

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

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Summary

- Motivation and key development steps
- Results 1: a new regional mean sea surface
- Results 2: trends and variability analysis (from monthly gridded product)
- Results 3: an experimental high temporal resolution grid
- The way forward



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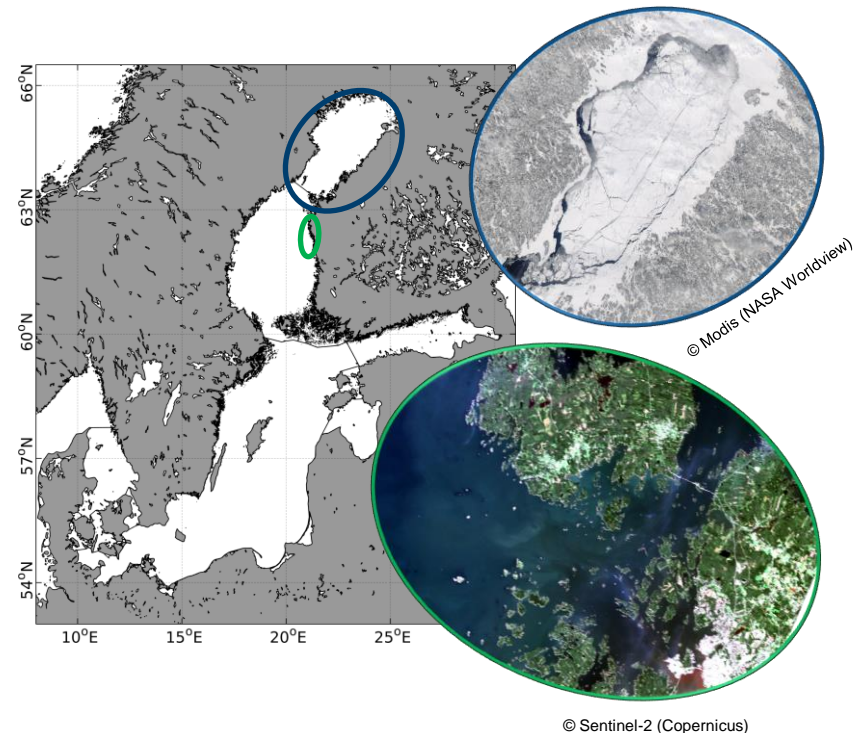
The Baltic+ Sea Level (BALTIC SEAL) – Motivation

What?

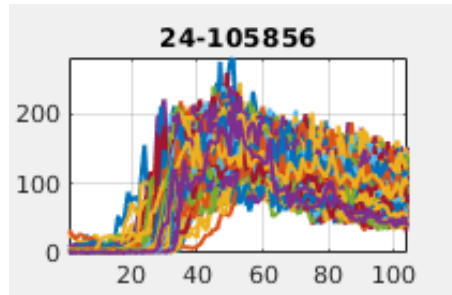
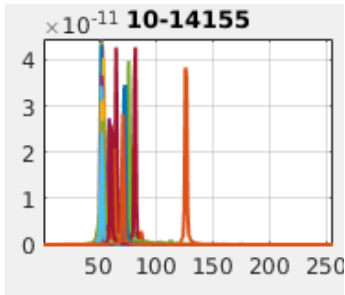
- Generation of a novel multi-mission sea level (MMSL) along-track and gridded product

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)



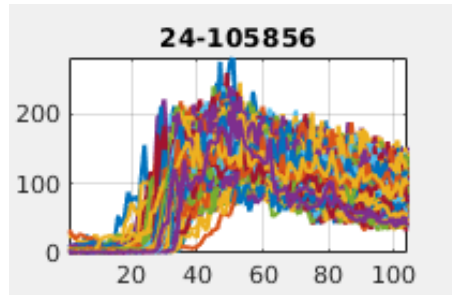
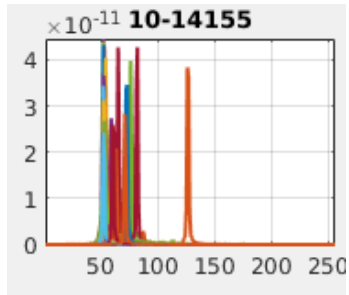
Baltic+ SEAL – Algorithm Development Challenges



UNSUPERVISED WAVEFORM
CLASSIFICATION

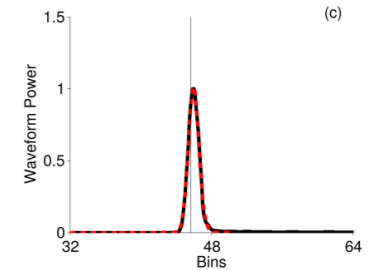
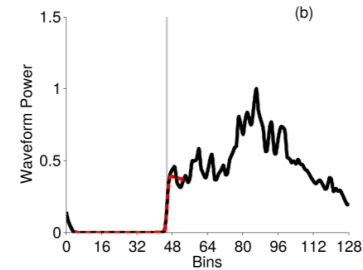


Baltic+ SEAL – Algorithm Development Challenges

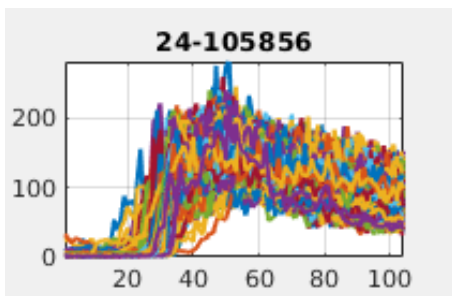
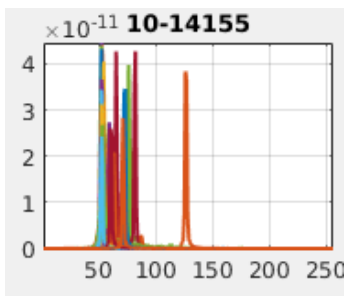


