SWIM ocean surface wave spectra L2S product

- overview
- (new) associated L2S / WW3 partitions dataset
- application to swell tracking

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CFOSAT mission

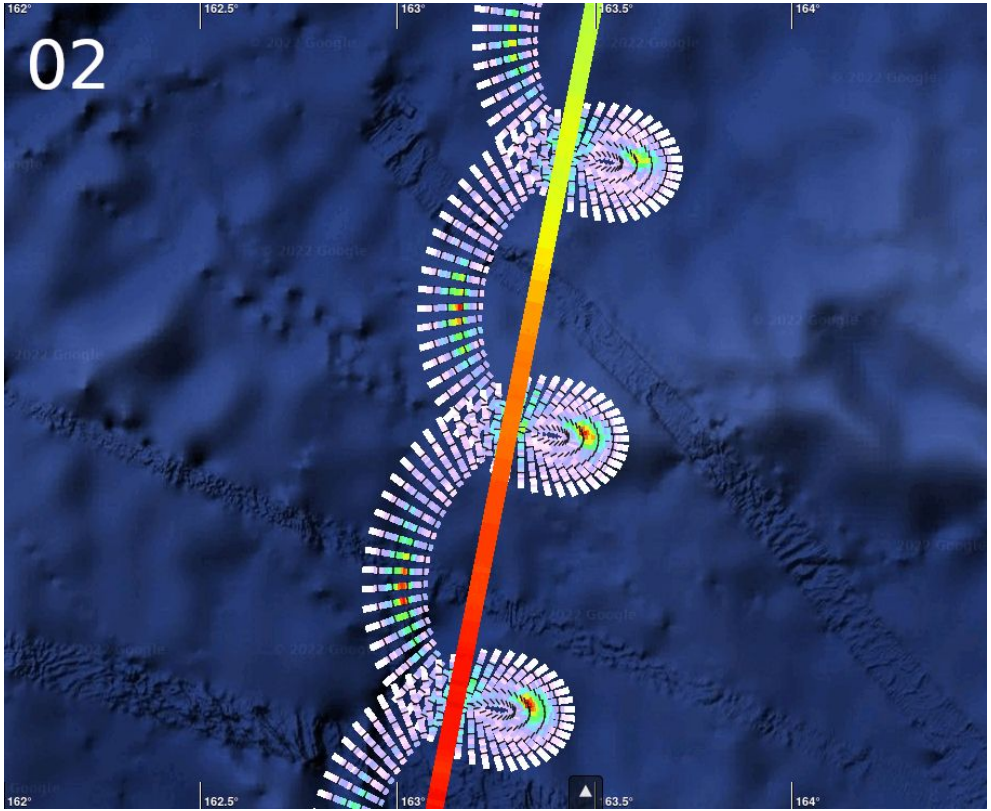
- Chinese-French Oceanic SATellite (CFOSAT) is a joint mission of the Chinese (CNSA) and French (CNES) space agencies devoted to the monitoring of the ocean surface wind and waves

- Launched in October 2018, CFOSAT carries 2 active sensors both in Ku-band:
  - SWIM dedicated to the measurements of directional wave spectra
  - SCAT dedicated to the measurements of ocean surface winds

- On french side, products are available through 2 centers
  - CNES Wind and Wave Instrument Center (CWWIC)
    - NRT L1 and L2 products
    - see https://www.aviso.altimetry.fr/en/data/products/wind/wave-products/wave-wind-cfosat-products.html
  - IFREMER Wind and Wave Operational Center (IWWOC)
    - delayed mode L2S to L3/L4 products
    - motivations: long and consistent time series to complete climate data series, synergy between SCAT/SWIM and alternative processing methods and testing
    - see https://cersat.ifremer.fr/fr/Projects/Recent-and-ongoing-projects/IWWOC

SWIM instrument

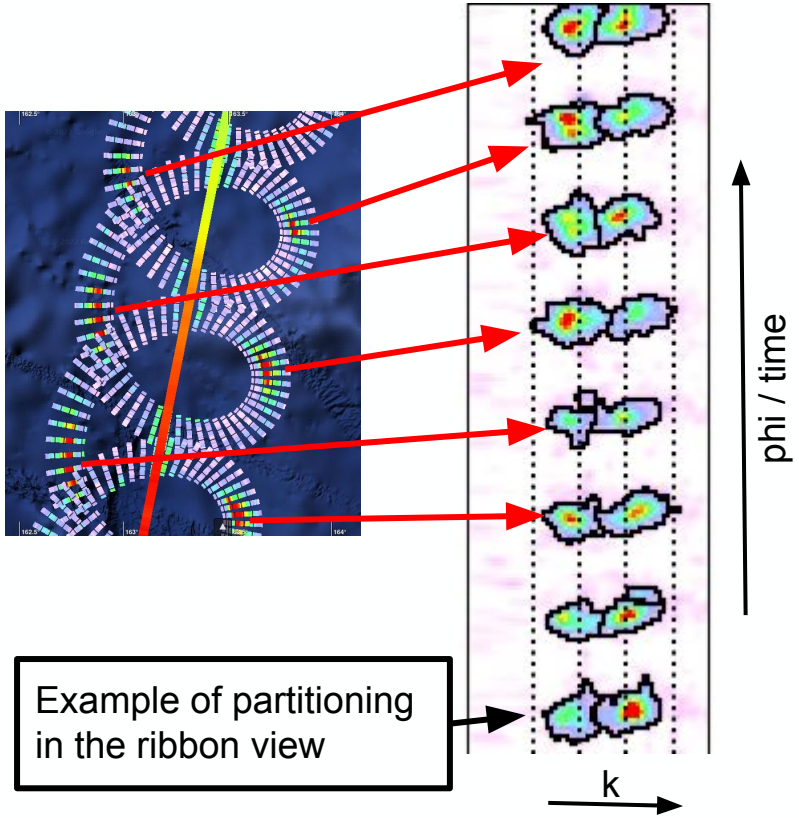
- SWIM (Surface Wave Investigation and Monitoring) measures the ocean surface wave related modulations in Ku band using a rotating instrument
- In nominal macrocycle mode, it provides a directional 1D wave spectra
  - every ~7 degrees
  - for each of its 5 beams at 2, 4, 6, 8, and 10° incidence angle
  - resulting in a very special cycloid ground footprint geometry.



