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Enhancing Data Sets through Data Assimilation

Lars Nerger
Alfred Wegener Institute for Polar and Marine Research Bremerhaven, Germany

M. Goodliff, H. Pradhan (AWI)
F. Schwichtenberg, I. Lorkowski, T. Brüning (BSH)
Watson Gregg (Nasa/GSFC)

ALFRED-WEGENER-INSTITUT
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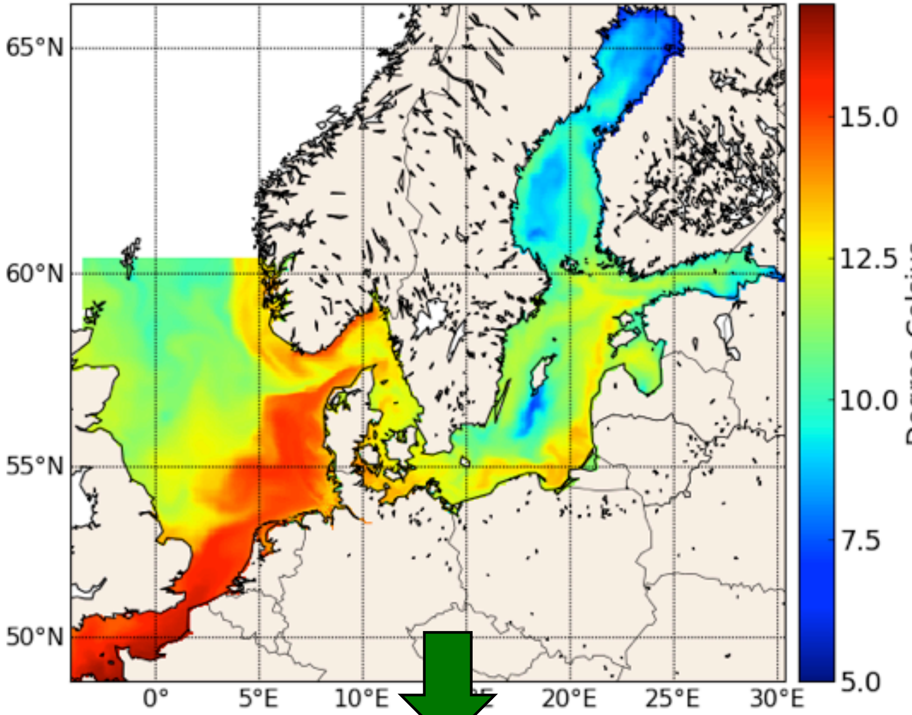
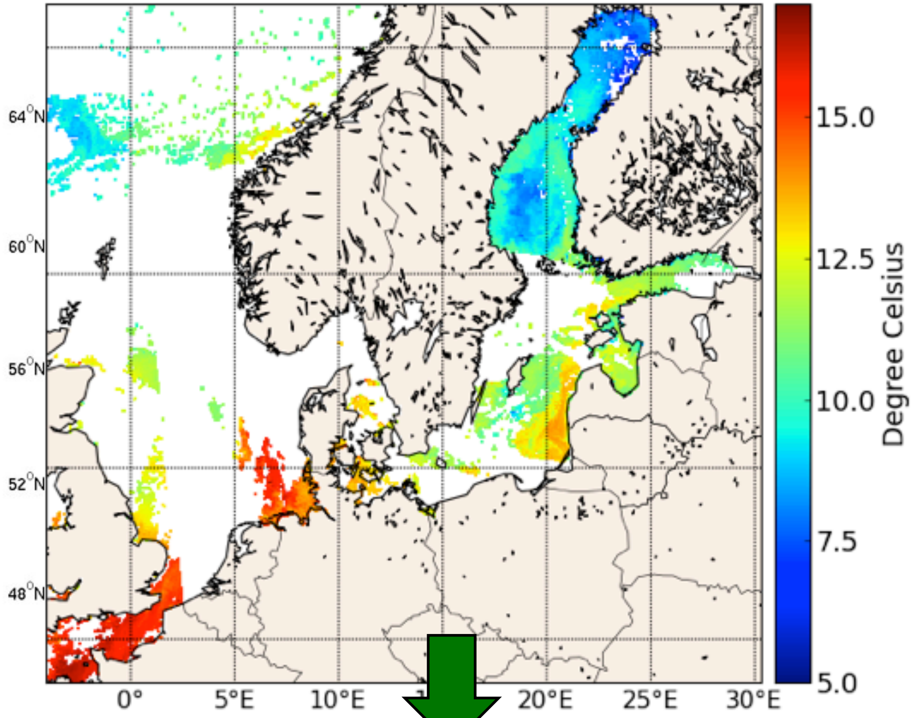
Motivation

Model surface temperature



Satellite surface temperature



Combine both sources of information

quantitatively by computer algorithm

→ Data Assimilation

Data Assimilation

Methodology to combine model with real data

- Optimal estimation of system state:
  - initial conditions (for weather/ocean forecasts, …)
  - state trajectory (temperature, concentrations, …)
  - parameters (ice strength, plankton growth, …)
  - fluxes (heat, primary production, …)
  - boundary conditions and 'forcing' (wind stress, …)

This talk

- More advanced: Improvement of model formulation
  - Detect systematic errors (bias)
  - Revise parameterizations based on parameter estimates