UNSUPERVISED WAVEFORM CLASSIFICATION

WAVEFORM RETRACKING

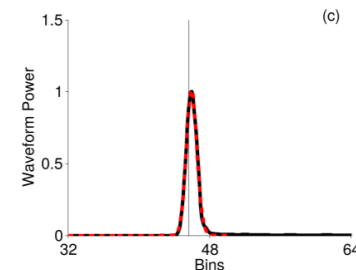
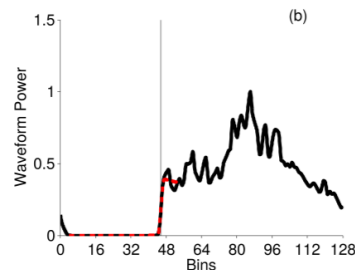


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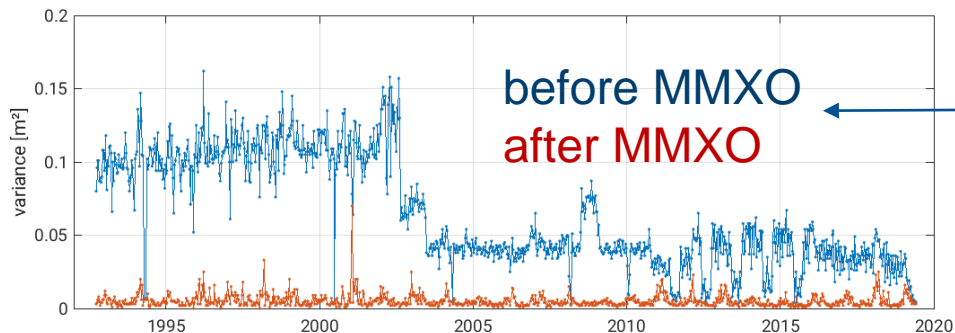


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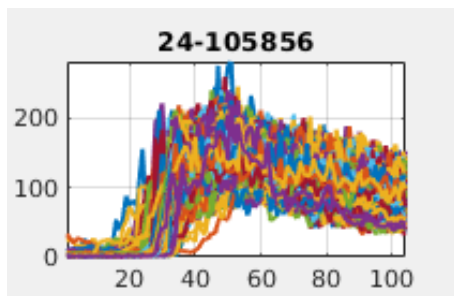
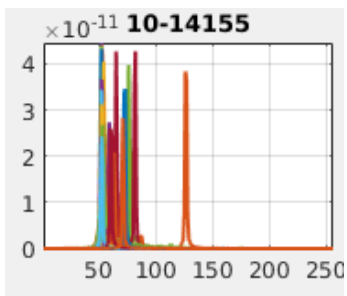
WAVEFORM RETRACKING



MULTIMISSION CROSSCALIBRATION

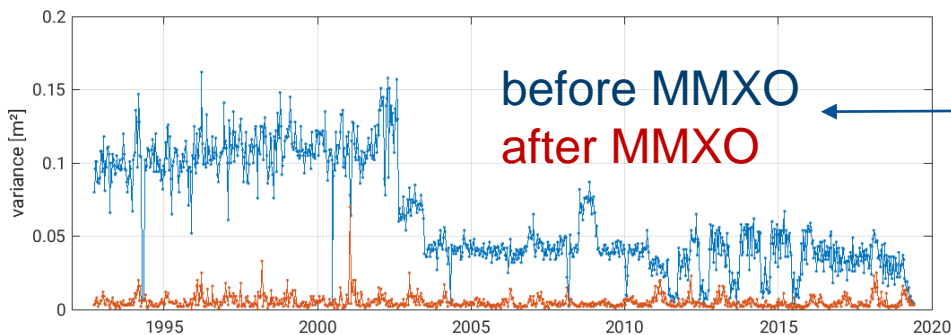
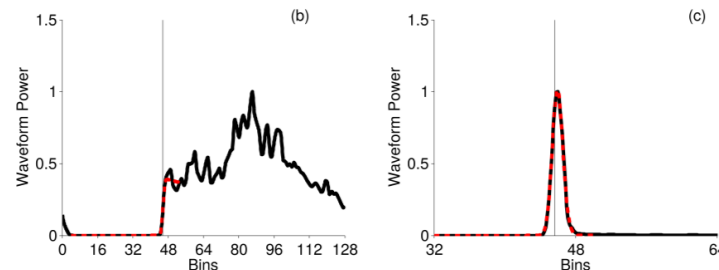


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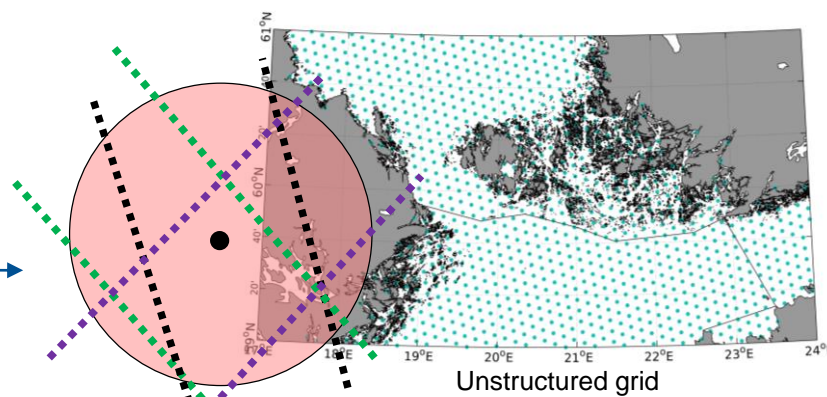
UNSUPERVISED WAVEFORM CLASSIFICATION

