OSTST 2023

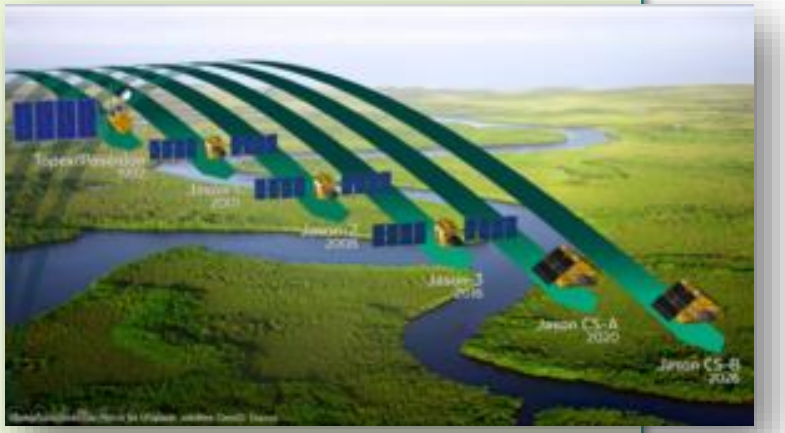
Using image processing technique to detect inland water bodies in S6-MF Fully-Focused SAR radargrams and improve water surface height retrieval

J.A. Daguzé[1], G. Calassou[1], S. Le Gac[2], F. Boy[2]
[1] CLS, [2] CNES

FF-SAR imagery for improved WSH estimate over rivers

The Rationale

In the last decades, space radar altimetry over inland water has become a major challenge. In particular, many efforts have been made to retrieve water level over rivers from complex nadir measurements due to heterogeneous backscattering scene. The water level is currently computed only at the intersections of the river network with the satellite ground track, so-called Virtual Station (VS). Time series are then computed at VS and made available widely for users via services like https://land.copernicus.eu/global/products/wl or https://hydroweb.theia-land.fr/.



But recent development of Fully-Focused Synthetic Aperture Radar (FF-SAR, [Egido and Smith, 2017]) altimetry offer new exiting perspectives over inland water because of its high along-track resolution and good signal-to-noise ratio (SNR). Looking at FF-SAR data over a case study, we intend here to exploit the nadir and off-nadir (cross-track direction) river signal in the 2D radargrams to retrieve the water surface height as long as the SNR and the tracking window allow it.

For that purpose, we tried to exploit the FF-SAR "image" over the Creuse River (CNES R&D study).

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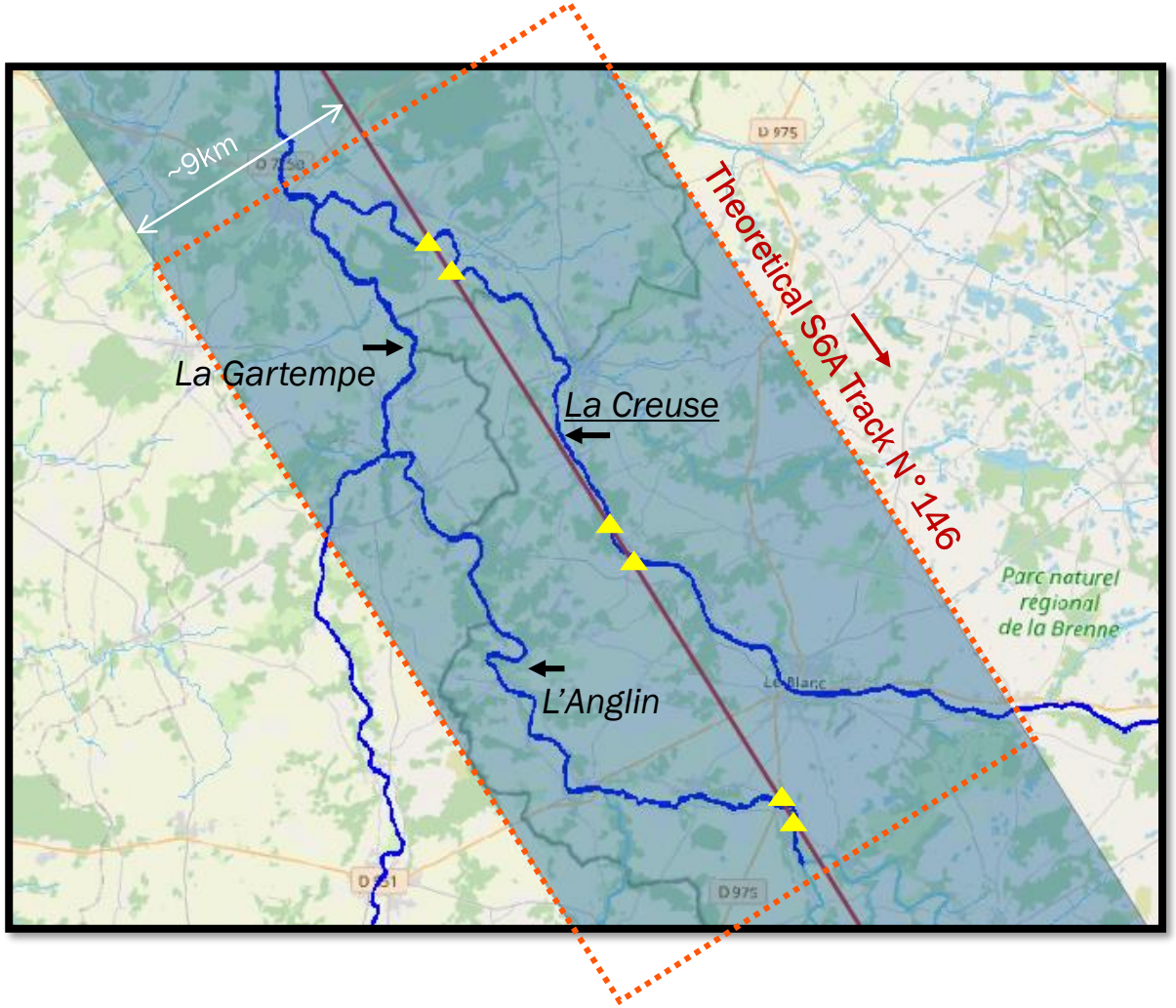
Case study :
Creuse River, France



Theoretical virtual station considering today's definition

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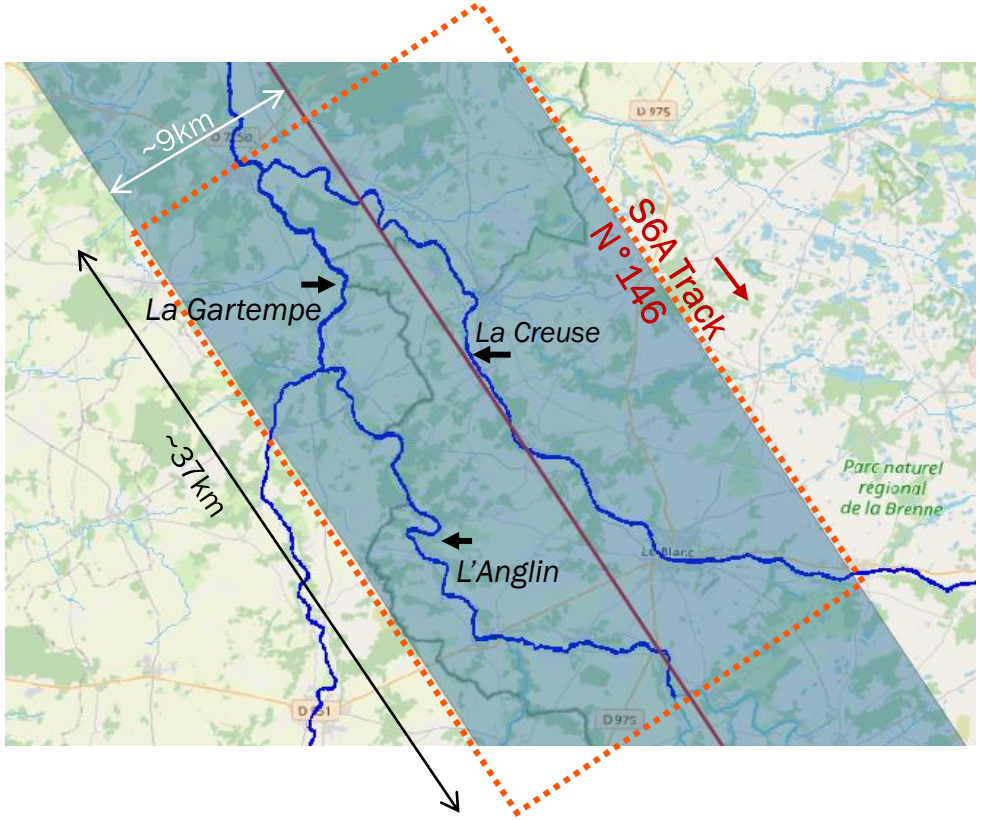
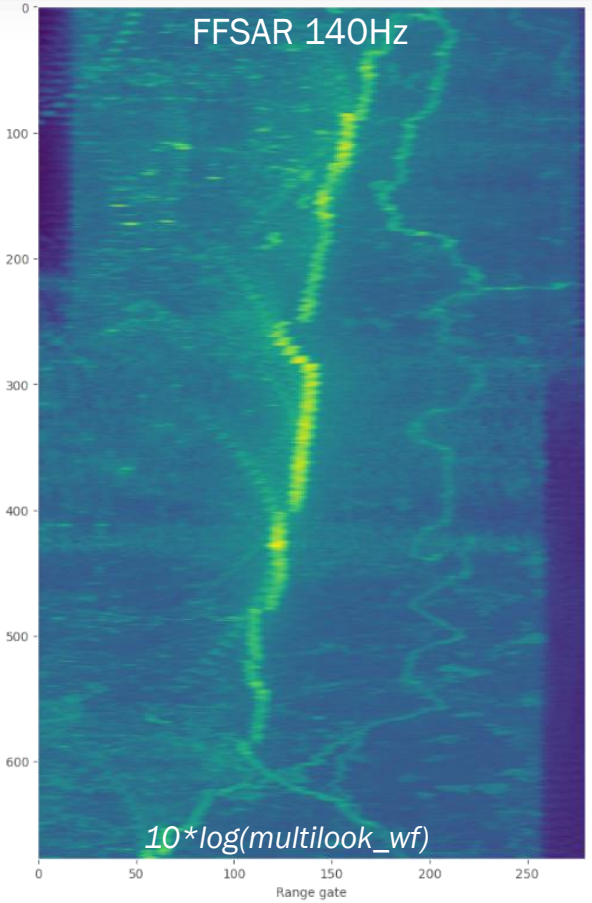
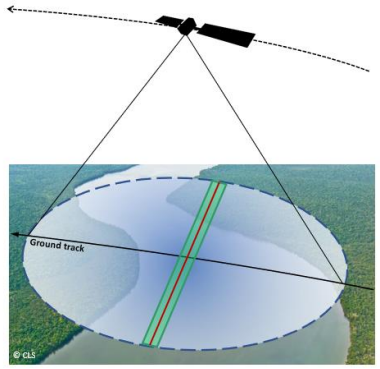
Creuse River, France





