Advances in NE-Atlantic Coastal Sea Level Change Monitoring by Delay Doppler Altimetry

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Goals

In this work we have analysed the impacts of RDSAR and unfocused-SAR processing on the estimated coastal sea level variability in the last 10 km from the coast.

The two goals are:

1) **Quality of the new estimated coastal sea level**
2) **Effect on variability and trends estimation**

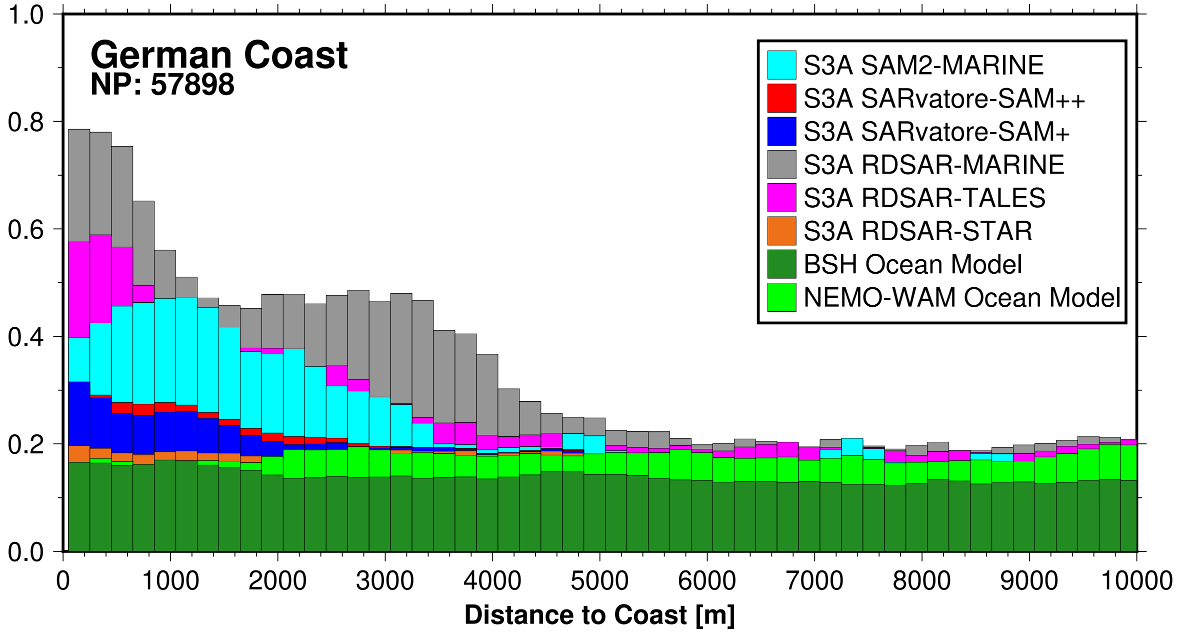
Data

Table 1. Processors output with selected options. The name of each product includes both the processing used from L1A to L1B (SAR/RDSAR) and the retracker used from L1B to L2 (SAM+, SAM++, SAM2, TALES, STAR).

	SAR-SAM2	SAR-SAM+ SAR-SAM++	SAR-SAM2-Marine	RDSAR-TALES	RDSAR-STAR
Satellite Mission	CS2	CS2/S3A	S3A	CS2/S3A	CS2/S3A
wf zero-padding	no	yes	no	yes	yes
N of range bins	128	256	128	256	256
hamming in coastal	no	yes	no	no	no
approx. beam forming	yes	yes	yes	no	no
antenna pattern corr.	no	no	no	no	no
Look up tables (LUT)	yes	yes	yes	no	no
wf retracking model	SAMOSA2	SAMOSA+,++	SAMOSA2	SINC2	Brown
Estimated par	t,A,σ_c	t,A,SWH	t,A,SWH	t,A,SWH	t,A,SWH
corr except SSB	from ref	ref	from ref	from ref	from ref

Quality of the new estimated coastal sea level

- improved processing of type RDSAR (Fenoglio and Buchhaupt, 2018)
- improved accuracy and precision with unfocused SAR SAMOSA+ and SAMOSA++ up to 3 km from coast (Dinardo et al., 2018, 2020).
- spatio-temporal coastal retracker STAR for LRM & RDSAR. Similar quality as SAR-SAMOSA+ for sea level height (Fenoglio et al., 2020).



