Multi-sensor approach towards coastal ocean processes monitoring

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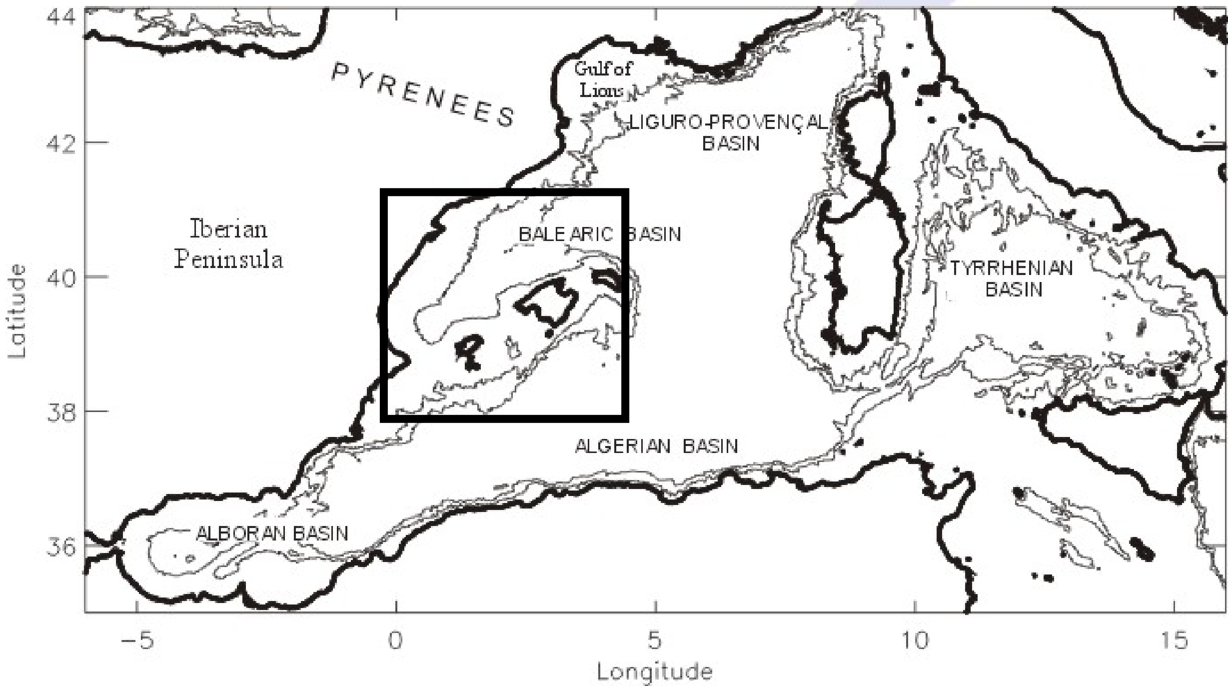
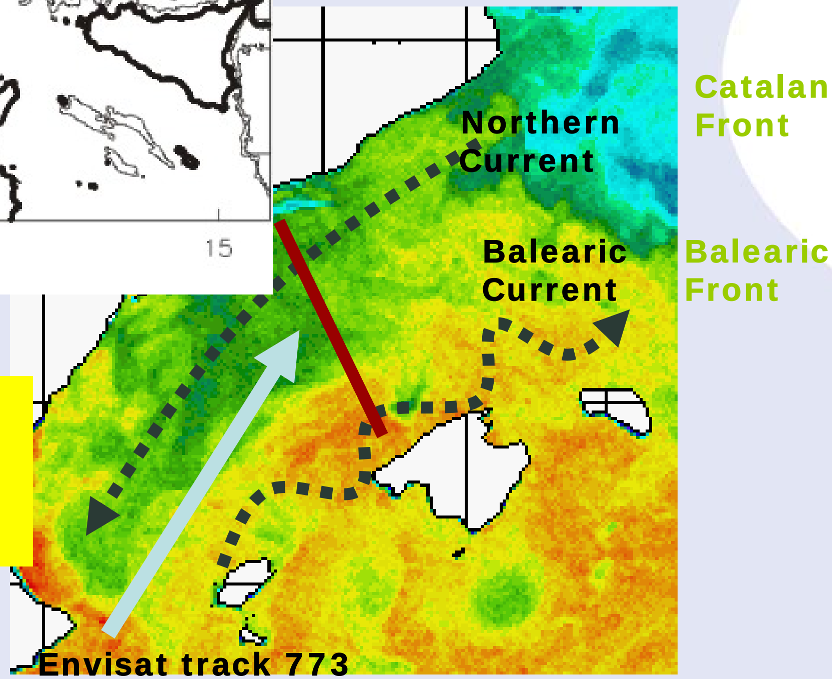
Outline

- Objectives
- Area of study and data sets
- Methodology
- Results: April 2008 mission
- Summary and Future Work

Area of Study: Balearic Sea





Sustained observational glider programme:

Missions simultaneous to Envisat passage along track 773 (perpendicular to the Balearic front)

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Objectives

SPECIFIC OBJECTIVES:

– Characterization of coastal fronts combining altimetry and glider data.

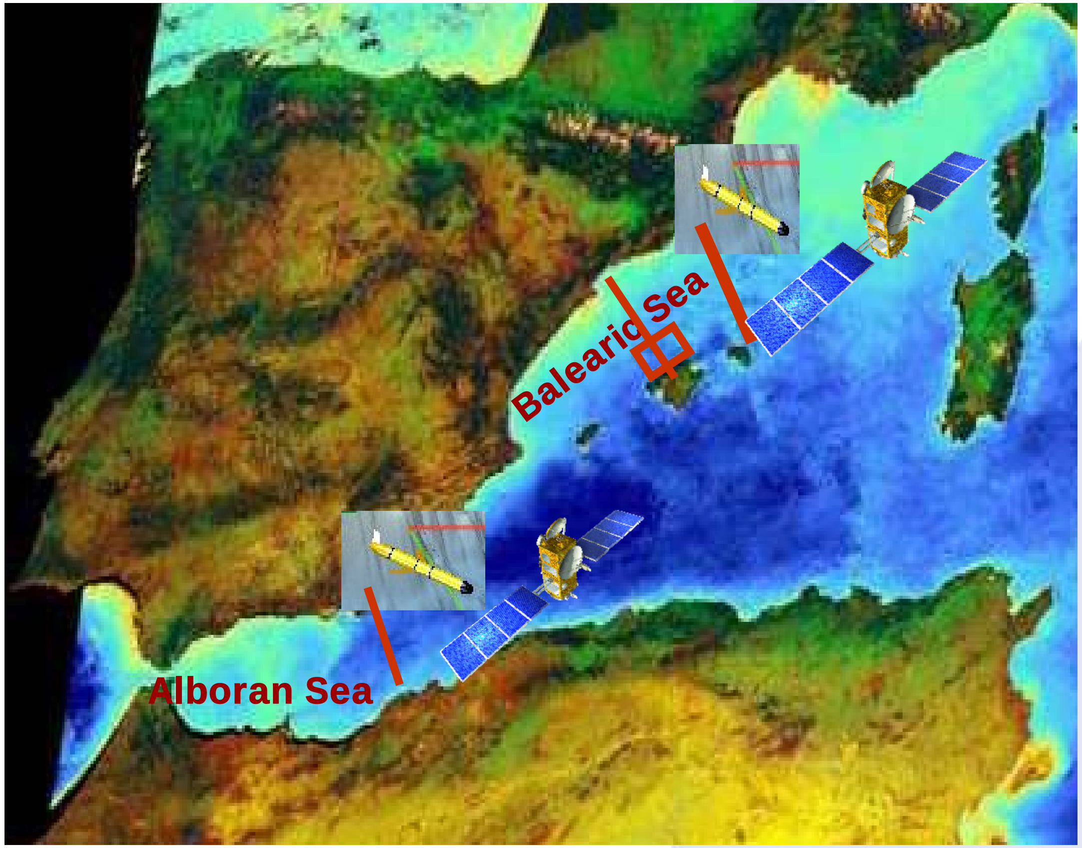
– Explore the use and limitations of altimetry data in the coastal area.

