Project: 944
Project title: EU H2020-project: PRIMAVERA
Project lead: Jin-Song von Storch (MPI-M), Thomas Jung (AWI)
Allocation period: 01.07.2018 – 31.12.2018

Achievements in 2017:

MPI-M:

In the first year of PRIMAVERA (November 2015 to October 2016), we have determined the cause of the strong decline in the strength of the Atlantic meridional overturning circulation (MOC) in the high-resolution version of MPI-ESM: Weaker surface winds leads to a decrease in the strength of the North Atlantic subpolar gyre and correspondingly the associated salt / heat transport across 50^{o}N, which causes a strong freshening / cooling of the subpolar North Atlantic. The latter results in a large sea-ice extent and a complete shut-down of the subpolar deep convection in the Labrador Sea.

From the knowledge gained through understanding the demise of the MOC in the high-resolution run, we are now able to stabilize the MOC strength in the high-resolution version of MPI-ESM at a value comparable to the low-resolution version via two different approaches.

1) Momentum flux adjustment

We have performed a 100-year long simulation (same length as CMIP6 HighResMIP simulations) with the high-resolution version in which the coupling wind stress over water is adjusted to "the mean state from the low-resolution version plus variability from high-resolution version". This results in a state of the subpolar North Atlantic that is comparable to the low-resolution version and a stable MOC strength. However, comparison with atmospheric reanalysis data reveals an improvement of the zonal wind stress pattern in the North Atlantic (especially the position of the jet stream) in the high-resolution version as opposed to the low resolution. In order to keep this improved pattern, we therefore perform a 100-year long simulation with the high-resolution version in which the coupling wind stress over water is adjusted to "the mean state from the high-resolution version multiplied by a factor of 1.5 plus variability from high-resolution version". The factor was chosen because in the subpolar North Atlantic, the zonal wind stress is about 1.5 times stronger in the low-resolution version. With respect to the state of the subpolar North Atlantic and the MOC strength, results are comparable to the simulation that applies the mean coupling wind stress from the low-resolution version. This is the approach, implemented in practice by representing the factor 1.5 increase of wind stress in terms of a constant wind stress correction term, we have decided to take for the production runs.

2) Freshwater flux correction

We have performed decadal-scale simulations with the high-resolution version in which the sea surface salinity is restored to EN4 (1950, same as ocean initialisation prescribed for CMIP6 HighResMIP simulations) with various relaxation time scales. This removes the subpolar fresh bias both at the surface and in the subsurface layers and thus results in a state of the subpolar North Atlantic comparable to that in the low-resolution version and a stable MOC strength. A relaxation time scale of 180 days is found to be the 'minimum restoring' that is sufficient to achieve a stable MOC. From such a simulation, surface freshwater fluxes to correct for the subpolar fresh bias have been diagnosed and applied to the high-resolution version. However, in the latter, the strength of the MOC declines a lot more than in the momentum flux-adjusted simulation. Therefore, this approach will not be considered for production runs.

CMIP6 HighResMIP and PRIMAVERA simulations (to be) performed in 2017:

- Historical (1950-2014) AMIP simulations with low- and high-resolution version
- Coupled spin-up (50 years), control (100 years) and historical (1950-2014) simulations with low-, high- and flux-adjusted high-resolution version

- Two 10-year time slices (2005-2014 and 2041-2050) with limited very-high frequency output with coupled low- and high-resolution version
- Two sensitivity experiments (10 ensemble members, 10-year long) regarding role of basin-scale sea surface temperature pattern (AMV+, AMV-) with coupled low- and high-resolution version

AWI:

From the start of the project end of 2015 up to the first half of 2017 we have defined, improved, and tested the meshes of our Finite Element Sea-ice Ocean Model FESOM in uncoupled and coupled mode. We have come up with optimized meshes for the low-resolution and the high-resolution coupled set-up. A paper on the mesh generation has been published in JAMES (Sein et al., 2016). A paper on the influence of the ocean resolution on the North Atlantic deep ocean bias is in preparation. Our low-resolution (LR) set-up which is not only used as a baseline version for PRIMAVERA HighResMIP but also for our PMIP (Palaeo Model Intercomparison Project) contribution to CMIP6 consists of FESOM1.4 with 130,000 wet surface nodes corresponding to a nominal resolution of 0.5 degrees with local refinement to about 0.25 degrees in dynamically active regions (referred to as CORE mesh) and ECHAM6.3 in T63L47 resolution. Our high-resolution (HR) set-up consists of FESOM1.4 with 1,300,000 wet surface nodes corresponding to a nominal resolution of 0.25 degrees with local refinement to about 0.08 degrees in dynamically active regions (referred to as BOLD mesh) and ECHAM6.3 in T127L95 resolution. This set-up is being used for the flagship simulations of PRIMAVERA. Benefits of resolution increase compared to the LR set-up have been demonstrated and are being further investigated.

Furthermore, we have tested and implemented the KPP vertical mixing scheme into FESOM1.4 resulting in the removal of the Labrador Sea freezing problem which was caused by a complete shut-down of the Labrador Sea deep convection. In addition, the introduction of a salt plume parameterization for brine rejection from sea ice has led to an improvement of Arctic and North Atlantic hydrography. While in the end of 2016 prototype PRIMAVERA simulations had been already performed with an AWI-CM version containing the KPP mixing scheme but not the salt plume parameterization and also not the final CMIP6 forcing data, since August the final production runs for PRIMAVERA HighResMIP are running. The prototype PRIMAVERA simulations are currently being used for the ERA-NET RUS project, a collaborative project between the Shirshov Institute for Oceanology in Moscow (Russia), the Universite des Alpes in Grenoble (France), and AWI to investigate the influence of resolution on air-sea interactions in the Gulf Stream / North Atlantic Stream region and the impact on cyclones and precipitation in the North Atlantic and European area. Complementary mixed resolution simulations (high-resolution atmosphere plus low-resolution ocean and low-resolution atmosphere plus high-resolution ocean) have been performed to isolate the influences from ocean and atmosphere high-resolution. Two papers on these results are in preparation.

<u>CMIP6 HighResMIP and PRIMAVERA simulations (to be) performed in 2017:</u>

- Coupled spin-up (50 years), control (150 years), 4xCO2 (150 years), and historical (1950-2014) simulations in LR and HR resolution
- Historical and scenario simulations in mixed resolution (150 years in high-resolution atmosphere / low-resolution ocean and 150 years in low-resolution atmosphere / high-resolution ocean) with prototype PRIMAVERA AWI-CM version
- Frontier ocean-only test simulations with 6 Million wet surface nodes

Reference

D. V. Sein, S. Danilov, A. Biastoch, J. V. Durgadoo, D. Sidorenko, S. Harig, and Q. Wang. Designing variable ocean model resolution based on the observed ocean variability. Journal of Advances in Modeling Earth Systems, 8(2):904–916, 2016. ISSN 1942-2466. doi:10.1002/2016MS000650. URL http://dx.doi.org/10.1002/2016MS000650.