TOWARDS USING SATELLITE ALTIMETRY FOR THE OBSERVATION OF COASTAL DYNAMICS.

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ABSTRACT

The objective of this study is to determine to what extent coastal processes can be observed with satellite altimetry. Therefore, we have used a new data processing approach developed in the context of the ALBICOCCA project (ALtimeter-Based Investigations in COrsica, Capraia and Contiguous Area). This approach uses improved local modelling of environmental corrections (MOG2D solutions), new experimental editing criteria and an inversion method to derive the mean sea surface. It substantially increases the number of valid data in the coastal domain and their accuracy. So far, we have used this original approach to reprocess all the TOPEX/POSEIDON altimetric data in three experimental areas: the NW Mediterranean Sea, the Northern Indian Ocean and the region of the Humboldt current system. We present the validated results and show some analyses of the coastal signal contained in these datasets.

INTRODUCTION

Over the last decade, altimetry has been shown to be a powerful tool to obtain informations about the dynamics of the deep-sea ocean. The potential of this type of data for the coastal domain is very important but is currently unexploited. Indeed, near coasts, the use of standard satellite altimetric products is challenging because the precision decreases dramatically. Indeed:

- The operational geophysical models used to correct the effects of tide and atmospheric high frequency forcing are not adapted to the coastal physics and introduce important errors.
- The radiometer data deteriorate strongly approaching the coast.
- The radar echo itself interfers with the surrounding land.
- The editing strategy is not well adapted to coastal zones.

Moreover, the space-time sampling of the satellites is generally too low to capture the variability of coastal ocean processes.
In the future, a new generation of altimetric missions will better fulfill the requirements of coastal domains. But in parallel, we need to develop improved post-treatment of altimetric data for coastal purposes and to analyse how best to combine information from altimetry with other coastal observations (tide gauges, coastal radar data, ...). This is why the Laboratoire d'Etudes en Géophysiques et Océanographie Spatiales (LEGOS) and the Center for Topographic studies of the Oceans and Hydrosphere (CTOH) are developing and testing a new altimetric data processing approach in the coastal zone.

SATELLITE ALTIMETRY IN THE COASTAL DOMAIN: DEVELOPMENTS

The new processing was originally developed for the Albicocca Project in the northwest Mediterranean Sea. The objective was to improve both the quantity and quality of sea surface measurements in coastal regions, mainly by using improved de-aliasing procedures (based on high accuracy, regional tidal and storm surges models) and by redefining the data editing strategy. The latter consists in eliminating not only flagged data, but also the neighbouring ones which usually contain also deficient values, and reconstructing those data with a Bezier polynomial technique when possible (Figure 1). SSH anomalies are then derived from a precise mean sea level calculated by inverse method (Figure 2). This allows to better resolve the short scales, especially in the coastal domain.

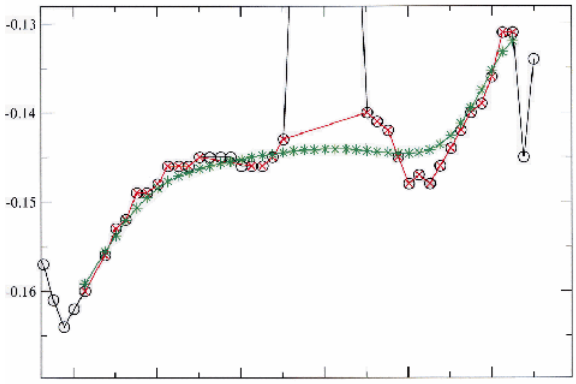

Figure 1: *T/P wet tropospheric corrections (Track 22, Cycle 95). Black: rough corrections. Red: valid corrections. Green: corrections reconstructed using a Bezier polynomial technique.*

