Along-track Level-2+ (L2P) Significant Wave Height (SWH) and Wind speed Sentinel-3&6 Product Handbook

Nomenclature: SALP-MU-S3_COP-OP-17127-CN

Issue: 3.0

Date: November 2022

Chronology Issues:			
Issue:	Date:	Validated by	Reason for change:
1.0	2018/11/05		Creation of the document
1.1	2019/02/19		Taking into account RID from NRT WAVE SRR
1.2	2020/10/16		Addition of L2P Wind speed in L2P WAVE products
1.3	2021/02/22		Precision concerning the S3 L2P Wind speed (Collard based on PLRM input)
1.4	2021/03/08		Taking into account RIDs from ORR (implementation of wind speed in L2P Wind/Wave products)
2.0	2021/05/10		Add of Sentinel-6A
2.1	2022/02/11		Taking into account RIDS on S6A from EUMETSAT
2.2	2022/04/05		Taking into account RIDS from L2P/L3 S6 ORR
3.0	2022/11/25		Using new wave calibration based on in-situ calibration between Jason-3 GdrF and buoyees

List of Acronyms:

ATBD	Algorithm Theoretical Baseline Document
ATP	Along Track Product
Aviso+	Archiving, Validation and Interpretation of Satellite Oceanographic data
CLS	Collecte, Localisation, Satellites
CMA	Centre Multimissions Altimetriques
Cnes	Centre National d'Etudes Spatiales
ECMWF	European Centre for Medium-range Weather Forecasting
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GDR	Geophysical Data Record(s)
GOT	Global Ocean Tides
IB	Inverse Barometer
IGDR	Interim Geophysical Data Record(s)
LRM	Low Resolution Mode
LWE	Large Wavelength Error
L2P	Level-2+ product: global 1 Hz along-track data over marine surfaces based on Level-2 products
MSS	Mean Sea Surface
MWR	Microwave Radiometer
Nasa	National Aeronautics and Space Administration
NRT	Near Real Time
NTC	Non Time Critical
OER	Orbit Error Reduction
OSDR	Operational Sensor Data Records
POE	Precise Orbit Ephemeris
RD	Reference Document
SAR	Synthetic Aperture Radar
Ssalto	Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise.
SLA	Sea Level Anomaly
SSB	Sea State Bias
SSH	Sea Surface Height
STC	Short Time Critical
TAI	IAT - International Atomic Time
T/P	Topex/Poseidon
UTC	Universal Time Coordinated

List of tables and figures

List of tables:

List of figures:

Applicable documents / reference documents

RD 1: Sentinel-3 Marine Altimetry L2P/L3 Service: Product Format Specification.
Reference: SALP-BC-S3_COP-OP-16778-CN

Bibliography

Abdalla, S., Ku-band radar altimeter surface wind speed algorithm, European Space Agency, (Special
Publication) ESA SP, 2007.

Charles E., Husson R., Mouche A., Ollivier A., Phillip A., Goimard G., Faugère Y., Dibarboure G., 2020. CMEMS WAVE-TAC, Recent upgrades and enrichment of the satellite constellation for near-real-time ocean waves characterization. OSTST meeting, October 2020, virtual. https://ostst.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/OSTST2020_WAVE-TAC.pdf

Collard, F., 2005, Algorithmes de vent et periode moyenne des vagues JASON a base de reseaux de neurons, BO-021-CLS-0407-RF, Boost Technologies, 33pp.

Dodet, G. and Piollé, J-F. (2022): Calibration of Level 2 Jason-3 GDR-F significant wave heights against in situ measurements. Technical Report (Ifremer).

Gourrion, J., D. Vandemark, S. Bailey, B. Chapron, G. P. Gommenginger, P. G. Challenor, and M. A. Srokosz, 2002. A two-parameter wind speed algorithm for Ku-Band altimeters, J. Atmos. and Oceanic Tech., 19, 2030-2048.

Sepulveda H. H., Queffeulou P. and Ardhuin F. (2015): Assessment of SARAL AltiKa wave height measurements relative to buoy, Jason-2 and Cryosat-2 data. Marine Geodesy, 38 (S1),449-465, doi: 10.1080/01490419.2014.1000470.

CMEMS Quality Information Document: WAVE Thematic Assembly Centre. WAVE_GLO_PHY_SWH_L3_NRT _014_001. Issue 3.3. https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-WAV-QUID-014-001.pdf

Queffeulou P. (2016): Validation of Jason-3 altimeter wave height measurements (poster). OSTST meeting, November 1-4, 2016, La Rochelle, France.

Queffeulou P. and Croizé-Fillon D. (2017): Global Altimeter SWH Data Set, version 11.4, February 2017. Technical report Ifremer. ftp://ftp.ifremer.fr/ifremer/cersat/products/swath/altimeters/waves/documentation/altimeter_wave_merge__11.4.pdf

Ray, C., C. Martin-Puig, M. P. Clarizia, G. Ruffini, S. Dinardo, C. Gommenginger, and J. Benveniste, 2015. SAR altimeter backscattered waveform model. IEEE Trans. Geosci. Rem. Sens, 53, 911-919.

(b) Ray, C., M. Roca, C. Martin-Puig, R. Escola, and A. Garcia, 2015. Amplitude and dilation compensation of the SAR altimeter backscattered power. IEEE Geosci. Rem. Sens, Lett. 12(12), 2473-2476.

Tolman et al. (2008): Altimeter wave data, Deep ocean and coastal use and issues. First Coastal Altimetry Workshop, Silver Spring, Maryland, USA, February 5-7, 2008.

http://cioss.coas.oregonstate.edu/CIOSS/workshops/Altimeter_workshop_08/Coastal_Alt_Presentations/18_Tolman_Sig_Wave_Ht.pdf

Contents

1. Introduction

The purpose of this document is to describe products generated by the 1Hz monomission along-track altimeter data processing segment for Sentinel-3A, Sentinel-3B and Sentinel-6A missions, named along-track L2P Significant Wave Height (SWH) and Wind Speed products.

The generation of Sentinel-3 products is part of the EUMETSAT Sentinel-3 Marine Altimetry L2P/L3 Service. The dissemination of those products is part of the Cnes AVISO-SALP (Service d'Altimétrie et Localisation Précise). The generation of Sentinel-6 products is part of the Jason-CS/Sentinel-6 Cooperation Agreement between CNES and EUMETSAT. Sentinel-6 products will be disseminated also by EUMETSAT.

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

2. Overview

2.1. ABC of the altimeter-derived SWH and wind speed measurements

The altimeter sends a spherical radar signal in the direction of the nadir. 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, i.e. the distance satellite-sea surface. The sea state surface elevation distribution impacts the speed at which the return signal is fully returned to the satellite. Hence, the Significant Wave Height (SWH) over ocean surfaces is determined from the slope of the front in the radar altimeter wave form. The higher the waves, the more the returned signal is spread in time. Hence, a long delay between the first returns and a full signal return will result in a long shadow in the wave form, which then indicates a high sea state (Figure 1 and Figure 2).

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

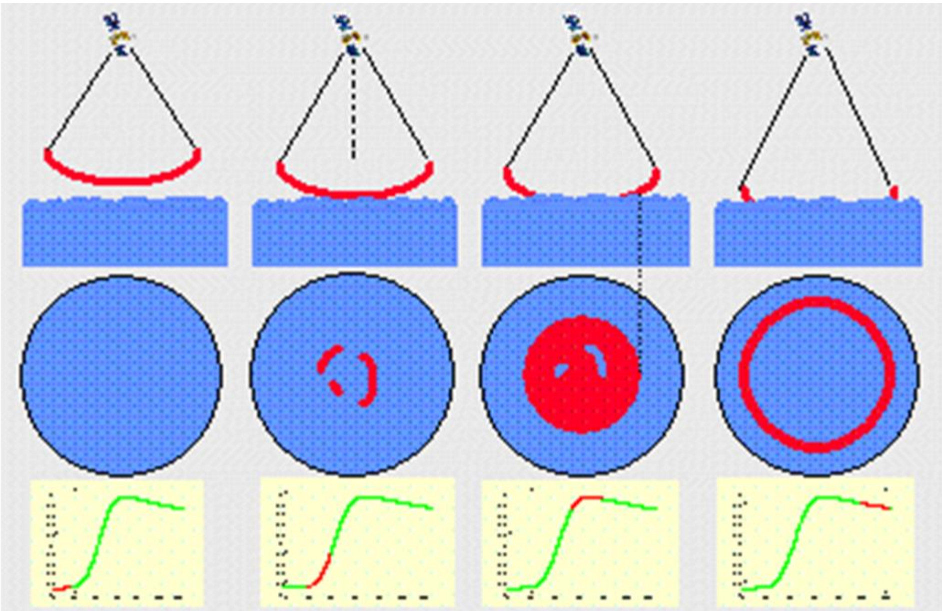


Figure 1: Formation of an echo over a sea surface with waves for conventional altimetry

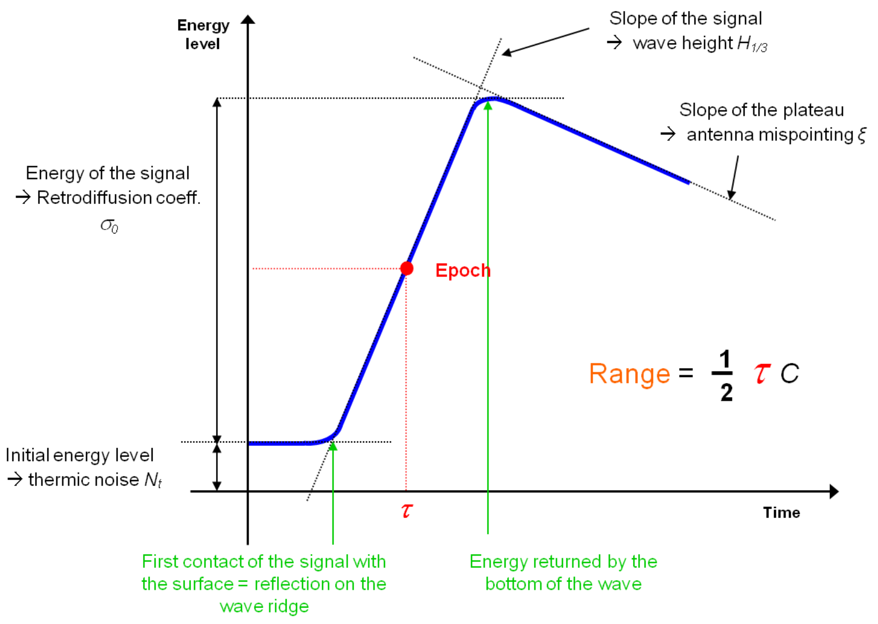


Figure 2: The altimeter waveform

Altimeter wind speeds (defined as the wind speed at a height of 10 m above the mean sea surface) are empirically retrieved by using either 1-parameter algorithm using only the backscattering coefficient (σ_0 in Figure 2) [Abdalla, 2007] or from 2-parameter algorithms using both σ0 and SWH parameters (such as Gourrion et al.[2002] or Collard [2005]).

2.2. Operating modes

In the Sentinel-3 SRAL and Sentinel-6 missions, there are two main modes of operation:

- High Resolution Mode, also known as Synthetic Aperture Radar mode (SAR)
- Low Resolution Mode (LRM)

The Sentinel-3 SRAL missions will normally be operated at High Resolution Mode (commonly called SAR mode). Low Resolution Mode (LRM) will be a back-up mode only.

The Sentinel-6A mission produces SAR and LRM products at the same time. F**or Sentinel-6A L2P/L3 Wave/wind products are based only on LRM data.**

SAR mode is designed to achieve high along-track resolution over relatively flat surfaces. This property can be exploited to increase the number of independent measurements over a given area and is a prerequisite for sea-ice thickness measurements, coastal waters, ice sheet margins, land and inland waters. The scientific justification of High Resolution Mode 100% coverage over the Earth is also applicable to open ocean surfaces because studies have shown that the best performance of this mode is over open ocean surfaces where topography is homogeneous (areas at least as large as the antenna footprint).

The detailed information can be found in Sentinel-3 User Handbook:

- Sentinel-3 SRAL Marine User Handbook (EUM/OPS-SEN3/MAN/17/920901)

The Jason-CS/Sentinel-6A User handbook is available in the confluence page.

Note that compared to LRM (on current altimetry missions such as SARAL/AltiKa, Envisat, Jason-1/2/3, ERS-1/2), the antenna footprint is reduced with the SAR technology and the noise on the measurement is reduced.

