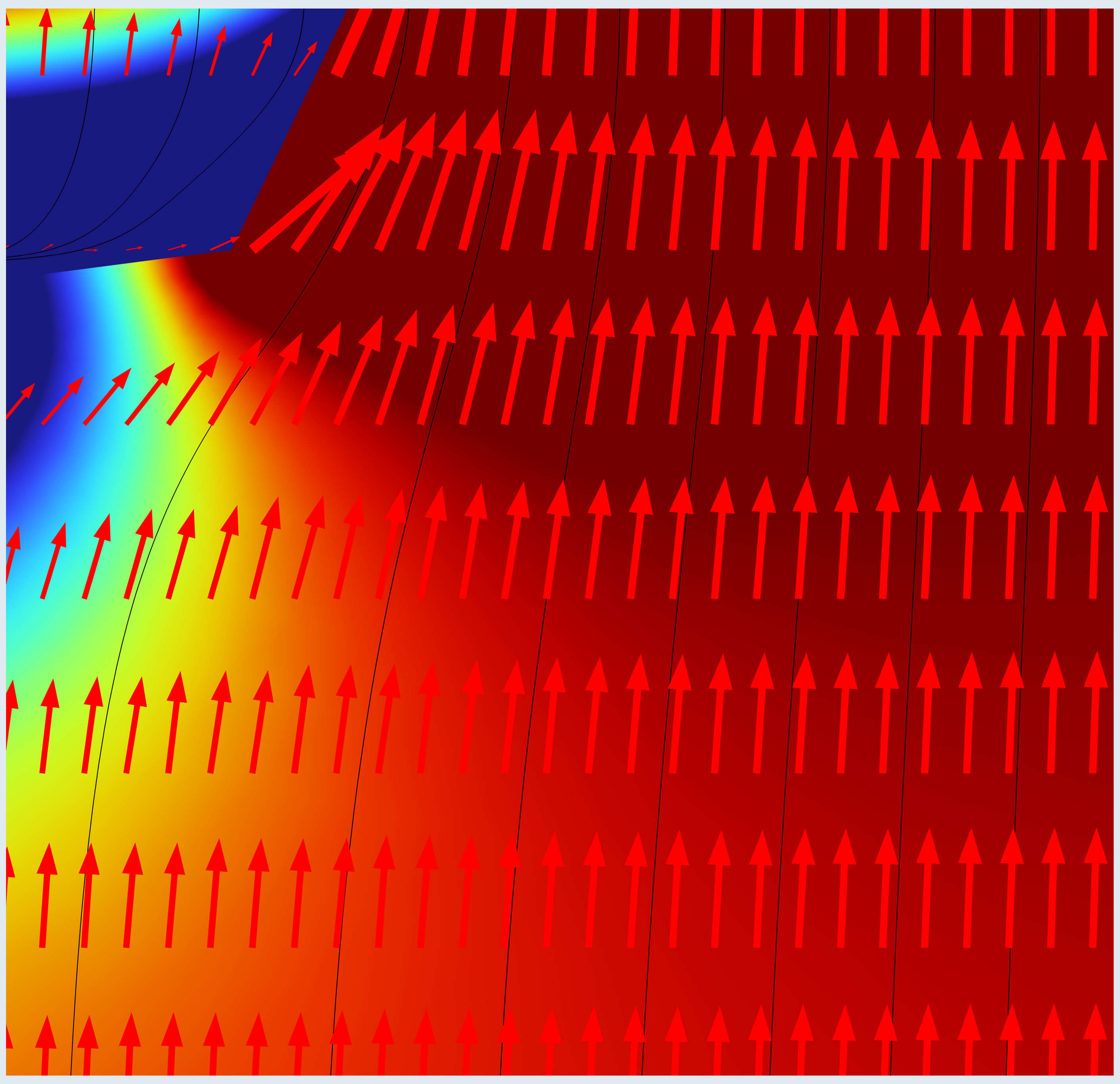

Investigations on Talik Forming During Changes to Cold Climates

An initial study of freezing dynamics in the underground over present-day Germany during the climate cooling leading to the last glacial maximum.

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Introduction

Ground freezing due to permafrost conditions basically shields surface waters from deep aquifers that are potentially contaminated by nuclear waste. A talik – an unfrozen zone in otherwise frozen underground – may form a hydraulic shortcut through the permafrost, though. The conditions for the forming of a talik must therefore be understood. An effective way to investigate this process is numerical modelling with varying model setups. To this end, a stringent mathematical framework has been derived and realized in COMSOL®. A first model provides insight into the dynamics of ground freezing and water movement even if a talik did not form in the present setup.

