Fully focused SAR altimetry studies for optimal data processing and new applications on different surfaces using S6-MF

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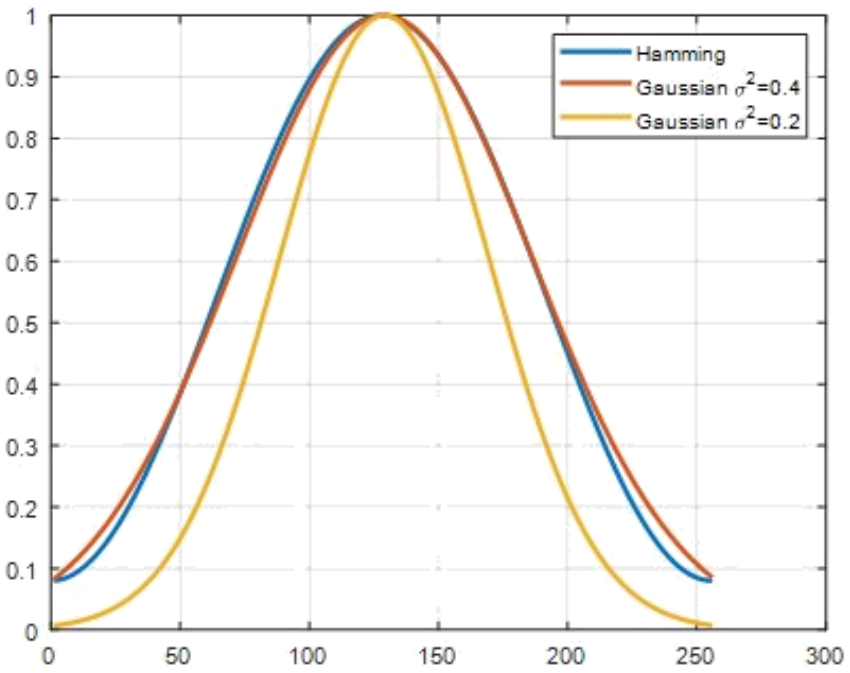
Context and Plan

CNES R&D studies and ESA project (S6JTEX) with objectives:

- To make use of the **high-resolution FF-SAR technique** [Egido and Smith, 2017] **to fully exploit the S6-MF capabilities** with a view to implement this solution in ground segment of current and future altimeter missions
- **To recommend optimal processing configurations** for the Omega-Kappa (WK) algorithm [Guccione et al., 2018] in various scenarios (transponder, rough and specular surfaces)
- **To develop new applications and potentially define new products** for different targets (long ocean waves, coastal regions, open-water leads and inland waters) **using new altimeter imagery capability**

FF-SAR Optimal Processing Configuration

Optimal configuration for FF-SAR WK processing for diffusive (open ocean) and specular surfaces (inland waters, open-water leads) by tuning the parameters: Percentage of Doppler bandwidth, integration time, **Doppler windowing**, replica mitigation, multilooking



Parameter	No antenna	Antenna only	Hamming	Gaussian 0.4	Gaussian 0.2
Resolution [m]	0.643	0.614	0.858	0.837	1.083
PSLR [dB]	-15.42	-14.11	-32.69	-35.26	-41.70
ISLR [dB]	-13.45	-11.86	-31.56	-32.85	-41.81
Replica [dB]	-30.7	-30.8	-34.8	-35.0	-37.0

Doppler windowing reduces the side lobes and replicas level at the expense of the resolution, this effect is amplified when the windowing is sharp

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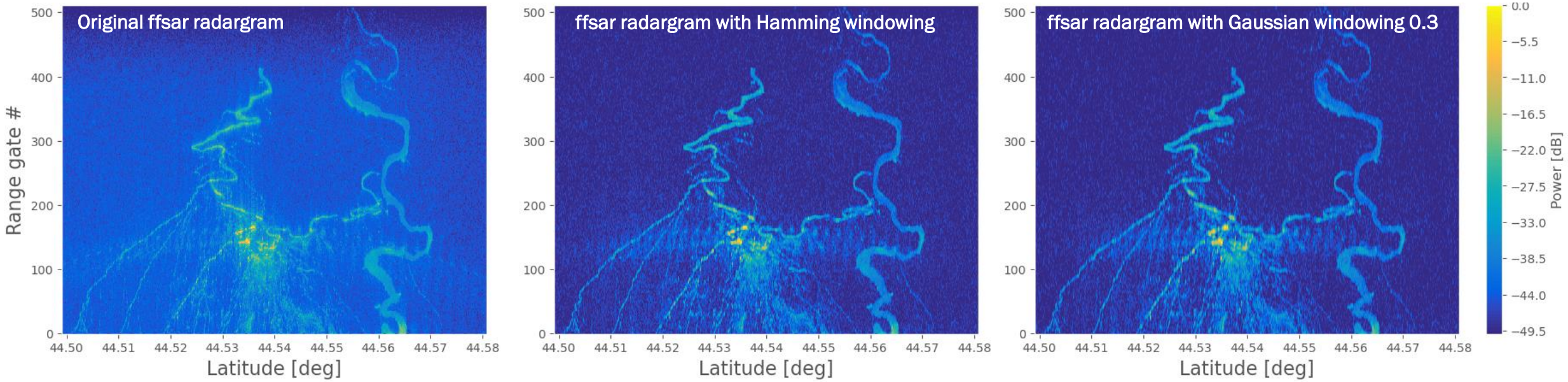
Lot River, France



More details in Amraoui et al., in preparation

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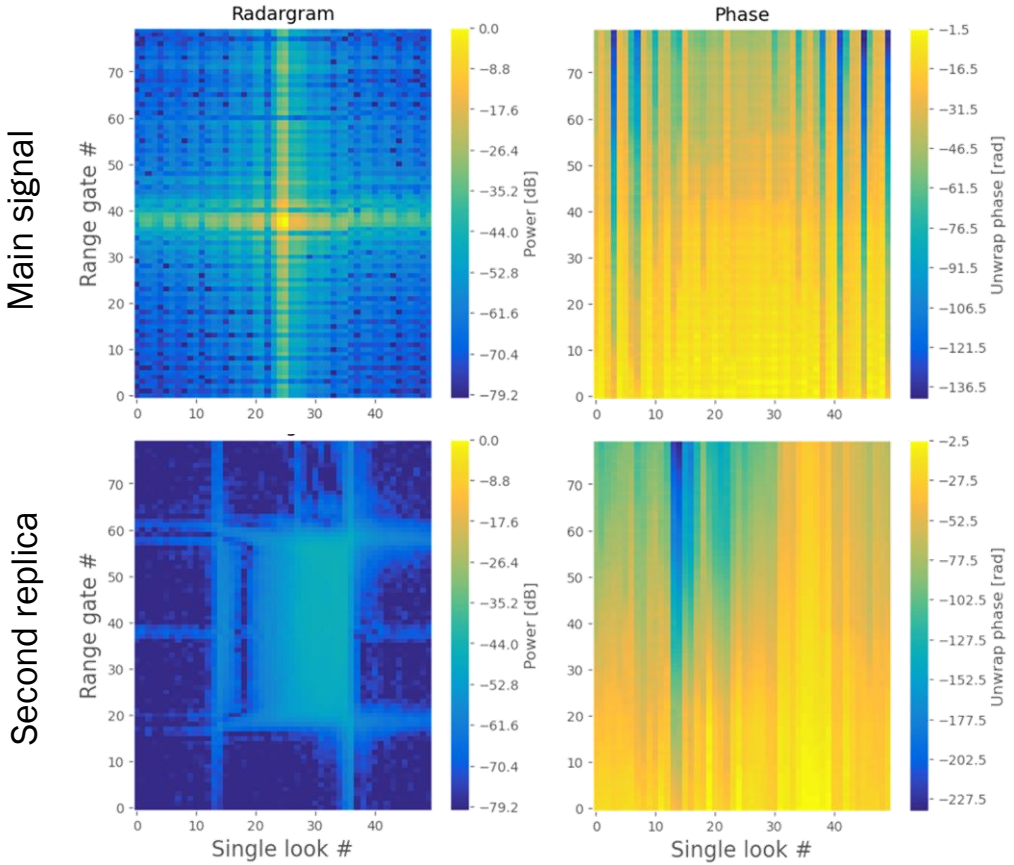
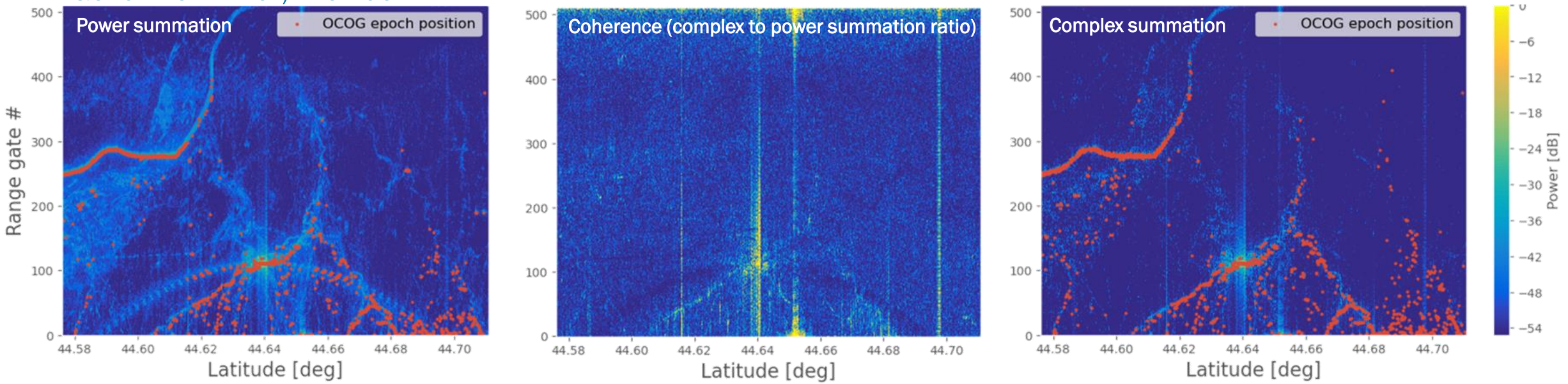


