

# FFSAR - COASTAL

## Fully Focused SAR Altimetry and innovative river level gauges for Coastal Monitoring

### Executive Summary Report Deliverable D4.3

Fully Focused SAR Altimetry and innovative river level gauges for Coastal Monitoring

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For FFSARCOASTAL team		19/09/23
For ESA		

## FFSAR Coastal Project - Introduction

The FFSAR-Coastal project was funded by the European Space Agency under the EO Science for Society Open Call. The project was kicked-off on 11<sup>th</sup> March 2022, and the Final Review meeting was held on 21<sup>st</sup> June 2023. The project timescale was extended from 12 months to 15 months, primarily to allow a minimum of 9 months of in-situ data to be collected from the specially installed vorteX.io micro-gauges.

FFSAR-Coastal applied the CLS/ESA/CNES SMAP Fully Focussed (FF) SAR altimetry processor (<https://github.com/cls-obsnadir-dev/SMAP-FFSAR>) on Sentinel-3 data and evaluated its potential to make a significant new contribution to coastal and estuarine monitoring systems, when coupled with innovative water level gauges for validation.

Two different environments were considered (see Figure 1):

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

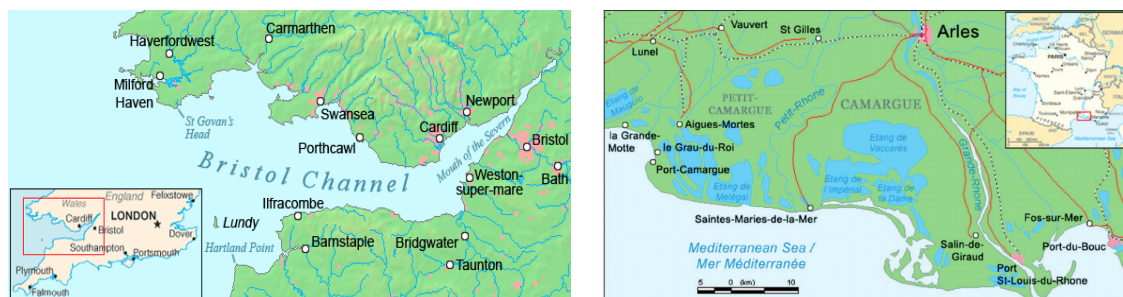


Figure 1 The two regions of interest investigated in the FFSAR-Coastal Project. Left: The Bristol Channel / Severn Estuary in the UK. Right: The Rhône delta in Southern France

Innovative in-situ water level gauges were used to validate the satellite data. Time series were provided by autonomous gauges placed at fixed locations, gauges mounted on drones were used to provide water level profiles between the fixed locations and satellite tracks.

FFSAR-Coastal investigated the potential applicability and benefits offered by FF SAR altimeter data in these two different environments. Analysis focused on the benefits offered by the very high along-track resolution in water level and backscatter that can be provided through Fully Focussed SAR processing. User agencies and groups from the two regions were consulted to identify gaps and priorities for monitoring requirements.

## Highlights of Results

### User Engagement and Application Road Map

French and UK users were consulted through a series of workshops, who contributed to identifying gaps in data provision, and priorities for improvement. The recommendations in the Application Road Map have been developed to address these priorities.

### Fully Focused SAR Processing and Water Level Analysis

After an investigation of different parameter settings in the SMAP processor (for posting rate and the illumination time) and of different L1b to L2 re-trackers, an initial processing recipe is recommended (illumination time of 2.3s, posting rate of 1000Hz). The DTU MWaPP (Multiple Waveform Persistent Peak) re-tracker was found to provide the best results for coastal and inland water targets (Figure 2)

