Temperature Assimilation into an Operational Coastal Ocean-Biogeochemical Model of the North and Baltic Seas: Weakly and Strongly Coupled Data Assimilation

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BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

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Overview

- Assess influence of SST assimilation on biogeochemical model
  - In North and Baltic Seas
- Examine weakly and strongly coupled assimilation
  - **weakly:** assimilation only changes physics; bgc reacts dynamically
  - **strongly:** assimilation directly changes physics and bgc variables using cross-covariances
- Does the ensemble estimate sufficiently realistic covariances between physical and biogeochemical model fields?

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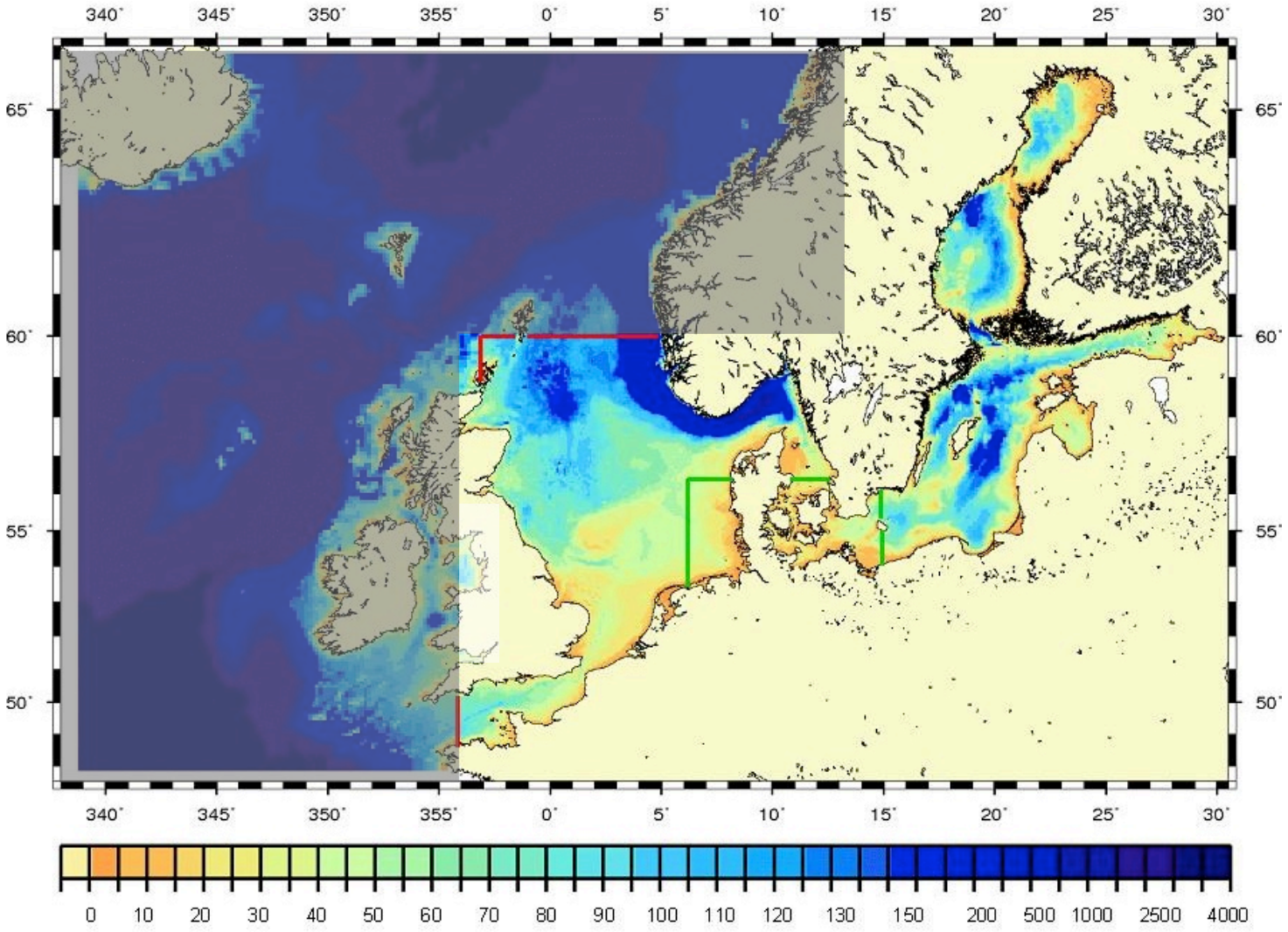
Operational BSH Model – HBM (Hiromb BOOS Model)

Grid nesting:

- **10 km grid**
- **5 km, 36 layers**
- **900 m, 25 layers**

10 km grid used offline as boundary condition



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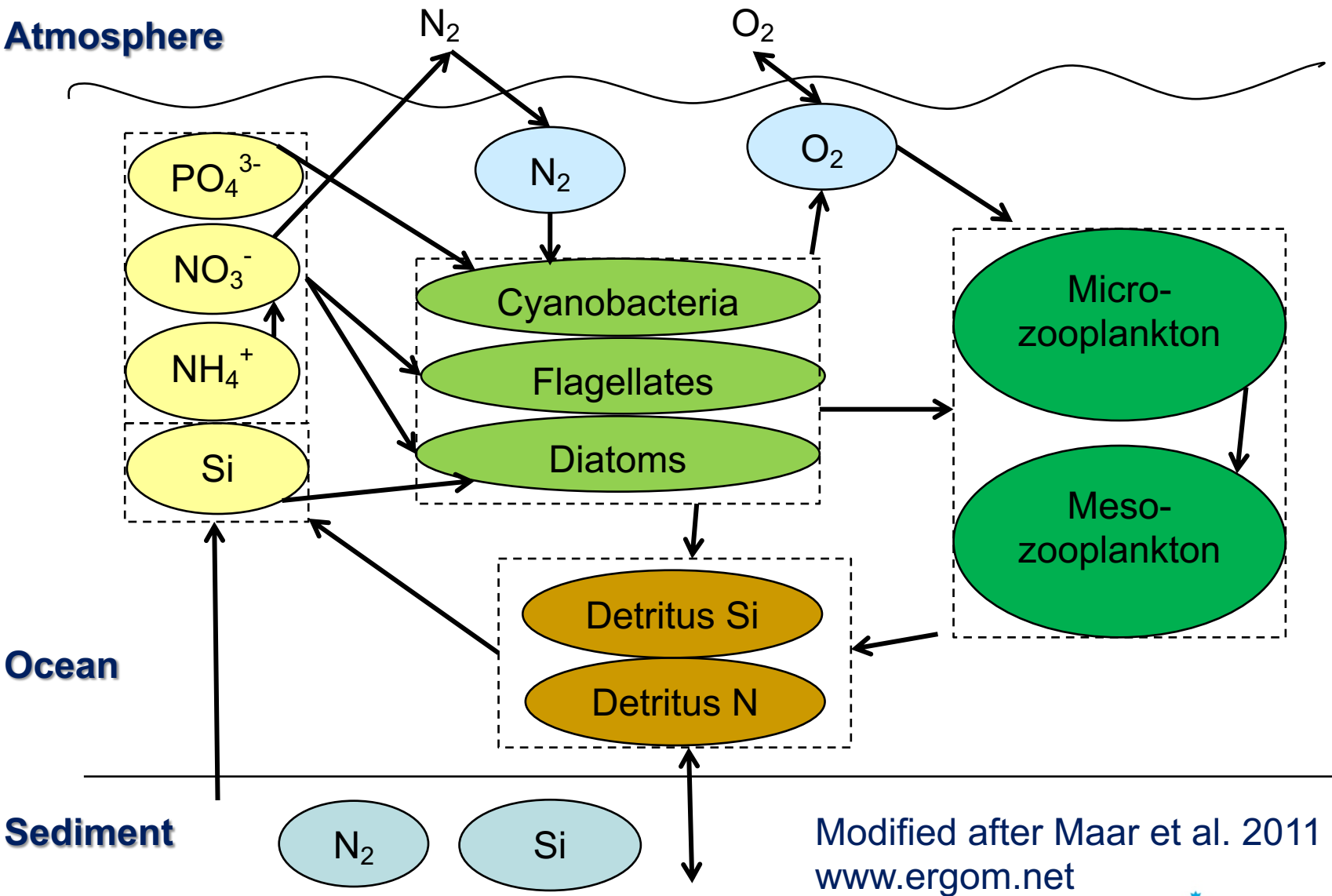
Michael Goodliff et al. – HBM-ERGOM SST Assimilation