For altimeters operating in SAR mode, both the leading edge and the trailing edge of the waveform are affected by changes in SWH, with the SAMOSA 2.5 model using both these parts of the waveform to determine the SWH value (Ray and al. 2015, Ray and al. 2015b).

When functioning in SAR mode, Sentinel-3 Pseudo Low Resolution Mod (PLRM) estimates can be derived too. This allows to consider the backscattered radar signal in a circular footprint as in conventional altimetry (rather than within stripes in SAR mode). PLRM estimates are not provided in the L2P/L3 products, except for the L2P wind speed which is computed with PLRM backscattering coefficient and PLRM significant wave height.

2.3. Orbits, Passes and Repeat cycle

'Orbit' is one revolution around the Earth by the satellite.

A satellite **'Pass' or 'Track'** is half a revolution of the Earth by the satellite from one extreme latitude to the opposite extreme latitude. Passes with odd numbers correspond to ascending orbits, from minimum to maximum latitude; passes with even numbers correspond to descending orbits, from maximum to minimum latitude.

'Repeat Cycle' is the time period that elapses until the satellite flies over the same location again. Every "pass file" of a given cycle (identified by its track number) flies over the same path as the pass file of every other cycle in the same repeat-cycle phase, and covers oceans basins continuously.

For Sentinel-3A and Sentinel-3B:

- the inclination is 98.65 deg;
- the passes are numbered from 1 to 770 representing a full repeat cycle ground track for the repetitive orbit;
- the repeat cycle is 27 days.

For Jason-CS/Sentinel-6A:

- the inclination is 66 deg;
- the passes are numbered from 1 to 254 representing a full repeat cycle ground track for the repetitive orbit;
- the repeat cycle is almost 10 days.

2.4. Production center description for the version covered by this document

The system's primary objective is to provide operational products of calibrated wind speed and calibrated significant wave height (SWH) data for Sentinel-3A, Sentinel-3B and Sentinel-6A missions. The processing sequence can be divided into 4 main steps, illustrated in Figure 3 and described in the next Sub-sections:

- Acquisition;
- Data editing;
- Calibration;

- Product generation.

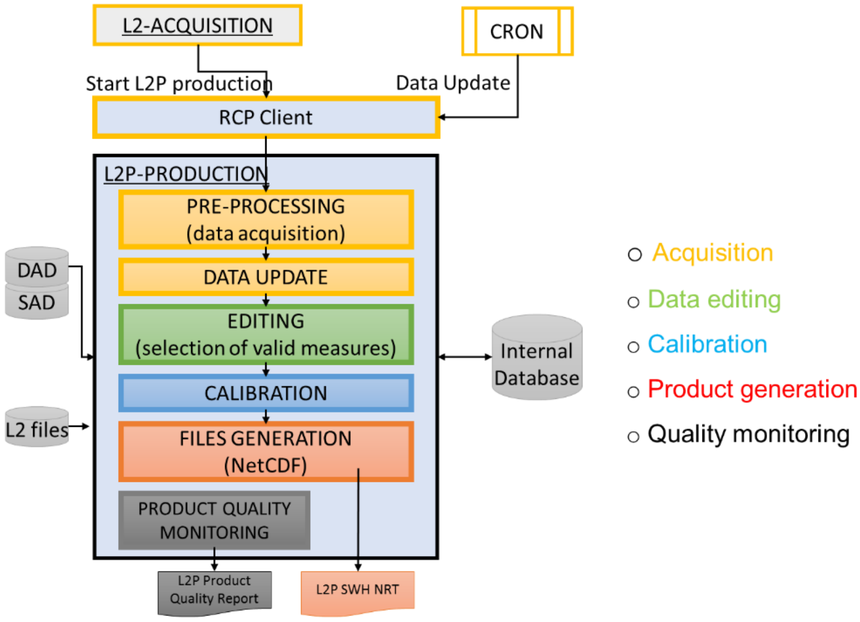


Figure 3: L2P Alti wind and waves production component

2.4.1. Acquisition

The altimeter measurements used in the system consist in Near-Real-Time (OGDR or NRT) Level 2 products from different missions. The Jason-3 mission is also taken into account as a cross calibration is performed between Jason-3 and Sentinel-3A, Jason-3 and Sentinel-3B and Jason-3 and Sentinel-6A. The data sources and delays are summarised in Table 1. Mission characteristics are presented in Table 2.

Mission	Type of product	Source	Availability delay
Sentinel-3A	NRT	EUMETSAT	~3h
Sentinel-3B	NRT	EUMETSAT	~3h
Sentinel-6A	NRT	EUMETSAT/CNES	~3h
Jason-3	OGDR	EUMETSAT/NOAA	~3h

Table 1: Source, delay and period of availability of the L2 altimeter data

Mission	Cycle duration (days)	Latitude range (°N/S)	Number of tracks per cycle	Inter-track distance at equator (km)	Sun-synchronous	Technology
Sentinel-3A	27	±81.5	770	~100	Yes	SAR + PLRM
Sentinel-3B	27	±81.5	770	~100	Yes	SAR + PLRM
Sentinel-6A	10	±66	254	~315	No	LRM + SAR
Jason-3	10	±66	254	~315	No	LRM

Table 2: Altimeter mission characteristics (for Sentinel-3 : SAR is used for wave and PLRM is used for wind speed, for Sentinel-6 : only LRM is used)

The acquisition processing has two main functions: acquisition and synchronization of dataflow as illustrated in Figure 4.

File acquisition

The purpose of the acquisition is to acquire new L2 files and new ancillary data (AUX files) needed to compute the products (orbit file, external corrections, etc.) for each data source.

Data synchronization

The synchronization function is synchronizing L2 data with all ancillary data (AUX files) needed to process L2P Wave data. Once the L2 data and all the associated ancillary data are available, they can be used for L2P production.

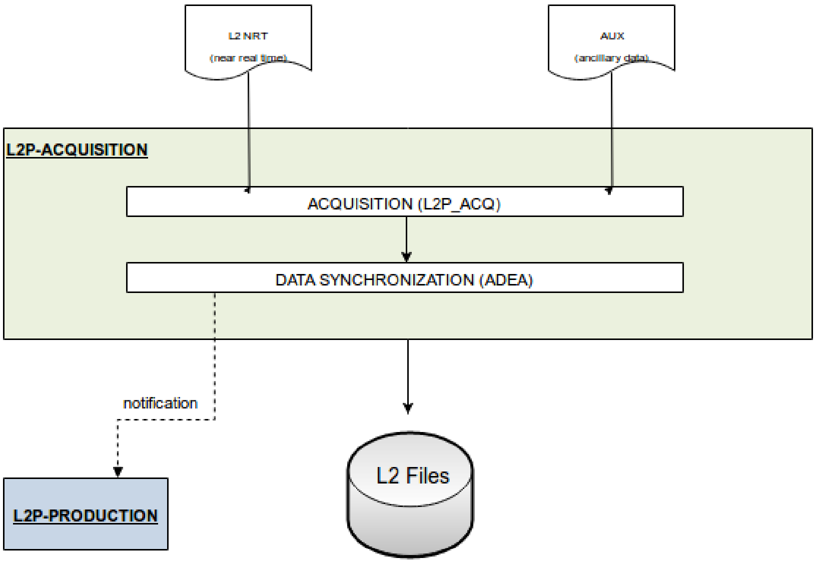


Figure 4: L2 acquisition processing

2.4.2. Data editing

2.4.2.1. Editing criteria

Quality Control on the input L2 data is a critical process applied to guarantee that the system uses only the most reliable altimeter data. The system is supplied with L2 products that contain data directly derived from altimeter measurements (e.g. range, sigma0, swh etc.) as well as geophysical data (e.g. dry and wet tropospheric correction, ionospheric correction, etc) and flags (e.g. surface type, ice presence, etc.). These values are provided at high (20 Hz for Jason-3, Sentinel-3A & B and Sentinel-6A) and low (1 Hz) frequency. Only the 1 Hz data are used in the L2P altimetry wind/wave system.

Data are selected as valid or invalid using a combination of various criteria such as quality flags and parameter thresholds (see Table 3: Editing criteria below for details). These criteria are adapted from the ones used for the Sea Level Anomaly (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

and wind speed estimation and therefore are not used in the wind/wave products generation. Consequently, no editing criterion was set for these parameters in the L2P wind/wave chain. For Sentinel-3A and Sentinel-3B, the criteria on the off-nadir angle is not activated since this value is not derived from the retracking in SAR mode and therefore its value does not provide information about

Parameter	Method	Jason-3	Sentinel-6A	Sentinel-3A &B	S3 Wind Speed/ SWH editings
Ice Flag	Flag value	Valid value: 0	Valid value: 0 or 5	Valid value: 0 or 5	Same for both
Surface type Flag	Flag value	Valid value: 0 or 1 (Caspian Sea only)	Valid value: 0 or 1 (Caspian Sea only)	Valid value: 0 or 1 (Caspian Sea only)	Same for both
Swh [m]	Threshold	Min: 0 max: 30	Min: 0 Max: 30	Min: 0 Max: 30	WS: PLRM SWH: SAR
Sigma0 [dB]	Threshold	Min: 9.38 max: 32.38	Min: 5 Max: 28	Min: 5 Max: 28	WS: PLRM SWH: SAR
Square off-nadir angle	Threshold	Min: -0.2 max: 0.64	N/A	N/A	Same for both
Wind speed [m/s]	Threshold	Min: 0 Max: 30	Min: 0 Max: 30	Min: 0 Max: 30	WS: Collard PLRM SWH: Abdalla SAR
Orbit - range [m]	Threshold	Min: -130 Max: 100	Min: -130 Max: 100	Min: -130 Max: 100	Same for both
Sigma0 standard deviation [dB]	Threshold	Min: 0 Max: if distance to shoreline <50 km: 2.5 else: 1	Min: 0 Max: 0.7	Min: 0 Max: 0.7	WS: PLRM SWH: SAR
Range standard deviation [m]	Threshold	Min: 0 Max: 0.0115*swh+0.2	Min: 0 Max: 0.006 * swh + 0.05	Min: 0 Max: 0.02*swh+0.12	WS: SWH PLRM SWH: SWH SAR
swh_numval_ku	Threshold	Min: 10	Min: 18	Min: 18	WS: PLRM SWH: SAR
swh_RMS_ku	Threshold	Min: 0 Max: Threshold(swh) as detailed below	Min: 0 Max: Threshold(swh) as detailed below	Min: 0 Max: Threshold(swh) as detailed below	WS: SAR SWH: SAR

data quality. Two separate editings are performed for wind speed and SWH. Specifications are mandated in the last column of the Table 3: Editing criteria.

Table 3: Editing criteria

The method to compute the threshold on swh_RMS_ku is described in Queffeulou 2016. It consists in determining a threshold on the 20Hz SWH standard dispersion. Such threshold is defined as the sum of the mean value and three times the standard deviation of the gaussian fitting the ln(SWH_STD) (e-base logarithm) distribution for each SWH bin (Figure 5). The curve representing the thresholds as a function of SWH is then filtered (red line in Figure 6). 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). This threshold depends on SWH and potentially on the processing baseline. It is recomputed when processing baseline evolutions impact the swh estimates.

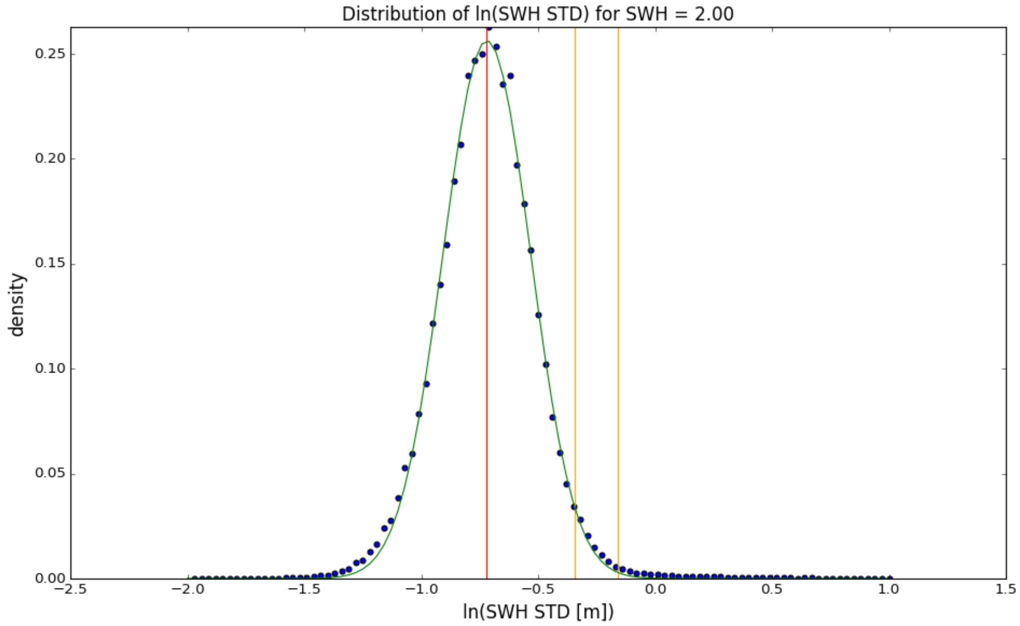


Figure 5: Distribution of ln(SWH_STD) for SWH between 2m and 2.1m (Jason-3 between 2017 july 11th and 2018 september 10th). The green line represents the gaussian fitting the distribution. The red line is the fitting gaussian mean, the orange lines represent mean + 2sigma and mean + 3 sigma.

