The Ifremer Wind and Wave Operation Center (**IWWOC**) for CFOSAT

Jean-François Piollé (1), **Gilles Guitton (2), Alexey Mironov (3),**
Yves Quilfen, Bertrand Chapron, Jean Tournadre, Fanny Ardhuin, Abderrahim Bentamy, Cédric Prevost, Erwan Bodéré, Dominique Briand (1), Fabrice Collard (2)

(1) Ifremer
(2) OceanDataLab
(3) eOdyn

IWWOC

Ifremer Wind and Wave Operation Center

FROGS **downstream** processing center,

Co-funded by CNES and Ifremer

Support by OceanDataLab & eOdyn experts

The objectives are to complement the CNES CWWIC NRT products by :

- **Experimental or innovative products**, combining both instruments
- **Long and consistent time series**, contribution to climate time series of wind and wave (CCI Sea State)
- **Advanced products** (L3/L4) – prepare transition to Copernicus Operational services

Data Processing **delayed mode**, allowing :

- Improved ancillary inputs
- Exploit synergy between SWIM and SCAT
- Multi sensor approaches (Sentinel-1, in situ, other altimeters & scatterometers) for greater sampling and space/time resolution
- Usage of a priori, past and future data, feedback
- Frequent reprocessing of full mission archive – long term homogeneity

Implemented and operated at Ifremer CERSAT satellite data center, supported by two departments (LOPS & SISMER)

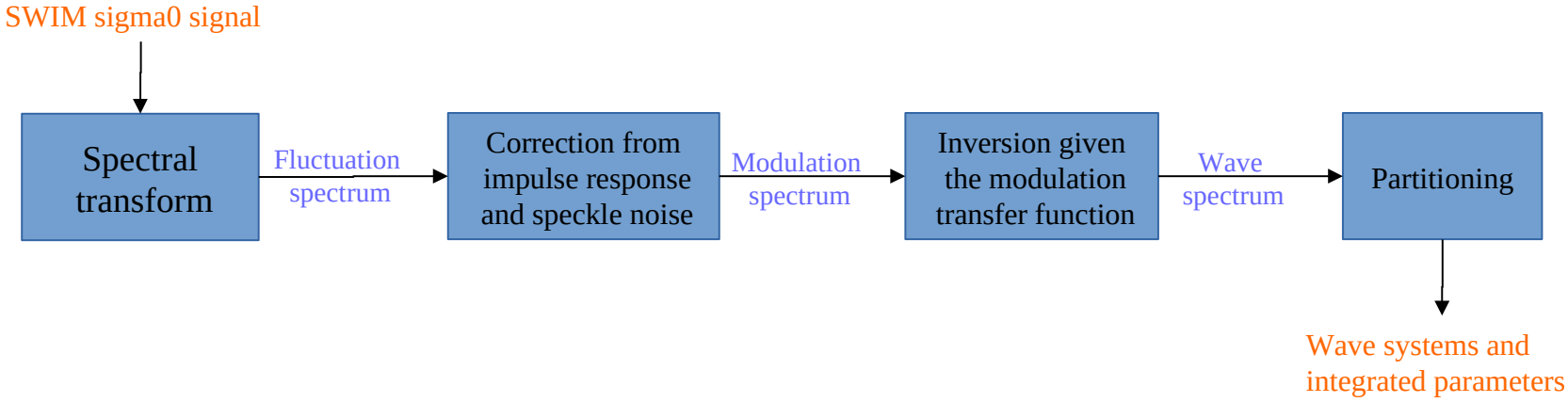
SWIM L2S and L4 products

IWWOC SWIM products

- **SWIM_L2S**: directional wave spectra measures and partitioning (integrated parameters) along SWIM acquisition
- **SWIM_L3**: statistics from L2S wave systems (and/or other L2 products) on a longitude / latitude grid
- **SWIM_L4**: propagation of L2S wave systems (and/or other L2 products) and refocusing to storm sources (fireworks analysis)

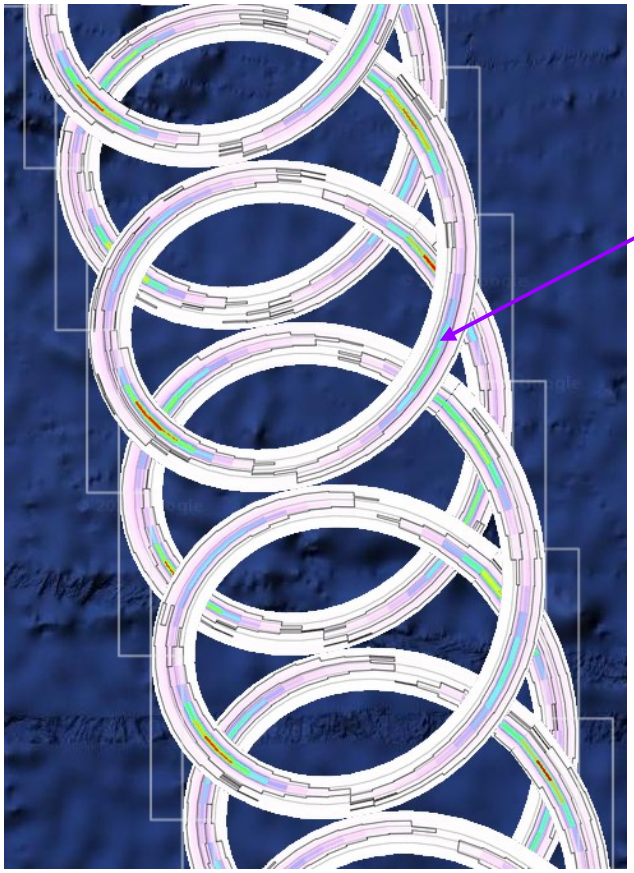
SWIM_L2S summary

- L2S motivations
  - taking advantage of the use of various ancillary data offered by delayed time
  - handling complex situations such as coastal areas and heterogeneous seas
  - having a flexible processing chain in order to facilitate algorithmic modifications and reprocessing
- Classical wave inversion scheme



SWIM_L2S partitioning

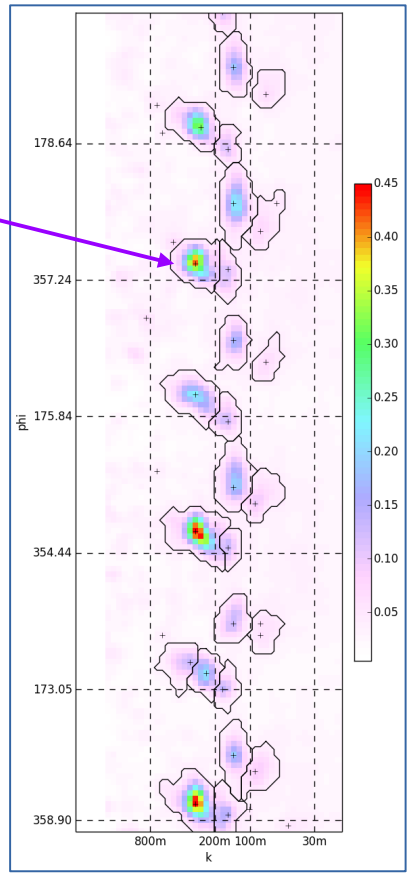
- Preservation of natural SWIM geometry (called ribbon by IWWOC people) for partitioning



Geographical view (10° beam)

The idea is to identify partitions along acquisition

Technically, it is done in k/phi space (right figure), similarly to classical 2D spectra except than phi is covering more than 360 degrees here



