Elbe Estuary and coast

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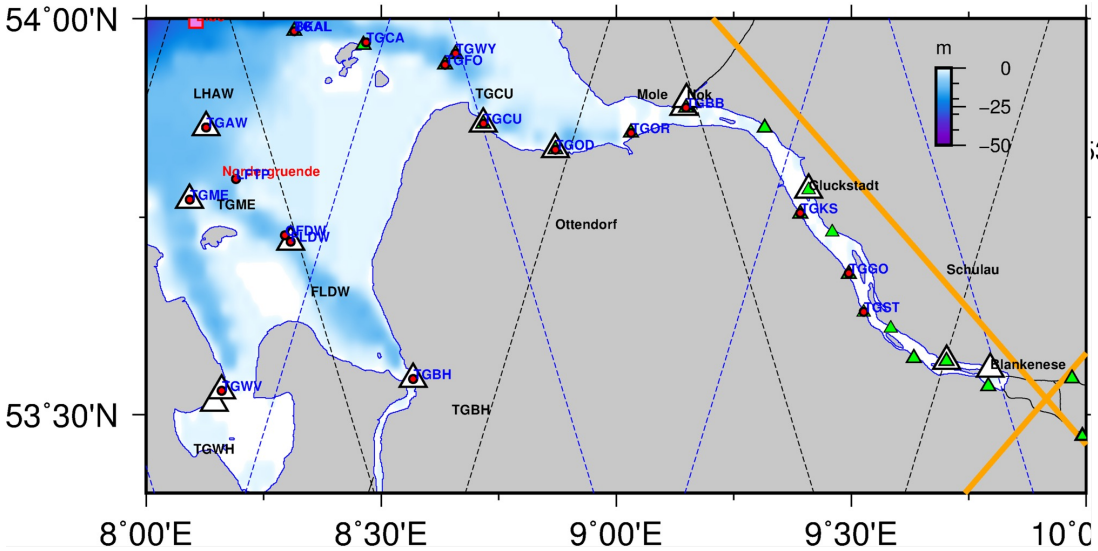
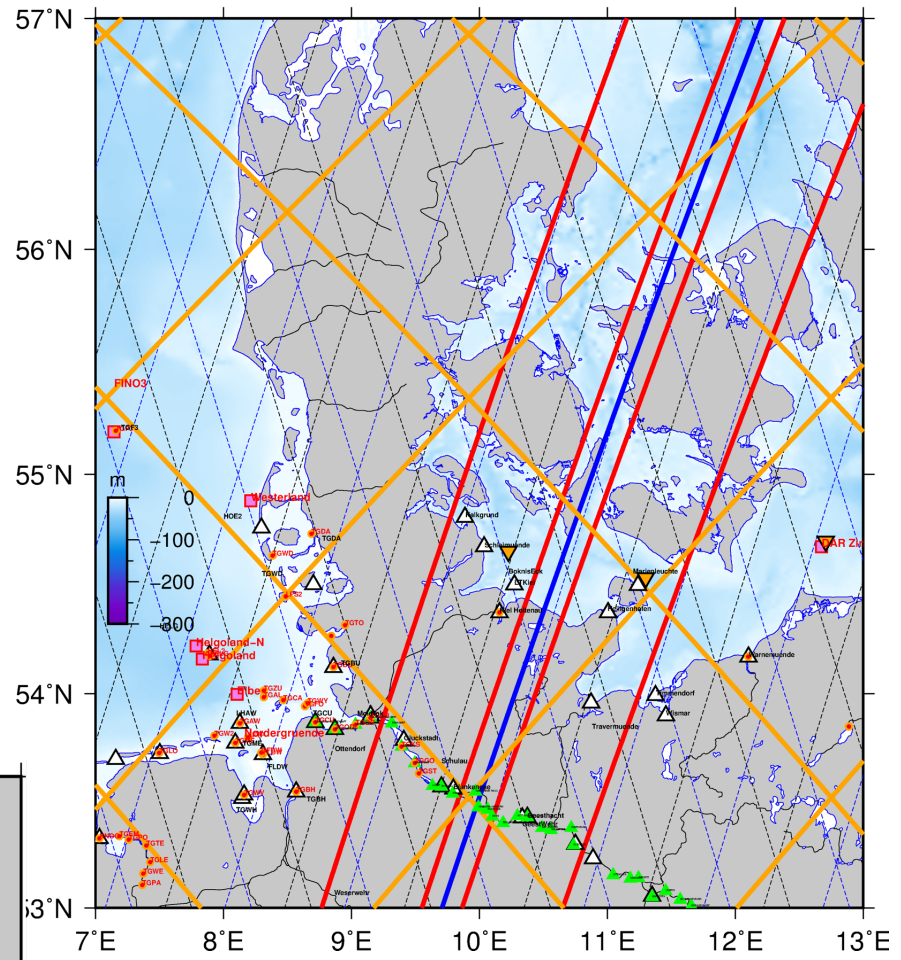
Elbe tidal river 70 km
North Sea coast
Baltic coast with Danish Straits

- Coastal and river mouth,
- separation of tides and discharge in estuaries
- Interaction of rivers and coastal circulation

