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The role of hydrological model complexity and uncertainty in climate change impact assessment

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Global climate change will impose remarkable regional alterations on landscape systems, regional water cycles in general and catchment hydrology in particular. It is understood that even the most sophisticated regional climate models, driven by GCMs, are not capable to fully project the exact future course of water related variables. While general trends are concurrently represented in most GCMs, large uncertainties still remain in the projected magnitude, variability and especially regional patterns. Still, these data are the best available source of information to develop adaptation strategies for water resources managers. They serve as driving inputs for subsequent hydrological models, which transfer the future climate signal into hydrological quantities at the watershed level. While scientific expertise has been collected about hydrologic model uncertainty for short to medium range forecasts, little quantitative knowledge is as yet available about the role of hydrological model complexity for climate change impact assessment. The presented study investigates the varieties of different model response and thus the planning options resulting for water authorities and managers. Three hydrological models, each representing a different model complexity in terms of process description, parameter space and spatial and temporal scale, are compared:

A) MOHYSE (Fortin & Turcotte 2006), a lumped bucket-type conceptual model, calibrated by means of the SCE-UA approach.

B) HYDROTEL (Fortin et al. 2001), a fully-operational, physically-based model, based on hydrological response units and calibrated also by means of the SCE-UA approach.

C) PROMET (Mauser 1997, Ludwig & Mauser 2000), a process-based, spatially explicit and un-calibrated environmental model for water balance, runoff formation and nutrient fluxes.

The study is performed in the Ammer watershed, a 709 km^2 catchment in the Bavarian alpine forelands, Germany. All models are driven and validated by a 30-year time-series (1971-2000) of observation data. It is expressed by objective functions, that all models, A and B due to calibration, perform almost equally well for runoff simulation over the validation period. Systematic deviances in the hydrographs and the spatial patterns of hydrologic variables are discussed. Virtual future climate (2071-2100) is generated by the Canadian Regional Climate Model (vers 3.7.1), driven by the Coupled Global Climate Model (vers. 2) based on an A2 emission scenario. The hydrological model performance is evaluated by a number of flow indicators, such as flood frequency, annual 7-day and 30-day low flow and maximum seasonal flows. It is demonstrated, that the modified climatic boundary conditions cause dramatic deviances in hydrologic model response. Model A shows a tremendous overestimation of evapotranspiration, while model B and C behave in a comparable range. Still, their significant differences, like spatially explicit patterns of summerly water shortage or spring flood intensity, highlight the necessity to extend and quantify the uncertainty discussion in climate change impact analysis towards the remarkable effect of hydrological model complexity. The suitable level of complexity and the implications for water managers are discussed for specific application purposes.