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ESA Cryosat Plus for Oceans

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Applicable documents

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RD 1 Manuel du processus Documentation
CLS-DOC

Acronyms List

CLS	Collecte Localisation Satellite
CPP	Cryosat Processing Protoype
ESA	European Space Agency
IC	Ionospheric Correction
IGS	International GNSS Service
GIM	Global Ionospheric Map
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
SPECTRE	Service and Products for ionospheric Electron Content and Tropospheric Refractivity over Europe
SSH	Sea Surface Height
TID	Travelling Ionospheric Disturbances
TEC	Total Electron Content
VTEC	Vertical Total Electron Content

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1. Introduction

1.1. Purpose and scope

This document aims at analysing the innovative Ionospheric Correction (IC) SPECTRE (Service and Products for ionospheric Electron Content and Tropospheric Refractivity over Europe) developed by Noveltis for the CryoSat-2 mission, in comparison with the IC model GIM (Global Ionospheric Map) supported by IGS (International GNSS Service). A set of dedicated diagnoses has been used to evaluate the quality of this regional oceanic 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 ionospheric correction methods that are compared (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 SPECTRE and the GIM ICs, at the same 1-Hz point locations along the CryoSat-2 tracks embedded in the European shelf sea and the Mediterranean, from May 2012 to January 2013. This includes all LRM data and most of SAR mode data over ocean in the European sea area as shown in Figure 1.

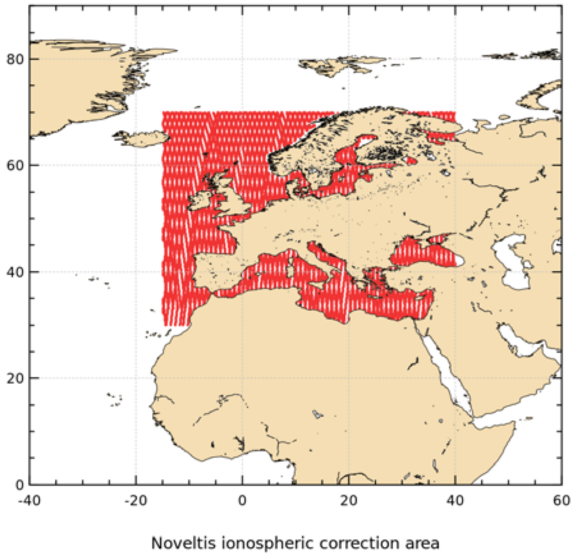

Figure 1: Coverage of the SPECTRE IC in July 2012.

The Figure 2 represents the valid points within this dataset. We notice only few missing ascending tracks in the south west part of the patch, and no impacts on this assessment would be expected. This anomaly was reported to the model responsible then identified on their side. A new delivery of the SPECTRE IC dataset was done in June 2014 , after this validation work.

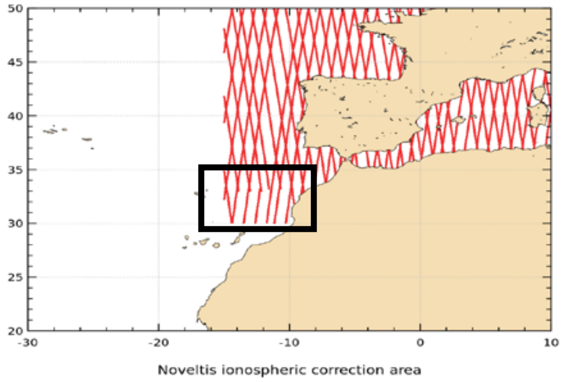

Figure 2: Coverage of the SPECTRE IC in July 2012 showing missing ascending data in the box.

The selected SPECTRE IC dataset contains approximately same points as processed by the Cryosat Processing Protoype (CPP), although with different time and locations. For an IC comparison (with the IC from GIM model) the SPECTRE IC values are thus computed by interpolation at each 1-Hz CPP point location within the CLS database.

It should be emphasized that the selected area is not the most appropriate to evaluate the performance of the ICs, since only low ionospheric signal amplitudes are present in this region.

