Coastal sea level trends from SAR altimetry

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- Motivation
- Methodology
- Results
- Conclusion

Motivation

German coast and inland water are well observed and investigated from in-situ and models

- Water height change
- Long scales for sea level rise and VLM
- Short scales for water extrems
- DDA opens new possibilities of coastal and estuary applications

Region of Interest & Data

Instrument	Agency	parameters
Tide gauges	BfG PSMSL	Discharge Q (15’) water level (1’) Water level (mon)
GPS	BGK SONEL	Tide gauge xyz Lon, Lat, h
Campaigns	CMEM	S profiles, currents profile & surf.
FINO stations	BSH	Water level
		Shape files Geodetic inf.
BSHcmod (NSE)	BSH	
GCOAST-SCHISM (coast) GCOAST-NEMO (NEA)	HZG	SLA, T, S, etc.
operational Elbe	TUHH	
CryoSat-2	ESA	SSH
Sentinel-3A,3B	Copernicus	SSH
Sentinel-2	Copernicus	Water extent

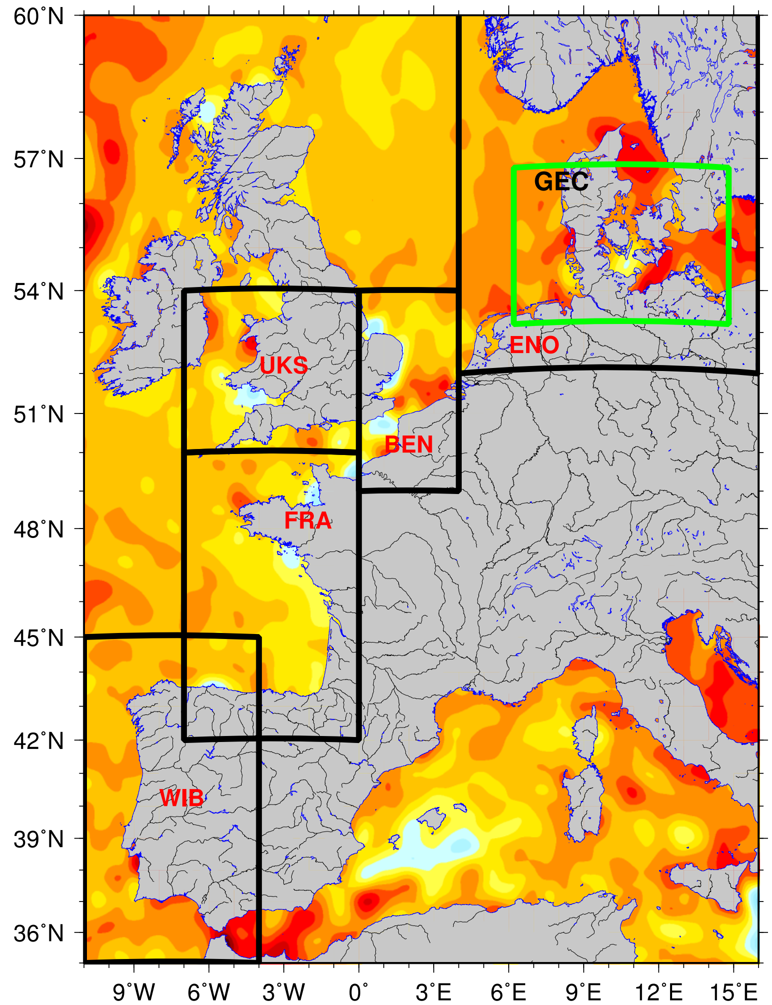


Figure 1: Region of study

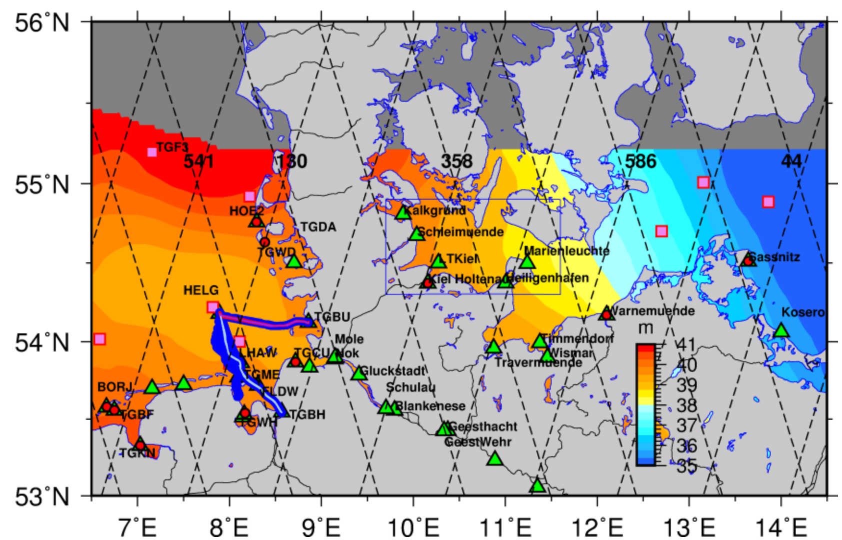
Regional Ocean Model simulations
(open & coastal seas & estuaries)

BSHcmod: regional ocean circulation model of German Federal Maritime and Hydrographic Agency

GCOAST (Geestacht COAstal SysTem) Helmholtz-Zentrum Geesthacht (HZG)

- **GCOAST-NEMO** gridded
- **GCOAST_SCHISM** unstructured

In-situ station with GPS: bfg, BSH, wsv



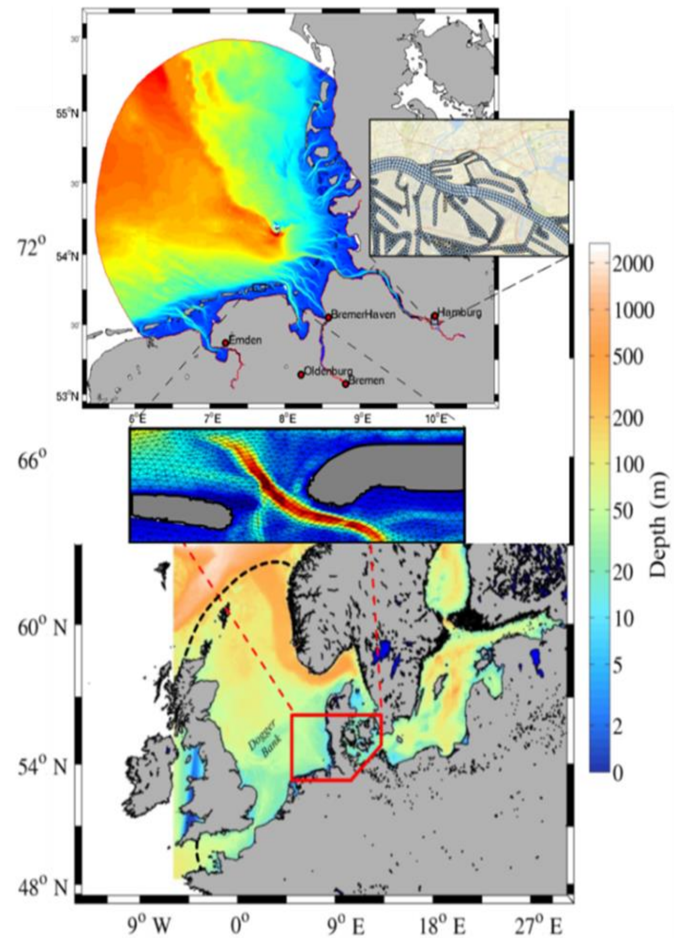


Figure 2: Sub-regions of study

Satellite Altimetry data

Table 1: Processors output with properties

	S-SAM2	S-SAM+ S-SAM++	M-SAM2	T-TALES	T-SINCS	B-STAR
wf zero-padding	no	yes	no	yes	yes	yes
N of range bins	128	256	128	256	256	256
hamming in coastal	no	yes	no	no	no	no
approx. beam forming	yes	yes	yes	no	no	no
antenna pattern corr.	no	no	no	no	no	no
Look up tables (LUT)	yes	no	no	no	no	no
wf retracking model	SAMOSA2	SAMOSA+,++	SAMOSA2	SINC2	SINCS	Brown
Estimated par	t,A,σ_c	t,A,SWH	t,A,SWH	t,A,SWH	t,A,SWH	t,A,SWH
corr except SSB	from ref	ref	from ref	from ref	from ref	from ref

