PDAF Parallel Data Assimilation Framework

ALFRED-WEGENER-INSTITUT
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Global Assimilation of Ocean-Color Data of Phytoplankton Functional Types: Impact of different datasets

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Overview

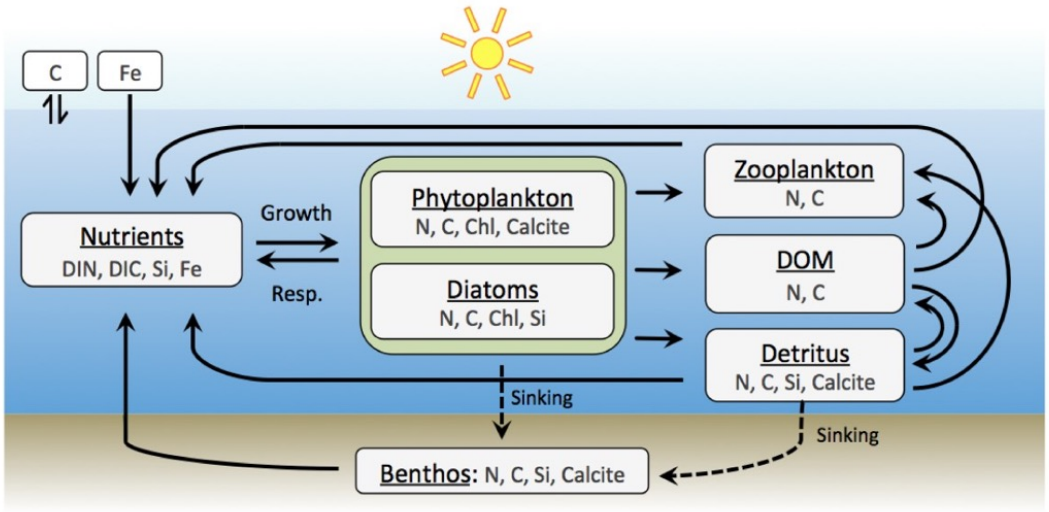
This contribution relates to the publication:

Pradhan, H.K., Voelker, C., Losa, S.N., Bracher, A., Nerger, L. (2020) Global assimilation of ocean-color data of phytoplankton functional types: Impact of different datasets. J. Geophys. Res. Oceans, 125, e2019JC015586, doi:10.1029/2019JC015586

Data Assimilation Application

We use a coupled ocean-ecosystem model

- **Physics:** MITgcm circulation model (Marshall et al., 1997)
  - Global configuration;
  - Resolution: 2 degrees, with refinement to 0.4 deg in southern hemisphere; 30 layers
- **Ecosystem:** Regulated Ecosystem Model (REcoM-2, Hauck et al., 2013)
  - Simulates biogeochemical processes and carbon cycle
  - 2 phytoplankton functional types (diatoms and small phytoplankton)



Research focus:

We want to improve the model representation of phytoplankton by assimilation of satellite chlorophyll data

