Analysis of altimetry errors using Argo and GRACE data

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Context & Objectives

The **validation of satellite altimeter sea level** measurements is a required step before downstream studies of these data. It is usually performed by the analysis of the internal consistency of each mission or by cross comparison between several missions. Here, the **steric sea level** Dynamic Heights Anomalies (DHA) provided by **Argo profiling floats** are used as **independent source of comparison** to analyze the **altimetry errors**. In addition, the missing **mass contribution** to the ocean derived from **GRACE** is also used to detect the **absolute altimeter drift.** The work presented is supported by the CNES / SALP project, an IFREMER/CORIOLIS contract and the EC E-AIMS project.

Objectives: (i) detect **drift** or jump in the **altimeter Sea Level Anomalies** (SLA), (ii) determine the **impact of a new altimeter standard** in the altimeter SLA computation and (ii) **validate the Argo dataset** by detecting anomalies in the floats time series.

Overview: We illustrate here examples of altimetry quality assessment thanks to Argo data (parts 1 to 4). The sensitivity of the method of comparison of both types of measurements to different parameters is then discussed (part 5). At last these comparisons also allow a quality control of the Argo floats (Guinehut et al., 2009) (part 6).

(1) Data and method of comparison

❑ **Data & Method (Valladeau et al., 2012, Legeais et al. 2014)**

Collocated **DHA + GRACE / SLA**

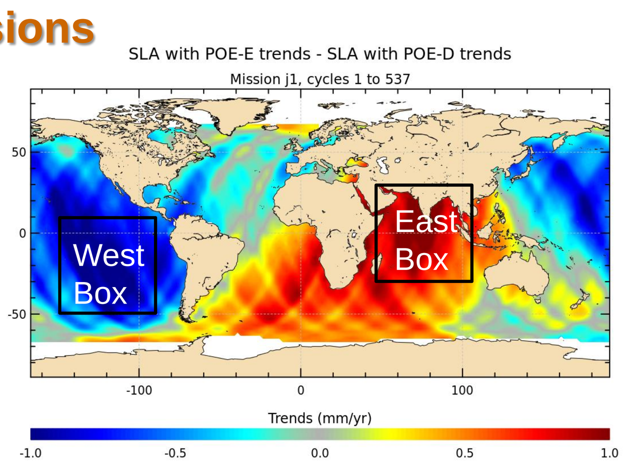
- **SLA** maps derived from 10-days box-averaged along-track data or gridded products
- **Argo** Coriolis-GDAC data base, synthetic climatology.
- **GRACE** GRGS V3 monthly maps (http://grgs.obs-mip.fr/grace); global ocean mean from Johnson & Chambers, 2013.

(2) Detection of drifts or jumps in altimeter missions

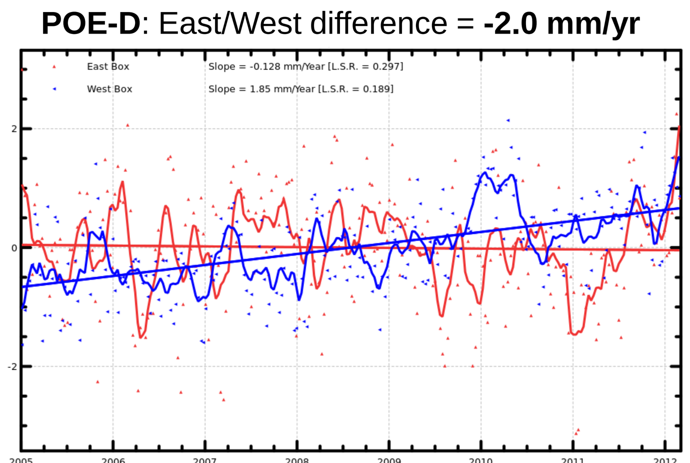
❑ **Regional Jason-1 MSL trend differences using successively orbit solution POE-E vs POE-D (±1mm/yr)**

- Which orbit standard shows the smallest hemispheric bias compared with in-situ T/S profiles (which are free of such a bias)?
- Selection of regions (East / West boxes) with maximum amplitude of the trend differences between both orbit standards.
- Strong MSL trend difference is observed for Jason-1 (ΔEast / West = **-2.0 mm/yr**).

