Comparing altimetry with Argo and GRACE data for quality assessment and mean sea level studies

J.F. Legeais, M. Ablain, S. Dupuy (CLS),
N. Picot (CNES)

Overview

- To date, the global assessment of altimeter data can be performed through:
  - The internal assessment of altimeter data (comparison of instrumental corrections with global models, calculation of SSH at crossovers)
  - The cross-calibration between altimeter missions
  - The **comparison with in-situ measurements** which are used as **external and independent** sources of comparison to better assess the multiple system performances

- In this way, altimetry is compared with Argo and GRACE data in the frame of the SALP project (CNES).

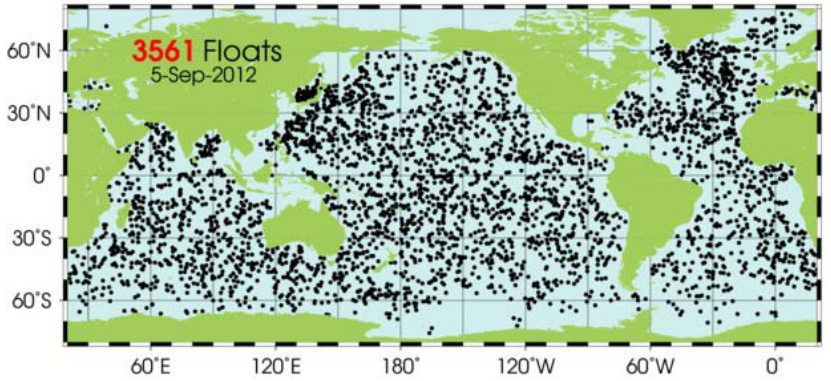
Objectives:

1. Detect global and regional **altimeter MSL drifts or anomalies**
2. Estimate the **impact of new altimeter standards** in the SSH computation

Datasets and methodology

Datasets:

- Altimetry provides the total height of the water column (mass and steric parts) which is compared with:
  - The steric Dynamic Heights Anomalies (DHA) derived from Argo T/S profiles (Coriolis-GDAC dataset; ref. 900 dbar)
    Almost global coverage of the open ocean (80%) with a 10-day sampling since mid-2004.



  - The mass contribution to the sea level derived from GRACE data is available as monthly grids from 2003 to 2012 (Chambers, 2006; http://grace.jpl.nasa.gov)

Methodology:

To perform the comparison of altimetry with Argo + GRACE data:

1. Along-track altimeter data are box-averaged in 10-days grids
2. Altimeter and GRACE grids are spatially and temporally interpolated at the position and time of each in-situ Argo profile
3. Global statistics and coherence analyses are performed between altimetry and the two independent datasets

- More information are available on AVISO website :

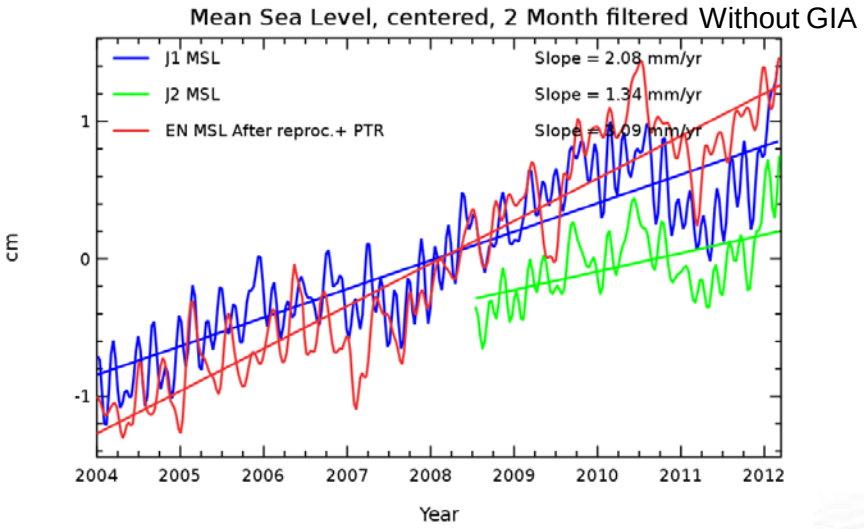
http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/insitu/annual_report_insitu_TS_2011.pdf

