A Study on the conformance of altimetry and in-situ surface data near coast

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Introduction

Altimetry data near to the coast are validated in the German Bight during 2000-2011 using a network of tide gauge and GNSS stations maintained by the German Federal Institute of Hydrology (BfG), the Federal Agency for Cartography and Geodesy (BKG) and the Waterway and Shipping Administration (WSV). The network consists of two off-shore measurement platforms and of stations both on the islands and the continent.

Data and Methodology

Waterlevels

- Minute-tide gauge data (TG) in 2000-2010 are made available by WSV [1].
- RADS [2] TX/J1/J2 and PISTACH J2 altimetry data with ECMW wet-tropo and IRI2007 ionophere corrections. Checked: hardware and dH status, ocean/non-ocean flags. Not applied: Ocean-tide and inverse-barometer corrections. Waveforms from SGDR.
- Significant Wave Height (SWH) derived from Cryosat measurements in SAR mode
- SWH measured by AWAC (Acoustiv Wave and Current Profiler) instruments at the off-shore platform FINO3 (http://www.fino3.de)

GNSS at tide gauges

- 19 permanent GNSS-sites (BfG) are installed at tide gauges, relative position of benchmark and GNSS marker are known and regarded as constant.
- 3 GNSS sites (BKG) are near tide gauges and are part of the EUREF Permanent GNSS Network (EPN) and of the German Geodetic Reference Network (GREF). The relative position of benchmark and GNSS marker is monitored by BfG and WSV.

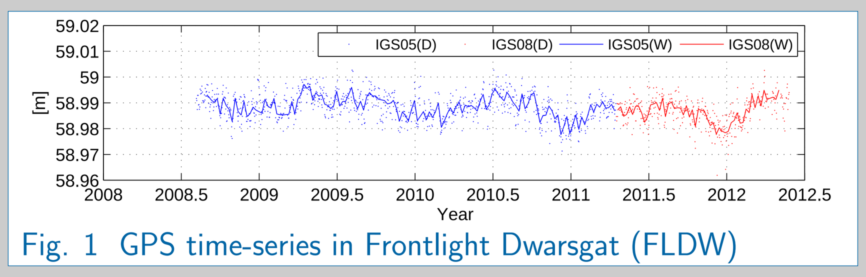

Fig. 1 GPS time-series in Frontlight Dwarsgat (FLDW)

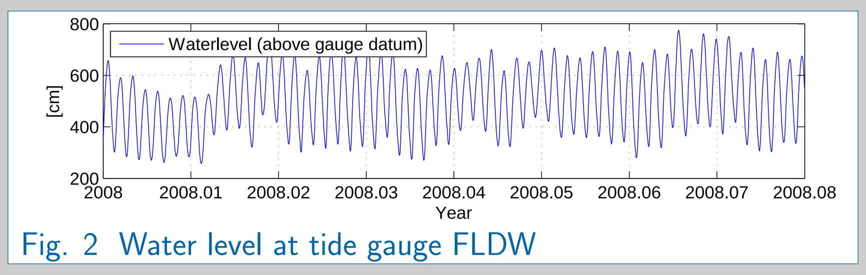

Fig. 2 Water level at tide gauge FLDW

Methodology

- The tide gauges of Helgoland (HELG), Langeoog (TGLA) and Wittdün (TGWD) (Pass 213 J2) are selected. Additionally Hörnum (HOE2, Pass 94) and Pellworm (TGPE, Pass 213) are used.
- The GNSS-stations HELG and HOE2 are EUREF-stations of BKG. The TG heights are derived by GNSS (mean value 2010). The processing includes 30 GNSS-sites and 10 IGS Frame sites as fiducial stations for IGS05 and ITRF2005 solutions. TGWD and TGLA are not equipped with continuous GNSS.

