



FURTHER DEVELOPMENTS*

SWOT-BASED GEOMETRIC GEOID SURFACE FOR APPROXIMATING AND VALIDATING GRAVIMETRIC MARINE GEOID MODELS

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16.09.2026

RECAP

$$N(\varphi, \lambda, t) = SSH(\varphi, \lambda, t) - DT(\varphi, \lambda, t)$$



Hydrodynamic model (HDM) –
Dynamic Topography

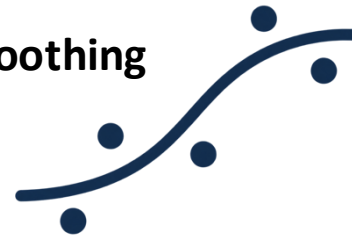


Tide gauges – **correction of the
HDM reference level**



SWOT KaRIn measurements –
Sea Surface Height

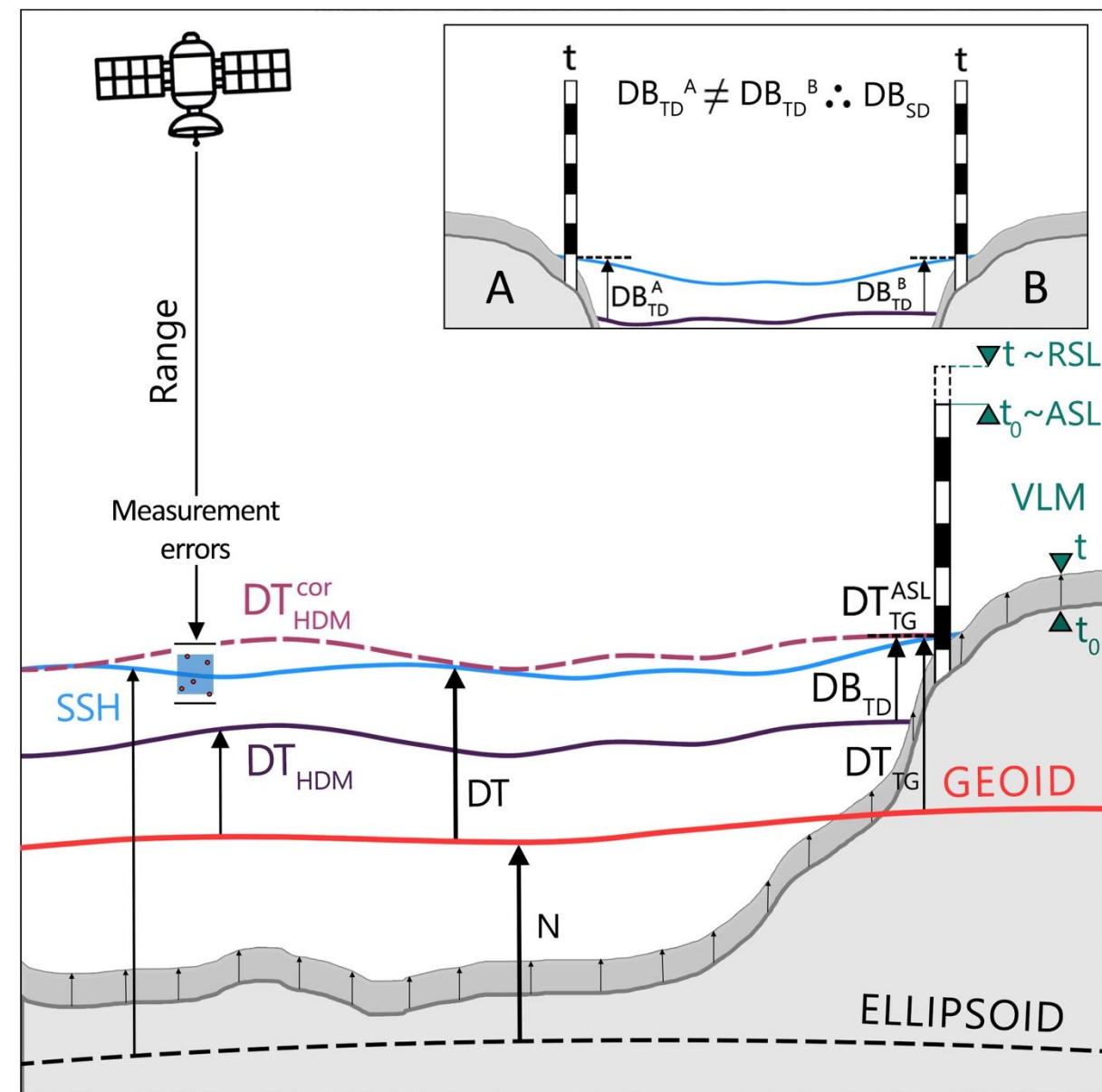
Smoothing



**GEOMETRIC SURFACE
APPROXIMATION**

RECAP - STEPS

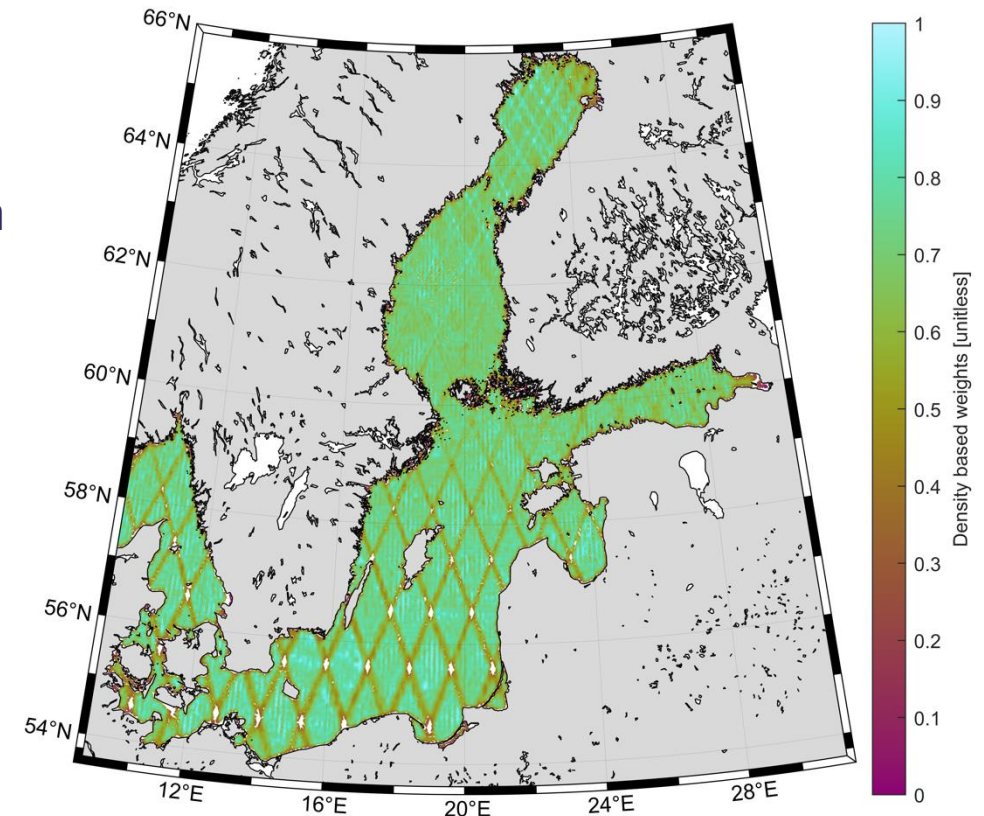
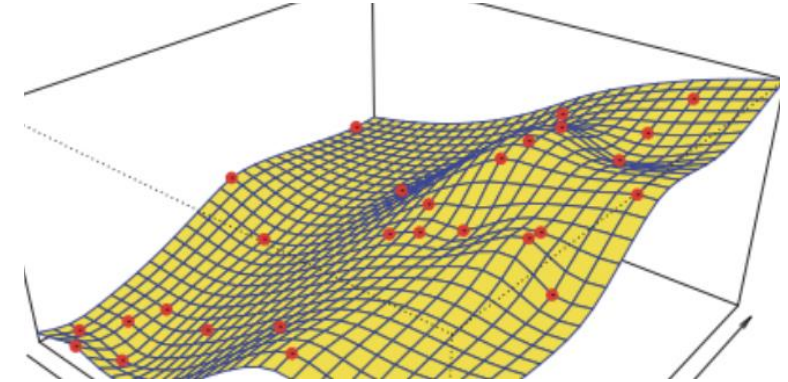
