X-TRACK, A NEW PROCESSING TOOL FOR ALTIMETRY IN COASTAL OCEANS

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ABSTRACT

Oceanographic applications using satellite altimeter data become very challenging when leaving the deep ocean for the coastal regions. Close to the coast, altimeter observations are often of lower quality for a number of reasons, including land contamination of the satellite footprints or inaccurate resolution of the corrections of the high frequency ocean response to tidal and atmospheric loading. This paper presents a new processing toolbox, called X-TRACK, to derive improved altimeter products, such as Sea Surface Heights (SSH), Mean Sea Surface Heights (MSSH) or Sea Level Anomalies (SLA), dedicated for coastal applications. Starting from classical Geophysical Data Records (GDR) products, particular attention is made to recover a maximum amount of exploitable data (dedicated data editing, interpolation of missing corrective terms). Where possible, local modelling of the high frequency response of the ocean to the tidal and atmospheric loading is applied instead of standard, global corrections given in the GDRs. In addition, orbit errors are reduced by a stability criterion and a high resolution mean sea surface consistent with the altimeter data set is computed along the satellite ground track. This poster presents promising results obtained in various coastal areas.

1. INTRODUCTION

Satellite altimetric missions in the last 15 years (TOPEX/Poseidon, ERS-1 and -2, GFO, Envisat and Jason-1) have resulted in great advances in marine research and operational oceanography, providing accurate sea level data (at centimetre error level) and high-value information products (including waves and wind) for fisheries planning, ship routing and offshore operations. However, pioneer studies in the middle of the 90s stated that it was possible to use altimeter data for non dedicated and marginal applications (coastal zones, continental lakes and rivers, flooding plains, sea or continental ices).

Actually, the coastal dynamics is very complex and the space-time sampling of the current altimeter missions is generally too low to capture such variability. So before next altimeter mission embarquing a new generation of altimeters are launched, particular post-processing of altimeter data must be defined and performed to exploit altimeter data in coastal areas.

2. DATA PROCESSING

The new processing presented hereinafter was originally developed within the framework of the ALBICOCCA (Altimeter-Based Investigations in Corsica, Capraia and Contiguous Areas) Project in the northwestern Mediterranean Sea. Additional developments lead to the X-TRACK altimeter data processor. The objective of this processor is to improve both the quantity and quality of altimeter sea surface measurements in coastal regions, mainly by redefining the data editing strategy to minimize the loss of data during the correction phase and by using improved local modelling of tidal and short-period atmospheric forcing, as recommended by earlier studies [1;10].

The usual validity checks for altimeter data editing have been designed for deep ocean regions. However, the relevance of these checks needs to be re-investigated in coastal systems where a particular care is required to select quality and sufficiently numerous altimeter data. In fact, the classical data editing is suspected to be excessively restrictive close to the coast, in particular because of the weak spatial resolution of the land flag from the radiometer swath, and therefore to limit the amount of exploitable altimeter data in an almost 50 km-width coastal strip. Moreover, the editing criteria are basically built on radiometer or altimeter measurements and/or derived parameters, which are often degraded in accuracy as their footprints are contaminated by land presence. The X-TRACK processor adopts therefore new data screening strategy and filtering techniques allowing to recover data that would otherwise be flagged as bad [9]. Figure 1 shows an example of data recovery along T/P track 222 for cycle 95 (22/04/1995). The original GDR sea level anomalies are affected by erroneous values in the wet tropospheric correction, and therefore flagged as bad. De-flagging and re-interpolation of the correction yields a reconstructed level profile. Reference [11] and [4] outlined the benefits of such a strategy to the overall improvement of altimeter products quality.

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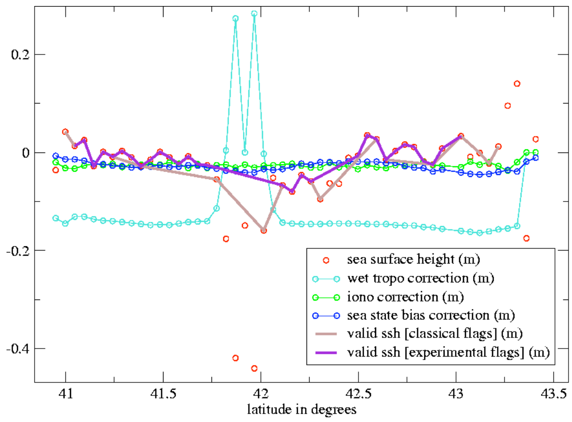

Figure 1: New data editing strategy. Circles: uncorrected sea level anomalies (SLA) and original corrections from the AVISO Geophysical Data Records (GDR). Brown line: SLA after application of the standard corrections from the GDR. Purple line: the new SLA profile computed with X-TRACK processor.

