Characterisation of the tropical cyclone induced wave field from satellite observations, in-situ data, and parametric model

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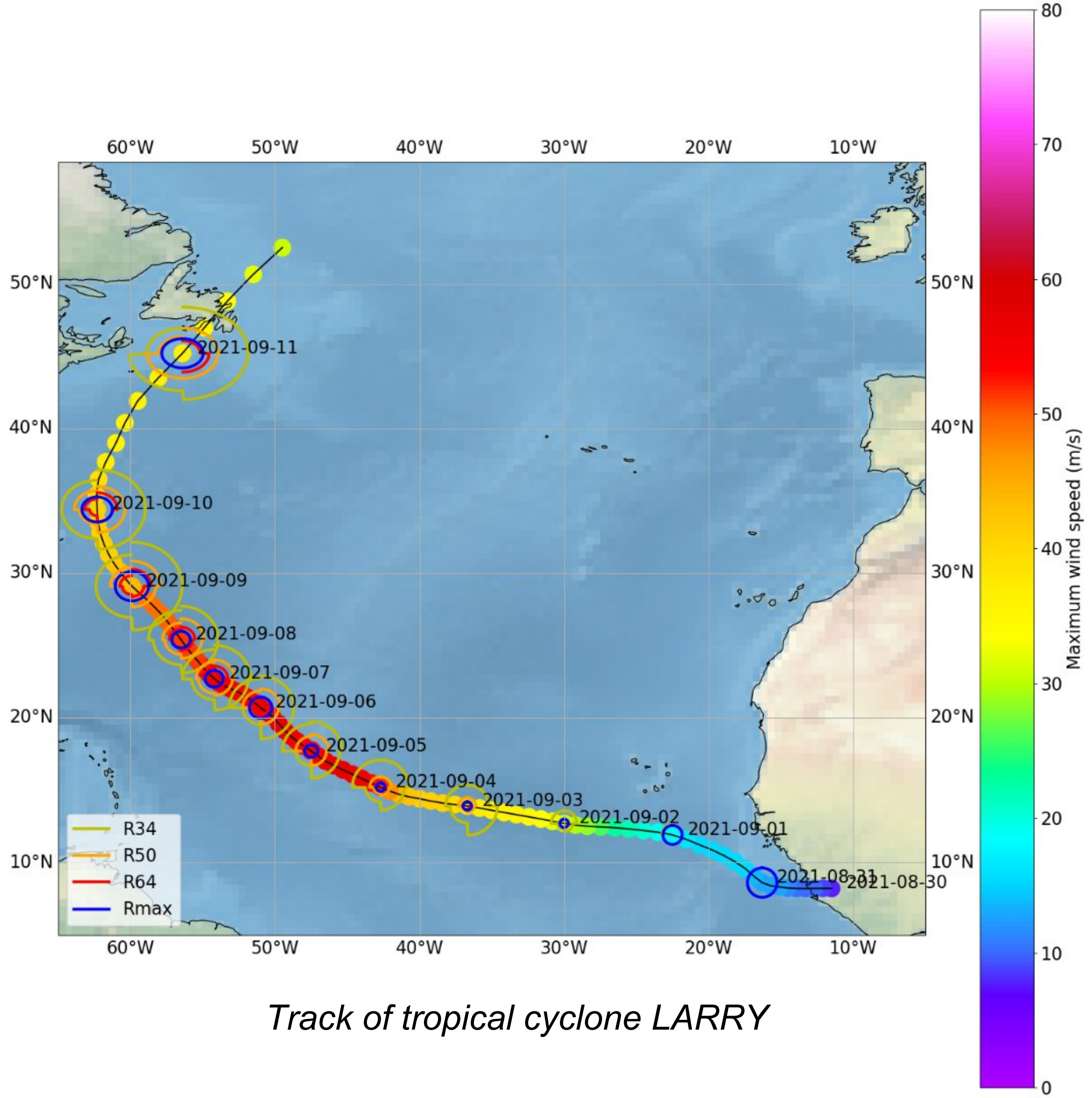
Fabrice Collard, Gilles Guitton, Maria Yurovskaya

CFOSAT ST Meeting, Saint Malo, 2021-09-13

Case study: Tropical cyclone LARRY, 2021

Main parameters of tropical cyclones along their track :

- Maximum wind speed
- Maximum wind radius
- Translation speed



Track of tropical cyclone LARRY

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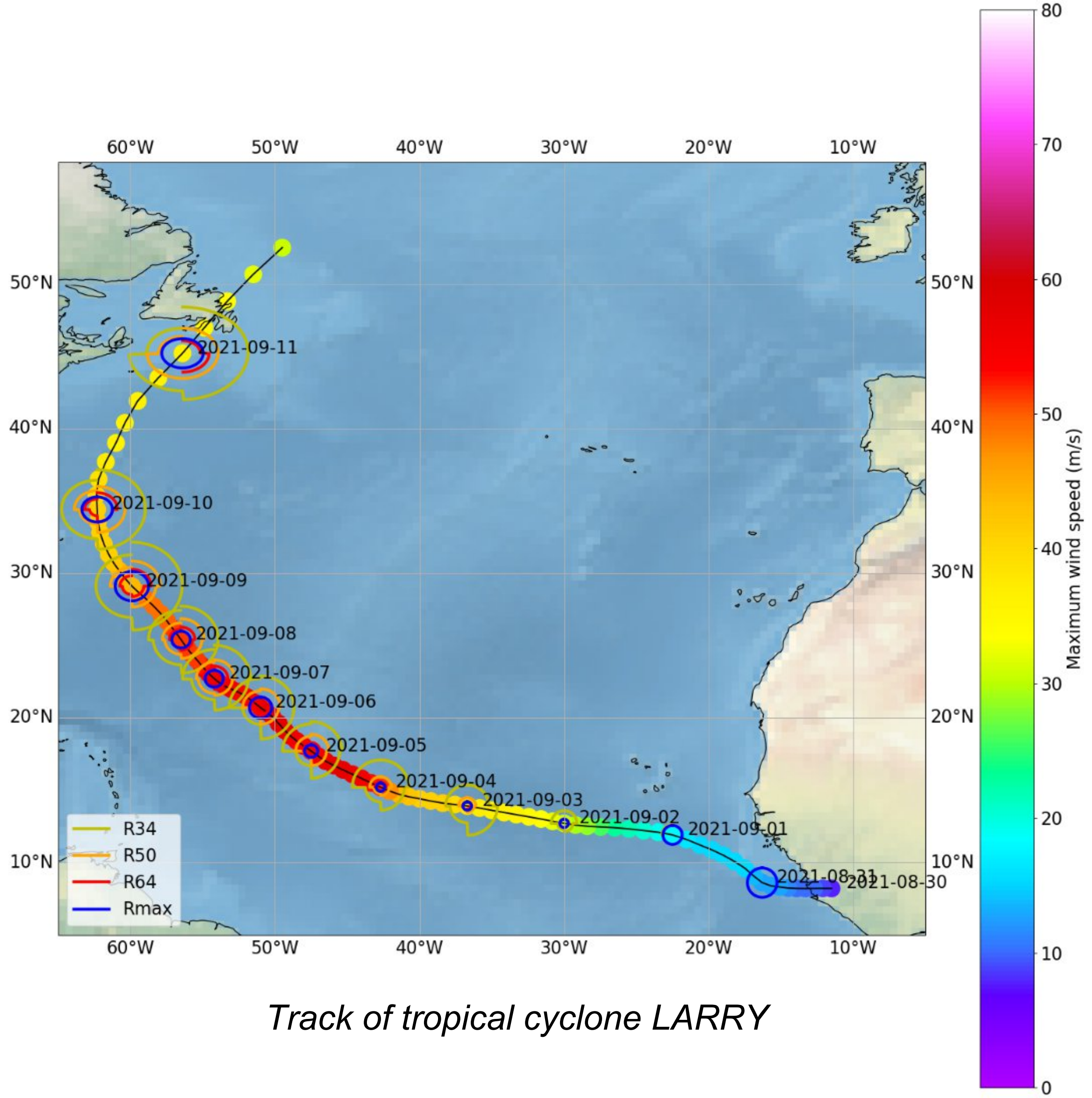

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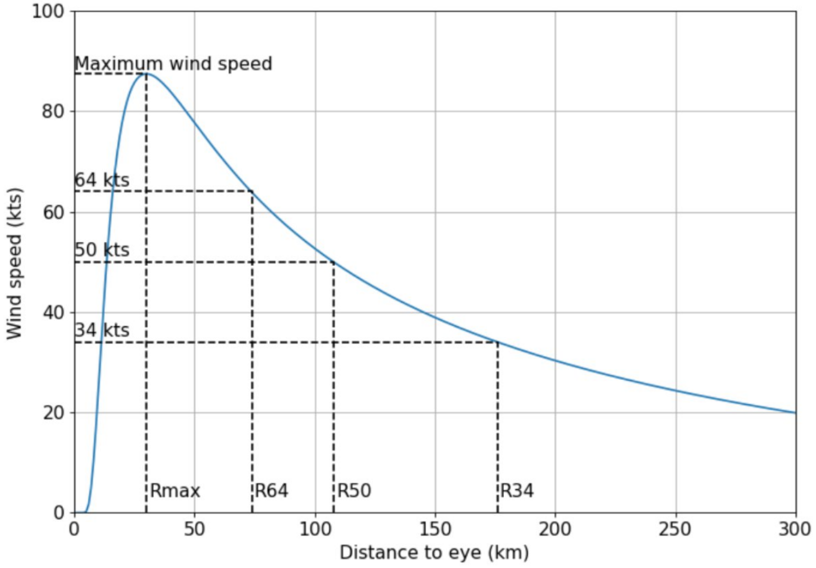

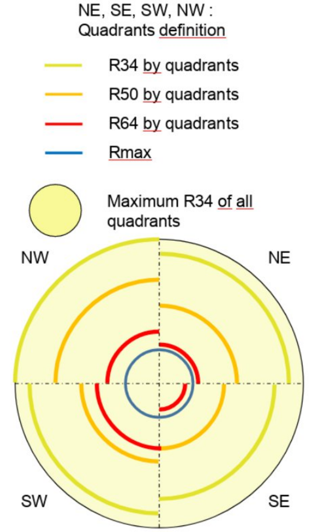

Tropical cyclone track (temporal resolution = 3 hours). Area of the tropical cyclone defined by the max of R34 for every quadrant

Objectives :

- **Characterize tropical cyclone induced wave field** thanks to satellite observations and in situ data, qualify and quantify the **contribution of CFOSAT** to the product
- Compare the results with those obtained thanks to a **parametric model** (Kudryavstev, 2021) to validate it
- **Perform statistics** on a large amount of tropical cyclones

TC waves algorithm definition

- Tropical cyclones and wave observations
- General approach

Tropical cyclones and wave observations

Satellite observations inside tropical cyclones may be disturbed by extreme meteorological conditions (rain, strong wind)

Outside the cyclone, quality of satellite observations **is expected to be better than inside**.

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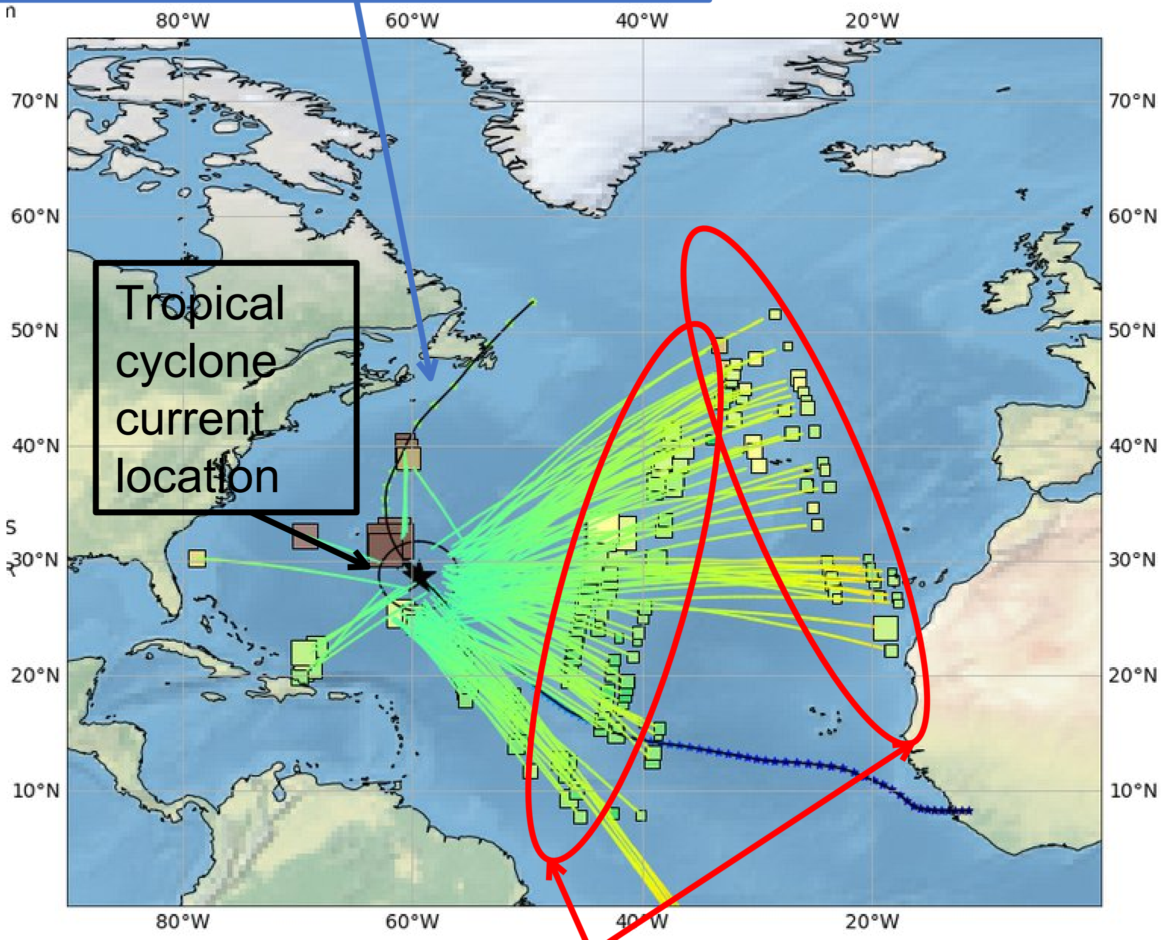
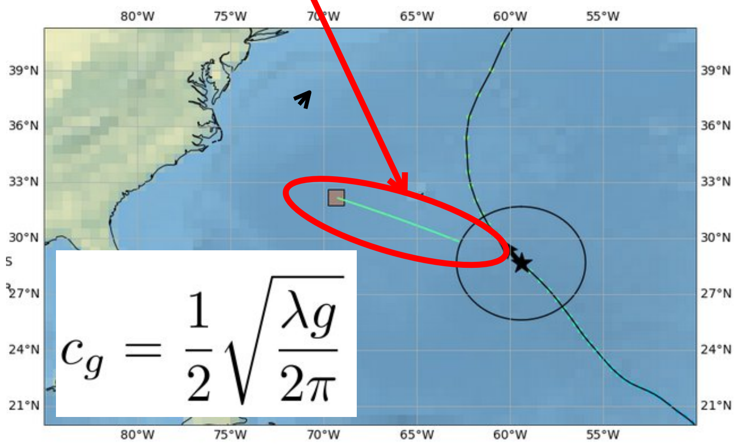
Black line: Tropical cyclone track



CFOSAT SWIM L2S wave partitions, back propagated to their source.
Colored lines: Back propagation trajectories

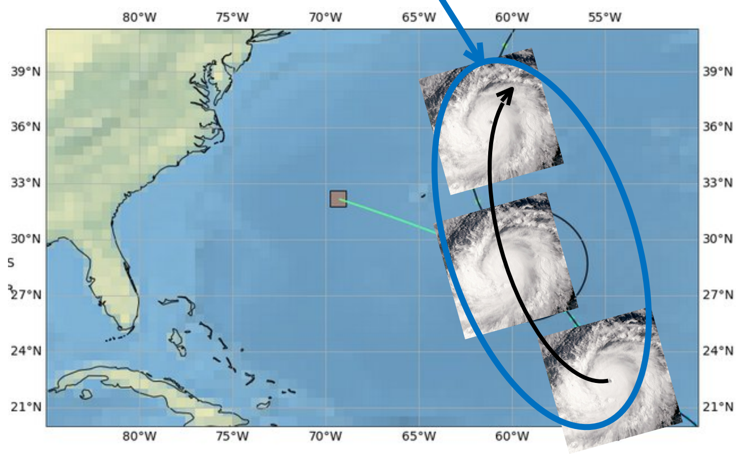
Dynamical co-location

Dataset of Wave partitions back propagated



$$c_g = \frac{1}{2}\sqrt{\frac{\lambda g}{2\pi}}$$

Tropical cyclone track



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Dynamical co - location unit

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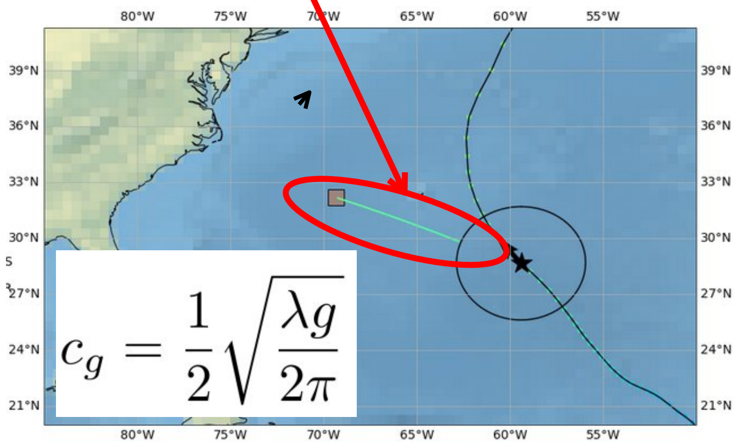

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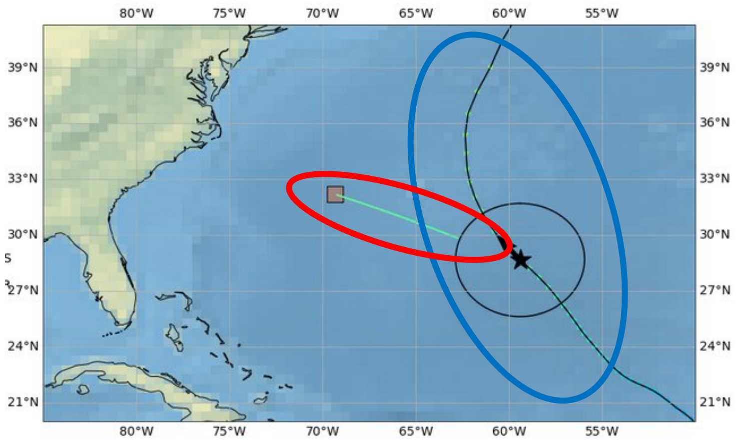
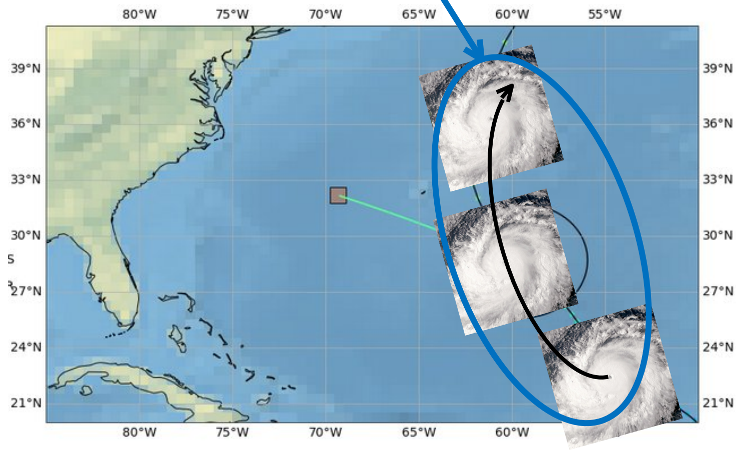


