Level-2+ Off-nadir products (L2PBOX) from SWIM instrument of CFOSAT

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1.2	2022/03/04	V. Quet A. Ollivier	Official version of the document
1.3	2024/04/25	M. Averseng A. Ollivier	Parasitic peaks filtering added

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List of Acronyms:

AVISO+	Archiving, Validation and Interpretation of Satellite Oceanographic data
CaSyS	CalVal Systematic SWIM
CF	Climate and Forecast
CFOSAT	China-France Oceanography Satellite
CLS	Collecte Localisation Satellites
CMEMS	Copernicus Marine Environment Monitoring Service
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
SWH	Significant wave height
SWIM	Surface Waves Investigation and Monitoring
TAC	Thematic Assembly Centre
UTC	Universal Time Coordinated

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Bibliography

[1] Hauser D. , C. Tison, T. Amiot, L. Delaye, N. Corcoral, and P. Castillan, "*SWIM: The first spaceborne wave scatterometer*," IEEE Trans. Geosci. Remote Sens., vol. 55, no. 5, pp. 3000–3014, May 2017, doi: 10.1109/TGRS.2017.2658672., https://hal-insu.archives-ouvertes.fr/insu-01456490/document

[2] Hauser D. et al., "*New Observations From the SWIM Radar On-Board CFOSAT: Instrument Validation and Ocean Wave Measurement Assessment*," in IEEE Transactions on Geoscience and Remote Sensing, vol. 59, no. 1, pp. 5-26, Jan. 2021, doi: 10.1109/TGRS.2020.2994372, https://hal-insu.archives-ouvertes.fr/insu-02324383v2/document

[3] Peureux et al., "*SWIM ocean waves spectra, illustration of performance*," https://cfosatst.aviso.altimetry.fr/fileadmin/user_upload/CFOSAT2021/presentations/P-CFOSAT2021-857.pdf

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1. Introduction: Context and product objectives

Dedicated to users unfamiliar with the mission, L2P products are added value products giving access to the largest community of users, including model assimilation actors.

In synergy with the needs of the WAVE-TAC (Thematic Assembly Centre), one of the eight TAC of the Copernicus Marine Environment Monitoring Service (CMEMS) project, SWIM L2P product intends to be an easy-to-ingest product, with comparable metrics.

The purpose of this document is to describe the Level-2P off-nadir products (L2PBOX) from SWIM instrument of CFOSAT. The instrument technology provides information from both Nadir and off-nadir (derived from the Level-2 wave spectrum).

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+ web site.

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 directional spectra of ocean waves from off-nadir observations

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°, 8° and 10° (Figure 1). The three beams with the largest incidence angle (6°, 8° and 10°) provide the 2D surface ocean wave spectra.

Among these, the 10° incidence beam was shown to be the most reliable and has been selected for dissemination of off-nadir information at this stage of the project CalVal studies (see [2] and [3]).