- **Range-smearing effect** [Ehlers et al., 2022] due to imperfect RCMC correction blurs the FFSAR grating lobes in range and azimuth (but stable in amplitude)
- **Phase variation effect** [Amraoui et al, *in preparation*] also due to RCMC mis-correction at replica positions. By making a **complex summation** instead of a power summation **while multilooking**, **SL interfere destructively** removing the replicas but also the incoherent signal

FF-SAR Optimal Processing Configuration

Optimal configuration for FF-SAR WK processing for diffusive (open ocean) and specular surfaces (inland waters, open-water leads) by tuning the parameters: Percentage of Doppler bandwidth, integration time, Doppler windowing, **replica mitigation**, multilooking

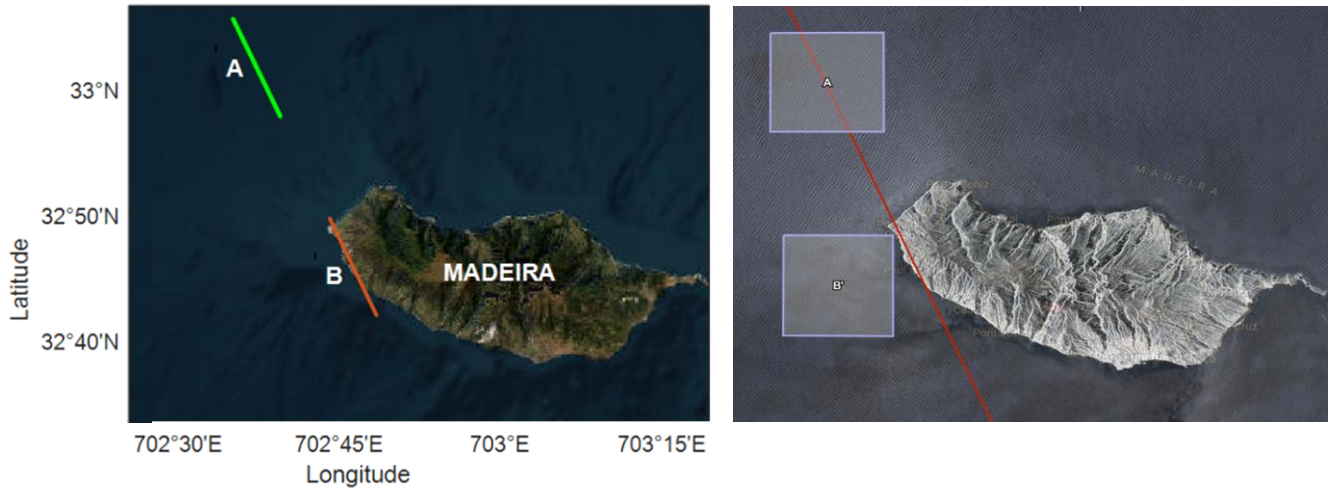
Garonna River, France



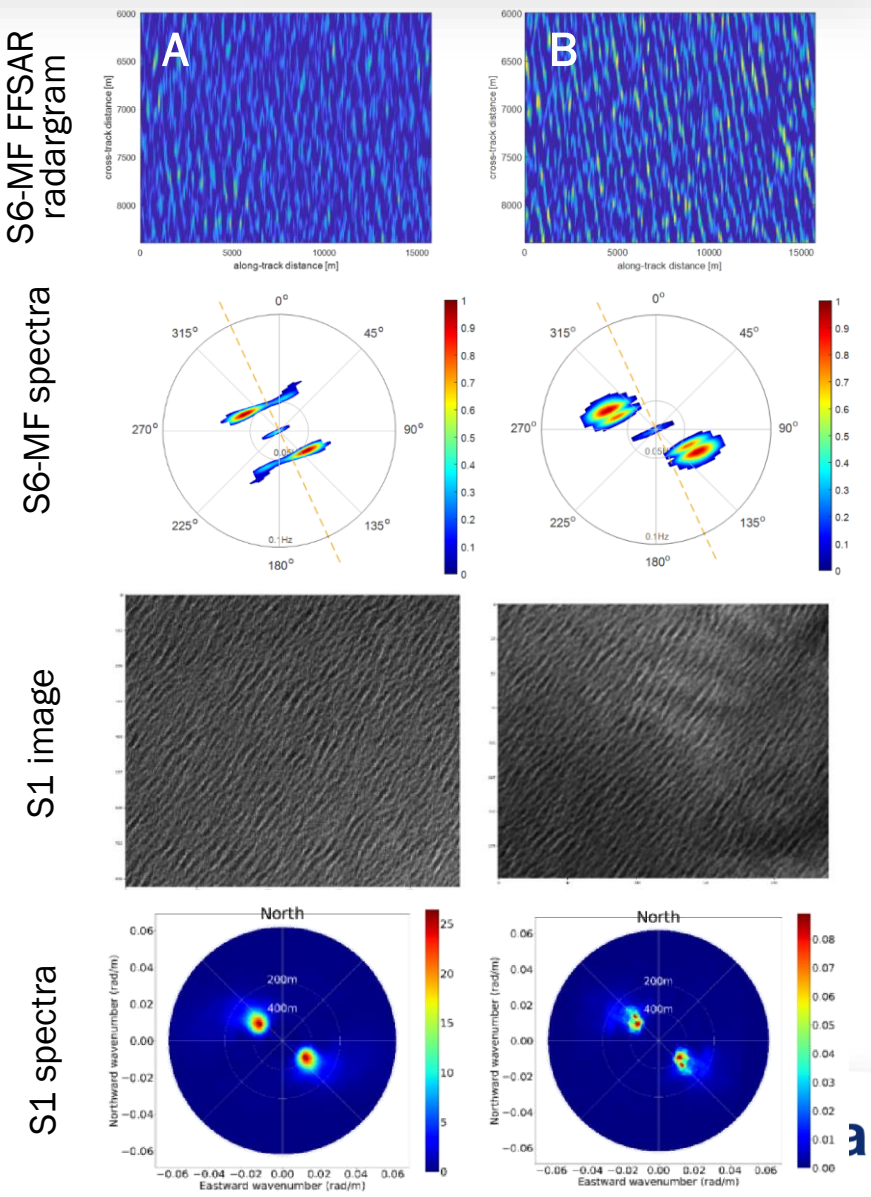
More details in Amraoui et al., in preparation

FF-SAR imagery for swell parameters retrieval

- **2D modulation spectra from S6-MF FFSAR data** allows swell parameter estimates: direction, amplitude and period [Altiparmaki et al., 2022] leading to new potential products and applications (e.g. assimilation in ocean wave models)

