The Aresys FF-SAR Service for Cryosat-2 at ESA GPOD

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Aresys FF-SAR Service for CryoSat-2 at ESA GPOD

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To enhance the portfolio of services available on the ESA Grid Processing on Demand (G-POD) platform, a new service for fully-focused SAR processing of CryoSat-2 SAR data is currently under validation (see case studies below), and is expected to be released to all users by the end of 2021.

The service is based on the AREALT-FF1 Processor Prototype, which has been developed by Aresys within the framework of the ESA-ESTEC contribution to the Sentinel-6 Mission. It produces fully-focused SAR altimetry waveforms exploiting the 2D transformed frequency domain focusing technique proposed by Guccione, P., Scagliola, M., & Giudici, D. (2018). Through the G-POD graphical interface, users can select CryoSat-2 data over a specific area of interest and set a series of parameters to tailor the processing. Output products, in netCDF format, will also include geophysical corrections and threshold peak & ALES-like empirical sub-waveform retracker estimates (ALES+FF-SAR, see Passaro et al. (2020)).

References

Guccione, P.; Scagliola, M.; Giudici, D. 2D Frequency Domain Fully Focused SAR Processing for High PRF Radar Altimeters. Remote Sens. 2018,10, 1943. https://doi.org/10.3390/rs10121943

Passaro et al. (2020) Baltic+ SEAL: Algorithm Theoretical Baseline Document (ATBD), Version 2.1. Technical report delivered under the Baltic+ SEAL project. DOI: 10.5270/esa.BalticSEAL.ATBDV2.1 (see Section 3 for details).

Aresys link -> http://www.aresys.it, G-POD link -> http://gpod.eo.esa.int, FF-SAR manual -> https://wiki.services.eoportal.org/tiki-index.php?page=FF-SAR+for+CryoSat-2+Service+User+Manual

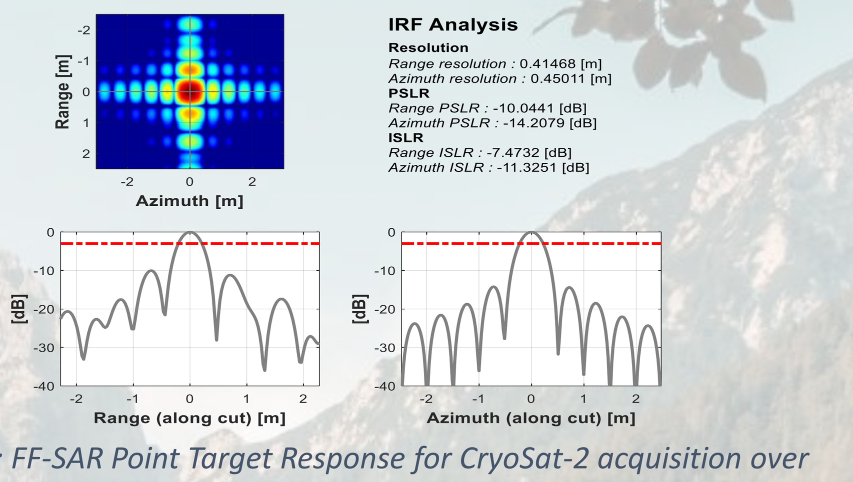

Figure 1: FF-SAR Point Target Response for CryoSat-2 acquisition over transponder obtained with AREALT-FF1 Processor Prototype.

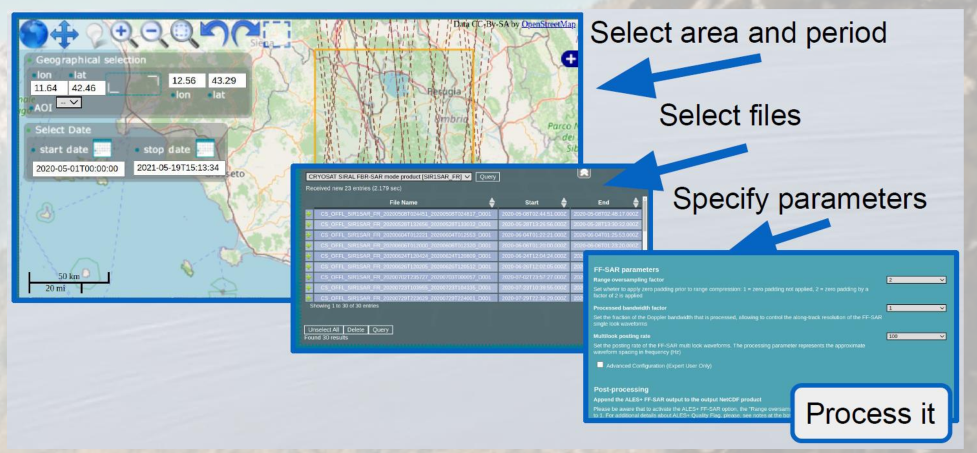

Figure 2: G-POD parameters and area of interest selection for FF-SAR processing.

