

Influence of the assimilation of sea surface height data on the ocean state in the North- and Baltic Seas

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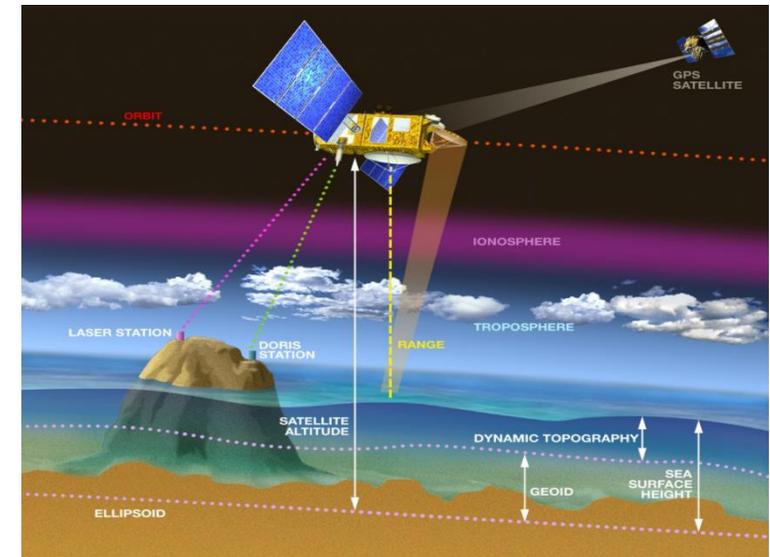
Motivation

- Social and socio-economic importance of the **North- and Baltic Seas**
- Madsen et al (2016) successfully assimilating a blended data product
- So far: **no assimilation of along-track satellite SLA** in this region
- Now: new techniques & multimission data

→ **Can along-track altimetry data be used to improve the ocean state estimate by Data Assimilation?**



Source: <https://www.srf.ch/news/panorama/sturm-xaver-das-schlimmste-steht-noch-bevor>



Source: https://www.aviso.altimetry.fr/gallery/entry_1_altimetry_principle.html

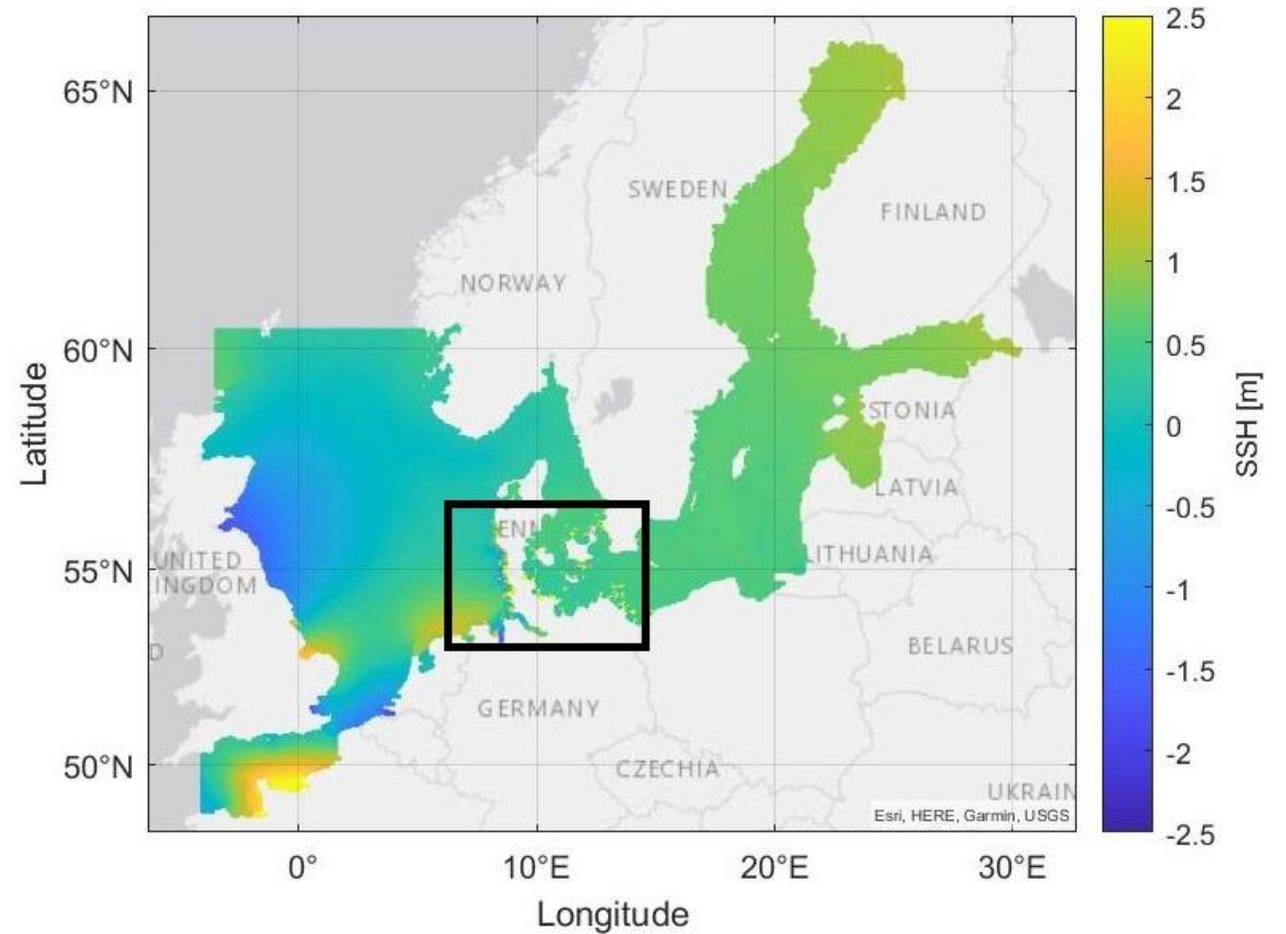


Model & Data

Model

- HIROMB-BOOS-Model (HBM)¹
- Operational ocean forecasting
- Nested grids:
 - Coarse grid: 5km
 - Fine grid: 900m
- SSH Reference: Modelnull