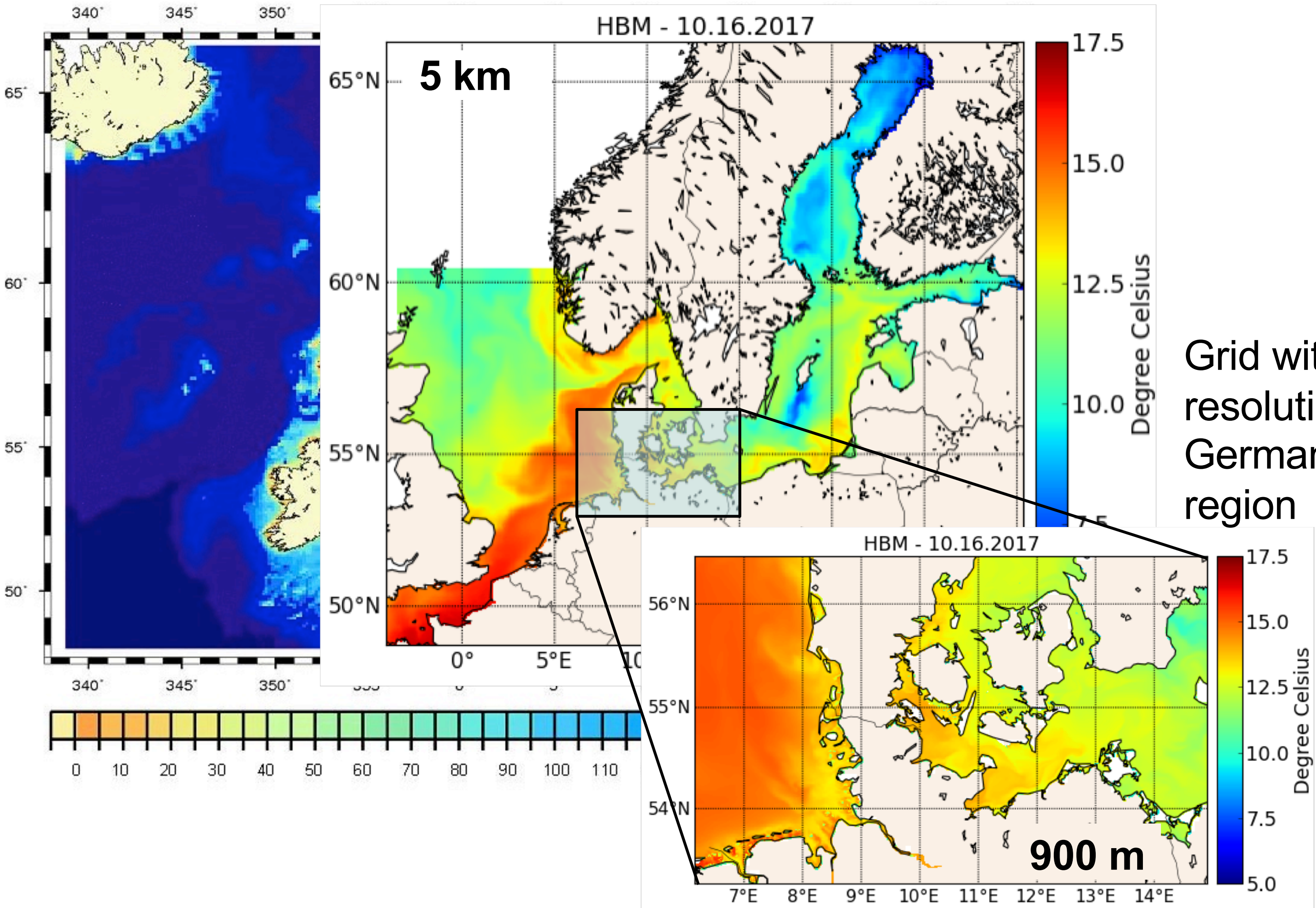
Example 1

Coastal ocean-biogeochemical state in the North- and Baltic Seas

Project *MeRamo* – cooperation with BSH

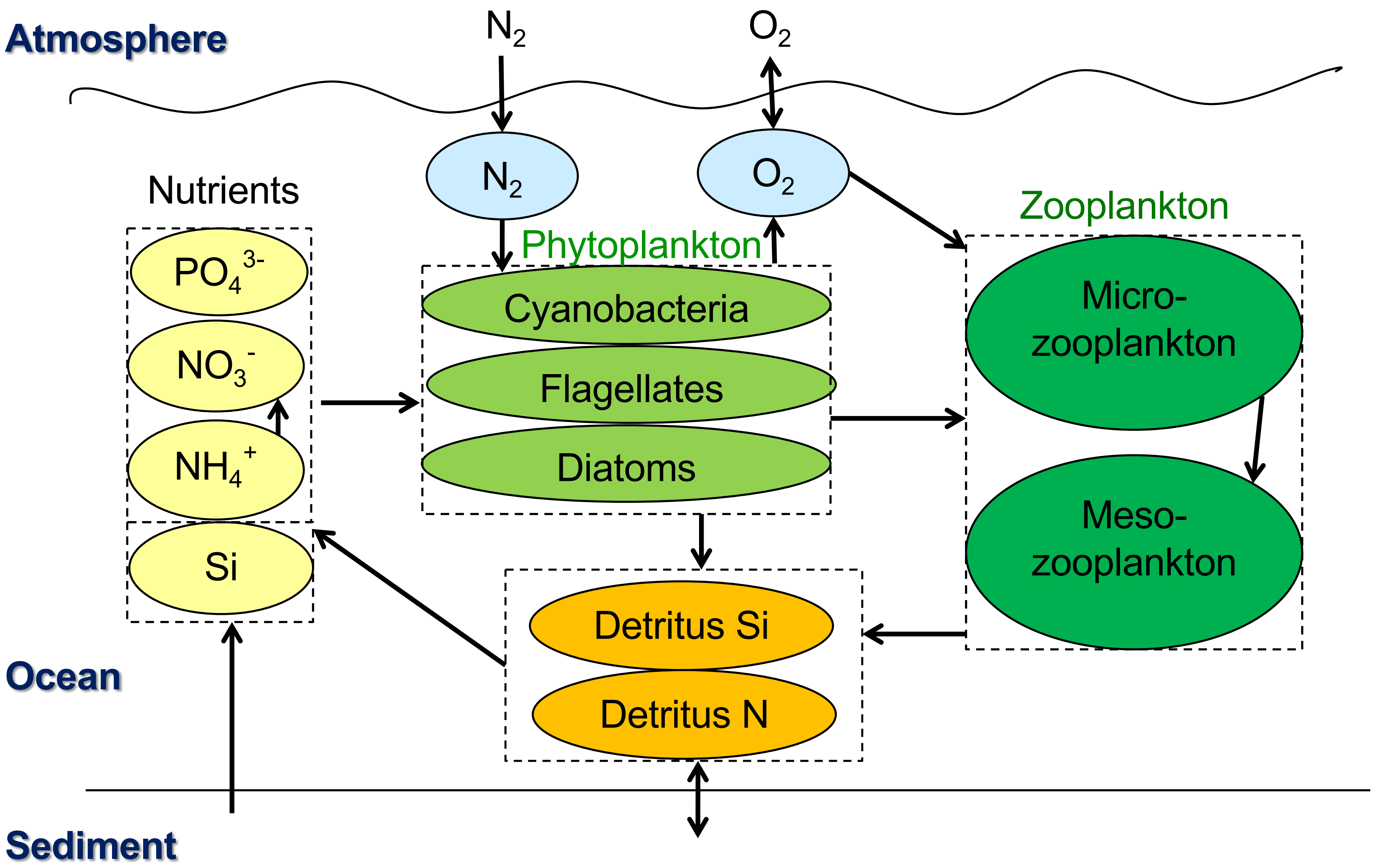
Model and Domain

HBM (Hiromb-BOOS Model) – operationally used at BSH



Grid with high resolution in German coastal region

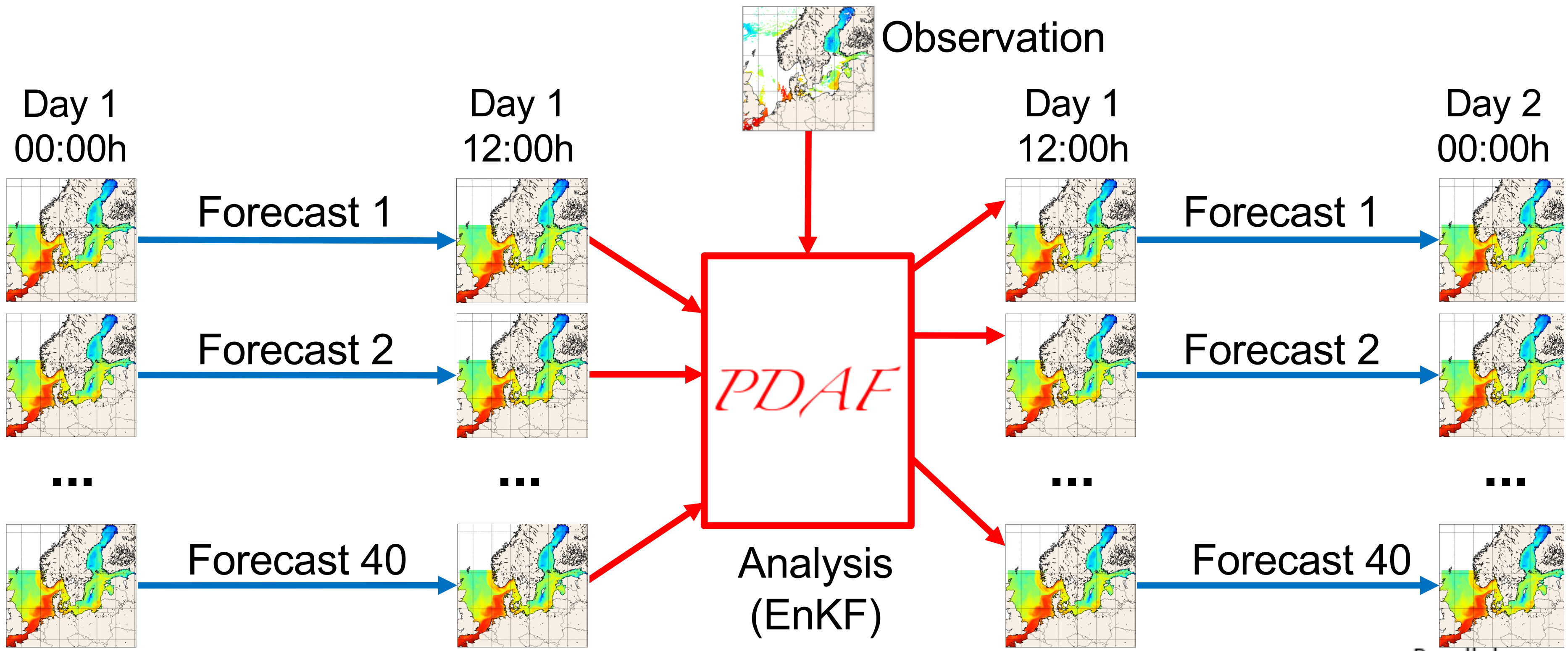
