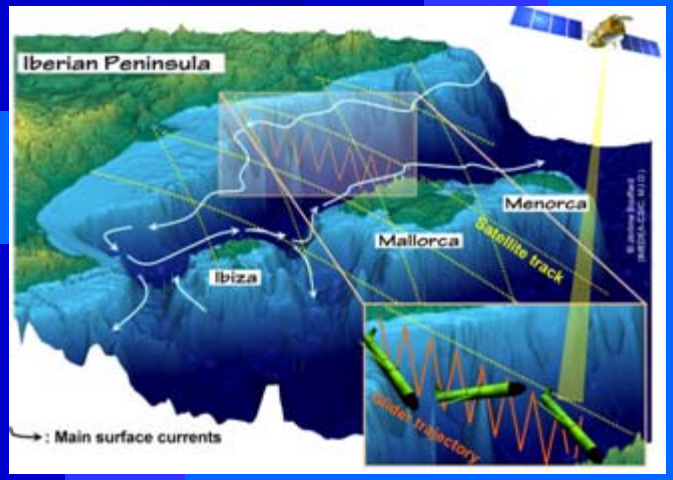


(3D) Coastal mesoscale from lagrangian analysis of altimetry and multi-sensor observations

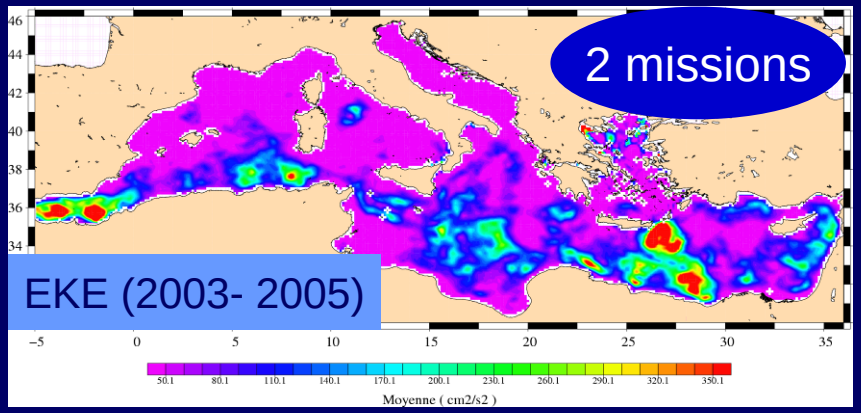
By Jerome Bouffard*
CNES post-doctoral fellow

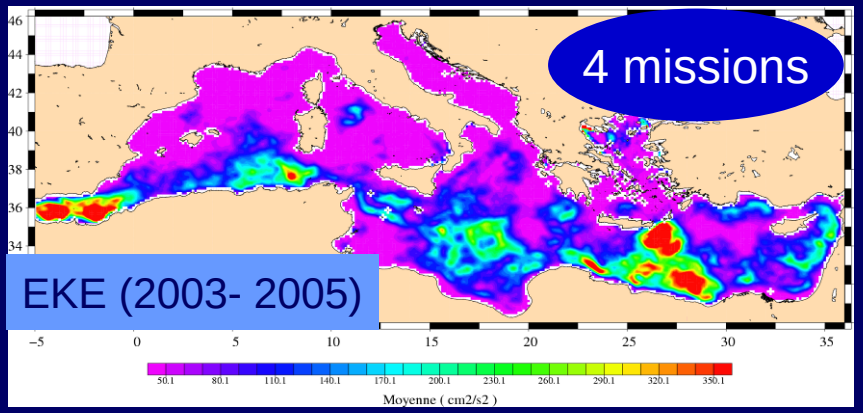
Anne Petrenko*, Andrea Doglioli*, Romain Escudier**, Ananda Pascual** and Francesco Nencioli*

**M.I.O*, *CNRS/IRD/AMU/USTV, Aix-Marseille Universite, France .*
***IMEDEA** (UIB, CSIC), Mallorca, Spain.*

Context and objective

- Multi-satellite improve the description of meso-scale in the open ocean *(Pascual et al., 2006; 2007)*





- Several pluri-disciplinary applications with promising results

  ➔ *ie* talk from *D'Ovidio et al., 2012*

- **But** the present configuration lacks resolution to correctly sample coastal mesoscale *(ie Dussurget et al., 2011; Nencioli et al., 2011; Bouffard et al., 2010)*

Generate higher resolution currents in the coastal domain

Outline

- **Zone of study**
- **Data and Methods**
- **Results :**
  - Eulerian approach (Influence of OI)
  - Lagrangian approach (Influence of OI & mean currents)
  - Reconstruction of sub-surface currents (*preliminary results*)
- **Conclusions**