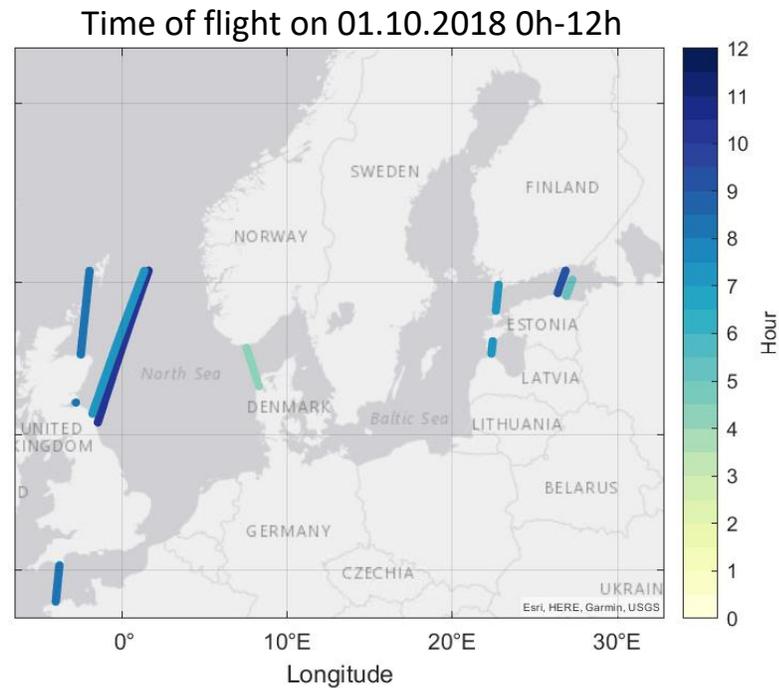
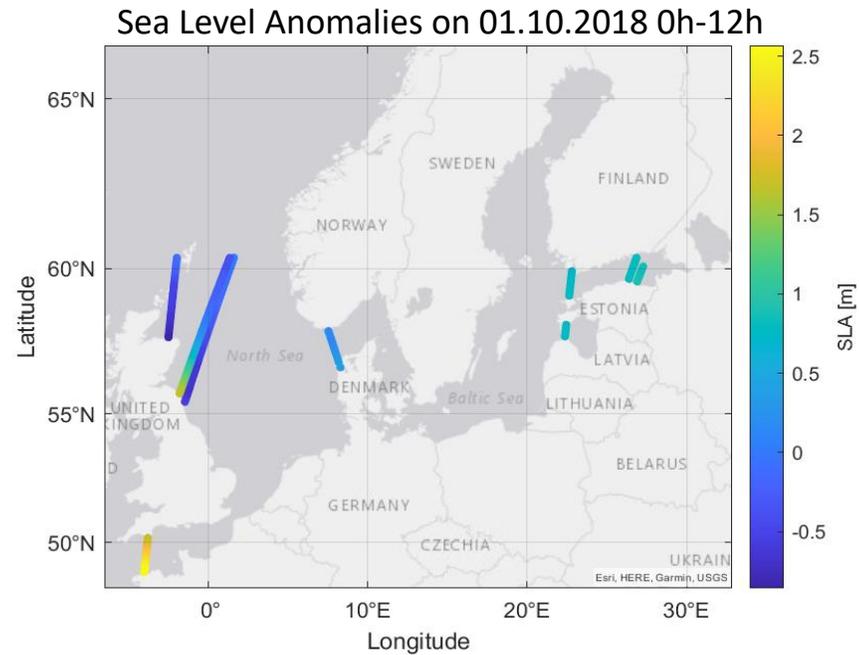
Sea Surface Height on 01.10.2018 00:00:00



1: FROM THE GERMAN FEDERAL MARITIME AND HYDROGRAPHIC AGENCY (BSH) IN PARTNERSHIP WITH THE DANISH METEOROLOGICAL INSTITUTE (DMI)

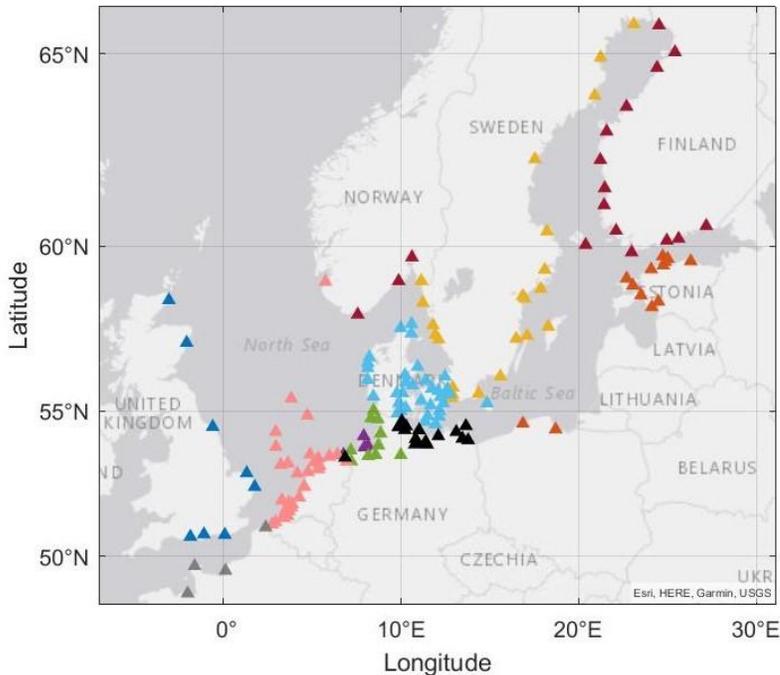
Altimetry SLA

- Data source: CMEMS²
- Along-track
- Multi-Mission (5 Satellites)
- SLA Reference: Mean Sea Level
- Bias to Model SSH:
 - North Sea: 9.5cm
 - Baltic Sea: 6cm
- Strong tides in North Sea
 - Time of flight important