Aliasing of the tides and short-period ocean response to meteorological forcing is a major problem when estimating the seasonal or longer time scales oceanic circulations in altimeter data. The energetic variability at periods shorter than 20 days clearly cannot be resolved by the nearly 10-day or 35-day repeat period of the Jason-1 and Envisat orbits and the classical solution consists in removing this barotropic signal by using models. Earlier studies have demonstrated that global tidal models, despite their impressive improvement during the past decade, are generally too few accurate over the shallow water areas to properly remove tidal effects in the altimeter measurements. Because of their insufficient spatial resolution that implies unresolved rapid changes in tidal features and an incorrect frictional dissipation, current global model cannot represent tides over continental shelves below a decimetre error level. Thus, where possible, local modelling of tides is preferred to FES2004 [7] or GOT00b global corrections given in the GDR products. In consequence, as an alternative to the global tidal correction available in the altimeter products, an optimised tidal spectrum has been defined for the Mediterranean Sea, mainly based on MOG2D regional tidal solutions and combined with global model FES2004 for the K_1 diurnal component. A regional spectrum is also available over the European shelf [8]. Usually, the effects of atmospheric pressure loading are corrected by the inverted barometer approximation, unless significant departure can be observed at high latitudes and over continental shelves and shallow waters areas. In reality, the sea surface variations depends both statically and dynamically on the meteorological forcing whereas the IB approximation formulates merely the hydrostatic equilibrium between the sea level and the applied atmospheric pressure gradients. Moreover, the IB assumption totally ignores wind-forced sea level variations which can prevail particularly around 10-days periods. Thus, following [3], a similar modelling approach has been carried out in the Mediterranean Sea from a regional mesh [6].

Until accurate estimates of the geoid small- and meso-scales undulations become available, the dynamic topography of the ocean is not fully accessible in the altimeter measurements. Thus, the ocean mean sea surface provides an alternative reference surface, suitable for the observation of the ocean variability. In the frame of coastal altimetry applications, an highly accurate mean sea surface is needed and there are no prior guaranty that the horizontal resolution of the global mean sea surface products are adequate, especially in the case of along-shore circulation studies. First, coastal circulation and bottom topography can be responsible for centimetric mean sea surface variability on very short wavelength. Also, the mean sea surface depends on the data set used to derive it in terms of editing, applied geophysical corrections and time window. Thus the X-TRACK processor permits to compute an along track mean sea surface consistent with the altimeter data set on a regular grid following the satellite ground track.

X-TRACK main products are along track sea surface heights (SSH), mean sea surface (MSS) and sea level anomalies (SLA) along the satellite ground track and/or colocated onto mean tracks. These products are available at both a 1Hz rate and a higher rate (10/20 Hz) for the TOPEX/Poseidon, Jason-1, Geosat-Follow-On and Envisat altimeter missions.

The following sections illustrate the use of X-TRACK sea level anomaly products for hydrodynamic model validation.

3. TIDAL MODEL COMPARISON

Tidal constants computed from 10 years of TOPEX/Poseidon sea level measurements are compared to the solutions of two tidal models over the Mediterranean Sea and the Kerguelen Archipelago. Altimeter-derived tidal constituents are computed from a harmonic analysis of the X-TRACK SLA onto mean tracks products. For the Mediterranean Sea, X-TRACK altimeter products are de-aliased by a combination of regional modelling of tides and short-period ocean response to meteorological forcing. For the Kerguelen Archipelago, X-TRACK altimeter products are de-aliased with global corrections FES2004 and Mog2D-G. In Figure 2 and Figure 3, altimeter-derived tidal constants are compared to the reference global tidal model FES2004. The overall root-mean-square (rms) error is 0.7cm on both M2 and K1 tidal constituents. This residual error is spatially constant over the whole northwestern Mediterranean Sea for both M2 and K1 tidal constituents and thus can be interpreted as the combination of, in one hand, residual modelling errors in FES2004 solutions and, in the other hand, residual noise in the altimeter measurements. On the north of the Gulf of Lion and along the Spanish coast, the increase of the error is probably due to unresolved high frequency dynamics in the de-aliasing corrections whereas the hot red spot in the north of Sardinia is caused by erroneous altimeter data (land contamination in the altimeter footprint).