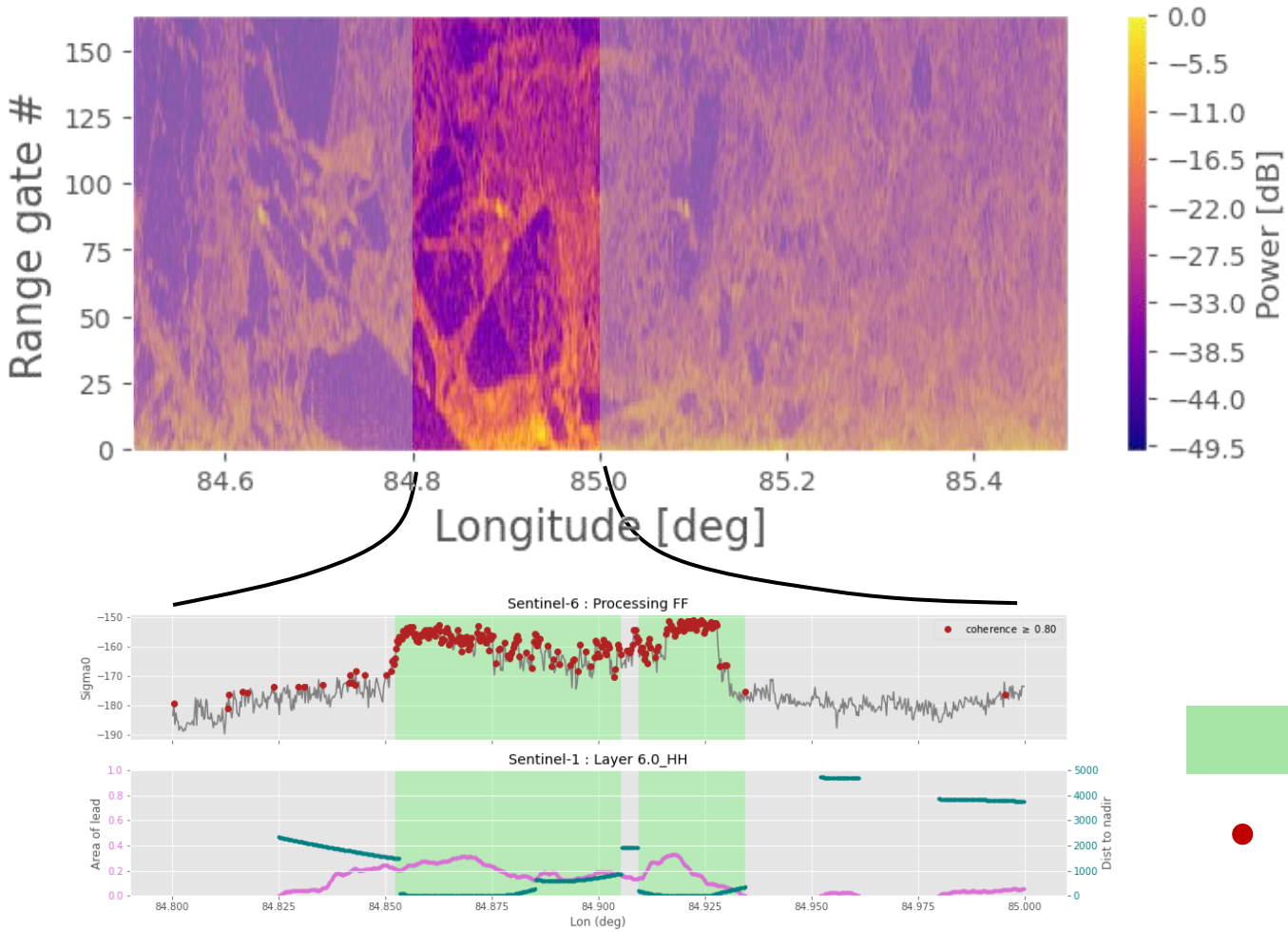


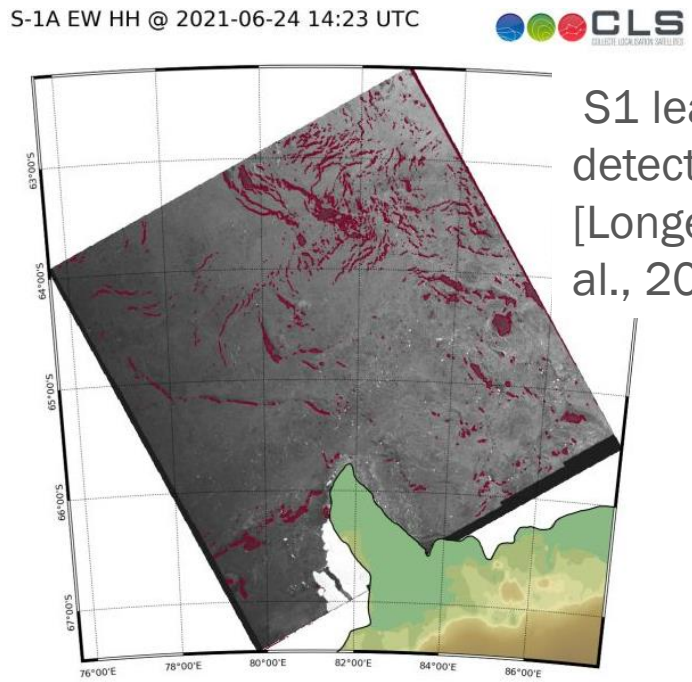
- Two additional peaks due to left/right ambiguity (on top of 180° ambiguity) can be eliminated in coastal region (case study from C. Maraldi) to ease comparison with S1 spectra



FF-SAR imagery for sea-ice leads detection

Good consistency between S6-MF FFSAR data and S1 data to detect sea-ice leads



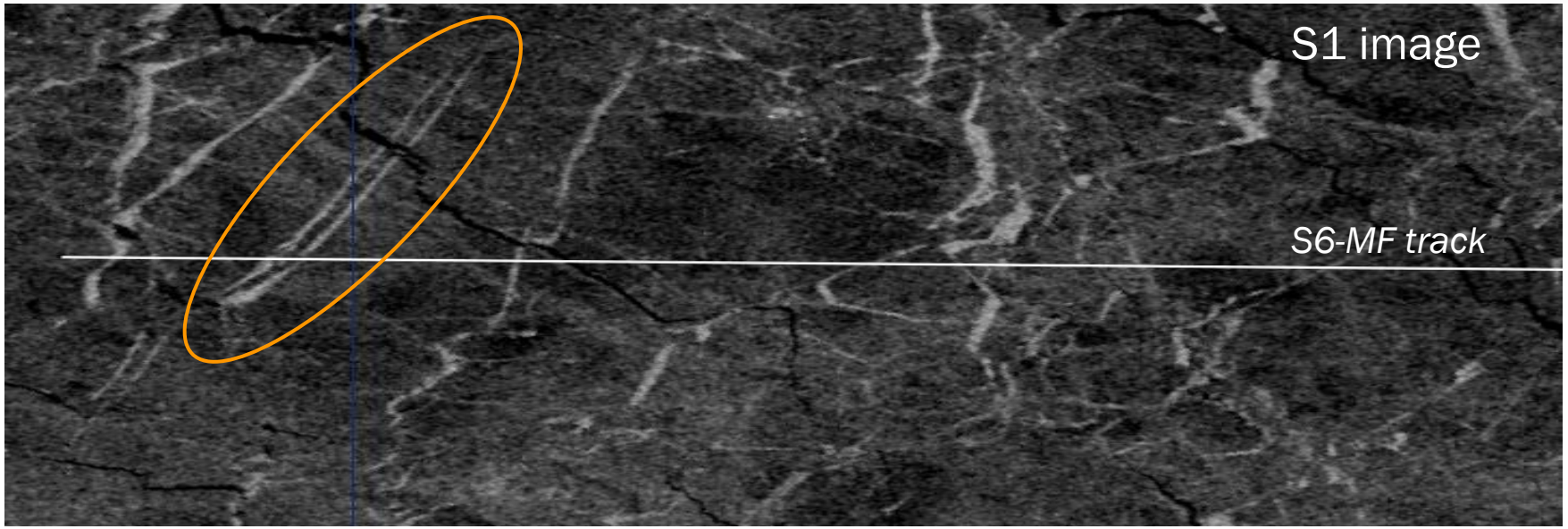


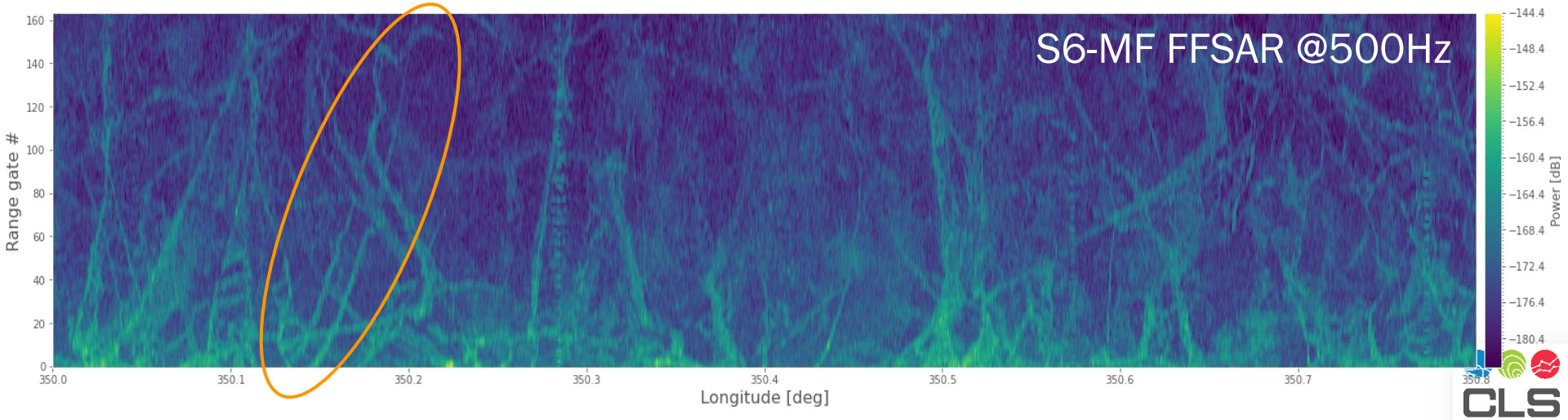
S1 leads detection [Longépé et al., 2019]