=> The detection of altimeter drift is possible by comparison with Argo profiles



POE-D: East/West difference = **-2.0 mm/yr**



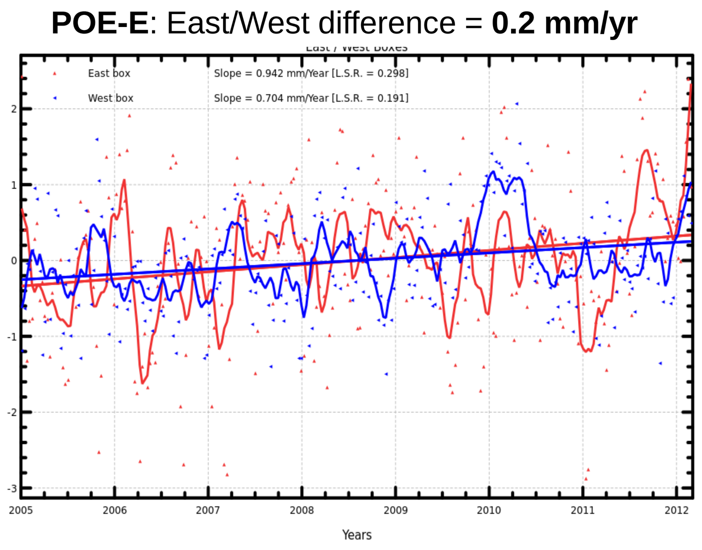
(3) Assessment of the impact of new altimeter standards in the SLA calculation

❑ **Test of the impact of POE-D orbit solution** (where long-term evolution of gravity fields has been improved)

- Strong impact on the Jason-1 East/West MSL trend difference with **POE-E**, now reduced to **+0.2 mm/yr**.
- Significant reduction of regional (hemispheric) altimeter MSL trend differences compared with in-situ profiles indicates that **POE-E provides an improvement**

=> The detection of the impact of a new altimeter standard is possible by comparison with Argo profiles (Couhert et al., 2014)

POE-E: East/West difference = **0.2 mm/yr**



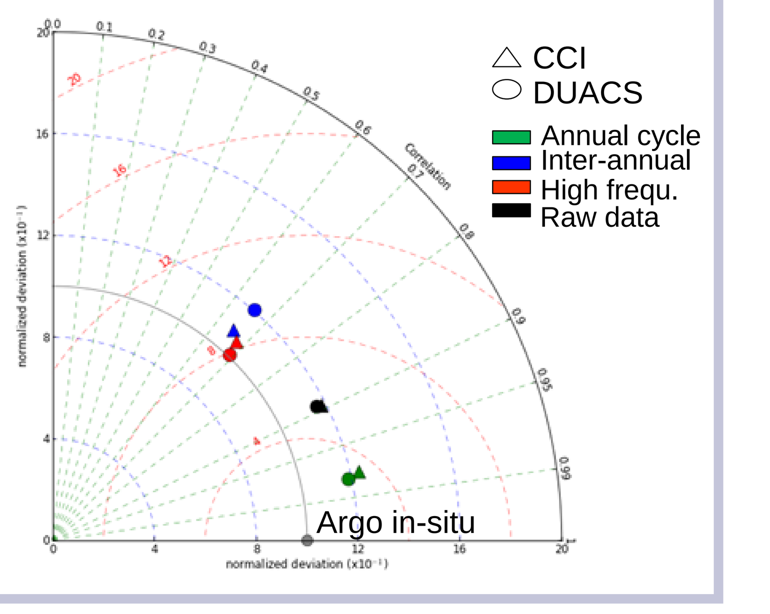
(4) Distinction of different altimeter products: analysis at different frequencies

Argo sea level estimations are used to characterize the discrepancies between two altimeter products (AVISO DUACS v2014 and Sea Level CCI v1.1):

➔ Separation of the **different frequencies** for a better discremination of the products: annual, inter-annual signals and the high frequencies.

➔ The Taylor diagram highlights the discrepancies between the two altimeter products using the Argo in-situ data as a reference.

This approach allows a better quality assessment of altimeter products



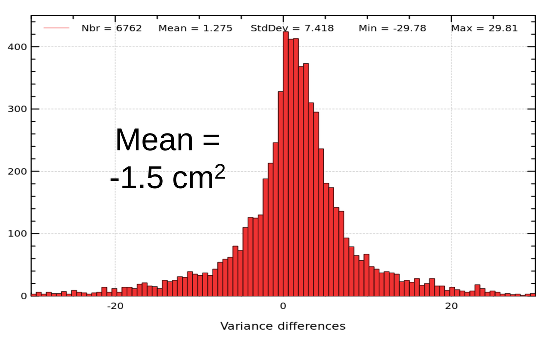
(5) Analysis of the sensitivity of the method of comparison

Context: Argo data can be used for the detection of altimeter drift / jump and the quality assessment of new altimeter standards or products. To which extent the **results are sensitive to the sampling and processing of the Argo and altimeter data?**

❑ **Pre-processing of altimeter data**

- Grids of 10-days box-averaged along-track altimeter data are computed for the comparison of a single mission with Argo data.
- The sensitivity of the method to the use of boxes of 1x1° versus 1x3° is analyzed:

➔ The global mean of the SLA-DHA differences (trend and annual cycle) are not affected but there is a reduction of 1.5 cm² of the variance differences with **1x3° boxes**.

