Level-2 SAR Ocean Surface Wind Products
Application to Tropical Cyclones

CYMS
with Sentinel-1

Product User Manual

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1 Introduction

This document is the user manual for the Synthetic Aperture Radar Ocean Surface Wind Level-2 product developed and processed by CLS/IFREMER.

1.1 Summary

The following products are delivered and are detailed in this user manual:

- SAR Ocean Surface Wind along track Level-2 product based on Radarsat-2, Sentinel-1A and Sentinel-1B measurements.
- SAR Ocean Surface Wind gridded Level-2 product based on Radarsat-2, Sentinel-1A and Sentinel-1B measurements.

They are produced in Near-Real-Time and available in an archive to ensure an homogeneous processing of archived data.

1.2 History of changes

July 2020: This version of this product has been created in May 2020. Details regarding the algorithms can be found in scientific papers [R1, R2, R3].

2 Description of the product specification

2.1 General information about the product

Table 1 - SAR Ocean Surface Wind along track Level-2 product

Product Name	L2 SARWND SWATH
Coverage	Global (Ocean) depending on SAR acquisition plan
Variables	Ocean surface wind speed [m/s] Ocean surface wind direction [deg]
Update frequency	• Operational NRT mode: Data-driven • Archive mode: N/A
Target delivery time	• Operational NRT: 1 hour after Copernicus Services Data Hub (cophub) availability • Archive mode: N/A
Temporal resolution	Instantaneous. One file contains few minutes of measurements
Horizontal resolution	3 km
Number of vertical levels	Surface only
Format	NetCDF-4

Table 2 - SAR Ocean Surface Wind gridded Level-2 product

Product Name	L2 SARWND GRIDDED
Geographic Coverage	Global (Ocean) depending on SAR acquisition plan
Variables	Ocean surface wind speed [m/s] Ocean surface wind direction [deg]
Update frequency	• Operational NRT mode : Data-driven • Archive mode: N/A
Target delivery time	• Operational NRT: 1 hour after CopHub availability • Archive mode : N/A
Temporal resolution	Instantaneous. One file contains few minutes of measurements

Horizontal resolution	3 km
Number of vertical levels	Surface only
Format	NetCDF-4

2.2 Details of dataset

Table 3 – Details of dataset : SARWND SWATH

L2 SARWND SWATH	
Variables names	**Long names**
time	Seconds since 1970-01-01 00:00:00
lon	Longitude at wind cell center
lat	Latitude at wind cell center
wind_speed	Ocean 10m Wind speed from co- and cross-polarization
wind_from_direction	Wind from direction (meteorological convention)
wind_streaks_orientation	Estimation of wind streaks orientation (180° ambiguity) based on local gradient method
wind_streaks_orientation_stddev	Estimation of the statistical error on the wind streaks orientation [R4].
mask_flag	Mask of data. Flag meaning : 0:valid 1:land 2:ice 3:no_valid
nrcs_detrend_co	Co-polarized Normalized Radar Cross Section detrended from incidence angle (nice display)
nrcs_detrend_cross	Cross-polarized Normalized Radar Cross Section detrended from incidence angle (nice display)
heterogeneity_mask	Heteroegenity mask. Flag meaning: homogeneous_NRCS, heterogeneous_from_co-polarization_NRCS, heterogeneous_from_cross-polarization_NRCS, heterogeneous_from_dual-polarization_NRCS

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nrcs_co	Co-polarized Normalized Radar Cross Section
nrcs_cross	Cross-polarized Normalized Radar Cross Section
elevation_angle	Elevation Angle at wind cell center
incidence_angle	Incidence angle at wind cell center

Table 4 – Details of dataset : SARWND GRIDDED

SARWING GRIDDED	
Variables names	**Long names**
time	Seconds since 1970-01-01 00:00:00
Y	projection_y_coordinate (Northing)
X	projection_x_coordinate (Easting)
lon	Longitude at wind cell center
lat	Latitude at wind cell center
wind_speed	Ocean 10m Wind speed from co- and cross-polarization
wind_from_direction	Wind from direction (meteorological convention)
mask_flag	Mask of data. Flag meaning : 0:valid 1:land 2:ice 3:no_valid
nrcs_detrend_co	Co-polarized Normalized Radar Cross Section detrended from incidence angle (nice display)
nrcs_detrend_cross	Cross-polarized Normalized Radar Cross Section detrended from incidence angle (nice display)
heterogeneity_mask	Heteroegenity mask. Flag meaning: homogeneous_NRCS, heterogeneous_from_co-polarization_NRCS, heterogeneous_from_cross-polarization_NRCS, heterogeneous_from_dual-polarization_NRCS
wind_streaks_orientation	Estimation of wind streaks orientation (180° ambiguity) based on local gradient method

wind_streaks_orientation_stddev	Estimation of the statistical error on the wind streaks orientation
nrcs_co	Co-polarized Normalized Radar Cross Section
nrcs_cross	Cross-polarized Normalized Radar Cross Section
elevation_angle	Elevation Angle at wind cell center
incidence_angle	Incidence angle at wind cell center

2.3 Product System Description

2.3.1 Overview

SAR ocean wind field Level-2 products are computed from Level-1 products acquired in wide swath modes for Sentinel-1 and Radarsat-2 missions.

Each SAR ocean wind field corresponds to the instantaneous wind field measured at the SAR acquisition time.

- The SARWING SWATH product is processed on a grid orientated along the satellite swath and regular in the image domain. Default resolution is 3 km and pixel spacing is 1 km.
- The SARWING GRIDDED product is processed on a regular grid.

