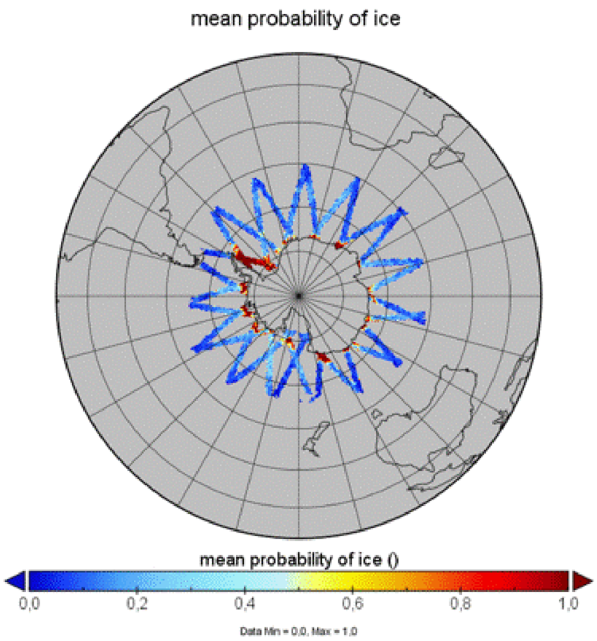
# CFOSAT SWIM ICE Products Handbook

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## List of Acronyms:

| | |
|---|---|
| ADT | Absolute Dynamic Topography |
| Aviso+ | Archiving, Validation and Interpretation of Satellite Oceanographic data |
| CMEMS | Copernicus Marine Environment Monitoring Service |
| Cnes | Centre National d'Etudes Spatiales |
| 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 |
| GMF | Geophysical Model Function |
| L1A | Level-1A product |
| L2 | Level-2 product |
| LSM | Land sea mask |
| SWH | Significant wave height |
| SWIM | Surface Waves Investigation and Monitoring |
| UTC | Universal Time Coordinated |

## Contents

# 1 Introduction

SWIM ICE product provides sea ice detection, sea ice probabilities indicators that can be used either to improve SWIM data assimilation or to take benefits of the CFOSAT polar coverage to complement other sea-ice information sources...

This document is the user manual for the **CFOSAT SWIM Ice** product. It presents the processing (input data and method applied), the product description, with the different files provided, the nomenclature & the file format and finally the access to the products.

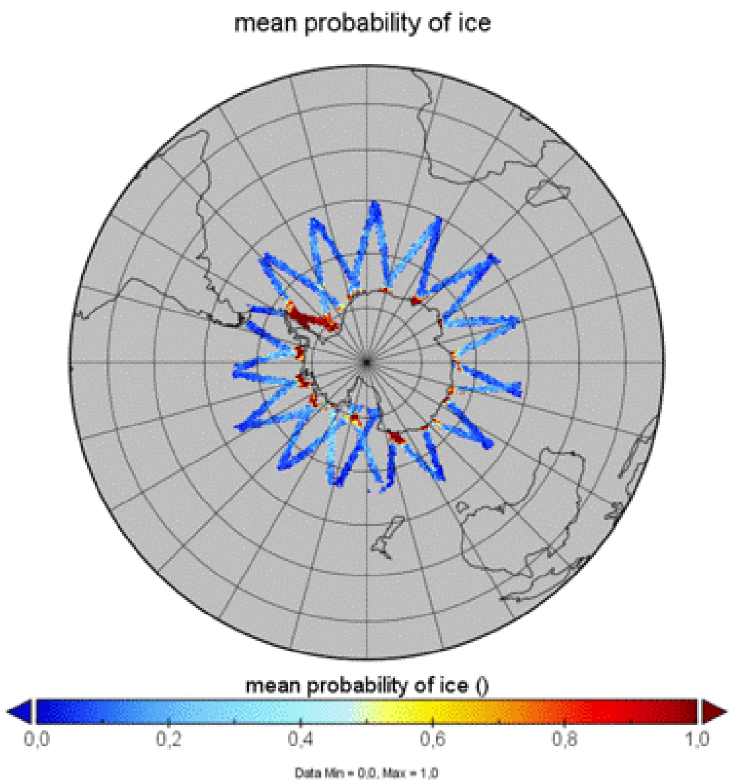



Figure 1: Daily snapshot of SWIM probability of ice on 1 february 2020

## 1.1 Acknowledgments

When using the CFOSAT SWIM ICE product, please cite: "This product was processed by CNES and distributed by AVISO+ (https://www.aviso.altimetry.fr) with support from CNES”

## 1.2 User’s feedback

The product is an experimental product. Therefore, each and every question, comment, example of use, and suggestion will help us improve the product. You’re welcome to ask or send them to aviso@altimetry.fr

# 2 CFOSAT SWIM ICE product

## 2.1 CFOSAT SWIM instrument

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]).

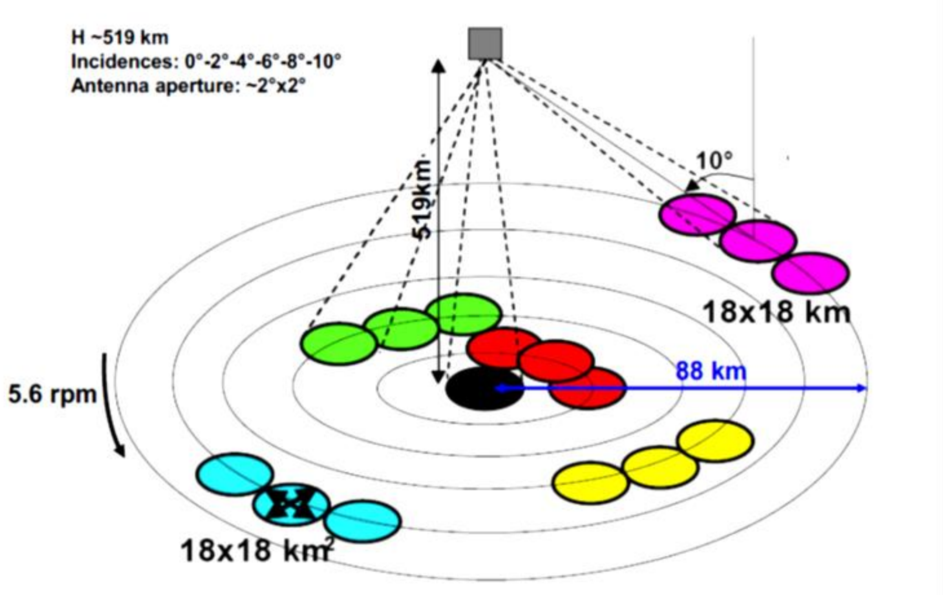



**Figure 1. SWIM scatterometer**

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) 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— 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— 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].