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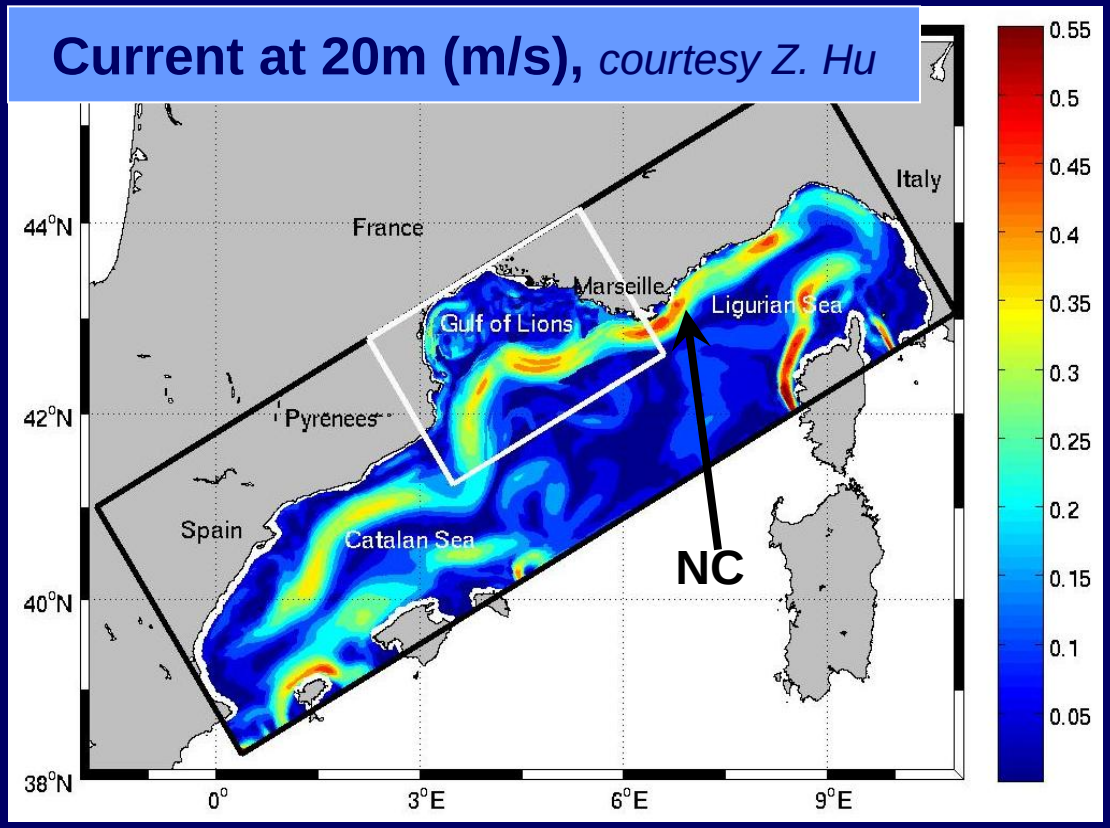
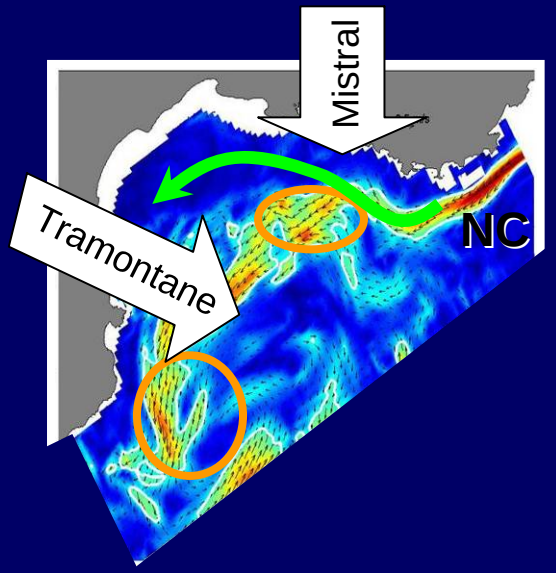
Zone of Study

- **The North Western Mediterranean Sea**

Current at 20m (m/s), *courtesy Z. Hu*





- **Northern Current (NC):** Seasonnal variability *(Gostan, 1967)* and **intrusion** over the GoL continental shelf *(Gatti et al., 2006)*
- **Intense meso-scale dynamics:** eddies, meanders *(Millot, 1991; Bouffard et al., 2010, 2012; Hu et al., 2009; Nencioli et al., 2011)* **BUT SMALL ROSSBY RADIUS**

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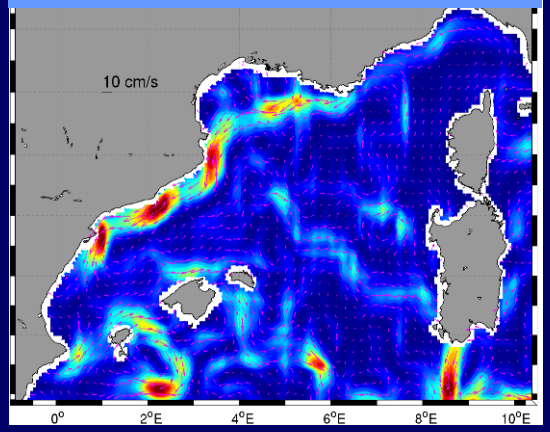
Data and methods

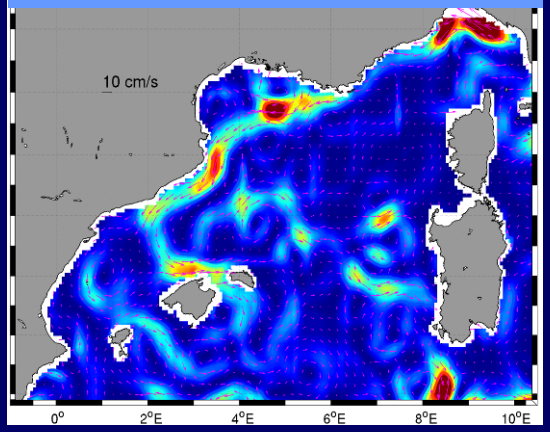
- **3 kinds of mean currents :**

Rio et al., 2007



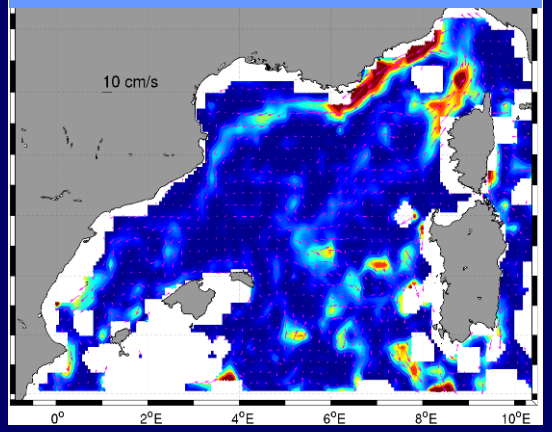
Model+drifters+altimetry

Dobricic et al., 2005

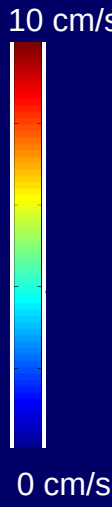


Model + data Assimilation

Poulain et al., 2012



Drifters



- **3 kinds of MSLA (2002-2010):**

AVISO

High Resolution (HR)

$$C(r,t) = e^{-\frac{r^2}{2L^2}} e^{-(\frac{t}{T})^2}$$

High Resolution + bathy

$$C(r,t) = e^{-\frac{r^2}{2L^2}} e^{-(\frac{t}{T})^2} e^{-(\frac{dPV}{\Phi})^2}$$

What is the impact of mean current ? Of Optimal Interpolation (OI) ?

