CFOSAT SCAT Sea ice Product (SCA_L3ICE_)

Product User Manual

Ifremer Wind & Wave Operational Center

Modifications

Ver.	Rev.	Date	Object
1	0	22/02/2022	Document creation (version 1)

Table of Contents

Open points......6

1 Introduction......7

1.1 Introduction......7

1.2 Document overview......7

1.3 Acronyms and definitions......7

1.3.1 Acronyms......7

1.3.2 Definitions......8

1.3.3 Mathematical notations......8

1.4 Documentation......10

1.4.1 Reference documents......10

2 General overview of mission and instrument......11

2.1 CFOSAT mission......11

2.2 SCAT Instrument......12

3 General overview of SCAT Sea Ice L3 processing......14

3.1 Grid......14

3.2 Inputs data......15

3.3 Processing......16

3.4 Output data......17

3.5 Data volume......18

4 Format......19

4.1 File naming......19

4.2 Content......19

Index of Figures

Figure 1: Illustration of SCAT swath and footprint..12

Figure 2: Maps of sea ice grid spatial coverage in Arctic (left) and Antarctic (right). From NSIDC documentation...14

Figure 3: Processing diagram of the SCAT L3 sea ice product.......................................17

Index of Tables

Table 1: Acronyms....8

Table 2: Definitions....8

Table 3: Mathematical notations....9

Table 4: Reference documents....10

Table 5: Scatterometer system parameters....13

1 Introduction

1.1 Introduction

This document describes the product content and the physical and mathematical description of the processing algorithms of the CFOSAT Scatterometer Sea Ice product (SCA_L3ICE_) generated at Ifremer Wind and Wave Operation Center (IWWOC).

1.2 Document overview

The structure of the document is as follows:

- Chapter 1 gives information about acronyms, definitions, mathematical notations and reference documents.
- Chapter 2 presents the CFOSAT mission context and the SWIM instrument.
- Chapter 3 contains the general description of SCA_L3ICE_ processing.
- Chapters 4 to 8 describe in detail the different steps of the SCA_L3ICE_ processing.
- Chapter 9 gives information about the format and content the SCA_L3ICE_ product.

1.3 Acronyms and definitions

1.3.1 Acronyms

Acronym	Signification
CERSAT	Centre ERS d'Archivage et de Traitement (Ifremer)
CFOSAT	China France Oceanography SATellite
CNES	Centre National d'Études Spatiales
CNSA	Chinese National Space Administration
CWDP	Cfosat Wind Data Processor
CWWIC	CNES Waves & Wind Instrument Center
FROGS	FRench Oceanographic Ground Segment
GMF	Geophysical Model Function
Ifremer	Institut Francais de Recherche pour l'Exploitation de la Mer
IRF	Impulse Response Function
IWWOC	Ifremer Wind & Wave Operational Center
LUT	LookUp Table
MTF	Modulation Transfer Function
NRCS	Normalized Radar Cross-Section
NRT	Near Real-Time
PRF	Pulse Repetition Frequency
SCAT	Rotating Fan-beam SCATterometer
SST	Sea Surface Temperature
SWIM	Surface Waves Investigation and Monitoring
TBC	To Be Confirmed
TBD	To Be Defined

WVC	Wind Vector Cell

Table 1: List of acronyms

1.3.2 Mathematical notations

Notation	Definition	Units
	Sea-ice concentration	%
	Slant range resolution	m
	Ground range resolution	m
	Effective ground range resolution	m
	Wavenumber spacing	rad/m
	Azimuth spacing	rad
	Slant range spacing	m
	NRCS fluctuations	*unitless*
	Ground range spacing	m
	Bathymetry elevation	m
	Significant wave height	m
	Wavenumber	rad/m
	Partition label	*unitless*
	Wavelength	m
	Number of range gates used for on-board average	*unitless*
	Ground range coverage	m
	Footprint azimuthal ground length (at 3dB)	m
	number of pulses used for on-board average	*unitless*
	Number of wavenumbers	*unitless*
	Number of pixels in slant range dimension	*S2-LPunitless*
	Number of pixels in ground range dimension	*unitless*

