

# Fully Focused SAR Altimetry and Innovative River Level Gauges for Coastal Monitoring – the FFSAR-Coastal Project

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## FFSAR – Coastal

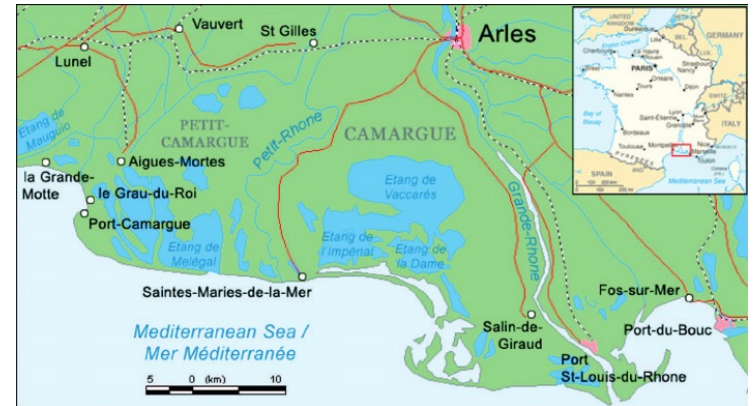
The FFSAR-Coastal Project is applying the SMAP Fully Focused SAR (FFSAR) altimetry processor on Sentinel-3A and Sentinel 3B data in order to evaluate the potential of FFSAR altimeter data to contribute to coastal and estuarine monitoring.

Two different environments :

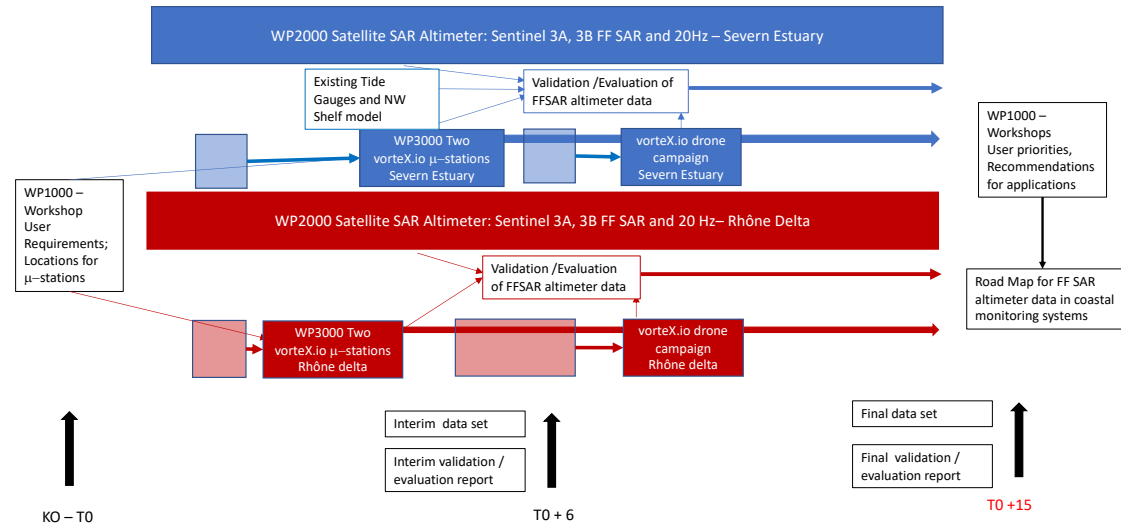
- The Severn Estuary : Highly dynamic mixed tidal estuary environment, confluence between a river and its estuary experiencing large tidal range and strong tidal currents.
- The lower Rhone Delta and Camargue: A low lying, flat river delta and wetland environment, susceptible to inundation and rising water levels.

Funded by **ESA** through the EO4Society Open Call

<https://www.satoc.eu/projects/ffsar/>



- Fully Focussed SAR processing (DTU)
  - Apply SMAP FFSAR processor for S3A, S3B data in Severn and Rhône areas
  - Validate against in-situ data, evaluate ability to map key features
  - Identify optimum processing choices
- vortex.io micro-gauges
  - Install 4 micro-gauges (2 per region) for in situ validation
  - Drone campaigns to map water level from in situ sites to satellite track
- User Engagement / Application Road Map (NOC, CCO)
  - Workshops > Roadmap for FFSAR processing in Coastal Monitoring Systems



## Vortex.io “micro” Gauges

- LiDAR, 8Mpx camera
- Real Time data
- Remote management
- Lightweight, small & easy to install

