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Water balance estimation in high Alpine terrain by combining distributed modeling and a neural network approach (Berchtesgaden Alps, Germany)

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The regional water balance of mountainous catchments in the northern limestone Alps is affected by the temporal and spatial variability of meteorological parameters, steep gradients and a complex hydrogeological situation. The karst aquifer with its subsurface flow channel network, fractures and rock matrix has so far unknown effects on the spatial and temporal dynamic of the water balance in a given Alpine catchment due to unknown storage capacities and water flux conditions. The impact of Alpine snow cover dynamics and resulting snowmelt is additionally affecting hydrological processes. However, mountainous regions are regarded as ′water towers′ and karst rocks as important and vulnerable aquifers for water supply and ecosystem functioning and distributed modeling is a common method to describe the annual water balance of a watershed for management purposes. Reliable distributed modeling cannot be implemented in high Alpine karst terrains by traditional approaches due to unknown storage processes at local and catchment scale. We present an artificial neural network extension of a distributed hydrological model (WaSiM-ETH) that allows to account for subsurface water transfer in a karstic environment. This method enables to describe the unknown subsurface boundary fluxes and account for them in the distributed model. The extension was developed for the Alpine catchment of the river “Berchtesgadener Ache” (Berchtesgaden Alps, Germany), which is characterized by extreme topography and calcareous rocks. The model assumes porous conditions and does not account for karstic environments, resulting in systematic mismatch of modeled and measured runoff in discharge curves at the outlet points of neighboring high alpine sub-catchments. We explicitly derive the algebraic transfer function of an artificial neural net to calculate the missing boundary fluxes. The result of the ANN is then implemented in the groundwater module of the distributed model as boundary flux, and considered during the consecutive model process. The boundary influx in the sub-catchment improved the distributed model, as performance increased from NSE = 0.34 to NSE = 0.57. In combination with a new snow modeling approach implemented in WaSiM-ETH in the study area (Project SnowNPB), this combined approach allows distributed quantification of water balance components including subsurface water transfer.