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Assimilation of SSH using tide gauge and coastal satellite altimetry observations

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Outline

- Blended product
  - Improvements using coastal altimetry
  - Validation
- Data assimilation experiments
  - Setup
  - Validation
- Conclusions

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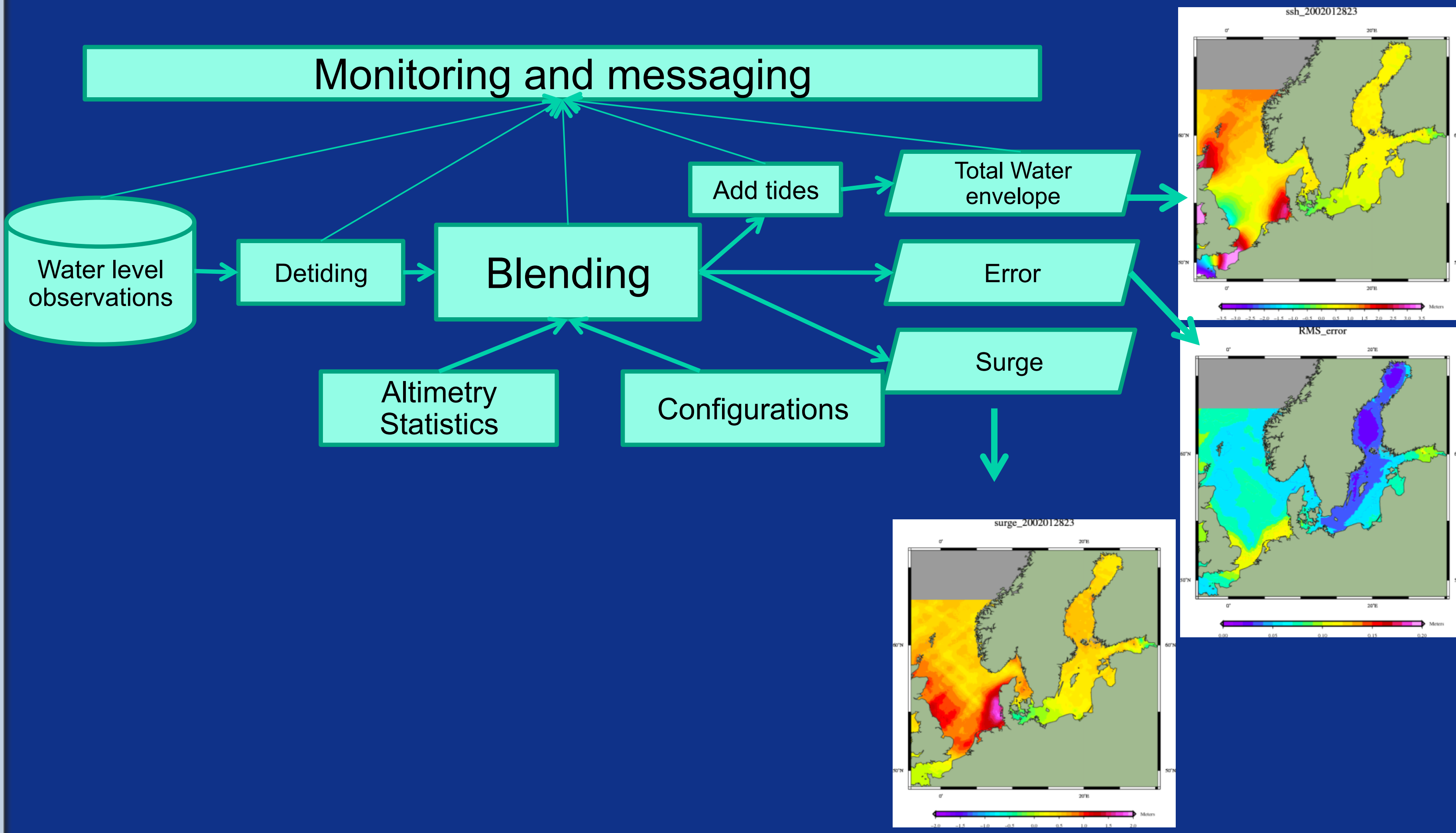
Statistical tide gauge and altimetry product

- Developed for operational applications and for data assimilation
- Use existing methodology from Høyer et al., 2002 and Madsen et al., 2007
    - Combine tide gauge observations using satellite altimetry
- Updated using coastal altimetry observations
- From along-track to gridded output

- 2 years, 2002 and 2003 and 5 Storm surge events (SEVs)
- Ready to run operational and NRT
    - Available at: http://www.storm-surge.info/

