ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

Decide on experimental setup for internal variability

M34b_Lot2.1.3.1

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1. Introduction

The variability of climate model output originates from several quite different sources.

The lack of knowledge of future greenhouse gas emissions is fundamental and can only be addressed by letting climate models answer what-if questions based on different assumed future emission scenarios, currently the family of Representative Concentration Pathways (RCP).

Model errors exist both for global and for regional models. They can have many forms, there are aspects, which are common for all models, like the necessity to parameterize sub-grid-scale processes, and there are aspects, which depend on the individual model. Quantification of model errors is addressed by performing and analysing as large ensembles as possible with the respective models, and comparisons to observed or reanalysed reality.

Finally, both reality and climate models exhibit internal variability on all time scales due to the chaotic and non-linear nature of the climate system. In a regional downscaling experiment both the global and the regional model will be a source of internal variability, but the effect of large circulation variability as simulated by the driving GCM will be dominating. To a certain extent this variability component could be quantified through analyses of control simulations from the entire set of Euro-CORDEX simulations available, challenges arise from the transient nature of the simulated climate and from the difference between climate models.

Large single-model ensemble simulations have been studied before. Deser et al. (2012) examined a 40-member ensemble of the CCSM3 global model in terms of e.g. the decade of emergence of statistical significance of various climate signals and quantified the influence of internal variability on significance. Also downscaling of single-model ensembles has been performed. Addor and Fischer (2014) downscaled a single-model transient-run GCM ensemble of 21 members of the NCAR CESM model with the COSMO-CLM regional climate model in 50km resolution in order to quantify the role of internal variability on transient climate change over the Alps. Aalbers et al. (2017) performed a large single-model ensemble of 16 members with 12km resolution for a part of Europe with boundary conditions from one GCM. This way, extreme precipitation, which has a very large natural variability, could be analysed in a much more robust way than what would have been possible with just one simulation.

In this project we focus on the downscaled internal variability and intend to investigate how the spread in weather modes originating from global models will manifest itself in the high-resolution signals simulated by RCMs. We intend to use more than a single regional model in order to study the relative effects of internal variability and model choice directly.

It has therefore been decided to perform a targeted analysis of internal variability for a few of the available model combinations in the larger GCM-RCM-scenario matrix under consideration in PRINCIPLES by performing regional downscaling of several ensemble models of selected GCMs. Through transient ensembles it is possible to quantify climate for selected periods with a relatively high degree of accuracy simply by having more simulated years available consistent with the climate under investigation.

2. Method

A few global modelling groups have already published output data useful for downscaling for several ensemble members. Among these are the Hadley Centre HadGEM2 model, the community EC-Earth model and the Max-Planck Institute model MPI-ESM-LR.

The total budget for simulations in PRINCIPLES is of the order of 60-75 transient simulations. It has been decided to spend most of these on completing the already quite well populated RCP8.5 GCM/RCM matrix and also to add further RCP2.6 simulations to this sparser matrix. However, some effort will be earmarked for this targeted investigation of internal variability.

One of these global models will be chosen, and a GCM single-model ensemble of at least 3 and probably 5 members will be used for downscaling by probably 3 of the regional climate models participating in PRINCIPLES. This would create a total ensemble of around 3x5=15 simulation members where an assessment can be made of both the downscaled internal climate variability and the variation of this quantity with the choice of GCM. Conversely, the existence of such an ensemble would enable an assessment of the effect of the RCM choice with as little pollution from internal variability as possible. It may be preferable to choose several emission scenarios in order to do a systematic investigation of emergence, i.e., at which point of time which climate change features become statistically significant compared to internal variability.

In Fig. 1, possible regions of the GCM-RCM-scenario matrix are indicated where single-model scenarios could be focused (dark grey areas) as well as areas where single simulations could be added (light grey); note that this is not yet finally decided. We have chosen these combination based on the existence of downscaled ensemble members before the project, such that the downscaled ensembles do not have to be created from scratch.

Status 20180225 **RCP8.5**	SMHI RCA4	ETHZ CCLM 4-8-17	HZG REMO	KNMI RACMO 22E	DMI HIRHAM5	CNRS WRF	MF ALADIN6	ICTP RegCM	MOHC HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1	1	1	1	1	1	#	*	*	6
ICHEC-EC-EARTH	1	1	1	2	1					6
CNRM-CERFACS-CNRM-CM5	1	1	1	*	#	#	1			4
NCC-NorESM1-M	1	*	*	#	1	#				2
MPI-M-MPI-ESM-LR	1	1	2	#	#					4
IPSL-IPSL-CM5A-MR	1					1				2
CCCma-CanESM2		1	1							2
MIROC-MIROC5		1	1							2
Total now	6	6	7	3	3	2	1	0	0	28

Status 20180125 **RCP4.5**	SMHI RCA	ETHZ CCLM	HZG REMO	KNMI RACMO	DMI HIRHA	CNRS WR	MF ALADI	ICTP RegC	MOHC HadGE	Total now

	4	4-8-17		22E	M5	F	N6	M	M3-RA	
MOHC-HadGEM2-ES	1	1		1						3
ICHEC-EC-EARTH	1	1		2	1					5
CNRM-CERFACS-CNRM-CM5	1	1	1				1			4
NCC-NorESM1-M										0
MPI-M-MPI-ESM-LR	1	1	2							4
IPSL-IPSL-CM5A-MR	1					1				2
Total now	5	4	3	3	1	1	1	0	0	18

Status RCP2.6 20180125	SMHI RCA4	ETHZ CCLM 4-8-17	HZG REMO	KNMI RACMO22E	DMI HIRHAM5	CNRS WRF	MF ALADIN6	ICTP RegCM	MOHC HadGEM3-RA	Total now
MOHC-HadGEM2-ES	1			1						2
ICHEC-EC-EARTH	1	1		1	1					4
CNRM-CERFACS-CNRM-CM5							1			1
NCC-NorESM1-M										0
MPI-M-MPI-ESM-LR	1	1	2			1				5
IPSL-IPSL-CM5A-MR										0
Total now	3	2	2	2	1	1	1	0	0	12

Figure 1 Overview of possible extensions of the existing GCMxRCMxscenario 3-dimensional matrix. The light grey areas could be filled up, and the dark grey areas could contain several ensemble members. Numbers indicate the number of existing simulations with the GCM, RCM and scenario in question. * indicates PRINCIPLE SC1 simulations, which have been decided upon; # indicates non-final choices of SC2 simulations.

3. References

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