

— Mean Sea Surface from SWOT – improvements along the Norwegian coast

Matea Tomić¹, Bjarke Nilsson², Matilde Dugoni², Michael G. Hart-Davis³, Ole B. Andersen²

¹School of Engineering, Aalto University, Espoo, Finland

²DTU Space, Kgs. Lyngby, Denmark

³DGFI, Technical University of Munich, Munich, Germany

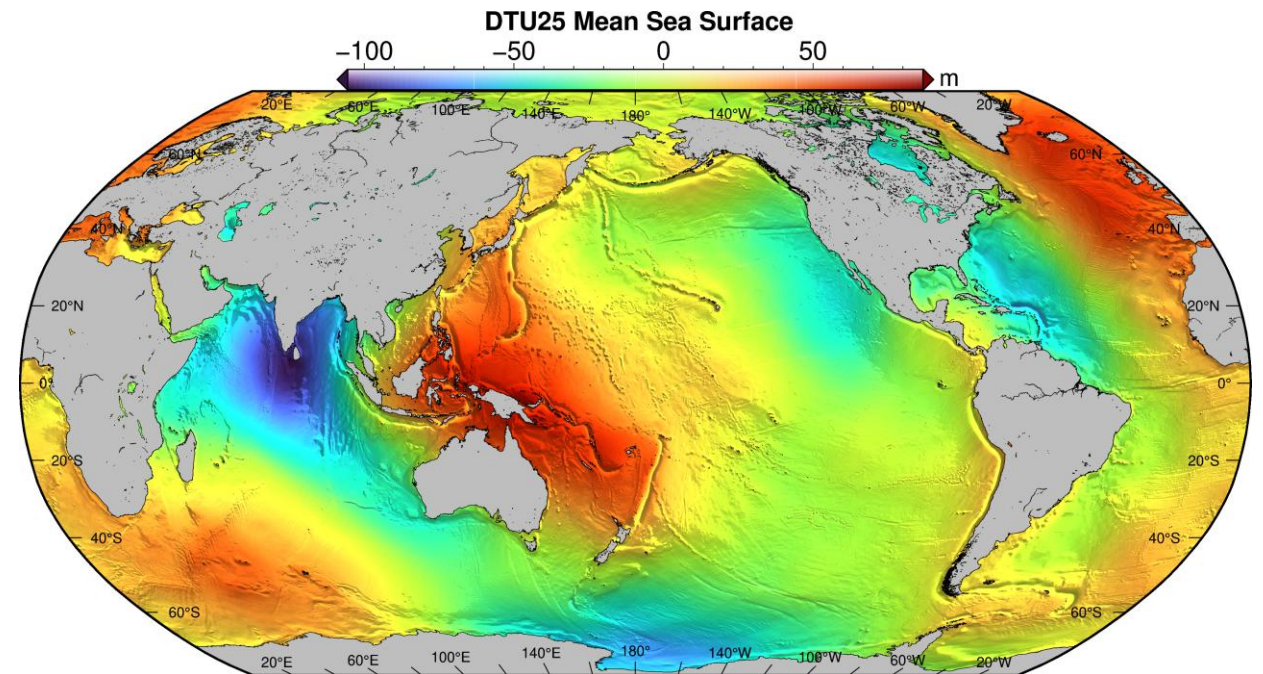
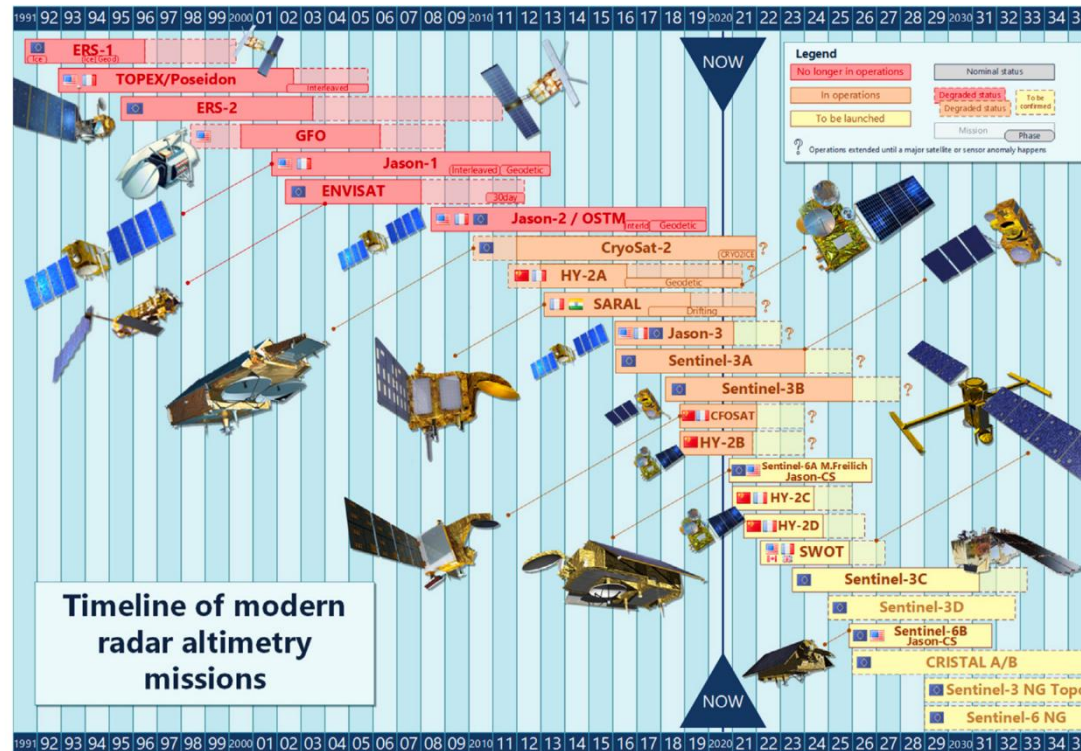
NKG General Assembly, 14-17 September 2026
Vilnius, Lithuania