Case study: Lake IJssel is located in The Netherlands, covers an area of approx. 1100km² and has an average depth of 5.5m. Lake heights (LH) produced by the FFSAR-GPOD service are compared with ones (FFSAR-DUT) produced by Kleinherenbrink et al., 2020[1] (Fig. 1a) and thereafter with Delay/Doppler SAR data (UFSAR-GPOD) obtained from the GPOD SARvatore CryoSat-2 service (Fig. 1b). Then, water level variations in the along-track direction are depicted in Fig. 2. In particular, FFSAR-GPOD data of 100 Hz (light blue) and 20Hz (red) are compared with FFSAR-DUT data of ~100 Hz (green) and UFSAR-GPOD OF 20Hz (black). The aforementioned datasets have been processed by using a 60% threshold retracker. ALES+ FFSAR-GPOD data of 100 Hz (yellow) are plotted as well. All datasets are baseline C.

Processing parameters:

	FFSAR-GPOD	FFSAR-DUT
Single-look wf spacing	~44 cm	~56 cm
Multilooking (n.wf)	181-182	200
Focusing method	Omega-Kappa	Back-projection
Retracker	60% threshold (Davis, 1997)[2]	

(1b)	FFSAR-GPOD	UFSAR-GPOD
Multilook posting rate	20Hz	
Retracker	60% threshold	SAMOSA+

Note 1: 100Hz FFSAR-GPOD→ approx. 64m along-track resolution. ~100Hz FFSAR-DUT→ approx. 100m along-track resolution.
Note 2: bias is calculated as the median of the dataset differences
Note 3: SD is calculated as 1.4826×median absolute deviation (Blewitt et al., 2016)[3]

GPOD FFSAR settings:

- range oversampling factor: set to 1
- zero padding (applied): set to 2
- multilook posting rate: 20 & 100Hz

Data editing:

- *Step 1*: Data alignment
- *Step 2*: Outlier-removal scheme
  - LH > 30 cm from median
  - LH > 3×SD from median

