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An Active-Distributed Temperature Sensing method to quantify groundwater – surface water exchanges

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Understanding and quantifying groundwater and surface water interactions are key elements for the management of water quality and quantity, but also for the preservation of groundwater dependent ecosystems and riparian habitat. We developed a methodology to quantify groundwater and surface water interactions, by setting up an active heat tracer experiment using fiber-optic distributed temperature sensing (FO-DTS).

The experimental setup consists in heating an armoured fiber-optic cable that has been previously deployed along the streambed within the sediments. Then, the increase in temperature along the heated cable is a function of the thermal properties of the sediments and of the fluid flow velocity within the sediments. The cable is heated electrically through the steel armouring of the cable while the elevations in temperature are continuously monitored. We tested this methodology on the Kerbernez catchment, located in south-western Brittany (France) and which is part of the AgrHys hydrological observatory. We deploy the cable in a first-order stream within this small agricultural catchment (0.12 km^2). Temperature was monitored along 60 meters of stream with a spatial and temporal resolution respectively equal to 29 cm and 30 s. To interpret the data, we used an analytical solution developed for geothermal energy that considers advection and conduction of temperature in porous media. To validate the use of the analytical solution and to define the limits of the method, a 2D numerical model has been developed. This model simulates heat transport and conduction with steady state fluid flow using the Conjugate Heat Transfer module of COMSOL Multiphysics ®.

During heating and cooling, the measured temperature was particularly variable along the section with temperature increases that range between 16 to 36°C. This variability can directly be associated with local variations of water fluxes by applying the appropriate analytical solution. Henceforth, it is possible to model field data, just by adjusting one free parameter: the flow velocity within the sediments. For the electrical power used, these preliminary tests permits to estimate fluxes between groundwater and surface water between 8.10-7 to 6.10-5 m.s-1. Thus, our results show that an active heat tracer experiment using fiber-optic distributed temperature sensing can be a promising and innovative method to quantify surface water and groundwater interactions.