Evaluation of coastal water level products in SAR mode

L. Fenoglio[1], H. Uyanik[1], B. Uebbing[1], S. Stolzenberger[1], C. Buchaupt[2], J. Kusche[1]

1) Institute of Geodesy and Geoinformation, University of Bonn
2) University of Maryland, USA

Abstract

Accurate knowledge of water height is of major importance to analyze causes and drivers of change and to plan protection measures.
Satellite delay doppler altimetry (DDA) is superior to conventional altimetry (CA). Goal of the HYDROCOASTAL project, funded under the ESA EO Science for Society Program, is to develop new processing for coastal and inland waters and characterize data performance and accuracy of the new CryoSat-2 and Sentinel-3A/B data in SAR mode.
At the University of Bonn the validation activity focuses on German Bight and Baltic Sea coasts and in the Elbe estuary, five retrackers are available. This study presents the validation results of all five retrackers based on the validation matrix agreed within the project. An in-house validation strategy matrix is used for comparison.

Methods and Data

Interval of study is June 2018 to May 2020 with the CryoSat-2, Sentinel-3A/B altimeter missions in SAR mode. Test area is the German Coast (GEC) and Bight Baltic (BB). The retrackers used are:

- Bonn STARS sub-waveforms coastal retracker
- DTU coastal retracker
- ESA SAMOSA2.5 open ocean retracker
- ISR coastal retracker
- TUM sub-waveforms coastal retracker

Sea level anomalies (SLA) and significant wave height (SWH) are cross-compared with in-situ. Skill metrics parameters are: bias, standard deviation of differences (stdd) and correlation. The in-house Spatio-Temporal Altimeter Retracker (STARS)is an adaptation of the STAR CA retracker and uses the functional waveform model SINCS which involves numerical convolutions.

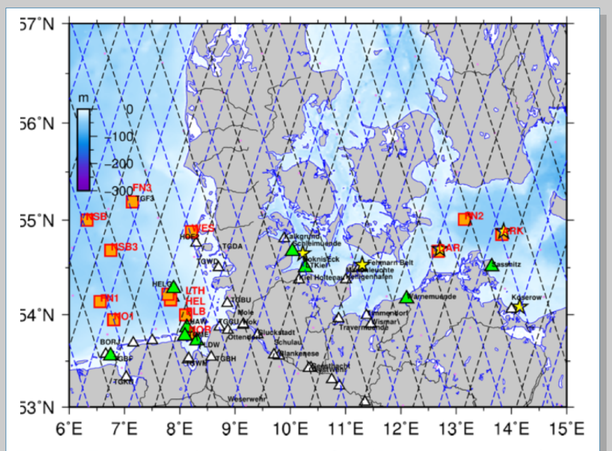

Fig. 1 Tide gauge locations with S3A/B ground-tracks, (green triangle) 9 TG and 8 buoys

Different stategies are used for Sentinel-3 and CryoSat-2 due to the different repeat period. For Sentinel-3, the along-track data are firstly binned in 20 Hz time-series, the statistics is evaluated at the 20 Hz along track location. See figures 4,5,6 and 7 in Helgoland(HELG). The statistics is averaged along track over a given range, including all points between 2 and 20 km from coast and within 20 km from the in-situ station. The statistics of differences between altimetric and in-situ is in table 1. Alternatively approach overpass (Fenoglio et al., 2020) is used, where one single measurement, the nearest to the in-situ, is retained per each pass to build the time series (Figs. 8-9). The results from methology of HYDROCOASTAL which suggest to average the observations over the track until 20 km shown in fig. 6 and 7.
For CryoSat-2 data are not binned and the time-series to be compared to the in-situ data are created with two alternatives. In the first data are averaged along-track in a selected area, the second alternative is the overpass approach.

Acknowledgement

We acknowledge IsardSAT, DTU, TUM, the European Space Agency and Bonn University for the altimetry data, BfG for the tide gauge data.

