Coastal Sea Level change in North Eastern Atlantic from SAR altimetry

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What is investigated

- At distances to coast smaller than 10 Kilometers the sea level change is derived from various altimeter datasets processed with different SAR and RDSAR processing schemes

- Ways of constructing the altimetric time series and comparison with in-situ data are attempted

- The impact of these new SAR observations in climate change studies is assessed by evaluating regional and local time series of sea level. Model comparison are made.

- VLM from GPS is compared to altimetry minus tide gauge rate at a set of 15 tide gauge stations

What is investigated

Scientific questions:

- Until which distance to coast provides SAR altimetry valuable sea level ?

- is long-term variability derived from SAR more accurate then sea level from conventional altimetry?

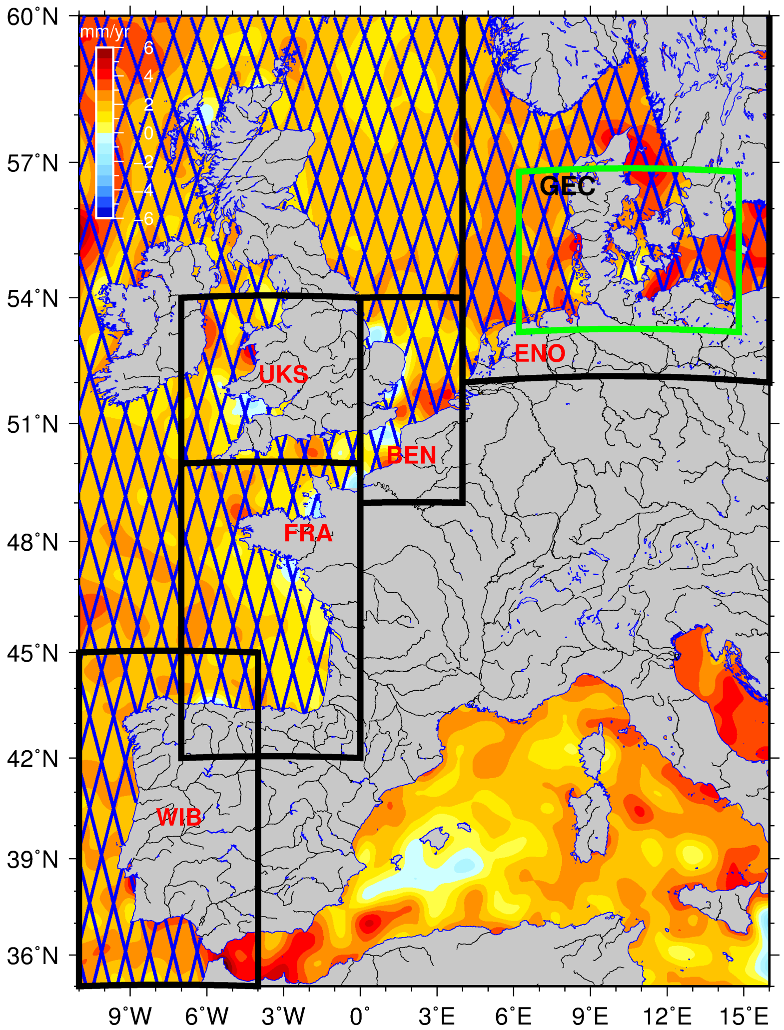


Figure 1. Region of analysis (with Sentinel-3A ground-tracks. Colours in the background is sea level trends over the interval 1993-2015 from SLCCI data

Altimeter datasets

Table 1: Processors output with properties

	SAR-SAM2	SAR-SAM+ S-SAM++	SAM2-Marine	RDSAR-TALES	RDSAR-STAR
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	no	no	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

How different is the power spectral content?

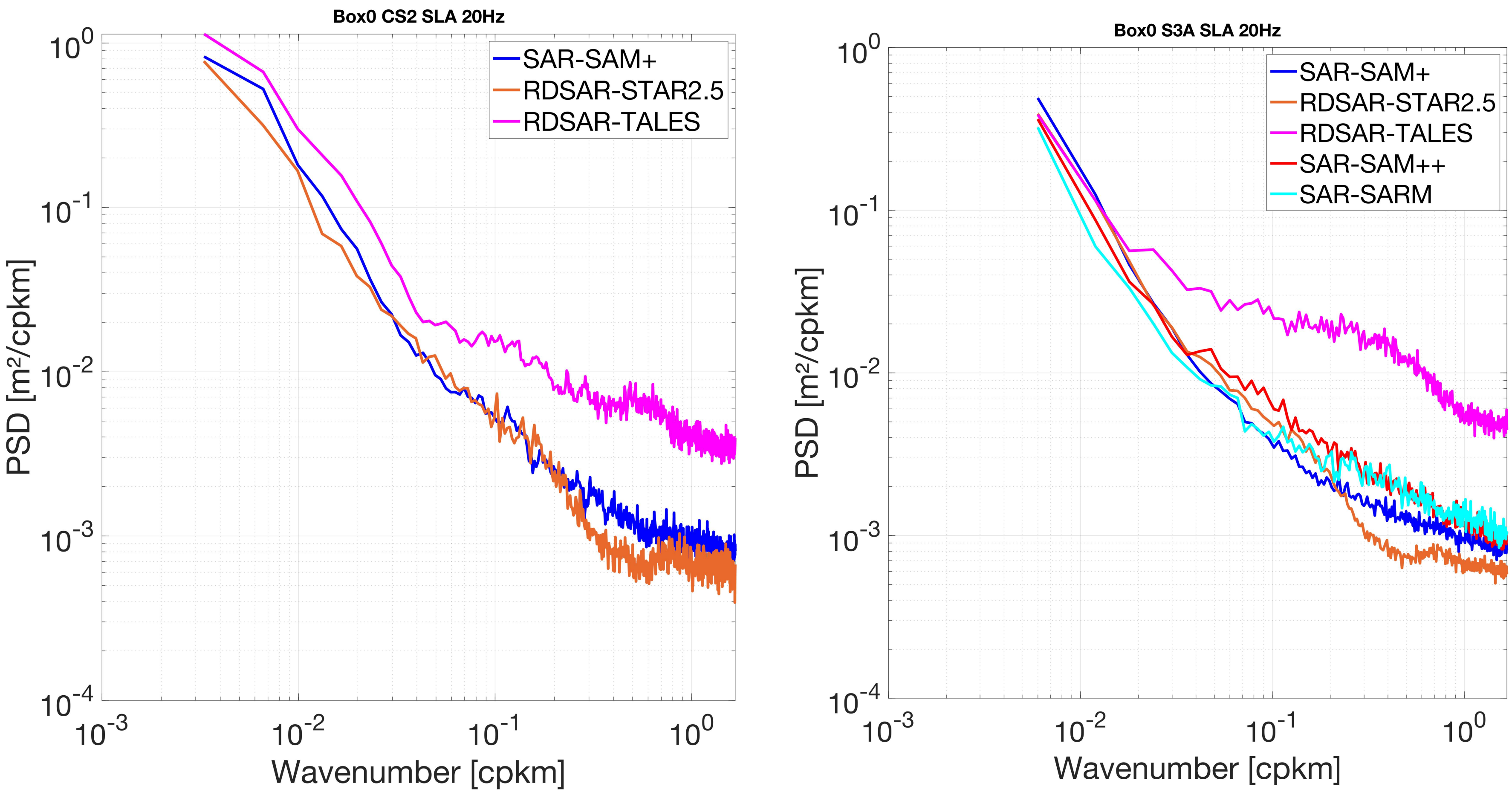


Figure 6. Spectra in region Box0 for CryoSat-2 (left) and Sentinel-3A (right).

How noisy near coast?