WAVEFORM RETRACKING



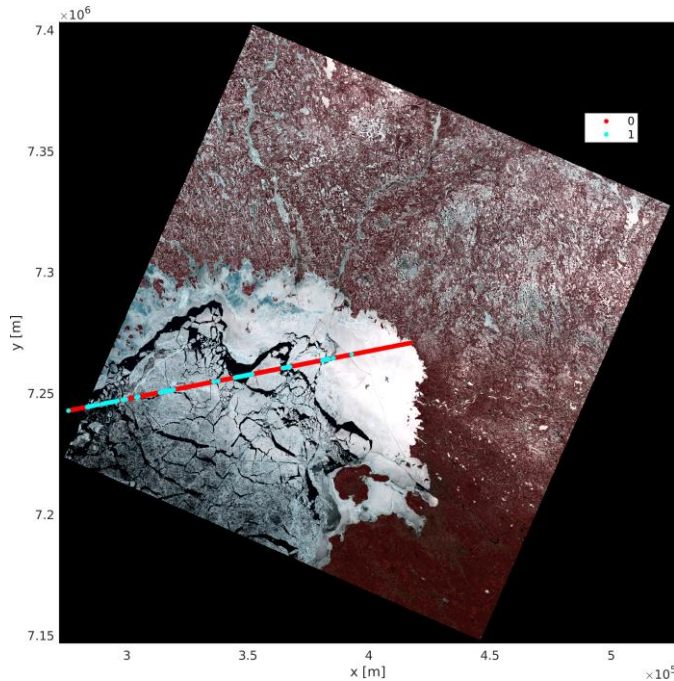
MULTIMISSION CROSSCALIBRATION

GRIDDING

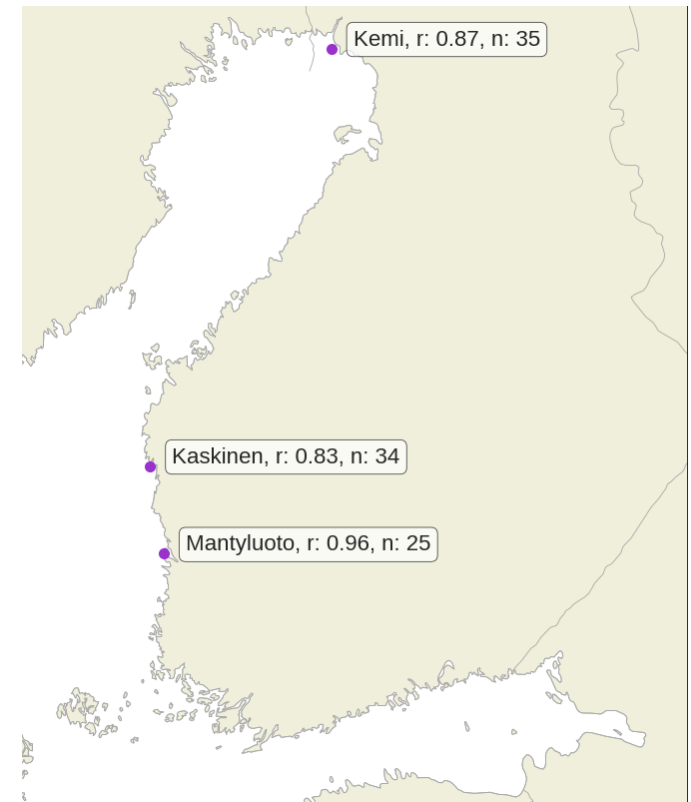


Baltic+ SEAL – Validation steps

Pearson's r for Cryosat 3-10 km away from the coast and TG



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](https://doi.org/10.3390/rs9060551), 2017c



