Combining directional swell measurements from satellites using Fireworks to enhance short-term swell forecasting: a use case

23/09/2025

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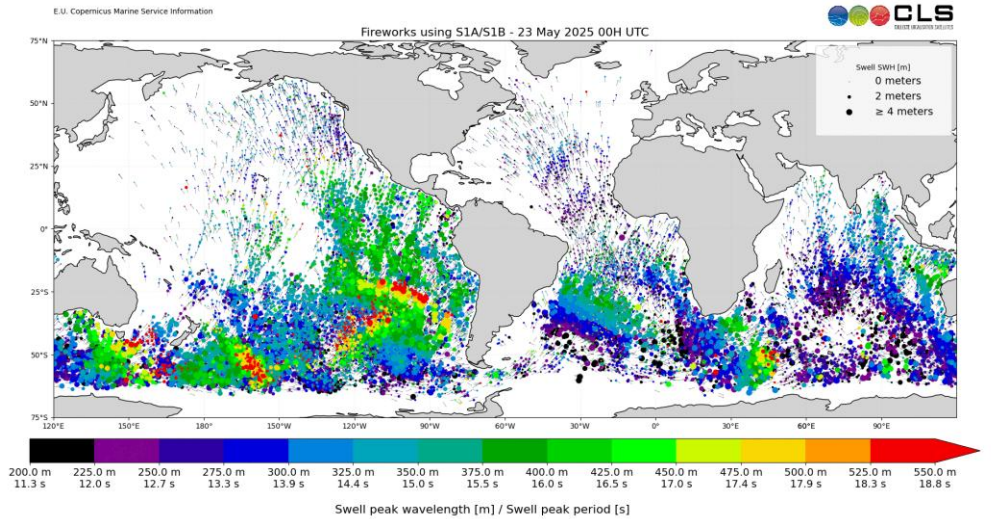
2 CNES, Toulouse, France
3 Univ. Brest, CNRS, Ifremer, IRD, LOPS, IUEM
4 OceanDataLab

1 - Fireworks processing

- Spectral wave product
- Part observation, part modelisation
- Input: estimated integral parameter by swell partition



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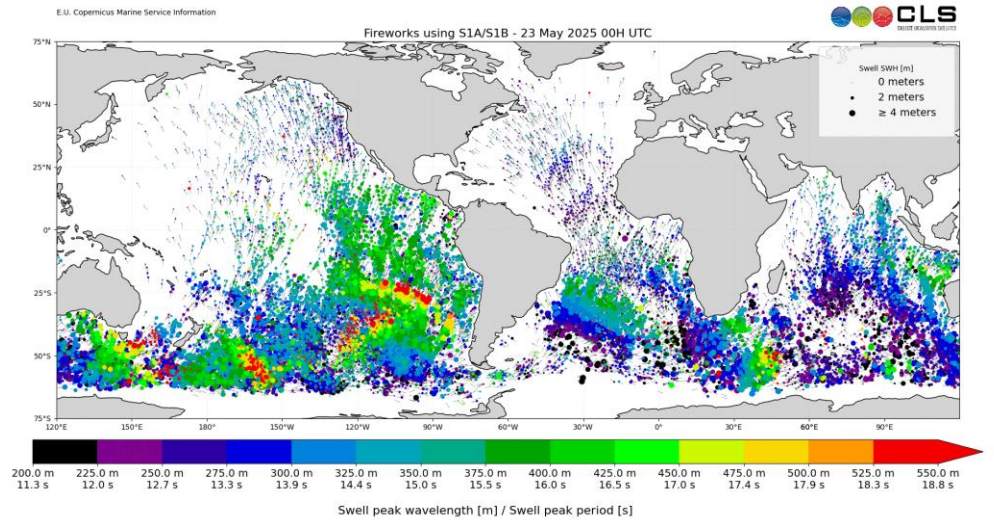

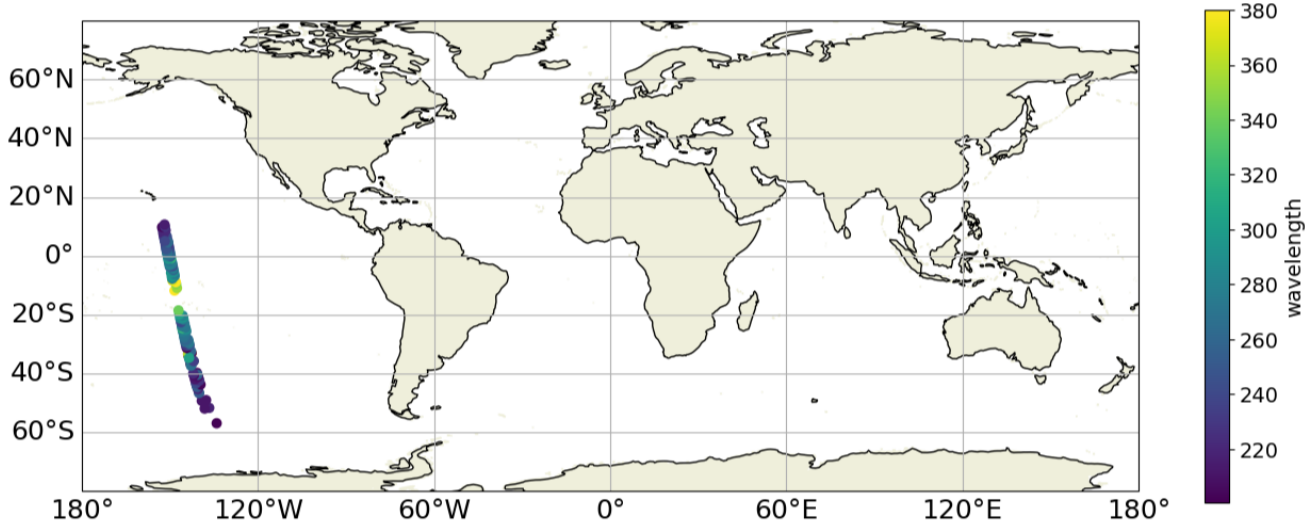

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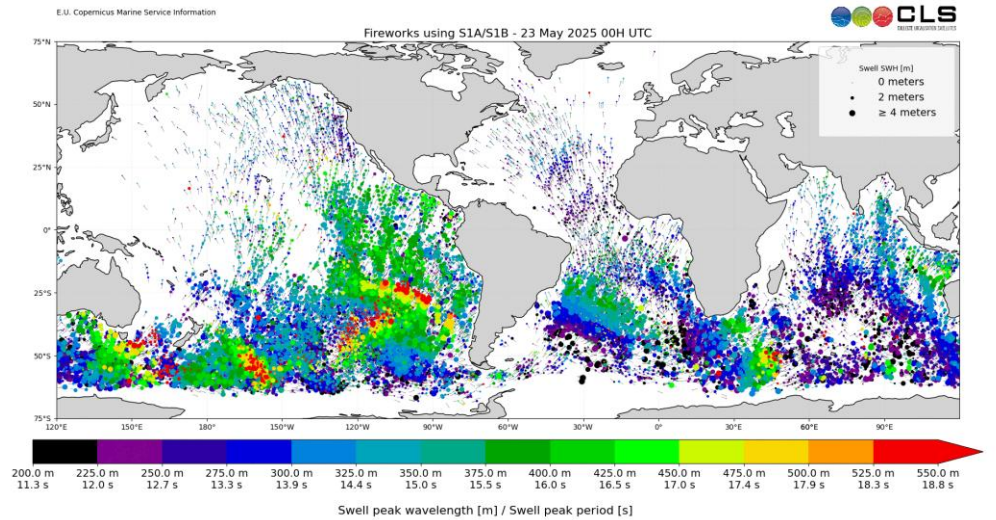