Biogeochemical model: ERGOM



Augmenting a Model for Data Assimilation

Couple PDAF (Parallel Data Assimilation Framework) with model

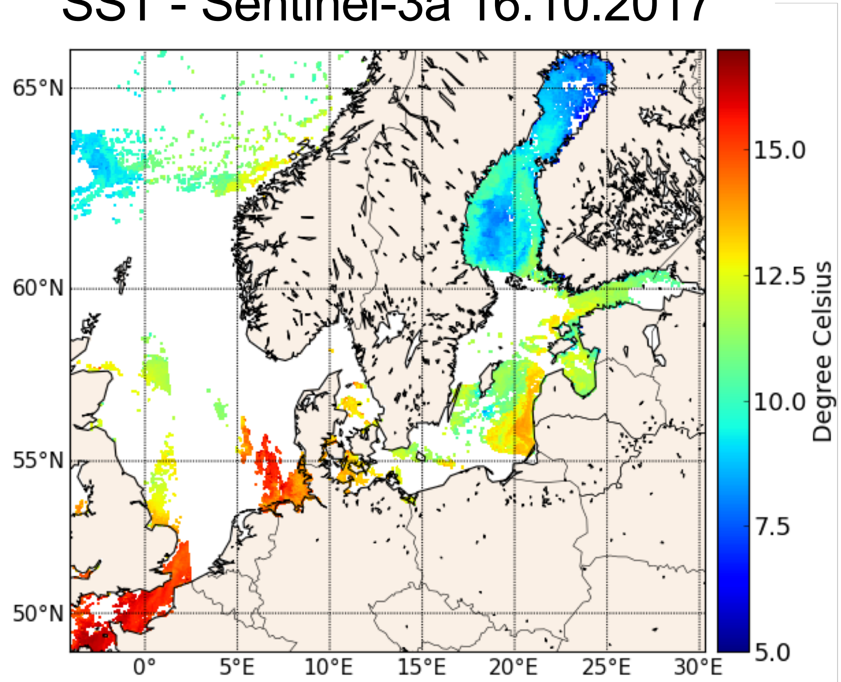
- Modify model to simulate ensemble of model states
- Insert correction step (analysis) to be executed each 12 model hours
- PDAF is free open-source Software developed at AWI (http://pdaf.awi.de)