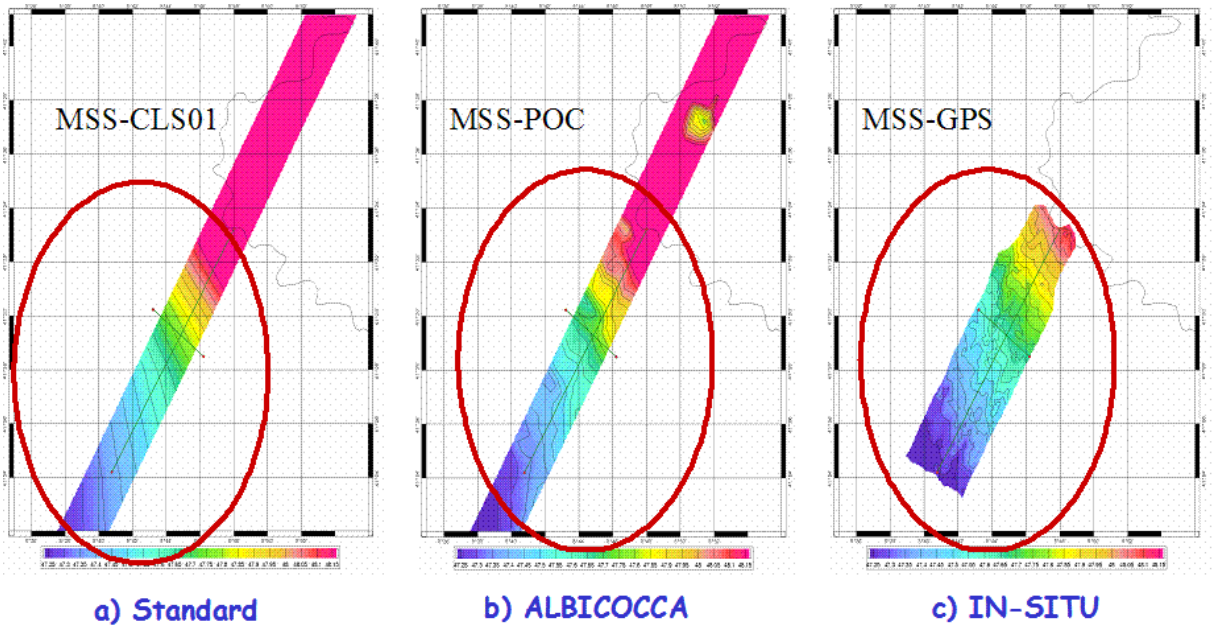

Figure 2 : *MSSH off Corsica, along T/P track 85 from a) the MSSH-CLS01 product, b) the Albicocca chain and c) GPS data.*

The Albicocca altimetry product has been first validated in the Ligurian Sea and Corsica Channel [1, 2]. The product has also been tested in two other areas: along the coasts of India [3] and along the coast of Peru/Chile.

APPLICATION TO THE NORTHERN INDIAN OCEAN.

All the T/P data have been reprocessed from cycle 5 to cycle 364 off the coasts of India using the experimental Albicocca chain. They have been systematically compared to data obtained using a standard processing. As it is observed on Figure 3, when using the experimental processing, the quantity of valid data has been increased by a factor of 1.3 on average. This can be explained by the use of the Bezier polynomial technique which allows to reconstruct erroneous corrections from valid ones, and then to recover data which are lost by a standard processing. Moreover, the noise level near the coast is strongly reduced (Figure 4).