Validation of classification with SAR and Optical images

Validation of sea level products through tide gauges

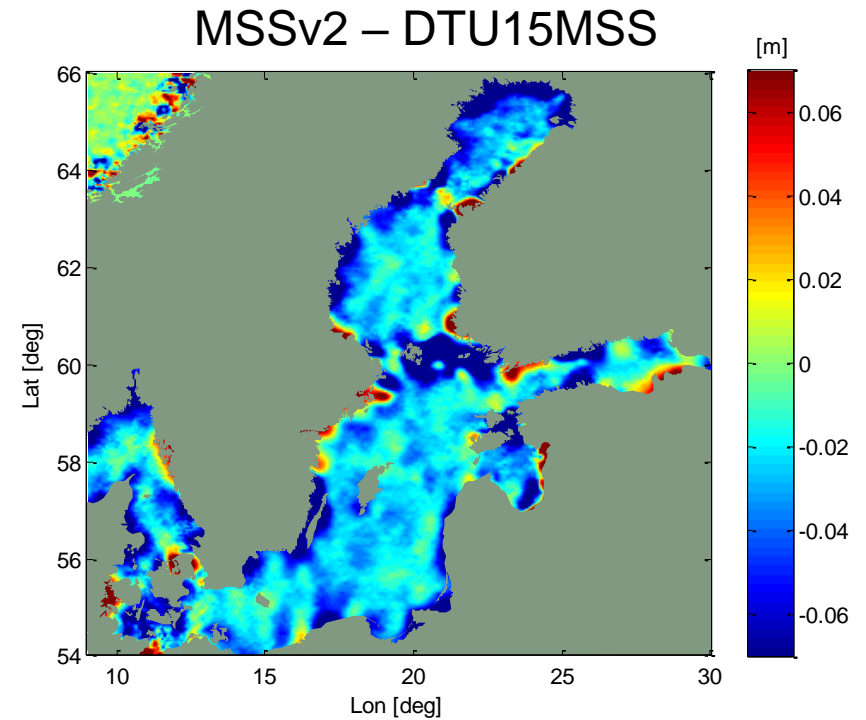
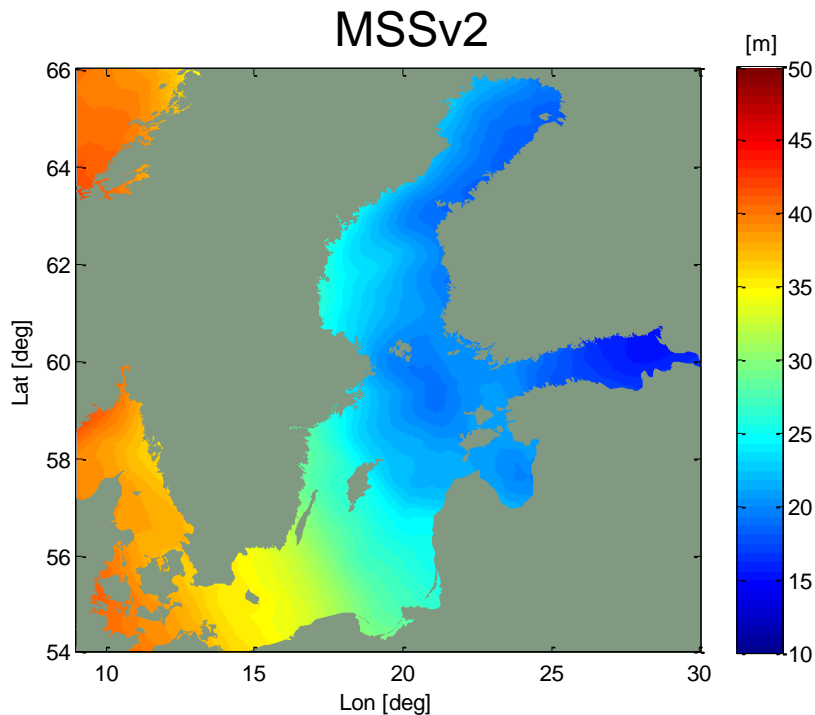


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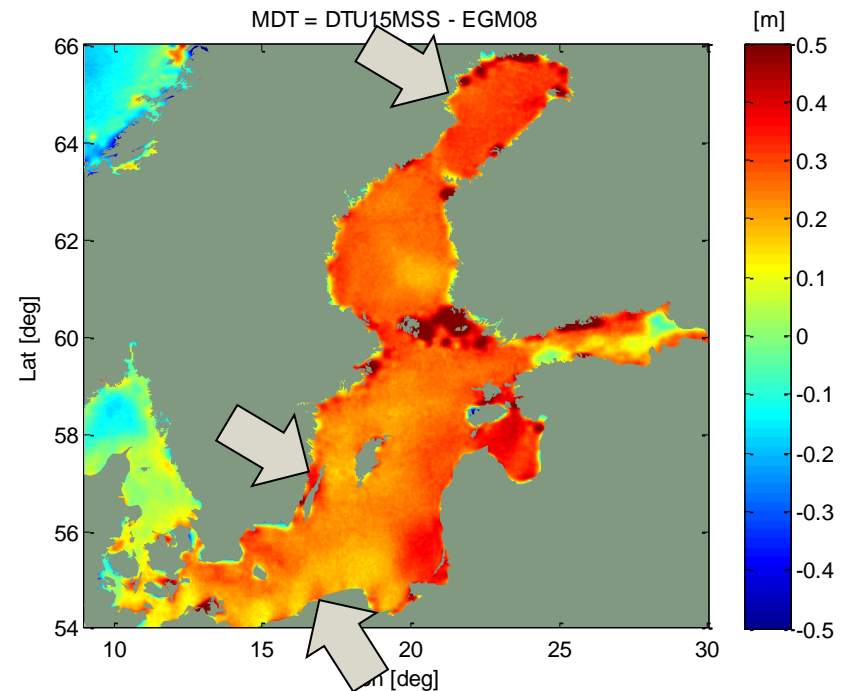
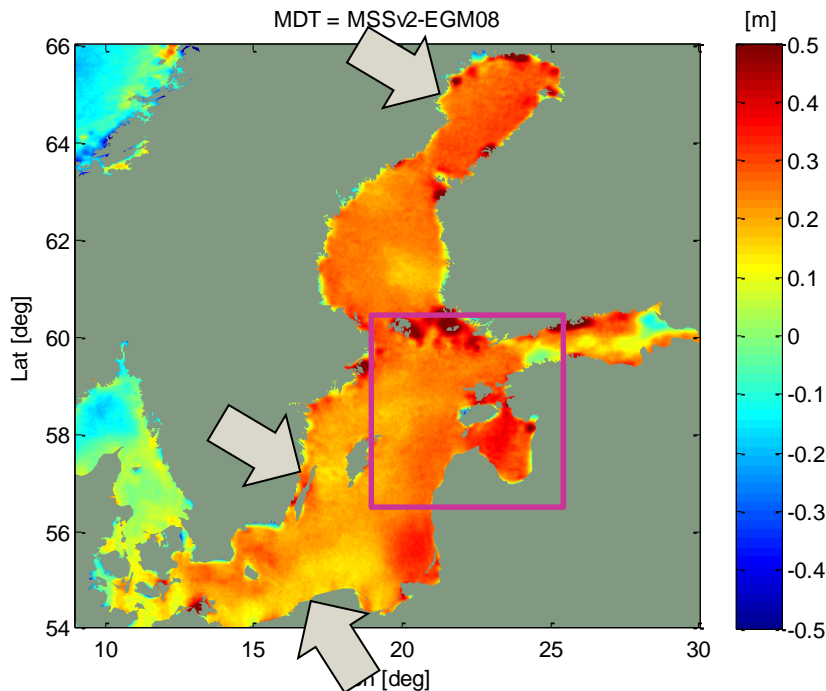
A Mean Sea Surface for the Baltic Sea

