Organic carbon characteristics and dynamics in thermokarst terrain on the Alaskan north slope

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Thermokarst processes have been accelerating since the 1950s in the Alaskan tundra (Chen et al. 2021; Jorgenson et al. 2006) which corresponds to warming permafrost temperatures (Biskaborn et al. 2019) and a disproportional warming climate of the Arctic region (Rantanen et al. 2022). On the Alaskan North Slope, thermokarst is steering the dynamics of thermokarst lakes and drained lake basins (DLBs; Jones et al. 2022), thereby thawing, mobilizing, and sequestering organic carbon. The consequences for the biogeochemical system, which holds significant amounts of organic carbon (Palmtag et al. 2022), remain understudied. In particular, the quality of organic carbon is an important factor for the mobilization potential and rates of release as greenhouse gases (Jongejans et al. 2021). In our study, we aim to investigate the soil organic carbon pool characteristics in a thermokarst terrain close to Utqiaġvik, Alaska.

Study area

The Alaskan North Slope lies within the continuous permafrost zone with a mean annual ground temperature of about -6 °C at the permafrost surface (Obu et al. 2019). Lakes and DLBs cover about 72 % of the landscape (Hinkel et al. 2003). Undisturbed uplands consist of Holocene deposits, which are underlain by Quaternary marine sediments (Eisner et al. 2005).

Methods

Sediment coring took place in 2022 and include permafrost cores from an upland and a DLB. Additionally, unfrozen sediments (i.e., taliks) of two thermokarst lakes (West Twin Lake and East Twin Lake) were cored. The up to 2 m long sediment cores were subsampled in approximately 5 cm steps. The multidisciplinary laboratory approach include bio-, hydrochemical and sedimentological investigations. n-Alkane biomarker analyses are conducted before and after a 12-month-long incubation experiment. Both the anaerob and aerob incubations are kept at 10 °C in dark conditions.

Results

Total organic carbon (TOC) contents are highly variable within the landscape. The upland core is organic-rich with maximum 35 wt% TOC in the upper meter. Below 100 cm depth TOC values are <10 wt%. The DLB has the highest variability of TOC values, ranging from 42 wt% at 8 cm depth to 2 wt% at 129 cm depth. TOC contents in the sediments from both West and East Twin Lake remain <17 wt%. The sediments are generally silty-sandy.

The permafrost is ice-rich in the upland and in the DLB, with minium ice contents of 43 wt% and 21 wt%, respectively. The sediments of West Twin Lake have a water content of >60 wt%. The water contents of the sediments of East Twin Lake range between and 64 (177 cm depth) and 16 wt% (290 cm depth).

All sediment cores reveal an increasing electrical conductivity (EC) with depth. In the upland this increase is observed below 140 cm depth and in the DLB below 98 cm depth. The porewater samples from the sediments of West Twin Lake all had <2 mS/cm, while the porewater from talik sediments of East Twin Lake has EC values of up to 43 mS/cm.

After two months of incubation, the anaerobic experiment indicated distinct developments. Microbial communities in the organic-rich sediments were predominantly producing methane while organic-poor sediments were characterized by primarily carbon dioxide production.

Outlook

The high heterogeneity of the parameters between and within the cores yield an intriguing baseline for further investigations and interpretations of the sediment characteristics. Particularly of interest is the talik of East Twin Lake, as it likely consists of thawed marine deposits that have a high salinity (Jones et al. 2023). The n-alkane patterns from our biomarker analysis will provide key variables for the understanding of organic carbon quality (changes) and mobilization in frozen and thawed sediments.

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