CalVal Saral/ Altika

Saral/ Altika reprocessing GDR-T Patch2

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List of tables and figures

List of Tables

List of Figures

List of items to be defined or to be confirmed

Applicable documents / reference documents

Contents

1. Introduction

This document presents the synthesis of the reprocessing of SARAL/AltiKa data in version GDR-T Patch 2. This work was performed at the CLS Space Oceanography Division in the frame of the SALP contract (N° 104685/00 TC n°6) supported by CNES. The GDR-T Patch 2 data were created with the following software versions:

- SPA: 4.1
- Bibli-Alti: V5.2p1
- Bibli N1: V4.2p1

GDR Cycles 1 to 7 were reprocessed. Previously this data were released in Patch1 version. The first cycle produced operationally in GDR-T Patch2 version (never produced in Patch1 version) was cycle 8. Though cycles 8 and 9 do not belong to the reprocessed cycles, they were included in some of the figures.

Patch2 contains the following evolutions:
Wind look-up table : The table provided by NOAA is used. This table is only based on the measured sigma0, taking into account the atmospheric attenuation (sigma0 at the surface). (Reference: Lillibridge et al. [13])

SSB look-up table : The table provided by R. Scharroo is used (same method as in [21]). We use only the significant wave height to compute the SSB.

Radiometer neural algorithm : Taking into account several months of AltiKa measurements, the neural network coefficients have been updated. Note that this modifies the radiometer related parameters (radiometer wet troposphere correction, atmospheric attenuation, radiometer liquid water content and radiometer water vapor content).

Ice-2 retracking algorithm : The algorithm has been updated taking into account the AltiKa Ka band specificities (ice2 algorithm was based on ENVISAT Ku band experience).

FES2012 tide model : This new tide model is included, improving the SSH accuracy in coastal zones. (Reference : http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/global-tidefes2004-fes99/description-fes2012.html)

Matching pursuit algorithm : The algorithm based on J. Tournadre proposal has been tuned to comply to AltiKa Ka band specificities.

MQE parameter scale factor : The scale factor of the MQE has been modified.

Update of the altimeter characterization file : The altimeter characterization file has been modified in order to account for 63 values of altimeter gain control loop (AGC). This has impacts over sea ice and land hydrology, in some cases the AGC was set to default value in current P1 products.

Doris on ground processing (Triode) : The Doris navigator ground processing has been upgraded to reduce the periodic signal observed on the altitude differences with MOE/POE.

The content of Patch1 can be consulted in **Content of Patch1**.

The O/I/GDR products switched to Patch2 version (in operations):

- OGDR: from 2014-02-06 10h46m58 onwards. The first OGDR product produced with Patch2 was SRL_OPN_2PTS010_0407_20140206_104658_20140206_122502.EUM.nc
- IGDR: from 2014-02-11 23h17m37 onwards. The first IGDR product produced with Patch2 was SRL_IPN_2PTP010_0566_20140211_231737_20140212_000755.CNES.nc
- GDR: the first GDR cycle produced operationally with Patch2 was cycle 8 (produced between 5th and 7th February 2014). The previous cycles were reprocessed.

A few products have one data less in Patch2 than in Patch1 (see table 1), but this was considered negligible, and no regenerating was requested for those products.

This report is divided in several chapters:

- Chapter **Data coverage and edited measurements** deals with data availability and editing for Patch2 data compared to Patch1 data
- Chapter **Global impact of Patch2** deals with the global impact of Patch2 data on along-track performances and performances at crossover points. It contains also some comparisons to Jason-2 data.
- Chapter **Impact of Patch2 on parameters and corrections** deals with the impact of Patch2 on several altimeter, radiometer and geophysical parameters
- Chapter **Investigations** deals with the impact of the bad USO file used for the Patch2 reprocessing
- Chapter **Conclusion** gives the conclusion of the Patch2 reprocessing
- The contents of Patch1 and Patch2 are recalled in chapters **Content of Patch1** and **Content of Patch2**

2. Data coverage and edited measurements

Hereafter the data availability and quality (edited data) are compared between Patch2 and Patch1 data.

2.1. Data availability

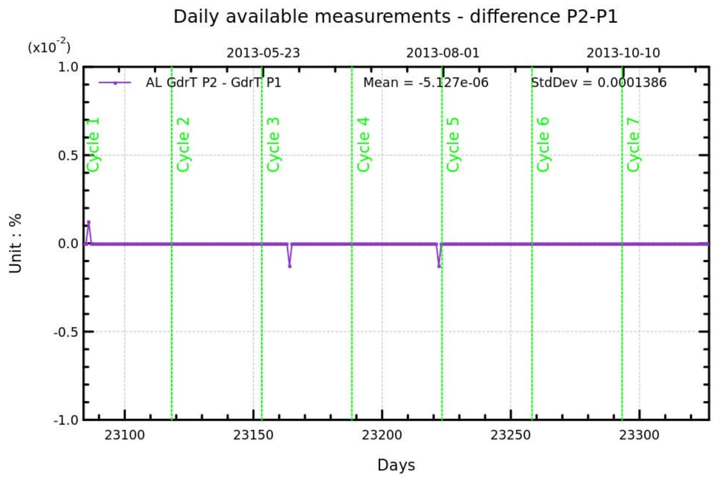


Figure 1: *Difference of percentage of Saral daily available data GDR-T P2 - P1*

The difference of the daily available data between Patch2 and Patch1 product versions (Figure 1) shows that there are as many data in Patch2 as in Patch1, but sometimes a few products (listed in table 1) have one measurement more or less in Patch2 than in Patch1. This difference is negligible.

Cycle	Pass	Nb data P1	Nb data P2
1	61	2856	2857
1	62	756	757
1	64	1360	1359
3	308	2863	2862
4	938	2487	2486
5	853	2811	2812
5	865	2837	2836

Table 1: *Comparison of number of data in P1 vs. P2. Green if P2 has more data than P1, red otherwise*

2.2. Data quality

The flags ice_flag and surface_type are unchanged between Patch1 and Patch2, as over the period of reprocessed data (cycle 1 to 7), the number of measurements edited by ice flag and surface type flag is the same in Patch2 and Patch1.
However, the editing by threshold criteria is slightly different (Figure 2).

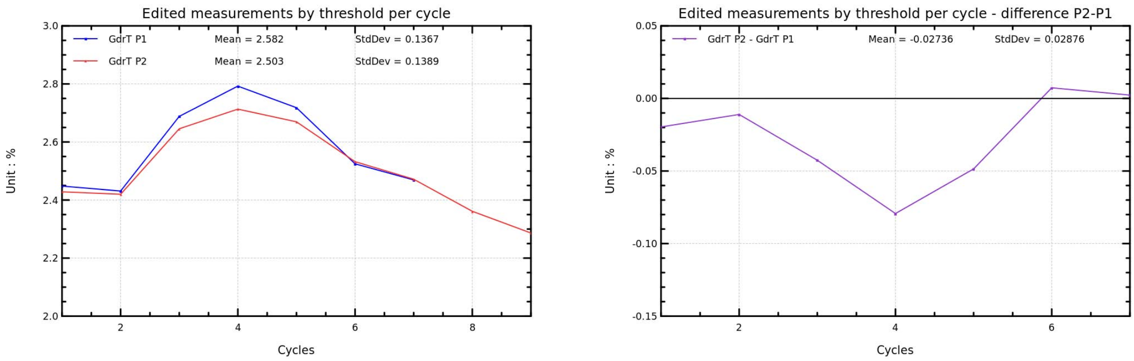


Figure 2: *Cycle per cycle monitoring of percentage of edited data by threshold criteria for Patch1 and Patch2 separately (left) and difference Patch2 - Patch1 (right)*

Generally, slightly less data (0.03 % corresponding in average to approximately 440 measurements per cycle) are edited by threshold criteria in Patch2 version than in Patch1 version, except for cycles 6 and 7 where a little more data are edited with Patch2.
The following table presents the mean percentage of edited data over cycle 1 to 7 for each threshold criterion.

Parameters	Min threshold	Max threshold	Unit	mean % of invalid data over cycles 1 to 7	
				P1	P2
Sea surface height	-130	100	m	0.46	0.46
Sea level anomaly	-2	2	m	0.68	0.80
Nb measurements of range	20	DV	_	1.11	1.11
Std. deviation of range	0	0.2	m	1.49	1.49
Square off nadir angle	-0.2	0.15	deg^2	0.31	0.31
Dry tropospheric correction	-2.5	-1.9	m	0.00	0.00
Combined atmospheric correction	-2	2	m	0.00	0.00
MWR wet tropospheric correction	-0.5	0	m	0.12	0.06
					.../...

Parameters	Min threshold	Max threshold	Unit	mean % of invalid data over cycles 1 to 7	
Significant wave height	0	11	m	0.38	0.38
Sea State Bias	-0.5	0.0025	m	0.32	0.29
Backscatter coefficient	3	30	dB	0.38	0.34
Nb measurements of sigma0	20	DV	_	1.04	1.04
Std. deviation of sigma0	0	1	dB	0.94	0.94
Ocean tide	-5	5	m	0.01	0.18
Equilibrium tide	-0.5	0.5	m	0.00	0.17
Earth tide	-1	1	m	0.00	0.00
Pole tide	-0.15	0.15	m	0.00	0.00
Altimeter wind speed	0	30	$m.s^{-1}$	0.48	0.29
Global statistics of edited measurements by thresholds	_	_	_	2.58	2.55

Table 2: *Table of parameters used for threshold editing (with minimum and maximum thresholds used). The last two columns show the mean percentage (over the reprocessed period) of edited data by each threshold criterion for Patch1 and Patch2 data version. Green if P2 edit less data than P1, red if P2 edit more data than P1, black if equal.*

For the period of reprocessed data, the Patch2 version edits 2.55% with the threshold criteria, whereas with Patch1 version 2.58% were edited. This slight increase of valid data is due to the following threshold criteria: the radiometer wet troposphere correction, the sea state bias, the backscatter coefficient and the altimeter wind speed. This is described in more detail in chapter 2.5..