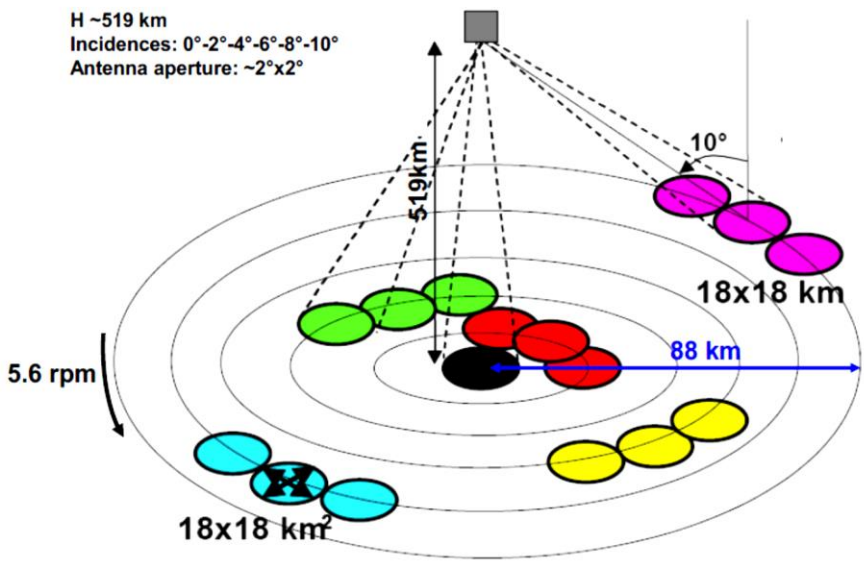

Figure 1. SWIM scatterometer

The principle of measurements is the following (see Hauser et al, 2017 for details). At the near-nadir incidence angles used by SWIM the transmitted signal is reflected by the sea surface towards the satellite thanks to a quasi-specular reflection generated by the presence of small facets (short waves). This quasi-specular backscattered signal is modulated within each footprint by the ocean waves (tilting effects by the presence of long waves). The maximum of modulation occurs for look angles close to the wave propagation direction. To the first order, these signal modulations are proportional to the slopes of the long waves. This allows estimations of the wave slope spectrum from the signal modulation spectrum (after correcting for speckle contamination) in each look direction. The wave spectrum is estimated from the modulation spectrum using a Modulation Transfer Function (MTF).

As the SWIM antenna continuously scans over 360°, the two-dimensional spectrum (in wave-number k and direction φ) can be derived by combining different look directions.

To build these directional wave spectra, off nadir boxes of about 90 x 70 km on each side of the satellite track (see Figure 2) are defined. The boxes include all azimuth in the range [0-180°] or [180°-360°]. The wave spectra are expressed as wave slope spectra in a $k-\varphi$ space with an ambiguity of ±180° in the propagation direction. Three main parameters are associated to these wave spectra: significant wave height, dominant wavelength, and dominant direction.

A 2D spectrum may contain information from multiple wave systems, for example, swell or wind sea. By defining different regions of the spectrum in the k−φ space (i.e., partitions), one can extract the wave partitions and their properties (significant wave height, wavelength, direction).

For more details about how SWIM measures the 2D density spectrum of waves, see [1].

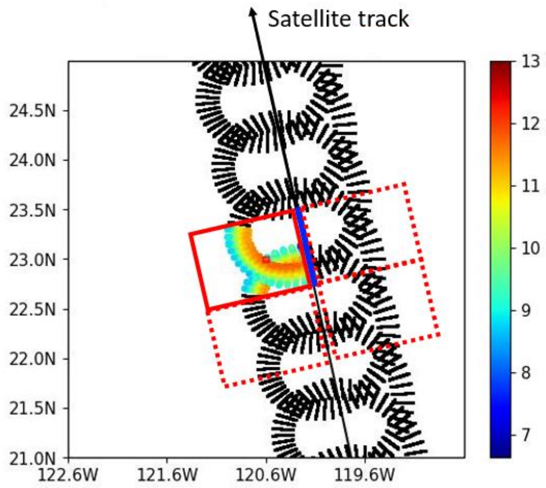

Figure 2. Example of a SWIM Off-nadir box (red solid box 90km wide/70km long) to the left of the satellite track, together with the associated nadir “box” (blue line along the track).

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 7:00;
- The inclinaison is 97.465 deg;
- The passes are numbered from 1 to 394 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 differences with L2 product

The SWIM L2PBOX products contain a selection of reliable, easy-to-ingest data extracted from the L2 products.

When available on the CalVal project side before the official ground segment update, improvements are brought to the computed fields (improvements and/or anomaly resolution...).

This provides CFOSAT off-nadir products in which users can directly access validated and filtered wave information without additional processing.

These off-nadir L2PBOX products contain:

- The 2D wave slope spectra from the 10° incidence beam (from L2) each defined over 24 directions and 32 wavenumbers. In addition, parasitic peaks (remaining noise floor in the slope spectra) which are present in some conditions (mainly for low sea-state conditions) are filtered out.The associated wave parameters (SWH, wavelength, and direction) integrated from the whole spectrum (from L2 excepted for the direction, corrected from an anomaly in the L2);
- The wave system parameters (for up to 3 systems) resulting from the partitioning of the 2D spectra (L2P dedicated);
- A spectrum validity flag resulting from an upstream CalVal analysis (L2P dedicated);
- The collocated nadir SWH averaged along track over the box’s length (from L2);
- The collocated nadir wind averaged along track over the box’s length (from L2);
- A flag associated to the averaged nadir information (from L2).

For the off-nadir information, the processing from L2 to L2P data can be divided in 4 main parts:

- Pre-processing;
- Data editing (with spectral symmetrisation);
- Partitioning of spectra;
- Product generation.

