Altimetry perspectives for the Baltic Sea Level

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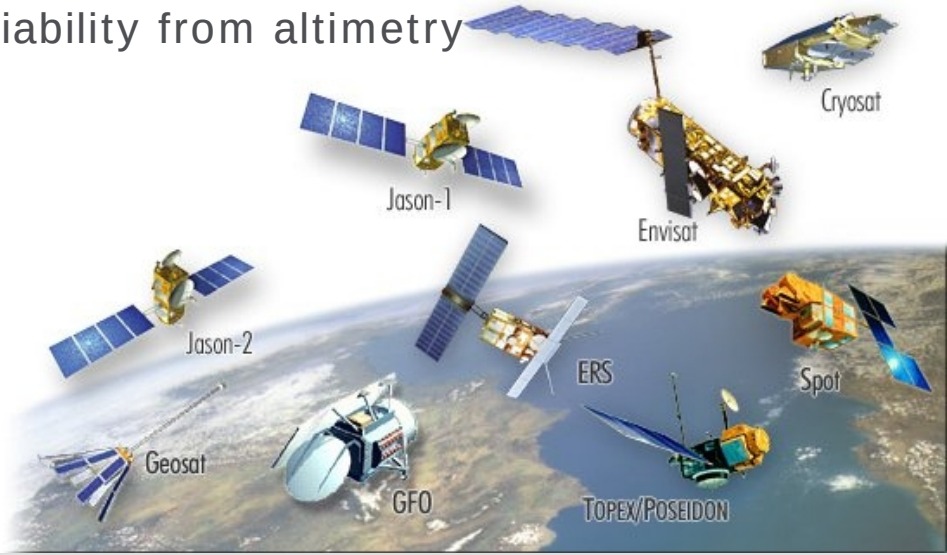
Agenda

- 2-slide introduction to coastal satellite altimetry
- Perspective 1: Altimetry for storm surge modelling
- Perspective 2: Sea level trends and variability from altimetry



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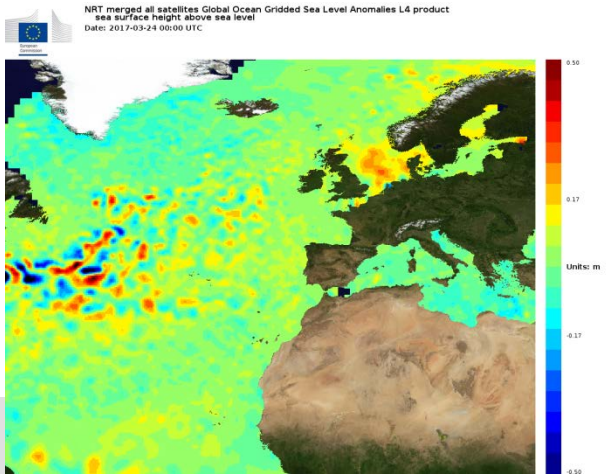
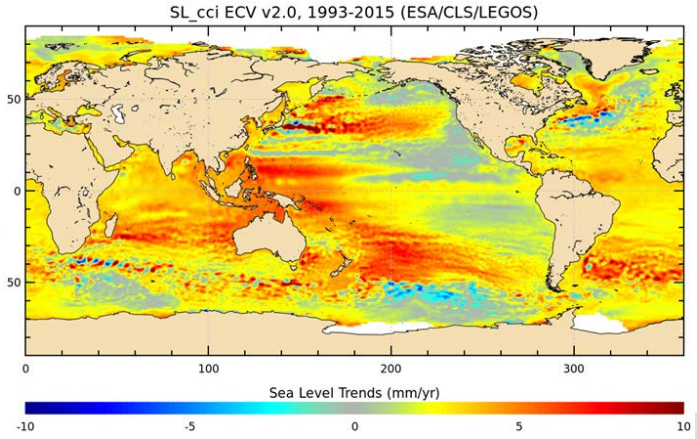
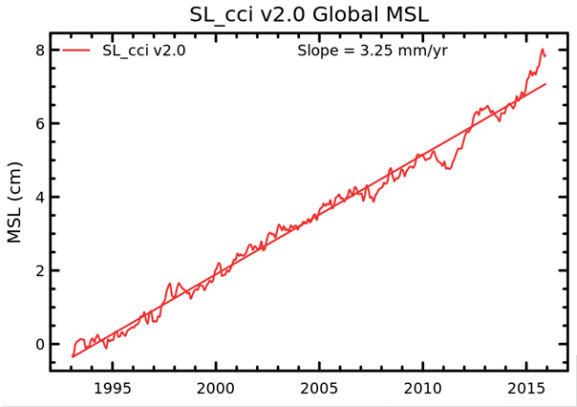
Satellite altimetry in the open ocean

