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PDAF Parallel Data Assimilation Framework

Improving the Prediction of Ocean Ecosystem Indicators by Assimilation of Satellite Observations into a Biogeochemical Model

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SEAMLESS

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Model: NEMO-NORDIC

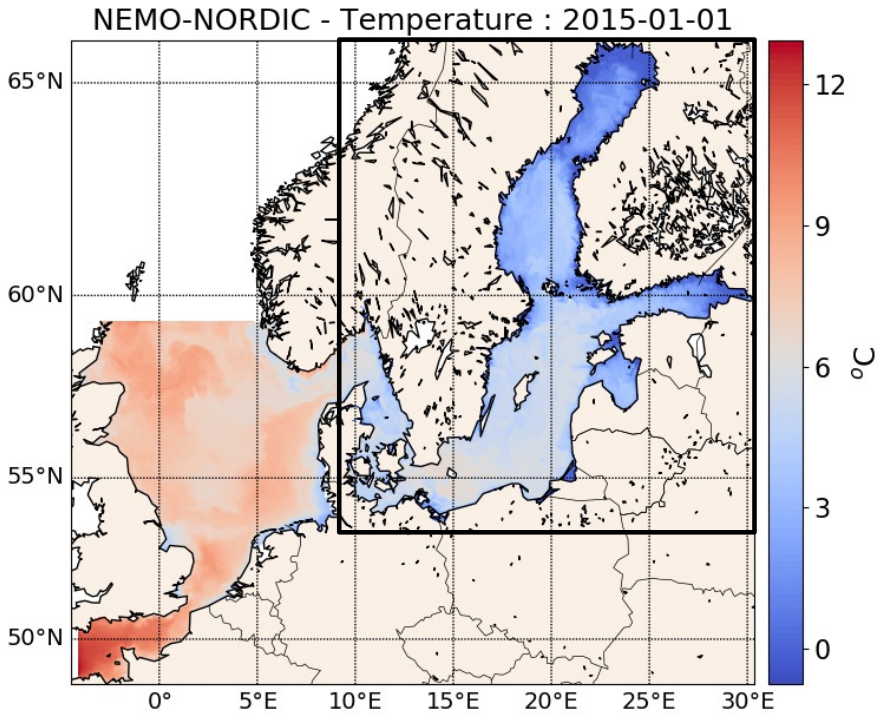
Operational configuration of European Copernicus Baltic Monitoring and Forecasting Center (BAL-MFC)

Model setup

- NEMO-NORDIC
- 1 nm resolution (~1.8km, ~1000x1200 grid points)
- 56 layers
- Time step 90 sec
- Open boundaries in North Sea and English Channel
  - BCs from separate model for North Atlantic

Operational use in CMEMS BAL-MFC

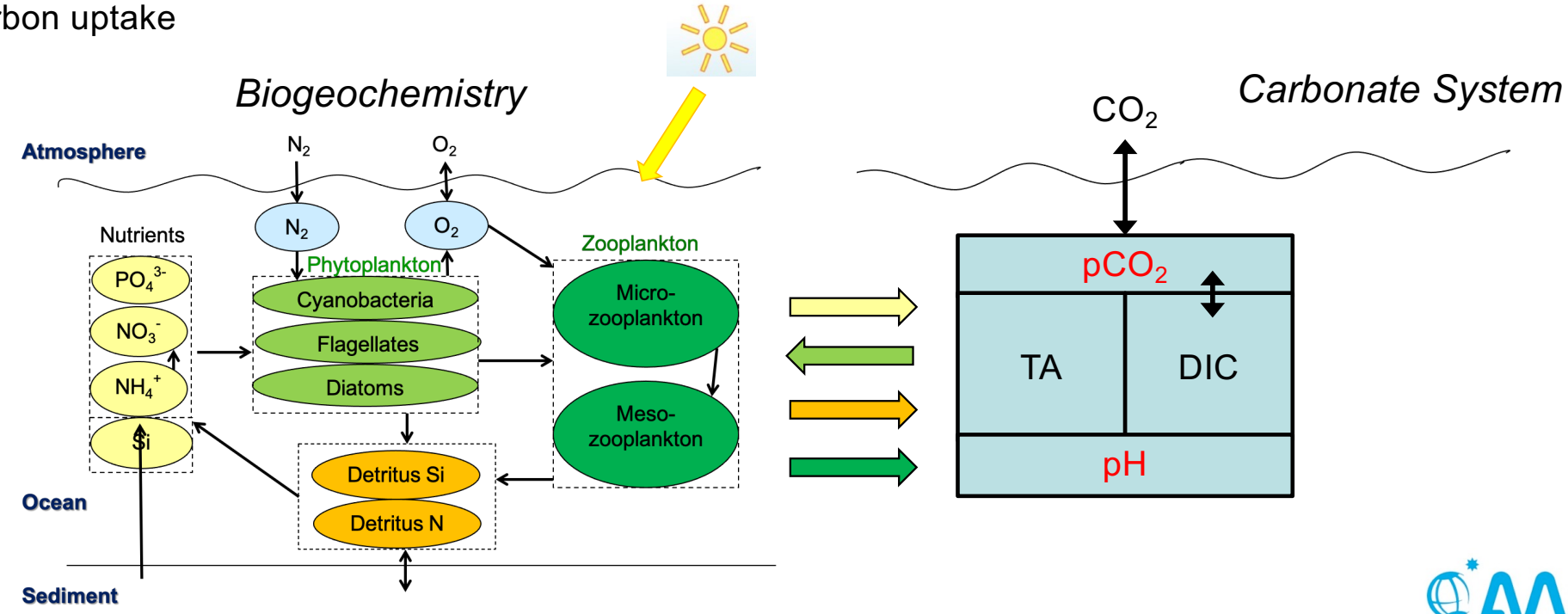
- Assimilation in offline mode utilizing PDAF
- Near-real time and multi-year products
- 'blue ocean' (physics)
  - assimilation of surface temperature
- 'green ocean' (Ecosystem, water quality)
  - Assimilation of nitrogen and oxygen profiles



