SERVICE ALTIMETRIE & LOCALISATION PRECISE

Cross-comparisons of Sea Surface Height derived from In-Situ and Altimeter measurements

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Overview

- This study is supported by CNES for TOPEX/Poseidon, Jason-1&2 altimeter and ESA for Envisat and in the frame of the SALP project.

- Its objective is to compare the Sea Surface Height (SSH) derived from altimetry and In-Situ measurements in order to :
  - Monitor the SSH bias between altimeter and external independent in-situ measurements in order to detect potential drift or jumps in altimeter MSL
  - Estimate improvements of new altimeter standards in the SSH calculation
  - Detect potential anomalies in in-situ datasets

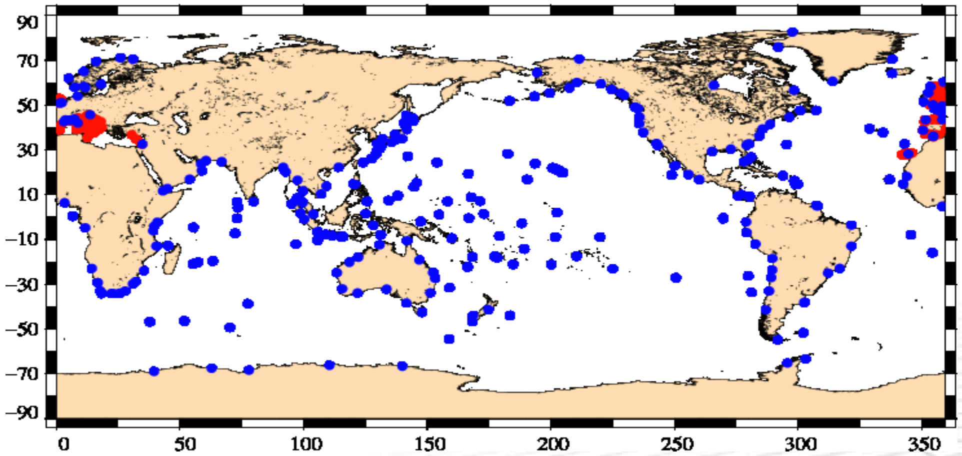
- In-situ data used are:
  - Tide gauges from global network (GLOSS/CLIVAR) and regional network (SONEL)
  - Temperature and Salinity profiles from ARGO data

- Here, we are focusing on main results concerning MSL drift or jumps

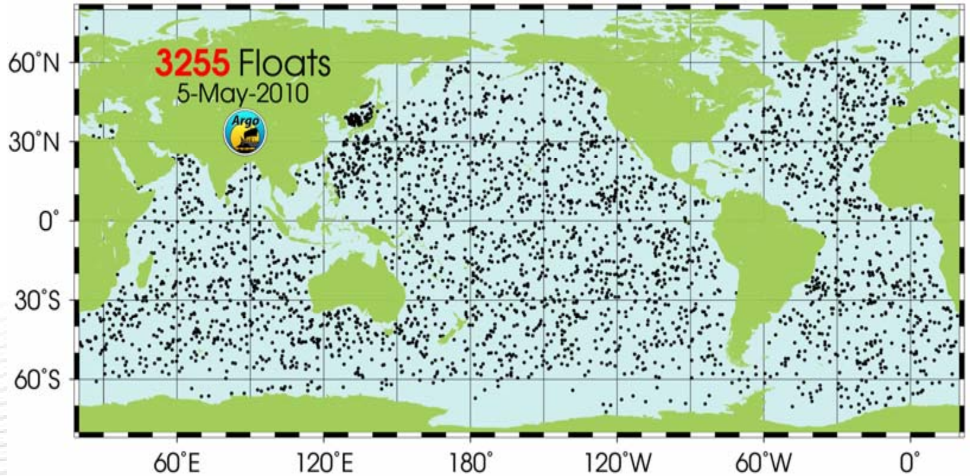
In-situ datasets and methodology

Description of in-situ datasets

- The main tide gauge network used is GLOSS/CLIVAR with a global coverage over all the altimeter period from 1992 onwards and with more than 300 tide-gauges. Regional networks as SONEL is also used
- Concerning T/S profiles, ARGO data are available from 2002 onwards with more than 3000 profiles available since November 2007.
- Both data are complementary since tide gauges provide a very good temporal sampling (hourly) but a poor spatial sampling with data only close to the coasts, whereas ARGO data are very well spread out over the open ocean but with only a 10-day sampling.



GLOSS/CLIVAR (blue dots) and SONEL networks (red dots): 398 tide gauges



Global comparison from mid-2004 with more than 3000 profiles and 80% of ocean surface covered

Methodology to compare tide gauge and altimetry SSH

- The comparison method is composed of the following steps :

⇒ Calculation of the altimeter and tide gauge SSH applying DAC and tidal corrections, MSS

⇒ Collocation of altimeter and in-situ data selecting the best altimeter correlated time data series with tide gauge one (within a maximal distance)

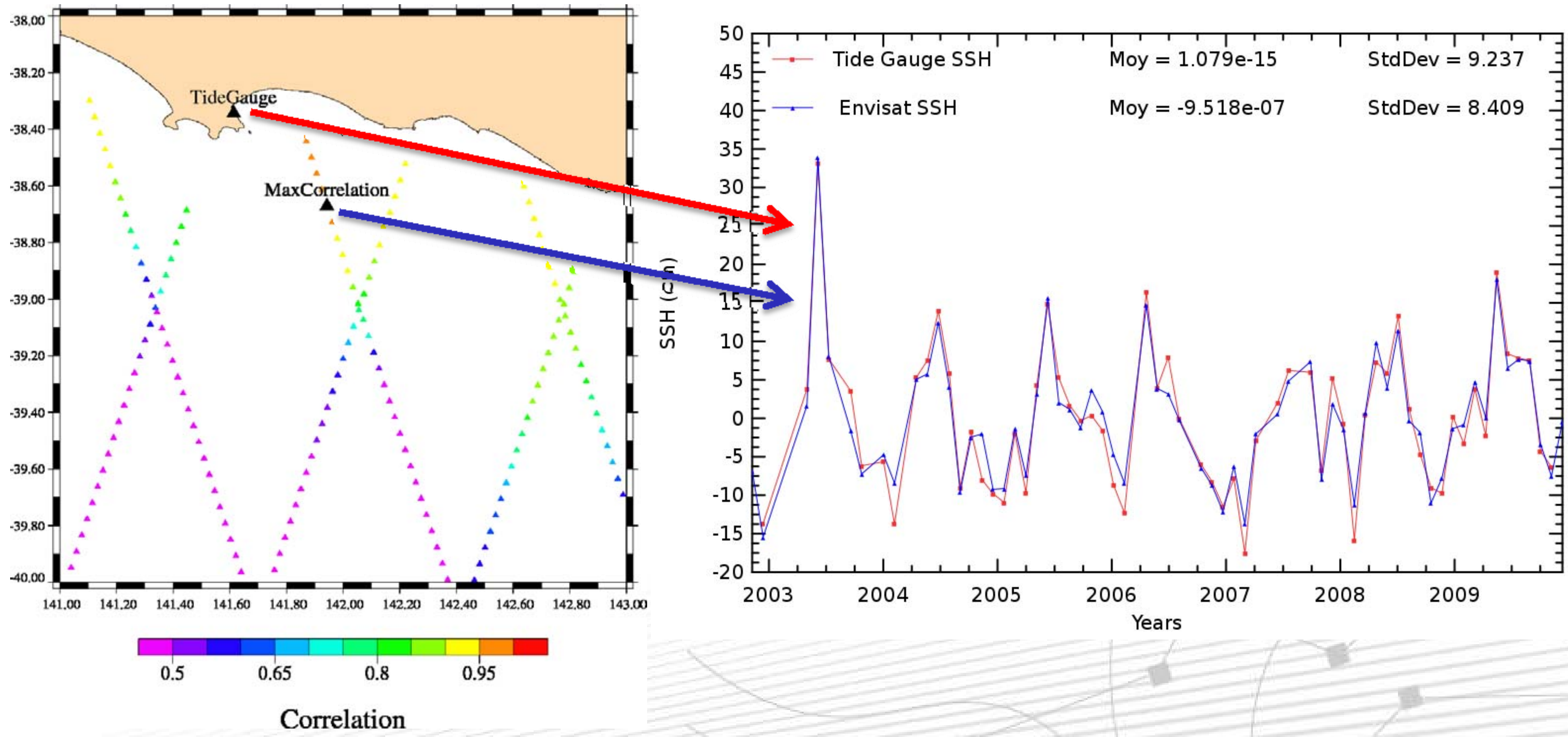
⇒ Calculation of SSH differences at each tide gauges after removing colocated time data series not well correlated enough (due geophysical processes, jump in tide gauges) and too short tide gauge time data series.