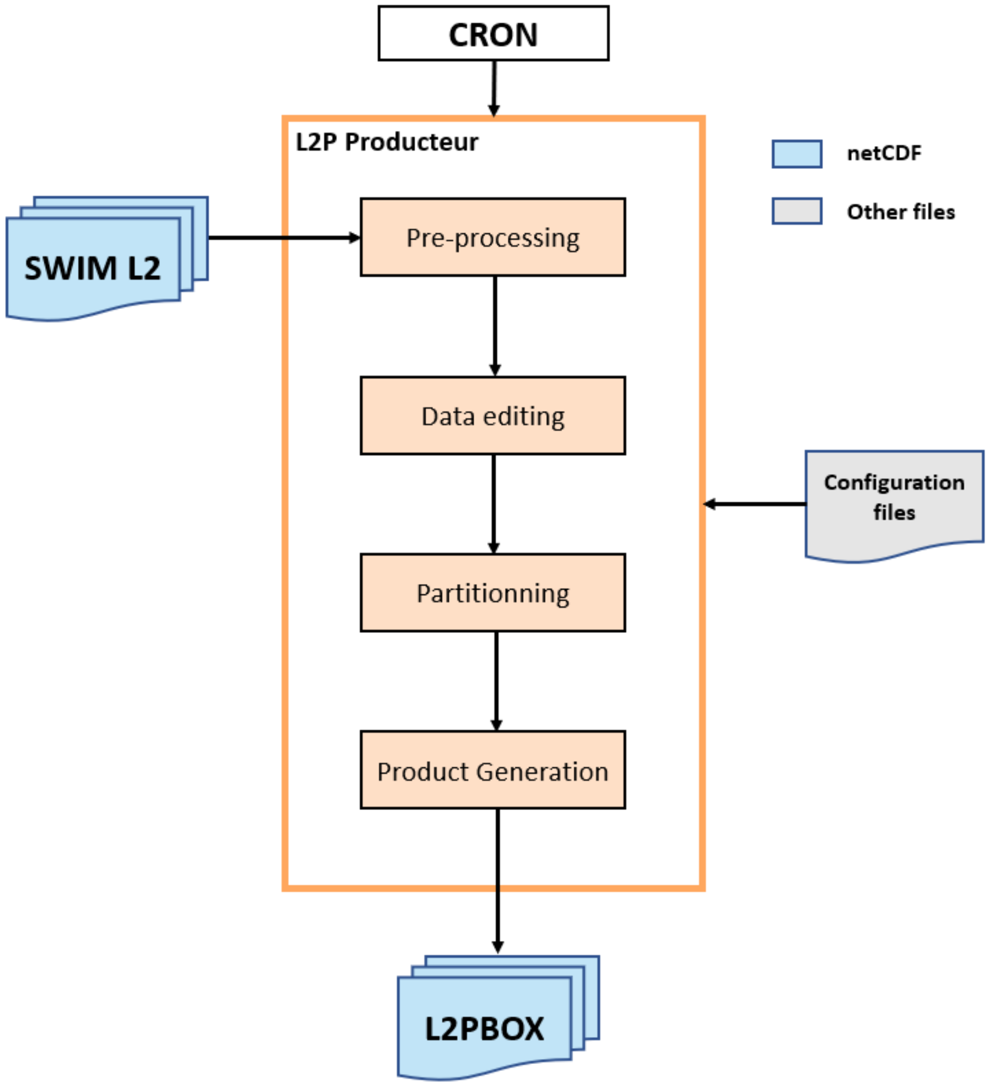

Figure 3. Processing L2PBOX Products from CFOSAT SWIM L2

3.2. Pre-processing

The main input files for this processing are the SWIM Level-2 products provided by the CNES CWWIC Centre and made available on the Aviso website (see 6).

The 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 editing (e.g.: latitude, longitude, nadir_swh_box, swh_ecmwf, etc);
- Defining the NetCDF attributes to be written in the output L2PBOX products.

Dimensions are set to be compliant with CF 1.6.

3.3. Data Editing

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 off-nadir beam observations as well as flags.

Parameter	Units	Method	Criterion or valid values
sea_ice_coverage_box	1	Threshold	x ≤ 0 (i.e. 0% sea ice in box)
land_coverage_box	1	Threshold	x ≤ 0 (i.e. 0% land in box)
pp_mean	m^2/rad	Threshold	x < 2000
Fraction of valid **k—φ** spectral bins	1	Threshold	X >= 1.0 (i.e., 100% valid spectrum)
SNR (signal to noise ratio**)**	1	Threshold	X > 1.1 (i.e. no parasitic peaks)

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. Flag and threshold editing criteria for details). To summarize, the L2PBOX off-nadir information are provided from boxes with no sea-ice, no land, when all spectral bins are present, for spectral energy without abnormal values (i.e., < 2000 m^2/rad). The latest filtering step concerns the parasitic peaks which are detected thanks to the comparison of a signal-to-noise ratio estimated over limited spectral intervals, to a given threshold. The signal to noise ratio is estimated in a given spectral domain as :

$$SNR = \frac{\langle F \rangle}{\sqrt{\langle F^2 \rangle - \langle F \rangle^2}}$$

The brackets indicate the mean operator over a grid of size 3 x 3 (k, φ) estimated in each spectral and azimuth bin. F is the 2D wave height spectrum ($F = \frac{E}{k^2}$) and E the 2D wave slope spectrum.