BGC Model: ERGOM

- original development for Baltic Sea (Neumann, 2000)
- based on nitrogen
- module for carbonate system was added by BAL-MFC
- Applications, e.g.
  - Water quality (nutrification, algal blooms, oxygen deficit zones)
  - Carbon uptake

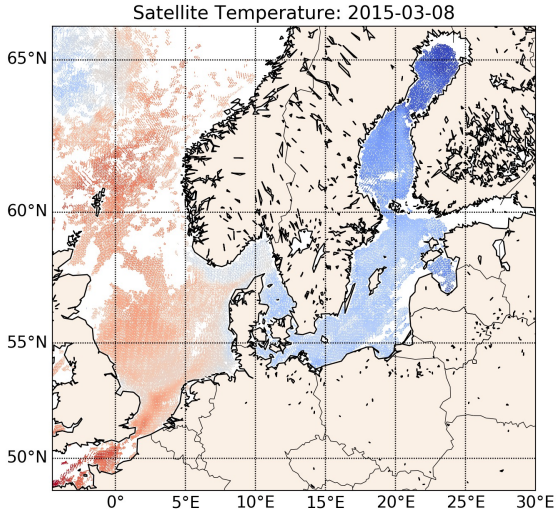
For data assimilation
- 20 model variables (16 prognostic, 4 diagnostic)
- Observed chlorophyll is diagnostic variable



Observations

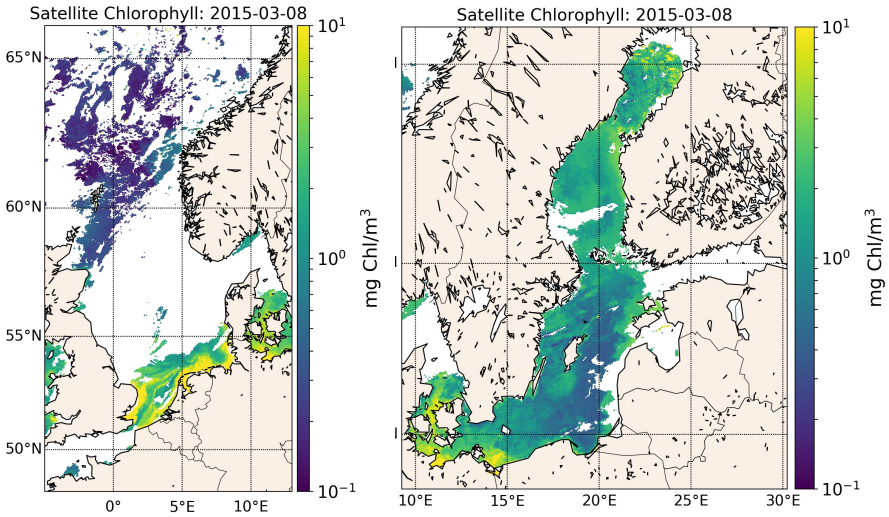
Sea Surface Temperature (*SST*)

- Level 3 data from CMEMS (multi-satellite product)
- resolution 0.02°
- available daily; data gaps cause by clouds
- observation error for DA: 0.8 °C
  (provided error fields not fully realistic)



Chlorophyll (*CHL*)

- Level 3 data ESA OC-CCI via CMEMS (multi-satellite multi-year)
- separate data products for North Sea and Baltic Sea
- resolution 1 km
- available daily
- observation error: relative error of 0.3
- Coverage lower than SST