- Get **HDM** and **TG** at the time of **SA** acquisition
- **Correct TG** for the **VLM**
- **Correct HDM Dynamic Bias** using **TG** (e.g., average difference, interpolation, deep learning)
- Subtract **instantaneous** corrected **DT** from **instantaneous SSH**
- **Average** resulting **N estimations** per SWOT coordinate
- Calculate **smoothed** version **or** use **GGM**
- Get **residuals** of **averaged and smoothed surfaces**
- **Smooth residuals** with more **flexible method** (e.g, TPS, LSC)



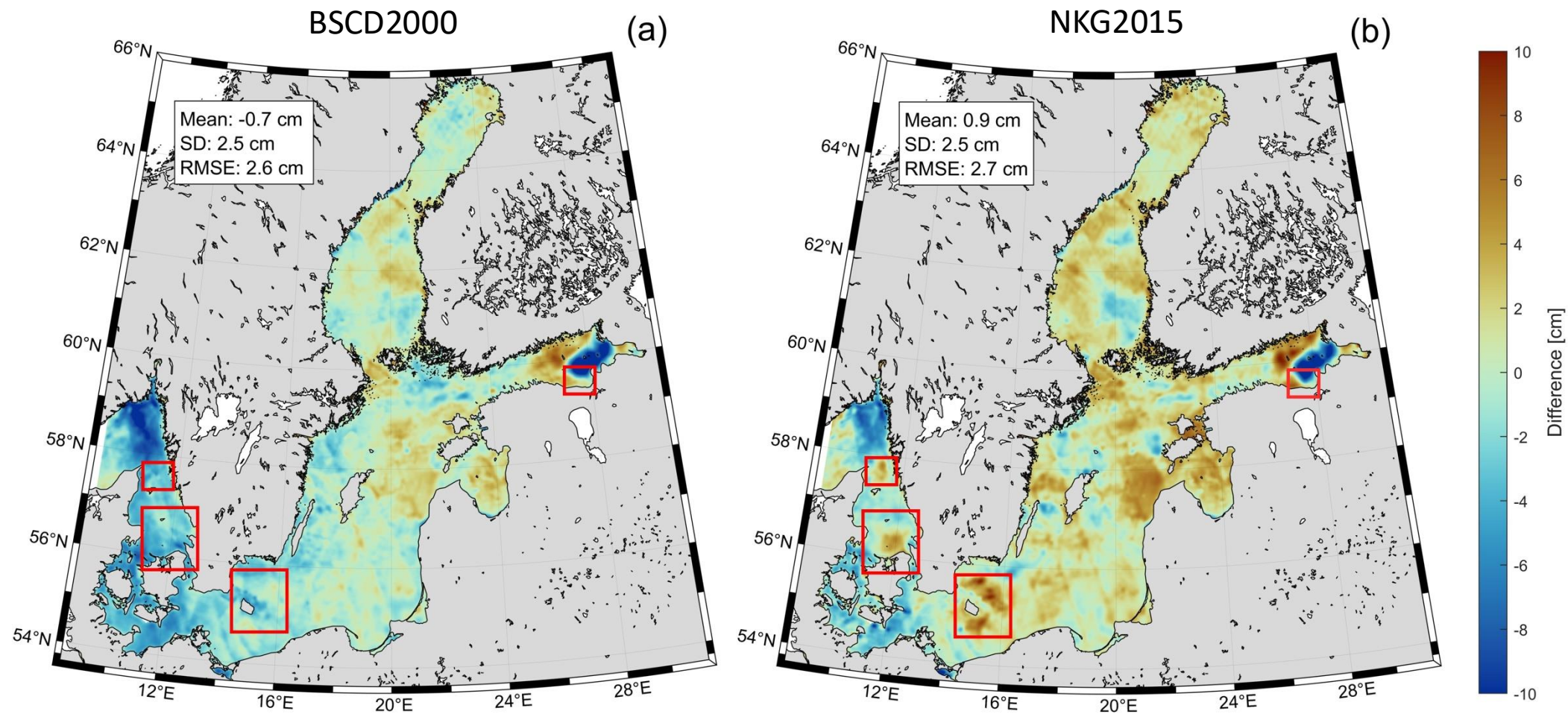
RECAP - SMOOTHING

Chosen smoothing method classical **Thin Plate Smoothing**, but:

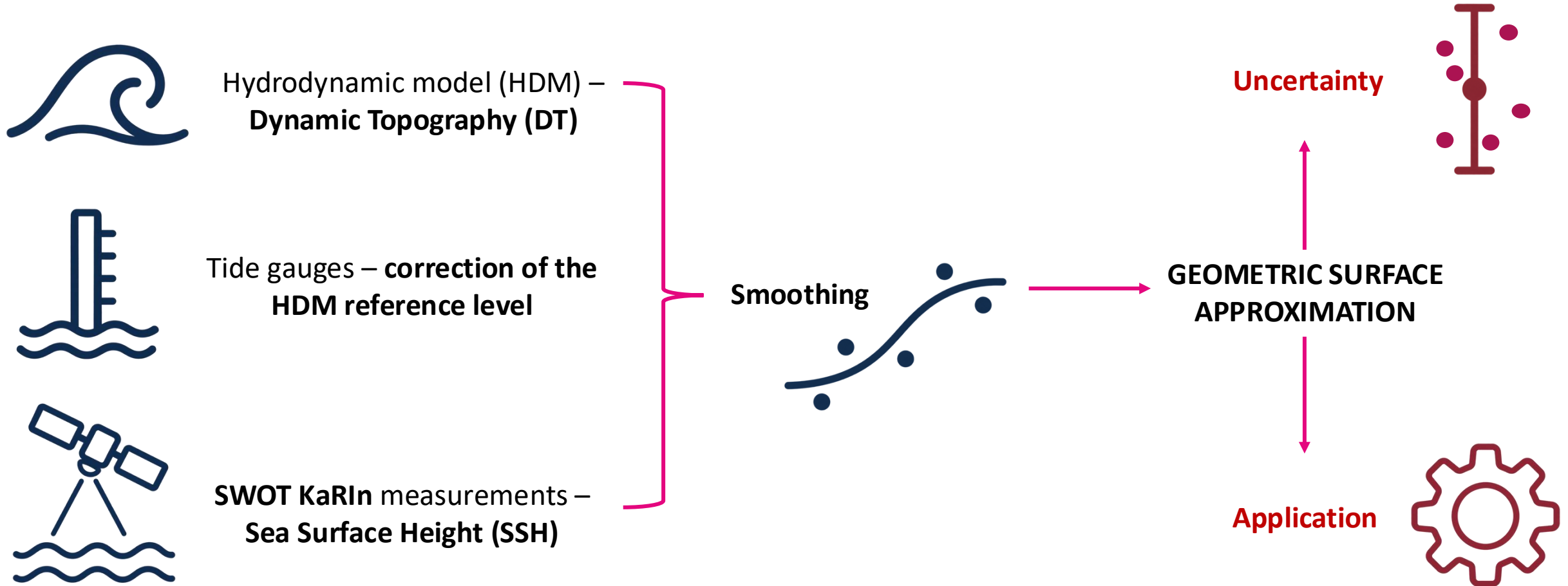
- **Iterative**
- **Random sub-sampling**
- Fitting to the random **residuals** and correcting surface **from previous iteration**
- **Density-based weights** to avoid edges, artifacts, data voids



RECAP - RESULTS

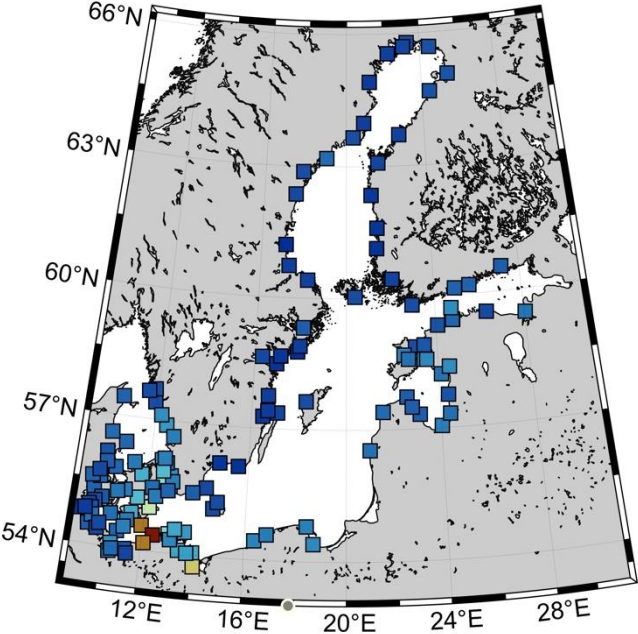


FURTHER DEVELOPMENTS



TG SENSITIVITY TEST

- Randomly selected TG in different configurations
- Results are mostly the same in terms of mean difference and standard deviation
- Elimination of the main 1D shift is essential and spatial DB get mostly averaged out
- Method is valid without extensive TG network
- Utilization of several selected reliable TG can be almost as good as all TG

