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

Strongly coupled data assimilation with the coupled ocean-atmosphere model AWI-CM: comparison with the weakly coupled data assimilation

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Multi-annual to Decadal Climate Predictability in the North Atlantic-Arctic Sector
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ESM Advanced Earth System Modelling Capacity

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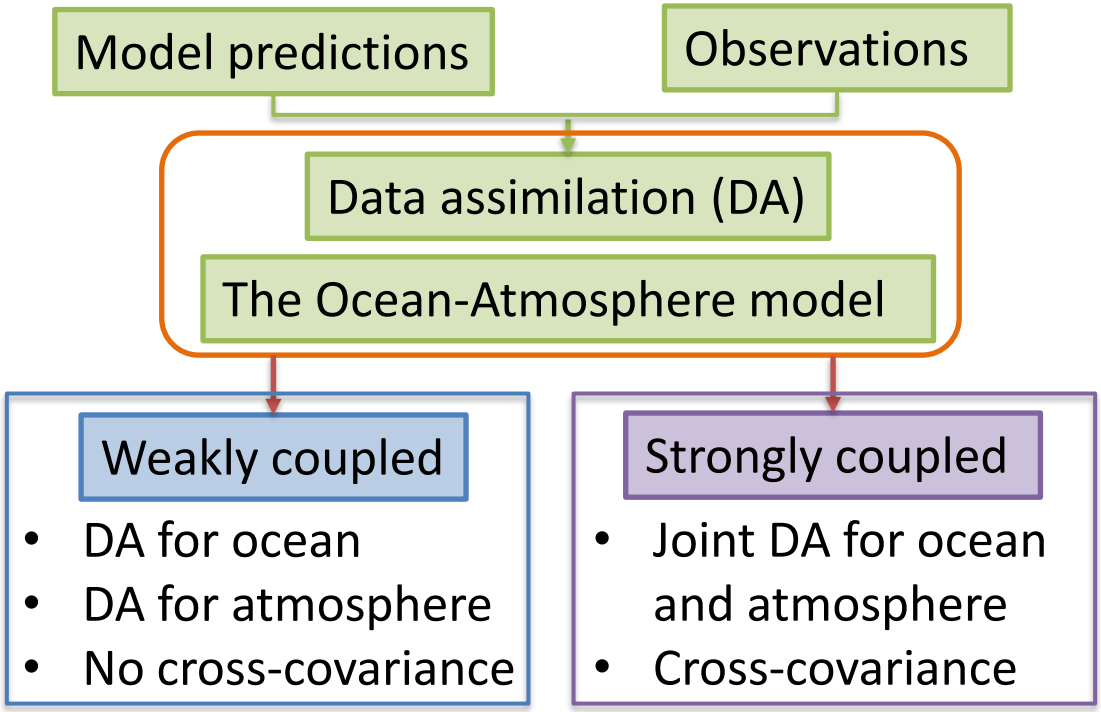
Coupled Data assimilation

Overview



Objective

- Investigate the impact of assimilating ocean observations into the ocean & atmosphere compartments in a coupled ocean-atmosphere model

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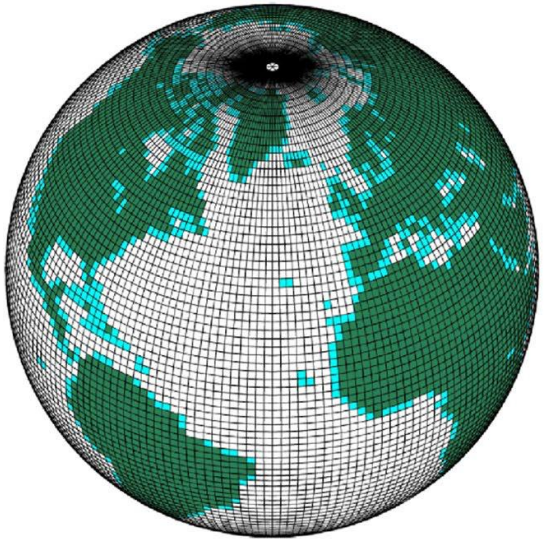
Coupled Model: AWI-CM-1.1

Atmosphere



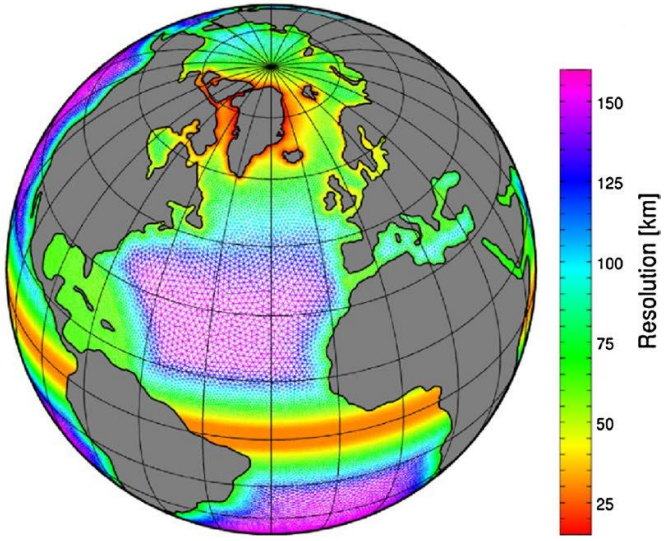
- ECHAM6
- JSBACH land surface

OASIS3-MCT

fluxes →

← **ocean/ice state**

Ocean



- FESOM1.4
- includes sea ice

Two separate executables for atmosphere and ocean run and parallel coupled through parallel communication