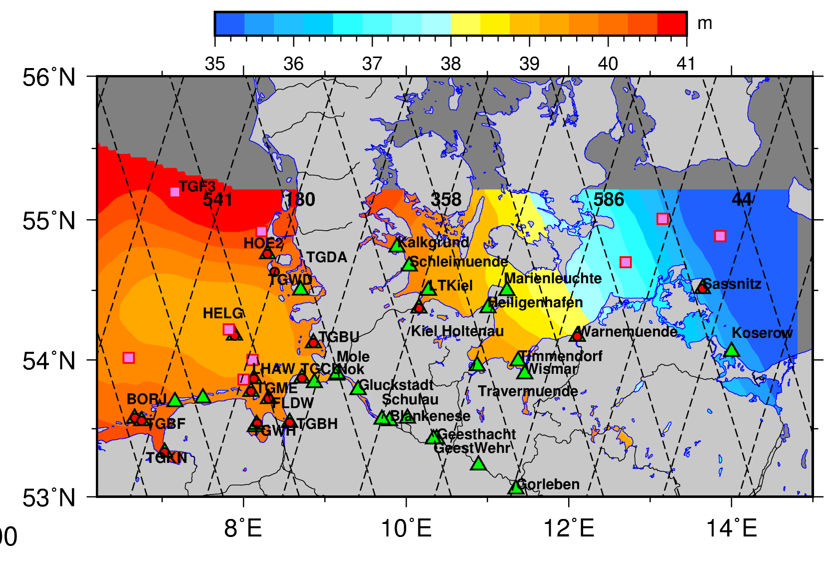
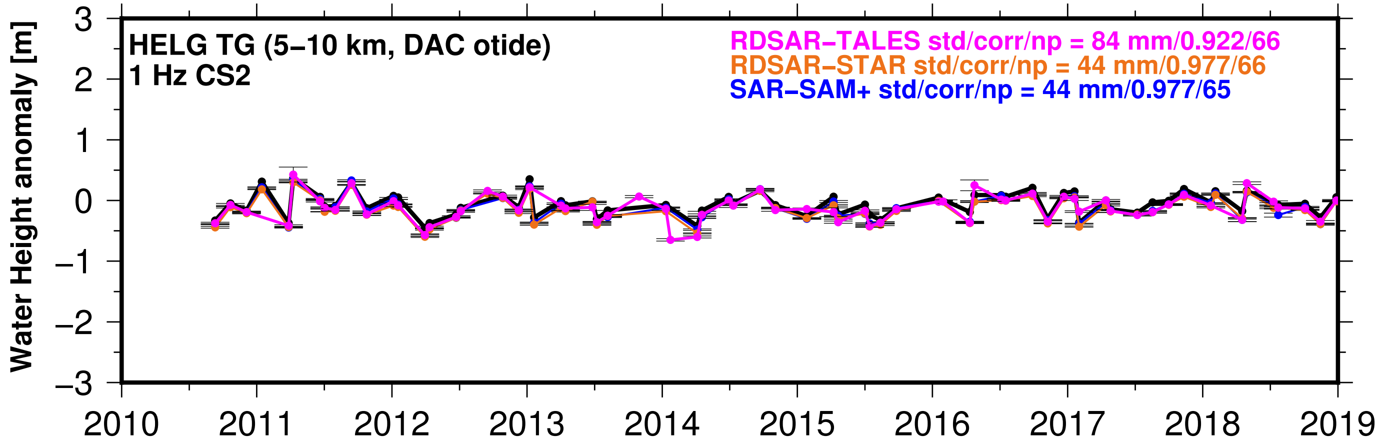


Fig. 1. Standard deviation of sea surface height anomaly in the GEC for altimeter products and ocean model. Sentinel-3.A from June 2016 to Dec. 2018. BSH and NEMO-WAM corrected for ocean tide model TPXO8. NP is the number of meas..

