Recent advances on mesoscale characterization in the Western Mediterranean Sea: complementarity between altimetry and other sensors

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SCIENTIFIC MOTIVATION:

- Satellite altimetry has provided a unique contribution to the global observation of the mesoscale processes.
- However, it is necessary to complement altimetry data with additional measurements to cover a wide range of spatial and temporal scales.

GENERAL OBJECTIVE:

- To improve our understanding and quantification of mesoscale variability by complementing altimetry with other platforms in the Western Mediterranean Sea.

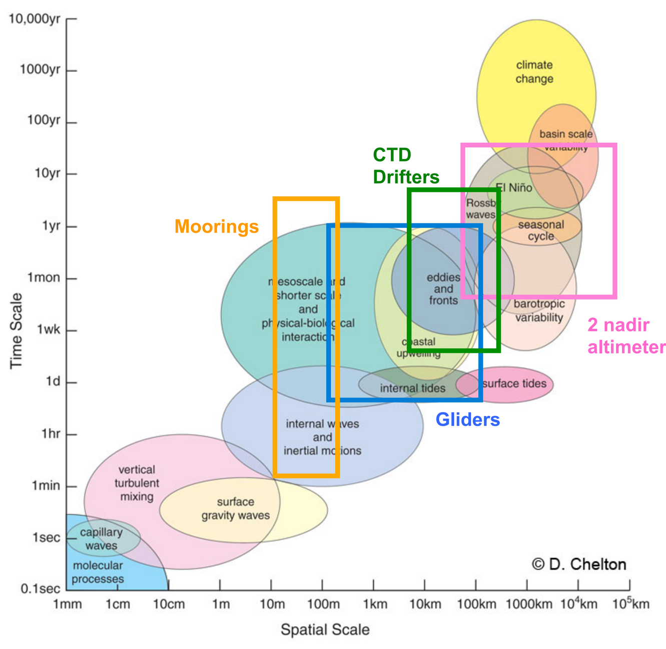


Figure 1: Temporal and spatial scales in the ocean (adapted from Chelton, 2001)

Context

The Mediterranean Sea is considered a reduced scale ocean laboratory where many phenomena that are present in different regions of the global ocean can be studied at a smaller scale: deep convection, shelf-slope exchanges, mesoscale and submesoscale dynamics, etc. Previous altimetric studies in the Mediterranean Sea (e.g. Larnicol et al. 2002; Pascual et al. 2007) have confirmed the complex combination of spatial and temporal scales affecting the sea surface variability.

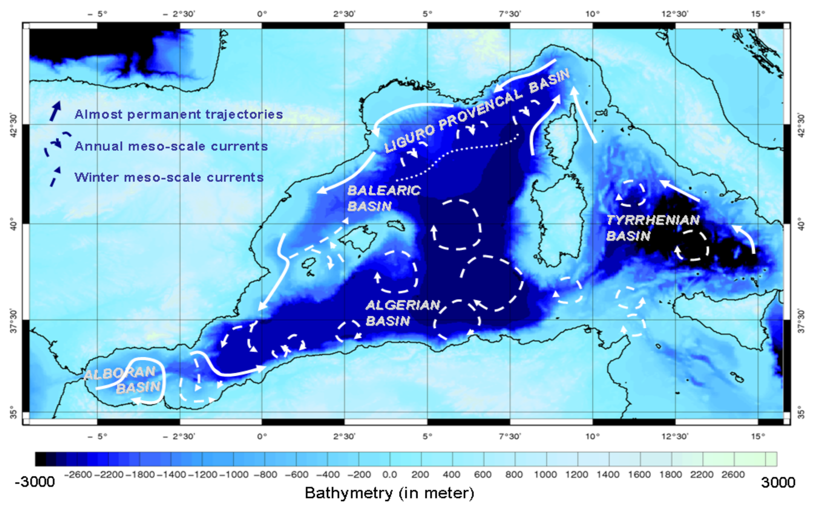
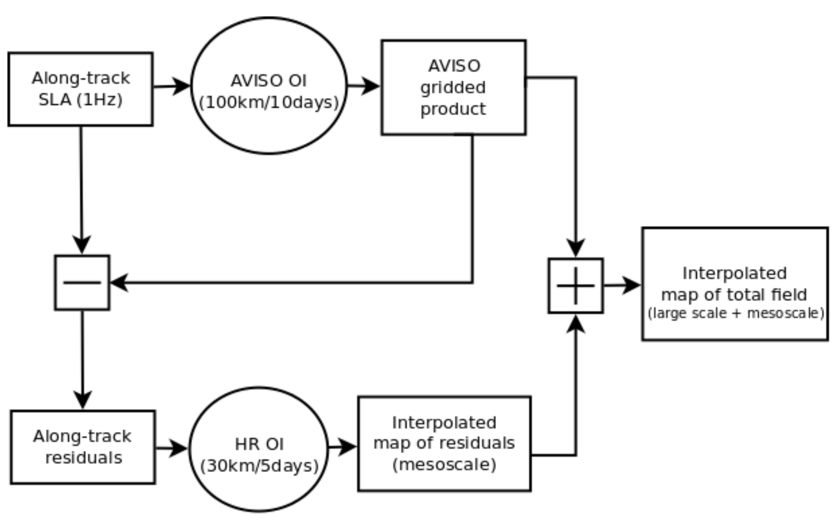


