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ESA Cryosat Plus for Oceans

Validation Report: WP5000 Regional tidal correction (Noveltis)

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Applicable documents

Reference documents

RD 1 Manuel du processus Documentation
CLS-DOC

Acronyms List

CLS	Collecte Localisation Satellite
COMAPI	Coastal Modeling for Altimetry Product Improvement
CPP	Cryosat Processing Protoype
ESA	European Space Agency
GOT	Goddard Ocean Tide
LRM	Low Resolution Mode
NA	Not Applicable
RD	Reference Document
RDSAR	Reduced Synthetic Aperture radar
SAR	Synthetic Aperture radar
SIRAL	Synthetic Aperture Interferometric Radar Altimeter
SLA	Sea level Anomalies
SSH	Sea Surface Height

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1. Introduction

1.1. Purpose and scope

This document aims at analysing the regional tidal correction based on the existing COMAPI tidal atlas for the CryoSat-2 mission, in comparison with the Goddard Ocean Tide (GOT) 4.8 tide correction A set of dedicated diagnoses has been used to evaluate the quality of this regional correction and see if it may improve the sea-level anomaly calculation.

The description and the analysis of all the differences that are reported herein were discussed in a strong scientific collaboration with the algorithm expert/responsible who provides a very useful support to assess the performances of their model, help to identify any unexpected behaviours and finally validate the content of this report.

1.2. Document structure

This document is structured into an introductory chapter followed by three chapters describing:

- the data used and coverage, and a short description of the two tide correction methods (section 2),
- the analysis of the results from the different diagnoses that are used to establish their performance (quantifying their skills and drawbacks) and their difference (section 3), and
- a discussion about these results (section 4).

2. Data and method overview

2.1. Data coverage and period

Two sets of CryoSat-2 sea level anomalies (SLA) have been computed, using the corrections based on the existing COMAPI tidal Atlas and the GOT4.8 model, for all CryoSat-2 tracks embedded in the North East Atlantic area, from May 2012 to January 2013. This includes predominantly SAR mode data and few LRM mode data.

The Figure 1 gives an idea of the COMAPI oceanic tide correction coverage in July 2012. Note that we observe a small number of missing ascending track portions (in LRM-mode) in the South West part of the coverage. The dataset was completed and delivered in June 2014, after this validation work, but it has no impact on the conclusions of this study.

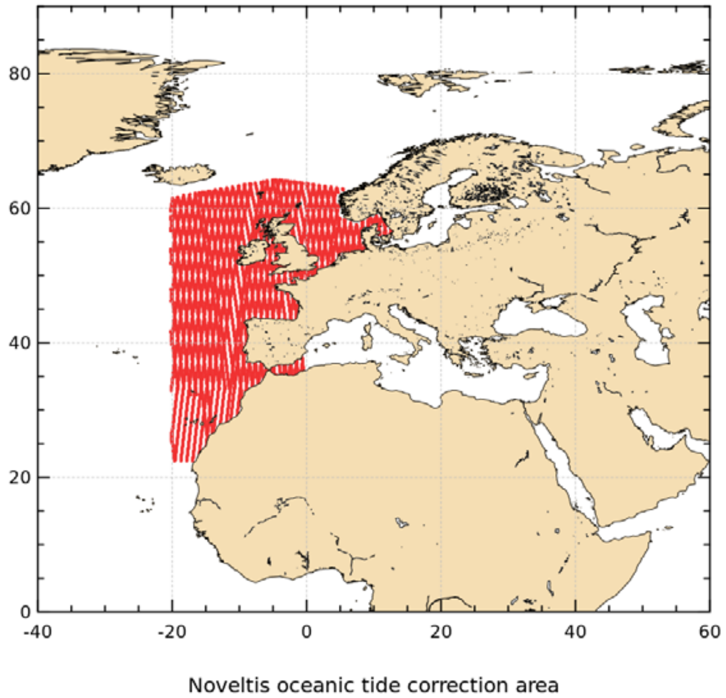

Figure 1: Coverage of the COMAPI oceanic tide correction in July 2012.

