Observing the Mediterranean sea surface during storms with Copernicus High Resolution satellites

Alexis Mouche (Ifremer), Romain Husson (CLS), Frédéric Nouguier (Ifremer), Nicolas Rascle (Ifremer), Aurélien Colin (CELAD), Quentin Febvre (Ifremer), Bertrand Chapron (Ifremer), Arthur Avenas (ESA), Lisa Maillard (Ifremer)

CYCLOBS

MEDICANES

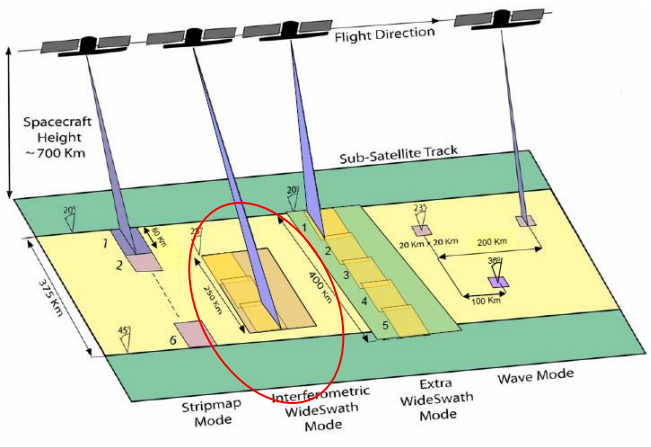
MPC-S1

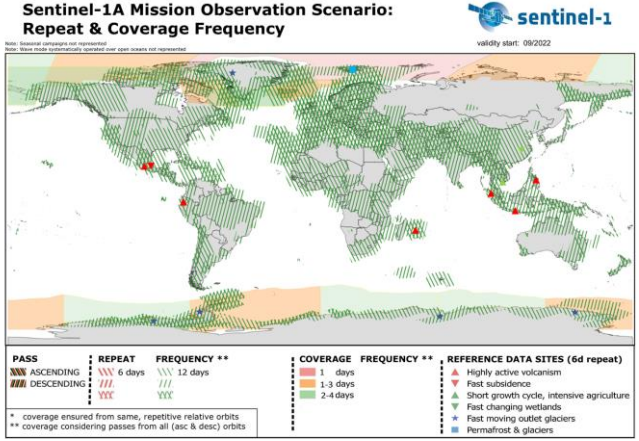
Outlines

- Background and motivations
- Sentinel-1 Rain rate and Ocean surface wind vector
- Sentinel-1 & Sentinel-2 Ocean surface waves

Background and Motivations

European SAR Constellation : Sentinel-1





Constellation of 2 satellites carrying C-Band SAR

- Sentinel-1A 04/2014 - …
- Sentinel-1B 04/2016 - 12/2021
- Sentinel-1C 2024 (TBC)
- Sentinel-1D 2025 (TBC)

Mediterranean Sea is covered with SAR acquisition performed in IW modes. Polarization used is VV+VH. Swath width is 250 km. Resolution is about 5mx20m

Level-2 Copernicus/ESA products only includes Ocean Surface wind vector (1km)

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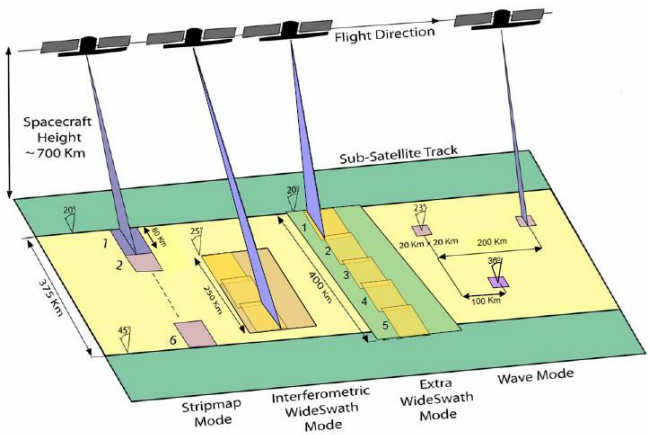

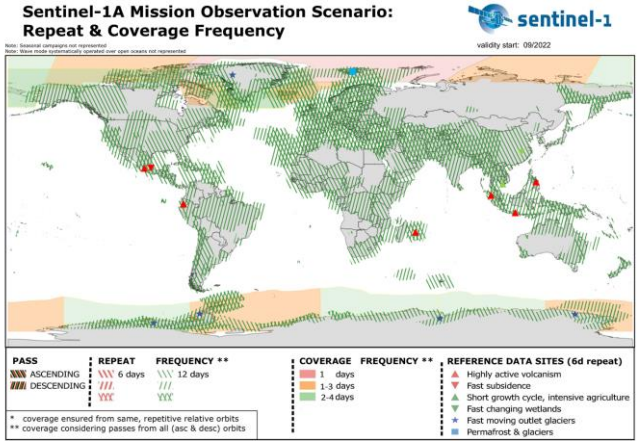

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Principles

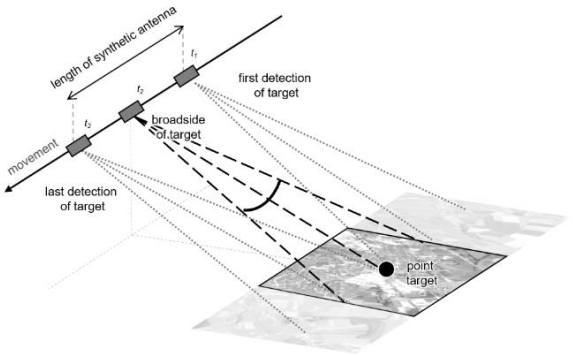


Figure 12: Principle of the synthetic aperture radar (SAR)

As the satellite moves forward, targets are detected multiple times by the radar beam.

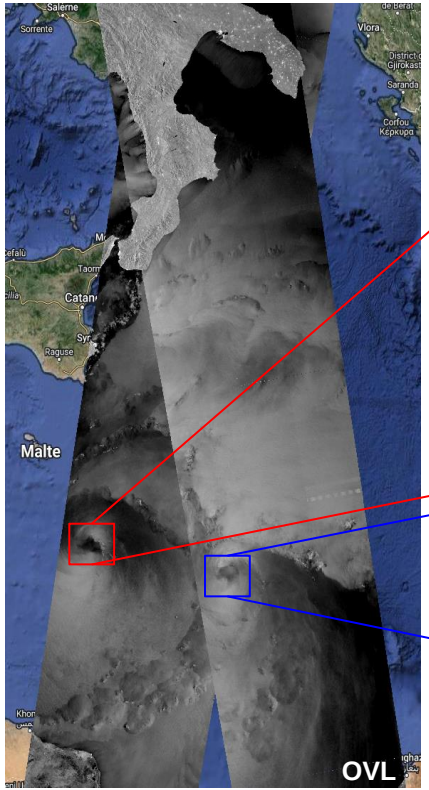
The time available to synthesize the aperture and achieve the high resolution can be split to produce several sub images at a lower resolution and corresponding to different acquisition times (0.1sec) : the looks.

Both high resolution and looks are used to derive geophysical products over Oceans.

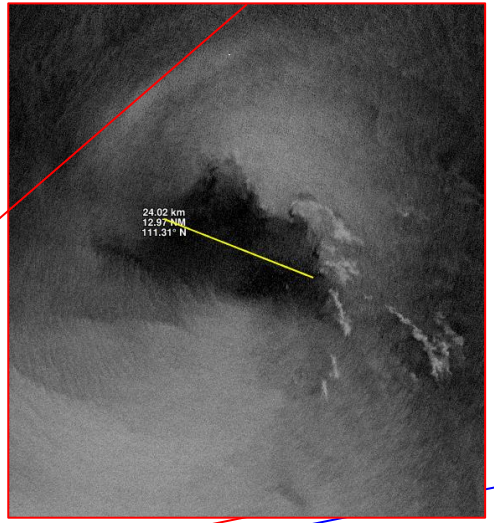
Compared to scatterometers, SAR has one single antenna.

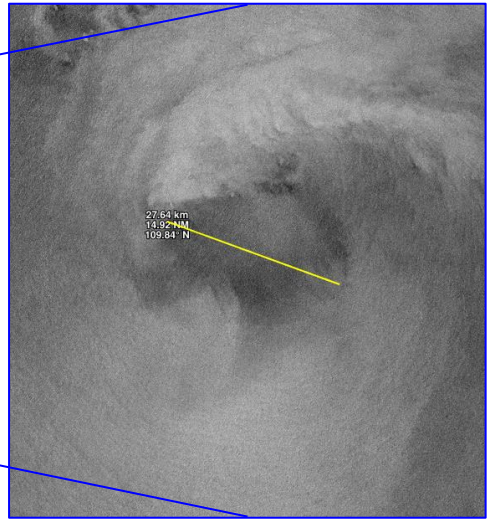
Background and Motivations

Co-existence of signatures at multi-scale and from different phenomena (Sentinel-1)



2021/10/26 morning/afternoon





- Storm eye diameter is about 24-28 km.
  It cannot be resolved by medium resolution observations such as scatterometers.

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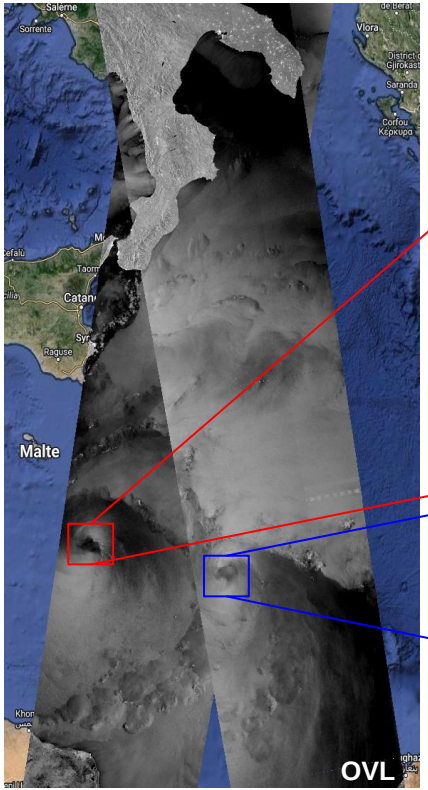

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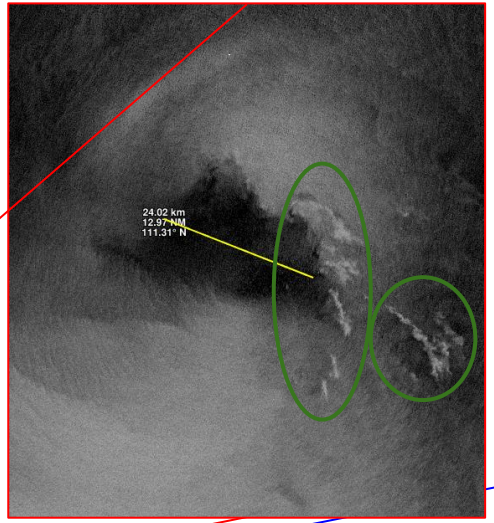
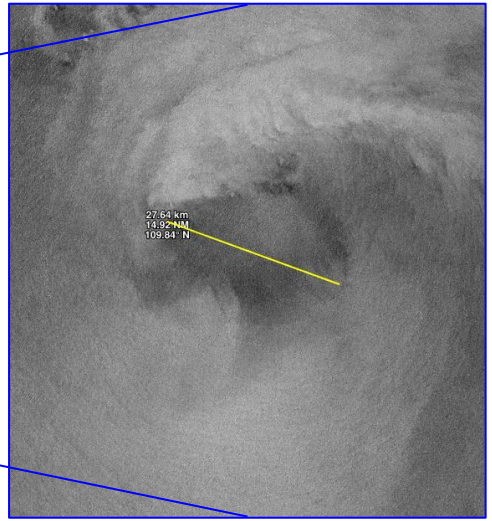




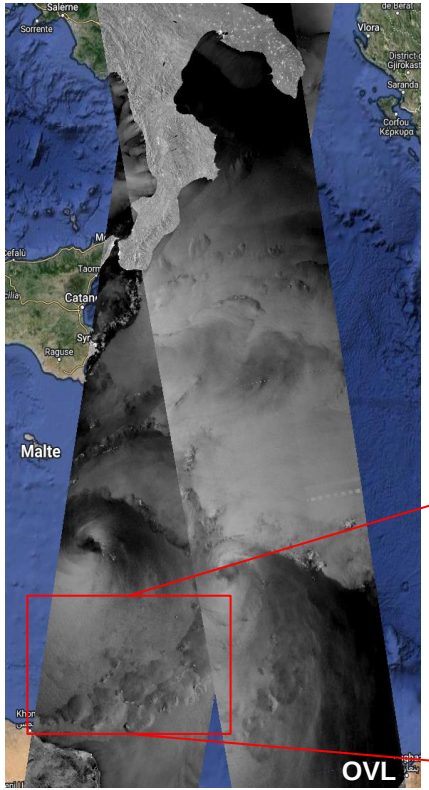
- Storm eye diameter is about 24-28 km.
  It cannot be resolved by medium resolution observations such as scatterometers.