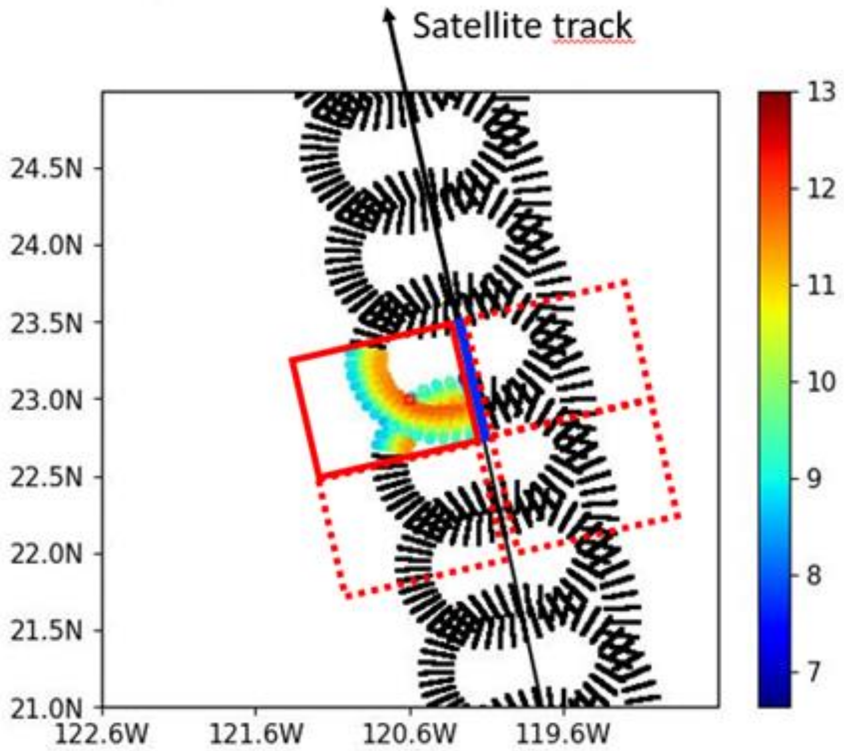
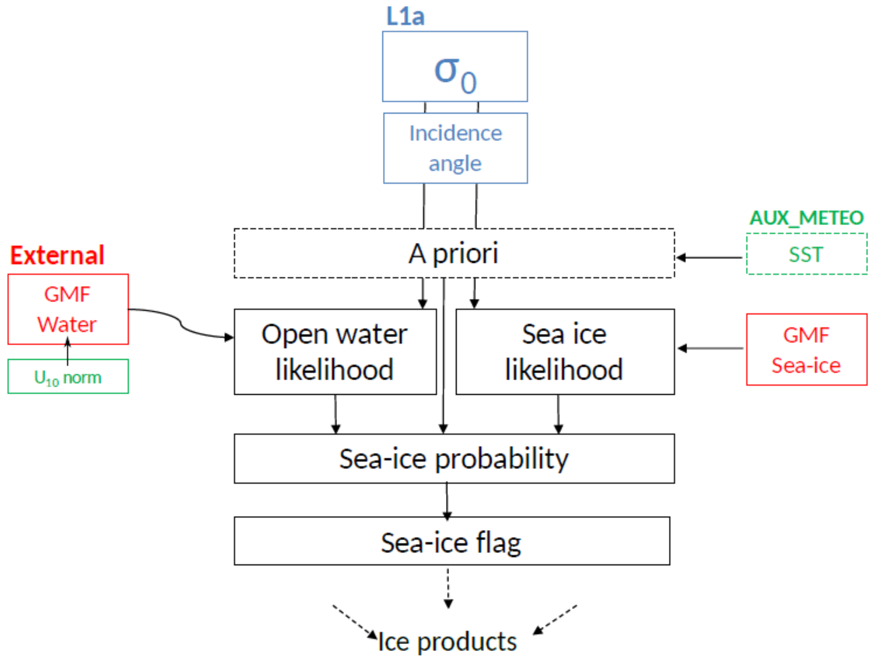



**Figure 2. Example of a SWIM Off-nadir box (red solid box 90km wide/70km long) to the left of the satellite track, together with the associated nadir "box" (blue line along the track).**

## 2.2 SWIM ICE PROCESSING

The principle of SWIM ICE algorithm is summarized in Figure 2 and explained in details in Peureux et al.2022 [3]. The method is based on a Bayesian method to estimate the probability of sea ice presence by comparison to backscatter radar references in sea ice and open water conditions. The signature of both open water and sea-ice radar backscatter is parameterized into Geophysical Model Function (GMF) computed from SWIM L2 mini-profiles products. A sea ice flag is activated when the probability of sea ice presence exceeds 0.5.




**SWIM sea_ice flagging algorithm summary. A NRCS and incidence angle pair from L1a products are compared to GMFs both assuming either sea_ice or openwater thanks to a likelihood estimate, given the measurement context (wind speed, beam number, etc.) A priori probability based on sea surface temperature is combined to the likelihood into a Bayezian scheme, from which a probability is derived and translated into a binary flag**

The ICEL2G products are generated by aggregating ice probability estimates from ICEL2 files over one day period. Minimum, maximum and mean probability of ice are computed for each grid box by considering all ICEL2 data available within a given grid box. The grid is regular in latitude and longitude with a resolution of 0.5° in both directions.

## 2.3 Product Description

### 2.3.1 Temporal availability

CFOSAT ICE L1A are available from the 27th of May 2022, corresponding to the upgrade of the CWWIC chain into version 6.0. ICEL2 and ICEL2G have been retreated and are available from the beginning of the mission.

### 2.3.2 Nomenclature

This is the generic model of filename for ICE L1A, ICE L2, ICEL2G products:

**CFO_OPXX_SWI_ICEL1A_F_<begin_date>T<begin_hour>_<end_date>T<end_hour>.nc**

**CFO_OPXX_SWI_ICEL2__F_<begin_date>T<begin_hour>_<end_date>T<end_hour>.nc**

**CFO_OPXX_SWI_ICEL2G_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 OP06 L1A products:

**CFO_OP06_SWI_ICEL1A_F_20230106T180424_20230106T194835.nc**

### 2.3.3 Format

All the products are distributed in NetCDF with norm CF 1.7.

