Near Real Time altimetry measurements of the storm surge Bodil, Denmark

Comparison with model and in-situ observations

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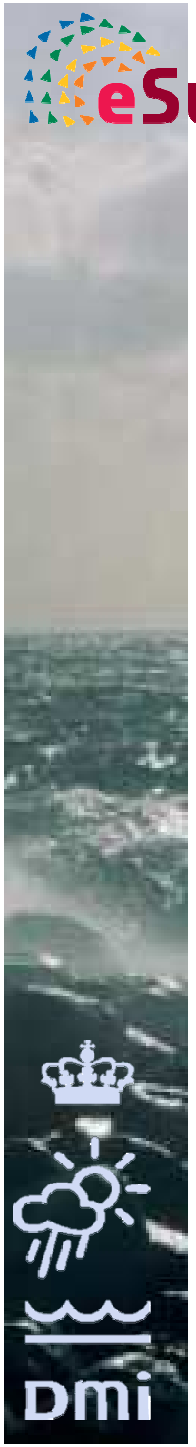
DMI

eSurge



Introduction – eSurge

The eSurge project aims to improve the modelling and forecasting of storm surges through the increased use of advanced satellite data

Today:

- North Sea – Baltic Sea transition zone for validation of coastal satellite altimetry
- The Bodil / Xaver storm surge
- Data assimilation of coastal sea level

esa

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Logica is now part of CGI.

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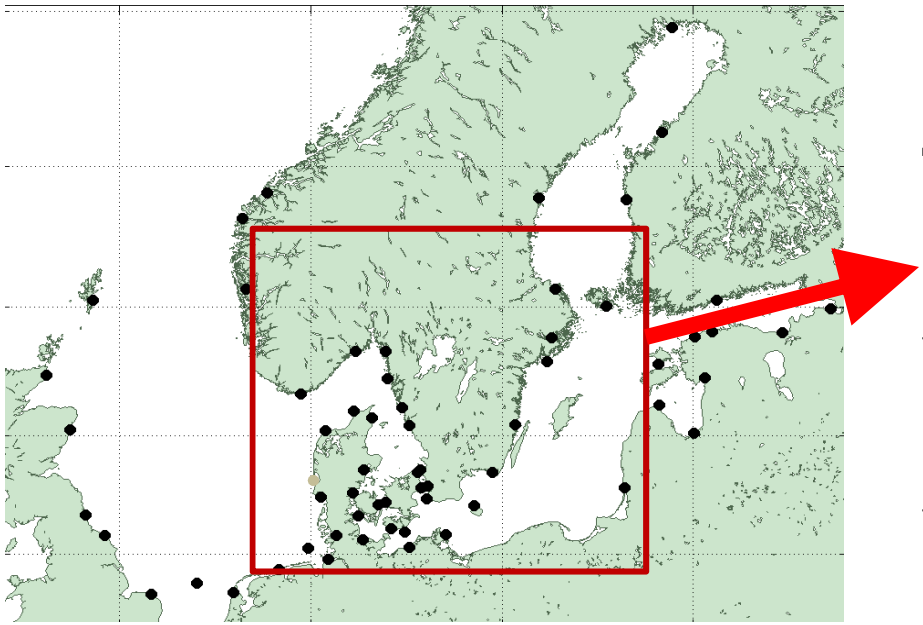
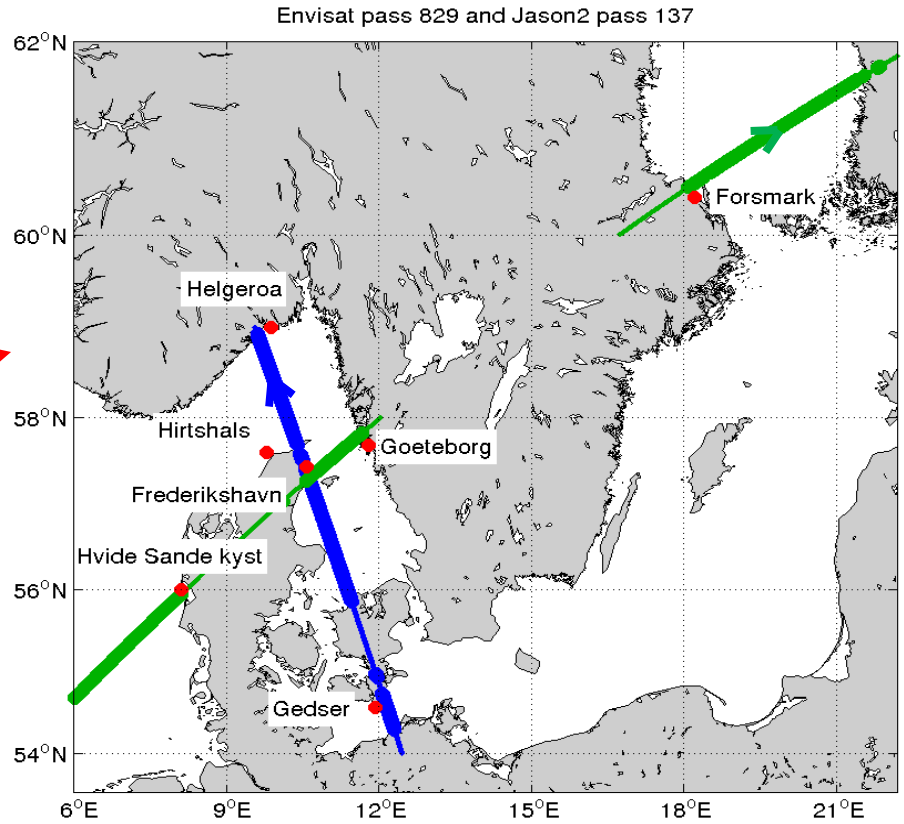
Ministerie van Infrastructuur en Milieu