⇒ Computation of the altimeter SSH drift from all the remaining time data series (after editing)

- More information are available on AVISO website :

http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/insitu/annual_report_insitu_2009.pdf

Methodology to compare tide gauge and altimetry SSH



Methodology to compare T/S profiles and altimetry SSH

- Altimeters measure the total height of the water column (mass and steric parts) whereas T/S in-situ profiles only measure the steric part

⇒ need to use of regression coefficients to extrapolate the steric content of T/S profiles to the total water column

⇒ Spatial / temporal interpolation between in-situ profiles and 10-days mean gridded EN data (to provide sufficient spatial density of data)

⇒ Global statistics and coherence analyses between two types of data

- More information are available on AVISO website :

http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/insitu/annual_report_insitu_TS_2009.pdf

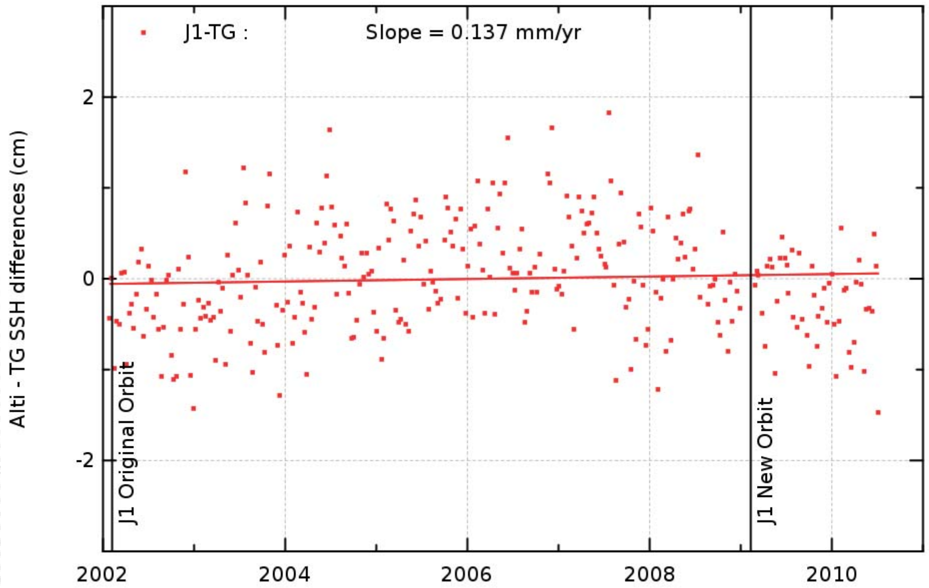
Jason-1 & 2 / in-situ SSH comparisons

Jason-1 and tide gauges SSH comparisons

- Jason-1 and TG SSH differences has been performed from GDR-C release
- No significant trend is detected (+ 0.1 mm/yr) within the method error (+/- 0.5 mm/yr) due to :

⇒ Crustal corrections do not exist for all TG

⇒ Colocalization error between altimetry and TG data (geophysical process differences, …)



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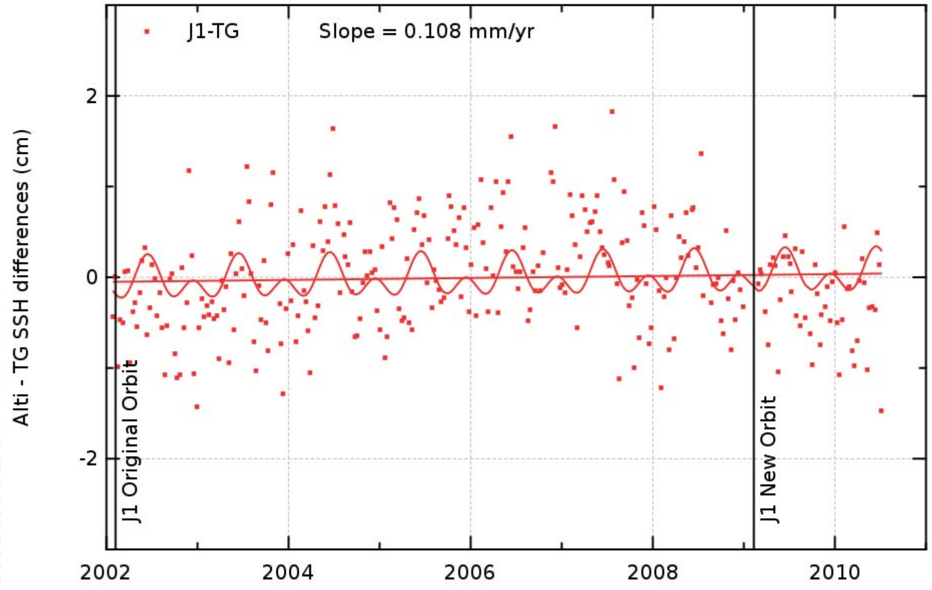
- For instance we observe annual and semi annual periodic signal on SSH differences (2 mm amplitude)