## FFSAR Coastal Installations

- Severn Estuary: Newport & Weston Super Mare\* (06/09/22)
- Rhône delta: Port St Louis du Rhône & Fos sur Mer (27/07/22)
- Data available online
- \* Replaced 6<sup>th</sup> April 2023

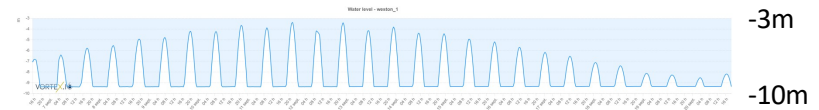
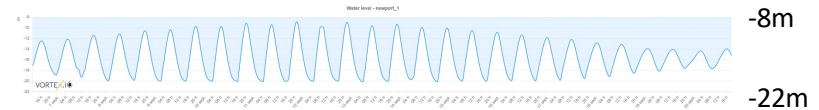
## Severn



S3A and S3B tracks



## Rhône



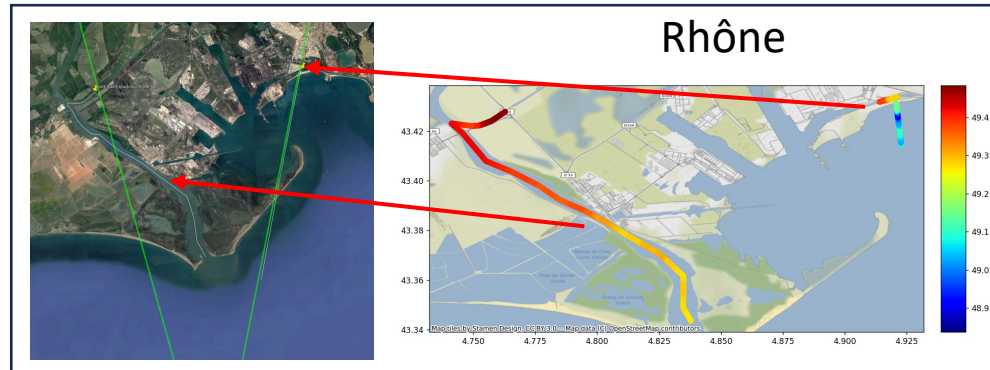
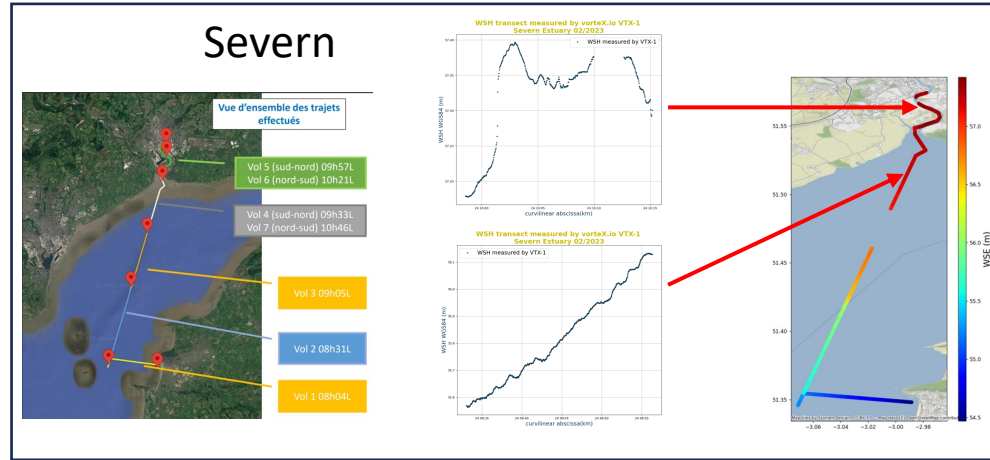
## Objective:

To connect water level at gauge to satellite track at the time of overpass.

- LiDAR: cm level accuracy, 50cm to 90m range
- 8Mpx camera: water mask, orthophotos
- 900g

## Deployments:

- Severn Estuary – 24/02/23 (from boat)
- Rhône Delta – 13/04/23 (from land)
- Timed to coincide with Sentinel 3B passes
- Data used to geo-reference micro gauge water levels
- Data available on-line



- Apply SMAP (Standalone Multi-Mission Altimetry Processor) to Sentinel 3A and 3B data
- Initial results used to identify the optimum processing choices, then applied to generate time series of data for selected tracks.
- Validation against in-situ data and models.
- Evaluate how well FFSAR altimeter data can resolve fine scale features in two different environments.
- Severn Estuary: Ability to capture small scale physical signals (surface gradients, currents, roughness signatures) in highly tidal regions and to detect and measure tidal asymmetry/gradients
- Rhône delta: Ability of FFSAR data to accurately map different low lying channels and filaments.