Mean Sea Surface

- The average height of the ocean surface in relation to the reference ellipsoid

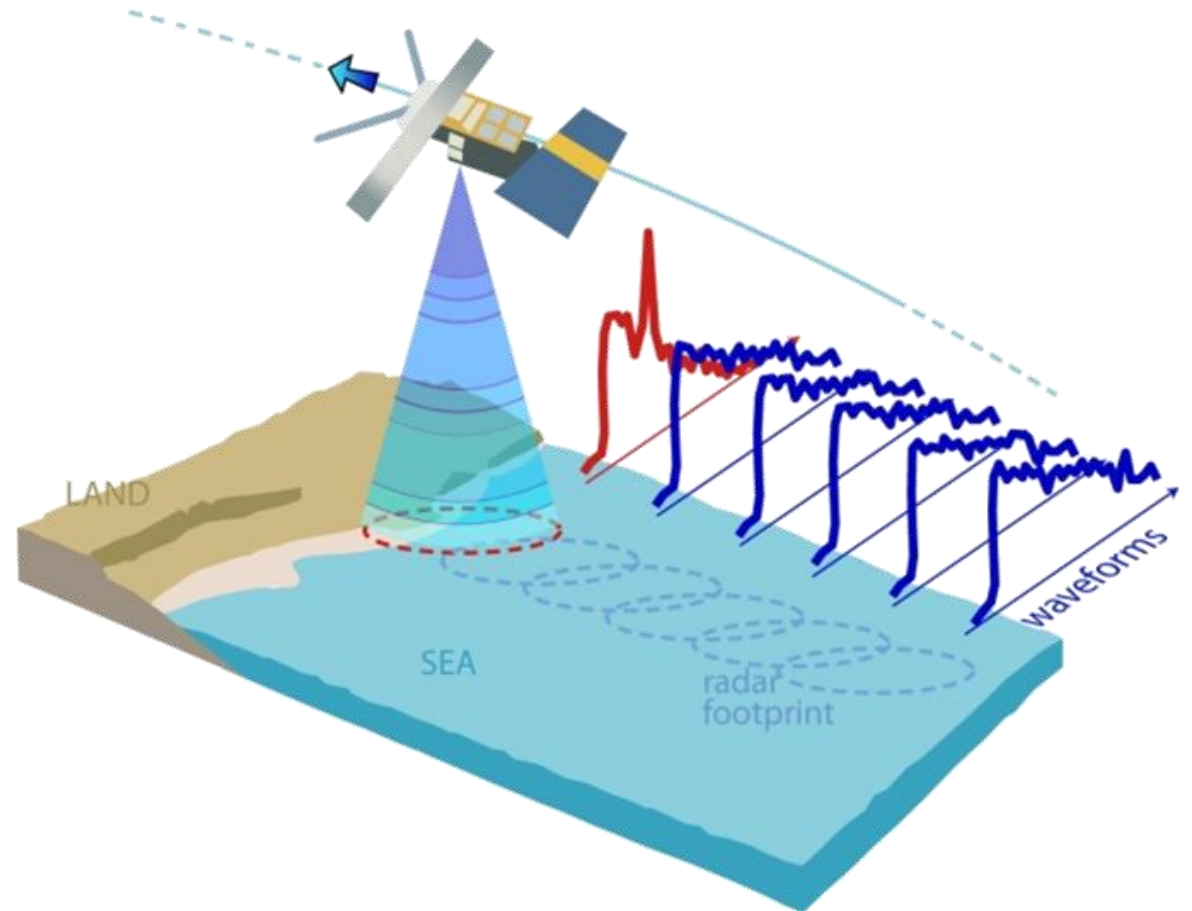
$$MSS = \frac{1}{T} \int_{t=-\infty}^{\infty} SSH(t)$$

- A long history of data

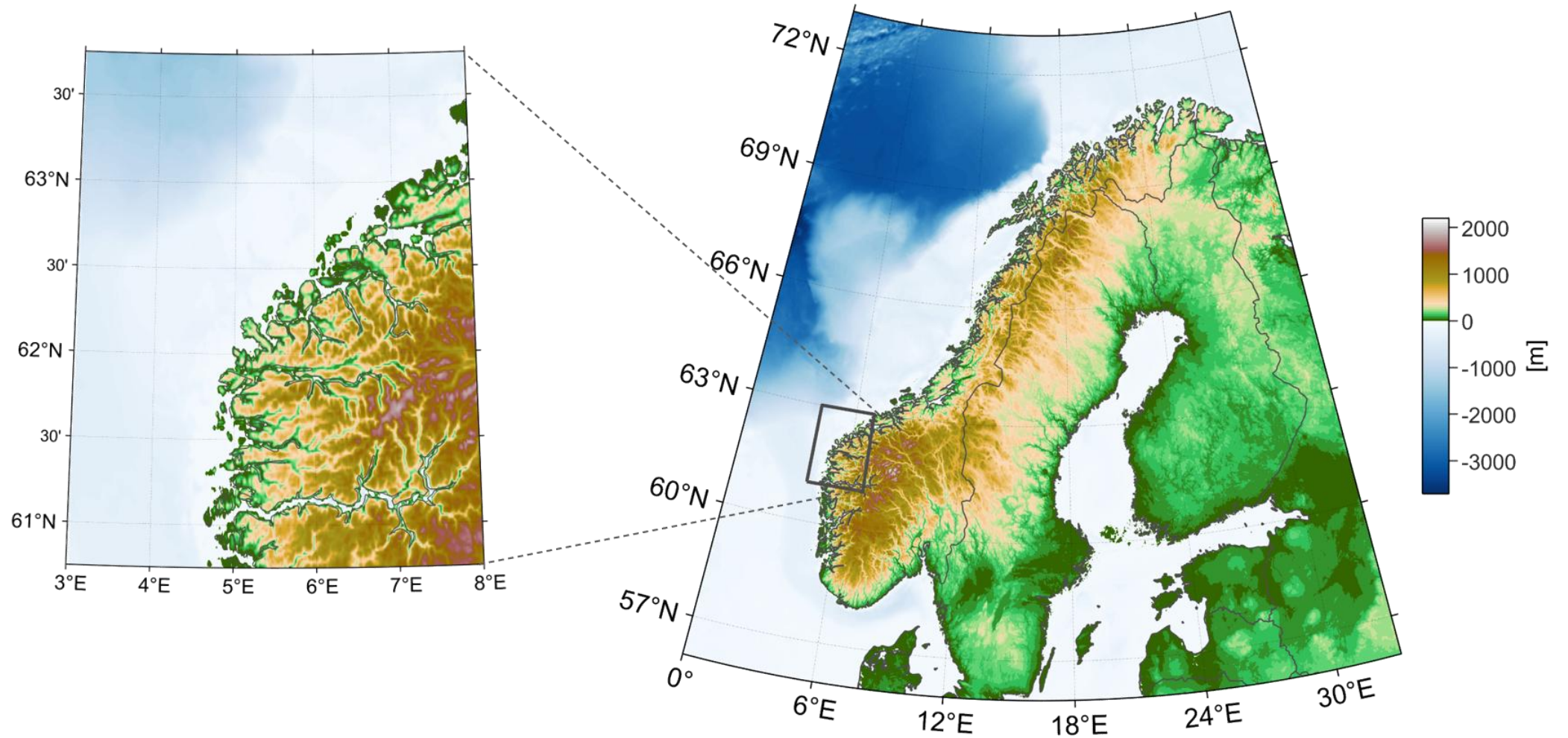


Challenges in coastal areas

- Land contamination
- Large footprints
- Bright targets (ships, shallow water, small islands)