Matrix view, ie k/phi space

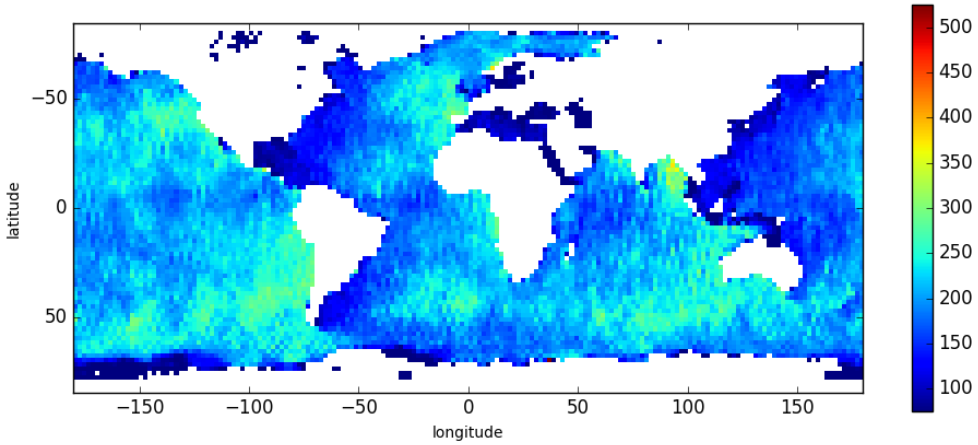
SWIM_L2S alternative usage

- Currently, many variables are kept in L2S output, so it may also serve as a starting product for research purposes:
  - Ancillary data colocated to SWIM signal (eg wind, ice, land)
  - Resampled sigma0 to regular ground range
  - Intermediate results (spectra) of wave inversion scheme

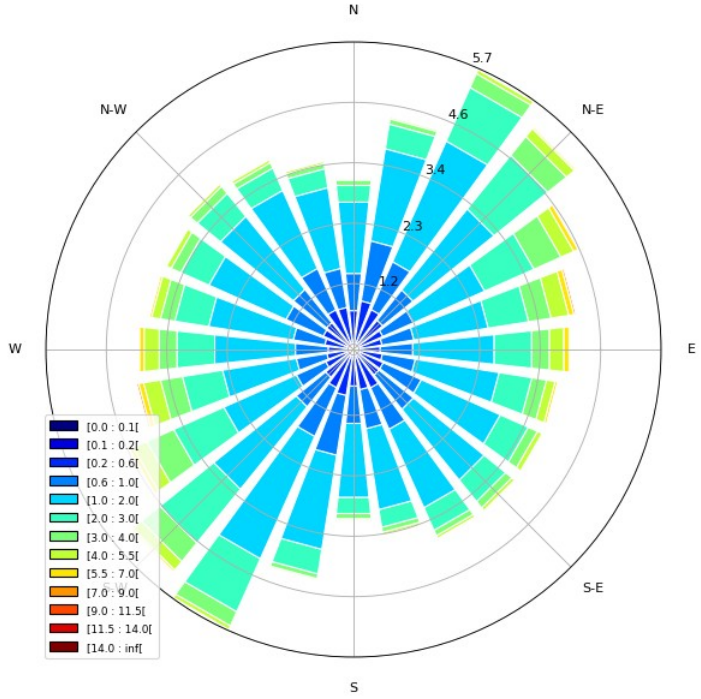
SWIM_L3 summary

- Product providing statistics from wave parameters (wavelength, direction, Hs) on a regular longitude / latitude grid (2°x2° bins) and for a given time window (eg 1 month)
- Simple stats (eg min/max/mean/std)
  - → expected to be used as a quick and easy way to qualify L2S performances (eg unexpected values or inter-comparison between L3 from L2S and L3 from different input)
- Joint distribution of parameters (eg joint direction and Hs)
  - → expected to serve as climatology with the benefit of the expected unique angular resolution of SWIM