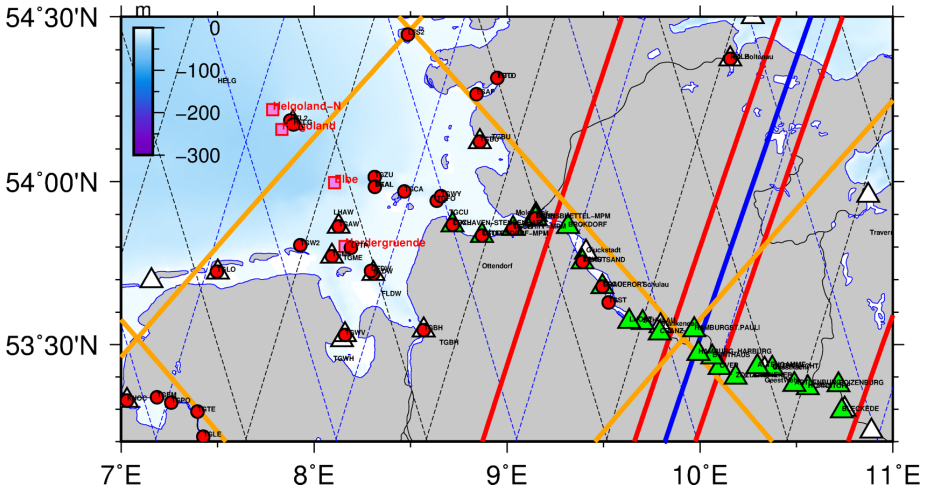


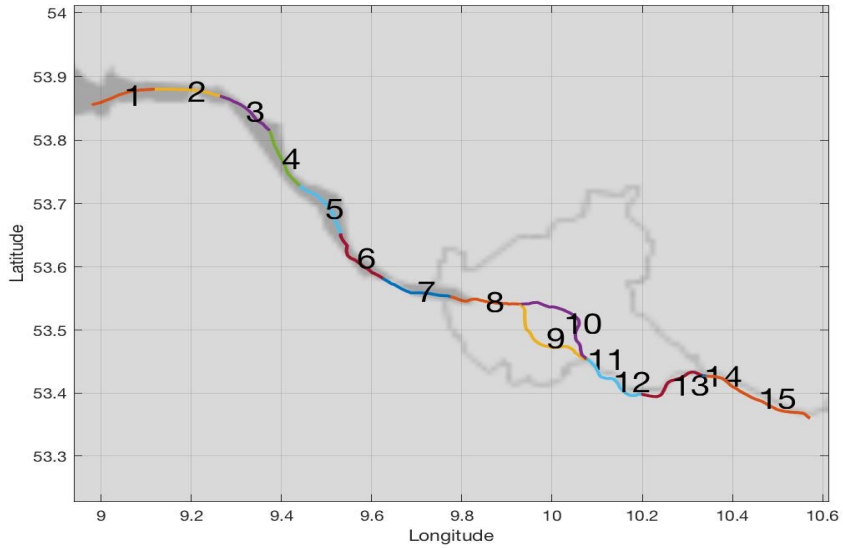


Instrumentation and data

Elbe Estuary and tidal river (70 km long, meso-tides 3-4m range)

- Discharge and tides interaction
- River plume
- Contribution to sea level change
- Wind effect, air-sea interaction





Measurements:

- Water height above ITRF (altimetry, in-situ)
- river discharge (RC)

Instrumentation

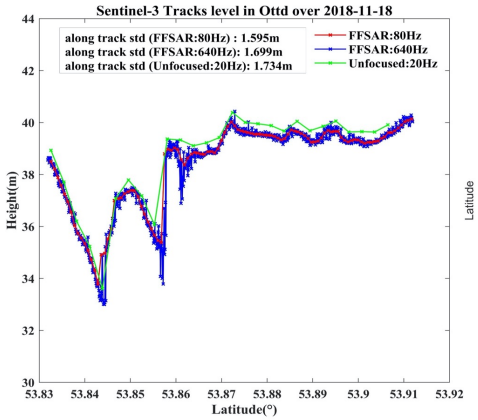
- geodetic GNSS (BfG), https://psmsl.org/data/gnssir/table.php
- GNSS-IR low coast (optional)

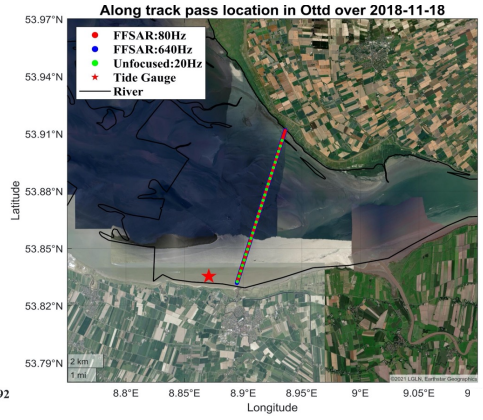
Auxiliary data:

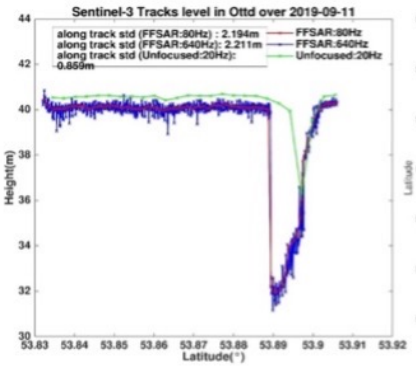
- River gauges (near real time, WSV)
- Multi-mission nadir altimeters (S3, S6, CS2, ICESAT-2)
- HR DTM
- Hydrodynamic Models
  1. SCHISM LR (operat.) 2023 Jun-July 2023
  2. SCHISM HR
  3. HUGO Legos WL
  4. BSH-HBMelbe WL&curr. (15-min), T, S (h)

