From unfocused to fully-focused SAR processing : benefits for different surfaces

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Context

- The Fully-Focused SAR is an innovative processing, introduced by Egido & Smith, that allows reducing the altimeter along-track resolution down to the theoretical limit (L/2).
- Resolution gain is profitable for both heterogeneous surfaces (inland water, sea ice) and homogeneous surfaces (ocean, continental ice).
- The FF-SAR level 1b processing has been implemented in the Sentinel-3A Processing Prototype and validated. We show here the benefits for various surfaces, with special emphasis on inland water measurement.

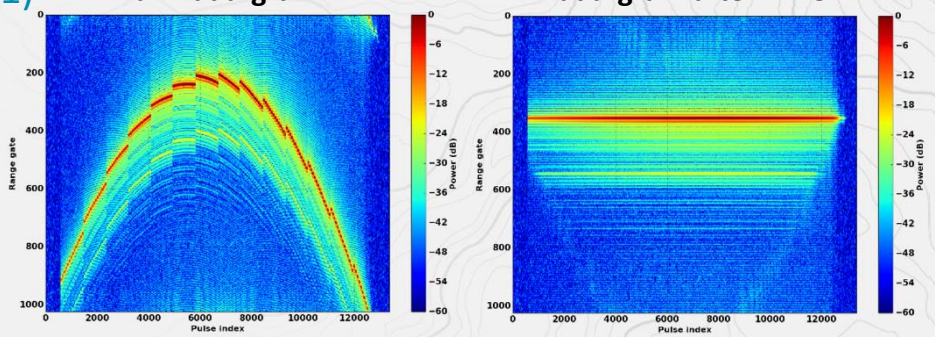
FF-SAR implementation and validation on transponder

Implementation based on the **back-projection algorithm** described by Egido & Smith and validated with CDN1 transponder data:

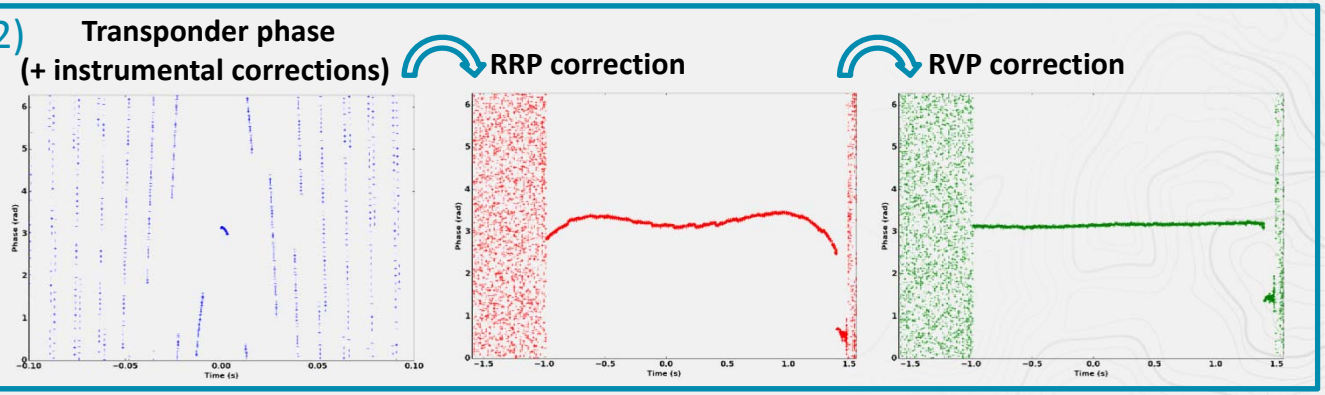
1) RMC to align in range the pulses with respect to the focusing point

2) phase matching and coherent pulse accumulation to perform along-track focusing

1)



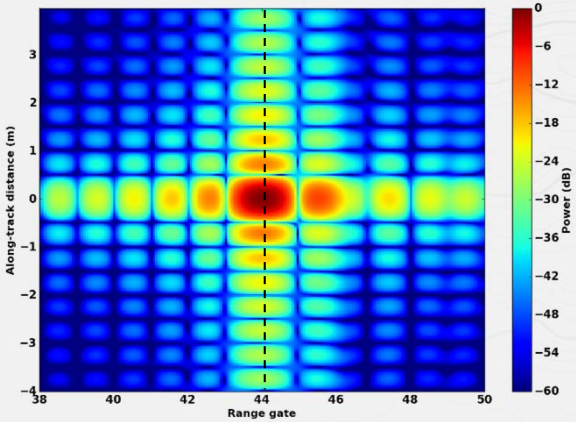
2)

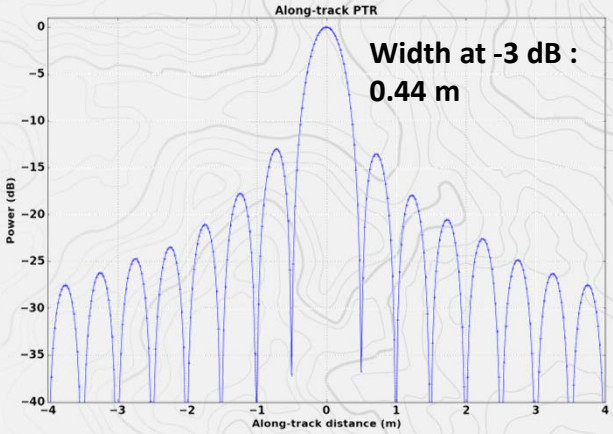


→ A small phase residual is not yet fully understood and empirically corrected. Ongoing investigation with instrumental experts to properly characterize it.

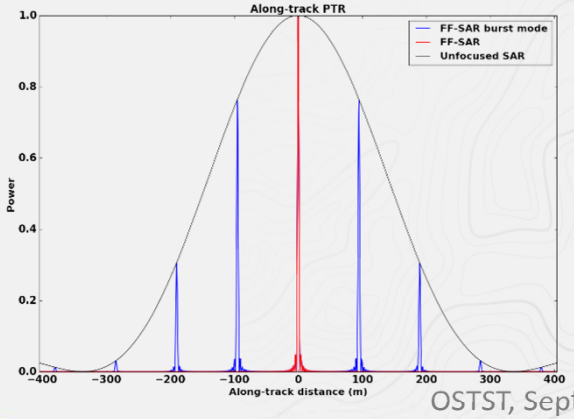
FF-SAR implementation and validation on transponder

- Impulse response is obtained by focusing at successive along-track positions around the transponder. **The maximum attainable resolution is achieved : 0.44 m.**





