SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2017
Project Title:	CMIP6 BSC contribution to HighResMIP (HighResMIP_BSC)
Computer Project Account:	spesiccf
Principal Investigator(s):	Louis-Philippe Caron
Affiliation:	Barcelona Supercomputing Center - Earth Science Department
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	January 1st, 2017
Expected end date:	December 31st, 2018 (we are requesting an extension to Dec. 31st 2019)

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	41.5M	50.4M	41.5M	1M
Data storage capacity	(Gbytes)	30K	30K	30K	59K

Summary of project objectives

(10 lines max)

The simulations performed within the context of HighResMIP_BSC will represent BSC's contribution to the HighResMIP coordinated exercise, which is part the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6). This exercise offers a framework for increasing synergies and building a large multi-model ensemble of high resolution simulations with a standard resolution counterpart following a common experimental protocol, i.e. a common integration period, forcing and boundary conditions (50 year long spin-up simulation, followed by a 100-year control simulations as well as a 100-year historical+future climate simulation (1950-2050)). The primary goal is to determine which processes can be represented reliably at typical CMIP5 resolutions and what is the minimum resolution required for an adequate representation of other processes as well as what are the limitations of representing such processes in lower resolution models.

Summary of problems encountered (if any)

(20 lines max)

Due to the large amount of data being produced, data transfer and storage is becoming an issue (the data's final destination is JASMIN, at BADC).. However this seems to be solved now and we are running a quality check on the data that were uploaded. Once this is completed, we will proceed to delete the data locally, freeing some space to resume the historical simulation.

We will not be able to complete the simulation for the period 2015-2049 until the future CMIP6 forcings become available. These forcings were expected to be available more than a year ago, but their delivery has been significantly delayed. These forcings are produced by a group external to this project and this delay impacts the climate community at large. We expect the forcings to become available during the summer, at which point, the historical simulation can be completed. This put us slightly behind schedule, but if the one-year extension request which accompanies this report is granted, it should not be an issue.

Summary of results of the current year *(from July of previous year to June of current year)*

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

We first completed the 50-year spin-up simulation. This simulation was compared to a different 50-year spin-up simulation performed by an EC-Earth partner (KNMI) which used a slightly different version of the model. The KNMI simulation was deemed to be closer to equilibrium and as such was selected as the starting point for the control and historical simulations. Ideally, it would have been possible to just run a very long spin up simulation until equilibrium was reached, but at the high-resolution considered here, such long spin up is not possible and a comparative approach was used to identify the model closest to equilibrium.

We then ran the 100-year control simulation at high (ocean: ORCA025, atmosphere: T511) and standard (ocean: ORCA1, atmosphere: T255) resolution of EC-Earth 3.2 (the latter was run locally). We have also started the corresponding historical simulation, but due to storage issue, this simulation had to be put on hold (see Problems Encountered section).

After comparing the control simulation with the standard-resolution version of EC-Earth, we detected an unrealistically cold climate over the North Atlantic and a very weak Atlantic Meridional Overturning Circulation (AMOC). We thus completed an additional low-resolution control experiments using different parameters (parameters which control the penetration of turbulent kinetic energy in the ocean and the thermal conductivity of snow) and a more realistic North Atlantic climate in order to provide another benchmark against which to compare the high-resolution simulations. This can be seen below, in Figures 1 and 2.

