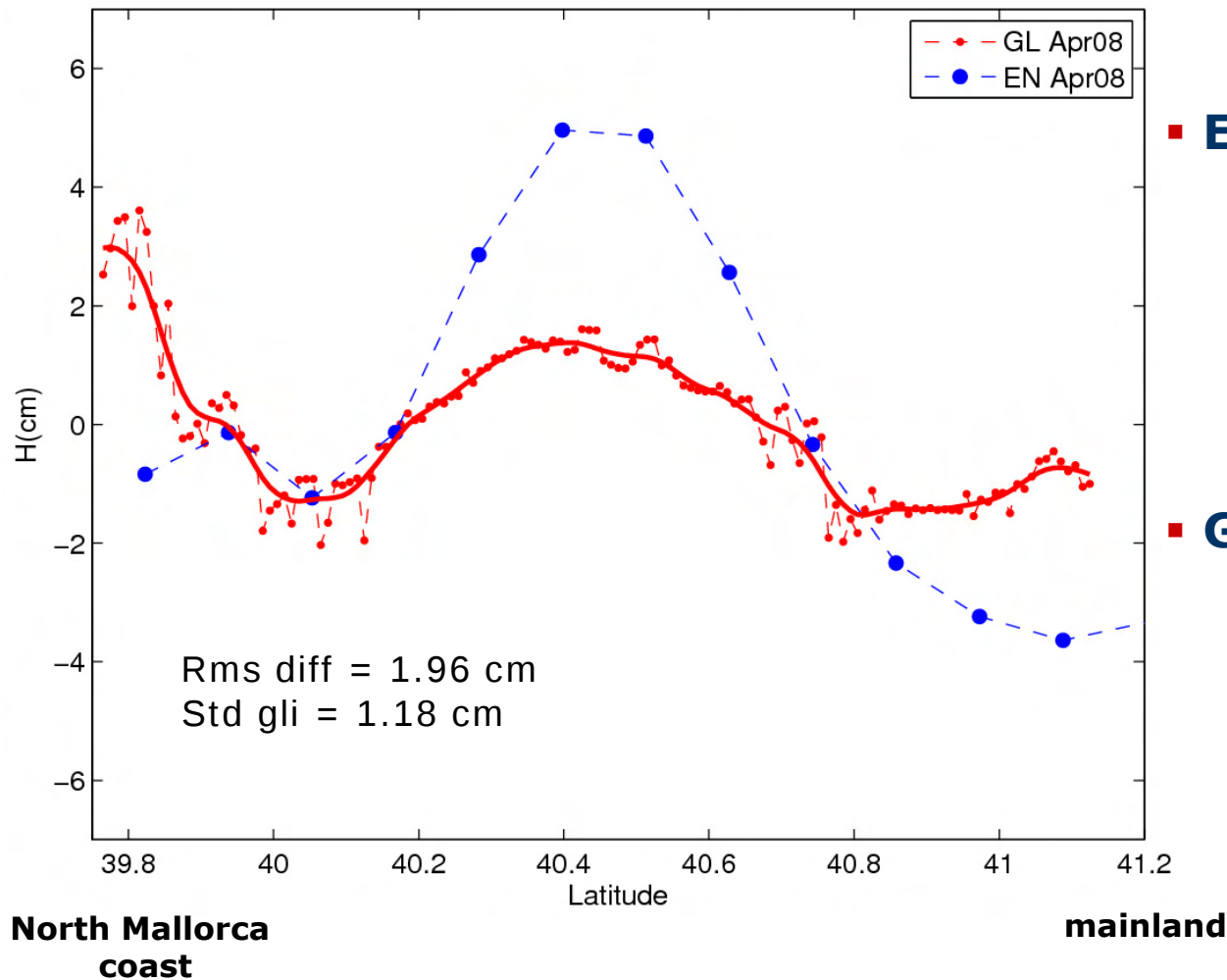
SST and altimetry during April mission



April 2008



mission: real time results



■ Envisat data reveals:

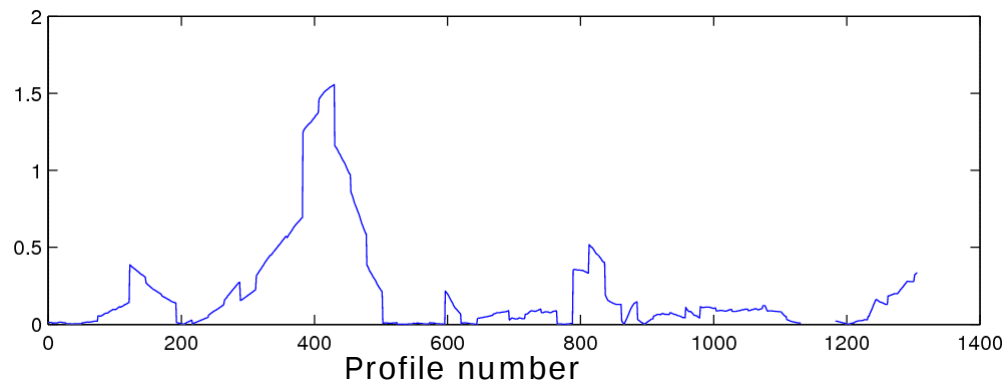
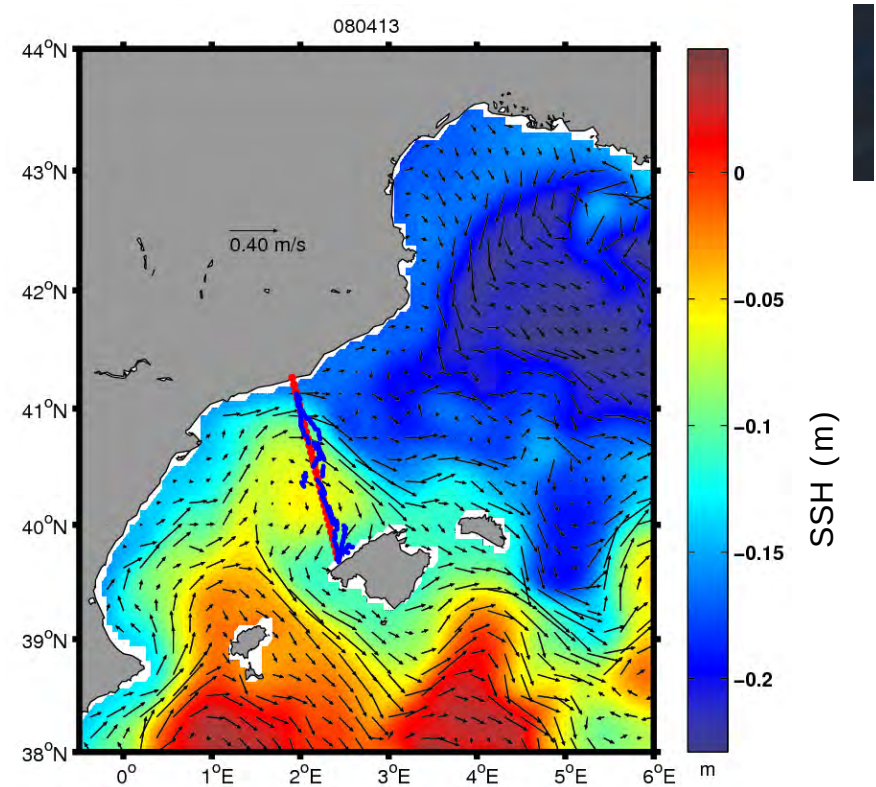
- intense anticyclonic circulation (7 cm amplitude and 80 km diameter).
- absence of Balearic front.

