Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

Baltic SEAL: new insights into the mean and variability of the sea level in the Satellite Altimetry era

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BALTIC SEAL

Table of Content

- Motivation and key development steps
- Results 1: a new regional mean sea surface
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- Results 3: an experimental high temporal resolution grid
- The way forward

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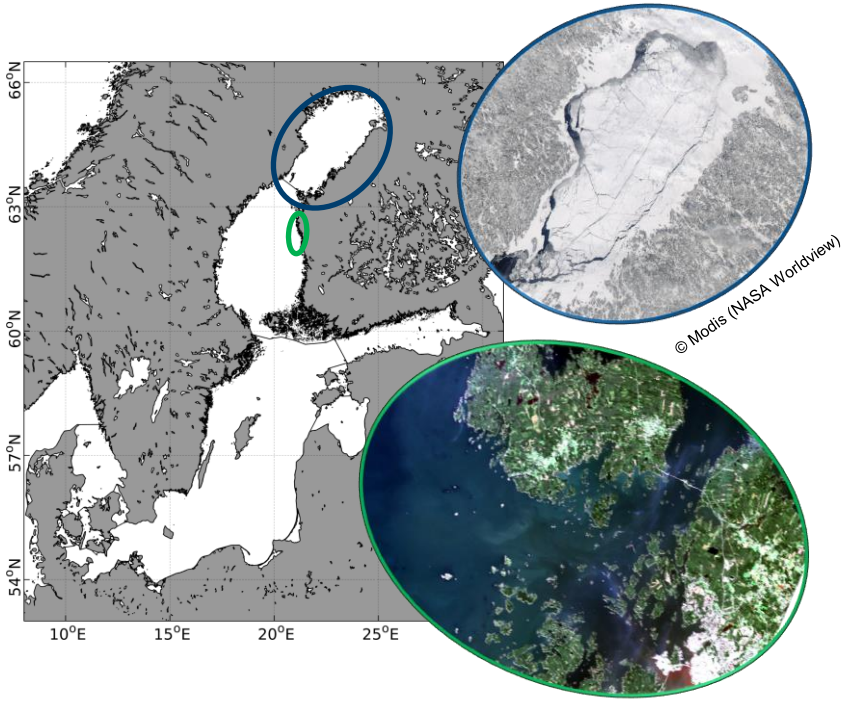
The Baltic+ Sea Level (BALTIC SEAL) – Motivation

What?

- Generation of a novel multi-mission sea level (MMSL) along-track and gridded product

Why?

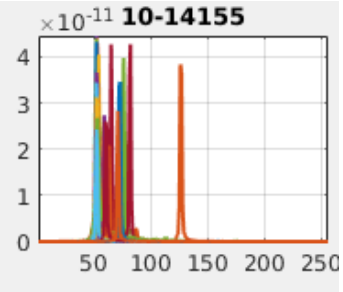
- Previous products do not include information from the sea-ice covered surface and from the coastal zone

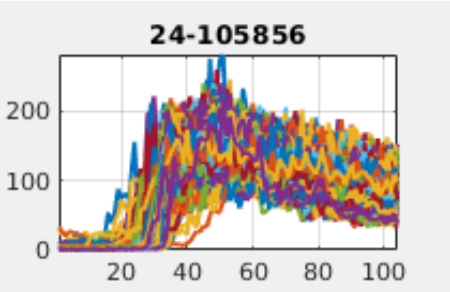


- Improvements in algorithms (classification, retracking), geophysical adjustments and corrections, radar techniques (Delay-Doppler Altimetry)

- Perfect laboratory for Satellite Altimetry (challenging coastlines, sea-ice coverage, small scale variability)

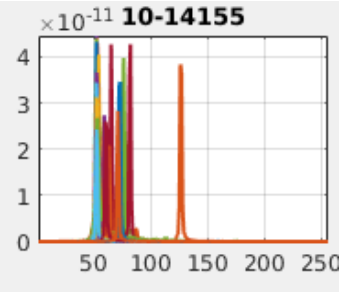
Baltic+ SEAL – Algorithm Development Challenges

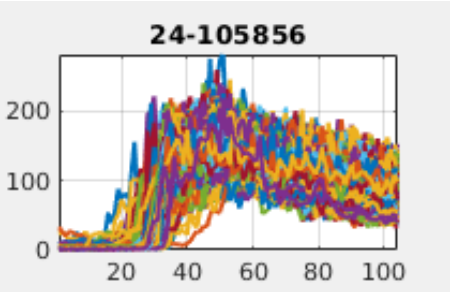




UNSUPERVISED WAVEFORM CLASSIFICATION

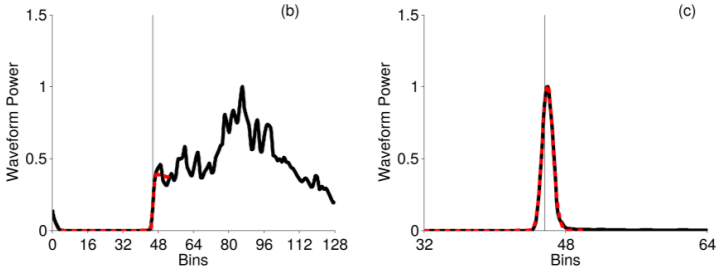
Baltic+ SEAL – Algorithm Development Challenges