Noise in coastal zone

SAR altimetry measures sea level up to few km from coast, its accuracy depends on the retracking. STARS data are the least noisy when compared with the other retrackers and has a good agreement with ESA. ISR and DTU are more noisy (Figs. 2-3)

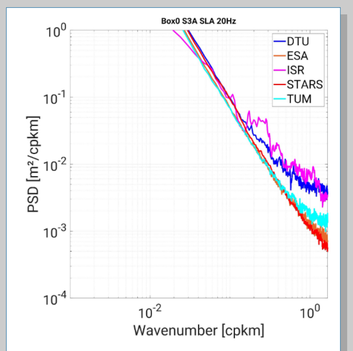

Fig. 2 Spectra of S3A SLA

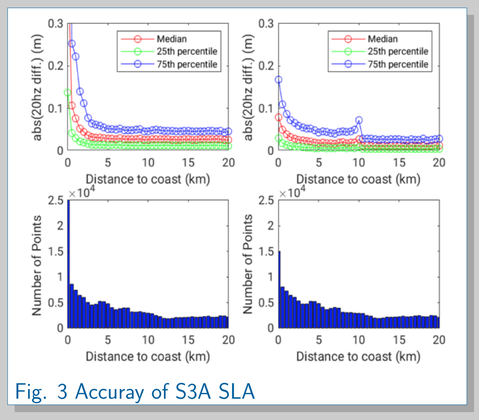

Fig. 3 Accuray of S3A SLA

Evaluation metrics of SLA

Correlation and standard deviation between binned along-track and in-situ data is shown at Helgoland(HELG) for S3A(fig. 4 and 5). The STDD is about 10 cm for all retrackers, but comparison shows more data in STARS than in ESA. Correlation is about 0.945 in vicinity of the tide gauge station(HELG).
Results at nine tide gauge are merged in fig. 8-11 with overpass method, the mean standard deviation is about 10 cm in agreement with the HYDROCOASTAL approach.

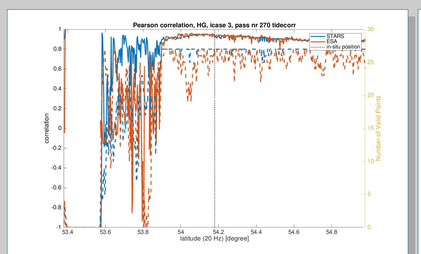

Fig. 4 S3A SLA - Correlation at HELG for ESA and BONN against insitu

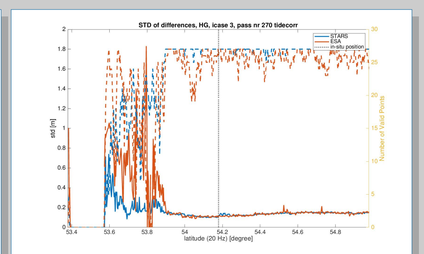

Fig. 5 S3A SLA - STDD at HELG for ESA and BONN against insitu

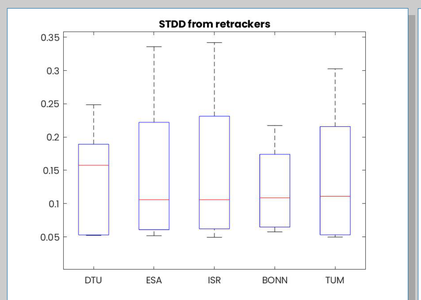

Fig. 6 Boxplots of S3A SLA against nine in-situ stations(HYDROCOASTAL method)

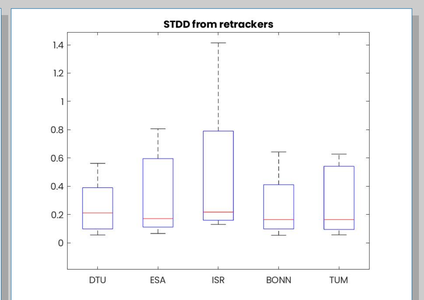

Fig. 7 Boxplots of CS2 SLA against nine in-situ stations(HYDROCOASTAL method)

Retracker	S3A stdd	S3A cor	S3B stdd	S3B cor	CS2 stdd	CS2 cor
DTU	0.158	0.887	0.102	0.937	0.212	0.775
ESA	0.106	0.946	0.109	0.928	0.172	0.858
ISR	0.104	0.947	0.110	0.927	0.170	0.844
BONN	0.109	0.944	0.112	0.929	0.160	0.854
TUM	0.111	0.943	0.108	0.930	0.157	0.876

Table 1: SLA Statistics of comparison between S3A, S3B, CS2 and Helgoland station averaged over the track

The statistics of differences of altimetric and in-situ SLA for HELG is given in Table 1.The DTU retracker is the noisiest with stdd 15 cm.

