CalVal Envisat

Envisat RA2/MWR ocean data validation and cross-calibration activities. Yearly report 2011.

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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 Envisat validation and cross calibration studies carried out at CLS during year 2011. It is basically concerned with long-term monitoring of the Envisat altimeter system over ocean.

Envisat GDR data are routinely ingested in the Calval 1-Hz altimeter database maintained by the CLS Spatial Oceanography Division 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). In this frame, besides continuous analysis in terms of altimeter data quality, Envisat GDR Quality Assessment Reports (e.g. Faugere et al. 2003 [38]) are routinely produced in conjunction with data dissemination.

For the first time, a whole mission reprocessing occurred in 2011. 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 mid 2002.

This annual report concerns the reprocessed data from GDR cycles 6 through 92 and routine 93 to 107 spanning nine and a half years (from 14-05-2002 to 21-11-2011). All relevant altimeter parameters deduced from Ocean 1 retracking, radiometer parameters and geophysical corrections are evaluated and tested.
For further information about the original GDR data before reprocessing, please refer to [12].
A document concerning the impact of reprocessing on the data will also be available in the frame of the reprocessing activities.

Some of the results described here were presented at the OSTST meeting (San Diego, October 2011) and at the Quality Working Group (QWG) meetings (Propriano, May 2011 and Roma, November 2011).

The work performed in terms of data quality assessment also includes cross-calibration with Jason-1 and Jason-2. This kind of comparisons between coincident altimeter missions provides a large number of estimations and consequently efficient long-term monitoring of instrument measurements. This enables the detection of instrument drifts and inter-mission biases essential to obtain a consistent multi-satellite data set. Note that ERS-2 mission is now over and no additional cross calibration with this mission was performed and shown in this report.

The various comparisons performed between the 3 missions cited above show a very good consistency with a standard deviation of cross-over differences of around 5.9 cm on the whole period. The geographically correlated biases between Envisat and Jason 2 also show a very good agreement of both data sets with still a East West bias increasing in time. This bias is shown to be reduced by the use of a new orbit standard.

Furthermore, methods of comparison to in situ dataset are also used to provide an external reference, complementary to the usual satellite cross comparisons.
Using these methods, particular studies were extensively carried on this year (notably Mean Sea Level studies) to show how the Envisat data can be further improved after the end of reprocessing in terms of global stability and regional biases.

After a preliminary section describing the data used, the report is split into 6 main sections: first, **data coverage** and measurement validity issues are presented. Second, a **monitoring of the main altimeter and radiometer parameters** is performed, describing the major impact in terms of data accuracy. Then, **performances** are assessed and discussed with respect to the major sources of errors. Then, Envisat **Sea Surface height** (SSH) difference at cross-overs and the SLA computed with **MSL** standards is monitored. Finally, an additional part presents the **particular investigations** that have been performed during this year:
- particular studies were performed concerning Mean Sea Level issues, notably:
o concerning the impact on the global drift of an error concerning an instrumental correction
o concerning the impact on the regional drift of the time variable gravity field included in the orbit standards
- the full validation of new preliminary GDR-D standards is then presented
- extensive study on cross calibration results was also performed. A step of average per box of the data was added to the cross comparison statistics computation. This exercise enables to get around the difference of sampling for different ground track missions. Without this step, the Jason-1 and 2 missions over-sample high latitude areas compared to Envisat with a significant impact on statistics interpretation. The monitoring were updated in that sense though, giving a better confidence in the data.
- with the increase of the solar activity, a particular point was underlined on the fact that the ionospheric correction, efficiently derived from the JPL GIM model is now beginning to degrade the data in some regions.
- then, a particular study was carried on to investigate the source of annual signal observed in the number of data edited on the Wet tropospheric correction criteria.
- Finally, a status on the SWH changes in the V2.1 reprocessed time series. It describes and explains the new characteristics of this parameter.

2. Quality overview

All the information concerning the historical data is available in 2010 Yearly Report. This year report only concerns the routine and reprocessed data after V2.1 update.

Ra-2 instrumental status:
Due to the permanent RA2 S-band power drop which occurred on January 17th 2008, 23:23:40 (Cycle 65 pass 289) all the S-band parameters, including the dual ionospheric correction and rain flag remain irrelevant and MUST NOT be used from this time.
Instead, users are advised to use the ionospheric correction from GIM model, which is available in GDR data products.

Since the loss of the S-Band at the beginning of year 2008, the solar activity was in a low period, therefore the use of the JPL-GIM model correction instead of the dual-frequency correction in the SSH equation was efficient and, data were weakly impacted in terms of variance. In 2011 the solar activity started to increase again and the degradation due to this correction is getting significant. A warning was sent to the community to warn about the mid wave length signal degrading the data since cyclic report 107 (October 2011).

No **USO anomaly** was noticed during 2011.
Yet, since V2.1 data standard the USO correction does not need to be taken into account anymore because it is included in the range.

Drifting phase:
This year, Envisat was entirely on its drifting phase. The 35 day cycle is now reduced to a 30 day pseudo cycle with a small drift estimated to +/-1.7km per cycle maximum (at respectively 50deg Latitude N/S) whereas it does not drift at 38deg N and S.
The impact on the data was already described in last year yearly report. This year, with more GDR data available, the impact on the data could be investigated further. Only a weak impact is noticed in the data quality (the visible impact concerns the SLA standard deviation) and the new Mean Sea Surface was shown to erase almost all this impact (see part 6.1.).
Note that the drift was observed to be higher than the one theoretically expected (+/-600m per cycle maximum was expected) see figure 1.

Missing measurements:
The unavailability of data over ocean for year 2011 is very low, about 1.3% in average.
The MWR unavailability is also rather stable and low, in average around 0.4%. Yet, during cycles 101 and 102, some instrument anomaly prevent from the MWR radiometer correction:
- Cycle 101: 18 passes (252-269)
- Cycle 102: 72 passes (724 to 795)

Long term monitoring of RA-2 and MWR parameters:
The ocean-1 altimeter and radiometer parameters are consistent with expected values. They have a very good stability and high performances, comparable to Jason-1 and Jason-2. A very good availability on every surface and very low editing ratios over ocean are observed since the beginning of the mission. The high frequency content of Ku-band Ra-2 parameters is very stable. Note that following a study developed in 8.1., a drift is now observed on the data from the

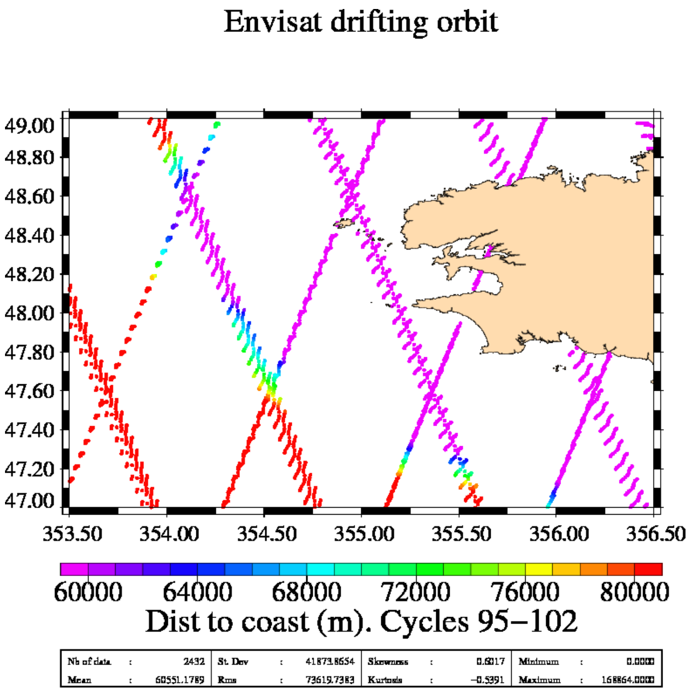

Figure 1: *Effect of the drifting phase near French coast. Cycles 96 to 107.*

beginning of the period, introduced by a wrong sign applied on an instrumental correction corrected at L1b level. This has a minor impact on mesoscale applications but a major impact that should be corrected for Mean Sea Level Climate applications.

The MWR performances are very good. Note that since the beginning of the mission, the instrumental parameters at 36.5 GHz were known to be slightly drifting. Moreover from cycle 46 onwards, the comparison to ECMWF model is hardened by the numerous improvements of this operational model inducing (around 1.5mm) jumps in the time series.

Mean Sea Level:
Comparisons between Jason-1 and Envisat Mean Sea Level trend estimated at CLS were carried on.
These studies are possible thanks to:
- the availability of a long Jason-1 reprocessed time series.
- an updated data series using as homogeneous terms as possible before the reprocessing campaign: Envisat POD orbit already reprocessed from cycle 10 onwards, geophysical corrections see part 3.2.2....
Particular focus was also made on the Time Delay Calibration Factor (position of the Point Target Response : PTR) an instrumental correction badly taken into the official products before reprocessing (lack of precision in the quantification step + error in the sign of the correction) which could introduce an unexpected drift affecting Envisat MSL data. This is detailed in part 8.1..
- In addition, comparison to in situ dataset (Argo TS profile and Tide gages) ingested to provide an external source of calibration are carried on. These activities are developed in [16] and [17].

Conclusions are that provided the correction of 2 errors concerning the PTR and the orbit, Envisat

reprocessed data enable to provide a Mean Sea Level very close to Jason-1 time series.
Compared to the update time series, the conclusions concerning the reprocessed data are not radically different yet, they enable to clarify and confirm the suspicions already noticed in previous yearly reports.
The first year of the mission (before 2004) still presents a strange behavior which should be investigated further.
On the rest of the period, differences between both missions can be analyzed more and more precisely. For instance, wet tropospheric correction still remains a large source of error in the trend computation for all missions. Using the ECMWF operational model for the whole mission is not totally satisfactory due to the frequent jumps induced by the model upgrades. On the other hand, the radiometric correction shows some long term instability (even with the homogenized V2.1 time series) which should be investigated.

3. Data used and processing

3.1. Data used

Envisat Geophysical Data Records (GDRs) from cycle 6 to cycle 107 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 homogeneous (so called V2.1 version) to the current production since 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 October 22nd 2011.

The Envisat GDR data are generated using two softwares: the IPF, from Level0 to Level1B, and the CMA, from Level1B to Level2.
Conversely to the previous yearly reports, the standard of the whole data is the same: the so-called V2.1 version, resulting from :
- IPF 6.04.L2 Version
- and CMA 9.3 Version

For any information concerning the historical data, please refer to the previous yearly report.

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

3.2. Processing

3.2.1. GDR products and quality assessment method

To perform this quality assessment work, conventional validation tools are used including editing procedures, crossover analysis, collinear differences, and a large number of statistical monitoring and visualization tools. All these tools are integrated and maintained as part of the CNES SALP altimetry ground segment and F-PAC (French Processing and Archiving Center) tools operated at CLS premises. Each cycle is carefully routinely analyzed before data release to end users. The main data quality features are reported in a cyclic quality assessment report available on http://www.aviso.oceanobs.com/html/donnees/calval/validation_report/en/welcome_uk.html. The purpose of this document is to report the major features of the data quality from the Envisat mission.

As for all other existing altimeters, the Envisat GDR data are ingested in the Calval 1-Hz altimeter database maintained by the CLS Spatial Oceanography Division. This allows us to cross-calibrate and cross-compare Envisat data to other missions. In this study data from Jason-1 (GDRs cycles 1 to 365) and Jason-2 (GDRs cycles 1 to 126) are used. Jason-1 is the most suitable for Envisat cross calibration as it is available throughout the Envisat mission and has been extensively calibrated to T/P (Dorandeu et al., 2004b [30]). Since January 2010 a full reprocessing of Jason-1 products in GDR C is fully available. Therefore, since January 2011 a new homogeneous Envisat/Jason-1 data set is available.

Comparisons between Jason-1 and Envisat altimeter and radiometer parameters have been carried out using 10-day dual crossovers for SSH comparison and 3-hour dual crossovers for altimeter and radiometer comparisons. The geographical distribution of the dual crossovers with short time lags strongly changes from one Envisat cycle to another. Indeed, contrary to Envisat which is sun-synchronous, Jason-1 observes the same place at the same local time every 12 cycles (around 120-day). Following the method detailed in Stum et al. (1998) [87], estimates of the differences are computed using a 120 day running window to keep a constant geographical coverage.
From July 2011, ERS-2 mission is finished. From this year onwards, the cross calibration with this mission will not be assessed anymore.

3.2.2. Particular updates added to the GDR products

In addition to the new homogeneous dataset provided by the V2.1 reprocessing only few updates were performed for the validation process. The corrections are directly read from GDR products except for 3 terms:

- **GOT 4.7 ocean tide** is used because its quality was already shown to be better than the FES 2004 or GOTOO available in the products (Yearly report 2009 [12]).

- **Sea ice flag**: A method has been developed to detect data corrupted by sea ice (see 4.3.1.). 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.

The few updates still necessary to complete the analysis are listed in the product disclaimer document available at http://earth.esa.int/dataproducts/availability/ [77]. Note that:

- **No S-Band anomaly is present in the data anymore**: Users are yet advised that the S Band anomaly flag available in the GDR must not be accounted for.

- **No more auxiliary files needed: the USO drift is now directly/properly corrected in the range.**
  The reprocessed data presented here can be used without any USO auxiliary file.
  Yet, during the reprocessing, some erroneous jumps in the USO computation of some products were identified and are still under investigation on IPF side.
  To avoid those erroneous jumps, users are advised to consider an appropriated editing of the data (see part 4.3.2.).
  The number of tracks impacted are synthetized in the "Anomaly report" table in Annexe of this document.

4. Missing and edited measurements

This section mainly intends to analyze the ability of the Envisat altimeter system to correctly sample ocean surfaces. This obviously includes the tracking capabilities, but also the frequency of unavailable data and the ratio of valid measurements likely to be used by applications after the editing process.

4.1. Missing measurements

From a theoretical ground track, a dedicated collocation tool allows determination of missing measurements relative to what is nominally expected. The cycle by cycle percentage of missing measurements over ocean has been plotted in Figure 2. The measurement unavailability over the whole mission is about 5% in average. Eleven cycles have more than 10% of unavailability. Passes 1 to 452 of cycle 15 have not been delivered because of a wrong setting of RA-2. Several long RA-2 events occurred during cycles 6, 7, 13, 14, 16, 22, 34, 48, 51, 53, 56 which resulted in a significant number of missing passes.
Since May 2008, following an improvement of the data dissemination the average ratio of missing RA2 measurements over ocean is much smaller than the previous years.
On the plot 2, the major impact on the data availability noticed is the signature of the maneuvers to change the orbit on cycle 95-96 which were uncomplete (see the cyclic report).
More anecdotally, a collision avoidance and a priority conflict with ATV were also noticed for cycle 101, with a weak impact on data.

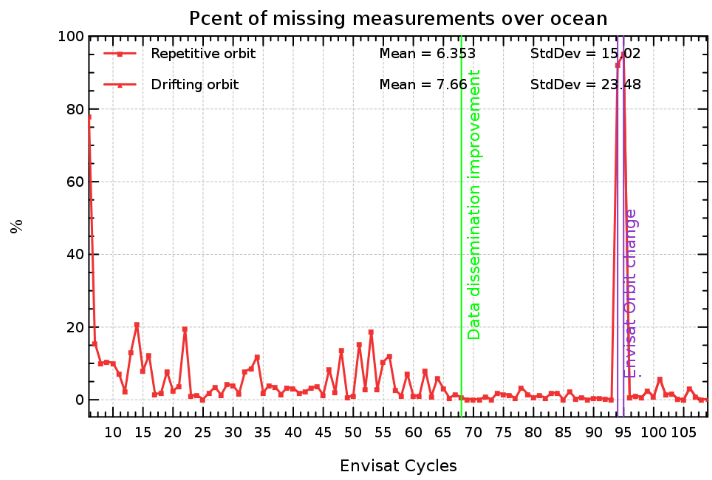

Figure 2: *Monitoring of the percentage of missing measurements relative to what is theoretically expected over ocean*

Figure 3 shows an example of missing measurements for cycle 107 . The measurements which are missing over the Himalaya are due to the IF Calibration Mode occurring on ascending passes only. This procedure was not always the same: for cycles prior to 55, it was performed over the Himalaya on both ascending and descending passes and for cycles 56 to 66 it was performed on ascending passes only but on the Rocky Mountains as well as on the Himalaya. Afterward, it is performed on ascending passes above the Himalaya only.

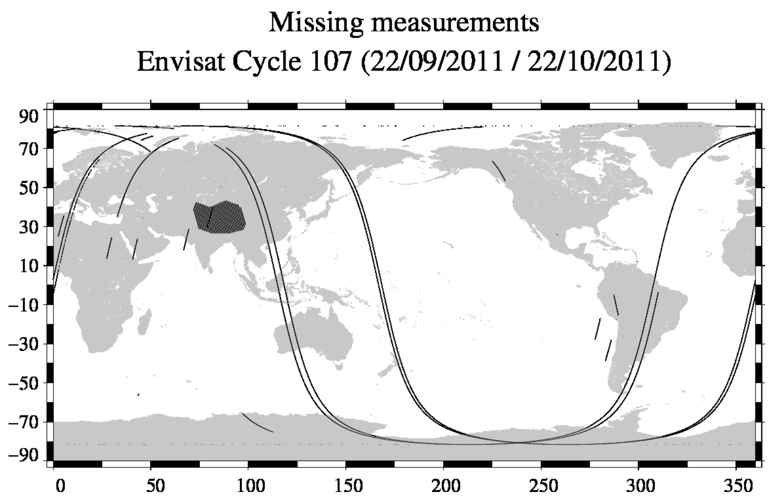

Figure 3: *Envisat missing measurements for cycle 107.*

It has been noticed that some pass segments were regularly missing. Figure 4 shows the pass segments missing more than 5 times over the 11 last cycles of the reprocessing period (cycles 82-92). Some of them are explained (PLO permanent acquisition sites (ESA/Rome, GAVDOS/Creta), others are not. Apart from that, the data retention rate is very good on every surface observed. This might be due to the tracker used by Envisat Ra-2, the Model Free Tracker (MFT).

Note that for the drifting phase cycles, this plot cannot be updated due to the method of projection on the theoretical track.

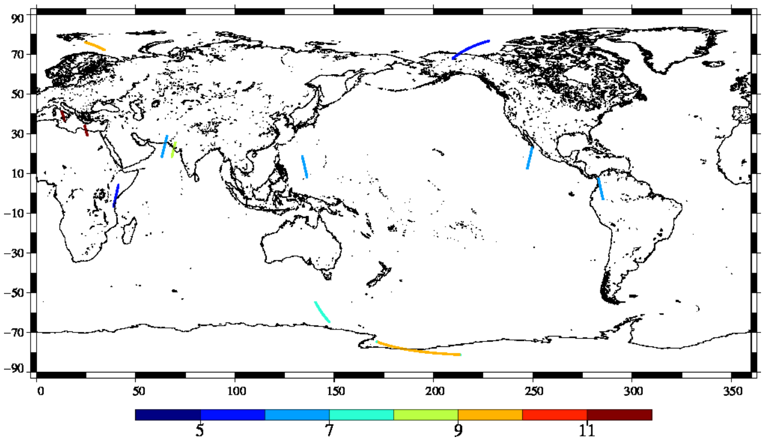

Figure 4: *Pass segments unavailable more than 5 times between cycles 82 and cycle 92. The color indicates the occurrence of unavailability*

Finally, the list of instrument and platform events is available in Part 10.1.. Apart from instrumental and platform events, up to 3% of measurements can be missing because of data generation problems at ground segment level: LRAC or PDHS level1 data generation problems or ingestion problems on F-PAC side.

4.2. 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. When the Land/sea radiometer flag is set to land over ocean, it means that the radiometer data is missing. The percentage of missing MWR corrections over ocean has been plotted in Figure 5. The radiometer unavailability is not constant: it is greater than 4% for cycles 14 to 19 and for cycles 58 and 60, and lower than 2% elsewhere.
During 2011, notably during cycles 101 and 102, some instrument anomaly prevent from the MWR radiometer correction:
- Cycle 101: 18 passes (252-269)
- Cycle 102: 72 passes (724 to 795)

4.3. Edited measurements

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

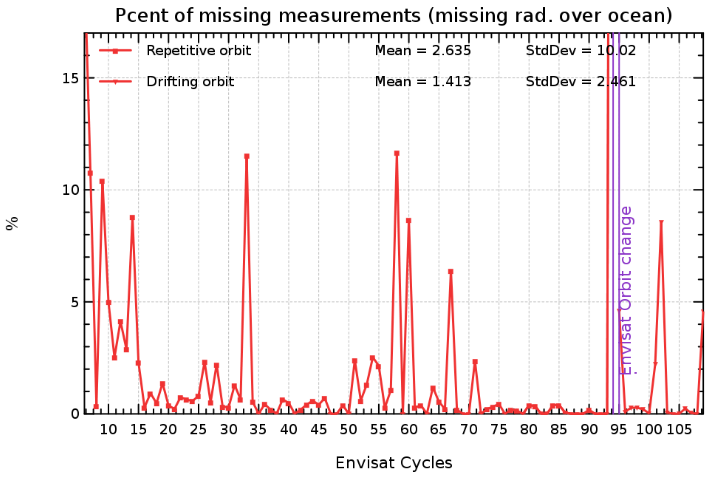

Figure 5: *Cycle per cycle percentages of missing MWR measurements*

4.3.1. Measurements impacted by Sea Ice

Since Envisat operates between 82N and 82S of latitude, sea ice detection is an important issue for oceanic applications. For the original GDR before reprocessing data, no ice flag is available in the Envisat products, but for reprocessed data, the developped method gives us a more severe flag than the one available in the product. This method enables to get rid of any spurious data during validation phase. A study performed during the validation phase showed that the combination of altimetric and radiometric criteria was particularly efficient to flag most of the data over ice. The method is described in detail in (Faugere et al, 2003 [39]). We employ the Peakiness parameter (Lillibridge et al, 2005 [62]) in conjunction with the MWR- ECMWF wet troposphere difference which appears to be a good means to complement the Peakiness parameter in all ice conditions.

The ratio of flagged measurements over ocean is plotted on Figure 6. For a more extensive comparison of this flag to the one included in the products, please see figure 57 in part **??**

In 2011, similarly to September 2007, a record-breaking minimum of flagged data for the Northern Hemisphere zone around cycles 61-63 see green curve Figure 6, due to a low ice extend record. This was observed by different Envisat instruments including its altimeter RA2. For the first time, an altimeter satellite could observe open ocean surfaces up to 82°N above North East Siberia during September-October 2007. Inaccurate Mean Sea Surface or tide models in this area might explain these low SLA performances. See further details on http://www.aviso.oceanobs.com/en/applications/glace/glaces-de-mer/l-etendue-des-glaces-de-l-arctique-vue-par-l-altimetre-d-envisat/index.html.

Note that similarly, in February 2006 and at the end of 2011, a record-breaking minimum of flagged data also occurred for the Southern Hemisphere zone around cycles 45 and 99, see blue curve Figure 6.

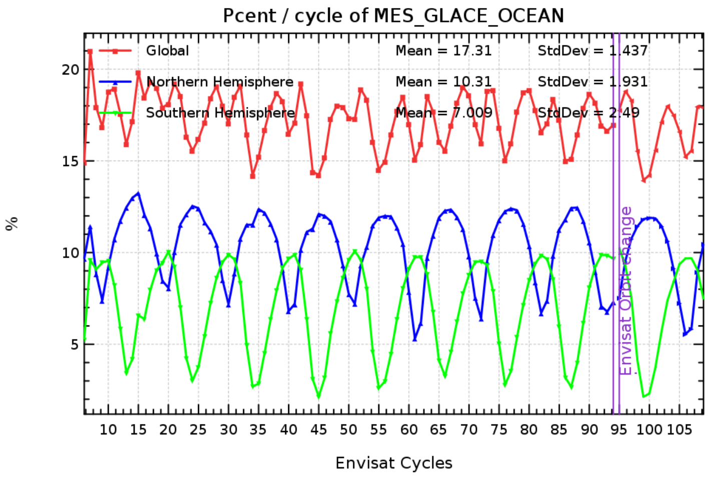

Figure 6: *% of edited points by sea ice flag over ocean*

4.3.2. Editing by thresholds

The second step of the editing procedure consists in using thresholds on several parameters. The minimum and maximum thresholds used in the routine quality assessment are given in table 1.

Parameter	Min thresholds	Max thresholds
Sea surface height (m)	−130	100
Variability relative to MSS (m)	−2	2
Number of 18Hz valid points	10	–
Std deviation of 18Hz range (m)	0	0.25
Off nadir angle from waveform (deg2)	−0.200	0.160
Dry troposphere correction (m)	−2.500	−1.900
Inverted barometer correction (m)	−2.000	2.000
MWR wet troposphere correction (m)	−0.500	0.001
Dual Ionosphere correction (m)	−0.200	−0.001
Significant waveheight (m)	0.0	11.0
Sea State Bias (m)	−0.5	0
		…/…

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Parameter	Min thresholds	Max thresholds
Backscatter coefficient (dB)	7	30
Ocean tide height (m)	−5	5
Long period tide height (m)	−0.500	0.500
Earth tide (m)	−1.000	1.000
Pole tide (m)	−5.000	5.000
RA2 wind speed (m/s)	0.000	30.000

Table 1: *E*diting criteria

The thresholds are maintained constant throughout the ENVISAT mission, so that monitoring the number of edited measurements allows a survey of data quality. The percentage of edited measurements over ocean for the main altimeter and radiometer parameters has been plotted in Figure 7.
For almost all the plots, Cycle 6 presents high values of edited percentage. This is probably due to the instrument tests (shift of band emission, see cyclic report...) and to the small amount of available data (only 242 passes produced over 1002). Similarly, cycles 95 and 96 have few data (orbit change maneuvers). This metric is not really relevant for these cycles.
The RMS of elementary measurements has the strongest ratio among the altimeter parameters, more than 1% in average with a slight annual oscillation probably due to sea state seasonal variations.
The number of elementary measurements 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.
The square of the off-nadir angle derived from waveforms leads to very stable editing ratio. Variations of this parameter can reveal actual platform mispointing, if any, but can also reveal waveform contamination by rain or by sea-ice. It is indeed computed from the slope of the waveform trailing edge. No seasonal signal is visible which may prove that the sea-ice detection method is efficient. Note also a small decrease of the value after the orbit shift, as already reported in the commissionning phase and stressed at ESA QWG Meetings 16 and 17.
The dual frequency 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).
The editing on Ku-band SWH and sigma0 threshold are stable, though slightly higher than for historical data processing because the null SWH class now includes more data.
Concerning MWR ratios, it presents a significant annual signal. 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 8.5..