Tide Gauges

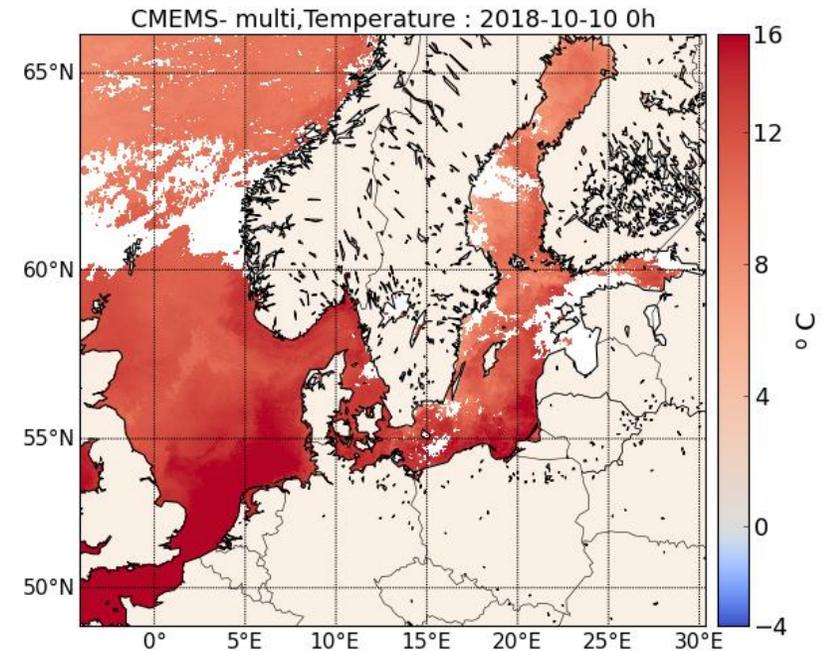
- Data source: CMEMS
- 161 validation TG stations
- Mainly along coastlines
- Adjusting reference level



- ▲ Admiralty Chart Datum
- ▲ BHS77
- ▲ BSCD2000
- ▲ DHHN92
- ▲ DHHN92 / Amsterdam
- ▲ DVR90
- ▲ MSL Baltic
- ▲ MSL North
- ▲ SNN76 / Kronstadt
- ▲ chart datum

CMEMS SST

- Data source: CMEMS
- Spatial resolution: 0.02°
- Temporal resolution: daily





Methodology

Methodology

- Study Period: October – December 2018
- Local Error Subspace Transform Kalman filter (LESTKF)³
- Asynchronous Data Assimilation⁴
 - Calculation at observation time
 - Evolving ensemble perturbations over time
 - Assimilation of all observations every 12h
- Ensemble size = 20
- Parallel Data Assimilation Framework⁵ (PDAF)

3 - NERGER, L., T. JANJIĆ, J. SCHRÖTER, AND W. HILLER (2012) ; 4 - SAKOV, P., G. EVENSEN, AND L. BERTINO (2010); 5 - NERGER, L. AND W. HILLER (2013), [HTTPS://PDAF.AWI.DE](https://pdafter.awi.de)