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.

#### 2.3.3.1 Dimensions

Several dimensions are defined in the ICE L1A products:

- n_tim : component of time;
- n_mcycles : number of macrocycles ;
- n_beam : number of beam ;
- n_swath_1: number of data points over the 2° beam swath ;
- n_swath_2: number of data points over the 4° beam swath ;
- n_swath_3: number of data points over the 6° beam swath ;
- n_swath_4: number of data points over the 8° beam swath ;
- n_swath_5: number of data points over the 10* beam swath;

In ICE L2 products, the dimensions are as follows:

- n_mcycles : number of macrocycles ;
- n_beam : number of beams
- n_tim : component of time

In ICEL2G products, the dimensions are:

- nlat : number of data points in latitude axis
- nlon : number of data point in longitude axis

### 2.3.3.2 Data Handling Variables

You will find hereafter the definitions of the variables defined in the product ICE L1A:

| Name of variable | Type | Content | Unit | Dimensions |
|---|---|---|---|---|
| **time_nr** | int | Time of each Near Range measurement | s+us since 2009-01-01 00:00:00 0:00 | n_mcycles, n_beam, n_tim |
| **p_ice_1** | float | Probability of ice detected from beam 1 | No unit | n_mcycles, n_swath_1 |
| **flagsi_1** | float | Sea Ice Flag from beam 1 | No unit | n_mcycles, n_swath_1 |
| **ci_1** | flaot | Sea Ice concentration detected from beam 1 | No unit | n_mcycles, n_swath_1 |
| **lat_l1a_1** | float | Latitude of each gate of the swath | degrees_north | n_mcycles, n_swath_1 |
| **lon_l1a_1** | float | Longitude of each gate of the swath | degrees_east | n_mcycles, n_swath_1 |
| **reliable_swath_1** | byte | Reliability flag showing the swath indices to be kept in the echo_l1a_1 | No unit | n_swath_1 |
| **p_ice_2** | float | Probability of ice detected from beam 2 | No unit | n_mcycles, n_swath_2 |
| **flagsi_2** | float | Sea Ice Flag from beam 2 | No unit | n_mcycles, n_swath_2 |
| **ci_2** | flaot | Sea Ice concentration detected from beam 2 | No unit | n_mcycles, n_swath_2 |
| **lat_l1a_2** | float | Latitude of each gate of the swath | degrees_north | n_mcycles, n_swath_2 |
| **lon_l1a_2** | float | Longitude of each gate of the swath | degrees_east | n_mcycles, n_swath_2 |
| **reliable_swath_2** | byte | Reliability flag showing the swath indices to be kept in the echo_l1a_2 | No unit | n_swath_2 |
| **p_ice_3** | float | Probability of ice detected from beam 3 (6°) | No unit | n_mcycles, n_swath_3 |
| **flagsi_3** | float | Sea Ice Flag from beam 3 | No unit | n_mcycles, n_swath_3 |
| **ci_3** | flaot | Sea Ice concentration detected from beam 3 | No unit | n_mcycles, n_swath_3 |
| **lat_l1a_3** | float | Latitude of each gate of the swath | degrees_north | n_mcycles, n_swath_3 |
| **lon_l1a_3** | float | Longitude of each gate of the swath | degrees_east | n_mcycles, n_swath_3 |
| **reliable_swath_3** | byte | Reliability flag showing the swath indices to be kept in the echo_l1a_3 | No unit | n_swath_3 |

| | | | | |
|---|---|---|---|---|
| **p_ice_4** | float | Probability of ice detected from beam 4 (8˚) | No unit | n_mcycles, n_swath_4 |
| **flagsi_4** | float | Sea Ice Flag from beam 4 | No unit | n_mcycles, n_swath_4 |
| **ci_4** | flaot | Sea Ice concentration detected from beam 4 | No unit | n_mcycles, n_swath_4 |
| **lat_l1a_4** | float | Latitude of each gate of the swath | degrees_north | n_mcycles, n_swath_4 |
| **lon_l1a_4** | float | Longitude of each gate of the swath | degrees_east | n_mcycles, n_swath_4 |
| **reliable_swath_4** | byte | Reliability flag showing the swath indices to be kept in the echo_l1a_4 | No unit | n_swath_4 |
| **p_ice_5** | float | Probability of ice detected from beam 5 (10˚) | No unit | n_mcycles, n_swath_5 |
| **flagsi_5** | float | Sea Ice Flag from beam 5 | No unit | n_mcycles, n_swath_5 |
| **ci_5** | flaot | Sea Ice concentration detected from beam 5 | No unit | n_mcycles, n_swath_5 |
| **lat_l1a_5** | float | Latitude of each gate of the swath | degrees_north | n_mcycles, n_swath_5 |
| **lon_l1a_5** | float | Longitude of each gate of the swath | degrees_east | n_mcycles, n_swath_5 |
| **reliable_swath_5** | byte | Reliability flag showing the swath indices to be kept in the echo_l1a_5 | No unit | n_swath_5 |

**Table 1.** Overview of data handling variables in ICE L1A file product

You will find hereafter the definitions of the variables defined in the product ICE L2:

| Name of variable | Type | Content | Unit | Dimensions |
|---|---|---|---|---|
| **Time_nr** | int | Time of each Near Range measurement | s+us since 2009-01-01 00:00:00 0:00 | n_mcycles, n_beam, n_tim |
| **lat** | float | Mean latitude over reliable swath | degrees_North | n_mcycles, n_beam |
| **lon** | float | Mean longitude over reliable swath | degrees_East | n_mcycles, n_beam |
| **p_ice_mean** | float | Probability of ice detected from beam 1 | No unit | n_mcycles, n_beam |
| **sea_ice_flag** | float | Sea Ice Flag | No unit | n_mcycles, n_beam |
| **likely_ice** | float | Sea ice likelyhood | No unit | n_mcycles, n_beam |
| **frac_ice** | double | Sea ice fraction over the swath | No unit | n_mcycles, n_beam |
| **p_ice_max** | float | Maximum sea ice probability | No unit | n_mcycles, n_beam |
| **sig** | float | Mean NRCS over the swath | No unit | n_mcycles, n_beam |
| **mu_water** | float | Openwater GMF | No unit | n_mcycles, n_beam |
| **sig_water** | float | open water GMF uncertainties | No unit | n_mcycles, n_beam |
| **mu_ice** | float | Sea ice GMF | No unit | n_mcycles, n_beam |
| **sig_ice** | float | sea ice GMF uncertainties | No unit | n_mcycles, n_beam |
| **lsm_ecmwf** | flaot | Land sea mask from ecmwf | No unit | n_mcycles, n_beam |
| **u10_ecmwf** | float | Zonal wind from ecmwf | No unit | n_mcycles, n_beam |
| **v10_ecmwf** | float | Meridional wind from ecmwf | No unit | n_mcycles, n_beam |
| **swh_ecmwf** | | Significant wave height from ecmwf | No unit | n_mcycles, n_beam |
| **sic_ecmwf** | | Sea ice content from ecmwf | No unit | n_mcycles, n_beam |

