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Weakly and strongly coupled data assimilation with the coupled ocean-atmosphere model AWI-CM

Qi Tang, Longjiang Mu, Dmitry Sidorenko, Lars Nerger

Alfred Wegener institute

Helmholtz centre for polar and marine research

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ESM Advanced Earth System Modelling Capacity

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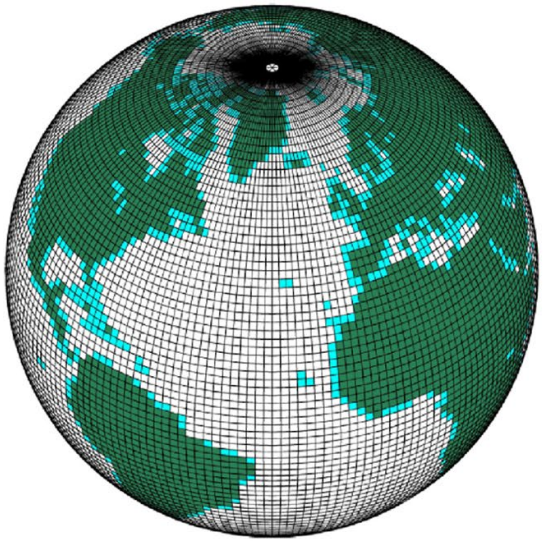
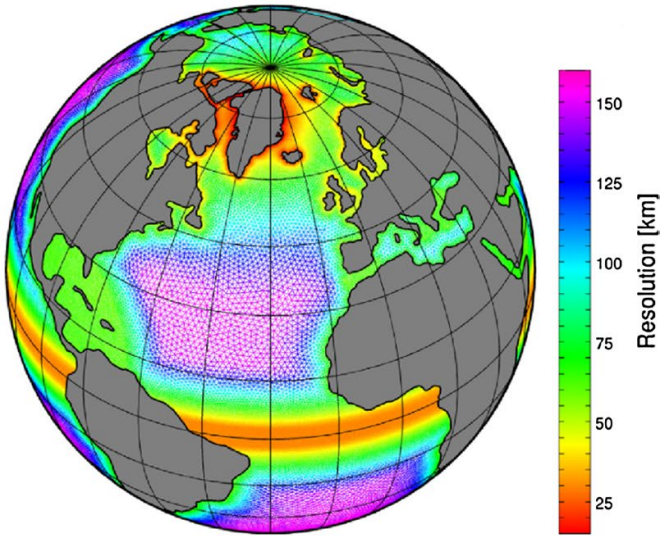
Data assimilation experiment



OASIS3-MCT

fluxes

ocean/ice state



- Assimilate Sea sruface temperature (SST)
- Comparison between WCDA and SCDA: state vector
  - WCDA: only the ocean variables
  - SCDA: both the ocean and the atmosphere variables
- DA method: Ensemble Kalman Filter (LESTKF)
- Ensemble size: 46

ESM

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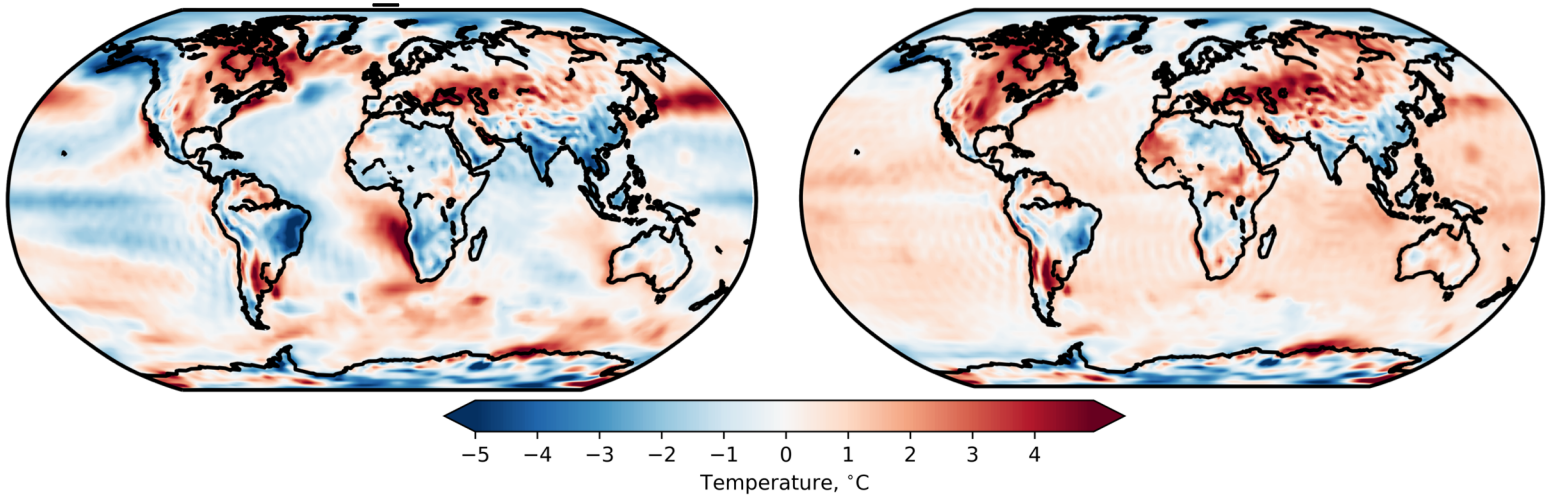
DA impact on the atmosphere