The COMAPI tide correction dataset delivered by Noveltis is computed for files provided by ESA. Because the ESA time and locations are different from the Cryosat Processing Prototype (CPP) products, the COMAPI tide corrections are interpolated at each 1-Hz CPP point location within the CLS database.

2.2. Method description

2.2.1. COMAPI tide correction (Noveltis)

If up-to-date global models are remarkably good for predicting tides at a global scale, near the coasts (and also in polar regions) they are less accurate than in the rest of the ocean. This limitation has led to higher-resolution regional models being developed in the coastal zones, allowing to better represent the complex ocean dynamics and the high spatial variability of the process in these specific areas.

The COMAPI atlas is a regional tidal model that has been developed in 2010 by Noveltis [Cancet et al, 2010] to generate ocean tide correction in the North East Atlantic ocean and the Mediterranean sea for correcting the tidal signal in the altimetry measurements. These regional tidal atlases are composed of a larger number of tidal constituents than the global models such as GOT4.8 to perform the tidal prediction.

The North East Atlantic is a complex area, which will allow us to assess the COMAPI tidal modeling improvements.

2.2.2. GOT4.8 tide model

The GOT4.8 is the last version of the GOT model produced by R.D. Ray [2011]. The difference with GOT4.7 is due to a better processing of the dry tropospheric correction for altimeter data (correcting for S1 and S2 effects).

2.2.3. Edited data

Data editing is necessary to remove altimeter measurements having lower accuracy. To analyze the consistency between both tide correction solutions in open and coastal ocean, only valid ocean data are selected (removing data corrupted by sea ice and rain). Specific editing criteria are applied, based on thresholds on different parameters.

3. Validation results and overall assessment

The overall objective of this validation exercise is to ensure that the COMAPI oceanic tide correction allows to obtain a better description of the sea level anomalies as it is theoretically expected (notably close to the coasts), compared to the global and state of the art ocean tide model GOT4.8.

The impact of using these both ocean tide models on the sea surface height (SSH) calculation has been analysed through the following diagnosis:

- Along track comparison with GOT4.8 model to highlight differences.
- Along track gain of variance to determine which one shows the best performances.
- Along-track spectral analysis to analyse the impact of each correction on the SLA power in function of the wavelength.

Since there are no loading effects in the COMAPI model, the oceanic loading tides are removed from the GOT4.8 model to make the comparison consistent.

It should be emphasized that diagnostic of SLA crossovers (for time differences between ascending and descending passes lower than 10 days) is not considered in this study. Too few points are found at crossovers (as shown in Figure 2) that would lead to unreliable statistically results.

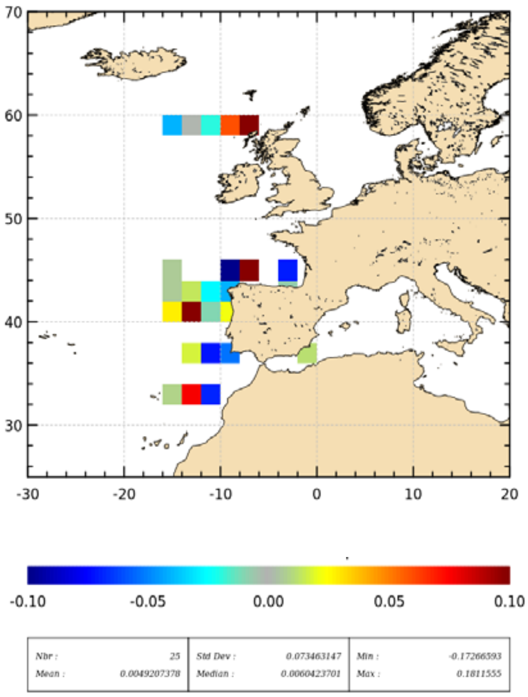

Figure 2: Location of the SSH crossovers differences from May 2012 to January 2013 for the CryoSat-2 mission.

