Along-track Nadir Level-2+ (L2P) Significant Wave Height (SWH) from SWIM instrument of CFOSAT

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Chronology Issues:			
Issue:	Date:	Validated by	Reason for change:
1.0	2020/04/08		Creation of the document
1.1	2021/05/18		Update description for version 1.1 of products
2.0	2021/05/25		Adding description and nomenclature of NTC (Non Time Critical) "Climate Series" products.
2.1	2021/09/10		New version of "Climate Series" NTC products (intercalibration with CCI v2.0)
3.0	2022/01/14		Adding description and nomenclature of NTC (Non Time Critical) high resolution (5 Hz) products.

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List of Acronyms:

AVISO+	Archiving, Validation and Interpretation of Satellite Oceanographic data
CaSyS	CalVal Systematic SWIM
CCI	ESA Climate Change Initiative
CF	Climate and Forecast
CFOSAT	China-France Oceanography Satellite
CLS	Collecte, Localisation, Satellites
CNES	Centre National d'Etudes Spatiales
COARDS	Cooperative Ocean/Atmopshere Reasearch Data Service
CWWIC	CNES Wind and Wave Instrument Center
ECMWF	European Centre for Medium-range Weather Forecasting
FROGS	Frogs Oceanographic Ground Segment
L2P	Level-2+ product: global 1 Hz along-track data (sea level anomaly, its components and validity flag) over marine surfaces based on Level-2 products
L2PDT	Level-2+ product Delayed Time (complete series delivered at once)
NRT	Near Real Time
SLA	Sea Level Anomaly
SWIM	Surface Waves Investigation and Monitoring
SWH	Significant Wave Height
UTC	Universal Time Coordinated

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Bibliography

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Contents

1. Introduction

The purpose of this document is to describe the Along-track Nadir Level-2+ (L2P) Significant Wave Height (SWH) from SWIM instrument of CFOSAT.

The generation of those products is part of the FRench Oceanographic Ground Segment (FROGS) of the CFOSAT Mission. The dissemination of those products is part of the Cnes Aviso+.

After a description of the input data, a short overview of the processing steps is presented. Then, complete information about user products is provided, giving nomenclature, format description, and software routines.

2. Overview

2.1. SWIM SWH nadir measurements

SWIM (Surface Waves Investigation and Monitoring instrument) is one of CFOSAT's radar instruments. It is a wave scatterometer operated at near-nadir incidences: 0° (nadir), 2°, 4°, 6°, 10° (Figure 1). At 0° incidence, SWIM behaves as a conventional altimeter, it sends a spherical radar signal in the nadir direction.

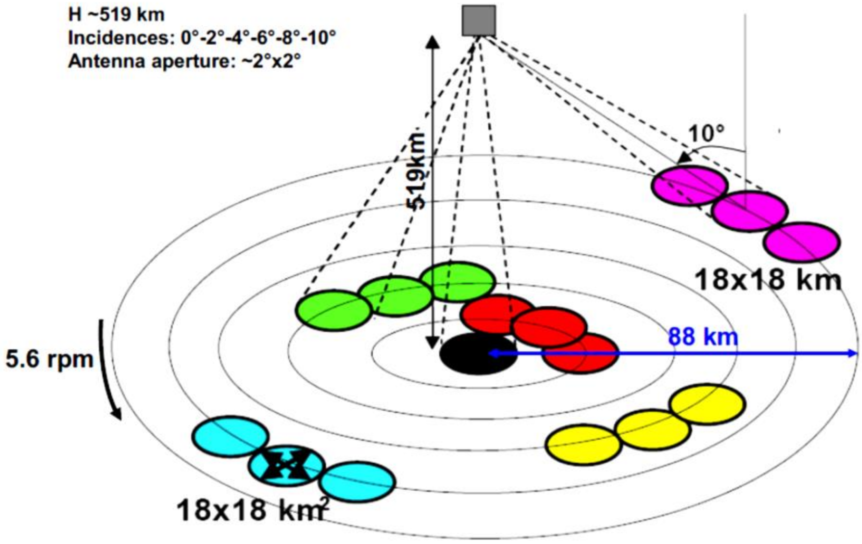

Figure 1. SWIM scatterometer

This signal is reflected by the sea surface and goes back to the satellite. The analysis of the returned signal allows the calculation of the time needed by the signal to go and come back from which can be deduced the distance satellite-sea surface. The sea state surface elevation distribution impacts the shape of the returned signal, the so-called "waveform".

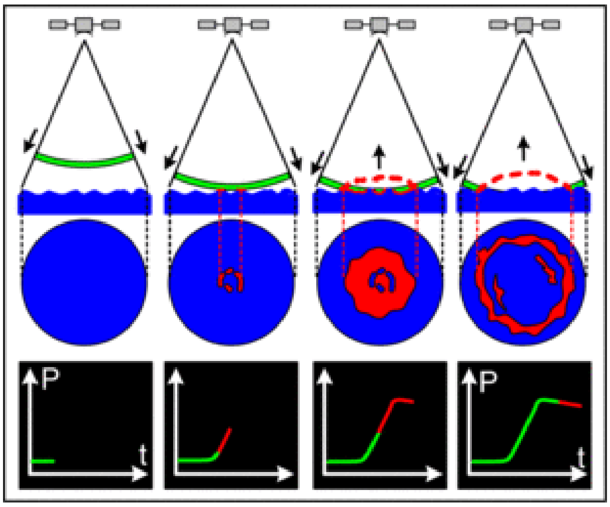

Figure 2. Formation of an echo over a sea surface with waves for conventional altimetry

While the signal is not reflected at the ocean surface, the altimeter only receives passive information from the natural radiations of the atmosphere, the “thermal noise”, that creates a low energy plateau. Then the signal propagates at the surface of the ocean, and, as the number of scatterers increases, the backscattered power increases as well. The pulse duration being limited, and because the antenna gain decreases when going far from nadir, the returned power of the echo decreases slowly. The resulting wave is called the “waveform” (Figure 2).

Hence, the SWH over ocean surfaces is determined from the slope between the leading edge and the highest point of the radar altimeter waveform. For high waves, it will take longer for the signal to propagate and return, resulting in a wider waveform. For very reflective surfaces and small waves, the waveform will be steeper, and the distance between the leading edge and the highest point will be smaller.