Example of 1D raw spectra projected over range footprint With nadir Hs

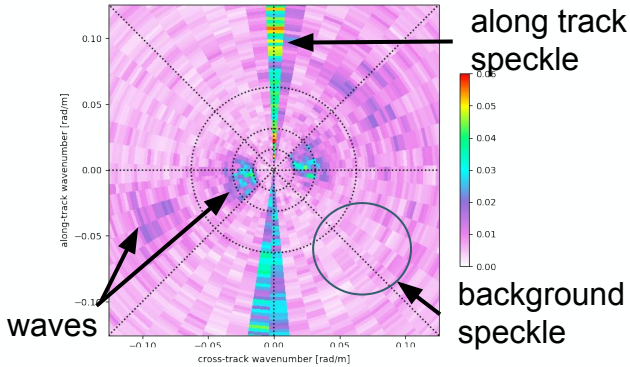
IWWOC SWIM L2S product overview

- L2S product is a L2 like product with the following features:
  - wave partitioning along the continuous cycloid (“ribbon view”)
  - speckle correction based on a learned look-up table
  - empirical MTF (not yet, work in progress)
  - all beams including 2 et 4 degrees beams (no onboard range migration)
  - includes variables of interest : sigma0, raw spectra, nadir variables, ancillary data
- First public release in early 2022 (version v1.0):
  - HTTP access: https://data-cersat.ifremer.fr/projects/iwwoc/swi_l2s/
  - FTP access: ftp://ftp.ifremer.fr/ifremer/cersat/projects/iwwoc/swi_l2s/

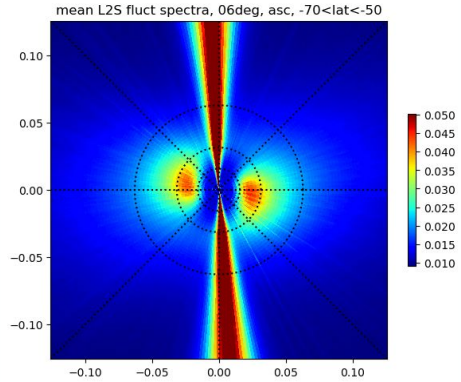


Speckle noise

- Speckle noise in the SWIM case is reduced by on-board averaging of many pulses
- 2 speckle regimes exist:
  - in the along-track directions, a poor diversity of phase changes between pulses make the speckle noise very correlated and less reduced by averaging
  - outside this along-track domain, the diversity of phase changes is good enough to have a good reduction of speckle level (background speckle)
- Characteristics of the along-track regime:
  - azimuthal position of maximum speckle varies with pass and latitude due to earth velocity
  - azimuthal width decreases as the angle of incidence increases, from ~27.5 degrees at beam 02 to ~10 degrees at beam 10



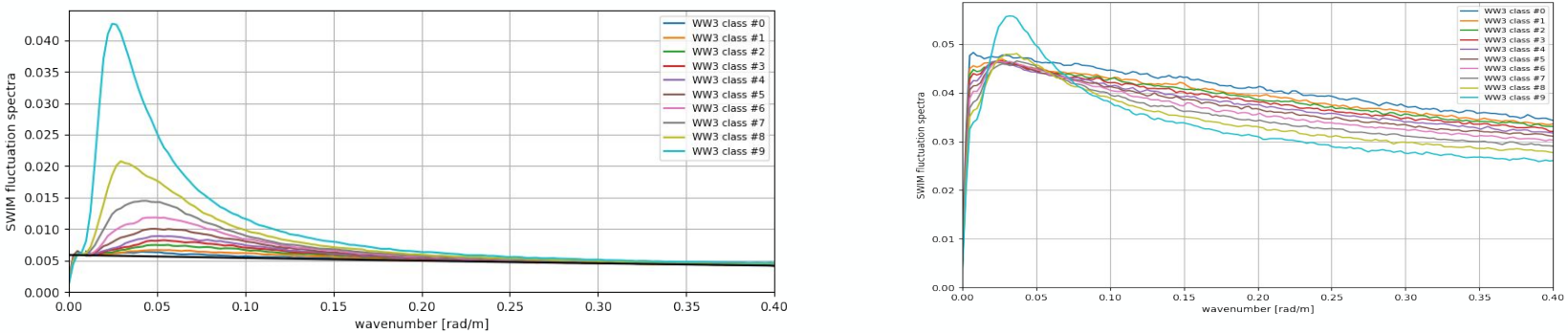
1 rotation (beam 10)



Average according to pass and latitude (beam 6)

Speckle noise

- Investigations on speckle also revealed that in the along-track regime, speckle noise varies with sea state



Averaged SWIM spectra according to WW3 energy in cross-track (left) and along-track (right)

⟶**L2S strategy for speckle correction** is to use a look-up table empirically learned according to the beam, the azimuth, the pass, the latitude and the wind (as a proxy of sea state)

Modulation transfer function (MTF)

- **Current L2S strategy:** MTF is theoretical (tilt effect, Jackson 1981) and parameterized with ancillary wind
  - Still some questions:
    - impact of wave directional spread on MTF
    - impact of range bunching especially at low incidence beams

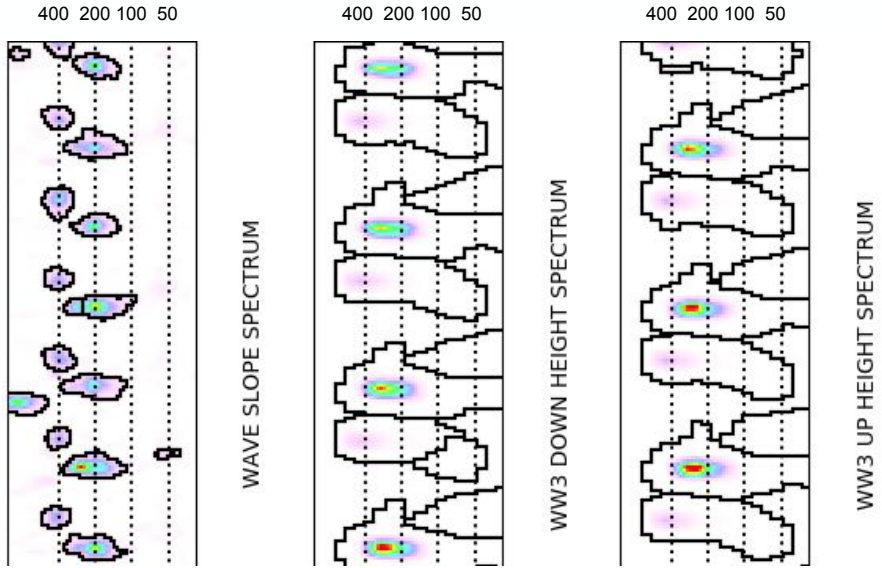
- **(work in progress) Data-driven MTF inversion:** Learn MTF directly from SWIM data, coupled with model and/or in situ data (WaveWatch3, buoy data)
  - classical statistical approach: understand the link between SWIM and “ground truth” according to beam, azimuth, wind, wave directional spread

    →**Creation of a L2S / WW3 partitions dataset, introduced in the next slides**
  - deep neural networks approach
    - Preliminary results show good mean performance, but more work is still needed
    - Multiple improvements to be explored (different network architectures, network pre-training on synthetic datasets, data augmentation, transfer learning, etc)