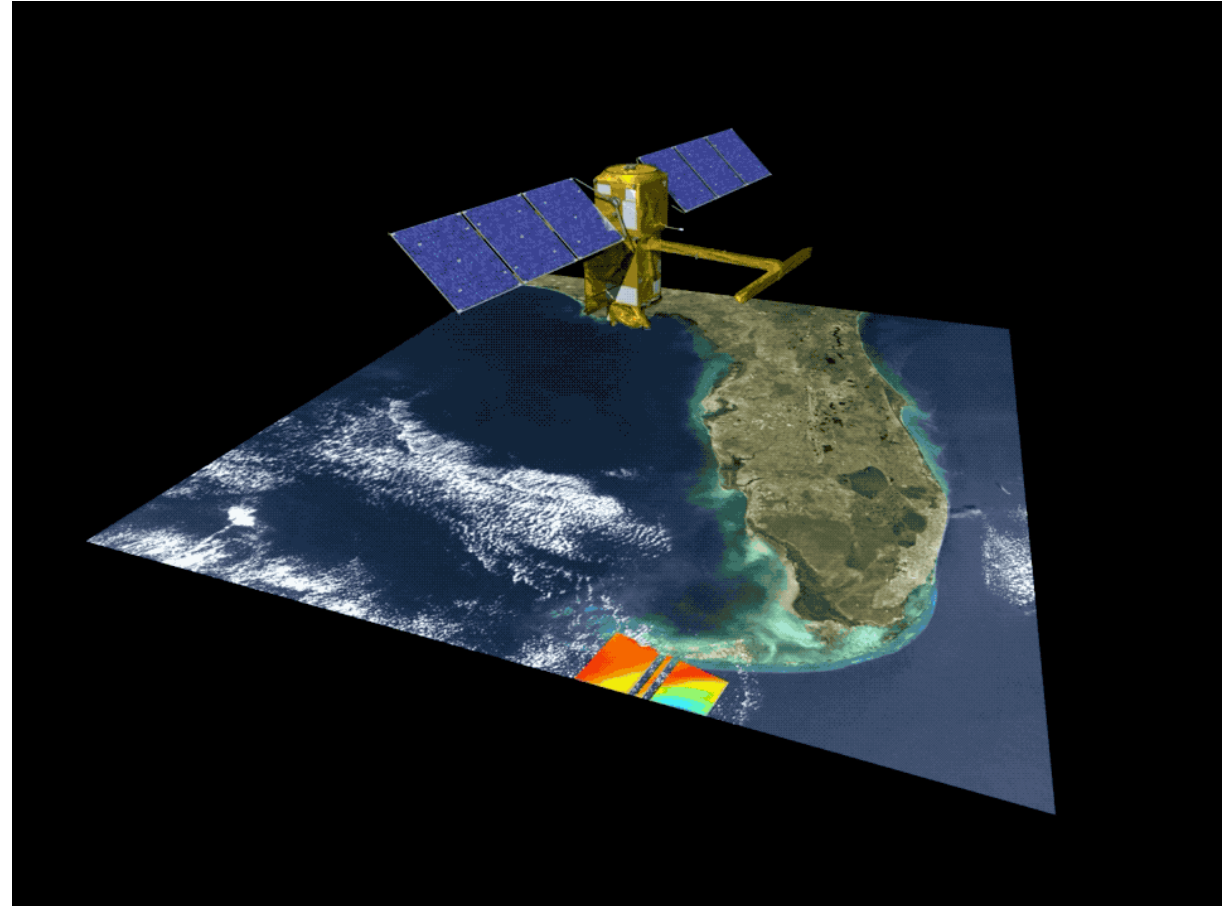


Challenges in coastal areas



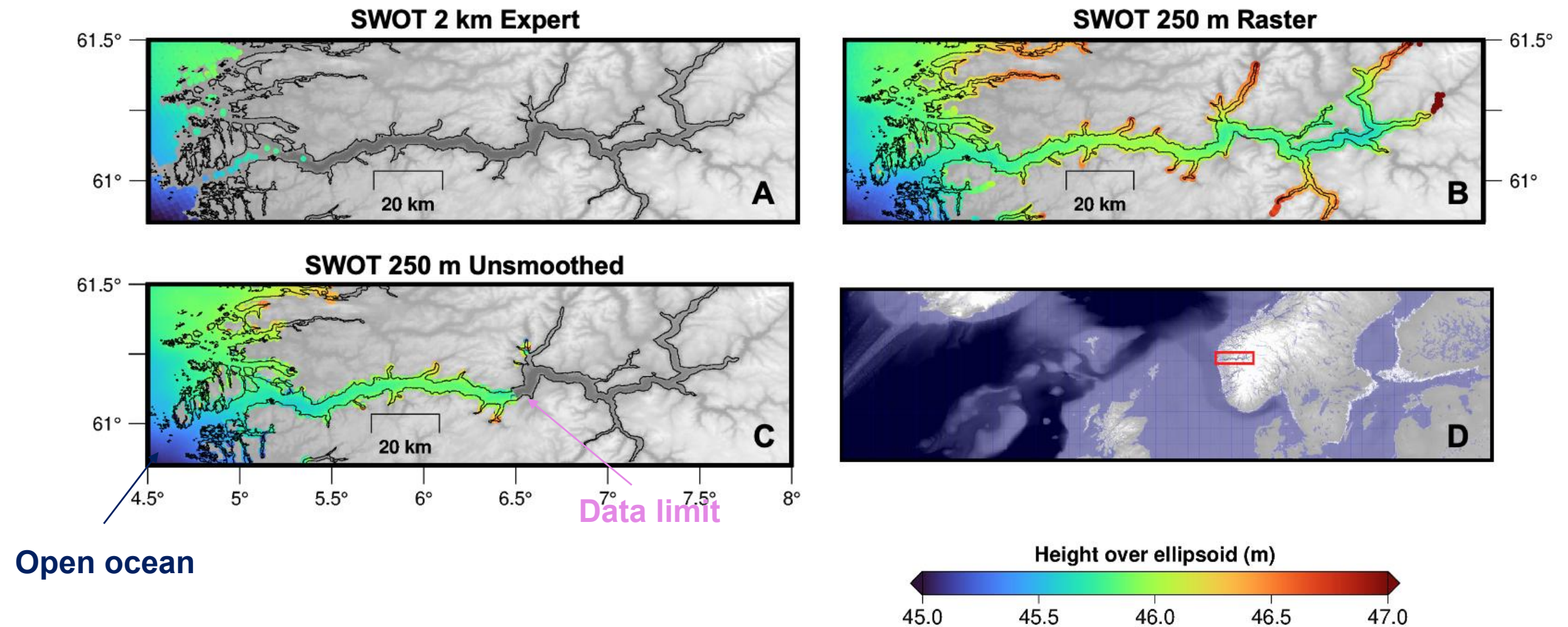
SWOT altimetry mission

- Wide-swath altimetry concept - based on the usage of radar interferometry at near-nadir incidence angles that enables centimeter-level accuracy of height measurements
- Suitable for the systematic mapping of small mesoscale and sub-mesoscale ocean features or smaller surface water bodies
- Ka-band Radar Interferometer (KaRIn) + the conventional nadir radar altimeter (Poseidon-3C)