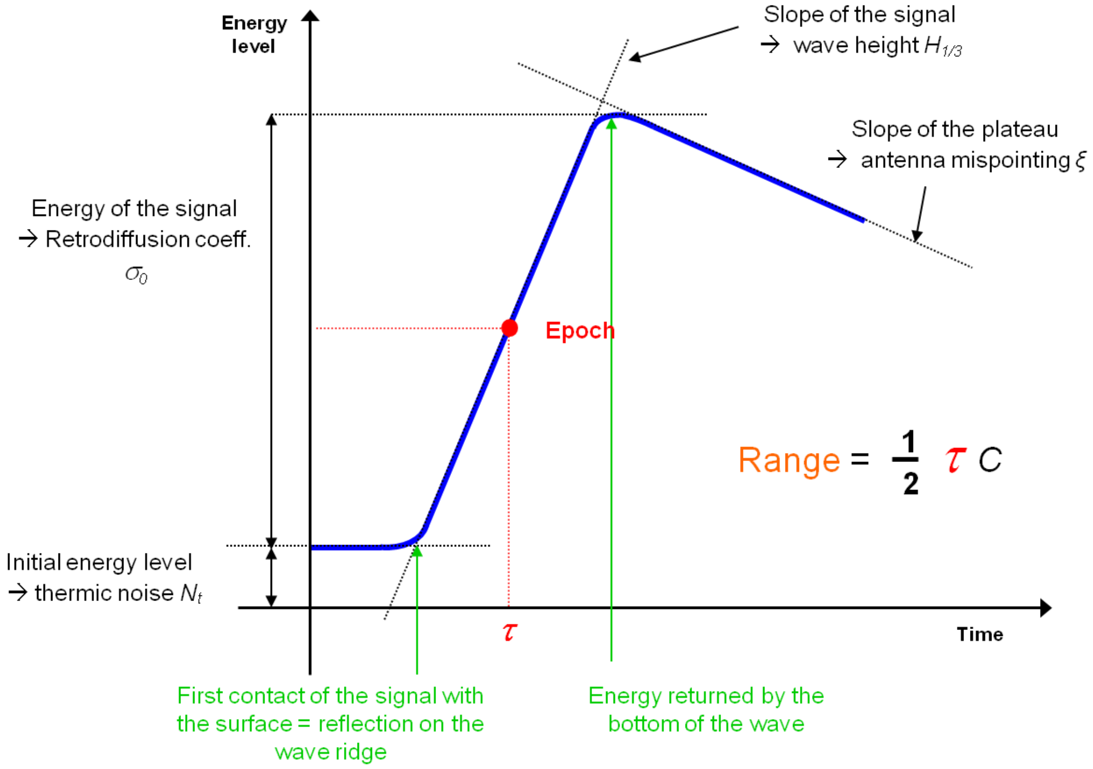

Figure 3. Nadir Waveform

The term SWH (or Hs) refers to the mean wave height of the highest third of the waves (also sometimes denoted $H_{1/3}$).

2.2. Orbits, Passes and Repeat cycle

‘Orbit’ is one revolution around the Earth by the satellite.

‘Repeat Cycle’ is the time period that elapses until the satellite flies over the same location again.

For CFOSAT:

- The orbit is sun-synchronous with an ascending pass at the equator around 7am;
- The inclinaison is 97.465 deg;
- The passes are numbered from 1 to 197 representing a full ‘repeat cycle’ for the repetitive orbit;
- The repeat cycle is 13 days, meaning that the same path is covered (within ± 20 km) every 13 days.

The localisation of orbits (for realised and extrapolated cycles) can be found on the AVISO+ web site:

https://www.aviso.altimetry.fr/en/data/tools/pass-locator.html

3. L2P files production

3.1. Overview

The SWIM L2P products intend to be a calibrated, easy-to-ingest product with comparable metrics. This is to provide user friendly CFOSAT nadir products where users can directly access to valid SWH content without additional processing. Nadir products will contain:

- only valid measurements of SWIM;
- a sub-ensemble of variables extracted from SWIM NRT files generated by the CWWIC;
- Calibrated and unbiased data in compliance with the nadir constellation reference frame.

The processing can be divided in 4 main parts:

- Pre-processing;
- Calibration;
- Data editing;
- Products generation.

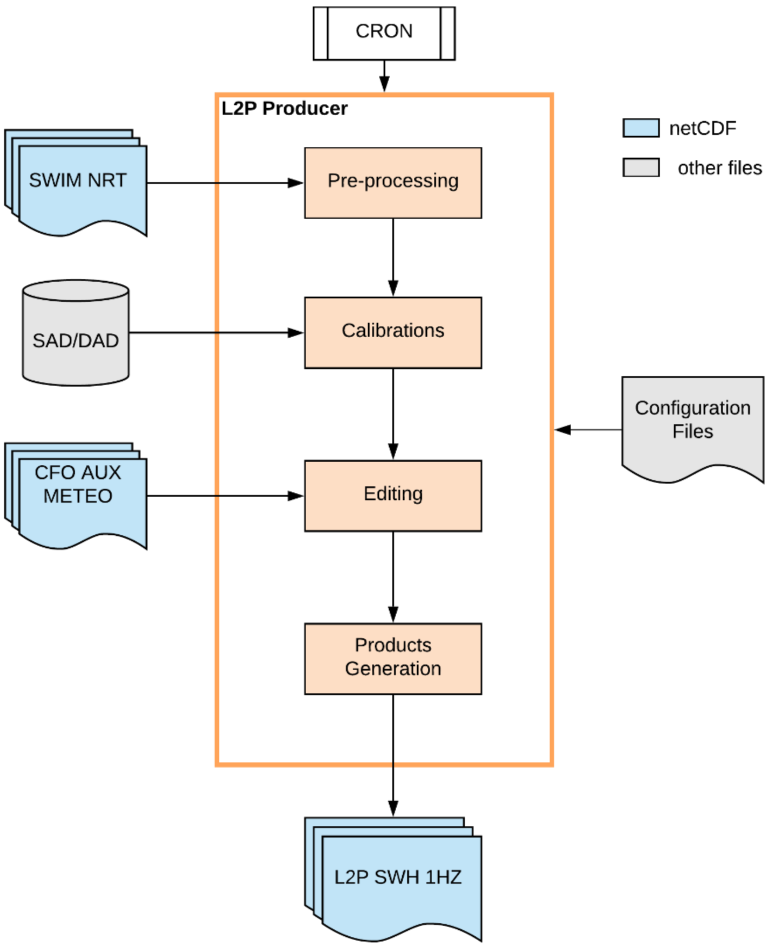

Figure 4. Processing L2P SWH CFOSAT

3.2. Pre-processing

The measurements used in the system consist in Near-Real-Time (NRT) CFOSAT Level-2 products. The Jason-3 mission is also considered in a cross calibration performed between Jason-3 and CFOSAT. The cross-calibration data (abacus) has been defined using crossover points between CFOSAT and Jason-3.

Pre-processing consists in:

- making a prior selection to process only new files;
- handling compliancy with C.F. 1-6;
- adapt and copy variables that do not need calibration or editing (e.g., latitude, longitude, …).

Dimensions are set to be compliant with CF 1.6.

3.3. Data Calibration

The data calibration consists in applying two corrections (see Figure 5): cross-calibration on the reference mission and absolute calibration on in-situ data. The first correction homogenizes SWH data by calibrating CFOSAT on the reference mission (Jason-3). The second one consists in applying a correction computed between the reference mission and in-situ measurements provided by buoys.

The next sub-sections describe the computation of: the cross-calibration and of the absolute calibration. The appendices 9 provides additional details and quantitative information of these calibrations.

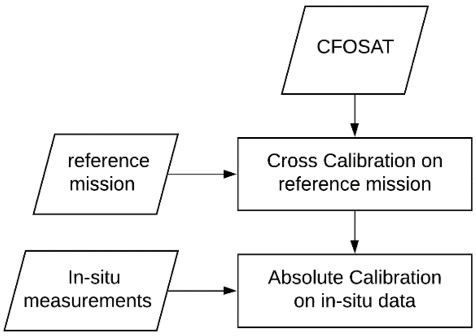

Figure 5. Description of the calibration process

3.3.1.1. Cross-calibration

The cross-calibration consists in determining the relation between the SWH measurements provided by two different missions. This relation is determined on a representative number of collocated measurements and then used in the operational system to homogenise the missions with respect to the reference one. Such a relation is expected to remain valid as long as instrumental drifts are not detected or ground segment evolutions do not affect the L2 products in input of the operational system. Should one of these evolve, another cross-calibration relation should be computed and implemented into the operational system.

Jason-3 is used as the reference mission as it is a conventional altimeter mission, expected to show robust results for SWH measurements.