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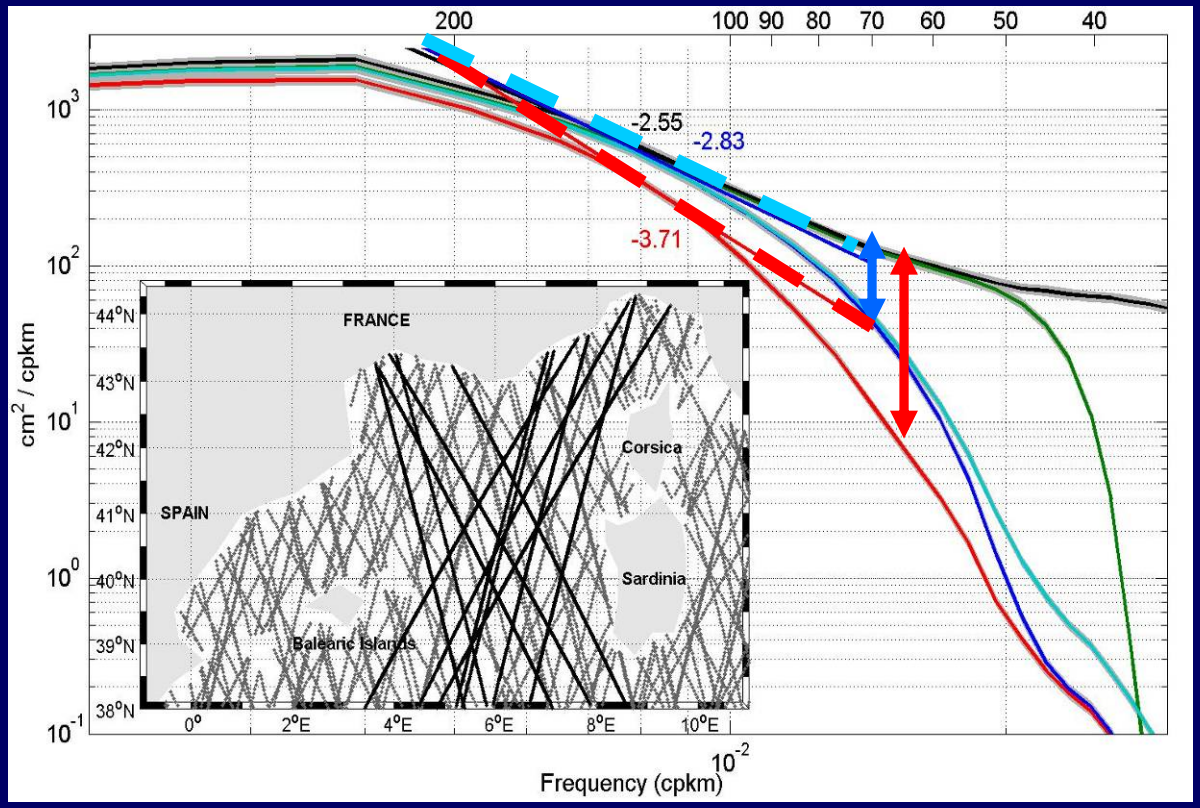
Eulerian approach : influence of OIs

- **Statistics at the bassin scale (Power Density Spectrum)**



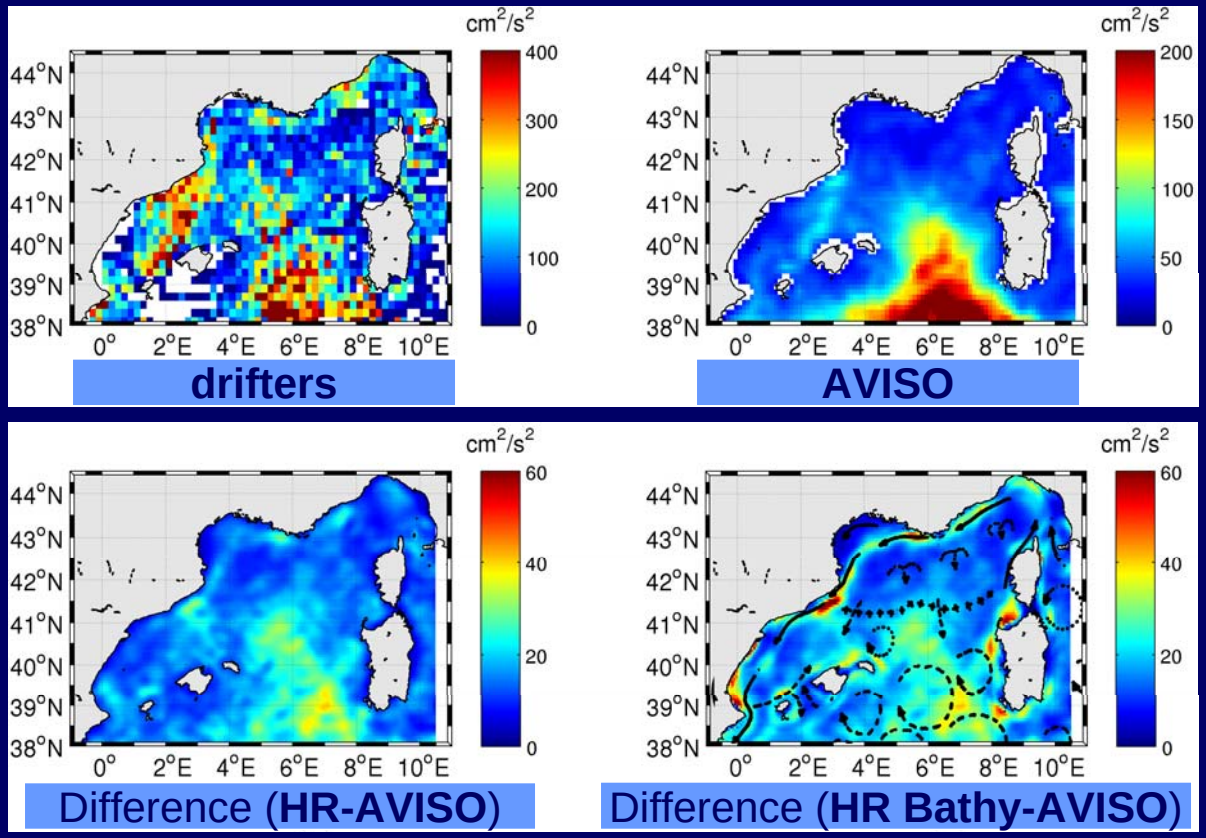
-- AVISO
-- HR
-- HR + Bathy
-- Along-track