Quality of sea level against in-situ

- SAR-SAM+ and RDSAR/STAR pointwise **comparison to TGs** (3-8 km from TG station) **with all corrections applied:** stdd 4 cm, corr 0.90 (S3A) in Helgoland; the accuracy does not decrease with the distance to coast.
- In estuaries and coastal zones with high tidal regimes, the discrepancy between altimetry and in-situ remains large (40 cm stdd with SAR-SAM+).
- CryoSat-2 and Sentinel-3A have similar accuracy



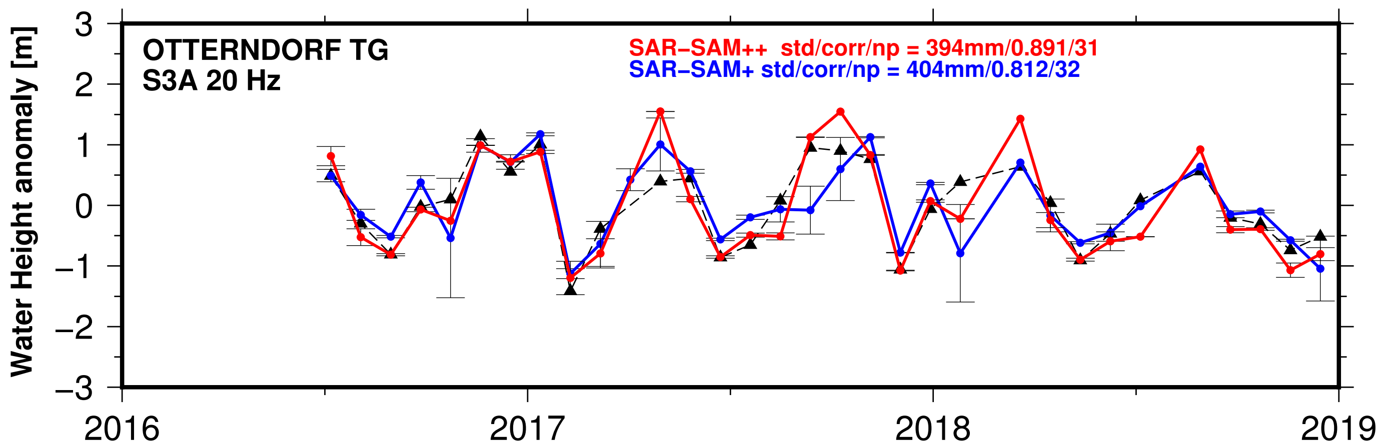
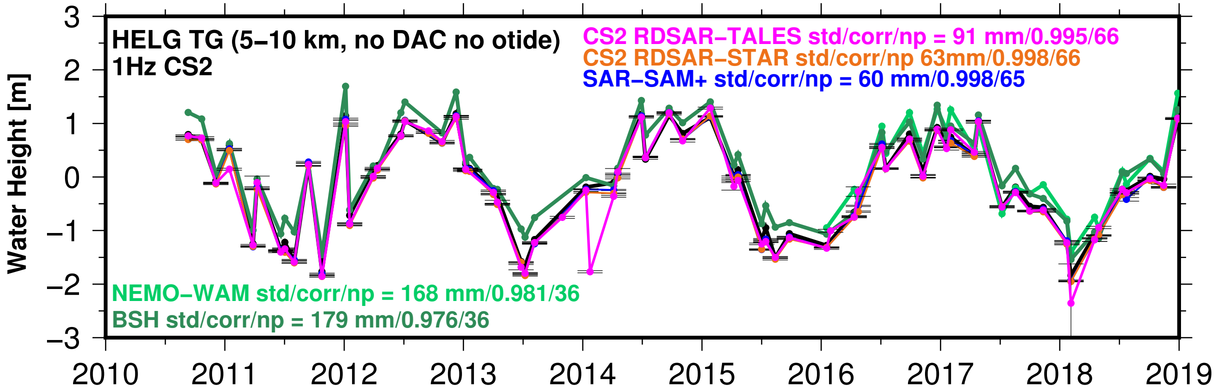


Fig. 2 Sea level anomalies (SLA) time-series: CryoSat-2 at TG Helgoland corrected for ocean tide and DAC (above) and Sentinel-3 at Ottendorf corrected (d).