Sustained observational program along altimetry track

Framework:

– **ECOOP / MyOcean EU project / OSTST proposal**

Glider Missions Background along altimetry tracks



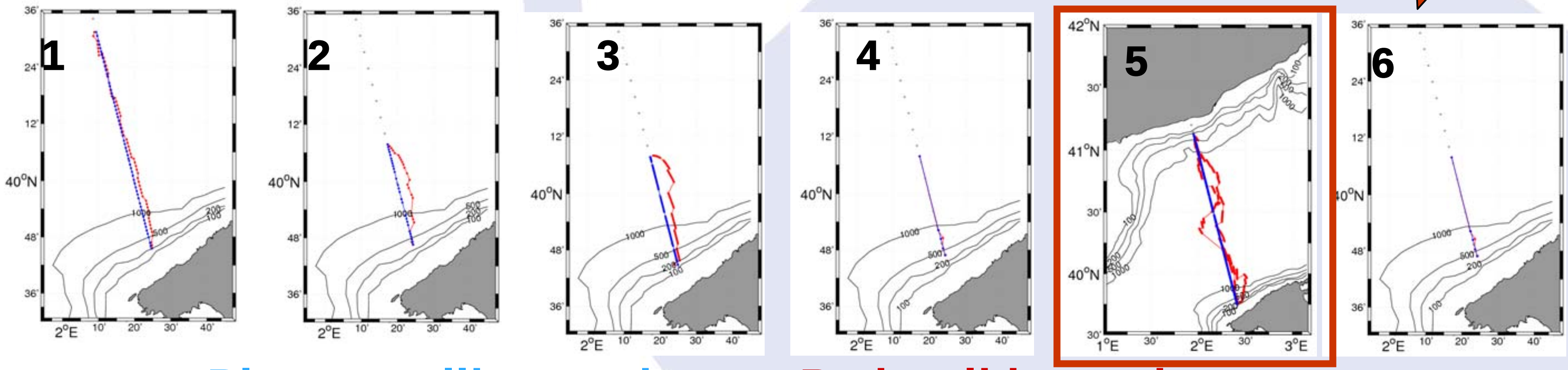
6000 full CTD casts
+ oxygen, chlorophyll
turbidity (180 m)

- **ENVISAT:**
  - **Balearic Sea**: T-773. Sustained glider observations (every 70 days): 6 missions up to now
- **JASON-1/2:**
  - **Alboran Sea**: T-172 (July 2008). Cycles Jason-2: 0 & 1
  - **Balearic Sea**: T-70 (August 2008). Cycles Jason-2: 4 & 5
- **JASON-1 (new orbit):**
  - **Balearic Sea:** T-70 (May 2009). SINOCOP experiment: Great challenge: 2 gliders covering an area of 50 x 40 km2: 3 missions

The Balearic Front: gliders missions

N. sampling	Dates	Envisat Cycle	Comments
1	6-13 Jul 2007	59	Complemented with CTD from oceanographic cruise. Z: 0 – 600 m H resolution: 5-12 Km
2	14-17 Sep 2007	61	-
3	23-27 Nov 2007	63	-
4	1-5 Feb 2008	65	Performed with CTD due to a failure of the glider
5	7-23 Apr 2008	67	Mainland coast reached
6	20-24 Jun 2008	69	

+3 missions in 2009



Blue: satellite track - Red : glider trajectory

First results

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Mesoscale dynamics of the Balearic Front, integrating glider, ship and satellite data

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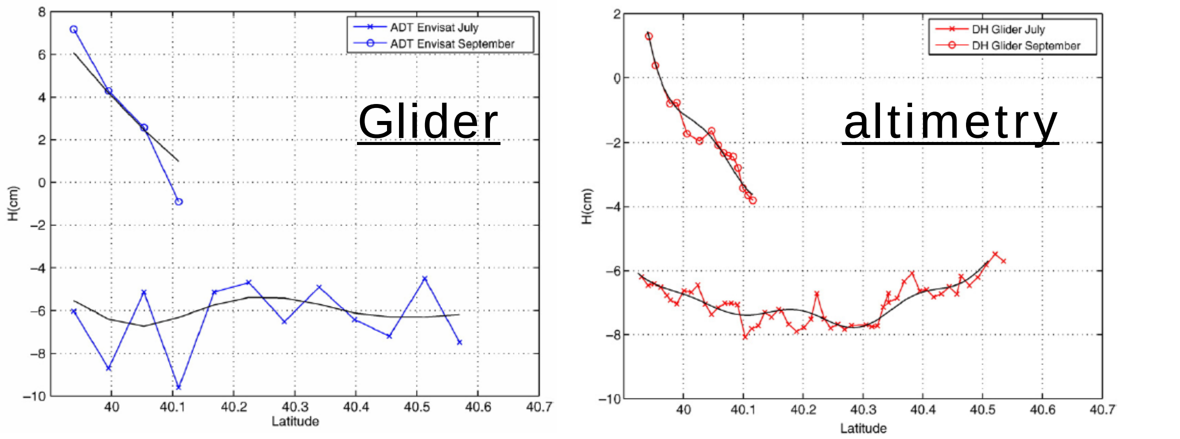
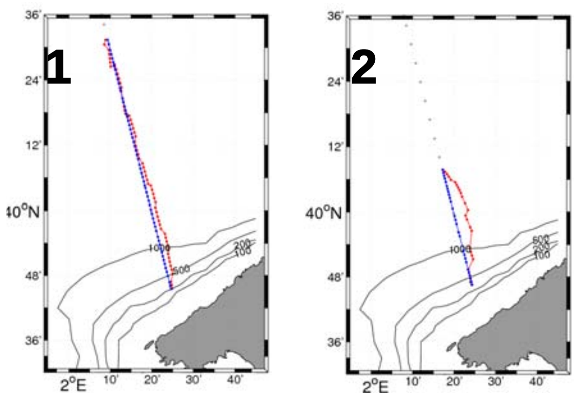