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

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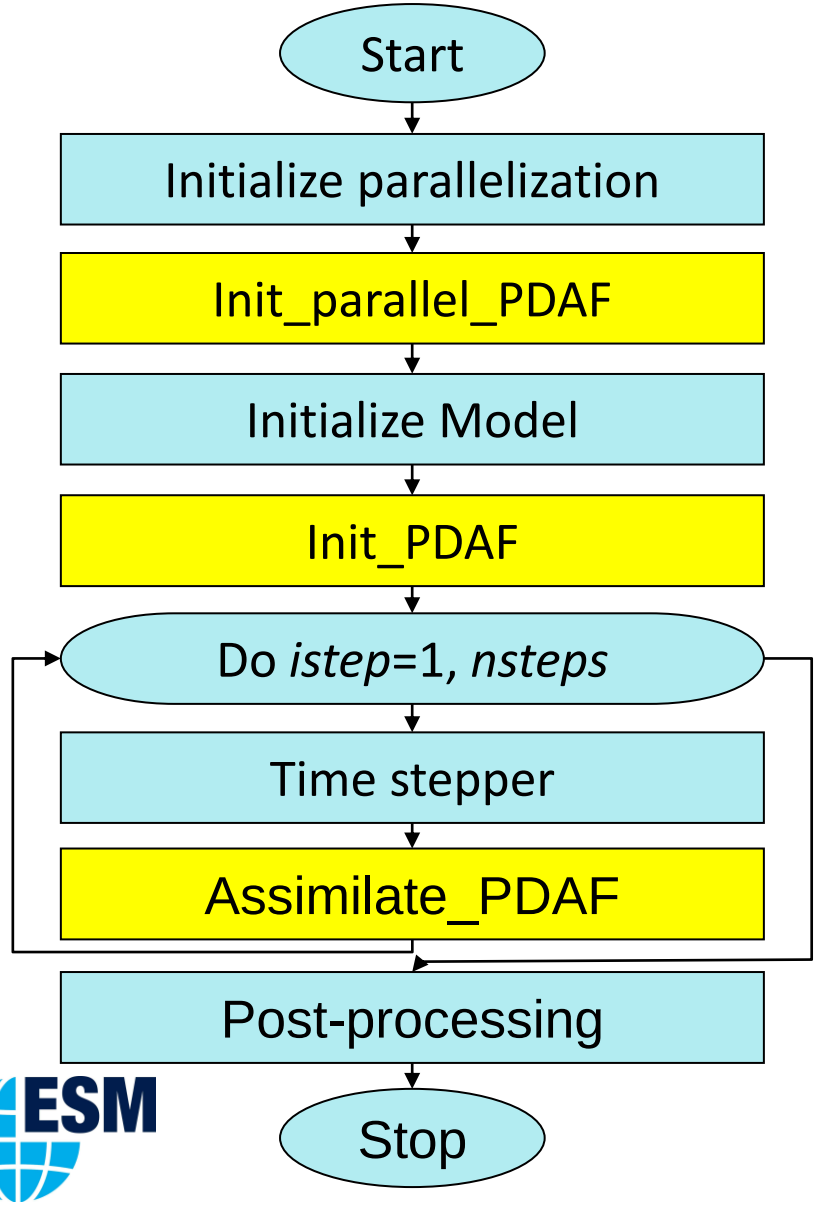
Data assimilation with PDAF



PDAF Parallel Data Assimilation Framework

- For ensemble data assimilation
- Provide fully-implemented & parallelized assimilation methods
- Easily useable with (probably) any numerical model

Open source:
Code, documentation & tutorials at

http://pdaf.awi.de

Model

Extension for data assimilation

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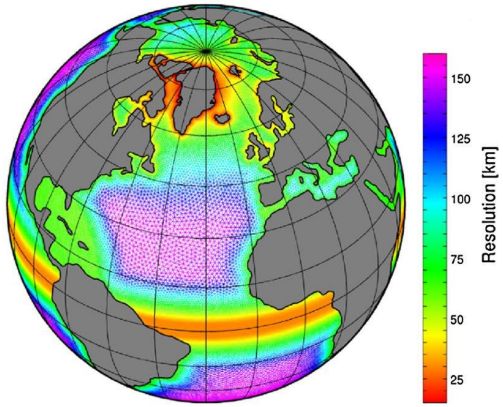
Numerical experiments