■ Glider data reveals:

- moderated anticyclonic signature.
- strong gradient near the coast corresponding to the Balearic front.

Projection error

- We use MFS SSH output to estimate the error of the data projection.
- This error only gives an approximate value of the actual error as it is assumed that the model resolves correctly the observed structure.

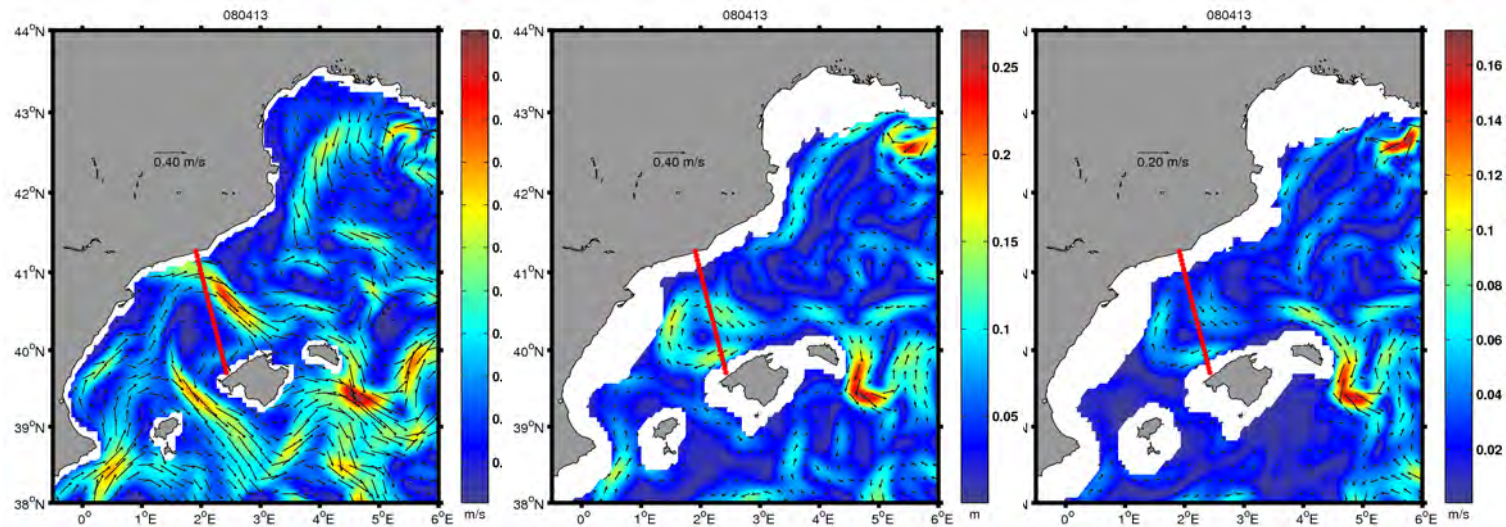


Abs diff between SSH at the glider position and SSH at the projected position on the track. Units are cm.

Max Diff = 1.6 cm

Averaged error: 2.7% of the signal variance.

MFS – Vel 0,176, 394 m



Max vel at surface: 30 cm/s

Max vel at 250 m: 10 cm/s



With a reference level of 180 m an important part of the signal is neglected

Combination of glider geostrophic velocities and integrated GPS currents

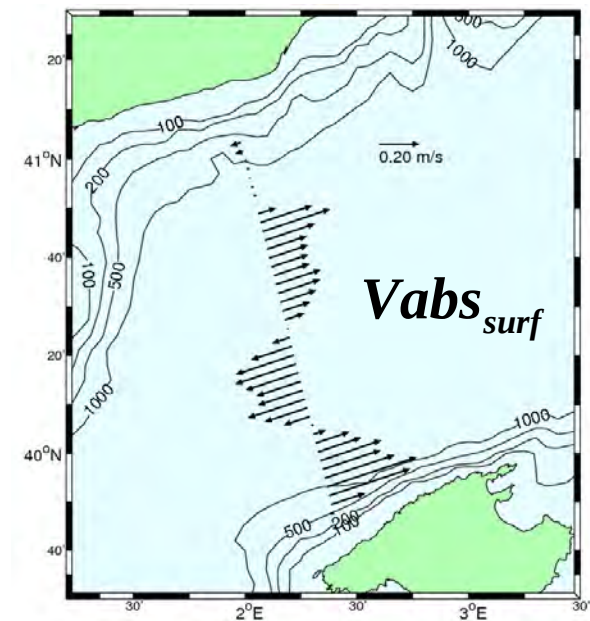
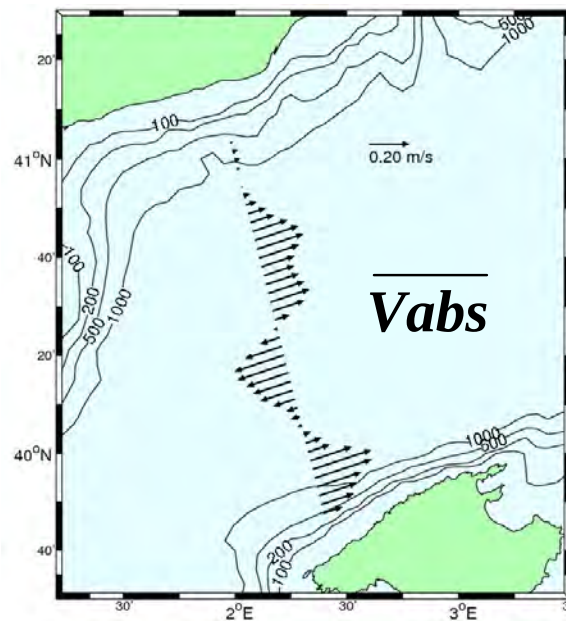
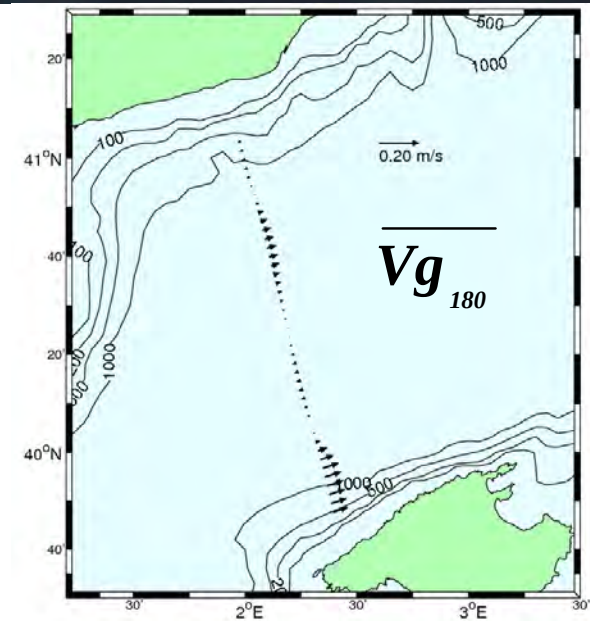
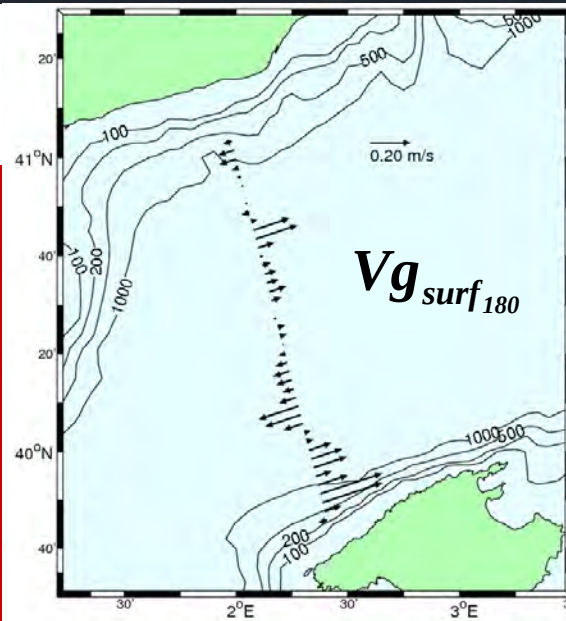