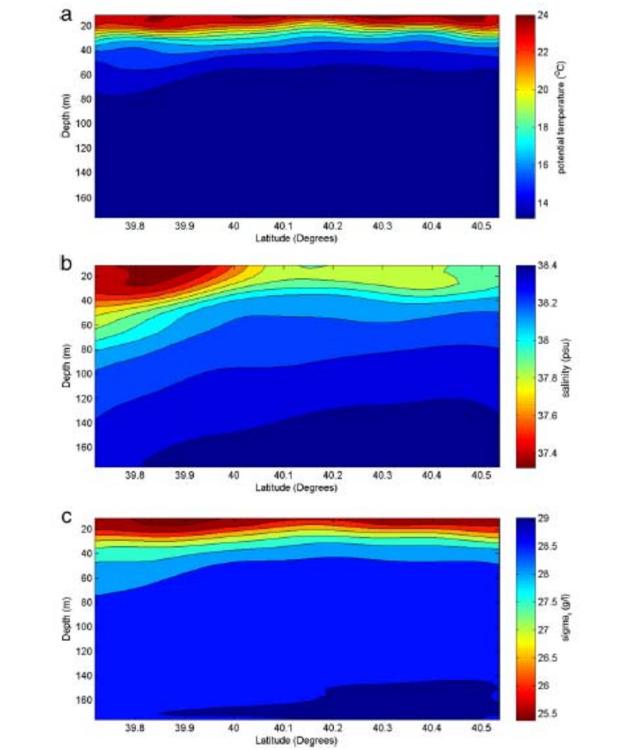


Fig. 3. Optimal Statistical Interpolated fields of temperature (°C), salinity (PSU) and density (sigma-t) from the glider mission, July 2007.

- Only 2 missions (2007)
- Standard altimetry AVISO products (1 Hz)

Data Sets

Envisat

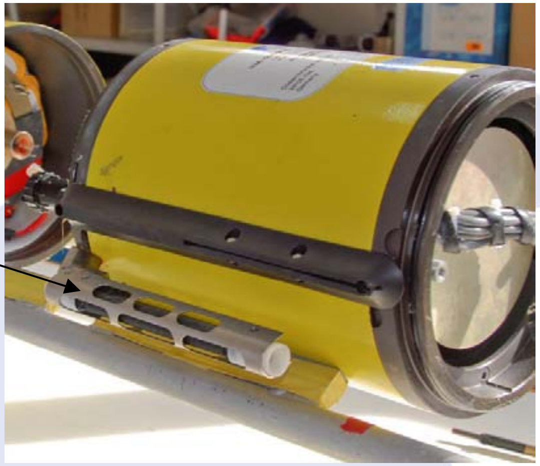
- Along track SLA (1 Hz / **20 Hz**)
  Horizontal resolution: 7 km / 500 m
- Corrections:
  Tides, HR HF barotropic motion (DAC), …
- Gridded products
- MDT: Mean Dynamic Topography (Rio et al. 2007)
- ADT = SLA + MDT

Glider

- **Variables:**
  P, T, S, oxig., chl., turb.
  Depth averaged GPS currents
- **Vertical extension:**
  10-180 m
- **Horizontal resolution: ~0.5 km**

Glider data processing: Thermal Lag issue on CTD data

- **Situation:**
  - Temperature sensor measures sea water temperature **outside** of the conductivity cell.
  - Conductivity sensor measures sea water conductivity **inside** of the conductivity cell.
  - Conductivity cell **walls store heat**, warming up in-cell water when moving to cooler waters, and cooling it down when moving to warmer waters.
  - Conductivity is affected by temperature.

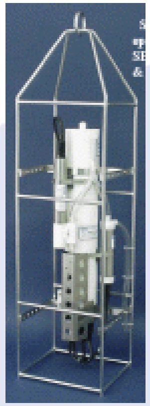


Result:

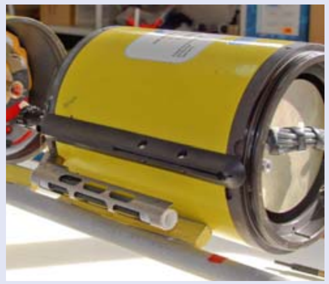
Salinity is computed from out-cell temperature and in-cell conductivity.
Salinity present important errors on strong temperature gradients (thermocline).

Glider data processing: Thermal Lag issue on CTD data

- **Previous works have studied this problem and proposed techniques to mitigate it:**
  - *Thermal Inertia of Conductivity Cells: Observations with a Sea-Bird Cell* (Lueck & Picklo, 1990).
  - *The Correction for Thermal-Lag Effects in Sea-Bird CTD Data* (Morison et al., 1994).
  - And many more references…



- **(Slocum) gliders arise new problems that make difficult to apply traditional techniques without modifications:**
  - CTD is not pumped. Therefore, flow speed depends on glider surge speed.
  - CTD sampling has low temporal resolution (~0.5 Hertz).
  - CTD sampling interval is not perfectly regular.



Glider data processing: Thermal Lag issue on CTD data

- **Some generalizations to correction techniques and their parameters estimation methods are under development to improve glider CTD data quality.**

