Sensitivity of groundwater adaptation decisions to uncertainties in climate change scenarios

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Abstract
Decision-making under uncertainty is about making the best possible decision given an uncertain environment. Expected global climate change introduces large uncertainties to planning decisions in climate sensitive sectors of society such as water resources, agriculture and others. It is generally recognised that society is going to have to cope with a changing climate even if mitigation measures such as the Kyoto Protocol are fully implemented. In order to avoid dangerous or undesirable climate impacts, adaptation to climate change is an essential response strategy. However, adaptation decisions are dependent on a variety of factors including information about uncertain climate impacts. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) concluded that many impact studies fail to adequately consider the uncertainties embedded in the scenarios they adopt, partly due to such uncertainties being poorly quantified in the climate scenarios themselves. This suggests that quantifying uncertainty in climate change projections is of great importance. This paper attempts to quantify the uncertainty involved in a climate change assessment in order to determine the sensitivity of adaptation decisions to climate scenario uncertainties.

The paper develops new methods for representing uncertainties in climate change scenarios for a range of spatial scales (from global to local) and for quantifying the frequency distributions of future climates at a variety of scales. Some of these distributions (for example, natural climate variability) can be objectively determined, while others (for example, future greenhouse gas emissions) can only be estimated subjectively using scenario analysis. The paper bridges the gap between scenario and uncertainty analysis using a combination of Bayesian and Monte Carlo methods.

A large enough number of runs from a General Circulation Model (GCM) are still not available for such an objective so we use the data that are currently available. We use a simple probabilistic climate model (Wigley and Raper, Science, 293 (2001) p 451-4) that emulates the results of GCMs from the IPCC TAR. This emulator samples uncertainty in greenhouse gas emissions, the climate sensitivity, the carbon cycle, ocean mixing, and aerosol forcing. We use results from the literature to constrain certain model parameters (e.g., climate

sensitivity). We then propagate this uncertainty to the nine GCMs used in the IPCC TAR through the pattern-scaling technique. This is done for two seasons (Winter - DJF, Summer - JJA) and two variables (surface temperature and precipitation). In order to combine the resulting probabilities we devised regional skill scores for the different GCMs (in essence model validation). These are based on model performance (how well the model simulates the observed climate) and on model convergence (how well models converge to the multi-model ensemble average in the future). Regional skill scores are calculated for each GCM, season and variable. The scores are then used to weigh different GCMs, when combining the deterministic GCM results for a particular grid box with the global probabilistic results, through pattern-scaling. Uncertainty in downscaling is examined using a stochastic weather generator. Such a probabilistic result fits better with the needs of designing appropriate management responses regarding adaptation to climate change, now increasingly recognised as a priority response to our changing climate.

The applicability of this type of probabilistic climate information is tested in a case study that focuses on groundwater recharge in East Anglia, in the UK. Adaptation decisions were elicited from stakeholders, who also advised us on their preferred decision-making framework. We explore the sensitivity of these decisions to ‘upstream’ uncertainties (which include uncertainty about different development paths, climate sensitivity, regionalisation, etc.) and investigate robust strategies with different decision-making frameworks.