	Azimuth angle	rad
	NRCS (Normalized Radar Cross Section)	*unitless*
	NRCS trend	*unitless*
	Wave spectrum noise level	m^2
	Fluctuation spectrum	m
	Impulse response spectrum	*unitless*
	Wave slope spectrum	m^2
	Speckle spectrum	m
	Modulation spectrum	m
	MTF (Modulation Transfer Function)	m^{-1}
	Incidence angle	rad
	Incidence angle at middle swath	rad
	Wind speed	m/s

Table 2: List of notations

1.4 Documentation

1.4.1 Reference documents

Notation	**Reference**
[RD1]	CFOSAT RFSCAT L1B Product Format Specification Risheng Yun
[RD2]	Arctic & Antarctic sea ice concentration and Arctic sea ice drift estimated from special sensor microwave data

	User's manual, version 2.1, February 2007 Robert Ezraty, Fanny Girard-Ardhuin, Jean-François Piollé
[RD3]	Ezraty, R., A. Cavanié, 1999: Intercomparison of backscatter maps over Arctic sea ice from NSCAT and the ERS scatterometer. J. Geophys. Res., vol 104, pp 11471-11483
[RD4]	Gohin, F. and A. Cavanie, 1994: A first try at identification of sea ice using the three beam scatterometer of ERS-A. I*nt. J. Remote Sensing*, vol 15, 6, pp 1221-1228
[RD5]	Pearson, 1990. *Map projections: theory and applications*. CRC Press. Boca Raton, Florida. 372 pages
[RD6]	Remund, Q.P., D.G. Long, 1999: Sea ice extent mapping using Ku band scatterometer data. J. Geophys. Res., vol 104, pp 11515-11527
[RD7]	Zec, J., D.G. Long, W.L. Jones, 1999: NSCAT normalized radar backscattering coefficient biases using homogeneous land targets. J. Geophys. Res., vol 104, pp 11557-11568

Table 3: List of reference documents

2 General overview of mission and instrument

2.1 CFOSAT satellite mission

The CFOSAT program is carried out through the cooperation between French and Chinese Space Agencies (CNES and CNSA respectively). CFOSAT aims at characterizing the ocean surfaces to better model, predicting the ocean states and improving the knowledge in ocean / atmosphere exchanges. The CFOSAT products help for marine and weather forecast and for climate monitoring.

The CFOSAT satellite embarks two payloads: SCAT, a wind scatterometer, and SWIM, a wave scatterometer to allow joint characterization of ocean surface winds and waves.

The SCAT instrument delivered by CNSA is dedicated to the global ocean vector wind measurement. The SWIM instrument delivered by CNES is dedicated to the measurement of the directional wave spectrum (height, direction and periodicity of waves). As parts of the French ground segment (FROGS managed by CNES), CNES and Ifremer deliver SCAT and SWIM products:

- NRT instrumental and geophysical products (L0 to L2) are processed at CWWIC (CNES). The data must be provided to users (meteorology agencies mainly) in NRT, i.e. in less than three hours from the acquisition.
- delayed time geophysical products (L2 to L4) are processed at IWWOC.

Both instruments contribute by their own and together to improve knowledge in the following fields:

- directional wave spectrum
- modeling and prediction of ocean surface wind and waves
- physical processes associated with surface wave evolution
- wind wave interactions
- interactions between surface waves and atmosphere or ocean
- wave evolution in coastal region
- polar ice sheet and marginal ice zones
- sea ice and iceberg movement monitoring
- land surfaces (surface soil moisture, soil roughness...)

