Scalable Coupled Ensemble Data Assimilation with AWI-CM and PDAF

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Overview

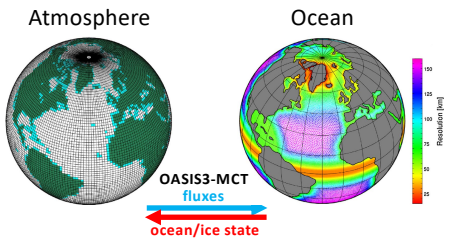
We show how to modify a coupled model so that we can use it for efficient ensemble data assimilation. The method uses a direct connection between the coupled model and the ensemble data assimilation framework PDAF [1, http://pdaf.awi.de]. Augmenting the model allows us to set up a data assimilation program with high flexibility and parallel scalability with only small changes to the model.

The direct connection is obtained by

1. adapting the source codes of the coupled model so that it is able to run an ensemble of model states
2. adding a filtering step to the source codes.

We discuss this connection for the coupled atmosphere-ocean model AWI-CM. For this coupled model, we have to augment the codes of both the ocean and atmosphere, adapt the parallelization, and add routines for the handling of observations and model fields specific for each model compartment.

Coupled Model: AWI-CM



AWI-CM [2] consists of two separate programs: FESOM for the the ocean and ECHAM6 with JSBACH for the atmosphere and land surface. They are coupled with OASIS3-MCT. Fluxes between the models are computed and exchanged each 6 hours by OASIS3-MCT.

Coupled Data Assimilation

Weakly Coupled Assimilation

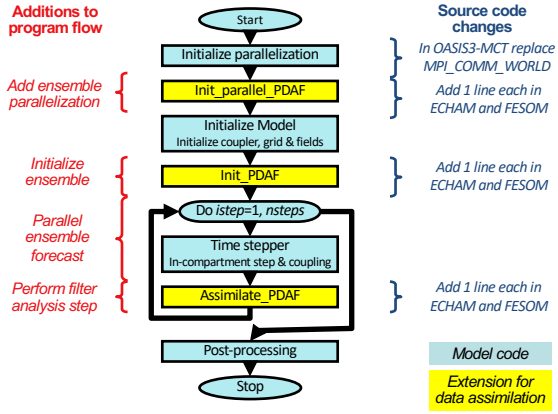
- Separate assimilation updates in atmosphere and ocean
- Separate state vectors for atmosphere and ocean
- No cross-covariances between compartments
- Other compartment only influenced dynamically in next forecast phase

Strongly Coupled Assimilation

- Joint assimilation update in atmosphere and ocean
- Joint state vector for atmosphere and ocean (distributed by parallelization)
- Utilize cross-covariances between compartments
- Assimilation influences all compartments directly

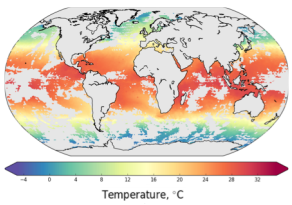
Data Assimilation with PDAF

PDAF provides parallelization support and fully-implemented and parallelized filters & smoothers. We add a few subroutine calls to model codes to enable ensemble assimilation without model restarts. PDAF is free open-source: Code, documentation and tutorials available at http://pdaf.awi.de.

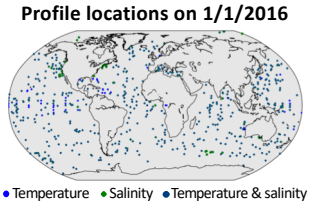


Observations

SST on 1/1/2016



Profile locations on 1/1/2016



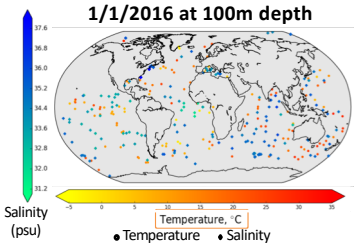
Satellite SST

- EU Copernicus Marine Service
- Global daily data
- Data gaps due to clouds

Temperature & salinity profiles

- EN4 data from UK MetOffice
- Global daily data
- Subsurface down to 5000m
- ~1000 profiles per day

Temperature & salinity 1/1/2016 at 100m depth

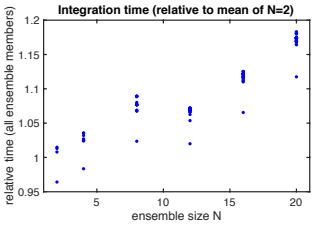


Assimilation Experiments

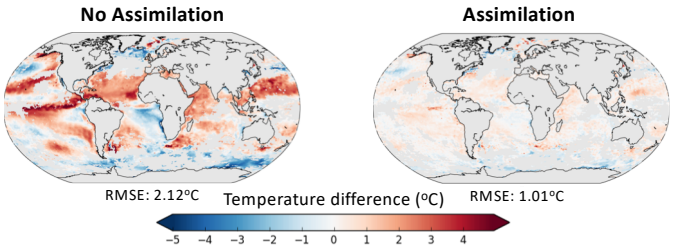
- Weakly coupled assimilation into the ocean
- State vector: ocean surface height, temperature, salinity, velocities
- Ensemble size: up to 46
- Assimilation method: Local Error-Subspace Transform Kalman Filter (LESTKF)
- Simulation period: year 2016, daily assimilation update

Compute Performance

- Run time for N=46: 12 hours (fully parallelized on 12,144 processors)
- Scaling test: increase ensemble size and number of processors
  - Slightly different forecast duration for each ensemble member
  - Run time only increases by 17% for 10-fold ensemble size

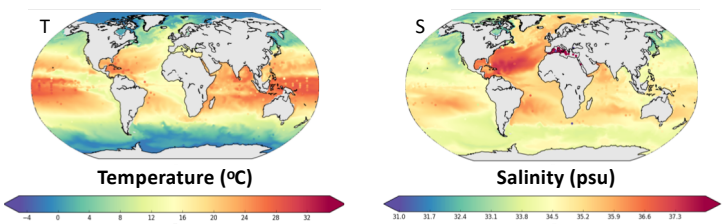


Results: Assimilation of SST



Temperature difference between model simulations and observations after 10 days. Initially there are very large temperature deviations as the coupled model does not know the reality. The assimilation significantly reduces the deviations from the observations globally.

Results: Assimilation of T & S Profiles



Model simulated and observed temperature and salinity at 100m depth after 4 assimilation days (observations shown as dots). There are still significant deviations, e.g. for the temperature in the equatorial region.

References:

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

[2] Sidorenko, D. et al. Towards multi-resolution global climate modeling with ECHAM6–FESOM. Part I: model formulation and mean climate, Clim. Dyn. (2015) 44: 757–780