- Measures sea surface height along satellite path using radar
  - Correction for atmospheric conditions etc.
- Routine merge of several satellites and interpolation to daily 2D field
- High quality assessment of global sea level rise







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Satellite altimetry in the Baltic Sea

Coastal regions need special treatment

- Special choice of atmospheric corrections etc. within ~50 km of the coast
- Re-tracking needed within ~10 km of the coast
- Spatial and temporal interpolation should consider coastal scales –
  or along-track data should be used

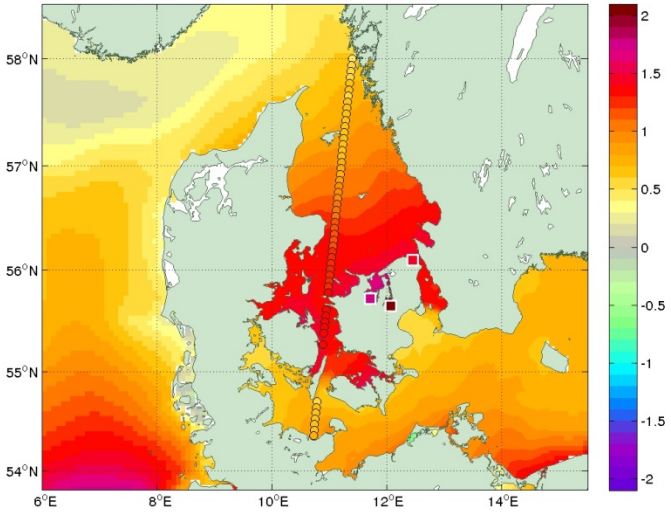
When these issues are properly handled, data are of high quality, especially in the Baltic Sea! (See Ole's presentation next)

Coastal altimetry for storm surge monitoring

Satellite altimetry can measure storm surges!

We propose to

1) Visualize altimetry measurement together with model forecasts and tide gauge observations, to prepare for assimilation.
2) Assimilate a blended altimetry – tide gauge product in the storm surge forecast system, to adjust mean sea level and seiches



Sea level (m) during storm surge Bodil/Xaver 2013 from model, satellite and selected tide gauges (Shutler et al., 2016).

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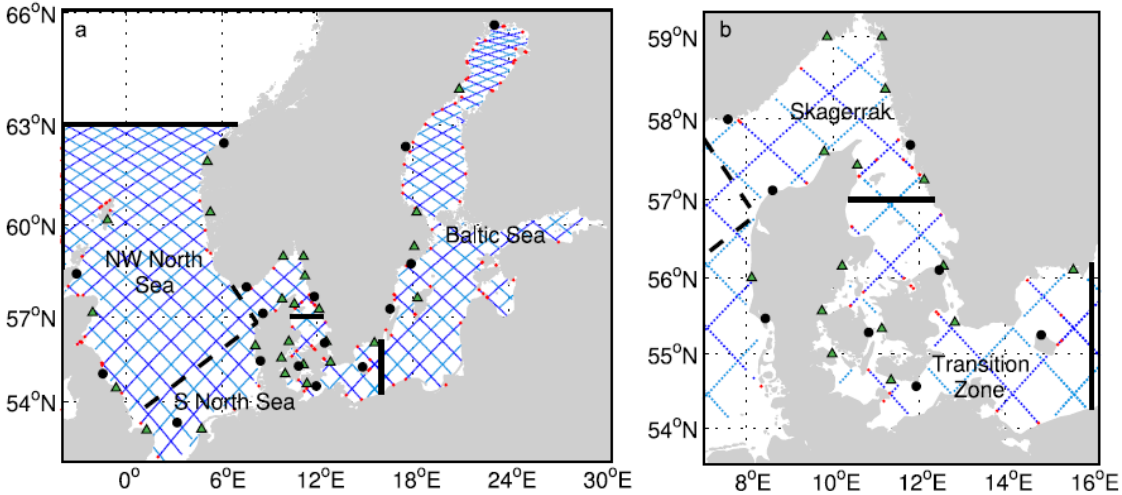
Blended altimetry – tide gauge product

We blend coastal satellite altimetry sea level observations with tide gauge data in a statistical model using multiple linear regression



The study zone with tide gages used for the blended product (black circles) and for independent validation (green triangles), altimetry tracks (dark blue: Jason2 1 Hz, red Jason 2 20 Hz, light blue Jason 1 interleaved).