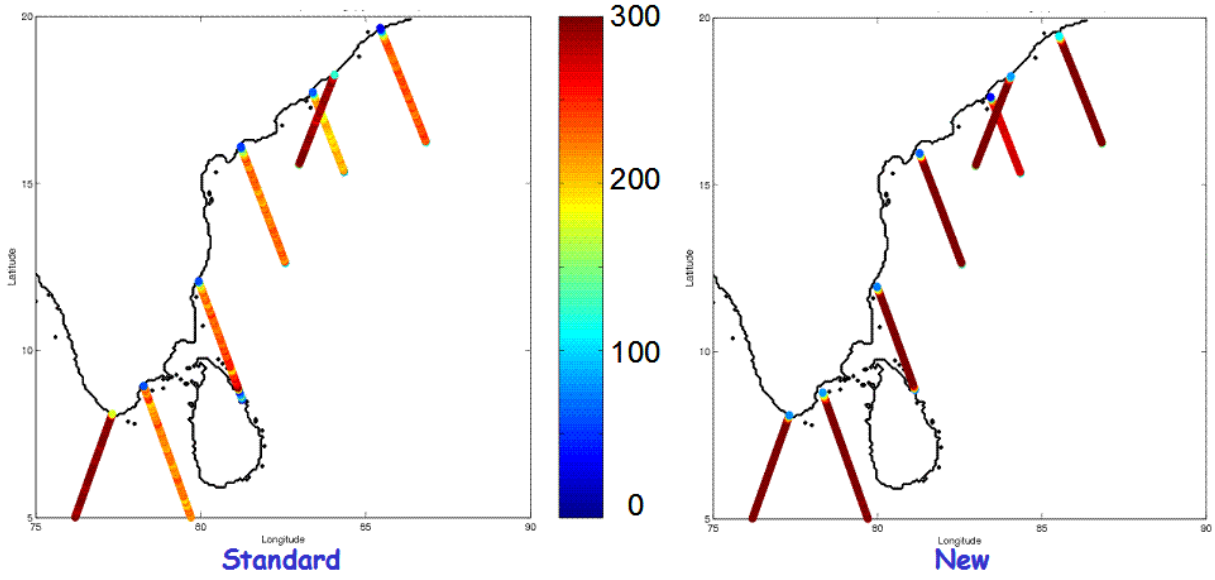

Figure 3 : *Number of valid T/P data obtained (from cycle 5 to cycle 364) a) when using a standard processing and b) when using the Albicocca chain.*

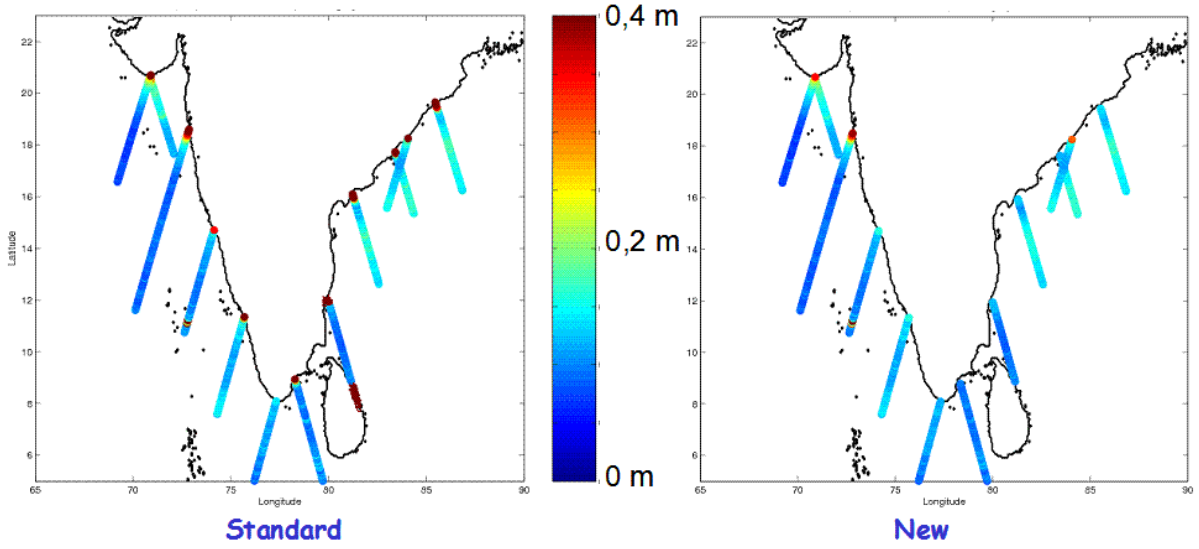

Figure 4 : *Alongtrack standard deviation obtained (from cycle 5 to cycle 364) a) when using a standard processing and b) when using the Albicocca chain.*

As validation purpose, the Albicocca altimetry product has then been systematically compared to tide gauge data. Figure 5 shows an example of this comparison for the Vishakhapatnam tide gauge. We observe a very good agreement between the tide gauge and the altimetric seasonal sea level variations. The negative anomalies from January to August are suggestive of coastal upwelling and the positive anomalies are suggestive of coastal downwelling after the monsoon. These two phases are associated with a reversal of the East India Coastal Current (EICC).