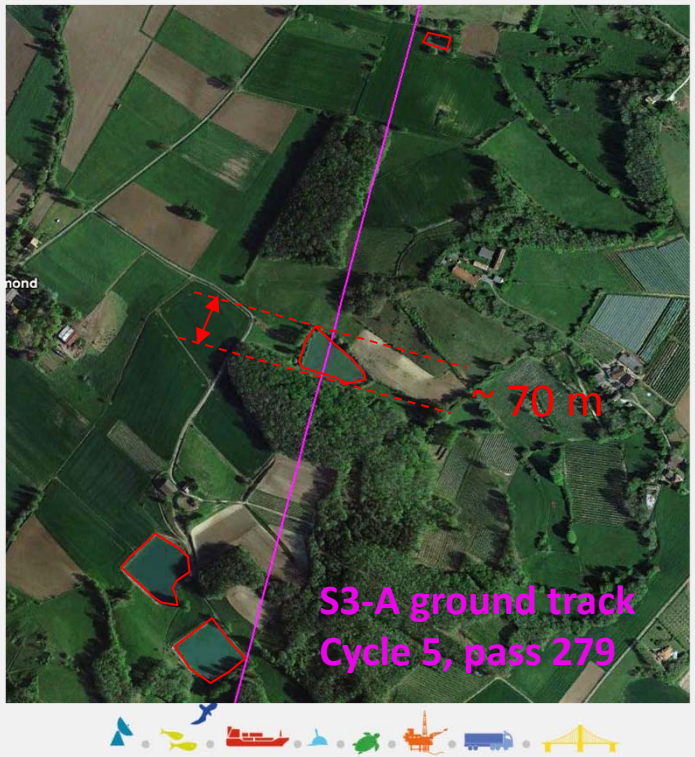
- Because of closed-burst operation, the PTR has evenly spaced high sidelobes, whose amplitude is modulated by the unfocused SAR impulse response.

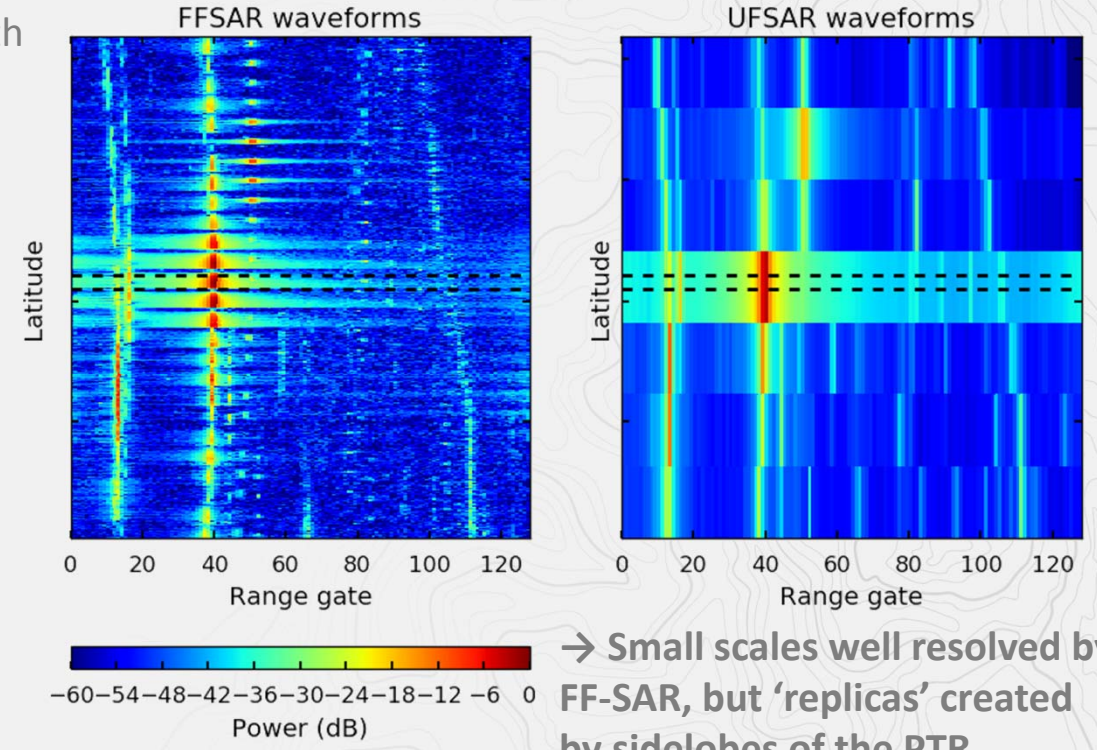


→ The high sidelobes are a limitation for current SAR altimeters (CS-2, S3) but will be reduced with the upcoming Sentinel-6 altimeter (interleaved mode).