Data from October 2010 to December 2018 (7 years of data)

S	=	SARVatore,	CS2, S3A *(Dinardo et al., 2018, and in review, Poster Dinardo SAMOSA++ this meeting)*
M	=	Marine Copernicus	S3A
T	=	Ubonn in TUDaBo	CS2, S3A *(Buchhaupt et al.., 2018 and in review)*
B	=	Ubonn	CS2, S3A

Corrections as in SAMOSA+/GPOD **except ocean tide TPX08 & GPD+** (GNSS-derived Path Delay Plus)

CryoSat-2 vs. Ocean Model BSHcmod STD

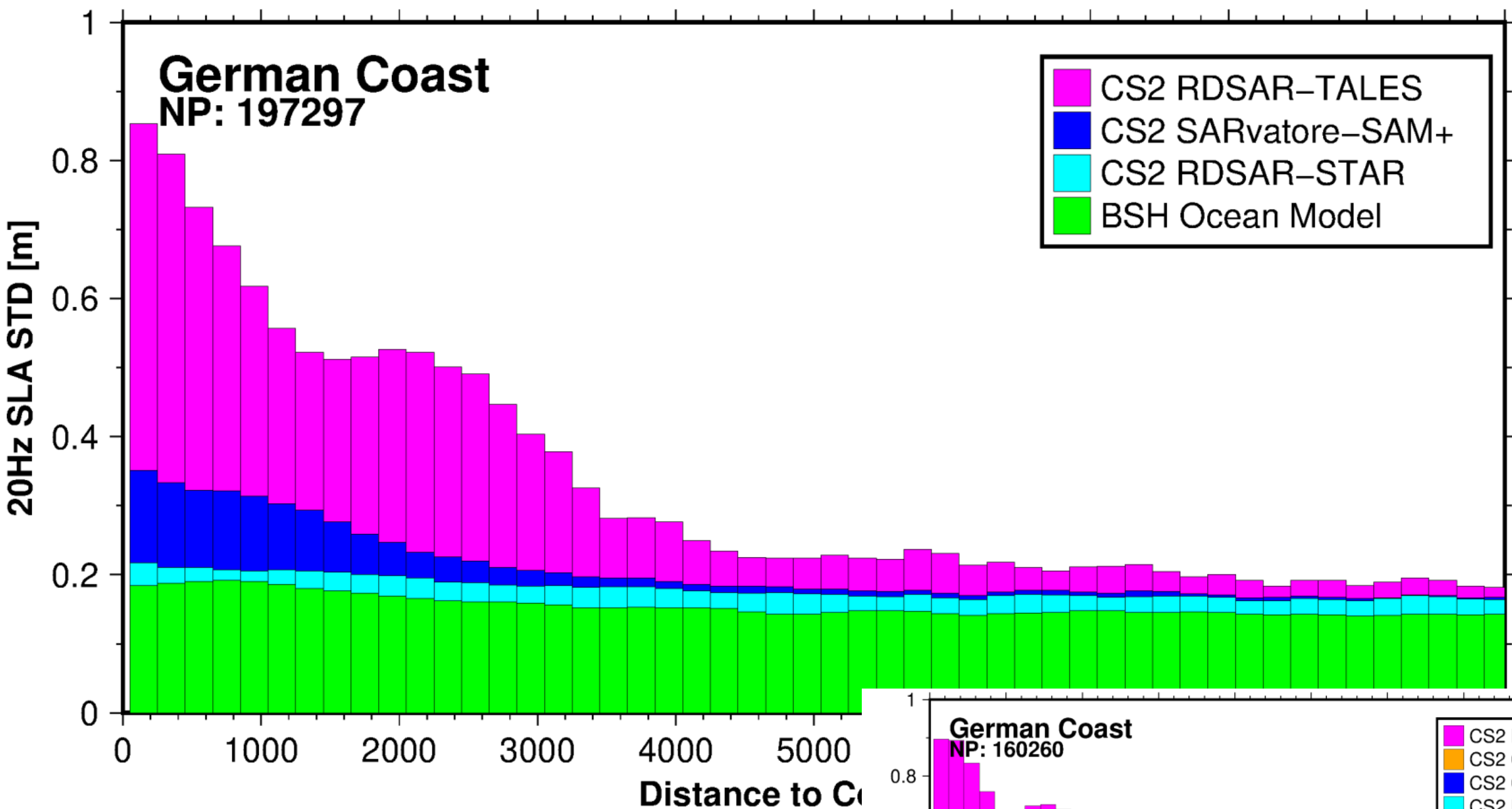
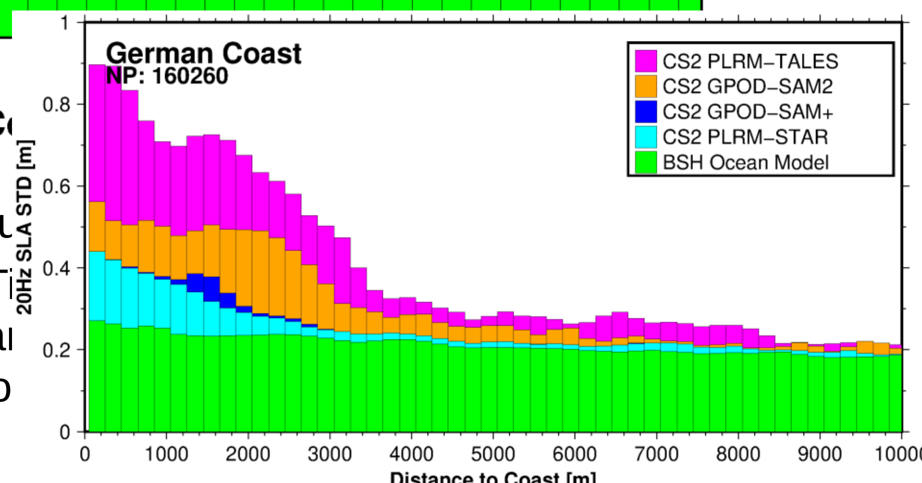


Figure 4: Standard deviation of **CryoSat-2** sea su
from **SAMOSA+, RDSAR STAR and TALES**. Th
The BSH ocean model height corrected for ocea
for the comparison (in green its standard deviatio