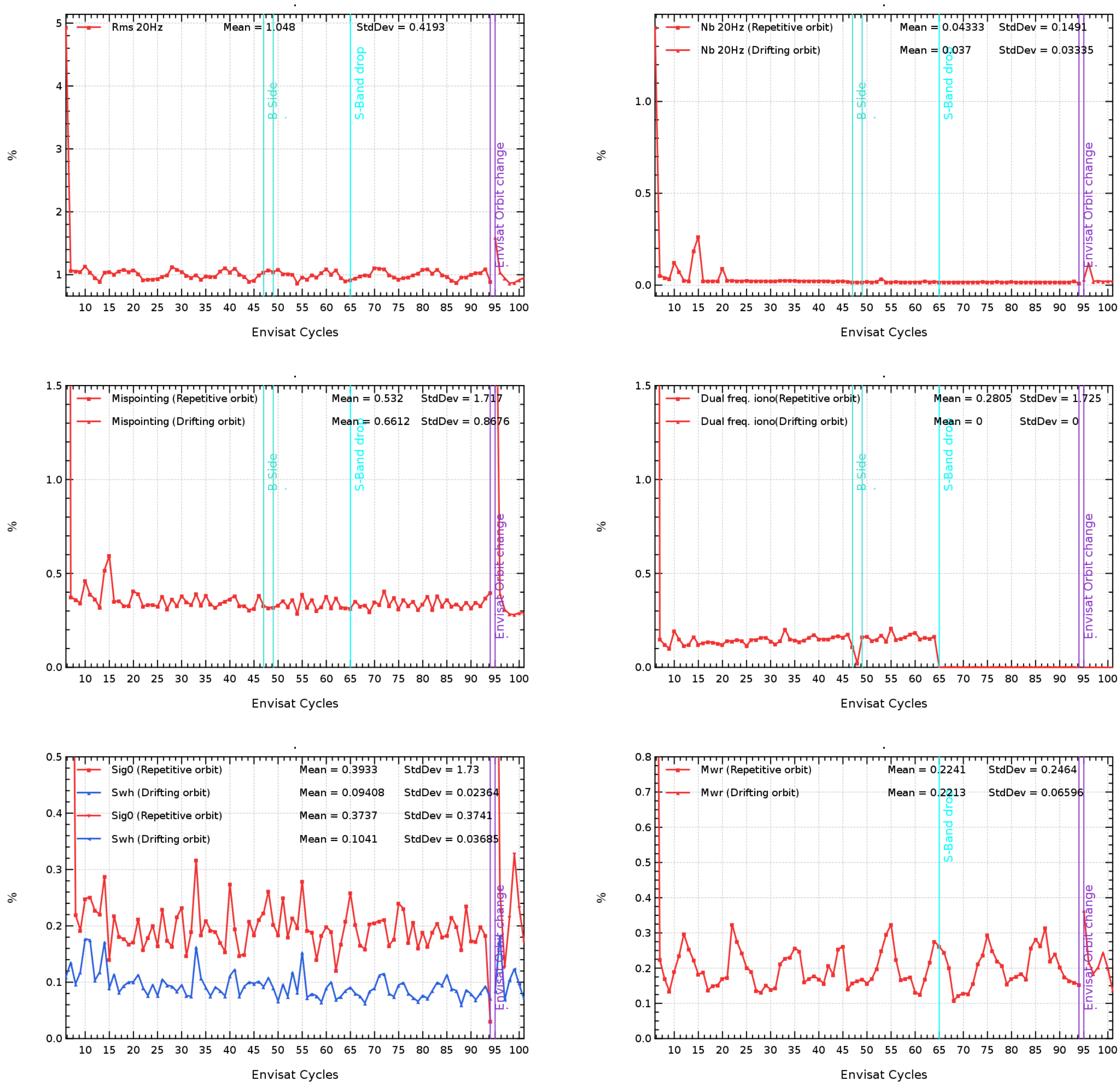

Figure 7: *Cycle per cycle percentages of edited measurements by the main Envisat altimeter and radiometer parameters:* ***Top-Left)*** *Rms of 20 Hz range measurements > 25 cm,* ***Top-Right)*** *Number of 20-Hz range measurements < 10,* ***Middle-Left)*** *Square of off-nadir angle (from waveforms) out of the [-0.2 deg2, 0.16 deg2] range,* ***Middle-Right)*** *Dual frequency ionosphere correction out of [-40 , 4 cm],* ***Bot-Left)****Ku-band Significant wave height greater than 11 m, Ku band backscatter coefficient out of the [7 dB, 30 dB] range,* ***Bot-Right)*** *MWR wet troposphere correction out of the [-50 cm, -0.1 cm] range.*

4.3.3. Editing on SLA

It has been necessary to apply additional editing criteria on SSH-MSS differences in order to remove remaining spurious data. The first criterion consists in removing measurements with SSH-MSS greater than 2m. The second criterion was necessary to detect measurements impacted

by maneuvers. Maneuvers are necessary to compensate the effect of gravitational forces but can have a strong impact on the orbit quality. Two types of maneuvers are operated to maintain the satellite ground track within the +/-1km deadband (and +/-200m after cycle 54, see 8) around the reference ground track: in-plane maneuvers, every 30-50 days, which only impact the altitude of the satellite and out-of-plane maneuvers, three times a year, to control the inclination of the satellite (Rudolph et al., 2005). The out-of-plane maneuvers are the most problematic for the orbit computation. The second criterion consists in testing the mean and standard deviation of the SSH-MSS over each entire pass. If one of the two values, computed on a selected dataset, is abnormally high, then the entire pass is edited.
Note that the figure 8) could not be completed for the drifting phase due to the method based on a theoretical track (which does not exist anymore).

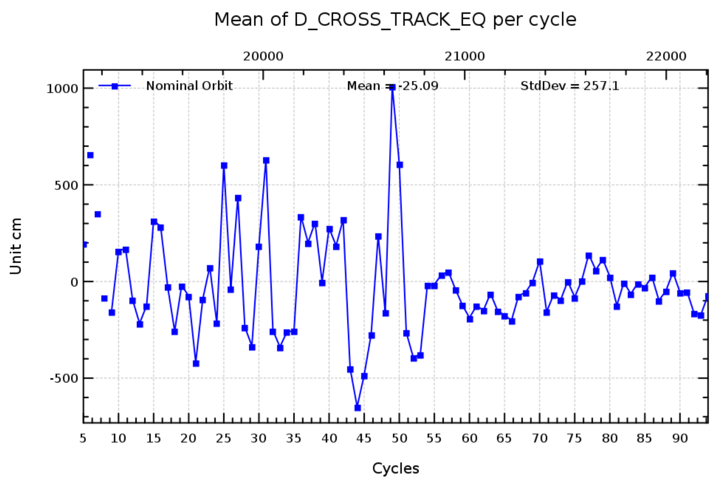

Figure 8: *Cross track deadband measured at equator by comparison to a theoretical track before the drifting phase.*

A specific study has been performed to determine how to compute the statistics, and what threshold should be applied. The statistics have to be computed on very stable area. The criteria for selecting the area and the thresholds are:

- The latitude: the range value can be degraded near the ice, despite the use of the ice flag. Moreover, the MSS is less accurate over 66 $^{\circ}$, as it has been computed without Topex data.
- The oceanic variability: the standard deviation of SLA can be very high because of the mesoscale variability. Areas with high oceanic variability have to be removed to detect the abnormally high standard deviation.
- The bathymetry and distance from the coast: A lot of corrections (tides for example) are less accurate in low bathymetry areas and near the coast (Japan sea).
- The sample: The statistic have to be computed on a significant number of points

All those criteria have been tested and combined as part as a specific study in a previous yearly report. The conclusion is that two criteria are needed:

1st criteria:
for small portion of pass (less than 200 points) the sample is not big enough to compute reliable statistic. The selection must not be severe: Selected areas: |latitude|<66 °, variability<30cm, bathymetry>1000m, distance to coast>100km Threshold: 30 cm on mean and standard deviation
2nd criteria:
for other passes Selected areas: |latitude|<66 °, variability<10cm, bathymetry>1000m, distance to coast>100km Threshold: 15 cm on mean and standard deviation

The percentage of edited measurements over ocean on these criteria has been plotted in Figure 9. On cycles 11, 12, 21 and 26, several full passes have been edited because of bad orbit quality related to out-of-plane maneuver or lack of Doris data (cycle 11).The special operation on RA-2 Chirp Bandwidth mentioned previously impacted the SSH editing ratio on cycle 47. Most of the data edited on this criteria are due to the jumps noticed on reprocessed USO correction (several hundreds of meters) and identified under the anomaly report number [IDEAS-PR-11-05520].
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.

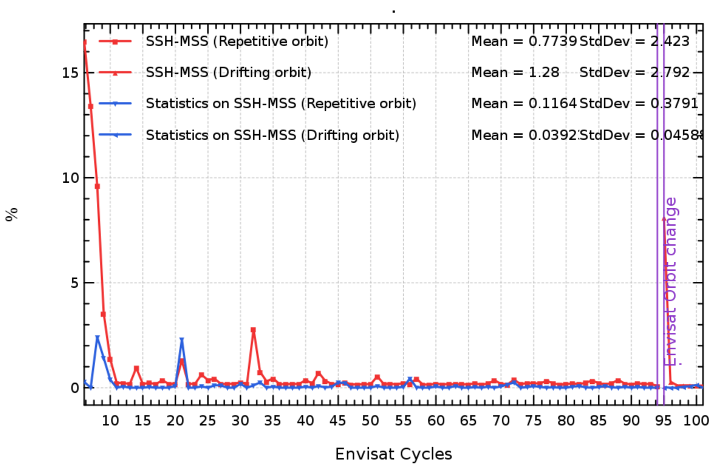

Figure 9: *SSH-MSS out of the [-2, 2m] and edited using thresholds on the mean and standard deviation of SSH-MSS on each pass*

As plotted above, some cycles are particularly impacted by a substantial editing on the two criterion previously defined. For cycle 6 to 9, different tunnings performed during this calibration phase have impacted the homogeneity of processing.
During **cycle 6**, 26 tracks are edited on the SLA criterion, on only 242 workable passes (760 tracks missing). Data was impacted by a DORIS event, orbit was extrapolated for this period with degraded performances. The **cycle 7** was impacted by some bandwidth shift tests, on 2002/06/18 and between 2002/06/26 and 2002/06/29 (20MHz for these two periods, 22 tracks rejected). For this cycle 95 tracks are impacted by wrong USO correction values too.
For **cycles 8 and 9**, respectively 90 and 33 tracks are rejected on this two SLA criterion, because of wrong USO correction.

For **cycle 14**, 6 passes (from 20/03/2003 11:07:17 to 20/03/2003 16:08:08) are entirely edited on SLA threshold. For these passes, USO correction was found to reach abnormal values (more than 150m) directly impacting the SLA.
Cycle 21 is impacted by a combination of events; 10 passes between 2003/10/27 and 2003/10/30 are impacted by short period of wrong USO correction applied to the range. During this cycle, high values of SLA were also observed consecutively to two altimeter restarts [RS/WT/INT] (pass 242 to 247, and pass 366 to 389). The SLA during instrument heating seemed to be badly corrected by the IPF USO correction, whereas the CMA USO correction looked correct for these high values. Finally, this cycle is impacted by an exceptionally high solar activity (two strong magnetic storms on 2003/10/30 and 2003/11/21), degrading the orbit quality and then the SLA, which is rejected for 16 tracks. For cycle 21, the data rejected on SLA criterion approximates 3.5%.
During **cycle 32**, 25 tracks are entirely rejected by SLA values. These passes are impacted by jumps of several meters visible on the SLA, caused by wrong USO correction periods. This cycle is the most impacted by SLA values out of thresholds on the whole reprocessing period caused by wrong USO correction, except cycles 6 to 9.

Note that the correction developed for expertise in CMA is not affected by these jumps. Yet the impact is rather weak: on the whole mission, around 300 tracks, were impacted by this anomaly (including around 200 before cycle 10).

5. Long term monitoring of altimeter and radiometer parameters

All GDR fields are systematically checked and carefully monitored as part of the Envisat routine calibration and validation tasks. However, only the main Ku-band parameters are presented here, as they are the most significant in terms of data quality and instrumental stability. Furthermore, all statistics are computed on valid ocean datasets after the editing procedure.

5.1. Number and standard deviation of 20Hz elementary Ku-Band data

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 10. These two parameters are nearly constant, which provides an indication of the RA-2 altimeter stability. The mean number of Ku 20Hz values over one cycle is about 19.97. This value is very high compared to other altimeters. It is almost not disturbed in wet areas or near the coast. The two drops on the Ku-band on cycles 14, 15 and 20 are due to wrong setting of the RA-2 just after recovery. A slight seasonal signal is visible on the mean RMS of Ku 20Hz. Higher values correspond to higher waves occurring during the austral winter. The mean value is about 9.0 cm. This value represents a rough estimation of the 20 Hz altimeter noise (Zanifé et al. 2003 [98], Vincent et al. 2003a [96]). Assuming that the 20Hz measurements have uncorrelated noise, it corresponds to a noise of about 2 cm at 1Hz. It is consistent with the expected noise values.

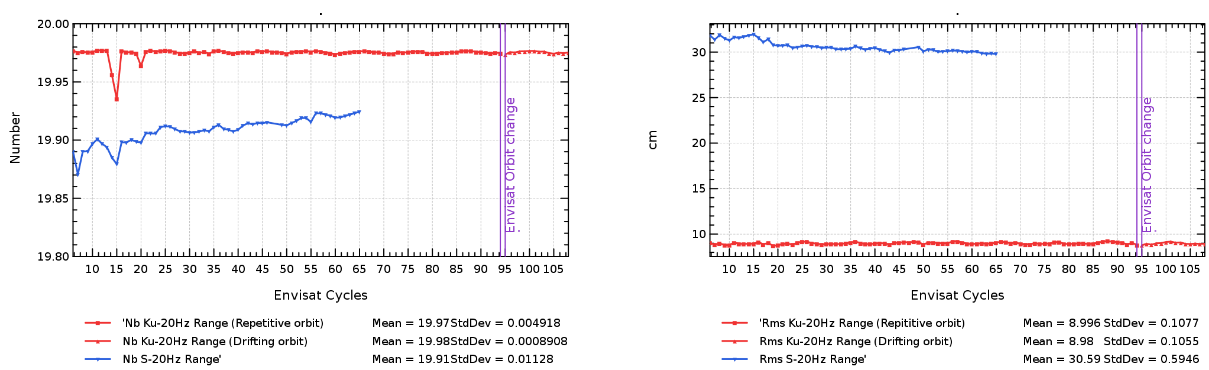

Figure 10: ***left****) Mean per cycle of the number of 20 Hz elementary range measurements used to compute 1 Hz range.* ***right****) Mean per cycle of the standard deviation of 20 Hz measurements.*

The corresponding S-Band parameters have a less stable behaviour. 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?).

The histogram of RMS of Ku Range on cycle 107 is plotted in figure 11.

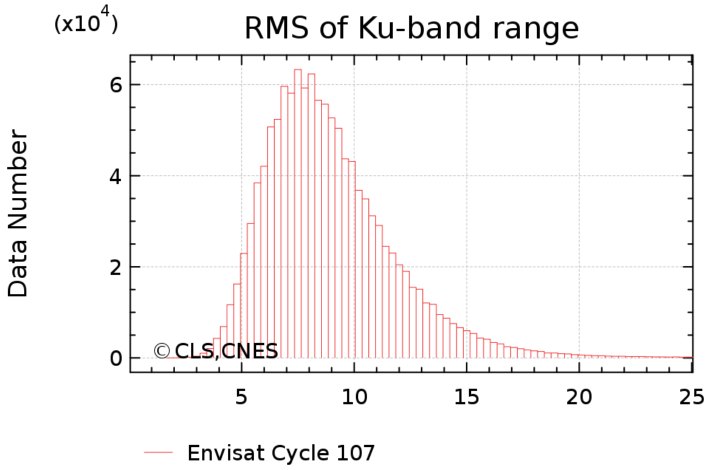

Figure 11: *Histogram of RMS of Ku range (cm). Cycle 107 .*

5.2. 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 12. The mean value presents a slight decreasing trend up to cycle 65 around a value of 0.005 deg2. The mean value observed during this period is not significant in terms of actual platform mispointing. This is due to the way the slope of the waveform trailing edge is computed.
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 (cf. details in part 3.1.).
At the end of the period, as noticed during the mini commissionning phase and QWG 17 the mispointing stabilises at a lower value than before the orbit change.

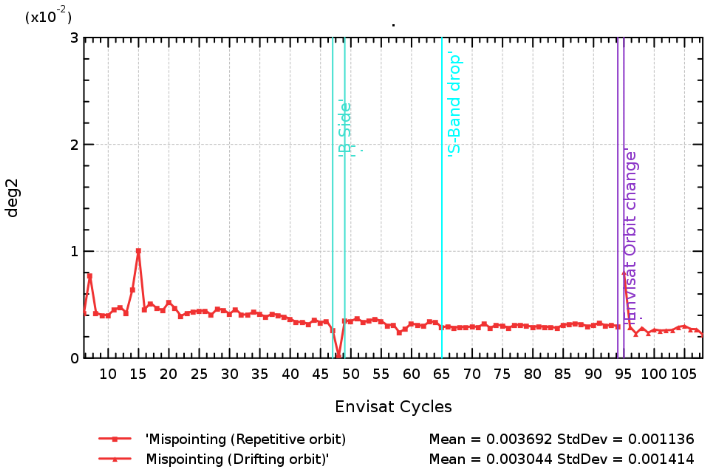

Figure 12: *Mean per cycle of the square of the off-nadir angle deduced from waveforms (deg^2).*

The histogram of the squared mispointing is plotted in figure 13.

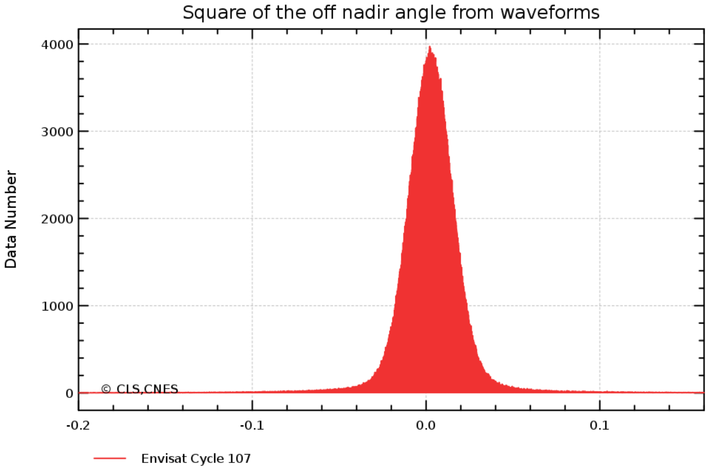

Figure 13: *Histogram of off-nadir angle from waveforms (deg^2). Cycle 107 .*

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5.3. Significant Wave Height

The cycle by cycle mean and standard deviation of Ku and S-Band SWH are also plotted in figure 14. Its monitoring reflects sea state variations (with a clear annual signal). The mean value of Ku SWH is 2.5 m. The S-Band mean SWH is drifting and rather lower (around 2m). The cycle by cycle mean of Envisat-Jason-1 differences is plotted in Figure 14.
These differences are quite stable (or slightly drifting before cycle 65) and centered around 0 since the V2.1 evolution on Envisat side (change of Sigmap value). Note that a study was performed on the SWH to understand the behavior of small waves, considered, by some users as degraded (see 8.6.).
As for range parameters, some strange behaviours on S-Band SWH are also noticed (see Figure 14): drifts on the standard deviation notably.

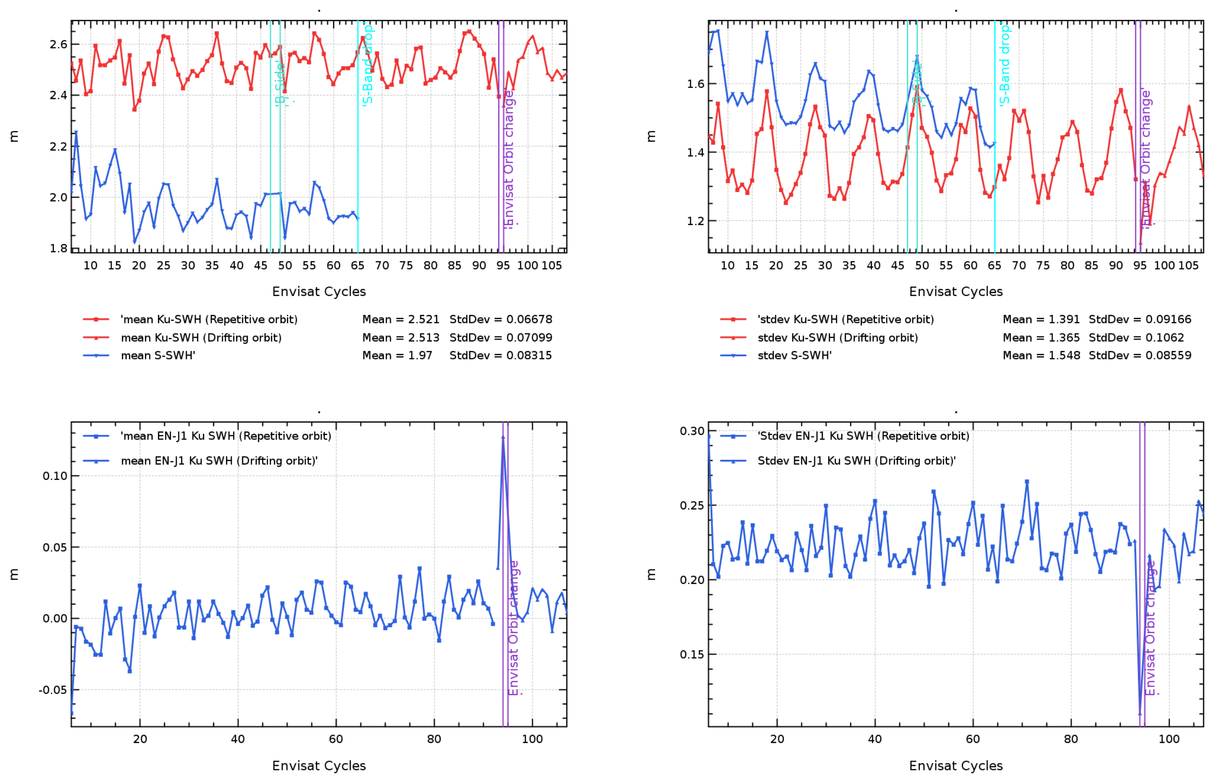

Figure 14: *Global statistics (m) of Envisat Ku and S SWH* ***top)*** *Mean and Standard deviation.* ***bottom)*** *Mean Envisat-Jason-1 Ku SWH differences at 3h EN/J1 crossovers.*

The histograms of Ku SWH is plotted in figure 15.

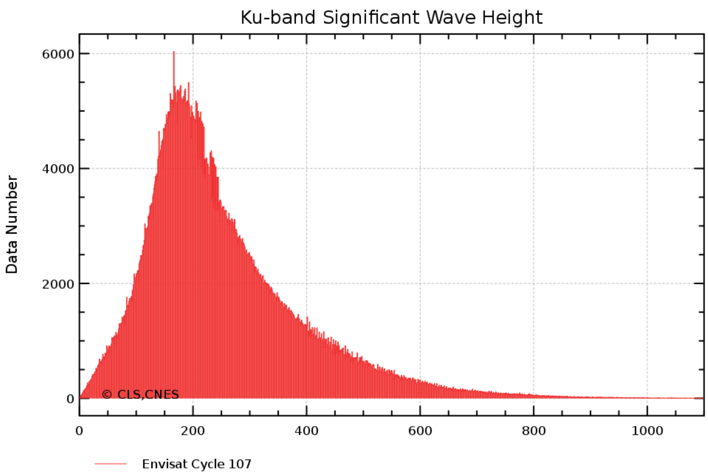

Figure 15: *Histogram of Ku SWH (m) Cycle 107 .*

5.4. Backscatter coefficient

The cycle by cycle mean and standard deviation Ku and S-Band Sigma0 are plotted in Figure 17. Note that a -3.5 dB bias has been applied (Roca et al., 2003 [79]) on the Ku-band Sigma0 in order to be compliant with the wind speed model (Witter and Chelton, 1991 [97]). The mean values in Ku band are stable, around 11 dB. The mean difference between Envisat and Jason-1 Ku-band Sigma0 is -3 dB. This high value is explained by the fact that, Envisat Sigma0 value has been biased and not Jason-1. This mean difference has increased by 4.10-2dB/year between cycles 38 and 140 Jason-1 (corresponding to cycle 13 to 41 of Envisat) and remains constant afterwards. This drift was checked to be unchanged after correcting it from the atmospheric attenuation computed with a homogeneous reprocessed set of brightness temperature. These sigma0 differences obviously impact the wind consistency between the two satellites. Note that the wind from the ECMWF model, which does not assimilate Jason-1 data, shows a very good agreement with the Jason-1 wind with a slope close to 6 cm/s/yr whereas Envisat wind trend is much lower, 1.3cm/s/year (see [4]. This trend difference could mean that the Envisat wind slightly drifts. Yet caution must be brought to this as Envisat is rather homogeneous to ERA-Interim reprocessed data, ECMWF solution free of most jumps and discontinuities seen in the operational model... This potential trend, though slight, has to be closely monitored. The global stability of this parameter was extensively studied in Ablain et al. 2012 submitted in Marine Geodesy (see [5]) and summurized in Jason-1 yearly report (available on Aviso web site).

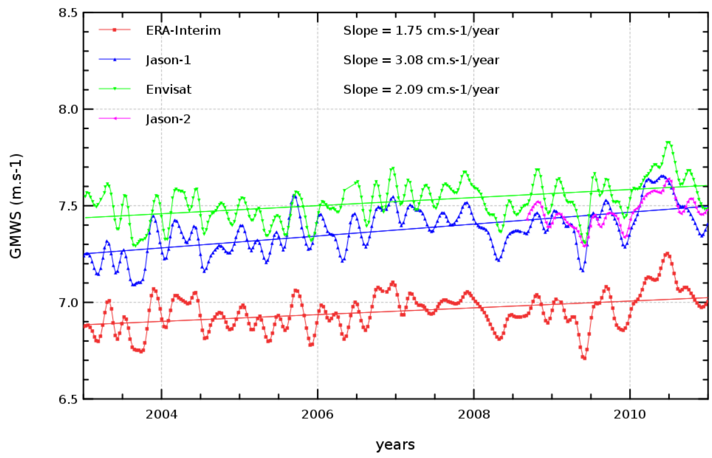

Figure 16: *Wind speed from different sources (EN, J1, ECMWF, NCEP).*

Histograms of Ku Sigma0 is plotted in figure 18. The Ku Sigma0 histogram has a good shape.

