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Modelling impacts of climate change on the hydrology of a Mongolian catchment using an appropriate permafrost conceptualization

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Climate change is expected to have considerable impacts on global water resources. Regional impacts will vary considerably depending on climatological, geographical and hydrological characteristics. A region which is particularly vulnerable to climate change is Central Asia. Precipitation in this area is low and highly variable in space and time, and river discharges are largely dependent on the melting of snow and ice. Changes in temperature and precipitation may seriously affect the timing, duration and intensity of high and low flows and hence water availablity in downstream areas. Mongolia is an example of a country where several of these vulnerable catchments can be found. Permafrost conditions prevail in large parts of the country and have a substantial influence on catchment hydrology, which might be altered by climate change. The objective of this study is to determine the impacts of future climate change on the hydrology of a Mongolian catchment, the Buyant River, taking into account permafrost conditions. This is done in two steps. First, four different permafrost conceptualizations within an existing conceptual hydrological model (HBV) are compared to select the most appropriate one. Two conceptualizations take permafrost into account by only calibrating under non-permafrost (summer) conditions and differ in their elevation representation of the catchment (single and multiple elevation zones). The other two conceptualizations explicitly simulate permafrost conditions by adding freezing and melt functions and an ice store to each of the three water stores of HBV. Five years have been used for calibration and five years for validation. Second, the impact of climate change on the hydrology of the Buyant River is determined by using the outputs of four Global Circulation Models (GCMs) for three SRES emission scenarios in HBV with the most appropriate permafrost conceptualization. The delta change method is used to translate output from GCMs to climate time series for future conditions. Results in the calibration are moderate to good for the conceptualizations with an explicit simulation of permafrost, where the model with one elevation zone performs better in the validation than the model with multiple elevation zones. The other two conceptualizations perform poor to moderate, particularly because groundwater flow persists in winter despite that this period is not considered in the calibration of these cases. The HBV model with explicit permafrost simulation and one elevation zone is used for climate change impact assessment. For the period 2080-2100, the discharge of the Buyant River is likely to increase in spring and most probably will decrease in summer and autumn, for some combinations of GCMs and scenarios considerably. Uncertainties in climate change impacts are large, where the uncertainty due to different GCMs is found to be more important than the uncertainty due to different scenarios. Additionally, uncertainties in downscaling, data and hydrological model structure and parameters can further complicate the analysis of the catchment's response to climate change.