Sentinel-1 lead : area of lead <40% and distance to nadir <1500m

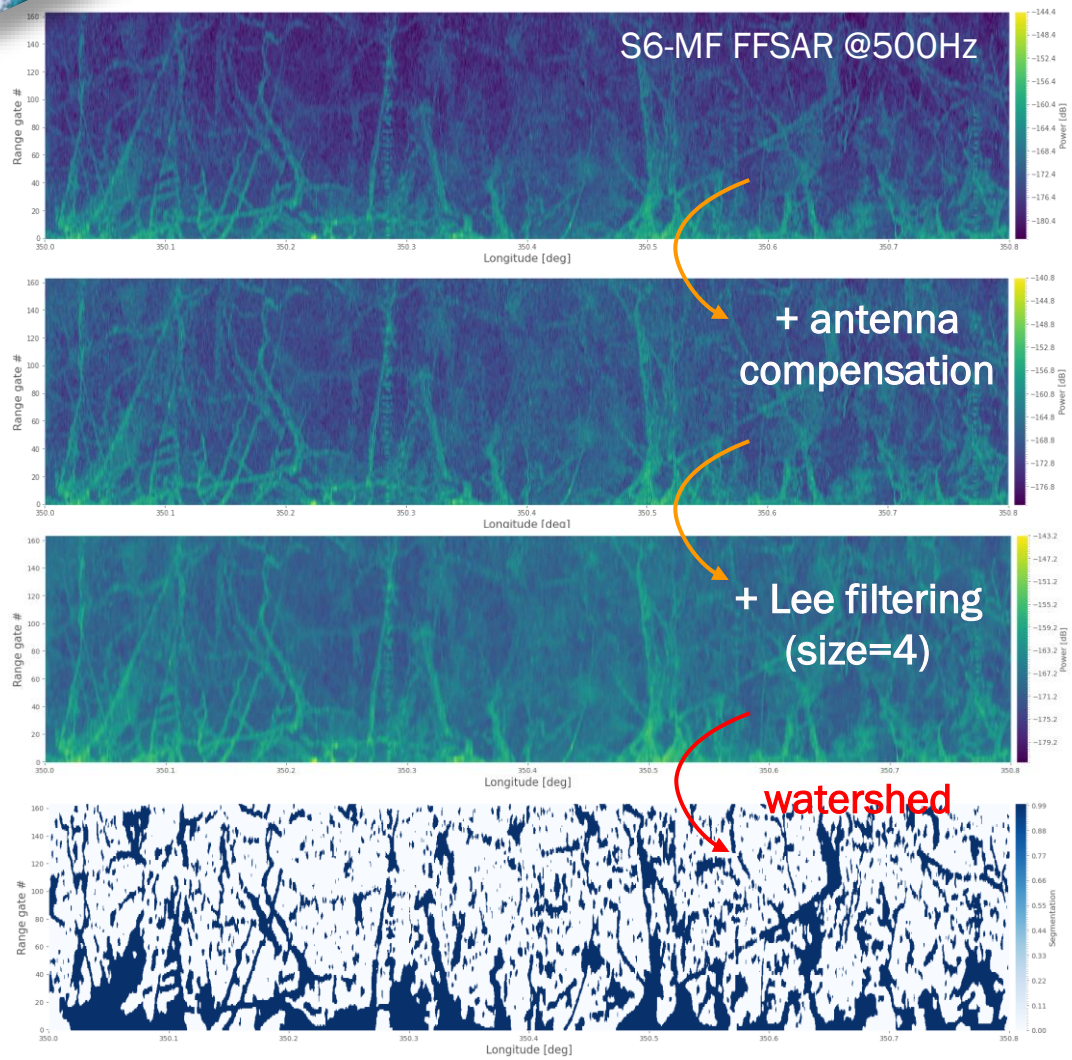
Sentinel-6 lead : coherence>0.8

FF-SAR imagery for sea-ice leads detection





FF-SAR imagery for sea-ice leads detection

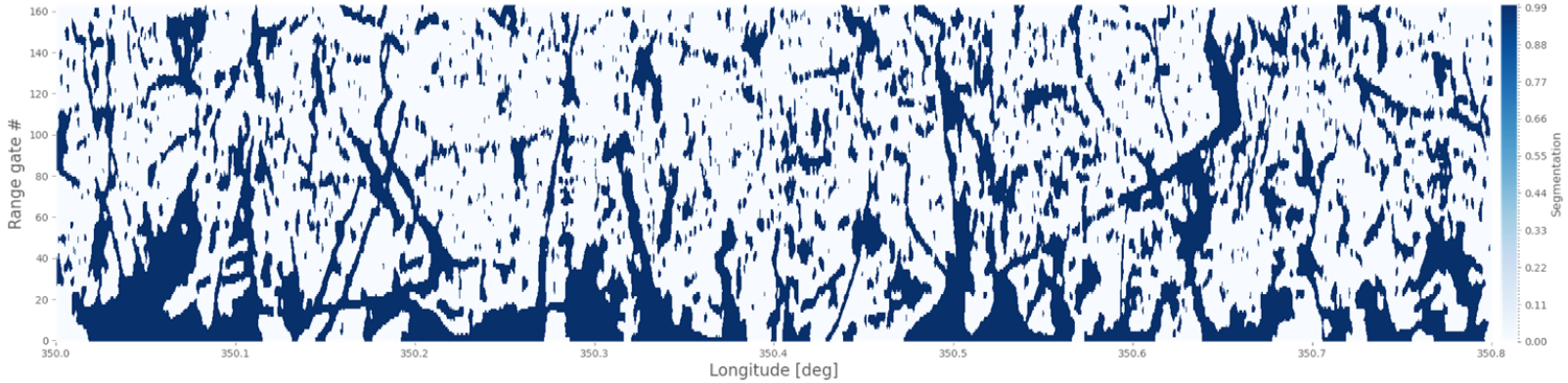


S1 lead detector can be adapted to S6-MF using the following methodology :

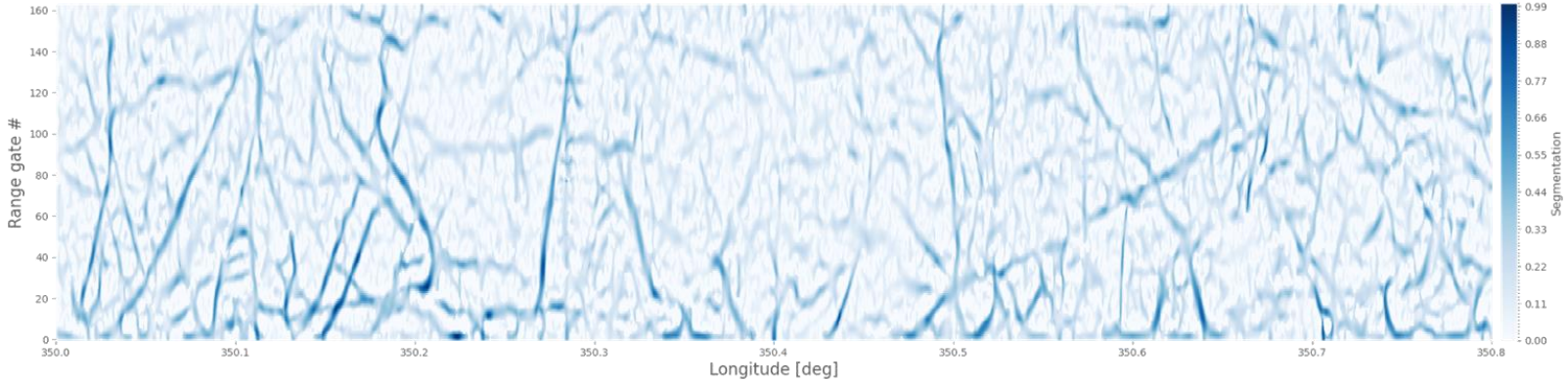
- To compensate the antenna gain to align the power in across-track direction
- To reduce the speckle noise by applying a Lee denoising filter to σ_0 values
- **Final watershed** lines are the segmentation of the filtered image into **leads and floes**

