Geophysical Research Abstracts
Vol. 18, EGU2016-15561, 2016
EGU General Assembly 2016

A numerical groundwater model to assess the hydrogeological behavior of a relict rock glacier aquifer (Niedere Tauern Range, Austria)

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A three dimensional numerical groundwater model representing a relict rock glacier with an extent of 0.17 km^2, located in the Eastern Alps (Schöneben rock glacier, Niedere Tauern Range, Austria) is used to highlight the impact of the major internal aquifer structures and the morphology of the aquifer base on the discharge behavior. The model is implemented in MODFLOW and calibrated using the discharge data of the spring. The recharge is determined based on precipitation and evapotranspiration which is calculated using a simple soil water balance model in combination with the monthly potential evapotranspiration. Data are provided by an automatic weather station on the Schöneben rock glacier where precipitation and air temperature are continuously measured. It is renounced to use a snow model in order to keep the model as simple as possible. Therefore the investigation is limited to the time periods from late summer to the beginning of the snowmelt in spring. The aquifer geometry and in particular the morphology of the aquifer base are based on geophysical investigations (ground penetrating radar and seismic refraction). However, due to gaps of the geophysical investigations the interpolation of the aquifer base at the margin of the rock glacier is related to uncertainties. Therefore, two different morphologies of the aquifer base were used which mainly differ in the slope of the south-eastern margin. Several model setups with increasing complexity of the internal structure (from homogeneous to heterogeneous) were applied to demonstrate the effects of the vertical (layering) and horizontal (preferential flow) aquifer heterogeneity on the discharge behavior. The results show that a model with a homogeneous setup cannot satisfyingly reproduce the discharge dynamics observed at the Schöneben rock glacier. With a heterogeneous setup, the model fit greatly improves but shows differences between the horizontally and vertically heterogeneous setups. The morphology of the aquifer base is important for the discharge behavior, especially when a simple internal structure is considered. However, with a more complex internal structure including a higher number of parameters, the impact of the aquifer base can be compensated through the calibration of the other aquifer parameters. Among the investigated model setups the best fit to the observed discharge is achieved in the calibration as well as in the validation by a combination of vertical and horizontal heterogeneities, which are related to differences in hydraulic conductivities of about three orders of magnitude (in the range of 1E-2 to 1E-5 m/s). This indicates that relict rock glaciers cannot be considered as simple homogeneous aquifer systems but as highly heterogeneous and that their consideration in alpine catchments is not straightforward.