2.2. Method description

2.2.1. SPECTRE IC (NOVELTIS)

The ionosphere causes a delay in the radar return signal (due to the presence of the electron plasma in the ionosphere slowing down the radar pulse) which is difficult to correct for mission with in particular non-embarked dual-frequency altimeter. The delay correction for the ionospheric electron density in the radar measurement can be accounted for using output from models of Total Electron Content (TEC), like GIM. But the main difficulty of these models is to be able to consider the variation of the electron density in the ionosphere at very low time scales (below the day where transient perturbations such as Travelling Ionospheric Disturbances (TID's) and local ionospheric gradients induced by magnetic storms, earthquakes, tsunamis … may occur), complicating the ionosphere correction.

SPECTRE is a distribution service, developed by Noveltis [Crespon, 2007] in collaboration with IPGP, CETP and ETHZ, which provides a mapping of Vertical Total Electron Content (VTEC) over Europe (based on the use of GPS data produced by dual frequencies receivers) sampled at 30 seconds with space resolution of 2.5° by 2.5°. For the purpose of the altimetry, it would allow to provide thus more accurate ionospheric path delay corrections in term of ionosphere dynamic (better resolution of small scale variations of the ionosphere) than these GIMs.

For this study, the IC is computed at each location and epoch along the CryoSat-2 tracks. It may be also estimated for any altimeter mission with no dual frequencies altimeter.

2.2.2. GIM IC (IGS)

IGS GIM is a combination of several different ionosphere models provided by IGS analysis centers (see Schaer [1998] for more information) that constitutes global TEC maps with spatial and temporal resolution (5°by 2.5° and two hours grids) lower than SPECTRE resolution.

2.2.3. Edited data

Data editing is necessary to remove altimeter measurements having lower accuracy. To analyze the consistency between both wet troposphere solutions in open 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 determine whether the SPECTRE IC solution allows to obtain or not a better description of the sea level anomalies (SLA) than with the GIM model, as it is theoretically expected by its high time and space resolution.

For this purpose, the validation of the SPECTRE IC is performed through the following diagnoses:

- Along track comparison with GIM IC to highlight differences,
- Along track gain of variance of SLA to determine which correction shows the best performances. Crossover gain of variance of SLA is not performed here since the number of crossovers in the area is too low.
- Along-track spectral analysis to analyse the impact of each correction on the SLA power in function of the wavelength.

3.1. Along track differences of the IC

We performed along track SLA differences between SPECTRE and GIM IC models in ascending and descending passes in order to better separate data of different local time/solar irradiance (since the variation of the ionospheric delay strongly depends on the local time of observations). The Figure 3 shows the map of the differences in ascending passes (left panel) and descending passes (right panel) for May 2012 to January 2013.

We notice large-spatial scale patterns in the along-track differences (for both open ocean and coastal regions) for which the bias is lower than 1.5cm, but no small-spatial scale variations are detected. Also note that these along-track plots don't represent in global the entire 9-month dataset, but the most recent passes only that overplot the older ones. The Figure 4 is revealing fine details of the difference for all ascending passes that were in part hidden in preceding figure. It shows notably that the bias between the two IC models is not as homogeneous as it appears in Figure 3, and may depend of the local time and season, since all the adjacent tracks represent different local time.