No editing is performed for the nadir “by-box” information. The SWH and wind variables (and their respective flags) are taken directly from the L2 products without editing or filtering.

3.4. Spectral Symmetry and integrated parameters

3.4.1. Symmetrisation of the SWIM spectrum

The spectra in the L2 products are provided between 0° and 180°, because of the directional ambiguity inherent to the SWIM measurements. In the L2PBOX, the spectra are given in the 0° to 360° range, obtained by performing a central symmetry. In other words, the spectrum is duplicated over the missing half of full azimuthal range. Since this procedure doubles the total energy present in the spectrum, each value of the 2D spectrum is divided by 2, to conserve the total energy.

The *phi_vector* variable is also modified from 12 bins to 24 bins, to reflect this evolution of the 2D spectrum.

3.4.2. Integrated Parameters

The wave system parameters (significant wave height, peak wavelength, and peak direction) are recalculated for consistency with the symmetrized spectrum, and because of an error in the direction reported in the original L2 products (version 5.1.2).

The peak wavelength and peak direction correspond to the dominant wavelength and direction in the 2D wave slope spectrum, noted here $E(k,\varphi)$.

The significant wave height is calculated with the formula:

$$H_s = 4 \times \sqrt{\iint F\,(k,\varphi)\; k\, dk\, d\varphi}$$

Where $F(k,\varphi)$ is the wave height spectrum with $F(k,\varphi) = \frac{E(k,\varphi)}{k^2}$

3.5. Partitioning

The entire spectrum of the 10° beam is partitioned into up to three wave systems detectable by SWIM, with the following procedure:

1. Smoothing of the spectrum with a 2D Gaussian kernel;
2. Definition of high energy areas in the 2D spectrum by applying a watershed method from all detected local maxima;
3. Merging of the low-contrast regions to create at most 3 partitions;
4. Estimation of the wave system parameters (SWH, peak wavelength, and peak direction) for each of these partitions;
5. The partitions are ranked by decreasing significant wave height.

Compared to the algorithm applied in the L2 processing, the main differences are:

- The addition of step 3 (merging of low-contrast regions);
- Some details in the watershed method may differ because of an upgrade of the software library used;
- The wave partitions are estimated in the wavelength range 30-500 m in the L2 products, and in the 20-500 m range for L2PBOX products.

The contours of the partitions (masks) are provided in the L2PBOX products as a 2D matrix (in k$-\varphi$) for each partition. The values are '0' for k$-\varphi$ bins outside the partition, '1' for bins inside the partition, and '-1' for the symmetric counterparts of these bins.

4. Product Presentation

4.1. Temporal Availability

CFOSAT L2PBOX products are available from the 25th of April 2019, corresponding to the upgrade of the CWWIC chain (L2 production) that corrected an error in the onboard processing of the spectral beams data. Prior to that date, no reliable wave spectrum is available. Up to now, the production has no ending date and is still on going.

4.2. Nomenclature

CFOSAT L2P filenames are named under CFOSAT L2 model:

CFO_OPXX_SWI_L2PBOX_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_L2PBOX_F_20200306T180424_20200306T194835.nc

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

Several dimensions are defined in the L2PBOX products:

- n_box: number of boxes in the current file;
- n_posneg: refers to the left/right side of the track (n_posneg=2);
- n_phi: number of azimuth angle bins;
- nk: number of wavenumber bins;
- nparam: number of wave parameters (nparam=3, for SWH, wavelength, and direction);
- npartitions: maximum number of partitions (npartitions=3).

5.1.2. Data Handling Variables

The variables defined in the product are listed and described in Table 2 for the nadir box related variables and Table 3 for the off-nadir variables. The corresponding L2 variable name is also provided for each L2PBOX variable, as well as modifications from the original values in the L2 products, if any.