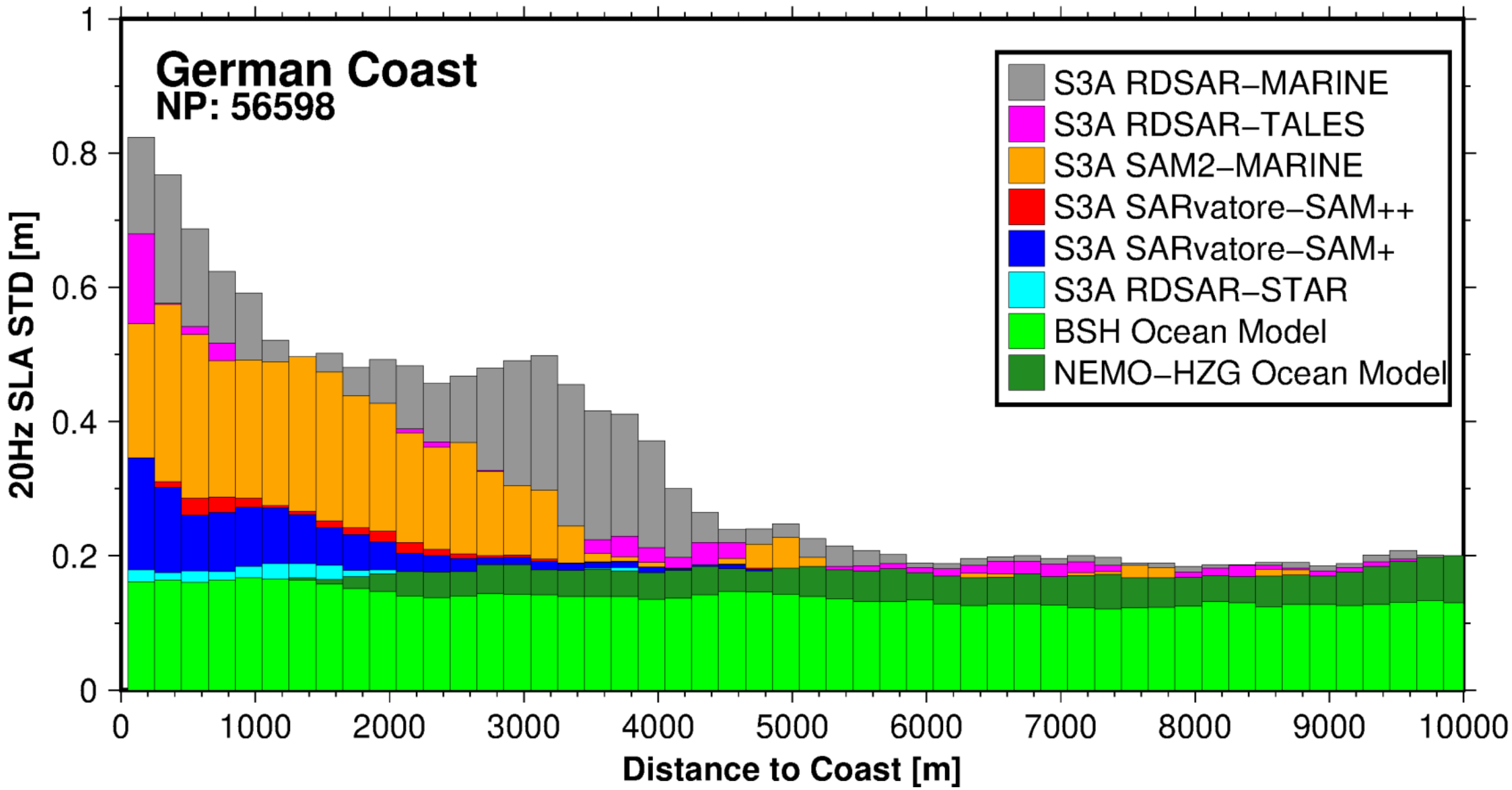


Figure 5: Standard deviation of **Sentinel-3** sea surface heights in the sub-region GEC for **SAR SAMOSA2-MARINE, SAMOSA+, SAMOSA++** and **RDSAR NARINE, STAR and TALES**. Time interval is **2016-06-15 to 2018-12-31**. Ocean models BSHcmod and HZG-NEMO height corrected for ocean tide from the model TPXO8 is reference for the comparison (in green its standard deviation).

CryoSat-2 STD in the other sub-regions

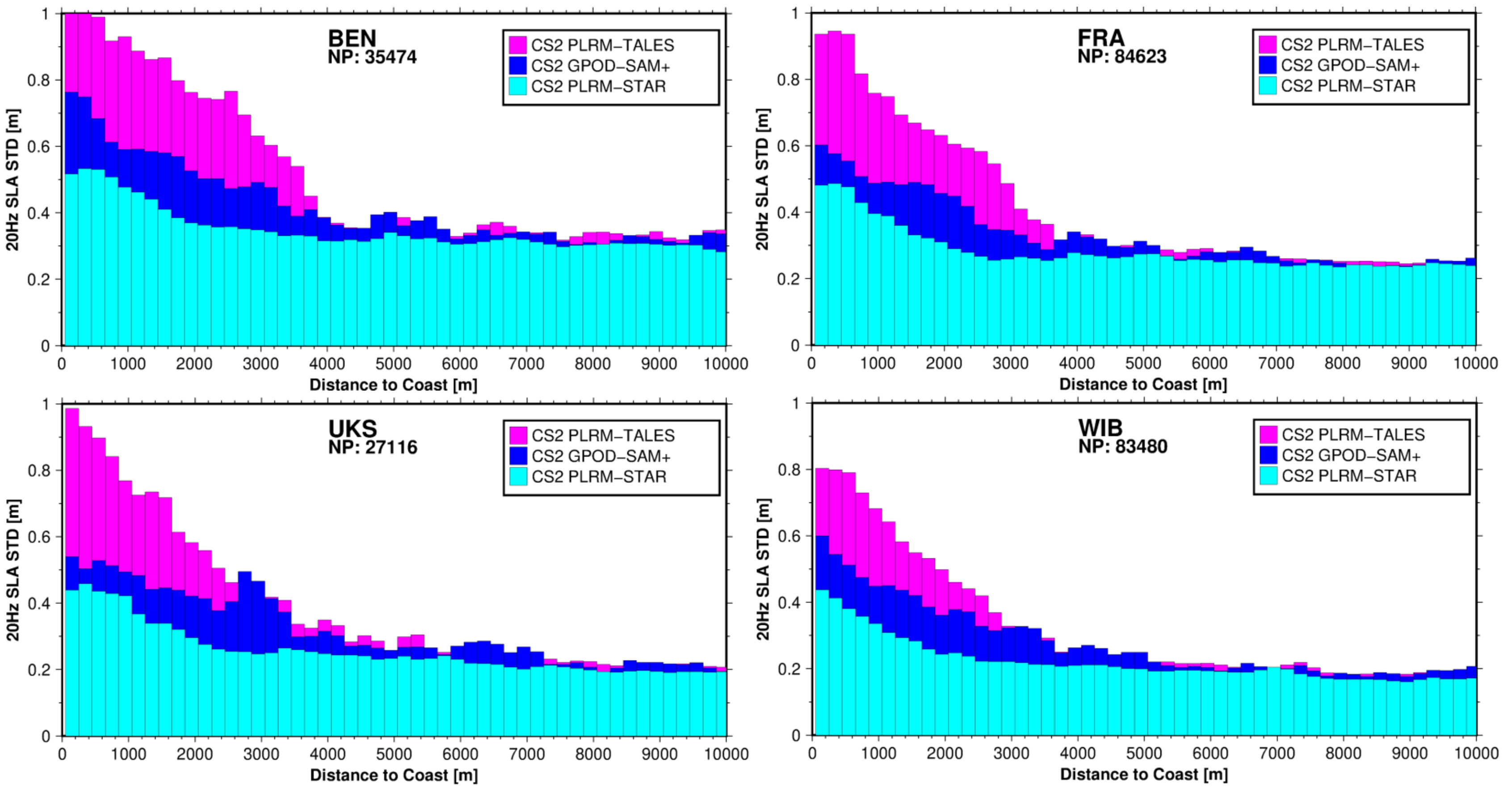
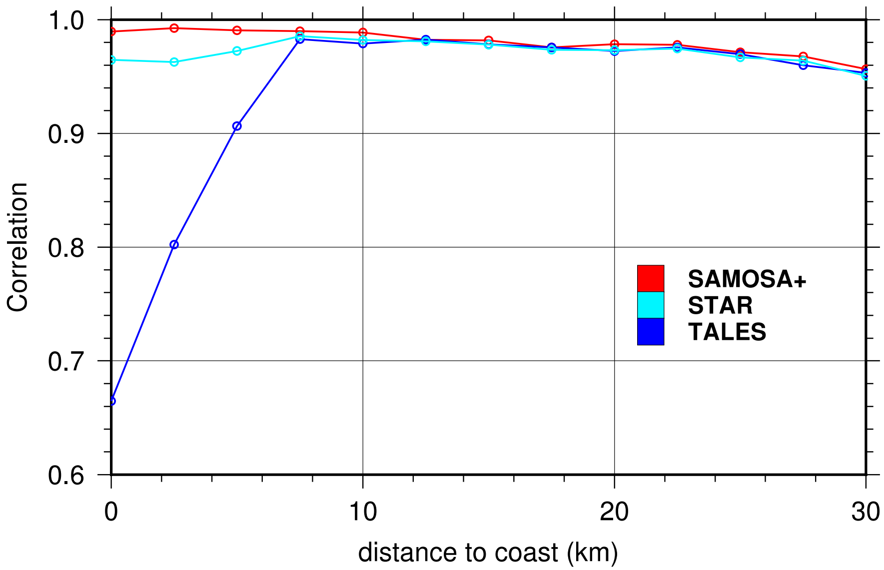


Figure 6: Standard deviation in the other four regions of sea surface height for the SAR **coastal** (SAMOSA+) processing and conventional altimetry coastal processing (STAR and TALES). Time interval is from 2011-04-08 to 2015-12-13.