- Signature of strongest rainfall are detected.
  It cannot be resolved by medium resolution observations

Background and Motivations

Co-existence of signatures at multi-scale and from different phenomena (Sentinel-1)

- Downdrafts reaching the surface can be observed in rain bands swirling around the eye



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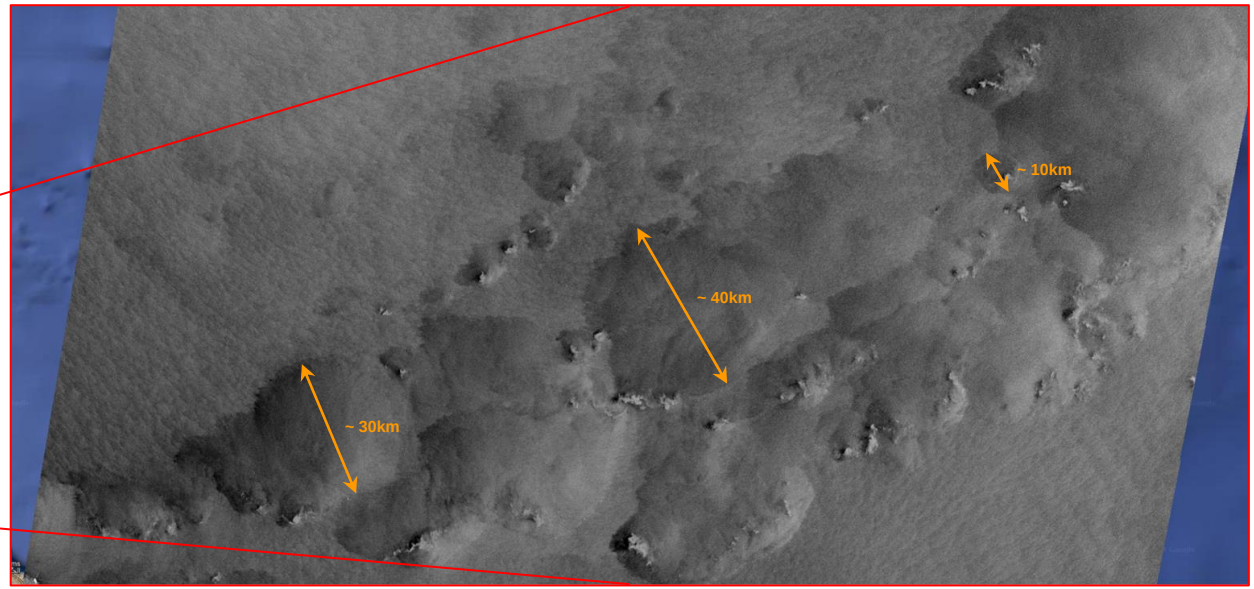

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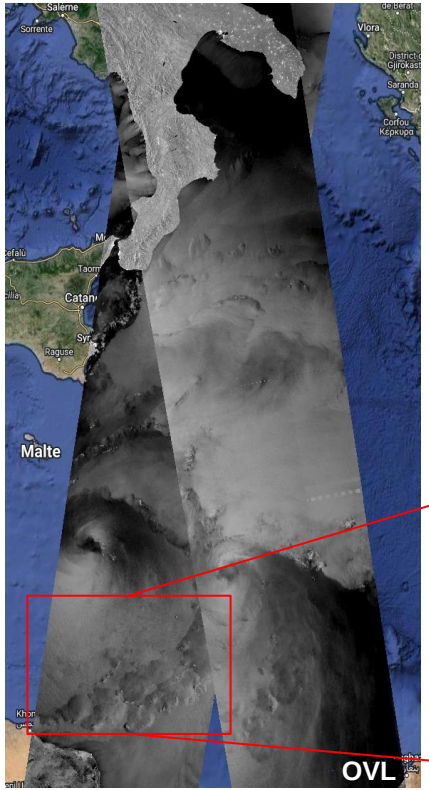

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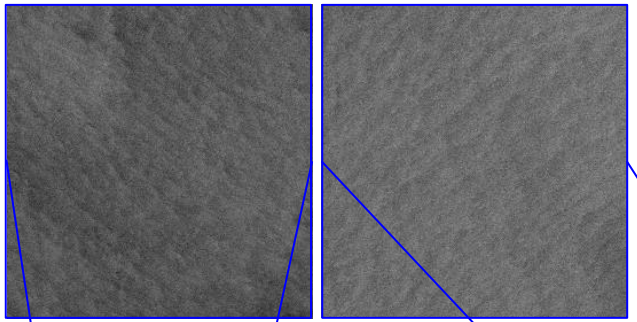

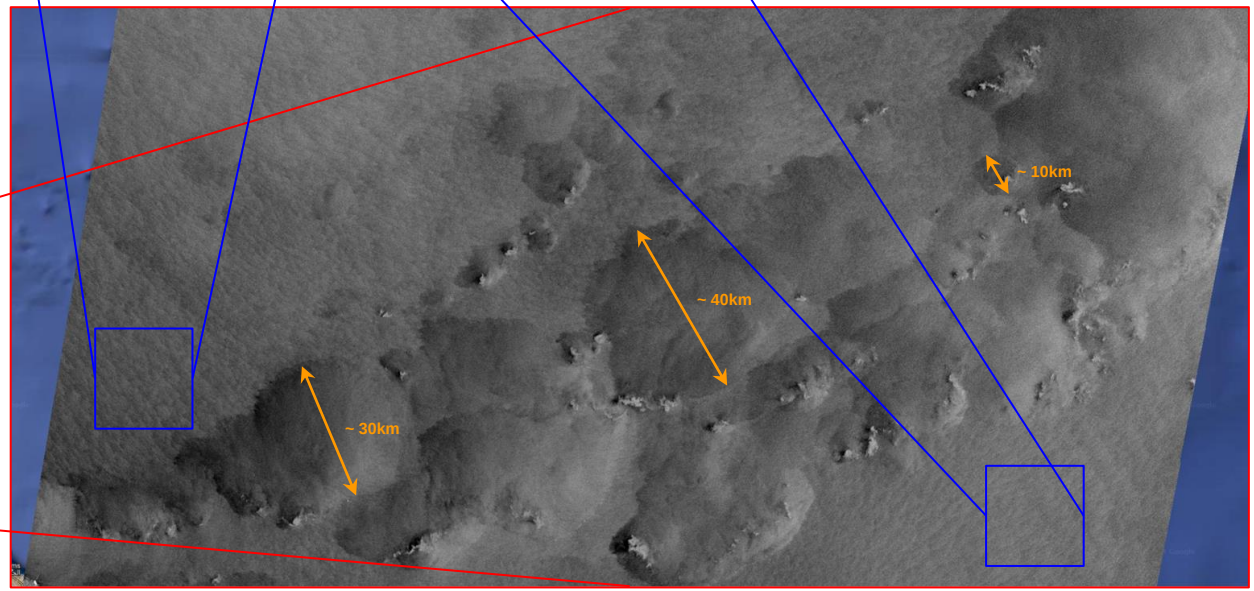

- Downdrafts reaching the surface can be observed in rain bands swirling around the eye
- Characteristics (orientation, size) of rolls in the Marine Atmospheric Boundary Layer can be observed

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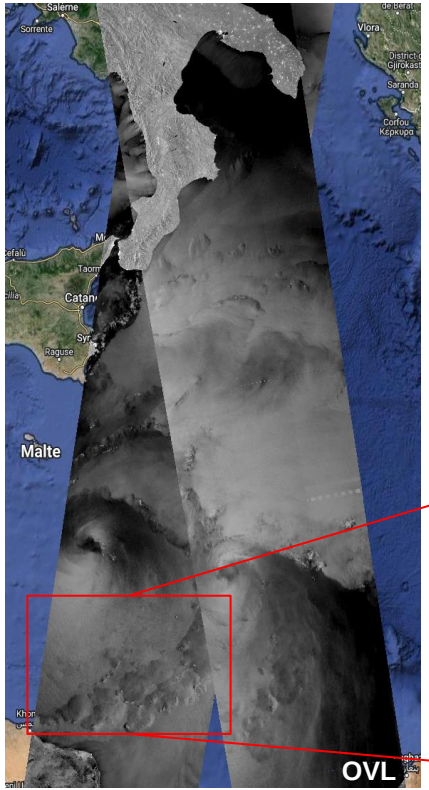
Co-existence of signatures at multi-scale and from different phenomena (Sentinel-1)



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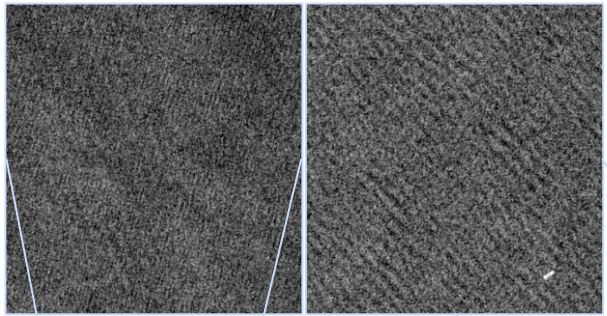

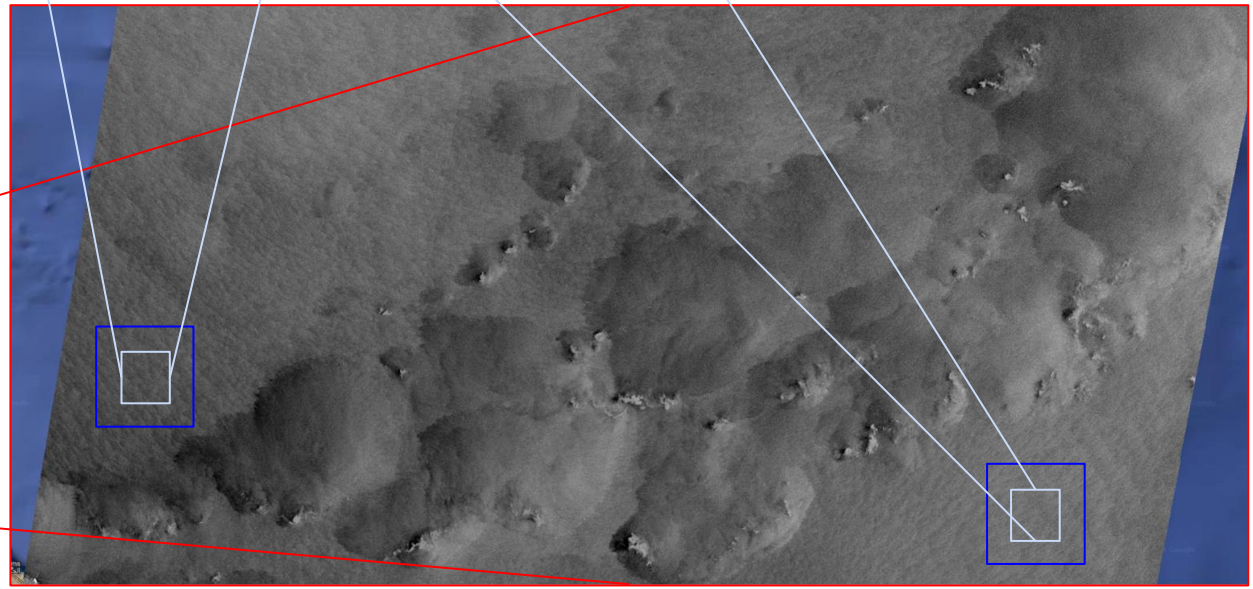

- Ocean surface waves can be detected using the full resolution of the image
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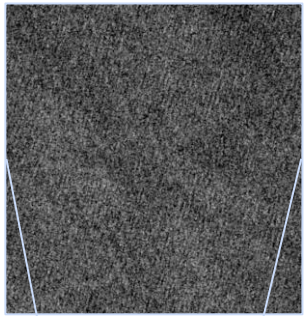