Blending method



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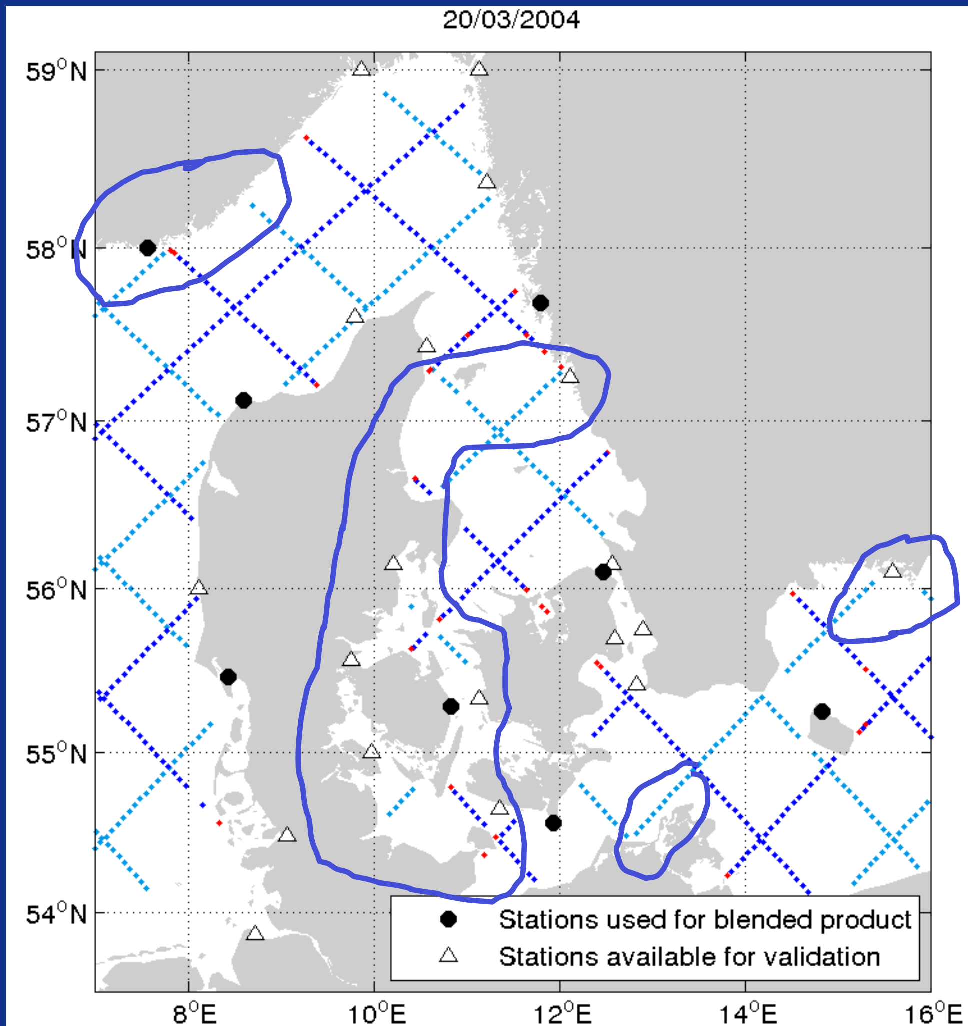
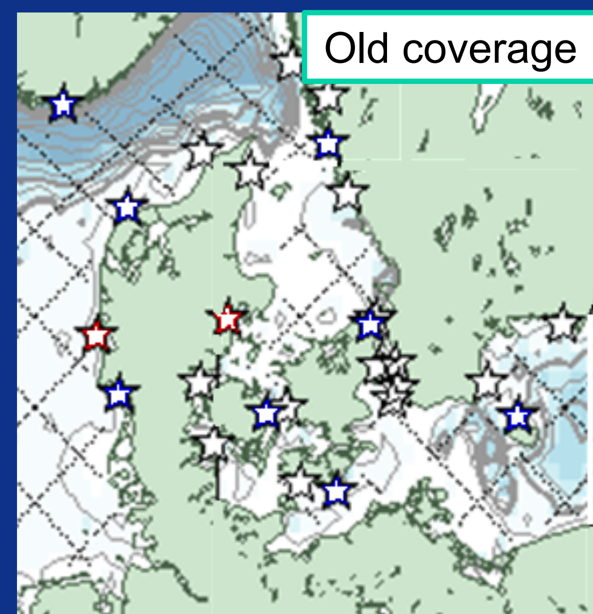
Enhanced data return from coastal 20 Hz



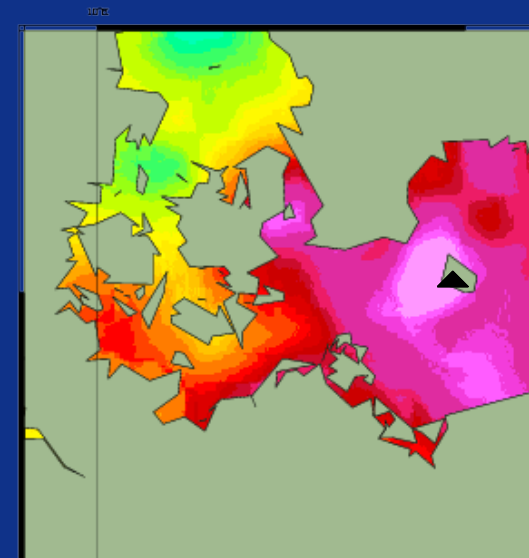
Tide gauges used for the blended product (black circles) and for independent validation (white triangles) and altimetry tracks (dark blue: Jason2 1 Hz, red Jason 2 20 Hz, light blue Jason 1 interleaved)

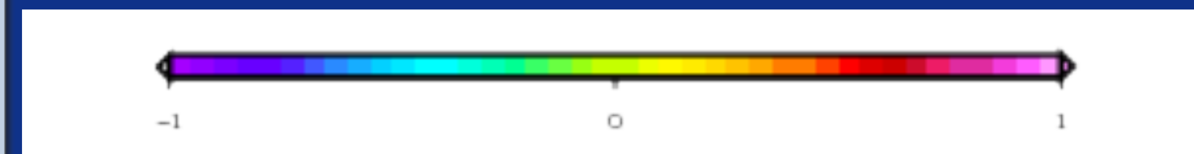
- More data now available in 1 Hz product (highlighted zones)
- 20 Hz product adds value close to the coast