Agreement decreases with increasing distance →
compare altimetry and tide gauge at nearest location (< 10 km)



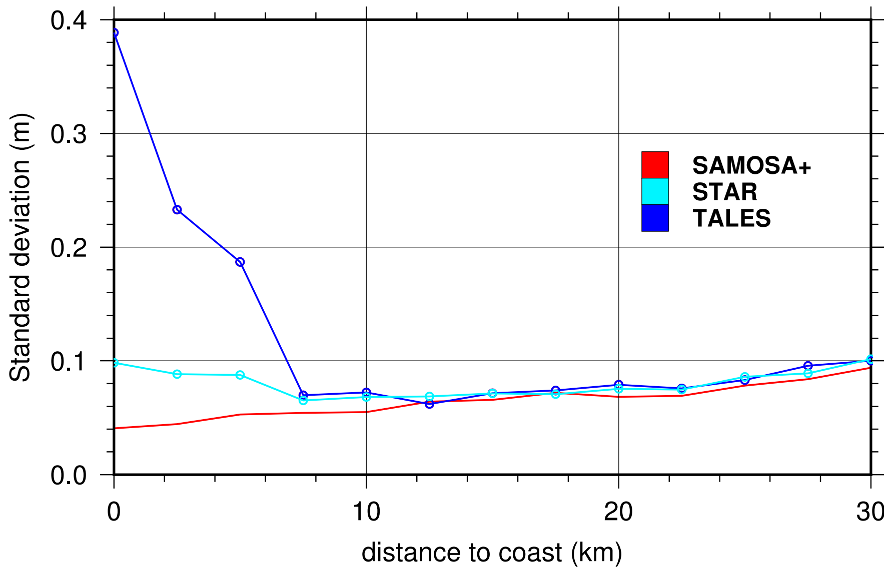


Figure 7: Cryosat-2 coastal and open sea (0 to 30 km) : Correlation (left) and standard deviation (right) of CryoSat-2 and the Helgoland sea level anomalies over the full time interval 2010-2018 (top).

Accuracy & Methodology of comparison

Accuracy = agreement with in-situ data and models

What is compared:

SLAs fully corrected (ocean tide and DAC)

SLA corrected for ocean tide and not for DAC

Three Methodologies of comparison:

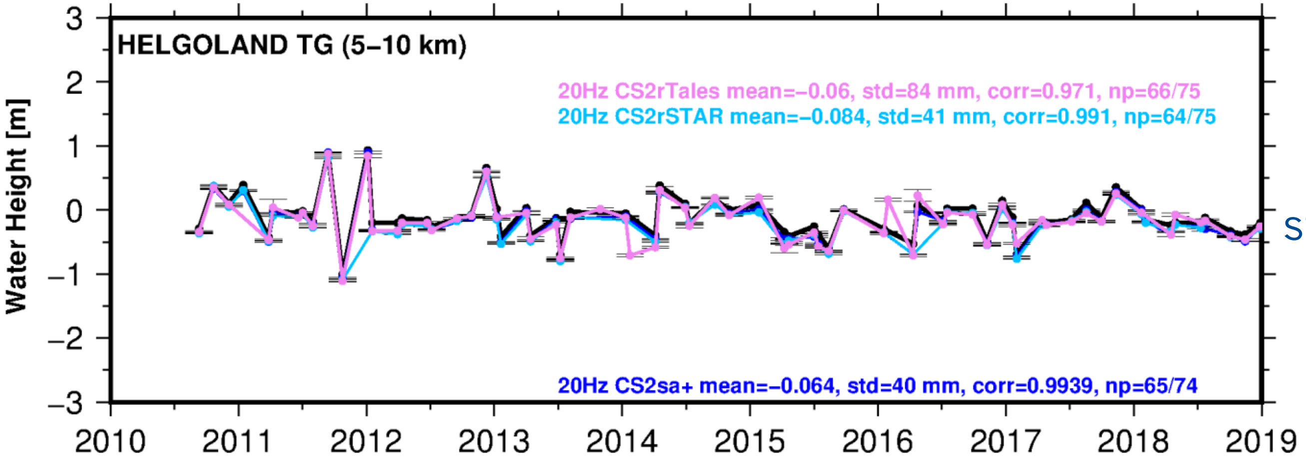
Meth 1. **Overpass**: Nearest point (1 Hz or 20 Hz) → altimeter accuracy

Meth 2. **VirtualPass**: Average over part of the track (more robust for river and estuary)

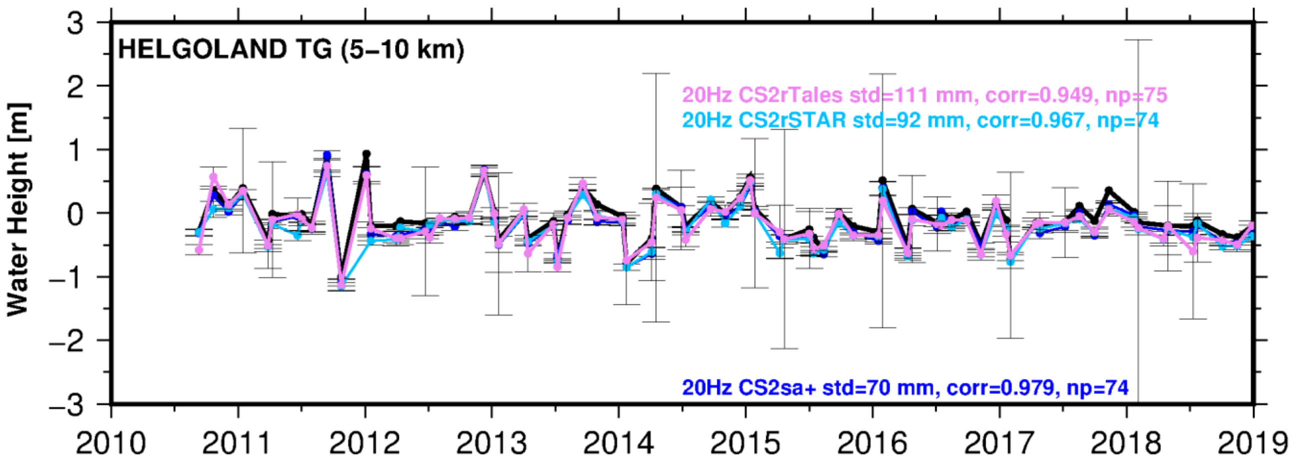
Meth 3. **C2grid:** : build ts from C2 in a grid and use time-series from nearest block

Open ocean (Helgoland)