Nevertheless, the sea level anomaly, the ocean tide and the equilibrium tide edit more data in Patch2. This is described in more detail in chapter 2.4..

2.3. Modification of the threshold for sea state bias (SSB)

During the validation of the reprocessed data it became evident, that the maximum of the sea state bias threshold criteria had to be modified from 0 cm to 0.25 cm for Patch2. Indeed, the maximum of the sea state bias (real not absolute value) occurs for the smallest significant wave height (SWH), which are for Saral/AltiKa 12.6 cm. For Patch1, the maximum of ocean SSB was always slightly negative, around -4.4 mm (so no data were edited by the maximum of the SSB threshold criteria). As the SSB has changed in Patch2, it's maximum becomes slightly positive (+2.5 mm). The figure 3 shows what is edited for Patch2 with the maximum threshold set to 0.25 cm for SSB (left) and what would be in addition edited if the sea state bias maximum threshold would stay at 0 (right). Not adjusting the maximum SSB threshold for Patch2 editing would result in editing all regions with very low SWH. As there is no reason suggesting that these data are invalid, the threshold was modified in order to keep them.

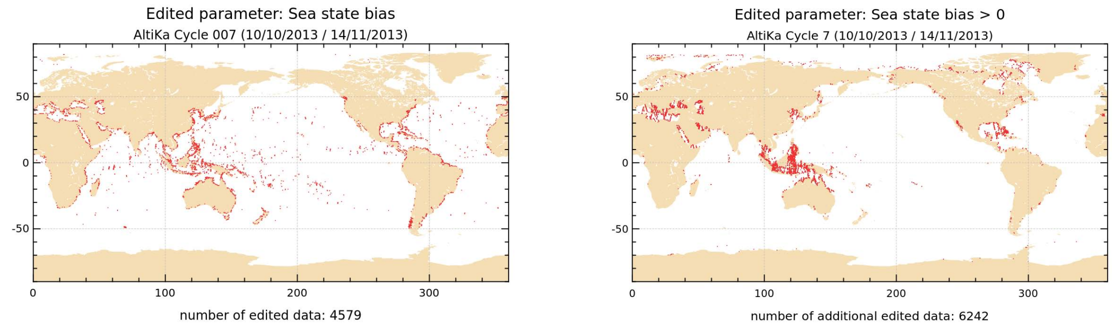


Figure 3: *Edited measurements for SSB P2 with thresholds set to min=-50cm and max=0.25cm (data with SSB at default value are also edited) for cycle 7 on the left. Map of data which would be additionally edited if the maximum SSB threshold stayed at 0 cm (data with SSB P2>0) are shown on the right.*

2.4. Parameters which edit more data in Patch2 than in Patch1

As we saw previously in table 2, the threshold criteria of the sea level anomaly, the geocentric ocean tide and the equilibrium long-period ocean tide height edit more data in Patch2. This is due to the equilibrium long period ocean tide height which is computed for Patch2 with FES2012 algorithm, which tests previously if the grid of the FES2012 tide atlas is defined or not. Consequently, the equilibrium tide is set to default values over land, including lakes and inland seas like Caspian Sea.

As the geocentric ocean tide height includes the equilibrium tide, the Got 4.8 ocean tide (ocean_tide_sol1)

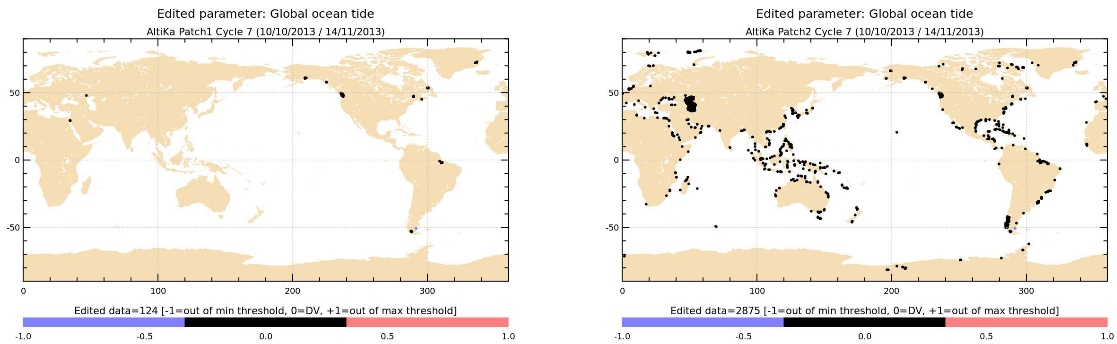


Figure 4: *Edited data (thresholds) for Patch1 (left) and Patch2 (right) ocean_tide_sol1.*

is also set to default value in the same places as the equilibrium tide, as shown on figure 4. This is also the case for FES2012 ocean tide.
These new default values on Patch2 ocean tide appear mainly on coastal areas and the Caspian Sea. Note that other small lakes were already edited in our database by the surface type flag (as we choose to only keep ocean data and the Caspian Sea), but they have also the Got 4.8 ocean tide at default value. Therefore the number of edited Got 4.8 ocean tide data rises from 124 in Patch1 (for cycle 7) to 2875 in Patch2.
As the sea level anomaly (SLA) includes the Got 4.8 ocean tide, the SLA data is also affected.

2.5. Parameters which edit less data in Patch2 than in Patch1

As we saw previously in table 2, several parameters such as the radiometer wet troposphere correction, the sea state bias, the backscatter coefficient and the altimeter wind speed edit less data in Patch2. These are all parameters which were modified between the two versions (see also **Content of Patch2**). The following figures (5, 6, 7 and 8) show for Cycle 7 how the number of edited data evolved between Patch1 and Patch2 and which kind of threshold editing (default values, out of minimum or maximum threshold) had flagged them.

The radiometer wet troposphere (figure 5) edits with Patch2 mainly data lower than the minimum threshold, which means wetter than -50 cm (this occurs mainly around tropics in wet regions) and sometimes data larger than the maximum threshold during maneuvers and also in coastal areas.
Compared to Patch1, there are less edited data on wet areas but slightly more edited data above the maximum threshold at high latitudes. This is related to the updated coefficients of the neural network algorithm computing the radiometer wet troposphere correction for Patch2 data (see also

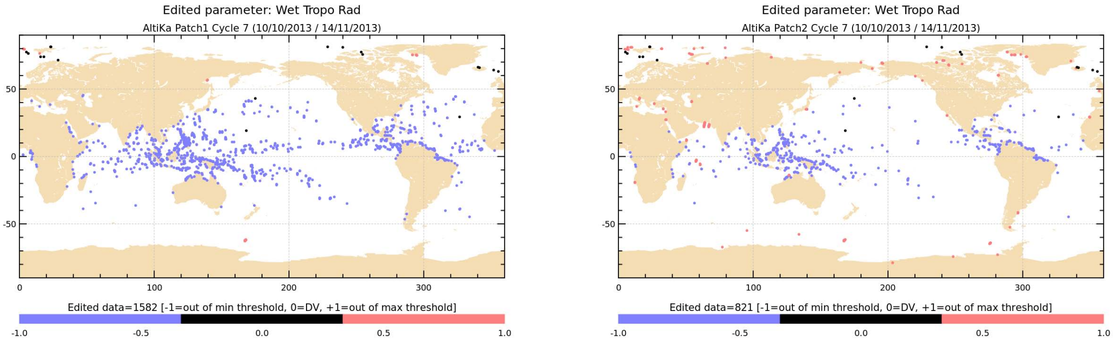


Figure 5: *Edited measurements for radiometer wet troposphere correction for Patch1 (left) and for Patch2 (right) data during AltiKa cycle 7*

chapter 4.1.).

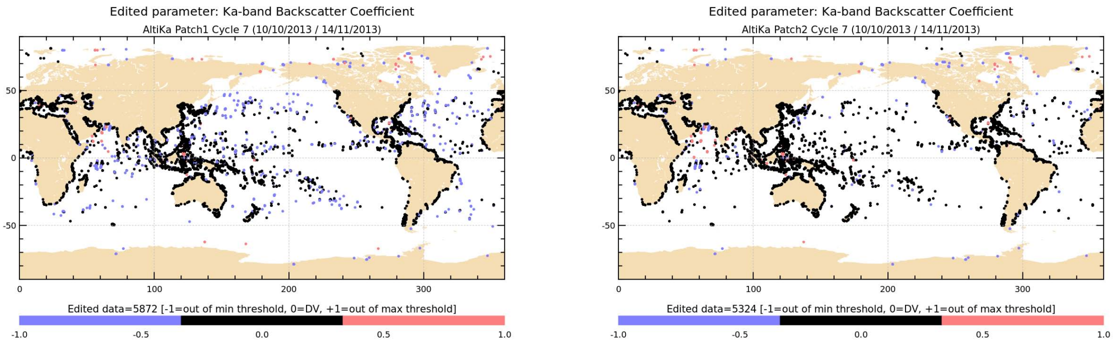


Figure 6: *Edited measurements for backscatter coefficient for Patch1 (left) and Patch2 (right) data during AltiKa cycle 7*

