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Deliverable D*6.7*

Stream 2 control and historic coupled runs

Deliverable Title	*Stream 2 control and historic coupled runs*	
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Lead Beneficiary	*Louis-Philippe Caron, BSC*	
Contributors	*Hannah Christensen, University of Oxford* *Susanna Corti, CNR* *Paolo Davini, CNR* *Oliver Gutjahr, MPI* *Rein Haarsma, KNMI* *Philippe Le Sager, KNMI* *Xavier Levine, BSC* *Katja Lohmann, MPI* *Marie-Pierre Moine, CERFACS* *Dian Putrasahan, MPI* *Malcolm Roberts, Met Office* *Chris Roberts, ECMWF* *Yohan Ruprich-Robert, BSC* *Jon Seddon, Met Office* *Dmitry Sein, AWI* *Tido Semmler, AWI* *Retish Senan, ECMWF* *Kristian Strommen, University of Oxford*	
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		CO - Confidential, only for members of the consortium, including the Commission services

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1. Executive Summary

Here, we provide a brief overview of stream 2 coupled experiments that have been completed by the different PRIMAVERA groups.

2. Project Objectives

With this deliverable, the project has contributed to the achievement of the following objectives (DOA, Part B Section 1.1) WP numbers are in brackets:

No.	Objective	Yes	No
A	To develop a new generation of global high-resolution climate models. *(3, 4, 6)*	X	
B	To develop new strategies and tools for evaluating global high-resolution climate models at a process level, and for quantifying the uncertainties in the predictions of regional climate. *(1, 2, 5, 9, 10)*		X
C	To provide new high-resolution protocols and flagship simulations for the World Climate Research Programme (WCRP)'s Coupled Model Intercomparison Project (CMIP6) project, to inform the Intergovernmental Panel on Climate Change (IPCC) assessments and in support of emerging Climate Services. *(4, 6, 9)*	X	
D	To explore the scientific and technological frontiers of capability in global climate modelling to provide guidance for the development of future generations of prediction systems, global climate and Earth System models (informing post-CMIP6 and beyond). *(3, 4)*		X
E	To advance understanding of past and future, natural and anthropogenic, drivers of variability and changes in European climate, including high impact events, by exploiting new capabilities in high-resolution global climate modelling. *(1, 2, 5)*		X
F	To produce new, more robust and trustworthy projections of European climate for the next few decades based on improved global models and advances in process understanding. *(2, 3, 5, 6, 10)*	X	
G	To engage with targeted end-user groups in key European economic sectors to strengthen their competitiveness, growth, resilience and ability by exploiting new scientific progress. *(10, 11)*		X
H	To establish cooperation between science and policy actions at European and international level, to support the development of effective climate change policies, optimize public decision making and increase capability to manage climate risks. *(5, 8, 10)*	X	

3. Detailed Report

The original plan for the coupled stream 2 simulations, as stated in WP6 description, was to produce a smaller number of high-resolution simulations, as compared to stream 1, but with improved model components derived from WP2 and WP3 and guided with input from user requirements (WP11). In discussions ahead of and during a project EMB meeting held at Schiphol on November 12, 2018, it was argued that the initial plan, as stated in the project description, might not be the best path forward, and had a number of difficulties:

1. Much of the new physics had not been tested at high resolutions
2. Not many models could use each model development, therefore leading to a small sample in each case
3. Biases could very well become worse in long simulations

Furthermore, it was argued in discussions about the design for Stream 2 that in order to adequately quantify the impact of increasing resolution, a larger ensemble size was required (stream 1 required only 1 ensemble member per configuration). Thus, given the considerable time that would be required to run the simulations as initially planned, the uncertainty as to whether it would be really useful and the need for larger ensemble, it was agreed that a large part of the effort for stream 2 would go into producing additional members and follow the same protocol as stream 1, but with a reduced output, as guided with the data request from stream 1 simulation. As a reminder, Figure 1 (below) presents the HighResMIP (stream 1) protocol, for coupled simulations.

The HighResMIP protocol divides the simulations in 4 distinct experiments:

1. a 50-year spinup, initialized using 1950 conditions and with constant 1950 forcings (labelled **spinup-1950**)
2. a 100-year control experiment started from the end of the spinup-1950 simulations and with constant 1950 forcings (labelled **control-1950**)
3. a 65-year simulation (1950-2014) initialized from the end of the spinup-1950 simulations but with forcings corresponding to forcings observed during the period 1950-2014 (labelled **hist-1950**)
4. a 36-year simulation (2015-2050) initialized from the end of the hist-1950 simulation and forced with emissions from the SSP5-85 scenario (equivalent to RSP 8.5 in CMIP5) (labelled **highres-future**).