❖ Region of Interest (ROI):

- **Latitude** (°) = [46.59; 46.80]
- **Transect**: ~37km (S6-MF track N°146, cycle 40)
- **Level-1b** processing: Fully-Focused SAR (using Omega-Kappa (WK) algorithm [Guccione et al., 2018])
- **FFSAR** configuration:
  - Sampling = 140Hz (spacing ~59m)
  - Range/azimuth windowing (Gaussian)
- **Nb** of multilooked waveform = 678
- **Waveform** range domain: [0-280] gates (RMC acquisition mode)



Conventional Altimetry
16 km of diameter

Unfocused SAR
~300 m in along-track direction
(450 m with Hamming window)
16 km in across-track direction

FF-SAR
~50 cm in along-track direction
16 km in across-track direction

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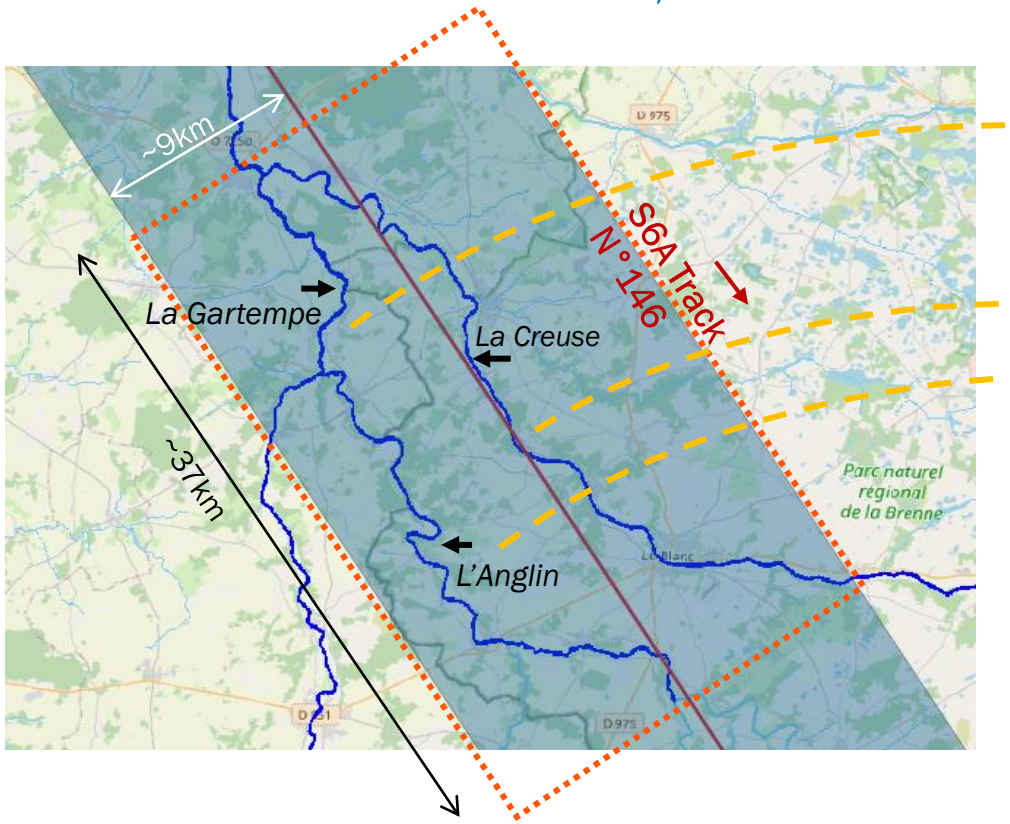
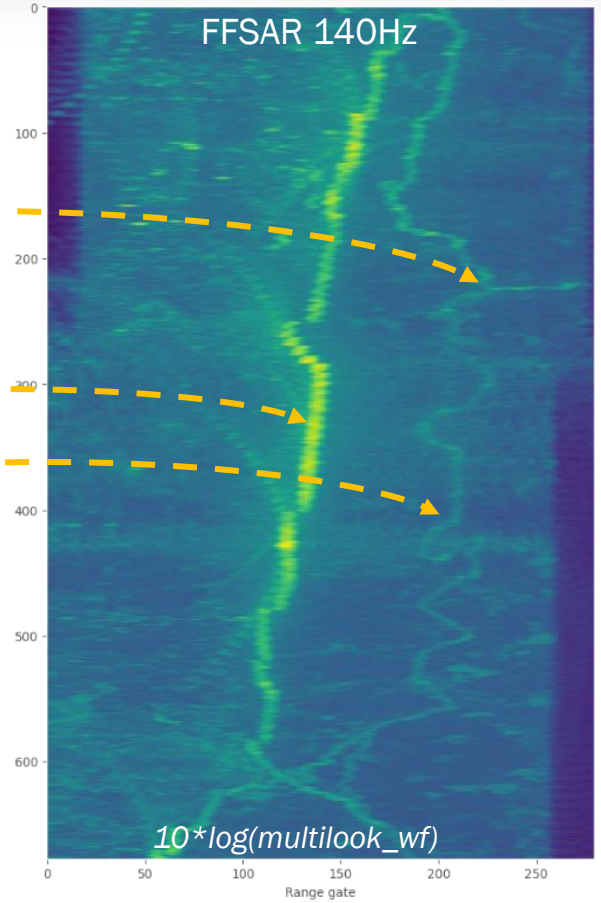
Creuse River, France





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- Level-1b processing: Fully-Focused SAR (using SMAP processor)
- FFSAR configuration:
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  - Azimuth windowing (Gaussian)
- Nb of multilooked waveform = 678
- Waveform range domain: [0-280] gates (RMC acquisition mode)

River's signals and features emerge at off-nadir range gates !

