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# Groundwater runoff in small river basin: retrospective analysis and projections due to climate change

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The analysis of the impact of observed and predicted climate variability on the total and groundwater runoff of the small river basin in humidal boreal conditions is considered on the basis of a physically based precipitation-runoff model. The model consists of two submodels. Surface precipitation transformations within a representative landscape element are simulated using the first SURFBAL submodel. It simulates the processes of snow accumulation on the surface of the earth, its melting during winter thaws and spring, the formation of surface runoff and potential ET, taking into account freezing and melting of soil cover. The results of the calculations are transferred to the second submodel, the groundwater flow model, as upper boundary conditions on the land surface for each landscape zone. The second model is based on MODFLOW2005 using the UZF package. This submodel calculates the flow rate in the unsaturated zone, groundwater recharge and ET, and the formation of surface and groundwater runoff within the basin.
In the first stage of the study, a retrospective analysis of the runoff in the studied basin was carried out on the basis of data on the dynamics of observed precipitation and temperature over the past 70 years. The results of this analysis have shown the long-term non-stationarity of the processes of total runoff formation, which is well in line with the observations of measured river runoff in the terminal gagging station. This non-stationarity is related to the increase in river flow and groundwater discharge in winter over the last 40-30 years due to the observed increase in winter temperatures.
At the second stage, the forecast calculations for the next 50 years have been carried out. For predictive simulation of precipitation and temperature series, the climatic generator LARS-WG was used, which generates time series of precipitation and daily temperature resolution based on forecasts of global circulation climate models from the CMIP5 family. For the forecasts 19 CMIP5 models were used.
The simulation results showed that the predicted groundwater runoff averaged over all climate models turned out to be more stable in the long-term and intra-annual section than the total surface runoff.The estimated intra-annual surface runoff hydrograph has changed in comparison with the retrospective period due to a decrease in the spring peak runoff of the river in the spring and an increase in winter runoff. The results of the forecast for different models from the CMIP5 family differ significantly. This is since all models predict a similar increase in the average annual temperature in the next 50 years. However, the predicted trends in annual precipitation vary greatly, from a 15-20% decrease in some models to a 20% increase in others.
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