Quantifying vertical streambed fluxes around woody structures using high-resolution temperature measurements.

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The quantification of water fluxes across streambeds is an important aspect in the study of groundwater-surface water interactions. One way to deduce fluxes is to use heat as an environmental tracer and measure streambed temperatures. In this study we quantified vertical streambed fluxes over a small reach of the Hammer Stream (West Sussex, UK) that is characterized by a heterogeneous streambed morphology and large woody debris. The Hammer Stream is a meandering lowland stream draining a catchment of 24.6 km² with mixed agricultural and forest areas.

Our 40 m-long study reach is situated in a deciduous forested valley, characterized by sand-dominated streambed sediments and several large-scale instream woody structures. Previous geophysical measurements identified extensive clay lenses at 1-2 m depth within the streambed, in parts disconnecting the upper streambed from the connected aquifer. Nine high-resolution-temperature sensors (HRTS) were deployed in the upper streambed along the investigated reach to monitor streambed temperatures over several days in different seasons (summer, autumn, winter) and to cover the diverse stream morphology. Each HRTS comprised a fiberoptic cable wrapped around a PVC tube and connected to a XT-DTS (Silixa, single-ended mode with alternating measurement directions) system. This setup allowed us to measure streambed temperatures at an effective vertical resolution of less than 0.5 cm about every 2 min. HRTS measurements were accompanied by surface water and air temperature measurements while previous studies provided information on streambed grain size and hydraulic conductivity.

For analyzing the temperature time-series data we made use of the LPMLEN method, embedded in a newly developed GUI that allows for easy-to-use model setup and estimation of vertical exchange fluxes and thermal streambed parameters. By solving the heat transport equation in the frequency domain for a finite model domain, the LPMLEN method is a continuation of the LPMLE3
method but unlike the latter can make use of temperature information from multiple \( n \) vertically deployed sensors while optimally taking into account measurement uncertainty during flux estimation.

Results show that streambed temperatures are variable in space and time, with warming/cooling patterns primarily driven by seasonal hydrometeorological conditions. High-flow conditions in winter led to increased hyporheic exchange around the large woody structures.