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Uncertainty of simulated groundwater levels arising from stochastic transient climate change scenarios

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The evaluation of climate change impact on groundwater reserves represents a difficult task because both hydrological and climatic processes are complex and difficult to model. In this study, we present an innovative methodology that combines the use of integrated surface – subsurface hydrological models with advanced stochastic transient climate change scenarios. This methodology is applied to the Geer basin (480 km^2) in Belgium, which is intensively exploited to supply the city of Liège (Belgium) with drinking water.
The physically-based, spatially-distributed, surface-subsurface flow model has been developed with the finite element model HydroGeoSphere . The simultaneous solution of surface and subsurface flow equations in HydroGeoSphere, as well as the internal calculation of the actual evapotranspiration as a function of the soil moisture at each node of the evaporative zone, enables a better representation of interconnected processes in all domains of the catchment (fully saturated zone, partially saturated zone, surface). Additionally, the use of both surface and subsurface observed data to calibrate the model better constrains the calibration of the different water balance terms. Crucially, in the context of climate change impacts on groundwater resources, the evaluation of groundwater recharge is improved. .
This surface-subsurface flow model is combined with advanced climate change scenarios for the Geer basin. Climate change simulations were obtained from six regional climate model (RCM) scenarios assuming the SRES A2 greenhouse gases emission (medium-high) scenario. These RCM scenarios were statistically downscaled using a transient stochastic weather generator technique, combining 'RainSim' and the 'CRU weather generator' for temperature and evapotranspiration time series. This downscaling technique exhibits three advantages compared with the 'delta change' method usually used in groundwater impact studies. (1) Corrections to climate model output are applied not only to the mean of climatic variables, but also across the statistical distributions of these variables. This is important as these distributions are expected to change in the future, with more extreme rainfall events, separated by longer dry periods. (2) The novel approach used in this study can simulate transient climate change from 2010 to 2085, rather than time series representative of a stationary climate for the period 2071-2100. (3) The weather generator is used to generate a large number of equiprobable climate change scenarios for each RCM, representative of the natural variability of the weather.
All of these scenarios are applied as input to the Geer basin model to assess the projected impact of climate change on groundwater levels, the uncertainty arising for different RCM projections and the uncertainty linked to natural climatic variability. Using the output results from all scenarios, 95% confidence intervals are calculated for each year and month between 2010 and 2085. The climate change scenarios for the Geer basin model predict hotter and drier summers and warmer and wetter winters. Considering the results of this study, it is very likely that groundwater levels and surface flow rates in the Geer basin will decrease by the end of the century. This is of concern because it also means that groundwater quantities available for abstraction will also decrease. However, this study also shows that the uncertainty of these projections is relatively large compared to the projected changes so that it remains difficult to confidently determine the magnitude of the decrease.
The use and combination of an integrated surface – subsurface model and stochastic climate change scenarios has never been used in previous climate change impact studies on groundwater resources. It constitutes an innovation and is an important tool for helping water managers to take decisions.