CalVal Envisat

Envisat RA2/MWR V3.0 reprocessing impact on ocean data

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LIST OF ACRONYMS

ECMWF	European Center for Medium range Weather Forecasts
GDR-A	Geophysical Data Record version A (before cycle 41 for Envisat mission)
GDR-B	Geophysical Data Record version B (after cycle 41 for Envisat mission)
MSL	Mean Sea Level
MWR	MicroWave Radiometer
POE	Precise Orbit Ephemeris
SLA	Sea Level Anomalies
SSB	Sea State Bias
USO	Ultra Stable Oscillator
PTR	Point Target Response

1. Introduction

This report is an overview of the impact of the V3.0 version reprocessing of Envisat altimeter system over ocean in the frame of the CNES Altimetry Ground Segment (SALP) and funded by ESA through F-PAC activities (SALP contract N° 104685 - lot1.2.A).

This whole mission reprocessing is the second one for Envisat altimetric data set, after a first version (V2.1) in 2012. All cycles from 6 to 113 (May 2002 to April 2012) were reprocessed into a homogeneous standard (so called V3.0 version and close to Sentinel-3's) and added to the current production time series.

The document presented here is a synthesis on the reprocessed data quality from GDR cycles 6 through 113 spanning ten years (from 14-05-2002 to 08-04-2012).

For further information about historical data, please refer to [14].

After a preliminary section describing the data used, the report is split into 6 main sections:
- first, the data used are presented, with a status of the geophysical content of the fields that have changed from the historical version to the new one.
- a global **overview** of the performances improvement is then synthetized.
- the **data coverage** and measurement validity issues are then presented.
- then, a **monitoring of the main altimeter and radiometer parameters** is performed, describing the major impact of reprocessing in terms of data accuracy.
- and finally the impact of the reprocessing on **Mean Sea Level** issues, threw cross calibration results, is detailed:
o on the **global** drift
o on the **regional** drift

2. Data used and processing

2.1. Data used, GDR V3 Standards

This document deals with the global impact of Envisat altimeter whole mission V3.0 reprocessing. The products validated consist of the L2 data over ocean, directly read from Geophysical Data Records (GDRs) from cycle 6 to cycle 113 , compared to the previous standard (so called V2.1 version).
Yet, for any information concerning the historical data and impact of each standard update, please refer to the Envisat yearly reports available on Aviso web site.

The Envisat GDR data are generated using two softwares: the ESA IPF, from Level0 to Level1B, and the CNES Bibli ALTI, from Level1B to Level2.
The V3 version, result from a L1 library=7.11, L2 library=V5.6p2, Processing Pilot=V5-1p1. The associated standards are illustrated on Figure 1 and presented here below:

- **MSS**: CNES CLS 2015 version is used. The difference with the previous CNES CLS 2011 solution is shown in Figure 3 (left). The DTU solution is also available inthe product but not used in this document. The difference between both solutions is plotted in Figure 3.

- **Ocean tides**: FES 2014b version is used.

- **Wet tropospheric corrections (and derived fields)**: improvement of the retrieval estimation (side lobe consideration and neural network optimized).

- **Orbit solution**: GDR-E used, including a homogeneous reprocessed gravity field.

- **Sea State Parameters**: New SSB table based on the new Sea Surface Height estimate (including all standards) and SWH Look Up tables correction (see impact on model-altimetry comparison Figure 4).

- **Filtered dual-frequency ionosphere correction**: A 300-km low pass filter is applied along track on the dual frequency ionosphere correction to reduce the noise of the correction (see impact on an along track example in Figure 5).

- **L1b processing**: IF mask update, USO correction new smoothing strategy, ICU evolution, PTR correction, previously provided in an external file, now included in the range field.

Baseline and GDR content

	Envisat V2.1 (+)	Envisat V3	Jason-1 last update
Range	Historical L1b (+PTR drift correction)	Including PTR and L1b updates	From GDR
Orbit	GDR-C (GDR-D)	GDR-E (GDR-D if DORIS missing)	GDR-E
Sea State Bias	SSB V2.1	SSB V3	SSB GDR-E
Ionosphere	Lanczos filtering for cycle <64, GIM after	Iterative filtering for cycle <64, GIM after	Iterative filtering
Wet troposphere	MWR V2.1 (V2.1+)	MWR 5 params solution	MWR replacement product
Dry troposphere	ECMWF gaussian grids based		
Combined atmospheric correction	MOG2D High Resolution		
Ocean tide	FES GOT4V8	FES 2014B	
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]		
Pole tide	WAHR 85	WAHR 85	DESAI 2015
MSS	CNES/CLS 2011	CNES/CLS 2015	

Figure 1: *Envisat V2.1 and V3 standards compared to Jason-1 ones*

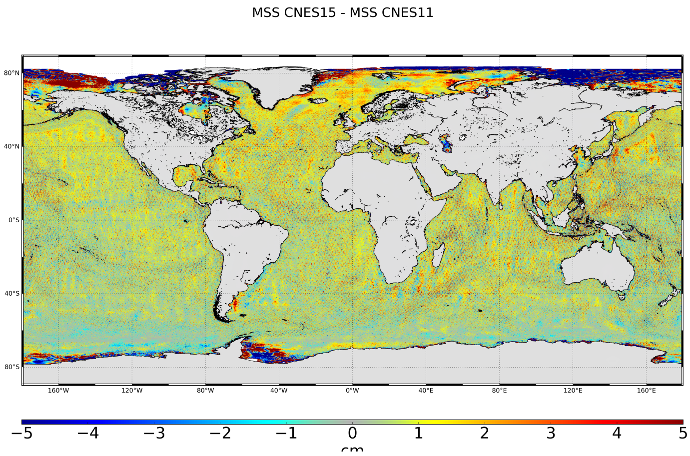

Figure 2: *Difference of MSS CNES CLS 2015 solution (After reprocessing) and CNES CLS 2011 (Before reprocessing). (After removal of reference frame shift from a 7 year reference to 15 year reference. Both are referenced over [1993, 2012].)*

The improvement of the reprocessed data quality is mainly explained by the geophysical corrections evolutions (MSS, Tides...) and a better understanding of some instrumental processing,resulting from studies performed on more recent missions (SARAL/Altika, S-3A...). They were chosen thanks to dedicated studies performed within different frames as descrided on the schema presented on Figure 6.

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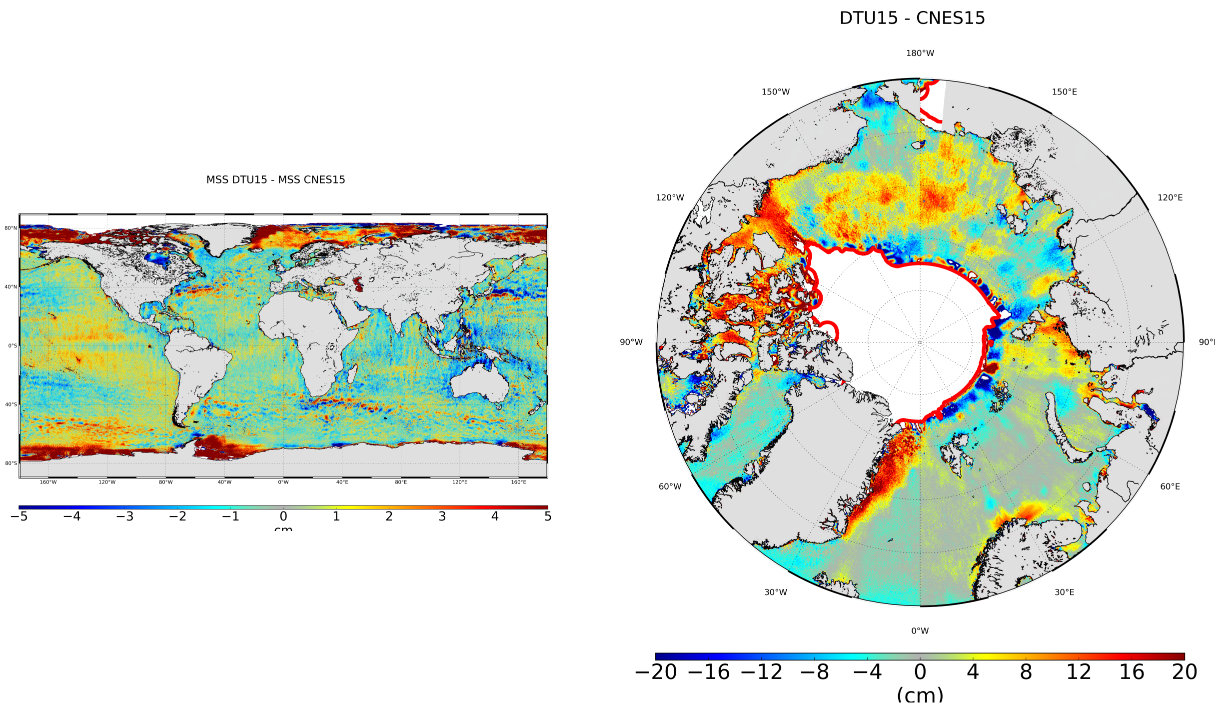


Figure 3: *Difference of MSS CNES CLS 2015 and DTU CLS 2015 solutions (both available in the products). Over all the oceans (Left) Over Artic (Right).*

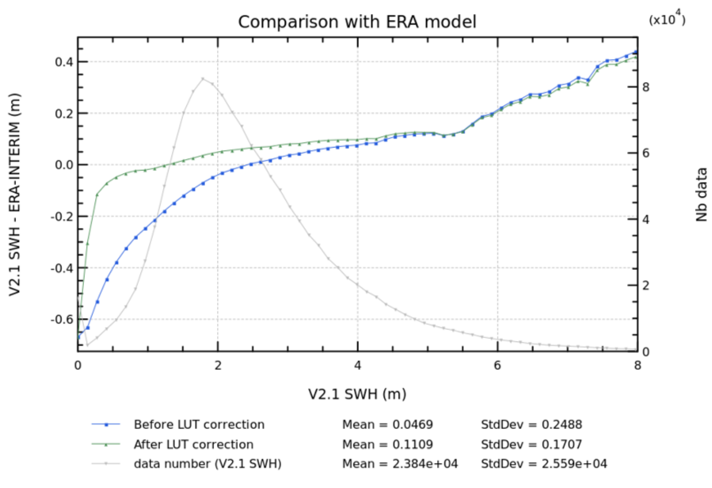


Figure 4: *Envisat V2.1 and V3 SWH compared to ERA interim ECMWF model. The impact of the Look Up tables now applied is observed.*

The validation process was based on 3 data basis as illustrated on Figure 7: the historical V2.1+ data set, the V3 data set, and an intermediated V3.0 prevalidation data set, including, before processing all the l2 proptotypes outputs coming from the study frames presented on Figure 6. The comparison between the historical and prevalidated dataset enabled to quantify the geophysical differences whereas the comparison between V3.0 and V3 data sets enables to check the l1b contribution and the potential implementations errors in the operational chain.