Focusing on a real target

Small pond on the S3-A ground track with many other water bodies nearby

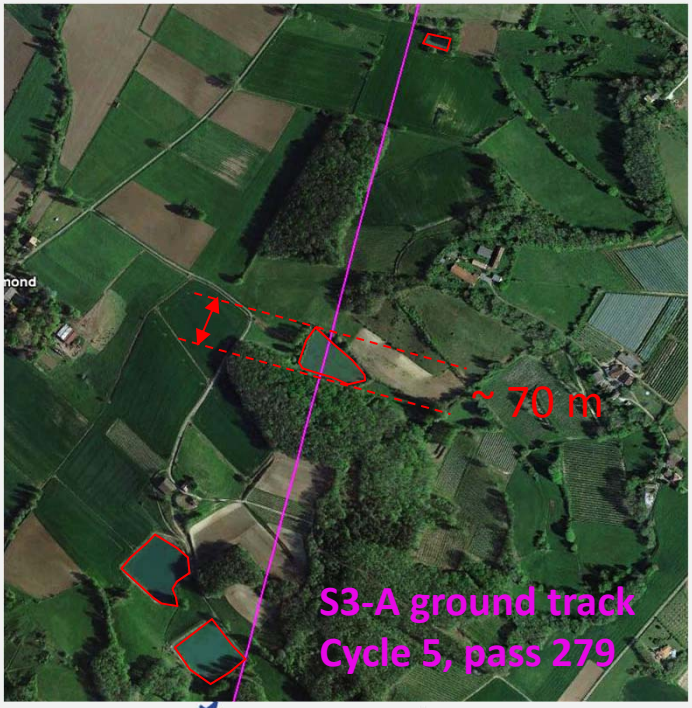


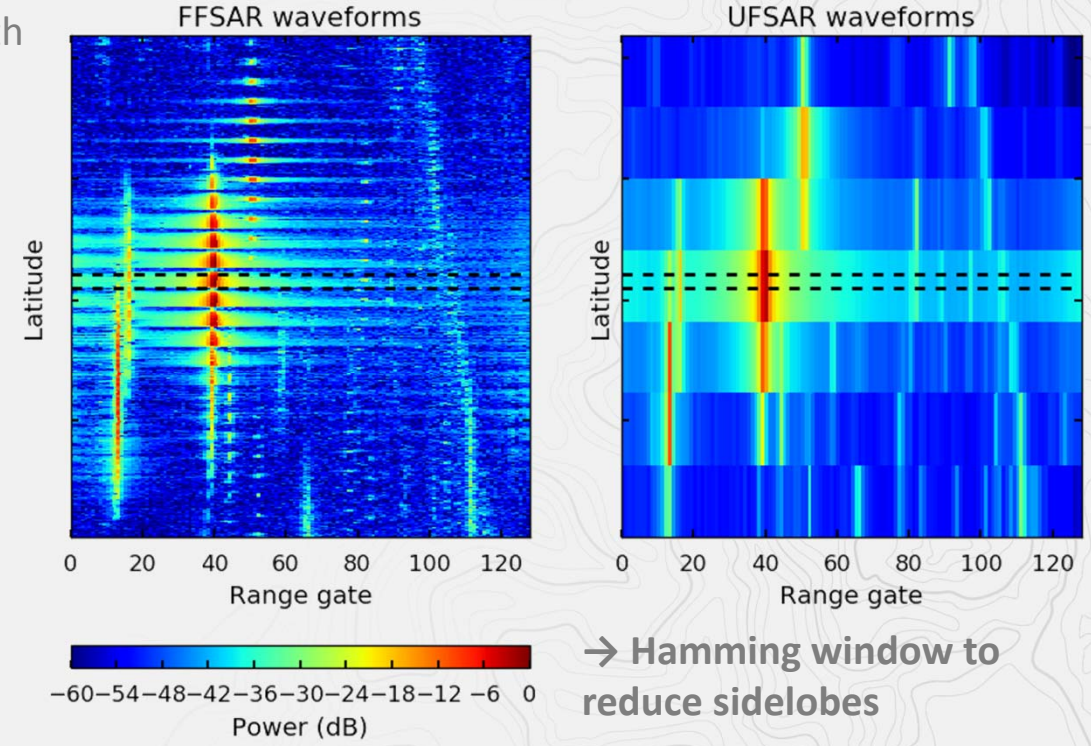


→ Small scales well resolved by FF-SAR, but 'replicas' created by sidelobes of the PTR

Focusing on a real target

Small pond on the S3-A ground track with many other water bodies nearby

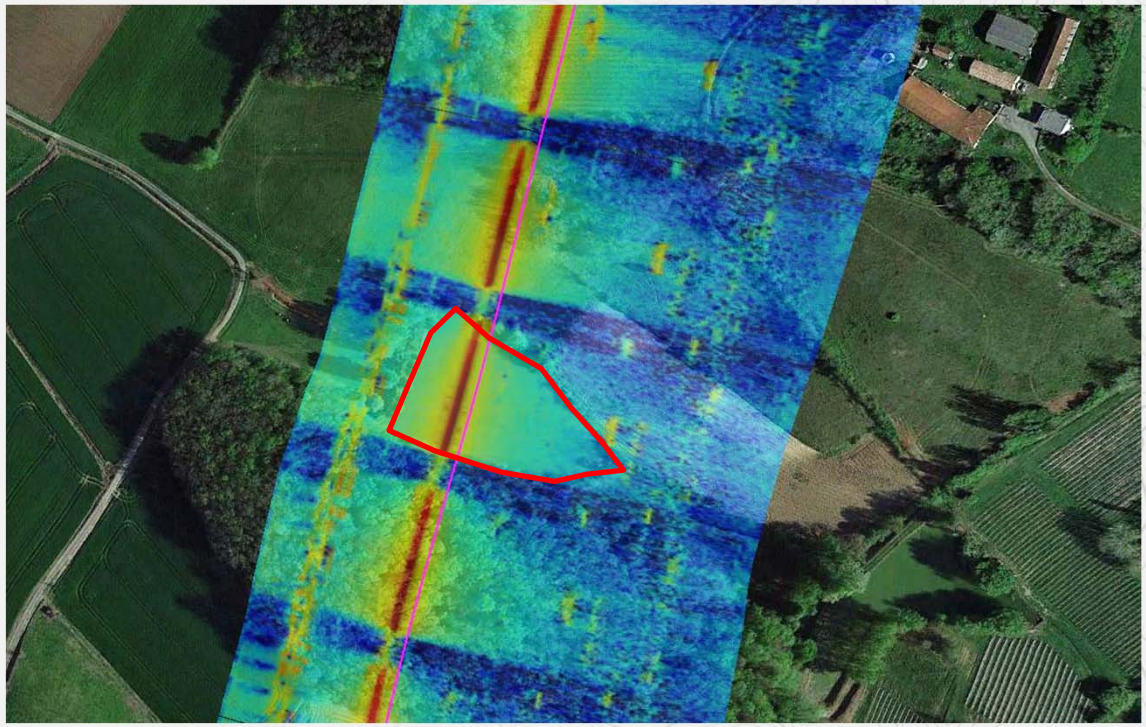




→ **Hamming window to reduce sidelobes**

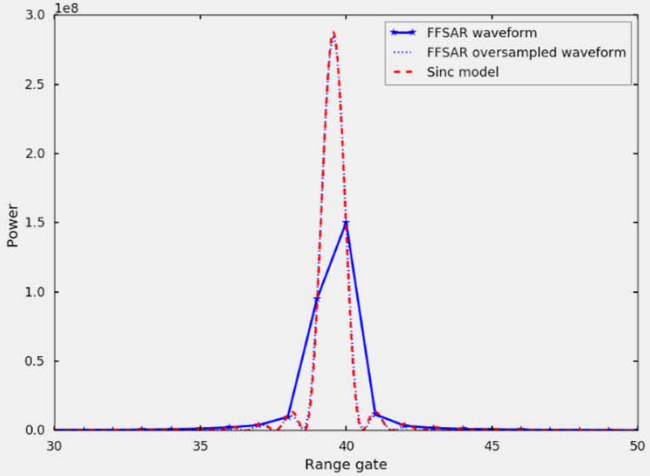
Focusing on a real target

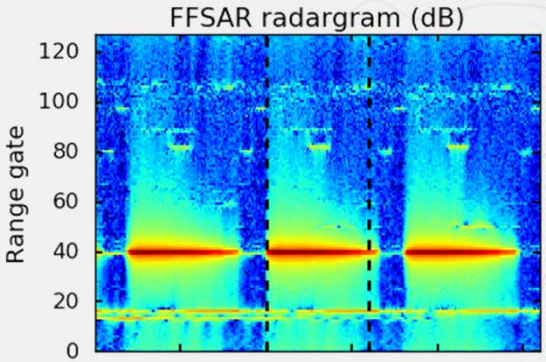
- FF-SAR radargram overlaid on the Google Earth image (caution, cross-track extension is not realistic) **: very sharp water/land transition !**
- The sidelobes of the FF-SAR impulse response create ‘replicas’ of the pond every ~ 100m.
- Here, the pond is small enough so that replicas remain outside the pond and don’t interfere with the main signal.