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



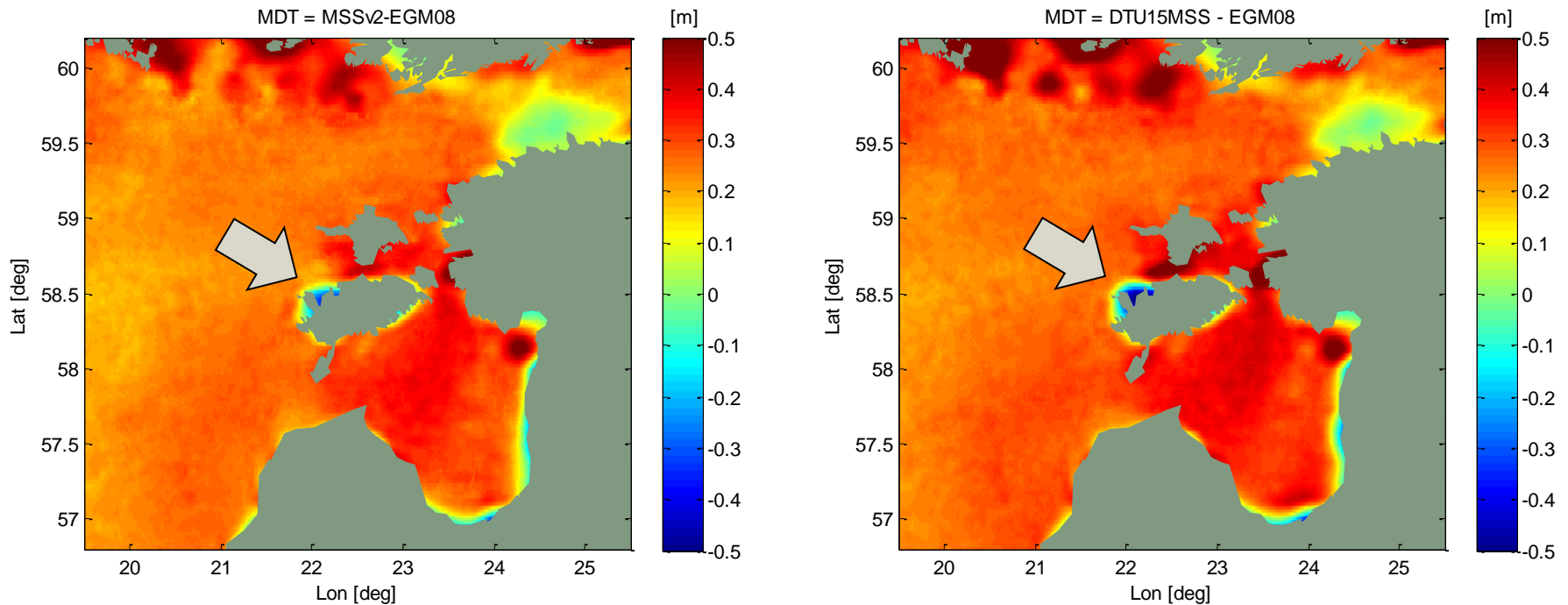
A Mean Sea Surface for the Baltic Sea

- Visual analysis by observing the MEAN DYNAMIC TOPOGRAPHY (mean sea surface – geoid) -> "the smoother, the better"



A Mean Sea Surface for the Baltic Sea

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





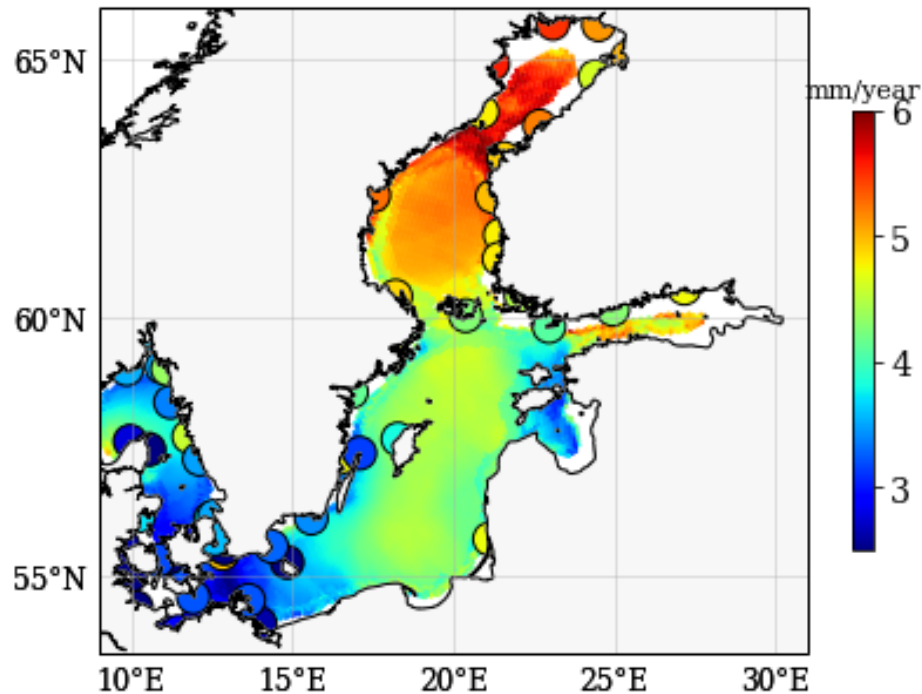
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Trends and Annual Cycle 1995-2018

