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On the potential use of Argo and Altimetry data to estimate vertical motion in the upper ocean

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Outline

- **Introduction**
- **Methodology**
- **Results: glider mission in Alboran Sea**
- **Conclusion & Discussion**
- **Future work**
- **General perspectives: OceanBit**

Introduction

- Vertical motion associated with mesoscale oceanic features is of fundamental importance for the exchanges of heat, fresh water and biogeochemical tracers between the surface and the ocean interior.

- Unfortunately, it is not yet possible to make direct measurements of values less than 1000 m day-1 of the vertical velocity. Instead, it can be inferred from a 3D snapshot of the density field by assuming a few simplifications in the quasi-geostrophic (QG) formulation.

OBJECTIVE OF THIS STUDY

- To investigate the feasibility of diagnosing vertical velocity combining in situ vertical profiles of temperature and salinity with satellite altimetry data.

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Methodology

- **Step 1:**
  - Use of Empirical Orthogonal Function (EOF) decomposition to merge vertical profiles with altimetry gridded fields, inferring the 3D density and dynamic height fields.
  - In the case of a single dominant mode, the modelled profile can be expressed as (Pascual and Gomis, 2003):

$$\Phi_{x,y}(p) = A_1(x,y)EOF_1(p)$$

  - Thus, obtaining the single amplitude $A_1(x,y)$ corresponding to each profile would be straightforward given the surface altimetry data $[\Phi_{x,y}(p_0)]$ and the surface component of the leading EOF $[EOF_1(p_0)]$ from vertical profiles (standard CTDs, ARGO floats, gliders).

Methodology

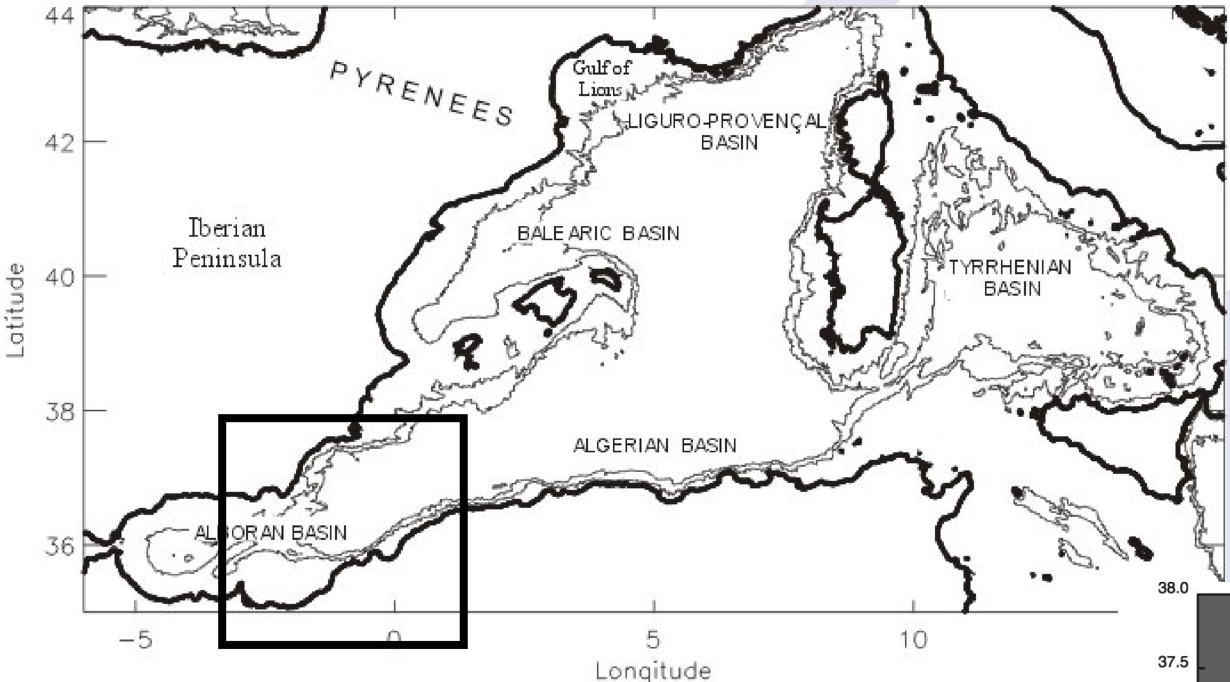
- **Step 2:**
  - Use of the QG Omega equation to examine vertical velocity.

$$f^2 \frac{\partial^2 \omega}{\partial z^2} + \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) \left(N^2 \omega \right) = \nabla_h Q$$

$$Q = \left[2f \left(\frac{\partial V}{\partial x} \frac{\partial U}{\partial z} + \frac{\partial V}{\partial y} \frac{\partial V}{\partial z} \right), -2f \left(\frac{\partial U}{\partial x} \frac{\partial U}{\partial z} + \frac{\partial U}{\partial y} \frac{\partial V}{\partial z} \right) \right]$$

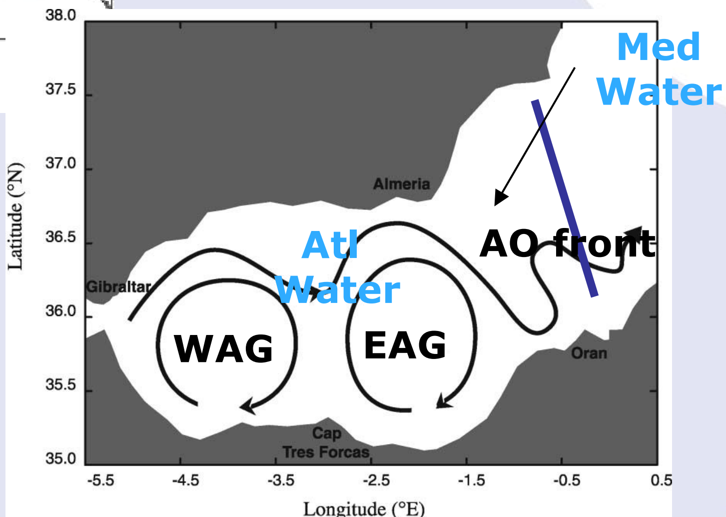
  - where (U,V) are the geostrophic velocity components.
  - By assuming a boundary conditions for ω and from a 3D snapshot of the density field, the vertical velocity can be inferred. We set w = 0 at the upper and lower boundaries and Neumann conditions at the lateral boundaries (Pinot et al., 1996).