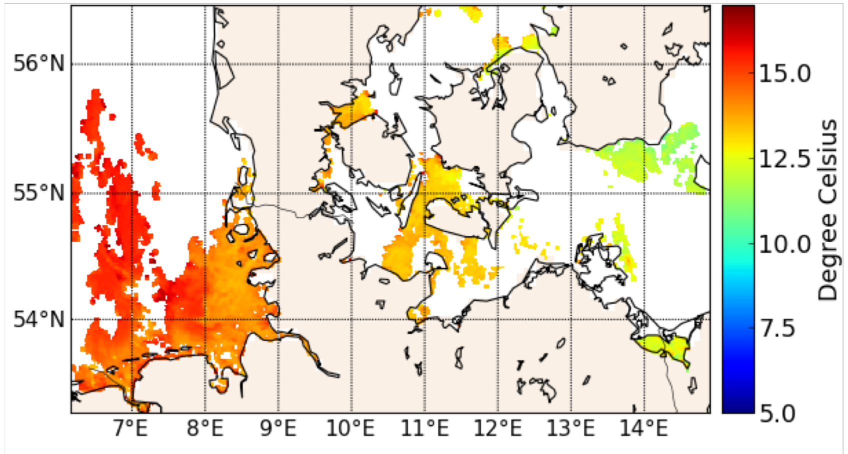


PDAF Parallel Data Assimilation Framework

Observations

SST - Sentinel-3a 16.10.2017





Used here:

- sea surface temperature (SST)
  - 2012: from NOAA satellites
  - 2017: from Sentinel-3a
- 12-hour composites
- Interpolated to both model grids (satellite data resolution ~1 km)
- Many data gaps (clouds)

Possible further data:

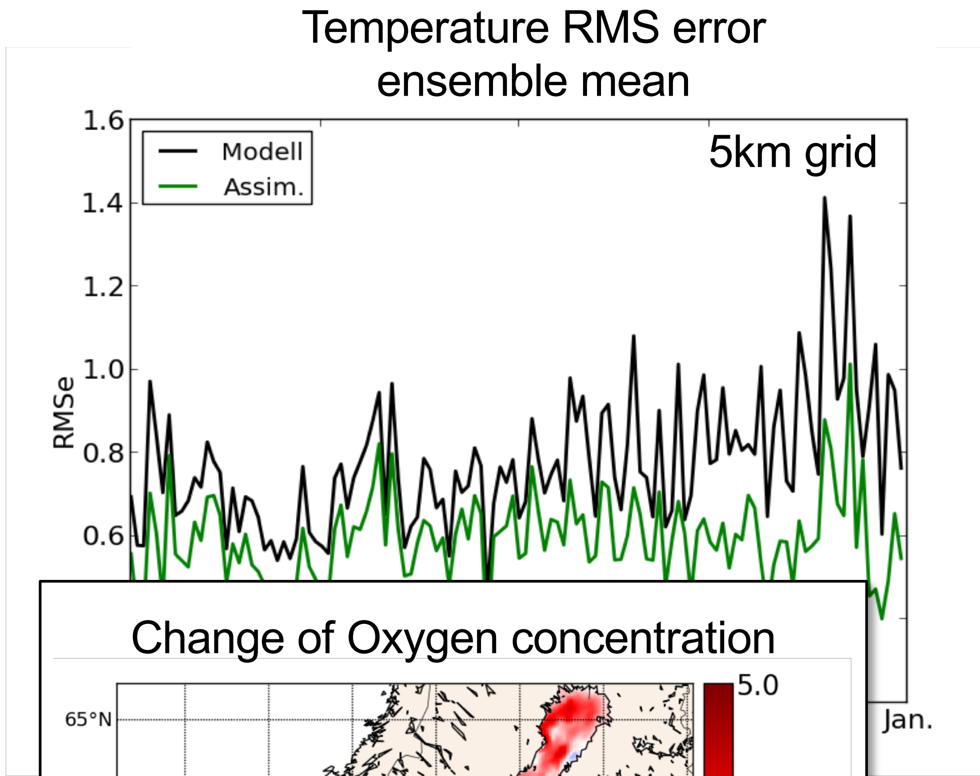
- Satellite ocean color (chlorophyll, diffuse attenuation, reflectance)
- In situ data (here used for validation)

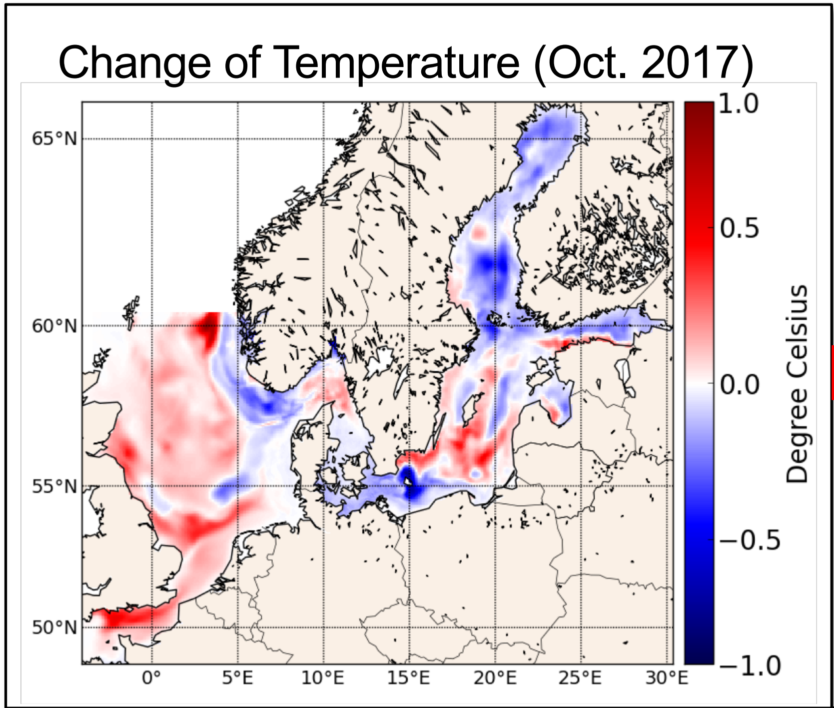
Influnce of Assimilation on Surface Temperature