2.2 SCAT Instrument

SCAT is another payload of CFOSAT. On-board Ku-band (13.256GHz) rotating fan-beam is able to measure the wind field over the ocean through electromagnetic backscatter. This rotating fan-beam concept combines the advantages of fixed fan-beam and rotating pencil-beam designs. The fan-beam rotates when the satellite passes over the ocean such that its footprint sweeps a donut-shape on the observed surface. The footprint is also called as pulse and each pulse contains multiple slices (Figure 1). The coverage swath is more than 1100 km width and gives multiple views with various geometry at one WVC.

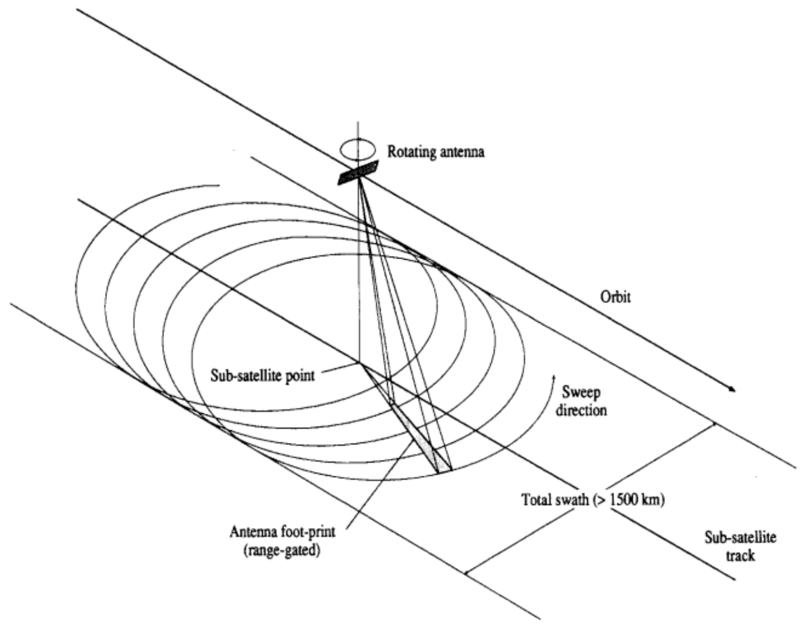

Figure 1: SCAT scanning geometry

The list of SCAT principle parameters is shown in the following table:

Frequency	Ku band (13.256 GHz)
Swath	1140 km
Footprint	320 km
Antenna scanning speed	0.356 rad/s
Pulse bandwidth	0.5 MHz

Polarization	VV and HH alternating
Incidence angle range	25.0~47.6 deg
Transmit power at HPA	120 W
WVC resolution	25 km
Duration of transmit pulse	1.35 ms
Duration of receiving pulse	2.70 ms
Time offset of receive window	3.88 ms
Pulse repetition frequency	75 Hz
Pulse bandwidth	0.5 MHz
Antenna pointing angle	40 deg

Table 4: SCAT instrument properties

3 General overview of SCAT Sea Ice L3 processing

Backscatter values over sea ice are a function of incidence angle and the sea ice type. With several SCAT incidence measurements, an incidence adjustment is mandatory over sea ice (Gohin and Cavanié 1994) to map daily averaged backscatter values accurately for geophysical use as it was done for the NSCAT Ku-band sensor. An incidence-adjustment backscatter map at 40° incidence angle is thus built in order to have reliable daily averaged backscatter maps.

Sea ice roughness from backscatter can be used later for sea ice displacement maps, sea ice type detection, sea ice edge. In the case of CFOSAT, the HH and VV polarization ratio will be used for sea ice studies, in particular sea ice edge criteria and ice type classification.

3.1 Grid

The backscatter data will be projected over a 12.5 km x 12.5 km on a stereo polar grid (Pearson 1990) which is commonly used by CERSAT data over the pole or the NSIDC (USA).

The Arctic & Antarctic concentration grids at 12.5 km resolution are presented in figure x. These are polar stereographic projections, the projection plane is tangent to the earth at 70°N latitude so that little or no distortion would occur in the ice zone.