Hiromb-BOOS Model

- Operational Model at BSH, DMI and FMI
- Regular model mesh
  - Coarse: horizontal 414 x 347 points, 36 layers
  - Fine: horizontal 630 x 387 points, 25 layers
- 2-way nesting
- Also used for CMEMS MFC-Baltic
  (with 4 nested grids; same assimilation framework in testing phase; now switching to NEMO-Nordic)

Biogeochemistry: ERGOM model



Modified after Maar et al. 2011
www.ergom.net

PDAF: A tool for data assimilation

PDAF Parallel Data Assimilation Framework

PDAF - Parallel Data Assimilation Framework

- provide support for ensemble forecasts
- provide fully-implemented parallelized filter algorithms
- easily useable with (probably) any numerical model (coupled also to MITgcm, NEMO, FESOM, TerrSysMP, …)
- separate development of model and assimilation methods
- makes good use of supercomputers; also runs on laptops
- ~300 registered users

Open source:
Code and documentation available at

http://pdaf.awi.de

BSH
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L. Nerger, W. Hiller, Computers & Geosciences 55 (2013) 110-118

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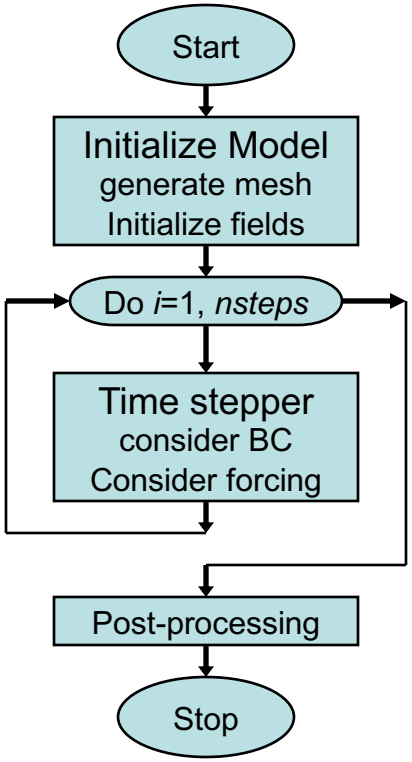
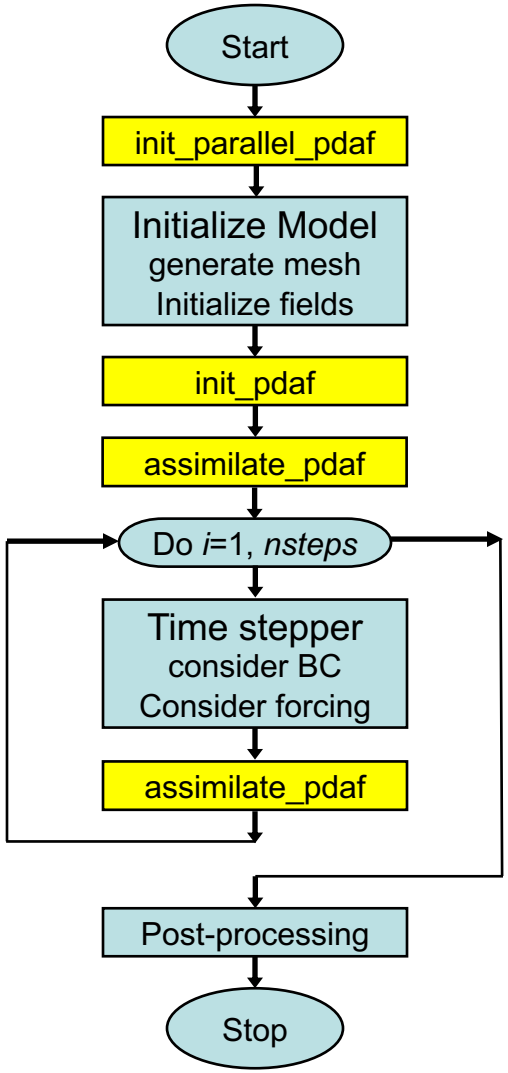
Extending a Model for Data Assimilation

