Carbon accumulation in thermokarst lakes: A biogeochemical comparison between Alaskan boreal and tundra lake deposits

Josefine Lenz[1, 2], Katey Walther Anthony[2], Matthias Winkel[2, 3], Susanne Liebner[3], Matthias Fuchs[1], Jens Strauss[1], Christopher Maio[4], Benjamin M. Jones[5], Guido Grosse[1]

[1] *Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Periglacial Research Section, Josefine.Lenz@awi.de*

[2] *University of Alaska Fairbanks, Institute of Northern Engineering*

[3] *Helmholtz Centre Potsdam - German Research Centre for Geosciences*

[4] *University of Alaska Fairbanks, Department of Geosciences*

[5] *US Geological Survey, Alaska Science Centre*

Abstract

Thermokarst lakes are widespread features of changing periglacial environments. In this study, we analyze total organic carbon content (TOC), C/N, stable carbon isotopes and methane concentration in pore water from sediments of 18 tundra lakes in West Alaska and 11 boreal lakes in Central Alaska in order to discuss differences in carbon accumulation, sources of organic matter and their role in the carbon cycle. While a wide range of TOC content was measured in West Alaska with highest TOC in lakes that initiated in drained lake basins, some boreal lakes in Central Alaska, like Goldstream Lake show surprisingly low TOC. Similar finding in CH_4 concentration suggest that state of permafrost, the age of the lakes and the catchment characteristics have an important influence on sources of organic carbon and, thus, different potential of thermokarst lakes to contribute to the global carbon cycle.

Keywords: thermokarst lake dynamics; permafrost degradation; sedimentology; total organic carbon; methane

Introduction

Thermokarst ponds and lakes give evidence for permafrost thaw and amplify deep thaw by talik development. During the thawing process, previously preserved organic matter is decomposed and potentially released as greenhouse gases carbon dioxide and methane. In the course of lake development and shoreline expansion, both, younger near-surface and older organic matter from slumping shores are potentially deposited in the lake basin. Lake internal bioproductivity is complementing carbon accumulation in lacustrine deposits and provides an additional source of young carbon transformed into greenhouse gases.

This study aims at identifying differences in carbon accumulation and carbon sources in different thermokarst lake settings to proof the importance of permafrost conditions, hydrological systems and lake genesis.

Compared study sites

Tundra lakes in West Alaska

Eighteen short lake cores of max. 73 cm length were retrieved near the border of continuous-discontinuous permafrost on the Central Seward Peninsula (Fig. 1a), in the Kobuk, Noatak, Selawik Deltas (Fig. 1b) in Western Alaska. They represent dynamic lakes, which have partly developed in deltaic deposits, in presumably not yet redeposited uplands and drained lake basins. Vegetation is dominated by tundra communities with only individual erect shrubs and trees.

Boreal lakes Central Alaska

Short and long cores up to 473 cm length were retrieved from eleven thermokarst lakes in Goldstream Valley in the region of Fairbanks in Central Alaska (Fig. 1c). They represent recent and Holocene lakes in a boreal, discontinuous permafrost valley with open and closed talik systems.

Methods

Lake sediment cores were retrieved in August 2016 and March 2017 using different coring systems (piston, hammer and vibracorer). In the laboratory at AWI Potsdam, cores were opened, described, subsampled and analyzed for total organic carbon (TOC), total nitrogen (TN) and stable carbon isotopes ($\delta^{13}C$). Selected sediment samples were taken to detect methane (CH_4) concentration in pore water (measured at GFZ Potsdam) and radiocarbon age of macrofossils.

First results and discussion

TOC of samples in eighteen lake sediment cores from West Alaska ranges from 0.6 to 42 wt.% with highest TOC stored in lakes which initiated in drained lake basins on the Central Seward Peninsula. In addition, individual lakes in the Kobuk Delta were characterized by TOC higher than 30 wt.% whereas lowest TOC was measured in sediments of lakes developed in upland remnants in the Kobuk Delta as well as in deltaic lakes of the Selawik Delta dominated by discontinuous permafrost. Similarly low TOC was measured for Goldstream Lake in boreal Central Alaska with a TOC of 2.2 wt.% averaged from 4 sediment cores. While this specific lake shows CH_4 seeps at actively expanding shorelines, its sediments have low CH_4 concentration of 214 ppm/g in near-shore sediments and slightly higher CH_4 concentration of 772 ppm/g in its central part.

