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Past climate changes and permafrost depth at the Lake El'gygytgyn site: implications from data and thermal modeling

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This study focuses on the temperature field observed in boreholes drilled as part of interdisciplinary scientific campaign targeting the El'gygytgyn crater lake in NE Russia. Temperature data are available from two sites: the lake borehole 5011-1 located near the center of the lake reaching 400 m depth, and the land borehole 5011-3 at the rim of the lake, with a depth of 140 m. Constraints on permafrost depth and past climate changes are derived from 2D numerical simulation of the thermal regime associated with the lake-related talik structure. The thermal properties of the subsurface needed for these simulations are based on laboratory measurements of representative cores from the quaternary sediments and the underlying impact-affected rock, complemented by further information from geophysical logs and data from published literature.

The temperature observations in the lake borehole 5011-1 are dominated by thermal perturbations related to the drilling process, and thus only give reliable values for the lowermost value in the borehole. Undisturbed temperature data recorded over more than two years are available in the 140 m deep land-based borehole 5011-3. The analysis of these observations allows determination of not only the recent mean annual ground surface temperature, but also the ground surface temperature history, though with large uncertainties. Besides some signals to be attributed to the warming from Pleistocene to Holocene, the data shows a strong evident for a comparatively large amplitude of the Little Ice Age (up to 4 K), with low temperatures prevailing far into the 20^{th} century. Other mechanisms like varying porosity may also have an influence on the temperature profile, however, sensitivity studies imply a major contribution from recent climate changes. We also address the issue of the possible shortcomings when using 2D instead of 3D modeling. We show that in this case, due to the large diameter-depth ratio of the lake, 2D modeling is sufficient for the studied processes.

We also study the long-term monitoring data from the very shallow part (down to 20 m) in order to constrain thermal properties of the permafrost regime, such as thermal diffusivity and porosity.