SAR acquisition may be performed everywhere, they are strongly driven by each SAR mission acquisition strategy:

- Sentinel-1 missions follow an acquisition plan. See here for Sentinel-1 missions.
- Radarsat-2 mission is commercial, and data may be directly ordered to MDA corporation.

Contiguous SAR acquisitions are systematically gathered by the system to build a single Level-2 product.

2.3.2 Processing chain usage

There are three different ways of using the SAR wind Level-2 product processing chain:

1. **Processing or the reprocessing of an existing dataset at CLS or IFREMER:** In this case a given Level-1 product dataset is identified and used as input of the processing chain to produce a corresponding Level-2 dataset. When Level-1 products are contiguous they are merged into a single Level-2 product (optional). These Level-2 products are disseminated.
2. **Building and processing of a new dataset from archive.** SAR Level-1 data can be obtained from the Copernicus archive, MDA or scientific collaborations. In this case, there is a preliminary stage to collect the Level-1 data. Once this is done, we are back to case 1 which is the processing of an existing dataset. Level-2 product are processed and disseminated.
3. **Building and processing of a dataset based on operating SAR systems.** Level-1 data are routinely and automatically downloaded after being acquired and made available on Copernicus Hub. Level-1 products are then automatically processed into Level-2 products and disseminated

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2.3.3 Processing chain example

CYMS: CYMS (https://www.esa-cyms.org/) is a ESA-funded project aiming at scaling up an operational service for Tropical Cyclone monitoring with Sentinel-1, in view of its potential integration as part of a Copernicus Service. For CYMS, the processing chain usage corresponds to both cases 3 and 1 presented in the previous section.

5-day Tropical track forecasts from operational meteorological agencies are used to order specific Sentinel-1 and Radarsat-2 acquisitions. Once Level-1 products are made available, they are automatically processed into Level-2 (case 1) and disseminated (eoda.cls.fr). More generally SAR Tropical Cyclone data obtained from CYMS and other means, are gathered in a Tropical Cyclone archive database of Level-1 and Level-2 products. The processing of both levels is maintained homogeneous and Level-2 products re-processed when significant updates are available (case 3). The archive is also disseminated (cyclobs.ifremer.fr).

2.4 Processing information

2.4.1 Update Time

Once the dataset to be processed is identified, the processing is fully data-driven. Each product contains the acquisition time (i.e. measurement time) and the processing time.

In the case of archive processing and reprocessing, update time is N/A. In the case where the processing chain deals with SAR data acquired by operating SAR missions, the update time is driven by each SAR mission acquisition plan. Overall, once a data is acquired, we target the dissemination of the Level-2 product in less than 1 hour.

2.4.2 Temporal Extent

It depends on the dataset considered for the processing. The system relies on Level-1 SAR data from Radarsat-2, Sentinel-1A and Sentinel-1B missions respectively launched in 2007, 2014 and 2016. The three of them are still active.

For a given SAR acquisition, the time extent is usually around 1 minute. For instance, to avoid distributing unwieldy products to end users, the Sentinel-1 Level-0 and Level-1 products are segmented into slices of defined length along a track. Slices are approximately 25 seconds in length for SM and IW and approximately 60 seconds in length for EW. Our Level-2 products are disseminated after gathering contiguous slices, yielding to time extent for a given Level-2 product up to minutes.

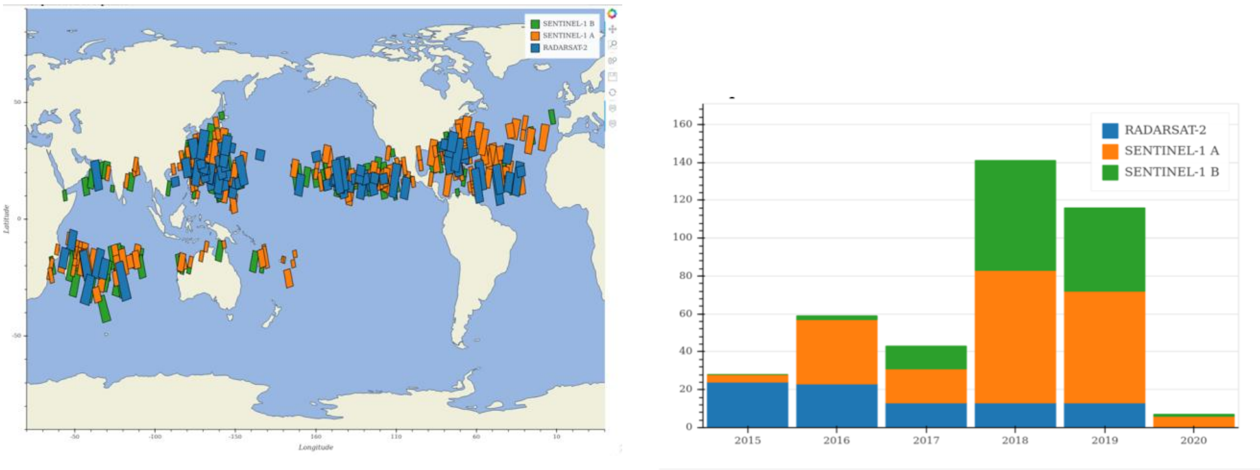
2.4.3 Time/Space averaging

There is no time averaging. The Ocean surface wind Level-2 products are instantaneous measurements.

There is a space averaging. Indeed, SAR Level-1 products are much higher resolution (typically tens of meter) than SAR Ocean surface wind Level-2 products. Indeed, the normalized radar cross section as measured by each SAR is averaged over few kilometers (default is 3 km for SARWND_SWATH product) to reduce speckle noise.