Constrain NEMO-ERGOM with Data Assimilation

PDAF Parallel Data Assimilation Framework
pdaf.awi.de

Integrate observations into the model

Online-coupled DA system

- Augmented NEMO-ERGOM with DA functionality provided by PDAF
- Utilize dynamic ensemble to estimate uncertainties and cross-covariances
- No model restarts required to apply DA

Updates variables in ensemble states

- 5 physics variables
- 16 ERGOM prognostic variables + 4 diagnostic variables

Assimilation setup

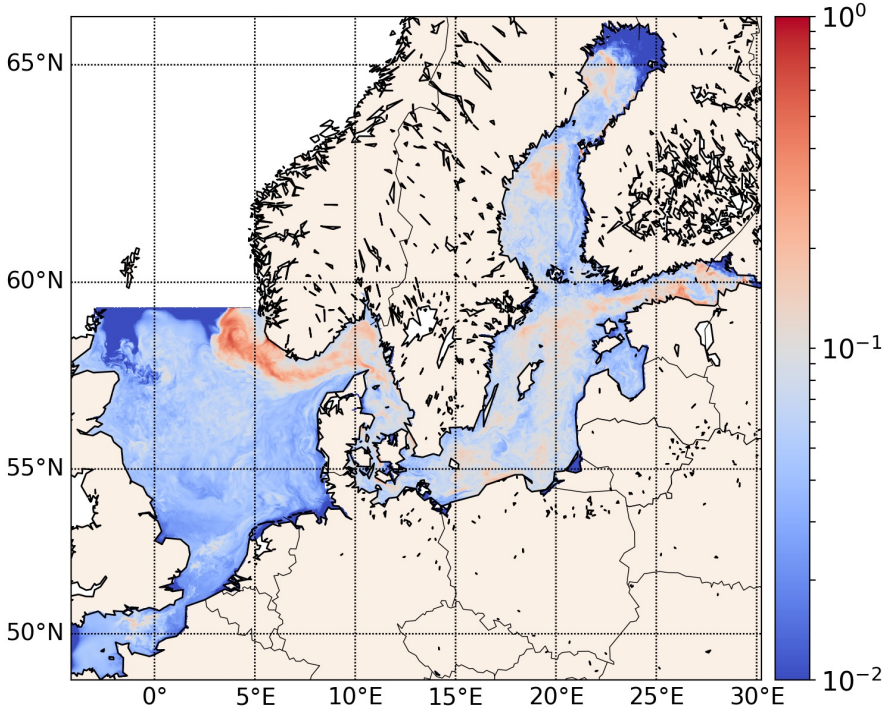
- ensemble Kalman filter LESTKF
- ensemble size: 30
- Daily assimilation for February – May 2015

