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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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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 Alaskan 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 the first quarter of the second year of this project has focused on continuing the group laboratory analyses on samples collected from the Year 1 field work. The first quarter has also focused on preparing plans for Year 2 field work (Spring 2010). Wooller and Ruppel also worked closely together and with other project personnel to formulate and present an extended overview of the project's results to date during the NETL all-PI meeting in Atlanta in late January. This presentation set the stage for hydrates-related climate research on the Alaskan North Slope; discussed the expected sources and sinks of methane in the system; reviewed basic geophysical imaging results; detailed sedimentological, microbial, magnetic, geochemical, geochronologic, and pore water analyses on recovered Lake Q cores obtained under ice-covered and ice-free conditions.

Comparative Seep Study, Year 2

The previous report documented October 2009 overflights that were carried out immediately after freeze-up in the sectors of the Alaskan North Slope of most critical interest for Year 2 field operations for this NETL-funded project. We had originally proposed to use a field site in the Prudhoe Bay area for Year 2 work. The rationale outlined in the original proposal was based on the presence of thick permafrost and an underlying thick gas hydrate stability zone on this part of the Slope, which contrasts sharply to the thin permafrost and near zero thickness hydrate stability zone near Atqasuk; our access to recovered gas hydrate samples and related compositional data from the Mt Elbert BP/DOE well drilled at Milne Point in 2007; and the availability of numerous data sets that could provide guidance about and context for gas sourcing of surface seeps in the Prudhoe area. The overflights were designed to carefully target areas where pingoes, the 'leaky' Eileen trend fault zone, and related features intersected lakes in the Prudhoe area. Even before the overflights, discussions with USGS and private sector geologists had made it clear that locating any ebullition sites in Prudhoe lakes was highly unlikely. In fact, the flights located no new seeps in either the central North Slope or the Prudhoe area. New seeps were found near Atqasuk on one of the USGS-organized flights, but our work increasingly suggests that the particular geology of the western sector of the North Slope and particularly the South Meade river valley largely controls the location and nature of such seeps, which are suspected to have no connection to the hydrate system.

To expand our study eastward in Year 2, we have instead decided to focus on a seep field within Lake Teshekpuk in the NPRA. Lake Teshekpuk is by far the largest lake on the North Slope and is located in an area with nominal permafrost thickness of several hundred meters. Controversy persists about the thickness of thawed permafrost beneath Lake Teshekpuk and the presence/absence of gas hydrate there. Several lines of evidence imply that any hydrate that may exist beneath the lake should be poised close to the point of dissociating, as should hydrate in some of the surrounding areas. Reconnaissance geophysical work carried out by the USGS and external partners in July 2009 in the northern part of Lake Teshekpuk revealed a well-developed pockmark located at ~5.5 m water depth and emitting methane to ~0.5 m above the lake bottom. Independent data supplied by USGS Anchorage through one of their collaborators point to possible methane plumes in the water column in the vicinity of the pockmark, leading us to believe that the feature is a seep field like those often encountered in the marine environment.

Working at Lake Teshekpuk instead of in the Prudhoe area has very significant logistical, financial, and scientific advantages that will directly contribute to successful outcomes for this project. First, we have an already-identified seepage area for focused study in Lake Teshekpuk, but would still be looking for a study site now 2 months before April coring if we remained inflexible and wed to the idea of working in Prudhoe. Second, the regulations associated with working in the Prudhoe area would have made conducting most of our scientific studies very difficult, if not impossible. Furthermore, the amount of training required to work in the Prudhoe area was prohibitive for project participants. Lake Teshekpuk offers a chance to work within the NPRA and subject to BLM and other regulations, but without some of the restrictions on equipment, freedom to choose exact sites, work hours, sample acquisition, and personnel that we would have experienced in the Prudhoe area. Third, the USGS Anchorage has a long presence and significant past data for Lake Teshekpuk, access to a cabin that has been appropriately outfitted by the USGS over the years to support other studies, and profound knowledge of the logistics of operating in this remote area. With the guidance of Ben Jones, a geographer at USGS Anchorage and (simultaneously) a graduate student at UAF, we are currently in the process of arranging for April coring at the seep site with personnel from UAF, the USGS, and Bremen. We have also identified a State of Alaska boat stored nearby that has been made available for geophysical surveys by Ruppel and Jones in mid-July 2010.

GIS/Geophysics (USGS): The USGS continues to expand the North Slope GIS with both publicly-available data and data that are accessible only on a restricted basis. This is providing contextual information for the interpretation of Atqasuk-area results, ready access to base maps for project researchers, and a means for spatially correlating the disparate data sets being acquired for this project. The USGS has also been continuing to process the geophysical data obtained in summer 2009, with particular emphasis on resolving navigational problems for the radar data and processing the Chirp results using different methodologies. In December 2009, the USGS conducted another equipment testing trip on Mystic Lake near Medford MA and located new methane seeps in an area that has been the focus of methane emissions studies by MIT Parsons Lab researchers for 2 decades. The USGS has also continued with equipment development in preparation for summer 2010, most recently mastering streaming of sonar data in real time and completing firmware upgrades that will provide combined downward and side-looking sonar for the Lake Teshekpuk work. In April 2010, USGS operations staff in Woods Hole will be participating in test cruise organized by Menlo Park for comparison of several seismic imaging systems, and the results of this effort should be helpful to resolve some instrumentation planning issues for July 2010 imaging work on Lake Teshekpuk. Of particular concern is determining whether multiple acoustics systems can be run simultaneously, which would provide a means for efficient collection of images that constrain lake-bottom/shallow features, intermediate depth features, and deep sublake features.