Name of variable	Type	Content	Unit	Dimensions	Name of equivalent L2 variable
time_nadir_l2	double	Time at the center of the nadir box with reference changed from 2009/01/01 to 2000/01/01	seconds since 2000-01-01 00:00:00 UTC	n_box	time_nadir_l2
lat_nadir_l2	int	Latitude of the center of the nadir box	degrees_north	n_box	lat_nadir_l2
lon_nadir_l2	int	Longitude of the center of the nadir box	degrees_east	n_box	lon_nadir_l2

nadir_swh_box	short	Nadir SWH compressed by nadir box	meters	n_box	nadir_swh_box
flag_valid_swh_box	byte	Quality flag for nadir_swh_box: 0: valid 1: invalid	none	n_box	flag_valid_swh_box
nadir_wind_box	short	Nadir wind speed value compressed by nadir box	meters / s	n_box	nadir_wind_box
flag_valid_wind_box	byte	Quality flag for nadir_wind_box: 0: valid 1: invalid	none	n_box	flag_valid_wind_box
phi_orbit_box	short	Angle between the orbit plane (i.e., track) and the geographical north	none	n_box	phi_orbit_box

Table 2. Description of L2PBOX netCDF variables related to the nadir (compressed by box)

Name of variable	Type	Content	Unit	Dimensions	Name of equivalent L2 variable
time_spec_l2	double	Time at the center of the off-nadir box with reference changed from 2009/01/01 to 2000/01/01	seconds since 2000-01-01 00:00:00 UTC	n_posneg, n_box	time_spec_l2
lat_spec_l2	int	Latitude of the center of the off-nadir box	degrees_north	n_posneg, n_box	lat_spec_l2
lon_spec_l2	int	Longitude of the center of the off-nadir box	degrees_east	n_posneg, n_box	lon_spec_l2
k_spectra	short	Wave number vector (values at the center of the wave number bins) redefined for the 20-500 m wavelength range (see 3.3)	1/meters	nk	k_spectra
phi_vector	short	Azimuth angle vector (values at the center of the azimuth angle bins), extended from [0°,180°] to [0°, 360°], see 3.4.1.	degrees	n_phi	phi_vector
swh_ecmwf	short	SWH from the ECMWF model data	meters	n_posneg, n_box	swh_ecmwf
u10_ecmwf	short	U wind speed from the ECMWF model data	meters/s	n_posneg, n_box	u10_ecmwf
v10_ecmwf	short	V wind speed from the ECMWF model data	meters/s	n_posneg, n_box	v10_ecmwf

wave_param	short	Wave parameters recalculated over the whole (symmetrized, see 3.4.2) spectrum of the 10° incidence beam. In order, the parameters are SWH, peak wavelength and peak direction.	meters, meters, degrees	nparam, n_posneg, n_box	**wave_param**
pp_mean	Short	2D mean slope spectrum of the 10° incidence beam only and filtered of parasitic peaks.	meters^2 / radians	nk, n_phi, n_posneg, n_box	**pp_mean**
flag_valid_pp_mean	Byte	Quality flag (see 3.3) on the 2D mean slope spectrum of the 10° incidence beam only.	none	nk, n_phi, n_posneg, n_box	none
wave_param_part	short	Wave parameters estimated on each of the partitions (see 3.4.2 Integrated Parameters) of the 10° slope spectrum only. For each partition, the parameters are, in order, the SWH, the peak wavelength and the peak direction	meters, meters, degrees	nparam, npartitions, n_posneg, n_box	none
mask_spectrum	Byte	Mask representing the extent of each of the partitions in the $k-\varphi$ space of the 10° slope spectrum, with '+/- 1' indicating bins included in a partition, and '0' for bins outside the partition.	none	nk, n_phi, npartitions, n_posneg, n_box	none
Number_of_partitions	Byte	Flag indicating the number of partitions detected in the 10° spectrum. Values are between 0 and 3.	none	n_posneg, n_box	none

Table 3. Description of L2PBOX netCDF variables related to the off-nadir information

Additional attributes may be available in L2PBOX files (see Appendix 8.1). They are providing information about the type of product or the processing and parameter used.

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/

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 operational news on the Aviso+ website:

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

6.2. Updates and reprocessing

6.2.1. L2PBOX Product version

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

Version	Delivery date	Period	FA	Evolution with respect to previous version
v1.1	2021-05-25	2019/04/25 to 2021/05/21		• New partitioning method (see 3.5) • Correction of direction parameter in L2 products (see 3.4.2) • Symetrization of the spectrum (given between 0-360°)
V1.2	2021-09-06	Since 2019/04/25		• Bug fix: the Peak direction of the 2D spectrum was not calculated properly.
V1.3	2024-04-25	Since 2019/04/25		Filtering of parasitic peaks (remaining noise) to improve spectrum quality

6.2.2. 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

6.3. 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)]."