Model setup

- Global model
- ECHAM6: T63L47
- FESOM: resolution 30-160km

FESOM mesh resolution

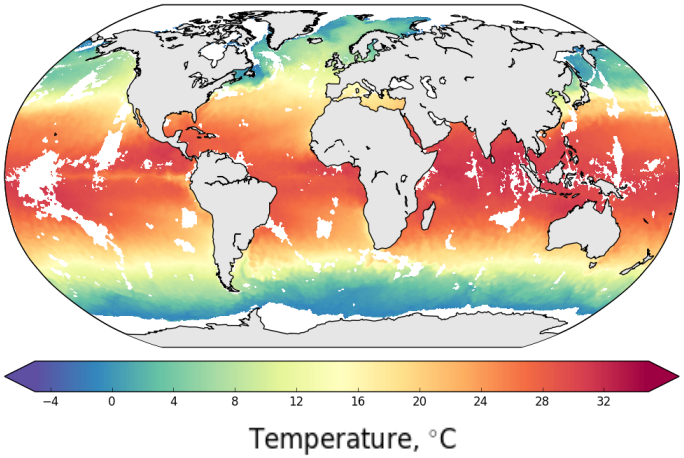


Data assimilation experiments

- Observations: Satellite SST
- Assimilation method: Ensemble Kalman Filter (LESTKF), ensemble size = 46
- Updated:
  - Weakly-coupled DA: ocean state (SSH, temperature, salinity and velocity)
  - Strongly-coupled DA: atmosphere state (temperature, surface pressure, vorticity, divergence, humidity and horizontal wind velocity) + ocean state
- Localization radius: 300km in horizontal direction, up to 600hPa in vertical direction
- Simulation period: year 2016, daily assimilation update
- Run time: 3.5h, fully parallelized using 12,000 processor cores

Data assimilation experiments

SST on Jan 1st, 2016



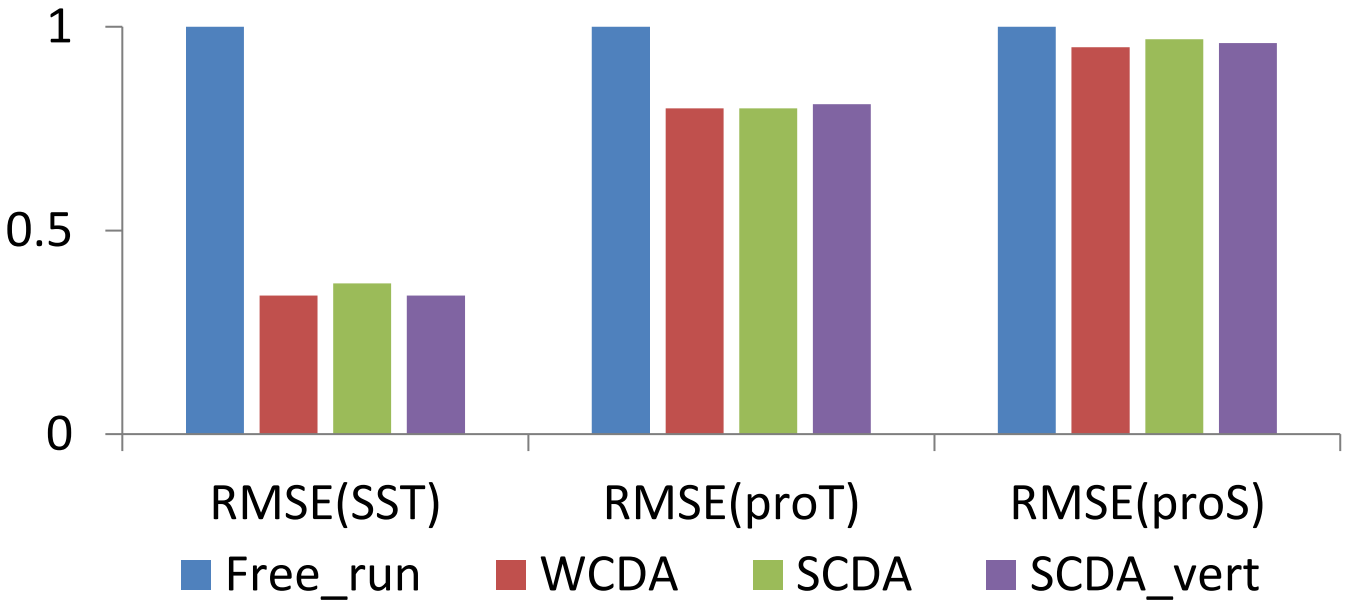
- Satellite sea surface temperature (level 3, EU Copernicus)
- Daily data
- Data gaps due to clouds
- interpolated to model grid
- Observation error: 0.8 °C

Data assimilation scenarios

Simulation scenario	Update ocean	Update atmosphere	Vertical localization for atmosphere
Free_run	N	N	N
WCDA	Y	N	N
SCDA	Y	Y	N
SCDA_vert	Y	Y	Y

Results: impact on the ocean

Relative RMSE of SST, subsurface temperature (proT) and salinity (proS)