AWI

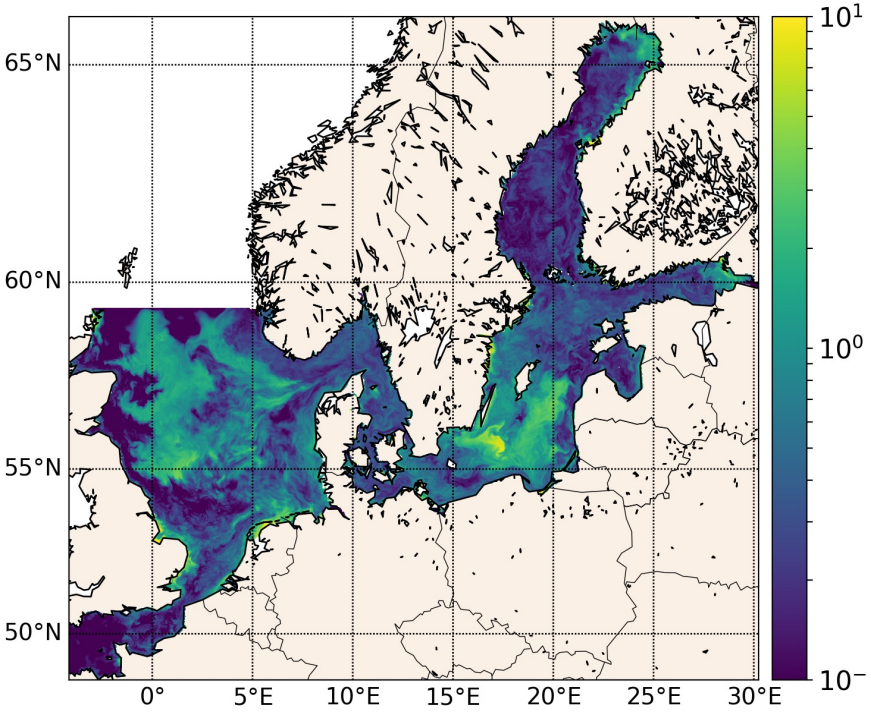
Uncertainty Estimates

Dynamic ensembles provide uncertainties (and covariances) for each day

Temperature on 2015-04-01
Standard deviation



Chlorophyll on 2015-04-01
Standard deviation



Forecasting: Initialized from DA

Ensemble run from Jan. 1, 2015

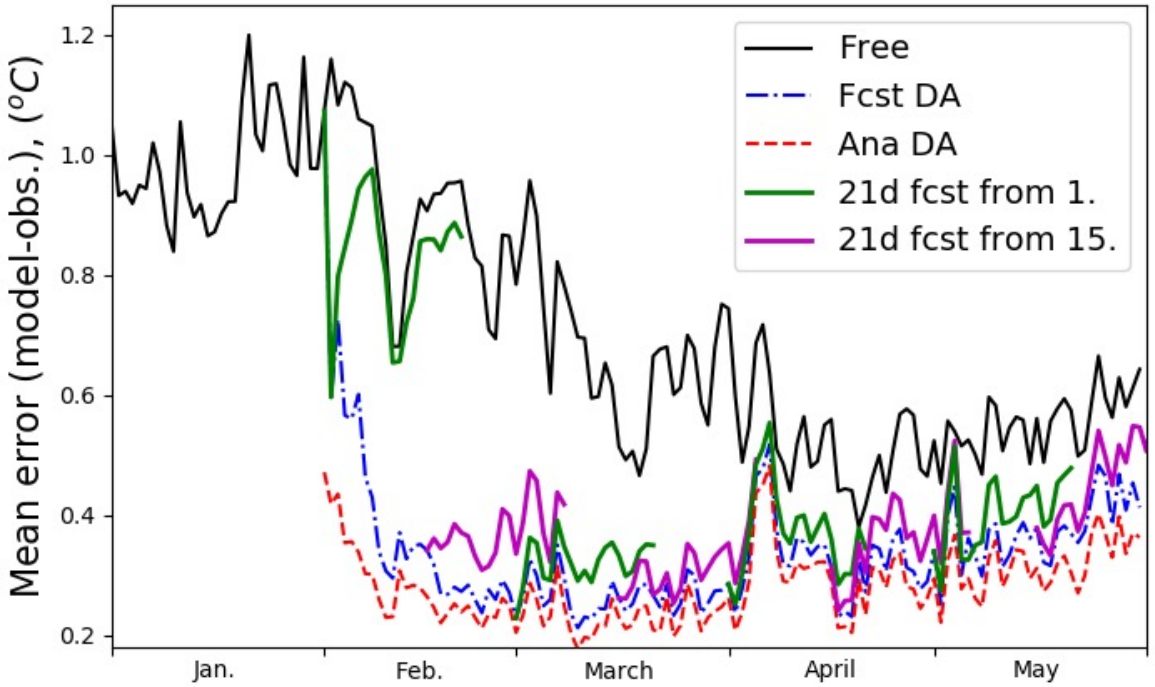
- ensemble perturbations in physics from EOFs (2nd-order exact sampling)
- ensemble central state from forecast
- perturb 15 process parameters of ERGOM

Data assimilation from Feb. 1, 2015

21-day forecasts

- Green: Initialized 1st of month
- Magenta: Initialized 15th of month
  - Slow error increases