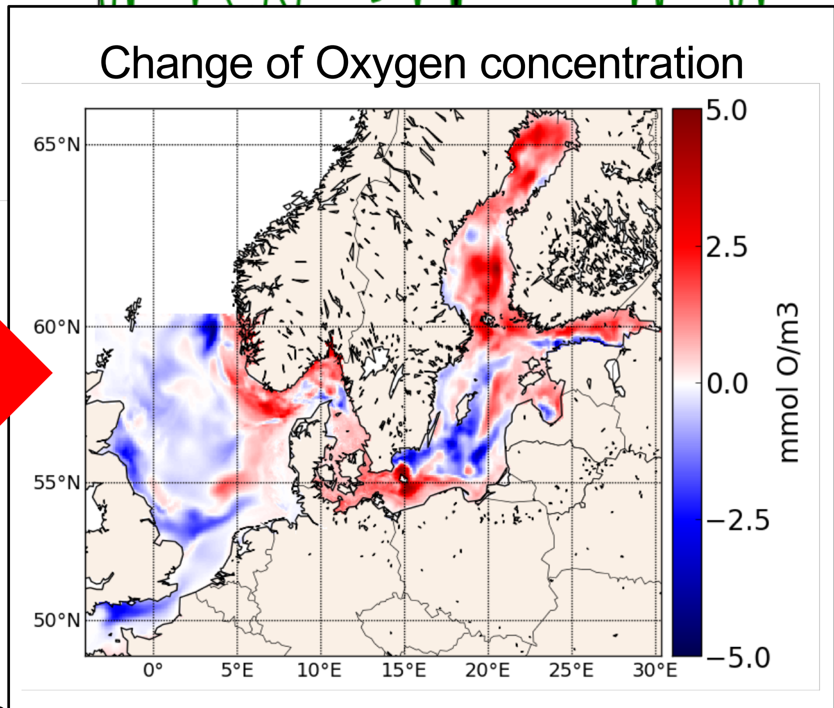
- root-mean square (RMS) error

RMS error (°C)

Grid	Model	Assim.
5km	0.78	0.60
900m	0.81	0.74



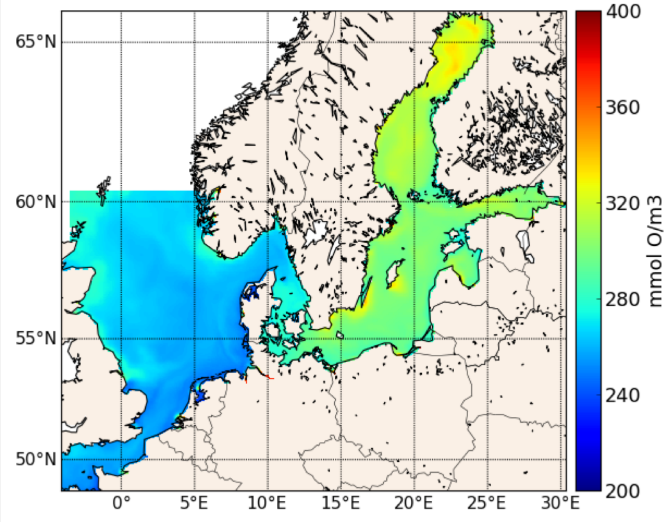




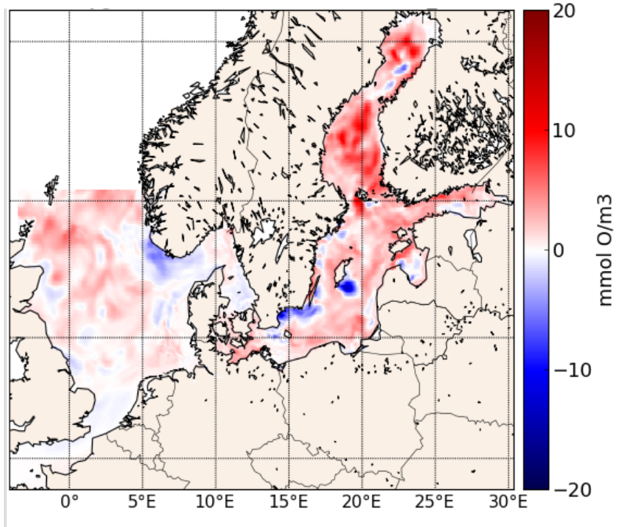
Influence of Assimilation on Ecosystem Variables

Oxygen – July 2012 (mmol O / m³)

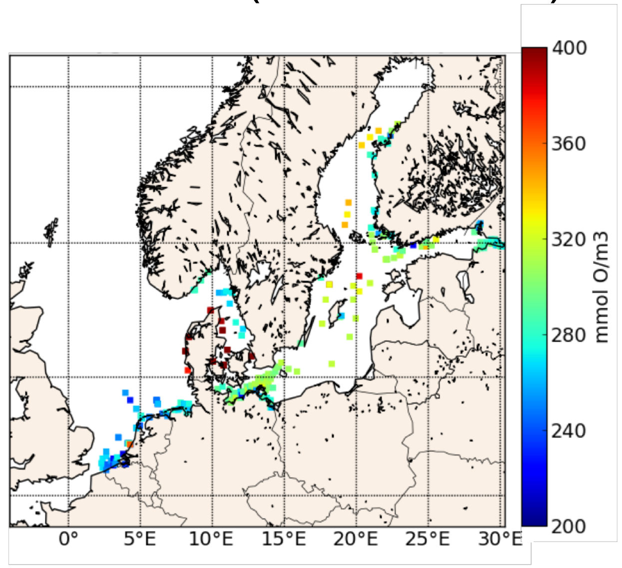
Model



Assimilation - Model

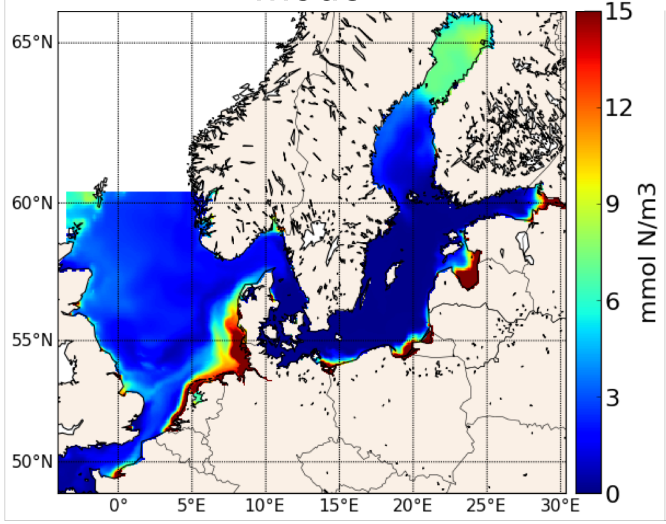


In situ data (ICES & DOD)

