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Intercomparison of runoff predictions by lumped and distributed models before and after climate change

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Hydrological models provide a framework to conceptualise and investigate the relationships between climate and water resources. Different types of hydrological models have been developed in the past ranging from simple empirical models over lumped conceptual models to complex, physically based, spatially distributed models. Although these models are widely used in hydrological climate change impact studies, little information is known about the impact of the structural differences between these hydrological models on the predictions. In this study three lumped, conceptual models, NAM, PDM and VHM, and two distributed models, MIKE SHE and WetSpa, were applied to the basin of the rivers Grote Nete & Grote Laak in Belgium. The model simulation results were analyzed and the model responses compared under past, present and hypothetical future climate conditions. The models have been developed based on a common dataset, and calibrated and validated against an identical set of model performance criteria including traditional measures and extreme values plots. The MIKE SHE model is additionally validated for results on groundwater heads since it is the only model considered with an extended 3-D groundwater component. All models were able to capture the flow dynamics very well with high efficiencies (NSE>0.7) and simulate the flow events during winter and summer periods very accurately. Extreme peak flows and low flow minima and their distributions match well with the empirical distributions derived for the considered simulation period, as well as during the summer and winter seasons separately. Also the groundwater heads in MIKE SHE and their seasonal variation had a high model performance. The calibrated models were subsequently tested on their capacities to predict the runoff under changing climate (rainfall and potential evapotranspiration) conditions. An innovative analysis that relates peak flow changes with underlying rainfall changes has been applied to empirically test the accuracy of the model-based runoff changes. The results showed the VHM and PDM models estimate higher changes in peak flows in comparison with the observations and the other models, especially for the lower peaks. When applying the 5 models to assess the impact of climate change on peak flows, the same findings were obtained. VHM and PDM simulate peak flow increases up to 50% by the wet climate scenarios for Belgium till 2100, whereas the increase by other models is limited to a maximum of 35%. Regarding the changes in low flows under changing climate conditions, the differences between the models are even larger. Under the dry scenario conditions by 2100 MIKE SHE is predicting the lowest changes of low flow minima (25%), while these changes are limited to 40-50% in the WetSpa, PDM and VHM simulations and 60% in the NAM results. The lower expected impact by MIKE SHE might be directly related to the more detailed 3-D groundwater component. All models predict a decrease in the low flows under future climate scenarios, but the magnitude of decrease strongly depends on the model structure.