Monitoring a shallow geothermal experiment in a sandy aquifer using electrical resistivity tomography : a feasability study.

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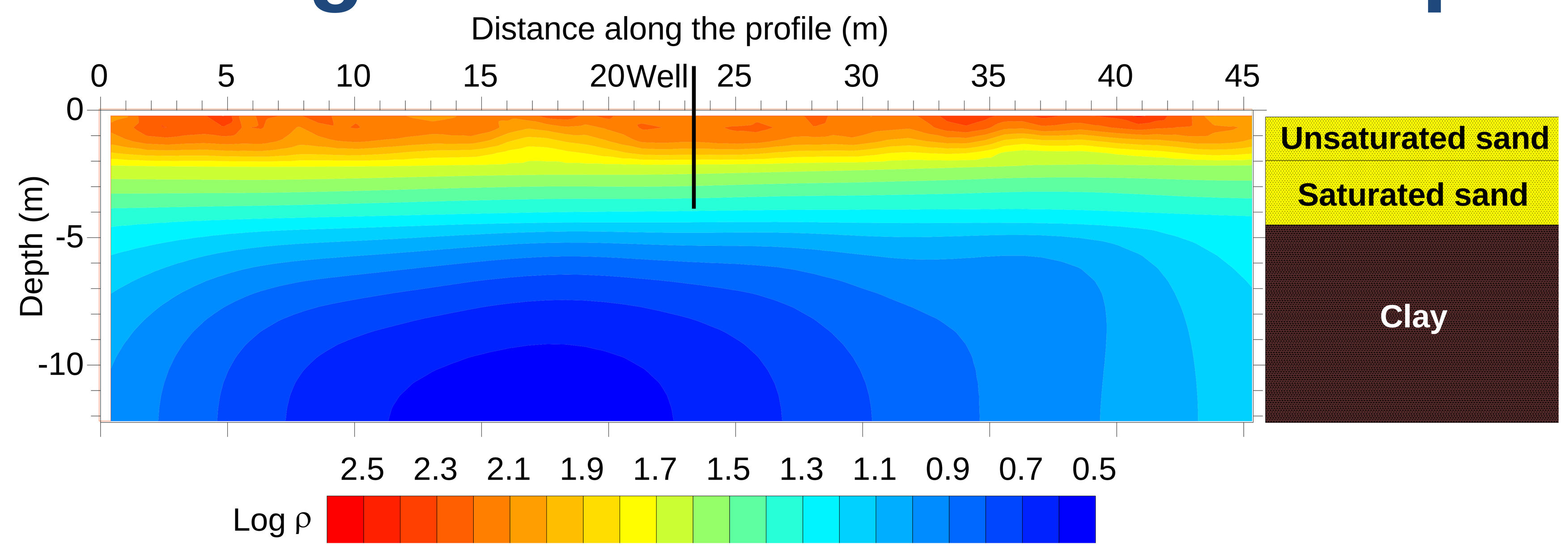
Introduction

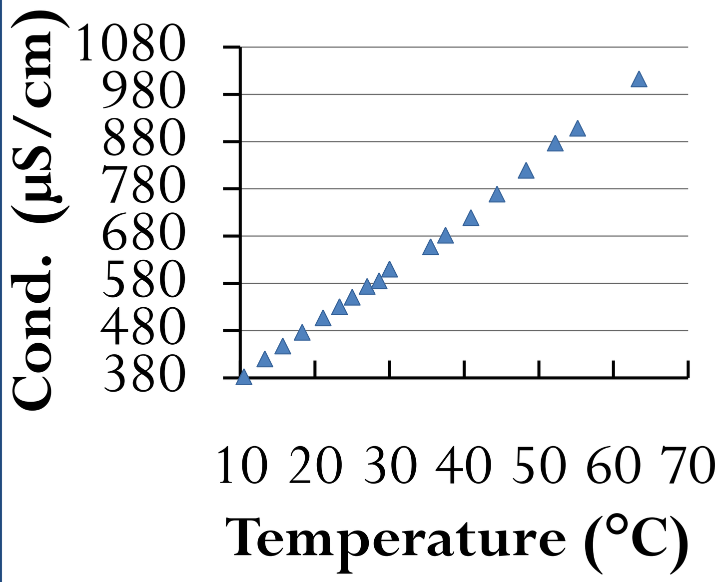
We monitored with electrical resistivity tomography a geothermal test on the campus of Ghent University (Belgium). We injected warm water (45°C) into a sandy aquifer where the groundwater has a temperature of 10°C (box 1) at a rate of 100 liter/hour during three days. Laboratory measurements indicated that we could expect at most a change of 2%/°C of the water electrical conductivity (box 2). The time-lapse series of electrical images show clearly the thermal plume corresponding to the injected water with a maximum change of minus 20% after 72 hours of injection (box 3). A comparison with a geothermal model (box 4) shows that the anomaly is well detected but also distorded due to the inversion regularization (smoothness constraint).

