Ocean model formulation influences climate sensitivity

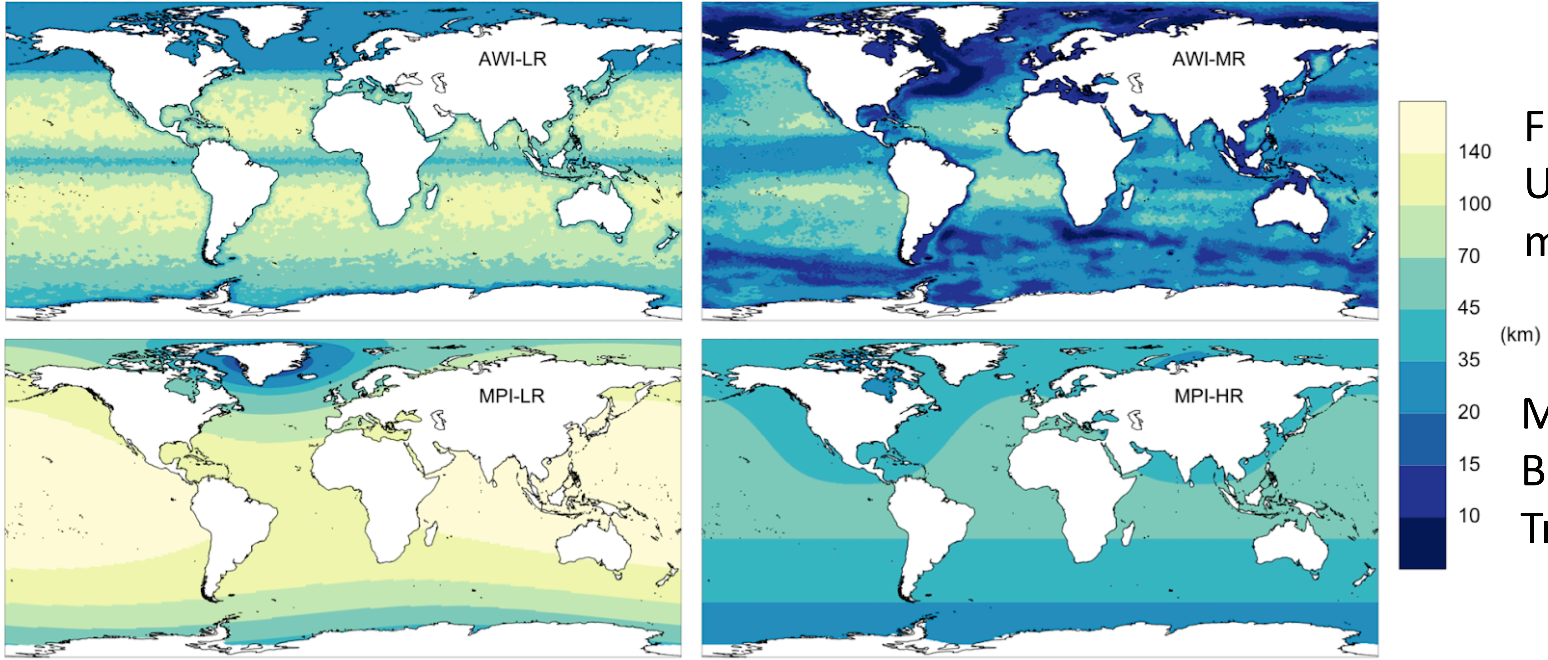
Tido Semmler[1], Johann Jungclaus[2], Christopher Danek[1], Helge F Goessling[1], Nikolay Koldunov[1], Thomas Rackow[1], and Dmitry Sidorenko[1]

[1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
[2]Max Planck Institute for Meteorology

Two CMIP6 models, two resolutions, same atmosphere / land model

- MPI-ESM and AWI-CM/ESM with ECHAM6.3 as atmosphere / land model without further tuning
- Ocean / sea ice component: MPIOM versus FESOM

Low resolution (km) | High resolution (km)



FESOM:
Unstructured mesh

MPIOM:
Bipolar mesh (LR)
Tripolar mesh (HR)

