CalVal Envisat

Envisat RA2/MWR 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 V2.1 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).

For the first time this year, a whole mission reprocessing occurred for Envisat altimetric data set. During one year, all cycles from 9 to 92 (September 2010) were reprocessed into a homogeneous standard (so called V2.1 version) and added to the current production time series. Furthermore, cycles 6 to 9 were processed for the first time, though giving access to 3 additional month of data dated in 2002.

Before the beginning of the reprocessing, a first estimation of the V2.1 impact on one cycle was performed and distributed to users on the ftp://diss-na-fp.eo.esa.int in a document named: V2_1_reprocessing_impact_on_altimetric_parameters.pdf. A first calval pass had enabled to notice a major error in the USO computation which delayed the reprocessing beginning. Once that problem fixed, the GDR and SGDR reprocessing resumed and data were distributed, together with a Release Note and a Cyclic report giving information about the data availability and quality, at a rhythm of 2 cycles per weak during one year at the following address :
ftp://diss-nas-fp.eo.esa.int
under the directory : altimetry_dataset_v2.1.
The document presented here is a synthesis on the reprocessed data quality from GDR cycles 6 through 92 spanning heigh and a half years (from 14-05-2002 to 13-09-2010).

To see the global quality of V2.1 version data up to 112 spanning nine and a half years (from 14-05-2002 to 21-11-2011) please refer to the 2011 yearly report [14].
For further information about historical data, please refer to [13].

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

An additional part presents the **particular investigations** that have been performed. Notably:
- a study was carried on the behavior of the Wet tropospheric correction at high latitudes with the new data set.
- a particular point is also made on the new USO correction.
- a status on the SWH changes in the V2.1 reprocessed time series which describes and explains the new characteristics of this parameter.
- the table of Anomalies opened on the flow during the reprocessing is also enclosed to the

document. This table was reported weekly to the persons involved in the project.

2. Data used and processing

2.1. Data used

This document deals with the global impact of Envisat altimeter whole mission reprocessing. Yet, for any information concerning the historical data and impact of each standard update, please refer to the Envisat yearly reports.
Envisat Geophysical Data Records (GDRs) from cycle 6 to cycle 92 have been used to derive the results presented in this report.
This data set is issue from the whole reprocessing campaign that spread from January 2010 to January 2011.
All cycles from 9 to 92 were reprocessed into a standard (so called V2.1 version) homogeneous to the current production starting from cycle 92 (September 2010). Furthermore, cycles 6 to 9 were processed for the first time, though giving access to 3 additional month of data in 2002. This corresponds to nearly nine and a half-years spanning from May 14th 2002 to November 11th 2011.

2.2. Particular WARNINGS 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, users are advised to use the ionospheric correction from GIM model and to not use the rain flag.
- **No "S-Band anomaly" is present in the data anymore**: Users are yet advised that the S Band anomaly flag available in the GDR is erroneous and must not be accounted for anymore.
- **No more USO auxiliary files needed**: the USO correction is now directly/properly corrected in the range.
Yet, during the reprocessing, some erroneous jumps in the USO computation of some products were identified and are still under investigation on IPF side. The CMA correction, developed for expert support only, does not present such anomalies.
To avoid those erroneous jumps, users are advised to consider an appropriate editing of the data (see part 4.3.).
The number of tracks impacted are synthesized in the "Anomaly report" table in Annexe of this document.

Note that for cycle 47-48, the altimeter instrument was switched to B-side during 37 days, from 15/05/2006 14:21:50 to 21/06/2006 11:37:32 (cycle 47 pass 794 to cycle 48 pass 847).

2.3. GDR Standards

The Envisat GDR data are generated using two softwares: the IPF, from Level0 to Level1B, and the CMA, from Level1B to Level2.
Unlike the previsou GDR version which was inhomogeneous, the standard of the whole data is now the same: the so-called V2.1 version, resulting from **IPF 6.04.L2 Version and CMA 9.3 Version**. The associated standards are presented on Figure 1.

Cycles	9-64	65 onwards
Orbit	GDR-C	
Range	Monthly IF Mask + USO correction + PTR properly sampled	
DAC	MOG2D-HR	
Ionospheric correction	Dual-Frequency with GDR-B S-Band SSB	GIM+8mm
Dry tropo	ECMWF including S1-S2 atmospheric tides	
Wet tropo	MWR Neural algo corrected from side lobes + new characterization files	
SSB	Homogeneous to GDR-C (2007)	
Ocean Tides	FES 2004 or GOT00	

Figure 1: *GDR standards on the V2.1 reprocessed GDR series*

Note that another change has to be mentionned, concerning the GIM ionospheric correction. After the S-Band loss, the bifrequency ionospheric correction is not available anymore. Instead, the JPL GIM model can efficiently be used. To avoid any jump between both series, users are advised to correct the model from a 8mm bias estimated on the difference computed over cycle 64.
The GIM correction 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 enabled to improve the consistency at cross overs and to avoid jumps at daily transitions (see part performances).
This correction was computed off line by an external chain, changing also the data on the period covering cycles 85-92. It improved both GDR and CLS-updated data sets.

Also note that for cycles 85-92, the only thing that changed compared to the historical data set are:
- the GIM ionospheric correction (minor)
- and the USO computation included into the range (the first version of USO correction included into the range was not correct for these cycles).

2.4. Particular updates added to the GDR products

Thanks to the new homogeneous dataset provided by the V2.1 reprocessing the updates usually listed to describe the data set used in this report, no update was performed in this report.
The corrections are directly read from GDR products except for 3 terms:

- **GOT 4.7 ocean tide** is used instead of the FES 2004 available in the products. The impact is low on the metrics presented in this document but this correction was choosen for its slighlty better quality (demonstrated in Yearly report 2009 [12]).

- **Sea ice flag**: A method has been developed to detect data corrupted by sea ice (see 4.3.). This flag is more severe than the one available in the product and enables to be sure to get rid of any spurious data for validation purposes

- **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. This correction is applied up to the cycle 64, after that, it cannot be computed anymore, due to the S-Band Power drop (17th January 2008) the GIM ionospheric correction is then used.

3. Quality overview/Performances

3.1. Improving the GDR time series

Globally, the reprocessed data are improved in terms of availability (see Figure 2), homogeneity and performances (see Figure 3).

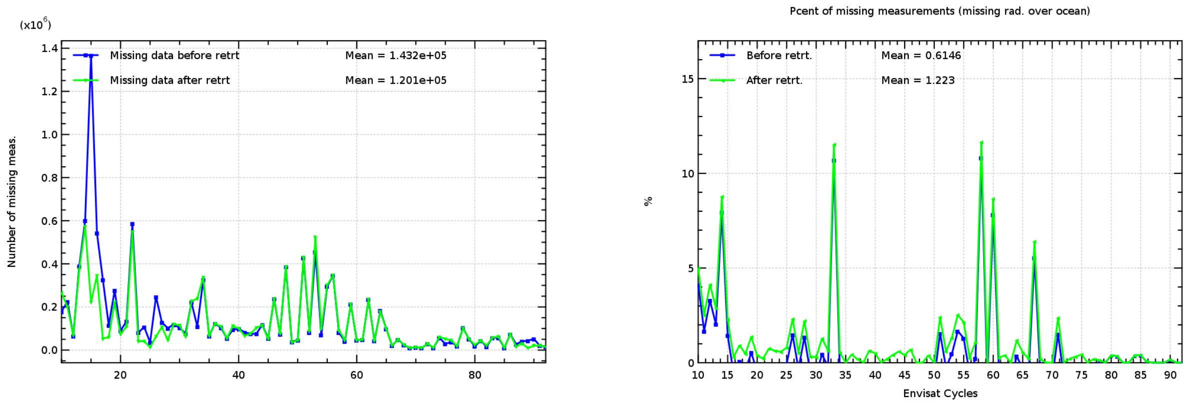

Figure 2: *Number of data available (left) and additional Radiometer missing over ocean (right) before reproc (blue), after reproc (green).*

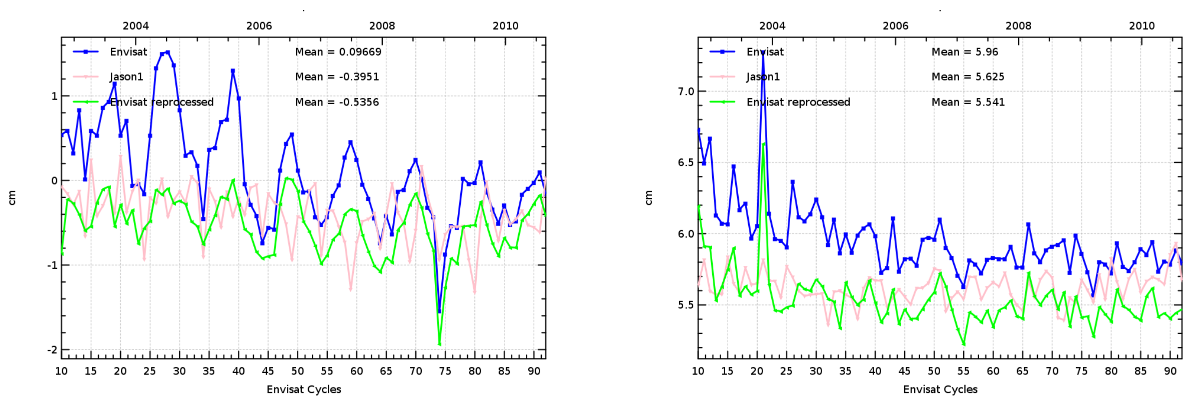

Figure 3: *Mean and Standard deviation of SSH difference at crossovers for Envisat before reproc (blue), after reproc (green) compared to Jason1 (pink).*

The mean SSH difference at crossovers has decreased a lot and the annual signal previously present has vanished almost totally, mainly due to the orbit standards.
The standard deviation SSH difference at crossovers has also decreased to slightly below Jason-1 value. The variance gain is around 4.8cm^2 when avoiding the high latitudes (lower than 50deg), low bathymetry (lower than 1000m) and high oceanic activity (higher than 20cm^2) (see Figure 4 left) with locally more than 8cm2 (as seen Figure 4 right).

Note that the minimum observed for cycle 74 is confirmed on reprocessed data. This was investigated and even if it was not totally explained, it is rather not due to any high latitude behavior (ice uncoverage for instance...).

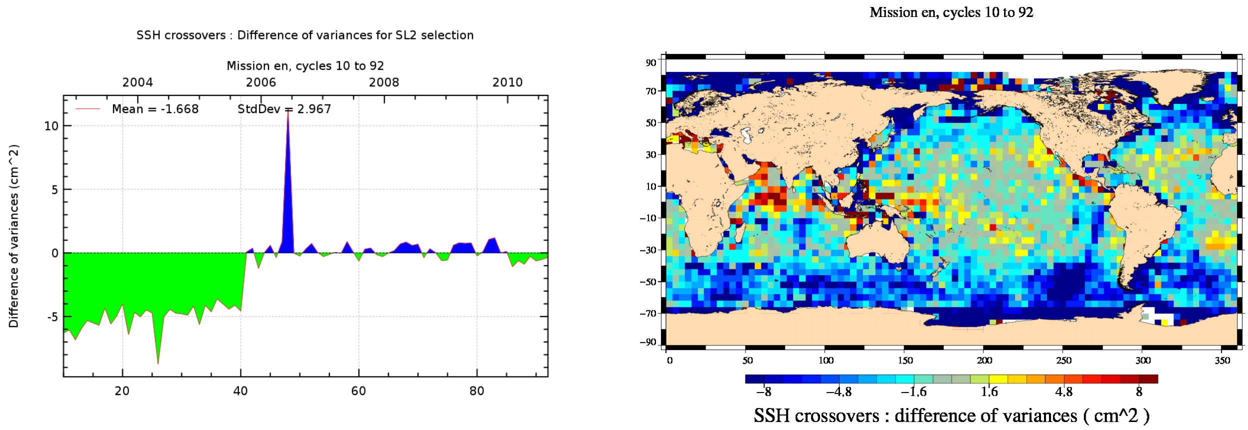

Figure 4: ***Left:*** *Variance difference of SSH at crossovers per cycle: SSH after/before reprocessing using raw GDR,* ***Right:*** *Map of this difference over cycles 6 to 92.*

Prior cycle 41 (Sept 2005), this improvement is mainly due to the orbit, geophysical parameters (notably Sea State Bias) homogenization. After cycle 85 the improvement is due to the USO correction implementation in IPF during V2 version and corrected in V2.1. In between, all data are also improved but the gain is hidden by 2 elements: it is degraded by the tropospheric correction and the SSB (using the new SWH).
Indeed, when replacing only the MWR before/after reprocessing in the SLA, the degradation observed is systematic, around 1,5cm2 (when avoiding the high latitudes, low bathymetry and high oceanic activity, as seen on Figure 5 left) with locally more than 5cm2 in very wet areas (as seen Figure 5 right). This is currently investigated by radiometer experts.

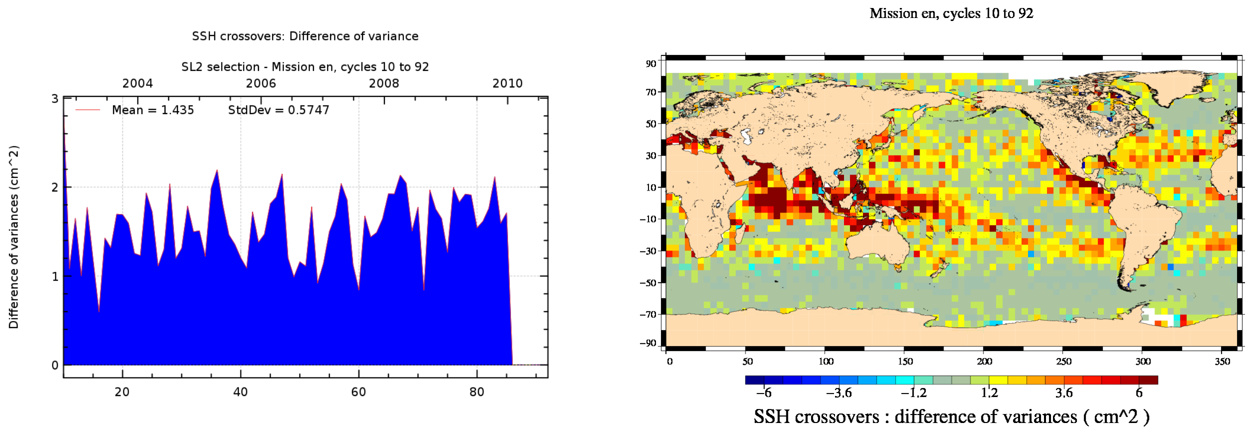

Figure 5: ***Left:*** *Variance difference of SSH at crossovers per cycle: SSH after reprocessing with MWR correction after/before reprocessing,* ***Right:*** *Map of this difference over cycles 6 to 92.*

Furthermore, with the change of sigmap, used for the computation of SWH, the change of Sea State Bias also had locally an impact on the variance gain at crossovers, as seen on Figure 6. This

mainly concerns low waves areas, as already mentionned (see Annexe 9.2.). The global impact is however weak (minor degradation of 0.1cm^2, all SWH mixed up but reaching more than 1cm^2 localy).
This is due to the fact that the SSB model used (Labroue 2007) was not tuned with reprocessed SSH values. Because SSB exercise is necessary an iterative operation, this is not worrying and this should be solved by new SSB model planned for 2012 (using the new reprocessed standards).

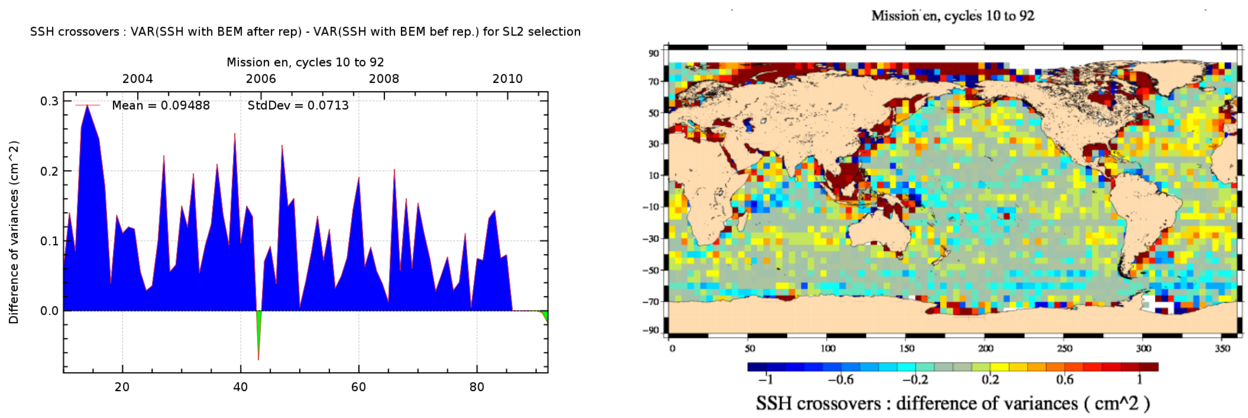

Figure 6: ***Left:*** *Variance difference of SSH at crossovers per cycle: SSH after-before reprocessing with SSB correction after-before reprocessing,* ***Right:*** *Map of this difference over cycles 6 to 92.*

Finally, impact of the ionospheric correction updated is sensible on long term stability (see part 5.1.3.) but negligible concerning the performences.

Conclusion, the reprocessed dataset is very much improved compared to the original GDR time series.
Yet, the remaining issues are well identified: they concern the radiometer wet tropospheric content (understood on radiometer expert side. A new version will soon be available to users) and the SSB, because of its iterative processing and it should be solved by new SSB model already planned for 2012 (using the new reprocessed standards).

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 are globally more available than the historical data set: see Figure 2 in part 3.1.. 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 coverage status and the Investigation requests (FA) is explained in a document SALP-RP-MA-OP-022027-CLS [16].

Note that the pass segments were regularly missing on historical data are still missing at the same place. Figure 7 shows the pass segments missing more than 20 times over the whole reprocessing period. Some of them are explained (PLO permanent acquisition sites (ESA/Rome, GAVDOS/Creta), others are not.

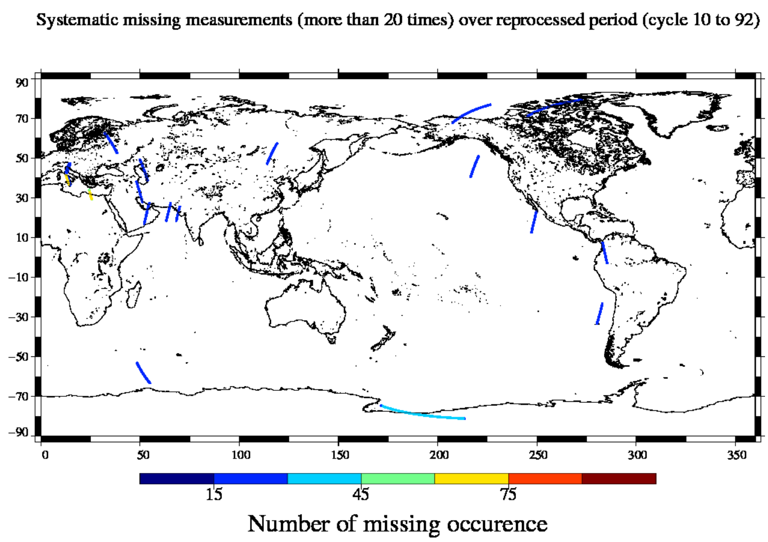

Figure 7: *Pass segments unavailable more than 20 times over the whole reprocessing period. The color indicates the occurrence of unavailability*

4.2. Additional missing MWR data

The Envisat MWR exhibits nearly 100% (Dedieu et al., 2005) of availability since the beginning of the mission. However, MWR corrections can be missing in the GDRs due to data generation problems at ground segment level. It is still true for reprocessed data. Some anomalies at Level 0 or 1b were raised during the reprocessing.