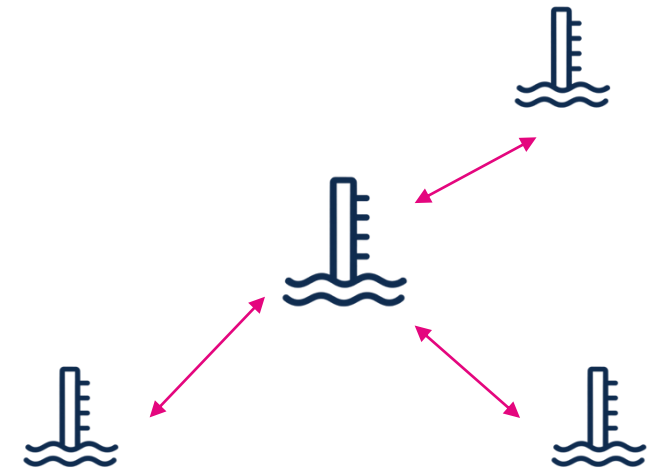


		Mean difference at the BSCD2000 geoid grid nodes, cm		σ of differences at the BSCD2000 geoid grid nodes, cm	
Description	Amount of TGs for computing DB surface for corresponding geoid test models	I*	II	I	II
	All 145 TGs	-0.6	X	2.6	X
	Random 15 TGs	1.2	1.1	2.6	2.6
	Random 30 TGs	0.5	2.1	2.2	2.7
	Random 60 TGs	1.6	1.5	2.6	2.6
	Random 120 TGs	1.4	1.5	2.6	2.6
	Selected 11 TGs (even spatial distribution, with min σ)	1.7	X	2.7	X
* the Roman I and II denote solutions with different random distribution of TGs. The non-random 11 TG station selection based surfaces are compared only once.					

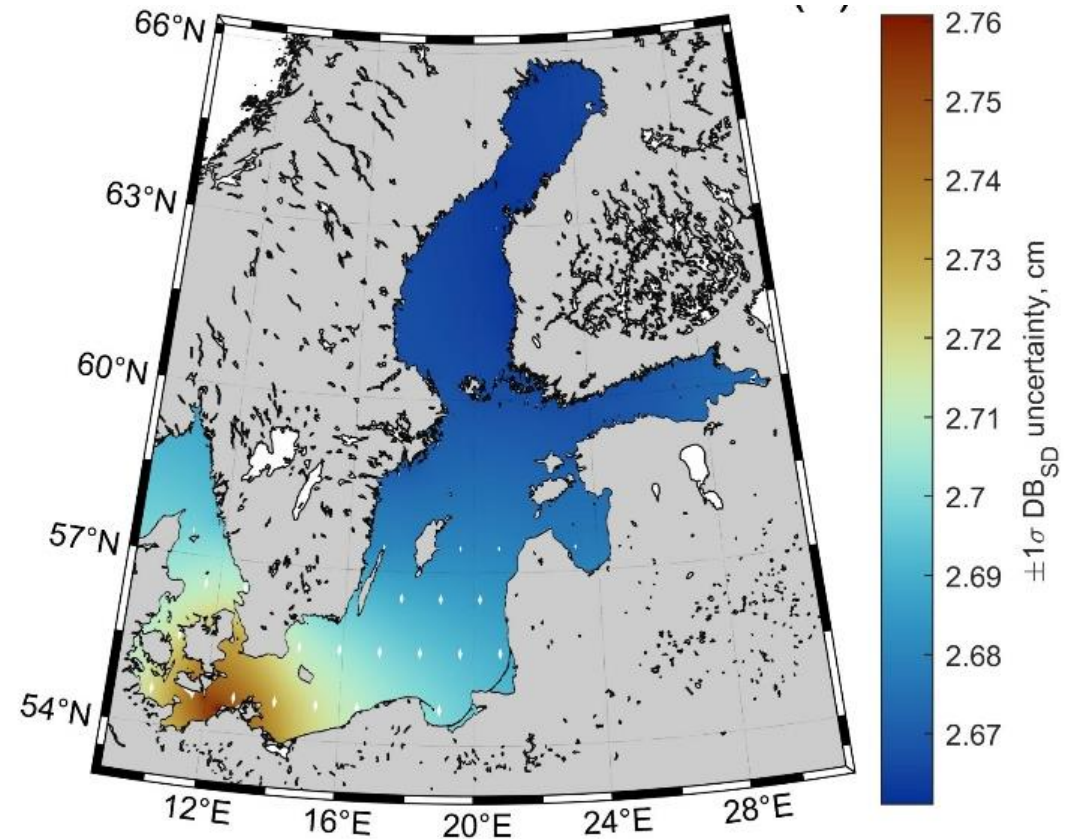
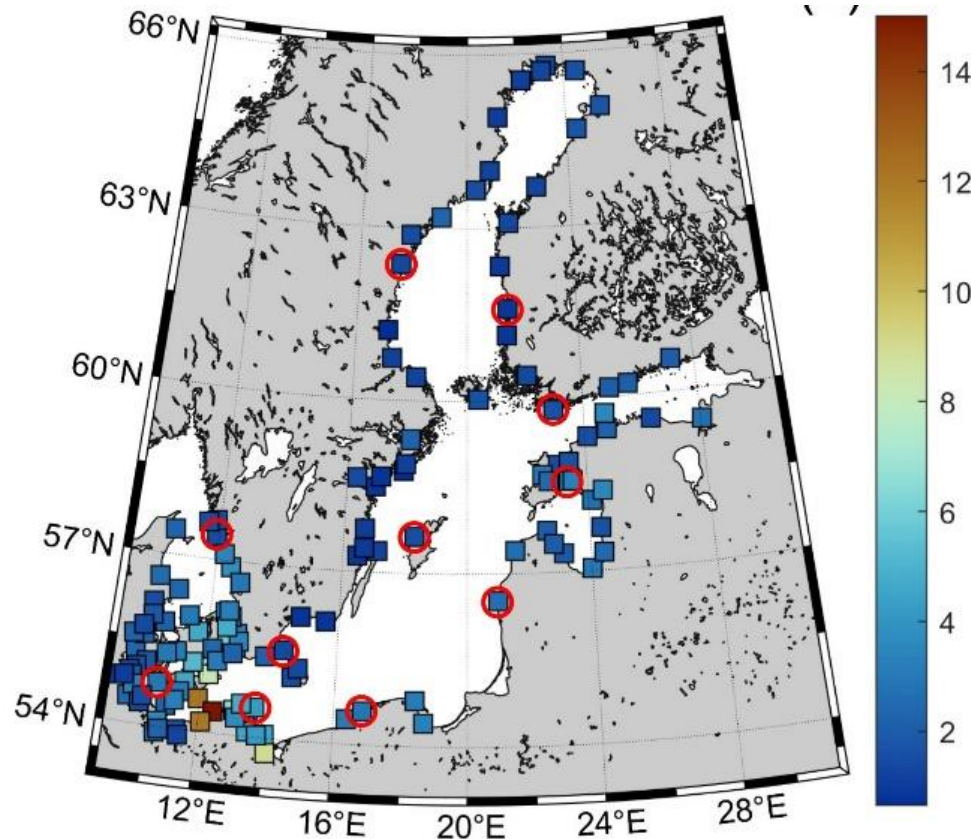
UNCERTAINTY– 1ST COMPONENT HDM DYNAMIC BIAS

