How to combine altimetric techniques with gliders in order to monitor 3D coastal mesoscale ?

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Objectives and issues

- **Specific objectives**
  - To **characterize** coastal (sub)mesoscale features
  - To **understand** the associated mechanisms
- **Approach**
  - **Compute** consistent altimetric and glider currents
  - **Explore** their physical content & limitations by direct comparisons
  - **Analyse** complementary multi-sensor in-situ and remote-sensing data in combination with regional modelling
- **Technical Issues**
  - **For Altimetry:** How to build valuable coastal altimetric AGCurrents ?
  - **For Glider:** How to solve the Reference Level issue ?
  - **For Model:** Is its representativity good enough for Mesoscale studies?

20Hz improved along-track altimetric data have been processed

14 glider missions have been performed along altimeter tracks (Jul. 2007 – Apr. 2010) in the WMED

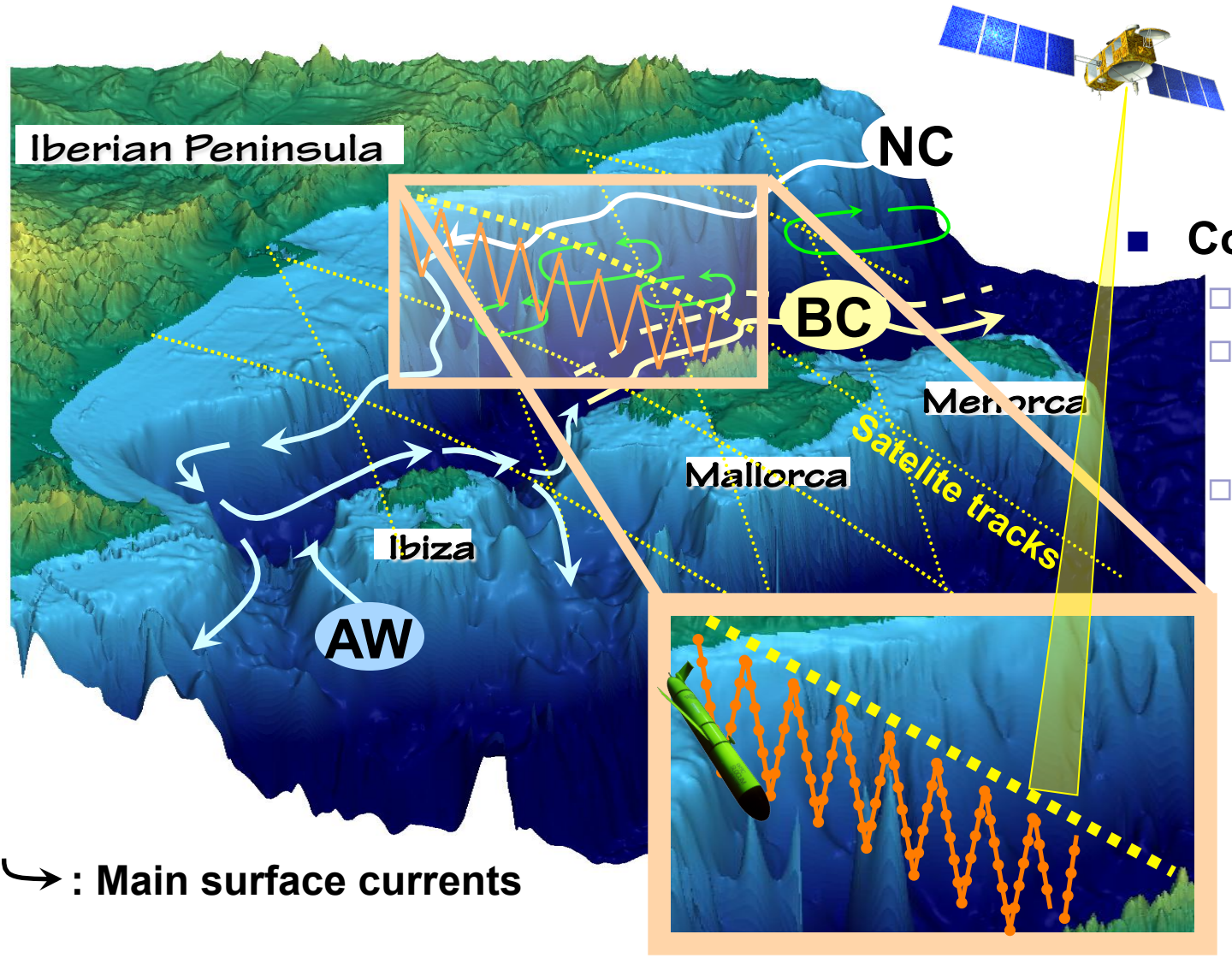
A 3D model (ROMS) has been implemented over the same period

Outline

- **Context**
  - Study zone
  - Data and model characteristics
  - Altimetric AGC computation
  - Glider AGC computation
- **Cross comparisons and physical content characterization**
  - At Surface
  - In depth
- **Origin and mecanisms associated to a observed small-scale eddy**
  - Relative vorticity
  - Relation between salinity and eddy intensity
- **Conclusions**

Context

Study zone



- **Complex dynamics**
  - At North: **NC**
  - At south **BC**, its associated **front** and **AW inflow**
  - In-between, mesoscale (eddies, meandering….) due to heterogenous water masses mixing

Multi-sensor integrated approach

Context

Data and model characteristics

Coastal ALTIMETRY (ENVISAT, J1, **J2**)

- **Variable:**
  * (M)SLA and along track SLA (1Hz / 20Hz) from a PISTACH experimental dataset
- **Horizontal resolution**
  * (M)SLA: 1/8°, 1Hz ~ 7km, 20Hz ~ 350m