    →tuesday afternoon: **Exploring statistical insights coupled with deep neural networks for the inversion of the MTF (Lopez Radcenco Manuel)**

L2S / WW3 partitions dataset

- **“CFO_OP05_SWI_WW3” products**
  - Routinely produced at IWWOC
    https://data-cersat.ifremer.fr/projects/iwwoc/colocations/
    ftp://ftp.ifremer.fr/ifremer/cersat/projects/iwwoc/colocations/
  - WW3 output in the SWIM L2S geometry: nearest model output in time/space interpolated in SWIM looking direction
    (both upwave and downwave versions)
  - Same geometry/format than L2S
  - Partitioning of the WW3 ribbon was recently added in the products (ongoing reprocessing)



SWIM L2S | WW3 downwave | WW3 upwave

L2S / WW3 partitions dataset

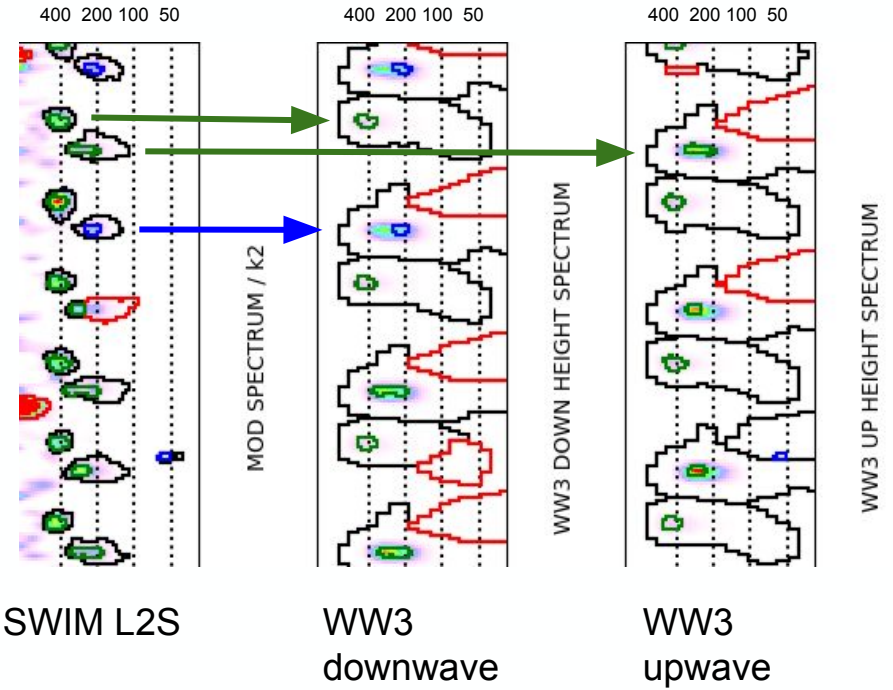
- Association methodology
  - for each L2S partition, find both WW3 downwave and upwave partitions with the minimal spectral distance between peaks. Between downwave and upwave, keep the most energetic partition around SWIM peak.
  - if many L2S partitions are associated to the same WW3 partition, keep only the association with the minimal spectral distance
  - for each association, compute the intersection of most energetic part (energy > max/2) of both L2S and WW3 partitions
  - for each association+intersection, we keep in the dataset many informations: peaks, energy, directional spread, frequency spread, wind (model), phi geo, phi, time, lat, lon, pass …

- Main assumption: SWIM peaks are computed from the SWIM modulation spectra divided by k^2 (theoretical MTF shape). So we assume that the real MTF does not move energy very differently than a MTF with a k^2 shape.

- Open question on model validity: can we trust more the model (energy) when model and SWIM exhibit close peaks ?

L2S / WW3 partitions dataset

- 4 association cases
  - black+green: intersection of partitions not null, peaks still inside intersection
  - black+blue: intersection of partitions not null, at least one peak outside
  - black empty: intersection of partitions is null (not shown here)
  - red: not associated or flagged (not written in the database)



L2S / WW3 partitions dataset

- The dataset was generated for the year 2021
- Analysis in progress, focusing on the “green” associations
- Proposal to discuss very preliminary results during Tuesday side workshop (Exploratory method and synergy)

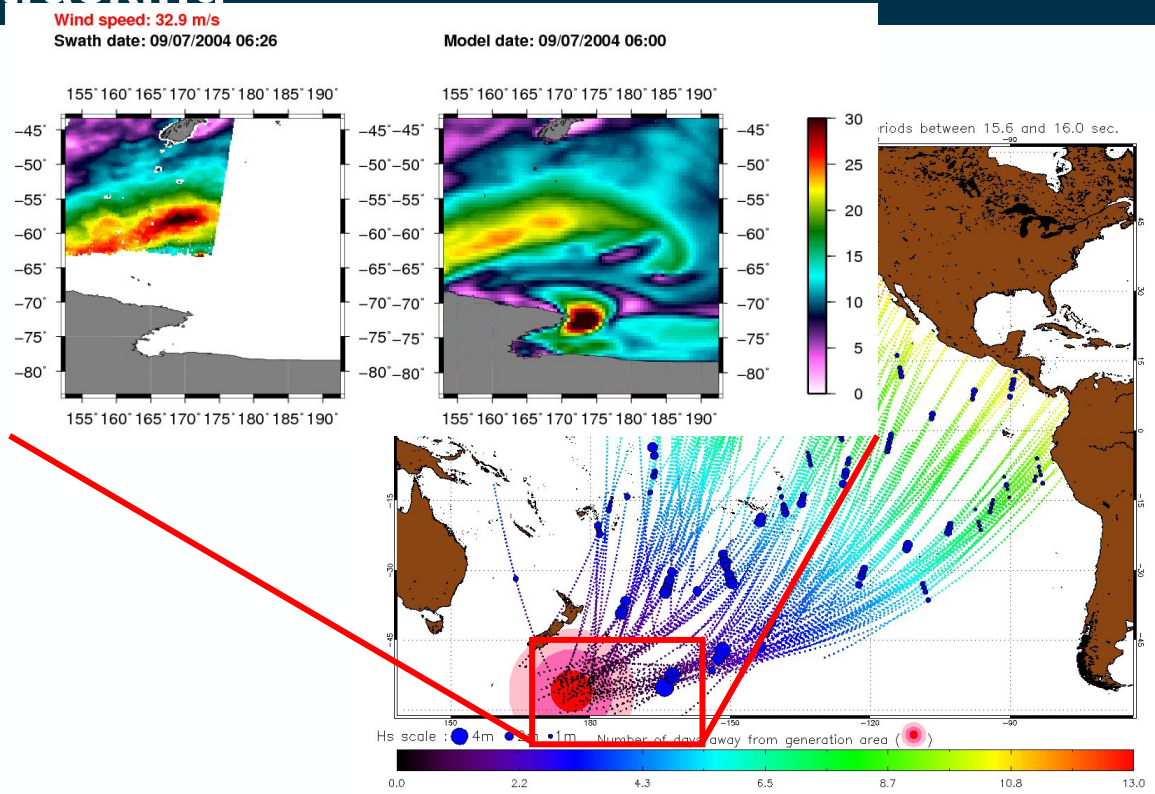
	Inter. with peaks	Inter. without peaks	No inter.
02	1 057 654	788 504	512 301
04	1 175 969	793 606	470 014
06	2 168 739	1 083 178	548 190
08	2 467 320	1 032 402	482 094
10	2 468 553	968 743	452 533