FF-SAR imagery for sea-ice leads detection

Watershed method (32% leads - 68% floes)



Ridge filter (12% leads - 88% floes) efficient for small lineic retrieval only

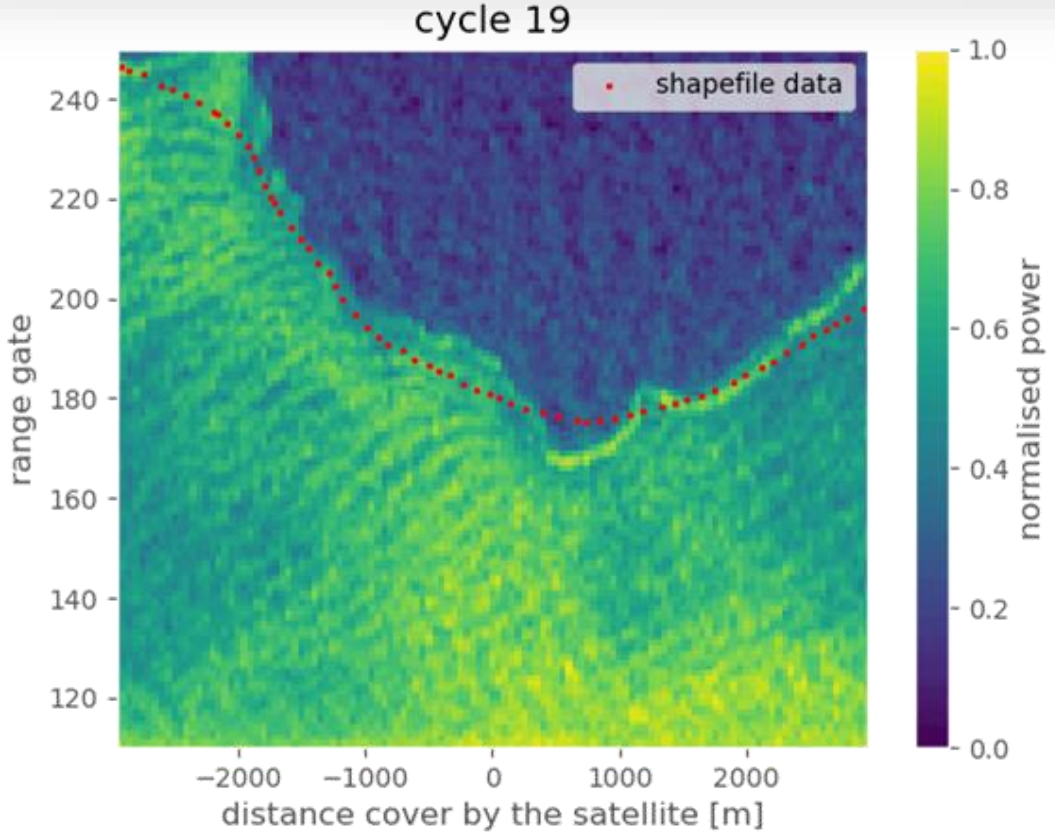


- 2D-view is an important source of information to know whether a sea-surface height is coming from a lead or a flow
- S6-MF imagery processing can also provide valuable information on **lead/floe coverage**

FF-SAR imagery for improved nearshore processing

Limitations of existing static files :

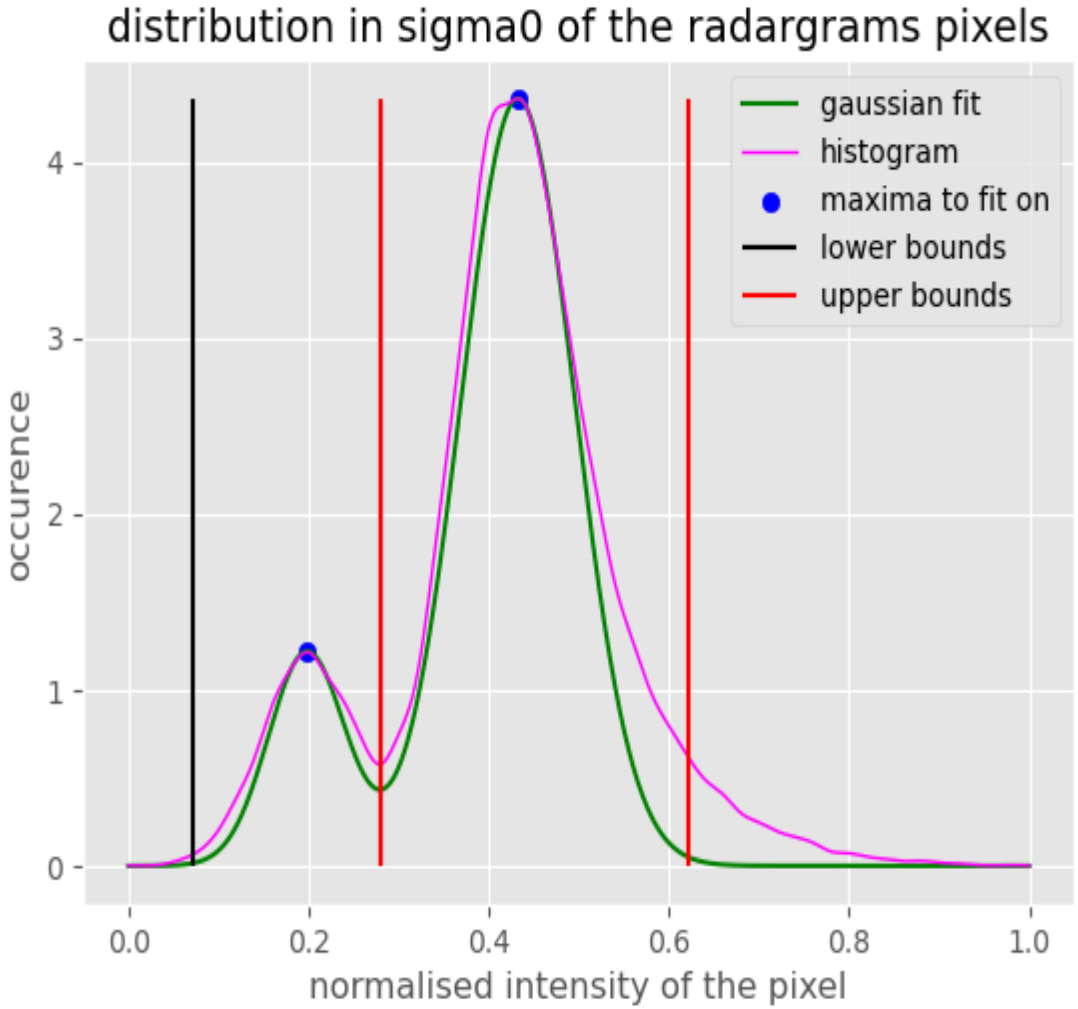
- **Inaccurate coastlines**
- Need accurate epoch estimate to position the coastline on the waveform
- Only inform on the position of land scatterers (of quite low reflectivity) and **not high specularity surfaces** (sandbanks, shallow waters ..)
- **Static in time and space**, not including natural phenomena such as tides or storms