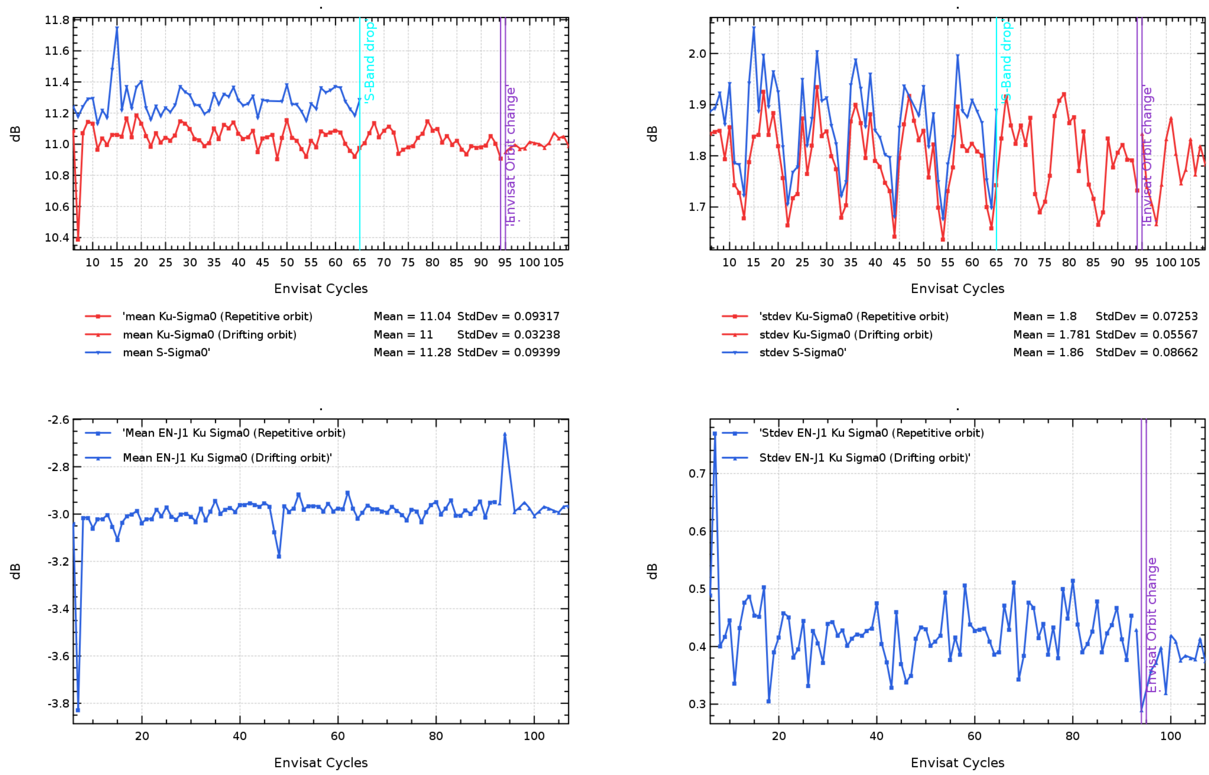

Figure 17: *Global statistics (dB) of* ***top****) Envisat Ku and S Sigma0 Mean and Standard deviation.* ***middle****) Mean Envisat-Jason-1 Ku Sigma0 differences at 3h EN/J1 crossovers.*

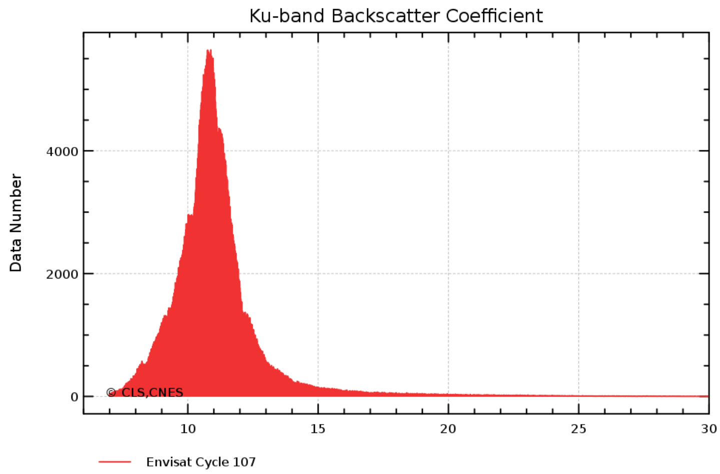

Figure 18: *Histogram of Ku Sigma0 (dB). Cycle 107 .*

5.5. Dual frequency ionosphere correction

As performed on TOPEX (Le Traon et al. 1994 [58]) and Jason-1 (Chambers et al. 2002 [27]) it is recommended to filter dual frequency ionosphere correction on each altimeter dataset to reduce noise. A 300-km low pass filter is thus applied along track on the dual frequency ionosphere correction. As previously mentioned, the JPL GIM ionosphere corrections are computed to assess the dual frequency altimeter based ionosphere correction. After the S-Band loss of Envisat (January 17th 2008), it was prefered to the DORIS correction also available to replace the bifrequency correction for its better performences. The same GIM model is used to compute the GIM corrections on Envisat and Jason-1. The quality of Envisat's ionosphere correction can thus be assessed by monitoring the dual-frequency -GIM based ionosphere correction on Jason-1. The cycle by cycle mean of dual frequency and JPL GIM ionosphere correction are also plotted in figure 19. Different trends are observed on the two curves.

The cycle by cycle mean of dual frequency and JPL GIM ionosphere correction are plotted in figure 19. The mean value of the two corrections clearly follows the solar activity periods (11 year solar cycle): decreasing from the beginning of Envisat mission to 2008 and increases again since late 2009, after a short stable period. The mean differences (GIM-Dual frequency), plotted in figure 19, is surprisingly stable around -0.8 cm whereas Jason-1 GIM-Dual presents a bigger bias for higher solar activities. This bias increasing for high values of ionospheric correction is also noticed, on Envisat, when comparing ascending (night time) and descending passes (in the daytime). This would suggest that the beginning of the mission is affected by an error which should be further investigated.
The standard deviation of the difference is plotted in figure 19. Here as well, the first year seams to have a chaotic behavior compared to Jason-1. Notice that, in this reprocessed series, a homogeneous sea state bias (SSB) has been used to correct the Ku and S-Band Ranges (Labroue 2004 [53]).

Concerning the discrepancies between both missions, note that, in terms of noise, the higher noise for Jason-1 is due to a higher noise in the C band (used for Jason-1 bifrequency ionosphere) than in S-Band (used for Envisat one). The filtering step applied on both ionospheres from the products enable to have comparable noise level for both missions. In terms of bias, differences are likely due to the difference of altitude for both missions, but the stability of Envisat ionosphere difference (Bifrequency-GIM) can also be seen as an anomaly at the beginning of Envisat mission (before cycle 22), reducing the dependency between the absolute value and the bias on this correction (observed on Jason-1). This would deserve more investigation.

This year, the increasing solar activity began to have an impact on the data quality. The mean difference of SSH at cross-over starts to be polluted by the signature of the ionospheric signal. A warning was sent to users and to the scientific community in that sense to try to find solution of improvement for this model, see 8.4..

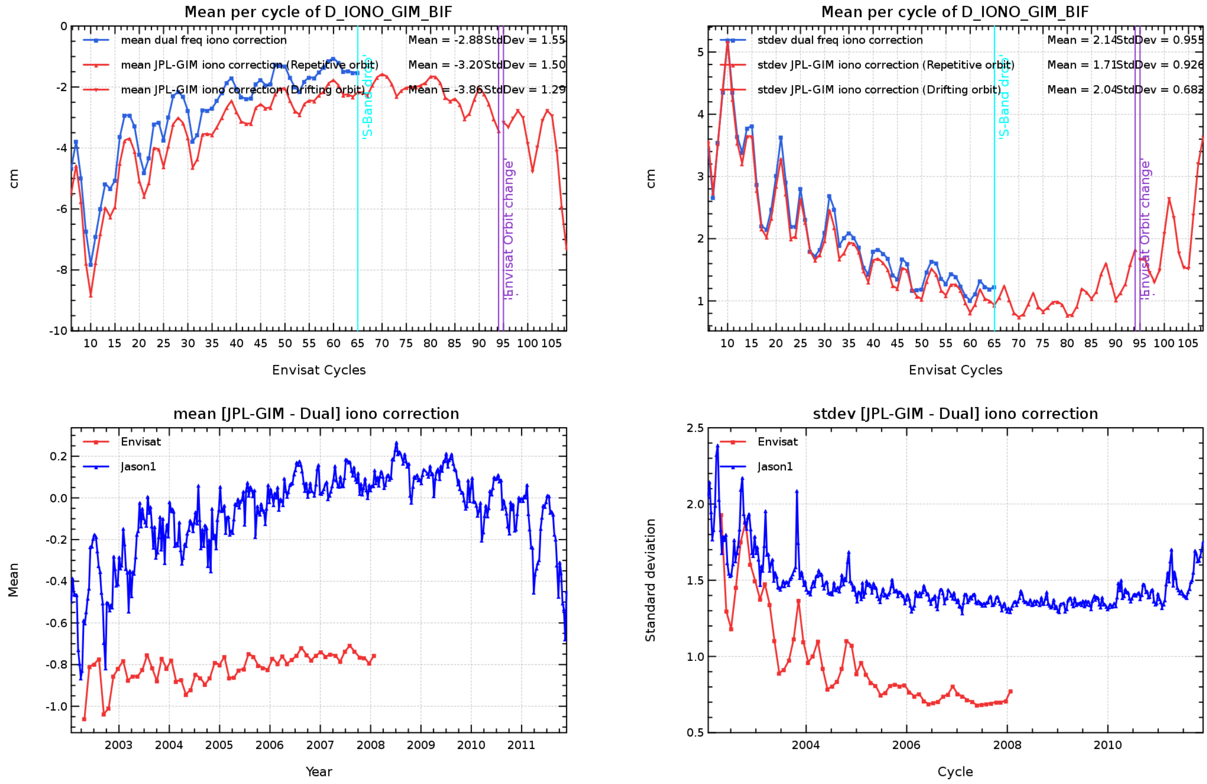

Figure 19: *Comparison of global statistics of Envisat dual-frequency and JPL-GIM ionosphere corrections (cm).* ***top****) Mean and standard deviation per cycle of Dual Frequency and GIM correction.* ***bot****) Mean and standard deviation of the differences for Envisat and Jason-1*

5.6. MWR wet troposphere correction

A neural network formulation is used in the inversion algorithm retrieving the wet troposphere correction from the measured brightness temperatures (Obligis et al., 2005 [72]). As an example, the scatter plot of MWR correction according to ECMWF model for cycle 107 is given in figure 20.

Since the beginning of the mission, the instrumental parameters at 36.5 GHz have been drifting and investigations are in progress to identify the source for these drifts. In particular, different behavior is observed depending on the brightness temperature values. A complete monitoring of all the radiometer parameters is available in the cyclic Envisat Microwave Radiometer Assessment available at http://earth.esa.int/pcs/envisat/mwr/reports/ ([76]).
Mean and standard deviation of Radiometric correction for Jason1, Jason2 and Envisat is plotted in figure 21 (top). It is also completed by (MWR-ECMWF model) monitoring, enlighting finer jumps and discrepancies in figure 21 (bottom). This difference is not really stable, though the global mean remains small. An annual signal of about 1.5mm of amplitude can be seen. Successive jumps on the ECMWF side (marked out by vertical lines on the plots (see ECMWF web site [32])) do have an impact on the data but this signal seams to be a difference of behavior between model and radiometer in some conditions. This signal becomes really clear and uncorrelated to the ECMWF updates when separating Ascending and Descending tracks (see Yearly report 2009).

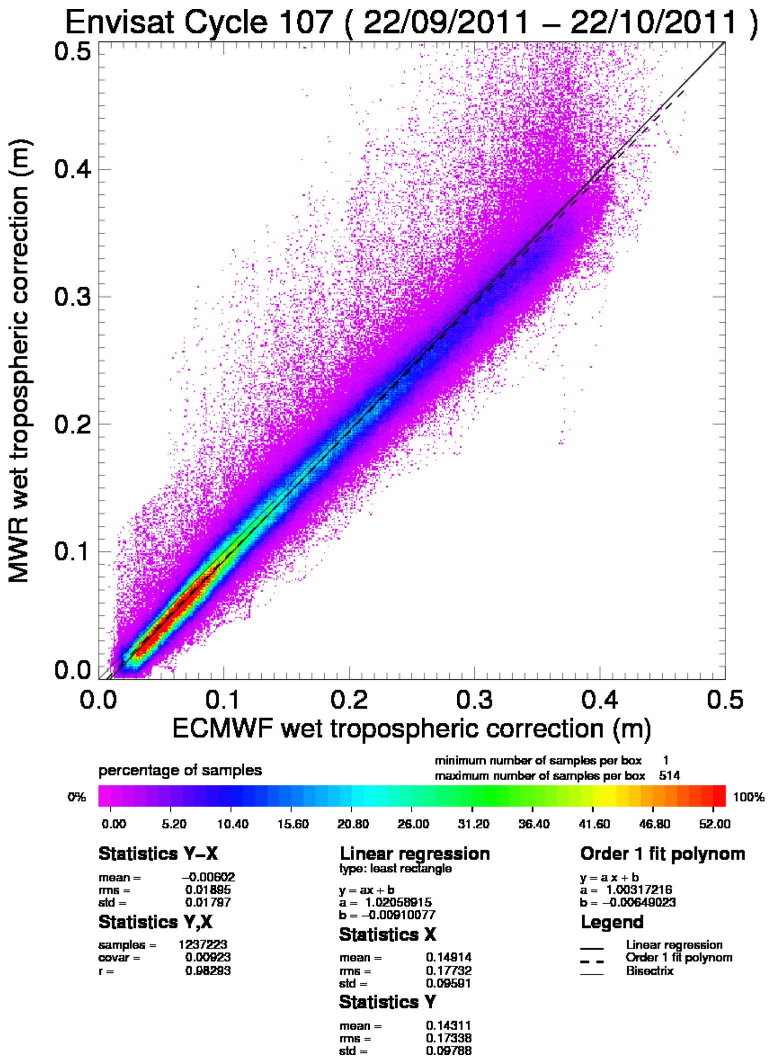

Figure 20: *Scatter plot of MWR correction according to ECMWF model (m)*

Furthermore, selections per values of wet troposphere also enlights this annual signal. This signal is still under investigations.
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 65 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, it could also be due to a larger amount of data taken into account at the end of the mission (see part 4.3.3..)
Note that in the version V2.1 this metric globally increased. This is under investigation.

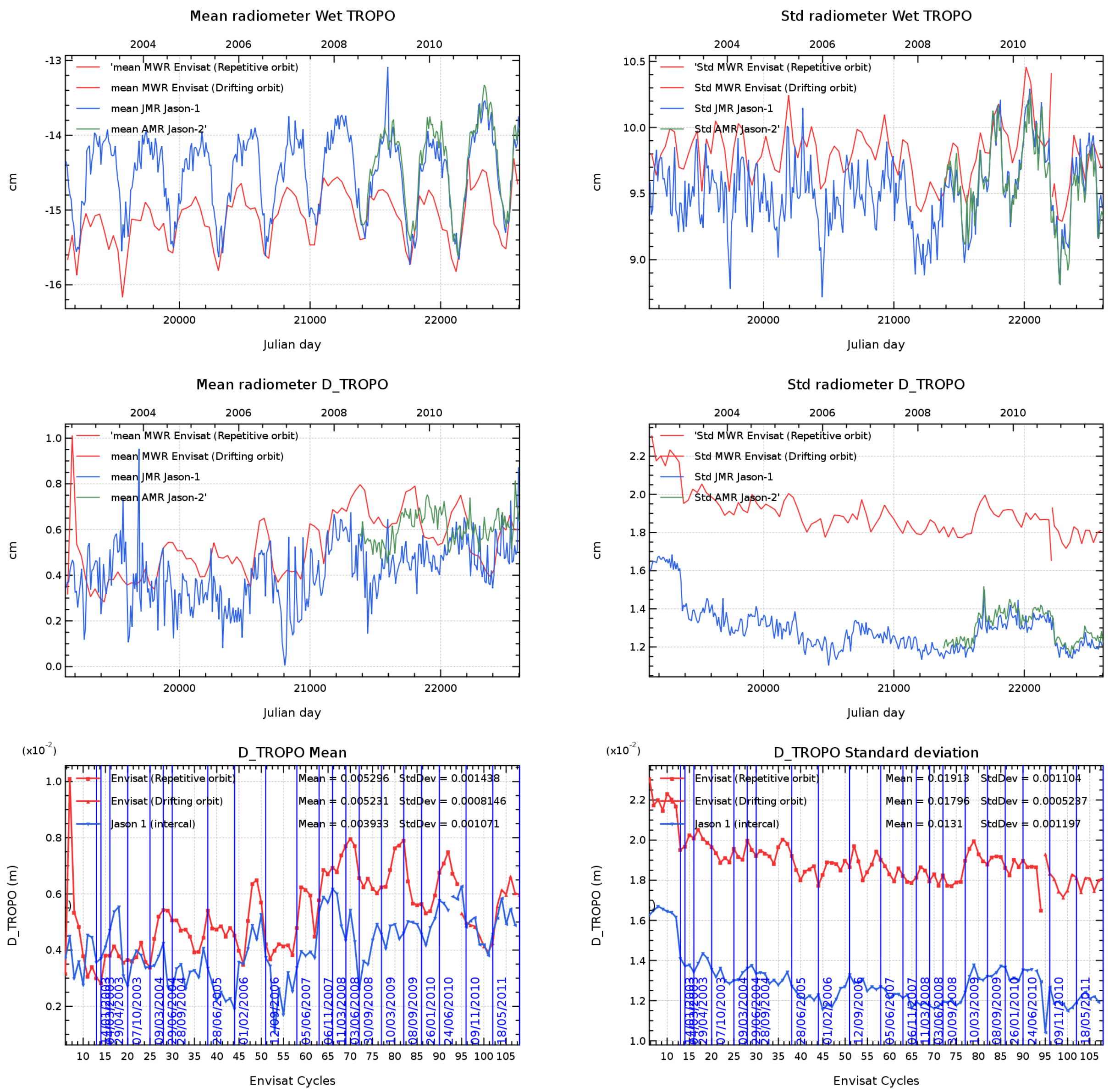

Figure 21: *Comparison of global statistics of Envisat MWR and ECMWF wet troposphere corrections (cm).* ***top****) Mean and standard deviation per cycle of MWR, JMR and AMR corrections* ***mid.****) Mean and standard deviation per cycle of the differences versus ECMWF model.****bot****) Mean and standard deviation of the differences versus ECMWF model. Vertical lines represent the major events.*

6. Sea Surface Height performance assessment

One of the main objectives of the Calibration and Validation activities is to assess the performance of the whole altimeter system. This means that the quality of each parameter of the product is evaluated, in particular if it is likely to be used in the Sea Surface Height (SSH) computations. Conventional tools like crossover differences and repeat-track analyses are systematically used in order to monitor the quality of the system.

6.1. SSH definition

The standard SSH calculation for Envisat is defined below.

$$SSH = Orbit - Altimeter\ Range - \sum_{i=1}^{n} Correction_i$$

$$\begin{aligned}
\sum_{i=1}^{n} Correction_i \quad = \quad & Dry\, troposphere\, correction : new\, S1\, and S2\, atmospheric\, tides\, applied \\
+ \quad & Combined\, atmospheric\, correction :\ MOG2D\, and\, inverse\, barometer \\
+ \quad & Radiometer\, wet\, troposphere\, correction \\
+ \quad & Filtered\, dual\, frequency\, ionospheric\, correction\, /GIM\, model\, after\, cycle\, 64 \\
+ \quad & Non\, parametric\, sea\, state\, bias\, correction \\
+ \quad & Geocentric\, ocean\, tide\, height,\ GOT\, 4.7 : is\, applied \\
+ \quad & Solid\, earth\, tide\, height \\
+ \quad & Geocentric\, pole\, tide\, height
\end{aligned}$$

As said in 3.2.1., the plots presented here concern the 2011 reprocessed data series, homogeneous in V2.1 standard.

6.2. Single crossover mean

SSH crossover differences are computed on a one-cycle basis, with a maximum time lag of 10 days, in order to reduce the impact of ocean variability which is a source of error in the performance estimation. The mean of crossover differences represents the average of SSH differences between ascending and descending passes. This difference can reflect orbit errors or errors in geophysical corrections. The fact that Envisat is Sun-synchronous can play a role since the ascending passes and descending passes respectively cross the equator at 10pm local time and 10am local time. Thus all the parameters with a daily cycle can induce errors resulting in ascending/descending differences. The error observed at crossovers can be split into two types: the time invariant errors and the time varying errors.

The time invariant geographic errors and the impact of different corrections was extensively studied in the 2008 yearly report ([11]).
More recent studies performed in 2009 had shown that using homogeneous GDR-C orbits homogenized a lot the crossovers. The residual East West bias observed on figure 22 on the comparisons between Envisat and Jason-1. This plot represents the average per year of SSH

difference (corrected with radiometer wet tropospheric correction) at dual cross overs EN-J1. This is also confirmed by figure 23 concerning the comparison Envisat and Jason-2. This bias, increasing in time, was shown to be reduced when using the GDR-D standards. This was studied this year and summarized in part 8.1..

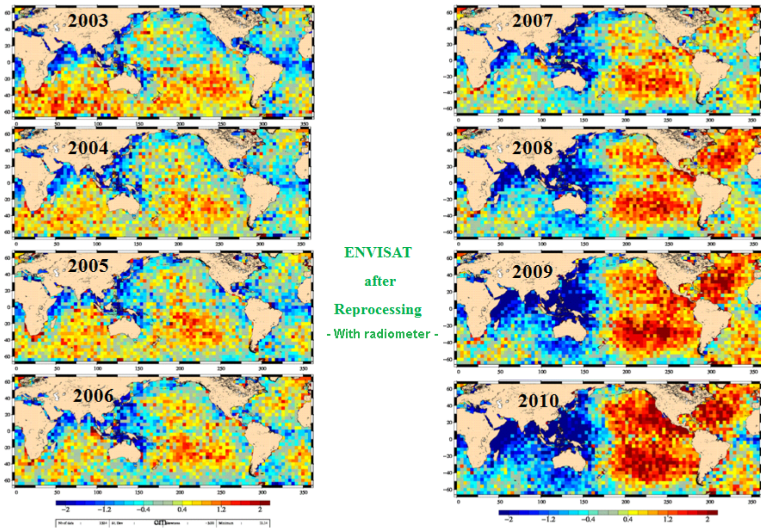

Figure 22: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centered (cm). A East West bias increasing in time is observed. After reprocessing. MWR Wet tropospheric correction is used.*

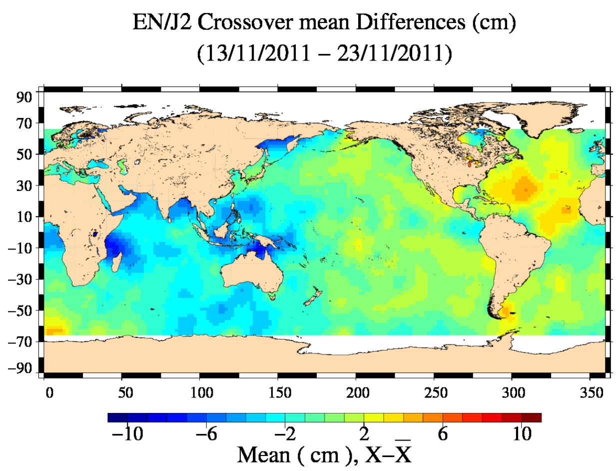

Figure 23: *Dual Crossover mean differences between Envisat and Jason-2 over Jason2 Cycle 124 (cm). The same East West bias is observed.*

Besides the systematic East/West errors, a time varying error can also be observed at crossovers. The cyclic mean ascending-descending SSH differences at crossovers shows this error in Figure 24. The cyclic mean crossover differences have been plotted in three different configurations: full data set, deep ocean data, and deep ocean data with low variability, and excluding high latitudes. A strong annual signal (decreased by reprocessing but still present) is evidenced on the 3 curves. Its

amplitude is approximately 1 cm and the mean value, slightly negative.
Note that for the very first cycles (before cycle 10) a bias is noticed, probably in relation with the small amount of valid data for these cycles.

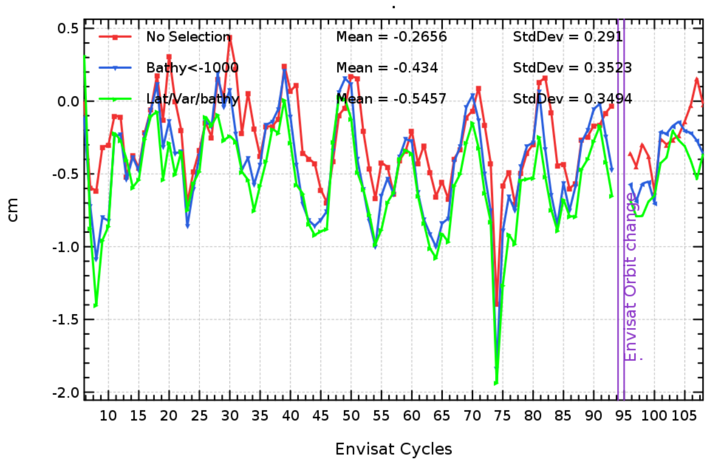

Figure 24: *Time varying crossover mean differences (cm). Cycle per cycle Envisat crossover mean differences. An annual cycle is clearly visible. Blue: shallow waters (1000 m) are excluded. Green: shallow waters excluded, latitude within [-50S, +50N], high ocean variability areas excluded*

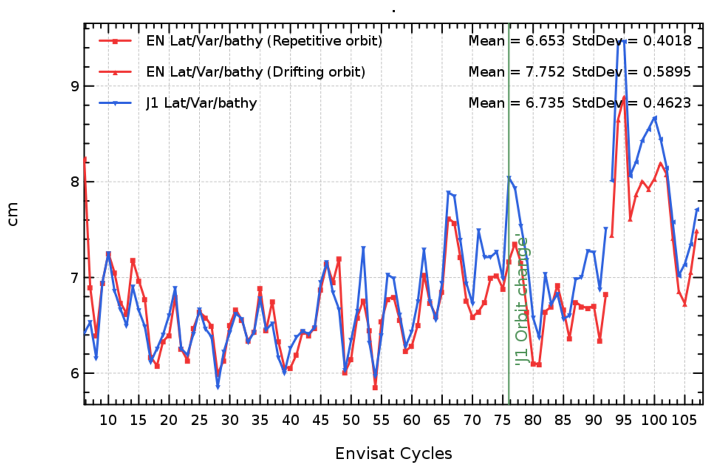

Figure 25: *Standard deviation of along track SLA (m), shallow waters excluded, latitude within [-50S, +50N], high ocean variability areas excluded*

Figure 25 is another way to show that both altimeters have very similar performances. Their along track SLA standard deviation is similar, around 6.7cm before the Envisat orbit change and slightly higher (7.7cm instead of 6.7cm) for the Envisat drifting phase.
Note that for this plot, average per box are performed before to compute the statistics. When performed along track, the statistics are different and Envisat metrics are below Jason-1. But this was an artifact due to the different geographic density of points, which is over estimated at high latitudes for Jason-1 compared to Envisat. The effect on the data of this additional step is detailed in part 8.3..