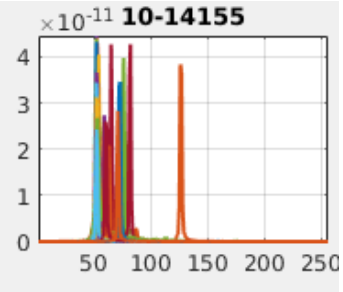


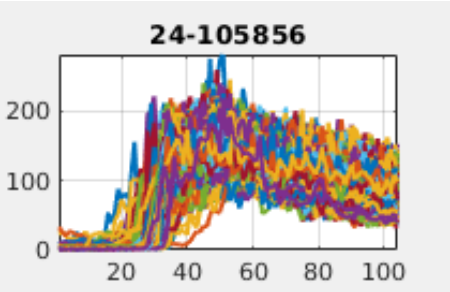
UNSUPERVISED WAVEFORM CLASSIFICATION

WAVEFORM RETRACKING



Baltic+ SEAL – Algorithm Development Challenges





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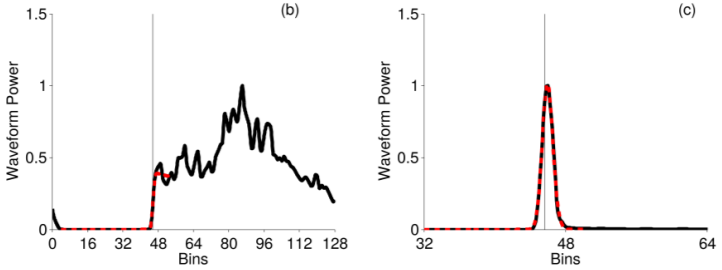
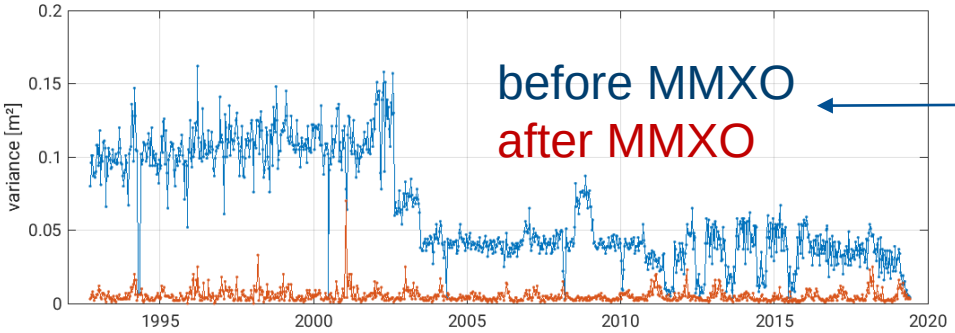
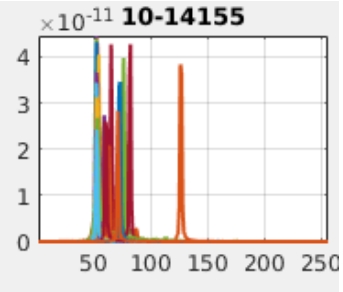
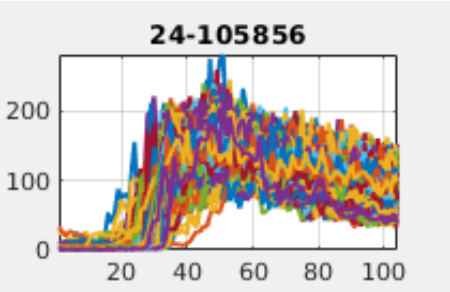




MULTIMISSION CROSSCALIBRATION

Baltic+ SEAL – Algorithm Development Challenges





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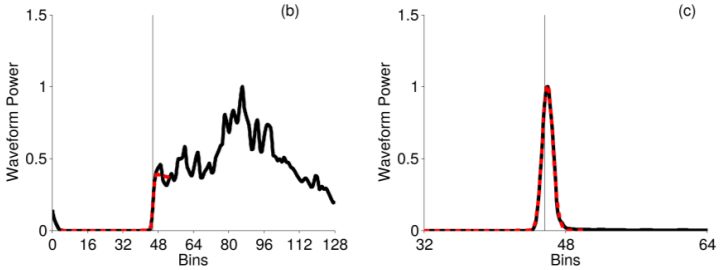
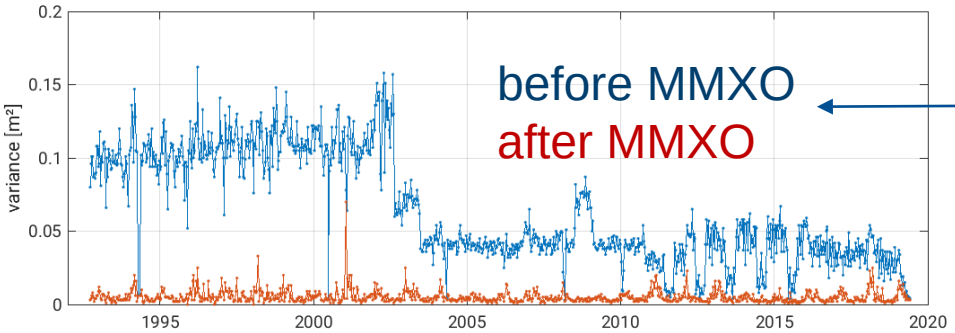
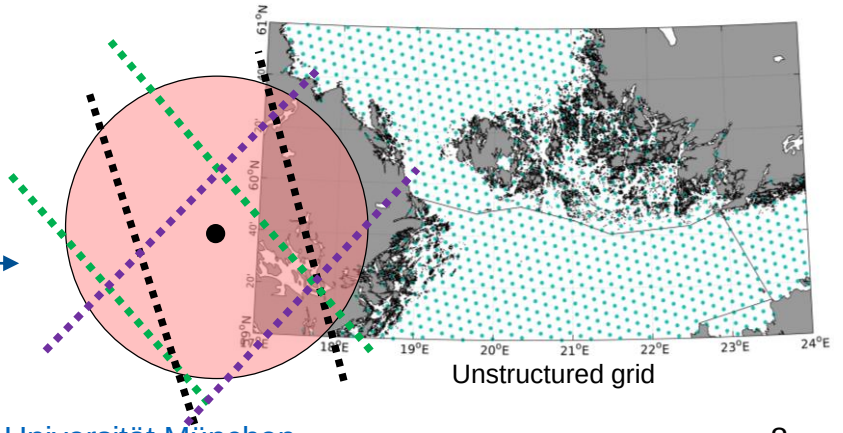