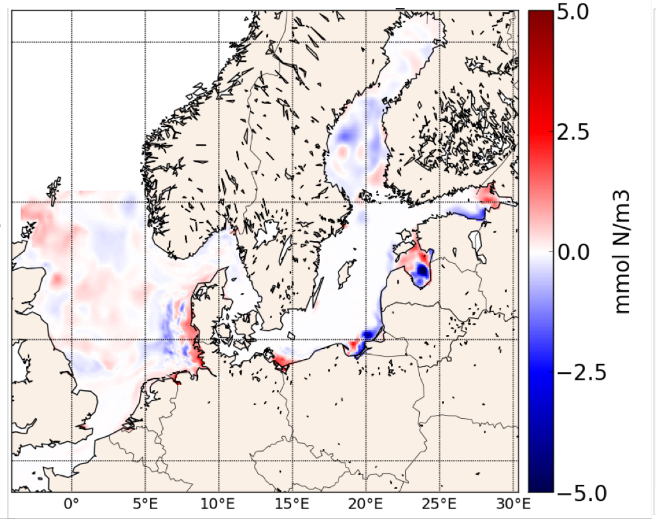


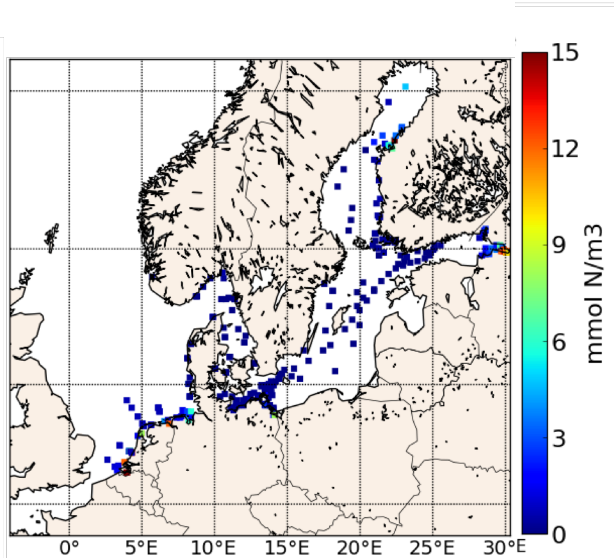
Nitrate – July 2012 (mmol N / m³)

Model



Assimilation - Model

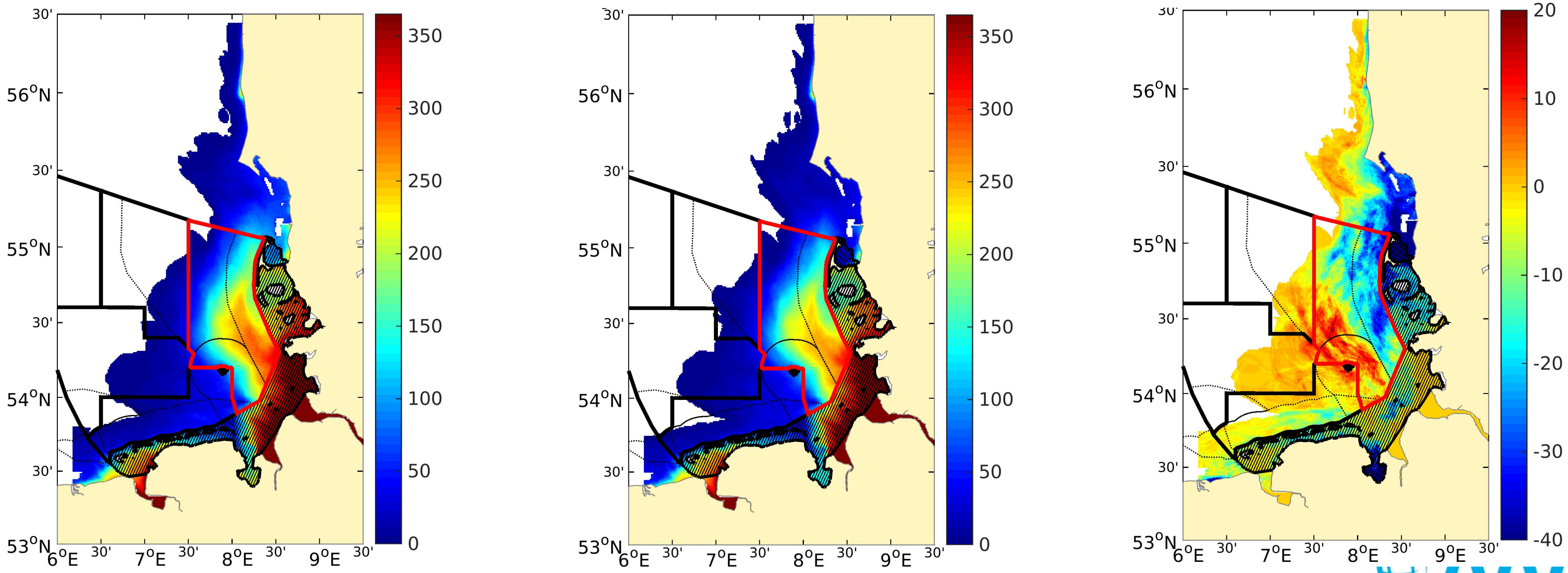




MSFD Indicators (unofficial result)

- EU Marine Strategy Framework Directive – requires monitoring
- MSFD Indicator: total nitrogen
  (nitrate, ammonium, nitrogen in phytoplankton, zooplankton, ..)
- OSPAR region ICNF (Inner Coastal North Frisian) – red frame
- Limit 23.66 mmol / m^3
- Number of days exceeding limit
  - Change due to assimilation: -30 to +12 days

Model | Assimilation | Assimilation – Model



Outcomes of applying data assimilation

Each 12 hours, at analysis time, we get

- complete surface temperature fields
  & 3D physical model state
- modified biogeochemical fields
- derived indicator quantities
- ensemble of 40 realizations

at 5 km and 900 m resolution

Example 2

Assimilation of Satellite Ocean Color Data into Ocean-biogeochemical Model

Project *IPSO* – AWI strategy fund

Coupled Model: MITgcm - REcoM

MITgcm

General ocean circulation model of MIT (*Marshall et al., 1997*).