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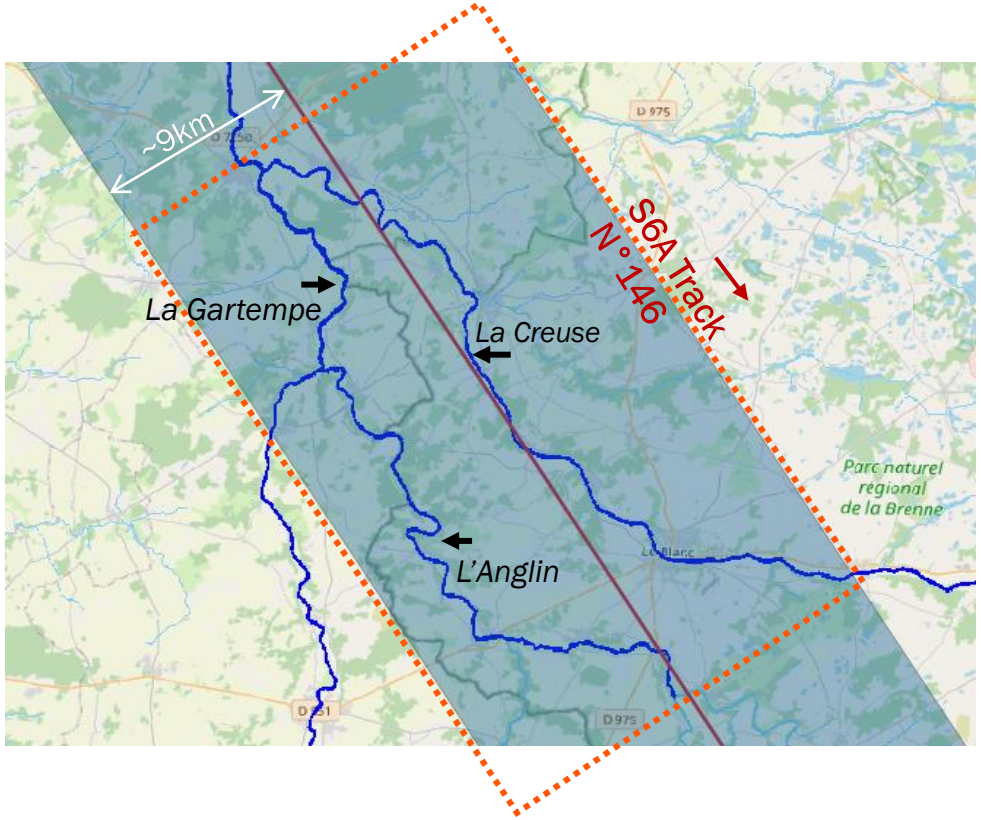
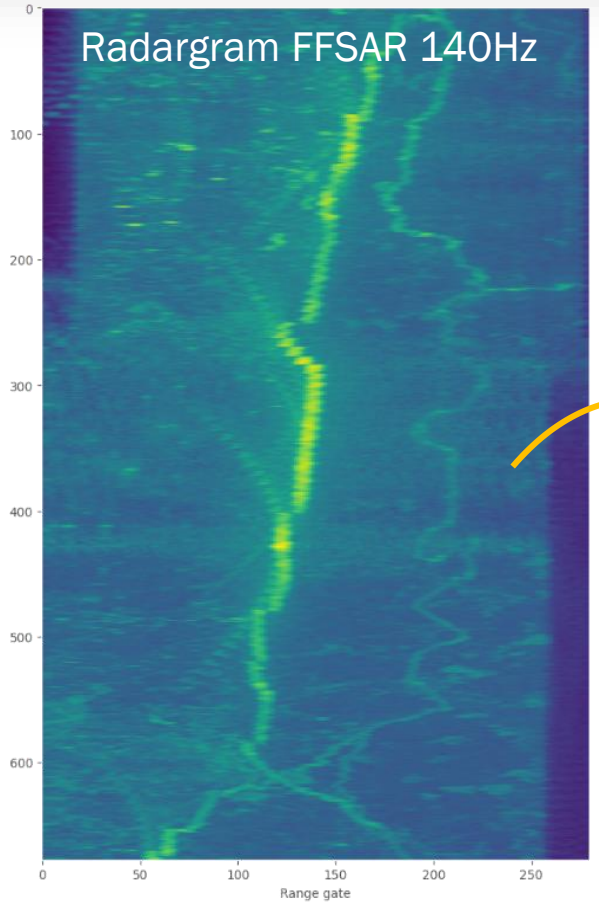
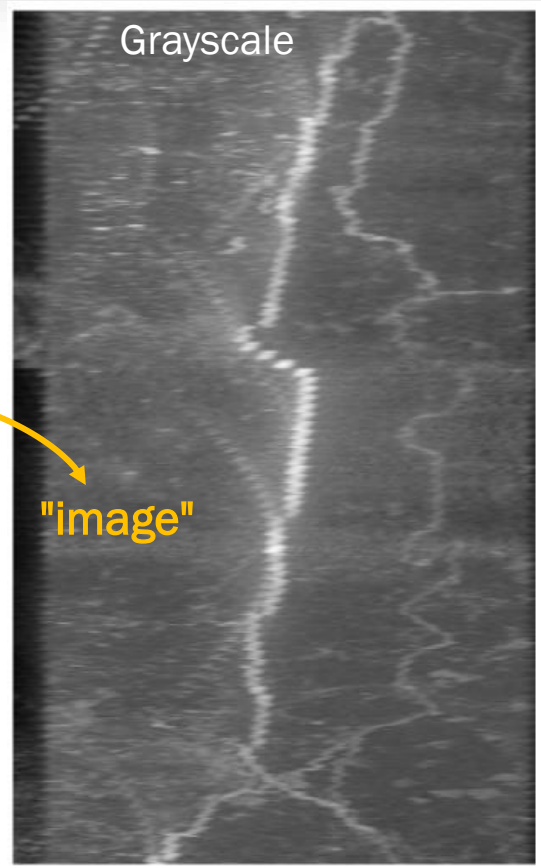
Creuse River, France







Question 1: How to use image processing technique to isolate the nadir and off-nadir river signal from a complex multiscatter scene

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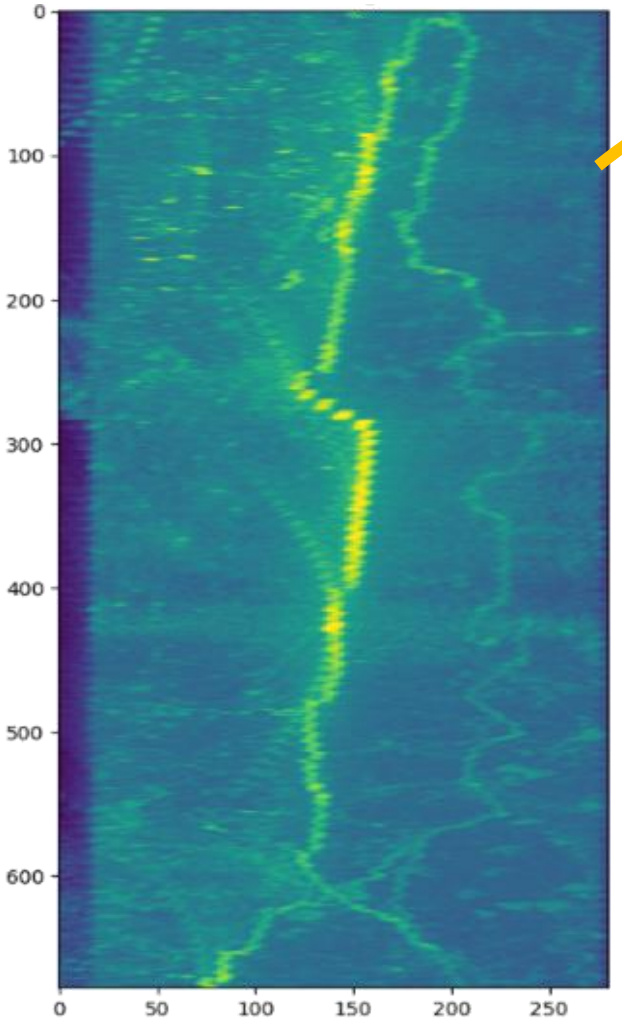
Radargram FFSAR 140Hz

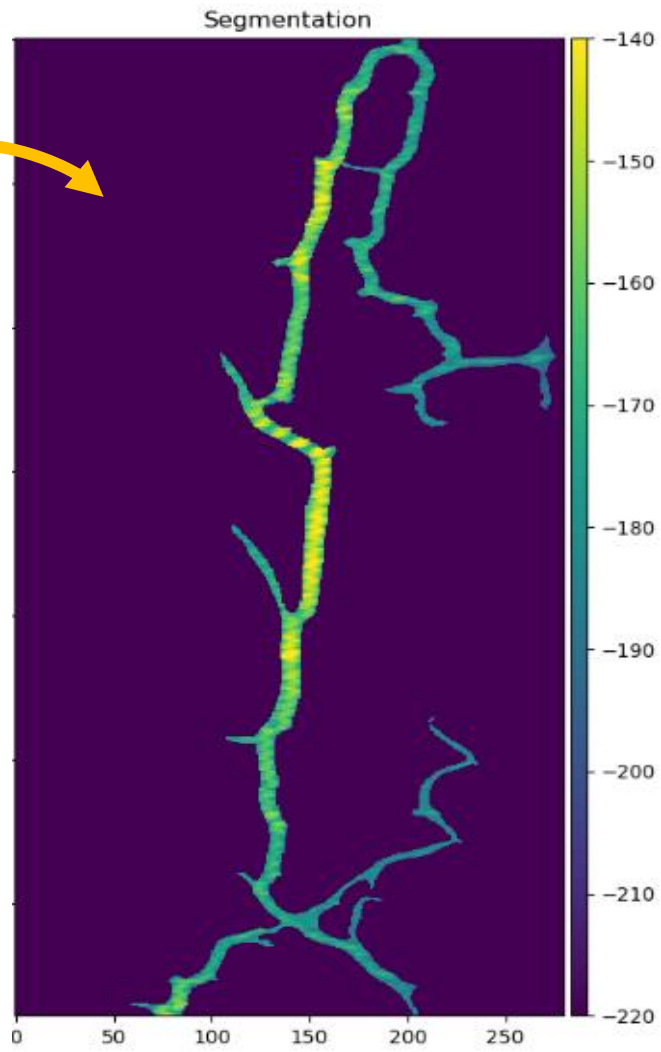


Segmentation strategy:

1. *Log scaling*
2. *Contrast stretching*
3. *Sato filtering,* *https://doi.org/10.1016/S1361-8415(98)80009-1)*
4. *Hysteresis thresholding*
5. *Keep the N longest*
6. *Medial axis (skeleton)*