Application of the method: glider profiles in the Alboran Sea

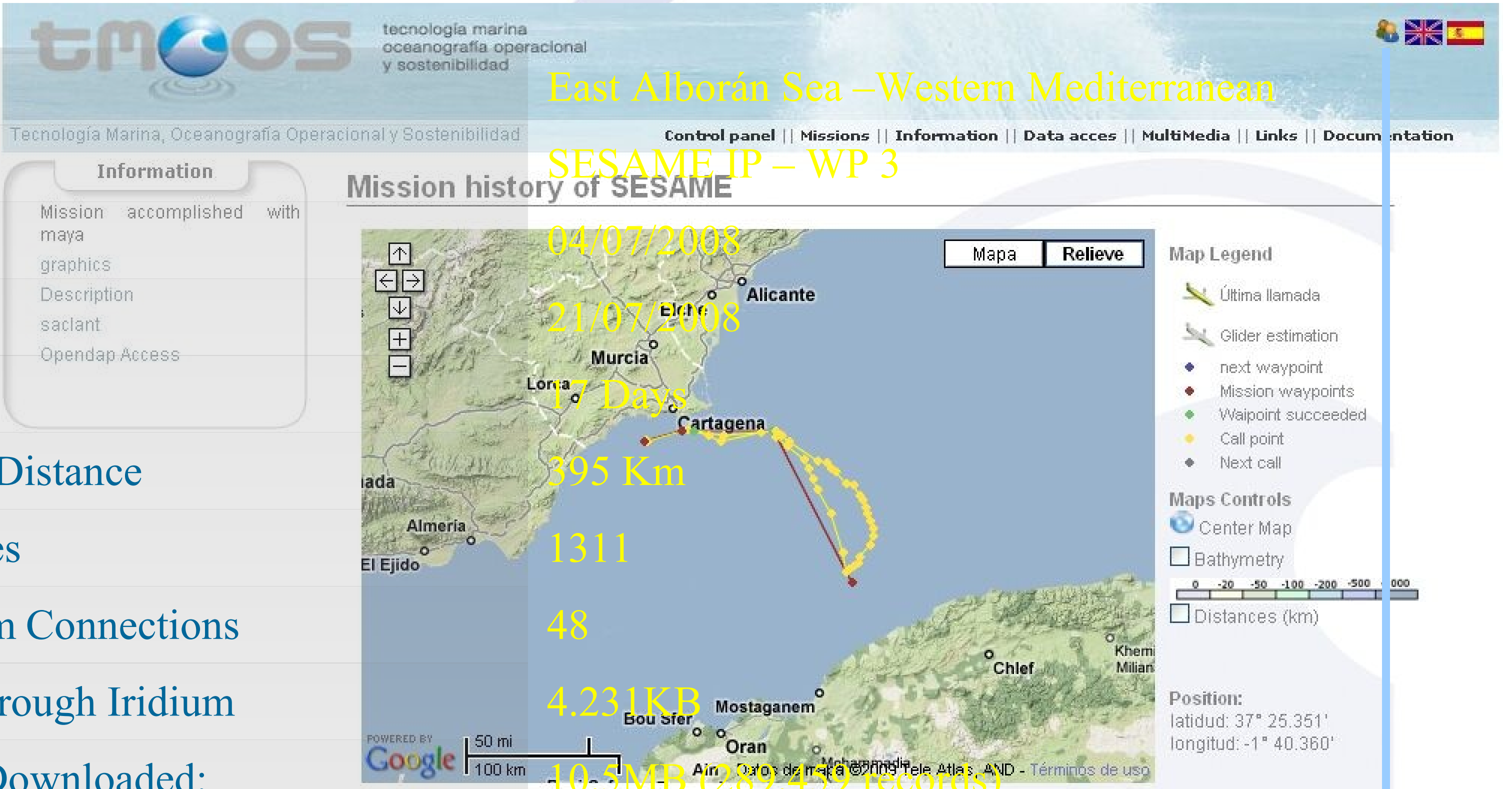


- Deployment of a glider in a very energetic area.
- To improve our knowledge on the driving mechanism in the area: Mesoscale structures (filaments, eddies,etc).
- Adjustment between AW/MW
- Altimetry Cal/val Jason1/2

Glider mission simultaneously to the passage of Jason 1 and Jason 2 passage (track 172). Just two weeks after Jason 2 launch.



Sesame-Alboran2008 mission



Area	East Alborán Sea –Western Mediterranean
Project	SESAME IP – WP 3
Start Date	04/07/2008
End Date	21/07/2008
Total Days	17 Days
Total Navigation Distance	395 Km
Number of Profiles	1311
Number of Iridium Connections	48
Data transmitted trough Iridium	4.231KB
Data Stored and Downloaded:	10.5MB (289.459 records)
Initial Batteries	15,08 Volts
Final Batteries	12,72 Volts
Events	Oxygen sensor had to be disabled before launching because of bad wire contact

(Slocum coastal glider)

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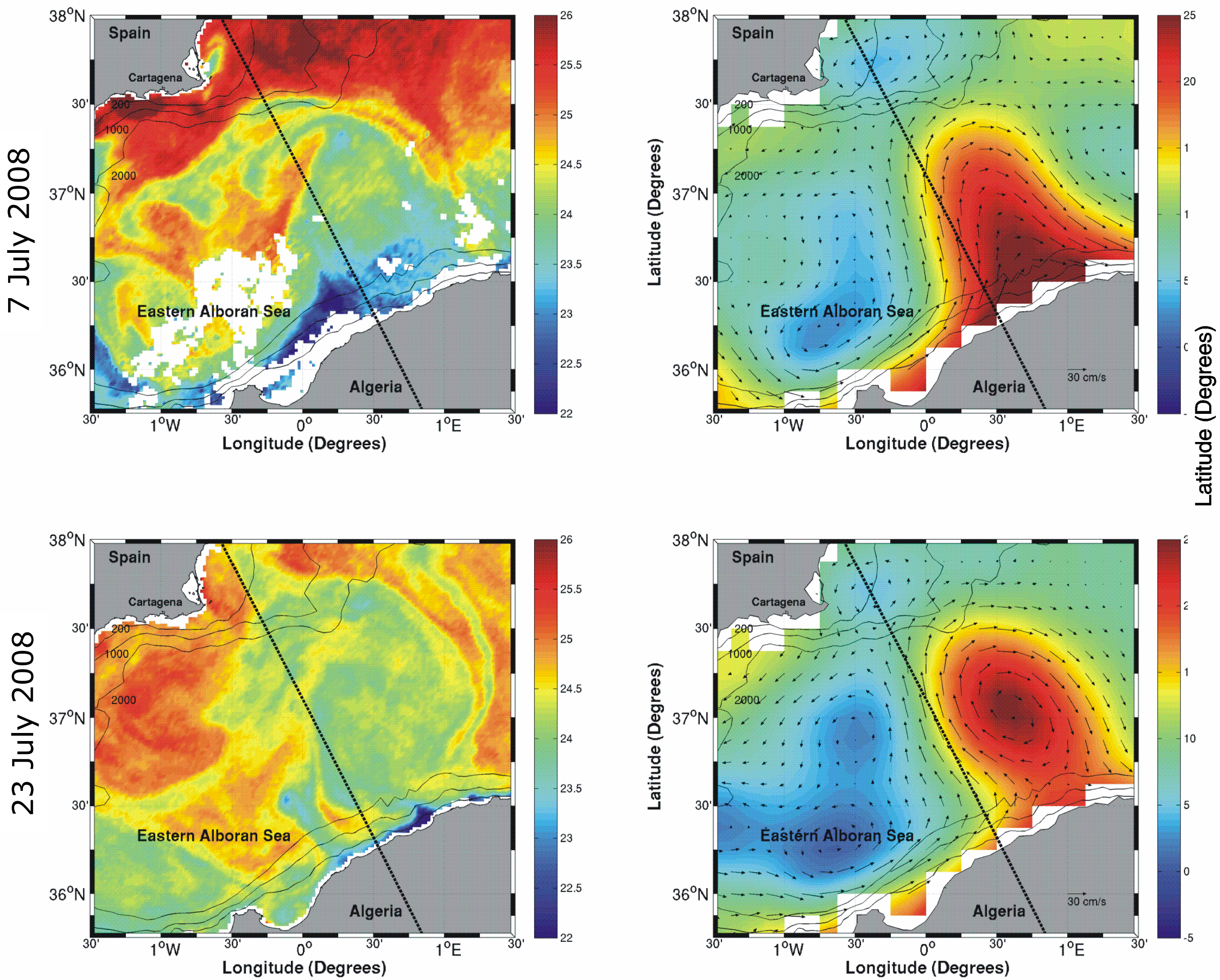
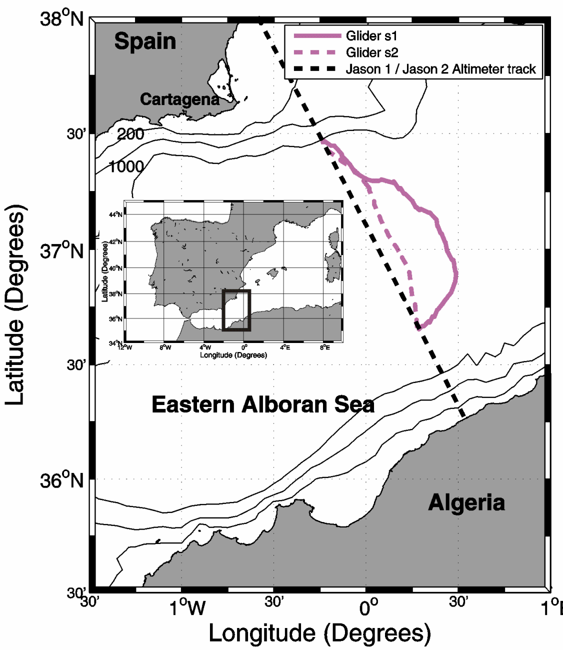
Sinoptic view from remote sensing data