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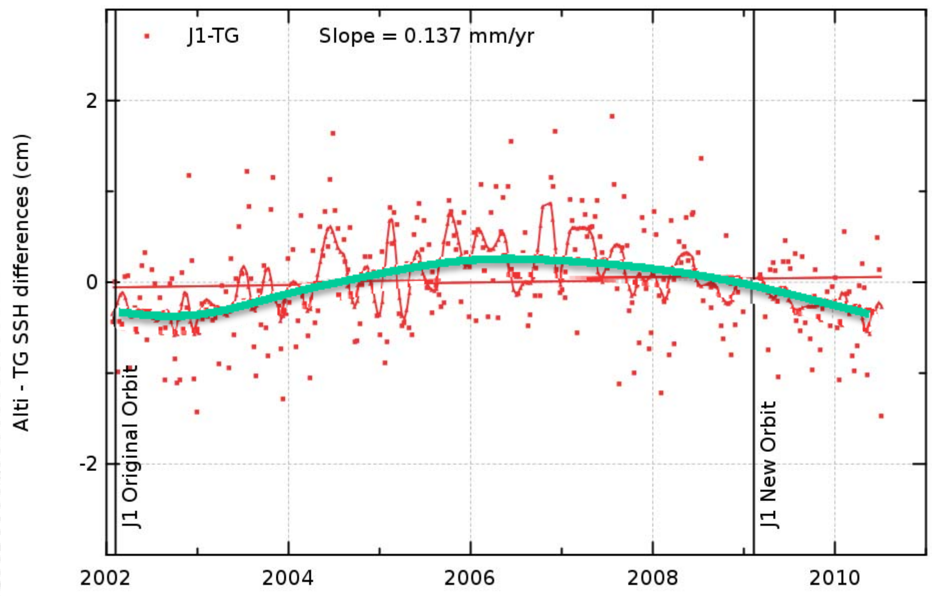
- For instance we observe annual and semi annual periodic signal on SSH differences (2 mm amplitude) : it is also the case with other altimeters !

- After filtering out signal lower than 2 months and removing periodic signals :

⇒ A parabolic curve is highlighted (~ 5 mm)

⇒ Under investigation



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⇒ Localization error between altimetry and TG data

- For instance we observe annual and semi annual periodic signal on SSH differences (2 mm amplitude) : it is also the case with other altimeters !

- After filtering out signal lover than 2 months and removing periodic signals :

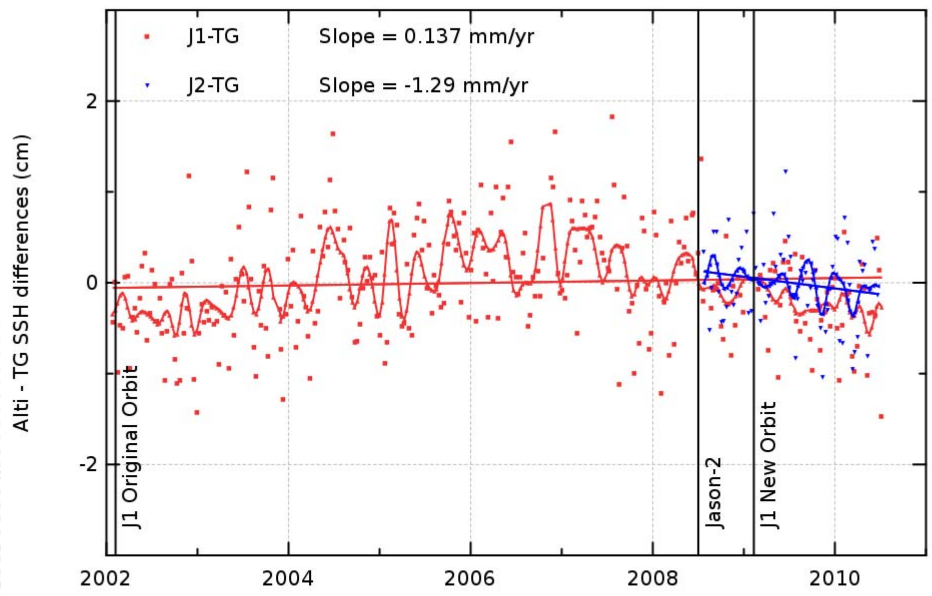
⇒ A parabolic curve is highlighted (~ 5 mm)

⇒ Under investigation

- Jason-2 and TG SSH differences have been also performed

⇒ A negative trend is calculated

⇒ It's not a significant result due to the short period : error of the method is important !



Envisat / in-situ SSH comparisons

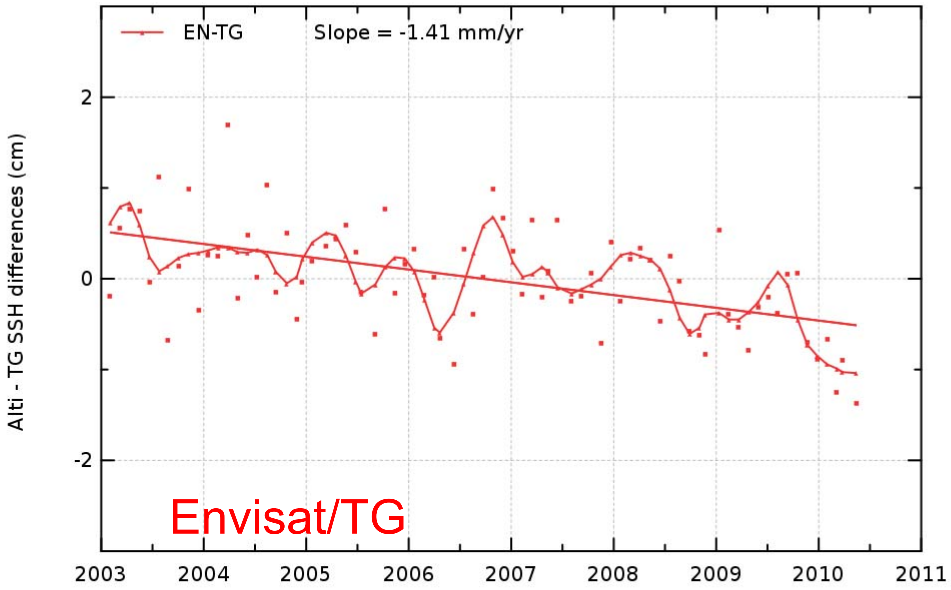
Envisat and tide gauges SSH comparisons

- Envisat and SSH differences have been computed from GDRs: not homogenous GDR A, B , C

⇒ Therefore some corrections have been updated with GDR-C standards (orbit,…)

⇒ But it remains some inhomogeneities (L1 processing, …) which impact the MSL stability