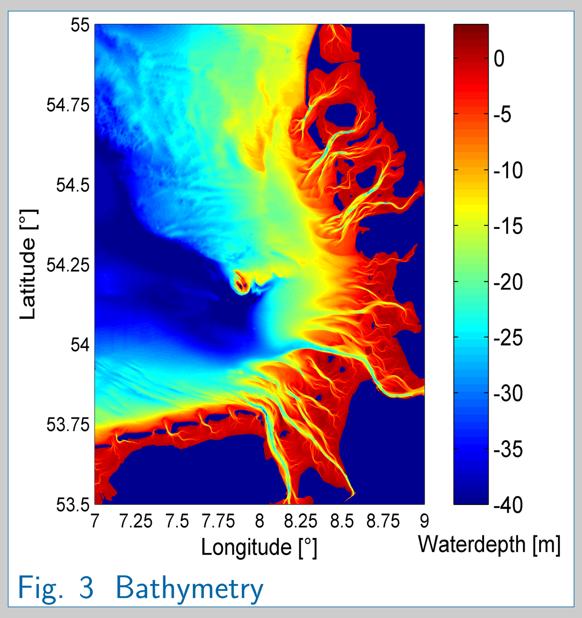

Fig. 3 Bathymetry

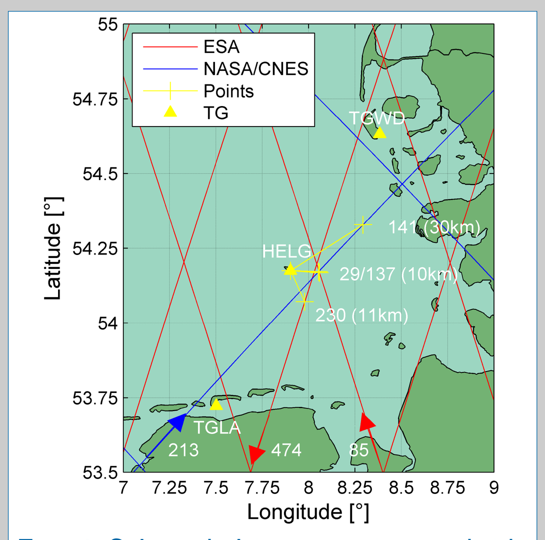

Fig. 4 Selected altimetry points and tide gauges

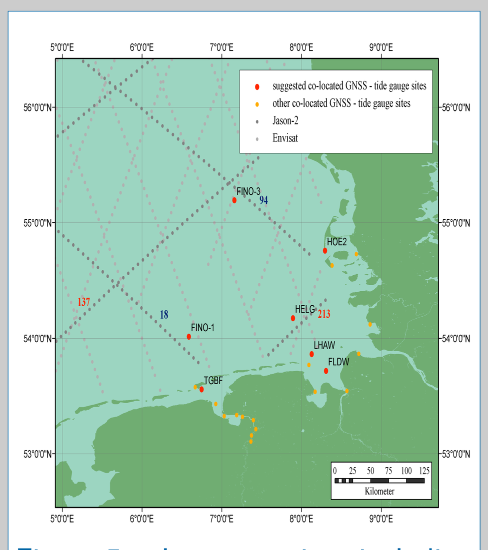

Fig. 5 Larger region including FINO3

Waveforms and Footprints

Large surfaces are out of water at low tide, therefore waveforms at a given location can differ from cycle to cycle. In Figs. 18-19 the footprint is computed using the mean SWH over the pass.

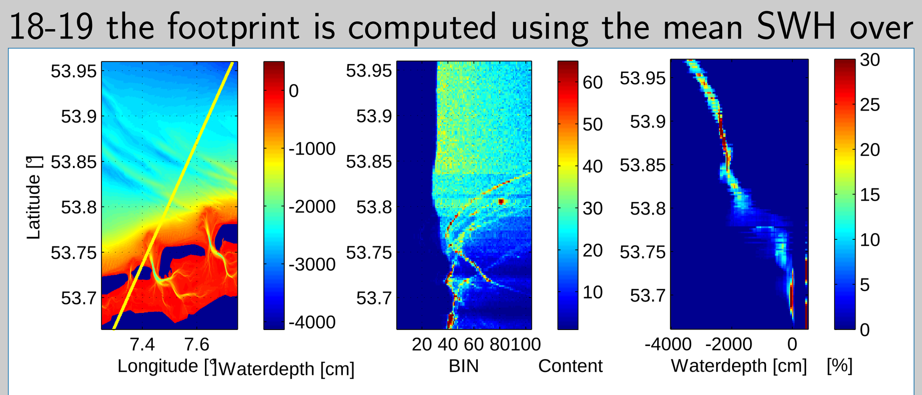

Fig. 16 Waveforms (middle) and distribution of water depth (right) along pass 213 (left) at high water (C40)