Estimation of the global altimeter MSL drift

Estimation of the global altimeter MSL drift (1/3)

- The reprocessing of the Envisat altimeter data has provided significant improvements of the mission and the data are now much more coherent with Jason-like missions (see Ollivier's presentation)
- Nevertheless, some differences remain between Envisat and Jason-1 altimeter MSL trends if focused over 2004-2012 period: +1.0 mm/yr is observed between Envisat and Jason-1

  ⇒ It suggests that the **drift** of one of these missions is greater than the other.



MSL trend differences (mm/yr)	Altimeter MSL (GIA incl.)
Jason-1	2.4
Envisat	3.4
Trend differences	**1.0**

- Do in-situ data provide useful information to estimate **which mission is closer to the reality?**
- We have shown that our method is very useful to detect altimeter relative differences, but:

  ⇒ Can we have confidence in the estimation of **the absolute altimeter MSL drift** ?

  ⇒ Can we detect a bias on the drift ?

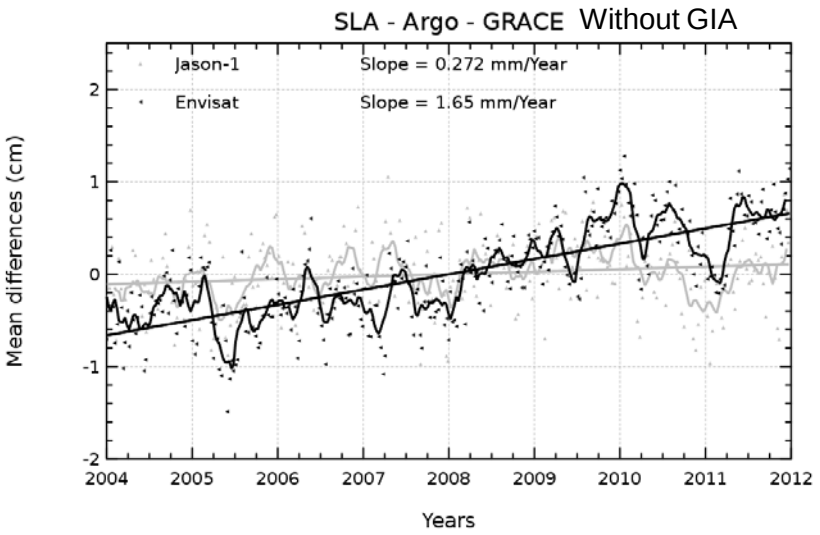
Estimation of the global altimeter MSL drift (2/3)

- The altimeter MSL is compared with the MSL from Argo + GRACE data (from 2004 onwards):

1. The altimeter MSL drift is greater for one of these missions than the other (1.4 mm/yr difference close to 1.0 mm/yr global difference).

   Error over this period estimated to be around ± 0.8 mm/yr, taking into account the errors associated with both types of data, their processing and colocation.

2. Absolute MSL drifts referenced to Argo + GRACE data suggests that the Envisat MSL drift is greater than the one of Jason-1 (2.0 *vs* 0.6 mm/yr*)*



MSL trend differences (mm/yr) (GIA included)	Altimeter MSL	MSL differences with Argo+GRACE
Jason-1	2.4	0.6
Envisat	3.4	2.0
Trend differences	**1.0**	**1.4**

