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

Thomas Hermans (1), Alexander Vandenbohede (2), Frederic Nguyen (1), and Luc Lebbe (2)

(1) Argenco, Liege University, Liege, Belgium (f.nguyen@ulg.ac.be), (2) Geology and Soil Science, Ghent University, Belgium

The use of low-enthalpy geothermal ressources is increasingly growing in Europe and around the world. This domain constitutes an essential field of research and development in the diversification of energy ressources to hinder global warming. The advantages of very low temperature systems are, first, that they are much more available than the geothermal high temperature, since the underground often contains important shallow aquifers (e.g. alluvial plains), and second, that their exploitation involve relatively low costs of implementation. Very low energy systems exhibit underground fluid with a temperature ranging from 5 to 30 ° C, which may be used for cooling or heating. The two main modes of exploitation of geothermal energy rely on the extraction of the hydrothermal fluid in the aquifer from wells and on the circulation of a heat transfer fluid in a closed and buried geothermal circuit.

Underground heat exchange and overall exploitation system design may be undertaken in an optimized and sustainable fashion if the parameters governing the coupled heat transport and flow equations are know to a certain degree. As for many underground reservoir problems, sufficient knowledge on the distribution of the parameters of interests (e.g. thermal conductivity, thermal diffusivity, thermomechanic dispersitivity, effective porosity) must be obtained to perform reliable predictions. Designing novel experiments to estimate those parameters in-situ is therefore essential. In this framework, we examine the feasibility of a thermal tracer experiment similar to the ones performed in hydrogeology or hydrogeophysics. The test consists in following the evolution of a heat plume through the underground as it is injected in one well and pumped to another one. The thermal tracer evolution is followed by gathering electrical resistivity (ERT) images in a time-lapse framework over 10 days.

In this contribution, we examine the potential of ERT to image such thermal plume and its contribution in calibrating coupled heat transport and flow models. This is first studied with numercial simulations in order to to select injection rate (200 l/h during 2 days) and extraction rate (1.5 m^3/h) as well as adequate electrode configurations to achieve sufficient imaging resolution. First numerical results indicate that this is feasible if favorable field conditions are met (low resistance data noise, relatively homogeneous medium). The second stage involves field experiments near the Belgian coastline where the subsurface is expected to be fairly laterally homogeneous (sands and peat, some clay). The site sclale is tens of meter, and the impervious bedrock (Ypresian clay) is located between 15 to 20 m. Electrical resistivities measured with EM39 device every 20 cm vary between 15 and 40 Ωm. Water conductivity is about 145 mS/m which leads to formation factor between 4.9 and 5.4 a the injection level. Maximum changes are expected in the area of the screens between -6.6 and -8.8m under the surface. We expect to increase the fluid temperature by over 20 degree Celcius. This should in turn decrease the bulk electrical conductivity, which ERT is sensitive to, by 40 percent given the temperature range.