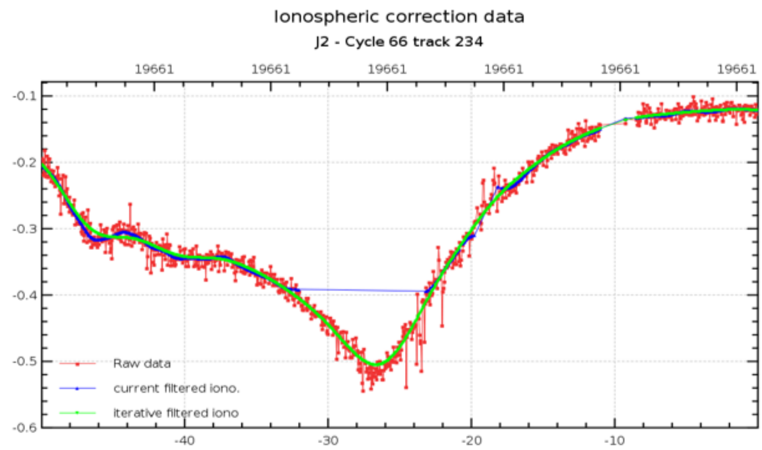


Figure 5: *Envisat V2.1 ionospheric correction before and after a Lanczos filter compared to the iterative filtering included in the V3 products.*

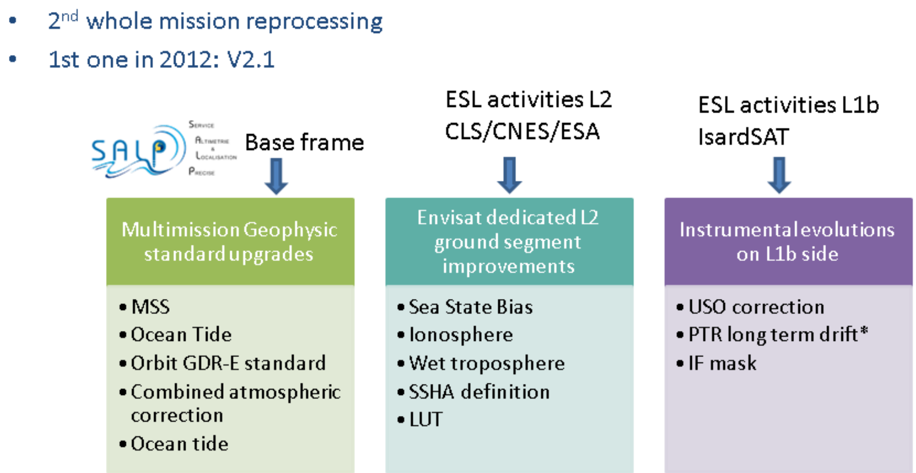


Figure 6: *GDR improvement improvement sources*

Proceeding this way enabled to anticipate a large majority of the evolution, to solve the errors before starting the real reprocessing and to fasten the interpretation of the final results.

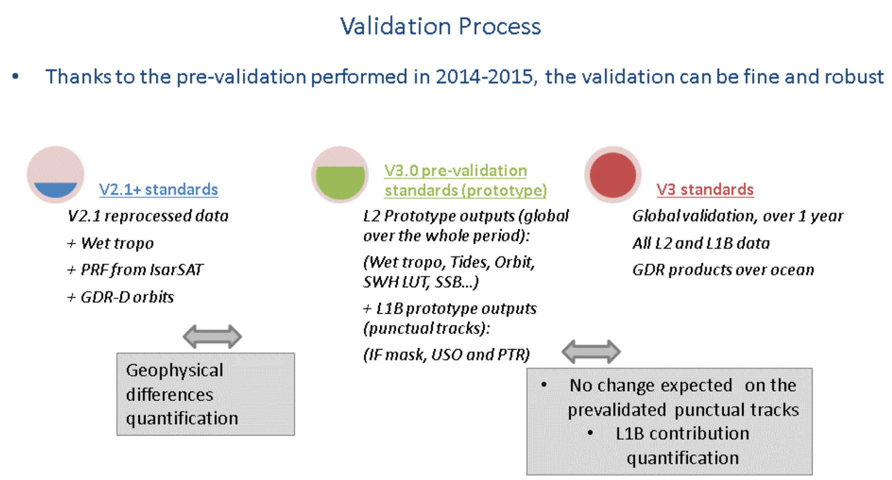


Figure 7: *Validation process for validation purpose*

2.2. Particular WARNINGS on data, for this standards version:

- As for historical data, **no S-Band is available in Envisat RA2 Data from January 17th 2008**, 23:23:40 (Cycle 65 pass 289) when S-band power drop occurred and was declared permanent. From cycle 65 onwards, S-Band related parameters are set to default values. Users are advised to use the ionospheric correction from GIM model and to not use the rain flag. To avoid jumps, between both series, users are advised to correct the model from a 8mm bias estimated on the difference computed over cycles 6 to 64.
- **No "S-Band anomaly" is present in the data anymore**: the error, in the ground segment was solved.
- **No more USO auxiliary files needed**: the USO correction is now directly/properly corrected in the range.
- **For cycle 47-48, the altimeter instrument was switched to B-side during 37 days**.This occured from 15/05/2006 14:21:50 to 21/06/2006 11:37:32 (cycle 47 pass 794 to cycle 48 pass 847). The biases induced by this change of instrument are discussed in part 8.1. for the parameters impacted (SLA, range and waveform related parameters). Also note that for almost the entire B-Side period (from, 05/20/2006 13:24:22) the S-Band was down. Users are advised to use the GIM model ionospheric correction with 8mm bias.

3. Quality performances overview

3.1. Improving the mesoscale observation skills

Compared to the last reprocessing, the resulting data set benefit for several improvements of the standards and therefore presents a much better capacity to describe mesoscale phenomena (improvement of error of Sea Surface Height (SSH) difference statistics at crossovers).
With a similar data availbality (see 4.1.) the homogeneity and performances are improved.

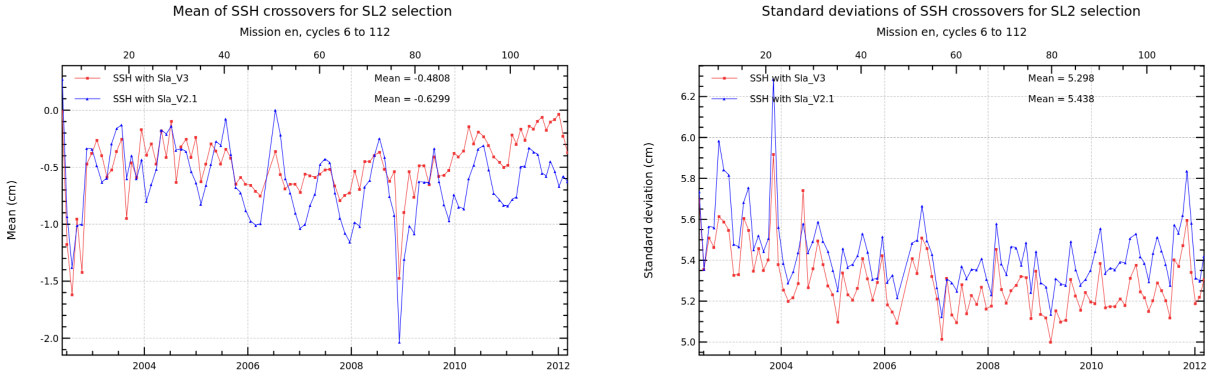
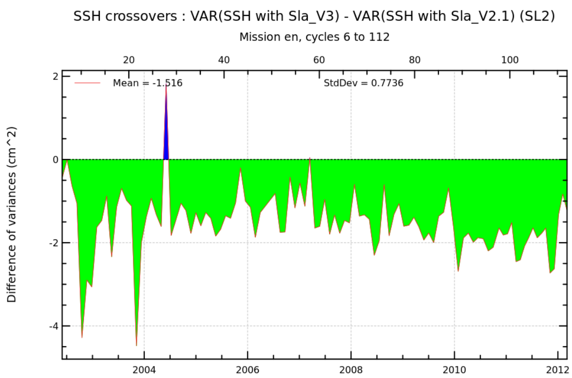


Figure 8: *Mean and Standard deviation of SSH difference at crossovers for Envisat before (blue) / after (red) reprocessing.*

The mean SSH difference at crossovers, relevant of the acsending descending passes consistancy, is more stable and the annual signal previously present has vanished almost totally, mainly due to the orbit standards (see Figure 8, left).
The standard deviation SSH difference at crossovers, relevant of the mesoscale error below 10 days, has also decreased significantly (see Figure 8, right).
The variance gain is around 1.5cm^2 with punctually more than 4cm^2 when avoiding the high latitudes (lower than 50deg), coastal zones (bathymetry lower than 1000m) and high oceanic activity (higher than 20cm^2) (see Figure 9 left). Geographycally, the best improvements are located at high latitudes and near coats where is greater than 8m^2 (as seen Figure 9 right).



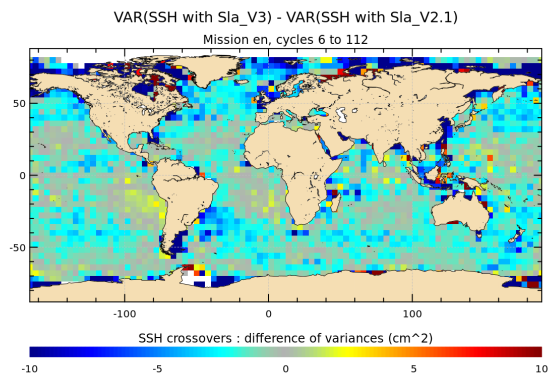


Figure 9: *Difference of SSH variance at crossovers : SSH crossovers variance after / before reprocessing.* ***Left:*** *variance gain per cycle* ***Right:*** *Map of difference over cycles 6 to 112 .*

3.2. Major contributors for the improvement

For this improvement, the two major contributors are the wet tropospheric correction and the ocean tides.
- Isolated from the other evolutions, with a V3 SLA definition, the radiometer (MWR, in its V2.1+ version) wet tropospheric correction before/after reprocessing counts for half of the improvement, as seen on Figure 10) with locally more than $3cm^2$ in very wet areas (as seen Figure 10 right).
- Similarly, the ocean tide correction correction before/after reprocessing (from GOT 4.8 to FES 2014) represents around 30% of the total improvement, as seen on Figure 10) with locally more than $10cm^2$ at high latitudes or near coasts (as seen Figure 11 right).
- the remaining 20% is divided by order on importance into Sea State Bias updates, including the Look up table correction of SWH, orbit standard, and filtered ionospheric correction.

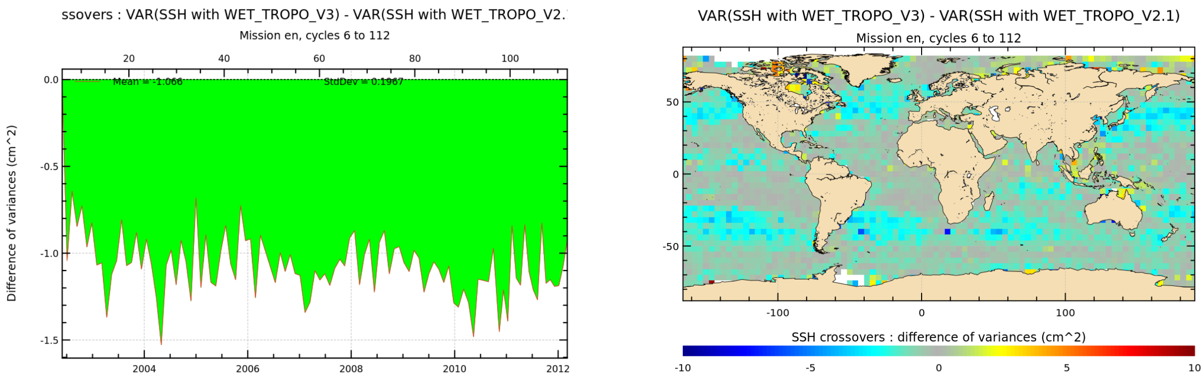


Figure 10: *Difference of SSH variance at crossovers : SSH crossovers variance when changing wet tropospheric correction only.* ***Left:*** *variance gain per cycle,* ***Right:*** *Map of this difference over cycles 6 to 112.*

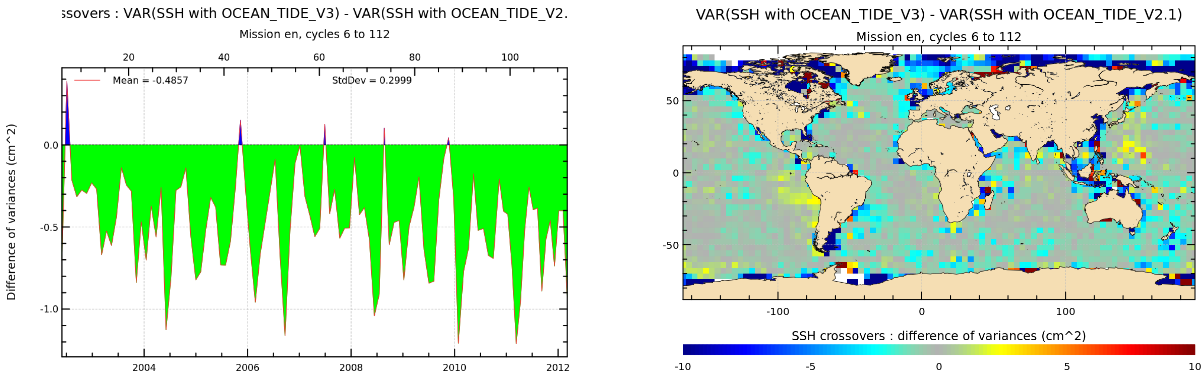


Figure 11: *Difference of SSH variance at crossovers : SSH crossovers variance when changing ocean tide correction only.* ***Left:*** *variance gain per cycle,* ***Right:*** *Map of this difference over cycles 6 to 112 .*

Conclusion, the reprocessed dataset is more accurate for mesoscale restitution. It is improved for this aspect compared to the original GDR time series.

