Sentinel-6 Hydrology Measurements Capability Demonstration

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Summary

- The Sentinel-6 altimeter (Poseidon-4) has an open burst SAR capability. After Fully-Focused SAR (FFSAR) ground processing ((1) Egido et al.), it can provide high resolution radargrams.
- This study, performed in collaboration between NASA/JPL and CNES, aims to demonstrate Sentinel-6 capability for hydrology. A section of the Garonne River near the city of Marmande (France) has been selected for this experiment. The width of the river in this area does not exceed 150m.
- The altimeter data have been processed by CNES (F. Boy and S. Le Gac), to generate FFSAR radargrams.
- Each agency has then independently developed algorithms to derive the river height.
- Results confirm Sentinel-6 data have great potential for hydrology.

(1) Fully Focused SAR Altimetry: Theory and Applications. January 2017.IEEE Transactions on Geoscience and Remote Sensing PP(99):1-15 DOI:10.1109/TGRS.2016.2607122

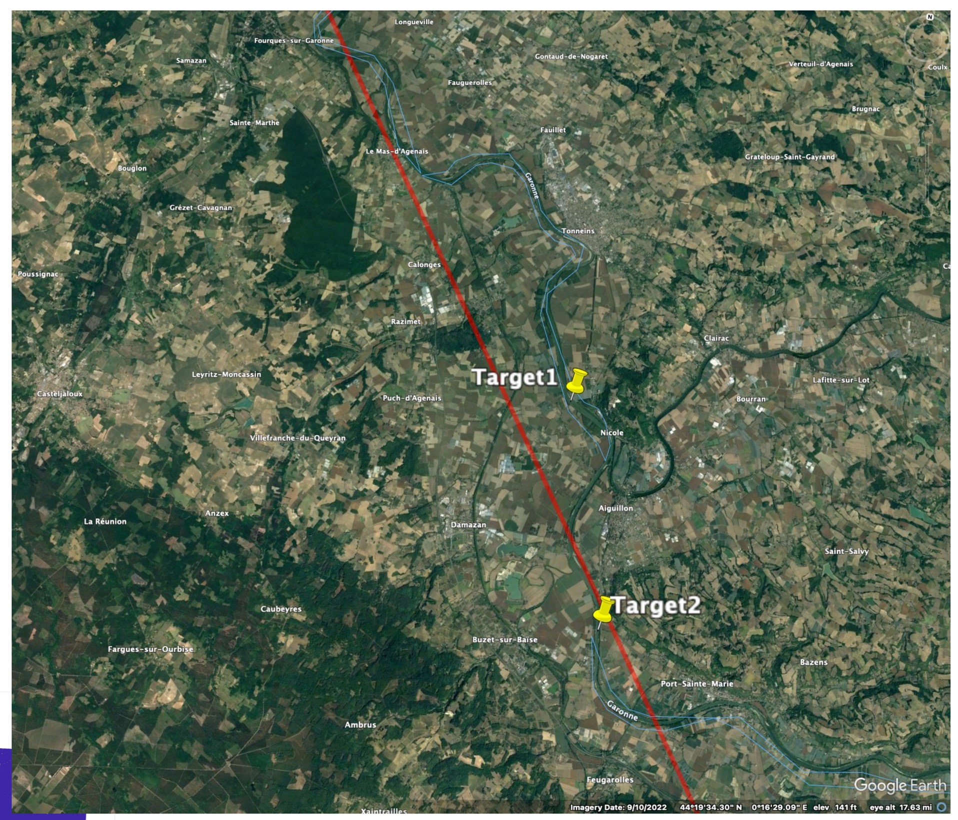

Figure 1 : Garonne River and targets

Inputs

- **Radargrams (FFSAR Waveforms)**
  - Waveforms have been processed by CNES using the FFSAR technique (Figure 3)
  - Waveforms are provided at ~700Hz corresponding to a sampling resolution better than 10m along track.
  - Range sampling resolution is ~ 19cm
- **Water Mask**
  - The mask (Figure 2) has been generated at JPL using Landsat-8 and Sentinel-2 data at 30m as input to the in house open-source developed software SIT-FUSE (Multi-Sensor Segmentation and Instance Tracking using Unsupervised Deep Learning).
  - SIT-FUSE leverages unsupervised and self-supervised machine learning (ML) to generate per-scene segmentations that were used to generate the water mask.