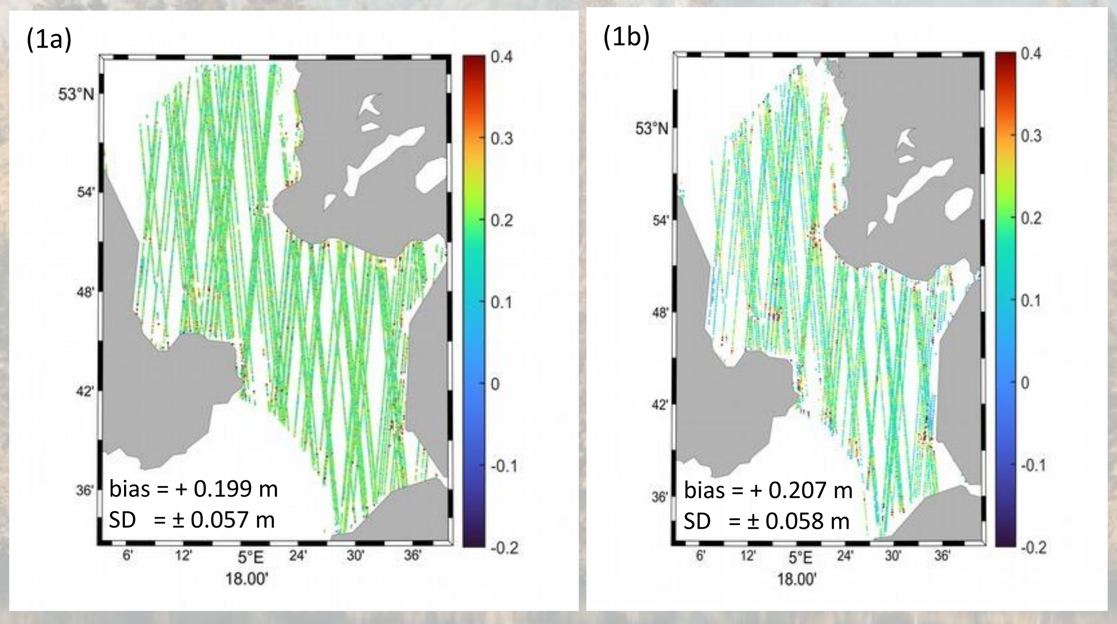

Fig. 1: GPOD-DUT LH differences [unit: meters]. Outliers: 14.5% of 60000 (1a) and 25% of 12000 (1b). CryoSat-2 data from 08/2010 to 06/2018

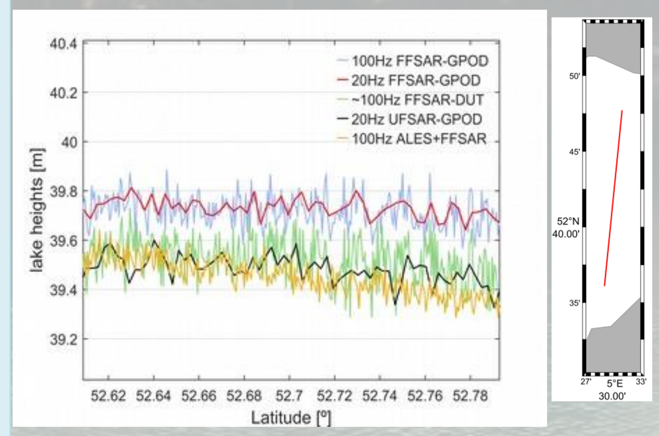

Fig. 2: Water level variations over the lake as captured by CryoSat-2 at 03/10/2020. FFSAR products are compared with UFSAR.

References:

[1]Blewitt, G., Kreemer, C., Hammond, W., & Gazeaux, J. (2016). MIDAS robust trend estimator for accurate GPS station velocities without step detection. Geophys. Res. Solid Earth, 121 , 2054-2068.
[2]Davis, C. (1997). A robust threshold retracking algorithm for measuring ice-sheet surface elevation change from satellite radar altimeters. IEEE Trans. Geosci. RemoteSens., 35(4), 974-979.
[3]Kleinherenbrink, M., Naeije, M., Slobbe, C., Egido, A., & Smith, W. (2020).The performance of CryoSat-2 fully-focussed SAR for inland water-level estimation. Remote sensing of Environment, 237 , 111589,ISSN 0034-4257.

TUDelft

Analysis over a narrow river, Amazon's tributary, Brazil

This Case study is a preliminary analysis of the CryoSat-2 FF-SAR data exploited to derive water level time series over a narrow river. Nhamunda river is a northern Amazon river's tributary of about ~100m width. The studied section is a downstream reach of ~150km long. Among selection criteria were the availability of contemporary gauging data (ANA station "Mineração Caima", code 16368000), the ability to derive river's longitudinal elevation mean profile and the absence of obstruction along the river reach, a long enough reach to cope with the space-time sampling of the CryoSat-2 geodetic orbit.
The time period of the study is 2017-01 – 2018-12.

FF-SAR parameters:

- No zero padding applied: 1
- Processed bandwidth factor: 1
- Multi-look posting rate: 500 Hz (=14m posting distance)
- Retrackers: Threshold, ALES+ FF-SAR (embed zero padding x2)

Water surface height processing:

- Geoid model: Eigen-6C4
- No range/tide corrections applied
- Migration of CryoSat-2 meas. along mean river profile to gauge location

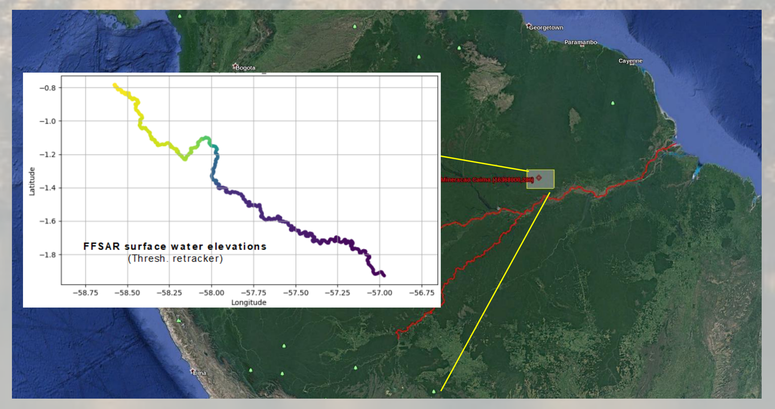

Fig 1: Study are over the Amazon basin. The processing box (zoomed in) is 1.5×1.0 degrees square.

