Linking the variability in CO_2 & CH_4 emissions from Arctic lakes and ponds with geomorphology and organic matter lability

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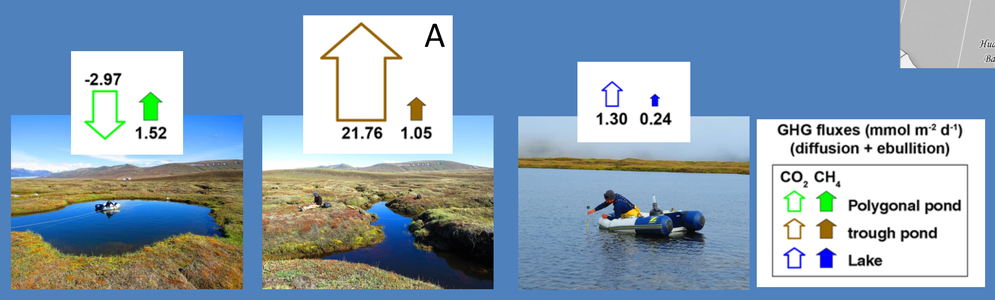
Rationale

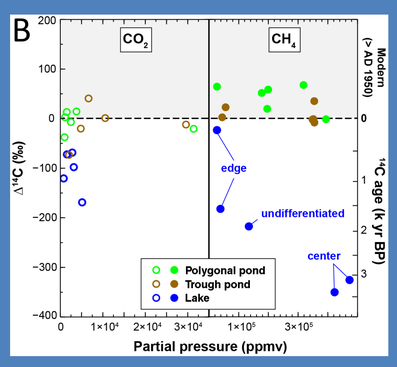
With ongoing climate change, longer thaw seasons and increased annual precipitation are expected over Arctic regions. Such conditions are favourable for both intensive and extensive permafrost thaw, mobilising organic matter (OM) from different sources and intensifying its flux to aquatic ecosystems. These systems are abundant over Arctic lowlands and are known to be hot-spots of microbial activity. The projected climate change, intensification of anoxia mobilization of labile OM could stimulate microbial activity, hence the emissions of CO_2 and CH_4 to the atmosphere.

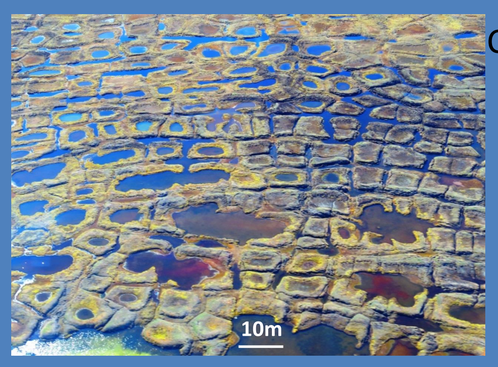
Study site

- The CEN station in Quarlikturvik Valley (73°09'N, 79°59'W) is on the western side of BYLOT ISLAND within Sirmilik national park, Nunavut, CANADA
- The valley is covered by organic rich sediments (15-45%) comprised of peat and aeolian silt
- The landscape is covered by deep continuous permafrost, with taliks underneath the lakes that are deeper than ~2m (maximum winter ice thickness)
- Dense ice-wedge network and snowmelt water both shape the landscape composed of dry tundra patches and shallow water bodies (comprising ~6% of the valley bottom)
- Polar climate with mean annual air temperature of -15°C and low precipitation (190mm)



Objective: Explain a large part of the variability in CO_2 and CH_4 emission rates observed from the aquatic systems associated with permafrost thaw by (1) the morphology of water bodies, (2) the physiochemical properties of the water column, and (3) the OM load and its lability.





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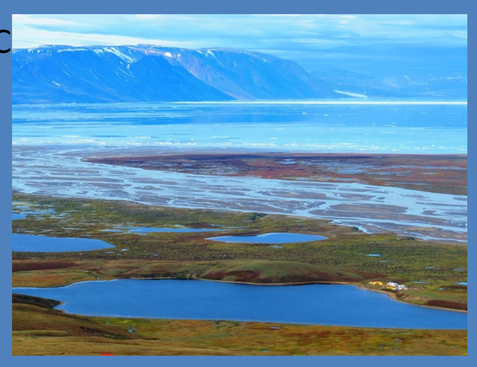
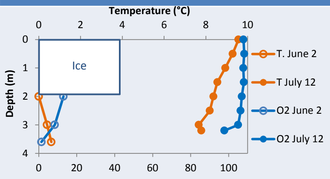
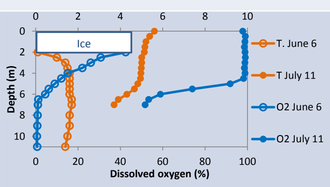
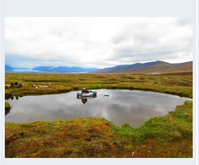
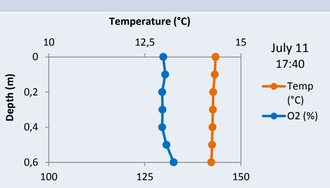
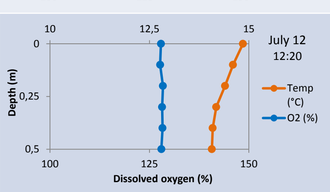
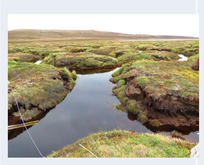
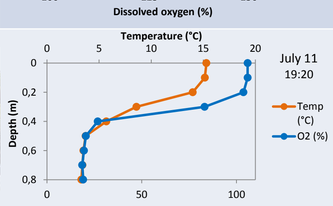
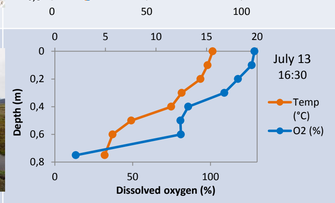


