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Assessment of injected warm plumes along a free surface flow channel using fiber-optic distributed temperature sensing and numerical simulations

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Understanding and predicting stream thermal regimes is a key goal for aquatic ecosystems resiliency to climate change. Mapping thermal anomalies finely becomes feasible thanks to methods such as fiber-optic distributed temperature sensing (FO-DTS). Despite being the main thermal anomalies in stream, groundwater inflows are difficult to detect because of high water stages and turbulent stream flow. We hypothesized that thresholds in flow regime and hydraulic parameters may affect thermal regime characterization. Our main objective was to test and validate the use of FO-DTS for the quantification of inflows in order to determine the physical processes behind these thresholds.

Experiments were carried out outdoor, using an open flow hydraulic channel. A warm water tank was used to simulate groundwater inflows with known discharge rates and temperatures. These discharge rates varied between 4 and 72% of the channel flow. Numerical experiments were also conducted to test the consistency of our experimental results and discriminate the effect of inflow rate and hydraulic parameters. The water temperature in the channel was monitored by Fiber-Optic Distributed Temperature Sensing with cables set on two lines, over three depths.

The injected warm plume was tracked along the channel and across the water stage to estimate temperature increases it induced. A relationship was found between these thermal anomalies and flow dynamic, defining different types of flow configurations. For given channel flow rate and water stage, a threshold for the inflow rate was identified at which the injected plume is not detectable by our means. The effect of the channel flow velocity over the plume spreading appears clearly with a dominance of advection for high flow rate. In addition, outdoor experiments were affected by atmospheric conditions (air temperature, solar radiation, etc.) while simulations allowed refining results without external artefacts and showed a good fit with measurements. This study shows how FO-DTS allows spatio-temporal characterization of a thermal anomaly to determine threshold values for its detection at given hydraulic conditions, with broad applications for hydrology, hydroecology and environmental sensing.