The periodograms of differences between the two different tide models would allow us to determine the impact of the COMAPI tide correction at time scales of interest, and describe which correction better reduces the periodic signals. But the 9-month temporal interval is too short and corrupted data due to the aliasing effect may occur (aliasing of tides at 249 days for N2 and 943 days for M2).

In addition, the particular CryoSat-2 orbit has made this study difficult since the satellite is operated in a non-repetitive orbit, with a drifting ground track, that requires to calculate the reduction of the altimeter residual variance for along-track residuals in geographical bins (1°x1° or 2°x2°).

3.1. Along track differences of the tide correction

We performed along track SLA differences between the COMAPI and the GOT4.8 models. The Figure 3 shows the map of the differences in ascending passes (left panel) and descending passes (right panel). Heterogeneous structures are observed in both open ocean and coastal regions (with value as high as few centimetres).

Some differences are normally expected in the coastal regions due to the difference in the model resolutions (0.5° for GOT4.8, 1/60° for COMAPI) and to the fact that the tidal signal is amplified in the coastal regions, which means higher errors in the models (complex bathymetry, non-linear interactions between the tidal waves, shorter scales – a few tens of km - than in the open ocean). A regional model is supposed to better model the short scales in the coastal regions.

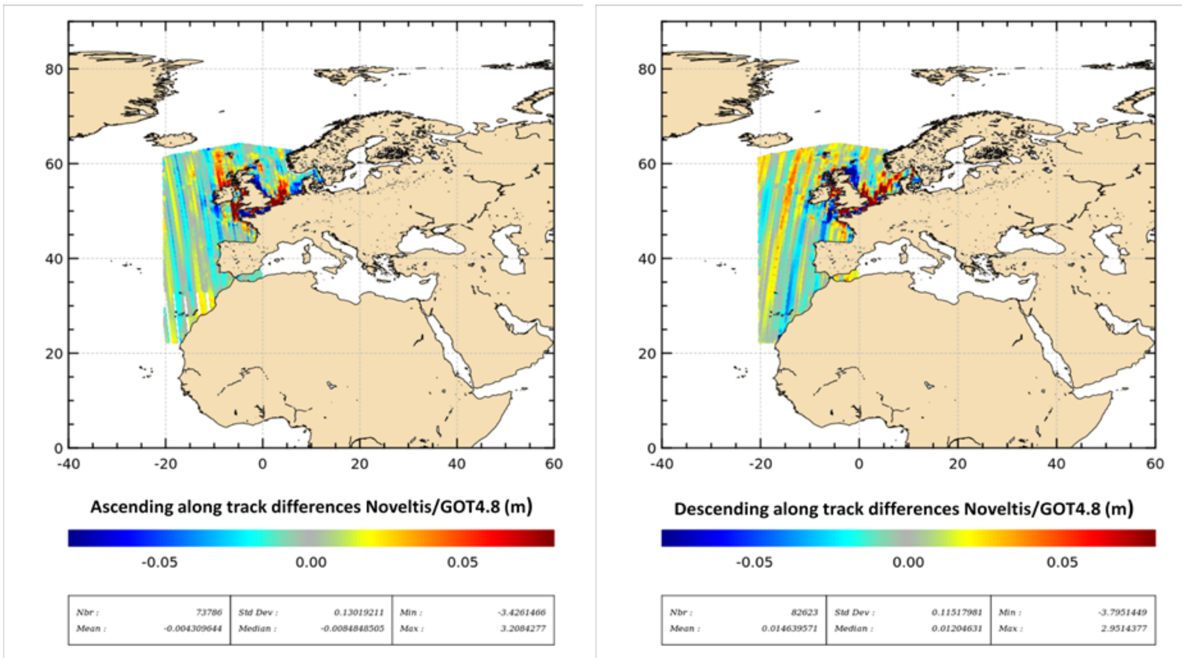

Figure 3: Along-track differences between COMAPI and GOT4.8 oceanic tide corrections for ascending passes (left panel) and descending passes (right panel)