Coastal/Estuary station (Otterndorf)



std (SAM+ - tg) =4 cm



std (SAM+ - tg) =7 cm

Figure 8: Cryosat-2 sla all corrections applied

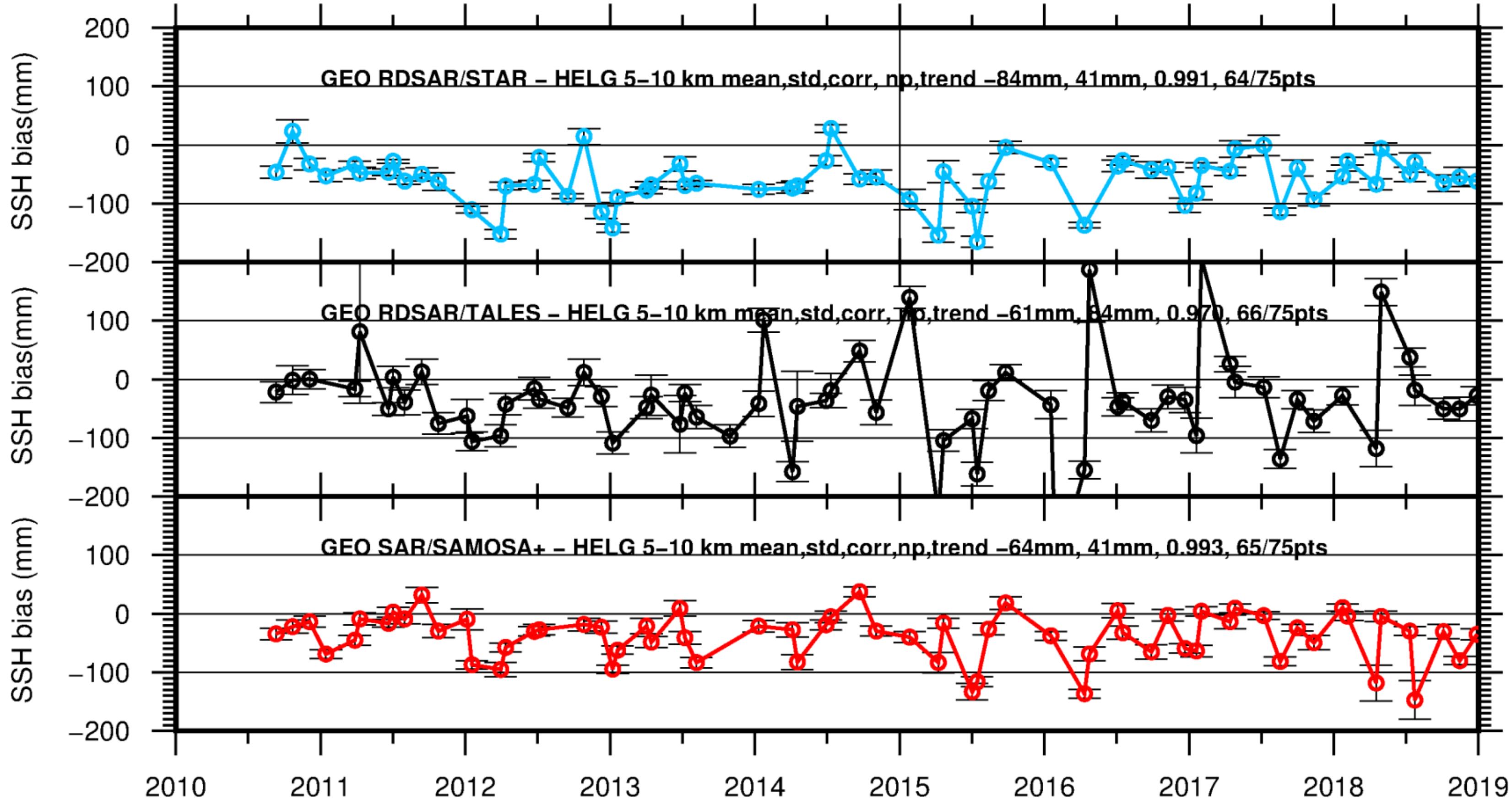
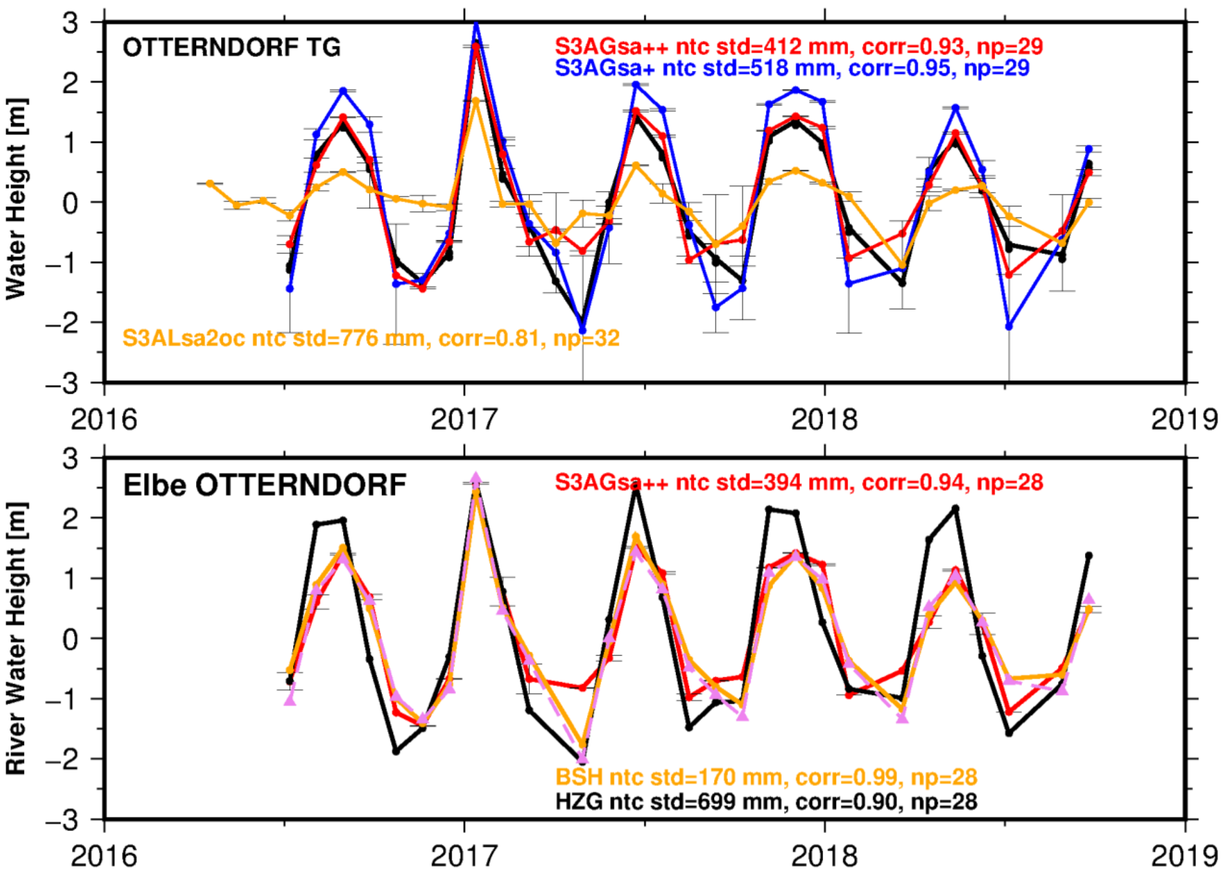


