Reducing uncertainties in estimates of methane bubbling from arctic lakes

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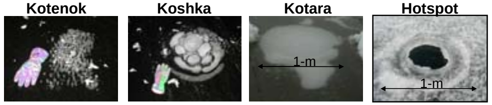
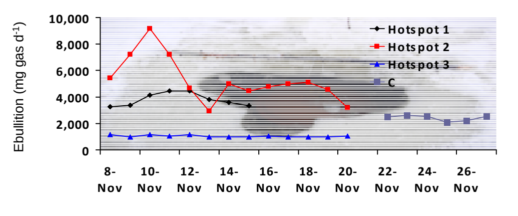
Point-source Classification



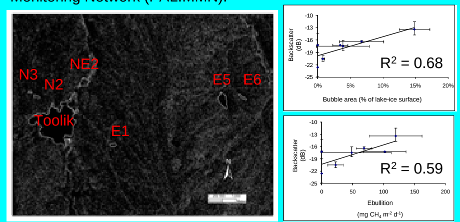
Kotenok	Koshka	Kotara	Hotspot
Weakest flux	Medium flux	Strong flux	Greatest flux
Isolated bubbles in multiple layers	Merged bubbles (>50%) in multiple layers	Closed-ice surface	Open hole in ice most of year
<50% merged bubbles	If big pocket, >25% of perimeter has isolated bubbles	One big pocket, multiple layers	Sometimes covered by thin snow or ice crust that is easily broken with fist or foot
<50 cm diam.	Usually >30 cm diam.	<25% perimeter isolated bubbles	
		Usually >40 cm diam.	

Methane bubbling is challenging to quantify because of its patchiness. A new technique of mapping **point sources** and **hotspots** of bubbling, which comprised 70% of total flux from study lakes, improved and increased whole-lake emissions estimates 2.5-14 fold in Alaska and Siberia.

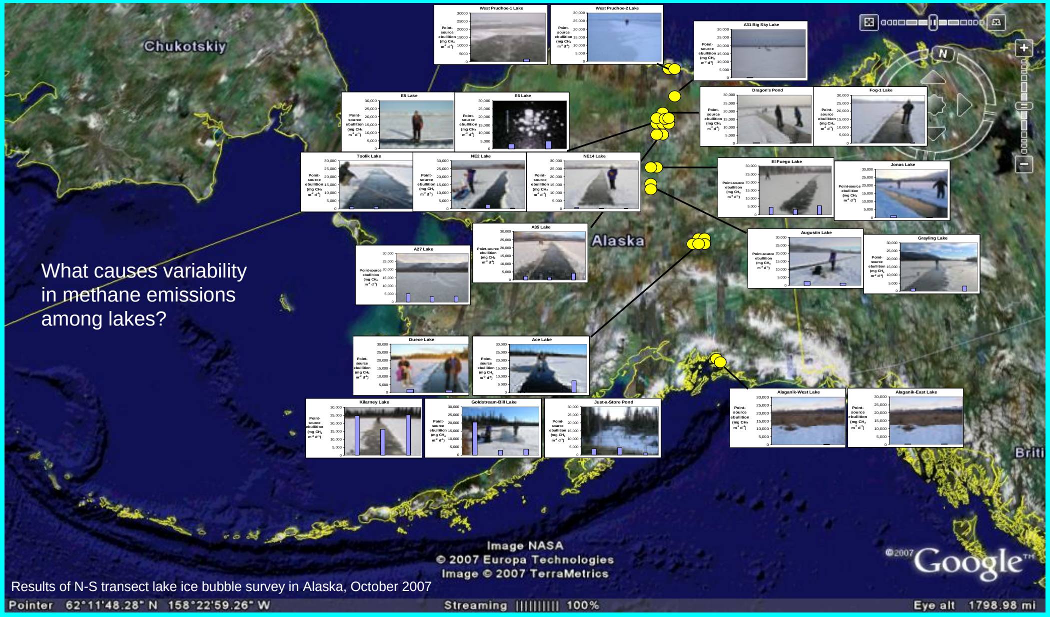


We are designing an automated ebullition sampler for long-term continuous measurements.