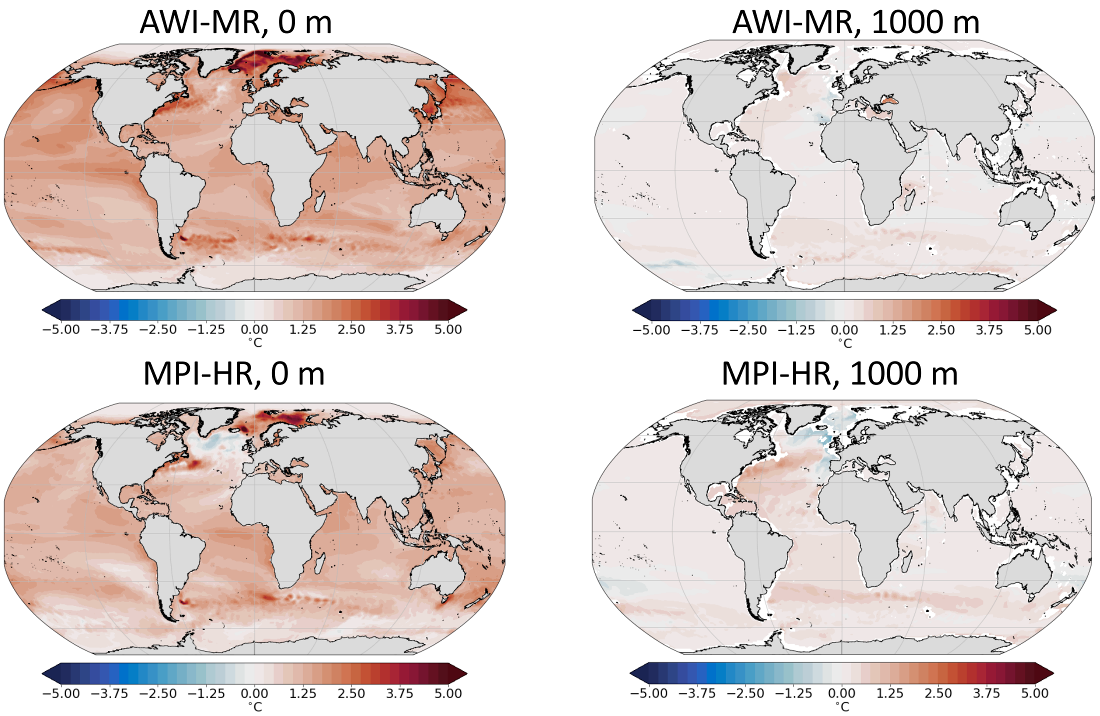
Different TCR / ECS

- Ocean model affects transient climate response (TCR) by up to 20%
- Ocean model affects equilibrium climate sensitivity (ECS) by up to 10%

	AWI-LR	MPI-LR	AWI-MR	MPI-HR
ECS (°C)	3.29±0.02	3.00*±0.02	3.16±0.03	2.98*±0.03
TCR (°C)	2.11	1.84	2.06	1.66

*by tuning (to match the observed historical development of 2 m temperature)

