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Predicting groundwater flow system discharge in the river network at the watershed scale

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The interaction between rivers and aquifers affects the quality and the quantity of surface and subsurface water since it plays a crucial role for solute transport, nutrient cycling and microbial transformations. The groundwater-surface water interface, better known as hyporheic zone, has a functional significance for the biogeochemical and ecological conditions of the fluvial ecosystem since it controls the flux of groundwater solutes discharging into rivers, and vice versa. The hyporheic processes are affected by the complex surrounding aquifer because the groundwater flow system obstructs the penetration of stream water into the sediments. The impact of large-scale stream-aquifer interactions on small scale exchange has generally been analyzed at local scales of a river reach, or even smaller. However, a complete comprehension of how hyporheic fluxes are affected by the groundwater system at watershed scale is still missing. Evaluating this influence is fundamental to predict the consequences of hyporheic exchange on water quality and stream ecology.

In order to better understand the actual structure of hyporheic exchange along the river network, we firstly examine the role of basin topography complexity in controlling river-aquifer interactions. To reach this target, we focus on the analysis of surface-subsurface water exchange at the watershed scale, taking into account the river-aquifer interactions induced by landscape topography. By way of a mathematical model, we aim to improve the estimation of the role of large scale hydraulic gradients on hyporheic exchange.

The potential of the method is demonstrated by the analysis of a benchmark case's study, which shows how the topographic conformation influences the stream-aquifer interaction and induces a substantial spatial variability of the groundwater discharge even among adjacent reaches along the stream. The vertical exchange velocity along the river evidences a lack of autocorrelation. Both the groundwater discharge and the pathway transit time distribution exhibit exponential tailing at river-watershed scale. These findings denote that the topographic conformation of the whole basin contributes to determine the spatial complexity of the groundwater flow field together with the geomorphological river configuration. This complexity reflects on the depth and the intensity of the hyporheic exchange since the hyporheic zone is confined and embedded by the groundwater system. The evaluation of the spatial distribution of water fluxes from and to the river network is useful to relate water quality and nutrient fluxes to anthropogenic activity in a watershed.