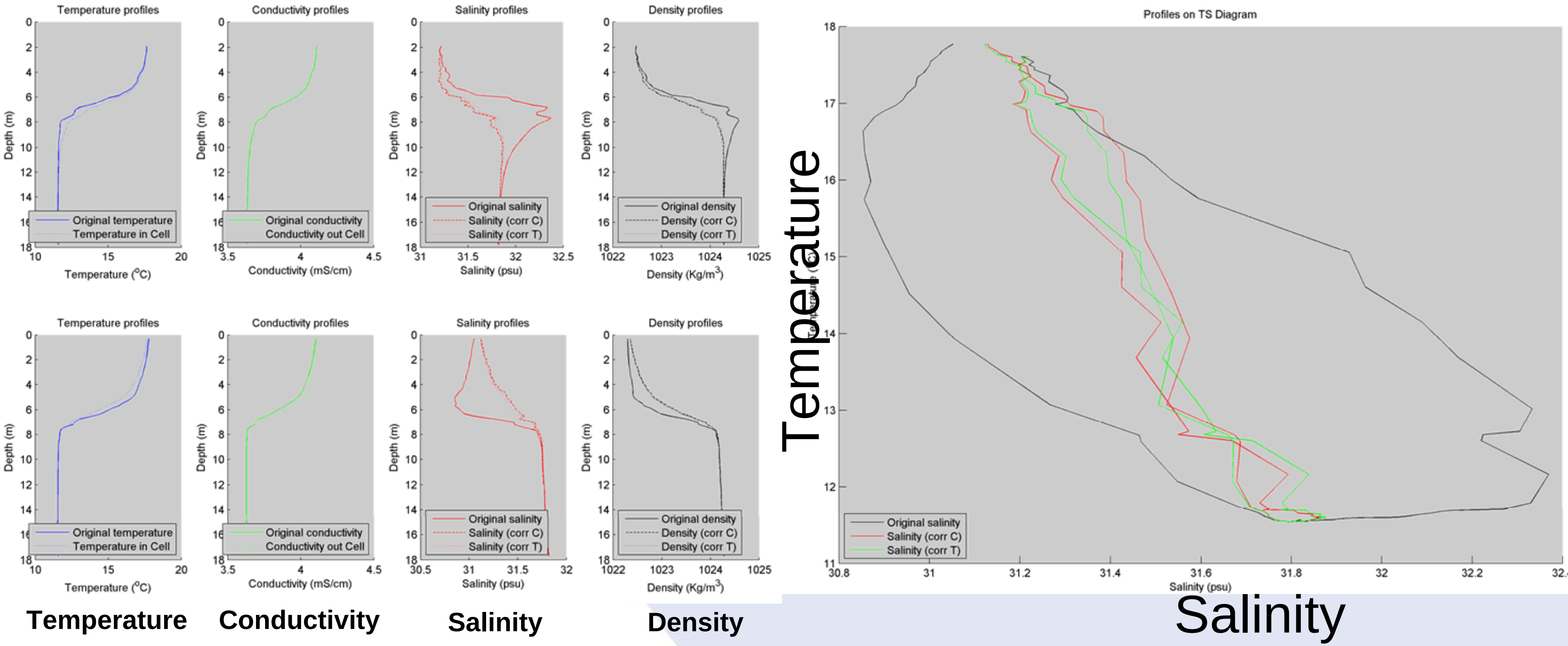
- **Time "constant" and magnitude are no longer constants dependent on CTD sensor, but also related to glider speed and attitude.**

A proposed methodology (Garau et al., 2009, in preparation)

- **Estimation of their relation is performed through a minimization process:**
  - Minimum area between two consecutive glider profiles in the TS diagram (assuming same water).
  - Minimum area between glider profile and CTD cast (ground truth).

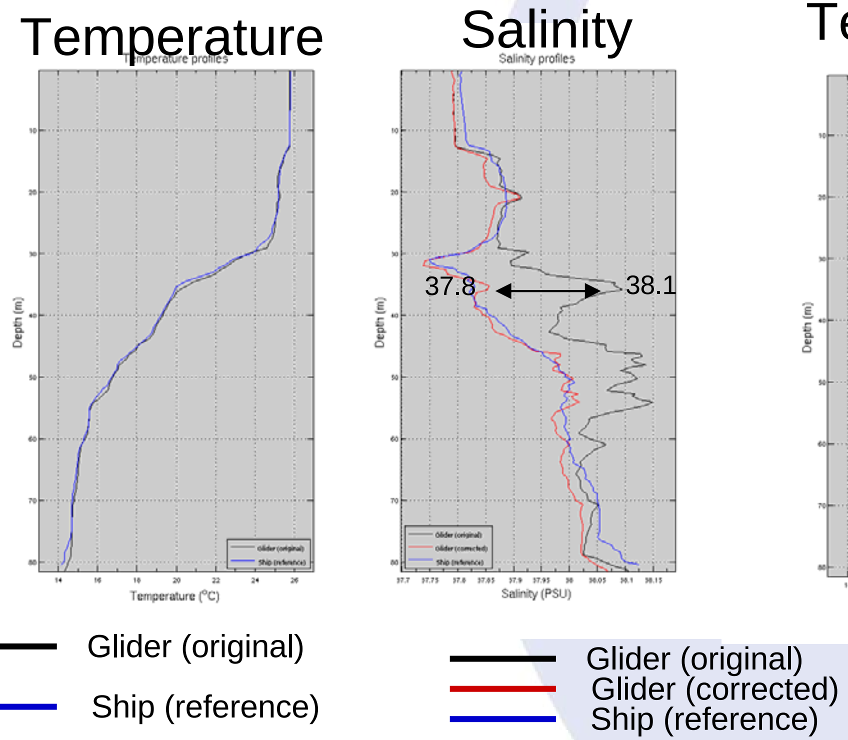
Glider data processing: Thermal Lag issue on CTD data

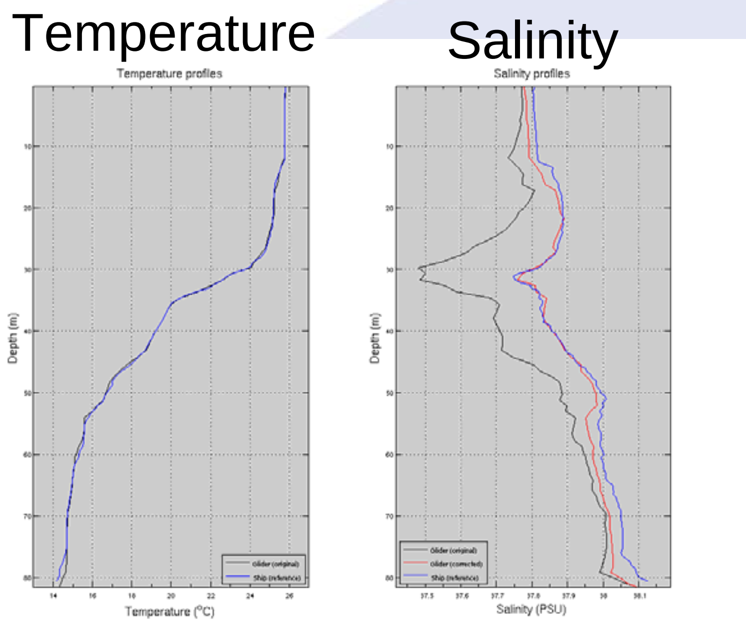
- **Glider downcast vs. glider upcast, promising results:**
  - Salinity spikes reduced.
  - TS hysteresis reduced.



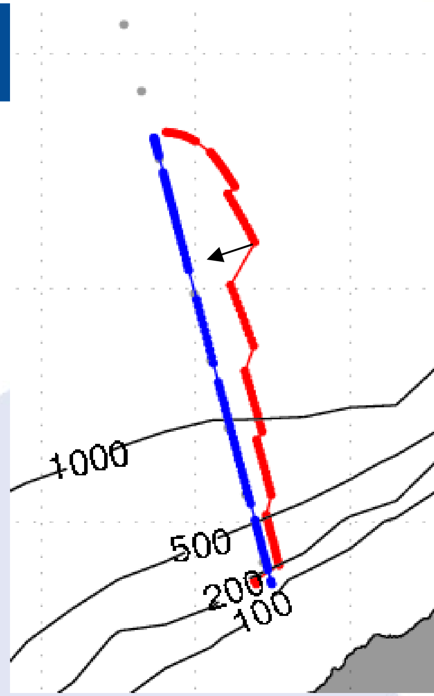
Glider data processing: Thermal Lag issue on CTD data

- **Glider vs. CTD cast, promising results:**
  - Salinity spikes reduced.
  - Better profile fitting.