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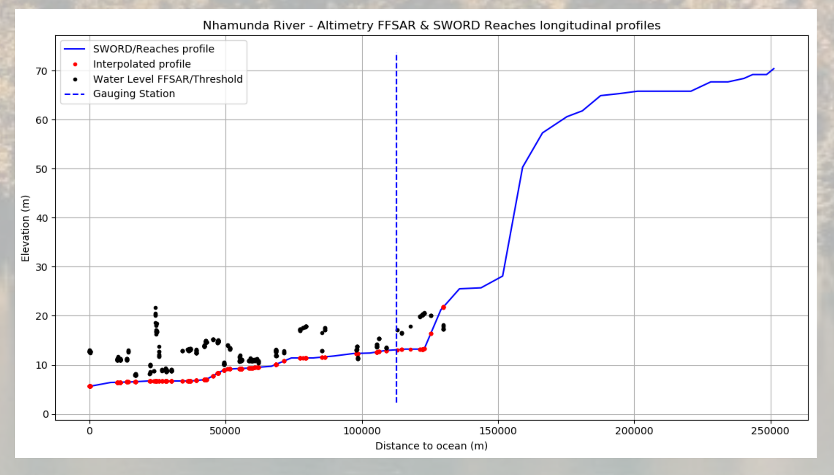

Fig 2: (Black dots) FF-SAR/Threshold retracker along the longitudinal path of the river. (Blue curve) Mean river profile derived from the SWORD data base and (vertical dashed line) the location of the ANA gauging station.

First analysis of extracted L2 measurements exhibits some outlier measurements in the FF-SAR data, for both Threshold and ALES+ FFSAR retrackers (Fig2 & 3). However, the temporal signature of the water level has been fairly captured (Fig. 3), considering the challenging aspect of the study.

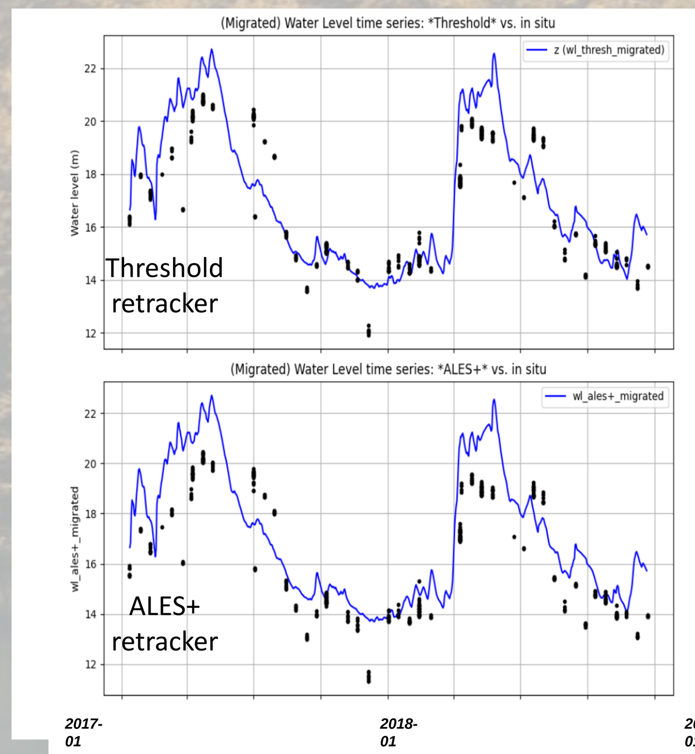

Fig 3: (Black) L2 river water level time series, (blue) gauging data.

Next steps : Try to improving FF-SAR settings (reduce bandwidth factor?) ; Compute real L3 time series ; quantified validation against in situ data.