- A significant negative drift is detected from 2003 onwards : -1.4 mm/yr



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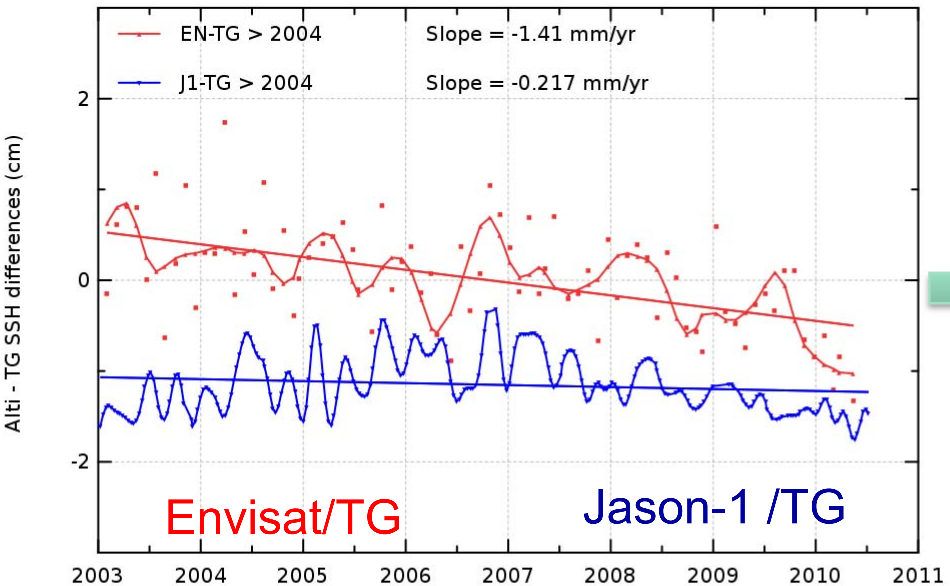
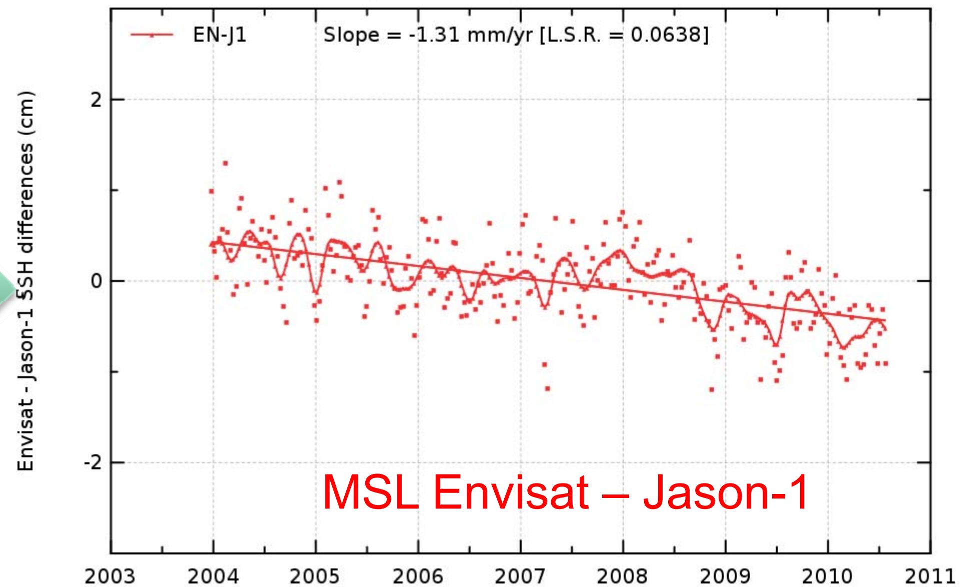
⇒ But it remains in homogeneity (L1 processing, …) which impact the MSL stability

- A significant negative drift is detected from 2003 onwards : -1.4 mm/yr

- The good drift consistency between global MSL differences and Alti/TG cross-comparisons for EN and J1 demonstrates the robustness of this in-situ method comparison.

Δ (EN/TG)/(J1/TG) = -1.2 mm/yr ⟺ Δ MSL(EN-J1)= -1.3 mm/yr



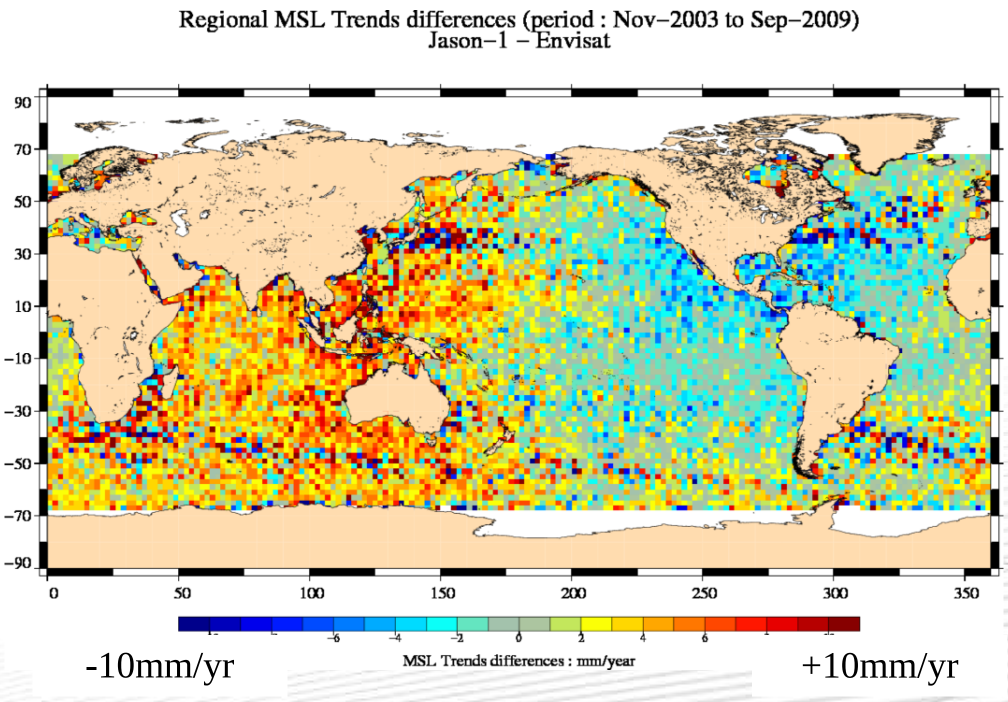


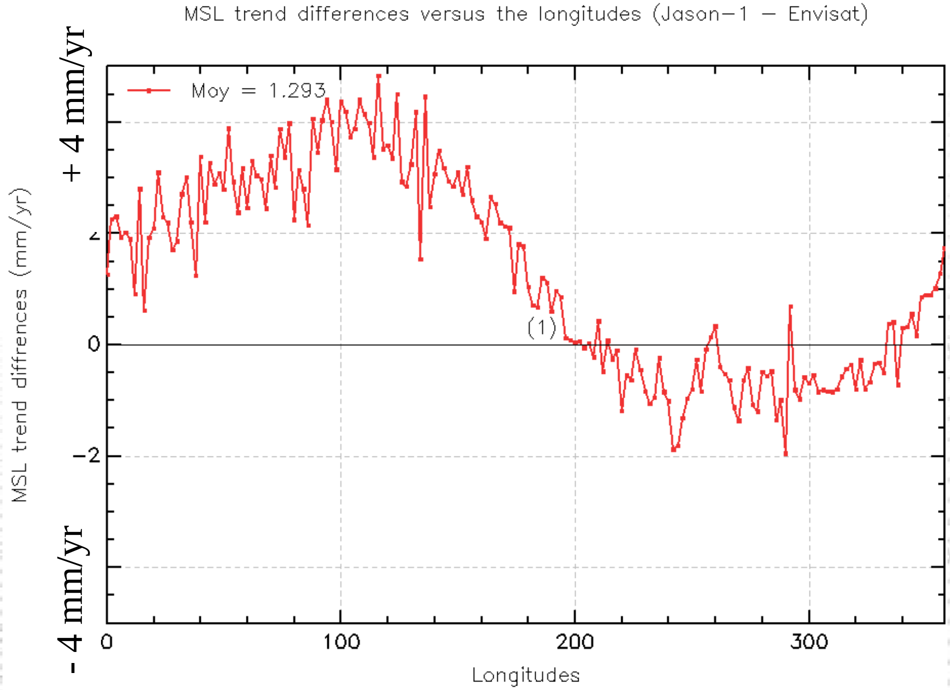
Envisat/Jason-1 regional MSL discrepancies