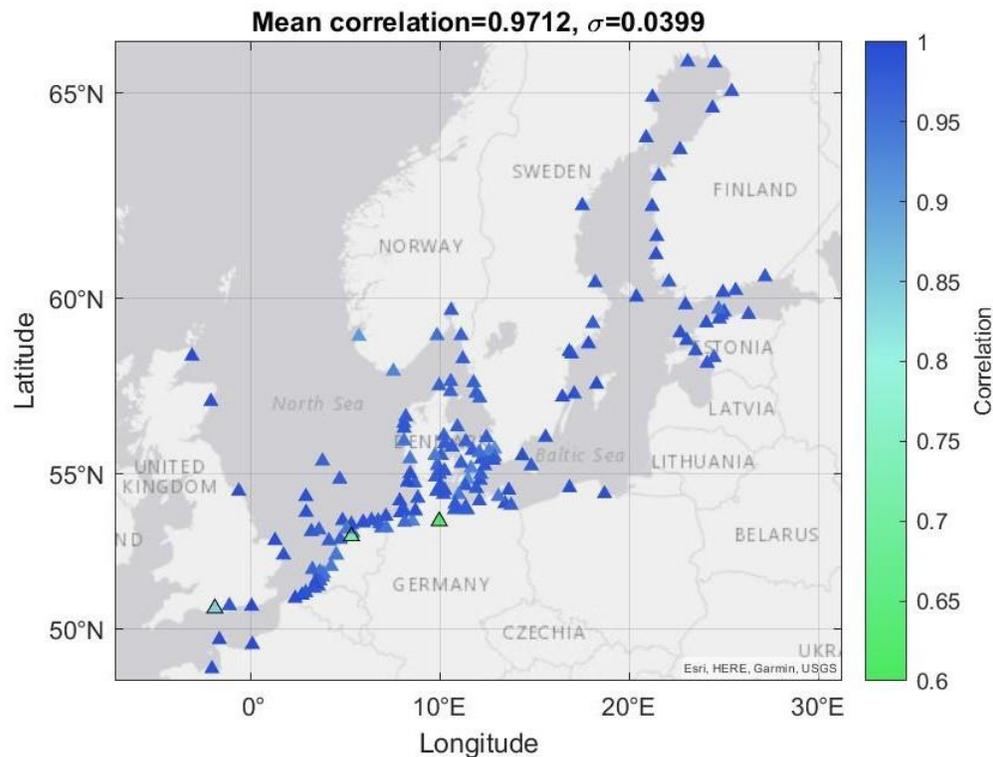


Results

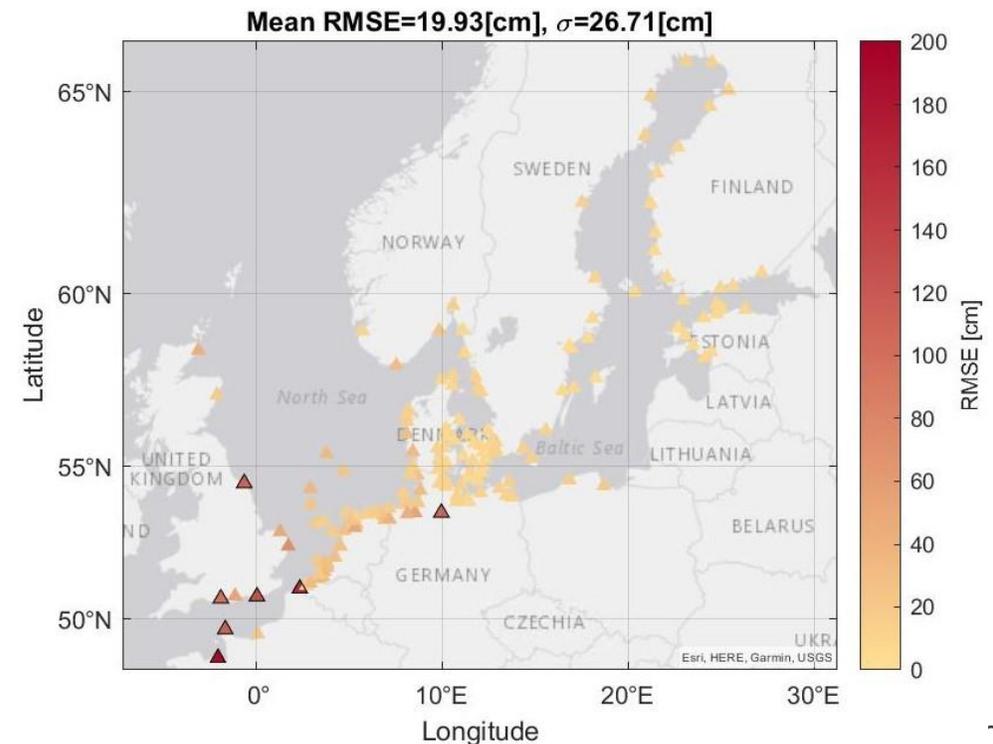
Free Run

- SSH tide gauge **validation**
- Model performance high: Mean correlation = 0.9712