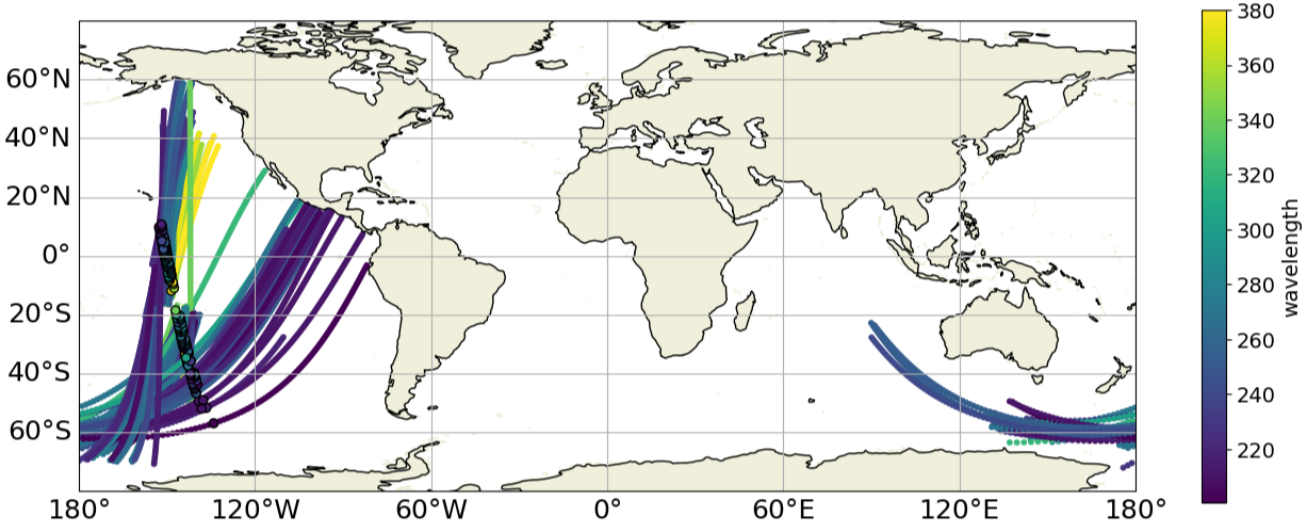

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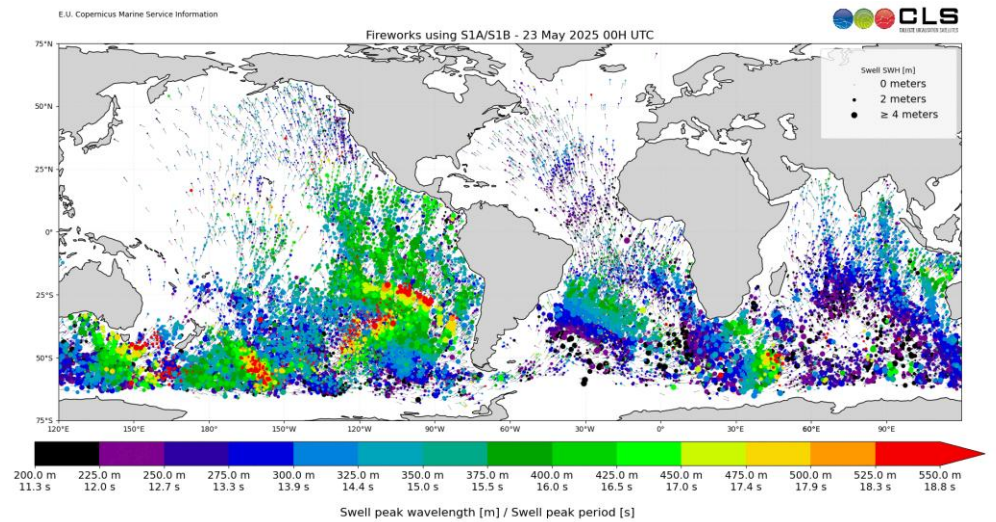

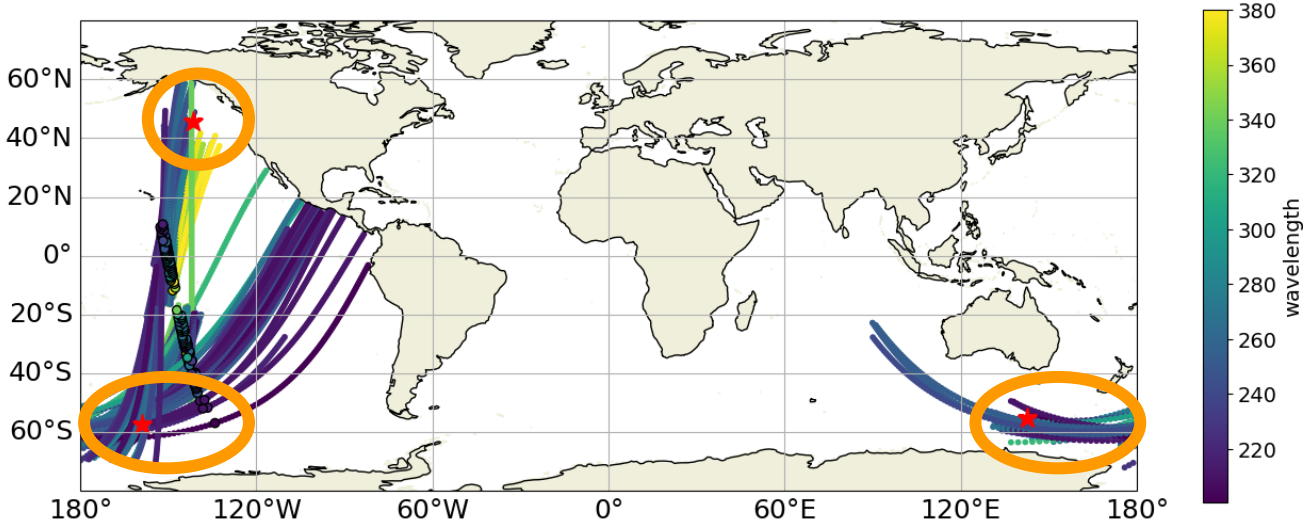

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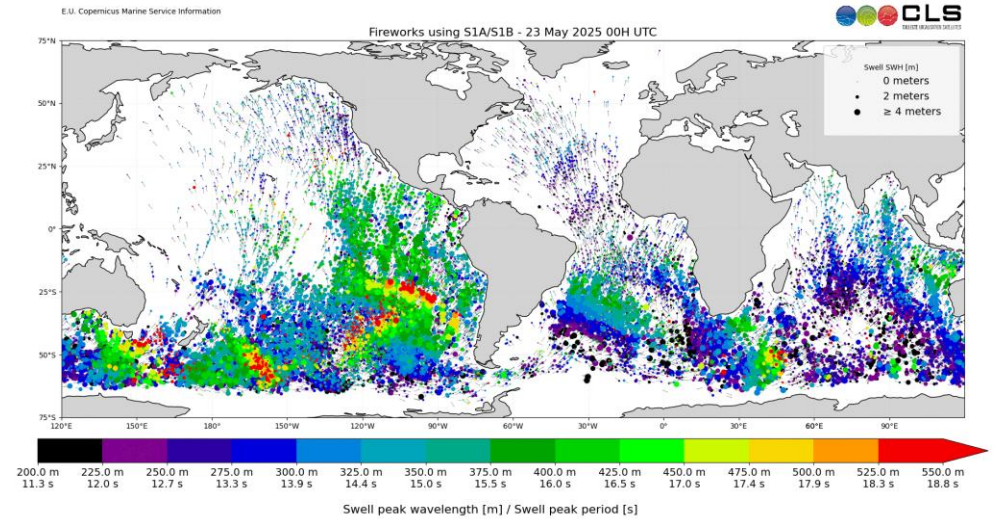
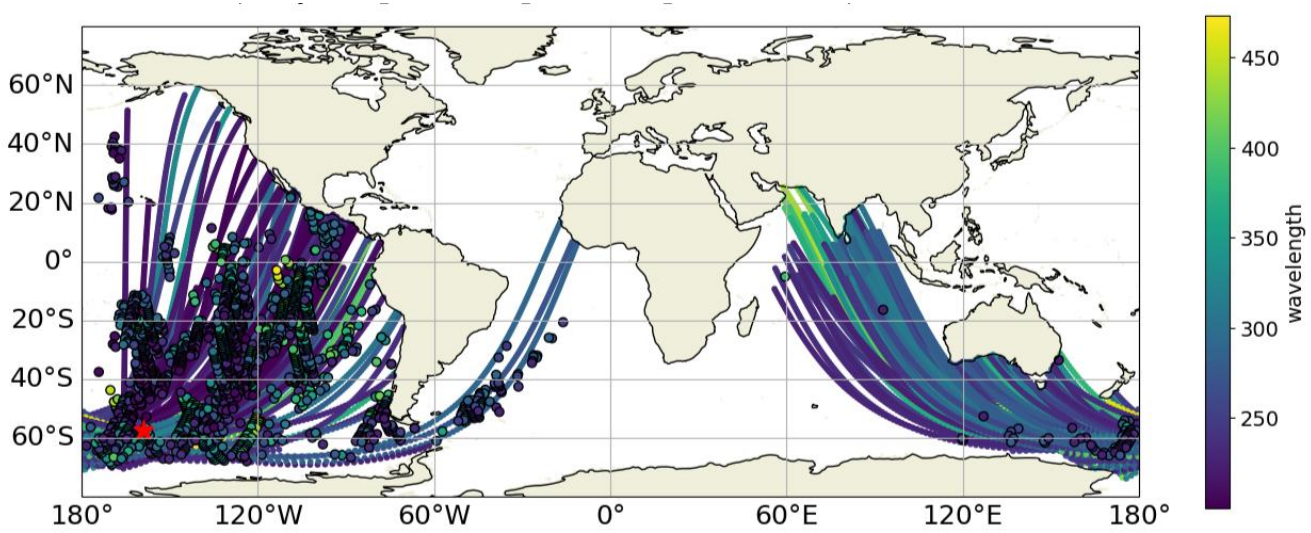
   → **L3 product generation**