The North Sea – Baltic Sea transition zone as a test bed for coastal altimetry





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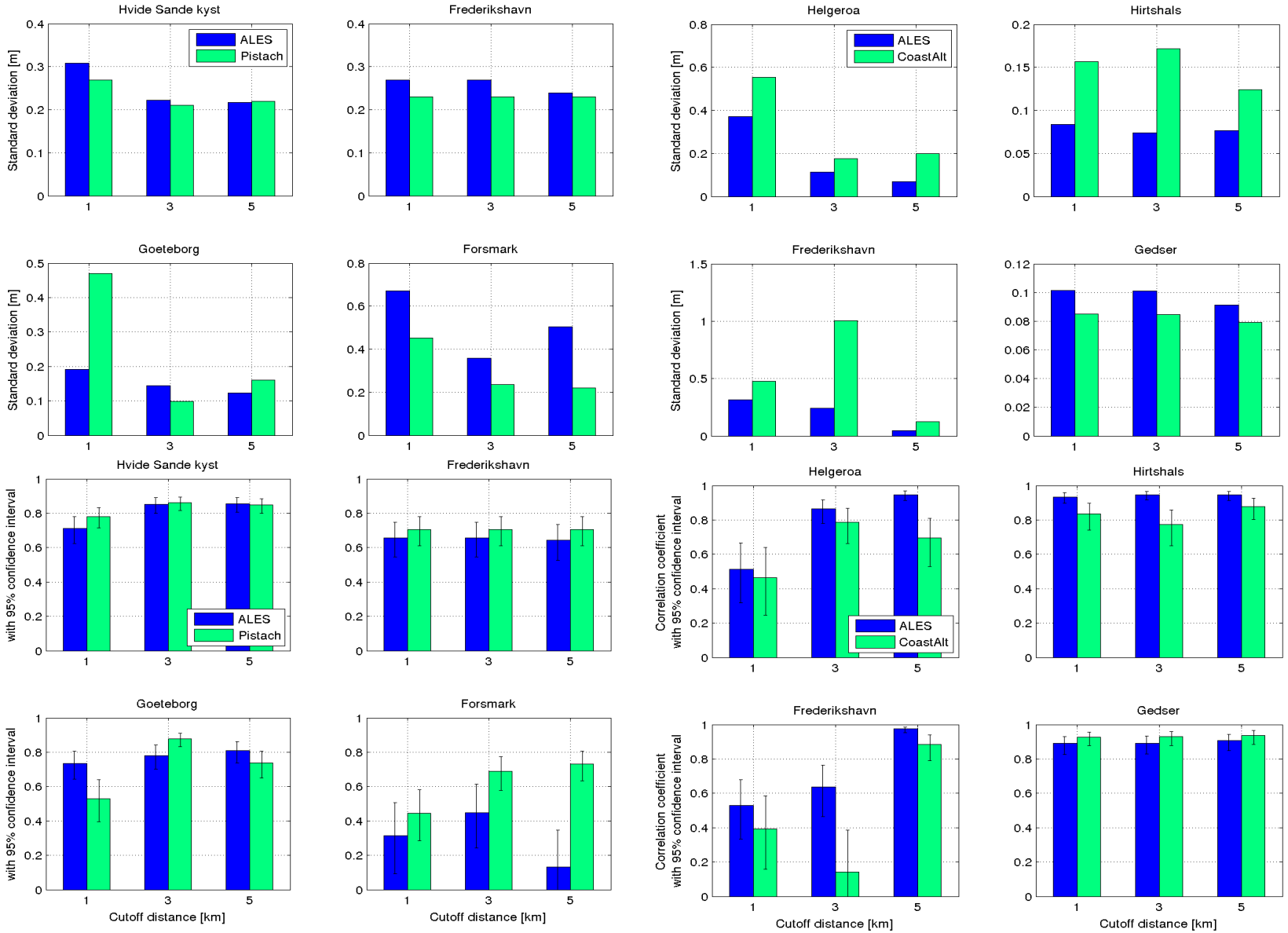
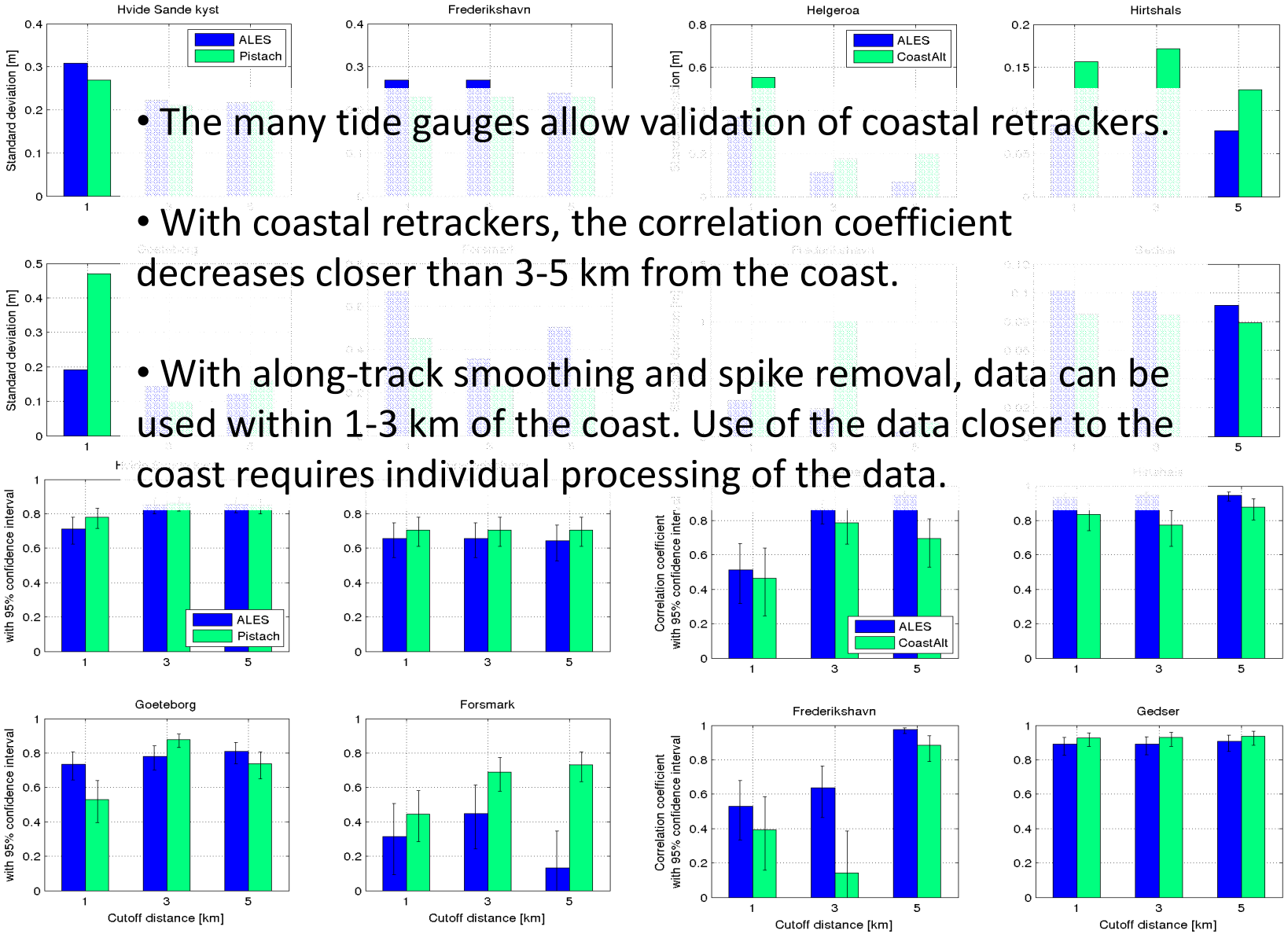