Table 2. Overview of data handling variables in ICE L2 file product

You will find hereafter the definitions of the variables defined in the product ICE L2G:

| Name of variable | Type | Content | Unit | Dimensions |
|---|---|---|---|---|
| **lat** | float | Latitude of grid points | degrees_North | nlat |
| **lon** | Float | Longitude of grid points | Degrees_East | nlon |

| | | | | |
|---|---|---|---|---|
| **p_ice_mean** | double | Mean ice probability within the grid box | No unit | nlat, nlon |
| **P_ice_min** | Double | Minimum of ice probability within the grid box | No unit | nlat,nlon |
| **P_ice_max** | Double | Maximum of ice probability within the grid box | No unit | nlat, nlon |

#### 2.3.3.3 Attributes

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

# 3 Products accessibility

The products are available via **(S)FTP (ftp-access.aviso.altimetry.fr) and the THREDDS Data Server (https://tds.aviso.altimetry.fr) using AVISO+ credentials:**

- You first need to register via the Aviso+ web portal and sign the License Agreement: https://www.aviso.altimetry.fr/en/data/data-access/registration-form.html
- You have to choose the product **"CFOSAT SWIM Ice products"** in the list of products

A login /Password will be provided via email with all the necessary information to access the products.

# 4 Contacts

For more information, please contact:

Aviso+ User Services
CLS
11 rue Hermès
Parc Technologique du canal
31520 Ramonville Cedex
France
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.

# 5 Examples of files

## 5.1 ICE L1A files

```
netcdf CFO_OP06_SWI_ICEL1A_F_20230216T195929_20230216T213226 {
dimensions:
n_swath_1 = 755 ;
n_mcycles = 26014 ;
n_beam = 5 ;
n_swath_2 = 933 ;
n_swath_3 = 2771 ;
n_swath_4 = 2639 ;
n_swath_5 = 3215 ;
variables:
float p_ice_1(n_mcycles, n_swath_1) ;
p_ice_1:long_name = " Probability of Sea Ice detected from beam 1 " ;
p_ice_1:units = "no_unit" ;
p_ice_1:_FillValue = NaNf ;
p_ice_1:missing_value = NaNf ;
float flagsi_1(n_mcycles, n_swath_1) ;
flagsi_1:long_name = "Sea Ice Flag from beam 1" ;
flagsi_1:units = "no_unit" ;
flagsi_1:_FillValue = NaNf ;
flagsi_1:missing_value = NaNf ;
float ci_1(n_mcycles, n_swath_1) ;
ci_1:long_name = " Sea Ice concentration detected from beam 1 " ;
ci_1:units = "no_unit" ;
ci_1:_FillValue = NaNf ;
ci_1:missing_value = NaNf ;
float p_ice_2(n_mcycles, n_swath_2) ;
p_ice_2:long_name = " Probability of Sea Ice detected from beam 2 " ;
p_ice_2:units = "no_unit" ;
p_ice_2:_FillValue = NaNf ;
p_ice_2:missing_value = NaNf ;
float flagsi_2(n_mcycles, n_swath_2) ;
flagsi_2:long_name = "Sea Ice Flag from beam 2" ;
flagsi_2:units = "no_unit" ;
flagsi_2:_FillValue = NaNf ;
flagsi_2:missing_value = NaNf ;
float ci_2(n_mcycles, n_swath_2) ;
ci_2:long_name = " Sea Ice concentration detected from beam 2 " ;
ci_2:units = "no_unit" ;
ci_2:_FillValue = NaNf ;
ci_2:missing_value = NaNf ;
float p_ice_3(n_mcycles, n_swath_3) ;
p_ice_3:long_name = " Probability of Sea Ice detected from beam 3 " ;
p_ice_3:units = "no_unit" ;
p_ice_3:_FillValue = NaNf ;
p_ice_3:missing_value = NaNf ;
float flagsi_3(n_mcycles, n_swath_3) ;
flagsi_3:long_name = "Sea Ice Flag from beam 3" ;
flagsi_3:units = "no_unit" ;
flagsi_3:_FillValue = NaNf ;
flagsi_3:missing_value = NaNf ;
float ci_3(n_mcycles, n_swath_3) ;
```

```
ci_3:long_name = " Sea Ice concentration detected from beam 3 " ;
ci_3:units = "no_unit" ;
ci_3:_FillValue = NaNf ;
ci_3:missing_value = NaNf ;
float p_ice_4(n_mcycles, n_swath_4) ;
p_ice_4:long_name = " Probability of Sea Ice detected from beam 4 " ;
p_ice_4:units = "no_unit" ;
p_ice_4:_FillValue = NaNf ;
p_ice_4:missing_value = NaNf ;
float flagsi_4(n_mcycles, n_swath_4) ;
flagsi_4:long_name = "Sea Ice Flag from beam 4" ;
flagsi_4:units = "no_unit" ;
flagsi_4:_FillValue = NaNf ;
flagsi_4:missing_value = NaNf ;
float ci_4(n_mcycles, n_swath_4) ;
ci_4:long_name = " Sea Ice concentration detected from beam 4 " ;
ci_4:units = "no_unit" ;
ci_4:_FillValue = NaNf ;
ci_4:missing_value = NaNf ;
float p_ice_5(n_mcycles, n_swath_5) ;
p_ice_5:long_name = " Probability of Sea Ice detected from beam 5 " ;
p_ice_5:units = "no_unit" ;
p_ice_5:_FillValue = NaNf ;
p_ice_5:missing_value = NaNf ;
float flagsi_5(n_mcycles, n_swath_5) ;
flagsi_5:long_name = "Sea Ice Flag from beam 5" ;
flagsi_5:units = "no_unit" ;
flagsi_5:_FillValue = NaNf ;
flagsi_5:missing_value = NaNf ;
float ci_5(n_mcycles, n_swath_5) ;
ci_5:long_name = " Sea Ice concentration detected from beam 5 " ;
ci_5:units = "no_unit" ;
ci_5:_FillValue = NaNf ;
ci_5:missing_value = NaNf ;
float lat_l1a_1(n_mcycles, n_swath_1) ;
lat_l1a_1:long_name = "Latitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the second incidence angle measurement" ;
lat_l1a_1:units = "degrees_north" ;
lat_l1a_1:_FillValue = 9.96921e+36f ;
lat_l1a_1:missing_value = 9.96921e+36f ;
lat_l1a_1:least_significant_digit = 3 ;
lat_l1a_1:references = "CF-GSFR-SP-802-CNES v04" ;
lat_l1a_1:comment = "optionnelle" ;
float lat_l1a_2(n_mcycles, n_swath_2) ;
lat_l1a_2:long_name = "Latitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the third incidence angle measurement" ;
lat_l1a_2:units = "degrees_north" ;
lat_l1a_2:_FillValue = 9.96921e+36f ;
lat_l1a_2:missing_value = 9.96921e+36f ;
lat_l1a_2:least_significant_digit = 3 ;
lat_l1a_2:references = "CF-GSFR-SP-802-CNES v04" ;
lat_l1a_2:comment = "optionnelle" ;
float lat_l1a_3(n_mcycles, n_swath_3) ;
lat_l1a_3:long_name = "Latitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the fourth incidence angle measurement" ;
lat_l1a_3:units = "degrees_north" ;
lat_l1a_3:_FillValue = 9.96921e+36f ;
lat_l1a_3:missing_value = 9.96921e+36f ;
```