SWIM_L3 examples



Example of simple stat, mean wavelength

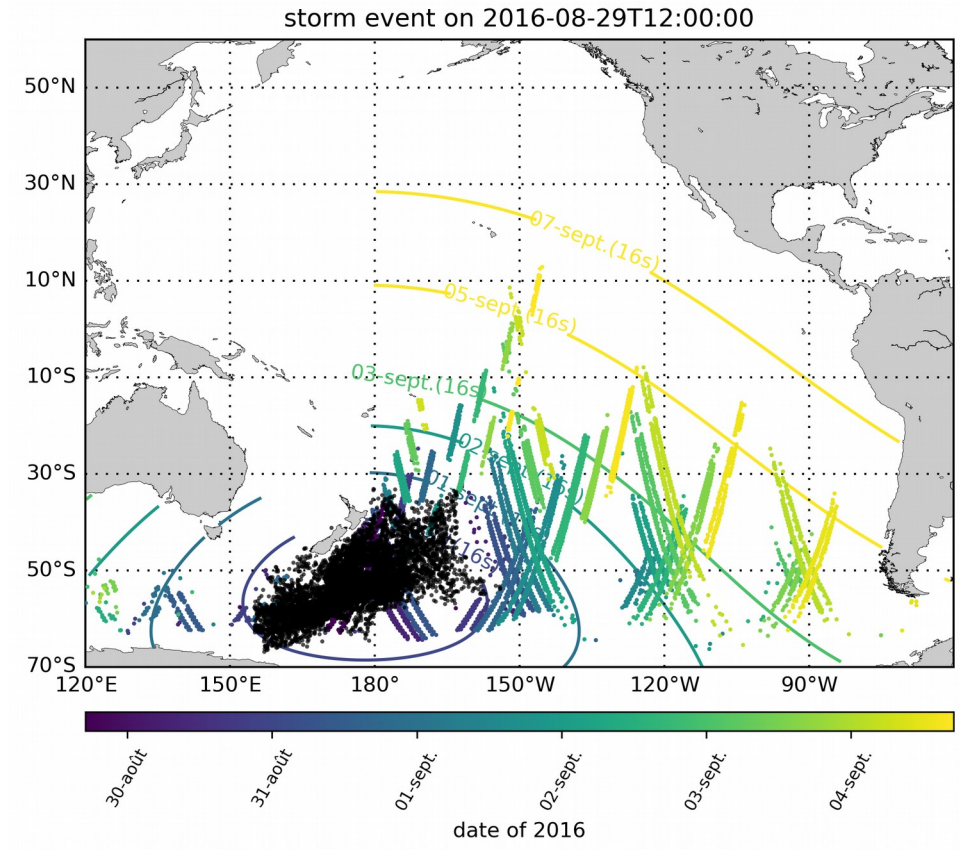


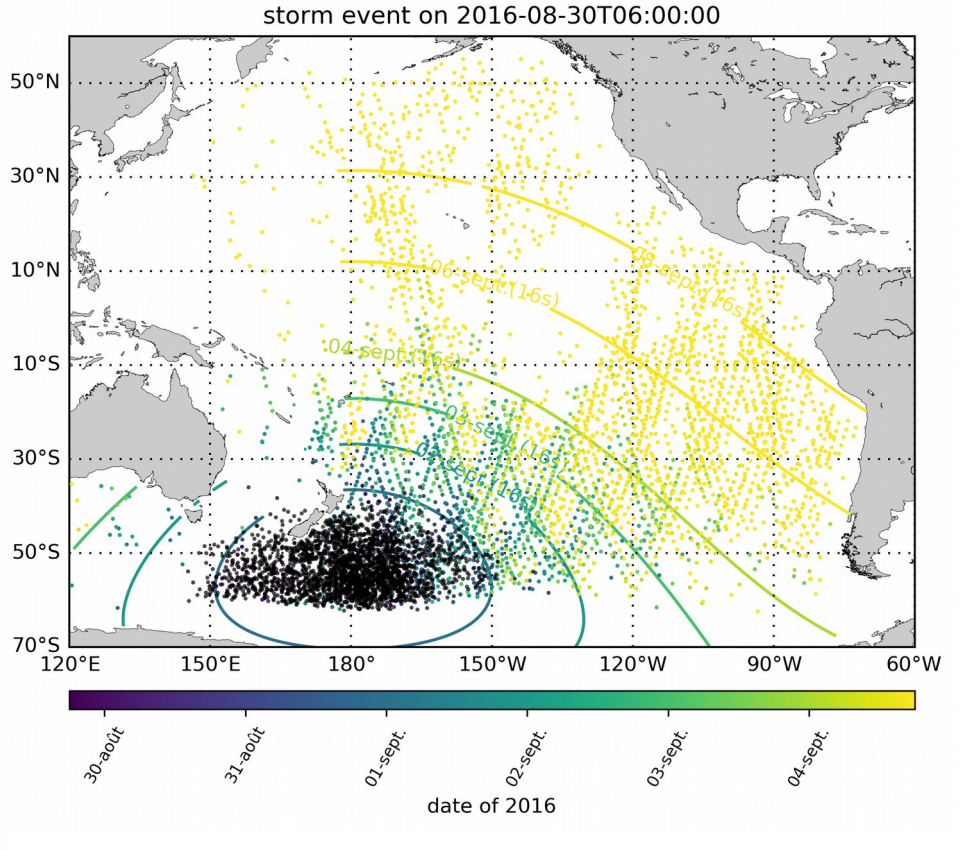
Example of joint distribution, Hs and wave direction (wave rose)
With unresolved SWIM directional ambiguity

SWIM_L4 summary

- Product providing propagated swell parameters and its associated storm
- Multi sensor product, at least SWIM L2S and S-1 L2 OCN products are expected to be used as inputs
- A part from scientific interest (waves generation / propagation mechanisms), L4 may also serve for cal/val:
  - eg. SWIM obs propagation to buoy or Sentinel-1 obs propagation to SWIM obs
  - Observations not associated to a storm (leftovers) may indicate a poor wave inversion.

SWIM_L4 examples





Example of wave observations (colored dots) associated to a storm source. Back-propagated observations are black dots. Left: SWIM simulations. Right: Sentinel-1 wave mode

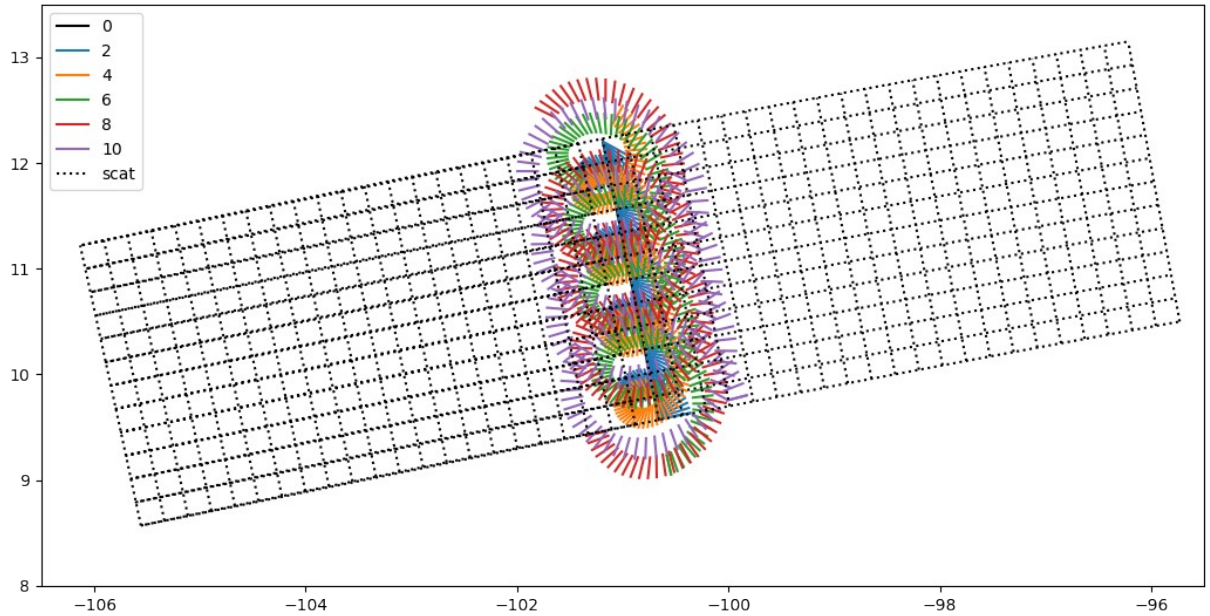
IWWOC SCAT products

SCAT_L2S and SWISCA_L2S Products

SCAT_L2S — the advanced sea surface wind product which benefits from the CFOSAT two instruments collocated measurements

SWISCA_L2S – collocated CFOSAT and model data product

SCAT_L2S Product



Courtesy : A.Mironov (eOdyn)

Example of superposed SWIM and SCAT observation swathes

SCAT L2S - wind vector (rain, ice) product from **combined SCAT** (moderate angle dual polarization) and **SWIM** (nadir, near-nadir) measurements

Purposes:

- wind vector inversion along the satellite track
- understanding of impact and relation of wind, wave currents and temperature on backscattered radar signal
- experimental framework for advanced wind inversion algorithms
- improved wind vector inversion in particular conditions (high winds, rain, ice, …)
- Input data for specialized oceanographic projects

SCAT L2S processing

Geophysical Modulation Function (GMF) maps sigma0 to antenna position (incidence angle, azimuth), and geophysical parameters of sea surface (wind vector, wave state, surface currents etc.)

Existing Ku-band GMFs

- SCAT: NSCAT-4 (same is an CWDP) HH and VV polarizations, incidence ang. Range 20°-54°
- SWIM: Gressani et al.(GPM-derived), ang. Range 0°-17°

SCAT L2S uses combined GMF where near-nadir and moderate incidence angle parts on the same level

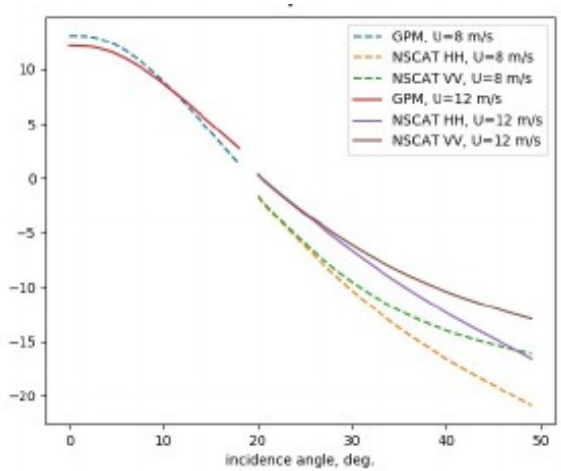
New wave state (Hs) dependent GMF for SWIM (and SCAT later) data

New cross-polarization, incidence angle independent GMF for SCAT

Multi-icidence angle inversion approach : classical Bayesian approach based on the minimization of **Maximum Likelihood Estimator** (MLE) adapted for two-instrument use (weighting coefficients, dynamic approach)

2DVAR modification for propagating solution from well-defined WVC to other parts of the swath