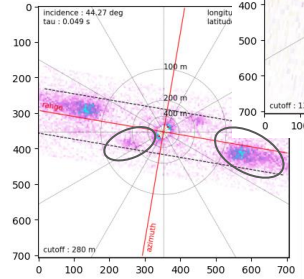

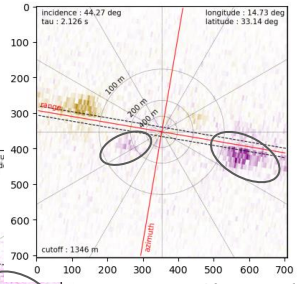

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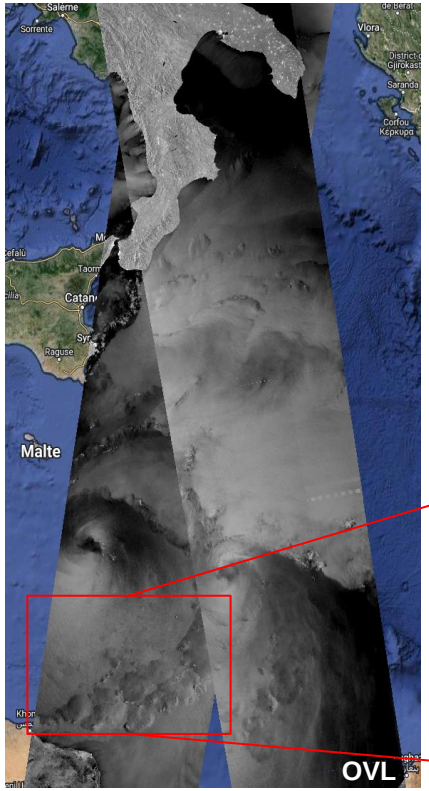

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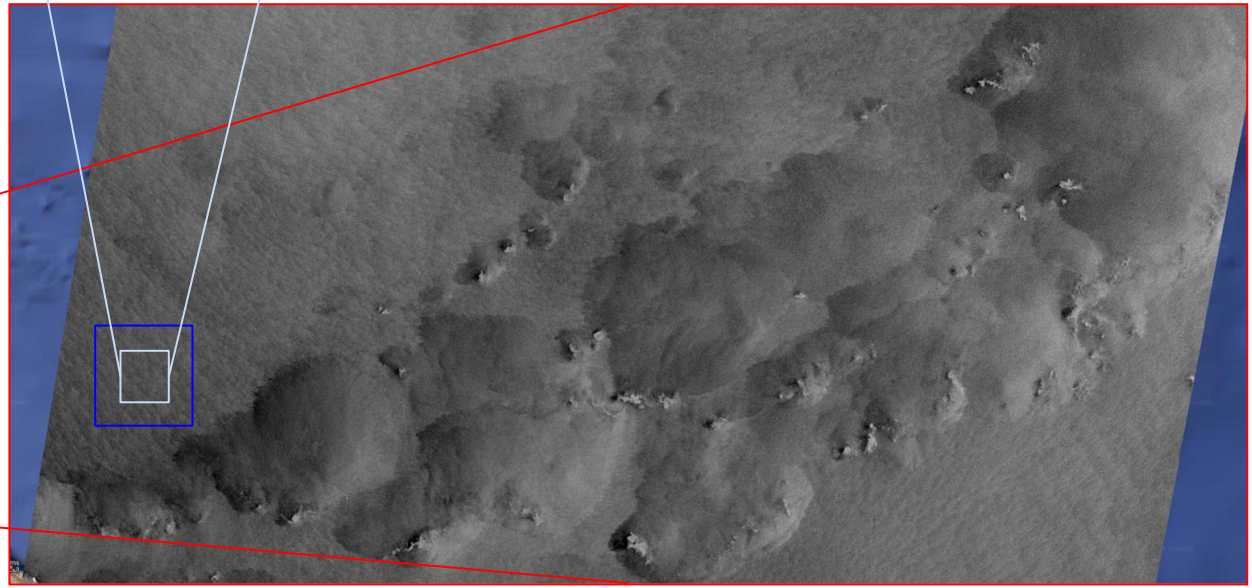


Background and Motivations

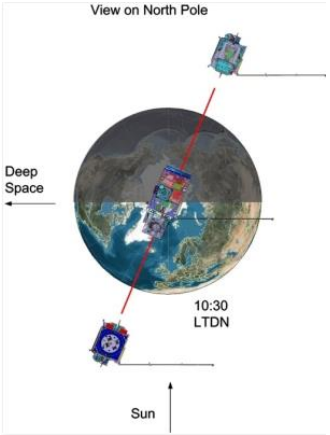
Objectives

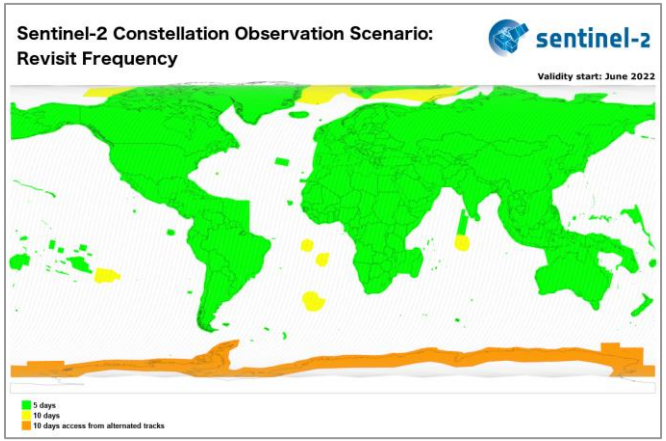
Sentinel-1

- Provide a joint estimate of sea state parameters and ocean surface wind field at high resolution (~1-5 km)
- Rain detection (~100 m)
- Characterize storms
  - From wind field
    - Storm centre location and storm eye geometry
    - Storm size
    - Identify frontal structure
  - From texture analysis
    - Map atmospheric conditions
  - From waves
    - Characterize distribution of waves energy, direction and wavelength with respect to storm properties (translation speed and wind structure)
- Investigate the potential of using other SAR missions

Background and Motivations

European SAR Constellation : Sentinel-2





Constellation of 2 satellites carrying optical instruments (multi-spectral imaging)

- Sentinel-2A 06/2015 - …
- Sentinel-2B 03/2017 - …
- Sentinel-2C (TBC)
- Sentinel-2D (TBC)

Mediterranean Sea is covered with Sentinel-2 acquisition producing images with a field of view of 290 km;

There is no Copernicus/ESA Level-2 products for ocean applications. Resolution is about 10-60 m.

Background and Motivations

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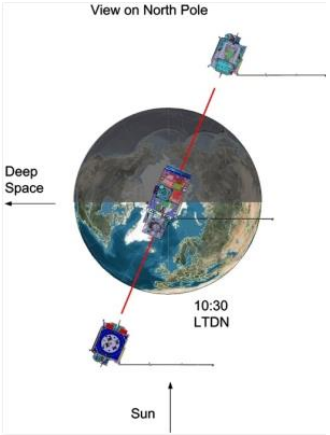

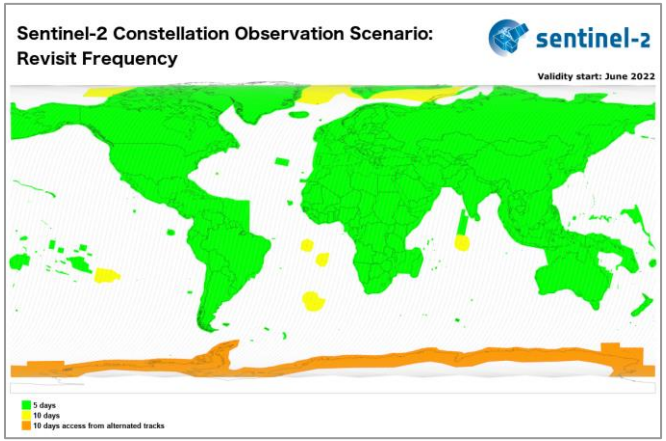

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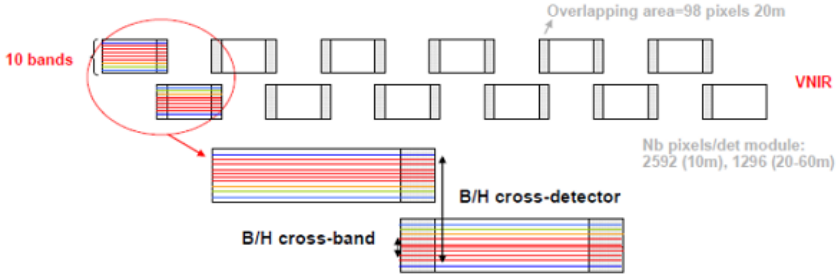
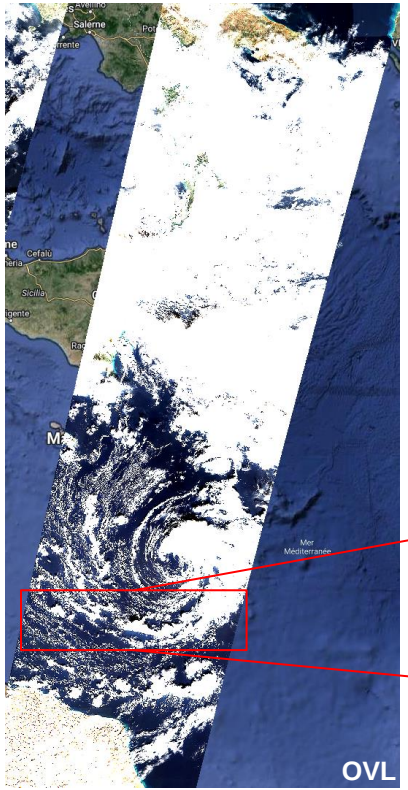


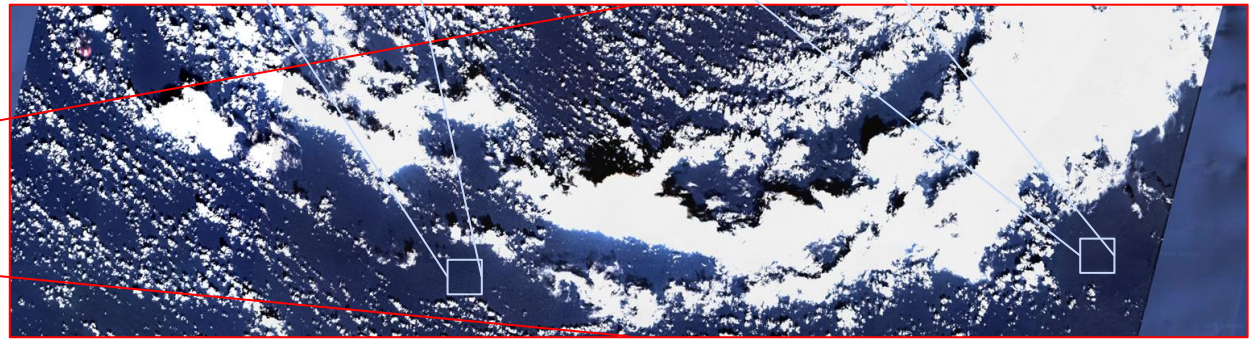
Direct analysis of the Brightness temperature modulation

Different observations of the same area are also possible by combining different bands obtained from one detector (~1sec) or by combining bands from two different detector in the overlapping area

Background and Motivations

Ocean surface waves in cloud-free areas (Sentinel-2)





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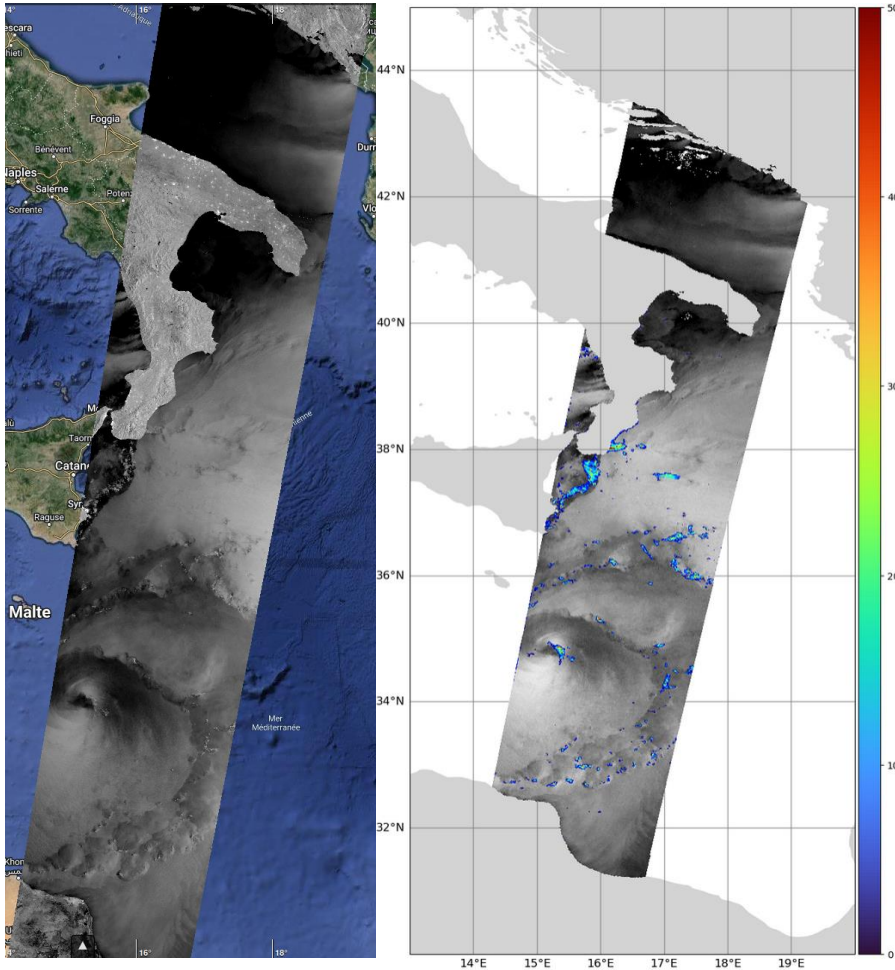
- Investigate the potential of using other SAR missions

Sentinel-2

- Provide characterization of ocean waves direction and wavelength within and outside of the storm

Sentinel-1 Rain rate and Ocean surface wind vector

Based on systematic co-locations between Sentinel-1 observations and rain rate measurements from ground-based radar, a statistical relationship between rain rate and radar backscattered signal (VV and VH) has been established.