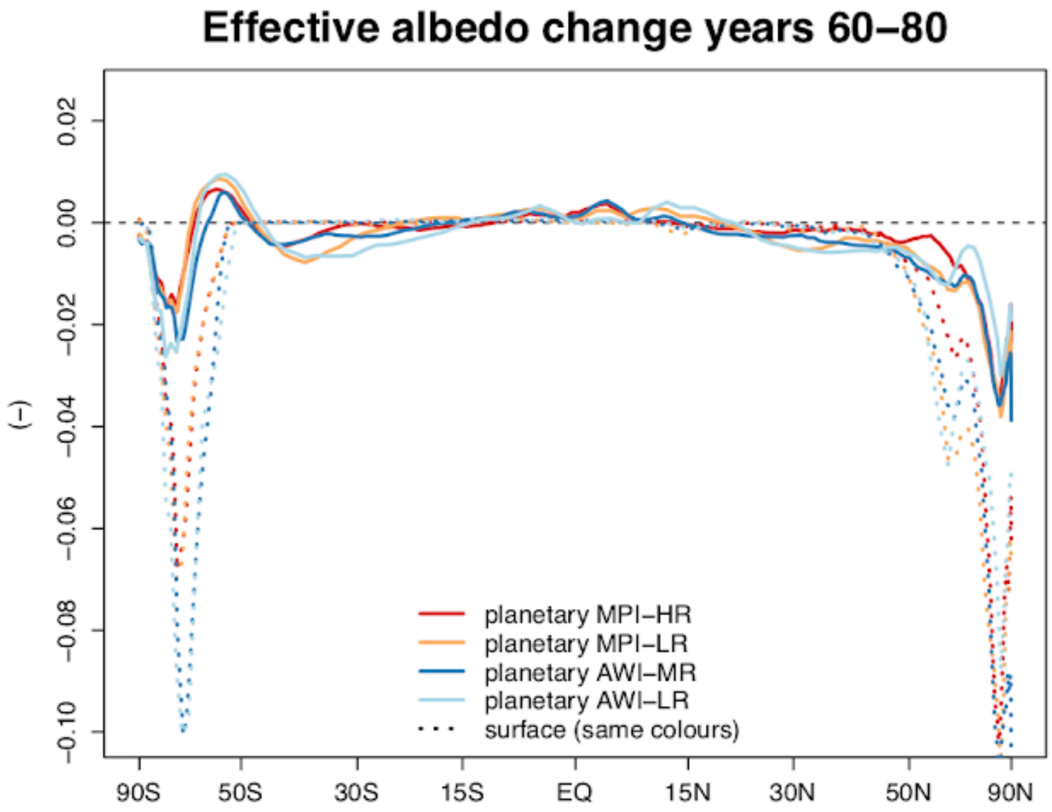
Different ocean temperature response



Ocean temperature change (°C) 1pctCO2 simulation years 60-80 compared to piControl

AWI model warms more at the surface than MPI model,
MPI model warms more at depth than AWI model

