3D Numerical Modelling Of Vertical Geothermal Probes

Jean-Marc Dedulle[1], Denis Nguyen[2]
1 SIMTEC 8, rue Duployé 38100 Grenoble
2 BRGM 1039 rue de Pinville 34000 Montpellier

Introduction: The Solargeotherm project is assessing the possibility of using vertical geothermal probes drilled into a rock mass (bedrock) for storing the thermal energy produced by solar panels and later releasing it. The research project relies on the installation of an experimental system and the use of heat transfer models.

Computational Methods: Calculating the temperature distribution within the heat transfer fluid is done at the surface (shell) on the inner radius of the probe's tube.

$$\rho C_p \frac{\partial T_f}{\partial t} + \nabla_t.(-k\nabla_t T_f) + \nabla_t.\left(\rho C_p T_f \mathbf{u}\right) = Q$$

The term 'heat source' relates to the heat exchange between the tube and the fluid. The exchange coefficient h determined from the Dittus-Boetler correlation.

$$Q = \frac{2\pi r dl}{\pi r^2 dl} h\left(T - T_f\right) = \frac{2}{r} h\left(T - T_f\right)$$

The temperatures of the tube, foam, sealing grout and bedrock are calculated from the heat transfer equation in 3D geometry.

$$\rho C_p \frac{\partial T}{\partial t} + \nabla.(-k\nabla T) = 0$$

Results: Figure 1 shows the numerical model simulation of the thermal shock's temperature changes against the experimental data for two simulated measurement positions along the probe. The simulated spatiotemporal evolutions, for different depths are comparable with experimental measurements, on both the injection tube (descending part) and return tube (rising part).

