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What do anhydrosugars in up to 420 kyrs old Lake El'gygytgyn sediments tell us about low-temperature fires of northeastern Siberia?

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Forest fires are an important factor of the global carbon cycle and high latitude ecosystems. Eastern Siberian tundra, summergreen larch-dominated boreal forest on permafrost and evergreen spruce- and pine-dominated boreal forest have characteristic fire regimes with varying fire frequencies and intensities. However, it is unknown which role fire plays in climate-vegetation-permafrost feedbacks and how high-latitude fire regimes and ecosystems will change in a warmer world – questions that are crucial considering that boreal and permafrost regions have been identified as tipping elements in the climate system (Lenton et al., 2008, PNAS).

Here, we investigate fire regime shifts during previous warmer-than-present interglacials, i.e. marine isotope stages (MIS) 5e and 11c, which were not influenced by human activity. We use specific biomass burning residues, i.e. monosaccharide anhydrides (anhydrosugars), that are a rather chemically reactive group of pyrogenic carbon. These molecules are mainly produced by low-temperature fires, but their pathways through the Earth system from source to sink and their stability in sedimentary deposits are very poorly constrained (Suciu et al. 2019, Biogeochemistry). A recent study (Dietze et al., 2020, ClimPastDisc) found anhydrosugars in up to 420 kyr old sediment of Lake El'gygytgyn (ICDP Site 5011-1), northeastern Siberia, and suggest that these molecular markers are suitable proxies for fires in Siberian summergreen boreal forests. Surprisingly, the ratios of the anhydrosugars levoglucosan to its isomers mannosan and galactosan were exceptionally low compared to published emission ratios from modern biomass burning, pointing to either a specific local biomass source and/or isomer-specific preservation.

To understand what anhydrosugars from interglacial Arctic lake sediments tell us about fire regime changes, we studied modern sediment samples from Lake El'gygytgyn, its catchment and from other lakes located in East Siberian summergreen and evergreen boreal forest. The latter lake systems represent spatial analogues to the conditions at Lake El'gygytgyn during MIS 5e and 11c, respectively. We analyzed anhydrosugars using ultra high-performance liquid chromatography coupled to a high-resolution mass spectrometer. We discuss the modern anhydrosugar concentrations and isomer ratios in context of (1) well-explored modern lake and catchment configurations and (2) multiple late glacial to interglacial results of Lake El'gygytgyn sediment cores. By better constraining the sources and (degradation) pathways that determine the proxy meaning of sedimentary anhydrosugars in northeastern Siberia, we provide a step forward to understand the regional pyrogenic carbon cycle and long-term feedbacks that are crucial for model predictions of future fire regime shifts in the high northern latitudes.