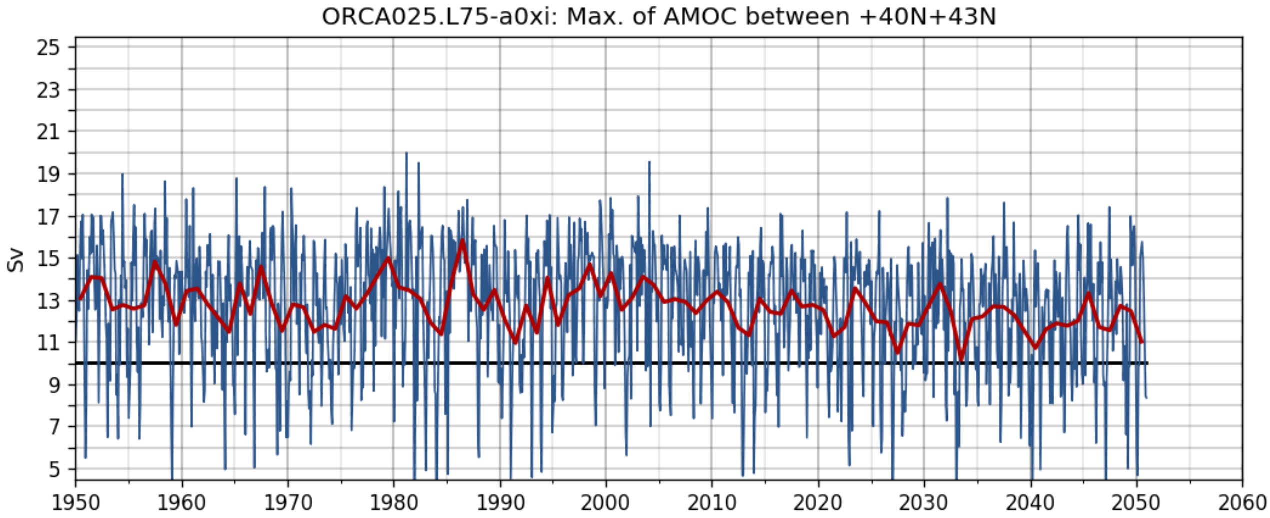

Figure 1: AMOC for high-resolution simulation. The thin blue line represents the monthly mean value while the red line represents the annual mean.

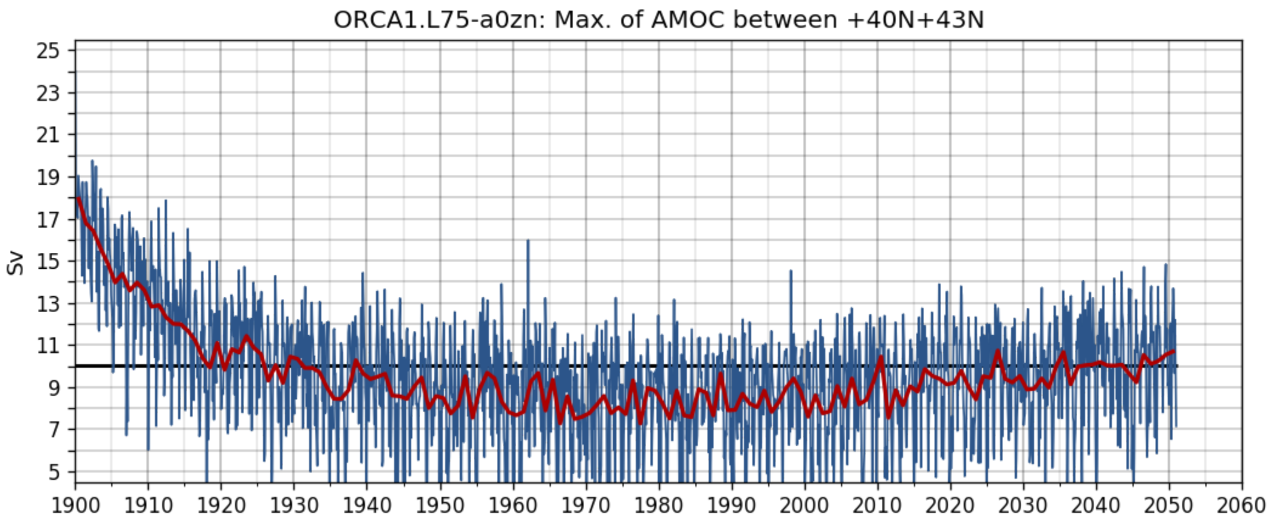

Figure 2: Same as Figure 1, but for the standard resolution simulation. Please note that the spin-up is included in this latest figure (years 1900-1949).

Figure 3 shows that the changes in the ocean parameters in the standard resolution version of the model improved the strength of the AMOC to a level comparable to the high-resolution simulation. The climate of the North Atlantic was also improved, but is not shown here.