Figure 8b: Cryosat-2 difference with in-situ

Accuracy and Methodology of comparison 2



std (SAM++ - tg) =41 cm

Figure 9: Sentinel--3 sla no ocean tide no DAC applied Methodology 2

VLM from PSMS and SLCCI database

TG	cor	stdd mm	al mm/y	tg mm/y	al-tg mm/y	G mm/y	int y	al-tg-G mm/y	al-tg km	tg-G km
TGBF	0.79	70	4.8 ± 1.7	5.0 ± 2.0	-0.2 ± 0.9	-1.1 ± 0.2	93-10	0.9	11.0	0.002
TGCU	0.60	112	2.7 ± 1.7	3.6 ± 2.0	-0.9 ± 0.9	-0.5 ± 0.3	93-11	-0.4	10.6	0.006
HOE2	0.79	70	4.3 ± 1.7	0.9 ± 2.0	3.4 ± 0.9	-0.4 ± 0.4	00-16	3.0	13.9	0.185
TGBU	0.56	113	3.3 ± 1.7	0.7 ± 2.0	2.6 ± 0.9	-1.2 ± 0.2	00-16	3.8	1.1	0.005
HELG	0.67	112	3.8 ± 1.7	3.4 ± 2.0	0.4 ± 0.9	0.5 ± 0.2	00-16	-0.1	6.1	0.533
LHAW	0.67	109	3.4 ± 1.7	6.2 ± 2.0	-2.8 ± 0.9	1.4 ± 0.2	95-16	4.2	1.3	0.008
FLDW	0.64	96	3.1 ± 1.7	3.9 ± 2.0	-0.8 ± 0.9	-0.3 ± 0.5	95-16	-0.5	11.3	0.001
TGME	0.67	106	3.4 ± 1.7	1.6 ± 2.0	1.8 ± 0.9	-2.2 ± 0.5	00-16	4.1	11.7	0.008
TGBH	0.61	109	3.3 ± 1.7	3.2 ± 2.0	0.1 ± 0.9	-1.3 ± 0.5	94-16	1.3	15.5	0.002
TGWH	0.63	94	2.7 ± 1.7	0.5 ± 2.0	2.2 ± 0.9	-1.0 ± 0.5	00-16	3.1	10.1	3.123
TGLA	0.69	100	2.7 ± 1.7	1.7 ± 2.0	1.1 ± 0.9	nan ± nan	00-16	nan	18.7	nan
TGKN	0.77	71	1.8 ± 1.7	3.7 ± 2.0	-1.9 ± 0.9	-3.1 ± 0.2	00-16	1.2	33.7	0.001
BORJ	0.73	77	0.9 ± 1.7	-1.0 ± 2.0	1.9 ± 0.9	-1.8 ± 0.2	00-16	3.7	11.3	0.402
TGWD	0.85	70	2.4 ± 1.7	3.2 ± 2.0	-0.8 ± 0.9	-0.2 ± 1.0	93-11	-0.5	10.3	0.001
WARN	0.85	55	2.9 ± 1.7	2.6 ± 2.0	0.3 ± 0.9	0.7 ± 0.6	95-16	-0.4	22.9	0.126
GEDS	0.82	59	3.8 ± 1.7	4.1 ± 2.0	-0.3 ± 0.9	0.6 ± 0.7	95-16	0.9	6.7	0.249
SASS	0.90	52	3.2 ± 1.7	3.1 ± 2.0	0.2 ± 0.9	0.8 ± 0.5	95-16	-0.7	12.7	0.308
TGKI	0.58	72	4.8 ± 1.7	1.7 ± 2.0	3.1 ± 0.9	0.7 ± 0.7	95-16	2.4	28.2	0.076

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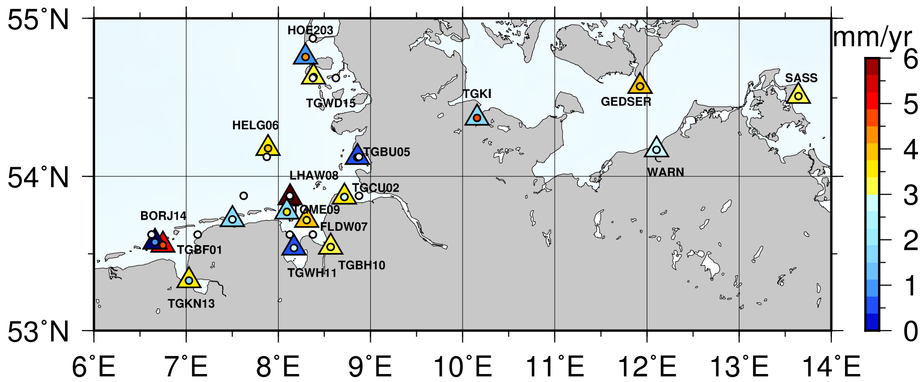
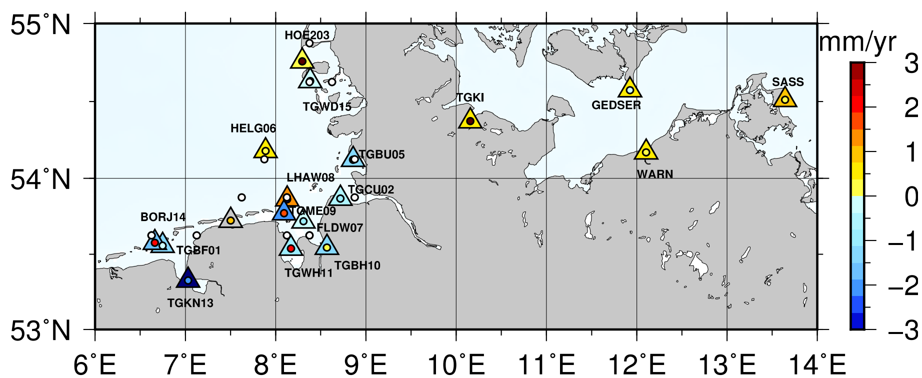
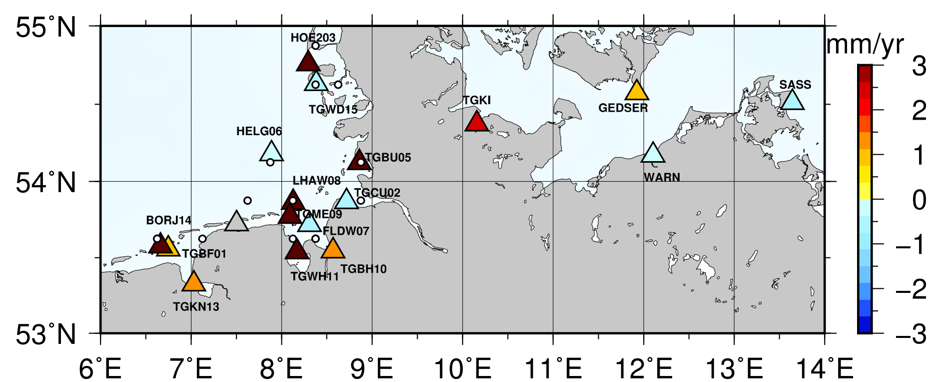
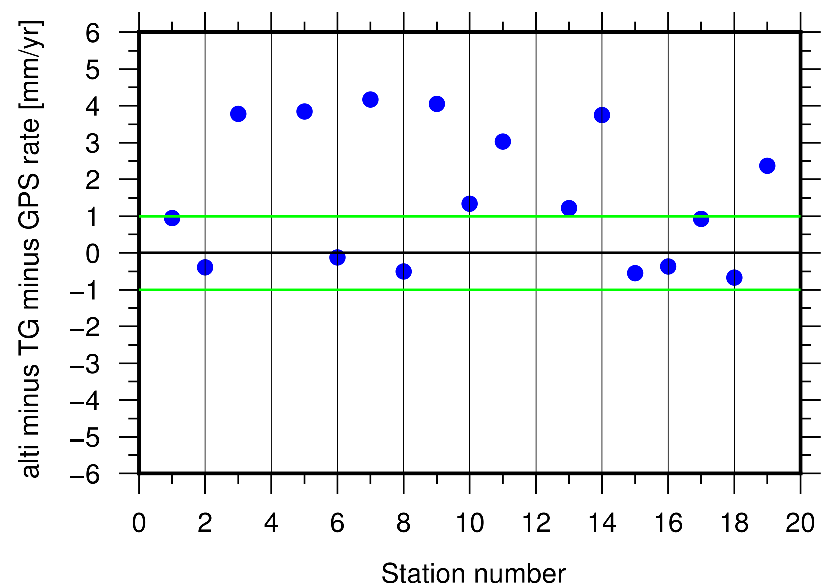
VLM from PSMS and SLCCI database

Figure 10:
(top) sea level trend from tide gauge (triangle) and altimetry (circle);
(middle) VLM from GPS (triangle) and from altimetry minus tide gauge;
(bottom) trend of differences al-tg-gps