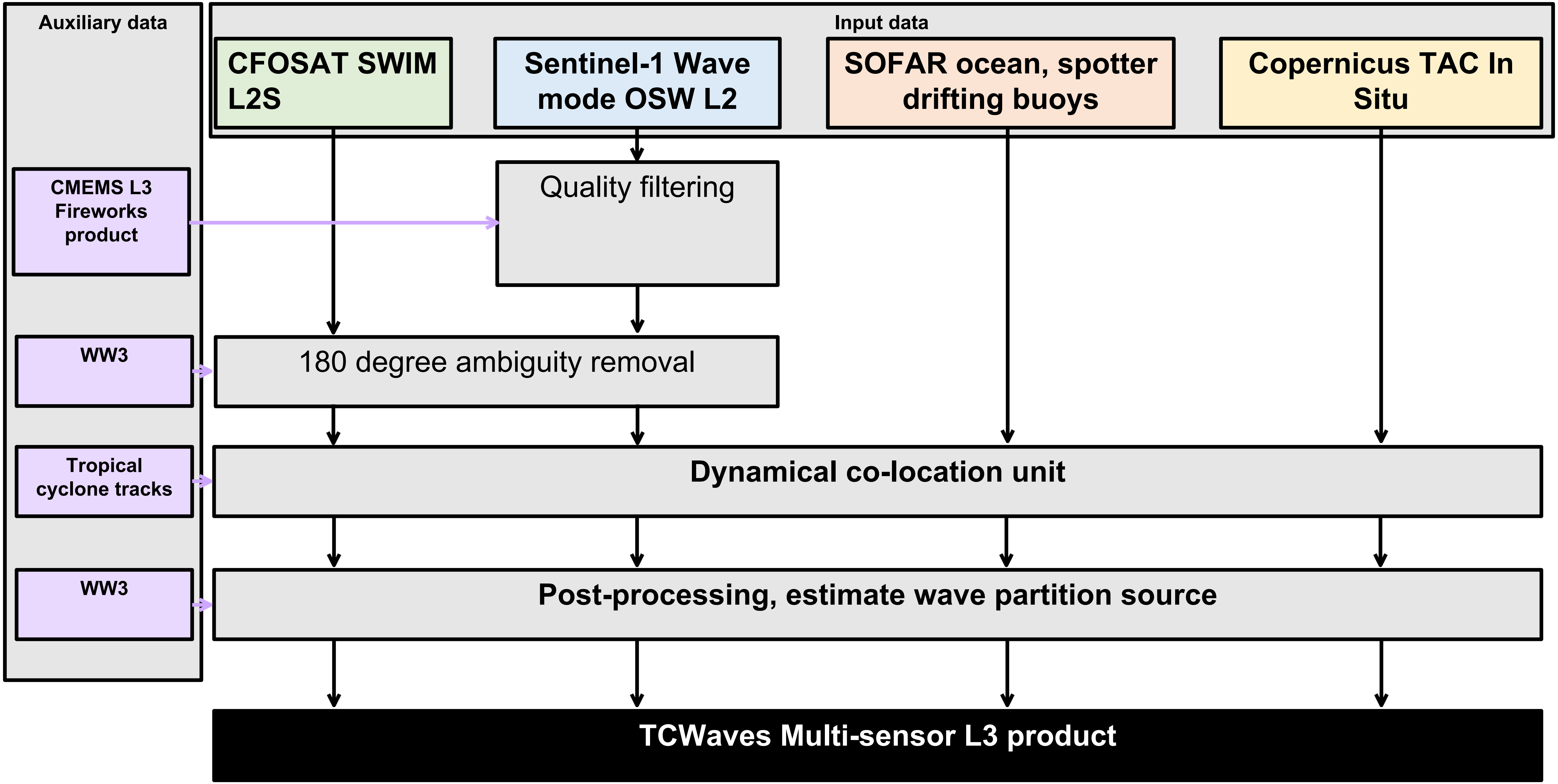


Wave partitions back propagated during **10 days**

Co-location between **back propagated wave partitions (wavelength, direction)** and **Tropical cyclone tracks**

Dataset of satellite wave partitions that are inside the TC at some point on their trajectory

TC Waves product algorithm synthesis

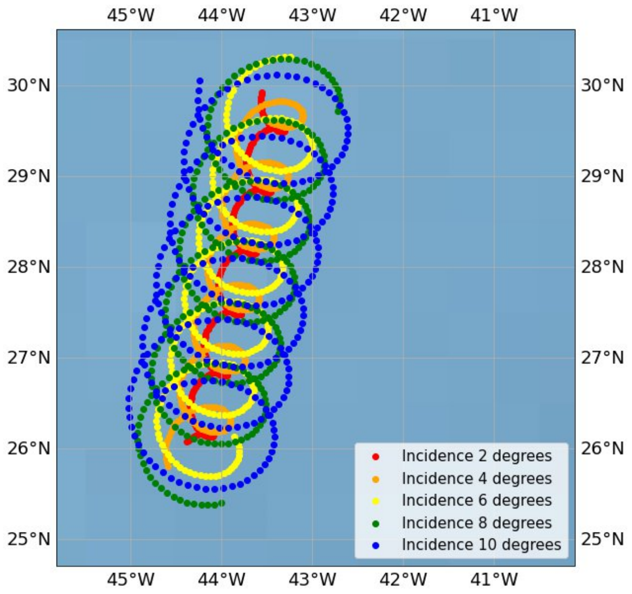


Data presentation

- CFOSAT SWIM L2S
- Sentinel-1 Wave mode
- In situ data

CFOSAT
SWIM L2S

- SWIM sensor, **L2S product**
- **Different beam incidences** : (0, 2, 4, 6, 8 and 10 degrees)
- **Global coverage**



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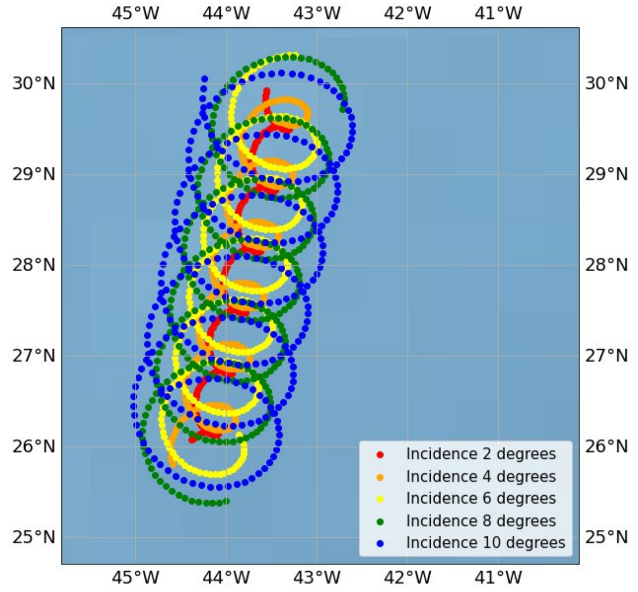
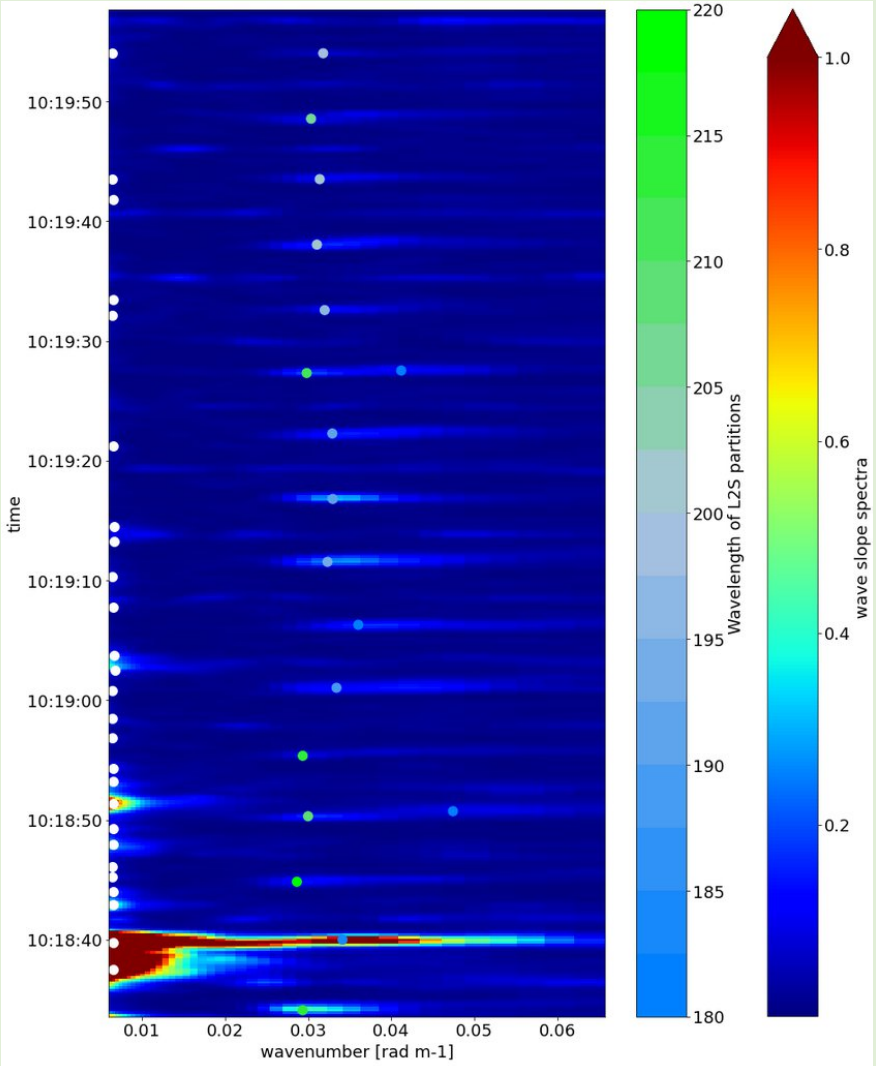
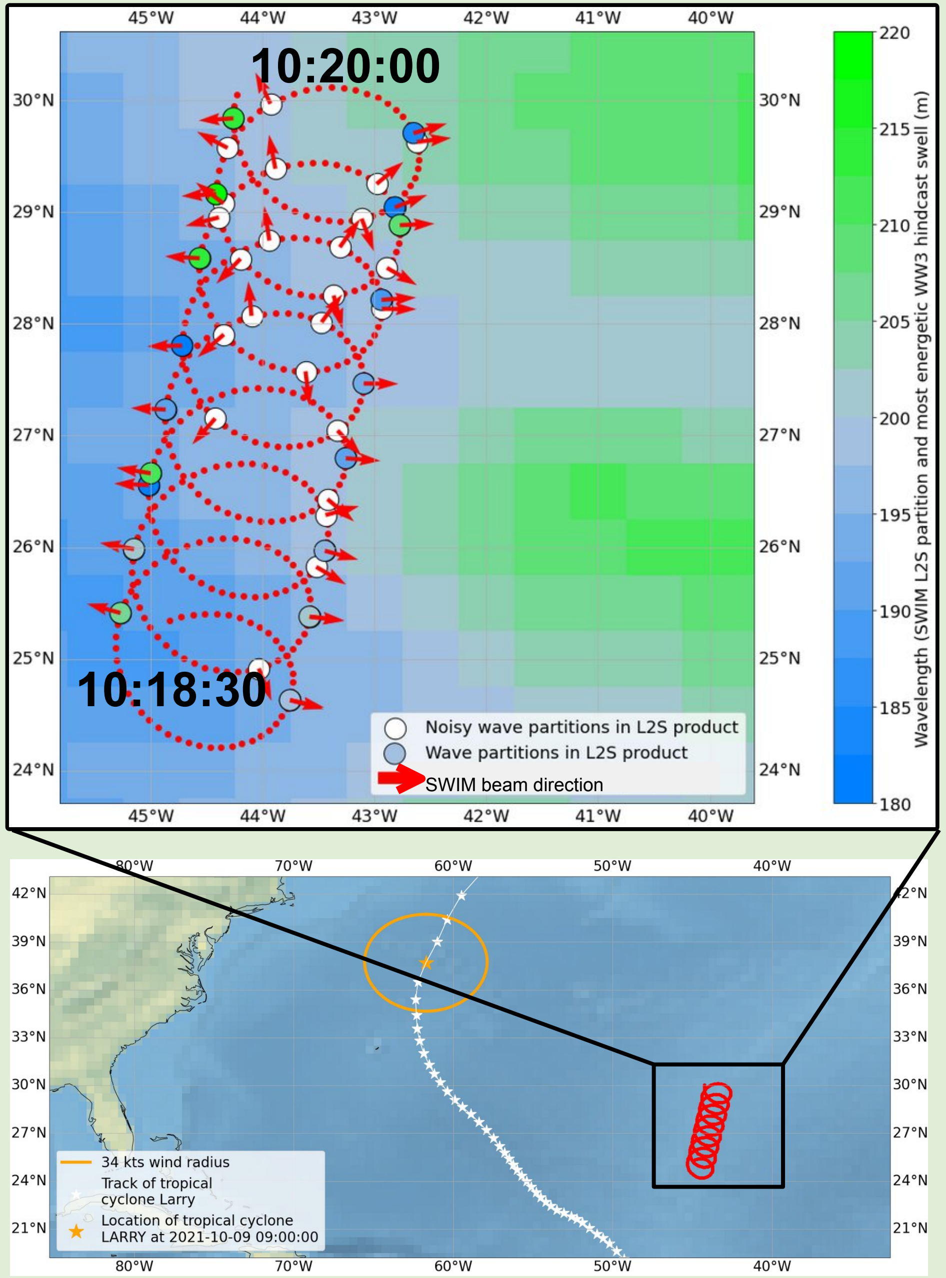


Example for an beam incidence of **10 degrees on 2021-09-10 between 10:18:30 and 10:20:00**





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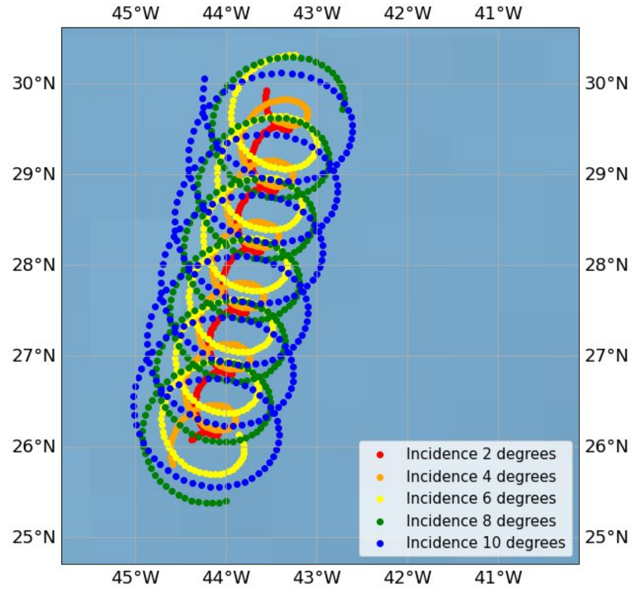

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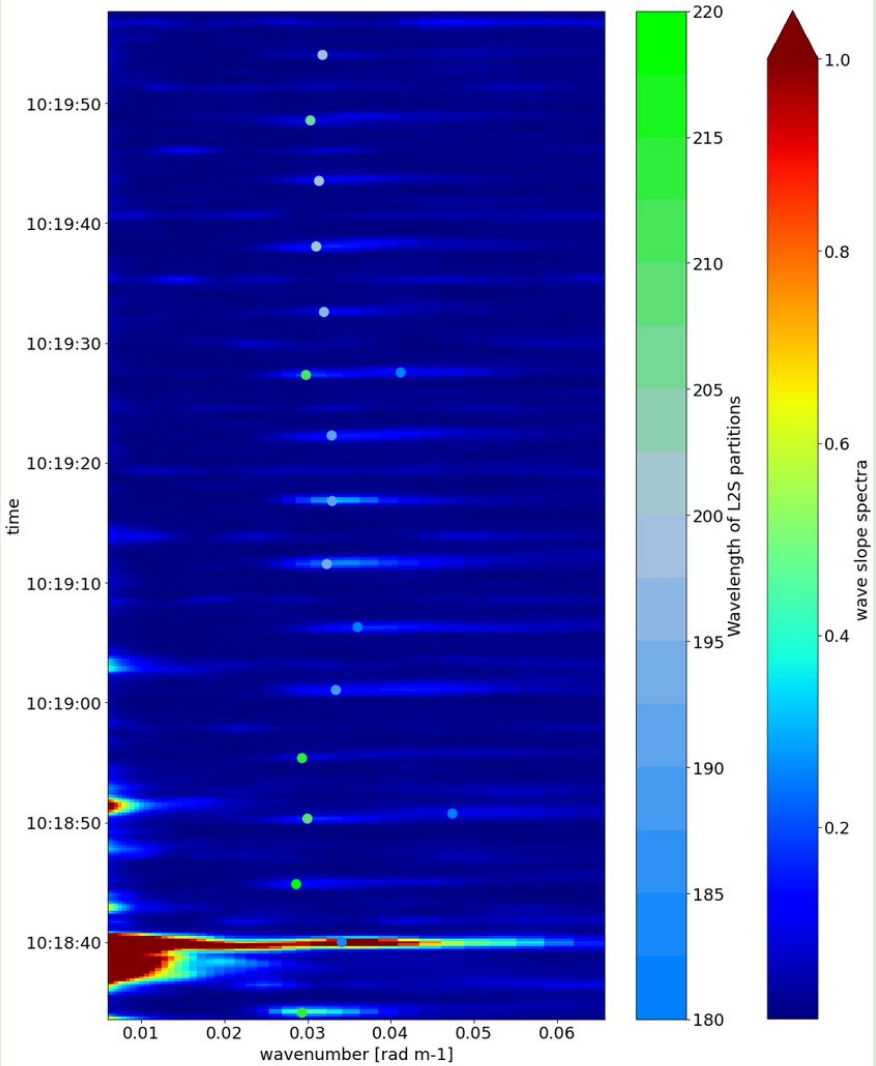
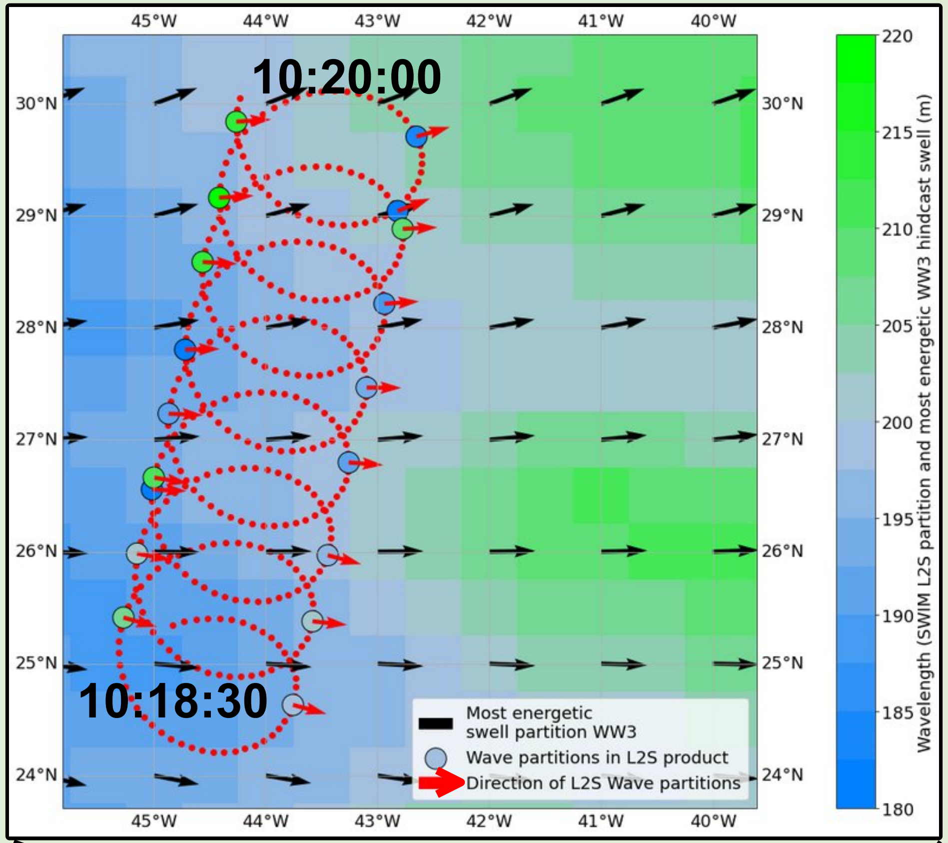
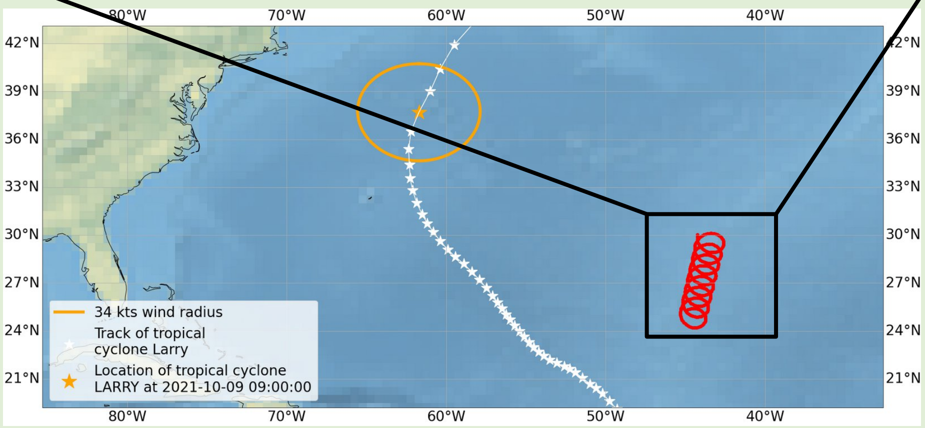
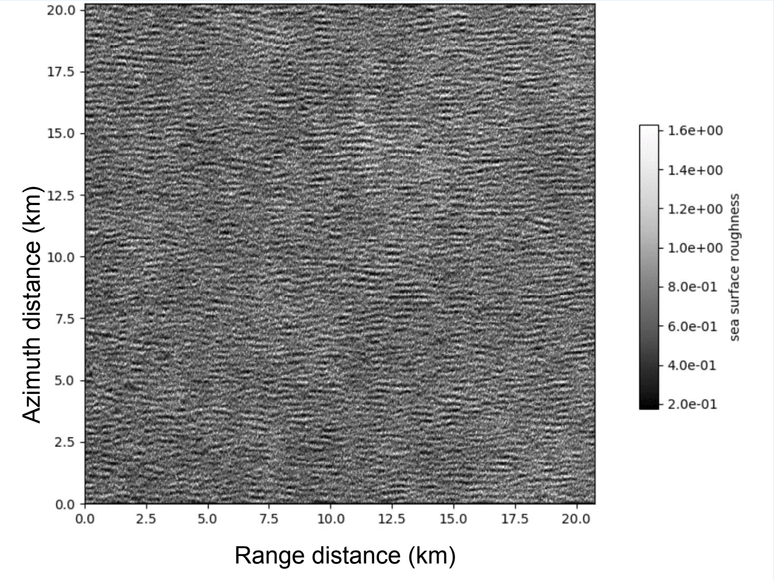