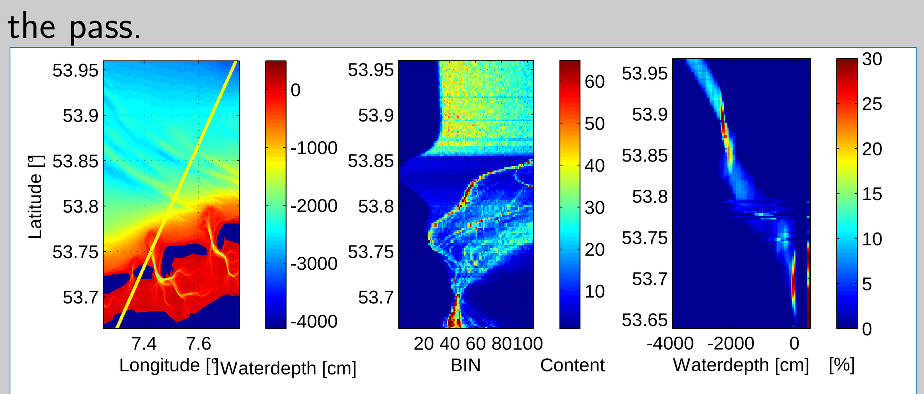

Fig. 17 Waveforms (middle) and distribution of water depth (right) along pass 213 (left) at low water (C50)

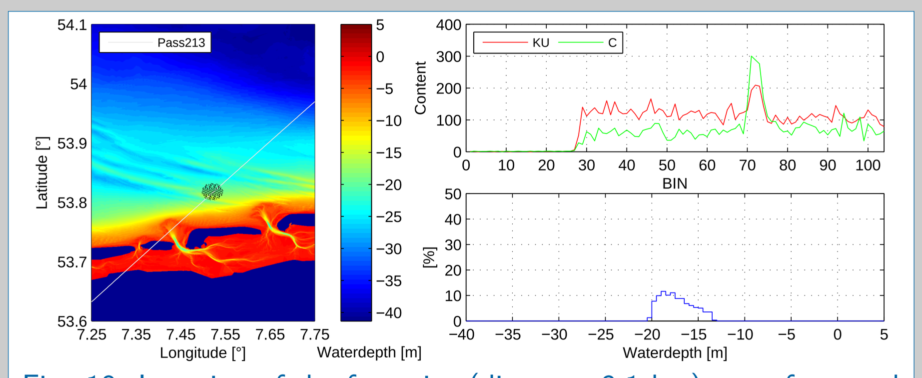

Fig. 18 Location of the footprint (diameter 3.1 km), waveform and depth as percentage in the footprint for Point 355 (P213, C40)

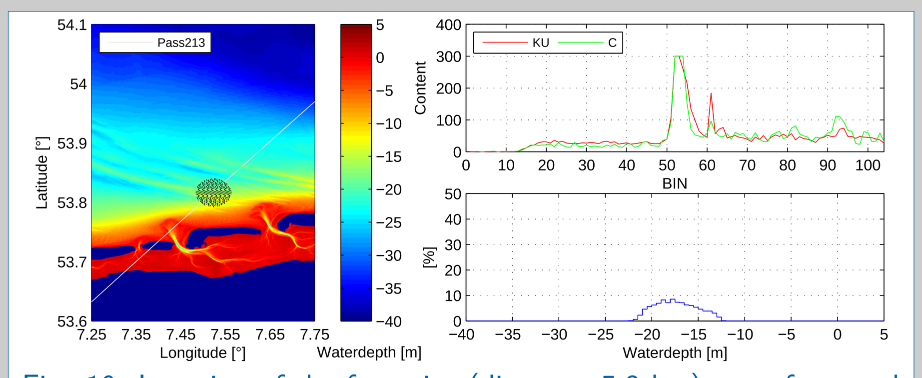

Fig. 19 Location of the footprint (diameter 5.3 km), waveform and depth as percentage in the footprint for Point 355 (P213, C50).

Validation of SWH Cryosat/SAR with AWAC instruments at FINO3

CRYOSAT 20Hz SWHs derived from SAR mode are compared to SWH measured by AWAC (Acoustiv Wave and Current Profiler) instruments at the off-shore platform FINO3 (http://www.fino3.de) (Fig.5) Correlation and STD of the differences are 0.82 and 0.42 m for 21 passes in 2011, for Cryosat 20 Hz data. (Tab. 3).