The role of arctic lakes in the global atmospheric methane budget is unknown. A recent first-order estimate suggests that arctic lakes are significant emitters of methane (24 ± 10 Tg CH_4 yr-1) contributing as much as ~6% of global atmospheric CH_4 sources annually (*Walter et al. 2007a*). Emissions from arctic lakes are projected to increase as permafrost thaws in the Arctic, releasing tens of thousands of teragrams to the atmosphere in the form of bubbles. In Siberia and Alaska emissions are particularly high from lakes influenced by thermokarst, or permafrost degradation, a process that discharges labile organic matter to anaerobic lake bottoms, fueling biological methane production. Additionally, aquatic plant productivity may be another prominent driver of methane production through annual supply of organic substrates. Complete thaw of permafrost beneath lakes may destabilize deeper methane sources such as hydrate methane and natural gas, providing pathways for the release of sub-permafrost and/or intra-permafrost methane from biogenic or thermogenic sources. Alternatively, emission of deep methane to the atmosphere may occur independently from permafrost warming dynamics, for instance through geological fault activity. Despite the potential for large releases of methane from lakes to the atmosphere, little is known about the occurrence, extent, and vulnerability of various methane sources. Here we present our efforts as part of the IPY to quantify, map, and project biological and geological methane emissions from lakes around the Arctic, and in particular in Alaska and Siberia in conjunction with permafrost degradation. This effort includes pioneering new methods of measuring methane bubbling (dominant mode of emissions) from lakes using field studies, geophysical measurements, numerical modeling, isotope geochemistry, remote sensing Synthetic Aperture Radar analysis and the establishment of a Pan-Arctic Lake-Ice Methane Monitoring Network (PALIMMN).



Methane bubbles trapped in lake ice cause a bright backscatter in Radarsat-1 Synthetic Aperture Radar imagery (*Walter et al. in press*), implications for upscaling.



Results of N-S transect lake ice bubble survey in Alaska, October 2007

Pan-Arctic Lake-Ice Methane Monitoring Network (PALIMMN)

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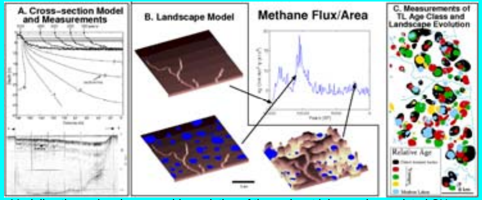
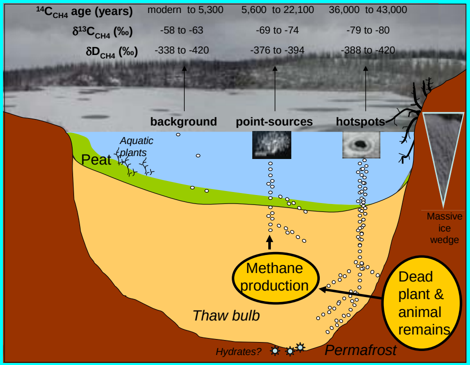
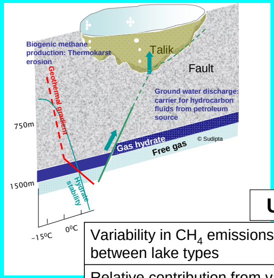
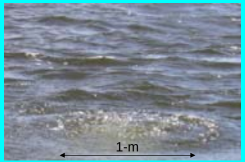


Modeling thermal and geomorphic evolution of thermokarst lakes and associated CH_4 emissions (*Plug & Werner 2006, West & Plug 2007, Walter et al. 2007b*).







High-emission gas seep in a tundra lake on the North Slope of Alaska's Brooks Range.

Uncertainties

Variability in CH_4 emissions between lake types	Drivers: lake age, size, substrate availability, redox, chemistry
Relative contribution from various organic matter substrates for CH_4	ancient C from permafrost vs. modern plant material
Regional variability in ice-rich yedoma permafrost C pool	% Ice, %C, thickness
Fate of permafrost C in non-yedoma thermokarst lakes	~450 Gt C in surface 1-m arctic permafrost: lability and fate.
Rate of conversion from C to CH_4	duration of hotspots unknown
Timing of permafrost thaw	centuries to millennia?
Landscape geomorphology and hydrology	Flat lowlands vs. hilly uplands
Other sources of permafrost-related CH_4	Natural gas seeps, hydrate destabilization- independent of permafrost thaw?

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