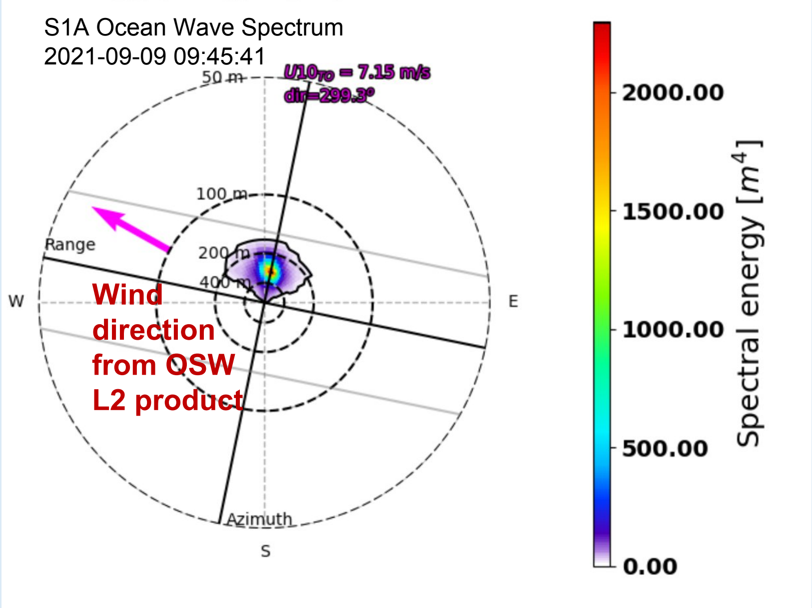




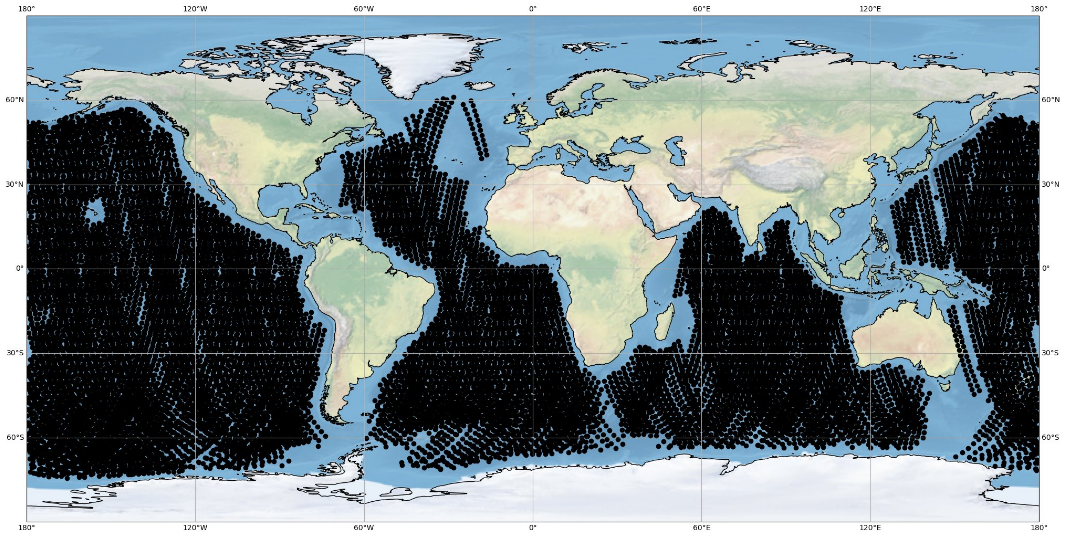
Other satellite data source : **Sentinel-1 Wave mode OSW L2**



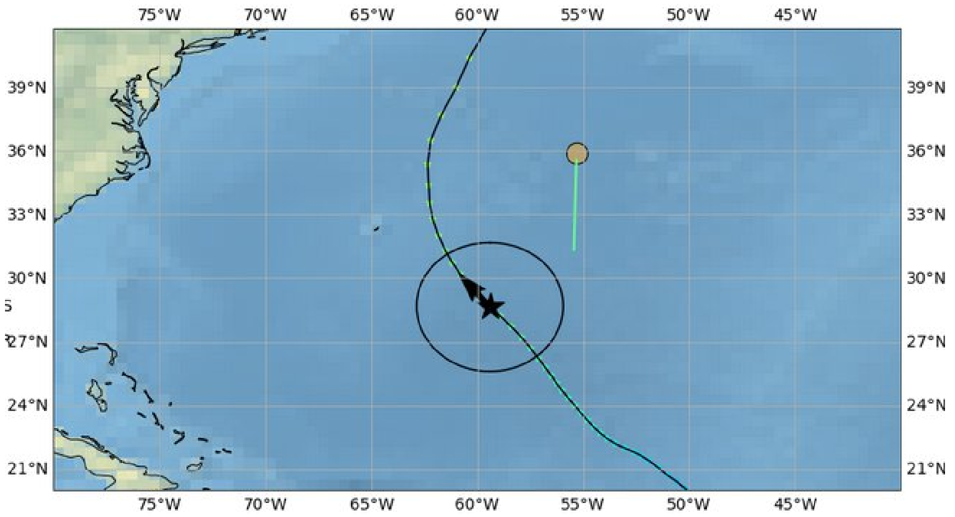
Sentinel-1 **sea surface roughness image...**



...and **associated L2 wave spectrum example**



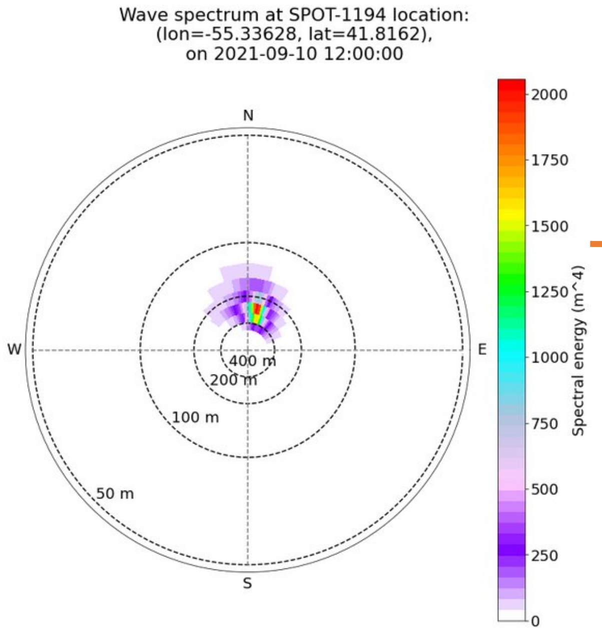
Sentinel-1A coverage between 2021-05-30 and 2021-06-10, (1 cycle, 12 days)

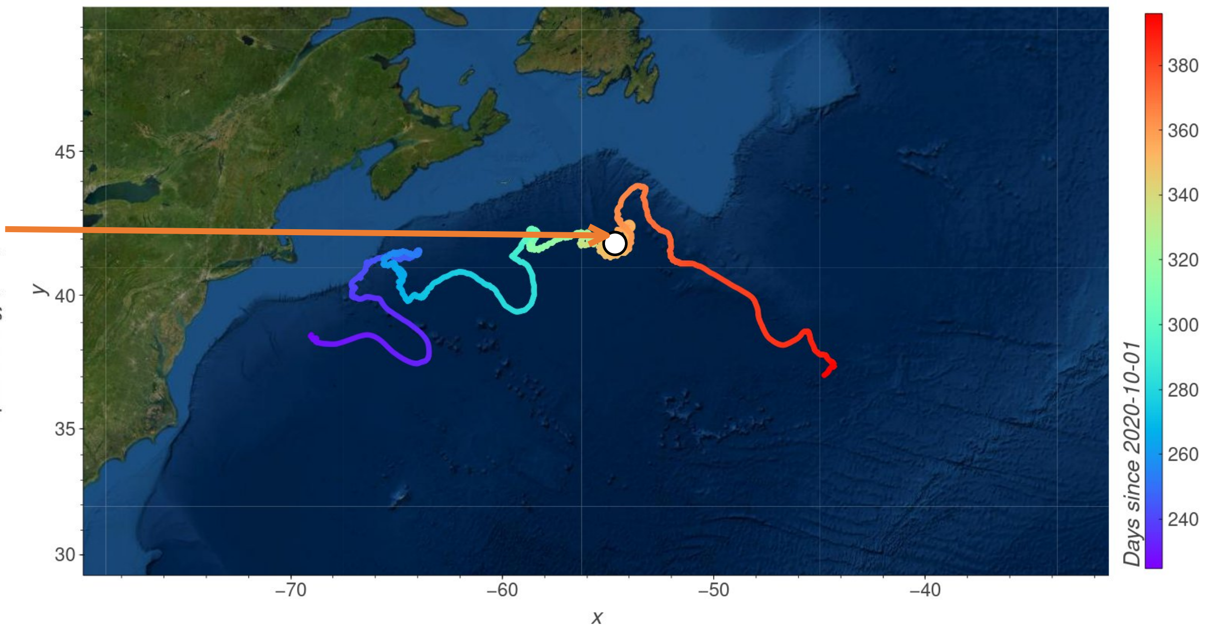


Location of observation with respect to Larry.

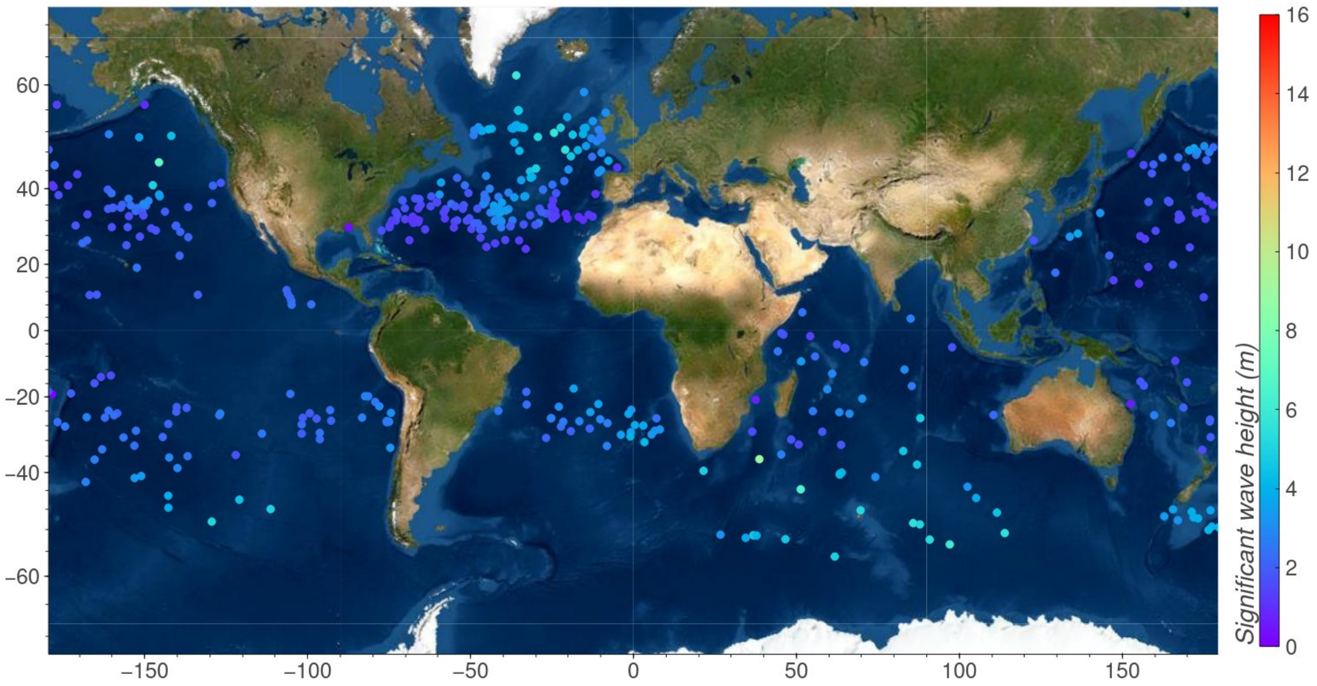
In situ data sources

SOFAR ocean, spotter drifting buoys





Trajectory of spotter : SPOT-0231, 9123 km traveled



Spotter coverage on 2021-09-26 22:00:00

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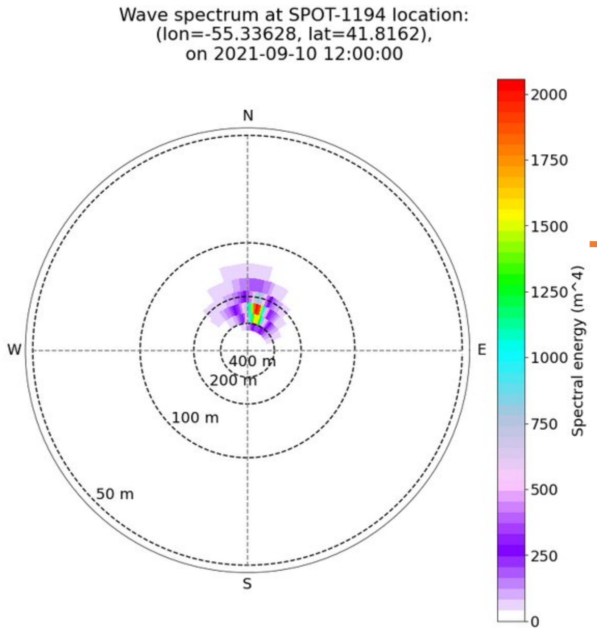

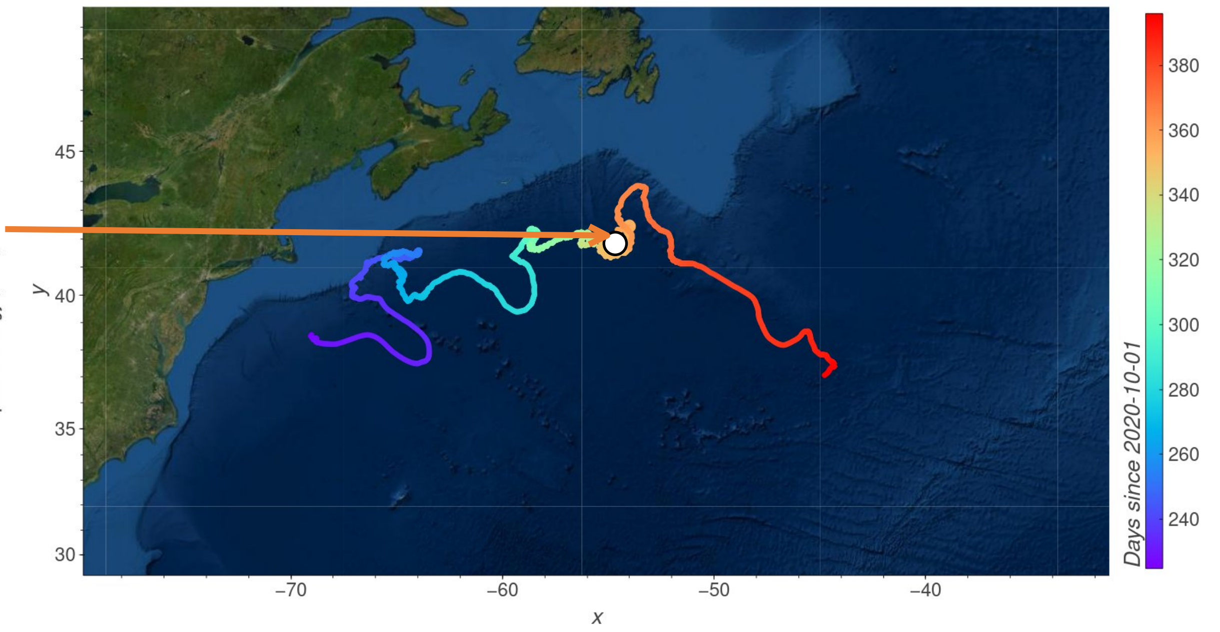

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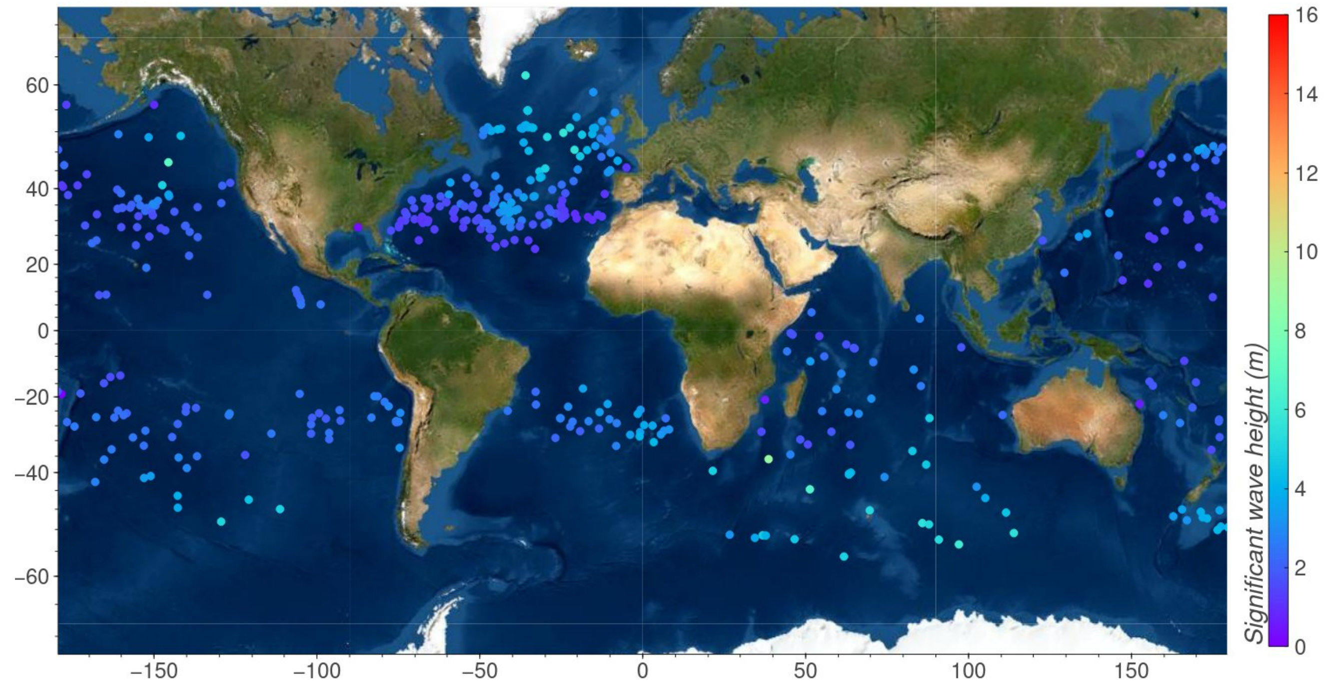
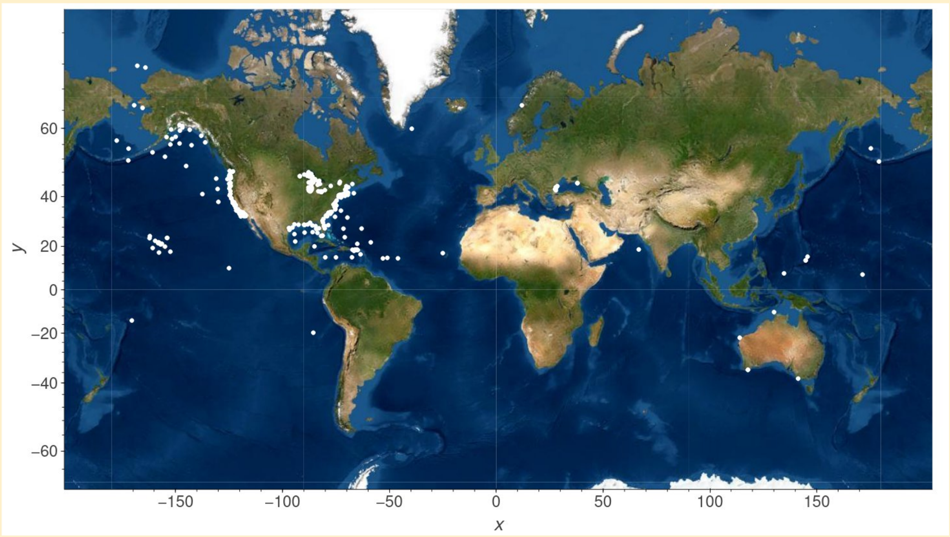