Limitation in coastal zone
Surface information

Complementary tools

COASTAL GLIDERS

- **Variables:**

* P, T, S, oxig., chl., turb., GPS positionning

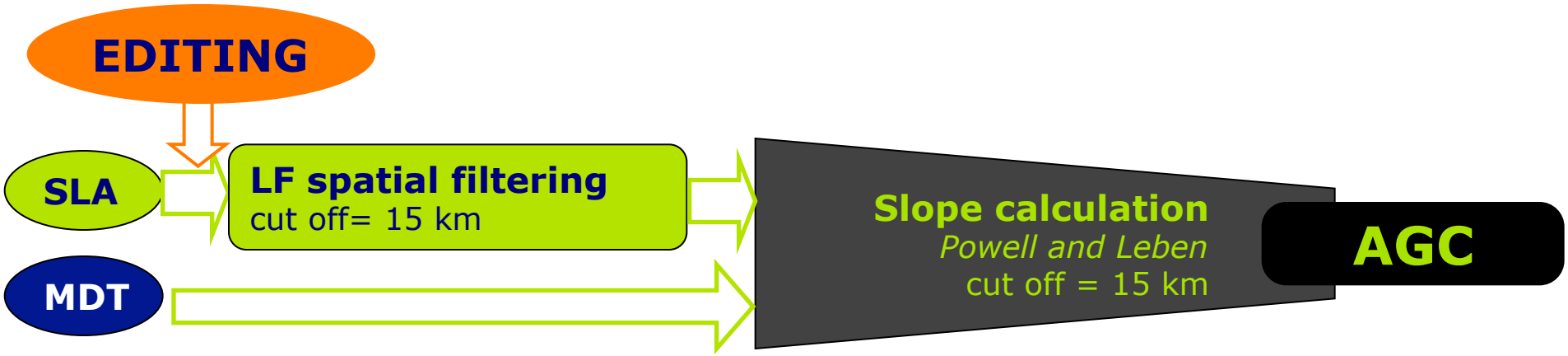
- **Horizontal resolution:**

* GPS: 6km, others: 300 m / 1.1 km

Ref. Level issue
Limited coverage

Context

Altimetric AGC computation (ref to ***Bouffard et al., JGR; October 2010***)

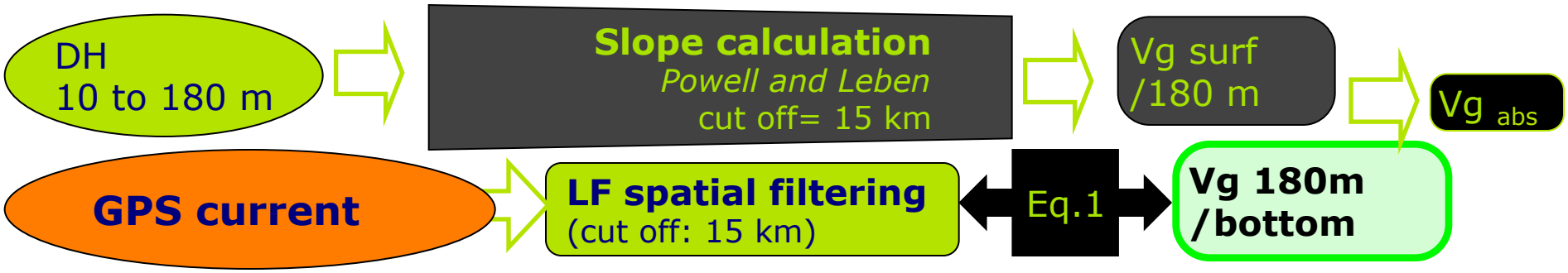


- Along track 20 Hz ENVISAT and **JASON satellites (*provided by CLS*)**
- **Coastal-oriented editing** strategy and filtering on the SLA have been applied whereas several **corrections** (*Iono: GIM vs Bi frequence ,wet tropo: Radiometric vs composite vs Radiometric decontamination, MSS: CLS vs DNCS,* etc.) and **retracking** technics (*MLE4, SVD, OCE3, RED3*) have been evaluated by direct comparisons with glider
- Slope: optimal filtering ➔ accross track **Absolute Geostrophic Current**

Context

Glider AGC computation

(ref to ***Bouffard et al., JGR; October 2010***)



- Dynamic height computed from T, S profiles with a ref. level 180 m.
- Computation of surface geostrophic velocities (Vg surf / 180m) from DH

$$Vg_{abs} = Vg_{surf_{180}} + Vg_{180_{bottom}}$$

Reference Level Correction (RLC)

- Computation of absolute geostrophic currents by **combining depth averaged relative geostrophic current** and **GPS currents:**

GPS currents — DH profile — unknown — mog2d model — Ekman + cyclostrophic

Eq.1

$$\overline{Vabs} = \overline{Vg_{180}} + \overline{Vg_{180_{bottom}}} + \overline{V_{bar\ wind}} + \overline{Vag} + \varepsilon$$

$\overline{\quad}$ *denotes vertical average over the upper 180 m (glider vertical extension)*

Context

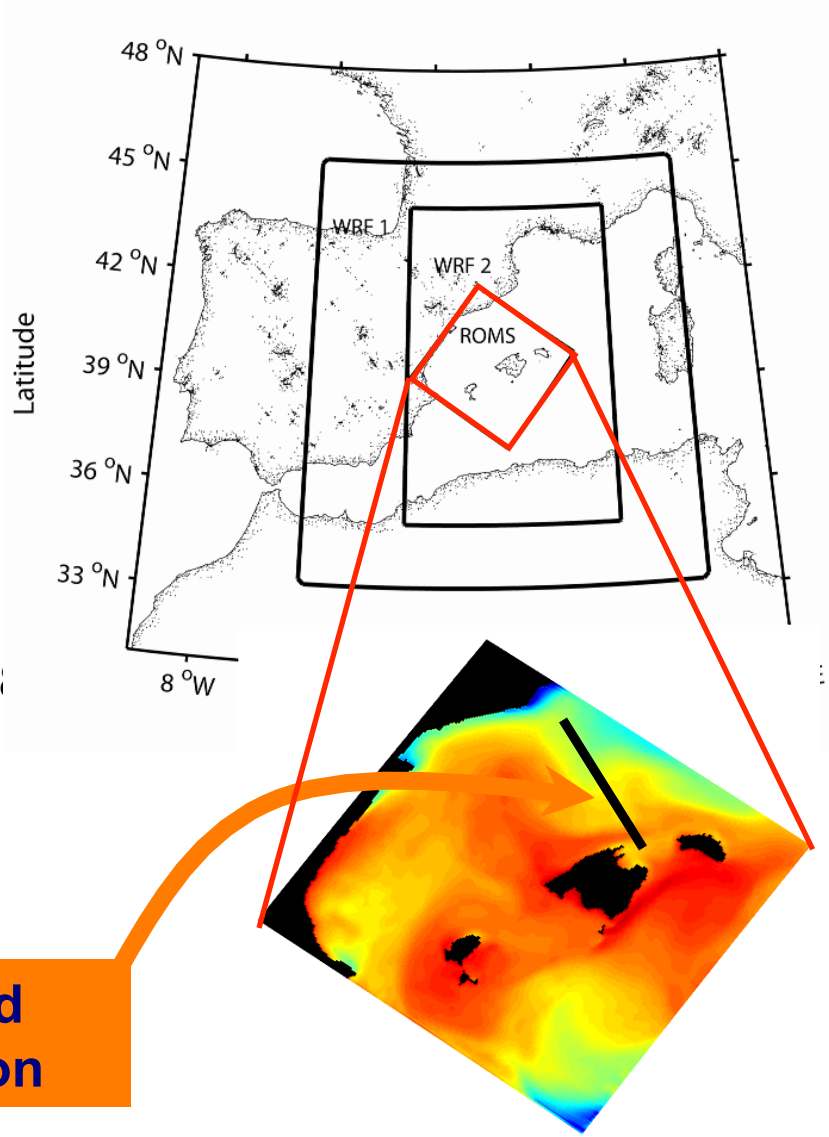
Data and model characteristics

Atmospheric model: WRF

- two nested grids : ***30km and 6km***,
- 47 vertical sigma levels.
- Boundary conditions: NCEP
- SST forcing: daily from CNR (5km)
- Period: 2007-2008