The crossover points between the two mission orbits are determined. For the SWH measurements calibration, only the crossover points with a time difference less than 3 hours are considered. This short delay ensures that both missions observe a scene that did not significantly evolve (when a longer dataset archive is available, this time difference can be lowered to 1 hour). The along-track SWH of CFOSAT and Jason-3 are interpolated at the selected crossover points. The interpolation technique uses a linear approximation in the along-track direction, based on the 1Hz data samples of each mission (SWIM and Jason-3).

Once the two mission measurements are collocated, the differences between the reference mission and the secondary mission SWHs are computed. The bias is plotted as a function of the secondary mission SWH to provide a height-dependent bias correction. The next step consists in fitting a polynomial function to the distribution of this bias. This function is stored in an abacus file used as an input in the L2P wave processing chain.

Quantitative details on the calibration relations for the NRT and the NTC products are provided in Appendices 9.2 and 9.2.

3.3.1.2. Absolute calibration

In addition to the inter-mission biases, an absolute calibration correction is applied. This absolute calibration aims at correcting the biases between in-situ measurements and satellite altimetry. The CFOSAT data is cross-calibrated on the reference mission Jason-3. Therefore, the absolute calibration is computed from the comparison of Jason-3 SWH to buoy measurements at collocated points.

Quantitative details on the absolute calibration relations for the NRT and NTC products are provided in Appendices 9.1 and 9.2.

3.4. Data Editing

3.4.1. Low resolution (1 Hz) Products

Quality Control on the input L2 data is a critical process; it is aimed at providing only the most reliable data. The system uses as input the L2 products which contain all the variables derived from the SWIM nadir beam observations (e.g., sigma0, compressed variables from 5Hz to 1Hz) as well as flags and calibrated 1Hz-nadir SWH obtained from the previous step (cf. 3.3). These values are provided at 1-Hz frequency except for the sea-ice coverage which is at 5Hz frequency.

Parameter	Units	Method	SWIM Valid Value or Min/Max
Nadir SWH 1Hz	m	Threshold	0 < x < 30
Nadir SWH 1Hz std	m	Abacus	X < Abacus Value
Nadir SWH 1Hz used native (Number of SWH-5Hz measures used to compute SWH-1Hz)	1	Threshold	4 ≤ x ≤ 10
Nadir wind 1Hz	m/s	Threshold	0 < x < 30
Nadir sigma0 1Hz	dB	Threshold	5 < x < 25
Nadir sigma0 1Hz std	dB	Threshold	0 < x < 2
Nadir sigma0 1Hz used native (Number of sigma0-5Hz measures used to compute SWH-1Hz)	1	Threshold	4 ≤ x ≤ 10
Flag valid SWH 1hz	1	Flag value	x = 0
Ice cover from ECMWF	pct	Flag value	x = 0.0

Table 1. Flag and threshold editing criteria

Data are selected as valid or invalid using a combination of various criteria such as quality flags and parameter thresholds (see Table 1 for details). These criteria are adapted from the ones used for the SLA in altimeter missions (e.g., Aviso/SALP 2016). Only criteria related to retracking derived values were selected. Geophysical parameters (e.g., tropospheric corrections) do not intervene in the SWH estimation and therefore are not used in the wave products generation. Consequently, no editing criterion was set for these parameters in the L2P wave chain. For CFOSAT, the criteria on the off-nadir angle are not activated since their values are not derived from the retracking, therefore their value do not provide information about SWH data quality. As CFOSAT is not an altimeter mission, there is no precise orbit determination; thus, the orbit and the range are not considered in the editing.

The method to compute the threshold on SWH RMS is described in Queffeulou P. (2016) [3]. This method has been tuned for CFOSAT 1Hz data. It consists in determining a threshold on the 1Hz SWH standard dispersion. Such a threshold is defined as the sum of the mean value and three times the standard deviation of the gaussian fit applied to ln(SWH_STD) (natural logarithm) distribution for each SWH bin (Figure 6). The curve representing the thresholds as a function of SWH is then filtered (red line in Figure 7: Left). Values for which 5m<SWH<9m are used to determine a linear fit used for SWH>5m. Finally, the threshold on ln(SWD_STD) is converted back into a threshold on SWH_STD (Figure 7: Right). This threshold depends on SWH and potentially on the processing baseline. It is recomputed when processing baseline evolutions impact the SWH estimation.

For example, on cycle 21 from July 19^{th} to August, 1^{st} 2019, this threshold edits 13,94% of data (continental data are not considered).

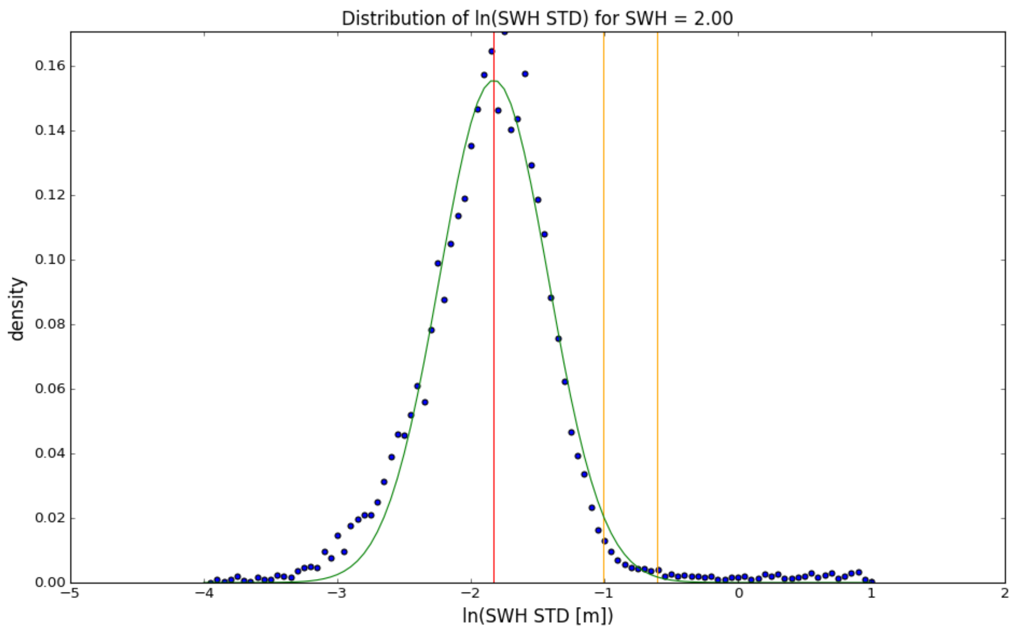

Figure 6. Distribution of ln(SWH_STD) for SWH between 2m and 2.1m, for 13 days of CFOSAT data from 2019 July 19^{th} to 2019 August 1^{st}. The green line represents the gaussian fit on the distribution. The red line is the mean from the gaussian fit, the orange lines represent mean+2sigma and mean+3sigma where sigma is the standard deviation.