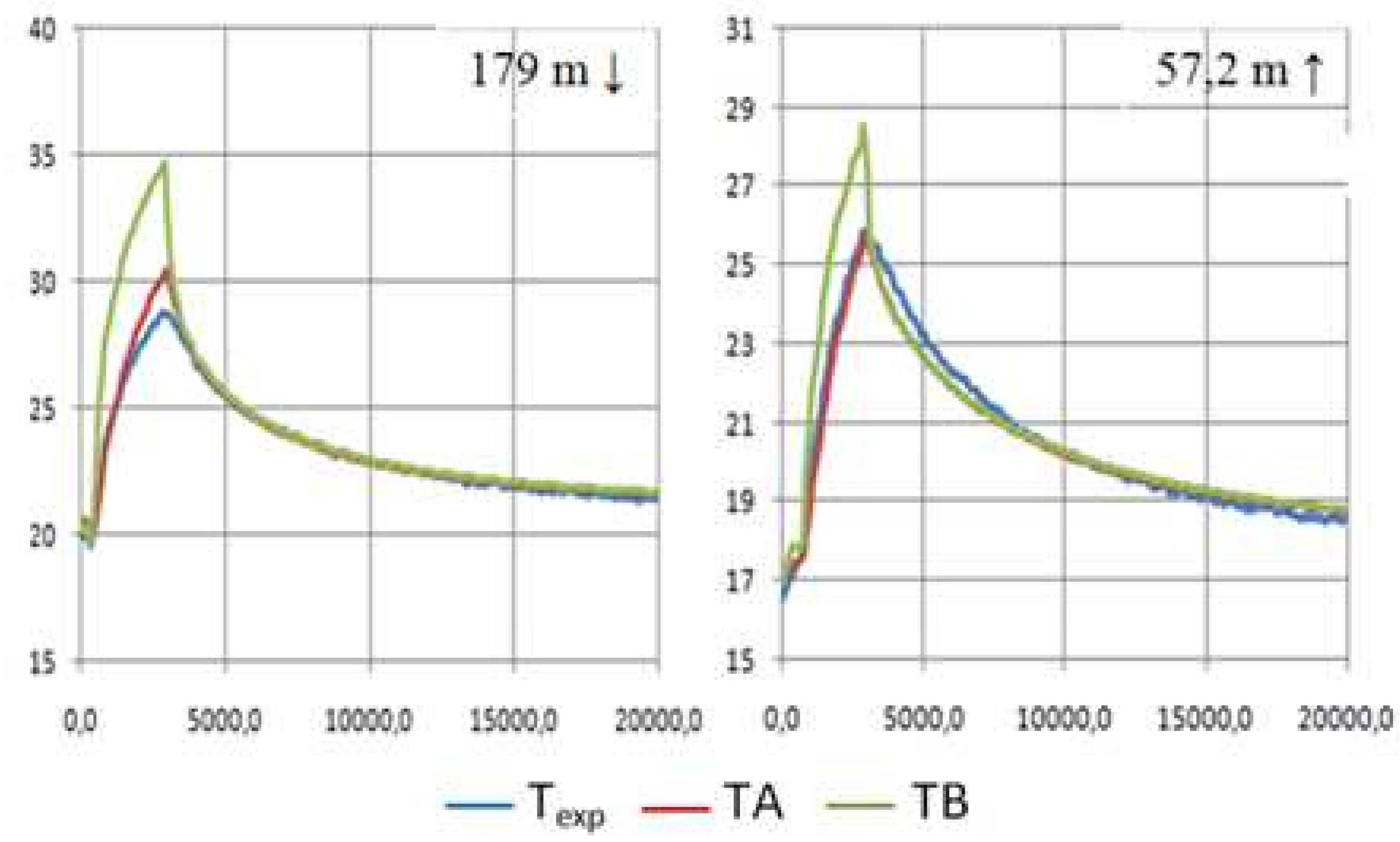

Figure 1. Thermal evolution with depth

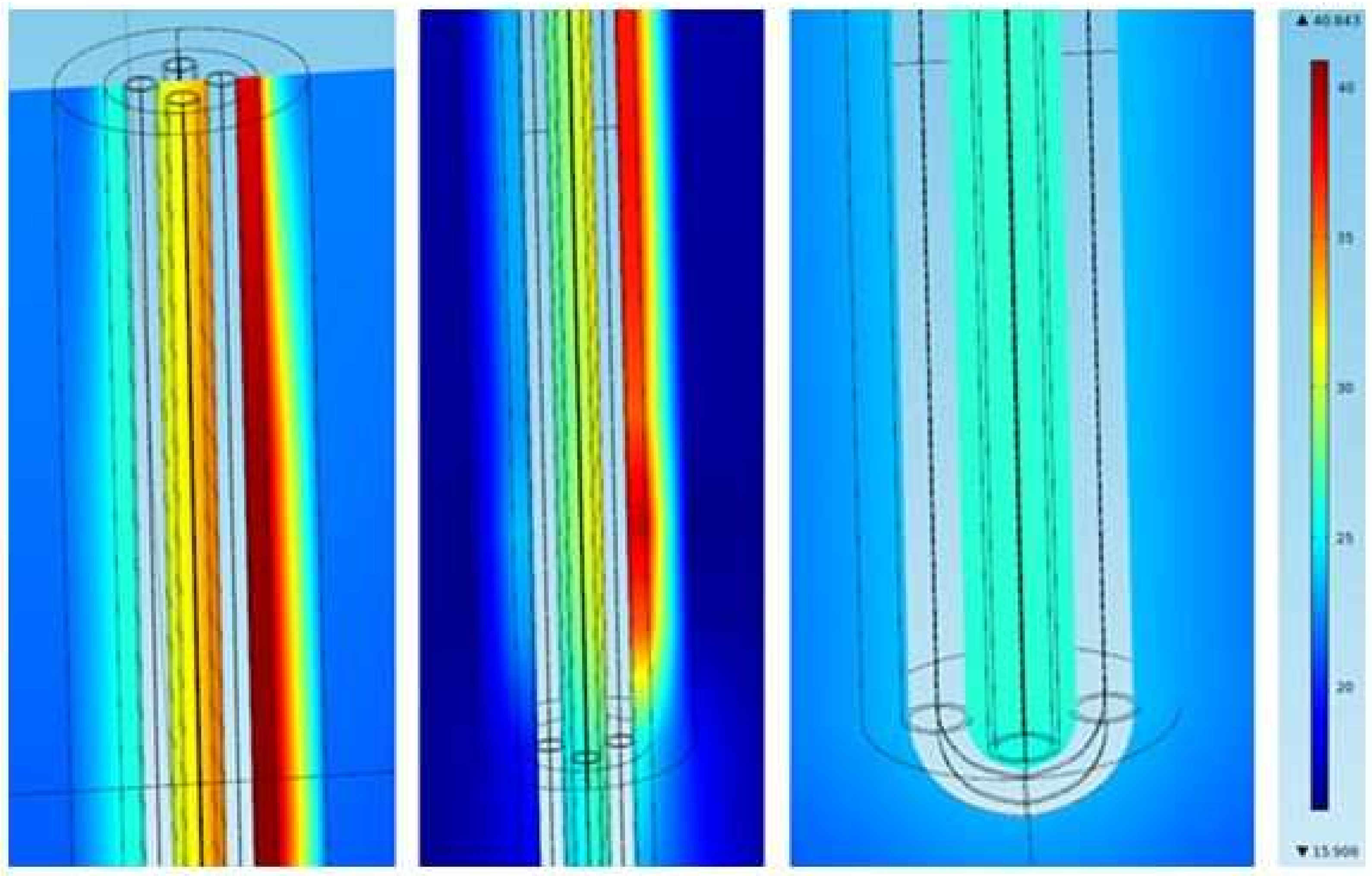

Figure 2. Spatial distribution of the temperature at t=6000s

Conclusions: The energy balance appears consistent. We now have a calibrated numerical model enabling us to simulate a variety of experimental patterns for the injection and withdrawal of heat in a rock mass (Figure 2).

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References:

1. Acuna J., Mogensen P., Palm B. (2009) – Distributed thermal response test on a U-pipe borehole heat exchanger. 11th Conf. on Energy Storage, Effstock2009, Stockholm, Sweden