Courtesy : A.Mironov (eOdyn)

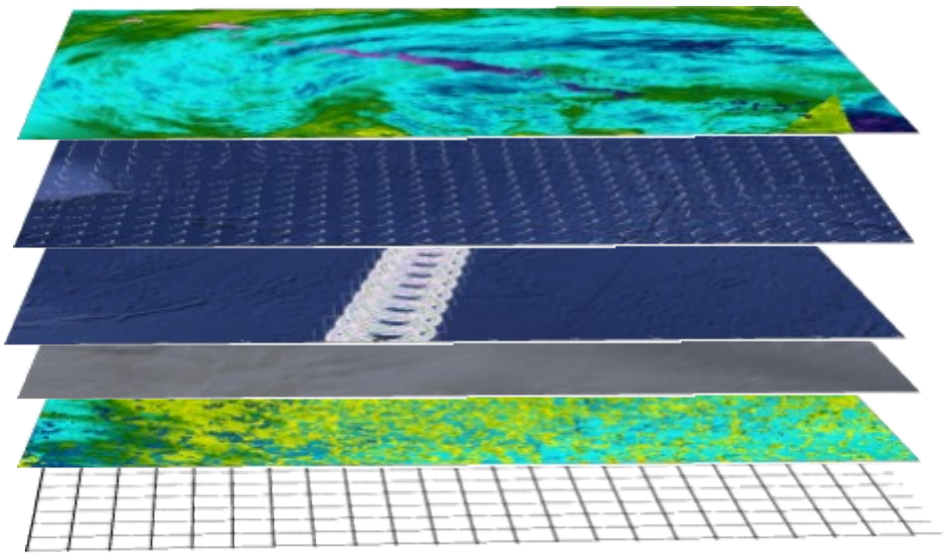


$$MLE_{SWIM/SCAT} = \frac{1}{N+1}\left(\sum_{i=1}^{N} \frac{\left(\sigma^0_{obs}(i) - \sigma^0_{GMF}(i)\right)^2}{K_{p,obs}(i)} + \frac{\left(\sigma^0_{SWIM} - \sigma^0_{GMF}\right)^2}{K_{SWIM}}\right).$$

SWISCA_L2S Product

The main idea of the SWISCAT_L2S is to provide a full set of collocated and homogenised data related to the CFOSAT mission.

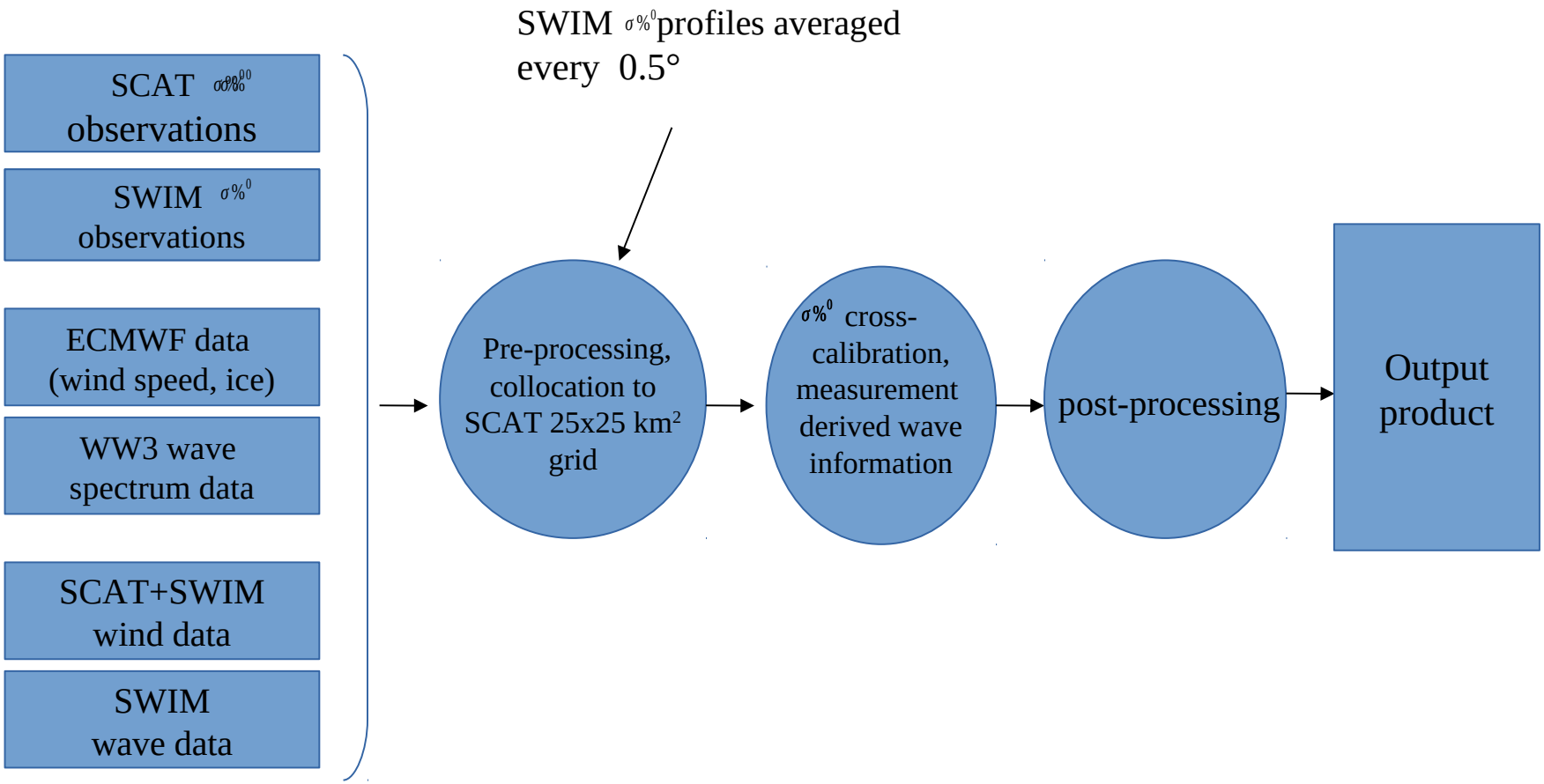
The product is dedicated for use in advanced remote sensing studies and in multi-source synergy ocean state and dynamics analysis.



Three sub-products :

- SWISCAT L2S A : colocated L2A (sigma0)
- SWISCAT L2S AUX : ancillary fields
- SWISCAT L2S B : colocated geophysical wind and wave parameters

SWISCA_L2S Processing



SWISCA_L2S processor work flow

SWISCA_L2S_AUX

SCAT L2B product enriched with additional ancillary fields from external sources (models, etc.)