Binary mask

Segmented image



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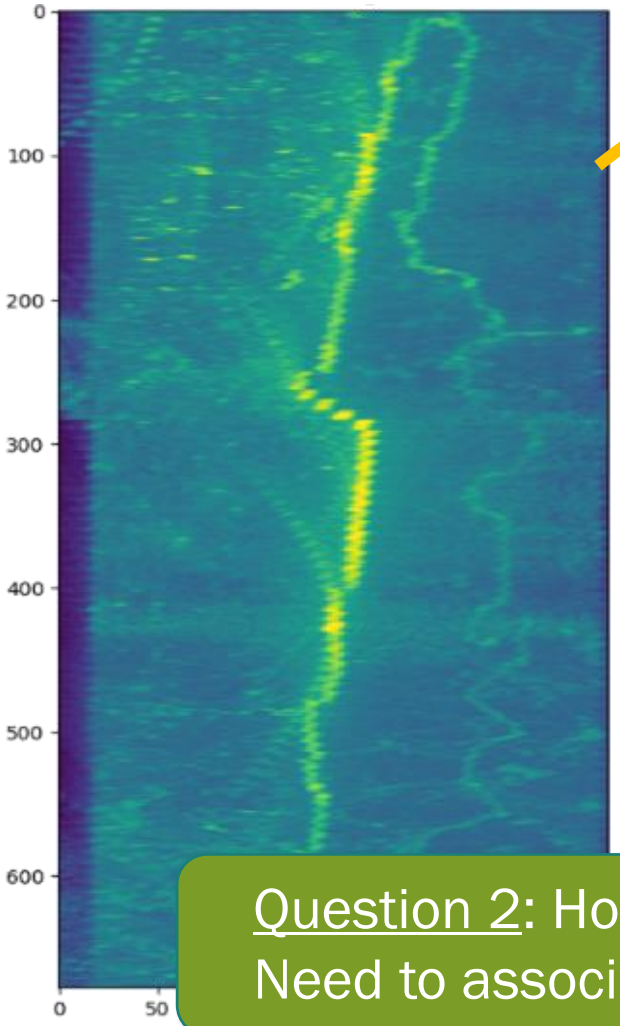
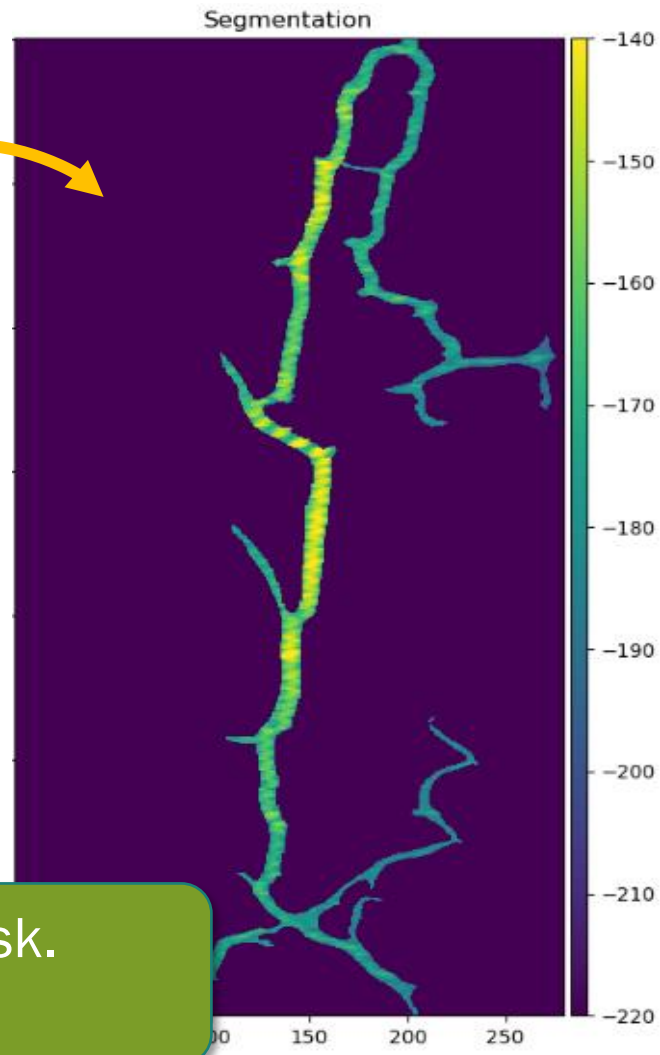
Radargram FFSAR 140Hz



Binary mask

Segmented image



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Question 2: How to separate selected water bodies within the mask. Need to associated IDs from external database.

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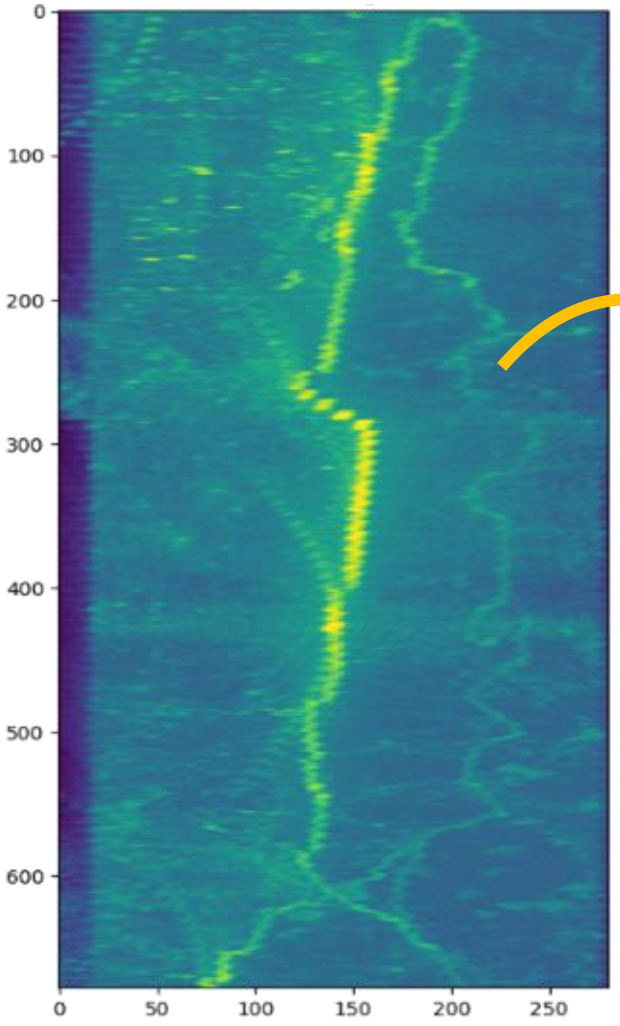
Radargram FFSAR 140Hz



Target mask

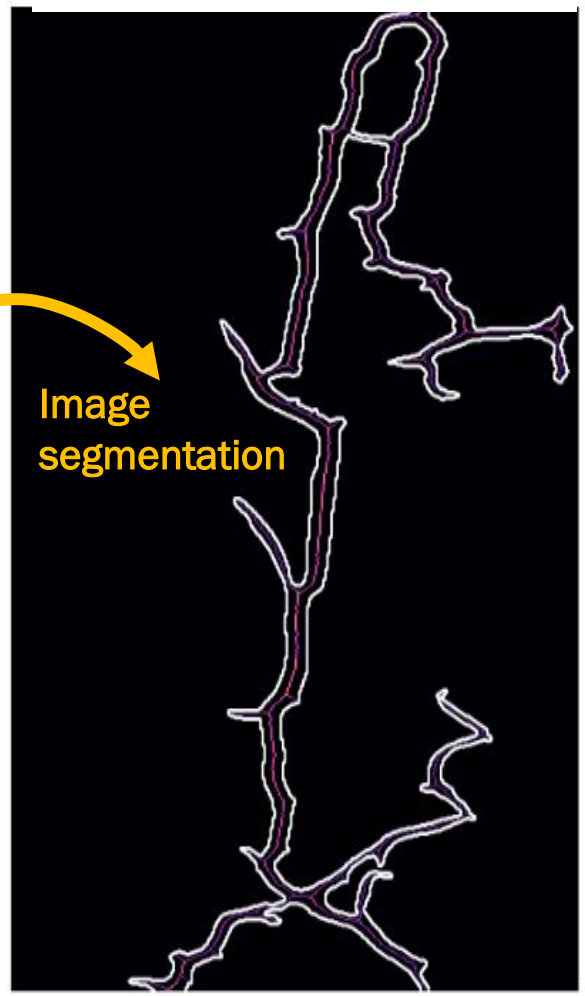
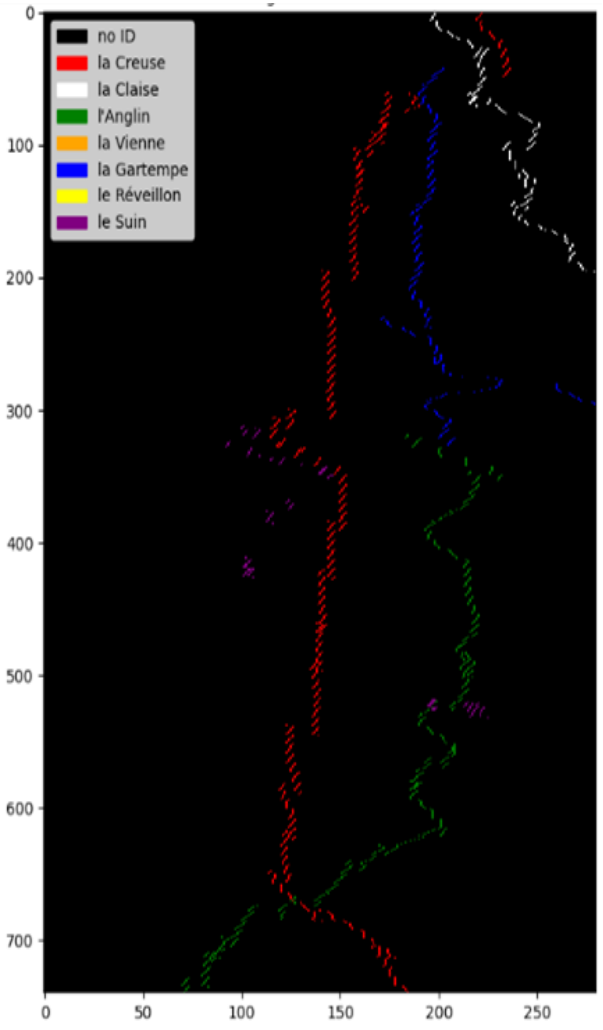