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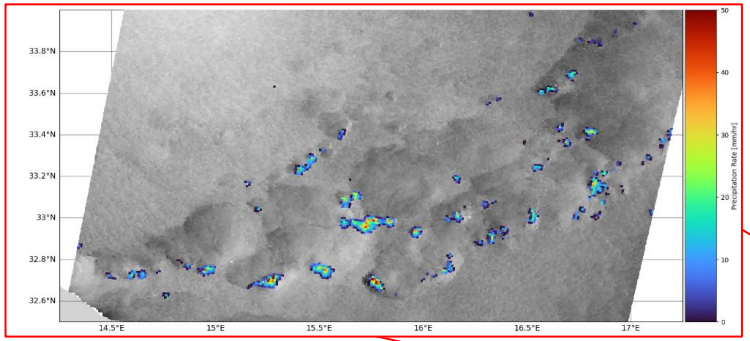
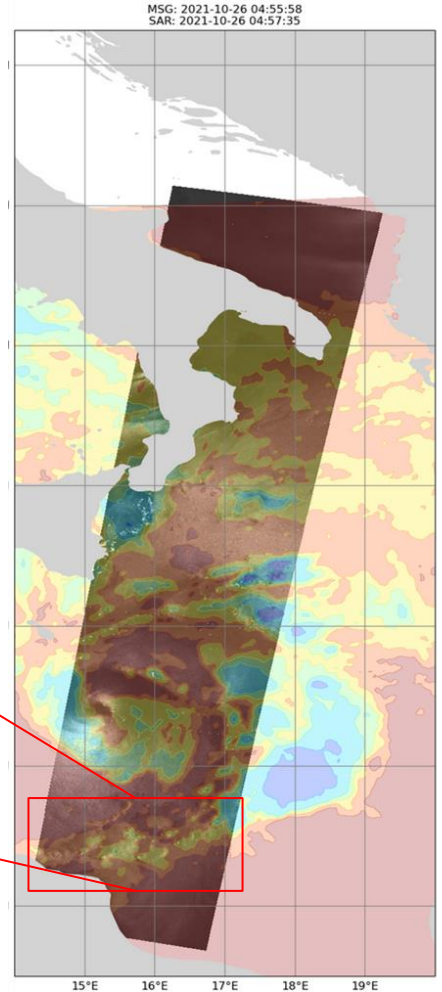
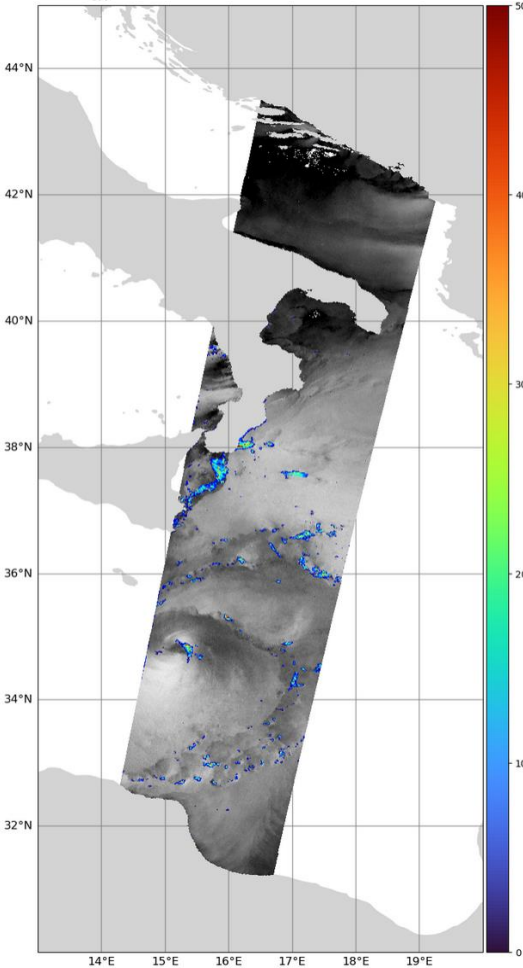
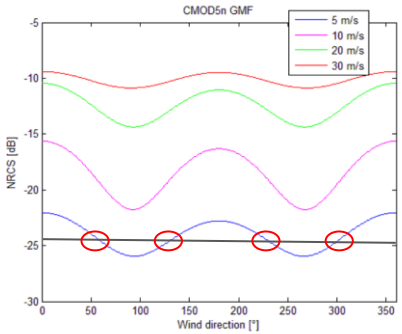


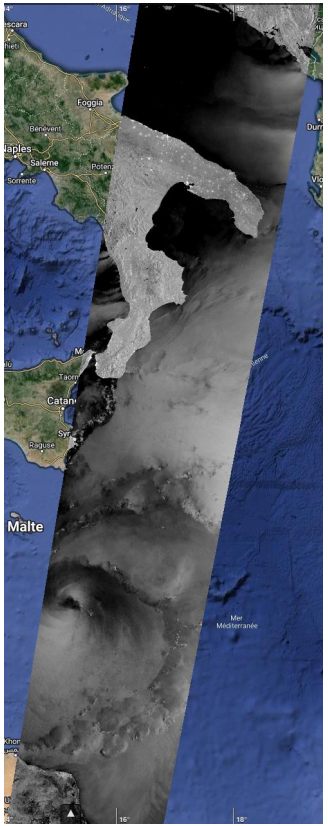




Sentinel-1 Rain rate and Ocean surface wind vector

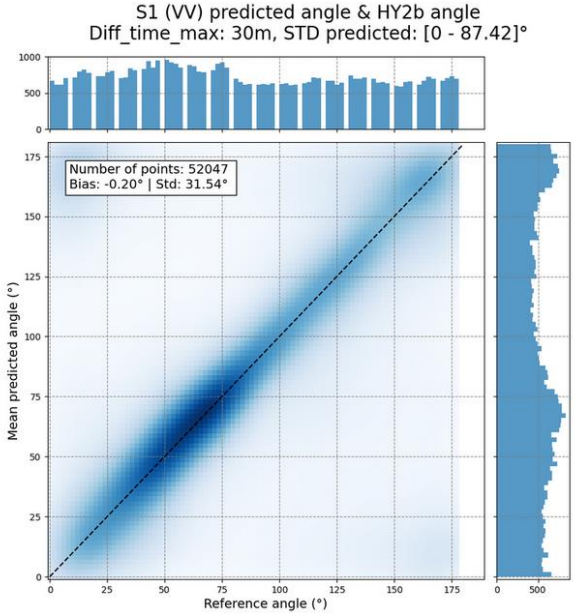
The wind inversion problem is under constrained if we rely only on the backscattered intensity (only one measurements)
High resolution and phase information from SAR are used to add constraints.

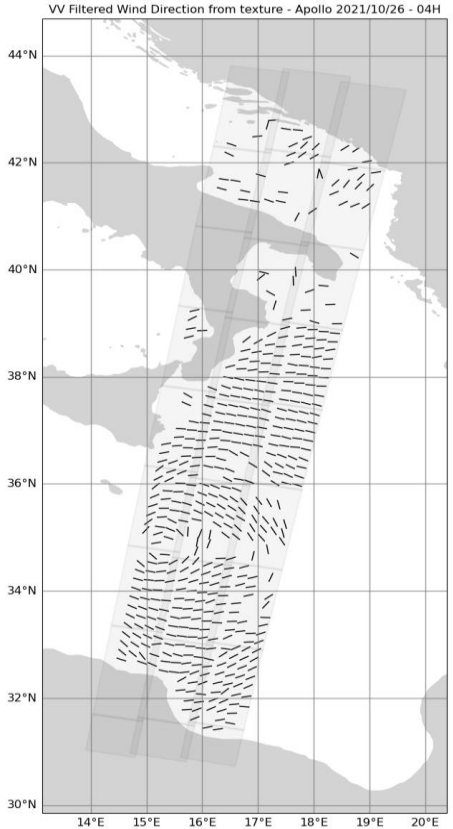


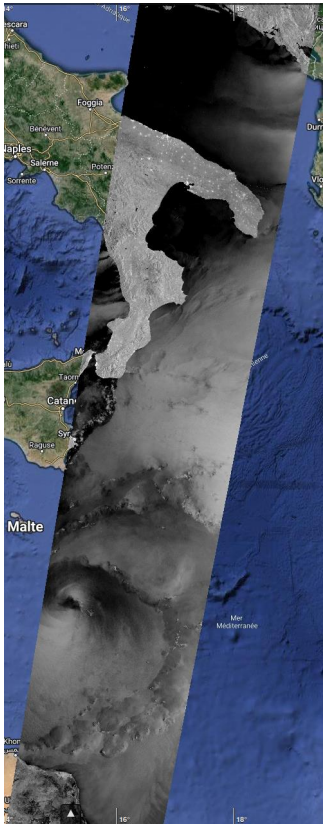


Sentinel-1 Rain rate and Ocean surface wind vector

Based on systematic co-locations of Sentinel-1 SAR measurements with WindSat radiometer wind products, a statistical relationship between the roughness texture and the wind direction has been developed for the two polarization channels.

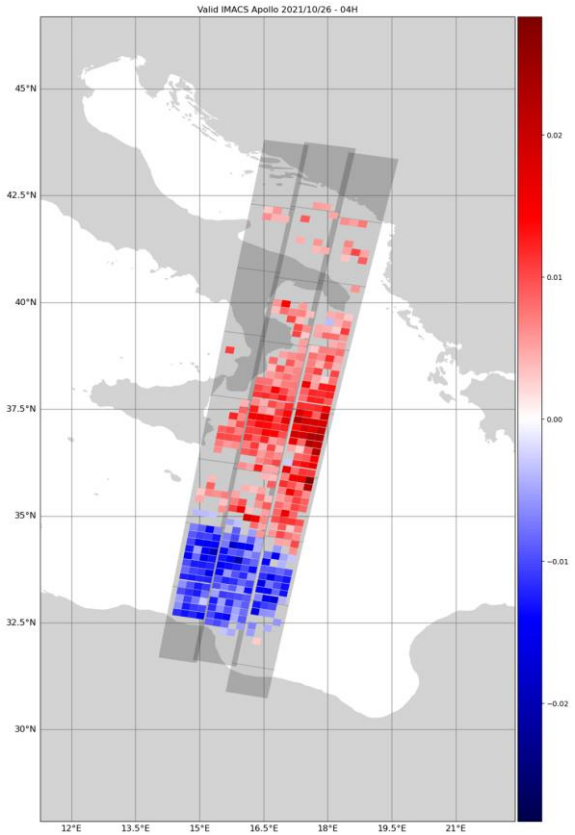


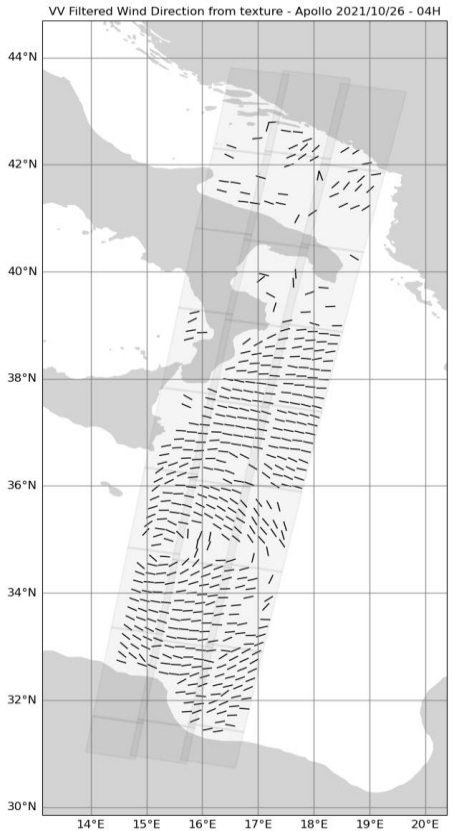


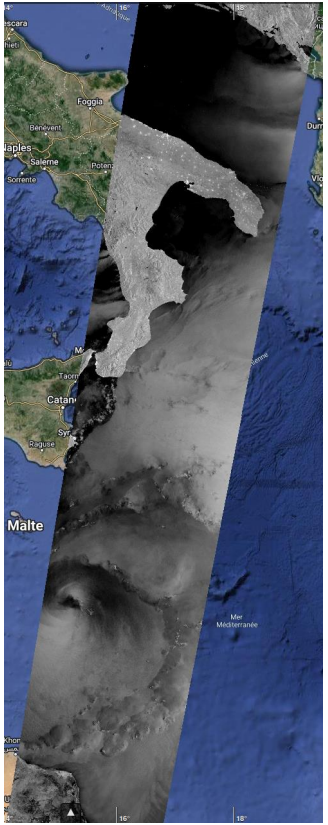


Sentinel-1 Rain rate and Ocean surface wind vector

The signature of the decametric wind waves displacements in the phase is used to remove the 180° ambiguity