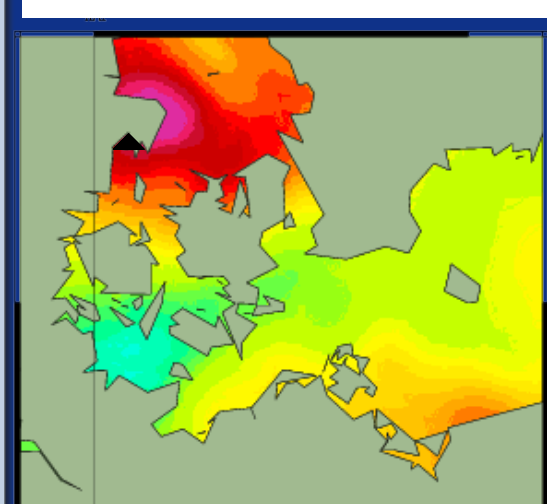


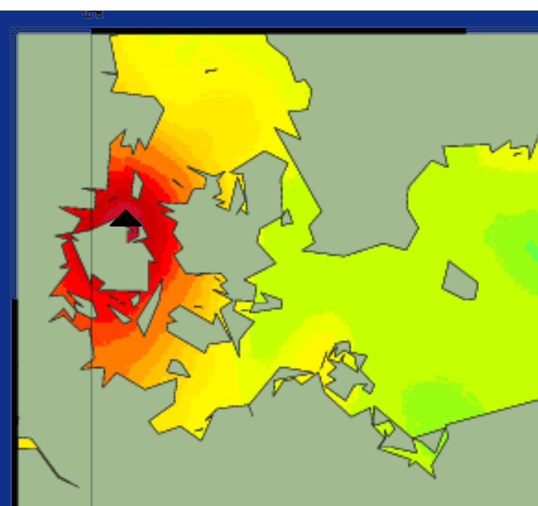
Gridded weights

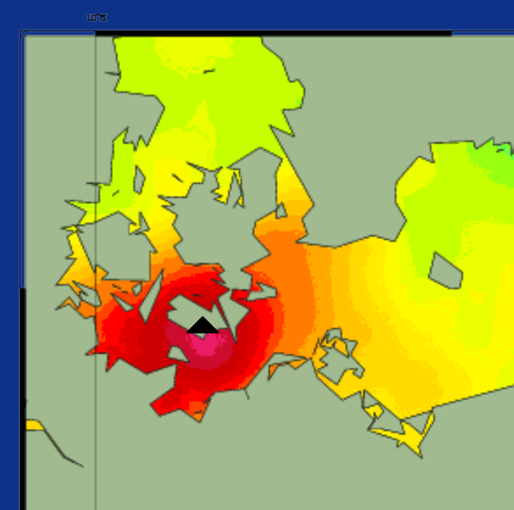
- Weights determined for three regions
  - North Sea
  - Transition Zone
  - Baltic sea