Figure 2: Sub-basins of the western Mediterranean Sea. The primary surface circulation patterns are indicated with continuous and discontinuous lines.

Method



To adjust the OI parameters, sensitivity tests based on Monte-Carlo analyses were performed. The values that optimize the signal-to-noise ratio were L = 30 km, T = 3 days and Φ = 0.7, with a measurement error variance of 3 cm^2.

HR OI methods:

1. HR: Optimal interpolation with smaller scales (Dussurget et al. 2011):

$$C_{ij} = e^{-\frac{|r_i - r_j|^2}{2L^2}} e^{-\frac{\Delta t^2}{T^2}}$$

r and t are the spatial and time coordinates of the studied point; L and T are the spatial and temporal correlation scales.

2. HR+bathy: Method 1 + bathymetry constraint (Davis et al. 1998):

$$C_{ij} = e^{-\frac{|r_i - r_j|^2}{2L^2}} e^{-\frac{\Delta t^2}{T^2}} e^{-\frac{F^2}{\Phi^2}} \qquad F = \frac{|PV_i - PV_j|}{\sqrt{PV_i^2 + PV_j^2}}$$

PV is potential vorticity, defined as PV = f/H. In this equation, f represents the Coriolis parameter, H corresponds to the bathymetry and Φ corresponds to a non-dimensional parameter.

Data

- **Altimetry : 2002- 2010**
  [5 satellites (en/tp/j1/j2/g2)]
  - Along Track data
  - AVISO interpolated regional product (Pujol et al., 2005)
    - 100 km and 10 days space and temporal correlation radius.
    - 1/8º, weekly
- **Auxiliary data:**
  - **In-situ measurements:** drifters (Poulain et al. 2012) and glider (IMEDEA/SOCIB).
  - **Bathymetry:** Smith & Sandwell Topography v9.1 (UCSD).

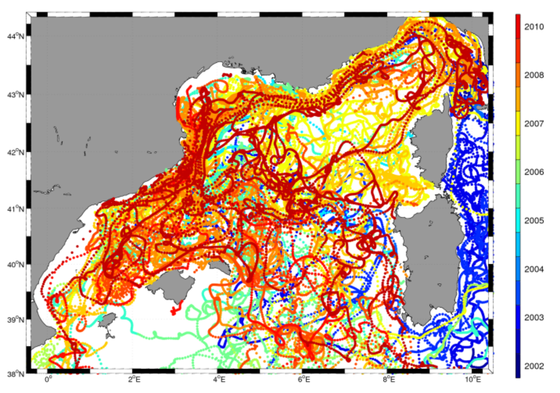
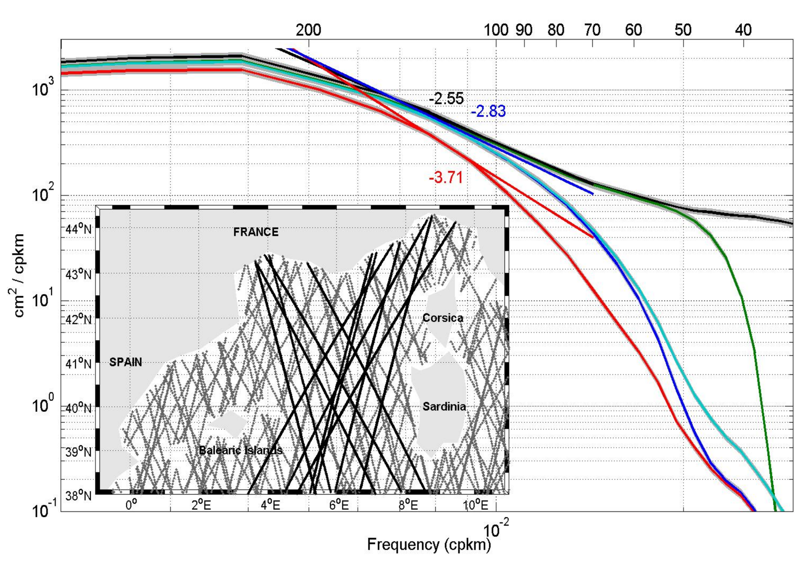


Figure 3: Drifter observations in the North Westen Mediterranean Sea. The color indicates the year of release.