Different albedo response

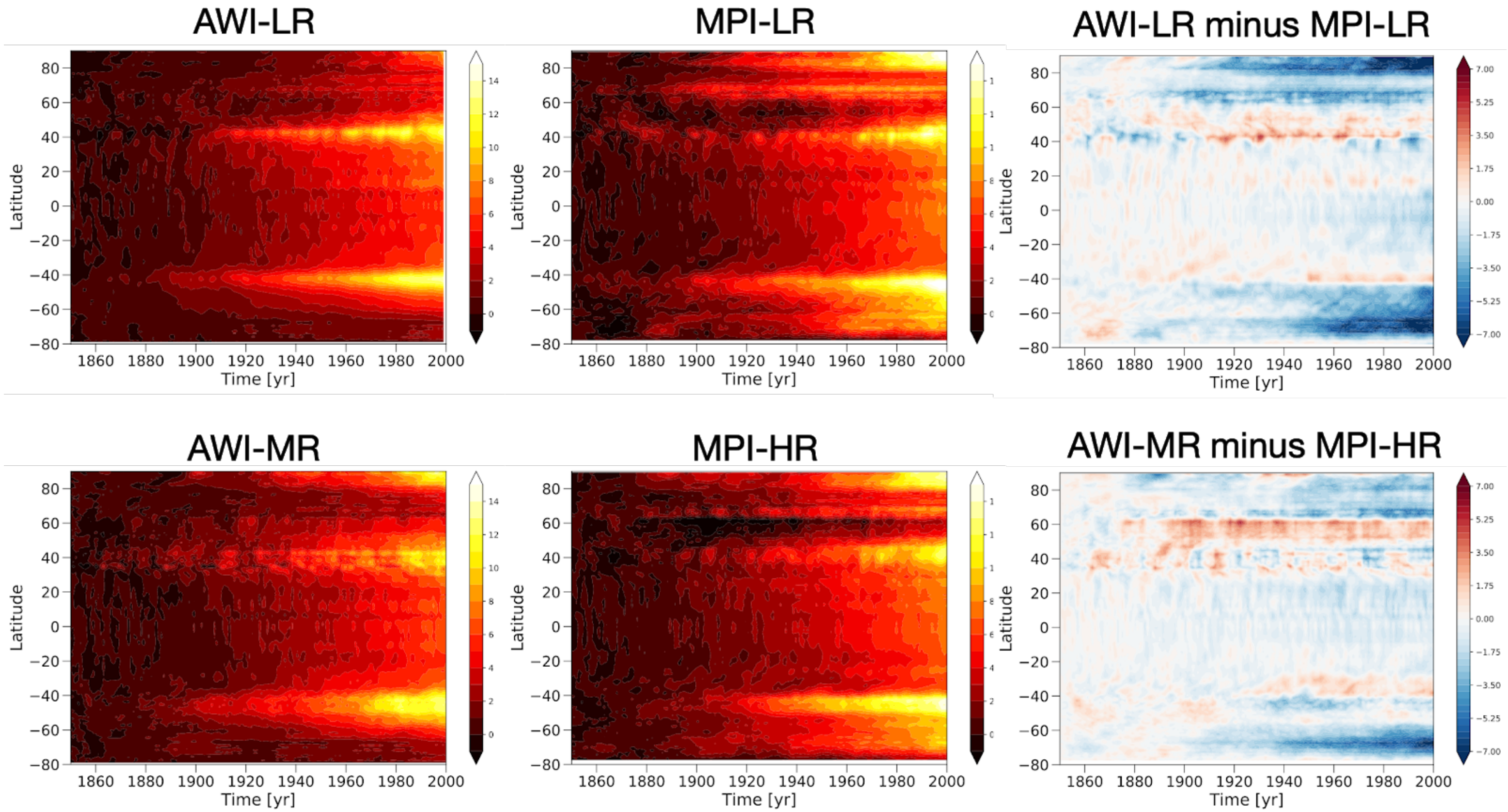


Planetary and surface albedo change (unity) 1pctCO2 simulation years 60-80 compared to piControl

AWI model shows stronger surface and to some extent planetary albedo declines in the southern Southern Ocean compared to MPI model – probably due to stronger Antarctic sea ice response because of stronger surface warming

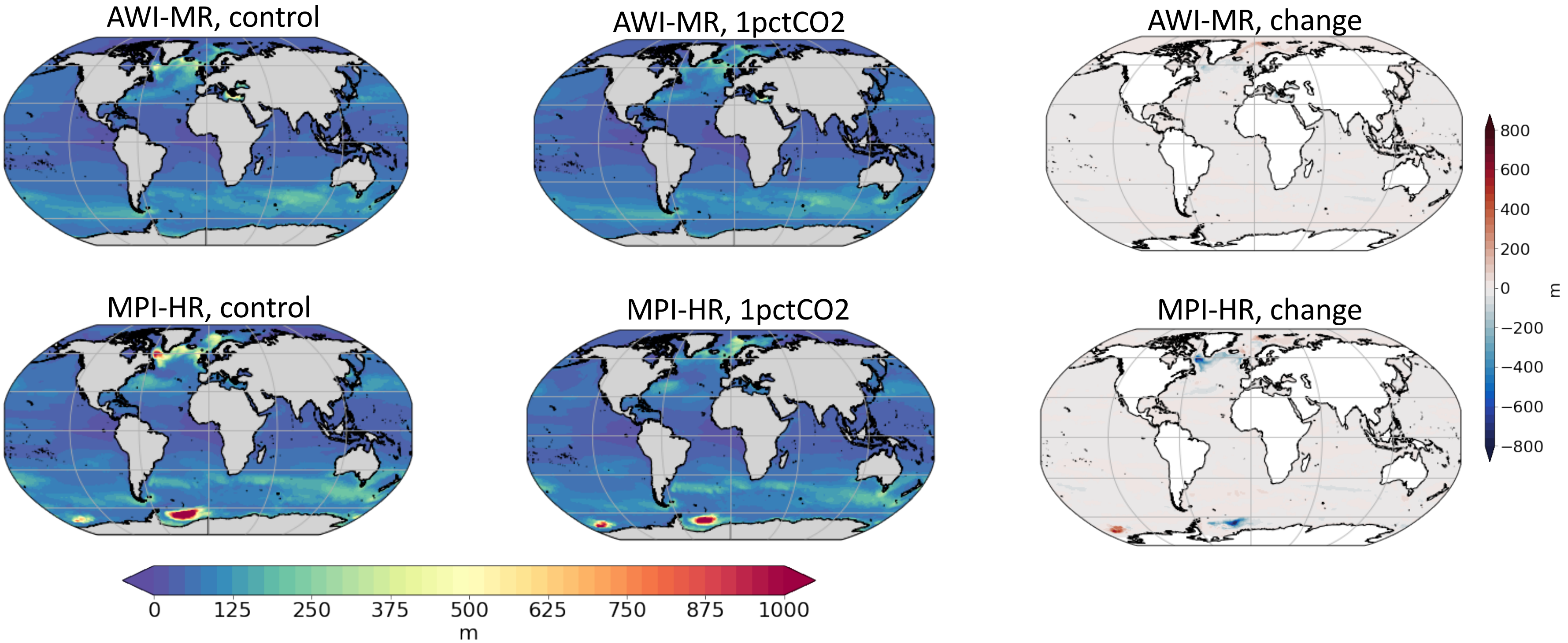
Different ocean heat uptake:

Zonal mean heat content density change 1pctCO2 versus piControl (J/m2*1e-9)



AWI model takes clearly less energy in high latitudes and slightly more energy in mid-latitudes than MPI model

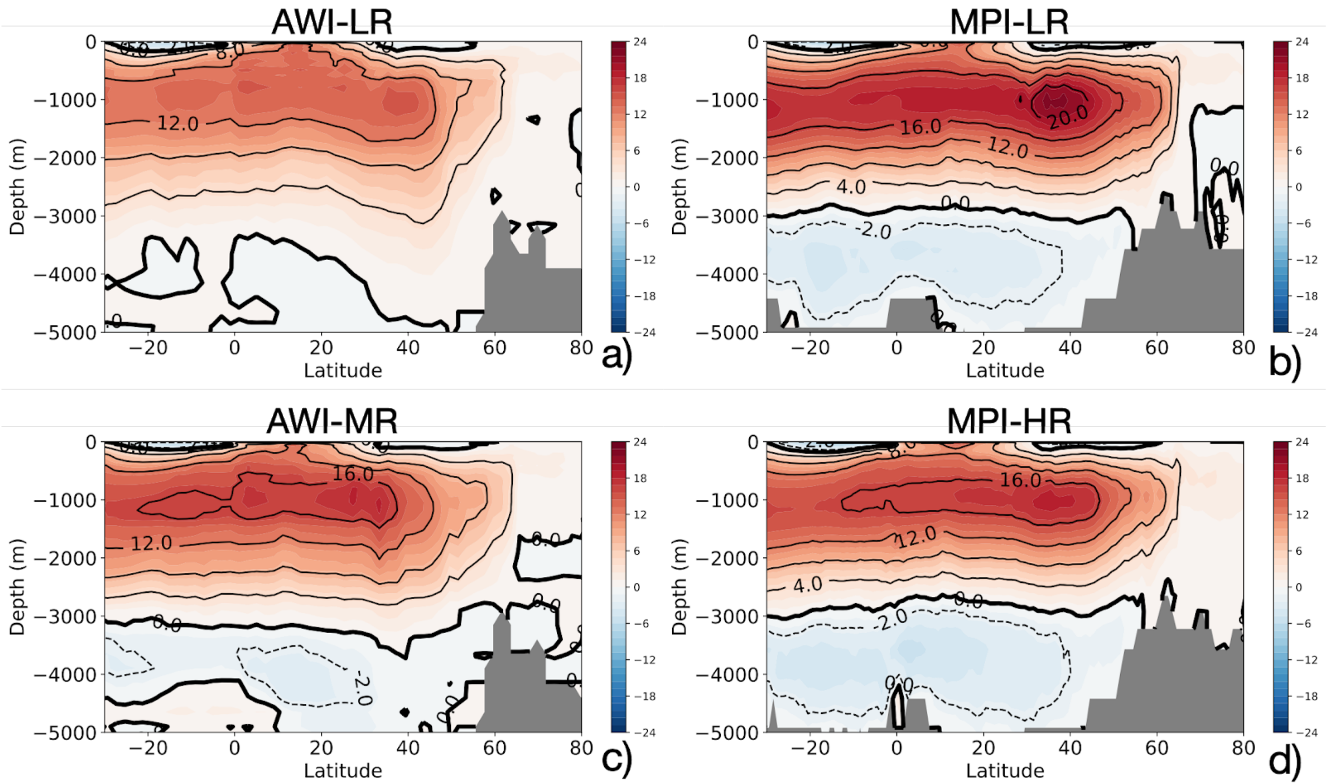
Different mixing response
Maximum mixed layer depth (m)



Maximum mixed layer depth (m) in piControl and 1pctCO2 years 60-80

AWI model shows less mixing than MPI model in high-latitude key regions and weaker changes with increasing greenhouse gases

AMOC (Sv)