The North Sea – Baltic Sea transition zone as a test bed for coastal altimetry

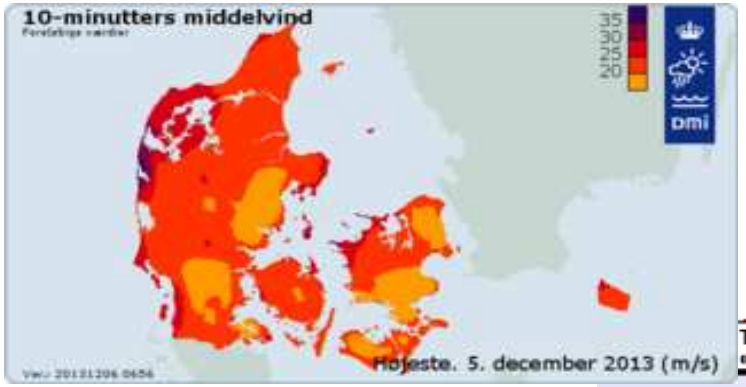


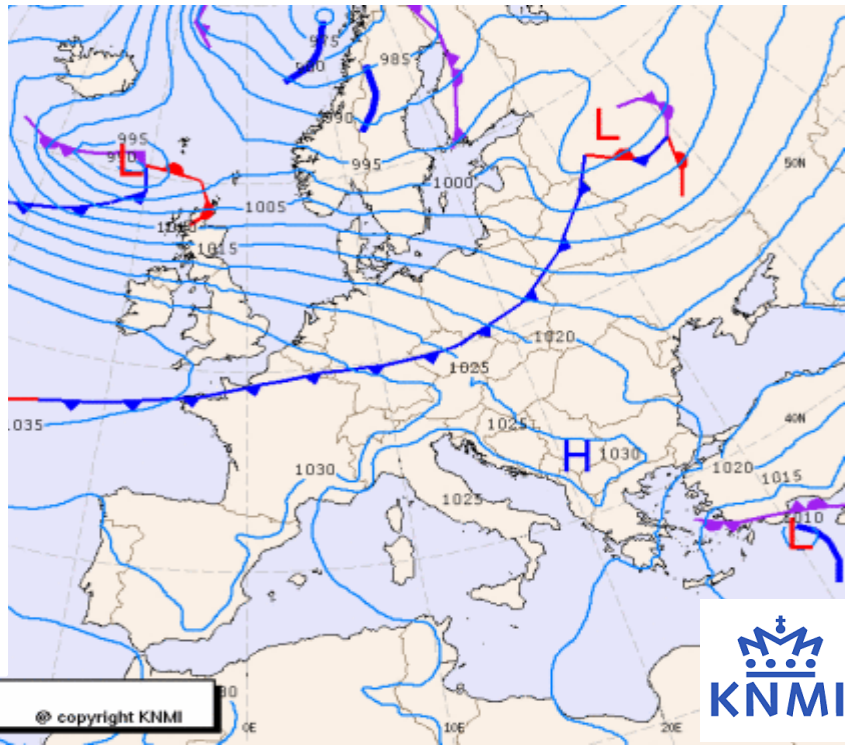
- The many tide gauges allow validation of coastal retrackers.
- With coastal retrackers, the correlation coefficient decreases closer than 3-5 km from the coast.
- With along-track smoothing and spike removal, data can be used within 1-3 km of the coast. Use of the data closer to the coast requires individual processing of the data.

The Bodil / Xaver storm

Cyclone Xaver (Bodil, Cameron, Ksawery, Sinter Klaas, Sven) 5-6 December 2013, was a winter storm that affected northern Europe.

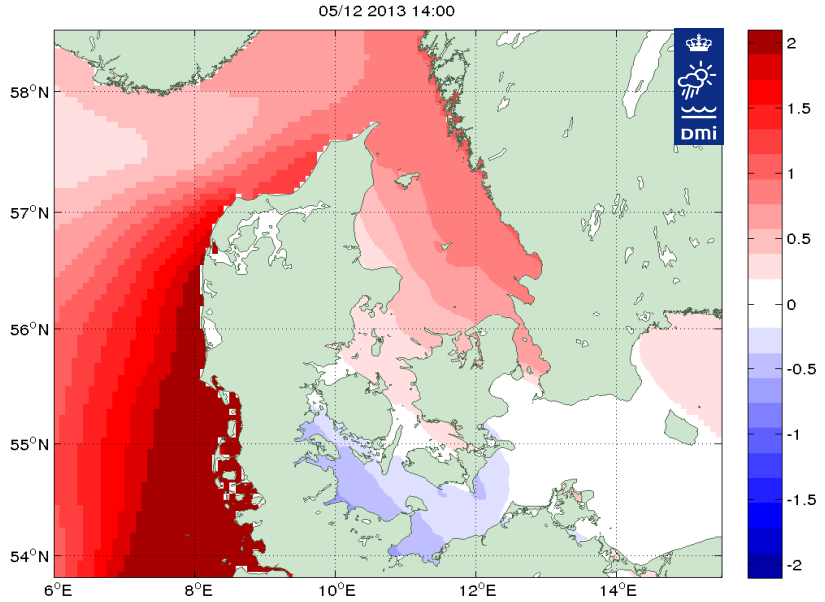
- Northern North Sea coast of Denmark: mean of 36,6 m/s (hurricane) on Dec. 5 (evening).
- First SW storm, then very long period of strong NW winds into Kattegat on Dec. 6.
- The storm and following storm surge was well forecasted, but in the days before the storm, DMI forecasters were uncertain if the forecast was correct.