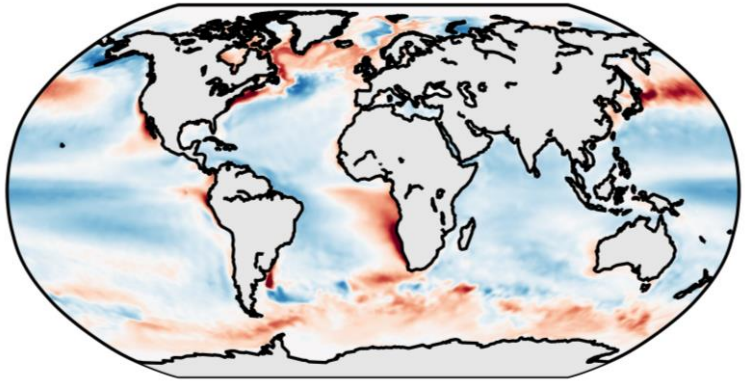


- Both WCDA and SCDA improve the prediction of the temperature.
- The SCDA run without vertical localization (SCDA) gives slightly larger (3%) RMSE(SST).
- The vertical localized SCDA run (SCDA_vert) gives the same RMSE(SST) as the WCDA.

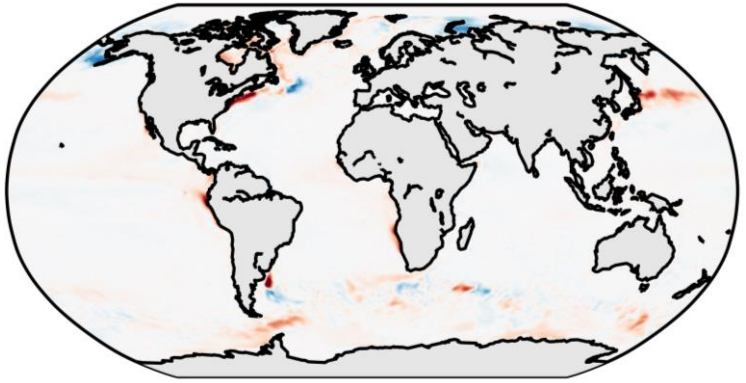
Results: impact on the ocean

SST difference between model simulations and observations

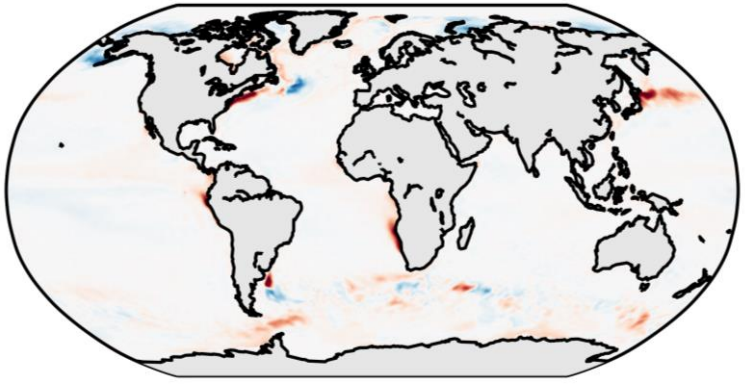
