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Newly dated permafrost deposits and their paleo-ecological inventory reveal a much warmer-than-today Eemian in Arctic Siberia

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Abstract. Fossil proxy records in Last Interglacial (LIG, ca. 130–115 ka) lacustrine thermokarst deposits now preserved in permafrost can provide insights into terrestrial Arctic environments during a period when northern hemisphere climate conditions were warmer than today and which might be considered a potential analog for a near-future warmer Arctic. Still, such records are scarce on a circum-Arctic scale and often poorly dated. Even more, the quantitative climate signals of LIG permafrost-preserved deposits have not yet been systematically explored.

Here, we synthesize geochronological, cryolithological, paleo-ecological, and modeling data from one of the most thoroughly studied LIG sites in NE Siberia, the permafrost sequences along the coasts of the Dmitry Laptev Strait, i.e., on Bol'shoy Lyakhovsky Island and at the Oyogos Yar coast. We provide chronostratigraphic evidence by new luminescence ages from lacustrine deposits exposed at the southern coast of Bol'shoy Lyakhovsky Island. The infrared-stimulated luminescence (IRSL) ages of 127.3±6.1 ka, 117.8±6.8 ka, and 117.6±6.0 ka capture the MIS 5e sub-stage, i.e., the LIG.

The LIG lacustrine deposits are mostly preserved in ice-wedge pseudomorphs of 1-3 m thickness with alternating layers of peaty plant detritus and clayish silt. Ripples and synsedimentary slumping structures indicate shallow-water conditions. The rich fossil record was examined for plant remains (macro-fossils, pollen, *seda*DNA), lipid biomarkers, and aquatic and terrestrial invertebrates (cladocera, mussels, snails, ostracods, chironomids, and beetles).

Most proxy data and also paleoclimate model results indicate a regional LIG climate significantly (ca. 5 to 10 °C) warmer than today. Plant macrofossil data reflect mean temperatures of the warmest month (MTWA) of 12.7–15.3 °C for Oyogos Yar and 10.3–12.9 °C for Bol'shoy Lyakhovsky, while pollen-based reconstructions show mean MTWA of 9.0±3.0 °C and 9.7±2.9 °C as well as mean annual precipitation (MAP) of 271±56 mm and 229±22 mm, respectively. The biomarker-based reconstruction of the Air Growing Season Temperature (Air GST) using GDGTs is 2.8±0.3 °C. The fossil beetle-based mutual climatic range is 8 to 10.5 °C for MTWA and –34 to –26 °C for the mean temperature of the coldest month (MTCO) on Bol'shoy Lyakhovsky Island and 8 to 14 °C for MWTA and –38 to –26 °C for MTCO on Oyogos Yar. The chironomid-based MTWA varies between 9.4±1.7 and 15.3±1.5 °C and the water depth (WD) between 1.7±0.9 and 5.6±1.0 m on Bol'shoy Lyakhovsky Island. Prior findings from Oyogos Yar in the literature suggest an MTWA of 12.9±0.9 °C and a WD of 2.2±1.1 m. The first-time application of clumped isotopes to permafrost-preserved biogenic calcite of ostracods and bivalves reconstruct near-surface water temperature of 10.3±3.0 °C and bottom water temperatures of 1.5±5.3 °C in thermokarst lakes during summers. PaleoMIP Model simulations (PIobs+(lig127k-PI)) of the LIG show warmer MTWA compared to modern conditions (by 4.4±1.0 °C for Bol'shoy Lyakhovsky and

4.5±1.2 °C for Oyogos Yar) but currently underestimate the Eemian warming reconstructed from our multiple paleoecological proxies.

The LIG warming mainly affected summer conditions, whereas modern and future warming will rather impact winter conditions. As the LIG annual mean temperature is often used as an analog for the future climate in the High Arctic, the proxy-model mismatch highlights the urgent need for more systematic quantitative proxy-based temperature reconstructions in the Arctic and more sophisticated Earth system models capable of capturing Arctic paleoenvironmental conditions.

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