ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Data Assimilation

Data assimilation combines observational information with numerical models to improve the model state and its prediction. The most common application of data assimilation is weather forecasting. However, also the state and prediction of ocean models can be improved by data assimilation, for example by utilizing satellite observations of sea surface temperature or sea surface height. Similarly, ocean-biogeochemical models can profit from the incorporation of satellite ocean chlorophyll data by correcting the values of biogeochmical fields or by estimating the parameters that control the processes in the model.

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Sequential Data Assimilation

The research work in the Scientific Computing group at AWI focuses on sequential data assimilation methods. Parallel ensemble-based Kalman filter algorithms are well suited for parallel high-performance computers as they are highly scalable. Recent research includes:

- Application of the LSEIK filter for state estimation in ocean models and coupled ocean-biogeochemical models. (Nerger et al. 2007; Nerger and Gregg 2007, 2008 ›)
- Studying the relation of common localization methods (the so-called "*covariance localization*" and the "*observation localization*"). This research led to the developent of a new localization method, the "*regulated localization*". (Janjic et al. 2011; Nerger et al. 2012a ›)
- Studying the relation of the SEIK with to the ETKF (Ensemble Transform Kalman Filter). This research motivated the development of a new filter formulation, the "*Error-subspace Transform Kalman Filter*" (ESTKF). (Nerger et al. 2012b ›)
- Studying the effect of nonlinearity on the performance of ensemble-based smoother algorithms. This research showed how the nonlinearity of a numerical model reduced the usable lag of a smoother as well as how the localization influences the lag. (Nerger et al. 2014 ›)
- Studying the rules that define define an optimal localization radius for ensemble Kalman filters (Kirchgessner et al. 2014 ›)
- Examing the interaction of serial observation processing and localization that leads to a de-stabilization of the filter analysis step in filters with serial observation processing like EAKF and EnSRF (Nerger 2015 ›)
- Data assimilation for forecast-improvements in the North Sea and Baltic Sea (Losa et al., 2012, 2014, Nerger et al., 2016 ›)
- Contributing to sea-ice data assimilation in cooperation with the National Marine Environmental Forecasting Center in Beijing, China (Yang et al., 2014, 2015, 2016 ›)
- Assessment of nonlinear filters or high-dimensional data assimilation into ocean models (Tödter et al 2016, Kirchgessner et al, 2017 ›)

Parallel Data Assimilation Framework - PDAF

Related to the research projects in which we studied and developed filter algorithms, the data assimilation framework PDAF › (Parallel Data Assimilation Framework) was developed. Initially, the framework allowed to easily compare different filter algorithms under identical conditions. Today, its main task is to simplify the implementation of parallelized data assimilation systems based on existing numerical models. PDAF provides complete implementations of sequential data assimilation algorithms, which are optimized for application on parallel computers (see Nerger and Hiller, 2013 ›).

More information on PDAF can be found on the AWI web page on PDAF › and on the project web pages of PDAF ↗ where also the source code package can be downloaded.

Projects

We participate in different research projects:

ESM

The project ESM (Advanced Earth System Modeling Capacity) is a cooperation project of 8 research centers f the Helmholtz Association. In the project we develop data assimilation capability for coupled Earth system models. Further we perform research in the optimal application of data assimilation for coupled model e.g. accounting for the different temporal and spatial scales of model compartments. For the data assimilation component, we utilize the software framework PDAF › . For the assessment of the influence of data assimilation we apply the data assimilation to the coupled atmosphere-ocean model AWI-CM.

More information can be found on the web site of the ESM project ↗ .

IPSO

In the project IPSO (Improving the prediction of photophysiology in the Southern Ocean by accounting for iron limitation, optical properties and

spectral satellite data information) the data assimilation group cooperates with the groups Marine Biogeosciences and Phytooptics . The project aims at improving the simulation of plankton dynamics and carbon fluxes in the Southern Ocean by enhancing the ecosystem model REcoM. This will be achieved by applying data assimilation with PDAF for improve the parameters and parameterizations of REcoM and by extending the model to account for light availability in several spectral bands as well photoprotection and photophysiological effects of iron limitation.

Completed Projects

MeRamo (2016-2018)

In the project MeRamo (Supporting the authorities that implement the EU Marine Strategy Framework Directive using an assimilative ecosystem model) we developed a data assimilation components for the coupled ocean-biogeochemical forecast model of the German Maritime and Hydrographic Agency (BSH) in the North and Baltic Seas. The data assimilation system uses PDAF and the operational model HBM coupled to the ecosystem model ERGOM. The project was funded by the German Ministry for Transport and Digital Infrastructure.

DeMarine (2012-2015)

In the project DeMarine-2 we continued to develop a data assimilation data system for the North and Baltic Seas for the German Maritime and Hydrographic Agency (BSH). The data assimilation system uses PDAF and the operational model HBM of the BSH. Initial work has been done in the previous project DeMarine Environment (Losa et al. 2012, Losa et al. 2013).

More information on DeMarine is available on the web pages of DeMarine .

Sangoma (EU FP7, years 2011-2015)

We participated in the EU-funded project SANGOMA (Stochastic Assimilation for the Next Generation Ocean Model Applications). In project unified tools for data assimilation, new assimilation algorithms and data assimilation benchmark applications were developed to support future operational systems with state-of-the-art data assimilation and related analysis tools.

More information is available on the web site of Sangoma .