MEASURING LONGITUDINAL RIVER PROFILE FROM SENTINEL-6 FF-SAR MODE

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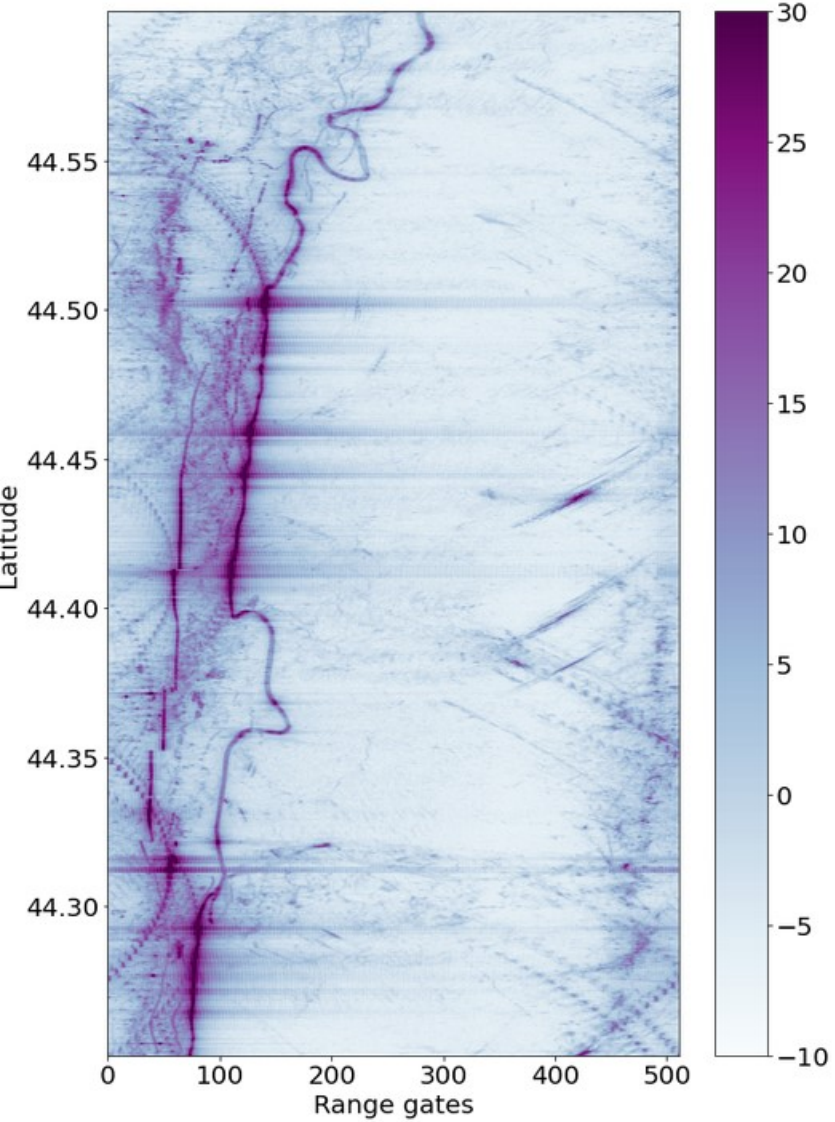
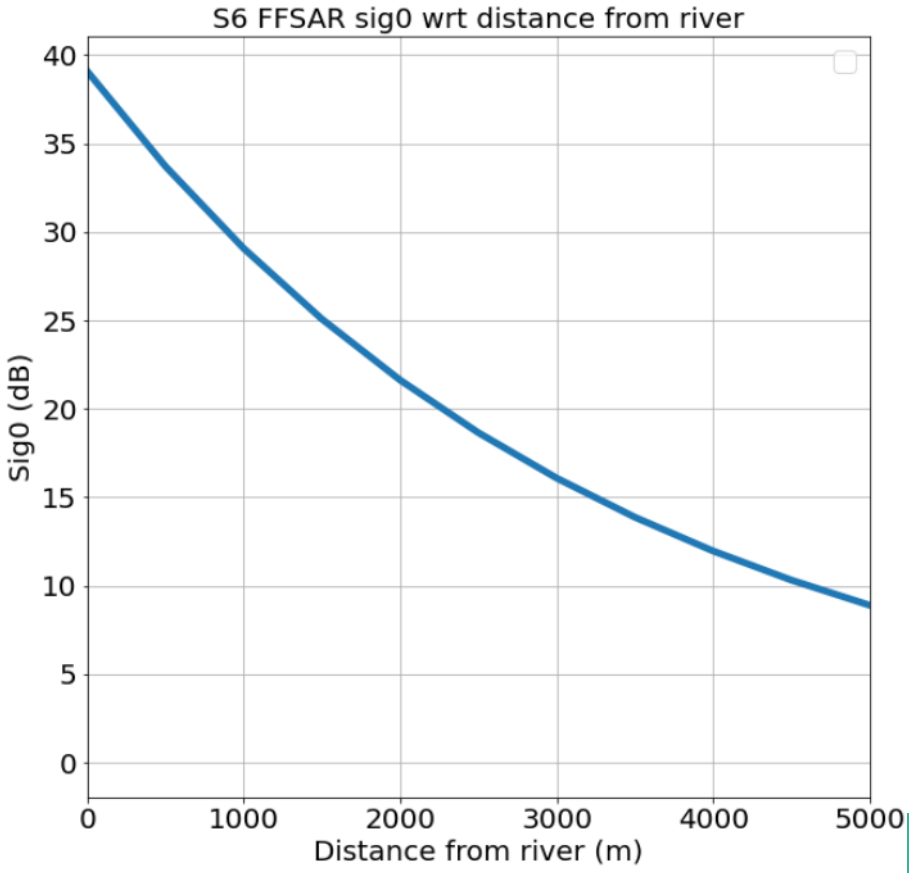
The beauty of Sentinel-6 FF-SAR mode



Example over Garonne (France), Sentinel-6 flies along the river

FFSAR configuration: **10m resolution**

Sharp and **powerful** signal**,** up to **4-5km off-nadir** (sig0>10dB)**.**

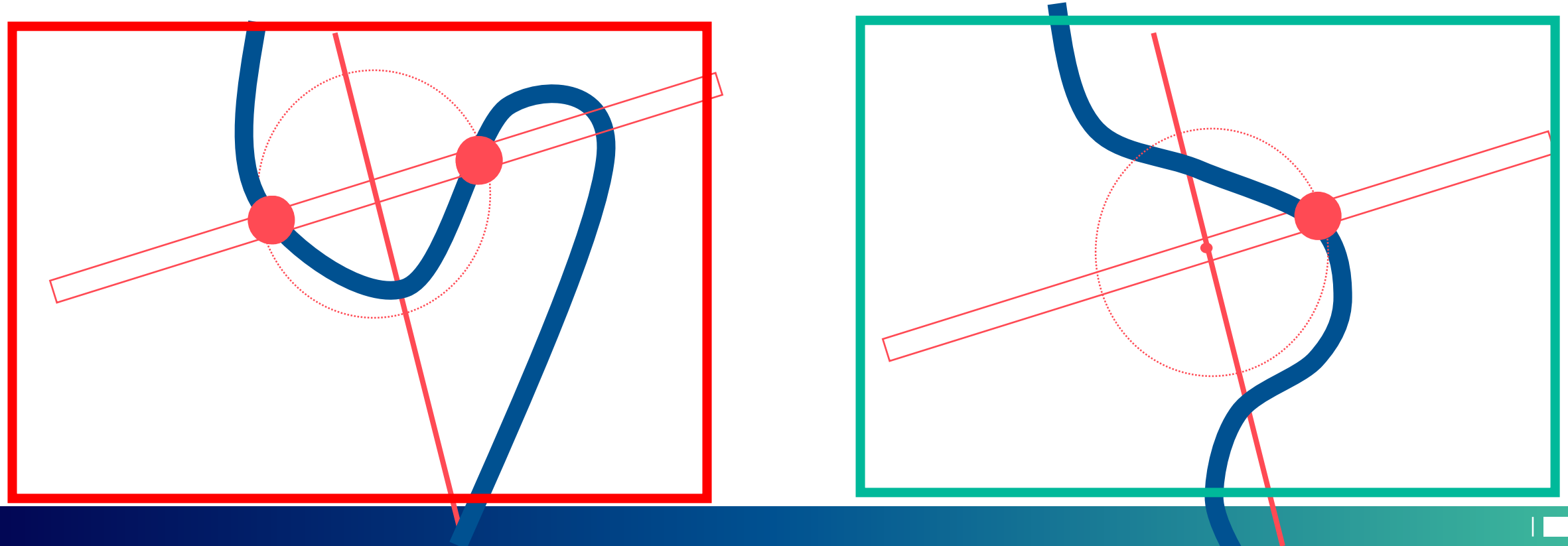


Can we really measure longitudinal river profile with nadir altimetry?

It requires to exploit **nadir & off-nadir** radar signals.

Up to now, radar altimetry has been limited to **nadir** observations. Otherwise, **right/left SAR radar ambiguities exposed to erroneous interpretation**.

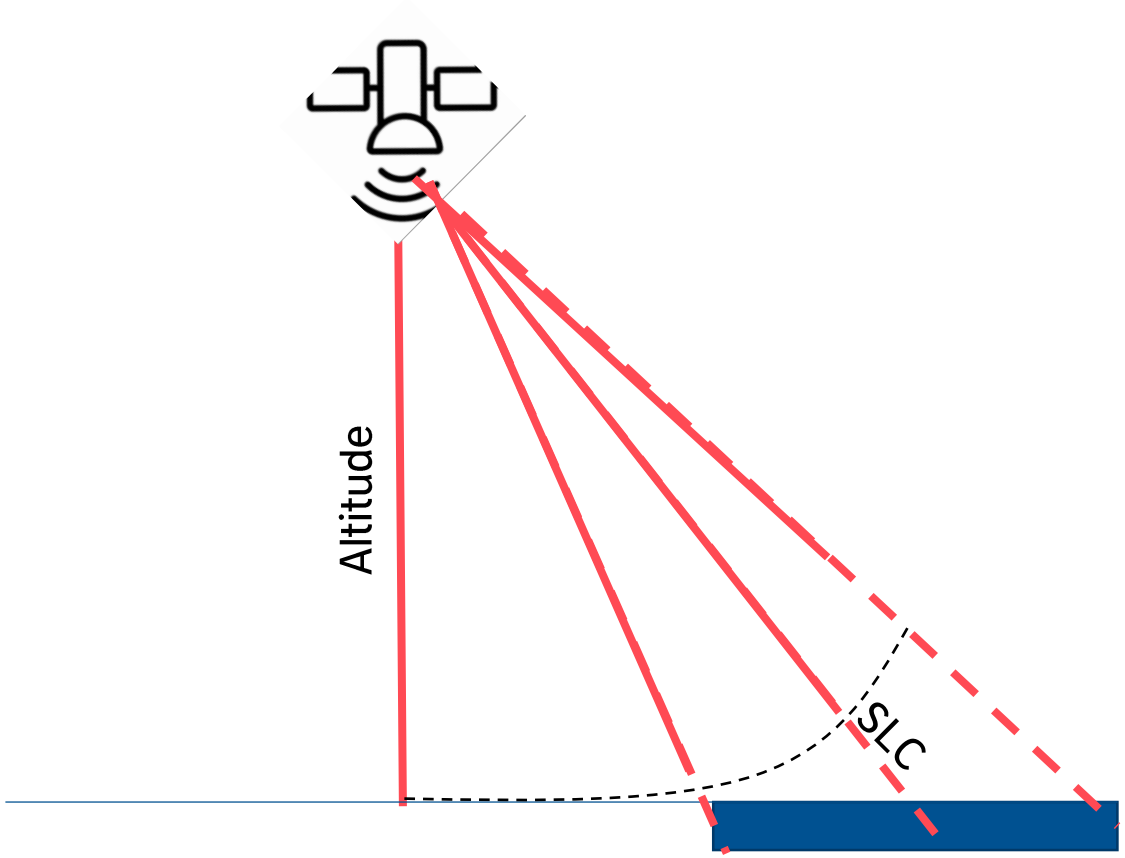
However, in certain (limited) cases, when the satellite flies along a river **AND** the river geometry ensure **a single cross-over section** between the SAR radar footprint and water ➔ **remaining ambiguities can be solved**

