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ESA Cryosat Plus for Oceans

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Applicable documents

Reference documents

RD 1 Boy and Moreau, 2013: F. Boy and T. Moreau, “Algorithm Theoretical Basis Document (ATBD) of the CPP RDSAR numerical retracker for oceans”, CNES report, **S3A-NT-SRAL-00098-CNES**

RD 2 Moreau et al., 2013: T. Moreau, F.Boy and M. Raynal, “Product Validation Report (PVR) of the CPP RDSAR numerical retracker for oceans”, **CLS-DOS-NT-13-155, WP4000 CP4O**

RD 3 Labroue S., F. Boy, N.Picot, M.Urvoy, M.Ablain 2011 First Quality Assessment of the CryoSat-2 Altimetric System over Ocean. ASR, http://dx.doi.org/10.1016/j.asr.2011.11.018

RD 4 Ollivier et al., 2013: A. Ollivier, M. Guibbaud and S. Labroue, “IOP/GOP ESA Product Validation Report”, **CLS-DOS-NT-13-286**

List of Contents

1. Introduction

1.1. Purpose and scope

This document aims at analysing the CPP (CNES Processing Prototype) PLRM retracking developed by CNES for the CryoSat-2 mission. A set of dedicated diagnoses has been used to evaluate the quality of this retracking.

The description and the analysis of all the differences that are reported herein were discussed in a strong scientific collaboration with the algorithm expert/responsible who provides a very useful support to assess the performances of their model, help to identify any unexpected behaviours and finally validate the content of this report.

1.2. Document structure

This document is structured into an introductory chapter followed by three chapters describing:

- the data used and coverage,
- the analysis of the results from the different diagnoses that are used to establish their performance (quantifying their skills and drawbacks), and
- a discussion about these results (section 4).

2. Data and method overview

2.1. Data coverage and period

One year of CryoSat-2 sea level anomalies (SLA) in PLRM mode have been computed at 20 Hz and 1 Hz over all the SAR areas acquired in SAR mode between May 2012 and April 2013.

2.2. Method description

2.2.1. PLRM CPP retracking

The method for the CPP SAR retracking is fully described in RD 1 and validation results were already delivered in RD 2.

2.2.2. Correcting estimates through adapted LUT

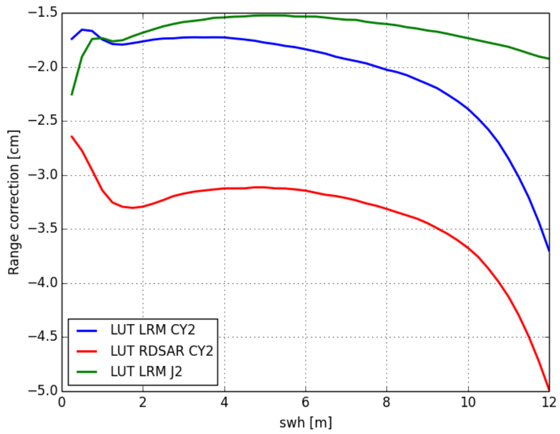
Compared to the results obtained at the writing of RD 2, PLRM data sets have been improved by adding the Look Up Table (LUT) corrections for epoch and SWH that take into account modelling of the PTR and the larger speckle present on PLRM waveforms.

The 4 parameters are then corrected to account for the Gaussian approximation of the Point Target Response (PTR) in the Brown ocean retracker, the ellipticity of the CryoSat-2 antenna, and its particular speckle reduction property (different from conventional altimetry mode), through pre-computed Look-Up correction Tables (LUT) as follows:

$$Range = Range_{estimated} + LUT_{range}$$

$$SWH = SWH_{estimated} + LUT_{SWH}$$

The existing PLRM CPP products are corrected applying a correction Lookup Table inherited from Jason-2, leading to possible bias in range and SWHs with the true values. As such, the correction LUT has been updated for LOTUS to take into account not only the approximation of the PTR in the retracking algorithm but also the speckle reduction property of the PLRM method. This PLRM dedicated correction depends on the wave height and could be as high as 3 cm in range and 20 cm in wave at 4m-wave height as shown in Figure 1. Significant differences are observed with the Jason-2 correction LUT.



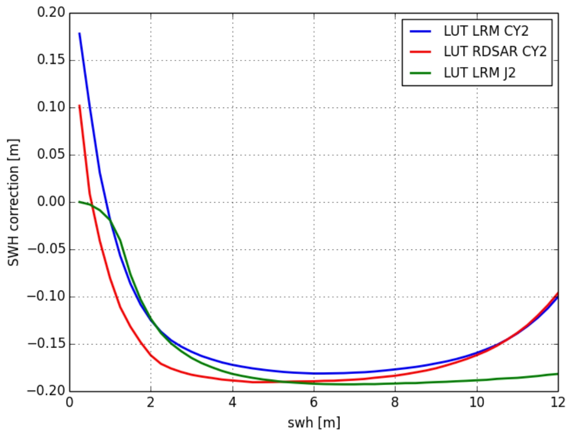


Figure 1 - Range and SWH look-up table used for LRM-mode and PLRM CPP products. Corrections are in cm for range and in m for wave height. The LRM Jason-2 look-up table is shown for comparison purposes only.

In turn, the correction on the sigma0 is of the order of a few hundredths of a dB; it is neglected in regard to the overall error budget on this parameter.

2.2.3. Edited data

Data editing is necessary to remove altimeter measurements having lower accuracy. To analyze the consistency between both wet troposphere solutions in open ocean, only valid ocean data are selected (removing data corrupted by sea ice and rain). Specific editing criteria are applied, based on thresholds on different parameters.

3. Validation results and overall assessment

The validation of SAR processing with Cryodat-2 mission is not straightforward because

1. the SAR mode is activated only over a few areas of the ocean. Therefore, we do not have a complete coverage of the different ocean regimes.
2. The PLRM mode is not co localised with the LRM measurements so a direct comparison between LRM and PLRM is not possible.

Therefore, we validated the PLRM data with two main diagnoses:

- Cross calibrating with Jason-2 mission
- Analysing the continuity between LRM and PLRM profiles at the LRM/SAR transitions

3.1. Cross calibration with Jason-2

Figure 2 shows the map of the mean SSH difference at crossovers between Cryosat-2 and Jason-2 SSH over the full year available. The CPP LRM processing descried in Labroue et al 2011 is used in the LRM zones and the PLRM data are used in the SAR areas. Jason-2 data have been corrected with the ECMWF wet tropospheric correction and GIM ionospheric correction in order to have the same standards between both missions. Our aim is to focus on the errors coming from the retracking processing rather than on the errors of the whole system.

The map mainly shows long wavelength errors of +/- 2 cm scale that affect both LRM and PLRM areas. We can hardly see any discontinuity between LRM and PLRM SSH over the largest SAR boxes: Equatorial Pacific and North East Atlantic. The map rather shows residual error in Cryosat-2 data correlated with the ionosphere signal. The negative and positive pattern of 2cm between 30N and 30S is very much correlated with the geomagnetic equator where the GIM errors are the largest. Note that the Pacific box is located in an area of strong ionosphere signal and possibly more affected by errors of the GIM model. For latitudes above 30°, the difference between Cryosat-2 and Jason-2 do not show any residual error.