Adopted to be a representative quantity for the comparison between the TGs

- One **main TG** is selected
- **DB time series** compared to the **three nearby TG**
- **Variance of differences** is calculated **per nearby TG**
- **Weighted by the distance** from main TG



TAL
TEC

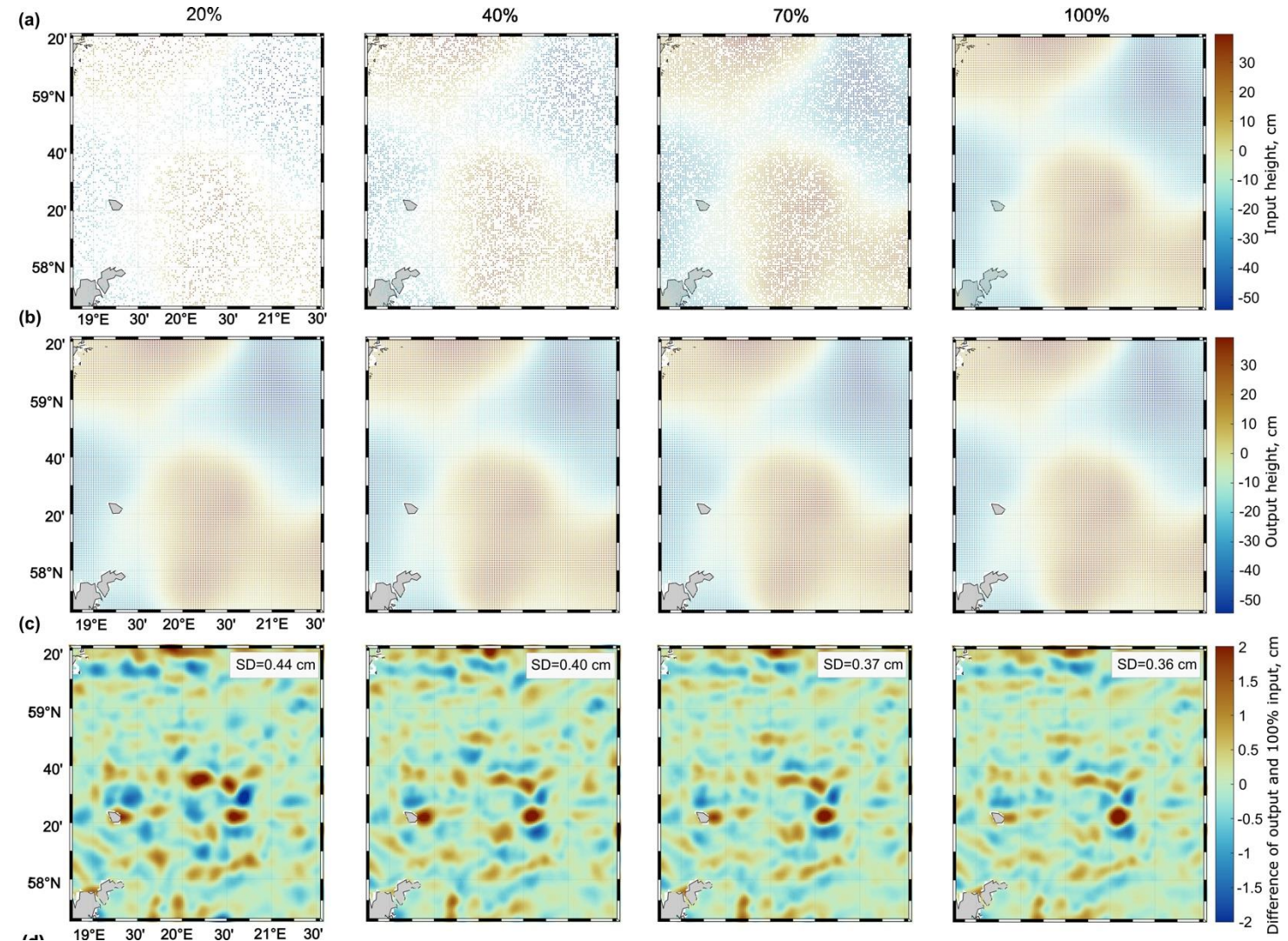


UNCERTAINTY – 2ND COMPONENT

TPS SMOOTHING

The **selected area** of BSCD2000 was **reconstructed** from **different randomly sampled points**