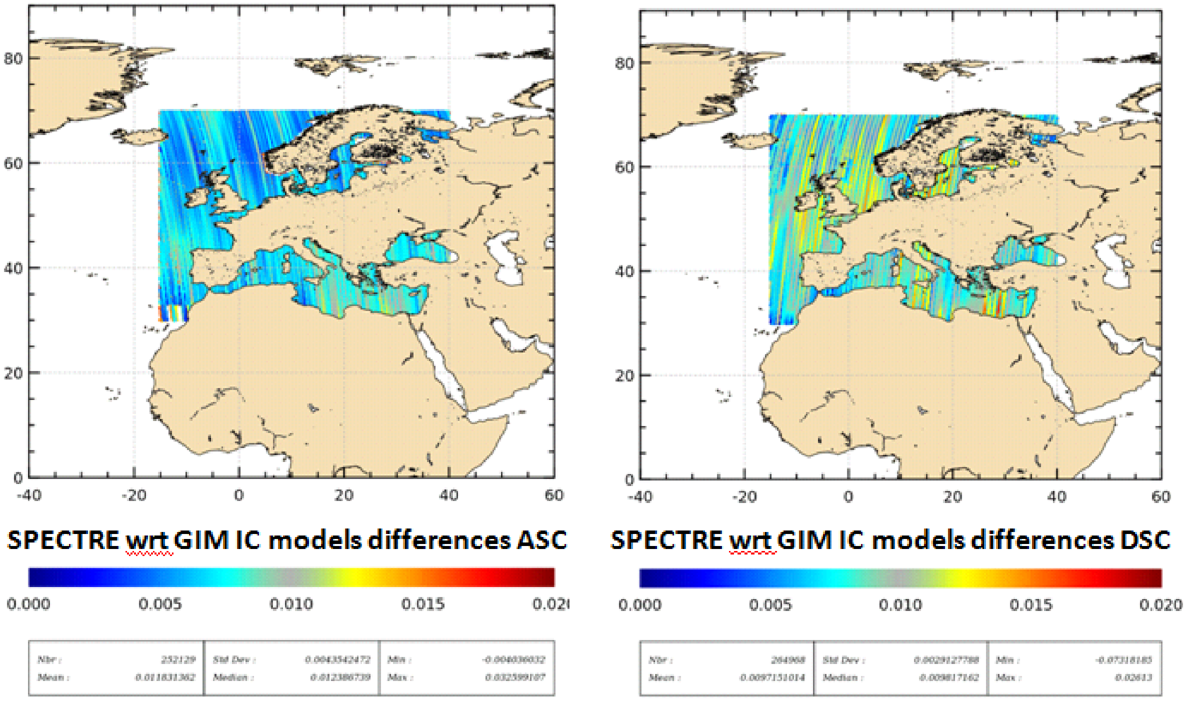

Figure 3: Map of the (SPECTRE - GIM) IC difference for ascending passes (left panel) and descending passes (right panel)

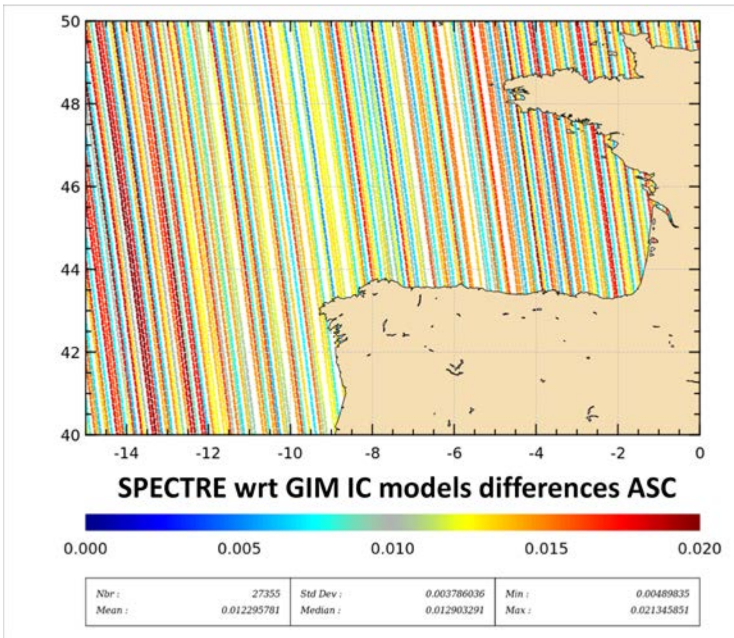

Figure 4: Map of the (SPECTRE - GIM) IC difference in m for ascending passes

Figure 5 shows differences between SPECTRE and GIM ICs as function of the local time. We observe that the bias is higher during day than night. Its maximum is also reached in summer time.