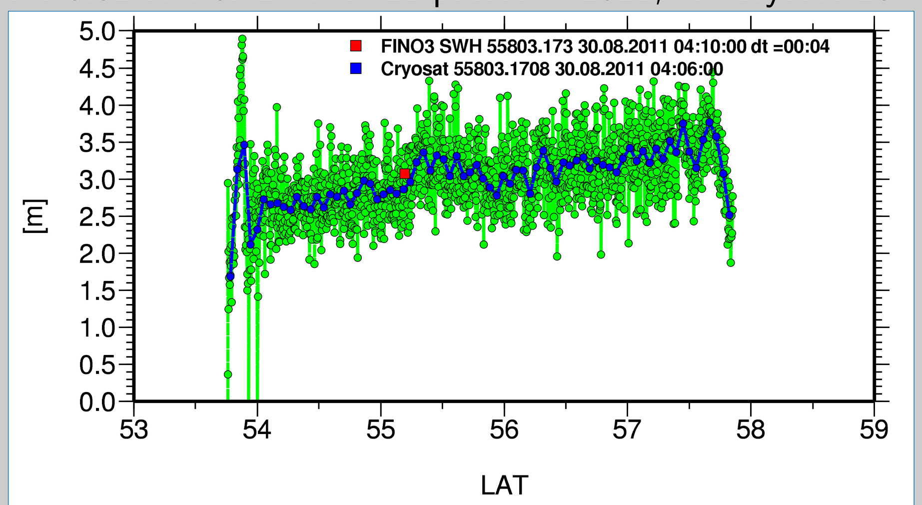

Fig. 20 SWH comparison at Cryosat overfly on August 30, 2011

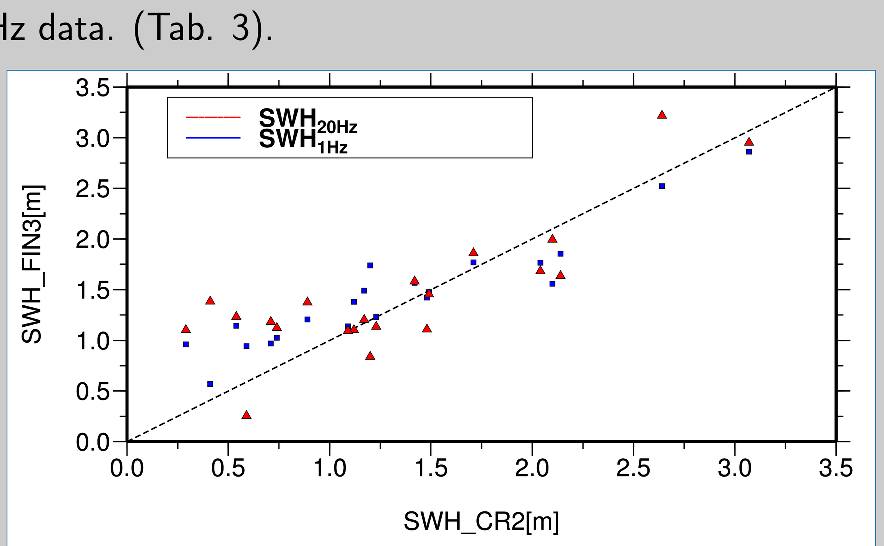

Fig. 21 Scatterplot of SWH Cryosat SAR and FINO3

Data	$Mean_{20Hz}$	STD_{20Hz}	RMS_{20Hz}	$Mean_{1Hz}$	STD_{1Hz}	RMS_{1Hz}
SWH CRYOSAT2	1.45	0.66	1.59	1.46	0.53	1.55
SWH FINO3	1.34	0.73	1.52	1.34	0.74	1.52
DIFF	0.12	0.42	0.43	1.12	0.31	0.32

Tab 3: Statistics of SWHs (m) from in-situ and Cryosat SAR data and of their differences for both 1 Hz and 20 Hz data.

Validation of altimetric products by comparison to in-situ data

Off-shore SSHs : Helgoland (50 km from the continent, Fig. 4)

In open sea, for standard products (RADS, GDR) the comparison of instantaneous 1-Hz altimetric and TG SSHs shows a good agreement. Interference from land is absent for passes near Helgoland. Distance between altimetry and tide gauge is 10 km at point 137 (Fig. 4), correlation 0.9 and standard deviation (STD) 6-7 cm, with absolute SSHs differences of a few centimeters (Table 1).