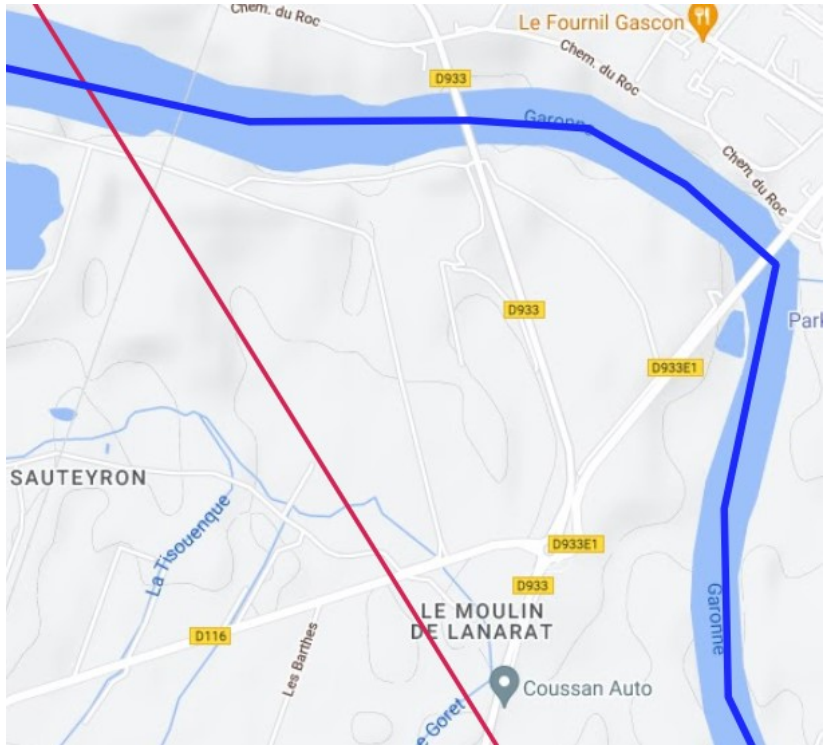


Slant Range Correction: approach and uncertainty

Off-nadir radar measurements have to be corrected for the **Slant Range Correction (SRC)**.

SRC is computed **using a river centerline** (built manually)**.** The center of the river is considered. But the signal can be potentially back-scattered by the outside of the river

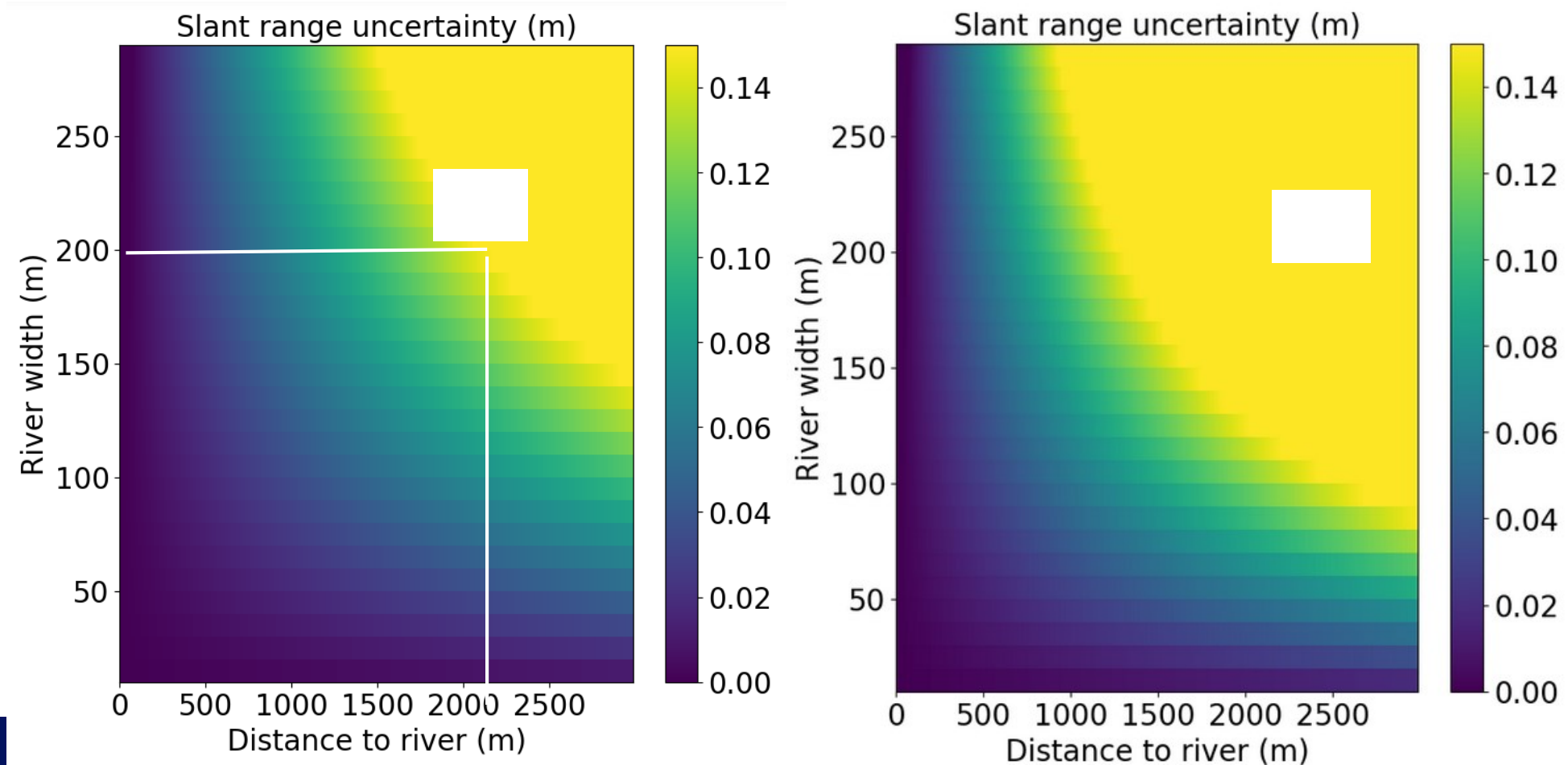




Slant Range Correction: approach and uncertainty

SRC uncertainty is directly linked to the **river width & the satellite altitude & the distance to river.**

This method will be **limited to river width < 200m** and **D < 2km** (uncertainty = 15cm). S3 will be even more limited.



How to retrack nadir & off-nadir waveforms?

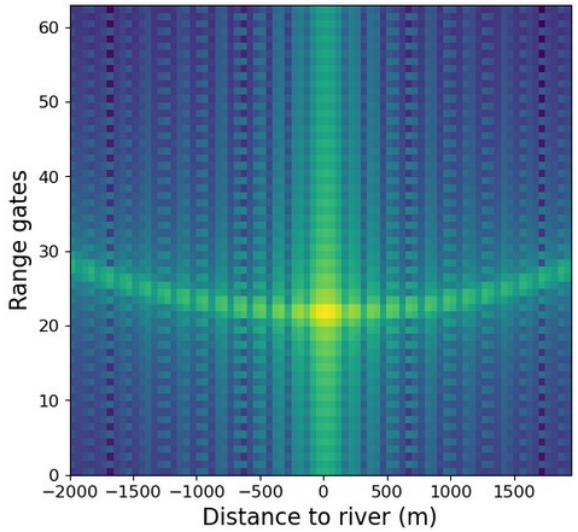
The radar waveforms will be either **specular at nadir** *(Abileah, 2021)* or **a mix of specular & diffuse signals when off-nadir.**

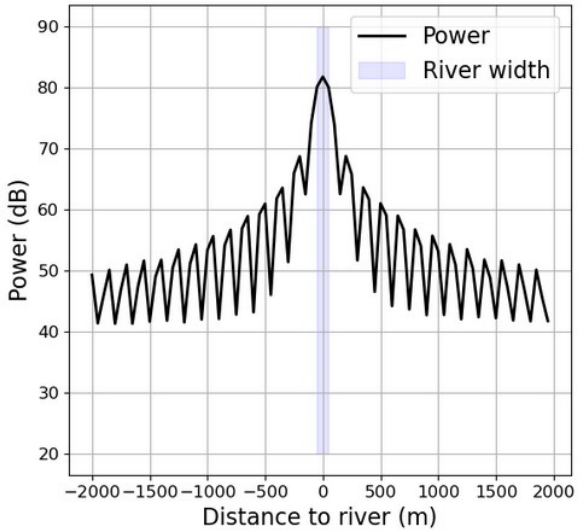
The advantage of slant view + FFSAR is the reduced water section: 10m long-track x river width

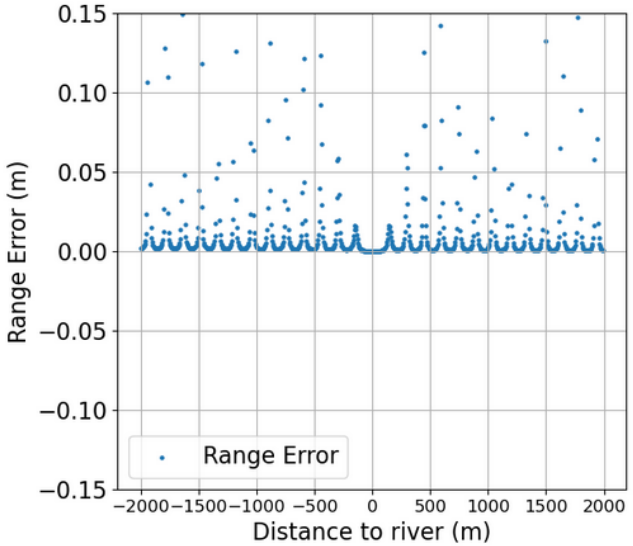
In both cases*, the waveform can be modelled with **sinc²** function whose **peak position** gives **the elevation of the river centerline**

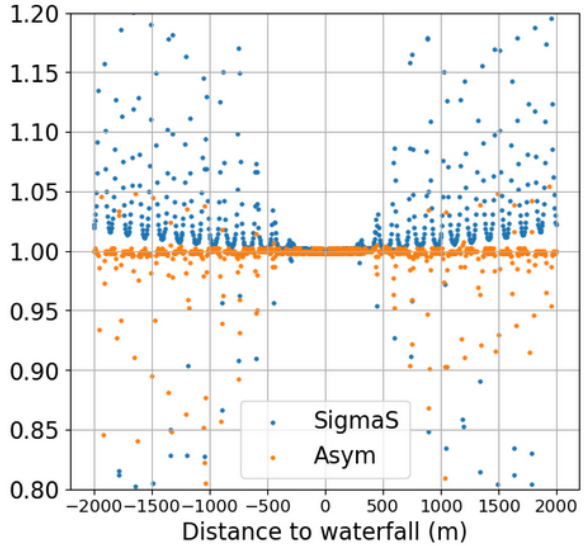
Specular simulations; river width = 100m, distance -2km/2km,

range error is computed considering a slant range correction at the center









** Considering the surface roughness is homogeneous in case of diffuse regime*

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In both cases*, the waveform can be modelled with **sinc²** function whose **peak position** gives **the elevation of the river centerline**