PDAF Parallel Data Assimilation Framework

Model

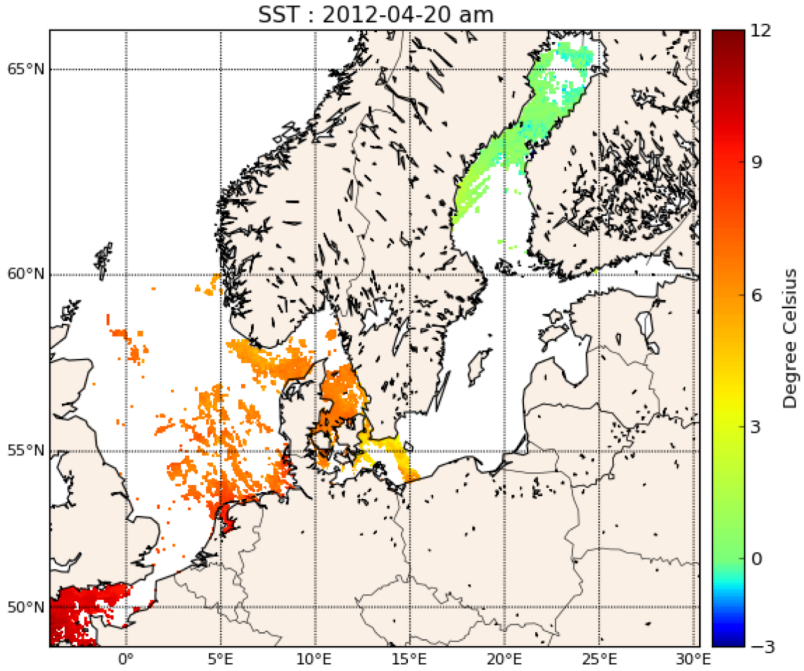


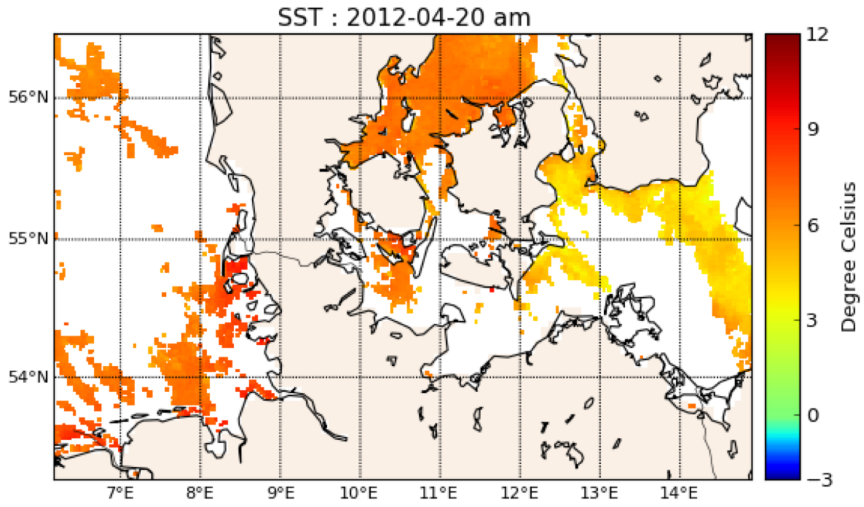


Extension for data assimilation

Enable ensemble forecasts using parallelization

Observations





- sea surface temperature
  - 2012: from NOAA satellites
  - 2017: from Sentinel-3a
- Interpolated to both model grids
- 12-hour composites
- Observation error: 0.8 °C

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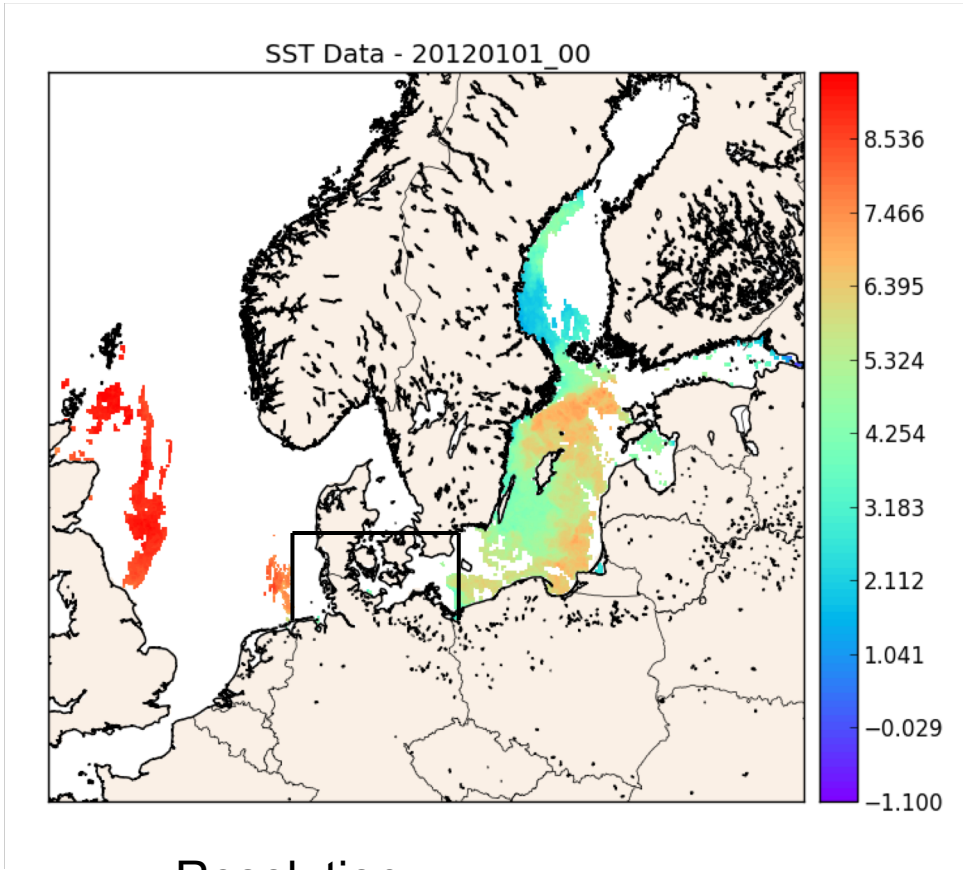
Localization in nested grids

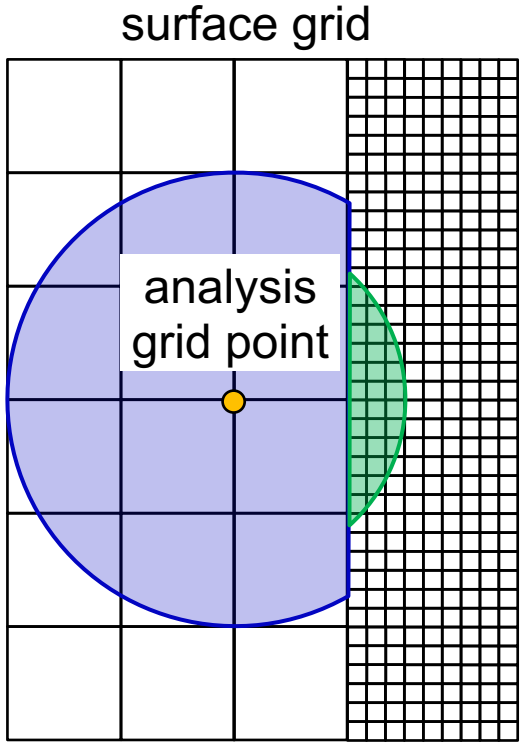


Resolution:

Coarse Grid = 3 nm

Fine Grid = 0.5 nmm

Interaction between two different grids at the boundary.



Used are:

Coarse:
50 km

Fine:
9 km

Observation location defines influence radius

Assimilation experiments

- Assimilate only SST
- Ensemble size: 40
- 2012: March – December (+ 2017 September – December)
- Analysis update every 12 hours
- Filter: LESTKF
- Generate ensemble from model variability over 1 month
- Assimilation experiments
  - weakly coupled: correct only physics;
    let biogeochemical field react dynamically
  - strongly coupled: correct physics and biogeochemistry
- For strongly coupled DA
  - treat biogeochemistry in log-concentrations
    (common practice with chlorophyll)

Comparison with assimilated SST data (4-12/2012)