In the open ocean, large patterns are observed in the differences, which seemed at first unexpected but are also observed in the GOT4.8/FES2012 differences on CryoSat-2 tracks (see in Figure 4). These patterns are actually explained by the subcycles and the non-repetitiveness of the CryoSat-2 orbit. They show that one model generally gives slightly larger (1-2cm) amplitudes than the other.

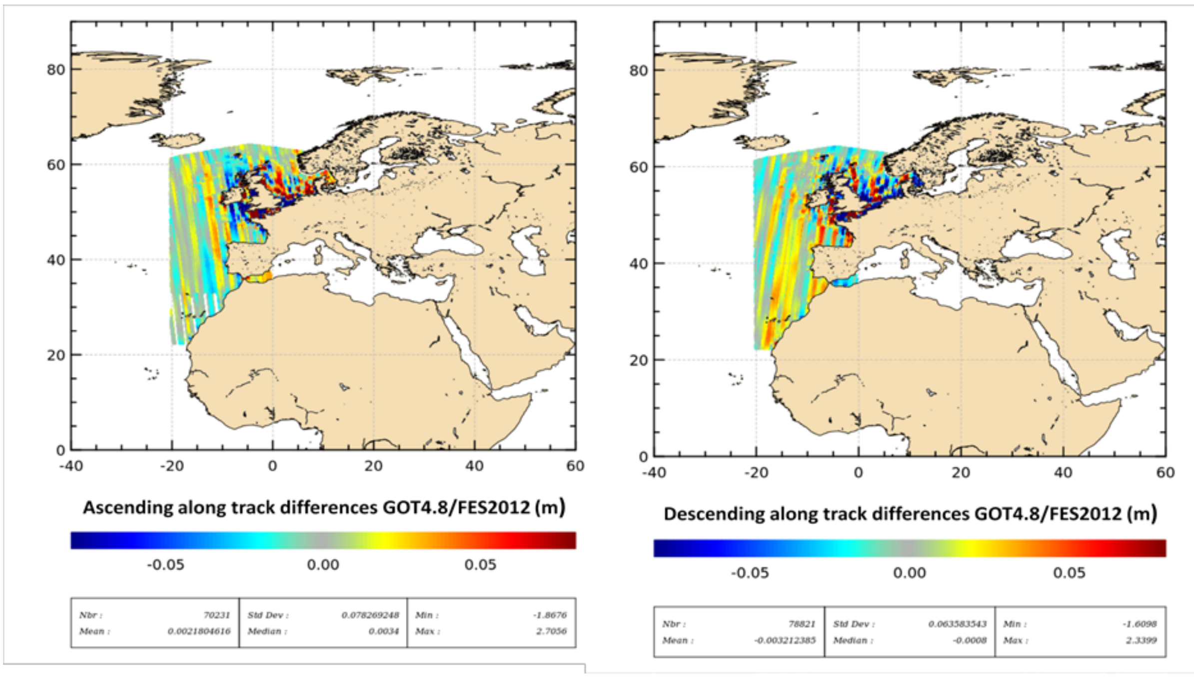

Figure 4: Along-track differences between Fes2012 and GOT4.8 oceanic tide corrections for ascending passes (left panel) and descending passes (right panel)

Figure 5 represents a plot of along-track SLA computed with both tide corrections as function of latitude. We can notice a global bias equal to 2cm in open ocean.