ton type data

Data Assimilation

PDAF Parallel Data Assimilation Framework

Apply ensemble data assimilation

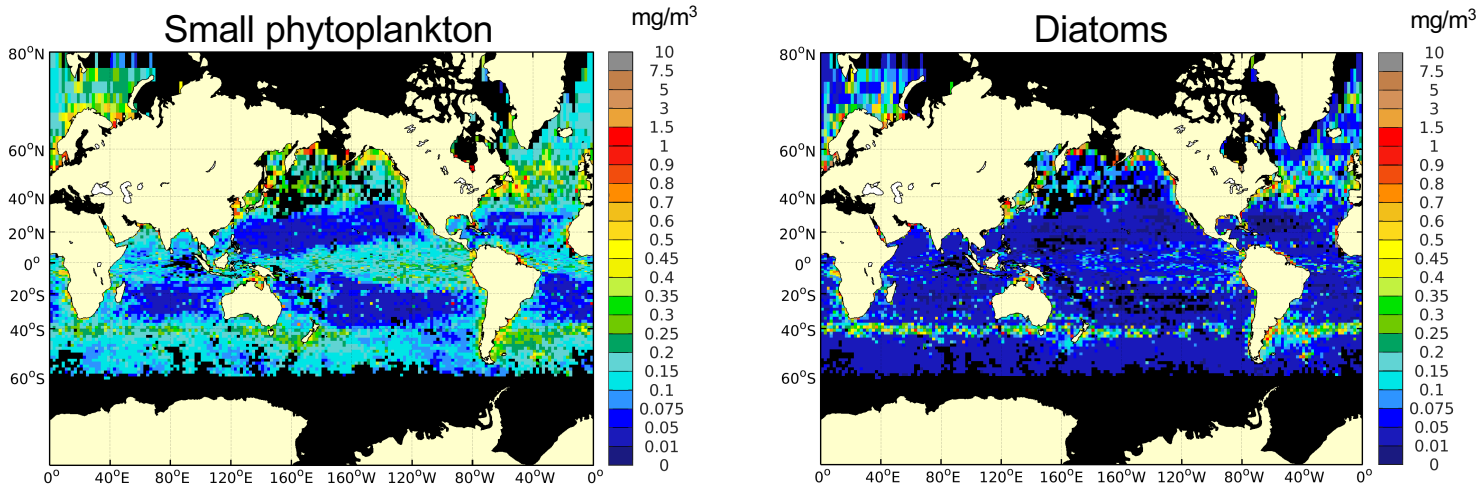
- Ensemble of model states estimates model state and uncertainty
- Use filter method LESTKF provided by Parallel Data Assimilation Framework (PDAF, open source, http://pdaf.awi.de)
- Assimilation updates 8 variables describing diatoms and small phytoplankton
- Assimilate each 5-th day over 2 years
- Ensemble size 20

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

AWI

Observations of Phytoplankton Group Data

Example: Phytoplankton group data SynSenPFT (Losa et al. 2017)



Observations are chlorophyll concentrations derived from satellite ‘ocean color’ data

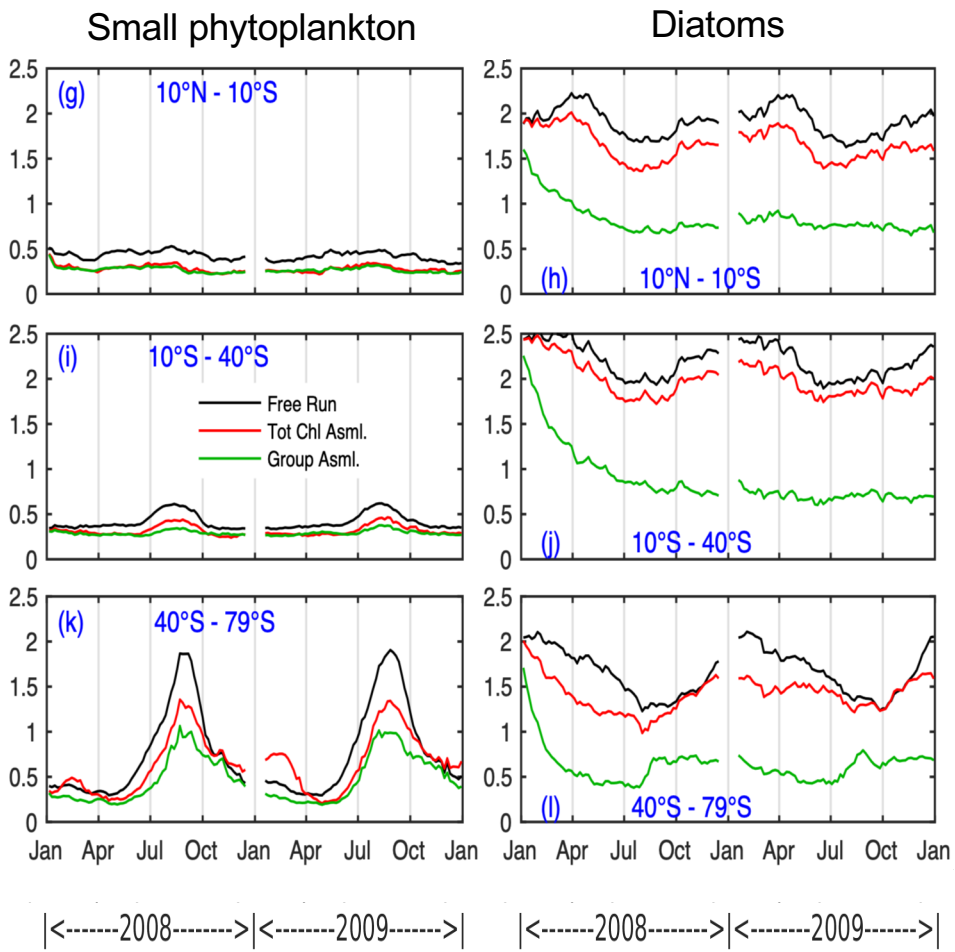
SynSenPFT: ‘synergistic’ combination of two data sets:

- OCPFT (Losa et al. 2017, based on Hirata 2011)
- PhytoDOAS (Bracher et al. 2017)

Losa, S. N., et al. (2017). *Frontiers in Marine Science*, *4*, 203.

Assimilation Effect of Phytoplankton Groups

logarithmic RMS errors (southern regions)



Assimilation cases

Red: Assimilate total chlorophyll (OC-CCI)

Green: Assimilate group data (SynSenPFT)

- RMS error with regard to SynSenPFT data

Total chlorophyll:

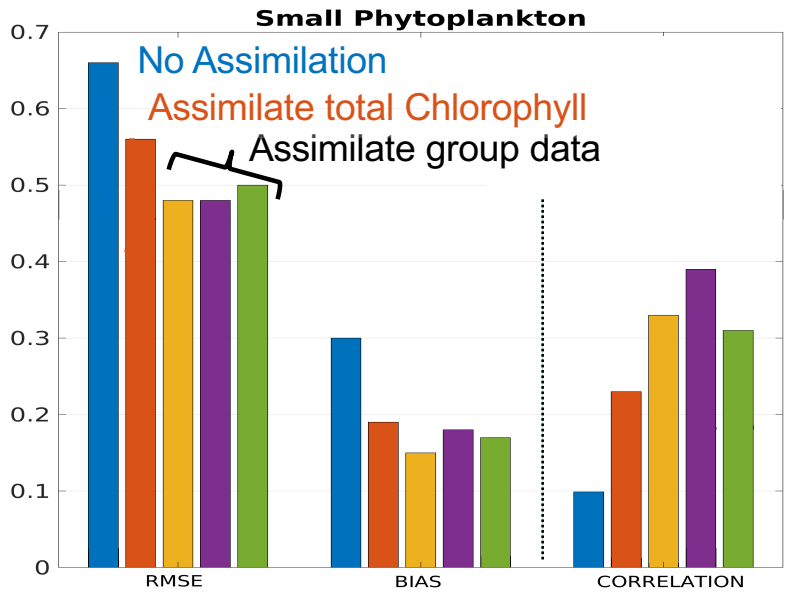
- improves both groups individually

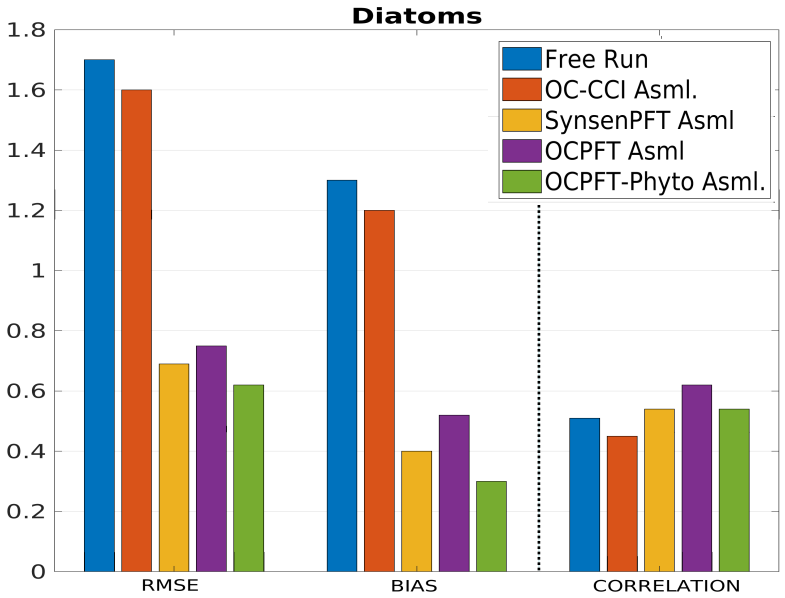
Chlorophyll group data :