Correlation

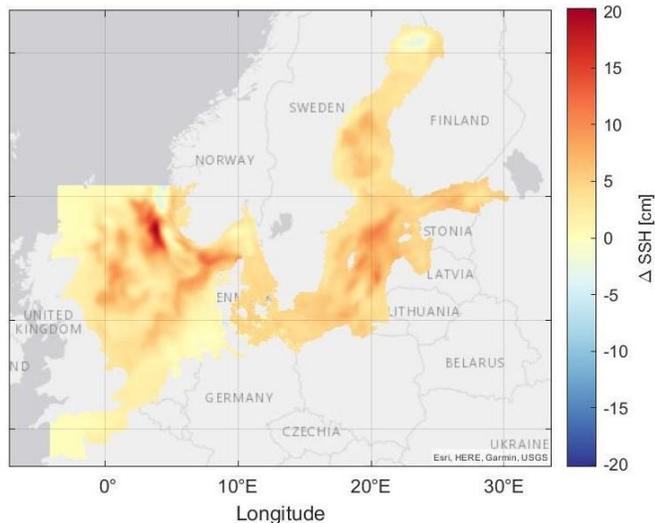


RMSE



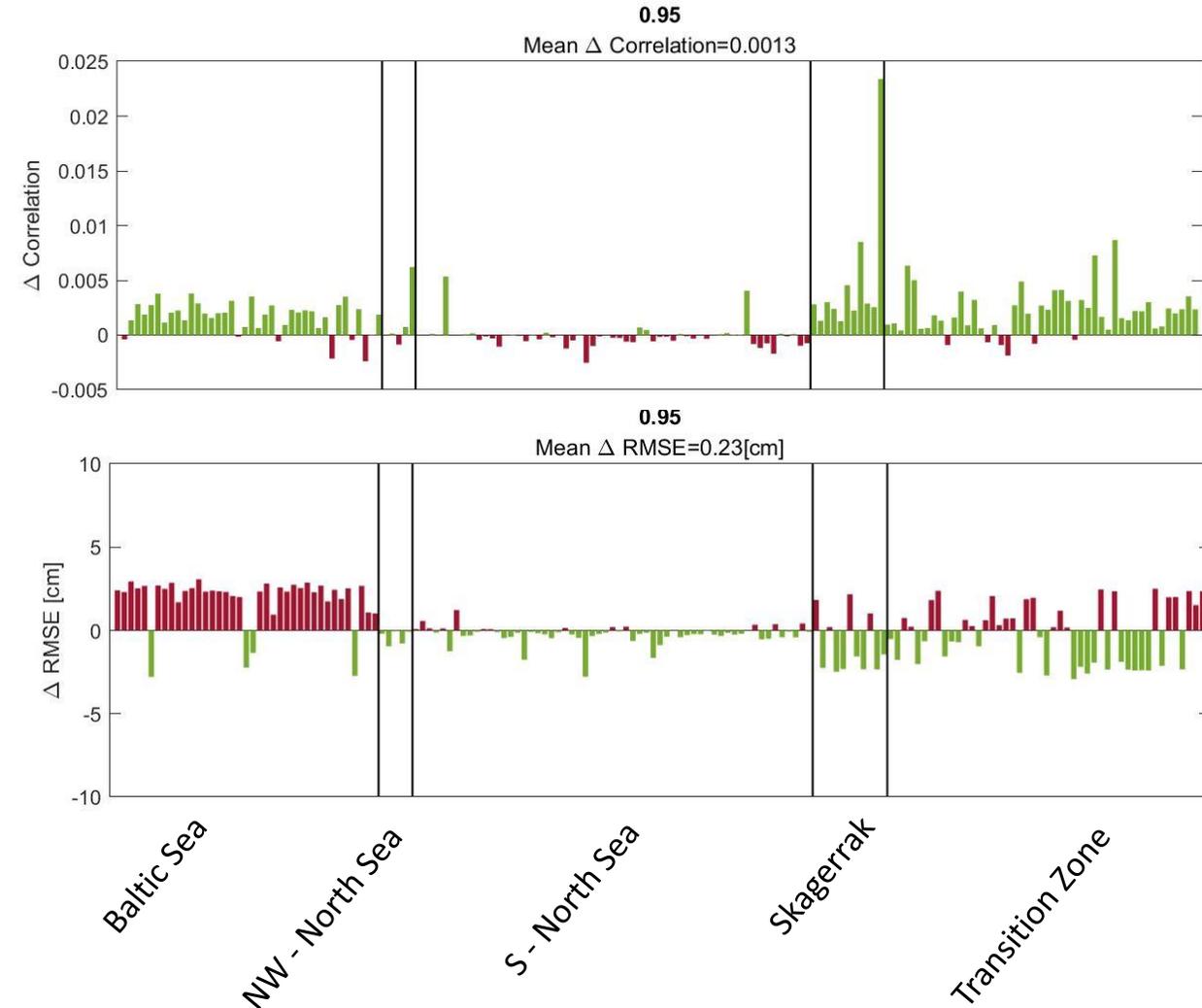
SLA Assimilation

- Forgetting factor: 0.95
- Localization radius: 75km
- **Effect:** Mainly increase of SSH
- **Validation** w.r.t. free run
 - Improvement in correlation up to 0.02 in Skagerrak
 - Improvement in RMSE up to 3cm
 - RMSE deterioration mainly in Baltic Sea



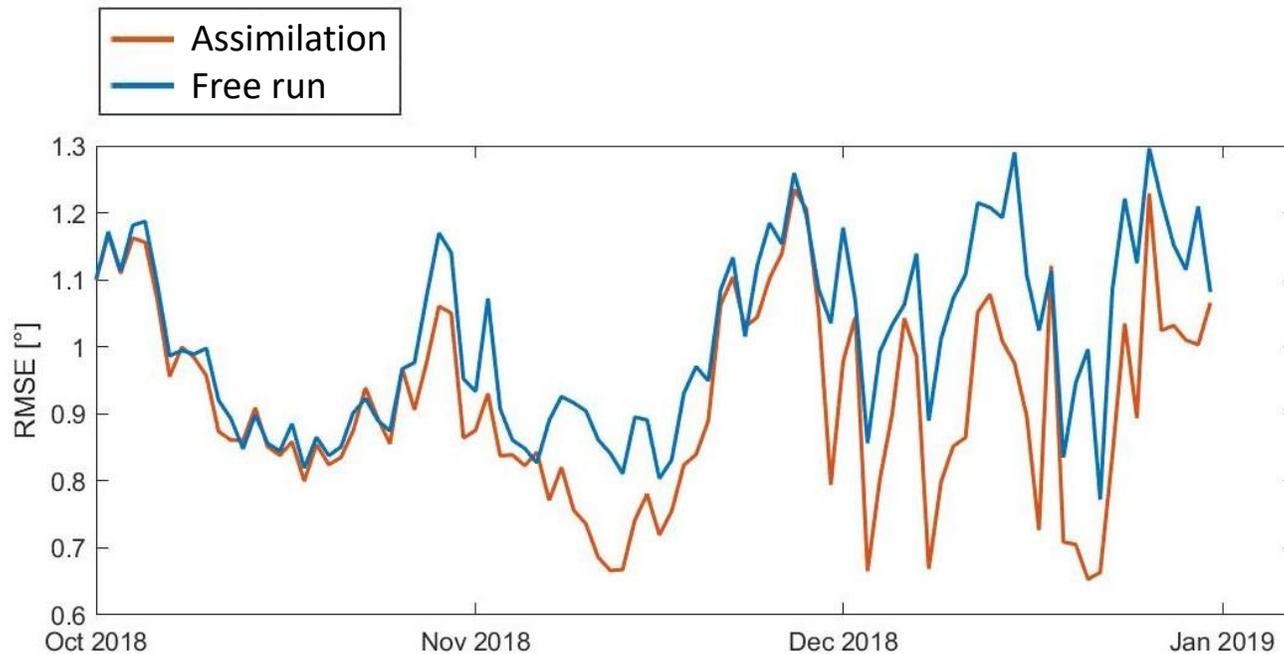
SSH: assimilation - free run
on 31.12.2018 24h