4. Missing and edited measurements

This part consists in analyzing the availability of data for Level 2 products over oceans before and after the reprocessing exercise. It results in the sum of missing data and bad quality data edited by the Calval step from the data set.

4.1. Missing measurements

The reprocessed data presents globally less gaps than the historical data set: see Figure 12 in part 3.2.. Yet, some differences may be due to the fact that they only consist in "consolidated data" whereas the historical data set was a mix of "consolidated" and "non consolidated data" thanks to a CMA data managing.
Otherwise most data were and are still missing for instrumental purposes as explained cycle per cycle on the cyclic reports available with the data.
The high value of missing data on cycles 95-96 are due to the altimeter turn off during the shift to its final orbit. Elsewhere, the coverage status and the Investigation requests (FA) are explained in a document SALP-RP-MA-OP-022027-CLS [17].

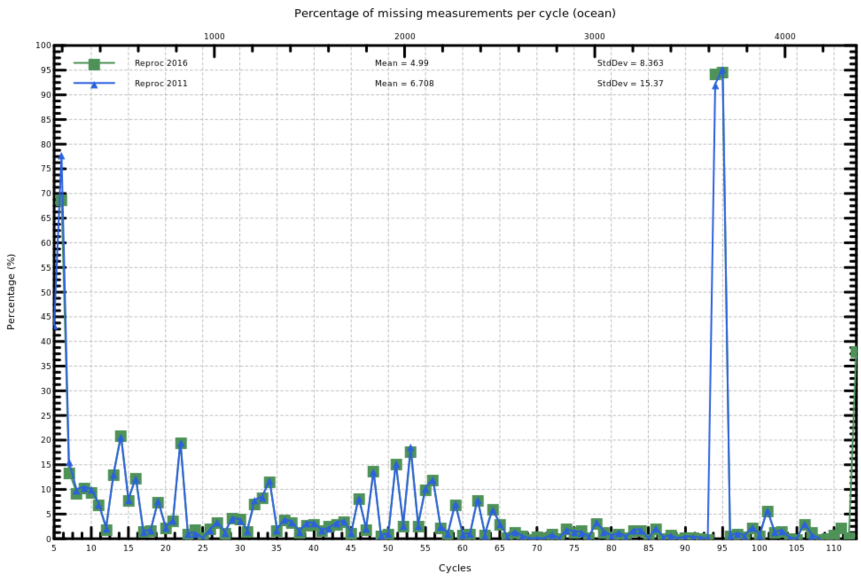


Figure 12: *Monitoring of the number of missing measurements relative to what is theoretically expected over ocean. Before (blue) / after (green) reprocessing.*

4.2. Edited measurements

Data editing is necessary to remove altimeter measurements having lower accuracy. The cumulated effect of all the steps is illustrated on Figure 13. It consists in:
- First: removing of data corrupted by sea ice, ice, rain (around 20% 14 left).
- Then, removing measurements out of thresholds tuned for several parameters (around 2% more 14 right).
- The third step uses cubic splines adjustments to the ENVISAT Sea Surface Height (SSH) to detect remaining spurious measurements.
- The last step consists in removing entire pass where SSH-MSS mean and standard deviation have unexpected value.
For more information, the editing method is detailed in the Yearly report [15].

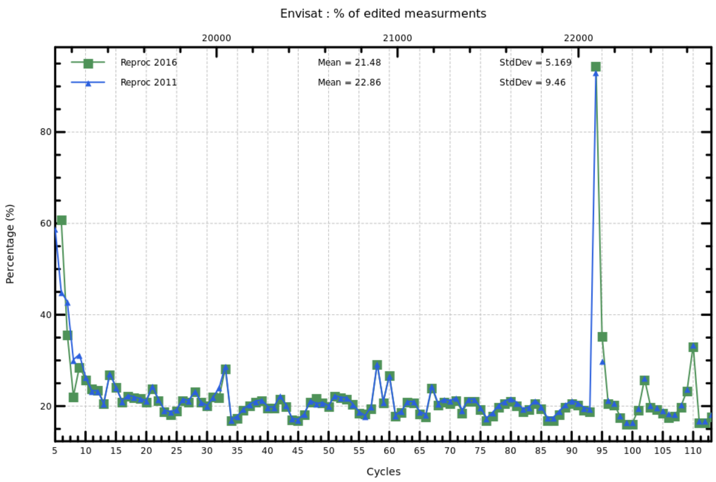


Figure 13: *Percentage of spurious data following the Calval editing criteria, before reproc (blue), after reprocessing (green).*

The most selecting steps are the two first ones, illustrated on Figure 14. The values of thresholds for each parameters are detailed in the Yearly report [15]). Here, we only focus on the difference before/after the reprocessing, which is very weak regarding these selection aspects.
The thresholds editing is stable for all parameters, except for the ionospheric correction which shifts from an instrumental based solution to a model solution. Globally, this criterion removes as many data as before until S-Band loss and less afterwards.
The analysis of each terms also shows that the number of data edited on SWH criteria and ionospheric correction is slightly increased. But on the other hand, the MWR and SLA out of threshold is lower.

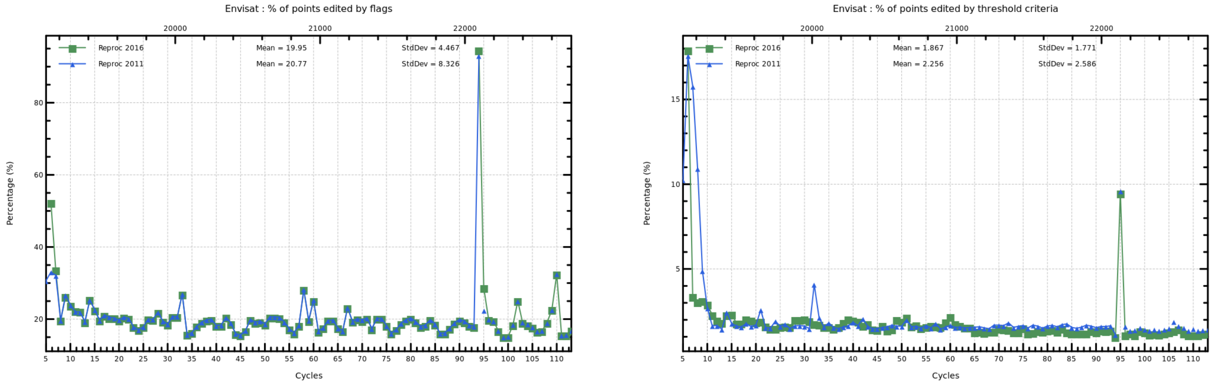


Figure 14: *Cycle per cycle percentages of edited measurements on flag (left) and threshold (right) criteria.*

5. ENVISAT Global bias explaination

The Sea Level Anomaly regional bias is significantly impacted by this reprocessing. Global maps of the SLA difference is plotted on 15.

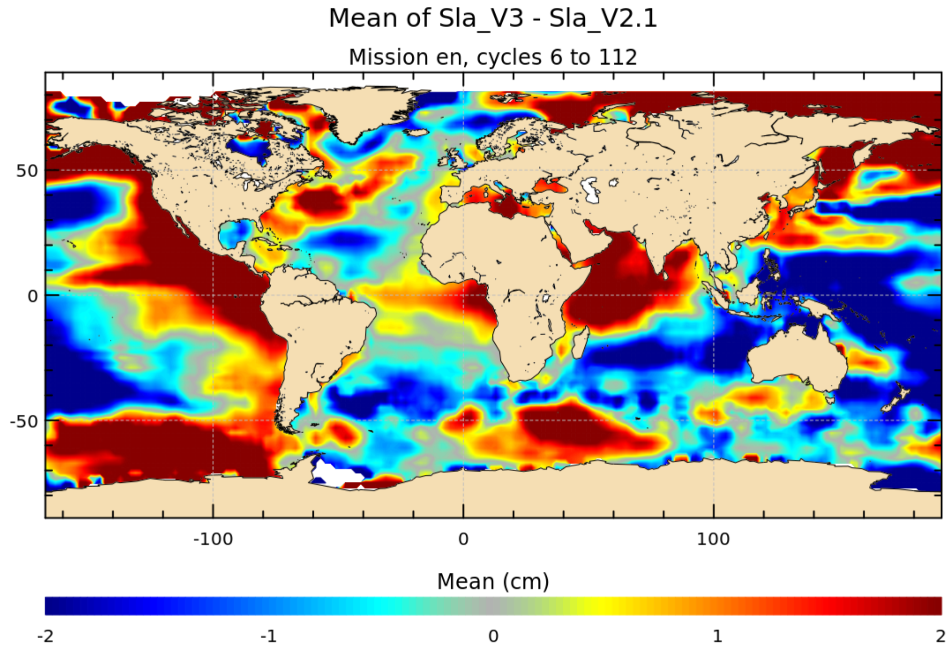


Figure 15: *Envisat V2.1 and V3 difference of total SLA over the whole mission.*

For this bias, the two major contributors are the MSS, the orbit, the SSB and the ocean tides.
- Isolated from the other evolutions, the radiometer (MWR) wet tropospheric correction before/after reprocessing counts for half of the bias, as seen on Figure 16) with locally more than $3cm^2$ in very wet areas (as seen Figure 10 right).
- Similarly, the ocean tide correction before/after reprocessing (from GOT 4.8 to FES 2014) represents around 30% of the total improvement, as seen on Figure 16) with locally more than $10cm^2$ at high latitudes or near coasts.
- the remaining 20% is divided by order on importance into Sea State Bias updates, including the Look up table correction of SWH, orbit standard (Figure 17 left), and filtered ionospheric correction. - the impact of range reprocessing is neglectible (Figure 17 right).