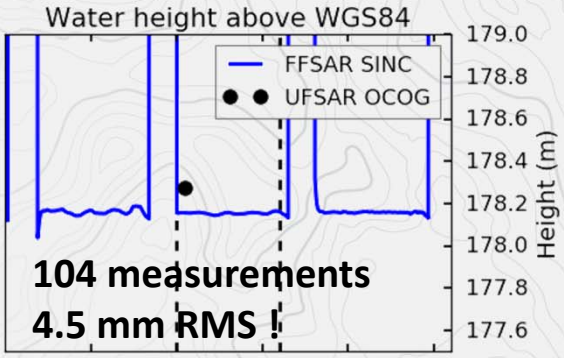


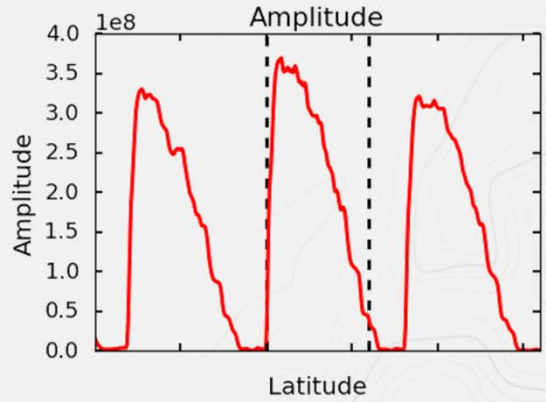
Retrieving the height of the pond

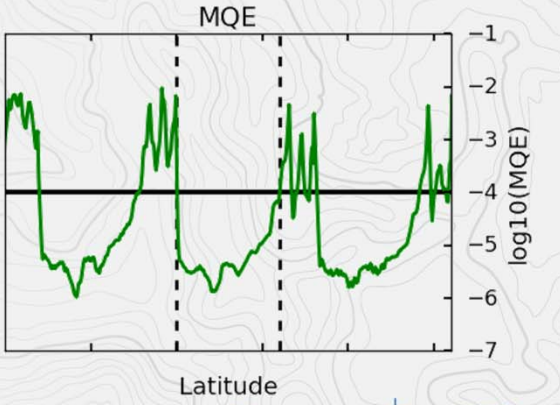
The pond is a very specular surface
→ FF-SAR individual zeropadded waveforms are retracked using a sinc model :



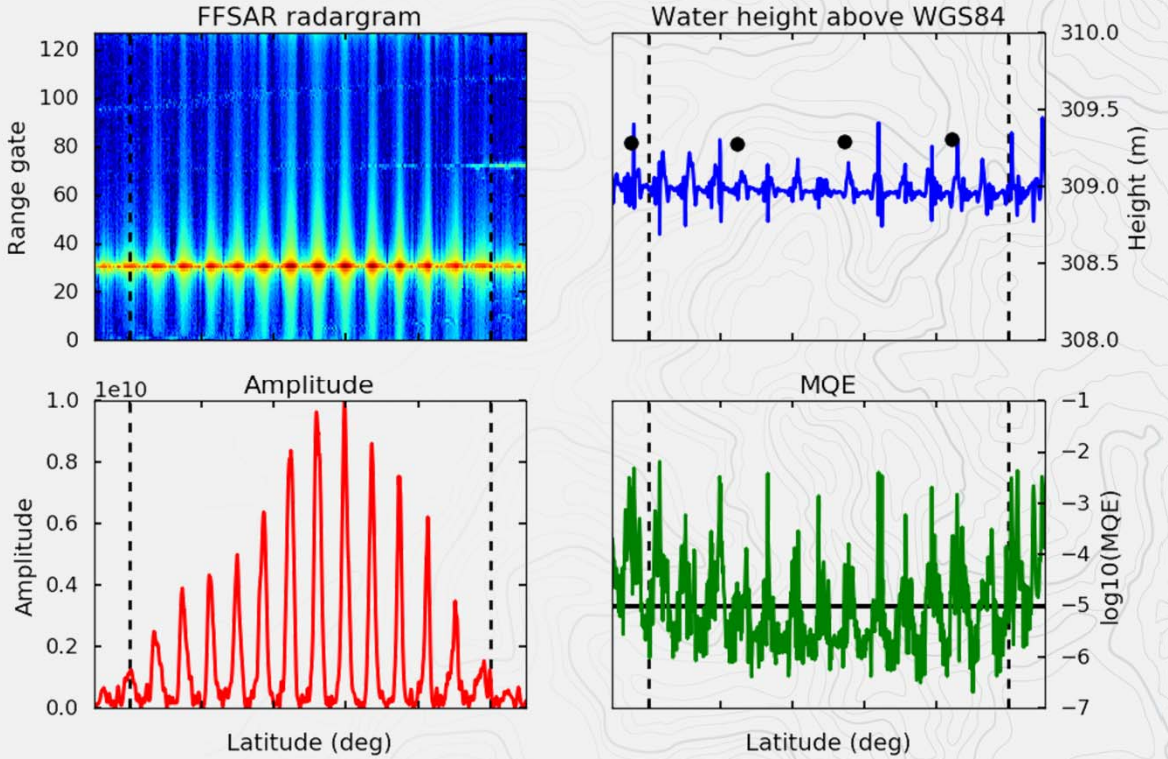








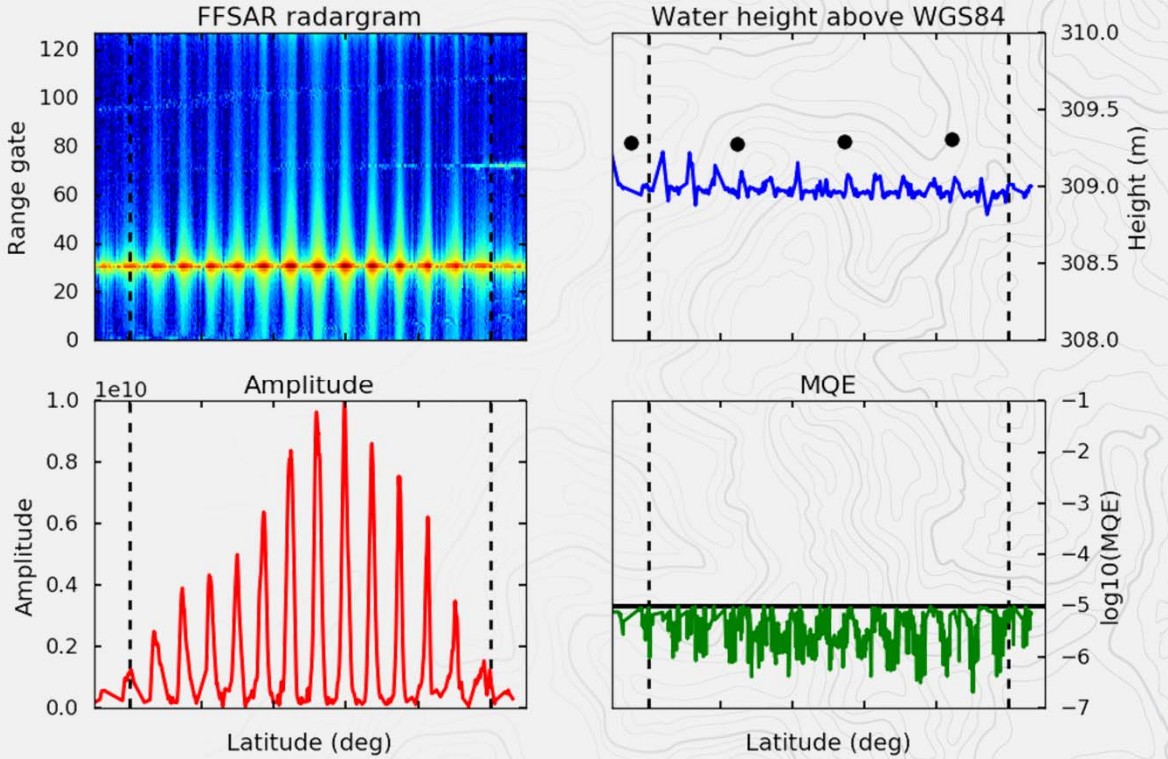
What about bigger targets ?