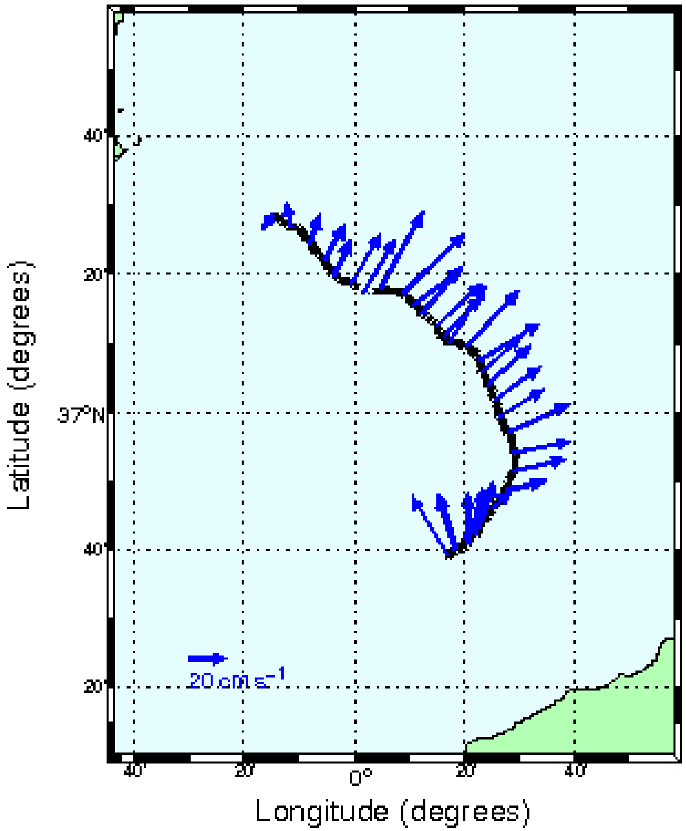




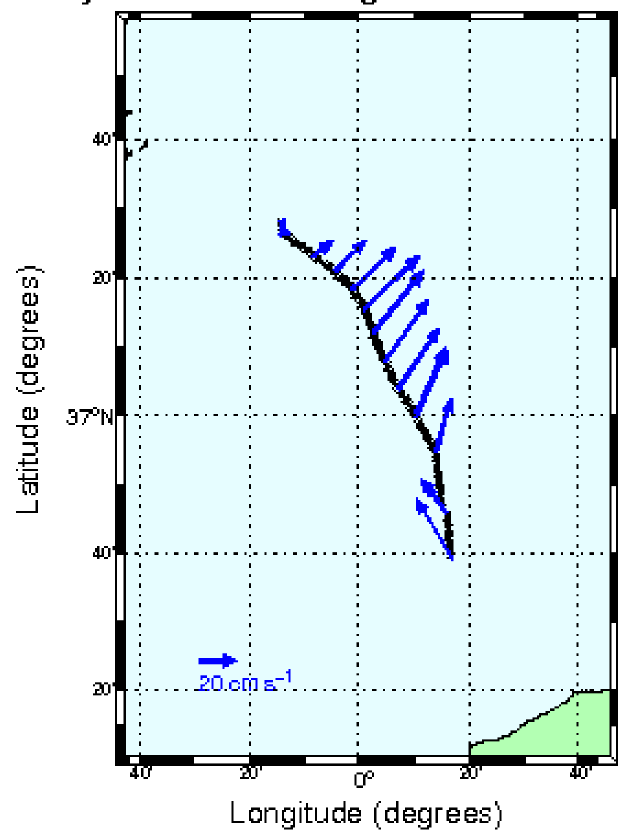
(Ruiz et al. GRL 2009)

