Developing a data assimilative forecasting system of the North and Baltic Seas biogeochemistry

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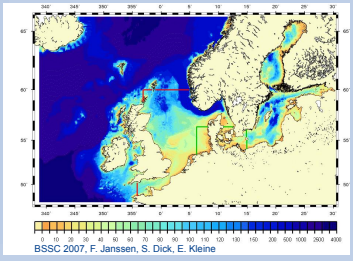
Abstract

A biogeochemical forecasting system of the North and Baltic Seas is developed based on the HIROMB-BOOS circulation Model (HBM) coupled with the ERGOM ecosystem model and augmented by data assimilation (DA). The DA system is built within the Parallel Data Assimilation Framework (Nerger et al., 2005, Nerger and Hiller, 2013) and has been validated by the German Federal Maritime and Hydrographic Agency (BSH) for sea surface temperature assimilation into the operated BSHcmod with the Singular Evolutive Interpolated Kalman (SEIK) filter (Pham, 1998). The DA system is further extended by assimilating chlorophyll concentrations. In the frame of the ensemble based DA techniques- SEIK and a sequential Importance Resampling (SIR) filter,- we consider various aspects and strategies of the biogeochemical state and parameter estimation when assimilating MODIS satellite chlorophyll "a" and NOAA's sea surface temperature observations. In particular, we identify crucial ecosystem parameters, investigate possible impacts of the assumed stoichiometry and scaling biogeochemical variables in the presence of non-Gaussianity on the forecasting system performance.

Forecasting system



HBM model

Grid nesting :

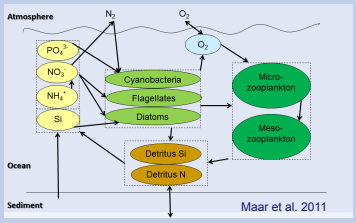
- **10 km grid**
- **5 km grid (36 vertical layers)**
- **900 m grid (25 vertical layers)**

DA system

Data assimilation system based on ensemble Kalman-type filtering (SEIK, Pham, 1998) has been transferred from the forecasting system developed for the currently operated by the BSH circulation model (BSHcmod, version 4) and tested for SST DA in the pre-operational phase in March 2011 (Losa et al., 2012, 2014).

Biogeochemical model

The schematic diagram of the biogeochemical model ERGOM coupled to the HBM.



Chlorophyll is not a prognostic model variable.

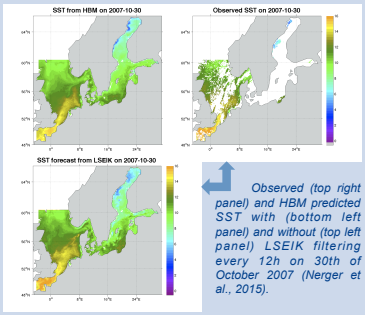
Converting from phytoplankton biomass, a constant or variable stoichiometry is assumed.

For the current experiments

$Chl\ a = (Phy_{dia} + Phy_{fla}) * 2.27 + Phy_{cya}$

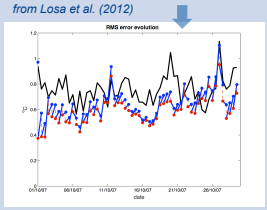
There is a need in evaluating both model and satellite derived information with independent observations.

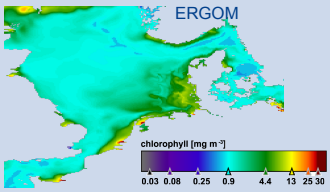
Model *vs* satellite observations

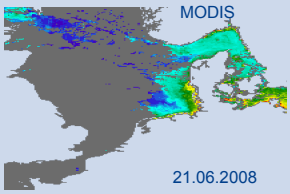


Observed (top right panel) and HBM predicted SST with (bottom left panel) and without (top left panel) LSEIK filtering every 12h on 30th of October 2007 (Nerger et al., 2015).

