# Regional cal/val for past and future missions

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## Abstract

Since 10 years the available network of in-situ stations in the German Bight and in Eastern Baltic is used for the validation of altimeter mission. Validation of SAR altimeters was done in the Rhine river. CALVAL activities have used dedicated in-situ, models, algorithms and external satellite data. Today plans are presented.

## Methods and Data

Space observations, in-situ and model data build a dense two-dimensional field of water height change. The study focuses on use of space-based height and slope to derive river discharge. Interval is from June 2016 to December 2021, the altimeter missions are :

- S3 Copernicus inland water Ocog, SAMOSA
- CS2 ESA inland water Ocog, Ocean
- S3 and C2 SAMOSA+ from Earth Console
- ICESAT-2

Virtual points (VP) are estimated as intersection of the centerline of the river extracted from the SWORD11 database and of the altimeter master ground-tracks (kml file). The time-series of Water Surface Elevation (WSE) are built with two different methods. In the first method, observations of one single virtual point (one-VS) are collected. In the second method time-series are constructed from observations at multiple VS (multi-VS) after correcting for the river mean slope, the river profile is computed by ICESAT-2 data.

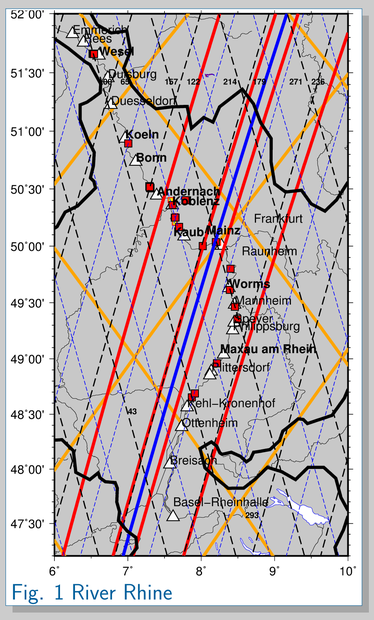


Fig. 1 River Rhine

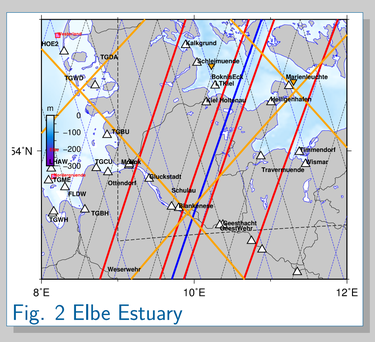


Fig. 2 Elbe Estuary

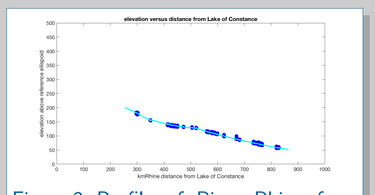


Fig. 3 Profile of River Rhine from ICESAT-2 and S3A Water heights

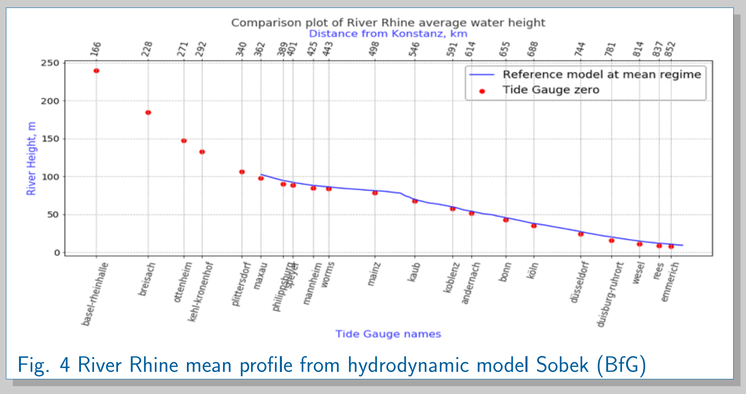


Fig. 4 River Rhine mean profile from hydrodynamic model Sobek (BfG)

## Bibliography

Fenoglio, L., Dinardo, S., Uebbing, B., Buchhaupt, C., Grtner, M., Staneva, J., Becker, M., Klos, A., Kusche, J. (2021). Advances in NE-Atlantic coastal Sea Level Change Monitoring from Delay Doppler Altimetry, Adv. Space Res.,68(2), pp. 571592, doi.org/10.1016/j.asr.2020.10.041.