→ Amplitude oscillations due to PTR sidelobes (reproducible in simulation)
Ongoing work to better characterize and compensate it.

What about bigger targets ?

→ MQE threshold editing efficiently identifies the distorted waveforms.



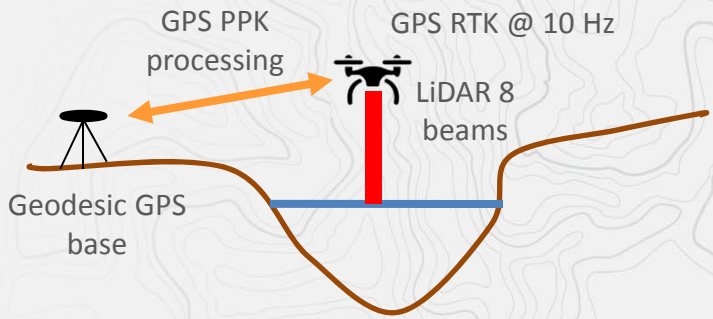
Performance assessment using Hydrones data

- Cal/Val campaign with HyDrones data over 6 rivers/lakes around Toulouse to assess performance (both precision and accuracy) over various hydrological targets.

- Same processing on the FF-SAR echoes : sinc retracking of the individual waveforms.

HyDrones #MK1.1 LiDAR altimeter :

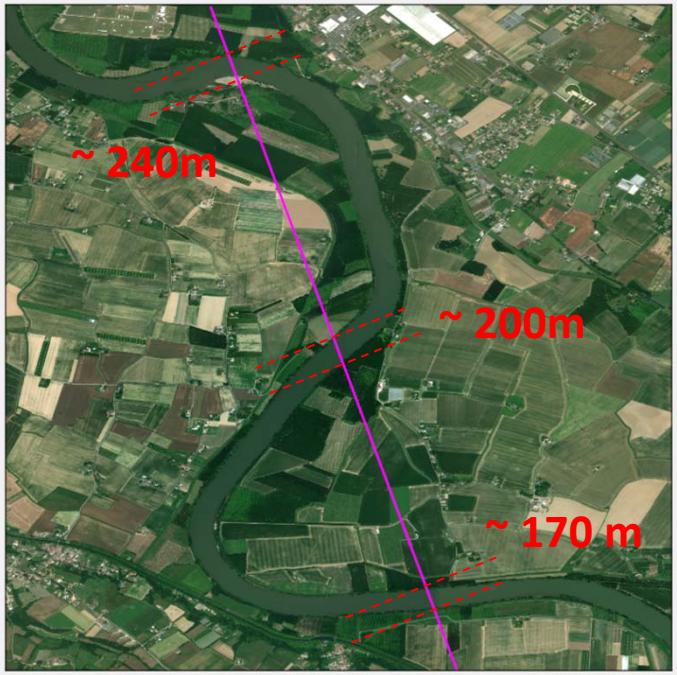
- 8 beams 905 nm, 20° horizontal swath
- 10Hz RTK GNSS
- 8 MegaPixels camera
- 80-100 m range