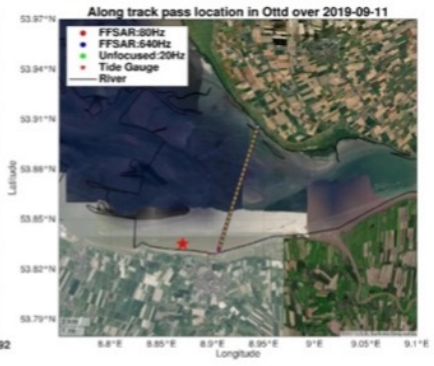
Fig. 1 In-situ data (above) and Reaches in the SWORD database (below)

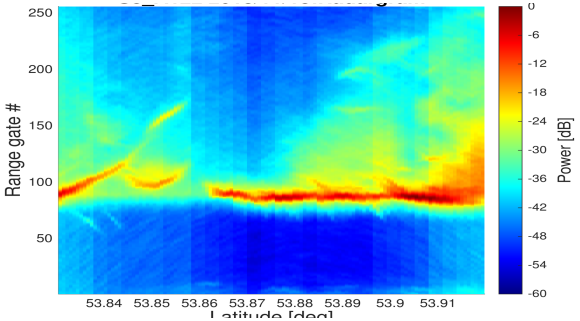
Accuracy of water surface elevation from nadir-altimetry