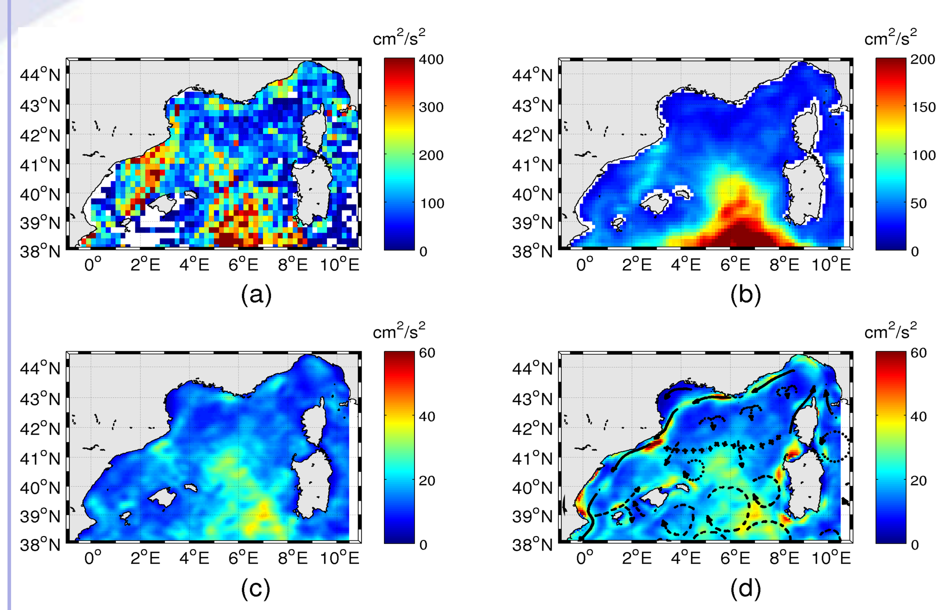
Spectral analysis



Wavenumber spectral slopes obtained from the new satellite-derived fields reveal a more realistic cascade of eddy energy.

Figure 4: The mean power spectra of the SLA for the different products, with the 95% confidence interval shaded in grey. The 1-Hz along-track data is represented by the black line and filtered at 42 km in green, the gridded AVISO product is represented by the red line, the HR product is represented by the dark blue line and the HR +bathy product is represented by the light blue line. The fitted slopes for the spectra between 70 and 250 km are plotted along with the value of the slope. For the gridded products (AVISO, HR and HR+bathy), the spectrum was computed from SLAs interpolated at the track locations. Bottom left corner: map with the position of the tracks.

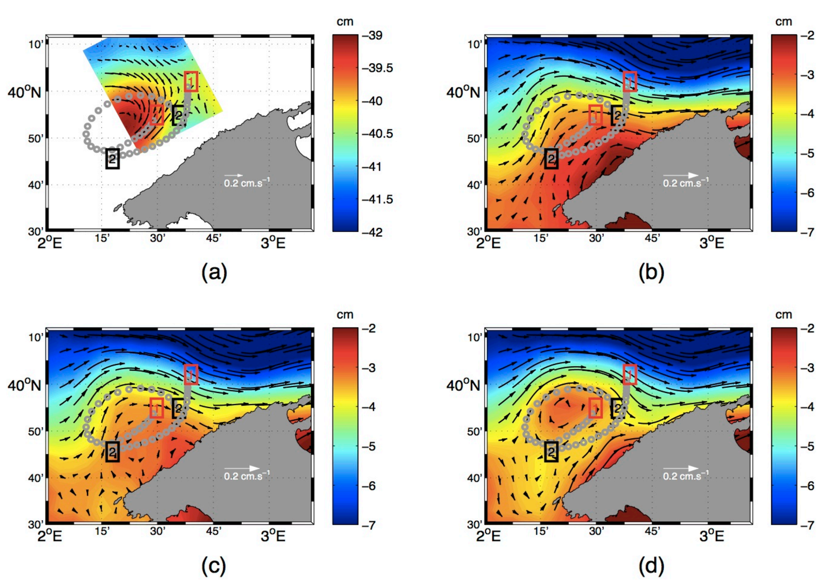
Mean eddy kinetic energy: comparison with drifters



The HR fields yield levels of eddy kinetic energy 25% higher than standard altimetry products, specifically over regions regularly impacted by baroclinic instabilities.

