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Fibre-optical distributed temperature sensing – Uncertainties and limitations

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Fibre-optical Distributed Temperature Sensing (DTS) appears to be the latest fashion when it comes to analysing hydrological fluxes as for instance the exchange of groundwater and surface water at aquifer-river or aquifer-lake interfaces. The relatively new technology allows for temperature observations with a precision of standard thermocouple sensors in sensational spatial and temporal resolution. The result, a spatially distributed temperature signal, can not only be used to identify the mixing patterns of water sources of different temperature with a 1-2 m resolution but also covers scales of several kilometres. If combined with heat transfer models, the distributed temperature data are frequently used to identify the advective flow component within the heat flow equation and thus allows for quantifying exchange fluxes at relatively large scales.
This study focuses on the investigation of the uncertainties and limitations of DTS applications for the qualitative and quantitative analysis of groundwater-surface water exchange fluxes. It compares the robustness of the DTS observed temperature signal for locations with rather gradual vs. discrete changes in streambed hydraulic conductivity and resulting aquifer-river exchange flow patterns.
Different setups of single ended and dual ended sampling modes have been applied on a 500m cable installed in a double loop at the streambed surface of a 250m stream reach of a UK lowland river. Temperature surveys were carried out at a permanently installed cable during summer conditions with up to 10C colder groundwater than surface water and during winter conditions with inverse temperature conditions when groundwater temperatures were approximately 2-3C higher than surface water temperatures.
The results of the surveys indicate that especially during summer conditions the large difference between groundwater and surface water temperatures results in a significant temperature anomaly in streambed areas with substantial groundwater up-welling. DTS identified cold anomalies within generally warmer streambed sediments enabled the prediction of discrete changes between hotspots of cold groundwater up-welling and locations with inhibited aquifer-river exchange. However, the uncertainties associated with the cable installation, sampling setup and data drift make a precise identification of smaller changes in streambed temperature rather challenging. As a result, the uncertainties of spatially distributed quantifications of exchange fluxes are high and might, in particular in areas of gradual and less distinct changes in the spatial distribution of the temperature signal, exceed the temperature signal we want to observe.

Our results suggest that although DTS is a robust technology for qualitative prediction of aquifer-river exchange flow patterns, its use for quantifying exchange fluxes has to be scrutinised against structural, experimental and instrumental uncertainties.