Assimilation of SST data in BSH operational circulation model for the North Sea and Baltic Sea: recent implementation and results

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

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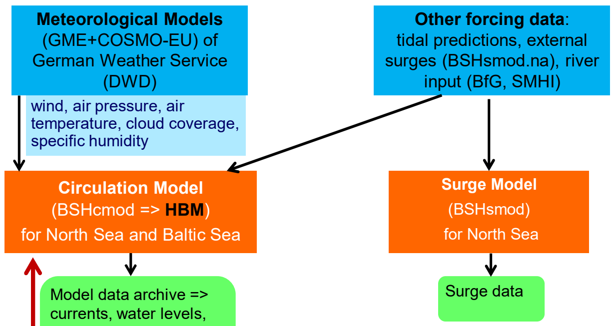
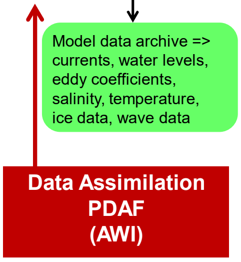
Aims of Assimilation System

With the aim of improving the forecast skill, an **ensemble data assimilation** (DA) system has been coupled with the operational circulation model for the North and Baltic Seas at the German Federal Maritime and Hydrographic Agency (BSH). The DA system uses the Local Error Subspace Kalman Transform Filter (**LESKTF**) algorithm in the Parallel Data Assimilation Framework **PDAF** (http://pdaf.awi.de)[1], which is a flexible software framework developed by the Alfred Wegener Institute (AWI). This DA system has been further developed within the framework of the Copernicus Marine Environment Monitoring Service (CMEMS).

Operational System of BSH with DA

The operational service at the BSH bases its model systems on the 3D baroclinic circulation model **HBM (HIROMB-BOOS Model)**, which provides the basic information for a couple of downstream services, like e.g. the sea level prediction and storm surge warning service for the German coast, or oil spill forecasting and search-and-rescue applications.





- **DA method**: Ensemble Kalman filter
  - Ensemble Kalman filter: Local Error Subspace Kalman Transform Filter (**LESKTF**) scheme (Nerger et al., 2012) in the Parallel Data Assimilation Framework (**PDAF**)
  - Ensemble size **8** (sufficient for good results)
  - Localization in horizontal and vertical
- **Observation data**: 2 SST satellite data sets
  The choice of the data set is based on the availability of the satellite data
  1) Advanced Very High Resolution Radiometer (**AVHRR**), which is processed, gridded and quality controlled by the BSH satellite data service
  2) **L3 CMEMS SST** product
- **Ensemble model states generation**: Initial model error variance/covariance matrix is computed using 12-hourly snapshots of HBM free run outputs over several months Empirical orthogonal functions (EOFs) are applied to generate the ensemble model states (**temperature, salinity, current velocities and sea surface elevation**)
- Satellite data are assimilated every 12 hours on a pre-operational basis

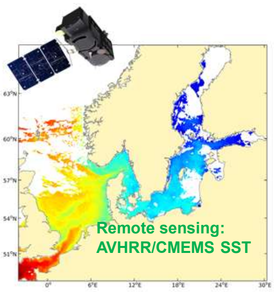


Figure 1.:**General structure of the coupled data assimilation system for the operational circulation model at BSH in Germany.**

Outlook

Data assimilation is under continuous development. It is planed to transfer the PDAF assimilation system into the large coupled system HBM-ERGOM for operational service at the BSH. Moreover, it is planed to extend the assimilation system to include more observations (e.g. biogeochemical observations or in-situ profiles). Within the framework of the CMEMS, an offline version of PDAF is now is developing with using nutrients and oxygen profiles in the Baltic Sea.

Reference:

[1] Nerger, L., Hiller, W., Schröter, J.(2005). PDAF - The Parallel Data Assimilation Framework: Experiences with Kalman Filtering, Use of high performance computing in meteorology : proceedings of the Eleventh ECMWF Workshop on the Use of High Performance Computing in Meteorology, Reading, UK, 25 - 29 October 2004 / Eds.: Walter Zwieflhofer; George Mozdzynski, Singapore: World Scientific, 63-83.

