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Probabilistic projections of regional temperature and precipitation change

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Given the expected and already observed impacts of climate change, there is growing consensus that global mean temperature rise should be limited to below 2 or 1.5 degrees. These global limits have been set in order to avoid intolerable regional impacts of global warming. Analysis of the risks involved needs systematic probabilistic projections of regional climate change for a given amount of global warming. Here, we present a linear mixed effects model (e.g. Bates and Pinheiro, 2001) that provides probabilistic projections of regional changes in temperature and precipitation based on the comprehensive set of AR4 AOGCM simulations and probabilistic projections of global mean temperature change as provided by a reduced complexity climate model.

The method makes use of the already established property that regional temperature and precipitation changes are fairly linearly related to global mean temperature change as simulated by current AOGCMs (e.g. Mearns et al., 2001, Mitchell, 2003, Giorgi 2008). This remarkable property forms the basis of the so called pattern scaling approaches. Our statistical approach goes beyond currently available scaling approaches (e.g. Giorgi et al., 2008) as it explicitly allows us to

1. estimate and compare the inter-model and inter-scenario variability of the scaling coefficients to validate the general assumption of scenario independence
2. take into account the correlation between the temperature and precipitation component of these variations
3. consider further predictors to broaden the predictor variables beyond global mean temperature alone.

Firstly, the scenario and run independence of the scaling coefficients is essential as it provides the foundation to inter-/extrapolate regional climate changes to other scenarios/ levels of global warming.
Secondly, AOGCMs showing a high temperature increase may also show a particularly high precipitation increase or vice versa. Thus inter-AOGCM (as well as inter-scenario or inter-run) variations of the temperature and precipitation scaling coefficients might be correlated leading to correlations of both components of the two dimensional uncertainty distribution of regional climate change. These are important whenever impacts depend on the interaction of temperature and precipitation changes. As an example we provide regional temperature and precipitation projections for the Greenland ice sheet where increasing precipitation may at least partly balance the loss due to increasing temperatures.
Thirdly, regional aerosol effects are known to be one of the most important limitations of simple pattern scaling approaches. By the example of East Asia we demonstrate how the basic model could be extended by an aerosol component to significantly improve the precipitation projections.