



SARWAVE

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Outline

- SARWAVE Project Overview
- Waves from SAR altimetry spectra
- Waves from S1 IWS TOPS
- Waves and futur algorithms
- Recommendations to ESA

Motivations

Ocean Surface Waves integrate wind forcing

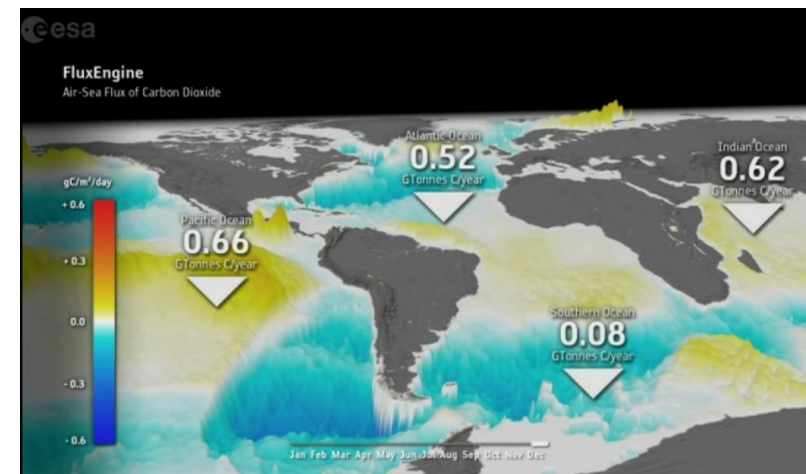
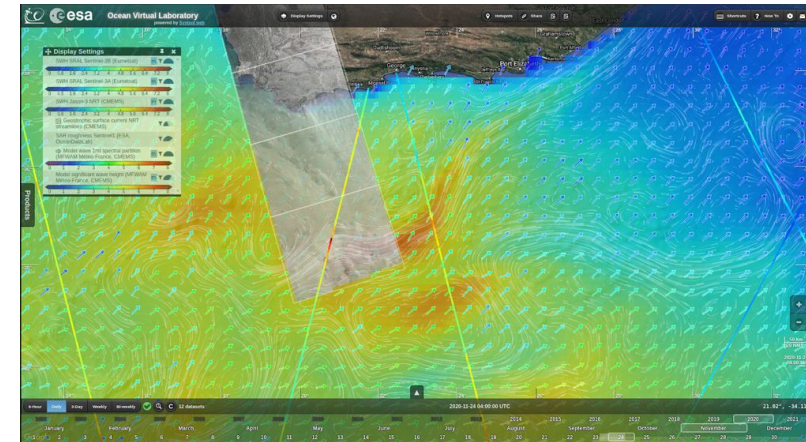
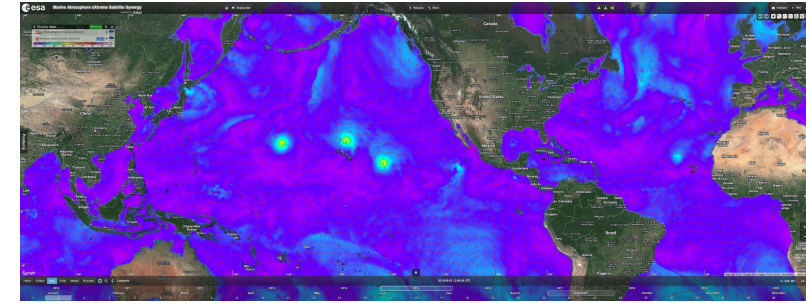
→ Open questions are still existing regarding the most extreme winds (MAXSS)

Waves-current interactions are poorly documented from space

→ There are no direct measurements of total surface current from space (WOC)

Waves play a role in air-sea interactions - often parameterized through wind measurements.

→ There are no direct fluxes measurements from space (Carbon Flux)



Motivations

There are very few measurements of ocean waves (directional) from space

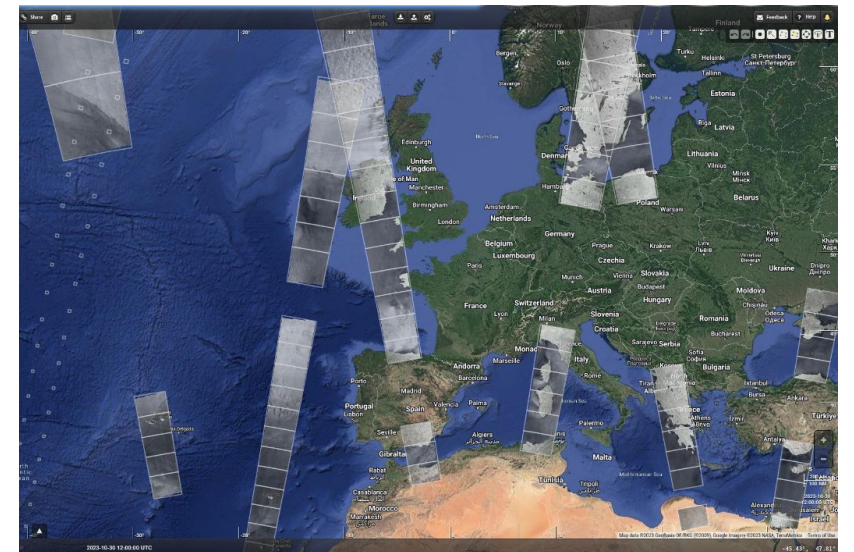
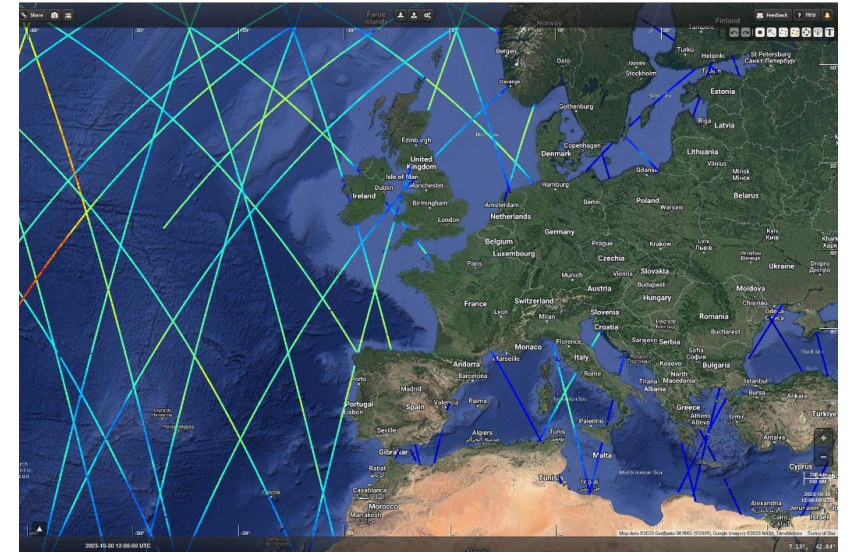
→ Altimeters (CCI SeaState, old and new), SWIM, Sentinel-2, SAR (L2 Wave Mode + L3/L4).

Sentinel-1 only provides ocean wave spectra from Wave Mode

→ There is no Copernicus waves products from Sentinel-1 Wide Swath mode acquisition.

→ Sentinel-1 performs routine acquisitions over European Seas.

→ The feasibility of ocean waves measurements in Marginal Ice zone has been demonstrated.

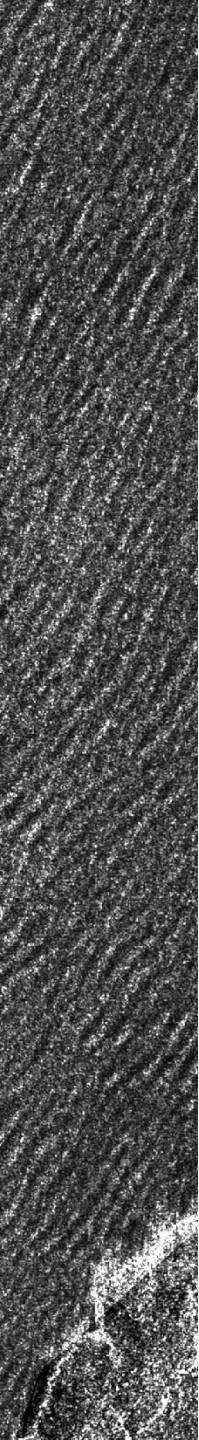


Objectives

1- Develop a new open-source sea state processor and Level-2 ocean waves product from Sentinel-1 IWS TOPS SAR images

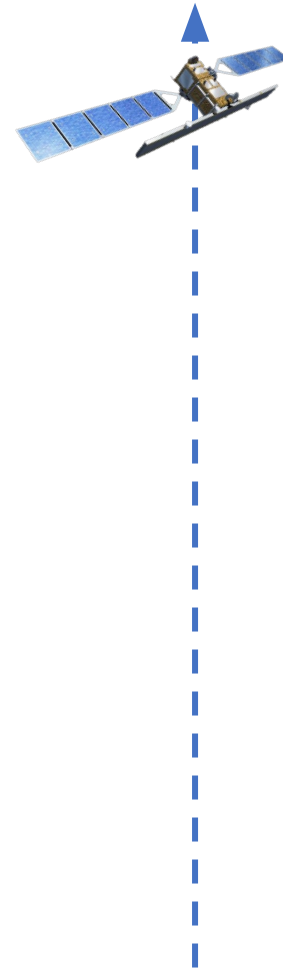
2- Generate prototype datasets over ocean, sea ice, and coastal areas. 1 Year of data focusing on European Seas.

3- Investigate synergies with other EO sensors and products

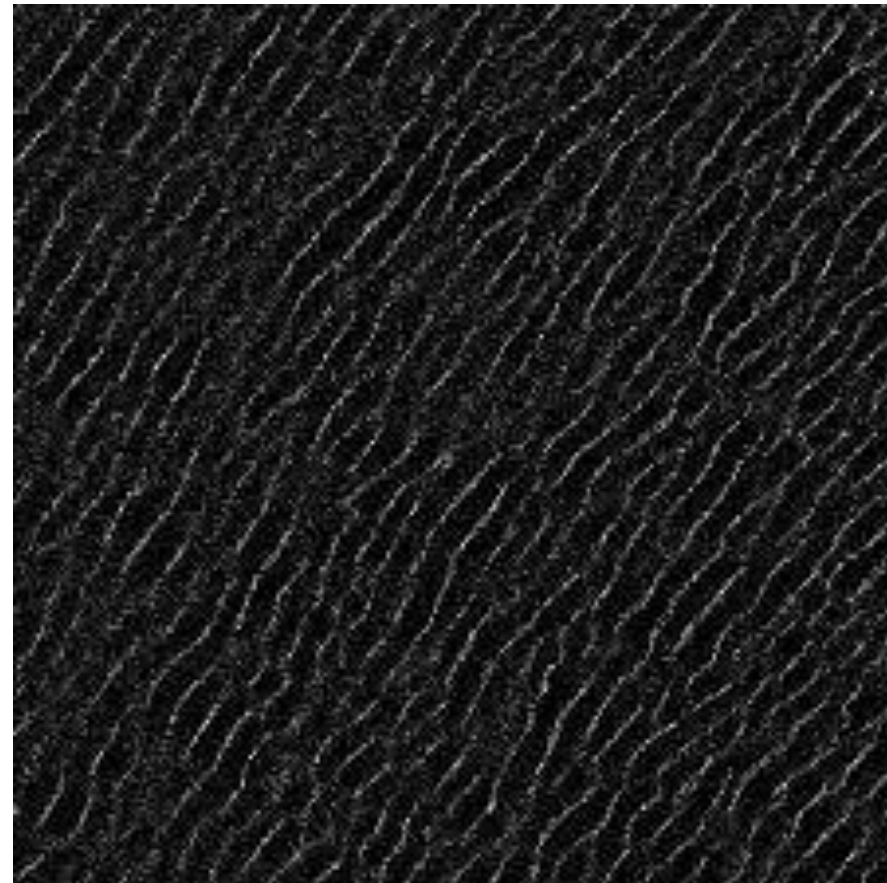
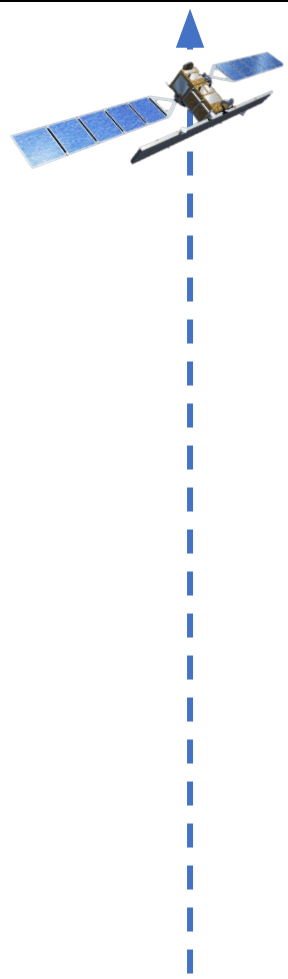
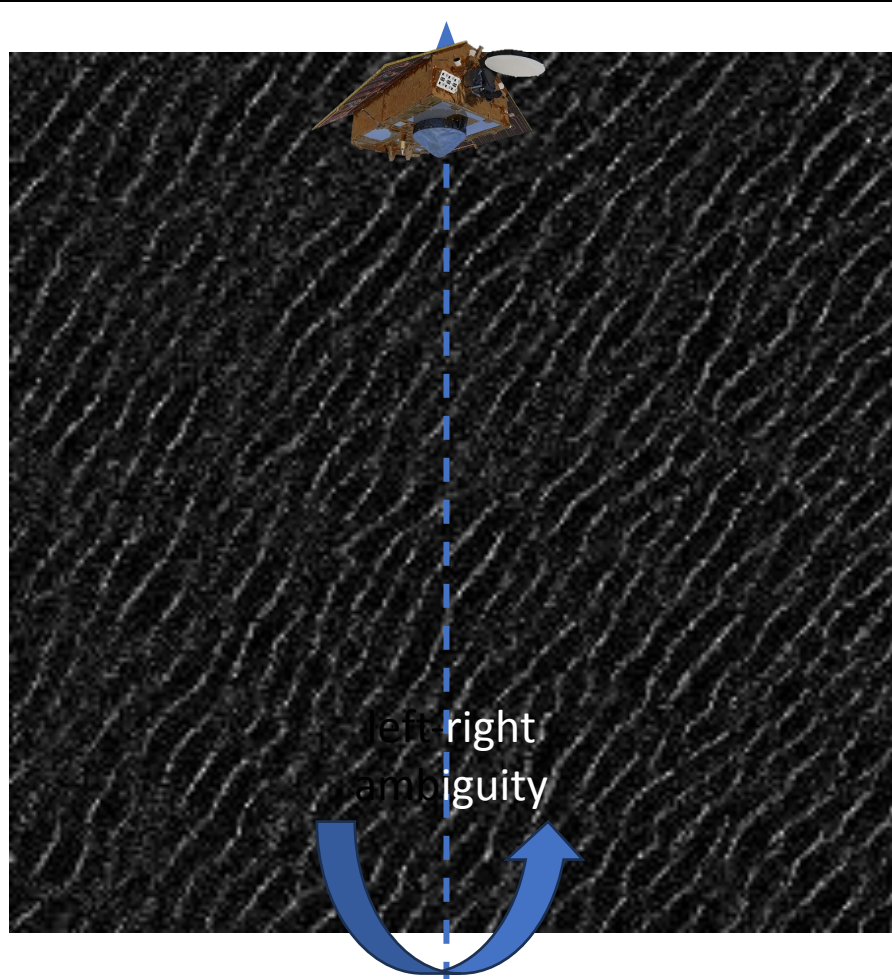