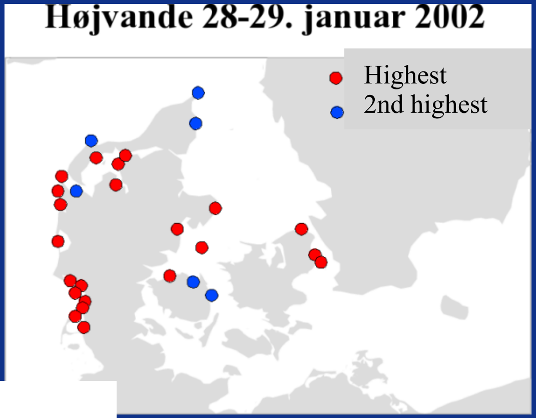


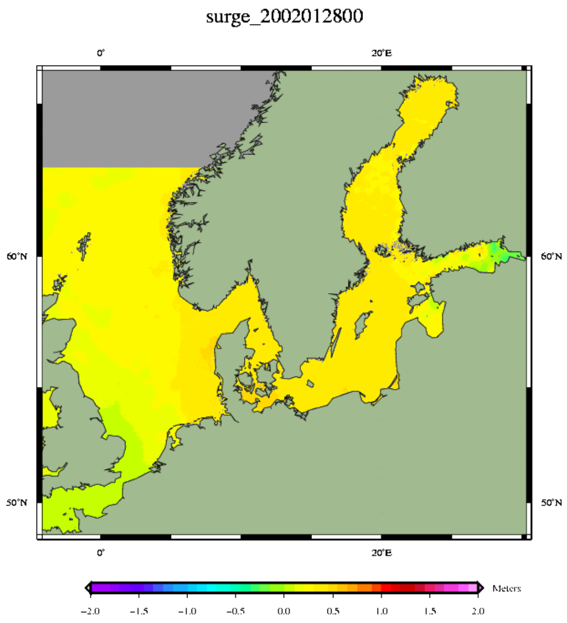


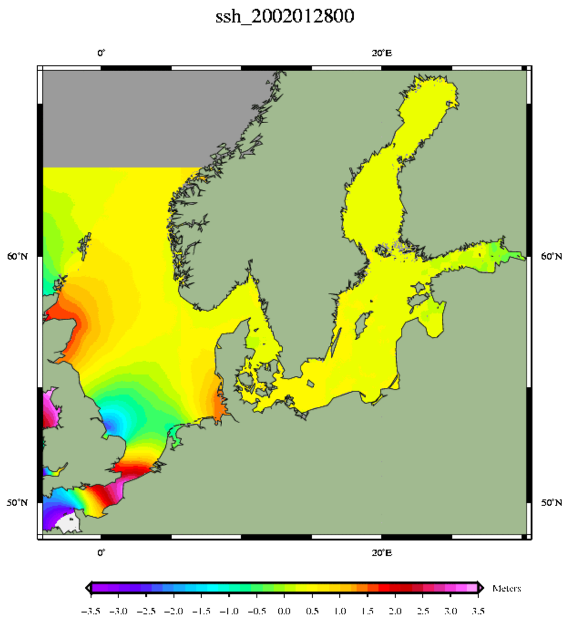


Example, January 2002

- Storm surge in the Danish west coast and Kattegat
- Highest water level: 28-29 January
- Captured well by the blended product







Validation of blended method

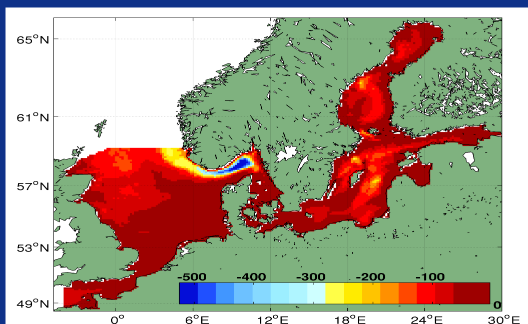
Station	RMSE [cm]		Correlation	
	New	Old	New	Old
Forsmark	6	6	0,95	0,97
Kungsholmsfort	4	4	0,98	0,98
Skanör	8	7	0,94	0,95
Rødbyhavn	8	8	0,96	0,95
Fynshav	10	11	0,91	0,89
Korsør	7	11	0,91	0,83
Fredericia	9	11	0,88	0,80
Aarhus	8	12	0,91	0,82
Viken	6	5	0,97	0,97
Ringhals	5	5	0,98	0,96
Smögen	6	6	0,95	0,95
Kungsvik	7	7	0,93	0,95
Frederikshavn	6	8	0,94	0,92
Hirtshals	8	10	0,94	0,93
Hvide Sande kyst	13	14	0,95	0,96
Cromer	15	20	0,80	0,60
Whitby	12	7	0,92	0,94
Aberdeen	9	8	0,87	0,92

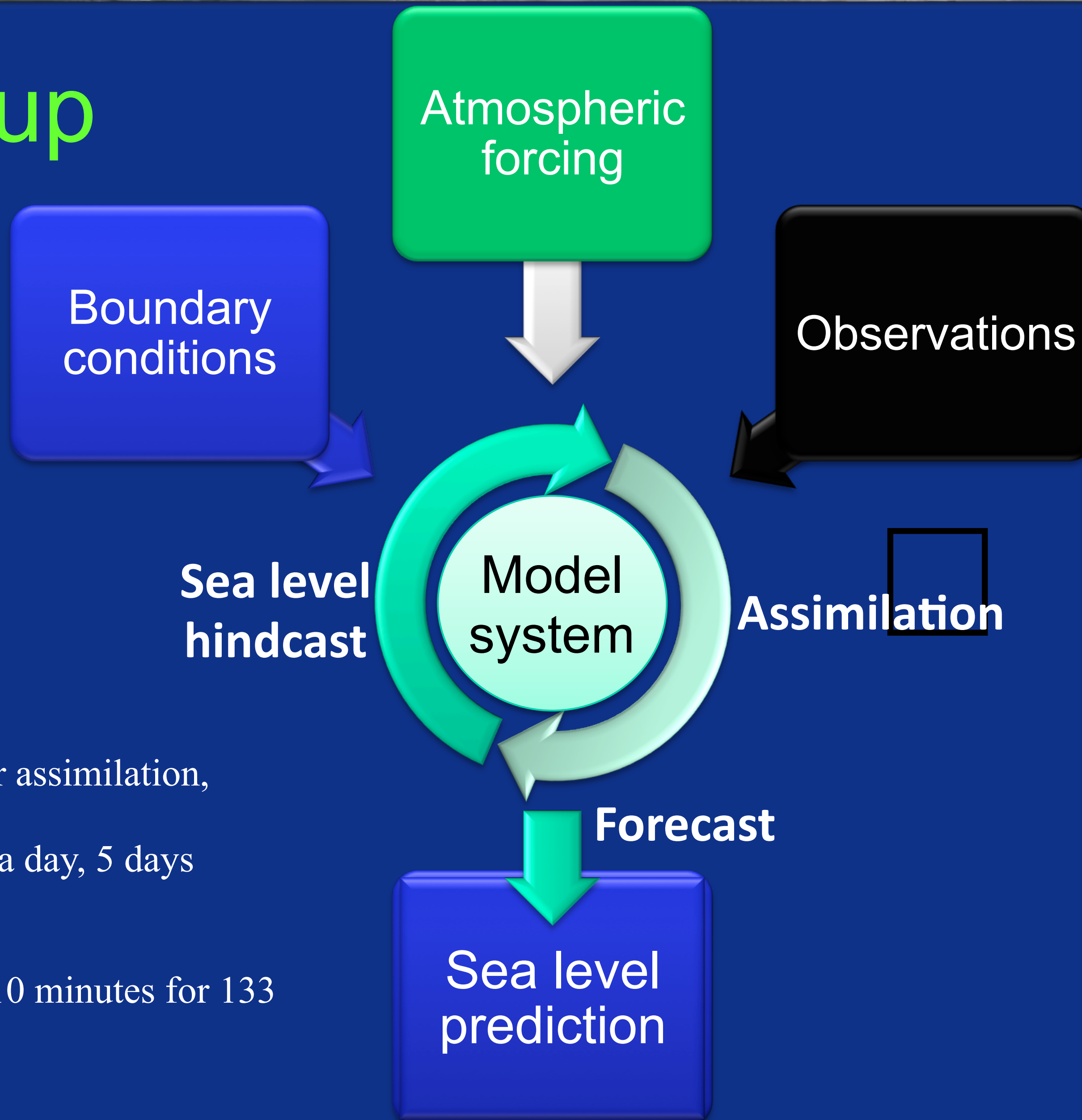
- RMS error reduced by 1-5 cm and correlation improved by up to 8 percentage points at most Danish stations
- For stations close to more open waters changes are small (except Cromer)

