Geophysical Research Abstracts
Vol. 21, EGU2019-13588, 2019
EGU General Assembly 2019

Assessment of groundwater recharge processes in a carbonate aquifer under semi-arid climate by an integrated surface-subsurface, multi-continuum model

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The Mediterranean karst aquifers are subjected to water scarcity problems due to increased water consumption as a result of population increase and specific climatic conditions (i.e., precipitation patterns). A thorough understanding of flow and transport dynamics based on numerical modeling is therefore required as a basis for sustainable water management practices. In particular, an accurate estimation of recharge rates is a challenge for predictive modeling of large-scale groundwater reservoirs. In this study, we assess the hydrological-hydrogeological cycle of the Western-Mountain-Aquifer (9000 km^2, located in Israel and the Palestinian Territories). The aquifer is characterized by deep, buried karst conduits as a result of the geological development during the Oligocene, the corresponding landscape development as well as paleo-canyons being generated during the Messinian event (6 Ma), determining today's discharge point at the Taninim/Timsah spring (Laskow et al., JoH, 2011). Fractures and conduits provide preferential flow paths in karstified rocks, collecting groundwater under rapid flow conditions, while the rock matrix provides substantial storage and slow drainage. Infiltration processes occur under highly variable conditions, i.e. discrete vertical flow in shafts and fractures and distributed, diffuse infiltration across the matrix blocks. Exposed karst features (i.e., sinkholes), a several hundred meters thick vadose zone, and erratic precipitation events aid this irregular flow dynamics, which require advanced numerical approaches to adequately account for these processes. Here, we employ the finite element, distributed, multi-continuum flow simulator HydroGeoSphere (Aquanty, 2015) on a high-performance-computing platform. HydroGeoSphere is highly flexible and simulates variably saturated subsurface flow coupled to an overland flow system, i.e. the hydrological cycle, starting from surface flow. Flow in the variably saturated fractured-porous subsurface is simulated using a double-continuum approach based on the Richards' equation with van Genuchten parameters. This way the duality of karstic flow, with rapid flow through conduits and slow flow through the rock matrix can be modelled, both in the vadose as well as in the phreatic zone. This concept is expected to account for the complex infiltration characteristics of the rock-soil landscape, local recharge along karst features, transmission losses of ephemeral streams (wadis), and highly variable precipitation patterns. The model shall finally be employed as a management tool of the aquifer.