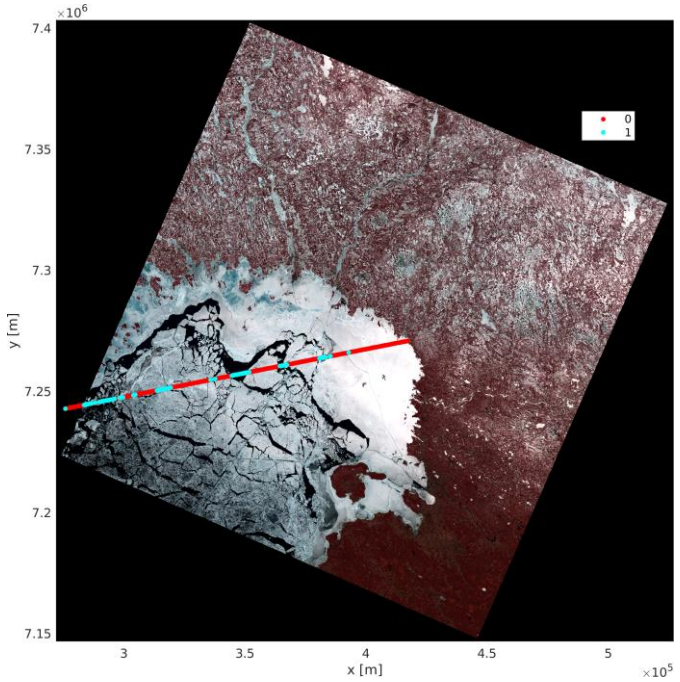


MULTIMISSION CROSSCALIBRATION

GRIDDING



Baltic+ SEAL – Validation steps



More info*: Müller F.L et al.*: **Monitoring the Arctic Seas: How Satellite Altimetry Can Be Used to Detect Open Water in Sea-Ice Regions**. Remote Sensing, 9(6), 551, 10.3390/rs9060551, 2017c

Validation of classification with SAR and Optical images

Validation of sea level products through tide gauges

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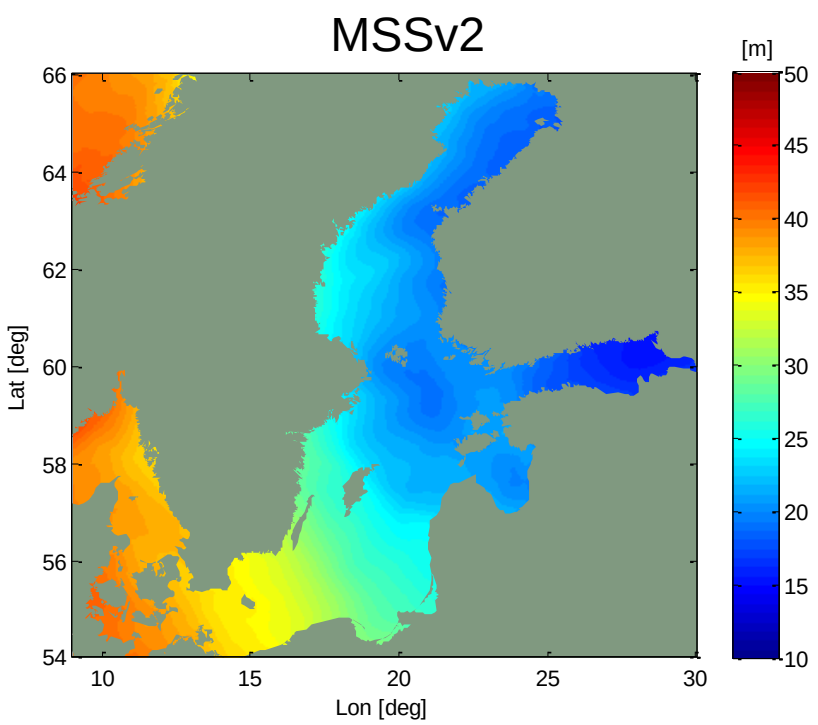
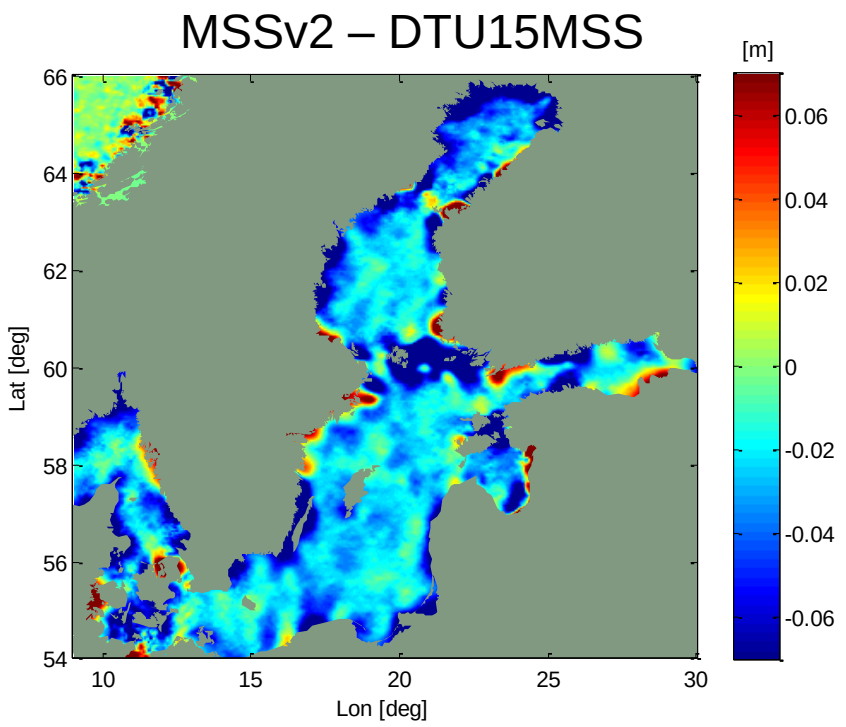
A Mean Sea Surface for the Baltic Sea