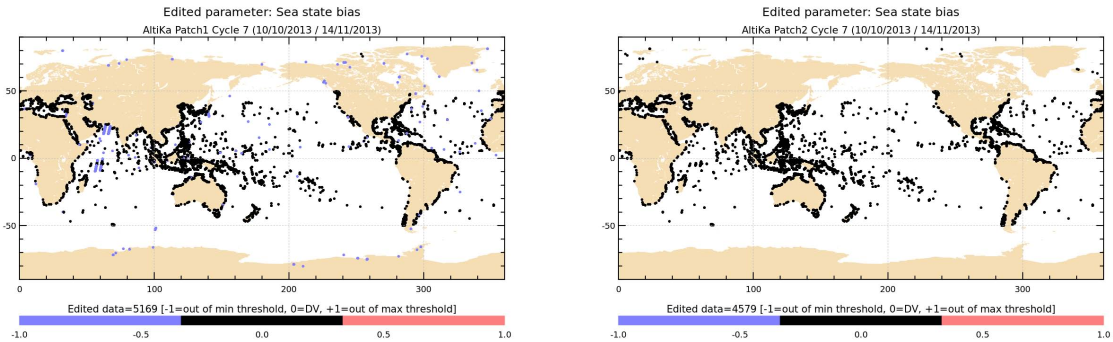


Figure 7: *Edited measurements for sea state bias correction for Patch1 (left) and for Patch2 (right) data during AltiKa cycle 7*

The backscatter coefficient (figure 6) edits with Patch2 mostly data having default values. These are mainly located near coasts, but also in wet regions (impact of rain). Some of the edited data are also out of thresholds (generally due to maneuvers). Compared to Patch1, the number of data edited because they were lower than the minimum threshold has decreased. This is related to the new atmospheric attenuation (see chapter 4.1.3.).

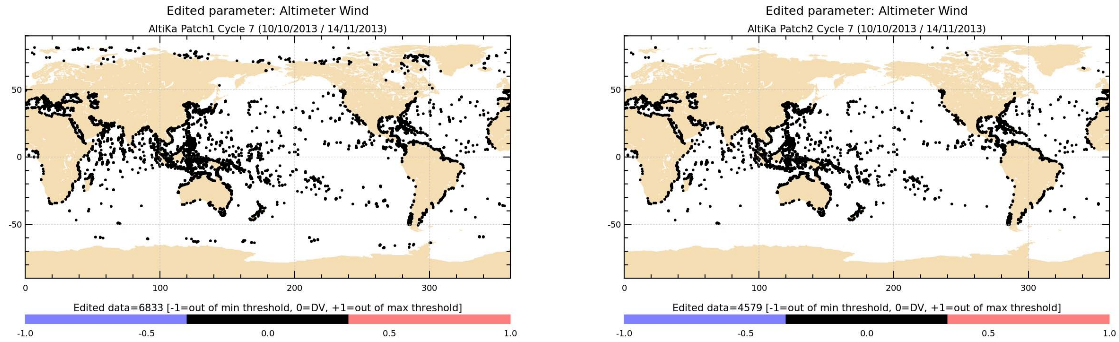


Figure 8: *Edited measurements for altimeter wind Patch1 (left) and Patch2 (right) during AltiKa cycle 7*

Edited measurements by sea state bias (figure 7) and altimeter wind (figure 8) are generally caused by default values. As for backscattering coefficient (which is used for altimeter wind speed calculation), these data are mainly located in coastal areas and wet regions. For Patch1 sea state bias, as it was linearly dependent on significant wave height, it occured that for very high significant wave height (e.g. during maneuvers), sea state bias had a very strong negative value and was therefore edited by the minimum threshold. For Patch2 sea state bias, there are generally no longer data edited by minimum threshold (as they are no longer linearly dependent on significant wave height). Nevertheless this does not mean that all sea state bias data (which are not set to default value) are valid. This is especially not the case during maneuvers, but these measurements are edited by other threshold criteria (significant wave height, backscattering coefficient, ...).

3. Global impact of Patch2

The modifications for Patch2 which have the most impact on the global performance of Saral/AltiKa data are the new sea state bias and radiometer wet troposphere correction. Their individual impacts are detailed in chapter **Impact of Patch2 on parameters and corrections**. Hereafter the global impact on the performance at crossover points and for along-track data is shown.

3.1. Global impact of Patch2 at crossover points

SSH crossover differences are the main tool to analyze the whole altimetry system performances. They allow us to analyze the SSH consistency between ascending and descending passes. However in order to reduce the impact of oceanic variability, we select crossovers with a maximum time lag of 10 days. This gives a measure of the performance on mesoscale time and spatial scales. Mean and standard deviation of SSH crossover differences are computed from the valid data set to estimate maps or a cycle by cycle monitoring over all the altimeter period of Saral/AltiKa. In order to monitor the performances over stable surfaces, additional editing is applied to remove shallow waters (bathymetry above -1000m), areas of high ocean variability (variability above 20 cm rms) and high latitudes ($> |50|deg$). SSH performances are then always estimated with equivalent conditions.
The main SSH calculation for Saral/AltiKa is defined below.

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

with $AltiKa\ Orbit = CNES\ orbit$ (standard D) for GDR products, and

$$\begin{aligned}
\sum_{i=1}^{n} Correction_i &= Dry\ troposphere\ correction \\
&+ Dynamical\ atmospheric\ correction \\
&+ Radiometer\ wet\ troposphere\ correction \\
&+ Ionospheric\ GIM\ correction \\
&+ Hybrid\ (for\ Patch2)\ sea\ state\ bias\ correction \\
&+ Ocean\ tide\ correction\ (including\ loading\ tide) \\
&+ Earth\ tide\ height \\
&+ Pole\ tide\ height
\end{aligned}$$

3.1.1. Mean of SSH crossover differences

Hereafter, analysis are done over the first 7 cycles of Saral/AltiKa using GDR products from P1 and P2. The map of SSH mean ascending/descending differences at crossovers should ideally by close to zero. Geographically correlated patterns on such maps indicate systematic differences between ascending and descending passes. This can indicate either problems in the orbit computation or with geophysical corrections. Comparing the maps of mean SSH differences for Patch1 and Patch2 (figure 9) shows that there is no significant modification. The map of Saral/AltiKa SSH differences at crossovers is still generally negative, except for :

- very high latitudes, especially east of Greenland
- a patch in southern Pacific and in the Gulf of Alaska

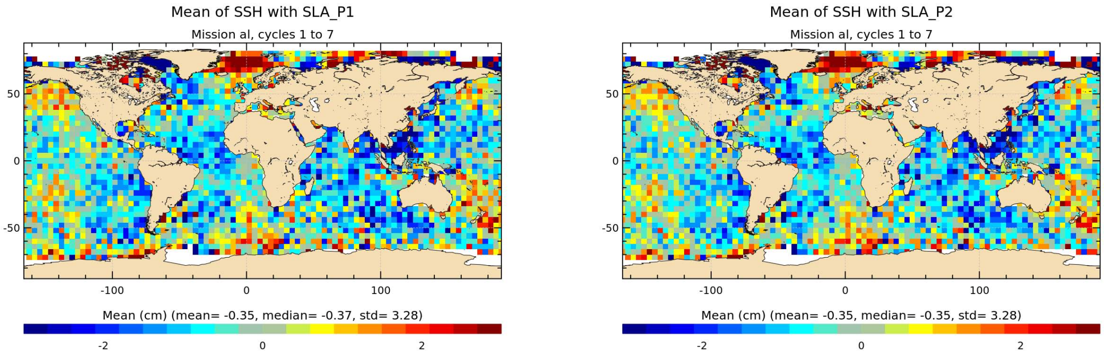


Figure 9: *Map of mean of SSH crossovers differences for Saral/AltiKa Patch1 (left) and Patch2 (right) for Saral cycles 1 to 7. Color scales are between ± 3 cm.*

3.2. Mean of SSH crossover differences between Saral and Jason-2

Dual-mission crossover performances are computed between Saral/AltiKa and Jason-2. Mean SSH differences at Saral/Jason-2 crossovers (figure 10) have a bias of about -6.5 cm (SRL-JA2) for Patch1 and of about -4.5 cm for Patch2, when using model wet troposphere correction (top). This bias is not yet explained. When using radiometer wet troposphere correction (bottom), the bias is for Patch1 smaller by a few mm (related to a bias of roughly 5 mm between radiometer and ECMWF wet troposphere corrections for Jason-2, whereas there was no bias between model and radiometer wet troposphere correction for Patch1 Saral/AltiKa data). Concerning Patch2 data, the global bias between Saral/AltiKa and Jason-2 using radiometer wet troposphere correction is similar to the one using model wet troposphere correction, as the difference between Patch2 radiometer and model wet troposphere correction for Saral/AltiKa is similar to the one of Jason-2. For Patch1, the map shows regional structures of about ± 2 cm. There is a strip of positive difference of about 2 cm around 50° S, a region with generally high significant wave height. This difference is due to differences in sea state bias, as Saral/AltiKa sea state bias of Patch1 was 3.5% of SWH value. Otherwise large scale differences are observable (positive difference in the Atlantic ocean and negative difference in the Pacific ocean).