Glider Data Processing



- Dynamic height (DH) computed from P, T, S profiles with a ref. level 180 m.
- Projection of the glider observation position onto the closest track point.
- Different filters (lanczos, loess, Powen-Leben) are used for the computation of surface geostrophic velocities (Vg surf 180) from DH.
- Computation of absolute geostrophic currents by combining Vg surf 180 and depth averaged GPS currents:

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

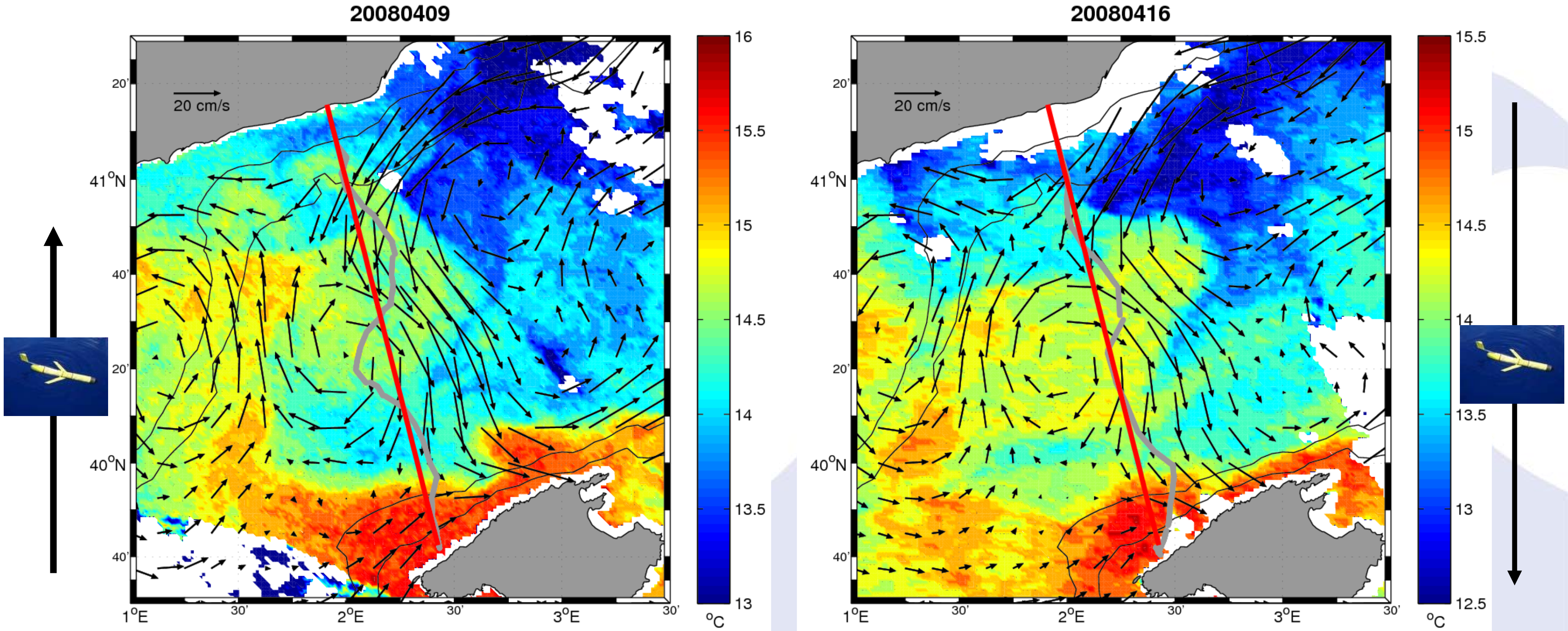
GPS currents — DH profile — unknown — mog2d model — Ekman + cyclostrophic

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

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

April 2008 mission: an intense eddy

Sinoptic view from remote sensing data



Color: SST. Source: ICM.

Vectors: Absolute geostrophic currents from DT merged altimeter gridded fields. Source: AVISO.

