Hydrological modeling of an alpine dolomite karst system

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Introduction

In karst hydrology modeling of the rainfall-runoff relationship can be made from different points of view: physical models, conceptual models, and black-box models. However, in most cases, due to the hydrologic complexity and limitation of data availability, conceptual or black-box models are applied. In this study we apply a conceptual model on a dolomite karst system in the Austrian Alps implementing explicitly all steps of a proper model development.

The study site is located in the northern part of the national park "Northern Limestone Alps". Its altitude ranges from 550 m to 956 m ASL. Due to the dominating dolomite, the catchment is not as heavily karstified as limestone karst systems, but shows typical karst features such as conduits and sink holes.

During an event in August 2009 two streams passing the study site (Weißenbach and Wilder Graben) were continuously monitored concerning their water levels before and after passing the study site. The stream sections and three additional springs were sampled for δ18O. Rainfall amount and δ18O was observed at a climate station.

Tracer experiments and age dating techniques showed the large heterogeneity of the hydrologic system: While some springs are dominated by preferential flow, others drain almost constant with ages >15 a. Moreover, the stream sections are characterized by large interflow contributions.

This integrated information allowed us to develop a conceptual model of the system shown on the left.

Proper model development

The numerical model consists of an overflow reservoir connected to three parallel linear reservoirs. The overflow reservoir represents the immobile storage of the system which is water content of the soil. It is controlled by two parameters, its maximum storage OF_max and its initial overflow deficit OF_0. The linear reservoirs below represent the slow flow, interflow and preferential flow components, controled by their storage constants K_slow, K_interflow and K_pool. Simple mixing equations were used for δ18O predictions.

Results

Flow predictions and δ18O predictions obtained by using an automatic calibration method are in good agreement with the observations. The model captures the variability between the different observation point for the discharge as well as δ18O. Deviations in predicting the δ18O peak values can be attributed to the simplicity of the mixing equations.

Evaluation

For evaluation regional sensitivity analysis was applied. If a parameter is not sensitive, its values will plot on a straight line; the larger the deviation from this line the higher the sensitivity. The blue lines show the results using only discharge, the red lines the sensitivity using both discharge and δ18O observations. While the senstivity of OF_max increases, K_interflow and K_pool decrease. Hence, δ18O increased the model performance for the soil storage and decreased it for the interflow and fast routeine.

Conclusions

In this study a simple model was applied to a dolomite karst system with different flow components draining diffuse and concentrated reservoirs at different locations. The model development process including characterization, system perception, numerical model development, implementation and evaluation raised the reliability of the model on the one hand and showed also ways for further improvement on the other hand.

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