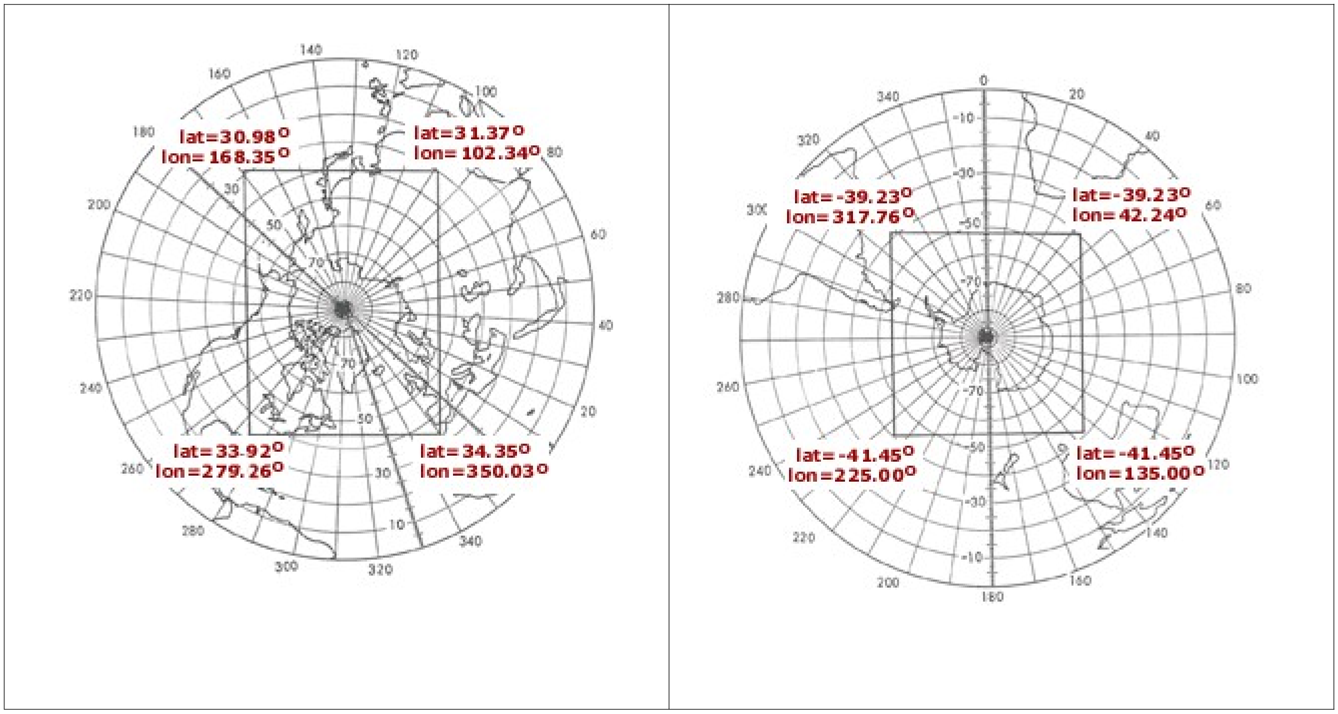

Figure 2: Definition of the used polar grids

3.2 Inputs data

The input data are the CFOSAT SCAT L1B passes collected over one day, from which the following variables are used:

- slice sigma0
- slice latitude
- slice longitude
- times
- slice incidence angles
- slice azimuth angles
- slice Kp

Note that the HH and VV files are processed separately in two different maps for each pole.

Ancillary sea concentration daily maps from SSM/I radiometer, produced at CERSAT, are also used for a better sea ice edge/open ocean mask.

All the sigma0 L1B data are selected at both polarizations, except those for which Kp is higher than 4% (to be tested and confirmed). The daily averaged backscatter maps at a resolution grid of 12.5 x 12.5 km (if possible) are built from the L1B data, incidences angles and Kp values.

Azimuth angles and time of the day are not used in the processing but are retained for future research studies into intermediate files separated over Arctic and Antarctic areas.