S3A **SAR-SAM+** | **RDSAR-TALES** | **RDSAR-STAR**

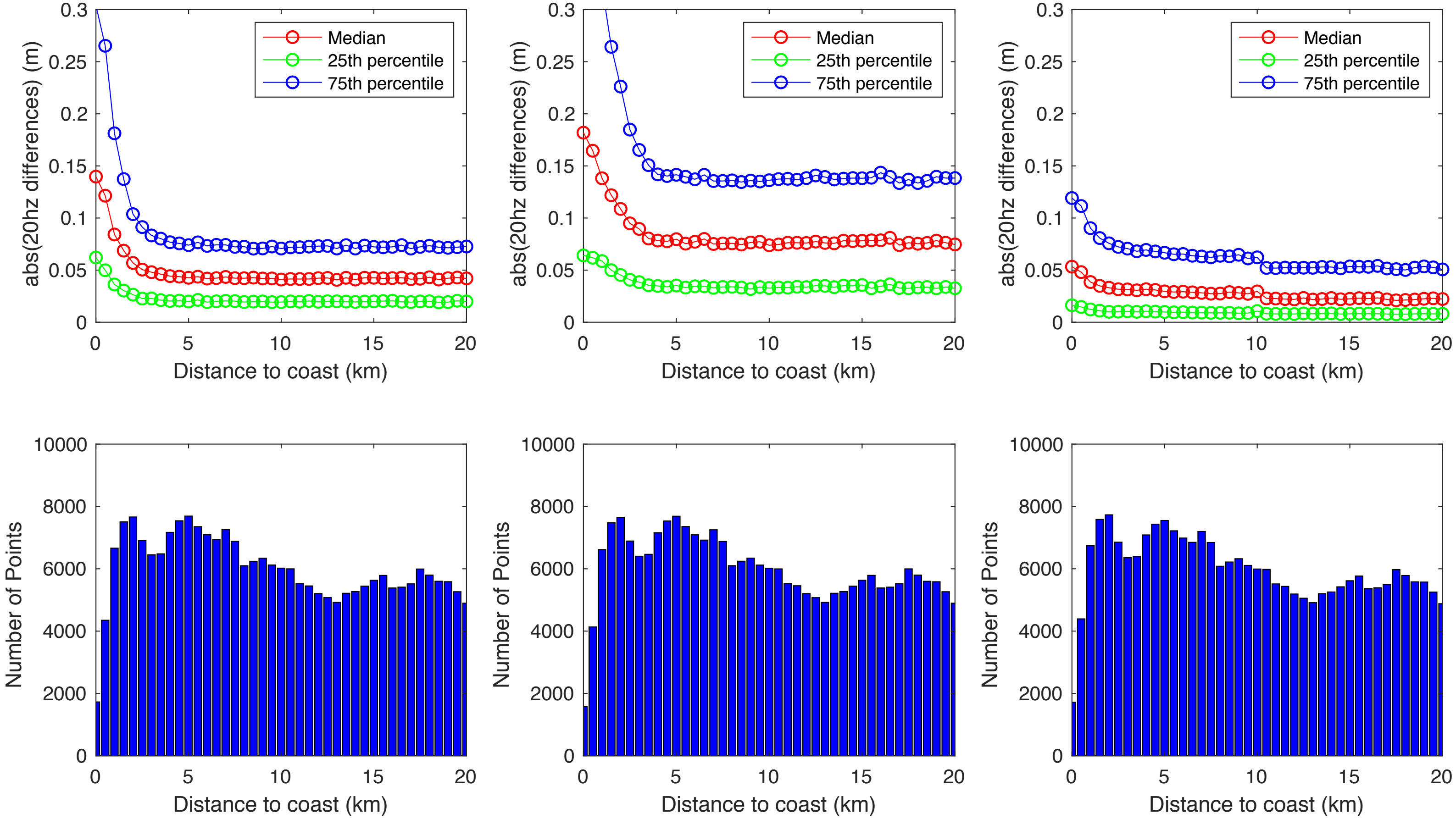


Figure 4. **Noise** (top) and number of observation (bottom) for 20 Hz Sentinel-3A **SAR-SAM+** (left) and **RDSAR-TALES** (centre) and **RDSAR-STAR** (right). Time interval is from 2016-06-15 to 2018-12-31.

: How good near coast?

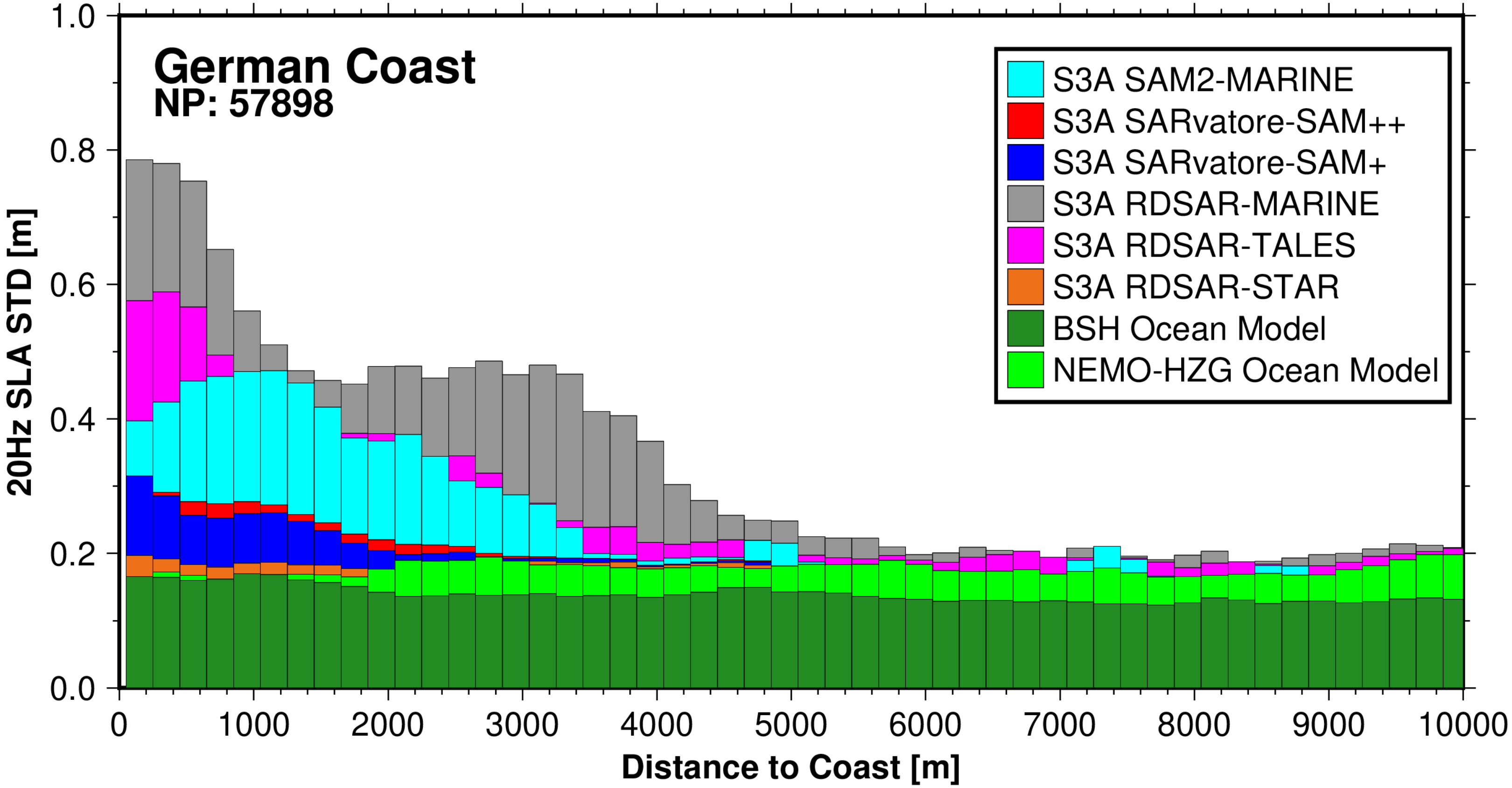


Figure 2b. Standard deviation of sea surface height anomaly in the sub-region GEC from altimeter products with various retrackers and from ocean model heights. Sentinel-3A with the SAMOSA+, RDSAR STAR and TALES solutions (as in Figure 2a for CryoSat-2) and in addition the Copernicus MARINE SAR and RDSAR and the GPOD SAMOSA++ solutions. Time interval is from June 2016 to December 2018 for Sentinel-3.