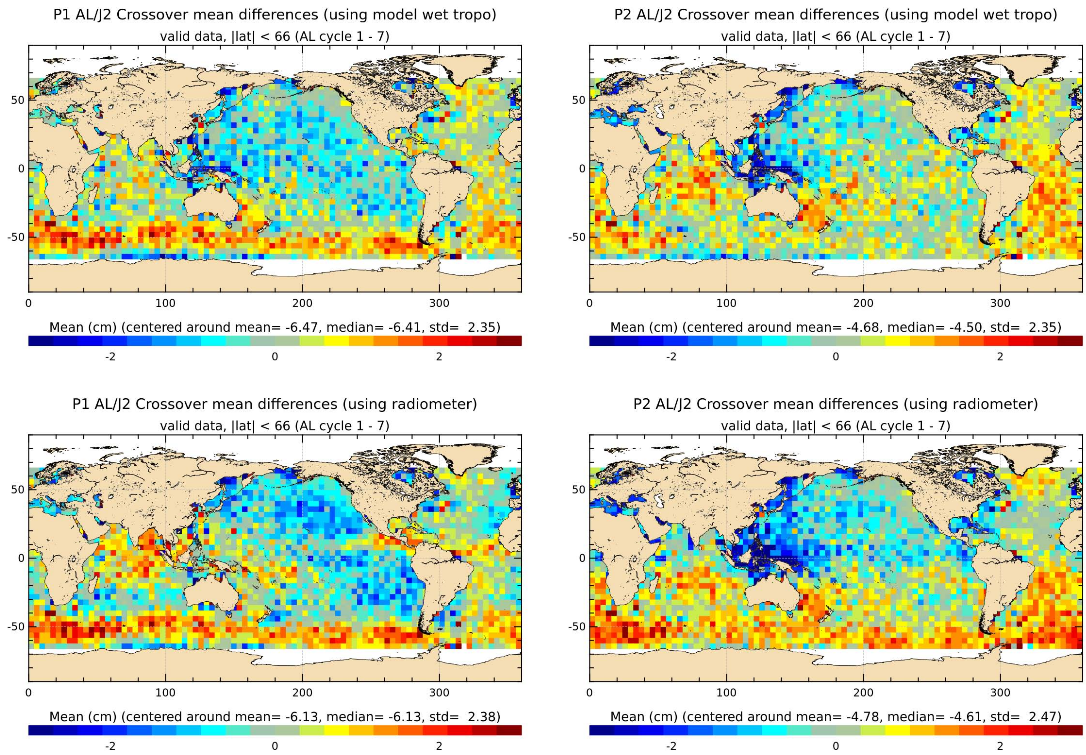


Figure 10: *Map of mean of SSH crossovers differences between Saral/AltiKa and Jason-2 using either radiometer wet troposphere correction (bottom) or ECMWF model wet troposphere correction (top) for both missions for Saral/AltiKa GDR data in Patch1 version (left) and Patch2 version (right). The maps are centered around the mean.*

For Patch1, the algorithm to compute radiometer wet troposphere correction for Saral/AltiKa was not fully tuned. Indeed differences in the tropical region (eastern Pacific, around Indonesia, ...) on the bottom left map of figure 10 (using radiometer wet troposphere correction for both missions) are related to the difference between the two radiometer wet troposphere corrections.

Concerning Patch2 regional SSH differences at Saral/Jason-2 crossovers (right side of figure 10) show that the strip of positive differences around 50° S has disappeared (thanks to the new SSB correction), but the amplitude of differences has increased for regions of small SWH (especially around Indonesia). Using radiometer wet troposphere correction seems to reveal a north/south bias between Saral/AltiKa and Jason-2.

The temporal evolution of the SSH difference at Saral/Jason-2 crossover points is monitored in order to detect if there are drifts or jumps indicating a problem in one of the missions. This monitoring is hereafter done using special selections (crossover points with bathymetry < -1000m, $|lat| < 50^{\circ}$, ocean variability < 0.2m). It is shown on figure 11. Whereas using model wet troposphere correction for both missions shows a quite stable curve (except for some cycle to cycle variations), using radiometer wet troposphere corrections reveals a drift at least during fall 2013. This is related to the Saral/AltiKa radiometer wet troposphere correction, which is impacted by the saturation of the hot calibration counts till 2013-10-22 (see also annual report 2013 of Saral/AltiKa [16]). The last part of the curves for Patch1 (cycle 7 on left of figure 11) seems to show an increased bias between Saral/AltiKa and Jason-2 (independently from using radiometer or model wet troposphere correction). This is not the case for Patch2. Patch2 increases therefore the homogeneity between Saral/AltiKa and Jason-2 data. This is likely related to the new sea state bias algorithm (see chapter **Investigations**).

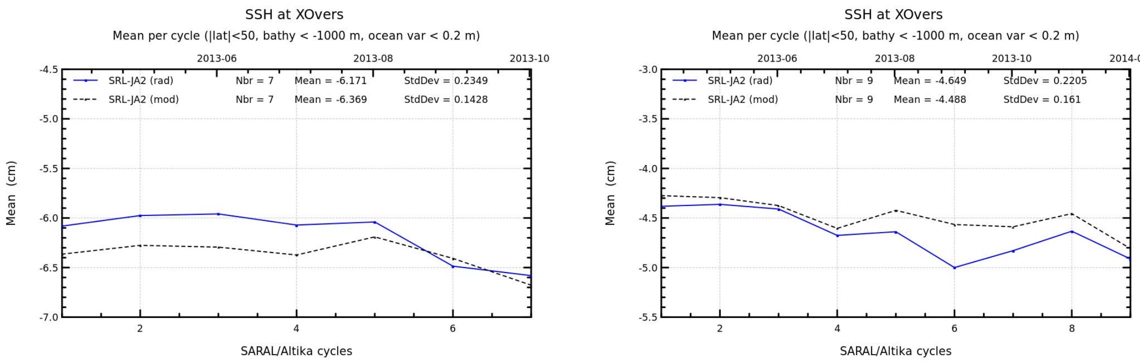


Figure 11: *Monitoring of mean of Saral - Jason-2 differences at crossovers using radiometer wet troposphere correction (blue line) or ECMWF model wet troposphere correction (dotted line) for GDR-T Patch1 (left) and Patch2 (right) data. Statistics are computed on base of Saral cycles.*

3.3. Standard deviation of SSH crossover differences

The standard deviation of SSH differences at crossovers is a measure of the overall system performance (considering mesoscale). Ideally this value is small, when not impacted by natural ocean variability. Using additional selections in order to remove shallow waters (bathymetry above -1000m), areas of high ocean variability (variability above 0.2 m rms) and high latitudes ($> |50|deg$), yields similar performances for Jason-2 and Saral/AltiKa for Patch1 data when using model wet troposphere correction (around 5.6 cm). Using radiometer wet troposphere correction improves the system performance for Jason-2 (the standard deviation is reduced to 5.4 cm), but not for Saral/AltiKa. Concerning Patch2 using the radiometer wet troposphere correction improves also the performance of Saral/AltiKa (5.3 cm). It is even slightly better than Jason-2. These statistics are computed over all selected crossover points for each cycle. Nevertheless the distribution of available crossover points varies strongly with latitude and is also quite different for Saral/AltiKa and Jason-2, related to the orbit configuration. Computing statistics per boxes, allows to level this difference (bottom of figure 12). The statistics yield with this method 2.7 cm for Saral/AltiKa and 2.4 cm for Jason-2.

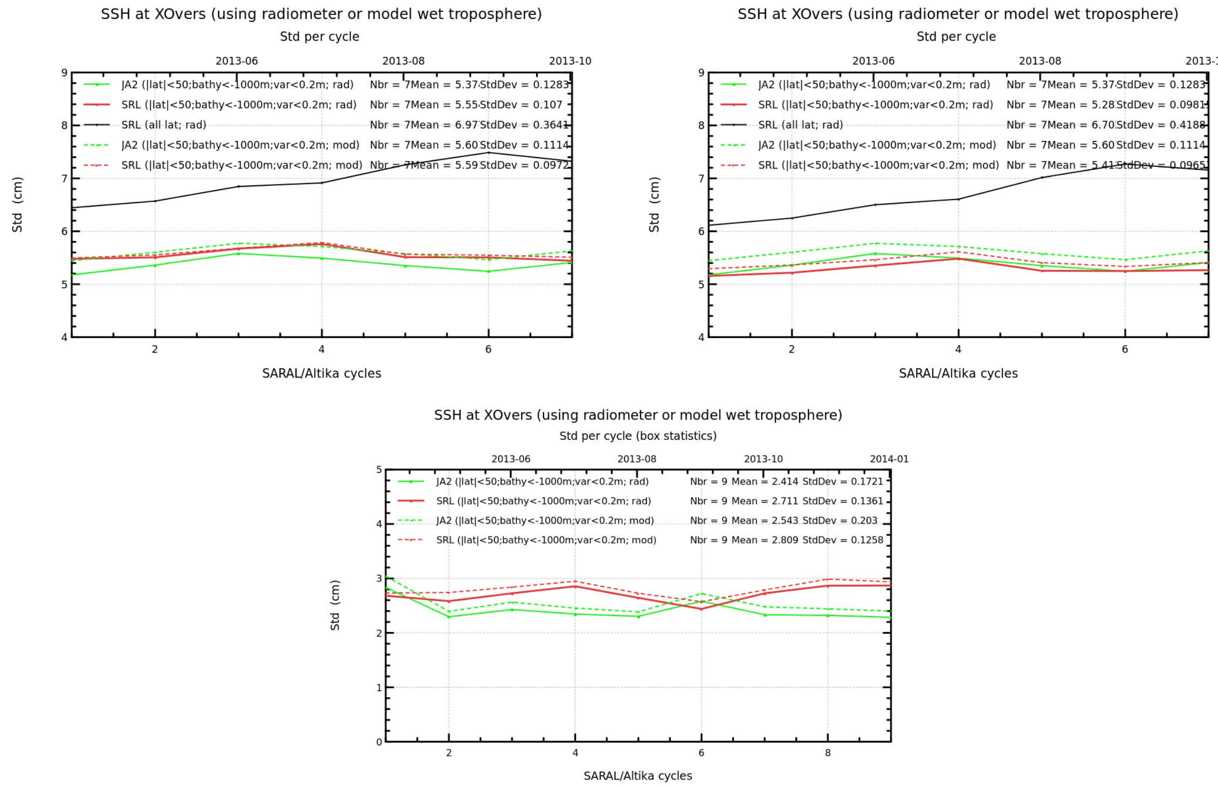


Figure 12: *Monitoring of standard deviation of SSH differences at crossovers using radiometer or ECMWF model wet troposphere correction for Saral/AltiKa and Jason-2 using Patch1 (left) and Patch2 (right) data. Statistics are computed on base of Saral cycles. Bottom: Patch 2 statistics computed for crossover points binned in 4°x4° boxes.*

Concerning the temporal evolution of the performance improvement of Saral/AltiKa using Patch2 data, instead of Patch1 data, top of figure 13 shows that this improvement is present over the whole period :

- The performance improvement is stronger when using radiometer wet troposphere correction, especially when considering valid crossover points without special selection (as Patch1 radiometer wet troposphere correction had especially problems in high latitudes), see top left of figure 13.