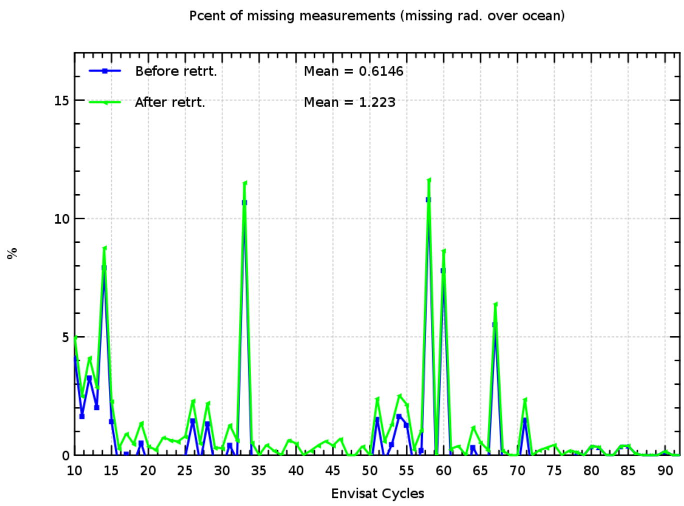

Figure 8: *Percentage of data edited because of a lack of radiometer, before reproc (blue), after reproc (green).*

4.3. Edited measurements

Data editing is necessary to remove altimeter measurements having lower accuracy. It consists in:
- First: removing of data corrupted by sea ice, ice, rain.
- Then, removing measurements out of thresholds tuned for several parameters.
- 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 [14].

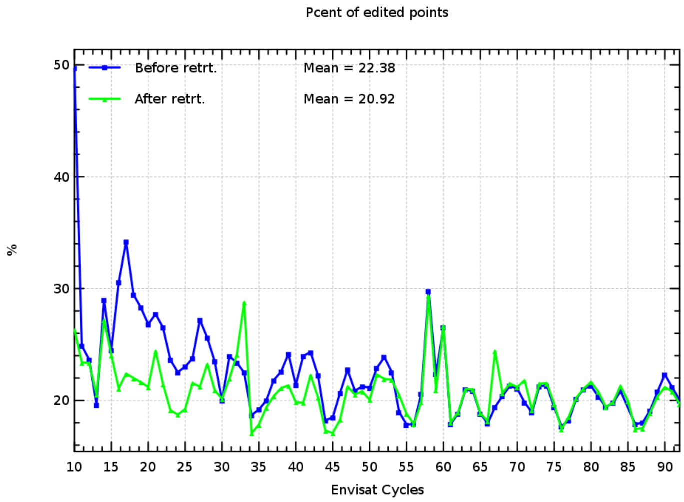

Figure 9: *Percentage of spurious data following the Calval editing criteria, before reproc (blue), after reproc (green).*

4.3.1. Anomalies identified in GDR flag content

One of the first step of the editing procedure consists in removing spurious data identified as such by some flags included in Envisat GDR products.
But, during the reprocessing some anomalies were identified concerning some of them. Users are advised to use them with care:
- IDEAS-PR-11-05519: the S Band anomaly flag available in the GDR must not be accounted for to remove the data. This flag only indicates when the anomaly occures (flag set to 1) in the Level 0 data. A processing is now applied at Level 1b and enables to recover the data at Level 2. Therefore data do not need to be discarded anymore.
- IDEAS-PR-1105519 : the rain flag was unrelevant for Lat ¡ 50deg South from cycle 10 to 25 when this was solved on CMA side. See Release Note of cycle 10.
- SALP-FT-8115 IDEAS-PR-11-05540: the USO correction is associated with a 3 state flag to identify the areas where this correction was badly computed. Yet, this flag seems to be unrelevant and must not be account for. See annexe 9.3..

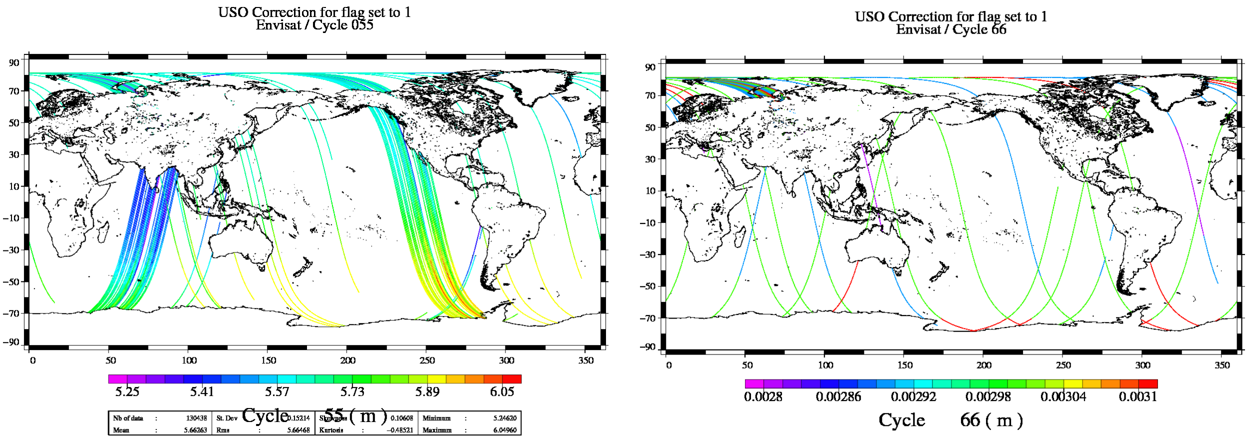

Figure 10: *USO Flag abnormally set to 1 for cycle 55 and 66.*

4.3.2. Threshold editing stability

Then, come the step of removing measurements out of thresholds for each parameters (the values are detailed in the Yearly report [14]). We only focus here on the difference before/after the reprocessing.

The thresholds editing is much stabilized for most parameters thanks to the now homogeneous time series, the editing concerning the different thresholds has been plotted in Figure 11.
For almost all the plots, Cycle 6 presents high values of edited percentage. This is probably due to tests performed during the commisionning phase but poorly documented. The small amount of available data (only 242 passes produced over 1002) has also an effect on the value represented in percentage. Similarly, cycles 95 and 96 have few data (orbit change maneuvers). This metric is not really relevant for these cycles. For cycles between 86 and 93, most parameters were also out of thresholds because of an USO implementation problem into the range (in V2 version).
Number of elementary measurements: it is stabilized at the level previously reached at cycle 54 (for an unknwomn reason) has a surprisingly low ratio compared to other missions except for cycles 14 and 20 when wrong configuration files were uploaded on-board after a RA-2 event.
Square of the off-nadir angle (derived from waveforms): it is now much more stable than the previous time series, impacted by 2 jumps due to inhomogeneous waveform filtering management.
Dual frequency ionospheric out of threshold: the ratio shows a very slight increasing trend from cycles 15 to 65 until the S-Band drop (on A-Side cycle 65 and during cycle 47-48 on B-Side configuration). Note that the drift is much reduced compared to the previous series (probably in relation with the PTR Time delay Calibration Factor resolution change in S-Band and Ku band).
Ku-band SWH out of threshold: this ratio is much more stable than the previous time series, impacted by a jump around cycle 54. It is though slightly higher than for historical data because the null SWH class now includes more data.
Ku-band Sigma0 out of threshold: this ratio is also much more stable than the previous time series, also impacted by a jump around cycle 54.
Concerning MWR ratios, it presents a significant annual signal whereas it was only present from cycle 41 onwards before. This signal was investigated and shown to be due to a residual annual signal in the ice coverage of Artic shelf. It is developed in part 9.1..

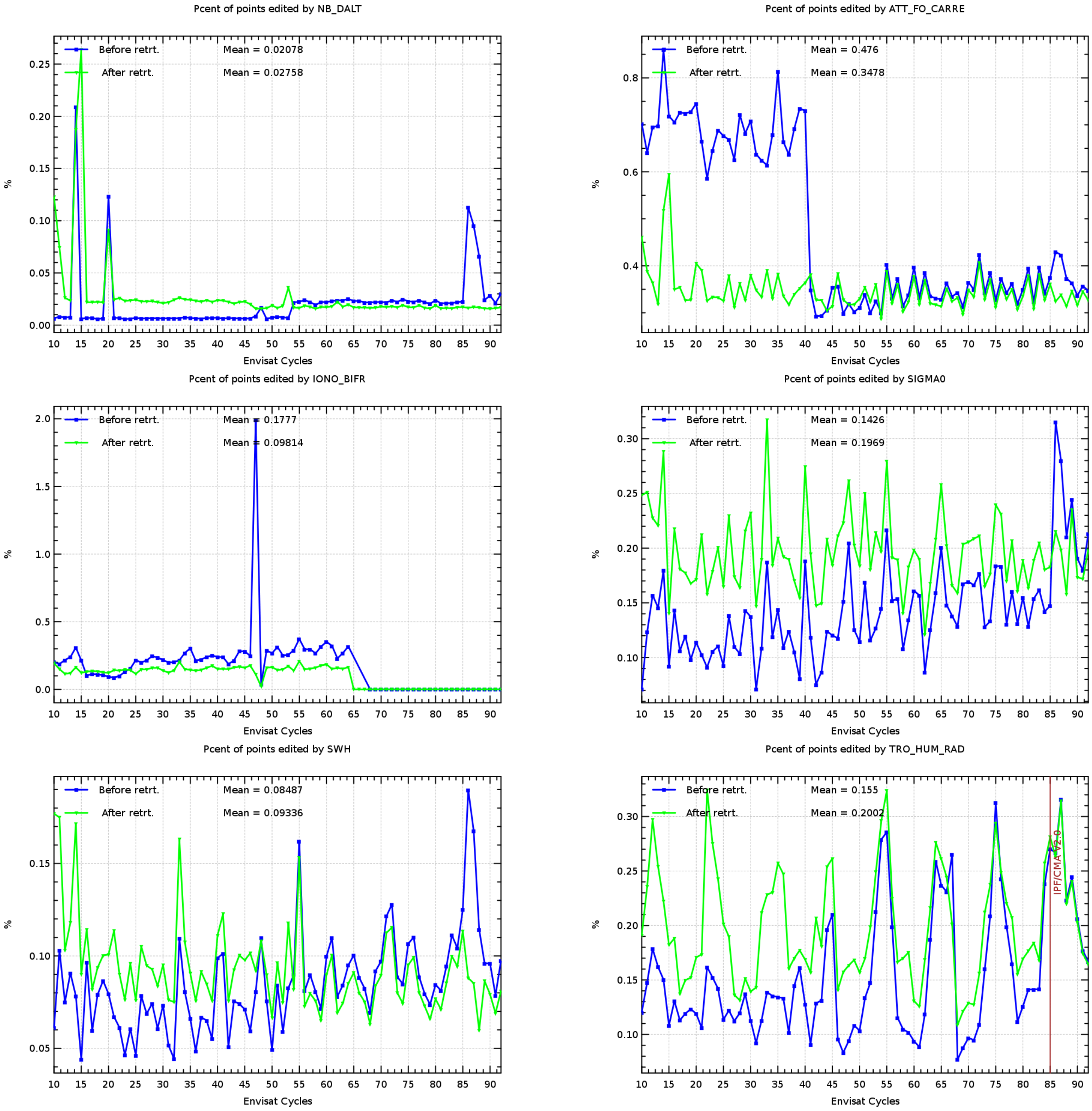

Figure 11: *Cycle per cycle percentages of edited measurements by the main Envisat altimeter and radiometer parameters:* ***Top-Left)*** *Number of 20-Hz range measurements < 10,* ***Top-Right)*** *Square of off-nadir angle (from waveforms) out of the [-0.2 deg2, 0.16 deg2] range,* ***Middle-Left)*** *Ku band backscatter coefficient out of the [7 dB, 30 dB] range,* ***Middle-Right)*** *Ku-band Significant wave height outside > 11 m,* ***Bot-Left)*** *Dual frequency ionosphere correction out of [-40 , 4 cm],* ***Bot-Right)*** *MWR wet troposphere correction out of the [-50 cm, -0.1 cm] range.*

4.3.3. Editing on SLA and USO computation problem

The last step of editing is applied on the SLA (SSH-MSS) differences in order to remove remaining spurious data. The details of these thresholds are developed in the Yearly report [14]. As seen on Figure 12, the results are globally similar for reprocessed and historical data except for one point concerning problems identified in the USO computation.

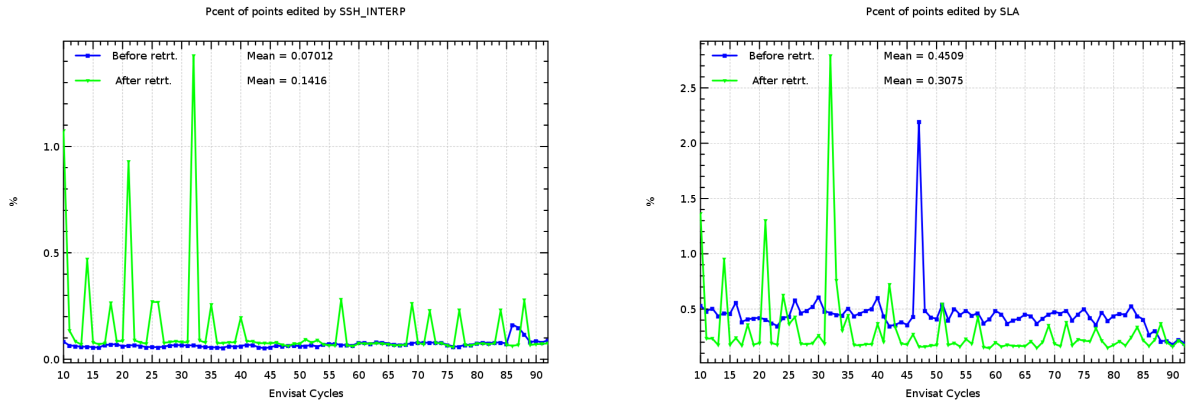

Figure 12: *SSH-MSS out of the [-2, 2m] and edited using thresholds on the mean and standard deviation of SSH-MSS on each pass*

Indeed, several problems were identified during the reprocessing concerning the computation of the USO correction. These anomalies directly impact the range and sign on the SSH. The anomalies were listed under the following PR numbers:
- SALP-FT-8058 or IDEAS-PR-11-5535: USO uncorrecting for heating periods (see cycles 20,21, 26 and 27, ex Figure 13)
- SALP-FT-8180 or IDEAS-PR-11-05569: Unstable USO correction at the beginning of anomaly period
- IDEAS-PR-11-05520: jumps of several meters (ex Figure 14).

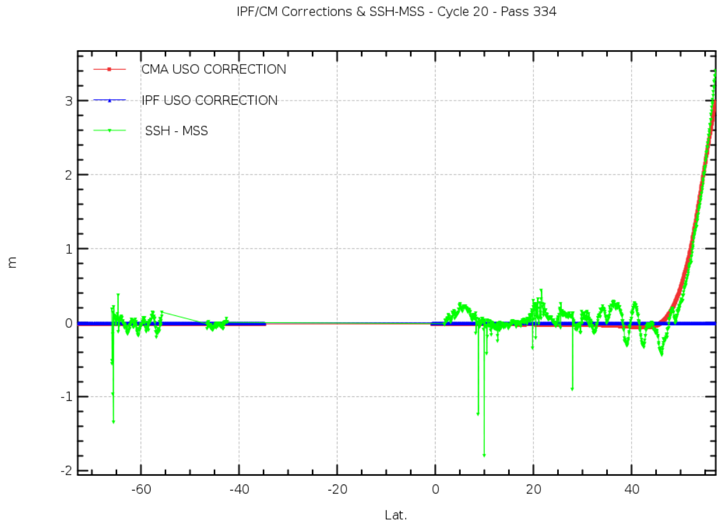

Figure 13: *Heating period badly taken into account by the IPF USO correction (ex cycle 20, pass 334).*

The two first problems come from the way USO is filtered during non anomaly period, fixing one value per track, which is sometimes not adapted to transition periods.
For instance, on cycle 56 an USO anomaly recovery, occurred at the beginning of cycle and impacted the SSH statistic editing per pass. The behavior of the Ultra Stable Oscillator (USO) clock frequency on this cycle is chaotic. The transitions between anomaly and normal mode has been very straight and the USO correction does not allow us to well correct some passes.

The third one (jumps noticed on reprocessed USO correction of several hundreds of meters), on the contrary, comes from an implementation problem and the anomaly could not be reproduced (nor investigated) with the IPF prototype.
Note that the correction developed for expertise purpose in CMA is not affected by these problems. A particular study was carried to compare those corrections on a MSL point of view. Yet the impact on data availabililty is rather weak: on the whole mission, around 300 tracks, were impacted by this anomaly (including around 200 only before cycle 10) ex Figure 14.

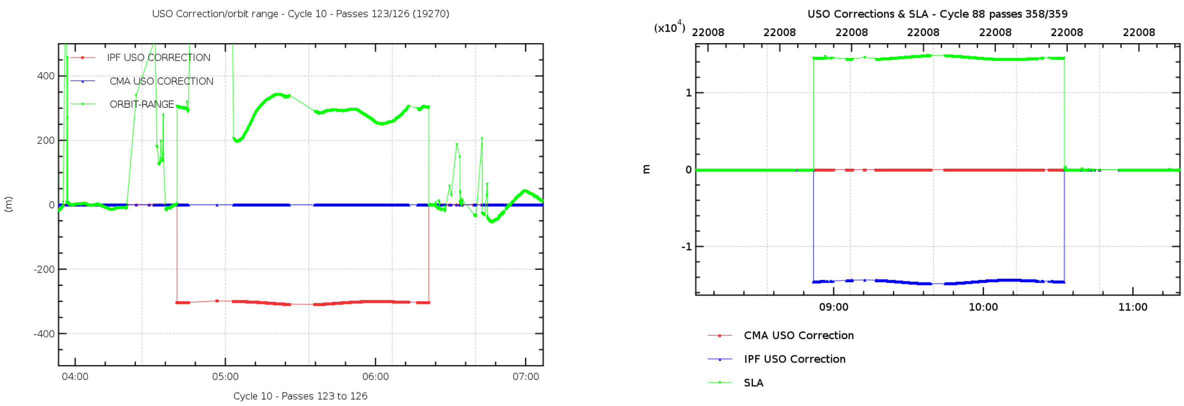

Figure 14: *USO jumps of the IPF USO correction with a direct impact on the SLA (ex left cycle 10, passes 123 to 126, right cycle 88 passes 358-359).*

4.3.4. Conclusion

Monitoring the number of spurious data enabled to have a first idea of the data availability. It also enables to rise some anomalies and to inform the users about particular behavior to take into account prior to any geophysical interpretation.

5. 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.

5.1. Range related parameters

5.1.1. 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 15. 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 (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. The drift previously hidden by a lack of resolution appears clearly now on both corrections (see Figure 15 bottom) but not on the difference (see Figure 16).