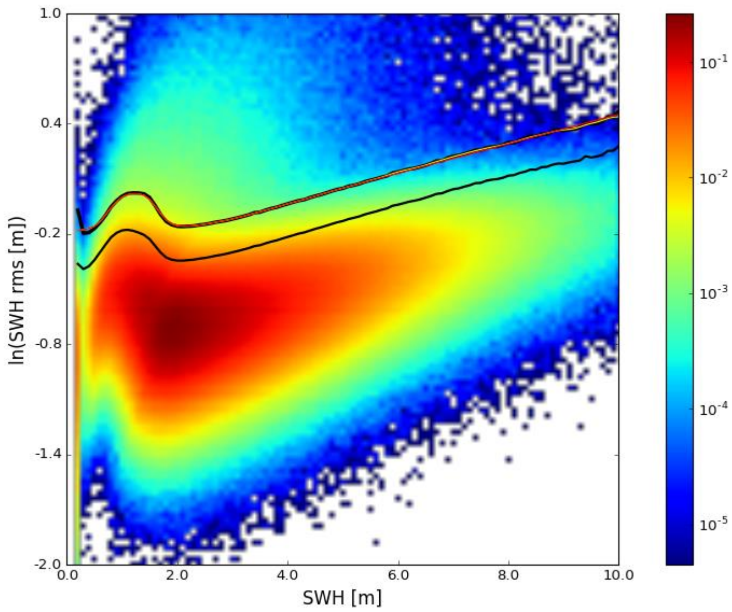


Figure 6: Density plot of SWH / ln(SWH_STD). The colour scales logarithmically. The black lines represent the mean+2sigma and mean +3sigma, computed for each swh bin as described in Figure 5. The red line represents the smoothed mean+3sigma curve for SWH<5m and consists in an affine function at higher SWH values.

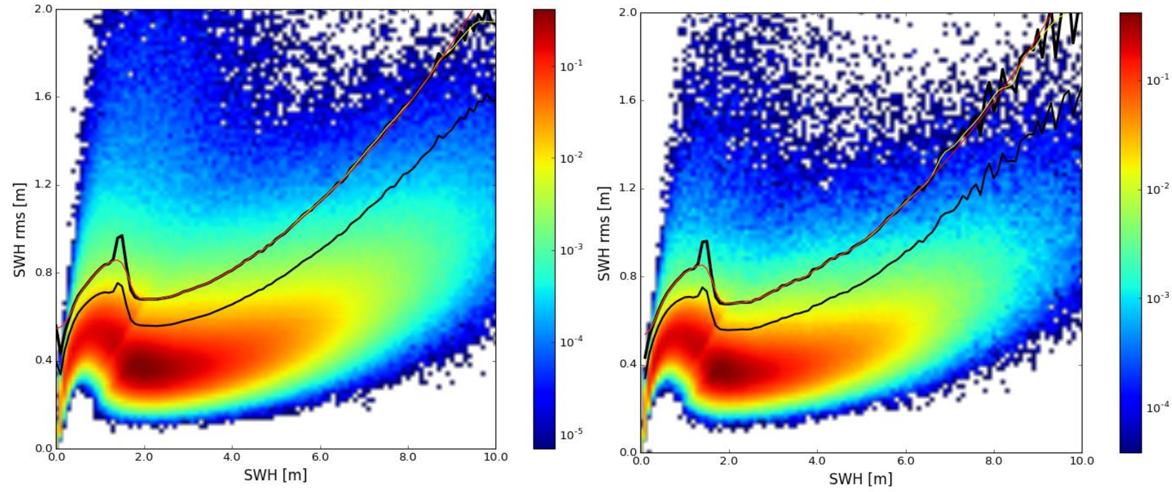


Figure 7: Density plots and computed thresholds. Left: S3A (2018 january 1st to 2018 november 6th to only account for data derived from L2 Baseline Collection 003 processing), Right: S3B (28 days of data between 2018 july 19th and 2018 october 1st). Density scales logarithmically.

2.4.3. Wind speed computation

Currently, Sentinel-3 wind speed estimations in L2 products are computed with the 1D Abdalla's model [Abdalla, 2007] following the Envisat strategy whereas all missions in the Jason series (from Jason-1 to Jason-CS/Sentinel-6) use the 2D Collard's model [Collard, 2005; Gourrion et al, 2002]. As reported by Tolman in his 2008 presentation [Tolman et al, 2008], the 2D model version better reduces the wave field impact in the altimeter retrieved wind speed (see Figure 8 which copied his slide) than the 1D version. For the Sentinel-3 L2P product, the wind speed estimations are updated to be in-line with Sentinel-6 choice.

Therefore, the L2P wind speed estimations come now from the Collard's model using PLRM input. Details are provided in appendix.

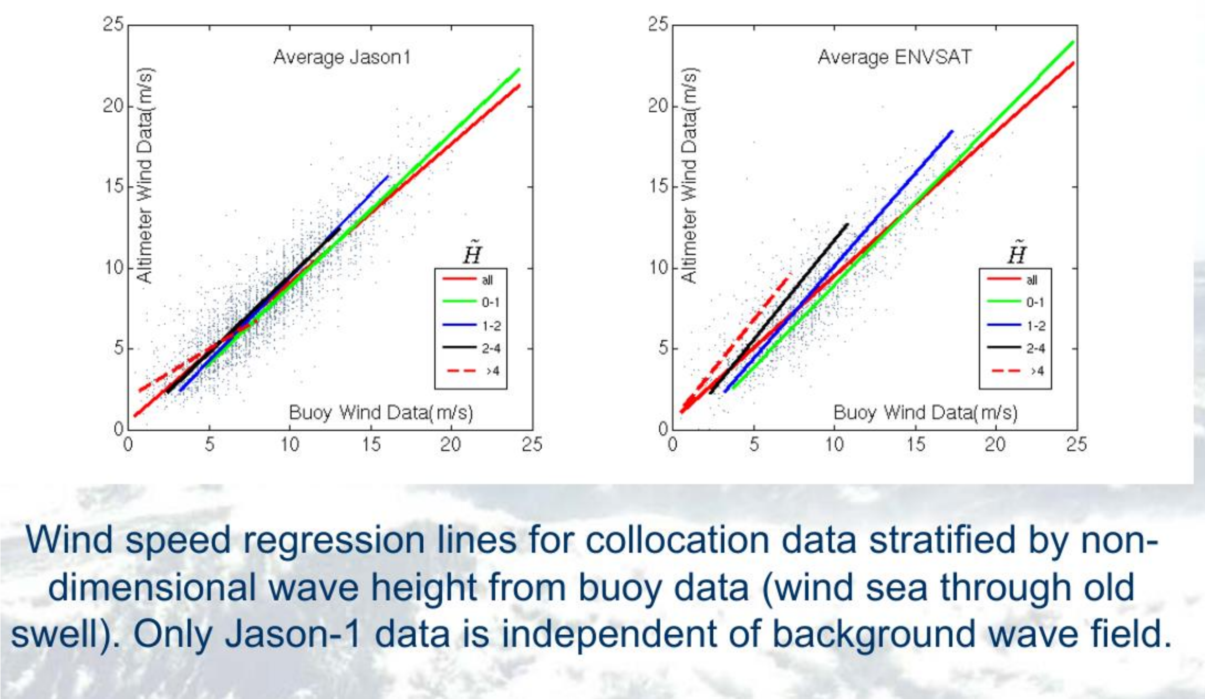


Figure 8: From Tolman et al, 2008.

2.4.4. SWH and wind speed Calibration

Calibration is divided in two main steps (see Figure 9): absolute calibration of the reference mission on in-situ data and cross-calibration of the secondary missions on the reference mission.

The first step consists of applying a correction computed between the reference mission and in-situ measurements provided by buoys. This step is done only for wave variable.

The second step consists in homogenising the data from the different missions. Significant wave height and wind speed measurements of every single mission are calibrated on those of a reference mission

Finally, another calibration step can be added in the process when L2 upstream products evolve for a mission already implemented in the L2P altimetry wave chain (see Figure 9, L2 version upgrade in yellow). A new calibration for the physical variables of interest is determined between the current and the upcoming L2 version and is added to the existing calibration of this mission in the L2P altimetry wave chain.

The next sub-sections describe the computation of the two main calibrations: absolute calibration and cross-calibration.

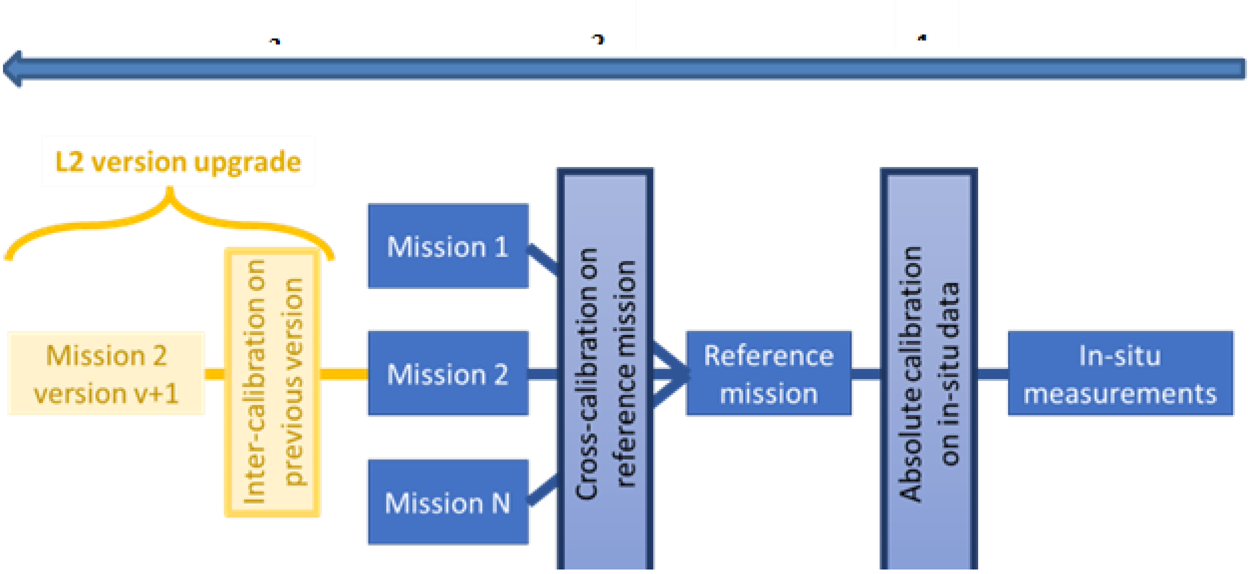


Figure 9: Description of the calibration process

2.4.4.1. Absolute calibration

The absolute calibration aims at correcting the biases between in-situ measurements and satellite altimetry. For the L2P wave/wind products version 3, a new absolute calibration was computed. It is computed using 4 years of homogeneous data from the reference mission (in this case Jason-3). Therefore, the absolute calibration is computed from the comparison of the reference mission significant wave heights to buoy measurements at collocated points. This look-up table is than applied in the operational system for significant wave height L2 data in order to obtain the L2P significant wave height for the reference mission. This absolute calibration is not performed for wind speed variable.

2.4.4.2. Cross-calibration

Cross-calibration consists in determining the relation between the significant wave height or wind speed 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 (which in the case of the significant wave height is already calibrated in the in-situ data). 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 and wind speed measurements.

Two different methods of collocation can be considered, depending on the orbit of the mission to be calibrated with respect to the orbit of the reference mission.

The first one is applied during the “tandem phase”, if it exists, between two missions: both satellites are on the same orbit separated by a few minutes. A very large number of spatially collocated measurements are therefore available for cross-calibration.

