Synergetic use of surface drifters and altimetry to increase resolution and accuracy of maps of sea level anomaly in the Gulf of Mexico

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Abstract

Strong improvements have been made in our knowledge of the surface ocean geostrophic circulation thanks to satellite observations. However, the synergy of different sources of observation (satellite and in-situ) is mandatory in order to go toward higher resolution. In this study, we combined altimetric along track Sea Level Anomalies (SLA) with geostrophic velocity estimated from surface drifters in order to map SLA and associated geostrophic current anomalies in the Gulf of Mexico.

First, an important work is done to pre-process drifter data to extract the geostrophic component of the signal in order to be consistent with physical content of altimetry. This step include estimate and remove of Ekman current, Stokes drift and wind slippage. Two kind of drifters are used:

- Drifters from the HMI Company are processed from 2014 to 2016 (this company, part of CLS group, launches their own drifter in the Gulf of Mexico for their downstream services).
- The drifters launched in the framework of the Lagrangian Submesoscale ExpeRiment (LASER) campaign (January-April 2015) are also processed and used for independent validation.

Second, drifters and along track SLA from Jason2, HY2, Saral and C2 are combined through multivariate objective analysis to map a time series of SLA and associated geostrophic current anomalies.

Finally, comparisons with independent data show the better agreement of maps merging both altimetry and drifters especially for the meridional component of geostrophic current.

Processing of the drifters

1- foreward/backward editing process as done by *Hansen and Poulain, 96*

2- Spike detection $|x_t| \geq |x_{t+1} \pm 2\sigma|$ (Figure 1)

3- Interpolation with regular frequency (6h00) with Epanechnikov kenel (Figure2)

4- Computation of the velocities (Figure 2)

5- Remove ageostrophic signal to have a physical content consitent with altimetry:

 5.1- Remove high frequency ageostrophic signal: Filter at 3days

 5.2- Remove Ekman model (Rio et al., 2014)

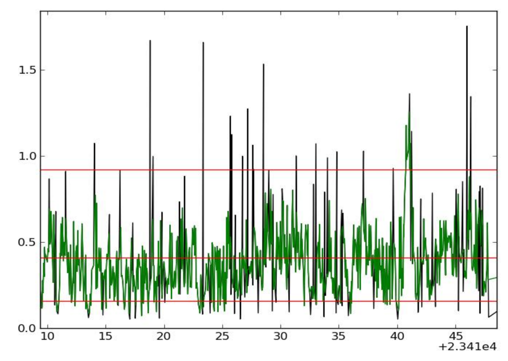


Figure1: example of the spike detection procedure on the drifter 67381: black: raw velocity; green: velocity filtered from spikes

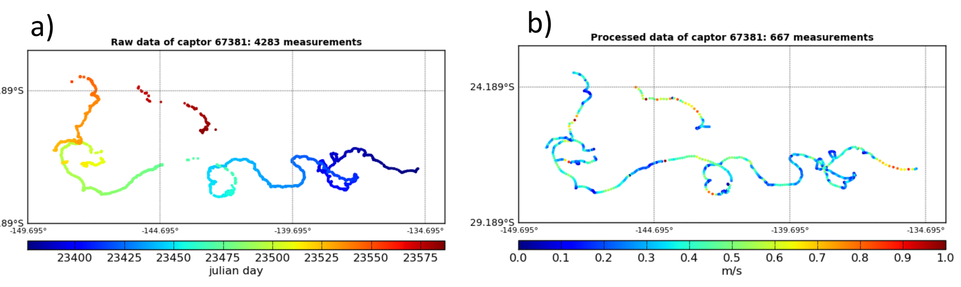


Figure2: example for one drifter of (a) raw data position and (b) regular interpolation and computation of the velocities

• **Ekman model**

Rio and Hernandez, 2014

$$\vec{u}_{buoy} - \vec{u}_{alti} = \vec{u}_e = \beta \vec{\tau} e^{i\theta}$$

Wind stress from ERA INTERIM

β and θ are estimated through least square fit by months and by boxes using (Figure3):

- At 15m: drogued svp drifters from AOML
- At 0m: Argo float drifting at the surface from YoMaHa database (Lebedev et al., 2007) because Argo float are less sensible to wind slippage

Figure 3 illustrates that, in accordance with Ekman spiral theory, the angle θ is smaller at the surface than at 15m while the amplitude coefficient β is higher at the surface than at 15 m.