: How good near coast?

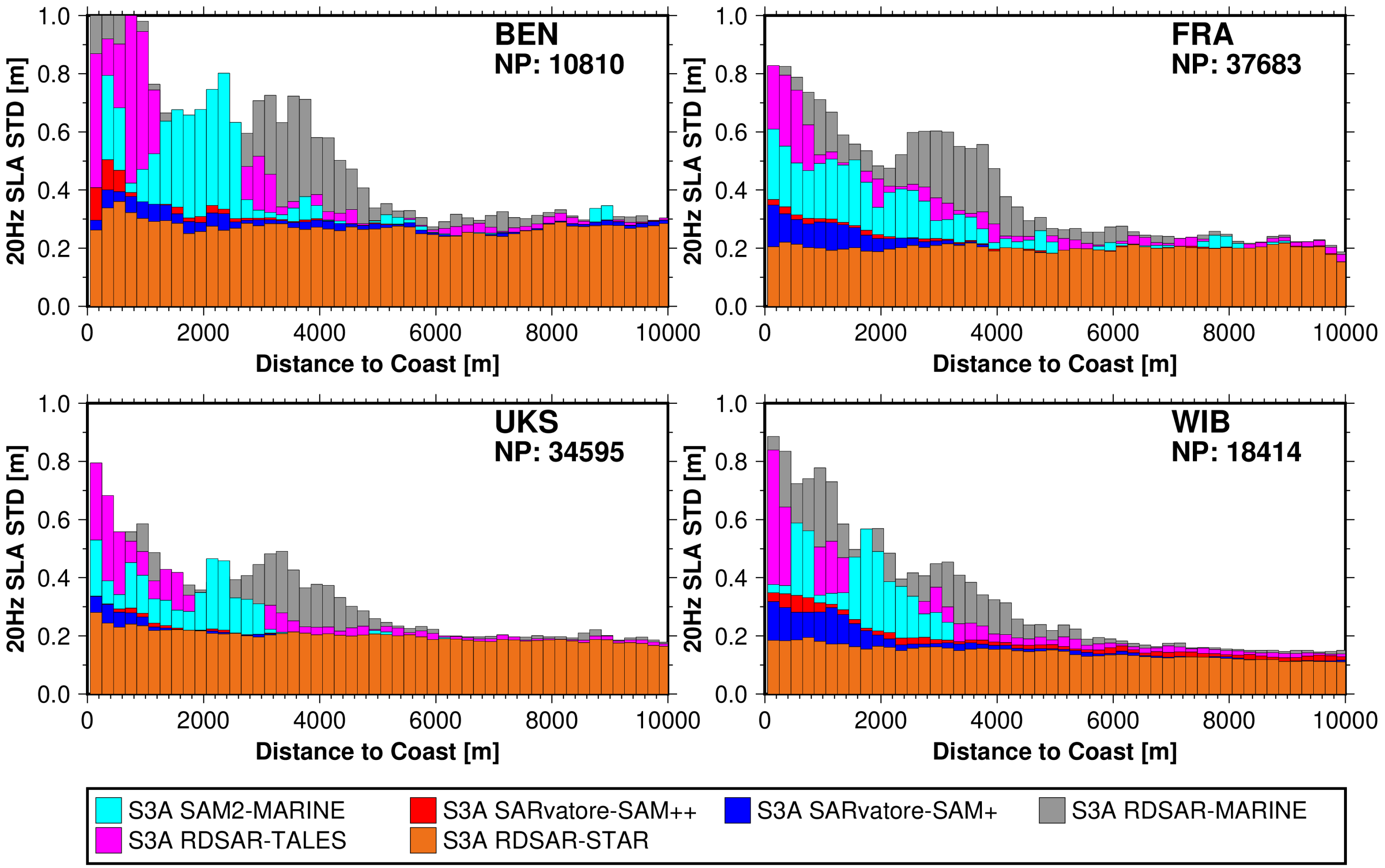


Figure 3b. Standard deviation of sea surface height anomaly in the four sub-region BEN, FRA, UKS and WIB from altimeter products with various retrackers as in Fig. 2b.

How accurate near coast?

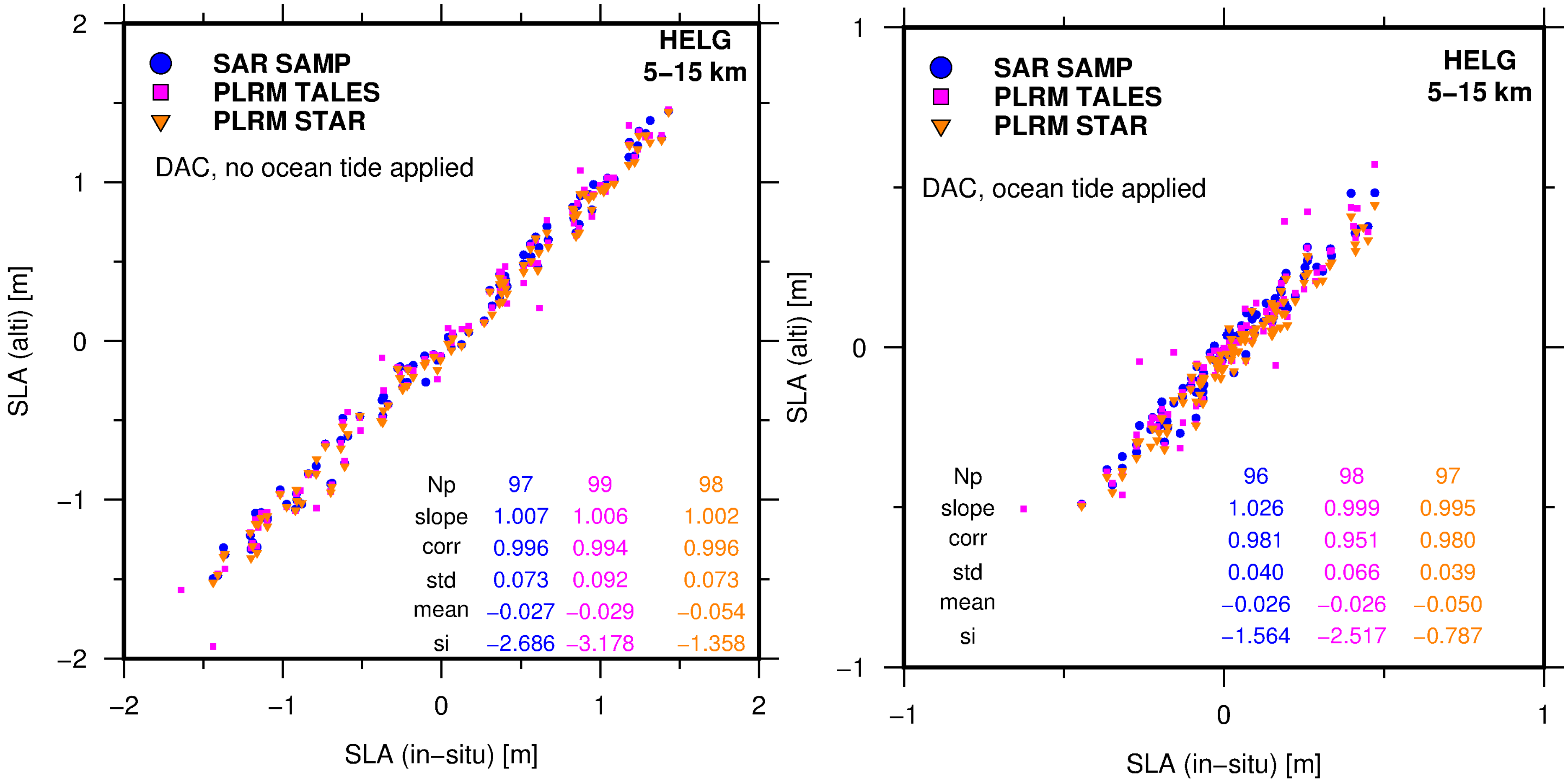


Figure 5. Cryosat-2 in coastal and open sea: Scatter Plot between tide gauge and altimetric SSHi from GPODC (circles), GPODO (triangle) and RDSAR TALES (square) and STAR (inverse triangle). Altimeter points are in coastal zone (0-10 km) (left) and open sea (> 10 Km) (right).