The second method is employed when the two missions are on different orbits or no validation phase is available. Crossover points between the two orbits are determined. In order to have sufficient cross-over point and cover different situations, a long period, ideally 1 year of homogeneous data is necessary. For SWH measurements calibration, only crossover points with a time difference lower 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 1 Hz along track data for each mission is then interpolated at the selected crossover points. The interpolation technique consists in spline approximation and accounts for the average noise associated with SWH measurements (12 cm rms for Jason-3 and 9 cm rms for Sentinel-3A, Sentinel-3B and Sentinel-6A. Such values correspond to the uncertainty on the 1 Hz significant wave height values computed from the high frequency values (20 Hz).

Once the two missions' measurements are collocated, the differences between the reference mission and the secondary mission significant wave heights are computed. The bias is plotted as a function of the secondary mission wave height in order 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 wind and waves processing chain.

Details on the calibration relations are provided in appendix.

3. Product Presentation

3.1. Temporal availability

Mission	Begin date	End date	Characteristics
NRT Sentinel-3A	21-02-2019	Ongoing	27-day cycles
NRT Sentinel-3B	21-02-2019	Ongoing	27-day cycles
NRT Sentinel-6A	06-04-2022	Ongoing	10-day cycles

Table 4. Temporal availability of LP2 Sentinel products.

3.2. Nomenclature

This is the generic model of L2P S3A and S3B filename is:

global_swh_l2p_<data_type>_<mission>_<cycle>_<pass>_<begin_date>_ <end_date>_<production_date>.nc

This is the generic model of L2P S6A filename is:

global_swh_l2p_<data_type>_<mission>_<mode>_<cycle>_<pass>_<begin_date>_ <end_date>_<production_date>.nc

The L2P products name components are:

- The type of data (nrt): <data_type>
- The mission (s3a/s3b/s6a): <mission>
- The data record mode (lr:LRM mode, hr: SAR mode): only for S6A products
- The cycle/pass considered: <cycle>_<pass>
- The begin and end dates of the data: <begin_date>_<end_date>
- The production date: <production_date>

This is two filenames example:

global_swh_l2p_nrt_s3a_C0036_P0664_20181010T035011_20181010T035634_20181010T120644.nc

global_swh_l2p_nrt_s6a_lr_C0014_P0085_20210329T211556_20210329T213023_20210511T155435.nc

4. Data Format

This chapter presents the data storage format and convention used for S3 and S6 L2P Wind and Waves 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:

http://www.unidata.ucar.edu/packages/netcdf/index.html.

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 (http://www.unidata.ucar.edu/software/netcdf):

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

4.1. L2P Wave Product Format

4.1.1. Dimensions

1 Dimension is defined:

- **time:** number of data in current file, sampled at 1Hz.

4.1.2. Data Handling Variables

You will find hereafter the definitions of the variables defined in the product:

Name of variable	Type	Content	Unit
time	double	Time of measurements	seconds since 2000-01-01 00:00:00 UTC
latitude	int	Latitude value of measurements	degrees_north
longitude	int	Longitude value of measurements	degrees_east
swh	short	Significant Wave Hight	meters
validation_flag	byte	Flag indicating if Significant Wave Height is valid (validation_flag=0) or not (validation_flag=1)	none
applied_bias	short	Significant Wave Height bias correction on main altimeter frequency band	meters
wind_speed	short	L2P wind speed	meters per second
applied_change_on_wind_speed	int	Difference between L2 and L2P wind speed	meters per second
validation_flag_wind	byte	Flag indicating if wind speed is valid (validation_flag=0) or not (validation_flag=1)	none
sigma0	short	backscattering coefficient used for wind speed computation	dB

Table 5. Overview of data handling variables in L2P Wind/Wave NetCDF file.

The mapping between variables of L2 products and variables of L2P products is available in Table 6.

4.1.2.1. 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.

4.1.2.2. Example of L2P Wave/Wind file

```
netcdf
global_swh_l2p_nrt_s3a_C0069_P0357_20210308T091139_20210308T095834_20210308T133121 {
dimensions:
        time = 2642 ;
variables:
        double time(time) ;
                time:long_name = "time (sec. since 2000-01-01)" ;
                time:standard_name = "time" ;
                time:units = "seconds since 2000-01-01 00:00:00.0" ;
                time:calendar = "gregorian" ;
                time:axis = "T" ;
        int latitude(time) ;
                latitude:scale_factor = 1.e-06 ;
                latitude:valid_min = -90000000 ;
                latitude:comments = "Positive latitude is North latitude, negative latitude is South
latitude." ;
                latitude:long_name = "latitude" ;
                latitude:standard_name = "latitude" ;
                latitude:units = "degrees_north" ;
                latitude:valid_max = 90000000 ;
        int longitude(time) ;
                longitude:scale_factor = 1.e-06 ;
                longitude:valid_min = 0 ;
                longitude:comments = "East longitude relative to Greenwich meridian" ;
                longitude:long_name = "longitude" ;
                longitude:standard_name = "longitude" ;
                longitude:units = "degrees_east" ;
                longitude:valid_max = 360000000 ;
        short swh(time) ;
                swh:_FillValue = -32767s ;
                swh:quality_flag = "validation_flag" ;
                swh:comment = "Bias corrected. Calibration relative to buoys [Sepulveda et al, 2015].
Initial L2 swh values can be recomputed using swh + applied_bias." ;
                swh:scale_factor = 0.001 ;
                swh:valid_min = 0s ;
                swh:coordinates = "longitude latitude" ;
                swh:long_name = "Significant Wave Height on main altimeter frequency band" ;
                swh:standard_name = "sea_surface_wave_significant_height" ;
                swh:units = "m" ;
                swh:valid_max = 32767s ;
        short applied_bias(time) ;
                applied_bias:_FillValue = -32767s ;
                applied_bias:comment = "bias correction for calibration relative to the reference
mission and buoys [Sepulveda et al, 2015]. 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 on main altimeter
frequency band" ;
                applied_bias:valid_min = -30000s ;
                applied_bias:units = "m" ;
                applied_bias:valid_max = 30000s ;
        short wind_speed(time) ;
                wind_speed:_FillValue = -32767s ;
```

```
		wind_speed:quality_flag = "validation_flag_wind" ;
		wind_speed:comment = "L2P wind speed." ;
		wind_speed:scale_factor = 0.001 ;
		wind_speed:valid_min = 0s ;
		wind_speed:coordinates = "longitude latitude" ;
		wind_speed:long_name = "Equivalent 10-m wind speed derived from altimeter measurements" ;
		wind_speed:standard_name = "wind_speed" ;
		wind_speed:units = "m s-1" ;
		wind_speed:valid_max = 32767s ;
	byte validation_flag(time) ;
		validation_flag:_FillValue = -127b ;
		validation_flag:flag_meanings = "valid_data_over_ocean rejected_data" ;
		validation_flag:long_name = "validation flag" ;
		validation_flag:coordinates = "longitude latitude" ;
		validation_flag:flag_values = 0b, 1b ;
	byte validation_flag_wind(time) ;
		validation_flag_wind:_FillValue = -127b ;
		validation_flag_wind:flag_meanings = "valid_data_over_ocean rejected_data" ;
		validation_flag_wind:long_name = "validation flag wind" ;
		validation_flag_wind:coordinates = "longitude latitude" ;
		validation_flag_wind:flag_values = 0b, 1b ;
	short sigma0(time) ;
		sigma0:_FillValue = -32767s ;
		sigma0:comment = "backscatter coefficient used for wind speed computation." ;
		sigma0:scale_factor = 0.01 ;
		sigma0:valid_min = 0s ;
		sigma0:coordinates = "longitude latitude" ;
		sigma0:long_name = "backscatter coefficient" ;
		sigma0:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
		sigma0:units = "dB" ;
		sigma0:valid_max = 32767s ;
	int applied_change_on_wind_speed(time) ;
		applied_change_on_wind_speed:_FillValue = -2147483647 ;
		applied_change_on_wind_speed:comment = "Initial L2 wind speed values can be recomputed using wind_speed + applied_change_on_wind_speed." ;
		applied_change_on_wind_speed:scale_factor = 0.001 ;
		applied_change_on_wind_speed:coordinates = "longitude latitude" ;
		applied_change_on_wind_speed:long_name = "Difference between L2 and L2P wind speed" ;
		applied_change_on_wind_speed:valid_min = -30000 ;
		applied_change_on_wind_speed:units = "m s-1" ;
		applied_change_on_wind_speed:valid_max = 30000 ;

// global attributes:
		:Conventions = "CF-1.6" ;
		:cycle_number = 69 ;
		:pass_number = 357 ;
		:absolute_pass_number = 52717 ;
		:first_meas_time = "2021-03-08 09:11:39" ;
		:last_meas_time = "2021-03-08 09:58:34" ;
		:comment = "Significant Wave Height and Wind Speed measured by altimetry" ;
		:creator_email = "aviso@altimetry.fr" ;
		:cdm_data_type = "swath" ;
		:references = "https://aviso.altimetry.fr" ;
		:platform = "Sentinel-3A" ;
		:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
```

```
                :keywords = "Oceans > Ocean Topography > Significant Wave Height, Oceans > Ocean Winds > Surface Winds" ;
                :institution = "CLS, CNES, EUMETSAT" ;
                :creator_name = "AVISO" ;
                :license = "https://www.aviso.altimetry.fr/fileadmin/documents/data/License_Aviso.pdf" ;
                :title = "NRT Sentinel-3A Global Ocean Along track significant wave height and wind speed L2P product" ;
                :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v37" ;
                :project = "EUMETSAT Sentinel-3 L2P/L3 marine altimetry service" ;
                :keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
                :contact = "aviso@altimetry.fr" ;
                :source = "Sentinel-3A measurements" ;
                :based_on = "Sentinel-3A NRT" ;
                :creator_url = "https://aviso.altimetry.fr" ;
                :processing_level = "L2P" ;
                :equator_time = "2021-03-08T09:33:22.174000" ;
                :equator_longitude = 186.7 ;
                :creation_date = "2021-03-08T13:31:21" ;
                :product_version = "2_0" ;
                :software_version = "L2PRT_SWH: 3.6.2; OCTANT: 13.3.0-20200605" ;
                :applied_bias_on_L2_sigma0 = "2.85" ;
}
```

4.2. Mapping between L2 and L2P variables

Hereafter the mapping between variables of L2 and L2P products is listed (in the case that L2P product contain the same content as L2 products):

Name of L2P variable	Name of L2 variable in S3/S6 products	Comment
time	time_01 / data_01/time	
latitude	lat_01 / data_01/latitude	
longitude	lon_01 / data_01/longitude	
swh	N/A	Note that in the L2P the provided swh value is based on L2 variable swh_ocean_01_ku , but calibrated on buoys
validation_flag	N/A	
applied_bias	N/A	Adding this value to swh allows recovering the original L2 swh value
wind_speed	N/A	The L2P wind speed is recomputed using the Gourrion algorithm with the Collard table with PLRM Sigma0 (+ bias) and SWH input. It is than cross-calibrated on the reference mission wind speed.
applied_change_on_wind_speed	N/A	Difference between L2 (wind_speed_alt_01_ku) and L2P wind speed
validation_flag_wind	N/A	

sigma0	N/A	Backscattering coefficient used for the wind speed computation. It corresponds to L2 (sig0_ocean_01_plrm_ku), but with a bias applied (value specified in global attribute of netcdf product)

Table 6. Mapping between variables in L2 and L2P files

5. Products accessibility

The Sentinel-3A & B and Sentinel-6A L2P products are available via **authenticated** servers as soon as end-user dissemination is allowed by mission authorities.

- On authenticated **Aviso+ FTP (online products)**:
    - You first need to register via the Aviso+ web portal and sign the License Agreement: http://www.aviso.altimetry.fr/en/en/data/data-access/registration-form.html. and select the product **"Wave Along-track Level-2+ (L2P) Sentinel-3"**

  The 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/no_cache/en/my-aviso-plus.html

- On the authenticated **Aviso+ CNES Data Center (archived products)**:

  Register and download on https://aviso-data-center.cnes.fr/

Sentinel-3 and Sentinel-6 products are also available in EUMETCAST and Sentinel-6 products also in the Data Centre.

Citation:

Please refer to the licence agreement to mention credits explicitly in function of your use (section 13. Licence specific to Sentinel-3 L2P products).

6. News, updates and reprocessing

6.1. Operational news

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

http://www.aviso.altimetry.fr/en/data/operational-news/index.html.

6.2. Updates and reprocessing

Since product_version 3_0 (installed on 29/11/2022) the L2P Wave/Wind products use a new absolute calibration between the reference mission (J3) and in-situ data.