SAR Altimetry

Altimetry (Nadir) ---vs--- SAR (Side looking)

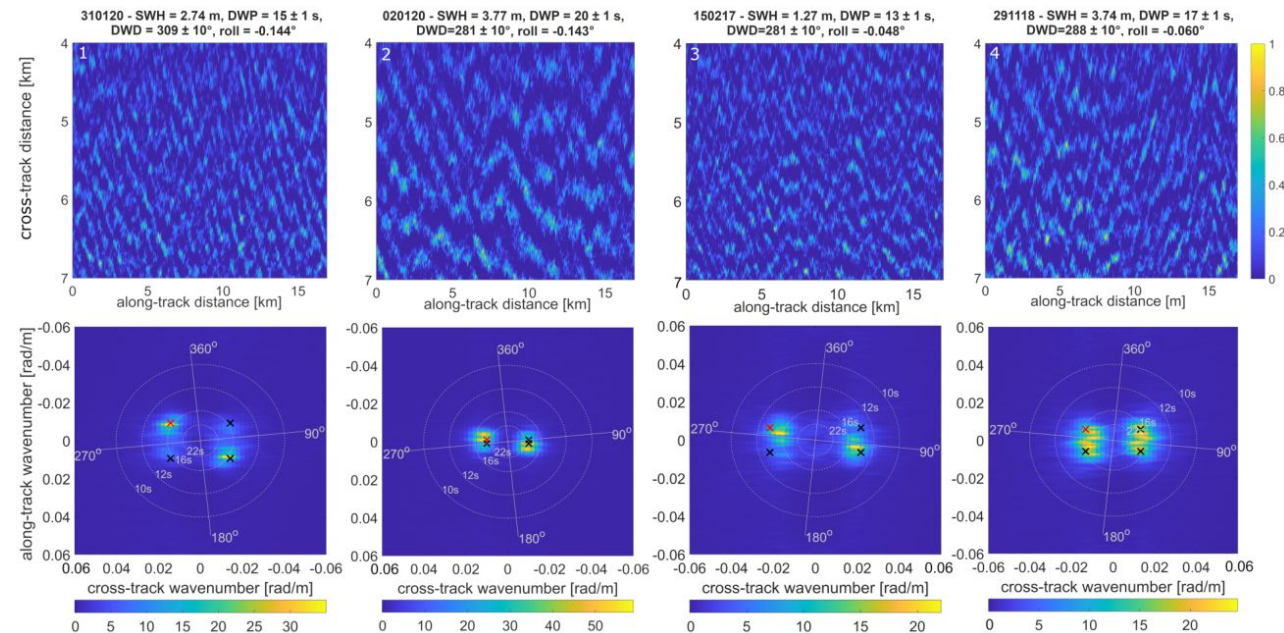


Altimetry (Nadir) ---vs--- SAR (Side looking)



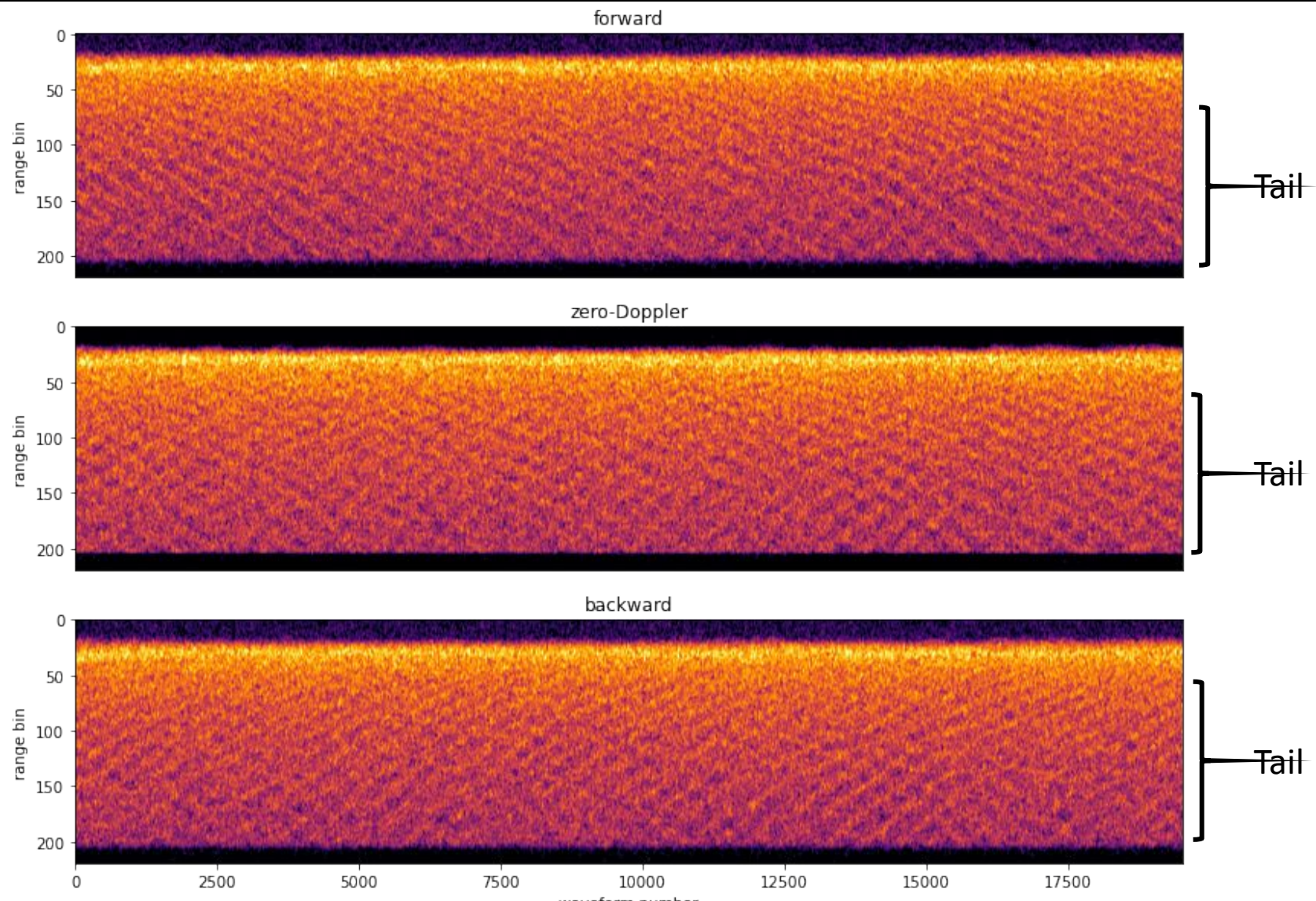
FF-SAR sublook processing

- [Altiparmaki et al 2022](#) demonstrated the feasibility of generating FF-SAR spectra and associating it to buoy-measured spectra



- The Sentinel-6 FF-SAR GPP processor has been adapted to provide sublooked L1B products:
 1. For a fixed illumination time, the aperture is split into N sub-apertures
 2. FFSAR processing is applied for each sub-aperture, obtaining N different waveforms or looks for each surface.

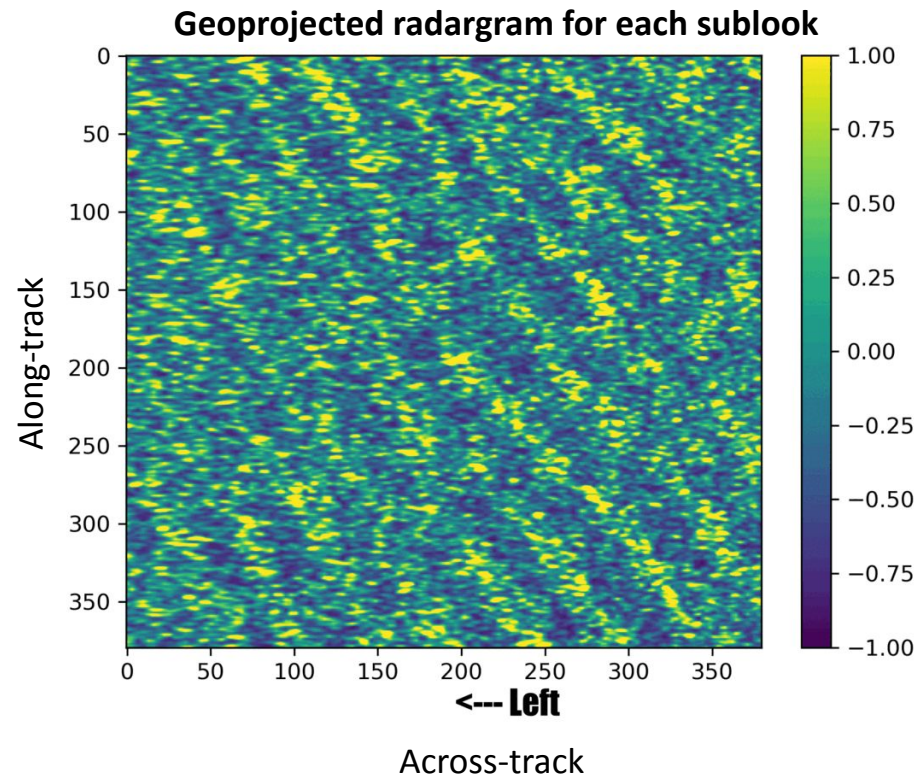
FF-SAR sublook processing



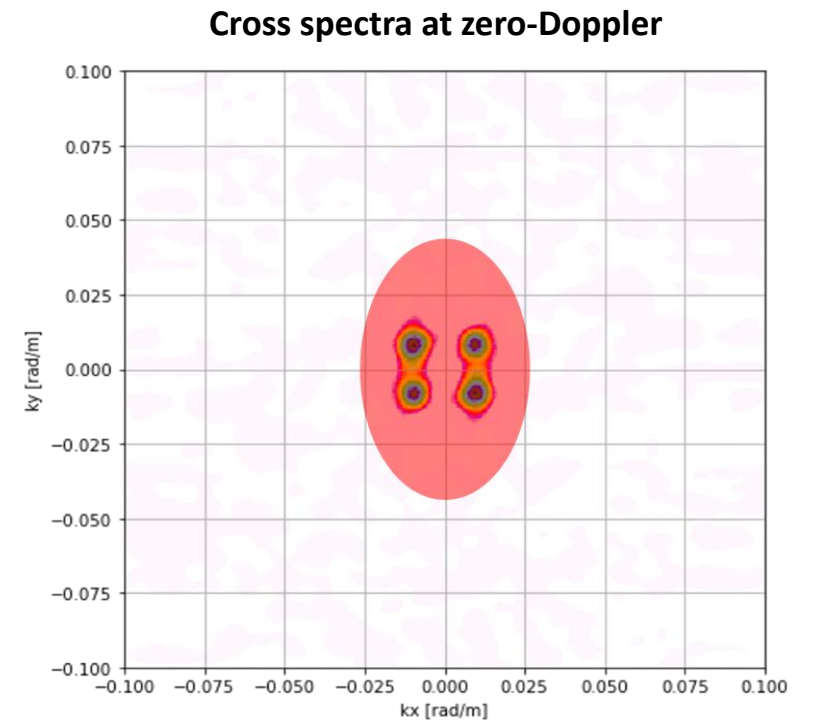
Altimetry SAR spectrum

We apply a **2D FFT** to the tail of the geoprojected radar waveforms.