Which data to use to construct time-series?

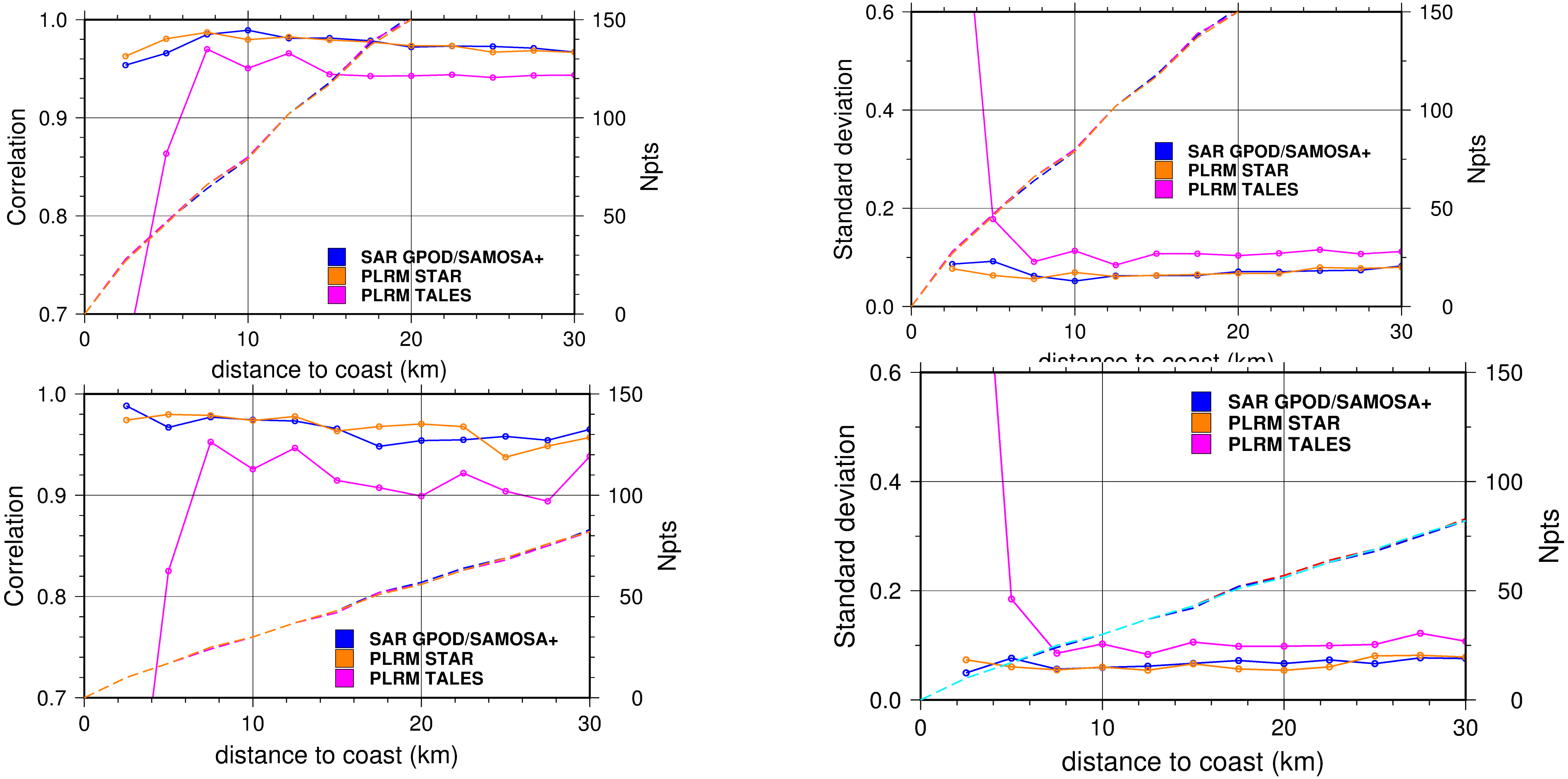
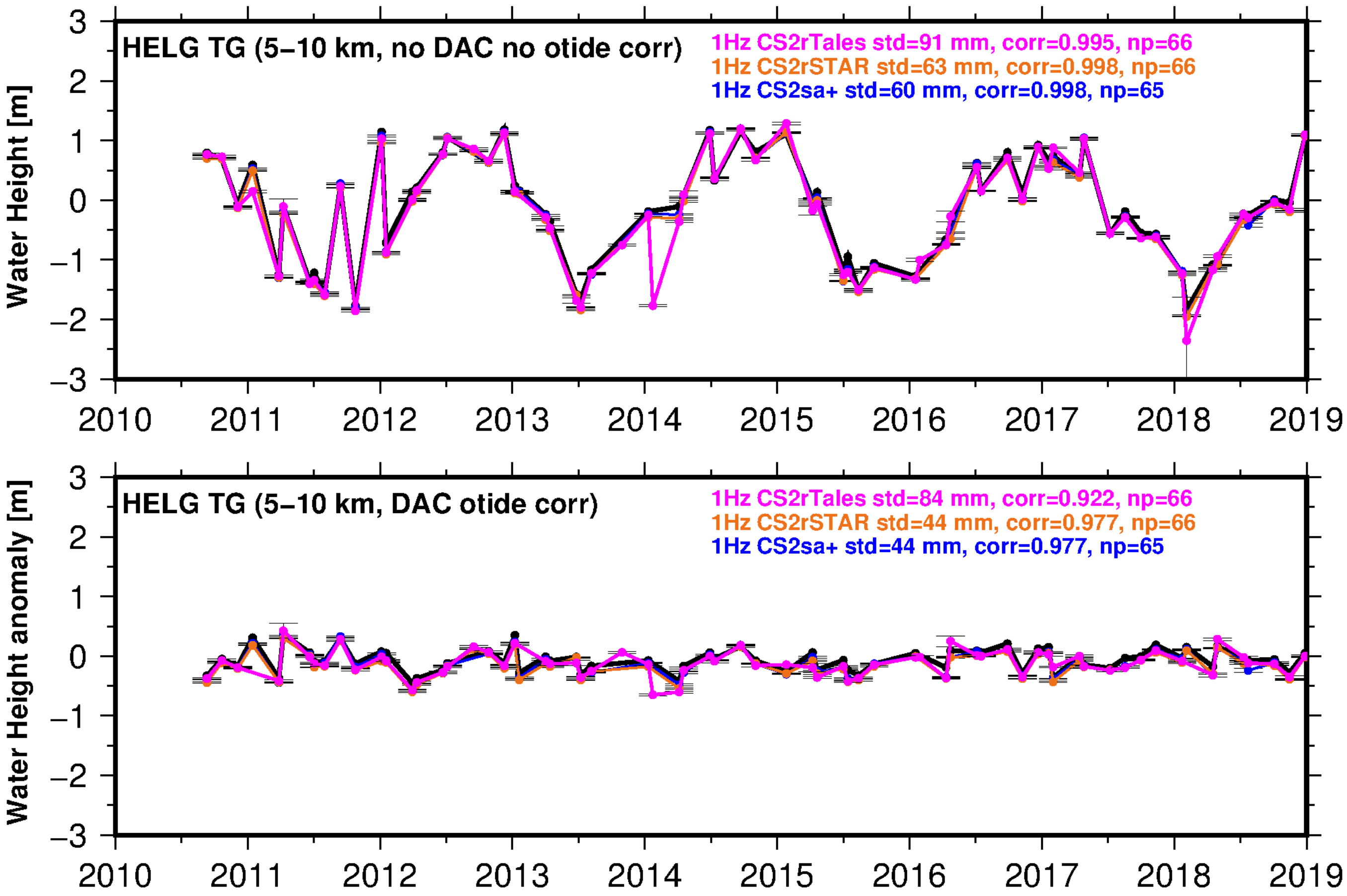