We tried to go further in the analysis of the LRM quality by separating ascending and descending passes in the crossover comparison with Jason-2, as shown in Figure 3. Once again, the PLRM areas show the same behaviour than the LRM data, without any noticeable discontinuity. Both maps exhibit stronger patterns that are linked to other errors in the Cryosat-2 system. The descending map is dominated by a strong negative anomaly of 3 cm which is located in the geomagnetic equator and is linked to GIM errors, as already stated. The ascending map is dominated by a signal of +/- 3 cm between eastern and western part of the globe that could be linked to residual orbit error in one of the two missions. The positive anomaly close to South America could be due to the South Atlantic Anomaly that would affect more Cryosat-2 ascending tracks.

The main conclusion from this global analysis is that the PLRM data show the same long wavelength errors than the LRM observations, which are not linked to the altimeter processing.

The same analysis is performed for SWH by analysing the crossovers with a time lag of 3 hours maximum. Indeed, the sea state varies much more rapidly than the ocean and considering to large time lag is not meaningful for SWH assessment. Figure 4 shows the mean map of the crossovers obtained over the full year of data. The number of observation is quite sparse between 40S and 40N which makes the assessment of the LRM quality more difficult. Nevertheless, there is no discontinuity between LRM and PLRM crossovers. The maps shows a bias globally negative of -5 cm, meaning that Cryosat-2 SWH are lower than Jason-2 waves, both in LRM and PLRM data sets. The under estimation of CPP SWH in LRM has already been observed on the comparison between CPP and GOP products, the ESA Level 2 GDR products over Ocean (study realized in the frame of the CalVal activities over ocean and presented at Cryosat QWG in January 2014, RD 4).

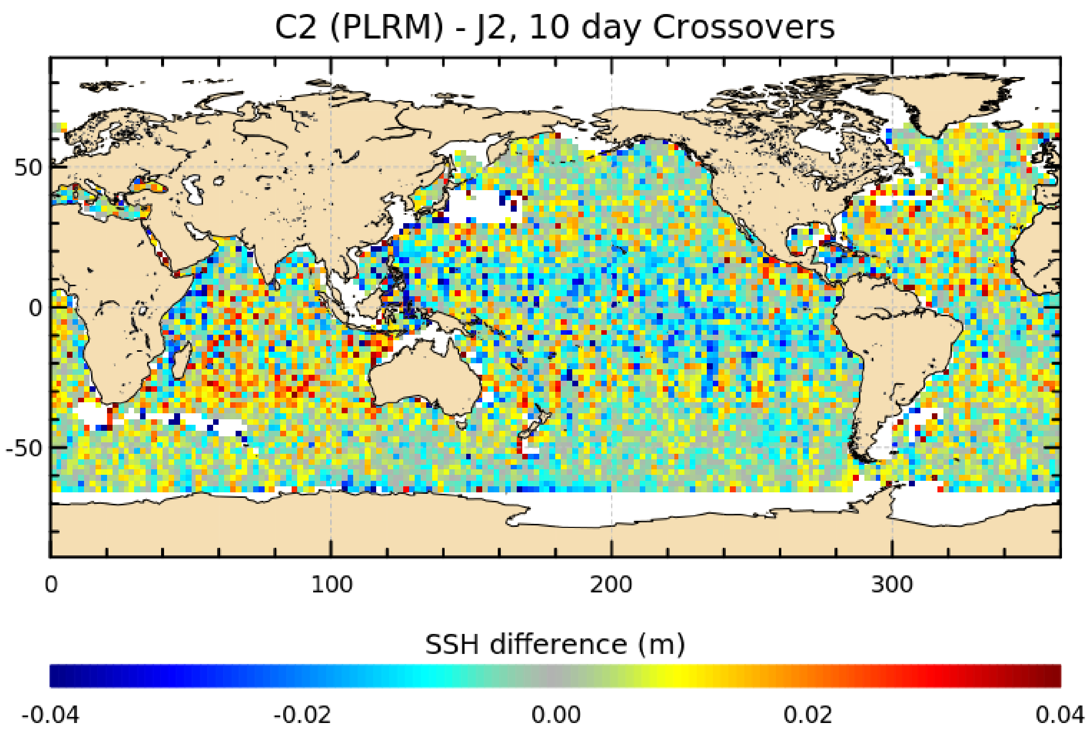


Figure 2 – Map of the mean SSH difference (m) between Cryosat-2 and Jason-2 10 day crossovers, period May 2012-April 2013

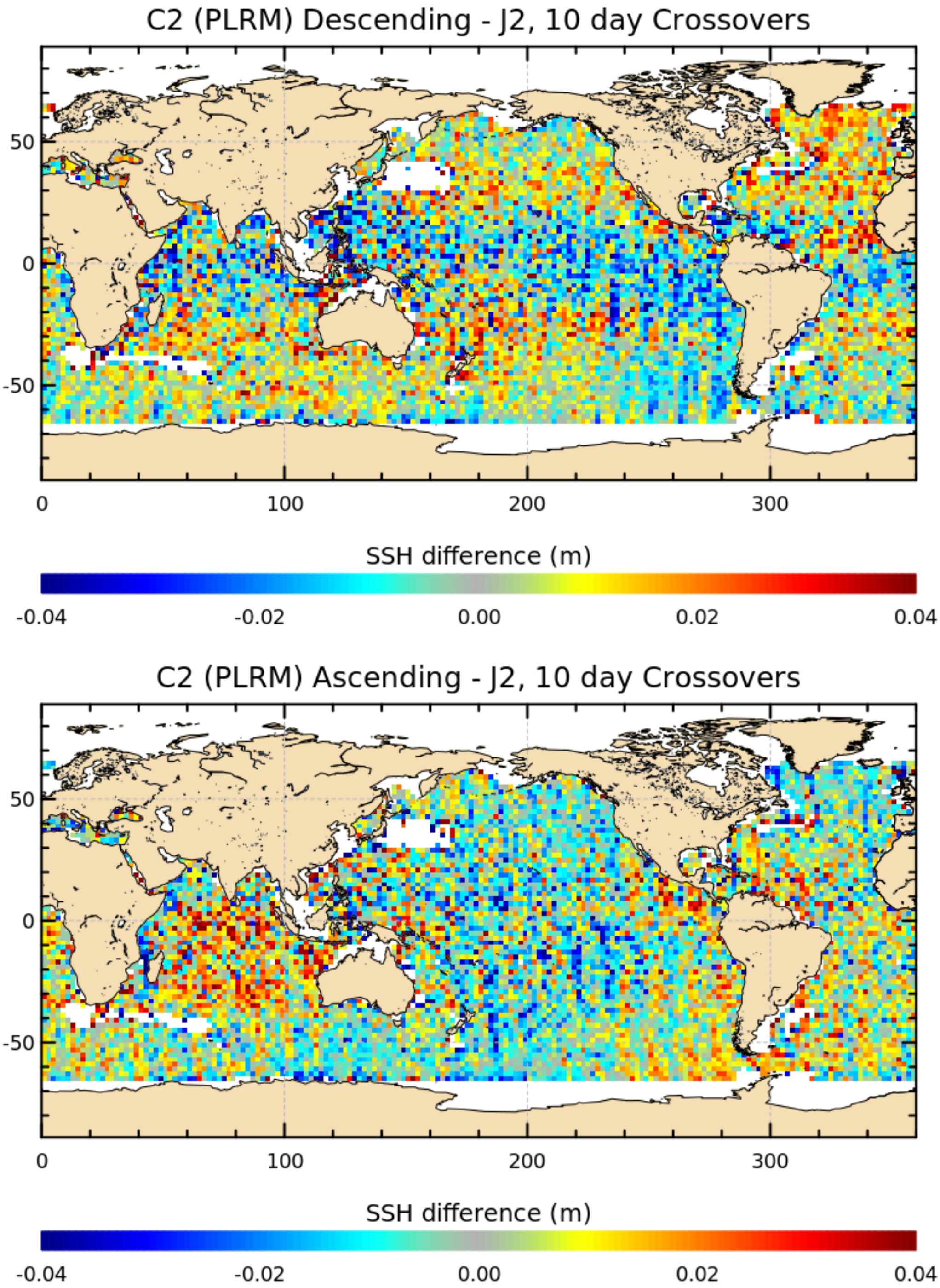


Figure 3 – Map of the mean SSH difference (m) between Cryosat-2 and Jason-2 10 day crossovers, period May 2012-April 2013, for descending passes (upper panel) and ascending passes (bottom panel)