$$V_{abs_surf} = Vg_{surf_{180}} + Vg_{180_bottom} + V_{bar} + V_{ag}$$

$$\overline{V_{abs}} = \overline{Vg_{180}} + Vg_{180_bottom} + V_{bar} + V_{ag}$$

$\overline{}$ denotes vertical average over the upper 180 m (vertical extension covered by the coastal glider)

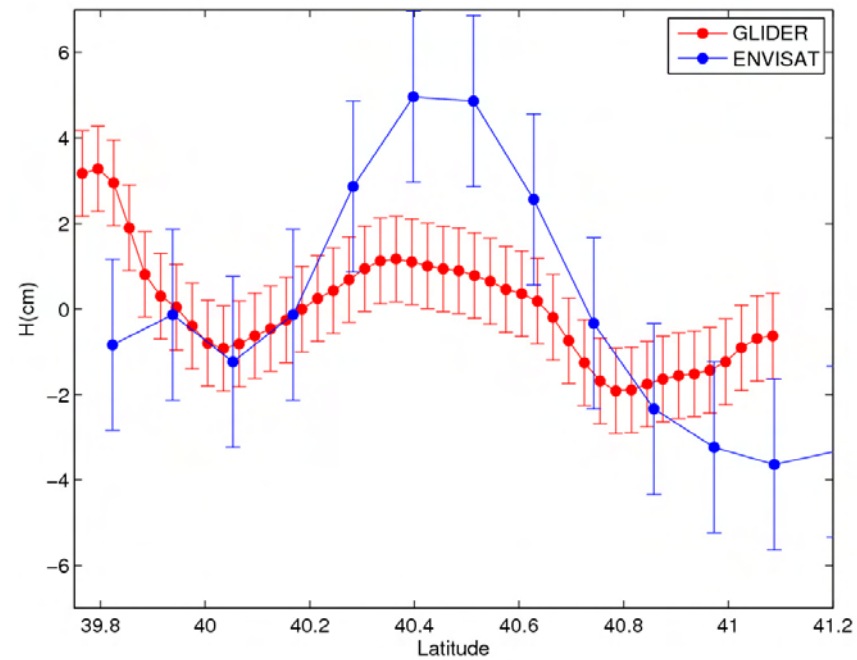
$$V_{abs_surf} = Vg_{surf_{180}} + \overline{V_{abs}} - \overline{Vg_{180}}$$