Figure 7. Cryosat-2 coastal and open sea (0 to 30 km) : Correlation (left) and standard deviation (right) of CryoSat-2 20 Hz altimetry and the Helgoland tide station over the full time interval 2010-2018 (top) and the shorter interval 2016-2018 (bottom). Times series are sea level anomalies corrected for ocean tide with model TPX08

Are sea level variations more accurate in SAR altimetry or CA?

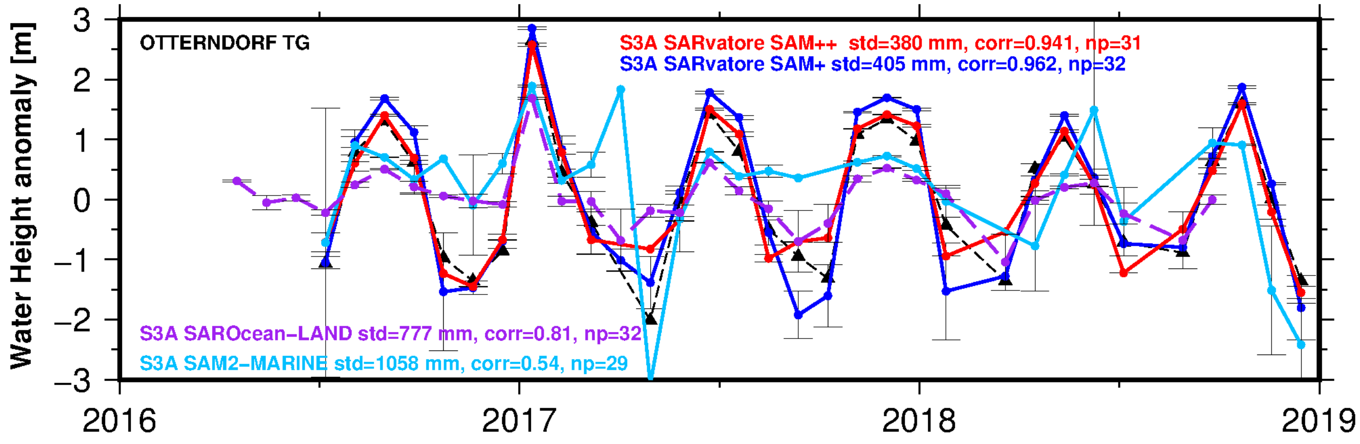


4 cm
with SAR-SAM+

Figure 9a+b Times series are sea level anomalies (SLA) : CryoSat-2 at tide gauge Helgoland uncorrected for ocean tide and DAC (a) and corrected (b). Method 1 used with Helgoland.

Coastal sea level

Are short and long-term variations more accurate than in CA?



40 cm

with SAR-SAM+

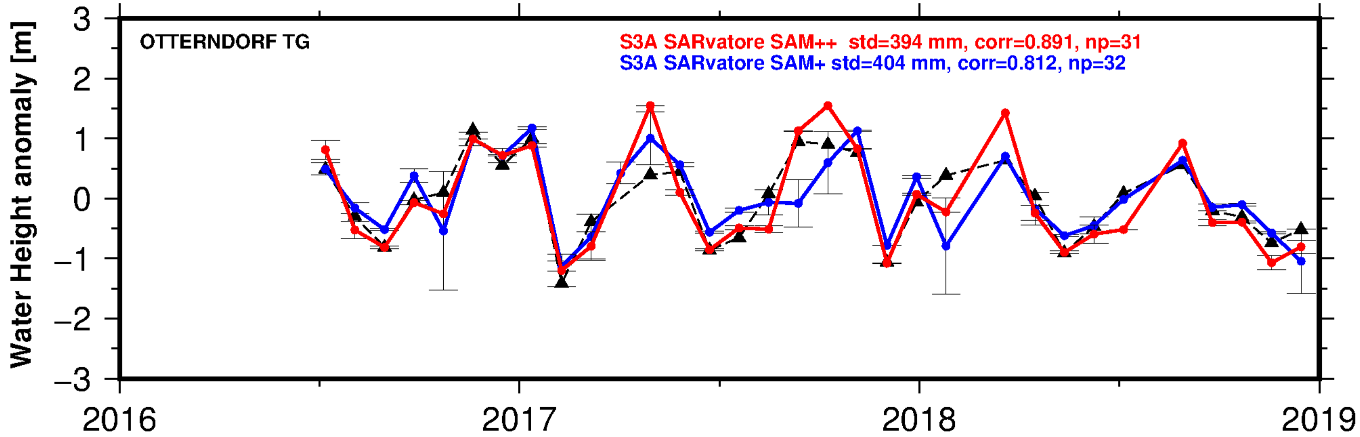


Figure 9c+d. Times series are sea level anomalies (SLA) : Sentinel-3 at Ottendorf uncorrected (c) and corrected (d) and uncorrected compared to threee ocean models. Method 1 used with Helgoland and Method 2 at Otterndorf

Monthly variability of coastal sea level

Are short and long-term variations more accurate in CA than in SAR?