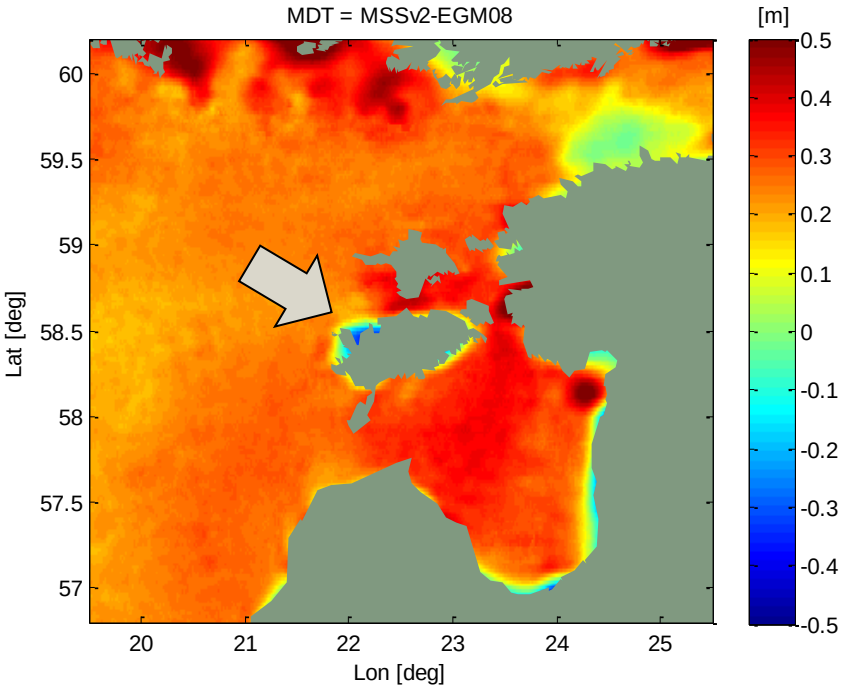
- Major improvements observed near the coast
- Regional Mean Sea Surface available, including quality flag

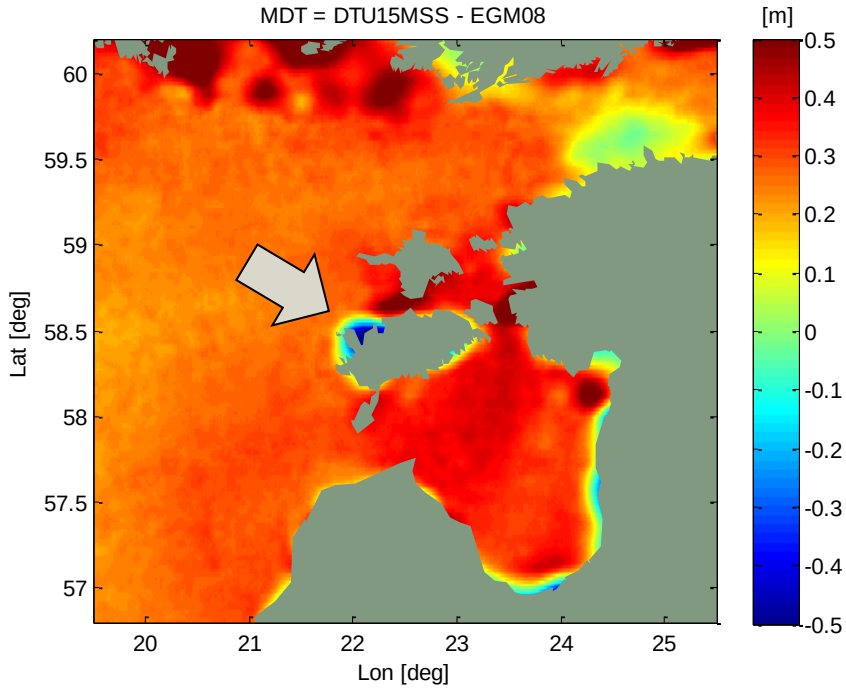




A Mean Sea Surface for the Baltic Sea

NOTE: Mean Dynamic Topography is getting more homogenous towards the coast.





