CP4O

Cryosat Plus for Oceans

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D4.2 Product Validation Report – Open Ocean

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Abstract

Within the frame of the CryoSat Plus for Ocean (CP4O) ESA project, the SAMOSA-3 fully analytical model, i.e. the current baseline implementation for the Sentinel-3 Level-2 processing, has been updated in order to be able to account for different Level-1 processing approaches. The model updates were focused on the appropriate handling of the energy distribution over the different echoes of the delay-Doppler stack, an application of a Look-Up Table (LUT) for the selection of a variable width Point Target Response (PTR) as a function of SWH, the complete implementation of the SAMOSA-2 model, and an appropriate estimation of the thermal noise from the SAR waveform.

The updated SAMOSA model was integrated within a full waveform retracker, which performs the joint estimation of Sea Surface Height (SSH), Significant Wave Height (SWH), and Sigma_0, by means of an iterative Levenberg-Marquardt minimization algorithm. Within the frame of CP4O, the SAMOSA model was adjusted to the Level-1 processing of the Cryosat Product Prototype (CPP) provided by CNES. The retracker was applied to these data in order to estimate the Level-2 geophysical parameters, which were cross-validated with the SSH, SWH, and Sigma0 provided within the CPP Level-1b product and calculated by means of a numerical retracker.

In order to perform a statistically representative comparison of the retracker outputs, two full sub-cycles of CryoSat data from the South Pacific SAR patch were analysed. It was determined that the geophysical parameter estimation of the CNES numerical and the Updated SAMOSA analytical retrackers are fully consistent and can be considered equivalent: for the 20 Hz product, the bias in the estimation of SSH from both retracker solutions is around 3 mm, with a standard deviation below 1 cm; for SWH, the bias is around 5 mm, with 12 cm standard deviation, for a SWH range between 0 and 8 meters; and finally, the estimation Sigma0 shows an error between both estimations below 0.1 dB in mean and standard deviation. The 1Hz products reduced even further the errors standard deviation by a factor of 4 in all of the geophysical parameters.

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Abbreviations and Definitions

CNES	Centre National d'Etudes Spatiales
CP4O	Cryosat Plus 4 Oceans
ESA	European Space Agency
SAR	Synthetic Aperture Radar
SSH	Sea Surface Height
STSE	Support To Science Element
SWH	Significant Wave Height

1 Introduction

The “Cryosat Plus for Oceans” (CP4O) project is supported under the ESA Support To Science Element Programme (STSE) and brings together an expert consortium comprising, CLS, DTU Space, isardSAT, NOC, Noveltis, SatOC, Starlab, TU Delft, and the University of Porto. The main objectives of CP4O are:

- to build a sound scientific basis for new scientific and operational applications of Cryosat-2 data over four different areas, which are: open ocean, polar ocean, coastal seas and sea-floor mapping.
- to generate and evaluate new methods and products that will enable the full exploitation of the capabilities of the Cryosat-2 SIRAL altimeter, and extend their application beyond the initial mission objectives.
- to ensure that the scientific return of the Cryosat-2 mission is maximised.

1.1 Purpose, Scope and Goals

This document constitutes the Product Validation Report for the Level-2 products for Open Ocean derived within the WP4000 – Product Development and Validation of the CP4O project. The Level-2 product was obtained from the Level-1b product provided by CNES within the frame of the CP4O contract, and derived by means of the Cryosat Processing Prototype (CPP).

Starlab derived the Level-2 products by means of the updated SAMOSA fully analytical retracker. Within the frame of CP4O, WP4000, the SAMOSA-3 model [Gommenginger et al., 2012], i.e. the current baseline implementation for the Sentinel-3 Level-2 processing, was updated in order to be able to account for different Level-1 processing approaches, and specifically for the CPP approach. These algorithms have been described in the CP4O deliverable D4.1 Algorithm Theoretical Basis Document – Open Oceans [Egido, 2014].

The goal of this document is to present the validation of the previously mentioned algorithms. The validation of the Level-2 product was performed over two CryoSat sub-cycles over the South East Pacific SAR patch, corresponding to 2x10^6 waveforms at 20 Hz. The comparison was done against the Sea Surface Height (SSH), Significant Wave Height (SWH), and Power Units (Pu), provided within the CPP Level-1b product. Those parameters are obtained by means of a numerical retracking process, and therefore they represent an independent data source with respect to the geophysical parameters estimated by means of the updated SAMOSA analytical model.

