Assimilation of satellite temperature and chlorophyll observations for improved ecosystem predictions in the Baltic Sea

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Overview

The CMEMS Monitoring and Forecasting Center for the Baltic Sea (BAL-MFC) uses NEMO coupled to the biogeochemical model ERGOM to compute reanalysis and forecasts for the Baltic Sea. Operationally, in situ observations of nutrients and oxygen are assimilated using the Parallel Data Assimilation Framework (PDAF, https://pdaf.awi.de) using Ensemble-OI with a fixed ensemble read from model snapshots.

In the EU-project SEAMLESS, we use the operational model setup as the basis for enhancements by a fully dynamical data assimilation approach. NEMO-ERGOM is augmented by the data-assimilation functionality of PDAF and NEMO-ERGOM-PDAF is run in ensemble mode. Using an ensemble of 30 members, satellite surface temperature and chlorophyll observation are assimilated daily. We assess the impact of the assimilation on the forecast skill with a focus on the biogeochemical variables. In addition, additional ecosystem indicators, like trophic efficiency, pH, and phytoplankton community structure are analyzed.

Model System

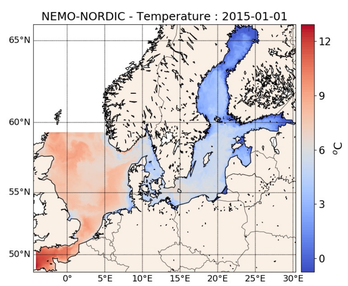
Operational model of CMEMS Baltic Monitoring and Forecasting Center (BAL-MFC):

NEMO-ERGOM

- NEMO 4.0 + sea ice SI3
- biogeochemical model ERGOM including carbon cycle

Configuration NEMO-NORDIC

- resolution 1.8 km; 56 layers
- time step 90 s



PDAF Data assimilation

NEMO-ERGOM and PDAF coupled online (single program)

- Ensemble Kalman filter: LESTKF
- Localization radius: 15 km
- Forgetting factor: 0.95
- Ensemble size: 30
- Daily assimilation February – May 2015

PDAF Parallel Data Assimilation Framework

State vector and ensemble:

- 5 physics variables
- 16 ERGOM prognostic variables + 4 diagnostic variables
- State dimension: $704 \cdot 10^6$

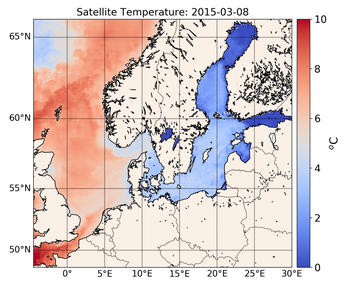
Assimilation updates:

- Weakly coupled DA
- Physics: only 3D temperature updated
- ERGOM: update 13 prognostic + 4 diagnostic variables (no update of LDON, DIC, ALK)

Observations

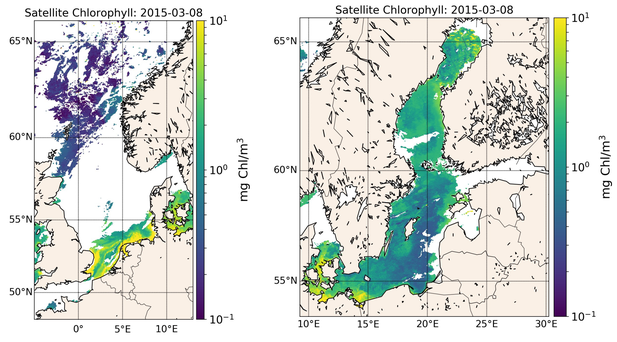
SST

- Level 4 ‘reprocessed’ data from CMEMS
- resolution 0.02° x 0.02°
- available daily
- observation error for DA: 0.8 °C



Chlorophyll

- Level 3 data from CMEMS (multi-satellite multi-year)
- separate data products for North Sea and Baltic Sea
- resolution 1 x 1 km
- available daily
- observation error: relative error of 0.3