Free run-obs



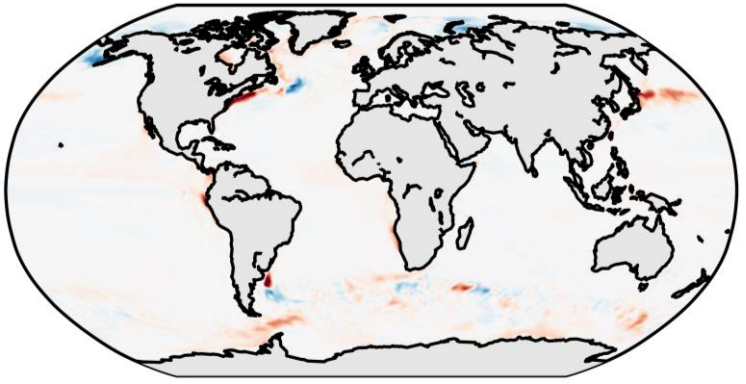
WCDA-obs

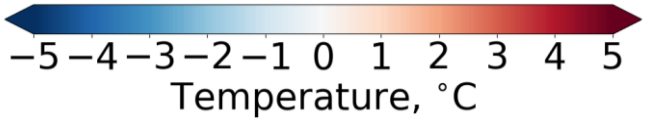


SCDA-obs



SCDA_vert-obs

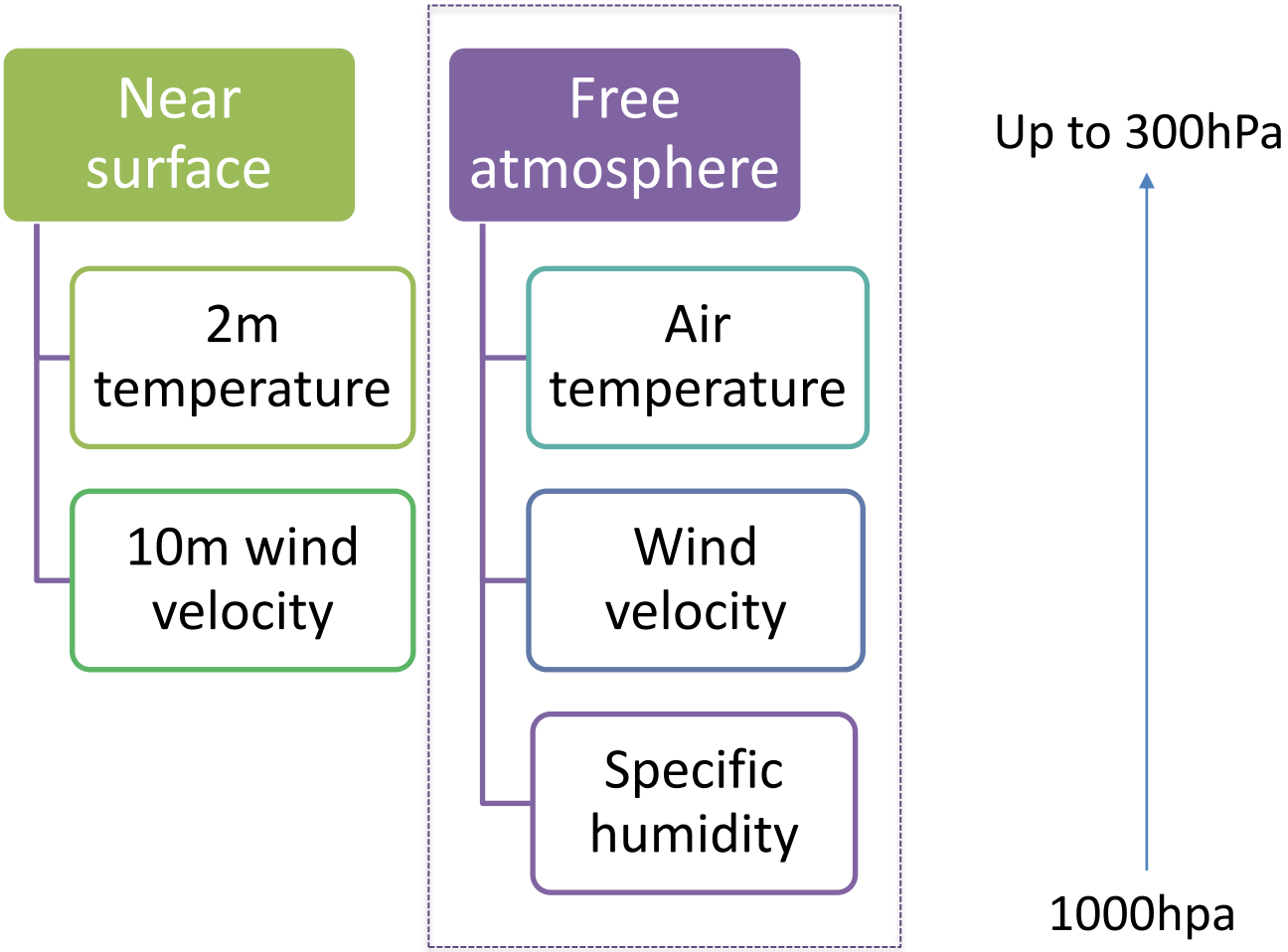




The bias patterns for the SCDA and WCDA are similar.

Results: impact on the atmosphere

Evaluated atmospheric variables: compared with ERA-interim data

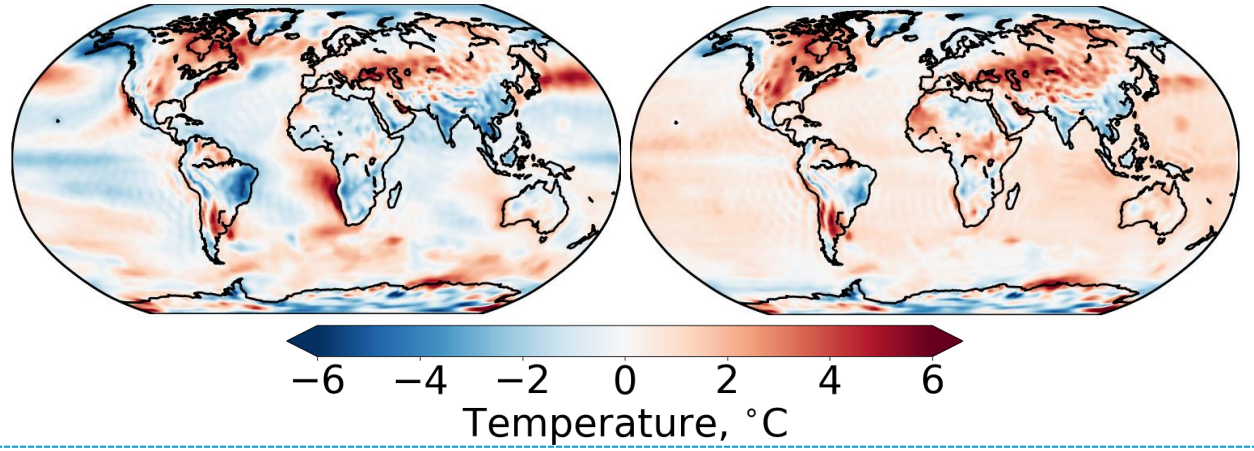


Results: impact on the atmosphere

2m temperature bias (model - ERA-interim)