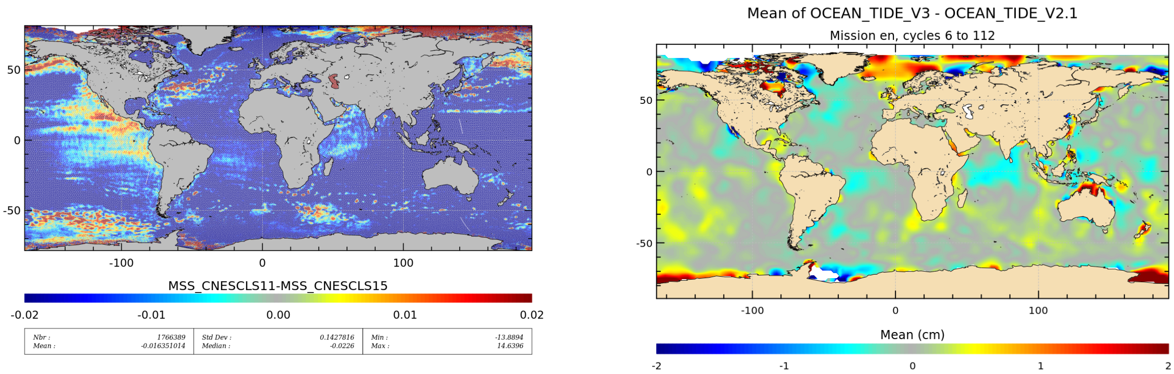


Figure 16: *Envisat V2.1 and V3 difference of correction over the whole mission.* ***Left:*** *wet troposheric correction,* ***Right:*** *Ocean tide.*

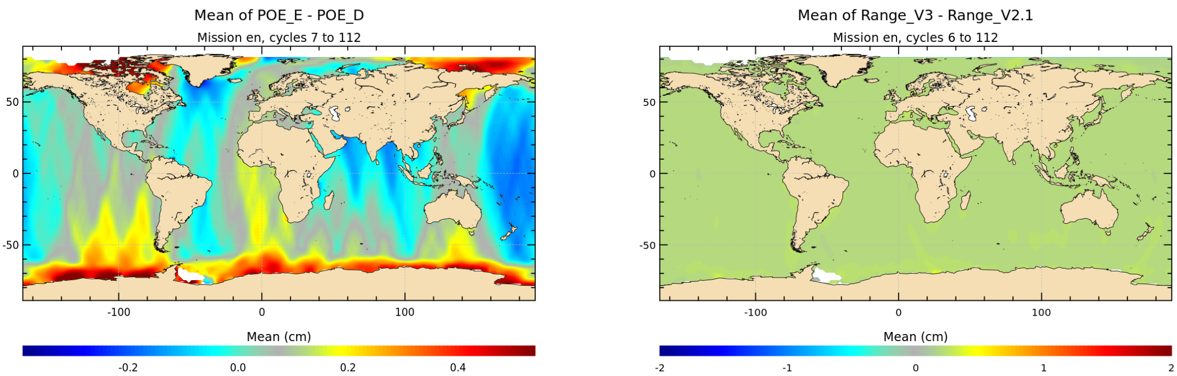


Figure 17: *Envisat V2.1 and V3 difference of correction over the whole mission.* ***Left:*** *Orbit difference,* ***Right:*** *Range only.*

Conclusion, the reprocessed dataset is more accurate for mesoscale restitution. It is improved for this aspect compared to the original GDR time series.

6. ENVISAT Global Mean Sea Level Trend

The Mean Sea Level trend is very weakly impacted by this V3 reprocessing. Unlikely, the previous reprocessing which had largely impacted this indicator thanks to a large improvement of the homogeneity throughout the mission life time and to the modification of an instrumental correction of data (the PTR drift, developped in Ollivier et al. 2012) [78].
This time, only weak improvements are noticed. The aim of this part is to characterize them.
The description of method and particular studies on this subject is detailed in [15].

6.1. Impact of the reprocessing on the global MSL

Since 2010, Envisat MSL is available on Aviso web page at: https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html. The description of the processing and the table of corrections used are available at https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level/processing-corrections.html.
It is computed with an updated series and results in the MSL seen on Figure 18 right.

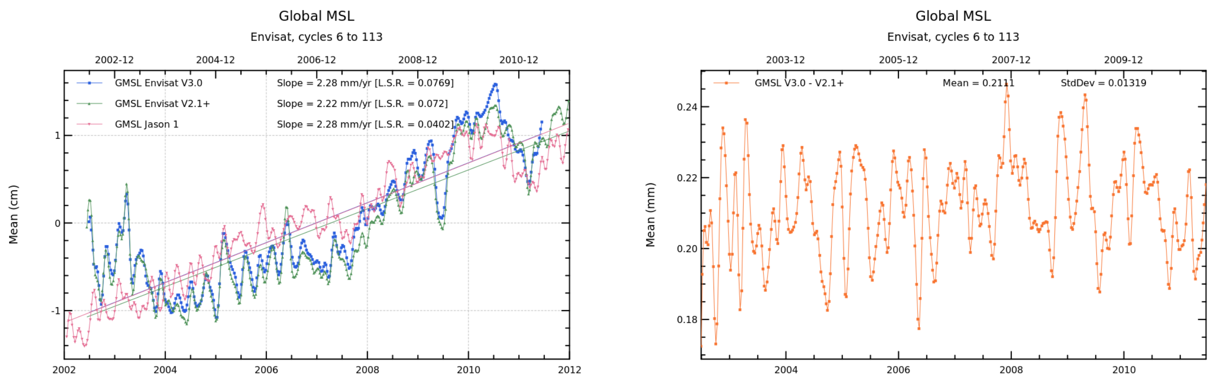


Figure 18: *Envisat GMSL comparison between V2.1/ V3 reprocessing and Jason-1.*

Envisat's MSL has various behaviors during its lifetime (even with reprocessed data) notably, a very odd decreasing trend at the beginning of the mission before 2004 (cycle 22). This behavior remains after the reprocessing (see 18. The value computed over the whole period is shifted from 2.22mm/yr to 2.28mm/yr by a 0.06mm/yr difference consisdered as negligeible regarding the criterion established within the Climate Change Initiative ESA project (significant above 0.1mm/yr, [10]).

These results, after reprocessing remain in line with what was previously published in ([78]).
The comparison to the in situ data set, detailed in ([6]).

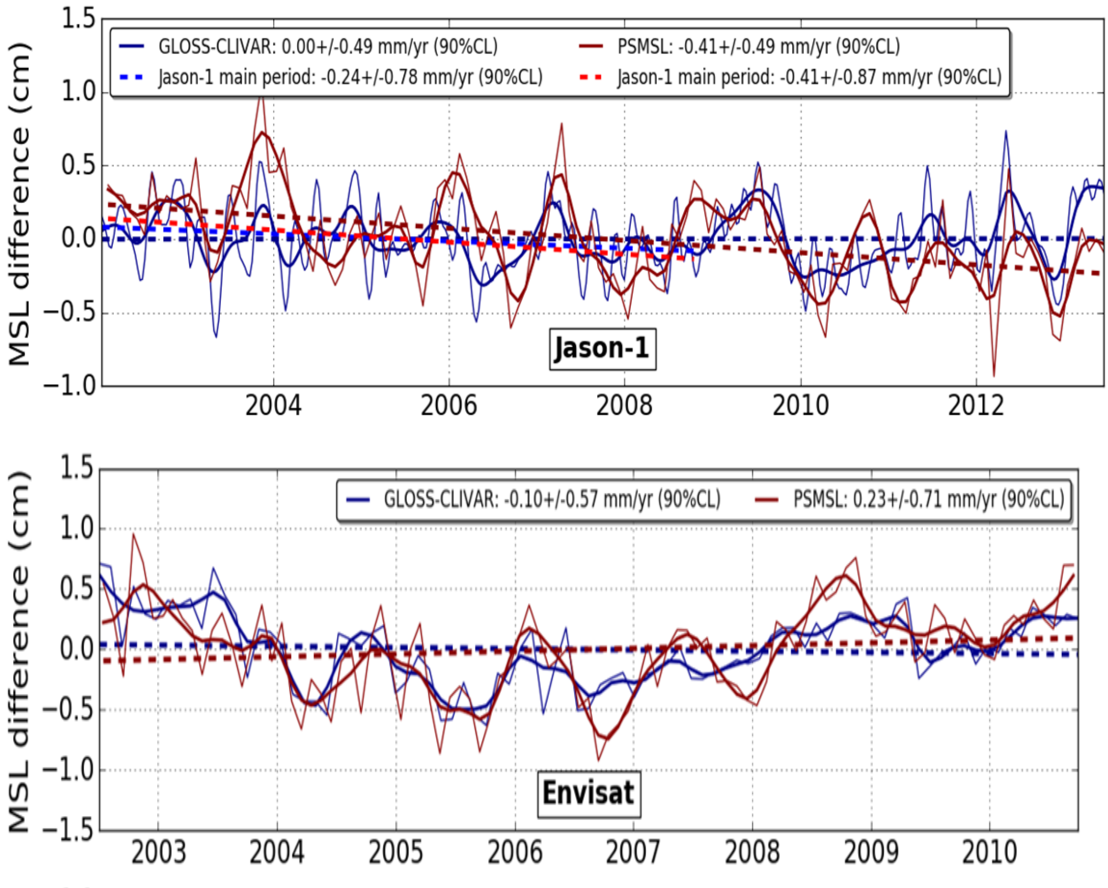


Figure 19: *Difference of SLA trend using Radiometer Wet tropospheric correction compared to the in situ tide gage time series for Jason-1 (top) and Envisat(bottom)*

6.2. Impact of the reprocessing on the regional MSL

The impact of the reprocssing on regional linear trend of MSL is plotted on Figure 20, mixing all tracks and Figure 21, separating ascending and descending tracks. is rather weak compared to the next reprocessing effect but a East West effect is shown to be corrected for.
The source of this trend difference is majoritary due to the orbit solution udate as shown on Figure 24 and Figure 23 which uses the new GDR-E precise orbit solution Figure 24 (right) instead of the GDR-D solution (left). The gravity field used for this solution is computed with GRACE measurements on the whole period wherease the GDR-D standards used an estimated extrapolated solution at the end of the series, thought impacting the interannual differences (rather than the linear trend) as shown on Figure 24.

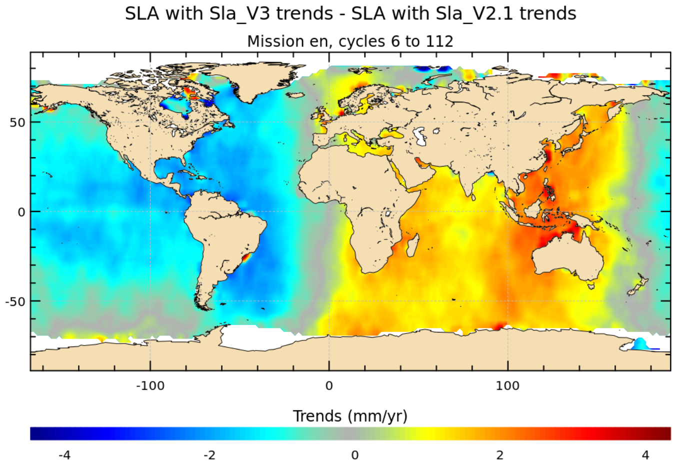


Figure 20: *Difference of SLA trend using Radiometer Wet tropospheric correction After-Before reprocessing.*

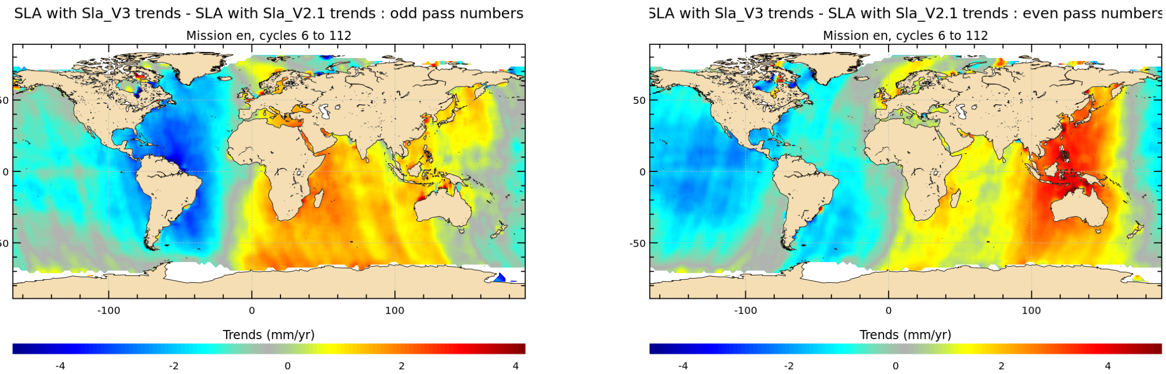


Figure 21: *Difference of SLA trend using Radiometer Wet tropospheric correction After-Before reprocessing.Left: Ascending tracks. Right: Descending tracks.*