Glider depth averaged currents

Glider trajectory and column integrated water currents estimations



Glider trajectory and column integrated water currents estimations



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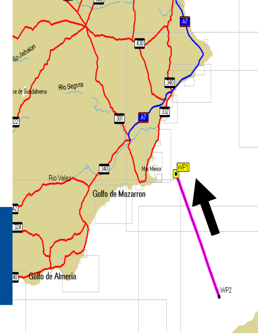
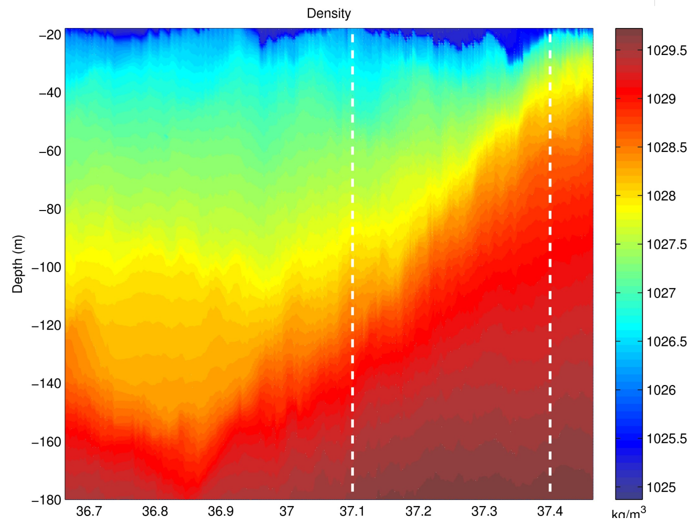
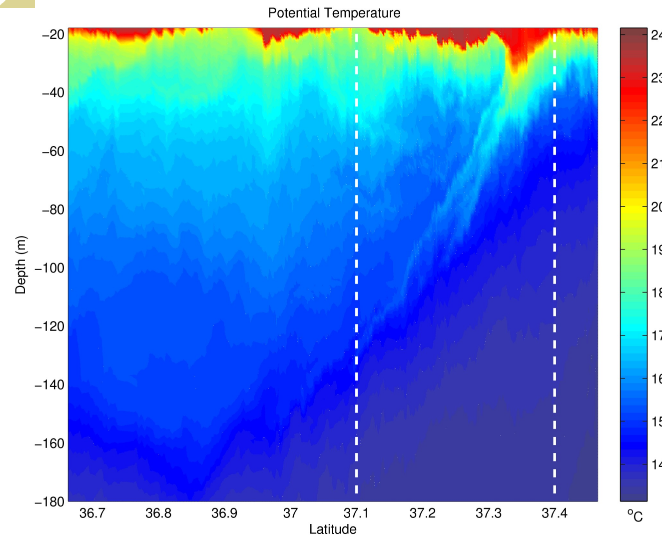
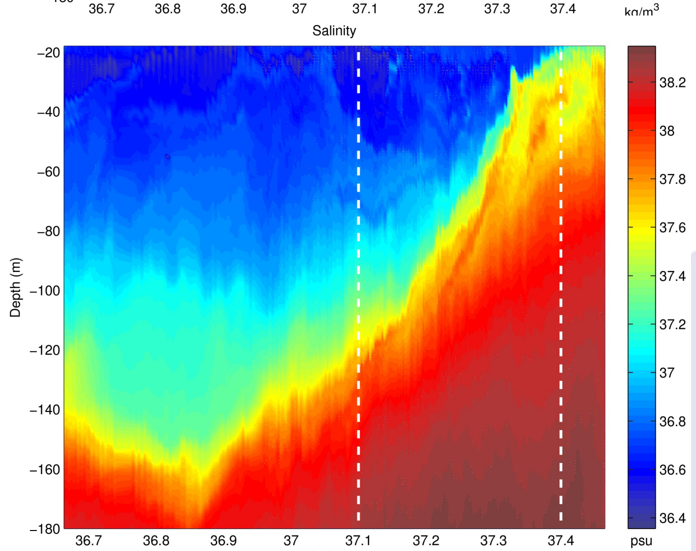
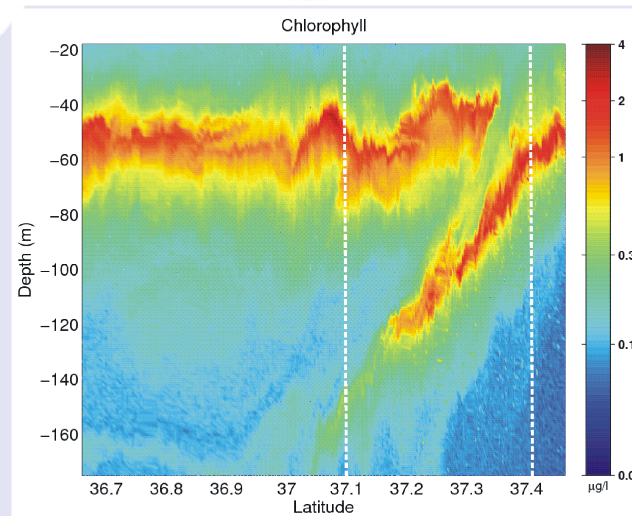
Vertical sections