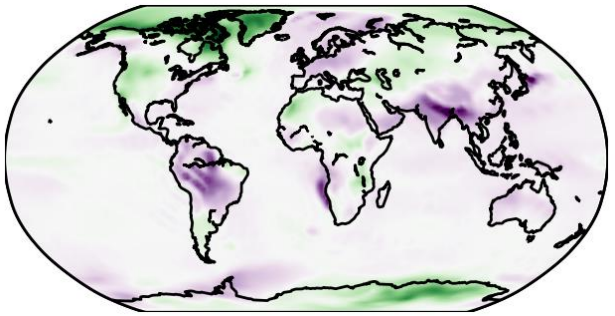
Free run

WCDA

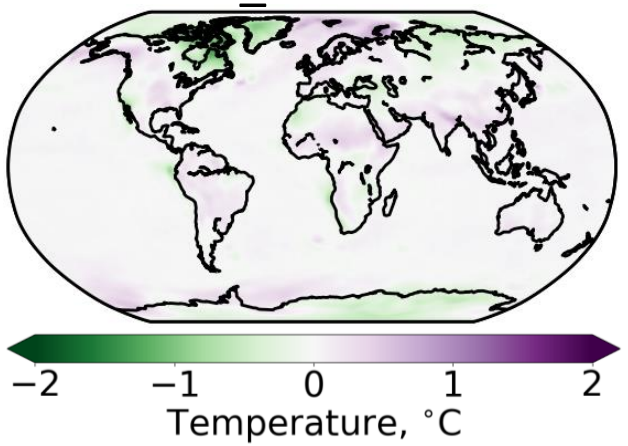


Differences

SCDA-WCDA



SCDA_vert-WCDA



- WCDA warms up the system almost everywhere
- The SCDA strengthens this:
  - less cold bias over the continent
  - the warm bias in some regions even larger
- The difference between the SCDA_vert and the WCDA is relatively small

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Results: impact on the atmosphere

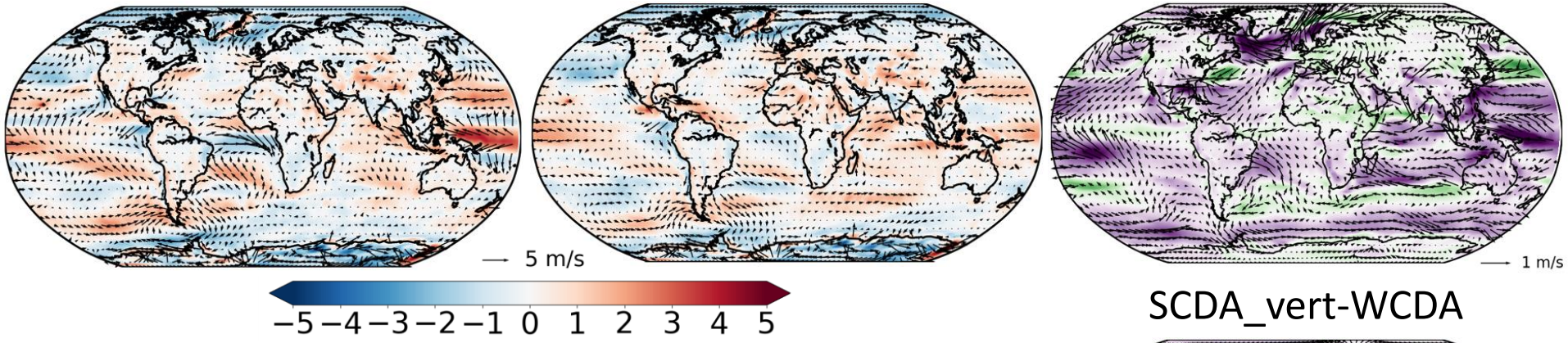
10m wind velocity bias (model - ERA-interim)

Differences

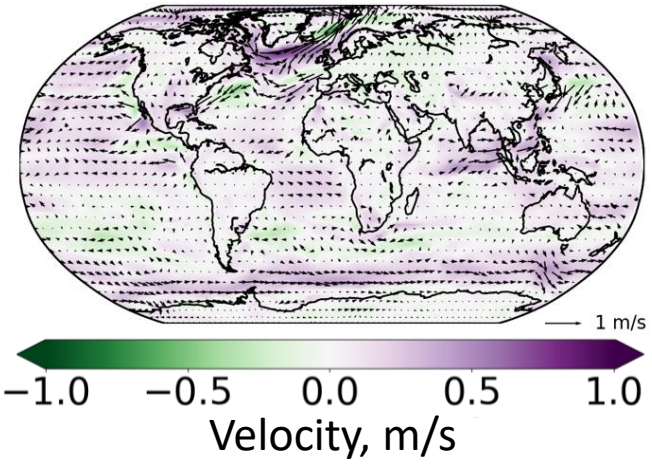
Free run

WCDA

SCDA-WCDA



SCDA_vert-WCDA



- SCDA and WCDA reduce positive and negative bias along the equator in the Pacific Ocean and the Atlantic Ocean, but the reduction by SCDA is smaller
- SCDA strengthens the positive bias in the Southern Indian Ocean
- The DA effect is similar between the SCDA_vert and the WCDA

