Multivariate Assimilation of Satellite Ocean Chlorophyll Data Into a Global Model - Prospects and Challenges

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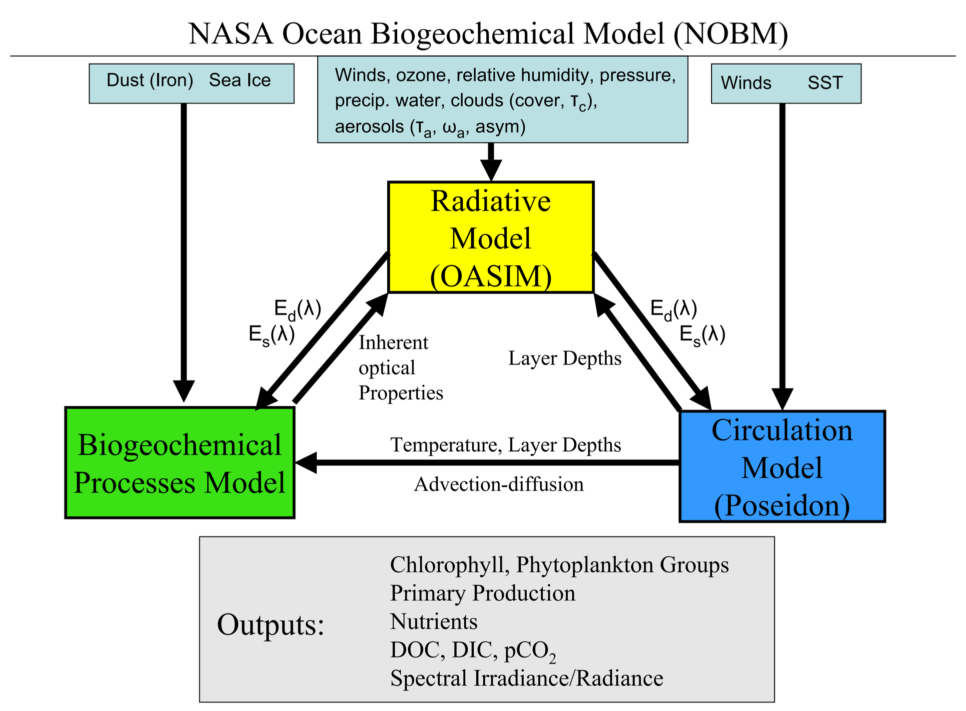
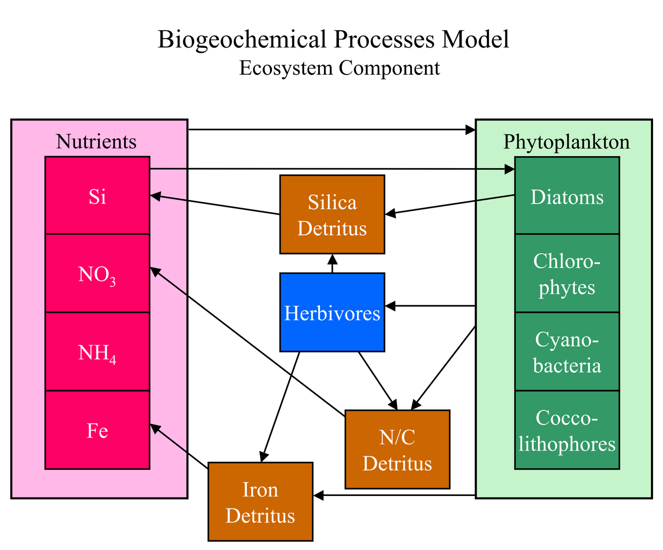
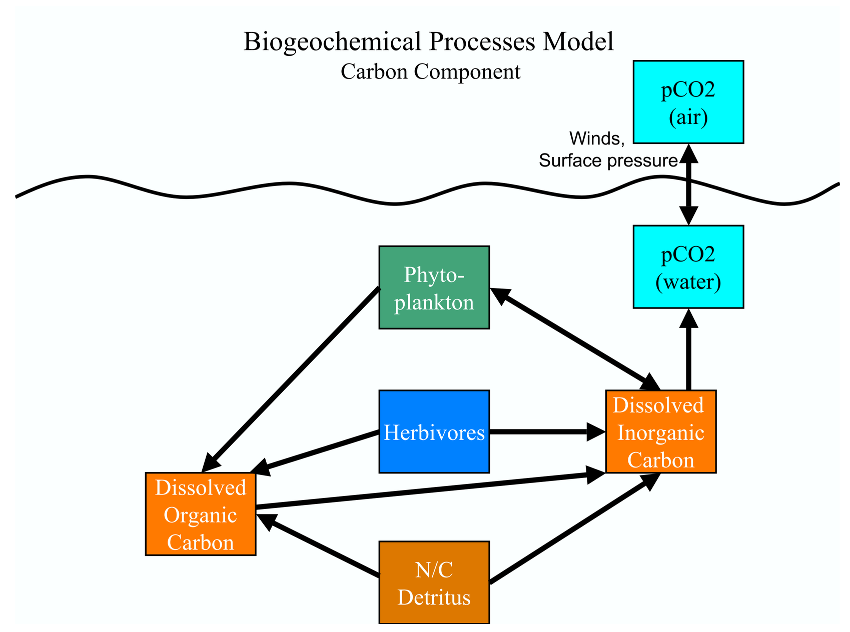
Introduction