Concerning the global evolution of this metric, we observe a degradation (both on Jason-1 and Envisat) at the end of the period. This is probably due to the fact that the SLA, referenced to the MSS_CLS01 is now getting further and further to the reference period and therefore includes some long term inter annual variability. This should be investigated further.

The effect of the drifting orbit on Envisat is very weak and can hardly be evidenced on plot 25. It can however be evidenced when filtering some wavelength only as shown on figure 26.

Figure 27 shows a global bias of 35cm between both mission, in agreement with the absolute calibration studies (see for instance Bonnefond et al. OSTST). A rather good consistency is observed on the whole period if the radiometer or the model is used even if some discrepancies are observed.
In terms of trend and stability however, a negative drift of around 2cm concerning EN-J1 over the whole period is observed. This drift is also visible on the comparison to Jason-2 (see 27 right) but only for part of the time series as the cross calibration with Envisat reprocessed data are not up to date yet. This effect was shown to be related to the PTR instrumental correction accounted for in the reprocessed data with a more accurate resolution but applied with a wrong sign on Envisat side.
This fact was evidenced and detailed in a climate orientated study and a paper submitted this year (detailed in 8.1.) and consists in a major step towards the understanding of Envisat long

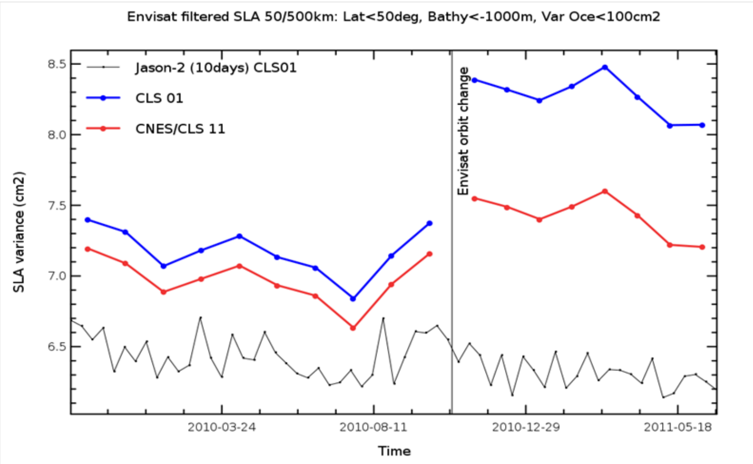

Figure 26: *Impact of the SLA reference out of the repeat track on the wavelength between 50km and 500km.*

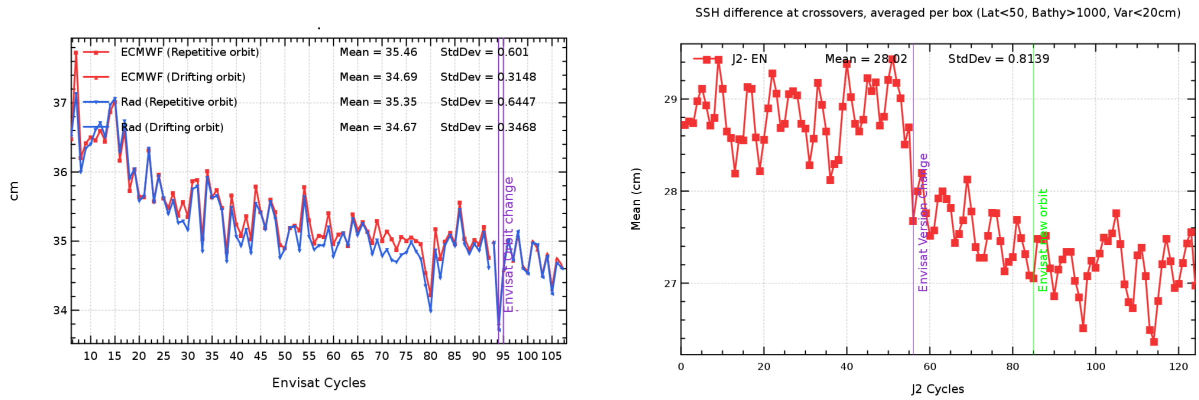

Figure 27: *Mean EN-J1 (left) and EN-J2 (right, Warning: for this plot Envisat data BEFORE REPROCESSING are used!) SSH differences at dual crossovers (cm) on global ocean*

term stability.
Note as well that the drift is increased for the first part of the mission (before 2004, cycle 22). This point is also identified to be the next challenge to be taken up for MSL purposes.

6.3. Variance at crossovers

The variance of crossover differences conventionally gives an estimate of the overall altimeter system performance. Indeed, it gathers error sources coming from orbit, geophysical corrections, instrumental noise, and part of the ocean variability. The standard deviation of the Envisat SSH crossover differences has been plotted in Figure 28, depending on three data selection criteria. Without any selection, a seasonal signal is observed because variations in sea ice coverage induce changes in ocean sampling by altimeter measurements. When only retaining deep ocean areas, excluding high latitudes (higher than 50 deg.) and high ocean variability areas, the standard deviation then gives reliable estimate of the altimeter system performances. In that case most of the cycles have a standard deviation between 5 and 6cm. But there are some exceptions that can be explained. Cycle 11 has a relative high value because of missing Doris data. Cycles 15 or before cycle 10 are higher because of the low number of crossover points. There are less than 10000 crossovers whereas other cycles lead to more than 20000. Cycle 21 has a strong value (7 cm) because of the combined effect of 2 maneuvers, intense solar activity between these 2 maneuvers, and lack of laser measurements between these two maneuvers. At the end of the series, the statistics increase, due to the GIM ionospheric correction relative degradation for higher solar activities as mentioned in the previous part and detailed in 8.4..

In order to compare Envisat and Jason-1 performances at crossovers, Envisat and Jason-1 crossovers have been computed on the same area excluding latitude higher than 50 degree, shallow waters and using exactly the same interpolation scheme to compute SSH values at crossover locations. A step of average per box is also performed, as for Figure 25 (the impact is detailed in part 8.3.). Performances at crossovers are compared, for the two satellites on Figure 29. The standard deviation of Envisat/Envisat and Jason-1/Jason-1 SSH crossover differences are respectively 6 cm and 5.7 cm along track and 2.6cm and 3.2cm after an average per box. Note that Jason-1 consistency at crossovers seem to degrade slightly whereas it improves for Envisat at the end of the series. The performances of the two missions are anyway very good and close.

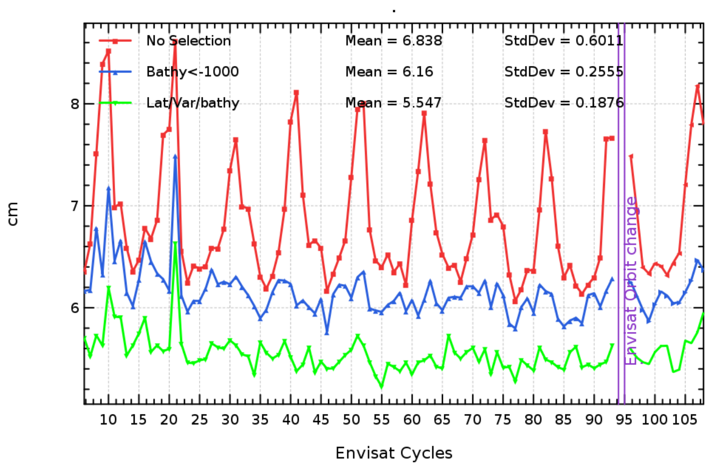

Figure 28: *Standard deviation (cm) of Envisat 35-day SSH crossover differences depending on data selection (with a maximum time lag of 10 days). Red: without any selection. Blue: shallow waters (1000 m) are excluded. Green: shallow waters excluded, latitude within [-50S, +50N], high ocean variability areas excluded.*

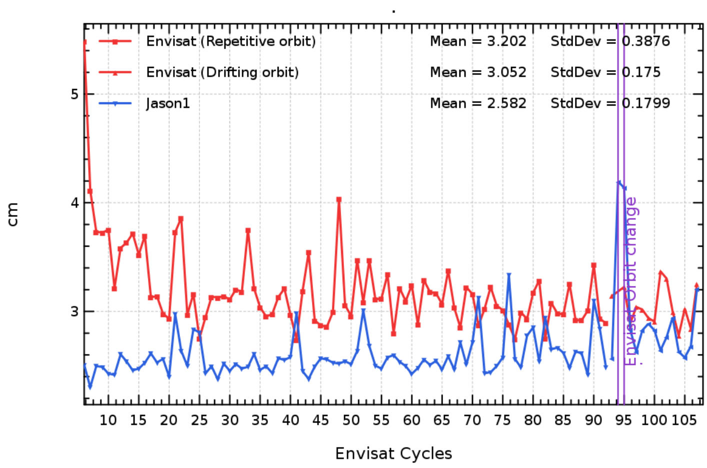

Figure 29: *Standard deviation (cm) of Envisat (red) and Jason-1 (blue) on 35-day SSH crossover differences with 4 by 4 average per box and shallow waters excluded, latitude within [-50S, +50N], high ocean variability areas excluded.*

7. ENVISAT Mean Sea Level Trend

Observing and understanding our climate evolution is a challenge in which altimetry can play a role through, notably, ocean topography monitoring studies. For the last two decades, satellite altimetry has provided reliable time series, highlighting a rise of around 3mm/year at global scale (Cazenave et al. 2004 (see [23], Ablain et al. 2009 (see [9])) of the Mean Sea Level (MSL).
By now, most Sea Level rise studies are based on the 3 NASA/CNES missions: TOPEX/Poseidon (1993-2005), followed by Jason-1 over (2002- onwards) and Jason-2 (from 2008 onwards). The primary role of these missions is the accurate measurement at global and regional scales for climate applications (OSTM/JASON-2 science and operation requirements, 2005). Additionally to these missions, the ESA polar orbiting satellite ERS-1 (1991 - 2000), ERS-2 (1995-2011) and Envisat (from 2002 onwards) have been successively launched, providing a precious and precise complementary data set to the NASA/CNES missions. ERS1, ERS2, Geosat-Follow-On (GFO), and Envisat enables a better restitution of the mesoscale variability at all latitudes and more especially between 66 and 82 deg where fewer altimetric observation is available. Their strong added values in multi-mission merged products such as SSALTO/Duacs Aviso products was already extensively shown in several publication concerning mesoscale variability studies (Pascual et al. 2006 (see [75], Le Traon et al. 2003 (see [60])).
Up to now, the quality and performances of ENVISAT mission were shown to be very good (Faugere et al 2006, see [43]) and with similar level of accuracy as Jason-1 and Jason-2's for mesoscale applications (Ollivier et al 2010, see [13]). Yet, Envisat GDR have long been suffering from an inhomogeneous time series and from major events affecting data quality which prevented users from using them directly for climate oriented studies. Dedicated updates and post processing enable to obtain a homogeneous data set. Thanks to this homogenizing work, fine cross-calibration analysis with other missions and in situ methods are possible. They allow to highlight some remaining differences and particularities of Envisat data.

Since Envisat launch, some discrepancies between its Mean Sea Level trend and other mission's were investigated. However after many improvements and updates over the whole time series, its similarity to Jason-1's MSL (used for climate studies) and to tide gauges after cycle 22 and even more significantly after cycle 41 is very encouraging. 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.

7.1. MSL recipe

In order to have comparable time resolution between Envisat and Jason-1, each point of the MSL monitoring are computed with quarter of Envisat cycle (35/4 = 8.75 days) periodicity: the closest fraction of cycle from 10 day-Jason-1 periodicity. Envisat's time series are computed by first averaging the data in 2x2 deg boxes and then by computing a global average with a weighting depending on the latitude (between 66deg N/S) following Dorandeu and Le Traon 1999 [28]. Time series are then smoothed with a 10 points (87.5 days) sliding window. This step enables to smooth the noise and to reduce the SNR (Signal to Noise Ratio) on the slope computation. The Sea Level Anomaly (SLA) formula is given below.

$$SLA = Orbit - Altimeter\ Range - MSS\ CLS01 - \sum_{i=1}^{n} Correction_i$$

with :

$$\begin{aligned}\sum_{i=1}^{n} Correction_i &= Dry\ troposphere\ correction \\ &+ Dynamic\ atmospheric\ correction \\ &+ Wet\ troposphere\ correction \\ &+ Ionospheric\ correction \\ &+ Sea\ state\ bias\ correction \\ &+ Ocean\ tide\ height \\ &+ Solid\ earth\ tide\ height \\ &+ Geocentric\ pole\ tide\ height\end{aligned}$$

This year, the geophysical corrections provided in the GDR products are totally homogeneous and described in part 3.2.2.. Reprocessed data (from cycle 6 to 92) were concatenated to the current data from 93 to 107 .

7.2. MSL global time series

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.
A first look at the raw (unfiltered and with annual, bi-annual and 60 days signal) SLA monitored on the whole time series with a severe selection on purely oceanic data (Lat<50deg and oceanic variability lower than 20cm) shows that the series can be split into 2 major parts (Figure 30):
- Before 2004 (cycle 22), the slope is clearly negative whereas
- After 2004 (cycle 22), the slope increases again, as expected.

The behavior of Envisat MSL is much lower than Jason-1 trend. 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. The detection and solution of the problem is developped in part 8.1..

Note that to confirm the different drifts, calibration work are performed to compare altimetric missions (including Envisat) to in situ tide gauges measurements. The results are detailed in [16] 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.

It was shown in previous studies and yearly report that the choice of wet tropospheric correction (from MWR or from ECMWF model) did have an impact on the data stability. This is explained by the monitoring of this correction on part 5.6..

The impact of the wet tropospheric choice 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 (using radiometers)	-1.6mm/year
J1-Tide gauge (using radiometers)	-0.1mm/year

Table 2: MSL trends in mm/year

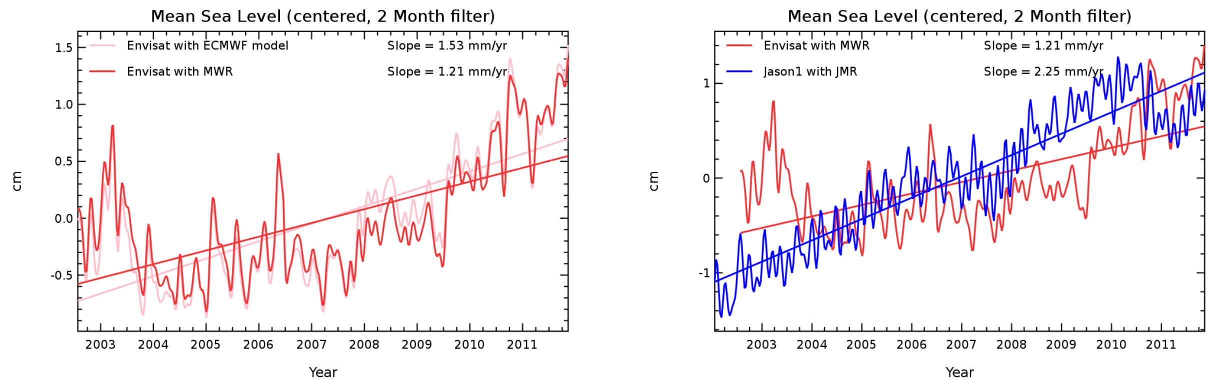

Figure 30: ***Left)****Envisat MSL using MWR and Radiometer Wet tropospheric model (centered),****Right)****Envisat reprocessed data (without PTR proper correction) and Jason-1 MSL using MWR and JMR (centered).*

The bad correlation and slope consistency between Envisat and Jason-1 after reprocessing (without any additional update) was anticipated in last yearly report (*the quantification effect will be cancelled in the reprocessed time series but not the drift. On the contrary it was shown that the way it is applied will increase the difference between both missions.*
Instrument orientated discussions conclude on that subject in early 2011 that the correction is currently applied with a wrong sign. This should be solved by the end of the reprocessing.).
This is developped in part 8.1..

7.3. MSL regional time series

Regional trends of MSL is also studied and monitored. The map of MSL trend using reprocessed data is not available yet. However, extensive studies were performed this year on that subject as developped in part 8.1..

8. Particular investigations

This year investigations were carried on. This part is dedicated to them.

8.1. Study on ENVISAT Mean Sea Level Trend

WARNING: for this part (partially performed before the end of the reprocessing), Envisat data BEFORE REPROCESSING, are used! They include some updates in the F-Pac dedicated data basis and enabled to anticipate most of the L2 evolutions included in the reprocessing.

Last studies (see 2008 Yearly Report) already show the sensitivity of MSL trend to wet tropospheric correction, orbit standards and instrumental corrections.
This year work was performed on those 3 types of error:
- Wet tropospheric correction North/South discrepancies between ECMWF and MWR
- Instrumental purpose through the PTR drift analysis
- and the orbit impact on East/West bias studies
They are presented hereafter.

8.1.1. Wet tropospheric correction North/South discrepancies

The choice of wet tropospheric correction (MWR or ECMWF) was shown to have an impact on MSL data as mentioned in part . For the global MSL, the impact was around 0.7mm/year on the historical data before 2010. It is now reduced to 0.3mm/year on the reprocessed data and on the whole period (until 2012).
The effect was shown this year to be also significant at regional scale. For instance, separating North and South hemisphere to compute the MSL enlightens (on historical data) a mean difference of:
- 0.8mm/year when using radiometer
- 0.02mm/year when using ECMWF operational model
This should be investigated further and tested with the reprocessed data to decide if this difference can be physically explained or if it is linked to a lack of accuracy of MWR and/or ECMWF model.

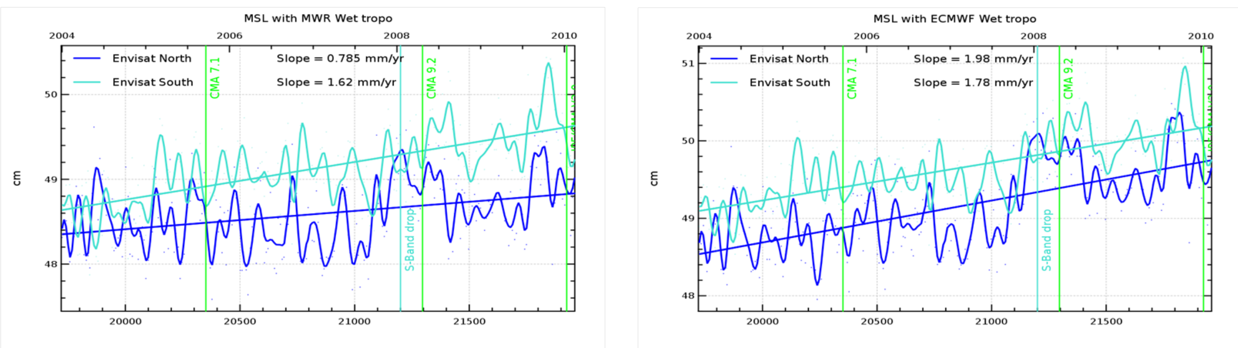

Figure 31: *Difference of MSL separating North and South hemisphere with Radiometer (left) or ECMWF (right) Wet tropospheric correction.*

8.1.2. In Flight Time Delay / PTR drift

Another study performed this year concerns the further investigations initiated in 2009 and carried on in 2010 and 2011 concerning the Point Target Response's drift (PTR).
A quick recall of the MSL behavior when considering the raw GDR data without any of the update performed off-line in the frame of F-Pac activity shows the real shape of MSL (see 32 left). This series is homogenised (see previous yearly reports) to obtain a series close to the reprocessed time series (except for the PTR resolution, the SWH and the MWR content).
The homogeneous MSL time series compared to Jason-1 series after 2003 enables to detect an error on Envisat side. Indeed, Figure 32 right, shows the MSL behaviour for Envisat and Jason-1. A good correlation of signal can be observed except for a drift difference of around 0.9mm/year and an additional divergence at the end of the series. The discrepancies between EN-J1 MSL evidences a jump at the end of the series of about 4 to 5mm between September 2008 and April 2009. This is also confirmed by a dual cross-over analysis (part 6.1.).
To confirm this anomaly, comparison between altimetric data and tide gauges were also used to show that the drift and the jump was due to Envisat data rather than to Jason-1. Thanks to a method developed in (Valladeau et al. 2012 ([95]) and [16]), the drift of the altimetric/tide gauges difference time series is around -1.9mm/year for Envisat, whereas it is 0.1mm/year for Jason-1 from 2003 to end 2010. All the diagnoses are totally in line, giving a good confidence in the results.

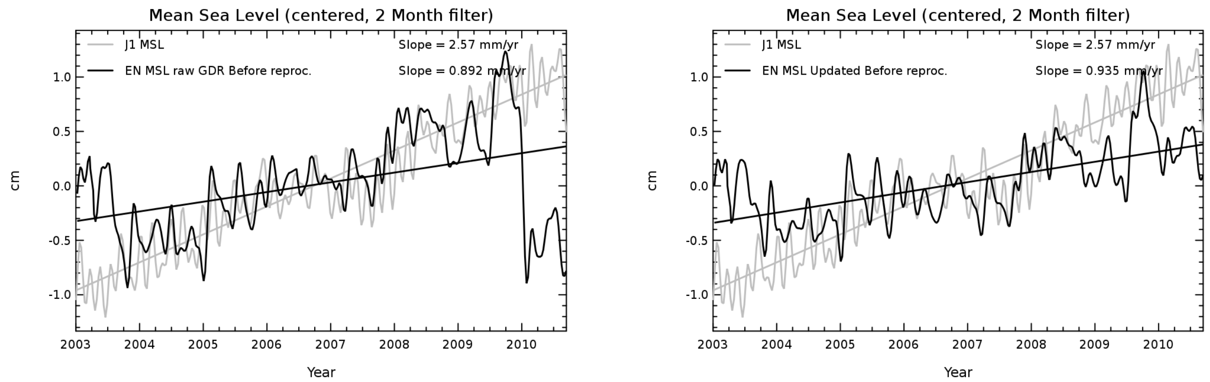

Figure 32: *Envisat and Jason-1 MSL using the raw GDR not updated before reprocessing (left) compared to the MSL updated (right) before reprocessing (PTR badly sampled).*

The jump observed thanks to the multi-mission analysis was correlated to a jump in the instrumental corrections (see Figure 33 grey plot) and reported to instrument expert teams (P. Thibaut et al. 2011, [88]). 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 33 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 Calval monitoring (see [16].)
Once finished the Envisat reprocessing, the effect of this instrumental correction could be fully appreciated. The MSL trend after reprocessing was indeed shown to have a degraded consistency

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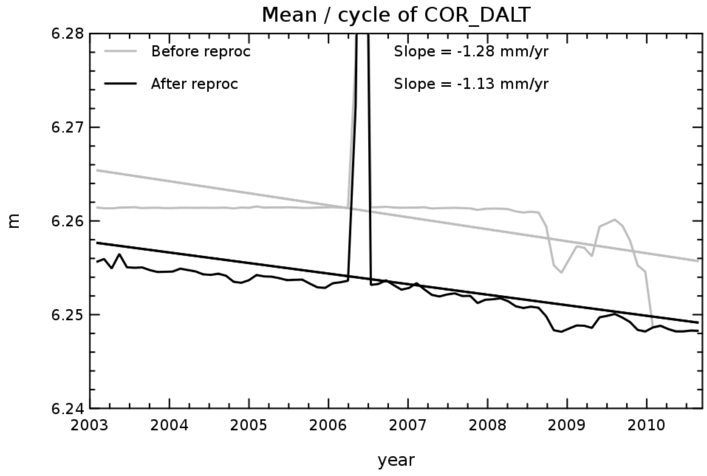

Figure 33: *Instrumental correction including PTR before and after reprocessing.*

with Jason-1 curve (see plot 34). Conversely, once +2xPTR applied, in order to correct for the wrong sign, a very good consistency is obtained between both missions.

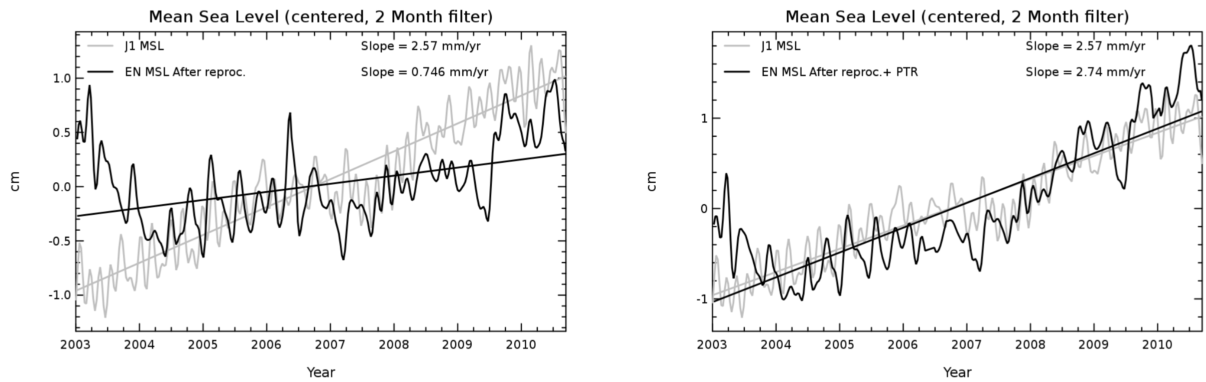

Figure 34: *Envisat and Jason-1 MSL using the GDR after reprocessing with PTR well sampled but with wrong sign (left) compared to the MSL after reprocessing with PTR well sampled but and good sign (right).*

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

Global MSL Trend using Radiometer Wet tropo	Until 2011
EN-J1 using raw GDR before Reproc	1.7mm/year
	.../...

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

Table 3: MSL 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.

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. The final one should do so.

8.1.3. Impact of gravity field model into orbit determination and regional drifts

This year, as a consequence of previous years conclusions, studies were performed concerning the regional long term stability of the MSL.
To evaluate the impact on the data, the consistency with Jason-1 was studies through 2 methods:
- comparison of geographic behaviours between Envisat and Jason-1 were performed by averaging the sea surface height difference at cross overs points. Figure 35 to 37 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.

The first diagnosis is applied comparing the GDR-C Jason-1 series to 4 data sets of Envisat data:

First of all, as a brief recall, the comparison of J1 to Envisat raw GDR before Reprocessing is plotted (using JMR/MWR radiometer wet tropospheric correction) (Figure 35) : strong geographical biases are observed, this data set is not usable for climate purpose.

