Active-Distributed Temperature Sensing to characterize flow in shallow aquifers

Project Framework

Over the last decade there is an increasing interest in using temperature as an indicator for water flow (e.g. Anderson, 2005, Klepikova et al., 2011, Saar, 2011, Rau et al., 2014). Moreover, the development of distributed temperature sensing (DTS) enable high spatial resolution sensing of temperature data continuously in space and time (e.g. Selker et al., 2006). Recently, Active-DTS (A-DTS, see Figure 1) approach was shown to provide measurements of fluid fluxes in boreholes. Based on this method, Read et al. (2014) proposed to measure vertical borehole flow velocities in fractured media. The method consists in measuring the difference in temperature between a heated and unheated fiber optic cable in the borehole. This difference can be then inverted to derive groundwater flux. Similar principle was also used by Liu et al. (2013) to provide qualitative indication of horizontal groundwater flux in a sand and gravel aquifer. Nevertheless, further research is needed in order to provide an accurate quantitative indirect measurements of groundwater flow in aquifers. Such an accurate in-situ estimation of the groundwater flow rate, including information on flow direction as well as information about vertical component of flow, is critical for assessment of transport in the subsurface.

Project Goals and Approach

The first objective of this Master thesis is to improve the interpretation of A-DTS tests during reservoir characterization in order to provide a relationship between flow in the aquifer and borehole temperature profiles. The temperature anomaly created by the heating cable is transported away from the cable through advection of water in the borehole and thermal conduction. As shown in Figure 1 (a) the measured average temperature increase produced by a heated cable is very sensitive to borehole flow velocities. A low groundwater flux implies that the temperature anomaly is transported only by thermal conduction and then the maximum temperature difference is observed. A higher groundwater flux implies a smaller heat-induced temperature increase. The velocity of the annular flow is, in turn, directly correlated with groundwater flow rate in the aquifer. During this Master thesis this relationship will be investigated by using flow and heat transfer numerical model at the borehole scale.

The second goal of this thesis is related to the improvement of the existing survey design (examples are given in Figure 1 b, c and d) in order to gain accuracy in the measurement of flow in an aquifer and to obtain insight about the direction of the groundwater flow. Laboratory experiment, coupled with a numerical approach, will be conducted in order to optimize the experimental set-up that will be used in the field. The student will build a tube flow model in transparent material with constrained boundary conditions. The objective is to 1) represent similar configurations that we will face in the field, 2) visualize the experiment in live and 3) optimize the setup. Furthermore, the final experimental set-up will be tested in the field, in the alluvial aquifer of Widen test site, located in the Thur valley.
The experiment will be conducted under ambient flow conditions and then under cross-borehole pumping conditions. Large number of observation boreholes will allow to characterize the site at a high spatial resolution. The test site has been subject to numerous hydraulic and geophysical tests, including pumping and tracer tests, geophysical surveys and temperature measurements, including fiber optic measurements (e.g. Coscia et al., 2011, Somogyvári et al., 2016). The results obtained during the experiment will be compared to existing data. Improvement strategies regarding the experiment will be discussed in perspective of this work.

![Figure 1](image)

Figure 1. (a) Heat-induced temperature increase at different groundwater flux rates thermal, (b) schematic of the groundwater flux characterization through A-DTS approach, (c) planar schematic view (from Liu et al., 2013), (d) Section of the A-DTS tool used by Read et al., 2014 with (i) centrally held heated FO-cable, (ii) reference FO-cable, (iii) power supply cable, and (iv) steel rope.

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**References**