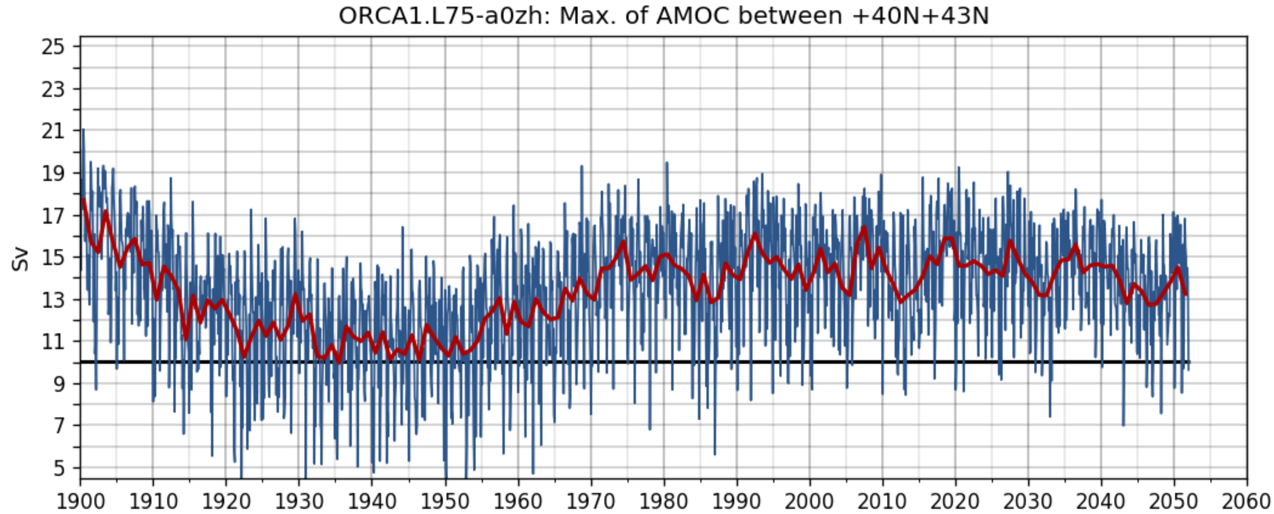

Figure 3: Same as Figure 1, but for the standard resolution simulation performed with modified ocean parameters.

We can also see from Figure 4 that the ocean in the high-resolution control simulation is continuously warming at a rate of ~0.025K/10 year and has not yet reach equilibrium after 150 years of simulations (the situation is similar at standard resolution). This is not entirely surprising given the short length of the spin-up (50 years only). For the deep ocean to reach quasi-equilibrium, a very long spin-up (thousands of years) would be necessary, which is not realistic with a high resolution climate model. To circumvent this problem and to remove the climate drift, a suite of ensemble simulations is needed, which can be used to estimate and remove the climate drift, particularly in locations where it is very strong, such as the deep ocean.

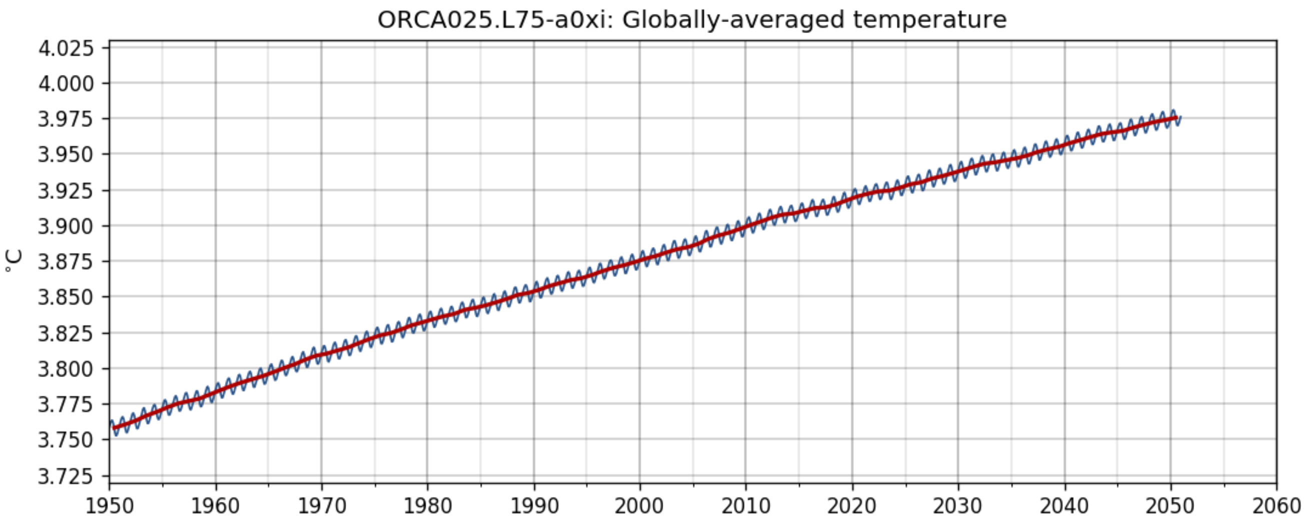

Figure 4: Globally averaged ocean temperature of the High-Resolution control simulation.

In terms of sea ice, while Antarctica seems to have stabilized (Figure 5, red line), it seems like the Arctic is still accumulating sea ice (Figure 5, blue line). The results are similar whether we look at sea ice extent or sea ice volume, and whether we look at the summer or the winter season.