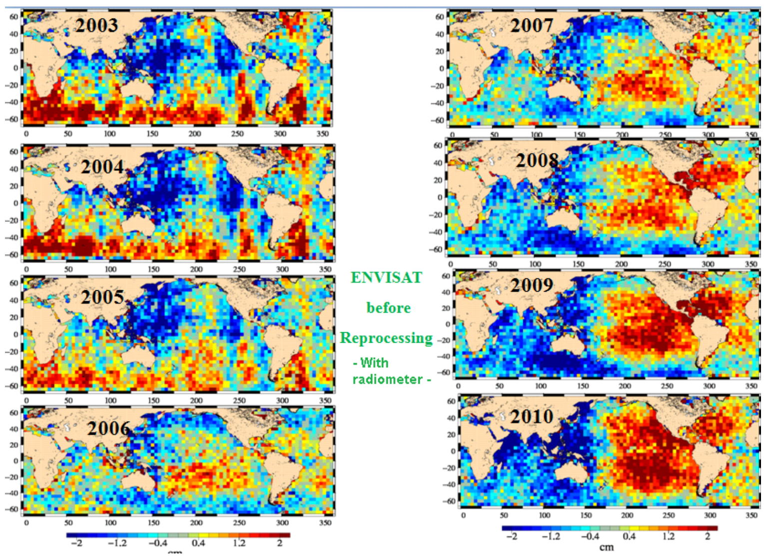

Figure 35: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centred (cm). Raw GDR before reprocessing (with JMR/MWR).*

Then, Jason-1 compared to the updated data before Reprocessing (using ECMWF wet tropospheric correction)(Figure 35) is plotted : the paterns are cleaner and it 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, [95]). 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, 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 ([25]) et al. 2010 and description of standards available at http://ids-doris.org/system/poe/poe-description.html) used in the 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.

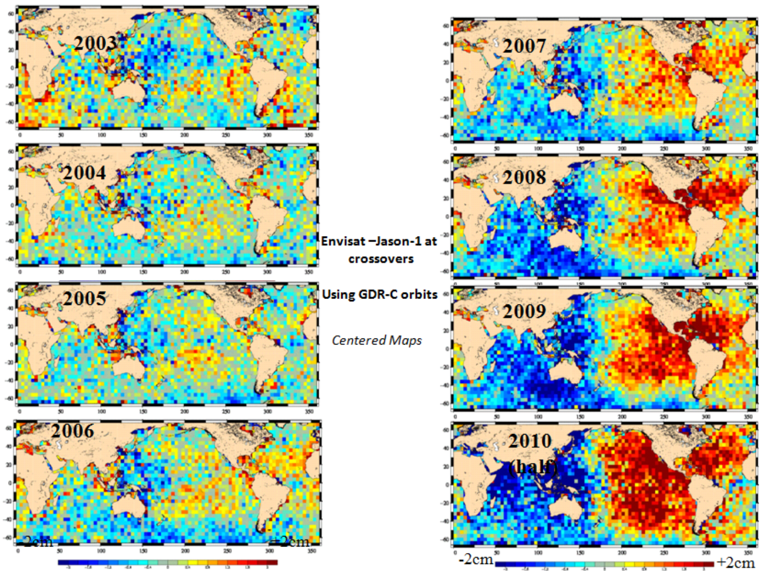

Figure 36: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centred (cm). Updated series before reprocessing (with ECMWF).*

In 2011 a later version of POD standards, preliminary GDR-D, was produced to account for this long term drift. It was shown this year to successfully reduce the East West bias. These standards include the gravity field EIGEN-GRGS-Release2bis (detailed in Cerri et al. 2011, see [26]), which results from a modelling on 10 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 have an opposite impact 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 37) : 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 (see part 8.2.).
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.

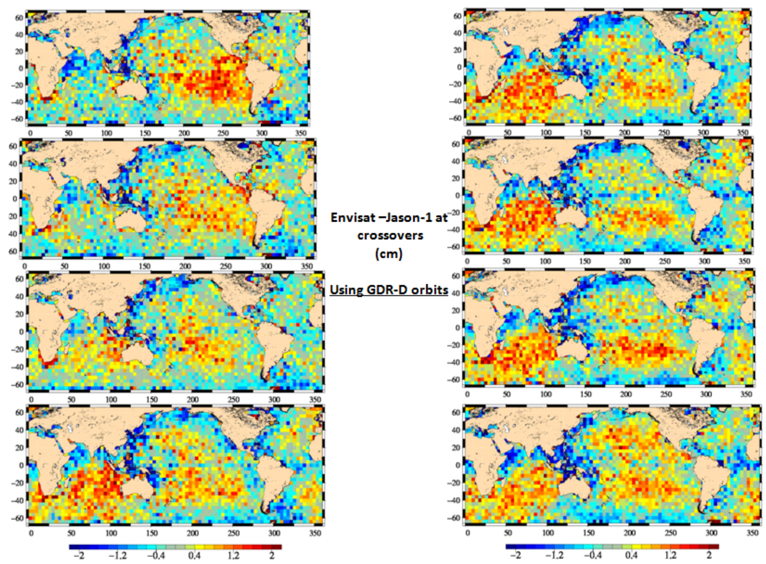

Figure 37: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centred (cm). Before reprocessing, using GDR-D orbit and JMR/MWR.*

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 part 8.2., as well as in the 2011 Yearly report of Jason-1 and 2.

Note that thanks to the use of GDR-D orbits, the East West bias disappear but isolated patches can still be observed.
Preliminary results would suggest that they are likely to be related to Wet tropospheric content differences between JMR and MWR.

After the reprocessing, the regional comparisons between Jason-1 and Envisat were computed again with model or radiometric wet tropospheric correction (Figure 39 and Figure 38): similar paterns as for the updated series are evidenced and removed by the use of ECMWF model. This should be investigated further.

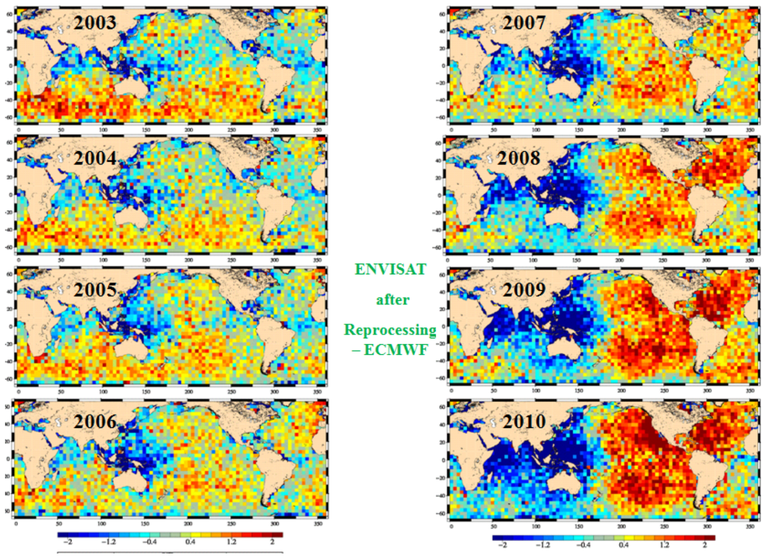

Figure 38: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centred (cm). After reprocessing (with ECMWF).*

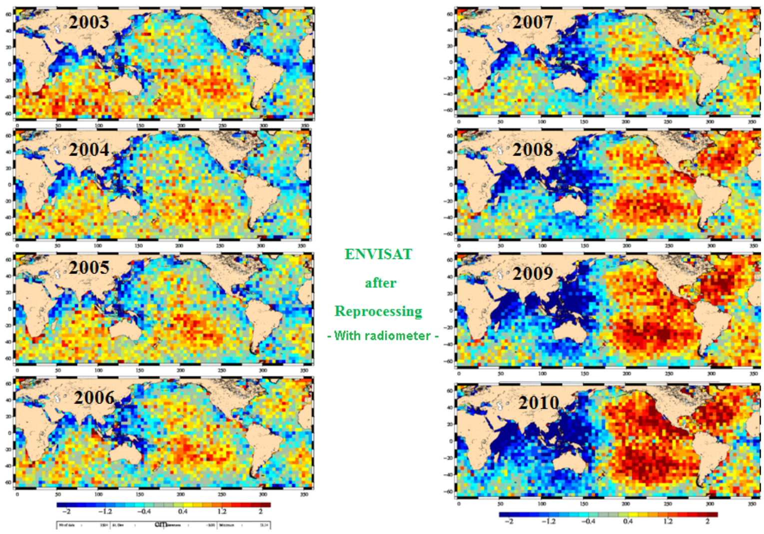

Figure 39: *Dual Crossover mean differences between Envisat and Jason-1 averaged per year and centred (cm). After reprocessing (with JMR/MWR).*

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

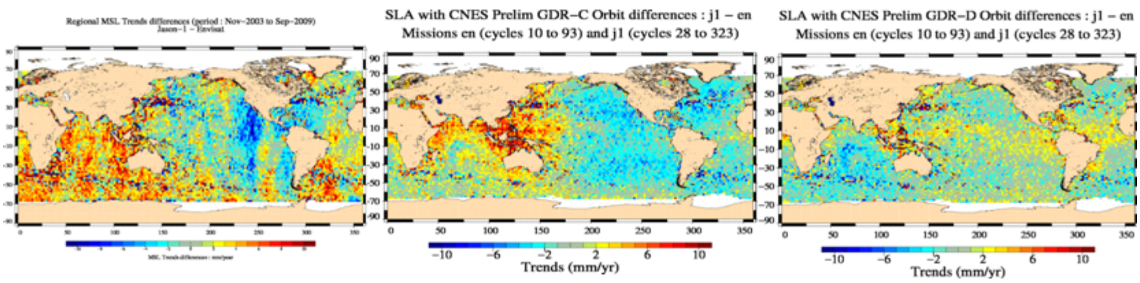

Figure 40: *Envisat minus Jason-1 trends difference*

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8.1.4. Conclusion

This year, sensitivity studies went on going on Envisat's MSL.
They enabled:
- to prove that the PTR drift of around 1mm/year in Envisat is still present and even increased on the reprocessed data, as anticipated in earlier yearly reports, OSTST and QWG.
- to prove that applying this correction with an opposite sign solves most of the discrepancies with Jason-1. This result is confirmed by comparison to in situ tide gauges (see in situ yearly report).
- to show the importance of the gravity field model in the orbit solution, notably on geographical trends. This is corrected with the GDR-D like solution and will also benefit to other missions such as Jason-1 or 2.
- to further analyse the wet tropospheric correction stability in order to better quantify the error budget remaining in the MSL estimation.

An effort was also performed to make Envisat MSL available to users in order to prove its pertinence in climate orientated studies.

Future work should be oriented on :
- testing the cumulated impact on the global and regional drift of the reprocessed data with the correct PTR sign and GDR-D orbits as soon as the GDR-D official orbits are distributed (beginning of 2011).

At global scale, the impact of these new orbits in their preliminary version and applied to the updated series was tested and shows to reduce by -0.2mm/year the Envisat MSL (with insignificant effect on Jason-1). The global difference between Envisat and Jason-1 would therefore be around 0.4mm/year on the period 2004-2010
- providing to users a way of updating the reprocessed data with the two major improvements demonstrated this year
- better understanding the first year of the mission abnormal behaviour
- keep on studying the impact of wet tropospheric correction on MSL trends (at global and regional scales)

Note that this will also be further investigated in the frame of CCI project initiated early 2011 (CCI: Climate Change Initiative) and on going in 2012.

8.2. Preliminary GDR-D orbit validation

In the frame of Mean Sea Level stability studies, cross calibrations methods, completed by in situ comparison methods enabled to evidence in 2010 a clear East West bias increasing in time on Envisat and Jason (see part 8.1.).
After investigations, this effect was related to a bad modeling of the gravity field into the orbit determination for the recent years. In fact the EIGEN-GL04S (see Cerri et al. 2010 and description of standards available at http://ids-doris.org/system/poe/poe-description.html) used in the 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.

In 2011 a later version of POD standards, preliminary GDR-D, was produced to account for this long term drift. It was shown this year to successfully reduce the East West bias increasing in time. These standards include the gravity field EIGEN-GRGS-Release2bis (detailed in (Cerri et al. 2011)), which results from a modeling on 8 years (2002-2011) instead of 3 years (2003-2005 for the EIGEN-GL04S (see Table 41)). 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.

	GDR-C	Preliminary GDR-D orbit
Variable gravity field	EIGEN-GL04S Drift:Annual+Semiannual 50x50 from EIGEN-GL04SANNUAL	EIGEN-GRGS_RL02bis_MEAN-FIELD
Signal modelled	Annual/semi annual	Annual/semi annual + drift
Period of estimation	2003-2005	2002-2011
Itrf	2005	2008

Figure 41: *GDR-D orbit characteristics*

To complete the analysis, and to assess the use of these standards in the GDR (will be done during 2012), a validation of a preliminary version of these orbit was performed in 2011. In fact, the quality of Precise Orbit Ephemeris is crucial for the quality of altimeter data. Inversely, studies using Sea Surface Height (SSH) calculation from altimeter or in-situ data enable to give insight in orbit quality for the different missions, to compare different orbit solutions for one mission and to compare the behavior of an orbit standard on different missions.

8.2.1. Comparison of Envisat CNES GDR-C and preliminary GDR-D evolution

Figure 42 left is the mean difference of CNES GDR-C and preliminary GDR-D orbits per cycle. The drift observed is the signature of the long term drift modeled in the preliminary GDR-D orbit standard when compared to the GDR-C standards. It is the main difference in the associated gravity field models EIGEN-GRGS-Release2bis and EIGEN-GL04S. The global slope of the difference is -0.2mm/year. Close to the expected and computed impact on MSL trend (see figure 43).

Figure 42 right is the Standard deviation of the difference of CNES GDR-C and preliminary GDR-D orbits per cycle. the minimum on year 2005 is the signature of the fact that the new gravity field is estimated over 8 years (2002-2011) instead of 3 years (2003-2005 for the EIGEN-GL04S centered in 2005.

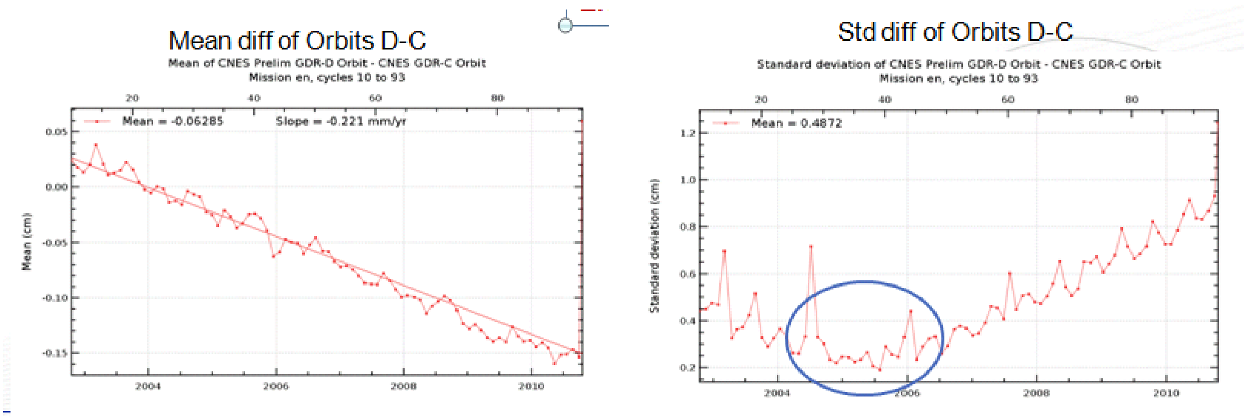


Figure 42: *Mean and Standard deviation of the difference CNES GDR-C and preliminary GDR-D orbits per cycle.*

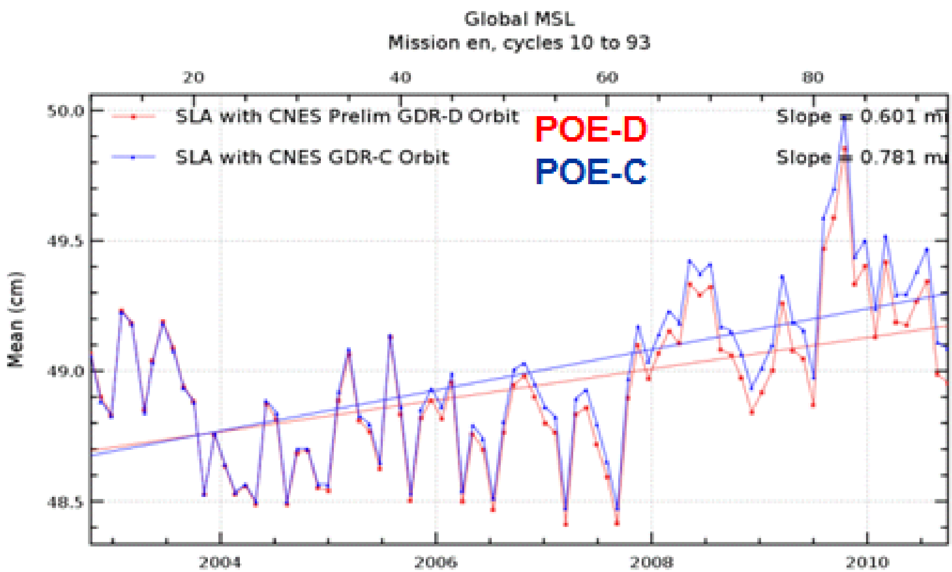


Figure 43: *Impact of the Prelim GDR-D compared to GDR-C orbit standard on the MSL trend.*

The impact on the ascending/descending discrepancy of the GDR-D is satisfactory because it is reduced (see figure 44) the difference of trend was around 0.5mm/yr with GDR-C standards. It is now reduced to -0.1mm/yr. Indeed the climate long term effect are not expected to sign at daily scales and day/night trends should be equivalent. This is a good result.

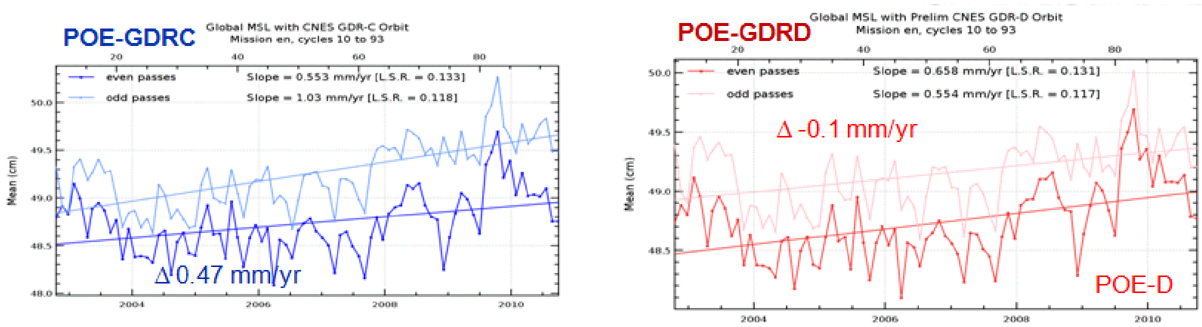


Figure 44: *Impact of the Preliminary GDR-D compared to GDR-C orbit standard on the Ascending/Descending trend consistency.*

8.2.2. Comparison of Envisat CNES GDR-C and preliminary GDR-D performance at cross overs and along track

The quality of the Envisat CNES preliminary GDR-D orbit in terms of SSH performance is tested through the variance gain at crossovers (compared to GDR-C orbit) (Figure 45). GDRD are seen to improve GDRC with an annual signal related with the annual signal modeled in the gravity field models. Similar results were obtained on Jason-1 and Jason-2 but with an opposite annual signal.
Note that the improvement is weak (but still!) before 2007 but more important afterwards.

Another test consists in analysing the variance of SLA signal along track with both orbit standards (Figure 46). The results are not immediate to interpret because the GDR-D show that the SLA standard deviation is increased with the new orbit (pink curve) mainly at the end of the period. Surprisingly, the effect on Jason-1 is exactly opposite and decrease at the end of the period (blue curve).

After investigations, this effect was interpreted as the fact that SLA computed with the new GDR-D orbit are getting further to the reference MSS (computed with non variable gravity fields. To get rid of this reference, the same analysis was then performed by referring the SLA to a mean profile computed with the GDR-D standards. The effect on the dispersion at the end of the series is much reduced with still an improvement noticed for Jason-1 (red) and Envisat (green).

8.2.3. Effect of the new gravity field in the consistency between Envisat and Jason-1

The main improvement provided by these new orbits consists in the reduction of the East/West bias increasing in time between Envisat and Jason-1. This is extensively developed in part 8.1..
In the frame of activity between altimeter Calval studies and POD teams (from CNES and ESOC), the impact of the gravity field on the East West bias could also be investigated using other orbits:
- ESOC POD team provided us a data set version V7 including the gravity field EIGEN-GRGS-Release2bis (as for CNES GDR-D)

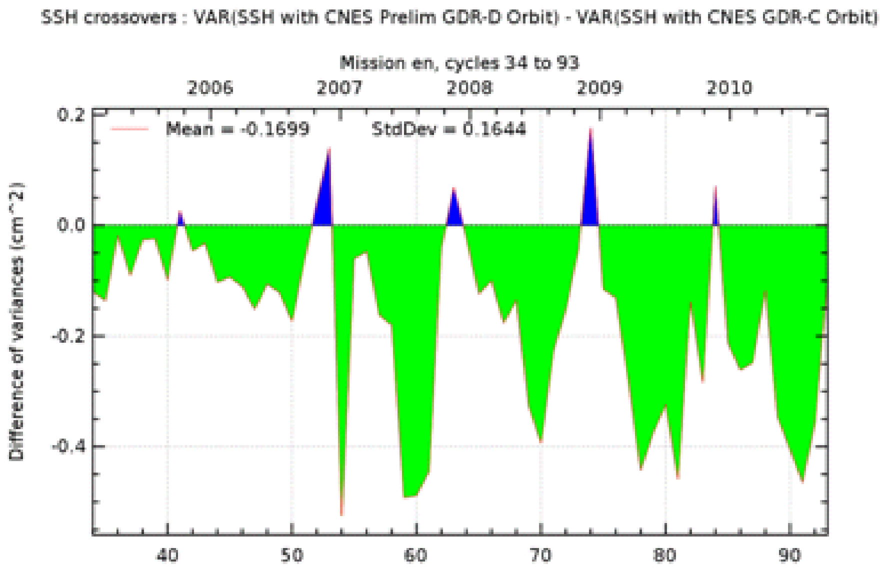


Figure 45: *Variance gain at cross-over of the Preliminary GDR-D compared to GDR-C orbit standard. Green color represents a better GDR-D standard.*

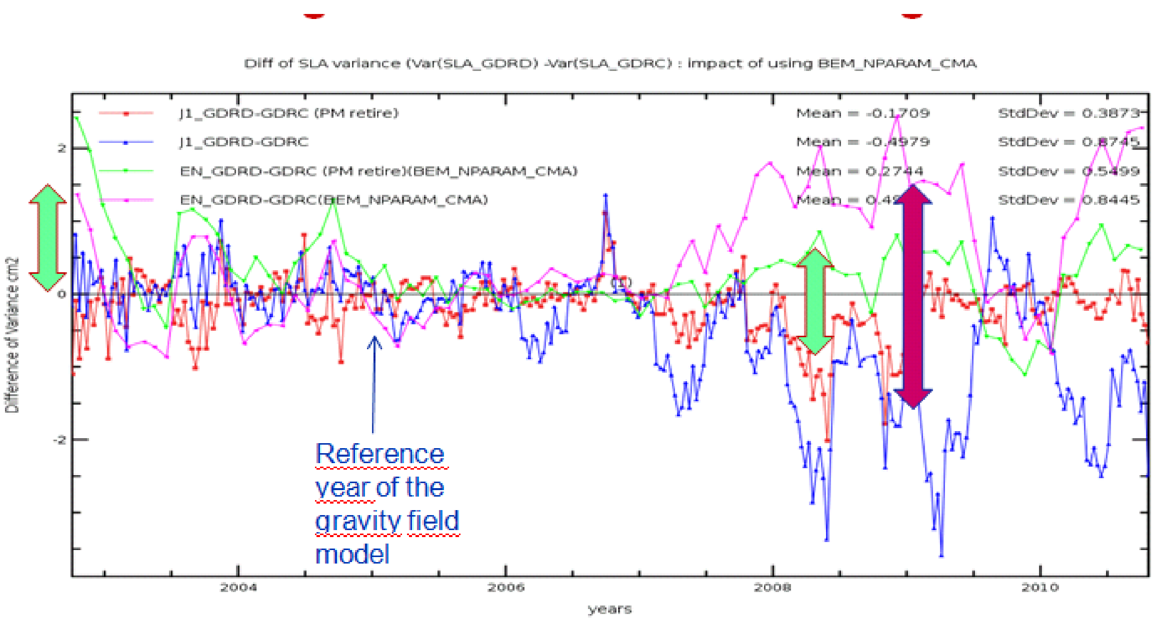


Figure 46: *Variance gain of SLA along track of the Preliminary GDR-D compared to GDR-C orbit standard. Green color represents a better GDR-D standard.*

- Grace 10 days produced by CNES SOD team and computed with a hight weight given to the gravity field measurements and a low weight given to the model component

Both show to reduce the East West bias, thus demonstrating the correlation with the gravity field and the SSH bias.