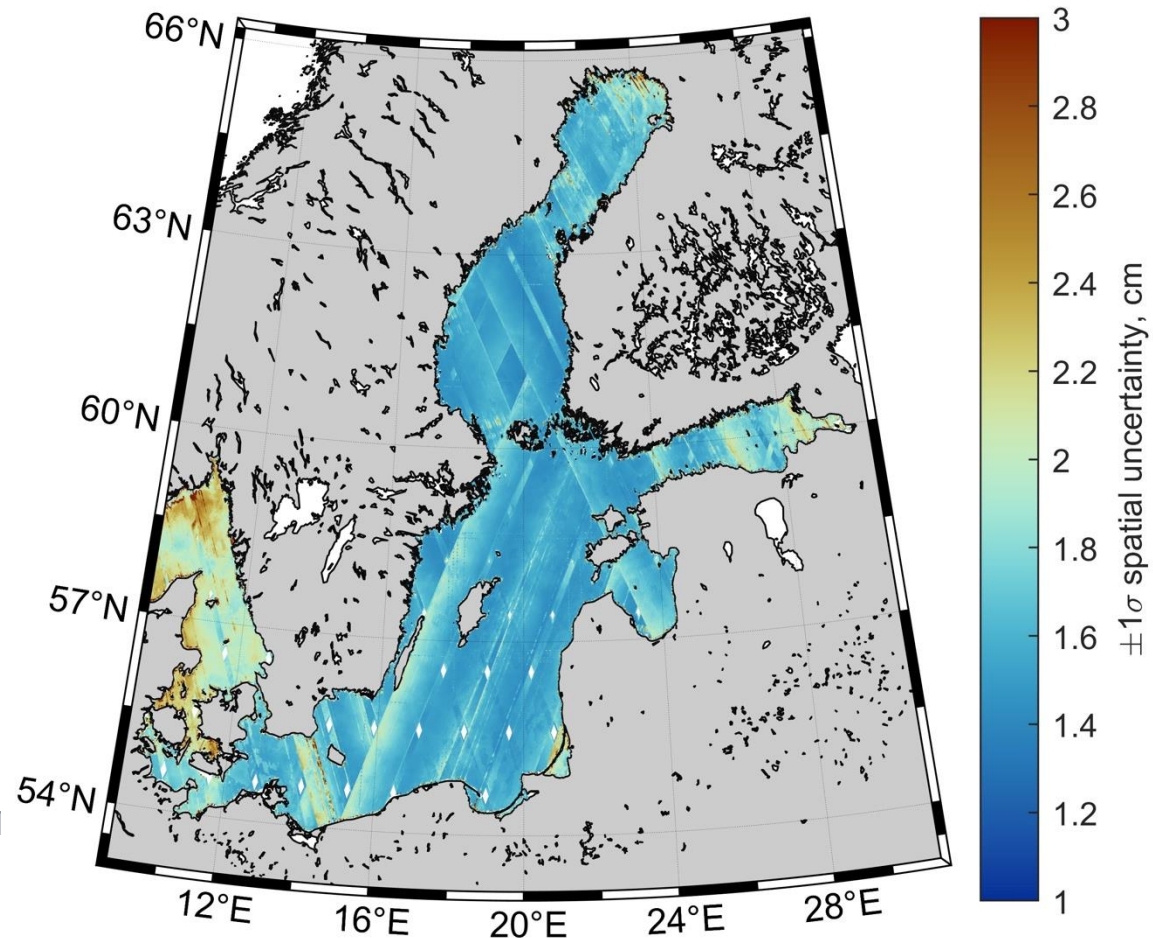
- Different configurations of 20 – 100%
- 28000 km² area
- Differences of TPS output and actual geoid are compared
- **1 σ STD** is estimated to be around **4 mm**
- **Occasional 1-2 cm underestimation** of the peaks



UNCERTAINTY – 3RD COMPONENT

TEMPORAL VARIABILITY OF N ESTIMATES

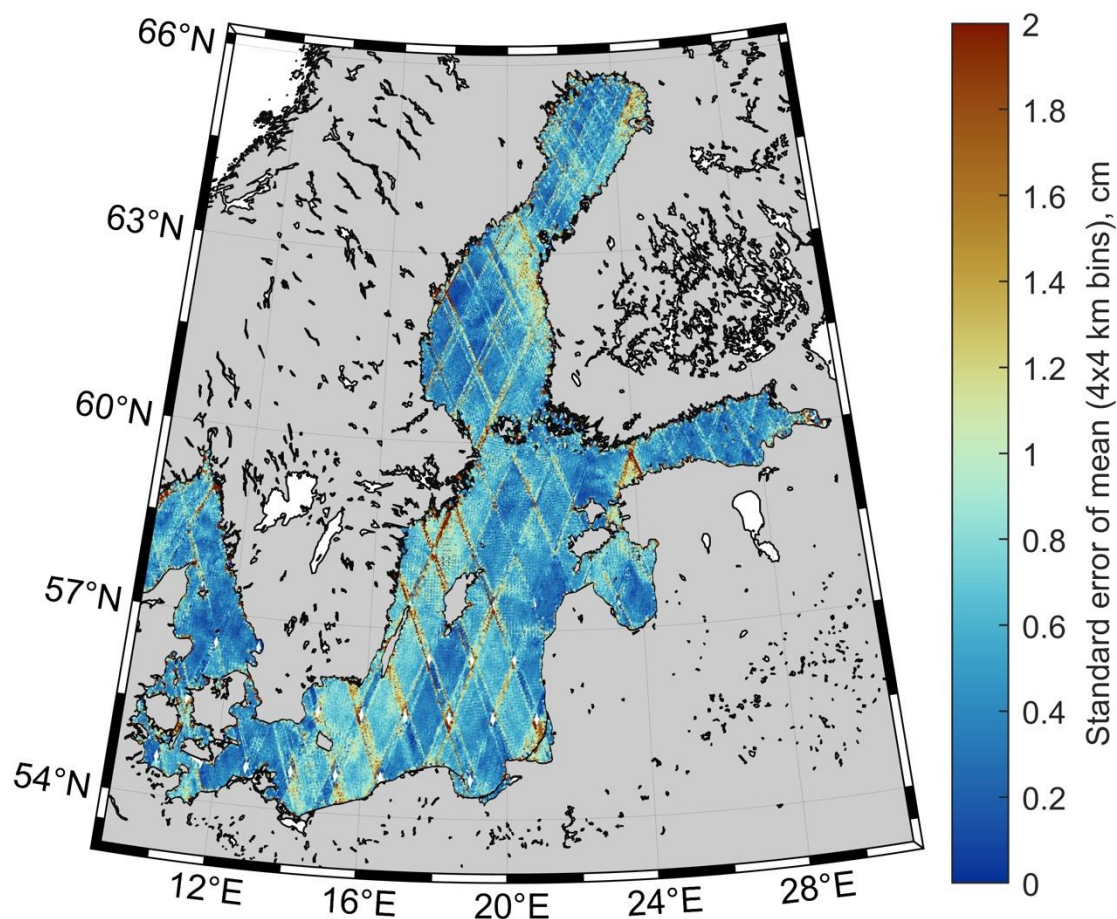
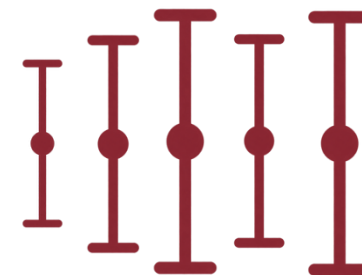
- **Temporal variability** is estimated **per each unique SWOT coordinate**
- Uncertainty is calculated as **standard error of the mean**
- Mostly represents **HDM limitations in modelling DT** and **systematic errors (e.g., KaRIn tilts)**