Number of L2S/WW3 partition pairs per beam and cases

First use of L2S for swell tracking

Firework analysis : Principle

- Extraction of swell systems parameters from wave spectra level2 products.
- Backward propagation to identify the swell origin (Storm source).
- Identification of all swell observations relative to a given Storm source.
- Determination of the propagation path by forward and backward propagation between observations (using deep water waves dispersion relation).

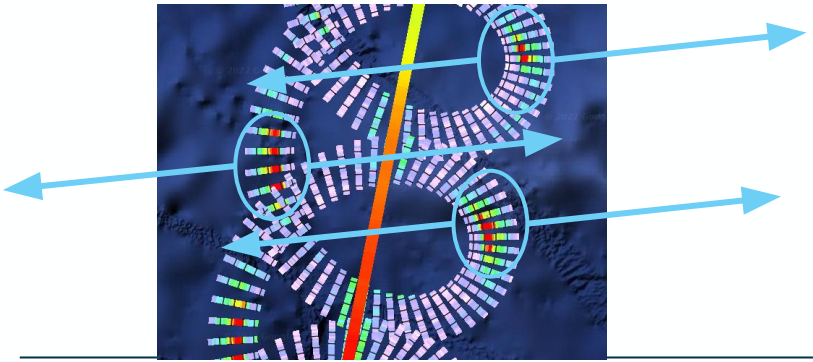


Propagation of 15-16s swell from July 8 to July 20, 2004, Envisat

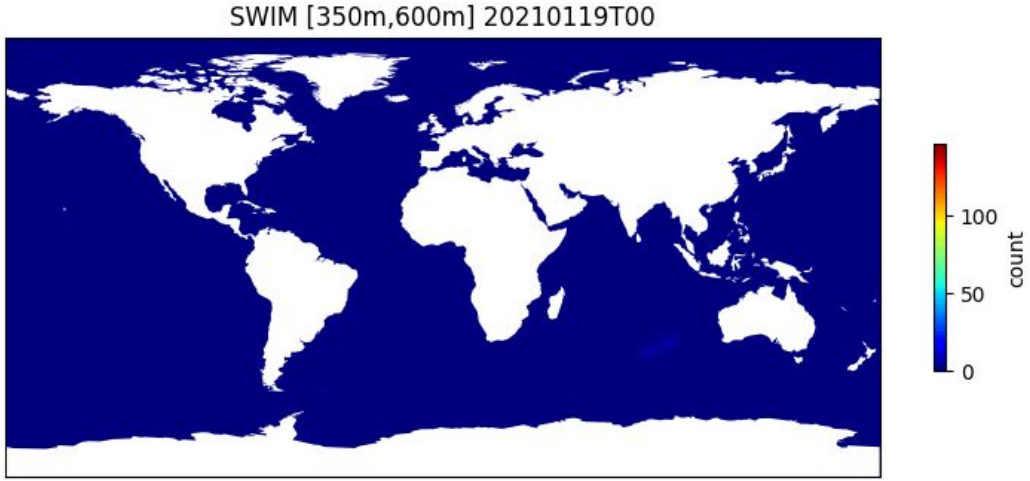
First use of L2S for swell tracking

L2S inputs

- L2S partitions from 2021-02-01 to 2021-02-14
- use of all 5 beams 2/4/6/8/10° (only wavelengths longer than 350m for beams 2 and 4 degrees)
- observations are back propagated in two opposite directions because of SWIM propagation 180° ambiguity



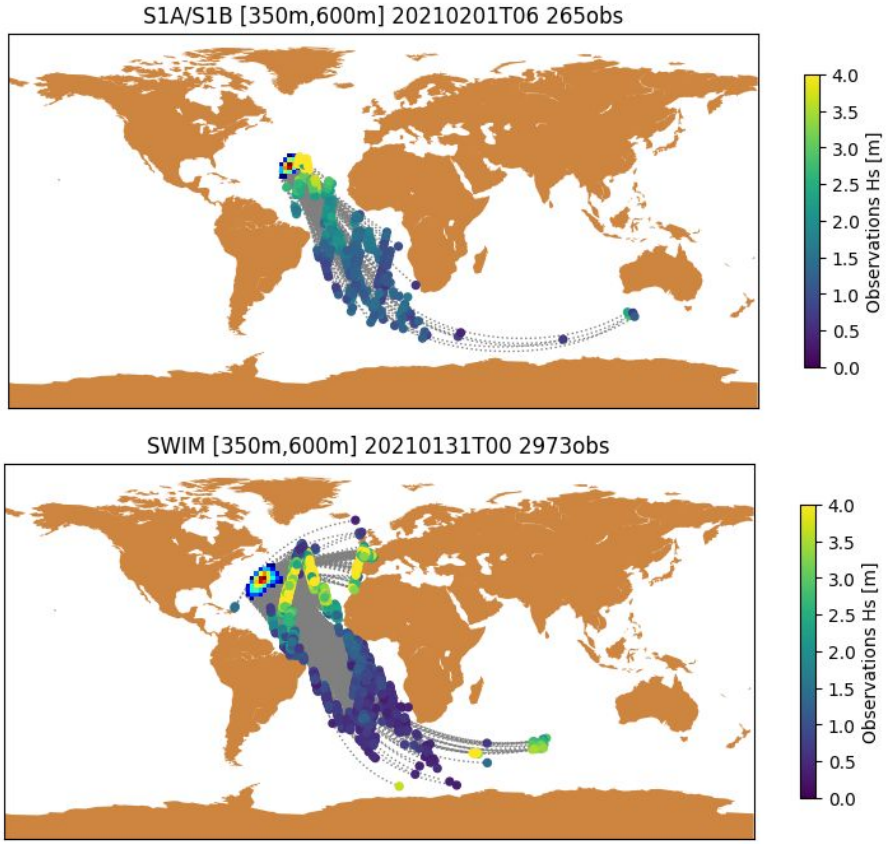
One month of SWIM back-propagation rays density