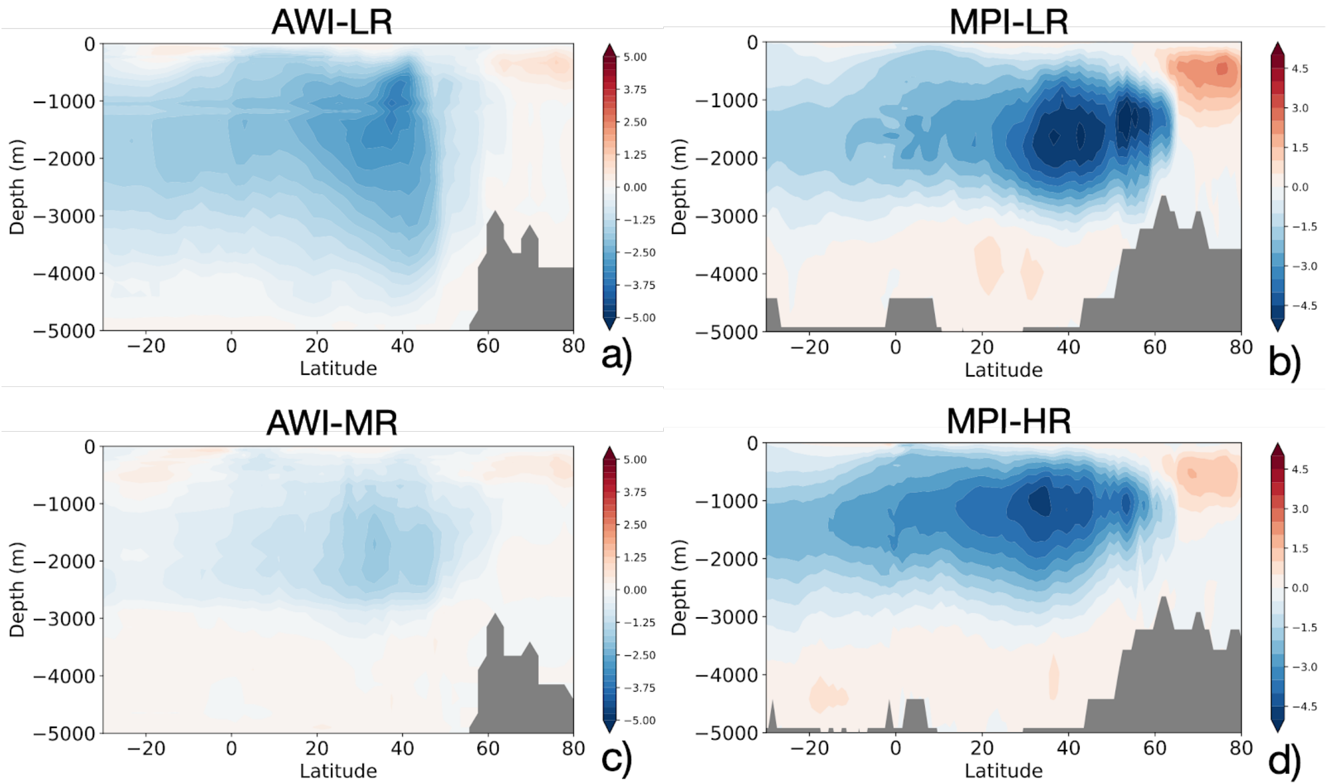
Atlantic meridional overturning circulation (Sv) for the piControl simulations

AWI-LR shows weakest AMOC, MPI-LR strongest

For the low resolution weaker high-latitude ocean mixing goes along with weaker AMOC

For the high resolution the AMOC is hardly different while the high-latitude ocean mixing is weaker in AWI compared to MPI models

AMOC response (Sv)



AMOC response (Sv) for years 60-80 of the 1pctCO2 simulations compared to piControl

AWI model shows weaker response compared to MPI model – consistent with weaker mixing response

Low resolution configurations show stronger response than high resolution configurations

Conclusions

Different ocean heat uptake in AWI configurations compared to MPI configurations through greenhouse gas forcing leads to different TCR and ECS

Faster surface temperature response in AWI configurations compared to MPI configurations goes along with a faster decline of surface albedo, in particular in the (southern) Southern Ocean due to sea ice decline

Deep ocean response in AWI configurations slower compared to MPI configurations. Therefore slower reaching of equilibrium in AWI configurations compared to MPI configurations.

Differences due to different ocean mixing (AWI shows less mixing than MPI)

AMOC contribution less clear

ECS should be mainly determined by the atmosphere model, but additional feedbacks (sea-ice, cloud formation) may depend on the ocean model as well.

Or could it be due to the calculation of ECS (Gregory method)?

Thanks to DKRZ (German Climate Computing Centre) for providing us with the computing time