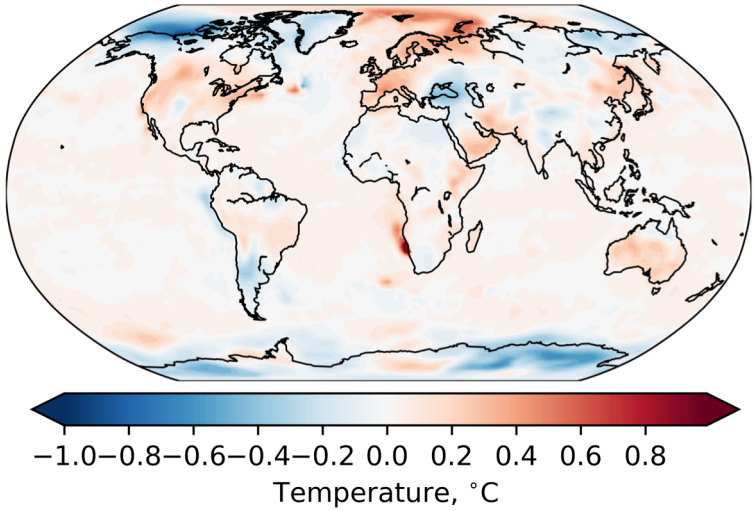
2m temperature deviations between model simulation and ECMWF reanalysis

Free_run

WCDA



Difference between SCDA and WCDA



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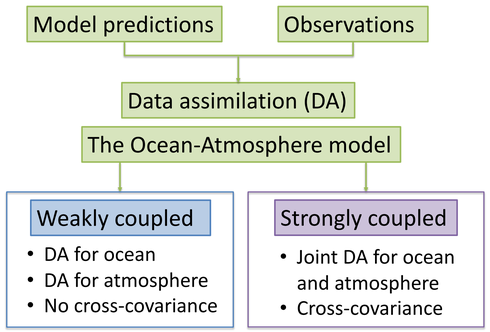
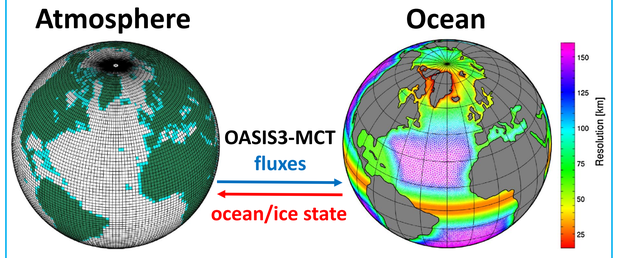
Overview



Coupled model: AWI-CM 1.4

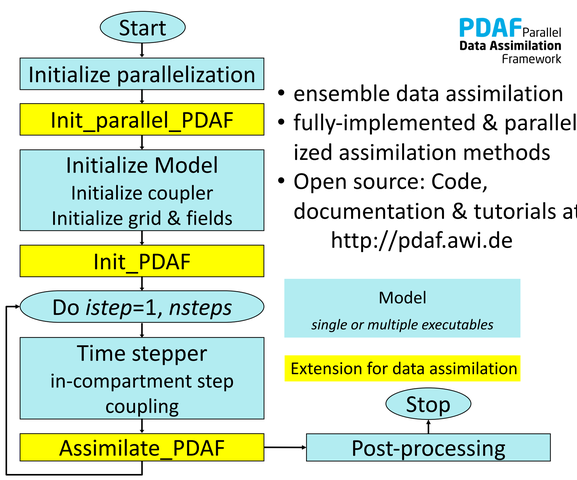


- ECHAM6
- JSBACH land surface
- FESOM1.4
- includes sea ice

Coupler library: OASIS3-MCT
Two separate executables for atmosphere and ocean

D. Sidorenko et al., Clim. Dyn. 44 (2015) 757

Data assimilation with PDAF



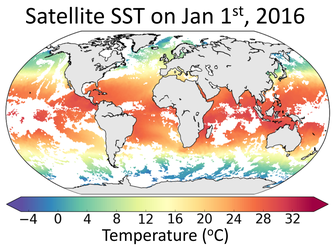
PDAF Parallel Data Assimilation Framework

- ensemble data assimilation
- fully-implemented & parallelized assimilation methods
- Open source: Code, documentation & tutorials at http://pdaf.awi.de

Observations

Sea surface temperature

- Satellite SST from EU Copernicus, level 3
- Daily data with data gaps due to clouds
- Original 0.1° X 0.1°, interpolated to unstructured ocean model grid