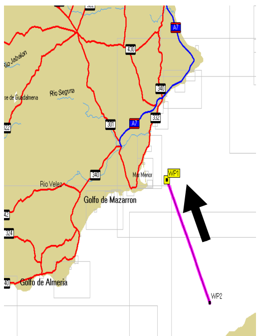


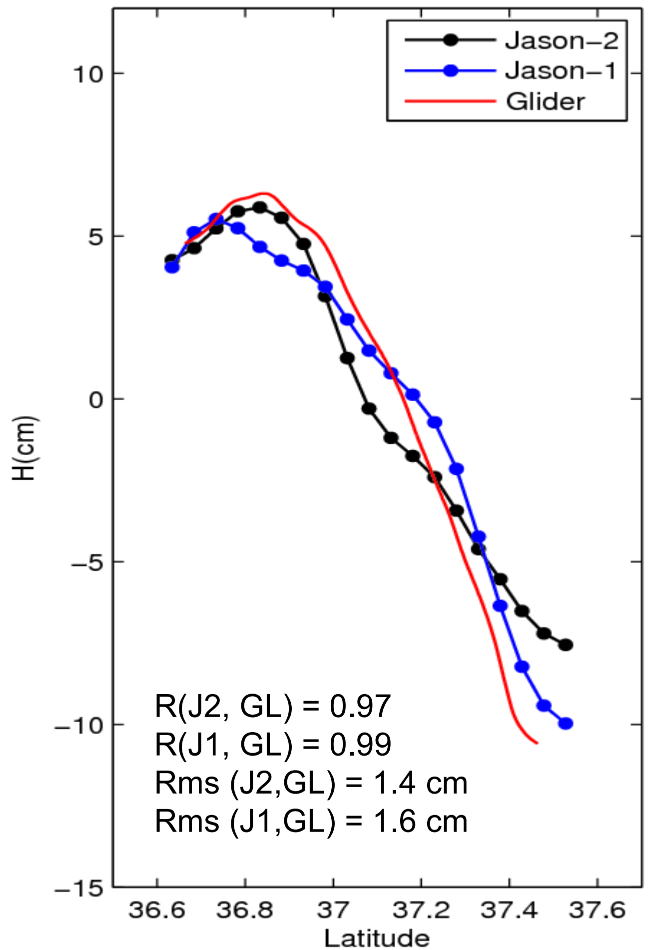


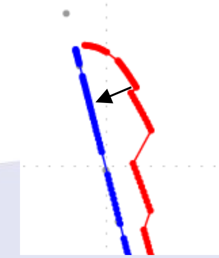
African Coast

Spanish Coast

Dh glider vs Jason 1 / Jason 2 altimeters

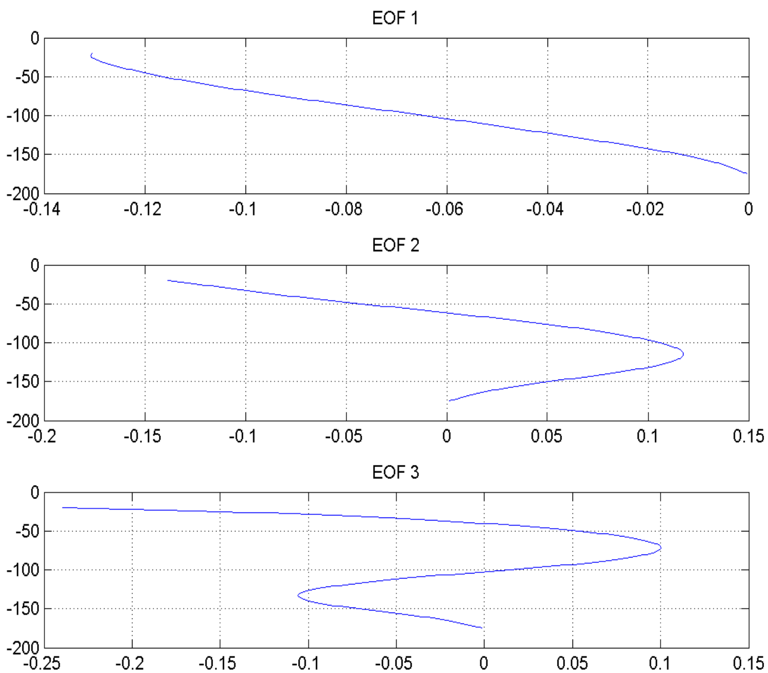




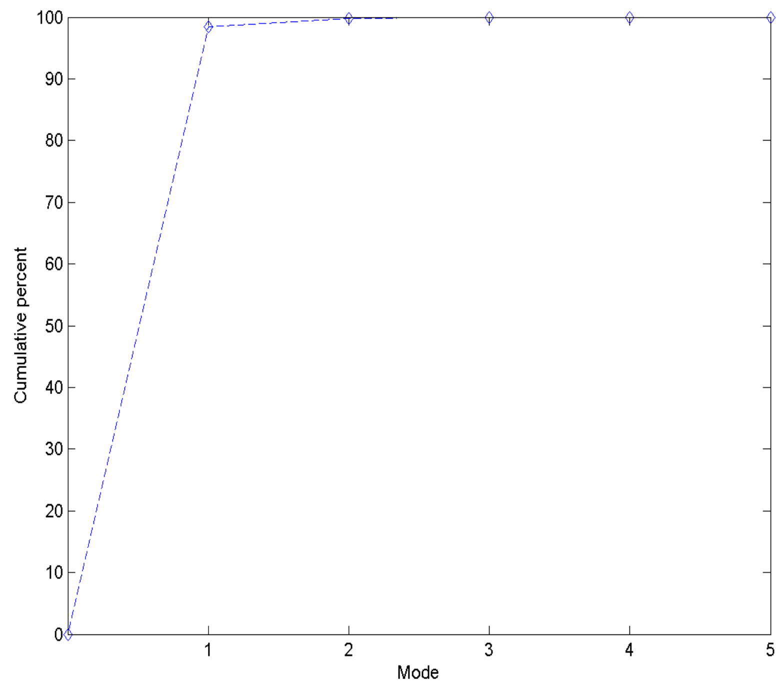


- Glider data:
  - Projection of the glider observation position onto the closest track point.
  - Observation values are not modified.
  - Dynamic height referred to 180 m.
  - Along track Lanczos filter.
- Altimetry data:
  - Altimetry data: along-track SLA + MDT(Rio et al JMS 2007).
  - Along track Lanczos filter.

Vertical EOFs



Leading EOFs obtained from glider data._



Cumulative percent variance explained by EOF modes.

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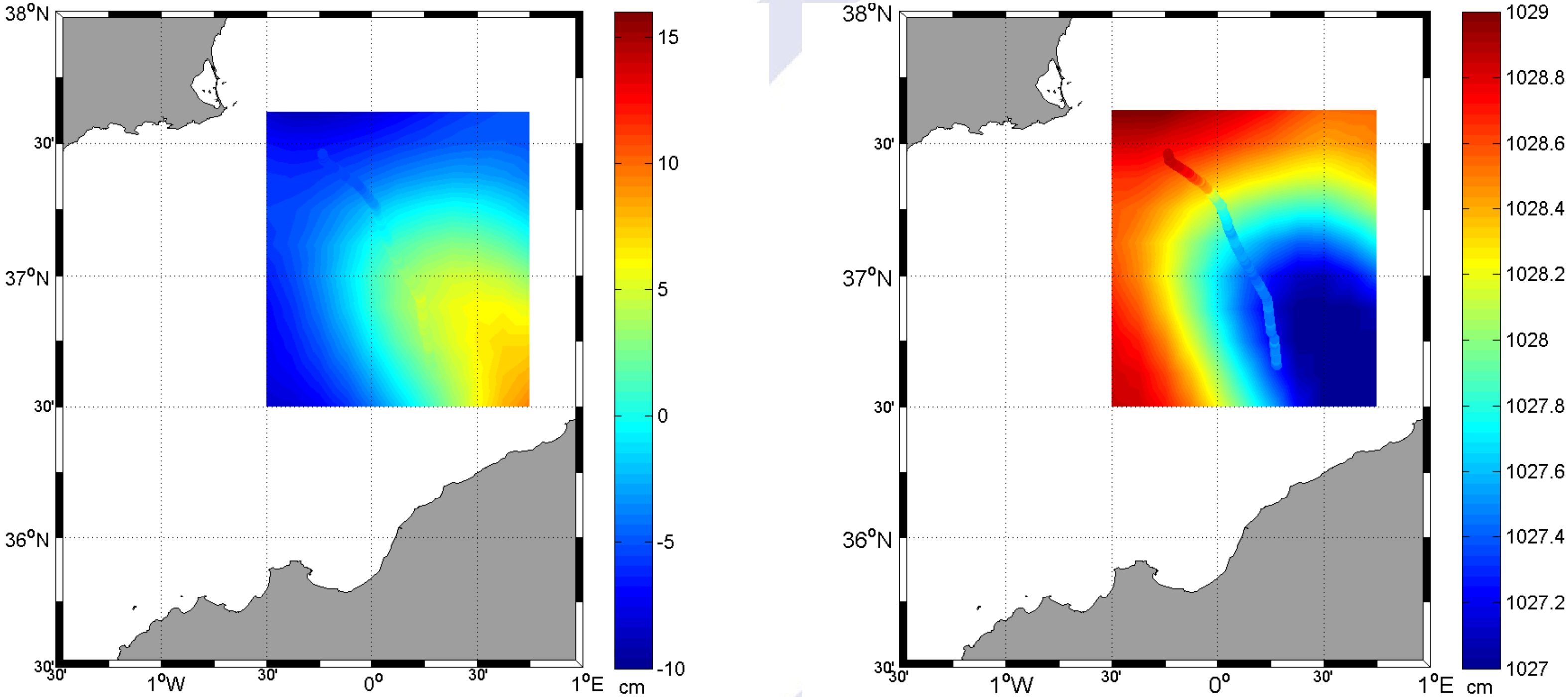
3D reconstruction

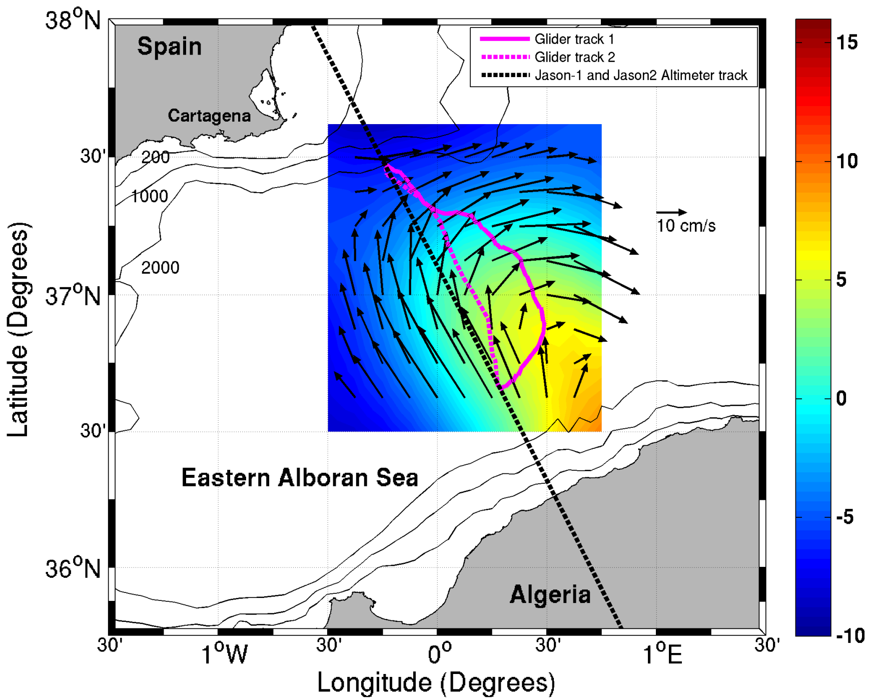


Reconstructed dynamic height field at 75 m depth. Colour dots correspond to dynamic height from glider at the same depth. b) as in a) but for density.