Root mean square error and correlations between independent tide gauge stations and blended model averaged within 75 km of the station.

Assimilation experiments

Model Setup





- Spatial resolution: 6/1 nm for assimilation, 3/0.5 nm operational
- Operational with 4 forecasts a day, 5 days ahead
- hourly 3-D fields
- SSH values extracted every 10 minutes for 133 stations

Assimilation experiments

Assimilation metod:

- Ensemble Optimum Interpolation
- A simplified form of Ensemble Kalman Filter, only integrating one forecast state forward (Evensen, 2004; Oke et al., 2003).
- Background error covariance matrix calculated from 80 ensemble members derived from a 20 year reanalysis simulation.
- It is suboptimal to Ensemble Kalman Filter, but computationally efficient.

Experiments:

- Two year simulations 2002-2003
- Five specific storm surge events →
- Reference and data assimilation run
    - Same surges on the outer boundary
    - Same tides
- Validation against independent tide gauge observations

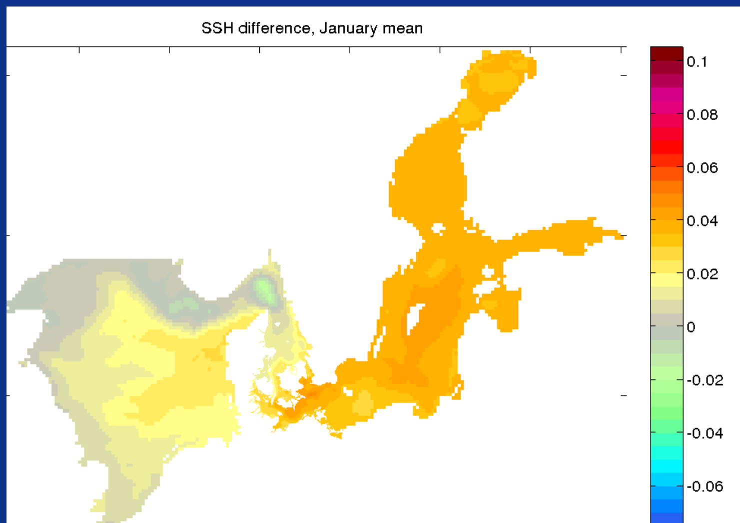
Case 1: 20020121 – 20020210
Case 2: 20020215 – 20020307
Case 3: 20031201 – 20031221
Case 4: 20040314 – 20040403
Case 5: 20050101 – 20050121

