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A new method for probabilistic assessment of regional climate impacts in dependence of cumulative GHG emission budgets

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Given the expected and already observed impacts of climate change there is growing agreement that global mean temperature rise should be limited to below 2 or 1.5 degrees. The translation of such a temperature target into guidelines for global emission reduction over the coming decades has become one of the most important and urgent tasks. In fact, there are four recent studies (Meinshausen et al. 2009, Allen et al. 2009, Matthews et al. 2009 and Zickfeld et al. 2009) which take a very comprehensive approach to quantifying the current uncertainties related to the question of what are the “allowed amounts” of global emissions given specific limits of global warming. Here, we present an extension of this budget approach allowing to focus on specific regional impacts. The method is based on probabilistic projections of regional temperature and precipitation changes providing the input for available impact functions. Using the example of Greenland’s surface mass balance (Gregory et al., 2006) we will demonstrate how the probability of specific impacts can be described in dependence of global GHG emission budgets taking into account the uncertainty of global mean temperature projections as well as uncertainties of regional climate patterns varying from AOGCM to AOGCM.

The method utilizes the AOGCM based linear relation between global mean temperature changes and regionally averaged changes in temperature and precipitation. It allows to handle the variations of regional climate projections from AR4 AOGCM runs independent of the uncertainties of global mean temperature change that are estimated by a simple climate model (Meinshausen et al., 2009). While the linearity of this link function is already established for temperature and to a lesser degree (depending on the region) also for precipitation (Santer et al. 1990; Mitchell et al. 1999; Giorgi et al., 2008; Solomon et al., 2009), we especially focus on the quantification of the uncertainty (in particularly the inter-AOGCM variations) of the associated scaling coefficients. Our approach is based on a linear mixed effects model (e.g. Bates and Pinheiro, 2001). In comparison to other scaling approaches we do not fit separate models for the temperature and precipitation data but we apply a two-dimensional model, i.e., we explicitly account for the fact that models (scenarios or runs) showing an especially high temperature increase may also show high precipitation increases or vice versa. Coupling the two-dimensional distribution of the scaling coefficients with the uncertainty distributions of global mean temperature change given different GHG emission trajectories finally provides time series of two dimensional uncertainty distributions of regional changes in temperature and precipitation, where both components might be correlated. These samples provide the input for regional specific impact functions.

In case of Greenland we use a function by Gregory et al., 2006 that allows us to calculate changes in sea level rise due to changes in Greenland’s surface mass balance in dependence of regionally averaged changes in temperature and precipitation. The precipitation signal turns out to be relatively strong for Greenland with AOGCMs consistently showing increasing precipitation with increasing global mean temperature. In addition, temperature and precipitation increases turned out to be highly correlated for Greenland: Models showing an especially high temperature increase also show high precipitation increases reflected by a correlation coefficient of 0.88 for the inter-model variations of both components of the scaling coefficients. Taking these correlations into account is especially important because the surface mass balance of the Greenland ice sheet critically depends on the interaction of the temperature and precipitation component of climate change: Increasing precipitation may at least partly balance the loss due to increasing temperatures.