1. Background at the UGent campus



A Wenner-Schlumberger array was chosen to collect the resistance measurements (823) based on the data quality of different arrays. Inversion of the data set, with an error level of 2.5% in relative and 10^{-3} Ohm in absolute, and including structural constraints from borehole evidences yields the image above (CRTOMO, [1]). The first layer (upper 2 m) correspond to unsaturated sands. From 2 m below the surface down to 4.5 m, the sands are saturated. At the depth of 4.5m, the resistivity values decrease due to the presence of clay, forming an impermeable bottom layer. The injecting well is positioned at 23.5 m on the image above and was drilled down to 4.6 m. As evidenced by the electrical tomography and nearby wells, the water table is nearly flat at the test site.

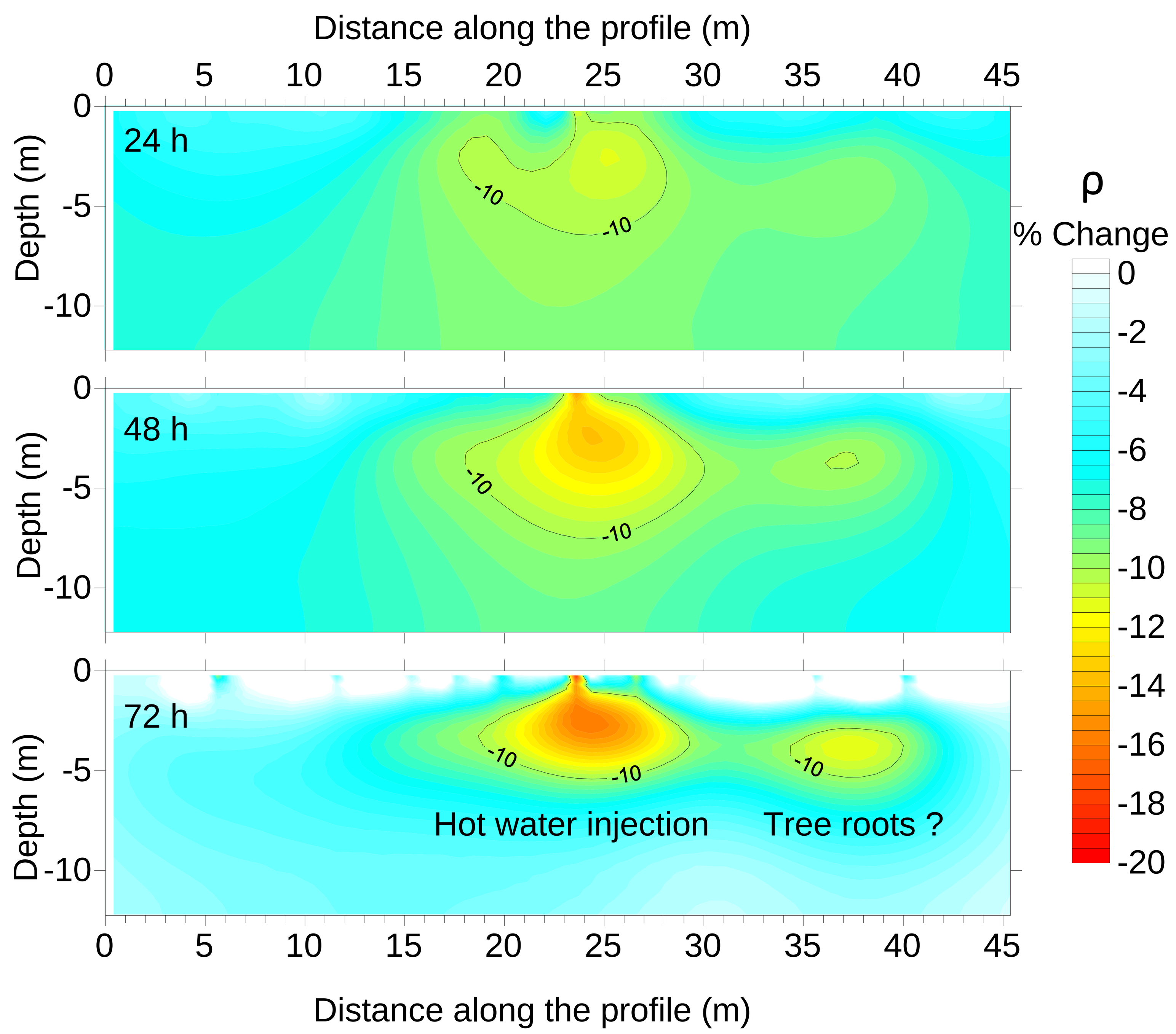
2. Conductivity Law



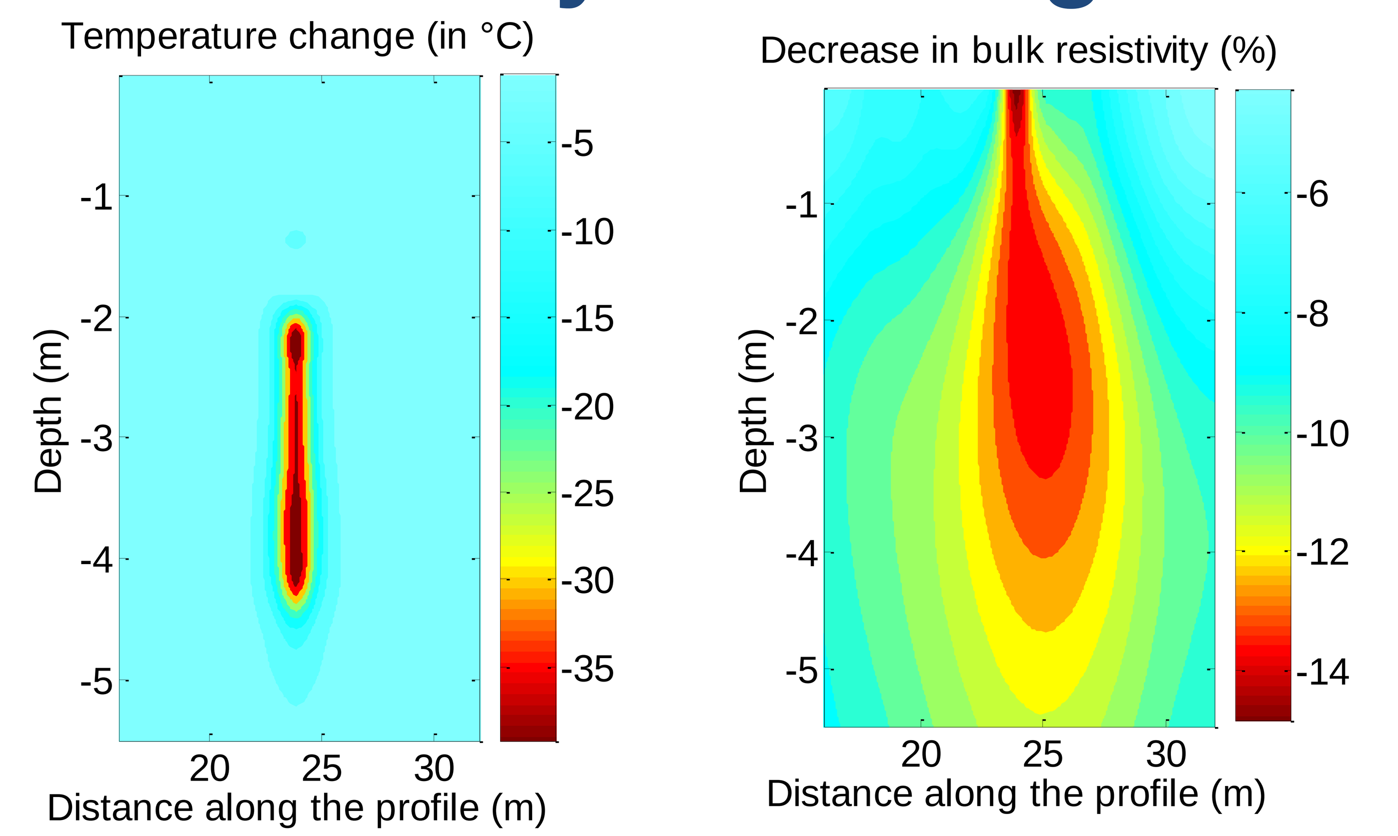
Laboratory measurements of water electrical conductivity indicate that the conductivity increases by 2.125% per degree Celsius following a linear trend, as evidenced by [2]. On this basis, we decided to inject, at a rate of 100 liter/hour, water with a temperature of 45°C in the groundwater which has a temperature of 10°C. This should lead to a change in conductivity of 400 µS/cm.

3. Time-lapse series

Using the background resistivity model (box 1), we inverted the resistivity changes required to reproduce the monitoring data 24 hours, 48 hours and 72 hours after injection of hot water (box 2). The results are displayed below in terms of percentage change in resistivity. The geothermal plume is detected at the location of the injection well as an increasing negative anomaly, in agreement with our petrophysical model (box 2), with a maximum change of 20% at the heart of the plume. The geophysical inversions show that the plume is limited in depth by the clay layer. Another change in resistivity is also spotted at 37 m along the profile and could be related to the effect of roots [3].



4. Validation by modeling



A first comparison between a geothermal model (MOCDENS3D, [4]) and the geophysical results 48 hours after injection shows that the plume is well recovered, but enlarged. This can be easily explained by the smoothness constraint used to regularized the inverse geophysical problem. The geophysical results also show a decrease of resistivity around the well near the surface that is not taken into account in the geothermal model. This may be explained by the heating of infiltration water after a snow event.

5. Perspectives

The use of low and moderate temperature geothermal resources is expected to grow strongly. We show that geophysical techniques are, in combination with boreholes, reliable tools to characterize the geothermal behavior of the subsurface for heat exchange in a porous media (sandy aquifer). The road ahead is to perform a more quantitative integration of our geophysical data and results in the geothermal modeling and to refine the geophysical imaging. Our approach should in-fine contribute to the development of in-situ techniques to characterize groundwater and porous matrix properties governing heat transfer in the subsurface.

References

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