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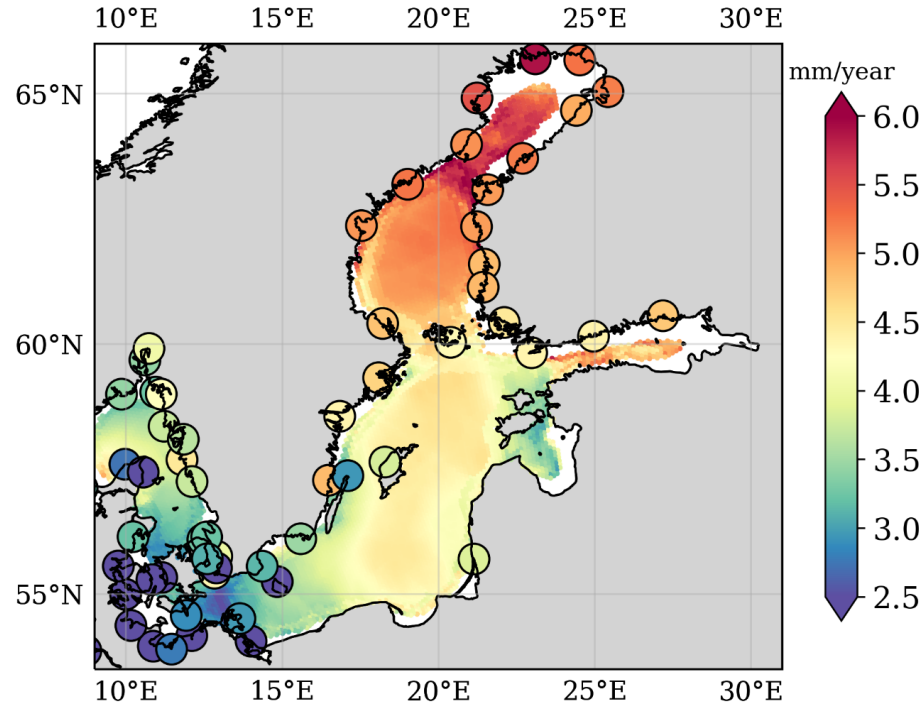
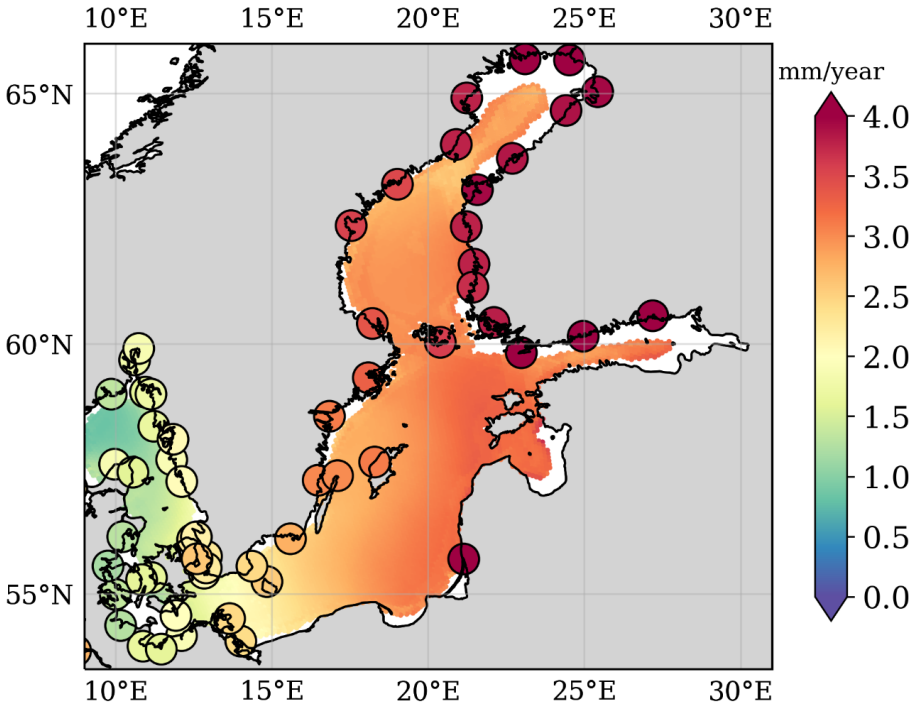
Trends and Annual Cycle 1995-2019

a) SAT and TG trends (NKG2016 corrected)



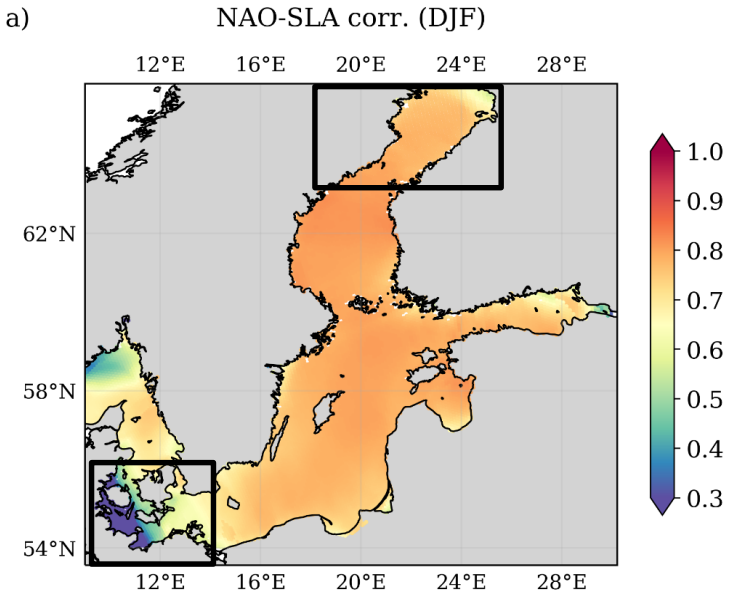
b) Trend uncertainties, AR1 (CI: 95%)