Method "Overpass" is used at Helgoland and Method "Virtualpoint" at Otterndorf

- **Altimetry agrees better with TGs that models**
- **comparison to TG HELG OTIDE and DAC not applied** (3-8 km from TG): has stdd 6 cm, corr 0.95 (S3A SAR-SAM+ or RDSAR/STAR) and stdd 18 cm, corr 0.9 (models).
- In estuaries and coastal zones, the stdd is larger (40 cm stdd S3A SAR-SAM+) and again 18 cm between model and TGs.



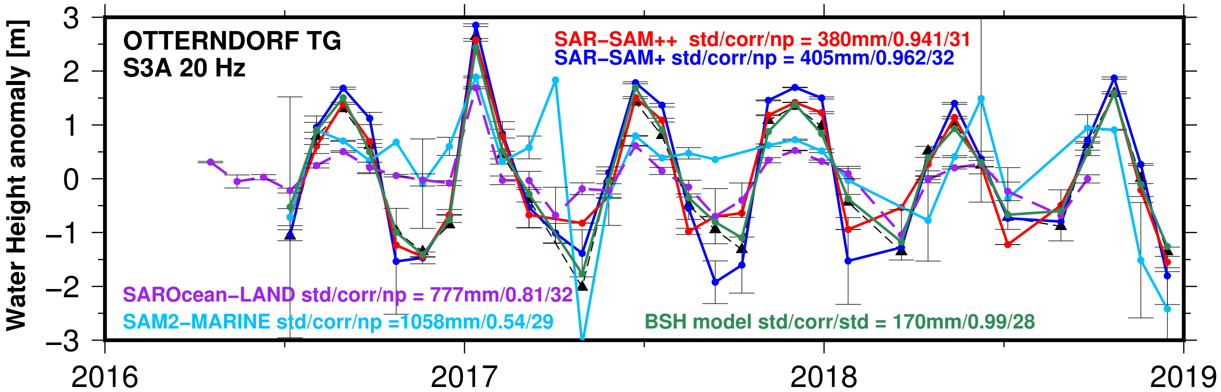


Fig. 3. Figures include comparison with ocean models. The sdd of model with TG is 17-18 cm at both locations.

Method "Overpass" is used at Helgoland and Method "Virtualpoint" at Otterndorf

SAR-SAM+ is superior to LRM **compared to models.**
SAR-SAM+ **regional coastal variability** (< 10 km from coast) agrees most favourably with high-resolution model NEMO-WAM with stdd 3.9 cm, corr 0.90 (S3A) and 4.8 cm, corr 0.84 (CS2).
This is twice the maximum sdd between altimeter data (SAR-SAM+ /RDSAR-TALES C2 stdd 2.3 cm, corr 0.96).

	SAM+/TALES	SAM+/SAM2	SAM+/SAM++	SAM+/STAR2.5
CS2 (corr)	0.9637	0.9959		
CS2 (mean)	0.0056	0.0023		
CS2 (stdd)	0.0232	0.0070		
S3A (corr)	0.9808	**0.9974**	0.9945	0.9942
S3A (mean)	0.0197	0.0175	-0.0230	-0.0241
S3A (stdd)	0.0155	**0.0059**	0.0082	0.0087

	SAM+/BSH	SAM+/NEMO	TALES/NEMO	STAR2.5-NEMO	SAM++/NEMO
CS2 (corr)	0.7486	**0.8396**	0.8451	0.8209	
CS2 (mean)	-0.1957	-0.0272	0.0339	0.0163	
CS2 (stdd)	-0.2984	**0.0481**	0.0479	0.0502	
S3A (corr)	0.7298	**0.8980**	0.8780	0.8800	**0.9139**
S3A (mean)	-0.0724	0.0017	0.0181	0.0065	0.0231
S3A (stdd)	0.0545	**0.0391**	0.0425	0.0423	**0.0374**

Tab. 2. Correlation, standard deviation of differences (stdd) and mean of difference between time-series in Fig. 4 (next page)

