Thermal performance of a deviated deep borehole heat exchanger: insights from a synthetic coupled model

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Introduction: Earth heat exchangers are drawing increasing attention and popularity due to their efficiency, sustainability and universality. However, the functioning and numerical modeling of deep borehole heat exchangers (DBHE) in contrast to those of shallow conventional systems, remain poorly known [1].

Computational methods: In this work, the influence of subsurface physical parameters, DBHE materials and operating settings had been investigated, in order to assess their impacts on deep-system performance. To this end, COMSOL Multiphysics, with Pipe Flow and Subsurface Modules, was used (**fig. 1**). A sensitivity analysis is conducted by varying one parameter at a time from the base scenario (BS) (**table 1**).

$$\rho A C_p \frac{\partial T}{\partial t} - \nabla \cdot A\lambda \nabla T + \rho A C_p u \cdot \nabla T = Q_f + Q_{wall} + Q_p$$

$$Q_{wall} = (HZ)_{eff}(T_{ext} - T)$$

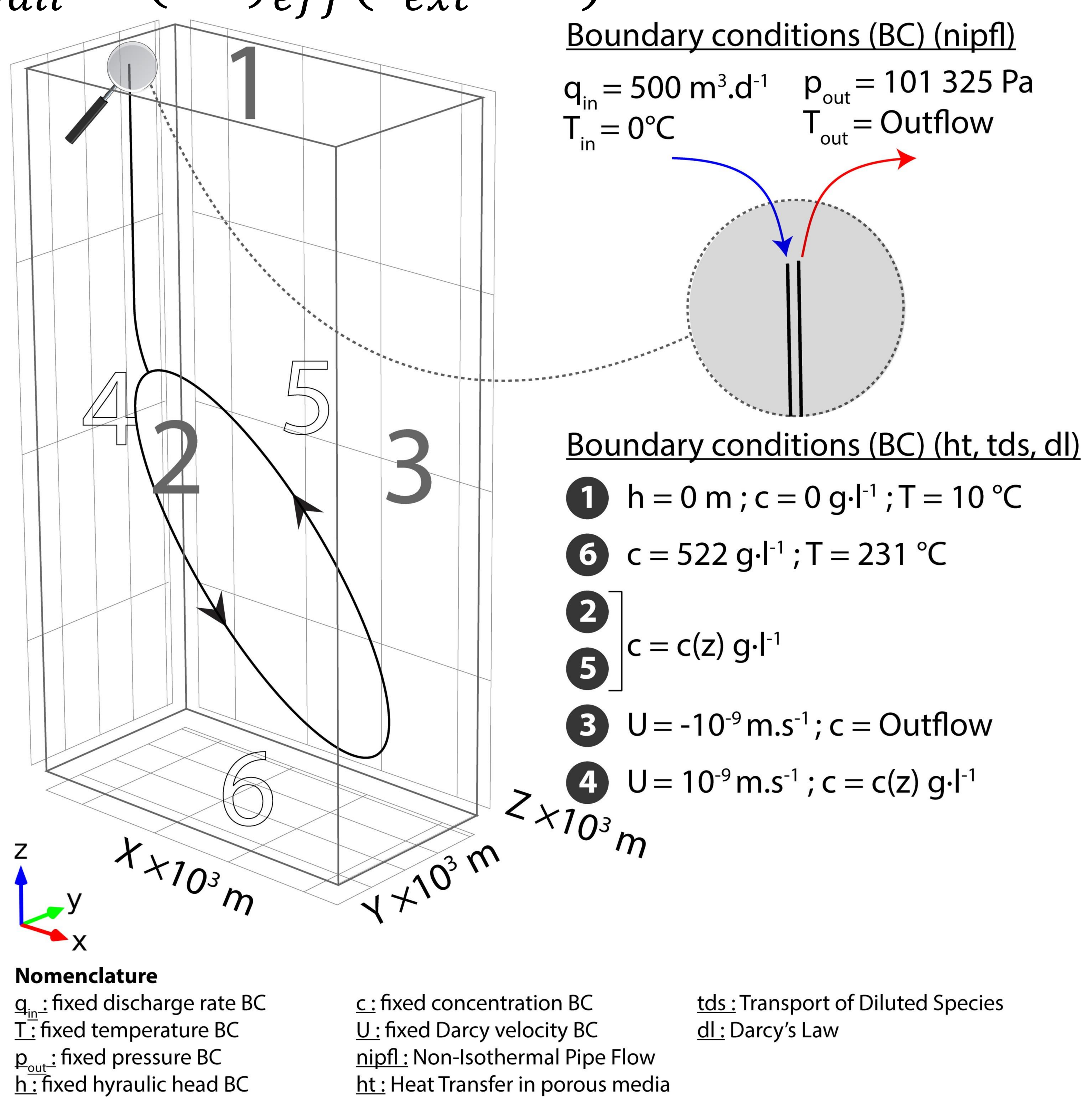

Figure 1. Boundary conditions and scheme of the model

Results: base scenario (BS) (**fig. 2**) and relative average specific heat extraction rate (**table 2**) are presented with restrictions due to confidentiality reasons.