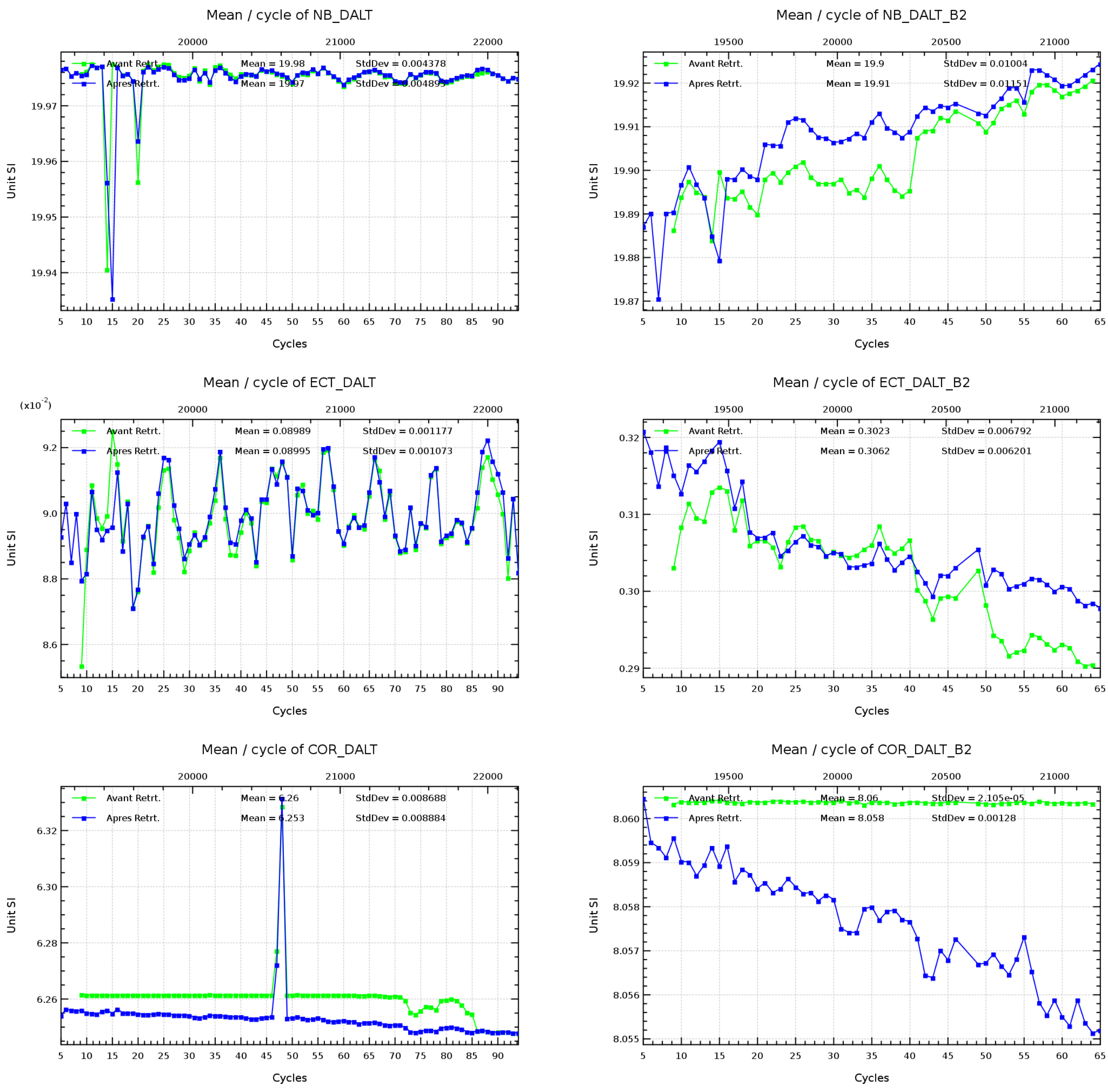

Figure 15: ***top**) Mean per cycle of the number of 20 Hz elementary range measurements used to compute 1 Hz range. **middle**) Mean per cycle of the standard deviation of 20 Hz measurements.**middle**) Mean per cycle of the sum of instrumental corrections including PTR drift. **left hand plots**: Ku band, **right hand plots**: S band*

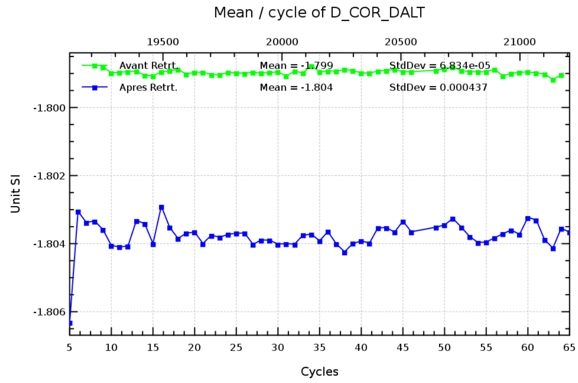

Figure 16: *Mean of difference per cycle of the sum of instrumental corrections including PTR drift (Ku-S).*

5.1.2. 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):

$$Iono(Ku) = 0.059 \; (\; Range(Ku) \; \text{-}Range(S) \;)$$

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 17. Further explanations of the signal observed is detailed in the yearly report.
The impact is null on the standard deviation per cycle (not shown here), and hardly seen on the ionospheric correction itself 17 (left). An impact appears on the comparison to the GIM model (right) from cycle 41 onwards, likely due to a jump on GIM time series due to a solar activity coefficient update.
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 [55]).

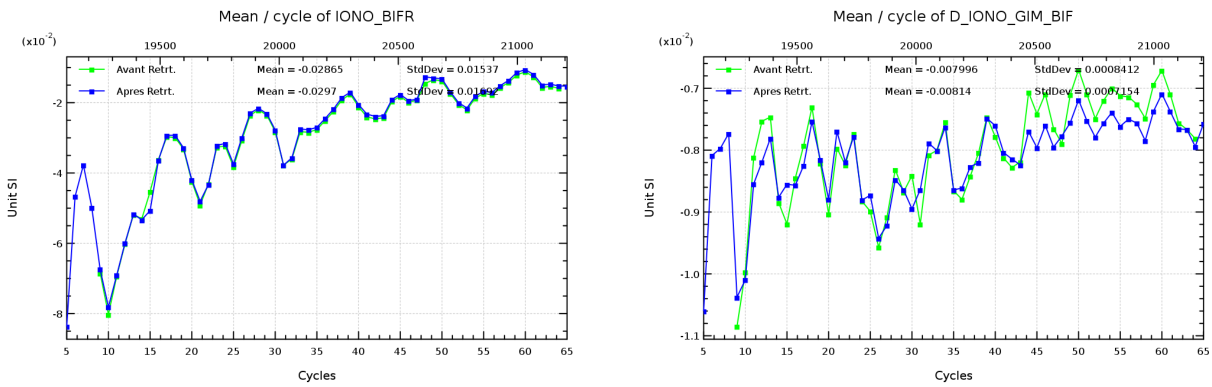

Figure 17: *Comparison of global statistics of Envisat dual-frequency and JPL-GIM ionosphere corrections (cm).* ***left****) Mean per cycle of Dual Frequency.* ***bot****) Mean of the differences versus GIM correction for Envisat*

5.1.3. 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. 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.

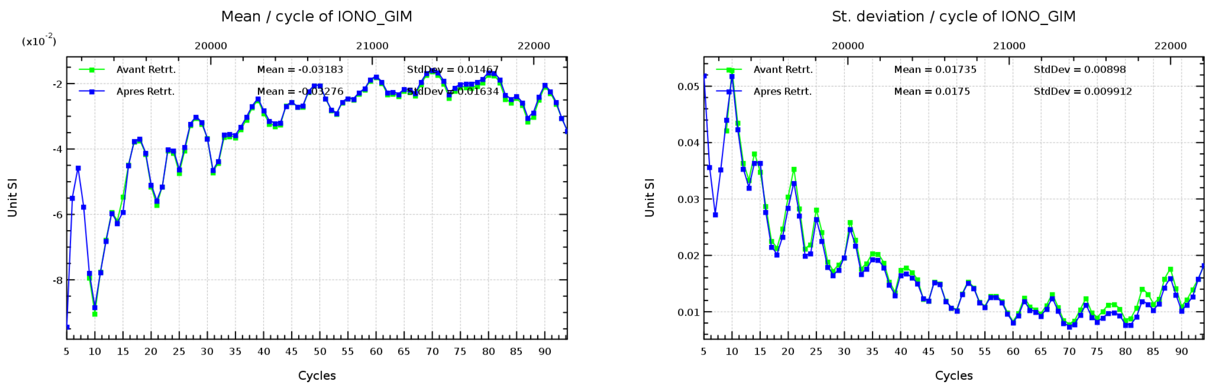

Figure 18: *Mean (left) and Std (right) per cycle of the JPL GIM ionospheric correction (m), the only one available after 2008 on Envisat because of the S-Band loss.*

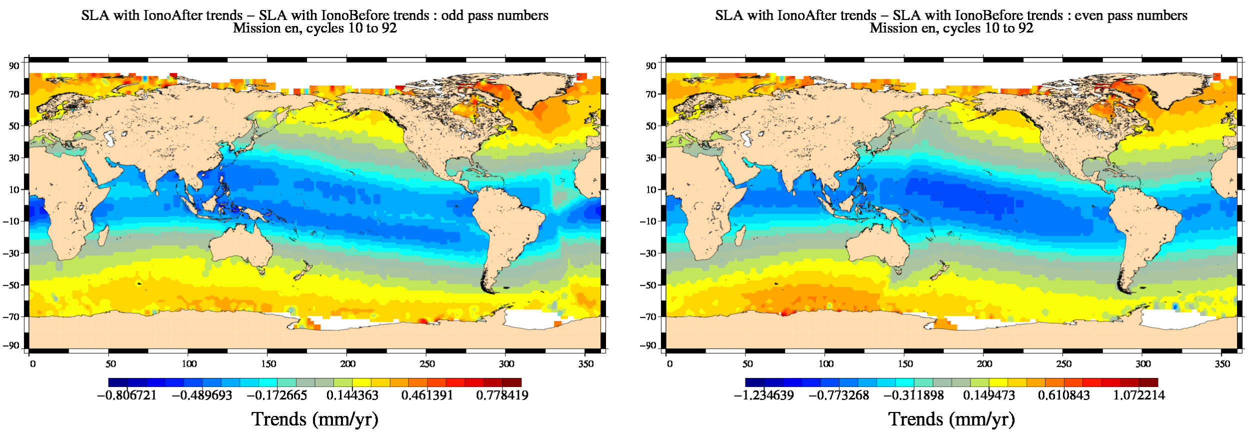

Figure 19: *Ascending (left) and Descending (right) Mean Sea Level trend difference between JPL GIM ionospheric correction before/after reprocessing(m). A small impact is observed at the days transition due to the method of estimation used.*

5.1.4. Conclusion on Range related parameters:

****

More homogeneous time series 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).

****

5.2. Waveform stability parameters

5.2.1. 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 20.
Before reprocessing, jumps are observed, due to an upgrade of the IF mask auxiliary data file (cycle 21/22) followed by a more regular update (every cycle since cycle 41). On cycle 41 the mispointing estimation was also improved (details in the 2010 yearly report). Note as well that a smaller value is noticed for the cycle 48, for which altimeter was turned to its B-Side for a short period.
After reprocessing, the mean value presents a slight decreasing trend up to cycle 65 around a value of 0.005 deg2.

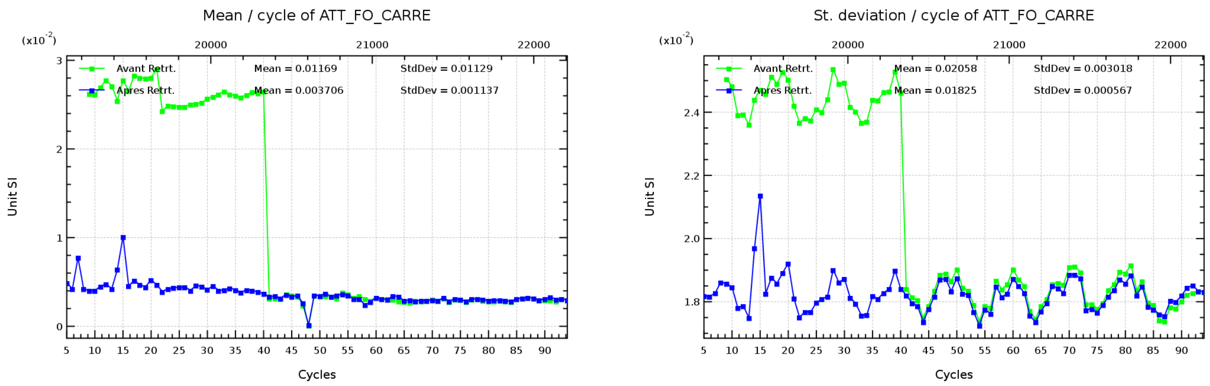

Figure 20: *Mean (left) and Std (right) per cycle of the square of the off-nadir angle deduced from waveforms (deg^2).*

5.2.2. Waveforms Peakiness

Like the mispointing, the peakiness is significant of the waveform stability. The plot 21 indicates changes of behaviors before reprocessing but removed on the reprocessed series.

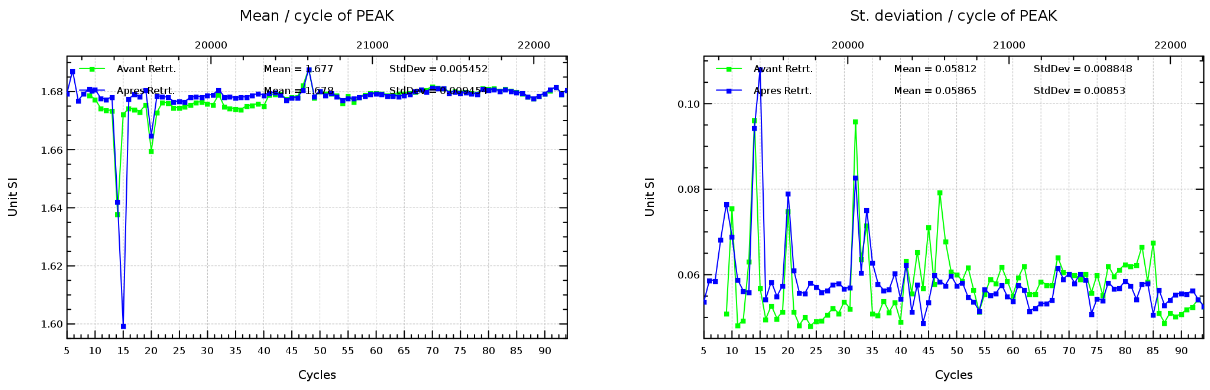

Figure 21: *Mean (left) and Std (right) per cycle of the waveforms peakiness (deg^2).*

5.2.3. Conclusion on Waveform stability parameters:

****

More homogeneous time series evidencing slight drifts on the mispointing until cycle 65.

****

5.3. Sea State parameters

5.3.1. Significant Wave Height

The cycle by cycle mean and standard deviation of Ku and S-Band SWH are plotted in figure 22. Its monitoring reflects sea state variations (with a clear annual signal). The mean value of Ku SWH is lower for the reprocessed data (2.5m instead of 2.63m). The S-Band mean SWH is drifting and rather lower than before reprocessing and from Ku-Band (around 2m instead of 2.6m). These differences are due to a change in IPF 6.2 version (and therefore in V2.1 GDR version) on Envisat side (change of Sigmap value). A study was performed on the SWH to understand the behavior of small waves, considered, by some users as degraded (see 9.2.).

As for range parameters, some strange behaviors on S-Band SWH are also noticed (see Figure 22): drifts on the standard deviation and mean value after reprocessing widely different from the Ku-Band one's.

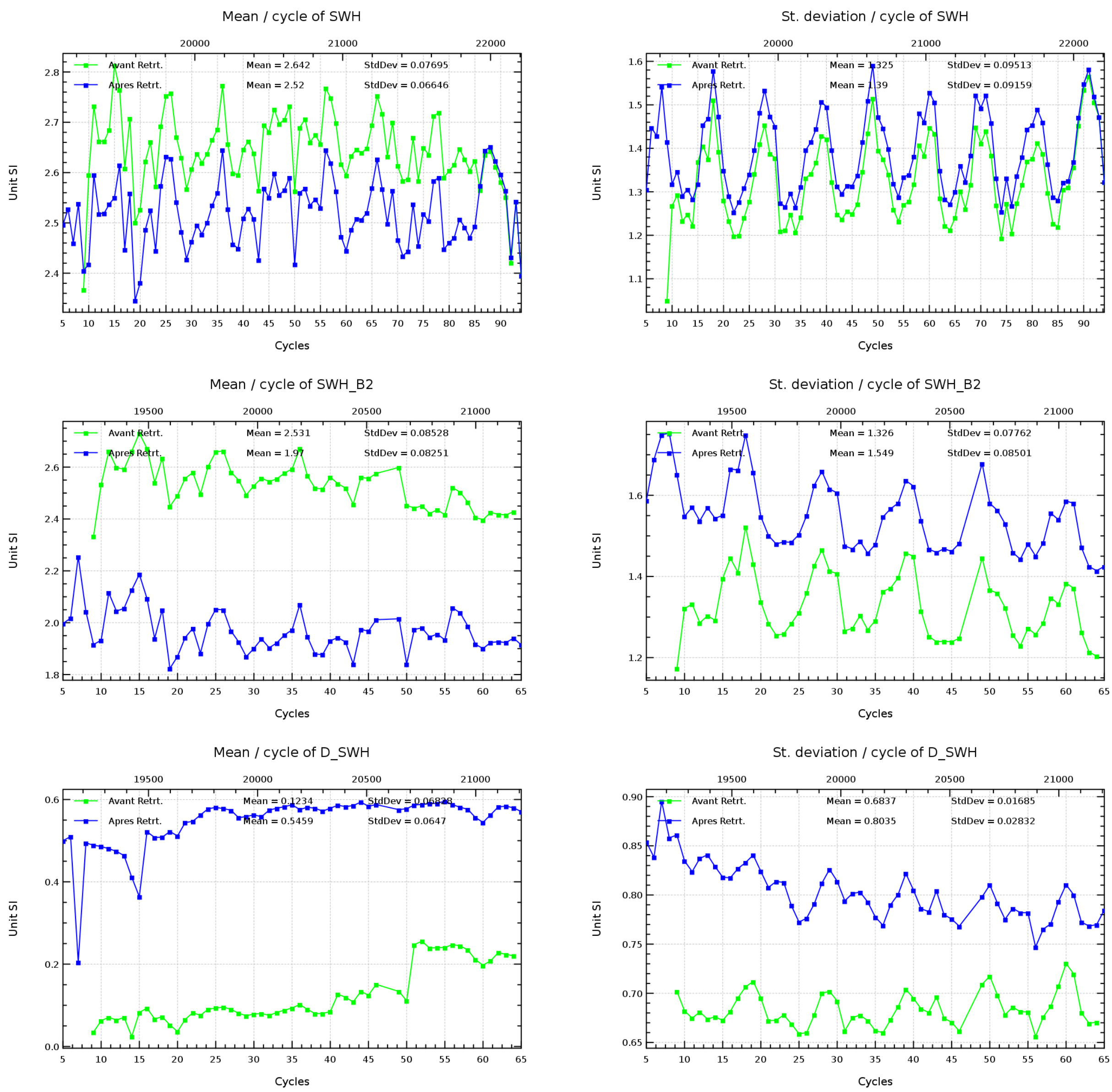

Figure 22: *Global statistics (m) of Envisat Ku and S SWH Mean and Standard deviation.*

5.3.2. 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 23).
The differences on Sigma0 essentially come from the atmospheric attenuation it is corrected from (illustrated on Figure 24). This term, impacted by new MWR coefficients has 3 modes: before cycle 15 where the value is lower (in Ku and S-Band), between 15 and 65 where a slight increasing drift is observed, and afterwards.

The impact of reprocessing on the wind (derived from Sigma0) is shown on Figure 25 were the homogenization of Jansen wind model (previously after cycle 41) is clear. A potential remaining

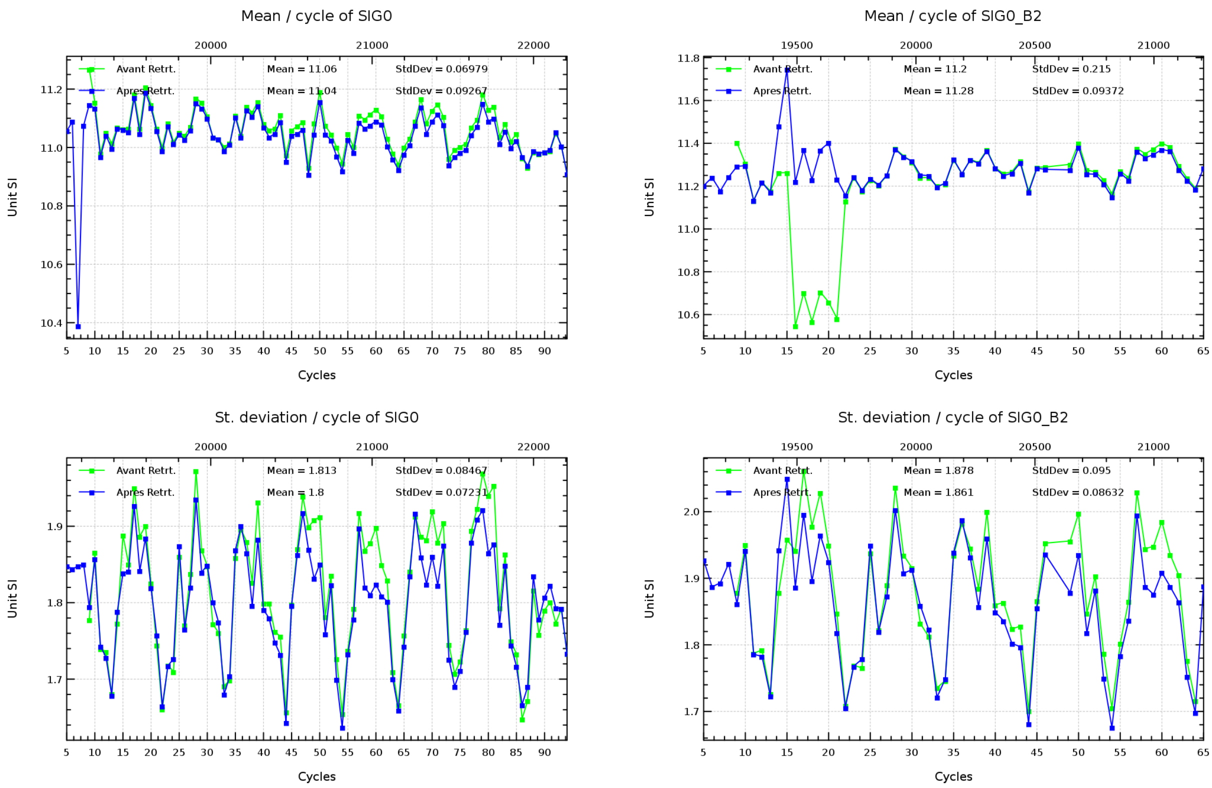

Figure 23: *Global statistics (dB) of Envisat Ku and S Sigma0 (dB) Mean and Standard deviation.*

trend, though slight, has to be closely monitored but could have physical origins. The global stability of this parameter was studied in Ablain et al. 2012 submitted in Marine Geodesy (see [5]).