Oceanic model: ROMS

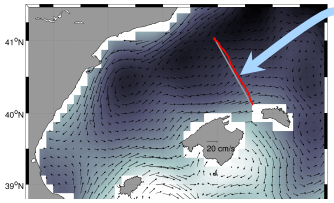
-32 sigma levels, spatial resolution : ~1.
-Boundaries conditions : MFS
-WRF 6km, every 3 hours
-bulk formulation.



Variables (T,S, current) are space and time interpolated at the glider location

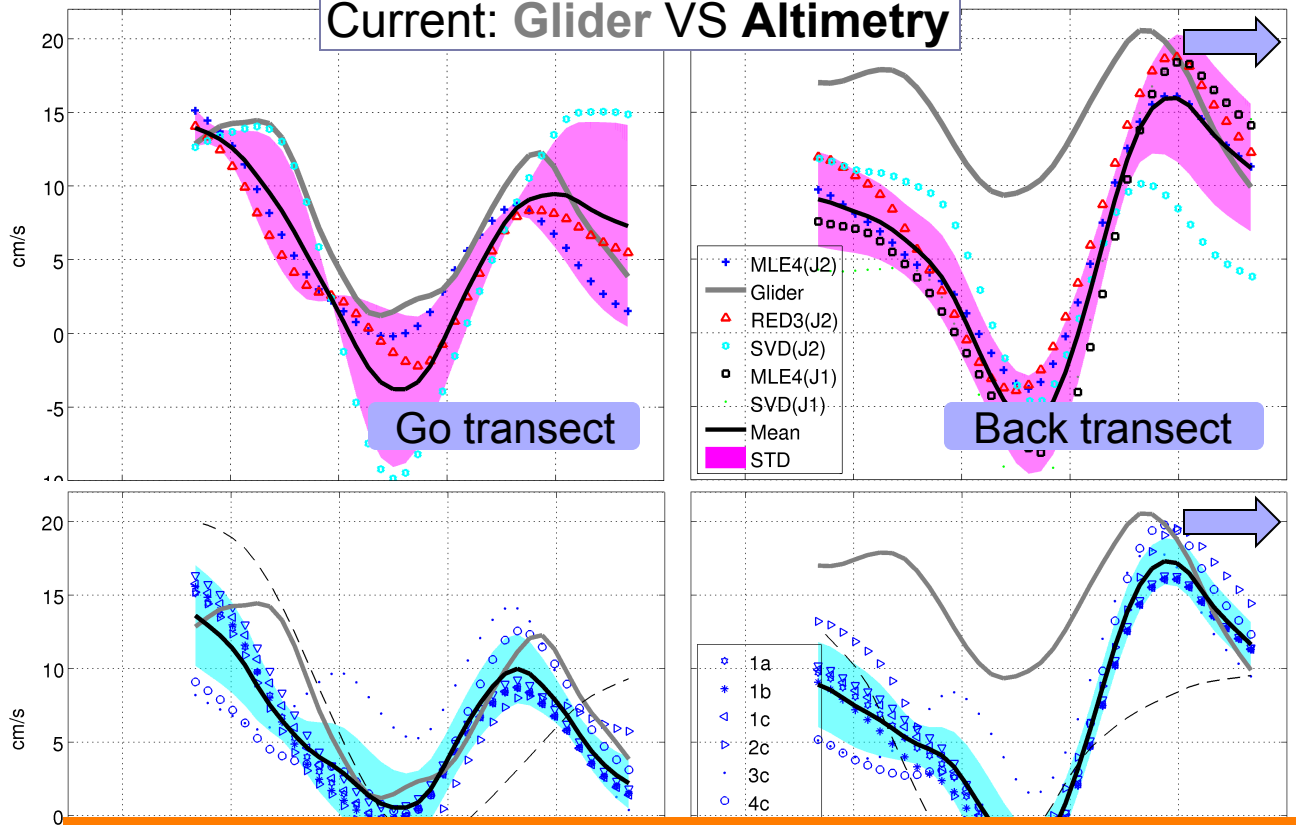
Cross comparisons and physical content characterization

At the surface



1D surface signals at glider locations

Current: Glider VS **Altimetry**

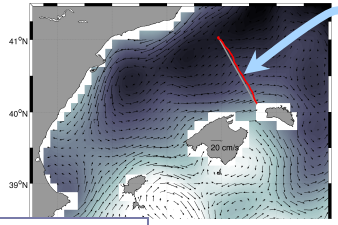


- **Impact of retracking:**
  - Except for OCE3 good agreement (J1-J2)
  - MLE4 and RED3 show close and better results at go (r: 0.9) than SVD
  - SVD improves results at back transect
- **Impact of corrections:**
  - Sensitivity to corrections (2.0 cm/s STD) lower than to retracking (3.2 cm/s STD)