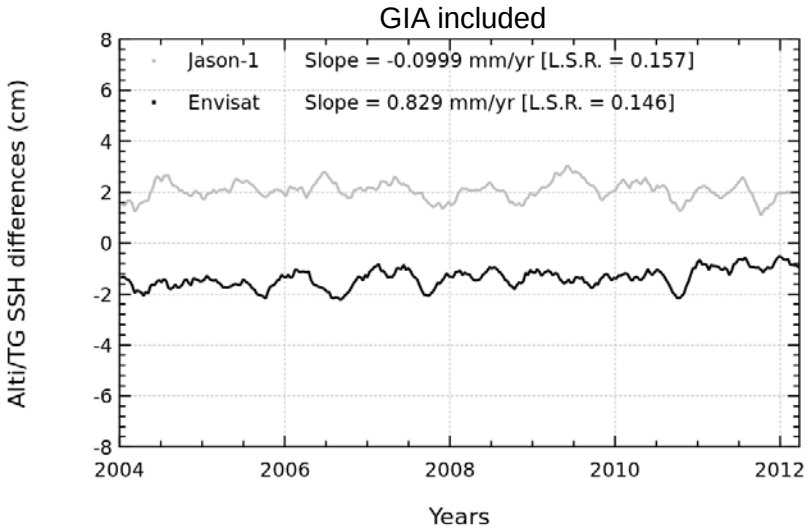
Estimation of the global altimeter MSL drift (3/3)

- These results are confirmed when compared with **tide gauges** (see Valladeau's poster):

1. The altimeter MSL drift is greater for one of these missions than the other (0.9 mm/yr difference close to 1.0 mm/yr)

   Error over this period estimated to be ± 0.7 mm/yr, taking into account the spatial sampling restricted to coastal areas and the terrestrial crustal movements.

2. Absolute drift compared with tide gauges suggest that the drift is greater for Envisat mission



MSL trend differences (mm/yr) (GIA included)	Altimeter MSL	MSL differences with Argo + GRACE	MSL differences with tide gauges
Jason-1	2.4	0.6	- 0.1
Envisat	3.4	2.0	0.8
Trend differences	**1.0**	**1.4**	**0.9**

The combination of different types of in-situ data allow to **detect** and **indicate the greater MSL drift of Envisat than the one of Jason-1** over the period 2004-2012.

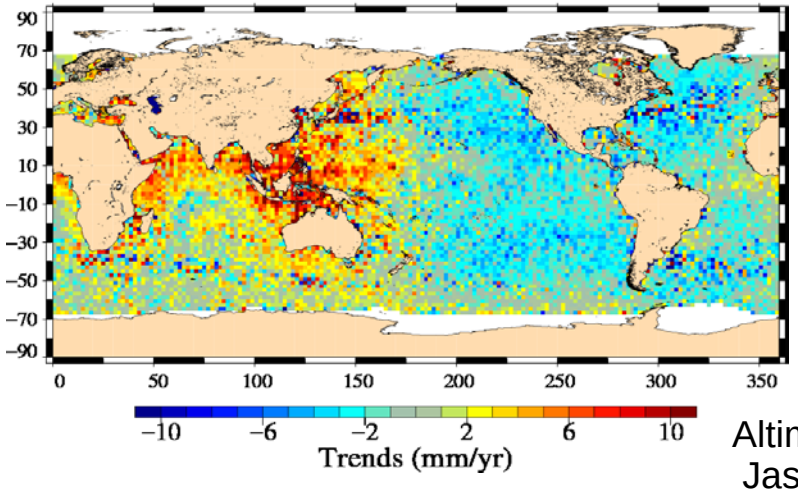
Detection of regional altimeter MSL drifts

Detection of regional altimeter MSL drift

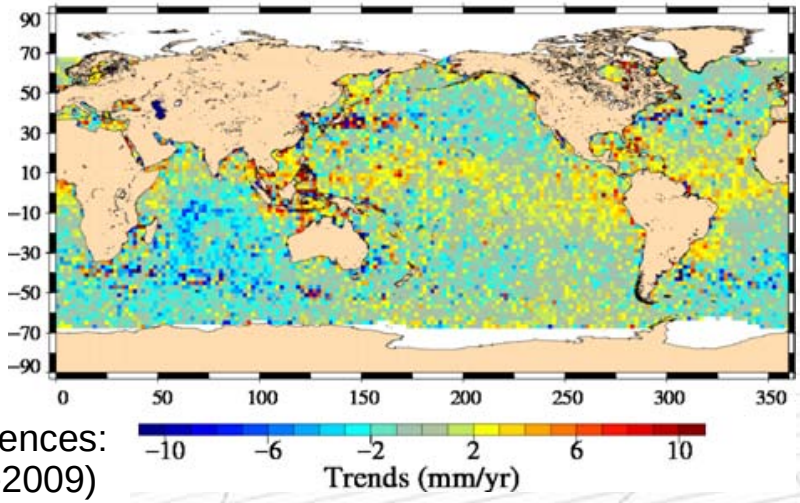
- We focus on the detection of Envisat/Jason-1 regional MSL trend discrepancies
- In 2010, an anomaly was observed in the MSL trend comparison between Jason-1 and Envisat : the regional MSL trend differences underline East/West discrepancies