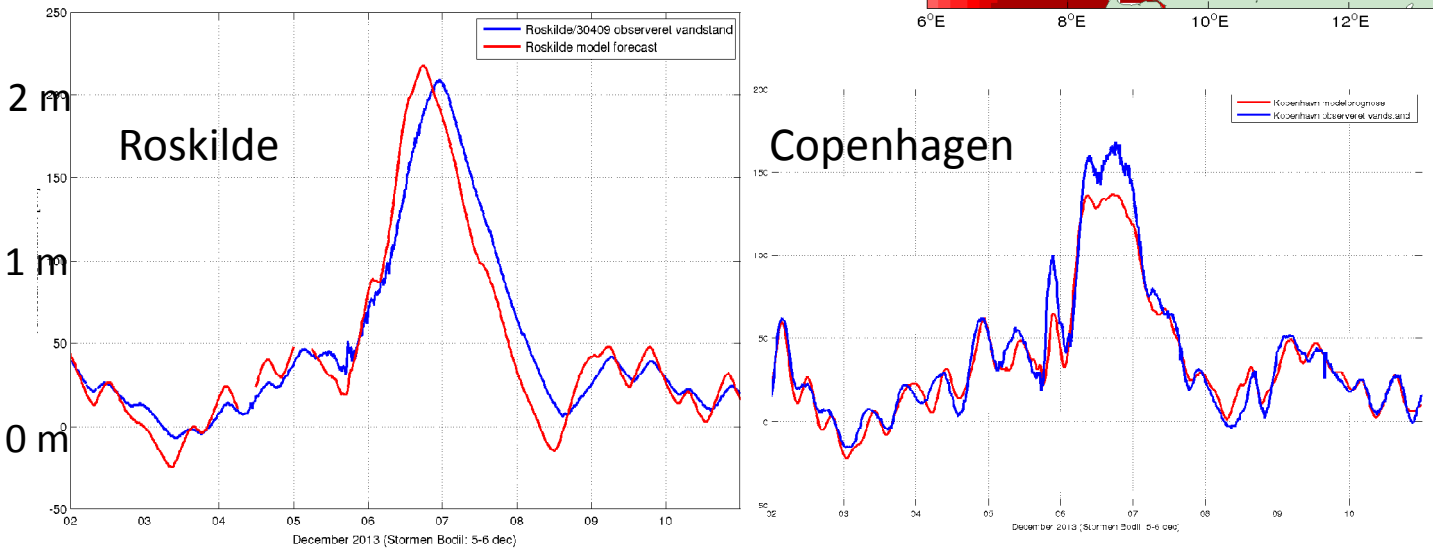




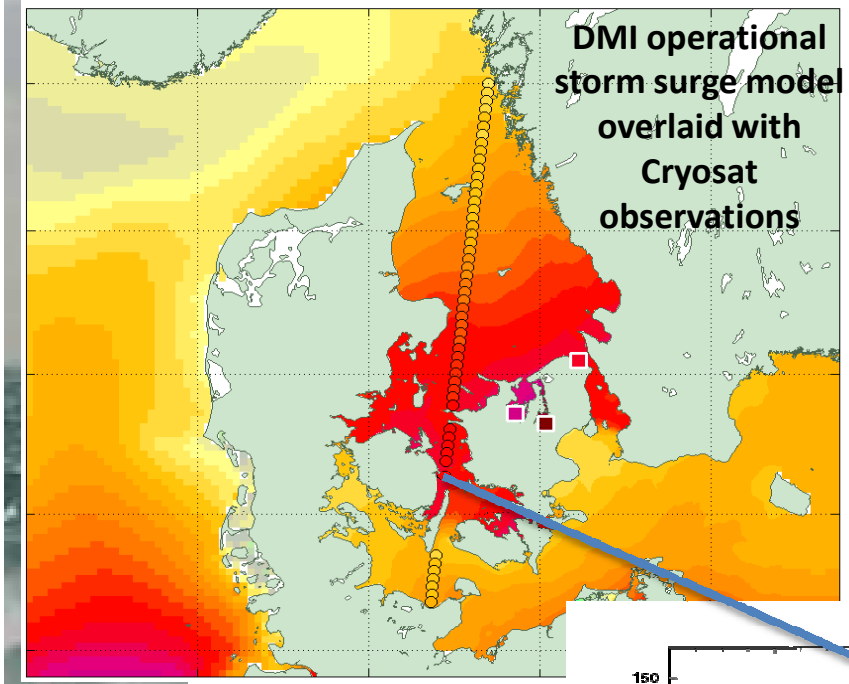
The Bodil / Xaver storm surge

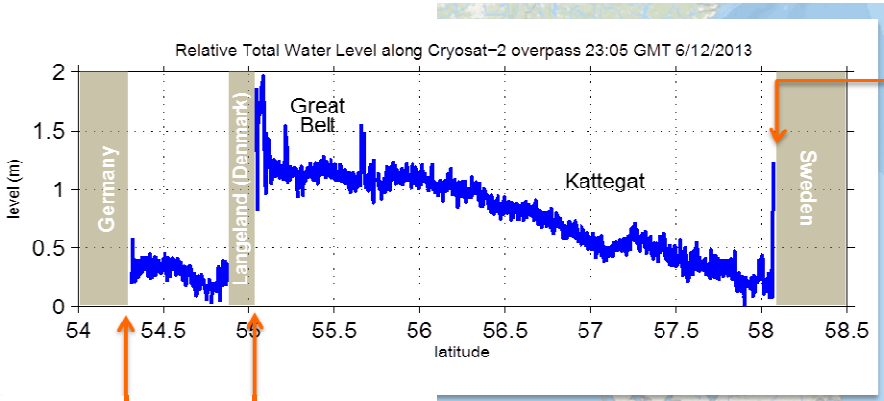
- Storm surge hit North Sea coast on Dec. 5 2013.
- Continued build-up in Kattegat and created 1000-year event on the northern coast of Zealand (Denmark), massive flooding of Roskilde Fjord and 400-year event in Copenhagen on Dec. 6.