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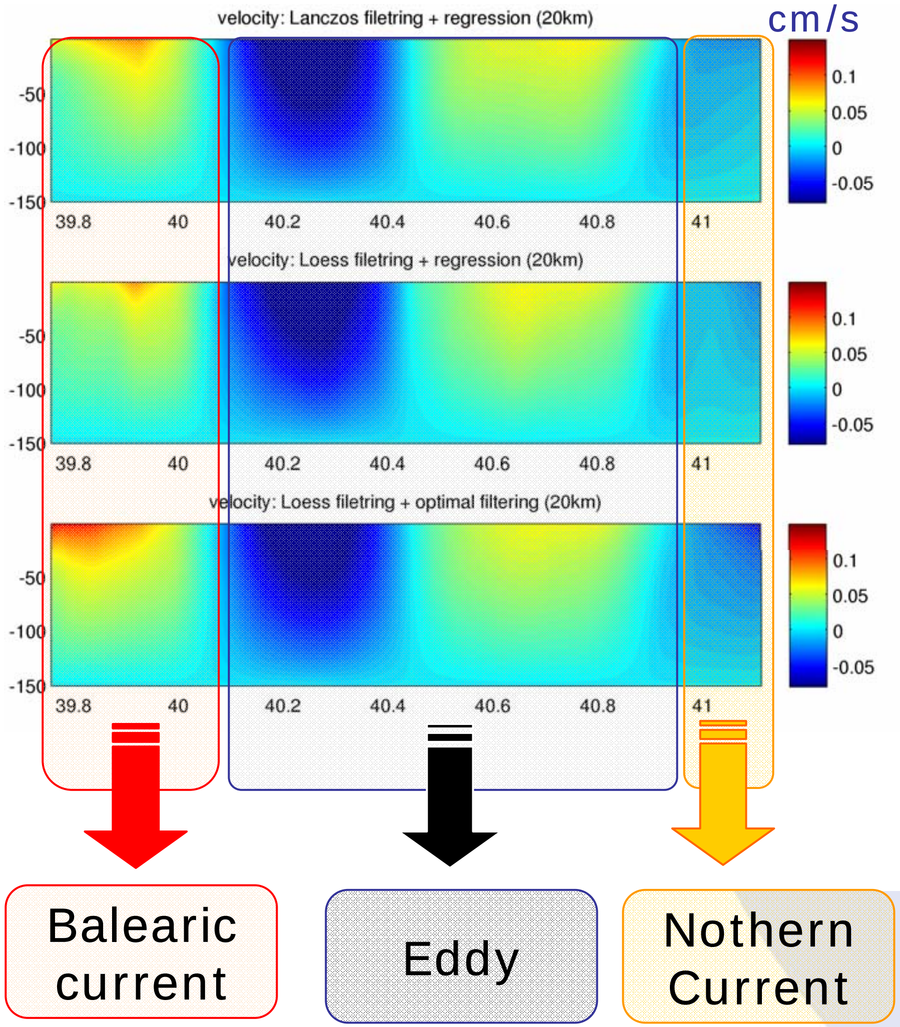
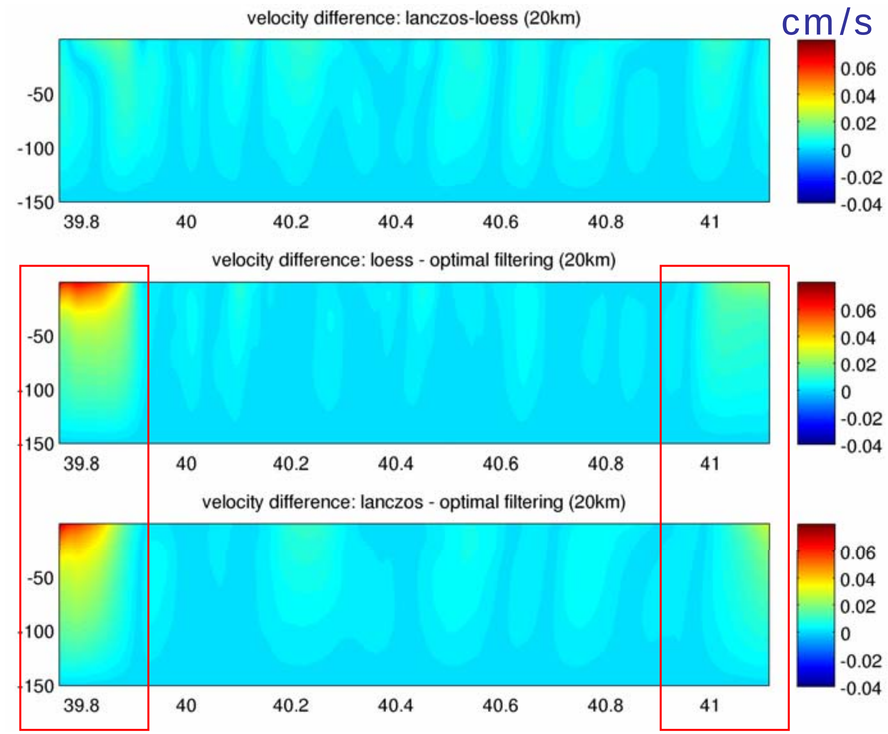
Glider results: geostrophic velocity calculation

- **Slope calculation: standard vs Powell et Leben (2004)**





- Main dynamical patterns both observed with the 3 methods
- Significant differences in the balearic and Iberic coastal zones (resp 6 and 3 cm/s)

(Bouffard et al., JGR, to be submitted)

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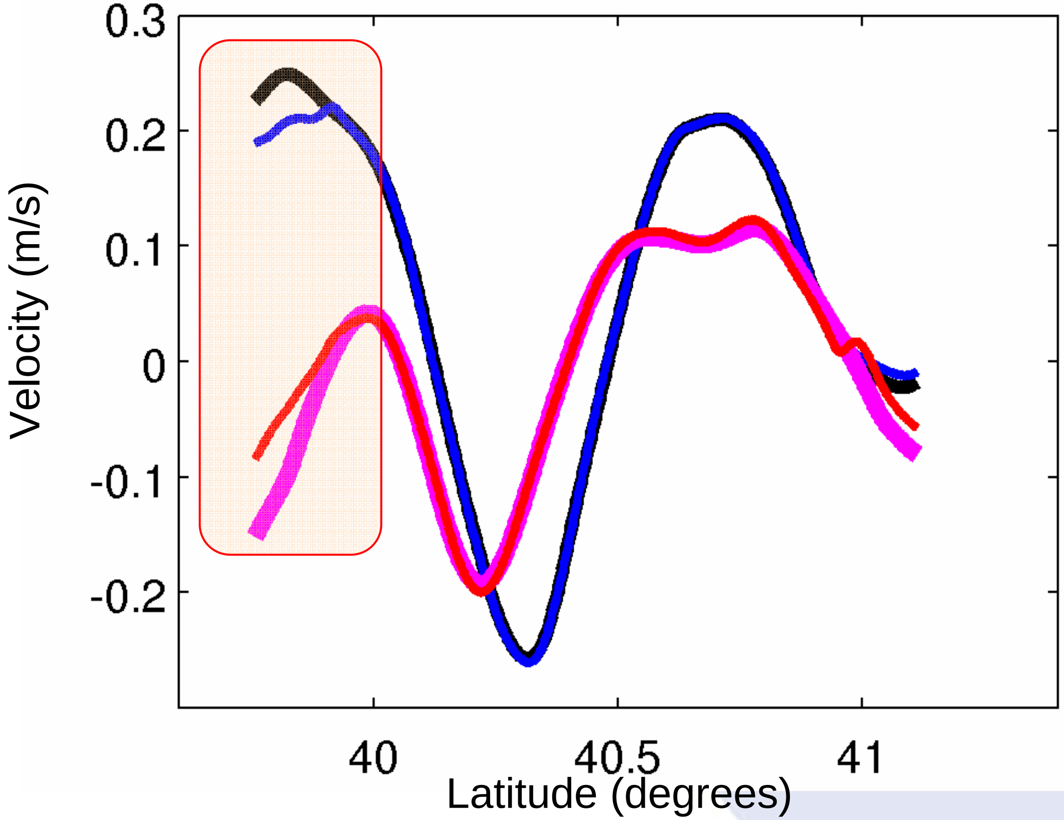
Glider vs altimetry currents

1 Hz data

Altimetry **VS** Glider



• Good agreement but **huge disagreements (>30cm/s) in the Balearic coastal zone and less amplitude in the glider.**