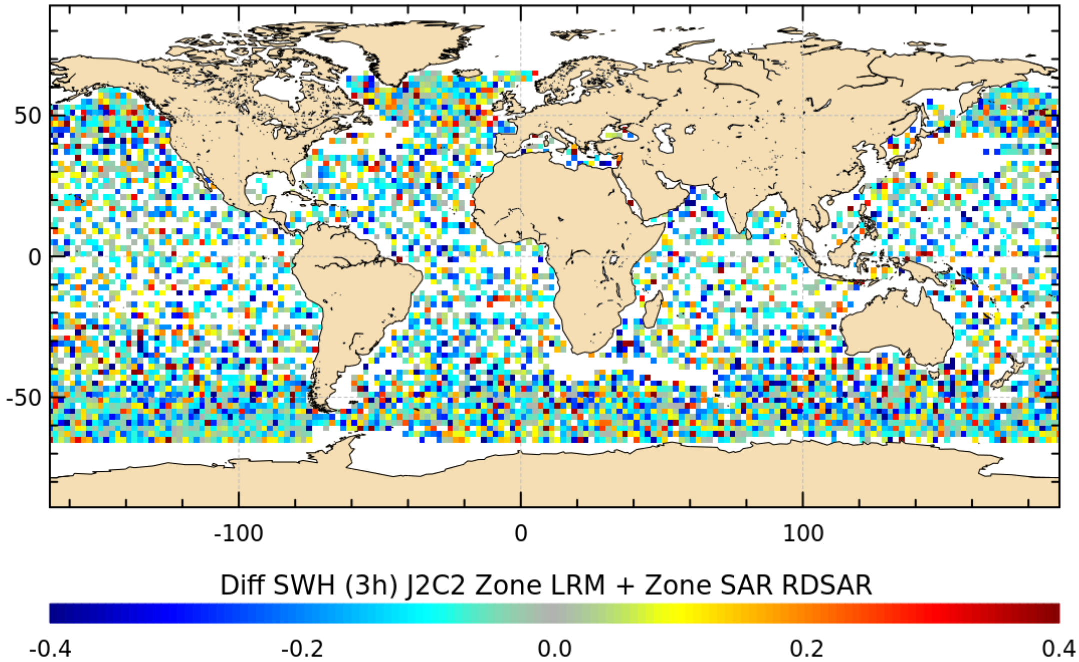


Figure 4 – Map of the mean SWH difference (m) between Cryosat-2 and Jason-2, 3 hour crossovers, period May 2012-April 2013

3.2. Focus on the continuity between LRM and PLRM data

In this section, we push forward the analysis of the continuity between LRM and PLRM data by focusing on several transitions between LRM and SAR zones. The analysis of the transition and continuity between LRM and PLRM processing is done over a SAR box:

- ✓ which coordinates are fixed during a long time serie
- ✓ where the transition is located at the same latitude for all longitudes in order to average the SLA wrt longitude. The average aims at reducing the oceanic variability and the long wavelength errors detected in the previous section and thus better estimate the mean bias on SLA between LRM and PLRM processing.

Since the geographic mask change in time (seasonally) so that the SAR mode is active for ice, the high latitudes at the fringe of ocean/sea ice transition cannot be used for this analysis.

Figure 5 and Figure 6 show the Pacific box where we performed most of the analyses because it is the largest area with fixed coordinates. We separated the analysis between the two periods because the SAR acquisition has been reduced from September,26 onward.

We also used the Atlantic transition represented in Figure 7.

Unfortunately, the other SAR acquisitions which have been fixed since the beginning of the mission, (the Agulhas Current and the South Atlantic box in Figure 8 and Figure 9) cannot be used neither because they do not provide fixed coordinates to average the data.