SST: RMSe for Baltic Sea & North Sea



DA: Effect on Chlorophyll

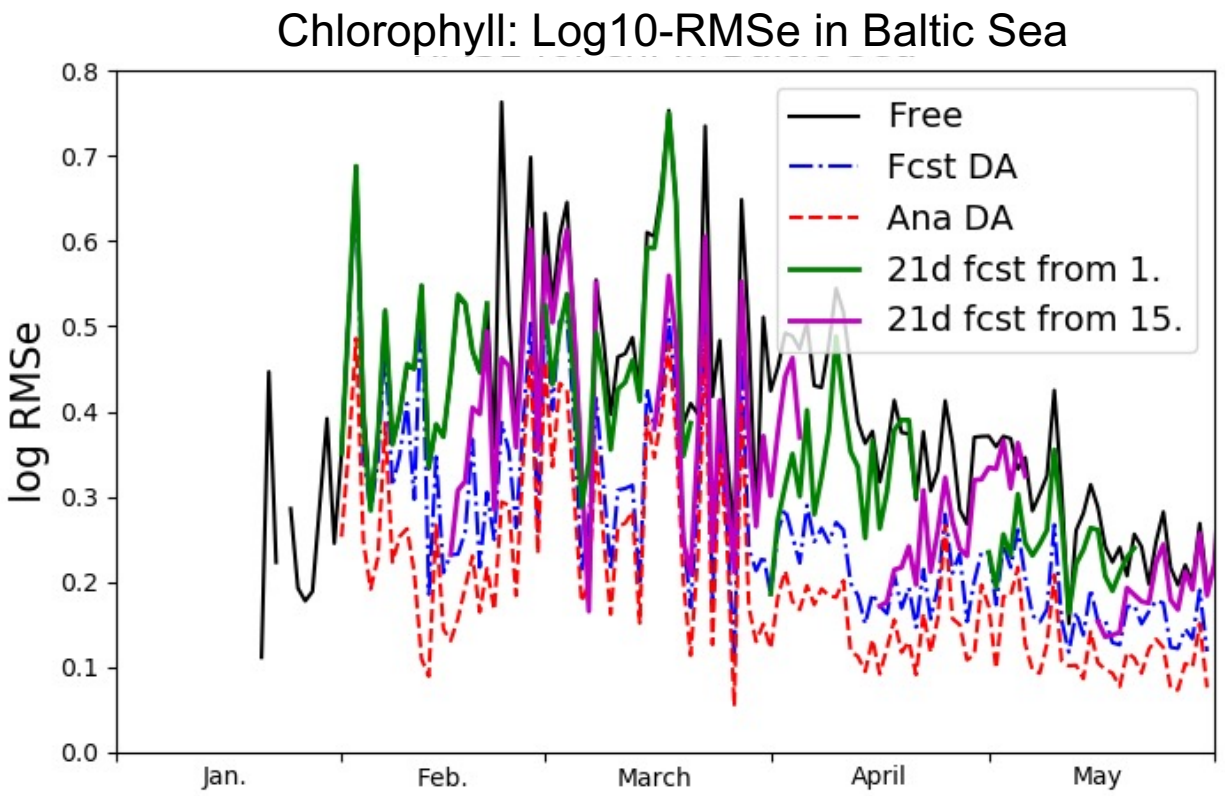
Daily assimilation from Feb. 1, 2015

- Log-RMSe reduced
- Strong fluctuations in February and March (varying data coverage)

21-day forecasts

- Green: Initialized 1st of month
- Magenta: Initialized 15th of month

- Larger error increase than for SST (lower forecast skill)



Effect of DA on longer forecasts: Chlorophyll

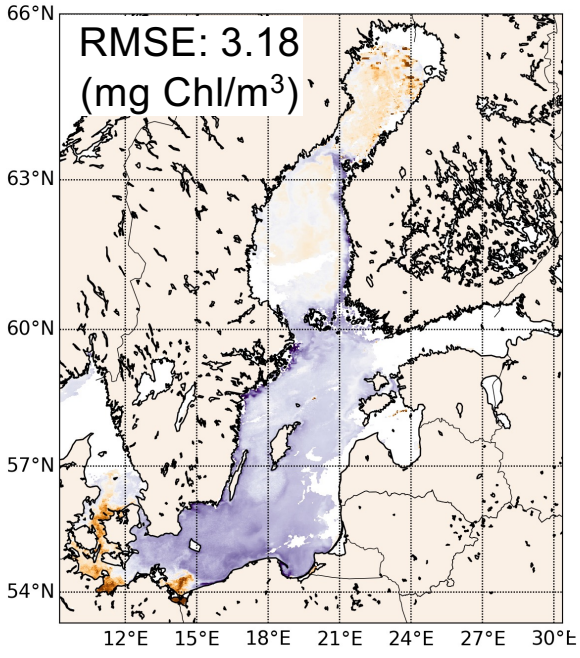
Performed 14-day ensemble forecasts initialized from DA analysis

- Error reduction in 24-h forecast: 33 %
  8-day forecast: 20 %
  14-day forecast: 5 %

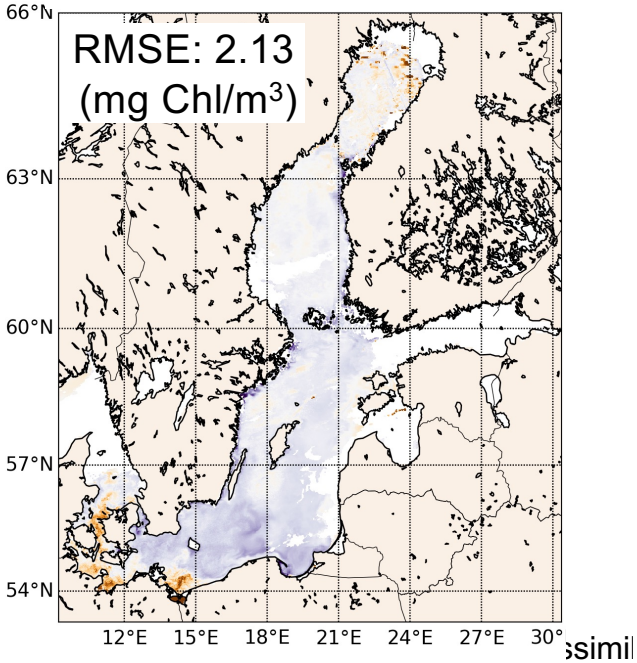
Faster error increase for biogeochemistry than physics
➜ caused by biases