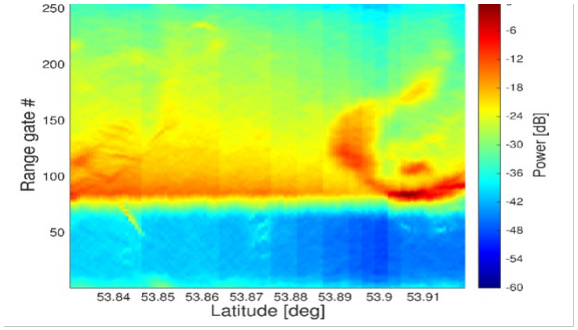


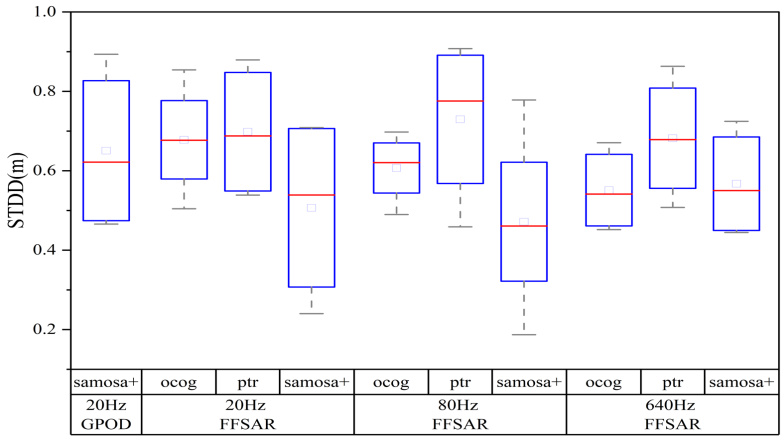


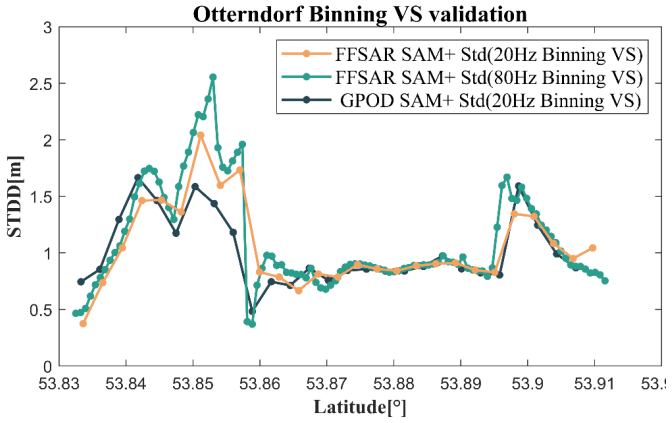










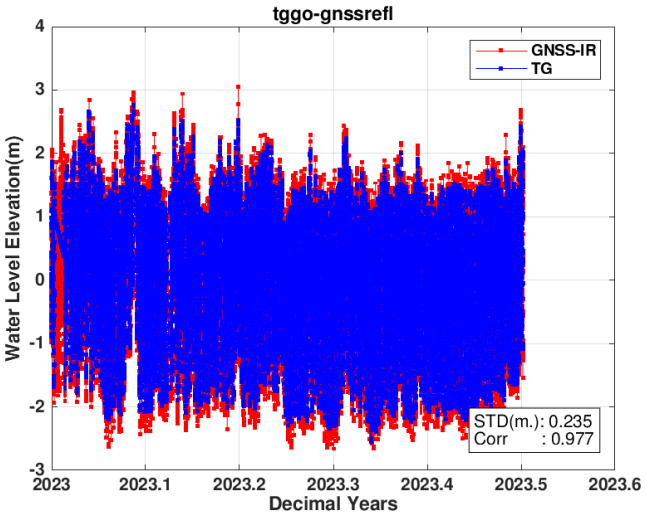


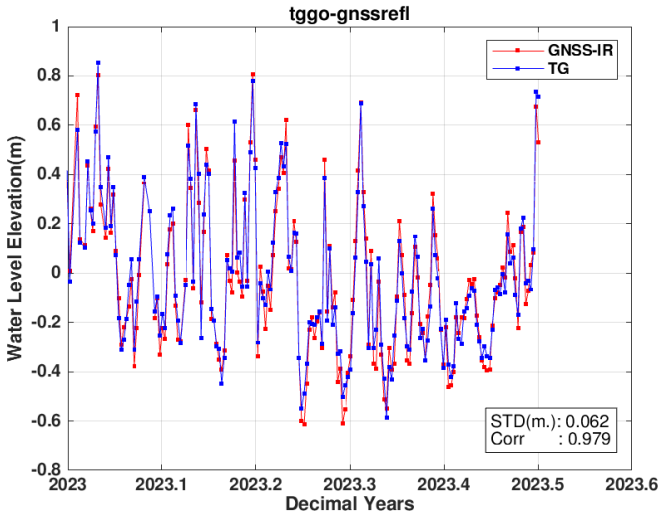
2016-2020 S3A (Ottendorf, Brünsbüttel, Schulau)
2018-2020 S3B (Glückstadt)

0.62	0.68	0.69	0.54	0.62	0.78	0.46	0.54	0.68	0.55
0.65	0.68	0.7	0.51	0.61	0.73	0.47	0.55	0.68	0.57

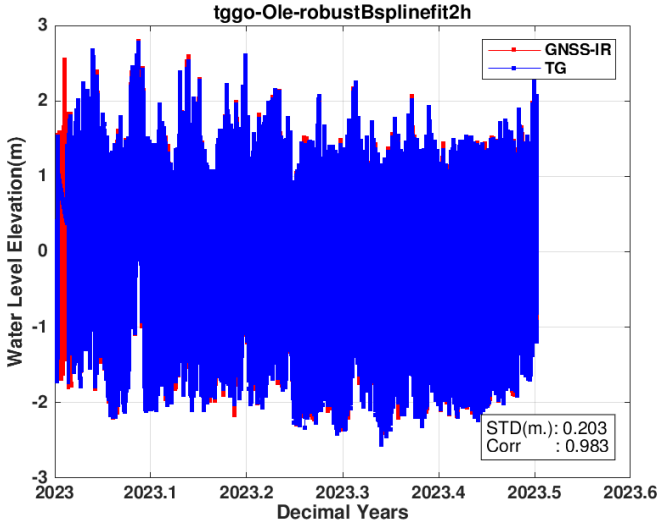
Fig. 2 : Boxplot of STDD at 4 TG in the Elbe UF-SAR and FF-SAR processing, various retrackers

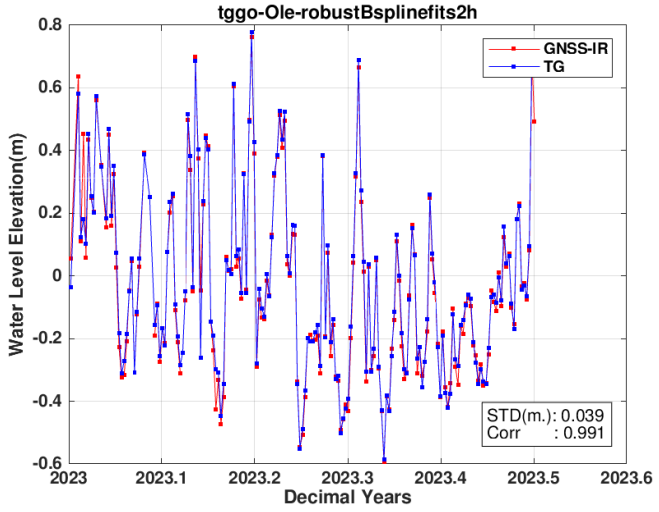
Water height from GNSS-R – Jan-July 2023





gnssrefl





BKG

Fig. 3 GNSS-R and gauge time-series subdaily (stdd 20 cm, left) and daily (stdd 6 and 4 right) in TGGO https://gnssrefl.readthedocs.io/en/latest/pages/README_install.html (K.Larson)

Accuracy of TUGO-Elbe Model

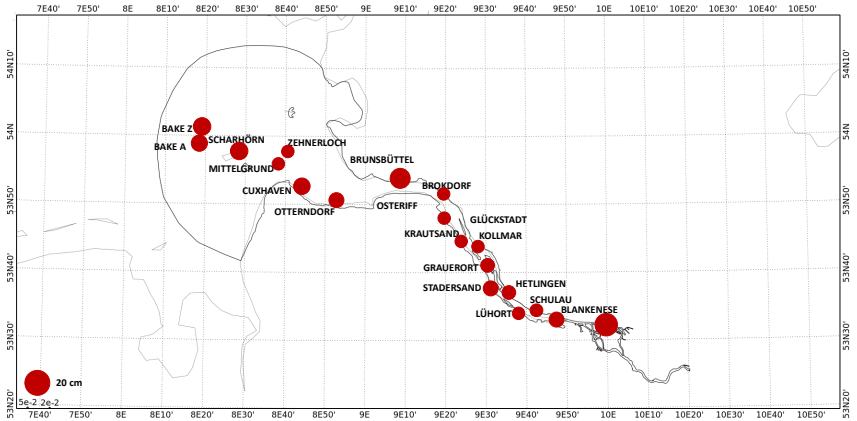


Fig. 4. TUGO domain and accuracy in the free run

TUGO Free run:

STDD < 20 cm

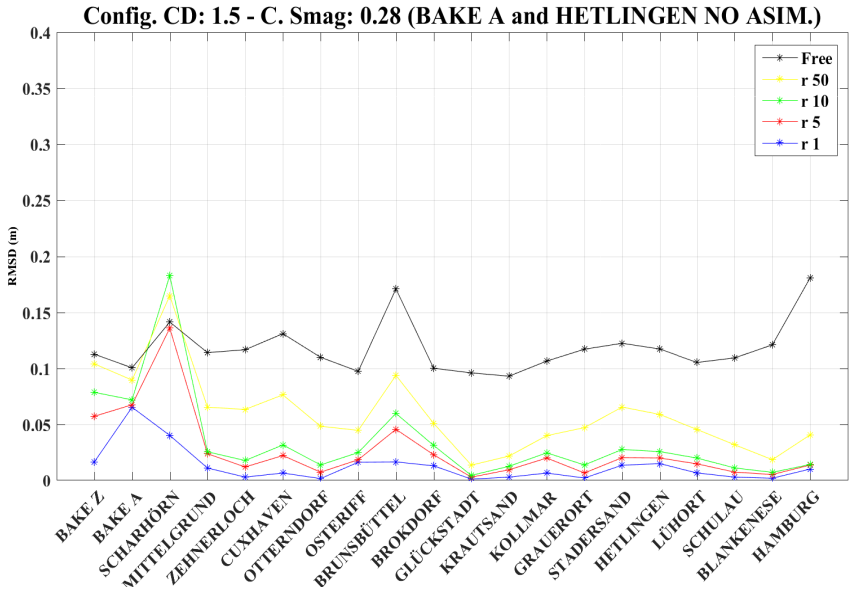


Fig. 5. TUGO domain and accuracy in free and assimilated runs

TUGO Assimilated run:

STDD < 2 cm

larger at TGs in open sea

Accuracy of SCHISM HR Model

Table 1. TG against Model SCHISM HR

	Dist (LR)	Corr (LR)	Stdd (LR)	Dist (HR)	Corr (HR)	Stdd (HR)
Blankenese	0.089	0.957	0.611	0.027	0.834	0.710
Brünsbüttel	0.120	0.934	0.464	0.100	0.861	0.545
Cuxhaven	0.105	0.950	0.397	0.171	0.884	0.535
Glückstadt	0.136	0.950	0.498	0.110	0.867	0.535
Nok_Brünsbüttel	1.017	-0.01	1.291	1.022	-0.145	1.054
Ottendorf	0.045	0.947	0.409	-	-	-
Schulau	0.102	0.962	0.560	0.015	0.834	0.681
GeestWehr	-	-	-	0.0345	0.813	0.663
Geesthacht				2.425	0.413	1.039

Table 2. TG against Model SCHISM HR - ocean tide corrected

	Dist(LR)	Corr(LR)	Stdd(LR)	Corr(HR)	Stdd(HR)
Blankenese	0.089	0.841	0.448	0.850	0.233
Brunsbuttel	0.120	0.920	0.312	0.870	0.204
Cuxhaven	0.105	0.929	0.239	0.880	0.194
Gluckstadt	0.136	0.924	0.341	0.868	0.213
Nok_Brunsbuttel	1.017	-0.075	0.820	-	-
Ottendorf	0.045	0.921	0.261	-	-
Schulau	0.102	0.866	0.396	0.849	0.235
GeestWehr	-	-	-	0.880	0.358
Geesthacht	-	-	-	0.524	0.674

SCHISM Free run:

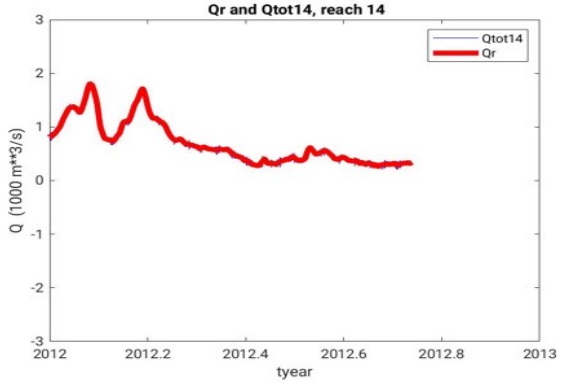
STDD 50 cm (no assimilation of TGs)

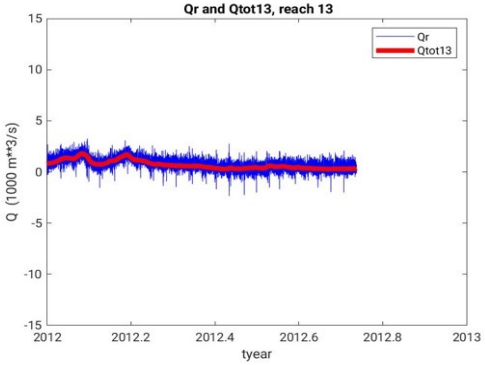
SCHISM de-tided

STDD < 20 cm

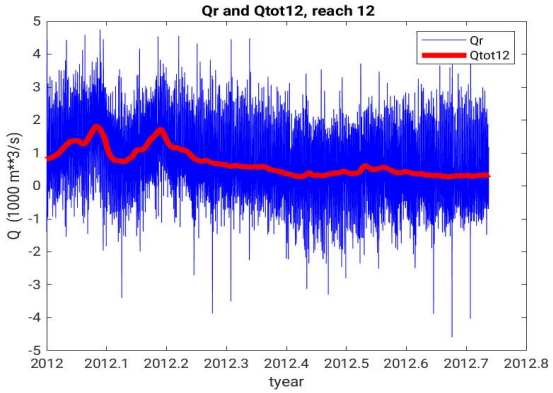
SCHISM models gives more parameters:
S, T, Larger STDD at tgs