Diffuse simulations; river width = 100m, distance -2km/2km,

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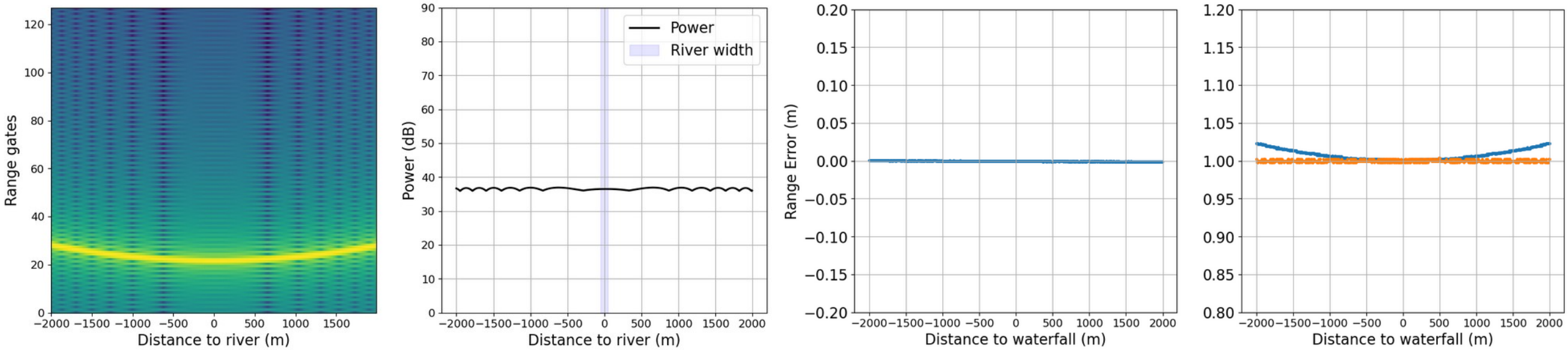


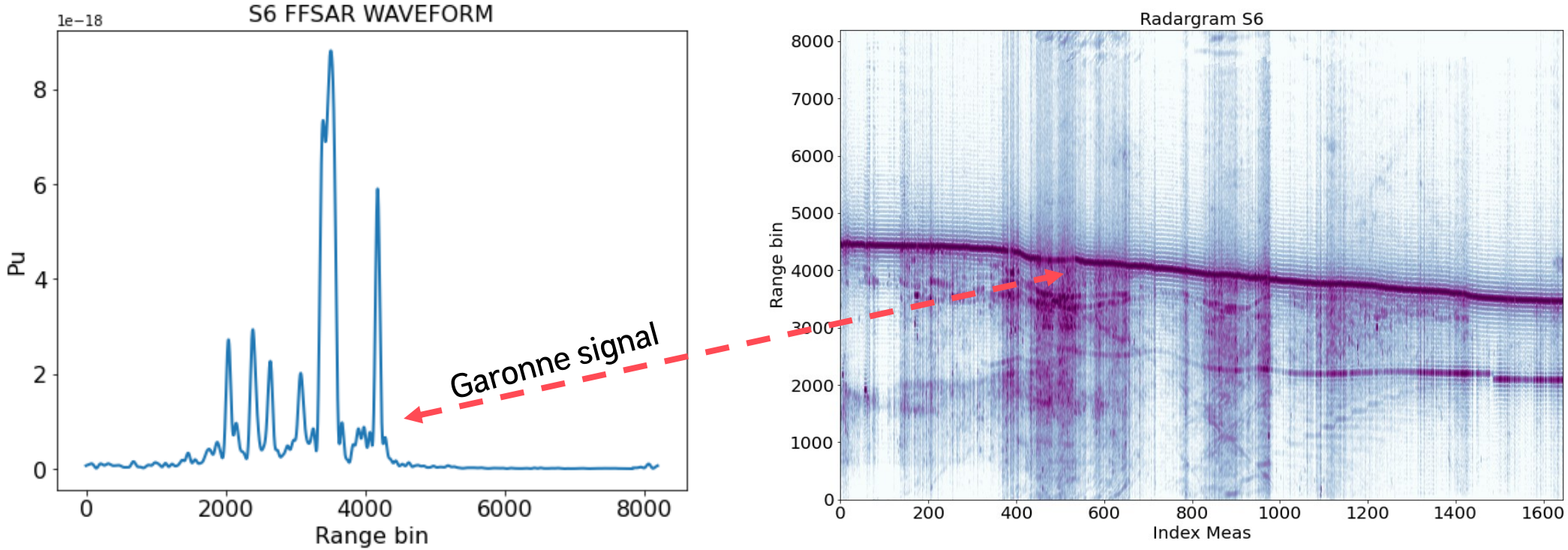
** Considering the surface roughness is homogeneous in case of diffuse regime*

How to retrack nadir & off-nadir waveforms?

Up to now, over inland waters, radar altimetry waveforms are processed individually, as it done over ocean.

Retracking can be lost in **ambiguous multi-targets** waveform ➔ risk to be trapped with large errors

Even worst with off-nadir waveforms. For example, where is the Garonne river here?

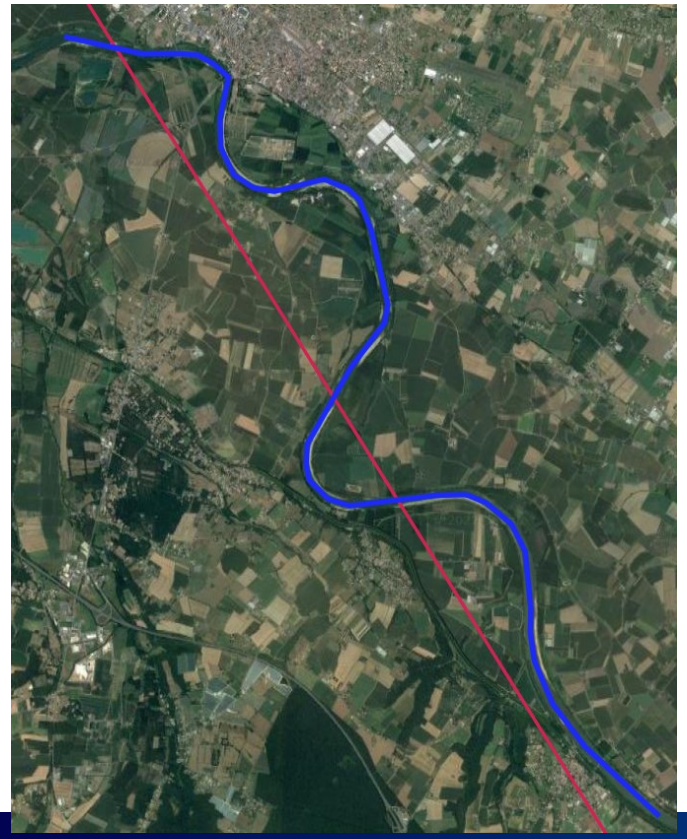


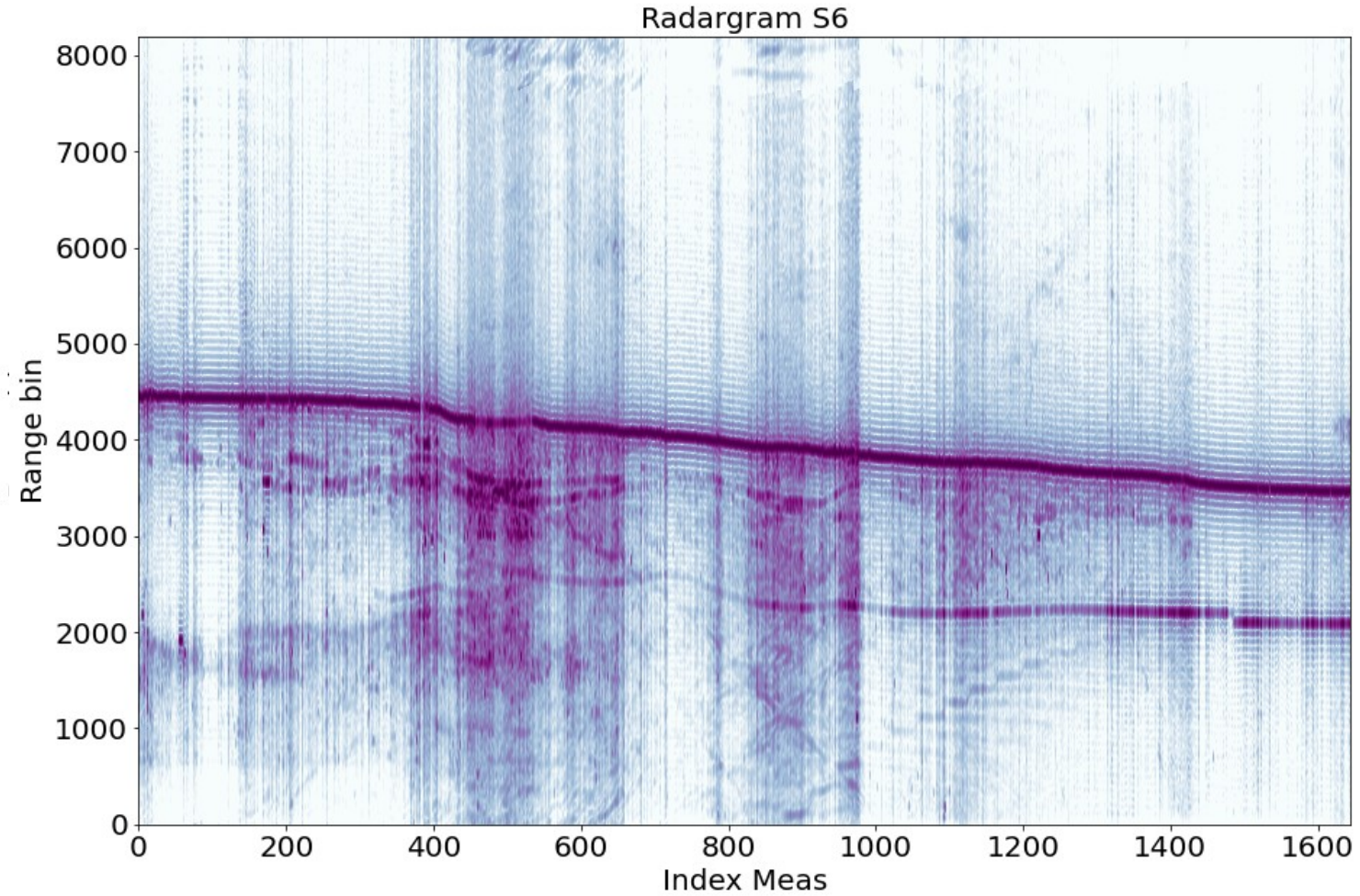
➔ **Requires to consider the whole radargramm!**

How to retrack nadir & off-nadir waveforms?