lat_l1a_3:least_significant_digit = 3 ;
lat_l1a_3:references = "CF-GSFR-SP-802-CNES v04" ;
lat_l1a_3:comment = "optionnelle" ;
float lat_l1a_4(n_mcycles, n_swath_4) ;
lat_l1a_4:long_name = "Latitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the fifth incidence angle measurement " ;
lat_l1a_4:units = "degrees_north" ;
lat_l1a_4:_FillValue = 9.96921e+36f ;
lat_l1a_4:missing_value = 9.96921e+36f ;
lat_l1a_4:least_significant_digit = 3 ;
lat_l1a_4:references = "CF-GSFR-SP-802-CNES v04" ;
lat_l1a_4:comment = "optionnelle" ;
float lat_l1a_5(n_mcycles, n_swath_5) ;
lat_l1a_5:long_name = "Latitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the sixth incidence angle measurement" ;
lat_l1a_5:units = "degrees_north" ;
lat_l1a_5:_FillValue = 9.96921e+36f ;
lat_l1a_5:missing_value = 9.96921e+36f ;
lat_l1a_5:least_significant_digit = 3 ;
lat_l1a_5:references = "CF-GSFR-SP-802-CNES v04" ;
lat_l1a_5:comment = "optionnelle" ;
float lon_l1a_1(n_mcycles, n_swath_1) ;
lon_l1a_1:long_name = "Longitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the second incidence angle measurement" ;
lon_l1a_1:units = "degrees_east" ;
lon_l1a_1:_FillValue = 9.96921e+36f ;
lon_l1a_1:missing_value = 9.96921e+36f ;
lon_l1a_1:least_significant_digit = 3 ;
lon_l1a_1:references = "CF-GSFR-SP-802-CNES v04" ;
lon_l1a_1:comment = "optionnelle" ;
float lon_l1a_2(n_mcycles, n_swath_2) ;
lon_l1a_2:long_name = "Longitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the third incidence angle measurement" ;
lon_l1a_2:units = "degrees_east" ;
lon_l1a_2:_FillValue = 9.96921e+36f ;
lon_l1a_2:missing_value = 9.96921e+36f ;
lon_l1a_2:least_significant_digit = 3 ;
lon_l1a_2:references = "CF-GSFR-SP-802-CNES v04" ;
lon_l1a_2:comment = "optionnelle" ;
float lon_l1a_3(n_mcycles, n_swath_3) ;
lon_l1a_3:long_name = "Longitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the fourth incidence angle measurement" ;
lon_l1a_3:units = "degrees_east" ;
lon_l1a_3:_FillValue = 9.96921e+36f ;
lon_l1a_3:missing_value = 9.96921e+36f ;
lon_l1a_3:least_significant_digit = 3 ;
lon_l1a_3:references = "CF-GSFR-SP-802-CNES v04" ;
lon_l1a_3:comment = "optionnelle" ;
float lon_l1a_4(n_mcycles, n_swath_4) ;
lon_l1a_4:long_name = "Longitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the fifth incidence angle measurement" ;
lon_l1a_4:units = "degrees_east" ;
lon_l1a_4:_FillValue = 9.96921e+36f ;
lon_l1a_4:missing_value = 9.96921e+36f ;
lon_l1a_4:least_significant_digit = 3 ;
lon_l1a_4:references = "CF-GSFR-SP-802-CNES v04" ;
lon_l1a_4:comment = "optionnelle" ;
float lon_l1a_5(n_mcycles, n_swath_5) ;