  ⇒ -3 mm/yr on East Ocean [0°,180°] and + 3mm/yr on West Ocean [180°,360°]

GDR-C orbit version



GDR-D orbit version

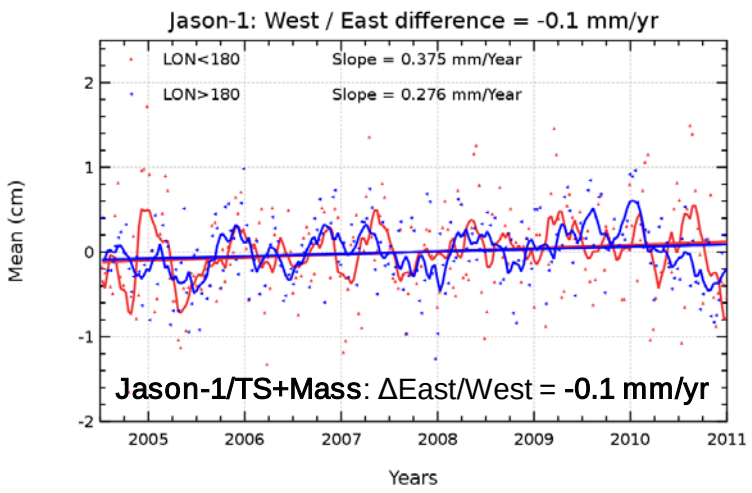


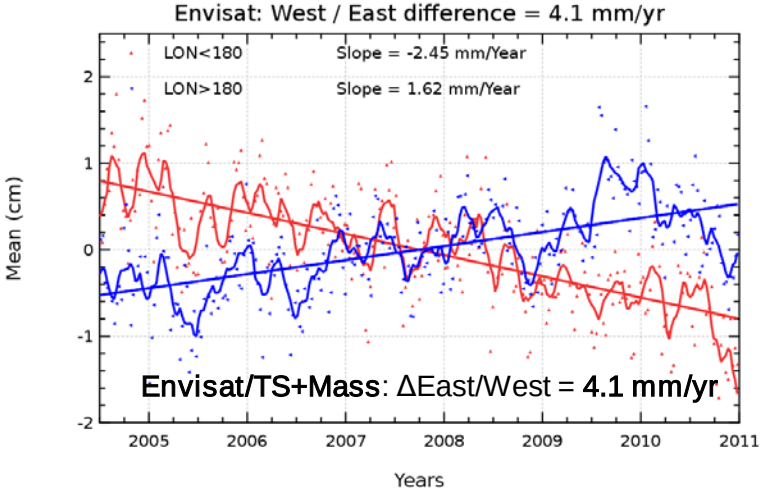
Altimeter MSL trend differences:
Jason-1 – Envisat (2003-2009)

- It has been further shown that this anomaly is related with the orbit calculation.
- With the use of the new CNES GDR-D orbit solution (where the long-term evolution of the gravity field has been improved: Cerri OSTST 2011), the longitudinal regional bias using GDR-C orbit solution is now solved.