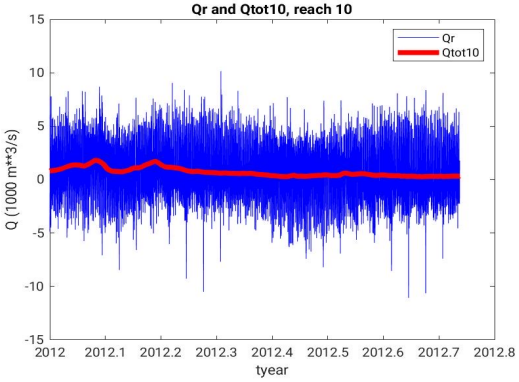
Method of Curbature

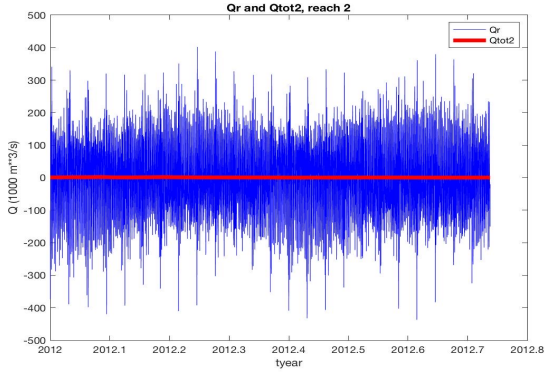




$$Q_{tot} = \sum_r Q_r - \int_\Omega \frac{\partial h}{\partial t} d\Omega.$$







input SCHISM HR
2012.0-2012.8

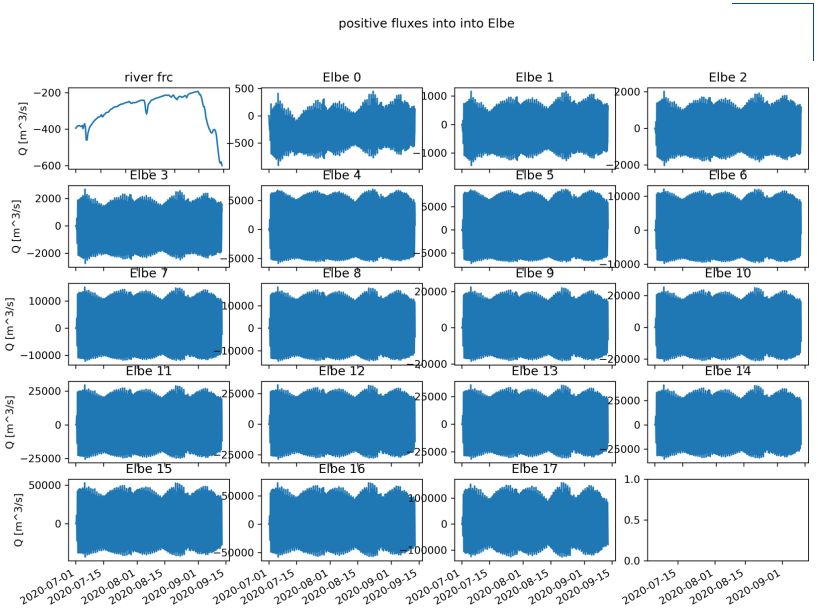
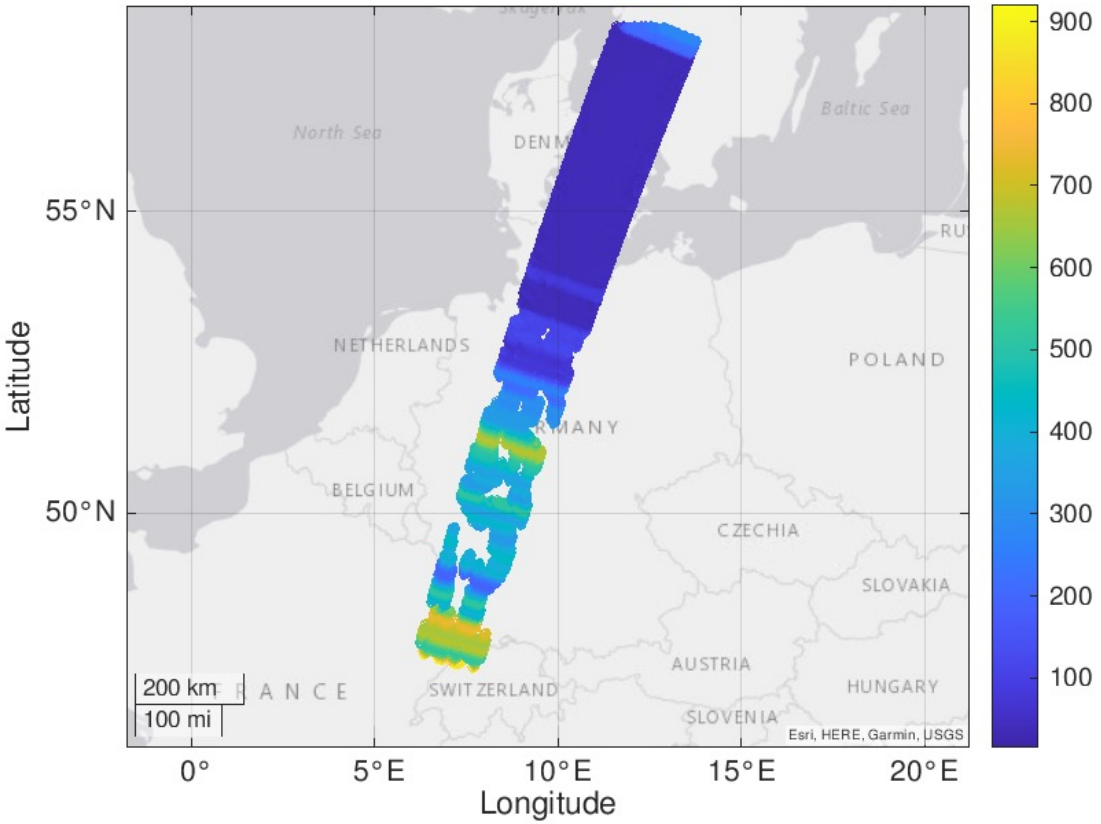


