An Active-Distributed Temperature Sensing method for measuring groundwater flow velocities into streambed sediments at high spatial resolution

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Regular abstract

In the last decades, the stream/groundwater interface received considerable attention since it controls many physical, geochemical and biological processes occurring in the stream or at the interface [1]. Thus, 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 habitats [2]. To support and guide water resources management, integrated surface and subsurface hydrologic models have been developed lately. Since integrated models take all components of the water cycle into account, they became powerful tools to understand groundwater and surface water processes and their interactions. However, extensive data are needed for parameterization and model calibration [3], which can limit the application of integrated models, especially when dealing with the groundwater/surface water interface. Indeed, localizing and quantifying groundwater/surface water exchanges remains challenging since exchange processes vary both in time and space [4,5], leading to an extreme heterogeneity in the distribution of fluid exchanges [6].

Here, we propose a new in-situ active Distributed Temperature Sensing method for measuring groundwater flow velocities in streambed sediments with an unprecedented high spatial resolution. The experimental setup consists in heating an armored fiber-optic cable, previously deployed along the streambed within the sediments. The temperature increase along the cable depends mainly on the sediments thermal properties and on groundwater flow velocities that dissipate heat through advection. We modeled field data using an analytical solution based on a Moving Infinite Line Source as thermal source, which was validated through a simple numerical model.

In the first instance, the method was tested on a first-order stream allowing (i) quantifying directly groundwater and surface water at reach scale by estimating Darcy flow velocities over more than two orders of magnitude and (ii) to characterize the complexity of exchange processes by estimating the spatial groundwater flow distribution along the stream and determining the spatial correlation of velocities. To go further and test the method on larger flow systems, we installed recently 600 m fiber-optic cables within the streambed of the Selune river (20 meters large). For this hydrologic system, exchanges between groundwater and surface water depend fully on human activities since water level in the river is controlled by dams while water table fluctuations are locally influenced by pumping in the nearby alluvial aquifer. With this installation, we aim to demonstrate that this method, which should lead to characterize exchanges at the groundwater/surface water interface (flow velocity and spatial groundwater flows distribution), turns out to be a key element in the development and the application of integrated surface and subsurface hydrologic models.
References: