A new hybrid approach for modelling groundwater flow in karst aquifers

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Abstract

Groundwater flow modelling in karst aquifers represents a real challenge that requires adapted methods. The applicability of an innovative hybrid approach for modelling groundwater flow in karst aquifers, namely the Hybrid Finite Element Mixing Cell (HFEMC) method, is evaluated. The hybrid approach consists in combining a classical finite element (FE) model, to model slow flow in the rock matrix, with spatially distributed lumped reservoirs, to model fast flow in the karst conduits network. Water exchanges between the rock matrix and the conduits network are accounted for by means of an internal Fourier boundary conditions (BC). This BC (1st order exchange relation) allows to control the magnitude of water transfers between fast and slow flow domains.

We tested the applicability of the HFEMC method on a schematic synthetic domain and on a real karst system. In the synthetic case analysis, we discussed dynamic processes of groundwater storage occurring in the karst system during a recharge pulse. The study focuses on the influence of selected parameters on representative variables such as the discharge curve of the karst system or pressure and mass transfers between conduits and rock matrix sub-domains. In this way, an inversion of the hydraulic gradient between karst conduits and the surrounding rock matrix is shown to occur during the recharge pulse. This phenomenon results in a temporary storage of water from conduits to the rock matrix, which impacts the modelled discharge curve. The first test performed on a real study site, the Noiraigue spring karst system (Jura mountains, Switzerland), exemplify the use of two separated lumped reservoirs for describing the conduits network, which allows to consider two base levels in the karst system. It also points out the challenges to face when modelling a complex natural karst system with the HFEMC approach.

The results obtained show that the HFEMC approach is a good candidate to model groundwater flow in karst aquifers.

Keywords
Karst, Groundwater flow modelling, Hybrid approach

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