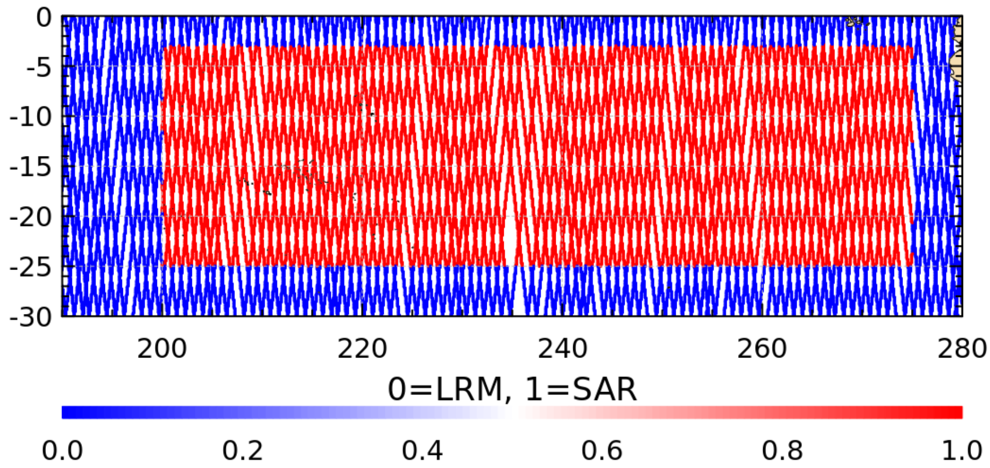


Figure 5 - Pacific box from May 2012-September 2012

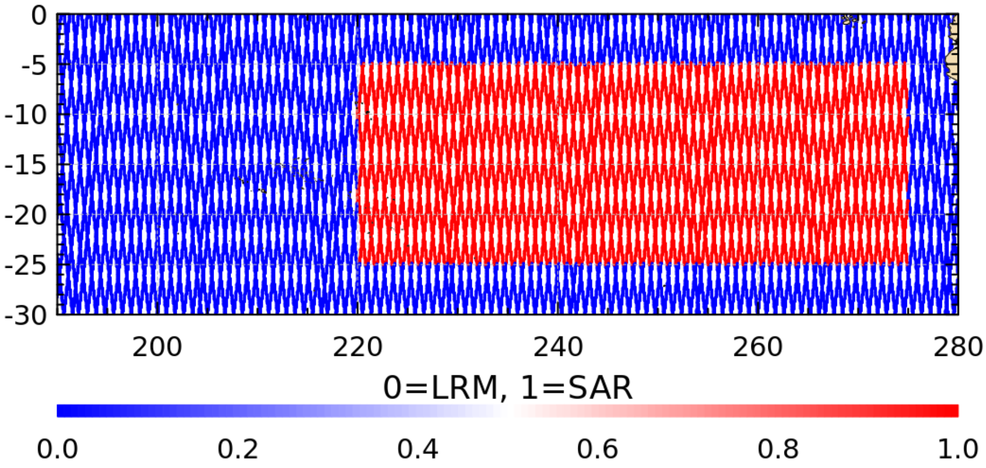


Figure 6 - Pacific box from September 2012 onward

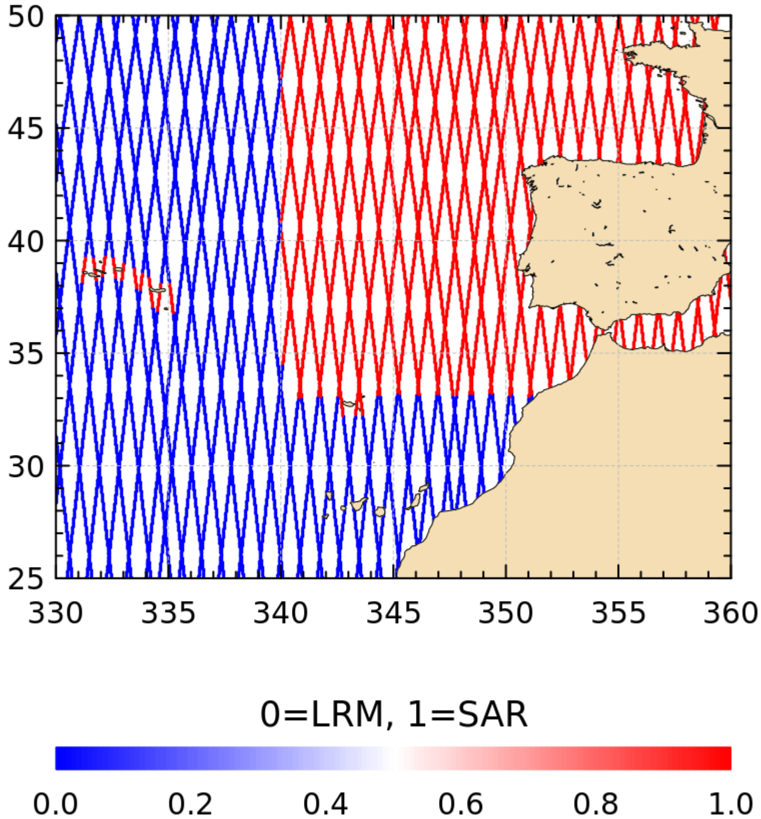


Figure 7 – Atlantic box acquired since the beginning of the mission. The south transition is fixed in time whereas the north transition moves depending on ice coverage. The analysis is done between 344 and 350 to avoid Madeira island in SAR mode.

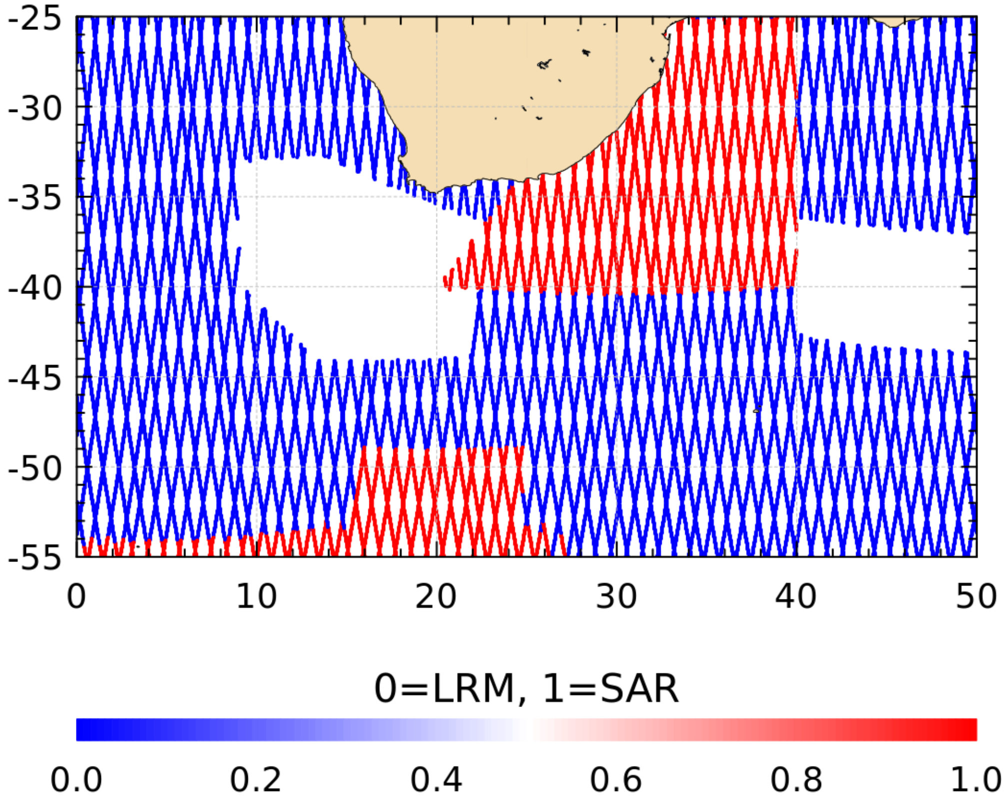


Figure 8 - Agulhas box acquired since the beginning of the mission. The south transition is not regular to analyse the continuity between LRM and PLRM

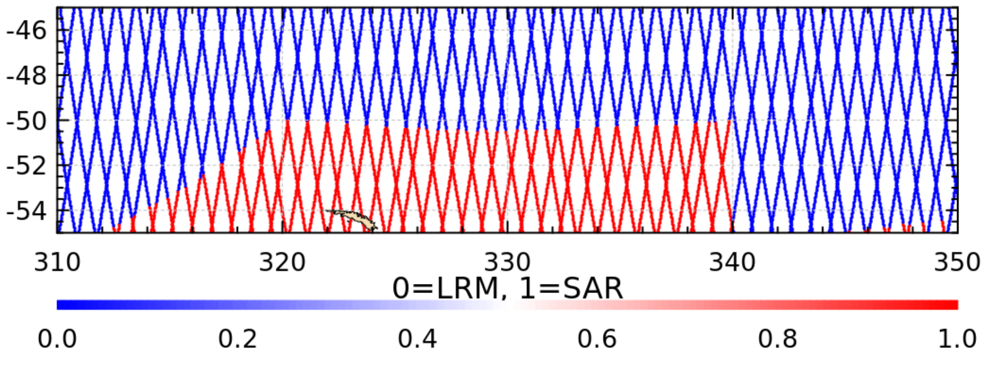


Figure 9 - Fixed box in South Atlantic acquired since the beginning of the mission. The south transition is not regular to analyse the continuity between LRM and PLRM

3.2.1. Transition over the Pacific box

3.2.1.1. SWH transition

The analysis is done over the larger patch of the Equatorial Pacific over the first five months (May to September) and then over the reduced patch over a six months period (October to March).

Over the period May-October 2012, we observe a seamless transition between LRM and PLRM processing at 25S and 3S and an excellent agreement with Jason-2 profile obtained on the same period and region. The SWH in LRM and PLRM appears to be too low compared to Jason-2 by 10 cm.

The same analysis is performed over the period September to March where the patch has been reduced. The transition between LRM and PLRM show a very small bias of 3 cm (PLRM being too low compared to LRM). Once the PLRM SWH are corrected for 3 cm bias, both curves exhibit a seamless transition. Note that the mean bias is closer to 5 cm between LRM and Jason-2 over this period. The fact that the bias on LRM SWH changes from 10 cm to 5 cm depending on the period considered could be due to instrumental drift not properly taken into account in CPP LRM processing.