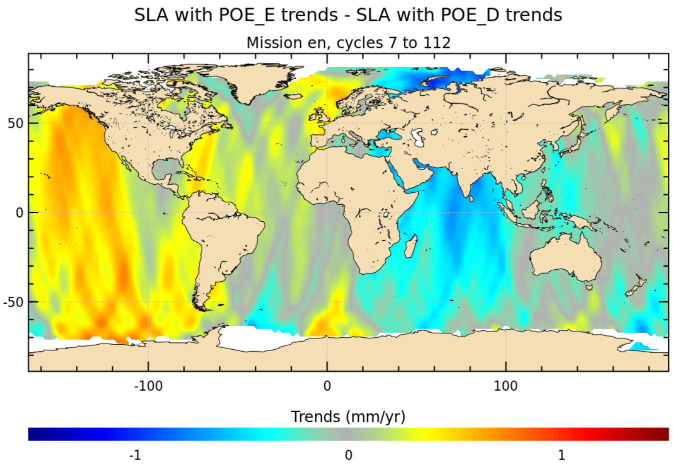


Figure 22: *Difference of SLA trend using GDR-E standard (After reprocessing) - GDR-D ones (Before reprocessing).*

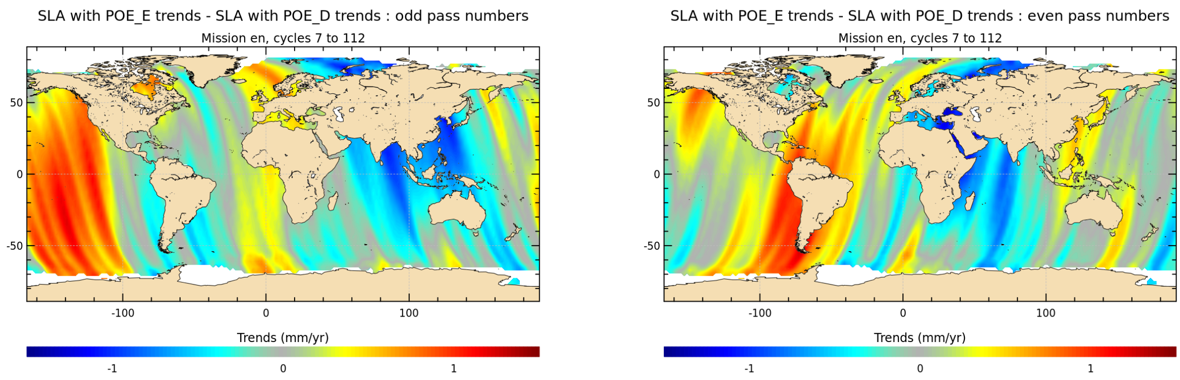


Figure 23: *Difference of SLA trend using GDR-E standard (After reprocessing) - GDR-D ones (Before reprocessing). Left: Ascending tracks. Right: Descending tracks.*

The impact of the reprocessing on regional linear trend of MSL is plotted on 20 mixing all tracks and 21

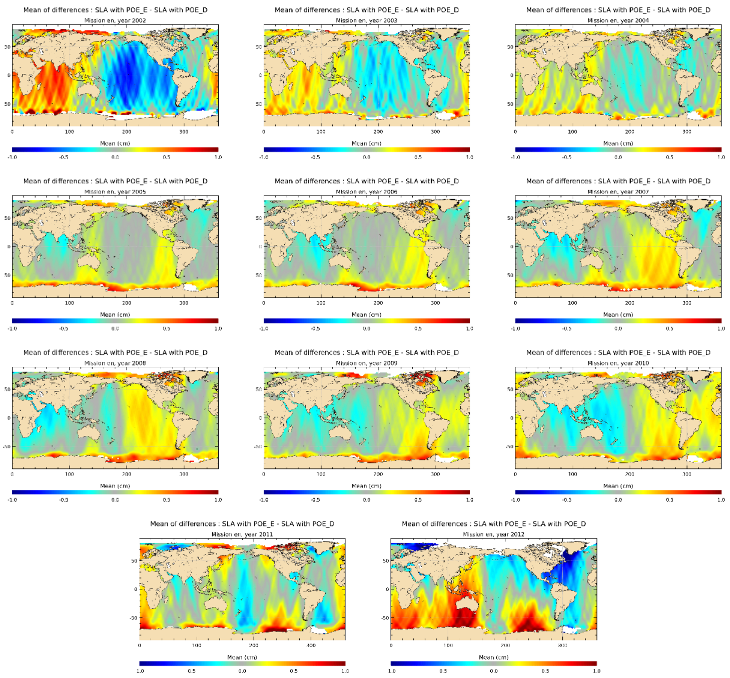


Figure 24: *Difference of SLA averaged per year using GDR-E standard (After reprocessing) - GDR-D ones (Before reprocessing).*

6.3. Conclusion

The impact of the reprocessing including the use of the wet tropospheric correction and the comparison to Jason-1 and to tide gauges external source are summed up in the table below:

Global MSL Trend	
EN MSL using MWR V2.1+	2.22mm/year
EN MSL using MWR V3	2.28mm/year
J1 MSL using JMR	2.28mm/year
EN-Tide gauge V3 reprocessing and PTR (using radiometers)	-0.1mm/year+/-0.57mm/year
J1-Tide gauge	0mm/year+/-0.49mm/year

Table 1: *M*SL trends in mm/year

These results could be completed by a comparison of altimetric data set to a Tide Gauge network. This method enables to assess the results by taking an external reference to the altimetry system. Similar behaviors are observed to the comparison with Jason-1.
The difference altimetry - tide gauge is around 0.1mm/year when using radiometer.

7. Long term monitoring of altimeter and radiometer parameters

This part offers a synthesis of the impact of the reprocessing on the GDR fields included in the Sea Surface height definition. Note that all statistics are computed on valid ocean datasets after the editing procedure, presented in section 4.2..

7.1. Range related parameters

7.1.1. Ku/S-Band range: drift noticed on S-Band

As part of the ground segment processing, a regression is performed to derive the 1 Hz range from 20 Hz data. Through an iterative regression process, elementary ranges too far from the regression line are discarded until convergence is reached. The mean number and RMS of Ku 20Hz elementary data used to compute the 1Hz average are plotted in figure 25. These two parameters are nearly constant, which provides an indication of the RA-2 altimeter stability on Ku band. On the contrary, S-Band similar metric indicate an unstable ratio (before and after reprocessing). The S-Band mean number and RMS of 20Hz measurements have respectively an increasing and decreasing trend. This drift, as well as the jump noticed around cycle 18 appearing on reprocessed data is not understood yet but should be investigated further (possible impact on the MSL drift at the beginning of the period).

Also note that the range is corrected from instrumental correction. One of them is the Time delay Calibration Factor (or PTR drift) whose quantification step was increased (since IPF6.02 version) for the reprocessing on both Ku and S-Bands.

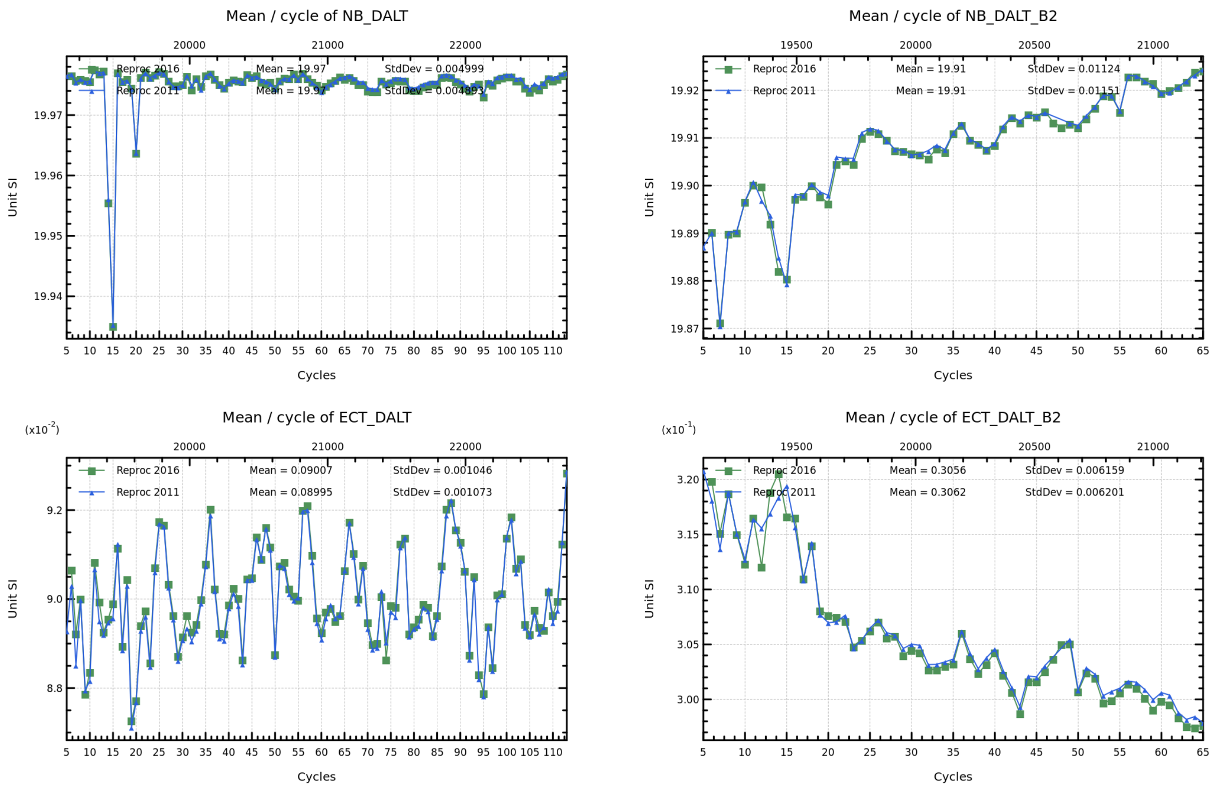


Figure 25: ***top****) Mean per cycle of the number of elementary range measurements used to compute 1 Hz range.* ***bottom****) Mean per cycle of the standard deviation of 20 Hz measurements.****left hand plots****: Ku band,* ***right hand plots****: S band*

7.1.2. Dual frequency ionosphere correction

The quality of S-Band range is directly linked to the bifrequency ionospheric correction quality by the formula (see RA2/MWR product handbook):

$$Iono(Ku) = 0.059 \ (\ Range(Ku) \ -Range(S) \ )$$

But as seen above, the difference of range is not impacted by the drifts because both drifts cancel each other in the reprocessed dataset.
Before S-Band loss of Envisat (January 17th 2008), when the bifrequency ionospheric correction was available, the impact of reprocessing on this parameter can be seen on Figure 26. When the S-Band loss occured, a 8mm bias (same as before reprocessing this) is observed between the model and the bifrequency correction. This bias must be applied to the model correction to compute a proper Mean Sea Level. Further explanations of the signal observed is detailed in the yearly reports available on Aviso (https://www.aviso.altimetry.fr/en/data/calval/systematic-calval.html).
The impact is null on the standard deviation per cycle (not shown here), and hardly seen on the ionospheric correction itself 26 (left). No impact is noticed on the comparison to the GIM model (right) from cycle 41 onwards.
Notice that, in this reprocessed series, a homogeneous sea state bias (SSB) has been used to correct the Ku and S-Band Ranges (Labroue 2007 [56]).