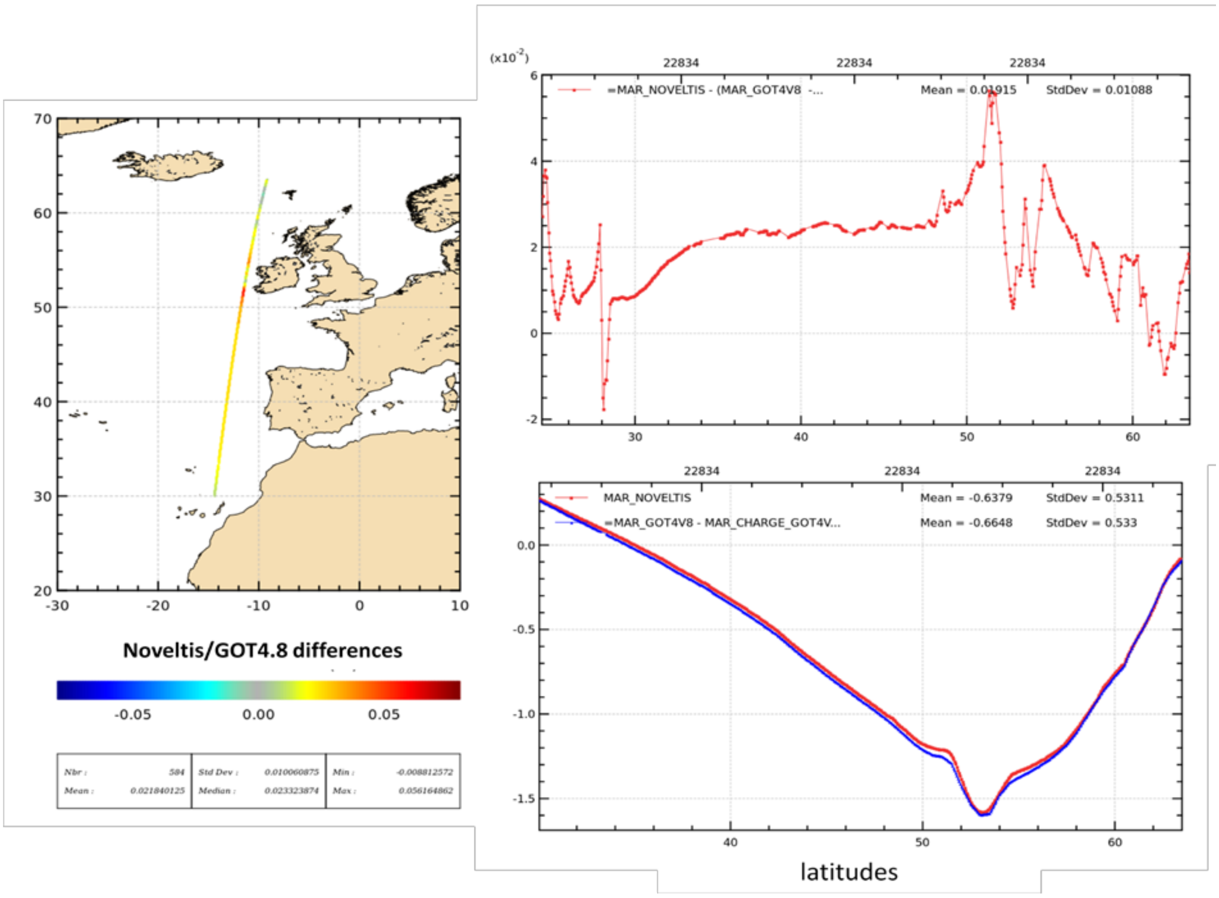

Figure 5: Along track tidal correction values from COMAPI and GOT4.8 models (bottom right) and their differences (top right) for one descending track in July 2012 (left panel).

3.2. Along track differences by grids (2°x2°)

Note that due to some critical aspect of this study (the period of data being shorter than at least one year), some short-scale waves (<10km of wavelength) averaged in large grid bins near the coast may average different phenomena leading to no valuable statistics (standard deviation). In turn, using smaller geographical bins would reduce significantly our number of observation per bins.