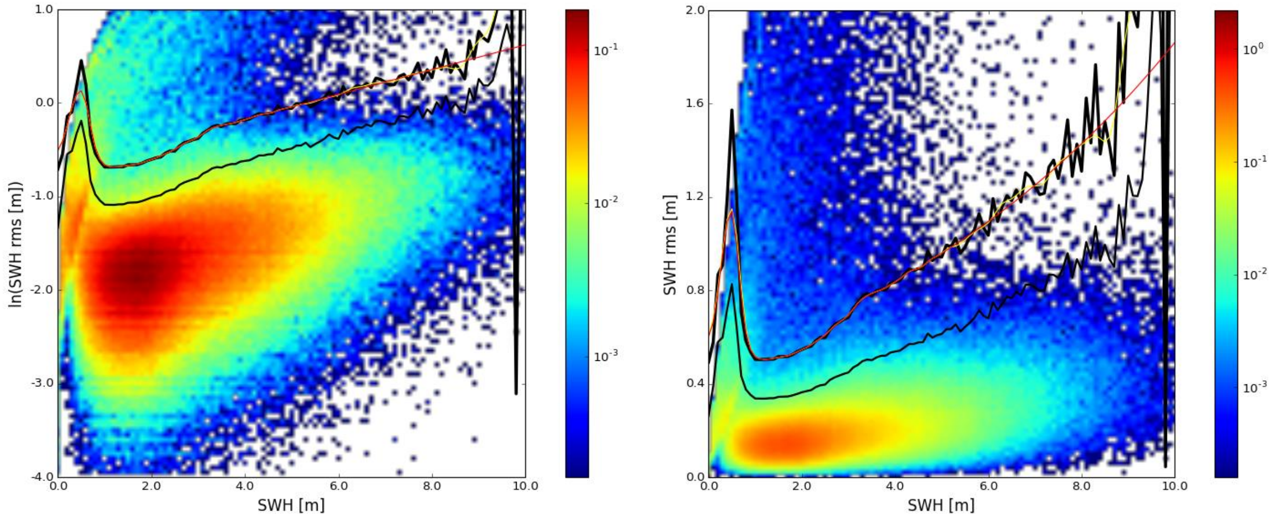

Figure 7. Density plots of ln(SWH RMS) and SWH RMS as a function of SWH, and their computed thresholds, for 13 days of CFOSAT data from 2019 July 19th to 2019 August 1st. The black lines represent mean+2sigma and mean+3sigma. Left: The red line represents the smoothed mean+3sigma curve for SWH<5m and for SWH ≥5m consist in an affine function. Density colour scales logarithmically. Right: The red line is the limits applied on std(swh)

3.4.2. High resolution (5 Hz) Products

Quality Control on the input L2 data is a critical process; it is aimed at providing only the most reliable data. The system uses as input the L2 products which contain all the variables derived from the SWIM nadir beam observations (e.g., sigma0, swh) as well as flags and calibrated 5Hz-nadir SWH obtained from the previous step (cf. 3.3). These values are provided at 5-Hz frequency.

With 5Hz data, the previous method cannot be used since there is no STD to compute from a compression process. Another method was developed: the iterative editing.

There are two steps in this method. First, some thresholds are applied on two variables (native nadir swh and sigma0) with the same thresholds as in previous method:

Parameter	Units	Method	SWIM Valid value or Min/max
Nadir SWH 5 Hz	M	Threshold	0 < x < 30
Nadir SIGMA0 5 Hz	dB	Threshold	5 < x < 25

Table 2. Flag and threshold editing criteria for 5 Hz products

Then comes the iterative component of this method.

The swh signal is filtered with a median and a lanczos filter. All points out of an interval defined by the filtered signal and a particular threshold are considered as outliers. This process is repeated a fixed number of times.

The choice of the threshold applied during this step is larger for larger significant wave height to allow the natural variability for stronger waves. The slope used to threshold is derived from the standard deviation of the signal and is chosen to remove 3 Sigma until SWH =2m.

An illustration of this evolution of standard deviation with respect to significant wave height is shown in the following figure.

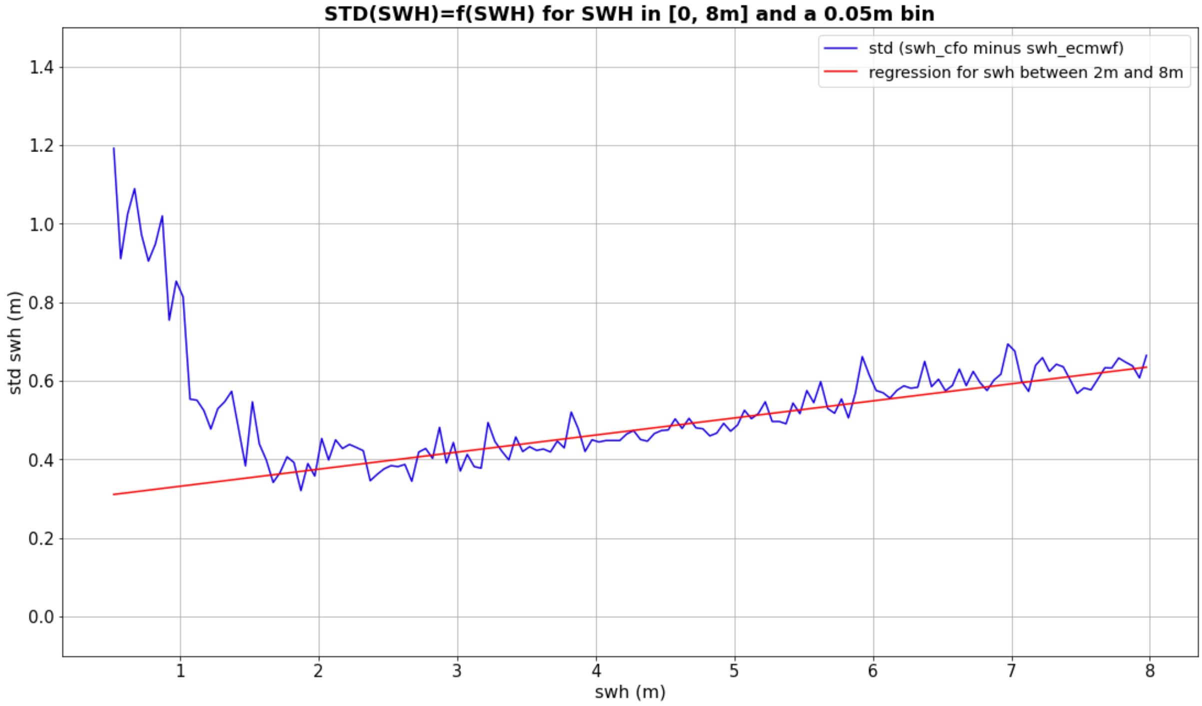

Figure 8. Evolution of standard deviation with respect to significant wave height

Then, Figure 9 illustrates the effect of the filtering and the iterative editing on an ocean track of CFOSAT (track number 302) from cycle number 86:

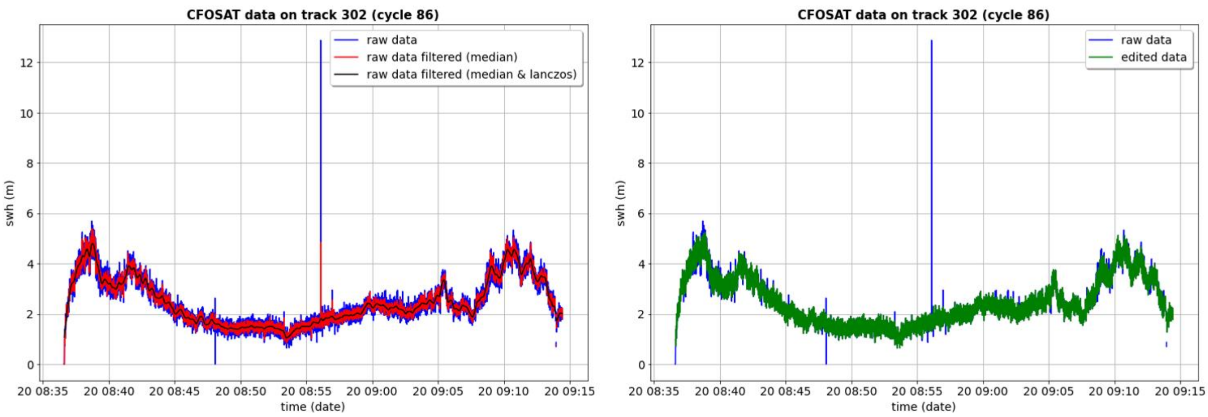

Figure 9. Illustration of raw data, filtered data and edited data with iterative editing

4. Product Presentation

4.1. Temporal Availability

Type of products	Starting date	Ending date
NRT L2P Nadir Products	2019/07/29	Today (production still going on)
NTC L2P Nadir Products	2018/11/03	2019/04/25
NTC L2P High Resolution Nadir Products	2018/11/03	2021/12/07

4.1.1.1. Near Real Time (NRT) L2P Nadir Products

CFOSAT Nadir L2P are available from the 29th of July 2019 (8h41), corresponding to the 4.3.2 baseline evolution for the CWWIC chain (L2 production). Production has no ending date as it is still on going.