Numerical experiments

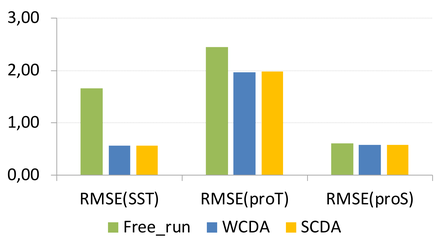
AWI-CM Model Setup

- Model resolution: 20-160 km for FESOM and T63L47 for ECHAM6
- Time step: 900s for FESOM, 400s for ECHAM6, coupling interval 1 hour

Data assimilation experiments

- Initial state and exchange fluxes: from long-term historical run
- Observation error: 0.8 °C for temperature and 0.5 psu for salinity
- Localization radius: 300km in horizontal direction, no vertical localization
- Simulation period: full year 2016, daily assimilation update
- DA Method: Ensemble Kalman Filter (LESTKF), ensemble size = 46
- Run time: 5.5 hours, using 12,000 processor cores on HLRN and JUWELS
- Updated:
  - Weakly-coupled DA: ocean state including SSH, temperature, salinity and velocity
  - Strongly-coupled DA: ocean states + atmosphere temperature

Results: Impact on the ocean



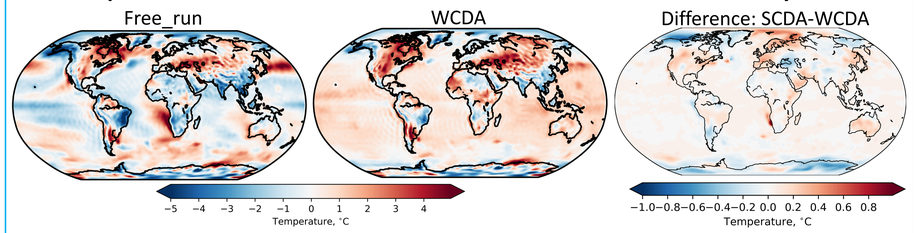
RMSE of SST, subsurface temperature (proT) and salinity (proS) for weakly coupled DA (WCDA) and strongly coupled DA (SCDA) for the whole one-year simulation period. The free run is also shown for comparison.

Acknowledgement

This work has received funding from the Initiative and Networking Fund of the Helmholtz Association through the project "Advanced Earth System Modelling Capacity (ESM)". The authors acknowledge the North-German Supercomputing Alliance (HLRN) for providing HPC resources that have contributed to the research results reported in this paper. The authors gratefully acknowledge the Jülich Supercomputing Centre (JSC) for providing computing time on the ESM partition of the supercomputer JUWELS.

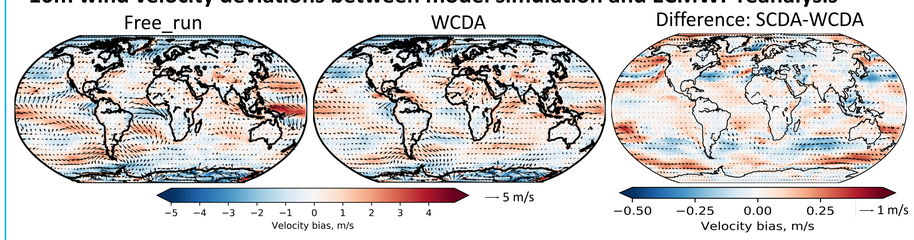
Results: Impact on the atmosphere

2m temperature deviations between model simulation and ECMWF reanalysis



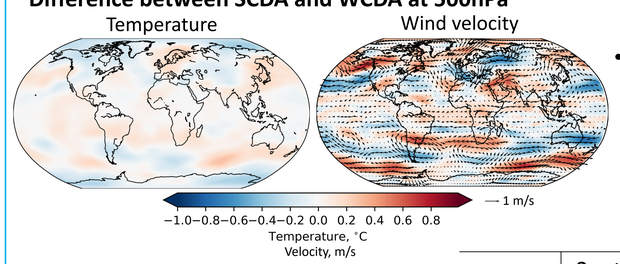
- DA globally reduces the bias over the ocean. SCDA performs better in the Arctic region.

10m wind velocity deviations between model simulation and ECMWF reanalysis



- DA reduces the bias mainly in the equatorial region.

Difference between SCDA and WCDA at 500hPa



- Difference for the temperature at 500hPa is small, but higher for the wind velocity in the middle and high latitudes.

- RMSE of 2m temperature and 10m wind velocity for WCDA and SCDA for the whole one-year simulation period.

	2m temperature	10m wind
Free_run	2.206	1.630
WCDA	1.974	1.499
SCDA	1.970	1.487

Conclusion

- Assimilation of SST improved the prediction of both SST and the subsurface T, for both the WCDA and SCDA.
- Assimilation of ocean observations into the ocean compartment in a coupled model improve the atmospheric prediction, e.g. the temperature and wind velocity, for both the WCDA and SCDA.
- Difference between WCDA and SCDA:
  - For the ocean: no difference
  - For the atmosphere: SCDA shows lightly better results than the WCDA.