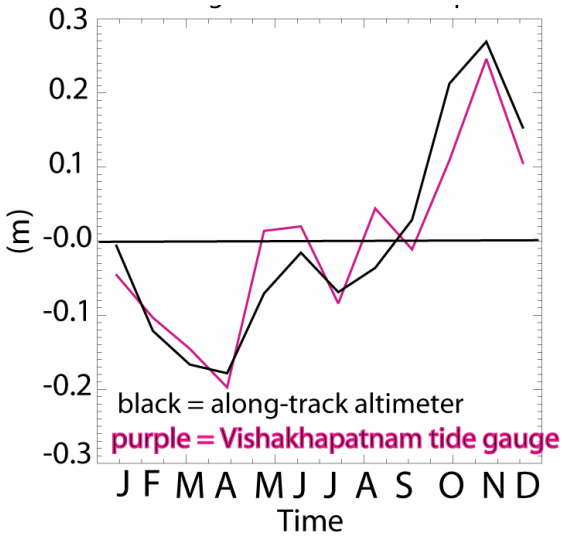

Figure 5 : *Seasonal sea level variation from tide gauge (purple) and from the altimetric station located 30 km offshore (black).*

<u>Coastal altimetry: a tool to monitor the coastal waveguide ?</u>

The major strength of altimetry, as compared to tide gauge, is that it allows monitoring the offshore extent of the coastal waveguide. If we focus on the arrival of downwelling waves during the post monsoon season (Figure 6), we can see a gradual build-up of sea level at the coast, with maxima in November. Note that the Albicocca altimetry product is in excellent agreement with in-situ data close to the shore.

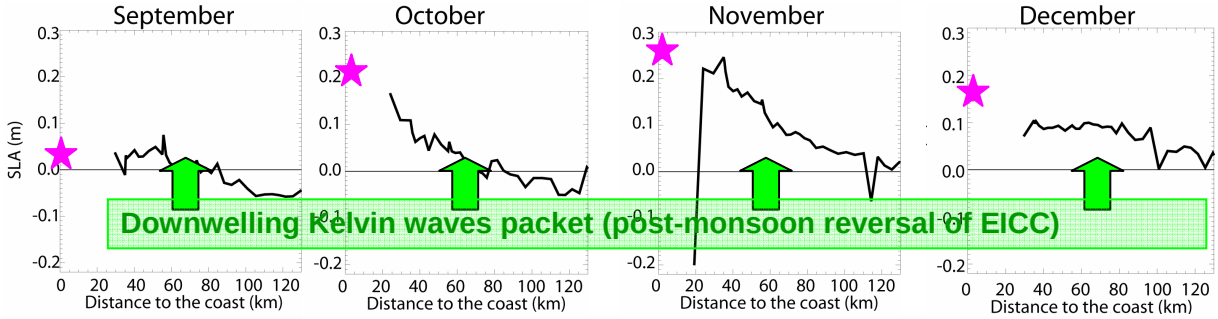

Figure 6 : *Alongtrack seasonal sea level variations (T/P – track 155) according to the distance to the coast (black). The corresponding tide gauge sea level anomaly is also indicated (purple star).*

APPLICATION TO THE HUMBOLDT CURRENT SYSTEM

All the T/P data have been reprocessed from cycle 5 to cycle 364 off Peru and Chile. Both these new altimetric data and altimetric data from standard products have then been systematically compared to tide gauge data (see Figure 7 for the tide gauge locations). The nearest T/P groundtrack point to each tide gauge is used to form comparison monthly time series. Figure 8 shows an example for the coastal station at Lobos, where sea level variations (with the seasonal cycle removed) from the two altimetry products are compared to the tide gauge. The standard deviation of the residual sea level obtained from the difference between altimetric and tide gauge data has also been calculated for different stations (Tab. 1).

Direct comparison of the different time series shows that using the Albiccocca processing allows a substantial improvement of the accuracy of altimetric data in the coastal domain. The standard deviation of the residual sea level has been reduced everywhere. The correlation between tide gauge and altimetric sea level variations has been systematically increased. This improvement is also evident at both seasonal and intra seasonal time scales.

The standard deviation of the residual sea level has also been calculated using a standard gridded altimetry product (AVISO). A comparison of the time series shows that this kind of product is generally too smooth to be used in coastal areas.