Since product_version 2_0 (08/04/2021) the L2P Wave products became L2P Wave/Wind products and also contain the L2P wind variable.

Information about updates and reprocessing are described in

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

7. Contacts

For more information, please contact:

Aviso+ User Services
CLS
11 rue Hermès
Parc Technologique du canal
F-31520 Ramonville Cedex
France
Tél: (+33) (0) 561 394 780
Fax: (+33) (0) 561 393 782
E-mail: aviso@altimetry.fr
On Internet: https://www.aviso.altimetry.fr/

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

The EUMETSAT User Service Helpdesk is available:
During normal working hours, Monday to Thursday 08:30–17:15 CET, Friday 08:30–16:00 CET.

Tel: +49 6151 807 3660/3770
Fax: +49 6151 807 3790

Email ops@eumetsat.int

8. Appendix

8.1. SWH Calibration information

8.1.1. Absolute calibration

Till L2P Wave/wind product_version 2_0, the absolute calibration of the reference mission on the in-situ (buoy measurements) was given by a linear correction [Queffeulou and Croizé-Fillon 2017]:

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

Equation 1: Linear correction for absolute calibration of Jason-2 SWH with respect to buoy measurements

This absolute calibration was computed from the comparison of Jason-2 significant wave heights to qualified NOAA NDBC buoy measurements at collocated points from 2008 to 2011. Besides, Queffeulou [2016] showed a remarkable agreement between the Jason-3 and Jason-2 1 Hz SWH during the commissioning phase. Therefore, according to these results, the linear correction computed for Jason-2 was applied to Jason-3 SWH to compensate for systematic errors. All the secondary missions were then cross-calibrated onto calibrated Jason-3. More recently, validation studies of NRT WAVE-TAC products (which use L2P Wave/wind products as input) with regards to in-situ measurements mainly located around US European coasts [Charles et al. 2020] showed a systematic positive bias comprised between 7 and 11 cm for the different missions.

For L2P wave/wind products with product_version 3_0 a new absolute calibration (Dodet and Piollé, 2022) was used in order to reduce the systematic bias. At least 4 years of stable measurements are required to obtain a sufficient number of collocations between satellite tracks and in-situ platforms. Therefore, the calibration was computed based on qualified Jason-3 GDR-F measurements from 2016 to 2021. Invalid values were edited, following the same processing as the operational L2P chain. The collocation and calibration table were computed by IFREMER following the same method as for the CCI+ Sea State version 2&3 datasets, in particular for the choice and qualification of in-situ measurements and the method of calculation of the correction.

The new absolute calibration takes the form of a look-up table. This enables the calibration to account for non-linearities in the comparison between the in situ and the altimetric data. The procedure involved binning the in situ-altimeter differences in overlapping bins, and for each the median value of the differences was taken. For SWH values between 1.5 m and 6 m a linear regression was calculated, which was extrapolated to SWHs higher than 6 m. Note that below 0.3m the number of matchups was too low to get a robust estimate of the median. Dodet and Piollé recommend therefore to not use the data below 0.3m. (For more information on the calibration, see Dodet and Piollé [2022]).

Figure 10 shows the old linear absolute calibration [Queffeulou and Croizé-Fillon 2017] used for L2P Wave/wind product_version 2_0 in orange and the new absolute calibration [Dodet and Piollé 2022] used for the L2P Wave/wind product_version 3_0 in blue.

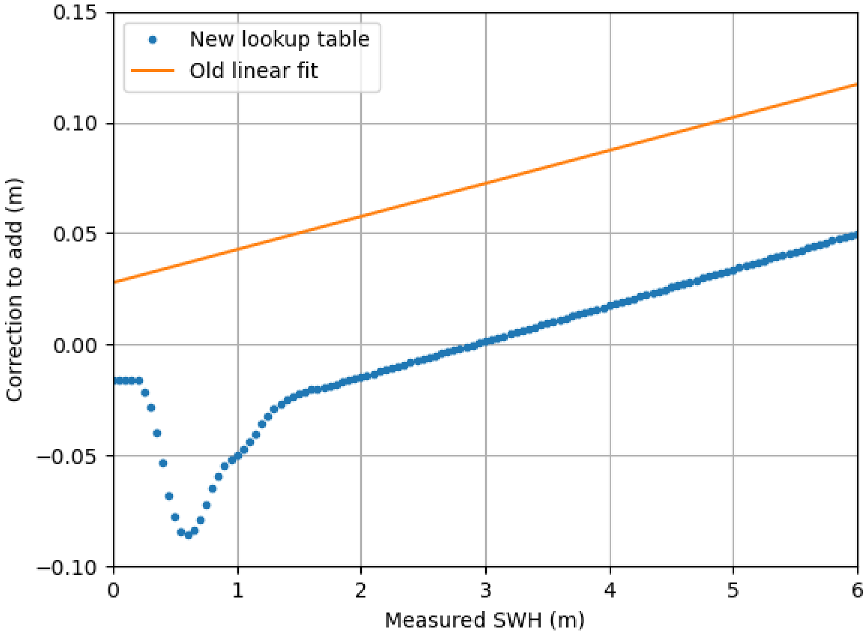


Figure 10: Graphical illustration of the new lookup table for Jason-3 (blue), with the old linear fit originally calculated for Jason-2 for comparison. For SWHs above 6 m the correction is a linear extrapolation. The corrections are added to the measured SWH.

8.1.2. Intercalibration between secondary missions and reference mission

8.1.2.1. Sentinel-3A SAR BC005 cross-calibration with Jason-3 L2P SWH

Sentinel-3A crossover points with Jason-3 were computed for the S3 L2 BC005 version over a 4 month period (July 8th 2022 to November 7th 2022). The starting date corresponds to the first entire day of BC005 version data. Only crossover point with time lag less than 3 hours are computed. Figure 11 presents the spatial distribution of the valid crossover points after editing. The number of points is larger at higher latitudes in the southern hemisphere, allowing sampling higher waves associated with extra-tropical storms.

The representativeness of the crossover points with respect to the ensemble of valid along-track points is checked by comparing the Sentinel-3A SWH distribution for the two ensembles of points (Figure 12). The distribution at the crossover points is skewed towards larger SWH values due to the larger density of crossover points at high latitudes where the mean SWH is larger than in the inter-tropical band. Despite these distribution differences, crossover points sample all range of significant wave height values from 0.5 to 6 m.

A linear fit between Sentinel-3A L2 SWH and Jason-3 L2P SWH at crossover points was computed over the range [1.5 - 6m]. As there are very few crossover points after 8m, the value for 8 m is applied for SWH larger than 8m.

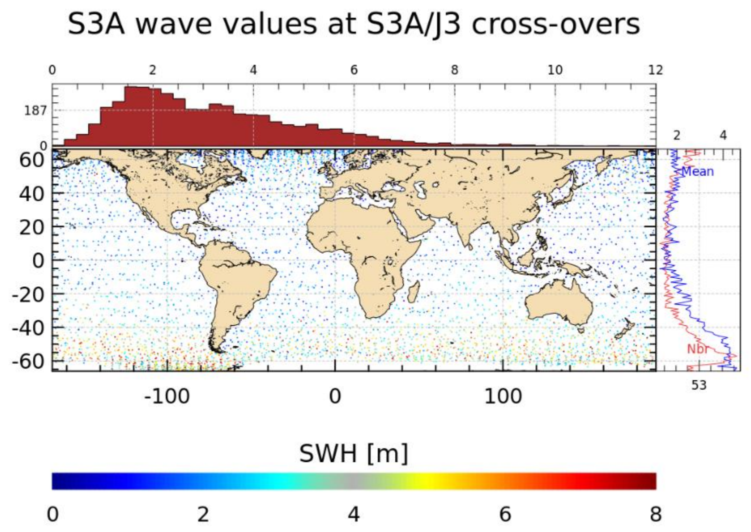


Figure 11: Spatial distribution of Sentine-3A and Jason-3 crossover points. Only valid points after editing are displayed. Top: histogram of the selected points. Right: Number of points and mean SWH valid values as a function of latitude.

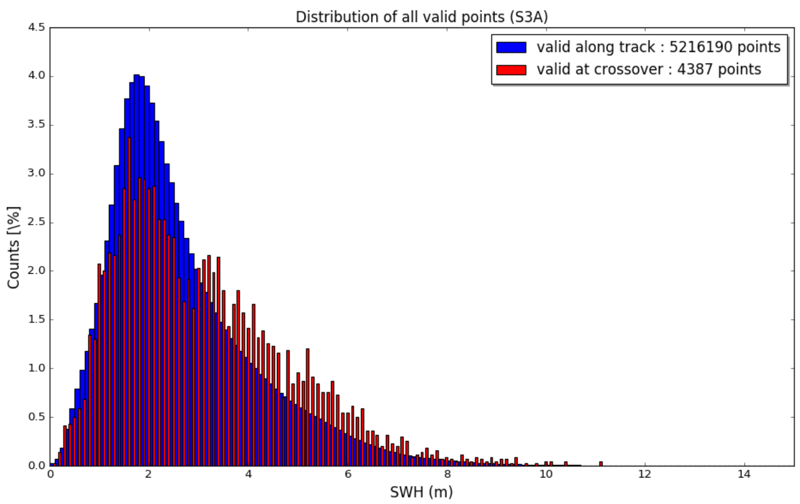


Figure 12: Valid Sentinel-3A points distribution over the cross-calibration period with Jason-3.

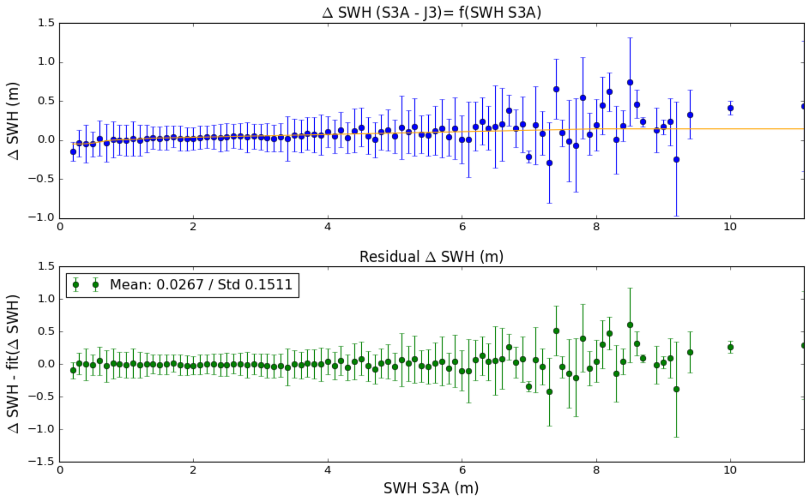


Figure 13: Median of the difference between S3-A SAR BC005 and Jason-3 L2P SWH values per 10 cm bin. Error bars represent the standard deviation of the difference inside each bin. The orange curve represents the linear fit. Bottom: Residuals between the median and the fit. The mean bias is of the order of 3 cm.

8.1.2.2. Sentinel-3B SAR BC005 cross-calibration with Jason-3 L2P SWH

Sentinel-3B crossover points with Jason-3 were computed for the S3 L2 BC005 version over a 4 month period (July 8th 2022 to November 7th 2022). The starting date corresponds to the first entire day of BC005 version data. Only crossover point with time lag less than 3 hours are computed. Figure 14 presents the spatial distribution of the valid crossover points after editing. The number of points is larger at higher latitudes in the southern hemisphere, allowing sampling higher waves associated with extra-tropical storms.

The representativeness of the crossover points with respect to the ensemble of valid along-track points is checked by comparing the Sentinel-3B SWH distribution for the two ensembles of points (Figure 15). The distribution at the crossover points is skewed towards larger SWH values due to the larger density of crossover points at high latitudes where the mean SWH is larger than in the inter-tropical band. Despite these distribution differences, crossover points sample all range of significant wave height values from 0.5 to 6 m.

A linear fit between Sentinel-3B L2 SWH and Jason-3 L2P SWH at crossover points was computed over the range [1.5 - 6m]. As there are very few crossover points after 8m, the value for 8 m is applied for SWH larger than 8m.

