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Research papers

Constraining hydrological model parameters using water isotopic compositions in a glacierized basin, Central Asia

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ABSTRACT

Water stable isotope signatures can provide valuable insights into the catchment internal runoff processes. However, the ability of the water isotope data to constrain the internal apportionments of runoff components in hydrological models for glacierized basins is not well understood. This study developed an approach to simultaneously model the water stable isotopic compositions and runoff processes in a glacierized basin in Central Asia. The fractionation and mixing processes of water stable isotopes in and from the various water sources were integrated into a glacio-hydrological model. The model parameters were calibrated on discharge, snow cover and glacier mass balance data, and additionally isotopic composition of streamflow. We investigated the value of water isotopic compositions for the calibration of model parameters, in comparison to calibration methods without using such measurements. Results indicate that: (1) The proposed isotope-hydrological integrated modeling approach was able to reproduce the isotopic composition of streamflow, and improved the model performance in the evaluation period; (2) Involving water isotopic composition for model calibration reduced the model parameter uncertainty, and helped to reduce the uncertainty in the quantification of runoff components; (3) The isotope-hydrological integrated modeling approach quantified the contributions of runoff components comparably to a three-component tracer-based end-member mixing analysis method for summer peak flows, and required less water tracer data. Our findings demonstrate the value of water isotopic compositions to improve the quantification of runoff components using hydrological models in glacierized basins.

1. Introduction

Glacierized basins substantially provide freshwater for the downstream agriculture and potable water supply, especially in warm and dry years (Prasch et al., 2013). However, changes in climate are altering the short- and long-term characteristics of runoff processes in these basins (Stahl and Moore, 2006; Stahl et al., 2008; Duethmann et al., 2015). Understanding changes in runoff generation processes is therefore critical to the downstream water resource utilization, considering the particular vulnerability of snow and glacier-dominated environments to changing climatic conditions (Barnett et al., 2005; Penna et al., 2014). Sound quantification of glacier melt, snowmelt, rainfall and groundwater contributions to the streamflow helps to understand the changes in freshwater availability provided by glacierized headwater basins (Jost et al., 2012).

Hydrological modeling is an effective tool to quantify changes in individual runoff components, providing insights into the catchment dynamics. A number of studies have modeled the contributions of runoff components to streamflow in glacierized basins (Jost et al., 2012; Lutz et al., 2014; He et al., 2015). For example, Verbunt et al. (2003) investigated the contributions of snowmelt and glacier melt to total runoff using a spatial-gridded hydrological model in high alpine catchments in Switzerland. Engelhardt et al. (2014) analyzed the spatial variations and temporal evolution of the water sources, including snowmelt, glacier melt and rainfall, by means of a distributed hydrological model in a Norway glacierized basin. Zhao et al. (2013)

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