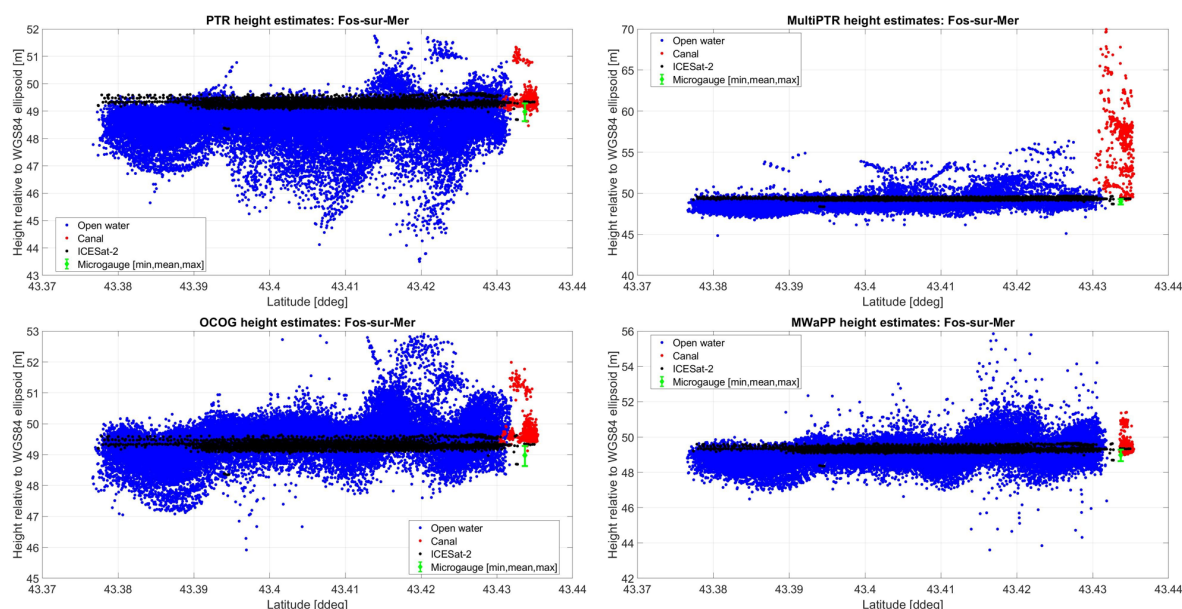


Figure 0 : FFSAR water levels estimated by the PTR, Multi-PTR, OCOG and MWaPP re-trackers (track S3B-179) close to the Fos sur mer vortex.io micro-gauge, as a function of latitude. The blue data points are over open water, the red dots in the canal. The black data points are ICESat-2 data with the same spatial and temporal origin as the FFSAR data. The green error bar represents the variance in the observed micro-gauge signal, with the minimum, median and maximum values defining a reference interval.

Based on the analysis carried out, we have found that the use of FFSAR processing is highly beneficial when observing small targets, water slopes, and near coastal areas. As this study only included a few sites that in addition are very different in terms of the water level variations, it is recommended to test and evaluate the use of FFSAR-based sea levels at more coastal sites and water levels at additional river sites to get a more solid understanding of the benefits of FFSAR.

The Severn Estuary tidal study from FFSAR revealed the ability to determine tides at kilometre spatial resolution from FF-SAR altimetry. These results are novel and interesting in the sense that we do find significant tidal residuals of up to 1.6 meters for M2 along the track at the sampling rate of 6 meters relative to the state-of-the-art Ocean tide model FES2016b (Figure 3).