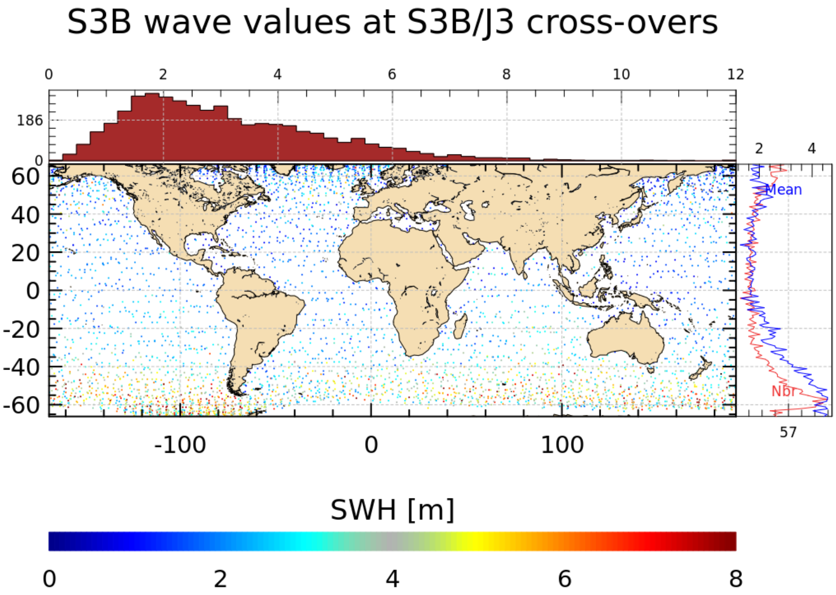


Figure 14: Spatial distribution of Sentine-3B and Jason-3 crossover points. Only valid points after editing are displayed. Top: histogram of the selected points. Right: Number of points and mean SWH valid values as a function of latitude.

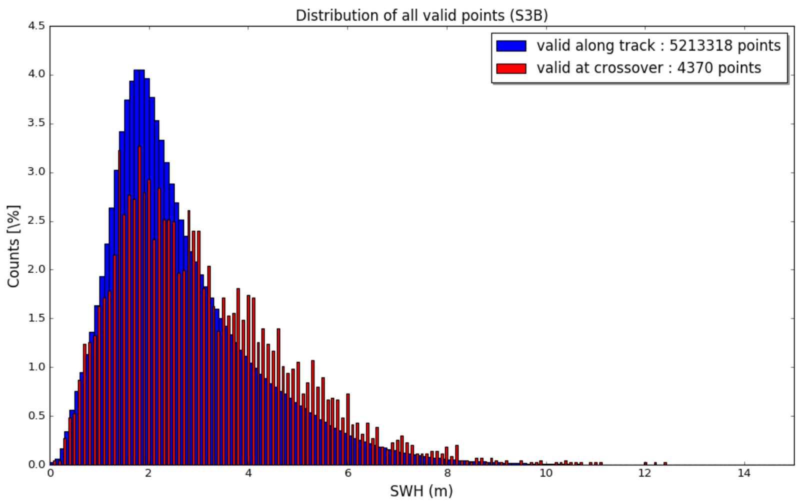


Figure 15: Valid Sentinel-3B points distribution over the cross-calibration period with Jason-3.

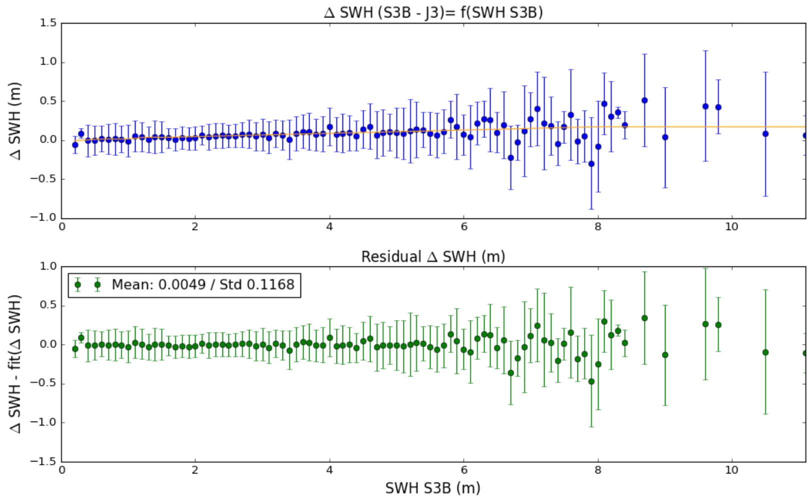


Figure 16: Median of the difference between S3-B SAR BC005 and Jason-3 L2P SWH values per 10 cm bin. Error bars represent the standard deviation of the difference inside each bin. The orange curve represents the linear fit. Bottom: Residuals between the median and the fit. The mean bias is of the order of 0.5 cm.

8.1.2.3. Sentinel-6A LRM cross-calibration with Jason-3 L2P SWH

A comparison between Sentinel-6A and Jason 3 significant wave heights and wind speed was performed over the tandem phase of the two satellites.
The significant wave height differences between Sentinel-6A and Jason 3 are represented as a function of Sentinel-6A swh values in Figure 17 : SWH difference as a function of S6A SWH values. The red curve represents the fitting formula. The residual mean swh difference between S6 and JA3 is arround 2cm.. Note that, the number of small and high waves is small and the comparison between both mission was not enough representative to build a reliable relationship. Also, we choose to use a constant fit at small waves and a linear fit at high waves.

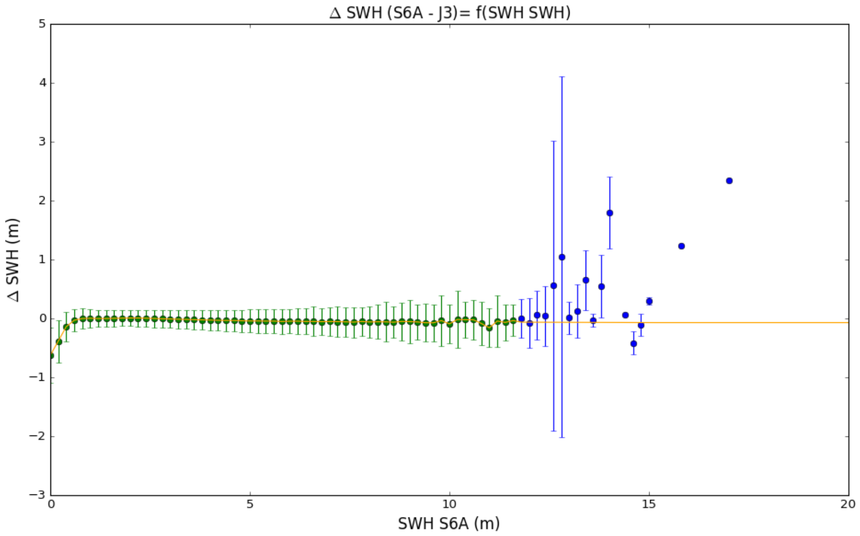


Figure 17 : SWH difference as a function of S6A SWH values. The red curve represents the fitting formula. The residual mean swh difference between S6 and JA3 is arround 2cm.

8.1.3. Validation of SWH Inter/Calibration

Note that for CMEMS need, L2P Wave/Wind data were regenerated from January 2020 onwards using the new absolute calibration (Dodet and Piollé 2022) and intercalibration (product_version 3_0). These products will be also made available on the archive **Aviso+ CNES Data Center.**

To validate the inter-calibration of the missions on the Jason-3 L2P SWH (which is already calibrated on the in-situ data using (Dodet and Piollé 2022), several analyses are done.

Figure 18 shows the median of binned SWH (top for L2 SWH, bottom for L2P SWH) in function of ERA5 SWH. ERA5 SWH is only used as a common comparison for all the missions. The binned L2 SWH shows different inclinations for each mission while L2P SWH shows a good agreement between each mission.

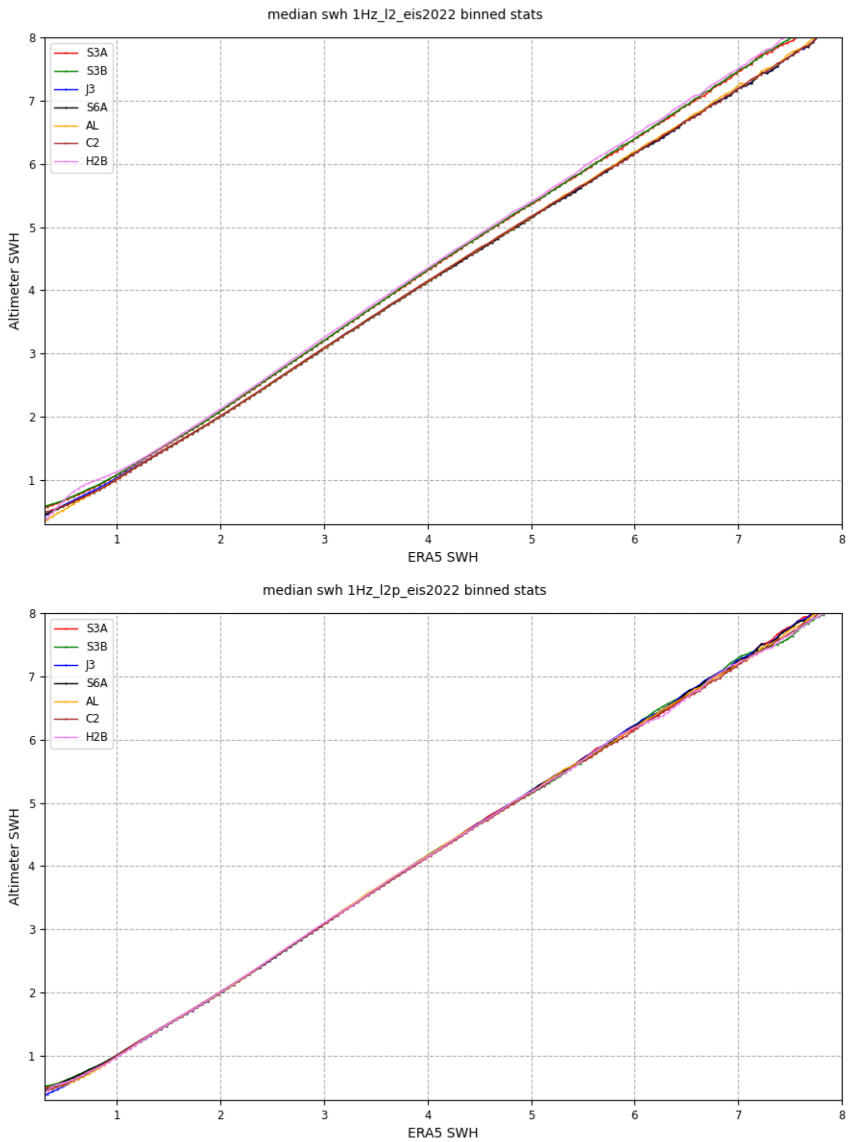


Figure 18: SWH binned of each mission compared to ERA5 model for L2 (top) dataset and L2P calibrated (bottom) dataset. There is a better correlation between ERA5 and all satellite over SWH after L2P calibration. Waves under 0.3m are not shown as the population is too small to be representative of the median.