Assessment of the Forecast

SST forecasts from the free model run and from the data assimilation run are compared with nighttime L3 CMEMS satellite product on a daily basis. Time series of temperature and salinity from free model runs and data assimilation runs are further compared with independent in-situ data on a monthly basis.

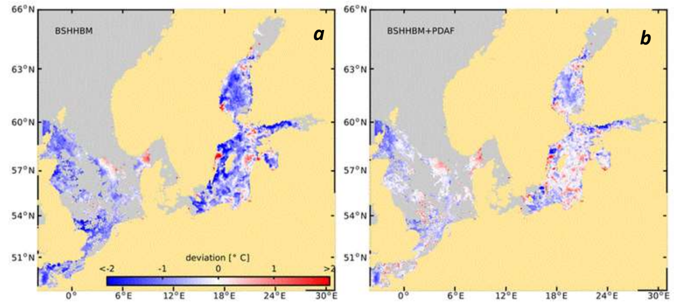


Figure 2.: **Daily cmparison with L3 SST satellite data: BIAS for the forecast without data assimilation (a), BIAS for the forecast with data assimilation (b) on 27. Sept. 2019.**

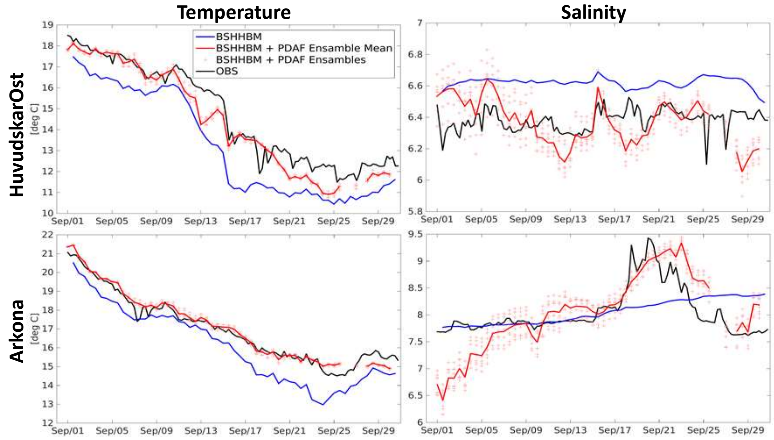


Figure 3.:**Time series of surface temperature and salinity at 2 MARNET stations in September 2019. The forecasts from free model runs and the runs including assimilation are compared with in-situ data.**

Both the daily and monthly validation shows that not only the forecast skill of temperature but also that of salinity have been generally improved. The increment in temporal variations of temperature and salinity from data assimilation runs is shown in the monthly validation.

Vertical Localization of DA

The comparison of the free model runs and the runs including SST assimilation shows that obvious changes in temperature and salinity can be found also in the deepwater, where the ensemble spreads are larger. To damp the spurious correlations, a linear vertical localization function has been further implemented and tested in the DA system.

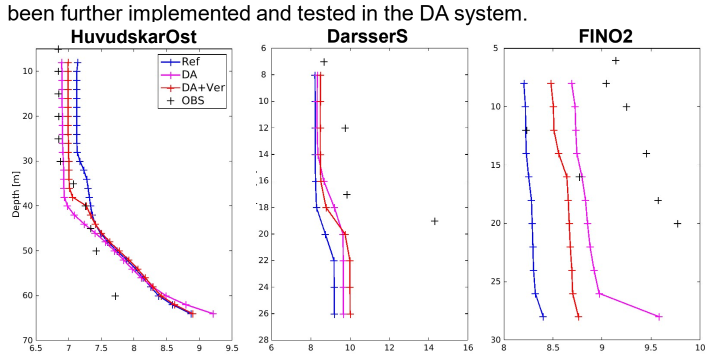


Figure 4. **Monthly mean of salinity profiles at several in-situ stations in the Baltic Sea and the North Sea for October 2018. The forecasts from free model runs, the runs including assimilation, the runs with vertical localization of data assimilation are compared with in-situ data.**

The results suggested that the LESKTF analysis is sensitive to the choice of the vertical localization scales. With choosing half depth of the whole water column as the vertical localization scale, the improvement of vertical temperature and salinity structure has been shown in the validation of the results with independent CMEMS in-situ Observations, especially at the stations in the Baltic sea.