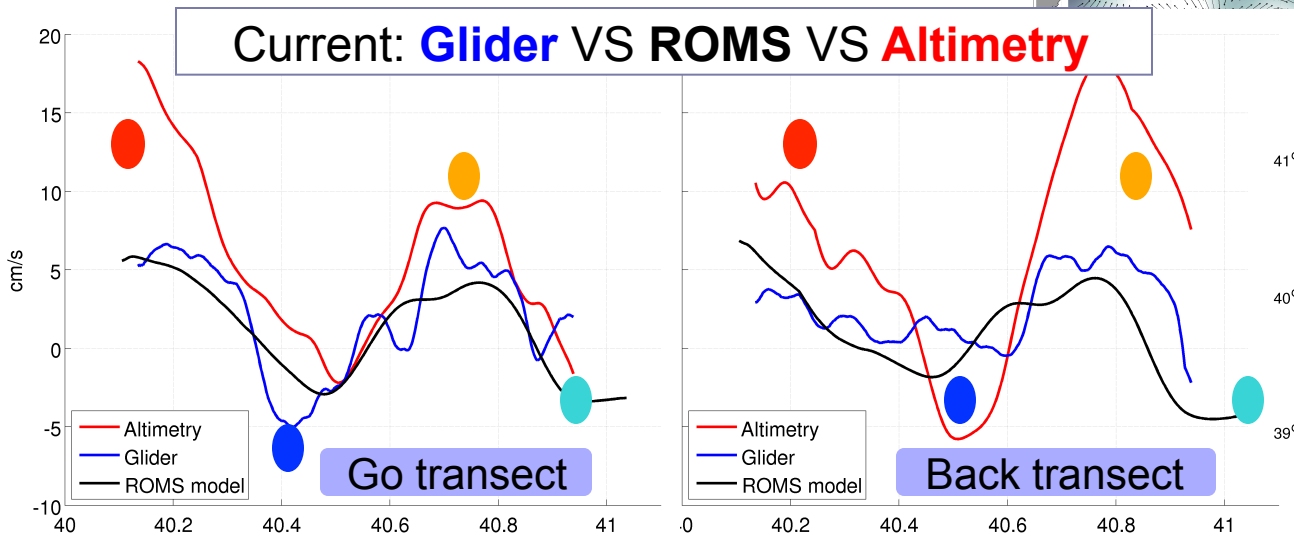
The best results are obtained with 20Hz edited data from RED3 or MLE4 retracking, GIM ionospheric correction and Radiometric Decontaminated Wet Tropo correction

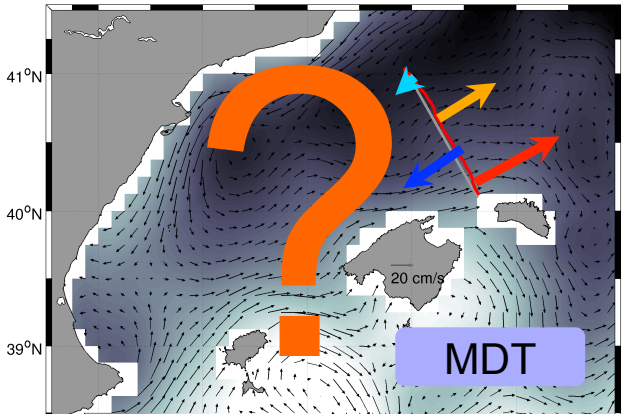
Cross comparisons and physical content characterization

- At the surface



1D surface signals at glider locations





- The surface Relative Geostrophic Currents built from glider (blue curve) and model (black curve) are in good agreement
- The surface Absolute Geostrophic Current derived from altimetry is also phased and show significant gradient in the cross-shore direction (**for what kind of oceanic structures ? Eddies ? Meanders ? Coastal currents ?**)

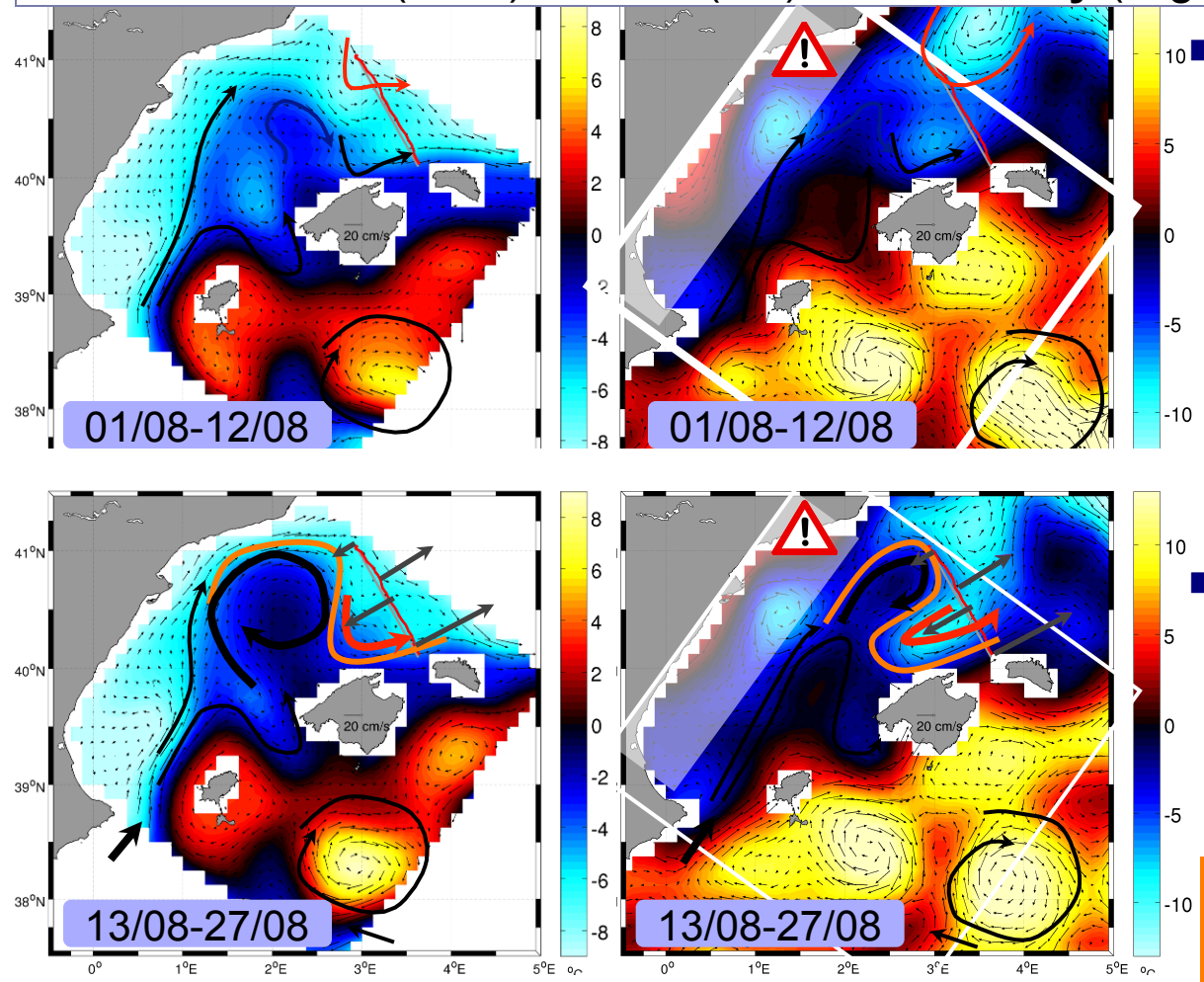
Need of a 2D synoptic view in order to localize oceanic features with respect to sporadic glider and along track altimetric measurements

Cross comparisons and physical content characterization

At the surface

2D surface signals

ADT+AGCurrent (cm/s): **ROMS** (left) VS **Altimetry** (Right)