- Using model wet troposphere correction, the performance improvement is slightly more important when using particular selections for crossovers points (leading to a variance reduction of 1 cm2 to 2.4 cm2), see top right of figure 13.

Regionally, the improvement is larger in regions of high SWH (strip around $50^{\circ}S$), but also in north Atlantic and in high northern latitudes, with local variance reductions of up to 10 cm2.

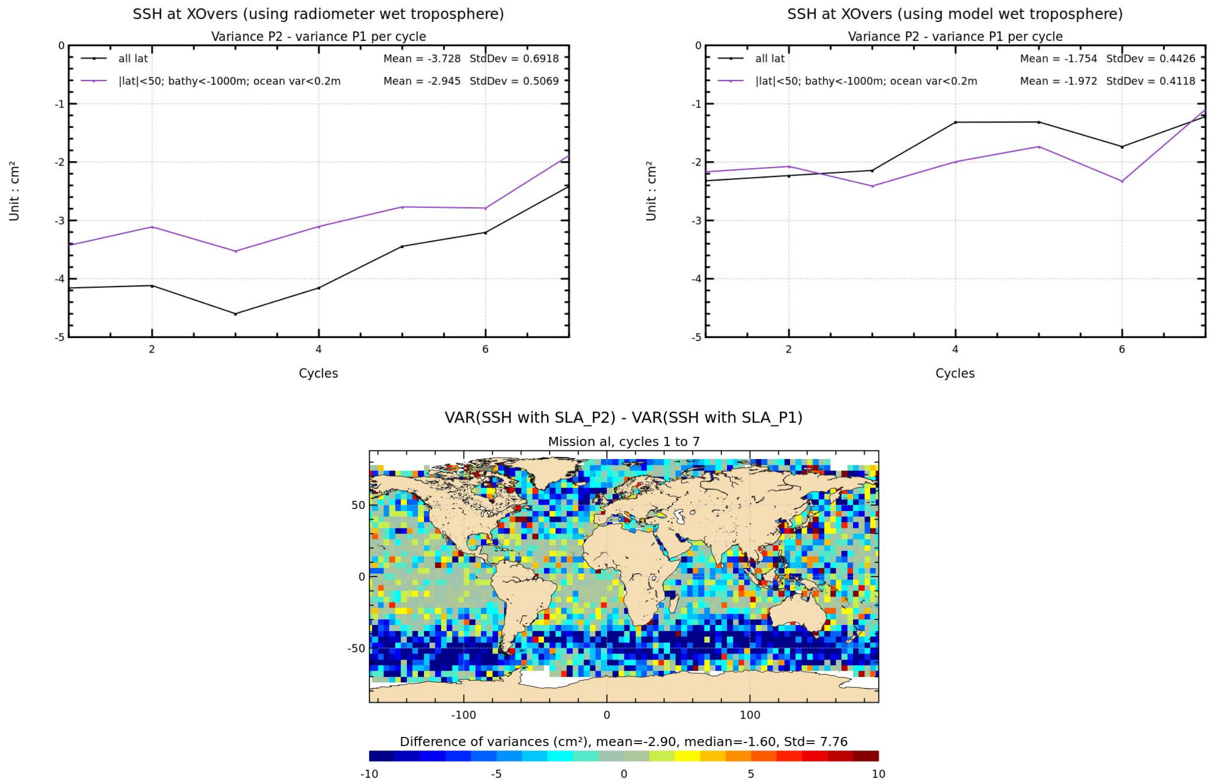


Figure 13: *Monitoring of variance differences of SSH differences at crossovers (top) between Patch2 and Patch1 data using radiometer (left) or ECMWF model wet troposphere (right) correction for Saral/AltiKa. Bottom: map of variance differences for Saral/AltiKa (using radiometer wet troposphere correction) between Patch2 and Patch1 data.*

3.4. Global impact of Patch2 for along-track data

Comparing SLA of Patch2 and Patch1 (left of figure 14) shows that the Patch2 SLA is in average 1.2 cm higher than Patch1 SLA. This is due to the Patch2 SSB solution (see chapter 4.3.), which has stronger values than Patch1 SSB solution (as SSB is a negative correction, the SLA value increases). Nevertheless this increase is not geographically homogeneous. In addition to the geographical differences due to the differences between the two SSB solutions, the new radiometer

wet troposphere correction (see chapter 4.1.1.) locally decreases SLA values. This is especially the case for the region around Indonesia.
The standard deviation of SLA (right of figure 14) decreases with Patch2 compared to Patch1 or Jason-2 over the whole period.

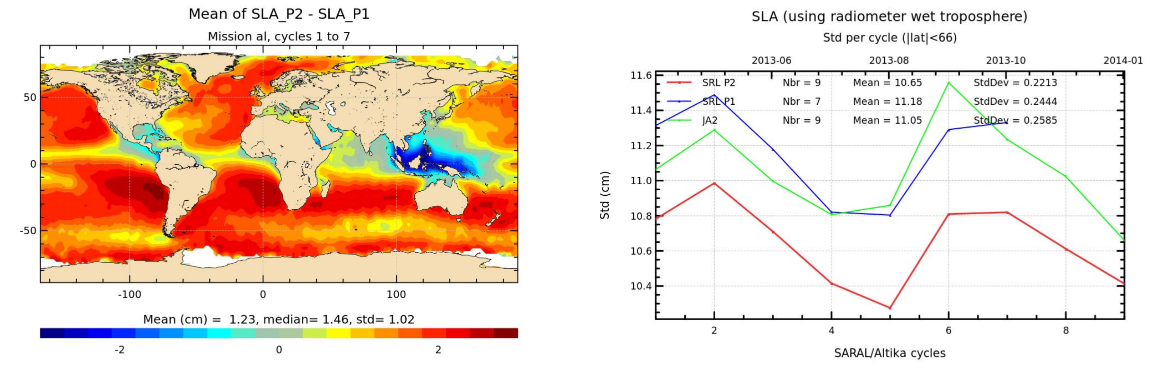


Figure 14: *Left: Map of SLA mean differences P2-P1 for Saral/AltiKa (using radiometer wet troposphere correction). Right: Monitoring of standard deviation of SLA (using radiometer wet troposphere) for Saral/AltiKa Patch1, Patch2 and Jason-2. Statistics are computed on base of Saral cycles.*

The daily mean of SLA is with Patch2 closer to zero (due to the new SSB solution, see chapter 4.3.). Patch2 SLA remains impacted by the saturation of the hot calibration counts, displaying a small jump when the onboard radiometer database was corrected. The difference of the daily mean of Patch2/Patch1 SLA shows a temporal evolution of several mm amplitude. The origin of this signal is explained in chapter **Investigations**.

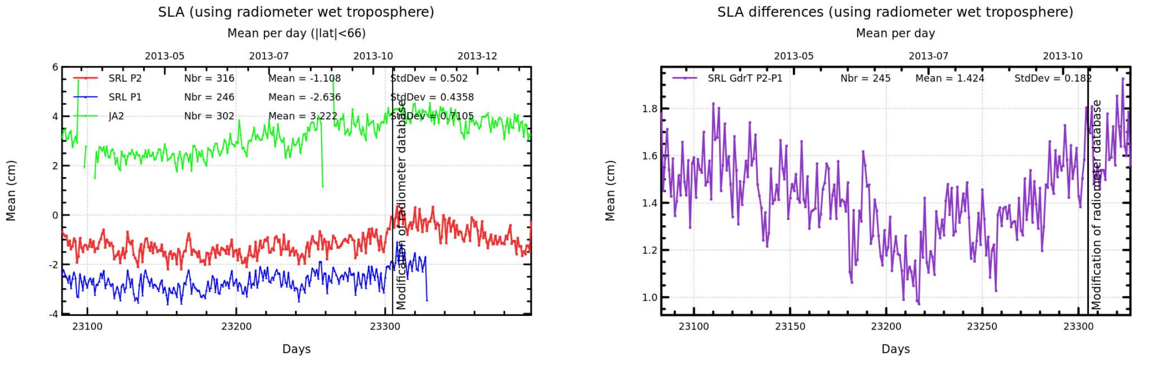


Figure 15: *Left: Monitoring of SLA mean per day (using radiometer wet troposphere) per day for Saral/AltiKa Patch1, Patch2 and Jason-2. Right: Monitoring of SLA mean differences Patch2-Patch1 per day for Saral/AltiKa.*

4. Impact of Patch2 on parameters and corrections

The details of the modifications on Saral/AltiKa data using Patch2 version are listed in **Content of Patch2**. Hereafter the impact on some main parameters are shown.
This concerns:

- the impact of the updated coefficients for the radiometer neural algorithm
- the sea state bias correction
- the altimeter wind speed

4.1. Impact of new radiometer neural algorithm

For Patch2, the neural network coefficients have been updated. This has an impact on the radiometer related parameters, such as the radiometer wet troposphere correction, but also on atmospheric attenuation, as well as on radiometer liquid water and water vapor content.