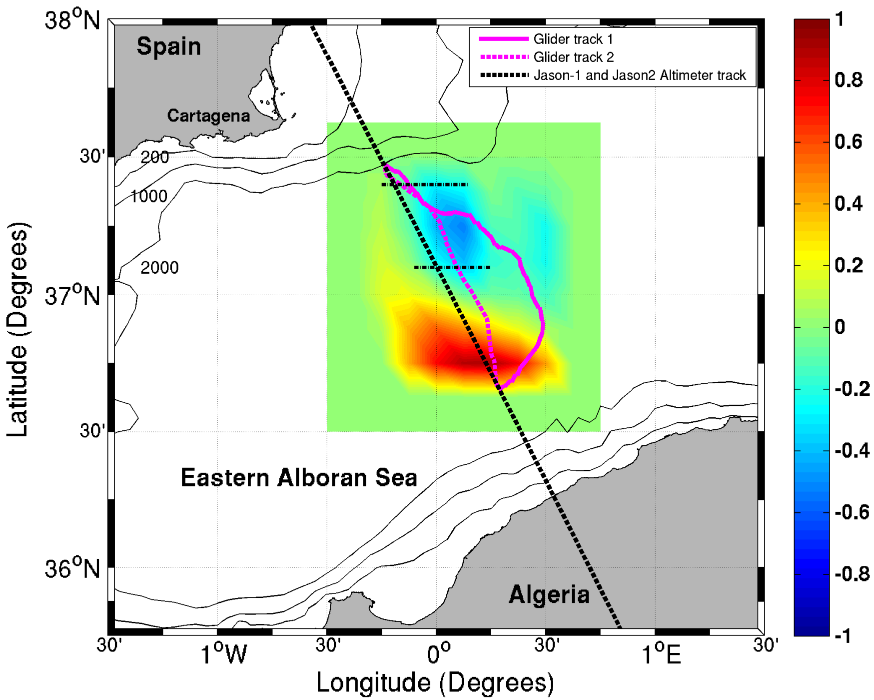
	Error variance (%)	Correlation
Dyn. Height	2.80	0.98
Density	4.12	0.98

Performance assessment of the reconstruction method.

3D Dh and QG vertical velocity



3D reconstructed dynamic height and geostrophic velocity at 75 m._



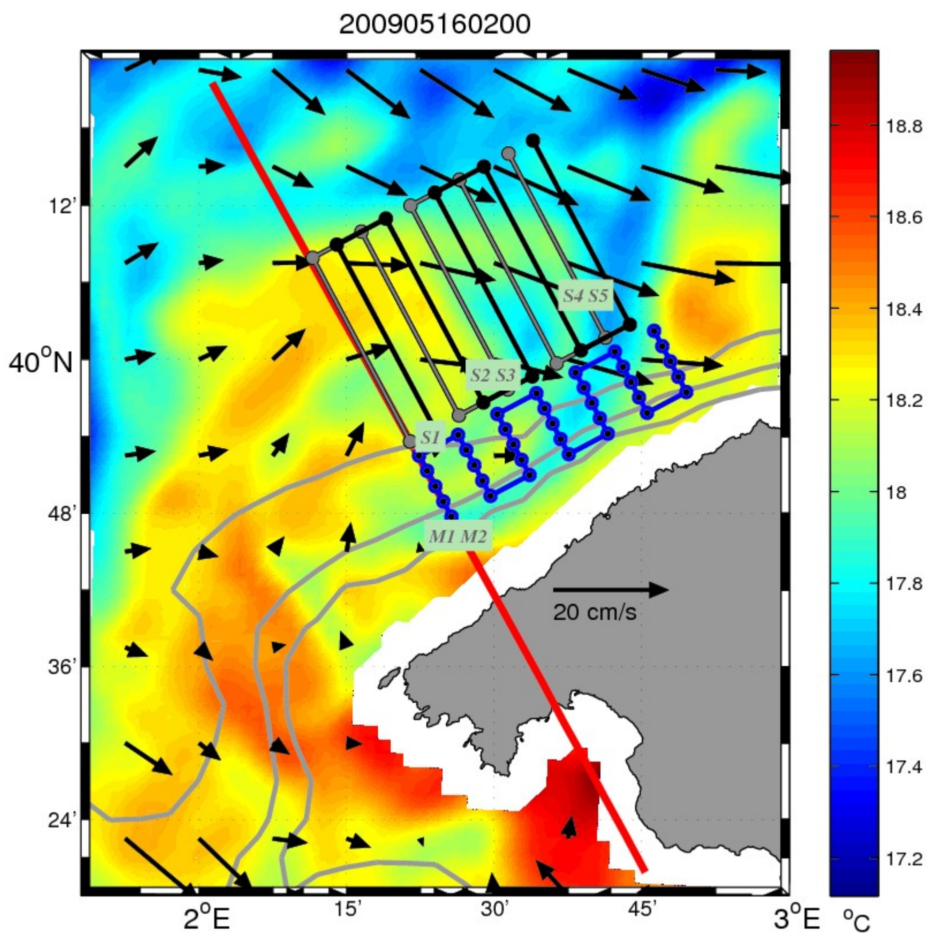
Quasi-geostrophic vertical velocity at 75 m. Units are m day-1._

(Ruiz et al. GRL 2009)

Conclusion & Discussion

- Glider data reveal **strong convergence between Atlantic and Mediterranean Waters**. The very high resolution shows the existence of strong interleaving features and in the northern part.
- DH derived from the **glider** and the ADT from **Jason-1** and **Jason-2** tandem mission reveals **high correlations** along the track followed by the three platforms.
- We propose a **method** that **blends along-track glider data with gridded altimeter** fields to provide a consistent and reliable 3D DH field.
- This study represents a first attempt on the combination of new glider technology data with altimetry observations to **diagnose vertical velocities**.
- The **vertical motion** diagnosed in our work is **consistent** (although the magnitude is smaller) with previous observational [Tintoré et al., 1991; Shearman et al., 1999] and modeling [Strass, 1994; Allen et al., 2001b] studies.
- The magnitude of the vertical velocity is significantly sensitive to the scales included in the analysis. In our case, the **100 km correlation** scale applied in the altimetry gridded fields is the constraint for the spectral band.

Future work



- Application of the method with ARGO data. Other reconstruction techniques such as those suggested by Guinehut et al. (2004) could be investigated.
- Exploration of SQG theory (Klein et al. 2008) .
- Use of SST measurements from high resolution infrared images to complement altimeter data (Isern-Fontanet et al. 2006).
- In the longer term, use of high-spatial resolution of the ocean surface topography (SWOT mission).
- Validation of vertical velocities with high resolution in situ data (e.g. SINOCOP experiment).