First use of L2S for swell tracking

Storm source seen by S1A/S1B WV (top) and SWIM (bottom) - refocusing

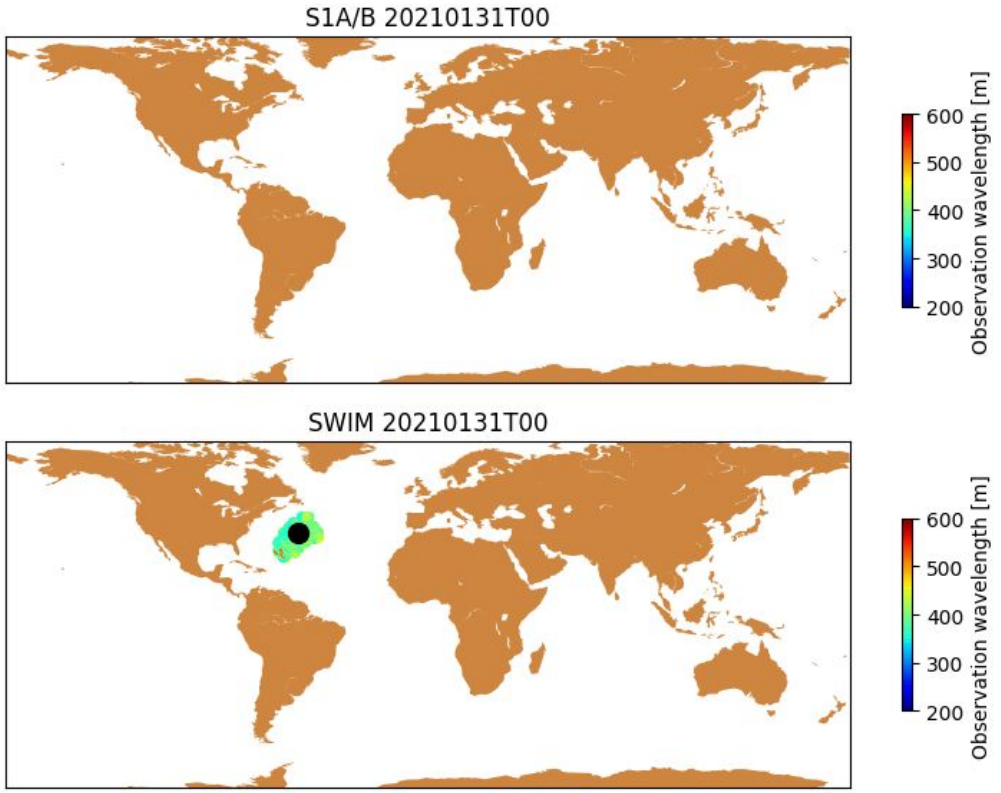
- higher density of observations with SWIM (factor 10)
- SWIM brings observations in North Atlantic where S1 WV mode is not acquired
- different overall sampling of SWIM (orbit daily drift about 380km to East) and S1 (1000km to West)



First use of L2S for swell tracking

One storm source seen by S1A/S1B WV (top) and SWIM (bottom)

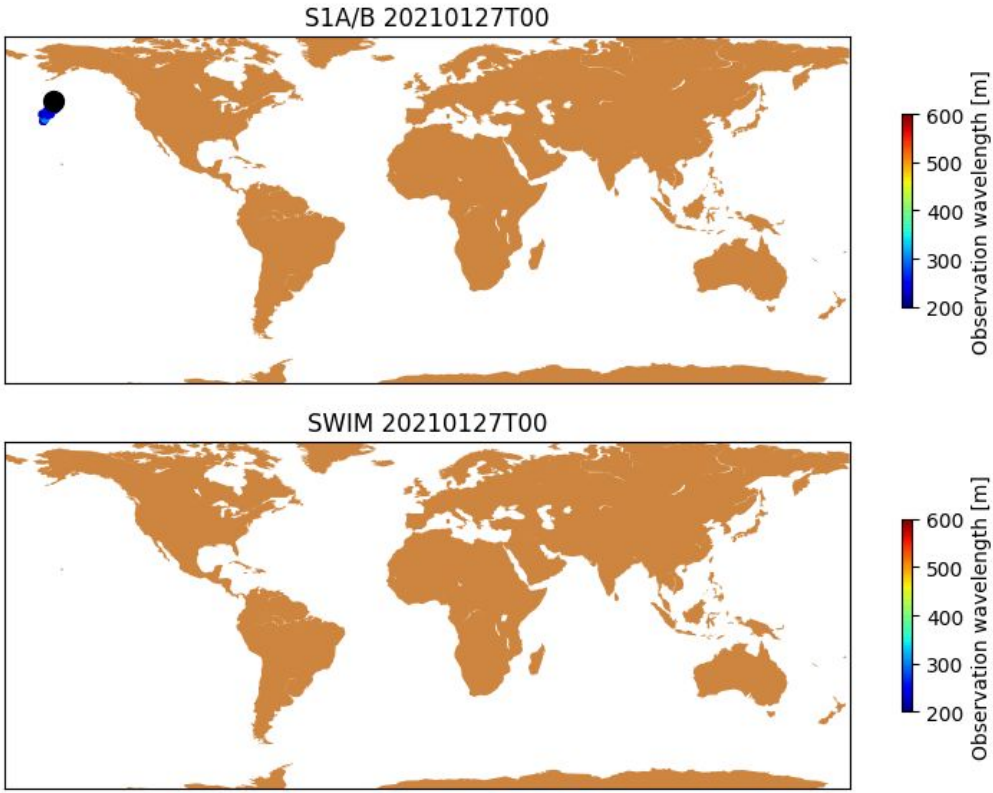
- animation including forward propagation