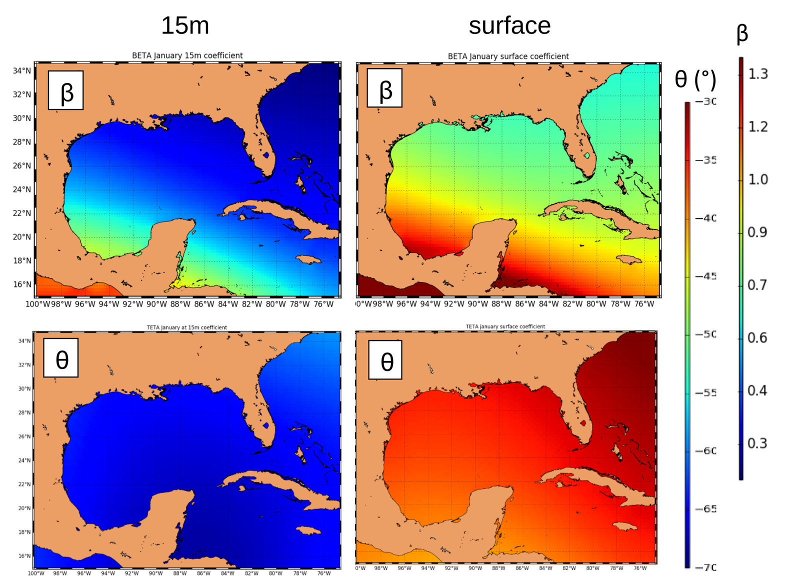


Figure 3: Ekman parameters (amplitude:β, angle: θ) in January at 15 meter depth and at the surface

Method: Merging altimetry and drifters to compute SLA and associated geostrophic current maps

We use a **Multivariate objective analysis** (Rio et al., 2014) to **map SLA** and associated **anomalies of geostrophic current** in the **Gulf of Mexico** from observation of:

- **Along track SLA**
- Anomalies of geostrophic current (u',v') estimated from **drifters**

The differences with the classical monovariate objective analysis using altimetric data only can reach locally 10 cm (Figure 6)

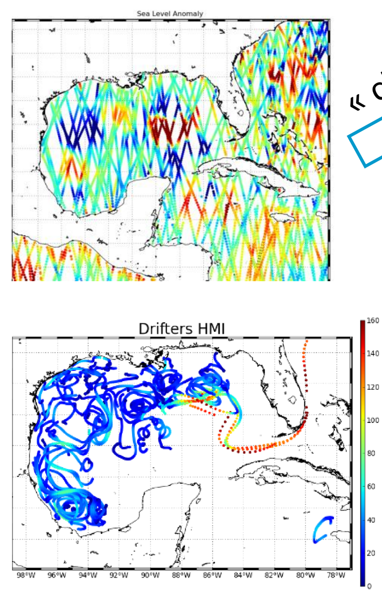


Figure 4 : (top) SLA observations and (bottom) HMI drifters

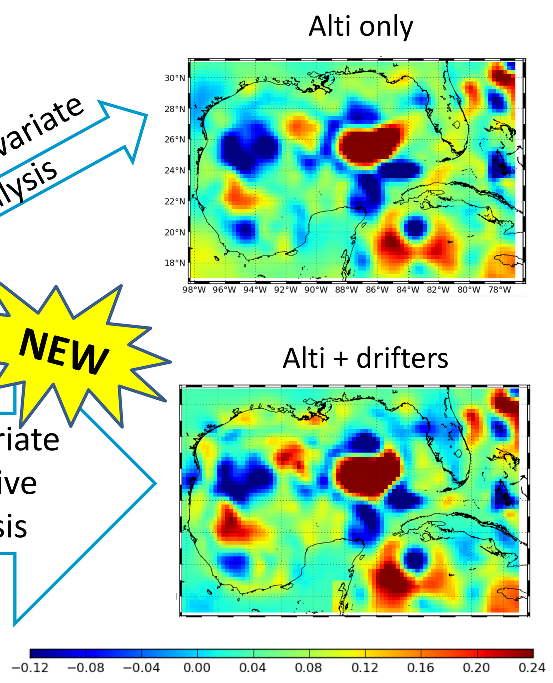


Figure 5 : Maps of Sea Level Anomalies (SLA) computed from objective analysis using (top) only altimetry and (bottom) altimetry + HMI drifters on 21/05/2014 (m)