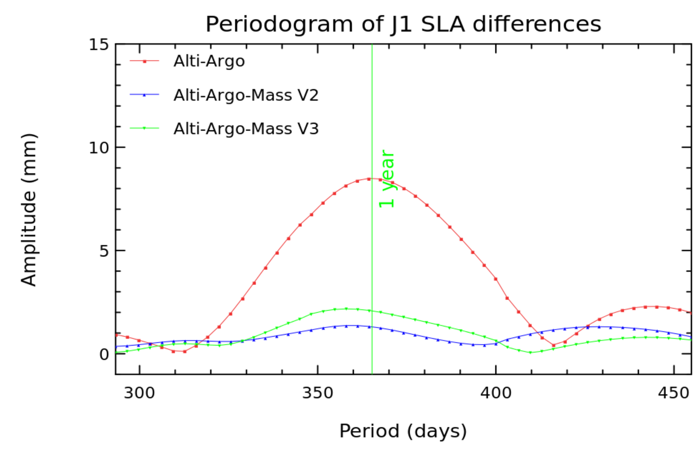


❑ **Absolute altimeter drift: impact of the mass contribution (GRACE)**

The addition of the mass contribution to the Argo data provides homogeneous physical content with altimeter data (deep steric missing).

➔ Strong **sensitivity** of the altimeter drift detection to the **GRACE dataset** (GRGS, Johnson & Chambers, 2013).

➔ Remaining uncertainties need to be reduced.

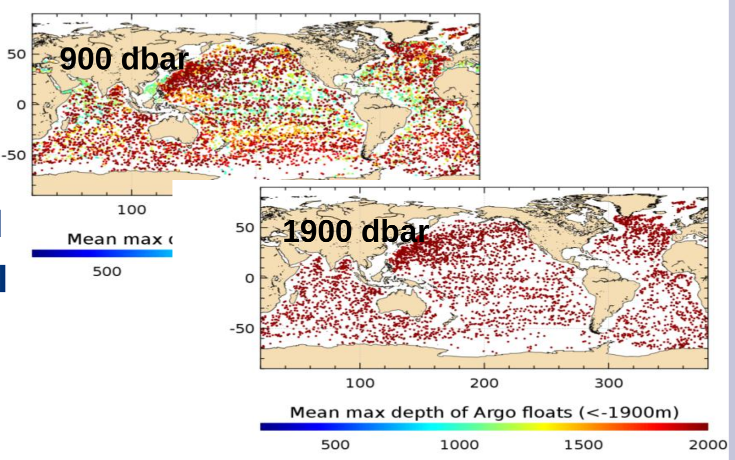


❑ **Sensitivity to the reference depth of Argo profiles**

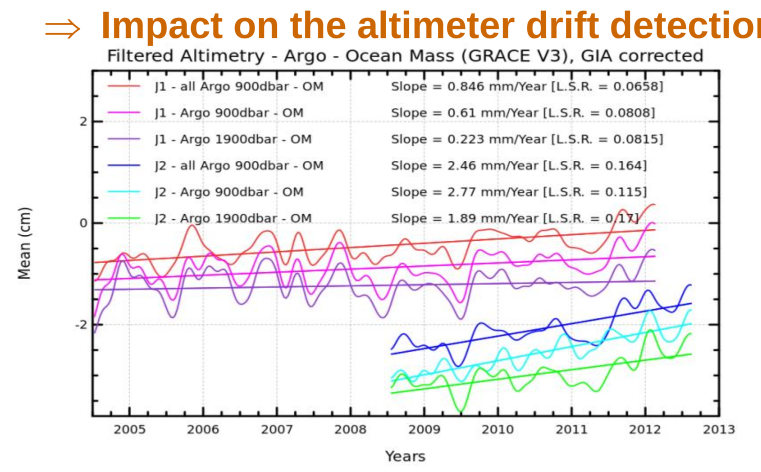
DH are computed with a reference level of integration of the T/S profiles.