- **Before the glider mission:**
  - General good agreement ROMS / AVISO MAP
  - Cyclonic gyre at North (CN >40.5°N) and intense anticyclonic Eddies at south
  - Small meandering, BC and AW inflow separated in 2 branches
- **During the glider mission:**
  - Increase of **AW inflow**
  - Current **meandering** at the interface between a **cyclonic** and **anticyclonic eddy**

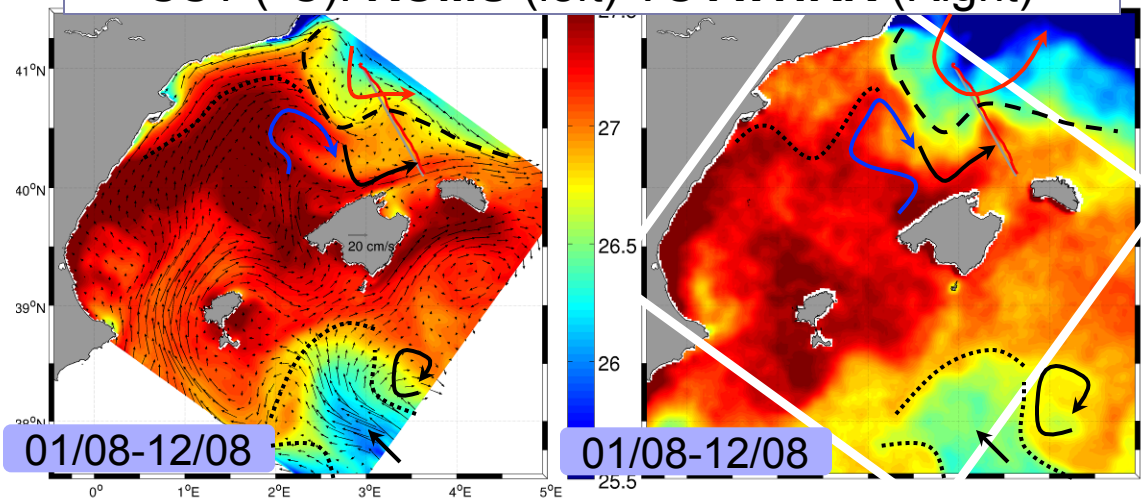
Should also be observed in SST

Cross comparisons and physical content characterization

2D surface signals

At the surface

SST (°C): **ROMS** (left) VS **AVHRR** (Right)

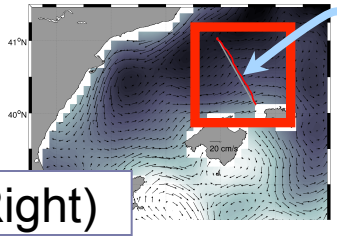


- **Before the Glider Mission:**
  - Very good agreement between ROMS, AVHRR SST and geostrophic current shown previsously
  - « Mushroom » at south
  - Front in temperature at north
- **During the glider mission**
  - The temperature front moves southward at the interface of two dynamical structures

Such strong interaction should induce instabilities observed at depth by glider profiles

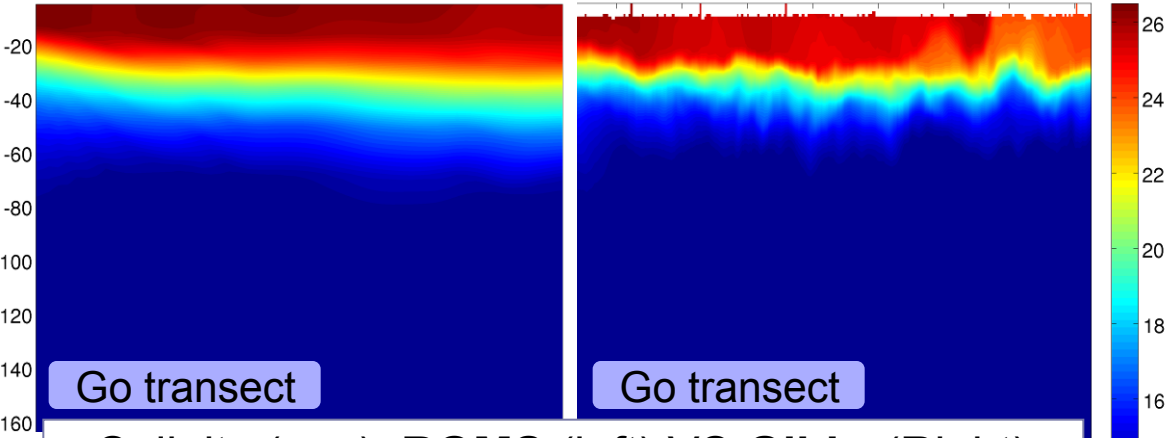
Cross comparisons and physical content characterization

- At depth

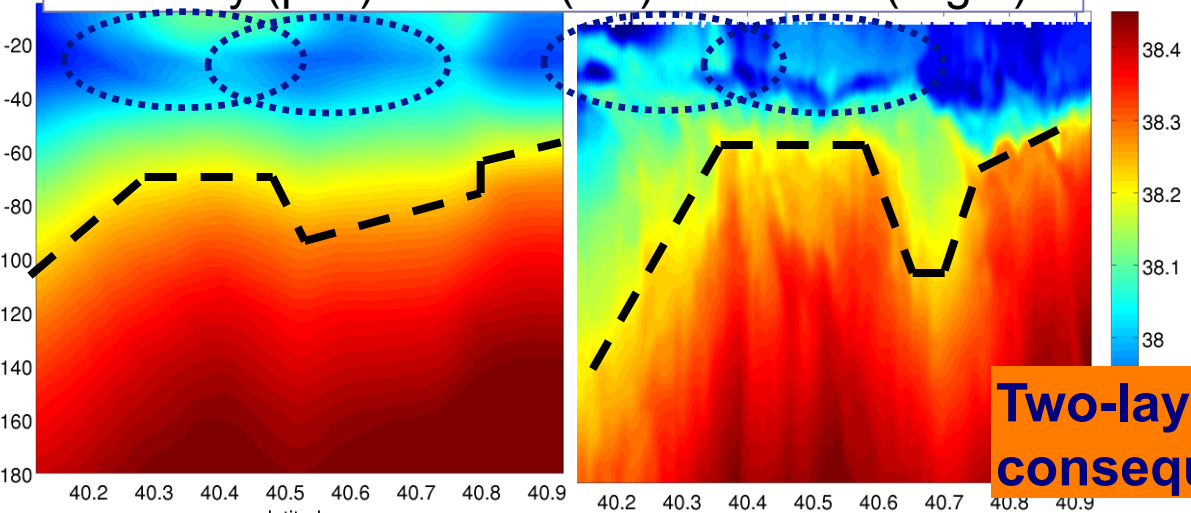


2D transect at glider locations

Potential Temp (°C): **ROMS** (left) VS **Glider**(Right)



