Assimilating NOAA SST data into BSH operational circulation model for the North and Baltic Seas:

What can we learn about the model and data?

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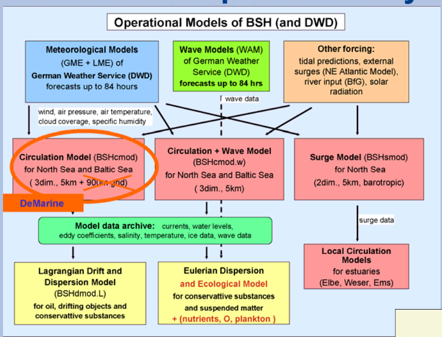
Abstract

Within the DeMarine-Environment project- as a part of the European Global Monitoring for Environment and Security (GMES) initiative,- a data assimilation (DA) system has been developed for the operational circulation model of the German Maritime and Hydrographic Agency (BSH). In order to improve forecast of hydrographic characteristics in the North and Baltic Seas, Singular Evolutive Interpolated Kalman (SEIK, Pham et al., 1998) filter algorithm has been locally implemented for assimilating NOAA sea surface temperature (SST) over the period 01.10.2007 - 30.09.2008. Significant error reduction has been achieved for SST forecast and, since 01.10.2010, the data assimilation system has been running at BSH in pre-operational phase. Some aspects of the system implementation however remain a challenge. The forecast quality is found to be dependent on the assumption about model and data error statistics which are not always if ever a priori known. However such a combination of the information from two different sources- the model and the data,- which one gets with a data assimilation, might itself improve our understanding of both these sources and help to optimize the system. Here we discuss SST data assimilation results obtained with several different (with respect to timing, period, frequency) forecasting schemes and initial error statistics.

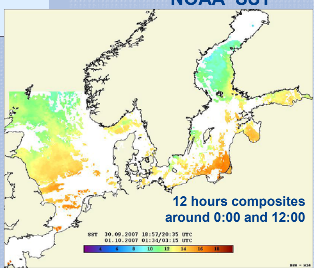
Operational System



Model setup

- horizontal grid spacing:
  ΔLon: 5' , ΔLat: 3' (~5km)
- number of vertical layers: 44
- layer thickness increases from top (~2 m) to depth
- bottom layer with approx. 3 m thickness (=> SPM)
- total no. of grid points: 2dim - 161.199, 3dim - 1.783.352
- time step 30s

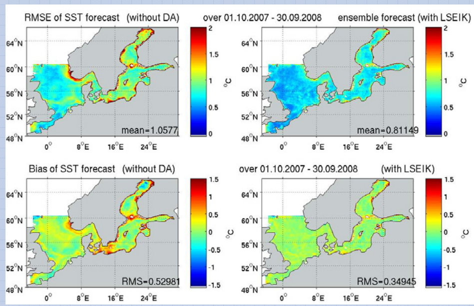
Remote Sensing Data: NOAA SST



The Circulation Model (BSHcmod V.4)

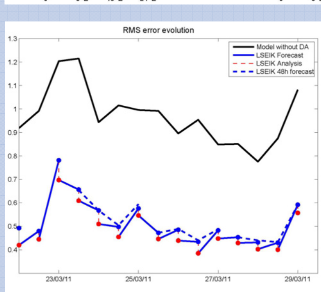
- three-dimensional shallow water equations, baroclinic, prognostic
- generalised vertical co-ordinates (Kleine, 2004*)
- mixing length formulation for horizontal and vertical turbulence
- sea ice dynamics (Hibler, 1979) and thermodynamics
- tidal forcing using 14 tidal constituents
- flooding and drying of tidal flats
- climatological boundary data for T and S (+sponge layer)

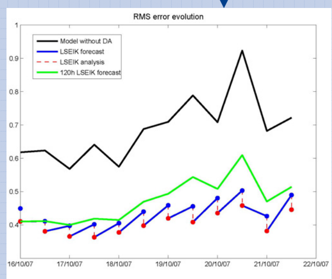
Assessing SST forecast over 10.2007-09.2008



Improvement of Sea Surface Temperature (SST) forecast in the North and the Baltic Seas when sequentially every 12 hours (at 0:00 and 12:00) assimilating satellite (NOAA) SST data into the BSH operational circulation model. Major improvement is the systematic errors correction, which gives us an opportunity for a longer (~ 5 days) forecast

RMS error temporal evolution over the period 16.10.2007 -- 21.10.2007 for simulated SST without data assimilation (black curve); LSEIK Analysis (red); SST ensemble mean forecast based on every 12 hours analysis (blue) and 5days forecast (green curve) initialized just once with the analysis obtained on 16.10.2007.