1.2 Documents

RD.1 Cryosat Plus for Oceans, Technical Proposal, SatOC, DTU Space, isardSAT, NOC, Noveltis, STARLAB, TU Delft, University of Porto and CLS, Response to ESA ITT AO/1-6827/11/I-NB, November 2011

RD.2 Cryosat Plus for Oceans - Scientific Requirements Consolidation (D1.1), STARLAB, NOC, CLS, DTU Space, SatOC, ESA Project Report, March 2013.

RD.3 Cryosat Plus for Oceans – Preliminary Analysis Review (D2.1), TU Delft, CLS, DTU Space, isardSAT, NOC, Noveltis, SatOC, STARLAB, University of Porto, ESA Project Report, May 2013.

RD.4 Cryosat Plus for Oceans – Data Set User Manual (D3.2), isardSAT, SatOC, CLS, DTU Space, NOC, Noveltis, STARLAB, TU Delft, University of Porto, ESA Project Report, May 2013.

RD.5 Cryosat Plus for Oceans, Project Plan v3.1, SatOC, May 2013

RD.6 Cryosat Plus for Oceans, Financial, Administrative and Management Proposal, SatOC, DTU Space, isardSAT, NOC, Noveltis, STARLAB, TU Delft, University of Porto and CLS, Response to ESA ITT AO/1-6827/11/I-NB, November 2011

2 Description of Experimental Datasets

The experimental dataset used for this analysis comprise CPP Level-1b data product for two CryoSat sub-cycles, corresponding to the months of July 2012 and January 2013, over the South Pacific SAR patch, (lat: 0ºN – 30ºS, lon: 220ºW – 285ºW). In Figure 2.1 the SAR mode patch over the Pacific Ocean can be observed.

One full sub-cycle corresponds with an approximate number of 140 tracks of the South Pacific patch, which contains around 1 x 10^6 SAR waveforms at 20 Hz. This constitutes a statistically representative dataset for the validation of the geophysical products obtained with the updated SAMOSA retracking.

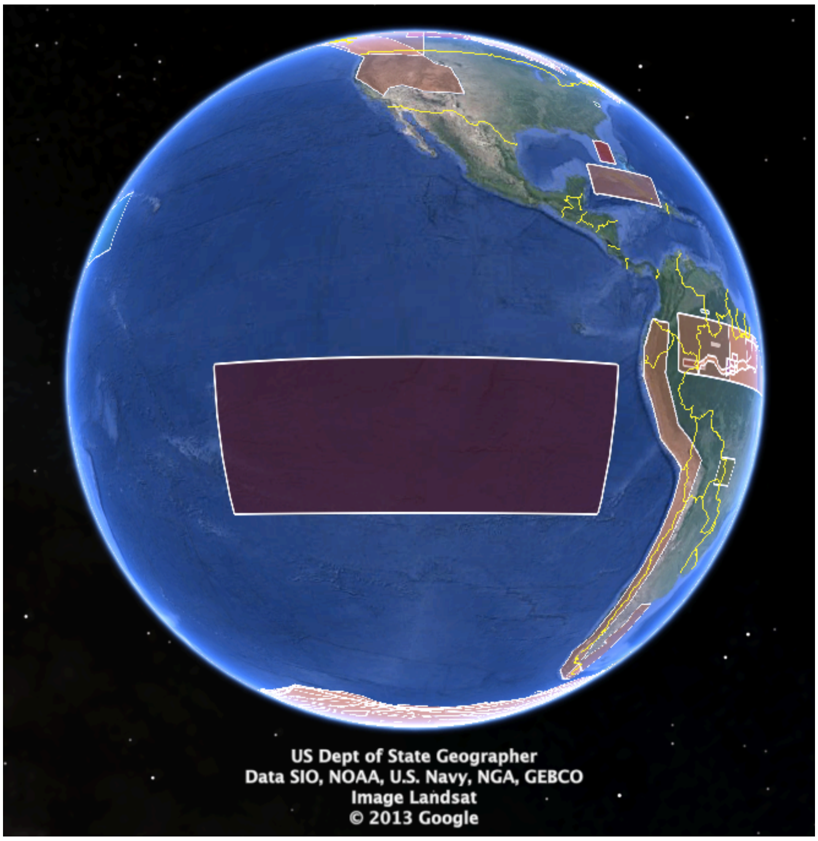

Figure 2.1: South Pacific Patch

3 Validation Activities

The validation of the Updated SAMOSA Model was carried out in two well-differentiated stages. In the first one, the validation was concentrated on a single track, selected from the North East Atlantic SAR patch:

CS_OPER_SIR1TKSA0__20120107T225227_20120107T225900_0001.DBL.DOP10.RES.DOP1B.RESDOP20.RES

This track was selected as a benchmarking tool for the development of the algorithm. This track covers more than 20 latitude degrees and has a SWH range between 2 and 6+ meters, which was considered representative of a general situation.