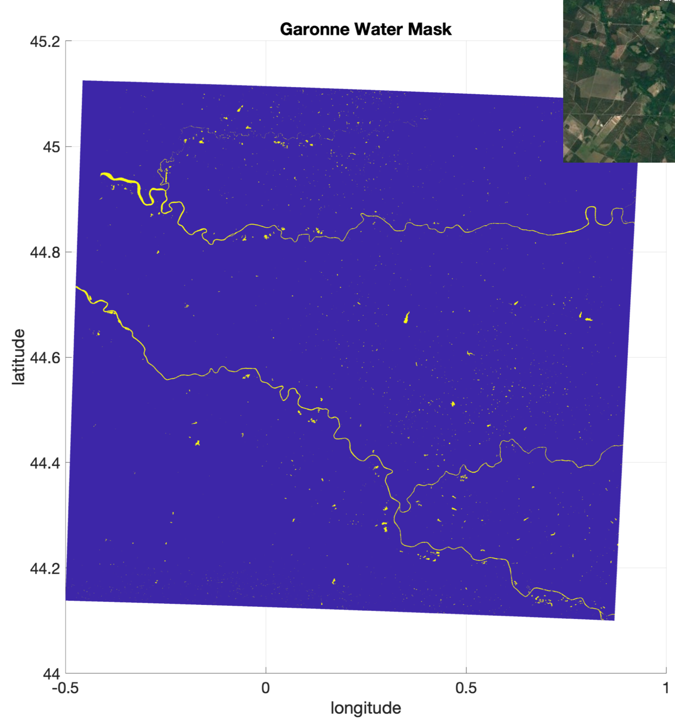

Figure 2 : Water Mask

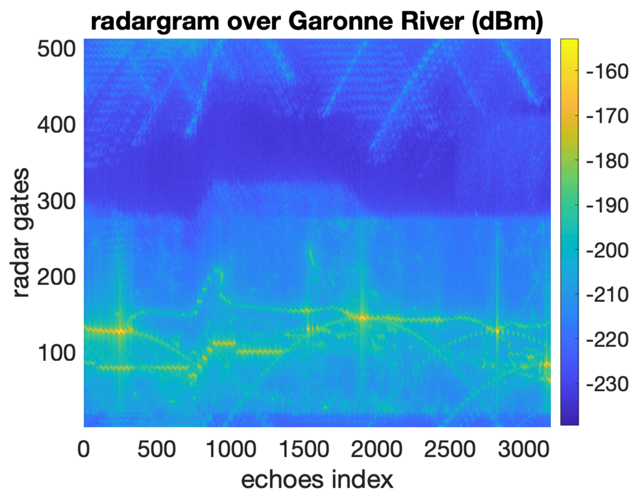

Figure 3 : FFSAR radargram

Processing

- **Water Mask Processing**
  - The mask is processed to select points corresponding to the Garonne River.
  - Processing steps include:
    - Extraction of Garonne points (Figure 4) using image dilation, points connectivity assessment and labeling.
    - Extraction of River "Skeleton" (Figure 5)
    - Iterative Skeleton Cleaning (Figure 6) based on convolution to suppress "side branches" points (artifacts from "skeletonizing" algorithm).
- **Model generation**
  - For each waveform, a theoretical range is computed as follows:
    - Selection of the points of the water mask corresponding to the current satellite position and resulting azimuth resolution swath (Figure 7).
    - Computation of theoretical range w.r.t. ellipsoid assuming the river main response corresponds to the closest water point in the swath (Figure 8) .
- **River Height** is derived from the difference between theoretical range and range derived from the waveforms.
  - The range from the waveforms is estimated detecting local amplitude maximum.
  - Using the model, only part of the waveform is selected to avoid false detection.
  - Some tuning has been necessary here. We are working on using supervised machine learning to have a fully automated and more accurate processing of the waveforms using the theoretical range model to better identify the signal from the river.