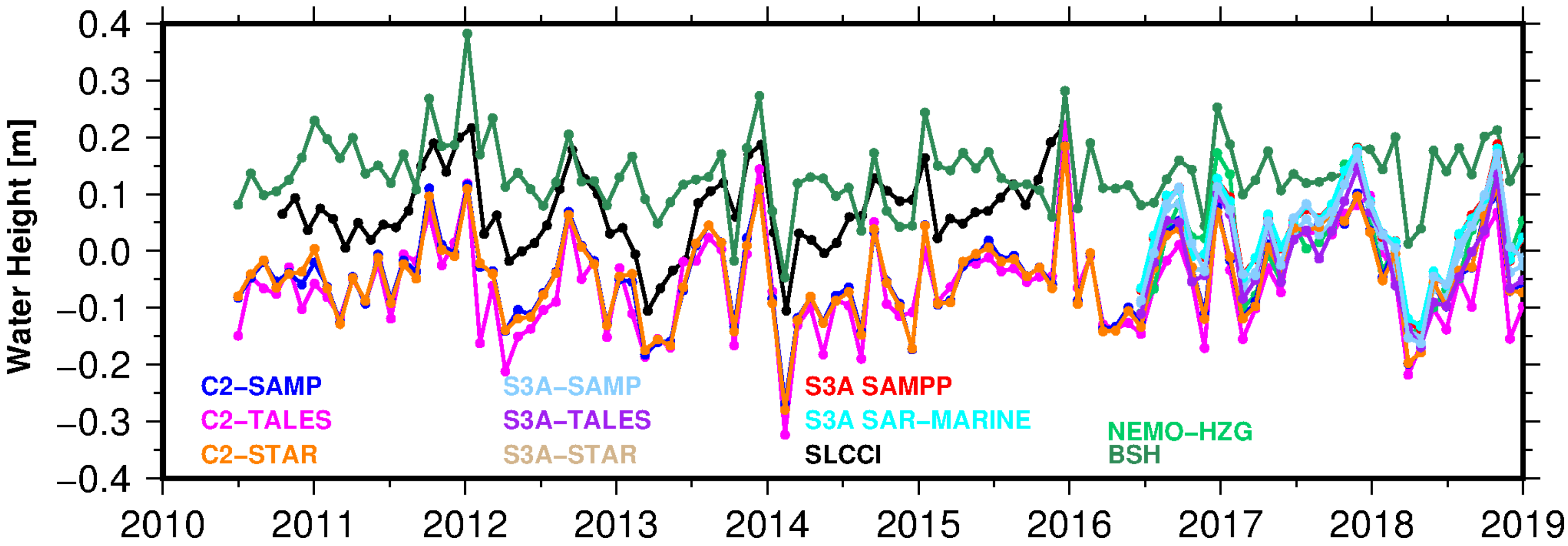


Figure 14. Monthly basin average in the GEC region from SLCCI (black) and ocean models (green) in open ocean and from CryoSat-2 TALES (purple), CryoSat-2 SAR/SAMOSA+ (blue), Sentinel-3 SAR/SAMOSA+(light blue) at distance to coast smaller than 10 km.

Are short and long-term variations more accurate CA and derived products ?

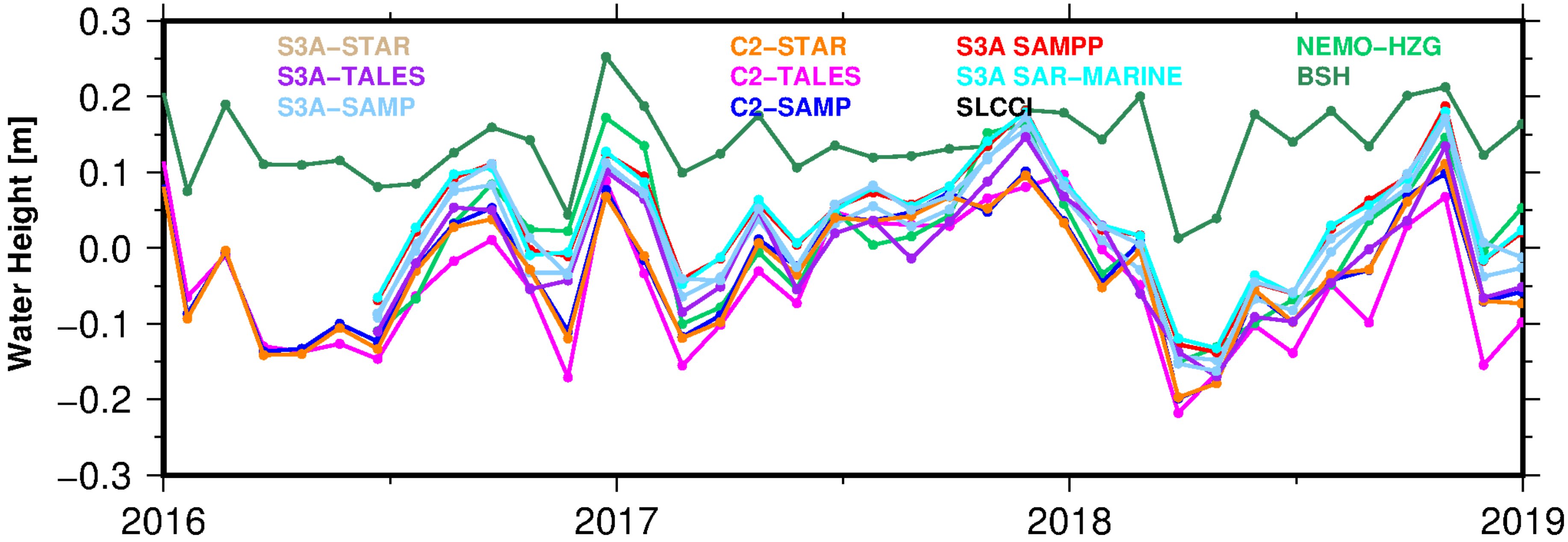


Figure 14. Monthly basin average in the GEC region from SLCCI (black) and ocean models (green) in open ocean and from CryoSat-2 TALES (purple), CryoSat-2 SAR/SAMOSA+ (blue), Sentinel-3 SAR/SAMOSA+(light blue) at distance to coast smaller than 10 km.

Altimetry from SLCCI grids

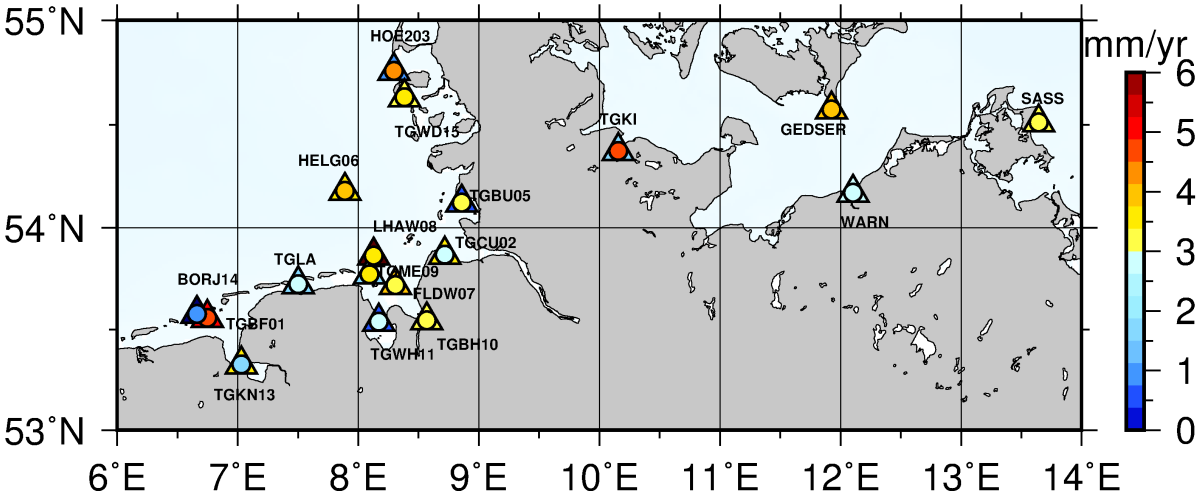
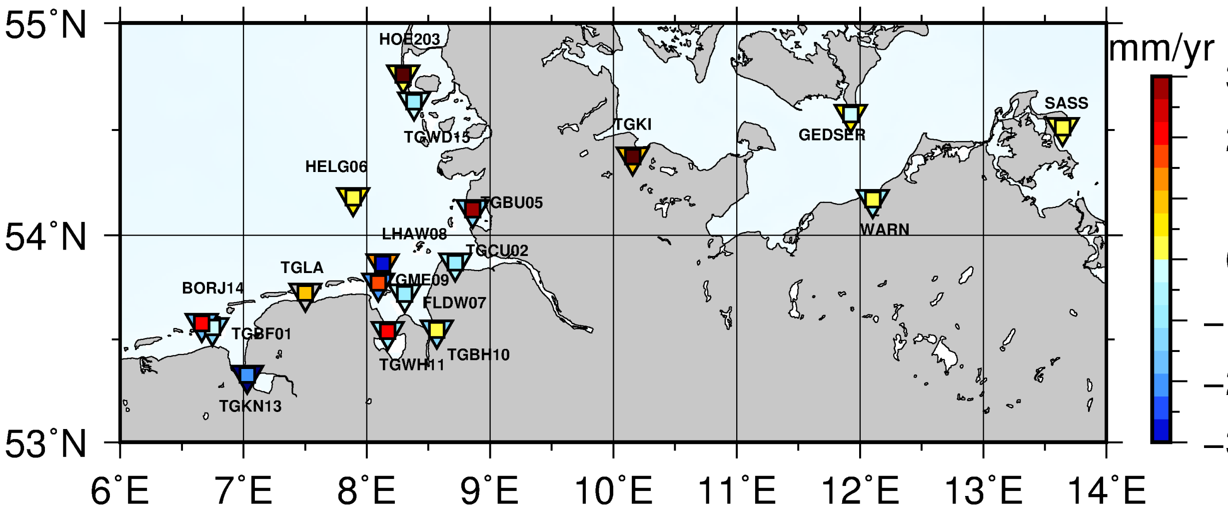