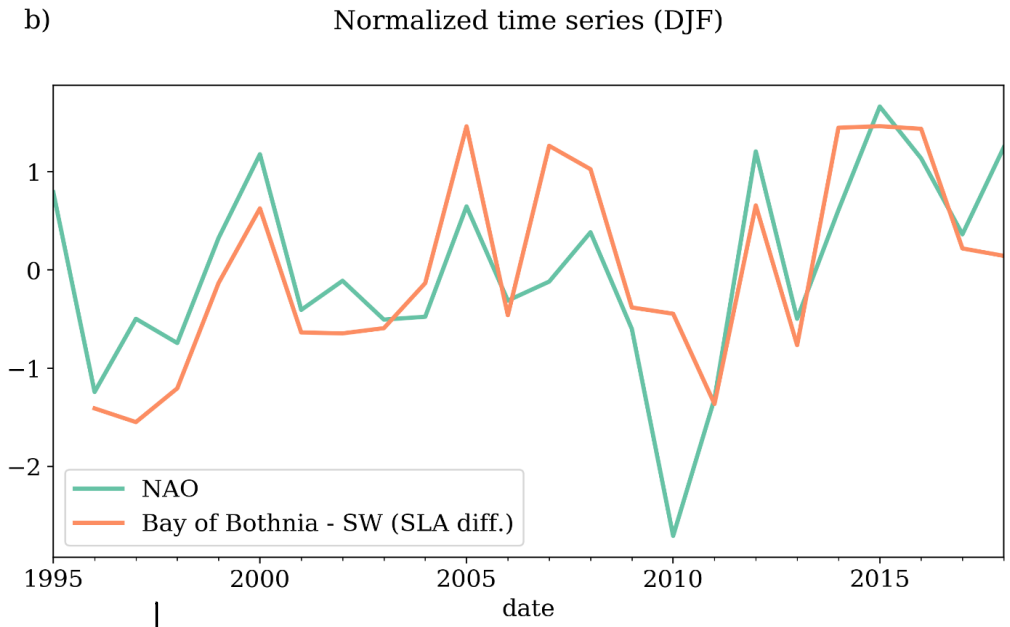


Trend: 4.27 ± 3.58 mm/year

Sea level is increasing all across the basin

Spatial gradients in the sea level trend





(see also e.g. Jevrejeva et al. 2005; Hünicke and Zorita 2006;
Karabil et al. 2018; Gräwe et al. 2019)

0.7
correlation

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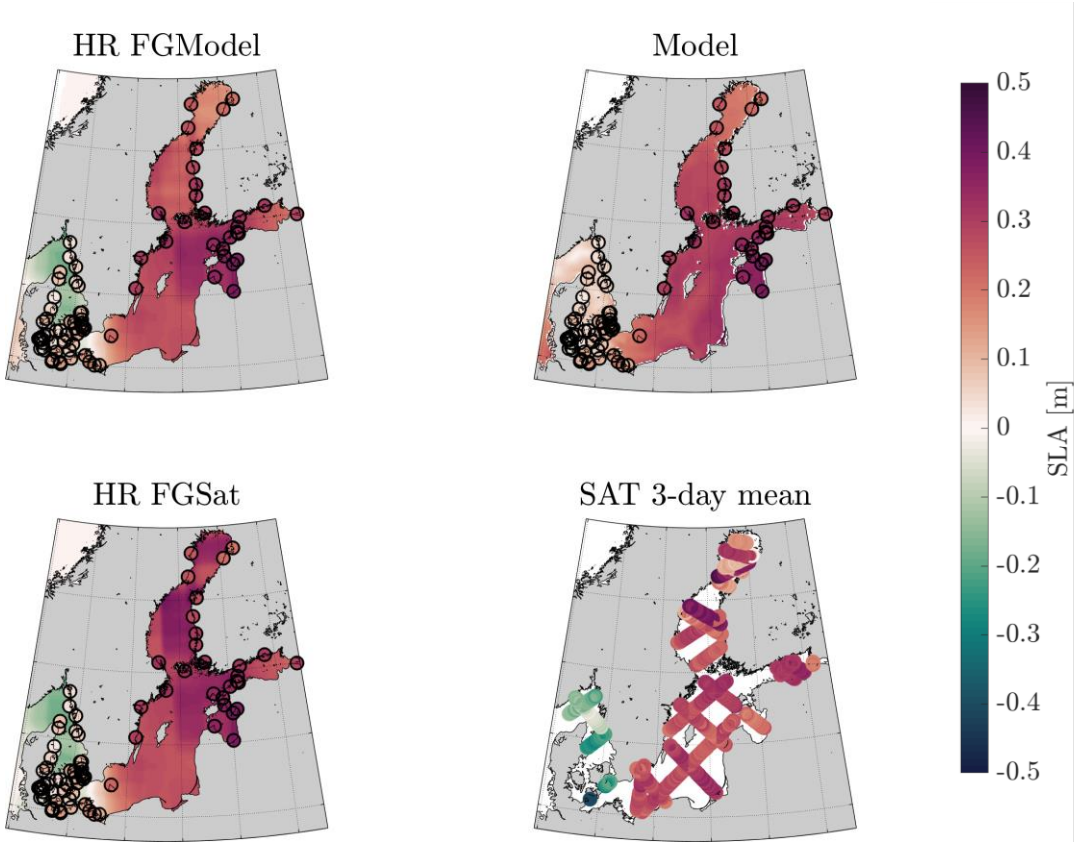
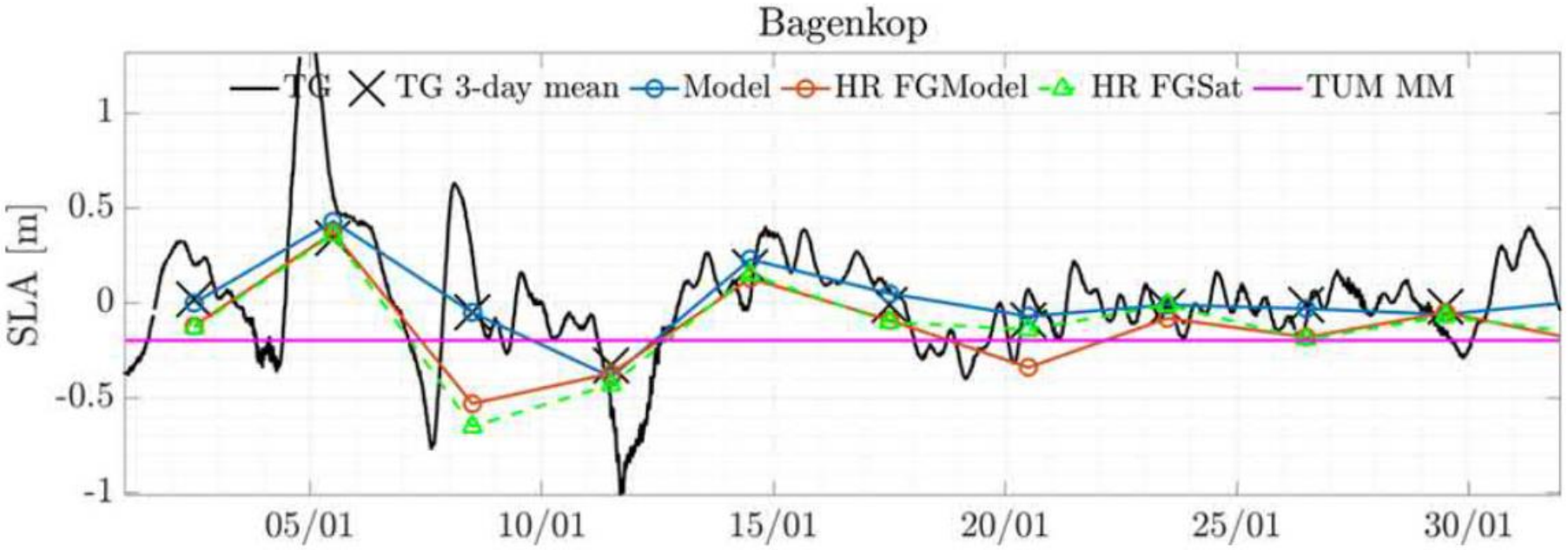
3-days experimental gridded product