Exploiting SAR altimetry: regional variability

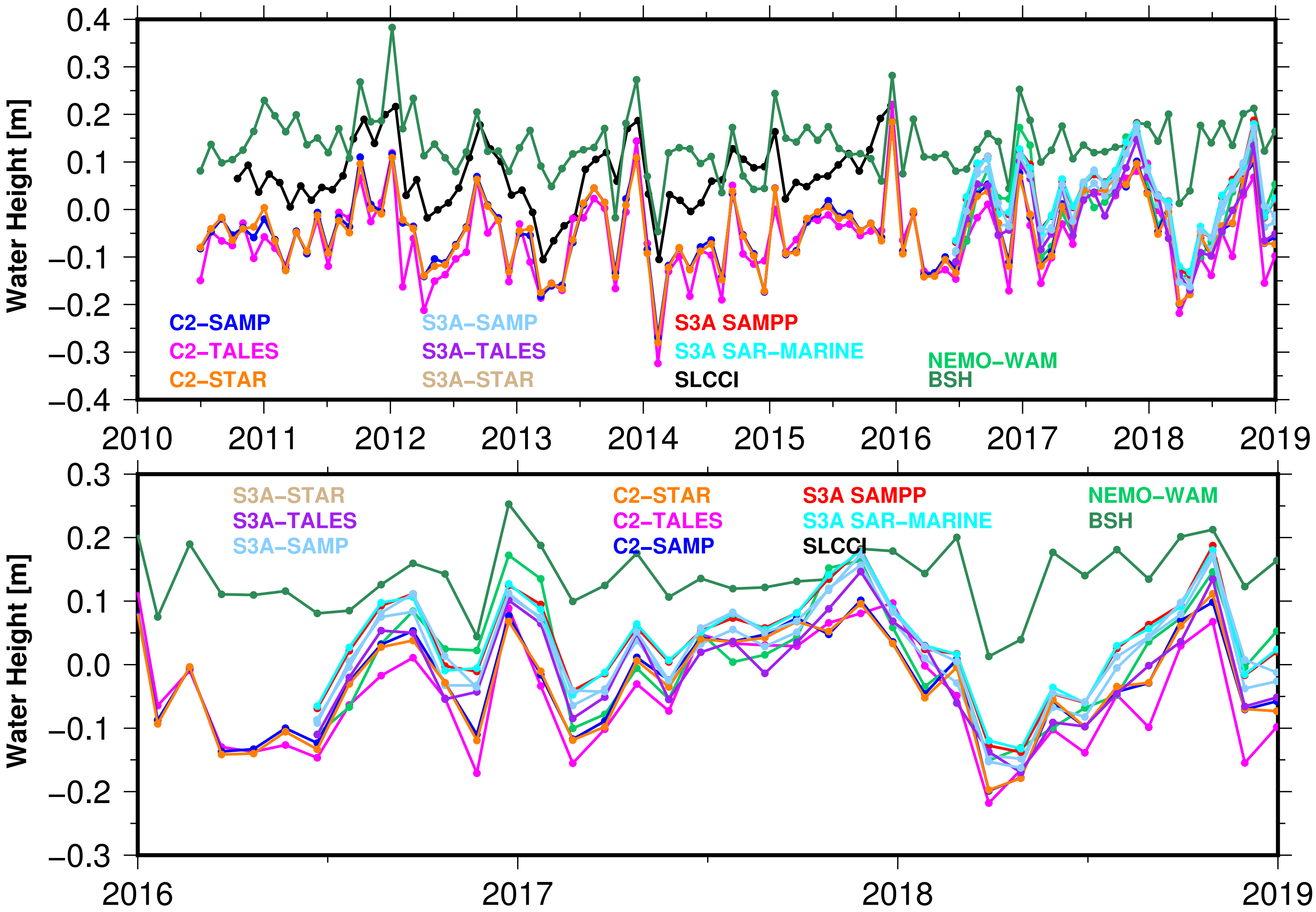


Fig. 4. Monthly basin average in the GEC region of ocean models and satellite ECV-SLCCI, CryoSat-2 and Sentinel-3 at distance to coast smaller than 10 km for both satellites (above) and for Sentinel-3 (bottom).