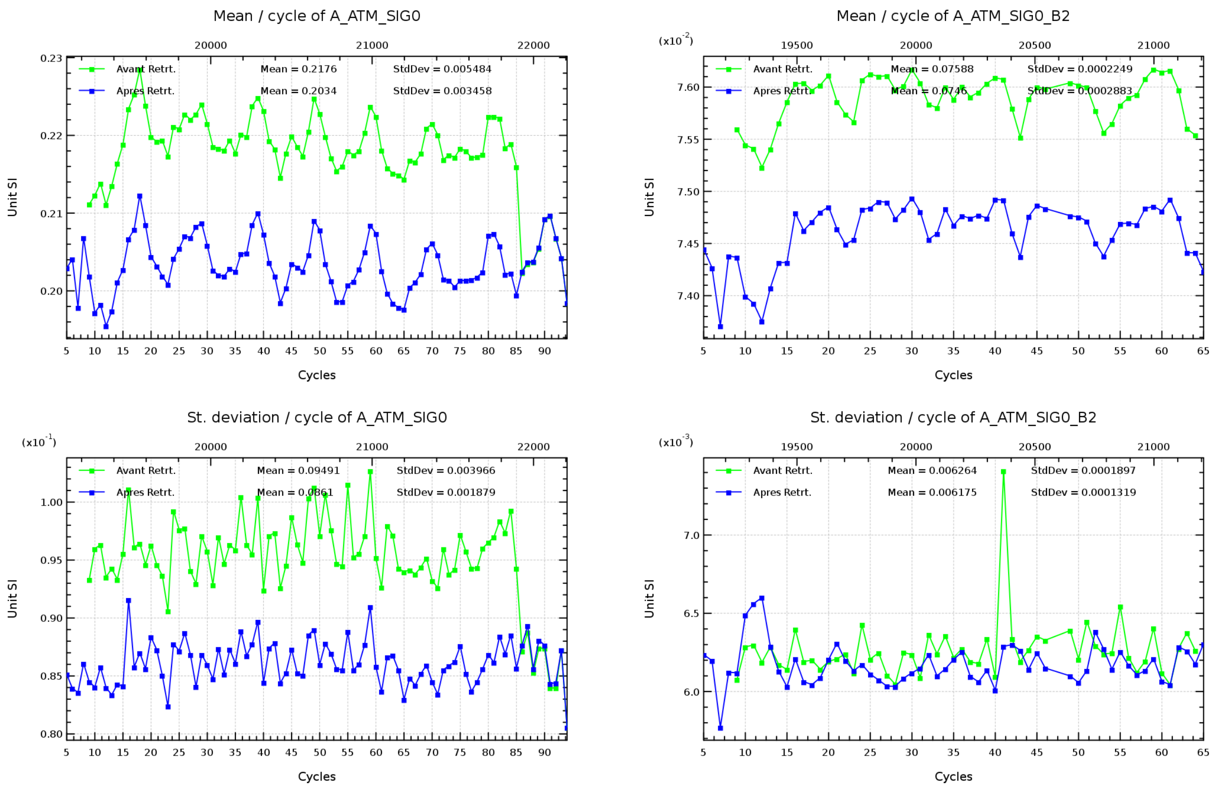

Figure 24: *Global statistics of Envisat Ku and S Sigma0 atmospheric attenuation (dB) Mean and Standard deviation.*

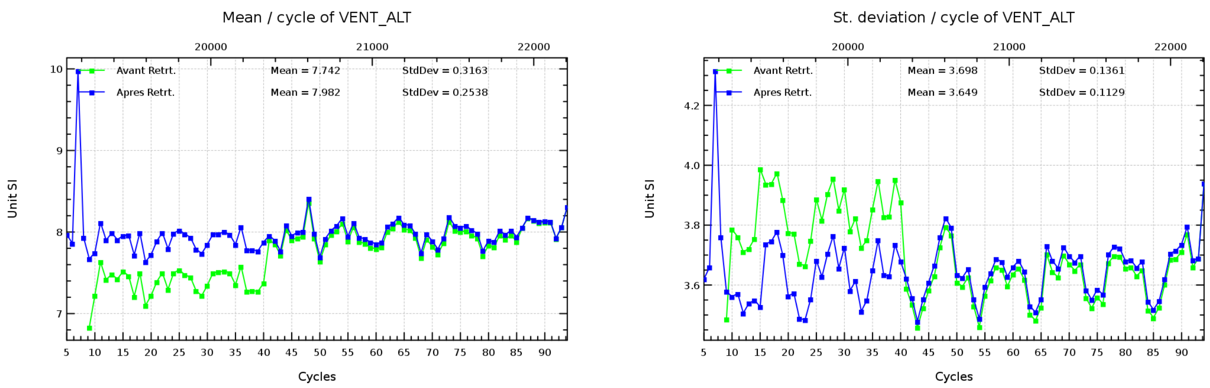

Figure 25: *Global statistics of Envisat Ku and S Wind (m/s) Mean and Standard deviation.*

5.3.3. 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 26 were the homogenization of Labroue 2007 model is observed (previously 3 different models were in the GDR before cycle 41, between 41 and 85 and afterwards).

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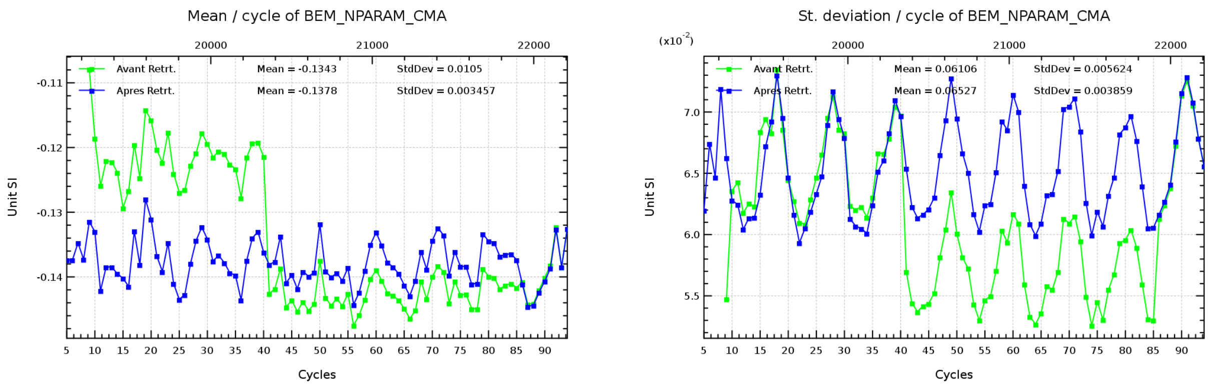

Figure 26: *Global statistics (m) of Envisat Ku Sea State Bias Mean and Standard deviation.*

5.3.4. Conclusion on Sea State parameters:

****

More homogeneous time series. Lower SWH average (by around 13cm Ku band and 60cm in S band) and higher dispersion (standard Deviation in Ku and S Band) due to the change of Sigmap in the SWH computation step. 3 states atmospheric attenuation behavior apart from cycles 15 and 65 with a very weak impact on Sigma0 and wind.

****

5.4. MWR wet troposphere correction

Mean and standard deviation of Radiometric wet tropospheric correction for Envisat is plotted in figure 27 (top). It is also completed by (MWR-ECMWF model) monitoring, enlightening finer jumps and discrepancies in figure 27 (bottom). This difference is not really stable on both before and after reprocessing series. An annual signal of about 1.5mm of amplitude can be seen on the reprocessed data (and only after cycle 41 before reprocessing). This is probably due to the Side Lobe correction now applied on the whole time series. The effect of this upgrade is also significant on the low class of wet tropospheric correction.

The standard deviation is also very variable throughout the mission. It drops down by 2 mm from cycle 13, decreases afterwards linearly from cycles 14 to 41 and adopts a chaotic behavior until cycle 62 where it stabilizes around 1.8 cm. This decrease coincidates with another change of model but because MWR seems to undergo a bigger jump than ECMWF series (probably in relation with the ECMWF change of version 6/11/2007).
Note that in the version V2.1 this metric globally increased (see part 3.1.).

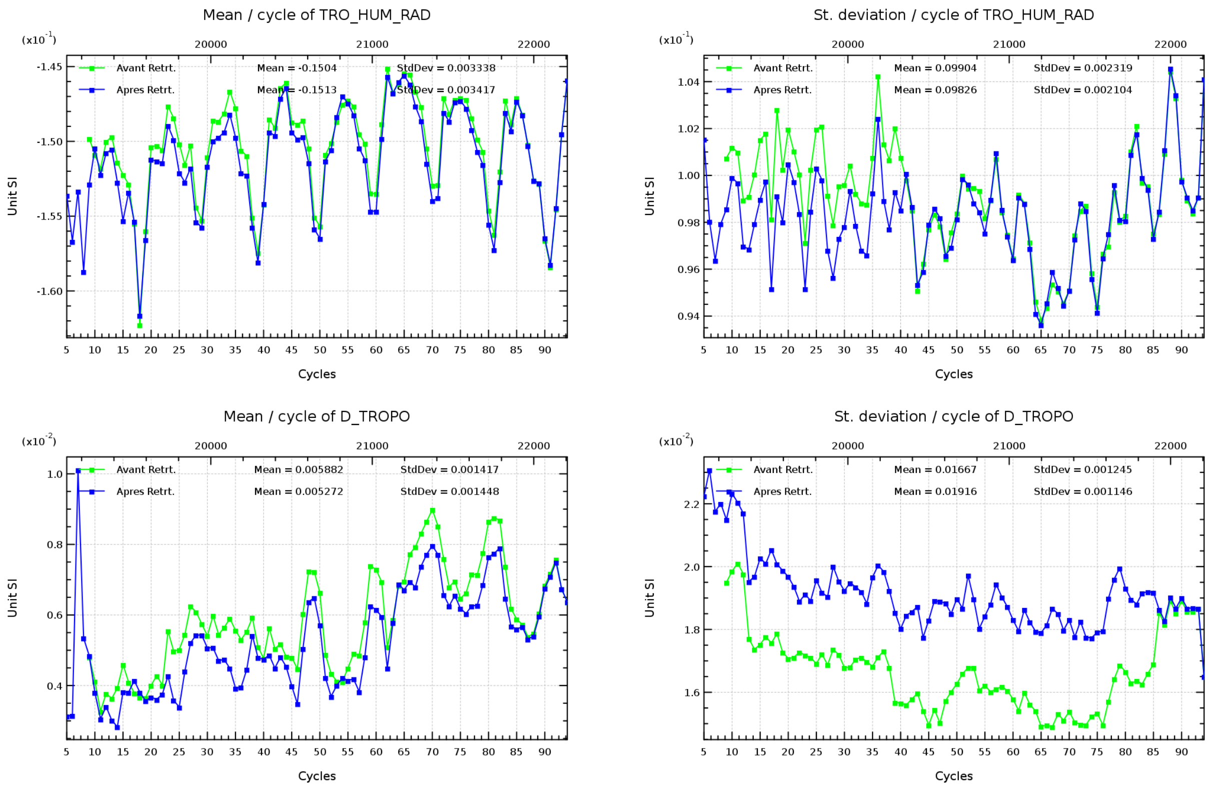

Figure 27: *Comparison of global statistics of Envisat MWR and ECMWF wet troposphere corrections (cm).* ***top****) Mean and standard deviation per cycle of MWR corrections* ***bot****) Mean and standard deviation of the differences versus ECMWF model.*

The latest 2 plots are completed by monitorings for 3 separated class of values: wet tropospheric content lower than 10cm correction (top), medium wet tropospheric content between 10 and 20cm correction (middle), wet tropospheric content higher than 20cm correction (bottom).

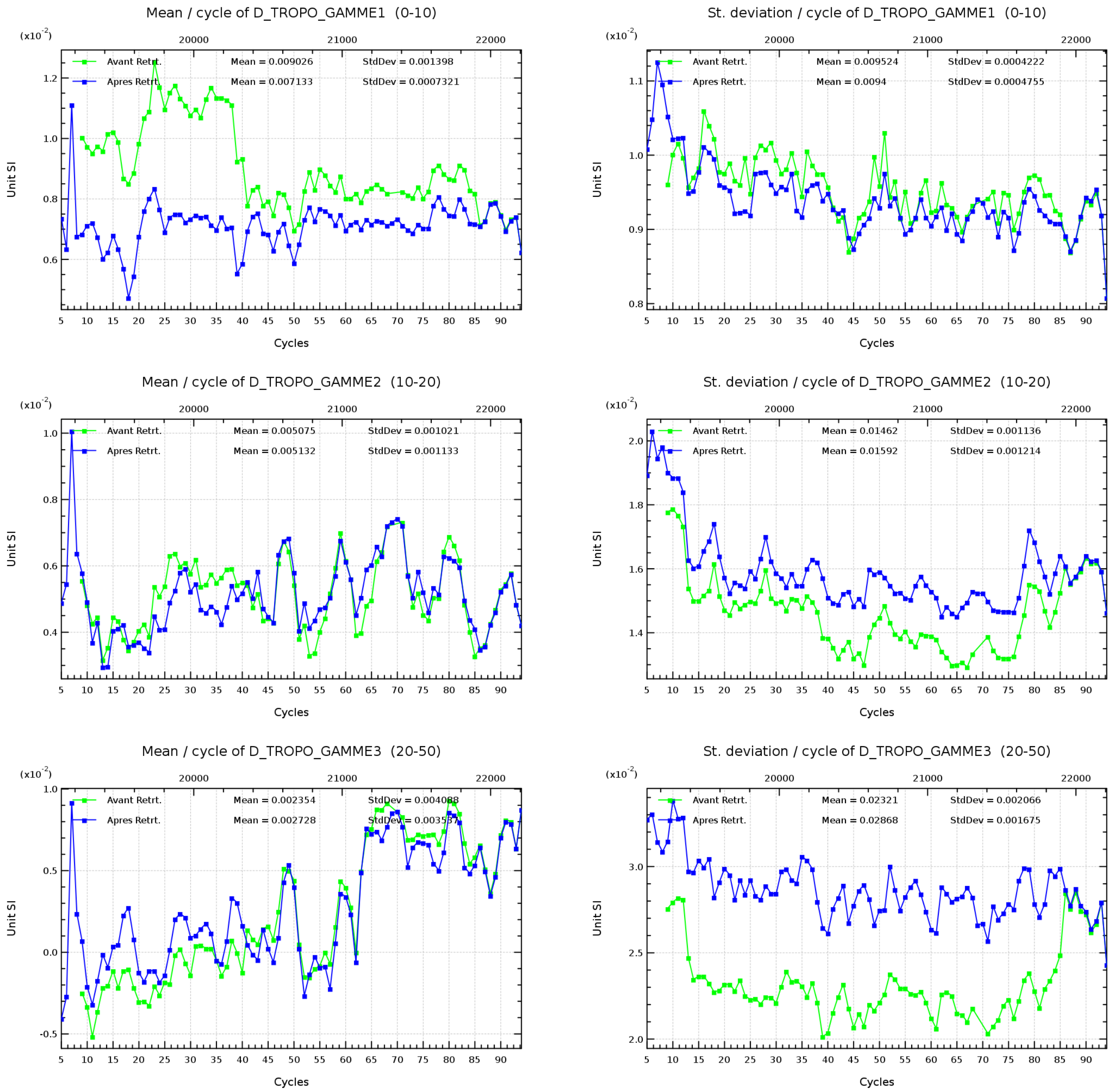

Figure 28: *Mean and standard deviation of the differences versus ECMWF model. Low (top), Medium (middle), High (bottom) wet tropo.*

Geographically, the impact of the change of tropospheric correction can also be illustrated by the plots 29, highlighting that the changes mainly impact the high tropospheric content areas.

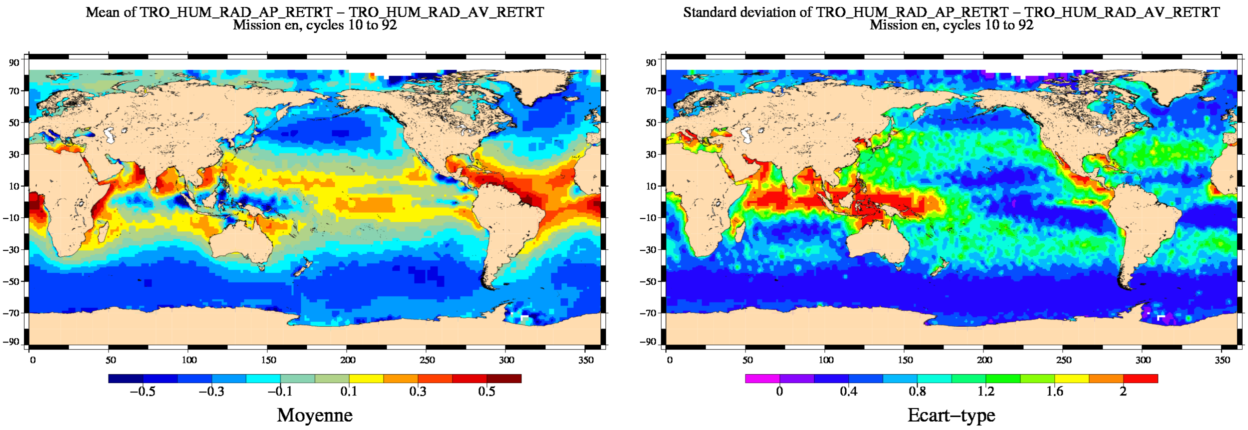

Figure 29: *Mean and Standard deviation of the difference of tropospheric correction before - after reprocessing.*

5.4.1. Conclusion on MWR parameters:

****

More homogeneous time series all corrected from side lobes (near coasts). A clear jump of high wet tropo content appears on cycle 62 (probably in relation with the ECMWF change of version 6/11/2007). Higher Wet Tropospheric correction average and dispersion (std) due to the change of calibration factors. This metric, wich could have been significant of a better high frequency restitution of the variability was demonstrated to have a unexpected impact on the data performences through a performance analysis at cross overs on the whole time series. This remaining issue is well identified: it is today understood on radiometer expert side. A new version will soon be available to users in order to correct for this effect.

****

5.5. General conclusion on the parameters monitoring

Impact of	Reprocessed GDR vs old series
Range related parameters:	More homogeneous time series 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).
Waveform stability parameters:	More homogeneous time series evidencing slight drifts on the mispointing until cycle 65.
Sea State parameters:	More homogeneous time series. Higher SWH average and dispersion (std) due to the change of Sigmap in the SWH computation step. 3 states atmospheric attenuation behavior apart from cycles 15 and 65 with a weak impact on Sigma0 and wind.
MWR parameters:	More homogeneous time series all corrected from side lobes (near coasts). A clear jump of high wet tropo content appears on cycle 62 (probably in relation with the ECMWF change of version 6/11/2007). Higher Wet Tropospheric correction average and dispersion (std) due to the change of calibration factors degrading significantly the quality at cross-overs (see part 3.1.). Understood by Radiometer experts and soon available to users.

Table 1: *I*mpact of the reprocessing on parameter monitoring

6. ENVISAT Global Mean Sea Level Trend

The Mean Sea Level trend analysis, is the altimetry application that gets the biggest benefits from the homogenization of the reprocessed data. In fact, a 1mm jump in a correction included in the SLA definition can sign as a more than 0.1mm/year on the 9 years time series.
The description of method and particular studies on this subject is detailed in [14].
The aim of this part is to synthesize how it was impacted by the reprocessing.

6.1. Impact of the reprocessing and PTR drift

One must be aware that using the raw GDR products was not relevant for Mean Sea Level climate studies (as seen on Figure 30 left).