UNCERTAINTY – 4TH COMPONENT

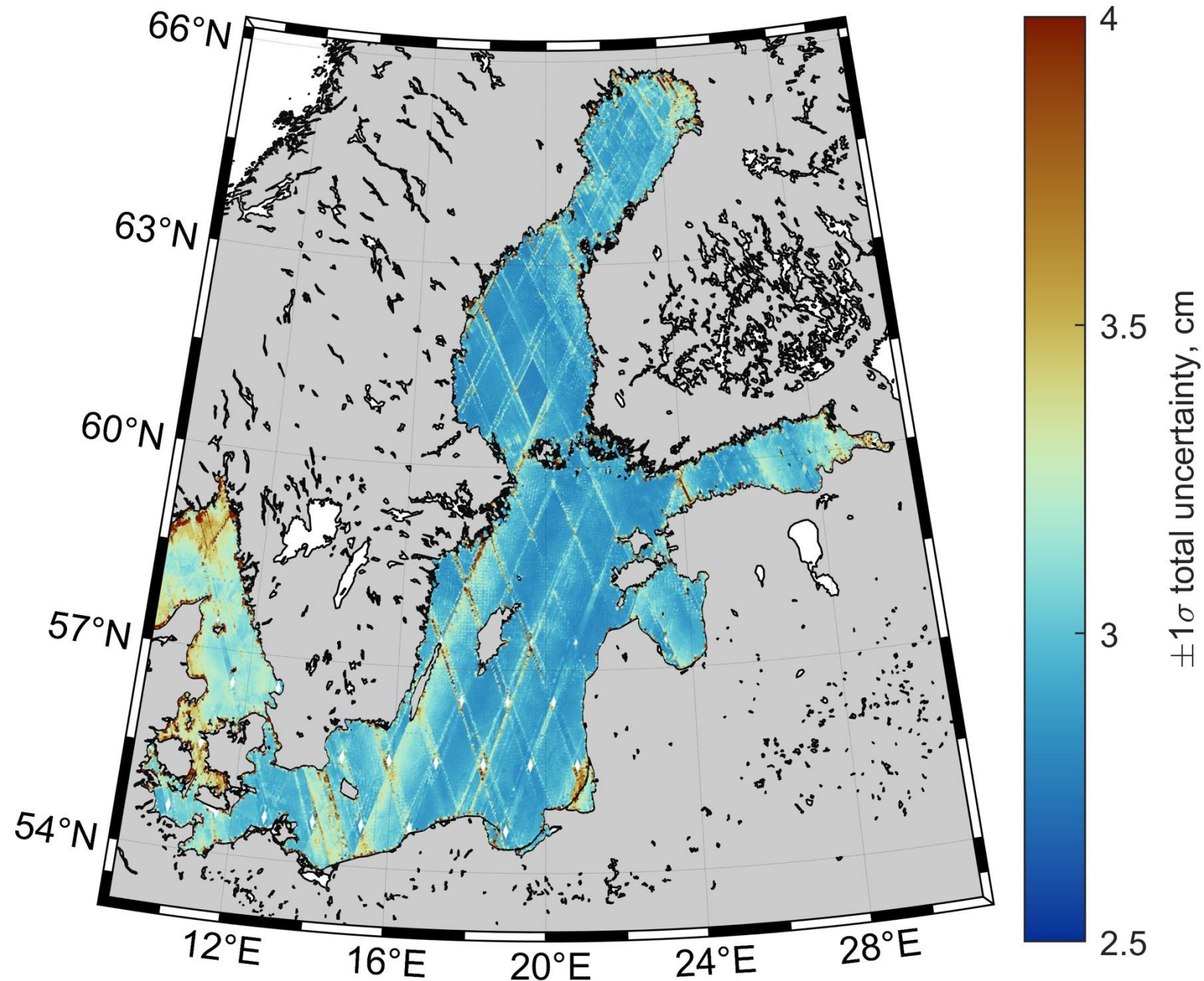
SPATIAL VARIABILITY OF THE N ESTIMATES

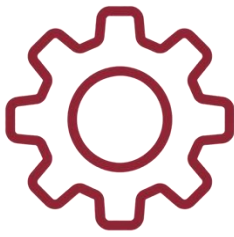
- Uncertainty based on **variance of nearby averaged N estimates** – bins of 4x4 km
- The **standard error of the mean per bin** is calculated
- Mostly represents **noise, artifacts and high-frequency errors from KaRIn measurements**



TOTAL UNCERTAINTY

1σ total uncertainty is:



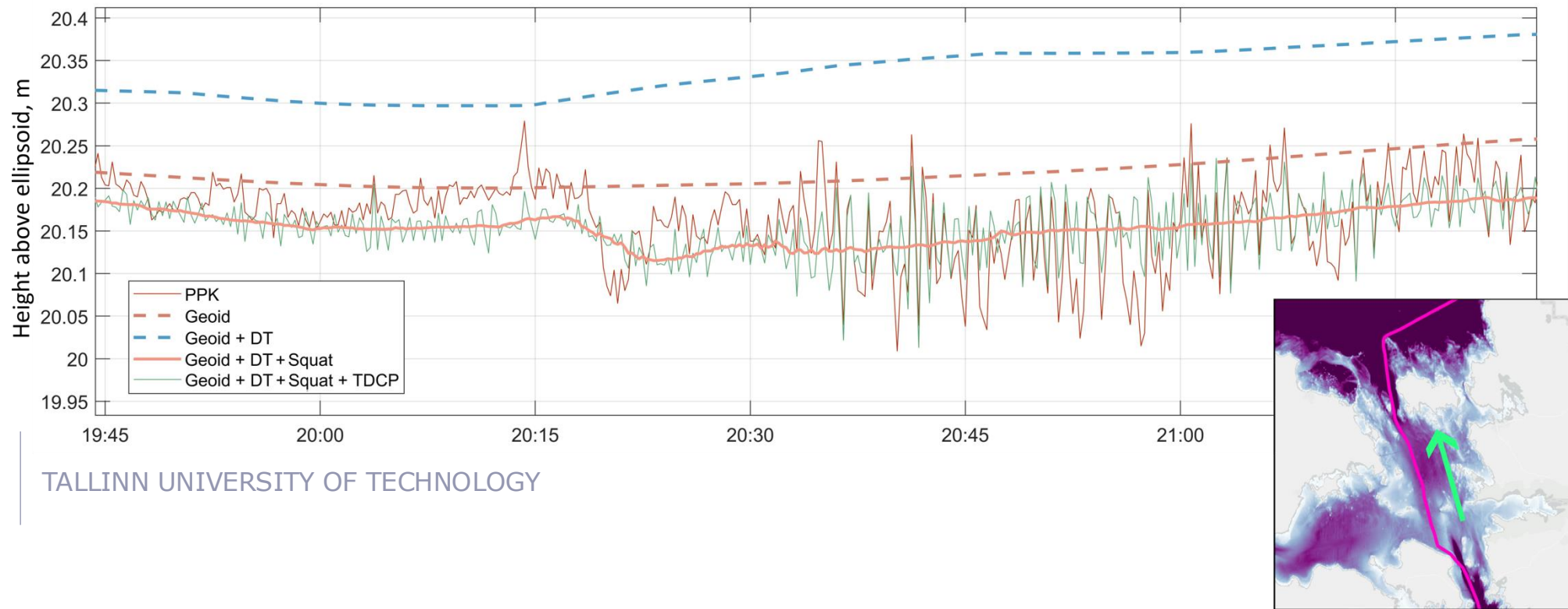


APPLICATION

YESTERDAY POSTER – UNDER KEEL CLEARANCE ASSESSMENT

Brief description

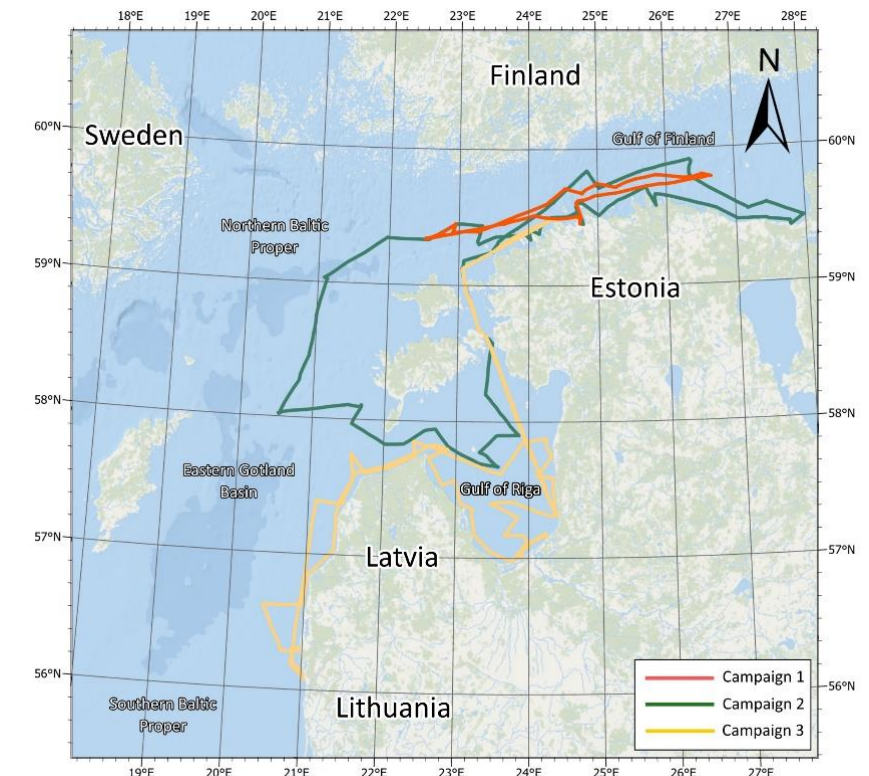
- Vertical position of the ship reconstructed as **Geoid+HDM+Squat+High-frequency** displacement
- Compared to the Post-Processed Kinematic GNSS



APPLICATION COMPARISON UTILIZING BSCD2000 AND SWOT-BASED SURFACE

- For the ~1800 km of the voyage – **comparison with PPK GNSS**
- **Adequate replacement** for **gravity data voids** for **maritime**

	BSCD2000	SWOT-based
RMSE, cm	7.2	7.4
STD, cm	6.9	7.4
Correlation, %	99.9	99.9



SWOT-BASED GEOMETRIC GEOID STORY

- Geometric surface was **derived**
- **Compared** to the BSCD2000 and NKG2015 geoid models
- **Sensitivity** to the density of the TG network **tested**
- Surface **uncertainty estimated**
- **Tested** in **application**

Future work:

- Experiments in other areas
- Unsmoothed SWOT version for smaller areas (e.g., Gulf of Finland data void)

THANK YOU



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