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A comparison of different heat tracing techniques for multi-scale investigations of exchange fluxes at aquifer-river interfaces

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Spatially distributed knowledge of exchange fluxes between groundwater and surface water at aquifer-river interfaces is essential to understand potential contamination pathways as well as estimate the natural attenuation functions of hyporheic streambed environments. Current methods of identifying aquifer-river exchange fluxes are limited to either relatively precise, but small scale methods (as for instance multi-level piezometers) or rather uncertain and spatially cumulative methods as tracer injections.

This study applies three different heat tracing methods and compares their applicability for identifying aquifer-river exchange flow patterns at different spatial and temporal scales.

2-D longitudinal thermocouple transect have been applied to the streambed to trace the depth propagation of the diurnal temperature amplitude in dependence of groundwater up-welling. Reach scale (1km) spatial patterns and temporal dynamics of aquifer-river exchange have been identified by a Fibre-Optical Distributed Temperature Sensing (FO-DTS) Network installed at the bed surface, producing streambed temperature maps in 2m spatial resolution. In order to analyse small-scale groundwater-surface water mixing in the top 25 cm of the streambed, an additional active heat pulse injection method has been applied, resulting in the identification of three-dimensional flow vector maps for the shallow streambed sediments. The combination of the three heat tracing methods determined that patterns of cold spots in streambed sediments can be attributed to fast groundwater up-welling in sandy and gravely sediments resulting in low hyporheic residence times. Contrasting conditions were found at warmer areas at the streambed surface where groundwater-surface water exchange was inhibited by the existence of peat or clay lenses within the streambed. These flow-inhibiting structures have been shown to cause semi-confined conditions in the up-welling groundwater, resulting in long residence times and increased redox-reactivity. Shallow mixing of groundwater and surface water has been found to be additionally controlled by lateral inflow from the riparian floodplain. Generally, the application of heat tracing methods leads to the identification of groundwater up-welling hotspots at different scales.

The results of this study indicate that the combination of the applied heat tracing methods provides a powerful tool for identifying spatial patterns of aquifer-river exchange fluxes at multiple spatial and temporal scales.