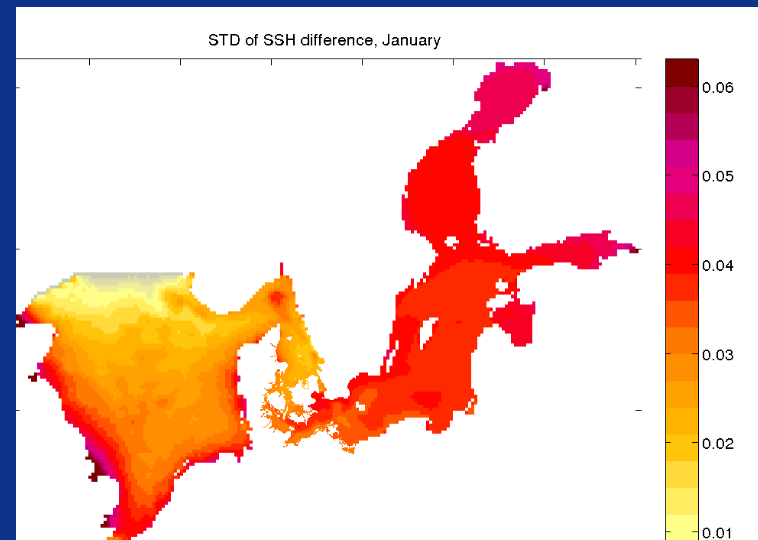
Impact of Assimilation, Assim-ref

Mean difference

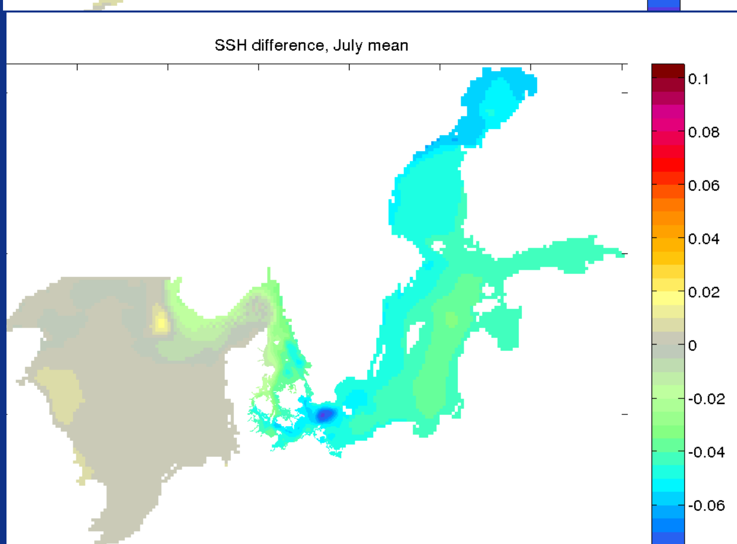
Stddev of differences

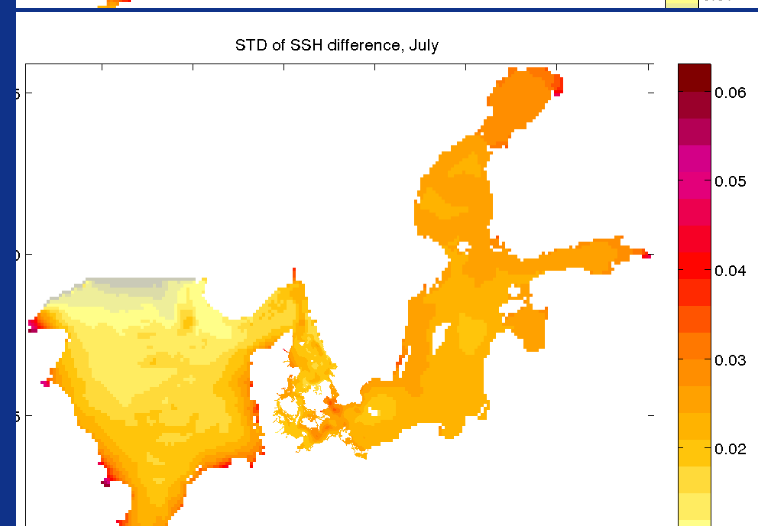
January





July





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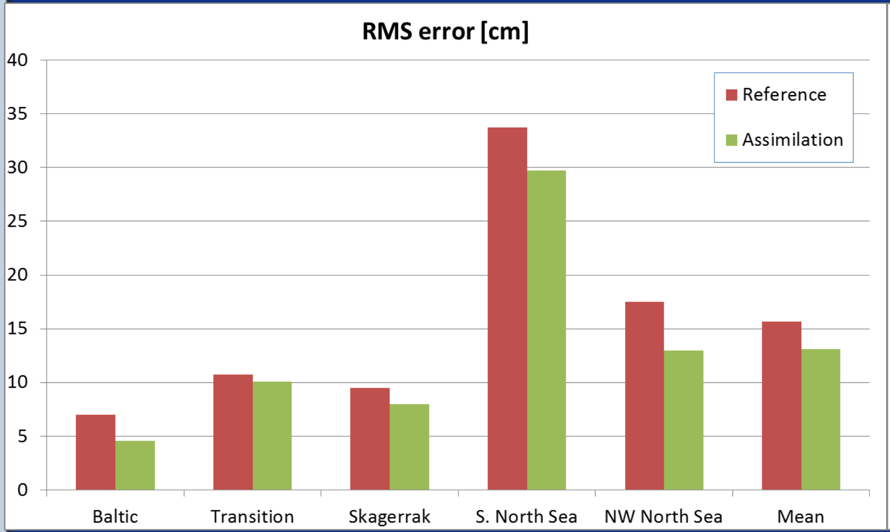
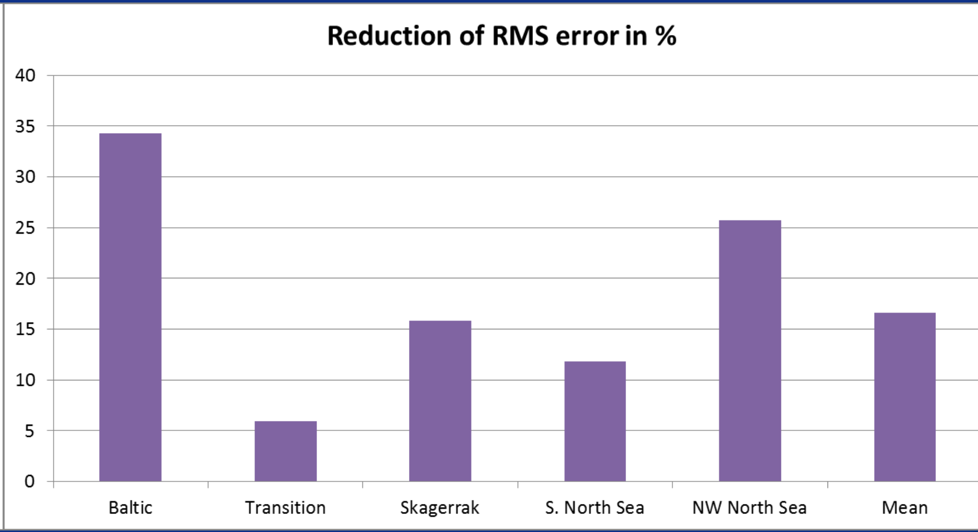
2-year simulation root mean square error