On a second stage a longer comparison was done over the South Pacific Patch for two CryoSat sub-cycles.

The Level-2 SAMOSA products were compared against the SSH, SWH, and Pu estimates computed by CNES and provided within the CPP Level-1b product. Those were calculated by means of a numerical retracking, and therefore constitute and independent data source for the validation of the Level-2 SAMOSA products.

The comparison was done against the Sea Surface Height (SSH), Significant Wave Height (SWH), and Power Units (Pu), that can ultimately be linked to normalized radar cross-section, (Sigma0).

3.1 Single Track Validation

In order to evaluate the retracker performance during the development of the algorithms, a statistical comparison was performed with the outputs of the SAR numerical model developed by CNES, and provided in the CPP Level-1b product. The results for the comparison of the SWH and SSH estimations provided by both retrackers are shown in Figure 3.1. Figure 3.1(a) shows the SWH SAMOSA and CPP estimates for the whole track, whereas Figure 3.1(b) depicts the SSH values. As can be observed, no significant differences are identified between both retracker solutions.

In order to be able to be sensitive to errors between both estimations the differences between the two solutions were analysed. Figure 3.2(a) shows the SWH difference between the updated SAMOSA retracker and the CPP solution. As can be observed, the SWH difference between both solutions is concentrated around zero with no significant slope along the whole track. This is verified if the SWH difference is represented against the CPP SWH estimation, Figure 3.2(b).

For the 1 Hz product, the SWH mean error and standard deviation yield 3 mm and 3.4 cm, respectively.

In a similar way, the SSH difference against the CPP product is shown in Figure 3.2 (c-d). A small trend is observed toward increasing SWH values, however this is still below 1 cm for the whole range. The SSH mean error and standard deviation equal 1 mm and 3 mm, respectively.