Spotter coverage on 2021-09-26 22:00:00

Copernicus TAC In Situ



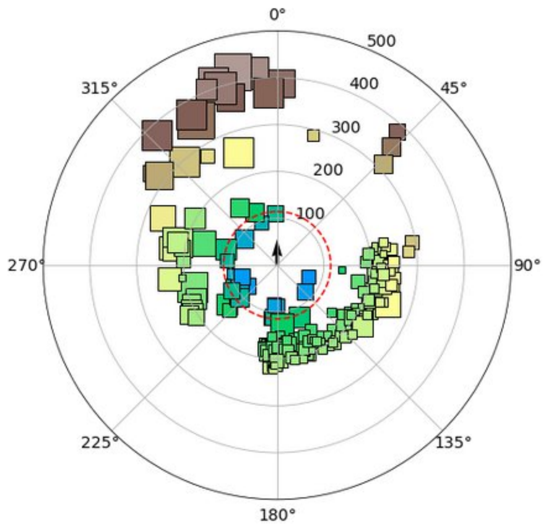
Copernicus In Situ coverage

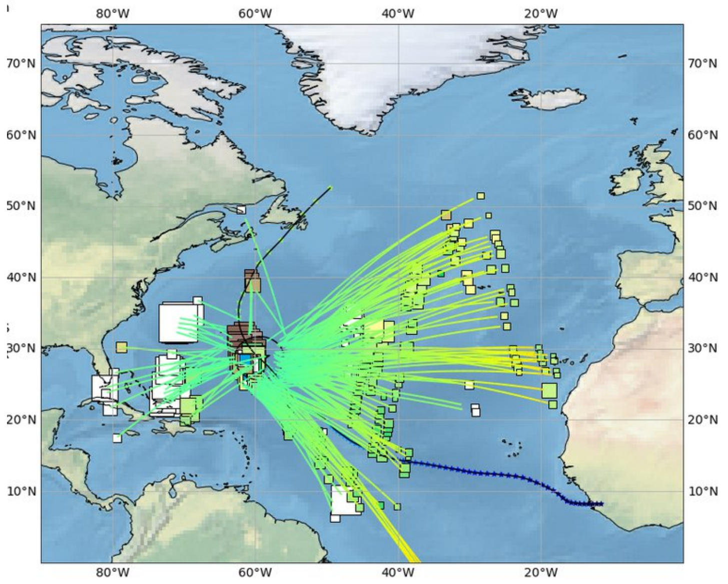
Results from TC waves product

- Impact of post processing
- Effect of SWIM beam incidence
- Data complementarity
- Extended fetch effect

Impact of post processing

Without post processing on September 8th, at 9 PM





Impact of post processing

Post processing consists in keeping only wave partitions that :

– **<u>were observed outside 34 kts wind radius of TC</u>**

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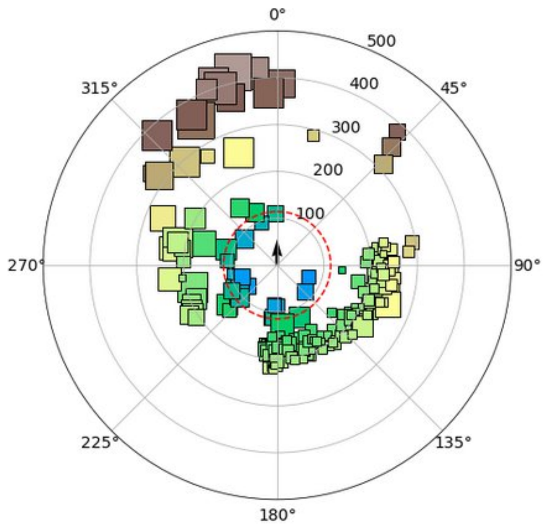

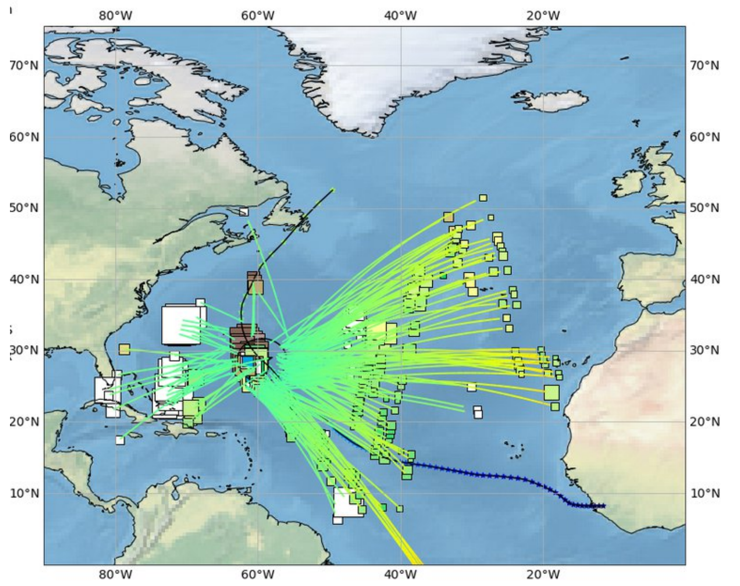

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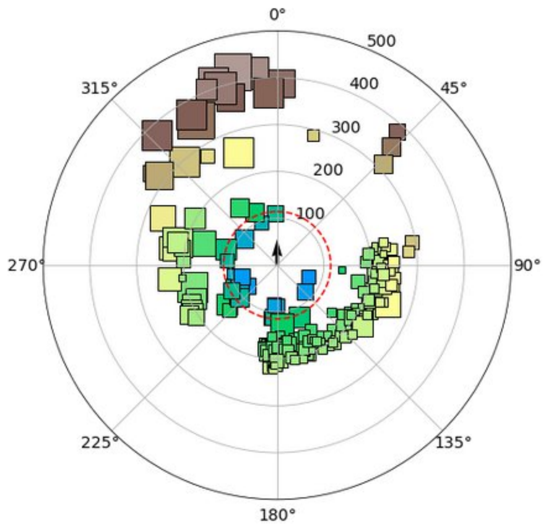

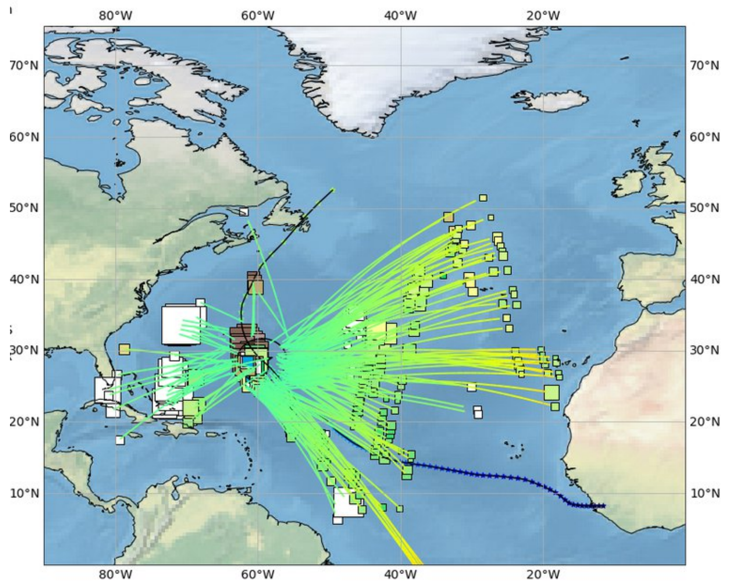

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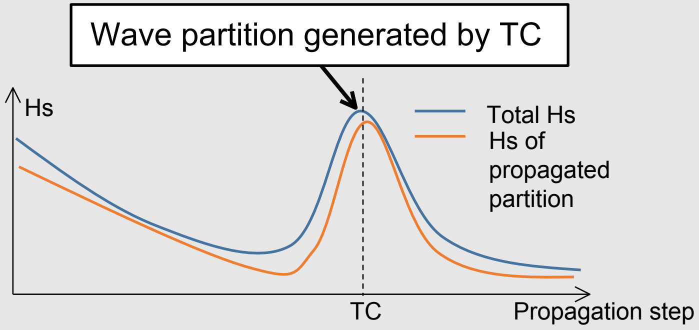
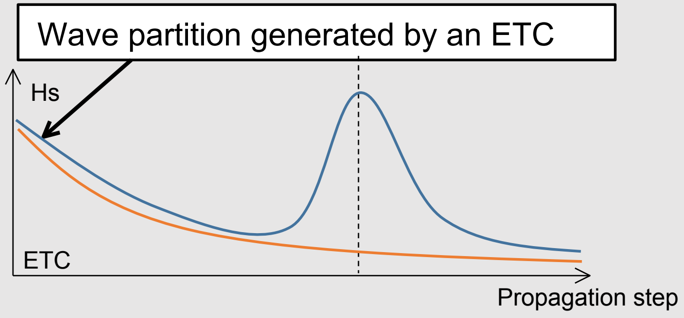
Compare hs of the corresponding partition into WW3 hindcast with total WW3 hindcast hs





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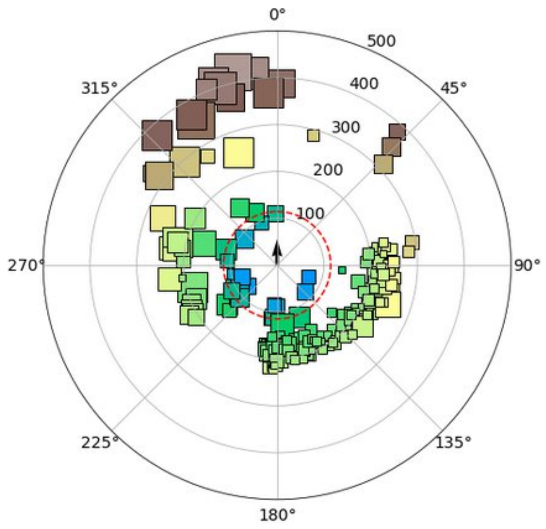

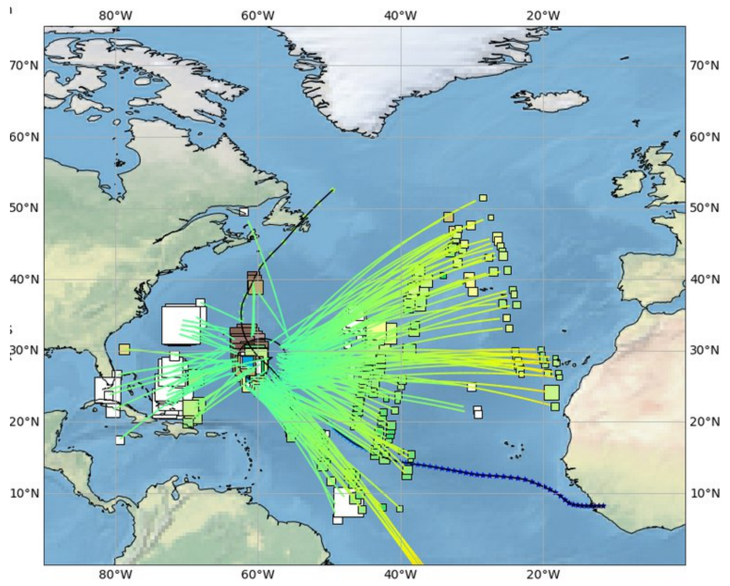

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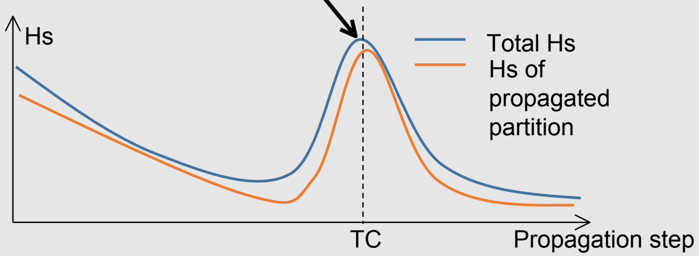
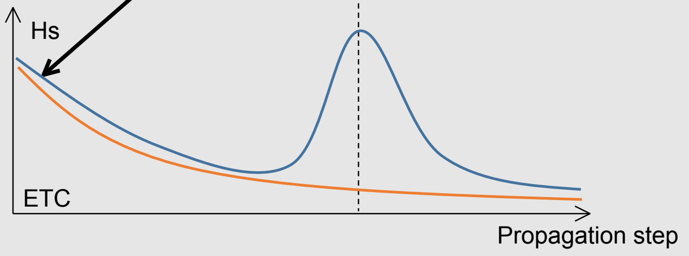
Wave partition generated by TC



Wave partition generated by an ETC



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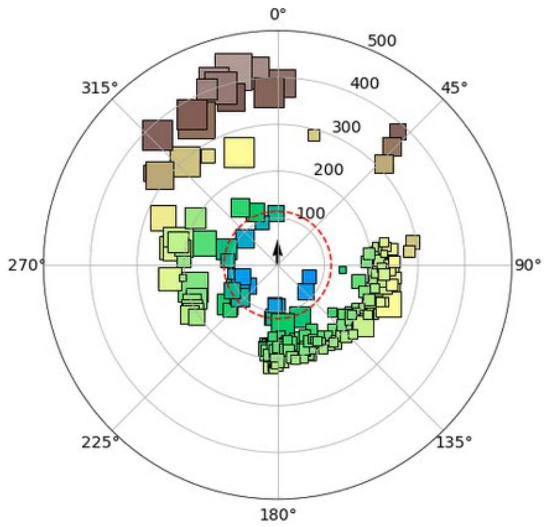
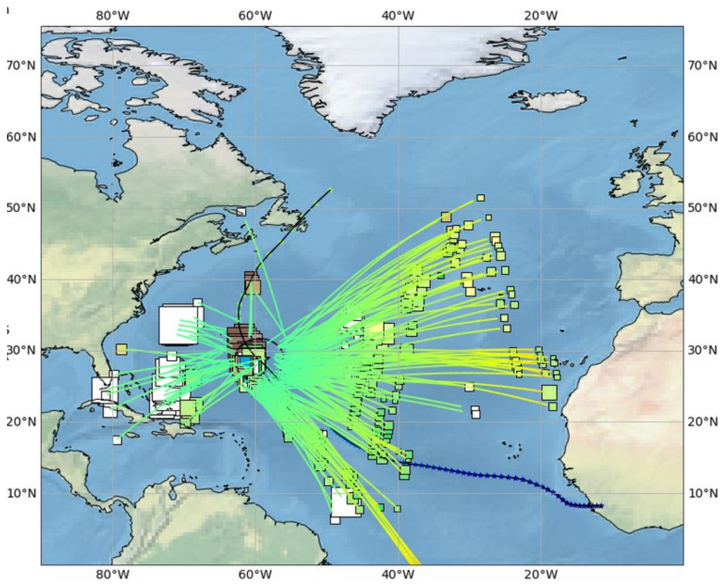
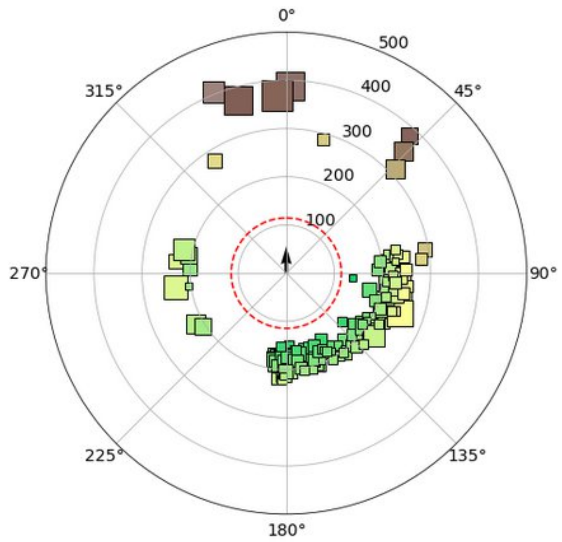
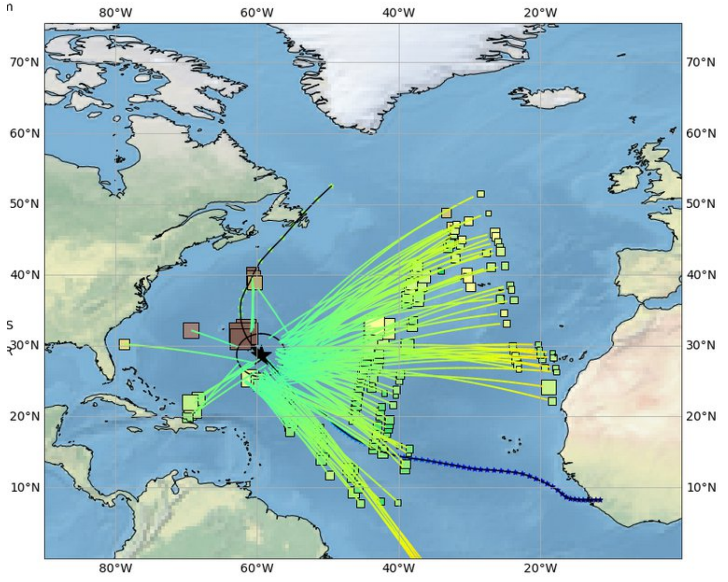




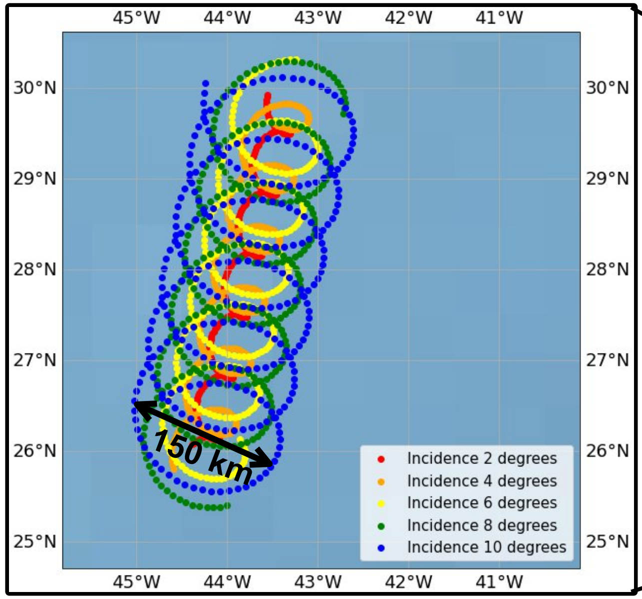
With post processing: The wave rose is more regular, noisy partitions, ETC induced partitions are filtered out.