Figure 11a+b

sea level trend from tide gauge (triangle) and SLCCI altimetry grids (circle);



VLM from GPS (square) and from altimetry minus tide gauge (inversed triangle);

al-tg-gps with altimetry from SLCCI grids

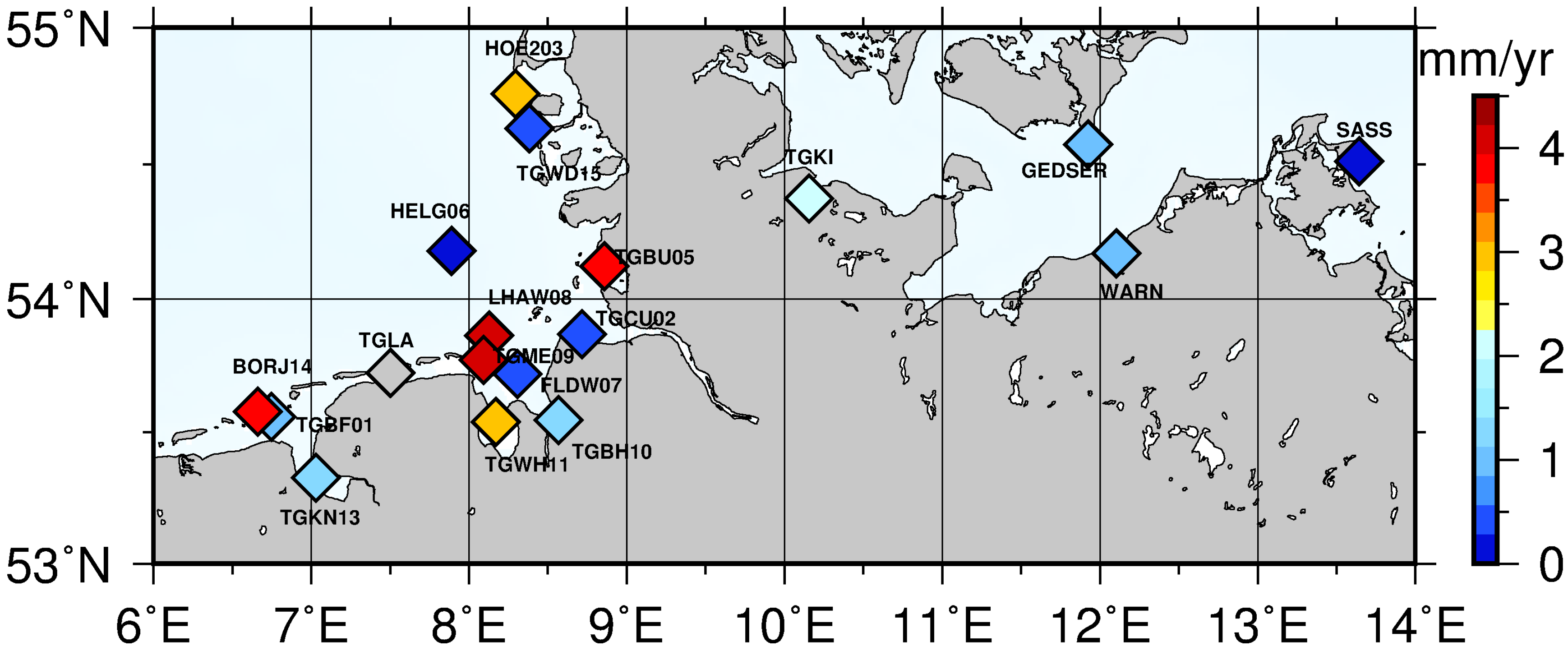
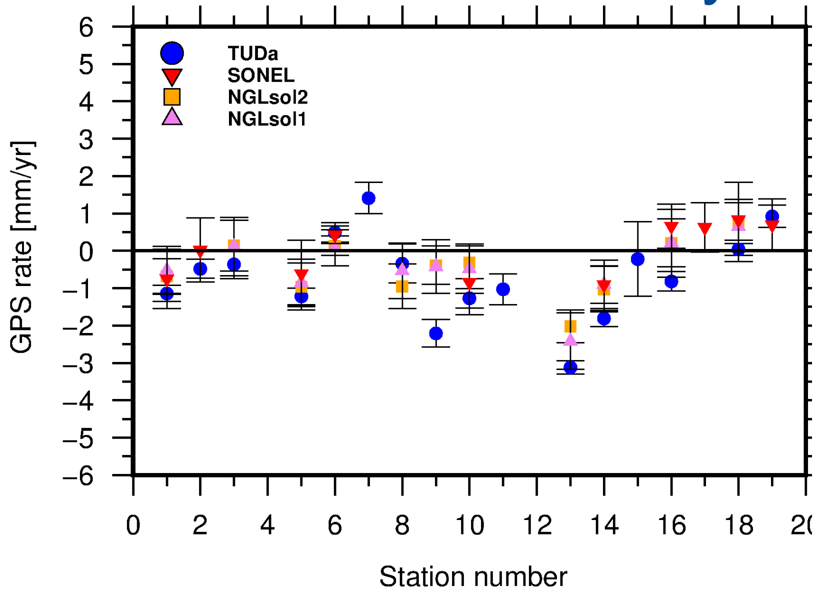
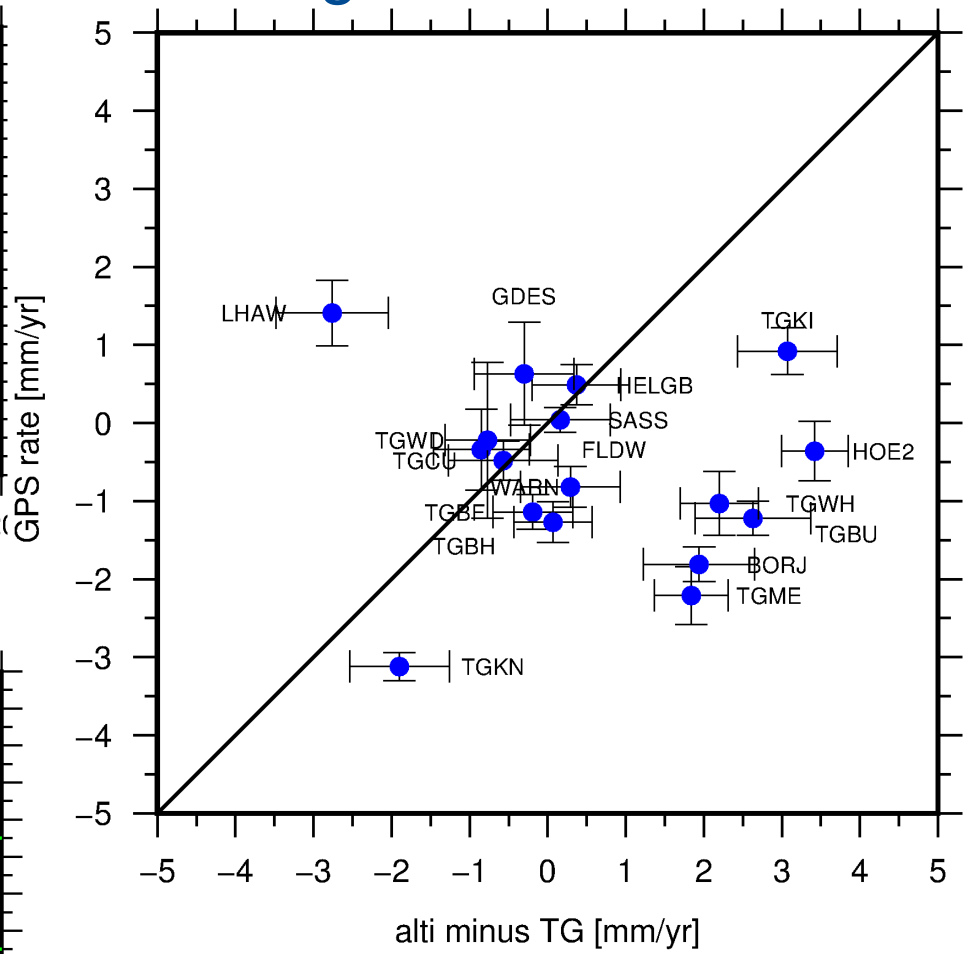