Exploiting SAR altimetry: trends

- We have considered LRM data in 1993-2015.
- Average trend 3 +/-1.3 mm/yr, 19 TG with > 15 years.
- Sea level trends tested comparing al-tg to GPS
- al-tg error is larger than twice the GPS error

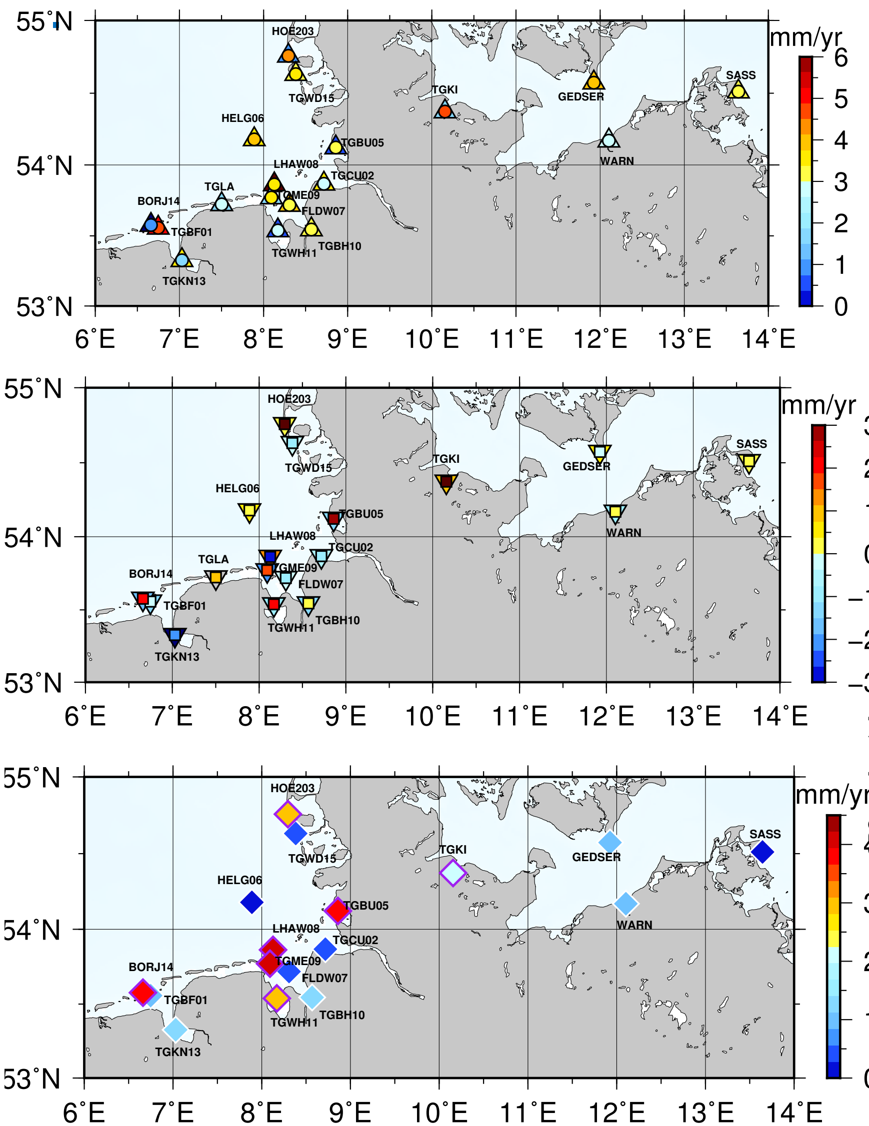


Fig. 5. (top) sea level trend from TG (triangle) and altimetry (circle); (middle) VLM from GPS (square) and from altimetry minus TG (al-tg, inversed triangle); (bottom) trend of differences al-tg-GPS with highlighted (purple border) locations with significant trend of difference.

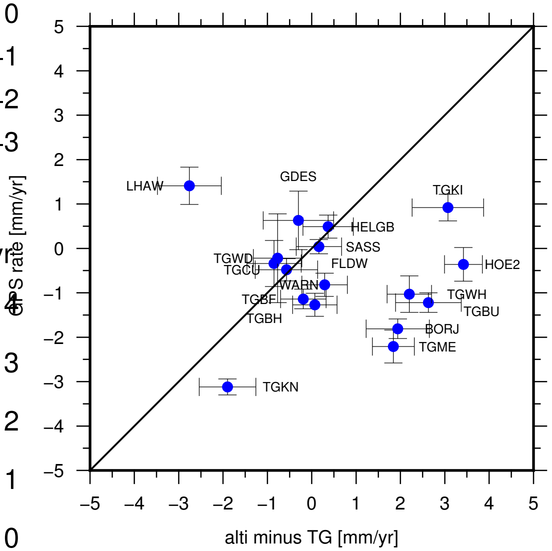


Fig. 6. Scatterplot of VLM from altimetry minus tide gauge vrs GPS rates for the GEC region.