Many improvements and updates were performed over the whole time series. Thanks to this work, the discrepancies of Envisat MSL compared to Jason-1 time series were studied, reduced and explained in the frame of F-Pac activity. Since 2010, Envisat MSL is available on Aviso web page at: http://www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/products-images/index.html. The description of the processing and the table of corrections used are available at http://www.aviso.oceanobs.com/en/news/ocean-indicators/mean-sea-level/processing-corrections/index.html.
It is computed with an updated series and results in the MSL seen on Figure 30 right.

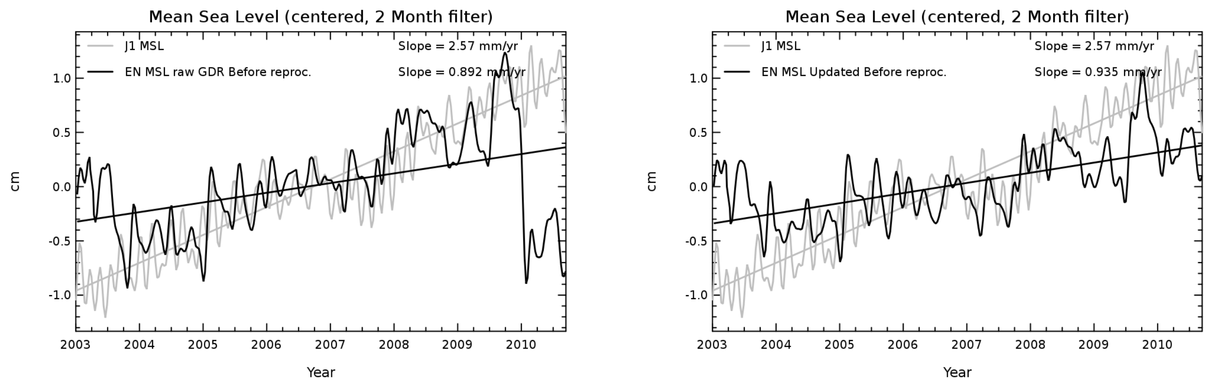

Figure 30: *Envisat and Jason-1 MSL using the raw GDR not updated before reprocessing (left) compared to the MSL updated (right) before reprocessing (PTR badly sampled).*

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 plot 32). It is also observed that Envisat MSL had a much lower trend than Jason-1.

Once reprocessed, the difference between both missions is even larger than the one previously observed on historical dataset. This point had been anticipated before the beginning of the reprocessing but the solution of the problem could only be confirmed and considered at the end of the processing. This point had been anticipated thanks to previous years studies which enabled to detect an error on Envisat side concerning an instrumental corrections and reported to instrument expert teams (P. Thibaut et al. 2011, [90]).
They were able to relate it to a too weak quantification step of one of the altimeter calibration correction. Indeed, in the processing chain, the point target response was sampled with a 3cm quantification step, preventing from observing properly the drift of 43 picoseconds in 7 years, which converted in height, is equivalent to 6.4 mm in 7 yr, or about 0.92 mm per year. Once the quantification step reduced to 1.8mm (see Figure 31 black plot), a drift, hidden until then, appeared and it was shown to increase the difference of mean Sea Level trend between Envisat and Jason-1 or tide gauges. Calval monitoring showed that the poor resolution of the sum of instrumental correction introduced a jump on the data series around September 2008 (see plot 30) traduced by a 1mm/year effect on the whole data series.

Note that to confirm the different drifts, calibration work are performed to compare altimetric missions (including Envisat) to in situ tide gauges measurement. The results are detailed in [18] available at http://www.aviso.oceanobs.com/fileadmin/documents/calval/validation_report/insitu/annual_report_insitu_2011.pdf. They were consolidated this year and enabled to quantify better the drifts of different missions by providing an external reference.

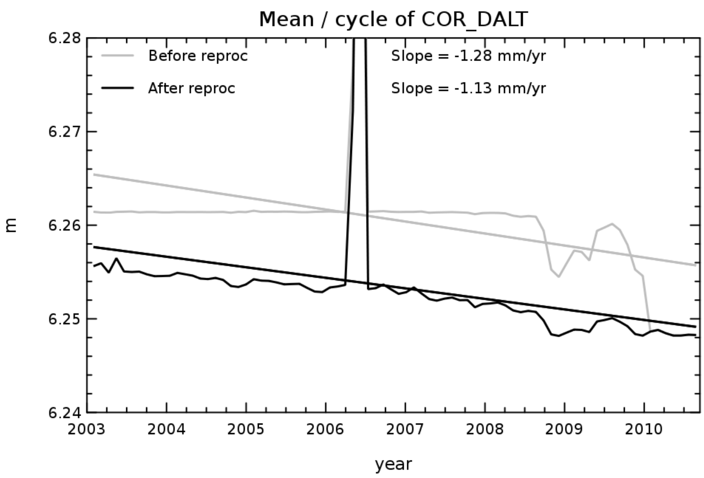

Figure 31: *Instrumental correction including PTR before and after reprocessing.*

Once the Envisat reprocessing finished, the effect of this instrumental correction could be fully appreciated. The MSL trend after reprocessing was indeed shown to have a degraded consistency with Jason-1 curve. Conversely, once +2xPTR applied (see plot 32), in order to correct for the wrong sign, a very good consistency is obtained between both missions after 2004.

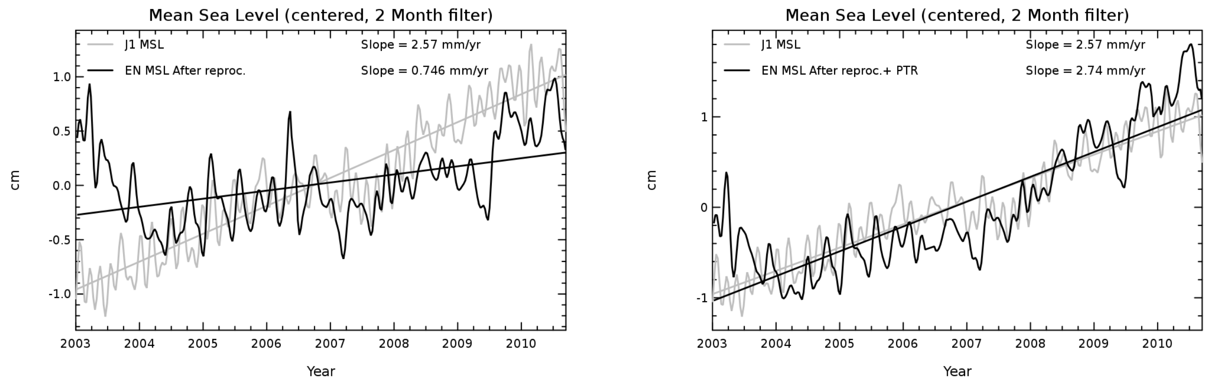

Figure 32: *Envisat and Jason-1 MSL using the GDR after reprocessing with PTR well sampled but with wrong sign (left) compared to the MSL after reprocessing with PTR well sampled but with correct sign (right).*

The slopes observed in different cases are summarized in the Table below.

Global MSL Trend using Radiometer Wet tropo	Until 2011	Until c92
EN-J1 using raw GDR before Reproc	1.7mm/year	0.9mm/year
EN-J1 using Updated data before Reproc	1.6mm/year	1.7mm/year
EN-J1 using raw GDR after Reproc	1.8mm/year	2.1mm/year
EN-J1 using raw GDR after Reproc + 2xPTR	-0.2mm/year	0.1mm/year

Table 2: *M*SL trends in mm/year

Part of these results were presented at the QWG17 and at the OSTST in a presentation available at: http://www.aviso.oceanobs.com/fileadmin/documents/OSTST/2011/oral/02_Thursday/Splinter4CV/02Pres_REVISEDOSTST2011_CrossCal_Envisat_AOllivier.pdf They were also presented in a paper submitted in Marine Geodesy in January 2012 and in Envisat RA2/MWR 2011 Yearly Report ([14]).

Warning: note that the PTR used for this study is not in L2 products and can therefore not be applied by users to the data. Status has to be made in 2012 to decide of the way ESA should provide such correction to users.
Also note that the one used here is not valid for the B-Side period: a 20cm bias seems to appear on this period. The final one should be in line with the rest of the series.

6.2. Impact of the reprocessing and Wet tropo correction

Even before the reprocessing, the wet tropospheric correction was identified as one of the major point of error affecting the MSL. The monitoring of this correction and the impact of reprocessing is detailed in part 5.4..
Here, the impact of this correction on the reprocessed MSL is detailled. The changed are due to:
- An update of the side lobe correction before cycle 41 (September 2005)
- An update of the characterization file everywhere

The impact on MSL is around +0.2mm/year in global, with a difference between North and South hemisphere much decreased after reprocessing: from 1.2mm/year South-North before reprocessing and 0.4mm/year afterwards over the cycles 6-80. This is a good result probably explained by the Side Lobe correction homogenisation over the time series.

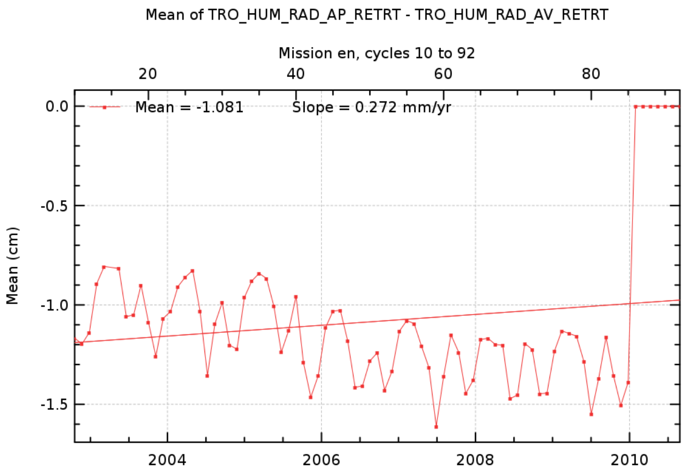

Figure 33: *Mean Envisat MWR Radiometer Wet tropospheric model After-Before reprocessing.*

The impact of the choice between wet tropospheric correction from MWR or from ECMWF model is now around 0.3mm/year on the period spanning cycles 6 to 80 with a still rather strong instability over the whole period due to the different ECMWF jumps (as see on Figure 34). This is to be related to the monitorings of part 5.4..

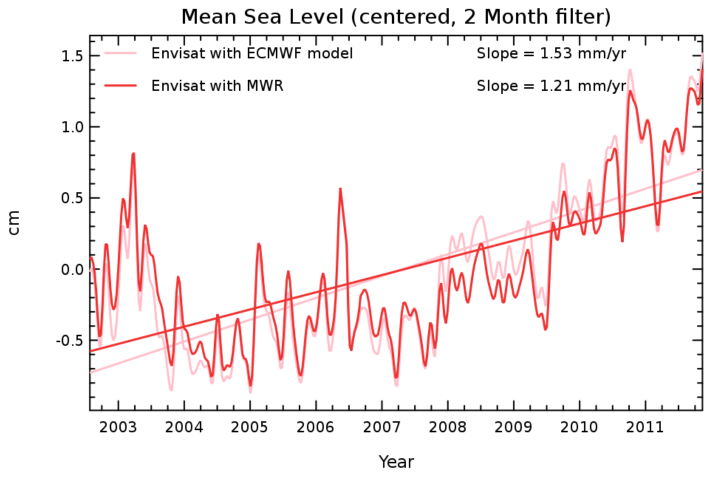

Figure 34: *Envisat MSL using MWR and Radiometer Wet tropospheric model (centered).*

6.3. Conclusion

The impact of the reprocessing including the use or not 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	Until 2011
EN MSL using MWR	1.21mm/year
J1 MSL using JMR	2.25mm/year
EN-J1 (using radiometers)	1.2mm/year
EN-J1 (using ECMWF)	1.9mm/year
EN-Tide gauge before reprocessing (using radiometers)	-1.9mm/year
EN-Tide gauge before reprocessing (using ECMWF)	-1.mm/year
EN-Tide gauge after reprocessing and PTR (using radiometers)	0.1mm/year
EN-Tide gauge after reprocessing and PTR (using ECMWF)	0.4mm/year
	.../...

Global MSL Trend	Until 2011
J1-Tide gauge	-0.1mm/year

Table 3: *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 when applying the PTR correction is reduced to 0.1mm/year when using radiometer and 0.4mm/year when using the ECMWF operational model.
Note that in relative, some differences remain on the figures. These differences are under investigation and could be linked to a different behaviors of the altimetric components in global and near coasts (notably the wet tropospheric content, known to be sensitive to this).

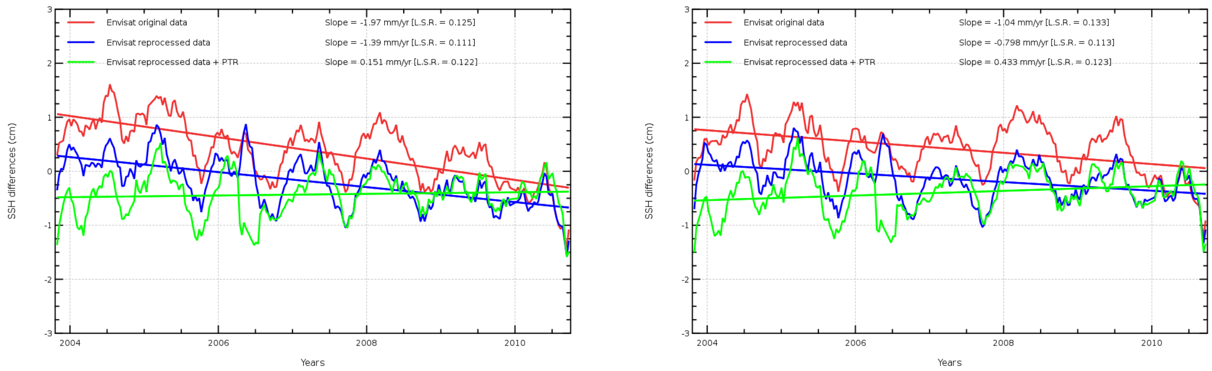

Figure 35: *Envisat difference altimetry - Tide Gauges, using MWR Radiometer (left) and ECMWF Wet tropospheric model (right) (centered).*

7. Cross calibration Envisat/Jason-1 and geographical biases

The reprocessing also had a strong impact on data concerning the geographical biases and further, on the regional map of MSL trend. The different patterns can be efficiently highlighted when comparing the Envisat to Jason-1 datasets. The consistency with Jason-1 was studied through 2 methods:
- comparison of geographic behaviors between Envisat and Jason-1 were performed by averaging the sea surface height difference at cross overs points. Figure 36 to 39 show the geographical centered difference between Envisat and Jason-1 at crossovers averaged over years 2002 to 2010. A selection on the lag between ascending and descending datation lower than 10 days is applied in order to get rid of most oceanic signal. The signature is positive over the American continent and negative over Asia with a 2cm amplitude.
- geographic difference of regional MSL Envisat -Jason-1 were also performed.

7.1. EN-J1 at cross overs, year per year evolution

Figure 36 to 39 show the geographical centered difference between Envisat and Jason-1 at crossovers averaged over years 2002 to 2010. A selection on the lag between ascending and descending datation lower than 10 days is applied in order to get rid of most oceanic signal.
The first diagnosis is applied comparing the GDR-C Jason-1 series to 3 Envisat data sets:
- Before reprocessing
- Before reprocessing with data update
- After reprocessing

7.1.1. EN-J1 at cross overs: regional time raw GDR series before reprocessing

First of all, the comparison of J1 to Envisat raw GDR before Reprocessing is plotted (using JMR/MWR radiometer wet tropospheric correction) (Figure 36) : strong geographical biases are observed, this data set is not usable for climate purpose. The signature is positive over the American continent and negative over Asia with a 2cm amplitude.

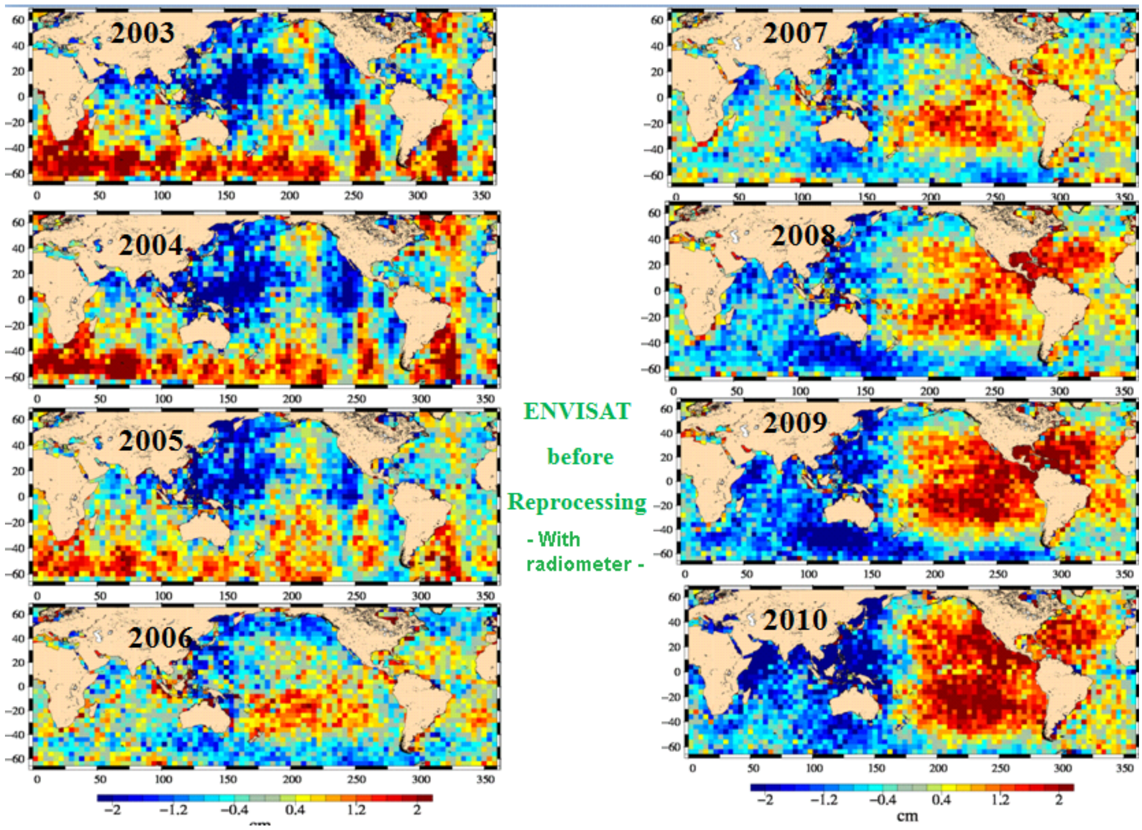

Figure 36: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centered (cm). Raw GDR before reprocessing (with JMR/MWR).*

7.1.2. EN-J1 at cross overs: regional time series after reprocessing

After the reprocessing, the regional comparisons between Jason-1 and Envisat were computed again with model or radiometric wet tropospheric correction (Figure 37 and Figure 38): the patterns are cleaner than the ones obserevd when using non reprocessed data and enabled to detect a clear East West bias increasing in time. For this study, comparison with Argo Temperature/Salinity Sea Level reconstructed from profiles measurements well spread on all oceans, helped to precise the differences between missions behaviour (Valladeau et al. 2012, [97]). In this case the exercise enabled to evidence that the East-West discrepancy between Envisat and Jason-1 was more important on Envisat than on Jason-1.
After investigations (performed on test data prior the end of the reprocessing), this effect was related to a bad modelling of the gravity field into the orbit determination for the recent years. In fact the EIGEN-GL04S (see Cerri ([27]) et al. 2010 and description of standards available at http://ids-doris.org/system/poe/poe-description.html) used in the new orbit standards (GDR-C POD) takes into account a semi-annual and annual time variability field but does not consider its long term drift. It is so fully representative of the Earth geoid around 2004 but does not take into account recent evolutions of the geoid mainly related to ice caps melting.
Furthermore, remaining patches are observed and shown to be removed by the use of ECMWF model (South Pacific red patch in 2005-2006). This should be investigated further.