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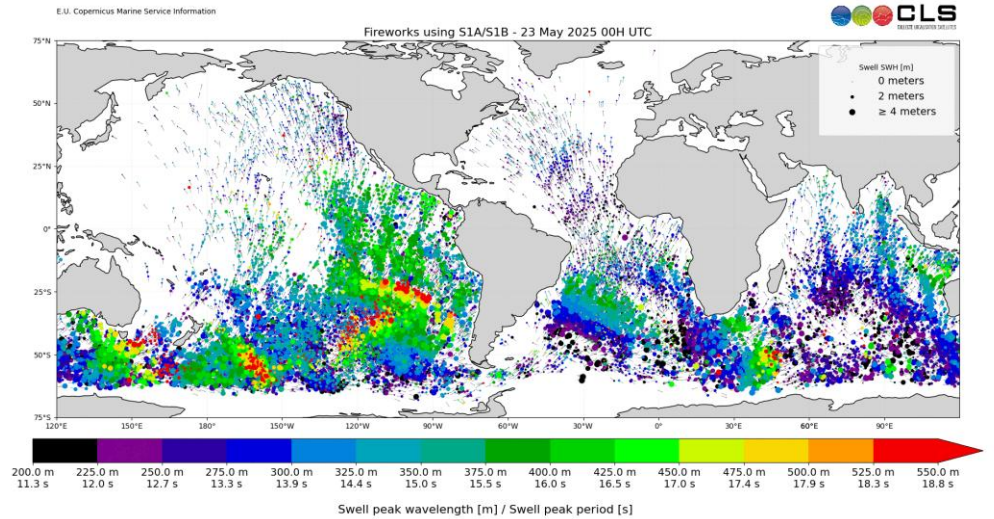
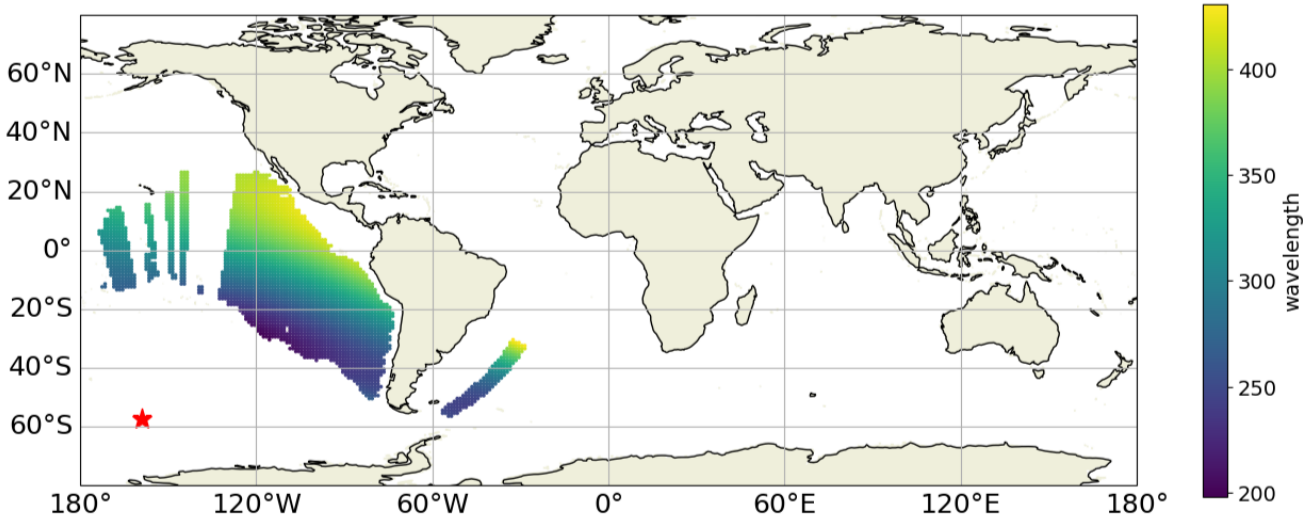
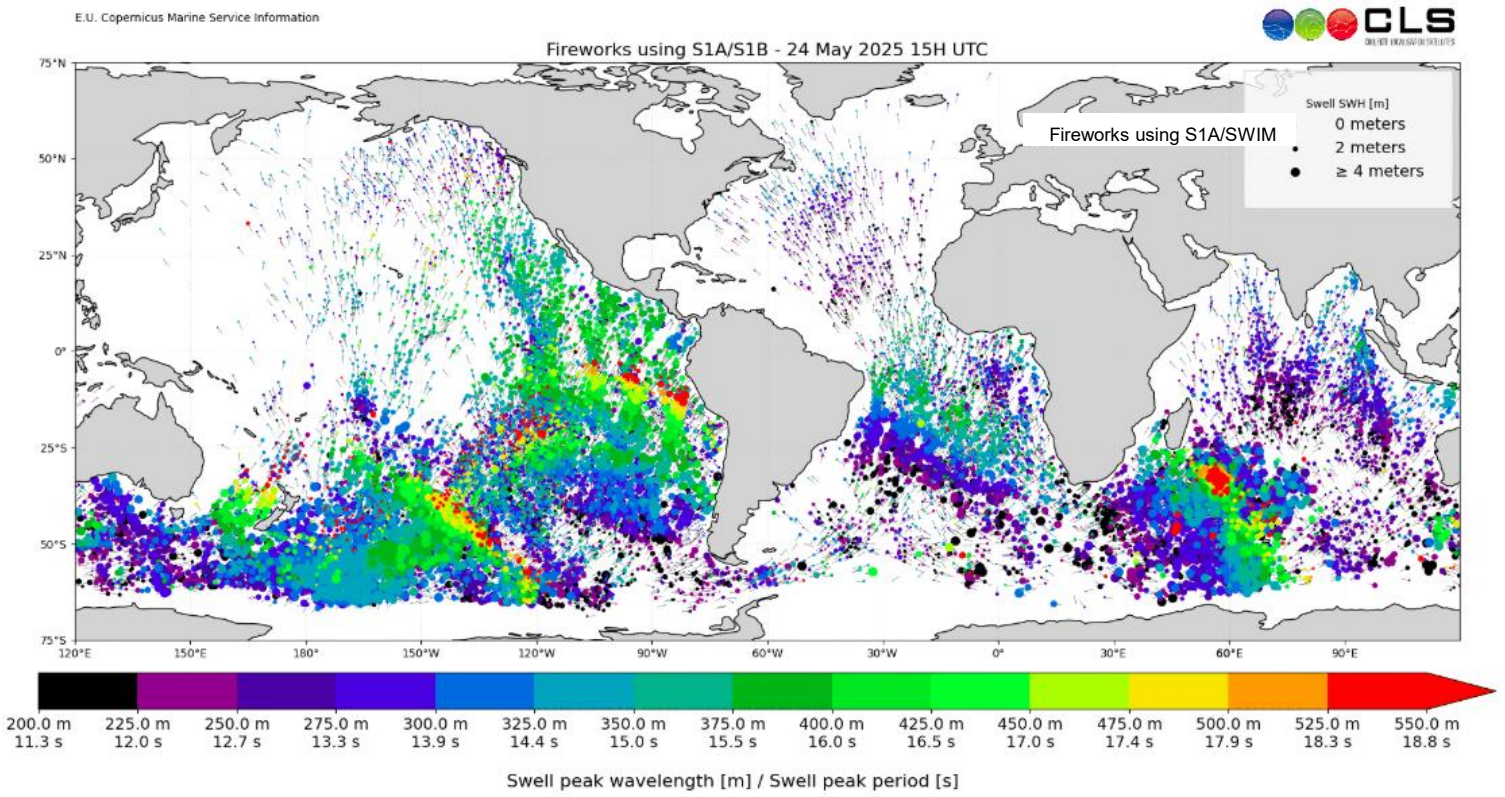
   → **L3 product generation**
5) Creation of a synthetic field by interpolation of the pseudo-obs on a (r,θ) centered on the storm
   → **L4 product generation**





1 - Fireworks processing

In the Copernicus Marine **Wave TAC**: **Sentinel-1 and SWIM L2P box** wave measurements are combined in a **swell monitoring** Level-3 and Level-4 products.



Visible at http://satwave-report.cls.fr/

https://data.marine.copernicus.eu/product/WAVE_GLO_WAV_L3_SPC_NRT_OBSERVATIONS_014_002/description

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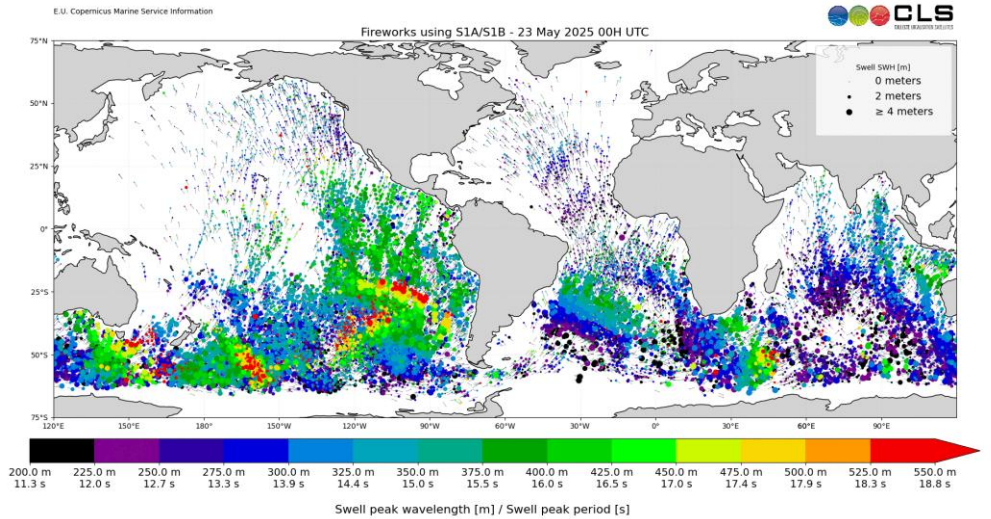


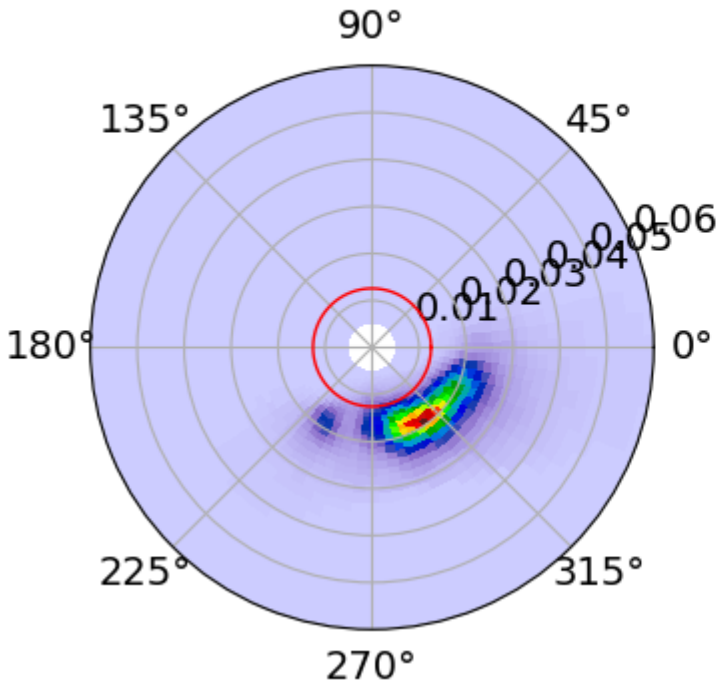
Main advantages:

- **Increases** the number of observations (~ multiply by 100)
- Way of **selecting relevant** spectral information
- Allow for **new cross-overs** between satellite and/or buoys.
- **Multi-sensor** analysis (only needs partition information)

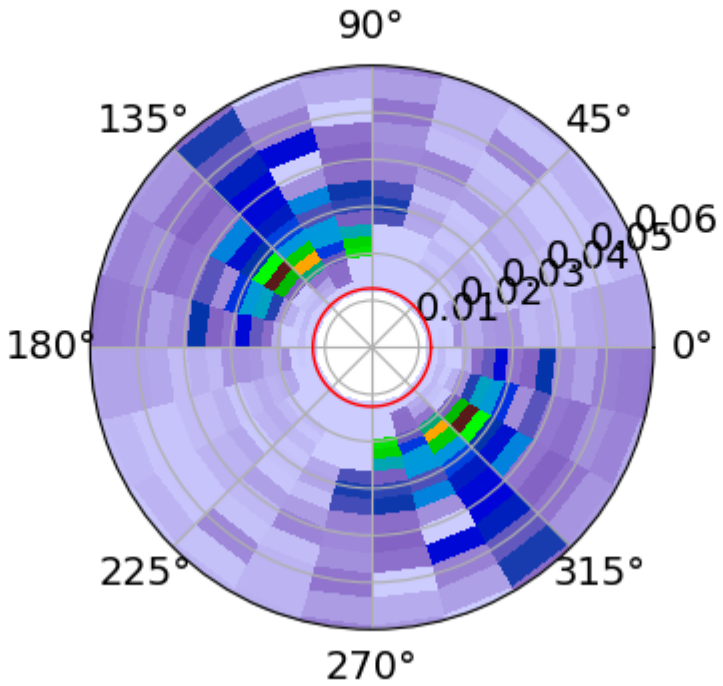
2- Directional spectra

=> Aim : to combine the different observations to see the complementarity and add these to a multi sensor product.

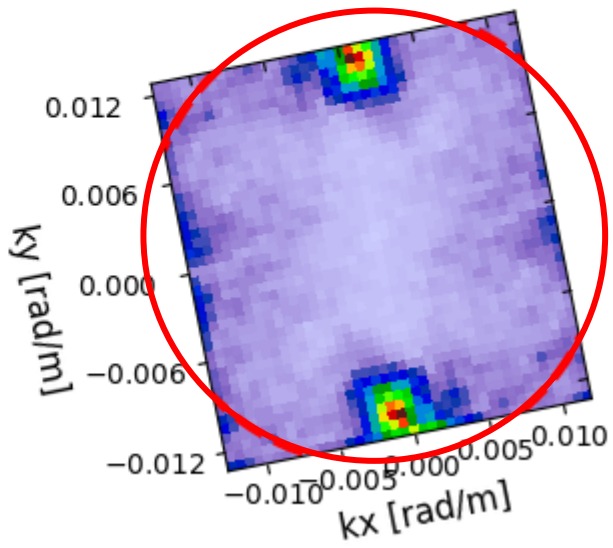
S1A : 11/24/23 05:40
lon :-176.47, lat:29.97



SWIM : 11/24/23 06:26
lon: 179.69, lat: 31.84

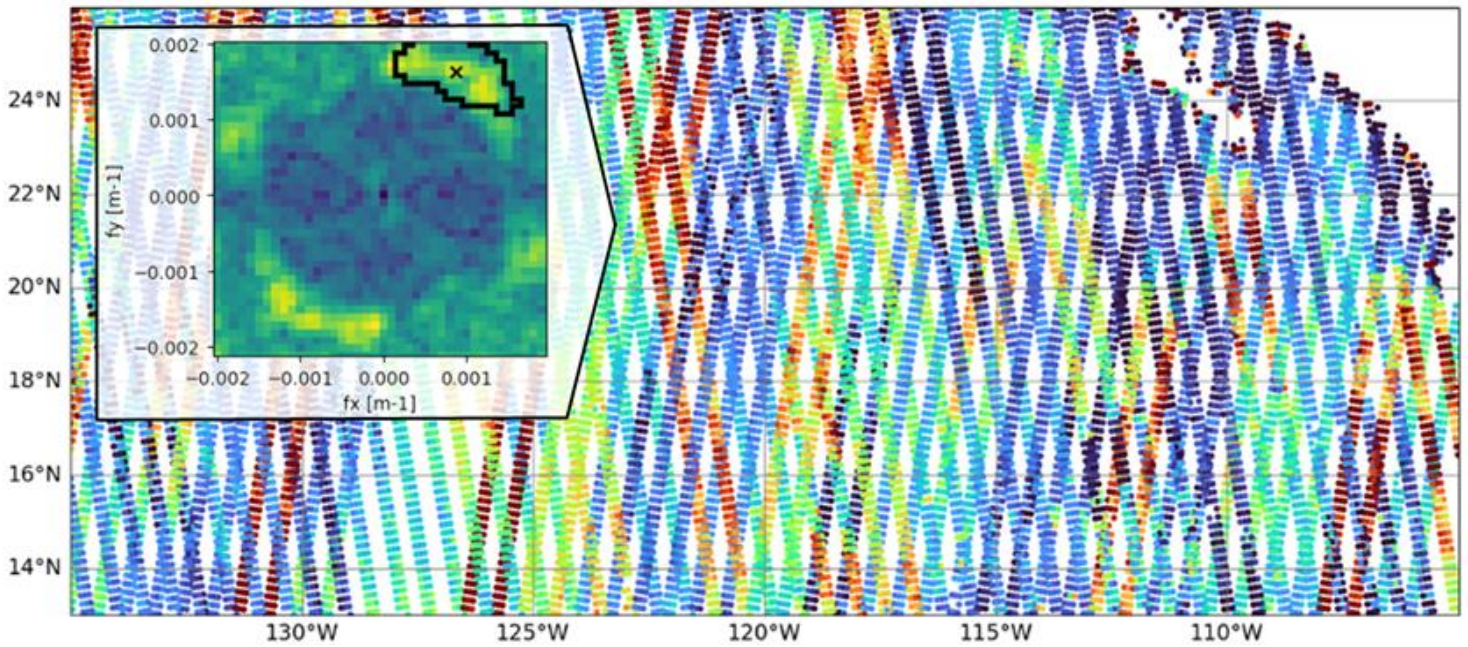


SWOT KarIn : 11/24/23 09:29
lon: 185.05, lat: 34.09



2- Data & Methods – New SWOT L3_LR_WIND_WAVE

- Derived from the Unsmoothed L3_LR_SSH product (DOI 10.24400/527896/A01-2024.003)
- Based on the algorithm presented in Ardhuin et al. 2024.
- Takes advantage of the KaRIn Low Rate (LR) chain's ability to resolve waves larger than about 500 meters in wavelength (about 18 s)