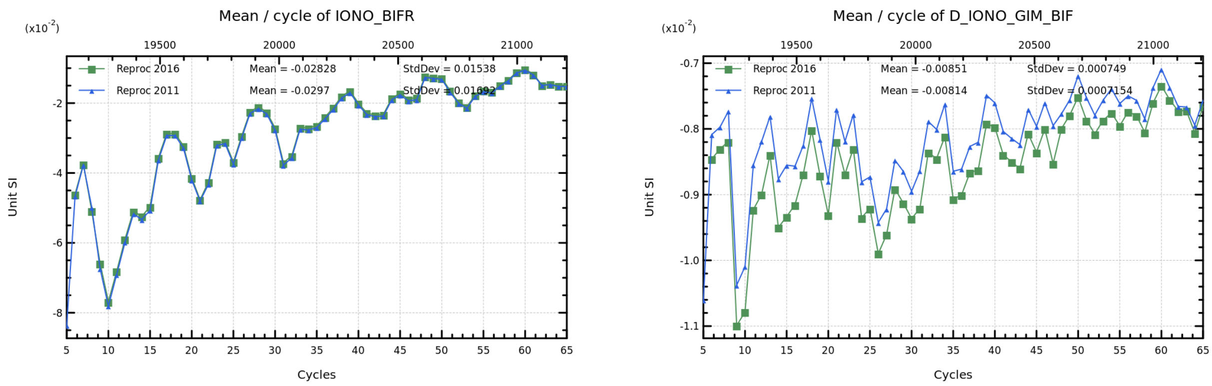


Figure 26: *Comparison of global statistics of Envisat dual-frequency and JPL-GIM ionosphere corrections (cm).* ***left)*** *Mean per cycle of Dual Frequency.* ***right)*** *Mean of the differences versus GIM correction for Envisat.*

7.1.3. GIM IRI Model Ionopsheric correction (only one available after 2008)

After the S-Band loss, the bifrequency ionospheric correction is not available anymore. Instead, the JPL GIM model is used (unchanged for the V3 reprocessing). The motinoring of this correction on the whole time series is plotted here below. It was recomputed for the reprocessing exercice, using:
- homogeneous solar activity coefficients computed a posteriori: this prevents from the potential jumps caused by the punctual updates on the historic time series.
- new JPL GIM grids, based on a delayed time algorithm (JPLG) instead of the usual real time algorithm (JPLQ): this has small impact at global cross overs but avoids jumps at daily transitions (around 330deg for ascending passes and 140deg for ascending passes).

This correction was computed off line by an external chain. It changes also the data on the period covering cycles 85-92, unlike most of the other standards fixed from cycle 85 onwards.

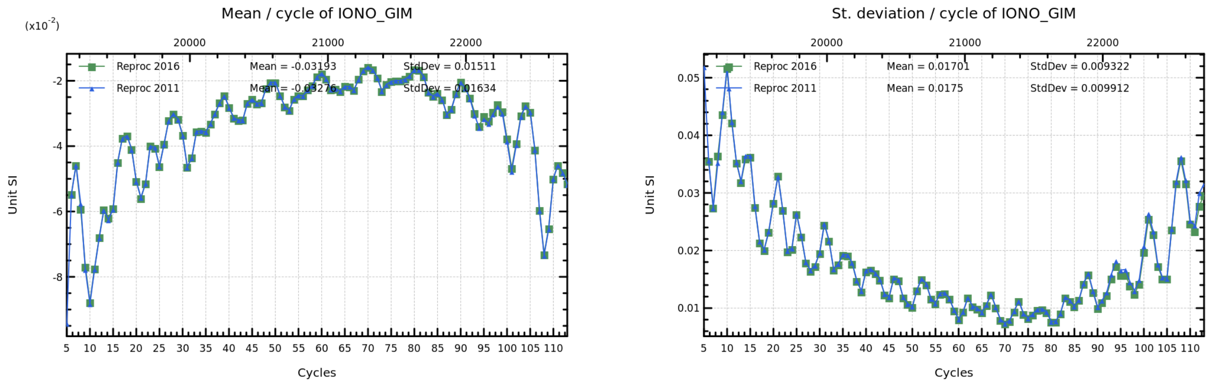


Figure 27: *Mean (left) and Std (right) per cycle of the JPL GIM ionospheric correction (m), the only one available after 2008 on Envisat because of the S-Band loss.*

7.1.4. Conclusion on Range related parameters:

****

Except for Side B, a homogeneous time series is observed, evidencing odd drifts on S-Band side with no visible impact on ionospheric correction. Odd behavior of the Ionospheric correction before cycle 22 (too stable and too high average by around 4-3mm). Hardly visible impact of the V3 reprocessing evolution.

****

7.2. Waveform stability parameters

7.2.1. Off-nadir angle from waveforms

The off-nadir angle is estimated from the waveform shape during the altimeter processing. The square of the off-nadir angle is plotted in Figure 28. Due to the change of IF mask applied at Level1 step, the waveform is slighlty reshaped. This has no impact on geophysical parameters after retracking. But induces a reduction of apparent mispointing (from 0.004 to 0.001deg^2) as well as a slight increase of the standard deviation. The slight reduction of standard deviation after the drifting orbit is explained by the altitude reduction that impacts the size of the ground track and therefore the antenna diagram impact on the trailing edge (of which the apparent mispointing is the slope).
Before and after reprocessing, the mean value presents a slight decreasing trend up to cycle 65 that stabilises without any clear explaination after the S-band loss.

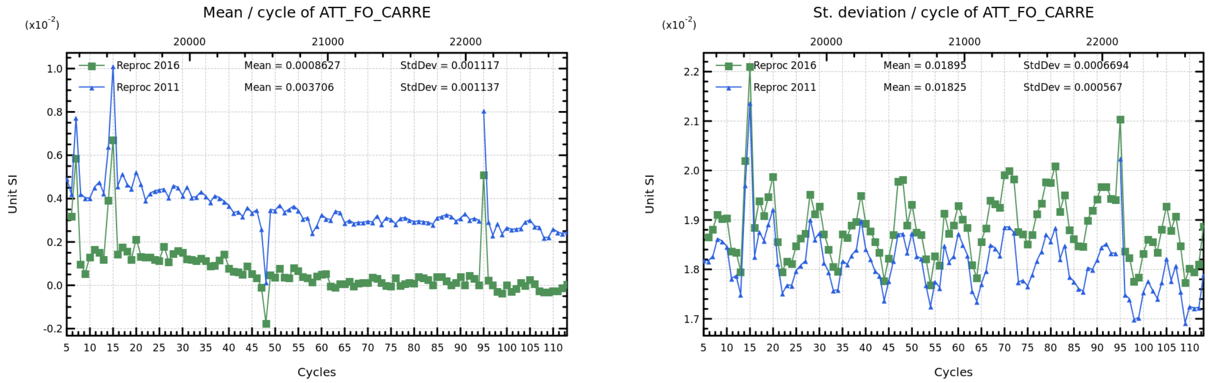


Figure 28: *Mean (left) and Std (right) per cycle of the square of the off-nadir angle deduced from waveforms (deg^2).*

7.2.2. Waveforms Peakiness

Like the mispointing, the peakiness is significant of the waveform stability. The plot 29 indicates changes of behaviors during the mission life time and particularly before reprocessing but removed on the reprocessed series after the drifting orbit due to the altitude reduction.

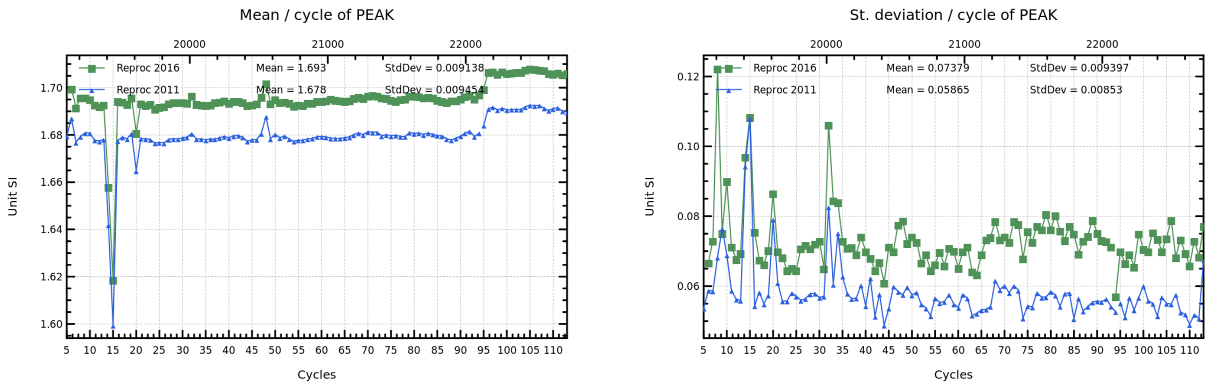


Figure 29: *Mean (left) and Std (right) per cycle of the waveforms peakiness (deg²).*

7.2.3. Conclusion on Waveform stability parameters:

****
Homogeneous time series evidencing slightly different biases over the whole time series. Small impact of the IF mask update for V3 reproccesing at level 1 with no impact on SLA.
****

7.3. Sea State parameters

7.3.1. Significant Wave Height

The cycle by cycle mean and standard deviation of Ku and S-Band SWH are plotted in figure 30. As before the reprocessing, its monitoring reflects sea state variations (with a clear annual signal). The mean value of Ku SWH is higher for the reprocessed data (2.6m instead of 2.5m). The S-Band mean SWH is drifting and rather lower from Ku-Band (around 2m instead of 2.6m), but unchaged from the previous reprocessing.

