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Exchange pattern in the hyporheic zone of boreal rivers

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Rivers and groundwater are two essential components of hydrological systems which due to their contrasting hydrochemical characteristics plays significantly different roles in transporting water and solutes across the landscape. The interaction between these two components takes place in the hyporheic zone, where the stream water and groundwater mix in permeable sediments below the stream channel. This interaction is driven by processes that occur on different temporal and spatial scales reflecting a spectrum of landscape morphologies ranging from small stream features to large geological structures. The water movement within the catchment is governed by morphology due to its control on the groundwater head. Small scale and large scale topographies cause dynamic and static head variation, respectively. Dynamic head is controlled by the flow velocity whereas static head is regulated by variation in the water surface elevation. Thus, hyporheic exchange models that include both small and large scale topographies provide improved understanding of hyporheic exchange properties.

Using COMSOL Multiphysics, the discharge patterns for both local hyporheic and regional catchment-scale groundwater flow were derived for the Krycklan Catchment (Sweden) with respect to the interacting circulation from a wide range of spatial scales in the watershed including those of the stream-bed. The general methodology was to divide the topography into three successive spatial scales: first the whole catchment was modeled in order to obtain the large-scale groundwater flow field. Secondly, the groundwater flow from the whole catchment was used as the boundary condition for a 1×1 km2 subdomain of the catchment. Finally, a 5×5 m2 region was used to represent the flow along the stream and its adjacent hyporheic zone. Due to lack of observation of the small scale topography of the stream bed a spectral approach was used to re-scale the topography from the 100×100 m2 scale to the 5×5 m2 scale. By doing this the flow field could be well represented down to decimeter scale and, thus, the hyporheic exchange patterns could also be included. Utilization of the moderate and large scale as the boundary condition for the small scale model output, allowed for characterizing the size (depth) and fragmentation of the hyporheic zone caused by the large-scale circulation of groundwater. The fragmentation of the hyporheic zone was quantified from the simulation results in terms of spatial statistics of the vertical flow velocity and expressed in terms of correlation length in semi-variance analyses.