Temporal evolution of the root mean squared (RMS) estimates of the SST forecast deviation from the satellite derived observation obtained with the pure HBM model and with LSEIK analysis (blue based on red) only for the grid with 5km horizontal resolution with the assumed error statistics from Losa et al. (2012)

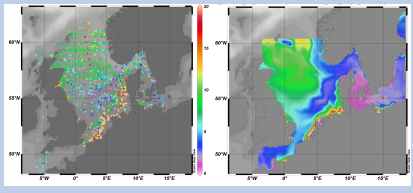






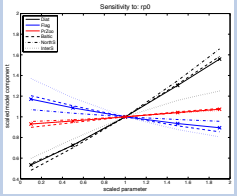
ERGOM assessment and sensitivity

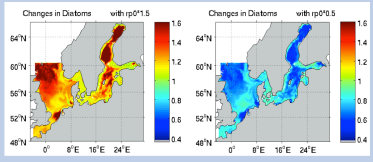
NOWESP Data (thanks to J. Pätsch, IFM UHH) Model



Model February monthly mean nitrate concentration (mMol N/m^3) in comparison against observations.

The sensitivity experiment consists on a series of HBM-ERGOM integrations with different values of the biogeochemical model parameters varying within the interval 'initial' ± 90%. The parameters are scaled with initial values. The model components are normalised by a reference model solution based on the initial parameters.

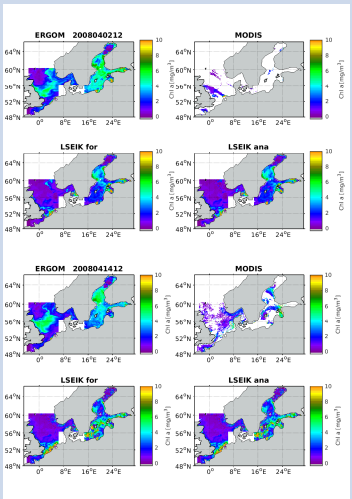




Sensitivity of the spatial distribution of the model surface diatoms to the maximum uptake rates at water temperature T_0 (rp0)

Sensitivity of the model diatoms, flagellates and zooplankton to the maximum uptake rates at T_0 (rp0) for the North Sea, Baltic Sea and in the region of the interaction between the North and Baltic seas.

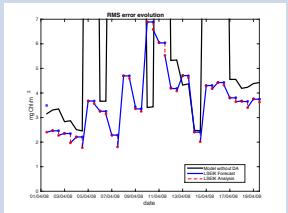
Chlorophyll data assimilation



LSEIK filtering is applied for the biogeochemical state estimation. To avoid problems related to the non-Gaussian nature of the ecosystem, the analysis is formulated and performed relative to ununited model state variables x' while model variables are $x = x'\tilde{x}$.

Chlorophyll forecast skill improvement on 02.04.2008 and 14.04.2008: spatial distribution of the Chl forecast with and without LSEIK filtering against MODIS observations.

To the bottom: Temporal evolution of the RMS differences between satellite Chl and HBM-ERGOM forecast (black), LSEIK analysis (red) and mean of the ensemble forecast (blue) based on the 12-hourly LSEIK analysis over the period 1.04.2008 – 19.04.2008.



Pham, D. T., J. Verron and L. Gourdeau (1998), Singular Evolutive Kalman filters for data assimilation in oceanography, C. R. Acad. Sci. Paris, Earth and Planetary Sciences, 326, 255–260.

Nerger, L., W. Hiller, J. Schröter (2005), PDAF - The Parallel Data Assimilation Framework: Experiences with Kalman Filtering, In: Zwieflhofer, W., Mozdzynski, G. (Eds.), Use of high performance computing in meteorology: proceedings of the Eleventh ECMWF Workshop on the Use of High Performance Computing in Meteorology. Singapore: World Scientific, Reading, UK, 63–83.

Nerger, L. and W. Hiller (2013), Software for Ensemble-based Data Assimilation Systems —Implementation Strategies and Scalability. Computers and Geosciences, 55, 110-118.

Losa, S.N., Danilov, S., Schröter, J., Nerger, L., Maßmann, S., Janssen, F. (2012). Assimilating NOAA SST data into the BSH operational circulation model for the North and Baltic Seas: Inference about the data. Journal of Marine Systems, 105-108, pp. 152–162.

Losa, S.N., Danilov, S., Schröter, J., Janjić, T., Nerger, L., Janssen, F. (2014). Assimilating NOAA SST data into the BSH operational circulation model for the North and Baltic Seas: Part 2. Sensitivity of the forecast's skill to the prior model error statistics. Journal of Marine Systems, 129, pp. 259–270. doi:10.1016/j.jmarsys.2013.06.011.

Nerger, L., S. N. Losa, T. Brüning, and F. Janssen (2015). The HBM-PDAF assimilation system for operational forecasts in the North and Baltic Seas. 7th EuroGOOS Conference Proceedings (submitted).