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Source characterization and temporal variation of methane seepage from thermokarst lakes on the Alaska North Slope in response to Arctic climate change

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QUARTERLY PROGRESS REPORT
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Summary

The goals of this research are to characterize the source, magnitude and temporal variability of methane seepage from two representative thermokarst lake areas within the Alaska North Slope gas hydrate province, assess the vulnerability of these areas to ongoing and future arctic climate change and determine if gas hydrate dissociation resulting from permafrost melting is contributing to the current lake emissions. Work during this quarter has focused on preparing presentations of the results related to all of the projects Tasks. The next quarter will also be dedicated to publishing the primary data from this project. Analyses have focused on four main lake locations referred to in this report: Lake Qalluuraq (referred to as Lake Q) and Lake Teshekpuk (both on Alaska's North Slope) and Lake Killarney and Goldstream Bill Lake (both in Alaska's interior). Additional sites (Burial Lake and Quartz Lake) have been added by Wooller to supplement Task 8. Analyses of samples from Year 1 field work are complete and data from this field work and sites are being included in a range of papers and presentations (see below). Analyses of samples from Lake Teshekpuk are being completed.

Tasks 1 through 6: These tasks relate to field activities and have been completed and reported on in previous quarterly reports.

Task 5.0 – Quantifying the short-term variability in methane emissions. Katey Walter Anthony: During the past quarter, co-I Katey Walter Anthony and colleagues published an article entitled "Geologic methane seeps along boundaries of arctic permafrost thaw and melting glaciers." The article summarizes the findings based on aerial and ground surveys of large, geologic methane seeps across Alaska. This project supported initial field work and aerial surveys in the Atqasuk region, at Lake Q and surrounding lakes, in which anomalous ebullition (bubbling) seeps were observed. "*Methane, a potent greenhouse gas, accumulates in subsurface hydrocarbon reservoirs. In the Arctic, impermeable icy permafrost and glacial overburden form a 'cryosphere cap' that traps gas leaking from these reservoirs, restricting flow to the atmosphere. The large size of the arctic geologic methane reservoir (>1,600 petagrams) relative to the atmospheric methane pool (~5 petagrams) implies that Earth's climate is sensitive to escape of even a small fraction of this methane. In this article we documented for the first time the release of geologic methane to the atmosphere from abundant gas seeps concentrated along boundaries of permafrost thaw and receding glaciers in Alaska. Through aerial and ground surveys we mapped >150,000 seeps identified as bubbling-induced open holes in lake ice. Subcap seeps had anomalously high fluxes, 14C-depletion, and stable isotope values matching known coalbed and thermogenic methane accumulations in Alaska. These correlations suggest that in a warming climate, continued disintegration of permafrost, glaciers, and parts of the polar ice sheets will relax pressure on subsurface seals and further open conduits, allowing a transient expulsion of geologic methane currently trapped by the cryosphere cap*." Additional field work was conducted at the interior Alaska thermokarst lake site, where we continued to monitor dissolved methane emissions from the lake during the open water season.

Walter Anthony, K. M., P. Anthony, G. Grosse, J. Chanton. 2012. Geologic methane seeps along boundaries of arctic permafrost thaw and melting glaciers, Nature Geoscience, DOI doi:org/10.1038/Ngeo1480.

Task 7.0 - Methane oxidation in Alaskan thermokarst lakes. Mary Beth Leigh (UAF) and Ruo He (UAF): Work on microbial studies during this quarter has focused on polishing, submission and revision of manuscripts reporting the identity and activity of aerobic and anaerobic methanotrophs in lake sediments and water. Three manuscripts are now in print in the three top ranked journals in the field of environmental microbiology and microbial ecology. An additional two manuscripts are in advanced stages of preparation for submission in the near future.

Manuscripts in print

He, R. M. J. Wooller, J. W. Pohlman, C. Catranis, J. Quensen, J. M. Tiedje, M. B. Leigh. 2012. Identification of functionally active aerobic methanotrophs in sediments from an arctic lake using stable isotope probing. *Environmental Microbiology* 14(6):1403-1419.

He, R. M. J. Wooller, J. W. Pohlman, J. Quensen, J. M. Tiedje, M. B. Leigh. Diversity of active aerobic methanotrophs along depth profiles of arctic and subarctic lake water column and sediments. *The ISME Journal*. doi:10.1038/ismej.2012.34

He, R. M. J. Wooller, J. W. Pohlman, J. Quensen, J. M. Tiedje, M. B. Leigh. 2012. Shifts in identity and activity of methanotrophs in arctic lake sediments in response to temperature changes. *Applied and Environmental Microbiology* 78(13):4715-4723.

Manuscripts in preparation

He, R. M. J. Wooller, J. W. Pohlman, J. Quensen, J. M. Tiedje, M. B. Leigh. Methane-derived carbon flow through arctic lake sediment microbial communities. *Manuscript in preparation.*

He, R. M. J. Wooller, J. W. Pohlman, J. Quensen, J. M. Tiedje, M. B. Leigh. Anaerobic methane oxidizers active in an arctic lake methane seep. *Manuscript in preparation.*

Task 8.0 - Establishing a long-term record of the variability in methane emissions in relation arctic climate change. Matthew Wooller (UAF) Pohlman (USGS) and Ruppel: Gas and chironomid samples have been collected along with gas flux measurement data from Lake Teshekpuk during the previous reporting period. Samples from the Teshekpuk sediment core have been submitted for radiocarbon dating and samples have also been sent to European collaborators to generate a temperature reconstruction. Collaborators at APU have also been preparing samples from the core for isotopic analyses. During the no-cost extension period, the USGS has (a) sponsored partial salary for USGS student employee/UAF graduate student Benjamin Gaglioti in Anchorage/Fairbanks in spring 2012; (b) provided funding for the determination of radiocarbon ages at the WHOI NOSAMS facility for core material from a range of North Slope lakes and samples from Lake Teshekpuk; (c) collaborated with M. Wooller on completion of the now-published Journal of Paleolimnology paper, which provides the first complete Holocene methane record for the Alaskan North Slope; and (d) helped with revisions to the Heintz et al. manuscript on seasonal oxidation rates and oxidation pathways in Lake Q. The Wooller et al. paper, as well as one of the papers led by Ruo He, were the subject of short press releases by the USGS at the time of publication. Some of the radiocarbon dating for (b) above

will be included in the PhD dissertation of B. Gaglioti. The USGS has also been working on finalizing geophysical data for inclusion in the USGS online database and on re-examining some of the satellite data that support interpretations previously made for Lake Q. Ruppel has used the GIS developed by the USGS for the project to provide coauthors on the Heintz et al paper with appropriate GIS layers for completion of the manuscript.

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