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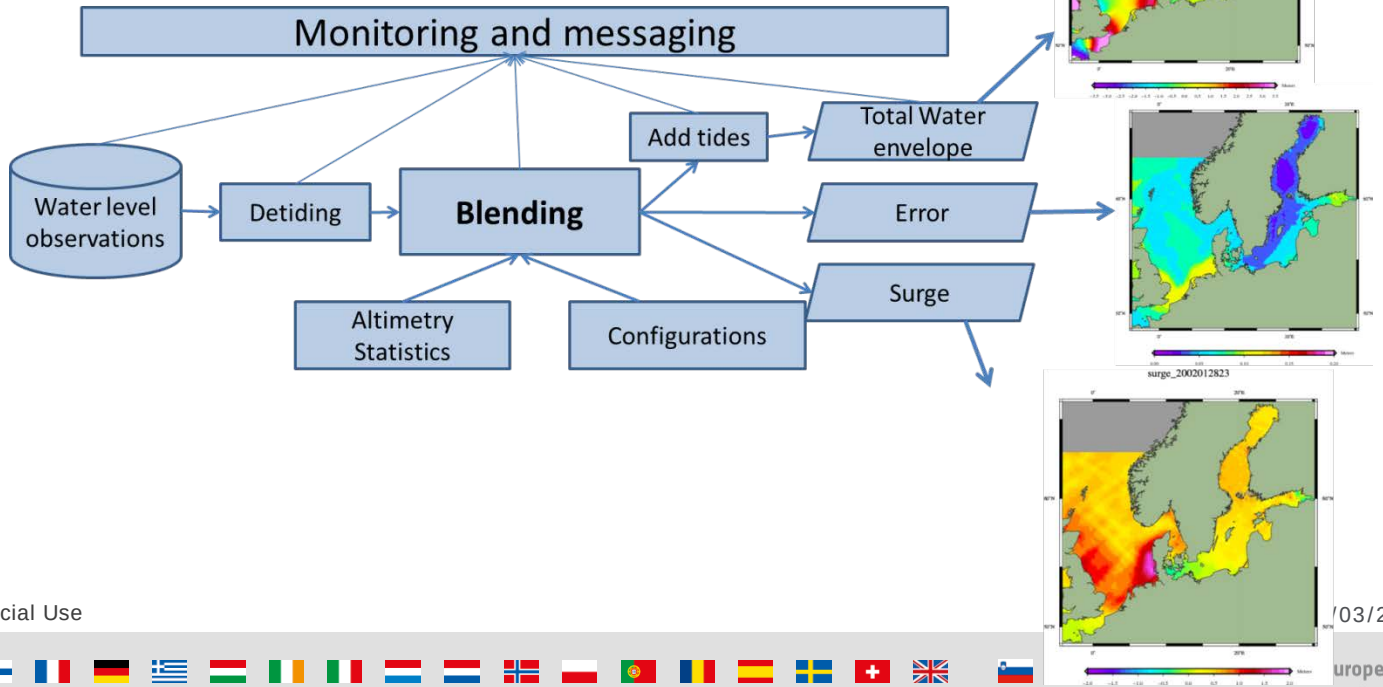
Blended altimetry – tide gauge product

Operational system



Assimilation

The DMI storm surge model system

- Domain: North Sea and Baltic Sea
- Spatial resolution: Two-way nested, 6/1 nm for assimilation, 3/0.5 nm operational
- SSH values extracted every 10 minutes for 133 stations

Assimilation method

- Ensemble Optimum Interpolation
- A simplified form of Ensemble Kalman Filter, only integrating one forecast state forward
- Background error covariance matrix calculated from 80 ensemble members derived from a 20 year reanalysis simulation.