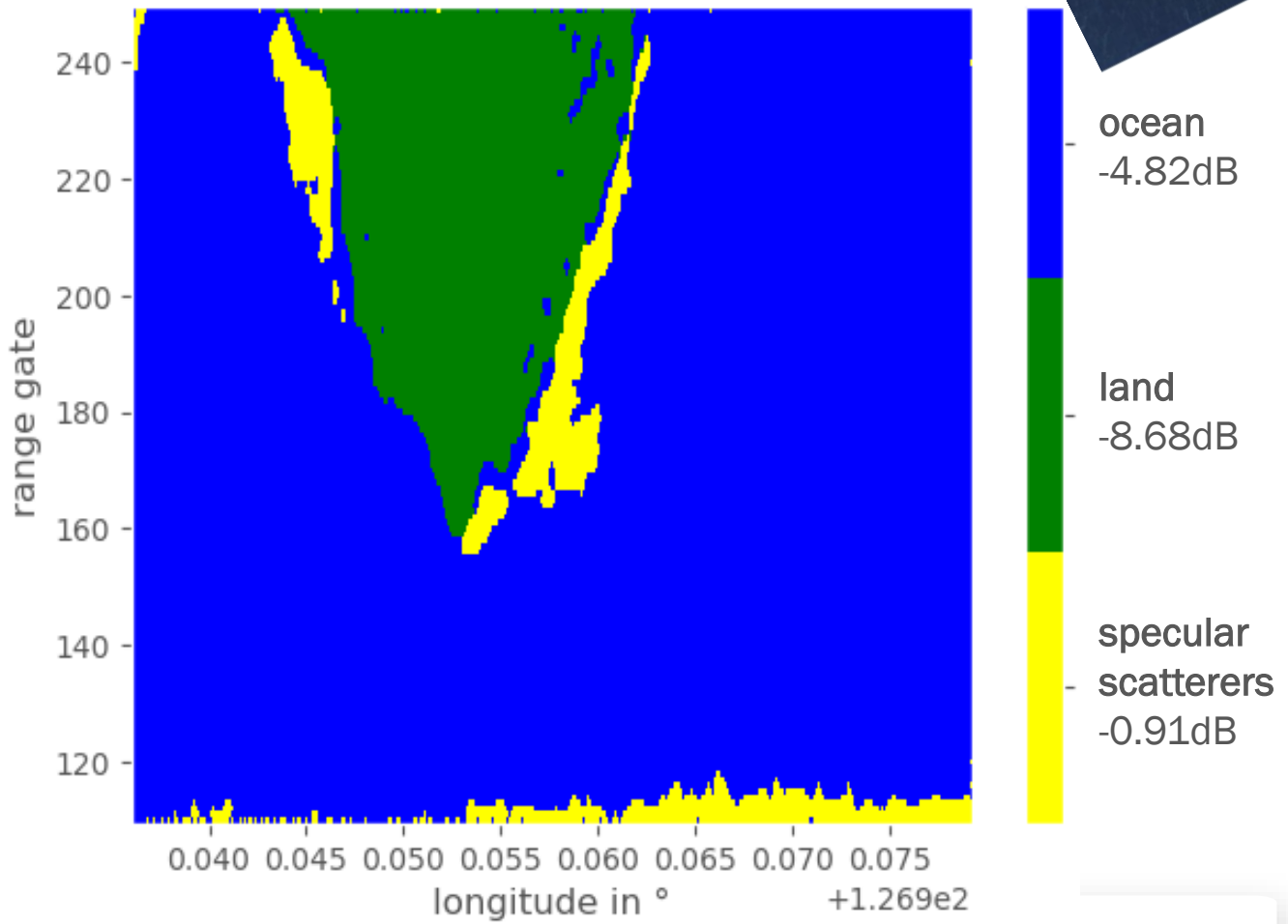


Development of a statistical distribution method :

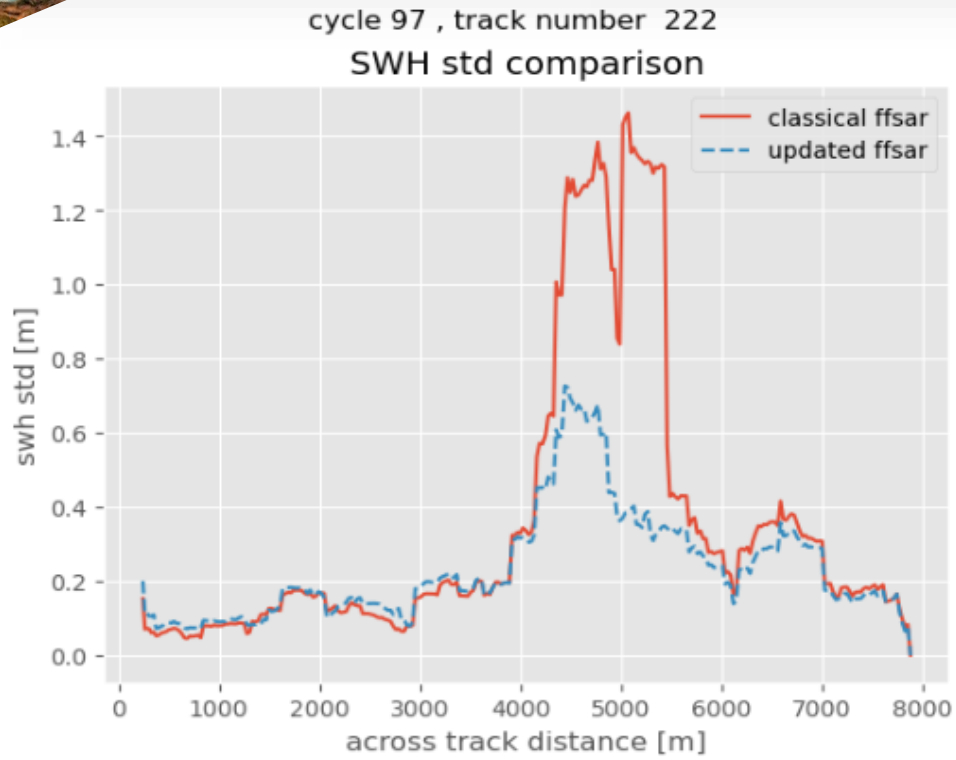
- Antenna gain compensation, filtering, point clouds classifier (σ_0 values)
- To distinguish features of different backscattering signatures
- And retrack only the identified ocean targets in the waveform

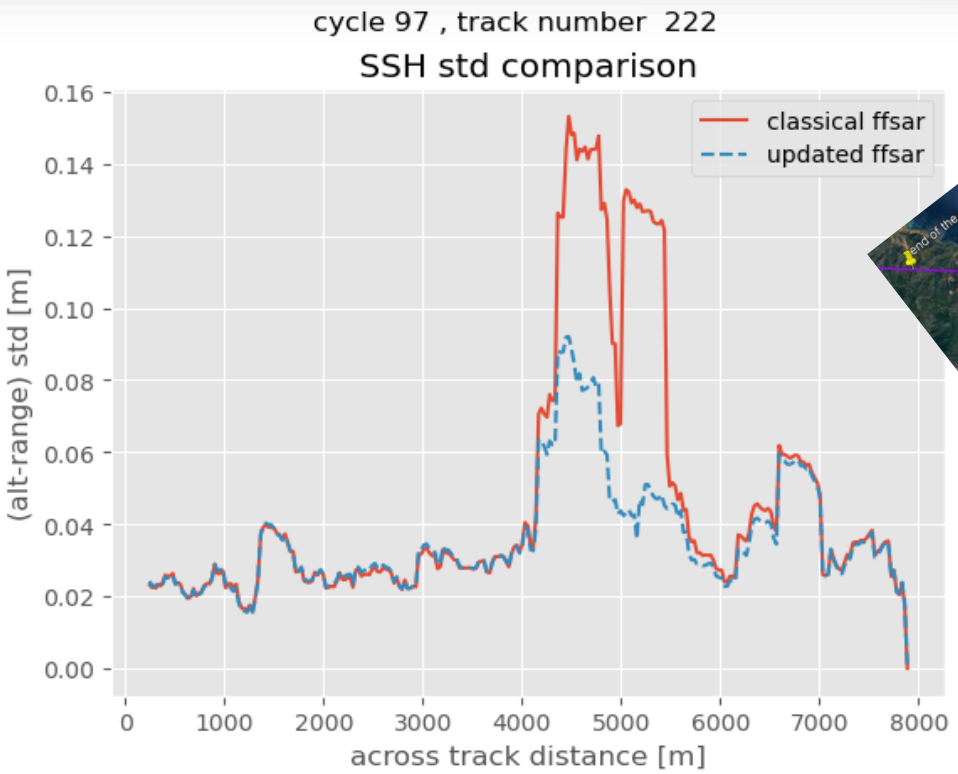
FF-SAR imagery for improved nearshore processing