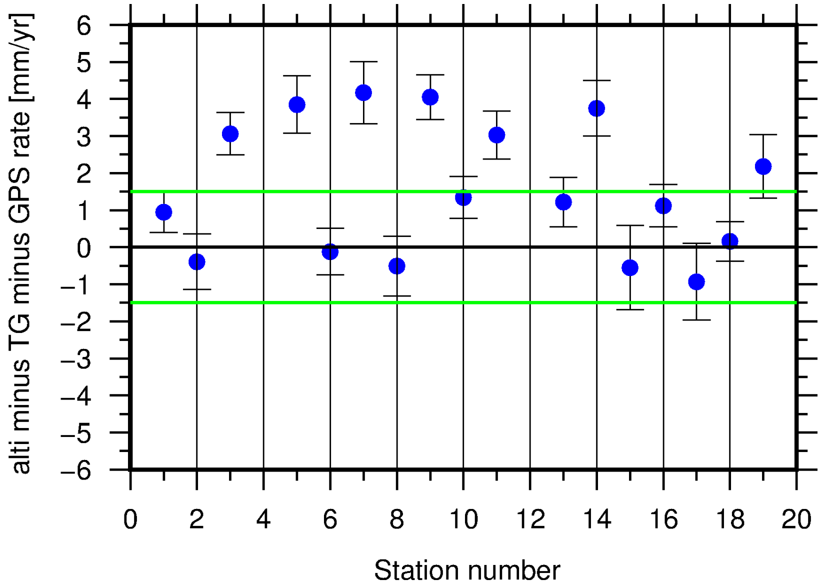
Figure 11c. trend of differences **al-tg-gps** (diamond)

Trends of coastal sea level

altimetry from SLCCI grids







Top/left: GPS rates used (blue) and other solutions
Bottom/right: altimetry minus tide gauge corrected for VLM from GPS with +/- 1.5 mm/yr line (green).
Above: Scatterplot of VLM from altimetry minus tide gauge vrs GPS rates for the GEC region.

altimetry in SAR mode SAR-SAM+

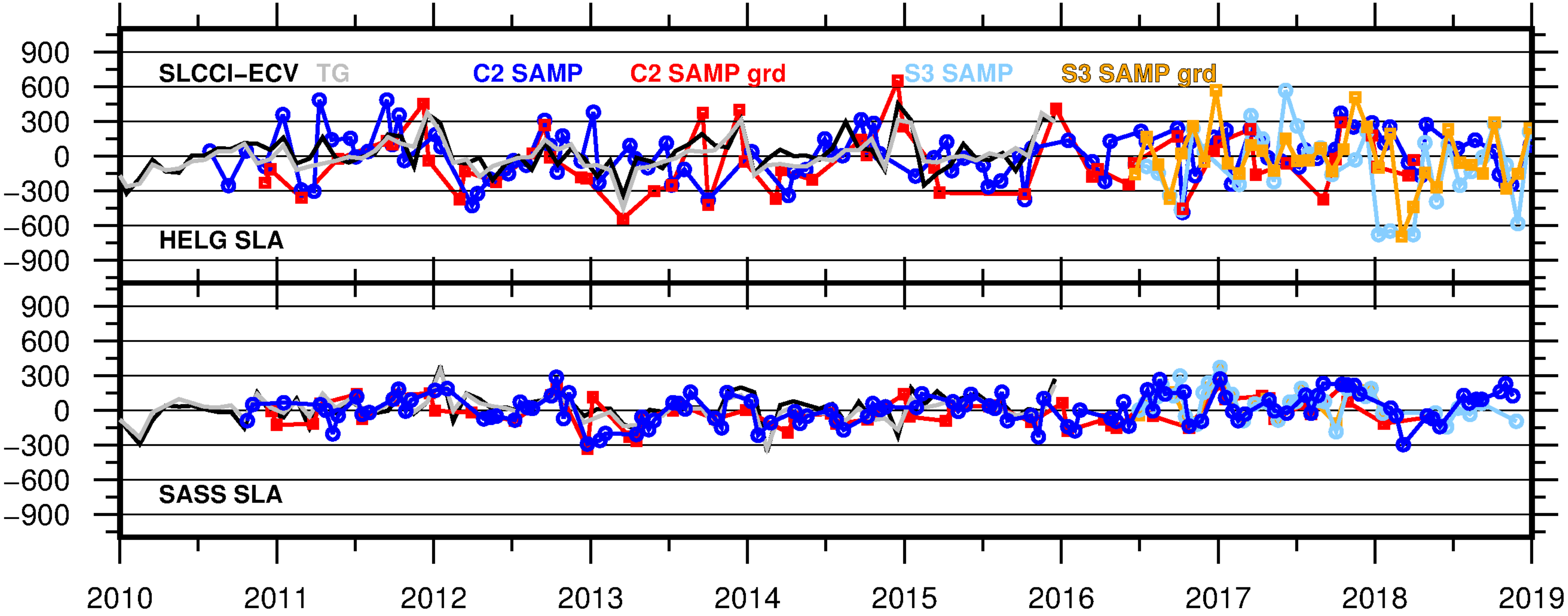


Table 6: Sea level trends at two tide gauge stations

Station	Dataset	Interval	Trend alt mm/yr	Trend tg mm/yr	Trend alt-tg mm/yr
HELG	SAR-SAM+	2010-2018	6.7098 +/- 7.4139	1.3178 +/- 7.6457	-0.0690 +/- 1.7787
SASS	SAR-SAM+	2010-2018	4.1595 +- 8.8164	3.7812 +- 7.9649	5.9981 +/- 1.2766

Conclusions

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- The use of SAR altimetry observations at distances to coast < 10 Km shows:
  - ➢ higher accuracy of SAR wrt RDSAR, small diff. wrt RDSAR-STAR
  - ➢ More good data in the 3-5 km distance to coast
  - ➢ dedicated coastal products have the highest accuracy
  - ➢ different post-processing for S3A & CS2 are needed to build time-series

- Seasonal, inter-annual sea level changes of SAR: SAR-SAM+ are in best agreement with NEMO-HZG ocean model.

- The trend the sea level from SLCCI (CA) and tide gauges corrected for land motion agree within 1.5 mm/yr at 10 of 17 stations

- Trends estimated at few tide gauges from 7 year of the SAR-SAM+ dataset agrees with the trends estimated from 22 years of conventional altimetry from the SLCCI-ECV dataset.

- The error of the trends is large due to the short interval of time. Longer time interval of SAR data is needed to detect trends

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