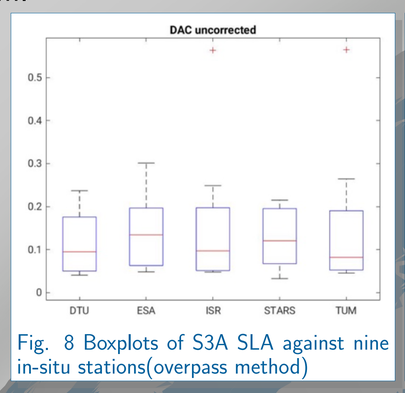

Fig. 8 Boxplots of S3A SLA against nine in-situ stations(overpass method)

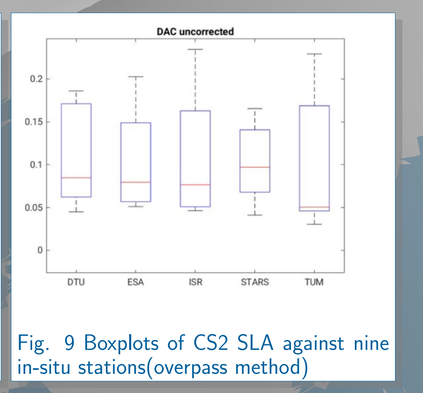

Fig. 9 Boxplots of CS2 SLA against nine in-situ stations(overpass method)

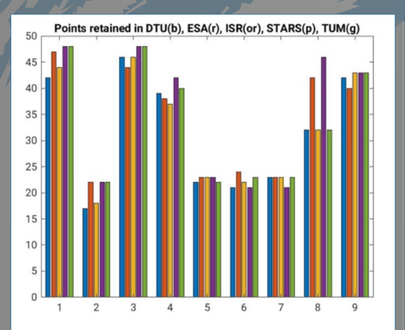

Fig. 10 S3A Points used per station

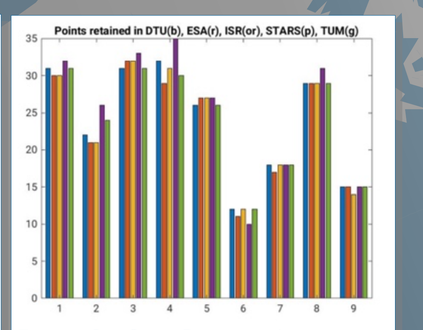

Fig. 11 CryoSat-2 Points used per station

Evaluation metrics and Variability of SWH

Using the same metrics, the metric for SWH is (20 Hz binnig and averaging) evaluated in Figs. 12 and 13.

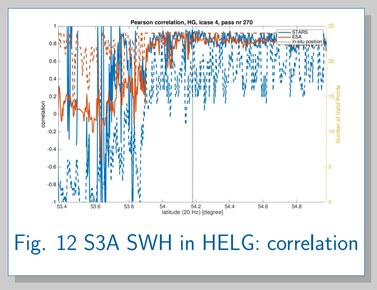

Fig. 12 S3A SWH in HELG: correlation

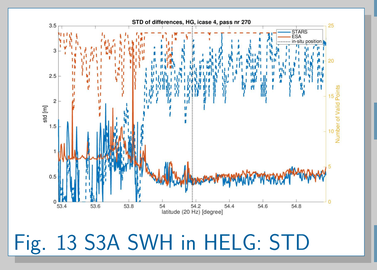

Fig. 13 S3A SWH in HELG: STD

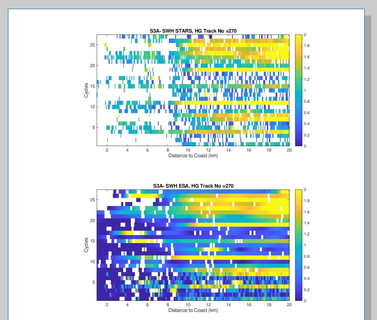

Fig. 14 S3A SWH in HELG for BONN and ESA

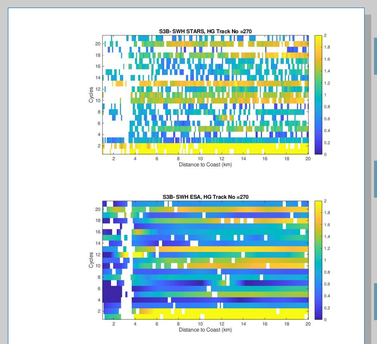

Fig. 15 S3A SWH in HELG for BONN and ESA

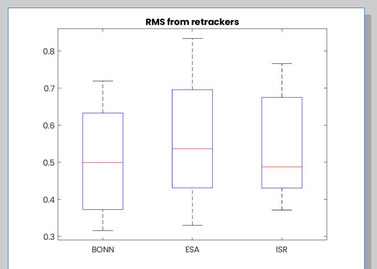

Fig. 16 Boxplots of S3A SWH against eight in-situ stations(HYDROCOASTAL method)