- Regional MSL trend differences between Jason-1 and Envisat underline East/West discrepancies (see Faugere's talk) :

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

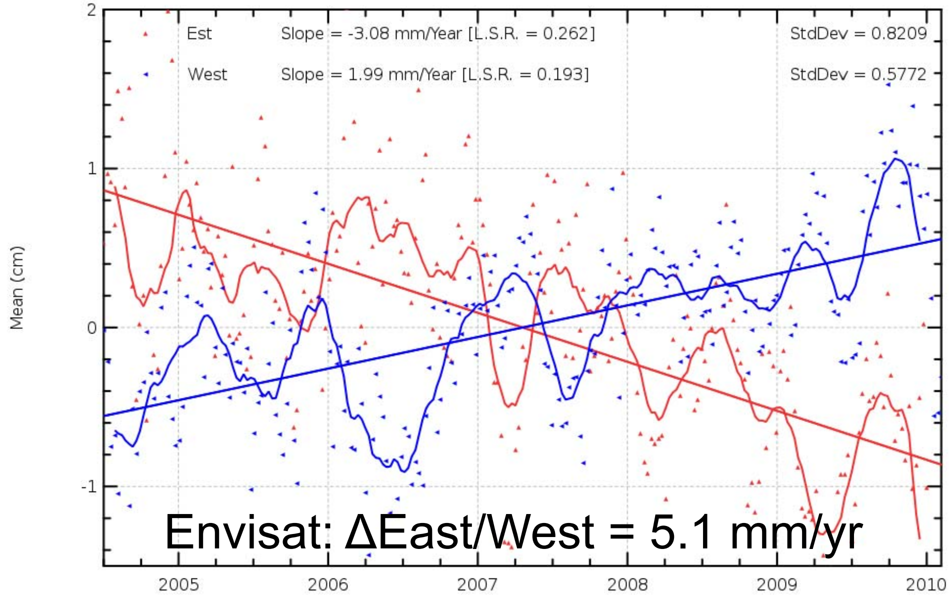
⇒ This strong longitude dependence displays a sinusoidal shape

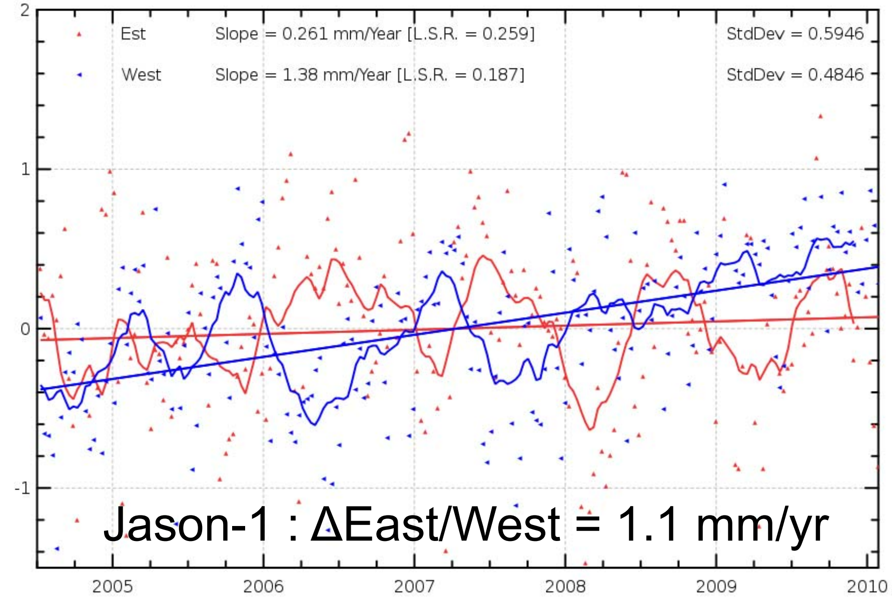




Envisat/Jason-1 regional MSL discrepancies

- We compute Envisat and Jason-1 SSH drift with T/S profiles separating East (0°/180°) and West (180°/360°) part
- We observe that the East/West drift is more homogenous comparing Jason-1 and T/S profiles than comparing Envisat and T/S profiles
- This probably demonstrates that the East/West regional differences observed between Jason-1 and Envisat is mainly due the Envisat MSL
- It could be in relationship with the orbit calculation : impact of variable gravity fields (under investigations).