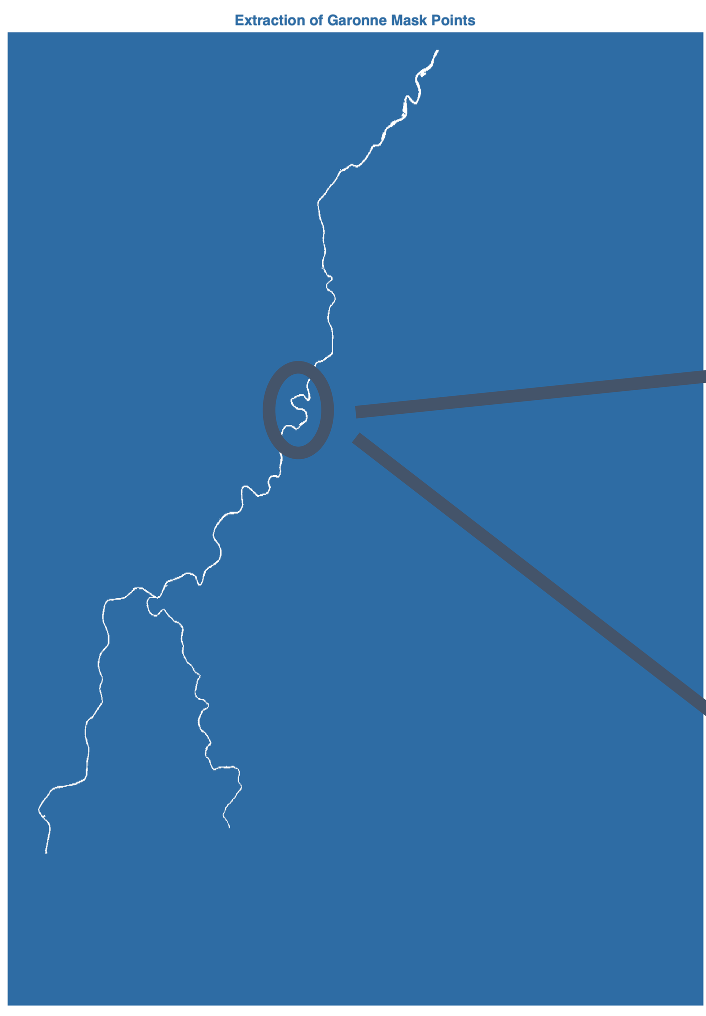

Figure 4 : Garonne river points extracted from the water mask

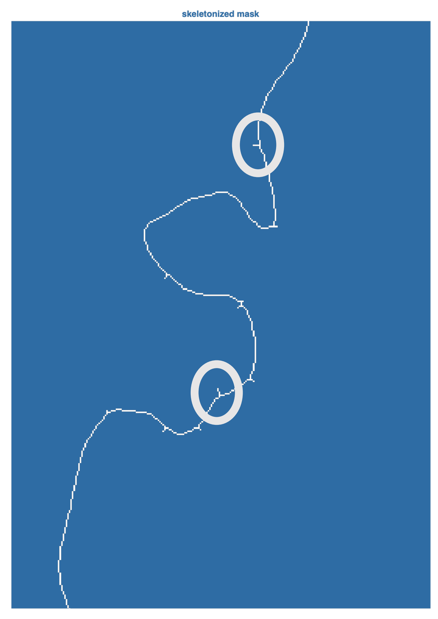

Figure 5 : River points skeleton

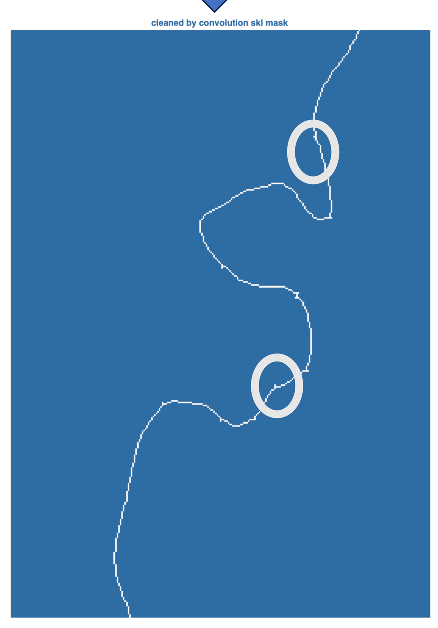

Figure 6 : River points skeleton after cleaning

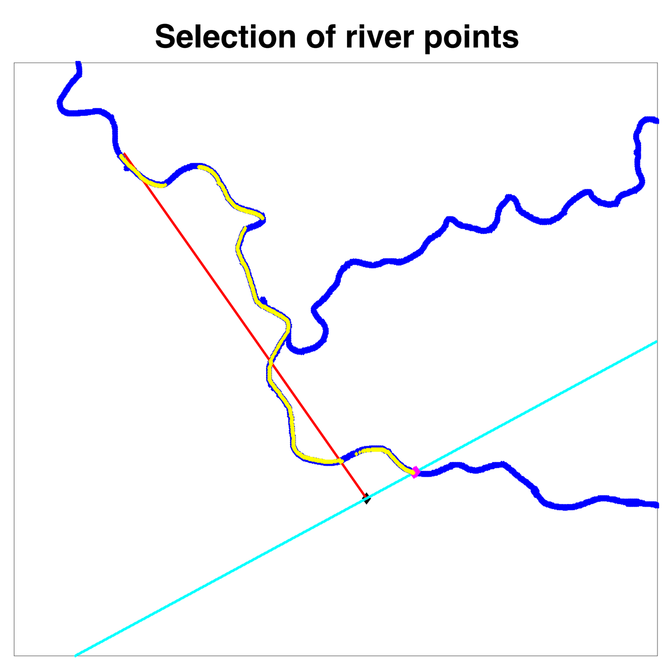

Figure 7: orbit positions (red) and corresponding river selected point (yellow). Current estimations are indicated with black and magenta points respectively. Line in cyan corresponds to the swath for the current position

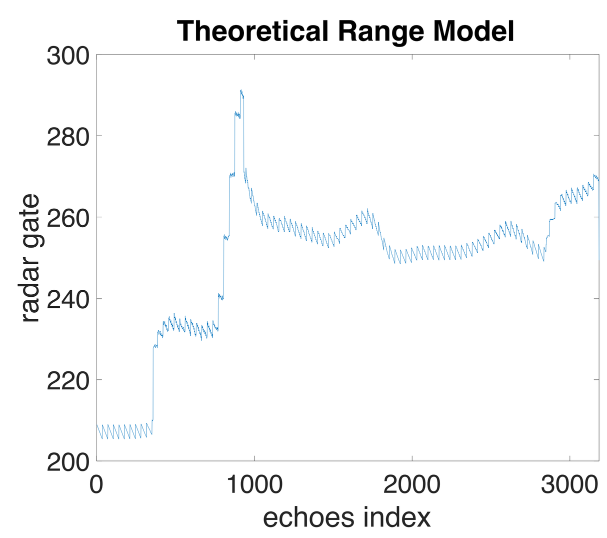

Figure 8 : Range Model

Results

- From the radargrams, water height profiles along the river (Figure 10) have been derived. Two targets have been defined to compute times series (Figure 9) at their respective location (Figure 1)
- While not yet perfect, the water height profile and the time series for the 2 targets have good consistency. Heights also have good agreement with Google Earth elevations.

Note: the height estimations for each target have been derived using only 1 waveform (700Hz) for each cycle. Applying some smoothing along the river could improve accuracy.