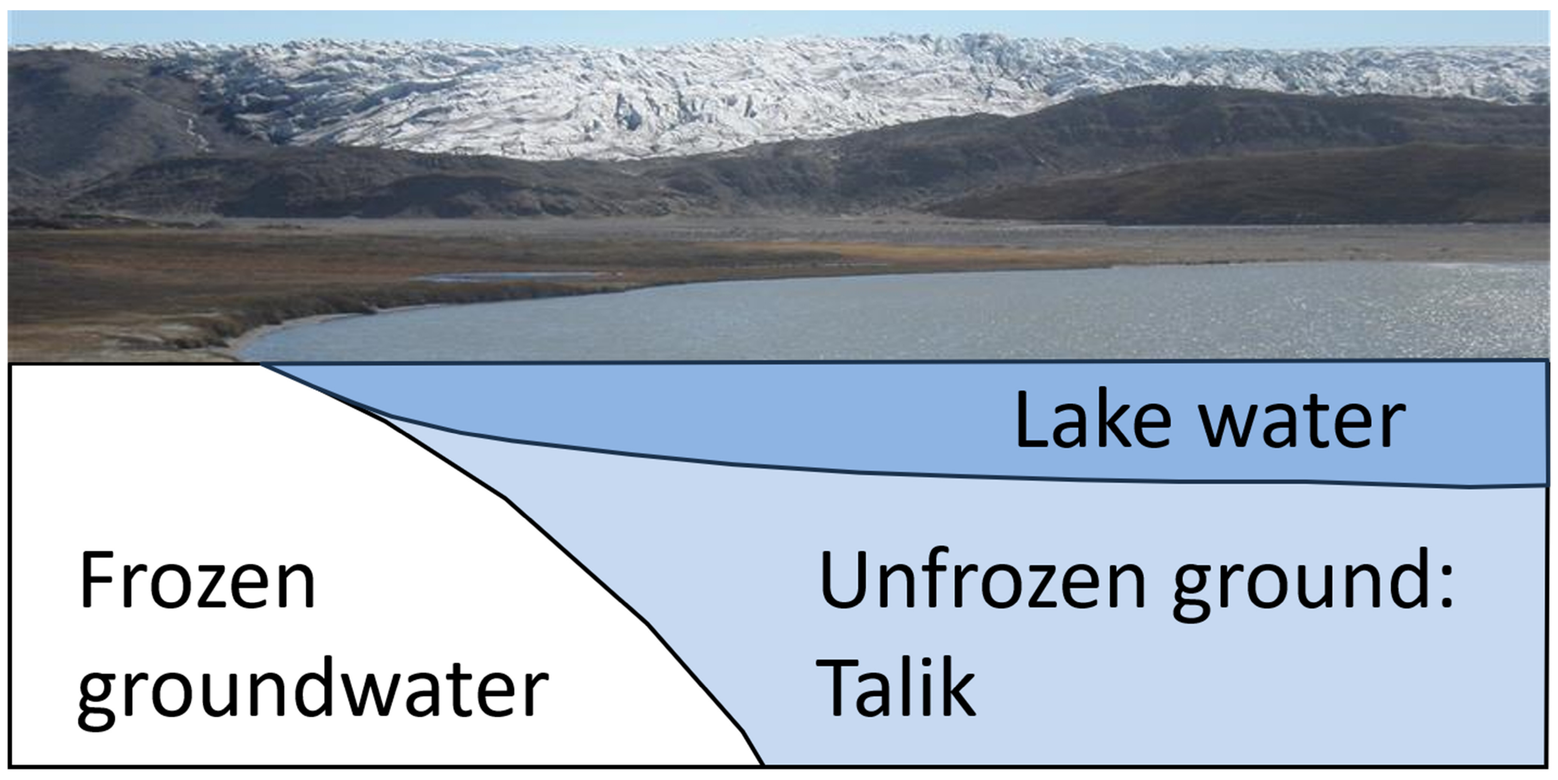

FIGURE 1. Idealized vertical cross-section through a lake under permafrost conditions.

Methodology

Groundwater and heat balance equations together with constitutive equations (CE) and equations of state (EOS) have been derived in [1]. Realization in COMSOL® involved coupling the interfaces "Darcy's Law" and "Heat Transfer in Porous Media". Quite some effort went into new simplified but accurate EOS as the range of validity for the ones provided by [1] proved to be insufficient. Also some effort was necessary for the CE describing the phase change behavior of water as this required some deeper understanding on the level of the equation view. A simplified temperature curve was assigned to the top of the model and a constant heat flux from earth's interior at the bottom. The domain consists of a lake on otherwise granitic ground in a 2D-axisymmetric geometry.

Results

The plot at the top left corner of this poster shows a vertical cross-section of the model depicting the total heat flux after 2000 years model time. This indicates a slowing of cooling in the area of the lake as shown in Figure 2, top right.