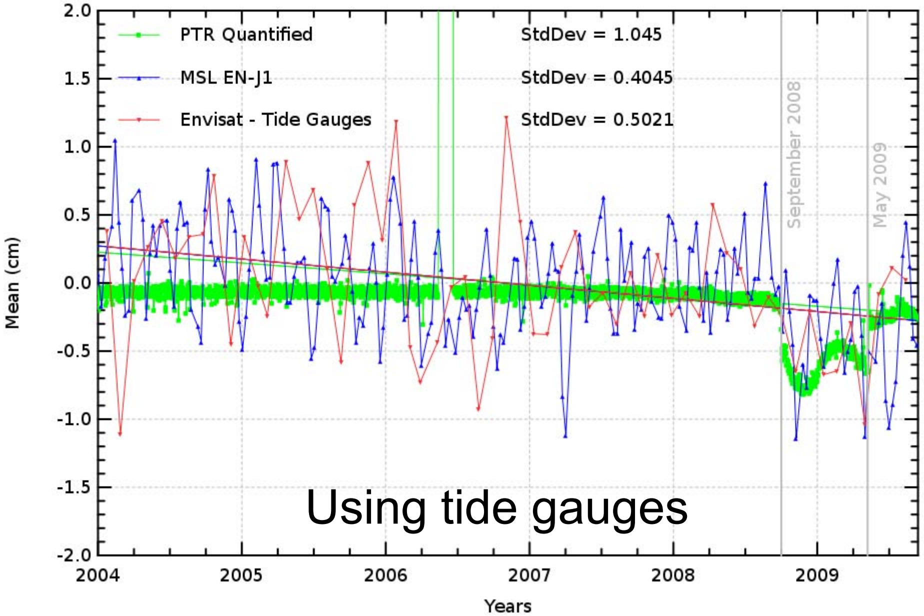


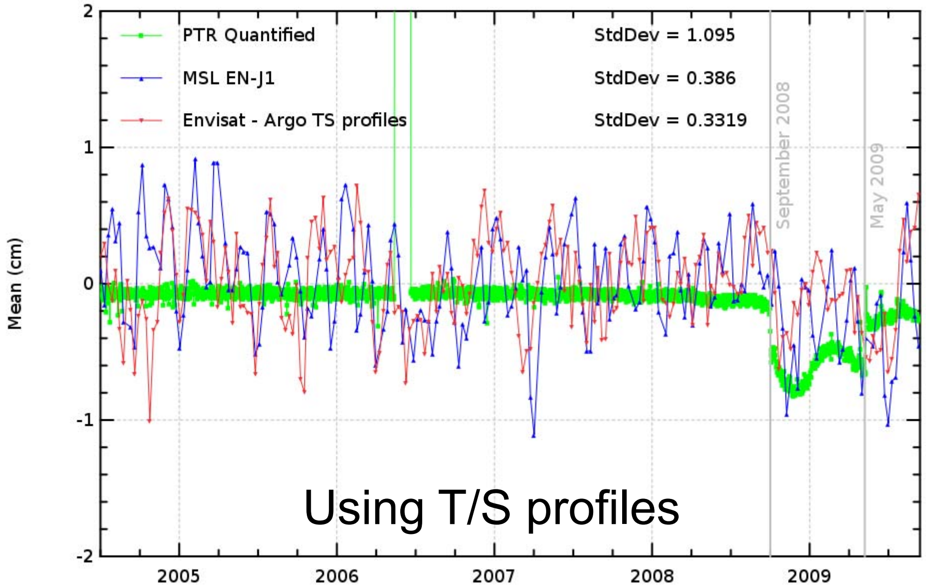
Detection of instrumental anomalies

- A PTR anomaly occurred between September 2008 and May 2009 (see Faugere's talk)
- Thanks to comparisons with in-situ data, we have observed and quantified the impact of this anomaly on the Envisat MSL:

⇒ This anomaly has been observed similarly using tide gauge or T/S profiles

⇒ This demonstrates the ability of these comparison methods (TG and T/S) to detect small jumps (5 mm) on the altimeter MSL

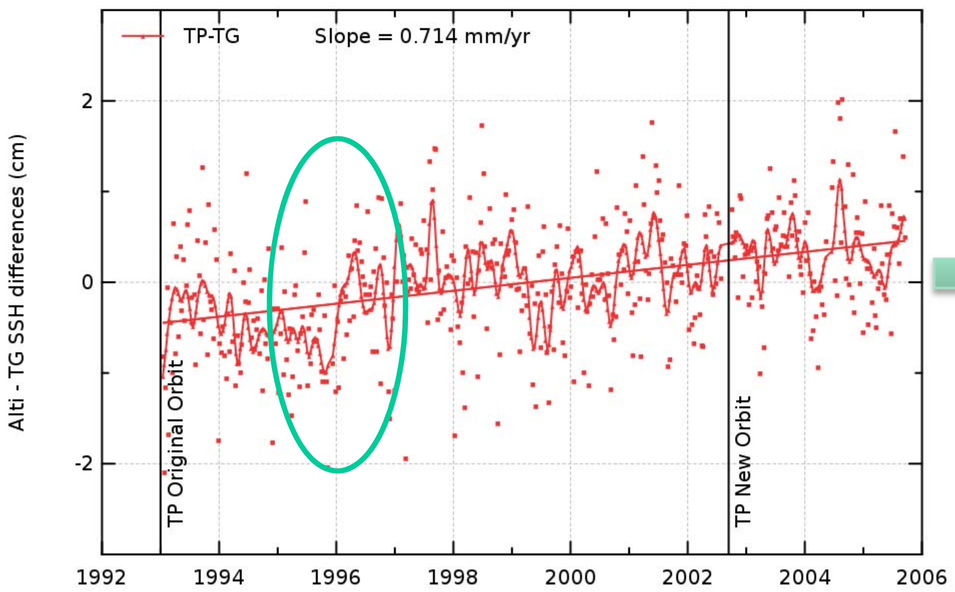


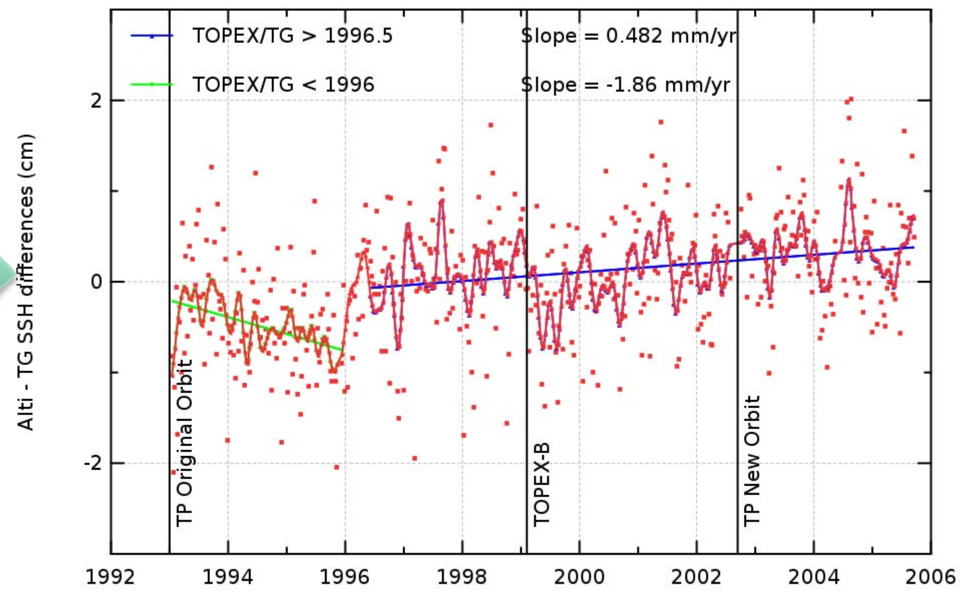


TOPEX / in-situ SSH comparisons

TOPEX and tide gauges SSH comparisons

- TOPEX and TG SSH differences have been performed from 1993 onwards from M-GDRs after updating best altimeter standards for TOPEX SSH (GSFC orbit, SSB, GOT4.7 tidal model, corrected TMR, …)
- A drift close to +0.7 mm/yr is detected
- After filtering out signals lower than 2 months, a jump close to 7 mm is highlighted in 1996 : drift is strongly negative before 1996 (-1.9 mm/yr) and slightly positive after (+0.4 mm/yr)
- This jump corresponds to M-GDR "B" reprocessing : to be investigate





Conclusion

Summary and Conclusion

- Summary :

⇒ Drifts, ramp or jump are detected on the altimetry mission by comparison with TG and T/S profiles

⇒ Jason-1 : no drift but a parabolic signal seems to be detected (~5 mm) => under investigation

⇒ Jason-2 : negative drift but to date, the period length is too short

⇒ TP : positive drift (+0.7 mm/yr) partly explained by a jump (7 mm) in 1996 => under investigation

⇒ Envisat : negative drift (-1.4 mm/yr) and a strong regional drift dependant on the longitudes (East/West) likely in relationship with the orbit calculation => GDR reprocessing should improve the Envisat long-term stability

⇒ T/S profiles / Alti comparisons provide similar global MSL drift estimation (not shown here) but the method error is higher (time data series shorter, different physical contents …)