International Altimetry Team (2021). Altimetry for the future: Building on 25 years of progress, Adv. Space Res.,68, pp. 319363, https://doi.org/10.1016/j.asr.2021.01.02

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## Evaluation of WSE from altimetry

Data selection and screening are from the "VirtualPass method" (Fenoglio et al. 2021, Hydrocoastal PVR). SAR altimetry measures water elevation in rivers, accuracy depends on the retracker. The highest accuracy is obtained from the SAMOSA+ (SAMP) retrackers. Copernicus standard products are noisier. The "Centerline method" used for non-repeat mission is less accurate.

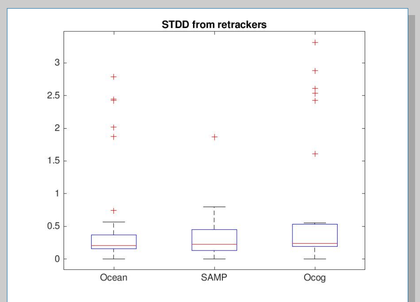


Fig. 5 Stdd of S3 SLA against in-situ

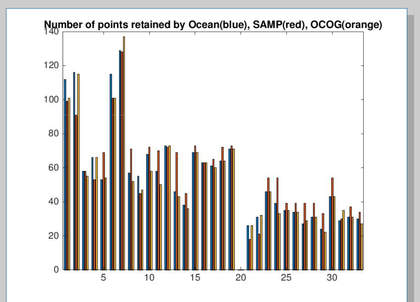


Fig. 6 Samples in compared time-series

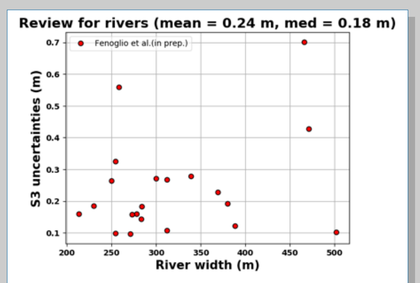


Fig. 7 Accuracy versus river width

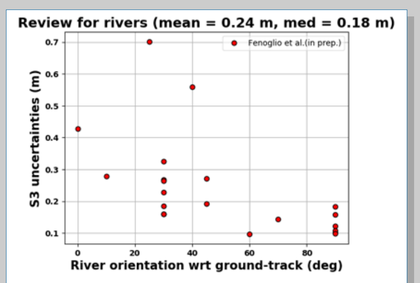


Fig. 8 Accuray versus orientation

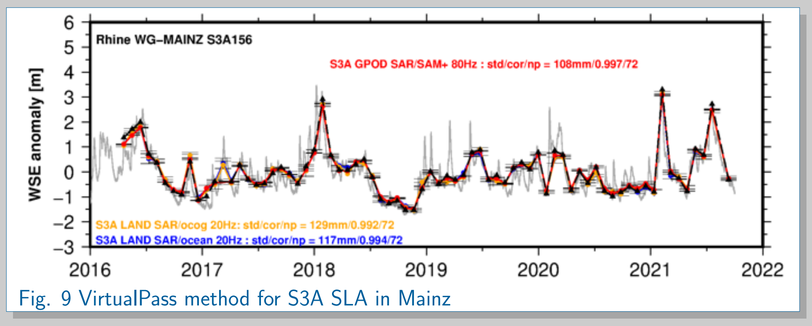


Fig. 9 VirtualPass method for S3A SLA in Mainz

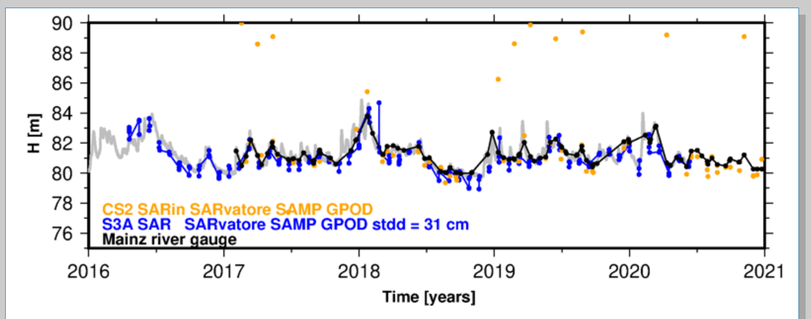


Fig. 10 Centerline Method for CS2 and S3A in Mainz

## Extremes in WSE from altimetry

The extreme water height of 15 July 2022 was observed by both gauges of the network and by the Sentinel-3 altimeters. Gauges time-series (lines) and altimeter observations (stars) are seen in figure 11. Sentinel-3 observations well match the corresponding gauges. In figure 12 the time evolution of river discharge measured by the same gauges is shown together with the precipitation rates in various cathcments, the Ahr catchment is clearly cause of the water extreme observed near Bonn on the same day.