Surface chlorophyll: model - observations

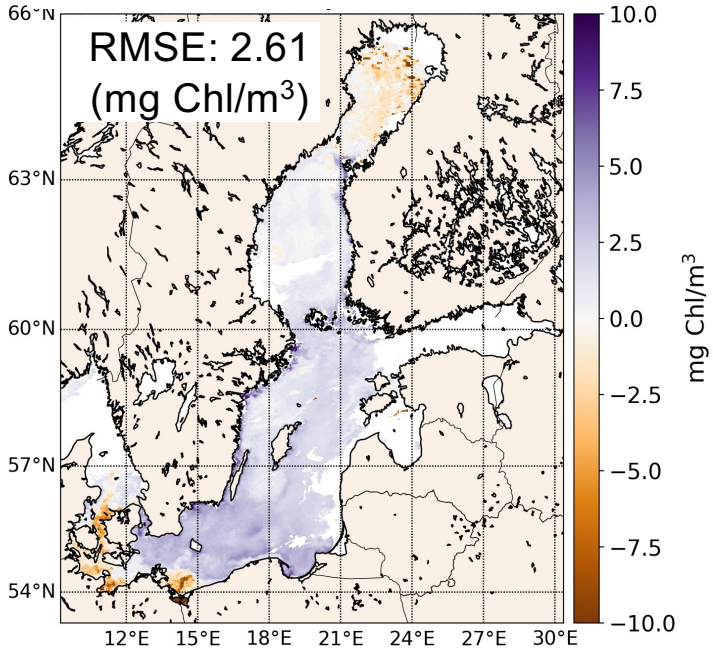
Free run on March 9



24h forecast (init March 8)



8-day forecast (init March 1)