➔ No height from profiles shallower than the reference level

➔ **A balance is to be found between horizontal / vertical sampling**



⇒ **Impact on the altimeter drift detection:**



The Jason-1 altimeter drift detection (sea level closure budget) is significantly affected by the change of reference level:

* 900 dbar profiles at positions of 1900 dbar profiles versus all 900dbar profiles :

⇒ **Impact of horizontal sampling**: **-0.2 mm/yr**

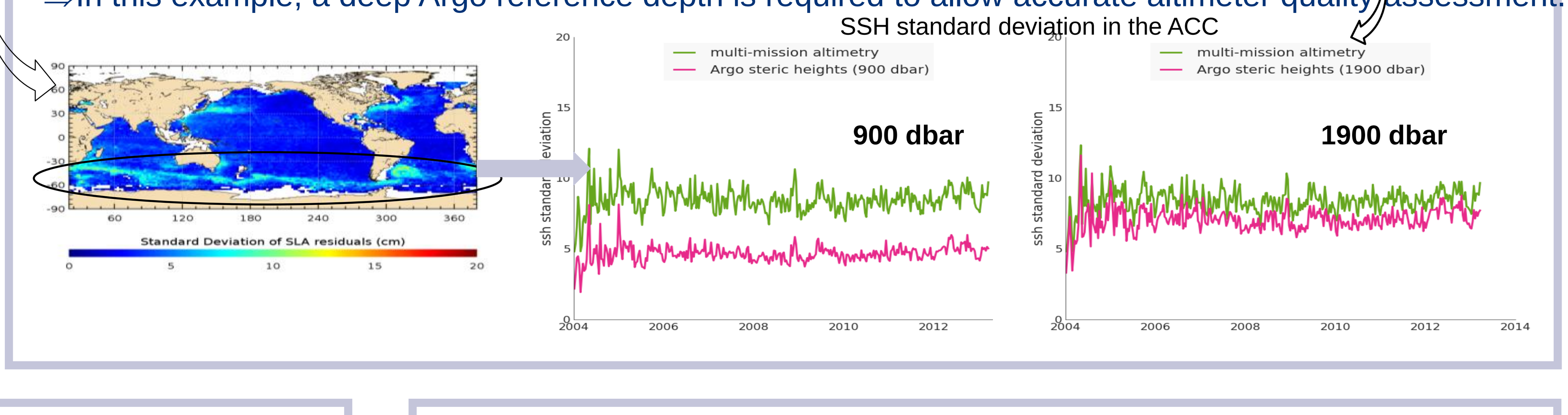
* 1900 dbar versus 900 dbar profiles from the same profiles:

⇒ **Impact of vertical sampling: -0.4 mm/yr**

⇒ **Impact in terms of variance:**

- The standard deviation of the SLA-DHA differences is higher in regions of high ocean variability.
- According to the region, the variance of the steric sea level may strongly differs depending of the Argo reference depth and the altimeter quality assessment can be affected:
- In the Antarctic Circumpolar Current: std dev (DHA 900 dbar) ≠ std dev.(SLA)
std dev.(DHA 1900 dbar) ~ std dev.(SLA)

⇒In this example, a deep Argo reference depth is required to allow accurate altimeter quality assessment.



(6) Validation of Argo floats through comparison with altimeter observations

❑ **Data & Method (Guinehut et al., 2009)**

For each Argo float time series : DHA = DH – Mean-DH / SLA

DH : Argo Coriolis-GDAC data base

DH calculated from T/S profile using a reference level at 200/400/900/1200/1900dbar

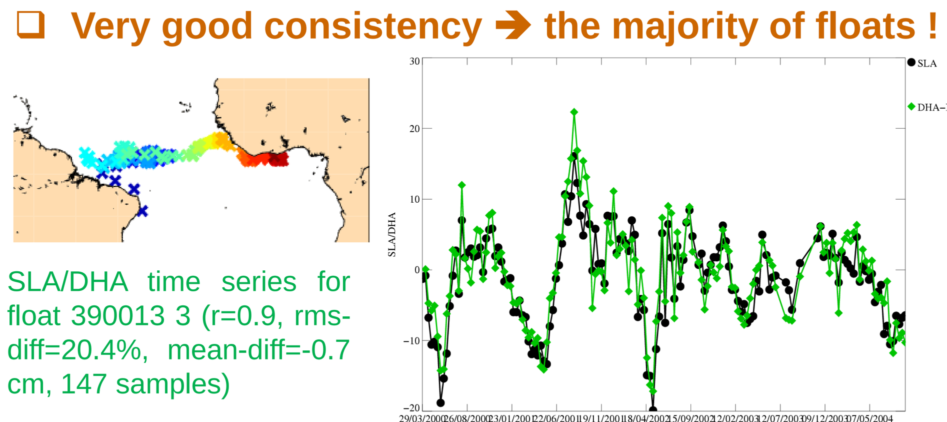
Mean-DH : Argo synthetic climatology

SLA : AVISO combined maps – co-located in time and space to the Argo measurements