# FF SAR Processing Options



Investigated different options involving series of trade offs:

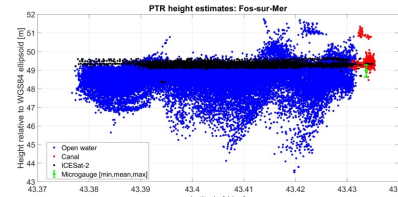
- “Noise” v along-track resolution
- Processing speed v precision
- Open ocean v enclosed water (canal) performance
- Used in-situ data and ICESAT-2 data for reference

**Final choices for both locations:**

**Illumination Time: 2.3s**

**Posting Rate: 1000 Hz**

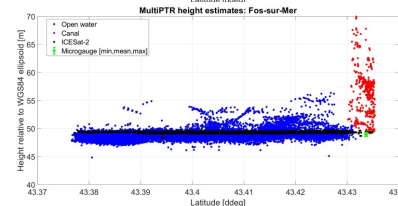
**Re-tracker: DTU MWaPP (Multi-Waveform, Persistent Peak)**



Re-trackers

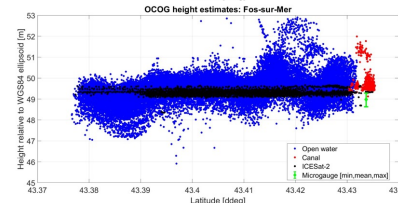
PTR

FFSAR open ocean water levels



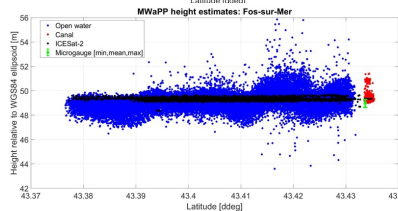
“Multi” PTR

FFSAR enclosed water (“canal”) water levels



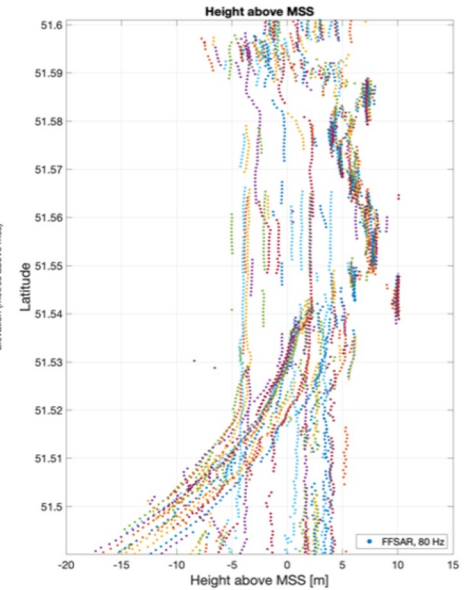
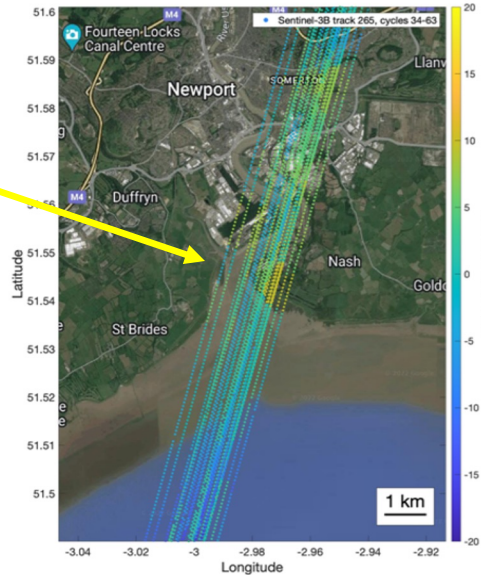
OCOG