3.3 Processing

The main idea of this step is to re-normalize SCAT observation to present constant incidence σ^0 dataset suitable for the use over sea ice on both hemispheres. 40° is chosen for the reference incidence angle (mid-swath) to be consistent with NSCAT Ku band data over sea ice (Ezraty and Cavanié 1999 for example), and previous works and datasets available from ERS (Gohin and Cavanie,1994).

$\sigma^0{}_{40}$ refers to this averaged σ^0 at 40° constant adjusted incidence. This adjustment is estimated using the mean slope resulting of the study of the dependence of the backscatter values to the incidence angles as it was done by Gohin and Cavanie (1994), or Remund and Long (1999).

It is typically useful to parameterize the dependence of σ^0 on incidence angles. Over the incidence angle range, typically 25° to 60°, the range of incidence angles used by scatterometers, sigma0 in dB can be approximately expressed as a linear function of incidence angle θ as :

$$\sigma^0 = A + B(\theta - \theta_{40})$$

where A and B depends on sea ice properties, azimuth angles and polarization. θ_{40} is the reference angle (here 40°).

The estimate should be done using dB values because A and B provide valuable information about surface parameters (Remund and Long, 1999).

To ensure enough data for the linear regression, we resample the data over 25 km x 25 km grid cells and report the results at 12.5 km x 12.5 km grid cells. We search the mean B parameter (=$d\sigma^0/d\theta$ slope at 25 km, referred to as m_{25km}) at each 25km grid cell and we apply it on the data at 12.5 km:

$$\sigma^0{}_{40}[12.5\ km] = \sigma^0{}_{\theta}[12.5\ km] + m_{25km}(\theta - \theta_{40})$$

Each averaged backscatter value in a grid cell is weighted by the inverse of the relative noise Kp (represents the standard deviation of the noise level of individual measurements).

For more details about this method, see Remund and Long (1999), Ezraty and Cavanié (1999), Zec and Long (1999).

The maps of $\sigma^0{}_{40}$ at 12.5 km are built as linear dB which is more practical to use and the other parameters can be inferred (standard deviation, flag, number of data per pixel). To infer the *masked* variables, the data are kept over the sea ice area only: for this, the sea ice extent will be estimated at 15% sea ice concentration as it is commonly used.

The final $\sigma^0{}_{40}$ are not estimated or a flag is set to *warning* if the slope is positive, the $\sigma^0{}_{40}$ in linear mode are negative or if the number of samples per grid cell is less than 2.

Here is the processing chain below:

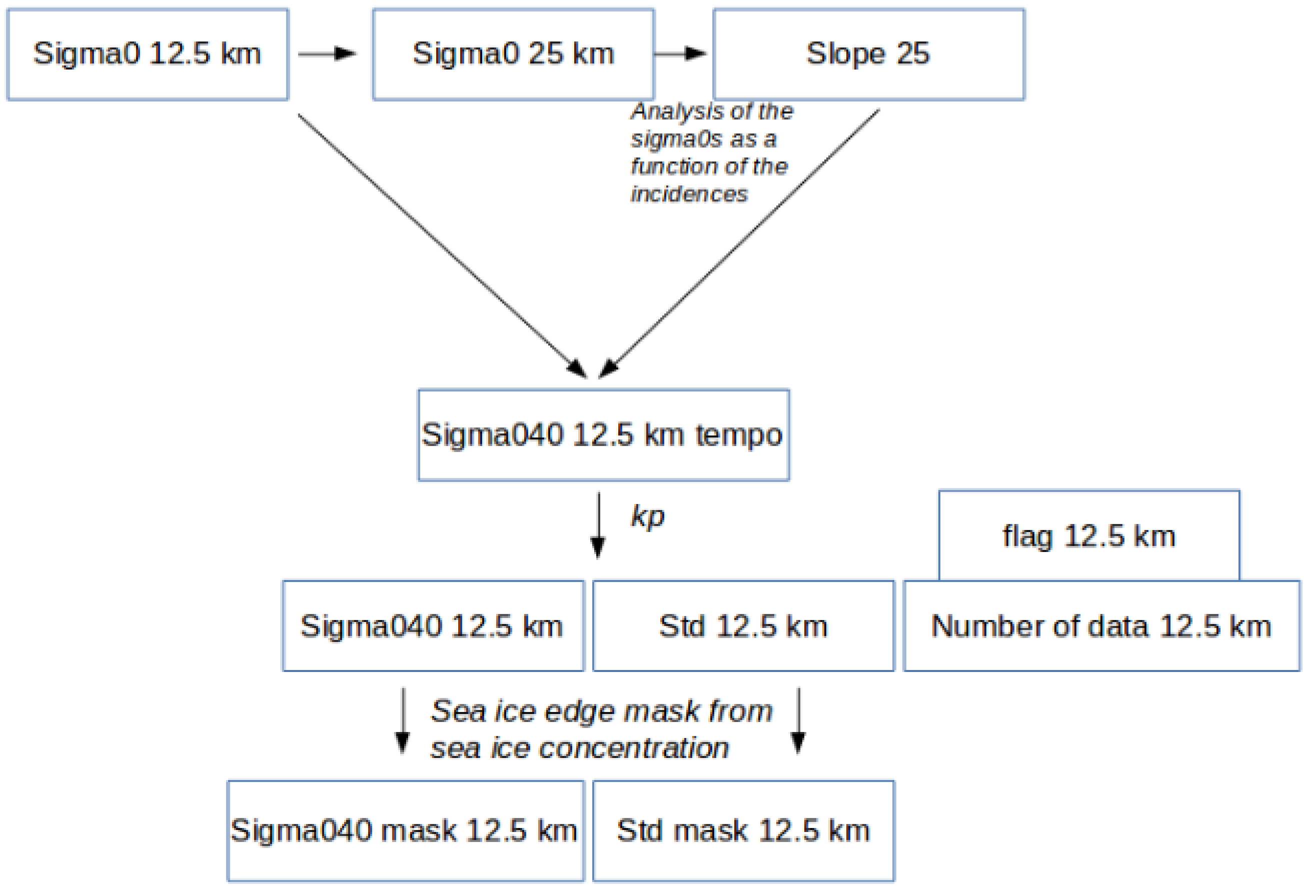

Figure 3: Processing workflow

This workflow is applied to each pole (Arctic/Antarctic) and polarization (HH/VV).

3.4 Output data

There is one file per pole (Arctic/Antarctic) and per polarization (HH/VV).

The output variables in each product files are:

- the $\sigma^0{}_{40}$ at 40° incidence over the polar area for the given polarization
- a flag mask discriminating the sea-ice / open water / land areas and giving the processing status (invalid, warning), for the given polarization
- the standard deviation of the $\sigma^0{}_{40}$ within each grid cell over the polar area for the given polarization

- the number of σ^0 used in each grid cell for the given polarization
- the slope $d\sigma^0/d\theta$ for the given polarization

Users with interest only on sea-ice should apply the provided sea-ice/open water mask to the data. If their interest is in the sea-ice edge or marginal ice zone, they should not use this mask. The standard deviation of the $\sigma^0{}_{40}$ can be used as an indicator of sea ice edge, showing the anisotropy of the σ^0 within the grid cells on a daily basis

We aim at providing 12.5 km grid resolution maps, but in case the resolution is too coarse, we would adapt our algorithm to a final 25 km grid resolution.

4 Data format and access

The product files are in NetCDF4 format, following the same conventions as other IWWOC products, complying to standard CF-1.7 and ACDD conventions.

Each file is about 24 MB daily for both hemispheres and polarizations.