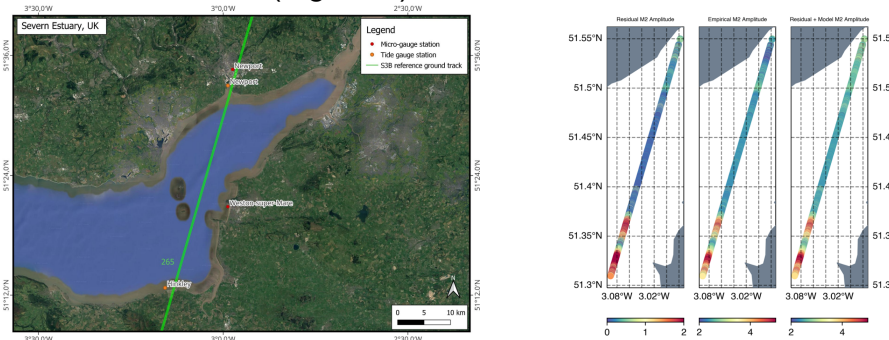


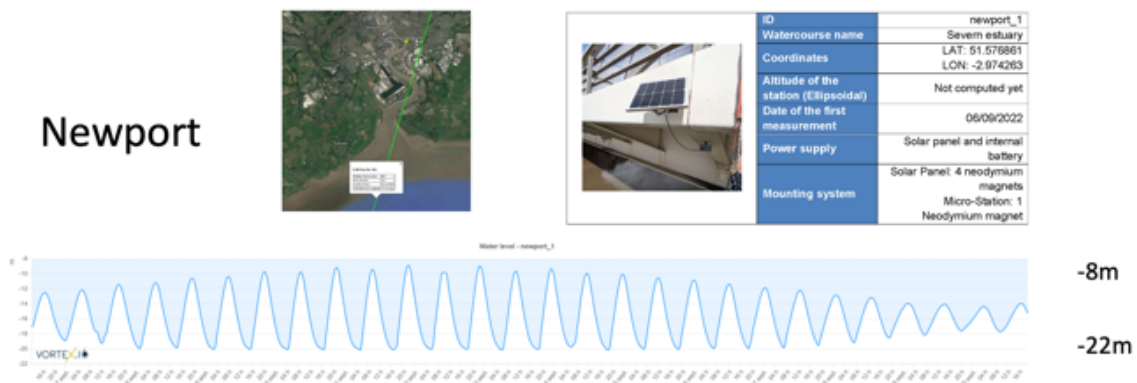
Figure 3 Left figure: Map of the Severn Estuary (UK), showing the Sentinel 3B reference ground track (green), and locations of in situ gauges. Right Figure left panel: Residual M2 tidal estimate (meters) to FES2014b along the transect from Weston to Newport. Central panel: Tidal estimate from the full sea surface height signal. Right Panel: Full tidal estimate (Residual + FES2014b)

### Installation and operation of micro-gauges and drone campaign

Four vortex.io micro-stations were successfully installed in the Rhône delta and in the Severn estuary close to, or below Sentinel-3 tracks. The capability and functionality of small, autonomous water level gauges for validation of satellite water level measurements was clearly demonstrated.

Drone flights were performed successfully over the Severn and Rhône estuaries, using the vortex.io lightweight LiDAR altimeter to measure water surface height (Figure 5).

Users expressed interest in the drone data because of the flexibility offered.





## Port St Louis du Rhône



ID	port-saint-louis-du-Rhône_1
Watercourse name	Rhône delta
Coordinates	LAT: 43.428108 LON: 4.763323
Altitude of the station (Ellipsoidal)	10.262 m
Date of the first measurement	07/27/2022
Power supply	Solar panel and internal battery
Mounting system	Solar Panel: 4 neodymium magnets Micro-Station 1 Neodymium magnet



Figure 4 Information on two of the vorteX.io micro-gauge sites and examples of the data. Top Newport (Wales), Bottom Port St Louis du Rhône (France).