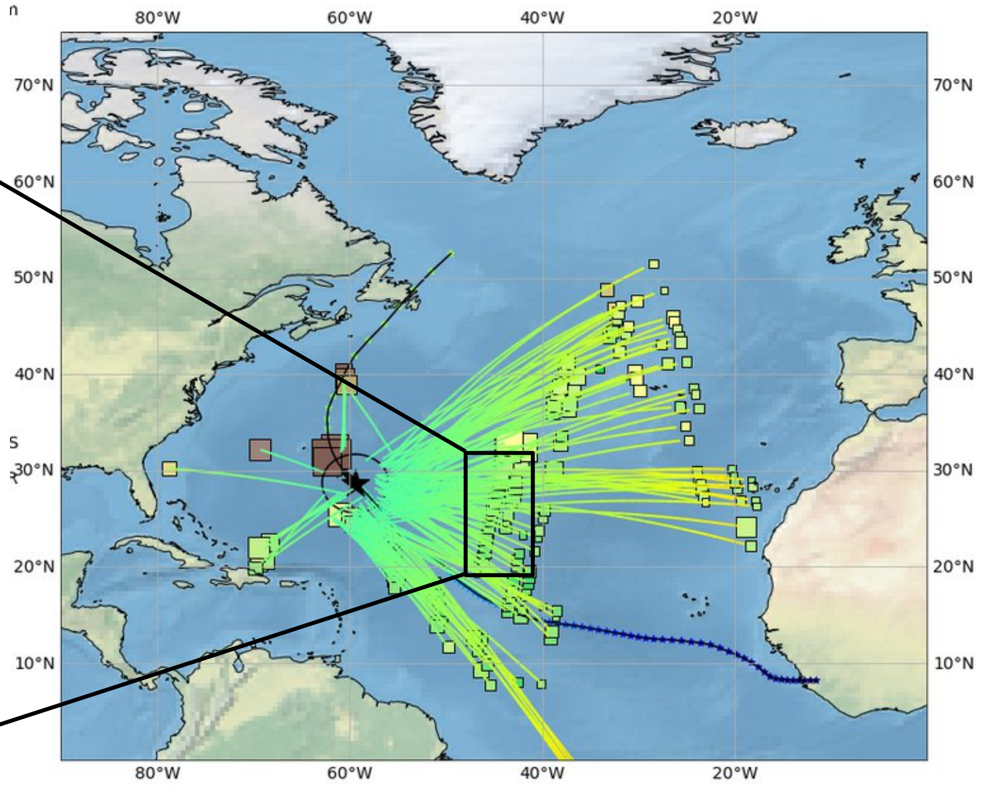




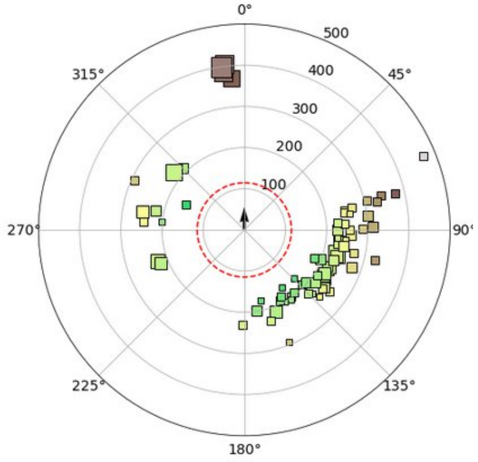
Effect of incidence angle (CFOSAT)

Far from the generation area, beam incidence does not seem to have an important effect on the wave rose.

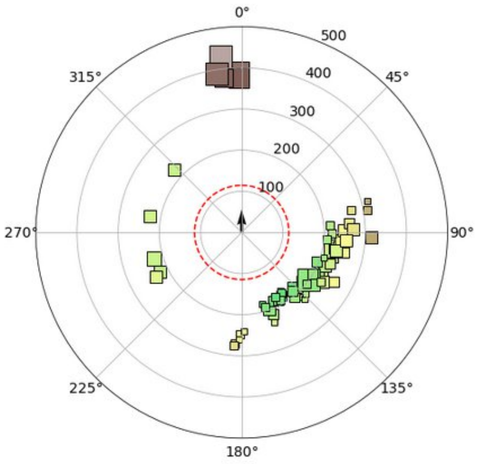




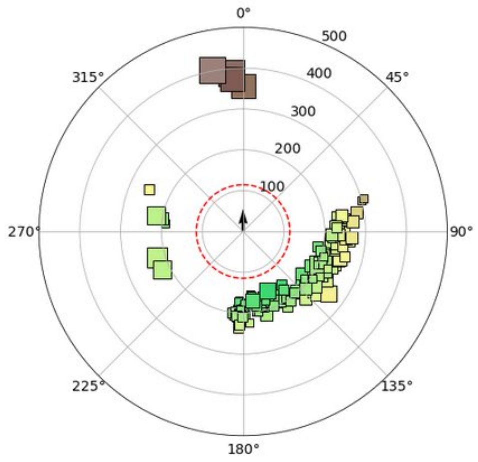
Beam 2°



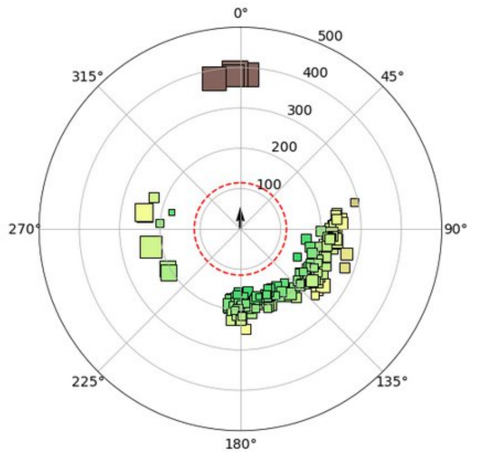
Beam 4°



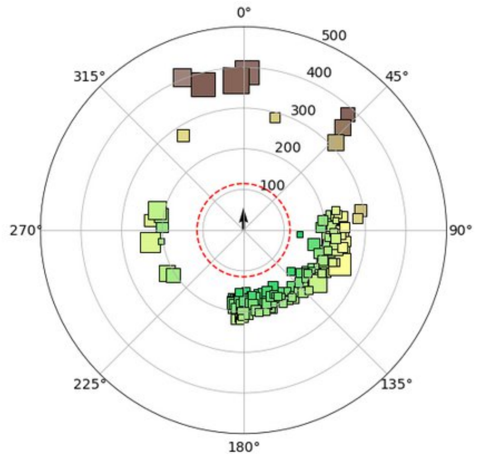
Beam 6°



Beam 8°



Beam 10°



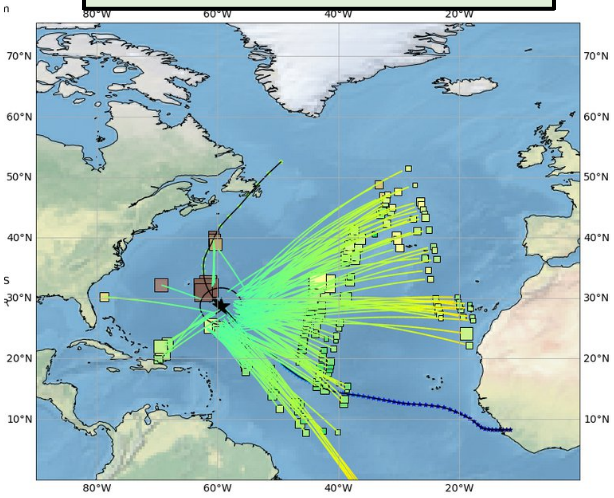
September 8th, at 9 PM

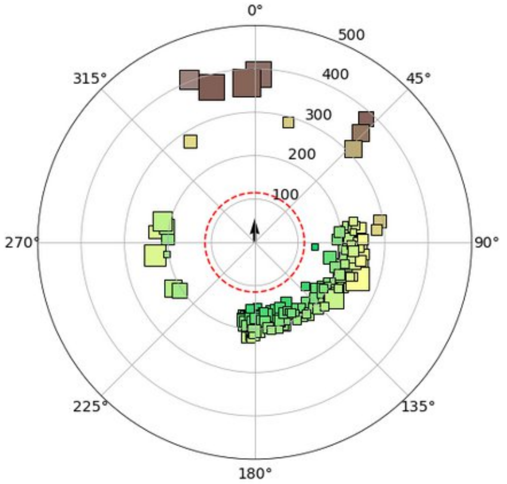
Data complementarity

Example for TC Larry, on September 8th, at 9 PM

Wave roses obtained for 4 different data sources

CFOSAT SWIM L2S, 10 ° Beam incidence





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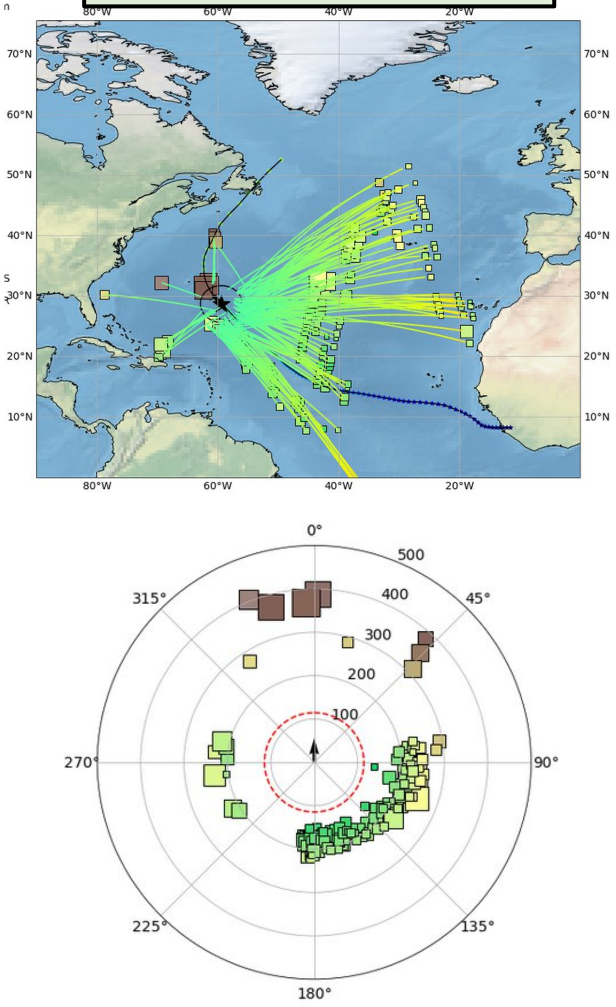
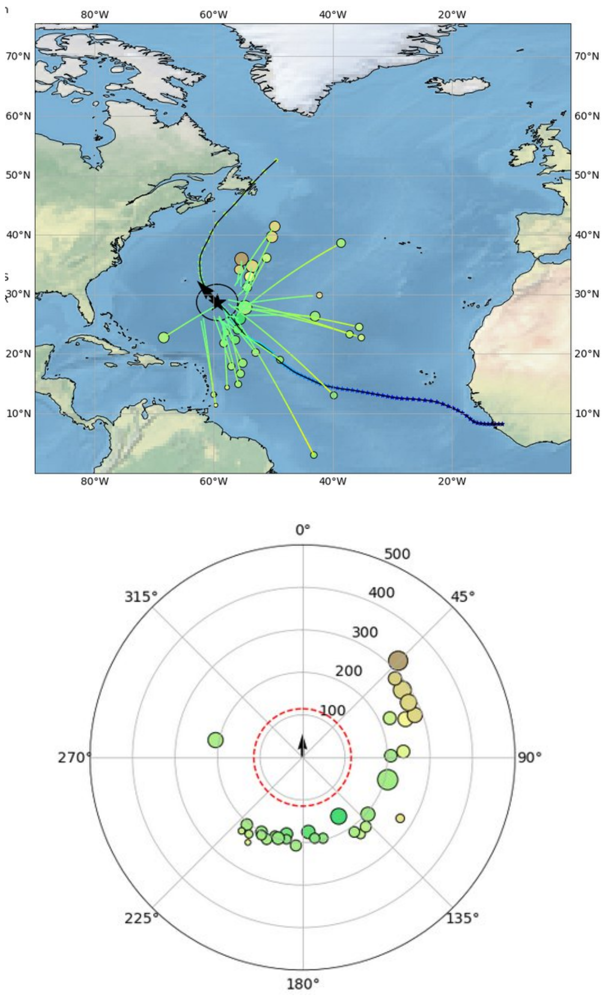


SENTINEL-1 WV OSW L2



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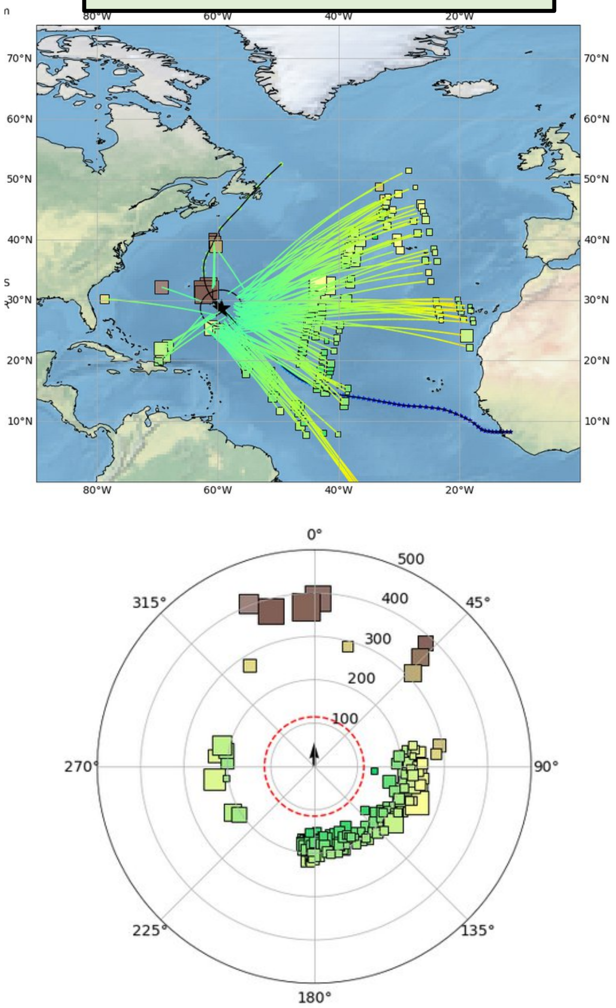

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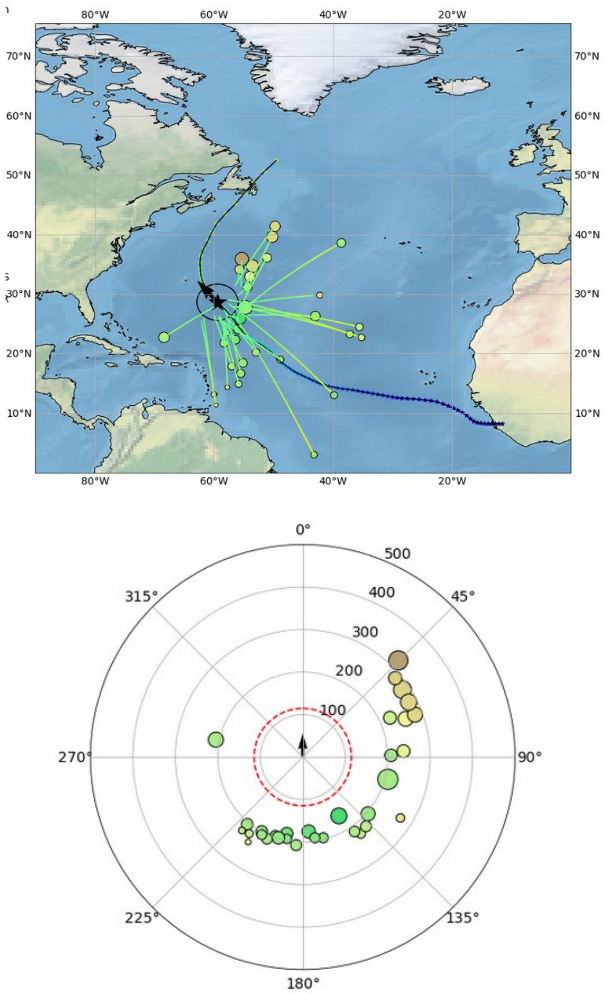
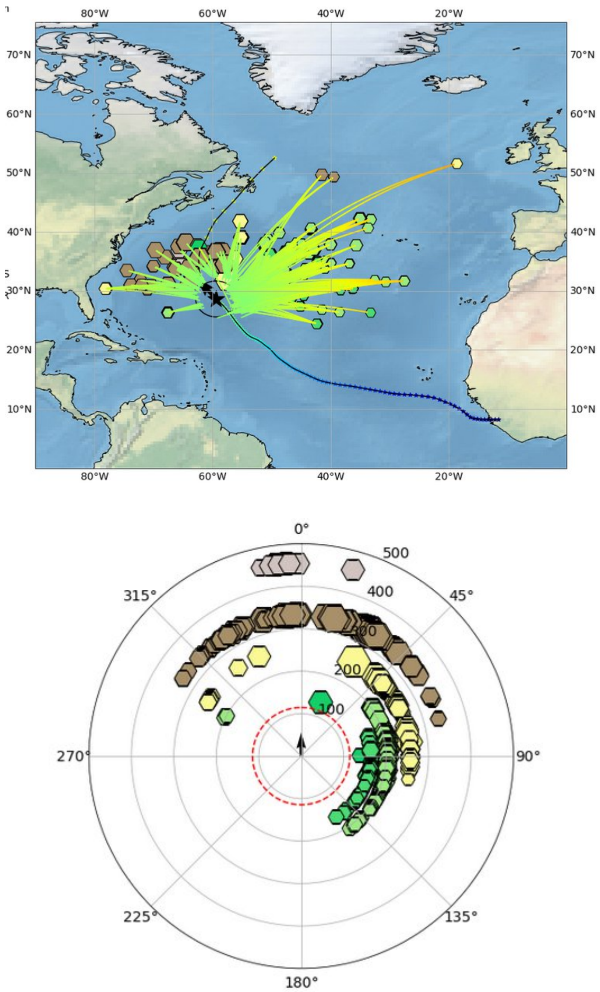


SPOTTER

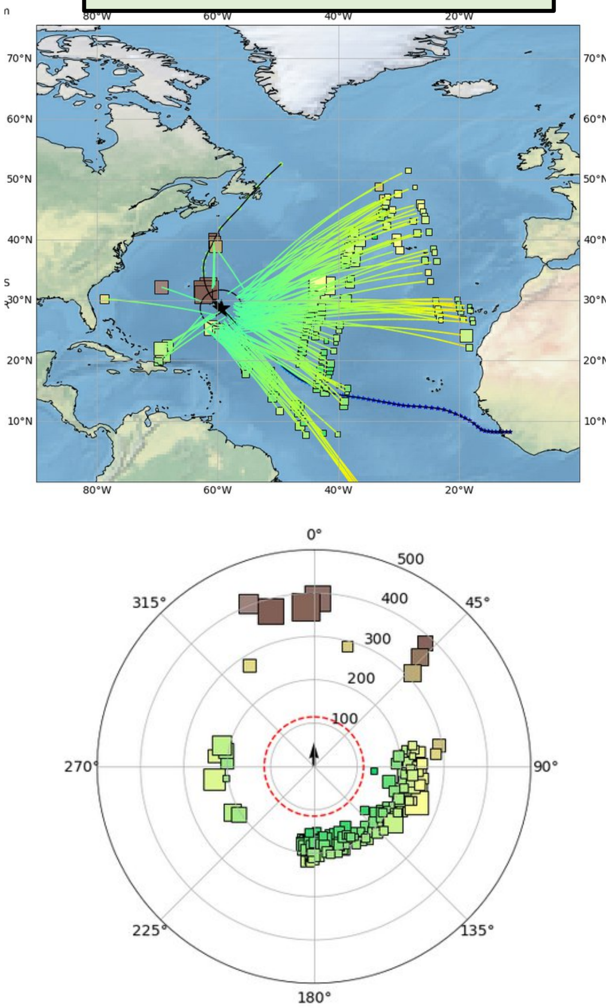


Data complementarity

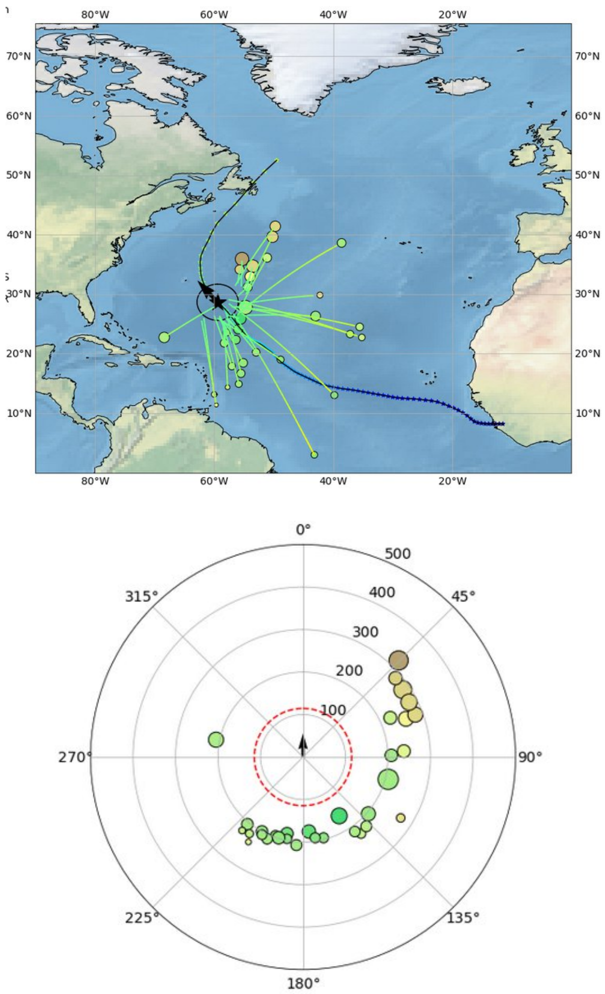
Example for TC Larry, on September 8th, at 9 PM