Image segmentation

Echo simulation using a priori



Using:

1. Static elevation
2. Contour (polygone)
3. IDs of each node corresponding to rivers

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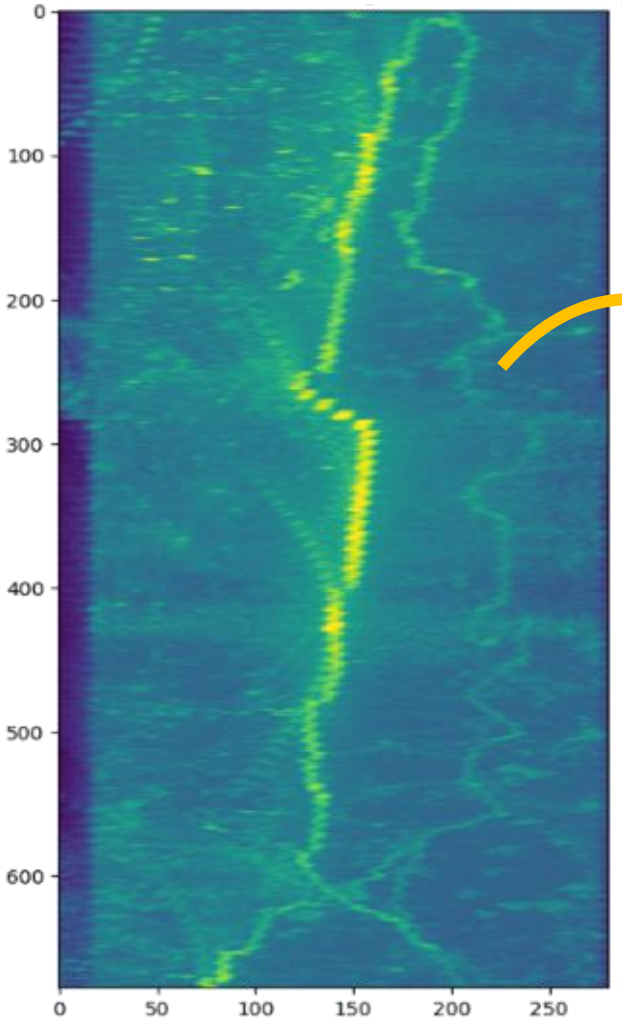
Radargram FFSAR 140Hz



Target mask

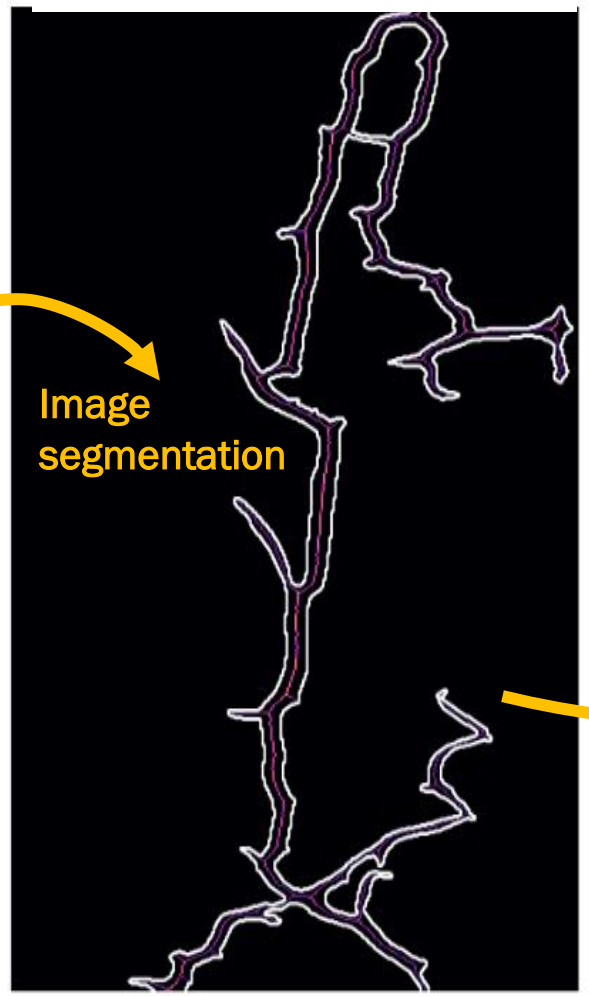
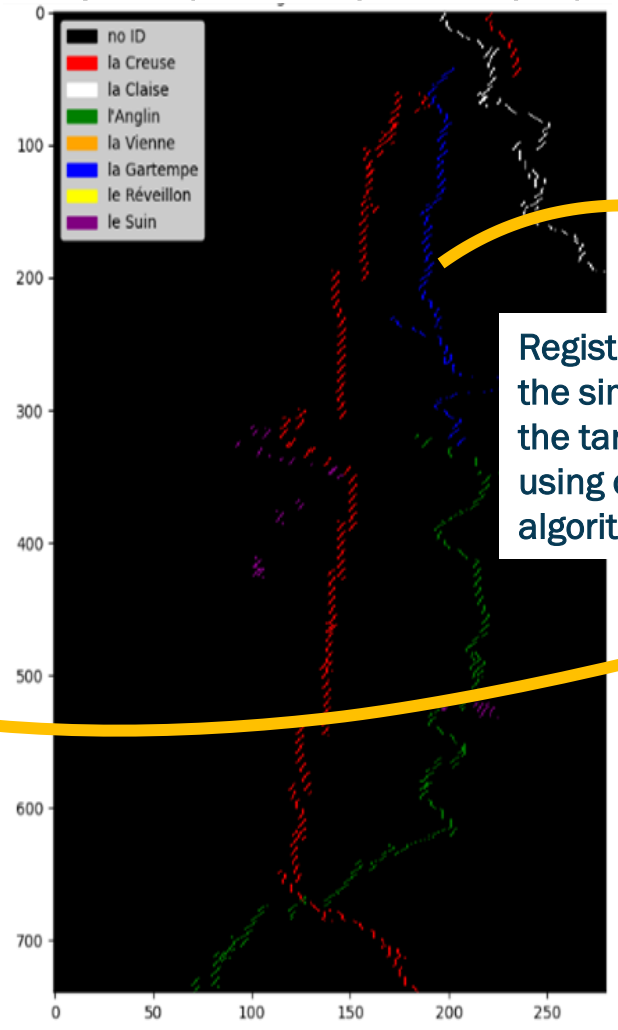


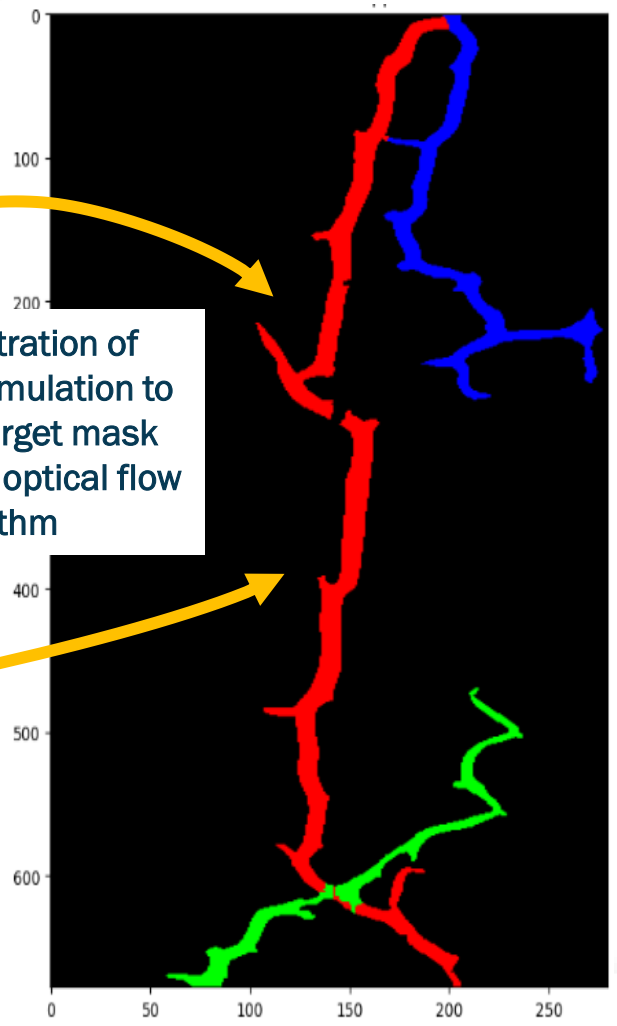
Image segmentation

Echo simulation using a priori (elevation/contour/ID)



Registration of the simulation to the target mask using optical flow algorithm

Target mask filled-in with Ids using watershed tech.



