Climate change signals of ENSEMBLES RT2b models

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This report is part of deliverable D1.2 of the EU FP7 project "ClimateCost", now published at the ENSEMBLES RT3 web site. It discusses the eleven regional climate model simulations in the ENSEMBLES archive that cover the period until the year 2099 according to the SRES A1B emission scenario.

Several criteria can be used in order to select a subset of these transient regional climate simulations residing at http://ensemblesrt3.dmi.dk/ –The deciding factor could be the quality of the RCM reproduction of historical climate. This has been extensively explored in the ENSEMBLES project; see forthcoming issue of *Climate Research* in 2011 on the ENSEMBLES project, or ENSEMBLES D3.2.2, available from http://www.ensembles-eu.metoffice.com/. However, it could also be the magnitude and pattern of climate change signals.

Here we shall explore the latter kind of selection criteria. In order to enable users of various impacts models to span the space of possible climate trajectories allowed by the A1B emission scenario, we shall give some rules of thumb. We have chosen to focus on four physical parameters: Summer and winter change from the 1961-1990 reference period in temperature and precipitation to a future period 2070-2099. We shall only look at average values over the whole of Europe, and we shall compare eleven simulations. These simulations are exactly those in the archive that cover the period 1951-2099. We have made the subjective choice to exclude simulations driven by the global models HadCM3Q3 and HadCM3Q16, which are versions of the HadCM3 model with perturbed parameterization ("low" and "high" climate sensitivity, respectively); the current climate is not simulated very well with these two models. The remaining simulations contain downscaling simulations of four different ENSEMBLES stream-1 GCM simulations: ECHAM5, BCM, ARPEGE and HadCM3Q0. Eight different RCMs have been used.[1]

In Table 1 we summarize the results for the relevant models:

Table 1 Average values over a common European area for two-meter temperature and for precipitation for two 30-year periods and for the four seasons

Average temperature (C)	Current climate (1961-1990)				Future climate (2070-2099)			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	DJF
ICTP-REGCM3_ECHAM5	2.8	7.7	15.9	9.7	5.8	10.4	18.9	12.7
MPI-M-REMO_ECHAM5	3.6	8.5	16.9	11.3	6.7	11.1	19.8	14.4
SMHIRCA_ECHAM5-r3	3.1	8.5	16.3	10.7	6.4	11.0	19.1	13.7
KNMI-RACMO2_ECHAM5	3.1	8.5	16.8	10.7	6.3	11.3	19.9	13.7
DMI-HIRHAM5_ECHAM5	3.8	9.0	17.5	11.6	6.9	11.6	20.0	14.5

[1] After the completion of this text, an error in the DMI-HIRHAM5_BCM simulation has been found for the period 2085-2099. The text will be updated as soon as a rerun has been analysed.

SMHIRCA_BCM	2.1	7.4	16.1	10.4	4.8	9.8	18.2	12.6
DMI-HIRHAM5_BCM	0.4	5.8	15.1	8.8	3.6	9.1	16.6	10.4
DMI-HIRHAM5_ARPEGE	3.5	7.9	17.4	12.3	6.1	10.3	20.0	14.6
CNRM-RM5.1_ARPEGE	2.5	7.7	17.6	10.5	5.1	10.3	20.8	13.0
ETHZ-CLM_HadCM3Q0	1.8	6.7	17.4	10.5	5.3	10.1	21.0	14.3
METO-HC_HadRM3Q0_HadCM3Q0	1.7	7.4	17.4	10.3	5.5	11.1	21.7	14.4

Average precipitation (mm/season)	Current climate (1961-1990)				Future climate (2070-2099)			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	DJF
ICTP-REGCM3_ECHAM5	256	197	181	248	267	193	184	262
MPI-M-REMO_ECHAM5	268	198	182	250	278	190	176	260
SMHIRCA_ECHAM5-r3	238	188	190	247	257	190	190	264
KNMI-RACMO2_ECHAM5	251	184	160	238	263	179	158	250
DMI-HIRHAM5_ECHAM5	328	245	220	327	353	249	232	353
SMHIRCA_BCM	288	250	277	320	309	263	266	322
DMI-HIRHAM5_BCM	278	202	164	271	295	212	160	275
DMI-HIRHAM5_ARPEGE	259	171	121	234	265	162	108	241
CNRM-RM5.1_ARPEGE	252	196	163	222	256	196	146	221
ETHZ-CLM_HadCM3Q0	252	170	118	243	275	173	110	256
METO-HC_HadRM3Q0_HadCM3Q0	234	190	155	214	256	190	143	223

Table 2 Climate change signal for each model winter and summer, and ensemble mean and standard deviation