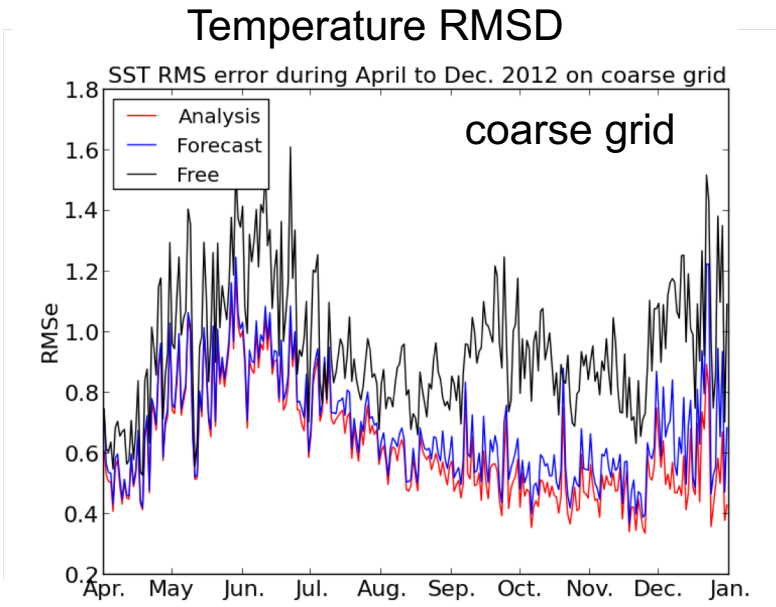
- RMS deviation from SST observations up to ~0.4 °C

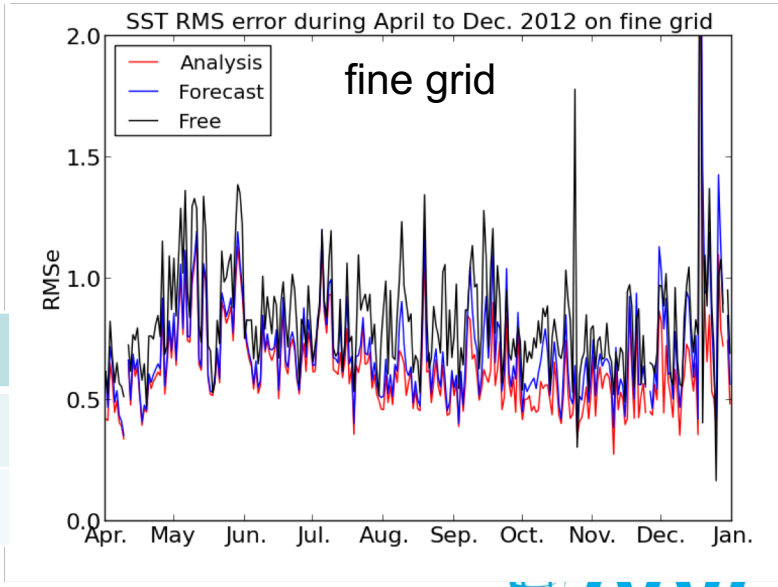
Coarse grid:

- Increasing error-reductions compared to free ensemble run

Fine grid:

- much stronger variability
- Forecast errors sometimes reach free ensemble run errors





RMS errors (deg. C)

	Free	Forec.	Ana.
Coarse	0.95	0.68	0.63
Fine	0.83	0.70	0.63

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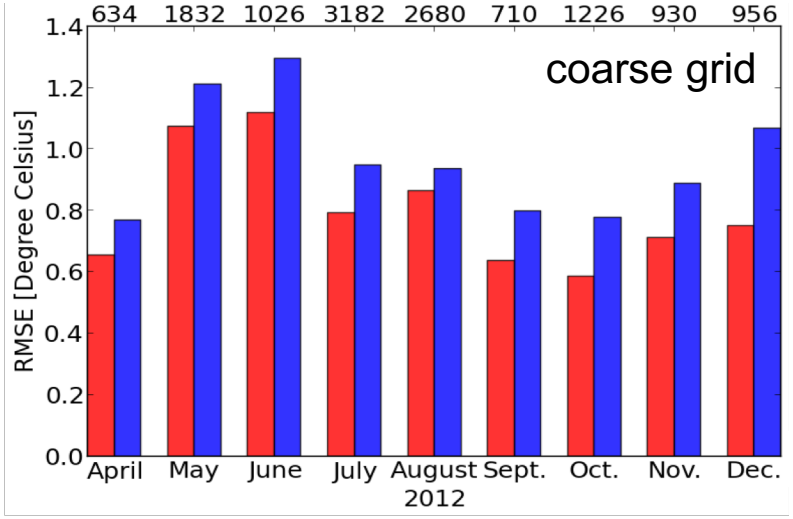
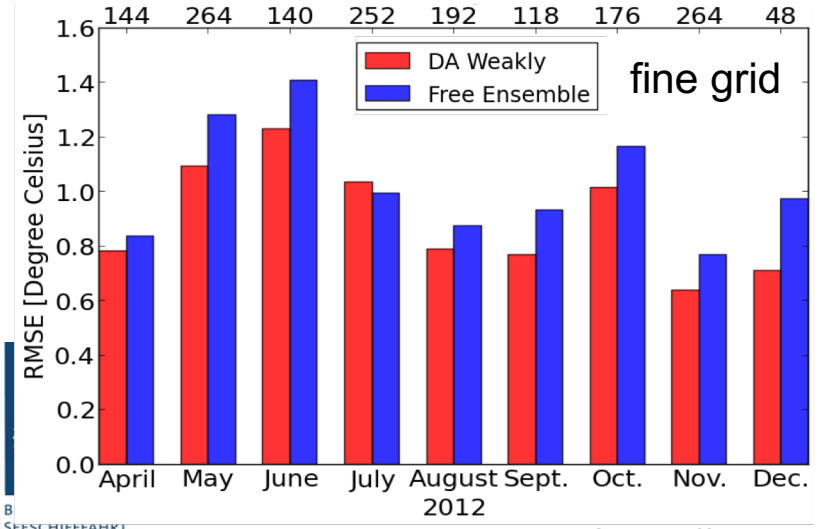
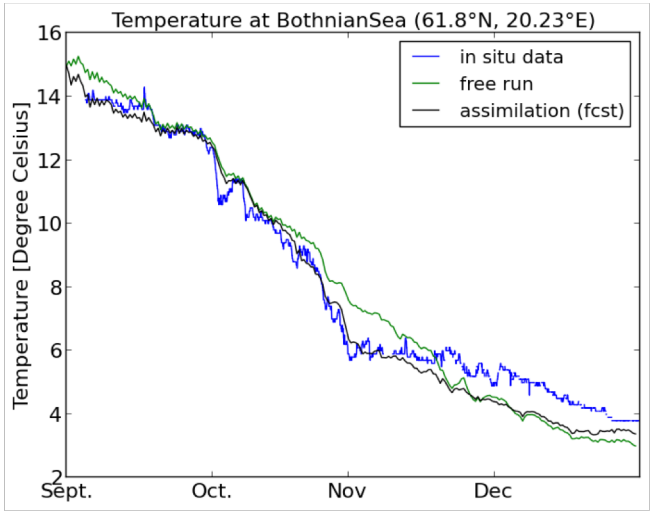
SST validation with in situ data

