# Performance estimation of recent tide models using altimetry and tide gauges measurements

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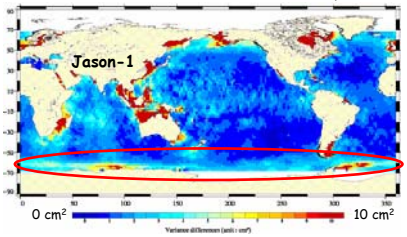
## Introduction

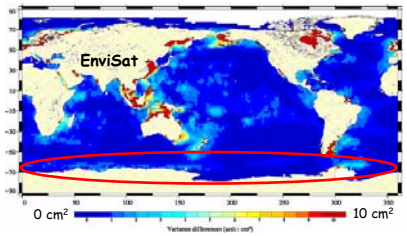
Thanks to its current accuracy and maturity, altimetry is considered as a fully operational observing system dedicated to various applications such as climate studies. Altimeter measurements are corrected from several geophysical parameters in order to isolate the oceanic variability and the tide correction is one of the most important.
**Models description:** Global tide models GOT00v2 (Ray 1999) and FES 2004 (Lyard et al. 2006) are commonly used as a reference for tide correction in the altimetry products (GDR). GOT00v2 is an empirical model based on altimeter data, while FES 2004 is a finite elements hydrodynamic model which assimilates altimeter and in situ data. The accuracy of both models in open ocean is centimetric but significant errors remain in shallow waters and in polar regions, due to the omission of compound tides and to sea ice effects on data respectively. New global models are now available (GOT4.7 (Ray 2008) and EOT08a (Savcenko & Bosch 2008)).
**Methods:** We use multi-mission (Topex-Poséidon, Jason-1 and EnviSat) altimetric analysis of Sea Surface Height (SSH) differences at crossovers, sea level anomalies (SLA) and in-situ measurements (tide gauges from several databases) to determine and compare their performances.

## Statistics on models

Variance of the difference between EOT08a and FES04 tide corrections are shown below for Jason-1 and Envisat missions (2005). Both missions reveal high variances (>10 cm²) in coastal areas. In open ocean variances are very low for Envisat (<1 cm²) with values up to 3 cm2 in restricted areas while values are higher for Jason-1 in open ocean and at high latitudes. These stronger differences detected on Jason-1 are likely due to some aliasing problems in EOT08a tide components, especially S2 due to the heliosynchronism of Envisat mission. Note that such differences are not detected with Envisat mission because of consistency of S2 residual with observations of this satellite.

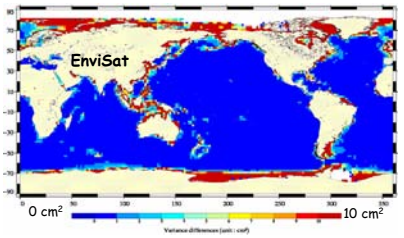



EOT08a vs FES04



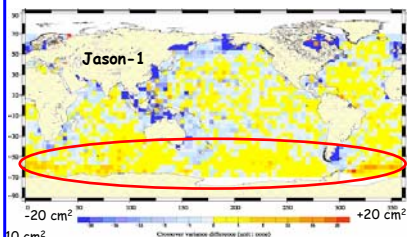

The map of the variance of the difference between GOT4.7 and GOT00V2 on years 2004-2005 of Envisat mission indicates no difference between models in open ocean. Differences are found in Hudson Bay, polar oceans and over continental shelves where high values of variances can be seen. Similar results are obtained with Jason-1 mission.

GOT4.7 vs GOT00v2

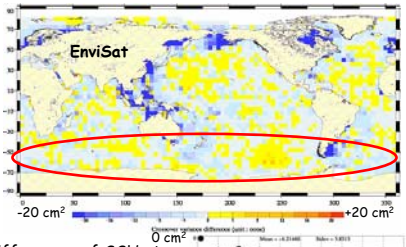


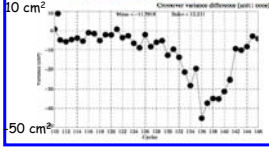

## Impact on SSH at crossovers

Maps below show the variance differences of SSH at crossovers with EOT08a vs FES04 for Jason-1 and Envisat missions (2005). Improvement of the SSH coherence at crossovers with EOT08a (negative / blue values) can be seen mainly in coastal areas (up to 20 cm²) with both missions. In open ocean, the improvement with EOT08a is weak with Envisat (+/- 2 cm²) whereas EOT08a deteriorates SSH coherence with Jason-1 (mean of 2-4 cm² and up to 10 cm²). This deterioration could be accounted for some aliasing problems in the S2 component of EOT08a, due to heliosynchronism of Envisat mission. This is not detected with Envisat mission because of consistency of S2 residuals with observations of this satellite.