Chlorophyll data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) is assimilated into the three-dimensional global NASA Ocean Biogeochemical Model (NOBM) for the period 1998-2004 using a multivariate configuration of the SEIK filter, which is an ensemble Kalman filter scheme. The SEIK filter is applied here with a localized analysis and simplified by the use of a constant covariance matrix. The multivariate assimilation is applied to update the four phytoplankton groups of the model as well as the simulated nitrate, ammonium, and N/C detritus fields at the surface. The chlorophyll estimates of the model can be significantly improved by the assimilation, resulting in complete daily chlorophyll fields of similar accuracy as the SeaWiFS data. The results are less clear for the nutrients. We discuss the behavior of the multivariate assimilation process and the challenges involved by it.

NASA Ocean Biogeochemical Model (NOBM)





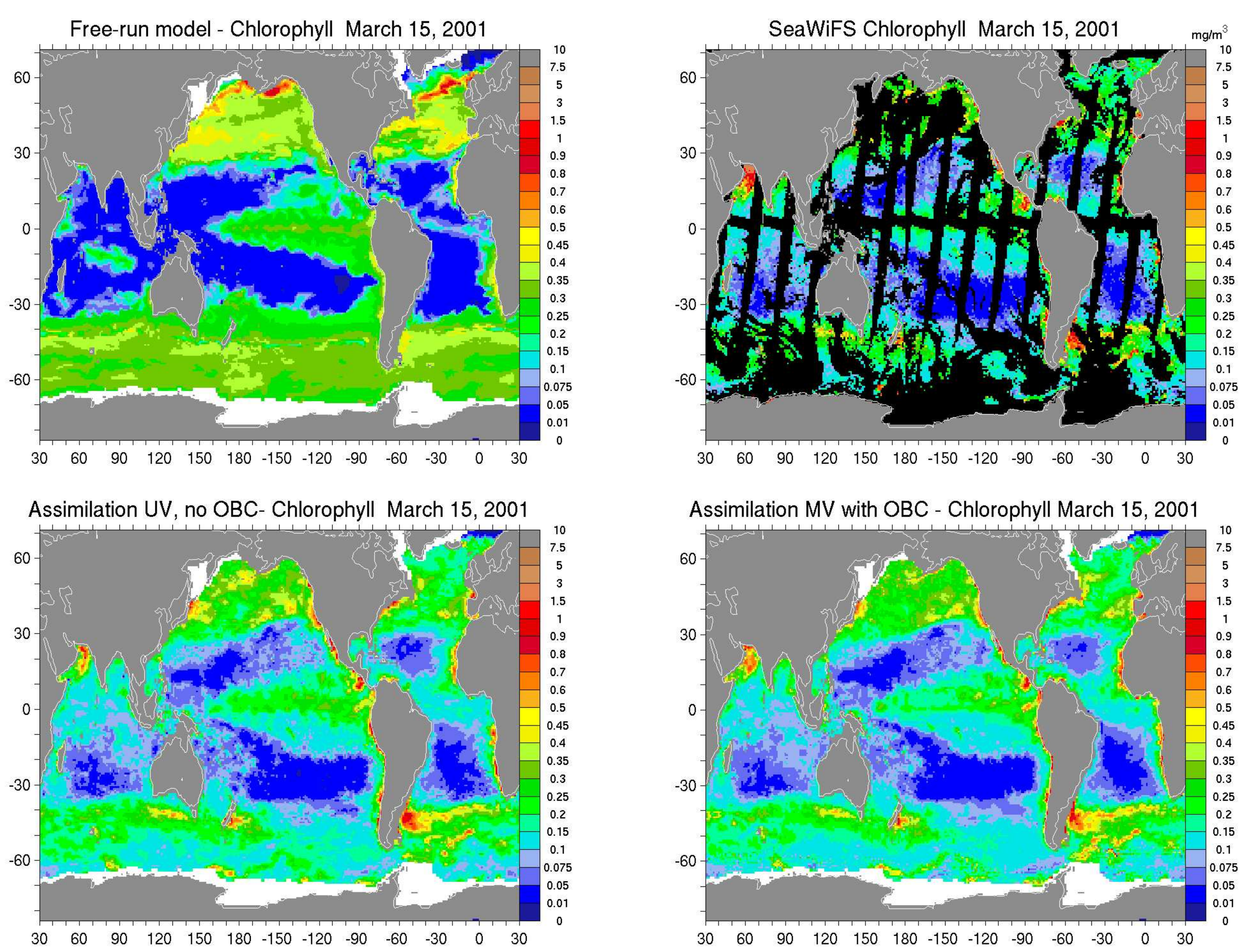


The general structure of the NOBM [2], as well as the details of the biogeochemical processes model components are shown above. The NOBM is integrated using transient monthly forcing. It is initialized with a state estimate for January 1998 obtained from a spin-up run over 20 years with monthly climatological forcing.