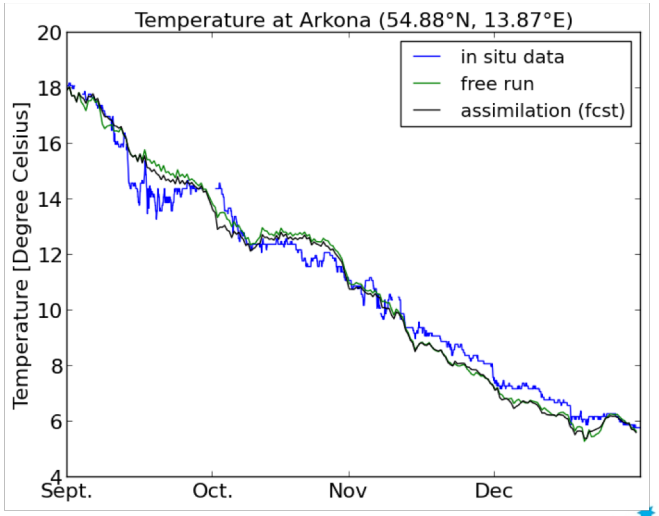
- 2012 (NOAA AVHRR)





- 2017 (Sentinel-3a)

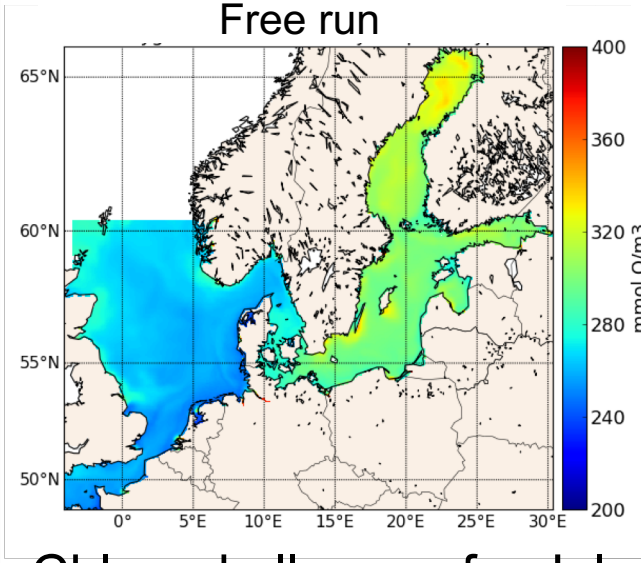




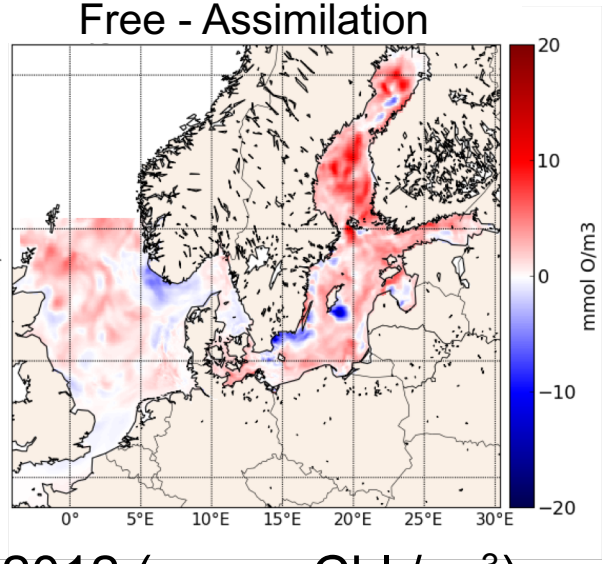
Weakly-coupled effect on biogeochemistry

Oxygen mean for July 2012 (as mmol O / m^3)

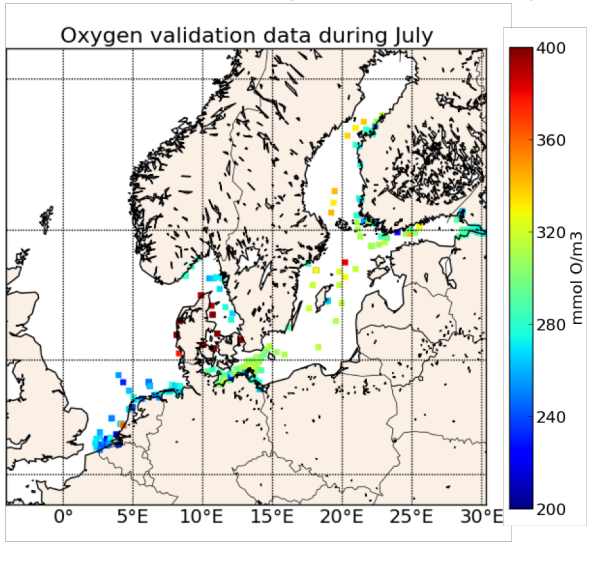
Free run



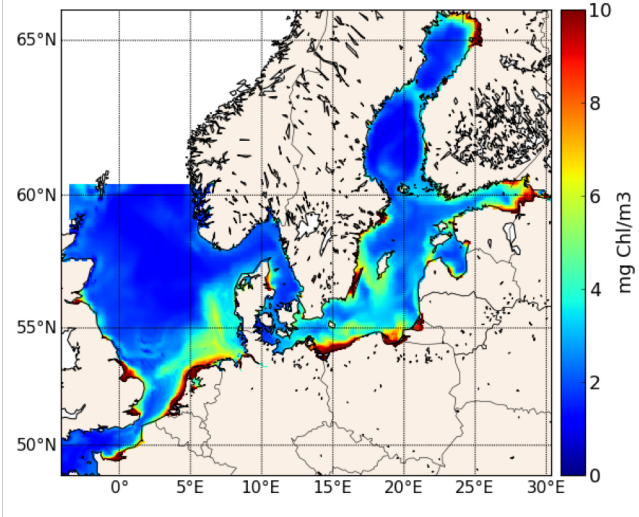
Free - Assimilation

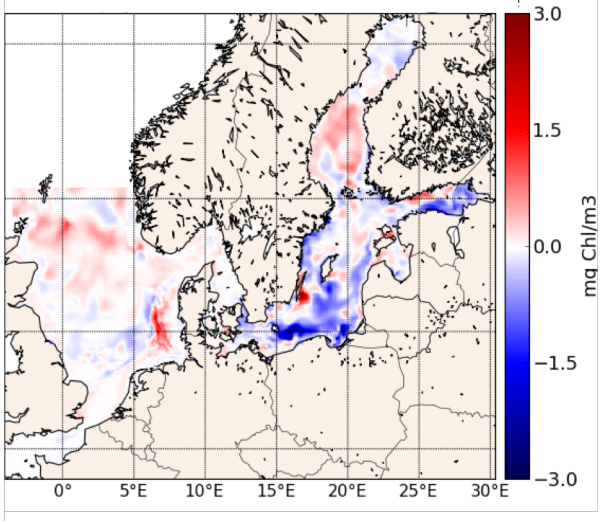


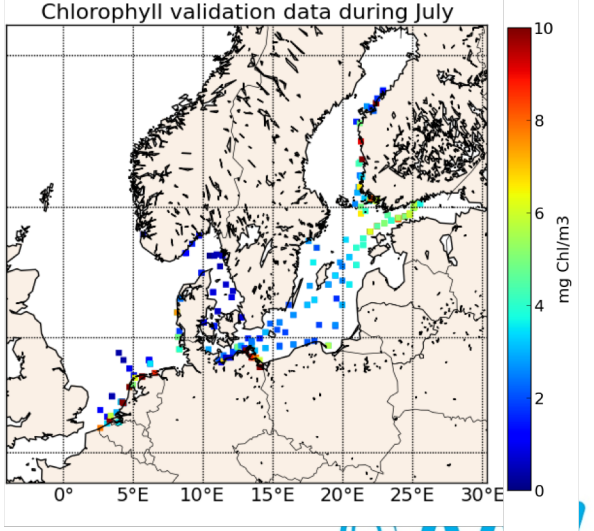
In situ data (ICES/DOD)