7. 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.

8. Appendix

8.1. Example of L2PBOX Off-nadir product File

```
netcdf CFO_OP06_SWI_L2PBOX_F_20240606T094546_20240606T111831 {
dimensions:
	n_phi = 24 ;
	n_box = 521 ;
	n_posneg = 2 ;
	nk = 32 ;
	nparam = 3 ;
	npartitions = 3 ;
variables:
	double time_nadir_l2(n_box) ;
		time_nadir_l2:units = "seconds since 2000-01-01 00:00:00.0" ;
		time_nadir_l2:axis = "T" ;
		time_nadir_l2:standard_name = "time" ;
		time_nadir_l2:calendar = "gregorian" ;
		time_nadir_l2:long_name = "Mean time of box area (sec. since 2000-01-01)" ;
	double time_spec_l2(n_posneg, n_box) ;
		time_spec_l2:units = "seconds since 2000-01-01 00:00:00.0" ;
		time_spec_l2:axis = "T" ;
		time_spec_l2:standard_name = "time" ;
		time_spec_l2:calendar = "gregorian" ;
		time_spec_l2:long_name = "Mean time of 2D spectrum coverage area (sec. since 2000-01-01)" ;
	float lat_nadir_l2(n_box) ;
		lat_nadir_l2:_FillValue = 9.96921e+36f ;
		lat_nadir_l2:long_name = "Mean latitude of nadir beam in each box" ;
		lat_nadir_l2:references = "CF-GSFR-SP-807-CNES" ;
		lat_nadir_l2:source = "" ;
		lat_nadir_l2:units = "degrees_north" ;
		lat_nadir_l2:valid_min = -90.f ;
		lat_nadir_l2:valid_max = 90.f ;
		lat_nadir_l2:least_significant_digit = 3 ;
	float lon_nadir_l2(n_box) ;
		lon_nadir_l2:_FillValue = 9.96921e+36f ;
```

```
			lon_nadir_l2:long_name = "Mean longitude of nadir beam in each box" ;
			lon_nadir_l2:references = "CF-GSFR-SP-807-CNES" ;
			lon_nadir_l2:source = "" ;
			lon_nadir_l2:units = "degrees_east" ;
			lon_nadir_l2:valid_min = -180.f ;
			lon_nadir_l2:valid_max = 180.f ;
			lon_nadir_l2:least_significant_digit = 3 ;
		float lat_spec_l2(n_posneg, n_box) ;
			lat_spec_l2:_FillValue = 9.96921e+36f ;
			lat_spec_l2:long_name = "Mean latitude of 2D spectrum coverage area, in middle of the box" ;
			lat_spec_l2:references = "CF-GSFR-SP-804-CNES" ;
			lat_spec_l2:source = "" ;
			lat_spec_l2:units = "degrees_north" ;
			lat_spec_l2:valid_min = -90.f ;
			lat_spec_l2:valid_max = 90.f ;
			lat_spec_l2:least_significant_digit = 3 ;
		float lon_spec_l2(n_posneg, n_box) ;
			lon_spec_l2:_FillValue = 9.96921e+36f ;
			lon_spec_l2:long_name = "Mean longitude of 2D spectrum coverage area, in middle of the box" ;
			lon_spec_l2:references = "CF-GSFR-SP-804-CNES" ;
			lon_spec_l2:source = "" ;
			lon_spec_l2:units = "degrees_east" ;
			lon_spec_l2:valid_min = -180.f ;
			lon_spec_l2:valid_max = 180.f ;
			lon_spec_l2:least_significant_digit = 3 ;
		float k_spectra(nk) ;
			k_spectra:_FillValue = 9.96921e+36f ;
			k_spectra:long_name = "Wave number vector" ;
			k_spectra:references = "CF-GSFR-SP-804-CNES" ;
			k_spectra:source = "" ;
			k_spectra:units = "m-1" ;
			k_spectra:valid_min = 0.f ;
			k_spectra:valid_max = 1.f ;
			k_spectra:least_significant_digit = 6 ;
		float phi_orbit_box(n_box) ;
			phi_orbit_box:_FillValue = 9.96921e+36f ;
			phi_orbit_box:long_name = "Angles between orbit plane and geographical North" ;
```

```
		phi_orbit_box:references = "CF-GSFR-SP-804-CNES" ;
		phi_orbit_box:source = "" ;
		phi_orbit_box:units = "radians" ;
		phi_orbit_box:valid_min = 0.f ;
		phi_orbit_box:valid_max = 7.f ;
		phi_orbit_box:least_significant_digit = 2 ;
	float nadir_swh_box(n_box) ;
		nadir_swh_box:_FillValue = 9.96921e+36f ;