This analysis shows a seamless transition between LRM and PLRM processing for SWH.

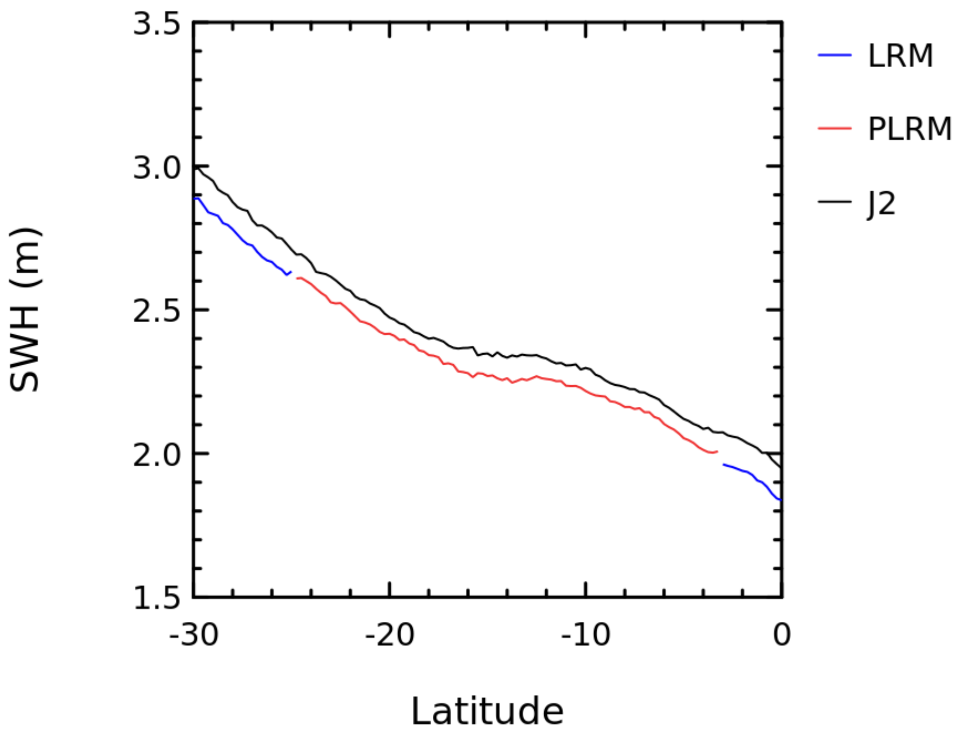


Figure 10 - SWH transition over the Pacific Mai 2012-October 2012

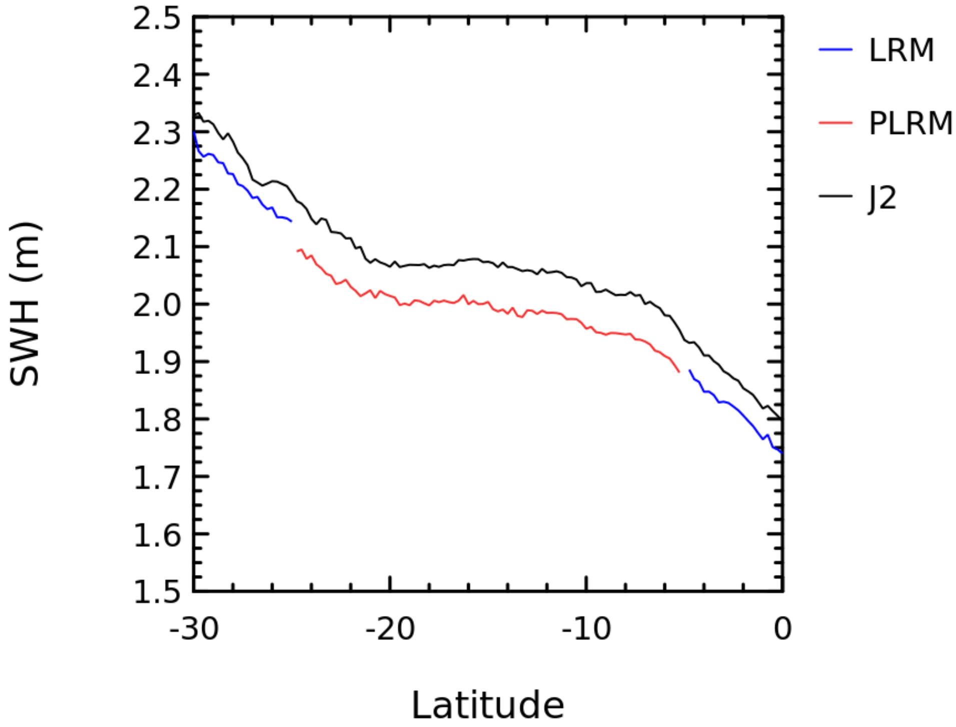


Figure 11 - SWH transition over the Pacific October 2012-March 2013

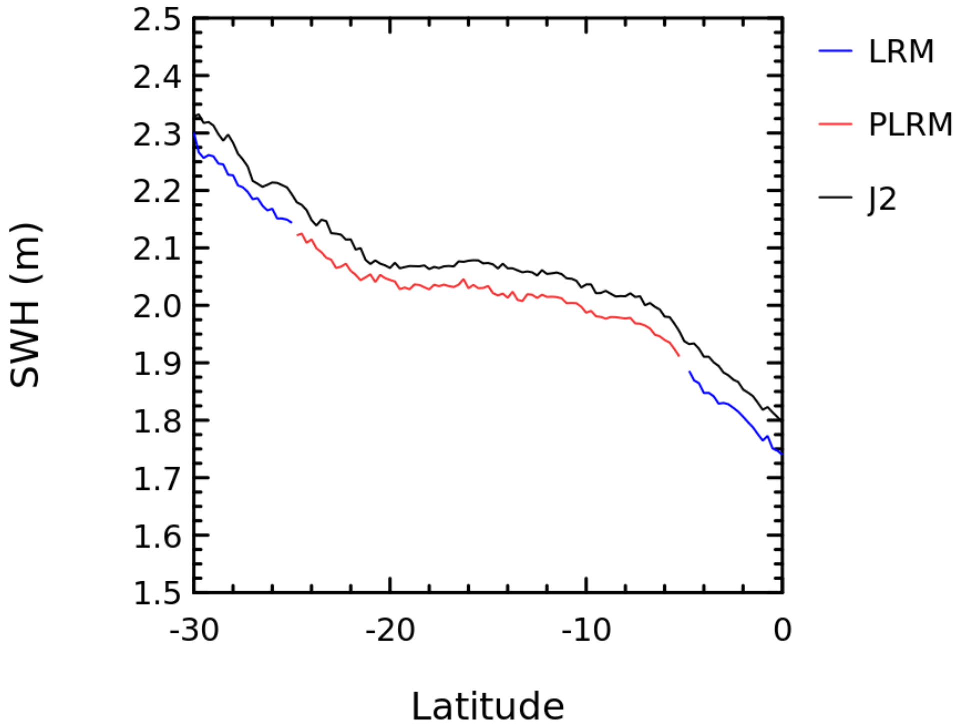


Figure 12 - SWH transition over the Pacific October 2012-March 2013 where the PLRM is artificially increased by 3 cm

3.2.1.2. SLA transition

The analysis is done over the larger patch over five months and then over the reduced patch over a six months period (October to March).