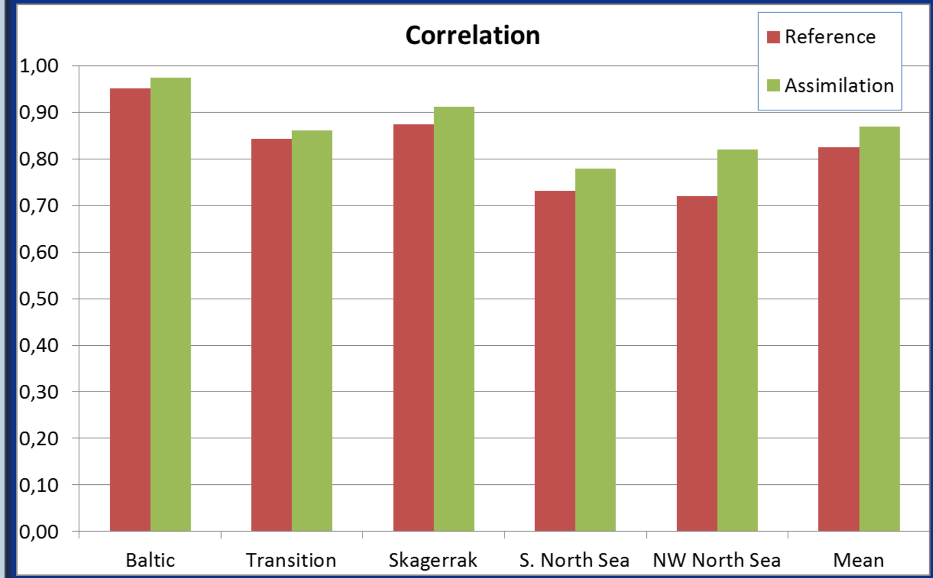
Root mean square error [cm] at independent validation stations, averaged by area and over 2 years

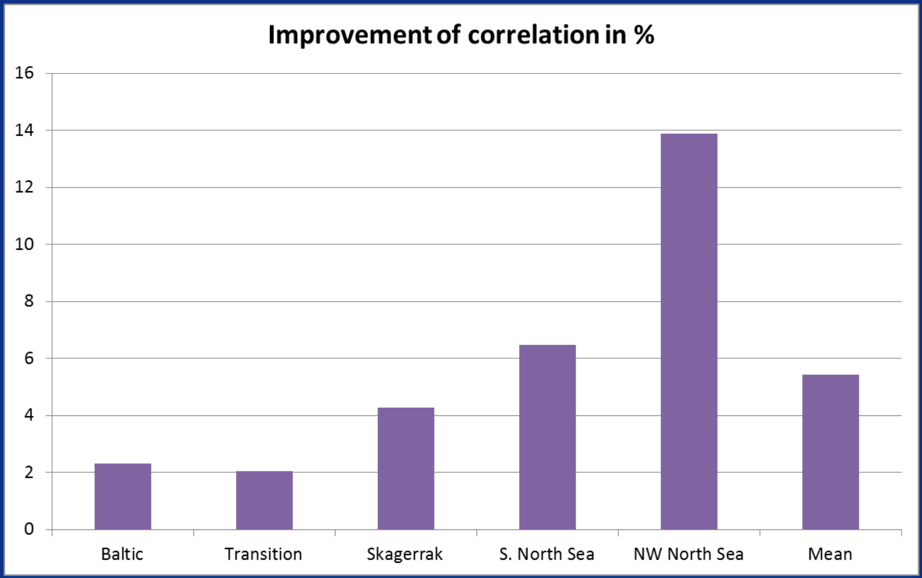




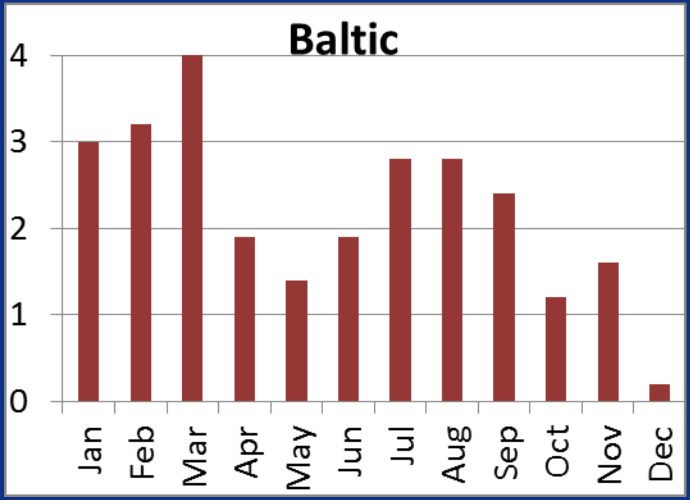
2-year simulation correlation

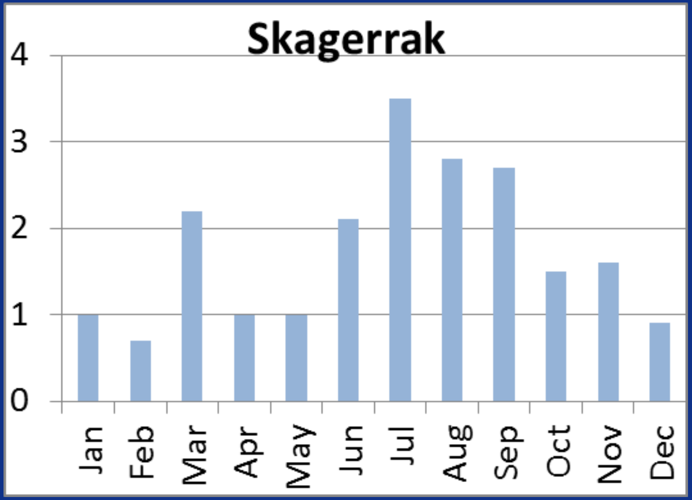
Correlation at independent validation stations, averaged by area and over 2 years