lon_l1a_5:long_name = "Longitude of each gate of the swath (on terrestrial ellipsoid), for each cycle of the sixth incidence angle measurement" ;
lon_l1a_5:units = "degrees_east" ;
lon_l1a_5:_FillValue = 9.96921e+36f ;
lon_l1a_5:missing_value = 9.96921e+36f ;
lon_l1a_5:least_significant_digit = 3 ;
lon_l1a_5:references = "CF-GSFR-SP-802-CNES v04" ;
lon_l1a_5:comment = "optionnelle" ;
byte reliable_swath_1(n_swath_1) ;
reliable_swath_1:long_name = "Reliability flag showing the swath indices to be kept in the echo_l1a_1 (part of the swath corrected with an the antenna gain accuracy within the specifications)" ;
reliable_swath_1:_FillValue = -127b ;
reliable_swath_1:missing_value = -127b ;
reliable_swath_1:least_significant_digit = 0 ;
reliable_swath_1:flag_values = 0b, 1b ;
reliable_swath_1:flag_meanings = "rejected index, reliable index" ;
reliable_swath_1:references = "CF-GSFR-SP-802-CNES v07" ;
reliable_swath_1:comment = "optionnelle" ;
byte reliable_swath_2(n_swath_2) ;
reliable_swath_2:long_name = "Reliability flag showing the swath indices to be kept in the echo_l1a_2 (part of the swath corrected with an the antenna gain accuracy within the specifications)" ;
reliable_swath_2:_FillValue = -127b ;
reliable_swath_2:missing_value = -127b ;
reliable_swath_2:least_significant_digit = 0 ;
reliable_swath_2:flag_values = 0b, 1b ;
reliable_swath_2:flag_meanings = "rejected index, reliable index" ;
reliable_swath_2:references = "CF-GSFR-SP-802-CNES v07" ;
reliable_swath_2:comment = "optionnelle" ;
byte reliable_swath_3(n_swath_3) ;
reliable_swath_3:long_name = "Reliability flag showing the swath indices to be kept in the echo_l1a_3 (part of the swath corrected with an the antenna gain accuracy within the specifications)" ;
reliable_swath_3:_FillValue = -127b ;
reliable_swath_3:missing_value = -127b ;
reliable_swath_3:least_significant_digit = 0 ;
reliable_swath_3:flag_values = 0b, 1b ;
reliable_swath_3:flag_meanings = "rejected index, reliable index" ;
reliable_swath_3:references = "CF-GSFR-SP-802-CNES v07" ;
reliable_swath_3:comment = "optionnelle" ;
byte reliable_swath_4(n_swath_4) ;
reliable_swath_4:long_name = "Reliability flag showing the swath indices to be kept in the echo_l1a_4 (part of the swath corrected with an the antenna gain accuracy within the specifications)" ;
reliable_swath_4:_FillValue = -127b ;
reliable_swath_4:missing_value = -127b ;
reliable_swath_4:least_significant_digit = 0 ;
reliable_swath_4:flag_values = 0b, 1b ;
reliable_swath_4:flag_meanings = "rejected index, reliable index" ;
reliable_swath_4:references = "CF-GSFR-SP-802-CNES v07" ;
reliable_swath_4:comment = "optionnelle" ;
byte reliable_swath_5(n_swath_5) ;
reliable_swath_5:long_name = "Reliability flag showing the swath indices to be kept in the echo_l1a_5(part of the swath corrected with an the antenna gain accuracy within the specifications)" ;
reliable_swath_5:_FillValue = -127b ;
reliable_swath_5:missing_value = -127b ;
reliable_swath_5:least_significant_digit = 0 ;
reliable_swath_5:flag_values = 0b, 1b ;
reliable_swath_5:flag_meanings = "rejected index, reliable index" ;
reliable_swath_5:references = "CF-GSFR-SP-802-CNES v07" ;

```
reliable_swath_5:comment = "optionnelle" ;
 int time_nr(n_mcycles, n_beam, n_tim) ;
   time_nr:_FillValue = -2147483647 ;
        time_nr:least_significant_digit = 0 ;
        time_nr:valid_min = 0 ;
        time_nr:valid_max = 662688000 ;
        time_nr:units = "s+us since 2009-01-01 00:00:00 0:00 " ;
        time_nr:long_name = "Time of each Near Range measurement, for each cycle and each incidence, relative to the reference time." ;
        time_nr:references = "CF-GSFR-SP-802-CNES v04" ;
        time_nr:comment = "" ;
        time_nr:source = "" ;

// global attributes:
:_NCProperties = "version=1|netcdflibversion=4.4.1|hdf5libversion=1.8.17" ;
:CDI = "Climate Data Interface version 1.9.8 (https://mpimet.mpg.de/cdi)" ;
:history = "Fri Feb 17 05:51:28 2023: cdo -f nc4c -z zip_9 copy in.nc CFO_OP06_SWI_ICEL1A_F_20230216T195929_20230216T213226.nc\n",
"none" ;
:source = "CFOSAT CWWIC SWIM AUX_METEO processor" ;
:institution = "CNES" ;
:Conventions = "CF-1.7" ;
:ECMWF_start_forecast = "2023-02-16T09:00:00Z" ;
:ECMWF_end_forecast = "2023-02-17T00:00:00Z" ;
:interpolation_mode = 1 ;
:coeff_atm_corr = "0.094000;-0.177000;-0.145000;0.274000;0.001450;0.000007;0.169000" ;
:GMF_openwater_version = "20200301_20210301_1y_water" ;
:references = "DDI CFOSAT - Ref. CF_GSFR-ICD-1094-CNES" ;
:title = "SWIM_L1A____product" ;
:date_created = "2023-02-16T21:43:50Z" ;
:product_version = "6.1.0" ;
:netcdf_version_id = "4.3.3.1" ;
:generator_center = "FROGS" ;
:generator_subcenter = "CWWIC" ;
:platform = "CFOSAT" ;
:sensor = "SWIM" ;
:time_coverage_start = "2023-02-16T19:59:29Z" ;
:time_coverage_end = "2023-02-16T21:32:26Z" ;
:time_coverage_duration = "0000-00-00T01:32:57Z" ;
:geospatial_lat_max = 82.63145f ;
:geospatial_lat_min = -82.63064f ;
:geospatial_lon_max = 179.9153f ;
:geospatial_lon_min = -179.7718f ;
:file_quality_index = 1 ;
:processing_level = "L1A" ;
:start_orbit_number = 23769 ;
:stop_orbit_number = 23770 ;
:equator_crossing_longitude = 326.85f ;
:equator_crossing_date = "2023-02-16T21:06:07Z" ;
:cycle = "121_2023-02-08T10:00:20Z_2023-02-21T09:59:16Z" ;
:trace = "256_2023-02-16T19:54:49Z_2023-02-16T20:42:19Z/257_2023-02-16T20:42:19Z_2023-02-16T21:29:50Z/258_2023-02-16T21:29:50Z_2023-02-16T22:17:20Z" ;
:swim_acquisition_mode = "nominal" ;
:ground_station = "IVK" ;
:antenna = "rotated" ;
:cdb_version = "23_32" ;
:input_files = "CFO_OPER_AUX_SWICDB_F_23_32_20160101T010000.bin\n",
"TMP_OP06_SWI_L0_____F_20230216T195929_20230216T213226.nc\n",
```