From Escudier al. (2012)

- Discrepancy between the along-track signal and AVISO for scales <150 km
- 50-100 km: **Increase of energy** on HR products. Agreement with the along-track
- Wavenumber spectral slopes from HR fields reveal a **more realistic cascade** of eddy energy

Eulerian approach : influence of OIs

Statistics at the bassin scale (EKE)

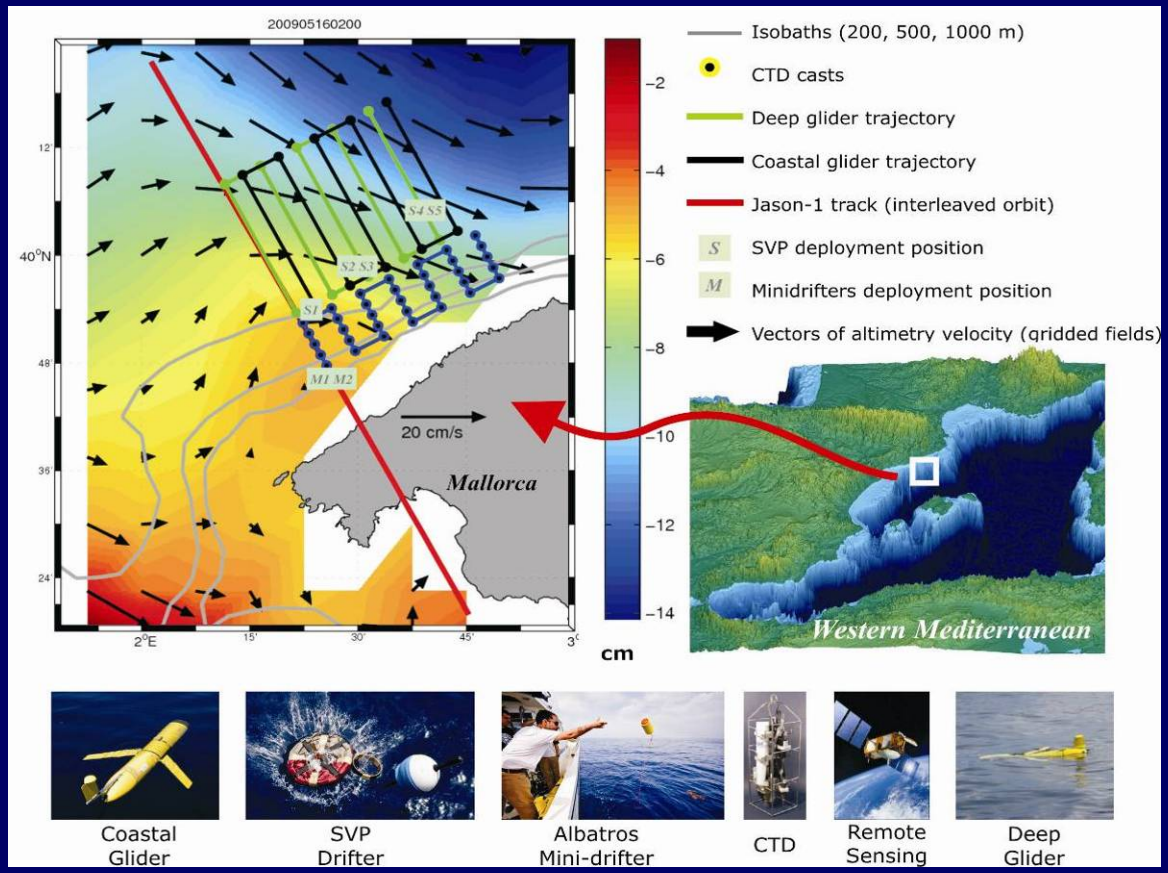


From Escudier al. (2012)

- **Significant differences** in the magnitude of EKE between altimetry and drifters.
- **HR** products exhibit a **higher average EKE** (~ 50 cm2/s2)
- EKE increase not homogeneous and appears more substantial **where strong mesoscale** instabilities are expected (e.g. *Millot, 1999*)