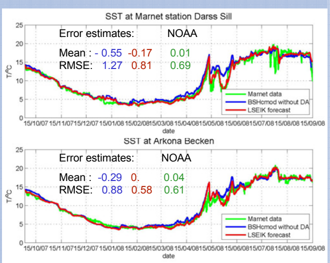
Validation with independent data

Sensitivity to the initial error statistics

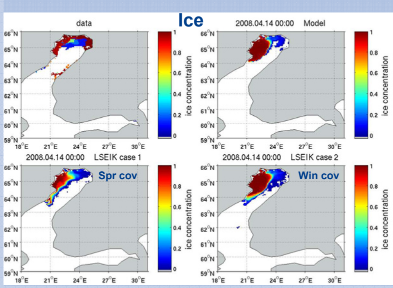
To combine the information from the model and the data, we have implemented Local SEIK filter algorithm (Nerger et al., 2006), but with different formulations of data error correlation (data weights equally, quasi Gaussian or exponentially dependent on distances from updated water column), σ_{sst}={0.5,0.8,1.8} °C and radius r of data influence of 50km or 100km. **Filtering with exponential weights, σ_{sst}=0.8 °C and r=100km produces better simulation of salinity, current velocities, sea surface elevation** (not shown).

Below illustrated is the impact of the initial model error variance/covariance matrix on ice concentration and bottom temeperature forecast. Such a matrix has been computed using 12 hours snapshots of BSHcmod integration over three autumn-winter (10-12.2007) or spring (03-05.2008) months.

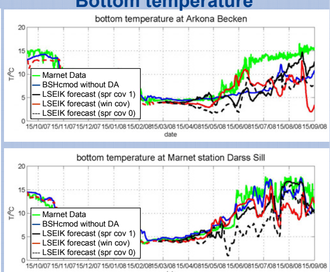
Time series at Marnet stations



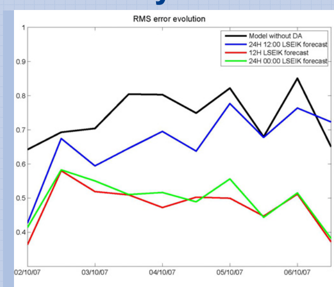
Ice



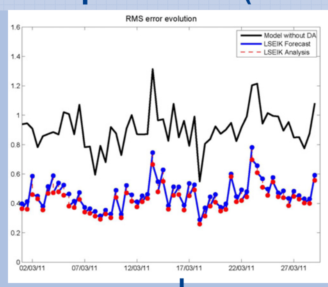
Bottom temperature



Bias in daytime data?

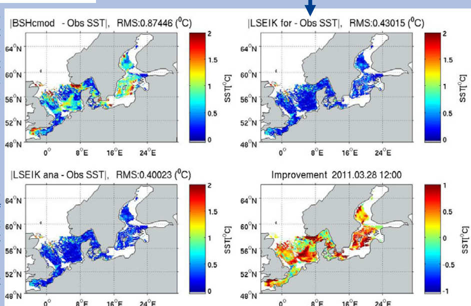


Pre-operational (03.2011)



Temporal evolution of SST RMS error for BSHcmod forecast without data assimilation (black); LSEIK forecast with DA every 12 hours at 0:00 and 12:00 (red); LSEIK forecast with the analysis every 24 hours at 0:00 (green); LSEIK forecast when assimilating the data every 24 hours at 12:00 (blue).

(To the right ►) SST forecast's skill improvement on 28.03.2011 12:00 when LSEIK filter implementing: absolute deviation from NOAA SST data of BSHcmod forecast without DA (upper-left panel) and LSEIK forecast (upper-right panel) and analysis (bottom-left panel); difference between the absolute deviations from the SST data of the forecast without and with DA (bottom-right panel).



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