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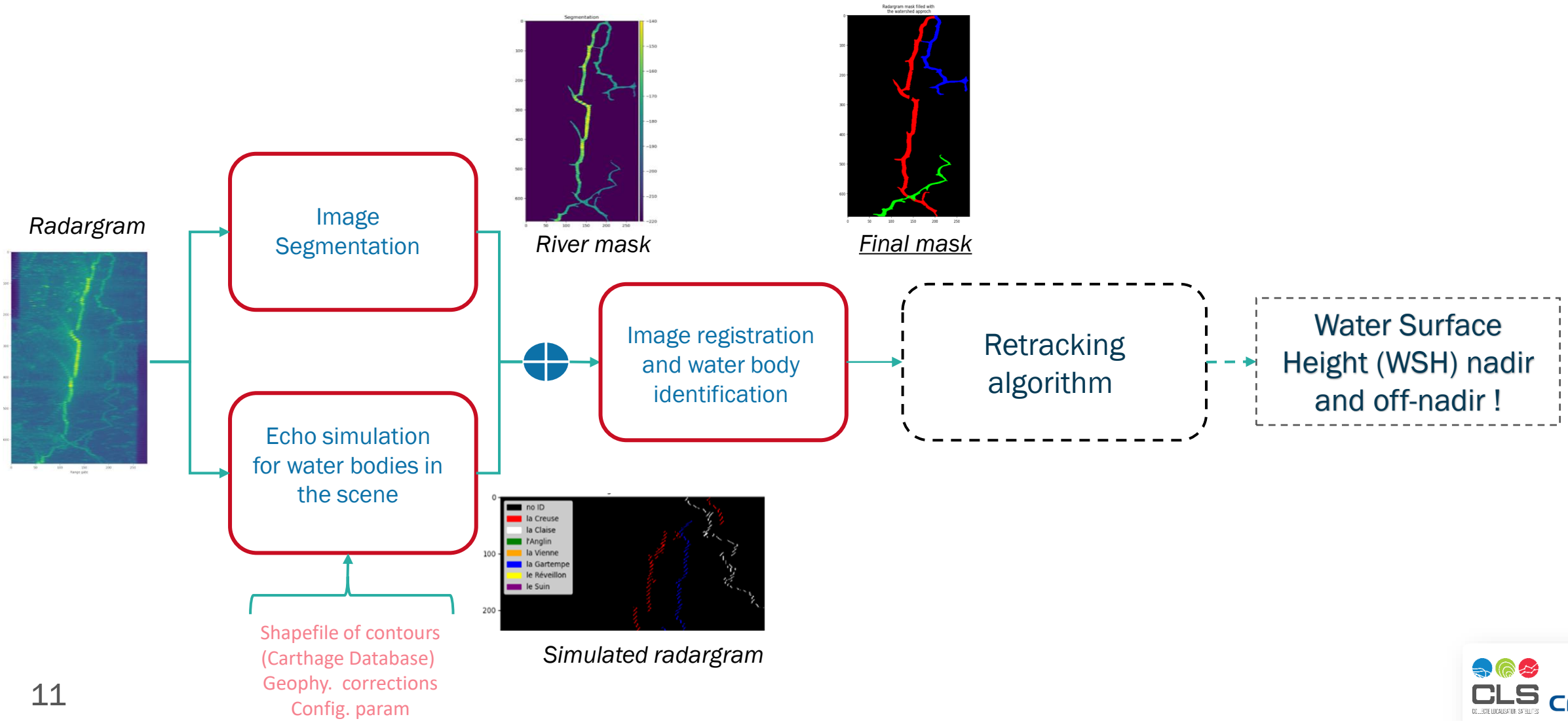
- ***Summary of the processing scheme***



FF-SAR imagery for improved WSH estimate over rivers

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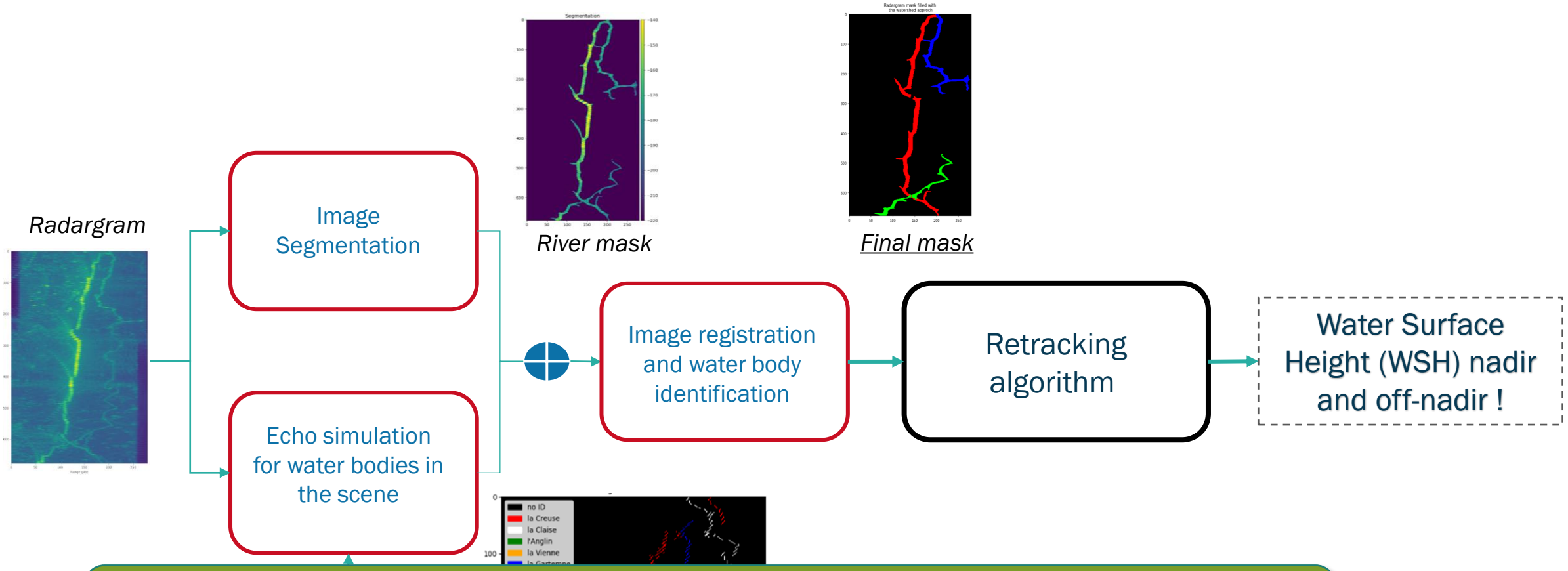

Question 3: How to retrieve water level of the selected rivers: Toward the retracking process.

Geophy. corrections
Config. param

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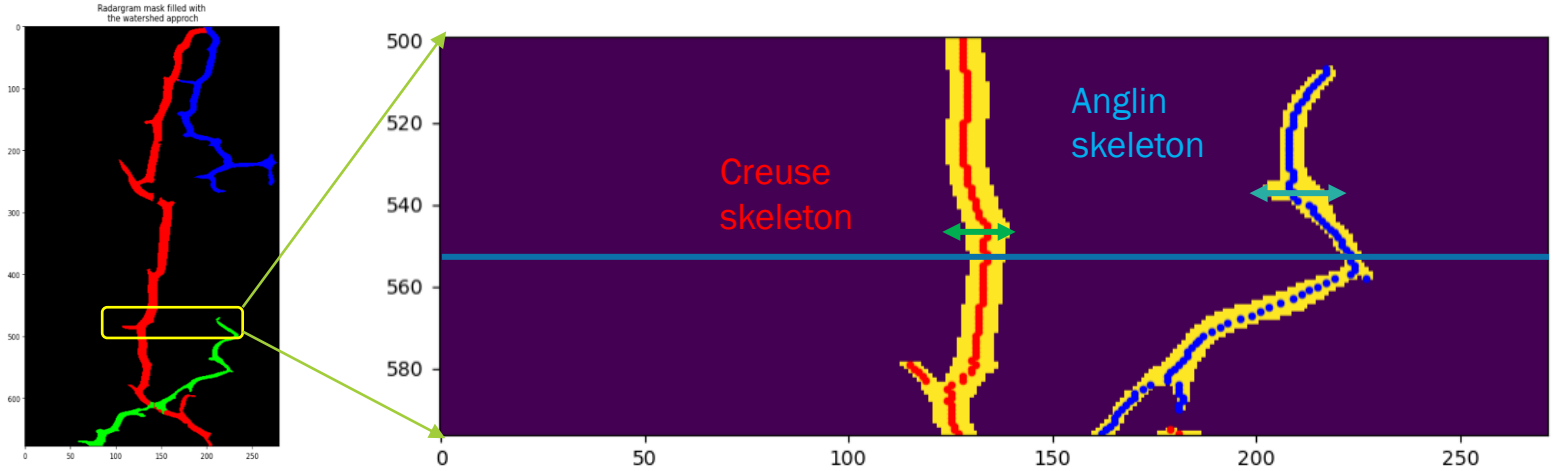
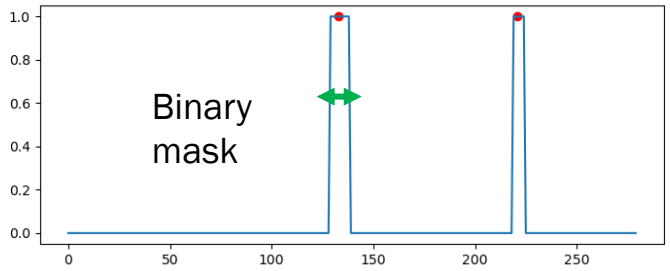
- *Handling particular situation before retracking*