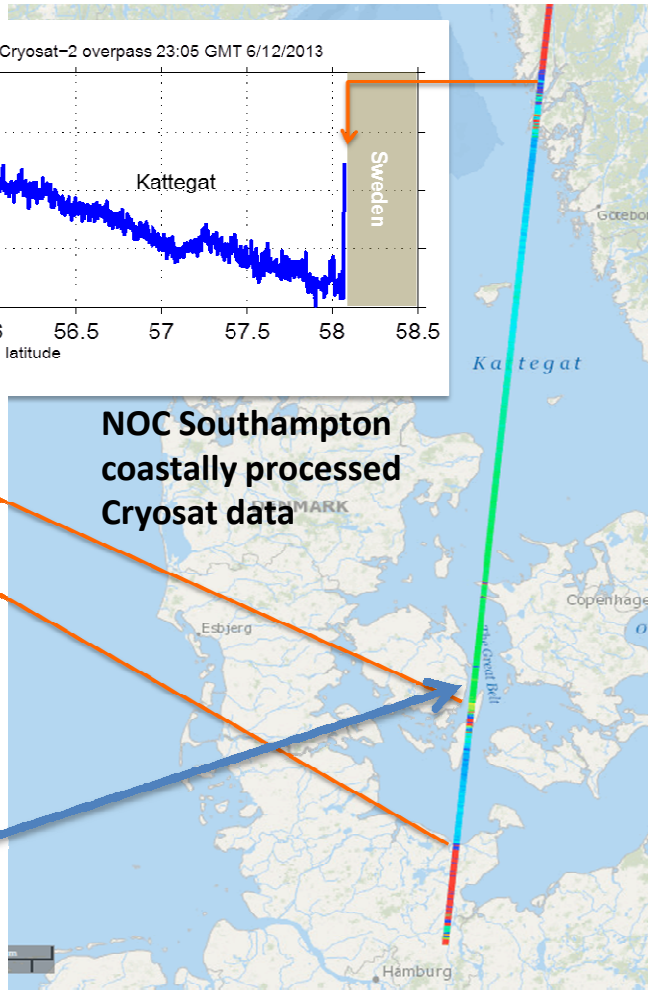


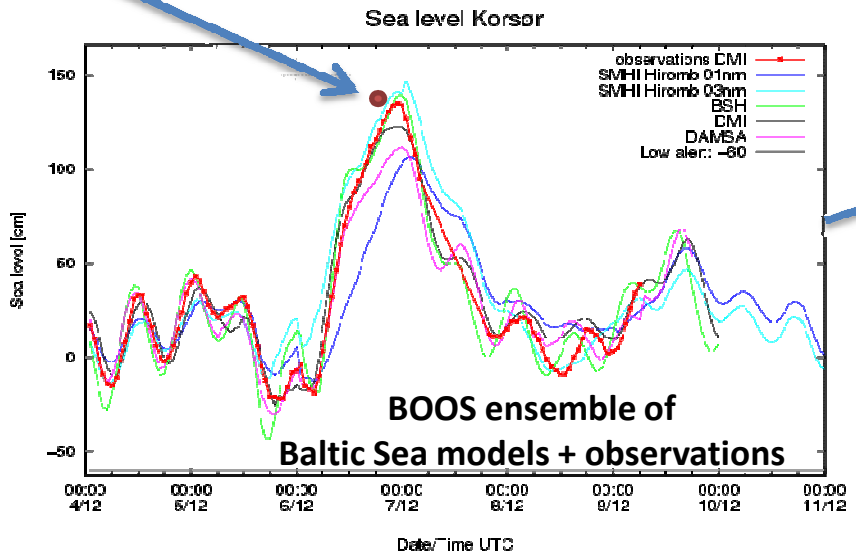


The Bodil / Xaver storm surge
Cryosat + Baltic Sea ensemble modelling



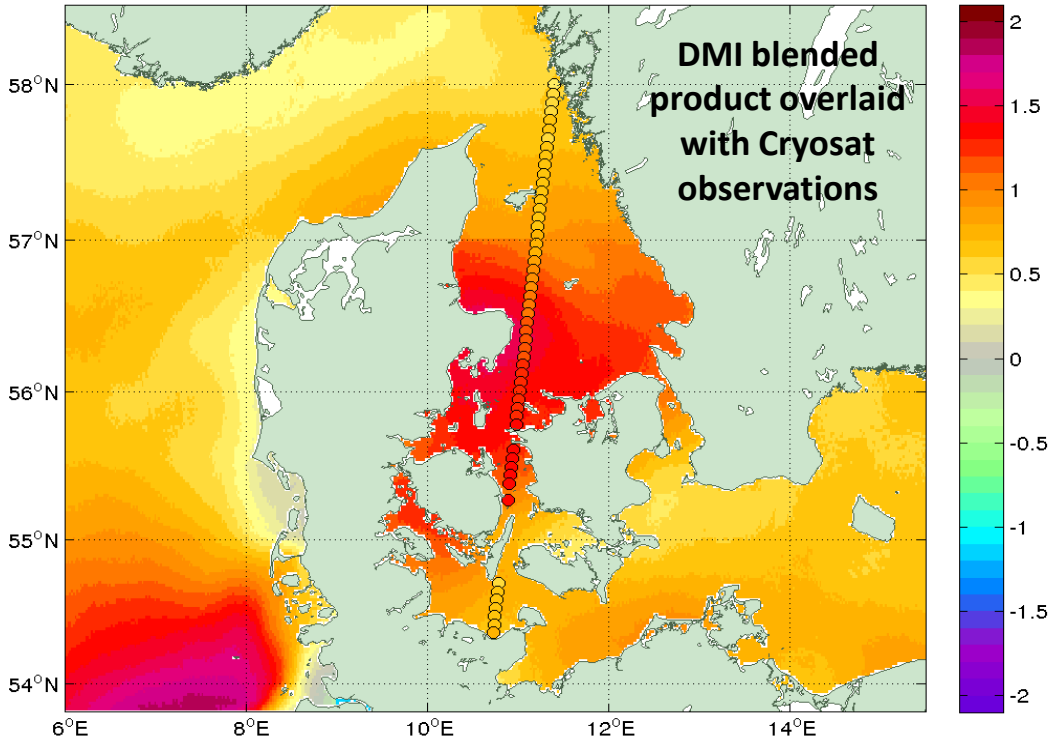






The Bodil / Xaver storm surge
DMI Blended satellite – tide gauge product

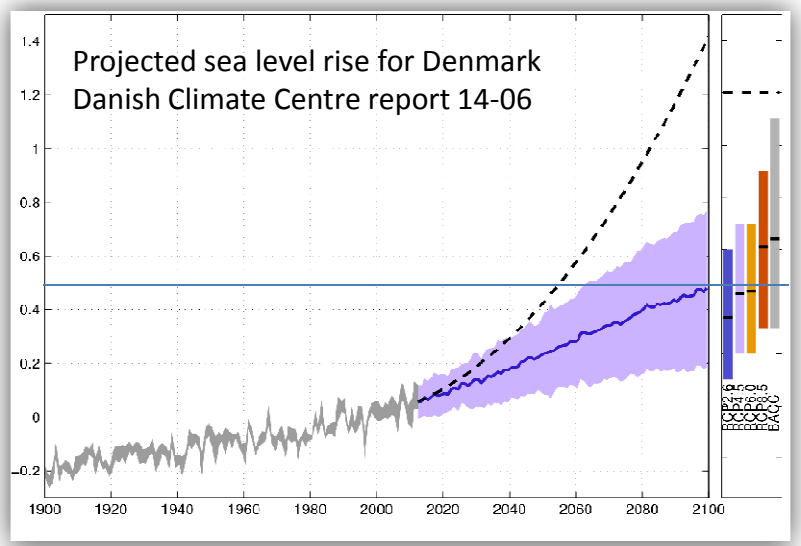
- Statistical model combining satellite altimetry with tide gauge data
- Available even when the satellites are not around…