To maximize the density of data points and reach statistical significance we consider gridded data with both ascending and descending passes.

3.2.1. Tide correction differences

The mean difference per bins is represented in Figure 6. There are quite few differences between tide corrections in the open ocean (0-1cm) but larger amplitudes (higher than 2cm) are observed in the NW European shelf sea (the channel and North Sea regions) where strong tidal mixing occurs.

Amplitude of differences could reach more than 5cm in this specific area of shallow marine waters. This is obviously expected since the GOT4.8 model suffers from low spatial resolution, and a reduced spectrum for non-linear waves compared to the COMAPI model.

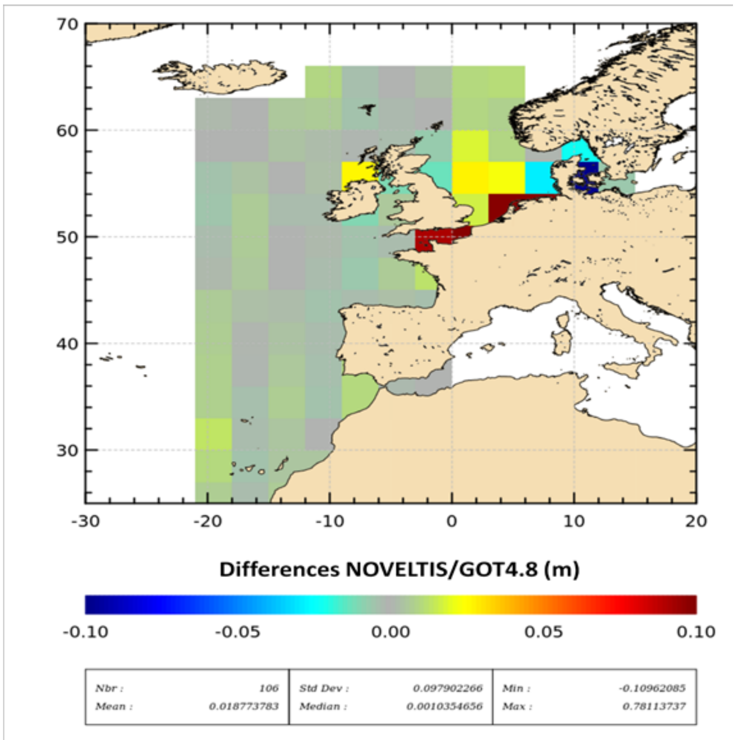

Figure 6: Grid of the differences between COMAPI and GOT4.8 tide corrections from May 2012 to January 2013

3.2.2. Variance of the tide correction differences

The variance of the differences is maximum in shallow water regions (European shelf). Results are comparable with a CLS study performed by L. Carrere [2010] which was dedicated to the analysis of the impact of using the COMAPI model or GOT4.7 on the SSH calculation for the Jason-2 mission.