In-situ gauge water levels



MWaPP

Ice-Sat2 output





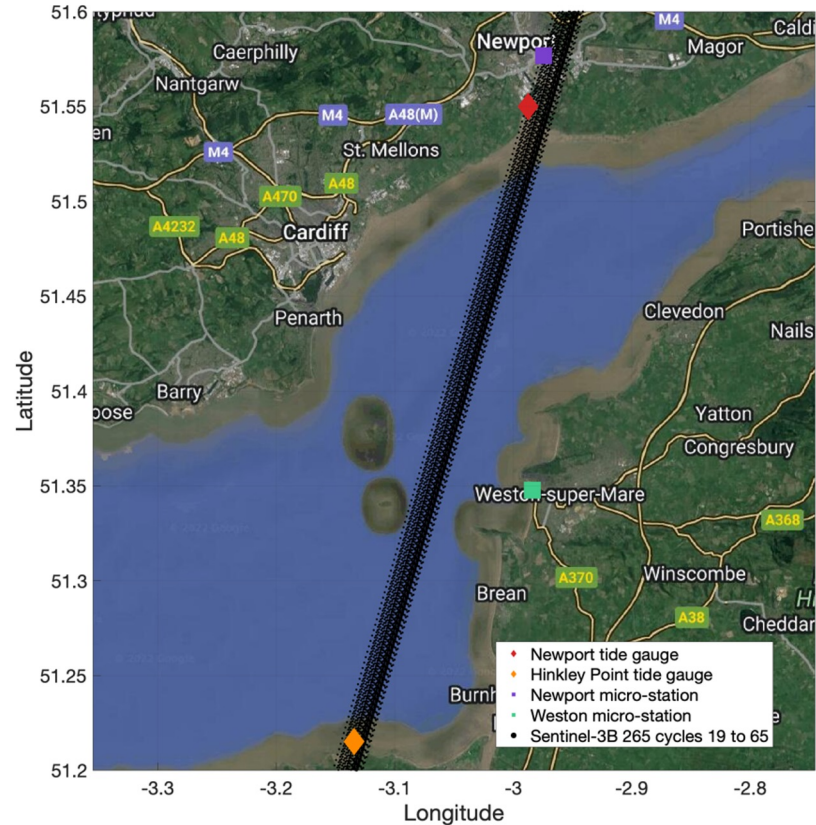
# FF SAR Processing – Severn Estuary 2

Track 265 from Sentinel-3B is close to several tide gauges and to the micro-stations

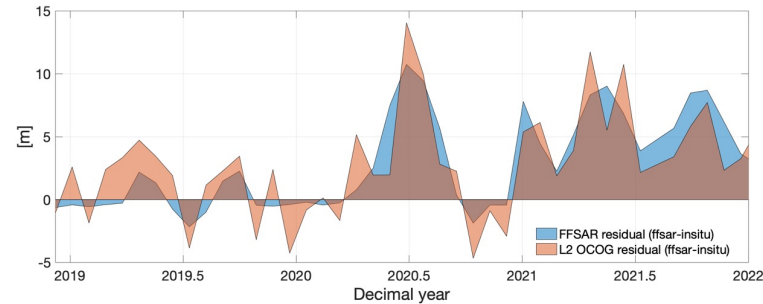
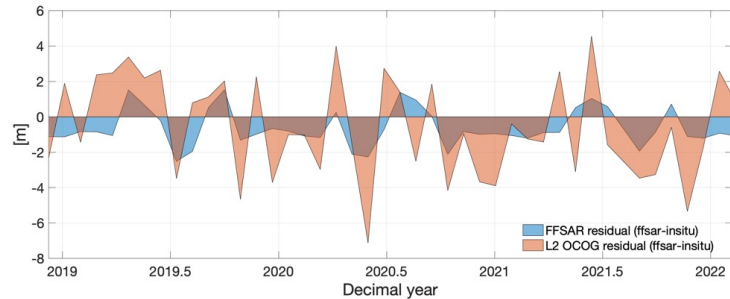
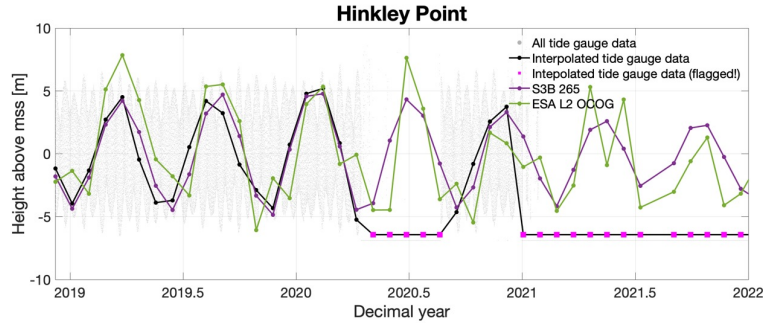
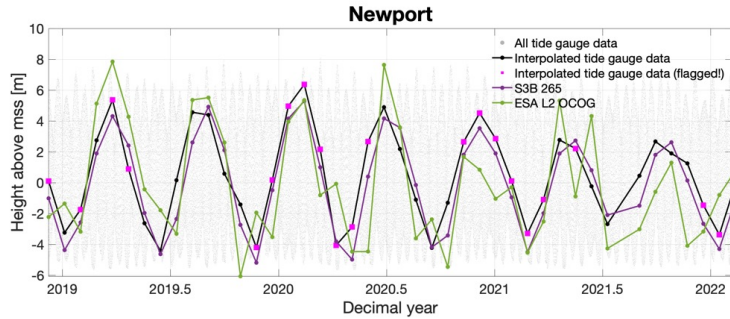
**Tide gauges used for validation of FFSAR data:**