- Correlation: 0.71
- Std diff: 10.4 cm/s
- Err var: 50 %

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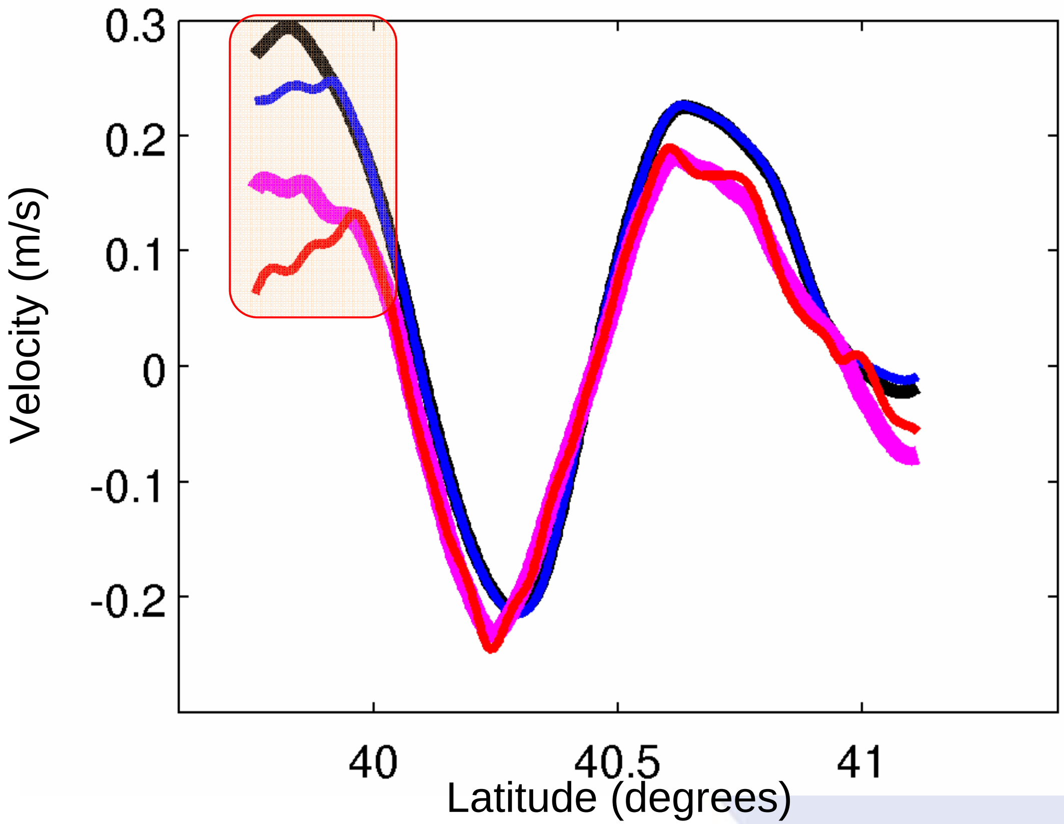
Glider vs altimetry currents

20 Hz data

Altimetry vs Glider



- P&L filtering impacts (black and magenta) only in the 20 km coastal band.
- 20 Hz improves the overall agreement between altimetry and glider velocities.
- Disagreements in the Balearic coastal zone are still significant but smaller than with 1 Hz.

- Correlation: 0.97
- Std diff: 4.0 cm/s
- Err var: 5 %

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Comparison Glider-altimetry

method 1: Statistics

Altimetry 1 hz, **Glider & MDT: 20 km filtered SLA,** standard slope calculation

		CTD surf 5.5 cm		CTD surf + *ref 180 m* 14.6 cm		CTD surf + *ref 180 m* *(correted Ekman + barotrope)* 14.7 cm	
		corr	Rms diff	corr	Rms diff	corr	Rms diff
Alti 12.2cm	1	**0.65**	**9.6**	**0.56**	**12.9**	**0.55**	**13.0**
	2	**0.28**	**11.9**	**0.46**	**14.8**	**0.44**	**15.4**
	int	0.58	10.1	0.56	12.7	0.55	13.0
Alti +*MDT old* 9.2 cm	1	**0.80**	**5.7**	**0.67**	**11.0**	**0.68**	**10.8**
	2	**0.59**	**7.4**	**0.69**	**11.4**	**0.68**	**12.1**
	int	0.76	6.2	0.71	10.4	0.70	10.5
Alti + *MDT new* 8.1 cm	1	**0.73**	**5.6**	**0.60**	**11.8**	**0.61**	**11.6**
	2	**0.78**	**5.2**	**0.73**	**11.2**	**0.73**	**11.7**
	int	0.72	5.6	0.65	11.2	0.65	11.2

- Temporal interpolations :improvement between 1 and 10 %
- Ekman and barotrope corrections: small negative impact of (<3%)
- MDT: Improvement of 10 and 16 % for respectively MDT_new and MDT_old

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Comparison Glider-altimetry

method 1: Statistics

Altimetry 20 hz, **Glider & MDT: 20 km filtered SLA,** standard slope calculation

		CTD surf 5.5 cm/s		CTD surf + *ref 180 m* 14.6 cm/s		CTD surf + ref 180 m *(correction Ek+ barot) 14.7 cm/s*	
		corr	Rms diff	corr	Rms diff	corr	Rms diff
Alti 14.2 cm/s	**1**	**0.86**	**9.8**	**0.82**	**8.6**	**0.82**	**8.9**
	2	**0.57**	**11.9**	**0.70**	**11.5**	**0.7**	**11.9**
	int	0.81	10.3	0.83	8.3	0.82	8.7
Alti + *MDT old* 12.2 cm/s	**1**	**0.97**	**6.8**	**0.92**	**5.9**	**0.92**	**5.8**
	2	**0.84**	**8.0**	**0.90**	**7.1**	**0.89**	**7.7**
	int	0.95	7.1	0.96	4.6	0.95	4.8
Alti + *MDT new* 11.3 cm/s	**1**	**0.86**	**7.0**	**0.82**	**8.6**	**0.82**	**8.4**
	2	**0.94**	**6.2**	**0.89**	**7.7**	**0.89**	**8.0**
	int	0.89	6.9	0.87	7.4	0.87	7.3

- Temporal interpolations :improvment between 6 and 10 %
- Ekman and barotrope corrections: small negative impact of (<5%)
- MDT: Improvment of 6 and 19 % for respectively MDT_new and MDT_old