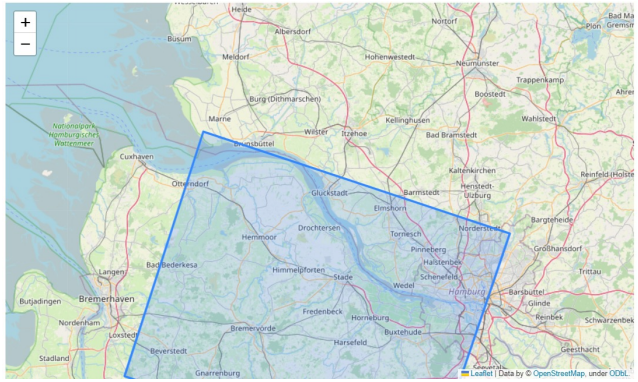
Fig. 7 HzG other method (2018)

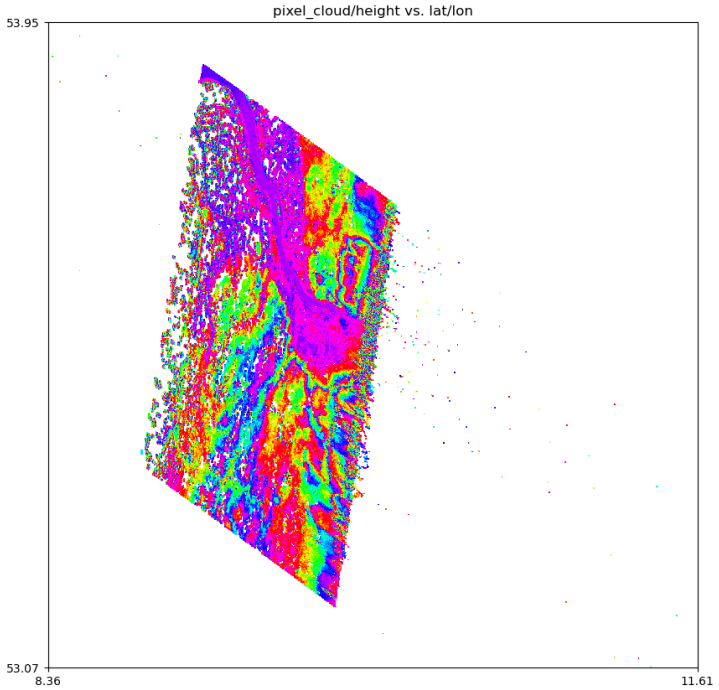
Fig. 6 Tidal discharge much larger than river discharge, order of magnitude is correct but high values may be associated with wetting and drying near boundary

