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Explicit modeling of groundwater-surface water interactions using a simple bucket-type model

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Longer dry spells can become critical for water supply and groundwater dependent ecosystems. During these dry spells groundwater is often the most relevant source for streams. Hence, the hydrological behavior of a catchment is often dominated by groundwater surface water interactions, which can vary considerably in space and time. While classical hydrological approaches hardly consider this spatial dependence, quantitative, hydrogeological modeling approaches can couple surface runoff processes and groundwater processes. Hydrogeological modeling can help to gain an improved understanding of catchment processes during low flow. However, due to their complex parametrization and large computational requirements, such hydrogeological models are difficult to employ at catchment scale, particularly for a larger set of catchments. Then bucket-type hydrological models remain a practical alternative. In this study we combine the strengths of both the hydrogeological and bucket-type hydrological models to better understand low flow processes and ultimately to use this knowledge for low flow projections.
Bucket-type hydrological models have traditionally not been developed with focus on the simulation of low flow. One consequence is that interactions between surface and groundwater are not explicitly considered. Water fluxes in bucket-type hydrological models are commonly simulated only in one direction, namely from the groundwater to the stream but not from the stream to the groundwater. This latter flux, however, can become more important during low flow situations. We therefore further developed the bucket-type hydrological model HBV to simulate low flow situations by allowing for exchange in both directions i.e. also from the stream to the groundwater. The additional HBV exchange box is developed by using a variety of synthetic hydrogeological models as training set that were generated using a fully coupled, physically based hydrogeological model. In this way processes that occur in different spatial settings within the catchment are translated to functional relationships and effective parameter values for the conceptual exchange box can be extracted. Here, we show the development and evaluation of the HBV exchange box. We further show a first application in real catchments and evaluate the model performance by comparing the simulations to benchmark models that do not consider groundwater surface water interaction.