



Application of a novel cascade-routing and reinfiltration concept with a Voronoi unstructured grid in MODFLOW 6, for an assessment of surface-water/groundwater interactions in a hard-rock catchment (Sardon, Spain)

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Abstract

Integrated hydrological modelling (IHM) can reliably characterize surface-water/groundwater interactions in complex hydrological systems such as hard-rock systems (HRS), located in water-limited environments (WLE). Such HRS-WLE conditions are represented by Sardon catchment (~80 km²) in Spain, where the MODFLOW 6 modelling environment was tested, applying the following improvements as compared to previous works in that catchment: a new conceptual model, driving forces redefined based on remote sensing data, an unstructured Voronoi grid, and, most importantly, a novel cascade-routing and reinfiltration (CRR) concept. In the standard MODFLOW 6, rejected infiltration and groundwater exfiltration have always been considered as sinks (evaporation). However, in reality, that water can not only evaporate but also reinfiltrate back to the subsurface or move as runoff towards drainage water bodies. The CRR improves surface–unsaturated-zone interactions and also surface-water/groundwater interactions. The standard and new capacities of MODFLOW 6 are presented in the transient model of the Sardon catchment, calibrated using 7 years of daily groundwater heads and streamflows. The results showed: the large spatio-temporal variability of the groundwater fluxes, the substantial role of groundwater exfiltration, the low catchment storage, the fast reaction of the water table and streams to rainfall, and the mosaic character of the net recharge. These characteristics are typical for HRS-WLEs with a shallow water table. MODFLOW 6 has many improvements compared to previous MODFLOW versions, so with the proposed CRR concept (still can be improved), the single-environment MODFLOW 6 has modelling capacity comparable with multi-environment IHMs, while being more flexible and more efficient.

Keywords Cascade-routing and reinfiltration (CRR) · Unstructured Voronoi grid · Fractured rocks · Semi-arid regions · Groundwater/surface-water relations

Introduction

Aquifers of hard-rock systems (HRSs) have not been given as much attention as other aquifer types, likely due to their low productivity and difficulties in water-well drilling

(Singhal and Gupta 2010). However, in many countries, hard-rock groundwater resources, even though small, represent the only freshwater supply for sustaining life. Therefore, there is a continuous need for improving the assessment of groundwater resources in HRSs, to more efficiently extract

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