2.4.4 Dataset exemples

Tropical Cyclones dataset (CYMS): It contains SAR data acquired over Tropical Cyclones. The database extent is 2017-present. The coverage is global as CYMS intends to provide SARWND products over all basins. The space averaging is 3km. A view of the database can be found here or below:



(a) *(b)*

Figure 1: Example of Ocean surface wind Level-2 product database (a) Coverage (b) Temporal extent

3 How to download a product

SAR Ocean surface wind products are disseminated through several schemes. This section explains to end-users can download the products through either CyclObs, EODA or an ftp.

3.1 Tropical Cyclone SAR wind product dissemination

3.1.1 Download a product through the CyclObs archive

There are two ways of downloading the data through CyclObs. None of them requires any registration. Details are given below or here

- *The Browser Solution*

CyclObs allows you to browse all SAR Ocean surface wind products over Tropical Cyclones. Data are stored with respect to Tropical cyclone names. For each Tropical page a link "Access data for this cyclone" is available to get access to the Level-2 products. A snapshot for Irma category-5 Tropical Cyclones CyclObs webpage is given below:

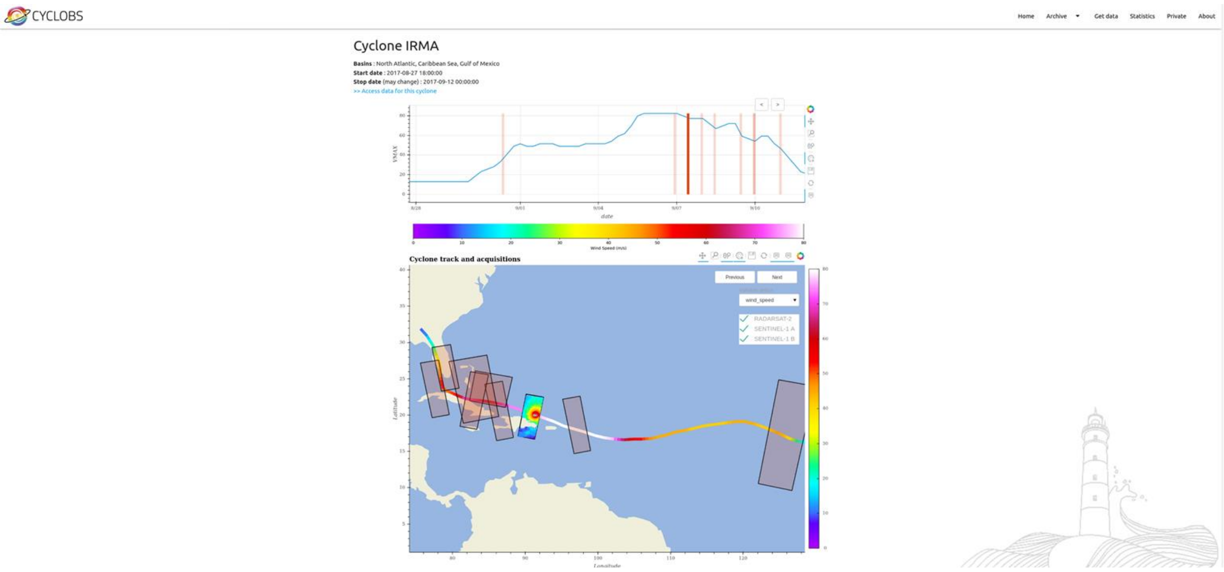


Figure 2 CyclObs webpage for Irma Tropical Cyclone. The link toward the SAR Ocean surface wind products for this particular cyclone is top left (blue).

- *The Command line solution*

Cyclobs allows you download the entire database or part of the database depending on time, location, Tropical cyclone name, intensity etc… using command lines. There are two steps : In a first step, the CyclObs Application Programming Interface (API) enables to retrieve meta-data characterizing satellite acquisitions and storms from CyclObs database. In a second step, the data are downloaded with respect to these meta-data.

CyclObs API

CyclObs API is used to retrieve a list of meta-data from our database. The API endpoint is an URL to be called from command line or a program to download the data. This argument is the key to specify what you will download. The CylObs API does not download the cyclone acquisitions, but only return a string in a csv-like format with comma as a separator, including information such as files location, cyclone ID etc…

The API base url is : https://cyclobs.ifremer.fr/app/api/getData

Building a customized API request URL to retrieve a cyclone acquisition list is a pre-requisite to download a customized set of data.

- URL building and testing

There are various endpoint parameters that you can use in the request URL to modify the output format and filter the results.

By entering the newly constructed URL in your browser, you can directly check if it is valid. If not, you should see an error explaining what's wrong. An invalid URL will return an HTTP status 400 along with an error string.

When you finally have the request URL you need, you can proceed on downloading the data.

- Exemples:
  - Acquisitions list for the Tropical Cyclone named IDA: We simply specify cyclone_name=IDAI in the URL arguments

URL = "https://cyclobs.ifremer.fr/app/api/getData?cyclone_name=IDAI"

  - Acquisitions list from the C-Band SAR instrument, the mission SENTINEL-1 A for the two Tropical Cyclones corresponding to storm identification code (sid for storm ID) wp202019 or sh182019

Note that this example also includes the following parameter include_cols=all argument. It allows to to return all the available columns in the output.

URL = "https://cyclobs.ifremer.fr/app/api/getData?sid=wp202019,sh182019&instrument=C-Band_Synthetic_Aperture_Radar&mission=SENTINEL-1_A&include_cols=all"

  - Acquisitions corresponding to only category-5 TC in one of the North Atlantic, North West Pacific or Norht East Pacific (NA,NWP and NEP) basins for the 2019 year.