First use of L2S for swell tracking

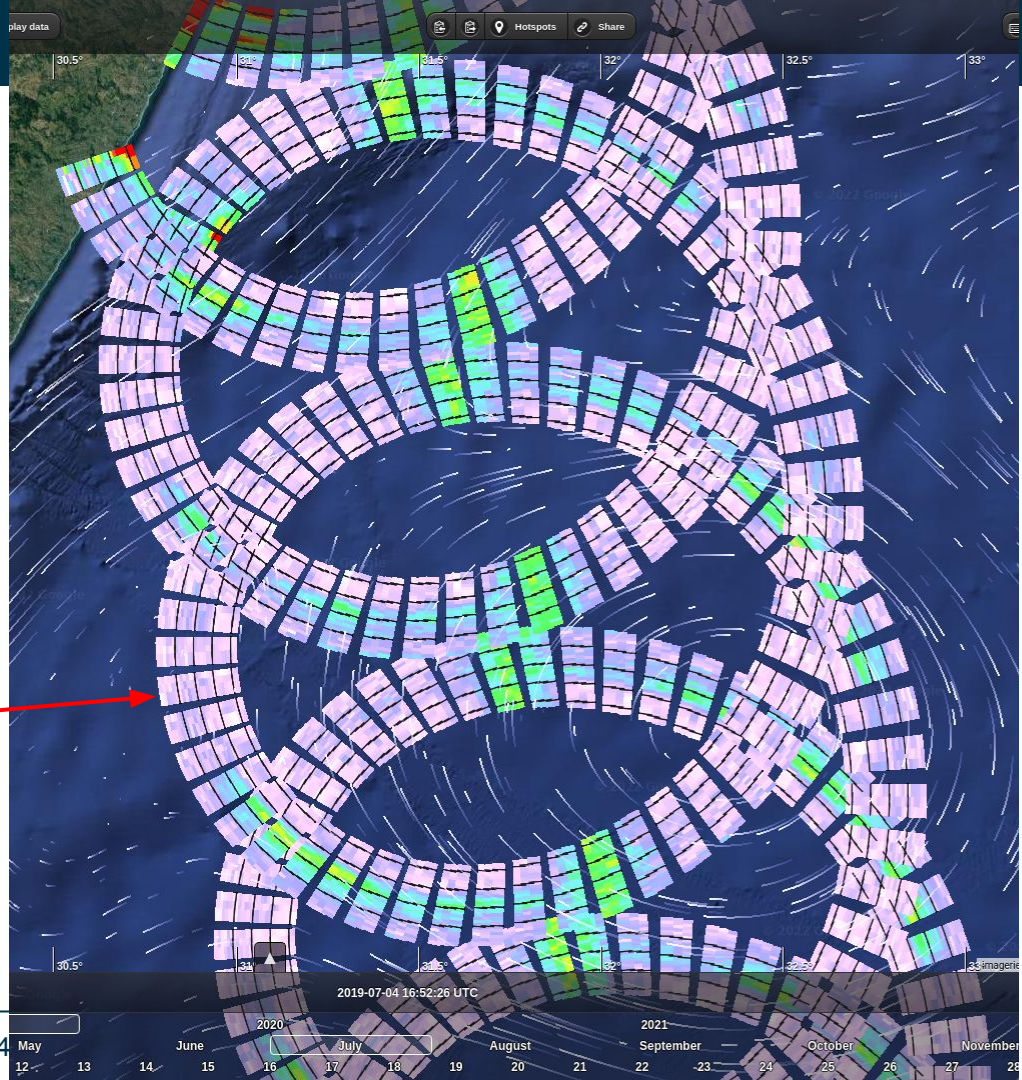
All storm sources seen by S1A/S1B WV (top) and SWIM (bottom) - propagation

- One month animation including forward propagation



CFOSAT portal

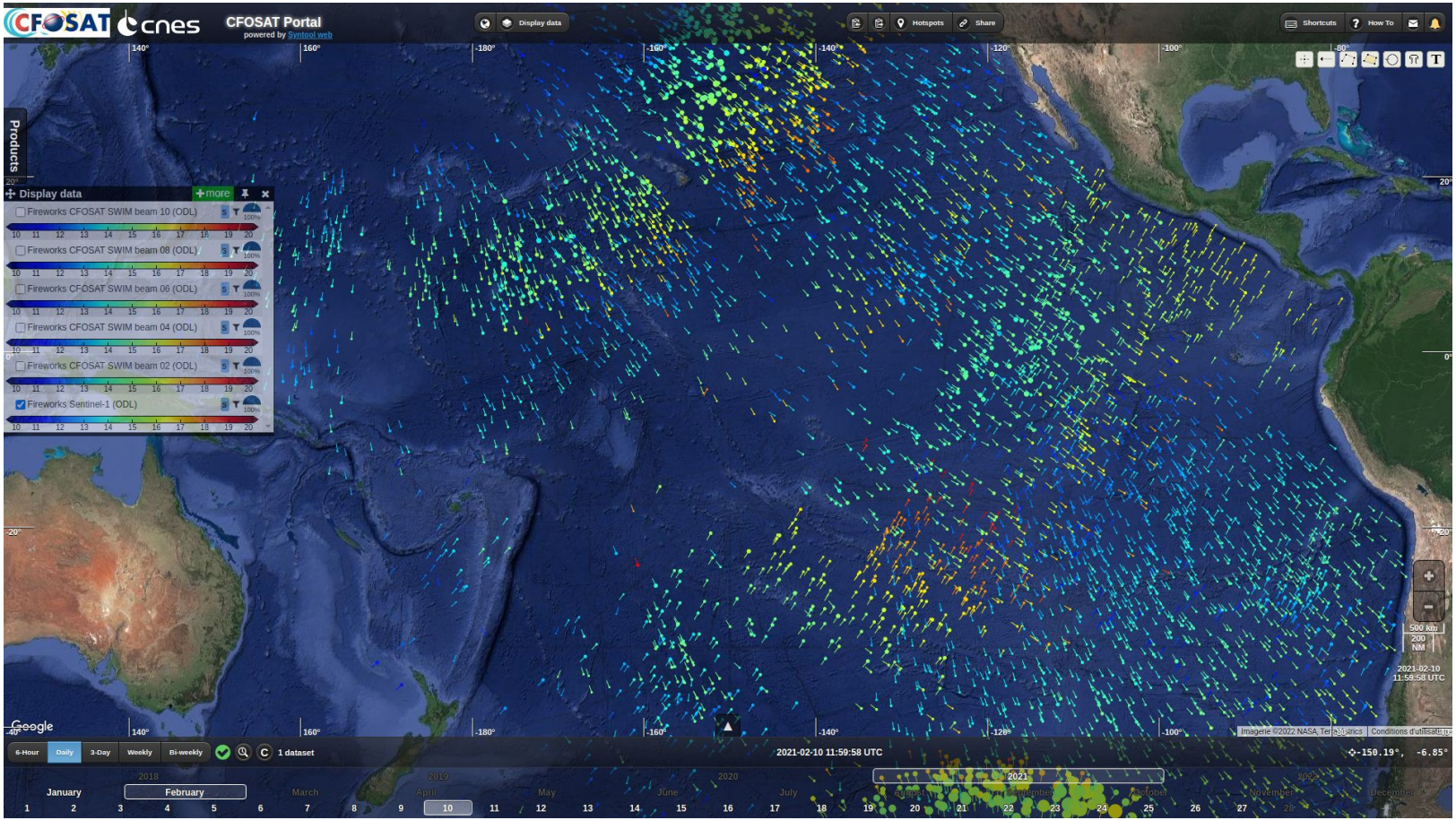
- Portal at https://cfosat.oceandatalab.com
  - A few L2S samples (raw spectra) as well as CWWIC L2 samples are visible
  - (New) Fireworks demo case https://odl.bzh/_knrgM78, see next slides
  - (New) L2S with a 0,2,10,10,10 macrocycle https://odl.bzh/6fguGixw