Wave roses obtained for 4 different data sources

CFOSAT SWIM L2S, 10 ° Beam incidence



SENTINEL-1 WV OSW L2



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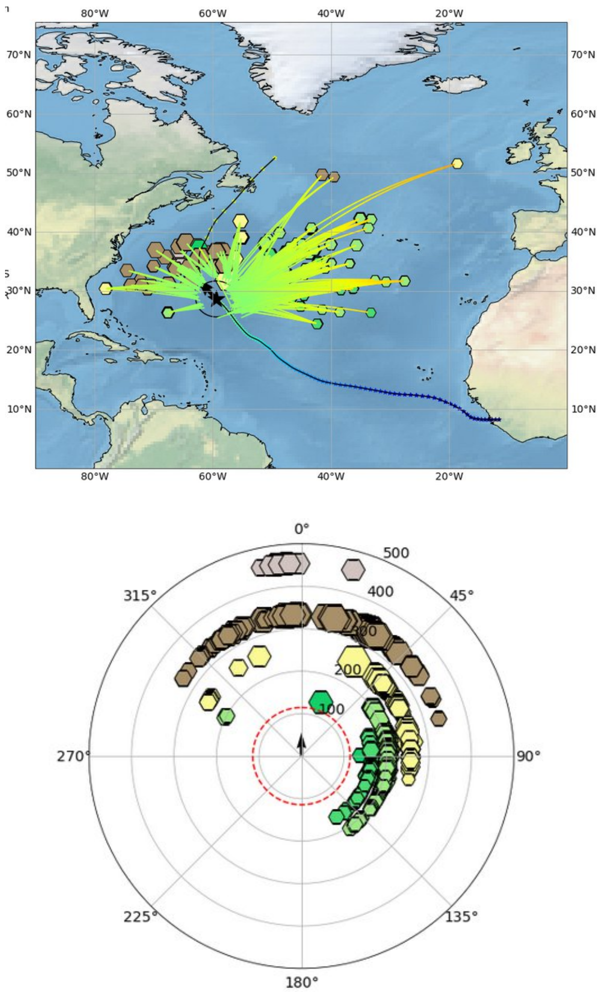
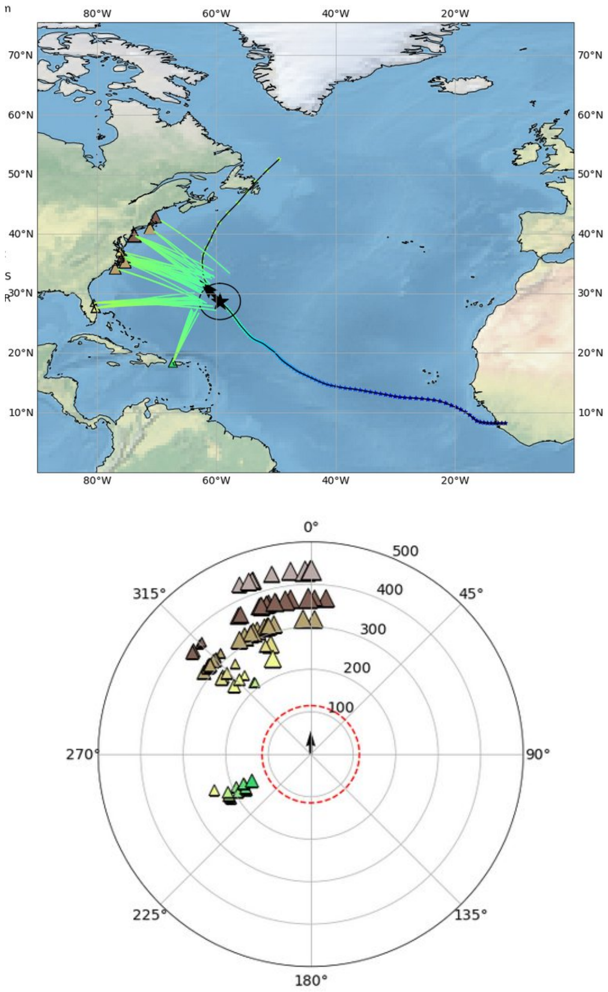
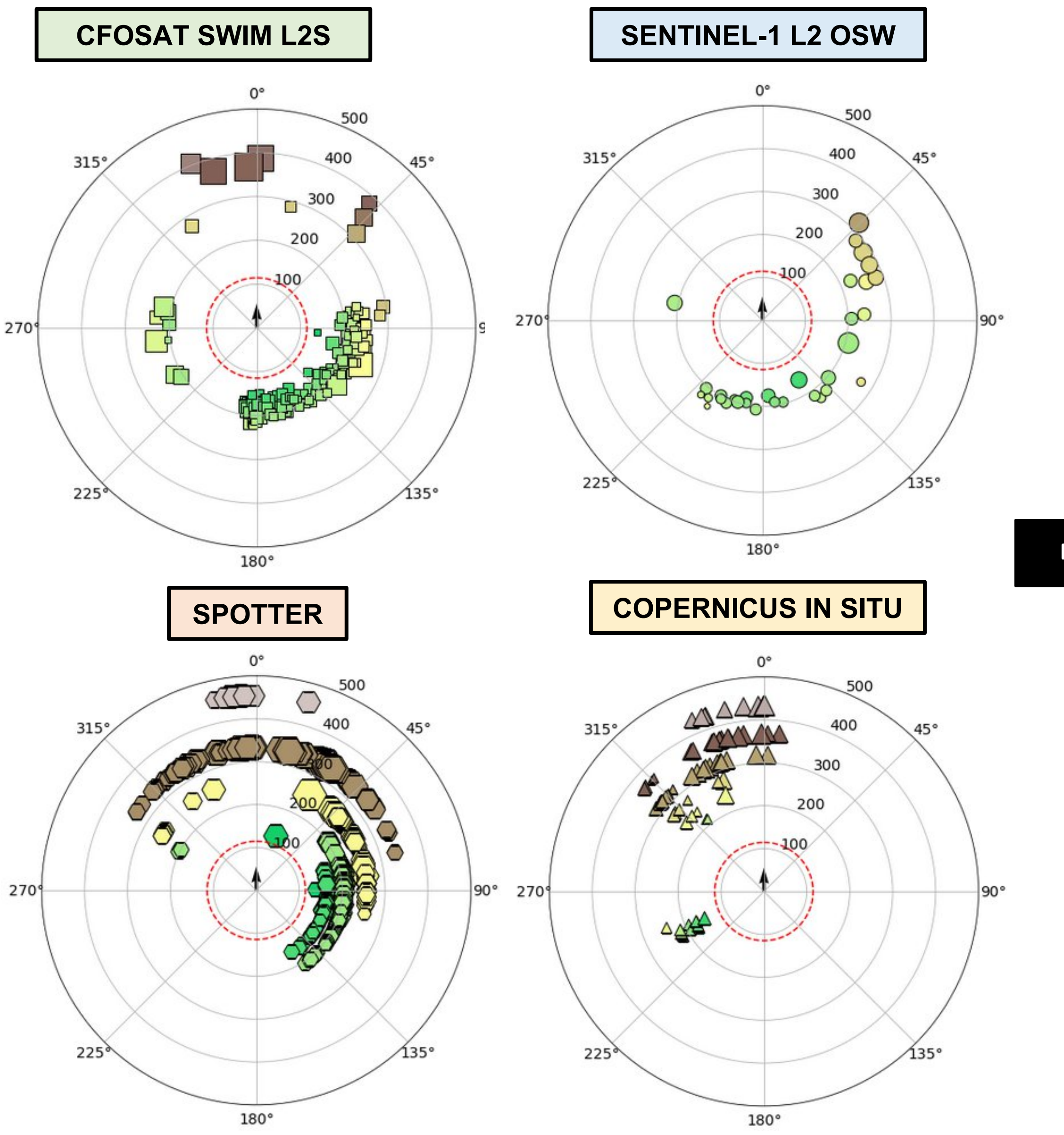


COPERNICUS IN SITU

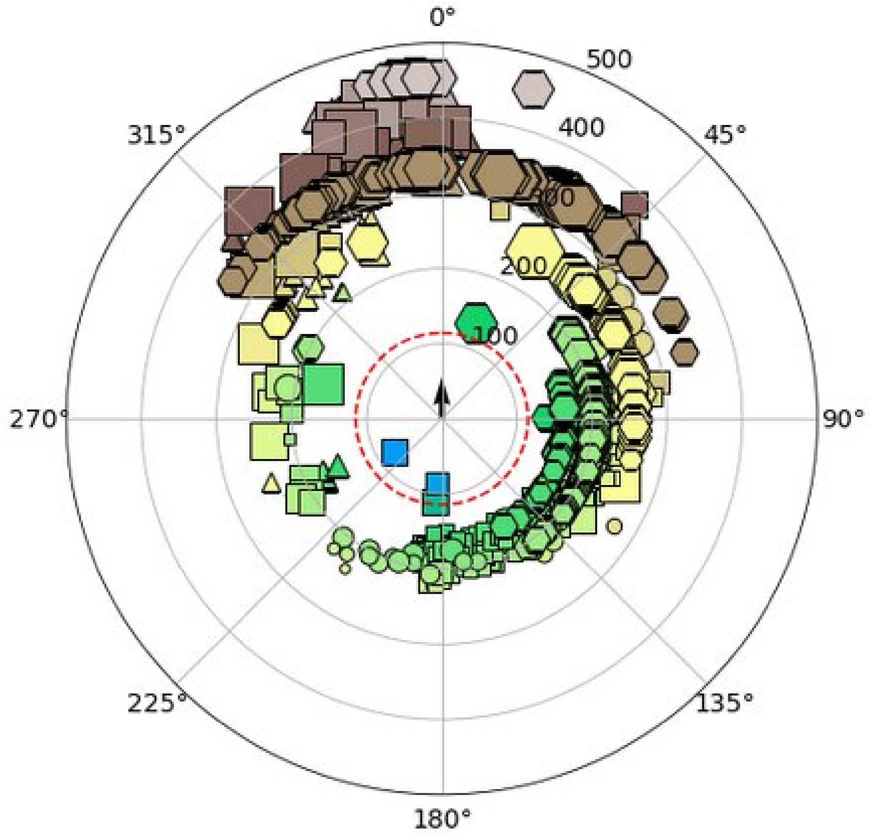


Wave roses by sensor



Full wave rose with the 4 data sources

The use of several data sources provides a better directional coverage of the wave rose

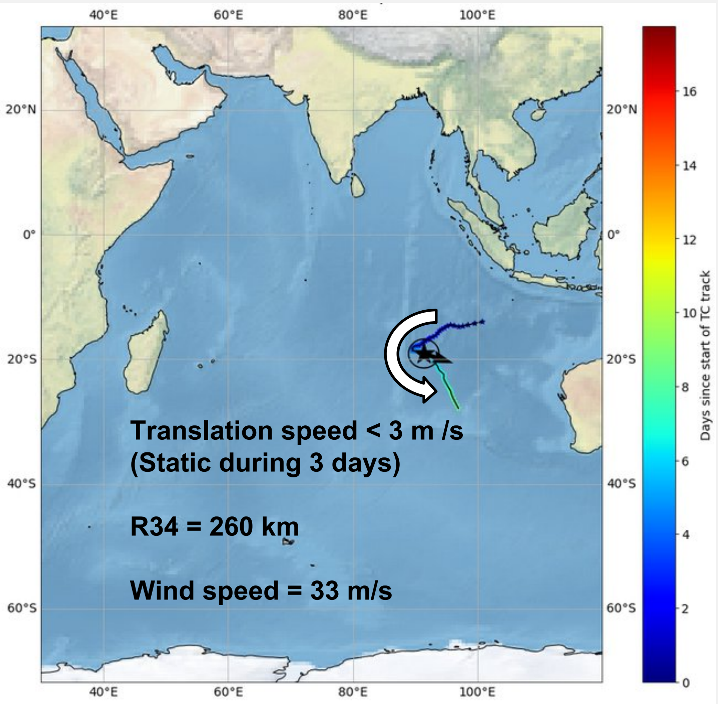


TC Larry, 2021, on September 8th, at 9 PM

Extended fetch effect

STATIONNARY

For a stationnary cyclone, same fetch on the right side than on the left side.



TC Marian 2021, on March 3rd, at 6 AM

Extended fetch effect

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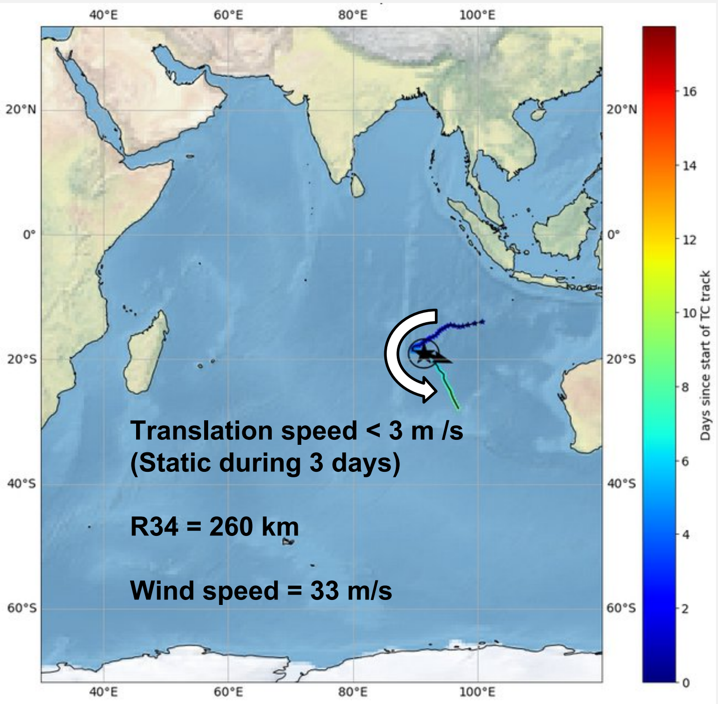

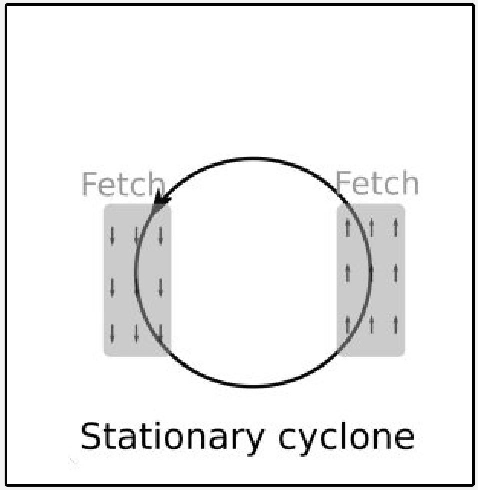

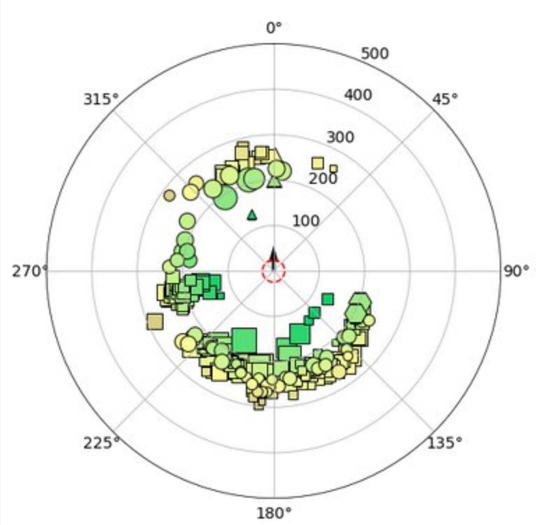

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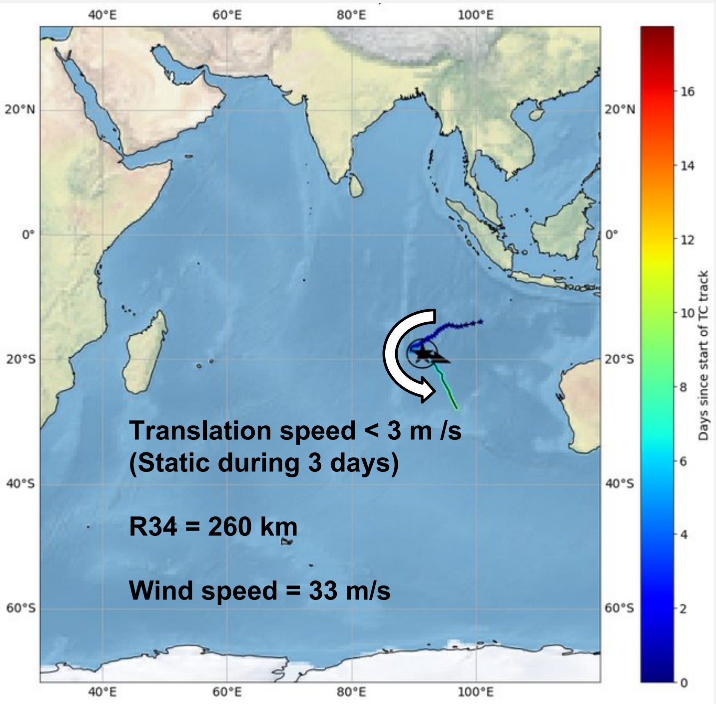
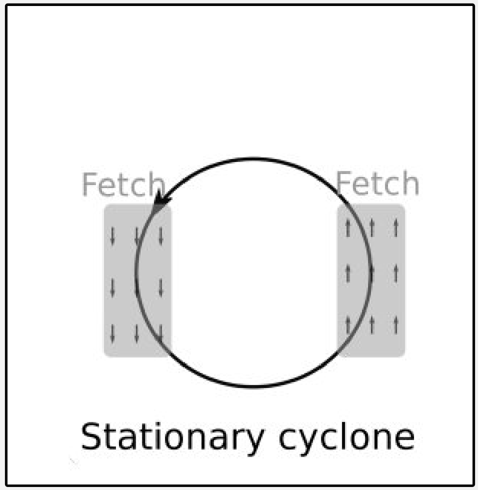
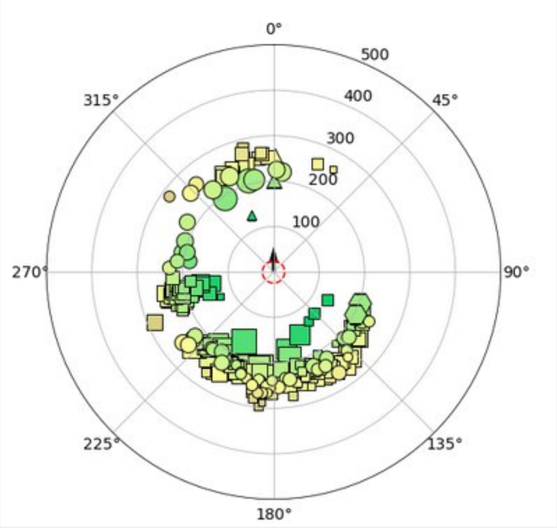


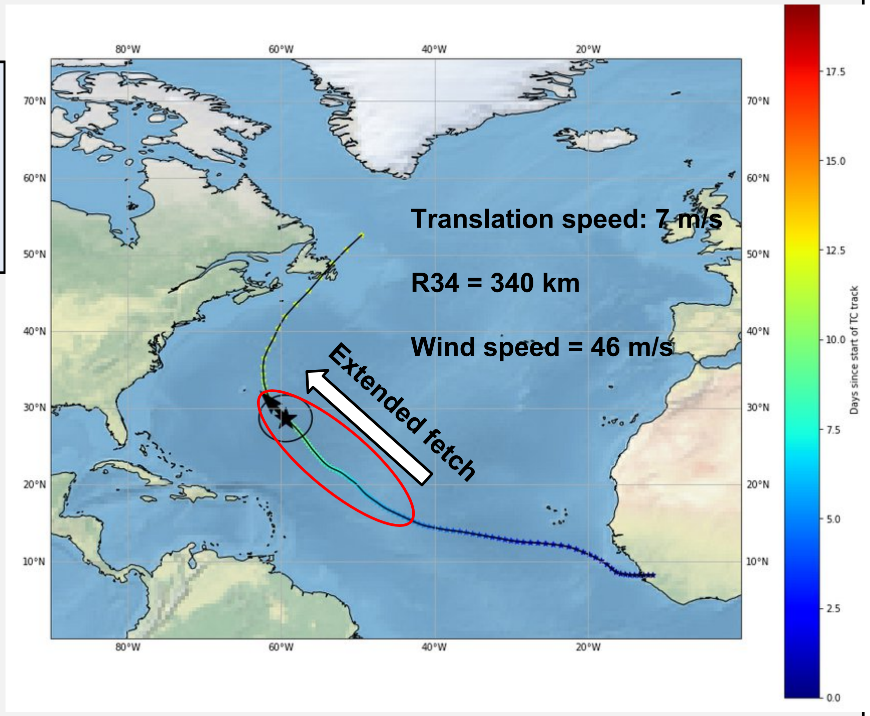




TC Marian 2021, on March 3rd, at 6 AM

TRANSLATING

For a translating cyclone, waves generated on the right side propagate in the same direction than the cyclone.



