EGU2012-11221

High resolution RCM simulations for Germany: validation and projected climate changes

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Introduction

- An increased variability in precipitation and temperature for the warming future climate is expected, which requires very often adaptation strategies for e.g. infrastructure
- For the development of adaptation strategies usually climate impact studies on a regional scale are performed, which require high resolution RCM simulations results
- Furthermore, the aspect of uncertainties of simulation results is crucial in this kind of impact studies.
- In this study, **ensembles of coupled climate-runoff simulations** are performed for the assessment of changes in flood hazard for small and medium sized river catchments in Germany.
- Our ensemble includes 2 GCMs (ECHAM5, CCCma3) and for one GCM (ECHAM5) three realizations with different initial conditions, **2 RMCs (CCLM, WRF) with a final spatial resolution of 7km and 1 hour output timestep** to provide climate input data for hydrological modelling of small and medium sized catchments in Germany (see Figure1); in addition REMO simulations within the projects “UBA” and “BFG are included (Jacob et al., 2007).

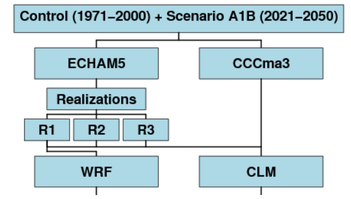

Figure 1: Schematic over the ensemble simulations strategy.

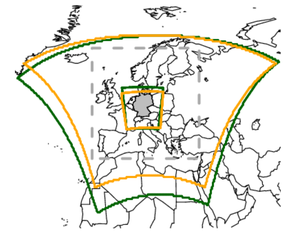

Figure 2: RCM double nesting strategy for CCLM (green) and WRF (orange)

Results of high resolution RCM simulations:

Validation

	DJF	MAM	JJA	SON	ANN
CLM-E40	-0.7	-1.1	-1.5	-0.6	-1.0
WRF-E40	-0.1	0.5	2.3	1.0	0.9
CLM-E5R1	-0.3	-0.6	-2.4	-0.8	-1.0
REMO-E5R1	-0.1	1.2	0.0	0.9	0.5
WRF-E5R1	0.2	0.8	0.6	0.3	0.5
CLM-E5R2	-0.4	-1.5	-2.2	-0.8	-1.2
REMO-E5R2	-0.1	0.0.	-0.2	0.7	0.1
CLM-E5R3	0.4	-1.0	2.3	-0.3	-0.8
CLM-C3	-1.9	-3.5	-4.3	-2.0	-2.9

	DJF	MAM	JJA	SON	ANN
CLM-E40	47	51	20	33	36
WRF-E40	37	29	-8	8	14
CLM-E5R1	76	62	48	61	60
REMO-E5R1	73	21	27	10	31
WRF-E5R1	54	25	19	29	30
CLM-E5R2	70	60	54	63	57
REMO-E5R2	83	33	32	19	39
CLM-E5R3	68	65	44	60	58
CLM-C3	68	59	58	54	59

Table 1: Fine nest seasonal and annual mean temperature bias [K] (top) and relative precipitation bias [%] (bottom) averaged over Germany between 1971 to 2000.

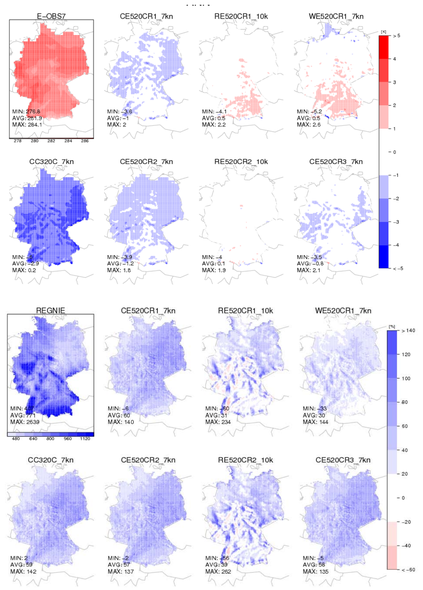

Figure 3: Difference map of annual temperature [K] in comparison to E-OBS data set (top) and relative bias in precipitation [%] compared to the REGNIE data set (bottom) for all ensemble members.