URL = "https://cyclobs.ifremer.fr/app/api/getData?cat_min=cat-5&basin=NA,NWP,NEP&acquisition_start_time=2019-01-01&acquisition_stop_time=2019-12-31&include_cols=all"

- API endpoint parameters

include_cols : comma separated list to format the csv-like output to include the given columns. Options are: cyclone_name, sid, data_url, acquisition_start_time, instrument, mission, vmax, basin. Defaults to cyclone_name,data_url

cyclone_name : commma separated list to filter wanted cyclones. Defaults to all cyclones.

sid : commma separated list to filter wanted storm id. Defaults to all storm ids.

instrument : commma separated list to filter wanted instruments. Defaults to all instruments. To see available values go to https://cyclobs.ifremer.fr/app/api/allInstruments

mission : comma separated list to filter wanted missions. Defaults to all missions. To see available values go to https://cyclobs.ifremer.fr/app/api/allMissions

basin : commma separated list to filter wanted basins. Defaults to all basins. To see available values go to https://cyclobs.ifremer.fr/app/api/allBasins

acquisition_start_time : returned acquisitions returned will have acquisition start time above or equal to startdate. Format : YYYY-MM-DD. Defaults to no time limit

acquisition_stop_time : returned acquisitions returned will have acquisition stop time below or equal to stopdate. Format : YYYY-MM-DD. Defaults to no time limit

cat_min : minimum category (including the cat_min given limit) wanted for cyclone's acquisitions. Can be : dep, storm or cat-X with X from 1 to 5. Defaults to no category lower limit

cat_max : maximum category (excluding the cat_max given limit) wanted for cyclone's acquisitions. Can be : dep, storm or cat-X with X from 1 to 5. Defaults to no category higher limit. cat_max must be above cat_min

product_type : product type choice, either 'swatch' or 'gridded'. SMOS mission will be excluded when selecting gridded type because we currently only generate swath type products for SMOS. Defaults to 'swath'

nopath : if set (no value needed) only the filenames will be returned in the column data_url

noheader : if set (no value needed) the csv header line will not be set in the ouput

Downloading the data

Once the API URL has been build to specify the filelist to download, many options exist. An example in bash is given here

```
#!/bin/bash# first step is to build the api url

#we just ask for 'data_url', and disable csv header with 'noheader'url_request="https://cyclobs.ifremer.fr/app/api/getData?sid=sh182019&instrument=C-Band_Synthetic_Aperture_Radar&include_cols=data_url&noheader"

# make a cd to download directory

mkdir -p /tmp/cyclobs && cd /tmp/cyclobs

wget -q -O- "$url_request" | xargs -n1 wget  -N
```

3.2 Download a product through EODA near-real-time interface

There are two ways of downloading the data through EODA and through FTP

The Browser Solution

EODA allows you to browse all SAR Ocean surface wind products over Tropical Cyclones. A dedicated documentation is available [here.]()

The availability of NRT products will be available in the general “CYMS/CYMS service chain”. The Tropical Cyclones will be then archived in the “SHOC20xx/nameTC” architecture.

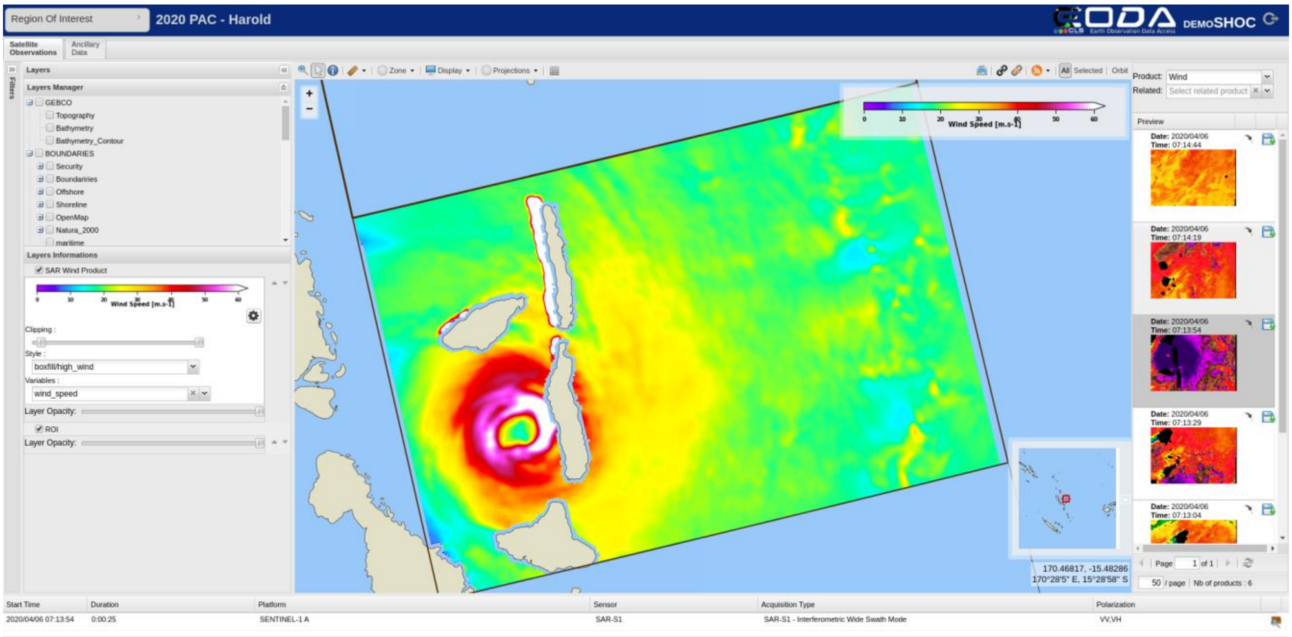


Figure 3 EODA webGIS with available products to download (see floppy disk icon on the right panel)

The FTP solution

The NRT processing chain disseminates the products as soon it is generated to the following FTP server

ftp://ftp.vigisat.cls.fr

login: CYMS

pwd: CYMSentinel1

Browse in the output/L2 directory where tropical cyclones are organized by year and then by name.

