Sub-surface Heat Rejection in Alternative Cooling Systems

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Introduction: In regions with hot climate air condition (AC) systems are one of the biggest consumers of electrical power. Power mainly stems from fossil sources. In order to reach the goal of low-carbon consumption, as agreed upon in the Paris 2015 treaty, alternative cooling systems that do not rely on fossil energy, could thus deliver a major contribution. Absorption cooling systems utilize thermal energy to produce chill. Solar and thermal energy can be employed as low grade heat sources. No fluorocarbons (as in conventional refrigerants) are used in the process. Their coefficient of performance (COP) depends strongly on a chill source, for which the sub-surface is an option. In our contribution we explore sub-surface heat rejection as part of an absorber system for residence house cooling.

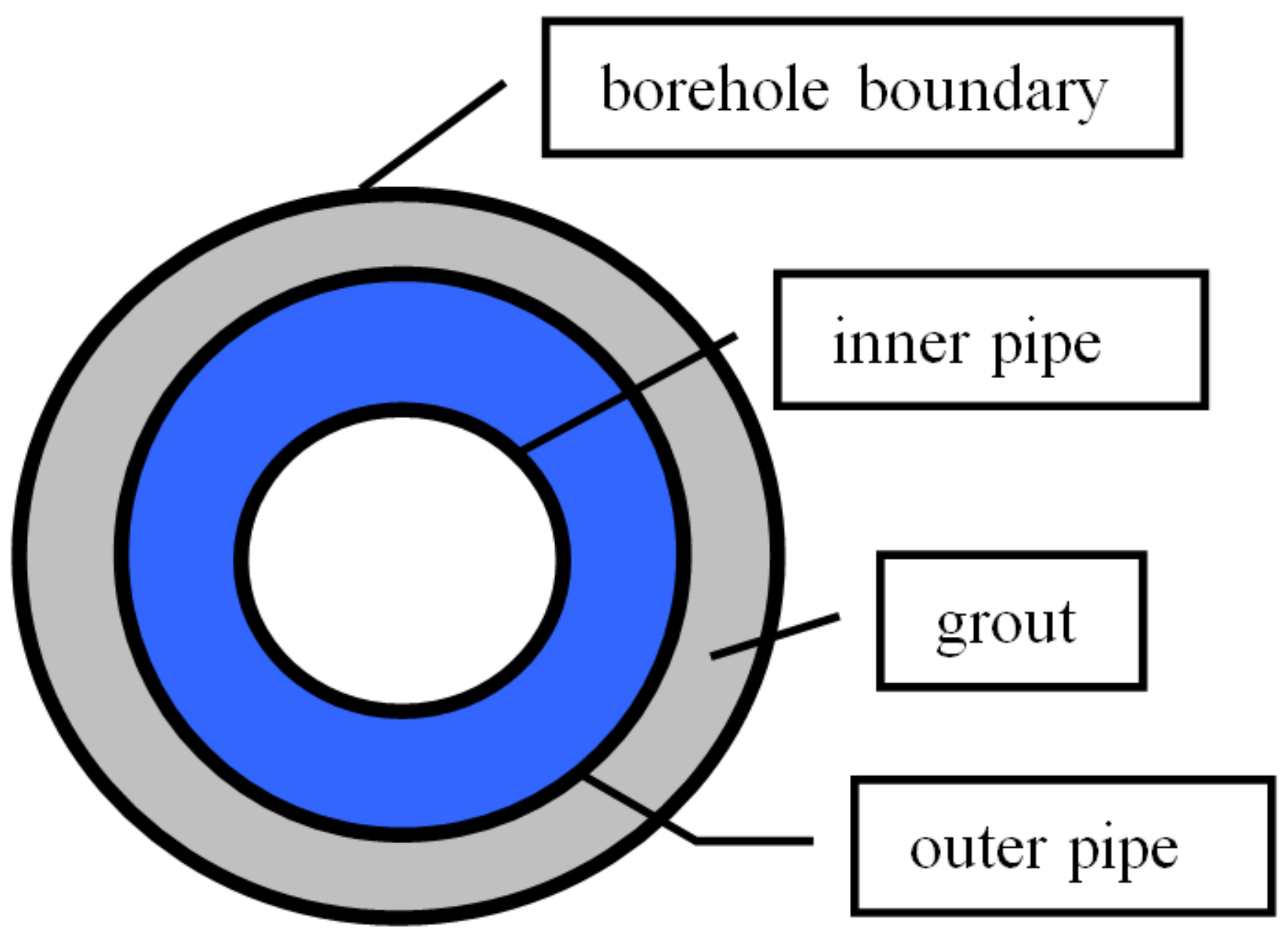

Figure 1. Sketch of cross-section through a co-axial pipe system

Model Set-up: The simulation is built up on the expertise of previous COMSOL models[1,2,3]. In contrast to former approaches we here explore and demonstrate the coupling techniques between 1D, 2D, and 3D domains, offered by COMSOL. Linear and general extrusionsare utilized to couple 1D pipe/borehole domains with the 2D (cross-section) or the 3D domain of the surrounding ground.