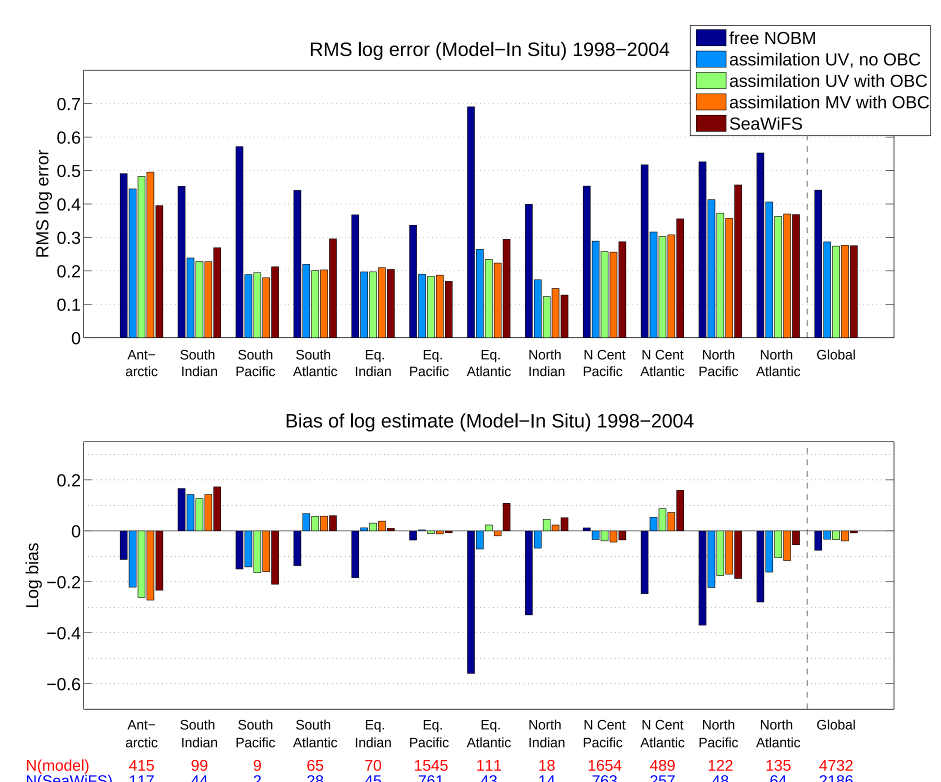
Experiments

Experiments are performed using the SEIK filter [1], a particular variant of an ensemble Kalman filter. The analysis updates are performed locally on each single grid point using observations available within some influence radius. Observations are weighted, in addition to their variance, according to their distance from a grid point which is updated. The covariance matrix is kept constant. The assimilation is performed daily to alleviate sampling problems caused by data gaps. It is known that the distribution of chlorophyll concentration is log-normal. Other variables are likely log-normally distributed, too. Accordingly, the filter