Figure 5: Eddy kinetic energy (EKE) over the period 2003-2010. The top panels are the mean values over this period obtained from the drifters (a) and the AVISO maps (b). The bottom panels show the difference between the HR (c) and HR+bathy (d) products and AVISO products. For the drifter map, the EKE is calculated from the drifter geostrophic velocity anomalies, obtained by subtracting the mean velocity computed in each bin of size 0.2° x 0.2°. The general circulation scheme is superposed on (d).

Case study I — Small eddy detection north of Mallorca island



Qualitative and quantitative comparisons with glider and drifter observations further confirm that the new altimetry product allows a better representation of mesoscale features.

Figure 6: Multi-sensor experiment north of Mallorca (14 May 2009): (a) The dynamic height computed from spatially interpolated glider and CTD temperature and salinity fields. The ADT overlapped by the derived geostrophic current from the (b) AVISO, (c) HR and (d) HR+bathy fields on the same date. The grey dots are the trajectories of drifting buoys launched at the same time (the red boxes with the number "1" indicate the initial positions, and the black boxes with the number "2" indicate the final positions).

Case study II — Validation of HR altimetry with glider measurements in the Ibiza channel

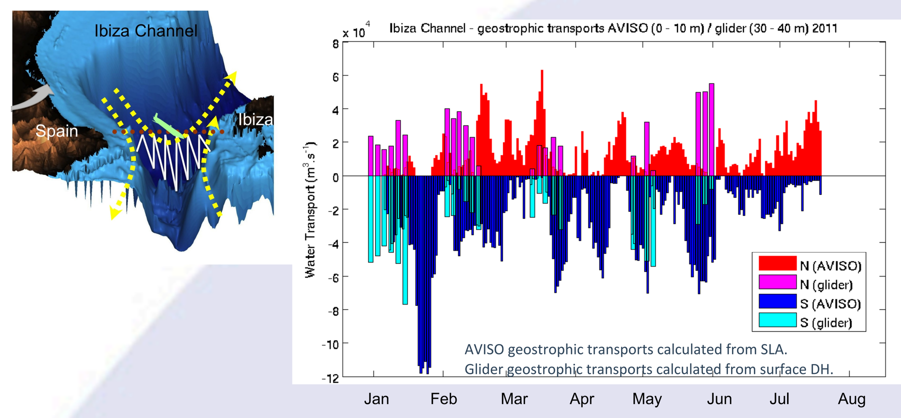


Figure 7: Surface transport across the Ibiza channel from glider and altimetry gridded fields provided by AVISO.

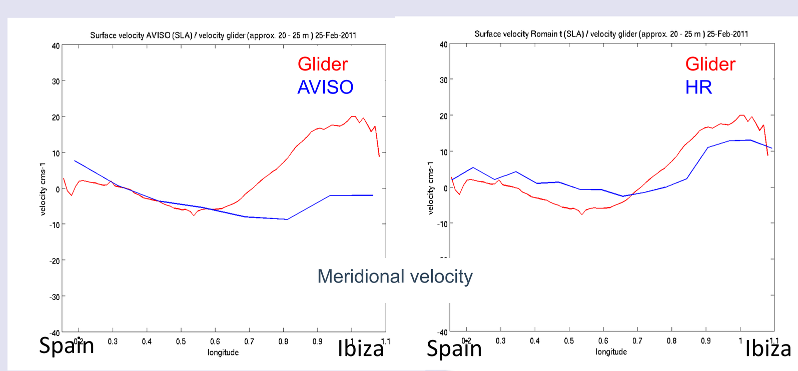


Figure 8: Glider versus altimetry surface geostrophic velocity across the Ibiza channel. Left: from standard AVISO data. Right: from HR products.

Glimpse of potential improvement with new HR dataset. Ongoing work.

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Summary & Outlook

- Glider and drifter observations provide complementary information to altimetry data and can be successfully used in synergy to study mesoscale dynamics.
- Integrated approach should also include models and other sensors (e.g. SST, OC, SS, ARGO, HF radar, moorings).
- Innovative methods to generate high-resolution altimeter maps have been developed and evaluated. The new fields allow to improve the coastal and mesoscale characterization.
- However, this improvement can only be obtained when an altimeter track intercepts, at least partially, the structure of interest.
- Needs:
  - Sustained in situ observations (coastal observatories, e.g.: SOCIB)
  - Sustained altimeter constellation (present critical situation)
  - Improved Mean Dynamic Topography (MDT)
- Looking forward to new altimeter missions: Saral/Altika, Sentinel-3, SWOT.