		nadir_swh_box:long_name = "Swh value from nadir processing compressed by box" ;
		nadir_swh_box:references = "CF-GSFR-SP-807-CNES" ;
		nadir_swh_box:source = "" ;
		nadir_swh_box:units = "m" ;
		nadir_swh_box:valid_min = 0.f ;
		nadir_swh_box:valid_max = 100.f ;
		nadir_swh_box:least_significant_digit = 3 ;
	byte flag_valid_swh_box(n_box) ;
		flag_valid_swh_box:_FillValue = -127b ;
		flag_valid_swh_box:flag_meanings = "valid invalid" ;
		flag_valid_swh_box:flag_values = 0b, 1b ;
		flag_valid_swh_box:long_name = "Quality flag on swh value" ;
		flag_valid_swh_box:references = "CF-GSFR-SP-807-CNES" ;
		flag_valid_swh_box:source = "" ;
		flag_valid_swh_box:least_significant_digit = 0 ;
	float nadir_wind_box(n_box) ;
		nadir_wind_box:_FillValue = 9.96921e+36f ;
		nadir_wind_box:long_name = "Wind speed value from nadir processing compressed
by box" ;
		nadir_wind_box:references = "CF-GSFR-SP-807-CNES" ;
		nadir_wind_box:source = "" ;
		nadir_wind_box:units = "m.s-1" ;
		nadir_wind_box:valid_min = 0.f ;
		nadir_wind_box:valid_max = 100.f ;
		nadir_wind_box:least_significant_digit = 3 ;
	byte flag_valid_wind_box(n_box) ;
		flag_valid_wind_box:_FillValue = -127b ;
		flag_valid_wind_box:flag_meanings = "valid invalid" ;
		flag_valid_wind_box:flag_values = 0b, 1b ;
		flag_valid_wind_box:long_name = "Quality flag on wind value" ;
		flag_valid_wind_box:references = "CF-GSFR-SP-807-CNES" ;
```

```
        flag_valid_wind_box:source = "" ;
        flag_valid_wind_box:least_significant_digit = 0 ;
    float swh_ecmwf(n_posneg, n_box) ;
        swh_ecmwf:_FillValue = 9.96921e+36f ;
        swh_ecmwf:long_name = "Significant wave height from ECMWF data" ;
        swh_ecmwf:references = "CF-GSFR-SP-804-CNES" ;
        swh_ecmwf:source = "" ;
        swh_ecmwf:units = "m" ;
        swh_ecmwf:valid_min = 0.f ;
        swh_ecmwf:valid_max = 50.f ;
        swh_ecmwf:least_significant_digit = 2 ;
    float u10_ecmwf(n_posneg, n_box) ;
        u10_ecmwf:_FillValue = 9.96921e+36f ;
        u10_ecmwf:long_name = "10 metres u wind speed from ECMWF data" ;
        u10_ecmwf:references = "CF-GSFR-SP-804-CNES" ;
        u10_ecmwf:source = "" ;
        u10_ecmwf:units = "m/s" ;
        u10_ecmwf:valid_min = -100.f ;
        u10_ecmwf:valid_max = 100.f ;
        u10_ecmwf:least_significant_digit = 2 ;
    float v10_ecmwf(n_posneg, n_box) ;
        v10_ecmwf:_FillValue = 9.96921e+36f ;
        v10_ecmwf:long_name = "10 metres v wind speed from ECMWF data" ;
        v10_ecmwf:references = "CF-GSFR-SP-804-CNES" ;
        v10_ecmwf:source = "" ;
        v10_ecmwf:units = "m/s" ;
        v10_ecmwf:valid_min = -100.f ;
        v10_ecmwf:valid_max = 100.f ;
        v10_ecmwf:least_significant_digit = 2 ;
    float phi_vector(n_phi) ;
        phi_vector:_FillValue = 9.96921e+36f ;
        phi_vector:valid_min = 0.f ;
        phi_vector:long_name = "Phi vector (center of bin)" ;
        phi_vector:least_significant_digit = 1LL ;
        phi_vector:units = "degree" ;
        phi_vector:valid_max = 360.f ;
        phi_vector:references = "CF-GSFR-SP-804-CNES" ;
        phi_vector:comment = "optionnelle" ;
```

```
phi_vector:source = "" ;
float wave_param(nparam, n_posneg, n_box) ;
wave_param:_FillValue = 9.96921e+36f ;