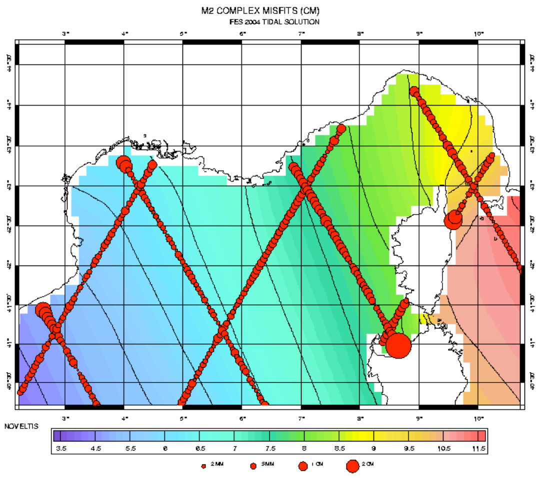

Figure 2: tidal misfits in the northwestern Mediterranean Sea for M2 constituent: background chart represents the tidal amplitude in cm from FES 2004 model. The size of the red circles is proportional to the modulus of the complex difference between model and observation.

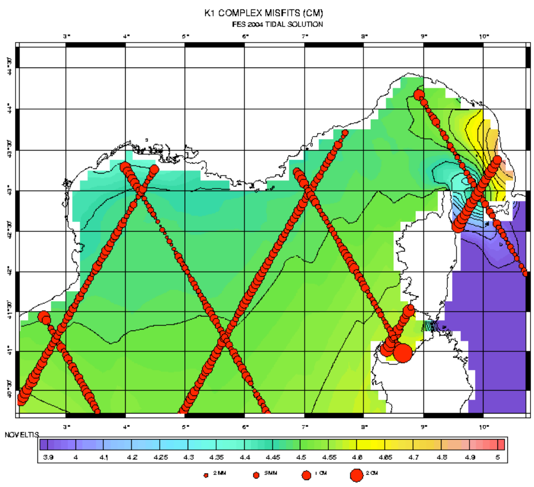

Figure 3: K1 tidal misfits in the northwestern Mediterranean Sea (same convention than Figure 2).

Over the Kerguelen Archipelago, the altimeter-derived tidal constants are compared to the tidal solutions of a new regional mesh under development at LEGOS and based on the Mog2D model. The preliminary tidal solutions of this model (Figure 4 and Figure 5) show a good agreement with the altimeter data: 1.3 cm rms for M2 and 1.0 cm RMS for K1. These results are very encouraging because they are very close to those obtained by comparison to FES 2004 solution over the same altimeter data set: 1.1 cm rms on M2 and 0.7 cm rms on K1. It is recalled here that Mog2D tidal model is a purely hydrodynamic model whereas FES2004 tidal solutions are greatly improved thanks to the assimilation of altimeter data.

After additional validation (energy budget), this promising tidal spectrum will be added in the list of X-TRACK regional tidal spectra for the furniture of improved products over the Kerguelen Archipelago.

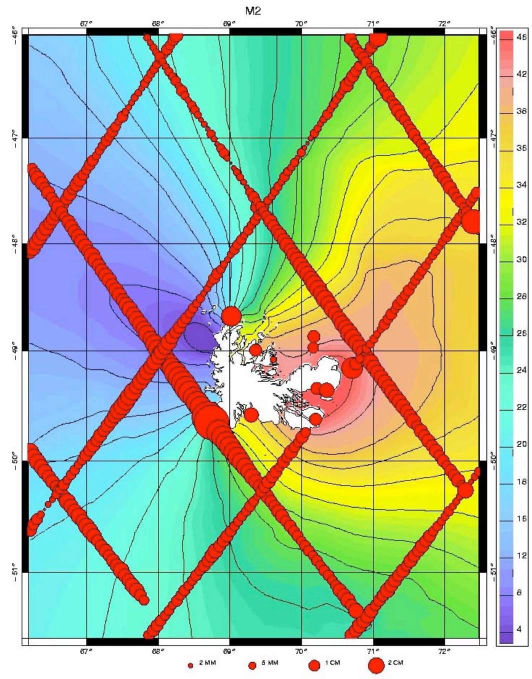

Figure 4: tidal misfits over the Kerguelen Archipelago for M2 constituent: background chart represents the tidal amplitude in cm from Mog2D tidal model. The size of the red circles is proportional to the modulus of the complex difference between model and observation. Isolated dots represent misfits at ROSAME network tide gauges.

