# Climate change scenarios over complex topography: assessing the added value of dynamical downscaling

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## 1. Introduction

There is a growing demand for reliable and up-to-date climate change information at local to regional scale in order to effectively manage future climate risks. The provision of climate change scenarios is a highly challenging task mainly due to the cascade of uncertainties ranging from emission uncertainties over model uncertainties down to uncertainties arising from natural fluctuations.

To sample part of these uncertainties, climate change scenarios are commonly constructed based on the joint evaluation of several future model projections. Moreover, since the information provided by general circulation models (GCMs) is too coarse for many applications, a subsequent downscaling step is necessary. This is often accommodated by running regional climate models (RCMs) driven by GCMs at their lateral boundaries.

In Switzerland, the RCM-GCM model suite of the EU project ENSEMBLES was the basis for generating the climate change scenarios “CH2011” (CH2011, 2011). Temperature and precipitation changes were evaluated as seasonal means for five regions and three future scenario periods. Uncertainties were assessed based on a Bayesian multi-model combination algorithm (Buser et al. 2009, Fischer et al. 2012). One limitation in the CH2011 scenarios is the way model and emission uncertainty is represented in the regional projections (in essence, too few GCMs are involved and all models run according to the A1B emission scenario only).

This study is part of the ELAPSE project which is related to the COST Action VALUE (http://www.value-cost.eu) and which aims at exploring the uncertainty in the existing Swiss scenarios. We inter-compare the regional climate change responses separately in the RCMs and in their driving GCMs. The ultimate goal is to derive scaling relationships that can be applied to GCM projections lacking an explicit dynamical downscaling step such as the CMIP5 model experiments (Taylor et al. 2009, 2012). If successful, this would allow expanding on the model sample size and emission scenarios.

## 2. Data & Method

Seasonal mean temperature and precipitation changes over the Alpine region defined in the PRUDENCE project (Christensen et al. 2007) are evaluated in two configurations of ENSEMBLES model projections: (a) in 14 coupled RCM-GCM projections at 25 km resolution and (b) in their driving GCM data at about 2.5° resolution (6 simulations). The projected changes and associated uncertainties (for the A1B emission scenario) are further compared to model projections from CMIP5. These GCM simulations run at horizontal resolutions between 1.8° and 3.75° depending on the model and in total comprise a number of 20 simulations according to the RCP6.0 scenario (comparable to A1B). The analysis is performed for 30-year scenario periods across the 21st century. As reference period we use 1980-2009 as in CH2011 (2011). In order to model projection uncertainty and internal decadal variability, we will apply the same Bayesian multi-model combination as described in Fischer et al. (2012).

## 3. Preliminary Results

First results show consistent climate change signals over the whole Alpine region for the two emission scenarios A1B (ENSEMBLES) and RCP6.0 (CMIP5). These scenarios lead to roughly the same cumulative carbon emissions over the course of the 21st century and are thus directly comparable. The largest differences between the data sets are found for summer temperature and precipitation change. Here, uncertainties are derived from the empirical distributions rather than through Bayesian statistics.

Whereas the ENSEMBLES GCMs project a warming in summer of up to about 7°C for 2070-2099 with respect to 1980-2009, about 1.3°C less is obtained by the ENSEMBLES RCMs and the more recent GCM simulations within CMIP5 (Fig. 1). In all seasons, the Alpine warming is smaller in ENSEMBLES RCMs and CMIP5 than in the ENSEMBLES GCMs. Surprisingly the ENSEMBLES RCMs do not reflect the signal of their driving GCMs but rather agree with the CMIP5 multi-model ensemble.

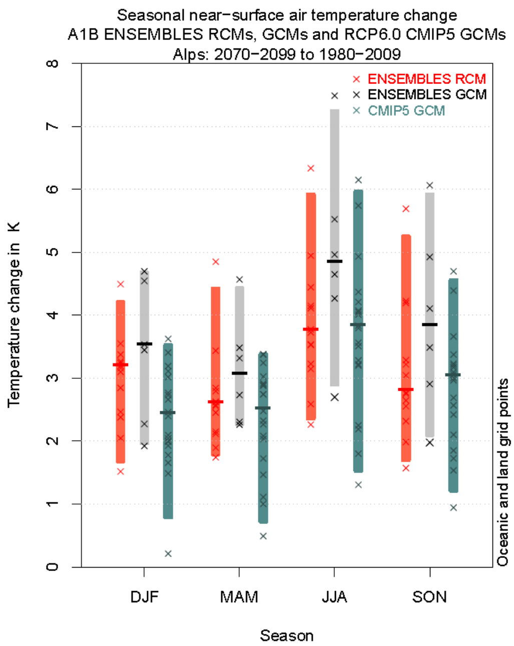


Figure 1. Expected seasonal temperature change (°C)

over the Alpine region for the scenario period 2070-2099 using 3 different multi-model sets. Bars indicate the 95% confidence interval. The crosses correspond to individual model projections. Number of models: 14, ENSEMBLES RCMs, 6 GCMs, 20 CMIP5 GCMs.