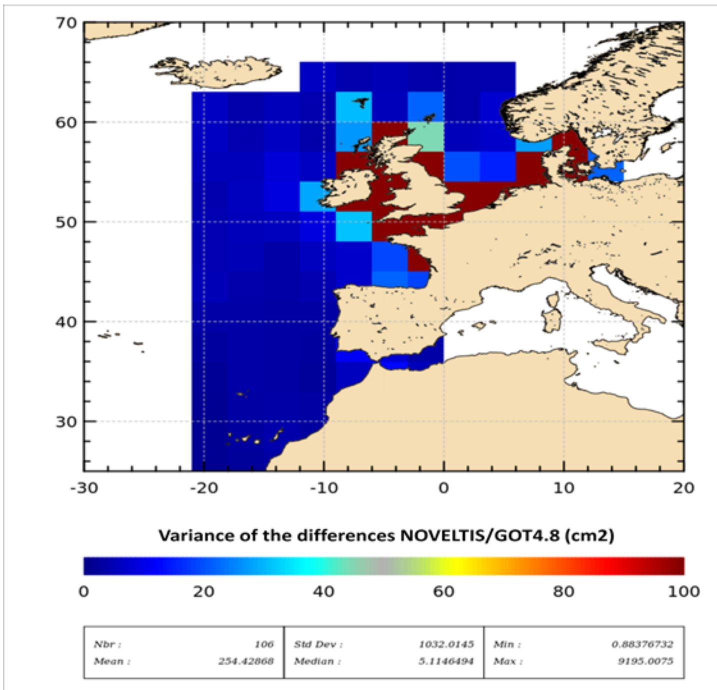

Figure 7: Variance of the differences between COMAPI and GOT4.8 tide corrections from May 2012 to January 2013.

3.2.3. Gain of variance

The Figure 8 presents the impact of the tidal models on SLA residual variance.

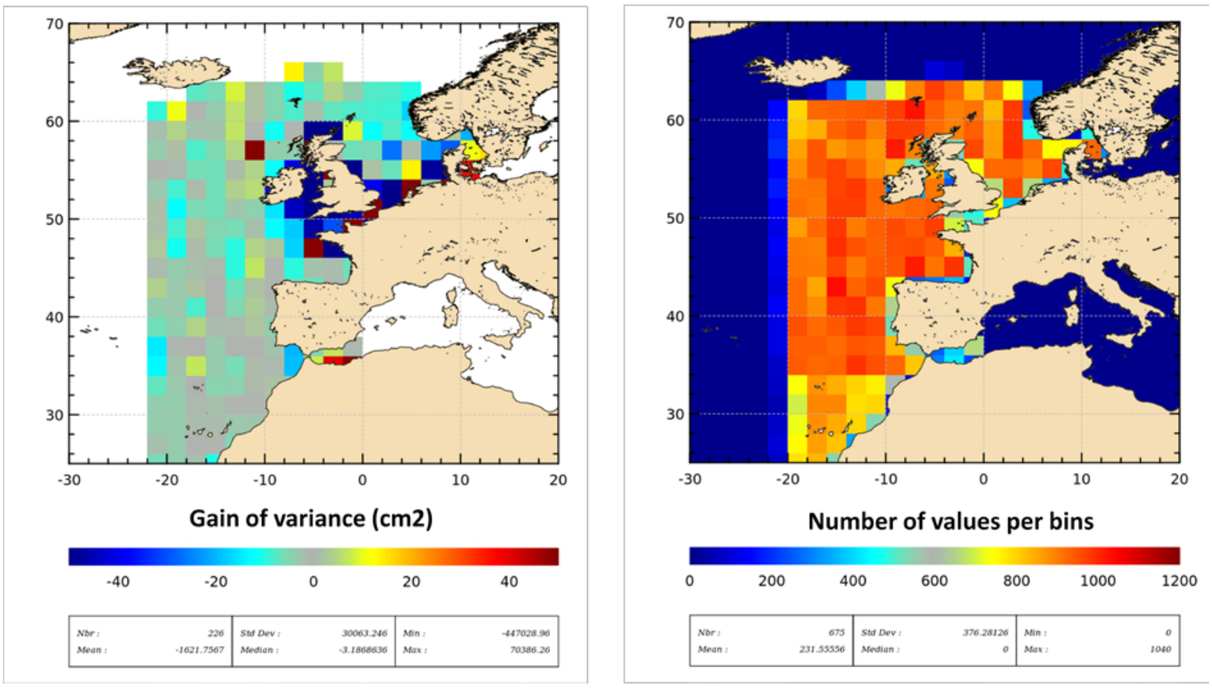

Figure 8: Gain of variance between SLA computed with COMAPI model and with GOT4.8 model (left panel) and the associated density (right panel)

First, we notice that the gain of variance when comparing COMAPI vs. GOT4.8 is globally near 0cm^2 in the open ocean (with a slight tendency to improvement with COMAPI) which confirms that the models are quite equivalent in open ocean as one could expect. Small amplitude and the large spatial scales of the tide in the open ocean lead to better modeling, and consequently lower errors in the models. This explains why they are very close in the open ocean.