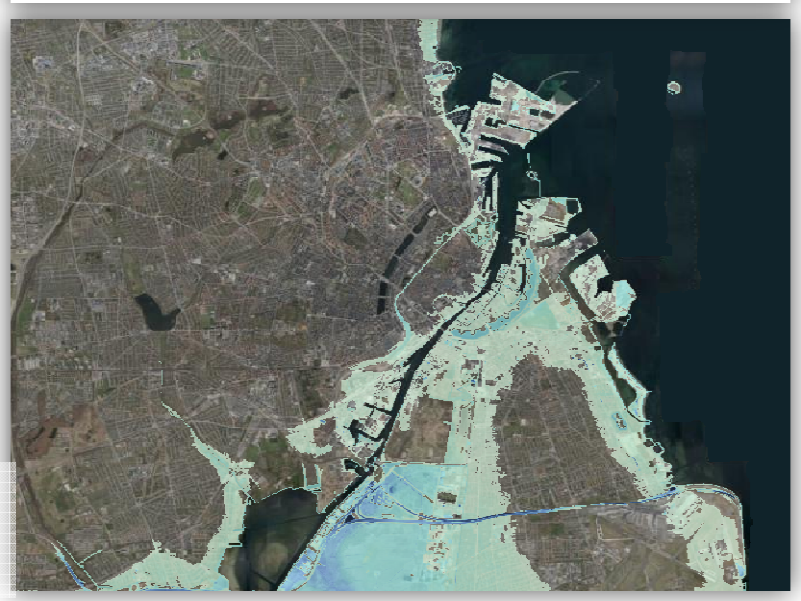


… more details on poster!

The Bodil / Xaver storm surge
Climate perspective

- The storm surge height in Copenhagen during Bodil was measured to be 1.68 m
- With a relative sea level rise of 0.5 m
  - this type of events will occur approximately every 8th year
  - A storm like Bodil would create a surge of 2.18 m, creating massive flooding
- This will massively increase the demand for storm surge forecasting



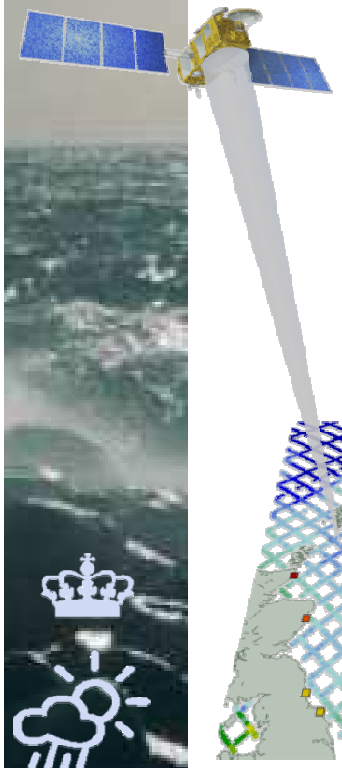


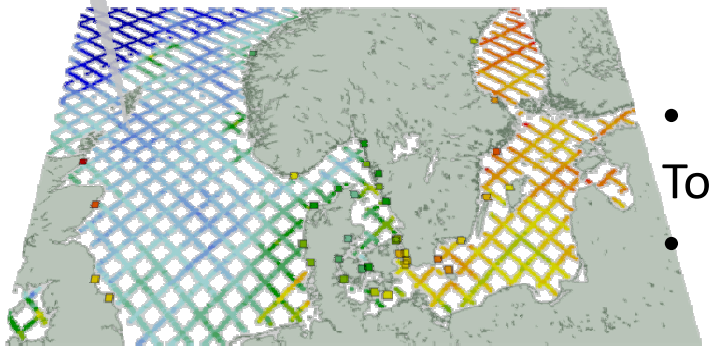
Flooding of Copenhagen with a static sea level of 2.2 m
http://www.klimatilpasning.dk/vaerktoejer/havvandpaaland/havvand-paa-land.aspx

Data source for assimilation
Tide gauges vs. altimetry

Tide gauges	*Altimetry*
High temporal resolution	10 or 30 day repeat cycle
Single points, mostly coastal	High resolution along-track, ~100 km between tracks*

* By using multi-satellite constellations, this may be improved





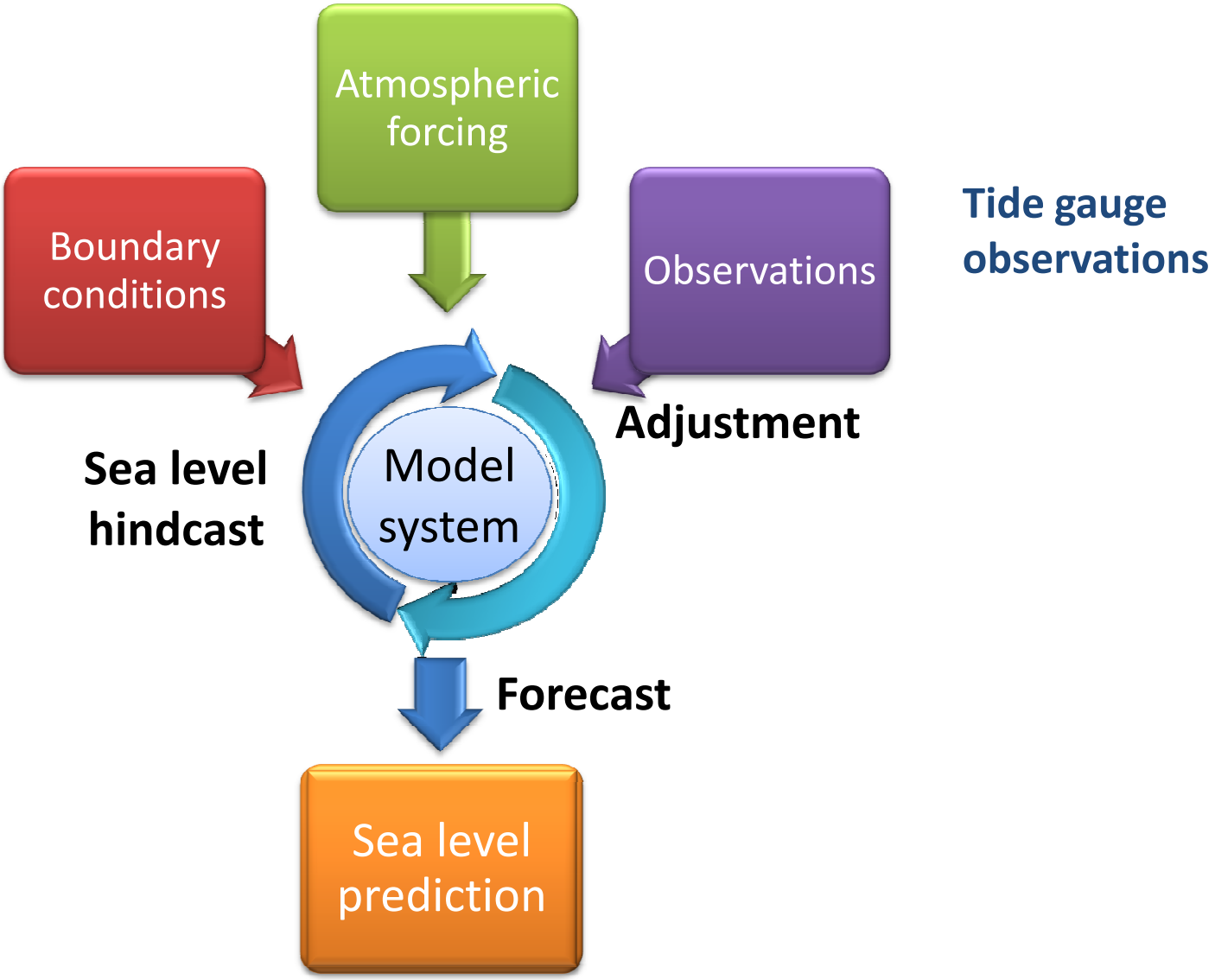
The DMI blended product combines

- The high temporal resolution and real-time availability of tide gauges
- The spatial cover of satellite altimetry