In West Alaska, substantial numbers of CH_4 producing microorganisms and pore water CH_4 concentrations were detected in lake sediments. Pore water CH_4 concentrations varied by two orders of magnitude ranging between 10 and slightly above 1000 µM (mean: 376 µM). The surface 2 cm of the lake sediments had similarly high mean CH_4 concentrations (387 µM) like the overall mean. Thus, even though all measured CH_4 concentrations were below saturation, our data suggest that thermokarst lake sediments in West Alaska are as a source of CH_4 to the water column.

While sample processing is ongoing, it can be assumed that the age of the lakes, state of permafrost (continuous vs. discontinuous) and the catchment characteristics (boreal vs. tundra) have an important influence on carbon accumulation rates and, thus, different potential of thermokarst lakes to contribute to the global carbon cycle.

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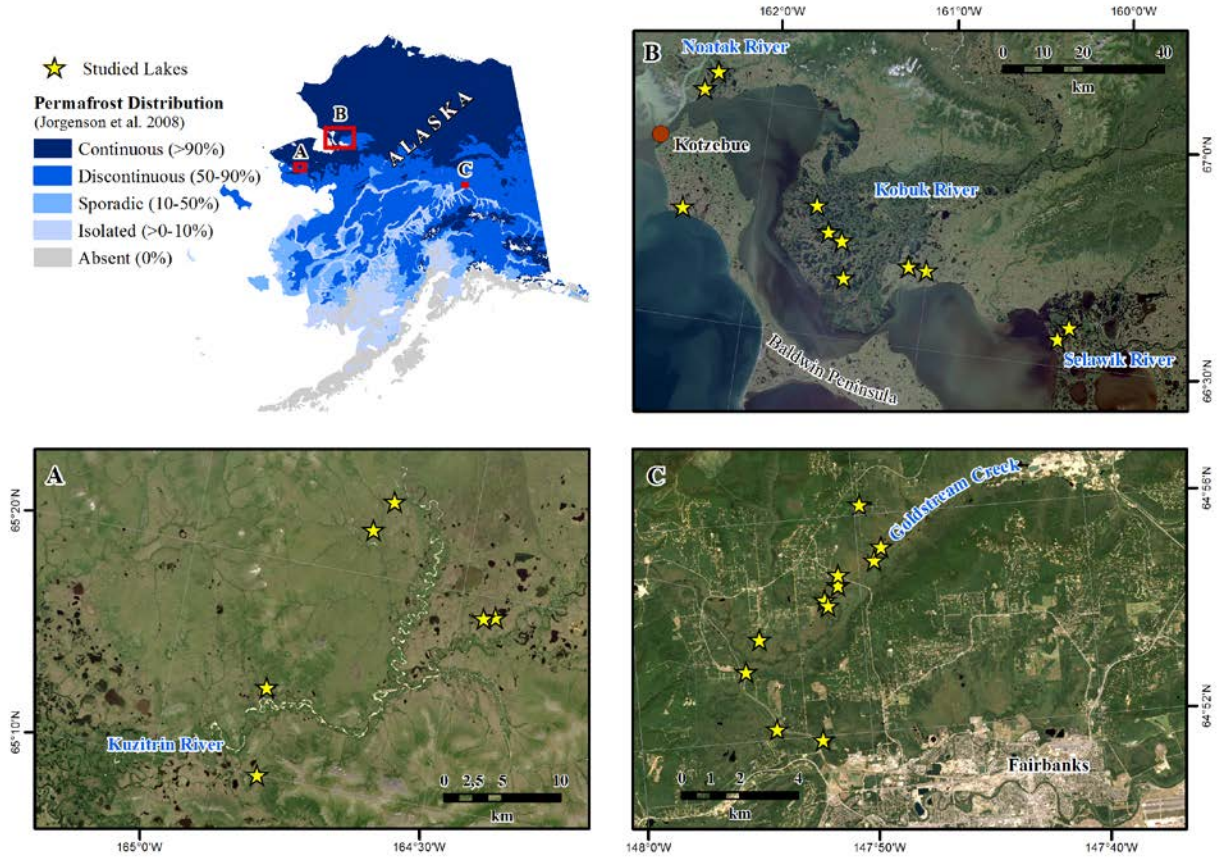

Figure: Studied lake sites located in continuous and discontinues permafrost region in Alaska in A) Central Seward Peninsula, B) in the Noatak, Kobuk and Selawik Deltas near Kotzebue in C) Goldstream Valley near Fairbanks (Source: true color composites of Landsat 8 satellite images. Map preparation M. Fuchs, AWI)