"CFO_OPER_CNF_F1a____20161205T000000_001.txt\n",
"CFO_OP06_SWI_L1ALT1_F_20230216T175009.nc" ;
:macrocycle_angle = "0;2;4;6;8;10" ;
:macrocycle_beam = "0;1;2;3;4;5" ;
:ldis = "1;4;4;2;3;3" ;
:nimp = "264;97;97;156;186;204" ;
:antenna_rotation_speed = 5.6f ;
:beam_elevation = "0.000000;2.300000;3.700000;5.550000;7.400000;9.250000" ;
:beam_width = "1.585000;1.530000;1.740000;1.860000;1.860000;1.890000" ;
:signal_sampling_in_radar_geometry = "0.374741;1.498962;1.498962;0.749481;1.124222;1.124222" ;
:signal_resolution_in_radar_geometry = "0.468426;1.873703;1.873703;0.936851;1.405277;1.405277"
;
:CDO = "Climate Data Operators version 1.9.8 (https://mpimet.mpg.de/cdo)" ;
}

## 5.2 ICE L2 files

```
netcdf CFO_OP06_SWI_ICEL2__F_20230216T120104_20230216T131916 {
dimensions:
n_mcycles = 21410 ;
n_beam = 5 ;
n_tim = 2 ;
variables:
float lat(n_mcycles, n_beam) ;
lat:_FillValue = NaNf ;
lat:valid_min = -90.f ;
lat:valid_max = 90.f ;
lat:units = "degrees_North" ;
lat:long_name = " Mean Latitude " ;
float lon(n_mcycles, n_beam) ;
lon:_FillValue = NaNf ;
lon:valid_min = -180.f ;
lon:valid_max = 180.f ;
lon:units = "degrees_East" ;
lon:long_name = " Mean Longitude " ;
float p_ice_mean(n_mcycles, n_beam) ;
p_ice_mean:_FillValue = NaNf ;
p_ice_mean:valid_min = 0.f ;
p_ice_mean:valid_max = 1.f ;
p_ice_mean:units = "no_unit" ;
p_ice_mean:long_name = "Sea Ice Probability" ;
p_ice_mean:reference = " " ;
float sea_ice_flag(n_mcycles, n_beam) ;
sea_ice_flag:_FillValue = NaNf ;
sea_ice_flag:valid_min = 0.f ;
sea_ice_flag:valid_max = 1.f ;
sea_ice_flag:units = "no_unit" ;
sea_ice_flag:long_name = " Sea Ice Flag " ;
float likely_ice(n_mcycles, n_beam) ;
likely_ice:_FillValue = NaNf ;
likely_ice:valid_min = 0.f ;
likely_ice:valid_max = 1.f ;
likely_ice:units = "no_unit" ;
likely_ice:long_name = "Sea Ice Likelyhood " ;
double frac_ice(n_mcycles, n_beam) ;
frac_ice:_FillValue = NaN ;
frac_ice:valid_min = 0. ;
frac_ice:valid_max = 1. ;
frac_ice:long_name = " Sea Ice Fraction over the swath" ;
float p_ice_max(n_mcycles, n_beam) ;
p_ice_max:_FillValue = NaNf ;
p_ice_max:valid_min = 0.f ;
p_ice_max:valid_max = 1.f ;
p_ice_max:units = "no_unit" ;
p_ice_max:long_name = "Maximum Sea Ice Probability" ;
float sig(n_mcycles, n_beam) ;
sig:_FillValue = NaNf ;
sig:valid_min = 0. ;
```

```
sig:valid_max = 1. ;
sig:long_name = " Mean NRCS over the swath" ;
float mu_water(n_mcycles, n_beam) ;
mu_water:_FillValue = NaNf ;
mu_water:valid_min = 0. ;
mu_water:valid_max = 1. ;
mu_water:long_name = "open water GMF " ;
float sig_water(n_mcycles, n_beam) ;
sig_water:_FillValue = NaNf ;
sig_water:valid_min = 0. ;
sig_water:valid_max = 1. ;
sig_water:long_name = " open water GMF uncertainties" ;
float mu_ice(n_mcycles, n_beam) ;
mu_ice:_FillValue = NaNf ;
mu_ice:valid_min = 0. ;
mu_ice:valid_max = 1. ;
mu_ice:long_name = "sea ice GMF " ;
float sig_ice(n_mcycles, n_beam) ;
sig_ice:_FillValue = NaNf ;
sig_ice:valid_min = 0. ;
sig_ice:valid_max = 1. ;
sig_ice:long_name = "sea ice GMF uncertainties" ;
float lsm_ecmwf(n_mcycles, n_beam) ;
lsm_ecmwf:_FillValue = 9.96921e+36f ;
lsm_ecmwf:least_significant_digit = 2 ;
lsm_ecmwf:long_name = "Land-Sea mask" ;
lsm_ecmwf:valid_min = 0.f ;
lsm_ecmwf:valid_max = 1.f ;
lsm_ecmwf:references = "CF-GSFR-SP-2424-CNES v3.9" ;
lsm_ecmwf:comment = "" ;
lsm_ecmwf:source = "" ;
float u10_ecmwf(n_mcycles, n_beam) ;
u10_ecmwf:_FillValue = 9.96921e+36f ;
u10_ecmwf:least_significant_digit = 2 ;
u10_ecmwf:long_name = "Wind at surface level" ;
u10_ecmwf:valid_min = -100.f ;
u10_ecmwf:units = "m/s" ;
u10_ecmwf:valid_max = 100.f ;
u10_ecmwf:references = "CF-GSFR-SP-2424-CNES v3.9" ;
u10_ecmwf:comment = "" ;
u10_ecmwf:source = "" ;
float v10_ecmwf(n_mcycles, n_beam) ;
v10_ecmwf:_FillValue = 9.96921e+36f ;
v10_ecmwf:least_significant_digit = 2 ;
v10_ecmwf:long_name = "Wind at surface level" ;
v10_ecmwf:valid_min = -100.f ;
v10_ecmwf:units = "m/s" ;
v10_ecmwf:valid_max = 100.f ;
v10_ecmwf:references = "CF-GSFR-SP-2424-CNES v3.9" ;
v10_ecmwf:comment = "" ;
v10_ecmwf:source = "" ;
float swh_ecmwf(n_mcycles, n_beam) ;
swh_ecmwf:_FillValue = 9.96921e+36f ;
swh_ecmwf:least_significant_digit = 2 ;
swh_ecmwf:long_name = "Significant wave height" ;
swh_ecmwf:valid_min = 0.f ;
swh_ecmwf:units = "m" ;
swh_ecmwf:valid_max = 50.f ;
```

```
swh_ecmwf:references = "CF-GSFR-SP-2424-CNES v3.9" ;
swh_ecmwf:comment = "" ;
swh_ecmwf:source = "" ;
float sic_ecmwf(n_mcycles, n_beam) ;
sic_ecmwf:_FillValue = 9.96921e+36f ;
sic_ecmwf:least_significant_digit = 2 ;
sic_ecmwf:long_name = "Sea ice cover" ;
sic_ecmwf:valid_min = 0.f ;
sic_ecmwf:units = "fraction" ;
sic_ecmwf:valid_max = 1.f ;
sic_ecmwf:references = "CF-GSFR-SP-2424-CNES v3.9" ;
sic_ecmwf:comment = "" ;
sic_ecmwf:source = "" ;
int time_nr(n_mcycles, n_beam, n_tim) ;
time_nr:_FillValue = -2147483647 ;
time_nr:least_significant_digit = 0 ;
time_nr:valid_min = 0 ;
time_nr:valid_max = 662688000 ;
time_nr:units = "s+us since 2009-01-01 00:00:00 0:00 " ;
time_nr:long_name = "Time of each Near Range measurement, for each cycle and each incidence, relative to the reference time." ;
time_nr:references = "CF-GSFR-SP-802-CNES v04" ;
time_nr:comment = "" ;
time_nr:source = "" ;

// global attributes:
:history = "none" ;
:institution = "CNES" ;
:references = "DDI CFOSAT - Ref. CF_GSFR-ICD-1094-CNES" ;
:Conventions = "CF-1.7" ;
:date_created = "2023-02-16T13:50:05Z" ;
:product_version = "6.1.0" ;
:netcdf_version_id = "4.3.3.1" ;
:generator_center = "FROGS" ;
:generator_subcenter = "CWWIC" ;
:platform = "CFOSAT" ;
:sensor = "SWIM" ;
:geospatial_lon_resolution = "" ;
:geospatial_lat_resolution = "" ;
:time_coverage_start = "2023-02-16T12:01:04Z" ;
:time_coverage_end = "2023-02-16T13:17:42Z" ;
:time_coverage_duration = "0000-00-00T01:16:38Z" ;
:geospatial_lat_max = 81.16418f ;
:geospatial_lat_min = -82.63541f ;
:geospatial_lon_max = 179.364f ;
:geospatial_lon_min = -177.912f ;
:file_quality_index = 1 ;
:comment = "" ;
:processing_level = "AUX_METEO" ;
:publisher_email = "" ;
:publisher_name = "" ;
:publisher_url = "" ;
:summary = "" ;
:start_orbit_number = 23764 ;
:stop_orbit_number = 23765 ;
:equator_crossing_longitude = 85.61f ;
:equator_crossing_date = "2023-02-16T13:11:04Z" ;
:cycle = "121_2023-02-08T10:00:20Z_2023-02-21T09:59:16Z" ;
```

```
:trace = "246_2023-02-16T11:59:46Z_2023-02-16T12:47:16Z/247_2023-02-16T12:47:16Z_2023-02-16T13:34:47Z" ;
:swim_acquisition_mode = "nominal" ;
:ground_station = "KRX" ;
:antenna = "rotated" ;
:cdb_version = "23_32" ;
:input_files =
"TMP_OP06_SWI_L1A____F_20230216T120104_20230216T131916.nc\nCFO_OPER_CNF_FECMWF_20161122T000000_001.txt\nCFO_OPER_AUX_SWICDB_F_23_32_20160101T010000.bin\nCFO_OPER_AUX_AECMFF_F_20230216T090000_20230217T000000.grb\nCFO_OPER_AUX_WECMFF_F_20230216T090000_20230217T000000.grb" ;
:source = "CFOSAT CWWIC SWIM AUX_METEO processor" ;
:ECMWF_start_forecast = "2023-02-16T09:00:00Z" ;
:ECMWF_end_forecast = "2023-02-17T00:00:00Z" ;
:interpolation_mode = 1 ;
:coeff_atm_corr = "0.094000;-0.177000;-0.145000;0.274000;0.001450;0.000007;0.169000" ;
:macrocycle_angle = "0;2;4;6;8;10" ;
:macrocycle_beam = "0;1;2;3;4;5" ;
:_NCProperties = "version=2,netcdf=4.7.4,hdf5=1.12.0," ;
:GMF_version = "GMF_20191101_20201101_1y_ice" ;
:title = "SWIM_L2ICE____product" ;
:contact = "cedric.tourain@cnes.fr" ;
}
```