- strongly improves representation of Diatoms
- Also improves small phytoplankton
- Changes phytoplankton community structure in Southern Ocean

➜ But: self consistent comparison

Verification with independent in situ measurements





- Assimilating total Chlorophyll and group data improves RMS error, bias, and correlation
- Larger improvements for group data assimilation (in particular for diatoms)
- Differences between different group assimilation cases smaller than from assimilation of total Chl.
- Joint assimilation of PCFT & PhytoDOAS beneficial for diatoms

Summary

- Assimilation of total Chlorophyll data
  - Improves both groups in REcoM2; still high errors for diatoms
- Assimilation of group data
  - Strongly improved diatom chlorophyll concentrations
  - Joint assimilation of OCPFT and PhytoDOAS data slightly better than with synergistic SynSenPFT data

Pradhan, H.K., Voelker, C., Losa, S.N., Bracher, A., Nerger, L. (2020). J. Geophys. Res. Oceans, 125, e2019JC015586, doi:10.1029/2019JC015586

Pradhan, H.K., Völker, C., Losa, S.N., Bracher, A., Nerger, L. (2019). J. Geophys. Res. Oceans, 124, 470-490, doi:10.1029/2018JC014329

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Global Assimilation of Ocean-Color Data of Phytoplankton Functional Types: Impact of Different Datasets

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Overview

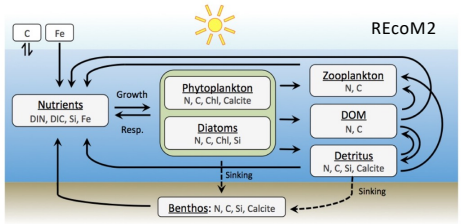
Phytoplankton functional type (PFT) data is assimilated into the global coupled ocean-ecosystem model MITgcm-REcoM2 for two years using a local ensemble Kalman filter.

The ecosystem model simulates two PFTs: small phytoplankton (SP) and diatoms. The PFTs are simulated by four variables each.

Three different sets of satellite PFT data are assimilated: OC-PFT, PhytoDOAS, and SynSenPFT, which is a synergistic product combining the independent PFT products OC-PFT and PhytoDOAS.

The effect of assimilating PFT data is compared with the assimilation of total chlorophyll data (TChla). Assimilating TChla constrains both PFTs through multivariate assimilation, i.e. using ensemble-estimated cross-covariances between TChla and chlorophyll in the phytoplankton types.

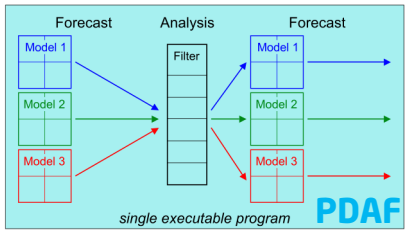
Model: MITgcm-REcoM2



The ocean circulation model of the MIT (MITgcm) is used in a global configuration with 30 layers. The horizontal resolution is 2 degrees with refinement to 0.4 degree toward Antarctica.

REcoM2 has two phytoplankton types, which are simulated by separate pools of carbon and chlorophyll.

Ensemble Data Assimilation

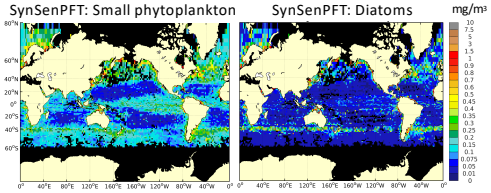


We estimate the concentrations and their uncertainty using an ensemble of model states created by perturbing process parameters in REcoM.

The data assimilation uses an ensemble of 20 members is used and observations are assimilated each 5-th day.

It is performed with PDAF (Parallel Data Assimilation Framework, [1], http://pdaf.awi.de) which augments the model with assimilation functionality.