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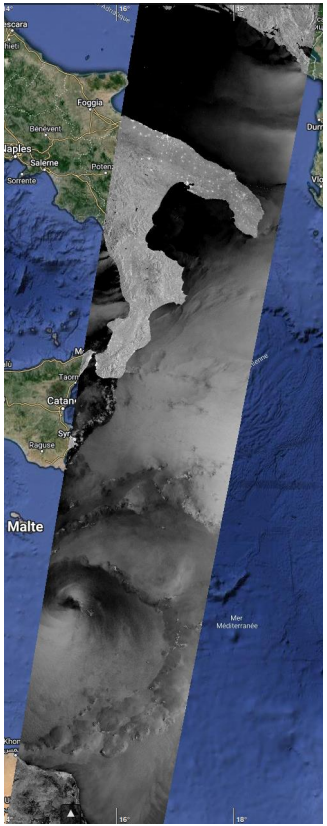
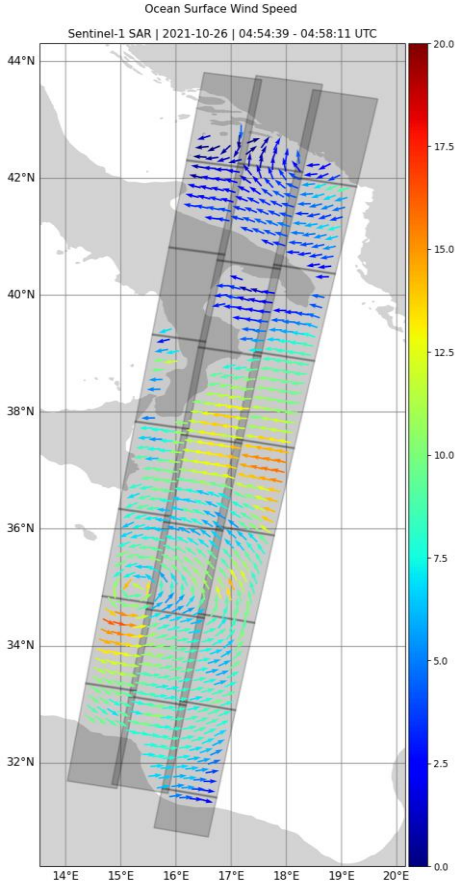
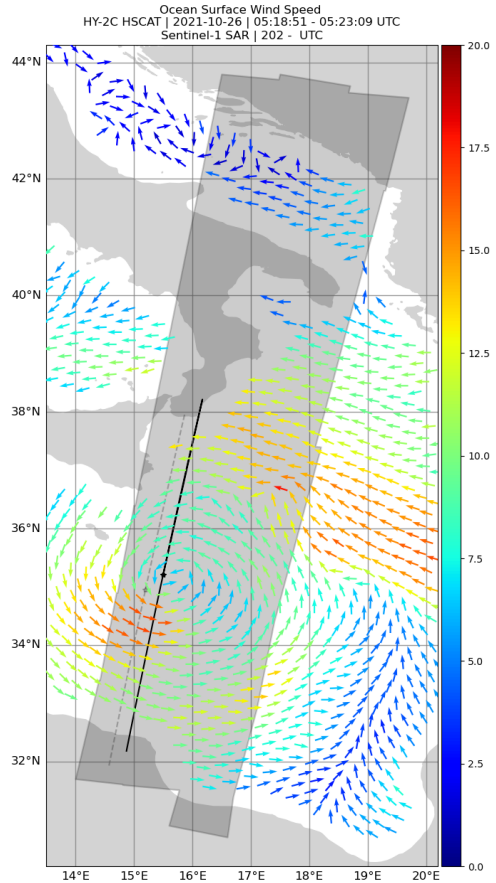
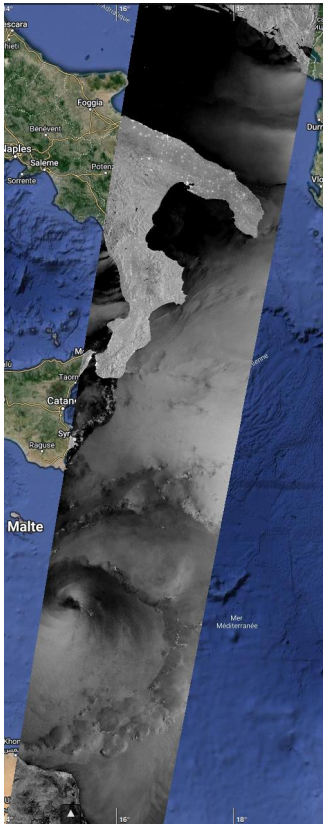


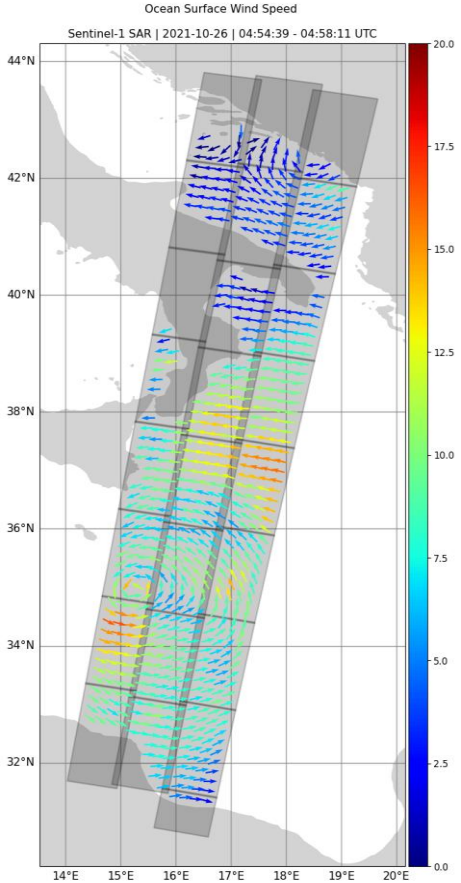


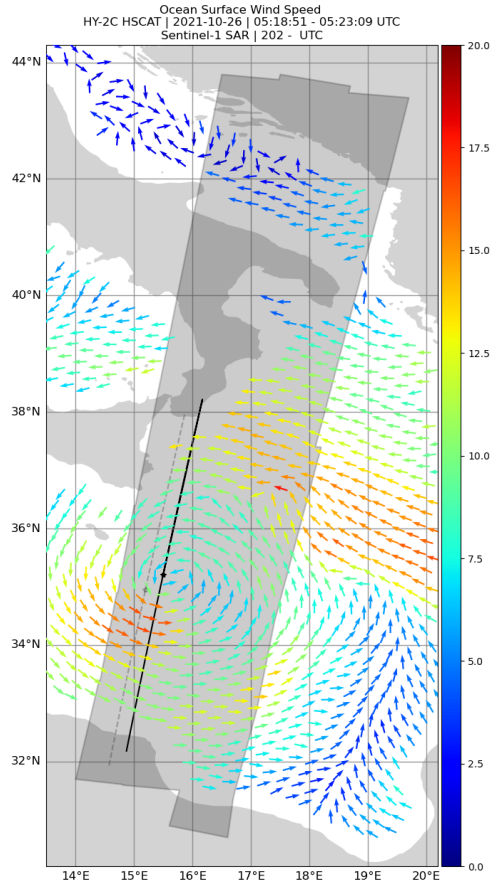


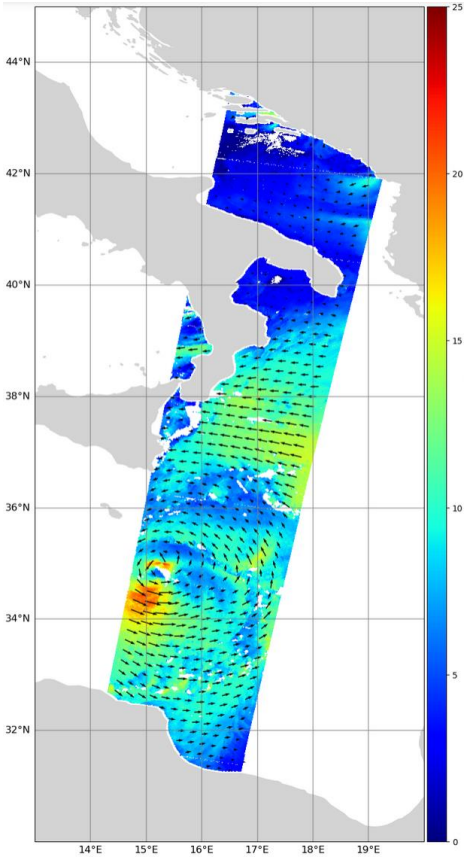
2021/10/26 morning

Sentinel-1 Rain rate and Ocean surface wind vector









2021/10/26 morning

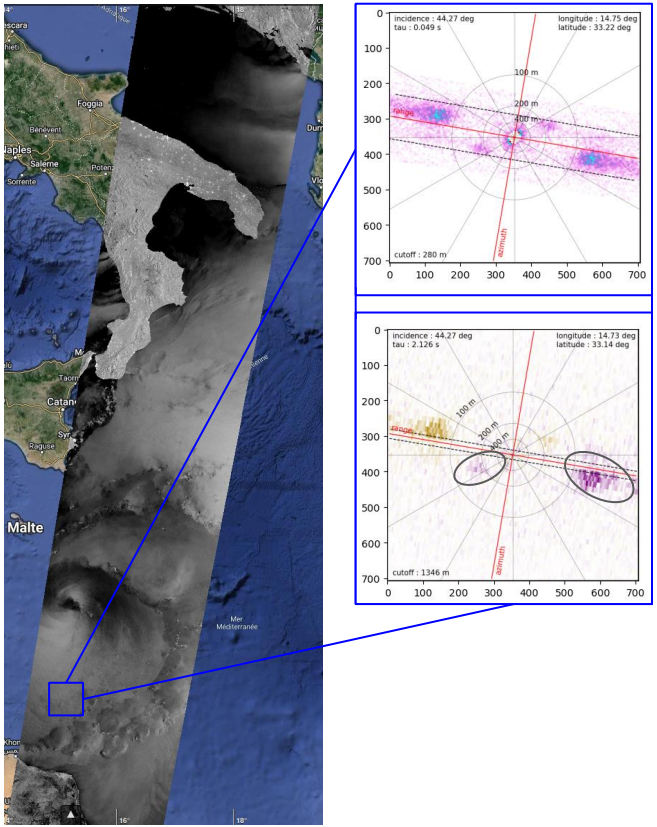
Sentinel-1 & Sentinel-2 Ocean surface waves

The radar backscattered signal and the Brightness Temperature measured at very high resolution can be used to computation image modulation spectra

These spectra provide information of the wave energy distribution as observed by the two instruments through a transfer function

The use of images of the same scene but acquired at different times allows for cross-spectra computation to trace the dynamics of the detected waves

For Sentinel-1, statistical approaches have been developed to relate spectral moments of cross-spectra to sea state parameters



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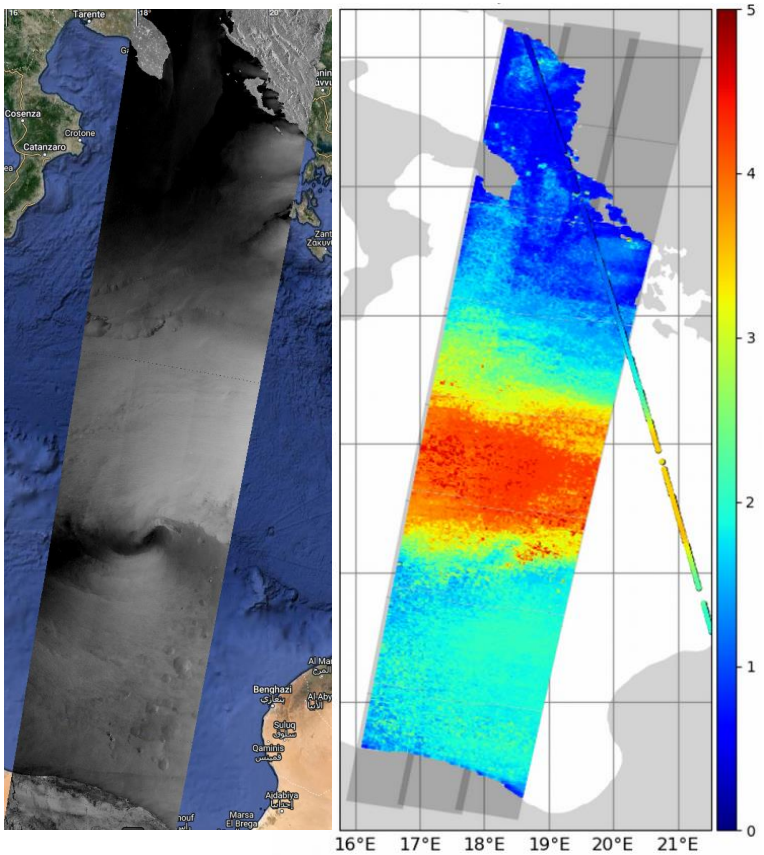