This case study analyses the CryoSat-2 FF-SAR data over the Elbe estuary and river (Figs. 1, 2). The time period from 2019-01 and 2020-02 includes a full CryoSat-2 geodetic orbit. The selected setting for FFSAR is: multi-look posting rate 200 Hz, zero padding applied, bandwidth factor 0.5, Threshold retracker. We first investigate the FF-SAR data quality, final goal is to extract time-series of water surface elevation and the elevation mean profile. The river Elbe has ~300-400m width between Geerstacht and Neue Darchau and larger in the estuarine part affected by ocean tides. The studied section is a downstream reach of ~150km long where gauge stations are available. The time period from 2019-01 and 2020-02 includes a full CryoSat-2 geodetic orbit.

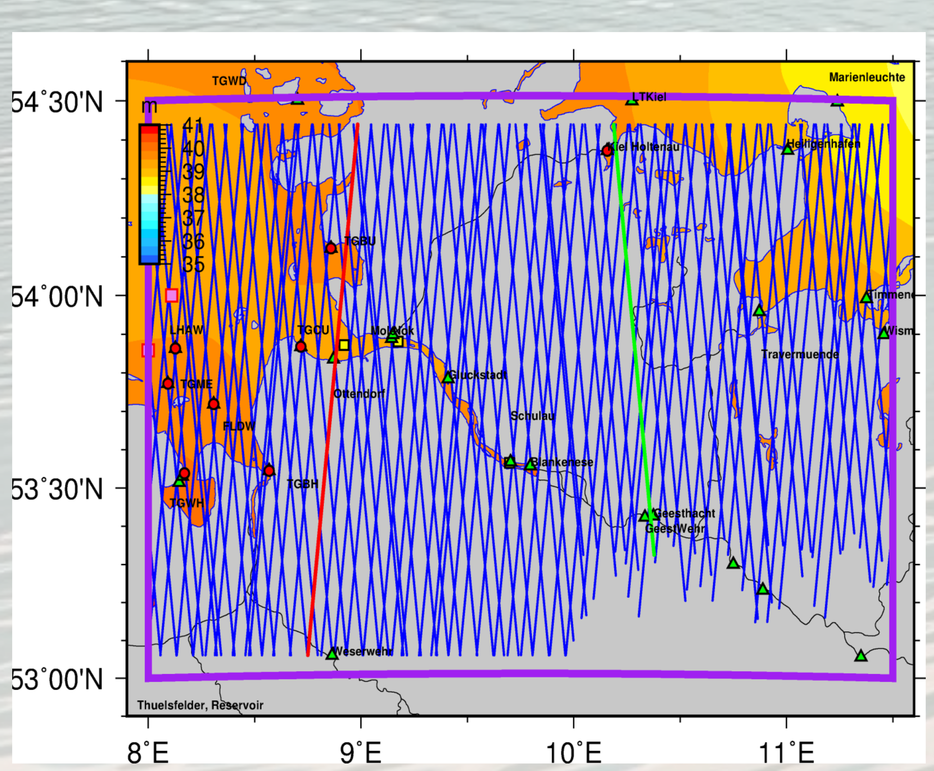

Figure 2. Analysed CryoSat-2 ground-tracks is the Elbe

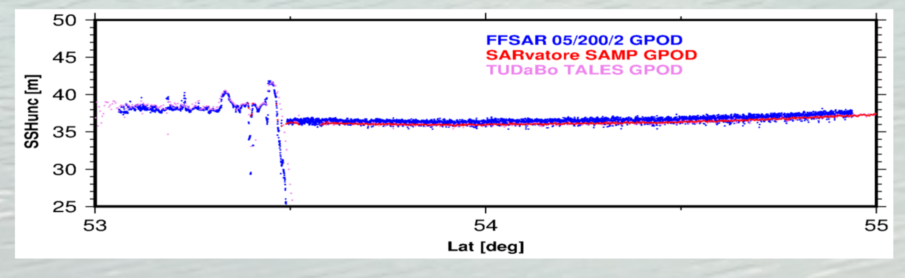

Figure 3. Uncorrected heights from FF-SAR (blue), unfocused SAR (red) and reduced SAR (violet) along open sea ground-track location in Fig. 1