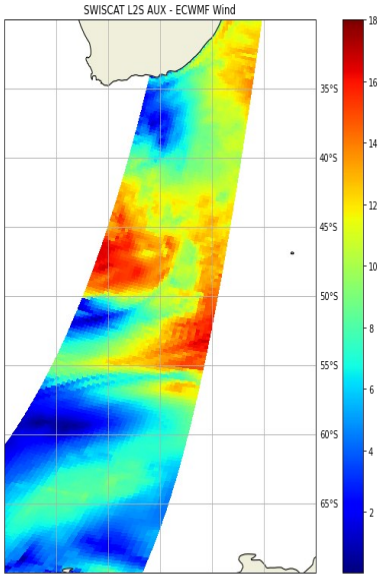
To support data analysis ; improvement of wind inversion

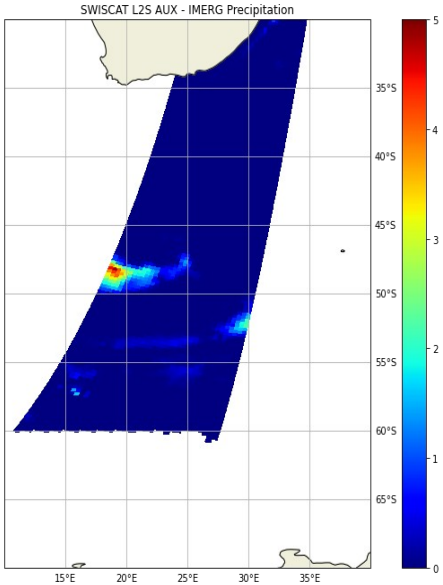
All ancillary fields are resampled onto SCAT geometry (WVC cells)

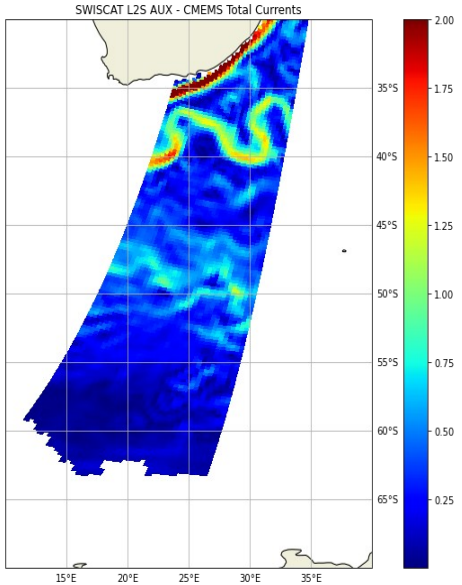
Example of ancillary fields :

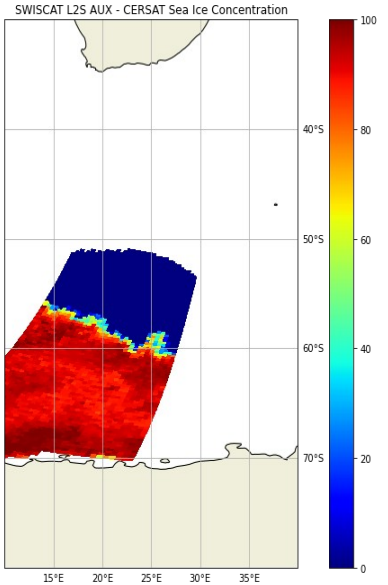
- Sea ice concentration (CERSAT/SSMI)
- Currents (CMEMS/GlobCurrent)
- ECMWF SST and Wind
- IMERG rain rate
- WaveWatch3 wave spectra

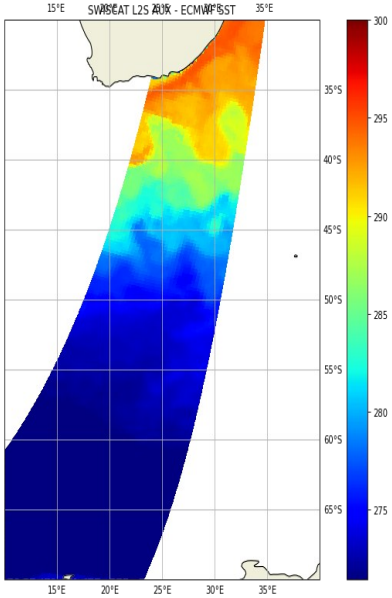
SWISCA_L2S_AUX content











Examples of ancillary fields added onto SCAT WVC grid

Advanced scatterometer products – sea ice

Gridded product on stereographic polar projection for **Arctic** and **Antarctic**.

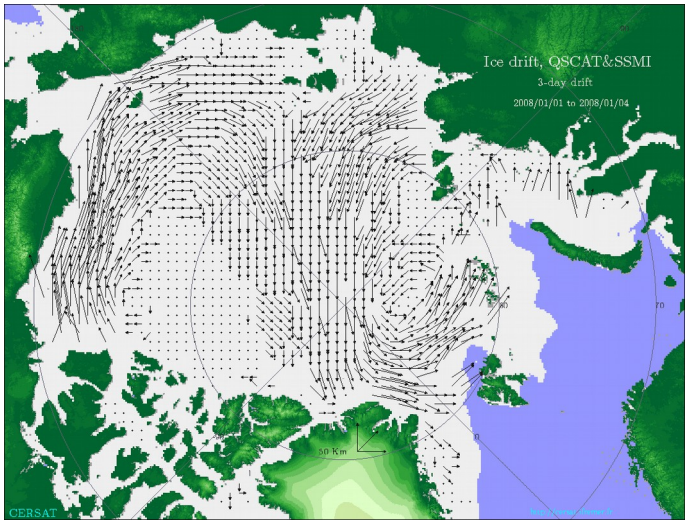
Sea-ice characterization (first year/ multi year ice) from CFOSAT SCAT backscatter and **ice mask**

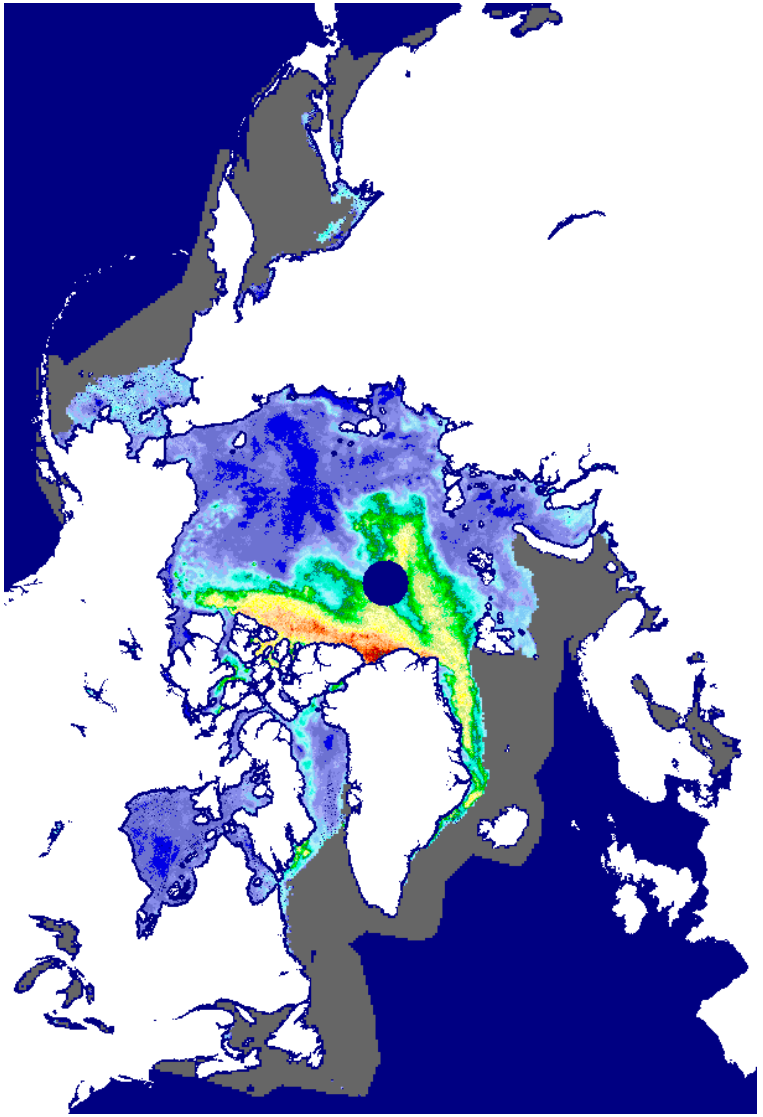
possible feedback as input to SCAT and SWIM L2 processing

At a later stage, **Sea-ice drift** derivation from cross correlation over sequences of backscatter maps will be available too, merging CFOSAT SCAT with other scatterometers and passive microwave radiometers.