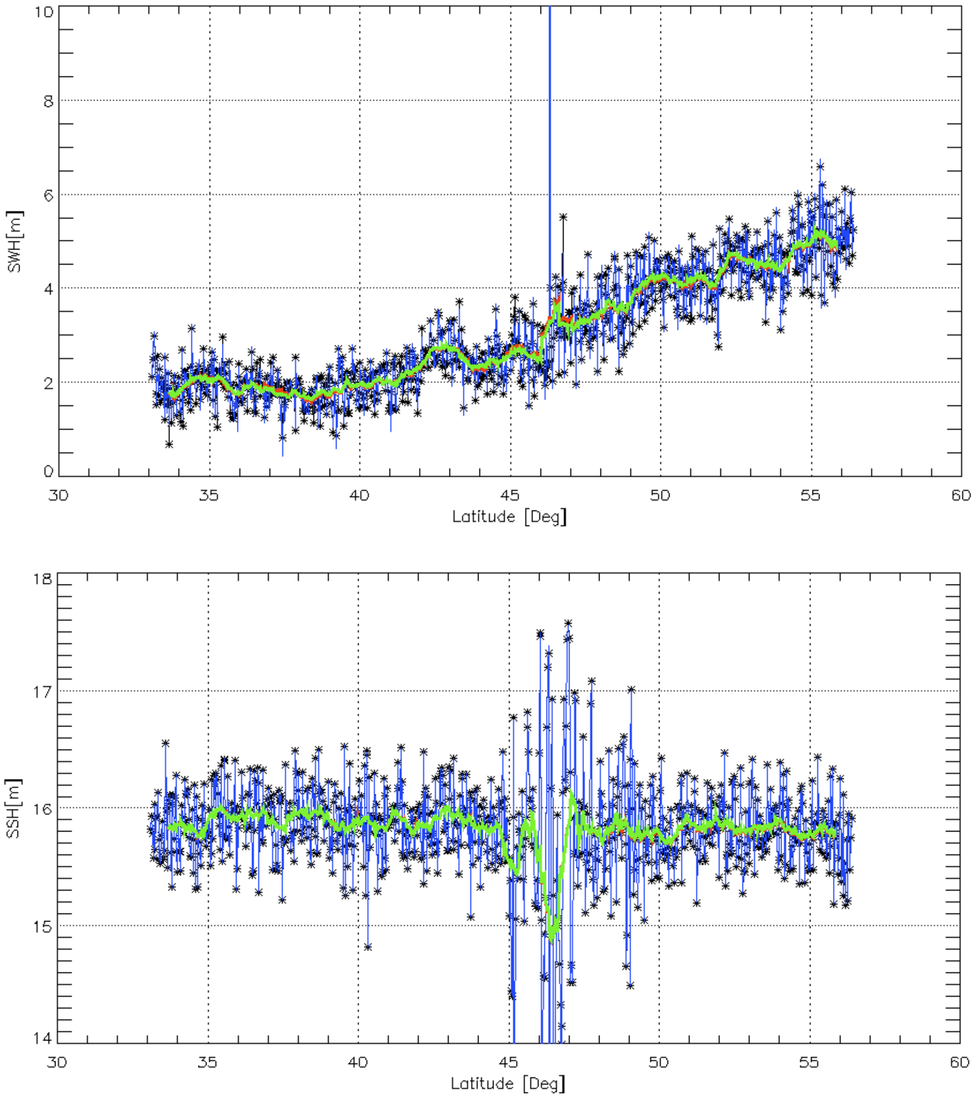

Figure 3.1: SWH and SSH estimates with CPP and SAMOSA retracker. In black: 20 Hz SAMOSA estimates; in blue: 20 Hz CPP estimates; in red: 1 Hz SAMOSA estimates; in green: 1 Hz CPP estimates.

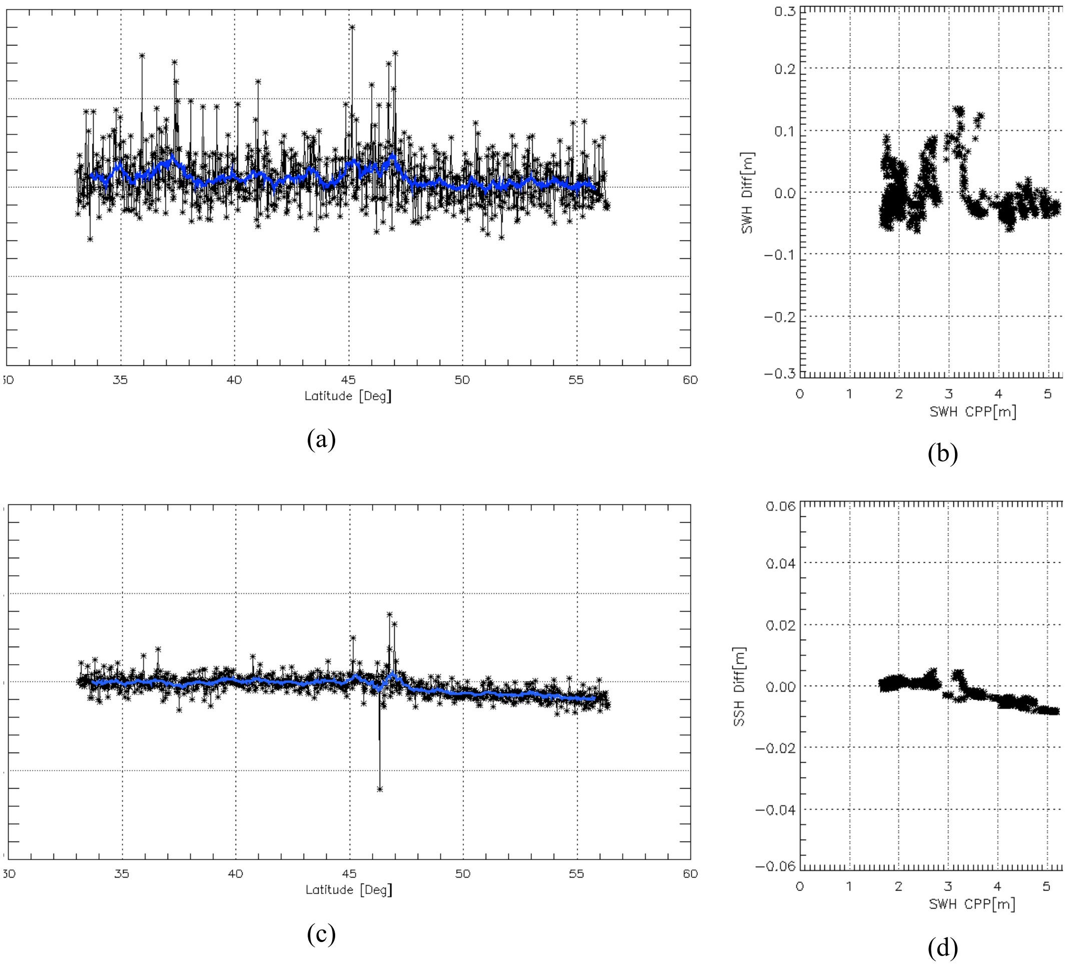

Figure 3.2: Difference between SAMOSA and CPP retracking solutions: (a) SWH difference along the track; (b) SWH difference vs CPP SWH estimation; (c) SSH difference along the track; (d) SSH difference vs CPP SWH estimation.

