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Distributed water balance modelling in a highly complex mountain catchment in the Swiss Alps: identifying the relevant parameter set

Martina Kauzlaric (1,2), Bruno Schädler (1,2), Rolf Weingartner (1,2)

(1) Institute of Geography, University of Bern, Bern, Switzerland, (2) Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland

The main objective of the MontanAqua transdisciplinary project is to develop strategies moving towards a more sustainable water resources management in the Crans-Montana-Sierre region (Valais) in view of global change. Therefore a detailed assessment of the available water resources in the study area today and in the future is needed. The study region is situated in the inner alpine zone, with strong altitudinal precipitation gradients: from the precipitation rich alpine ridge down to the dry Rhône plain. A typical plateau glacier at the top of it is partly drained through the karstic underground formations and linked to various springs. The main anthropogenic influences on the system are reservoirs and diversions to the irrigation channels. Thus the study area does not cover a classical hydrological basin as the water flows frequently across natural hydrographic boundaries. This is a big challenge from a hydrological point of view, as we cannot easily achieve a closed, measured water balance.
A representative climatological measurement network covering altitudinal belts as well as the main land cover types has been recently installed, but the calibration and validation of a hydrological model require longer time series. The general lack of comprehensive historical data in the catchment reduces the degree of process conceptualization possible, as well as prohibits reliable parameter estimation. The parametrization of physically based models using only physical system characteristics is of practical impossibility, since bulk properties of the hydrological system have to be estimated at model element scales which are usually coarser compared to the measurement scale.
Thus besides the need for a physically based hydrological model, a flexible discretization is essential. It minimizes the resolution of spatial discretization (fewest number of elements to preserve the essential physics) while still capturing the local heterogeneities in parameters and process dynamics.
The Penn State Integrated Hydrologic Model (PIHM) (Kumar,2009) has been selected to estimate the available natural water resource for the whole study area. It is a semi-discrete, physically-based model which includes: channel routing, overland flow, subsurface saturated and unsaturated flow, rainfall interception, snow melting and evapotranspiration. Its unstructured mesh decomposition offers a flexible domain decomposition strategy for efficient and accurate integration of the physiographic, climatic and hydrographic watershed and allows to divert water into irrigation channels or introduce water e.g. from sources.
The scale independent parameters and their ranges are established a priori with values obtained from the literature or from site experiments, and extrapolated in space based on stationary catchment attributes (mainly soil and land cover data).
After a variance-based sensitivity analysis, where model output variance is decomposed into relative contributions from individual parameters and parameter interactions (van Werkhoven et al.,2008), calibration is performed only for a limited number of parameters to which the model is most sensitive. This ‘constrained’ calibration is based on case studies in the headwaters of the basin. There, rivers are still uninfluenced or anthropogenic control on them is easily quantifiable. Calibration is carried out against historical discharge and climatological measurements.
The present study addresses the problem of identifying parameters with a primary impact on model response with the application of data sets commonly available in mountainous regions, and nevertheless allowing enough model complexity to reduce parameter estimation efforts as well as predictive model uncertainty.
Because of the structural and dynamical complexity of processes in mountainous areas, the upper watershed area of the catchment provides a rigorous evaluation framework for the approach. It represents a challenging investigation ground, where the high climatic sensitivity as well as modelling weaknesses, compensation of errors, and the possible amplification of the latter two should be evidenced concurrently.

Reference

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