4 Files nomenclature and format

4.1 File nomenclature

The Nomenclature for both SARWING SWATH and SARWING GRIDDED products is

<sensor>-<acquisition_mode>-<product>-<slice_post_processing>-<start_date>-<stop_date>-<resolution>-<orbit>_<product_type>.nc, where

- <sensor> = sensor. It can be
    - s1a=Sentinel-1A;
    - s1b=Sentinel-1B
    - rs2=Radarsat-2
- <acquisition_mode> = acquisition mode. It can be
    - iw=interferometric wide swath,
    - ew=extended wide swath.

  To date for Radarsar-2, this place is empty.
- <product> = It is product=OWI for Ocean surface wind product.
- <slice_post_processing> = slices post-processing. It can be
    - cc=slices at native Level-2 product resolution are concatenated.
    - cm=slices Level-2 product resolution are concatenated and resolution is degraded (resolution is indicated in the netCDF file and in the filename - see filename nomenclature).
    - ocn=only one slice at native Level-2 product resolution. No product concatenation.
- <start_date> and <stop_date> = start and stop dates corresponding to the datatake included in the product. Dates format is YYYYMMDDtHHMMSS, where:
    - YYYY = Year
    - MM = Month
    - DD = Day
    - t stands for UTC time
    - HH = Hour
    - mm = Minutes
    - SS = seconds
- <resolution> = SAR Ocean surface wind Level-2 product resolution
- <orbit> = Orbit number
- <product_type> = product types it can be

- sw = SARWING SWATH product
- gs = SARWING GRIDDED product

An exemple of SAR Ocean wind speed along track product product is given here:

s1a-iw-owi-cm-20170906t221913-20170906t222118-000003-01EB43_sw.nc. In this case the acquisition has been performed by Sentinel-1A in interferometric wide swath mode, processed into Ocean surface wind Level-2, post-processed to be concatenated and change resolution to be 3km. Acquisition start time is 2017/09/06 at 22:19:13 UTC. Acquisition stop time is 2017/09/06 at 22:21:18 UTC. This product is along track.

4.2 File format

The products are stored using the NetCDF format.

NetCDF (Network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The NetCDF library also defines machine-independent format for representing scientific data. Together, the interface, library,and format support the creation, access, and sharing of scientific data. The NetCDF software was developed at the Unidata Program Center in Boulder, Colorado. The NetCDF libraries define a machine-independent format for representing scientific data. Please see Unidata NetCDF pages for more information, and to retrieve NetCDF software package.

In short, NetCDF data is:

- Self-Describing. A NetCDF file includes information about the data it contains.
- Architecture-independent. A NetCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.
- Direct-access. A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
- Appendable. Data can be appended to a NetCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a NetCDF dataset can be changed, though this sometimes causes the dataset to be copied.
- Sharable. One writer and multiple readers may simultaneously access the same NetCDF file.

4.3 File size

As a SAR Ocean surface wind Level-2 product can be the result of a concatenation of slices, the size is depends ont the slice number. Typically when only one slice is considered to build

- the SARWING SWATH product, the size is about 3-4 Mo
- the SARWING GRID product, the size is about 3-4 Mo

4.4 File usage Examples

4.4.1 SARWING SWATH product

https://cyclobs.ifremer.fr/app/docs/ includes exemples for downloading and plotting data with Python

4.4.2 SARWING GRIDDED product

https://cyclobs.ifremer.fr/app/docs/ includes exemples for downloading and plotting data with Python