The difference of TG and altimetric SSHs increases when the distance between the two points increases (Figs. 6,7). It depends on the phase of the tide and is maximum at low tide. An empirical correction can be derived. Applying the tide model correction does not reduce the difference (Figure 8,9)

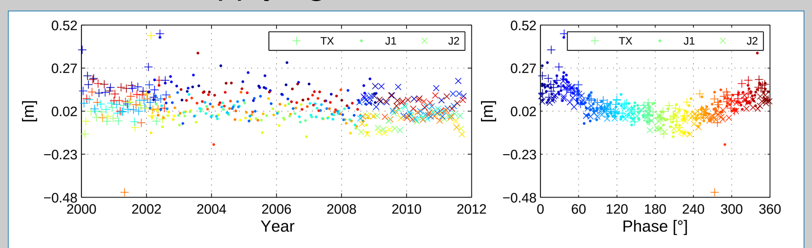

Fig. 6 Differences of istantaneous SSH_{ell} at altimetric point 137 (TX, J1 and J2) and at tide gauge Helgoland as function of time (left) and of phase lag (right)

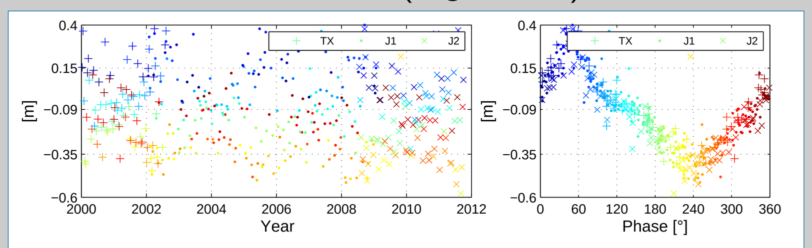

Fig. 7 Differences of instantaneous SSH_{ell} at altimetric point 131 (TX, J1, J2) and at tide gauge Helgoland as function of time (left) and of phase lag (right)

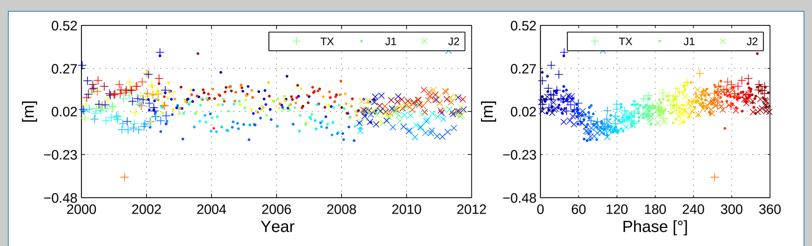

Fig. 8 As above but with ocean tide model FES2004 applied to both SSHs

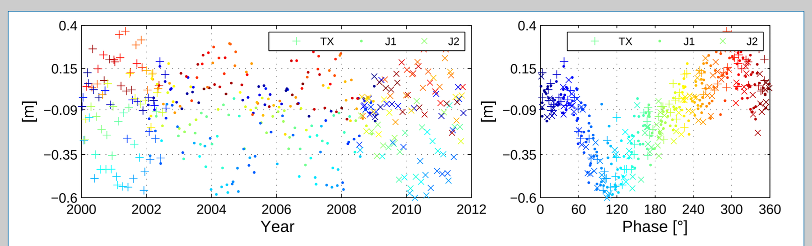

Fig. 9 As above but with ocean tide model FES2004 applied to both SSHs

Mission	Correlation	Distance	Difference SSH_{ell}		Difference SSH_{EGM08}		number of
			mean value	std	mean value	std	observations
		[km]	[cm]	[cm]	[cm]	[cm]	obs./max.
TX-A	0.9987	10.2	1.7	6.4	2.4	6.4	75/109
J1-A	0.9981	10.2	5.1	7.9	5.8	7.9	222/257
J2-A	0.9987	10.2	6.7	7.4	7.4	7.4	65/95
E2-A	0.9984	10.5	6.6	8.3	7.5	8.1	44/60
N1-A	0.9978	10.7	8.1	7.7	9.5	7.76	23/30

Tab 1: Tide gauge and altimeter at Helgoland with altimeter points 139 (TX-J1-J2) and 29 (E2-N1).