4.1.1. Impact on radiometer wet troposphere correction

The updated neural network coefficients impact the radiometer wet troposphere especially in wet regions, with differences (compared to Patch1) higher than 2 cm, especially in the Indonesian region (see left side of figure 16). Some small differences appear also in higher latitudes. Globally there is a difference of around 5 mm between the two solutions (with Patch2 having smaller absolute values than Patch1), see also right side of figure 16.

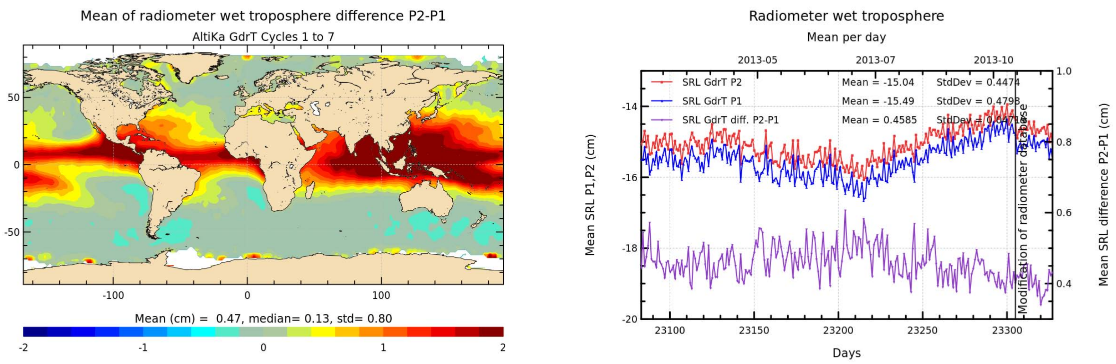
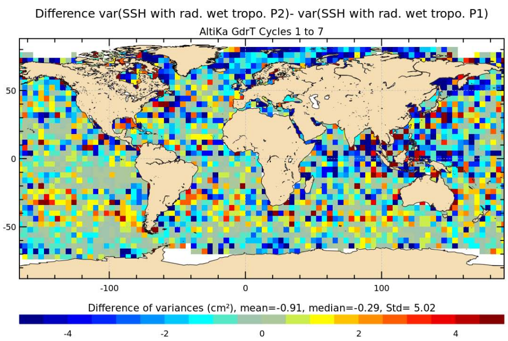


Figure 16: *Map of radiometer wet troposphere mean difference Patch2 - Patch1 for GdrT Saral/AltiKa cycles 1 to 7 (left) and daily monitoring of radiometer wet troposphere mean for Patch1, Patch2 and difference Patch2 - Patch1 (right)*

The system performance at SSH crossovers is slightly improved when using geographical selections (around 0.35 cm2) and significantly when using no particular selections on crossover points (1.2 cm2), see right of figure 17. This is especially due to improvements in high latitudes in northern hemisphere (left of figure 17).



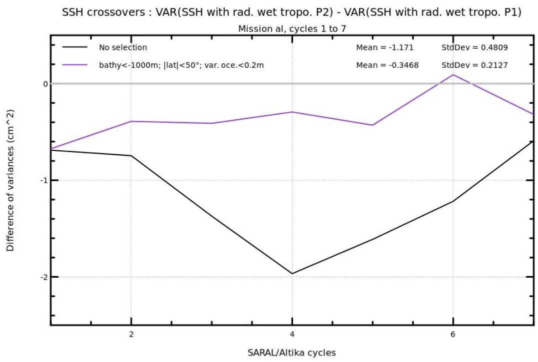


Figure 17: *Map of difference of variance(SSH with radiometer wet troposphere Patch2) - var(SSH with rad. wet tropo. Patch1) for GdrT Saral/AltiKa cycles 1 to 7 (left) and cycle by cycle monitoring of difference of variance(SSH with radiometer wet troposphere Patch2) - variance(SSH with radiometer wet troposphere Patch1) (right)*

4.1.2. Impact on atmospheric attenuation and backscatter coefficient

The updated coefficients for the radiometer neural network algorithm has also an impact on the atmospheric attenuation. Globally for Patch2 it increases by 0.2 dB (right side of figure 18) and is therefore closer to the value computed from model outputs (see [13]). Regionally, there are smaller differences in high latitudes and slightly stronger differences in low and moderate latitudes (see map on left side of figure 18). As all radiometer related corrections, atmospheric attenuation is impacted by the hot calibration saturation and shows a drift, which is corrected when the onboard radiometer database was modified.

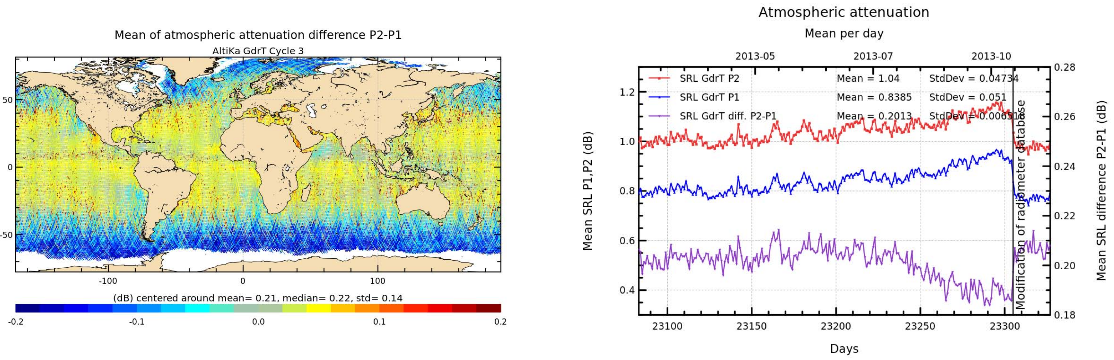


Figure 18: *Map of atmospheric attenuation mean difference Patch2 - Patch1 for GdrT Saral/AltiKa cycle 3 (left) and daily monitoring of atmospheric attenuation mean for Patch1, Patch2 and difference Patch2 - Patch1 (right)*

As the backscatter coefficient includes the atmospheric attenuation, the Patch2 backscatter coefficient is also increased by approximatively 0.2 dB. But, as Saral/AltiKa is a Ka-band altimeter its backscatter coefficient is smaller than the one of Jason-2 and their histogram shapes are also different.

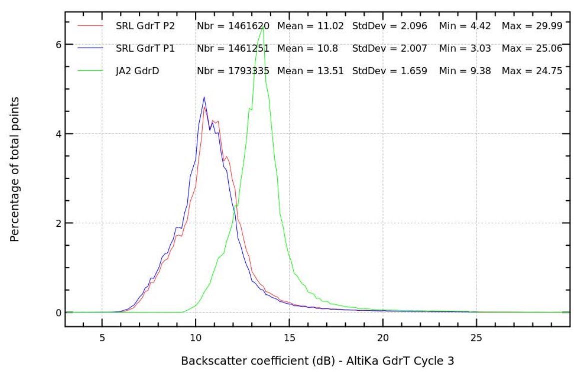


Figure 19: *Histogram of backscatter coefficient for Patch1 and Patch2 GdrT Saral/AltiKa cycle 3*

4.1.3. Impact on radiometer liquid water and water vapor

Two other parameters modified by the updated coefficients of the radiometer neural network algorithm are the radiometer liquid water and water vapor content. Global mean differences between the solutions of radiometer liquid water are 0.05 kg/m2 and 0.6 kg/m2 for water vapor content. Both parameters are also impacted by the hot calibration saturation.
Especially the radiometer water vapor reacts more physically in Patch2 than in Patch1 (as it is now much better correlated with the absolute value of radiometer wet troposphere correction).

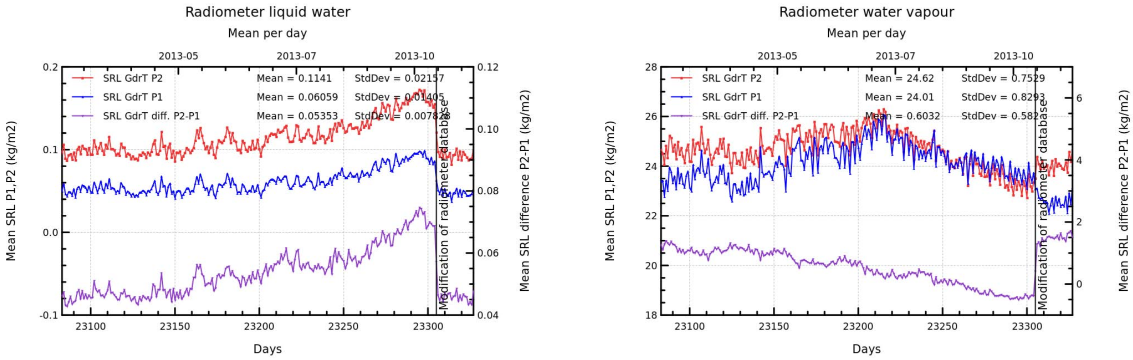


Figure 20: *Daily monitoring of radiometer liquid water mean (left) and radiometer water vapor mean (right) for Patch1, Patch2 and difference Patch2 - Patch1 GdrT Saral/AltiKa*

4.2. Impact of new sea state bias (SSB) correction

In Patch1 version, the sea state bias was as a first approximation set equal to -3.5% of SWH. For Patch2 a hybrid SSB solution developed by R. Scharroo was used (this SSB was computed using the same method as in [21]). The Patch2 SSB solution is in absolute values around 1.8 cm stronger (which increases the Patch2 SLA) than the Patch1 solution. This is related to the method of SSB computation (hybrid method). Nevertheless this bias varies regionally (see left of figure 21). Regions with very small or very high significant wave height are less modified than the other regions. This means that the Patch1 SSB was in these regions overestimated compared to other regions. The difference of Patch2 and Patch1 SSB solution (right of figure 21) shows a temporal signal. This is related to the Patch1 SSB (or rather to the temporal evolution of the significant wave height).