4.1.1.2. Non Time Critical (NTC) "Climate Series" L2P Nadir Products

The "Climate Series" L2PDT Nadir products are delivered by blocks of data, when a major update of the processing, including calibration, justifies it. For the current version (v1.1) of the L2PDT products, the temporal availability ranges from the beginning of the mission (2018/11/03 to 2021/05/31), in other words, about 9 months of additional data compared to the full series of NRT products.

Furthermore, L2PDT data are available on a 6-month period earlier than L2, from the beginning of the mission (2018/11/03) to the beginning of L2 distribution (2019/04/25). Over this time, L2 are not available to users due to a degradation of the spectral information before the end of the mission calibration phase.

4.1.1.3. Non Time Critical (NTC) "Climate Series" high resolution L2P Nadir Products

High resolution L2P Nadir products are available from the beginning of the mission (11th November 2018, first SWIM L2 data available), to their production date in one shot: currently 7th December 2021.

4.2. Nomenclature

4.2.1.1. Near Real Time (NRT) L2P Nadir Products

CFOSAT NRT L2P filenames are named under CFOSAT L2 model:

CFO_OPXX_SWI_L2P____F_<begin_date>T<begin_hour>_<end_date>T<end_hour>.nc

Where the name

components are:

- OPXX: where XX corresponds to the current version of the L2 products;
- <begin_date> under Year-Month-Day format : YYYYMMDD;
- <end_date> under Year-Month-Day format : YYYYMMDD;
- <begin_hour> under Hour-Minute-Second format : HHmmss;
- <end_hour> under Hour-Minute-Second format : HHmmss.

This is a filename example corresponding to the current OP05 L2 products:

CFO_OP05_SWI_L2P____F_20200306T180424_20200306T194835.nc

4.2.1.2. Non Time Critical (NTC) "Climate Series" L2P Nadir Products

CFOSAT NTC L2P filenames are named following the nomenclature:

CFO______SWI_L2PDT__F_<begin_date>T<begin_hour>_<end_date>T<end_hour>.nc

Where the name components are:

- <begin_date> under Year-Month-Day format : YYYYMMDD;
- <end_date> under Year-Month-Day format : YYYYMMDD;
- <begin_hour> under Hour-Minute-Second format : HHmmss;
- <end_hour> under Hour-Minute-Second format : HHmmss.

This is a filename example:

CFO______SWI_L2PDT__F_20200306T180424_20200306T194835.nc

Note the difference between the NTC and the NRT products, where "OP05" (indicated the L2 processing CWWIC chain version) was replaced by '____' in the filenames.

4.2.1.3. Non Time Critical (NTC) "Climate Series" high resolution L2P Nadir Products

CFOSAT NTC L2P high resolution (5 Hz) are named following the nomenclature:

CFO_OP05_SWI_L2P5Hz_F_<begin_date>T<begin_hour>_<end_date>T<end_hour>.nc

Where the name components are:

- <begin_date> under Year-Month-Day format : YYYYMMDD;
- <end_date> under Year-Month-Day format : YYYYMMDD;
- <begin_hour> under Hour-Minute-Second format : HHmmss;
- <end_hour> under Hour-Minute-Second format : HHmmss.

This is a filename example:

CFO_OP05_SWI_L2P5Hz_F_20200306T180424_20200306T194835.nc

Note that the NTC characteristic of those products is not present in the name itself of the products, but as a global attribute.

5. Data Format

This chapter presents the data storage format and convention used for CFOSAT L2P Wave products. All products are distributed in NetCDF-4 with norm CF. NetCDF (Network Common Data Form) is an open source, generic and multi-platform format developed by Unidata. An exhaustive presentation of NetCDF and additional conventions is available on the following web site:

https://www.unidata.ucar.edu/software/netcdf/

All basic NetCDF conventions are applied to files. Additionally, the files are based on the attribute data tags defined by the Cooperative Ocean/Atmopshere Reasearch Data Service (COARDS) and Climate Forecast (CF) metadata conventions. The CF convention generalises and extends the COARDS convention but relaxes the COARDS constraints on dimension and order and specifies methods for reducing the size of datasets. A wide range of software is available to write or read NetCDF/CF files. API made available by UNIDATA:

- C/C++/Fortran;
- Java;
- MATLAB, Objective-C, Perl, Python, R, Ruby, Tcl/Tk.

5.1. L2P Wave Product Format

5.1.1. Dimensions

One dimension is defined:

- time: number of data in current file, sampled at 1Hz or 5 Hz whether one is looking at a low or a high resolution product

5.1.2. Data Handling Variables

Variables defined in the product have the following definitions:

Name of variable	Type	Content	Unit	Timeliness
latitude	int	Latitude value of measurements	degrees_north	all
longitude	int	Longitude value of measurements	degrees_east	all
time	double	Time of measurements	seconds since 2000-01-01 00:00:00 UTC	all
validation_flag	byte	Validity of Significant wave Height valid=(validation_flag=0), invalid=(validation_flag=1)	none	all
swh	short	Significant wave height	meters	all
applied_bias	short	Value of the applied bias (see 3.3)	meters	all

Table 3. Description of L2P NetCDF variables

The mapping between variables of L2 products and variables of L2P products is available in Table 4.

5.1.2.1. Attributes

Additional attributes may be available in L2P wave files. They are providing information about the type of product or the processing and parameter used.