Effect of DA on Ecosystem Indicators: Plankton community

SEAMLESS project selected several ecosystem indicators

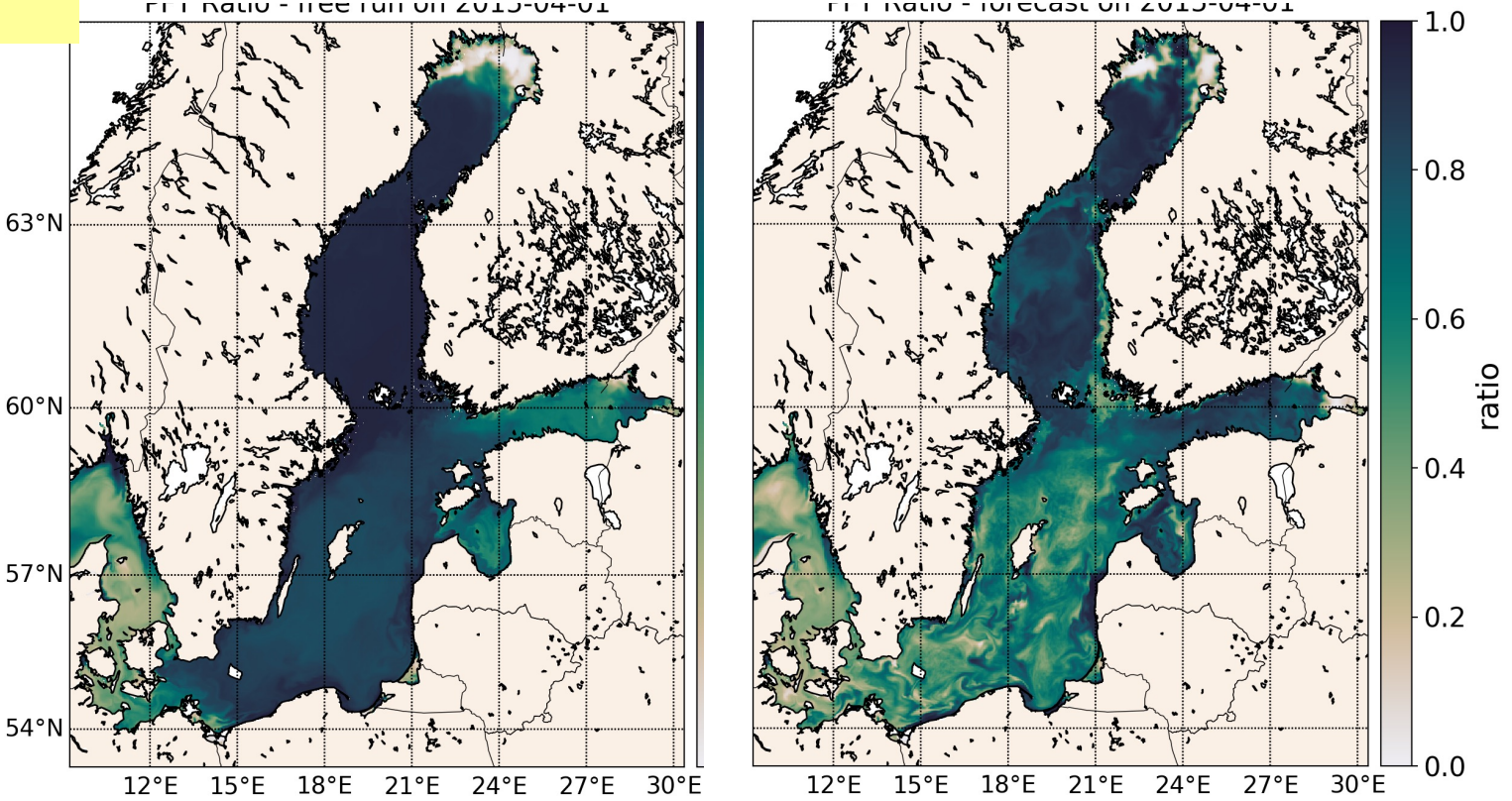
Ratio of diatoms to total phytoplankton

DA reduces relative abundance of diatoms in several regions

(validation in progress)