- Conclusion :

⇒ It's important to underline the synergy of both methods (TG and T/S) to estimate the altimetry MSL drift:

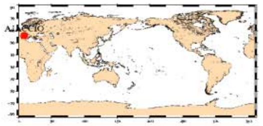
  ⇒ while tide gauge measurements provide long time series but limited spatial sampling, T/S profiles provide global coverage but are available on a shorter time period

⇒ Finally, thanks to the cross-comparisons between results provided by different approaches (global comparison between altimetry missions, Alti/TG and Alti/TS comparisons), the estimate of the MSL drift from altimetry is more and more reliable and accurate (globally and regionally)

TIDE GAUGE : SO0300

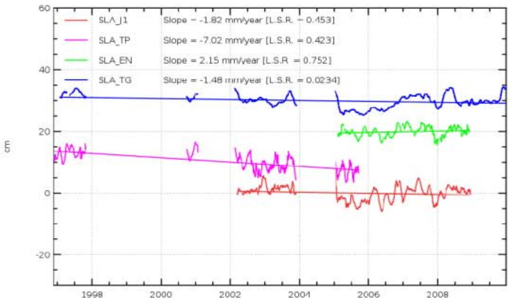
Tide Gauge identification

Tide Gauge Network	SONEL
Location (Lat/Lon)	41.93 deg / 8.76 deg
Time series coverage	From 25/07/1981 to 19/02/2010
Vertical movements drift	YES

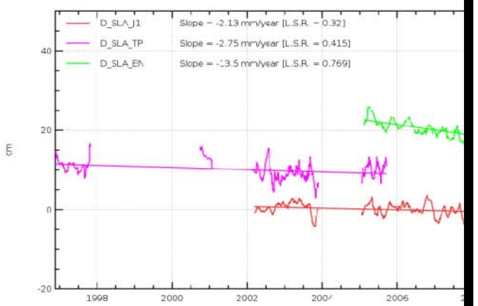


Temporal SSH comparisons with T/P, Envisat, Jason-1 and Jason-2

Monitoring of SSH

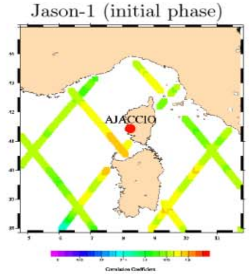


Monitoring of SSH differences

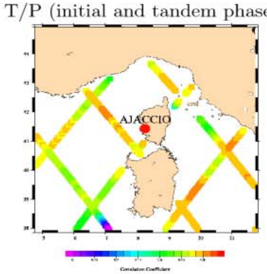


Maps of SSH correlation with Jason-1, T/P and Envisat

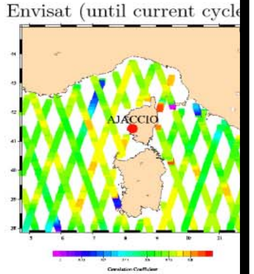
Jason-1 (initial phase)



T/P (initial and tandem phase)



Envisat (until current cycle



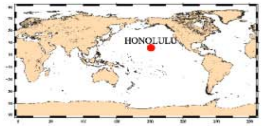
Tide Gauge reliability

	T/P	T/P (tandem)	Jason-1	Jason-2	Envisat
Minimal distance from TG	xx kms	xx kms	xx kms	xx kms	xx kms
TG crustal drift	12.6 mm/yr	12.6 mm/yr	12.6 mm/yr	- mm/yr	12.6 mm/y
Maximal SSH correlation	0.93	0.92	0.89	-	0.99
Non-filtered SSH diff RMS	5 cm	10 cm	4.3 cm	- cm	5.4 cm
Filtered SSH diff RMS	1.9 cm	2.2 cm	1.7 cm	- cm	2.7 cm
SSH differences slope	1.7 mm/yr	3.1 mm/yr	-2.1 mm/yr	- mm/yr	-13.5 mm/
Quality control	KO	KO	KO	-	KO

TIDE GAUGE : WO0057

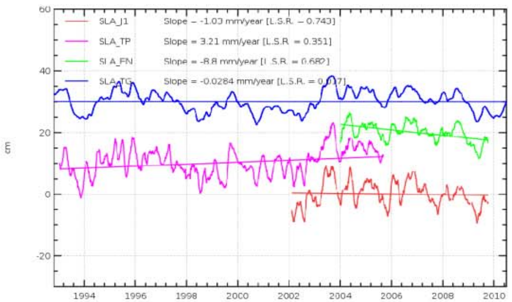
Tide Gauge identification

Tide Gauge Network	WOCE
Location (Lat/Lon)	21.31 deg / 202.13 deg
Time series coverage	From 01/01/1950 to 31/08/2010
Vertical movements drift	YES

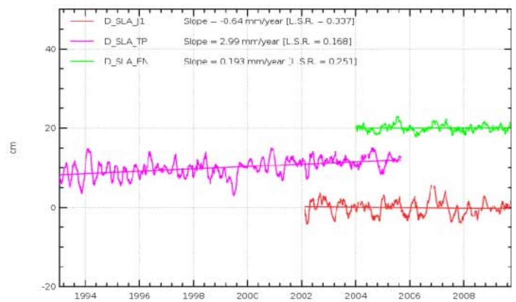


Temporal SSH comparisons with T/P, Envisat, Jason-1 and Jason-2

Monitoring of SSH

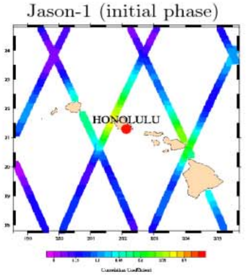


Monitoring of SSH differences

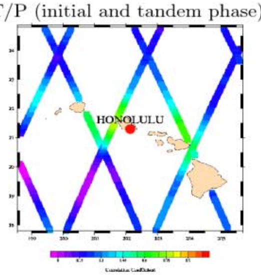


Maps of SSH correlation with Jason-1, T/P and Envisat

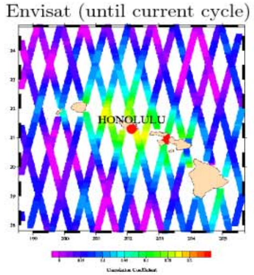
Jason-1 (initial phase)



T/P (initial and tandem phase)



Envisat (until current cycle)