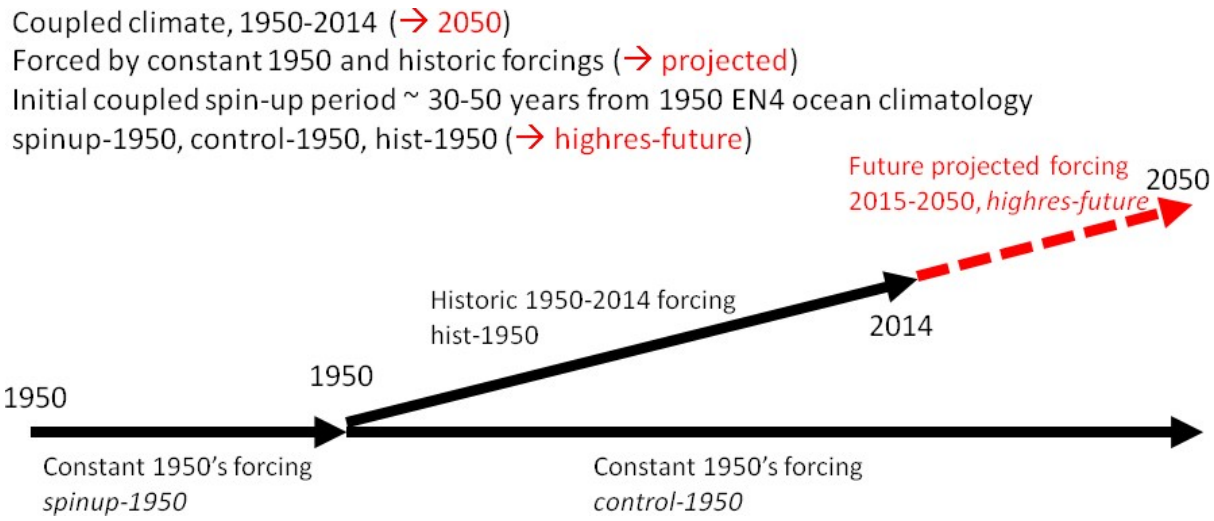

Figure 1: HighResMIP protocol.

Summary tables for each of the different components is provided in the appendix and the table below summarizes the number of simulations which were produced in stream 2 (excluding spinup-1950).

Control-1950	Number of ensemble members	Number of simulated years
Standard resolution	8	1750
Intermediate resolution	2	600
High resolution	6	630
Hist-1950		
Standard resolution	20	1300
Intermediate resolution	6	390
High resolution	13	845
Highres-future		
Standard resolution	9	374
Intermediate resolution	2	72
High resolution	9	374

A few items to note:

- As can be seen from the tables, there is no agreement between models as to what constitute standard and high resolution.

- Most groups had only two resolutions (standard and high), but two models (HadGEM3, ECMWF-IFS) opted for intermediate resolutions.
- The additional control simulations ranged 100 years to 900 (standard resolution), to 500 (intermediate) and to 150 (high) years.
- For hist-1950, 1300 and 845 new simulated years were produced at standard and high resolution respectively.
- For highres-future, most ensemble members cover the period 2015-2050, except for one member of EC-Earth3P, which covers the period 2015-2100 at both standard and high resolutions.

Beside the additional HighResMIP simulations, three additional sets of simulations were performed within stream 2:

The first set, referred to as **future-2050**, is a continuation of the highres-future experiment, but with the forcing remaining constant at the 2050 level, starting in 2050. The goal of this experiment is to increase the event set, rather than the ensemble size and to look at changes in variability in the warmer climate. These simulations are also directly comparable to the control-1950 simulations. This experiment was performed with the HadGEM3 model.

The second set, referred to as **4xCO2**, quadruples the amount of CO2 in the atmosphere at the end of the spinup-1950 simulation and is then run for 100 years. With such a strong forcing, we expect a fast response and less years for the signal to emerge. This experiment was performed with the MPI-ESM model.

Finally, the last set is a set of experiments at standard resolution following the hist-1950 protocol, but using stochastic physics. Comparison with the standard hist-1950 simulations will provide information on how sub-grid scale variability affects the resolved scale variability and the benefit of resolution with respect to stochastic physics in the representation of the climate. This experiment was performed with the EC-Earth3P model.