5.1.2.2. Description of L2P NRT Nadir Products

```
netcdf CFO_OP05_SWI_L2P____F_20210518T190152_20210518T204438 {
dimensions:
        time = 6163 ;
variables:
        int latitude(time) ;
                latitude:long_name = "latitude" ;
                latitude:standard_name = "latitude" ;
                latitude:scale_factor = 1.e-06 ;
                latitude:units = "degrees_north" ;
                latitude:valid_max = 90000000LL ;
                latitude:valid_min = -90000000LL ;
                latitude:comments = "Positive latitude is North latitude, negative
                                     latitude is South latitude." ;
        int longitude(time) ;
                longitude:long_name = "longitude" ;
                longitude:standard_name = "longitude" ;
                longitude:scale_factor = 1.e-06 ;
                longitude:units = "degrees_east" ;
                longitude:valid_max = 360000000LL ;
                longitude:valid_min = 0LL ;
                longitude:comments = "East longitude relative to Greenwich meridian" ;
        double time(time) ;
                time:units = "seconds since 2000-01-01 00:00:00.0" ;
                time:long_name = "time (sec. since 2000-01-01)" ;
                time:standard_name = "time" ;
                time:calendar = "gregorian" ;
                time:axis = "T" ;
        byte validation_flag(time) ;
                validation_flag:_FillValue = -127b ;
                validation_flag:flag_meanings = "valid_data_over_ocean rejected_data" ;
                validation_flag:flag_values = 0b, 1b ;
                validation_flag:coordinates = "longitude latitude" ;
                validation_flag:long_name = "validation flag" ;
        short swh(time) ;
                swh:_FillValue = -32767s ;
```

```
            swh:quality_flag = "validation_flag" ;
            swh:scale_factor = 0.001 ;
            swh:standard_name = "sea_surface_wave_significant_height" ;
            swh:comment = "Bias corrected. Calibration relative to buoys [Sepulveda
                          et al, 2015]. Initial L2 swh values can be recomputed
                          using swh + applied_bias." ;
            swh:long_name = "Significant Wave Height on main altimeter frequency
                             band" ;
            swh:valid_min = 0LL ;
            swh:coordinates = "longitude latitude" ;
            swh:units = "m" ;
            swh:valid_max = 32767LL ;
      short applied_bias(time) ;
            applied_bias:_FillValue = -32767s ;
            applied_bias:comment = "bias correction for calibration. The bias
                                   correction depends on the swh value. This bias
                                   is already taken into account in the swh
                                   variable." ;
            applied_bias:scale_factor = 0.001 ;
            applied_bias:coordinates = "longitude latitude" ;
            applied_bias:long_name = "Significant Wave Height bias correction" ;
            applied_bias:valid_min = -30000LL ;
            applied_bias:units = "m" ;
            applied_bias:valid_max = 30000LL ;

// global attributes:
            :platform = "CFOSAT" ;
            :sensor = "SWIM" ;
            :institution = "CNES" ;
            :contact = "" ;
            :comment = "Significant Wave Height measured by altimetry" ;
            :last_meas_time = "2021-05-18 20:44:37" ;
            :software_version = "production_l2p: 2.6.1" ;
            :product_version = "1.1" ;
            :Conventions = "CF-1.6" ;
            :first_meas_time = "2021-05-18 19:01:53" ;
            :creation_date = "2021-05-18T21:30:22" ;
            :processing_level = "L2P" ;
}
```

5.1.2.3. Description of L2P NTC Nadir Products

The NTC products differ from the NRT products in their names (see 4.2), and in the fact that they have an additional attribute `oper_version = 'OPxx'`, which refers to the CWWIC processing chain version, e.g., 'OP05' for CWWIC v 5.1.2 currently.

5.1.2.4. Description of L2P NTC High Resolution Products

High resolution NTC Products differ from other NTC products in their names (see 4.2). They also have additional global attributes: number of cycles, number of pass and type of products that clarify the fact that they are NTC products because it does not appear in their names.

5.2. Mapping between L2 and L2P variables

Hereafter the mapping between variables of SWIM NRT and SWIM L2P products is listed (in the case that L2P products contain the same content as L2 products). The mapping is the same for the L2P NTC products and high resolution L2P NTC products. There are only the names of L2 variables for time, latitude, longitude and swh that are modified for high resolution products.

Name of L2P variable	Name of L2 NRT variable	Content
latitude	lat_nadir_1Hz lat_anad_0 (5 Hz)	Latitude value of measurements
longitude	lon_nadir_1Hz lon_anad_0 (5 Hz)	Longitude value of measurements
time	time_nadir_1Hz time_nadir_native (5 Hz)	Time of measurements
validation_flag		Validity of Significant wave height valid=(validation_flag=0), invalid=(validation_flag=1)
swh		Note that in 1Hz L2P products the provided swh value is based on L2 variable 'nadir_swh_1Hz' but calibrated on Jason-3 and buoys. In 5 Hz L2P products, the provided swh value is based on L2 variable 'nadir_swh_native'
applied_bias		Adding this value to swh allows recovering the original L2 swh value

Table 4. Mapping between variables in SWIM NRT and L2P files

6. Products policy and accessibility

The use of the CFOSAT L2P products is described in the AVISO+ License Agreement.

CFOSAT L2P products are available via authenticated servers:

- On authenticated AVISO+ FTP (online products):
    - You need to register via AVISO+ web portal and sign the License Agreement: http://www.aviso.altimetry.fr/en/data/data-access/registration-form.html and select the product "Wave / wind CFOSAT products".

  Information to access the data will be sent by email.

    - Once you are registered, the access to the products is given in your personal MY AVISO+ account in the 'product page' available on: https://www.aviso.altimetry.fr/en/my-aviso-plus.html

- On the authenticated AVISO+ CNES Data Center (archived products):
  Register and download on https://aviso-data-center.cnes.fr/

7. News, updates and reprocessing

7.1. Operational news

To be kept informed about events occurring on the satellites and on the potential services interruption, see the operational news on the Aviso+ website:

https://www.aviso.altimetry.fr/en/news/operational-news-and-status.html

7.2. Updates and reprocessing

7.2.1. L2P NRT Nadir Product version

The evolutions hereafter are listed in the same directory as the data in the version information file changelog.md

Version	Delivery date	FA	Evolution with respect to previous version
v1.0	2019-07-01		• Initial release
v1.1	2021-03-30	FA-Nad-001	• Update to file nomenclature for L2P NRT • Handling of non-nominal acquisition modes (e.g., 0°-0°-8°), during which a larger number of nadir native points (> 5) may be present. The thresholds for the parameters “nadir_swh_1hz_used_native” and “nadir_sigma0_1hz_used_native” (see Table 1) have been changed from [4,5] to [4,10].
V1.2	2021-09-07	FA-Nad-002	• Bug correction: the field “applied_bias” did not correspond to the whole bias applied to the data. It contained only the cross-calibration bias, without the contribution of the absolute calibration. Now, the applied bias is such that non-corrected initial SWH value (from L2 products) can be recovered with ‘swh + applied_bias’ as stated in the field attributes.

7.2.2. L2P NTC Nadir Product version

The evolutions hereafter are listed in the same directory as the data in the version information file changelog.md

Version	Delivery date	FA	Evolution with respect to previous version
v1.1	2021-06-07		• First release of L2P Nadir NTC (delayed time) “Climate Series” products from 2018/11/03 2021/05/31 (see 4.1.1.2).
v2.0	2021-09-07		• Cross-calibration performed with CCI v2 J3-abacus (absolute-calibration included)

7.2.3. High Resolution L2P NTC Nadir Product version

The evolution hereafter are listed in the same directory as the data in the version information file changelog.md.

Version	Delivery date	FA	Evolution with respect to previous version
v1.0	2022-01-14		• First release of high resolution L2P Nadir NTC (delayed time) "Climate Series" products from 2018/11/03 2021/12/07 (see 4.1.1.3).

7.2.4. General information

Information about updates and reprocessing are described in

https://www.aviso.altimetry.fr/data/product-information/updates-and-reprocessing/monomission-data-updates.html

7.3. Additional Data and Citation

Information about the starting dates of each cycle can be found at the following webpage under Localisation of Measurements:

https://www.aviso.altimetry.fr/en/missions/current-missions/cfosat.html

RECOMMENDATIONS TO CFOSAT USERS ON PUBLICATION POLICY:

The first scientific publications on CFOSAT data will be authored by members who participated to the verification and CAL/VAL phase since the satellite launch. Two papers, one on SWIM and one on SCAT are currently under review for publication in IEEE Trans. on Geoscience and Remote Sensing (02/2020).