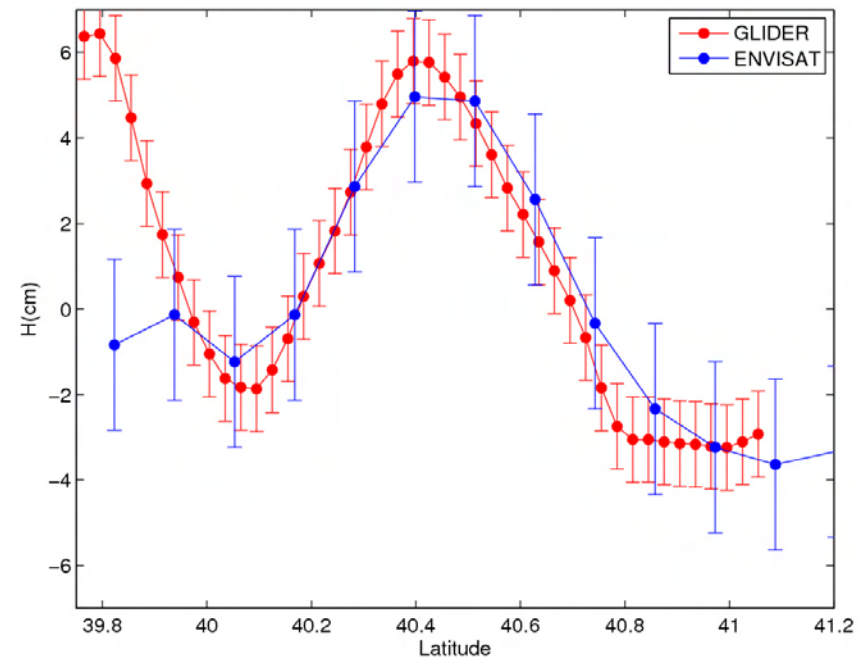
Glider vs. altimetry



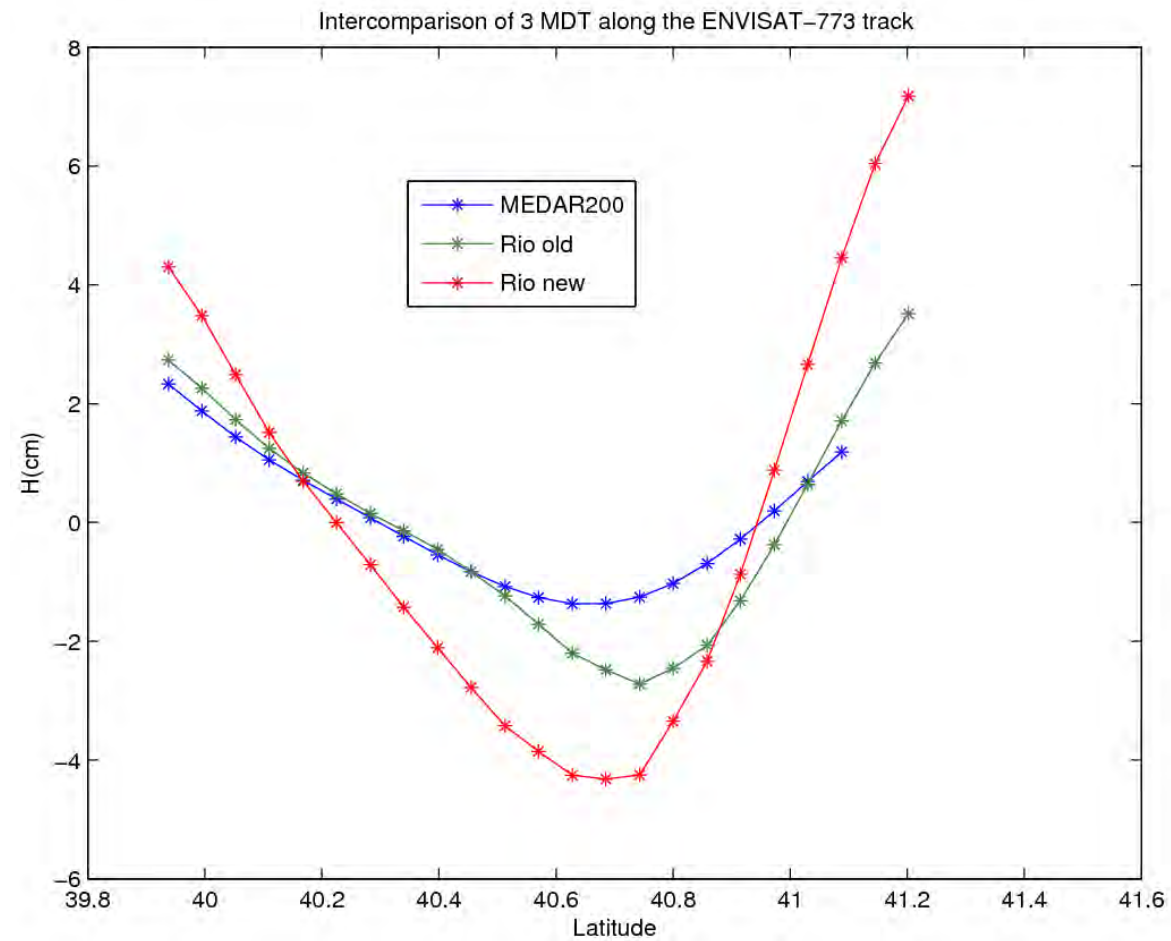
BEFORE CORRECTION



AFTER CORRECTION



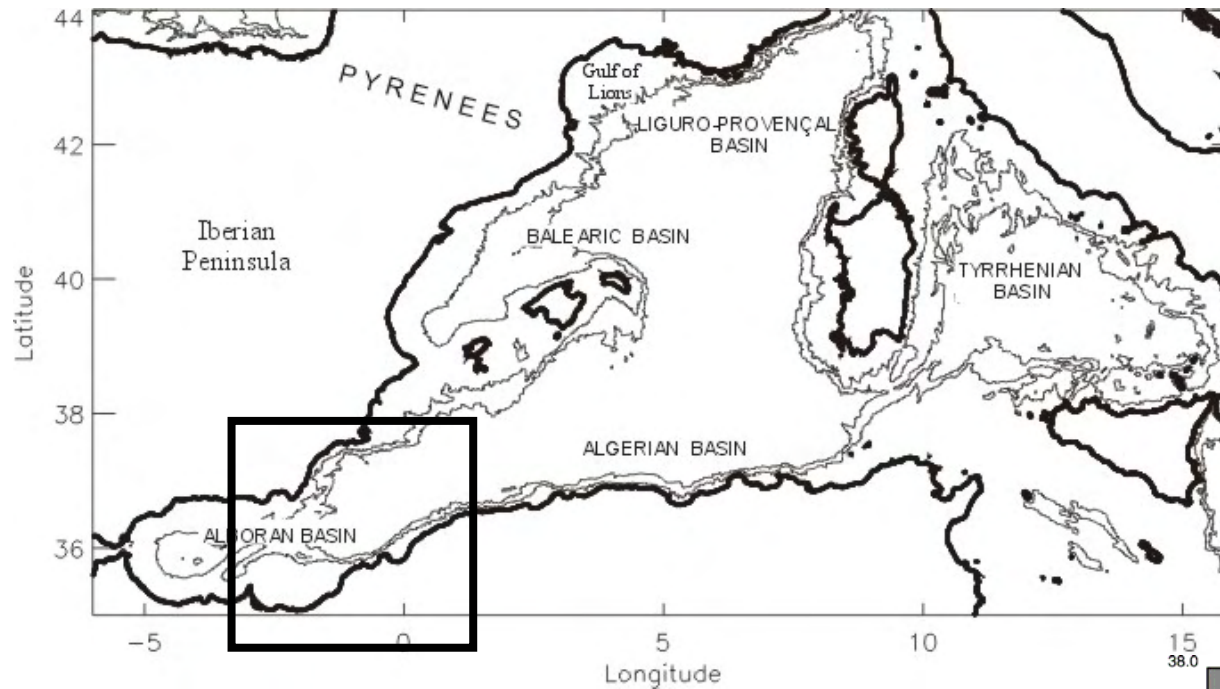
Intercomparison MDT



Examples of glider missions

I. The Eastern Alboran Sea

Area of study – III : Eastern Alboran Sea



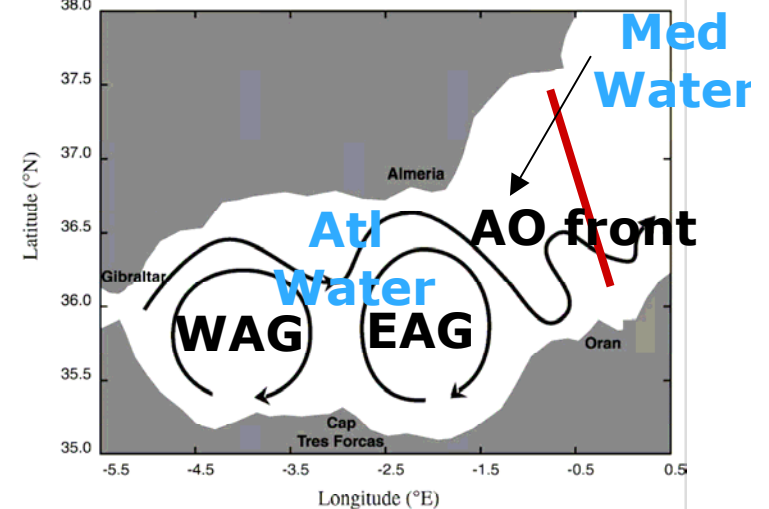
- Deployment of a glider in a very energetic area.

- To improve our knowledge on the driving mechanism in the area: Mesoscale structures (filaments, eddies, etc).