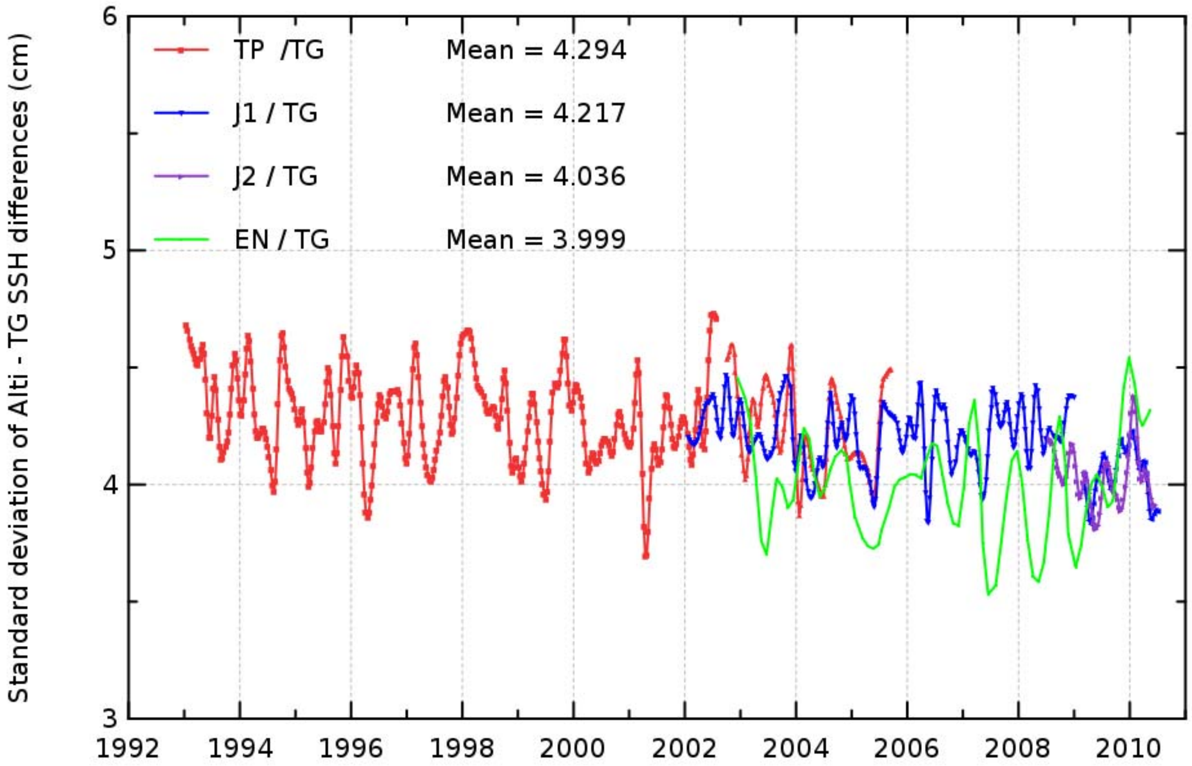


Tide Gauge reliability

	T/P	T/P (tandem)	Jason-1	Jason-2	Envisat
Minimal distance from TG	xx kms	xx kms	xx kms	xx kms	xx kms
TG crustal drift	-0.1 mm/yr	-0.1 mm/yr	-0.1 mm/yr	- mm/yr	-0.1 mm/yr
Maximal SSH correlation	0.78	0.81	0.82	-	0.84
Non-filtered SSH diff RMS	5.8 cm	6.8 cm	5.7 cm	- cm	4.8 cm
Filtered SSH diff RMS	2.4 cm	1.1 cm	2 cm	- cm	1 cm
SSH differences slope	2.5 mm/yr	-1.5 mm/yr	-0.6 mm/yr	- mm/yr	0.2 mm/yr
Quality control	OK	OK	OK	-	OK

Envisat and tide gauges SSH comparisons

- Standard deviation of SSH/TG SSH differences



Jason-1 SSH calculation : altimetry standards applied

- Jason-1 GDR products have been used and last and homogenous altimetry standards have been applied in order to improve the Jason-1 SSH calculation.

SSH Field Name	Altimetry Standards
Orbit	CNES POE (GDR-C standards)
Mean Sea Surface (MSS)	MSS CLS01 (v1)
Dry troposphere	ECMWF model computed
Wet troposphere	Jason-1 radiometer (JMR)
Ionosphere	Filtered dual-frequency altimeter range measurements
Sea State Bias	Non parametric SSB (GDR product)
Ocean tide and loading tide	GOT4.7 (S1 parameter is included)
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]
Pole tide	[Wahr, 1985]
Combined atmospheric correction	High Resolution Mog2D Model [Carrère and Lyard, 2003] + inverse barometer computed from ECMWF model (rectangular grids)
Specific corrections	Jason-1 / T/P global MSL bias

Jason-2 SSH calculation : altimetry standards applied

- Jason-2 GDR products have been used and last and homogenous altimetry standards have been applied in order to improve the Jason-2 SSH calculation.

SSH Field Name	Altimetry Standards
Orbit	CNES POE (GDR-C standards)
Mean Sea Surface (MSS)	MSS CLS01 (v1)
Dry troposphere	ECMWF model computed
Wet troposphere	Jason-2 radiometer (AMR)
Ionosphere	Filtered dual-frequency altimeter range measurements
Sea State Bias	Non parametric SSB (GDR product)
Ocean tide and loading tide	GOT4.7 (S1 parameter is included)
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]
Pole tide	[Wahr, 1985]
Combined atmospheric correction	High Resolution Mog2D Model [Carrère and Lyard, 2003] + inverse barometer computed from ECMWF model (rectangular grids)
Specific corrections	Jason-2 / T/P global MSL bias

Envisat SSH calculation : altimetry standards applied

- Envisat GDR products have been used and last and homogenous altimetry standards have been applied in order to improve the Envisat SSH calculation.

SSH Field Name	Altimetry Standards
Orbit	Cycle 15 onwards: CNES POE (GDR-C standards)
Mean Sea Surface (MSS)	MSS CLS01 (v1)
Dry troposphere	ECMWF model computed
Wet troposphere	MWR (corrected from side lobes from cycle 41)
Ionosphere	Dual-Frequency Updated with S-Band SSB (< cycle 65) GIM model + global bias of 8 mm (>= cycle 65)
Sea State Bias	Updated homogeneous to GDR-B
Ocean tide and loading tide	GOT4.7 (S1 parameter is included)
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]
Pole tide	[Wahr, 1985]
Combined atmospheric correction	High Resolution Mog2D Model [Carrère and Lyard, 2003] + inverse barometer computed from ECMWF model (rectangular grids)
Specific corrections	USO correction from auxiliary files + bias for side-B

TOPEX/Poseidon SSH calculation : altimetry standards applied

- T/P homogeneous products have been used for the SSH calculation, especially with the new SSB correction from the 2-parameter Gourrion's method (SWH and Sigma-0)

SSH Field Name	Altimetry Standards
Orbit	GSFC POE (09/2008), ITRF2005+Grace
Mean Sea Surface (MSS)	MSS CLS01 (v1)
Dry troposphere	ECMWF model computed
Wet troposphere	TMR with drift correction [Scharoo et al. 2004] and empirical correction of yaw maneuvers [2005 annual validation report]
Ionosphere	Filtered dual-frequency altimeter range measurements (for TOPEX) and Doris (for Poseidon)
Sea State Bias	Non parametric SSB (for TOPEX), BM4 formula (for Poseidon)
Ocean tide and loading tide	GOT4.7 (S1 parameter is included)
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]
Pole tide	[Wahr, 1985]
Combined atmospheric correction	High Resolution Mog2D Model [Carrère and Lyard, 2003] + inverse barometer computed from ECMWF model (rectangular grids)
Specific corrections	Doris/Altimeter ionospheric bias, TOPEX-A/TOPEX-B bias and TOPEX/Poseidon bias