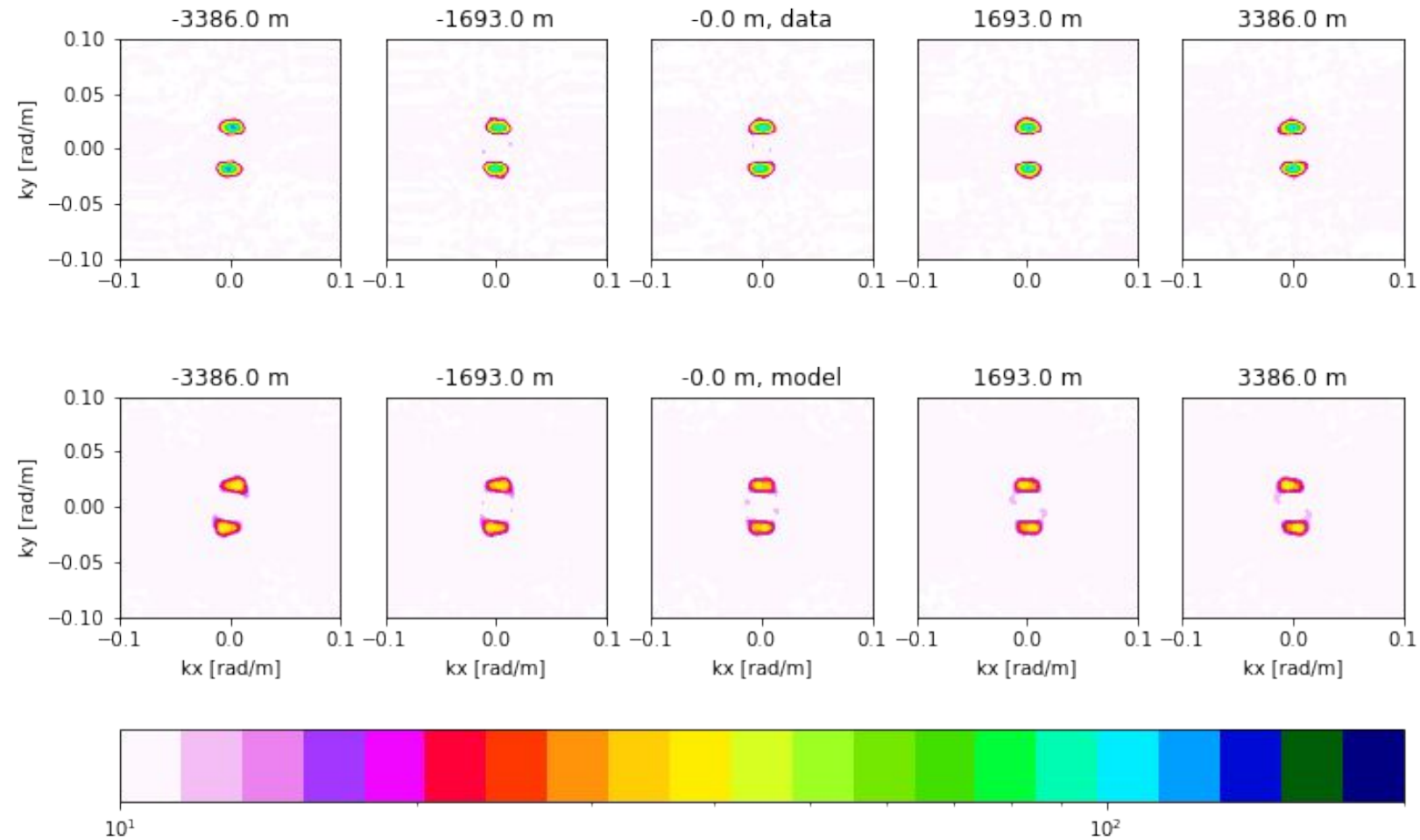
We compute the **cross-product** between sublooks to obtain the **cross-spectra**.



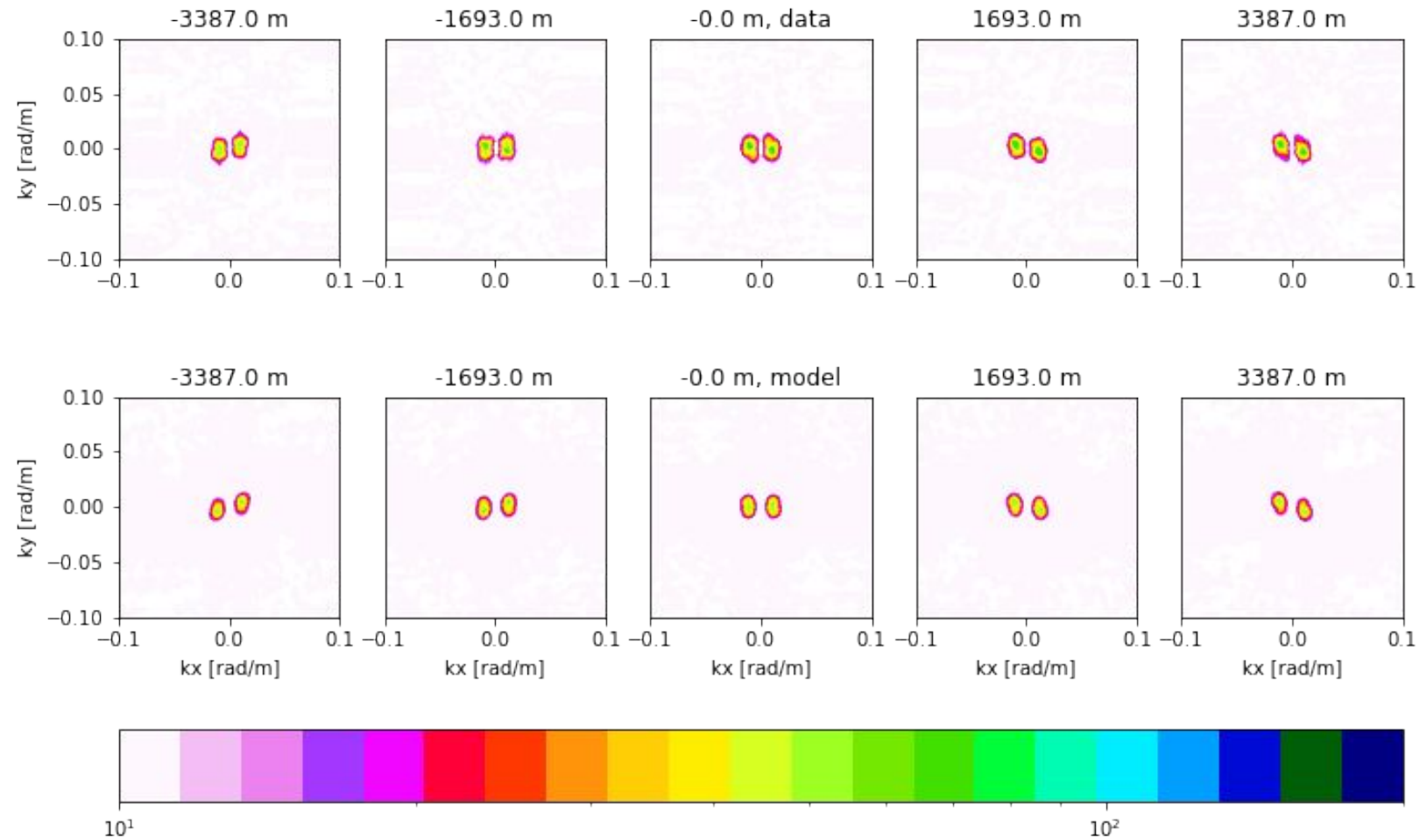
FFT + Cross-product



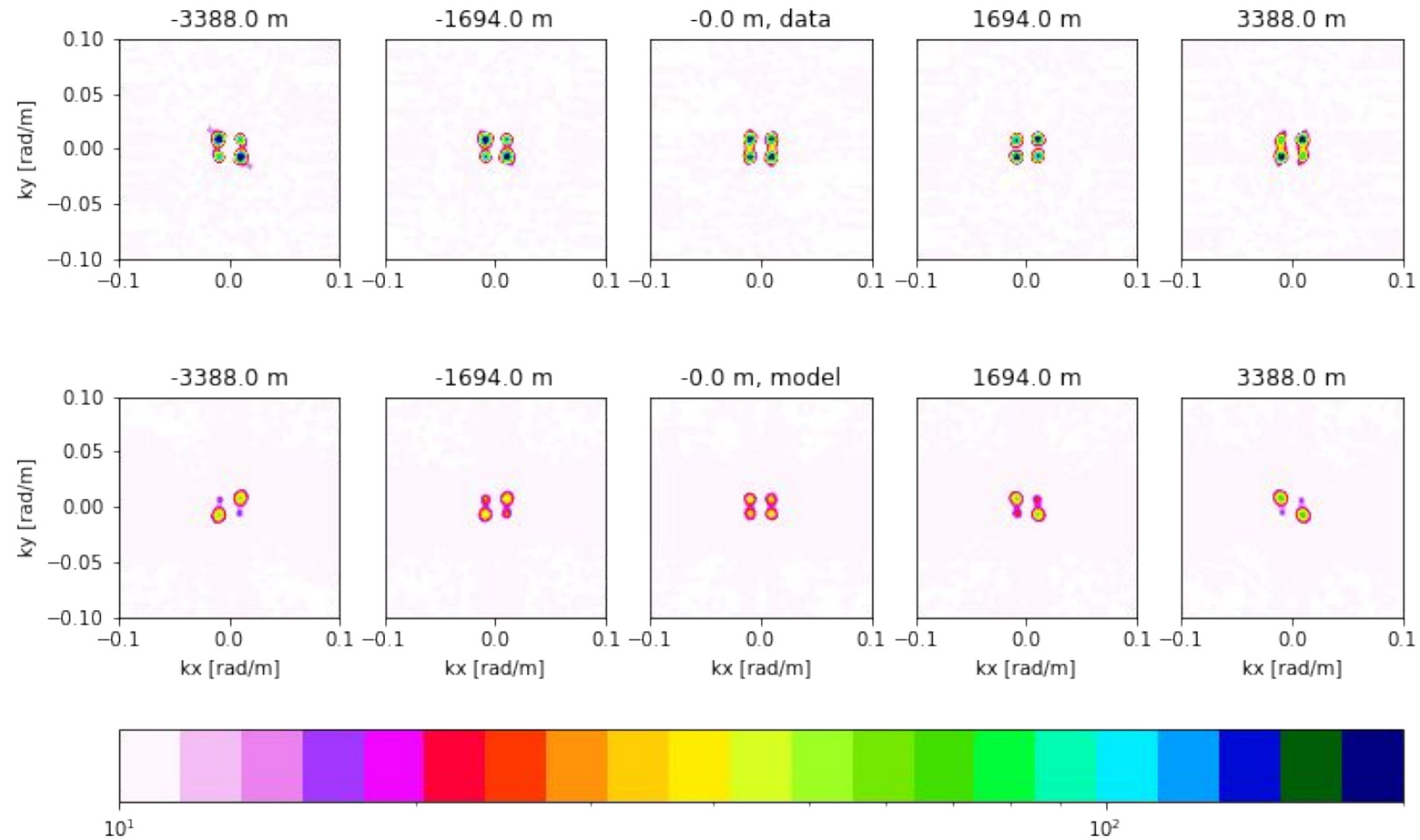
Along-track swell



Across-track swell

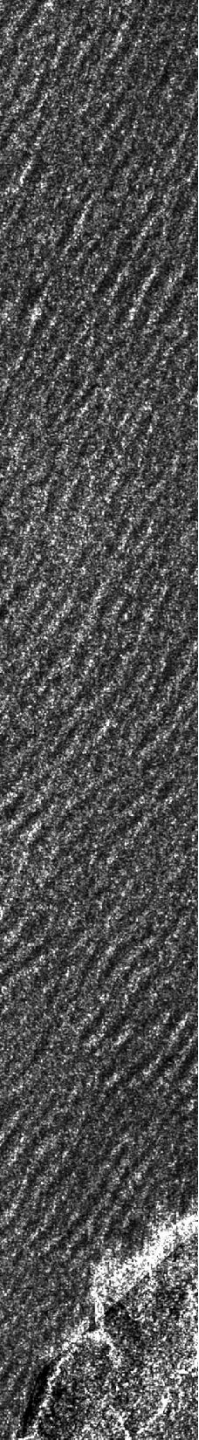


More swell



Altimetry SAR spectrum

- Parameters to estimate: swell-wave energy, mean/peak wavelength (mean/peak direction).
- Input: Altimetry SAR spectrum features and altimetry L2 parameters (moments, cut-off, backscatter, SWH).
- Method: regression.