**Newport**

**Hinkley Point**



## Time Series comparison with Tide Gauges



Generally good agreement but RMSE of 1.2 m.

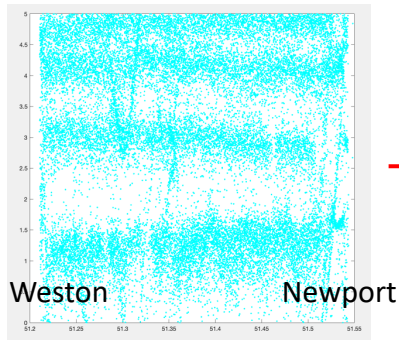
Improvement on RMSE ~3m from ESA OCOG retracker!



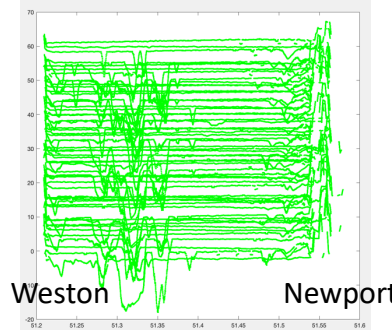
(1) Raw FFSAR processed data, S3B track 265.  
 MWaPP retracker, 1000Hz or 6m sampling

(2) Smoothing over 15 points (80m)  
 • “Snagging” is significant – “tide” related?  
 • Thought to be from coastal smooth water targets (Locked harbours)

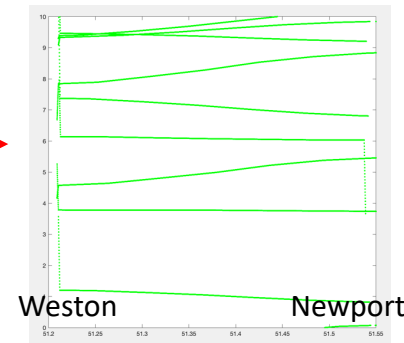
(3) Further smoothing (120m) and remove snagging  
 • Different sea level slopes for different passes (different tidal conditions)  
 • ~ 1.0m difference in water level over 20km



13 July 2023

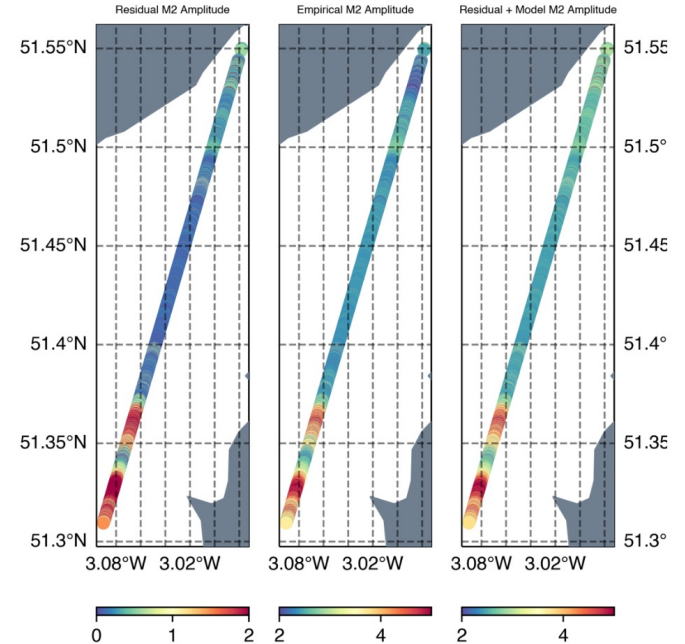


IUGG 2023 – JG06 Monitoring Sea Level Changes by Satellite and in situ Measurements



# Interpretation of FFSAR data in Severn Estuary – Detailed M<sub>2</sub> Tidal Model

Sentinel-3 orbit means daily tidal constituents are aliased, but analysis of other constituents is possible  
 Initial analysis of M<sub>2</sub> constituent carried out at 120m resolution  
 Interesting high-frequency resolution, not seen in FES2014b (8 km res).  
 Are the amplitude variations related to flow around islands?