Global configuration

80°N - 80°S, 30 layers

Resolution:

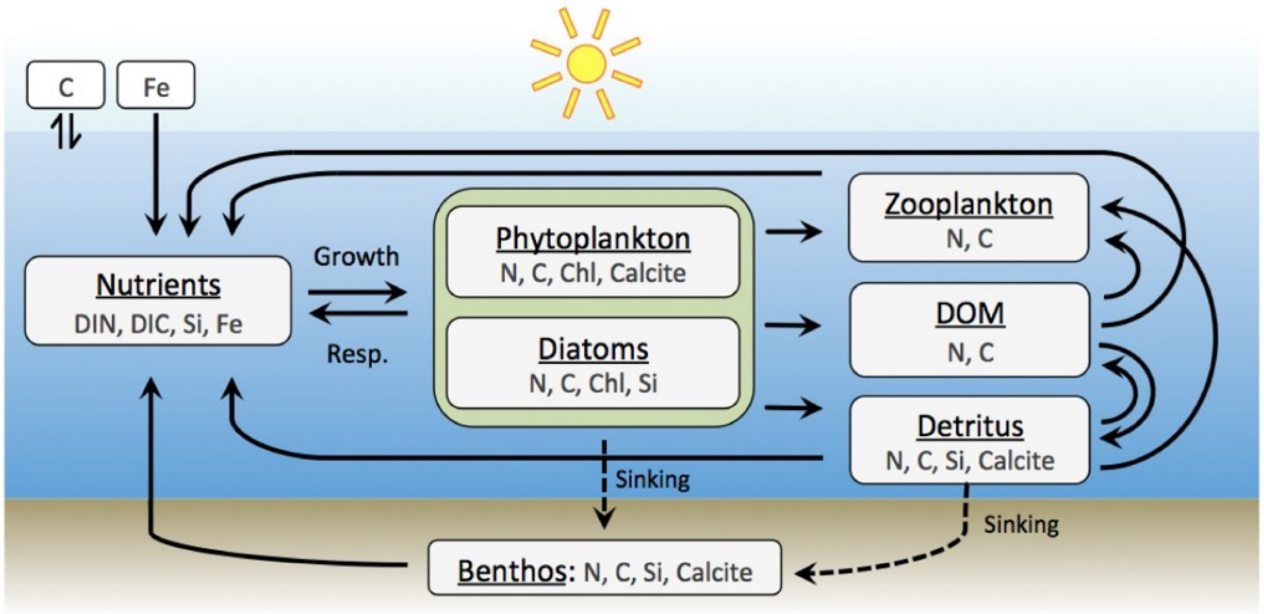
lon : 2 deg

lat : 2 deg in North
up to 0.38 deg in South

layers : 10 m – 500 m

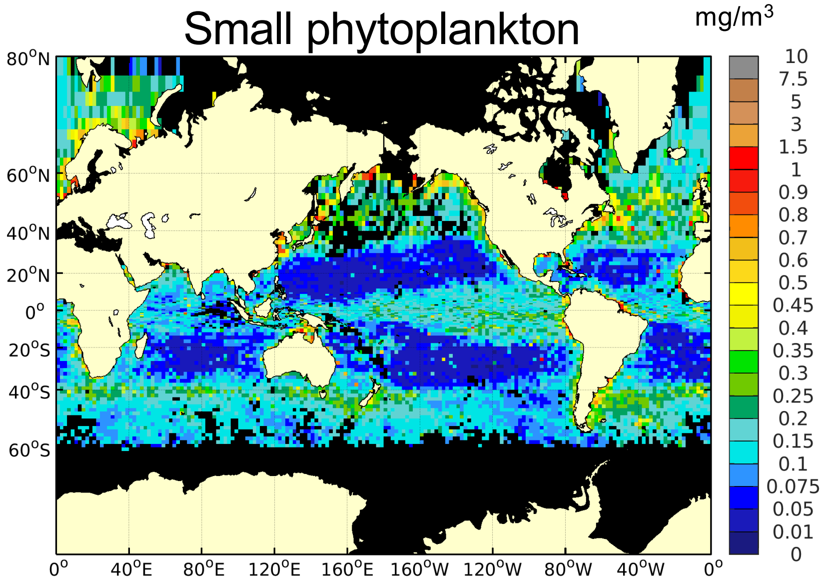
REcoM-2

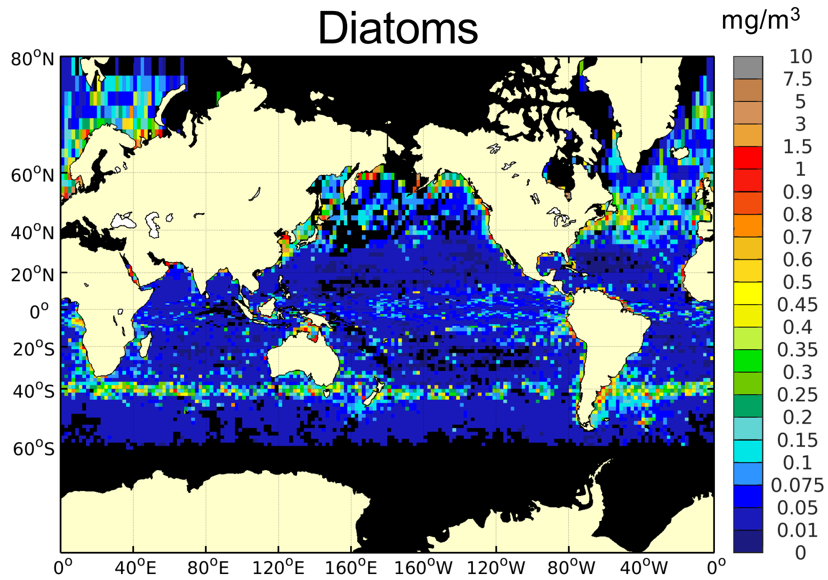
Regulated **Eco**system **M**odel – Version **2**
(Hauck et al., 2013)



Assimilation of chlorophyll data for phytoplankton groups

Assimilated data:
Total chlorophyll data from OC-CCI
and Phytoplankton group data SynSenPFT (Losa et al. 2018)