acts on logarithms of all variables. The filter is applied either univariately (UV) to update only surface chlorophyll, or multivariately (MV) updating also nitrate, ammonium, and N/C detritus. In addition, an online bias correction (OBC) algorithm is applied, which uses the same ensemble as the filter with a globally constant weight fraction of 30%.

Total Chlorophyll



The assimilation improves the total surface chlorophyll in both the univariate (UV) and multivariate (MV) cases.

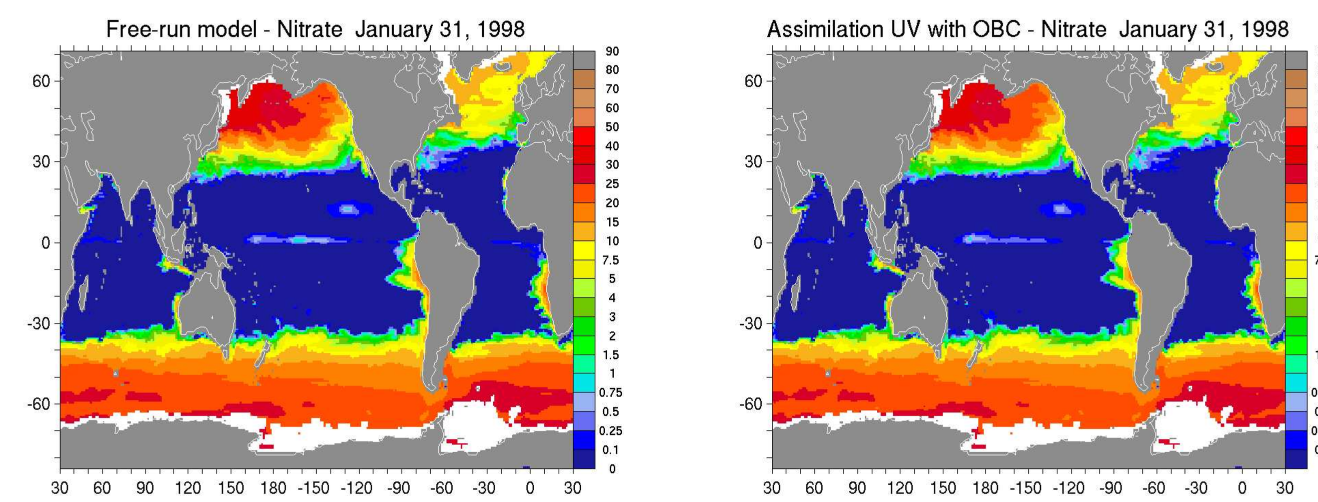


Comparison of the model and SeaWiFS data with in situ data. The assimilation reduces the error in the model state regionally below that of the SeaWiFS data.