Radargramm construction:

- High 0-Padding (x64)
- Waveforms alignment compensating for [Alt-H0] and slant range correction



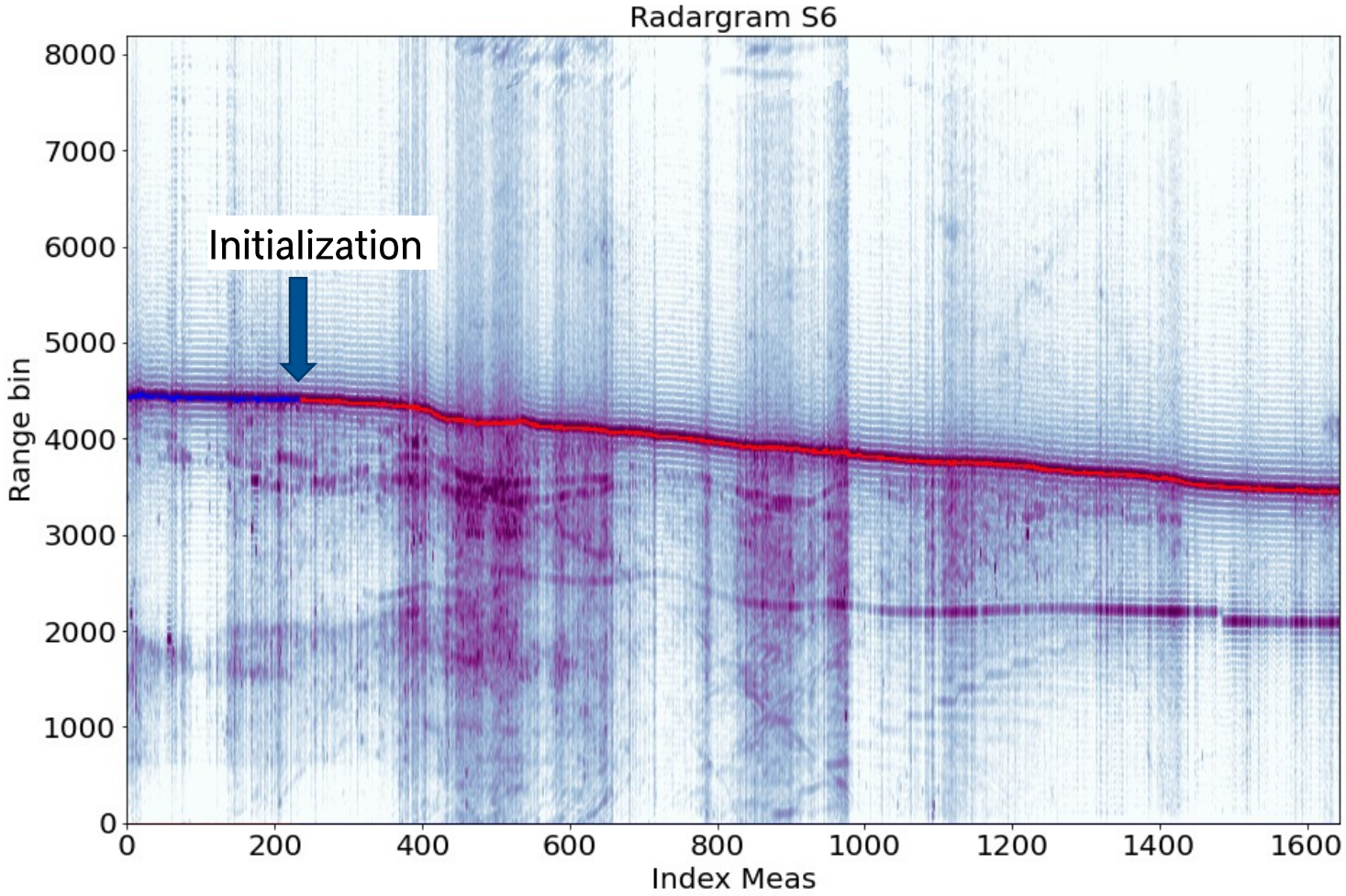


We can already see the longitudinal river profile!

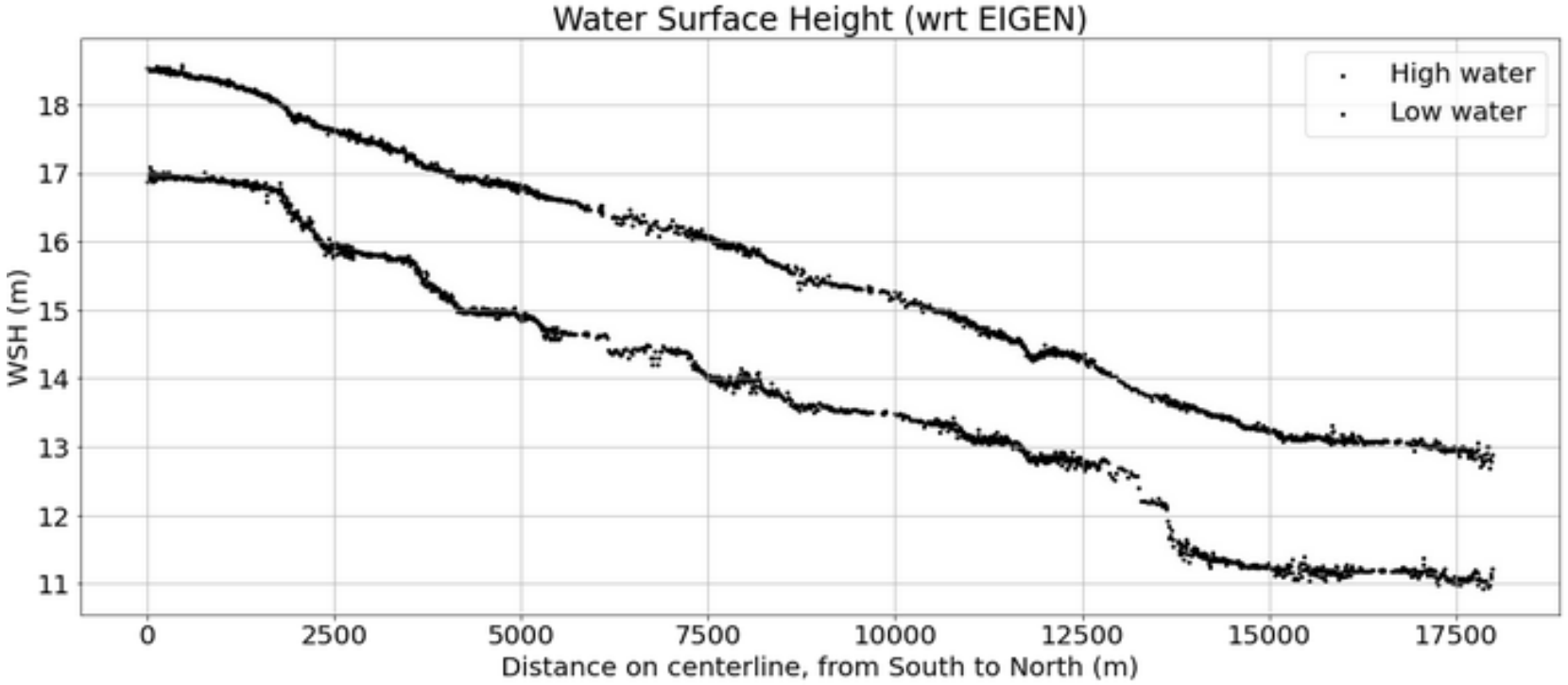
How to retrack nadir & off-nadir waveforms?

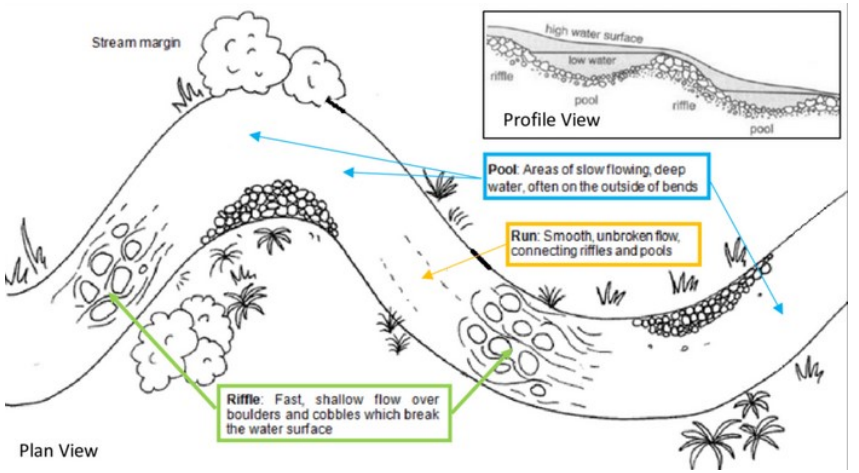
Retracking approach: Supervised retracking:

- Radargramm construction
- Initialization: 1st WSH estimation over a location with high level of confidence (for example @nadir)
- Back/forth propagation
- Next estimates are searched in a short interval (+/- half gate) wrt to previous one to “track” the signal coming from the river
- It works since two consecutive measurements are very close thanks to the high resolution and sampling
- RTK = peak position with high 0pad



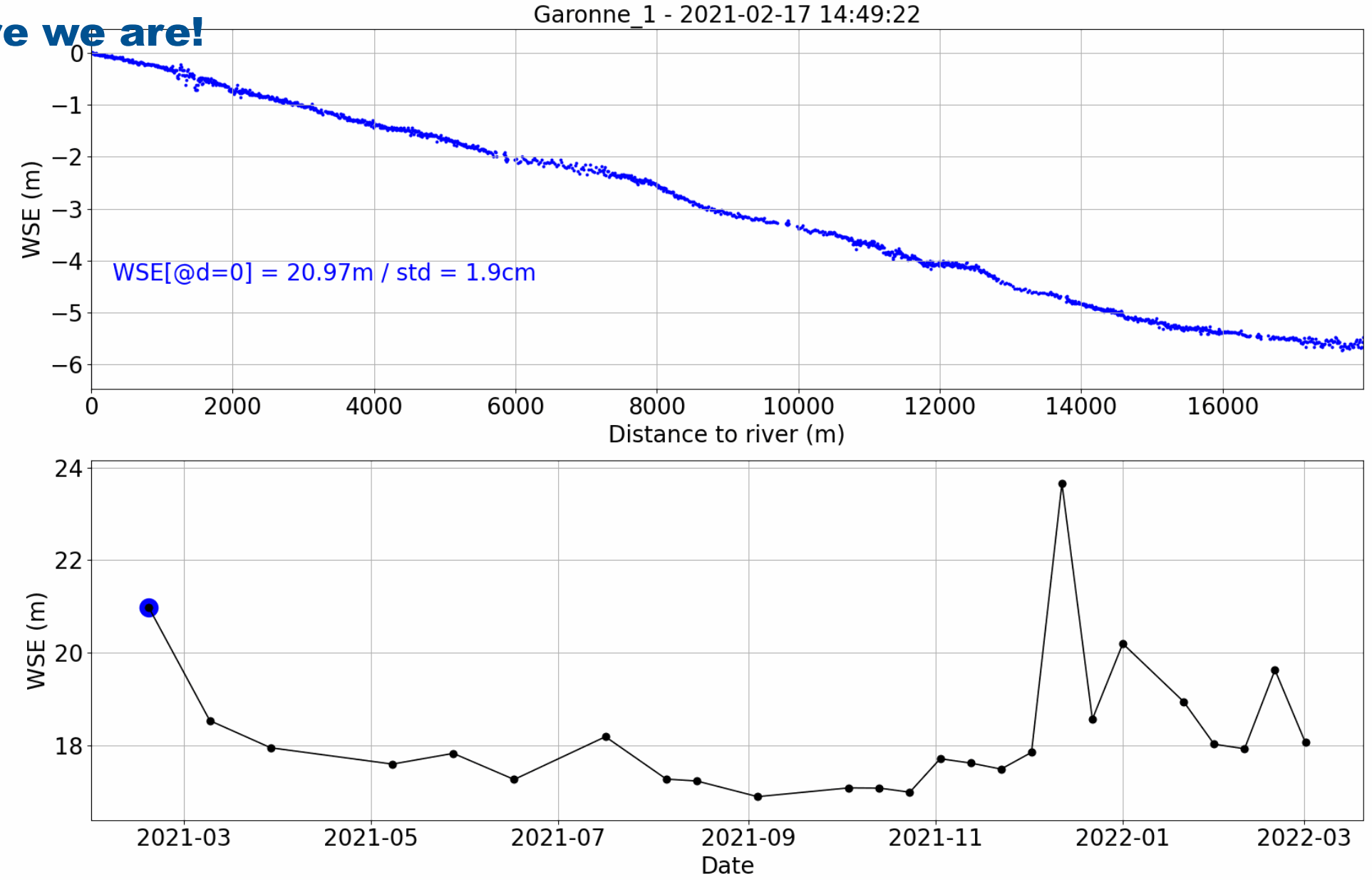
And here we are!