Figure **19** shows how L2P calibration reduce significantly the differences between each mission (some from more than 10 cm to less than 2 cm) as a mean over the globe with **the** **same global weighted mean method as for** GMSL **is used to have a homogeneous geographical data repartition to compare all mission together.** **This method shows improvements of intermission homogeneity not** only over cross track points**.**

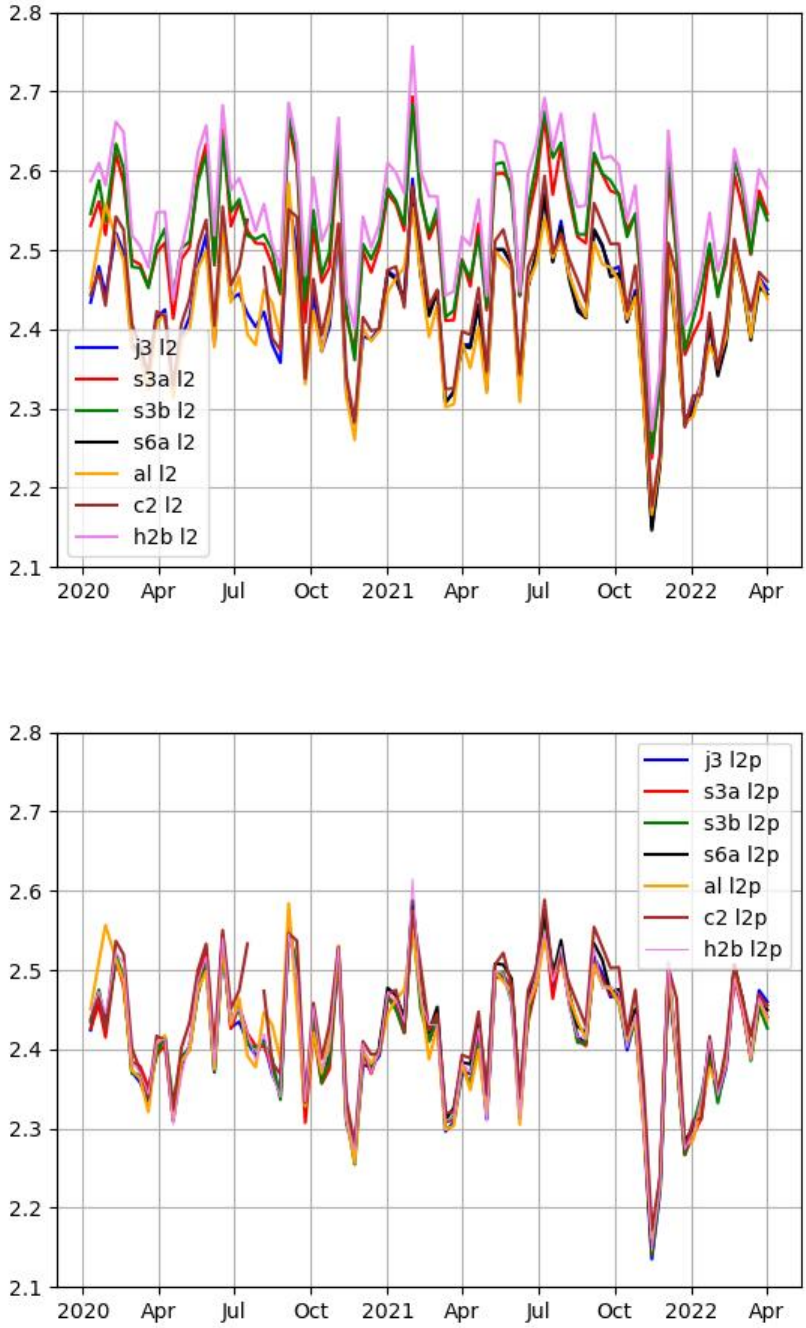


Figure 19: SWH 10 day global weighted mean (m) for L2 (top) dataset and L2P calibrated (bottom) dataset for each mission. The same global weighted mean method as for GMSL is used to have a homogeneous geographical data repartition to compare all mission together.

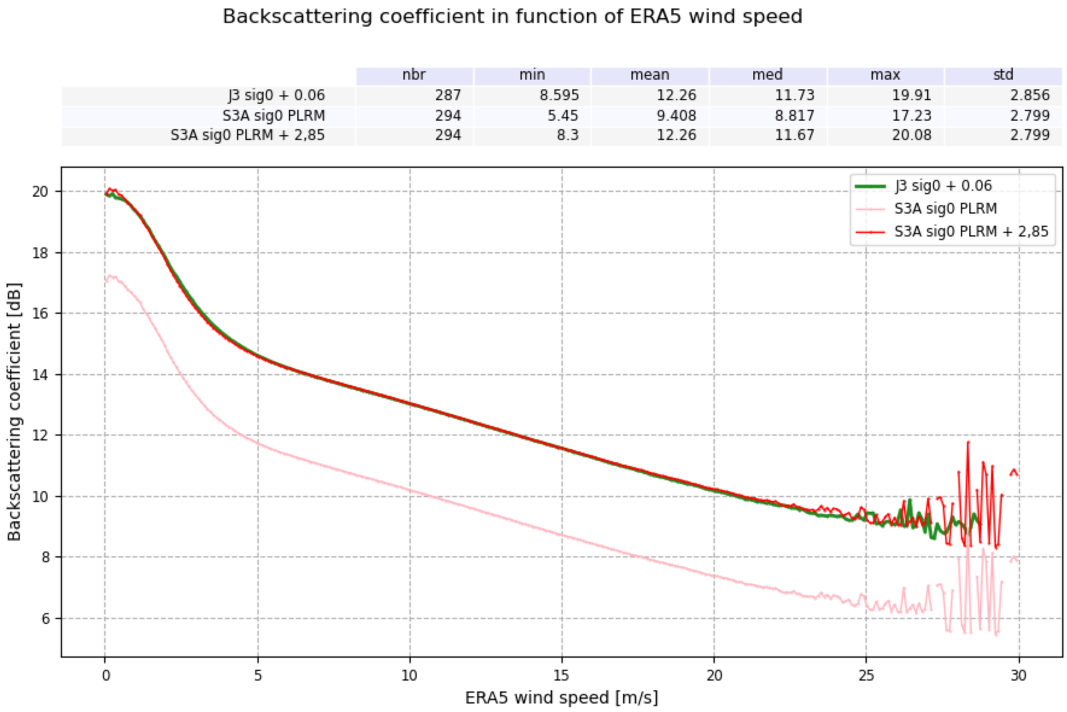
To verify the performance of the new calibration, an independent data set (buoys) was needed. See QUID on CMEMS site for more information.

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

8.2. L2P wind speed information

8.2.1. Computing two-parameter wind speed (Gourion algorithm with Collard table)

In order to apply the Collard's model (which was developed from Jason-1 data based on collocations with QuikSCAT scatterometer data) to data from other altimeter missions, a simple approach consisting in the application of a bias shift on backscattering coefficient looks efficient. This approach is already used in Jason-3 ground segment to generate the GDR-F products (a bias of 0.06 dB is applied to nominal Ku-band (MLE4) backscattering coefficient before wind speed calculation). Figure 20 shows the backscattering coefficient of Sentinel-3A (PLRM data) and Jason-3 as a function of ERA5 wind speed, used as an external data source to better evaluate the needed sigma0 bias. The use of the ERA-5 reference allows the determination of a global bias between the data from the two missions. One year of data (mid 2016 to mid 2017) was used for this analysis with Sentinel-3A data from Baseline Collection 004 reprocessing and Jason-3 GDR-F data (nominal and shifted curves are shown). Applying a bias of 2.85 dB to S3A PLRM backscattering coefficient shows that the sigma0 curve as a function of ERA5 wind speed becomes very close to the Jason-3 GDR-F one (except for high backscattering coefficients values which are quite noisy for Sentinel-3A).



	nbr	min	mean	med	max	std
J3 sig0 + 0.06	287	8.595	12.26	11.73	19.91	2.856
S3A sig0 PLRM	294	5.45	9.408	8.817	17.23	2.799
S3A sig0 PLRM + 2,85	294	8.3	12.26	11.67	20.08	2.799

Figure 20: Backscattering coefficient in function of ERA5 wind speed for S3A L2 PLRM sigma0 (light pink), S3A PLRM sigma0 with 2.85dB bias applied (red), and Jason-3 L2 GdrF sigma0 with 0.06 dB bias applied (as it is done in Jason-3 ground segment prior wind speed computation). Only valid backscattering coefficient data are used.

Currently a one-year period common between Jason-3 Gdr-F and Sentinel-3B Baseline Collection 004 is not yet available, as the operational switch to Jason-3 Gdr-F standard took place end of October 2020, the reprocessing of Jason-3 in standard Gdr-F has just started and Sentinel-3B starts after the study year available of Jason-3 in standard F (mid-2016 mid-2017).

Therefore the sigma0 distribution of Sentinel-3B was fitted over Sentinel-3A (+ sigma0 Sentinel-3A bias: 2.85 dB) distribution which is already fitted on Jason-3 F sigma0 distribution (Figure 21). This gives a bias of 2.80 to be applied on Sentinel-3B PLRM sigma0 before Collard wind speed computation.

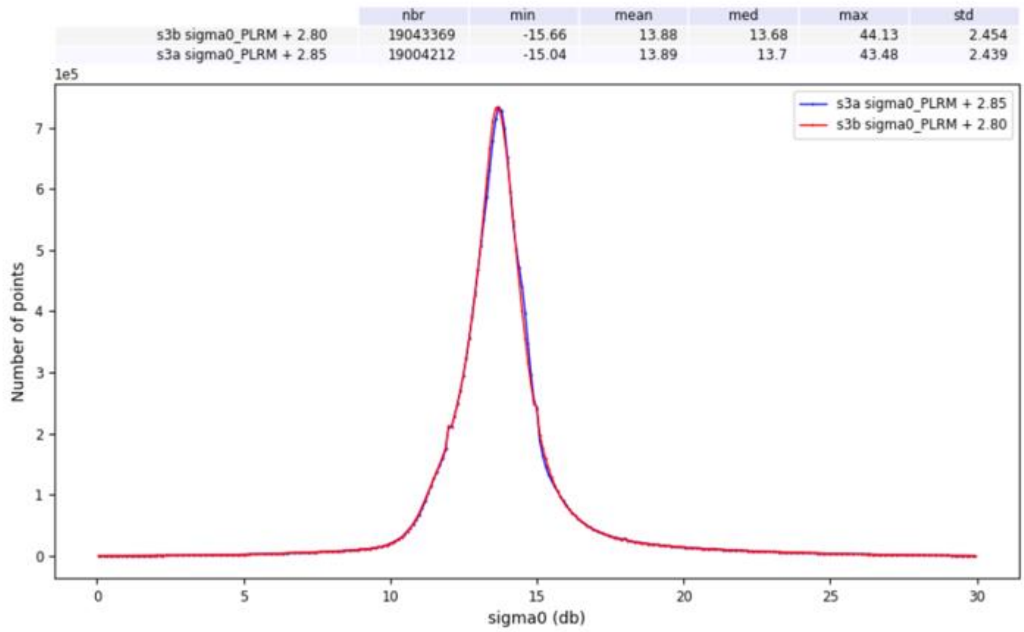


Figure 21: Sigma0 distribution of S3A (+ 2.85 dB) (blue line) and S3B (+2.80 dB) (red line) over the period mid-2018 mid-2019.

When using the Collard wind speed (left side of Figure 22) the wind speed is much more independent of significant wave height classes than when using the wind speed from L2 products (right side of Figure 22).

As seen in Figure 22 (left panel), the use of the Collard's model helps to reduce significantly the SWH impact on S3A retrieved wind speed estimations when one compares with the plot based on L2 products (right panel of Figure 22). The SWH dependency cannot be totally removed because the

Collard's model was fitting based on MLE3 retracked data. The Samosa retracking does not display exactly the same correlations between sigma0 and SWH than one looks at MLE3 data.

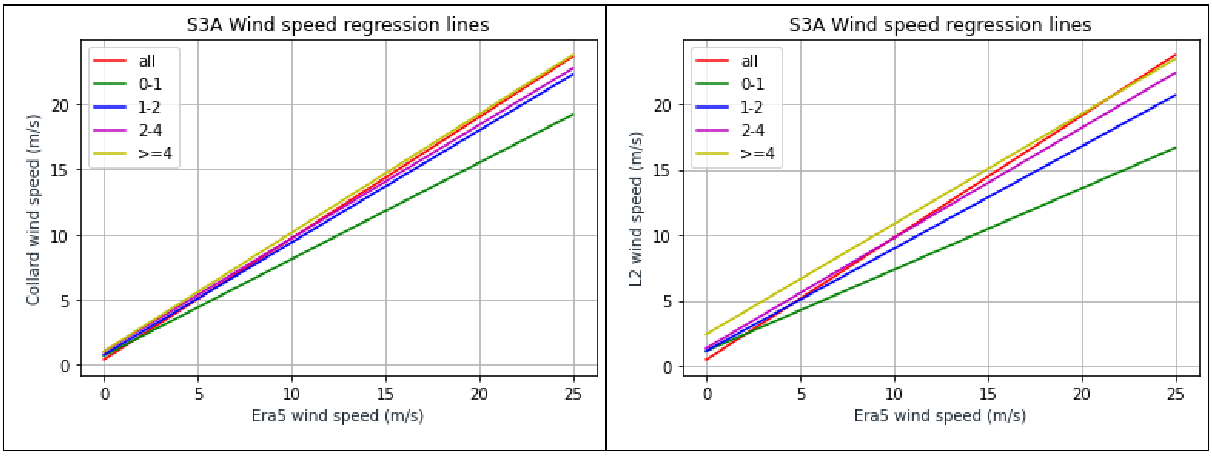


Figure 22: Sentinel-3A altimeter wind speed regression lines in function of ERA wind speed for several significant wave height classes (all classes (red), 0 to 1 m (green), 1 to 2 m (blue), 2 to 4 m (lilac), higher than 4 m (yellow). Left: using Collard wind speed. Right: using L2 (Abdalla) wind speed.