Eulerian approach : influence of OIs

- **Focus on a specific period: SINOCOP (May 2009)**



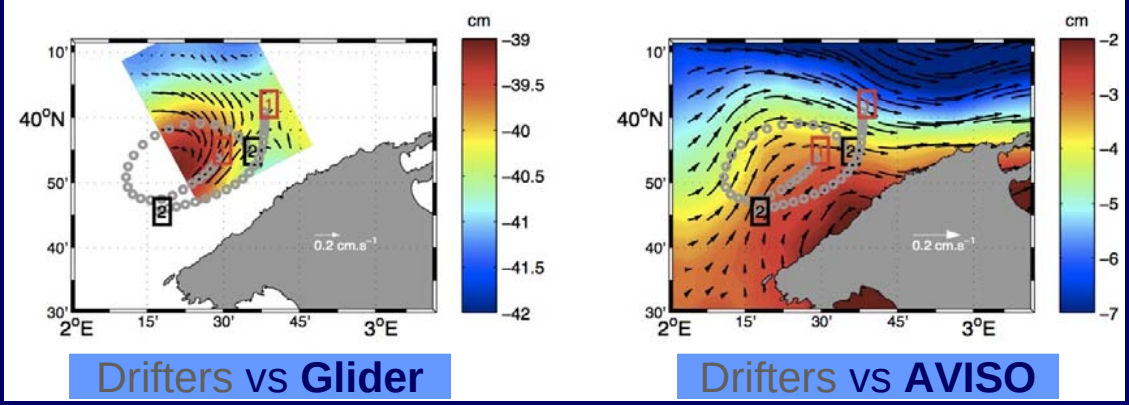
Sistema **IN**tegrado de **OC**eanografía **OP**eraciona (IMEDEA, Mallorca)

From Pascual al. (2010)

- **Specific objective :** To study mesoscale processes of a coastal front using a multi-sensor observational approach.
- **Observations:** Gliders, drifters, standard CTDs together with remote sensing

Eulerian approach : influence of OIs

- **Focus on a specific period: SINOCOP (May 2009)**



From Escudier al. (2012)

- AVISO map is unable to correctly reproduce the southern recirculation of the eddy.
- **Better for HR** but does not perform very well near the coast.
- When the **bathymetric constraint** is used, more **accurate representation** of the eddy both qualitatively (more “eddy like”) and statistically (corr >0.90)

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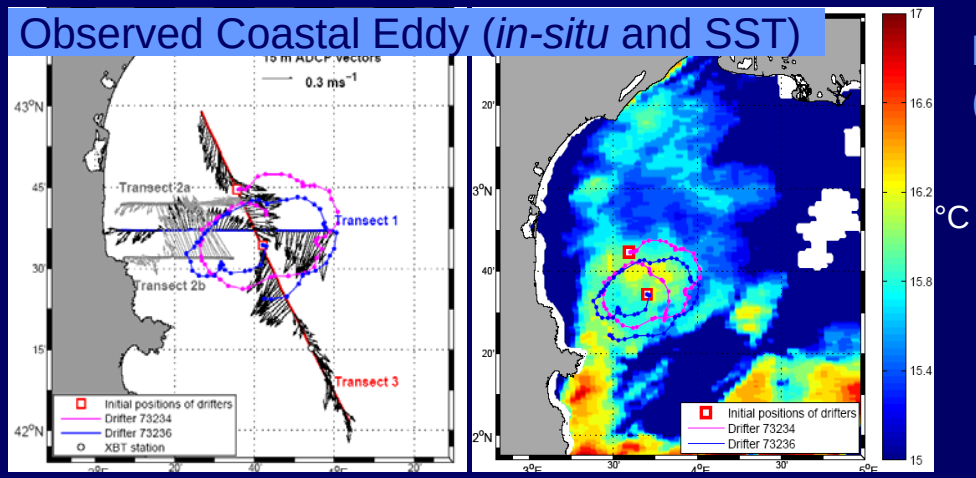
Lagrangian approach : influence of OIs and mean currents

- **Focus on a specific period: LATEX (08, 09, 10)**

Observed Coastal Eddy (*in-situ* and SST)



LAgrangian **T**ransport **Ex**periment (MIO, Marseille)

From Hu al. (2008)

- **Specific objective :** Understand the influences of coastal mesoscale eddies on physical – biogeochemical interactions and cross-shelf exchanges
- **Methodology:** Multi-disciplinary project (*In-situ* measurements & modeling)

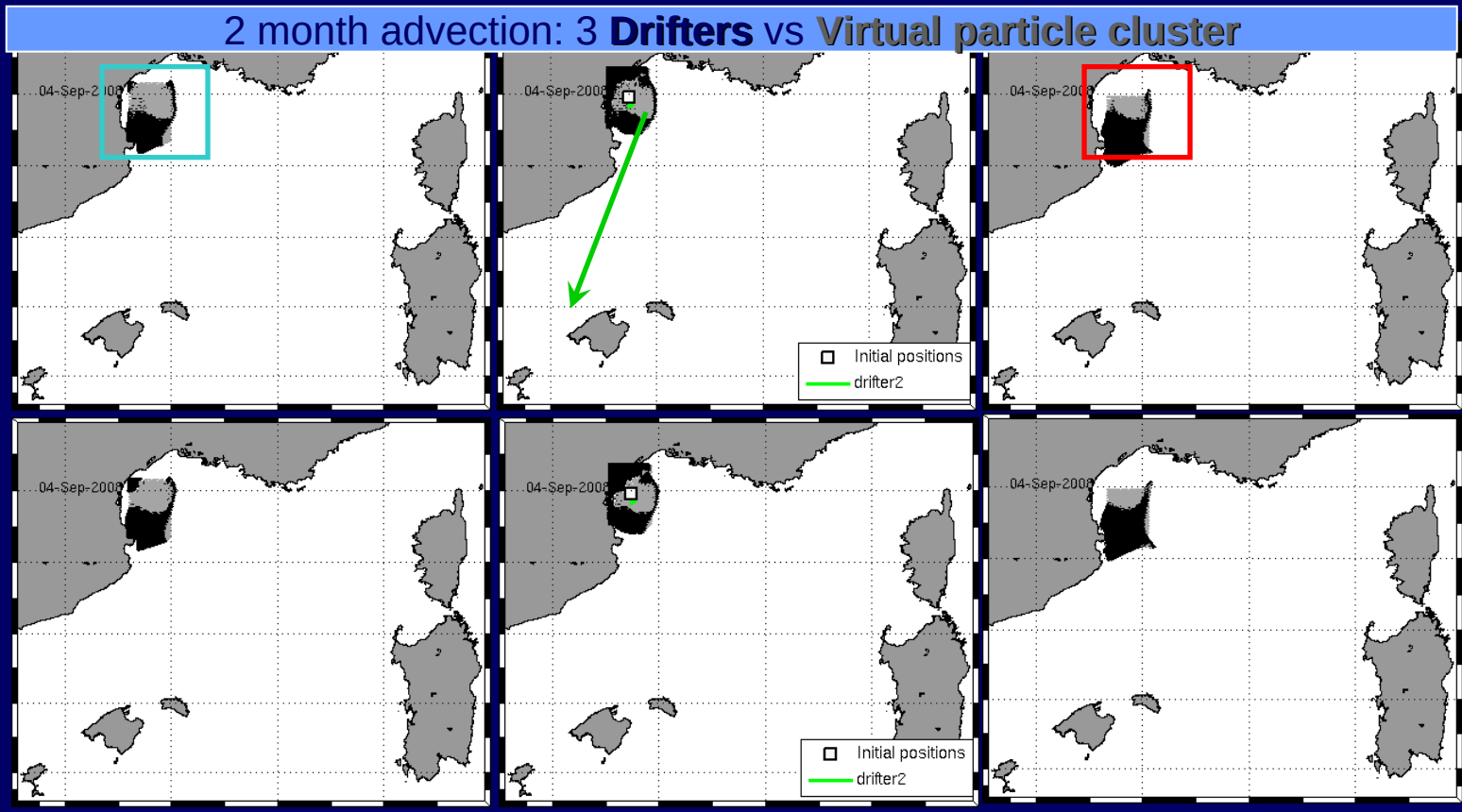
Are gridded fields able to reproduce coastal features ?