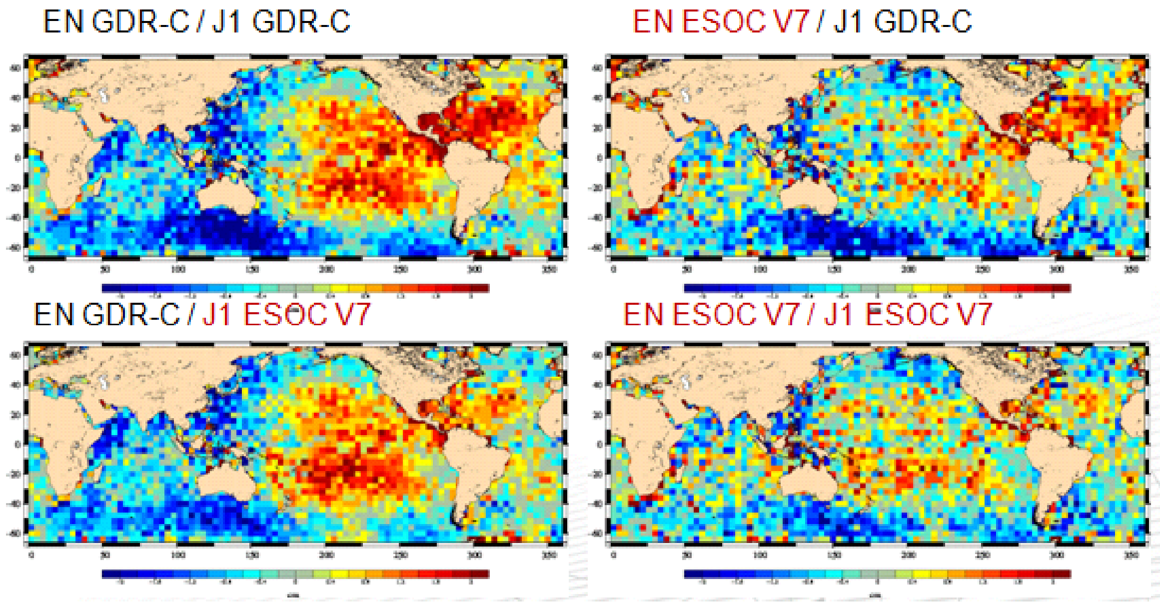


Figure 47: *Impact of ESOC V7 standards compared to GDR-C standards on the East West biases observed at dual cross-overs between EN and J1 over 2008*

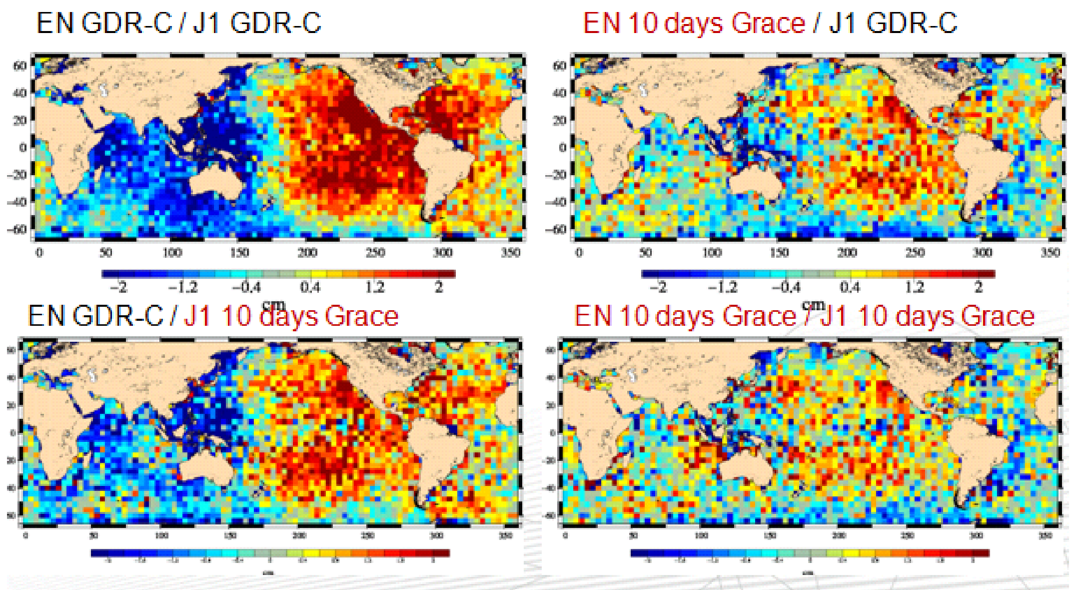


Figure 48: *Impact of 10days grace standards compared to GDR-C standards on the East West biases observed at dual cross-overs between EN and J1 over 2010*

8.2.4. Conclusion

The correlation with the gravity field modeled in the orbit solutions and the SSH geographical biases observed when comparing different missions was demonstrated. The GDR-D standard were validated in a preliminary form on an updated dataset. The operational generation of these orbits was decided for 2012. The impact should be tested on the reprocessed dataset now available.

8.3. Intercalibration EN/J1: a new approach

During this year, a new approach for Envisat/Jason-1 intercalibration has been developped.
The major evolution of the new intercalibration chain consists in statistics calculated per box and not more along track. The chain creates 4°X4° boxes for latitudes between 66°S and 66°N, and for longitudes between 0 and 360°. Then statistics are calculated for each box: mean, variance, standard deviation, min, max, number of values per box.
This method allows to compensate the possible sampling differences between the two considered missions. This choice gives credence to multi mission comparisons while limiting the local impact of each mission, and particularly the high latitudes data impact.
Several results have been observed on geophysical parameters or SSH, and are summarised here.

8.3.1. North/South effect: more pertinent data

As we can see on the SWH mean by cycle plot, the stats per box method allows limiting the noise created by high latitudes data. Indeed, the curves given by the new intercalibration method show a less noisy signal than in the previous version. The two new curves seems to be more consistent for the two missions:

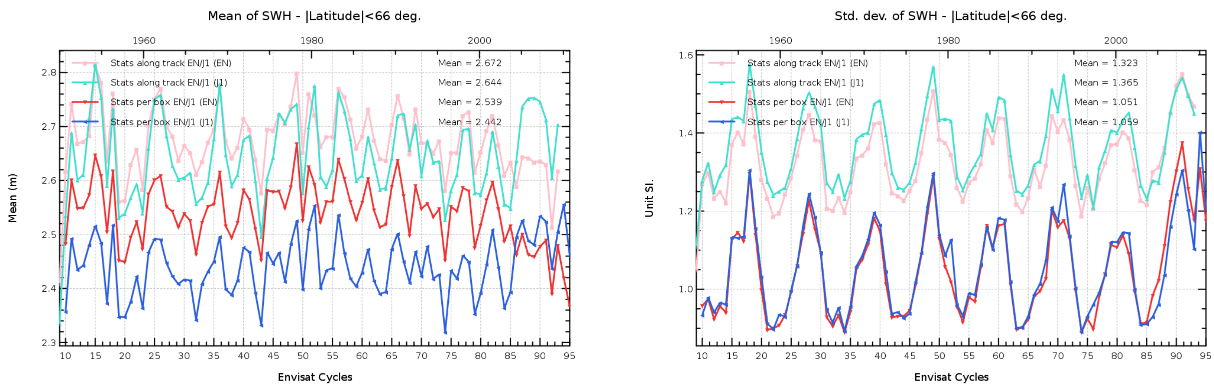


Figure 49: *Method comparison for SWH* ***Left)*** *Mean and* ***Right)*** *Standard deviation*

After the cycle 85 and with the per box intercalibration version, the impact of V2.1 Envisat version change is more clearly represented. The signal is less disturbed and then seems to be more pertinent than along tracks statistics.
This observation is more visible on the standard deviation plot; with the V2.1 version, the Envisat SWH standard deviation calculated by cycle also increases in relation to J1 data, which is evidence of the version change and that we did not see with along track statistics.

Globally, the stats per box calculation is more relevant for geophysical parameters strongly influenced by North/South effect.

8.3.2. Low frequency gain

The stats per box gives importance to low frequency signals by reducing the high frequency noise. If we consider the Envisat SSH at crossovers, before cycle 41, the GDR-A were used and then impacted the signal with geographical effects. Unlike the along track statistics, the stats per box calculation underlines this behaviour and clearly shows the drift caused by GDR-A use.

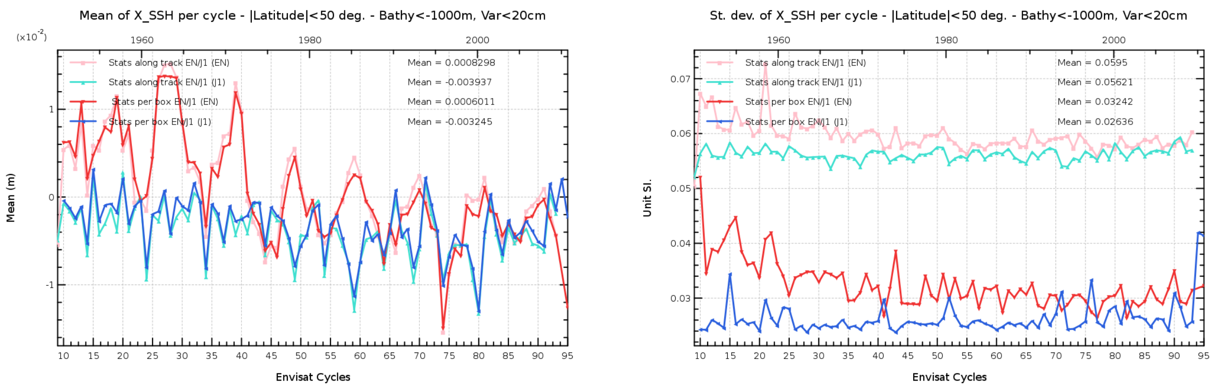


Figure 50: *SSH at crossovers EN/J1, **Left)** Mean and **Right)** Standard deviation*

On the D_TROPO standard deviation plot, the ECMWF version changes are no longer visible because the signal high frequency content is less visible.

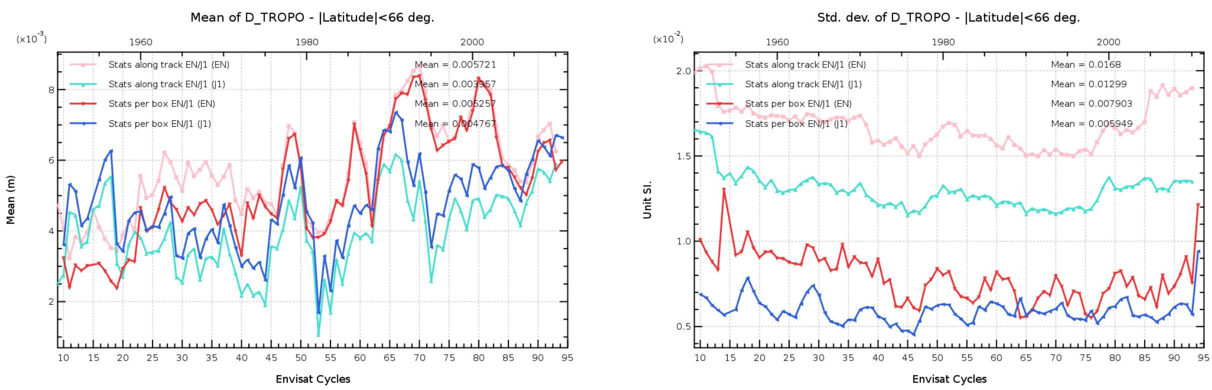


Figure 51: *Difference of tropospheric correction ([Rad-ECMWF model]) by cycle, **Left)** Mean and **Right)** Standard deviation*

On tropospheric correction mean plot (radiometer-model), we see the impact of Envisat cycle 41 evolution (restriction of side lobes effects). This evolution allows to limit the impact of side lobes disturbing signal along coasts. After the cycle 41, we observe the overlay of the two curves for Envisat. We can easily imagine that the per box method smoothes the impact of side lobes along coasts, bad values are first locally averaged and then integrated to the mean by cycle. As a consequence the mean by cycle given by per box method is close to the corrected signal after cycle

41.

8.3.3. Annual signal decrease

On the standard deviation of SSH at crossover plot, the curves ploted with per box method are not impacted by an annual signal, contrary to the standard deviation calculated along track. This plot shows that the limitation of high latitudes noise impacts the wave height mean by cycle and also the annual signal on the whole data.

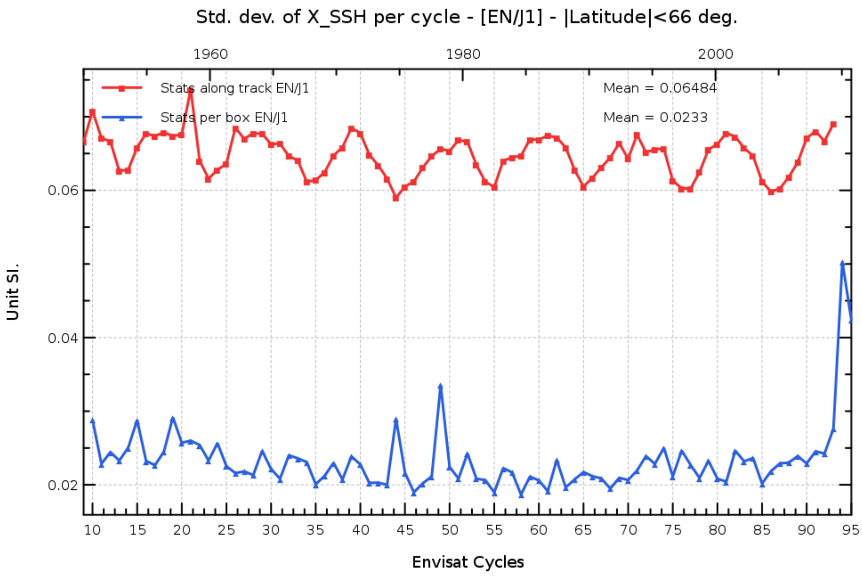


Figure 52: *Standard deviation of SSH at crossovers*

8.4. Impact of solar activity increase on data quality

After the cyclic validation of cycle 107 on Envisat, an e-mail was sent to the scientific community to warn about the regional degradation of Envisat data quality. It underlines that the S-Band loss is starting to produce an effect, hidden until now by the fact that this instrument event occurred in a low activity period.

Mail sent on the 8/12/2011 to the JPL GIM experts and ESA with the attached document here below.
Hi all

As briefly discussed with Shailen and Attila during the AGU, you will find attach a brief note that describes the current degradation of the ionospheric correction quality observed on ENVISAT mission (derived from JPL GIM_Q NRT maps). It is worth to notice that the same degradation is also applicable to the Cryosat mission (Ku band single frequency altimeter). So 2 current altimeter satellites will have degraded performances in coming months and years and the degradation is already noticed since mid 2009.

Last but not least, we also noticed recently (as part of the ESA CCI project) that the DUACS level4 products are impacted by the ENVISAT and/or ERS1/2 ionospheric data quality. This was not expected (as those missions are using Topex/Jason-1/2 missions to correct for some of the remaining bias or differences) but reinforce the need for an improvement of current of past data JPL GIM maps (if feasible...).

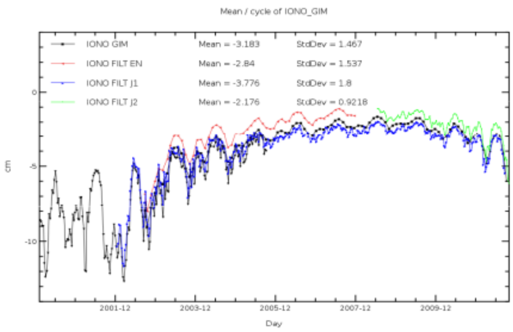
Any support from NASA/JPL to further improve the ionospheric data quality derived from JPL maps will be highly appreciated.

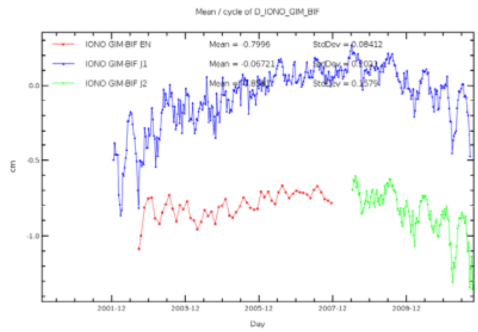
Waiting for your feedbacks,
Best regards,

NPicot

Long term monitoring of ionospheric correction

Since the S-Band loss, Envisat iono correction was efficiently replaced by the JPL GIM model.
But the solar activity (reprensented by a higher value of the mean correction) is increasing again since mid 2009 following a 11 year period signal (see left hand plot).
The monitoring of the difference iono GIM-Bifrequency correction on Jason-1 and Jason-2 (see right hand plot) enlights that the error on the model is higher when the solar activity increases (around 5mm more than in 2008).
The GIM model is therefore becoming less and less efficient for Envisat.



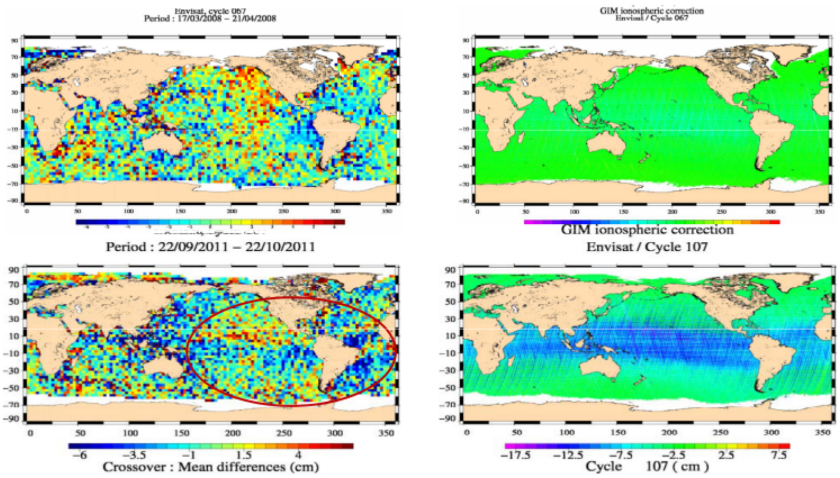


Impact at cross overs

The degradation of the iono GIM-Bifrequency on Envisat data is starting to be visible on the statistics at crossovers on which a signal is starts to appear (mostly in the Atlantic).
Note that the phenomenon is amplified att cross overs due to the strong diurnal signal on iono correction and sun-synchronism of the mission).

Cycle 67: begining of 2008

Cycle 107: end of 2011



The ionospheric correction degradation on Envisat is becoming an issue :

- for long term global Mean Sea Level monitoring (see suggested solution: Envisat GIM correction fitted on J1 Bifrequency iono correction Envisat Yearly Report 2010)

- for merged multi mission products (see YF CCI presentation QWG 17) because of their wave length and high variability.

8.5. Editing on SLA caused by MWR

8.5.1. 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 53). 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 analyse why more data are edited with this annual signature.

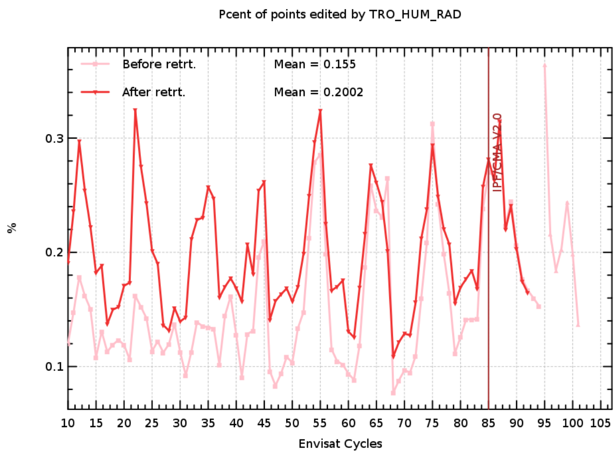


Figure 53: *Editing on MWR correction, before and after reprocessing*

8.5.2. 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 $|radiometer. - model| > 0.10$, 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 outside -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 54.

After investigation, these rejected data on high latitudes did not correspond to ice area but were rather situated on ice limit (see figure 55). 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 definition could change the fitting of ice shelf.

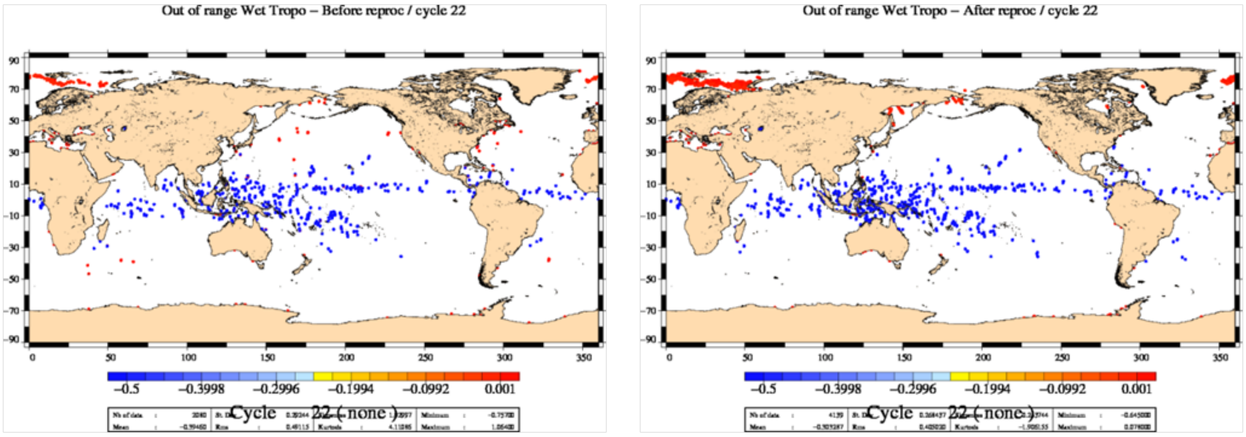


Figure 54: *Editing on MWR correction for cycle 22 (North winter) - Before/After reprocessing*

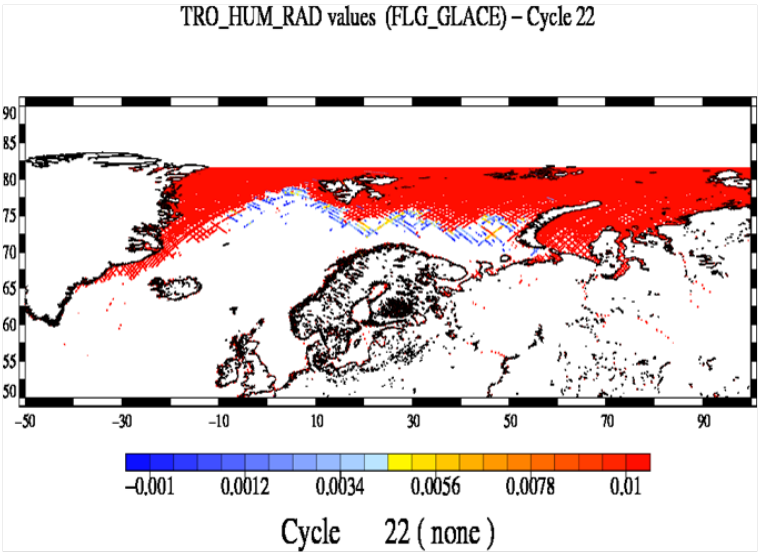


Figure 55: *Wet tropospheric correction values edited on high latitudes - **red:** ice from Calval Ice Flag - cycle 22*

8.5.3. 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 57 shows that the GDR Ice flag detects less ice than the one used for validation purpose (Calval flag).

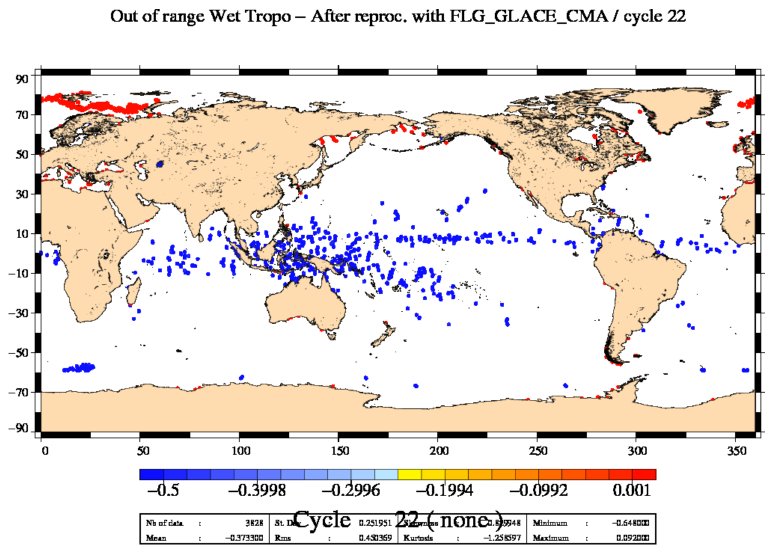


Figure 56: *Editing on MWR correction for cycle 22 (North winter) with GDR Ice Flag*

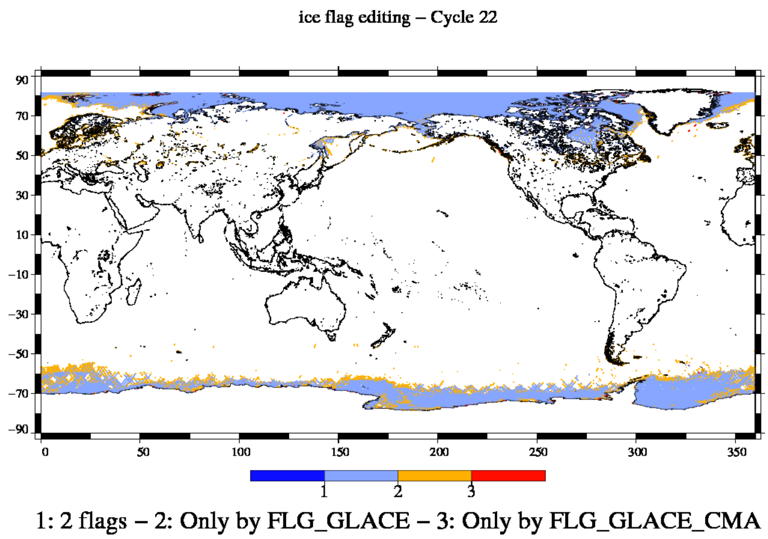


Figure 57: *Ice detection by Calval and GDR Ice Flags for cycle 22* ***blue****:Ice for both GDR/Calval flags,* ***red****: Ice only for GDR flag,* ***orange****: Ice only for Calval flag.*

8.5.4. 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 a 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.

8.6. 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 Jason-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.

