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Challenging the distributed temperature sensing technique for estimating groundwater discharge to streams through controlled artificial point source experiment

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Spatially confined groundwater discharge can contribute significantly to stream discharge. Distributed fibre optic temperature sensing (DTS) of stream water has been successfully used to localize- and quantify groundwater discharge from this type "point sources" (PS) in small first-order streams. During periods when stream and groundwater temperatures differ PS appear as abrupt step in longitudinal stream water temperature distribution. Based on stream temperature observation up- and downstream of a point source and estimated or measured groundwater temperature the proportion of groundwater inflow to stream discharge can be quantified using simple mixing models.

However so far this method has not been quantitatively verified, nor has a detailed uncertainty analysis of the method been conducted. The relative accuracy of this method is expected to decrease nonlinear with decreasing proportions of lateral inflow. Furthermore it depends on the temperature differences (ΔT) between groundwater and surface water and on the accuracy of temperature measurement itself. The latter could be affected by different sources of errors. For example it has been shown that a direct impact of solar radiation on fibre optic cables can lead to errors in temperature measurements in small streams due to low water depth. Considerable uncertainty might also be related to the determination of groundwater temperature through direct measurements or derived from the DTS signal.

In order to directly validate the method and asses it's uncertainty we performed a set of artificial point source experiments with controlled lateral inflow rates to a natural stream. The experiments were carried out at the Vollnkirchener Bach, a small head water stream in Hessen, Germany in November and December 2011 during a low flow period. A DTS system was installed along a 1.2 km sub reach of the stream. Stream discharge was measured using a gauging flume installed directly upstream of the artificial PS. Lateral inflow was simulated using a pumping system connected to a 2 m^3 water tank. Pumping rates were controlled using a magnetic inductive flowmeter and kept constant for a time period of 30 minutes to 1.5 hours depending on the simulated inflow rate. Different temperatures of lateral inflow were adjusted by heating the water in the tank (for summer experiments a cooling by ice cubes could be realized). With this setup, different proportions of lateral inflow to stream flow ranging from 2 to 20%, could be simulated for different ΔT's (2-7°C) between stream- and inflowing water. Results indicate that the estimation of groundwater discharge through DTS is working properly, but that the method is very sensitive to the determination of the PS groundwater temperature. The span of adjusted ΔT and inflow rates of the artificial system are currently used to perform a thorough uncertainty analysis of the DTS method and to derive thresholds for detection limits.