Modelling techniques for studying ice wedges with ground-penetrating radar

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SUMMARY

Geophysical methods are widely used in permafrost environments to explore subsurface structures and their properties. Ground-penetrating radar (GPR) is a non-destructive geophysical method, which has proven its potential in permafrost studies, mostly in delineating the bottom of the active layer or imaging subsurface stratigraphy. However, when investigating ground ice like ice wedges, GPR data typically show complex reflection patterns. To accurately image such complex subsurface structures, sophisticated procedures of processing and interpretation are required. During this work, we focused on the physical and numerical modelling of an ice wedge in addition to the traditional GPR profiling. We intend to confirm current assumptions (hyperbolic wave patterns) and find new features that we can use to evaluate the shape and size of the ice body.

We constructed the 3D wedge from Styrofoam and put it into water and sand. Such host mediums are less complex than natural field conditions but allow us to detect even out-of-plane reflections, typically recorded below the signal-to-noise ratio. Using a classical survey system, we got high-quality results, which we used to identify typical patterns of ice in the host medium. To optimize our physical model experiment, we performed numerical modelling in advance. We implemented the physical modelling in a plastic tank (1.1 m × 0.9 m × 0.5 m), which contained the host medium and the wedge model. We used plastic tracks to guide our 1 GHz antenna sledge across our physical model. Furthermore, we set up a self-tracking total station to measure the antenna position.

Afterwards we compared our results with field GPR data collected on the two sites in Eastern Siberia: Samoylov Island and Chara depression. In both cases, the ice wedges were evident in the outcrops, and we used the outcrop-based sketches to build realistic numerical models.
The combination of numerical modelling and physical modelling showed a distinct benefit for analysing field data and to improve the interpretation.

Key words: ice wedge, permafrost, ground-penetrating radar, physical modelling, numerical modelling