Projected climate changes

	DJF	MAM	JJA	SON	ANN
CLM-E5R1	**1.4**	0.2	**1.1**	**1.5**	**1.0**
REMO-E5R1	**1.6**	0.2	**0.9**	**1.2**	**1.0**
WRF-E5R1	**1.6**	0.3	0.6	**1.4**	**1.0**
CLM-E5R2	**1.9**	**1.0**	**0.7**	**1.5**	**1.3**
REMO-E5R2	**2.0**	**1.0**	**0.9**	**1.6**	**1.3**
CLM-E5R3	0.7	**0.7**	**0.8**	**1.0**	**0.8**
CLM-C3	**1.0**	**0.9**	**1.2**	**1.3**	**1.1**
ENS mean	1.4	0.6	0.9	1.4	1.1
ENS sd	0.5	0.4	0.2	0.2	0.2

	DJF	MAM	JJA	SON	ANN
CLM-E5R1	1.3	5.0	-7.9	9.3	1.9
REMO-E5R1	-8.1	9.1	-1.6	**14.9**	3.6
WRF-E5R1	0.4	**15.9**	6.2	12.9	**8.8**
CLM-E5R2	**12.3**	**12.8**	-0.6	1.8	**6.6**
REMO-E5R2	-4.2	8.7	3.7	1.4	2.4
CLM-E5R3	9.6	-0.7	-5.0	6.0	2.5
CLM-C3	-3.7	6.8	**-8.9**	-1.6	-1.9
ENS mean	1.1	8.2	-2	6.4	3.4
ENS sd	7.5	5.4	5.7	6.2	3.5

Table 2: Projected fine nest seasonal and annual mean temperature changes [K] (top) and relative precipitation changes [%] (bottom) averaged over Germany between 1971 to 2000 and 2021 to 2050. Numbers in bold font are statistically significant at the 95% confidence interval. .

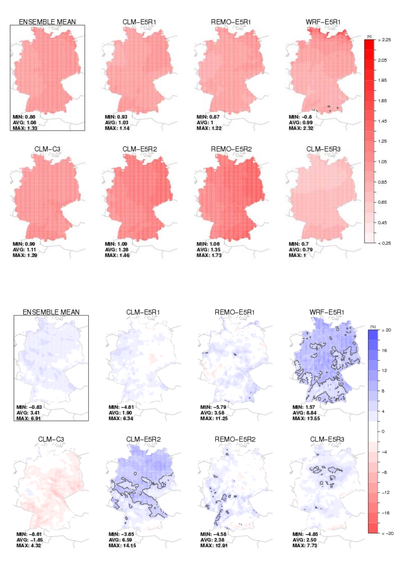

Figure 4: Projected annual mean temperature change [K] (top) and annual precipitation change [%] (bottom) between 1971 to 2000 and 2021 to 2050 for all ensemble members and the ensemble mean; contours delineate significant and non-significant regions at the 95% confidence interval. Note, that for temperature almost all regions are significant.

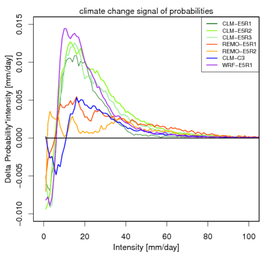

Figure 5: Projected change of precipitation PDFs over Germany between 1971 to 2000 and 2021 to 2050 for all ensemble members

Conclusions:

Validation of RCM results:

- GCM biases are transferred to RCMs
- RCM biases do not add up with further nesting in this study, i.e. biases from coarse nest are transferred to fine nest
- CLM model adds a cold and wet bias throughout the domains
- WRF adds a lower mean bias for temperature and precipitation for most of Europe
- Benefit of fine nest (7km) simulations: bringing high detail in spatial patterns and an added value to precipitation intensity distribution.

Climate Change Signals:

- All GCMs project a warming over Europe and an increase of annual precipitation in northern and a decrease in southern Europe.
- RCMs results tend to less warming compared to GCMs.
- The impact of the RCM on the climate change signal is more dominant for precipitation compared to temperature.
- The significance tests show a robust temperature increase for the ensemble.
- For precipitation the projected changes are not robust.
- Despite the different biases of the RCMs, the range of projected climate change signals for temperature and precipitation are much closer.

References:

- Berg, P., Wagner, S., Kunstmann, H., Schädler, G., 2011. High resolution RCM simulations for Germany: Part I - validation. Clim. Dyn. submitted October 2011.
- Schädler, G., Berg, P., Düthmann, D., Feldmann, H., Ihringer, J., Kunstmann, H., Liebert, J., Merz, B., Ott, I., Wagner, S., 2012: Flood hazard in a changing climate. CEDIM-report, (http://www.cedim.de/download/Flood Hazards in a Changing limate.pdf)
- Wagner, S., Berg, P., Schädler, G., Kunstmann, H., 2011. High resolution RCM simulations for Germany: Part II - projected climate changes. Clim. Dyn. submitted October 2011.

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