It is recommended that all further publications based on CFOSAT data cite one of these first two publications (depending on whether they deal with SCAT or SWIM). The publications co-authored by several members and groups of the Joint Science Team is firmly encouraged.

All the publications and communications based on CFOSAT data must be forwarded to CNSA and CNES (send to aviso@altimetry.fr who will transmit) and they all must acknowledge CNSA and CNES as having ownership of the CFOSAT science products. The acknowledgement sentence is: "All CFOSAT data are provided by courtesy of CNSA and CNES [under science proposals XXX. (XXX=proposal id)]."

8. Contacts

For more information, please contact:

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On Internet: https://www.aviso.altimetry.fr/

The user service is also interested in user feedback; questions, comments, proposals, requests are much welcome.

9. Appendix

9.1. Calibration of the NRT products

9.1.1. Cross-Calibration

For the NRT products, the CFOSAT crossover points with Jason-3 were computed on a 117-day period (November 1st, 2018 to February 26th, 2019). The starting date corresponds to the beginning of the production of CFOSAT product with AWWAIS 4.2 (CWWIC Product Version).

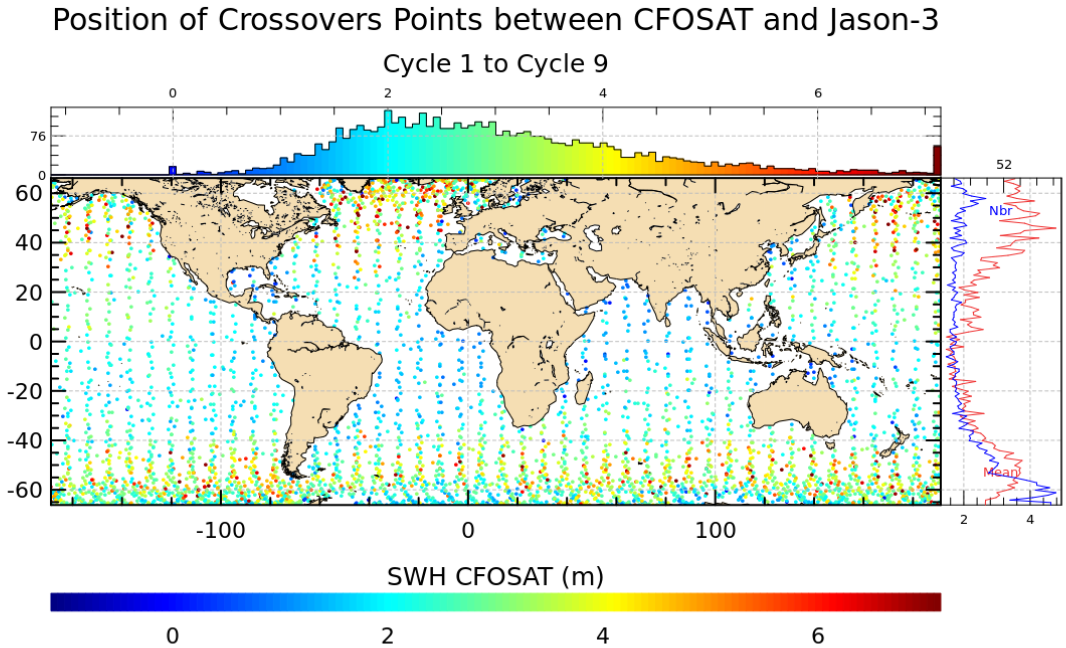

Figure 10. Spatial Distribution of Jason-3 and CFOSAT Crossover points

The crossover method was performed with a time constraint of a 3-hour difference between the two satellites. The blue dots in Figure 11 (top) represent the median of the difference between CFOSAT and Jason-3 SWH values inside each 10-cm bin of the CFOSAT population.

A linear fit is performed to determine the bias as a function of the significant wave height. The selected fitting function is the one computed over the [1-6 m] range (orange) as it samples most of the population.

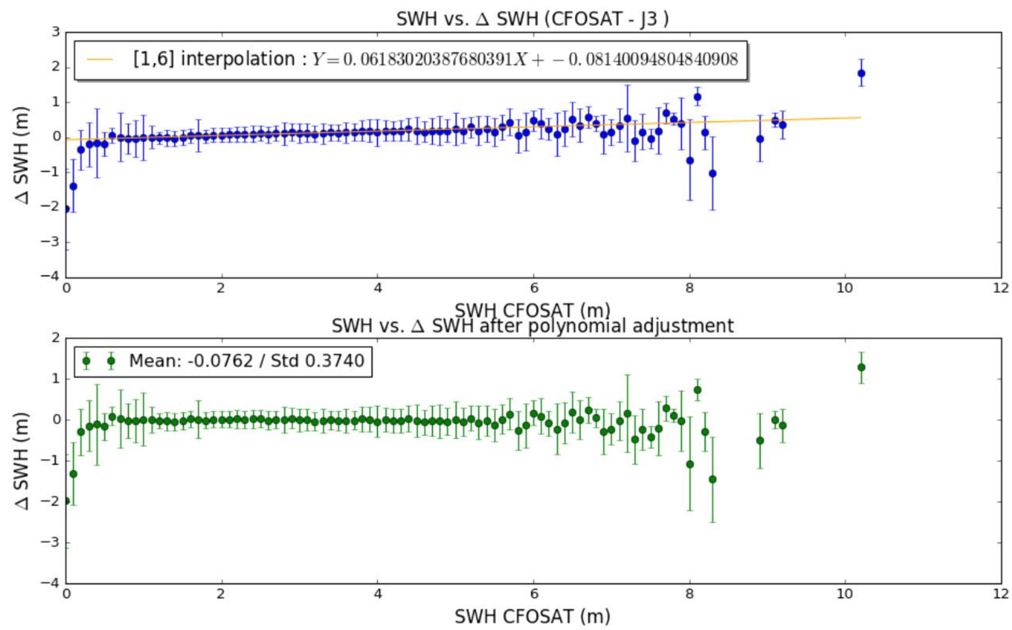

Figure 11. Top: Median of the difference between CFOSAT and J3 SWH values at crossovers points per 10cm bin. Error bars represent the standard deviation of the difference inside each bin. The orange curve represents the linear fit over the [1-6] meters range. Bottom: Residuals between the median and the fit.

The linear correction retrieved for cross-calibration between CFOSAT and Jason-3 is:

$$Corr(CFO/J3) = 0.0618H - 0.081$$

Equation 1: Linear correction between CFOSAT and Jason-3 SWH

9.1.2. Absolute Calibration

Once inter-mission biases are removed, using the cross-calibration corrections described in the previous section, an absolute calibration correction is applied to all missions. This absolute calibration aims at correcting the biases between in-situ measurements and satellite altimetry. All the missions are cross-calibrated on the reference mission Jason-3. Therefore, the absolute calibration is computed from the comparison of Jason-3 significant wave heights to buoy measurements at collocated points.

According to results from Queffeulou [3], performances for Jason-3 are very similar to those given by Jason-2 and can thus be applied to compensate for systematic errors. The linear correction is given below (Queffeulou and Croizé-Fillon 2017 [4]):

$$Corr(J2/buoys) = 1.0149H + 0.0277$$

Equation 2: Linear correction for absolute calibration of Jason-2 SWH with respect to buoy measurements

Comparisons between Jason-3 and Jason-2 along-track 1 Hz collocated measurements during Jason-3 commissioning (same track, 80 s difference between the two altimeters), were performed to compare sea state sensed by the two altimeters at the same geographical location (Figure 12). The left plot shows 1 Hz collocated SWH for Jason-3 and Jason-2, which show remarkable agreement. The regression line is very close to the unity. The bias is less than 2 mm and the RMSD is about 19 cm. The right plot shows a symmetrical distribution of the SWH RMS which indicates similar precisions.