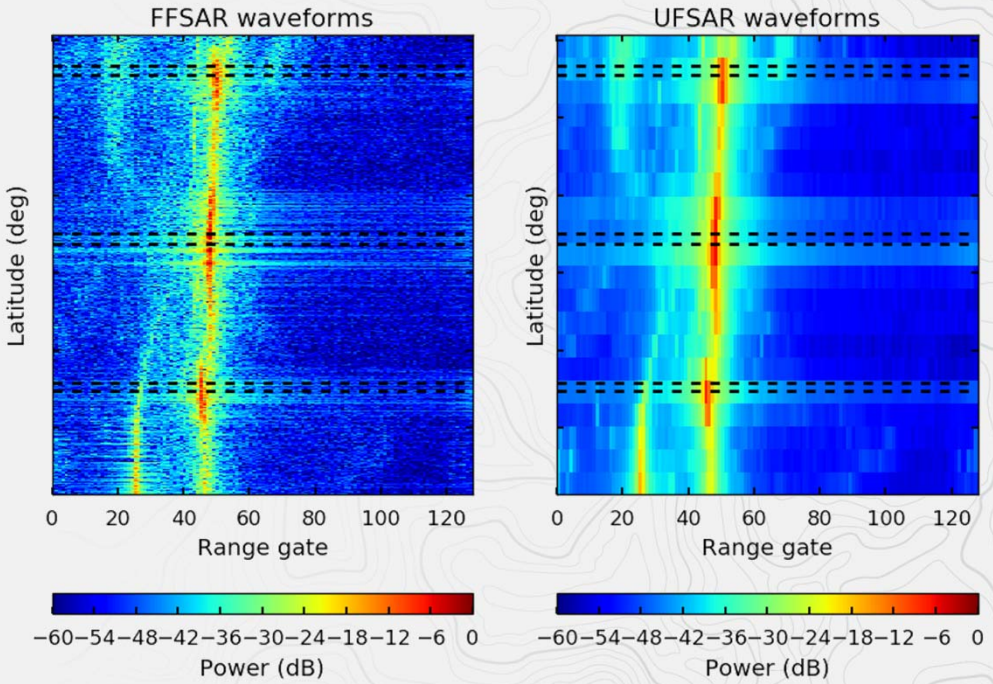


For more information : https://hydrones.cls.fr

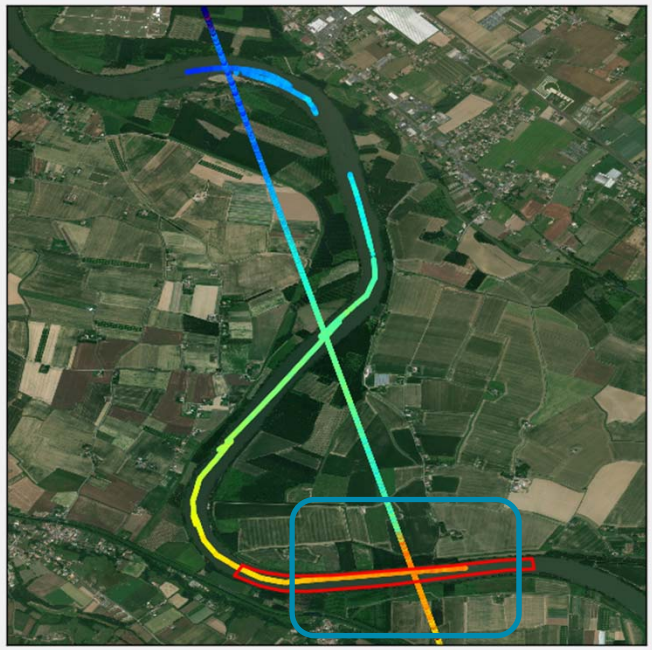
Garonne river, Marmande, June 22nd

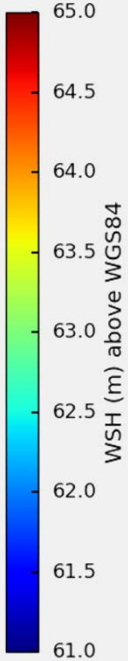
S3-A ground track, cycle 32, pass 300

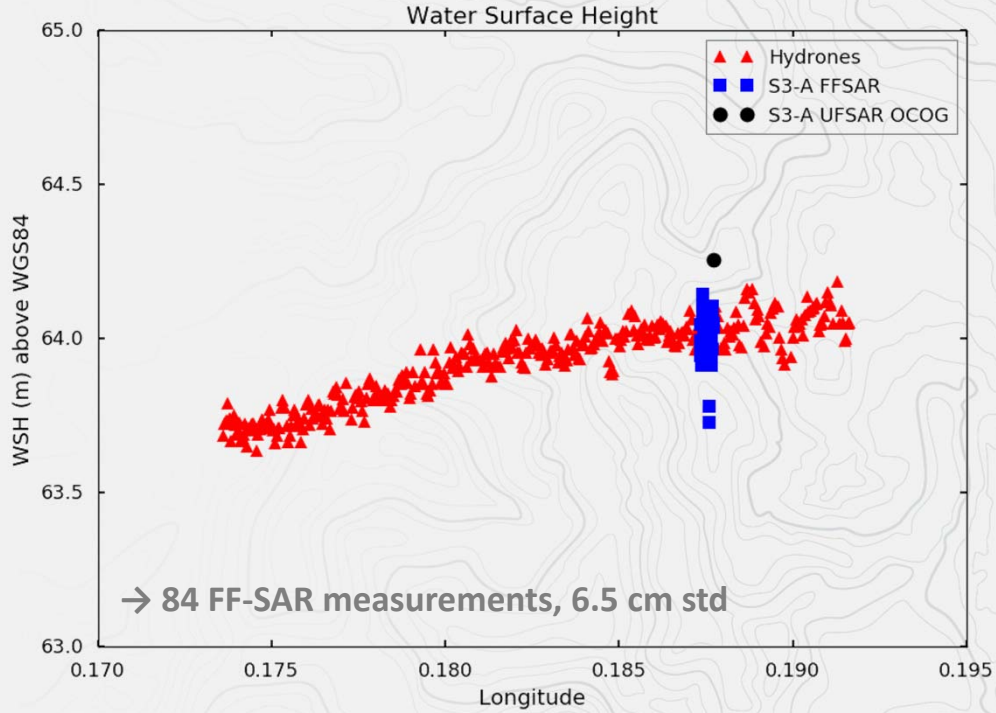




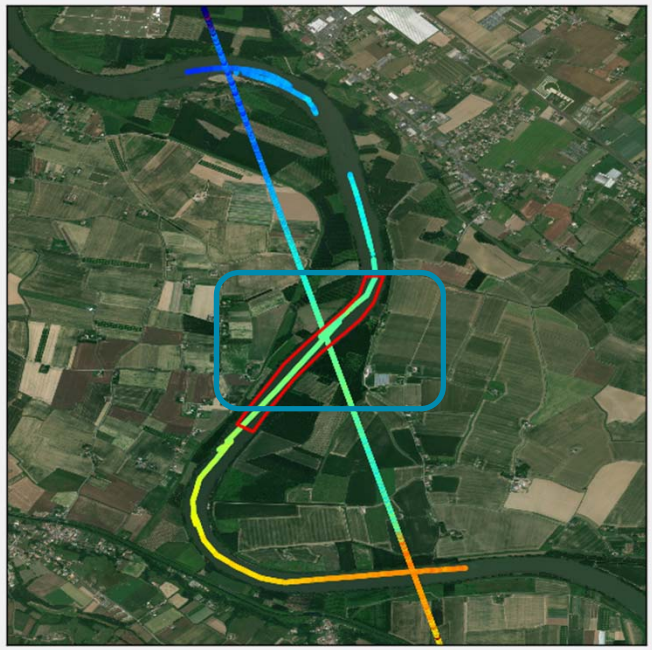
Garonne river, Marmande, June 22nd