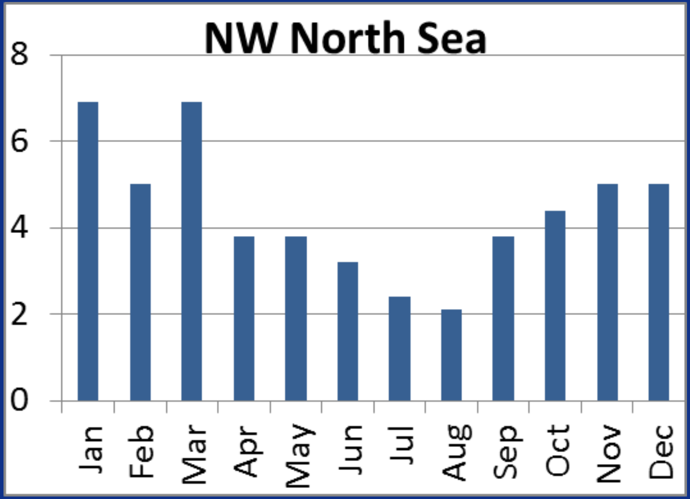




2-year simulation: Seasonality in reduction of RMS error [cm]

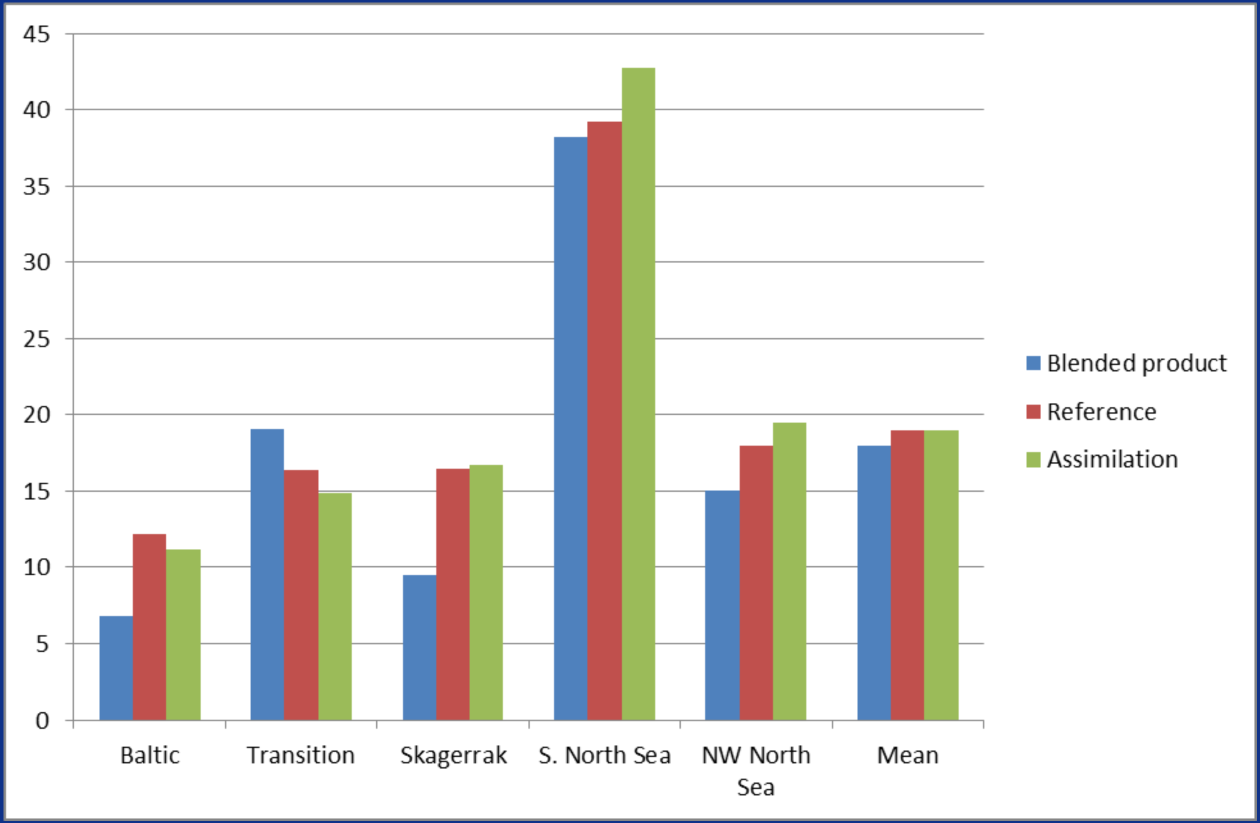






Storm surge cases:
Statistics after 1 hour of assimilation

Root mean square error [cm] at independent validation stations, averaged by area and over 5 days for all 5 cases (25 days in total)



Conclusions

- Statistical product improved using coastal altimetry and gridded fields
- Data assimilation improves the performance of the model, up to 30 % in RMS error
- Improvements consistent for all regions
- Assimilating storm surge situations is challenging