FF-SAR imagery for improved nearshore processing

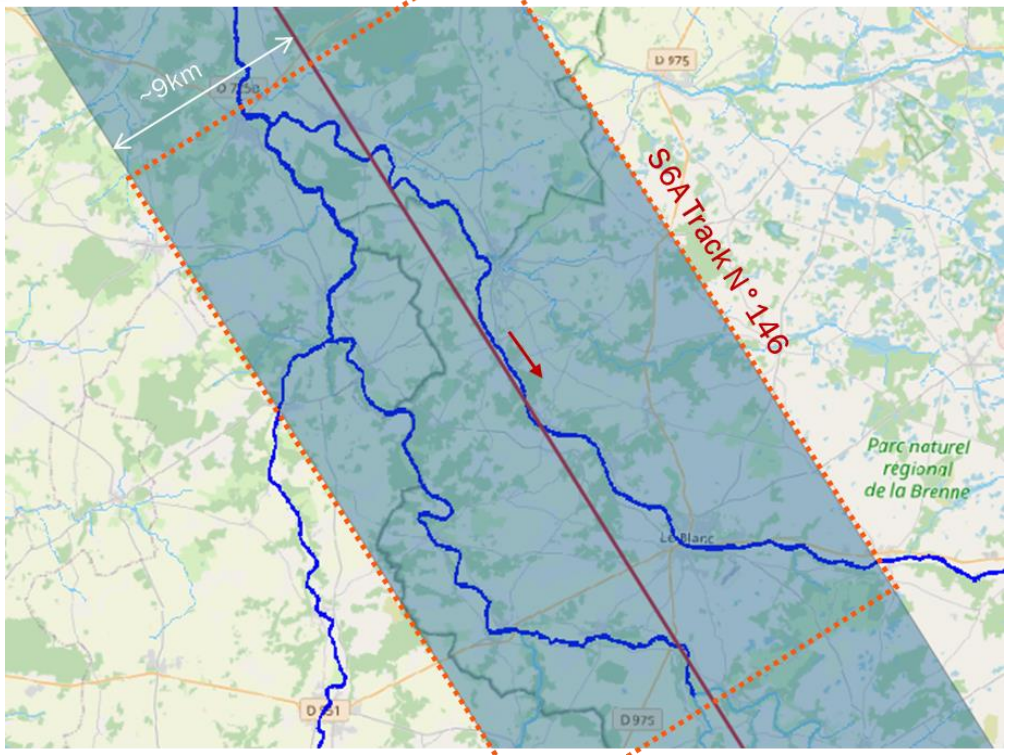


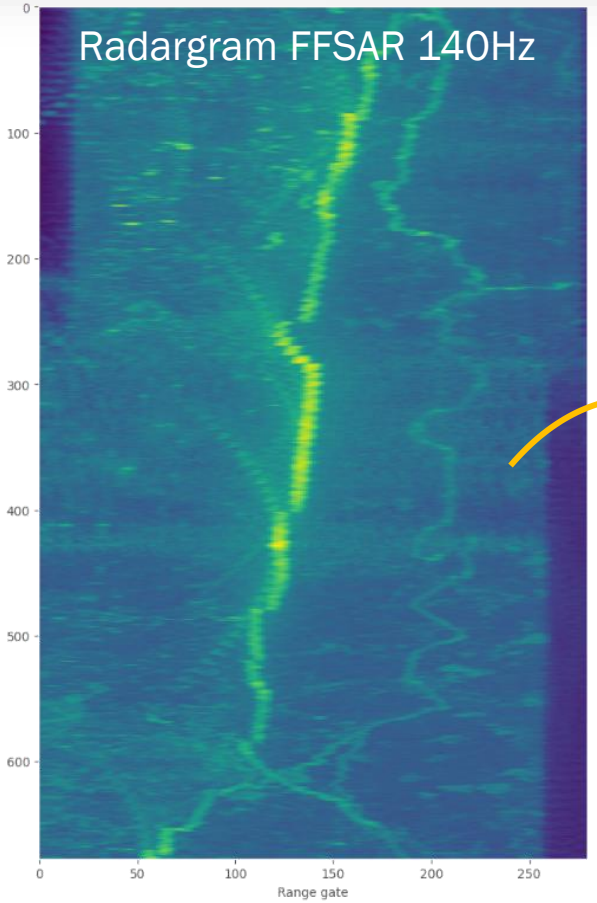


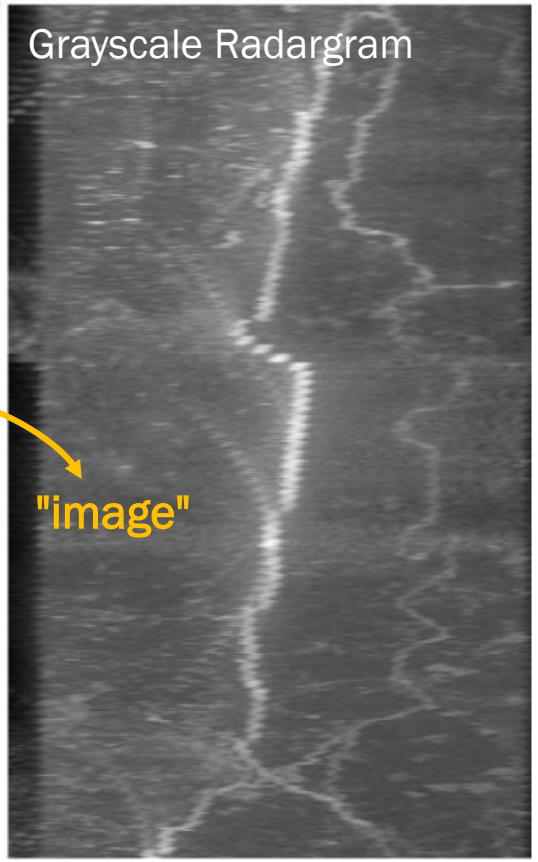
- Improve performance of parameter estimates thanks to a better robustness to specular points and mitigation of hooking effect
- To possibly estimate the dynamics of the coastal contours' changes (with marching square algorithm)
- See Ferrer et al., COA2023_002 poster

FF-SAR imagery for improved WSH estimate over rivers

Creuse River, France





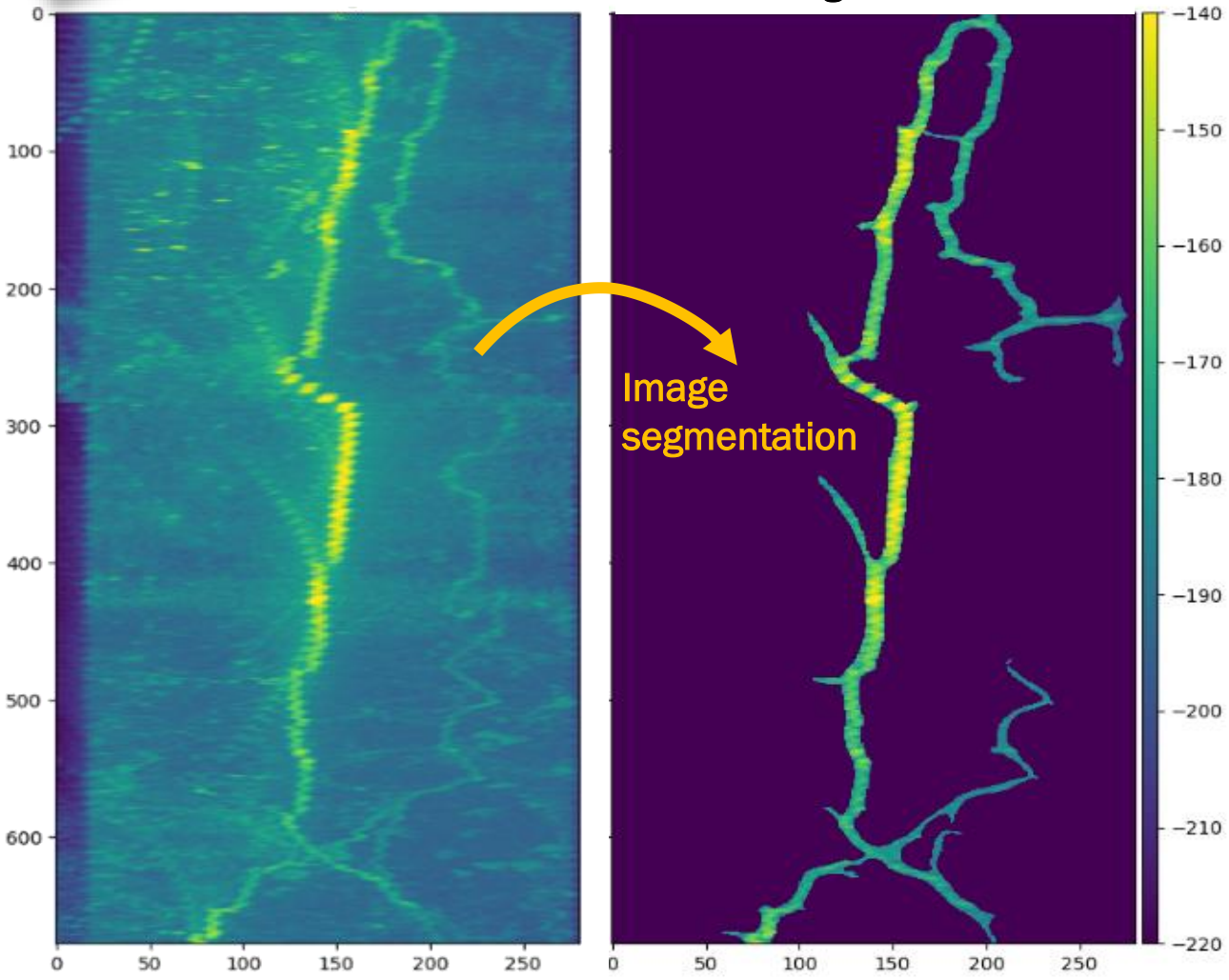


- Use of image processing technique to retrieve the nadir/off-nadir river signal among complex multiscatter scene
- See Daguzé et al. in Forums Sessions (IP: Measurement and Retracking)

