Analysis of precipitation changes in Central Europe within the next decades based on simulations with a high resolution RCM ensemble

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1. Introduction

The 4th IPCC report summarises the effects on precipitation for Europe based on global climate models (GCM) simulations as follows: In northern Europe the climate will become moister – especially during winter – and the Mediterranean region will be much drier in the future – especially for the summer months - than it is today. Central Europe lies in the transition region between these two regimes. This is reflected in the fact that the current GCMs do not give a consistent picture of the precipitation characteristics for this region in the 21st century. Possible reasons for that may be that mountain ridges like the Alps are not adequately accounted for in the coarse resolution of GCMs and that climate change induced changes in weather patterns are highly variable in this region.

In this study we focus on that part of Central Europe situated between 47.5°N to 52°N and 5°E to 13°E (cf. Fig. 1).

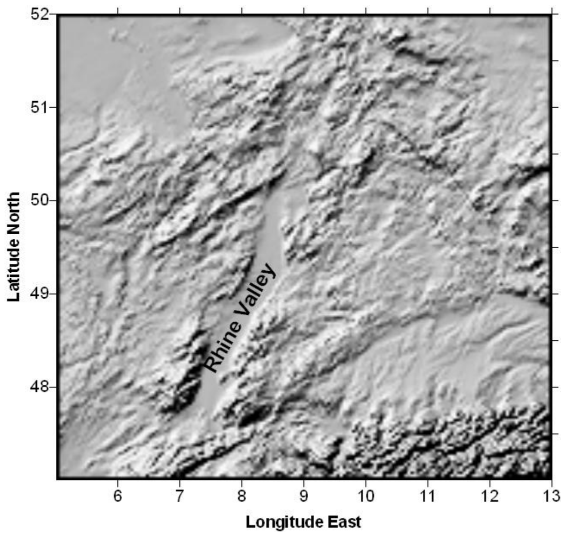

Figure 1: Orography detail of the study area.

This includes regions with complex topography north of the Alps from eastern France to Bavaria, for instance the Upper Rhine Valley and the Black Forest, regions where trends in temperature and precipitation over the last decades have been observed to be significant and higher than average. Furthermore, it includes densely populated narrow valleys prone to flash floods, making detailed knowledge of future precipitation scenarios - including uncertainty estimates – essential for the development of adaptation measures. Therefore, high-resolution simulations with regional climate models (RCMs) are necessary to derive reliable estimates of the upcoming changes in the precipitation pattern.

We analyse climate simulations over several decades performed with RCMs on grid sizes below 20 km for Central Europe and focus on possible precipitation changes until the middle of this century. We will discuss climatological precipitation as well as heavy precipitation events with a 10-year return period.

2. Ensemble Description

Our ensemble is based on a number of long-term simulations performed with the RCMs COSMO-CLM (with 18 km and 7 km resolution) and REMO (with a horizontal resolution of 10 km). Up to now, all RCM simulations are driven by ECHAM5 IPCC runs. The RCM simulations have been comprehensively evaluated against gridded observation data (*Feldmann et al.*, 2008) and include different realisations of present day and future climate as well as different IPCC scenarios for future emissions.

Table 1: List of ensemble simulations. Numbers after the underscore indicate the realisation.

Model/Data set	Grid size	Period	Simulations
REMO UBA simulations	10 km	1971-2000	C20_1
		2011-2040	A1B_1, B1_1, A2_1
COSMO CLM Consortial Runs	18 km	1971-2000	C20_1, C20_2, C20_3
		2011-2040	A1B_1, A1B_2, B1_1, B1_2
CCLM	7 km	1971-2000	C20_1, C20_3
		2011-2040	A1B_1, A1B_3

The 30 year projection covers the period 2011 – 2040. During this phase the greenhouse gas emissions of the different scenarios do not differ much, but the variations still have an effect on the internal variability. The climate change effects during the projection period are compared to a reference period from 1971 – 2000. Overall the ensemble consists of 6 members for the present-day climate simulations and 9 members for the projections.

3. Methodology

An important aspect is the assessment of the uncertainty of regional projections. For that purpose, we evaluate the ensemble of simulations to establish estimates and assess the regional changes in the precipitation regime. In addition, the use of a set of realizations provides the opportunity to broaden the data basis for an extreme values analysis for a given period.

A good representation of the present day climate in the models is necessary but not sufficient to derive reliable estimates of future climate. As an additional criterion we use the agreement between the ensemble members: if a majority of simulations shows a similar behaviour in a given region, despite their different setups or states of internal variability, we can have more confidence in the climate change estimates.

For the climatological precipitation, the statistical significance of the changes has been calculated using the non-parametric Wilcoxon test. The extreme values have been calculated using the peak-over-threshold approach and fitting a Kappa distribution on the highest 10% of the distribution (Früh et al. 2008). Here the significance of the climate change signal has been derived by calculating confidence intervals via bootstrapping.

4. Results

We will discuss the following findings:

RCM simulations provide added value: whereas by construction the GCMs see no spatial variability below their grid size and exhibit low ensemble agreement, the RCM ensemble results show considerable spatial variability of the precipitation distribution. Although the results for the different models and setups show discrepancies especially in some regions with complex topography, there are distinct regions of high ensemble agreement concerning increase/decrease of precipitation (Fig. 2).

The different realisations of future climate do not differ significantly between the emissions scenarios used (possibly in contrast to temperature). However, there are larger variations between the different realisations of each emission scenario. This indicates that for precipitation the internal variability is dominant over the differences between the IPCC SRES scenarios until the middle of the 21st century. Also, the three realisations for the present-day climate (CLM-CR C20) do not differ significantly.

Future and present-day mean precipitation differs significantly for yearly totals and the winter season, but less for the summer season.

There is a marked tendency towards increased variability (standard deviation/mean) in the future precipitation for all seasons, with higher 95th percentile during all seasons and lower 5th percentile of summer precipitations, i.e. a tendency towards a more extreme climate.

Changes in the spatial patterns of heavy precipitation events are not necessarily coincident with the patterns for climatological precipitation.

There seems to be a northwest to southeast gradient in the precipitation changes indicating a combination of the transition from the Mediterranean to northern European regime with the transition from Atlantic to continental conditions.

5. Outlook

In a next step, we will augment the ensemble by RCM simulations driven by other GCMs.

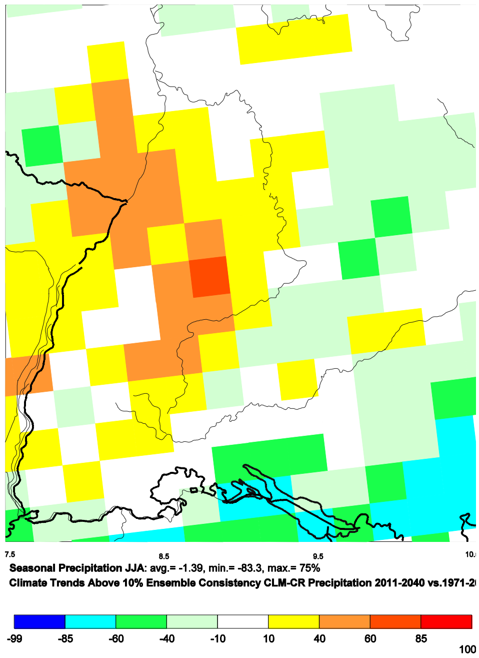

Figure 2: Percentage agreement between the ensemble members for the climate change signal 2011 – 2040 vs. 1971 – 2000 for JJA mean precipitation changes above 10% (absolute).

References

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