Salinity (psu): **ROMS** (left) VS **Glider**(Right)

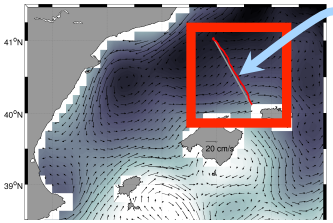


- **Temperature:**
  - Good agreement
  - Small horizontal gradients
- **Salinity:**
  - Small-scale features in mixed layer very different from structures in depth
  - Marked gradients (depth > 50 m) associated with (sub) surface mesoscale

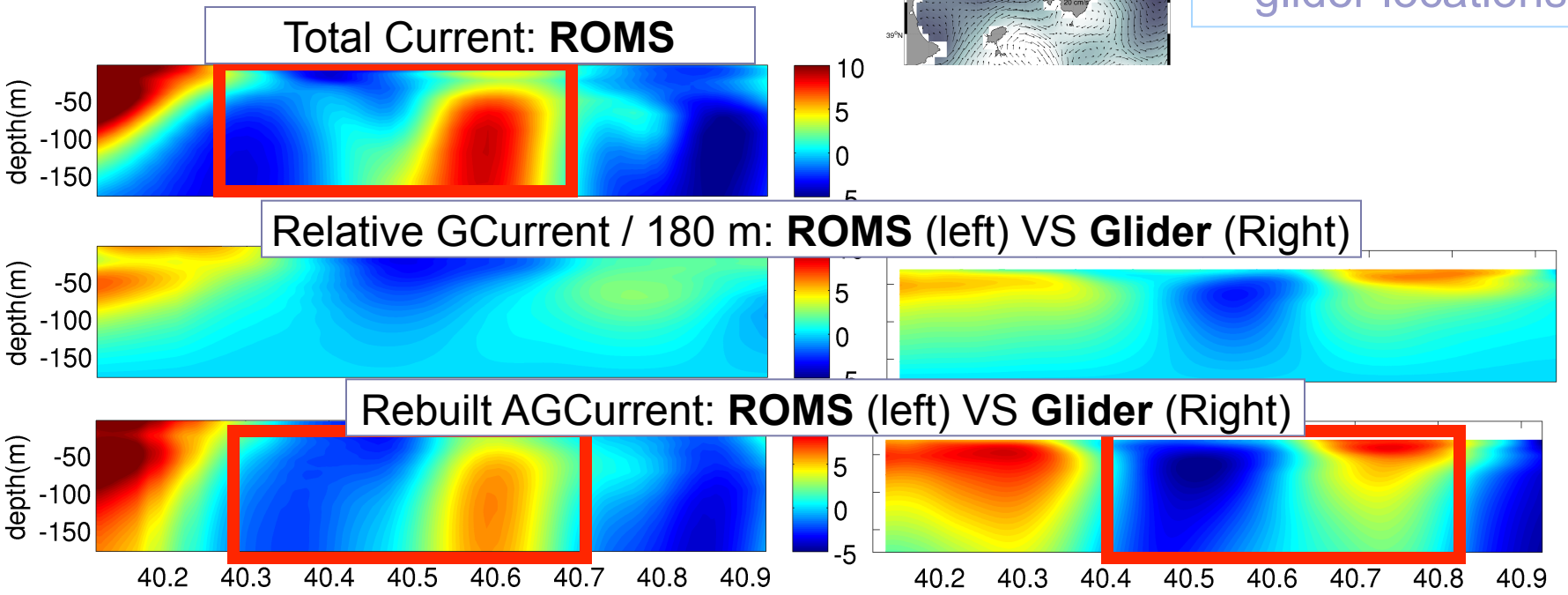
Two-layer dynamical system: What consequences for currents ?

Cross comparisons and physical content characterization

- **At depth**



2D transect at glider locations

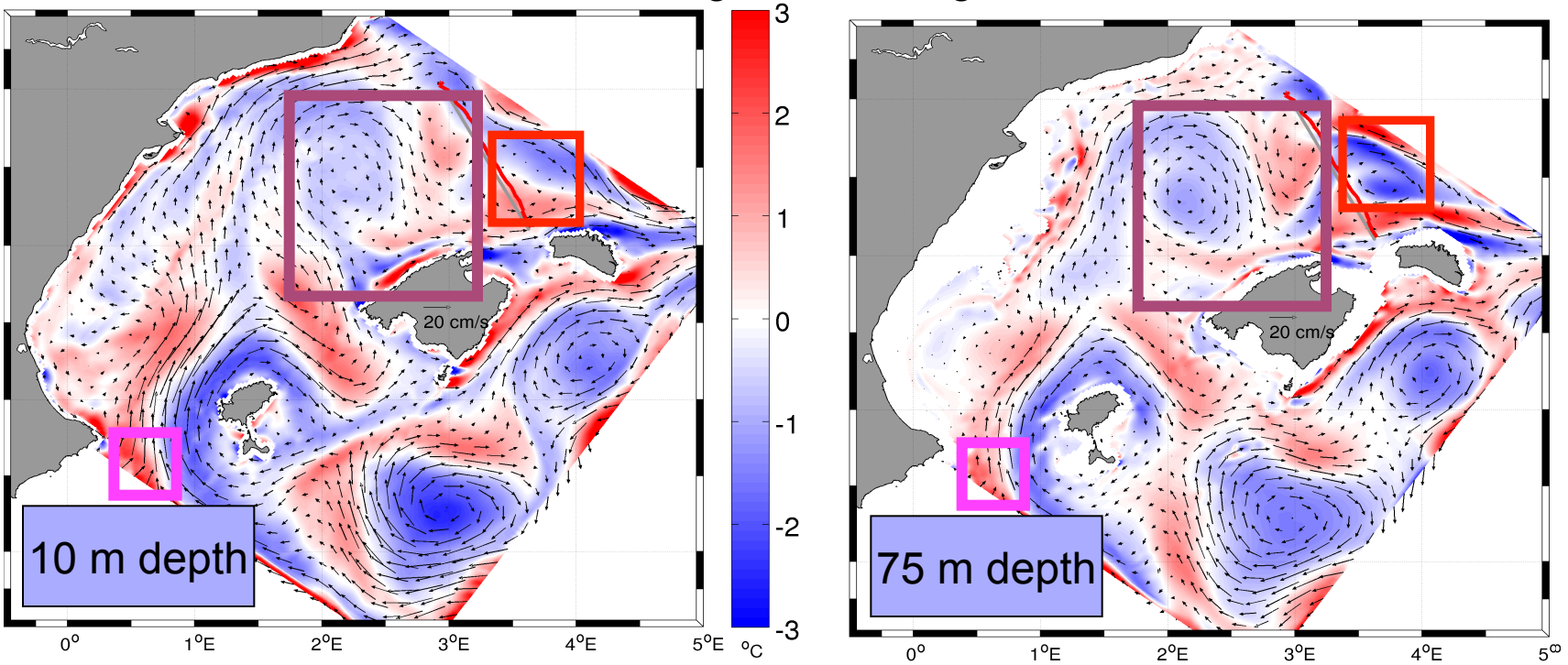


- In the model, the **« Total current » is very different from the « Relative geostrophic current »** because the surface doesn't reflect what happens at depth (see previously).
- **When the RLC is applied** the « Rebuilt AGC » is in **agreement** with the « total

A strong current is observed, specifically in depth: What are the associated forcing and mechanisms ?