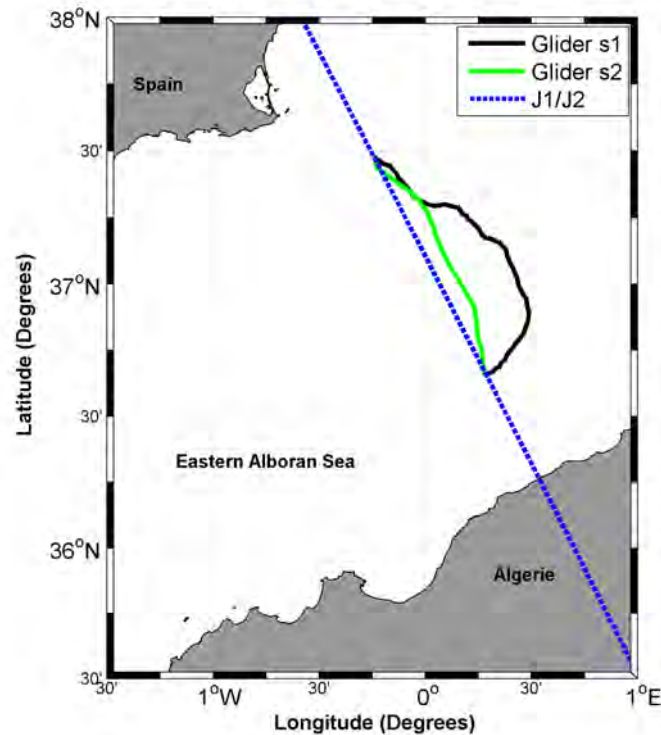
- Adjustment between AW/MW

- Altimetry Cal/val Jason1/2

Glider mission simultaneously to the passage of Jason 1 and Jason 2 passage -track 172



Path planning analysis

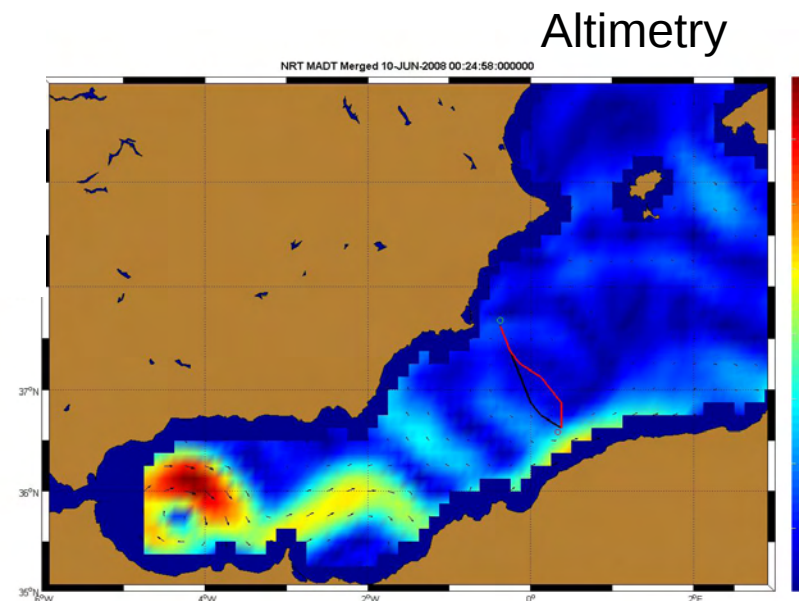


Tool developed by Garau et al. (2005)

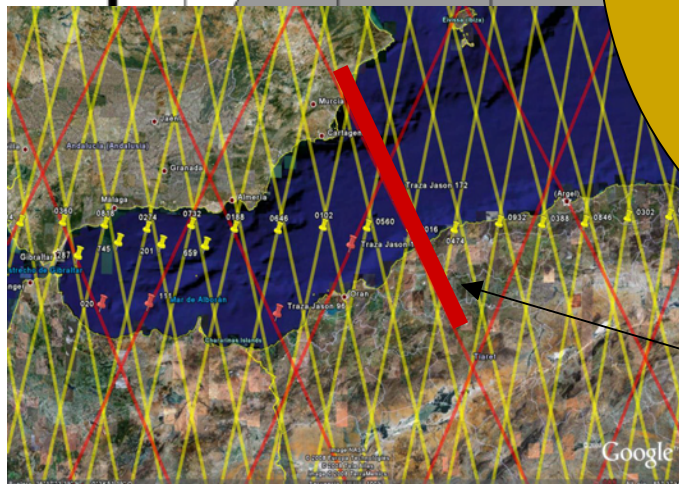
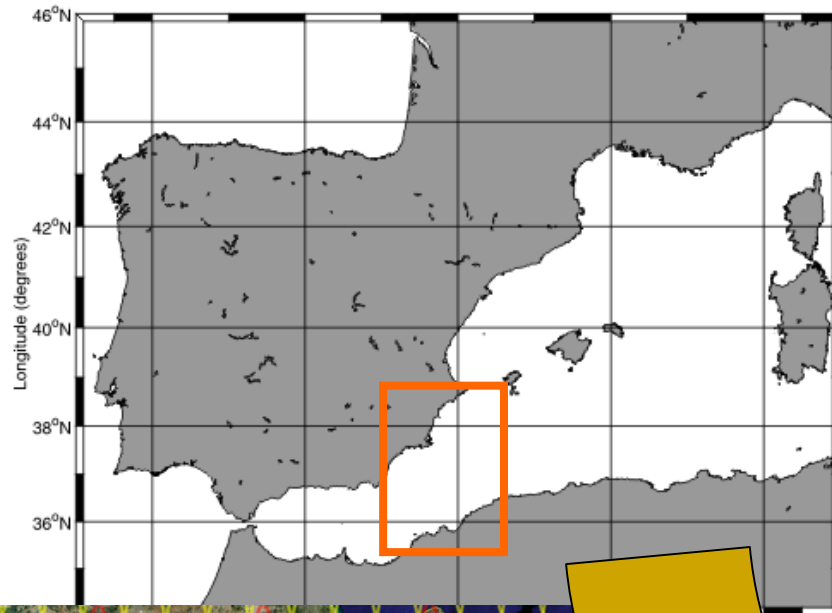
We have developed a tool to a priori test the feasibility of the glider mission using three different types of available velocity fields:

- **MFS**
- **Mean Dynamic Topography**
- **Altimetry Sea Level Anomaly.**

The application then provides an estimation of real glider trajectory and the time needed for the glider to perform the mission.