3.2 Extended Validation

The two sub-cycle of over the South Pacific patch were processed in Starlab premises. The implementation of the retracker is done in IDL. A parallel processing approach was adopted to speed up the processing. The average processing time per sub-cycle, i.e. 1 x 10^6 SAR waveforms, amounts to 10 hours, with a commercial off the shelf (COTS) computer: Intel Core i7® at 3.2 GHz, 6 cores, 2 threads/core, 64 GByte RAM. The result of the comparison with the CPP product solutions is presented in the next sub-sections.

3.2.1 Sea Surface Height Error Analysis

For SSH, the comparison between the solutions obtained with the SAMOSA and CPP retrackers is provided in Figure 3.3 (a) and Figure 3.3 (b) for July 2012 and January 2013, respectively. As can be observed, the scatter plots show that both solutions are fully consistent; nor trend or bias is observed in any of the two sub-cycles. To better observe any possible discrepancies between both solutions, the error, i.e. SSH SAMOSA – SSH CPP, is represented in Figure 3.4 as a function of the CPP solutions, which is considered as the ground truth in this analysis. The density plots show the distribution concentrated around zero for the whole SSH range. The 20 Hz error bias for both periods is 3 mm, with a standard deviation of 1.4 cm. The 1 Hz product yields an error standard deviation of 2 mm.