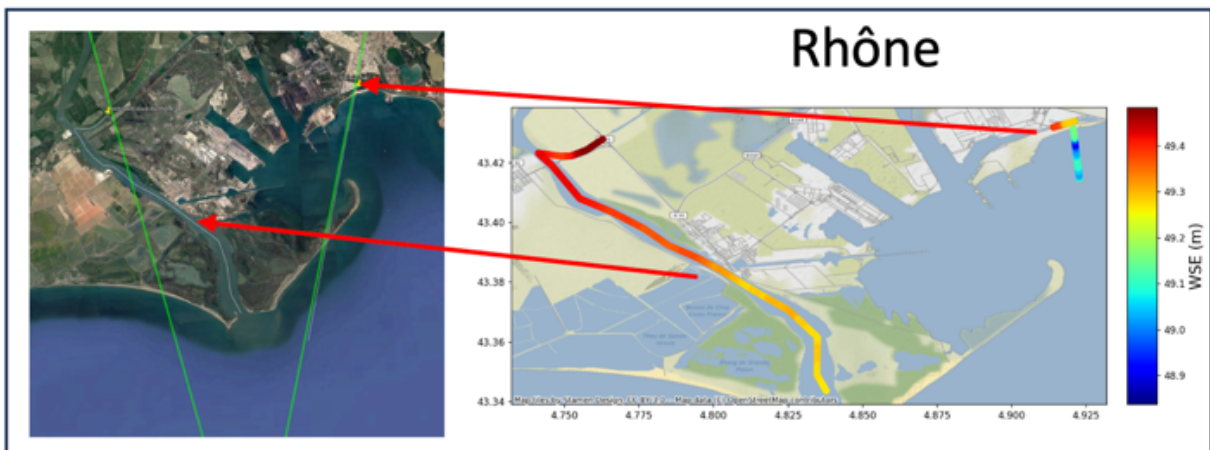
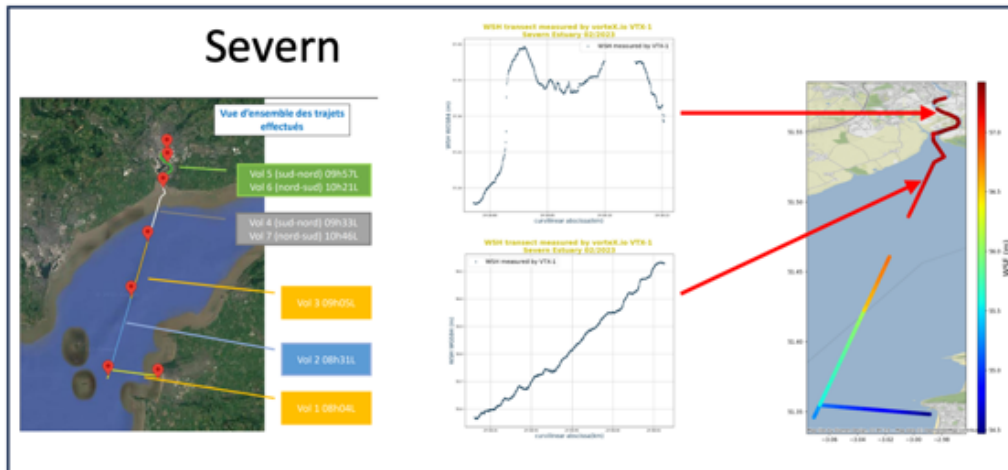


Figure 5 The vorteX.io drone campaign over the Severn Estuary (UK) - Top, and Rhône delta (France – bottom). Left panel shows the locations of the individual flights; the centre panels (top panel only) give the water level profiles for Severn flight segments 4 and 5; the right panel shows the along track water surface elevations.

## Project Outputs

We list the main project outputs below, which are available from the project web site <https://www.satoc.eu/projects/ffsar/index.html>. See also <https://eo4society.esa.int/projects/ffsar-coastal/>

### Reports

- FFSAR Coastal Application Road Map
- FFSAR Coastal Data Set of Processed Altimeter Data
- FFSAR Coastal Product Validation and Evaluation Report
- FFSAR Coastal In Situ Data Campaign Report
- FFSAR Coastal In Situ data set format

### Data Sets

- Along track FFSAR processed data for three Sentinel 3B tracks
- FFSAR processed Sentinel 3B altimeter water level time series data for six locations.
- Time series data from the four vorteX.io micro-gauges.
- vorteX.io drone lidar water level profile data from 2 flight series over the Severn and Rhône.

The project data sets are available through a dedicated page on the UK Coastal Monitoring Web Site, at: <https://www.coastalmonitoring.org/ccoresources/FFSAR-Coastal/>

## Project Recommendations

The project identified 13 recommendations for further research.

1. FFSAR-Coastal processing “recipe”
2. Further FFSAR processing research – Different coastal locations and environments.
3. Multi-satellite study – Sea state impact on FFSAR.
4. Isolate Nadir Reflections.
5. Micro-gauges for satellite data validation.
6. Drones with lidar for coastal research and satellite validation.
7. Extreme Events Study

8. Priority areas for FFSAR and UFSAR processing.
9. Coastal FFSAR altimeter products.
10. Guidelines for use of FFSAR processed altimeter data.
11. FFSAR for Inter Tidal Bathymetry
12. Inland water FFSAR altimeter products.
13. FFSAR altimeter products – coast and river interface.
14. FFSAR altimeter products – Small scale variability in tides.