Summary

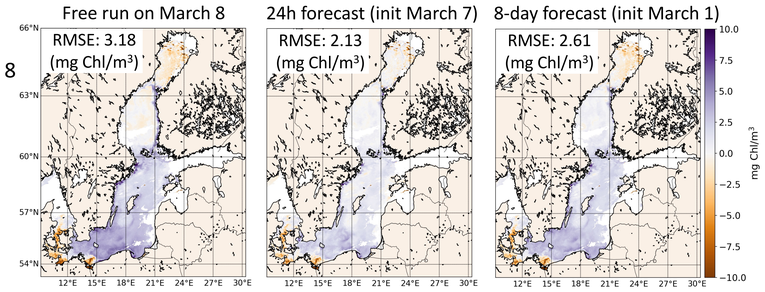
- Forecast skill after 8 days on March 8:
  - 20% lower error for chlorophyll (5% after 14 days)
    43% lower error for SST (35% after 14 days)
  - longer forecast skill for temperature than chlorophyll
- DA influences ecosystem indicators:
  - phytoplankton community and trophic efficiency
  - small effect on pH
- The DA system is in wide parts generic. It can also be adapted to other model configurations or components, e.g. to include sea ice in the assimilation.
- The developments in SEAMLESS are independent from the BAL-MFC operational developments, but we will make them available to the operational service.

Assimilation and Forecast Performance

Surface Chlorophyll:

Difference between model and observations on March 8

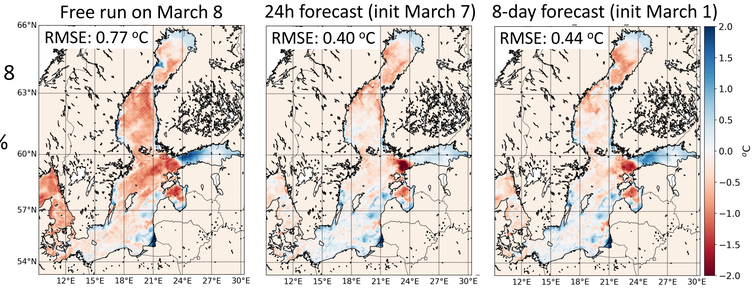
- **24h DA forecast**: widely smaller deviation from obs. than free run
- **8-day forecast** initialized from DA on March 1: increased deviations, but less than free run



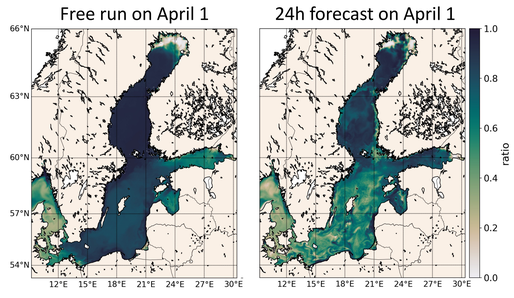
Surface Temperature:

Difference between model and observations on March 8

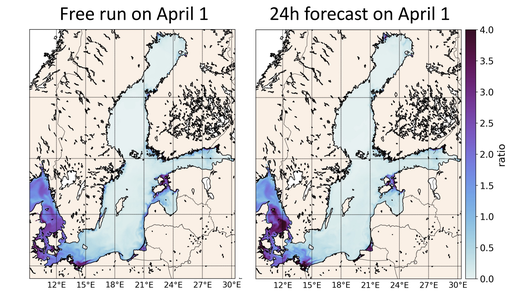
- **24h DA forecast**: RMS errors redued by 50% compared to free run
- **8-day forecast** initialized from DA on March 1: only slightly larger RMS errors than 24h forecast



Influence on Ecosystem Indicators

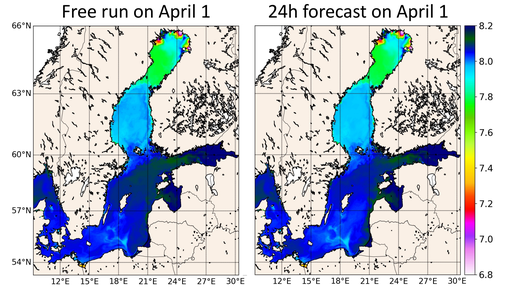


Ratio of diatoms to total phytoplankton
DA reduces relative abundance of diatoms in several regions



Trophic efficiency: zooplankton / phytoplankton
On April 1 only significant zooplankton in the transition zone to North Sea. DA increases the ratio.

pH
Significant variations in the Baltic Sea. The DA lowers pH slightly in the Baltic proper and Bothnian Sea



PDAF is open source.
The code, and documentation are available at **http://pdaf.awi.de**

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