## 5.3 ICE L2G files

```
netcdf CFO_OP06_SWI_ICEL2G_F_20240117T000000_20240118T000000 {
dimensions:
	nlat = 360 ;
	nlon = 720 ;
variables:
	float lat(nlat) ;
		lat:units = "degrees_north" ;
		lat:long_name = "latitude" ;
	float lon(nlon) ;
		lon:units = "degrees_east" ;
		lon:long_name = "longitude" ;
	double p_ice_mean(nlat, nlon) ;
		p_ice_mean:_FillValue = NaN ;
		p_ice_mean:long_name = "mean probability of ice" ;
		p_ice_mean:valid_min = 0. ;
		p_ice_mean:valid_max = 1. ;
	double p_ice_max(nlat, nlon) ;
		p_ice_max:_FillValue = NaN ;
		p_ice_max:long_name = "maximum probability of ice" ;
		p_ice_max:valid_min = 0. ;
		p_ice_max:valid_max = 1. ;
	double p_ice_min(nlat, nlon) ;
		p_ice_min:_FillValue = NaN ;
		p_ice_min:long_name = "minimum probability of ice" ;
		p_ice_min:valid_min = 0. ;
		p_ice_min:valid_max = 1. ;

// global attributes:
		:institution = "CNES" ;
		:GMF_version = "GMF_20191101_20201101_1y_ice" ;
		:references = "DDI CFOSAT - Ref. CF_GSFR-ICD-1094-CNES" ;
```

```
            :platform = "CFOSAT" ;
            :sensor = "SWIM" ;
            :generator_center = "FROGS" ;
            :title = "SWIM_ICEL2G____product" ;
            :contact = "cedric.tourain@cnes.fr" ;
}
```

## Bibliography

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[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, C., Longépé, N., Mouche, A., Tison, C., Tourain, C., Lachiver, J.-M., & Hauser, D. (2022). Sea-ice detection from near-nadir Ku-band echoes from CFOSAT/SWIM scatterometer. Earth and Space Science, 9, e2021EA002046. https://doi.org/10.1029/2021EA002046