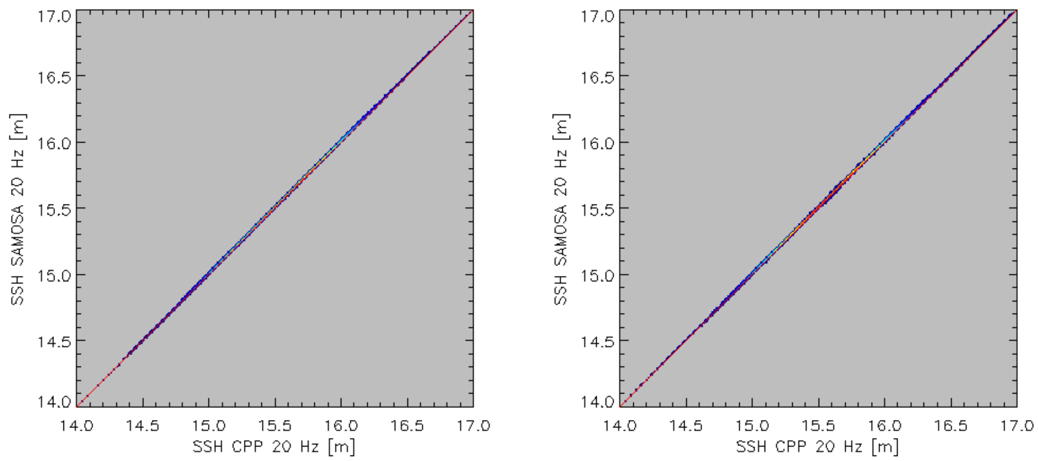

Figure 3.3: SSH Scatter plot. (a) July 2012; (b) January 2013

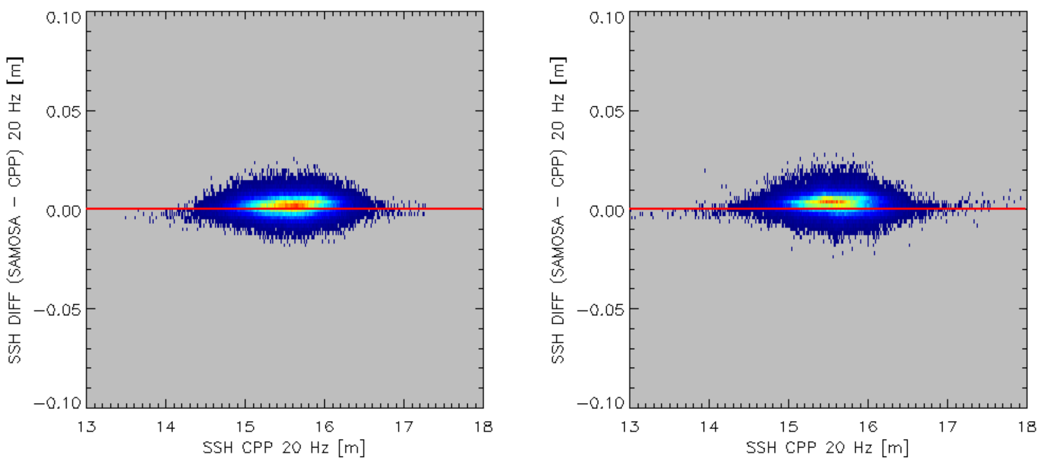

Figure 3.4: SSH error (SSH SAMOSA – SSH CPP) vs SSH CPP

3.2.2 Significant Wave Height Error Analysis

In the same way as for SSH, the SWH solutions from the SAMOSA and CPP retrackers were compared. The scatter plots for the two sub-cycles under analysis are shown in Figure 3.5. As can be observed, the 1:1 trend is maintained throughout the whole SWH range. The plots of the SWH differences show that the error is concentrated around zero. This is confirmed by the mean and standard deviation of the error. The SWH error bias yields 6 mm and -9 mm for the months of July and January, respectively. The error standard deviation between the 20 Hz products yields 12 cm, and 15 cm. The 1 Hz product reduces the error standard deviation by a factor of 4.5.

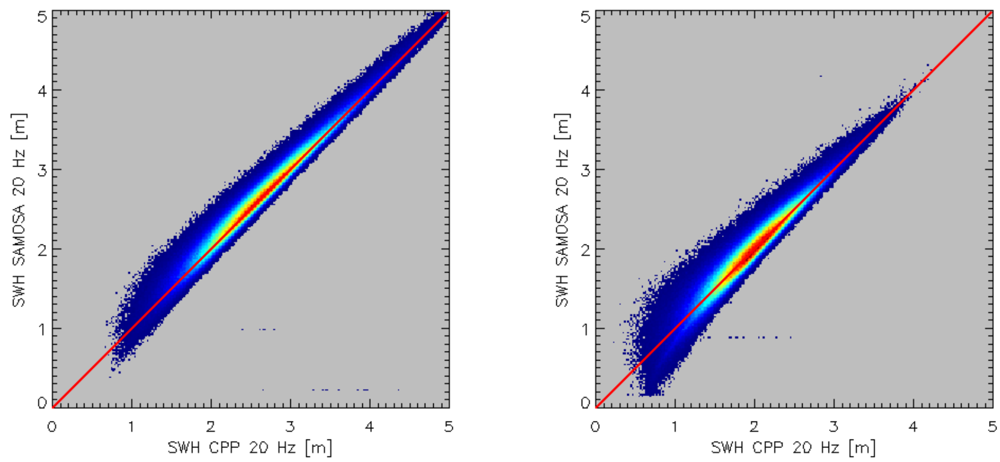

Figure 3.5: SWH Scatter plot. (a) July 2012; (b) January 2013.

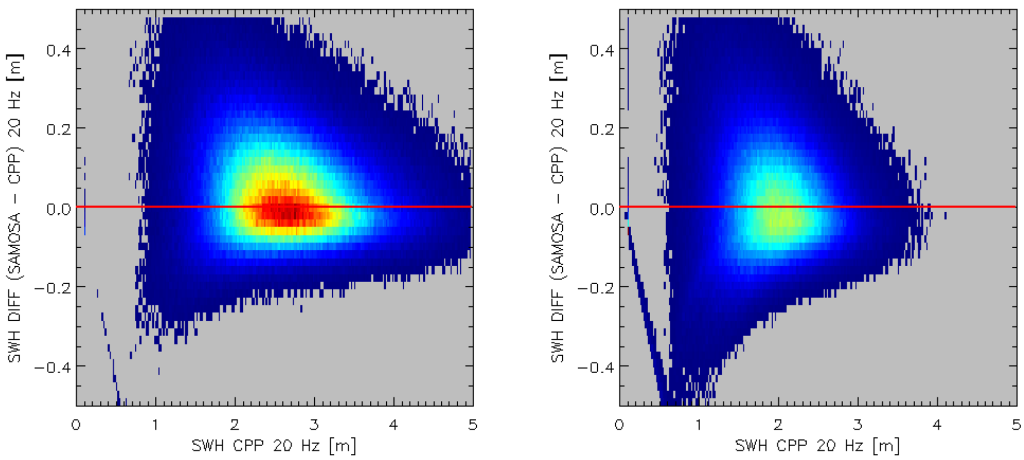

Figure 3.6: SWH error (SWH SAMOSA – SWH CPP) vs SWH CPP.

3.2.3 Waveform Power (Pu) Error Analysis

The last parameter under analysis is the waveform power (Pu). As can be observed from Figure 3.7 and Figure 3.8, the estimation of Pu is fully consistent between the updated SAMOSA retracker, and the CPP retracker. No significant trends were observed neither in the scatter plot nor in the error density plots.