SAT and TG trends (NKG2016 corrected)

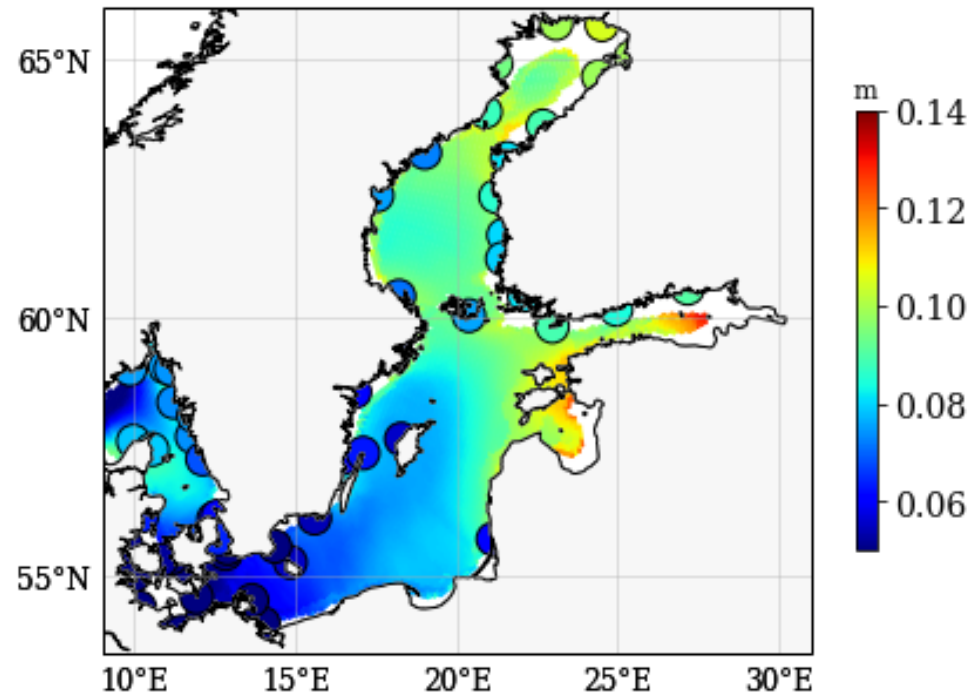
10°E 15°E 20°E 25°E 30°E



Trend: 4.27 ± 3.58 mm/year

SAT and TG annual cycle

10°E 15°E 20°E 25°E 30°E



Annual cycle amplitude: 7.67 cm

Sea level is increasing all across the basin

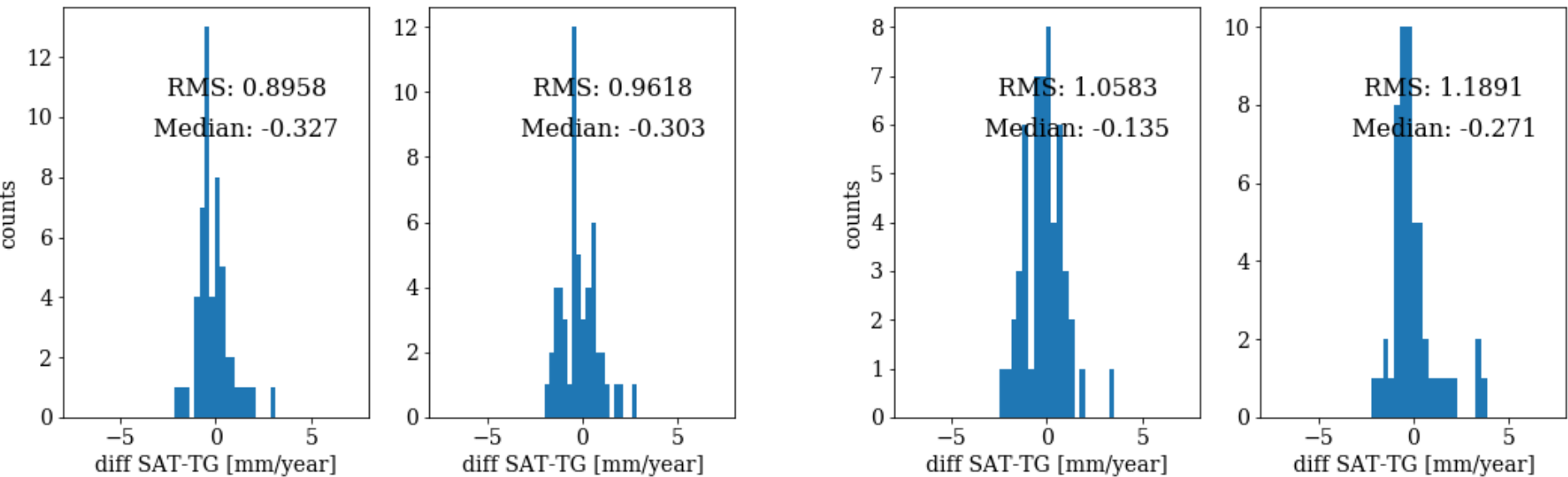
Comparison of trends

Baltic+

AVISO

Baltic+

SL_cci



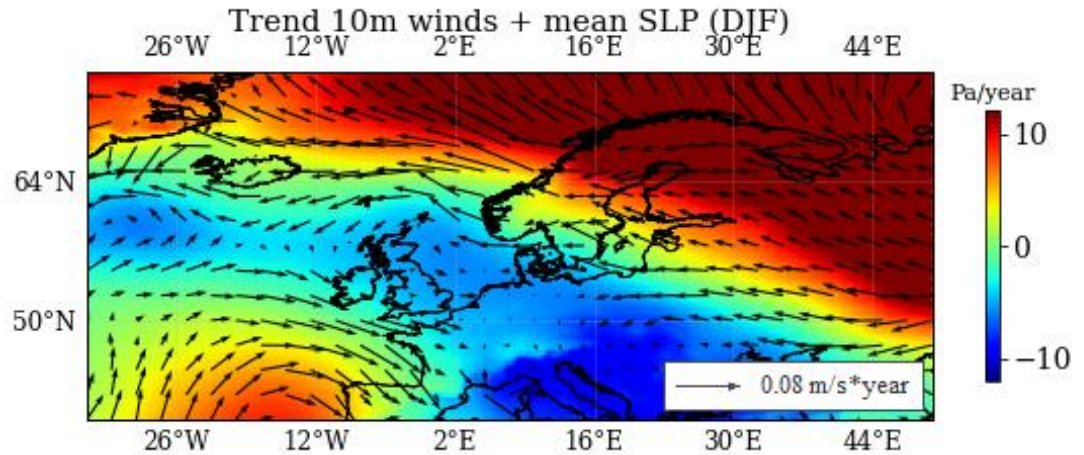
1995-2018

1995-2015

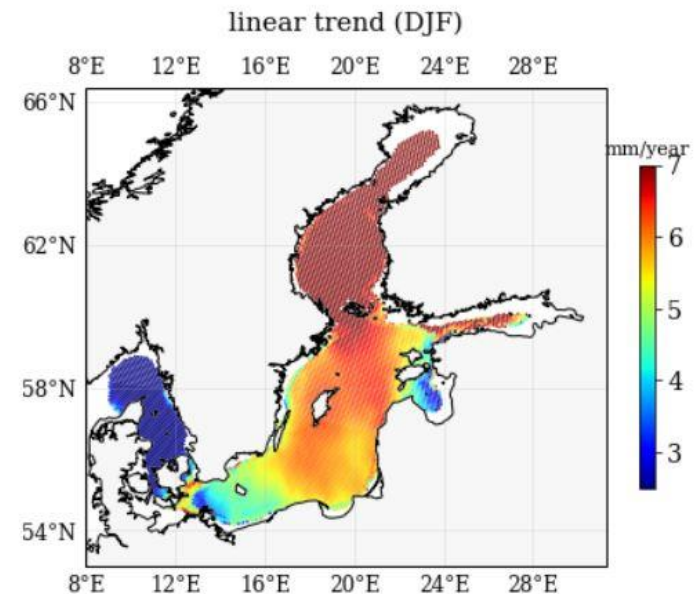