The curves obtained over the first period show a seamless transition between LRM and PLRM below the centimetre level. Given the oceanic variability at both transitions, it is remarkable to find such an agreement between LRM and PLRM observations. There is also a very close agreement between Jason-2 and Cryosat-2 SLA profiles.

Figure 14 shows the same analysis, but separating between ascending and descending passes. The agreement is not as excellent as for the previous analysis, with possibly a 5 mm discontinuity for ascending tracks at 25S. Such differences that appear between ascending and descending passes could be explained by residual time tag bias on LRM data that would induce a few mm of bias between ascending and descending transitions.

Over the second period, a bias appears between LRM and PLRM profiles and seems to be close to 1 cm for both transitions (Figure 15). Once the PLRM SLA is decreased by 1.2 cm, the curves do not show any residual discontinuity between LRM and PLRM over both transitions (Figure 16). Once again, there is also a remarkable agreement between Jason-2 and Cryosat-2 SLA profiles.

We now separate between ascending and descending tracks. Figure TBD shows the curves obtained when applying the bias of -1.2 cm on the PLRM SLA. The descending tracks exhibit no discontinuity whereas the ascending tracks do not match as well but the transition is below the centimeter for ascending track.

This analysis shows that the PLRM provide a seamless transition with LRM data for SLA over a period of 5 months and then a bias of 1.2 cm appears on the second period. There is no explanation for having a bias that would evolve with time, except that the instrumental drift of the altimeter would not be properly tackled in the CPP processing. We know that the IF mask applied in the CPP processing is constant and a possible drift of the PTR is not accounted for. We would need a longer time serie to further check the temporal evolution of the bias between LRM and PLRM processing.

We also observe discrepancies between ascending and descending transitions, suggesting that an error would affect ascending tracks in this area.

Going below the centimetre to check the seamless transition between LRM and PLRM in all cases is certainly quite challenging, given the few areas in SAR mode and the complexity of the signals that have to be taken into account. This is why getting transitions at centimeter level in all the cases analysed in this study is excellent and it fully validates the PLRM processing compared to the LRM standard that we are used to in altimetry.

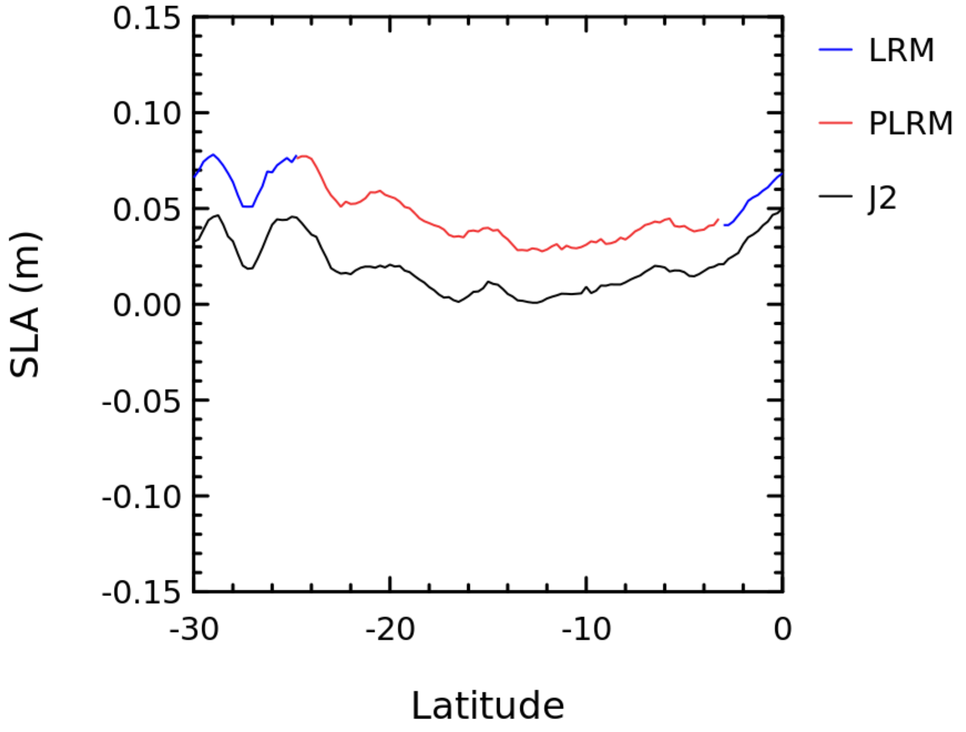


Figure 13 - SLA transition over the Pacific May 2012- September 2012

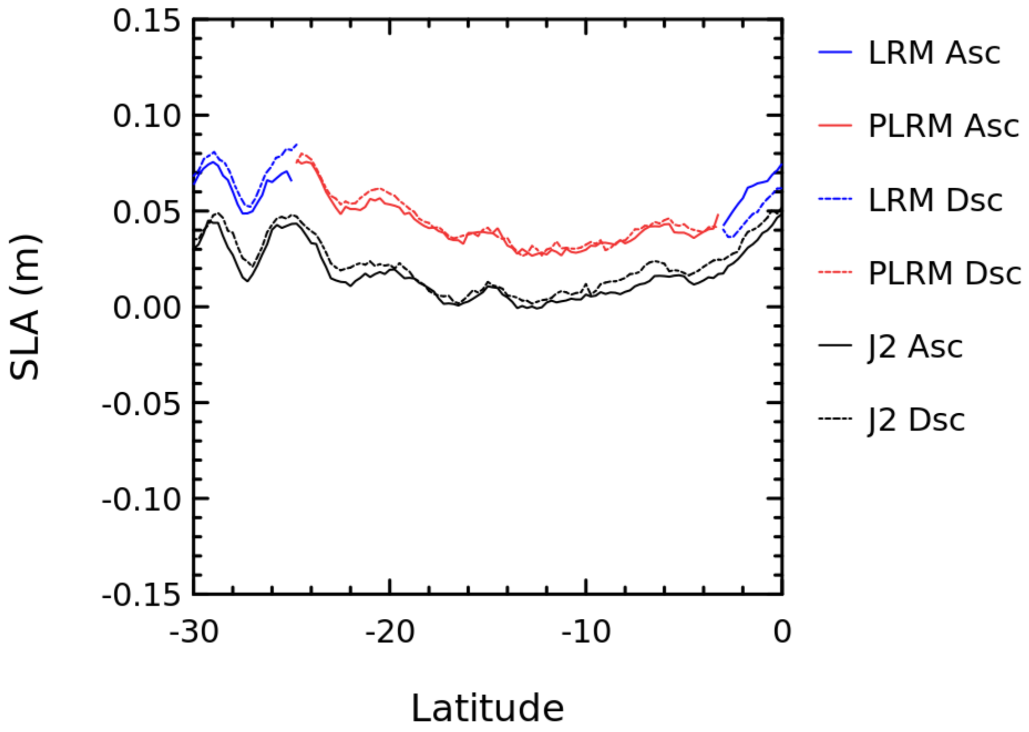


Figure 14 - SLA transition over the Pacific May 2012- September 2012, separation between ascending (solid line) and descending (dashed line) passes