4.5 SAR Ocean wind field Level-2 product File content

4.5.1 SARWING SWATH product

Exemple of SARWING SWATH product file content

```
{
dimensions:
	time = 1 ;
	y = 695 ;
	x = 254 ;
variables:
	int time(time) ;
		time:standard_name = "time" ;
		time:units = "seconds since 1970-01-01 00:00:00" ;
		time:calendar = "gregorian" ;
	float lon(time, y, x) ;
		lon:_FillValue = 1.e+20f ;
		lon:long_name = "Longitude at wind cell center" ;
		lon:standard_name = "longitude" ;
		lon:units = "degrees_east" ;
	float lat(time, y, x) ;
		lat:_FillValue = 1.e+20f ;
		lat:long_name = "Latitude at wind cell center" ;
		lat:standard_name = "latitude" ;
		lat:units = "degrees_north" ;
	float wind_speed(time, y, x) ;
		wind_speed:_FillValue = -9999.f ;
		wind_speed:coordinates = "time lat lon" ;
		wind_speed:units = "m/s" ;
		wind_speed:long_name = "Ocean 10m Wind speed from co- and cross- polarization" ;
	float wind_from_direction(time, y, x) ;
		wind_from_direction:_FillValue = -9999.f ;
		wind_from_direction:coordinates = "time lat lon" ;
		wind_from_direction:long_name = "Wind from direction (meteorological convention)" ;
```

```
            wind_from_direction:units = "degrees" ;
      float wind_streaks_orientation(time, y, x) ;
            wind_streaks_orientation:_FillValue = -999.f ;
            wind_streaks_orientation:long_name = "Estimation of wind streaks orientation (180° ambiguity) based on local gradient method" ;
            wind_streaks_orientation:units = "degrees" ;
            wind_streaks_orientation:coordinates = "time lat lon" ;
      float wind_streaks_orientation_stddev(time, y, x) ;
            wind_streaks_orientation_stddev:_FillValue = -999.f ;
            wind_streaks_orientation_stddev:long_name = "Estimation of the statistical error on the wind streaks orientation" ;
            wind_streaks_orientation_stddev:units = "degrees" ;
            wind_streaks_orientation_stddev:coordinates = "time lat lon" ;
      short mask_flag(time, y, x) ;
            mask_flag:_FillValue = 16959s ;
            mask_flag:long_name = "Mask of data" ;
            mask_flag:valid_range = 0s, 3s ;
            mask_flag:flag_values = 0b, 1b, 2b, 3b ;
            mask_flag:flag_meanings = "valid land ice no_valid" ;
            mask_flag:coordinates = "time lat lon" ;
      short heterogeneity_mask(time, y, x) ;
            heterogeneity_mask:_FillValue = 16959s ;
            heterogeneity_mask:long_name = "Quality flag taking into account the local heterogeneity" ;
            heterogeneity_mask:valid_range = 0s, 3s ;
            heterogeneity_mask:flag_values = 0b, 3b ;
            heterogeneity_mask:flag_meanings = "homogeneous_NRCS, heterogeneous_from_co-polarization_NRCS, heterogeneous_from_cross-polarization_NRCS, heterogeneous_from_dual-polarization_NRCS" ;
            heterogeneity_mask:coordinates = "time lat lon" ;
      float nrcs_detrend_co(time, y, x) ;
            nrcs_detrend_co:_FillValue = 1.e+20f ;
            nrcs_detrend_co:long_name = "Nice display" ;
            nrcs_detrend_co:coordinates = "time lat lon" ;
      float nrcs_detrend_cross(time, y, x) ;
            nrcs_detrend_cross:_FillValue = 1.e+20f ;
            nrcs_detrend_cross:long_name = "Nice display" ;
            nrcs_detrend_cross:coordinates = "time lat lon" ;
      float nrcs_co(time, y, x) ;
            nrcs_co:_FillValue = 1.e+20f ;
```

```
            nrcs_co:long_name = "Normalized Radar Cross Section" ;
            nrcs_co:units = "m^2 / m^2" ;
            nrcs_co:coordinates = "time lat lon" ;
      float nrcs_cross(time, y, x) ;
            nrcs_cross:_FillValue = 1.e+20f ;
            nrcs_cross:long_name = "Normalized Radar Cross Section" ;
            nrcs_cross:units = "m^2 / m^2" ;
            nrcs_cross:coordinates = "time lat lon" ;
      float incidence_angle(time, y, x) ;
            incidence_angle:_FillValue = 1.e+20f ;
            incidence_angle:long_name = "Incidence angle at wind cell center" ;
            incidence_angle:units = "degrees" ;
            incidence_angle:coordinates = "time lat lon" ;
      float elevation_angle(time, y, x) ;
            elevation_angle:_FillValue = 1.e+20f ;
            elevation_angle:long_name = "Elevation Angle at wind cell center" ;
            elevation_angle:units = "degrees" ;
            elevation_angle:coordinates = "time lat lon" ;


// global attributes:
      :Conventions = "CF-1.6" ;
      :title = "SAR ocean surface wind field" ;
      :institution = "IFREMER/CLS" ;
      :reference = "Mouche Alexis, Chapron Bertrand, Knaff John, Zhao Yuan, Zhang Biao, Combot Clement (2019). Copolarized and Cross-Polarized SAR Measurements for High-Resolution Description of Major Hurricane Wind Structures: Application to Irma Category 5 Hurricane. Journal Of Geophysical Research-oceans, 124(6), 3905-3922. https://doi.org/10.1029/2019JC015056" ;
      :measurementDate = "2019-10-12T08:41:20Z" ;
      :sourceProduct=
"S1B_IW_GRDH_1SDV_20191012T084028_20191012T084057_018440_022BD1_8AF9.SAFE
S1B_IW_GRDH_1SDV_20191012T084057_20191012T084122_018440_022BD1_0C48.SAFE
S1B_IW_GRDH_1SDV_20191012T084122_20191012T084147_018440_022BD1_55BE.SAFE
S1B_IW_GRDH_1SDV_20191012T084147_20191012T084212_018440_022BD1_8DFA.SAFE" ;
      :missionName = "SENTINEL-1 B" ;
      :polarization = "VV/VH" ;
      :footprint = "POLYGON((138.93082 31.22521, 141.54996 31.62882, 140.30005 37.875313, 137.46426 37.47851, 138.93082 31.22521))" ;
      :l2ProcessingUtcTime = "02-Jul-2020 08:32:03.632661" ;
      :version = "1.1.dev37+g59dce52" ;
```

```
}

}
```