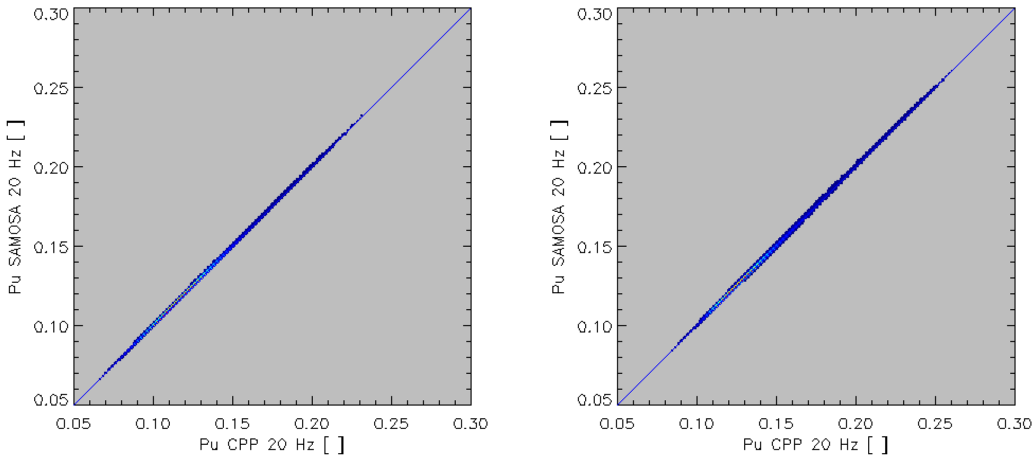

Figure 3.7: Pu Scatter plot. (a) July 2012; (b) January 2013.

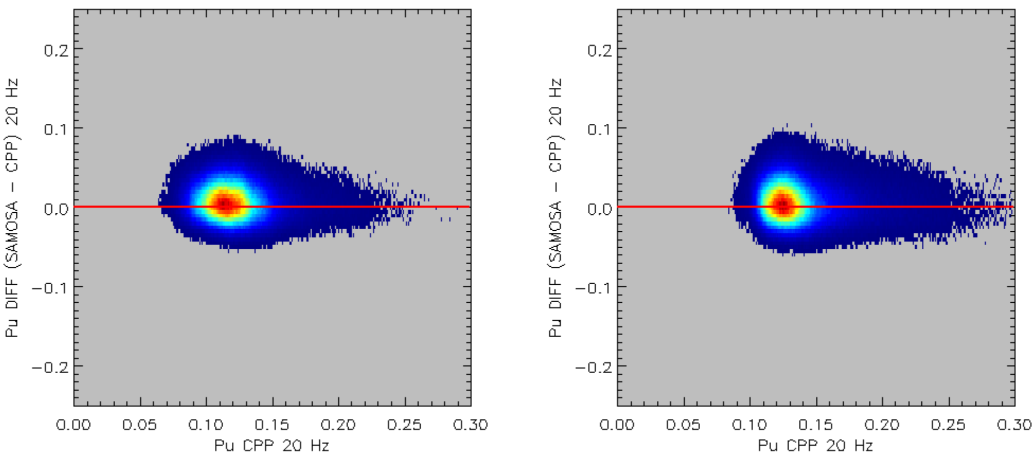

Figure 3.8: Pu error (Pu SAMOSA – Pu CPP) vs Pu CPP.

3.2.4 SSH and Pu Differences against CPP SWH

The SSH and Pu differences between the SAMOSA and CPP retracking solutions were represented against the SWH value estimated in CPP in order to observe any possible trends of SSH and Pu with respect to SWH.

The density plots for these metrics for the months of July 2012 and January 2013 and depicted in Figures Figure 3.9 and Figure 3.10. As in previous cases the distribution of the errors were unbiased, i.e. concentrated around zero, with no trends in all the observed SWH range.