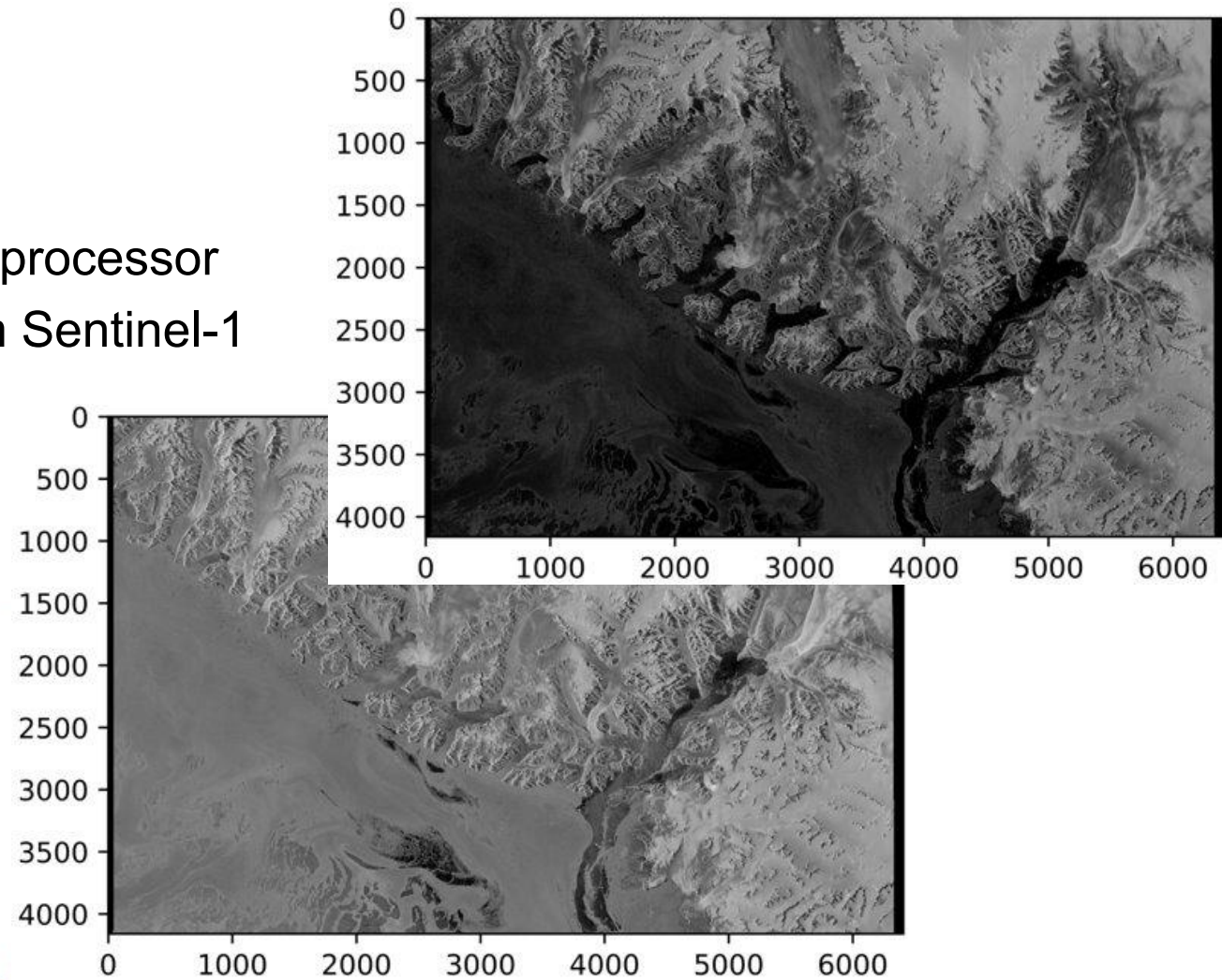
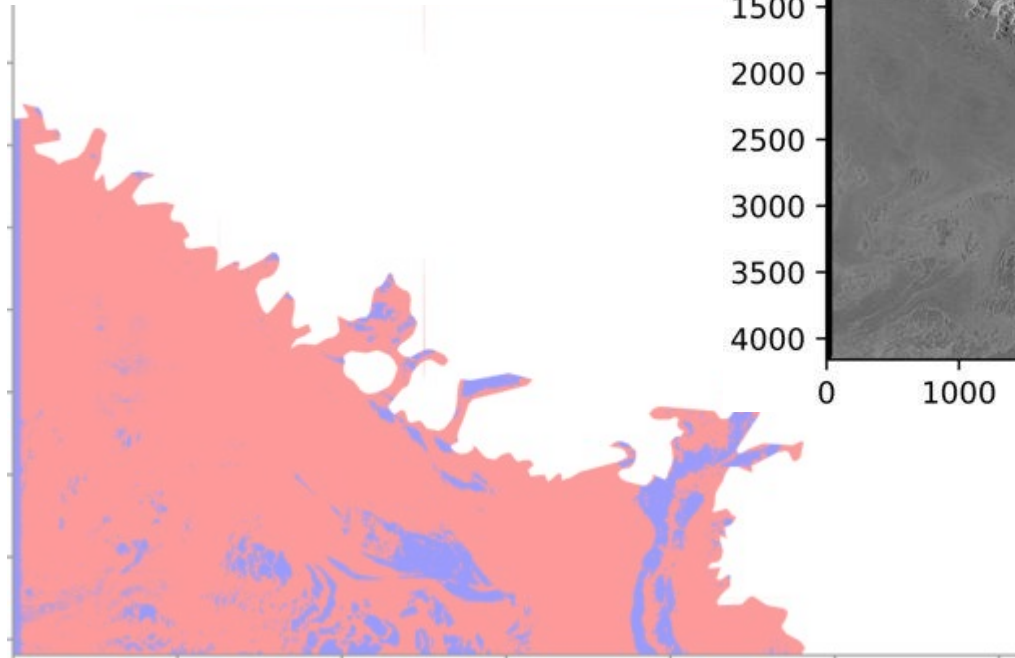
SAR (Sentinel-1)

Objectives

1. Develop a new open-source sea state processor and Level-2 ocean waves product from Sentinel-1 IWS TOPS SAR images
2. Generate prototype datasets over ocean, sea ice, and coastal areas. 1 Year of data focusing on European Seas.
3. Investigate synergies with other EO sensors and products

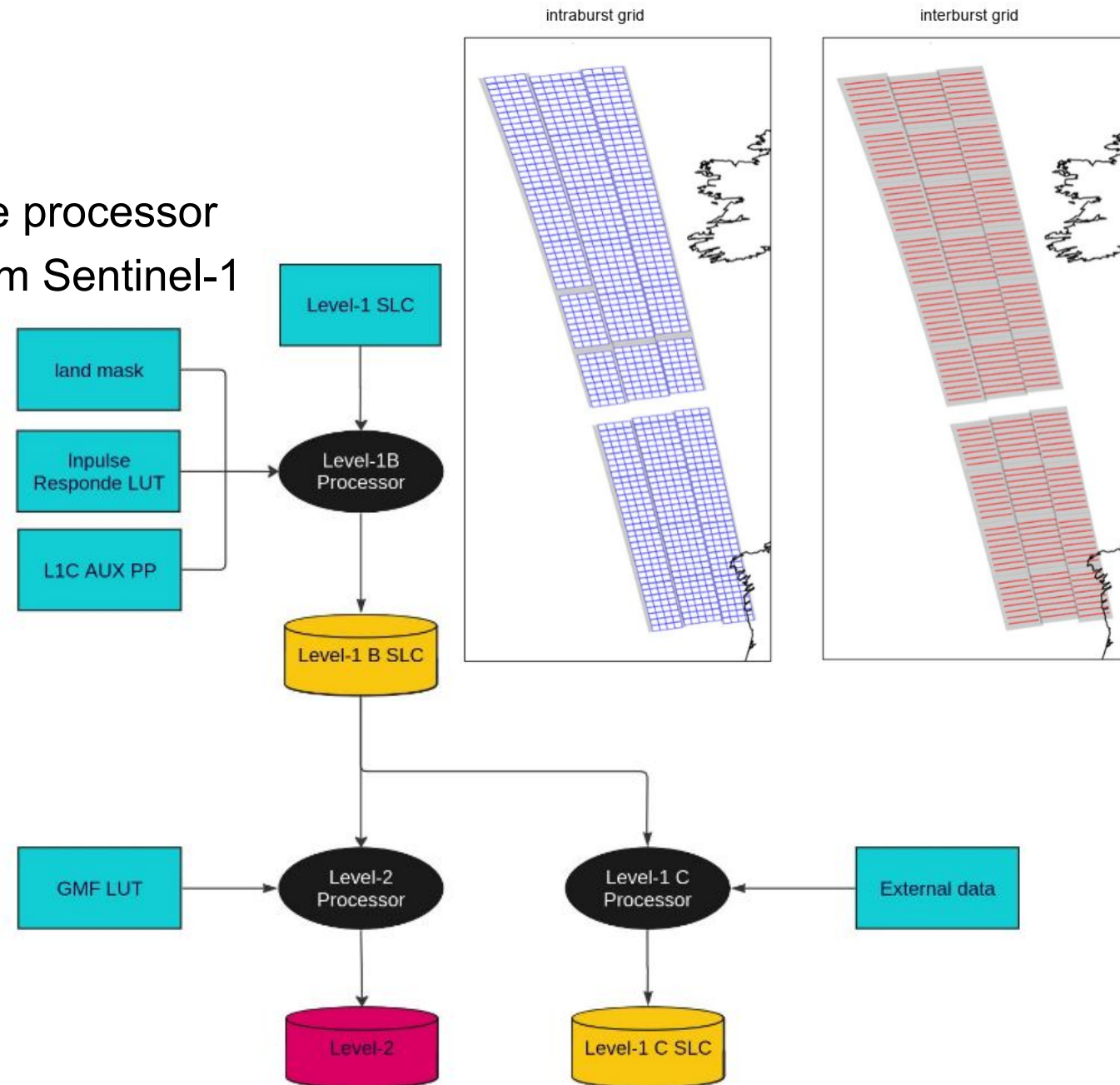
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 - Sea-ice detection (AI4Arctic / ASIP)



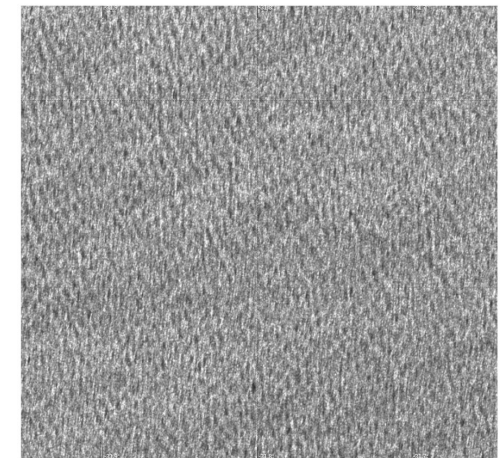
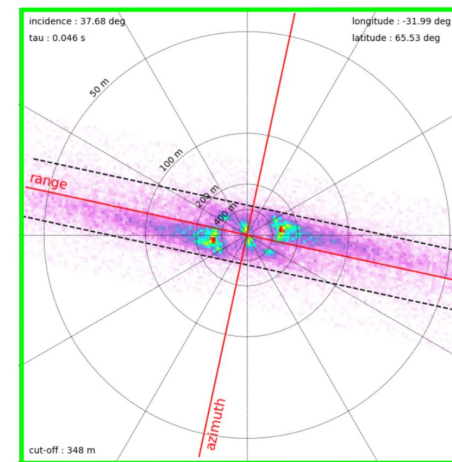
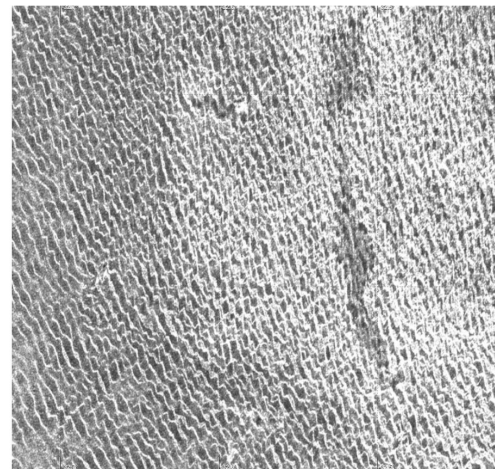
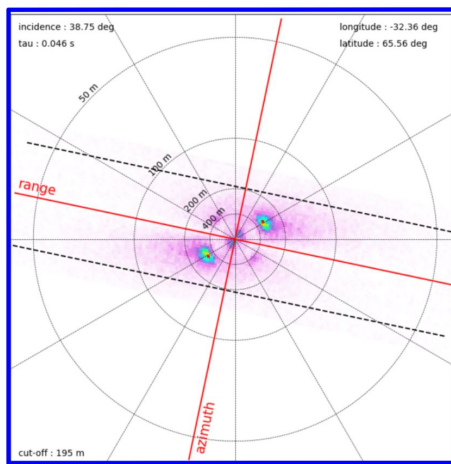
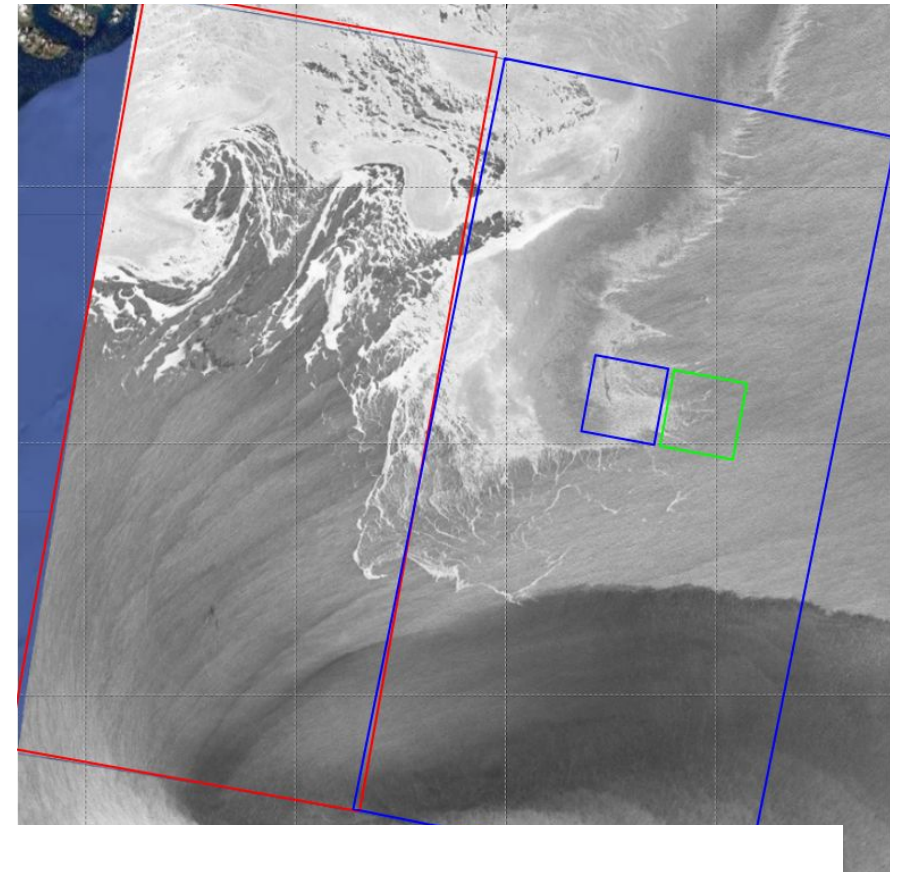
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 - Waves inversion in MIZ
 - Waves inversion in ocean