Origin and mechanisms associated with a 3D observed small-scale eddy

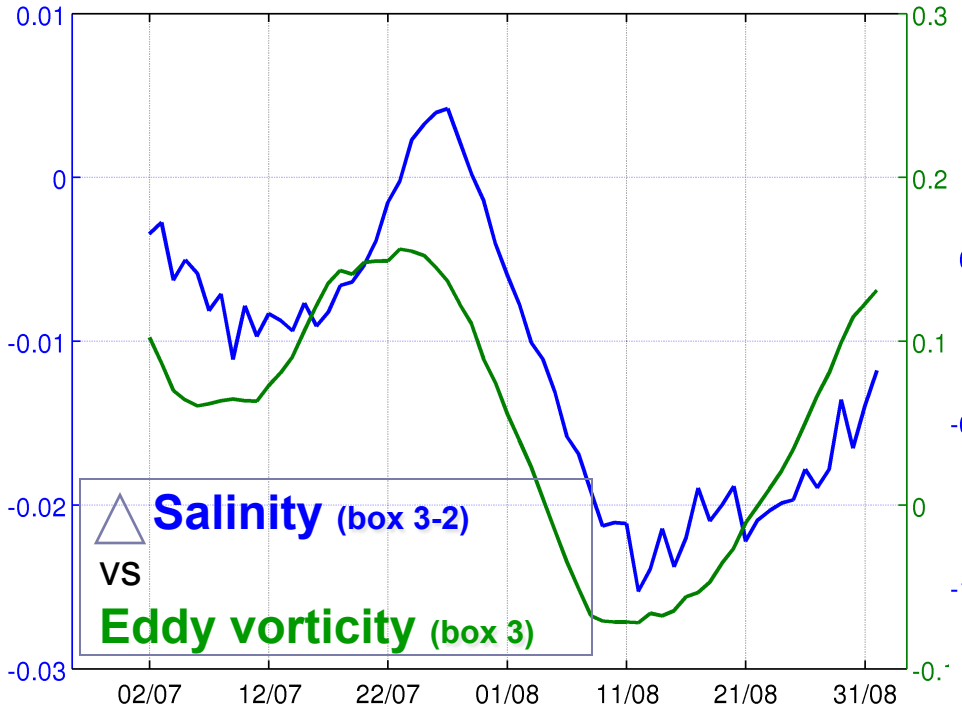
- **Relative vorticity** 13 August – 27 August

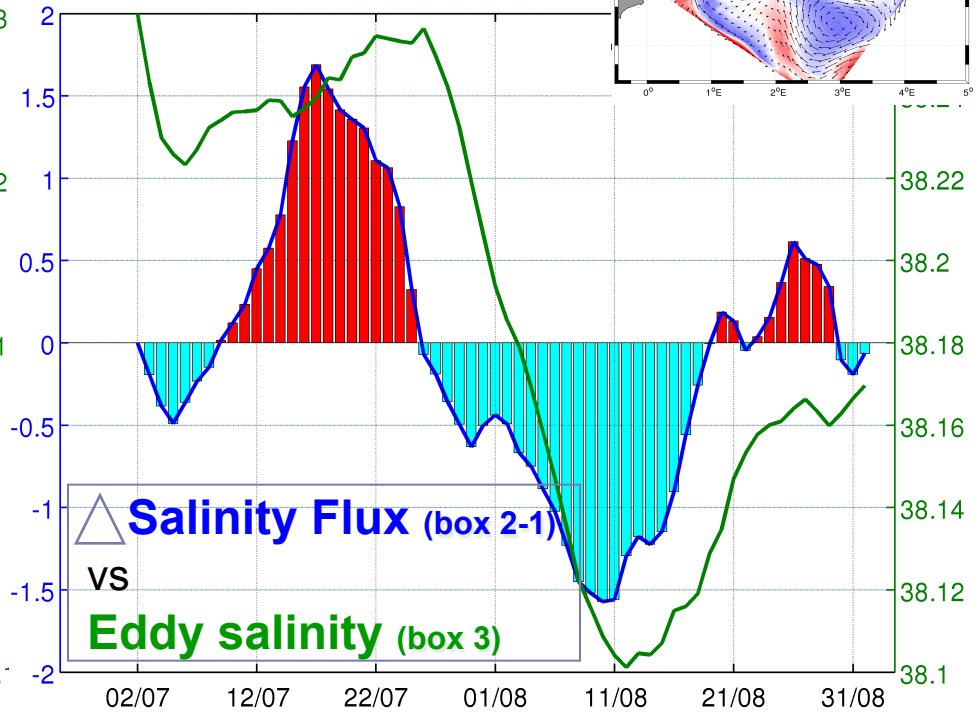


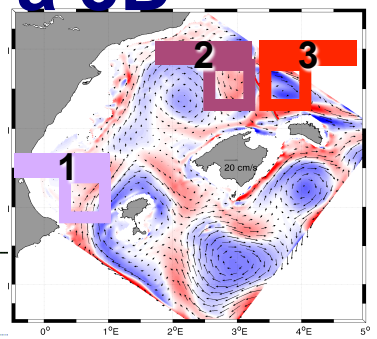
- 2 eddies are observed at the surface and at depth with opposite and strong vorticity
- These structures will progressively loose intensity and move (northward for anticyclonic eddy and southward for the cyclonic one) until mid August.
- Then, the anticyclonic eddy expand and a **secondary small-scale anticylonic structure** is generated with currents stronger at depth (in agreement with glider)