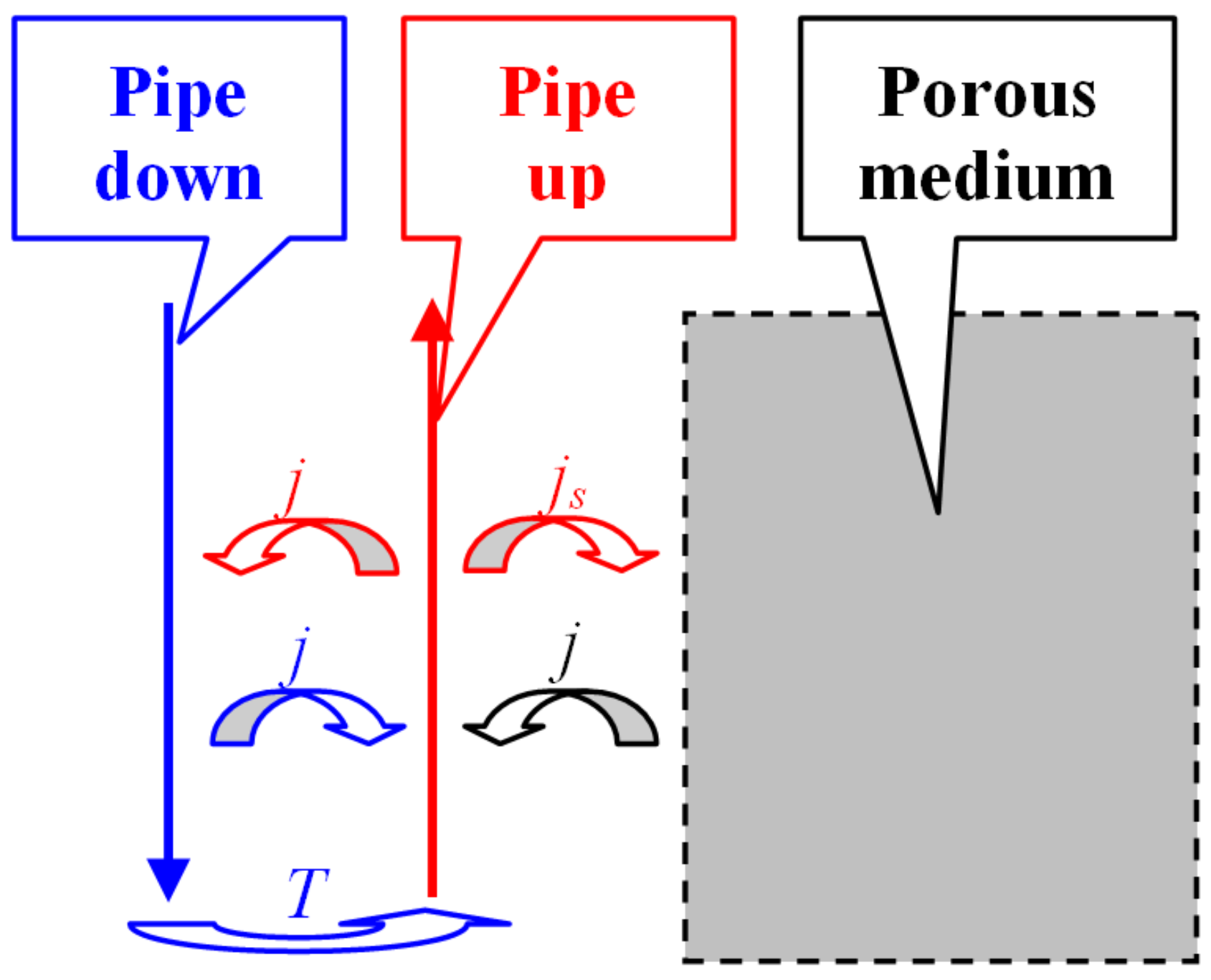

Figure 2. Sketch of components and extrusions

Computational Methods: In the different domains heat transport equations are solved: eq. (1) in 1D domains (pipes), eq. (2) in the surrounding 2D or 3D domains

$$(\rho C)_f \frac{\partial T}{\partial t} + \frac{\partial}{\partial x}\Big((\rho C)_f T v\Big) = -\frac{\partial}{\partial x}\cdot \lambda_f \frac{\partial T}{\partial x} + j \qquad (1)$$

$$(\rho C)\frac{\partial T}{\partial t} + \nabla\cdot\Big((\rho C)_f T\mathbf{q}\Big) = -\nabla\cdot\lambda\nabla T \qquad (2)$$

with

Temperature T, heat capacity of fluid $(\rho C)_f$, fluid thermal conductivity λ_f, flow velocity v and sinks/sources j, specific heat capacity of the fluid-solid system (ρC), its thermal conductivity λ, Darcy velocity $\mathbf{q}$

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Results: Example simulations with the described model are shown in Figure 3. Two figures show the temperature distribution in the porous medium around a borehole of 300 m length. One result was obtained for a location without groundwater flow, the other for a location with groundwater flow. Elevated temperatures in downstream direction are clearly visible. The groundwater table was modelled to lie in about 40 m depth. In the unsaturated zone above the groundwater table there is no horizontal flow component, and there are thus no elevated temperatures in any direction.