The sea level trends of the merged LRM and SAR altimetry time-series are consistent with the LRM trends over the complete altimeter interval 1993-2019.

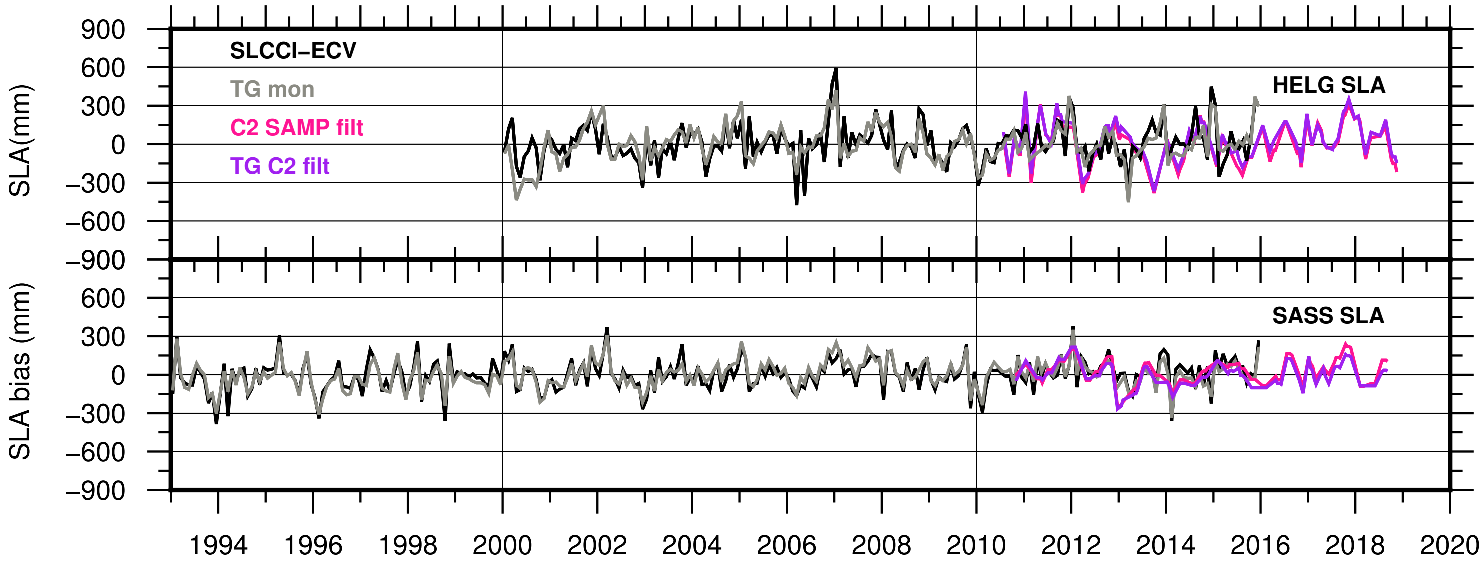


Fig. 7. Sea level time-series from in-situ data, multi-mission altimetry (SLCCI) and from CryoSat-2 at Helgoland (top) and Sassnitz (bottom) over the complete altimeter period 1993-2019. The filtered CryoSat-2 time-series correspond to the nearest point (C2 SAMP filt). In-situ data are the monthly records and the filtered time-series corresponding to C2 SAMP filt.

Conclusions

- Accuracy and precision improves with dedicated coastal retrackers
- Data gap is reduced to 3 km from coast using SAR-SAM+/++ & RDSAR/STAR
- SAR data agrees with models better than LRM regionally < 10 km from coast
- Trends of merged SAR+LRM is consistent with the LRM trends.

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