Hydrological modeling of an alpine dolomite karst system

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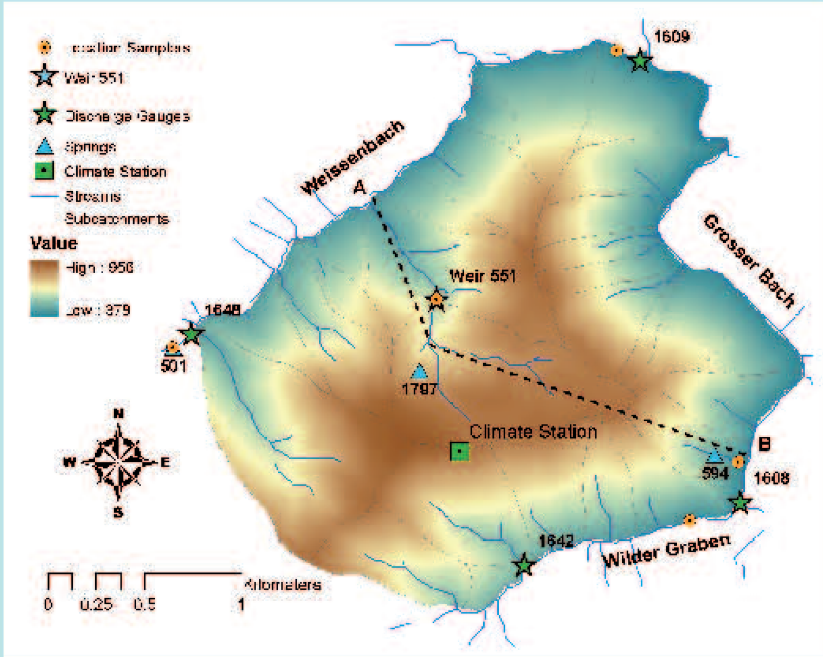
HYDROLOGY

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 explicitely all steps of a proper model development.

Proper model development

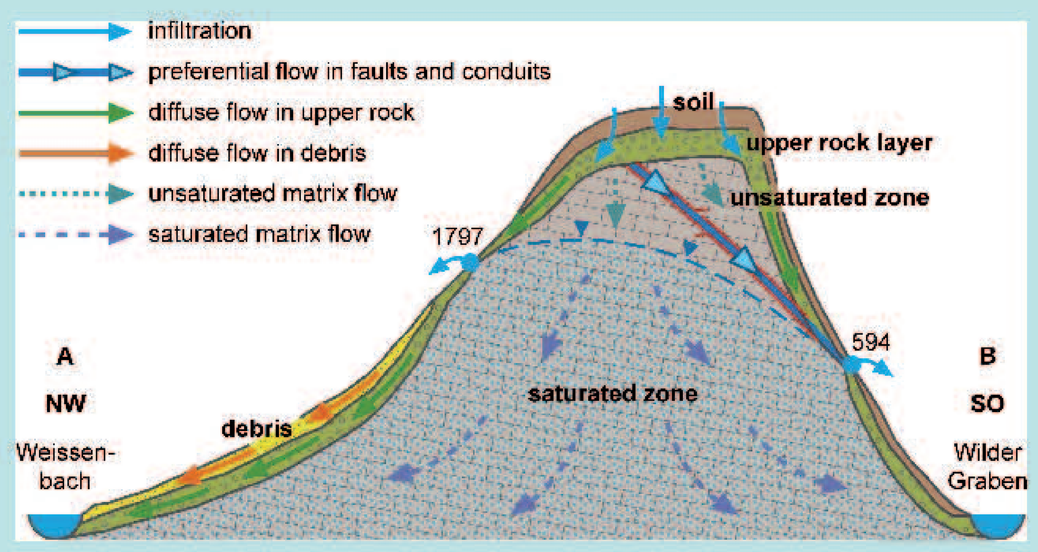
Characterization



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 $\delta^{18}O$. Rainfall amount and $\delta^{18}O$ was observed at a climate station.

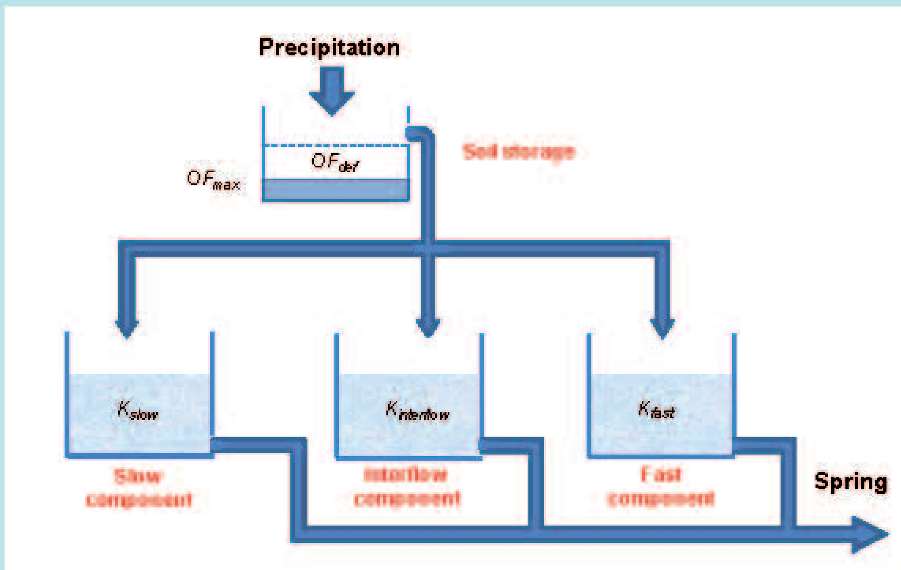
Perception



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 contbribations.