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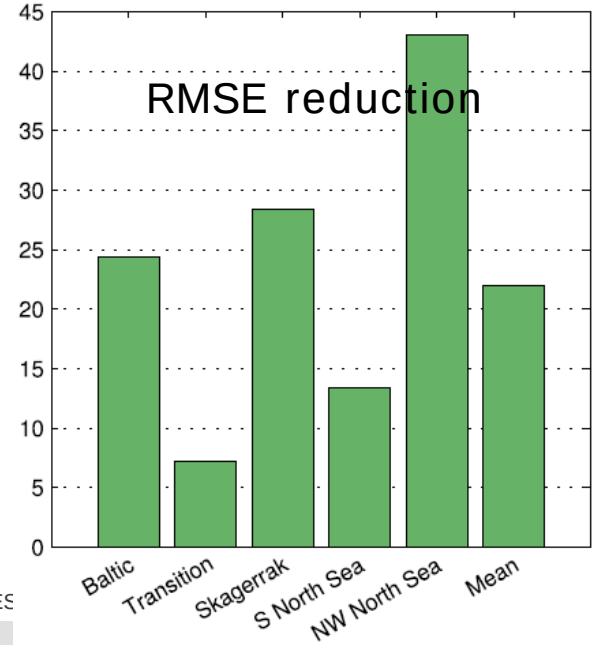
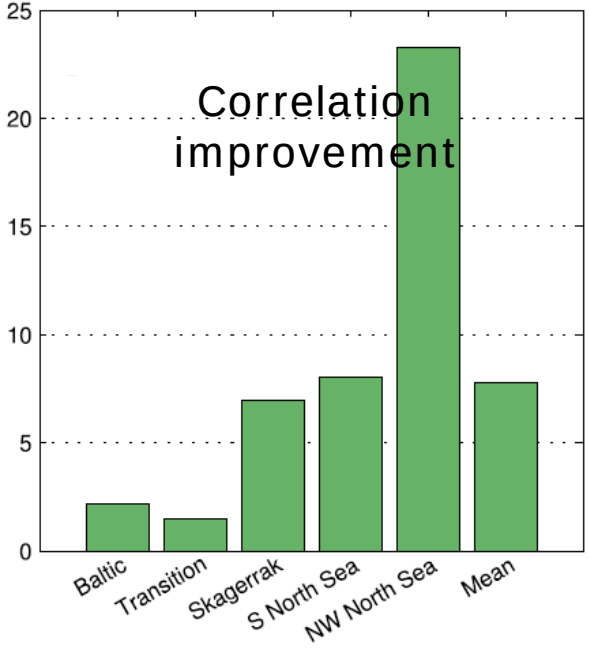
Assimilation Results

2 year test simulation validated against independent tide gauges



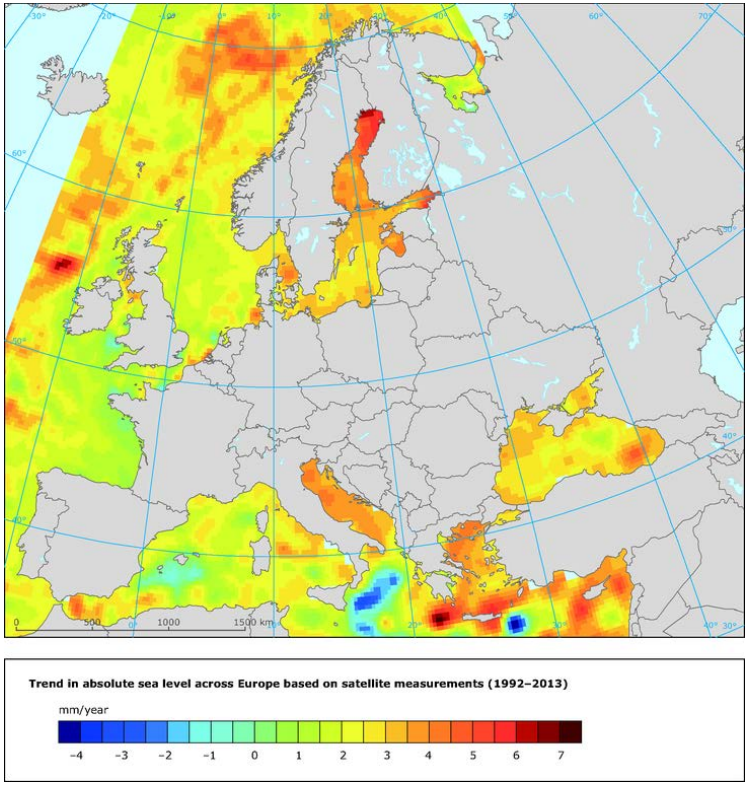


Reduction in RMS error (left, %) and improvement in correlation (right, %) by assimilation, when comparing to independent validation stations, averaged by area for the five validation areas, and the mean of the five areas.

Baltic sea level trends and variability from altimetry

– too good to be true?