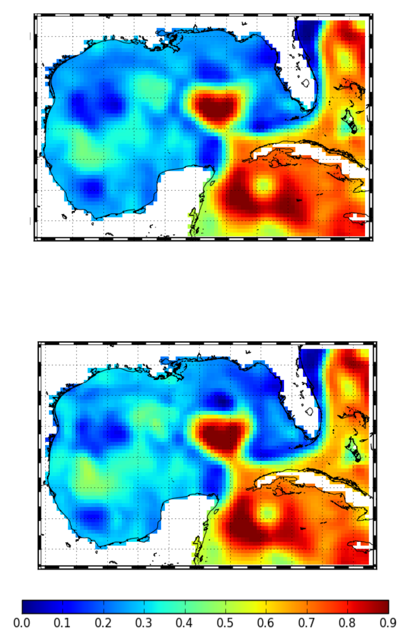


Figure 6 : Maps of Absolute dynamic topography (ADT) computed by adding MDT CNES-CLS13 to SLA mapped on Figure 5 (m)

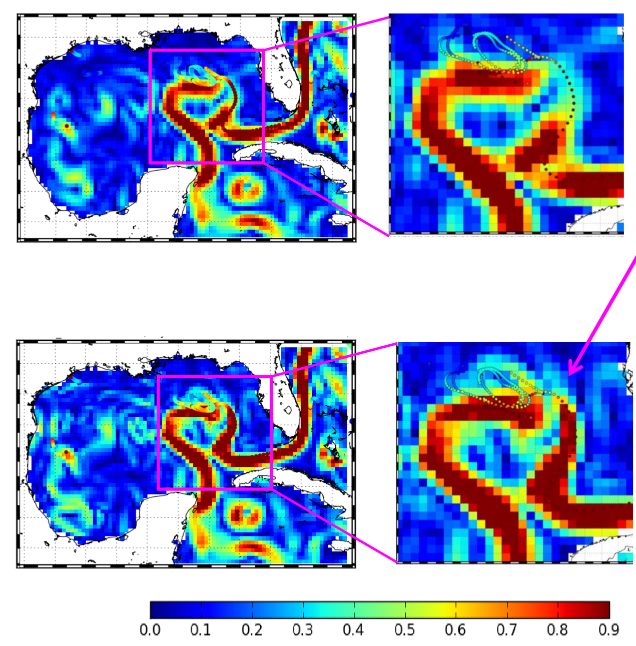


Figure 7 : Intensity of the geostrophic currents associated with ADT mapped on Figure 6 (m/s). The dots are independant estimate of geostrophic current intensity from AOML drifters

- **Better agreement with independant AOML** drifters when both altimetry and HMI drifters are used
- **Improvement of the meridional branch** of the loop current

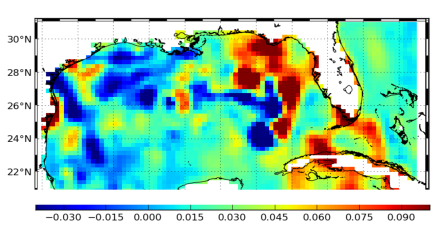


Figure 8 : Differences (m) of maps from Figure 5

Validation of a long time series (h2,j2,al + drifters)

To have **independant dataset** to validate the long time serie, we first compute daily **maps without using c2** from 01/09/2105 to 30/04/2016. We have 2 time series of maps:

- Merged maps using 3 altimetric dataset (h2,j2 and al) and drifters from HMI
- Reference maps from altimetry only (h2,j2 and al)

Validation results (Table1, Table 2 and Table 3) show:

→ Merged and reference maps have similar performances in comparaison with zonal geostrophic velocities estimated from LASER drifters (Table1);

→ **Merged maps improved** significantly **meridional component** (Table1) because the zonal component is already well resolved using altimetric tracks mainly oriented north/south;

→ **Statistic results are relevent** since statistics of across track velocities from c2 and zonal velocities from LASER drifters are similar (Table1 and Table 3)

→ Merged maps (alti+drfiers) and reference maps (alti only) have similar performances in comparaison with c2 (Table2 and Table3);

