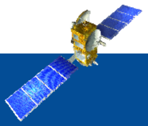
Vertical motion in the upper ocean from glider and altimetry data



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1. Introduction

Vertical motion associated with mesoscale oceanic features such as fronts, meanders, eddies and filaments 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

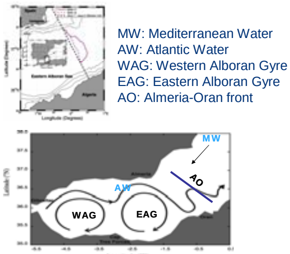
To investigate the feasibility of diagnosing vertical velocity combining in situ vertical profiles of temperature and salinity with satellite altimetry data.

Abstract

This study represents a first attempt to combine new glider technology data with altimetry measurements to understand the upper ocean dynamics and vertical exchanges in areas with intense horizontal density gradients. In July 2008, just two weeks after Jason-2 altimeter was launched, a glider mission took place along a satellite track in the Alboran Sea (Western Mediterranean). The mission was designed to be almost simultaneous with the satellite passage. Dynamic height from glider reveals a sharp gradient (~15 cm) and corresponds very well with the absolute dynamic topography from Jason-1 & Jason-2 tandem mission (r > 0.97, rms differences < 1.6 cm). We blend both data sets (glider and altimetry) to obtain a consistent and reliable 3D dynamic height field. Using quasi-geostrophic dynamics, we diagnose large-scale vertical motions (~1 m day^{-1}) which may provide a local mechanism for the subduction of the chlorophyll tongue observed by the glider.

2. Data set

We used a Slocum coastal glider that collected **1311 profiles (CTD, fluorescence and turbidity)** between the surface and 180 m. The mission took place from July 4 to 18, 2008 and was designed to cross the eastern Alboran Sea (Figure 1). The along-track glider data resolution is about 0.5 km. All variables gathered have been averaged vertically to 1 dbar bins. The **glider trajectory** was established to be **coincident with the altimetry satellite track 172** of the tandem mission **Jason-1** and **Jason-2**.



MW: Mediterranean Water
AW: Atlantic Water
WAG: Western Alboran Gyre
EAG: Eastern Alboran Gyre
AO: Almeria-Oran front

Figure 1. Study area showing the glider tracks (top) and sketch of the general circulation in the Alboran sea (bottom).

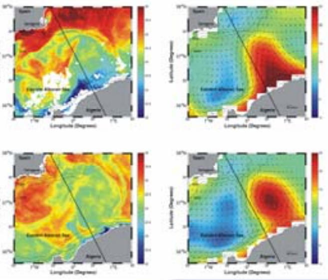


Figure 2. Night AVHRR SST images and interpolated altimeter maps of ADT with surface geostrophic currents overimposed for 7 and 23 July 2008 (Ruiz et al., 2009).

SST and altimetry data

SST images (Figure 2) reveal the presence of a relative cold jet flowing along the African coast (Atlantic jet) and a mesoscale instability developing between 0º and 0.5ºE (beginning of the Algerian current). After 2 weeks, this instability becomes an antyciclonic eddy of about 90 km diameter with a clear eastward displacement and secondary filaments interacting with warmer Mediterranean Water in the edge of the eddy. Altimetry maps, with associated horizontal geostrophic velocities of about 50 cms^{-1} (Figure 2), confirm the evolution of these structures.

3. 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):

$$\Phi_{x,y}(p) = A_1(x,y)\mathrm{EOF}_1(p)$$

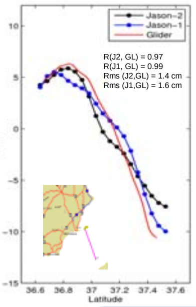
Thus, obtaining $A_1(x,y)$, the single amplitude corresponding to each profile would be straightforward given the surface altimetry data $[\Phi_{x,y}(p_0)]$ and the surface component of the leading EOF $[\mathrm{EOF}_1(p_0)]$ from vertical profiles.

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

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

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

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].



R(J2, GL) = 0.97
R(J1, GL) = 0.99
Rms (J2,GL) = 1.4 cm
Rms (J1,GL) = 1.6 cm

Figure 3. Dynamic height computed along glider track and Abslolute Dynamic Topography along 172 Jason-1 and Jason-2 altimeters track.

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: SLA + MDT [Rio et al JMS 2007].
Along track Lanczos filter.

4. Results and conclusions

Performance assessment of the reconstruction method.

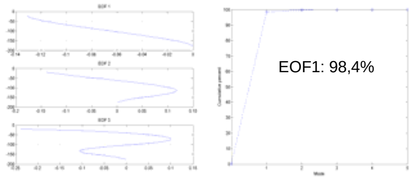


Figure 4. Leading EOFs obtained from glider data and cumulative percent variance explained by EOF modes.

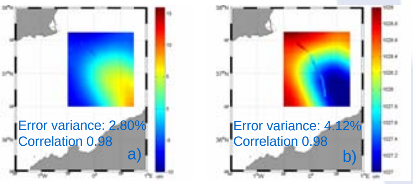


Figure 5. a) Reconstructed dynamic height field at 75 m depth. Colour dots correspond to dynamic height from glider at the same depth. b) as in a) but for density.

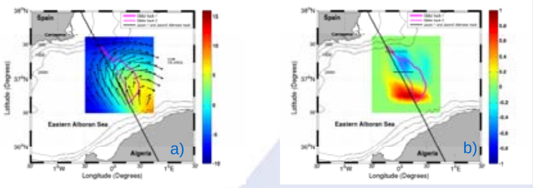


Figure 6. a) 3D reconstructed dynamic height and geostrophic velocity at 75 m. b) quasi-geostrophic vertical velocity at 75 m (right). Units are m day^{-1}.

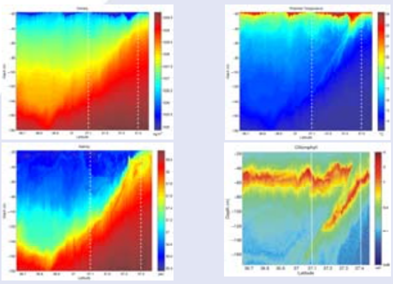


Figure 7. Vertical section of temperature, salinity, density and chlorophyll from glider section 2.

- This study represents a first attempt on the combination of new glider technology data with altimetry observations to diagnose vertical velocities.
- DH derived from the new autonomous vehicle 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.
- The magnitude of the vertical velocity is significantly sensitive to the scales included in the analysis. The vertical motion reported in this work is associated with the large-scale field observed in the study area. Tintoré et al. [1991] also found vertical velocities of +/-1 mday^{-1} associated with the large scale circulation (~90 km diameter eddies observed in the Alboran Sea).

5. Future work

- Use of high-spatial resolution of the ocean surface topography that will be available thanks to the SWOT mission.
- Application of the method to other zones and with ARGO data.

For a full list of references used in this poster, please contact Simón Ruiz at simon.ruiz@uib.es