In case of precipitation (Fig. 2), the ENSEMBLES RCMs as well as the driving GCMs project a statistically significant drying in summer at the end of the 21st century (down to -40% in case of the ENSEMBLES GCMs). This expected drying is much less clear in the case for the larger ensemble of CMIP5 models. They project an ensemble mean precipitation change of about -8% but uncertainties range between -30% and +20%. Hence precipitation may increase or decrease even in summer. For the other seasons result are roughly comparable.

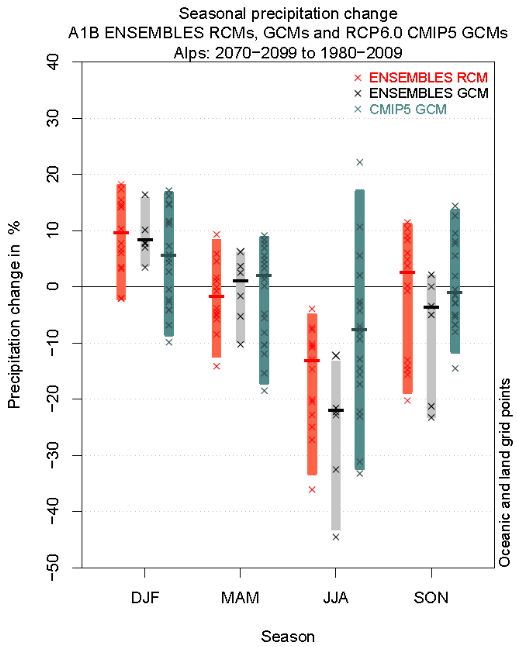


Figure 2. Same as Fig. 1, but for relative precipitation change (%).

## 4. Summary and Outlook

A first insight into the relationship of the climate change signal from RCM projections and from its driving GCM projections could be gained with the help of raw model output. Strongest differences were detected in summer for both precipitation and temperature.

This analysis is the basis for subsequent studies aiming to test whether robust scaling factors among the joint multi-model projections can be derived and to quantify what the associated uncertainties are. In this way, the so-derived (probabilistic) regional climate response could largely extend our model data basis and uncertainty estimates of regional climate change. To this stage, clear differences were found between the different multi-model settings. It remains unclear if similar relationships exist for other parameters besides temperature and precipitation.

## References

Buser, C. M., Künsch, H. R., Lüthi, D., Wild, M., Schär, C. (2009). Bayesian multi-model projection of climate: bias assumptions and interannual variability. Climate Dynamics, 33(6), 849-868.

CH2011 (2011), Swiss Climate Change Scenarios CH2011, published by C2SM, MeteoSwiss, ETH, NCCR Climate and OcCC, Zurich, Switzerland, 88 pp, ISBN: 978-3-033-03065-7.

Christensen, J. H., Carter, T. R. , Rummukainen, M., Amanatidis, G. (2007). Evaluating the performance and utility of regional, climate models: the PRUDENCE project. Climatic Change 81, 1-6.

Fischer, A. M., Weigel, A. P., Buser, C. M., Knutti, R., Künsch, H. R., Liniger, M. A., Appenzeller, C. (2012). Climate change projections for Switzerland based on a Bayesian multi-model approach. International Journal of Climatology, 32(15), 2348-2371.

Taylor, K. E., Stouffer, R. J., Meehl, G. A. (2009). A Summary of the CMIP5 Experiment Design. Retrieved November 2013, from CMIP5 Coupled Model Intercomparison Project: http://cmip-pcmdi.llnl.gov/cmip5/experiment_design.html.

Taylor, K. E., Balaji, V., Hankin, S., Juckes, M., Lawrence, B., Pascoe, S. (2012). CMIP5 Data Reference Syntax (DRS) and Controlled Vocabularies. Retrieved from CMIP5 Coupled Model Intercomparison Project: http://cmip-pcmdi.llnl.gov/cmip5/.