Figure s: A) Average GHG emission rates from water bodies on Bylot Island, B) ^{14}C age of ebullition gas (from Bouchard et al. 2015), C) Landscape at the study site

Water body characteristics

Water bodies	Photos	Vertical profiles	DOC (mg L^{-1})	TP (µg L^{-1})
BYL 66 (Thermokarst lake)			3.0-4.3	10-26
BYL36 (Kettle lake)			4.1-4.3	6-17
BYL80 (Coalesced polygonal pond)			10.6-11.1	19-23
BYL30 (Coalesced polygonal pond)			12.2-13.9	8-21
BYL27 (Ice-wedge trough pond)			10.9-14.3	19-55
BYL24 (Ice-wedge trough pond)			8.8-13.6	16-35

Soil and sediment incubations

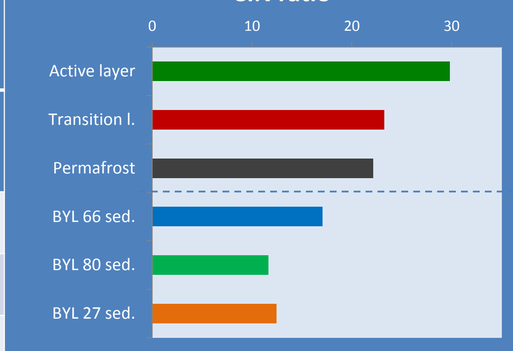
- Incubations lasting ~2 weeks, under in situ conditions (dark)
- Incubated materials: 3 depths of a terrestrial core and 3 sediments from different water bodies
- Soil/sediment incubated with pond water (type 1) or leached in pond water and filtered through GFF filters (type 2).

Incubated materials	Gas production rate § (µM gOC^{-1} d^{-1})			^{14}C age (yr BP)
	Type 1 CO_2	Type 1 CH_4	Type 2 CO_2	Type 1 CO_2
Active layer	28.66	3.24	2.01	Modern
Transition layer	22.03	0	1.83	5 ±15
Permafrost	26.38	0	1.43	655 ±15
BYL66 sediment	11.74	0.17	2.70	1695 ±15
BYL80 sediment*	31.80	15.60	2.86	Modern
BYL27 sediment**	22.70	0.14	2.30	970 ±15

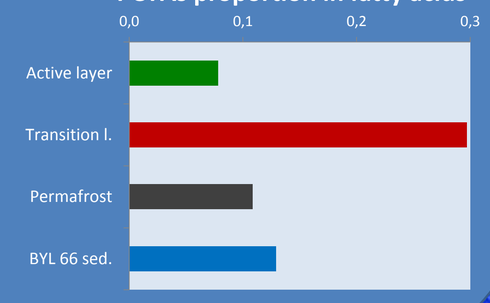
* The bottom of polygonal ponds are covered with benthic cyanobacterial mats
**The sediments of IWT ponds are mainly composed of eroded material from the shores

§ Rates from experiment Type 1 are presented in absolute values, whereas from Type 2 are given as relative to control sample (incubation of pond water without addition of soil OM)

C:N ratio



PUFAs proportion in fatty acids



Preliminary conclusions

- Active layer material shows the highest rates of GHG production among terrestrial soils, and C:N ratio supports this result. This layer may receive fresh OM from growing plants. Also, as we deal with syngenetic permafrost, the deeper layers may have already been exposed to degradation before being integrated into permafrost, lowering modern-day lability.
- Sediment of polygonal pond BYL80 shows the highest GHG production rate among lacustrine sediments, potentially related to the fresh OM released by actively growing cyanobacterial mats in this pond. However, C:N ratios are not following the trend as for terrestrial sediments (higher for materials with higher GHG production rates), but aquatic OM is more diverse and from different sources. More replicated incubations may help to resolve such trends (& pending FA).
- Results obtained from the lability experiments are not sufficient to explain the variability in GHG emissions observed in situ. The morphology and thermal structure of these ecosystems, as well as the erosional flux of OM, likely additionally influence water column GHG storage and emission rates. These will be closely studied in the upcoming field season.
- ^{14}C age of CO_2 respired during the incubation ranged from modern (active layer and BYL 80 cyanobacterial mats; both pools most recently deposited) to ~1700 yr BP (thermokarst lake sediments), with a consistent increase in age with depth in the terrestrial core.
- Interestingly, although ^{14}C incubation results indicate that eroded sediments in IWT ponds are labile as the respired CO_2 is almost a thousand years old (over a 2-week incubation), in situ observations indicate mostly modern age for the GHG emitted by these water bodies.

2016 field season

- Continue incubation experiments with more replicates, under controlled laboratory conditions, and lasting longer (4 weeks), aiming to relate proxies that are easy to obtain (e.g. C:N ratio, fatty acids) with rates and amounts of GHG produced
- Study the relationship between shore erosion intensity levels and pond morphology with DOC concentrations and GHG fluxes.

Other team members' interests

Frédéric Bouchard – modes (ebullition, diffusion) and sources (stable isotopes, 14C) of GHG emissions and paleolimnology of thermokarst and kettle lakes

Thomas Pacoureau – priming effect on the microbial use of allochthonous OM

Flora Mazoyer – sunlight effect on the lability of OM

Projects supervised by Isabelle Laurion, Daniel Fortier and Milla Rautio

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