4.1 File naming

The file nomenclature is as follow:

```
CFO_OPER_SCA_L3ICE__F_<YYYYMMDDTHHMMSS>_<YYYYMMDDTHHMMSS>_<pole>_<spatial_resolution>_<polarization>_<version>.nc
```

where:

- <YYYYMMDDTHHMMSS> are the start and end date/time of the product's temporal coverage in ISO format
- <pole> is the covered pole area (NORTH for Arctic, SOUTH for Antarctic)
- <spatial_resolution> is the grid resolution (012 for 12.5km)
- <polarization> is the polarization of the averaged σ^0 (HH or VV)
- <version> as x.y.z (ex: 0.1.0)

Typically, for one day there will be four files named as follow:

- CFO_OPER_SCA_L3ICE__F_20201001T000000_20201001T235959_NORTH_012_HH_0.1.0.nc
- CFO_OPER_SCA_L3ICE__F_20201001T000000_20201001T235959_NORTH_012_VV_0.1.0.nc
- CFO_OPER_SCA_L3ICE__F_20201001T000000_20201001T235959_SOUTH_012_HH_0.1.0.nc
- CFO_OPER_SCA_L3ICE__F_20201001T000000_20201001T235959_SOUTH_012_VV_0.1.0.nc

4.2 Content

Here is an example of the structure for one day file over the Arctic area for one polarization.

```
netcdf
CFO_OPER_SCA_L3ICE__F_20201001T000000_20201001T235959_NORTH_012_HH_0.1.0 {
dimensions:
	y = 896 ;
	x = 608 ;
	time = 1 ;
variables:
	double lat(y, x) ;
		lat:_FillValue = 1.e+20 ;
		lat:axis = "Y" ;
		lat:standard_name = "latitude" ;
	double lon(y, x) ;
		lon:_FillValue = 1.e+20 ;
		lon:axis = "X" ;
		lon:standard_name = "longitude" ;
	int64 time(time) ;
		time:_FillValue = -9223372036854775808LL ;
		time:axis = "T" ;
		time:standard_name = "time" ;
		time:units = "days since 2020-10-01 00:00:00" ;
		time:calendar = "proleptic_gregorian" ;
	float backscatter_at_inc_40(y, x) ;
		backscatter_at_inc_40:_FillValue = 1.e+20f ;
		backscatter_at_inc_40:long_name = "linear backscatter in sea ice
areas adjusted at incidence angle of 40 degrees" ;
		backscatter_at_inc_40:units = "1" ;
		backscatter_at_inc_40:coordinates = "lon lat" ;
	float standard_deviation(y, x) ;
		standard_deviation:_FillValue = 1.e+20f ;
		standard_deviation:long_name = "standard deviation of
backscatter values within each pixel" ;
		standard_deviation:units = "1" ;
		standard_deviation:coordinates = "lon lat" ;
	float nb_samples(y, x) ;
		nb_samples:_FillValue = 1.e+20f ;
		nb_samples:long_name = "number of backscatter values averaged
within eachpixel" ;
		nb_samples:units = "1" ;
```

```
		nb_samples:coordinates = "lon lat" ;
	double sea_ice_fraction(y, x) ;
		sea_ice_fraction:_FillValue = 1.e+20 ;
		sea_ice_fraction:standard_name = "s" ;
		sea_ice_fraction:authority = "CF-1.7" ;
		sea_ice_fraction:long_name = "sea ice fraction from SSM/I" ;
		sea_ice_fraction:units = "1" ;
		sea_ice_fraction:coordinates = "lon lat" ;
	float flags(y, x) ;
		flags:_FillValue = 1.e+20f ;
		flags:flag_masks = 1b, 2b ;
		flags:flag_meanings = "sea_ice land" ;
		flags:long_name = "flags" ;
		flags:coordinates = "lon lat" ;

// global attributes:
		:Conventions = "CF-1.7, ACDD-1.3, ISO 8601" ;
		:id = "CFO_IWWOC_SCA_L3ICE_1D_012_ARC_HH" ;
		:title = "CFOSAT SCAT 12.5km Arctic Sea-Ice Backscatter Maps in HH polarization" ;
		:summary = "SCAT onboard CFOSAT Daily Arctic Level 3 Sea-Ice Backscatter Maps on 12.5km Polar Grid, in horizontal polarization" ;