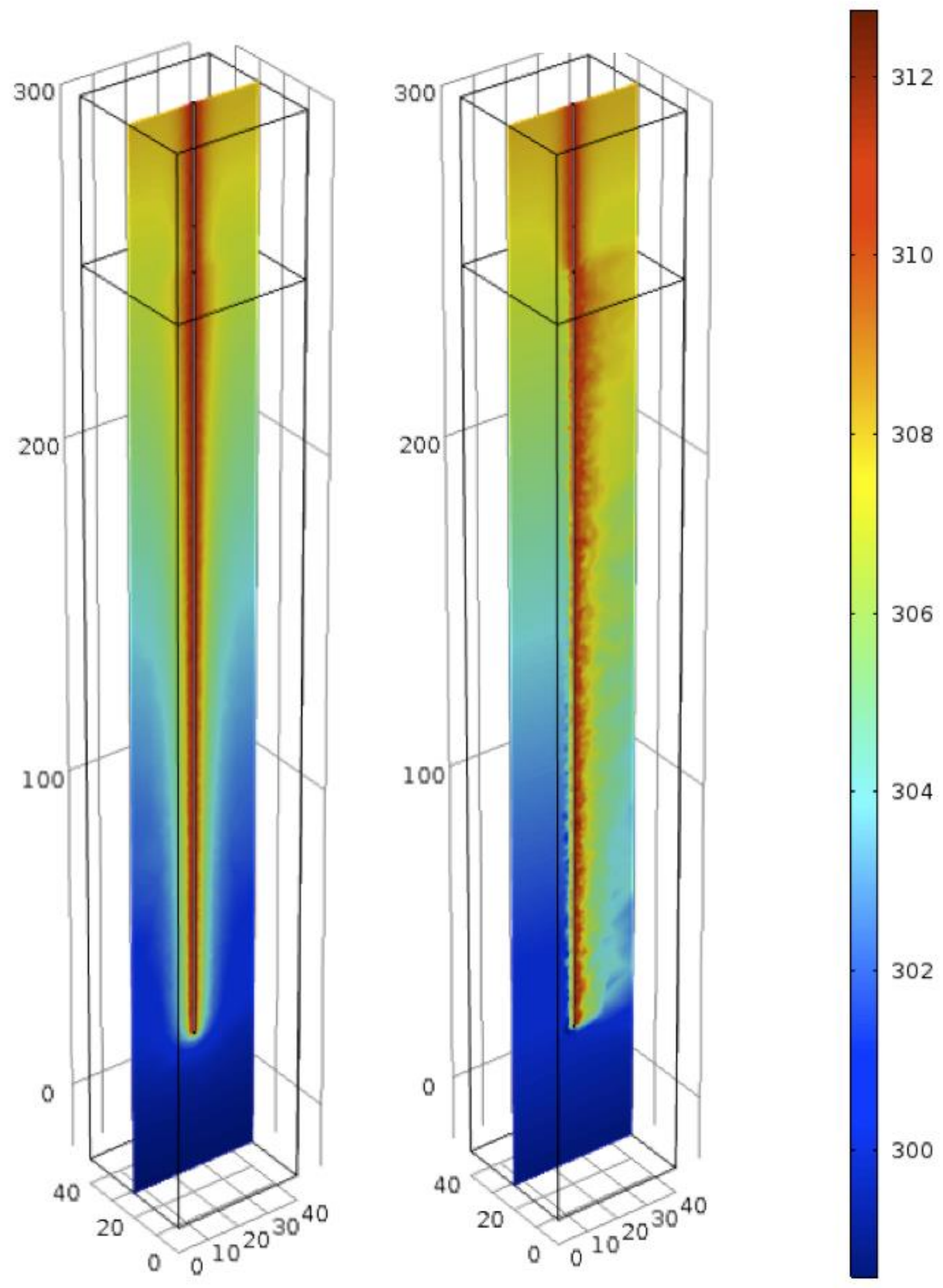

Figure 3. Temperature (° K) field around borehole; left: no groundwater flow; right: with groundwater flow

Conclusions: We described the set-up of a model for heat rejection in the sub-surface. The pipe system is represented by two 1D geometries, which are coupled to the geometry of the surrounding porous medium, which can be 2D cylindrical or 3D. Coupling is performed by general and linear extrusions.

The presented research was performed at German Univ. of Technology in Oman (GUtech), in connection with the Technical University of Berlin (TUB), Geoforschungszentrum Potsdam (GFZ) and the Institute of Advanced Technology Integration (IATI) Muscat (Oman), and reflects parts of a thesis handed in at Utrecht University.

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Excerpt from the Proceedings of the 2016 COMSOL Conference in Munich