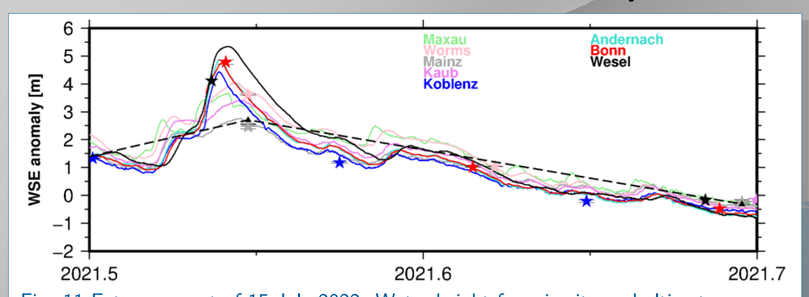


Fig. 11 Extreme event of 15 July 2022: Water height from in-situ and altimetry

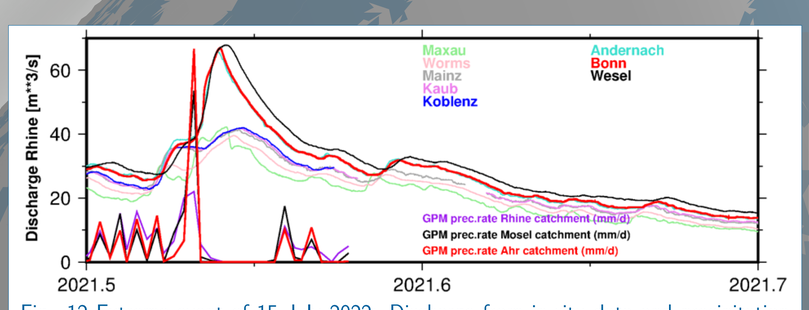


Fig. 12 Extreme event of 15 July 2022: Discharge from in-situ data and precipitation rate in Rhine (violet), Mosel (black) and Ahr (red) catchments

## Slope from altimetry and river discharge

A slope accuracy of 1.7 cm/km is a SWOT mission requirement. Today, river slope is computed from space from multiple crossing of a same nadir-altimetry track. Depth and width are from a DTM, here from Sobek model. Discharge is estimated from slope, depth and width (Figs.13-15) by adjusting coefficients and conductance in Bjerklie, 2013 (Fig.16).

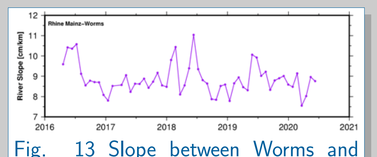


Fig. 13 Slope between Worms and Mainz

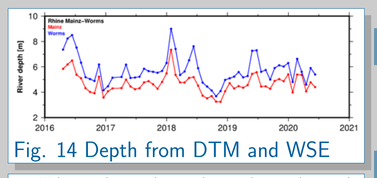


Fig. 14 Depth from DTM and WSE

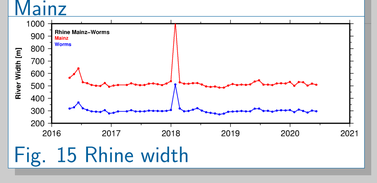


Fig. 15 Rhine width

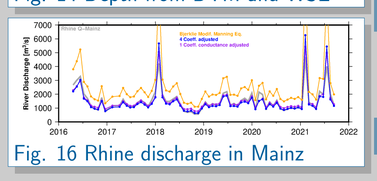


Fig. 16 Rhine discharge in Mainz

At each location along the river, the slope variability is derived from 30 scenaria (Fig. 17). While its mean is almost constant for all scenaria (Fig. 18), its range is larger for lower scenaria (Figs. 19, 21) and its variability depends on the location (Figs. 20, 22).