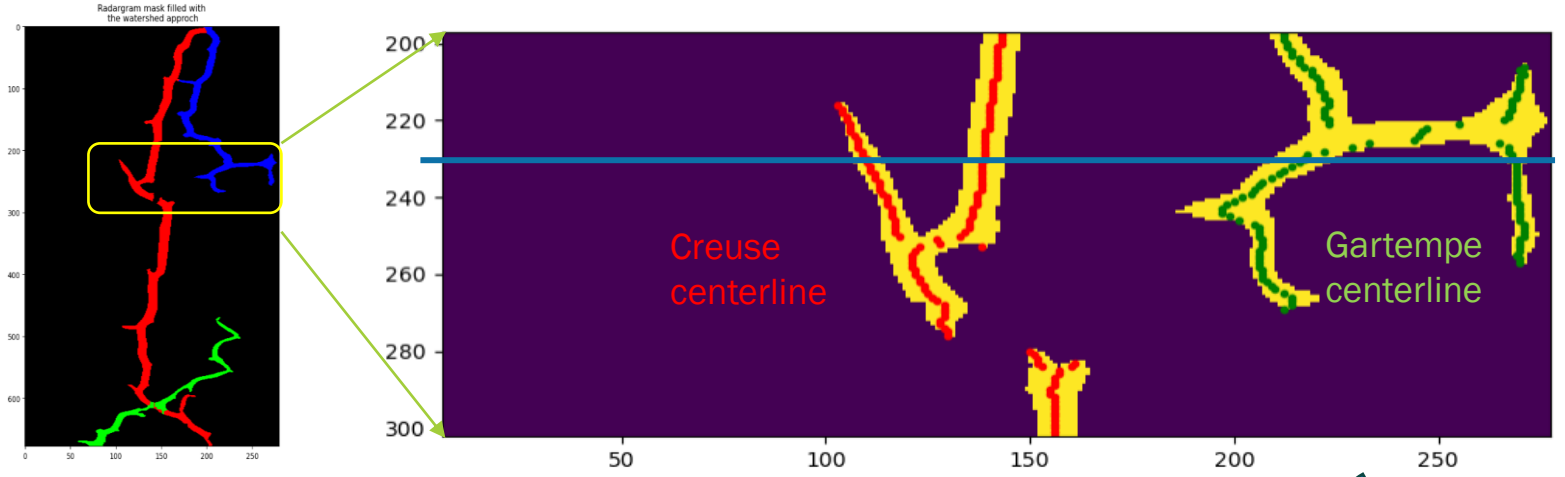
- ❑ Extraction of the skeleton of the mask and for each water body (of different ID)
- ❑ Extraction of the reduced window (width ↔).



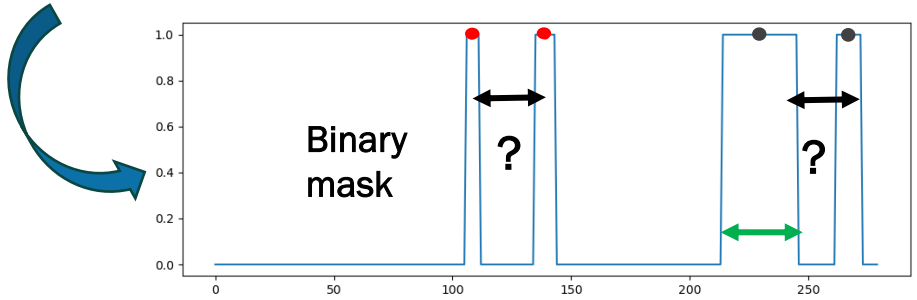
- ➢ Prior information (center + width) used as prior information in the retracking process.

FF-SAR imagery for improved WSH estimate over rivers

- *Handling particular situation before retracking*



- To deal with situation of more than one interval candidates:
  - By default, use of the Carthage WSH prior information +/- 10 meters width



- Prior information (center + width) used as prior information in the retracking process.

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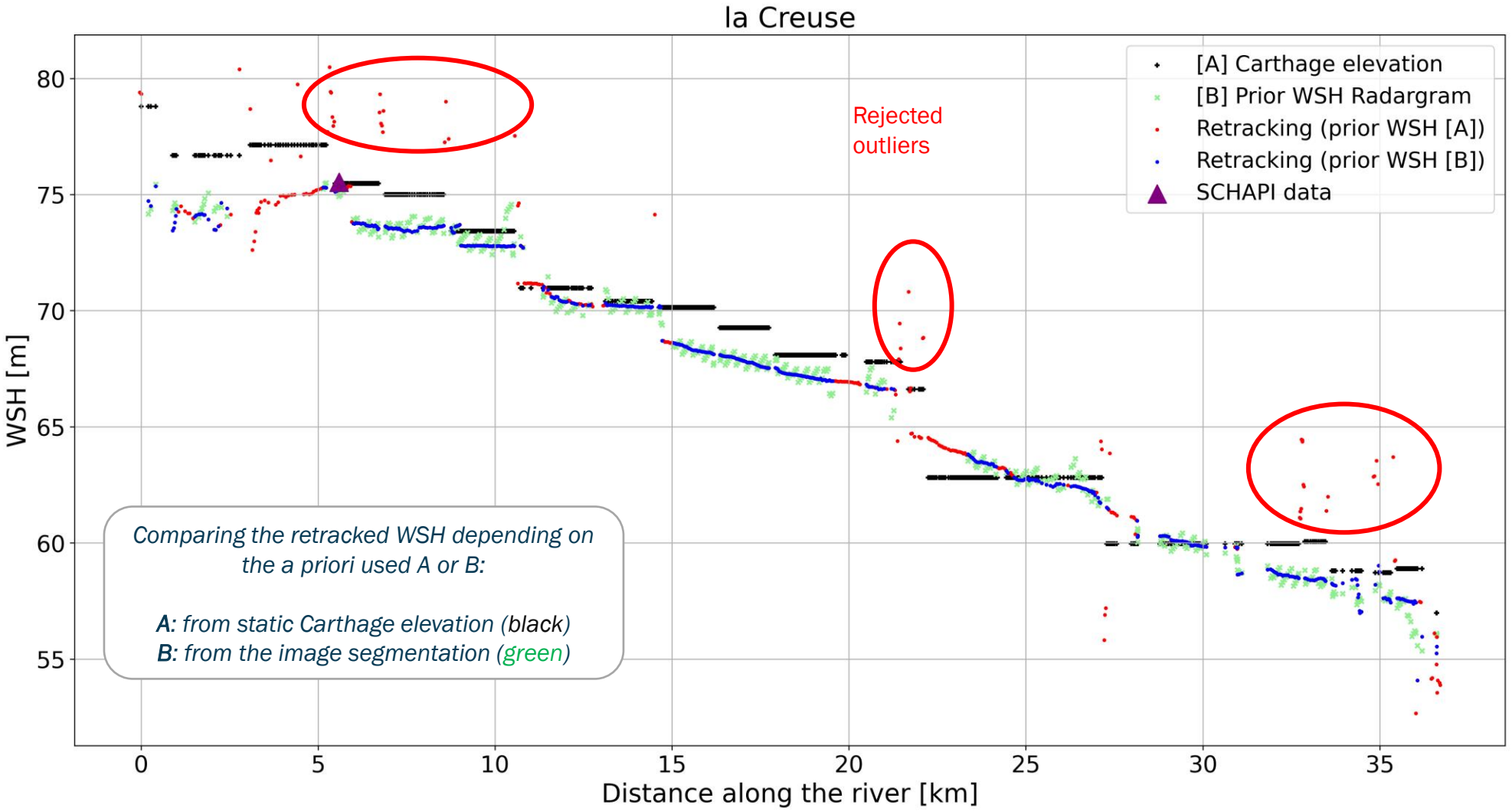
- Finally retracking reduced individual waveform using *Sinc2* function.



Main observations:

- ✓ *Where B (green) is available, WSH is computed (blue) using the prior elevation coming from the segmented radargram instead of the static Carthage A (black).*
- ✓ *Doing so, some outliers values are rejects (red dots within circles).*
- ✓ *Where B is not available, WSH is obtained using default a priori A.*
- ✓ *Percentage of retracked WSH using B (~ availability of the mask):*