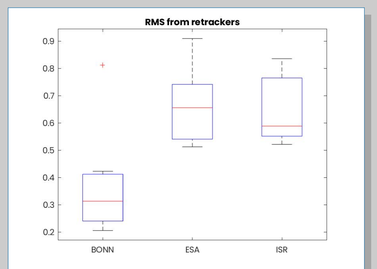

Fig. 17 Boxplots of CS2 SWH against eight in-situ stations(HYDROCOASTAL method)

Table 2 gives the statistics of the comparison at Helgoland of SLA and SWH obtained by averaging the statistics between 2-20 km.
The stdd of SWH is higher for S3A (40 cm) than for S3B (20 cm). The performance of the ESA and STARS retrackers for small SWH is seen in figures 12-17 above. For points at less than 20 km from the coast, SWH which are NaN in STARS are zero in ESA and ISR.
The Boxplot below (Fig. 18-21) show that also for the SWH in CS2 the retracker of Uni Bonn has the best performance.

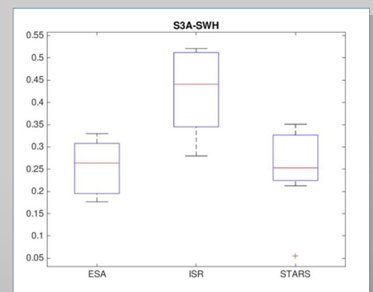

Fig. 18 Boxplots of comparison SWH from S3A and 8 in-situ stations

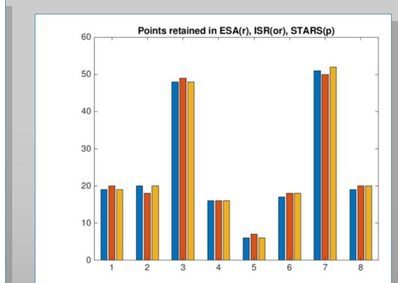

Fig. 19 Points used per station

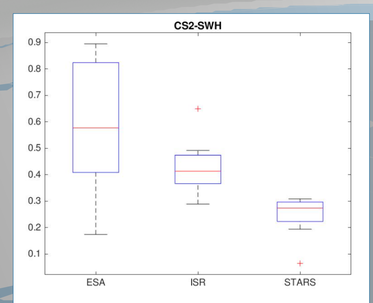

Fig. 20 Boxplots. Comparison SWH from CS2 and 8 in-situ stations

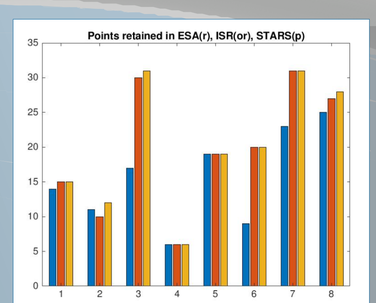

Fig. 21 CS2 Points used per station

Retracker	S3A stdd	S3A cor	S3B stdd	S3B cor	CS2 stdd	CS2 cor
ESA	0.396	0.885	0.156	0.970	0.98	0.657
ISR	0.454	0.847	0.175	0.958	0.44	0.896
STARS	0.397	0.889	0.178	0.958	0.26	0.966

Table 2: Statistics of SWH for S3A and S3B at Helgoland TG station

Conclusions

- BONN retracker is the less noisy and has good agreeement with in-situ especially for SWH
- BONN retracker has a discontinuity in precision at 10 km from coast, can be removed. No effect on data quality
- BONN retracker has NaN in SWH, which correspond to zeros in other retrackers.
- DTU is noisier than TUM and IRS

Contact
Luciana Fenoglio,
fenoglio@uni-bonn.de,
www.igg.uni-bonn.de/apmg