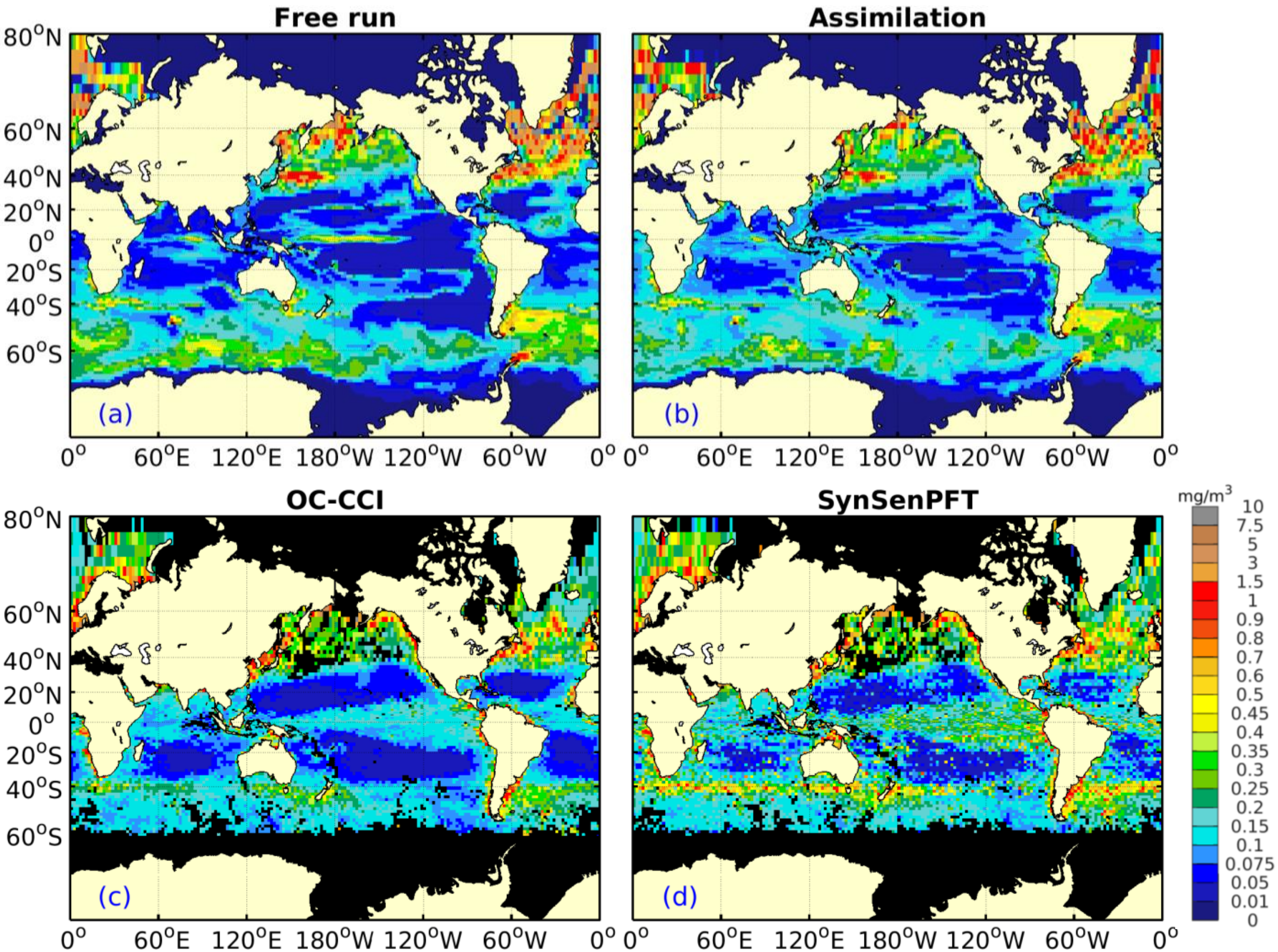




Assimilation:

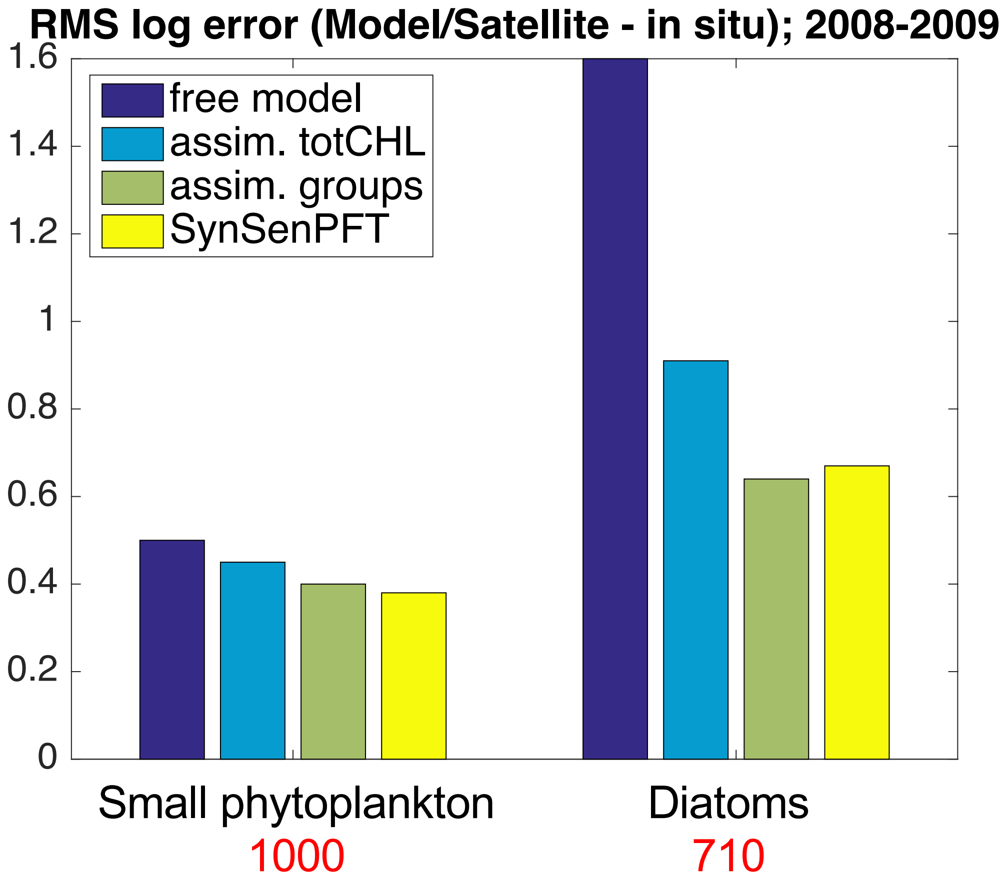
- Assimilate each 5th day for years 2008 & 2009
- Handle logarithmic concentrations
- Validate with in situ data

Assimilation effect on Total Chlorophyll (April 20, 2008)



Pradhan et al., J. Geophy. Res. Oceans, *under review*

Validation with in situ data



- Assimilation of total chlorophyll or SynSenPFT group data
- Validation with independent data

- Assimilation of total Chlorophyll improves both groups
- Stronger error-reductions for group data assimilation
- Stronger error-reductions for Diatoms (slightly below SynSenPFT for group data assimilation)

→ global (gap-free) fields with similar error as SynSenPFT

Summary

- Data assimilation merges observational data with model data
  - Allows
    - to dynamically interpolate through data gaps
    - improve data quality where observational data exists
  - → Yields data products at resolution of model grid
- Multivariate data assimilation also constrains unobserved variables
  - Opportunity to generate additional data products
- Ensemble data assimilation also provides uncertainty estimates

Thank you!

Lars.Nerger@awi.de