- Combination of 3-days of altimetry along-track observations (SAT 3-day), with 3-day-mean of tide gauges (circles) to generate blended gridded products (HR FGModel, HR FGSat)

3-day period: 1st of January to 3rd of January (2017)

3-days experimental gridded product



- A potential use of this HR product is to improve through observations the preconditions for storm surge simulations before extreme sea level events.

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Where do we go from here? The „Baltic Sea Lab“…

1) **Synergies:** multi-variable observation of Atlantic Inflow and recirculation within the Baltic Sea (using salinity and temperature dataset)

2) Synergies: increase the performances of **Vertical Land Motion** estimation by Tide Gauge-Altimetry, perfect validation set up thanks to extensive GNSS network and the geodetic SAR technique

3) **Wave Height** climate, variability, trends and extremes: latest wave height data based on advanced altimetry processing show significant progresses in the coastal zone, and abatement of the measurement noise and wave spectral variability. The Baltic Sea shall „host“ both exploitation work and research on further improvements!

4) Advanced **coastal altimetry grids**: Baltic+ SEAL first attempt to produce them. Further studies shall investigate: irregular capsize, covariance based on external dataset, integration/validation for SWOT

5) **Export best practice** to other regions with complex coastlines and/or partial sea-ice coverage

Thank you and Acknowledgment

These developments were produced by a multi-disciplinary team spanning four countries – the Technical University of Munich (DE), the Technical University of Denmark's Space Institute (DK), the Finnish Meteorological Institute (FI), the Danish Meteorological Institute (DK), and University College Cork (IE). This collaboration was overseen, and supported by ESA under the Baltic+ element of the European Space Agency's Earth Observation Envelope Programme 5 (EOEP5) Regional Initiative. It arose in direct response to major discussion points gathered during the "Baltic from Space Workshop" hosted by FMI in Helsinki in March, 2017.

BALTIC SEAL

Thank you for reading and listening!

For further information, go to http://www.balticseal.eu, or contact info@balticseal.eu

SPARE SLIDES

More Information

Product download and documentation is available via the Baltic SEAL website. This includes the requirements analysis, validation reports, algorithm theoretical basis documents, and impact assessment reports. The scientific roadmap is also made available, charting a course forward for the various scientific advances made by the Baltic SEAL team.

The Product Handbook describing the dataset is:

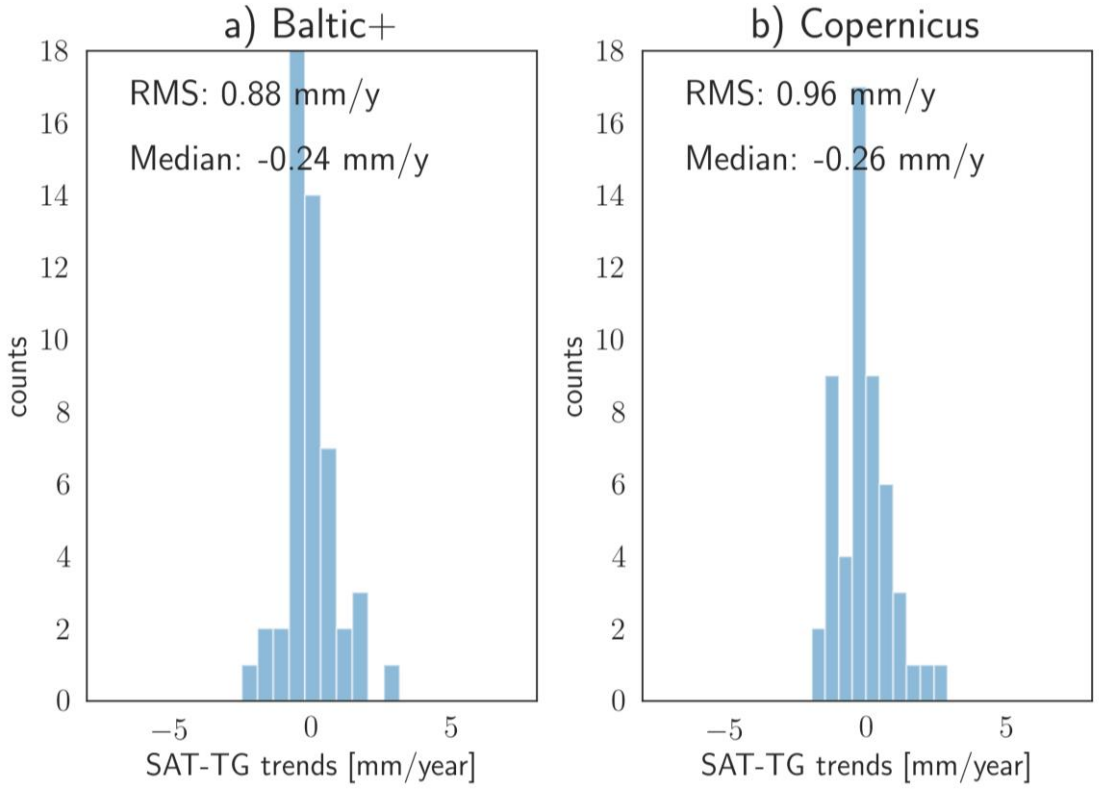
Passaro, M., Müller, F., Dettmering, D., Abulaitjiang, A., Rautiainen, L., Scarrott, R.G., Chalençon, E., Sweeney, M., (2021).Baltic SEAL: Product Handbook, Version 1.1.Reportdelivered under the BalticSEALproject (ESA contract no. 000126590/19/I/BG). DOI: http://doi.org/10.5270/esa.BalticSEAL.PH1.1