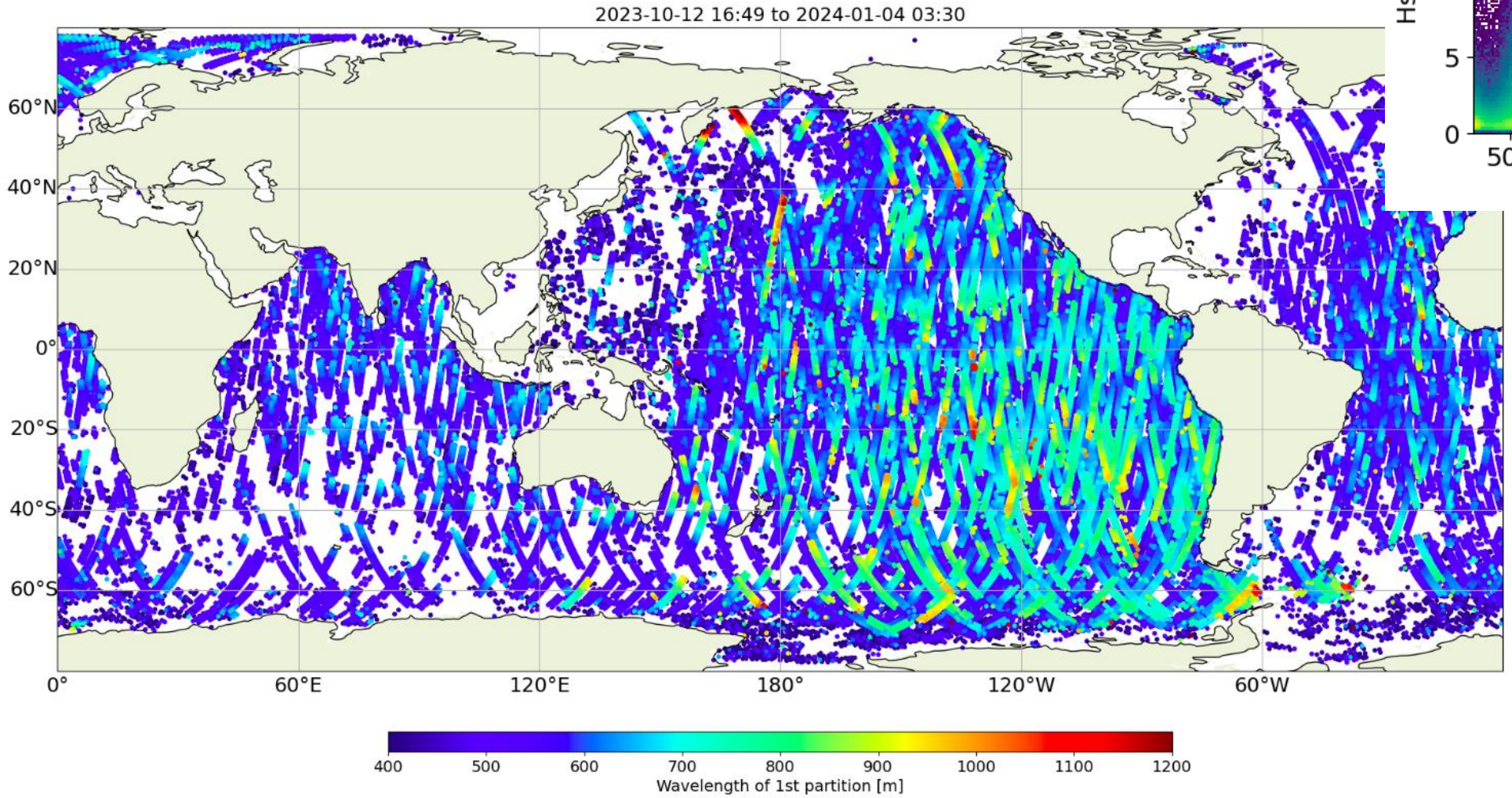


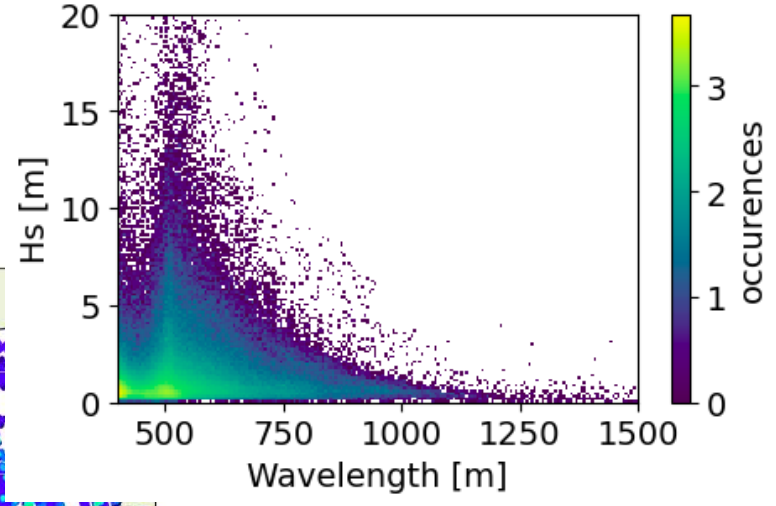
AVISO/DUACS., 2025. SWOT Level-3 KaRIn Wind Wave Extended (v2.0) [Data set]. CNES. https://doi.org/10.24400/527896/a01-2024.017

Ardhuin, F., Molero, B., Bohé, A., Nouguier, F., Collard, F., Houghton, I., et al.(2024). Phase-resolved swells across ocean basins in SWOT altimetry data: Revealing centimeter-scale wave heights including coastal reflection. Geophysical Research Letters, 51, e2024GL109658. https://doi.org/10.1029/2024GL109658

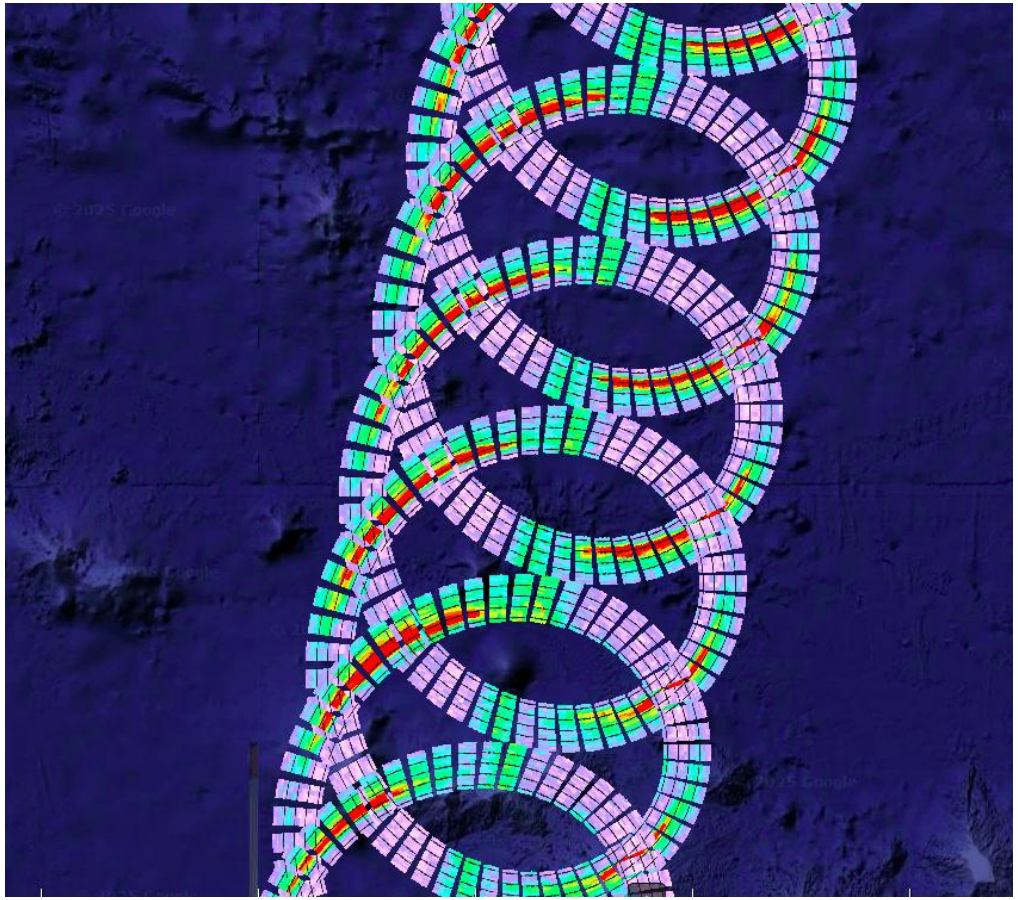
2- Data & Methods – New SWOT L3_LR_WIND_WAVE

- We apply this on cycles 5 to 8 (from 2023-10-12 to 2024-01-04)





2- Data & Methods – New SWIM L2S dataset



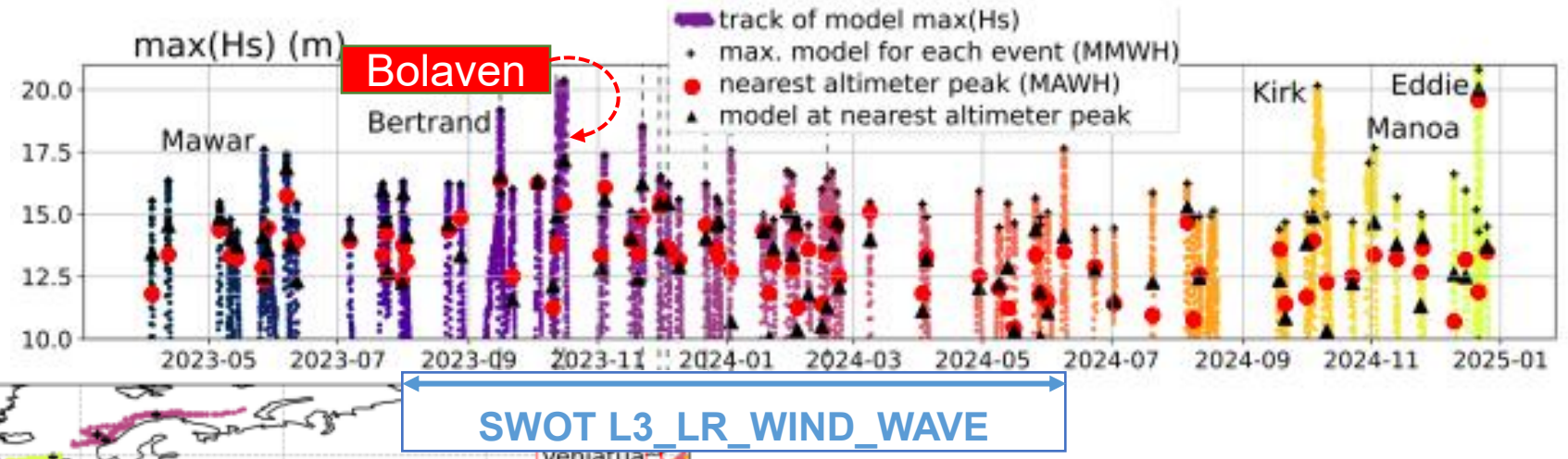
- Alternative processing of SWIM L2 (10° incidence)
- Wavelength **not limited to 500 m**
- Smoother spectra
- Partitions computed on sequential 1D spectra