Wind speed Collard used on L2P products is based on sigma0 PLRM (+2.85 dB for S3A and 2.80 dB for S3B) and SWH PLRM data instead of SAR data for several reasons:

- Show better agreements with blended wind speed reference and reduce regional bias
- No correlation with satellite radial velocity
- Impact of both SWH and swell on SAR SWH estimations along with a waveform centering dependency

8.2.2. Intercalibration on reference mission

8.2.2.1. Sentinel-3A

Wind speed abacus is computed for S3A Collard wind speed based on PLRM data (Baseline Collection 004) over the period mid-2016 and mid-2017 based on the section 2.4.4.2. This period has been chosen for wind speed calibration calculation because we need one year in common between J3F and the last baseline of S3A. S3A wind speed calibration abacus is based on J3 F standard. Results of the calibration is show in the Figure 23. Wind speed mean difference at crossover before calibration is about 0.1 m/s between J3F and S3A during the period mid-2016 and mid-2017 (Figure 23 top). Abacus is created using interpolation spline from bin 0 to 18 m/s and linear interpolation is used for bin superior to 18 m/s. In addition, we can say that mean value at crossover between J3F and S3A are really close during this period, which results to small bias correction in abacus (about 0.07 m/s in average). Residual values are show in Figure 23 (bottom) and correspond to the mean wind speed crossover between J3F and S3A after calibration. Residual values are small and about 0.04m/s in average over the period mid-2016 mid-2017. However, we can notice that residual has got higher value for extreme wind speed.

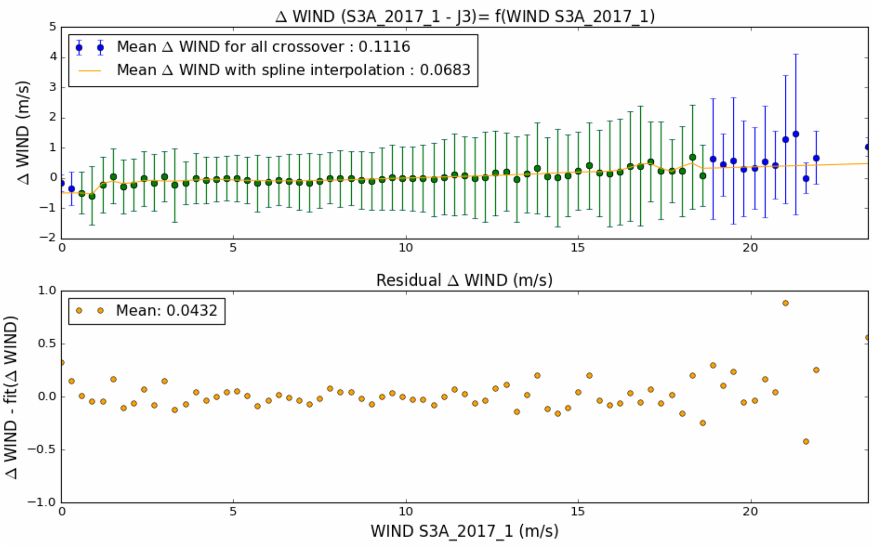


Figure 23: Wind speed calibration between J3 standard F and S3A during the period mid-2016 mid-2017. Top: wind speed mean difference at crossover; green dots correspond to bin with enough values to use for abacus calculation; blue dots correspond to bin with not enough values to use for abacus calculation; yellow line corresponds to the abacus values, bottom: Mean difference at crossover between J3 F standard and S3A after calibration.

This abacus will be used for operational treatment. Figure 24 show mean wind speed at crossover between J3F and S3A before (green line) and after calibration (blue line) between mid-November 2020 to mid-February 2021. We can notice that after calibration (blue line) residual value on mean wind speed difference at crossover remains (about -0.14 m/s in average). From December 2020 we observed a bias of about -0.2 m/s in average for mean wind speed difference at crossover between J3F and S3A. Furthermore, we saw on Figure 23 that correction applied with S3A abacus is small in average (about 0.04 m/s). Therefore, we can not expect to correct this recent bias observed (cf section 2.4.4.1). Creating an abacus for period from mid-November 2020 to mid-February 2021 gives better results after calibration (not shown). However, a three months abacus can not be used for the whole year because an entire year is mandatory to compute calibration abacus to represents all situations. The Figure 24 shows that improvements could be made on intercalibration process by using new methods such as quantile-quantile or artificial intelligence.

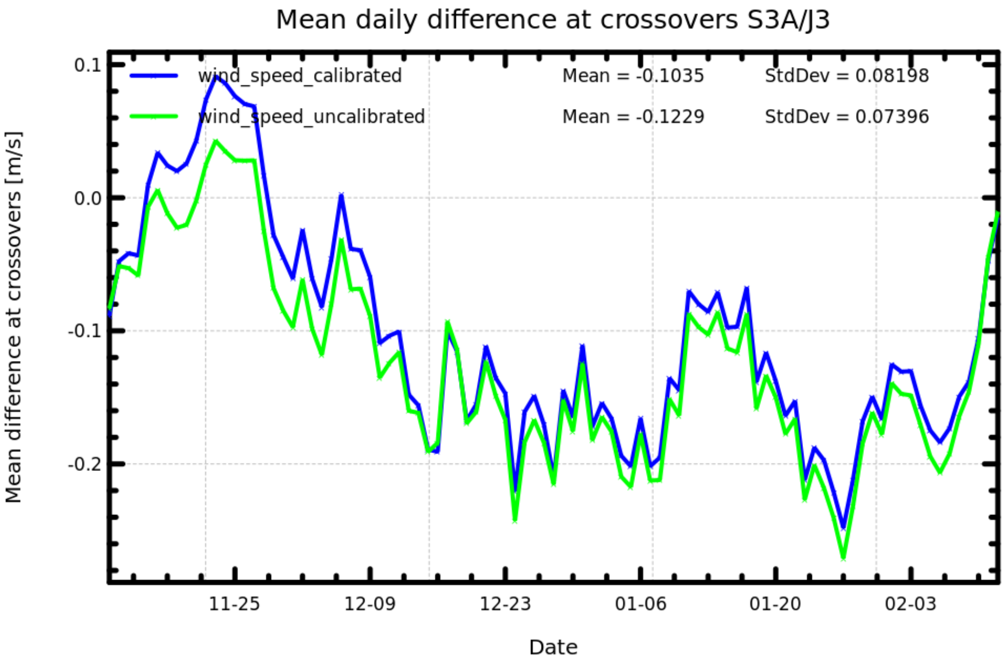


Figure 24: Mean of significant wind speed difference at crossovers (3h constraint). Sentinel-3A / Jason-3 crossovers. The green line represents the daily mean between the valid uncalibrated wind speed values.

8.2.2.2. Sentinel-3B

To create S3B abacus we needed to make it in two steps because as we said we need an entire one-year period in common between J3F and S3B, which is not yet available. Therefore a first calibration between J3 standard D and S3B Baseline Collection 004 products (over the year 2019) is done (this lowers the S3B Collard wind speed by (averaged over windspeed interval of 0 to 17 m/s) 0.29 m/s and in a second step an abacus containing a bias between J3 standard D and J3 standard F is applied (this increases the wind speed by (averaged over windspeed interval of 0 to 17 m/s) 0.36 m/s. The S3B Collard wind speed is therefore in average slightly increased after the intercalibration process. Figure 25 shows the S3B wind speed values before (green line) and after (blue line) calibration. After calibration, the mean average wind speed difference at crossover is closer to 0 than before calibration.

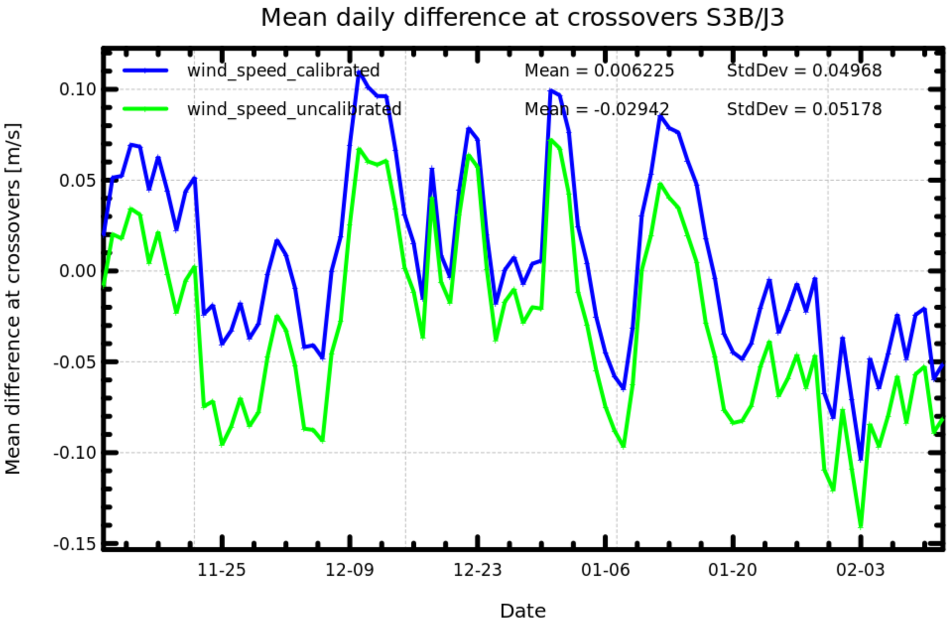


Figure 25: Mean of wind speed difference at crossovers (3h constraint). Sentinel-3B / Jason-3 crossovers. The green line represents the daily mean between the valid uncalibrated wind speed values.

8.2.2.3. Sentinel-6A

A comparison between Sentinel-6A and Jason 3 wind was performed over the tandem phase of the two satellites. This was done from 10/11/2021 to 25/11/2021 (after switch to side B). This corresponds to the planned operational behavior over oceanic surfaces.
The wind differences between Sentinel-6A and Jason 3 are represented as a function of Sentinel-6A wind values in Figure 26.

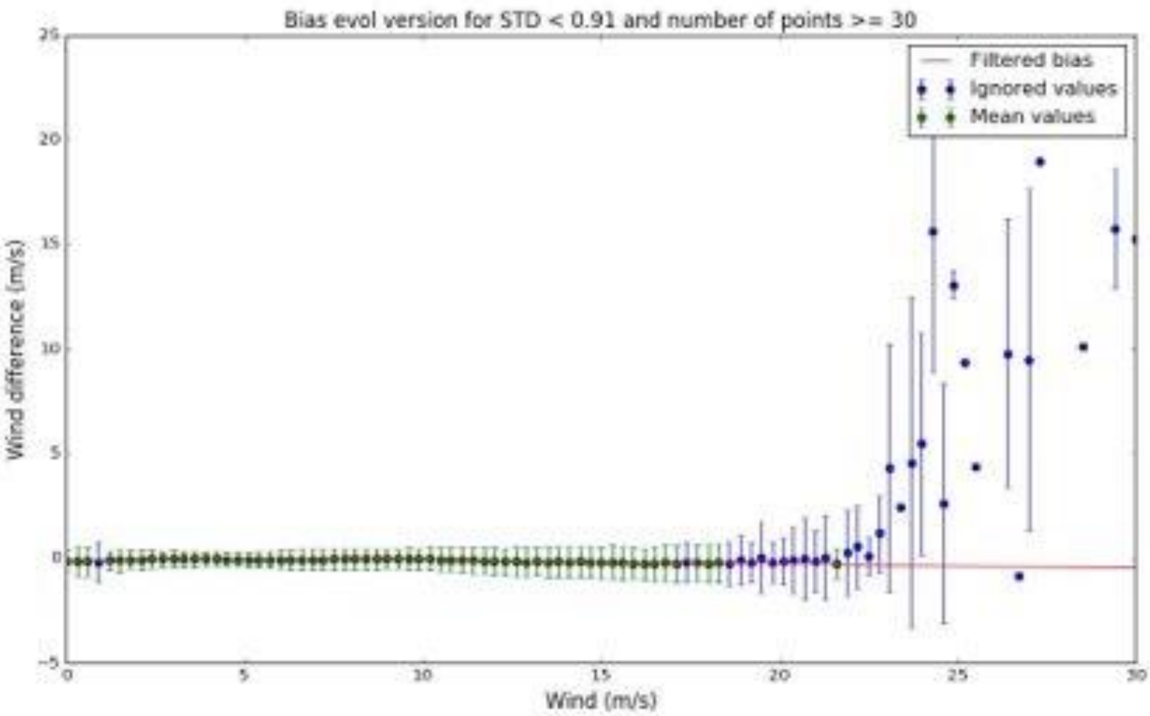


Figure 26 : Wind difference as a function of S6A wind values. The red curve represents the fitting formula.