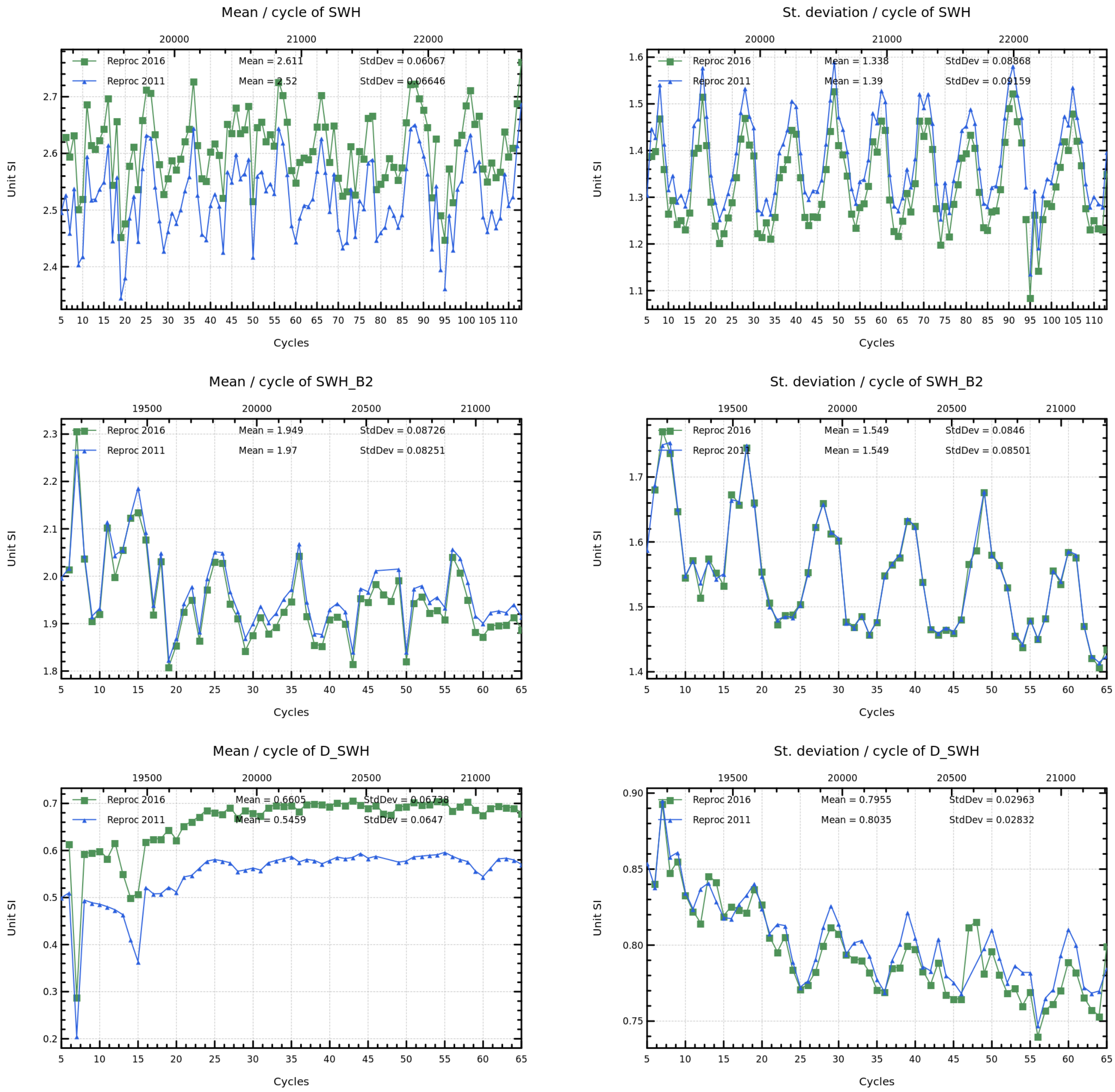


Figure 30: *Global statistics (m) of Envisat Ku and S SWH Mean (right) and Standard deviation (left) of the Ku-band SWH (top), S-band SWH (middle) and difference Ku-S (bottom).*

7.3.2. Backscatter coefficient, Wind and atmospheric attenuation

The cycle by cycle mean and standard deviation Ku and S-Band Sigma0 is only weakly impacted by the reprocessing. The changes noticed on both Ku and S band are weak (see Figure 31).
The differences on Sigma0 essentially come from the atmospheric attenuation from which it is corrected (illustrated on Figure 32)with a very weak impact on the standard deviation only due to a better restitution of geophysic variability.

The negligible impact of reprocessing on the wind (derived from Sigma0) is shown on Figure 33 using Jansen wind model. A potential remaining trend, though slight, has to be closely monitored

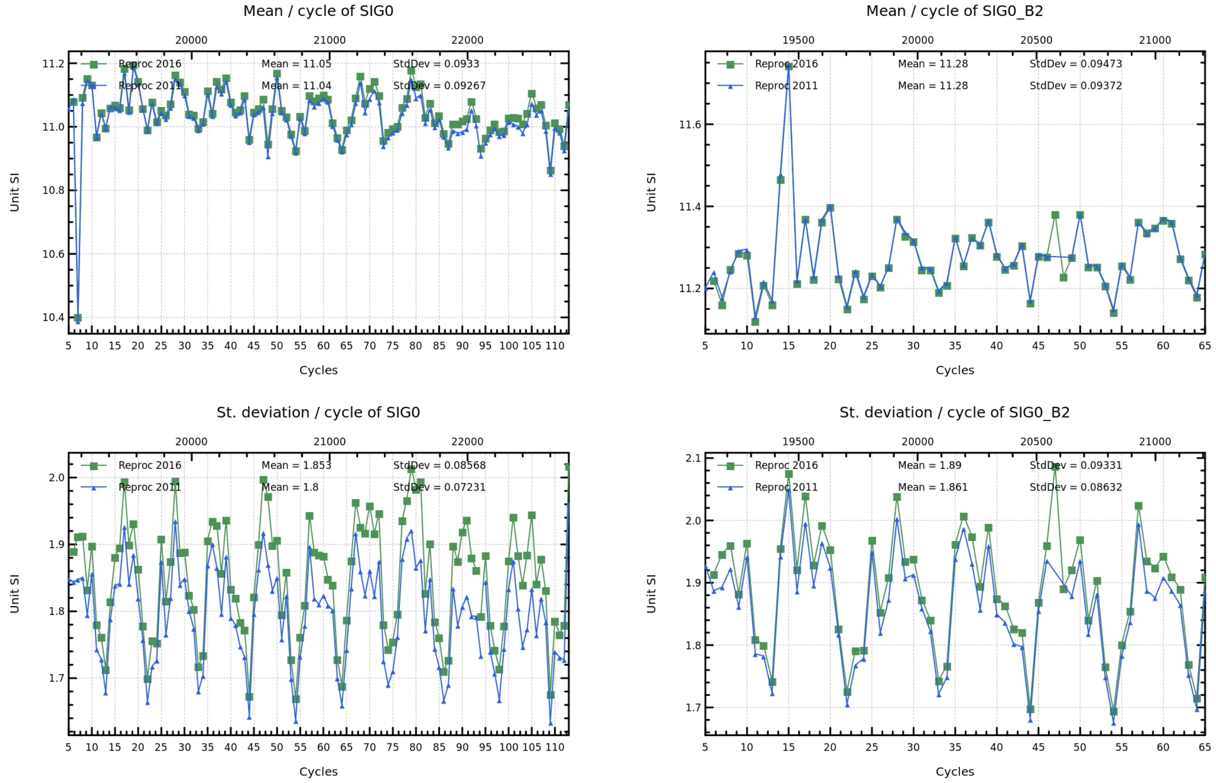


Figure 31: *Global statistics (dB) of Envisat Ku and S Sigma0 (dB) Mean and Standard deviation.*

but could have physical origins. The global stability of this parameter was studied in Ablain et al. 2012 published in Marine Geodesy (see [5]).

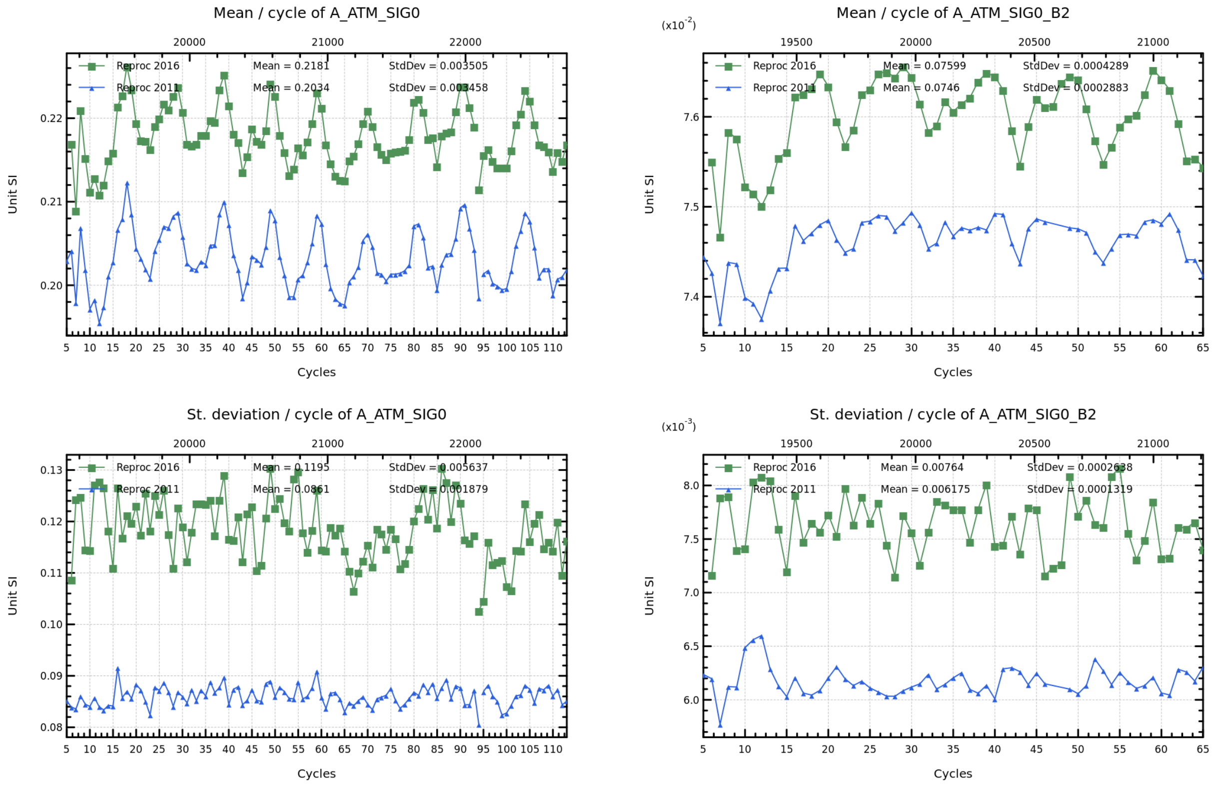


Figure 32: *Global statistics of Envisat Ku and S Sigma0 atmospheric attenuation (dB) Mean and Standard deviation.*

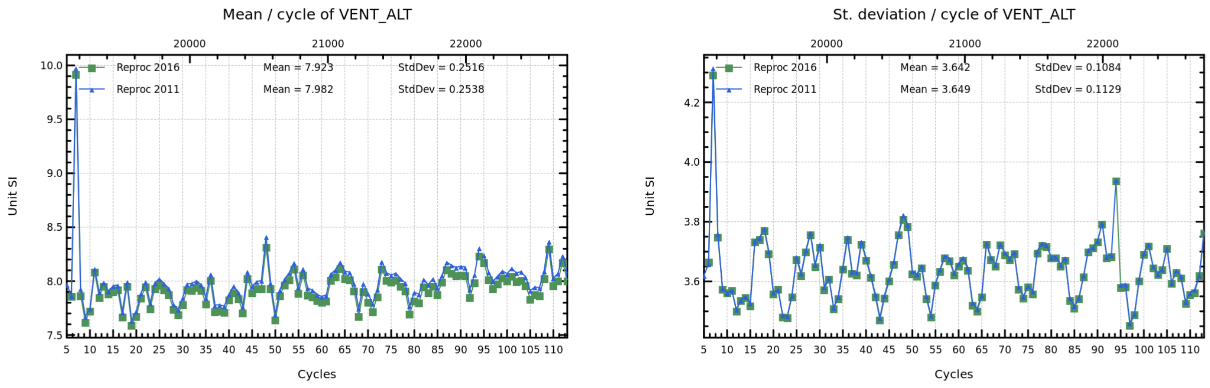


Figure 33: *Global statistics of Envisat Ku and S Wind (m/s) Mean and Standard deviation.*

7.3.3. Sea State Bias

The impact of reprocessing on the Sea State Bias (resulting from the update of wind, waves and models) is shown on Figure 34. The global bias has slightly changed due to LUT applied to SWH and to a new estimation of the SSB abacus empirically deduced from the new dataset corrected by all new standards (notably, the orbit and the wet tropospheric correction).