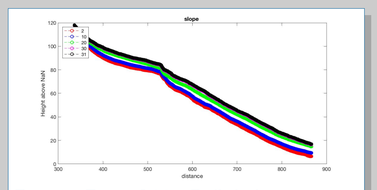


Fig. 17 Five of 32 1D-Sobek scenaria

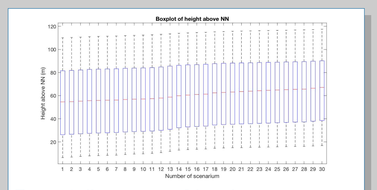


Fig. 18 Statistics of height vrs scenaria

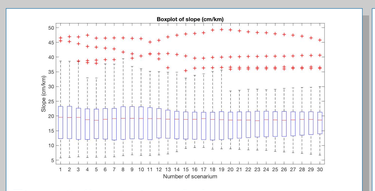


Fig. 19 Statistics of slope vrs scenaria

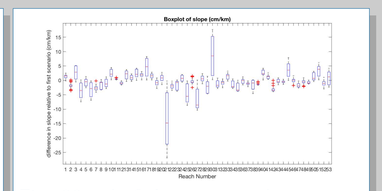


Fig. 20 std of slope vrs reach

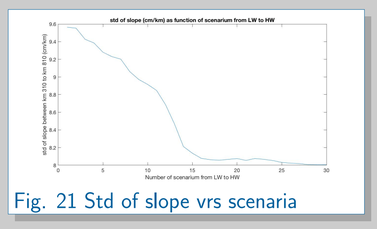


Fig. 21 Std of slope vrs scenaria

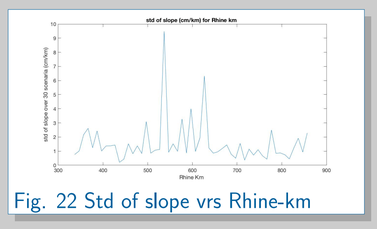


Fig. 22 Std of slope vrs Rhine-km

## New with SWOT altimetry

Temporal and spatial sampling of single and multi nadir-altimetry is a limitation in coastal zone and for wavelenght $< 100$ km. SWOT wide-swath altimetry increases spatial and temporal sampling and allow detection of spatial wavelenghts $< 100$ km and higher revisiting time ($< 5$ times in 21 days in Fig. 23). SWOT simulation by CNES Large Scale Simulator in Mainz (Figs. 24-25).

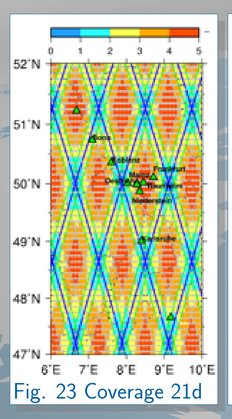


Fig. 23 Coverage 21d

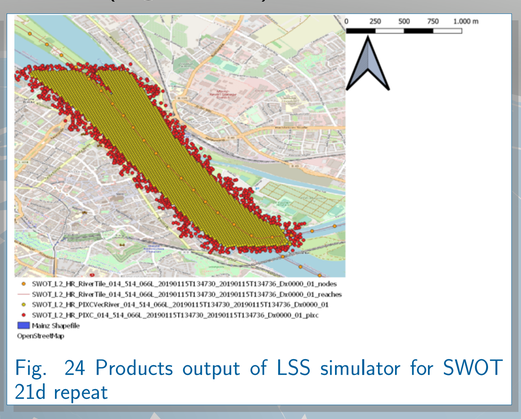


Fig. 24 Products output of LSS simulator for SWOT 21d repeat

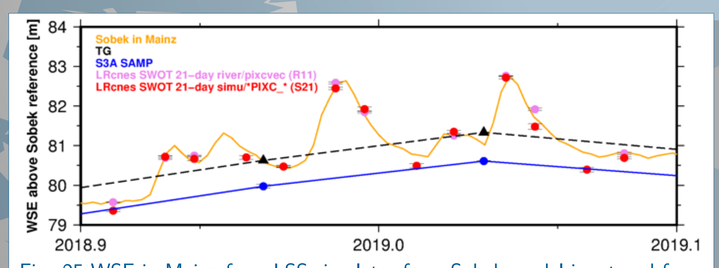


Fig. 25 WSE in Mainz from LSS simulator from Sobek model input and from real S3A altimetry (blue circle) and river gauge (black triangle) at S3A revisit

## Conclusions

- 10 cm accuracy in SAR altimetry with SAMOSA+
- multi-mission altimetry has sub-optimal sampling
- SWOT altimetry denser spatial and temporal sampling

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