Lagrangian approach : influence of OIs and mean currents

- **Focus on a specific period: LATEX08**

MSLA HR+bathy + **MDT Dobricic**

MSLA AVISO + **MDT Rio**



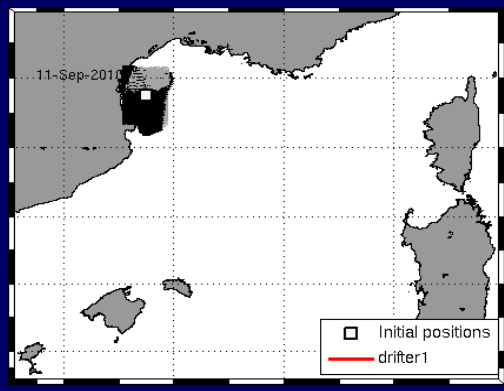
- Coastal eddy (**drifter 1** and **3**) reproduced by the *HR+bathy+Dobricic currents*
- Better **qualitative** agreement with **drifter 2** for *HR+bathy+Dobric currents*

How to quantify the respective impacts of OI and mean ?

Lagrangian approach : influence of OIs and mean currents

Methods to evaluate altimetric trajectories

- **Step 1:** For each drifter, advection *(RK4, D'ovidio et al., 2004)* of virtual particles launched close to initial positions using the 9 products

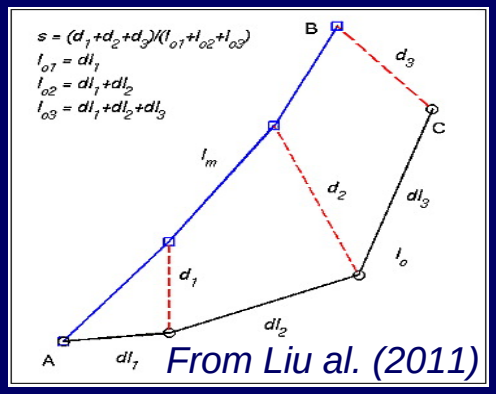


- **Step 2:** For each particle and time step, Normalized Cumulative Separation Distance computation **(s)**.

$$s = \sum_{i=1}^{N} d_i \Big/ \sum_{i=1}^{N} l_{oi},$$

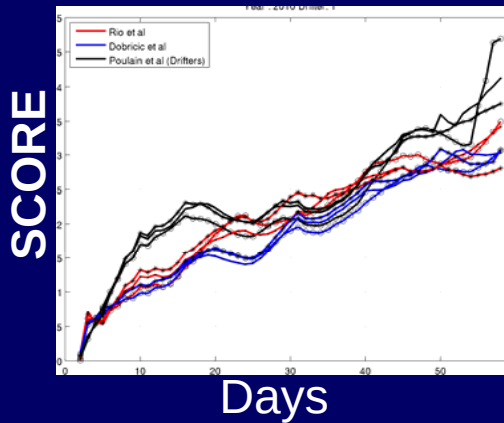
d: separation distance between the altimetric and drifter endpoints

l: length of the drifter trajectory



- **Step 3:** **SCORE**=Average of the 50% best **s** index. The smaller the **SCORE** value, the better the performance

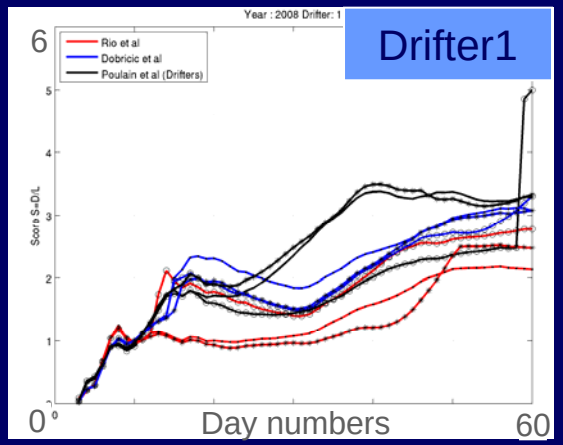
- **Step 4:** For each drifter and for the 9 altimetric products, time evolution of the **SCORE**

