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Optimal modelling approaches to quantify large-scale and long-term groundwater recharge and water resources in karst aquifers under Mediterranean climate

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The Mediterranean region is one of the "hotspots" of predicted shift in climate and will be affected by increasing water scarcity in the near future. Karstified aquifers are vulnerable to changes in the hydrological cycle due to their high hydraulic conductivity and low storage capacity. We aim to design an optimal management strategy of carbonate aquifers under Mediterranean climate and therefore we have to answer the following questions: what is the available quantity of groundwater, how can it be assessed appropriately, and how will the water resource develop in the long-term?

For this goal two numerical approaches for the Western Mountain Aquifer, a transboundary aquifer between Israel and the Palestinian Territories, with a size of 9,000 km^2 are compared: i) a process-based deterministic and ii) a stochastic numerical model. The aquifer is developed since 1950 and constitutes today the main freshwater resource for both countries. HydroGeoSphere is used to simulate the hydrological-hydrogeological system with a deterministic multi-continuum approach. This concept represents characteristics of the rock-soil landscape, local recharge along karst features, transmission losses of ephemeral streams (wadis), and erratic precipitation pattern most accurately. However, due to the large number of hydraulic parameters simulation results are subjected to high parameter uncertainty.

A stochastic single-continuum modelling concept using MODFLOW is developed to consider parameter uncertainty, data scarcity, and the aquifer genesis. The single-continuum model is parameterised with a stochastic prediction of the karst networks distribution. Parameterization and location of the karst features are defined with probability density functions. Within the stochastic model the unsaturated zone is assigned as boundary condition based on a spectral analysis of long-term spring discharge measurements. The spectral analysis assesses the relation between precipitation and spring discharge to derive a transfer function that represents the entire karst system behaviour and its hydrological characteristics using a set of lumped parameters.

Both numerical flow models are calibrated using an inversion of time series of piezometric pressure heads and spring discharge measured between 1951 – 2006.

Climate projections show that during winter mean temperatures will rise in the recharge area by up to 2°C increasing evaporation rates distinctively. However, total precipitation will decrease by 20%. Climate modelling indicates that a larger proportion of rainfall will occur during extreme events with an increase of the total amount of 10% affectingly mostly the Northern recharge area. We therefore expect, that the impact of regional shifts in climate on recharge rates and groundwater resources will be impressive. Therefore, based on the calibrated groundwater models and newly developed TF the response of the groundwater system and recharge to changes in climate is analyzed. For this purpose, climate data from a high-resolution (∼8 km grid) regional climate model between 2041-2070 are currently investigated.

The methods and findings of the case study are then generalized for the global transfer to other hard-rock aquifers under Mediterranean climate conditions, e.g. in California, employing an empirical hydro-pedotransfer functions (HPTFs). The newly developed HPTFs will give daily percolation rates, requiring only easy accessible input data like precipitation and potential evaporation.