NHR-project hbk00095: Application of ensemble data assimilation for improved prediction of ocean ecosystem indicators

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Overview

This project studied the effect of assimilating observations of ocean physics and biology onto the prediction of ecosystem indicators like particulate organic carbon, trophic efficiency, or dissolved oxygen. The ocean circulation model NEMO was used in the NEMO-NORDIC configuration for the North- and Baltic Seas. The model is coupled to the ocean-biogeochemical model ERGOM. For the data assimilation, ensemble-based filters were applied that are provided by the Parallel Data Assimilation Framework PDAF (Nerger and Hiller, 2013, https://pdaf.awi.de). The direct combination of NEMO-ERGOM with PDAF provided a highly-scalable data assimilation system that strongly benefits from the computational resources of the HLRN. Next to studying the influence of assimilating different ocean physics and biology observations onto the prediction of the ecological indicators, the effects of combined assimilation of physical and biological observations and of the application of linear ensemble Kalman filters and nonlinear particle-based filters were assessed.

The work of this project was part Project SEAMLESS - Services based on Ecosystem data AssiMiLation: Essential Science and Solutions (https://www.seamlessproject.org) funded by the EU Horizon-2020 program. The aim of this project was to perform research to improve new and improved indicators of climate-change impacts and food security in marine ecosystems through the application of data assimilation. These developments were provided to the EU Copernicus Marine Service CMEMS (http://marine.copernicus.eu) which runs different operational marine forecasting centers.

Model System

In this project we used the ocean circulation model NEMO (Madec et al. 2008). NEMO is a widely used model for research but it is also used operationally at CMEMS. The particular variant of NEMO we use here is NEMO-NORDIC (Hordoir et al. 2019) in an upgraded version, which is based on NEMO 4.0 and uses a resolution of 1 nautical mile and 56 model layers. The Baltic Monitoring and Forecasting Center (BAL-MFC) performs operational services with this model. The configuration covers the full North Sea and Baltic Sea. The high resolution for the large regional domain provides a large potential for scaling by using domain-decomposition. In addition, the model setup uses the IO-Server XIOS to allow for efficient parallel IO. The biogeochemistry model is ERGOM (Neumann 2000, Maar 2011). The model simulates biogeochemical progresses and includes bacteria, two phytoplankton groups as well nutrients, zooplankton and detritus. In addition, a carbonate cycle allows to simulate the partial pressure of CO_2, pH, and particulate carbon.

In preparation of the project, we have already coupled PDAF directly into NEMO using the approach discussed by Nerger and Hiller (2013). By inserting subroutine calls that modify the model to become an ensemble model and by including an assimilation step, this approach allows for the best scalability and less disk output. In particulate, by keeping the ensemble information in memory the complete ensemble only needs to be written into files for model restarts. The dynamic ensemble integrations will be important for accurate error variance and covariance estimations for the data assimilation. During the project, satellite observations of sea surface temperature (SST) and of total surface chlorophyll-a (CHL) provided by CMEMS were assimilated. The assimilation was performed daily using an ensemble of 30 model state realizations. The system runs fully parallel. Thus, the data assimilative model is configured to run 30 instances of NEMO-ERGOM, each using 2 compute nodes of the HLRN.

Results

The data assimilation is started at February 1, 2015 and runs until May 31, 2015. Figure 1 shows the observed and modeled surface chlorophyll (CHL) concentration on May 1. As Fig. 1e shows, on May 1, the observations nearly only available in the transition zone to the North Sea and in the central part of the Baltic Sea. Figure 1a shows the concentration without data assimilation (free run) with increased conccentrations in the central Baltic. The panels b to d of Fig. 1 show the effect when assimilating only single observation types, or both jointly. Assimilating only SST data has a limited effect on the chlorophyll. The overall best result is obtained when both data types are jointly assimilated (Fig. 1d).