4.5.2 SARWING GRIDDED product

Exemple of SARWND GRIDDED product file content (will sligthly change).

```
{
dimensions:
        time = 1 ;
        y = 741 ;
        x = 377 ;
variables:
        int time(time) ;
                time:standard_name = "time" ;
                time:units = "seconds since 1970-01-01" ;
                time:calendar = "gregorian" ;
        int y(y) ;
                y:standard_name = "projection_y_coordinate" ;
                y:long_name = "Northing" ;
                y:units = "m" ;
        int x(x) ;
                x:standard_name = "projection_x_coordinate" ;
                x:long_name = "Easting" ;
                x:units = "m" ;
        float lon(time, y, x) ;
                lon:_FillValue = 1.e+20f ;
                lon:long_name = "Longitude at wind cell center" ;
                lon:standard_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:grid_mapping = "spatial_ref" ;
                lon:coordinates = "spatial_ref" ;
        float lat(time, y, x) ;
                lat:_FillValue = 1.e+20f ;
```

lat:long_name = "Latitude at wind cell center" ;

lat:standard_name = "latitude" ;

lat:units = "degrees_north" ;

lat:grid_mapping = "spatial_ref" ;

lat:coordinates = "spatial_ref" ;

float nrcs_detrend_cross(time, y, x) ;

nrcs_detrend_cross:_FillValue = 1.e+20f ;

nrcs_detrend_cross:long_name = "Nice display" ;

nrcs_detrend_cross:grid_mapping = "spatial_ref" ;

nrcs_detrend_cross:coordinates = "spatial_ref" ;

short heterogeneity_mask(time, y, x) ;

heterogeneity_mask:_FillValue = 16959s ;

heterogeneity_mask:long_name = "Quality flag taking into account the local heterogeneity" ;

heterogeneity_mask:valid_range = 0s, 3s ;

heterogeneity_mask:flag_values = 0b, 3b ;

heterogeneity_mask:flag_meanings = "homogeneous_NRCS, heterogeneous_from_co-polarization_NRCS, heterogeneous_from_cross-polarization_NRCS, heterogeneous_from_dual-polarization_NRCS" ;

heterogeneity_mask:grid_mapping = "spatial_ref" ;

heterogeneity_mask:coordinates = "spatial_ref" ;

float wind_streaks_orientation_stddev(time, y, x) ;

wind_streaks_orientation_stddev:_FillValue = -999.f ;

wind_streaks_orientation_stddev:long_name = "Estimation of the statistical error on the wind streaks orientation" ;

wind_streaks_orientation_stddev:units = "degrees" ;

wind_streaks_orientation_stddev:grid_mapping = "spatial_ref" ;

wind_streaks_orientation_stddev:coordinates = "spatial_ref" ;

float nrcs_detrend_co(time, y, x) ;

nrcs_detrend_co:_FillValue = 1.e+20f ;

nrcs_detrend_co:long_name = "Nice display" ;

nrcs_detrend_co:grid_mapping = "spatial_ref" ;

nrcs_detrend_co:coordinates = "spatial_ref" ;

float incidence_angle(time, y, x) ;

```
		incidence_angle:_FillValue = 1.e+20f ;
		incidence_angle:long_name = "Incidence angle at wind cell center" ;
		incidence_angle:units = "degrees" ;
		incidence_angle:grid_mapping = "spatial_ref" ;
		incidence_angle:coordinates = "spatial_ref" ;
	float nrcs_co(time, y, x) ;
		nrcs_co:_FillValue = 1.e+20f ;
		nrcs_co:long_name = "Normalized Radar Cross Section" ;
		nrcs_co:units = "m^2 / m^2" ;
		nrcs_co:grid_mapping = "spatial_ref" ;
		nrcs_co:coordinates = "spatial_ref" ;
	float wind_from_direction(time, y, x) ;
		wind_from_direction:_FillValue = -9999.f ;
		wind_from_direction:long_name = "Wind from direction (meteorological convention)" ;
		wind_from_direction:units = "degrees" ;
		wind_from_direction:grid_mapping = "spatial_ref" ;
		wind_from_direction:coordinates = "spatial_ref" ;
	float nrcs_cross(time, y, x) ;
		nrcs_cross:_FillValue = 1.e+20f ;
		nrcs_cross:long_name = "Normalized Radar Cross Section" ;
		nrcs_cross:units = "m^2 / m^2" ;
		nrcs_cross:grid_mapping = "spatial_ref" ;
		nrcs_cross:coordinates = "spatial_ref" ;
	float wind_speed(time, y, x) ;
		wind_speed:_FillValue = -9999.f ;
		wind_speed:units = "m/s" ;
		wind_speed:long_name = "Ocean 10m Wind speed from co- and cross- polarization" ;
		wind_speed:grid_mapping = "spatial_ref" ;
		wind_speed:coordinates = "spatial_ref" ;
	float wind_streaks_orientation(time, y, x) ;
		wind_streaks_orientation:_FillValue = -999.f ;
		wind_streaks_orientation:long_name = "Estimation of wind streaks orientation (180°
	ambiguity) based on local gradient method" ;
```

```
            wind_streaks_orientation:units = "degrees" ;
            wind_streaks_orientation:grid_mapping = "spatial_ref" ;
            wind_streaks_orientation:coordinates = "spatial_ref" ;
      float elevation_angle(time, y, x) ;
            elevation_angle:_FillValue = 1.e+20f ;
            elevation_angle:long_name = "Elevation Angle at wind cell center" ;
            elevation_angle:units = "degrees" ;
            elevation_angle:grid_mapping = "spatial_ref" ;
            elevation_angle:coordinates = "spatial_ref" ;
      short mask_flag(time, y, x) ;
            mask_flag:_FillValue = 16959s ;
            mask_flag:long_name = "Mask of data" ;
            mask_flag:valid_range = 0s, 3s ;
            mask_flag:flag_values = 0b, 1b, 2b, 3b ;
            mask_flag:flag_meanings = "valid land ice no_valid" ;
            mask_flag:grid_mapping = "spatial_ref" ;
            mask_flag:coordinates = "spatial_ref" ;
      int spatial_ref ;
            spatial_ref:spatial_ref = "PROJCS[\"unknown\",GEOGCS[\"unknown\",DATUM[\"Unknown based on WGS84 ellipsoid\",SPHEROID[\"WGS 84\",6378137,298.257223563,AUTHORITY[\"EPSG\",\"7030\"]],PRIMEM[\"Greenwich\",0,AUTHORITY[\"EPSG\",\"8901\"]],UNIT[\"degree\",0.0174532925199433,AUTHORITY[\"EPSG\",\"9122\"]]],PROJECTION[\"Azimuthal_Equidistant\"],PARAMETER[\"latitude_of_center\",34.560977935791],PARAMETER[\"longitude_of_center\",139.570388793945],PARAMETER[\"false_easting\",0],PARAMETER[\"false_northing\",0],UNIT[\"metre\",1,AUTHORITY[\"EPSG\",\"9001\"]],AXIS[\"Easting\",EAST],AXIS[\"Northing\",NORTH]]" ;
            spatial_ref:crs_wkt = "PROJCS[\"unknown\",GEOGCS[\"unknown\",DATUM[\"Unknown based on WGS84 ellipsoid\",SPHEROID[\"WGS 84\",6378137,298.257223563,AUTHORITY[\"EPSG\",\"7030\"]],PRIMEM[\"Greenwich\",0,AUTHORITY[\"EPSG\",\"8901\"]],UNIT[\"degree\",0.0174532925199433,AUTHORITY[\"EPSG\",\"9122\"]]],PROJECTION[\"Azimuthal_Equidistant\"],PARAMETER[\"latitude_of_center\",34.560977935791],PARAMETER[\"longitude_of_center\",139.570388793945],PARAMETER[\"false_easting\",0],PARAMETER[\"false_northing\",0],UNIT[\"metre\",1,AUTHORITY[\"EPSG\",\"9001\"]],AXIS[\"Easting\",EAST],AXIS[\"Northing\",NORTH]]" ;
// global attributes:
      :Conventions = "CF-1.6" ;
      :title = "SAR ocean surface wind field" ;
```