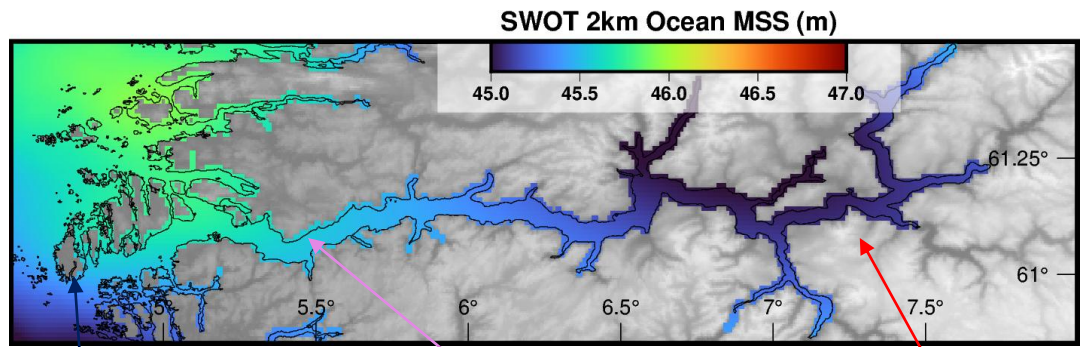
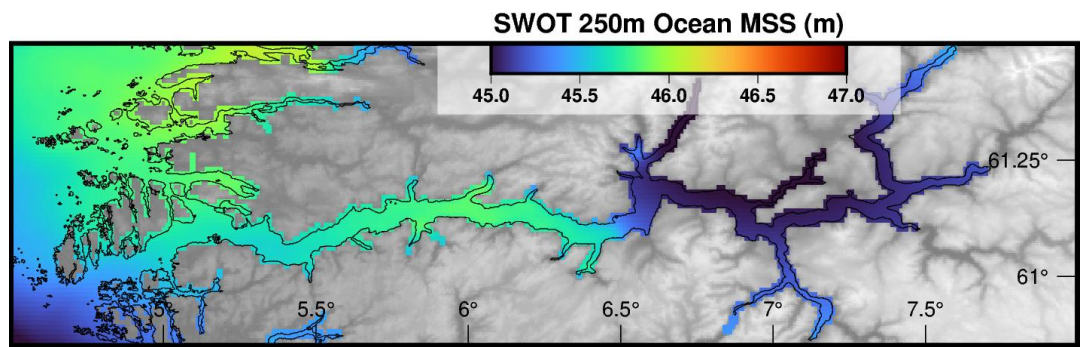
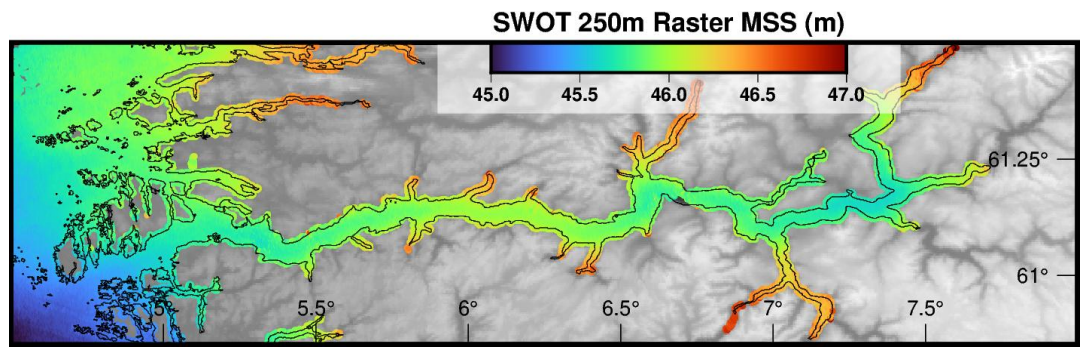
An animation showing how SWOT collects data over the state of Florida (NASA, 2024)

Coastal zone challenges – data coverage



A!

Coastal zone challenges – data coverage



A!
Open ocean

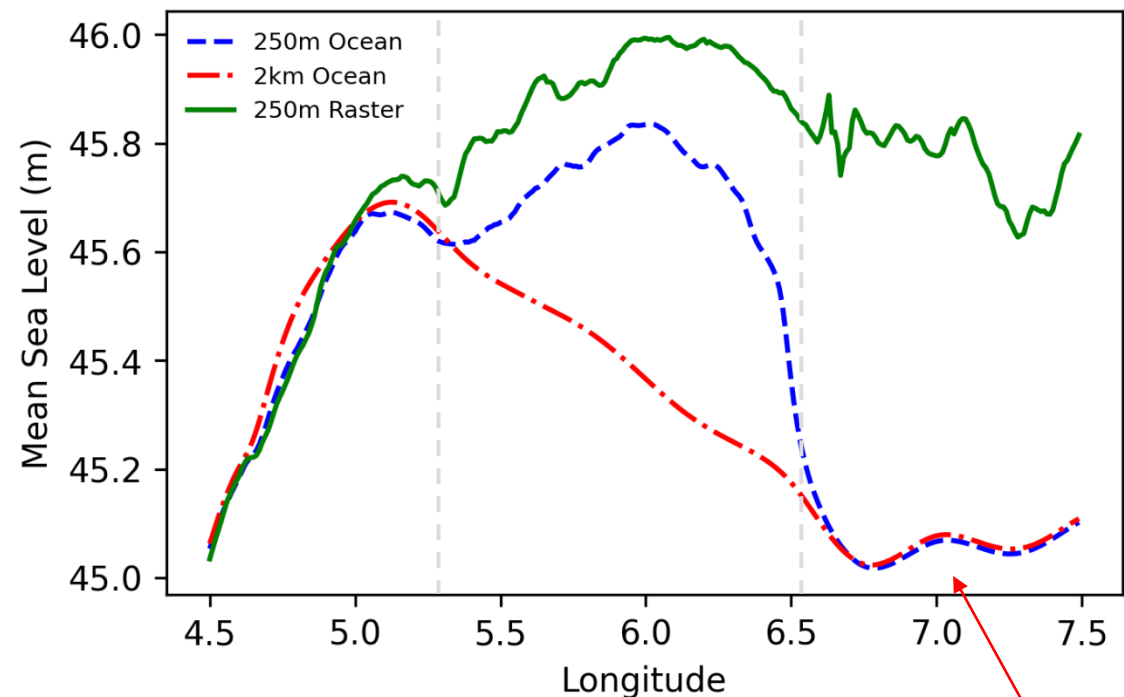
Data limit

extrapolation

Why we can use 250m raster and not 250m ocean:

- We have to estimate tidal constituents **along with** Mean Sea Level

Data limit

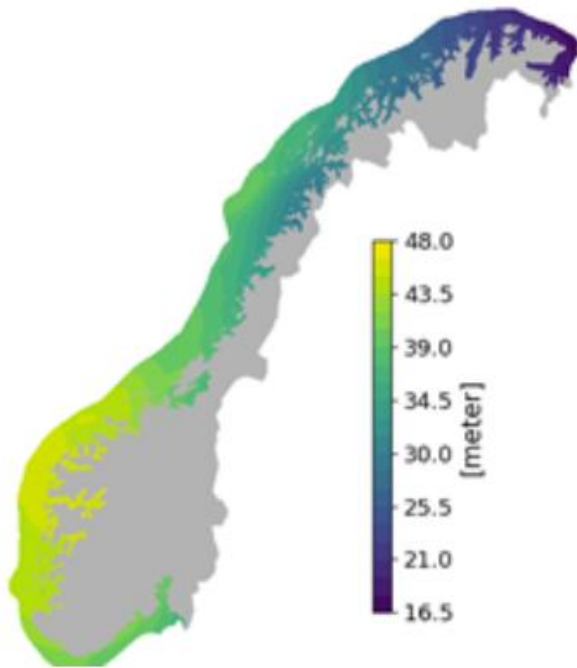


24.9.2026
extrapolation

Validation datasets

Regional separation model – MSL over ellipsoid

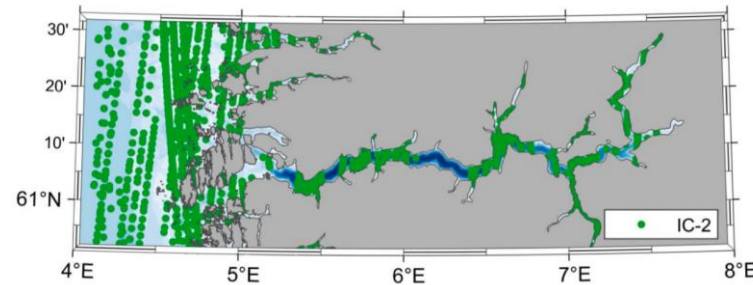
Based on in situ (TG + GNSS) data



ICESat-2

Pointwise measurements

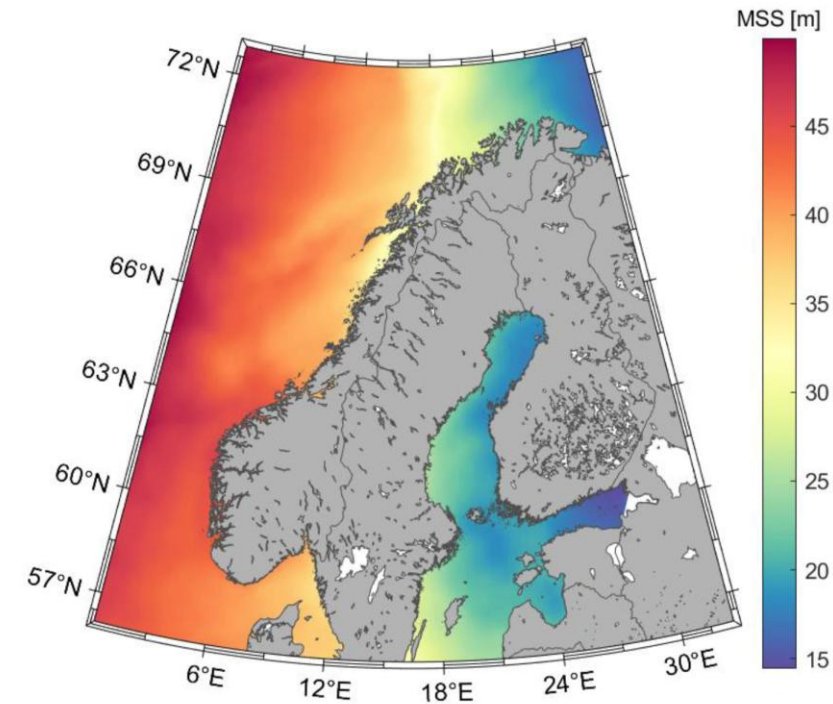
Large coverage but large noise



Tomić M., Andersen OB.
<https://doi.org/10.3390/rs15163974>

Regional MSS models

Based on satellite altimetry data



MSL over ellipsoid

SWOT 2km

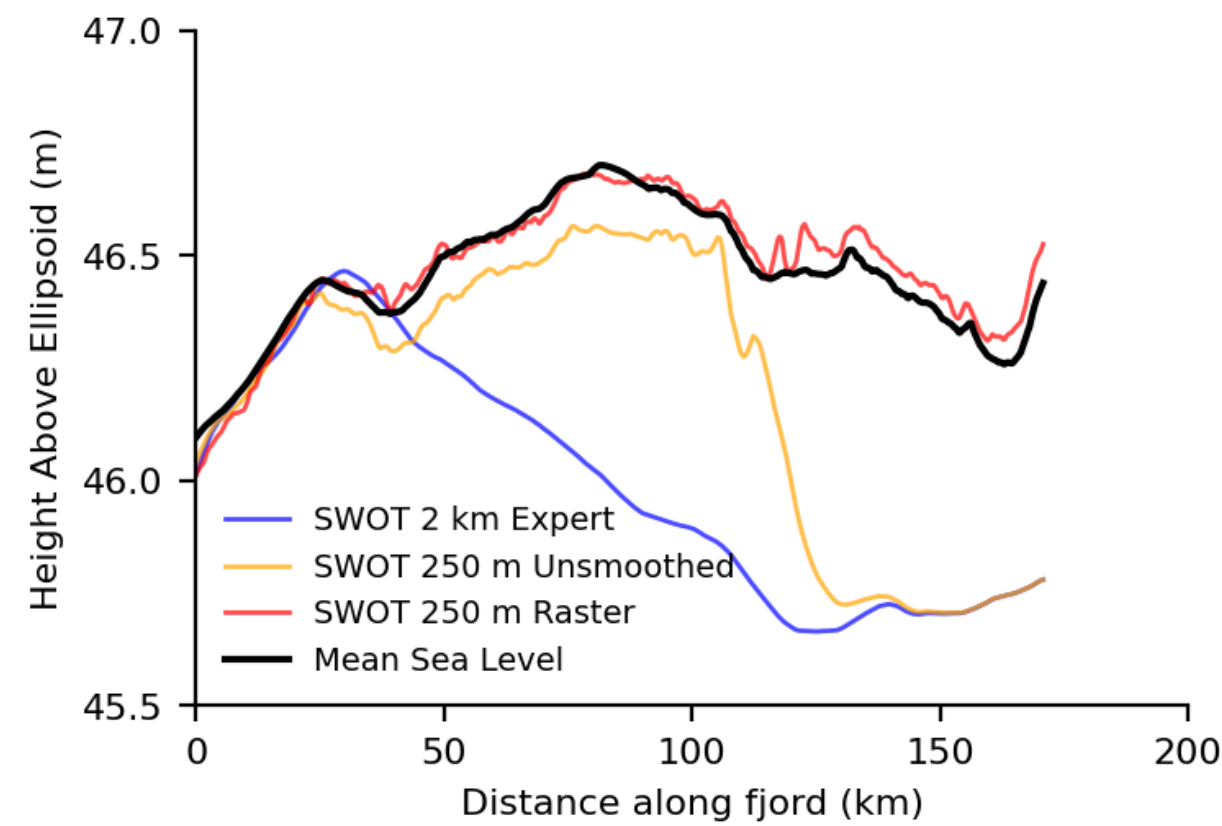
- Mean: -0.34 m
- SD: 0.37 m
- RMSE: 0.50 m

SWOT 250m

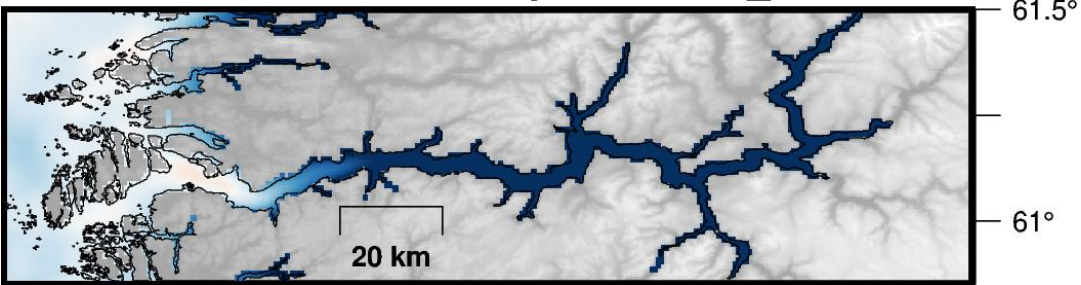
- Mean: -0.19 m
- SD: 0.31 m
- RMSE: 0.31 m