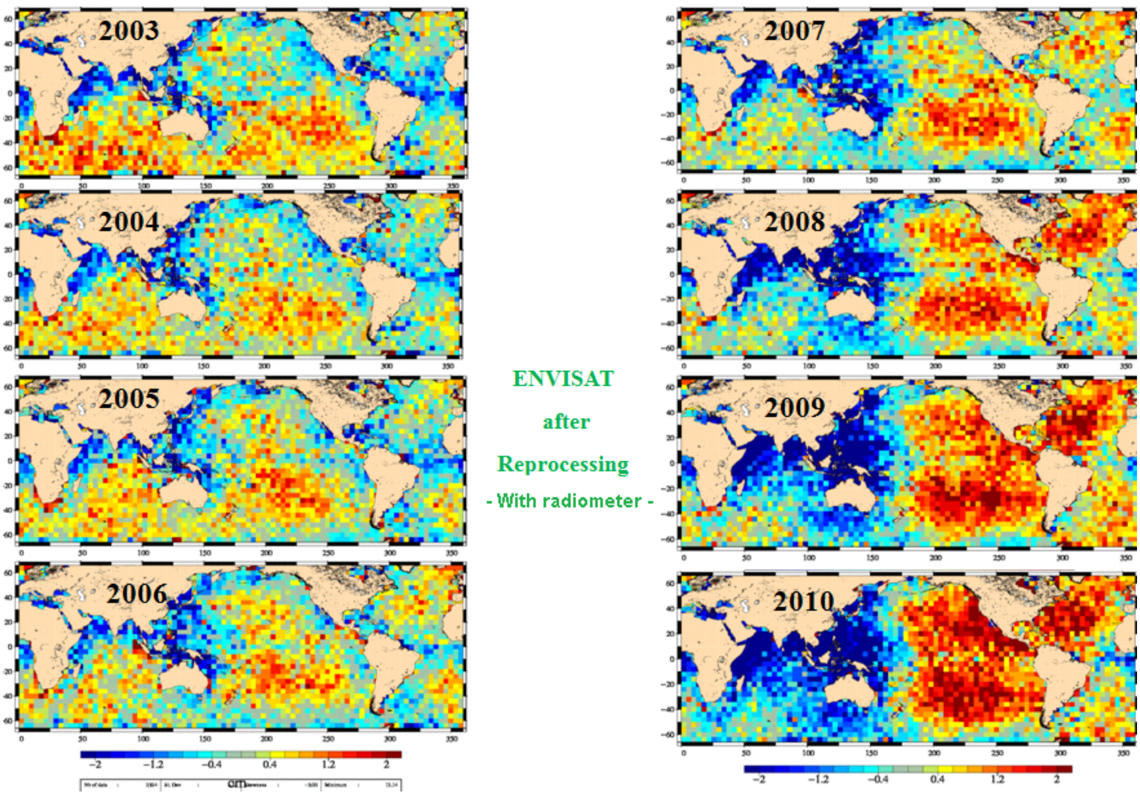

Figure 37: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centered (cm). After reprocessing (with JMR/MWR).*

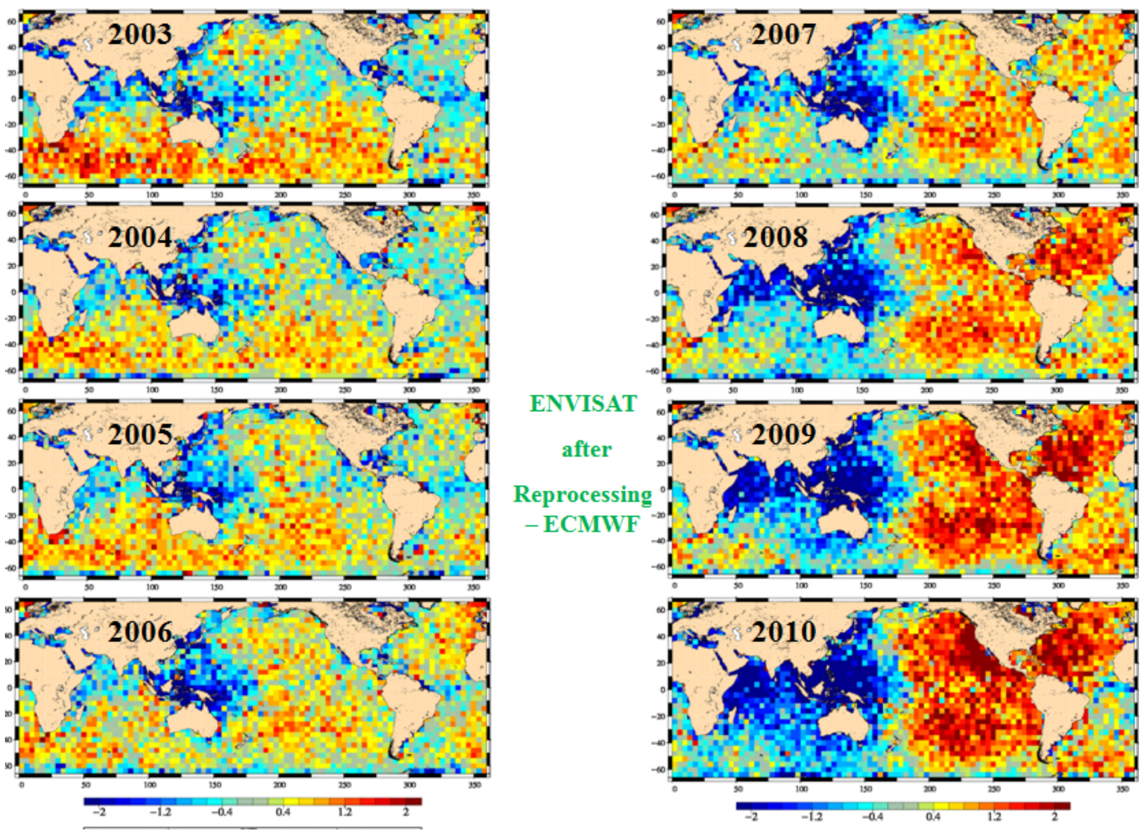

Figure 38: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centered (cm). After reprocessing (with ECMWF).*

7.1.3. EN-J1 at cross overs : regional time series after reprocessing + Future GDR-D orbit standards

In 2011 a later version of POD standards, preliminary GDR-D, was produced to avoid this long term drift. It was shown this year to successfully reduce the East West bias increasing in time (see Figure 7). These standards include the gravity field EIGEN-GRGS-Release2bis (detailed in (Cerri et al. 2011, see [28]), which results from a modelling on 8 years (2002-2011) instead of 3 years (2003-2005 for the EIGEN-GL04S). It includes a semi-annual and annual time variability field as well as a long term drift term which was shown to appears with a different sign and amplitude on Envisat and Jason-1 data, and consequently in a greater way in the difference Envisat minus Jason-1. This point is illustrated on the comparison of Jason-1 to Envisat updated data before reprocessing using GDR-D like preliminary orbits (using MWR and JMR wet tropospheric correction)(Figure 39) : the East West bias disappears.
The improvement of the consistency between Envisat and Jason-1 was shown to be a cumulated effect of the improvement of both data sets. Multimission cross over analysis over 2008 shows that using the GDR-D POE standards for Jason-1 and not on Envisat reduces partially the East West bias. Only the cumulated effect of both mission's update is totally efficient. This result underlines that cross calibrations studies are useful to help improving all altimetric missions.
In terms of regional Mean Sea Level evolution, this result is major, reducing (as shown on Figure 40 right) the geographically correlated difference of drift between two independent missions. +6mm/year differences are now reduced to +3mm/year, though increasing the confidence in both dataset for climate studies.

Thanks to this study and after a larger validation of the performance improvement for Jason-1, Jason-2 and Envisat, this standard will be used in the off line products in 2012.
The validation of this orbit is detailed in the 2011 Yearly report of Jason-1 and 2.

Note that thanks to the use of GDR-D orbits, the East West bias disappears but isolated patches can still be observed.
The results shown above when comparing the reprocessed SLA with ECMWF or MWR would suggest them to be related to Wet tropospheric content differences between JMR and MWR.

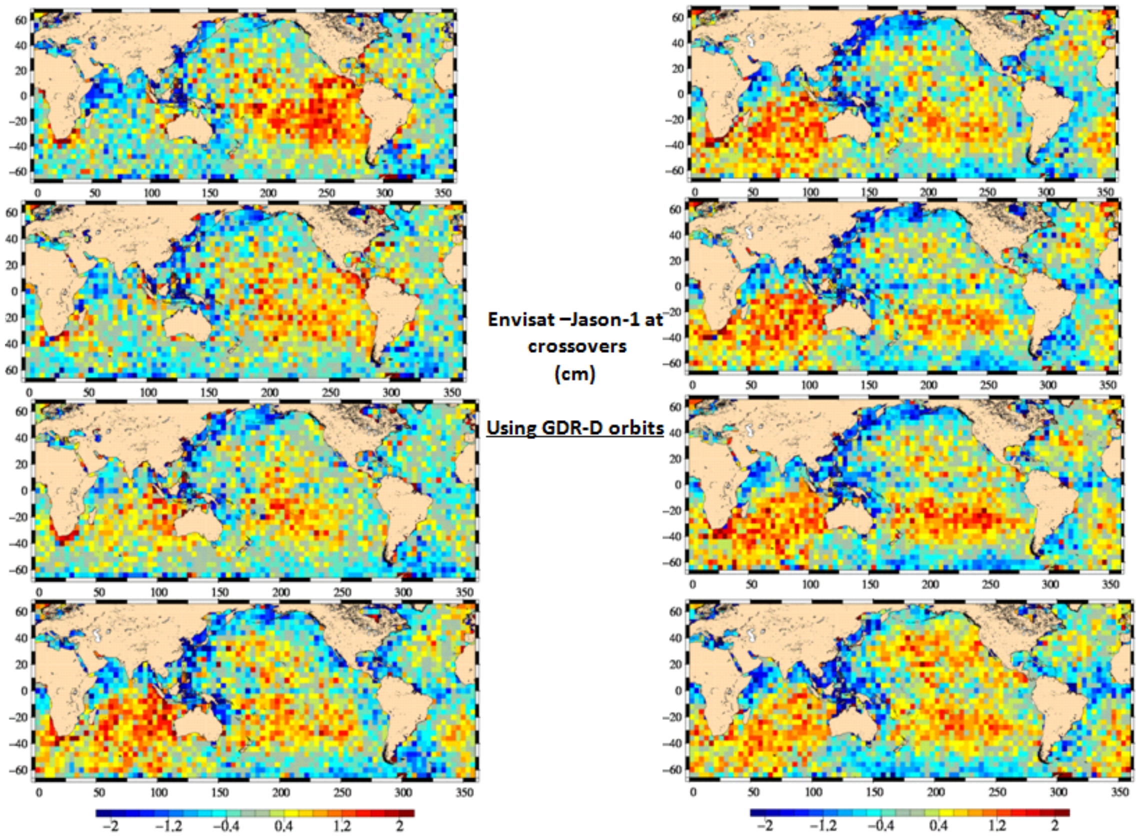

Figure 39: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centered (cm). Before reprocessing, using GDR-D orbit and JMR/MWR.*

7.2. EN-J1 regional MSL

The second diagnosis is totally in line with the results presented above. It consists in plotting maps of the difference of MSL trend between Jason-1 and Envisat over the same period (2003-2011).

7.2.1. EN-J1 regional MSL: impact of the reprocessing

The impact of updating Envisat data series is observed. Notably, the use of the new GDR-C precise orbit solution 40 (right) instead of the GDR-A-B-C solution (left): geographic trends differences are now cleaned from short wave length geographical patches (vertical stripes reaching 1cm/year difference between both missions). The remaining difference was analyzed and enabled to evidence the impact of the gravity field. The same diagnosis applied to raw GDR data before reprocessing with GDR-D orbits (right) shows that the effect on global trends is significant.

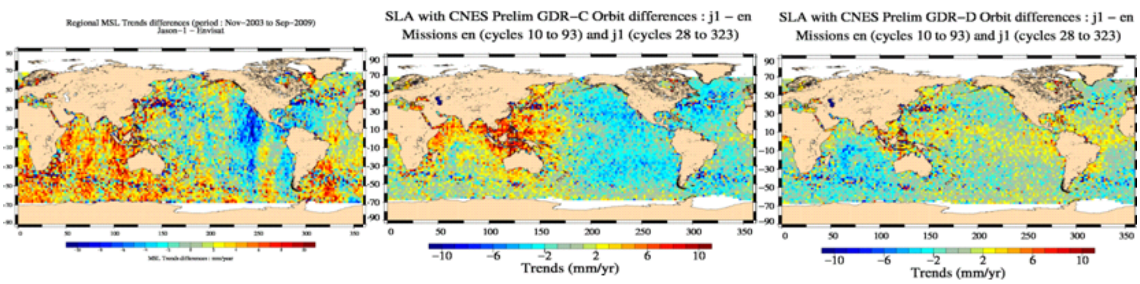

Figure 40: *Envisat minus Jason-1 trends difference*

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7.2.2. EN-J1 regional MSL : impact of MWR Wet tropospheric correction

The map 41 shows the difference of MSL trend between MWR before - after the reprocessing. The impact of MWR characterization file and side lobe correction changes is locally significant(+/- 1.5mm/year), with large patterns leaking around the continents.

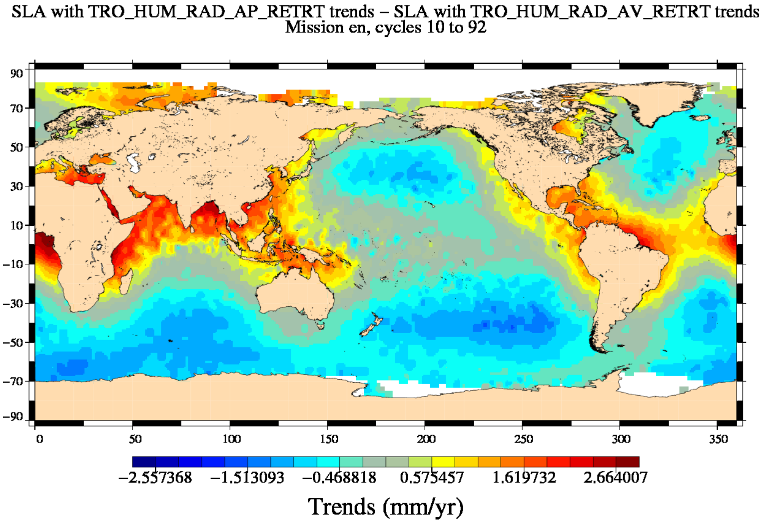


Figure 41: *Mean differences of slope for Envisat after reprocessing, using MWR before or after reprocessing.*

7.3. Conclusion

Finally, the reprocessing has very much improved the consistency between altimetric missions, reaching a level of accuracy close to the updated time series. Yet, as already mentionned in part **??**, the wet tropospheric correction in wet areas and the SSB in low waves areas are slighly degraded. The signature of this effect is observable thanks to multimission comparisons and will be investigated further.

8. Conclusion

8.1. Conclusion on the data quality

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. For the first time this year, all the Geophysical Data Record (GDR) products were reprocessed in a homogeneous standard and delivered to users after validation.
The **reprocessing** of the whole Envisat altimetric mission was one of the major activity this year. It ended, in a full respect of the scheduled calendar, mid January. 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, as it is essential 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 for GDR raw data set!
- The new MWR characteristics were shown to degrade the global quality of data. In terms of performances at cross overs as well as on the point of view of the consistency with Jason-1, the degradation was estimated to around $1cm^2$. This is under investigation on radiometer experts side.
- The Global Mean Sea Level trend of raw GDR was very much impacted by this reprocessing. The homogenization of processing enables to get more confidence in the data and to have GDR almost in line with the updated time series already available on Aviso web site for scientific purpose. Yet, a remaining error concerning the sign of the PTR still prevent the data to give reliable data used as it is. To solve this, the impact of a reverse PTR was tested and shown to give much better results.
- The regional Mean Sea Level, as well as the consistency with Jason-1 was also analyzed in terms of geographical bias. Here as well, the reprocessed data were shown to be perfectible thanks to the use of a new orbit standard, soon available and solving a long term regional drift.

Conclusion, the reprocessed dataset is very much improved compared to the original GDR time series. However, some remaining issues are well identified: they concern the radiometer wet tropospheric content (understood and shown to be possibly corrected) and the SSB, because of its iterative processing and it should be solved by new SSB model already planned for 2012 (using the new reprocessed standards).

8.2. Further improvements already anticipated

Studies could already be carried on and more improvement are still anticipated:
- During the reprocessing some anomalies encountered were corrected. For instance concerning the Rain flag anomaly detected on cycle 10 and solved from cycle 26 until then end.
- The sign of the PTR instrumental correction was shown to improve a lot the global Mean Sea Level Trend. A way of making it available to users is under discussion but the idea is already ratified.
- Furthermore, a new standard of orbit should also be available soon, resolving the remaining issues concerning the East West discrepencies between Jason1, Jason2 and Envisat. This new version improves the quality of all missions as well as Cryosat's orbit. The signature on the Regional Mean Sea Level will be sensible. It wil also improve the consistency between the altimetric missions, enabling to go further in the refinement of data quality.
- A new Sea State Bias, because of its iterative processing is also being prepared to take into account all the reprocessed updates. For that specific point, however, understanding the degradation of the low wave height would be usefull in order to manage it properly in this "end of chain" correction.
- Finally, the radiometer processing and the unexpected behavior of reprocessed data was investigated recentely by radiometer experts. The cause of the problem detailled in this document was found and a solution should be soon available to users, in addition to the on line products. Furthermore an improvement of the coastal restitution is also under developpement and could also be available soon in addition to the products.

9. Additionnal studies on specific points - Appendix

9.1. Editing on SLA caused by MWR

9.1.1. Observation of the problem

The number of data edited on the "MWR wet tropospheric correction" criteria for the reprocessed data has increased compared to the historical data (see figure 42). Furthermore, it presents a significant annual signal, observed, since GDR-B standards on historical data (mid 2005). In relation to the thresholds applied, we tried to analyze why more data are edited with this annual signature.

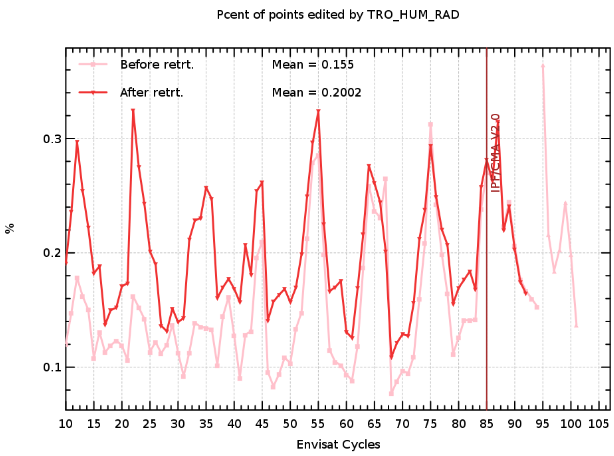


Figure 42: *Editing on MWR correction, before and after reprocessing*

9.1.2. Analysis of the problem

In the validation process, data on ice are first rejected, taking into account, among other things, the difference between wet tropospheric correction and model (if wet $|tropo. - model| > 0.10$, the data can be detected as ice). After this first step of validation, data are rejected "by wet tropospheric correction threshold" if the MWR data is between -0,5m and -0,001m.
If we separate the rejected data according to the min and max thresholds, we observe that the rejected data by maximum threshold correspond to high latitudes, especially during winter in north hemisphere (cycle 22 for example) as seen on figure 43.