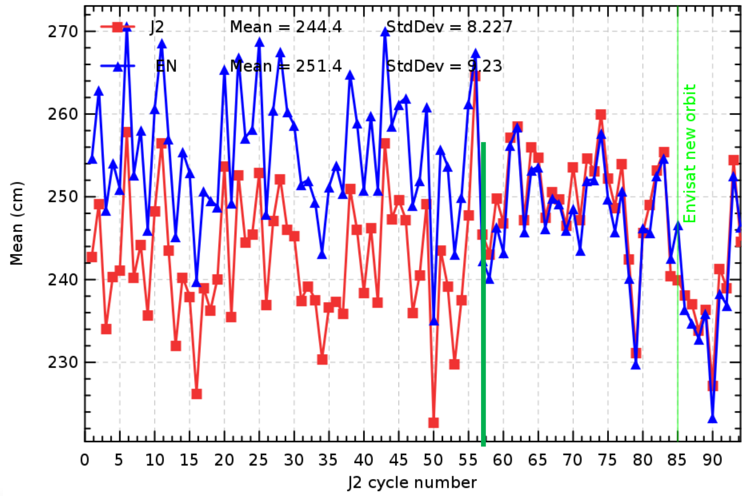
1. Position of the problem

- 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

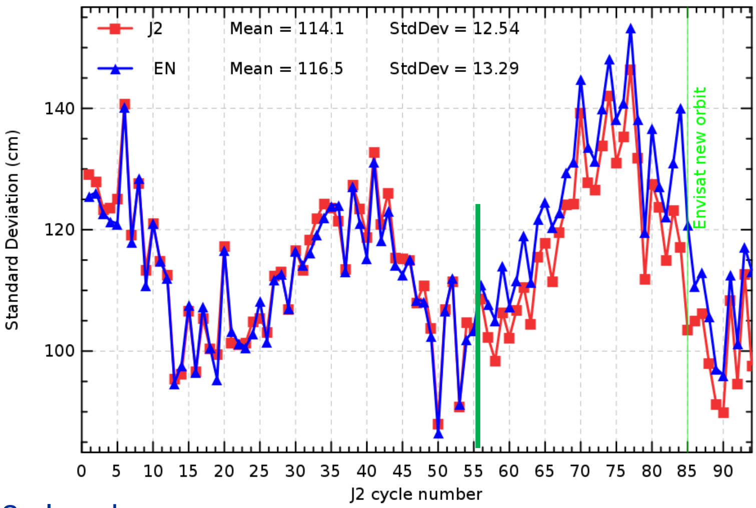


Comparison to Jason-2 also shows:

- More complient mean for Envisat and Jason-2

V2.1 version impact on SWH noise 1Hz

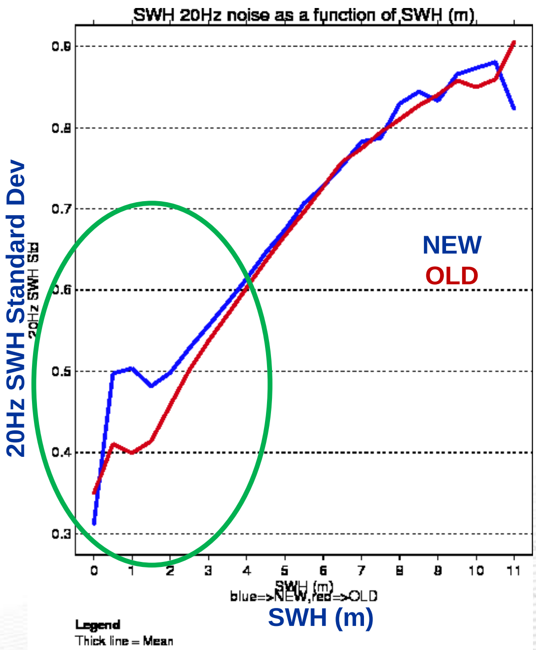
Std per J2 cycle



Comparison to Jason-2 also shows:

- Stronger standard deviation

V2.1 version impact on SWH noise 20Hz



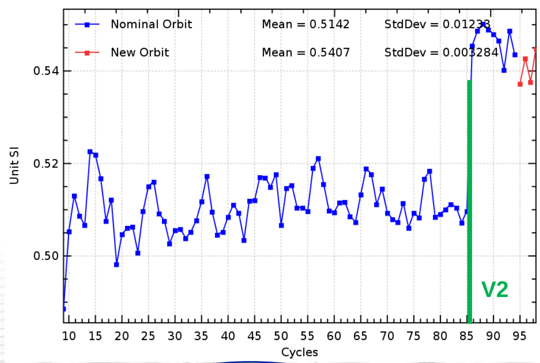
An analysis on 20Hz data was performed

Increase of 1Hz SWH standard deviation per cycle:

- 1.3m to 1.4m in global

Strong increase of 20Hz SWH standard deviation:

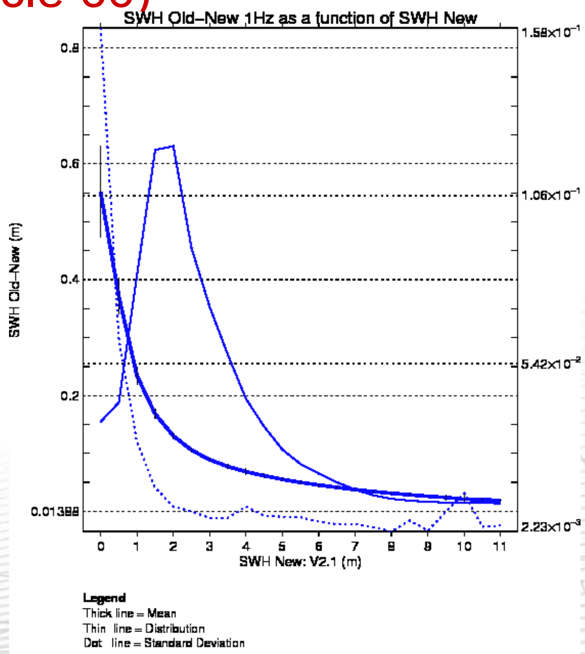
- 50cm to 54cm in global
- 40cm to 50cm for SWH<3m



20Hz SWH Std Dev

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

- Only small waves (<1Hz) inpacted



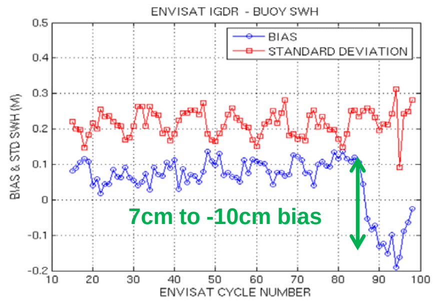
2. Users feed back

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

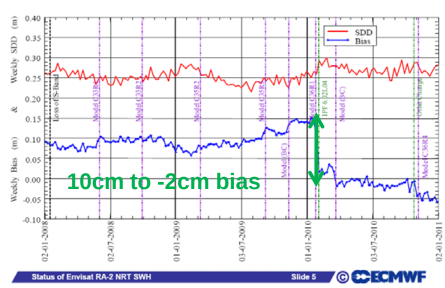


- to WAM model (see ECMWF presentation)

➔

From Saleh Abdalla

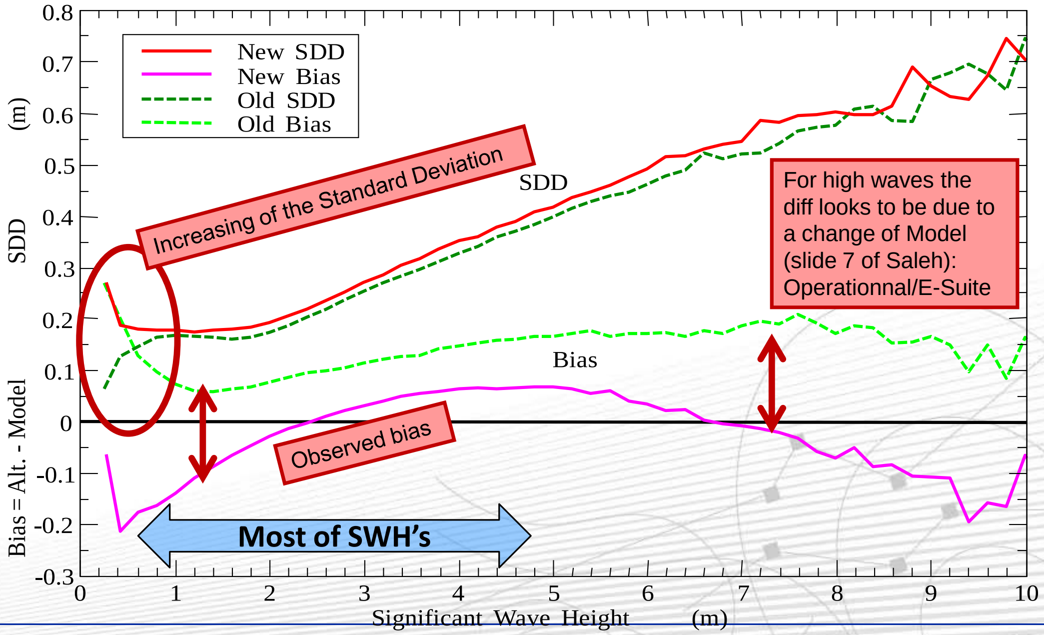
Time series of Ku-band SWH bias (RA2 - model) & St. Dev. Diff.



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

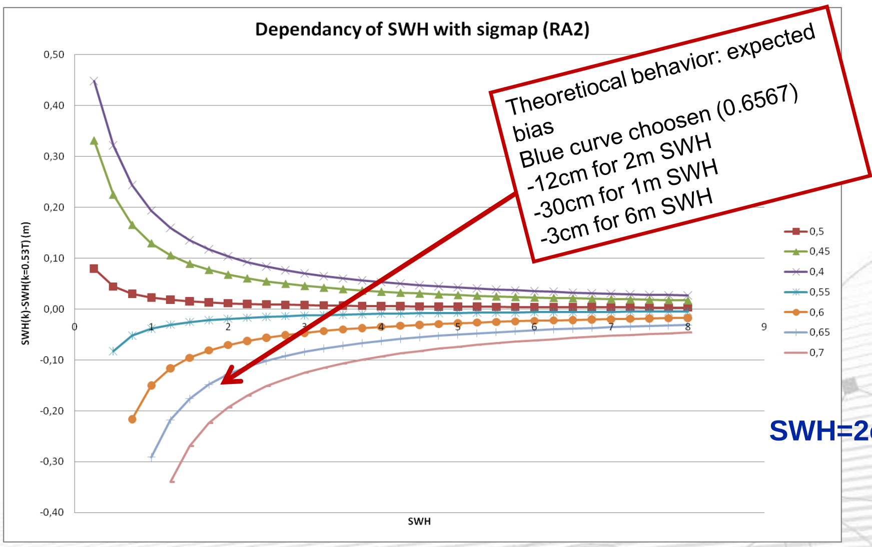
- P. Bonnefond also impacted because Corsica is a small wave area

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

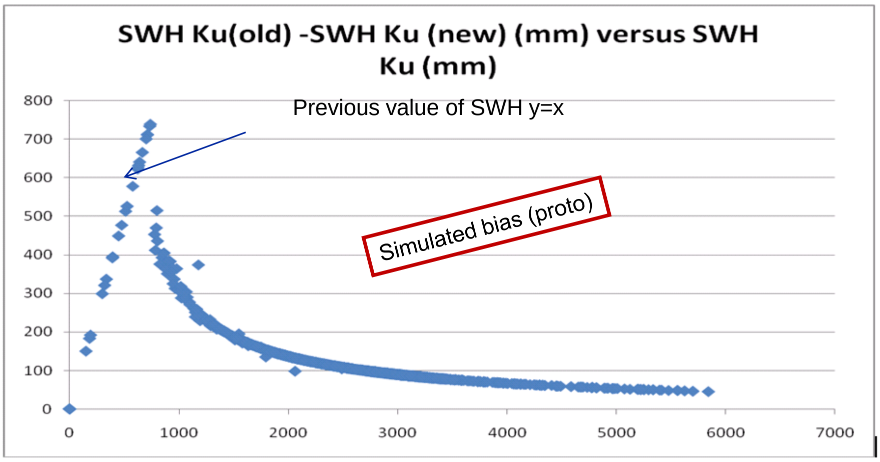


Figure 3-7 : SWH Ku(old) -swhKu (new) versus SWH Ku

Yes!:

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

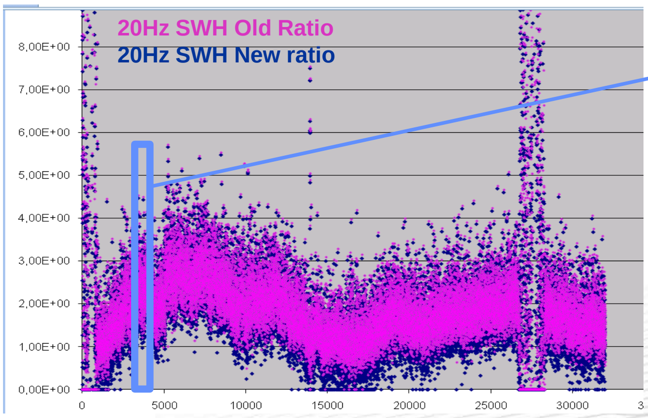
Theoretical/Observed bias differences

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. Conclusion

A statistical evaluation of Envisat altimetric measurements over ocean has been presented in this report with more than nine years of data now available. For the first time this year, all the Geophysical Data Record (GDR) products were reprocessed on the whole time series. The products were delivered to users after validation. Envisat altimetric measurements show good general results.
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 2012. Some investigations impacting the current data set since cycle 86 (V2 version), were carried on and presented here. Others will be detailed, as well as the global impact of the reprocessing, in a synthesis document being prepared. The new products are shown in this document to improve the high quality level of the Envisat altimetric mission and will make easier the data merging for multi-mission altimetry, as it is essential for oceanography and applications.

The data presented in this document are homogeneous, improved and were recently shown to be perfectible on a MSL point of view. The major points to underline are:
- A very good **availability** of Envisat data on the last 2.5 years was noticed thanks to an improvement of the data dissemination since May 2008.

- The **S-Band loss** is considered to be permanent and all the S-band parameters MUST NOT be used anymore. The dual ionospheric correction has to be replaced by the JPL GIM Ionospheric correction. Since the end of the year the impact is starting to be visible on the data quality, due to the solar activity increasing again. This could become problematic in addition to the impact for MSL studies regarding the instabilities noticed on the GIM correction.

- The **USO anomaly** still did not affect Ra-2 this year and since January the 23th 2008. Anyhow, in v2.1 reprocessed data, no more auxiliary files are needed anymore because it is now directly corrected into the range.

- The **SLA performance** is very good, at the same level as Jason-1 and Jason-2 with geographical differences between Envisat and Jason-1 reaching the cm level. This year the method of cross comparison was enriched and tuned to better take into account the geographical discrepancies of observation on different missions, giving more confidence in the metrics obtained.

- Extensive studies of comparison to **in situ data** (Tide gages and TS profile) were performed this year again, helping to characterize the differences between Jason-1 and Envisat missions. They enabled, for instance, to evidence the reduction of East/west discrepancies after improvement of the time variable gravity field in both missions. They also enabled to show the great improvement on global MSL trend (see Valladeau et al 2012).

- The Envisat **Mean Sea Level trend** is still an issue and was studied again this year. As during the previousyears, sensitivity studies have been performed on Envisat's MSL and enabled:
* to prove that the PTR drift of around 1mm/year in Envisat is still present and even increased on the reprocessed data, as anticipated in earlier yearly reports, OSTST and QWG.
* to prove that applying this correction with an opposite sign solves most of the discrepancies with Jason-1. This result is confirmed by comparison to in situ tide gages (see in situ yearly report).

* to show the importance of the gravity field model in the orbit solution, notably on geographical trends. This is corrected with the GDR-D like solution and will also benefit to other missions such as Jason-1 or 2.
* to further analyse the wet tropospheric correction stability in order to better quantify the error budget remaining in the MSL estimation.
An effort was also performed to make Envisat MSL available to users in order to be assessed from a scientific point of view in climate orientated studies.

Future work should be oriented on :
* testing the cumulated impact on the global and regional drift of the reprocessed data with the correct PTR sign and GDR-D orbits as soon as the GDR-D official orbits are distributed.
At global scale, the impact of these new orbits in their preliminary version and applied to the updated series was tested and shows to reduce by -0.2mm/year the Envisat MSL (with insignificant effect on Jason-1). The global difference between Envisat and Jason-1 would therefore be around 0.4mm/year on the period 2004-2010
* providing to users a way of updating the reprocessed data with the two major improvements demonstrated this year
* better understanding abnormal behavior of the first year of the mission
* keep on studying the impact of wet tropospheric correction on MSL trends (at global and regional scales)

10. Appendix 1: Instrument and platform status

10.1. ACRONYMS

The main acronyms used to describe the events are explained below.
CMA: Centre Multimission Altimetrique
CTI tables: Configuration Table Interface. They contain the setting of the instruments and are uploaded on board after a switch off, a reset
HTR Refuse: Heater Refuse
ICU: Instrument Control Unit, a part of the distributed command and control function implemented on ESA spacecraft. The unit receives, decodes and executes high-level commands for its instrument, and autonomously performs health-checking and parameter monitoring. In the event of anomalies it takes autonomous recovery actions.
IPF: Instrument Processing Facilities
MCMD: Macrocommand
OBDH: On Board Data Handling
OCM: Orbit Controle Mode/maneuvre
P/L SOL: Payload Switch Off Line
SEU: Single Event Upset
SM-SOL by PMC: SM Switch Off Line by Payload Main Computer
SW: Software
TM: Telemetry
USO: Ultra Stable Oscillator

Cycle 006

- Doris Doppler Instrument nominal mode with median frequency bandwidth pre-positionning (required for DORIS incident recovery) (2002/05/16 00:00:00 to 2003/05/19 12:00:00 TAI)
- Payload anomaly, DORIS MVR switch OFF (2002/05/27 01:38:37 to 2002/06/03)
- Orbit Maintenance Maneuver (2002/06/01 10:26:20 to 2002/06/01 13:16:46 TAI)
- Doris Doppler Instrument nominal mode with median frequency bandwidth pre-positionning (required for DORIS incident recovery) (2002/06/03 00:00:00 to 2003/06/11 12:00:00 TAI)

Cycle 007

- Orbit Maintenance Maneuver (2002/07/06 03:47:52 to 2002/07/06 06:38:14 TAI)
- Interface Control Unit anomaly (2002/07/06 08:02:00 to 2002/07/09 14:00:00)

Cycle 008

- Orbit Maintenance Maneuver (2002/08/06 03:38:08 to 2002/08/06 06:28:33 TAI)
- Orbit Maintenance Maneuver (2002/08/26 17:07:44 to 2002/08/26 19:58:09 TAI)

Cycle 009

- Payload switch down to load new software (2002/09/08 06:46:03 to 2002/09/10)
- Orbit Inclination Maneuver (2002/09/09 23:35:34 to 2002/09/10 01:48:59 TAI)

- Orbit Maintenance Maneuver (2002/09/11 01:55:32 to 2002/09/11 03:55:38 TAI)
- Interface Control Unit anomaly (2002/09/15 02:53:00 to 2002/09/17 10:56:00)

Cycle 010

- RA-2 went to STBY/Refuse (2002/10/09 09 13:34:22 to 2002/10/10 08:56:53)

Cycle 011

- Ra2 switch-down - Planned SM-SOL by PMC1 (2002/11/18 04:38:00 to 2002/11/19 19:19:21,Pass 382-429)
- DORIS Navigator switch-down - Planned SM-SOL by PMC1 (2002/11/18 04:38:02 to 2002/11/22 12:40:00, Pass 382-505)
- MWR switch-down - Planned SM-SOL by PMC1 (2002/11/18 04:37:59 to 2002/11/20 12:20:06, Pass 382-448)
- Orbit Maintenance Maneuver (2002/11/07 18:15:51 to 2002/11/07 21:06:17,Pass 83-85)
- Orbit Maintenance Maneuver (2002/11/29 03:35:30 to 2002/11/29 06:25:57,Pass 696-698)

Cycle 012

- RA-2 went to HTR-0 Refuse (2002/12/21 04:31:26 to 2002/12/21 12:52:00, Pass 325-333)
- Orbit Inclination Maneuver (2002/12/18 04:28:18 to 2002/12/18 06:36:46, Pass 238-240)
- Orbit Maintenance Maneuver (2002/12/18 22:17:22 to 2002/12/19 00:17:34, Pass 259-261)

Cycle 013

- RA-2 went to HTR-0 Refuse (2003-01-16 01:52:36 to 2003-01-17 17:00:35)
- RA-2 went to suspend mode (2003-01-25 23:56:36 to 2003-01-27 19:54:02)
- Orbit Maintenance Maneuver (2003/01/14 00:55:17 to 2003/01/14 03:45:42 TAI)
- Orbit Maintenance Maneuver (2003/02/11 23:04:49 to 2003/02/12 01:04:57 TAI)

Cycle 014

- SEU's caused a Software Anomaly (2003/03/02 02:46:44 to 2003/03/03 16:46:35).
- Subsystems unavailable - Autonmous P/L switch-off (2003/03/15 04:21:08 to 2003/03/17 19:00:13)
- RA2 in HTR0/Refuse due to HPA primery bus undercurrent (2003/03/17 21:09:32 to 2003/03/18 18:50:40)
- Orbit Maintenance Maneuver (2003/02/21 03:42:57 to 2003/02/21 05:53:24)
- Orbit Maintenance Maneuver (2003/03/03 23:51:14 to 2003/03/04 01:51:22)

Cycle 015

- Wrong setting of Ra2 parameters (no CTI tables have been up-loaded on-board) from 18 Mar 2003 18:50:40 to 9 Apr 2003 17:12:24, Pass 1 to 452

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- RA-2 unavailability (Format Header Error forcing ICU to RS/WT/INI) from 8 Apr 2003 15:08:57.000 to 9 Apr 2003 17:12:24.000, Pass 437 to 452
- RA-2 unavailability (Format Header Error forcing ICU to RS/WT/INI) from 8 Apr 2003 15:08:57.000 to 9 Apr 2003 17:12:24.000, Pass 613 to 624
- RA-2 unavailability: Multiple SEU caused ICU switchdown (2003/04/24 13:20:09 to 2003/04/25 09:15:36,879 to 901)
- Orbit Maintenance Maneuver (2003/04/04 00:40:48 to 2003/04/04 02:40:56 TAI)

Cycle 016

- RA2 unavailability (known SEU failure) (from 5 May 2003 12:30:17.000 to 6 May 2003 10:01:10.000, Pass 191 to 215)
- RA-2 unavailability (ICU in SUSPEND due to TM FMT Error when a Reduced FMT was requested) (from 11 May 2003 11:06:33.000 to 12 May 2003 10:14:35.726, Pass 361 to 387)
- Orbit Maintenance Maneuver (from 2003/05/14 22:40:13 to 2003/05/15 00:40:19 TAI, Pass 460 to 462)
- RA-2 unavailability (Switch-down for PMC SW upgrade and OCM) from 18 May 2003 06:25:17.000 to 19 May 2003 15:59:28.000, Pass 548 to 602)
- MWR unavailability (Switch-down for PMC SW upgrade and OCM) from 18 May 2003 06:25:24.000 to 19 May 2003 14:45:40.000, Pass 548 to 602)
- DORIS unavailability (Switch-down for PMC SW upgrade and OCM) from 18 May 2003 06:25:25.000 to 19 May 2003 13:21:28.000, Pass 548 to 602)
- Orbit Inclination Maneuver (from 2003/05/20 04:11:53 to 2003/05/20 06:23:31 TAI, Pass 610 to 612)
- RA-2 unavailability (ICU went to RS/WT/INI) from 1 Jun 2003 14:36:40.000 to 2 Jun 2003 09:20:35.000, Pass967 to 987

Cycle 017

- Orbit Maintenance Maneuver (from 2003/06/07 01:08:16 to 2003/06/07 03:08:23 TAI, Pass 119 to 122)

Cycle 018

- Orbit Maintenance Maneuver (from 2003/07/11 0:58:45 to 2003/07/11 03:49:08 TAI, Pass 90 to 94)
- RA2 unavailability (RA-2 in STBY/REF due to MCMD timeout) (from 26 Jul 2003 15:28:11 to 26 Jul 2003 17:25:35, Pass 538)
- RA2 unavailability (RA-2 picked up Mission Planning schedule) (from 31 Jul 2003 16:11:02 to 31 Jul 2003 18:06:30, Pass 682)
- Orbit Maintenance Maneuver (from 2003/07/11 0:58:45 to 2003/07/11 03:49:08 TAI), Pass 91 to 94)

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Cycle 019

- Orbit Maintenance Maneuver (from 2003/08/15 1:31:29 to 2003/08/15 03:31:35 TAI, Pass 91 to 93)
- RA-2 went to STBY/Refuse due to Individual Echoes MCMD Timeout (from 2003-08-15 16:40:21 to 2003-08-15 18:35:35, Pass 110)
- RA-2 went to STBY/Refuse due to Individual Echoes MCMD Timeout (from 2003-08-30 15:28:00 to 2003-08-30 20:47:35, Pass 538 to 543)
- PLSOL . Instrument Switch OFF/ON (from 2003-09-04 22:52:52 to 2003-09-06 16:41:09, Pass 689 to 738)

Cycle 020

- RA-2 in STANDBY / REFUSE MODE (from 2003-09-21 15:36:40 to 2003-09-21 17:33:30, Pass 166 to 167)
- RA-2 is in RS/WT/INT mode (from 2003-09-27 00:28:08 to 2003-09-27 12:52:00, Pass 320 to 333)
- Wrong setting of Ra2 parameters (no CTI tables have been up-loaded on-board) (from 2003-09-27 12:52:00 to 2003-09-30 12:45:00, Pass 334 to 407)
- Orbit Maintenance Maneuver (2003/09/30 00:40:53 to 2003/09/30 02:41:00 TAI, Pass 405 to 407)

Cycle 021

- Orbit Inclination Maneuver (2003/10/28 04:56:18 to 2003/10/28 07:09:44 TAI, Pass 210 to 212)
- RA-2 is in RS/WT/INT mode. 29 Oct 2003 06 :47 :04 to 29 Oct 2003 12 :58 :35, Pass 242 to 247)
- Orbit Maintenance Maneuver (2003/10/31 01:13:10 to 2003/10/31 03:13:25 TAI, Pass 291 to 293)
- RA-2 is in RS/WT/INT mode. TM format header error (02 Nov 2003 15 :16 :56 to 03 Nov 2003 12 :08 :35, Pass 366 to 389)
- Orbit Maintenance Maneuver (2003/11/18 23:02:30 to 2003/11/19 01:52:55 TAI, Pass 833 to 835)

Cycle 022

- RA-2 is in RS/WT/INT mode (2003-11-26 13:31:20 to 2003-11-26 19:39:35, Pass 49 to 54)
- RA-2 PLSOL . Instrument Switch OFF/ON (2003-12-03 07:18:43 to 2003-12-05 16:35:05, Pass 241 to 308)
- MWR PLSOL . Instrument Switch OFF/ON (2003-12-03 07:18:43 to 2003-12-04 18:45:41)
- RA-2 is in RS/WT/INT mode. (2003-12-06 15:55:52 to 2003-12-10 19:16:36, Pass 338 to 455)
- Orbit Maintenance Maneuver (2003/12/15 21:02:28 to 2003/12/15 23:02:36, Pass 601 to 603)

- Orbit Maintenance Maneuver (2003/12/26 21:03:30 to 2003/12/26 23:03:34, Pass 916 to 918)

Cycle 023

- Orbit Maintenance Maneuver (2004/01/21 23:54:27 to 2004/01/22 01:54:37))
- Orbit Maintenance Maneuver (2004/01/26 22:26:07 to 2004/01/27 00:26:11))

Cycle 024

- Orbit Inclination Maneuver (2004/02/04 04:46:39 to 2004/02/04 06:58:05)
- Orbit Maintenance Maneuver (2004/02/05 11:17:21 to 2004/02/05 13:17:23)
- Orbit Maintenance Maneuver (2004/02/24 11:48:39 to 2004/02/24 13:48:45)

