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Relations between RCMs and GCMs in the ENSEMBLES simulations

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Current climate change projections are based on comprehensive multi-model ensembles of global and regional simulations. These are large collections of climate model data mainly based on availability. A major problem in drawing conclusions from these simulations are the inter-model dependencies which exist e.g. through identical model physics or similar parametrizations. In the case of different regional climate models (RCMs) driven by a single global model, these dependencies become particularly strong due to shared boundary conditions. The goal of our study is to thoroughly investigate the interplay of RCMs and their drivers and to see how much additional information RCMs can provide for regional averages of temperature or precipitation.

In this study we analyze the results from the EU ENSEMBLES project, an assessment of European climate change (Hewitt and Griggs, 2004). We aggregate monthly mean temperatures over eight European climate regions and decompose the time series of the observations, the driver and its corresponding RCM into a sum of mean, trend, seasonal cycle and residuals by ordinary least squares. We also compute standard deviations of the residuals which measure interannual variability and correlations between residuals of the RCM and its driver. We analyze the aforementioned dependence between different regional climate models and address a key source of uncertainty in regional climate projections: the transfer of biases from the global to the regional model at the lateral boundaries. In the control period (1961-1990), biases are defined as differences between observations and climate simulations.

We find that RCMs can add value to GCMs, especially in regions of complex topography. Here, RCMs are generally able to simulate temperature values more realistically due to their higher spatial resolution. Still, the lateral boundaries exert a strong forcing. Since RCMs inherit the general circulation of their driver at these boundaries similar year-to-year temperature fluctuations occur. Furthermore, different RCMs driven by the same GCM depict similar biases. These RCM-GCM relations do not change from the control to the scenario period.

Based on these findings we employ a Bayesian hierarchical statistical model that decomposes the effects from regional climate models themselves and their driving global climate models. We use an additive structure for the biases of RCMs driven by GCMs in the prior and a simple Markovian dependence for the interannual fluctuations. In doing so, we are able to exploit the whole data matrix of the ENSEMBLES project for obtaining combined projections, together with an assessment of their uncertainty.