Gas Fingerprinting (USGS): Working with the in-house noble gas lab, the USGS has completed analyses of the seep gases collected from Lake Q in 2009. While there are still some difficulties to overcome with these analyses, the Lake Q samples do not reveal the atomic-mass-dependent partitioning of noble gases that is considered characteristic of methane hydrates, providing further evidence that ebullition in Lake Q is not related to hydrate degassing. On the other hand, degassing of stored methane hydrate samples from both permafrost and marine settings does produce the expected noble gas signature, although the impact of long storage in liquid nitrogen cannot be completely removed from the results. The USGS is working on further refinement of sampling/degassing methods and could potentially re-examine some natural hydrate samples this year. USGS personnel have already outlined to appropriate partners our need for new, fresh hydrate samples, ideally across a range of depths, when future coring projects take place. These samples will be critical to further development of the noble gas fingerprinting methods.

Task 5.0 and 6.0 - Measuring methane flux on multiple temporal scales. Katey Walter Anthony (UAF): There is no change in the scope of the work concerning measuring the methane emissions from our study sites. Since the last report, our efforts have focused on measuring methane flux from 15 discrete bubbling seeps in Goldstream lake, in the Fairbanks area, using automated bubble traps. Winter can be challenging due to thick ice conditions. Our technicians are hand-spearing over a cubic meter of ice at each seep site to maintain the loggers - this is a really big job, but requires careful manual work in order not to destroy the hardware of the traps and loggers that are hung beneath the ice surface all winter. We have sorted out a number of technical challenges with making these winter time measurements, and to date have several months of data from the seeps. We have also collected regular gas samples from a number of the seeps for geochemical analyses of mixing ratios and isotopes. Winter time gas samples seem to have a consistently high methane content. We will continue making flux measurements through the rest of the winter, summer and next year. These flux and geochemical measurements will inform us about the consistency of seep methane flux as well as variability in methane production pathways and carbon sources. We also hope to return to Lake Q to finish the flux work that we started at the main seep in October 2009.

Task 7.0 - Methane oxidation in Alaskan thermokarst lakes. Mary Beth Leigh (UAF) and Ruo He (UAF): SIP incubations and community analyses of methane oxidizing microorganisms SIP experiments are underway to identify methanotrophs in sediment samples. Sediment samples were incubated with $^{13}CH_4$ or $^{12}CH_4$ (control) in the laboratory under both aerobic and anaerobic conditions. The incubation is in progress and will be continued until a series of specific quantities of CH_4 are oxidized. When target oxidation extents are reached, the SIP samples will be harvested and frozen for later analyses of the identity and community structure of methane oxidizing microorganisms. Substantial methane utilization has already been detected in many microcosms, and some SIP analyses have been initiated. DNA was extracted from the sediment SIP samples and was subjected to isopycnic centrifugation using cesium trifluoroacetate gradients and fractionated using established methods. DNA distributions in the series of fractions from both ^{13}C-incubated samples and control (^{12}C-incubated) samples were determined using quantitative real time polymerase chain reaction (RTm-PCR) with universal bacterial 16S rRNA primers. Substantial quantities of ^{13}C-DNA were detected in many samples. ^{13}C-DNA-containing fractions were subjected to community profiling using terminal restriction fragment length polymorphism (T-RFLP). Preliminary results indicate methane-oxidizing bacteria are diverse in the lake sediments and community structure varies with sediment depth. Methanotrophs have been successfully cultivated from water samples taken from different lake depths using enrichment cultures with methanotroph medium. DNA was extracted from the culturable methanotrophs, and the community structure and diversity of culturable methanotrophs was analyzed using T-RFLP of bacterial 16S rRNA. Methanotrophs cultivated from lake water appear to be largely different consortia from those detected in sediments by SIP.

Task 8.0 - Establishing a long-term record of the variability in methane emissions in relation arctic climate change (UAF and USGS): Matthew Wooller (UAF) and Ben Gaglioti (UAF) have primarily been involved in conducting measurements on the paleo cores (e.g. LQ-West, LQ-CM- Paleo, Terrapin Station and Coffee lake) collected from the Year 1 field work. Gaglioti continues to prepare samples of chironomids for stable oxygen isotope analysis to reconstruct past climate change at the site over the ~12,000 years represented by core LQ-West. The preparation of these types of samples is exceedingly time consuming, requiring individual fossils to be picked and cleaned from the sediment samples. Wooller met with Kelly Rose from NETL, while they both attend the Jan. Atlanta NETL meeting, to discuss lithological findings from the Year 1 cores. Wooller and Gaglioti have modified the design of the coring equipment used during the Year 1 field work. These modifications are currently been made to the hammer coring system by a shop technician to aid sampling in the field. These modifications will be completed by the 2010 spring field work. Wooller and Gaglioti are conducting practice coring at lakes close to Fairbanks that are similar in depth as Lake Teshekpuk, to help further streamline field operations in Year 2. Numerous conference calls and meetings have been taking place during this quarter between USGS and UAF to coordinate Year 2 field work at Lake Teshekpuk. Pohlman (USGS) has recently completed preliminary analyses of new biomarker data from the Lake Q cores with help from Marcus Elvert in Kai Hinrichs' laboratory in Bremen.   Compared to well-studied marine systems, lake systems with strong terrestrial inputs are proving more challenging for biomarker studies. Initially, the analyses were designed to look for biomarkers that have previously been identified as an indicator of AOM. While these biomarkers are present, another compound somewhat interferes with its signal in the detector. Attention has therefore turned to an alternative biomarker whose $\delta^{13}C$ values are consistent with methane oxidation/incorporation.   An important result has been the close correlation of the concentration in this fossil aerobic methanotroph biomarker with the $\delta^{13}C$ results obtained on chironomid remains obtained from the same samples. These data provide a qualitative record for methane dynamics in the Arctic over the past 12,000 years.

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