Most of the data that are planned to be shared through the PRIMAVERA DMT are already available. The exceptions are

- Spinup-1950:
  - EC-Earth3P, (r1i1p2f1). Status: cmorized and already uploaded on Jasmin. Waiting for QC confirmation. Should be available by mid-October.
- Control-1950
  - AWI-CM-1.1 (r1i3p1f1). Status: data currently being cmorized. Should be available by the end of October.
- Hist-1950 + Highres-future
  - HadGEM3-GC31 (intermediate resolution). Status: data currently being cmorized. Should be available by the end of October.
  - CNRM-CM6-1 (standard and high resolution). Status: cmorization completed. Should be available through ESGF by the end of October
  - AWI-CM-1.1 Status: Hist-1950 are on JASMIN passing validation. Highres-future currently being cmorized. Should be available by the end of October

Peer reviewed articles

The different climate models used to perform the simulations are described in:

Gutjahr, O., D. Putrasahan, K. Lohmann, J. H. Jungclaus, J.-S. von Storch, N. Brüggemann, H. Haak, and A. Stössel, 2019: Max Planck Institute Earth System Model (MPI-ESM1.2) for the High-Resolution Model Intercomparison Project (HighResMIP), Geosci. Model Dev., 12, 3241-3281, https://doi.org/10.5194/gmd-12-3241-2019.

Roberts, C. D., R. Senan, F. Molteni, S. Boussetta, M. Mayer and S. Keeley, 2018: Climate model configurations of the ECMWF Integrated Forecast System (ECMWF-IFS cycle 43r1) for HighResMIP. Geosci. Model Dev., 11, 3681-3712, https://doi.org/10.5194/gmd-11-3681-2018.

Roberts, M. J., Baker, A., Blockley, E. W., Calvert, D., Coward, A., Hewitt, H. T., Jackson, L. C., Kuhlbrodt, T., Mathiot, P., Roberts, C. D., Schiemann, R., Seddon, J., Vannière, B., and Vidale, P. L.: Description of the resolution hierarchy of the global coupled HadGEM3-GC3.1 model as used in CMIP6 HighResMIP experiments, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-148.

Sidorenko, D. , Rackow, T. , Jung, T. , Semmler, T. , Barbi, D. , Danilov, S. , Dethloff, K. , Dorn, W. , Fieg, K. , Gößling, H. F. , Handorf, D. , Harig, S. , Hiller, W. , Juricke, S. , Losch, M. , Schröter, J. , Sein, D.V. and Wang, Q. (2014): Towards multi-resolution global climate modeling with ECHAM6–FESOM. Part I: model formulation and mean climate, Climate Dynamics . doi: 10.1007/s00382-014-2290-6

Voldoire, A., and Coauthors, 2019: Evaluation of CMIP6 DECK Experiments with CNRM-CM6-1. J. Adv. Model. Earth Syst., https://doi.org/10.1029/2019MS001683.

Each of the dataset will also have an associated doi:

Met Office

HadGEM3-GC31-LL - http://doi.org/10.22033/ESGF/CMIP6.1901

HadGEM3-GC31-MM - http://doi.org/10.22033/ESGF/CMIP6.1902

HadGEM3-GC31-HH - http://doi.org/10.22033/ESGF/CMIP6.445

HadGEM3-GC31-HH - http://doi.org/10.22033/ESGF/CMIP6.1822

AWI

CM-1-1-LR - http://doi.org/10.22033/ESGF/CMIP6.1209

CM-1-1-HR - http://doi.org/10.22033/ESGF/CMIP6.1202

ECMWF

ECMWF-IFS-LR - http://doi.org/10.22033/ESGF/CMIP6.2463

ECMWF-IFS-HR - http://doi.org/10.22033/ESGF/CMIP6.2461

CNRM-CERFACS

CNRM-CM6-1 - upcoming

CNRM-CM6-1-HR - upcoming

EC-Earth Consortium

EC-Earth3P - upcoming

EC-Earth3P-HR - upcoming

MPI-M

MPI-ESM1-2-HR - upcoming

MPI-ESM1-2-XR - upcoming

Up-to-date information on the publications of the various simulations can be found on the PRIMAVERA website: https://www.primavera-h2020.eu/modelling/.

Future Publications

The EC-Earth3P model will be described in Haarsma et al. (in prep).

Key points

- The focus of stream 2 simulations has been on increasing the ensemble size of simulations. Hence, for most simulations, the protocol is the same as stream 1.
- All planned stream 2 simulations have been completed.
- Most of the data is already available on Jasmin through the DMT. The remaining data are expected to be there by the end of October.

4. Lessons Learnt

Based on the variables that were requested for analysis, which represent only a small fraction of all the data produced, the initial data request appears to have been much too large for the need of the project. It remains to be seen whether the variables that have not been used so far will generate interest once made available to the wider scientific community.

5. Links Built

The simulations performed as part of stream 2 will increase the contribution of PRIMAVERA to HighResMIP.