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Hyporheic flow pattern based on the coupling of regional and stream scales: Case of Krycklan Catchment area

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Water resources intense development within the past century has had an enormous impact on hydrological systems especially on rivers and groundwater resources. A river basin is a flow system involving the interaction between surface water and groundwater. This interaction occurs in terrestrial and coastal zone and even in arid and semi-arid areas, where surface water overlie on a permeable sediment. A key zone for the interaction between surface water and groundwater is the hyporheic zone, which forms by stream water that in- and exfiltrating in the permeable sediments surrounding the river corridor. Groundwater and hyporheic flows arise due to different range of topographical scales and their relative importance is investigated in this study.
Krycklan is a well-monitored research catchment in which the data collection for more than 90 years has comprised hydrology, biochemistry, and aquatic ecology. The catchment is located in a boreal area of northern Sweden. The head-water streams begin in mountainous area and fall to the Baltic Sea near the city of Umea.
In this paper, COMSOL Multi-physics simulation software has been used to model the subsurface flow of the whole Krycklan catchment in order to reach a comprehensive understanding of large-scale groundwater circulation and its impact of the stream hyporheic flows. The model statement is based on the 3D Laplace equation, which has been applied independently on two ranges of topographical scales to obtain a superimposed solution. Steady state simulation has been done based on the simplified assumption of constant boundary conditions of the groundwater surface and otherwise non-flow boundaries. The hydraulic head of the groundwater surface was taken as the topography, which apply as an approximation in wet climate with shallow soil layers. The results demonstrated how the ratio of the topographical amplitudes on different scales affect the size (depth) and fragmentation of the hyporheic zone. “Fragmentation” was defined in terms of spatial statistics of the vertical flow velocity and quantified in terms of correlation length in a semi-variance analyses. The river bed elevation represents range of wavelengths of relevance for controlling the upwelling of deeper groundwater (not originating from the stream flow). Based on the relation between topographical amplitudes of harmonic (Fourier) functions, the exchange velocity in hyporheic zone can be calculated exactly. Finally, by superposing these two models and analyzing the results of both large scale and small scale including the pressure head, hyporheic exchange; show a distinct effect of the large scale groundwater flow on the small scale hyporheic flow velocity in Krycklan catchment area.