General perspectives: OceanBIT

GENERAL OBJECTIVE

to develop an Observing and Forecasting System, a scientific and technological infrastructure which will be <u>open to international access and collaboration</u> to:

- Respond to the major scientific and technological challenges of the next decade as well as to the strategic needs of society related to new observing and forecasting operational oceanography capabilities in the coastal ocean.

OceanBIT Components

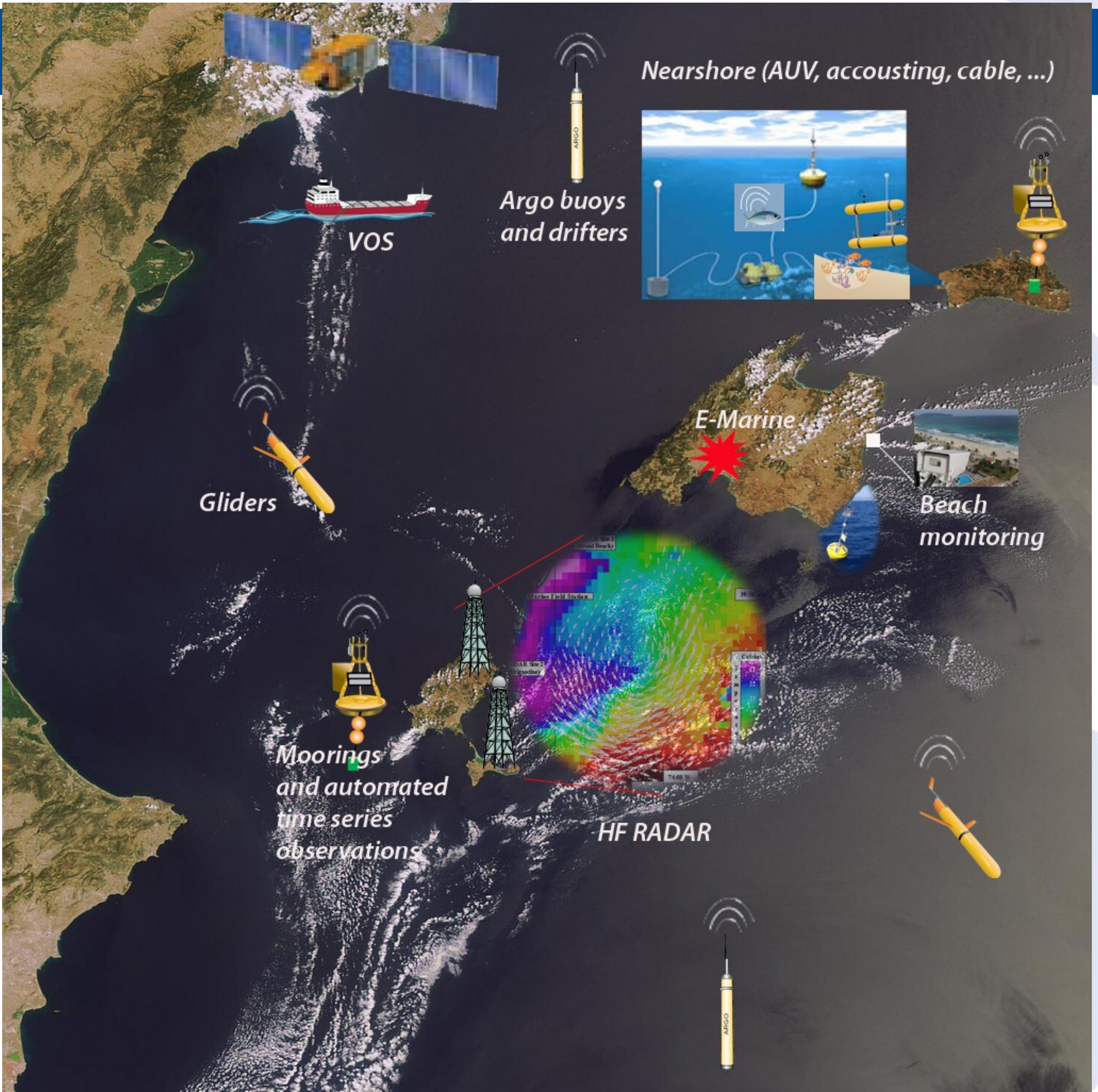
1. **Observational**
   - in situ moored and drifting sensing systems (SVPs, ARGO,..)
   - Coastal and offshore instrumented installations
   - Remote sensing from satellites
   - Shore-based remote sensing with radar
   - Gliders,…

1. **Forecasting**
   - Ocean currents and wave at different scales
   - Ecosystem variability
   - Data assimilation and analysis at overlapping spatial and temporal scales

1. **Data management**
   - Quality control and Web access in open source
   - Effective data archiving, internationally accepted protocols, delivery and communication

OceanBIT Facilities

1. R/V Coastal Ocean Ship facility
2. Anchored Buoys facility
3. Ferry box, VOS, and fishing fleet facility
4. Gliders facility
5. AUV’s facility
6. ARGO floats and Surface Drifters (SVP) facility
7. Radar
8. Satellite facility
9. Nearshore beach monitoring system
10. E_marine: data Management facility (including visualization and communications, QC, etc)



OceanBIT Spanish framework: ICTS MICINN

- OceanBIT is a joint initiative between the Spanish Government (Ministry of Science and Innovation -MICINN) and the Balearic Islands Government (Conselleria d'Economia, Hisenda i Innovació).
- OceanBIT is a new Consortium with legal entity, following a proposal initially prepared back in 2006.
- Approved funding: 36 million Euros, including 14 million Euro for scientific equipment and facilities and 2 million Euros/year for running costs during 11 years (2010-2021).
- Activities planned for 2009 specifically include preparation of the implementation plan and the formal inclusion of key partners in the Balearic Islands, such as CSIC, IEO and UIB in the Consortium
- Co-operative agreements with other international institutions are also foreseen in the very near future.

OceanBIT Scientific Objectives

3 major topics have been identified in line with international priorities for the next decade and taking into account environmental needs and technical capacity of the Balearic Islands:

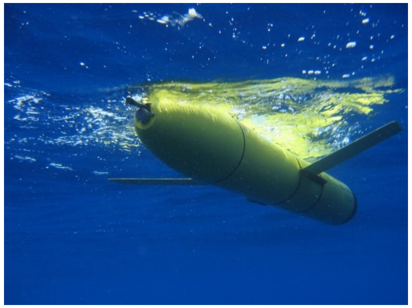
1) Near-shore hydrodynamics and morpho-dynamics. Wave-current interactions and sediment transport.

2) Oceanography in the coastal, shelf and open seas. Marine resources variability and sustainability.