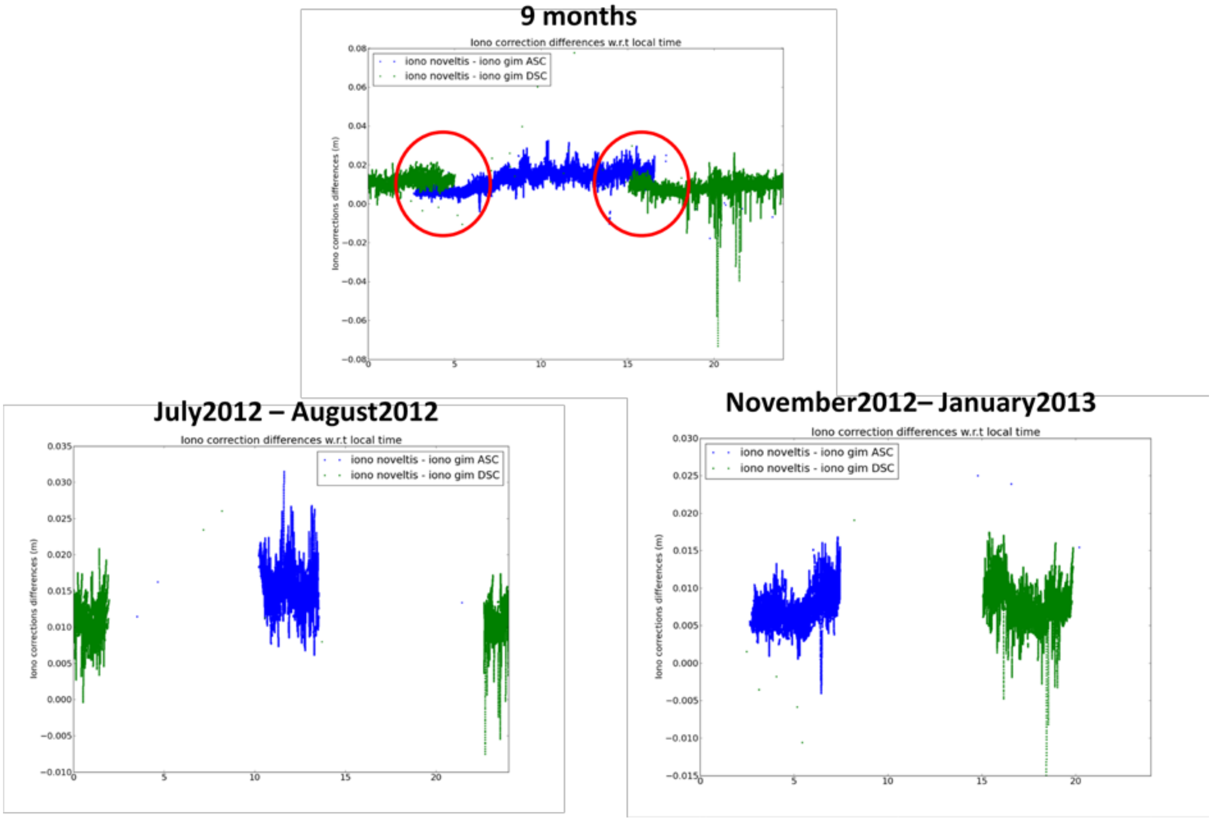

Figure 5: (SPECTRE - GIM) IC difference in meters as function of the local time. Ascending passes are plotted in blue, descending passes in green

Note that the discontinuity of the differences between ascending and descending passes most likely reflects a difference in season, for the same local time. Furthermore, the observed bias during night may be explained by the use of inhomogeneous values of Total Electron Content between models.

In global the mean bias is around 1cm and uniformly distributed in open ocean and coastal regions (noticeably higher in ascending passes).

Figure 6 clearly shows that the ICs difference varies with season. We notice 1.5cm of bias in summer time whereas the bias is of 0.6cm in winter.

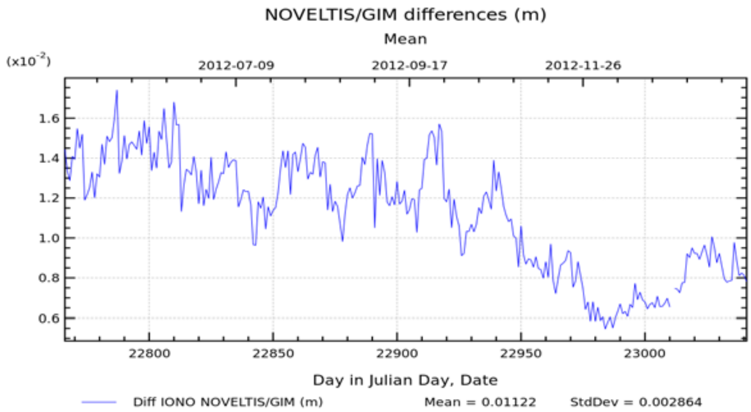

Figure 6: Mean difference per day between (SPECTRE - GIM) ICs

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

3.2.1. Variance of the IC differences

The variance of the differences is lower in descending passes for which the observations are mostly carried out during night (at local time) as seen in Figure 7.