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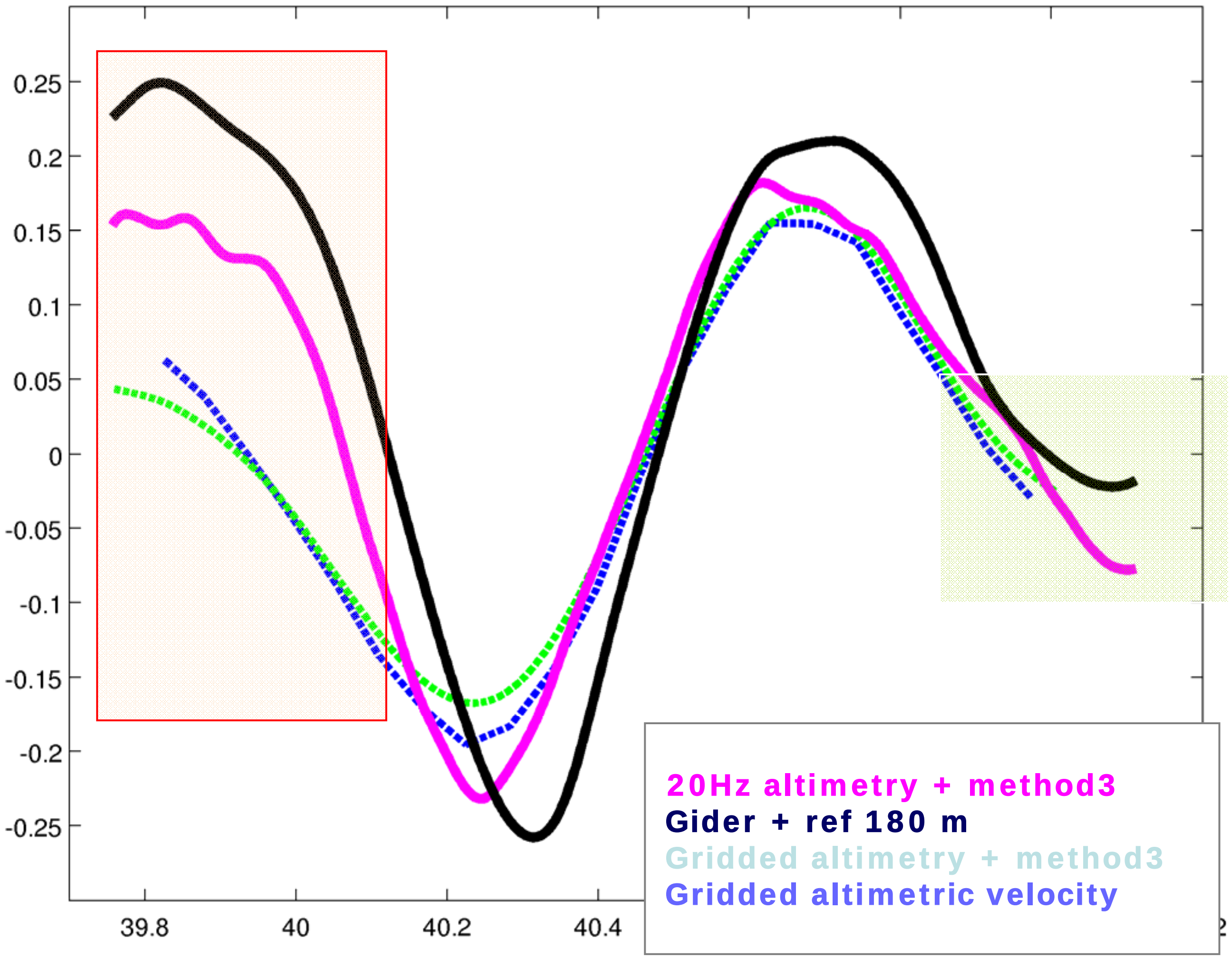
Comparison Glider-altimetry
comparison with gridded products



Along track HF more adapted than gridded data

- Less amplitudes in the gridded produtcs
- Huge differences in the balearic coastal zone
- Similar performences in the Iberic coastal zones .
- Less coastal data in the gridded products

(Bouffard et al., JGR, to be submitted)

Summary & Future Work

- Gliders are useful platforms for exploring limitations of coastal altimetry.
- New methodology and data processing in the velocity computation improves the altimetry-glider comparisons.
- The impact of usig HF along track altimetric data is tremendous in the coastal zone (cor = 0.97, error variance = 5%).
- Future work:
  - Dedicated mean dynamic topography
  - Multi-sensor approach experiments
  - Data assimilation into numerical models to better understand coastal and mesoscale dynamics (collaboration with J. Zavala – Univ. Rutgers).

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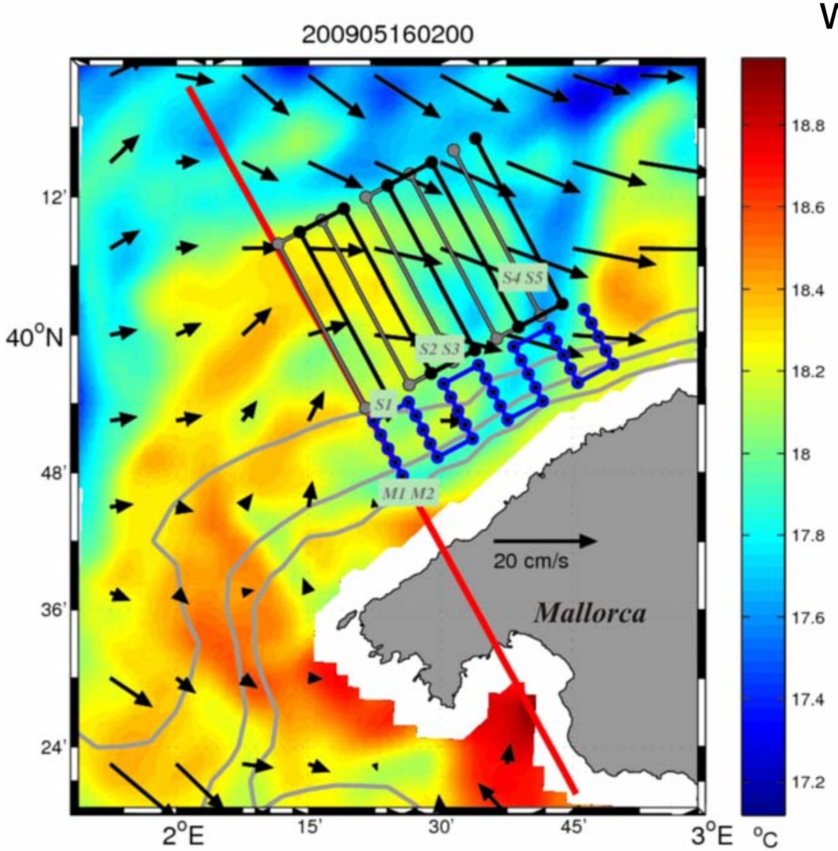
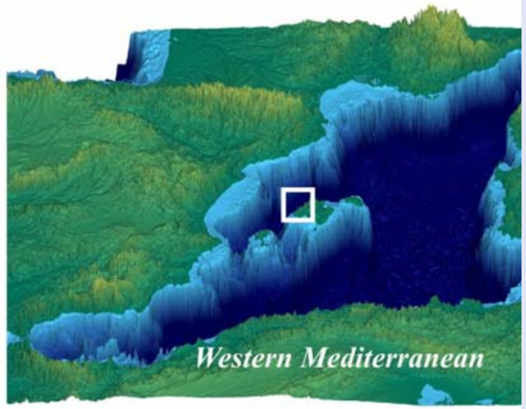
Multi-sensor approach: SINOCOP sampling

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





May 2009

BIG CHALLENGE:
First time that IMEDEA:

-Performs a mission with two gliders simultaneously.

- Acquires, processes and distributes data in real time from gliders, drifters, mini-drifters...


Coastal Glider


SVP Drifter


Albatros Mini-drifter


CTD


Remote Sensing


Deep Glider

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Thank you for your attention