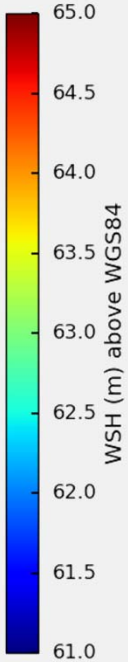


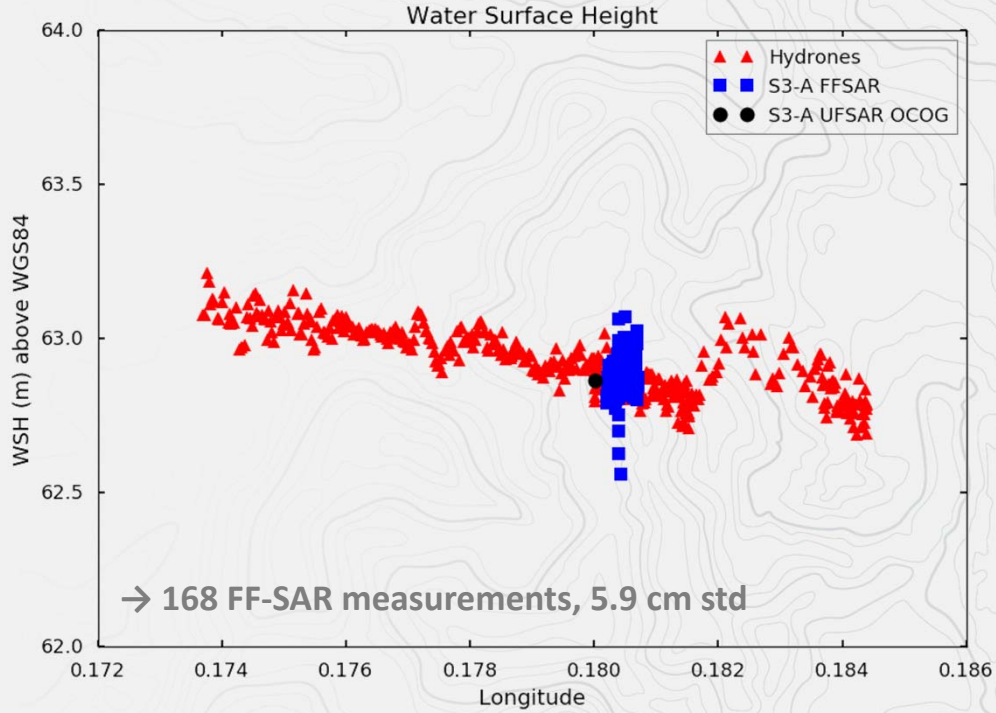




Garonne river, Marmande, June 22nd







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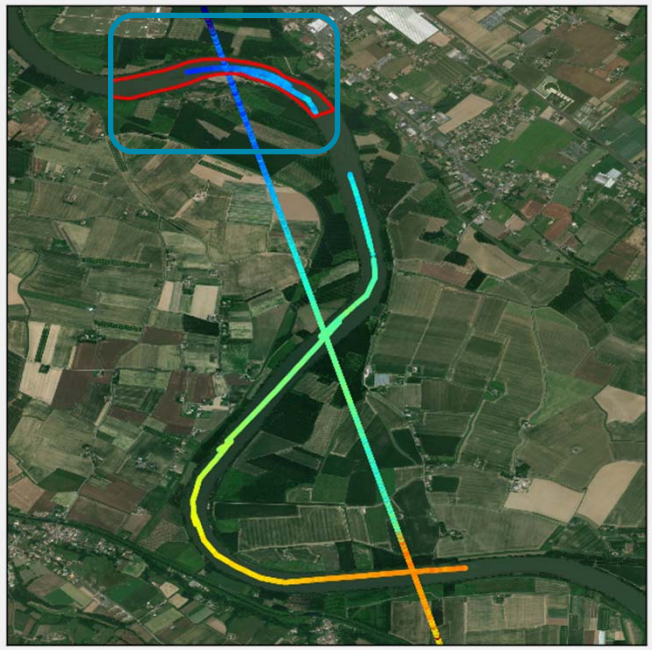
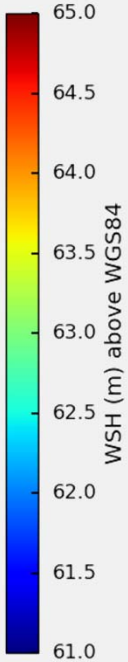
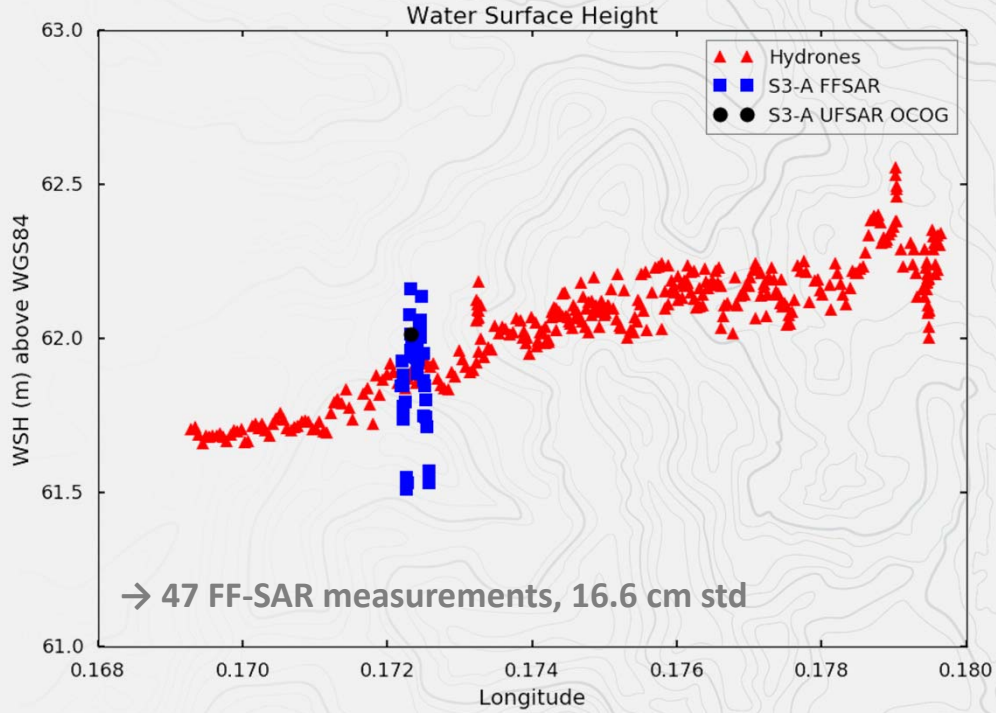
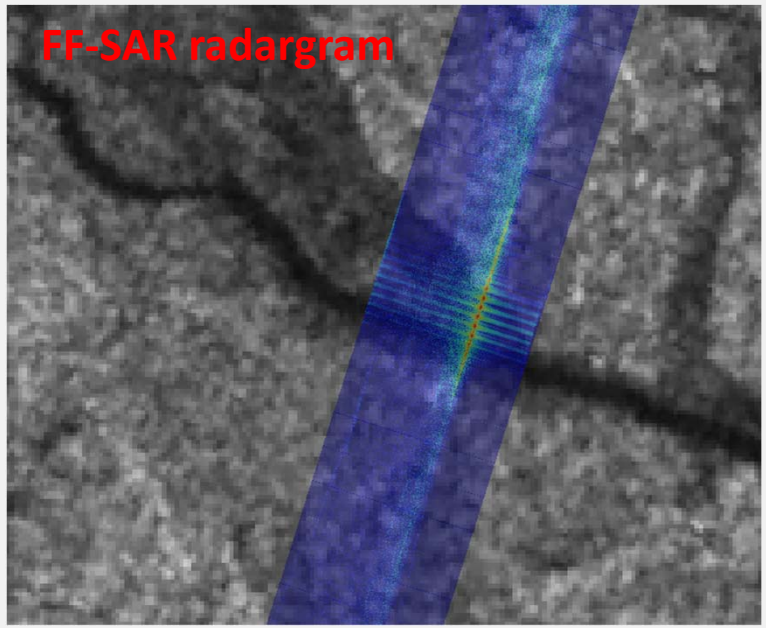
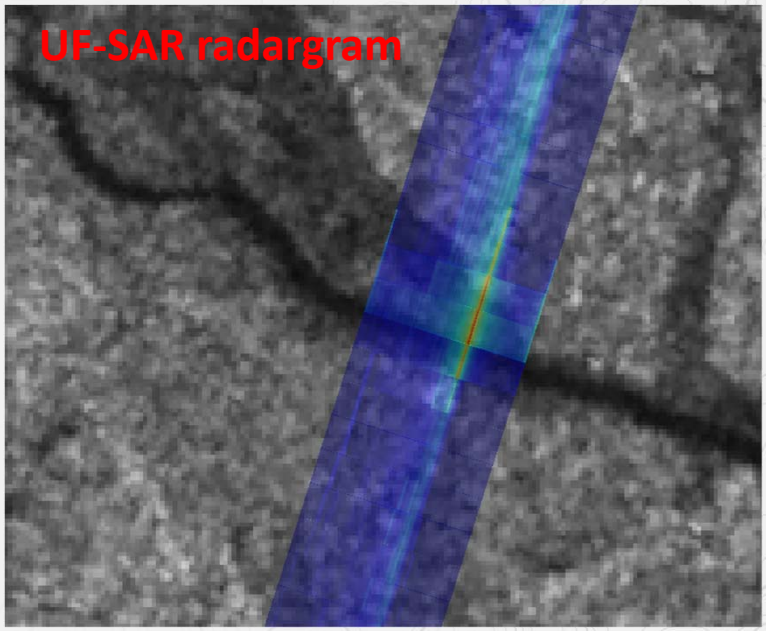