Analysis in global shows a clear reduction of the variance (-3 cm^2). The improvement is clearly localised in shallow water regions (Irish Sea, Channel and North Sea where a variance reduction greater than 25cm2 may be observed), which is coherent with the pattern of the difference between both models. However we notice a raise of the variance at very few locations; this degradation might be explained by outlier combined with a poor presence of measurements.

Once again these results are comparable with those obtained by Loren Carrere [2010].

3.3. Spectral analysis

A spectral analysis was also carried out to evaluate the differences between SLA computed with the COMAPI model and with the GOT4.8 model as a function of spatial scales. Both data sets exhibit similar behavior, although the energy of the SLA with COMAPI is lower in particular for scales 50 - 200km (European shelf). This means that the COMAPI model enables to correct more tidal signal in the altimetry SLA than the GOT4.8 model, at these scales.

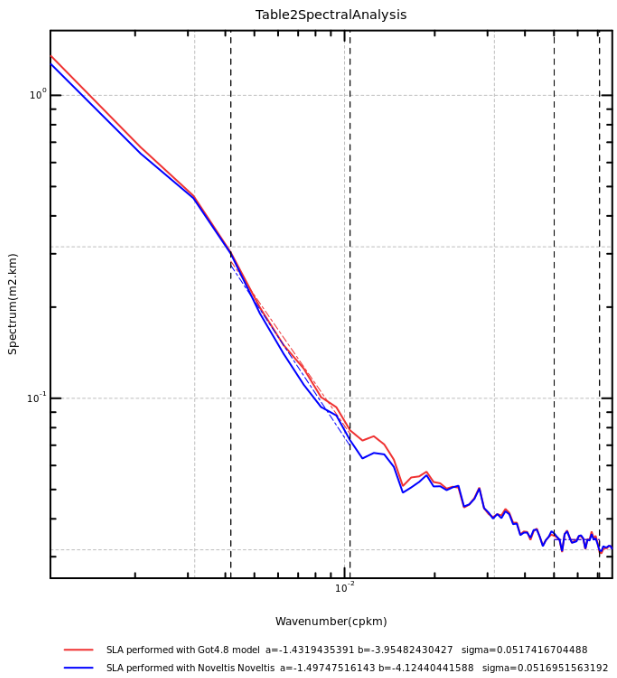

Figure 9: Spectra of the sea level anomaly computed with COMAPI model (blue) and with the GOT4.8 model (red)

4. Conclusion

COMAPI and GOT4.8 tidal models have been compared in term of reduction of the altimeter residual variance.

Results show that the COMAPI tidal model allows reducing appreciably the residual variance (for along-tracks residuals) in shallow waters regions with a variance reduction greater than 3 cm^2; both models are equivalent in deep ocean.

The improvement of the COMAPI model is also notable through spectra diagnosis.

This new correction is relevant for improving radar altimetry products (in LRM and SAR modes) primarily for the oceanic coastal area (but also for the open ocean).

5. References

[Cancet et al., 2010]: M. Cancet, M. Lux, C. Pénard, F. Lyard, F. Birol, L. Roblou, J. Lamouroux, S. Bourgogne and E. Bronner, *"COMAPI: new regional tide atlases and high frequency dynamical atmospheric correction"*, presented at the 2010 Ocean Surface Topography Science Team Meeting.

[Carrère, 2010]: L. Carrère, *"Rapport de l'étude d'intégration des modèles TUGO régionaux COMAPI dans PISTACH"*, CLS-DOS-NT-10-155, V1.0, 2010.

[Ray, 2011]: R.D. Ray, "*High precision comparisons of bottom-pressure altimetric tides*", presented at the 2011 Ocean Surface Topography Science Team Meeting.