TC Larry, 2021, on September 8th, at 9 PM

Extended fetch effect

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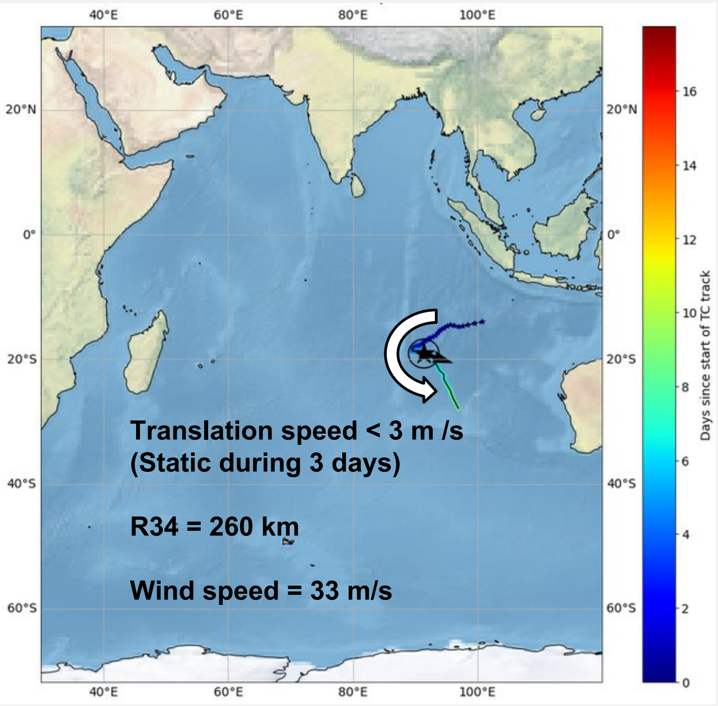
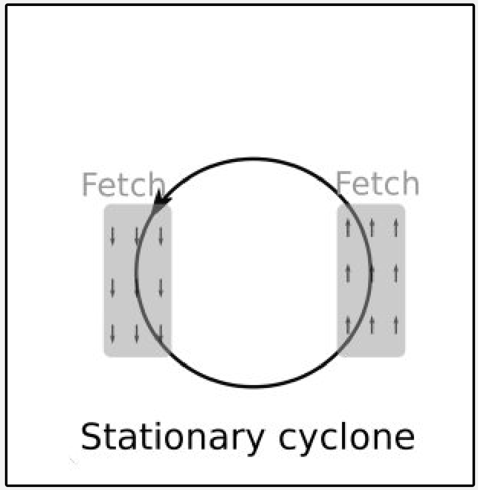
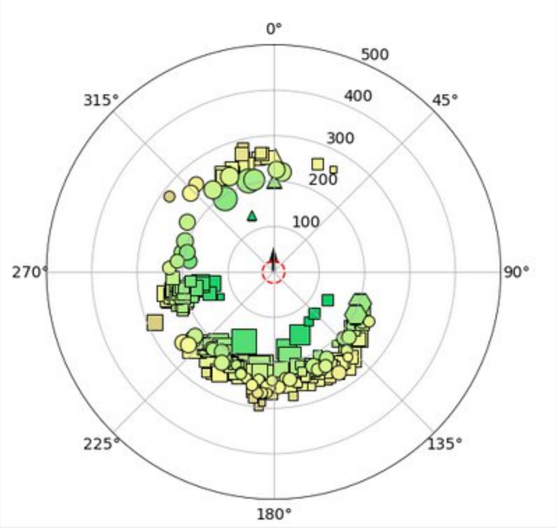






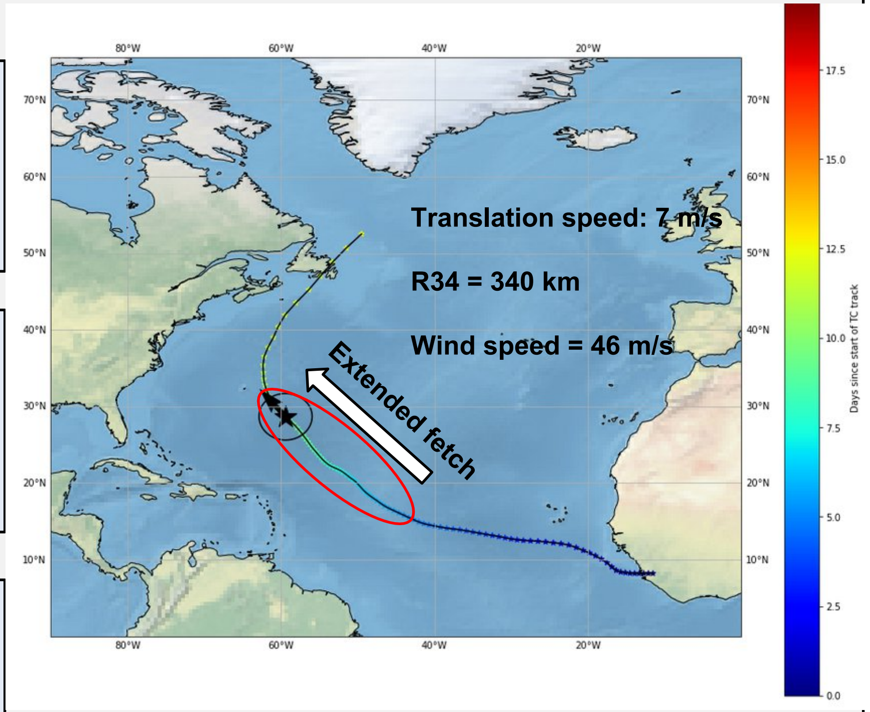
TC Marian 2021, on March 3rd, at 6 AM

TRANSLATING

For a translating cyclone, waves generated on the right side propagate in the same direction than the cyclone.

Waves propagating in the direction of the cyclone **stay under wind influence during a longer time** than waves generated on the left side.

Longer wavelengths are expected for waves propagating in the TC translation direction than for those propagating in the opposite direction.



TC Larry, 2021, on September 8th, at 9 PM

Extended fetch effect

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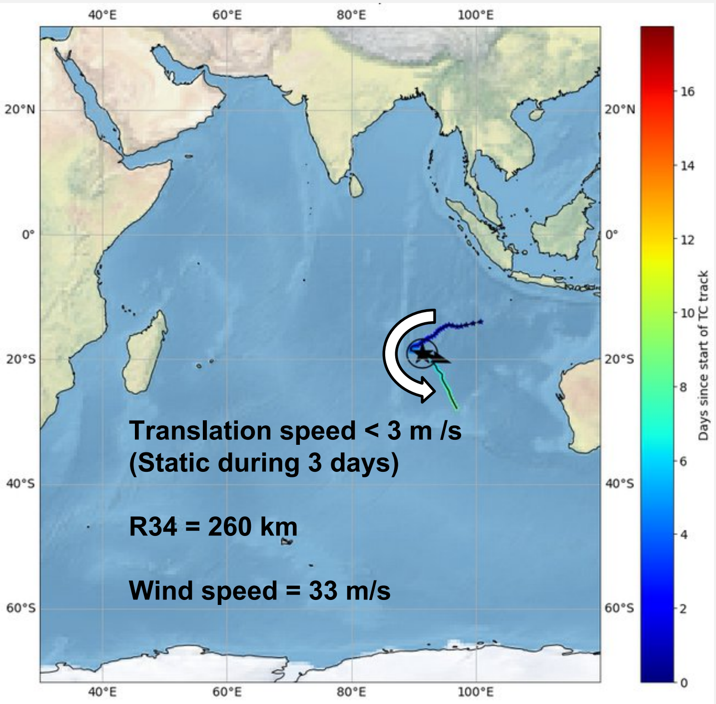

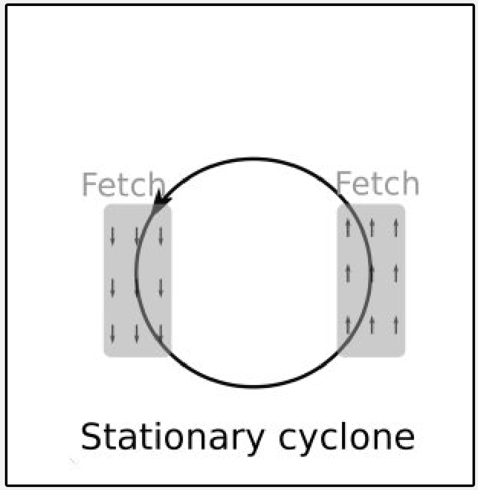

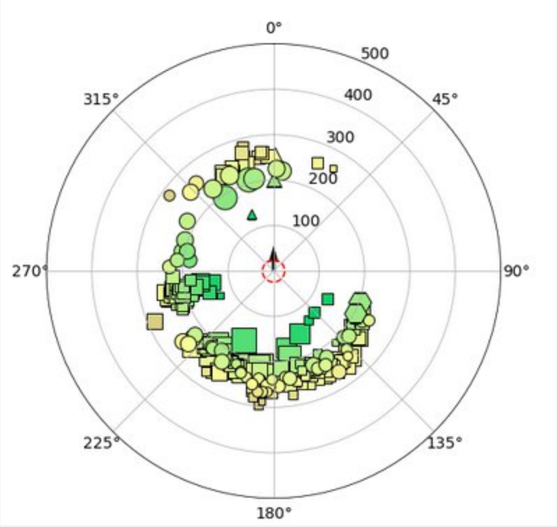

TC Marian 2021, on March 3rd, at 6 AM

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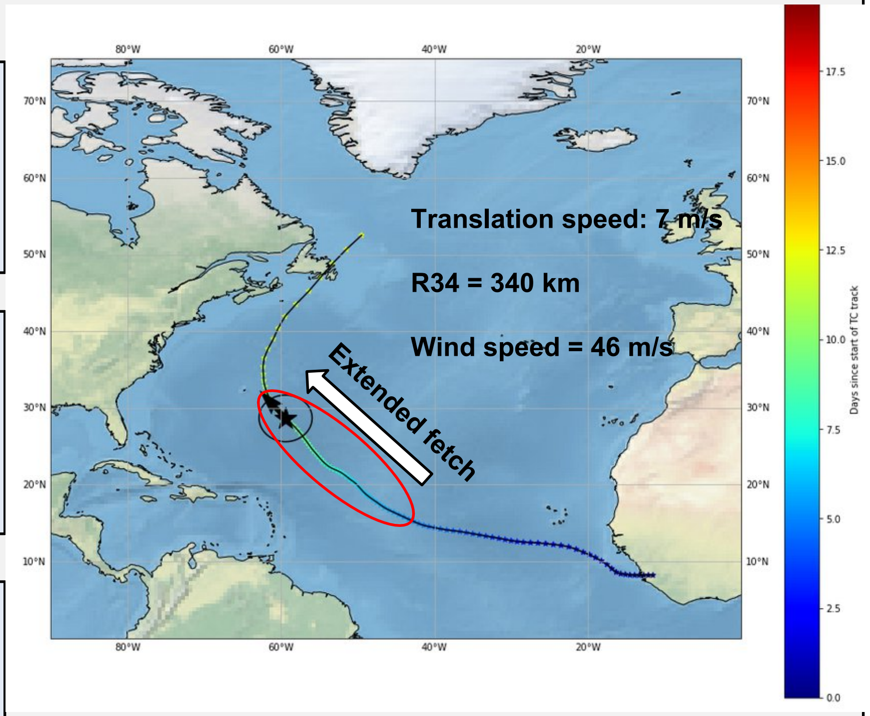
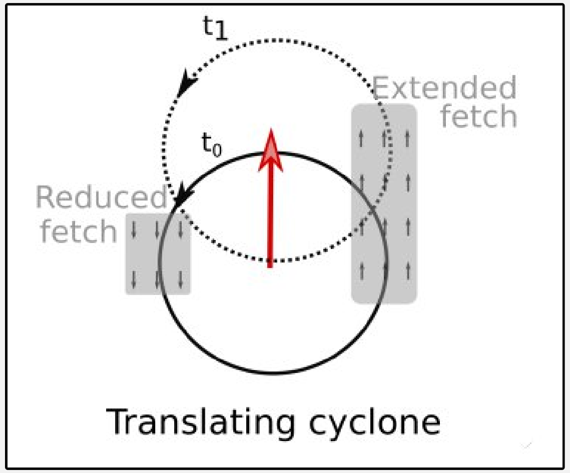
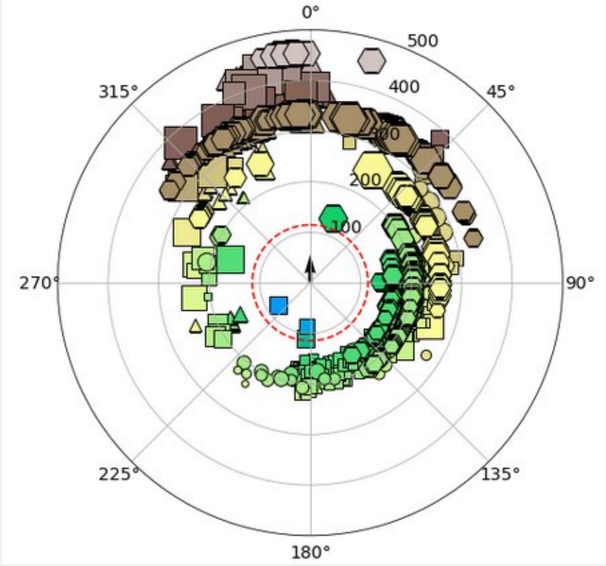






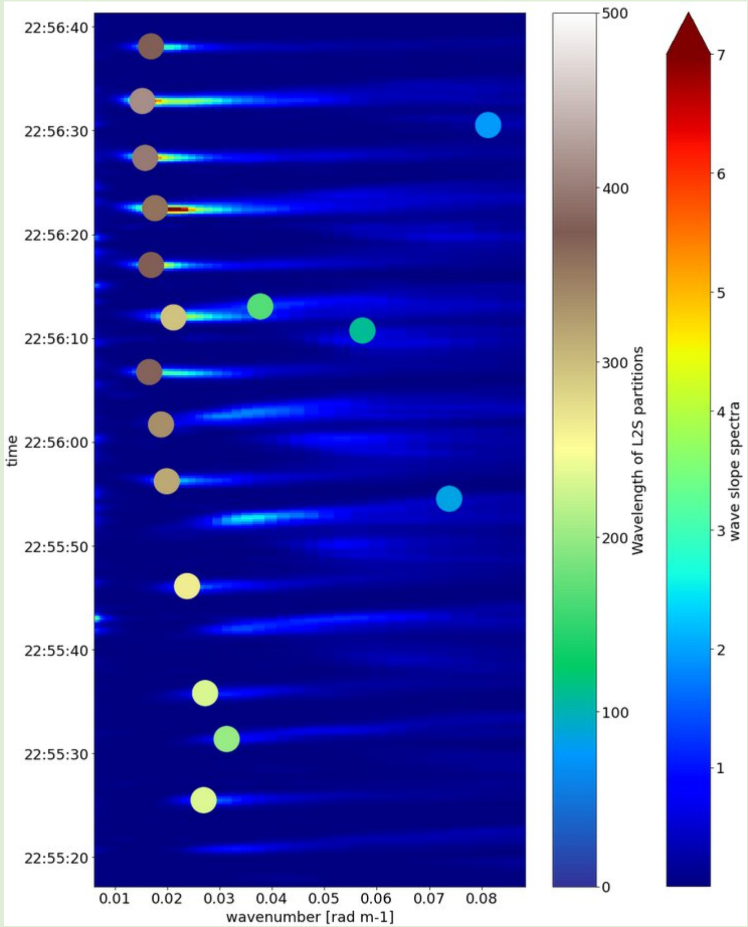
TC Larry, 2021, on September 8th, at 9 PM