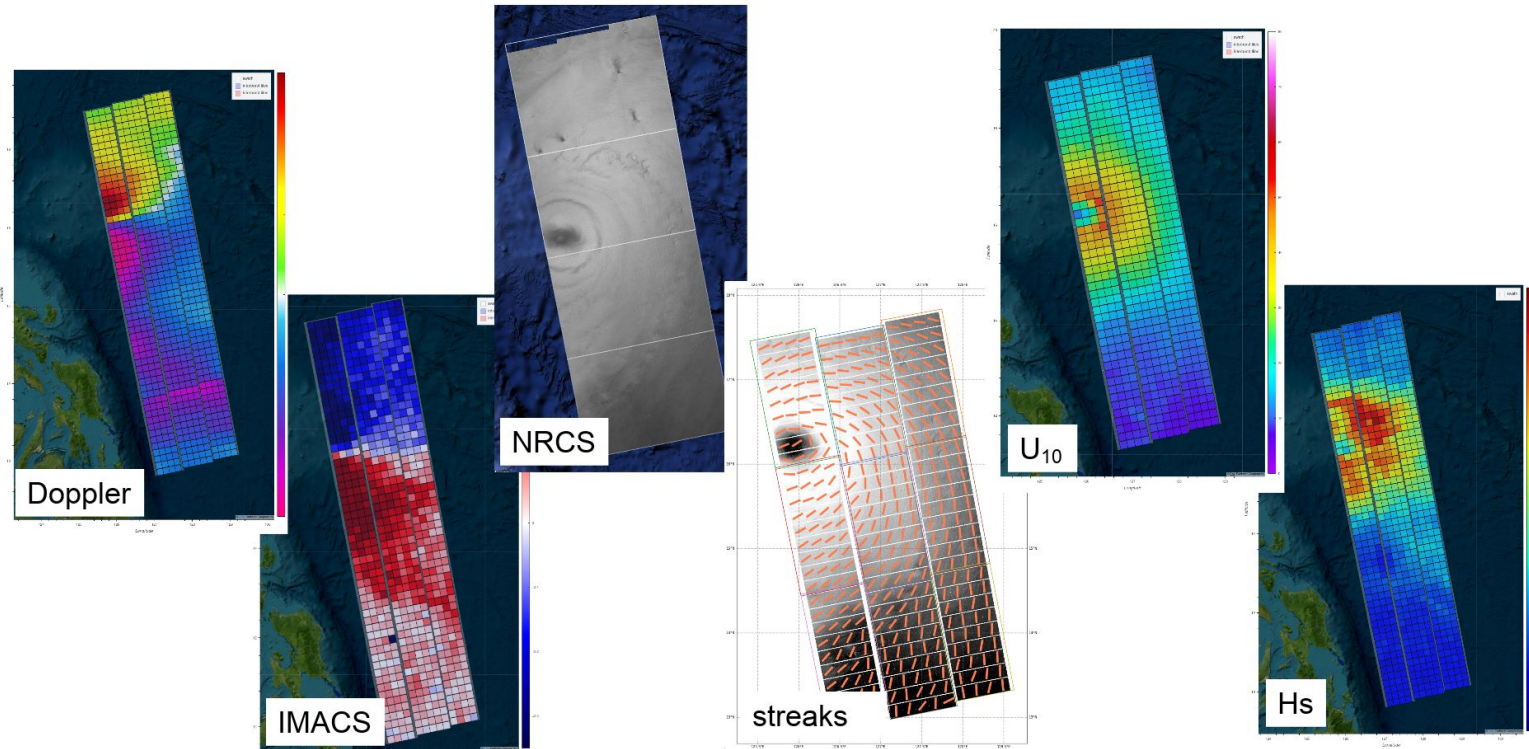
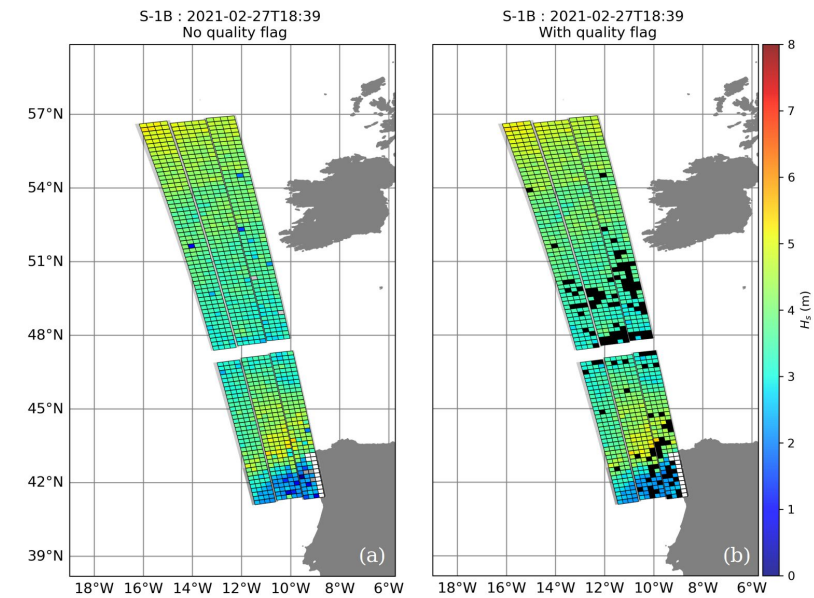
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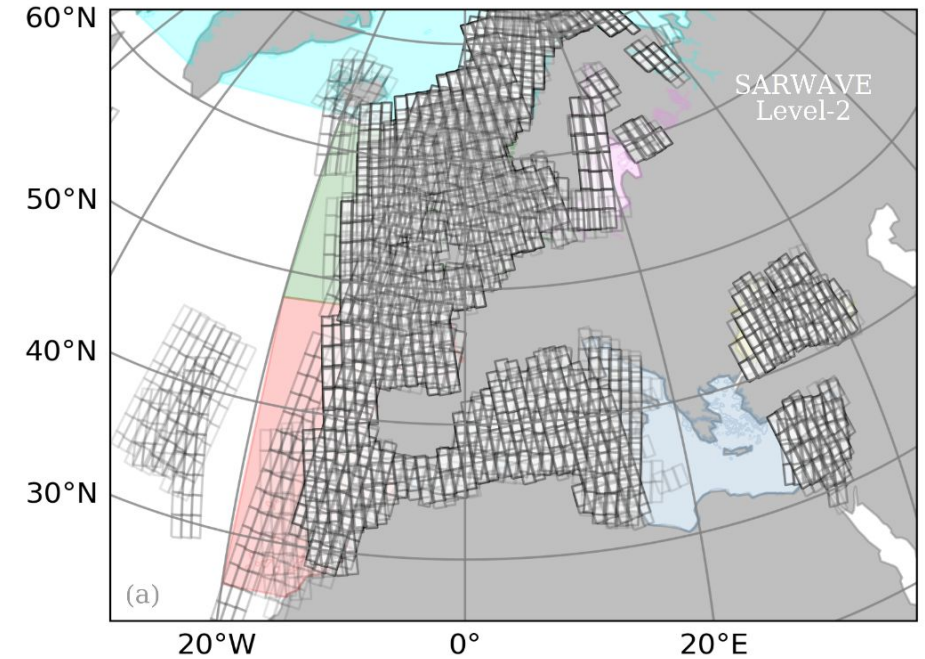
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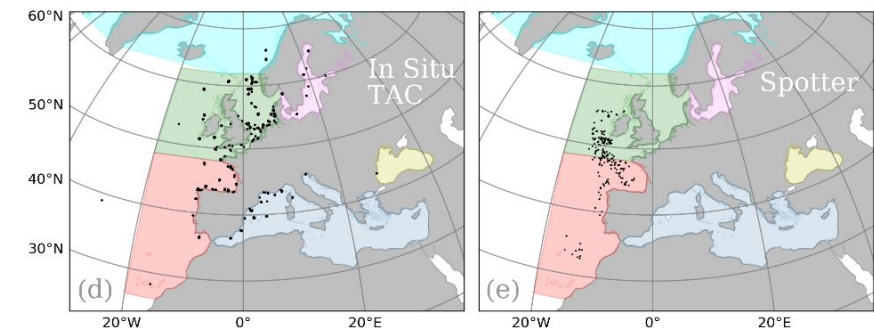
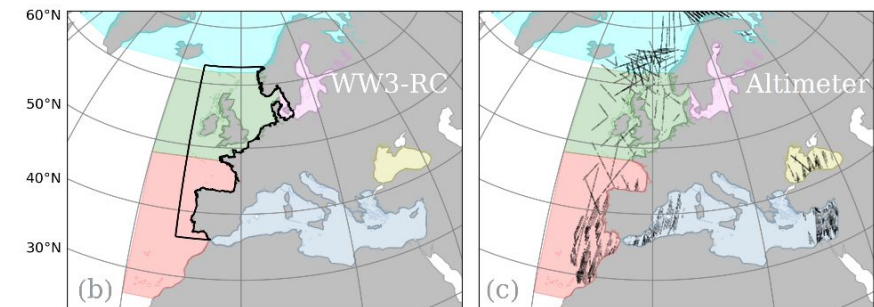
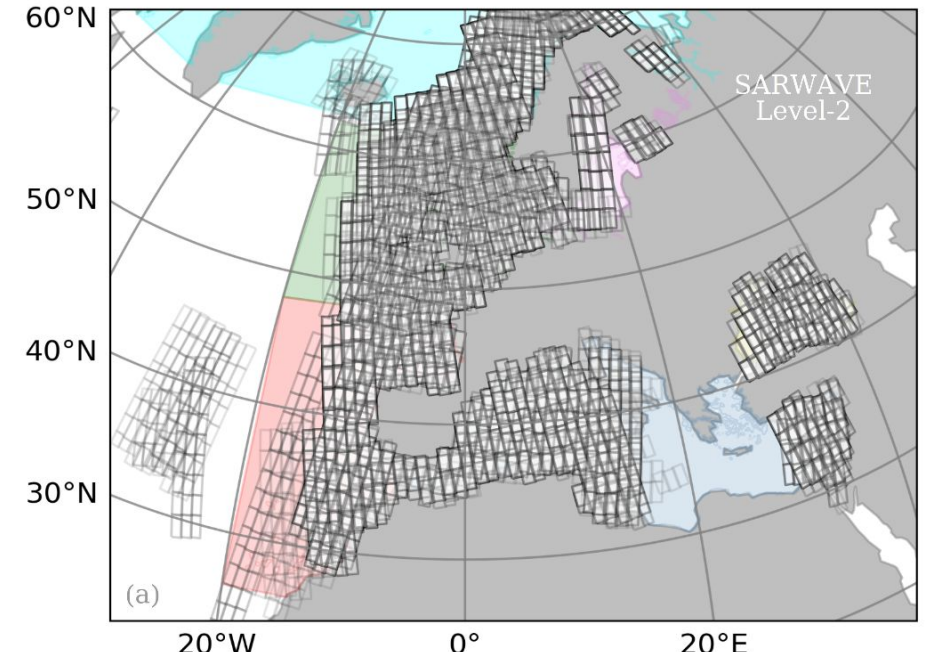
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 - generated (DIAS through NoR)



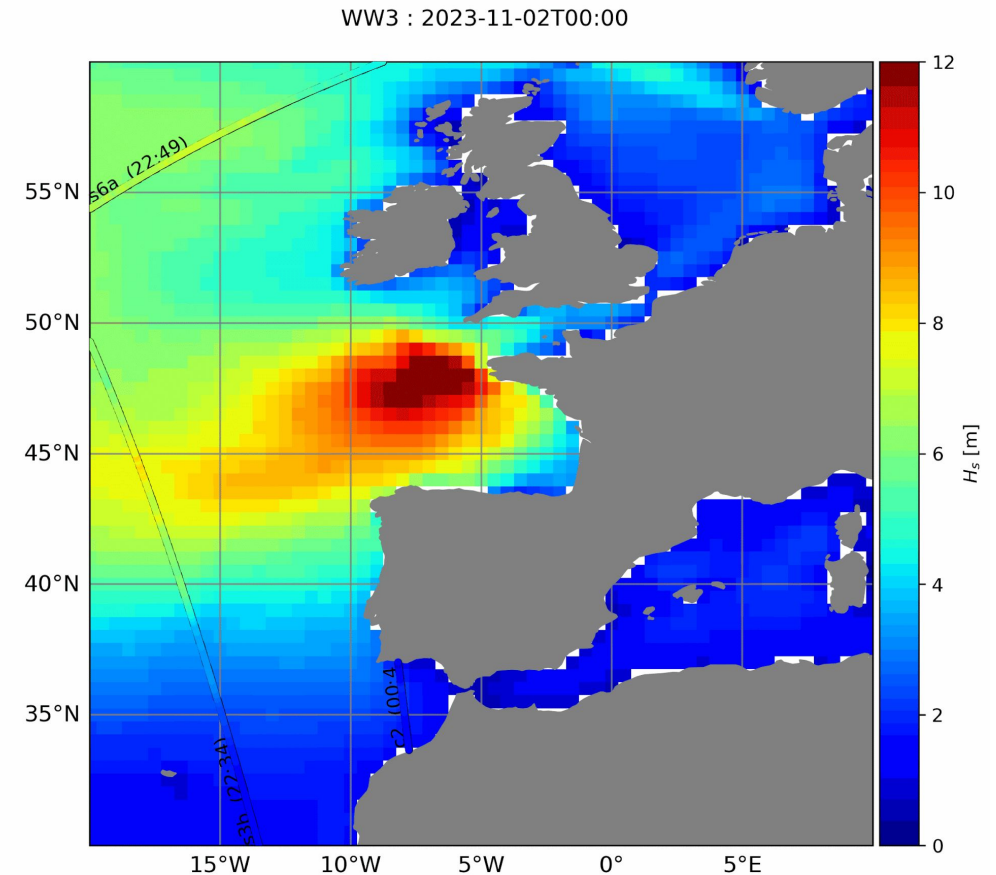
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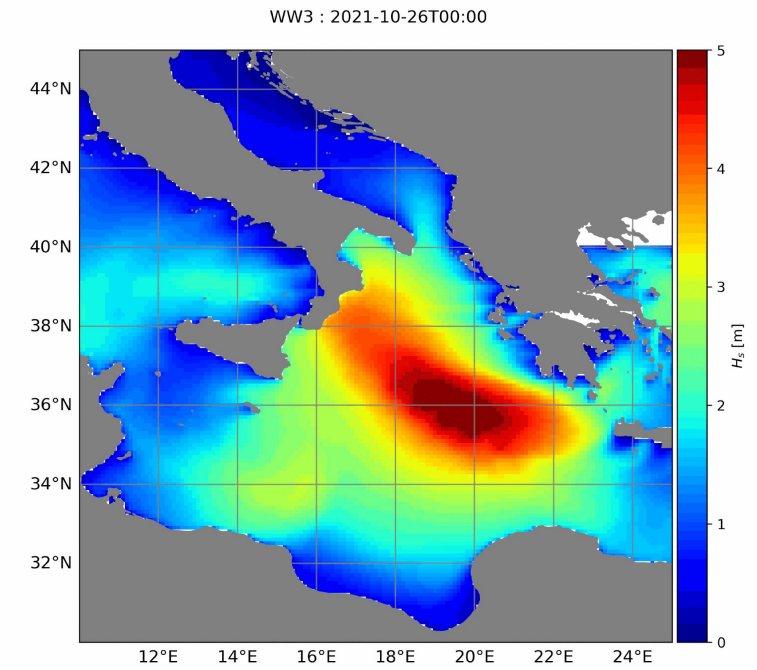
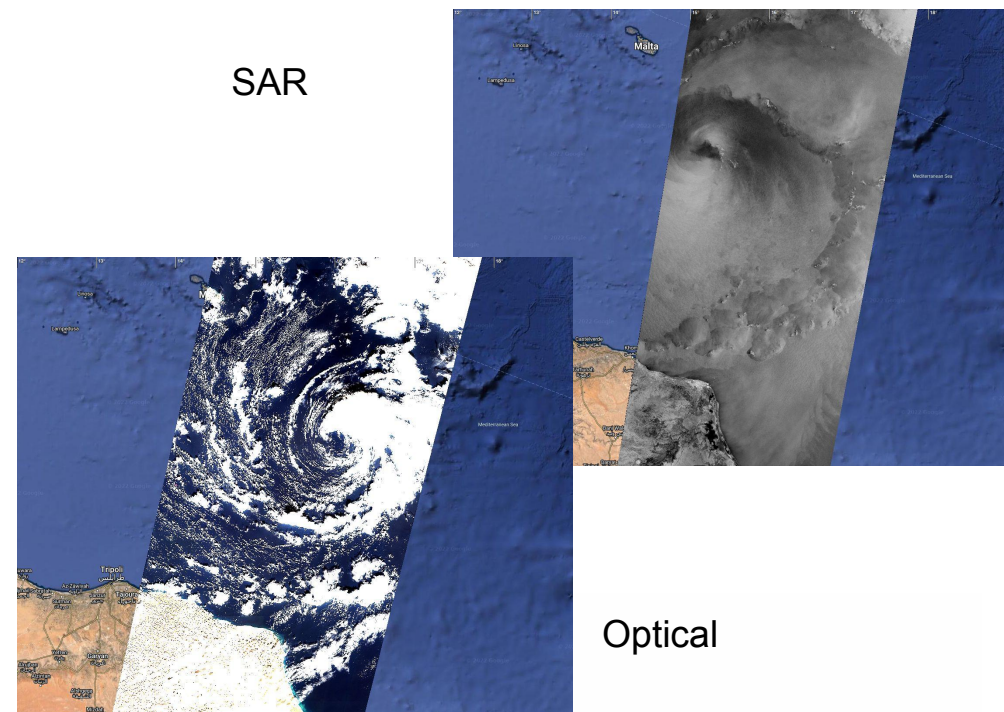
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 - Extremes