3 cycles

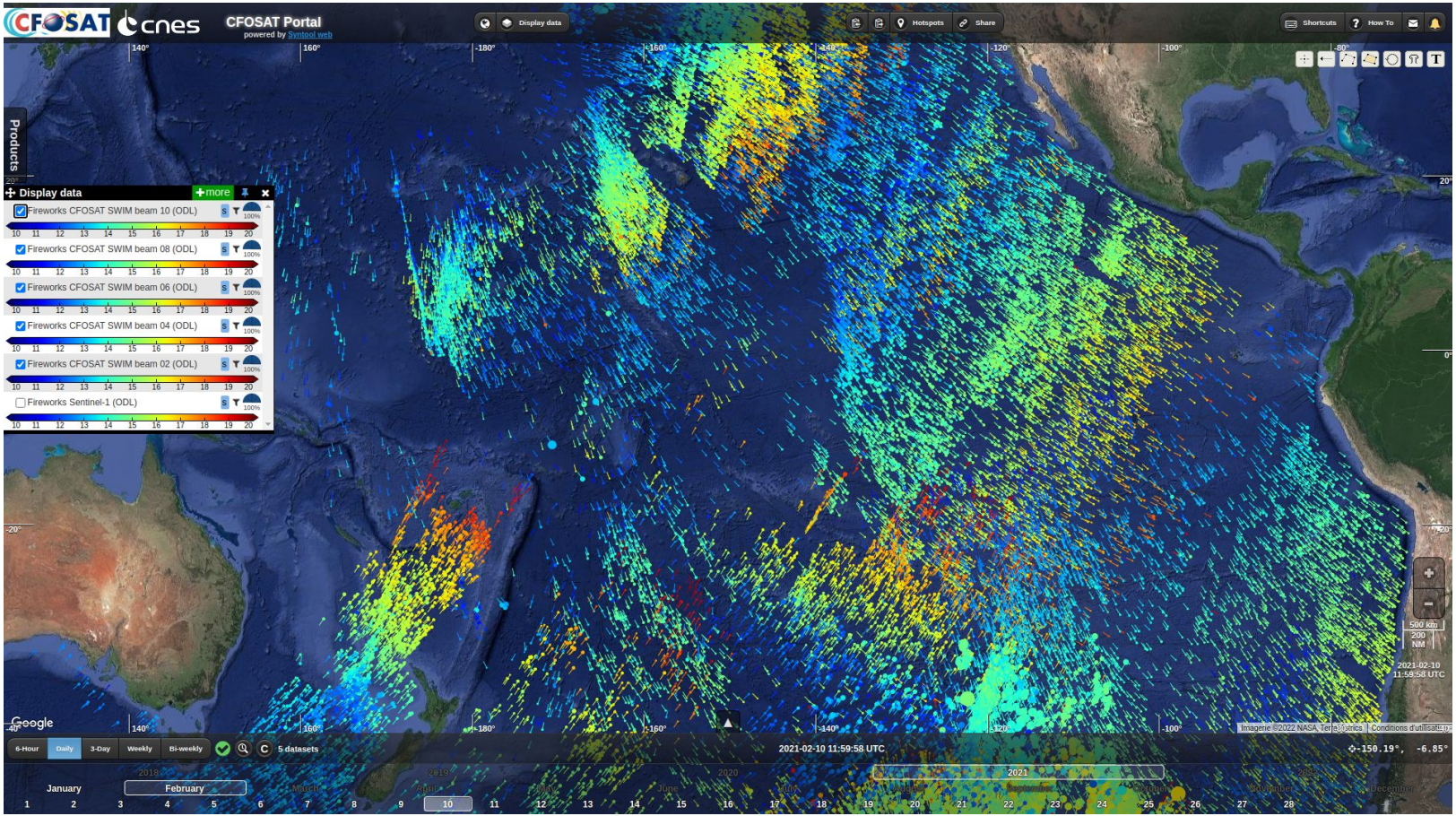
CFOSAT portal, swell tracking demo case

S1
A & B

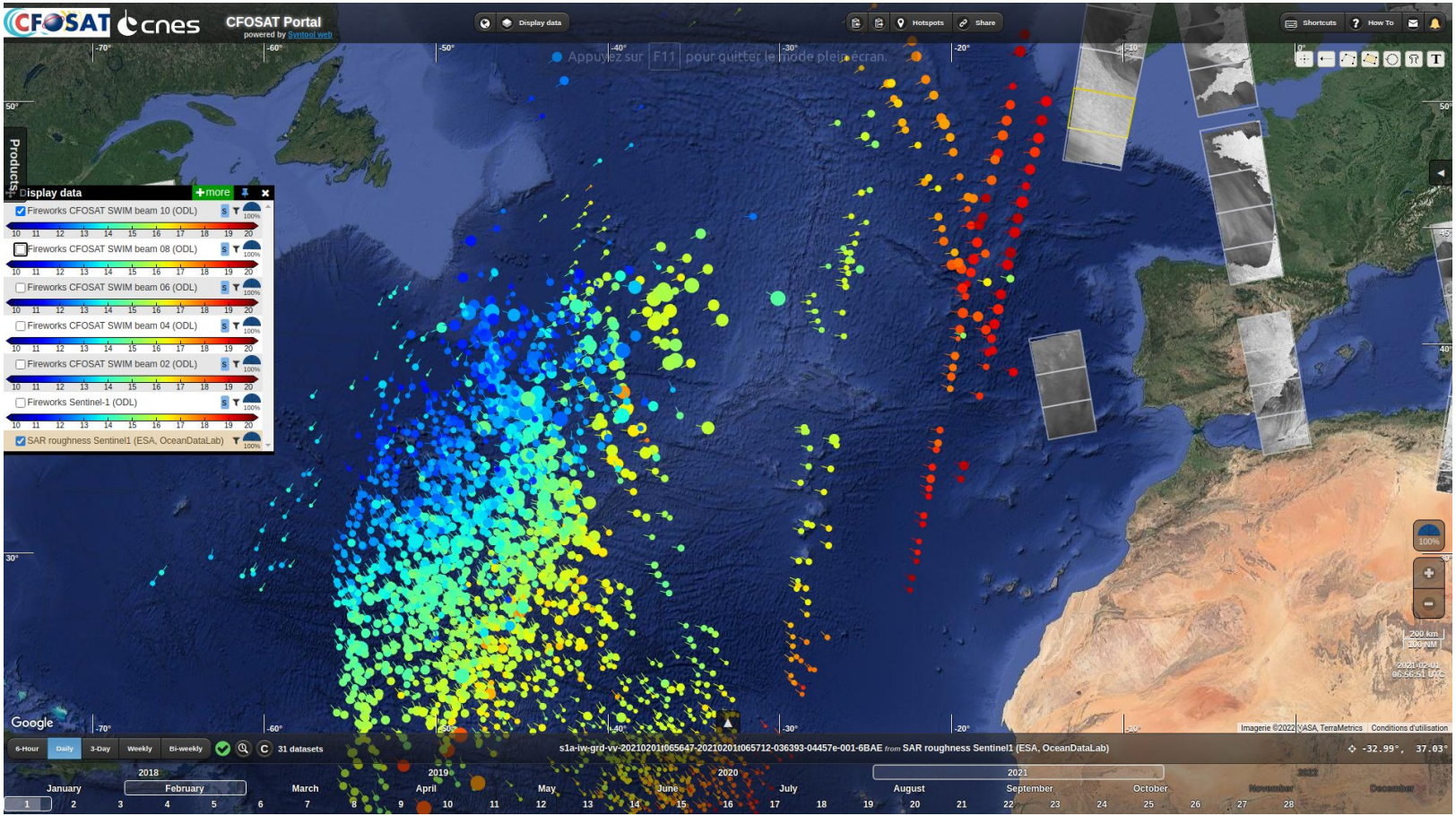


CFOSAT portal, swell tracking demo case

SWIM
All beams



SWIM
Beam 10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CFOSAT Portal
powered by Syntool web
Display data
Hotspots
Share
Shortcuts
How To
Appuyez sur F11 pour quitter le mode plein écran.
Products
Display data
+more
Fireworks CFOSAT SWIM beam 10 (ODL)
Fireworks CFOSAT SWIM beam 08 (ODL)
Fireworks CFOSAT SWIM beam 06 (ODL)
Fireworks CFOSAT SWIM beam 04 (ODL)
Fireworks CFOSAT SWIM beam 02 (ODL)
Fireworks Sentinel-1 (ODL)
SAR roughness Sentinel1 (ESA, OceanDataLab)
Google
6-Hour
Daily
3-Day
Weekly
Bi-weekly
31 datasets
s1a-iw-grd-vv-20210201065647-20210201065712-036393-04457e-001-6BAE from SAR roughness Sentinel1 (ESA, OceanDataLab)