Conclusions

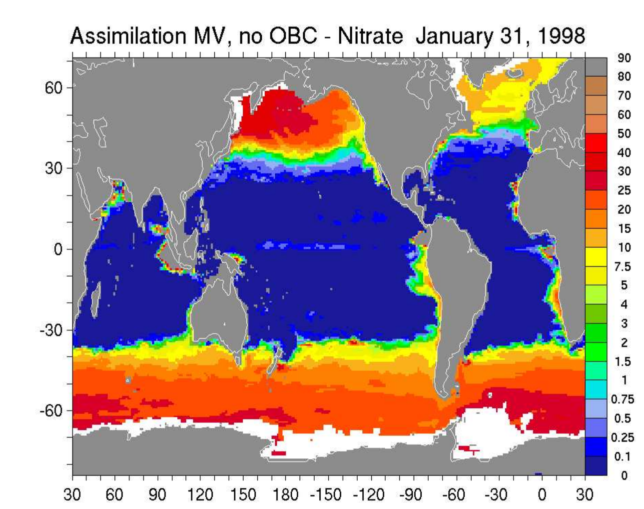
- Complete total surface chlorophyll fields can be estimated by combining the daily SeaWiFS data with the model. The global accuracy of the estimate is comparable to that of SeaWiFS. In wide regions the assimilation estimate is more accurate.
- Online bias estimation is effective in reducing bias in the state estimate. Better tuning of the bias estimation, e.g. by regional weights, is still required.
- Multivariate assimilation has only a small influence on the estimate of total chlorophyll. Regionally the results can be improved or deteriorated.
- The multivariate assimilation is unstable without bias correction, as the estimated nitrate concentrations can become extremely high. Bias correction can improve the stability, but results in smaller improvements of non-observed fields. Overall, the stability of the multivariate assimilation is still an issue which needs more attention.

Nitrate

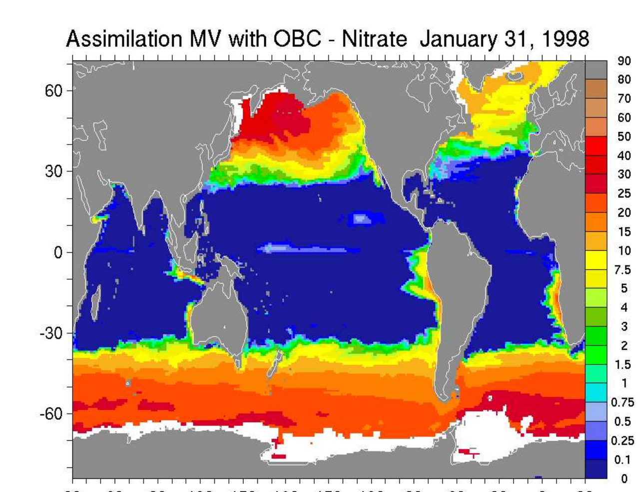


Univariate assimilation with bias correction has only a very small effect on nitrate.

Multivariate assimilation without bias correction improves nitrate in the North Pacifi c and North Atlantic, but shows regional problems, e.g. near the equator, which cause the assimilation program to crash in February 1998.



With bias correction, the multivariate assimilation is stabilized, but the improvements are weakened. At some locations the updates deteriorate the nitrate fi eld. For smaller weights of the bias, the improvements are larger, but the stability is reduced.



References

[1] Nerger, L., W. Hiller, and J. Schröter. 2005. A comparison of error subspace Kalman fi lters. *Tellus*, 57A:715–735

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