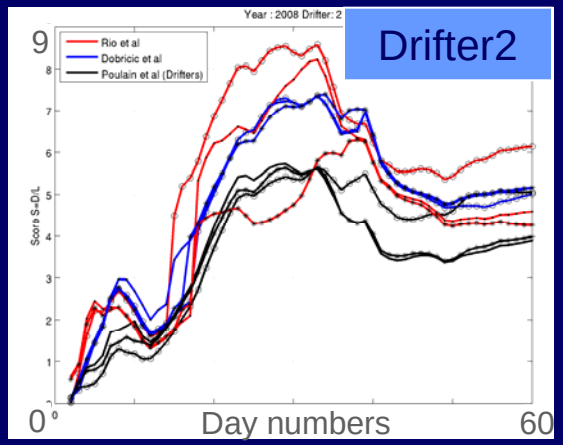


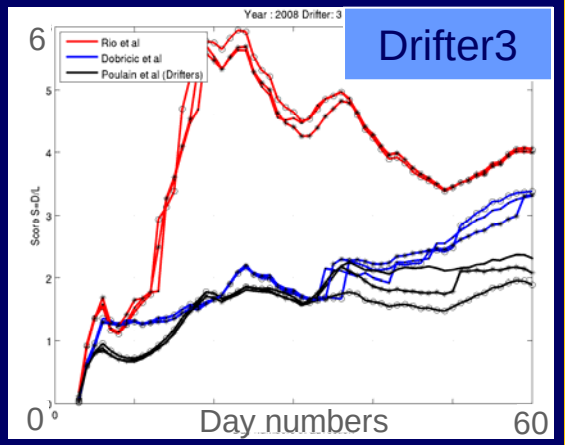
Lagrangian approach : influence of OIs and mean currents

Statistical results for the 9 products (LATEX08):

SCORE = D/L



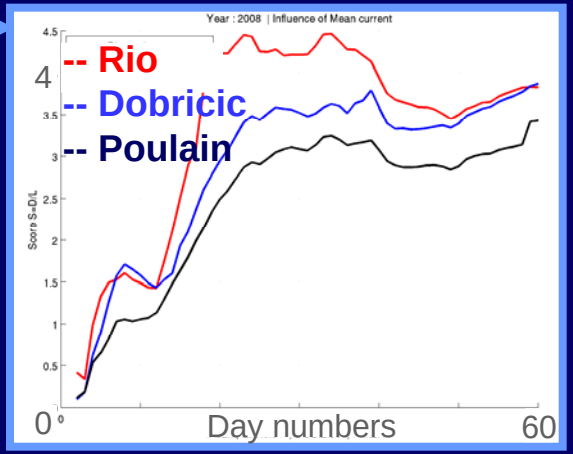


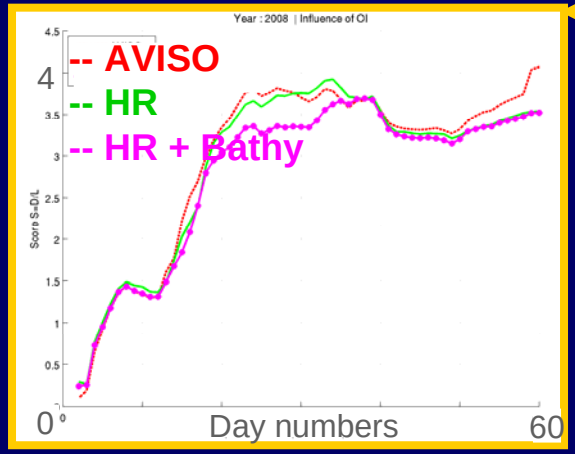


- Significant differences function of the altimetric product

Influence of Mean and OI (LATEX08)

SCORE = D/L





- **Average score per mean**
  - Better results with Dob. and Poulain than Rio (**>13 %**)
- **Average score per OI**
  - Better results with HR + bathy than AVISO (**~10 %**)

Lagrangian approach : influence of OIs and mean currents

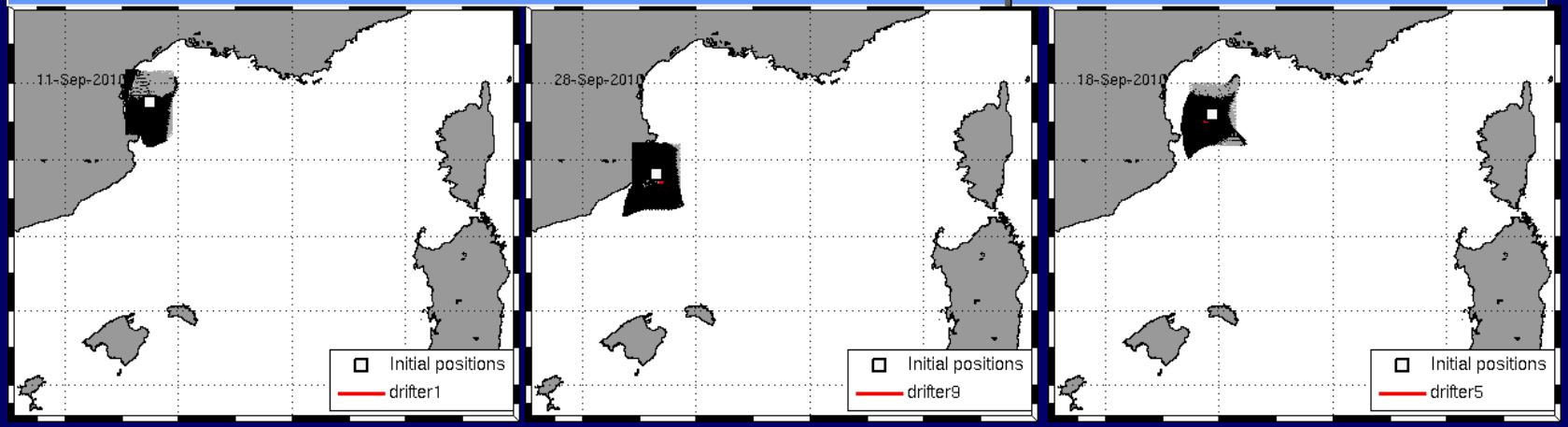
Focus on a specific period (LATEX10):