Coastal region

The consistency is lower at the coast, where the correlation is reduced and the STD of differences with TG increases (e.g. at Borkum with distance d_{a-tg} of 24 km the STD is 10.4 cm.

With the PISTACH coastal product more data near coast are available. The data processed with retracker RED3 perform at best in the comparison with tide gauges. The statistics of the comparison with TGs (corr, std, number of points) is shown for two stations TGLA (land-sea) and TGWD (sea-land) for each location (20 Hz measurements) along Pass 213. In Figs. 10, 11 the three parameters are given as function of latitude, in Figs. 12, 13 as function of the distance to land.

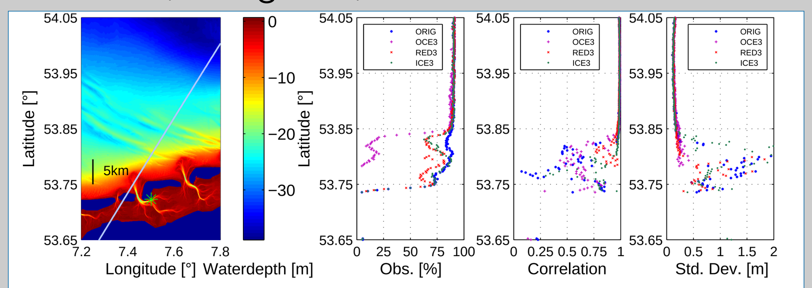

Fig. 10 Pass 213: number of valid observations, correlation and STD relativ to tide geuge Langeoog