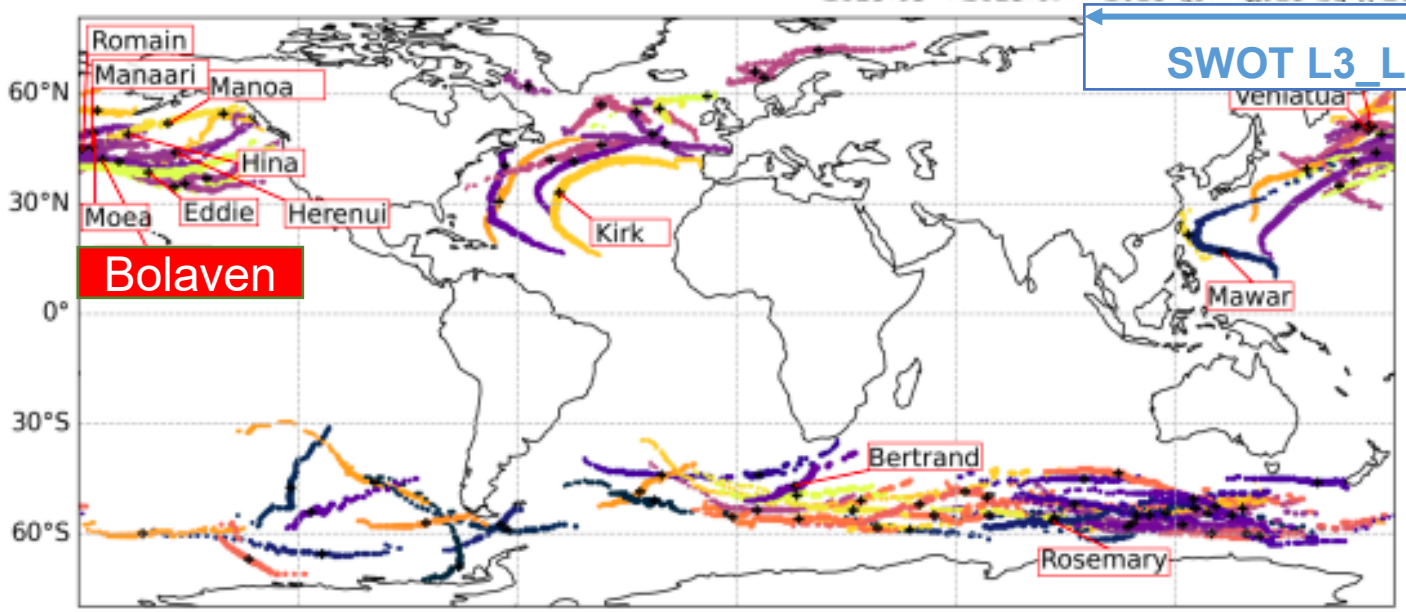
Available at
https://data-cersat.ifremer.fr/projects/iwwoc/swi_l2s/v2.1

Ifremer / CERSAT. 2025. Global Ocean Directional Wave Parameters Level 2S from SWIM onboard CFOSAT for IWWOC project. Ver. 2.1. Ifremer, Plouzane, France. Dataset accessed [2025-09-23]. DOI: 10.12770/12cfed8d-7645-442b-b8ef-a8d08decbaed

3- Case study

- Selection based on work on Long swells and extreme storms by Ardhuin et al 2025



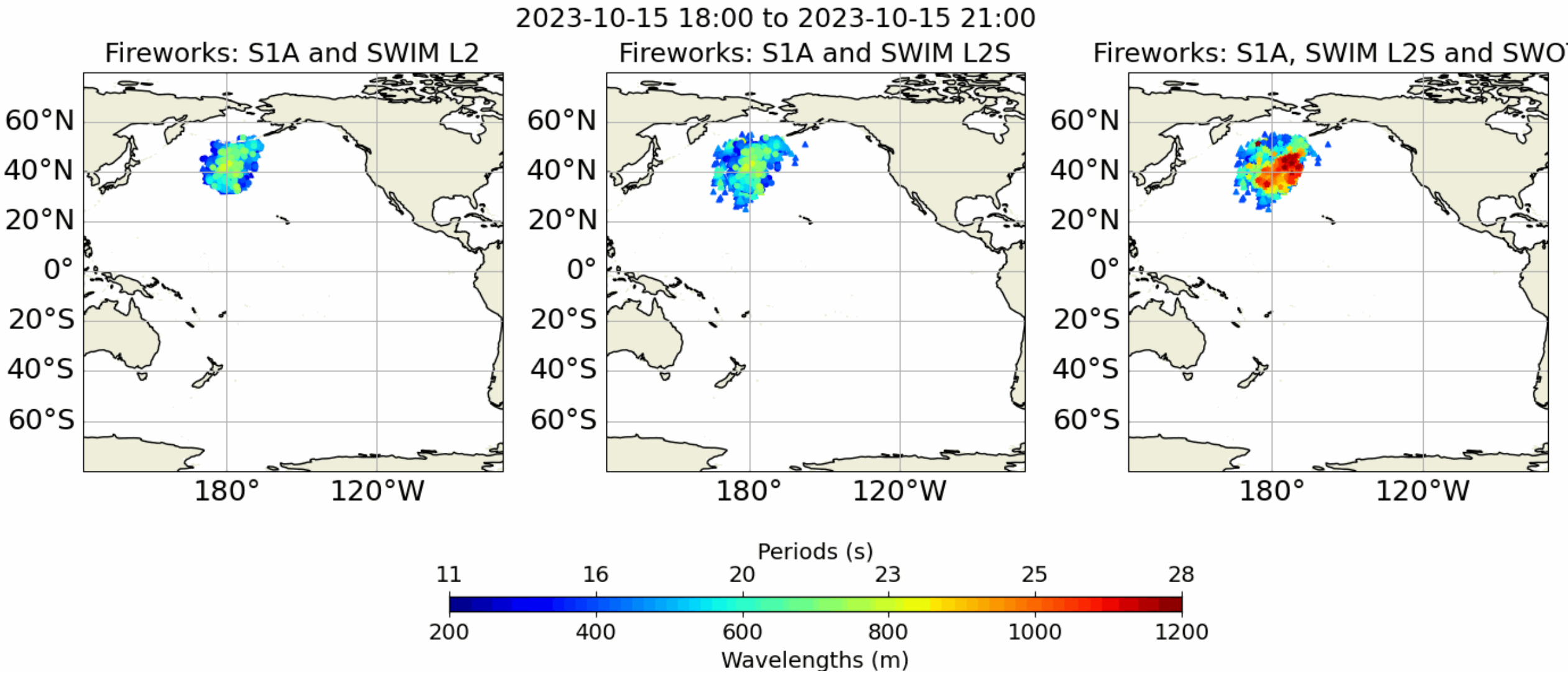


Storm in the Pacific Ocean:

- Bolaven : 16 Oct 2023

Fabrice Ardhuin, Taina Postec, Mickael Accensi, et al. Sizing the largest ocean waves using the SWOT mission. ESS Open Archive . June 02, 2025. DOI: 10.22541/essoar.174250978.85245614/v2