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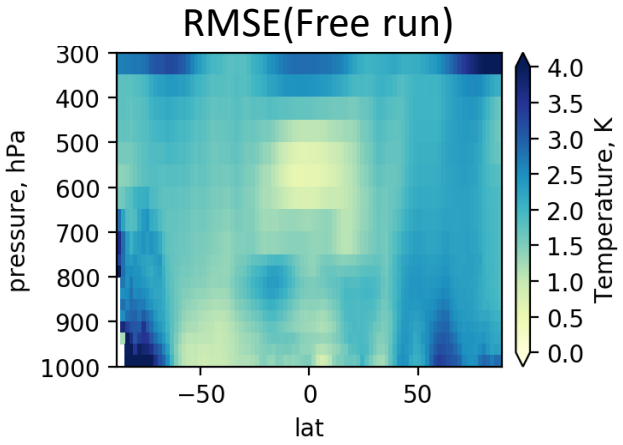
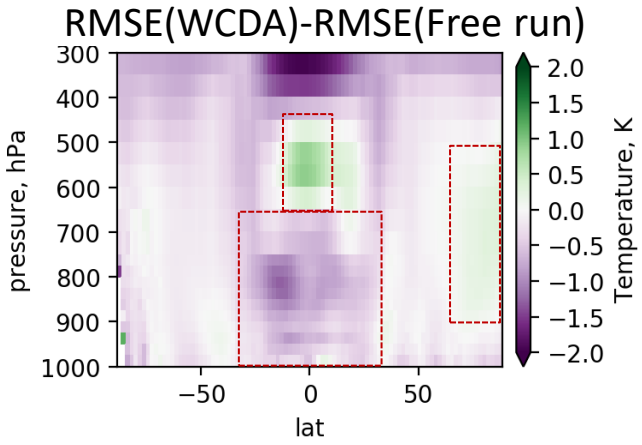
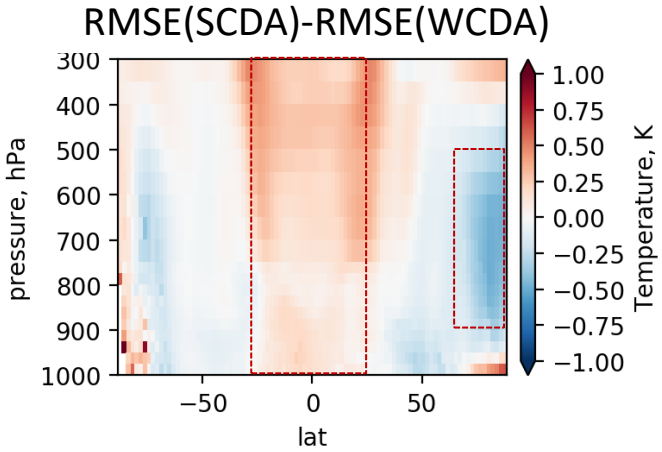
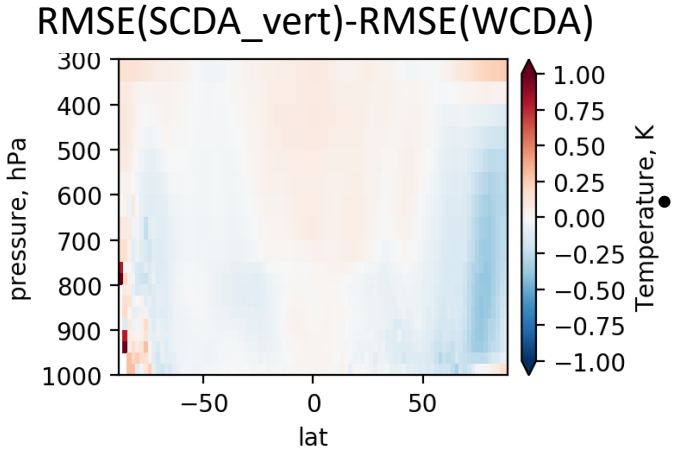
Results: impact on the atmosphere

Zonal mean RMSE of **temperature** up to 300hPa averaged over March to December









- >650hPa: RMSE largely reduced (30°N-30°S)
- 900hPa-500hPa: RMSE increased by WCDA in the Arctic but decreased by two SCDAs
- 650hPa-450hPa: DA increases the RMSE (10°N -10°S);
- SCDA gives larger (max. 0.75K) RMSE (25°N -25°S) but smaller RMSE in the high latitude regions;
- Difference between WCDA and SCDA_vert is still minor except the positive influence in the Arctic.