		:keywords = "Oceans > Sea Ice > Ice Roughness" ;
		:acknowledgement = "These data were obtained from the Ifremer Wind and Wave Operation Center (IWWOC), at IFREMER/CERSAT, Plouzane (France)" ;
		:license = "free and open access and usage" ;
		:format_version = "2.0" ;
		:product_version = "1.0" ;
		:processing_level = "L3" ;
		:history = "Created with CERSAT Sea-Ice processor v2.0" ;
		:program = "CFOSAT" ;
		:project = "FROGS/IWWOC" ;
		:publisher_name = "CERSAT" ;
		:publisher_url = "http://cersat.ifremer.fr" ;
		:publisher_email = "cersat@ifremer.fr" ;
		:publisher_institution = "Ifremer" ;
		:publisher_type = "institution" ;
		:creator_name = "FROGS/IWWOC" ;
		:creator_url = "http://cersat.ifremer.fr" ;
		:creator_email = "cersat@ifremer.fr" ;
```

```
		:creator_institution = "Ifremer,CNES" ;
		:creator_type = "institution" ;
		:contributor_name = "CNES" ;
		:contributor_role = "funding" ;
		:references = "http://archimer.ifremer.fr/doc/2009/acte-6970.pdf" ;
		:source = "SCAT L1B - CFOSAT [CNSA]" ;
		:source_version = "" ;
		:platform = "CFOSAT" ;
		:platform_type = "low earth orbiter" ;
		:platform_vocabulary = "CEOS" ;
		:instrument = "SCAT" ;
		:instrument_type = "scatterometer" ;
		:instrument_vocabulary = "CEOS" ;
		:band = "Ku" ;
		:polarization = "HH" ;
		:spatial_resolution = "12.5 km" ;
		:time_coverage_resolution = "P1D" ;
		:processing_software = "CERSAT Sea-Ice processor v2.0" ;
		:geospatial_bounds = "POLYGON ((-180. 90., -180. 60., 180. 60., 180. 90., -180. 90.))" ;
		:geospatial_bounds_crs = "EPSG:3411" ;
		:scientific_support_contact = "Fanny Ardhuin (fardhuin@ifremer.fr)" ;
		:technical_support_contact = "cersat@ifremer.fr" ;
		:time_coverage_start = "2020-10-01T00:00:00Z" ;
		:time_coverage_end = "2020-10-01T00:00:00Z" ;
		:naming_authority = "fr.ifremer.cersat" ;
		:Metadata_Conventions = "Climate and Forecast (CF) 1.7, Attribute Convention for Data Discovery (ACDD) 1.3" ;
		:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention" ;
		:keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science Keywords" ;
		:institution = "Institut Francais de Recherche et d\'Exploitation de la Mer/Centre de Recherche et d\'Exploitation satellitaire" ;
		:institution_abbreviation = "ifremer/cersat" ;
		:geospatial_lat_units = "degrees" ;
		:geospatial_lon_units = "degrees" ;
		:geospatial_vertical_units = "meters above mean sea level" ;
```

```
            :geospatial_vertical_positive = "up" ;
            :date_created = "2020-10-21T05:33:05Z" ;
            :date_modified = "2020-10-21T05:33:05Z" ;
}
```

4.3 Access

The CFOSAT sea-ice data can be accessed from Ifremer both through FTP and HTTPS:

For FTP:

ftp://ftp.ifremer.fr/ifremer/cersat/projects/iwwoc/

For HTTPS:

https://data-cersat.ifremer.fr/projects/iwwoc/sca_l3ice_/

No login or password is required but you are encouraged to register at:

https://forms.ifremer.fr/lops-siam/access-to-iwwoc-cfosat-data/

Registering allows us to know about our data usage and to notify you in case of major changes or updates.