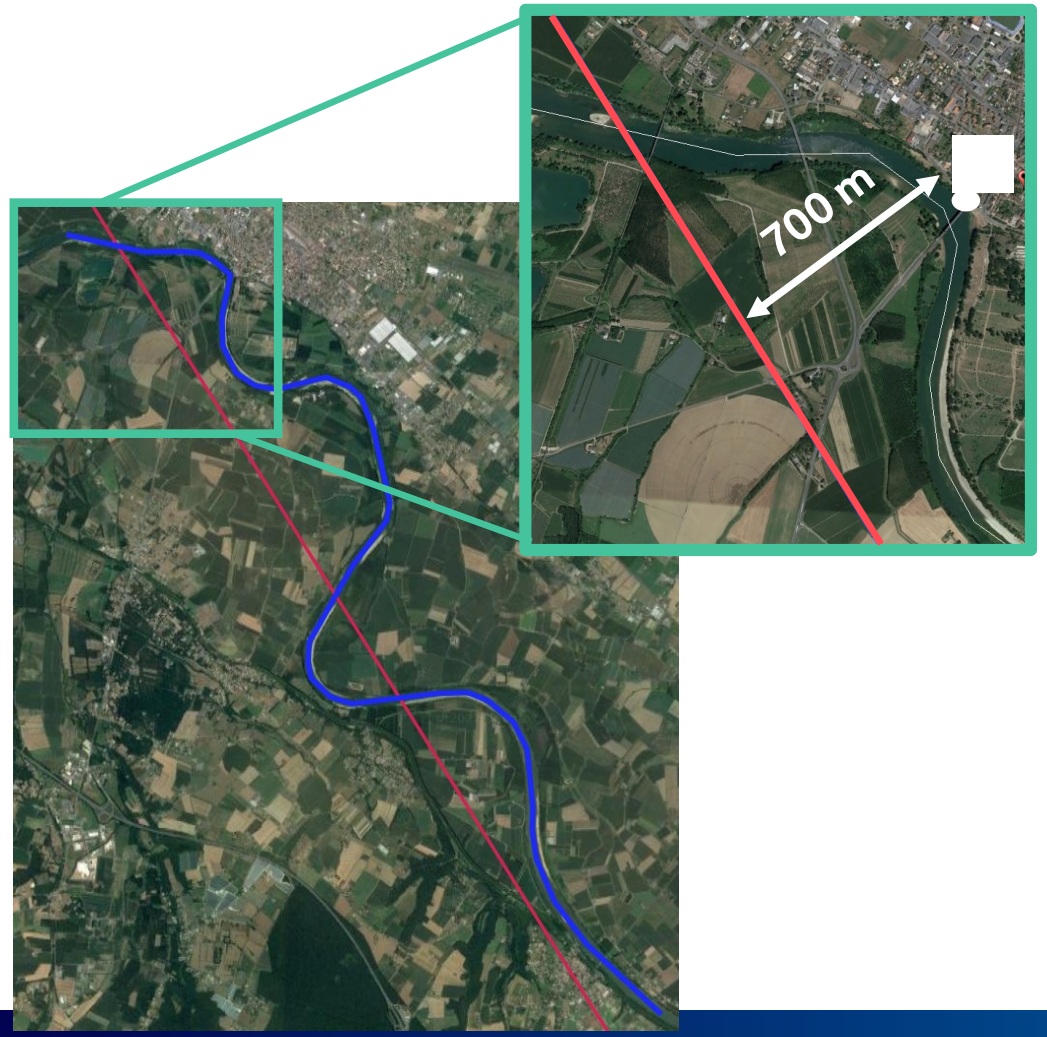
Sentinel-6 exhibits riffles and pools, that disappear when water elevation increases

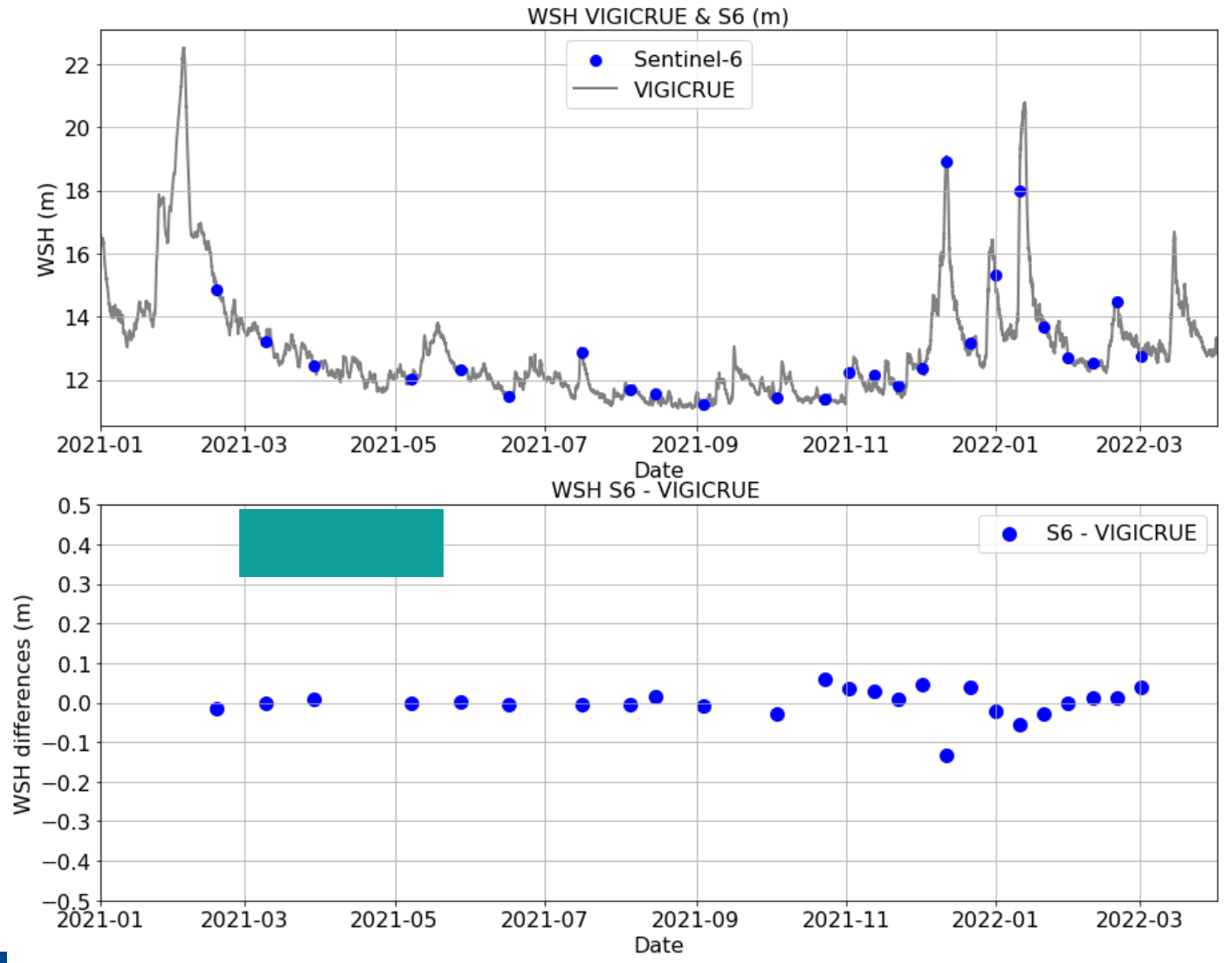
And here we are!



Validation

Using in-situ gauge (VIGICRUE network) located in Marmande. **Excellent agreement** : **3.7 cm RMS**