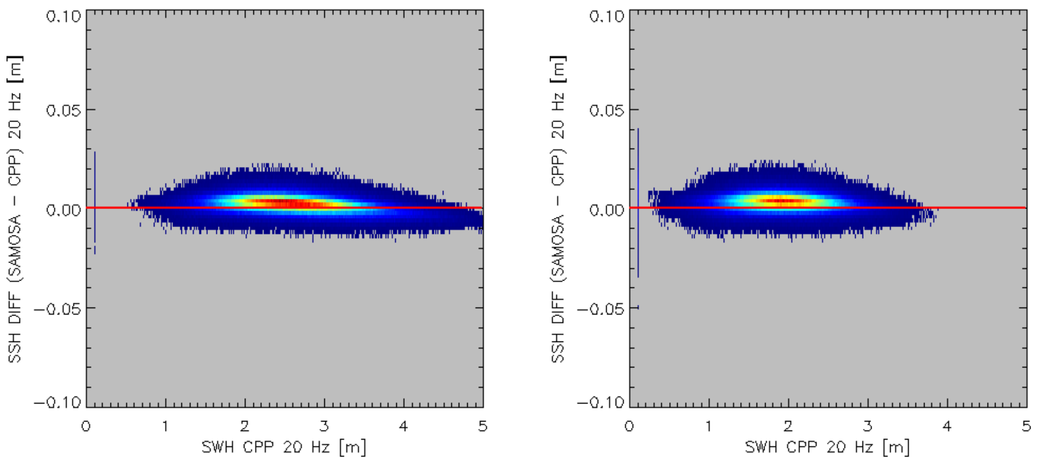

Figure 3.9: SSH Difference (SSH SAMOSA – SSH CPP) vs SWH CPP.

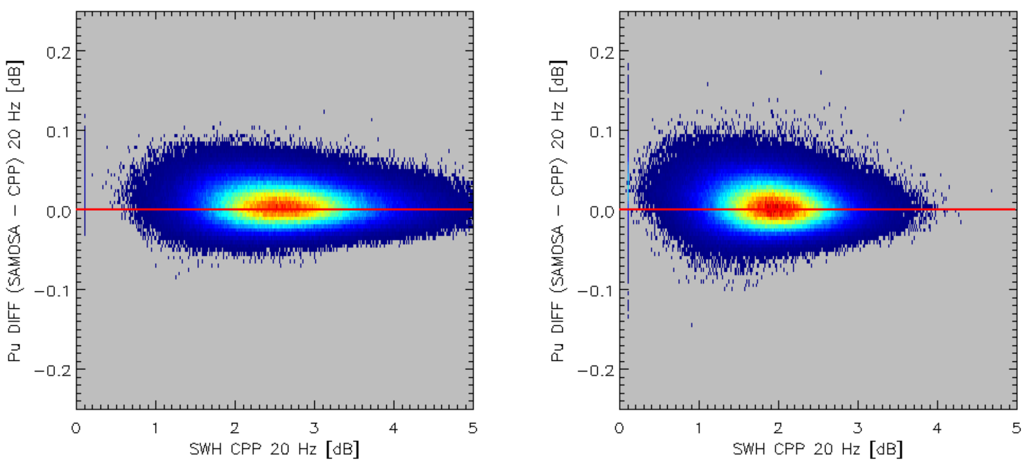

Figure 3.10: Pu Difference (Pu SAMOSA – Pu CPP) vs SWH CPP.

4 Conclusions

This report has presented the validation activities performed within the frame of WP4000 – Product Development and Validation of the Cryosat plus for Ocean (CP4O) ESA project. The Level-2 products processed by means of the updated SAMOSA model, were compared against the SSH, SWH and Pu values provided within the Level-1b CPP product. These data were provided by CNES within the frame of the CP4O contract.

In order to perform a statistically representative comparison of the retracker outputs, two full sub-cycles of CryoSat data from the South Pacific SAR patch were analysed. It was determined that the geophysical parameter estimation of the CNES numerical and the Updated SAMOSA analytical retrackers are fully consistent and can be considered equivalent: for the 20 Hz product, the bias in the estimation of SSH from both retracker solutions is around 3 mm, with a standard deviation below 1 cm; for SWH, the bias is around 5 mm, with 12 cm standard deviation, for a SWH range between 0 and 8 meters; and finally, the estimation Sigma0 shows an error between both estimations below 0.1 Pu in mean and standard deviation. The 1Hz products reduce even further the errors standard deviation by a factor of 4 in all of the geophysical parameters.

Further work entails the validation of this fully analytical retracker with an extended dataset, including also other independent data sources. However, these results already demonstrate the potentiality of the updated SAMOSA retracker for the generation of Level-2 products.

5 References

[Egido, 2014]: A. Egido, *"D4.1 Algorithm Theoretical and Validation Document – Open Ocean",* CP4O WP4000 Technical Note, ESA/ESRIN Contract No. 4000106169/12/I-NB "Cryosat Plus for Oceans", Version 1.0, 14 July 2014.

[Gommenginger et al., 2012]: C. Gommenginger, C. Martin-Puig , M. Srokosz, M. Caparrini, S. Dinardo, and B. Lucas, "*Detailed Processing Model of the Sentinel-3 SRAL SAR altimeter ocean waveform retracker*", SAMOSA3 WP2300 technical Note, ESRIN Contract No. 20698/07/I-LG "Development of SAR Altimetry Mode Studies and Applications over Ocean, Coastal Zones and Inland Water", Version 2.1.0, 16 March 2012, 75 pages.