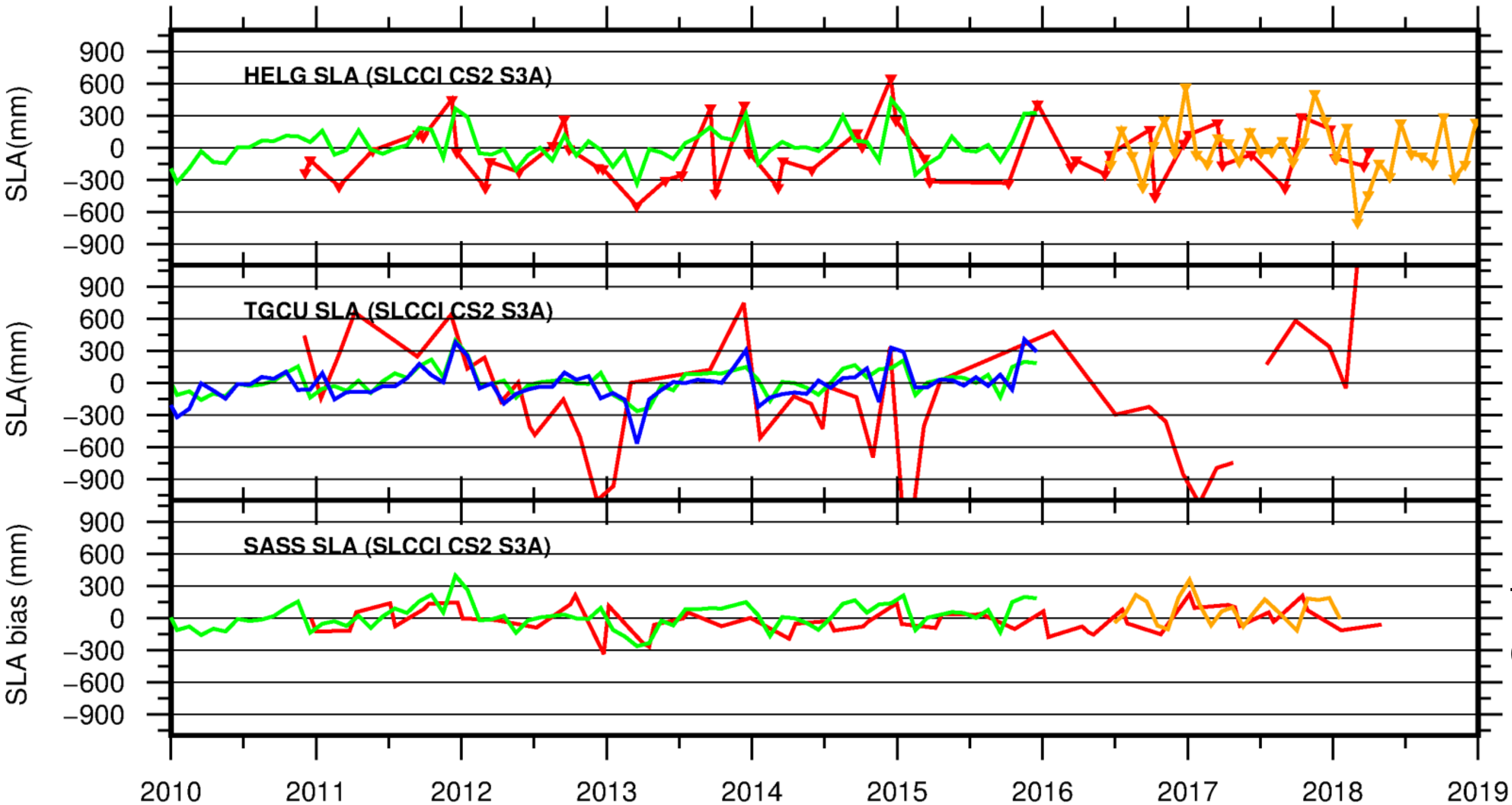








Data



TG 3.8+/-1.7
C2 2.3+/2.7

TG 3.2+/-2.7
C2 3.4+/2.9

Figure 11: time series SLCCI and from gridded CryoSat-2

Agreement between SLCCI and C2 at few tide gauges is promising, but signals is small and long time-series needed.

Long term change

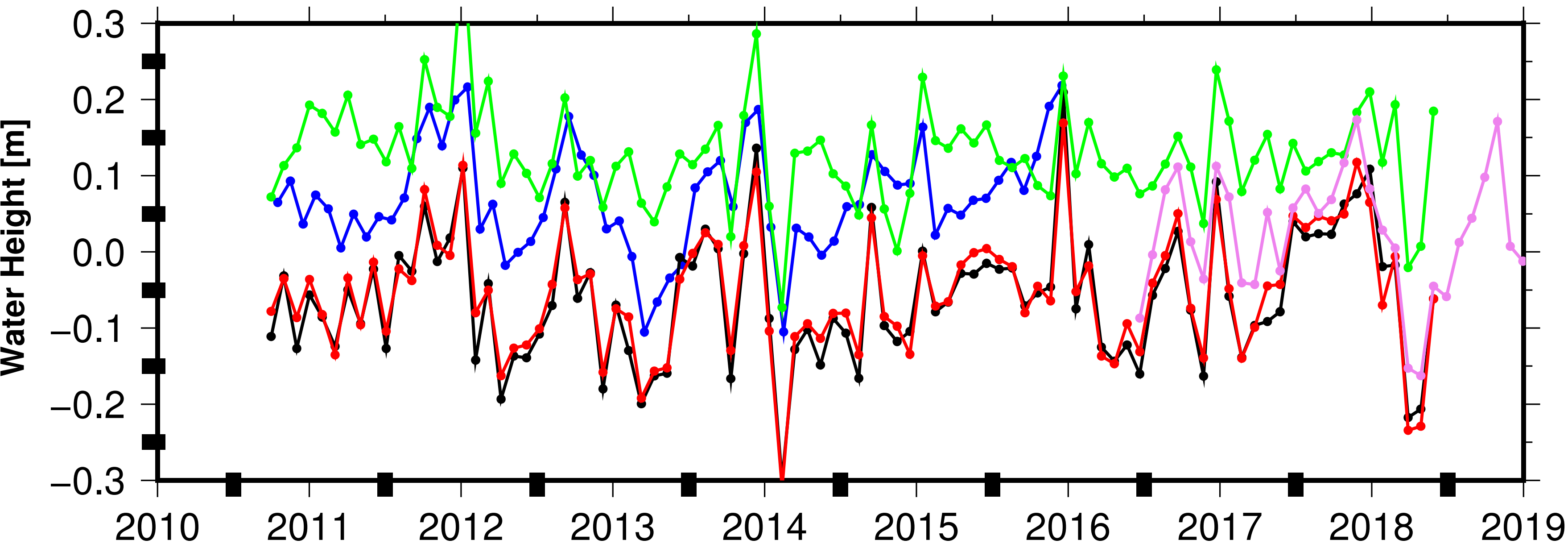


Figure 12: time series SLCCI (blue) and from gridded CryoSat-2 in the 10 km band (red-SAM+ and black (STAR).