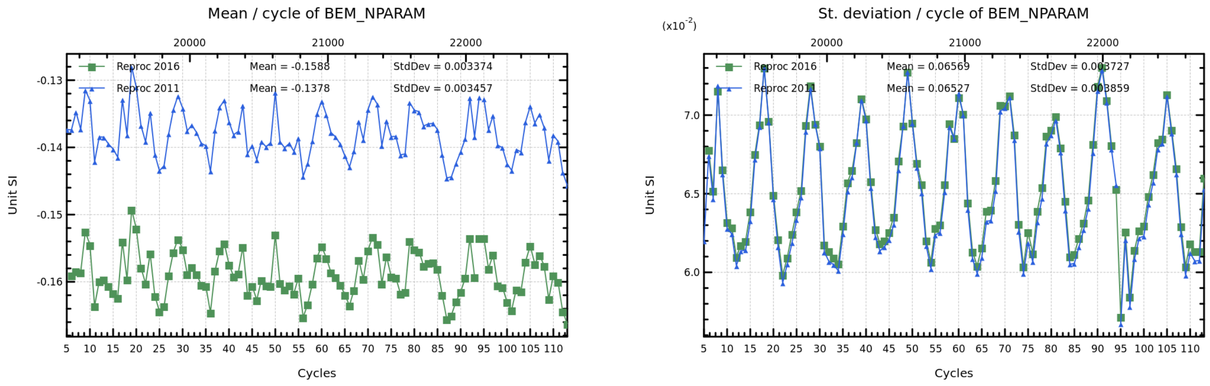


Figure 34: *Global statistics (m) of Envisat Ku Sea State Bias Mean and Standard deviation.*

7.3.4. Conclusion on Sea State parameters:

****

Higher SWH average (by around 10cm Ku band only) and lower dispersion (standard Deviation in Ku Band). Slightly higher atmospheric attenuation behavior with a very weak impact on Sigma0 and wind. Globally, Sea State bias slighly changed due to new standard dataset used in input of the abacus empirical estimation process.

****

7.4. MWR wet troposphere correction

Mean and standard deviation of Radiometric wet tropospheric correction (2016 V3 versus 2011 v2.1+) for Envisat is plotted in figure 35.

In average, the reprocessing impact is very weak contrarly to the strong impact on the error reduction at crossovers illustrated in part 3.2.. The standard deviation is also globally reduced after reprocessing thanks to a more accurate inversion method applied at Level 1 in the ground segment.

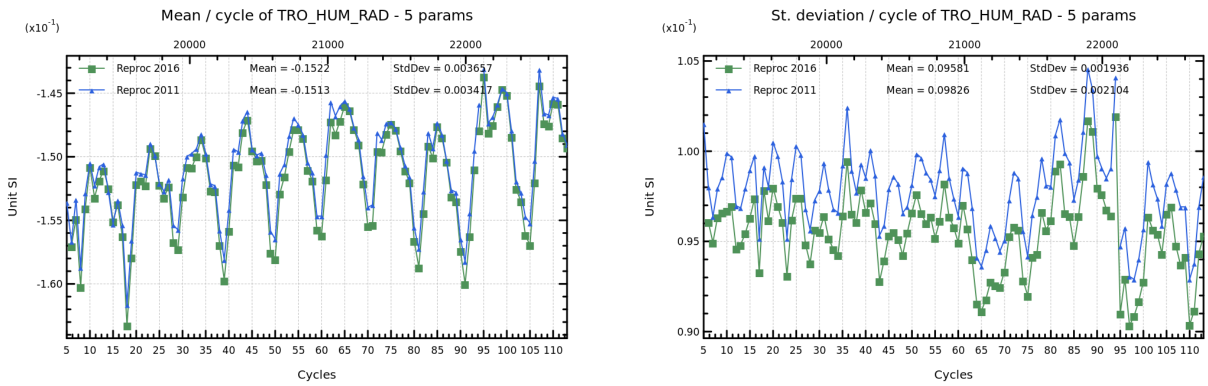


Figure 35: *Comparison of global statistics of Envisat MWR wet troposphere corrections (cm). Mean and standard deviation per cycle of MWR corrections.*

7.4.1. Conclusion on MWR parameters:

****

Weak impact on average compared to the V2.1+ verion of the wet tropospheric correction but significant reduction of noise and better relevance of the geophysical meaning inducing a significant variance reduction of the SLA as shown in part 3.2..

****

7.5. General conclusion on the parameters monitoring

Impact of	Reprocessed GDR vs old series
Range related parameters:	Very weak impact compared to the V2.1+ version of the GDR (including USO correction and PTR drift)
Waveform stability parameters:	Slighlty modified homogeneous time series evidencing slight drifts on the mispointing until cycle 65 with no visible impact on range data.
Sea State parameters:	Slighty changed time series due to SWH LUT applied, atmospheric attenuation improved and new estimation of the SSB based on the new baseline.
MWR parameters:	More relevant time series improving significantly the SLA performances.

Table 2: *I*mpact of the reprocessing on parameter monitoring

8. Conclusion

A statistical evaluation of Envisat whole mission reprocessing on altimetric measurements over ocean has been presented in this report. With more than nine years of data available. The Geophysical Data Record (GDR) products were reprocessed in a homogeneous standard and delivered to users after validation.
The new products are shown in this document to improve the high quality level of the Envisat altimetric mission which will make easier the data merging for multi-mission altimetry, an essential step for oceanography and applications.

To many point, these reprocessed data are better than the previous dataset:
- In terms of available and valid data, the coverage is better, notably thanks to a better availability of MWR at the beginning of the mission
- In terms of performance at cross-overs, the quality is also improved : the annual signal and average of Mean SSH is decreased, as well as the standard deviation. The gain was estimated to around $4.8cm^2$ with some maximums of $8cm^2$. This is very significant compared to the previous GDR data set!
- The new MWR characteristics were shown to improve largely the global quality of data. As well as the new tide model, the new MSS and the new orbit standard.
- The Global and regional Mean Sea Level trend is very weakly impacted though the effort was put, this time, on the mesoscale restitution, rather than long term drift, as during V2.1 reprocessing.

8.1. Status on the B-Side period

CalVal side B

- The S-band related data are still not set to DV from cycle 47 track 936 to cycle 48 track 846
  ➔ will be done before distribution to users.

- Parameters impacted by the L1b evolutions ➔ new Side A/ Side B biases

  - » Range
  - » Ionosphere correction
  - » Sigma 0
  - » Wind
  - » SLA, SSHA

CalVal side B

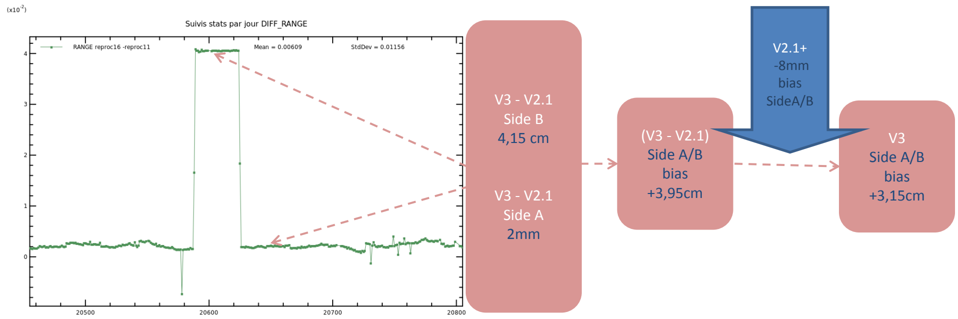
- The S-band related data are still not set to DV from cycle 47 track 936 to cycle 48 track 846
  ➔ will be done before distribution to users.

- Parameters impacted by the L1b evolutions ➔ new Side A/ Side B biaises

  - » Range
  - » Ionosphere correction
  - » Sigma 0
  - » Wind
  - » SLA, SSHA

New users' recommandations

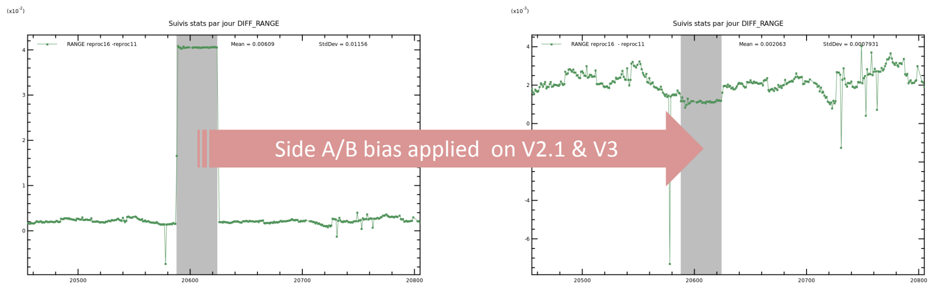
I. RANGE



I. RANGE

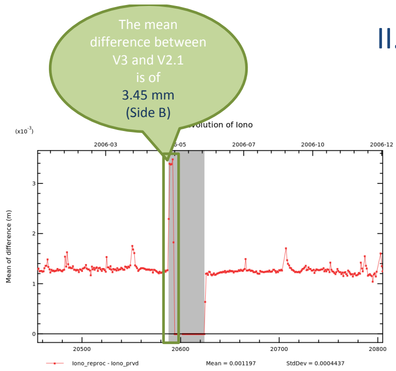
No Side A/B biases

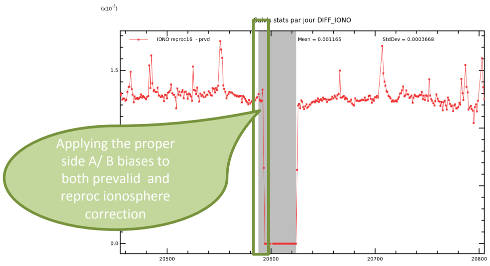
Side A/B biases



3.15 cm Side A/B bias confirmed by IsardSat ESL experts to be due to the difference between both altimeters.

II. IONO

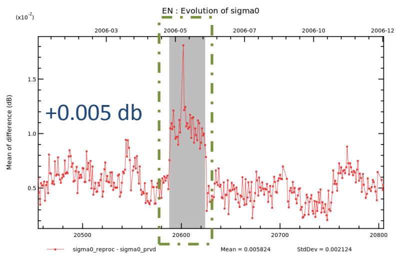


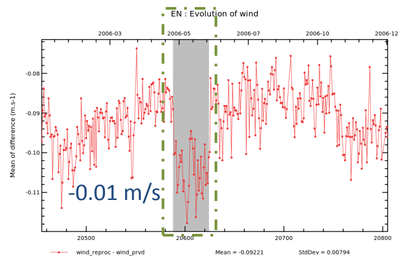


III. SIG0 and Wind

SigMa0

Wind



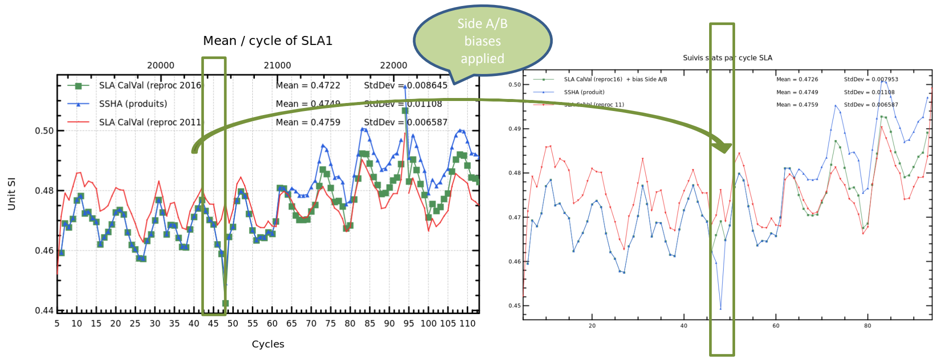


Marginal impact of side A/B biases

Negligible impact of side A/B biases

Page 6

V.SLA & SSHA



CalVal Side B

Side A/B biases on SLA parameters

	V2.1+	V3
Range	-8mm	+3.15 cm
Ionosphere correction	-0.3 mm	+1.85 mm
SLA	+8.3 mm	-3.33 cm

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