Validation criteria per TG station: assimilation – free run

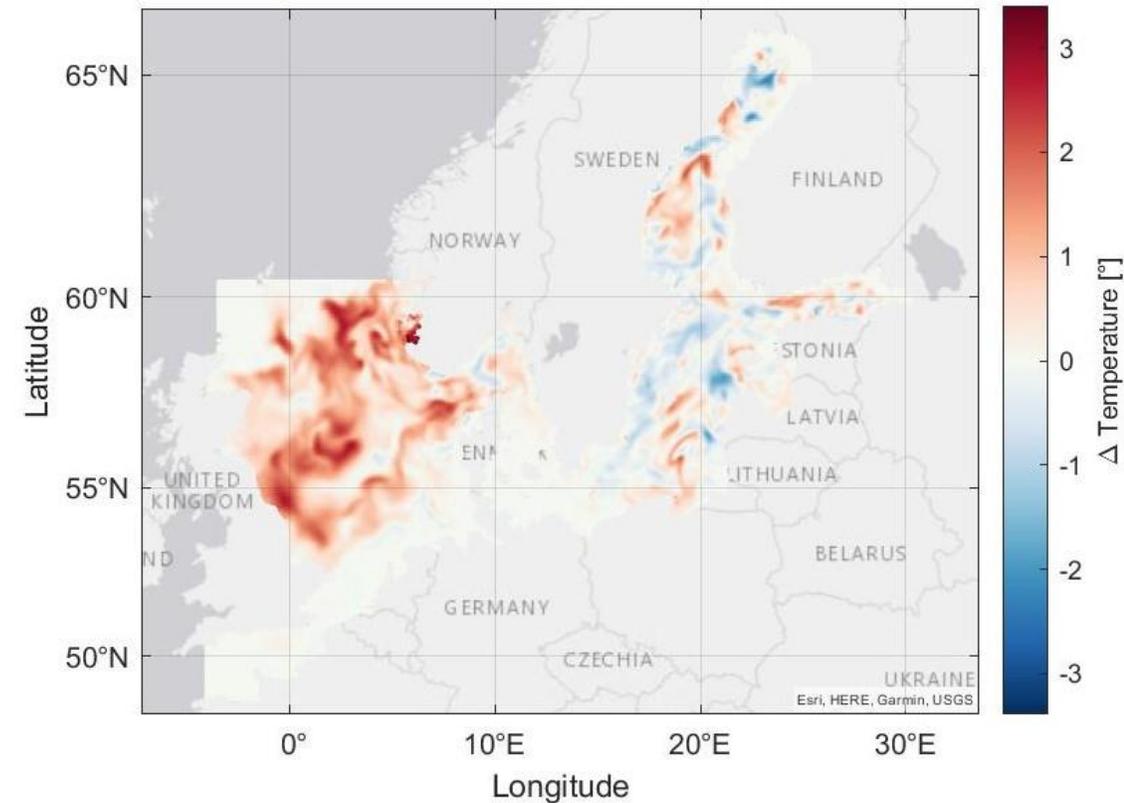


SLA Assimilation

- Increase in SST up to 3° mainly in North Sea
- In Baltic Sea minor increase and decrease in SST
- **Decrease** of average RMSE from 1.01° to 0.9°



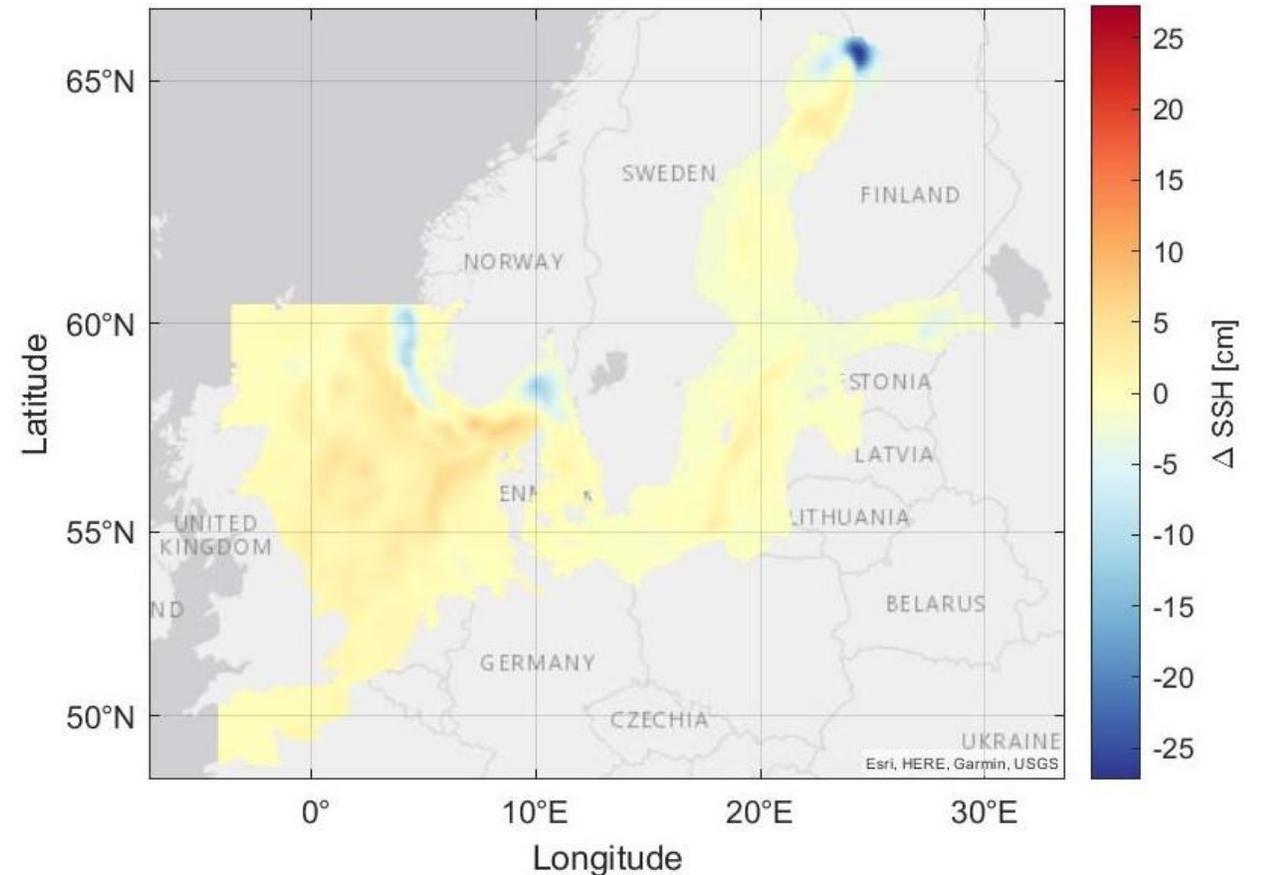
SST: assimilation – free run on 31.12.2018



Bias corrected SLA Assimilation

- Bias primary cause of uplift
 - Now accounted for bias
 - North Sea: 9.5cm, Baltic Sea: 6cm
- Overall less strong effects
- Baltic Sea SSH **decreased** by 3cm
- North Sea SSH **increase** up to 5cm