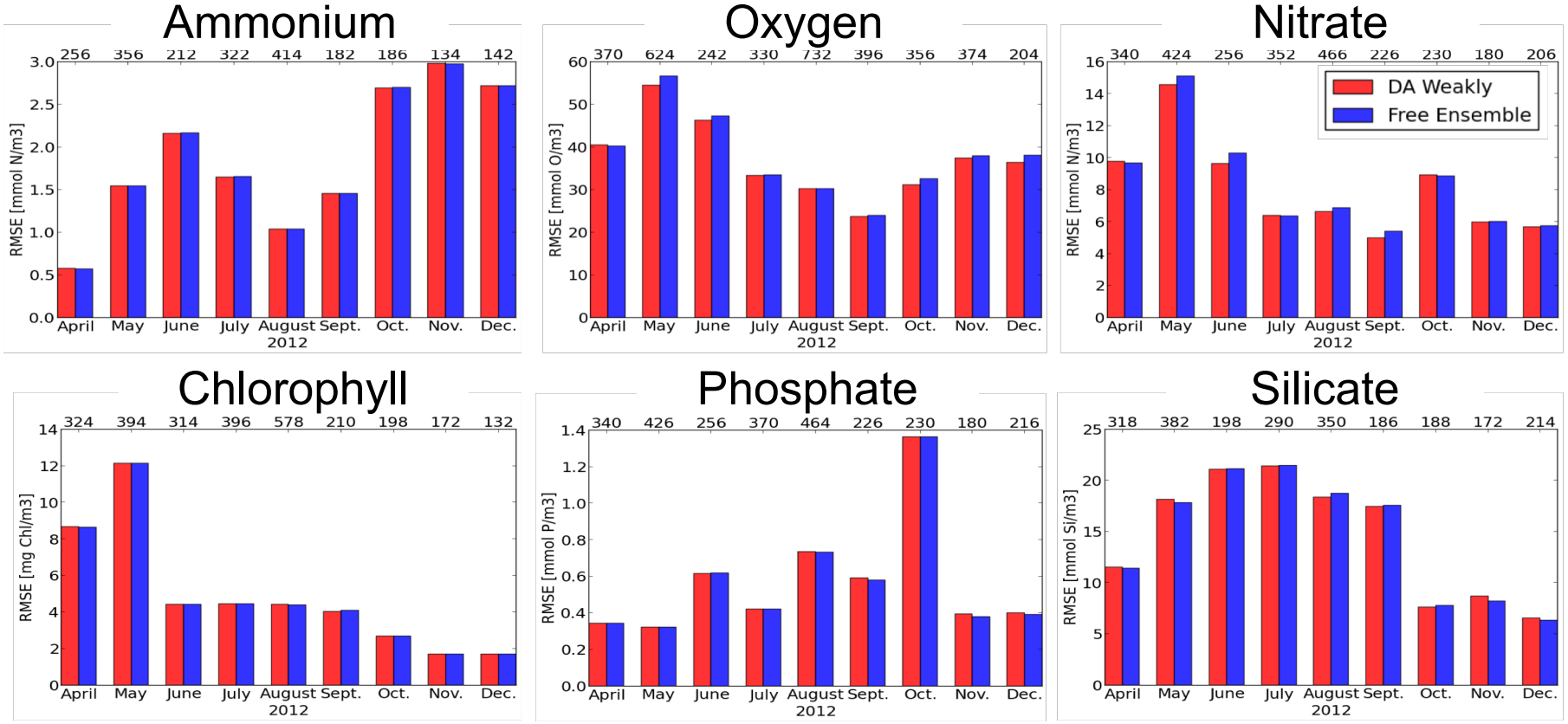
Chlorophyll mean for July 2012 (as mg Chl / m^3)







BGC validation with in situ data – weakly coupled



- Very small influence of weakly coupled DA
- In situ data not co-located with large changes

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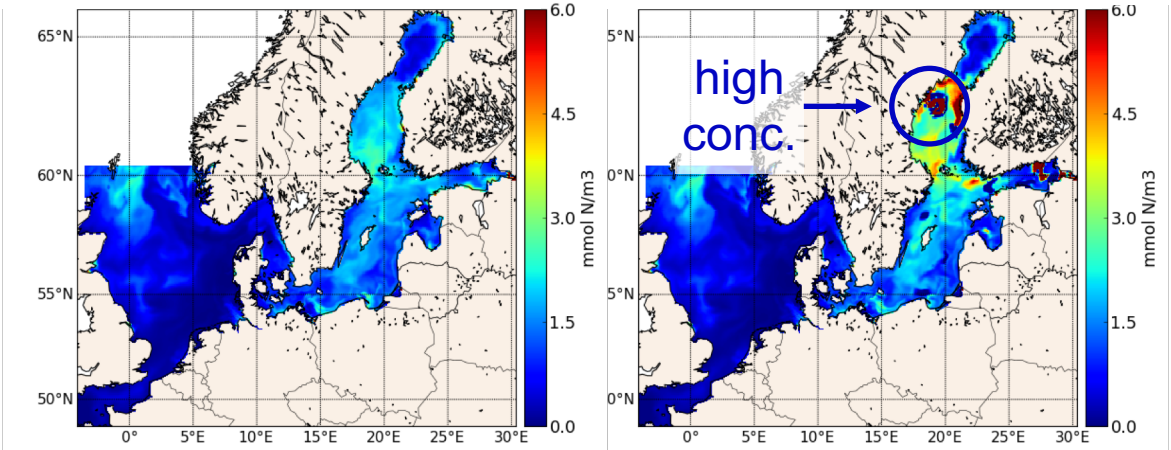
Strongly coupled SST assimilation

Diatoms – April 30, 2012 at surface (ensemble size 20)