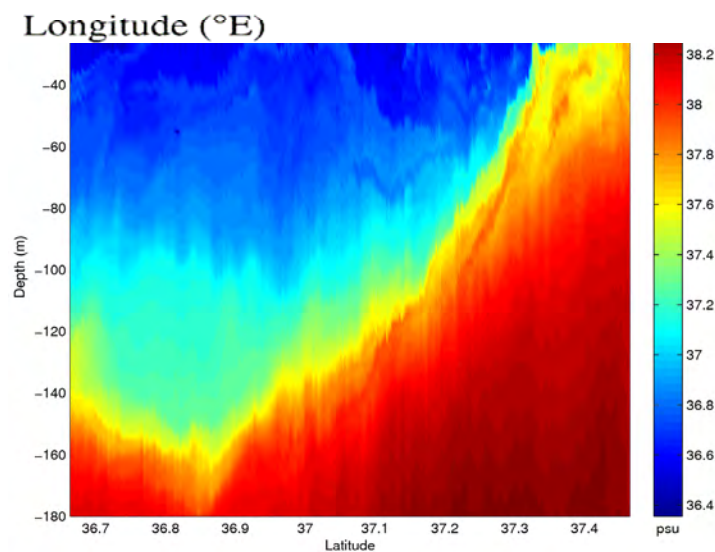
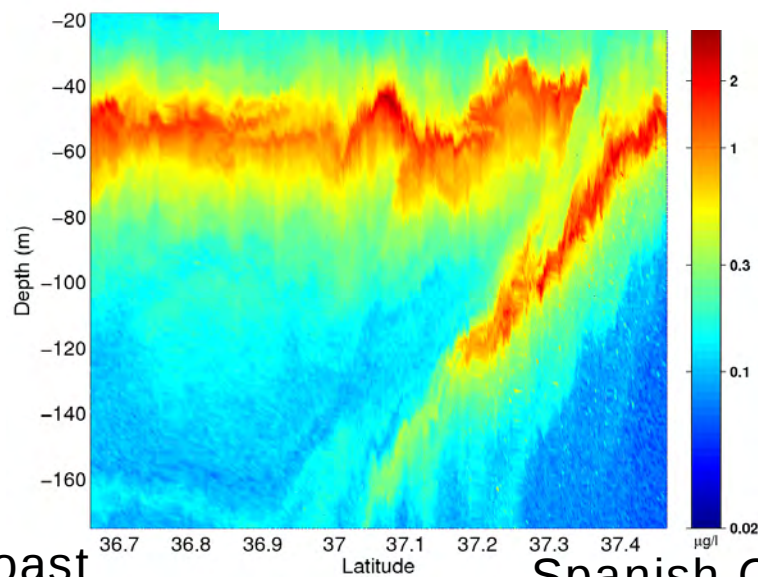
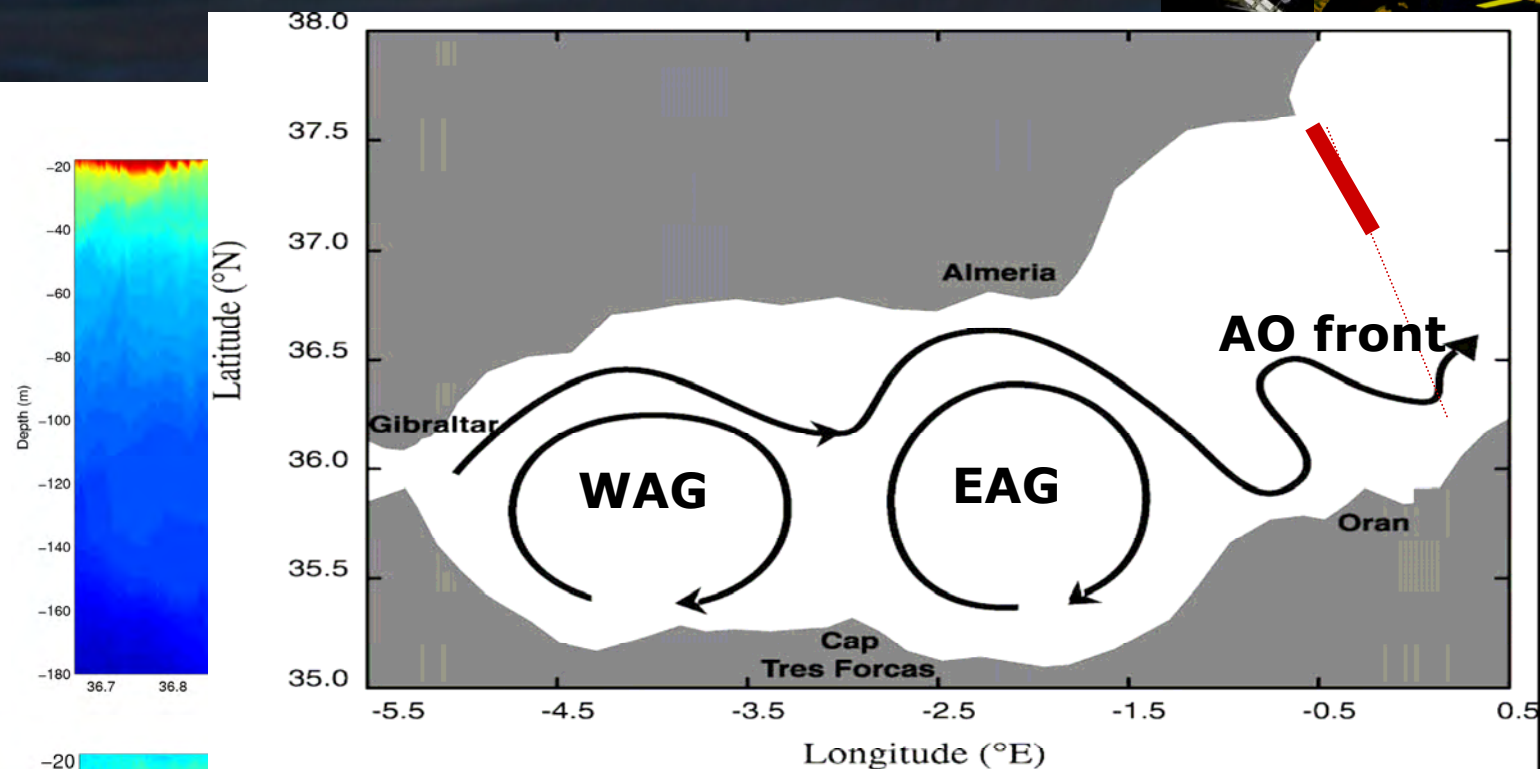