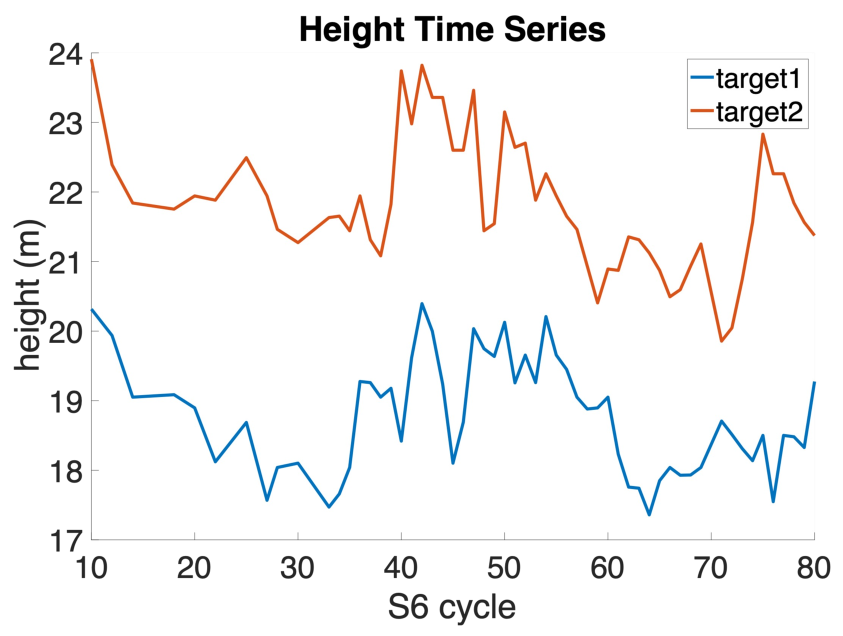

Figure 9 : River Height Time Series for Target 1&2

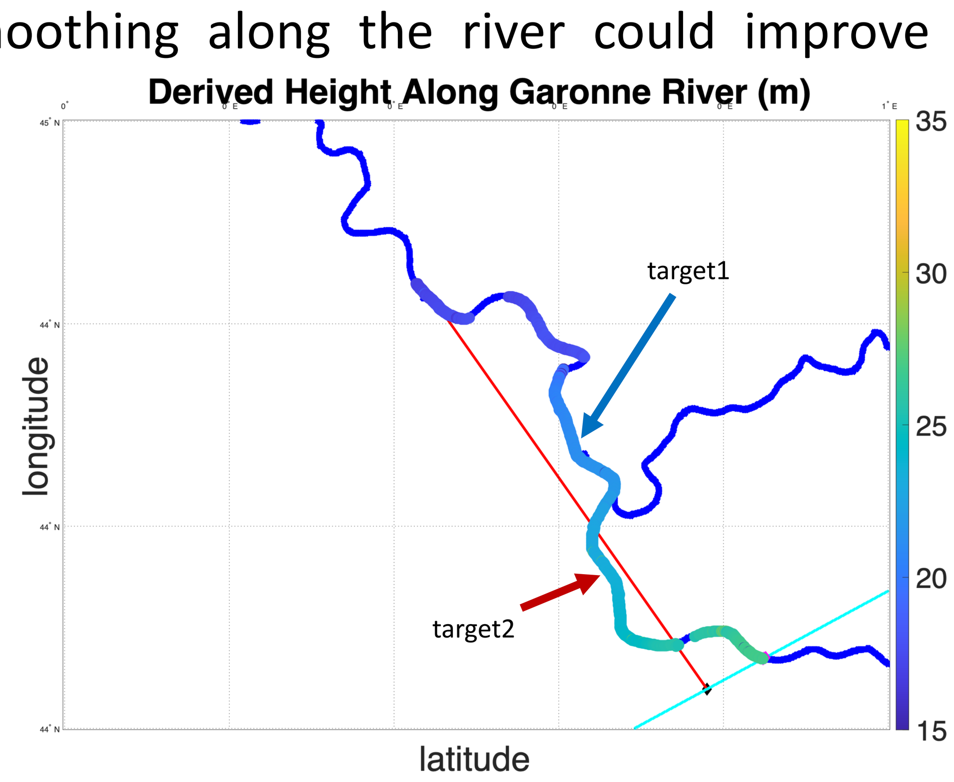

Figure 10 : River Height Profile

Conclusions

- **This study demonstrates a capability to use Sentinel-6 to monitor relatively narrow rivers (width ~ 150m).**
- **The next step will be to use machine learning techniques to improve the height estimates from the altimeter waveforms. It should increase the reliability and the degree of automatism to operate the tool over a large number of targets.**

OSTST 2023 San Juan, Puerto Rico

This research was carried out at the Jet Propulsion Laboratory and the California Institute of Technology under a contract with the National Aeronautics and Space Administration.

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