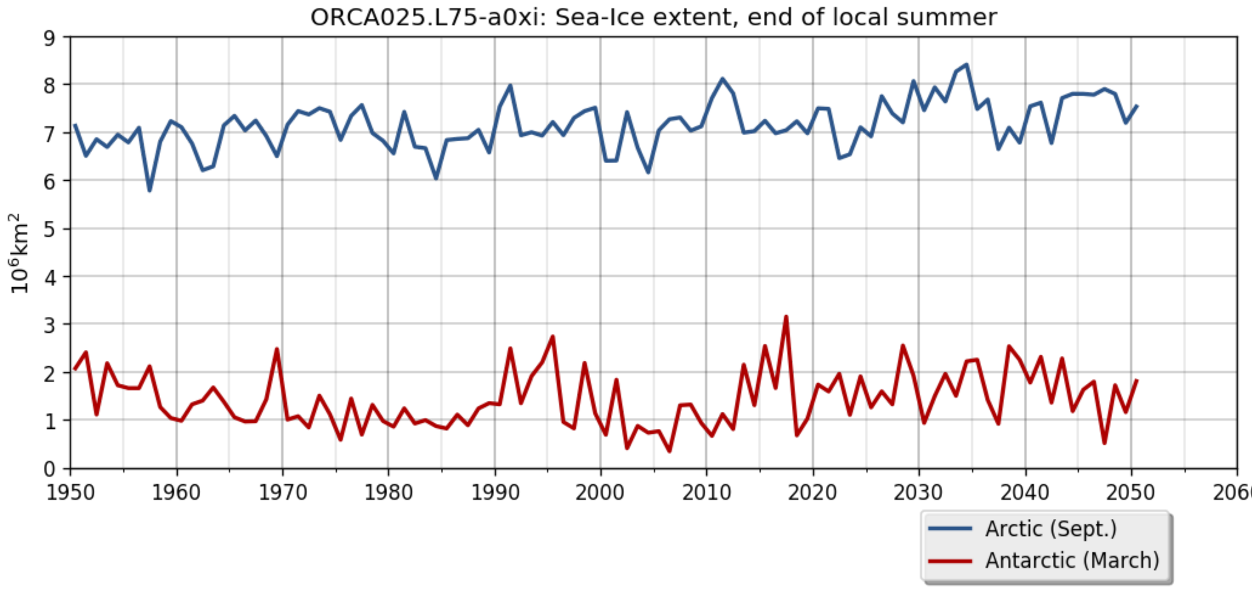

Figure 5: Sea ice extent at the end of the local summer for both the North and South poles of the High-Resolution control simulation.

These simulations are currently being analyzed in order to investigate the relationship between SST and ocean heat uptake (OHU) on decadal timescales and the impact of the resolution on that relationship (Exarchou and Drijfhout, in preparation). We find, based on the regression of the ocean heat content on the global mean SST, that on decadal timescales, the dominant players in natural variability are the convection sites in the Labrador Sea and the Nordic Sea in the North, and the Ross Sea in the South (Figure 6).

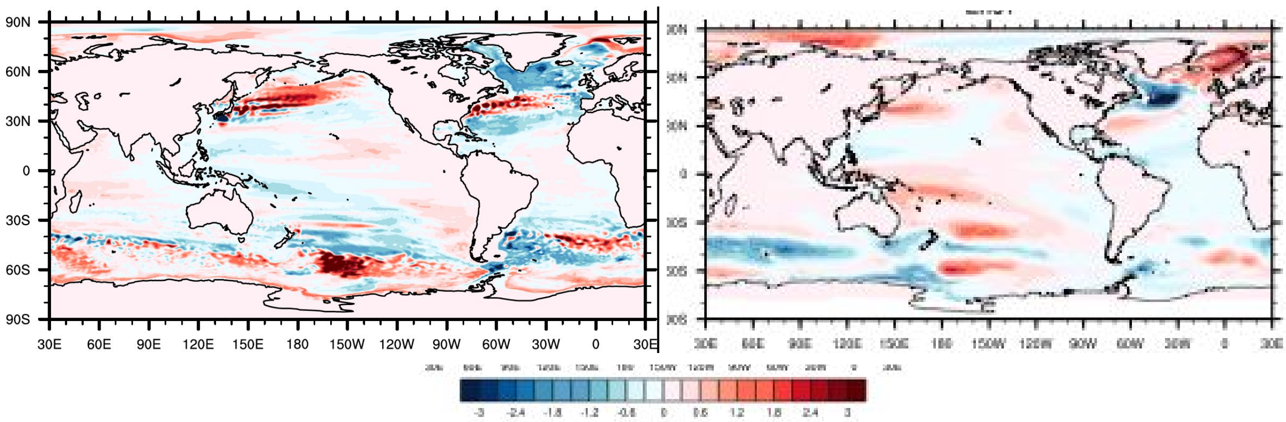

Figure 6: Regression of the global mean SST on total ocean heat content (in 10^{10} J/C) for the control simulations in high (left) and low (right) resolution. A high pass filter of 13 years has been applied to the timeseries in order to remove interannual variability.