Ciaran & Domingo Storms (2023)

Status

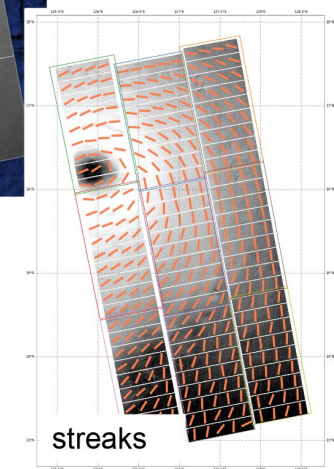
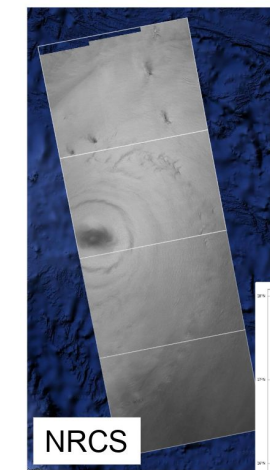
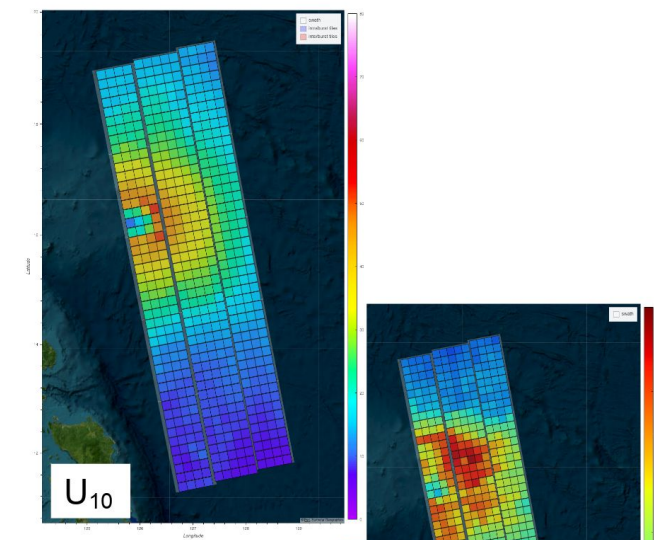
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Apollo Medicane

Status

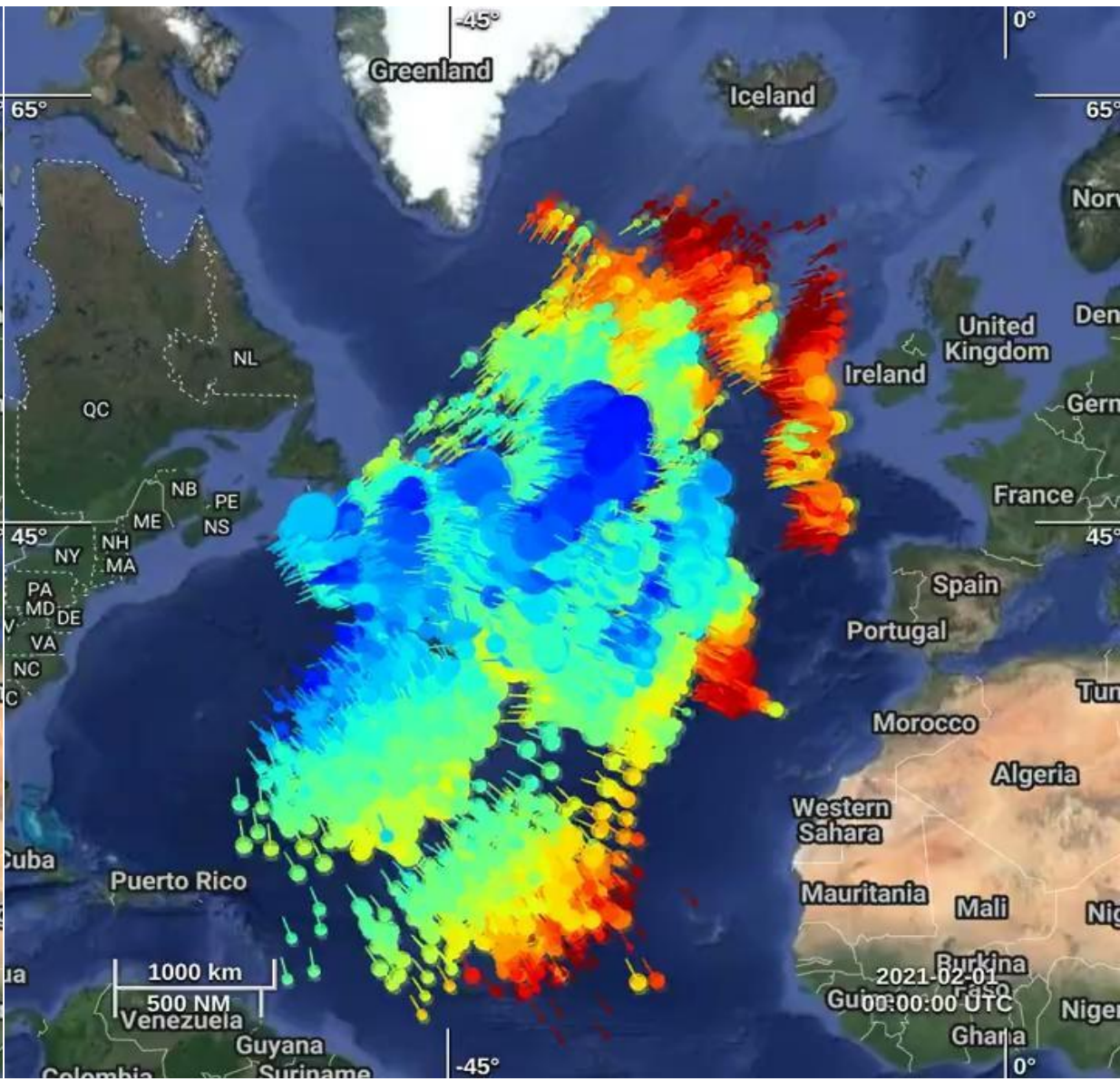
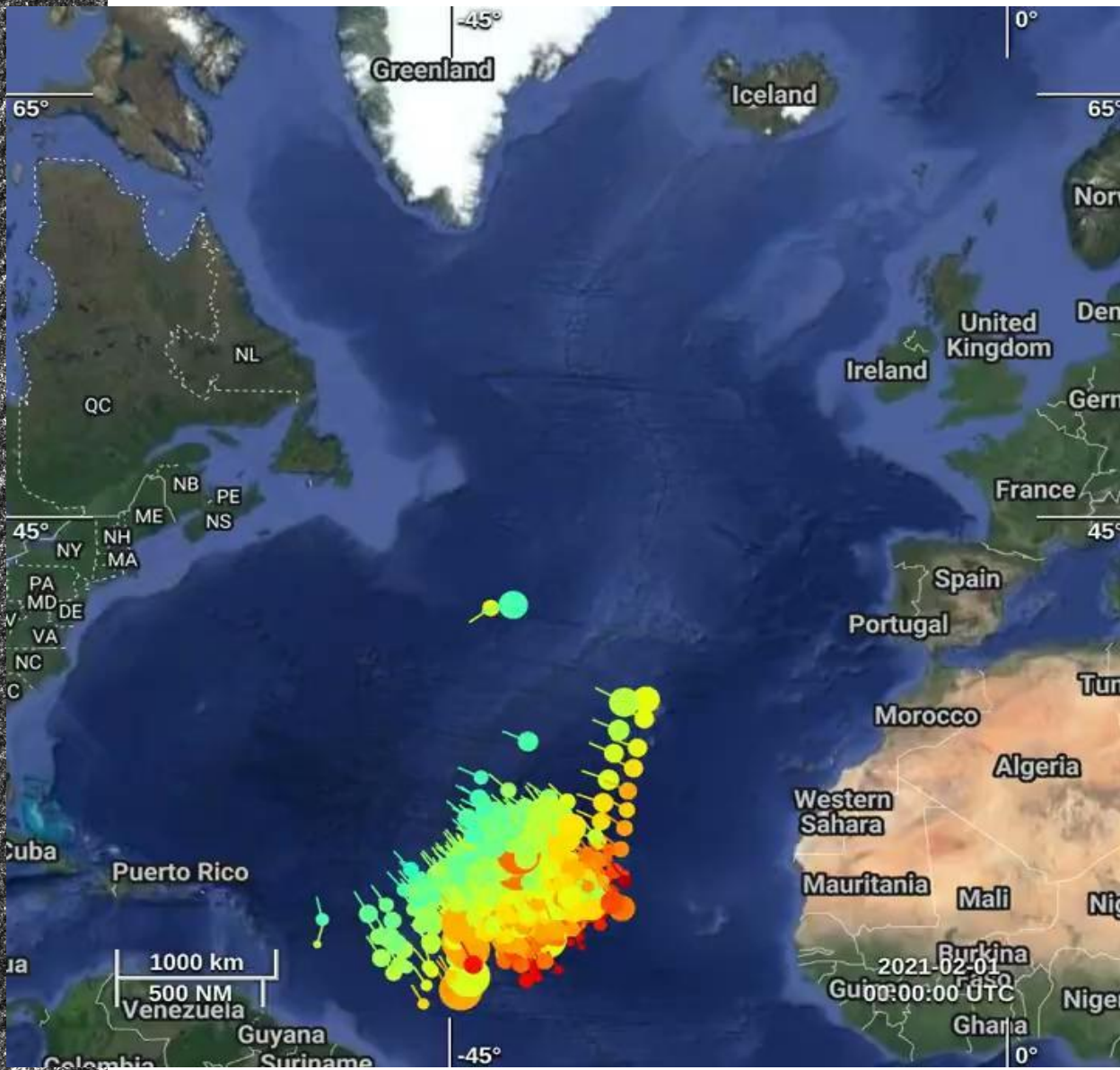
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Surigae Tropical Cyclone (cat-5)

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3. Investigate synergies with other EO sensors and products
 - Wave Mode (Copernicus) and IW mode (SARWAVE) spectra combination