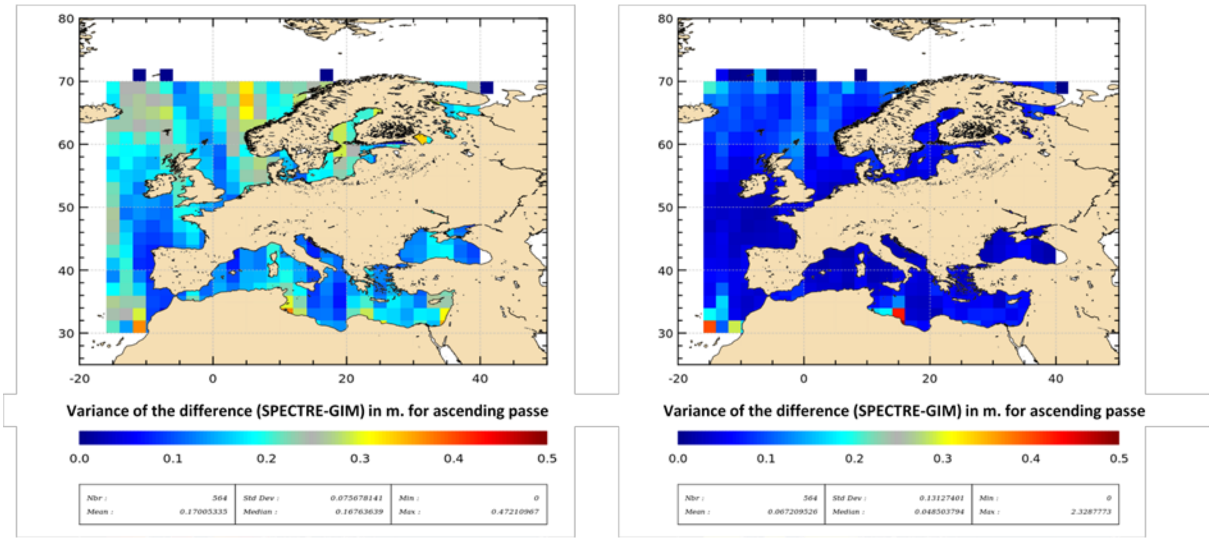

Figure 7: Variance of the differences between SPECTRE and GIM ICs in meters for ascending passes (left panel) and descending passes (right panel)