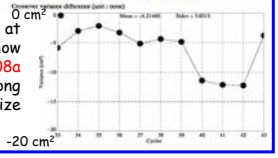



EOT08a vs FES04



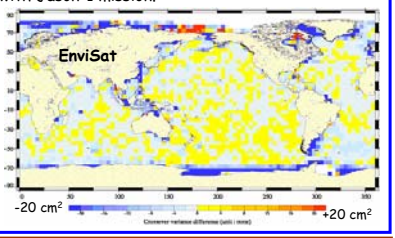




Time series (2005) of the variance differences of SSH at crossovers for Jason-1 and Envisat missions show systematically negative values meaning that EOT08a reduces SSH variance compared with FES04. A strong annual signal is detected corresponding to the varying size of ice covered areas in both hemispheres.

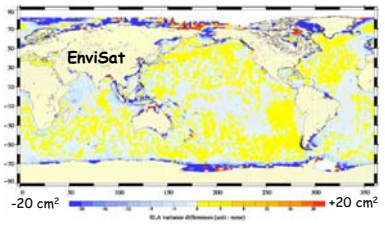



The use of GOT4.7 reduces the variance of SSH at crossovers of Envisat mainly in coastal areas (negative / blue values) and particularly in Antarctic and Artic regions. Deterioration is locally found in Hudson Bay and Bering strait likely due to seasonal ice cover problems. Similar results are obtained with Jason-1 mission.

GOT4.7 vs GOT00v2

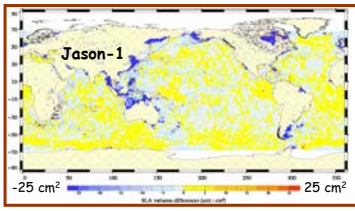



GOT4.7 vs GOT00v2




The map of variance differences of along-track SLA on Envisat mission (2004-2005) confirm the analysis at crossovers: GOT4.7 reduces SLA variance in coastal areas (negative / blue values) except in Hudson Bay and Bering strait and has almost no impact in open ocean.

## Impact on along-track SLA

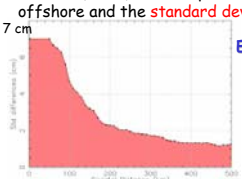



EOT08a vs FES04

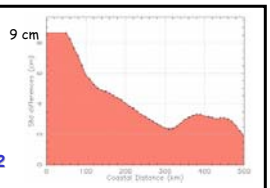
The map of variance differences of along-track SLA on Jason-1 mission (2005) confirm the analysis at crossovers: EOT08a reduces SLA variance in coastal areas (negative / blue values). Deterioration (positive / yellow values) is still observed at +/-60° of latitude due to some aliasing problems of EOT08a tide components (S2).

## Coastal evaluation

In opposition with above maps, we quantify here the reduction of SSH variance at crossovers with EOT08a compared with FES04 versus distance offshore for Envisat mission (2005). The improvement with EOT08a sharply increases at about 160 km offshore and the standard deviation difference reaches 7 cm at 50 km from the coast.




EOT08a vs FES04

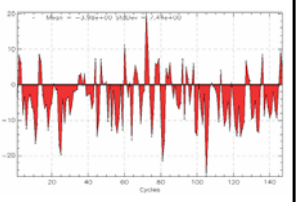



GOT4.7 vs GOT00v2

Concerning GOT4.7 to GOT00V2 comparison for Envisat mission (2004-2005), the standard deviation difference also increases towards the coast and reaches 9 cm at 50 km offshore

## Comparison with in situ measurements (tide gauges)

Tide gauges enable to evaluate the coherence between SLA from altimetry and SLA from tidal gauges time series both corrected from either GOT4.7 or GOT00V2. The analysis over 2002-2006 with Jason-1 shows an improvement of this coherence of 4 cm2 when using GOT4.7 instead of GOT00V2 (cf figure).



Moreover the reduction of variance obtained with EOT08a or FES04 models are compared at the position of 135 tide gauges: the use of EOT08a instead of FES04 allows a reduction of variance of 13 cm² when averaged over all tide gauges.

## Conclusions & Perspectives

* Global statistics and comparison with tidal time series have shown that EOT08a tide model is better than FES04 in coastal areas. Nevertheless, deterioration is observed in open ocean and mainly at high latitudes and in equatorial zones. This deterioration is accounted for some aliasing problems in the S2 tide component (and others ?) of EOT08a. GOT4.7 tide model is better than GOT00V2 in coastal zones and results are similar in open ocean.
The comparison between EOT08a and GOT4.7 has also been studied and GOT4.7 is globally better than EOT08a in coastal zones and in open ocean except in very few areas.
* In the future, assimilation of data is essential to maintain good performances of models in open ocean and still improve the transition to coastal zones. In these areas, more observations are needed to improve the modelling of non linear tides (with short wavelengths) and secondary waves (with weak amplitudes), which are not well resolved by actual altimetric systems. The new available global GEBCO 30" bathymetry and local high resolution bathymetry should enable significant improvement of global/local modelling of tides. Moreover, the performances of global models will be improved in coastal areas thanks to the coupling with high resolution local models which are being developed.

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