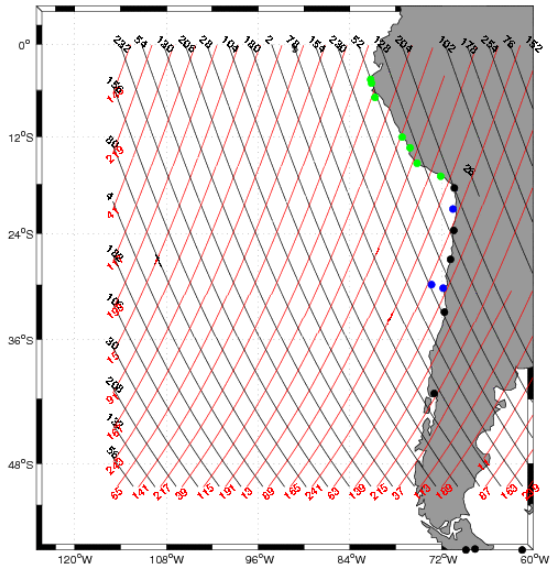

Figure 7 *: T/P reference groundtracks and position of tide gauge stations (circles) off Peru and Chile.*

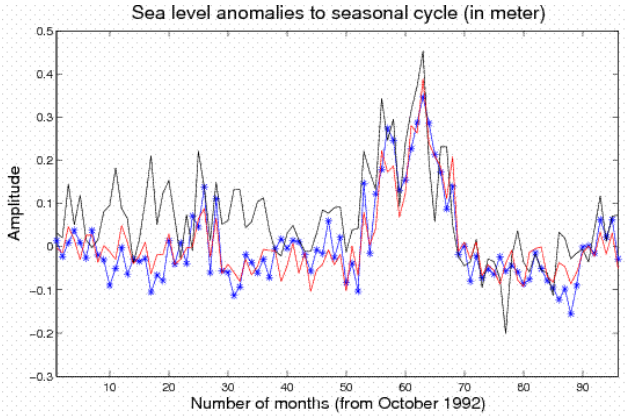

Figure 8 : *Sea level anomalies with respect to the seasonal cycle at Lobos (6.93°S) for a) tide gauge data (blue), and for alongtrack T/P coastal data using b) a standard processing (black) and c) the the Albicocca chain (red).*

PRODUCT		**LOBOS (6.93°S)**	**SANJUAN (15.37°S)**	**MATARANI (17.0°S)**	**CALDERA (27.07°S)**	**VALPARAISO (33.03°S)**
Gridded product (AVISO)	RMSdiff	5.44	8 cm	6.2 cm	5.25 cm	7.05 cm
Alongtrack standard	RMSdiff	8.17 cm	5.8 cm	9.6 cm	6.54 cm	4.55 cm
Alongtrack Albicocca	RMSdiff	4.69 cm	5.7 cm	5.53 cm	5.2 cm	4.4 cm
Gridded product (AVISO)	Correlation	82%	15%	20%	38%	3%
Alongtrack standard	Correlation	65%	62%	15%	21%	67%
Alongtrack Albicocca	Correlation	87%	62%	48%	59%	71%

Tab. 1 : Correlation and standard deviation of the difference between tide gauge sea level variations and different altimetry products.

Coastal altimetry: a tool to document coastal mesoscale processes?

The oceanic variability of the South-Eastern Pacific is peculiar in that the coastal variability off Peru and Chile connects the equatorial Kelvin waves to the extra-tropical Rossby waves at a variety of timescales, from intraseasonal to interannual. Thus disturbances from equatorial origins can be observed as far as 40°S along the coast. The altimetric data near the coast offers the opportunity not only to document the coastally trapped wave activity but also the processes associated to the mesoscale variability that has an impact on the rich Humboldt ecosystem. There is also hope that it will help validating the regional oceanic models that are being developped for this region.

CONCLUSION AND PERSPECTIVES

Using official altimetric products close to the coast is challenging. The future generation of altimetric missions (AltiKa, Wittex,…) will better fulfil the requirements of coastal domains. In parallel, we have to develop new generation of processing chains. As it is shown, solutions exist to improve the accuracy of altimetric data near the coasts. A new data processing approach is proposed and evaluated in three experimental areas for TOPEX/Poseidon data. Analysis of coincident tide gauge and altimetric sea level variations shows that this approach allows a reduction of uncertainty. The altimetry is able to capture the seasonal and interannual signals but also intraseasonal time scales. Although this study is not sufficient to draw definitive conclusions, we suggest that altimetric data offers the opportunity to document the coastally trapped wave activity and processes associated to the mesoscale variability near the coasts. Further studies will concentrate on new developments, on improving the quality and coverage of altimetric corrections for other altimetric missions (Envisat, Jason, GFO) and on the development of methods to combine data from the different missions in the coastal domain.

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