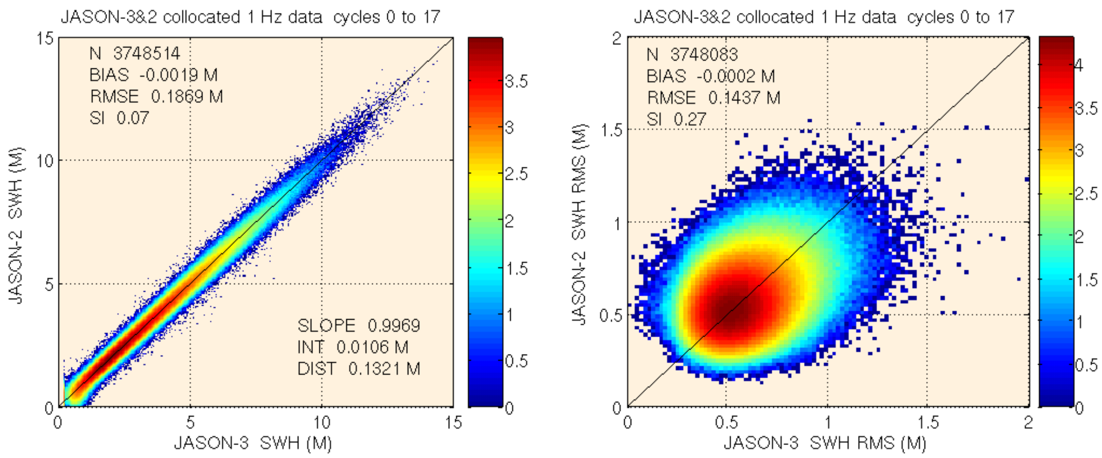

Figure 12. JASON-3 and JASON-2 1-Hz collocated SWH (left) and SWH RMS (right) (SWH RMS filtering applied). Extracted from Queffeulou [3].

9.2. Calibration of the NTC products

9.2.1. Cross-Calibration and Absolute Calibration

For the NTC products, the calibration was performed using the CCI v2.0 Jason-3 products which constitute a reference for climate applications. The data delivered by the CCI projet already include the absolute calibration with respect to in-situ buoys measurements. Therefore, the 'absolute calibration' step described above for the NRT products (see 9.1.2) does not need to be performed for the NTC products.

The CFOSAT crossover points with Jason-3 were computed on a 151-days period (from 2019/01/01 to 2019/06/01) due to the CCI v2 Jason-3 availability. We note that since the common period for the SWIM and J3 dataset used for the calibration covers less than 1-year, the correction applied has some limitations due to possible seasonal effects. It will be computed again as soon as the CCI time series will get longer.

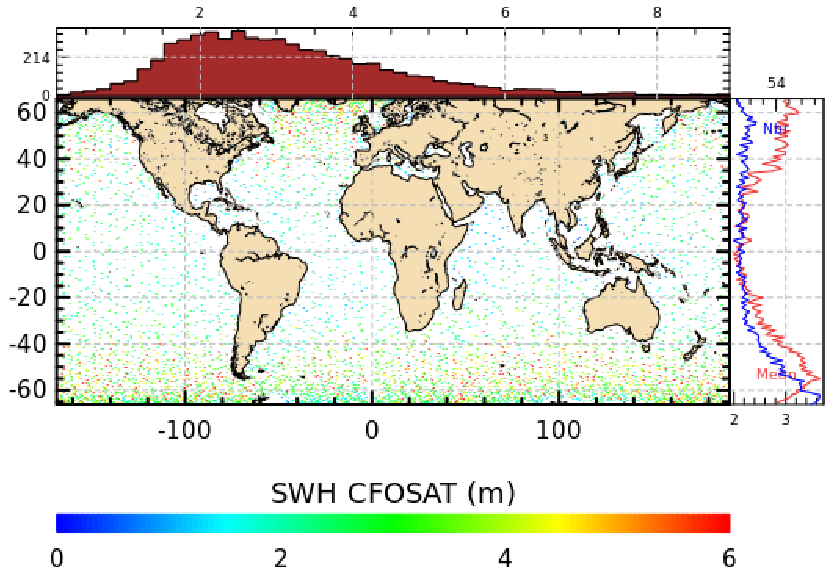

Figure 13. Spatial Distribution of CCI v2.0 Jason-3 and CFOSAT crossover points

The crossover method was performed with a time constraint of a 3-hour difference between the two satellites. The blue dots in Figure 12 (top) represent the median of the difference between CFOSAT and CCI v2.0 Jason-3 SWH values inside each 10 cm bin of the CFOSAT population.

A linear fit is performed to determine the bias as a function of the significant wave height. The selected fitting function is the one computed over [1 – 6 m] range (orange) as it samples most of the population.

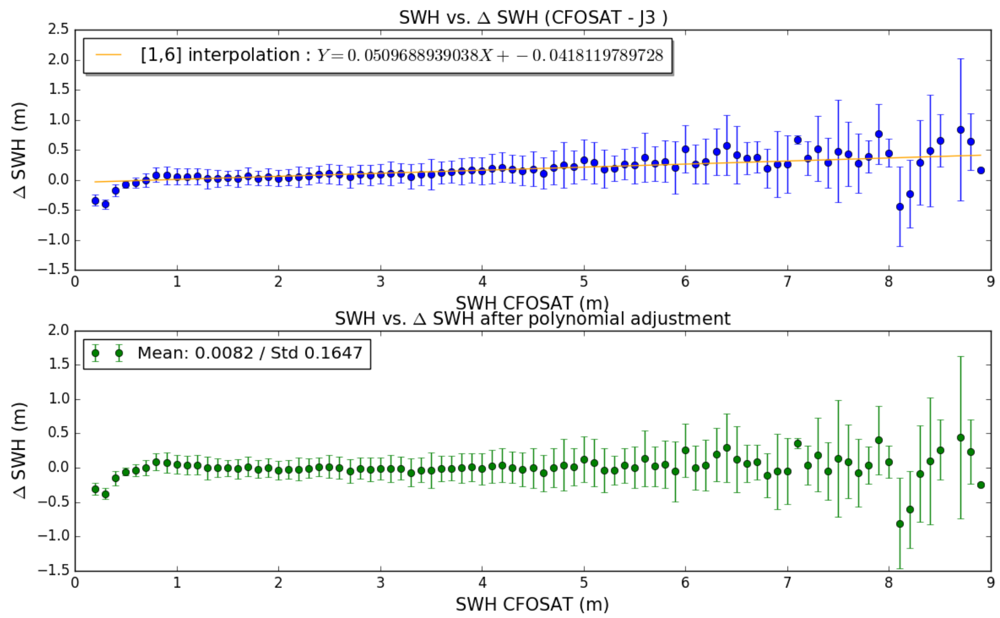

Figure 14. Top: Median if the differences between CFOSAT and CCI v2.0 J3 SWH values at crossovers points per 10-cm bin. Error bars represent the standard deviation of

the difference inside each bin. The orange curve represents the linear fit over the [1 - 6] meters range. Bottom: Residuals between the median and the fit.

The linear correction retrieved for cross-calibration between CFOSAT and the CCI v2.0 Jason-3 data is:

$$Corr(CFO\ /\ J3) = 0.05097\ H - 0.0418$$

Equation 3: Linear correction between CFOSAT and CCI v2.0 Jason-3 SWH