Climate change signal	Temperature (K)		Precipitation (mm)	
	DJF	JJA	DJF	JJA
ICTP-REGCM3_ECHAM5	2.97	2.97	11.05	3.76
MPI-M-REMO_ECHAM5	3.14	2.92	9.75	-6.32
SMHIRCA_ECHAM5-r3	3.26	2.83	18.91	0.28
KNMI-RACMO2_ECHAM5	3.11	3.02	12.37	-2.10
DMI-HIRHAM5_ECHAM5	3.09	2.49	24.45	12.07
SMHIRCA_BCM	2.66	2.13	21.13	-10.44

DMI-HIRHAM5_BCM	3.24	1.55	17.18	-3.70
DMI-HIRHAM5_ARPEGE	2.62	2.63	6.22	-13.05
CNRM-RM5.1_ARPEGE	2.69	3.23	4.27	-17.17
ETHZ-CLM_HadCM3Q0	3.53	3.62	23.37	-7.28
METO-HC_HadRM3Q0_HadCM3Q0	3.78	4.33	21.47	-12.54
Ensemble average	3.10	2.88	15.47	-3.96
Ensemble standard deviation	0.36	0.73	6.71	8.31

It is not straightforward to compare changes in temperature and changes in precipitation on an equal footing. In Table 2 we show the change in temperature and precipitation in winter and summer, as well as the ensemble average and standard deviation. As a simple way forward, we have chosen to calculate the difference between the climate change signal for each model and the ensemble average, and normalize this quantity with the ensemble standard deviation of the quantity and season in question. Changes in precipitation have been calculated as absolute changes for each model, but it is not expected to be very different if relative changes are used. The result of this exercise is seen in Table 3. As an example, the HC downscaling of HadCM3Q0 exhibits a summer warming that exceeds the ensemble average by around twice the intra-ensemble spread of summer warming signals.

Table 3 Normalized deviation of individual European climate change for the winter and summer quantities listed in Table 2. Deviation of the signal from the ensemble mean is expressed in units of the intra-ensemble climate change standard deviation. The rank illustrates which simulations are closest to the ensemble average.

Normalized climate change	Temperature		Precipitation		RMS total	Rank
	DJF	JJA	DJF	JJA		
ICTP-REGCM3_ECHAM5	-0.366	0.121	-0.625	1.054	1.28	4
MPI-M-REMO_ECHAM5	0.100	0.051	-0.810	-0.140	0.83	2
SMHIRCA_ECHAM5-r3	0.444	-0.072	0.487	0.642	0.92	3
KNMI-RACMO2_ECHAM5	0.025	0.183	-0.439	0.359	0.60	1
DMI-HIRHAM5_ECHAM5	-0.020	-0.539	1.272	2.039	2.46	10
SMHIRCA_BCM	-1.219	-1.032	0.801	-0.628	1.89	6
DMI-HIRHAM5_BCM	0.388	-1.825	0.243	0.170	1.89	5
DMI-HIRHAM5_ARPEGE	-1.320	-0.343	-1.309	-0.938	2.11	8
CNRM-RM5.1_ARPEGE	-1.123	0.473	-1.586	-1.426	2.46	9
ETHZ-CLM_HadCM3Q0	1.204	1.005	1.119	-0.254	1.94	7
METO-HC_HadRM3Q0_HadCM3Q0	1.889	1.977	0.850	-0.878	2.99	11

An inspection of Tables 2 and 3 reveals that the most average model is KNMI-RACMO2_ECHAM5, *i.e.*, the model where the squared sum of the four climate change deviations is the smallest. The most anomalous simulations are METO-HC_HadRM3Q0_HadCM3Q0 (winter: high warming and wetting; summer: high warming and drying) followed by DMI-HIRHAM5_ECHAM5 (winter: average warming and high wetting; summer: low warming and anomalous wetting) and CNRM-RM5.1_ARPEGE (winter: low warming and low wetting; summer: rather high warming and anomalous drying). The ECHAM5-driven simulations are close to the average, at least partly due to the fact that they are the most frequent. They generally have a more positive summer precipitation signal than the others. BCM-driven simulations have a low warming in summer and an above-average wetting in winter. ARPEGE shows a very low winter warming, very small wetting in winter and a strong drying in summer. HadCM3Q0, finally, causes strong warming summer and winter, and strong wetting in winter.

It is important to note that this is a quite coarse ranking of the model simulations. We are only looking at two out of many model variables, and we have not at all looked at regional differences between climate change signals. Large-scale circulation changes will in general be different between the GCM simulations driving the regional downscaling simulations; the current list contains four different GCM simulations: five downscaling simulations of ECHAM5-r3, two of HadCM3Q0, ARPEGE and BCM.

The ranking in Table 3 should not be interpreted as a quality mark. There is an obvious bias arising from the fact that ECHAM5 is dominating as a driver, and there is no reason to believe that this global simulation has a higher quality than the others. Rather, the rank should help to choose a number of simulations that would span the space of possible climate change. How many of the simulations that can be used, obviously depends on the impacts model.