Complement long time series processed for Copernicus/ CMEMS with other scatterometers

Refer to F. Girard-Ardhuin presentation in this workshop





SURFACE WIND ANALYSES: L3 CFOSAT SCAT PRODUCTS

Topic: Determination of regular in space and time wind fields: Global Daily / 0.25°×0.25° Wind Fields Based on the Use of IWWOC L2b Retrievals

Why:

- Allow estimation of surface winds which accuracy is similar to L2b.
- Allow easier use of scatterometer data (exp. Forcing and process studies)
- Reduce discovery of lower level data
- Allow data screening before use
- Allow access and use to users beyond satellite community

Requirements:

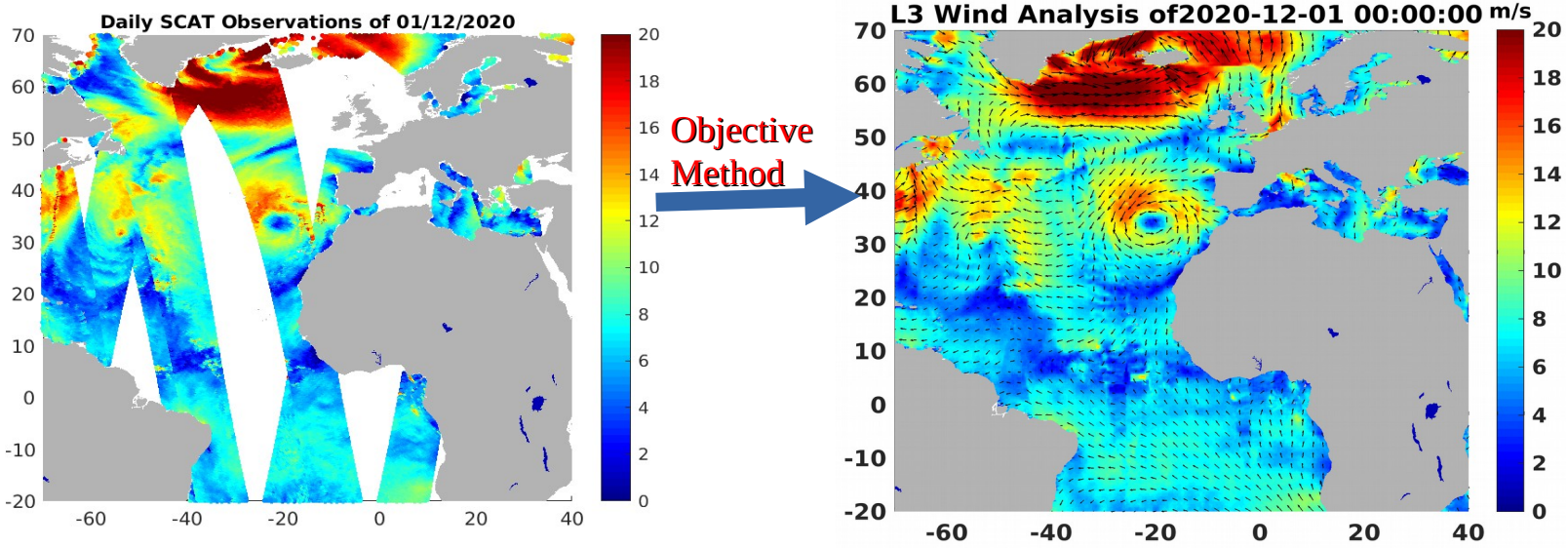
- Determination of RFSCAT wind retrieval (L2b) accuracy
- Determination of wind spatial-temporal characteristics
- Determination of the objective method aiming at the calculation of L3 winds
- Determination of L3 wind accuracy

Data:

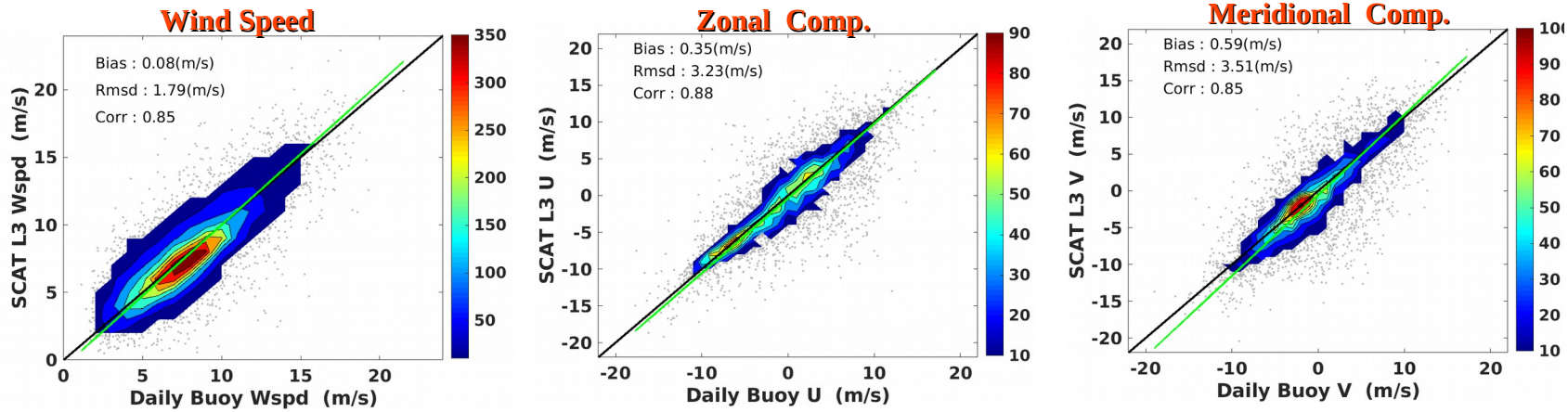
- Ifremer (>May, 1st 2020) RFSCAT wind retrievals (L2b)
- Operational ECMWF 10m wind analyses
- Buoy atmospheric and oceanic measurements

Courtesy : A. Bentamy (Ifremer/LOPS)

SURFACE WIND ANALYSES: L3 CFOSAT SCAT PRODUCTS



Accuracy Issues: **Comprehensive Comparisons with Daily Buoy Wind Estimates**



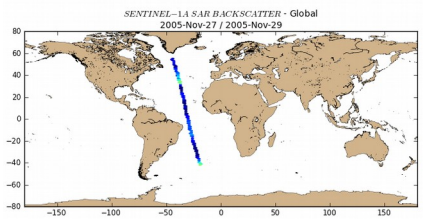
Courtesy : A. Bentamy (Ifremer/LOPS)