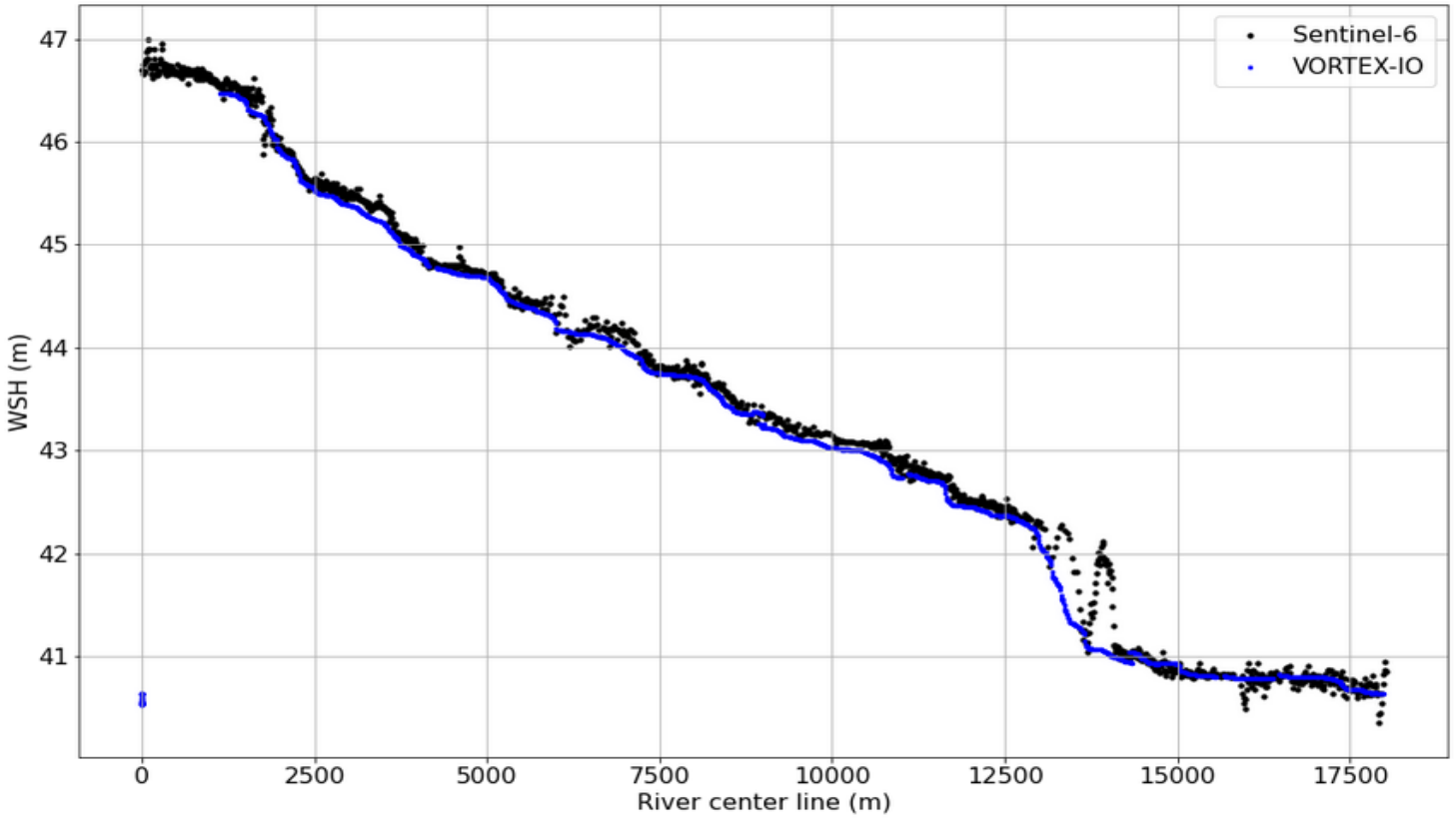


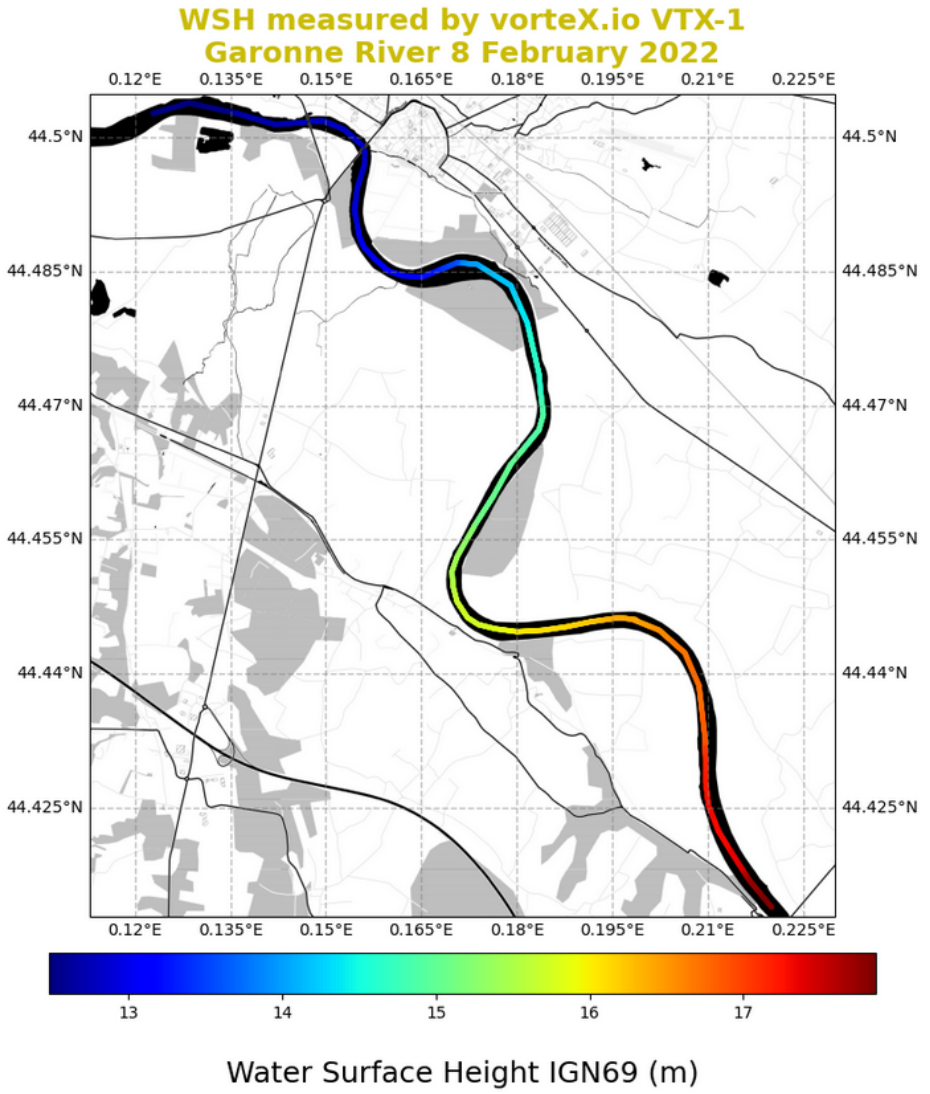


Validation

Using VORTEX-IO (Lidar on-board UAVs).

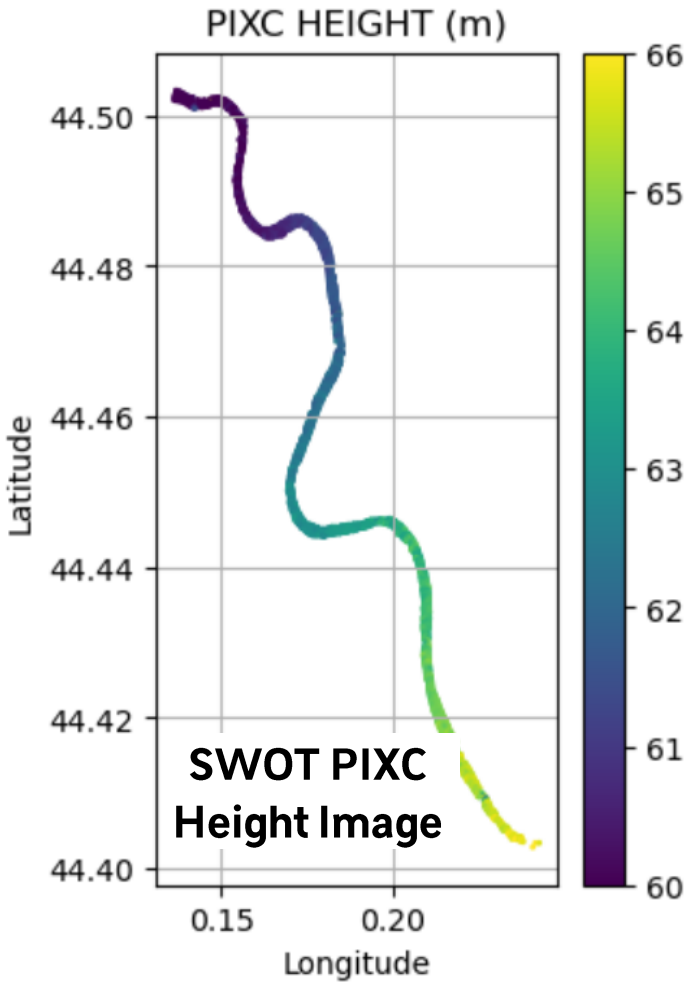
- **Excellent agreement (3cm RMS @100m resolution!!!)**
- @nadir, bias is only 1.3cm

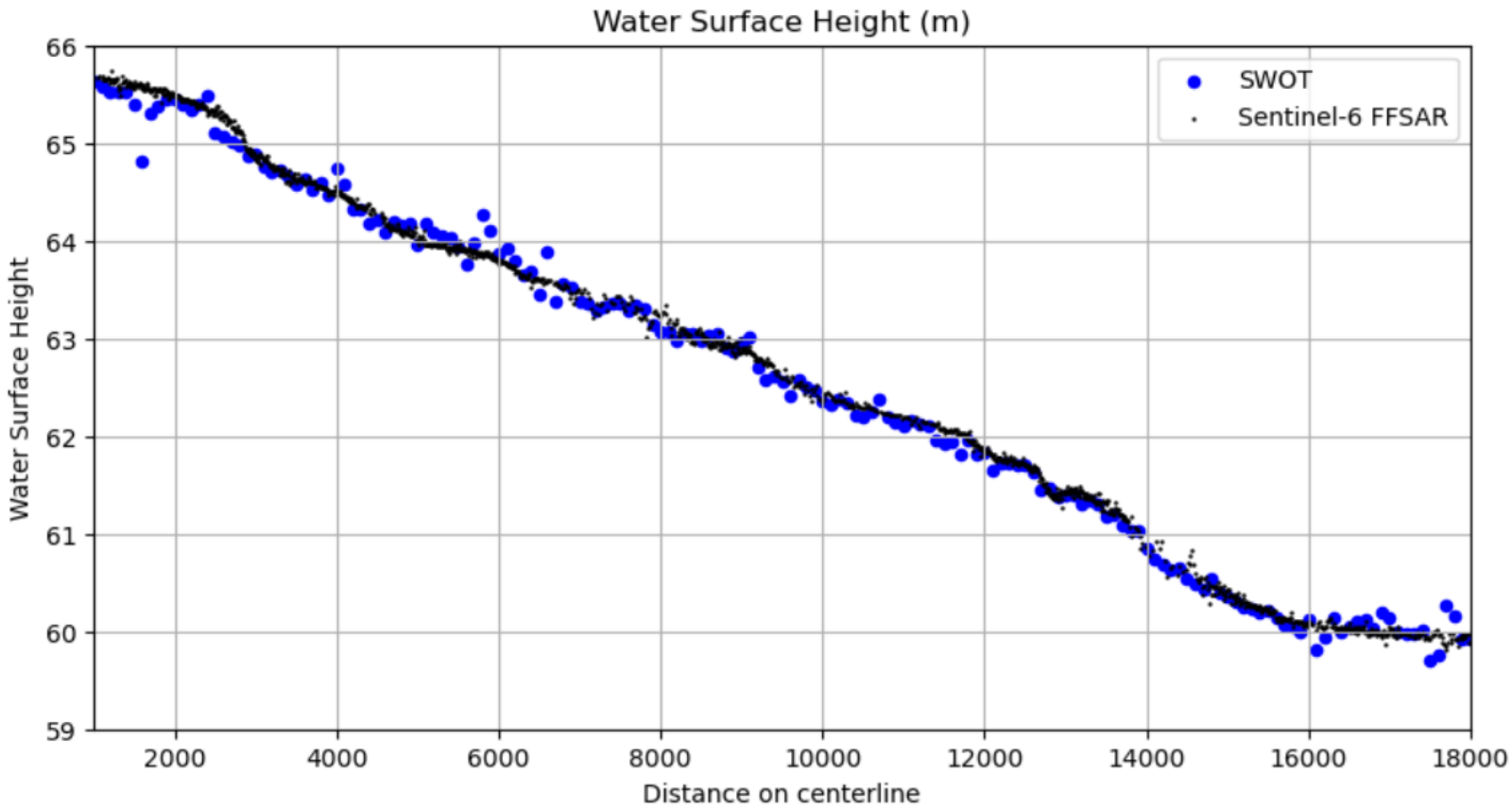




Comparison with SWOT

Excellent agreement with SWOT (pre-validated beta-product, @100m resolution, no bias applied anywhere)