3) Climate impact and climate variability effects in the Mediterranean Sea. Regional variability and ecosystems variability in a global change context

SINOCOP experiment: Balearic Sea 2009

"a multi-sensor approach"



General objective:

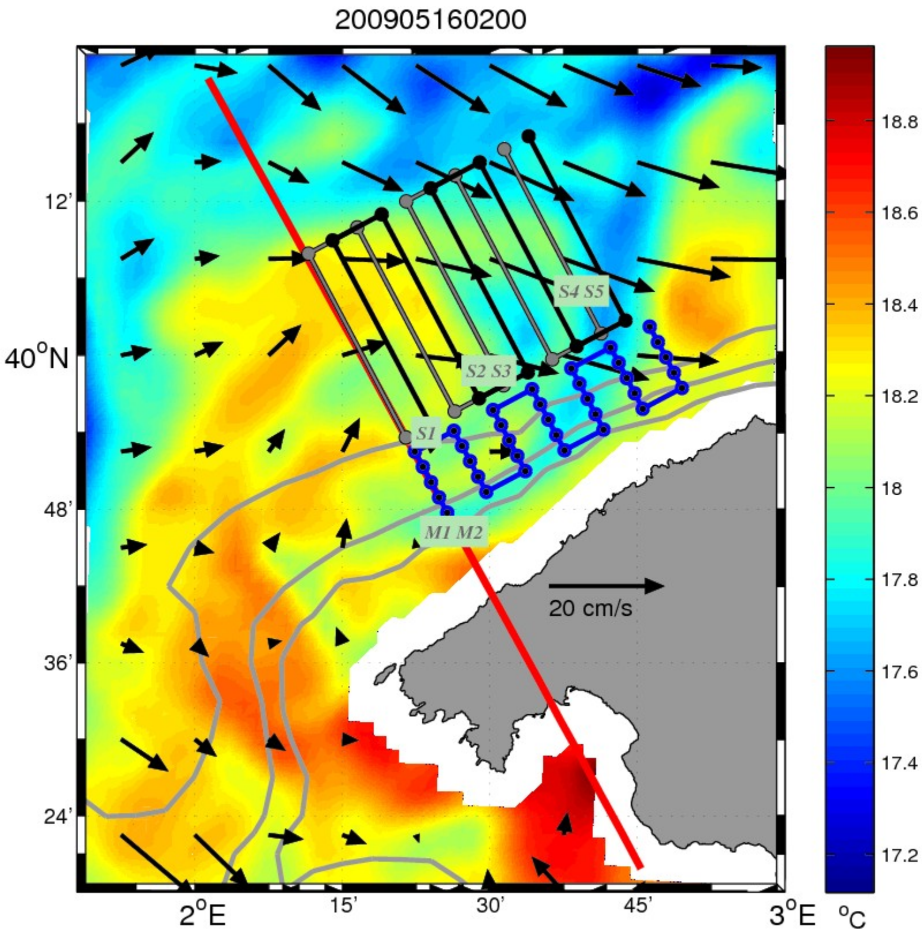
To study mesoscale and sub-mesoscale processes of a coastal front using a multi-sensor observational approach combined with numerical modelling.

Observations: gliders, drifters, standard CTDs together with remote sensing images (altimetry, SST and ocean color).

Specific objectives:

1) to investigate the limitations and potential improvements of altimetry in the coastal area
2) to develop methods for the combination of different sensors
3) to estimate vertical velocities and derived variables to study coastal dynamics

SINOCOP sampling



Red line is the Jason-1 70 track. Black and grey lines represent the glider missions. Blue dots are CTD casts. S1-S5 represent SVP drifters and M1-2 are minidrifters. Arrows correspond to absolute dynamic topography derived from altimetry and the color contour is SST (16/05/2009). Isobaths are 200 m, 500 m and 1000 m.

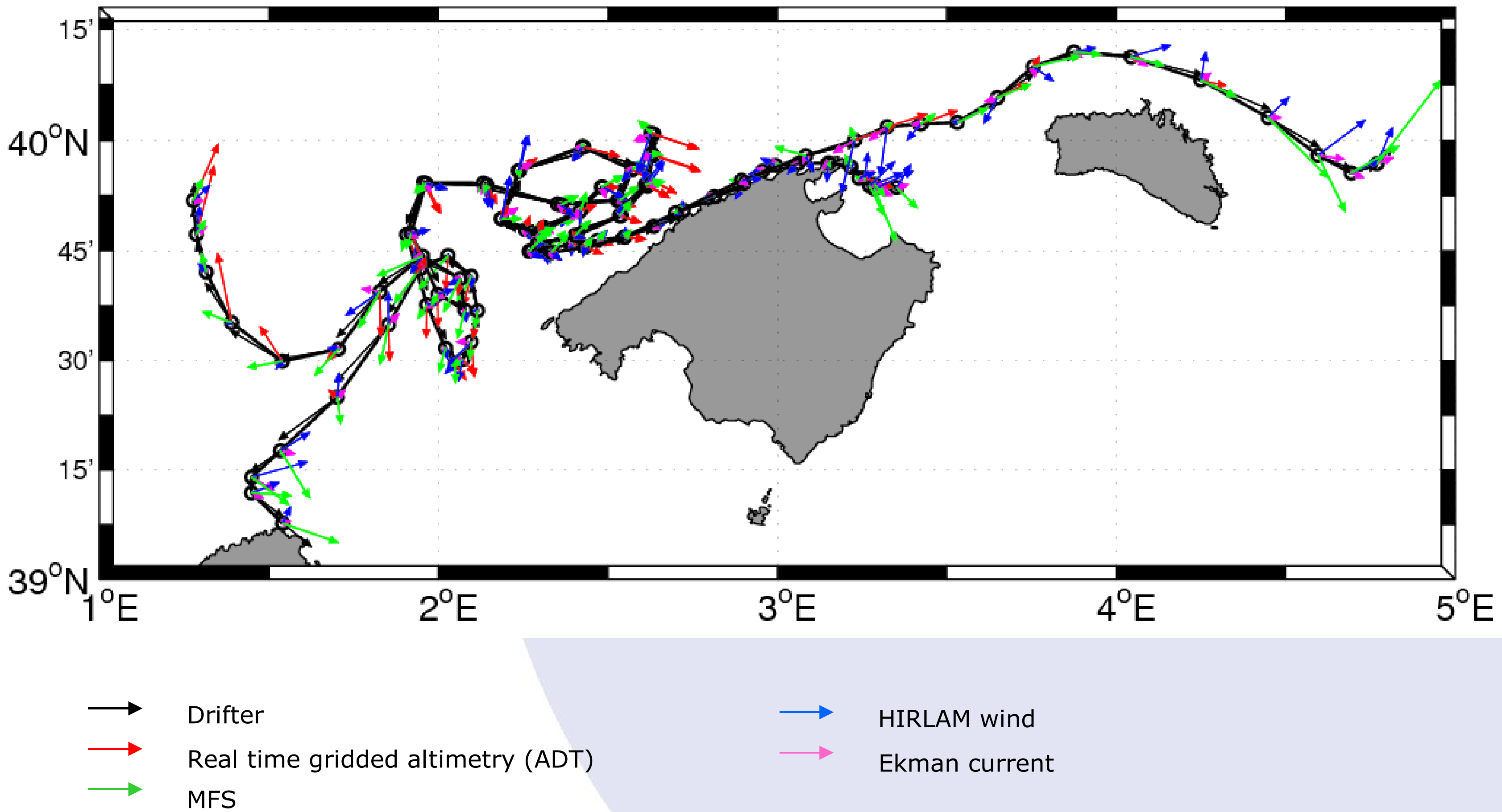
BIG CHALLENGE:
First time that IMEDEA:

Performs a mission with a deep glider
Performs a mission with two gliders
Acquires, processes and distributes data in real time

www.imedea.uib-csic.es/tmoos/sinocop/

Drifter trajectories during SINOCOP experiment

11/5/2009 – 10/6/2009



SINOCOP drifters & SST & altimetry