***weakly* coupled** ***strongly* coupled**

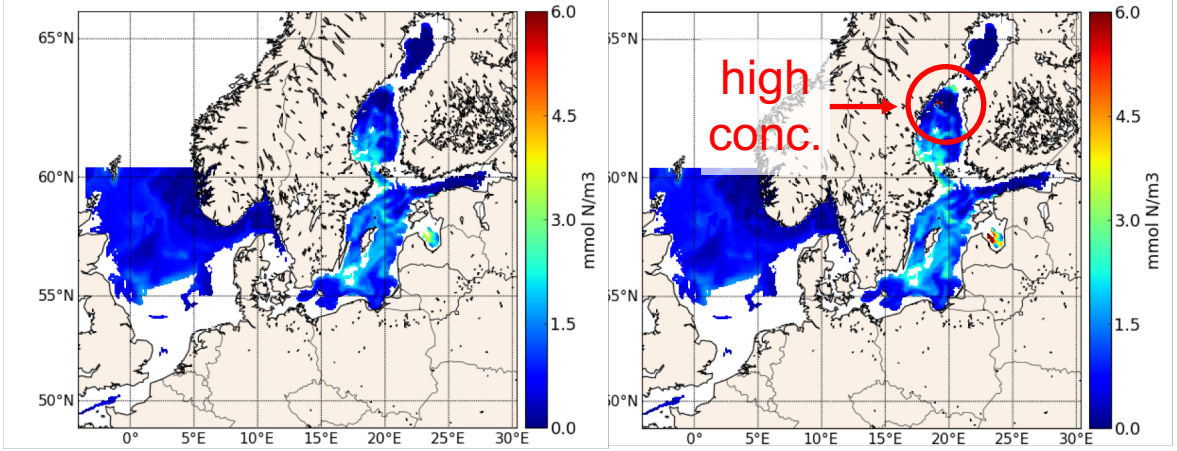


Unrealistically high concentration in Baltic (~8000 mmol N/m^3)

Problem starts earier at depth

Diatoms – April 16, 2012 at ~45 m depth (level 17)

***weakly* coupled** ***strongly* coupled**



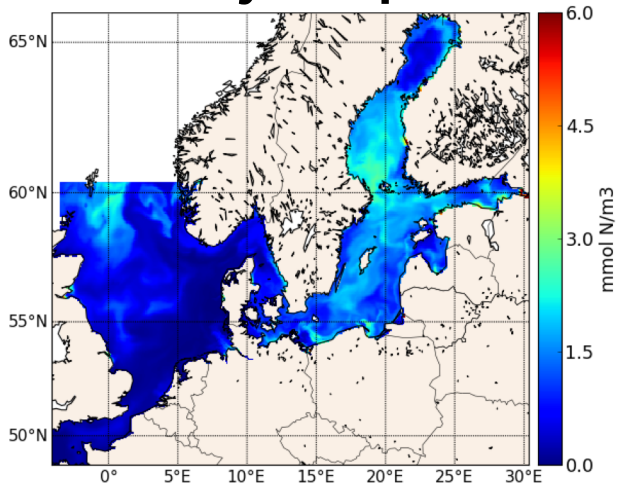
How to treat this problem?

- ➢ Reduce vertical assimilation influence (only for BGC)

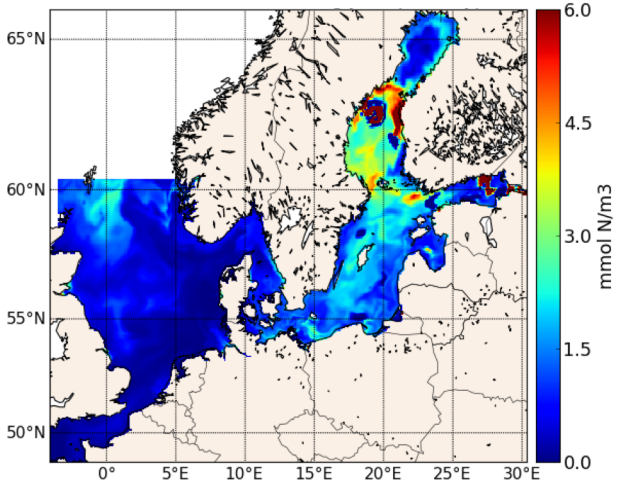
Vertical localization

Diatoms – April 30, 2012 at surface

***weakly* coupled**

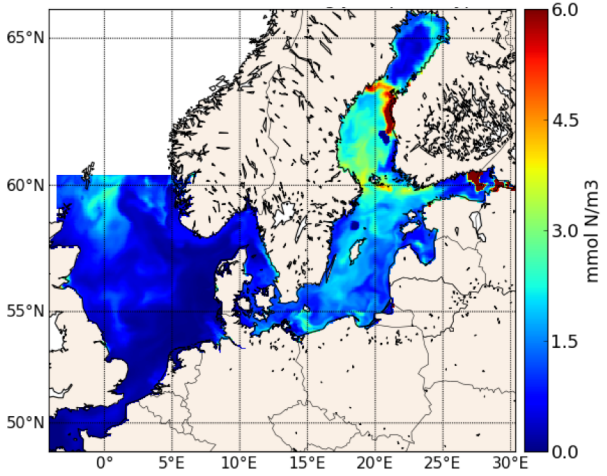


***strongly* – full vertical**

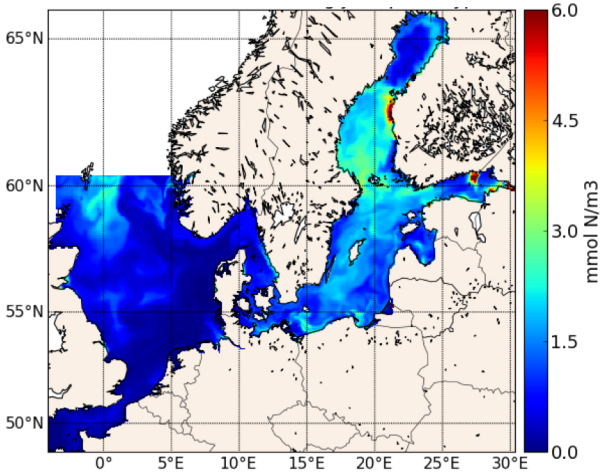


Linear reduction of assimilation influence with depth

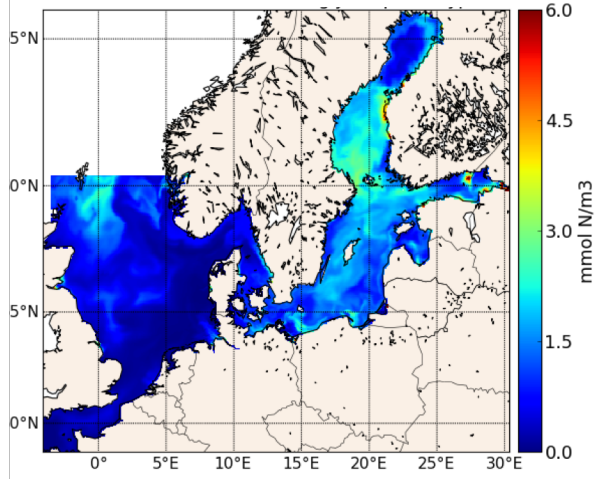
***strongly,* vertloc 25m**



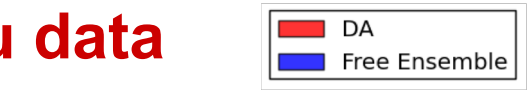
***strongly,* vertloc 10m**



***strongly,* vertloc 5m**

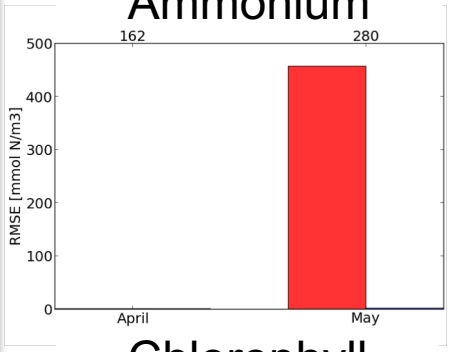


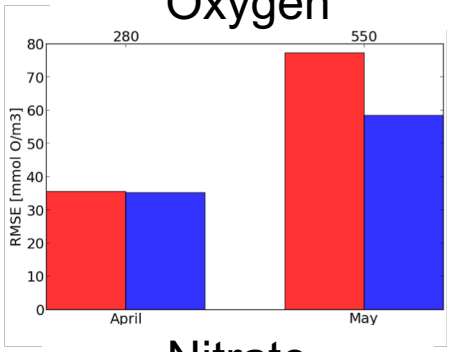
Strongly coupled - validation with in situ data