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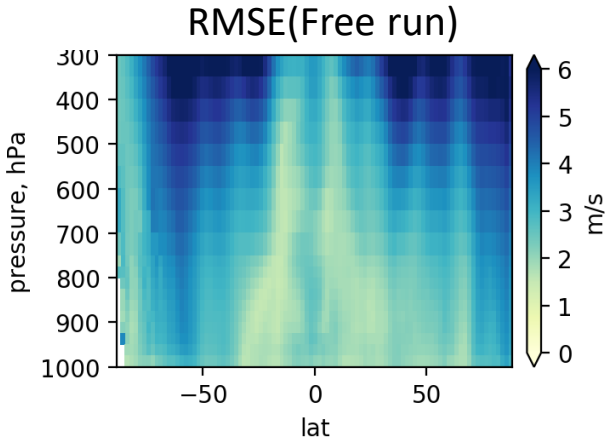
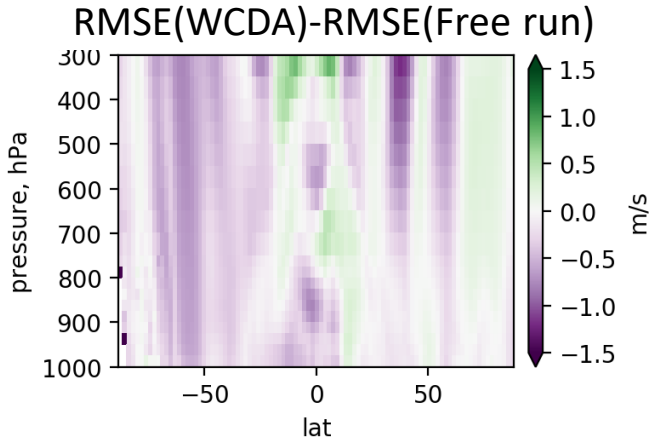
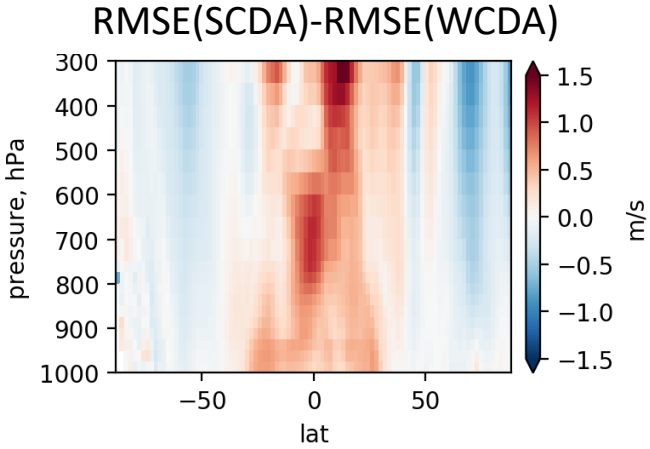
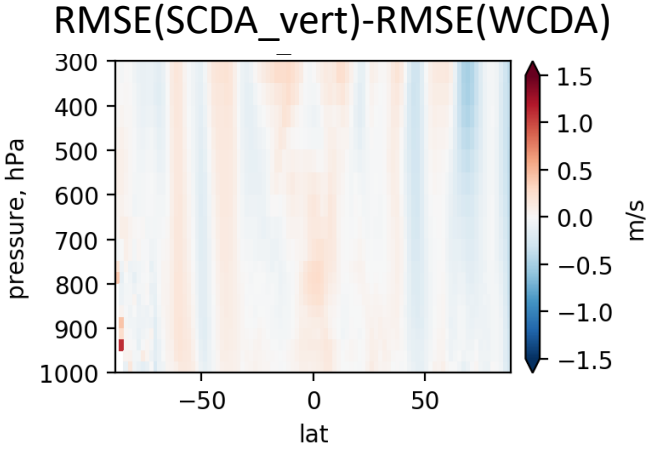
Results: impact on the atmosphere

Zonal mean RMSE of horizontal **wind velocity** up to 300hPa averaged over March to December









- >800hPa: in the equatorial region RMSE by WCDA and SCDA_vert reduced
- SCDA gives larger RMSE in 25°N-25°S than the free run and the WCDA from ground up to 300hPa, but for the rest of the regions the RMSE is reduced
- The SCDA run with vertical localization gives similar results as the WCDA run

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Summary

- The SCDA of SST observations yield a similar performance in simulating the ocean as the WCDA.
- For the atmosphere:
  - the SCDA gives overall slightly worse results than the WCDA if no vertical localization is carried out.
  - If vertical localization is implemented in the atmosphere so that DA increments are constrained to the lower troposphere, the difference between the SCDA and the WCDA is quite minor except in high latitudes.
  - An exception is the Arctic region, where the SCDA with/without vertical localization improves the atmospheric state.

Thank you!