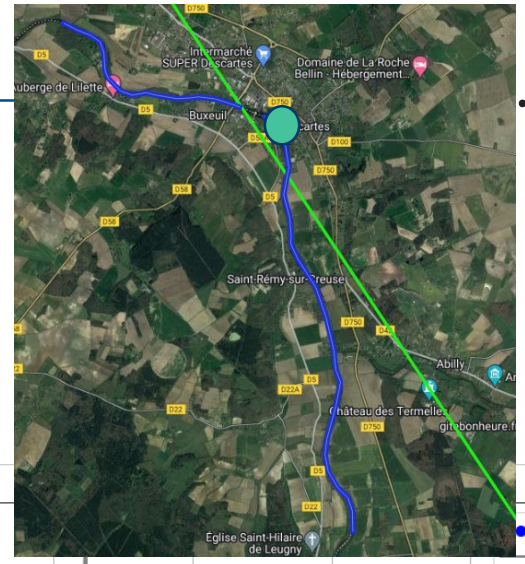


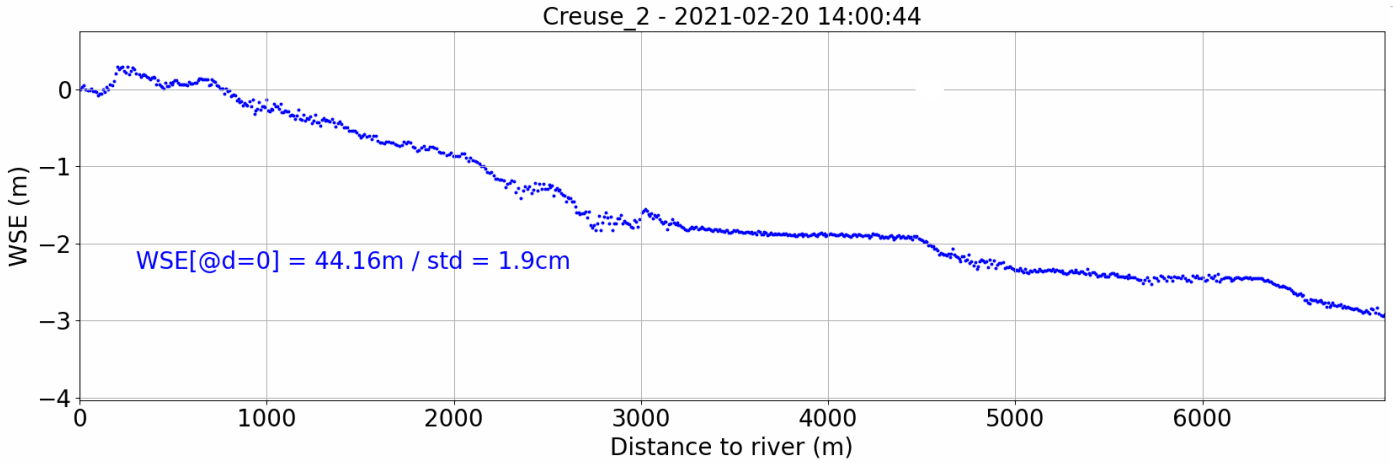


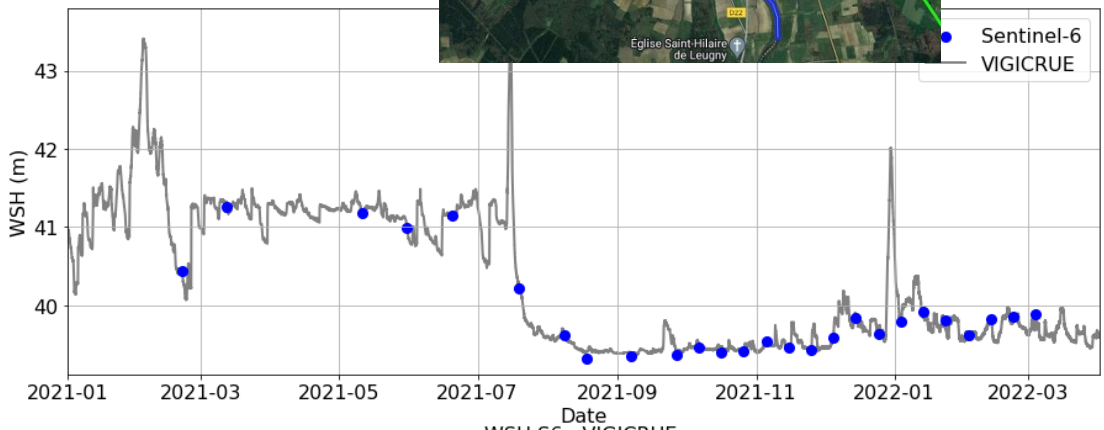
Other examples

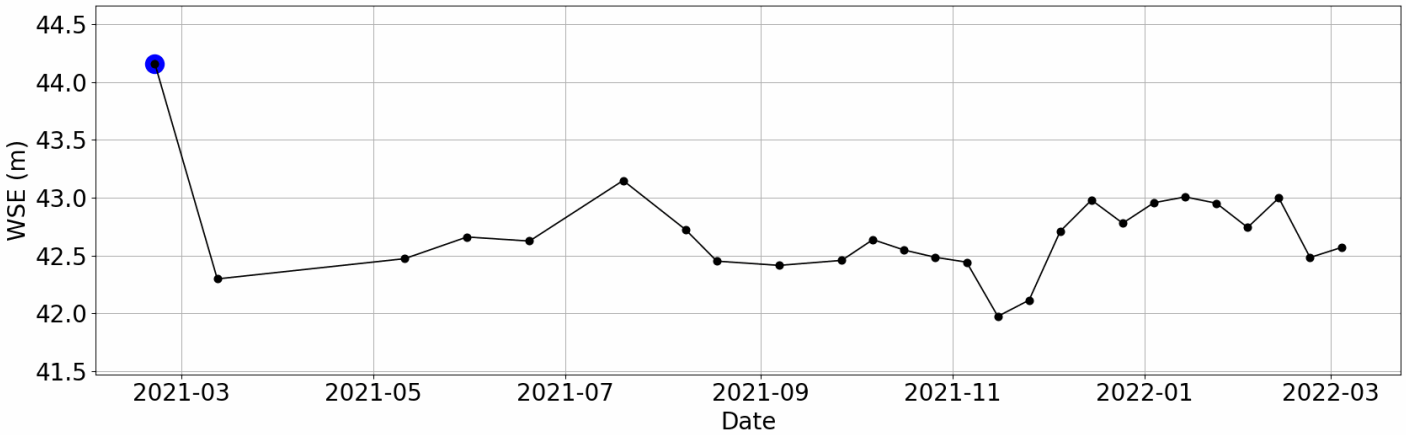
La Creuse River (France), width=140m

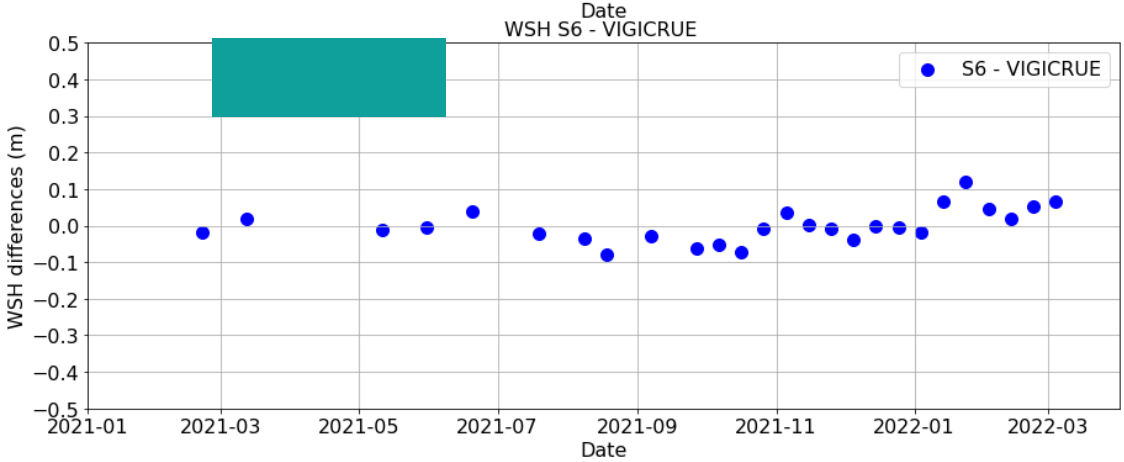
- VIGICRUE station almost @nadir ➔ **Excellent agreement** : **4.6cm RMS**