3- Case study -Bolaven



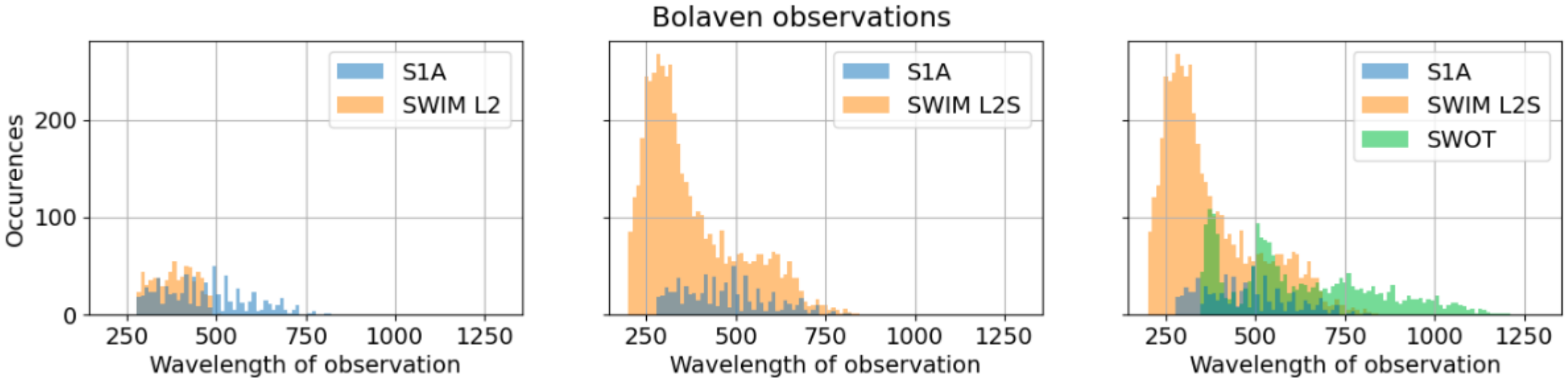
3- Case study

Repartition of the observations' wavelength by satellite

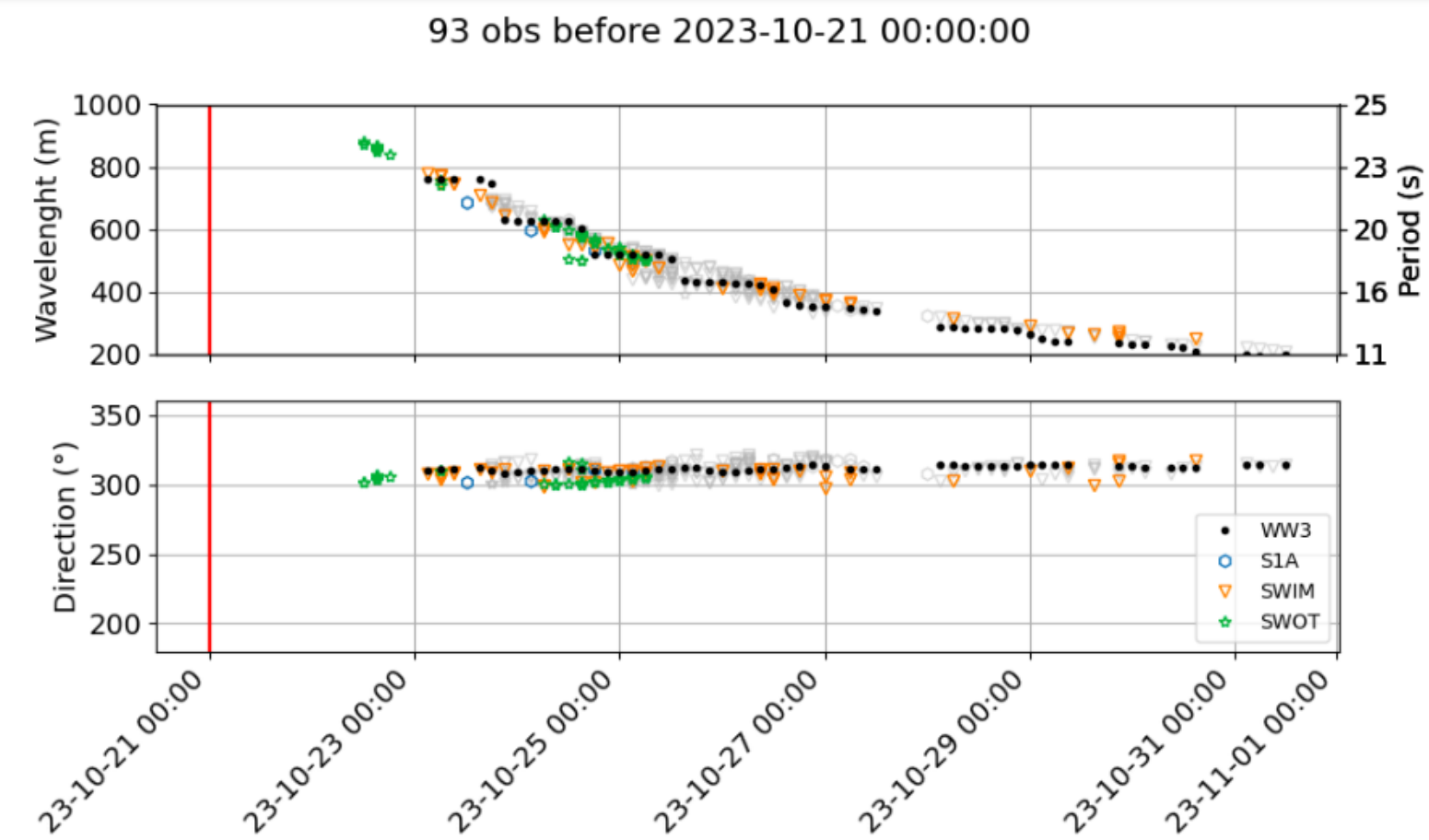
- Complementarity between satellites
- SWIM L2S covers wavelength that were not seen by classical product
- SWOT enables to cover a large range of wavelength where we the other satellites are "blind"

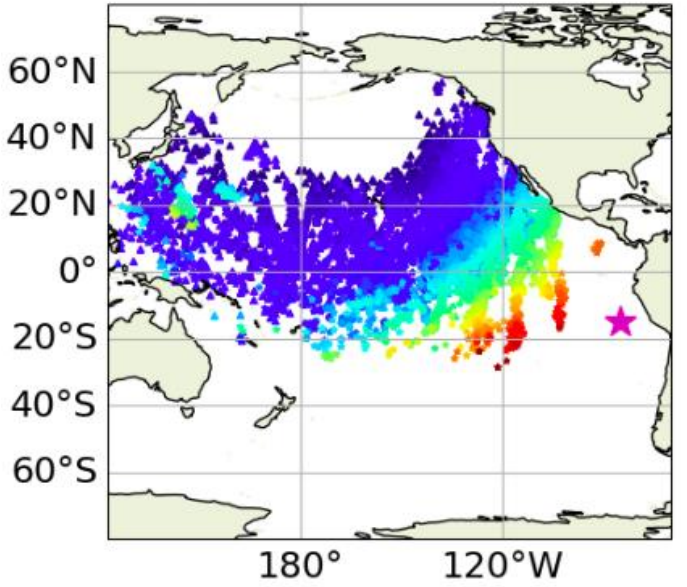
==> **SWOT is a game changer** for fore-runners (long swells of small amplitude that propagate faster)

==> **SWIM L2S is a great improvement** compared to the classical product



3- Case study – Towards Early Warning System





- Virtual buoy offshore Peru
- Compared to WW3 model

=> Good agreement in Wvl and dir

The arrival of the swell is well captured by the Fireworks

=> First step towards Early Warning System

In colour, pseudo obs. already integrated by 21/10/2023

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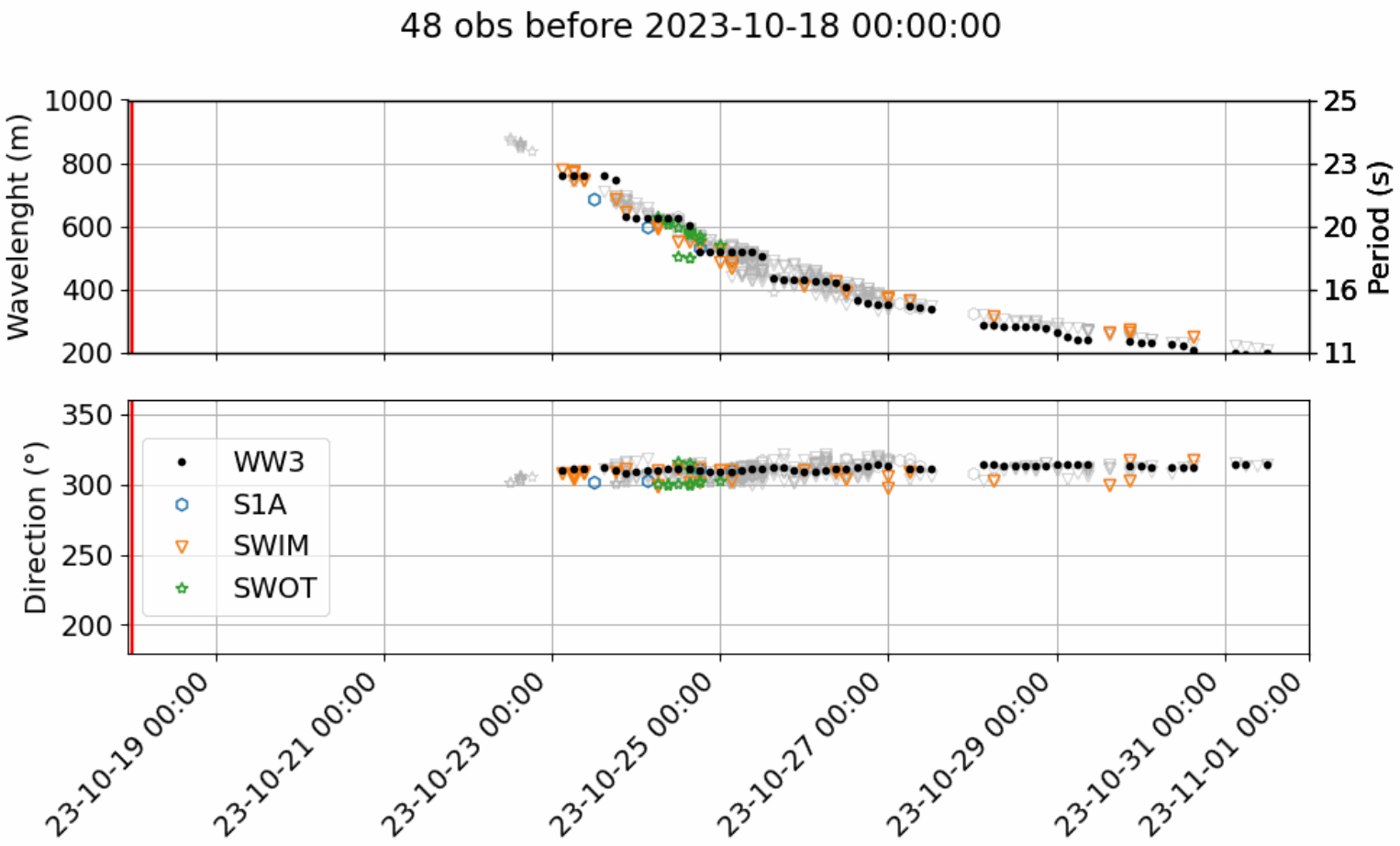

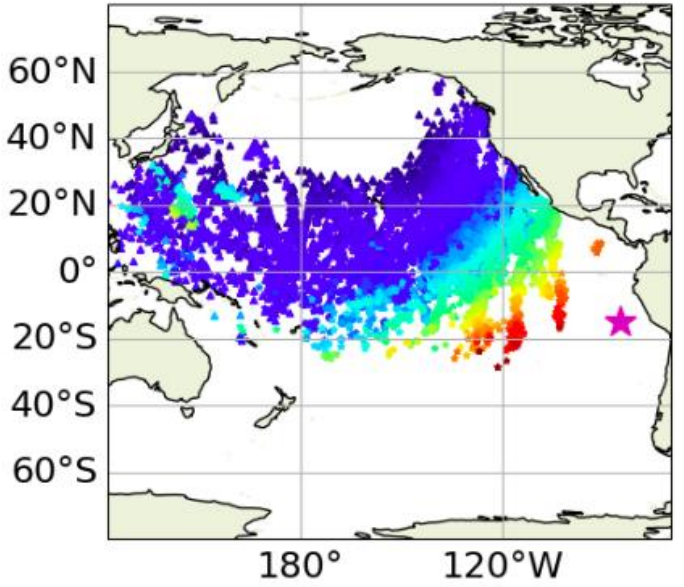

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4- Conclusions & Perspectives

Combining Sentinel-1, SWIM and SWOT

- Unique complementarity in terms of wavelength
- Both SWOT L3 and SWIM L2S are able to see long wavelength, of interest for forerunners studies

==> To be included on the WAVE TAC products (NRT) in the medium to long term

Virtual buoys and Early Warning Capability

- Fireworks processing shows potential to implement an Early Warning System for the arrival of big swells
- Some cases more favorable than others (distance to the storm generation etc.)