SWOT Raster 250m

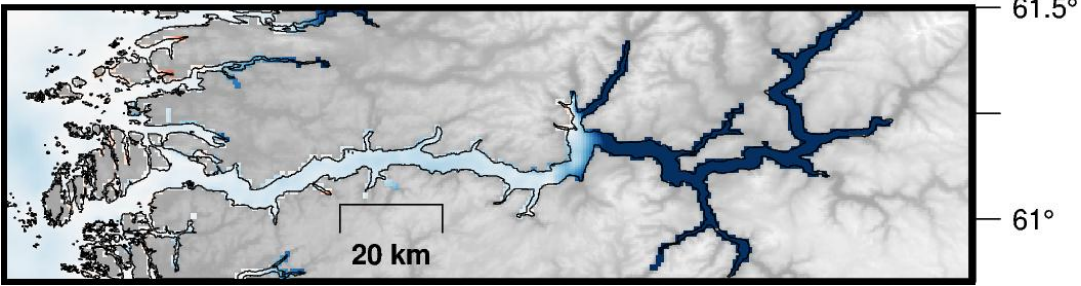
- Mean: 0.00 m
- SD: 0.07 m
- RMSE: 0.07 m



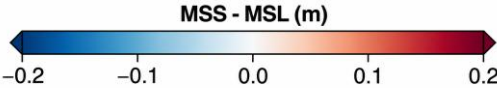
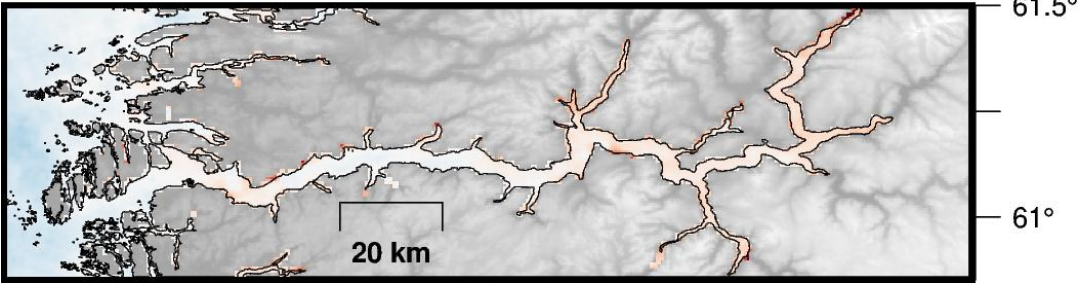
SWOT 2 km Expert – MSL_KV



SWOT 250 m Unsmoothed – MSL_KV

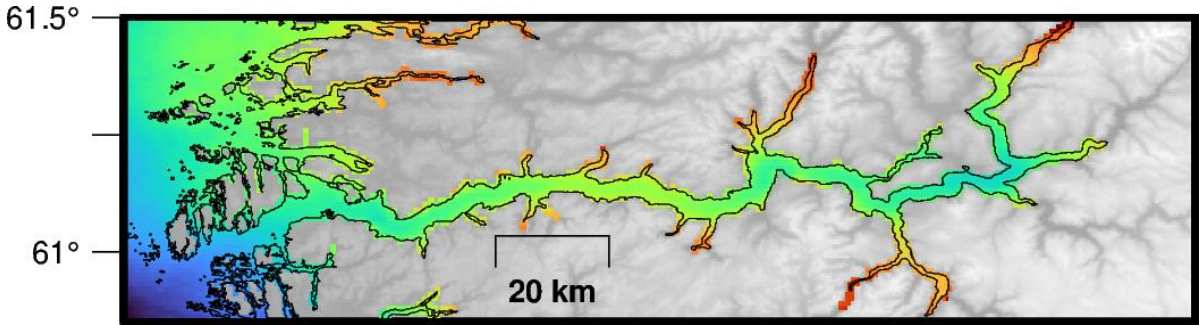


SWOT 250 m Raster – MSL_KV

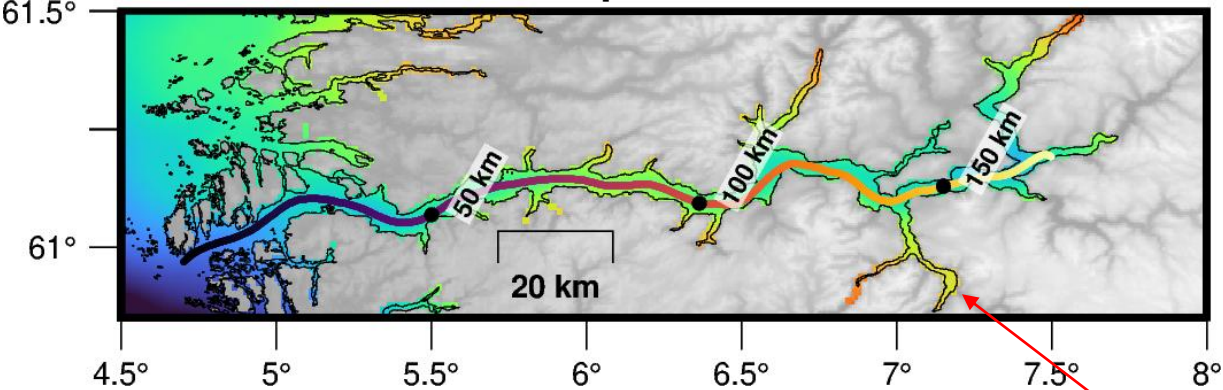


MSL over ellipsoid

SWOT 250 m Raster



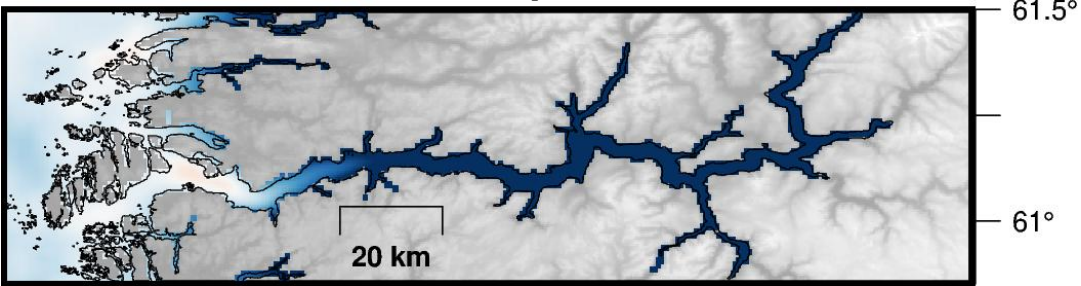
MSL over ellipsoid



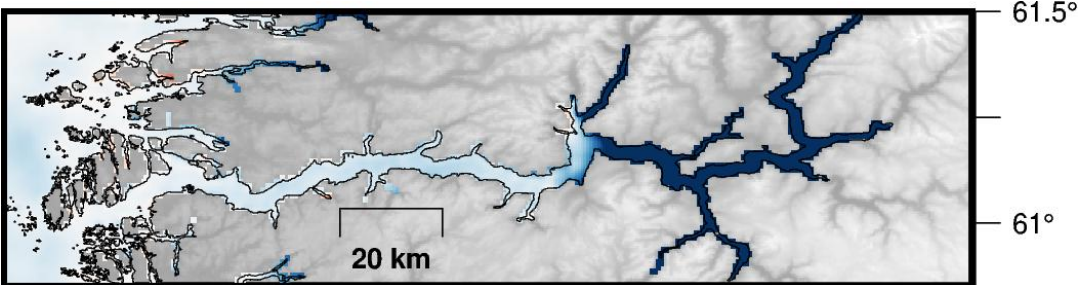
A!