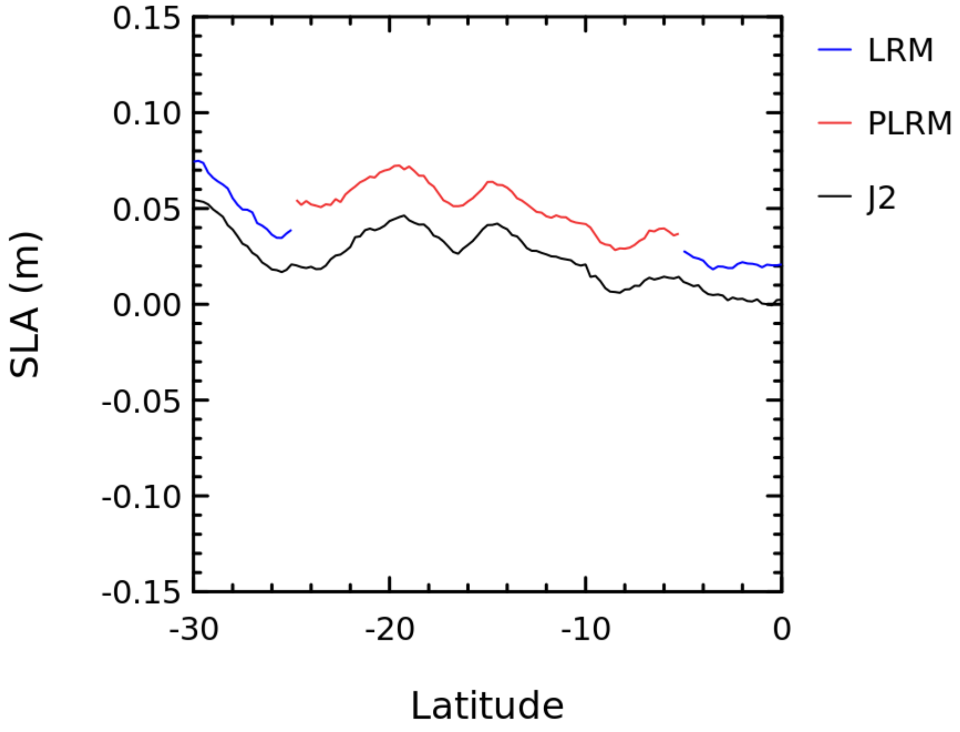


Figure 15 – SLA transition over the Pacific October 2012-March 2013

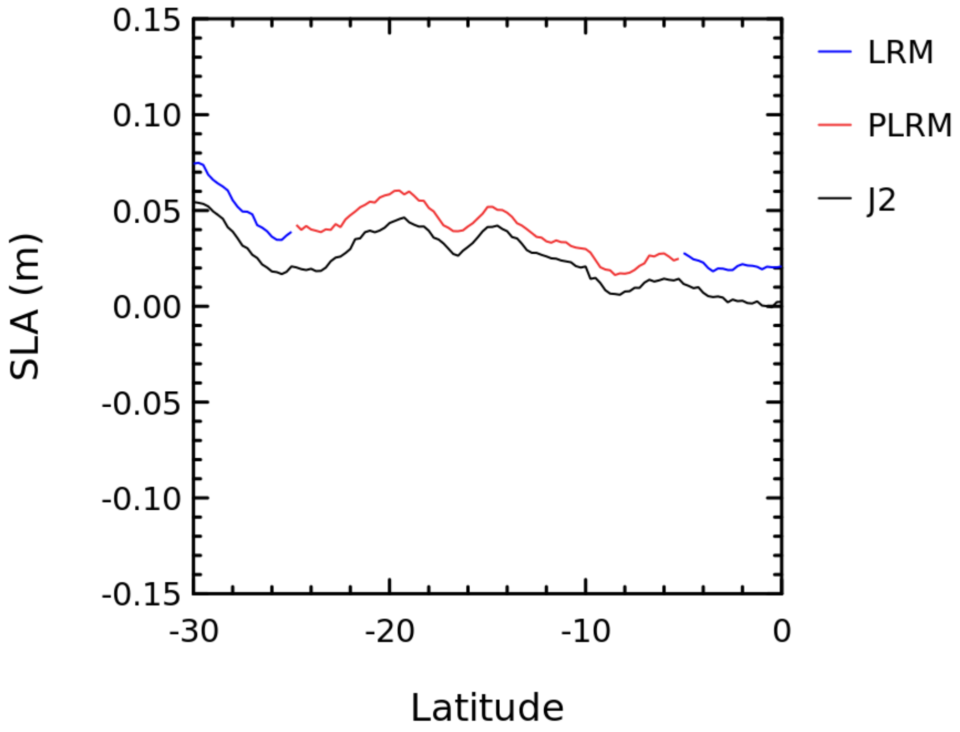


Figure 16 – SLA transition over the Pacific October 2012-March 2013 where the PLRM is artificially lowered by 1.2 cm

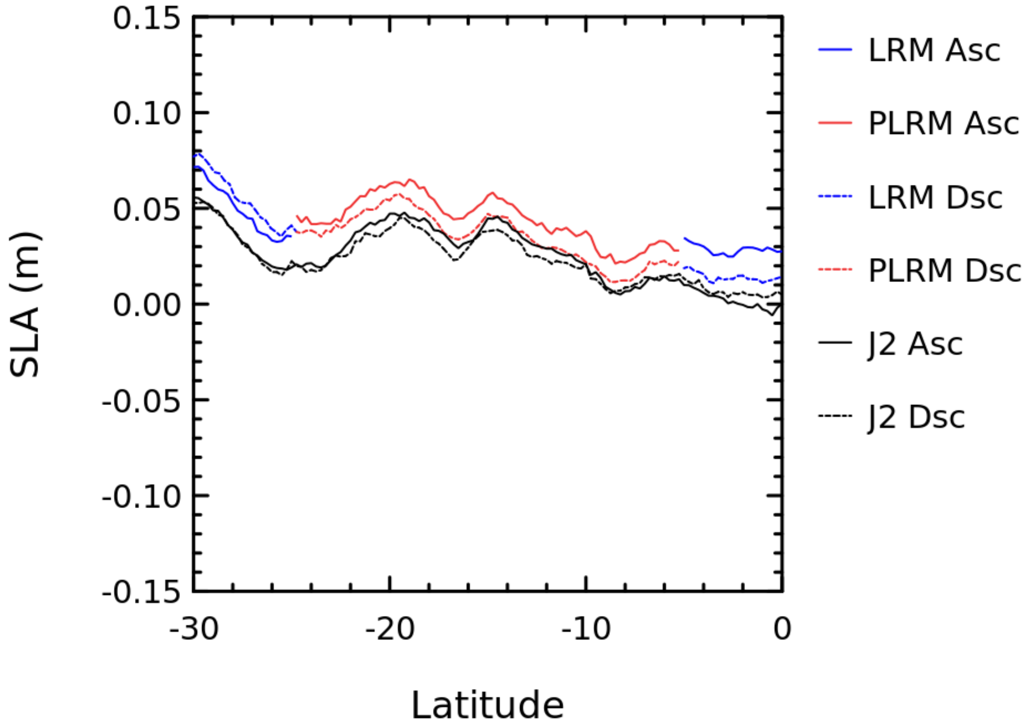


Figure 17 - SLA transition over the Pacific October 2012-March 2013 where the PLRM is artificially lowered by 1.2 cm for ascending (solid line) and descending passes (dashed line)

3.2.2. Transition over the Atlantic box

Over this area, the selected zone for the transition is very small and we are left with very few tracks to be averaged for Cryosat-2 (only 16 tracks per month) and even less for Jason-2 mission which has a larger distance between two adjacent tracks.