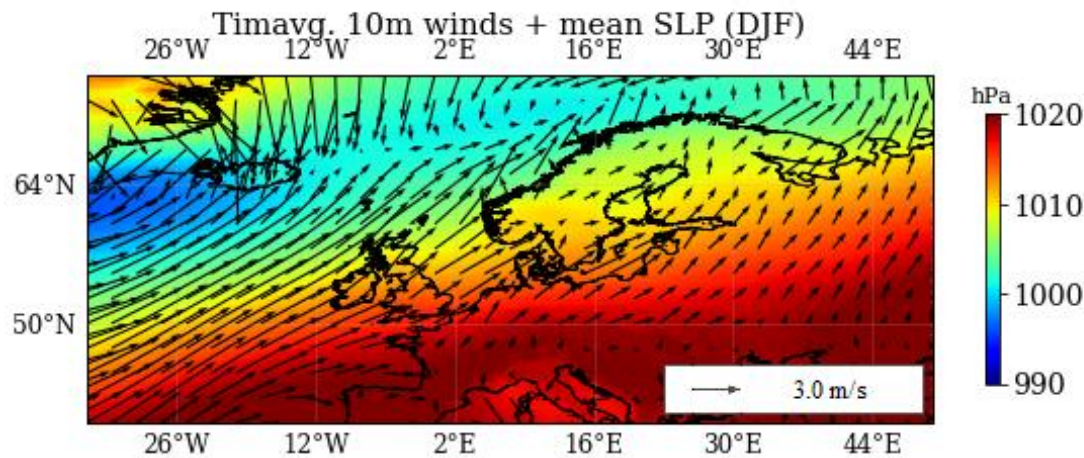
AVISO: Monthly averaged MSLA (all satellites) from <https://www.aviso.altimetry.fr/index.php?id=1526#c10358>

Sea Level ECV v2.0, Legeais et al., 2018, Quartly et al., 2017

Spatial gradients in the sea level trend



- Decreased Ekman transport towards the south-west (water accumulation in N-E)
- Increased SSH trends in northerly regions
- Strongest changes of winds are in agreement with stronger trend gradients in winter season