-32.99°, 37.03°
2018
2019
2020
2021
2022
January
February
March
April
May
June
July
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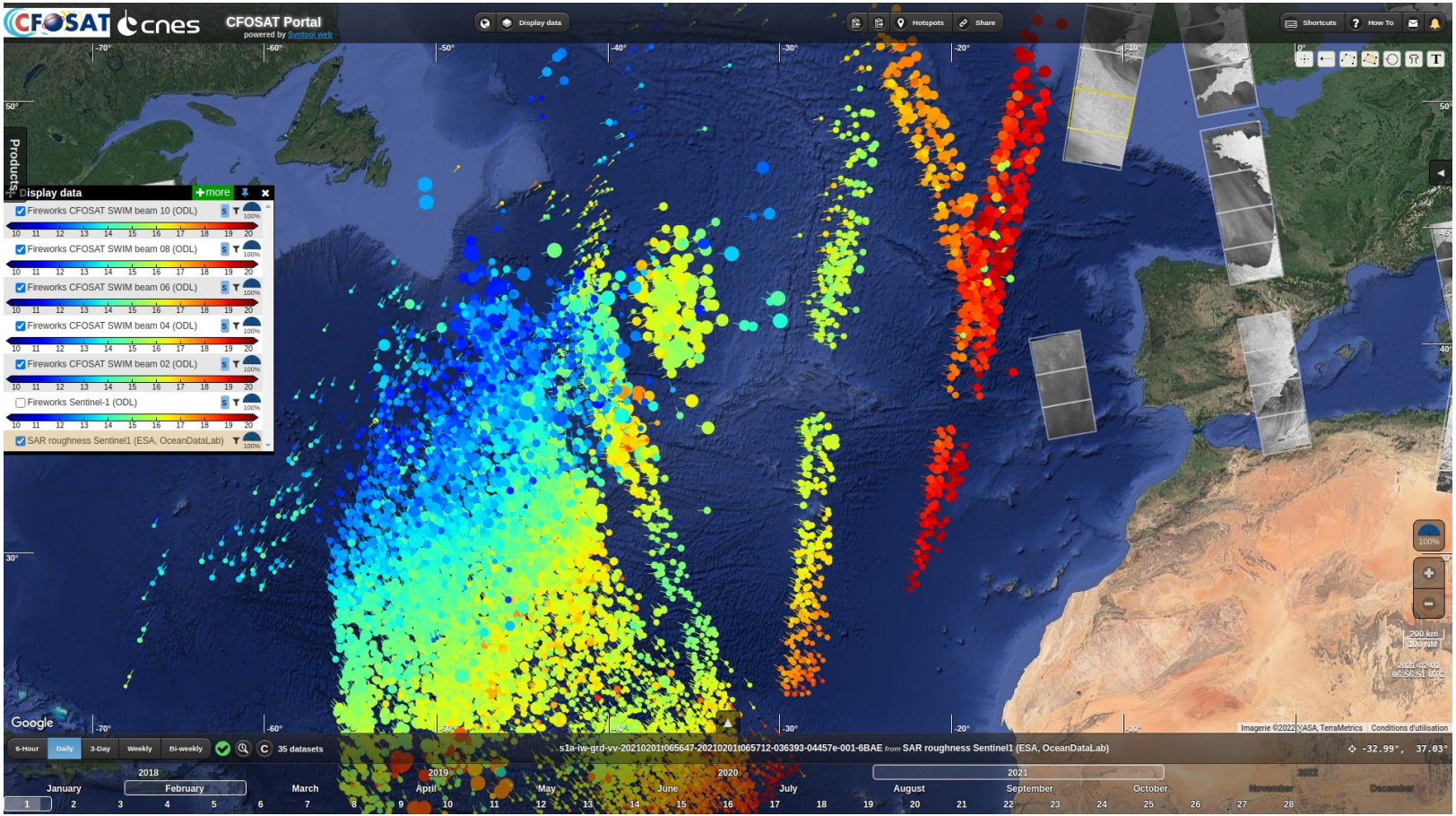
September
October
November
December

SWIM
All beams



L2S limitations and evolutions

- L2S is still a young product (freshly released). To be used with caution for climatological studies because of:
  - MTF not yet learned making Hs questionable
  - False detection of wave partitions

  –> Feedbacks are welcome !

- Short-term evolutions : planned for 2022
  - MTF learning from observations
  - partitioning improvement
    - reduce number of false partitions (beam synergy)
    - propagation ambiguity removal (model a priori, fireworks feedback, …)
  - systematic production of L3 products (gridded partition parameters statistics) and L4 products (fireworks).

Thank you !