- Within the EMODnet Baltic Sea Basin Checkpoint, we have reconstructed past sea level variability of the Baltic Sea
- The reconstruction is used to validate the ESA sea level CCI variability in the Baltic Sea
- Once validated, the absolute sea level trends can be used in the Checkpoint reconstruction



Sea level trend map as provided by EEA

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EMODnet Baltic Sea Checkpoint combined in-situ & model product

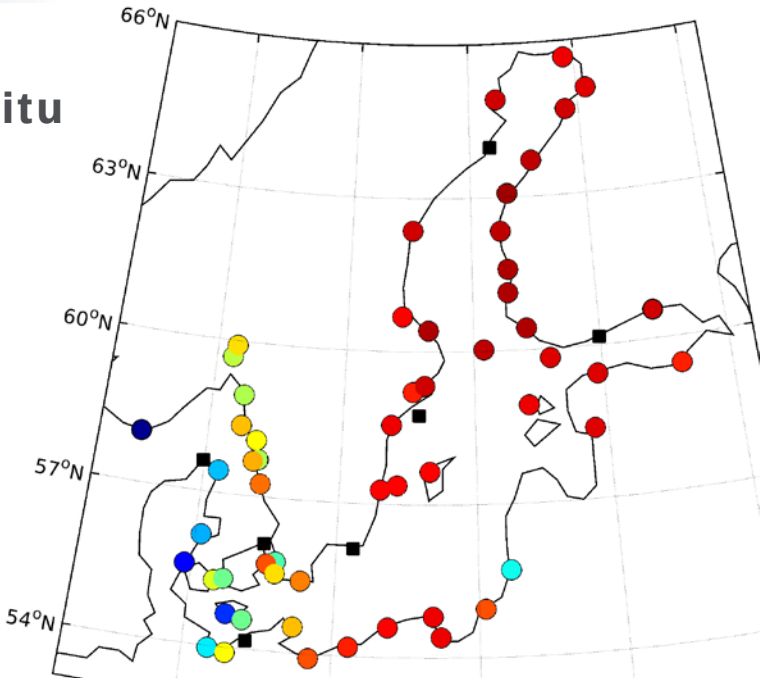
2D sea level fields were reconstructed based on statistical modelling using least squares regression

- monthly tide gauge observations 1900-2014
- model reanalysis from Copernicus

Validated against 56 independent tide gauges

- average correlation 96%
- average RMS error of 3.8 cm

This is better than the reanalysis (average correlation 88%, RMS 6 cm)



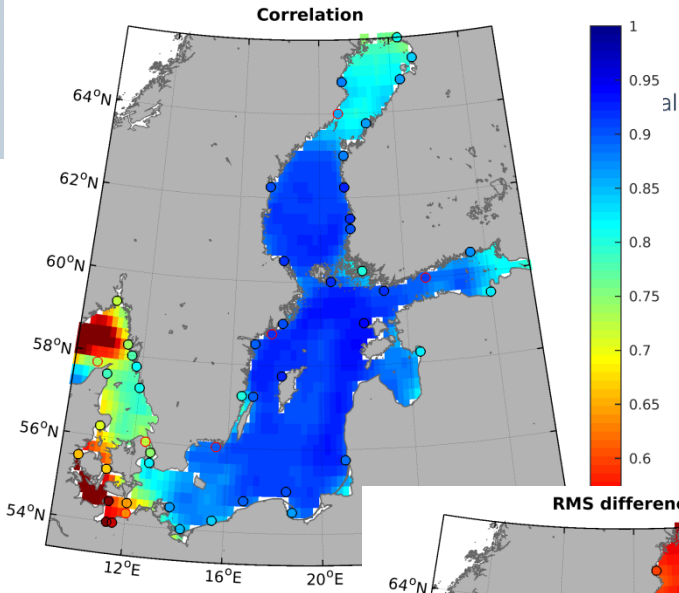
Correlation of reconstructed SSH variability with independent tide gauges [%] Coloured circles: Validation stations. Black squares: Stations used for reconstruction

