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KaRaMel: a semi-distributed Rainfall-Recharge-Discharge model to assess the spatial variability of flows in karst aquifers

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Physically-based, distributed modelling approaches are usually preferred for assessing recharge of porous aquifers. In most cases, such approaches are inapplicable to karst systems because of insufficient knowledge of karst heterogeneity. Lumped models allow recharge assessment at catchment scale, but they are by nature unable to provide insights on its spatial variability. Semi-distributed models are a priori suitable for assessing the spatial variability of recharge, but lack of physical significance of their parameters may confront to equifinality issues and thus hinder their relevance to cope with spatial variability.

This work aims to strengthen the link between the parameters of semi-distributed models and environmental variables. Recharge may vary greatly depending on numerous environmental variables mainly related to the properties of climate, soil and geology of the aquifer. We assume that these three factors are the main parameters for spatial distribution of recharge and thus for discharge at the outlet of the karst. We thus hypothesize that the implementation of these variables in a rainfall-recharge-discharge model should improve both the assessment of the spatial variability of recharge (which can not be evaluated by direct measurements) and the simulation of discharge at the outlet of karst system (which is a measured variable).

Taking into account that knowledge of aquifer properties decreases with depth, we propose a semi-distributed model structure with a parameterization adapted to the contrasted levels of knowledge in the different karst compartments: i) the spatial variability of the atmosphere-vegetation-soil system is derived from environmental variables ; consideration of this upper compartment makes it possible to model the daily distribution of the recharge, ii) the less constrained underground flows are assumed to have a coarser distribution at the catchment scale.

The proposed semi-distributed rainfall-recharge-discharge model is applied to the karst aquifer of Fontaine de Vaucluse (South-East of France). Combined direct and indirect use of heterogeneity sources in the model parameterization effectively improves the simulation of the aquifer discharge, which confirms the adequacy of the proposed approach for the assessment of recharge distribution. Our simulation results show high contrasts in annual recharge and groundwater storage throughout the catchment. Half of the system could suffer from storage deficit, while the other half is oversupplied. Such information is crucial for sustainable resource management. Spatial distribution of precipitation also strongly influences discharge at the outlet, suggesting that semi-distributed or distributed models may be needed to accurately assess the impact of climate change on groundwater resources.