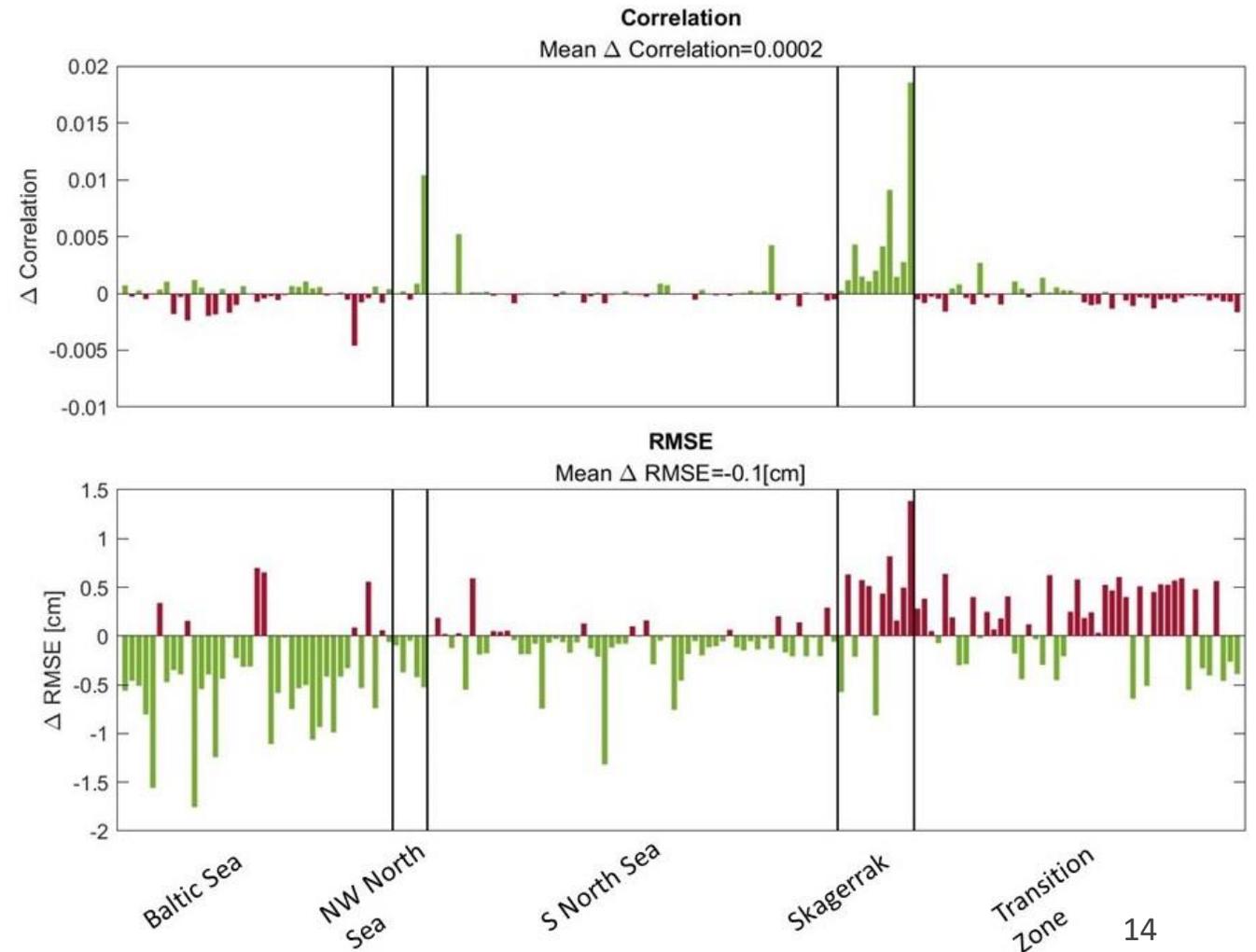
SSH: assimilation + bias correction- free run on 31.12.2018



Bias corrected SLA Assimilation

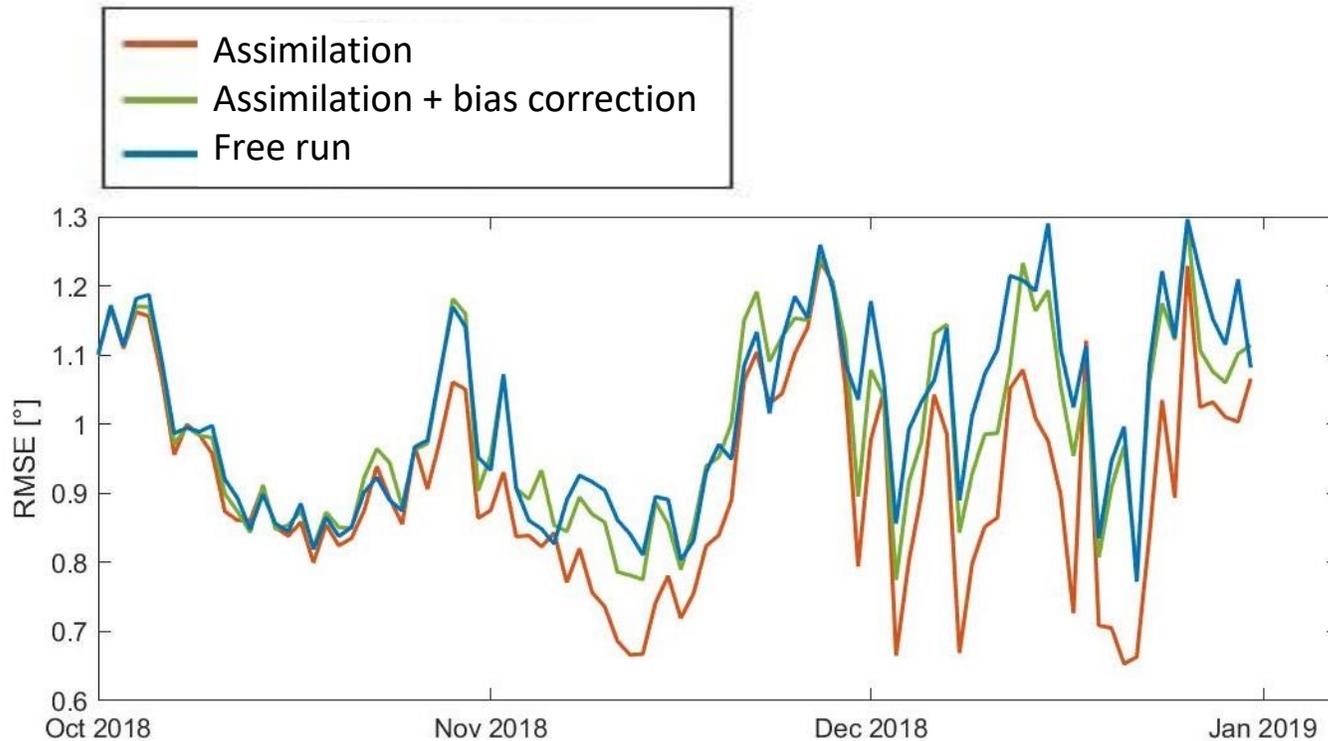
- Strong influence on validation criteria
- Less correlation improvement for most regions
- Strong RMSE improvement in Baltic Sea up to 1.7cm
- Deterioration in Skagerrak and Transition Zone
 - Same track corrected partly for North- and Baltic Sea bias