3.2.2. Gain of variance

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

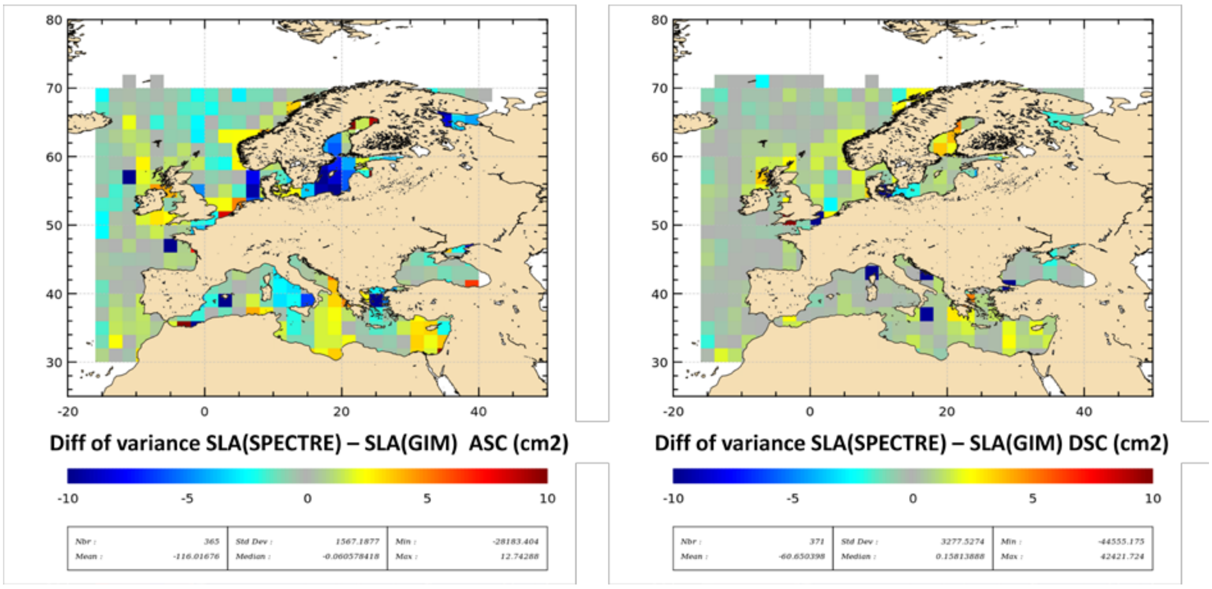

Figure 8: Gain of variance between SLA computed with SPECTRE model and with GIM model for ascending passes (left) and descending passes (right)

A variance reduction greater than $5cm^2$ is observed during day (in ascending passes) in the Baltic sea and locally in the north sea. Elsewhere there are both increase and reduction of variance of smaller amplitude. It would be interesting to analyse whether the variance reduction is geographically related to the number of GPS observations or not (the enhancement of the density of GPS measurements would normally improve the space resolution of the TEC maps and also provide better TEC estimations).

In descending passes (notably during night), a slight increase of variance is observed globally.

We compute the gain of variance for different local time to better characterize the performance of the ICs wrt the local time. Figure 9and Figure 10 do not exhibit improvement of the SPECTRE IC compared to GIM IC. The noticeable differences are observed in the time period 2h00-5h00, and 15h00-16h00 for which the increase of the variance is impacted by the seasonal effect (consistent with the Figure 5).

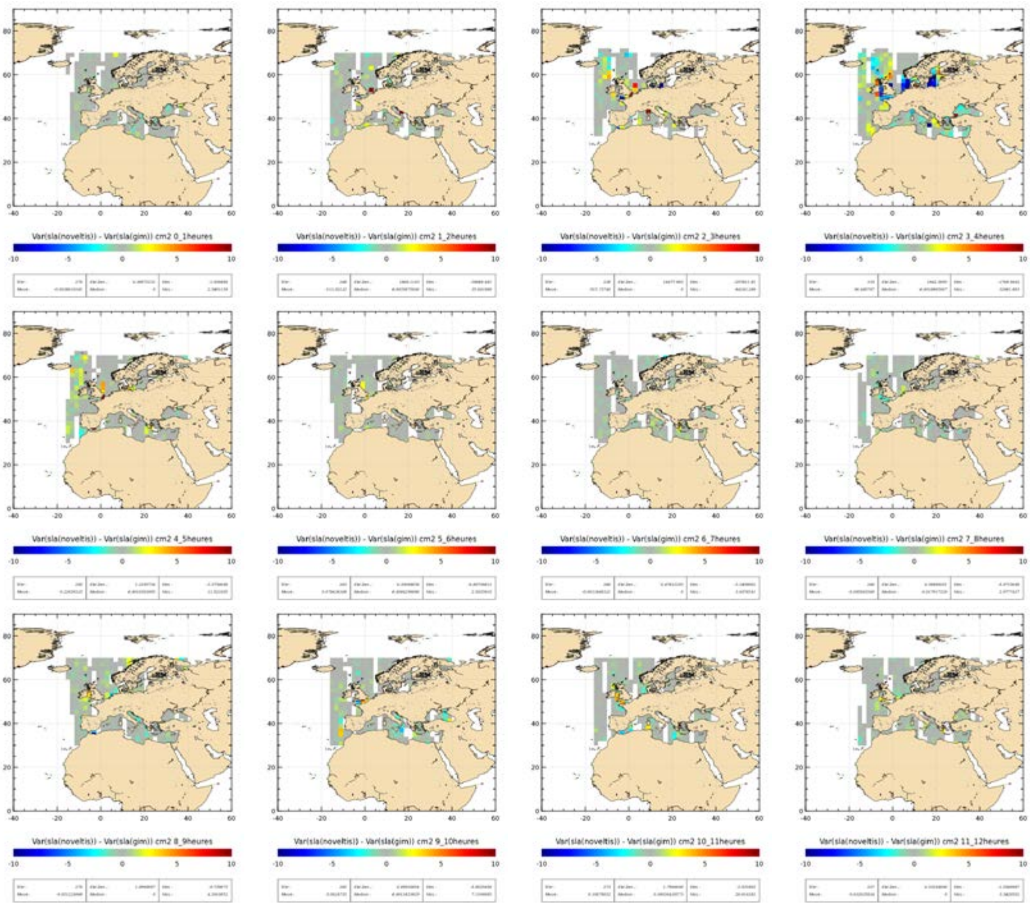

Figure 9: Gain of variance between SLA computed with SPECTRE model and with GIM model for different local time in hourly interval (from 0h00 to 11h00)