Detection of regional altimeter MSL drift (2/3)

- As the Argo network is very well spread out over the open ocean, such regional bias is perfectly detected by comparison with Argo + GRACE independent measurements :
- Time series of sea surface heights differences between altimetry and Argo + GRACE data are computed for both Jason-1 and Envisat missions.
- Then, the drifts of these differences are estimated separating East (0°/180°) and West (180°/360°) parts in order to detect which mission is closest to the in-situ reference



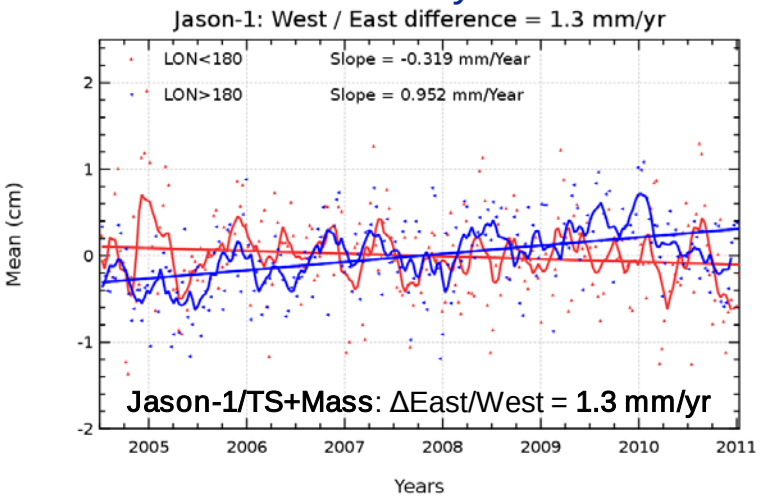


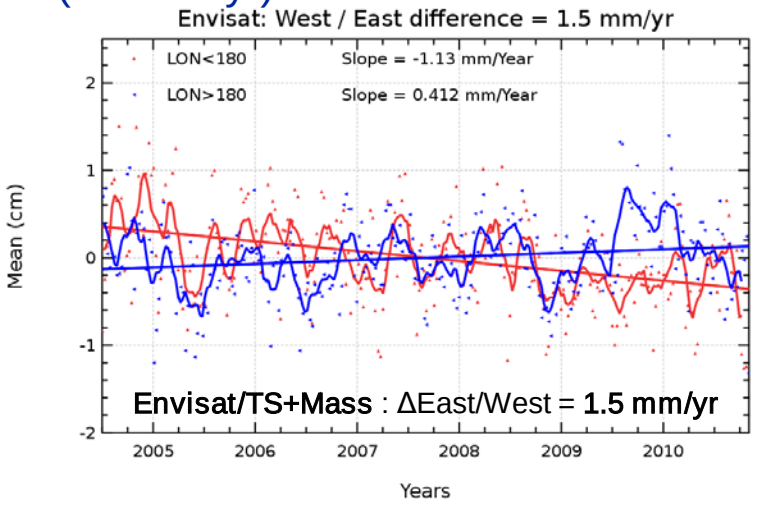
- No difference (**-0.1 mm/yr**) is observed for Jason-1 whereas a strong trend difference is detected for Envisat (ΔEast/West = **4.1 mm/yr**).
- It highlights that the anomaly is mainly associated with the Envisat mission (expected since Envisat orbit is lower and the satellite is thus more affected by gravity effects).

⇒ Thus, the comparison with Argo and GRACE data has enabled us to detect an anomaly in the altimeter measurements

Detection of regional altimeter MSL drift (3/3)

- Argo and GRACE independent data are also used to assess the impact of using the new GDR-D orbit solution in the SSH calculation.
- The same comparison of altimetry (using the new orbit) with Argo + GRACE data is computed:
  - ⇒ The Envisat East / West trend difference is now reduced from 4.1 mm/yr to 1.5 mm/yr. The use of the GDR-D orbit solution has a strong impact.
  - ⇒ The new orbit makes both missions more homogeneous since the Jason-1 East/West trends difference is now very close to the Envisat results (1.3 mm/yr)





- But, a strong residual hemispheric bias is detected for JA-1 (1.3 *vs* -0.1 mm/yr with GDR-C orbit)!
- Origin: ➢ Residual error of the method concerning regional estimation of the MSL trends ?
  - ➢ Residual error in the orbit determination ?
- Such diagnoses could be performed with new orbit solutions, such as GSFC solutions