3.2.2.1. SWH transition

Figure 18 shows the transition between LRM and PLRM SWH obtained over the full year of data. We find a seamless transition between both data sets and a very close agreement with Jason-2 profile, especially before and after the transition.

In this case, no constant bias appears between Cryosat-2 and Jason-2. It could be due to different wave regimes that are averaged in this area since there is more variability between summer time and winter time compared to the equatorial Pacific. Therefore the sampling of the sea states is too different between Jason-2 and Cryosat-2 to be able to estimate a mean bias between both missions.

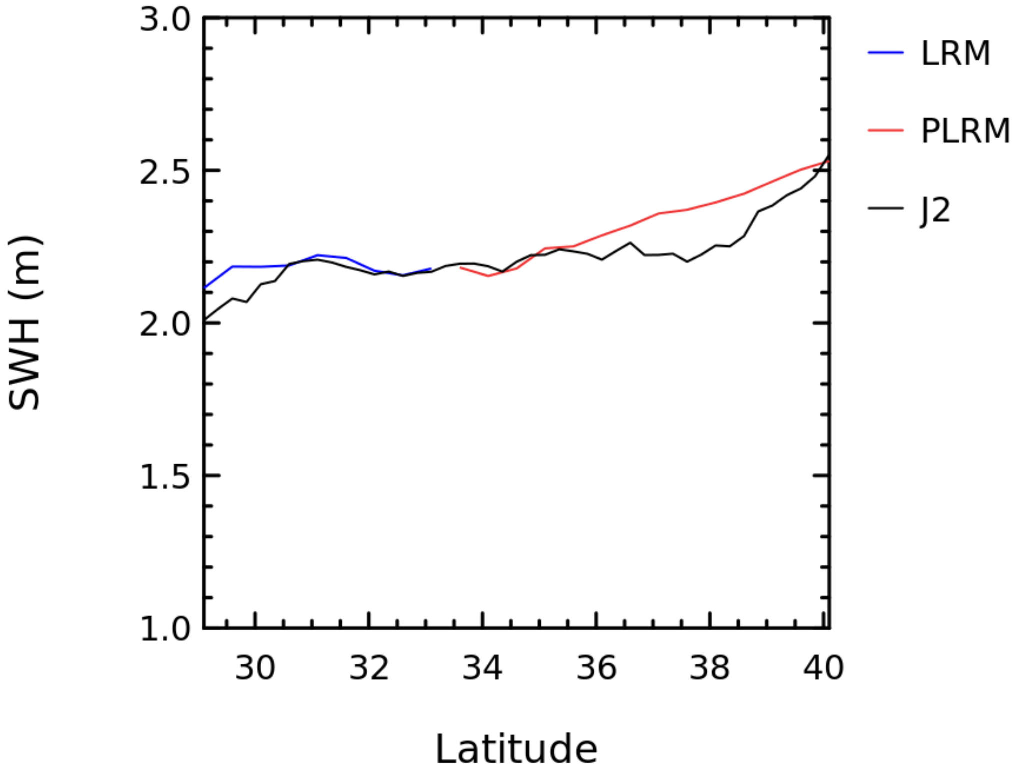


Figure 18 - SWH transition over the Atlantic May 2012-March 2013

3.2.2.2. SLA transition

Figure 19 shows the transition between LRM and PLRM SLA obtained over the full year of data. We also find a seamless transition between both data sets. The analysis in this region is trickier because the transition between LRM and SAR boxes is located on a 4 cm gradient of SLA (observed on Jason-2), but the LRM and PLRM have well captured the 4 cm gradient of the se level.

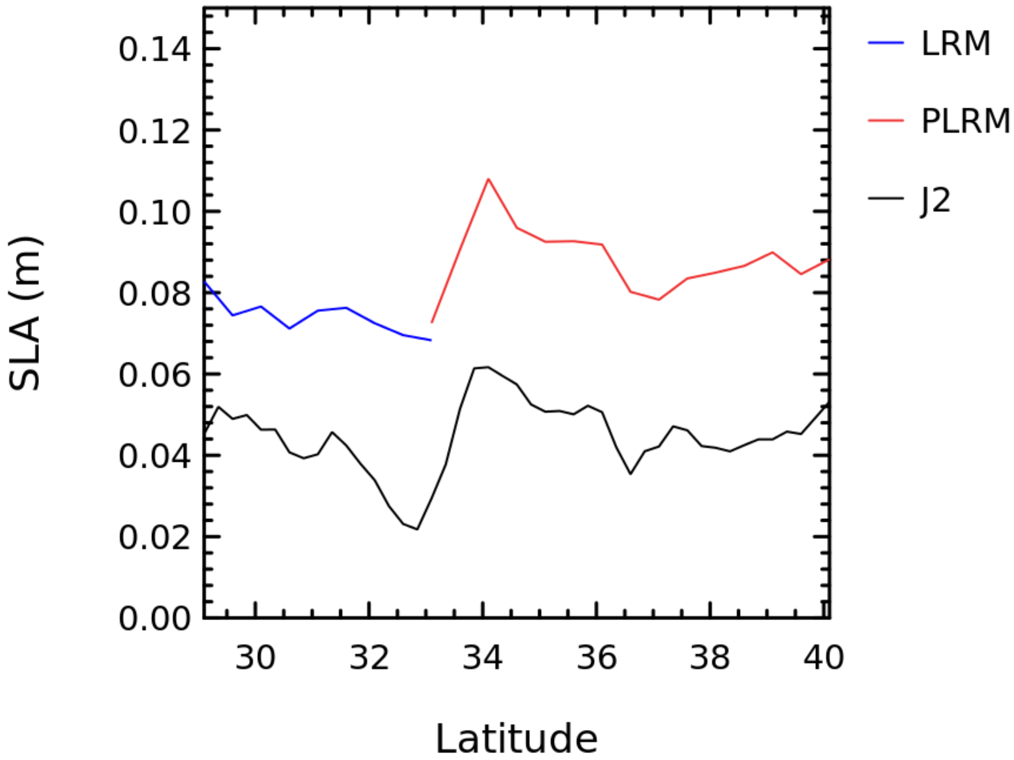


Figure 19 - SLA transition over the Atlantic May 2012-March 2013

4. Conclusions

The main findings are summarised below:

1. This analysis shows that the PLRM provide a seamless transition with LRM data for SWH.
2. We find a bias of 5 to 10 cm on LRM and PLRM SWH, SWH being too low compared to Jason-2 SWH.
3. This analysis shows that the PLRM provide a seamless transition with LRM data for SLA over most of the analysed cases.
4. Over the Pacific, a bias of 1.2 cm appears on the SLA averaged during the second period. There is no explanation for having a bias that would evolve with time, except that the instrumental drift of the altimeter would not be properly tackled in the CPP processing. We know that the IF mask applied in the CPP processing is constant and a possible drift of the PTR is not accounted for. We would need a longer time serie to further check the temporal evolution of the bias between LRM and PLRM processing.
5. We also observe discrepancies between ascending and descending transitions over the Pacific, suggesting that an error would affect ascending tracks in the Pacific area.
6. Going below the centimetre to check the seamless transition between LRM and PLRM in all cases is certainly quite challenging, given the few areas in SAR mode and the complexity of the signals that have to be taken into account. This is why getting transitions at centimeter level in all the cases analysed in this study is excellent and it fully validates the PLRM processing compared to the LRM standard that we are used to in altimetry.