Geophysical Research Abstracts,
Vol. 11, EGU2009-2611, 2009
EGU General Assembly 2009
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Distributed Temperature Sensing – a Useful Tool for Investigation of Surface Water – Groundwater Interaction

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In recent years, the transition zone between surface water bodies and groundwater, known as the hyporheic zone, has been identified as crucial for the ecological status of the open-water body and the quality of groundwater. The hyporheic exchange processes vary both in time and space. For the assessment of water quality of both water bodies reliable models and measurements of the exchange rates and their variability are needed.

A wide range of methods and technologies exist to estimate water fluxes between surface water and groundwater. Due to recent developments in sensor techniques and data logging work on heat as a tracer in hydrological systems advances, especially with focus on surface water – groundwater interactions. Here, we evaluate the use of Distributed Temperature Sensing (DTS) for the qualitative and quantitative investigation of groundwater discharge into and groundwater recharge from a river.

DTS is based on the temperature dependence of Raman scattering. Light from a laser pulse is scattered along an optical fiber of up to several km length, which is the sensor of the DTS system. By sampling the the back-scattered light with high temporal resolution, the temperature along the fiber can be measured with high accuracy (0.1 K) and high spatial resolution (1 m). We used DTS at a test side at River Thur in North-East Switzerland. Here, the river is loosing and the aquifer is drained by two side-channels, enabling us to test DTS for both, groundwater recharge from the river and groundwater discharge into the side-channels.

For estimation of seepage rates, we measured highly resolved vertical temperature profiles in the river bed. For this application, we wrapped an optical fiber around a piezometer tube and measured the temperature distribution along the fiber. Due to the wrapping, we obtained a vertical resolution of approximately 5 mm. We analyzed the temperature time series by means of Dynamic Harmonic Regression as presented by Keery et al. (2007). From the travel time and attenuation of the diurnal time signal, we estimated the apparent velocity and diffusivity of temperature propagation, which then can be used to quantify infiltration rates. A particular strength of the new measuring technique lies in the high spatial and temporal resolution, enabling us to detect non-uniformity and temporal changes in vertical water fluxes.

In the side-channels, we have laterally laid out optical fibers to detect zones of groundwater discharge. As groundwater temperatures differ from river temperatures, local exfiltration of groundwater leads to a local change of the temperature at the river bottom. A limitation of lateral DTS data is that exchange rates cannot directly be quantified. Therefore, we used DTS for streambed temperature mapping. Then certain exfiltration zones undergo further investigation using time series of streambed temperature profiles obtained in piezometers.

J. Keery, A. Binley, N. Crook and J.W.N. Smith (2007) Temporal and spatial variability of groundwater–surface water fluxes: Development and application of an analytical method using temperature time series, Journal of Hydrology, 336, 1-16.