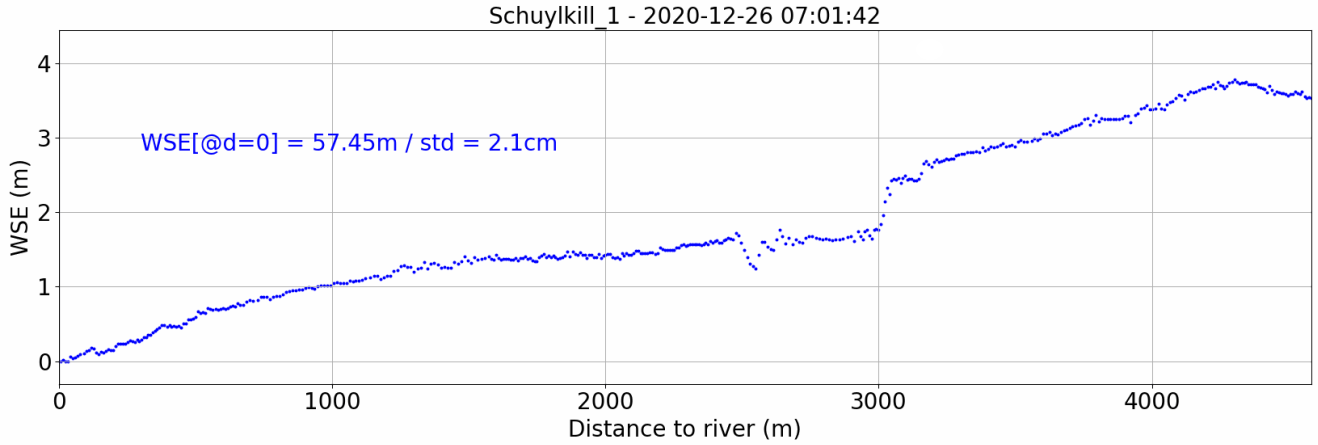


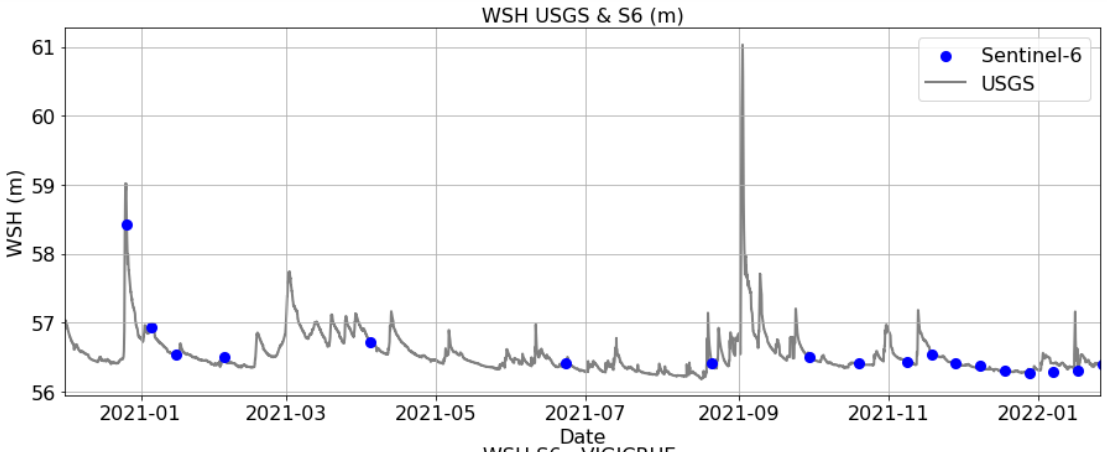


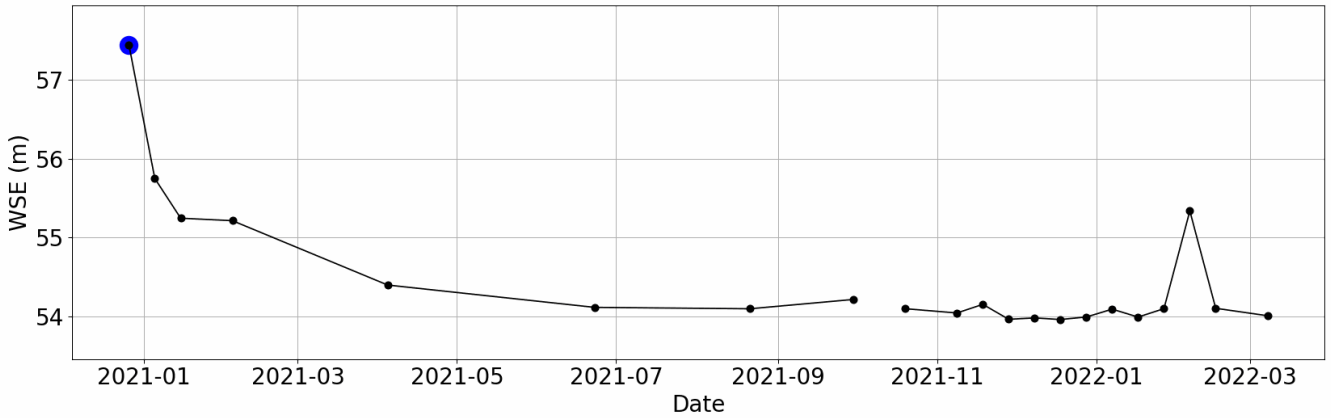
Other examples

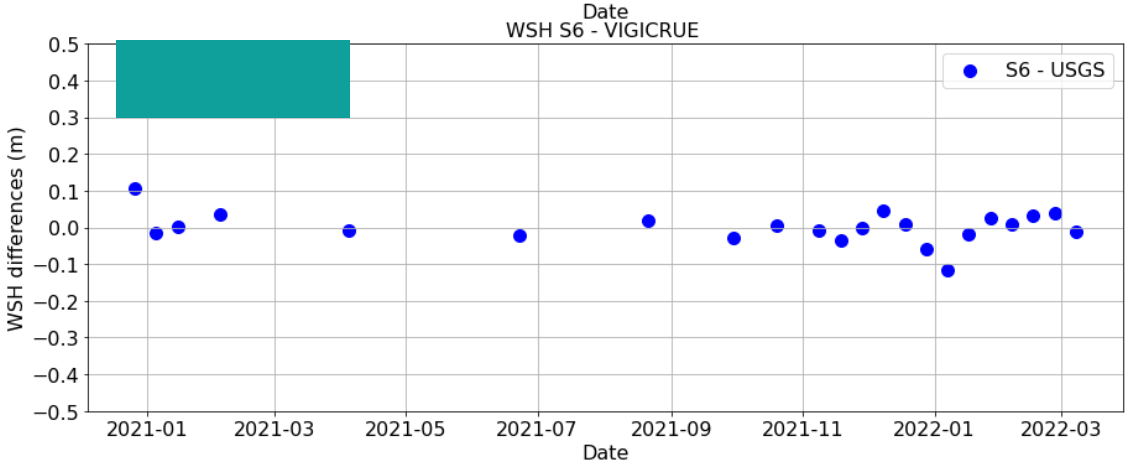
Schuylkill River (Reading, USA, **under SWOT1D**), width=70m

- From 1,800 to 2,800m to the USGS station, Complex urban surrounding
- **Very good agreement with USGS station** (**4.2 cm RMS**)





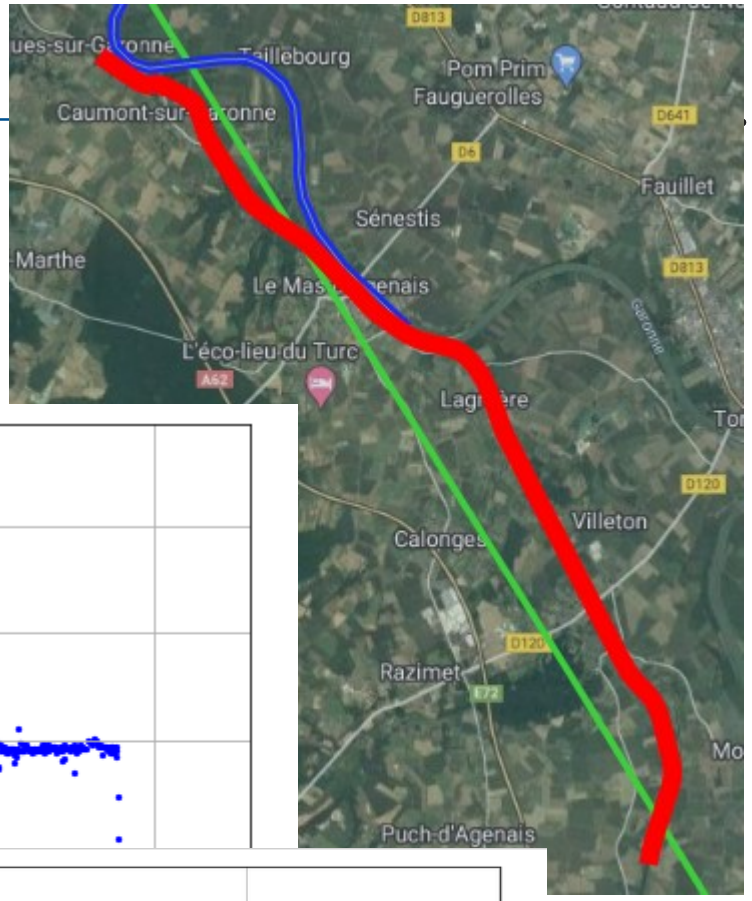


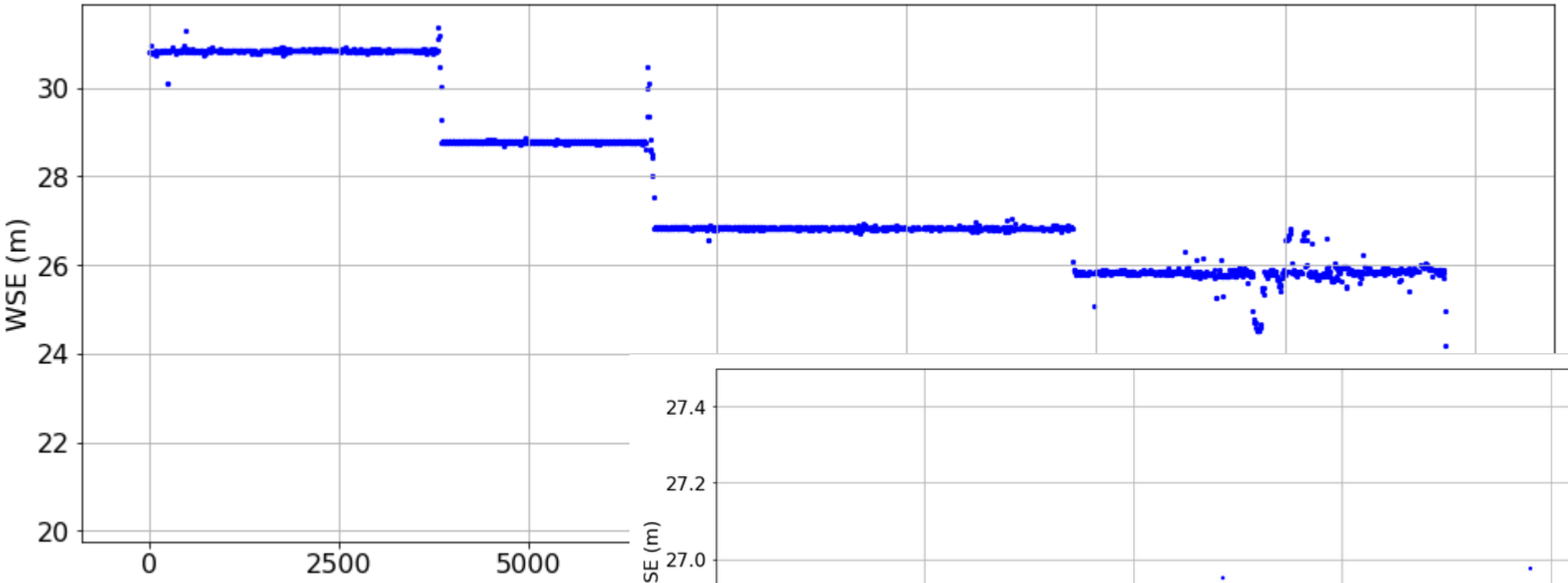


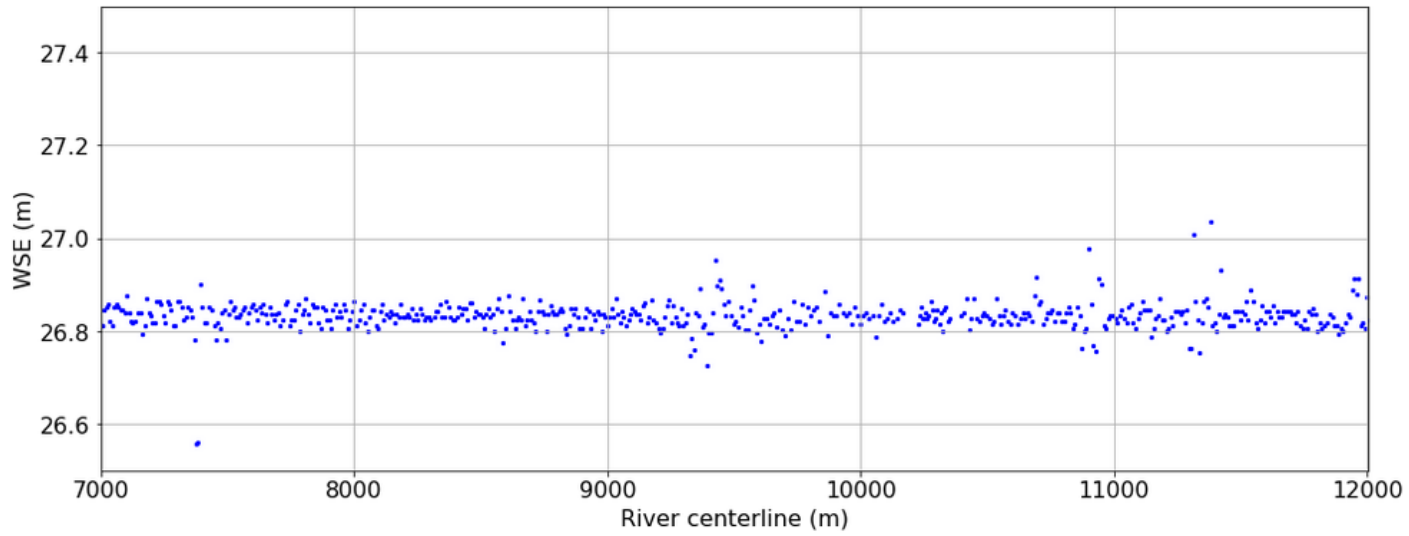
Other examples

Garonne Canal (France, **under SWOT1D**), width=15m

- Small canals with locks ➔ need to relax the supervision to jump locks







Conclusions

Using this technique, over limited cases, Sentinel-6 can provide very accurate longitudinal river profiles

- Useful dataset for the validation of the SWOT mission which will provide river profiles globally

- Collaboration with CERFACS to improve river modelling and flooding event prediction using S6 Garonne profile

- On-going work with CLS (JA Daguze, see OSTST forum) to develop new approaches based on image processing to overcome some of the current limitations ➔ objective is to highly densify virtual stations ➔ +/-4km corridor around the track (OSTST, 2023 Forum session).

- We are collaborating with other groups, dealing with similar challenges (F. Ehlers TU Delft, JD Desjonquères JPL -> see poster session)

Take-away message (beyond this work…)

- Sentinel-6 is the best nadir altimeter in town for the observation of rivers and lakes.

- For the first time & consistently, 10cm RMS total uncertainty looks achievable over rivers, even at 4km cross-track in certain acquisition configurations.