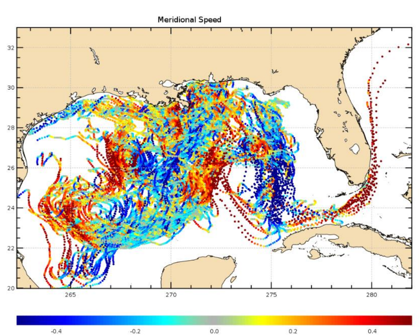


Figure 9: meridional velocity of drifter form the LASER experiment (m)

▪ Validation against independant geostrophic velocity estimated from drifters from the Lagrangian Submesoscale ExpeRiment (LASER) campaign

Table1: statistics of comparison against LASER drifters over 1/1/2016 to 30/4/2016 (U = zonal component, V = meridional component)

	Alti + Drifters	Alti only
RMSD U / V (cm/s)	14.69 / 15.57	14.7 / 16.93
RMSD U / V (% RMS drifters)	75 / 71	75 / 77
CorU / CorV	0.62 / 0.7	0.61 / 0.63

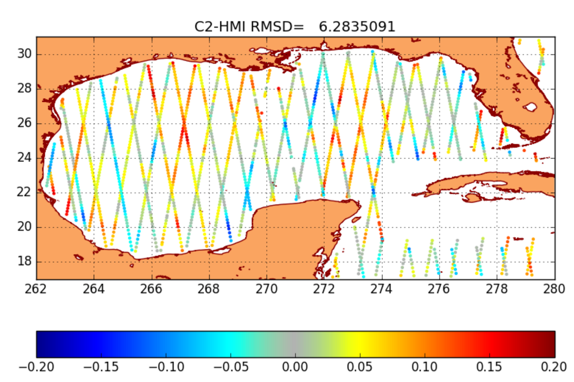


Figure 10: Difference between along track SLA from C2 and SLA mapped from alti+drifters over October 2015

▪ Validation against independant along-track SLA and across track geostrophic current anomalies (u') from C2

Table2: statistics of comparison to C2 over the full period 1/09/2015 to 30/4/2016

	Alti + Drifters	Alti only
RMSD SLA (cm)	6.38	6.24
RMSD SLA (% RMS SLA c2)	33.9	33.1
RMSD u' (cm/s)	15.06	14.88

Table3: statistiques of comparison to C2 over the LASER period 1/1/2016 to 30/4/2016

	Alti + Drifters	Alti only
RMSD SLA (cm)	6.09	6.06
RMSD u' (cm/s)	14.13	13.97

Computation of the best estimate (h2,j2,al,C2 + drifters): demonstration dataset

▪ **Description of the dataset:**

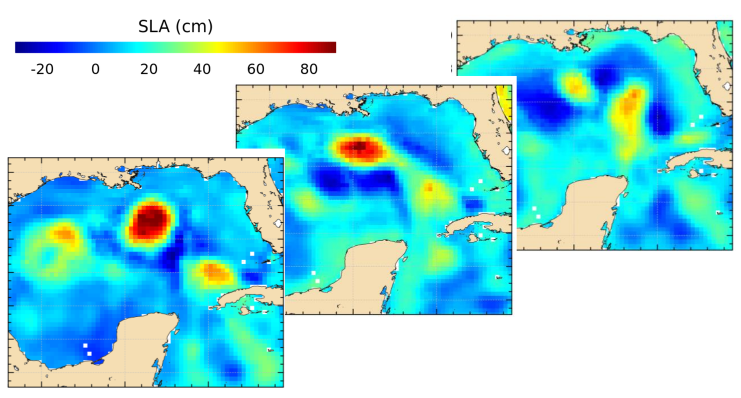
Time period: daily maps from 01/09/2015 to 30/04/2016

Area: Gulf of Mexico

Upstream:

- drifters from HMI (processed to extract anomalies of geostrophic current)
- Altimetric along track SLA from Jason2, AltiKA, HY2 and Cryosat 2

Output variables: SLA, zonal and meridional anomalies of geostrophic current



▪ **Quality of the dataset:**

Table 4 shows that

→ Statistics are improved compared with Table 1 (without C2)

→ **The estimate from alti+drifters gives better results than alti only mainly for the meridional component.**

Table4: statistiques of comparison against LASER drifters over 1/1/2016 to 30/4/2016 (U = zonal component, V = meridional component)

	Alti + Drifters	Alti only
RMSD U / V (cm/s)	14.4 / 14.7	14.8 / 16.7
CorU / CorV	0.64 / 0.73	0.61 / 0.63

References:

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Available in November 2017 as demonstration dataset on AVISO (www.aviso.altimetry.fr)