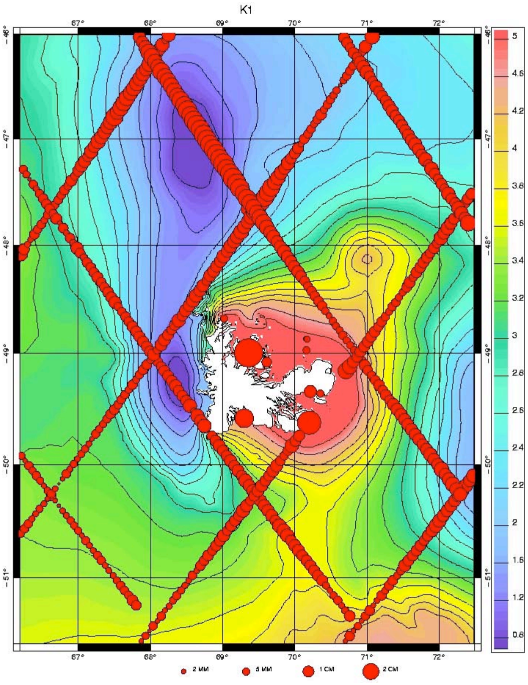

Figure 5: K1 tidal misfits over the Kerguelen Archipelago (same convention than Figure 4)

4. OCEAN CIRCULATION MODEL COMPARISON

In this section, X-TRACK along track SLA products are compared to Symphonie model simulations [5]. In this simulation, the Symphonie model is forced by the wind fields from ALADIN gridded products (courtesy of Météo-France), air-sea fluxes are derived from bulk formulas and a general circulation term (from MERCATOR products) is prescribed at open boundaries using the VIFOP platform [2]. The model is run over July-August 2004 on a Cartesian C grid, with 45 vertical levels (generalized sigma coordinates) and a 3 km-horizontal grid resolution. The altimeter data set is made of Jason-1 X-TRACK along track SLA products. Moreover, altimeter data have been low-pass-filtered to remove length scales lower than 50km.

The comparison between filtered observations and model outputs (Fig. 6, bottom) shows a good agreement in the typical synoptic scale and meso-scale, indicating a good representation of these processes by the model. The model is less efficient in representing shorter space scales, as seen on the comparison with unfiltered data (Fig. 6, top). Improvements in modelling need to be made in order to fully represent these scales, especially in the framework of operational monitoring of the coastal dynamics.

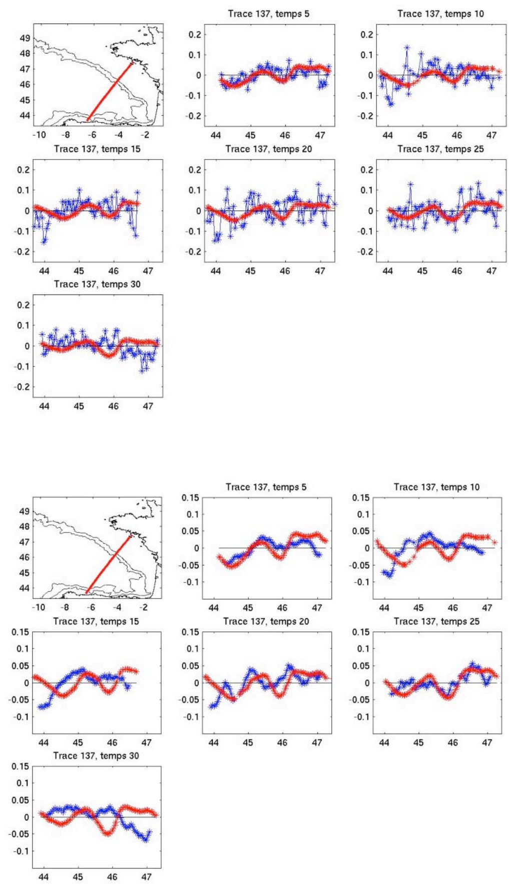

Figure 6: sea level anomalies comparisons in the Bay of Biscay along Jason-1 ground track 137. Blue: altimeter data. Red: Symphonie model. The top panel (a) illustrates comparisons between Jason-1 along track sea level anomalies and Symphonie model outputs every 10 days (July-August 2004). The bottom panel (b) illustrates similar comparisons where altimeter data have been low-pass filtered (50km).

5. CONCLUDING REMARKS

Whereas the coastal dynamics signal is usually poorly captured in the standard altimeter products due to a large error budget, the new toolbox presented here permits to provide the scientific community with improved altimeter data products. This paper shows the quality of X-TRACK along track SLA products for validation of coastal and regional models.

Concerning the estimation of tidal constituents, the X-TRACK processor permits the residual error to reach the centimetre error level as for deep ocean products both for semi-enclosed seas with micro-tidal features (Mediterreanean Sea) and for deep non polar seas with complex tides (Kerguelen Archipelago). These new observations of tides, in addition to fully-validated tide gauge data, would be valuable in the future for constraining tidal models of coastal and marginal seas with data assimilation. For coastal ocean circulation model, thanks to X-TRACK improved products, the altimeter error budget is reduced in coastal regions and coastal meso- and short scales dynamics are now observable in altimeter measurements. This promising result opens up the way to an operational monitoring of coastal environnement (GMES framework), provided an overall improvement of short scales representation in coastal models.

6. AKNOWLEDGEMENTS

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