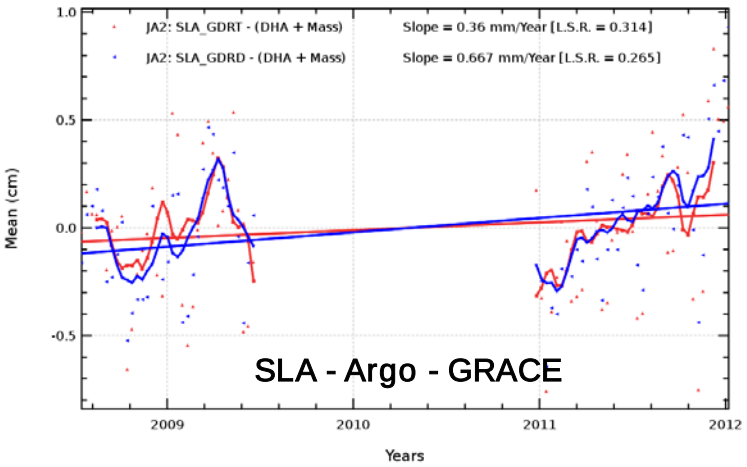
Estimation of the impact of new altimeter standard

Estimation of the impact of new altimeter standard

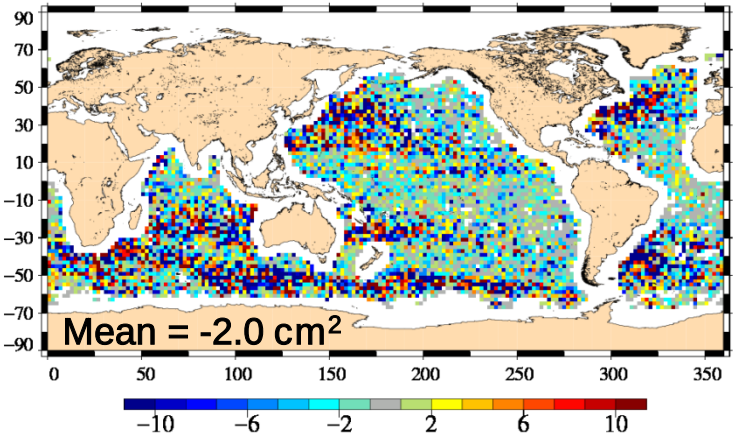
Impact of the Jason-2 GDR-D reprocessing

- Jason-2 altimeter data have been partly reprocessed with GDR-D standards (see Philipps' poster)
- Argo and GRACE independent measurements are used to estimate the impact of this reprocessing

MSL trend differences: Jason-2 GDR-D – GDR-T (mm/yr)	Global altimeter MSL	Reference to Argo + GRACE	Reference to tide gauges
	+ 0.3	+ 0.3	+ 0.3



- Perfect agreement when compared with in-situ measurements!
- The main contribution to this rise is the new wet troposphere correction



- Increase of the coherence between altimeter and Argo + GRACE data with GDR-D standards by 2 cm²

- The 2.5 yrs of available reprocessed Jason-2 GDR-D data show promising results
- The comparison with in-situ measurements will be adapted to estimate the impact of the reprocessing when all data will be available

Summary :

- The comparison of altimeter measurements with combined in-situ Argo profiles and GRACE data in the open ocean is very useful and accurate:
  - To detect global and regional altimeter MSL drift or anomalies
  - To assess the impact of new altimeter standards
- We have demonstrate:
  - The ability of our method to detect relative MSL trend differences with a reduced uncertainty,
  - That we can be relatively confident in the estimation of the absolute altimeter MSL drift

Conclusion :

⇒ Our method will also be useful to assess the impact of the 2013 reprocessing of DUACS merged DT products.

⇒ There is a strong synergy with the method of comparison with tide gauges to provide quality assessment of altimetry (see Valladeau & Legeais, Mar. Geod. 2012)

Thanks to the cross-comparisons between results provided by different approaches (cross comparison between altimeter missions, comparison with Argo and with tide gauges), the estimate of the altimeter MSL drift is more and more reliable and accurate (globally and regionally)