Table 1. Parameters examined in the sensitivity analysis, their base scenario values as well as upper/lower limits

Parameter	Unit	Lower limit	Base value	Upper limit
λ_s	$J.m^{-1}.s^{-1}.K^{-1}$	1.5	3	4.5
$\rho_s C_s$	10^{+6} $J \cdot m^{-3}.K^{-1}$	1.5	2.5	3.5
ω	1	0.01	0.1	0.2
α_L	m	0.1	0.5	10
λ_g	$J.m^{-1}.s^{-1}.K^{-1}$	1	2	5
e_p	m	0	6.1×10^{-5}	4.6×10^{-5}
T_{in}	°C	-5	0	5
Q_{in}	$m^3 \cdot d^{-1}$	250	500	1000

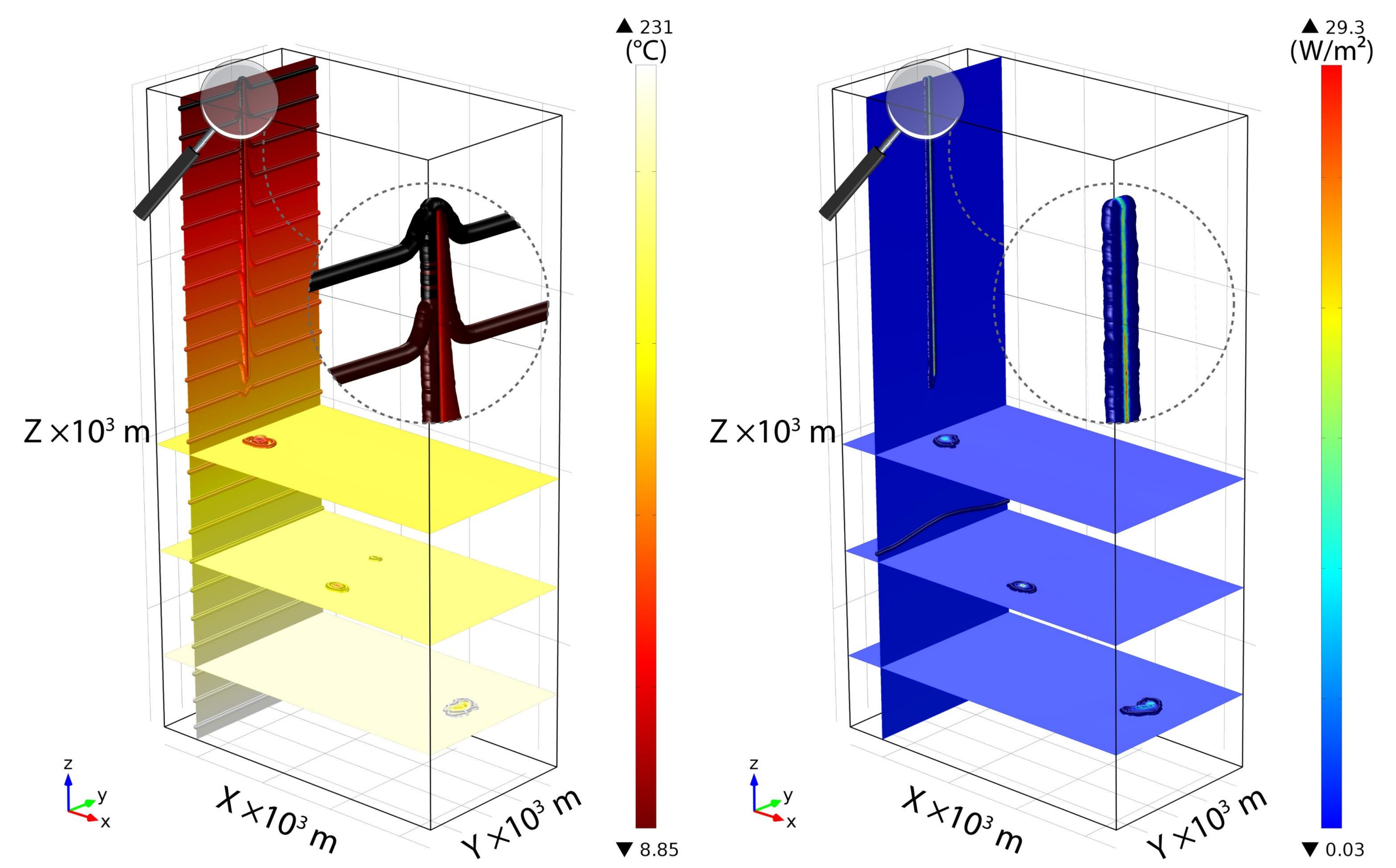

Figure 2. Temperature (left) and gradient magnitude (right) distributions in porous media for the BS after 50 years

Table 2. Summary of relative average specific heat extraction rate with respect to BS over 50 years

Parameter	Relative average specific heat extraction rate	
	Lower limit	Upper limit
λ_s	+25%	-15%
$\rho_s C_s$	0%	0%
ω	-3%	+3%
α_L	0%	0%
λ_g	3%	-3%
e_{pipe}	0%	0%
T_{in}	-1%	0%
Q_{in}	-35%	+17%

Conclusions: Parameters affecting thermal performance of the DBHE the most are associated with conductive components of heat flow. Thermal short-circuit between ascending and descending fluid was emphasized and need to be specifically studied.

References:

1. Le Lous, M.; Larroque, F.; Dupuy, A.; Moignard, A., Thermal performance of a deep borehole heat exchanger, *Geothermics, 57*, 157 – 172 (2015)

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