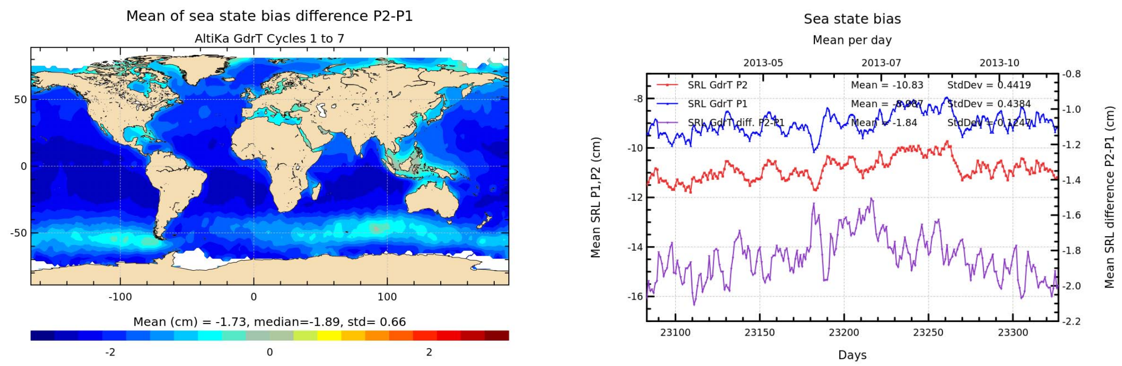
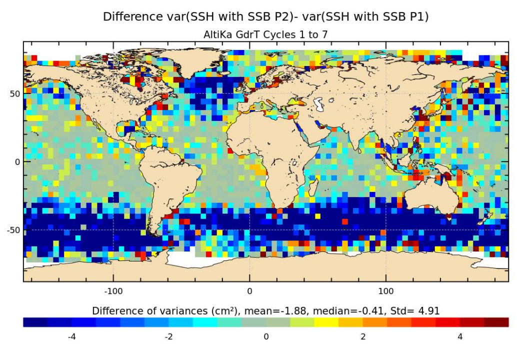


Figure 21: *Map of sea state bias mean difference Patch2 - Patch1 for GdrT Saral/AltiKa cycles 1 to 7 (left) and daily monitoring of sea state bias mean for Patch1, Patch2 and difference Patch2 - Patch1 (right)*

The Patch2 SSB solution improves the Saral/AltiKa system performance strongly in regions of high significant wave height (strip of 50°S, north Atlantic), see left of figure 22. This improvement over Patch1 is always present (right of figure 22), but its amplitude varies especially when not using special selections for crossover points (as high SWH, which are generally present at latitudes of 50° and above, varies also with season).



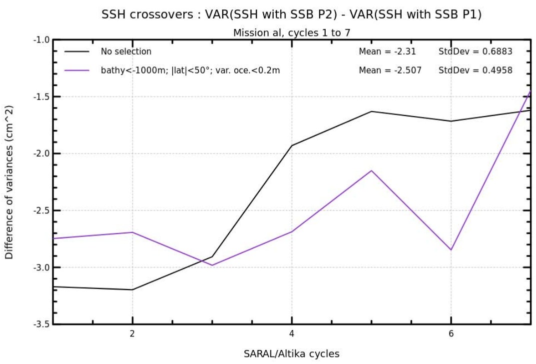
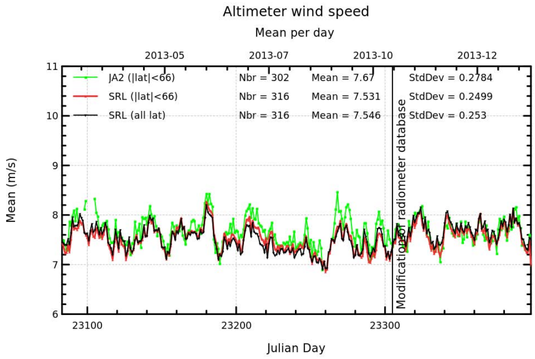


Figure 22: *Map of difference of variance(SSH with SSB Patch2) - var(SSH with SSB Patch1) for GdrT Saral/AltiKa cycles 1 to 7 (left) and cycle by cycle monitoring of difference of variance(SSH with SSB Patch2) - variance(SSH with SSB Patch1) (right)*

4.3. Impact of altimeter wind speed

The altimeter wind speed present in Patch1 was not usable, since the look-up table from Jason-1 was used, but the Ka-band backscattering coefficient is very different from the Ku-band one. For Patch2 version, the altimeter wind speed algorithm developed by [13] for Ka-band altimetry was used.

The Patch2 altimeter wind speed has similar values as the Jason-2 altimeter wind speed. The monitoring of the daily mean shows similar signals for both satellites (left of figure 23). Nevertheless, as altimeter wind speed is computed with backscattering coefficient, the Saral/AltiKa altimeter wind speed is also slightly impacted (up to 0.3 m/s) by the hot calibration saturation, as shown by the comparison with model wind speed (right of figure 23).



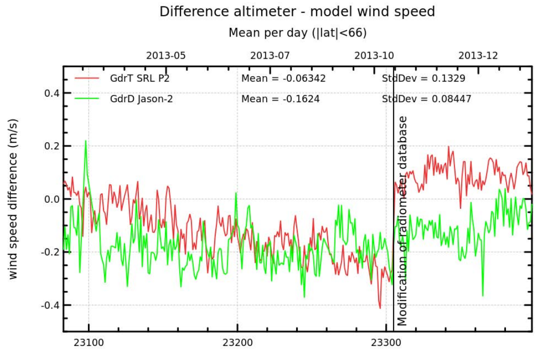


Figure 23: *Left: Daily monitoring of altimeter wind for GdrT Patch2 Saral/AltiKa for all latitudes (black), $|lat| < 66^\circ$ (red) and GdrD Jason-2 (green). Right: Daily monitoring of difference of altimeter wind - model wind for GdrT Patch2 Saral/AltiKa (red) and GdrD Jason-2 (green).*

The histogram of altimeter and model wind speed reveals a kind of bi-model shape for Saral/AltiKa altimeter wind speed. Furthermore, it starts only around 1 m/s.

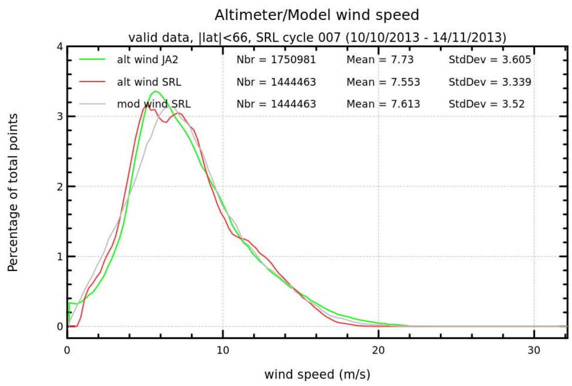


Figure 24: *Histogram of altimeter and model wind speed for GdrT Saral/AltiKa and GdrD Jason-2 during AltiKa cycle 7*

5. Investigations

The difference of the daily mean of Saral/AltiKa SLA between Patch1 and Patch2 shows a temporal evolution of several mm amplitude (see figure 25).

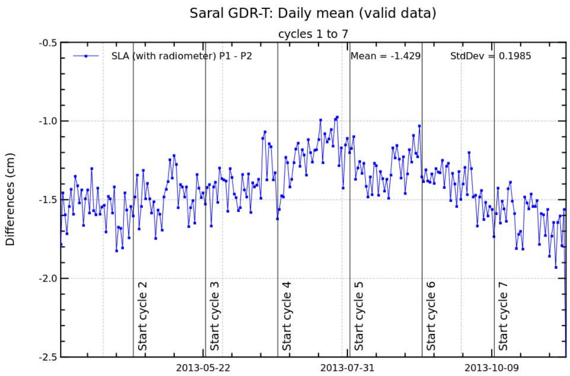


Figure 25: *Daily monitoring of SLA mean differences (Patch1 - Patch2) using radiometer wet troposphere correction*

This evolution has two main contributors:

- The SSB differences between Patch2 and Patch1 (here -3.5%*SWH) show also a temporal evolution (left side of figure 26). This evolution in the difference of the SSB solutions is likely explained by the fact, that the 3.5%*SWH solution is linearly dependent on significant wave height and overestimates the SSB for high wave heights. Especially the high SWH around 50˚S vary in function of the season.
- Due to a problem in the USO file used for reprocessing, a small drift occurs on "net instrumental correction on the range" (net_instr_corr_range) between Patch1 and Patch2 (see right side of figure 26). It reaches its maximum value (1.4 mm) on 2013-10-01 around 03h49 (cycle 6, pass 0743). This impacts also the range. This will be corrected for Patch3.