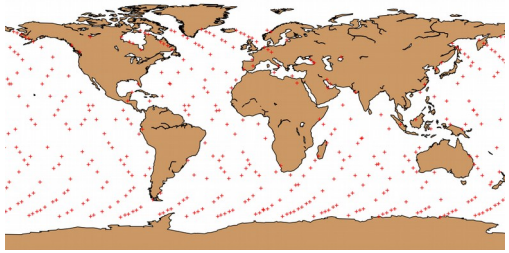
cal/val support product and services

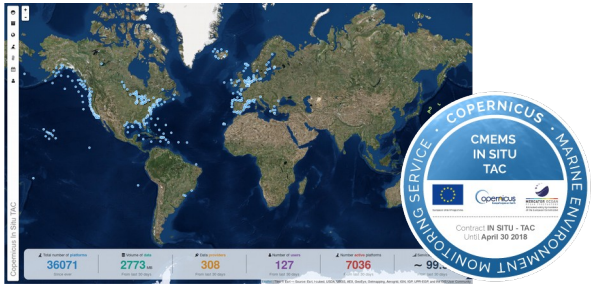
CFOSAT SWIM & SCAT products

Different products are generated to support cal/val activities

- Colocalization with WaveWatch3 => complete wave spectra over each SCAT (L2B) and SWIM (L2, L2S) measurement locations
- Satellite cross-overs
- In situ match-ups (coming soon)
- Data access on demand (Jean-François Piollé, jfpiolle@ifremer.fr)

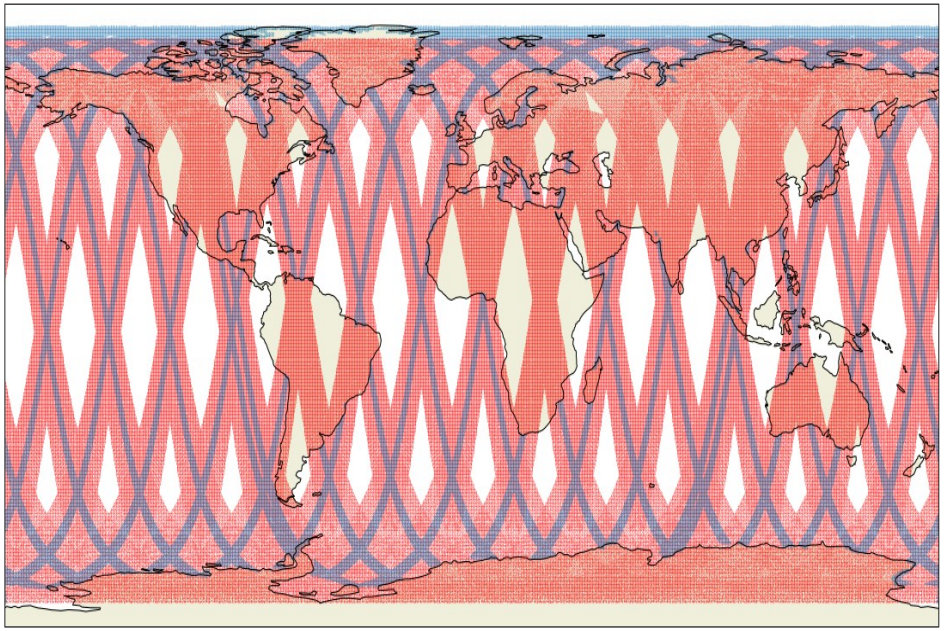






Colocation with WaveWatch3

- Ifremer WaveWatch3 operational configuration - global, hourly, 0.25°
- Extraction of the locations & times of SCAT wind cells and SWIM boxes
- Daily run of WW3 model
- Extraction of WW3 spectra over the SWIM/SCAT locations - NetCDF
- Resampling over SCAT & SWIM products (colocation product)



3 colocation products:

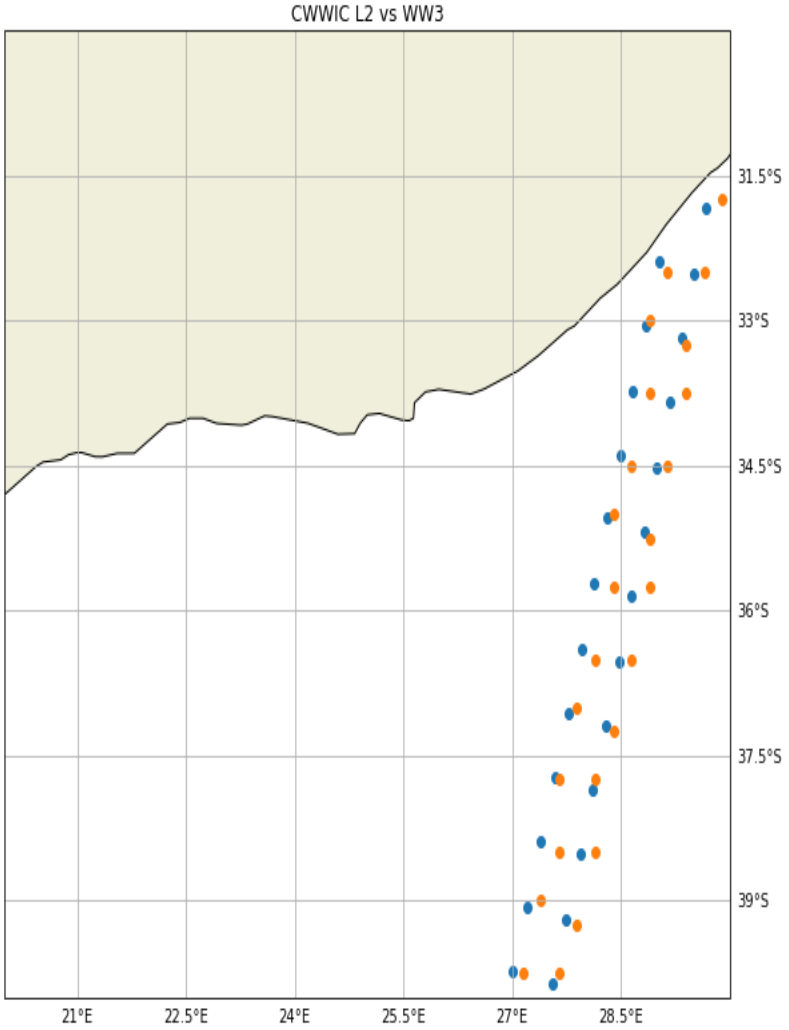
- WW3 onto SCAT wind cells [SWISCA_L2S___/AUX]
- WW3 onto CWWIC L2 wave boxes
- WW3 onto IWWOC L2S
- One colocation product per input (orbit file)

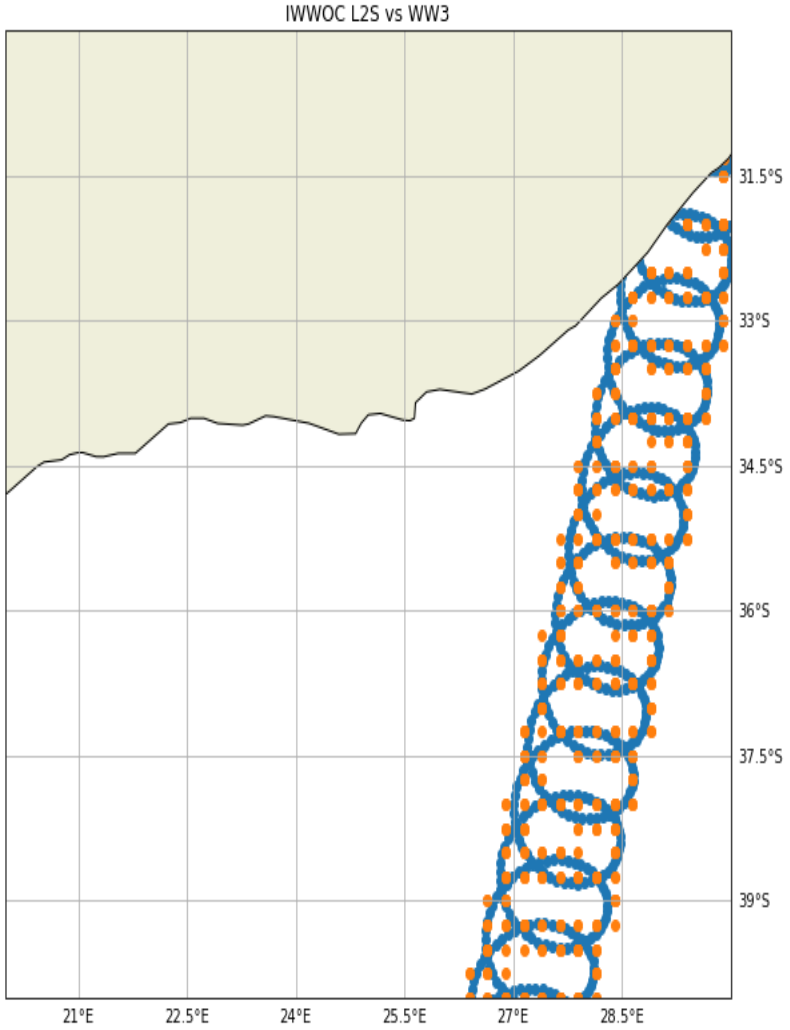
Variables:

- Spectral density
- Forcing fields: current, wind, friction velocity, air sea temperature difference
- Other parameters can be added

Example of CWWIC L2 and IWWOC L2S match-ups w/ww3

In blue SWIM measurements, in orange the closest calculated WW3 spectra





Satellite cross-overs

Satellite cross-overs for SCAT & SWIM

Based on the systematic indexing of the CFOSAT, SAR, altimeter, scatterometer & other missions in this table

Cross-over pairs generated on demand and wrt colocation possibilities

CFOSAT SWI L2ANAD (CWWIC)
CFOSAT SCAT L2A (CWWIC)
AltiKa IGDR (CNES/Aviso)
Jason-3 IGDR (CNES/Aviso)
CryoSat-2 (ESA)
Sentinel-3A SRAL (Eumetsat)
Sentinel-3B SRAL (Eumetsat)
Sentinel-1A SAR WM (ESA)
Sentinel-1B SAR WM (ESA)
GPM Ku L2 (JAXA)
SCATSAT-1 (OSI SAF)
HY2B (OSI SAF)
ASCAT-A (OSI SAF)
ASCAT-B (OSI SAF)
SMOS L2 Wind (ESA/Ifremer)

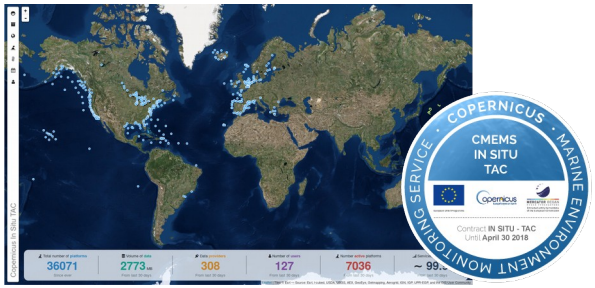
In situ match-ups

CMEMS In Situ TAC used for wave & wind measurements

Ongoing work on the selection of relevant buoys wrt distance to coast, precision, … and additional QC rules

Match-up production system for CCI Sea State missions, CFOSAT - based on felyx software

Integration ongoing



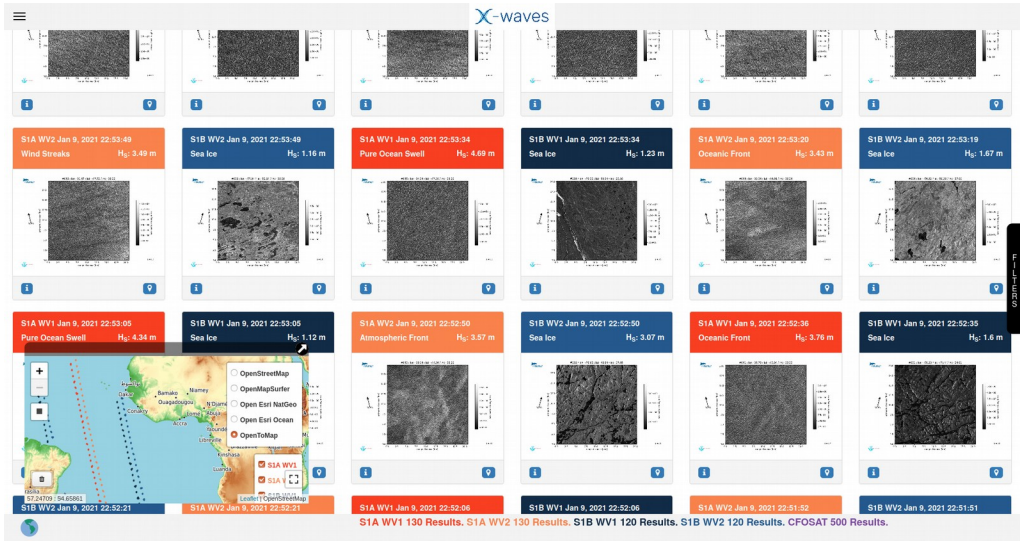
calv/val tools

CFOSAT cal/val monitoring interface

http://oceanwavesremotesensing.ifremer.fr/cfosat

X-waves : multi-mission wave visualization

https://xwaves.ifremer.fr/#/quicklook

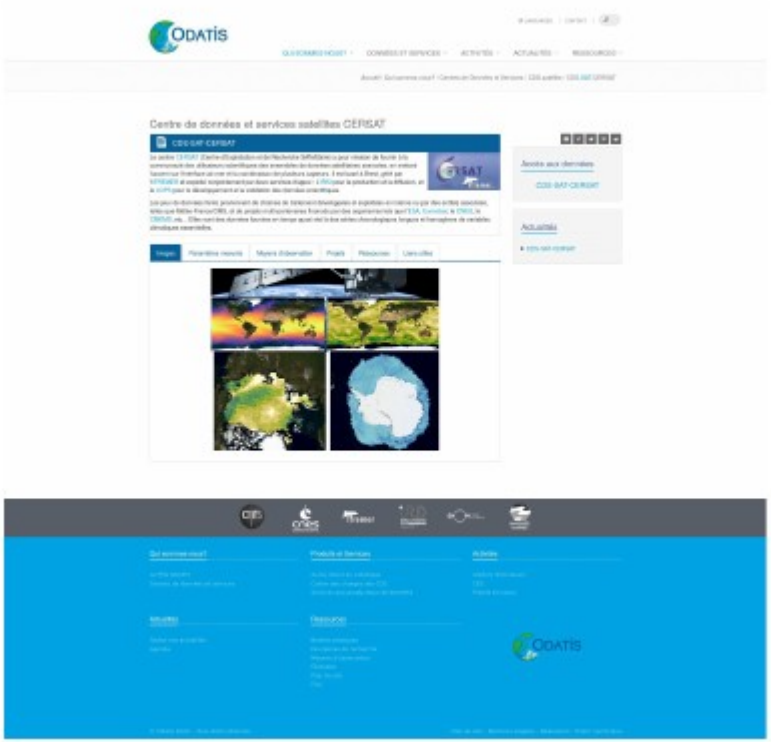


Visualization (syntool)

IWWOC products availability

IWWOC products : when and where ?

- Implementation of alternative methods and SCAT/SWIM synergy first required investigation and analysis of upstream data
- IWWOC products are being finalized and validated
- Release of the first products expected mid-2021
- Announcement will be made to user community
- Data will be available through ODATIS portal



https://www.odatis-ocean.fr