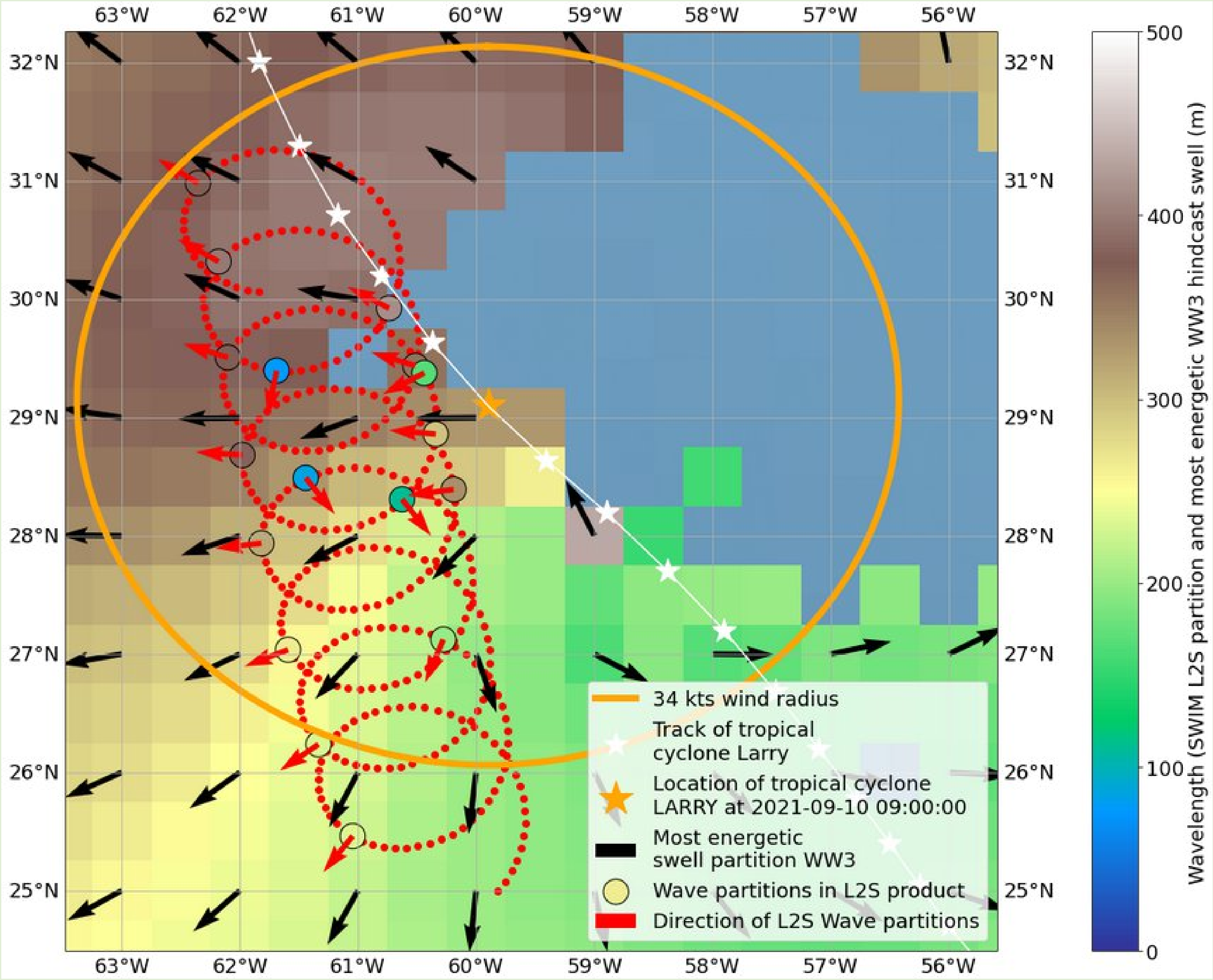
Analysis of a CFOSAT pass inside Larry

L2S product inside tropical cyclone Larry

Example for an beam incidence of **10 degrees on 2021-09-08 , near TC LARRY**

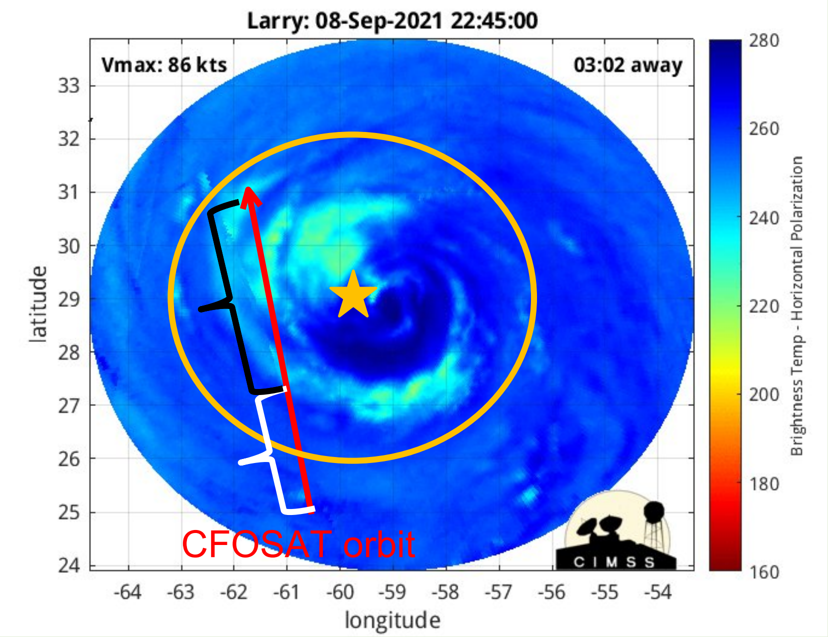
Variability along a single cycloid, or **along different cycloids** due to strong wavelength gradients

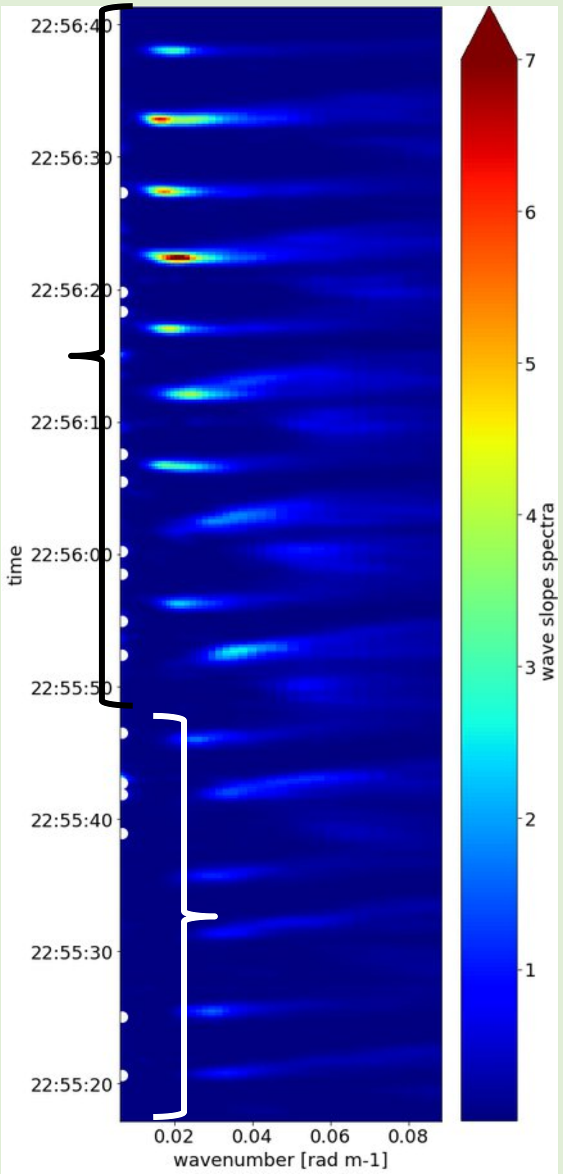




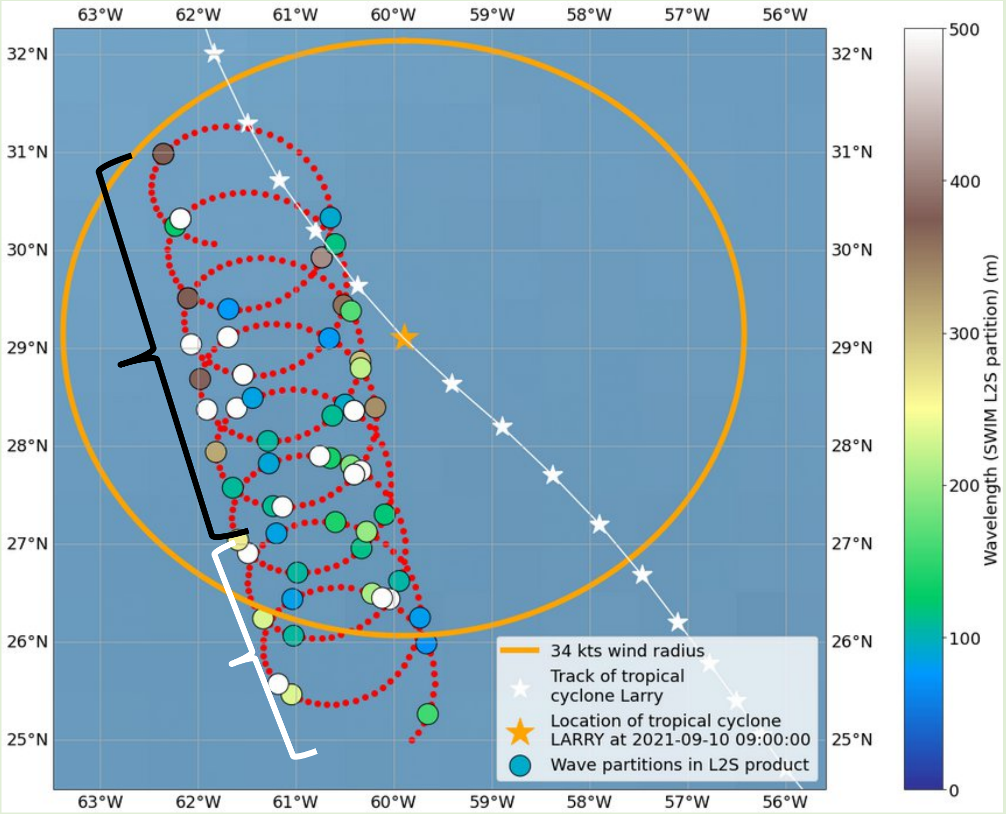
L2S product inside tropical cyclone Larry

Rain impact: use of the MIMIC product





Wave partitions from L2S product, white points are noise



Rain impact on the frequency of noisy partitions is difficult to state

In this example, it is possible to acquire wave systems inside TC in rainy areas.

Conclusions

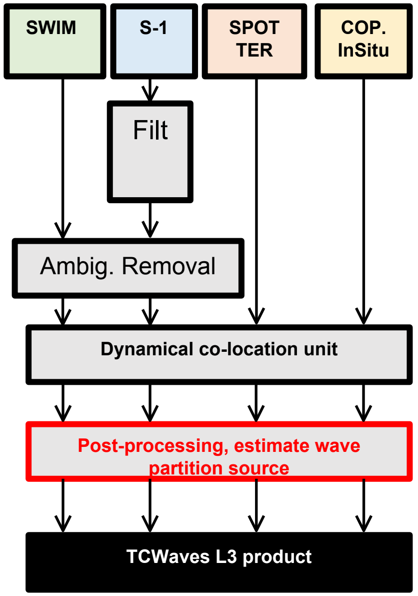
- **Ouside tropical cyclones**, the TC waves product from 4 different wave data sources can provide a representation of the tropical cyclone induced wave field, and bring to light physical processes such as extended fetch effect

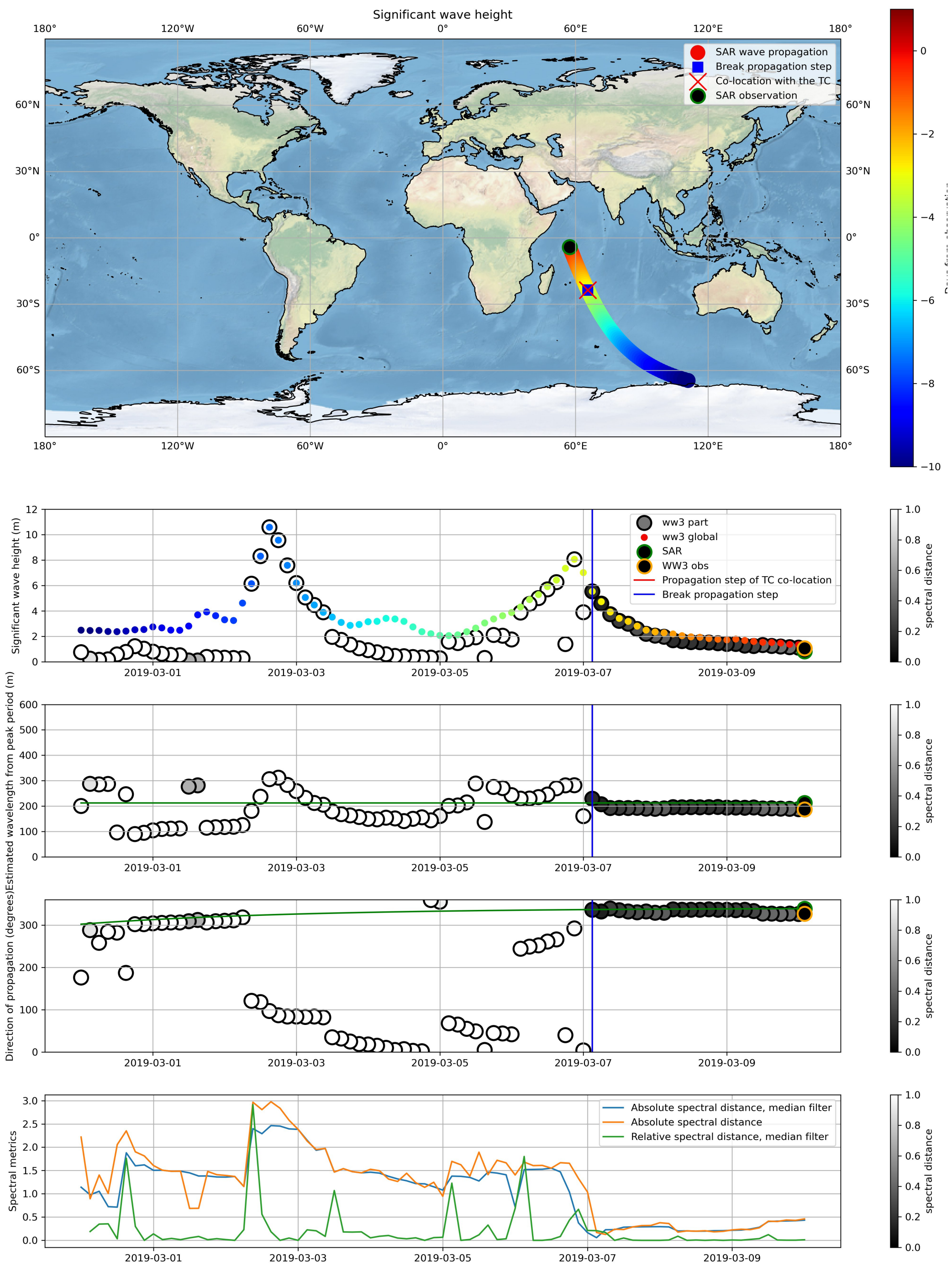
- **Inside tropical cyclones**, the use of different beam incidences would allow to describe the strong wavelength and direction gradients

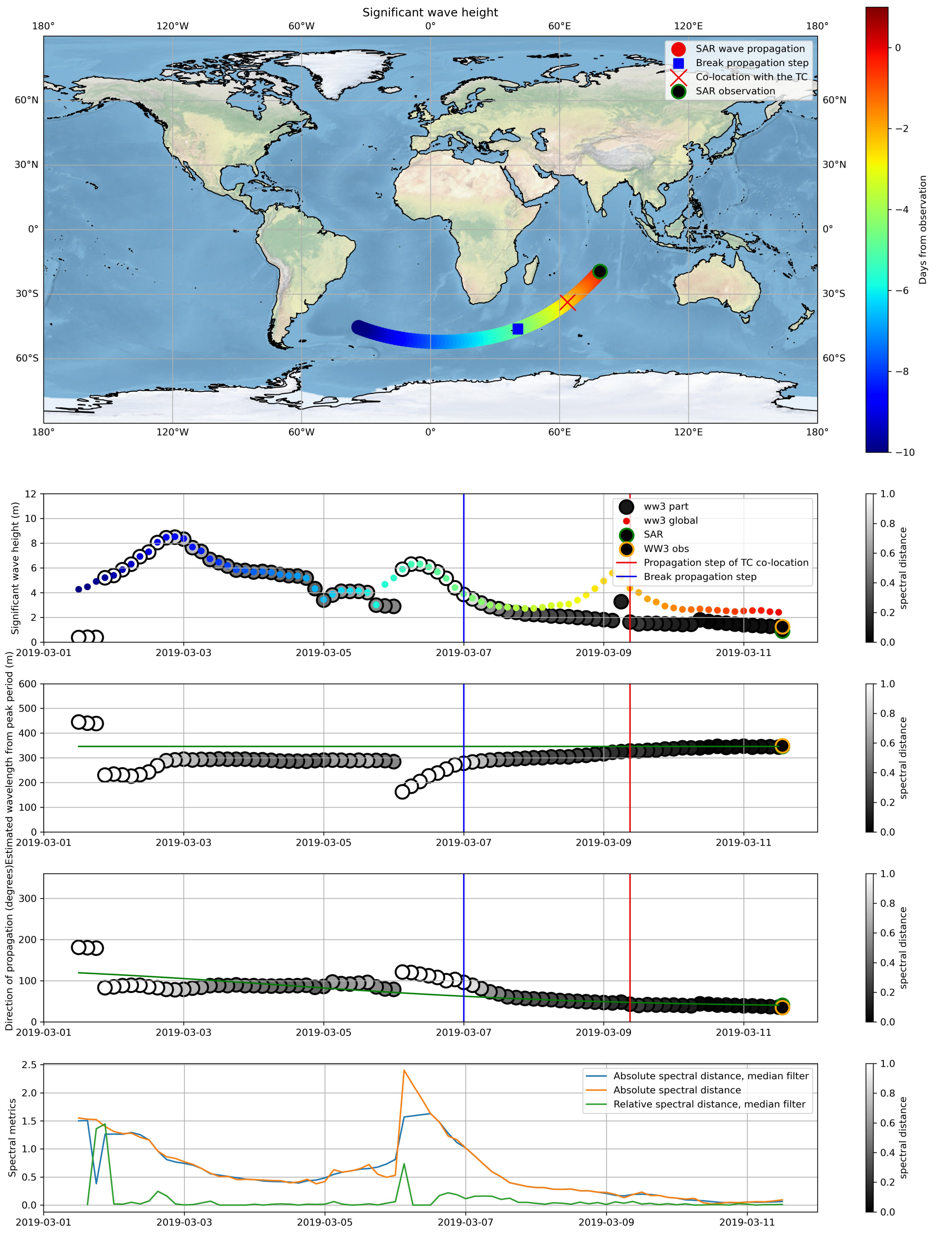
- **Next steps of analysis :**
  - Compare the TC Waves roses to those generated thanks to a 2D parametric model (Kudryavtsev et al. 2021).
  - Perform statistics on a large amount of tropical cyclones to check the influence of tropical cyclones characteristics on the generated waves (maximum wind speed, translation speed, maximum wind radius...)

Backup slides

Post Processing unit



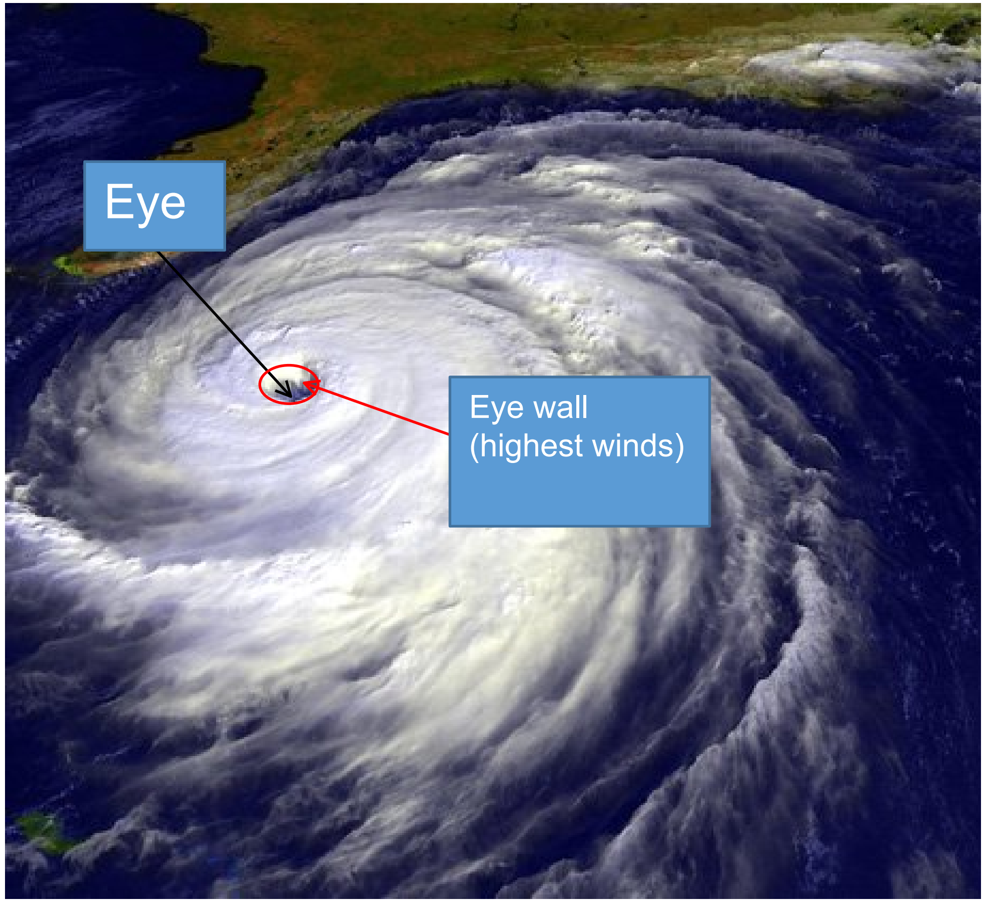




Context

IPCC AR6 report, summary for policymakers :

" The proportion of intense tropical cyclones (categories 4-5) and peak wind speeds of the most intense tropical cyclones are projected to increase at the global scale with increasing global warming (high confidence). "



Potential applications

- Waves forecasting
- Protection of coastal areas
- Offshore wind turbines

Objectives :

- **Characterize tropical cyclone induced wave field** thanks to satellite observations and in situ data, qualify and quantify the **contribution of CFOSAT** to the product
- Compare the results with those obtained thanks to a **parametric model** (Kudryavstev, 2021) to validate it
- **Perform statistics** on a large amount of tropical cyclones