The lead-lag correlations between global mean SST and the different components in the surface fluxes (Figure 7) reveal that, in the low resolution model, on decadal timescales, the solar fluxes heat (cool) the ocean about 5 years before the SST warming (cooling), and the turbulent and long wave respond with upward (downward) heat flux anomalies to dampen this warming (cooling) 5 years later. For the high resolution, there is a different type of variability, the reason for which we are currently exploring.

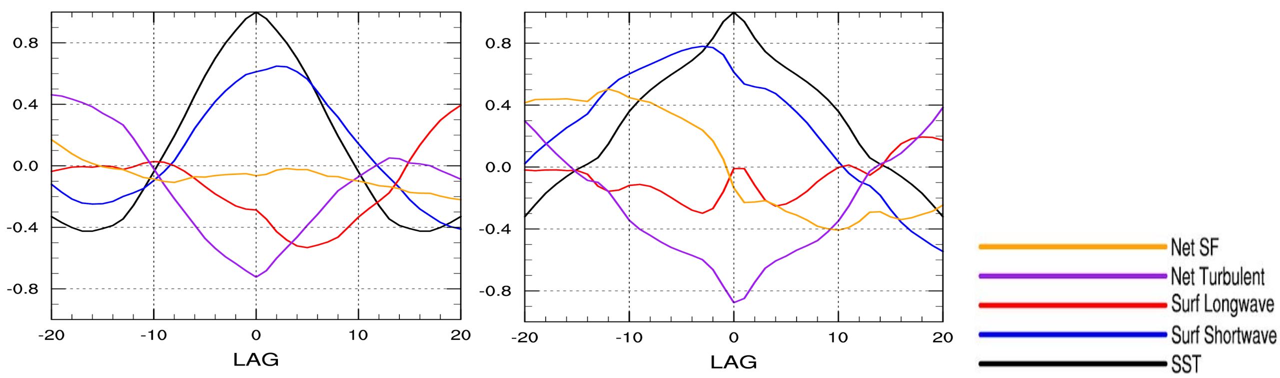

Figure 7: Lead-lag correlation between SST and the different components of the surface fluxes (positive lags when the SST leads) for the high (left) and low (right) resolution. Black line is autocorrelation of the SST. A high pass filter of 13 years has been applied to the timeseries in order to remove interannual variability.

Data Management

These simulations are done in the context of the H2020 project PRIMAVERA and as such the data produced here are made available through the JASMIN server. All the data produced have been cmorized and most of these data have already been uploaded to JASMIN. We are currently in the process of doing a quality check on the uploaded data to ensure that they meet the necessary requirements, after which they will be made available to PRIMAVERA partners, and later on, to the scientific community at large through the ESGF archives.

List of publications/reports from the project with complete references

1. Once the simulations are completed and made available, they will receive a persistent data identifiers (DOIs), which has already been reserved.

2. Exarchou, E. and S. Drijfhout. The relationship between surface climate, and the ocean heat uptake arising from natural variability , and the impact of the resolution. In preparation for Climate Dynamics.

3. A manuscript detailing the EC-Earth model used to perform the simulations required by the HighResMIP protocol as well as some key results from the simulations is currently in preparation (lead author: Rein Haarsma, from KNMI):

   Rein Haarsma et al., The PRIMAVERA versions EC-Earth:EC-Earth3P and EC-Earth3P-HR. Description and validation In preparation for Geoscientific Model Development

Summary of plans for the continuation of the project

(10 lines max)

We plan to complete the high-resolution historical simulation as well as both the standard and high-resolution future scenario simulations once the future forcings become available. Once the simulations are completed, the data will be cmorized and uploaded to JASMIN to share with other

PRIMAVERA partners and later to the science community at large. Once these simulations are completed, we will also start the analysis on the impact and benefits of increased resolution on a number of physical processes, as detailed in the original proposal.

Should the requested 1-year extension[1] be granted, we plan to also run a spin-up of an even higher version of EC-Earth. This version, currently in the last testing phase, is constructed using NEMO at 0.125 degree resolution and IFS at T1279 resolution.

[1] A modification to the original project accompanies this report.