Origin and mechanisms associated with a 3D observed small scale eddy

- Relation between salinity and eddy intensity







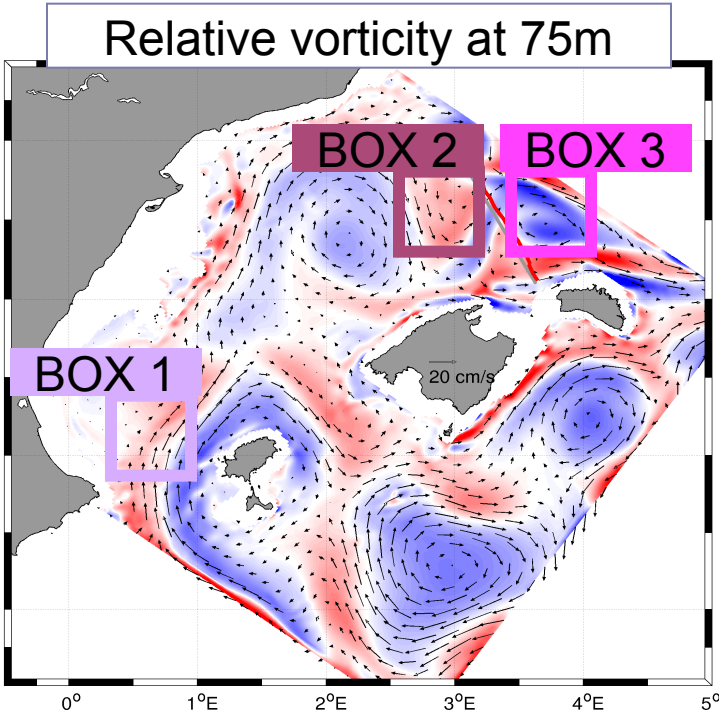
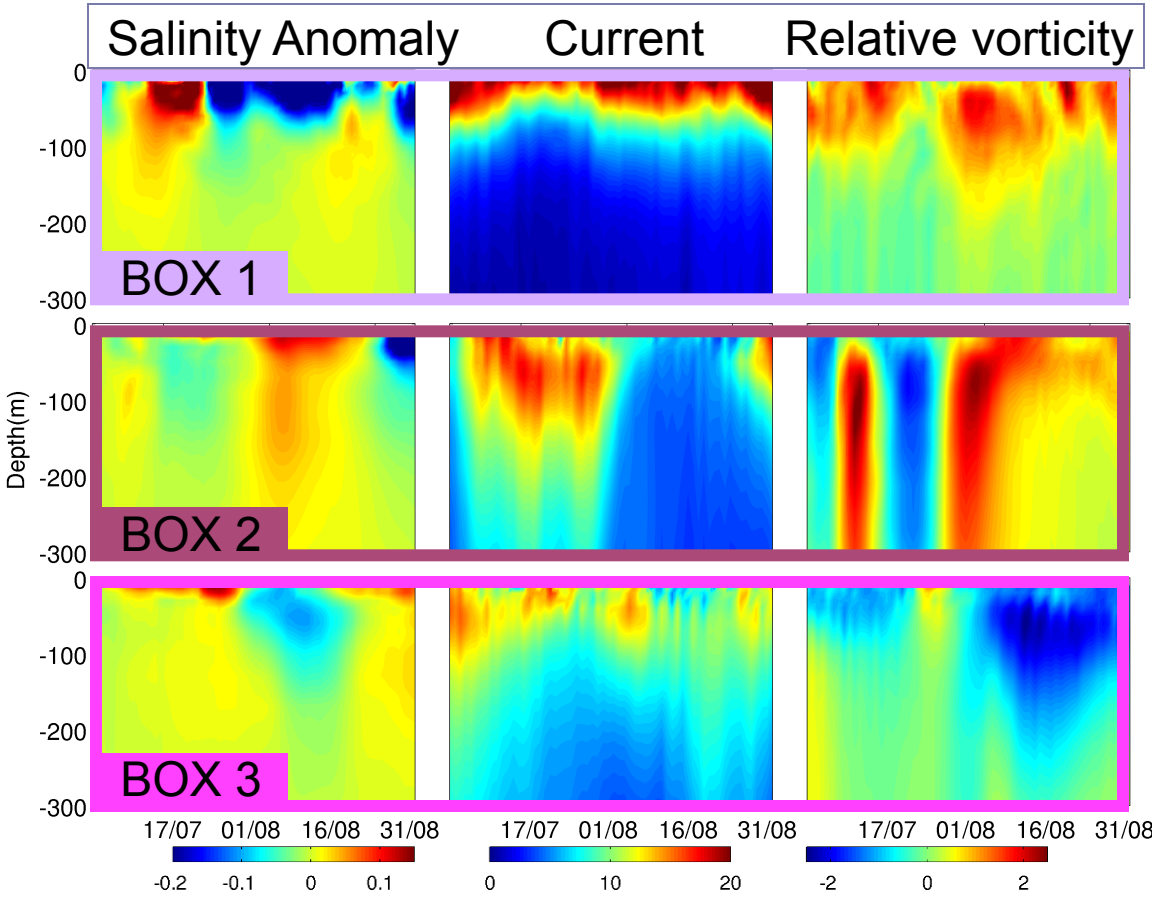
- The vorticity inside the small-scale anticyclonic eddy (**Box 3**) seems controlled by the local salinity grandient (5-day lag correlation of 0.95)
- This strong gradient is the result of a massive AW water inflow at south (**Box 1**) that interact with more salty MAW at North (**Box 2**). The more intense the salinity flux of AW is, the stronger the salinity gradient at the eddy location (**Box 3**)

Conclusions

- New methodologies have been developped and tested to **improve the altimetry-glider consistency** by partially solving the Reference Level issue for glider and using 20Hz data for altimetry
- In addition to **editing** and **20Hz sampling** (cf. *Bouffard et al., 2010*), altimetric **retracking** technics and **corrections** have also been shown to be key aspects for improving altimetry in coastal area
- In this study a **multi-sensor integrated approach** has allowed to **characterize a small scale (sub)surface and anticyclonic eddy.**
- Its vorticity is controlled by **salinity gradients** (and **not temperature**) resulting from an AW inflow interacting with the return loop of the NC at north.
- This structure is **clearly observed at depth** whereas this is partially hidden by chaotic (sub)mesoscale features occurring only in the mixed layer.
- Reasonable agreements between multi-sensor data and the ROMS model show also promising perspectives for **operational applications including data assimilation** (*eg.* ***SOCIB*** *coastal observatory and MyOcean FP7 project*)

Reference (2day-old paper):

Bouffard, J., A. Pascual, S. Ruiz, Y. Faugère, and J. Tintoré (2010), Coastal and mesoscale dynamics characterization using altimetry and gliders: A case study in the Balearic Sea, ***J. Geophys. Res.*****,** 115, C10029, doi:10.1029/2009JC006087.

Origin and mechanisms associated with a 3D observed small-scale eddy

- Water mass characteristics