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Assessing climate change impact by integrated hydrological modelling

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Future climate may have a profound effect on the freshwater cycle, which must be taken into consideration by water management for future planning. Developments in the future climate are nevertheless uncertain, thus adding to the challenge of managing an uncertain system. To support the water managers at various levels in Denmark, the national water resources model (DK-model) (Højberg et al., 2012; Stisen et al., 2012) was used to propagate future climate to hydrological response under considerations of the main sources of uncertainty.

The DK-model is a physically based and fully distributed model constructed on the basis of the MIKE SHE/MIKE11 model system describing groundwater and surface water systems and the interaction between the domains. The model has been constructed for the entire 43.000 km2 land area of Denmark only excluding minor islands. Future climate from General Circulation Models (GCM) was downscaled by Regional Climate Models (RCM) by a distribution-based scaling method (Seaby et al., 2012). The same dataset was used to train all combinations of GCM-RCMs and they were found to represent the mean and variance at the seasonal basis equally well. Changes in hydrological response were computed by comparing the short term development from the period 1990 – 2010 to 2021 – 2050, which is the time span relevant for water management. To account for uncertainty in future climate predictions, hydrological response from the DK-model using nine combinations of GCMs and RCMs was analysed for two catchments representing the various hydrogeological conditions in Denmark. Three GCM-RCM combinations displaying high, mean and low future impacts were selected as representative climate models for which climate impact studies were carried out for the entire country. Parameter uncertainty was addressed by sensitivity analysis and was generally found to be of less importance compared to the uncertainty spanned by the GCM-RCM combinations.

Analysis of the simulations showed some unexpected results, where climate models predicting the largest increase in net precipitation did not result in the largest increase in groundwater heads. This was found to be the result of different initial conditions (1990 – 2010) for the various climate models. In some areas a combination of a high initial groundwater head and an increase in precipitation towards 2021 – 2050 resulted in a groundwater head raise that reached the drainage or the surface water system. This will increase the exchange from the groundwater to the surface water system, but reduce the raise in groundwater heads. An alternative climate model, with a lower initial head can thus predict a higher increase in the groundwater head, although the increase in precipitation is lower. This illustrates an extra dimension in the uncertainty assessment, namely the climate models capability of simulating the current climatic conditions in a way that can reproduce the observed hydrological response.

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