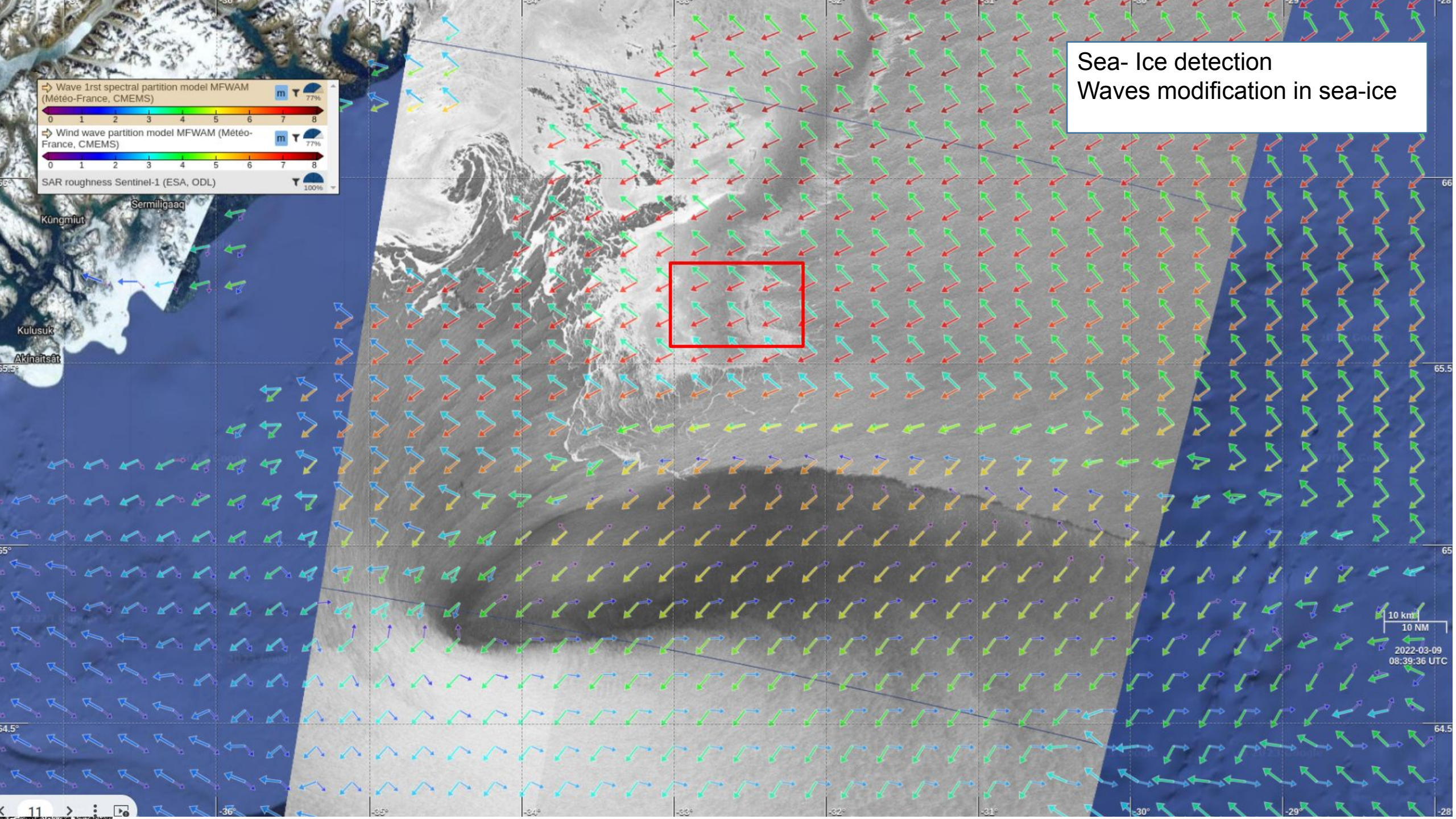
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Develop a new open-source sea state processor and Level-2 ocean waves product from Sentinel-1 IWS TOPS SAR images

Generate prototype datasets over ocean, sea ice, and coastal areas. 1 Year of data focusing on European Seas.

Investigate synergies with other EO sensors and products

- Ocean surface waves in sea-ice



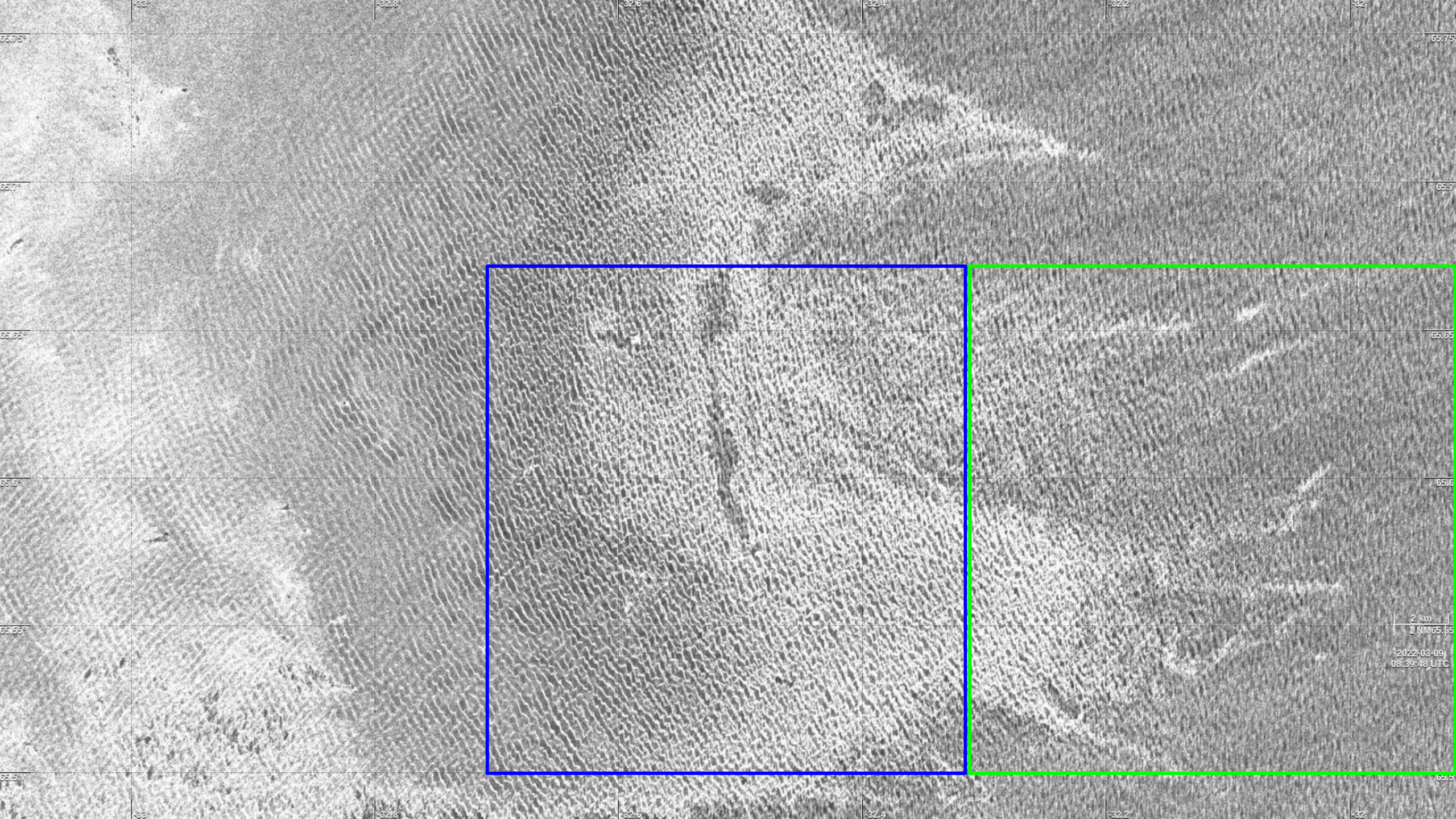
Sea- Ice detection
Waves modification in sea-ice

Wave 1st spectral partition model MFWAM (Météo-France, CMEMS)
0 1 2 3 4 5 6 7 8 m 77%

Wind wave partition model MFWAM (Météo-France, CMEMS)
0 1 2 3 4 5 6 7 8 m 77%

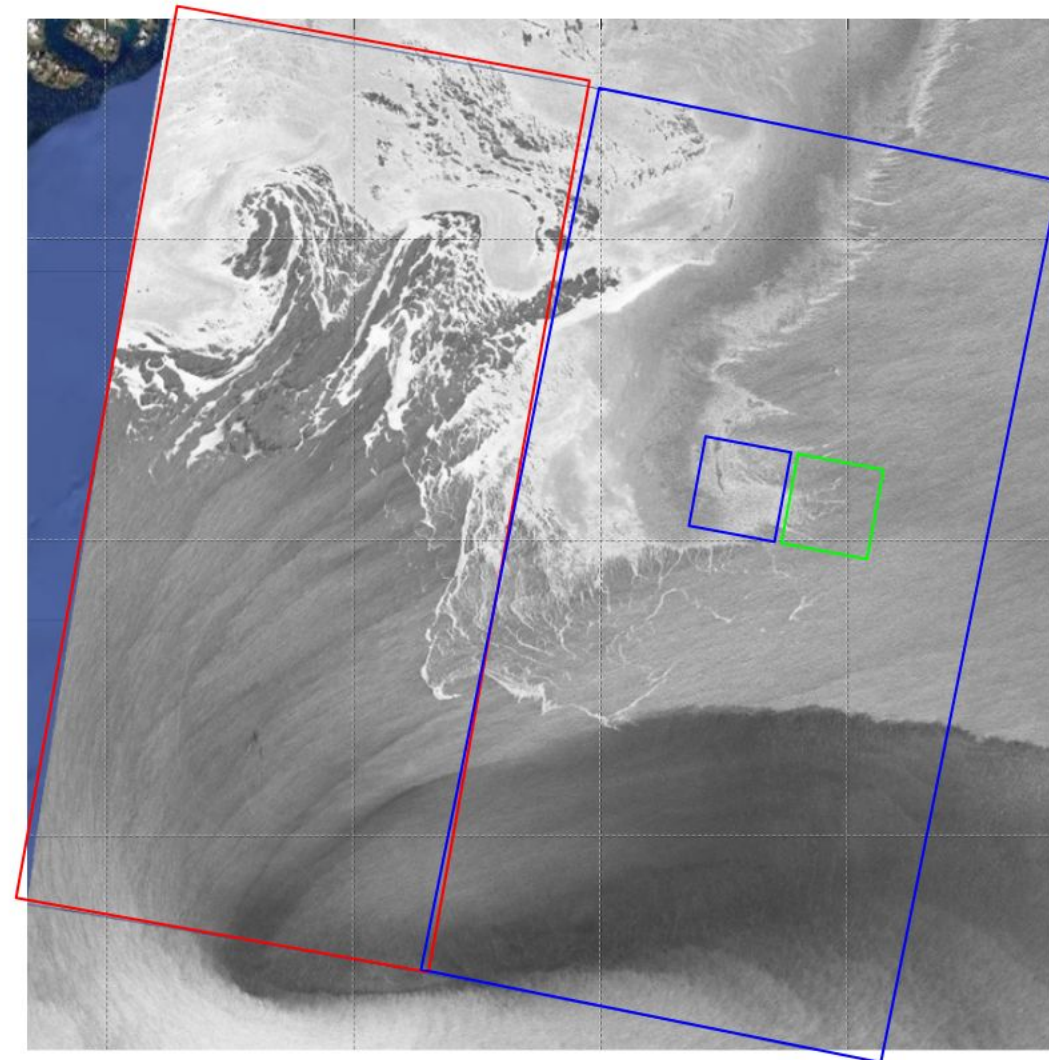
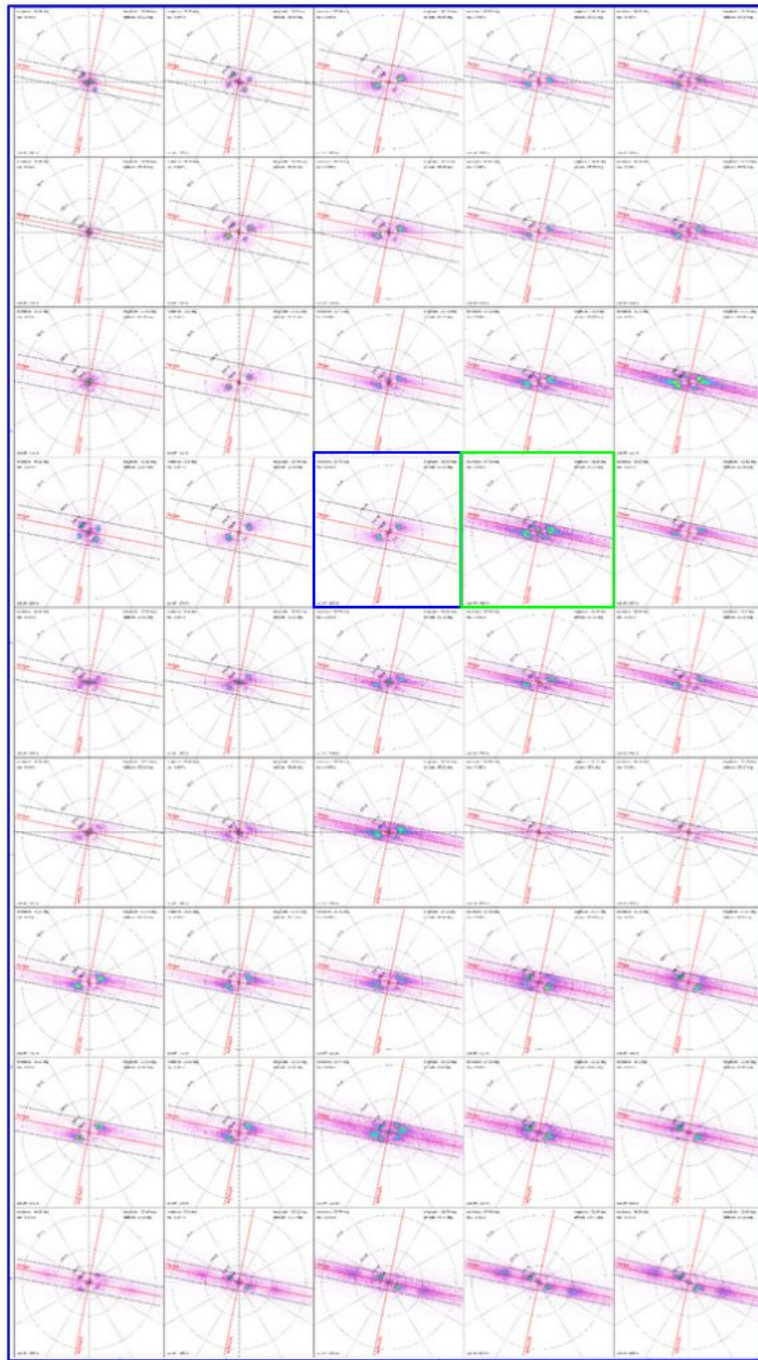
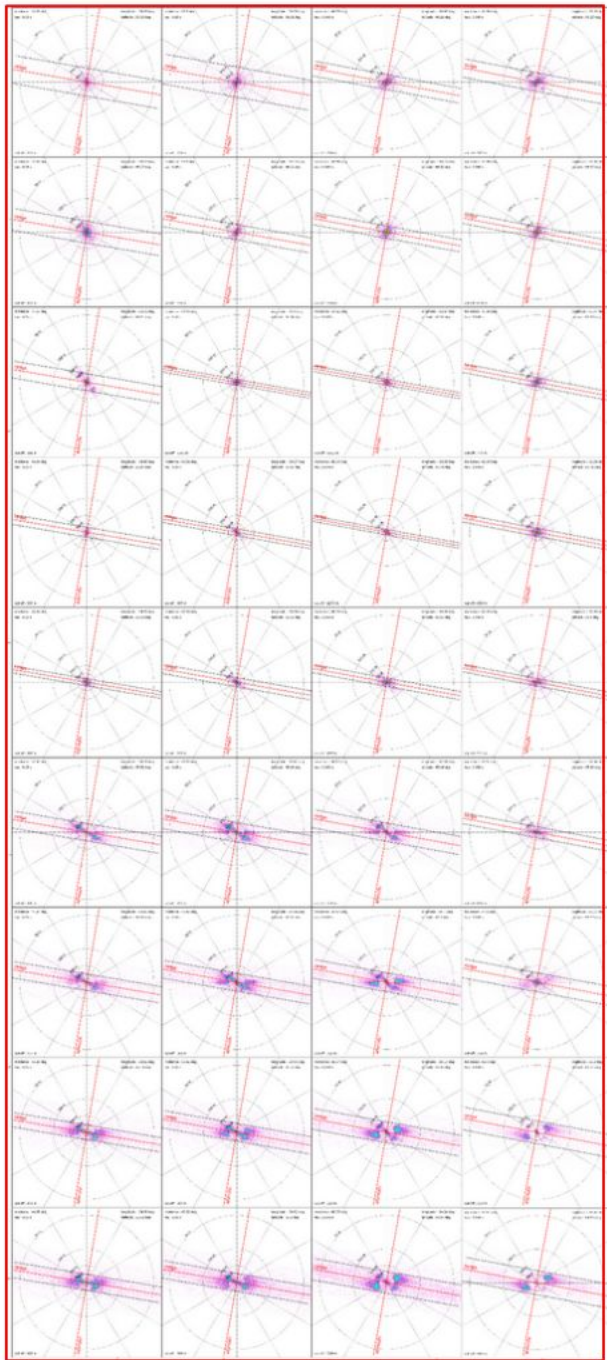
SAR roughness Sentinel-1 (ESA, ODL) 100%