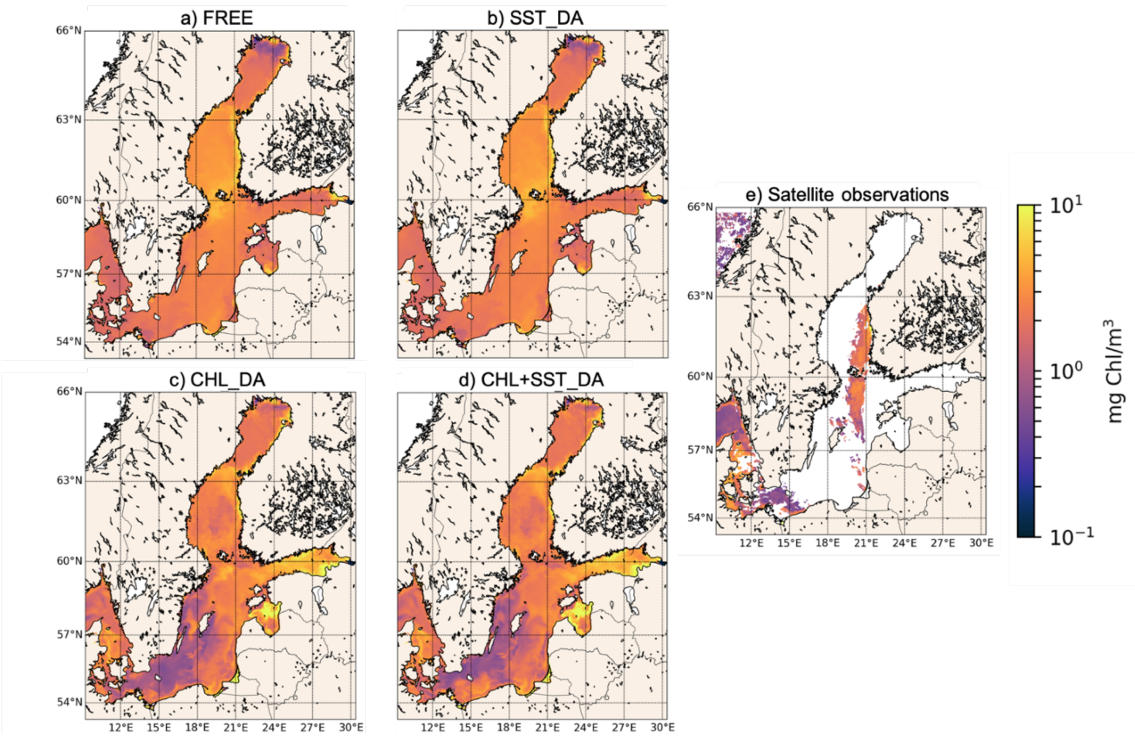

Figure 1: Chlorophyll in the Baltic Sea on May 1, 2015. Shown are (a) the free run and forecasts from experiments (b) assimilation of only SST data (SST_DA), (c) assimilation of only chlorophyll data (CHL_DA), (d) combined assimilation (CHL+SST_DA), and (e) the observed chlorophyll concentration.

A particular focus of the project was on the station 'Arkona Basin' which is located at (13.87°E, 54.88°N) in the Southern Baltic just north of the island of Rügen. Figure 2 shows the development of the surface chlorophyll concentration and SST at this station for the period January to May 2015. The free run shows that a phytoplankton bloom starts already at the beginning of February. Compared to the observations, the model overestimates the concentrations during the bloom. The assimilation of chlorophyll data reduces this overestimation. The temperature is overall already well represented by the model. However, theassimilation of SST data reduces the deviation of the model from the satellite data.

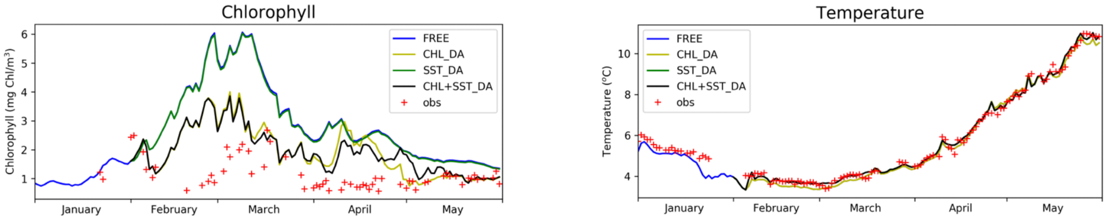

Figure 1: Development of the concentration of surface chlorophyll (left) and surface temperature (light) at the station Arkona. The lines show the different experiments: (blue) free ensemble run; (light green) assimilation of chlorophyll, (dark green) assimilation of SST; (black) combined assimilation of chlorophyll and SST. The red crosses show the satellite observations.

References

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