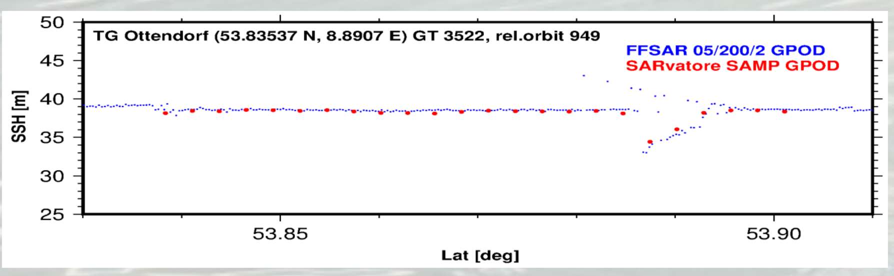

Figure 4. Water heights from FF-SAR at Ottendorf (red track in Fig. 1).

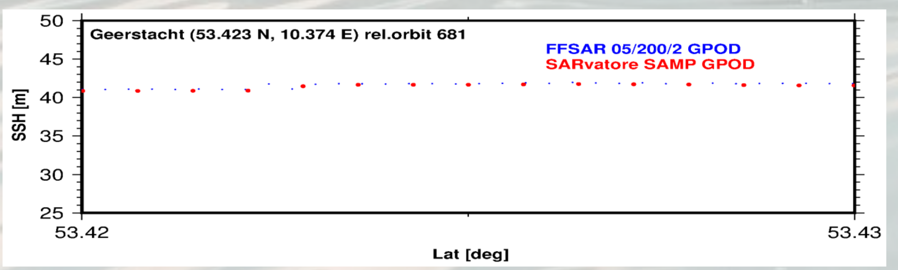

Figure 5. Water heights from FF-SAR at Geerstacht (green track in Fig. 1).

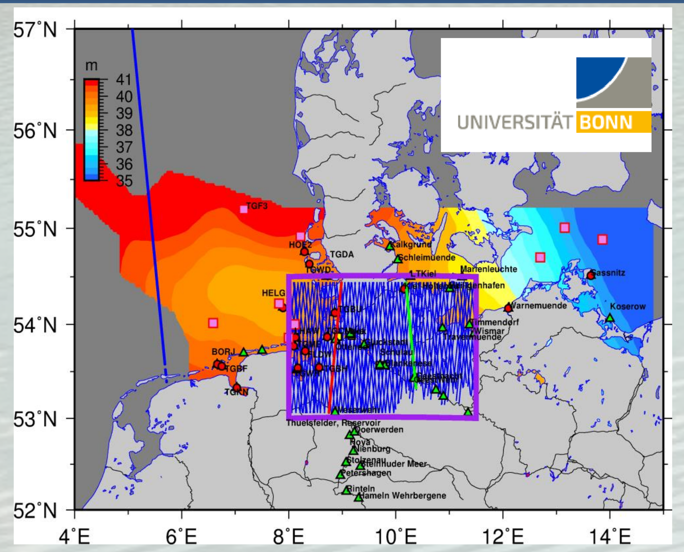

Figure 1. Region of analysis

Comparing along-track in coastal and open ocean the FFSAR with GPOD SARVatore and TUDaBo data, FF-SAR data are found noisier than the other products (Fig.3).

In the estuarine intertidal and in the river parts, instead FF-SAR agrees well with the SAMOSA+ SARVatore data and data have higher resolution. Figs. 4 and 5 show the water heights in Otterndorf and in Geerstacht, the water body has width of 13 km and 400 m. SAMOSA+ SARVatore and FF-SAR have no relative bias.

Next steps: evaluate profile and construct time-series to be validated with river gauges

DTU Space National Space Institute

Evaluation over the Canadian River, US

In this study, CryoSat-2 FF-SAR data over the Canadian River in the Mississippi basin was evaluated. This river has a width of a few hundred meters. The FF-SAR derived water levels were evaluated using ICESat-2 laser altimetry data and gauge data from the USGS https://maps.waterdata.usgs.gov/mapper/index.html

