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Spatial variation of river-ice thickness in a meandering river

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Abstract

The spatial variation of river-ice thickness in three contiguous meandering bends was determined via ground-penetrating radar technology and traditional borehole measurements. Applying high-frequency GPR enables detailed surveying of the variation in river-ice thickness and the boundary of floating and grounded (i.e., bottom-fast) ice in a relatively large area. Extensive verification of river-ice thickness based on GPR profiling was performed by comparing the radar data with ground truth ice thickness measurements. This revealed that the GPR method is suitable for river-ice thickness calculation with a mean absolute error of ±3 cm, equivalent to 5% mean percentage error in the case of 50-centimeter-thick ice, although snow cover on top of the ice or a possibly non-homogeneous ice surface reduces GPR measurement accuracy and the usability of the method for detailed ice-thickness measurements. The ice-thickness variation in a meandering river was observed to be quite large, with the maximum difference of 32 cm in mean ice thickness between cross sections. However, the observed mean ice thickness yielded a reasonable match with the theoretical mean thickness calculated with a widely used analytical ice-thickness growth equation. The vertically averaged flow velocities measured with an acoustic Doppler current profiler and bottom depths were surveyed from 148 boreholes, which enables discussing the influence of flow velocity and river morphology on the ice thickness's variation.

Keywords: river ice thickness; GPR; bottom-fast ice; Stefan's equation; flow velocity; ADCP

Graphical abstract

Highlights

- Mid-winter ice thickness in a subarctic meandering river showed high spatial variation
- The ice thickness was reduced around apices of the meander bends
- Ground-penetrating radar displayed good accuracy for the river-ice thickness profiling
- Floating ice and bottom-fast ice are easily detectable with ground-penetrating radar