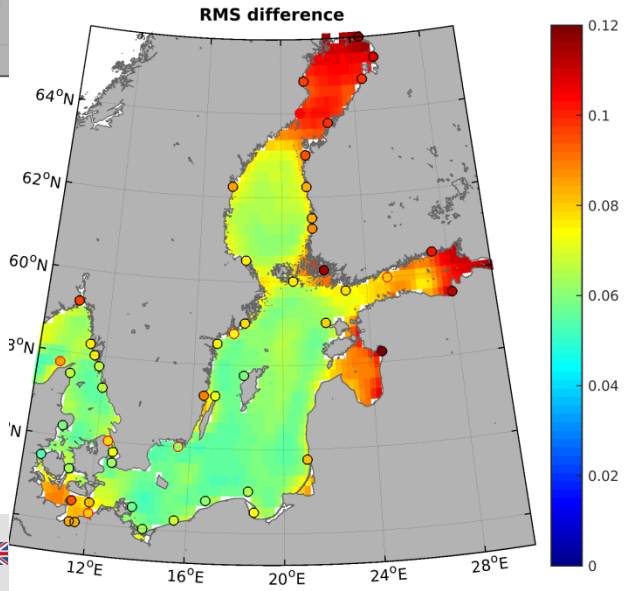
Validation of the sea level CCI

The Sea Level CCI anomalies were validated against the independent SSH reconstruction and tide gauges

- The correlation between the datasets is high in the central Baltic away from ice infected areas, but low in the transition zone to the North Sea
- Root mean square (RMS) errors are increased in much of the northern Baltic

This is used to mask the CCI data

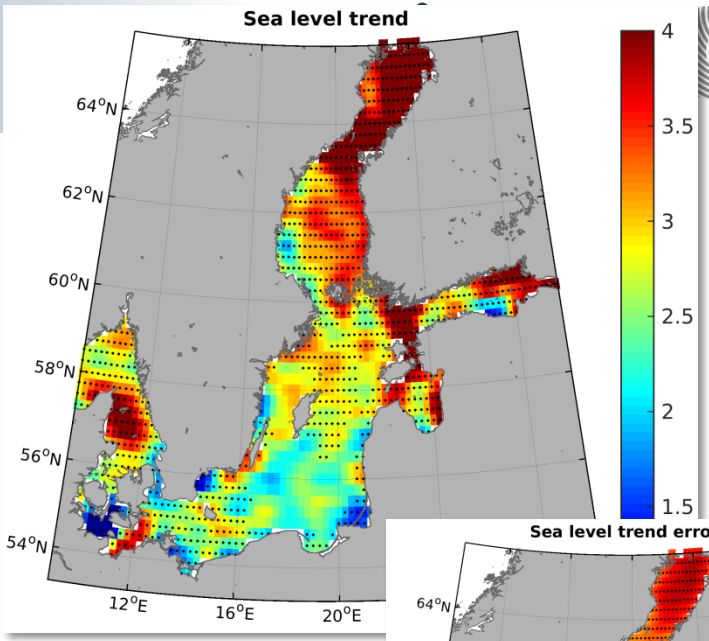


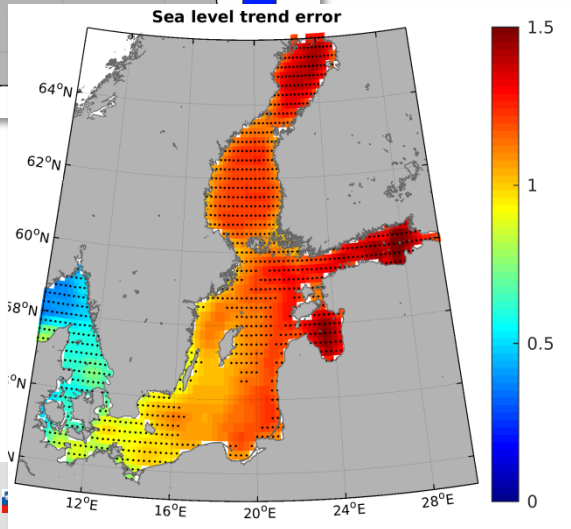


Conclusions

- Good quality in the southern open parts of the Baltic Proper
- The coastal zone, areas with sea ice, and areas of high natural variability needs special treatment
- The increased uncertainty is not reflected in the provided error field

Outlook: CCI sea level trends from high quality regions will help determine absolute sea level trends for the entire Baltic Sea in EMODnet Baltic Checkpoint.





Top: zoom on the Baltic Sea. Black dots denote areas with increased validation errors. Bottom: Trend error fields as provided by the Sea level CCI

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Summary

- High quality satellite altimetry is available for the Baltic Sea, but most parts require special coastal treatment
- Satellite altimetry measures storm surges, when the timing is right, and could be used for online verification of forecast models
- Assimilation of blended altimetry and tide gauge data in a storm surge model shows consistently improved average error statistics
- Global sea level trend products, such as the ESA sea level CCI, must be used with care in the coastal region
- The quality of sea level trend products in the coastal region can be improved!