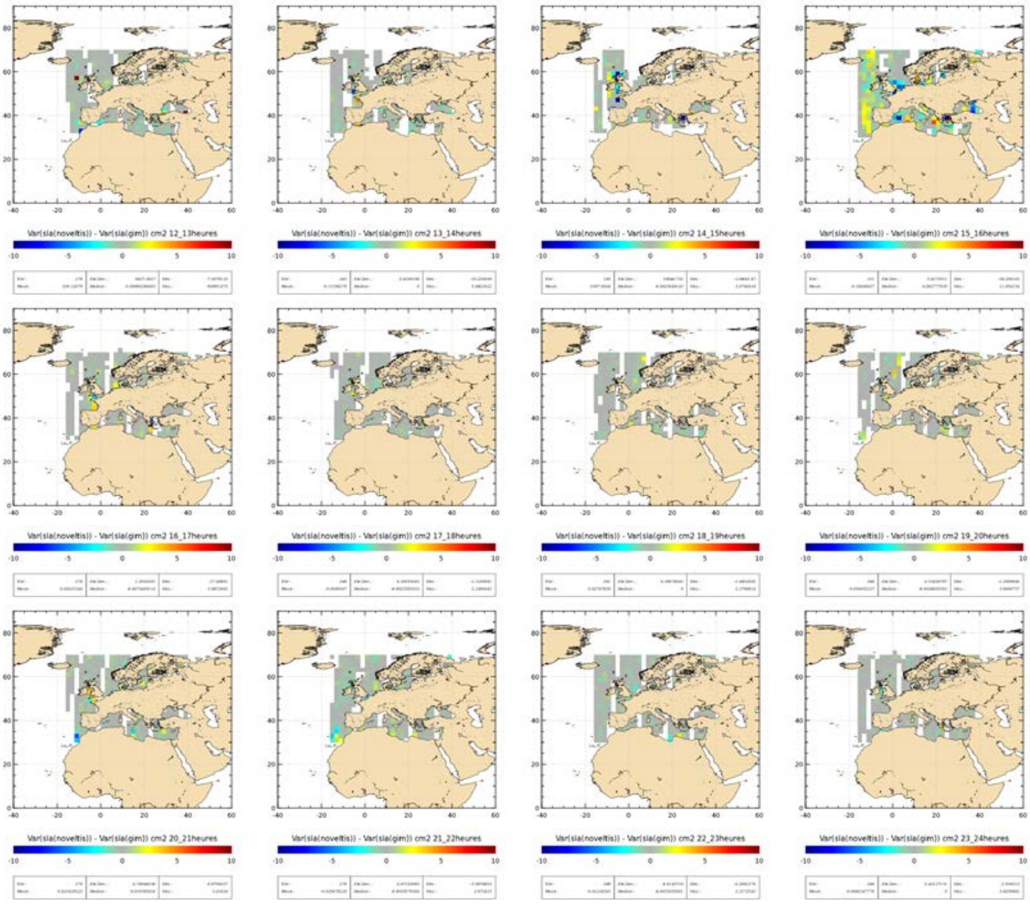

Figure 10: Gain of variance between SLA computed with SPECTRE model and with GIM model for different local time in hourly interval (from 12h00 to 23h00)

The reliability of the diagnosis of the variance reduction have been examined by evaluating the difference of variance between a SLA grid corrected by an ionospheric fixed value (-2cm) and a SLA grid corrected by the SPECTRE model (see Figure 11). As expected the mean computed difference shows a clear increase of variance (~4cm²) which would confirm that SPECTRE obviously better models the state of the ionosphere.