FF-SAR imagery for improved WSH estimate over rivers

Radargram FFSAR 140Hz

Target mask



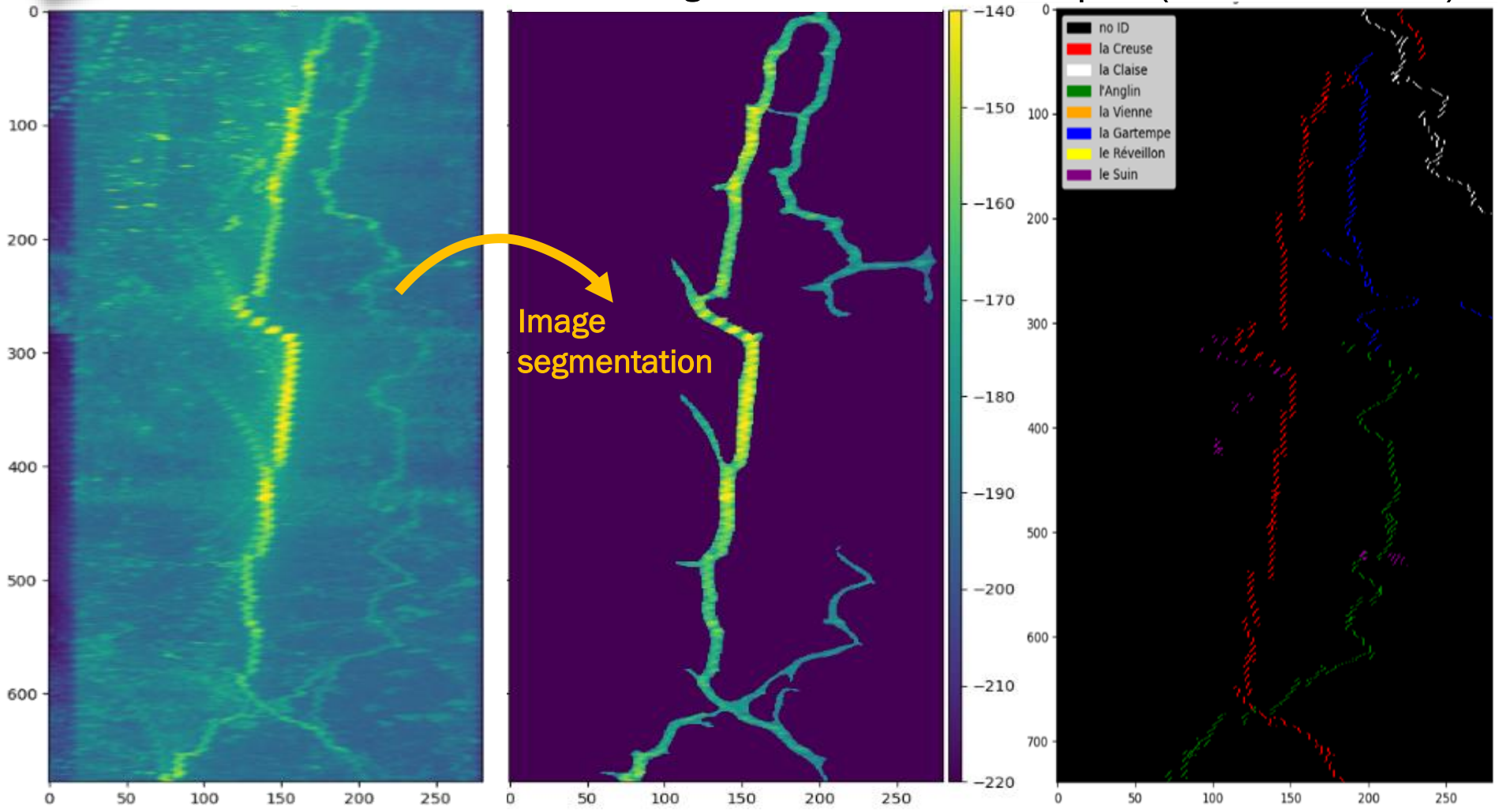
FF-SAR imagery for improved WSH estimate over rivers

Radargram FFSAR 140Hz

Target mask

Image segmentation

Echo simulation using a priori (elevation & contour)



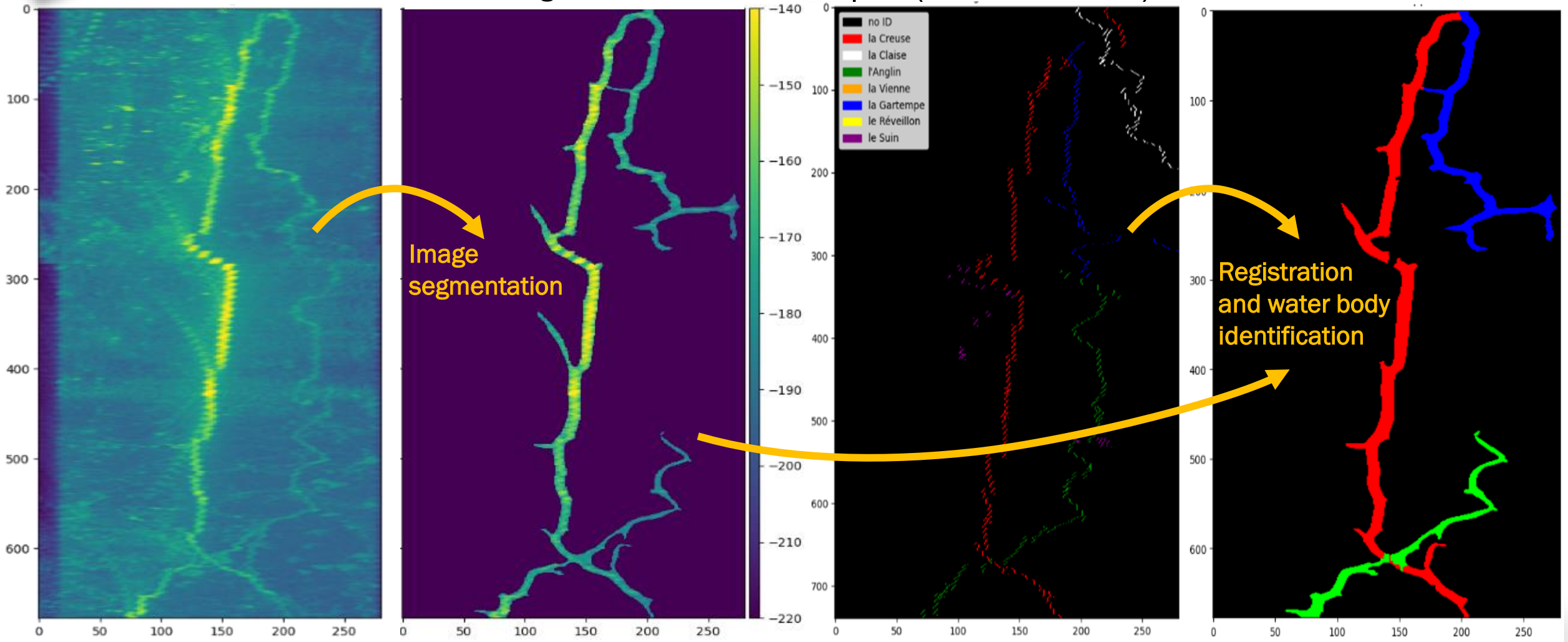
FF-SAR imagery for improved WSH estimate over rivers

Radargram FFSAR 140Hz

Target mask

Echo simulation using a priori (elevation & contour)

Target mask filled-in with watershed



Conclusions

- **Imagery with FF-SAR data offers new possibilities and perspectives in nadir-pointing radar altimetry**, opening up avenues for new applications and products over different surfaces (open ocean, coastal, open water leads, rivers/lakes and possibly land ice)
- It requires however the altimeter **to operate with a strict interleaved pulse arrangement** to fully exploit the capabilities of this technique, but also **needs enhanced on-ground computational resources** to allow such processing
- **Studies continue with CNES to actively pursue the exploitation of the FFSAR imagery paving the way for a new altimeter era**

THANK YOU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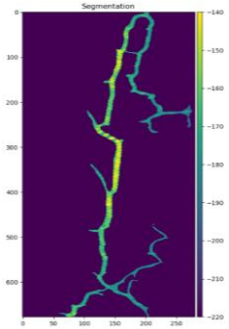
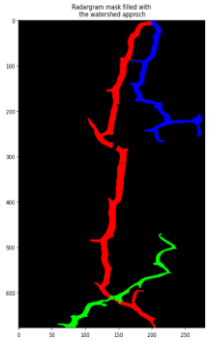
FF-SAR imagery for improved WSH estimate over rivers

- *Processing scheme*



River mask



Water body mask

Radargram

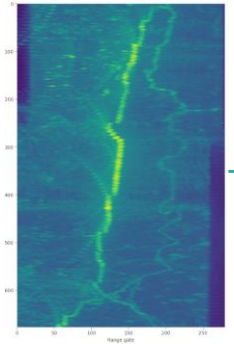


Image Segmentation

Echo simulation for water bodies in the scene

Shapefile of contours
Geophy. corrections
Config. param

Image registration and water body identification

Retracking algorithm
(with appropriate slant range correction)

Water Surface Height (WSH) nadir and off-nadir !