After investigation, these rejected data on high latitudes did not correspond to ice area but were rather situated on ice shelves (see figure 44). According to the validation process, these data present high values of tropospheric correction and not rejected by ice flag.
As the ice flag depends on wet tropospheric value, the reduction of max threshold in ice flag

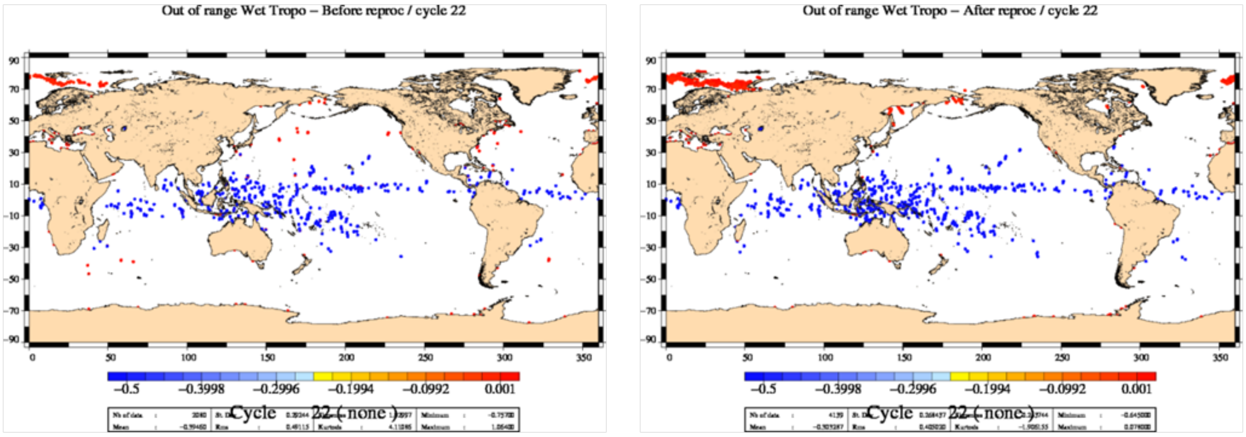


Figure 43: *Editing on MWR correction for cycle 22 (North winter) - Before/After reprocessing*

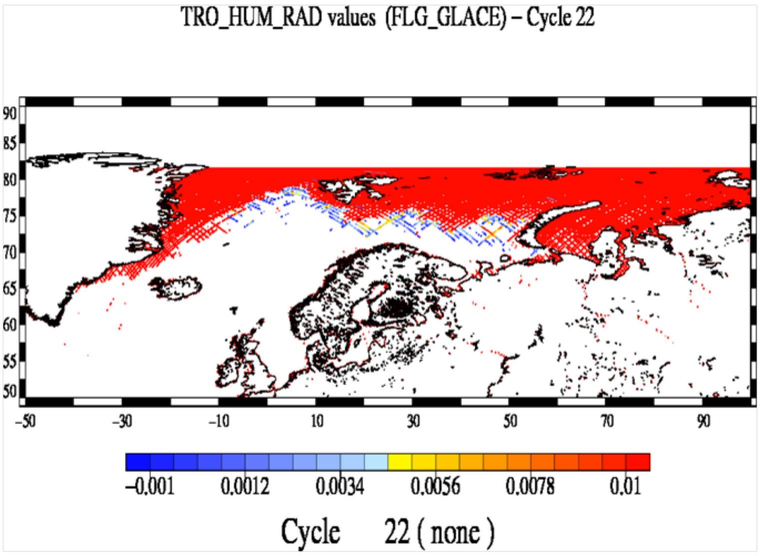


Figure 44: *Wet tropospheric correction values edited on high latitudes -* ***red:*** *ice from Calval Ice Flag - cycle 22*

definition could change the fitting of ice shelf.

9.1.3. Comparison with the GDR product flag (Tran et al.)

If we consider the ice flag included in the GDR products (Tran et al.) the phenomenon is increased. By construction this flag (developed for scientific purpose) is less severe than the one used for validation purpose. Figure 46 shows that the GDR Ice flag detects less ice than the one used for validation purpose (Calval flag).

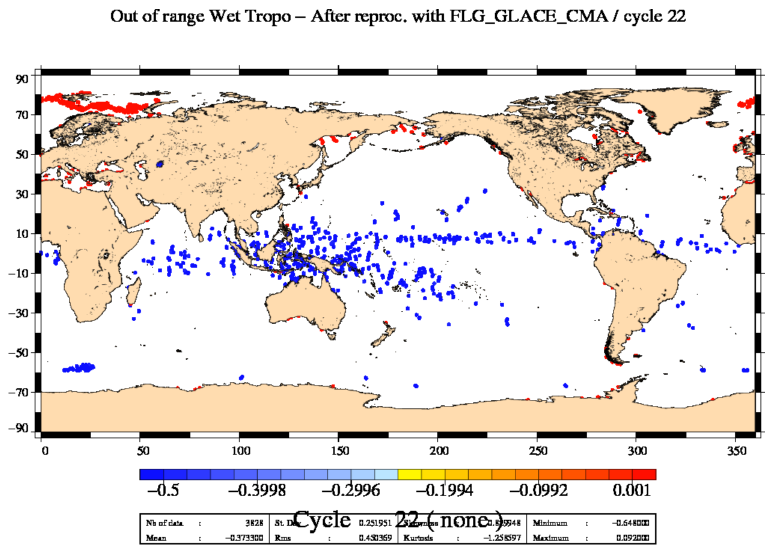


Figure 45: *Editing on MWR correction for cycle 22 (North winter) with GDR Ice Flag*

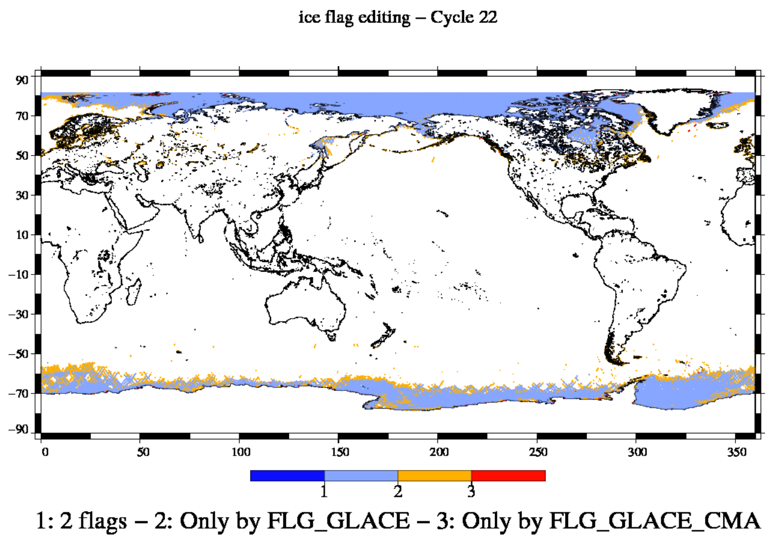


Figure 46: *Ice detection by Calval and GDR Ice Flags for cycle 22* ***blue***:*Ice for both GDR/Calval flags,* ***red***: *Ice only for GDR flag,* ***orange***: *Ice only for Calval flag.*

9.1.4. Conclusion

With the reprocessed data two changes occurred on radiometer: - a new calibration which increases the dispersion of the wet tropospheric correction derived from MWR
- side lobe correction which enables to get a more relevant value of wet tropospheric correction near coasts and near ice shelves.

The cumulate impact on extreme positive values of tropospheric correction drives to an over editing of data at high latitudes including an annual signal.

The new data rejected are "too high for our thresholds" but not identified as ice. 2 ice flags were tested the one from GDR and the one used for validation purposes which is more severe in order to get rid of any ice contaminated SLA.
Thus, we can imagine that the ice flag definition could be updated to take into account the new calibration of radiometer and to improve and refine this validation step.
This should be investigated further in the frame of a more global analysis on the new characteristics of MWR wet tropospheric content.

9.2. Status on the V2.1 standard SWH

The computation of SWH for the reprocessed data was changed at L1b level. This provokes a global reduction of the mean value, allowing Envisat SWH to be more consistent with Jason-1 and 2 missions and to models.
Yet, the bias is SWH depending and small waves are more impacted than high ones.
The document below characterize the new behavior of Envisat SWH and explains the new behavior of small waves in terms of mean value and noise. This was raised by some users (Bonnefond P., Queffelou P.) to be a point of concern.

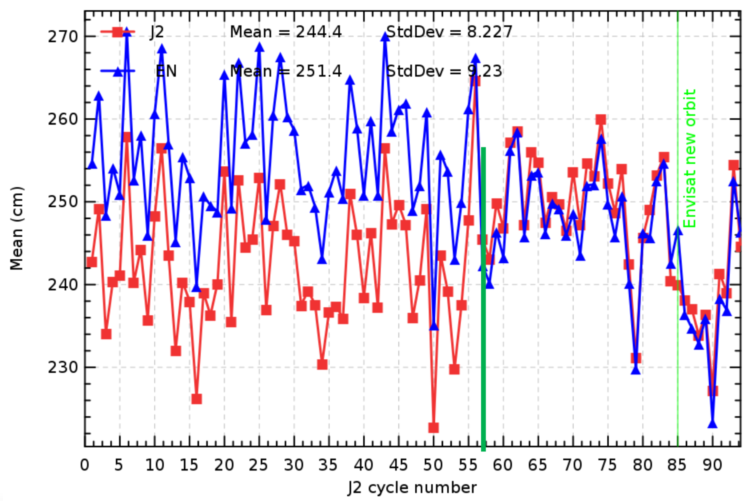
1. Position of the problem

- 2 issues concerning the SWH in version V2.1:
  - Bias on SWH: on average more complient to other missions (J1,J2) and to WAM model

  But:
  - Too strong bias of small waves
  - Higher noise of SWH (visible at 1Hz and 20Hz for SWH < 1m)

V2.1 version impact on SWH bias

Average per J2 cycle

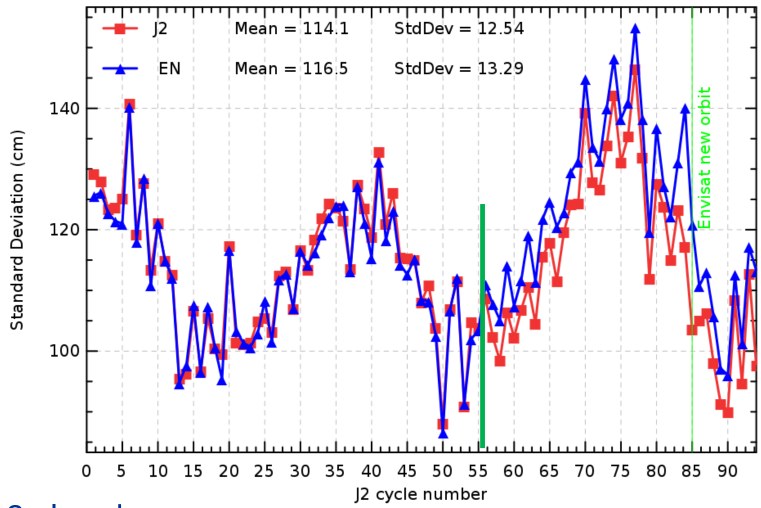


Comparison to Jason-2 also shows:

- More complient mean for Envisat and Jason-2

V2.1 version impact on SWH noise 1Hz

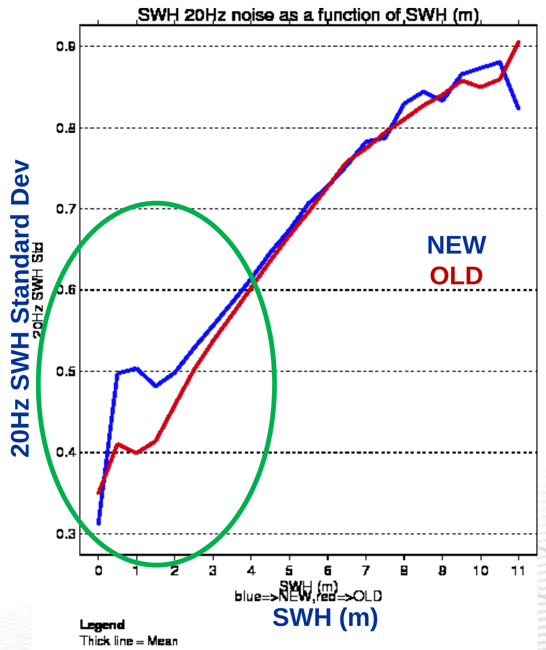
Std per J2 cycle



Comparison to Jason-2 also shows:

- Stronger standard deviation

V2.1 version impact on SWH noise 20Hz



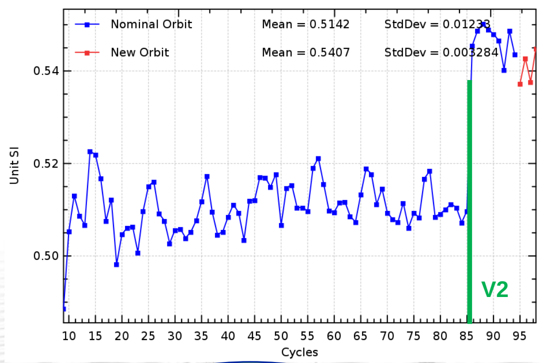
An analysis on 20Hz data was performed

Increase of 1Hz SWH standard deviation per cycle:

- 1.3m to 1.4m in global

Strong increase of 20Hz SWH standard deviation:

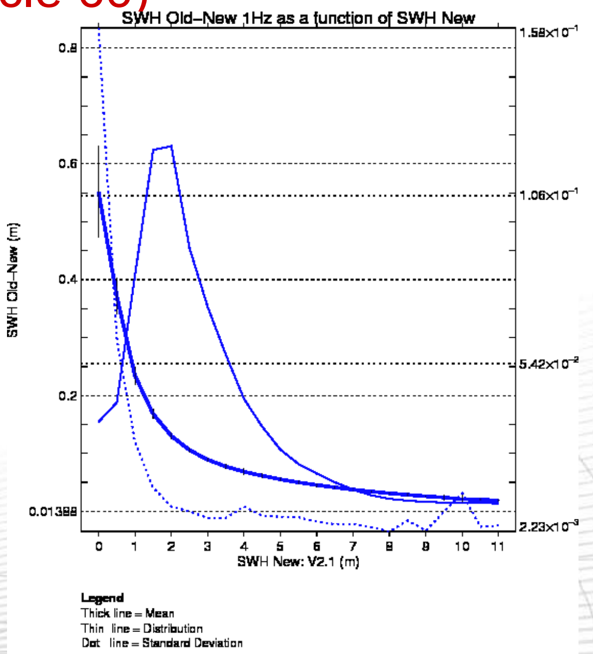
- 50cm to 54cm in global
- 40cm to 50cm for SWH<3m



20Hz SWH Std Dev

V2.1 version impact on SWH biais and noise at 1Hz (cycle 60)

- Only small waves (<1Hz) inpacted



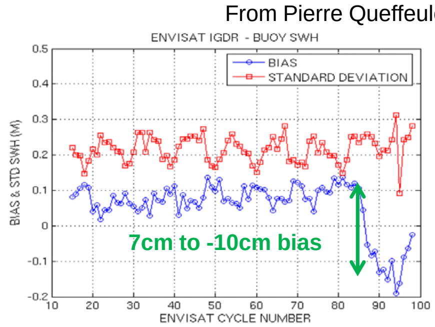
2. Users feed back

Change of Sigmap value in V2.1 IPF/CMA

SWH V2.1 globally more complient :

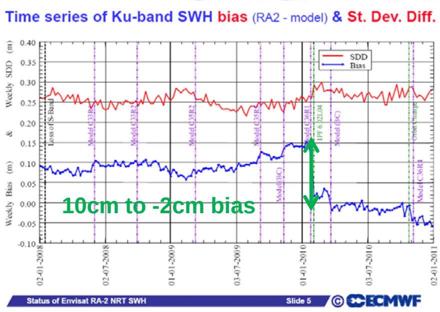
- to buoys except for small waves (see P Queffelou work) ➔

From Pierre Queffeulou



- to WAM model (see ECMWF presentation) ➔

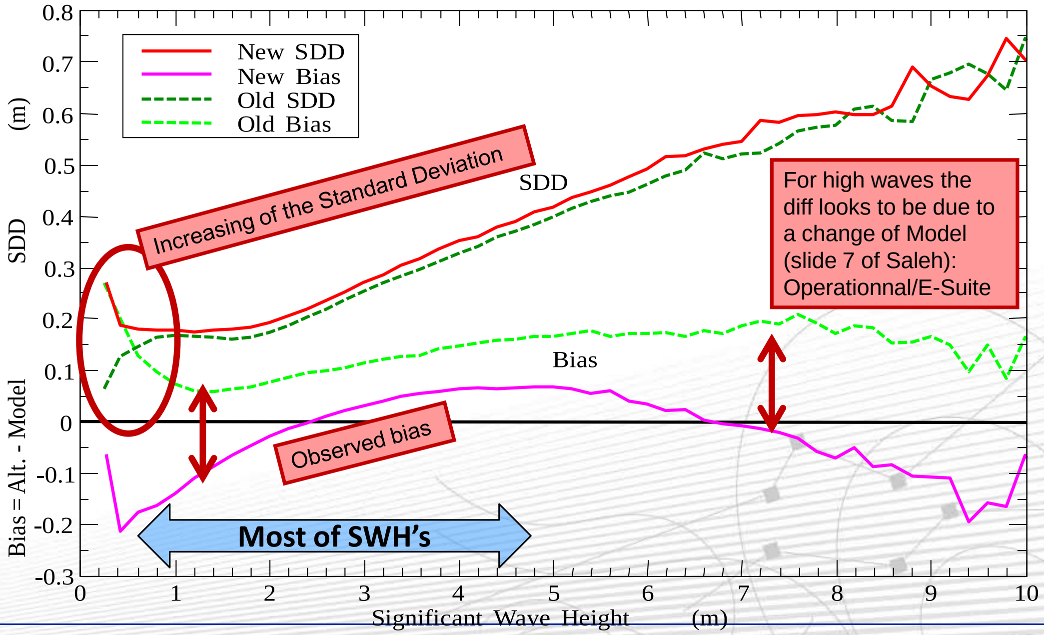
From Saleh Abdalla



BUT both see stronger bias and standard deviation degradation for SWH<3m

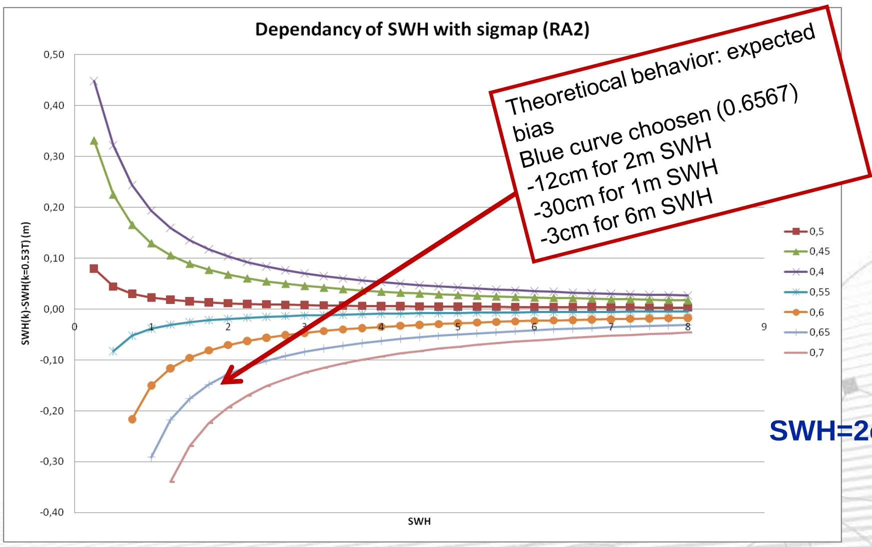
- P. Bonnefond also impacted because Corsica is a small wave area

Ku-band SWH bias (RA2 - model) & St. Dev. Diff. as functions of SWH



3. Do we explain that?

Impact of sigmap on SWH comparison done for RA2 with sigmap = 0.53 T



Yes!:

It is explained theoretically (see theoretical dependancy from P. Thibaut)

SWH=2c√(Sigmac²-Sigmap²)

Proto simulation for sigmap=0.6567T

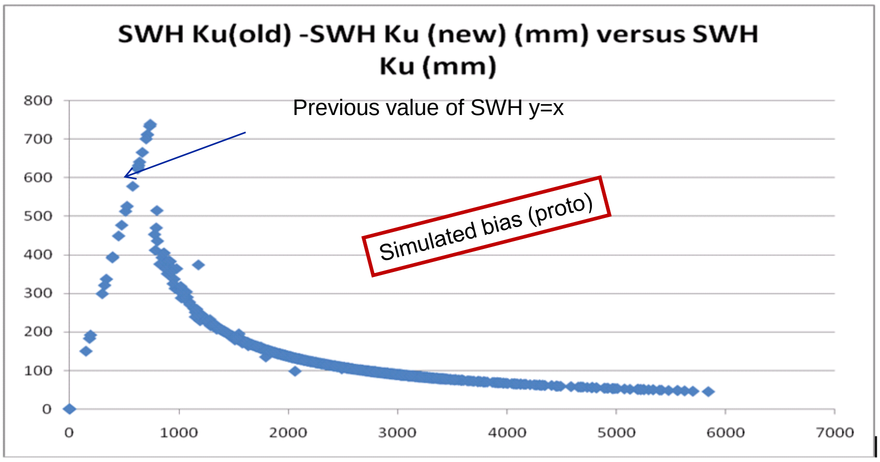


Figure 3-7 : SWH Ku(old) -swhKu (new) versus SWH Ku

Yes!:

It was simulated in the proto (see simulated dependancy from B. Soussi)

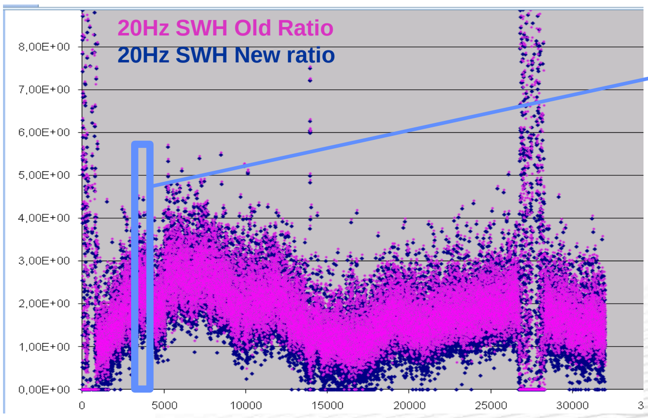
Theoretical/Observed bias differences

SWH	Theoretical bias introduced by sigmap coef from 0.53 to 0.6567	Observed bias RA2 SWH - ECMWF model before V2.1	Observed bias RA2 SWH - ECMWF model after V2.1	Observed bias introduced by V2.1 model change	
1m	-30cm	+7cm	-12cm	-19cm	Real SWH slighly higher than theory
2m	-12cm	+8cm	-2cm	-10cm	Expected
6m	-3cm	+18cm	+2cm	-16cm	Obs diff higher than theory (linked to Model change?)