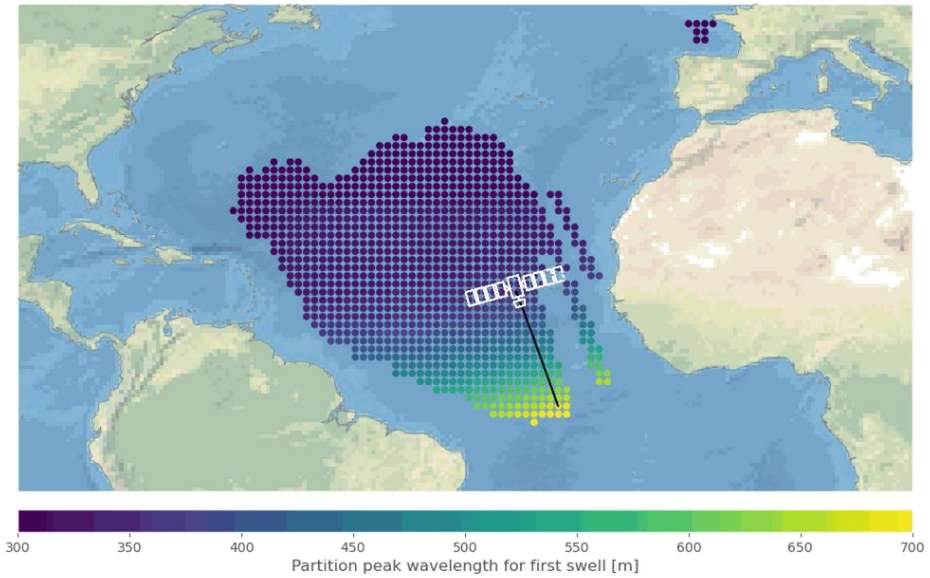
==> Further studies planned in the framework of the 'France 20-30' project

'The more the merrier'

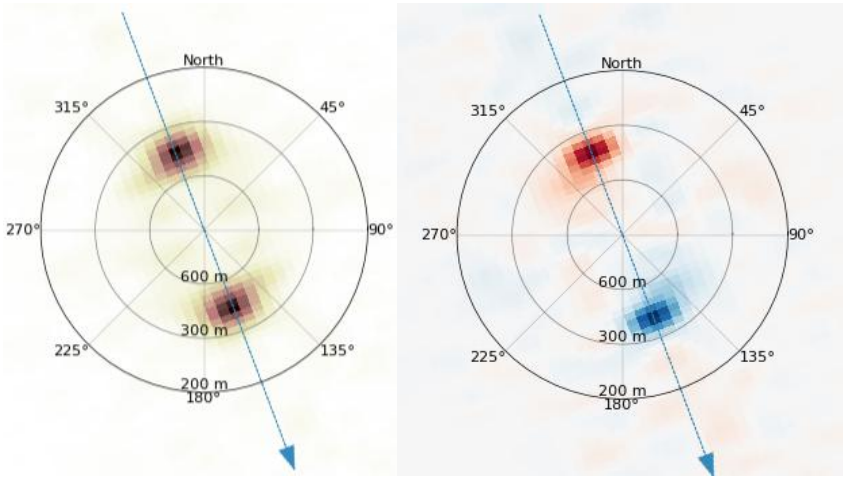
- Adding relevant observations ==> increase the coverage and the Early Warning capability of the Fireworks
- From previous presentation ==> colleagues started to use our product to roughly evaluate new spectra from S6 SAR-doppler altimeter !!!

4- Perspectives - 'the more the merrier'

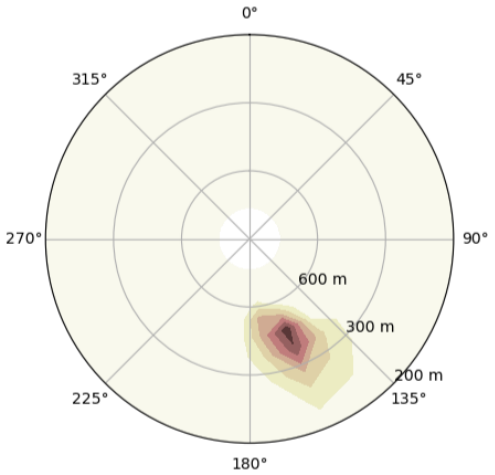
L4 2022-03-13T12:00:00

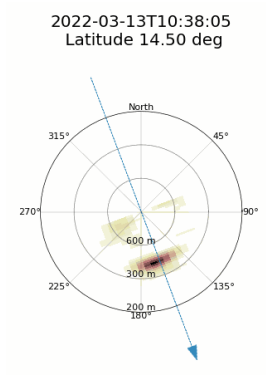


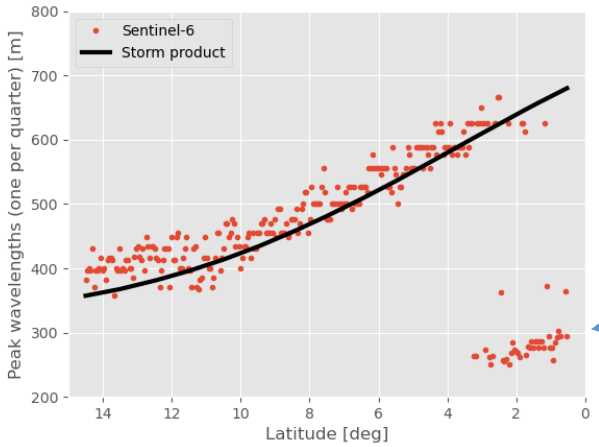
Sentinel 6, 12°N

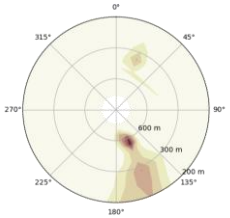


ERA5, 12°N 28°W, 10:00









(another swell)

Credits to Laetitia Rodet (CLS) et al., EUMETSAT Conference 2025

Thank you.

2- Data & Methods – New SWOT L3_LR_WIND_WAVE

Light product :

- *more user friendly, less variables, only one (box_dim, tile_dim) couple*
  - 40 km boxes + 5 km tiles

Extended product :

- *Highly detailed, integrating all relevant variables with multiple (box_dim, tile_dim) couples.*
  - 40 km boxes + 5 km tiles
  - 40 km boxes + 10 km tiles
  - 20 km boxes + 10 km tiles
  - 10 km boxes + 5 km tiles

Boxes :

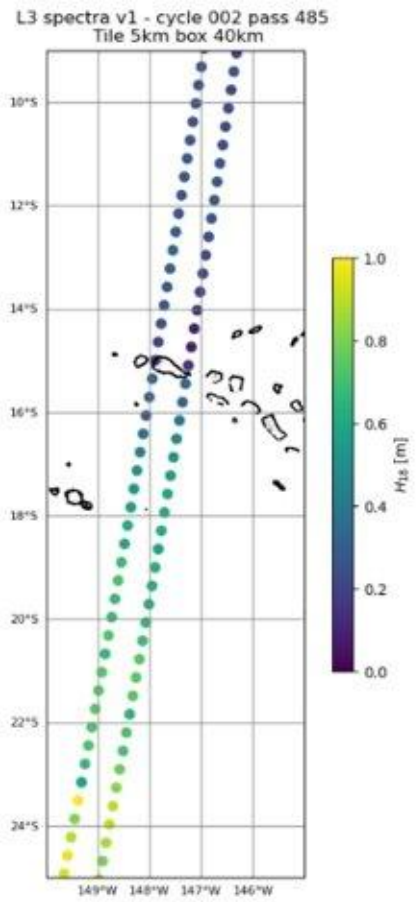
50% cross track overlapping

No overlap along the track

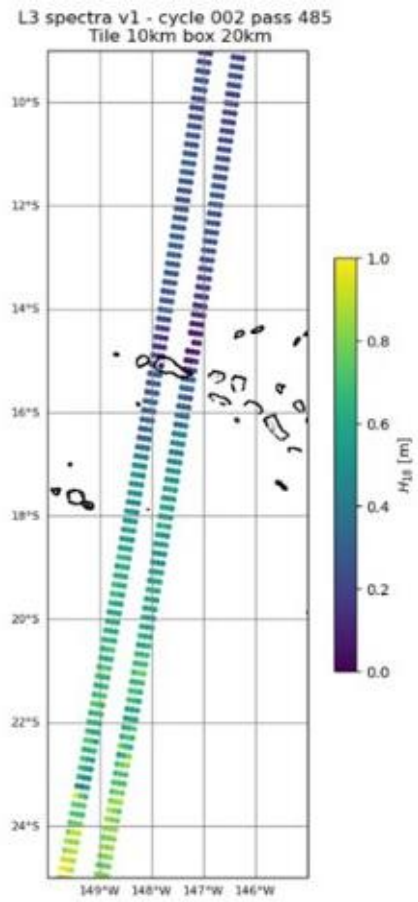
Tiles :

50% cross track & along track overlapping

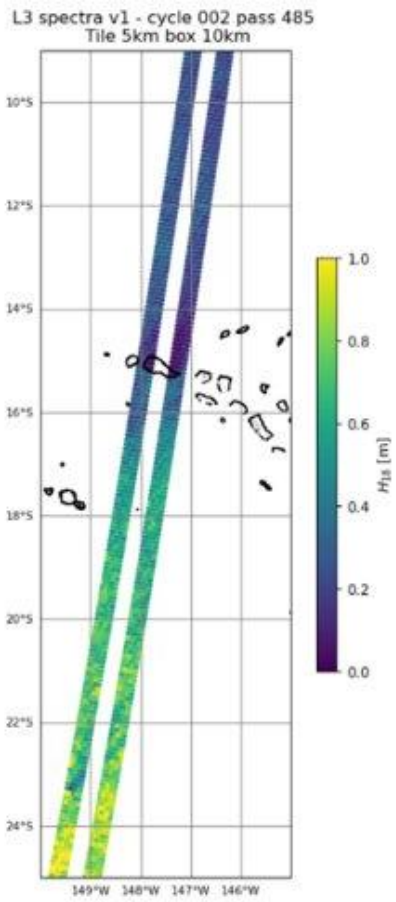
40km boxes



20km boxes



10km boxes



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