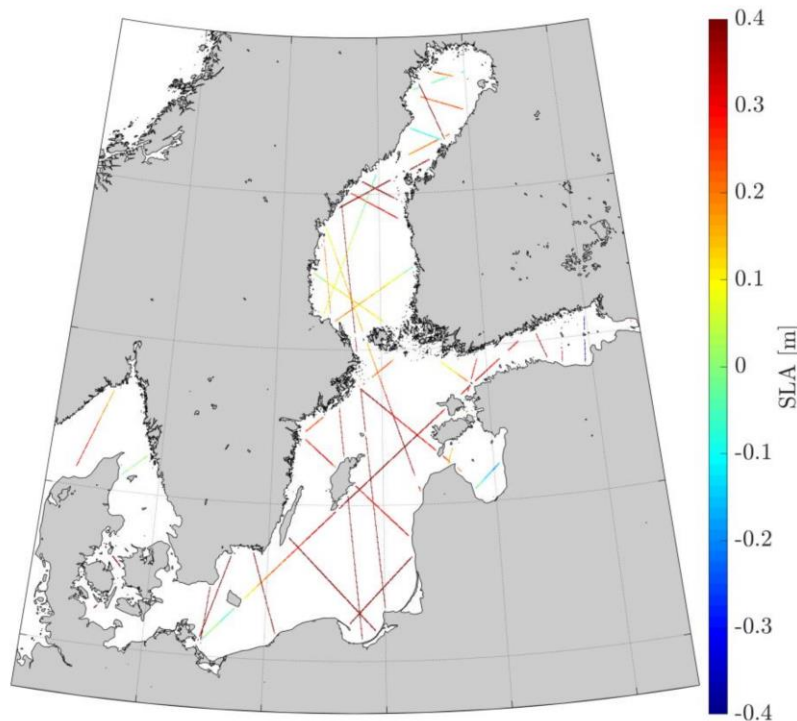




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3-days experimental gridded product



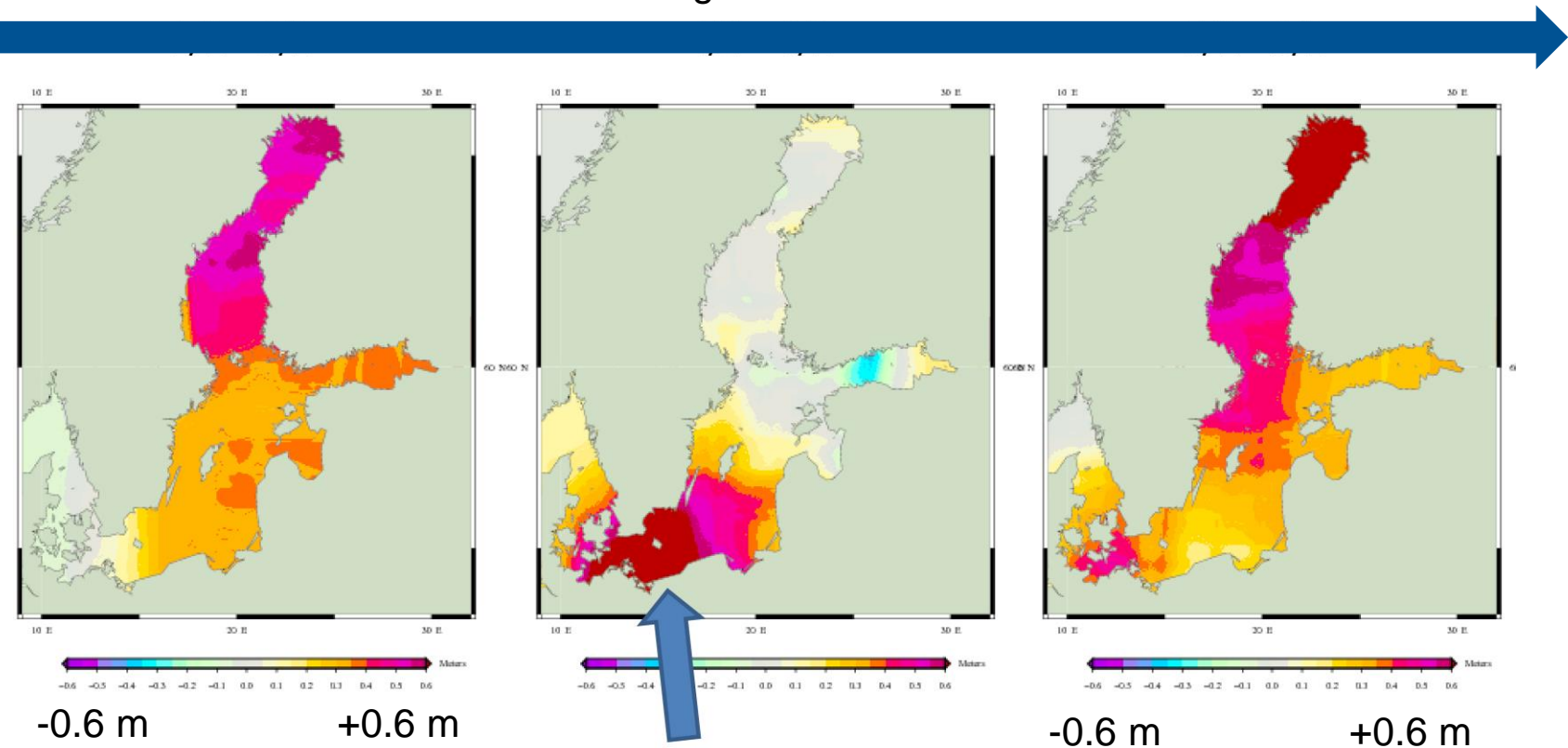
- Identification and analysis of storm surge events
- In particular provision of the initial state of the sea level before the surge event, to more accurately predict the surge through models

3-days experimental gridded product

Before...

...During...

...After



Silent storm surge

January 2017



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

- 1) **Synergies: Baltic+ Salinity** Dynamics and Baltic+ SEAL, multi-variable observation of Atlantic Inflow and recirculation within the Baltic Sea
- 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 developed within Baltic+ Theme 5
- 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 capsizes, 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