Cycle 025

- Orbit Maintenance Maneuver (2004/04/07 20:05:30 to 2004/04/07 22:05:34)

Cycle 026

- RA-2 in STANDBY/REF DUE TO MCMD H202 FAILURE (2004-22-04 15:15:36 2004-22-04 17:07:05)
- RA-2 Switch down to RESET/WAIT due to too many SEU's reported. (2004-05-10 02:06:31 2004-05-10 11:27:30)
- Orbit Inclination Maneuver (2004/04/14 04:43:02 2004/04/14 06:55:00)
- Orbit Maintenance Maneuver (2004/05/07 01:08:56 2004/05/07 03:09:04)

Cycle 027

- RA2 went to suspend owing to repeated type 10 entries in report format (2004/05/31 02:45:27 to 2004/05/31 12:01:50)
- No DORIS data from 2004/06/06 13:00:00 to 2004/06/14 14:52:00. Following an onboard incident, Doris instrument has been switched to the redundant chain. Doris data are unavailable from June, 6th to June, 14th. To allow GDR production, POE with laser only data have been produced during this period.
- RA2 in SUSPEND Mode (2004/06/21 14:47:51 to 2004/06/21 19:24:30, Pass 995 to 999)

Cycle 028

- RA2 in ICU rs/wt/ini (2004/07/18 13:47:03 to 2004/07/18 19:59:00, Pass 765 to 771)
- Orbit Maintenance Maneuver (2004/06/30 08:08:29 to 2004/06/30 10:08:35, Pass 242 to 244)

Cycle 029

- RA2 in ICU RS/WT/INI. (SDU problem in RAM) (2004/08/10 15:00:39 to 2004/08/11 10:59:30, Pass 423 to 445)
- Orbit Maintenance Maneuver (2004/08/17 02:04:20 to 2004/08/17 04:04:26 , Pass 607 to 609)

Cycle 030

- RA2 in ICU RS/WT/INI. (SDU problem in RAM) (2004/09/26 13:39:50 to 2004/09/27 16:23:30, Pass 765-795)
- Abnormal behaviour of the RA-2 sensor (2004/09/27 16:23:30 to 2004-09-29 10:21:07, Pass 796-846)
- Collision avoidance Maneuver (2004/09/01 22:52:27 to 2004/09/02 00:52:37, Pass 60-62)
- Collision avoidance Maneuver (2004/09/02 23:44:27 to 2004/09/03 01:44:37, Pass 89-91)
- Orbit Inclination Maneuver (2004/09/21 04:14:37 to 2004/09/21 06:29:19, Pass 610-612)
- Orbit Maintenance Maneuver (2004/09/24 03:53:38 to 2004/09/24 05:53:46, Pass 695-697)

Cycle 031

- Collision avoidance Maneuver (2004/10/22 03:20:22 to 2004/10/22 07:00:41, Pass 495-498)
- High solar activity (Pass 974-1002)

Cycle 032

- RA2 in RS/WT/INI. 2004/11/23 13:25:58 to 2004/11/24 14:10:10, Pass 421-449
- RA2 Format header error. 2004/12/01 10:22:30 to 2004/12/01 15:34:29, Pass 647-651
- Orbit Maintenance Maneuver (2004/11/12 01:07:57 to 2004/11/12 03:08:06,Pass 91-93)

Cycle 033

- RA-2 went to RS/WT/INI due RBI (2004/12/27 02:49:10 to 2004/12/27 13:49:30, 380 to 391)
- Orbit Maintenance Maneuver (2004/12/17 01:03:48 to 2004/12/17 03:03:52, 91 to 93)
- Orbit Maintenance Maneuver (2005/01/05 23:10:28 ro 2005/01/06 01:10:36, 661 to 663)
- Orbit Inclination Maneuver (2005/01/07 04:25:17 to 2005/01/07 06:38:53, 696 to 698)

Cycle 034

- RA-2 went to RS/WT/INI Mode (2005/01/26 15:50:30 to 2005/01/26 21:07:30, 252 to 257)
- Orbit Maintenance Maneuver (2005/02/18 01:23:24 to 2005/02/18 03:23:28, 893 to 894)

Cycle 035

- RA-2 went to RS/WT/INI Mode (2005/03/18 04:35:34 to 2005/03/18 12:58:00, 697 to 705)
- Orbit Maintenance Maneuver (2005/03/17 04:51:26 to 2005/03/17 07:06:31, 668 to 669)

Cycle 036

- RA-2 went to RS/WT/INI mode (2005/04/18 05:01:10 to 2005/04/18 13:22:32, 583 to 591)
- RA-2 went to RS/WT/INI mode (2005/04/18 37:58:10 to 2005/04/24 11:42:30, 742 to 761)

Cycle 037

- RA-2 went to ICU in RS/WT/INI (RBI ERR 71) (2005/05/14 23:56:37 to 2005/05/15 10:53:45, 348 to 359)
- RA-2 went to ICU in RS/WT/INI (2005/05/21 00:10:45 to 2005/05/21 10:55:35, 520 to 531)

Cycle 038

- RA-2 went to ICU in RS/WT/INI (2005/07/04 04:41:10 to 2005/07/04 11:19:39, 783 t0 789)

Cycle 039

- RA-2 went to ICU in RS/WT/INI (2005/07/16 13:32:21 to 2005/07/16 19:58:52,135 to 141)
- RA-2 went to ICU in RS/WT/INI (2005/07/17 14:43:49 to 2005/07/17 19:20:30,165 to 169)
- RA-2 went to ICU in RS/WT/INI (2005/07/29 00:41:41 to 2005/07/29 09:58:30,492 to 501)
- Orbit Maintenance Maneuver (2005/08/09 22:45:44 to 2005/08/10 00:45:50 TAI)

Cycle 040

- RA-2 went to ICU in RS/WT/INI (2005/08/16 16:41:57 to 2005/08/16 20:22:30,24 to 27)
- RA-2 went to ICU in RS/WT/INI (2005/08/30 16:01:25 to 2005/08/30 19:43:00,424 to 427)
- RA-2 went to ICU in RS/WT/INI (2005/09/12 15:53:09 to 2005/09/12 19:47:00,796 to 799)
- Orbit Maintenance Maneuver (2005/09/07 05:19:53 to 2005/09/07 07:36:31 TAI)

Cycle 041

- RA-2 went to ICU in RS/WT/INI (2005/09/20 12:19:17 to 2005/09/20 18:56:00,19 to 25)
- RA-2 went in RS/WT/INI (2005/10/04 12:47:33 to 2005/10/04 16:35:30,420 to 423)
- Orbit Maintenance Maneuver (2005/10/06 02:19:10 to 2005/10/06 02:19:14 TAI)

Cycle 042

- RA-2 went in RS/WT/INI following Uncontrolled S/W Action (2005/10/28 05:34:13 to 2005/10/28 10:39:00,97 to 101)

Cycle 043

- RA-2 went in RS/WT/INI following Uncontrolled S/W Action (2006/01/02 12:56:35 2006/01/02 18:09:30,993 to 997)

Cycle 044

- RA-2 went in RS/WT/INI following Multiple SEU Anomaly (ref AR-614) (2006/01/12 14:20:35 to 2006/01/12 19:12:30,279 to 283)
- RA-2 went in RS/WT/INI(2006/01/30 02:07:15 to 2006/01/30 11:29:00,780 to 789)
- RA-2 went in RS/WT/INI following Uncontrolled S/W Action (2006/02/01 05:17:56 to 2006/02/01 12:04:30,841 to 847)

- RA-2 went in RS/WT/INI following Uncontrolled S/W Action (2006/02/01 16:30:28 to 2006/02/01 18:36:30,854 to 855)
- Orbit Inclination Maneuver (2006/01/10 05:54:24 to 2006/01/10 06:11:24)

Cycle 045

- RA-2 went in RA2 back to operations following TM format anomaly (2006/03/13 09:36:51 to 2006/03/13 17:40:00,989 to 997))

Cycle 046

- RA-2 switch to STBY and back to measurement to get useful telemetry related to USO (2006/03/17 12:04:00 to 2006/03/17 13:26:00,104 to 107)
- Orbit Inclination Maneuver (2006/03/28 05:33:20 to 2006/03/28 05:52:11 TAI)
- Payload anomaly DORIS MVR switch off (no data from) (2006/04/06 02:09:00 to 2006/04/08 12:40:00 TAI)
- RA2 back to operations following TM format anomaly (2006/04/06 12:31:00 to 2006/04/08 12:31:00,664 to 735)
- Doris Doppler Instrument nominal mode with median frequency bandwidth pre-positionning (required for DORIS incident recovery) (2004/04/08 12:40:00 to 2006/04/14 09:00:00 TAI)
- Payload anomaly DORIS Reset (2006/04/14 09:00:09)

Cycle 047

- On 12th-13th May, a special operation was executed to limit RA-2 Chirp Bandwidth to 80MHz (starting from 12/05/2006 at 15:51:37, pass 710) and then 20 MHz (starting from 13/05/2006 at 03:57:57, Pass 724). The instrument was returned to 320MHz on 13/05/2006 at 15:10:17, Pass 738. Users are strongly advised not to use passes 710-738
- The instrument sub-system Radio Frequency Module (RFM) was switched to its B-side on 15 May 2006 at 14:21:50, Pass 790
- RA-2 BACK TO OPERATIONS AFTER 2 CONSECUTIVE SEU ANOMALIES (19 May 2006 09:24:32 and 19 May 2006 19:13:00)

Cycle 048

- RFM switched to its nominal configuration side (A-side) on the 2006/06/21 at 13:20:15, Pass 850
- RA-2 Back to Measurement following Uncontrolled S/W Action (2006/06/25 15:01:36 to 2006/06/25 19:46:00, passes 967-971)

Cycle 049

- none

Cycle 050

- RA-2 Back to Measurement following Multiple SEU Anomaly (2006/08/01 01:14:40 to 2006/08/01 08:54:30,6 to 13)

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- Foccserver have been re-booted and is up and running. The problem was probably due to a HW failure at ESRIN (IECF) which caused all the user slots to be occupied(2006/08/17 00:00:41 to 2006/08/17 11:10:00,TAI)

Cycle 051

- RA-2 Back to Measurement following a Service Module Anomaly (2006/09/7 16:40:30 to 2006/09/10 15:47:30,80 to 166)
- Orbit Inclination Maneuver (2006/09/13 05:22:17 to 2006/09/13 05:40:29)
- Interruption of the Envisat data transmission via the ESA Data Relay Satellite Artemis (anomaly with Envisat Ka-band antenna) from 2006/09/26 until 2006/10/1,630 to 641, 658 to 669, 686 to 697, 716 to 725, 744 to 755)

Cycle 052

- RA-2 Back to Measurement following a Service Module Anomaly (2006/10/26 04:02:43 to 2006/10/26 10:32:00,467 to 473)
- RA-2 Back to Measurement following a Service Module Anomaly (2006/11/02 15:20:19 to 2006/11/02 20:07:00,681 to 685)

Cycle 053

- RA-2 Back to Measurement following Multiple SEU Anomaly (2006/11/26 08:01:06 to 2006/11/26 17:32:00, 358-367)
- Available again in Measurement after SM Memory Maintenance (2006/11/28 07:40:00 to 2006/11/29 17:23:00,413-469)
- The entire payload switched off (Due to a LVL 3 PROTOCOL ERROR AND INTERRUPT) (2006/12/12 18:02:17 to 2006/12/15 15:54:00,826-909)

Cycle 054

- HSM input reset (2006/12/27 14:18:50 to 2006/12/28 10:51:48)

Cycle 055

- Orbit Inclination Maneuver (2007/01/23 04:33:06 to 2007/01/23 04:51:50; 9)
- RA-2 recovered from STANDBY / REFUSE MODE and back to MEASUREMENT (2007/02/01 15:15:30 to 2007/02/01 17:11:30, 280-281)
- RA-2 return to operation from RESET/WAIT due to MCMD Transfer Acknowledge Error (2007/02/16 00:47:49 to 2007/02/16 11:07:00, 692-703)
- RA-2 return to operation from HT0/REF due to low HPA PBC current (2007/02/17 00:45:47 to 2007/02/19 11:11:00, 721-789)

Cycle 056

- No event

Cycle 057

- Orbit Inclination Maneuver (2007/04/03 04:34:42 to 2007/04/03 04:50:14)
- RA-2 Return to Mesurement from HEATER 0 / REFUSE MODE due to HPA bus current OOL (2007/04/03 12:37:27 3 to 2007/04/03 13:48:00)
- RA-2 Return to Measurement after HEATER 0 / REFUSE MODE due to HPA bus current OOL (2007/04/04 09:49:12 to 2007/04/04 11:30:00)
- RA-2 back to measurement from STBY/REFUSE following HTR0/REFUSE MODE (2007/04/09 05:08:51 to 2007/04/09 10:36:30)

Cycle 058

- The MWR instrument switched into Stand-by/Refuse mode following an on-board anomaly (2007/05/26 13:20:29 to 2007/05/30 13:41:06, 535-649)

Cycle 059

- RA-2 recovered back to measurement from HTR1/REF0 (2007/06/30 00:37:55 to 2007/06/02 09:51:00,520-587)

Cycle 060

- RA-2 returned to Measurement from HTR1/REF due to a Telemetry error.(2007/07/19 01:08:026 to 2007/07/19 07:38:00,63-69)
- Orbit Inclination Maneuver (2007/07/17 04:41:26 to 2007/07/17 04:43:42,9)

Cycle 061

- Payload switch-off due to Service Module Anomaly (Global AOCS Surveillance triggered) (24 Sep 2007 12:27:00 to 27 Sep 2007 11:13:30,993-1002)

Cycle 062

- Payload switch-off due to Service Module Anomaly (Global AOCS Surveillance ered).(24 Sep 2007 12:27:00 to 27 Sep 2007 11:13:30,1-7)
- Orbit Inclination Maneuver (27 Sep 2007 05:16:25 to 27 Sep 2007 05:31:15)
- MCMD Transfer Acknowledge Error caused the ICU to be put into Reset/Wait Mode. This is one of the expected anomalies and RA-2 was back to measurement on the same day. (2 Oct 2007 16:15:55 to 2 Oct 2007 20:09:30,224-227)

Cycle 063

- The instrument was switched to Suspend by the PMC following consecutive TM format errors, the mode was commanded back to Measurement on the same day.(8 Nov 2007 13:31:47 to 8 Nov 2007 17:24:30)

Cycle 064

- Planned payload unavailability for OCM and Maintenance (3 Dec 2007 22:00:00 to 4 Dec 2007 13:50:00, passes 2 to 21)
- Orbit Inclination Maneuver (4 Dec 2007 04:34:54 to 4 Dec 2007 04:49:55)

- RA-2 Back to Measurement following TM Format Anomaly (9 Dec 2007 20:45:11 to 10 Dec 2007 09:14:30, passes 172 to 187)
- RA-2 was switched down into Standby for the System Memory Test (13 Dec 2007 06:44:00 to 13 Dec 2007 12:39:30, passes 270 to 277)

Cycle 065

- On 16th January an anomaly occurred in the HSM from 16 Jan 2008 16:11:00 to 17 Jan 2008 10:35:21, passes 253 to 276
- Envisat RA-2 (A-Side) S-band transmission power suddenly dropped on 17 January 2008, 23:23:40, UTC. Consequently, all S-band parameters as well as the dual ionospheric correction are not relevant anymore and must not be used from this date onwards.

Cycle 066

- Orbit Inclination Maneuver (2008/02/12 03:35:23 to 2008/02/12 05:49:28, 9)

Cycle 067

- None

Cycle 068

- Orbit Inclination Maneuver (2008/04/22 start : 04:37:04 TAI, end : 04:47:48 TAI).

Cycle 069

- None

Cycle 070

- Orbit Inclination Maneuver (2008/07/01 from 04:41:17 to 04:43:49 TAI).

Cycle 071

- None

Cycle 072

- Orbit Inclination Maneuver (2008/09/09 from 04:34:21 to 2008/09/09 04:50:26 TAI).
- From 2008/09/11 18:59:00 TAI to 2008/09/12 01:13:00 TAI, ARTEMIS (ENVISAT relay satellite) was unavailable due to ATV operation. This impacted the data availability from pass 86 to 90.

Cycle 073

- During the period covered by cycle 073 one SFCM maneuvre was executed as planned on the 7th of September at 01:36:05.

Cycle 074

- 2008/11/18 04:35:33 Orbit Inclination Maneuver (end : 2008/11/18 04:49:13 TAI)
- 2008/11/30 20:25:00 Artemis acquisition antenna was damaged by a strong hail. No data from 2008/11/30 20:25:00 TAI to 2008/12/01 07:14:00 TAI

- 2008/12/19 03:12:32 Orbit Maintenance Maneuver (end : 2008/12/19 03:12:34 TAI)

Cycle 075

- None

Cycle 076

- 2009/01/27 03:35:18 Orbit Inclination Maneuver (end : 2009/01/27 05:49:30 TAI)
- 2009/01/28 01:26:31 Orbit Maintenance Maneuver (end : 2009/01/28 03:26:37 TAI)
- 2009/02/17 03:27:51 Orbit Maintenance Maneuver (end : 2009/02/17 03:27:54 TAI)

Cycle 077

- 2009/03/13 03:06:29 Orbit Maintenance Maneuver (end : 2009/03/13 03:06:31 TAI)

Cycle 078

- 2009/04/07 04:34:26 Orbit Inclination Maneuver (end : 2009/04/07 04:50:21 TAI)
- 2009/04/15 22:16:36 Orbit Maintenance Maneuver (end : 2009/04/15 23:56:44 TAI)
- 2009/04/21 02:50:33 Orbit Maintenance Maneuver (end : 2009/04/21 02:50:35 TAI)
- 2009/04/28 13:04:50 Failure of the HSM (High Speed Mutliplexer), no data from 2009/04/28 13:04:50 TAI to 2009/04/29 14:57:28 TAI

Cycle 079

- 2009/05/20 01:32:33 Orbit Maintenance Maneuver (end : 2009/05/20 03:13:11 TAI)

Cycle 080

- 2009/07/09 03:01:12 Orbit Maintenance Maneuver (end : 2009/07/09 03:01:16 TAI)

Cycle 081

- 2009/07/21 04:40:21 Orbit Inclination Maneuver (end : 2009/07/21 04:44:35 TAI)
- 2009/07/23 02:00:32 Orbit Maintenance Maneuver (end : 2009/07/23 02:50:50 TAI)

Cycle 082

- None

Cycle 083

- 2009/09/29 04:33:42 Orbit Inclination Maneuver (end : 2009/09/29 04:51:00 TAI)
- 2009/10/15 01:56:42 Orbit Maintenance Maneuver (end : 2009/10/15 01:56:44 TAI)

Cycle 084

- 2009/11/04 07:51:36 Orbit Maintenance Maneuver (end : 2009/11/04 09:32:30 TAI)
- 2009/11/06 02:35:08 Orbit Maintenance Maneuver (end : 2009/11/06 02:35:10 TAI)
- 2009/12/03 03:04:03 Orbit Maintenance Maneuver (end : 2009/12/03 03:04:06 TAI)

.

Cycle 085

- 2009/12/08 04:34:40 Orbit Inclination Maneuver (end : 2009/12/08 04:59:57 TAI)
- 2009/12/09 22:18:47 Orbit Maintenance Maneuver (end : 2009/12/09 22:18:53 TAI)
- 2009/12/18 02:24:03 Orbit Maintenance Maneuver (end : 2009/12/18 02:24:05 TAI)

Cycle 086

- 2010/01/21 01:03:29 Orbit Maintenance Maneuver (end: 2011/01/21 04:44:32 TAI)
- 2010/01/22 01:52:33 Orbit Maintenance Maneuver (end: 2011/01/22 01:52:38 TAI)
- 2010/01/23 17:02:10 Diode software failure (end : 2010/01/26 21:03:30 TAI)
- 2010/01/23 17:03:20 DORIS instrument in Fixed-Frequency Doppler Search mode (so-called : waiting mode) from 2010/01/23 17:03:20 TAI to 2010/01/26 21:00:48 TAI
- 2010/01/27 20:15:28 DORIS instrument in Fixed-Frequency Doppler Search mode (so-called : waiting mode) from 2010/01/27 20:15:28 TAI to 2010/01/29 14:04:48 TAI
- 2010/01/27 20:13:30 Diode software failure (end : 2010/01/29 14:26:10 TAI)

Cycle 087

- 2010/02/16 04:33:58 Orbit Inclination Maneuver (end : 2010/02/16 04:50:39 TAI)
- 2010/02/22 21:13:54 Orbit Maintenance Maneuver (end : 2010/02/22 22:04:15 TAI)
- 2010/03/17 17:24:29 Orbit Maintenance Maneuver (end : 2010/03/17 19:05:15 TAI)

Cycle 088

- 2010/04/11 01:09:00 Not acquired at Esrin due to a scheduled USV-2 TL-72H launch. No data from 2010/04/11 01:09:00 TAI to 2010/04/11 07:28:00 TAI
- 2010/04/17 03:03:27 Orbit Maintenance Maneuver (end : 2010/04/17 04:44:06 TAI)

Cycle 089

- 2010/04/27 04:37:05 Orbit Inclination Maneuver (end : 2010/04/27 04:47:30 TAI)
- 2010/05/28 02:35:15 Orbit Maintenance Maneuver (end : 2010/05/28 04:15:53 TAI)

Cycle 090

- 2010/06/25 03:22:57 Orbit Maintenance Maneuver (end : 2010/06/25 03:23:01 TAI)
- 2010/06/30 23:06:08 DORIS instrument in Fixed-Frequency Doppler Search mode (so-called : waiting mode) from 2010/06/30 23:06:08 TAI to 2010/07/01 01:56:48 TAI
- 2010/07/02 07:43:28 DORIS instrument in Fixed-Frequency Doppler Search mode (so-called : waiting mode) from 2010/07/02 07:43:28 TAI to 2010/07/02 21:48:28 TAI

Cycle 091

- 2010/07/06 04:37:29 Orbit Inclination Maneuver (end : 2010/07/06 04:47:06 TAI)

- 2010/07/07 02:03:35 Orbit Maintenance Maneuver (end : 2010/07/07 02:03:37 TAI)
- 2010/07/30 05:20:14 Orbit Maintenance Maneuver (end : 2010/07/30 05:20:17 TAI)

Cycle 092

- 2010/08/23 21:41:33 Orbit Maintenance Maneuver (end : 2010/08/23 21:41:36 TAI)

Cycle 093

- 2010/09/24 03:39:33 Orbit Maintenance Maneuver (end : 2010/09/24 03:39:35 TAI)
- 2010/10/15 03:03:25 Orbit Maintenance Maneuver (end : 2010/10/15 05:03:28 TAI)

Cycle 094

- 20-10-2010 23:52:00 to 21-10-2010 06:34:22 - KBS-2 down due to EPC2 power relay status OFF

Cycle 095

- Up to 26-10-2010 07:56: planned interruption during change of orbit
- 2010/10/26 13:49:13 Orbit Maintenance Maneuver (end : 2010/10/26 16:42:43 TAI)

Cycle 096

- 2010/11/25 03:16:03 Orbit Maintenance Maneuver (end : 2010/11/25 04:56:20 TAI)
- 2010/11/22 07:02:12 Orbit Maintenance Maneuver (end : 2010/11/22 08:42:30 TAI)
- 2010/11/04 20:40:53 Orbit Maintenance Maneuver (end : 2010/11/04 21:31:14 TAI)

Cycle 097

- 2010/12/17 06:12:15 Orbit Maintenance Maneuver (end : 2010/12/17 06:12:19 TAI)
- 2010/12/01 20:51:28 Orbit Maintenance Maneuver (end : 2010/12/02 00:12:08 TAI)

Cycle 098

- 2011/01/14 01:58:18 Orbit Maintenance Maneuver (end : 2011/01/14 01:58:22 TAI)

Cycle 099

- 2011/02/18 05:10:16 Orbit Maintenance Maneuver (end : 2011/02/18 05:10:20 TAI)
- RA2 instrument down [EOFC 59618 (1PN) EN-UNA-2011/0026] (2011/02/21, from 16:29:39 to 21:15:38)

Cycle 100

- 2011/03/17 00:51:32 Orbit Maintenance Maneuver (end : 2011/03/17 02:31:50 TAI)
- ATV-2 Envisat Emergency activity [EOFC 60464] (2011/03/22, from 02:21:59 to 07:06:28)

Cycle 101

- RA2 in RS/WT/INI due to TM Format Anomaly (2011/04/0, from 00:19:00 to 10:54:37)

- [RA2] Payload /PEB Switch-off due to Service Module Anomaly (2011/04/03, from 15:50:32 to 2011/04/04 15:39:37)
- 2011/04/08 09:43:20 Orbit Maintenance Maneuver (end : 2011/04/08 09:43:28 TAI)
- 2011/04/16 14:17:07 Orbit Maintenance Maneuver (end : 2011/04/16 14:17:11 TAI)

Cycle 102

- ICU anomaly (2011/04/27, from 03:25:47 to 10:03:38)
- 2011/05/05 01:02:53 Orbit Maintenance Maneuver (end : 2011/05/05 01:03:01 TAI)
- No data from 2011/05/21 00:53:11 TAI to 2011/05/23 10:24:32 TAI - DORIS Instrument Failure
- ARTEMIS : Service rejected by emergency ATV (2011/05/23, from 20:10:41 to 23:02:09)

Cycle 103

- 2011/06/01 02:41:56 Orbit Maintenance Maneuver (end : 2011/06/01 03:32:01 TAI)
- 2011/06/16 04:00:10 Orbit Maintenance Maneuver (end : 2011/06/16 05:40:28 TAI)

Cycle 104

- 2011/07/13 01:08:17 Orbit Maintenance Maneuver (end : 2011/07/13 04:48:34 TAI)
- 2011/07/14 03:24:16 Orbit Maintenance Maneuver (end : 2011/07/14 07:04:48 TAI)

Cycle 105

- 2011/08/11 00:55:16 Orbit Maintenance Maneuver (end : 2011/08/11 02:35:32 TAI)
- 2011/08/17 22:46:22 Orbit Maintenance Maneuver (end : 2011/08/18 00:26:59 TAI)
- 2011/08/23 00:38:33 Orbit Maintenance Maneuver (end : 2011/08/23 00:38:35 TAI)

Cycle 106 Nothing to report.

Cycle 107

- 2011/10/14 03:11:18 Orbit Maintenance Maneuver (end : 2011/10/14 03:11:26 TAI)
- 2011/09/30 03:37:33 Orbit Maintenance Maneuver (end : 2011/09/30 04:27:39 TAI)
- 2011/09/23 01:19:06 Orbit Maintenance Maneuver (end : 2011/09/23 02:59:24 TAI)

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