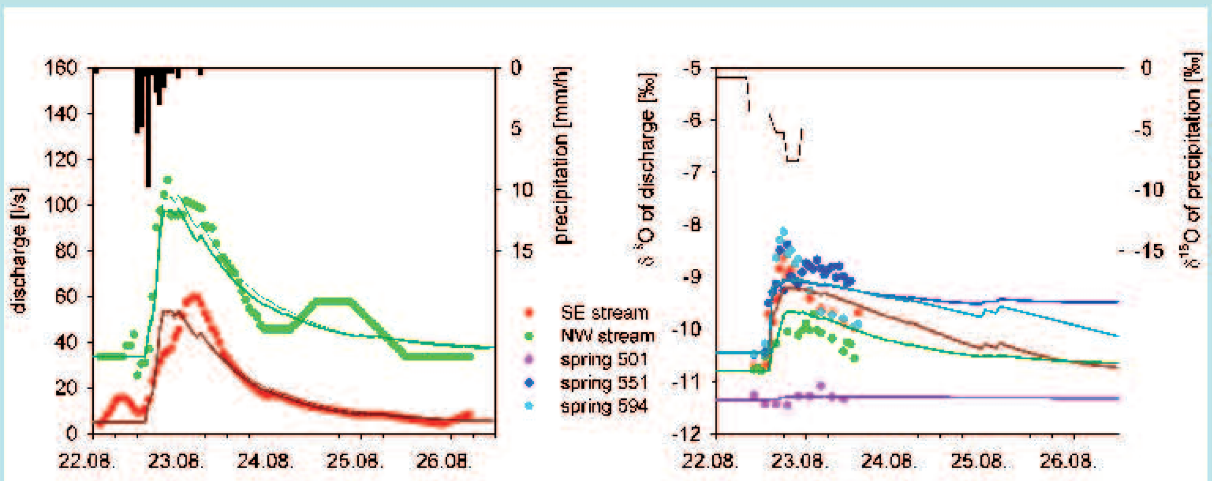
This integrated information allowed us to develop a perceptual model of the system shown on the left.

Model structure



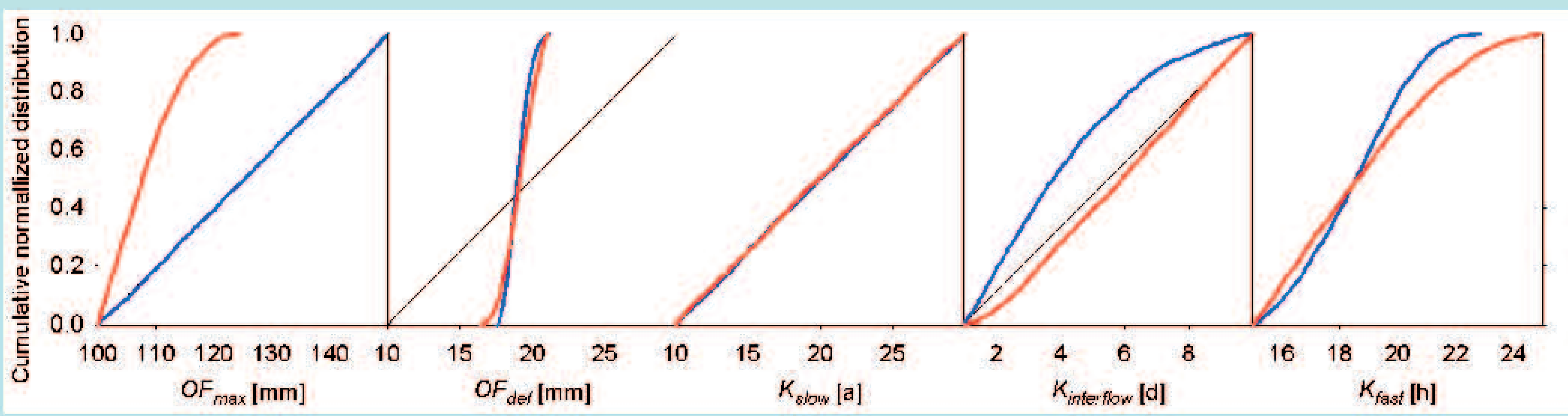
The numerical model consists of an overflow reservoir connected to three parallel linear reservoirs. The overflow reservoir represents the immobile storage of the system which is water content of the soil. It is controlled by two parameters, its maximum storage OF_{max} and its initial overflow deficit OF_{def}. The linear reservoirs below represent the slow flow, interflow and preferential flow components, controled by their storage constants K_{slow}, $K_{interflow}$ and K_{fast}. Simple mixing equations were used for $\delta^{18}O$ predictions.

Results



Flow predictions and $\delta^{18}O$ 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 dirscharge as well as $\delta^{18}O$. Deviations in predicting the $\delta^{18}O$ 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 $\delta^{18}O$ observations. While the senitivity of OF_{max} increases, $K_{interflow}$ and K_{fast} decrease. Hence, $\delta^{18}O$ increased the model performance for the soil storage and decreased it for the interflow and fast routine.

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.

Acknowledgements

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