Freezing occurs over about 70,000 years model time and the freezing front advances during this time down to a depth of about 150 m (Figure 2, bottom right). Groundwater flow is only driven by the freezing of water as the less dense ice displaces the remaining water. Consequently, flow is extremely slow so that heat flow is essentially conductive in this model. Density variations with depth due to changing of pressure and temperature are not enough to initiate convective flow and a concurrent heat transport.

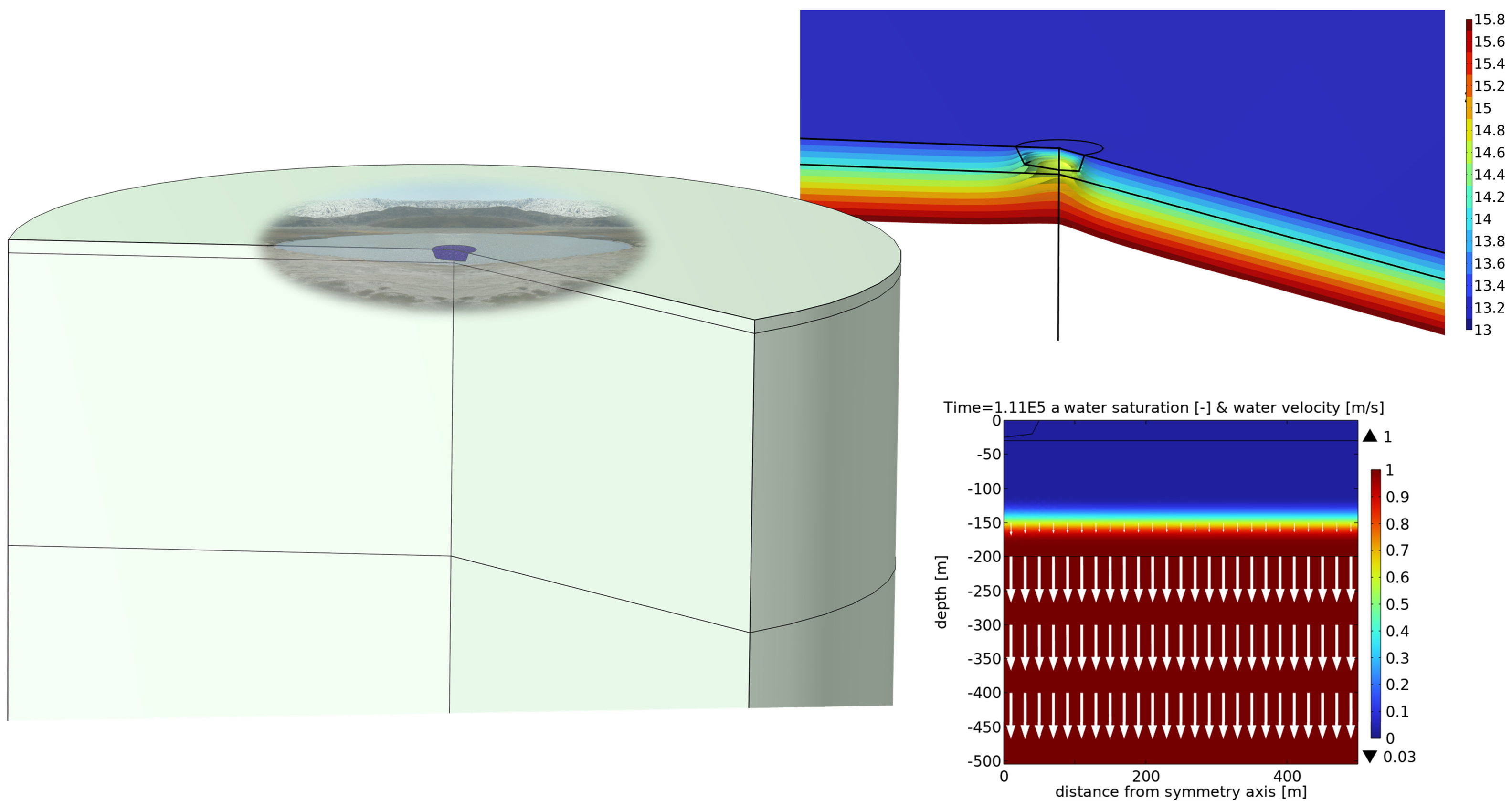

FIGURE 2. left: model domain;
top right: temperature around the lake at 2000 years;
bottom right: water saturation and water velocity at 111.500 years.

REFERENCES

1. K.-P. Kröhn, "Basics for groundwater flow under permafrost conditions in the context of radioactive waste storage," FKZ 02 E 11809A (BMWi), Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, report GRS-707, Braunschweig, 2023.

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