Assimilated Observations



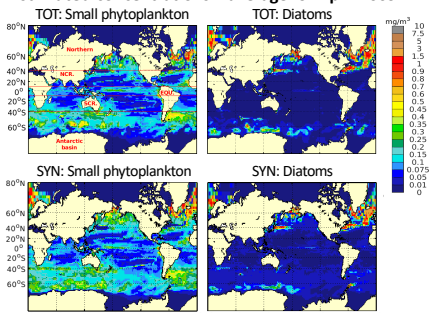
The experiments assimilate total chlorophyll concentrations or different data sets of plankton type data:

- **FREE:** No assimilation
- **TOT:** Assimilate total chlorophyll from OC-CCI
- **OPT**: Assimilate data from OC-PFT algorithm
- **PDS**: Assimilate data from PhytoDOAS algorithm
- **SYN**: Assimilate synergistic product SynSenPFT, which combines OC-PFT and PhytoDOAS
- **OPTpds**: Jointly assimilate OC-PFT and PhytoDOAS

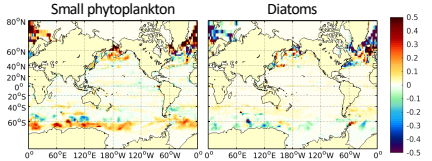
Effect of Plankton Type Assimilation

Plankton type data provides direct information about both types in REcoM2. In contrast, assimilating total chlorophyll uses the ensemble estimate of cross-covariances between total chlorophyll and the chlorophyll concentration of each plankton type. Using the direct information results in larger corrections, in particular for diatoms.

Estimated concentrations – average for April 2009



Difference: PFT DA – total Chlorophyll DA (SYN – TOT)

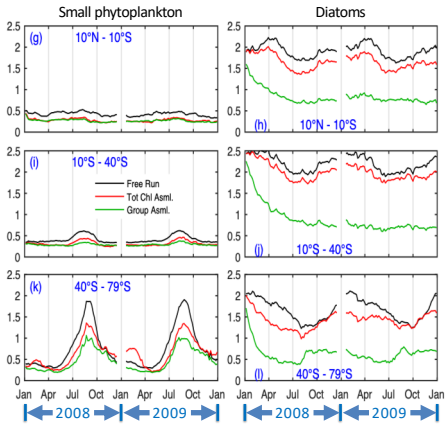


Time-varying RMS Errors

The root-mean square errors with regard to the satellite plankton type observations show that assimilating the types strongly reduced the RMSE for diatoms. However, also for small phytoplankton the errors are lower.

The Southern Ocean shows significant seasonal variation of the RMSE.

RMSE in latitude regions – Southern hemisphere



References:

[1] Nerger, L., Hiller, W. Software for Ensemble-based Data Assimilation Systems - Implementation Strategies and Scalability. Comp. & Geosci., (2013) 55: 110-118

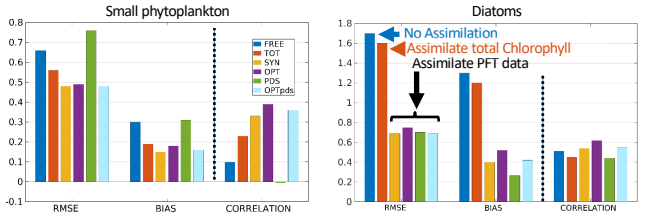
[2] Pradhan, H.K., Völker, C., Losa, S.N., Bracher, A., Nerger, L. (2020) Global assimilation of ocean-color data of phytoplankton functional types: Impact of different datasets. J. Geophys. Res. Oceans, 125, e2019JC015586, doi:10.1029/2019JC015586

Assessment with Independent Data

We assess the estimated phytoplankton type concentrations with independent in situ data computing the RMSE, bias and correlation coefficient.

The assimilation of total chlorophyll reduces the RMSE and bias for both types, but more pronounced for small phytoplankton.

The assimilation of type data leads to a further improvement, which is very strong for Diatoms. The joint assimilation of OC-PFT and PhytoDOAS data leads to the overall best result among the different type assimilation experiments.



Summary

- Satellite chlorophyll data for phytoplankton functional types (PFTs) and total chlorophyll was assimilated.
- For independent in situ data, the assimilation of PFT data results in significantly lower errors than multivariate assimilation of total chlorophyll.
- Jointly assimilating type data generated using the OC-PFT and PhytoDOAS methods yields the smallest errors.
- Assimilatiing PhytoDOAS data lead to high errors in small phytoplankton.
- Assimilating the synergistic SynSenPFT data results in comparable RMSE and bias, but slightly lower correlations.