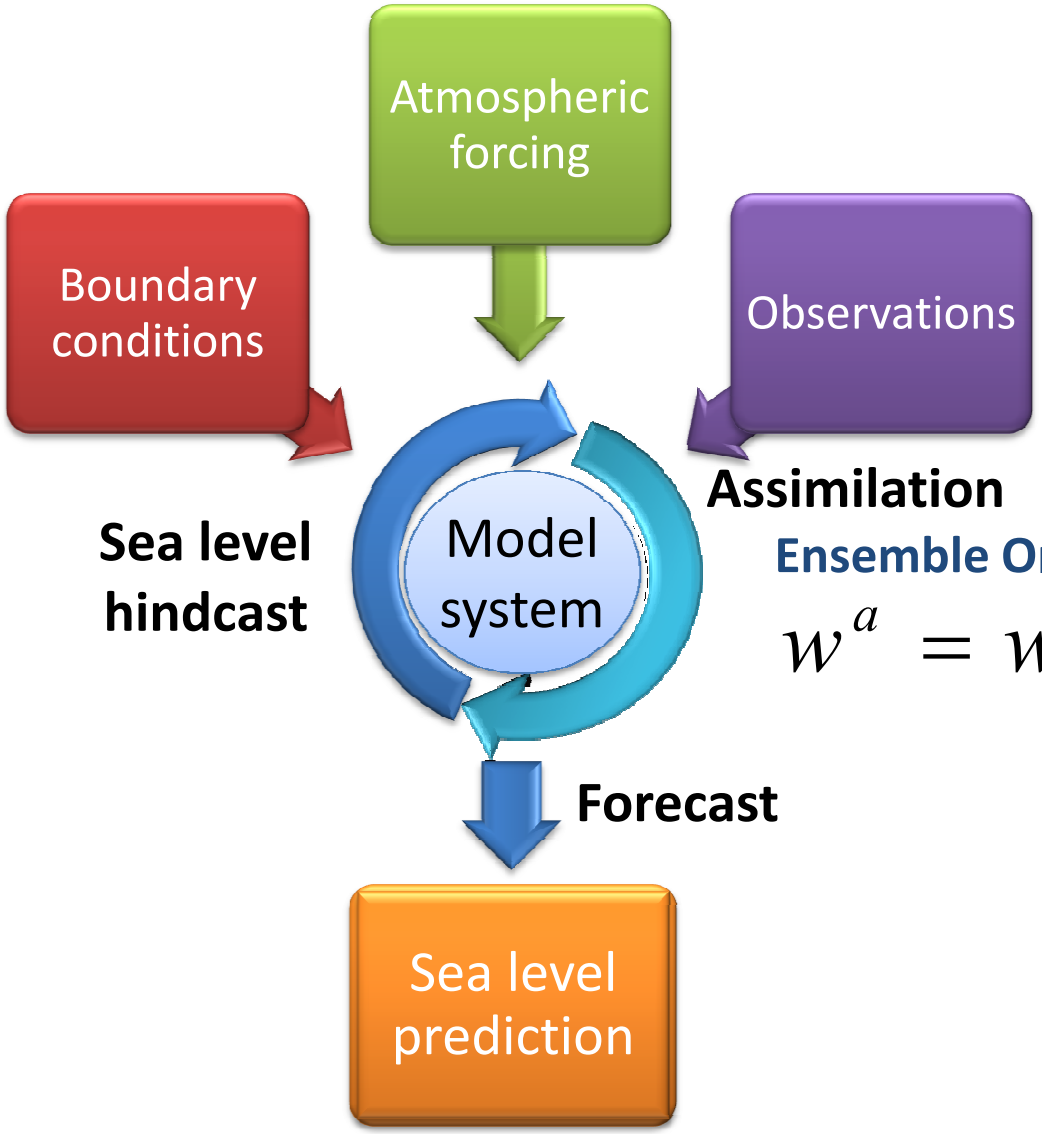
To provide

- NRT hourly now-cast of sea level (2D or along-track)
- Based on observations
- Independent of weather forecast
- Independent of hydrodynamic ocean models