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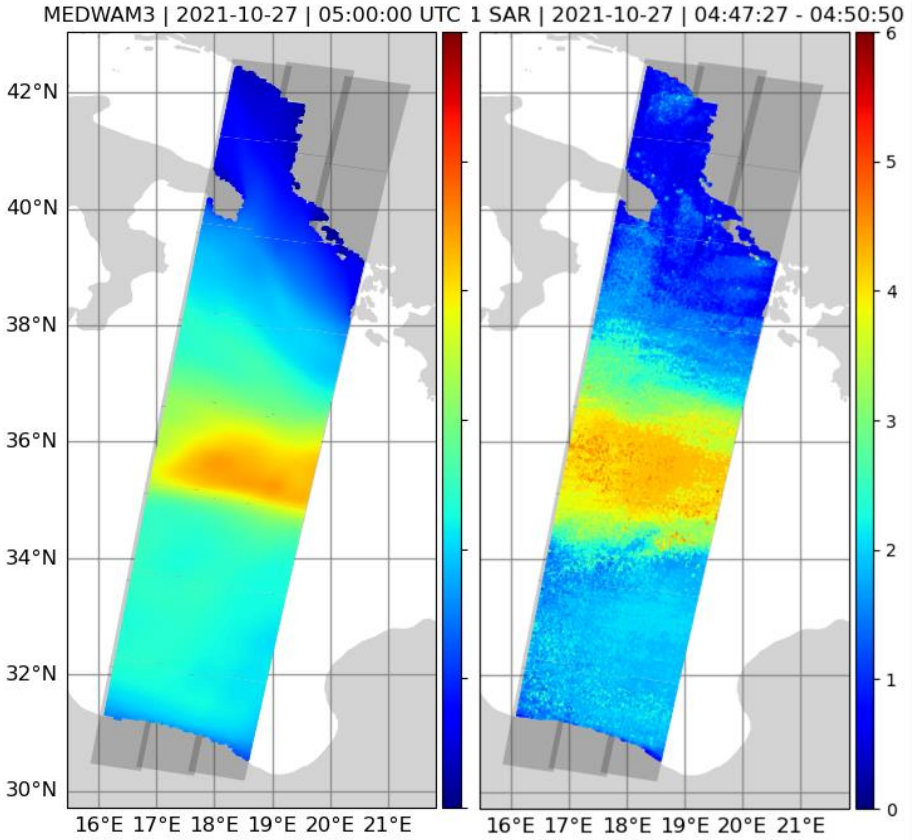

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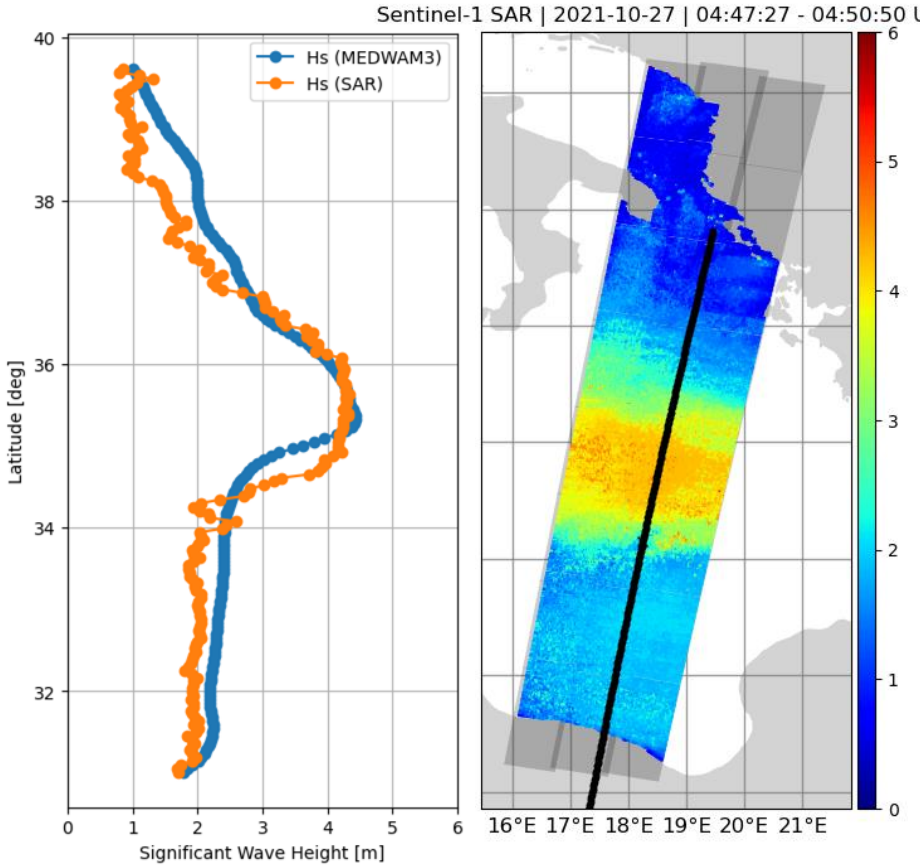

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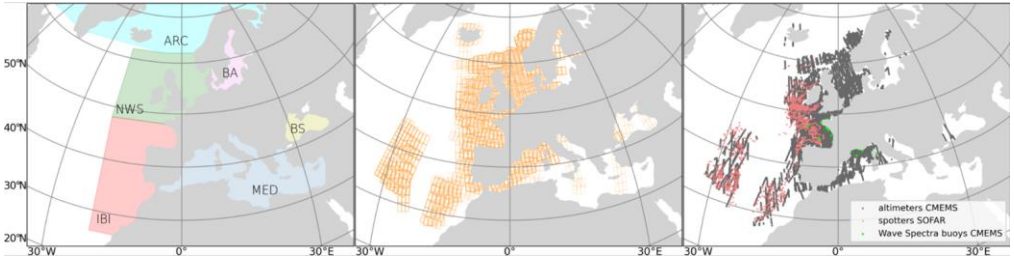
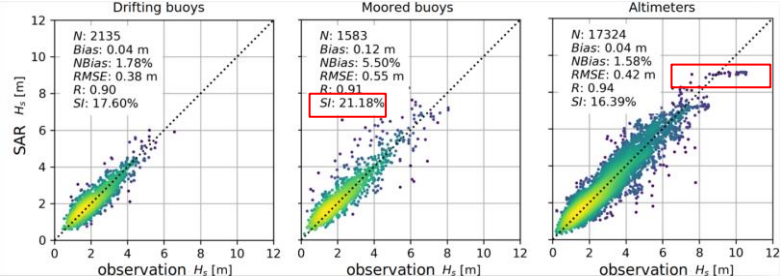
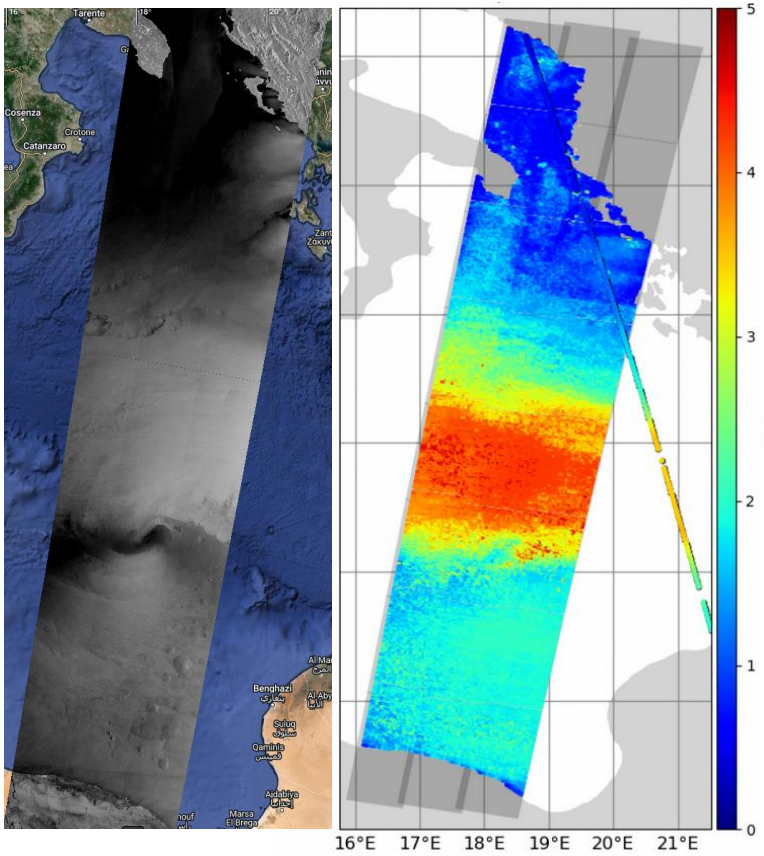


RMSE of about 40 cm is found against drifting buoys. More uncertainties are found in coastal areas and for the most extreme sea states.





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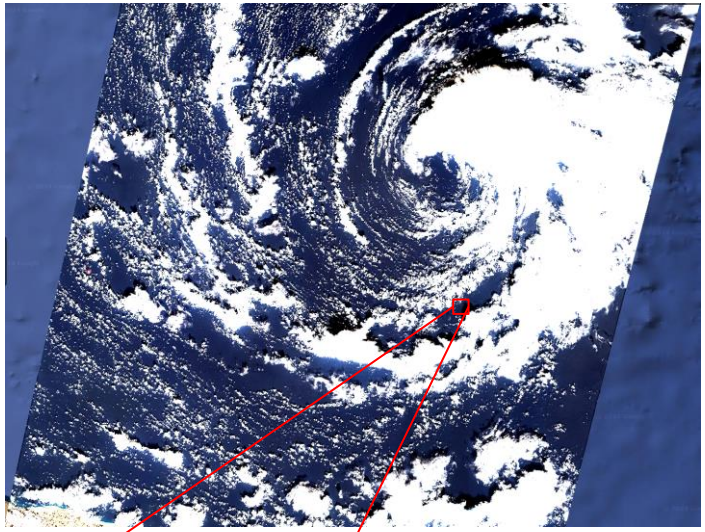
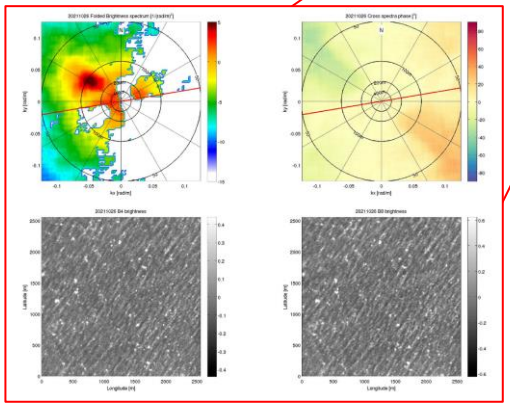
- work is going-on to develop the transfer function between the Brightness temperature spectrum and the wave spectrum.
- The wind-waves description is expected to be more accurate than for Sentinel-1 SAR