The Eastern Alboran Sea



172 Jason 1 and 2 track

First results– Section 2



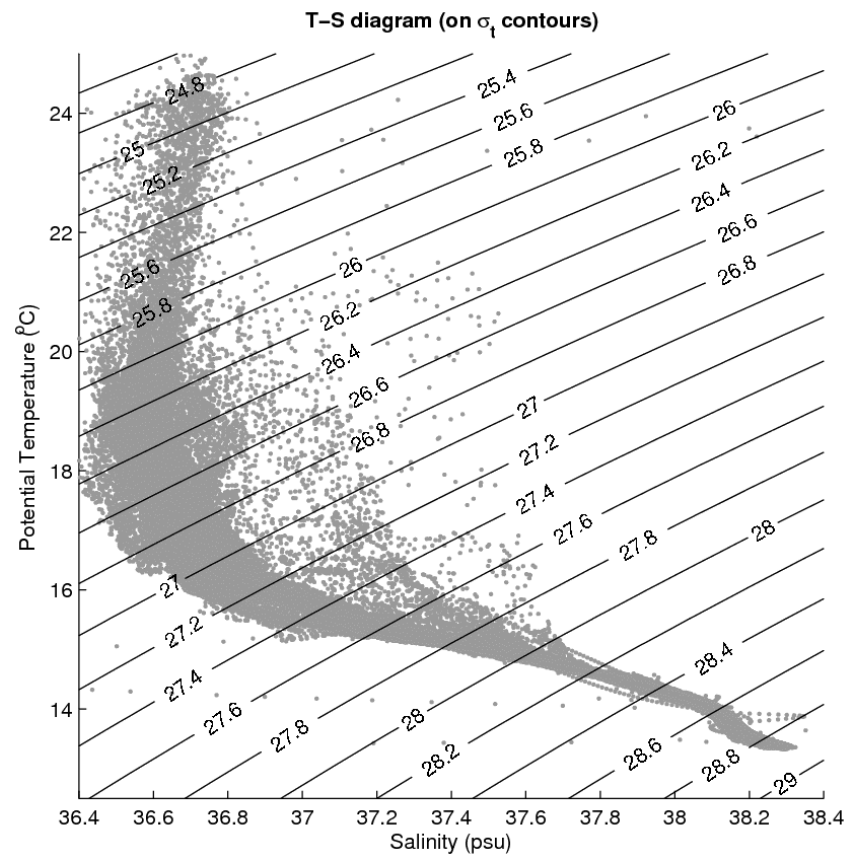
African Coast

Spanish Coast

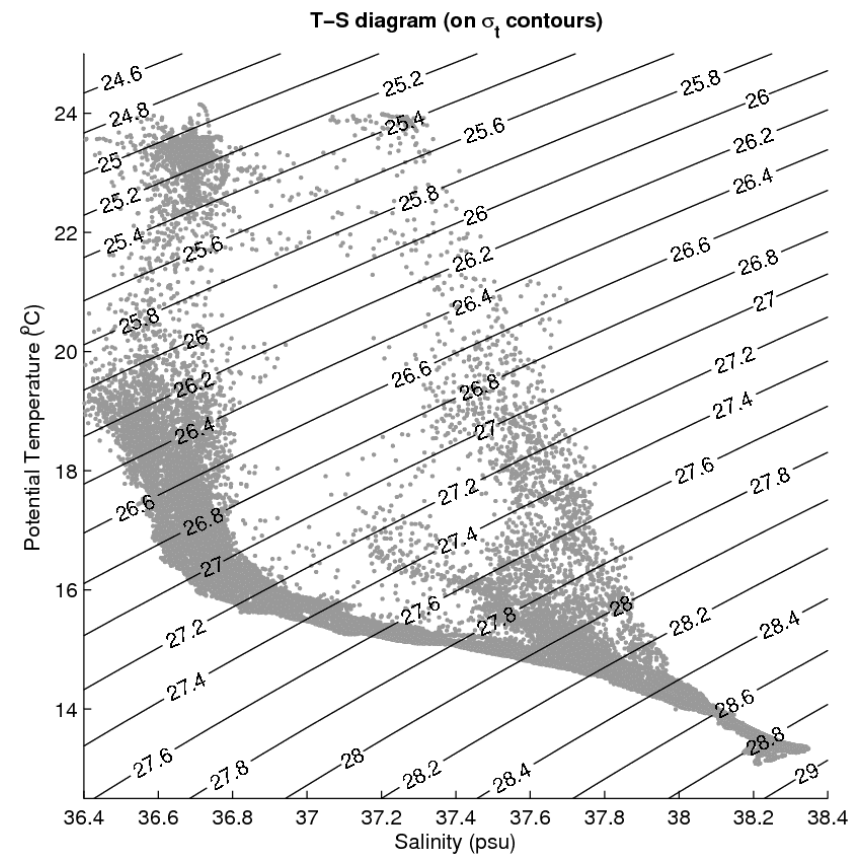
TS diagram



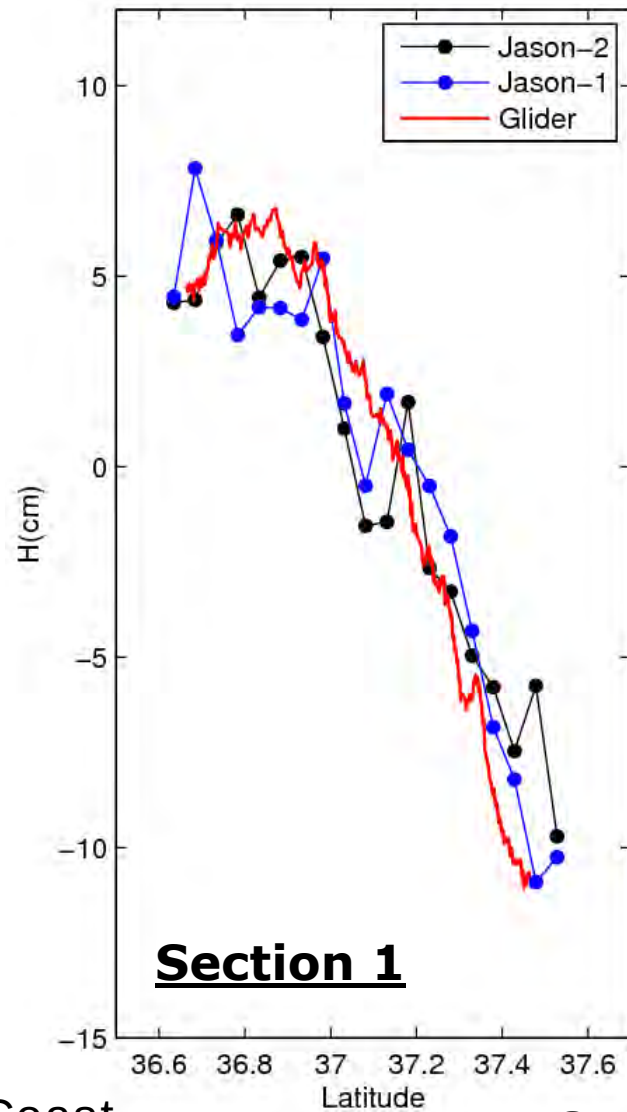
SECTION 1



SECTION 2

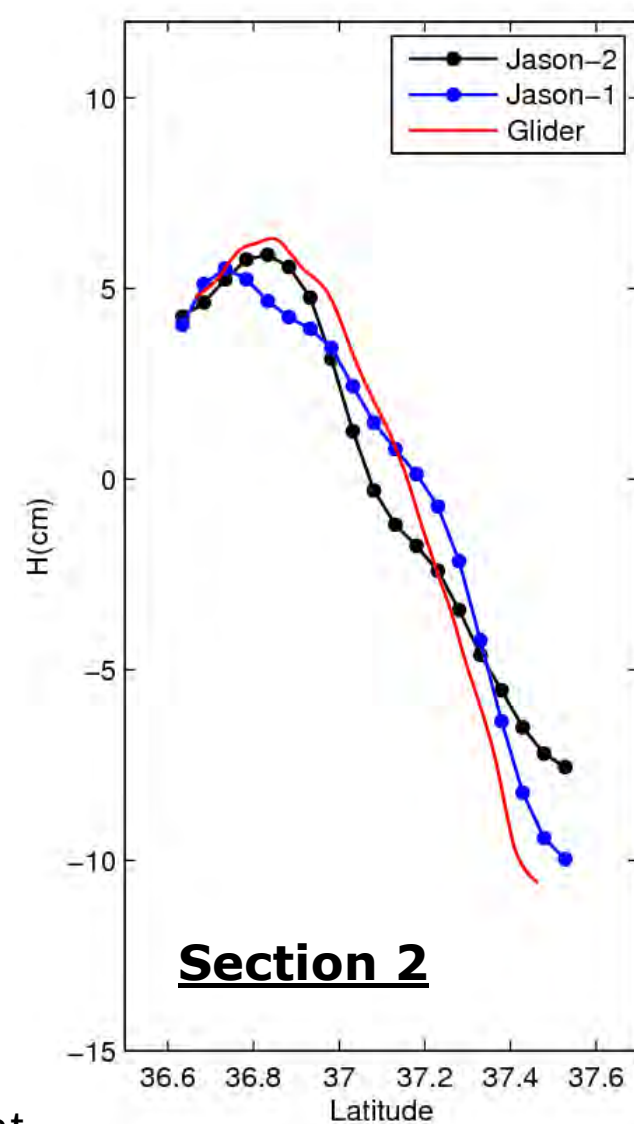


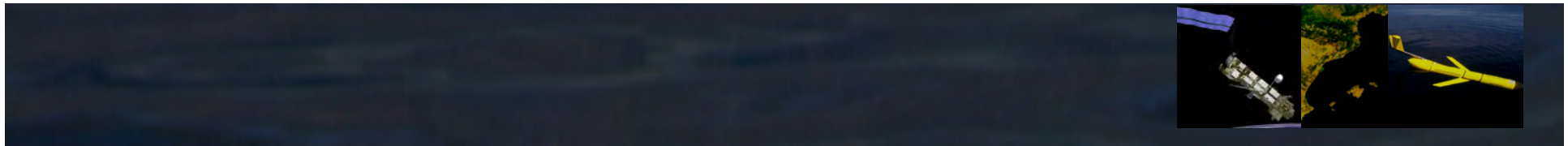
DH vs glider



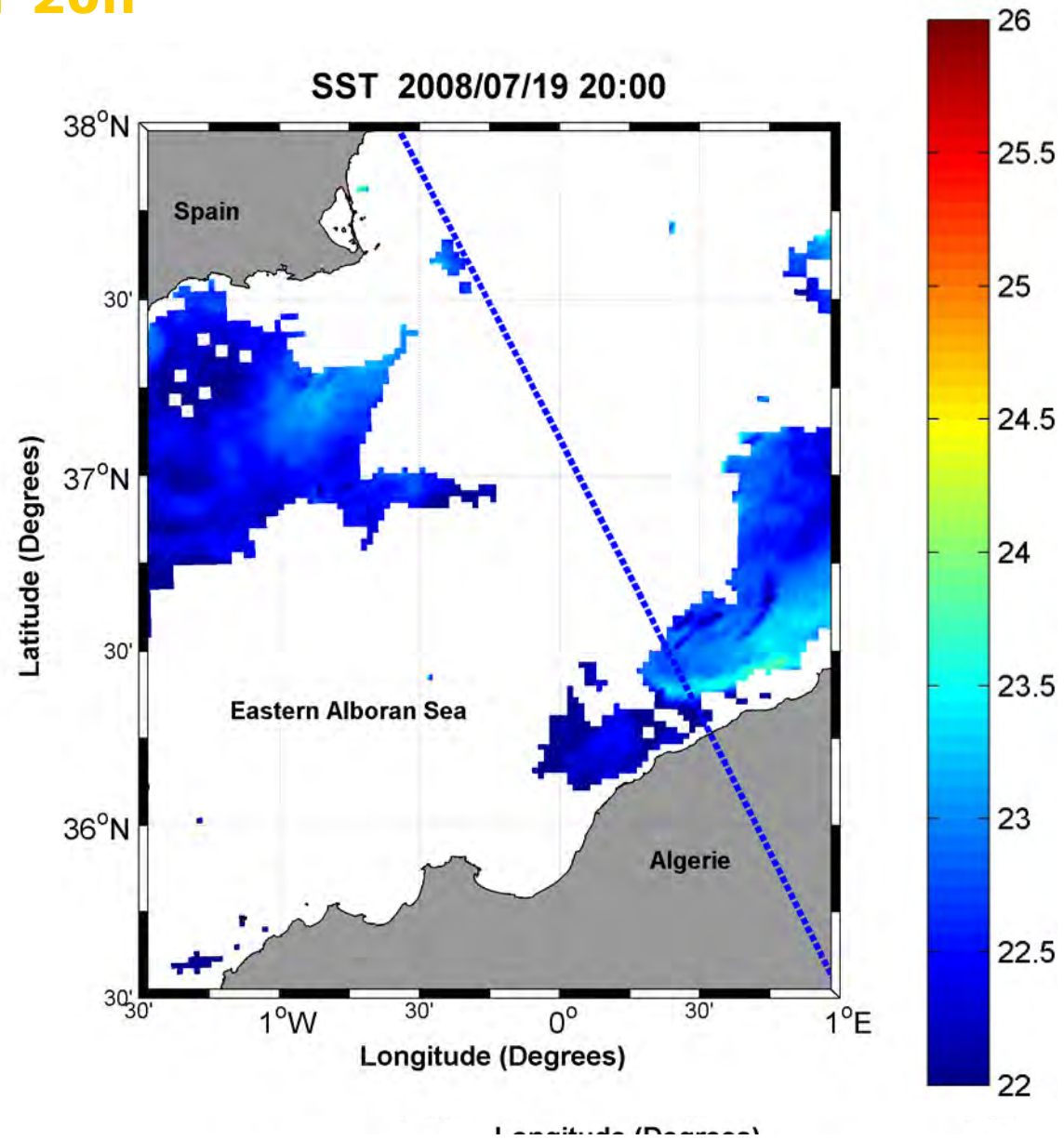
African Coast

Spanish Coast





SST 20h

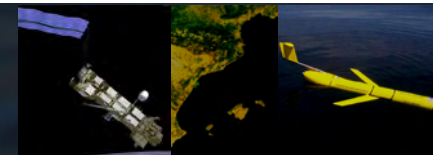


Summary



- Successful glider missions in the Western Mediterranean: data collection, data transmission, real-time processing.
- Balearic front: Balearic front detected in salinity with lower values near coast and characterized by temporal variability.
- Filtered ENVISAT data are in relative good agreement with glider dyn.h., although altimetry observations near the coast are missing in some cases.
- April mission 2008 : appearance of an anomalous anticyclonic eddy detected by altimetry, glider, SST and model data. Differences between glider and altimetry are likely due to the anticyclonic eddy was not completely sampled by the glider (deep glider for next time)
- Eastern Alboran Sea 2008: Preliminary results show the existence of strong convergence between Atlantic and Mediterranean Waters. The very high resolution shows the existence of strong interleaving features in the northern part.

Work in progress



- ❑ Develop new tools for glider data analysis.
- ❑ Glider data assimilation
- ❑ R&D of improved altimeter corrections

(tidal model, mean profile, MOG2D HR, troposphere correction). HF sampling and data recovery near coast.

- ❑ Collaboration with CLS & Rutgers.

- ❑ New missions for 2009

(Balearic Sea, Alboran Sea, etc)