80.4%

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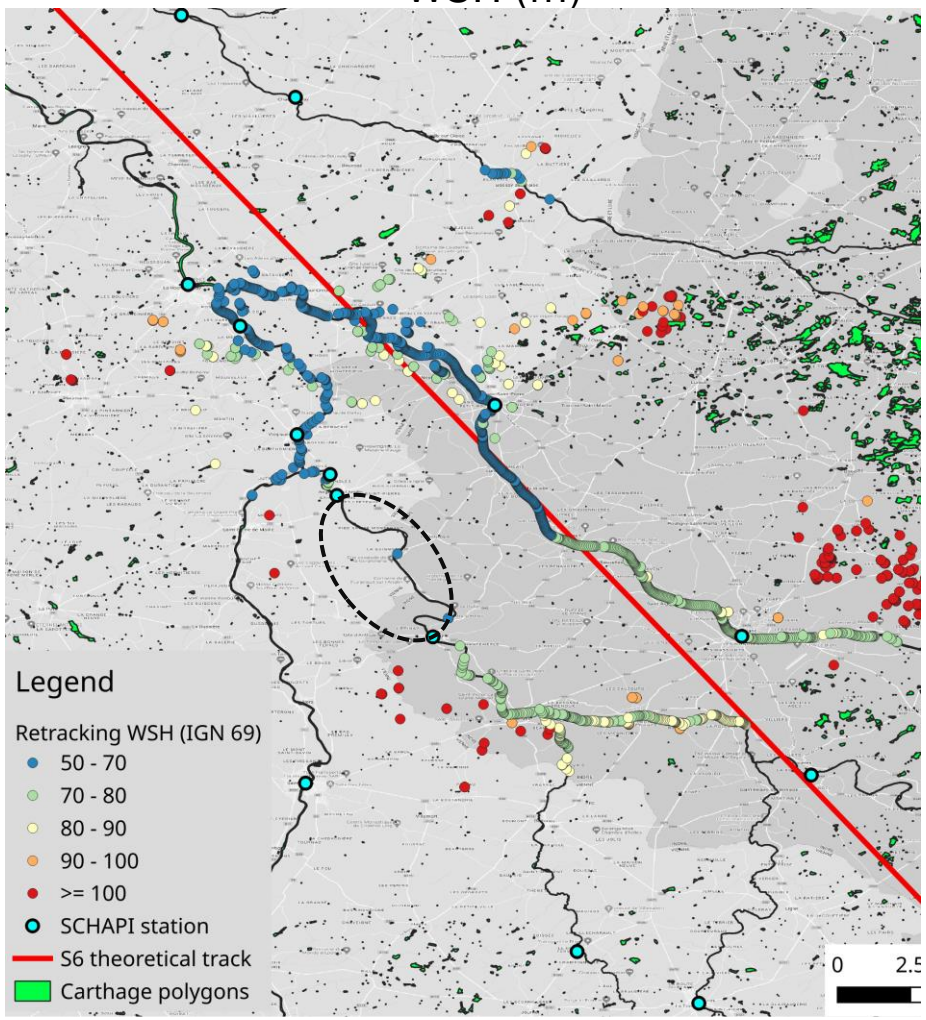
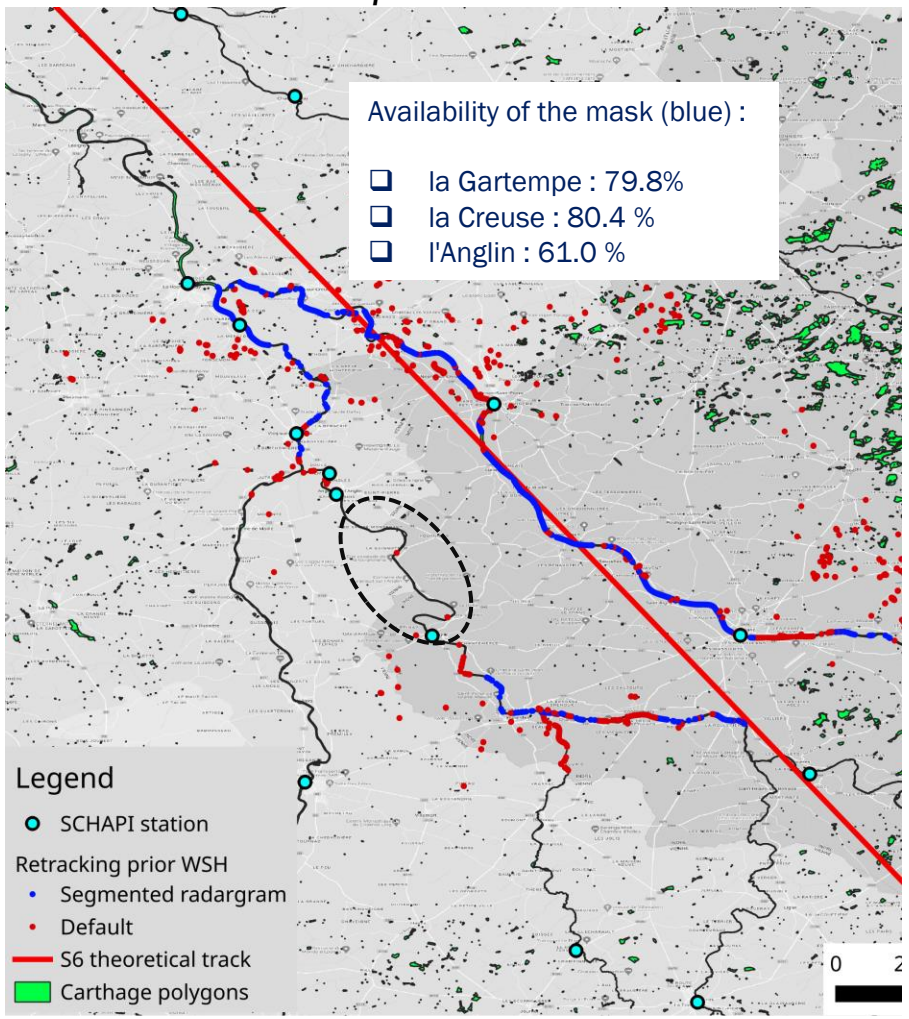
- *Looking at the bigger picture (QGIS visu)*

WSH (m)



A priori used



Missing WSH and *a priori*

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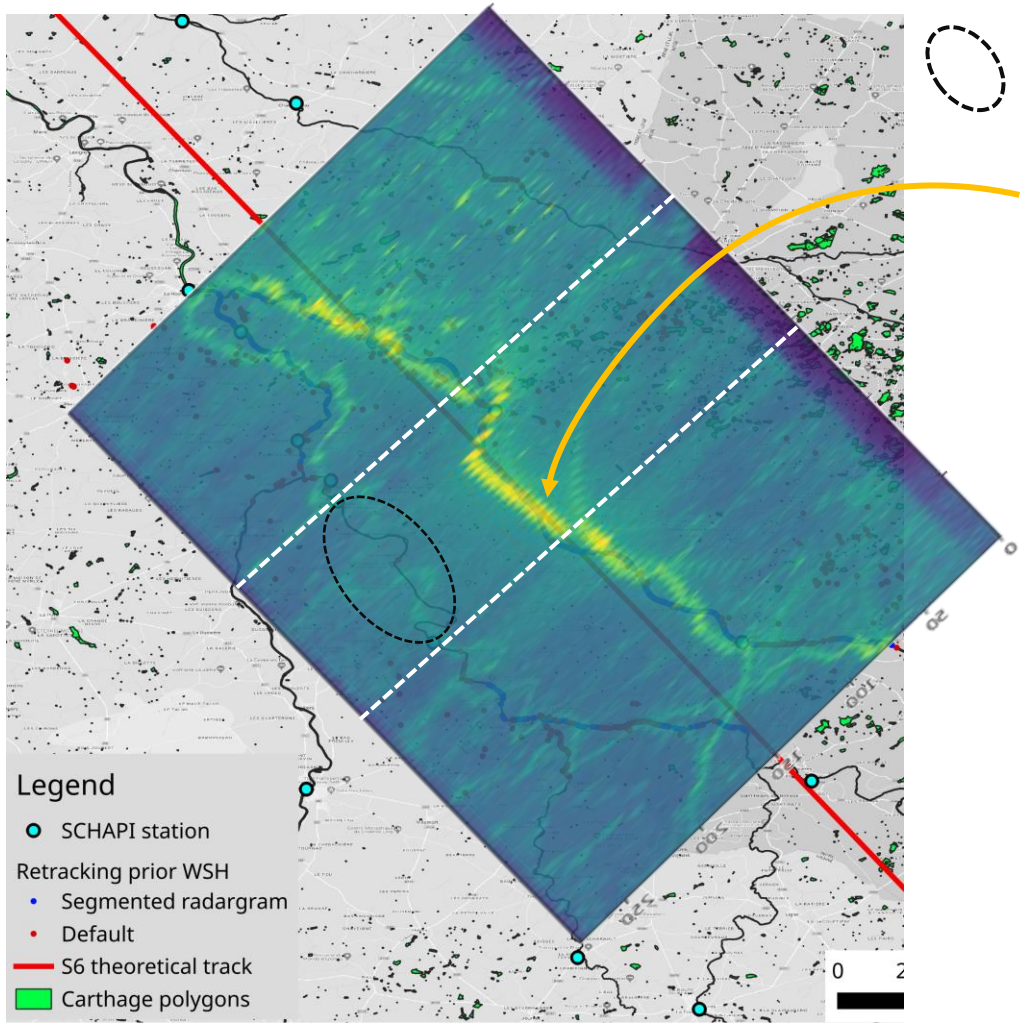
- *Looking at the bigger picture (QGIS visu)*



Missing WSH and a priori

Due to strong backscattering of the Creuse river at nadir of the satellite:

- ❑ The off-nadir signal of Anglin river is too weak to be detected by the image segmentation.
- ❑ Also peak power normalisaztion rejected this part in the retracing process.

➢ Need to investigate how to recover the weakest signal (if possible)

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Conclusion

We showed that it was possible to isolate the water bodies signal from the 2D radargrams using image segmentation technique. Then we performed a simple echo simulation using the Carthage Database (contour + elevation) that enabled us to associate water rivers IDs within the binary mask in order to define dedicated reduced retracking window for each rivers of interest in the scene.

Finally, a Sinc2 retracking was performed (corrected from the slant range for off-nadir targets) to determined the surface water level of the Creuse river along the Sentinel-6-MF track N°146 of cycle 40. Next work will be to process more data and cycles to assess performance and compare altimetry time series to in situ station data. Also, better physical modelling of the signal return could be investigated as done over lakes by the Lake Processing Prototype (Boy et al, 2022, doi: 10.1109/TGRS.2021.3137034*)*

These first results are encouraging and show very good potential. Work is still on-going in order to exploit the full capability of the FF-SAR signal over inland water.

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THANK YOU !