For further information, go to http://www.balticseal.eu, or contact info@balticseal.eu

An article has been submitted to Frontiers in Marine Science:

Passaro M., Müller F.L., Oelsmann J., Rautiainen L., Dettmering D., Hart-Davis M.G., Abulaitijiang A., Andersen O.B., Høyer J.L., Madsen K.S., Ringgaard I.M., Särkkä J., Scarrott R., Schwatke S., Seitz F., Tuomi L., Restano M., Benveniste J.: Absolute Baltic Sea Level Trends in the Satellite Altimetry Era: A Revisit, Frontiers in Marine Science, under review.

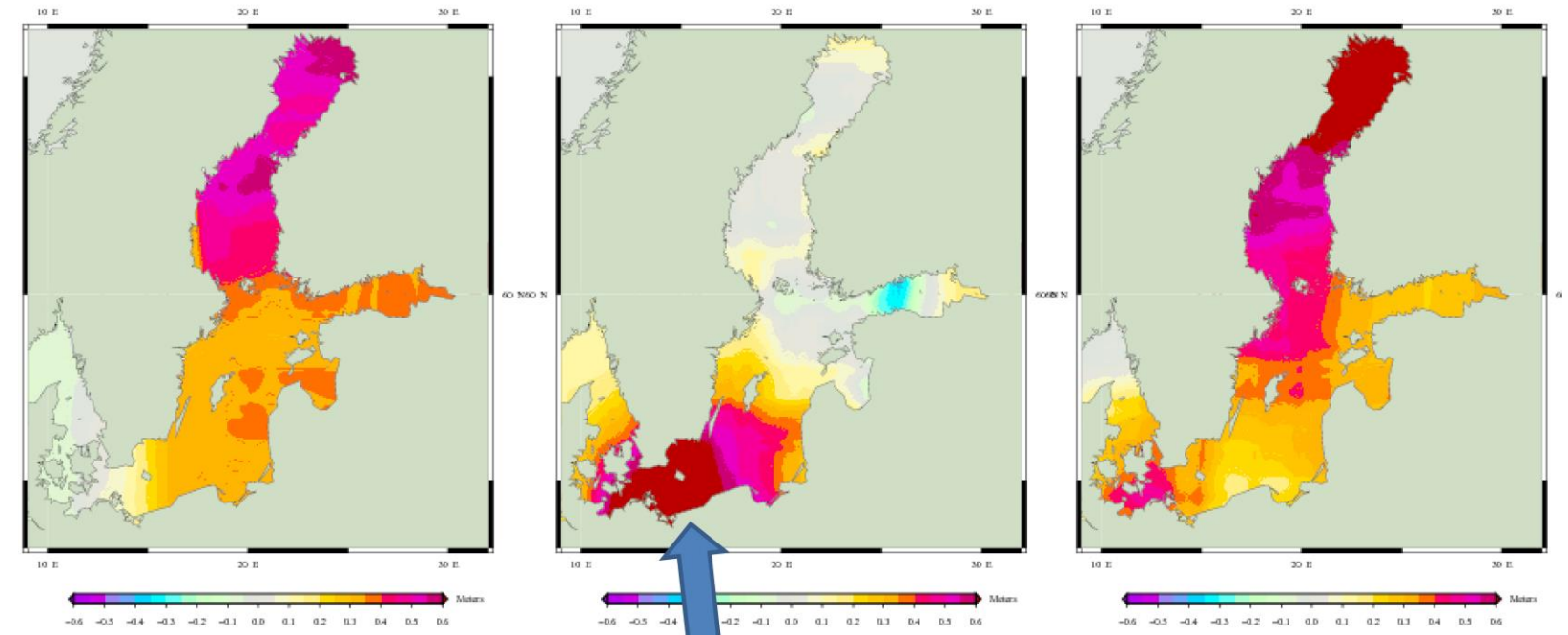
Comparison of trends



53 Tide gauges (Holgate et al., 2013; PSMSL, 2020) used to compare absolute sea level trends are corrected for DAC (Carrère and Lyard, 2003) and vertical land motions (NKG2016LU, Vestøl et al., 2019); Gridded products CMEMS, http://marine.copernicus.eu,

3-days experimental gridded product

Before… …During… …After



Silent storm surge

January 2017