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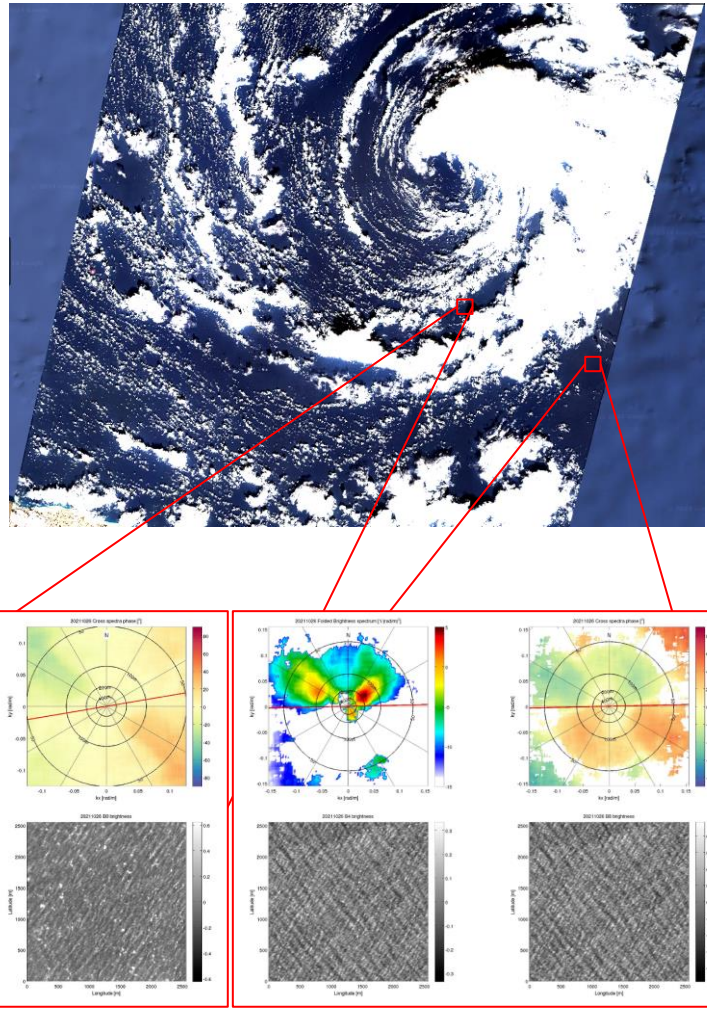

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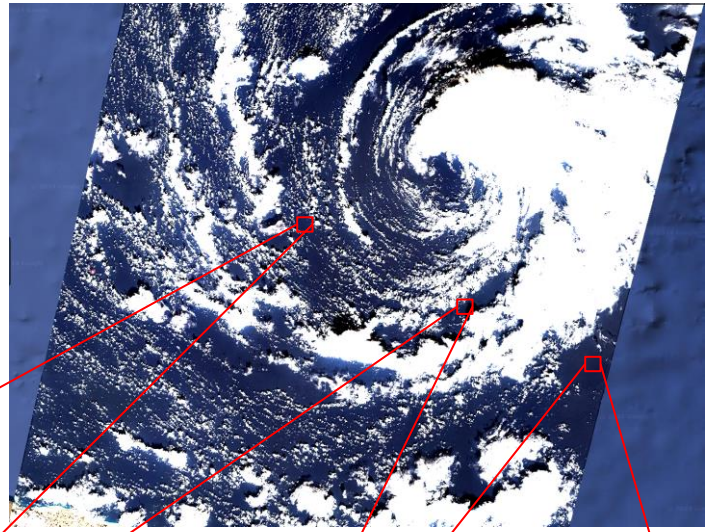

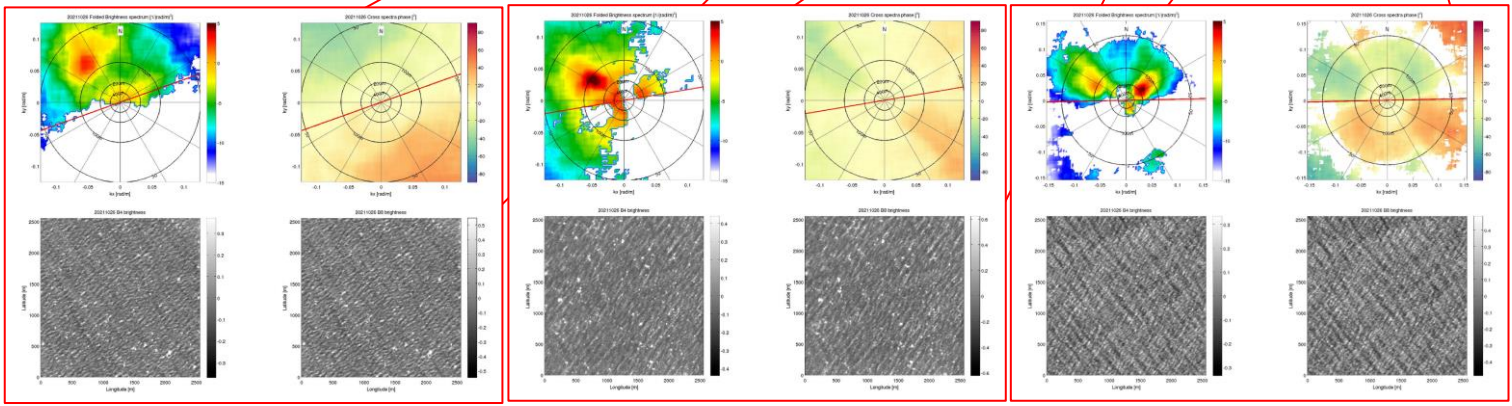

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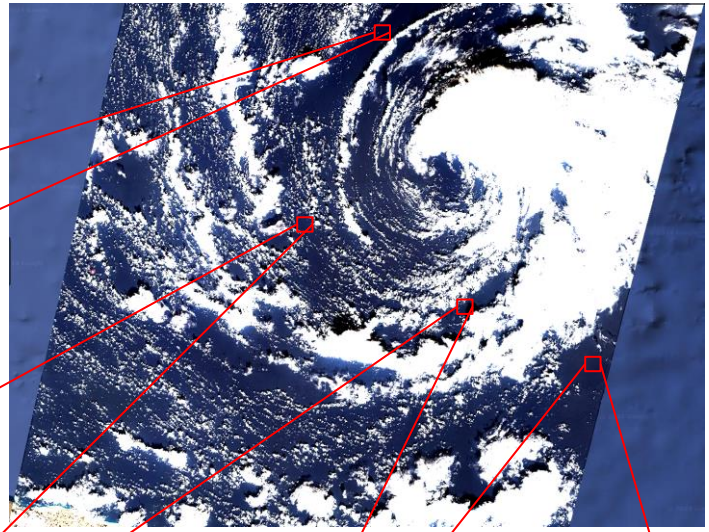

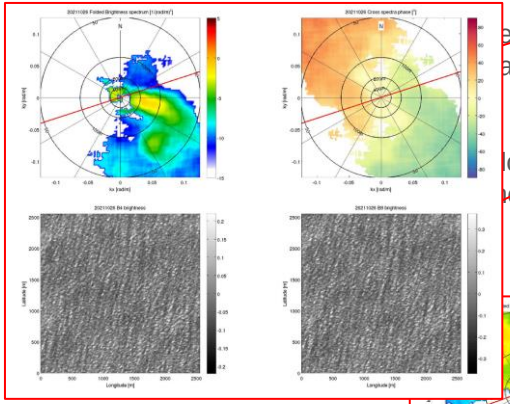

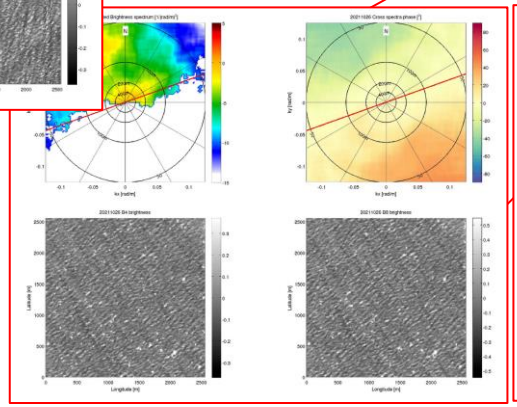

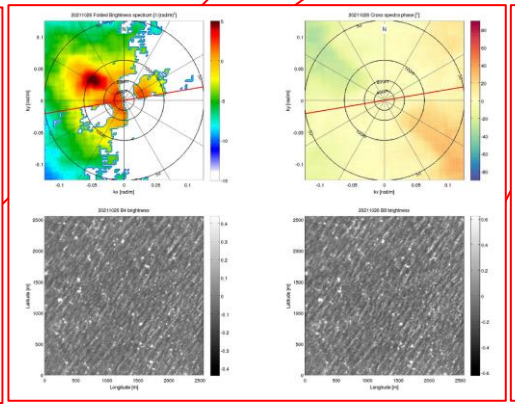

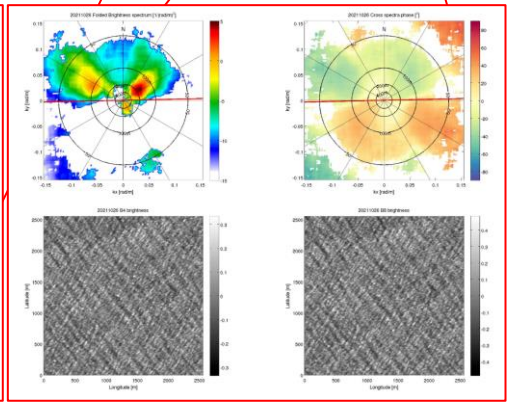

Conclusions

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- A first version/set of algorithm/products can provide jointly information on
    - Rain rate (100m) : rain may be subject to further improvements in the case of extreme winds
    - Ocean surface wind field (1 km) : Wind direction and associated error needs to be included in the products
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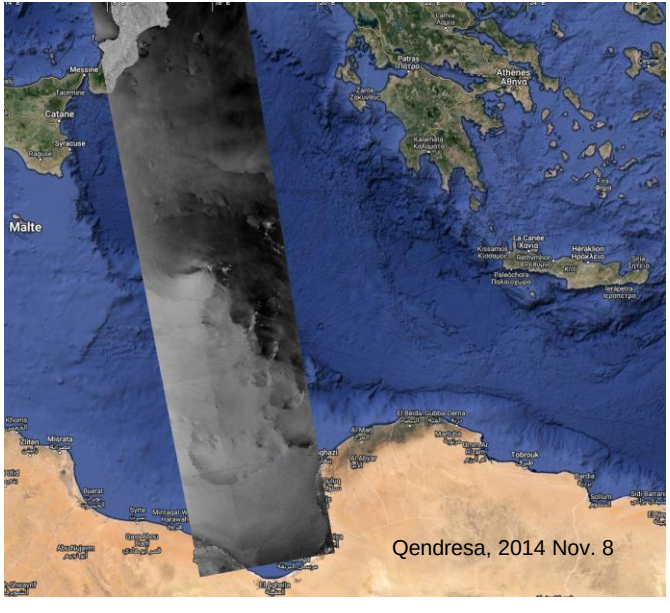

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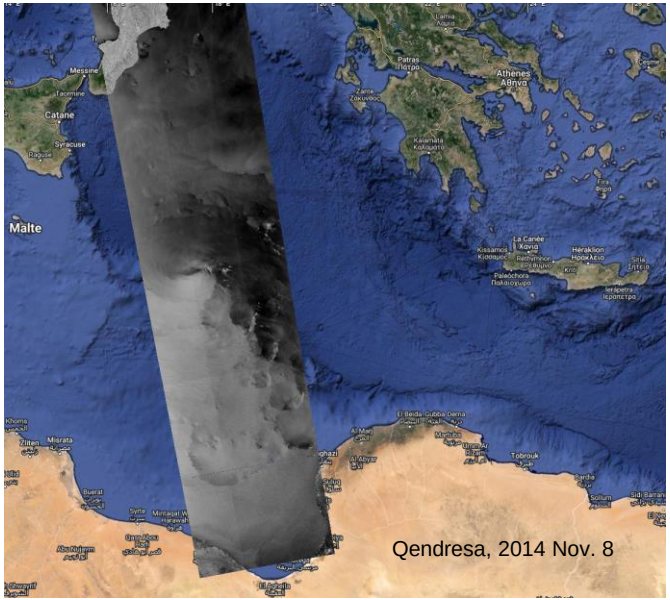