=> The structure of the SWH dependancy is slighly different but small amount of data due to histogram repartition.

Increasing of the standard deviation

Due to the non linearity of the sigmap ratio impact, the standard deviation increases for small waves:



Ex for 20 values of a 1Hz SWH	Min	Max	Max - Min
Old ratio	2.04m	4.04m	2m
New ratio	1.90m	3.97m	2.07m
New-Old	14cm	7cm	+7cm ampli-tude

4. Conclusions

- Conclusion
  - The bias on SWH mean is correlated to the SWH value : in line with the theory.
  - The value choosen for the sigmap by IsardSat seems optimal for 2m waves (reduction of 12cm in average): the SWH are, on average more complient to the models and Jason's
  - But the effect on small waves is less in line with the models/buoys: too strong correction
  - The noise is also higher for small waves
- Tests on SWH before/after show that the change of SWH behavior is complient with the change of sigmap (from 0,53 to 0,6567)
- The increase of noise is a direct consequence of the non linear dependancy of SWH to Sigmap

5. What do we do then?

- Solution proposed?
  - Try to choose an other Sigmap, better fitted, in order not to degrade small waves? They were too high compared to Buoys/models they are now too small…
  - Evaluating the stability of the sigmap throughout the mission? See impact of the variability of PTR width observed in the frame of CCI studies.
  - Developping table correction to correct for the non linear observed effect? such as for Jason1 and 2 (see P. Thibaut proposal in ESL FUP 2011).

9.3. USO Anomaly Flag abnormally set to 1

Dear Pierre, Sabrina, Monica,

You will find enclosed a small document I wrote including additional information concerning the IDEAS-PR-11-05540 "USO Anomaly Flag abnormally set to 1".
The flag we are talking about is (following the volume 14 Product handbook):
USO validity flag
0: no errors detected
1: anomaly in USO value detected
and it seems to be "abnormally" related to the calibration areas...
Hope this will help
Best regards

Annabelle

FA SALP-FT-8115 IDEAS-PR-11-05540

FA Open: *USO Anomaly Flag abnormally set to 1*

- This flag is described in the User Handbook vol14(page 109/231): http://earth.esa.int/pub/ESA_DOC/ENVISAT/Vol14_Ra2mwr_4C.pdf

As:

bit 2: USO validity flag

- 0: no errors detected
- 1: anomaly in USO value detected

What does this flag contain exactly? And why is it regularly set to 1?

Hereafter a new behavior noticed following the change of calibration strategy at cycle 31.

Flag USO Anomaly and calibration strategy

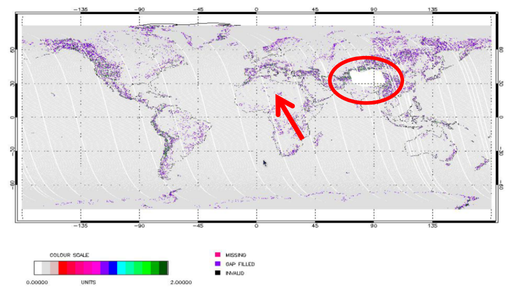


Figure 5: RA-2 Chirp ID for ascending passes during cycle 30 Cycle before 30

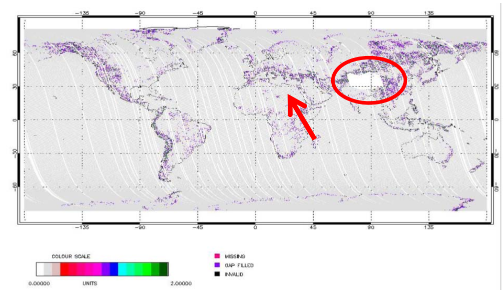


Figure 4: RA-2 Chirp ID for ascending passes during cycle 32 Cycle after 30

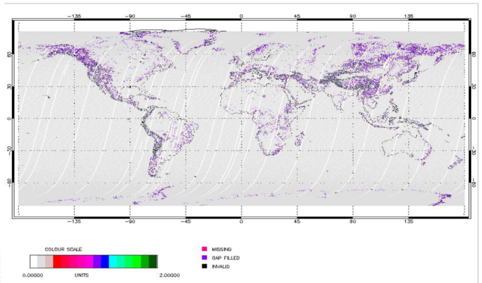


Figure 6: RA-2 Chirp ID for descending passes during cycle 30

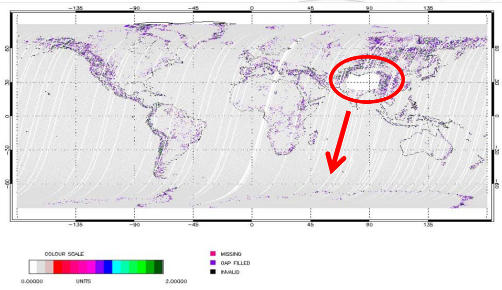
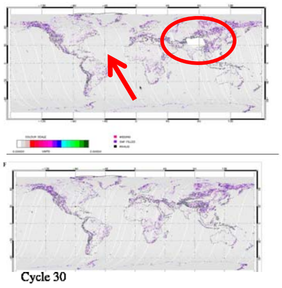


Figure 5: RA-2 Chirp ID for descending passes during cycle 32

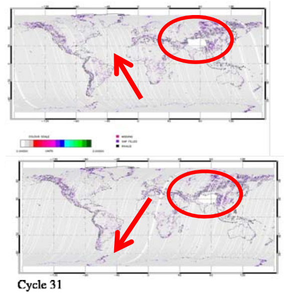
Extracted from ECAR report

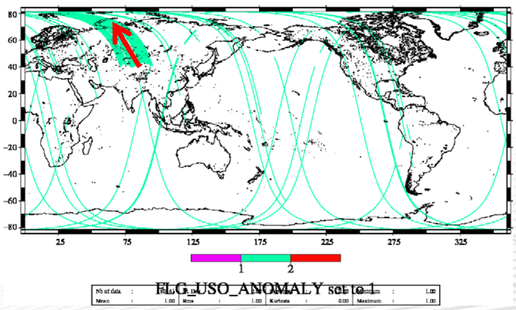
Flag USO Anomaly and calibration strategy

Cycle before 30

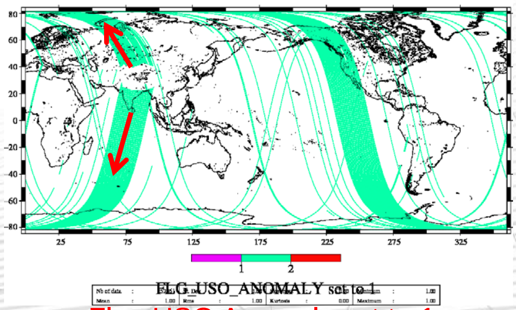


Cycle after 30





Flag USO Anomaly set to 1



Flag USO Anomaly set to 1

9.4. Table of ENVISAT Reprocessing Anomalies

.

Cycles	IDEAS-PR-11-05519 Rain Flag unrelevant for Lat<-50°	IDEAS-PR-11-05520 USO jumps (several meters)	SALP-FT-8058 IDEAS-PR-11-5535 USO uncorrecting for heating periods	S Band Flag abnormally set to 1	SALP-FT-8115 IDEAS-PR-11-05540 USO Anomaly Flag abnormally set to 1	SALP-FT-8115 IDEAS-PR-11-05540 USO Anomaly Flag abnormally set to 0	SALP-FT-8180 IDEAS-PR-11-05569 Unstable USO correction at the beginning of anomaly period	SALP-FT-8429 USO Period randomly not smoothed in L2 data	SALP-FT-8430 SLA not usable for cycle 5 (+/-20cm oscillations)	Other comment
	Cycle impacted: Yes/No	Number of passes impacted	Number of passes impacted	Cycle impacted: Yes/No	Approximative number of passes impacted	Approximative number of passes impacted	Approximative number of passes impacted	Approximative number of passes impacted	Approximative number of passes impacted	
5	N		0	Y				>100	>400	The cycle is incomplete: out of 635 passes, around 100 are impacted by a DIODE reset and 100 have no radiometer. The remaining 400 passes are very degraded. The USO anomaly impacts the whole cycle 5. Even after the appropriated correction (spline filtered) le SLA remains unusable. The cycle is not validated nore distributed to users. Under investigation on DPQC side.
6	N	0	0	Y	10					2002/05/16: SLA is out of range for 26 passes due to a DORIS event. Orbit was extrapolated for this period with degraded performances No TEC Grids (pas de iono DORIS))
7	N	95	0	Y	50					1/95 passes are impacted by unrelevant values of USO correction applied to the range; 2/Radiometer is also missing for 30 seconds segments in specific areas (North-West Atlantic and South West Australia). 3/22 passes are entirely edited during bandwith shift test periods, on 2002/06/18 and between 2002/06/26 and 2002/06/29 (20MHz for these two periods) => direct impact on dual ionospheric correction over ocean and consequently on the SLA (3m bias on SLA) 4/Anomalous jumps are noticed on the mispointing and on all parameters related to the waveform (Peakiness,SWH (Ku) -SWH (S), Sigma0 (Ku) - Sigma0 (S), Nb20Hz (Ku) - Nb20Hz (S)), in particular between tracks 630 and 880 (2002/07/10 - 2002/07/18). The documentation available for this period relates events which could have an impact on data: between 2002/07/10 and 2002/07/18, wrong default values of CTI tables were taken into account. SPSA patch installations are mentioned on 2002/07/08, 2002/07/18 and 2002/07/22. 5/jump on tropospheric correction difference with model (pass 630 to 880) No TEC Grids (pas de iono DORIS))
8	N	90	0	Y	50					90 passes are impacted by unrelevant values of USO correction applied to the range; passes 410/411 (06-08-2002, from 04:26:48 to 06:07:23):edited, orbit maintenance maneuver (03:38:08 to 06:28:33) No TEC Grids (pas de iono DORIS)
9	N	33	0	Y	40					33 passes are impacted by unrelevant values of USO correction applied to the range; Pass 862 (2002/09/25, from 23:22:08 to 00:12:25) is unvalidated due to the orbit maintenance maneuver planned on 2002/09/25, from 22:21:11 to 01:11:34, slightly impacting the orbit quality. For tracks 773 & 900, statistics of along track SLA are locally higher than usual due to a strong oceanic variability near South Africa No TEC Grids (pas de iono DORIS))
10	Y	12	0	Y						
11	Y	0	0	Y	20					
12	Y	0	0	Y	17					
13	Y	0	0	Y	10					
14	Y	6	0	Y	20					
15	Y	0	0	Y	20					
16	Y	0	0	Y	20					
17	Y	0	0	Y	30					
18	Y	2	0	Y	20					
19	Y	0	0	Y	30					
20	Y	0	1	Y	40					
21	Y	10	2	Y	40					2 magnétic storms impacting the orbit. 19 passes impacted
22	Y	0	0	Y	20					
23	Y	0	0	Y	40					
24	Y	4	0	Y	50					
25	Y	2	0	Y	30					
26	N	2	1	Y	30					
27	N	0	1	Y	20					over editing probably due to a high oceanic variability near South Africa. 1 pass impacted
28	N	0	0	Y	15					
29	N	0	0	Y	20					
30	N	0	0	Y	20	51				
31	N	0	0	Y	90					From cycle 31 change of calibration strategy over Himalaya.
32	N	25	0	Y	90					
33	N	6	0	Y	90					
34	N	1	0	Y	90					
35	N	2	0	Y	90					
36	N	0	0	Y	90					
37	N	0	0	Y	90					
38	N	0	0	Y	90					
39	N	0	0	Y	90					
40	N	1	0	Y	90					
41	N	0	0	Y	90					
42	N	6	0	Y	90					
43	N	0	0	Y	90					Passes 948/949 (just after the leap second of 1st January 2006): wrong management of the leap second. Datation offset by one second for most of those passes => Large impact on the orbit data quality (of the order of 25 meters).
44	N	0	0	Y	90	154	1			Abnormal values of the IPF correction (included into the range) linked to unstabilities of the correction at product extremities at the beginning of USO anomaly period (track 848) Non-reprocessed ECMWF grids used for 2 days (31/01 - 01/02) for this cycle => millimetric oscillations on dry tropo. correction, not visible on SLA
45	N	0	0	Y	90	80				Passes 150 to 230: drift and 30cm jump on the average per track of the dif- ference between the 2 channels (Ku-S) (SWH(Ku)-SWH(S), ECT_SWH(Ku)- ECT_SWH(S), ECT_DALT(Ku) - ECT_DALT(S))
46	N	0	0	Y	90	833				passes 902-1002: no DORIS data, SLA slightly degraded
47	N	0	0	Y	90	790				- the cycle in A-side configuration (1-794) is entirely affected by the USO anomaly starting on 08-04-2006, correctly corrected; - Bandwidth shift tests: passes 710/736 - B-Side shift test : 794-1002 - B-Side S-Band power drop: 936-1002 Use of GIM ionospheric correction in CALVAL treatments for the whole B-Side period (15 May 2006 at 14 :21 :50 (cycle 47 pass 794) to 21 June 2006 at 11 :37 :32 (cycle 48 pass 847)). On passes 710/736, 20cm bias on dual ionospheric correction AND 3m bias on Ku-S range difference => 3m bias on SLA (erroneous configuration file? ...)
48	N	0	0	Y	90	152				the cycle in A-side configuration (850-1002) is entirely affected by the USO anomaly starting on 08-04-2006, correctly corrected; - B-Side shift test : 1-847 For 4 passes (22,188,344,674) during the B-side shift, the A|B-Side flag (FLG_ALT) is set to 0 (A-Side) instead of 1 (B-Side) - B-Side S-Band power drop: 1-847 Use of GIM ionospheric correction in CALVAL treatments for the whole B-Side period (15 May 2006 at 14 :21 :50 (cycle 47 pass 794) to 21 June 2006 at 11 :37 :32 (cycle 48 pass 847)).
49	N	0	0	Y		912				
50	N	0	0	Y		912				
51	N	0	0	Y		912				SLA out of range for passes 186 to 188 due to a strong DORIS event: after a platform incident (07/09/2006 at 16h39 TU), all DORIS parameters (except the OUS) were turned off and a general reset was performed on the 11/09/2006 at 10h29 TU. Orbit was extrapolated for this period (about 4 days) with degraded performances.
52	N	0	0	Y		912				
53	N	0	0	Y		912				
54	N	0	0	Y		912				
55	N	0	0	Y		912	1			Pass 515: unstabilities of the correction at product extremities in anomaly mode

56	**N**	0	0	Y		912				RA_CON file datation problem impacting data. OK after redelivery. Pass 79, 80, 90 and 99 chaotic behavior of the USO clock: too sharp edges cannot be perfectly corrected and sign on the SLA. From cycle 56 change of calibration strategy over Himalaya and Rocky mountains.
57	**N**	2	0	Y	90					
58	**N**	0	0	Y	90					
59	**N**	0	0	Y	90					
60	**N**	0	0	Y	90					SLA out of range for pass 9 due a degraded orbit during inclinaison maneuver
61	**N**	0	0	Y	90					SLA Std record breaking linked to low ice extend record.
62	**N**	0	0	Y		912				SLA Std record breaking linked to low ice extend record. DORIS ionospheric correction missing (78 to 88 ,missing TEC grids from 25/09/2007 to 27/09/2007).
63	**N**	0	0	Y		980				Pass 980: straight front in USO correction anomaly/non anomaly transition.
64	**N**	0	0	Y		982				
65	**N**	0	0	Y		450				Ten hours after the recovery of the HSM anomaly on the 17 January 2008, a drop of the RA2 S-band trans-mission power occurred ==> all the S-band parameters, as well as the dual ionospheric correction and rain flag are not relevant and MUST NOT be used from the following date: 17 January 2008, 23:23:40 (Cycle 65 pass 289). **The dual ionospheric correction must be replaced by GIM ionospheric model from this date**(warning: bias between both iono corrections: 8mm).
66	**N**	0	0	Y	20					a limited number of tracks are concerned by the USO anomaly flag abnormally set to 1 for cycle 66, compared to previous cycles.
67	**N**	0	0	Y	10					63 passes entirely edited on the radiometer land flag (Gap MWR-0,no MWR correction). From cycle 67 change of calibration strategy only over Himalaya.
68	**N**	0	0	Y	12					
69	**N**	2	0	Y	20					Passes 84/85: unrelevant values of USO correction applied to the range are observed (jumps of several meters visible on the SLA).
70	**N**	0	0	Y	10					
71	**N**	0	0	Y	20					strong eddy near South Africa; 4 tracks édited by SLA st. dev. out of thresholds.
72	**N**	2	0	Y	30					strong eddy near South Africa; 5 tracks édited by SLA st. dev. out of thresholds 2 tracks impacted by an USO jump (entirely edited by SLA stats out of threshold) inclination maneuver (1 pass edited)
73	**N**	0	0	Y	25					
74	**N**	0	0	Y	25					
75	**N**	0	0	Y	20					pass 261 edited on the SLA criteria due to a bad handling of the Leap second correction
76	**N**	0	0	Y	20					During cycle 76 a Platform anomaly occurred between 15th and 16th February 2009. This failure caused the on-board software to execute an automatic reconfiguration including immediate transition to Yaw Stellar Mode (YSM). The anomaly can be linked to the appearance of a very bright object across the Star Tracker field of view causing a software halt. Recovery was successfully performed leading to a transition back to the nominal operating mode. No impact on SLA. inclination maneuver (1 pass edited)
77	**N**	2	0	Y	20					The mispointing mean per track plot shows a jump of values between tracks 83 and 108 (2009/03/06) with no impact on SLA: Platform anomaly = > automatic reconfiguration including immediate transition to Yaw Stellar Mode (The same anomaly with the same signature already occurred notably on the previous cycle, see cycle 76). Tracks 758/759 edited: USO jump (few points of CMA reference correction field seem to be impacted)
78	**N**	0	0	Y	30					inclination maneuver (1 pass edited)
79	**N**	0	0	Y	30					
80	**N**	0	0	Y	20					
81	**N**	0	0	Y	20					inclination maneuver (1 pass edited)
82	**N**	0	0	Y	30					Pass 808: statistics of along track SLA locally higher than usual due to a strong oceanic variability near South Indonesia
83	**N**	0	0	Y	20					inclination maneuver (1 pass edited)
84	**N**	2	0	Y	20					Tracks 722/723 edited: USO jump
85	**N**	0	0	Y	20					inclination maneuver (1 pass edited)
86	**N**	0	0	Y	15					1 pass edited due to an orbit maintenance maneuver (2010/01/21,from 01:03:29 to 04:44:32), slightly impacting the orbit quality.
87	**N**	0	0	Y	10					inclination maneuver (1 pass edited)
88	**N**	2	0	Y	10					Erroenous ECMWF files taken into account for reprocessing (testing files), CMA. 300 tracks impacted. Reprocessed. Passes 358/359: USO jumps
89	**N**	0	0	Y	10					Erroenous ECMWF files taken into account for reprocessing (testing files), CMA. 10 tracks impacted. Reprocessed. 1 pass (9) edited due to an orbit maintenance maneuver (2010/04/27,from 04:37:05 to 04:47:30).
90	**N**	0	0	Y	10					
91	**N**	0	0	Y	10					1 pass (9) edited due to an orbit maintenance maneuver (2010/07/06,from 04:37:29 to 04:47:06).
92	**N**	0	0	Y	10					

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