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Simulating Climate Change Impacts on the Recharge Dynamics of a Mediterranean Karst Aquifer

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Integrated surface-subsurface flow models solving the Richards' equation allow to simulate flow within all compartments (e.g. vadose, phreatic and surface zone) and their reciprocal interaction, and provide a useful tool to investigate the impact of climatic changes on infiltration dynamics. The Mediterranean karst aquifers are in particular prone to shifting climates, as a decrease in mean precipitation with increasing intensity and frequency of short-duration extreme rainfall, may have a significant impact on recharge dynamics and the overall water budget. Here, we use the finite element, distributed, multi-continuum flow simulator HydroGeoSphere (Aquanty, 2015) on a high-performance-computing platform to simulate infiltration and groundwater flow of the Western-Mountain-Aquifer (WMA) considering changing hydrologic conditions. A thin soil cover and abundant exposed bare karstic carbonate rock compose the recharge area, providing efficient pathways for fast direct infiltration along karst features (e.g., sinkholes and dolines). The lowered total annual precipitation may not result in a decrease in recharge since the severity and frequency of individual rainfall storms are projected to increase.

To account for the duality of karst flow dynamics, both in the vadose and phreatic zones, with rapid flow through conduits and slow flow through the fractured rock matrix, we apply a double-continuum approach based on the volume-effective Richards' equation with van Genuchten parameters. A 2-D friction-based overland flow continuum, coupled via a first-order exchange term to the subsurface, accounts for overland flow due to infiltration excess. This allows to represent the partitioning of rainfall into diffuse and rapid direct recharge, e.g., along dry valleys or sinkholes. This modeling approach, therefore, accounts for complex spatially distributed infiltration characteristics of the rock-soil landscape, with focused recharge along karst features and transmission losses of ephemeral streams (wadis) under variable precipitation patterns.

To get a better understanding of the complex interaction dynamics of the surface and subsurface domain in a coupled unsaturated single- and dual-continuum model we carried out small-scale process-oriented studies. Two types of synthetic karst features, (1) a dry valley averaged from field data (i.e., Wadi Natuf) and (2) an analytical generalized doline, were investigated. Geometries close to natural systems, such as sub-catchments of the WMA, were implemented. Sensitivity studies reveal complex dependencies of domain properties on linear- and log-scales. However, the exchange parameters controlling the coupling between the subsurface continua are insensitive.