DMI storm surge forecast system today



DMI storm surge forecast system with data assimilation of coastal sea level

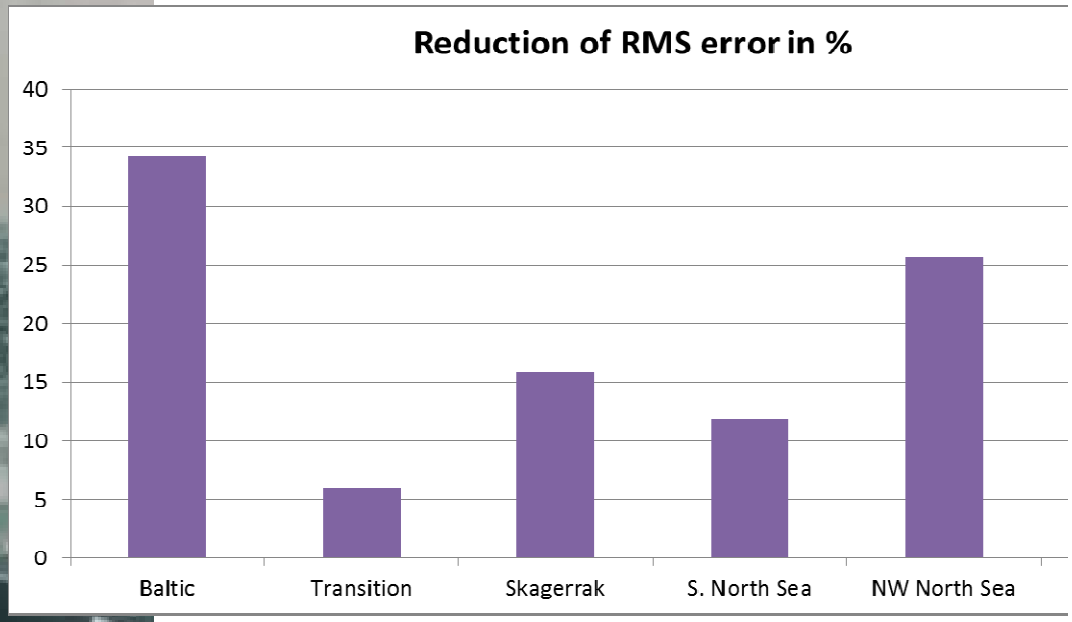


DMI blended sea level product

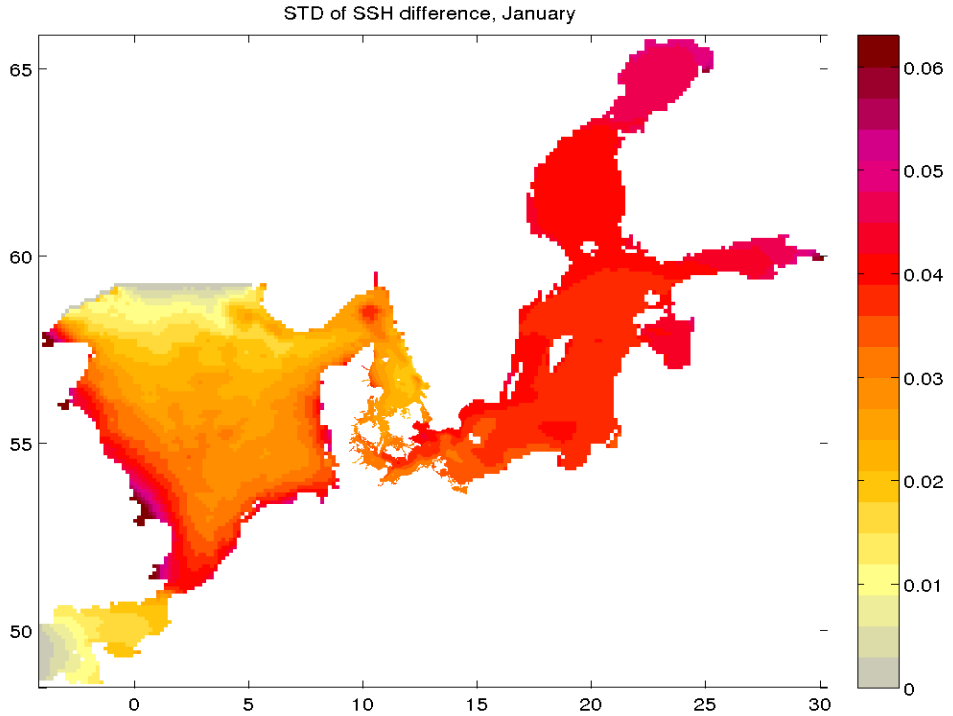
Ensemble Optimum Interpolation (EnOI)

$$w^a = w^f + K(w^0 - Hw^f)$$

Improvement by assimilation in 2-year experimental simulation



Root mean square error reduction at independent validation stations, averaged by area and over 2 years.

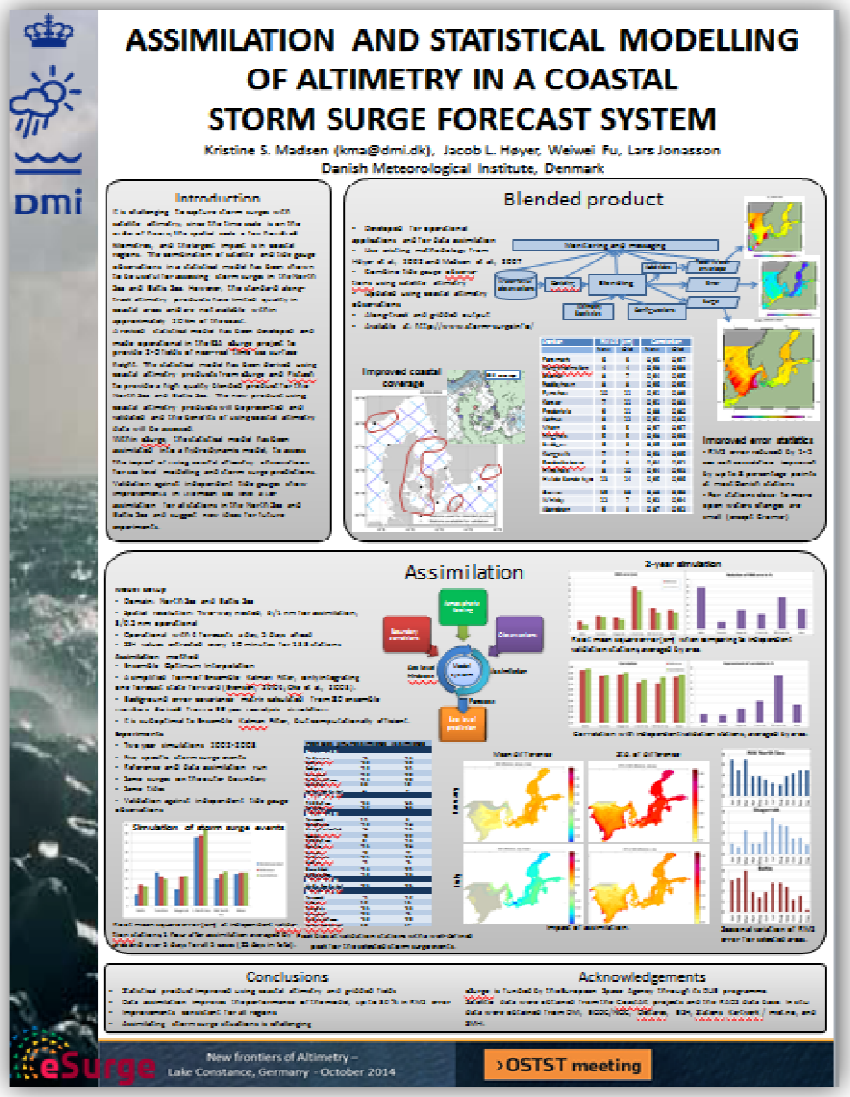


Standard deviation of change made by assimilation, January 2003 and 2004.

Assimilating coastal sea level into the DMI storm surge model

More details on poster tomorrow:

Madsen et al., session title Science Results from Satellite Altimetry: Finer scale ocean processes (mesoscale and coastal)



Summary

- The Xaver/Bodil storm surge was massive, but also showed how storm surge forecasting greatly benefit from alternative data sources.

- The North Sea – Baltic Sea transition zone is a great place to test altimetry products, due to varied coastline and ocean types, and very high number of tide gauges.

- Assimilation of blended pro-duct using coastal satellite altimetry and tide gauge observations improve RMS errors by up to 34% in the North Sea – Baltic Sea area.