:institution = "IFREMER/CLS" ;

:reference = "Mouche Alexis, Chapron Bertrand, Knaff John, Zhao Yuan, Zhang Biao, Combot Clement (2019). Copolarized and Cross-Polarized SAR Measurements for High-Resolution Description of Major Hurricane Wind Structures: Application to Irma Category 5 Hurricane. Journal Of Geophysical Research-oceans, 124(6), 3905-3922. https://doi.org/10.1029/2019JC015056" ;

:measurementDate = "2019-10-12T08:41:20Z" ;

:sourceProduct = "S1B_IW_GRDH_1SDV_20191012T084028_20191012T084057_018440_022BD1_8AF9.SAFE S1B_IW_GRDH_1SDV_20191012T084057_20191012T084122_018440_022BD1_0C48.SAFE S1B_IW_GRDH_1SDV_20191012T084122_20191012T084147_018440_022BD1_55BE.SAFE S1B_IW_GRDH_1SDV_20191012T084147_20191012T084212_018440_022BD1_8DFA.SAFE" ;

:missionName = "SENTINEL-1 B" ;

:polarization = "VV/VH" ;

:footprint = "POLYGON((138.93082 31.22521, 141.54996 31.62882, 140.30005 37.875313, 137.46426 37.47851, 138.93082 31.22521))" ;

:l2ProcessingUtcTime = "02-Jul-2020 08:32:03.632661" ;

:version = "1.1.dev37+g59dce52" ;

:grid_mapping = "spatial_ref" ;

}

Appendix A - Glossary and Abbreviations

Acronym	Full name
API	Application Programming Interface
CLS	Collecte Localisation Satellite
CSA	Canadian Space Agency
CyClObs	Cyclone Observations (archive web portal)
EODA	Earth Observation Data Access (near real time web portal)
ESA	European Space Agency
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
MDA	MacDonald Dettwiler and Associates
NRT	Near Real Time
SAR	Synthetic Aperture Radar
SM, IW and EW	Strip Map, Interferometric Wide and Extended Wide swath modes for Sentinel-1 mission.
URL	Uniform Resource Locator

Appendix B - References

R1 - Mouche Alexis, Chapron Bertrand, Knaff John, Zhao Yuan, Zhang Biao, Combot Clement (2019). Copolarized and Cross-Polarized SAR Measurements for High-Resolution Description of Major Hurricane Wind Structures: Application to Irma Category 5 Hurricane. Journal Of Geophysical Research-oceans, 124(6), 3905-3922. https://doi.org/10.1029/2019JC015056

R2 - Zhao Yuan, Mouche Alexis, Chapron Bertrand, Reul Nicolas (2018). Direct Comparison Between Active C-Band Radar and Passive L-Band Radiometer Measurements: Extreme Event Cases. IEEE Geoscience And Remote Sensing Letters, 15(6), 897-901. https://doi.org/10.1109/LGRS.2018.2811712

R3 - Mouche Alexis, Chapron Bertrand, Zhang Biao, Husson Romain (2017). Combined Co- and Cross-Polarized SAR Measurements Under Extreme Wind Conditions. IEEE Transactions On Geoscience And Remote Sensing, 55(12), 6746-6755. https://doi.org/10.1109/TGRS.2017.2732508

R4 – Husson Romain, Mouche Alexis, Longépé Nicolas, Berger Henrick - Sentinel-1 Images pre-processing for wind retrieval. Draft paper