Conclusions

- Significant advances in coastal-– estuaries observations

  - SAMOSA+ and STAR give the best performances

  - STDD with in-situ : Coastal 4 cm – 20 cm
  - Estuaries STDD 10 time larger due to tide models inaccuracies (40 cm). Tide modelling limiting factor is data analysis

  - Long term good agreement between SAR mode evaluated in the 10 km band and multi-mission SLCCI database

  - For trend computation the CryoSat-2 7 year interval is short. First results are promising

Bibliography

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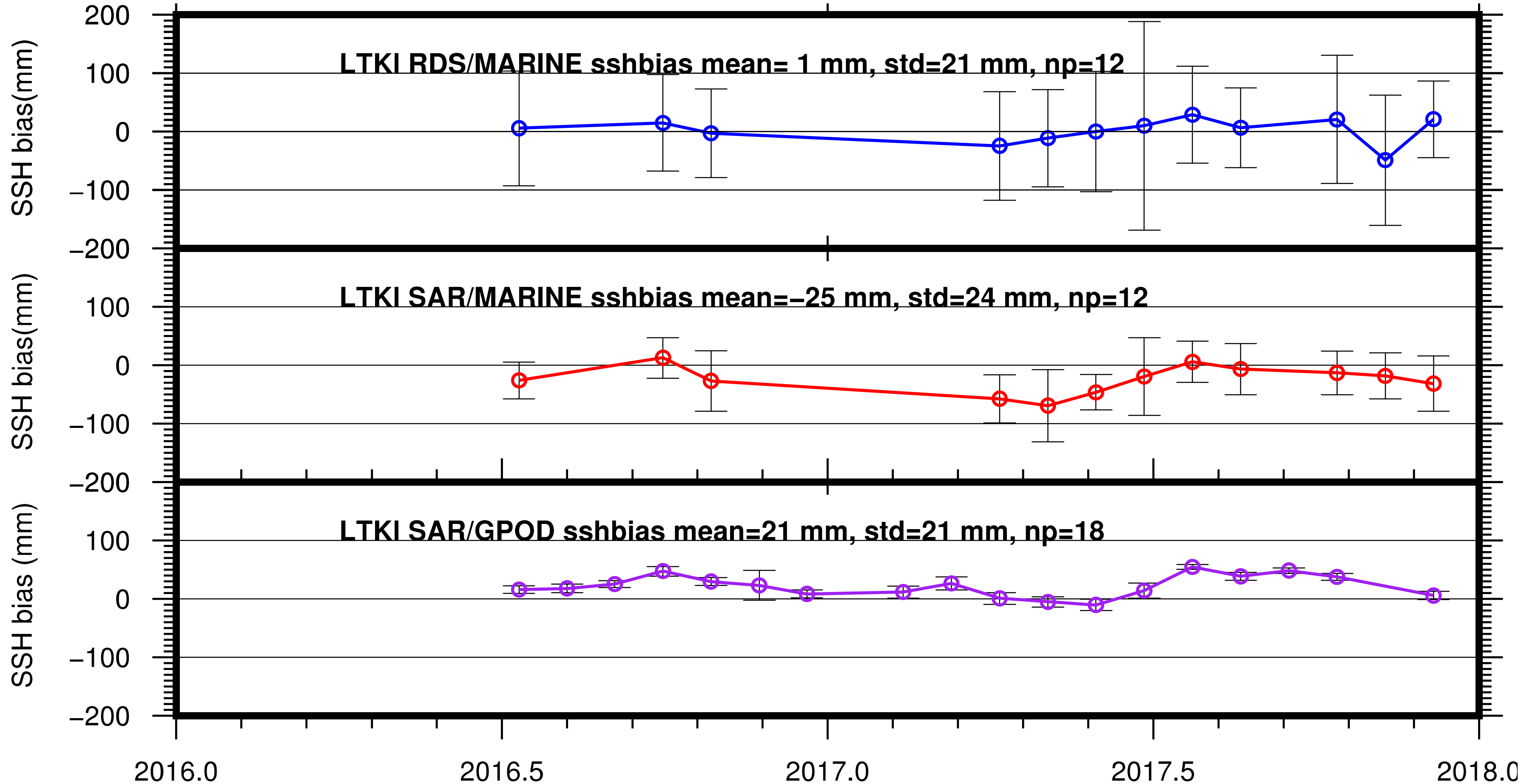
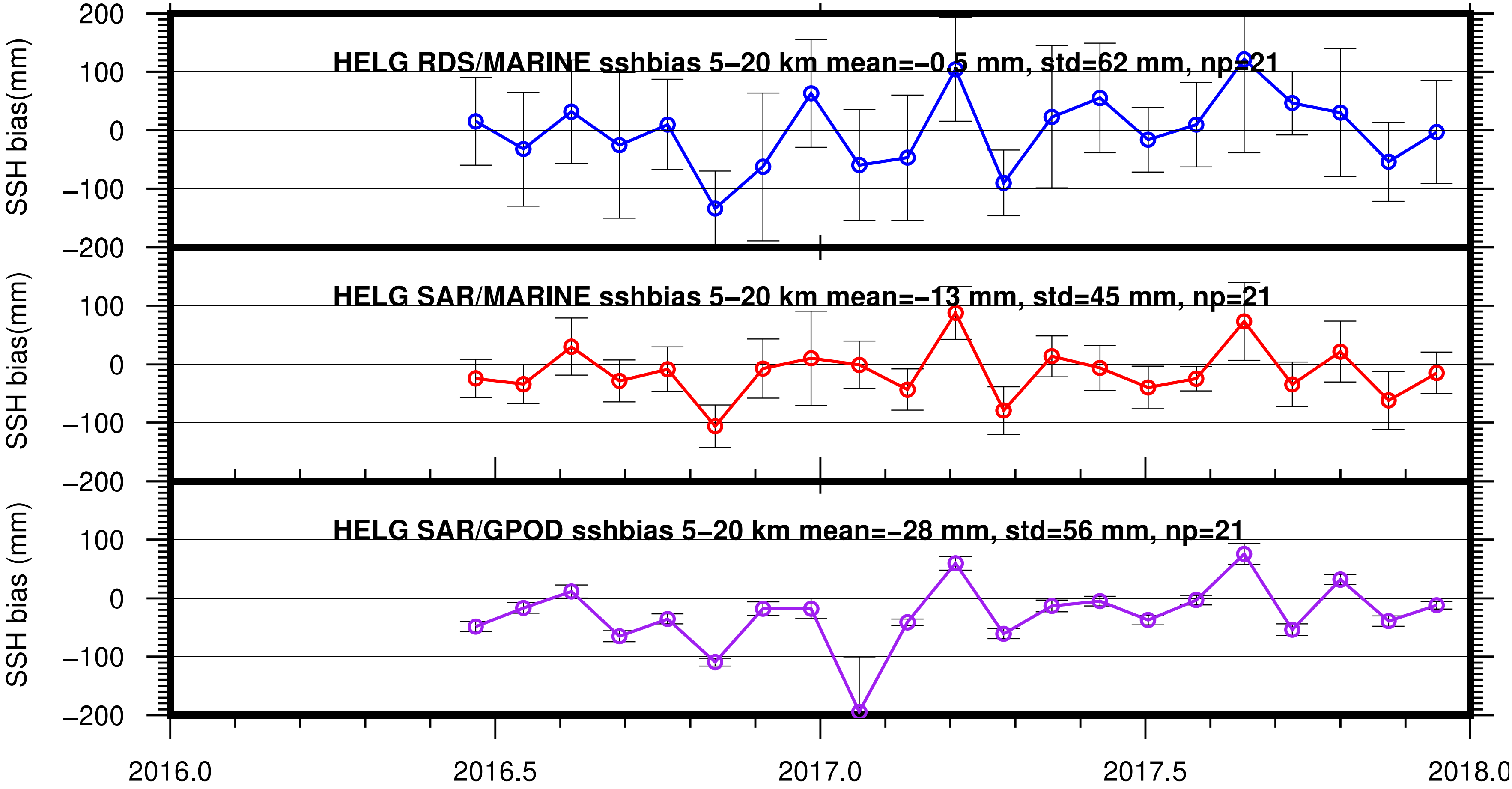
What we observe now with satellite altimetry – coastal



Fenoglio et al., in review

- ***S3A (15.06.2016-31.12.2017) at Lichthouse KIEL (no GPS → no absolute calibration)***
  - **Marine RDSAR**
  - MARINE SAR
  - **GPOD SAR SAMOSA+** (coastal retracker, Dinardo et al, 2017)

What we observe now with satellite altimetry – coastal



Fenoglio et al., in review

- ***S3A (15.06.2016-31.12.2017) at HELGOLAND (GPS → absolute calibration)***
  - **Marine RDSAR**
  - MARINE SAR
  - **GPOD SAR SAMOSA+** (coastal retracker, Dinardo et al, 2017)