HR bathy

+

Dobricic

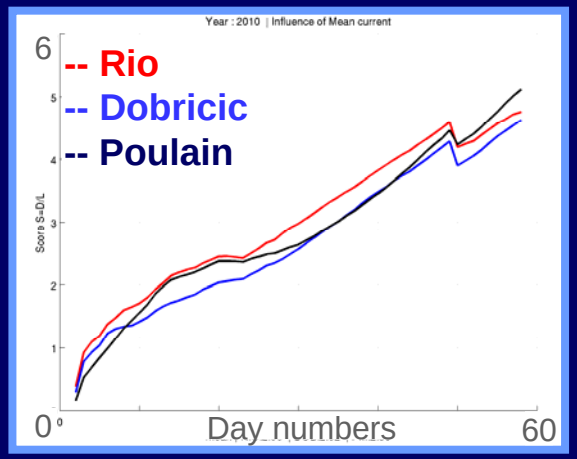
2 month advection: **10 drifters** vs virtual particle cluster

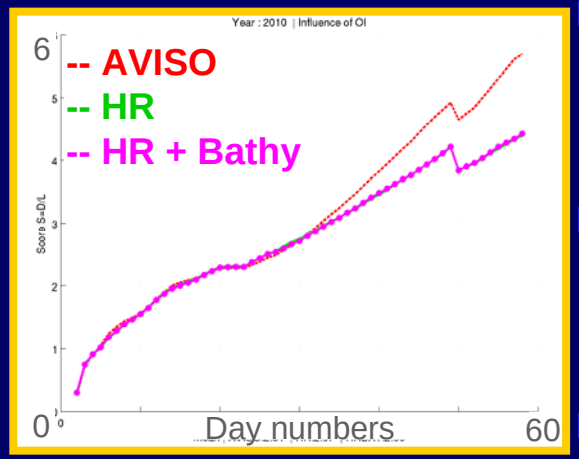


- In these 3 examples, most mesoscale features are quite well reproduced

Influence of Mean and OI (LATEX10)

SCORE = D/L





- **Average score per mean**
  - Better results with Dob. and Poulain than Rio (**>11 %**)
- **Average score per OI**
  - Better results with HR + bathy than AVISO (**~10 %**)
- **Equivalent results in 2009**

Outline

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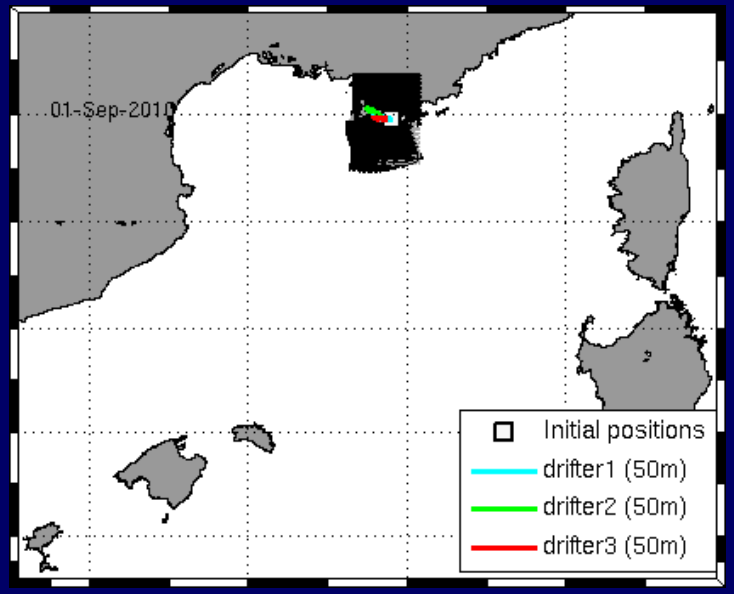
- **Conclusions**

Reconstruction of sub-surface currents

- **Methods**
  - Vertical climatological EOF from the SYMPHONIE regional model (POC)
  - Vertical projection using the 1st mode *(Bouffard et al.,2010: OSTST and CAW)*

- **Comparisons with 3 drifters at 50 m**



  - Disagreement during the first weeks: Underestimation of Altimetric current? Ageostrophic features ?
  - 1 month latter, better agreement: **Drifter 2** advected by a NC southward branch ? **Drifter 1** & **3** by a NC return loop ? Eddy ?

- **Exemple of application (on going work)**
  - Forecasting and quantifying shored *Pelagia noctiluca* Jellyfish (DVM➔ can reach until 400 during the day)

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Conclusions

- Alternative methods to generate high-resolution maps were developed
- Eulerian and lagrangian approaches were adopted to evaluate them
- We confirm that new OI (*described by Escudier et al., 2012*) and alternative mean currents allow to improve coastal mesoscale characterization (>20 %)
- **However,** the limited space/time coverage of the few satellites is a limitation to the long-term tracking of small-scale eddies
- Waiting SWOT, the study of coastal mesoscale requires to use a denser satellite constellation or additonal measurements
- Here, the combination of surface signals and vertical EOFs is tested to investigate the distribution of jellyfish along the coast (*ongoing work*)
- **However**, the relation between surface and sub-surface mesoscale is still a challenging issue requiring theorical developments (*ie talk from P. Klein*)

Thank you for your attention

Escudier, R., J. Bouffard, A. Pascual, P.-M. Poulain, M.-I. Pujol, 2012 : Improvement of coastal and mesoscale observation from space: Application to the Northwestern Mediterranean Sea, *submitted to GRL* ("*AVISO Image of the month*", September 2012)

Bouffard et al., (2012c): On the influence of coastal mesoscale dynamics on the jellyfish trajectories and distributions, *paper in preparation* ("*AVISO Image of month*", May 2012)