Validation criteria per TG station: assimilation + bias correction – free run

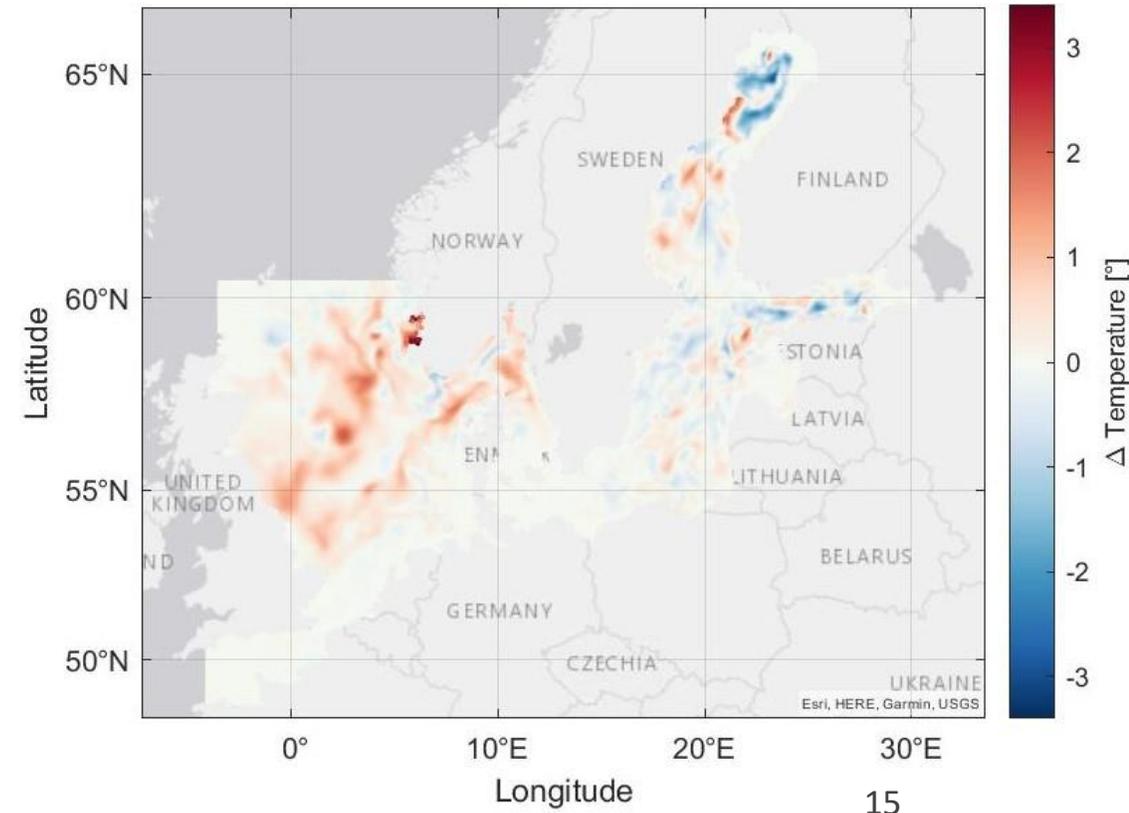


Bias corrected SLA Assimilation

- Less distinct influence
- 0.02° average RMSE improvement to free run



SST: assimilation with bias correction - free run on 31.12.2018



Conclusion

→ Can along-track altimetry data be used to improve the ocean state estimate by Data Assimilation?

- Assimilation of along-track altimetry SLA has **positive** effect
 - Improvements in SSH correlation up to 0.02
 - Improvements in SSH RMSE up to 3cm
 - Improvements in SST RMSE up to 0.35°
 - Especially in Baltic Sea, North-Western and Southern North Sea
- Overall very small changes in validation criteria

Sources

■ Pictures

- **Xaver 2013:** <https://www.srf.ch/news/panorama/sturm-xaver-das-schlimmste-steht-noch-bevor>
- **Altimetry:** https://www.aviso.altimetry.fr/gallery/entry_1_altimetry_principle.html

■ Paper references

- **LESTKF:** *Nerger, L., T. Janjić, J. Schröter, and W. Hiller (2012). A unification of ensemble square root Kalman filters. Monthly Weather Review 140(7), 2335–2345*
- **Asynchronous DA:** *Sakov, P., G. Evensen, and L. Bertino (2010). Asynchronous data assimilation with the EnKF. Tellus A: Dynamic Meteorology and Oceanography 62(1), 24–29.*
- **PDAF:** *Nerger, L. and W. Hiller (2013). Software for ensemble-based data assimilation systems—Implementation strategies and scalability. Computers & Geosciences 55, 110–118*

■ Data sources

- **Model:** *BSH and DMI*
- **Altimetry SLA, SST and TG:** *Copernicus*



Appendix

Study Area