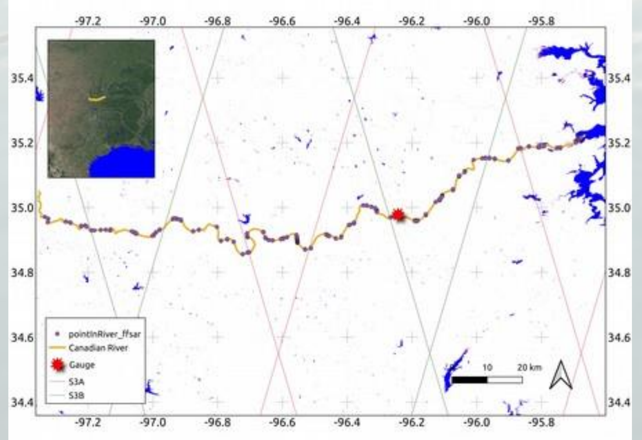

Figure 1: Study area

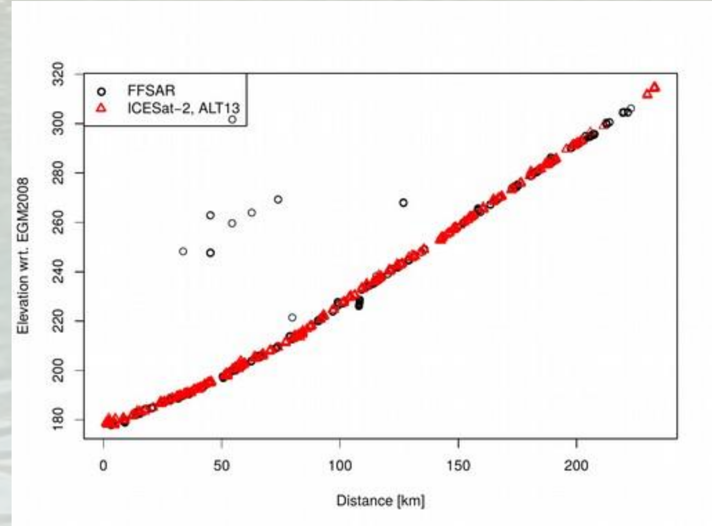

Figure 2: FF-SAR and ICESat-2 water levels plotted against distance along the reach.

In the study we considered water levels based on different retrackers including the ALES+ and threshold retrackers. To enhance the amount of data we selected a *posting rate of 500* and the *band width of 0.5*. To compare the altimetry data to the gauge data we need to create a water level time series at the location of the gauge. We use the C2 FF-SAR data and ICESat-2 data to compile a time series.

The time series is constructed using data available along a reach of approximately 200 km (see Figure 1 and 2).

- Firstly, the data is projected to the centreline of the river. Providing the data as a function of space and time
- The data is then combined via a state-space model (*model paper submitted to RSE*)

As seen on Figure 3, we are able to identify the main water level signal. We find RMSE values of approximately 30 cm and a correlation of 0.6. The result is similar for all the retrackers.

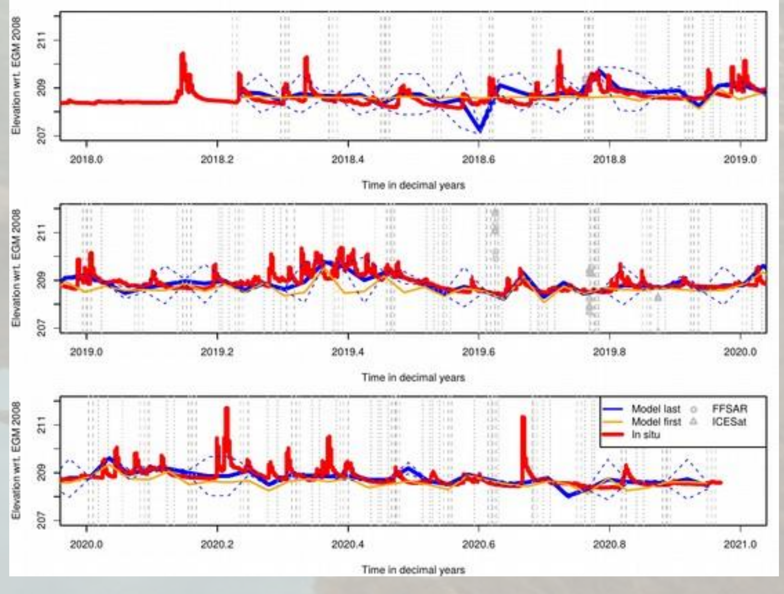

Figure 3: The reconstructed water level time series (blue) compared to the gauge water levels (red). The grey lines indicates the times where data is available