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Impacts of climate change on runoff in a Northern-Alpine watershed, assessed from an ensemble of climate models

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The complex process of runoff genesis in Alpine watersheds results from a combination of higher precipitation induced by orographic effects, reduced evapotranspiration rates caused by relatively low mean temperatures, and temporary storage in form of snow and ice. Global climate change may lead to a modification of these factors and thus may have considerable impacts on runoff.

The aim of this investigation was to assess how climate change may impact the average and extreme runoff in an Alpine watershed. The catchment of the river Lech (1,000 km^2) in the Northern Alps (Austria) was selected as study area. An ensemble of RCMs, driven by different GCMs, was used to simulate current (1971-2000) and future (2070-2099) climate. The data was provided by the EU-funded project ENSEMBLES and is based on the IPCC SRES A1B emission scenario. The simulations were performed with a horizontal resolution of about 25 x 25km. In order to overcome the gap between the grid-based RCM output and station site required input data of the hydrological model, two different techniques were applied. The first one is referred as delta change approach and is well-known as a simple and robust downscaling technique. Relative changes between the present climate and the future scenarios as simulated by RCMs were transferred to an observed historical time series (1971-2000) of precipitation and temperature. The second technique bias-corrected the RCM output using quantile-quantile mapping for precipitation and a monthly scaling for temperature. Quantile-quantile mapping adjusts the mean and the variability of the simulated precipitation by matching the cumulative density function (cdf) of the control simulation with the cdf of the observation. The transformation was then applied to each quantile of the climate scenario, under the assumption that the bias are identical for the same probability in the control run and the future scenario. The cdfs were calculated on a monthly level and the correction was applied on daily precipitation values. Daily temperatures were bias-corrected by adding a monthly scaling factor obtained from the difference between observation and the control simulation of the RCM.

The climate simulation data was used to drive the semi-distributed hydrological model HQsim to examine possible changes in runoff regime and flooding risk. When forcing the hydrological model with bias-corrected climate data from the control run of the RCMs, a good agreement between observed and simulated average and extreme runoff was detected. The impacts of climate change on runoff indicate large seasonally varying changes. Both a decrease in monthly runoff during summer and an increase in winter minimize the inter-annual disparities between low runoff in winter and high runoff in spring and summer. An analysis of floods shows a significant increase in flood hazard until the end of this century. Due to these changes water management will face new challenges in future.

The innovative character of the proposed study lies in the use of an ensemble of climate models as well as the application of different downscaling techniques. Thereby, it was possible to carry out an assessment of the uncertainties involved in the hydrological projections. The overall agreement of the obtained results suggests confidence in the simulations.