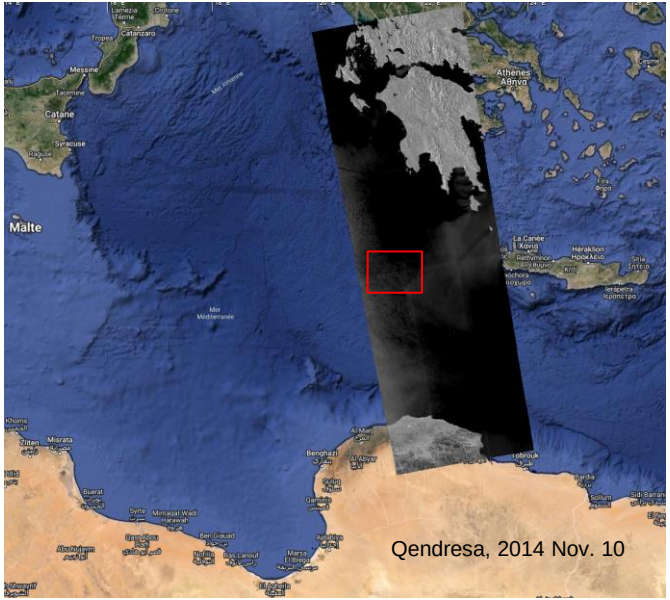

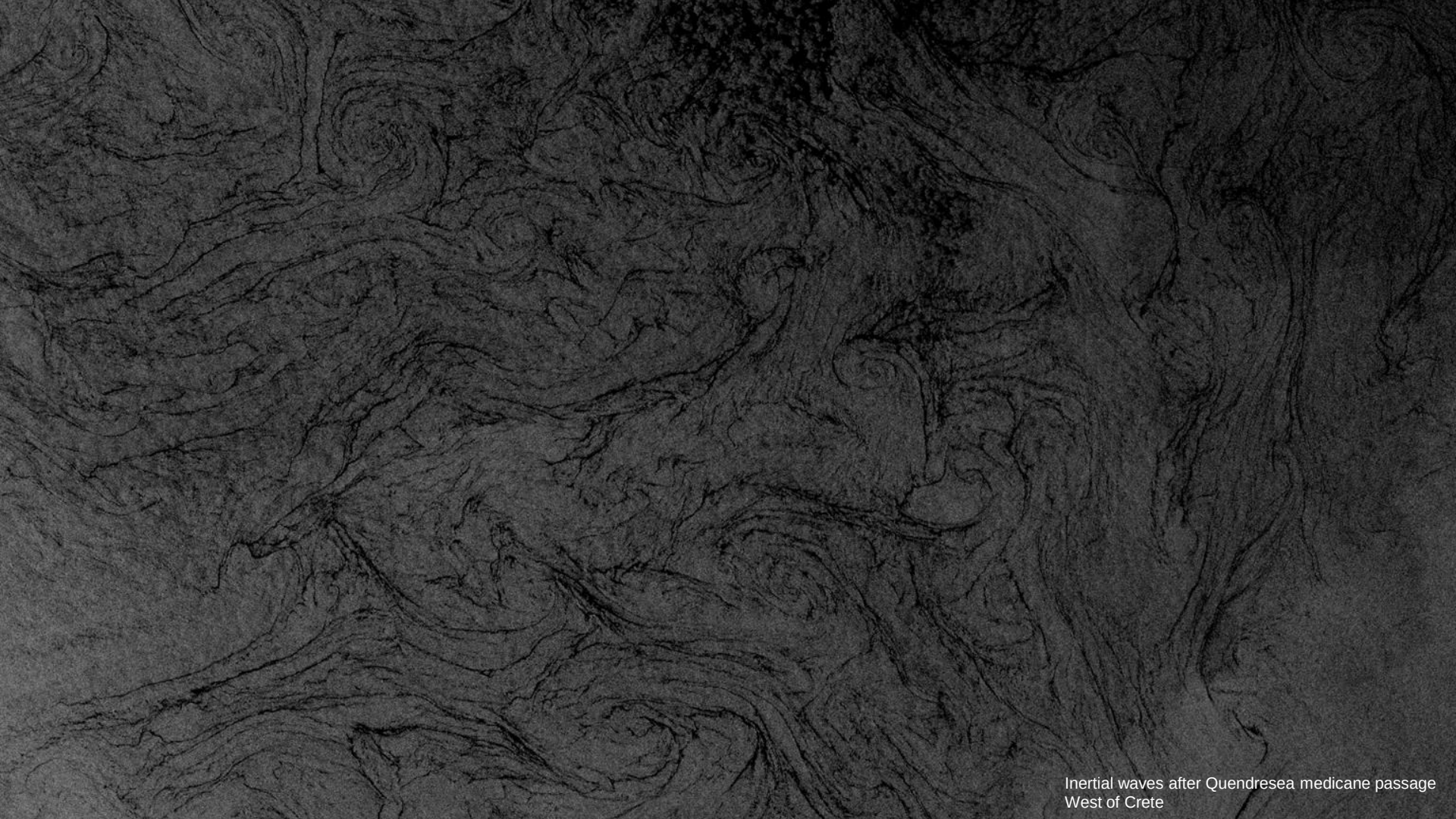

Inertial waves after Quendresea medicane passage
West of Crete

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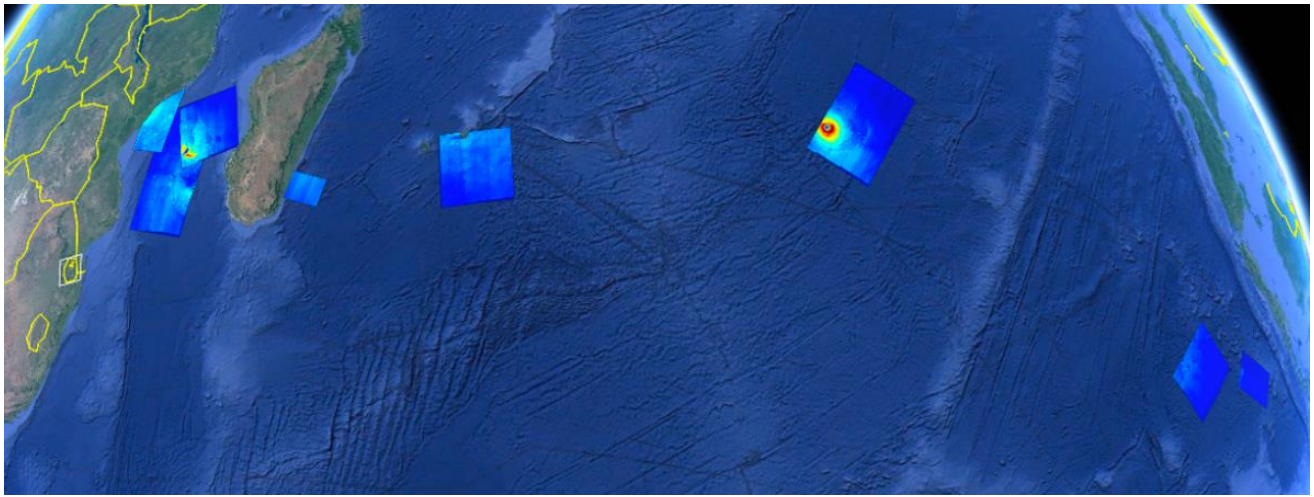

S-1

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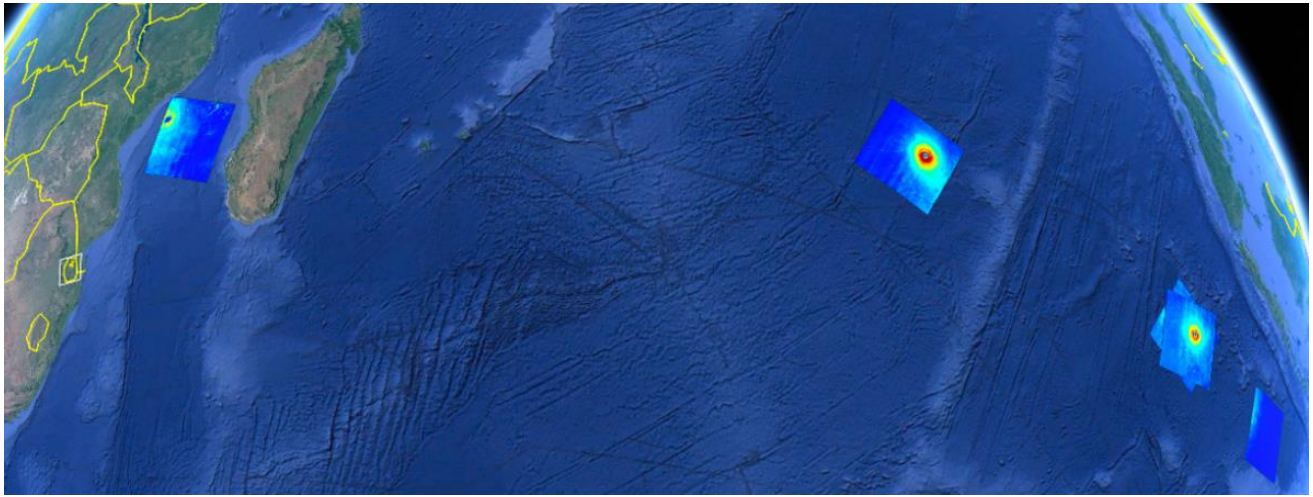

RS-2

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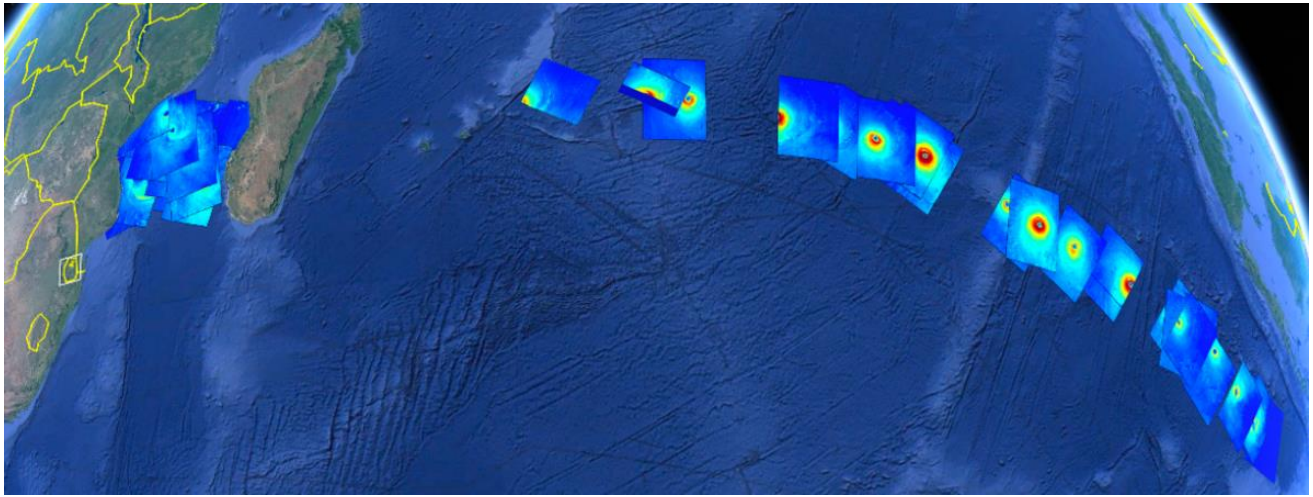
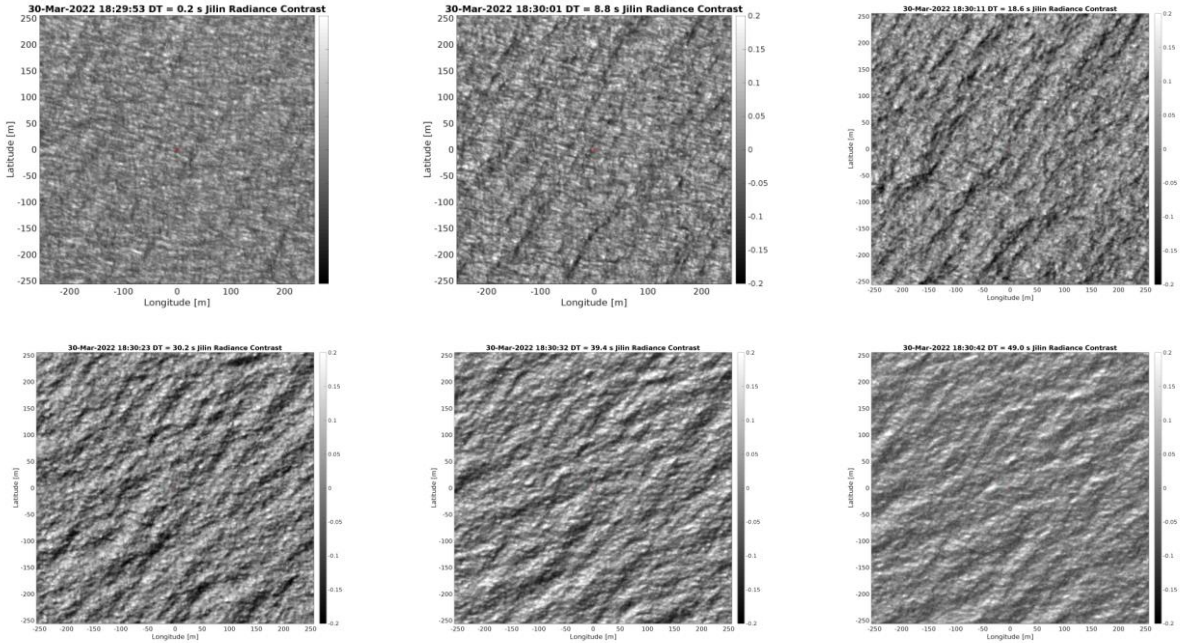


S-1 + RS-2 + RCM-1/2/3

Conclusions

Sentinel-2

- In cloud-free area, optical images can be used to trace the waves evolution (Wavelength, Direction) including swell and wind waves.
- Active research to define the transfer function and range of validity



Jilin video acquisitions (> 60 s) to check the multiple azimuth sunglint effect on waves detection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MEDICANES
MPC-S1