Differences in side-fjords

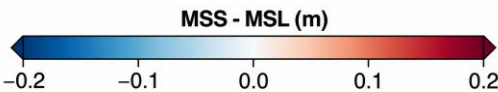
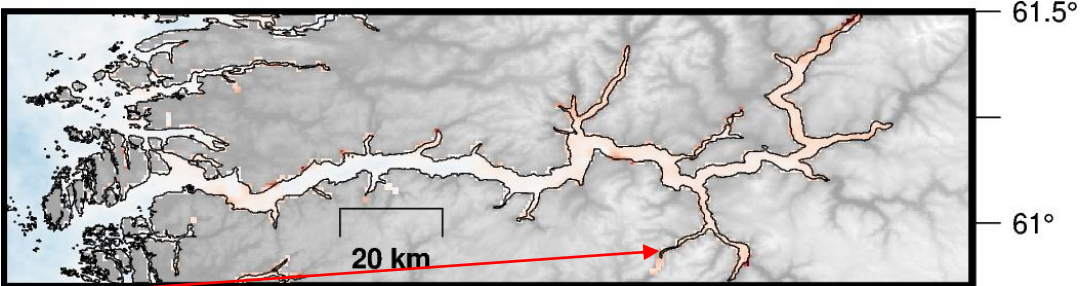
SWOT 2 km Expert – MSL



SWOT 250 m Unsmoothed - MSL



SWOT 250 m Raster - MSL



ICESat-2 data

WEST of 6.5 longitude

SWOT 2km

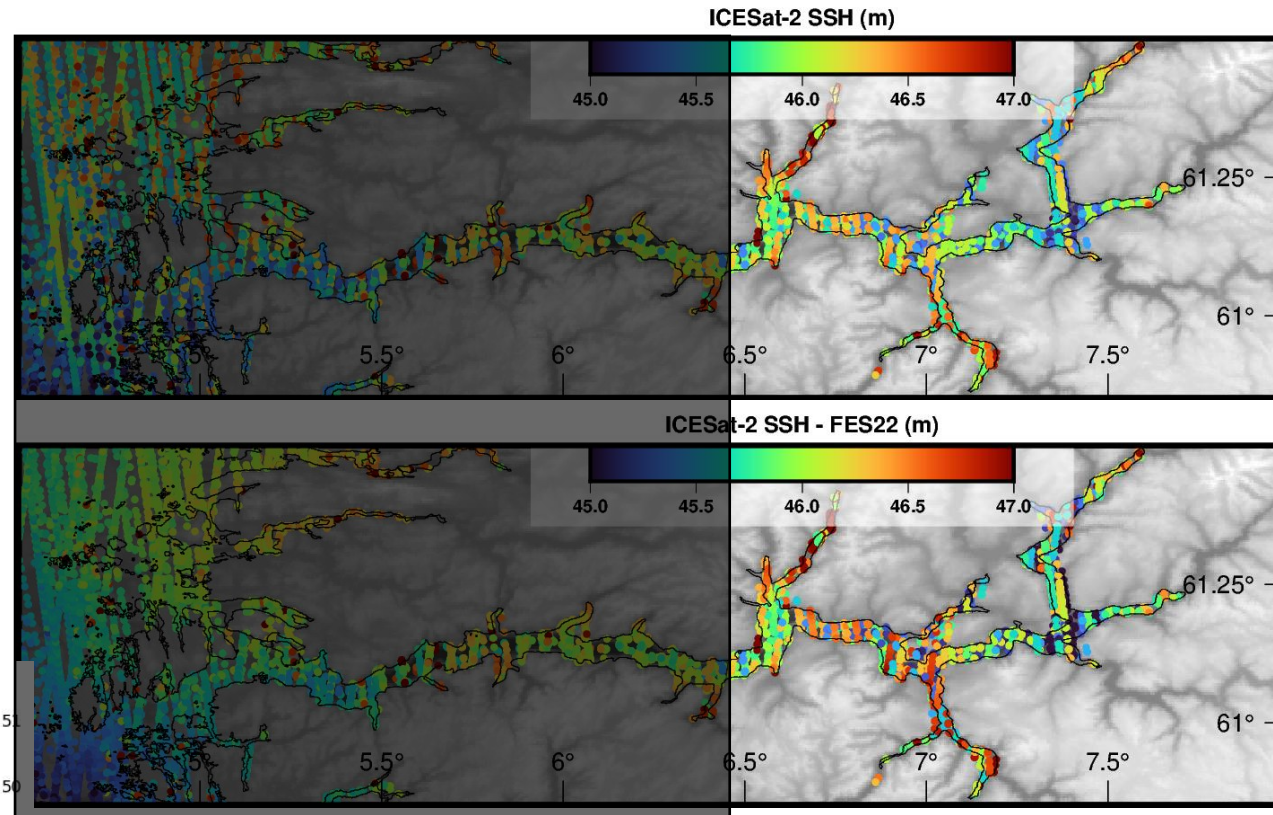
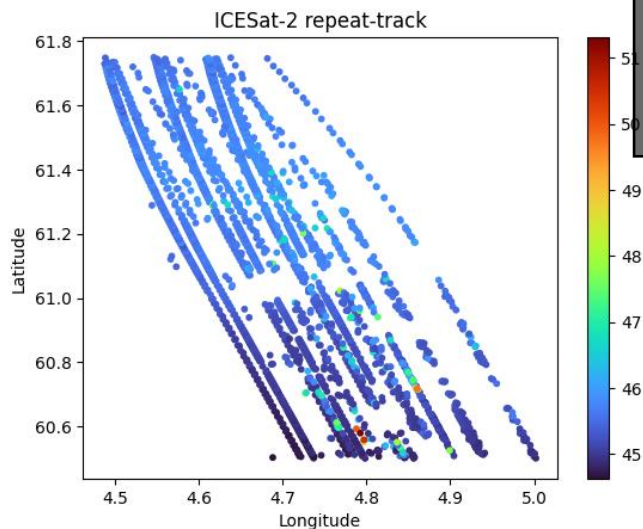
- Mean -0.34 m
- RMSE 0.61 m

SWOT 250m

- Mean -0.28 m
- RMSE 0.57 m

SWOT Raster 250m

- Mean -0.02 m
- RMSE 0.38 m



East of 6.5 longitude

SWOT 2km

- Mean -0.80 m
- RMSE 0.98 m

SWOT 250m

- Mean -0.79 m
- RMSE 0.95 m

SWOT Raster 250m

- Mean -0.07 m
- RMSE 0.50 m

NMBU MSS models

- NMBU18MSS – based only on radar altimetry data
- NMBU23MSS – SAR + ICESat-2

Difference with SWOT raster:

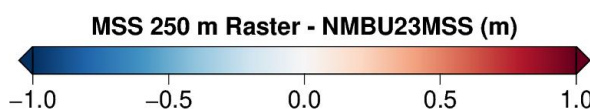
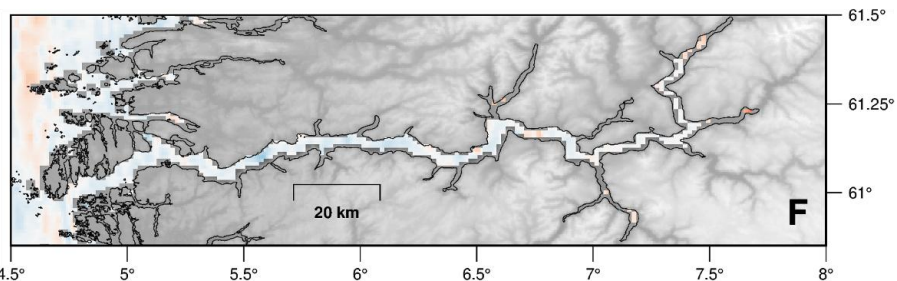
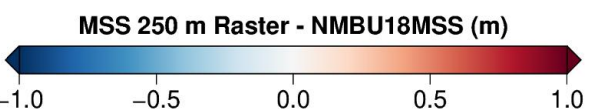
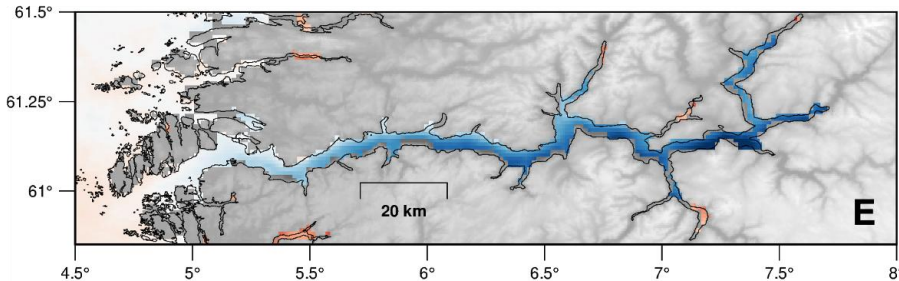
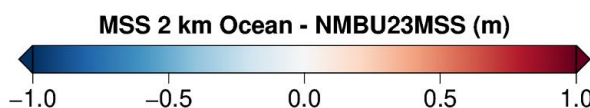
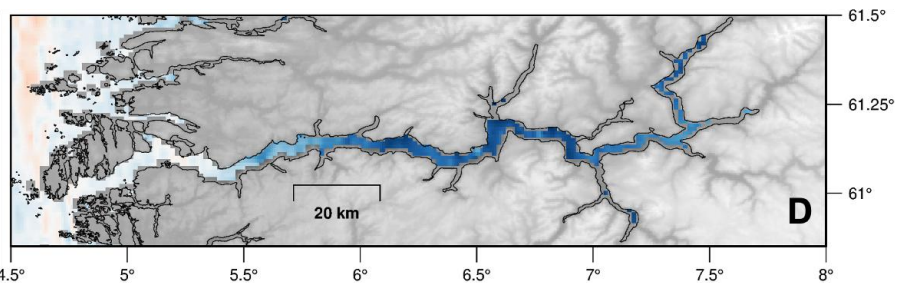
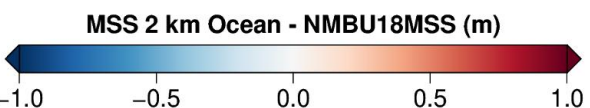
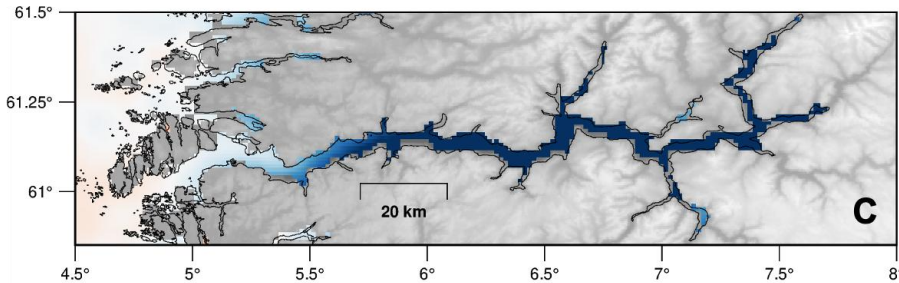
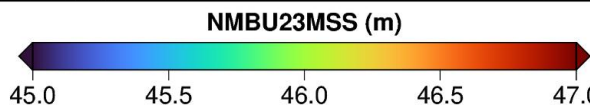
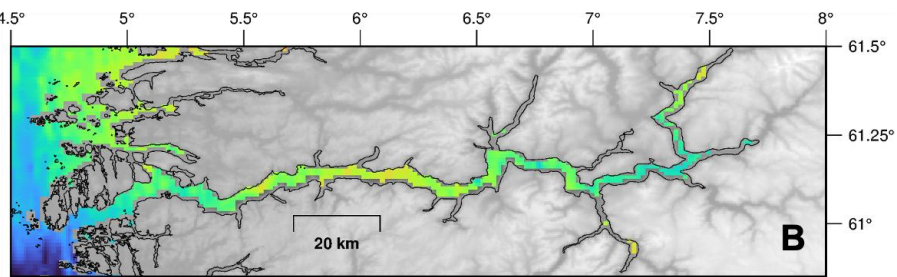
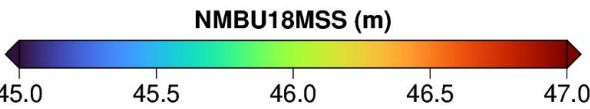
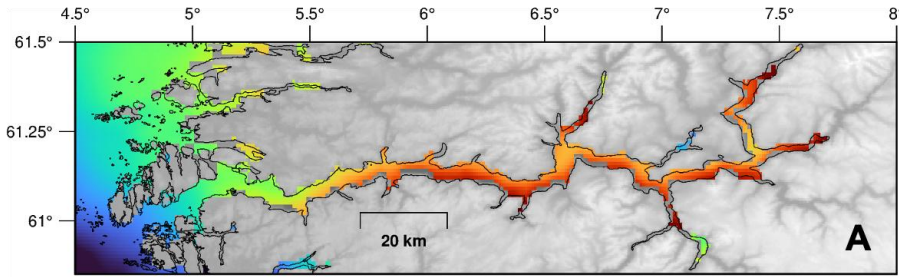
NBMU18MSS

- Mean 0.13 m
- RMSE 0.35 m

NBMU23MSS

- Mean 0.03 m
- RMSE **0.09 m**

A!



Key takeaways

- SWOT 250 km raster provides data in the whole Sognefjorden
- Very good results in comparison with NMA separation model based on in situ data
- Problems with ICESat-2 data in the part of the fjord east of 6.5 degrees
- Compared to NMBU MSS models, better results are obtained in comparison with NMBU23, that includes ICESat-2 laser altimetry data, than NMBU18, based only on radar altimetry data
- Study is planned to be published soon (manuscript in preparation)

A!

—

Kiitos
aalto.fi