❑ **Differences between DHA and SLA can arise from :**

- Differences in the physical content of the two data sets ➔ use of mean statistics
- Problems in SLA ➔ assumed to be perfect for the study
- Problems in the Mean-DH / Inconsistencies of Mean-DH versus DH ➔ use of synth. clim.
- **Problems in DH** (i.e. the Argo data set)

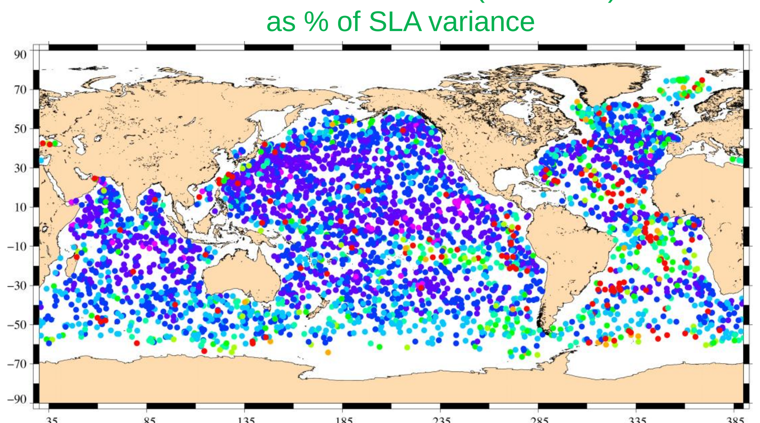
❑ **Very good consistency ➔ the majority of floats !**



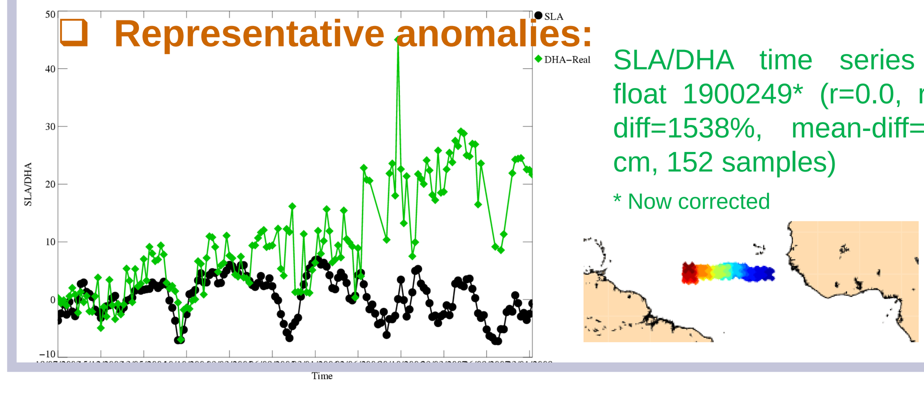
SLA/DHA time series for float 390013 3 (r=0.9, rms-diff=20.4%, mean-diff=-0.7 cm, 147 samples)

❑ **Questionable floats can be extracted by comparing to the neighbors**

Rms of the differences (SLA-DHA) as % of SLA variance



❑ **Representative anomalies:**



SLA/DHA time series for float 1900249* (r=0.0, rms-diff=1538%, mean-diff=-9.0 cm, 152 samples)

* Now corrected

❑ **Diffusion of the results**

- About 10 new floats extracted every 3 months
- Diffusion through the AIC, PI and DM-operators are asked to correct the anomalies

Summary & Future work

- Comparison of altimeter SLA with Argo in-situ steric heights: method successfully used for **detecting global drifts and regional anomalies, validating altimeter standards** and **characterize differences between products.**
- Strong **synergy** with **tide gauges** comparisons & cross calibrations analyses, which increases confidence in results.
- **Sensitivity factors**: Argo reference depth, GRACE solution, colocation method.
- **Perspective**: Argo network evolution with **deep floats** deployments (4 000 dbar); better qualification of future altimetry missions (AltiKa, Sentinel-3, Jason-CS…).
- **General consistency check** of the whole **Argo** data set ➔ consistent dataset to be used for climate studies or in assimilation/validation tools ➔ Results regularly updated.

References

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