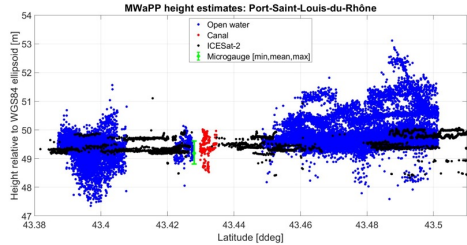


- Low-lying river delta with wetlands.
- 20 Hz resolution will provide only a single height estimate across the river.
- The high number of calm water surfaces within the altimeter footprint makes the measurements very noisy, often leading to wrong water level estimates.
- Using FF-SAR the resolution can be increased all the way up to 0.5 m.



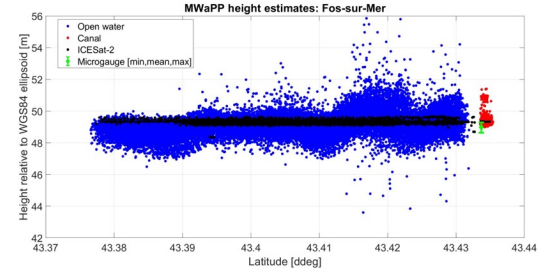
## Port St Louis

Canal connected to main river

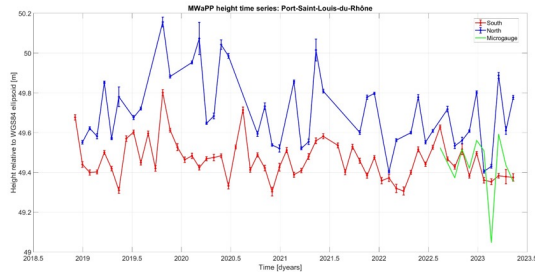


## Fos Sur Mer

Narrow Canal (60m wide)

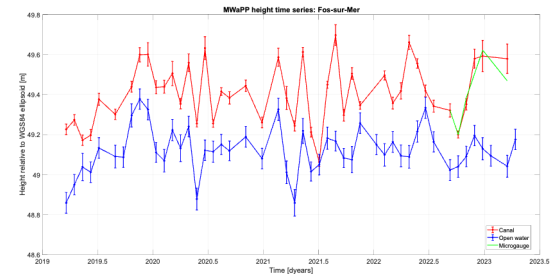


FFSAR processing (with MWaPP retracker) reliably captures canal and river water levels



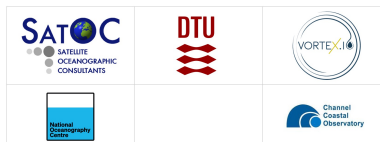
FFSAR processing can be used to estimate river water level gradient between **south** and **north** crossings. Changes in time.

FFSAR processing (with MWaPP retracker) reliably captures canal water levels



FFSAR time series agrees with in situ gauge

- Optimal FFSAR processing options found for Severn and Rhône
- Good agreement found between in situ data and FFSAR processed data with MWaPP retracker (improvement on standard SAR altimeter products)
- Able to measure the water level in small targets (60 m width).
- Able to measure small-scale water level variations, < 10 cm for the Rhône.
- Tracks running parallel to rivers offers detailed information on river slopes.
- Tracks across estuaries can be used to estimate along-track slopes (~100m resolution), and used for tidal analysis



## Data Sets

- FFSAR S3A and S3B data sets: Severn Estuary and Rhône delta
  - Along track data and time series
  - Vortex.io micro-station time series data
- Drone campaign data

<https://cco.geodata.soton.ac.uk/ccoresources/FFSAR-Coastal/>

## Product Validation and Evaluation Reports

- Validation against in-situ and model data
- Evaluation:
  - Small scale physical signals in highly tidal regions
  - Tidal asymmetry/gradients across estuaries
  - Detectability of small water bodies
  - Estimation of river water level gradients

## Application Road Map

- Key requirements from User Groups
- Recommendations for application of FFSAR in coastal monitoring systems.
- Recommendations for use of “micro” gauges as part of coastal monitoring systems

<https://eo4society.esa.int/projects/ffsar-coastal/>