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From watershed- to stream-reach-scale: the influence of multiple spatial scales on surface water-groundwater exchange

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Surface water bodies continuously interact with the subsurface and it is by now widely known that the hyporheic zone plays a key role in the mixing of river water with shallow groundwater. Hyporheic exchange occurs over a very wide range of spatial and temporal scales and the exchange processes at different scales interact and determine a complex system of nested flow cells. This intricacy results from the multiplicity of spatial scale that characterize landscape and river morphology.
In the last years, many processes that regulate the surface-groundwater interactions have been elucidated and a more holistic view of groundwater and surface water has been adopted. However, despite several insights on the mechanisms of hyporheic exchange have been achieved, many important aspects remain to be clarified, i.e. how surface-groundwater interactions influence solute transport, microbial activity and biogeochemical transformations at the scale of entire watersheds. To date a deep knowledge of small-scale processes has been developed but what is lacking is a unifying overview of the role of surface water-groundwater exchange for the health of the whole water system at larger scales, i.e. the scale of the entire basin.
In order to better understand the complex multiscale nature of spatial patterns of surface-subsurface exchange, we aim to assess the importance of the individual scales included in the range between watershed scale to stream reach scale. Hence, we study the large-scale subsurface flow field taking into account the surface-groundwater interactions induced by landscape topography from the basin scale to smaller scales ranging from tens of kilometers to tens of meters. The aim of this research is to analyze how individual topographic scales affect the flow field and to understand which ones are the most important and should be focused on.
To study the impact of various scales of landscape topography we apply an analytical model that provides an exact solution of the underlying three dimensional groundwater flow and a numerical particle tracking routine that allows to obtain streamlines and residence time distributions from the flow field. Therefore, starting from a previously published mathematical tool we set the goal of investigating the interaction between the scales and clarifying their role. We consider real basin examples and describe subsurface flow at the landscape scale, identifying inflow patterns of groundwater to the river network, in order to obtain, in the near future, results to be used for conserving, managing and restoring of a riverine ecosystem.