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Effects of the aquifer heterogeneity in heat production from low enthalpy geothermal systems

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Open-loop shallow geothermal systems, which exploit shallow aquifers as a heat source or sink, have a great potential to reduce greenhouse gas emissions related to the heating and cooling of buildings. In order to limit the depletion of groundwater resources water is generally reinjected into the same aquifer after the heat exchange, as a consequence a thermal plume develops within the aquifer. Furthermore a share of the reinjected water may come back to the abstraction wells, inducing a progressive thermal alteration of the abstracted water temperature that may even result in the plant failure. This phenomenon, known as thermal recycling, strongly depends on the hydraulic conductivity of the aquifer. The design models commonly adopted in the practice assume a homogeneous domain with constant hydraulic conductivity, this assumption, however, is not realistic: neglecting the natural heterogeneity of hydraulic properties of the porous medium may result in large prediction errors.

In this study, we aim to quantify the impact of the different heat transport dynamics in aquifers on the thermal plume development. A stochastic model, which explicitly considers the spatial variability of the hydrological properties, such as the hydraulic conductivity, is developed for low enthalpy geothermal systems. The thermal breakthrough curve at the extraction well is obtained by applying a Lagrangian model and assuming a steady state velocity field. Relevant quantities of thermal recycling, such as the thermal breakthrough time, are adopted for the evaluation of the effects of the hydrogeological and geometrical parameters of the systems.

The results of our study emphasize how the correct representation of the aquifer heterogeneity is fundamental in the design of shallow geothermal systems and in the correct heat plume assessment.