SWOT-Karin in the Elbe data in L2_LR and H2_HR

SWOT_L2_LR_SSH_Expert_494_003_20230417T203730_20230417T212801_PIB0_01

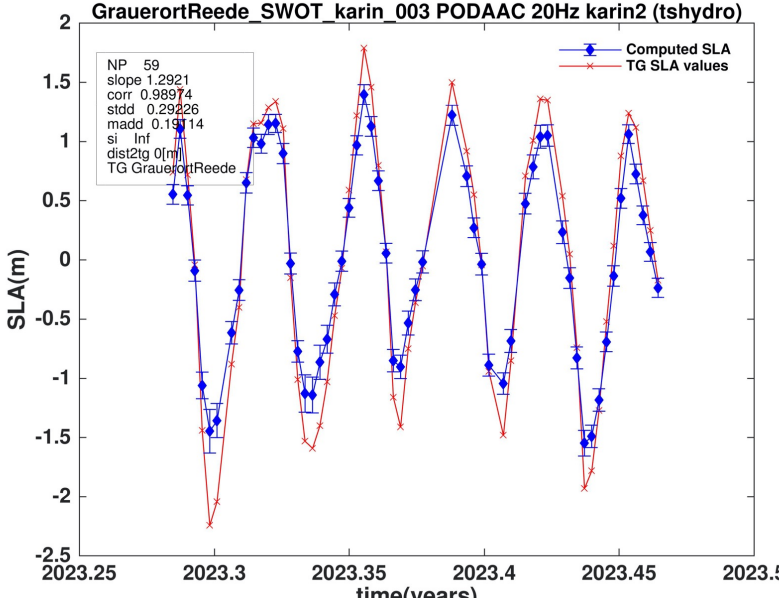


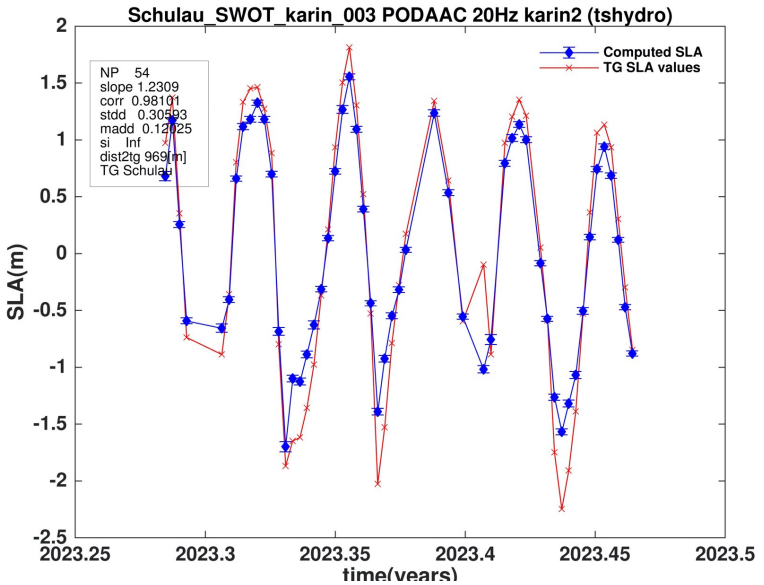


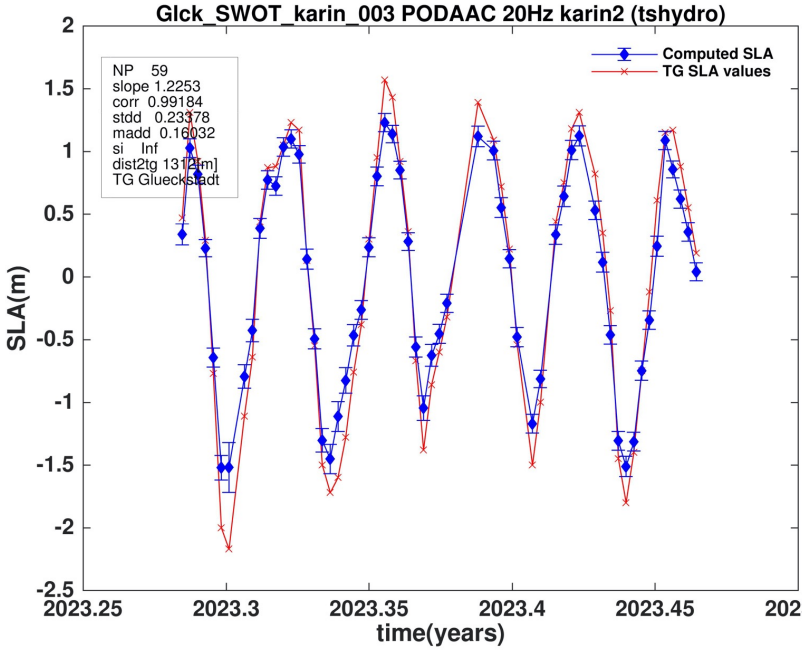


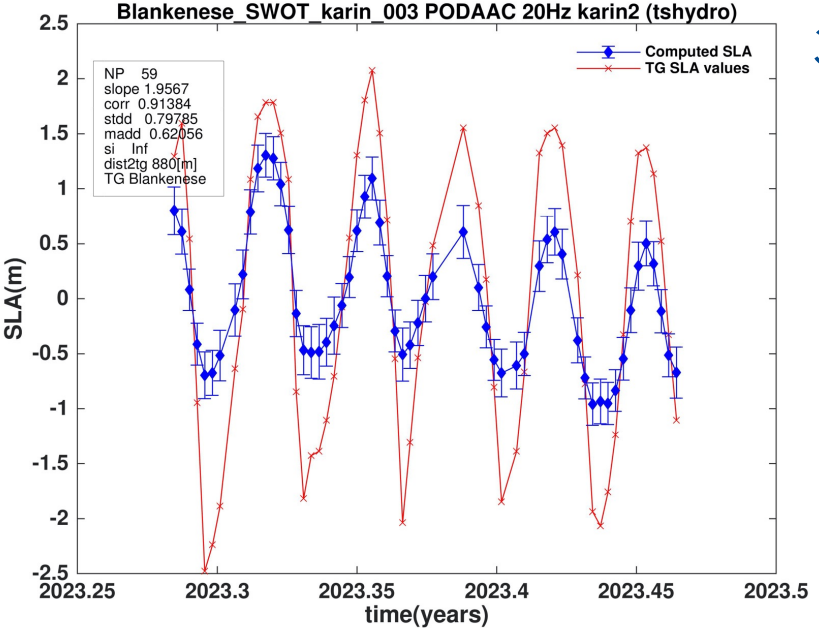
In SWOT_L2_HR_PIXC_503_003

First comparison of SWOT-Karin L2_LR and in-situ data









STDD < 30 cm
3 of 4 stations

Conclusions and *Outlook for cal/val Phase and science phase*

- **SAR nadir-Altimetry**
  - SAR nadir-altimetry, contamination also in FFSAR
  - Error in coastal region, estuary 40 cm, Compare WSE with in-situ
- **GNSS-R** STDD 20 cm (sub-diurnal), 5 cm daily
- **Models**
  - TUGO simulated heights only
  - SCHISM noisy
  - other
- **First SWOT results**
  - STDD 20-30 cm with in-situ gauges
- **Outlook: tidal propagation, tidal discharge from space** from SWOT and SAR altimetry for estuarine & river processes (e.g. salinity fronts, salinity slopes), effect of temporal sampling