wave_param:long_name = "Wave parameters (SWH, peak wavelength, peak direction) of the whole spectrum at beam 10 degrees" ;
wave_param:least_significant_digit = 3LL ;
wave_param:units = "1" ;
wave_param:valid_max = 2000.f ;
wave_param:references = "CF-GSFR-SP-804-CNES" ;
wave_param:comment = "optionnelle" ;
float pp_mean(nk, n_phi, n_posneg, n_box) ;
pp_mean:_FillValue = 9.96921e+36f ;
pp_mean:long_name = "Best 2D mean slope spectrum for spectral beam 10 degrees" ;
pp_mean:least_significant_digit = 3LL ;
pp_mean:valid_max = 100.f ;
pp_mean:units = "m^2 / radians" ;
pp_mean:references = "CF-GSFR-SP-804-CNES" ;
pp_mean:comment = "optionnelle" ;
byte flag_valid_pp_mean(nk, n_phi, n_posneg, n_box) ;
flag_valid_pp_mean:_FillValue = -127b ;
flag_valid_pp_mean:long_name = "validation flag for the 2D mean slope spectrum for spectral beam 10 degrees (all criteria)" ;
flag_valid_pp_mean:flag_values = 0b, 1b ;
flag_valid_pp_mean:flag_meanings = "valid invalid" ;
float wave_param_part(nparam, npartitions, n_posneg, n_box) ;
wave_param_part:_FillValue = 9.96921e+36f ;
wave_param_part:long_name = "Wave parameters (SWH, peak wavelength, peak direction) of the partitions detected in the beam 10 degrees" ;
wave_param_part:least_significant_digit = 3LL ;
wave_param_part:valid_max = 2000.f ;
wave_param_part:units = "1" ;
wave_param_part:references = "CF-GSFR-SP-804-CNES" ;
wave_param_part:comment = "optionnelle" ;
byte mask_spectrum(nk, n_phi, npartitions, n_posneg, n_box) ;
mask_spectrum:_FillValue = -127b ;
mask_spectrum:long_name = "Mask of the partitions detected on pp_mean (1 and -1 indicate the partitions and its symmetric counterpart, 0 is outside partition)" ;
mask_spectrum:least_significant_digit = 0LL ;
mask_spectrum:valid_min = -1b ;
```

```
		mask_spectrum:valid_max = 1b ;
		mask_spectrum:references = "CF-GSFR-SP-804-CNES" ;
		mask_spectrum:comment = "optionnelle" ;
		mask_spectrum:flag_values = -1b, 0b, 1b ;
		mask_spectrum:flag_meanings = "first_part_of_the_partition no_partition second_part_of_the_partition" ;
	byte number_of_partitions(n_posneg, n_box) ;
		number_of_partitions:_FillValue = -127b ;
		number_of_partitions:long_name = "Integer giving the number of detected partitions (0 to 3) on pp_mean" ;
		number_of_partitions:flag_meanings = "0_identified_partition 1_identified_partition 2_identified_partitions 3_identified_partitions" ;
		number_of_partitions:least_significant_digit = 0LL ;
		number_of_partitions:flag_values = 0b, 1b, 2b, 3b ;
		number_of_partitions:references = "CF-GSFR-SP-804-CNES" ;
		number_of_partitions:comment = "optionnelle" ;


// global attributes:
		:platform = "CFOSAT" ;
		:sensor = "SWIM" ;
		:institution = "CNES" ;
		:contact = "aollivier@groupcls.com, maverseng@groupcls.com" ;
		:ars = 5.6f ;
		:dphi = 15.f ;
		:cycle = "158_2024-06-03T09:37:49Z_2024-06-16T09:37:44Z" ;
		:wlmin = "30.f" ;
		:wlmax = "500.f" ;
		:product_version = "1.3" ;
		:software_version = "production_l2p: 2.7.1" ;
		:creation_date = "2024-06-06T12:45:35" ;
		:processing_level = "L2P" ;
		:oper_version = "OP06" ;
		:Conventions = "CF-1.6" ;
		:wave_spectra_beam = "10" ;
		:comment = "SWIM off-nadir products selected from Beam 10 degrees, and SWIM nadir products averaged by box" ;
		:first_meas_time = "2024-06-06 09:45:46" ;
		:last_meas_time = "2024-06-06 11:18:29" ;
}
```