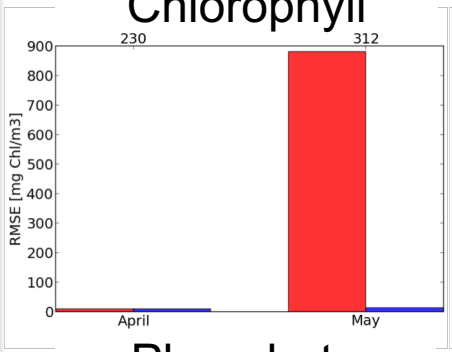


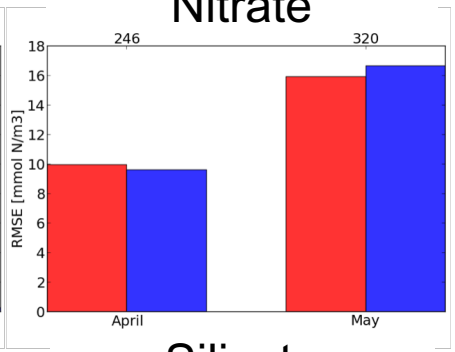
Baltic Sea

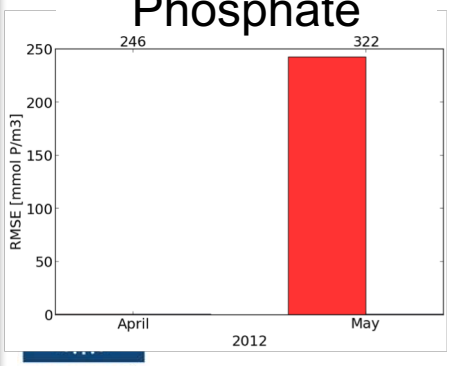
localization depth: **5 m**

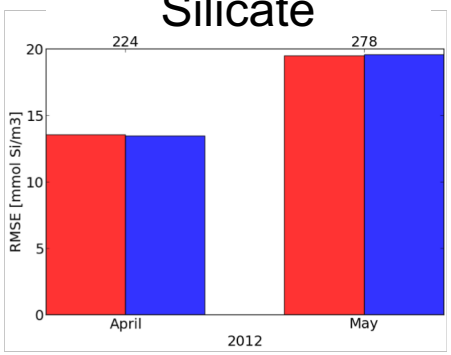






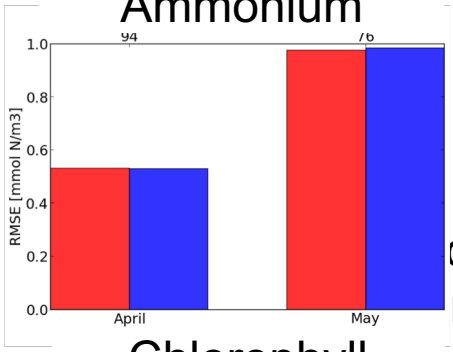


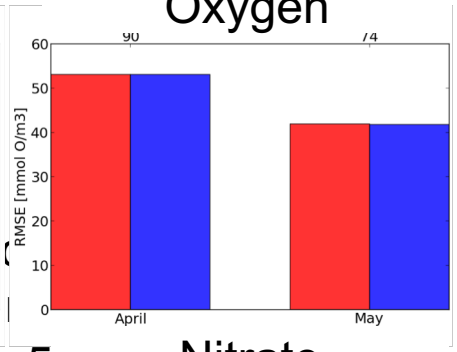


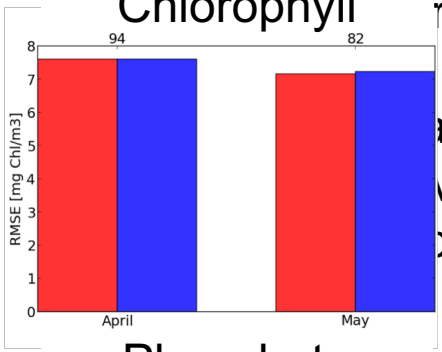


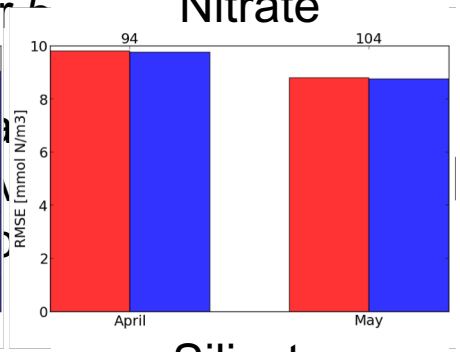
North Sea

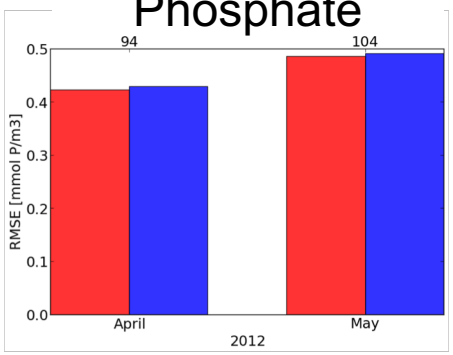
localization depth: **25 m**

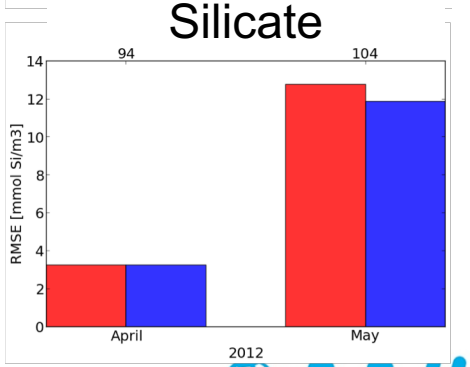












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Summary

- Assimilation of SST data into coupled physical-geochemical model
- Assimilation effects:
  - **SST:** up to 0.3°C lower errors (as expected)
  - **Salinity:** mixed effect (not shown)
  - **Weakly-coupled**:
    - locally significant changes
    - Comparison with in situ data: very small changes
  - **Strongly-coupled**:
    - Unrealistic concentrations without vertical localization
    - Vertical localization helps in North Sea, partly in Baltic
    - Comparison with in situ data: very small changes
    - ➢ Cross-covariances not realistic (insufficient model skill)

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Thank you!

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