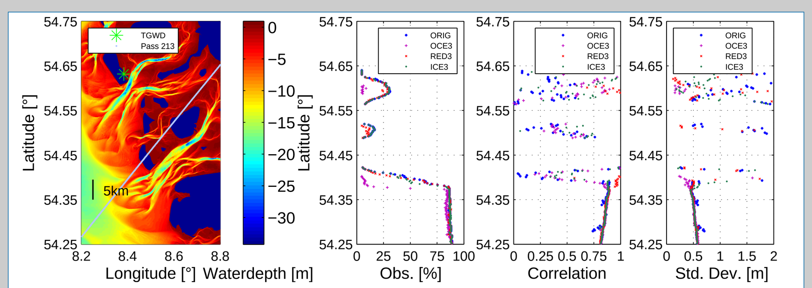

Fig. 11 Pass 213: the same as previous figure for tide gauge Wittdün

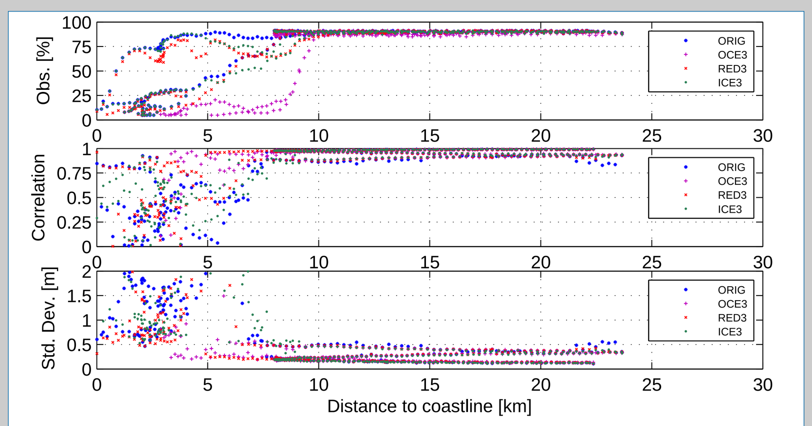

Fig. 12 Pass 213: the same as Fig. 9 as function of distance to land

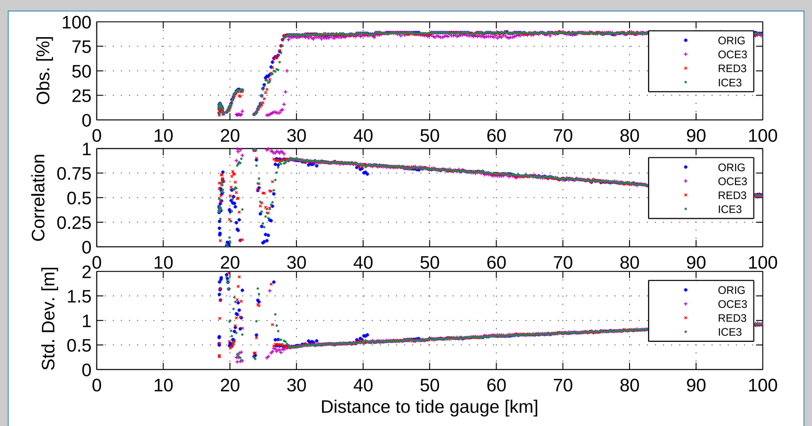

Fig. 13 Pass 213: the same as Fig. 9 as function of distance from pegel

Altimetric sea level anomalies near coast are noisy in Fig. 14. In a location at 10 km from the TG the RED3 retracker gives the smallest differences between altimetry and tide gauges (Fig. 15, Tab. 2).

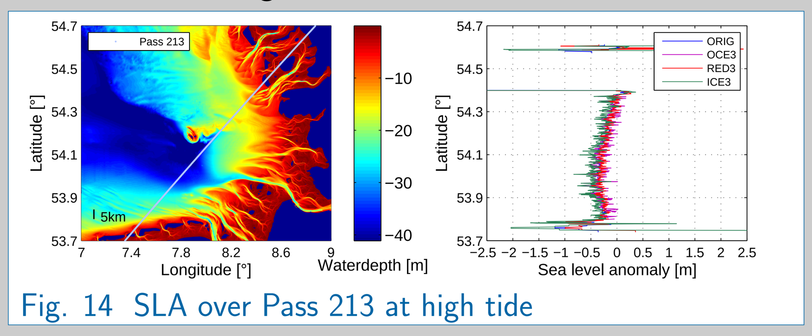

Fig. 14 SLA over Pass 213 at high tide

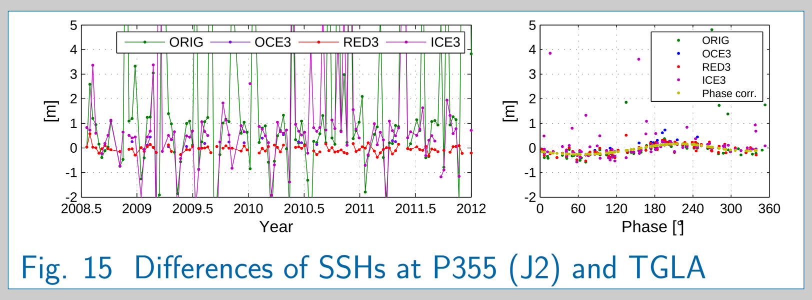

Fig. 15 Differences of SSHs at P355 (J2) and TGLA

Point/TG	Product	Correlation	Distance	STD	Number of observations
			[km]	[cm]	obs./max.
355/TGLA	GRD	0.49	10.5	354	106/118
355/TGLA	OCE3	0.79	10.5	23	15/118
355/TGLA	RED3	0.97	10.5	19	85/118
355/TGLA	ICE3	0.53	10.5	190	96/118

Tab 2: Number of observations, correlation and STD of altimetric and TGLA tide gauge SSHs at point 355.

Conclusions

- Our approach allows the absolute comparison of SSH_{ell} from GNSS-TG stations and altimetry
- The retracker RED3 in the Pistach coastal product gives the best agreement with tide gauge sea level in terms of correlation, standard deviation of the differences and retained observations. For a point at 10 km from coast we have correlation 0.97, std 19 cm and 85% of data.
- The Pistach data are a significant improvement of the level 2 GDR between 5 and 10 km from the coast
- At less than 4 kilometers from the coast also PISTACH data are too noisy.
- PISTACH data are not available at some locations (e.g. tideland).
- Significant Wave Heights (SWH) from Cryosat SAR agree with AWAC SWH products within 0.4 metres

References

[1] P. Goffinet, J Blasi, A. Sudau, and G. Liebsch. National Report of Germany. *GLOSS-Report*, pages 1–5, April 2011.

[2] M. Naeije, R. Scharroo, R. Doornbos, and E. Schrama. Global altimetry sea level service. report GO 52320, NIVR/DEOS, The Netherlands, The Netherlands, 2008.

Acknowledgements

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PSGD

bfg Bundesanstalt für Gewässerkunde

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