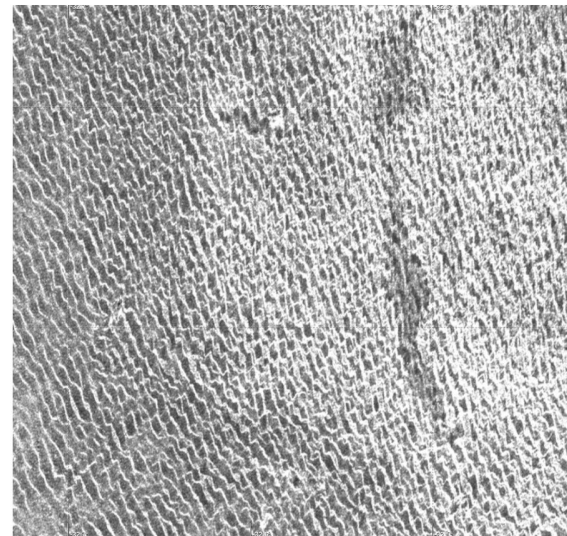
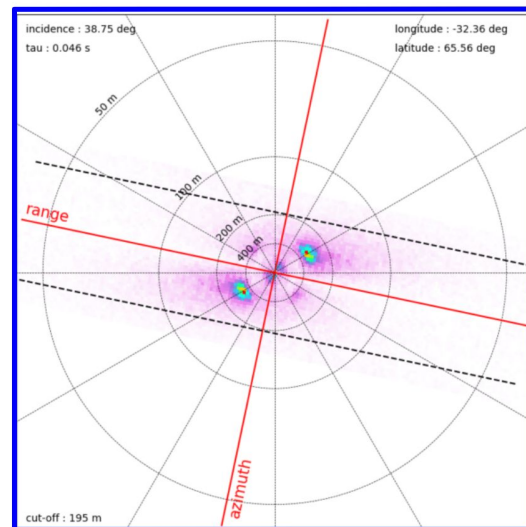
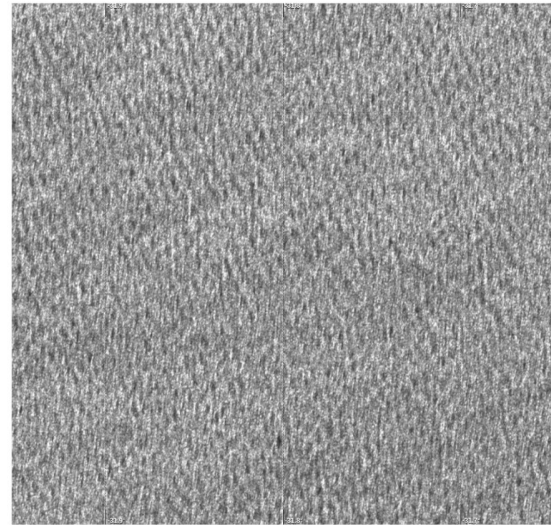
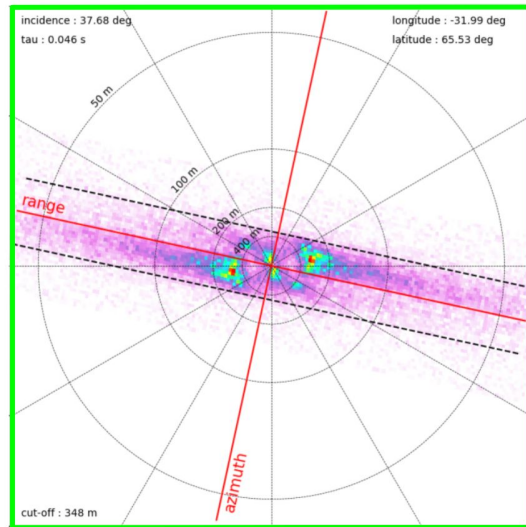
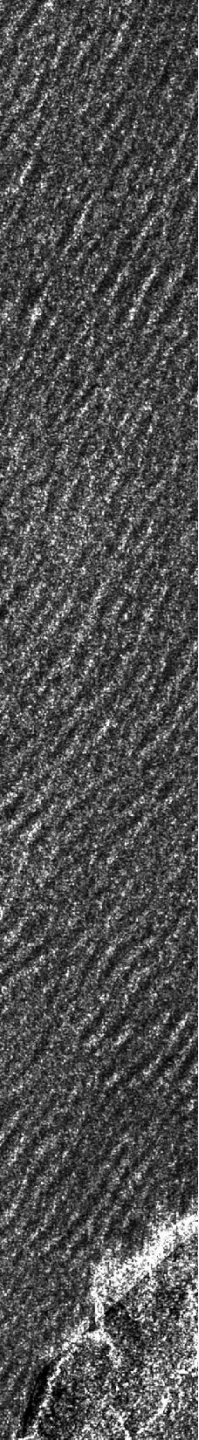
10 km
10 NM
2022-03-09
08:39:36 UTC



2 km
1 NM

2022-03-09
08:39:48 UTC





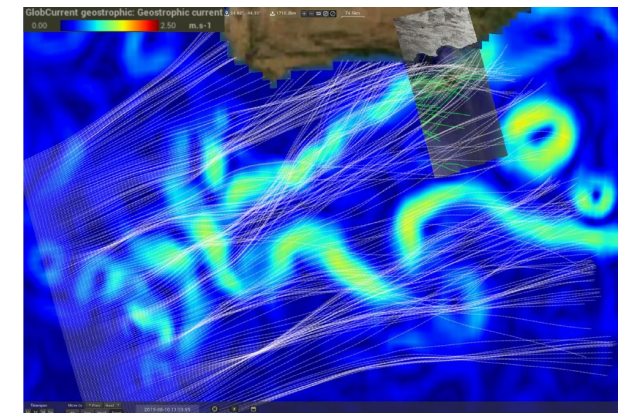
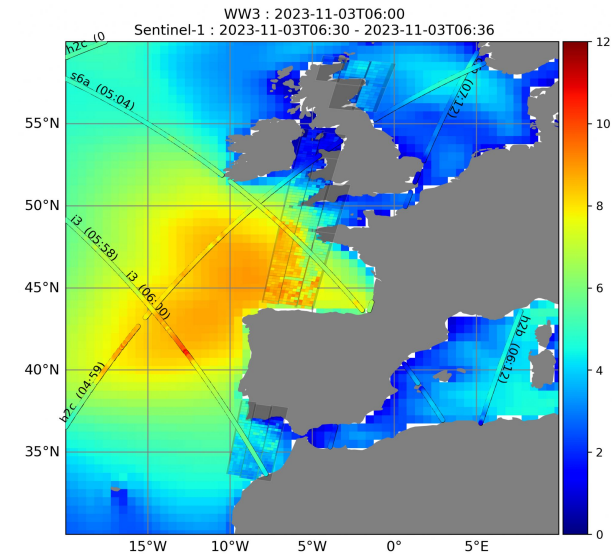
Current and future SARWAVE outcomes

1. Recent Achievements

- Processing capacity deployed at Ifremer
- First version of L1B/L2 products available for consortium
- On-going product validation activity

2. Open scientific challenges

- Full directive wave spectrum retrieval from SAR having limited (nonlinear) imaging capabilities
- Propose and test new coherent inversion strategies
- Characterise sea state variability based on multi-sensors approach for complex situations (MIZ, Extremes, wave-current interaction)



SARWAVE perspectives and recommendations

Foreseen short-term activities

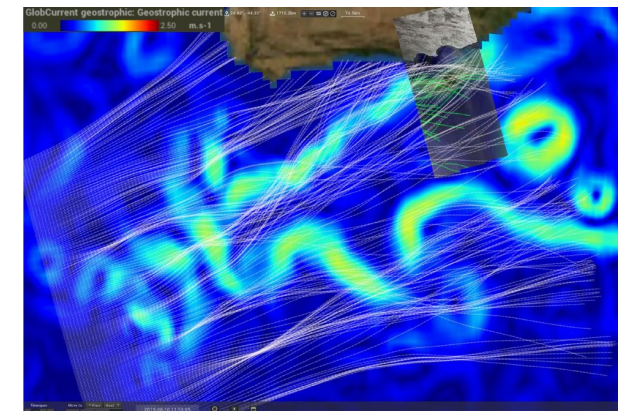
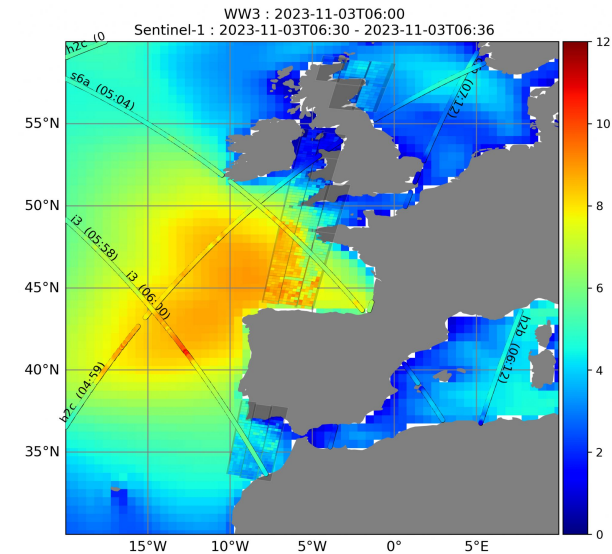
- Sentinel-1 - SWOT synergies / cross-comparison / Validation
- Publicly shared SARWAVE outputs (1 year of L1B/L2 product over european seas) for users feedback
- Integrate SARWAVE achievements in MPC-Sentinel-1 activities to enrich Copernicus L2 ocean products.

Long-term & scientific perspectives

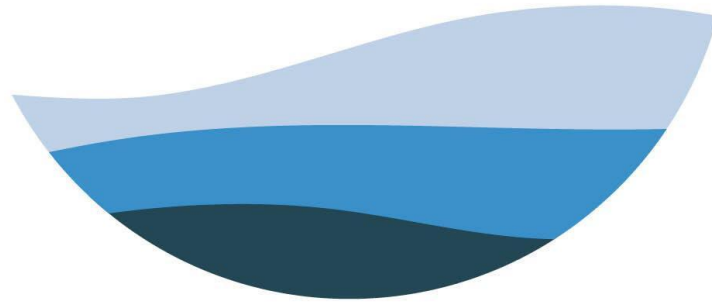
- Wave-current interactions analysis (wide swath)
- High-Resolution gradient analysis (Hs, wind, ...)
- Consistency of wind/waves in extremes

Recommendations

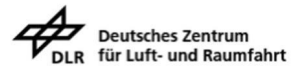
- Provide recommendations for ocean parameter retrieval strategies for Next-Gen Earth Observation system (Sentinel-1 NG, Rose-L, Harmony, ...)
- There is a need for in-situ waves measurements with drifting buoys network for validation and algorithm development activities



sarwave



Partners



Funded by

