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# Numerical Modeling of Freezing and Melting Processes around a Borehole Heat Exchanger

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**Abstract**

In ground sourced heat pump (GSHP) systems, heat energy stored in the shallow subsurface is extracted through borehole heat exchangers (BHE) and then utilized for domestic heating. In cold regions, the continuous heat deficit in the vicinity of the BHE can cause freezing of the surrounding soil. Its material properties, such as permeability and heat conductivity, will then significantly change and lead to a series of coupled thermal, hydraulic, and mechanical processes. In particular, the heat exchange performance of the BHE will be altered, and the frozen soil may also induce ground lift or subsidence in the vicinity of the building.

As the first step of modelling this coupled system, we followed the approach proposed by Al-Khoury et al (2010) and Diersch et al (2011), where the BHE has been fully integrated into the numerical model in a dual-continuum way. Additionally, we extended the existing heat transport module in the numerical simulator OpenGeoSys to include the freezing and melting processes, whereas the ice volume fraction in the soil is non-linearly dependent on the temperature, and the soil properties were determined based on the degree of freezing/melting. The non-linearity of the coupled model was numerically solved by a Newton scheme.

The extended model has been verified by comparing numerical results against analytical solutions and also findings from other numerical codes. Moreover, we proposed and simulated a hypothetical scenario, where ice is gradually forming around a BHE in response to the continuous operation of a heat pump. The model is capable of reproducing the thermodynamic freezing process as well as the heat transport affected by it. Future work will be focused on the integration of deformation processes into the model.

**Key Words**

Ground Sourced Heat Pump (GSHP); Borehole Heat Exchanger (BHE); Numerical Modeling; Heat transport; Freezing and Melting; OpenGeoSys.

**Literature**

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