Free run on April 1

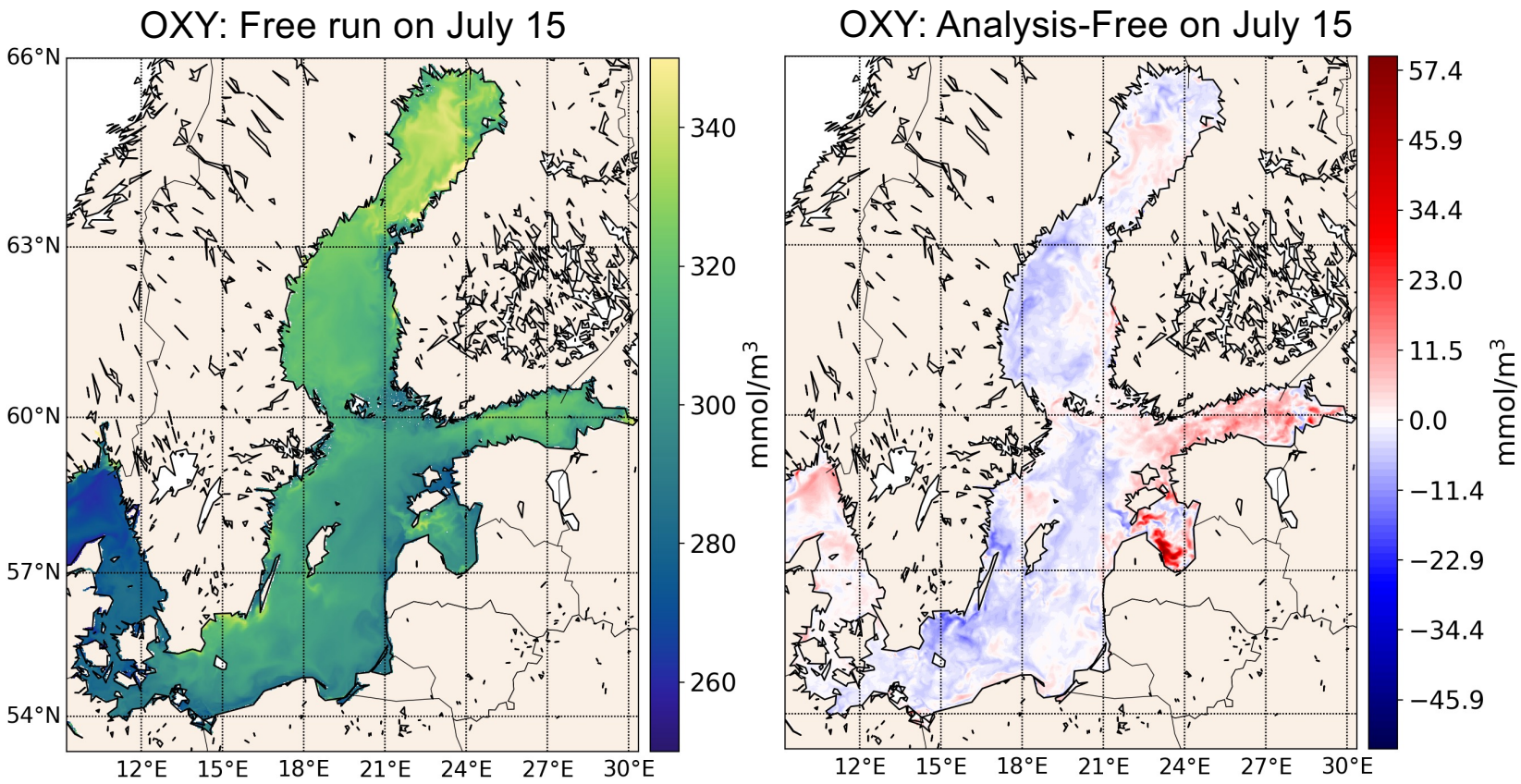
24h forecast on April 1



Effect of DA on Ecosystem Indicators: Oxygen

Oxygen

DA increases concentrations in Gulfs of Finland and Riga (eastern Baltic), lower conc. In most regions



Effect of DA on Ecosystem Indicators: Trophic efficiency

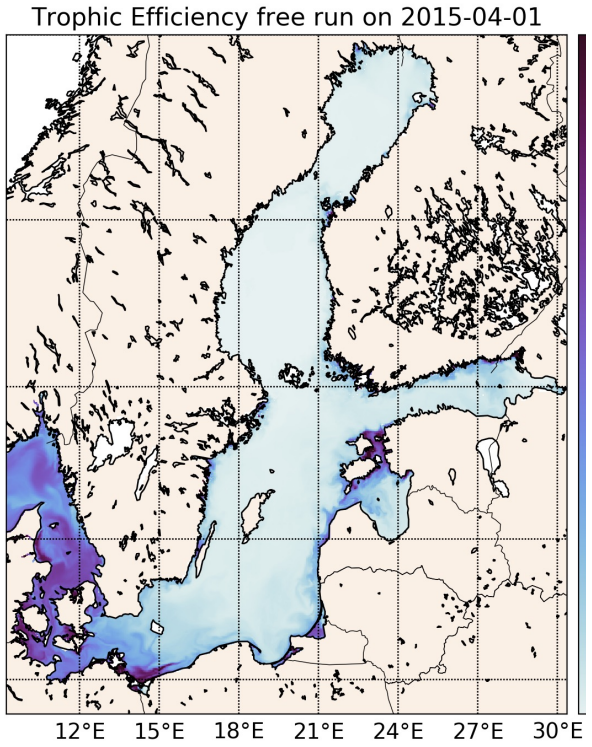
Trophic efficiency: zooplankton / phytoplankton

On April 1 only significant zooplankton in the transition zone to North Sea

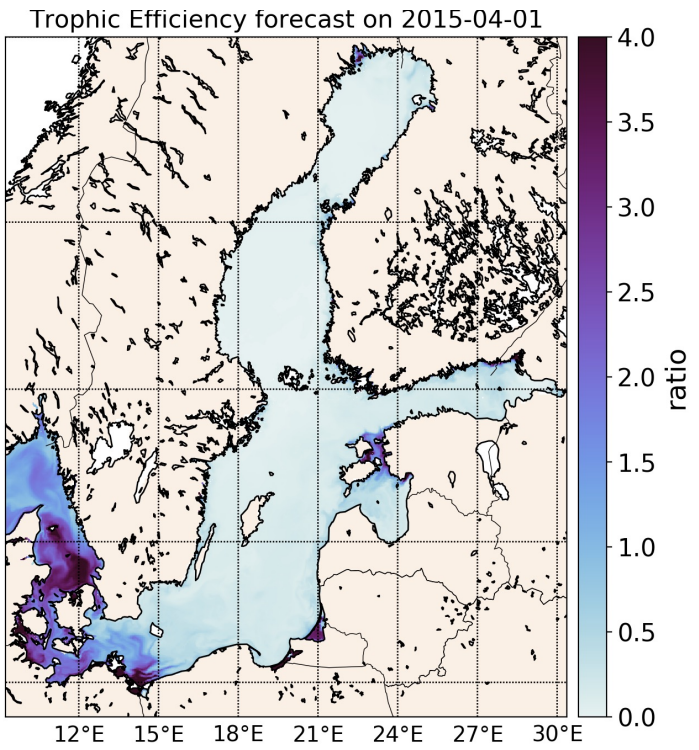
DA increases the ratio

Higher values further north e.g. in May

Free run on April 1



24h forecast on April 1



Summary

PDAF Parallel Data Assimilation Framework

- Coupled assimilation of satellite SST and chlorophyll using PDAF enhancing the currently used operational forecasting system
- Combined SST+CHL assimilation improves result over CHL-only assimilation (best is combined weakly-strongly coupled assimilation)

- System allows predictions of the ecosystem state and derived indicators
- Improvements in temperature and chlorophyll in analysis and forecasts up to 21 days
- Changes in ecosystem indicators