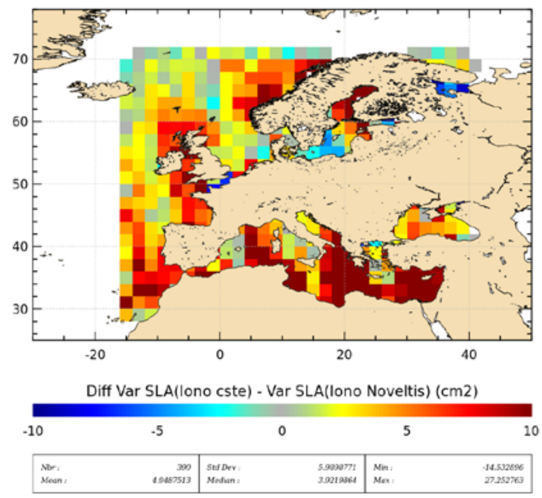

Figure 11: Gain of variance between SLA computed with constant IC (-2cm) and with SPECTRE model

3.3. Spectral analysis

A spectral analysis was also carried out to evaluate the differences between SLA computed with the SPECTRE model and with the GIM model as a function of spatial scales.

Figure 12 shows that both data sets exhibit exactly same behaviour. This result would confirm our first guess that the enhancement of the time and space resolution from SPECTRE compared to GIM doesn't improve the SLA determination for short wavelength scales.

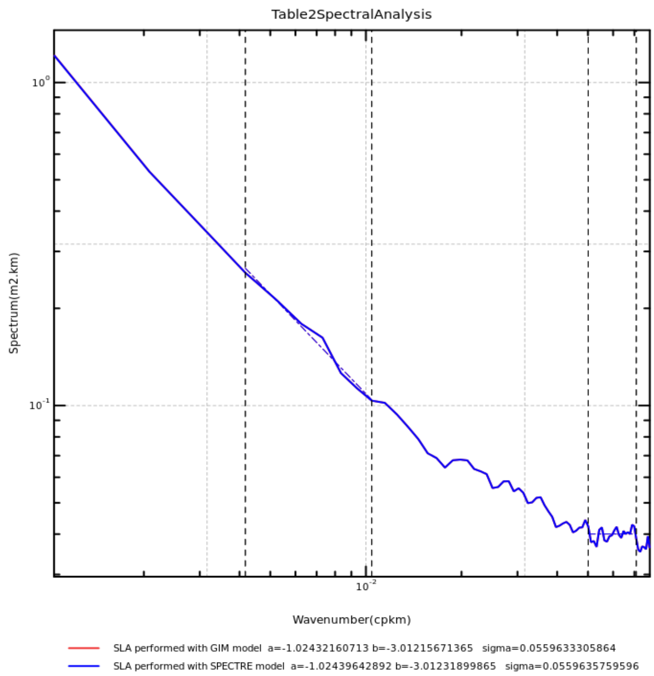

Figure 12: Spectra of the sea level anomaly computed with the SPECTRE model (blue) and with the GIM model (red)

4. Conclusion

In conclusion, it emerged from this study that both ionospheric correction solutions (from SPECTRE and GIM models) show quite similar results.

Based on the use of traditional method analysis (along-track gain of SLA variance), it is however difficult to conclude with some certainty whether this new high-sampled temporal correction (SPECTRE) makes any substantial improvement or not. The spectral analysis does not point to any improvement either.

Many studies have already demonstrated that smoothing the ionospheric correction from bi-frequency satellite altimeters over hundreds of km improves the variance of the SLA. GIM is indeed used classically with a rough space and time resolution for correcting mono-frequency altimeter satellite. It is however not evident to say whether the enhancement of the temporal resolution (to reveal small-scale variations) is improving or not the variance, particularly for the CryoSat-2 SAR mode data.

5. References

[Crespon, 2007] : F. Crespon, E. Jeansou, J. Helbert, G. Moreaux, P. Lognonné, P.E. Godet, R. Garcia, *"SPECTRE (www.noveltis.fr/spectre): a web Service for Ionospheric Products"*, in Proceddings of the 1st Colloquium Scientific and Fundamental Aspects of the Galileo Programme, October 1-4, 2007, Toulouse, France.

[Schaer, 1998]: S. Schaer, W. Gurtner and J. Felstens, "*IONEX: The Ionosphere Map Exchange Format Version 1, February 25, 1998*", in Proceddings of the 1998 IGS Analysis Centers Workshop, ESOC, Darmstadt, Germany, p. 233-247, February 9-11, 1998.