Sea ice with S1/S3 co-located data

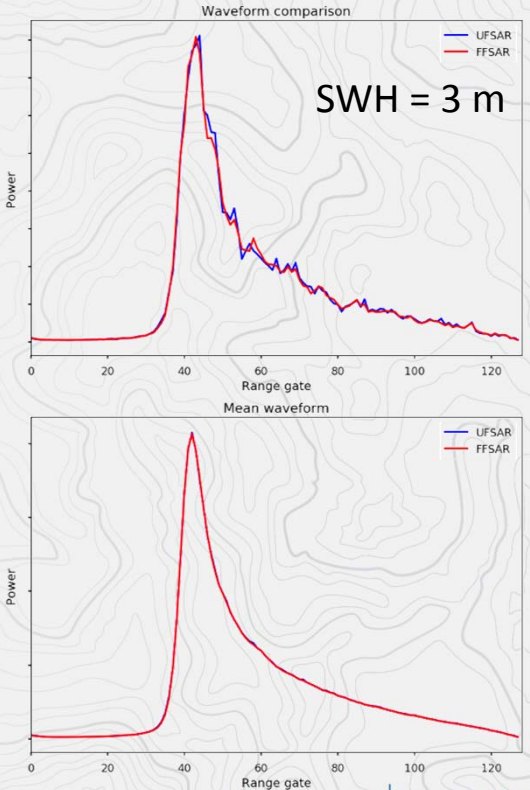




- Same expected benefits as in inland water brought by high resolution
- But two difficulties : replicas systematically contaminate floes and spatial averaging needed to reduce speckle on floes.

First results over ocean

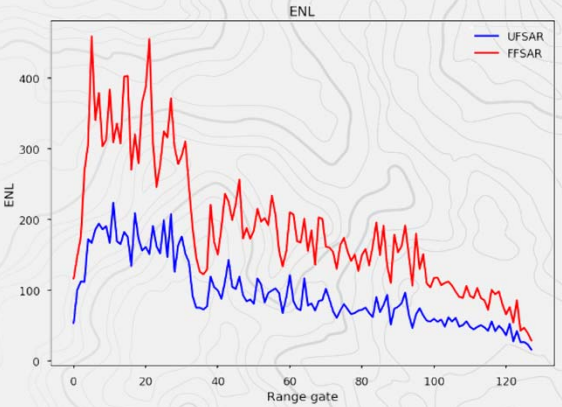
- Over ocean, the individual FF-SAR have to be spatially averaged to reduce speckle noise, going back to a 20 Hz posting rate.
- The FF-SAR echoes are very similar to the unfocused SAR echoes even if the along-track impulse response is changed. FF-SAR might be more impacted than unfocused SAR by surface motion, as the coherent processing time is longer.
- The S3PP retracking has not been adapted to the FF-SAR PTR yet, so we use the unfocused SAR retracking.

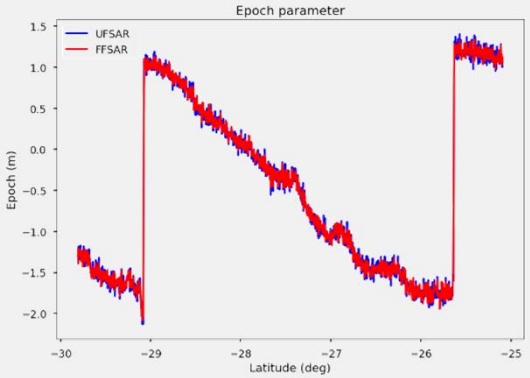


First results over ocean

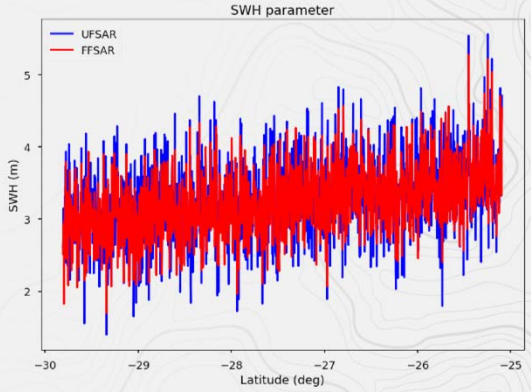
- The FF-SAR allows to reduce speckle noise more efficiently than unfocused SAR (the Equivalent Number of Look is approximately two times higer).

- Consequently, the noise level on the geophysical estimates is reduced by a factor ~ √2:





SSH 20 Hz noise:
5.7 cm vs 7.3 cm
SSH bias:
0.1 cm



SWH 20 Hz noise:
39.4 cm vs 50.4 cm
SWH bias:
-3.5 cm

Conclusions & perspectives

- Fully-Focused SAR does bring **significant improvement** over many surfaces (inland water, sea-ice, ocean). Improvement is expected to be even more important with the upcomming Sentinel 6 mission (open-burst mode).
- **Hydrology**: very high potential, better sampling/precision/accuracy than previous processings. A one-year reprocessing campaign over the French rivers/lakes referenced in the S3 OLTC tables is planned to fully assess the performance.
- **Sea-ice:** benefit is expected but an adapted post-processing is needed.
- **Ocean:** significant noise reduction. Plan to adapt our retracking model and process one or several cycles of data to analyse performances in terms of noise level, biases, sensitivity to sea state conditions, spectral analysis etc.

Thank you for your attention !