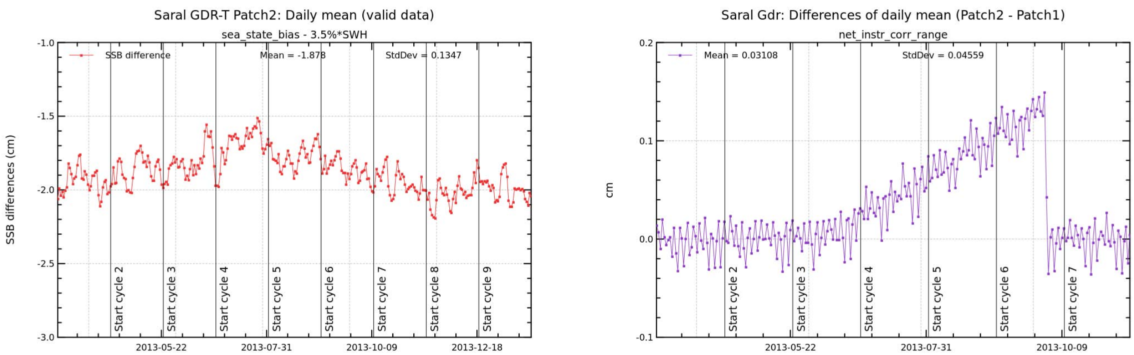


Figure 26: *Daily monitoring of SSB (left) and net instrumental correction on the range (right) differences between Patch1 and Patch2.*

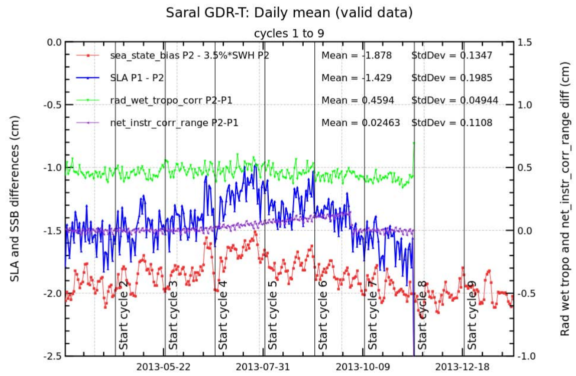


Figure 27: *Daily monitoring of SLA differences (Patch1 - Patch2) using radiometer wet troposphere correction, superposed with SSB (red), radiometer wet troposphere correction (green) and net instrumental correction on the range (lilac) differences. Left ordinate concerns SLA and SSB, right ordinate concerns radiometer wet troposphere correction and net instrumental correction on the range.*

Monitoring of several Patch1/Patch2 differences are superposed on figure 27. It shows that the temporal variations (drifts around cycles 4 and 5, small jump during cycle 6) in the Patch1/Patch2 SLA differences are very well correlated with the temporal evolutions in the differences of mainly the sea state bias and to a lesser extent of the net instrumental corrections on range. The temporal evolution in the Patch1/Patch2 radiometer wet troposphere correction difference (around 1 mm) is negligible.

6. Conclusion

Saral/AltiKa GDR cycles 1 to 7 were reprocessed in GDR-T Patch2 version, from cycle 8 onwards the operational production of GDR's used also Patch2. Saral/AltiKa GDR data are therefore now available in a homogeneous dataset (Patch2).

During the validation of the reprocessed products the following minor anomalies were detected:

- The geocentric ocean tide (GOT4.8) has in Patch2 no data over land, including enclosed water bodies such as Caspian Sea. Furthermore this impacts some data near coasts. This is due to the equilibrium long-period tide height (included in the global ocean tide) which for Patch2 is computed with FES2012 algorithm, which tests previously if the grid of the FES2012 tide atlas is defined or not. Consequently, the equilibrium tide is set to default values over land (and therefore also the geocentric ocean tide).
- The USO file used for the reprocessing has a problem. This leads to a small drift on the "net instrumental correction on the range" (net_instr_corr_range) between Patch1 and Patch2. This drift starts around 2013-06-12 and reaches its maximum value (1.4 mm) on 2013-10-01 around 03h49 (cycle 6, pass 0743). This impacts also the range.

These minor anomalies will be corrected in Patch3 version.

The main improvements for the Patch2 data are:

- Updated coefficients for the radiometer neural network algorithm
- A new sea state bias look-up table provided by R. Scharroo (computed with several cycles of Saral/AltiKa data)
- A wind look-up table provided by NOAA is used. It was specially computed for Ka-band altimetry [13]
- The FES2012 tide model is used instead of FES2004

Comparisons with Patch1 data and Jason-2 have shown, that Saral/AltiKa Patch2 data :

- have now a realistic altimeter wind speed
- have a more adapted sea state bias and radiometer wet troposphere correction

These novelties in Patch2 data lead to a significant improvement of the Saral/AltiKa mesoscale system performance at crossover points and for along-track data. Furthermore, some geographical correlated differences between Saral/AltiKa and Jason-2 (at crossover points) disappear (especially a strip around $50^\circ S$) and new difference signals become visible.

7. Glossary

CLS Collecte Localisation Satellites

CNES Centre National d'Etudes Spatiales

ECMWF European Centre for Medium-range Weather Forecasting

GDR Geophysical Data Record

GDR-T Geophysical Data Record version T (test)

GIM Global Ionosphere Maps

GOT Global Ocean Tide

IGDR Interim Geophysical Data Record

MOE Medium Orbit Ephemeris

MQE Mean Quadratic Error

MWR MicroWave Radiometer

POE Precise Orbit Ephemeris

OGDR Operational Geophysical Data Record

SALP Service d'Altimétrie et de Localisation Précise

SARAL Satellite with ARgos and ALtika

SSH Sea Surface Height

SLA Sea Level Anomaly

SSB Sea State Bias

SWH Significant Wave Height

8. References

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9. Annex

9.1. Content of Patch1

Hereafter the content of Patch1 is recalled. All GDR data were produced with this patch, wereas IGDR data were only produced with this patch from cycle 4 pass 395 onwards.

Altimeter calibration file : The altimeter calibration stability has been analysed. Based on the actual data, we have implemented an averaging of the calibrations over a 7 days window for the low pass filter (identical to Jason-2) and 3 days for the internal path delay and total power (not used on Jason-2). This will slightly reduce the daily noise observed in the altimeter calibration data.

Altimeter characterization file : We have updated the altimeter characterization file using the flight calibration of the gain values (4 calibrations performed). The impact is very small (of the order of 0.01 dB).

Retracking look-up tables : We have updated the ocean retracking look-up tables using the flight calibration data (PTR). The impact is very small on the range and sigma0 values but of the order of 15 cms on SWH for low sea states.

MQE : We have analyzed the altimeter flight data and based on the observed MQE values over ocean a threshold of 2.3E-3 (Jason-2 value is 8E-3) is used for the 1Hz data computation.

Neural network : A first linear relation has been computed between the measured BT and the simulated one. This linear relation is applied on the 23.8 GHz only – the same analysis will be conducted on the 37 GHz and sigma0. This generates a bias on the radiometer wet tropospheric correction which is now much more consistent with the model one.

Atmospheric attenuation : The value outputted by the neural algorithm is now recorded in the level2 products (it was set to 0 at the beginning of the mission). Rad_water_vapor and rad_liquid_water: The values have been corrected to comply with the actual unit in the level2 products (kg/m^2). But the rad_liquid_water remains not reliable as an anomaly has been noticed in the neural network.

SSHA : The radiometer wet tropospheric correction is now used to compute this value (the model value was used at the beginning of the mission).

Controls parameters : The threshold values have been updated with the flight data. This is a first tuning – additional work is necessary.

9.2. Content of Patch2

Hereafter the content of Patch2 is recalled. It has been activated in beginning of February 2014. GDRs have been produced using Patch2 from cycle 8 onwards. Cycles 1 to 7 have been reprocessed with the Patch2.

Wind look-up table : The table provided by NOAA is used. This table is only based on the measured sigma0, taking into account the atmospheric attenuation (sigma0 at the surface). (Reference: Lillibridge et al. [13])

SSB look-up table : The table provided by R. Scharroo is used (same method as in [21]). We use only the significant wave height to compute the SSB.

Radiometer neural algorithm : Taking into account several months of AltiKa measurements, the neural network coefficients have been updated. Note that this modifies the radiometer related parameters (radiometer wet troposphere correction, atmospheric attenuation, radiometer liquid water content and radiometer water vapor content).

Ice-2 retracking algorithm : The algorithm has been updated taking into account the AltiKa Ka band specificities (ice2 algorithm was based on ENVISAT Ku band experience).

FES2012 tide model : This new tide model is included, improving the SSH accuracy in coastal zones. (Reference : http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/global-tidefes2004-fes99/description-fes2012.html)

Matching pursuit algorithm : The algorithm based on J. Tournadre proposal has been tuned to comply to AltiKa Ka band specificities.

MQE parameter scale factor : The scale factor of the MQE has been modified.

Update of the altimeter characterization file : The altimeter characterization file has been modified in order to account for 63 values of altimeter gain control loop (AGC). This has impacts over sea ice and land hydrology, in some cases the AGC was set to default value in current P1 products.

Doris on ground processing (Triode) : The Doris navigator ground processing has been upgraded to reduce the periodic signal observed on the altitude differences with MOE/POE.