Experimental study of methane emission from lake seeps of Western Siberia permafrost zone

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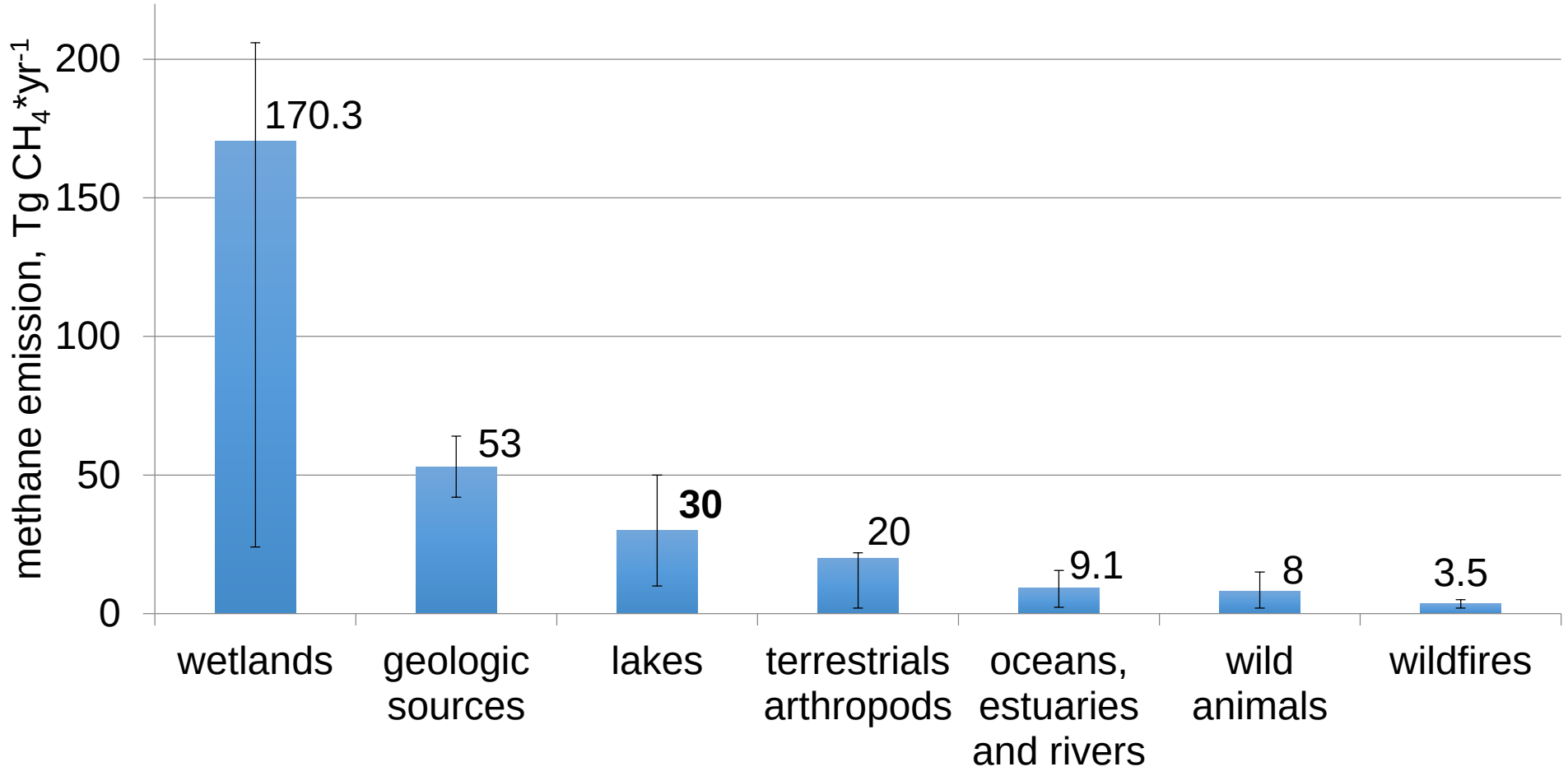
Introduction

Natural sources of methane contribute 35–50% to the global atmospheric emission. Among them, lakes are the third-biggest source emitting 10–50 $TgCH_4*yr^{-1}$.



Contribution of natural methane sources to global emission [Anderson et al., 2010].

Purpose and objectives

The purpose of our research was to study lake gas seeps in Western Siberia as a source of greenhouse gas methane. Two main objectives were set:

- assessment of the methane emission into the atmosphere from lake seeps;
- identification of the seep methane origin.

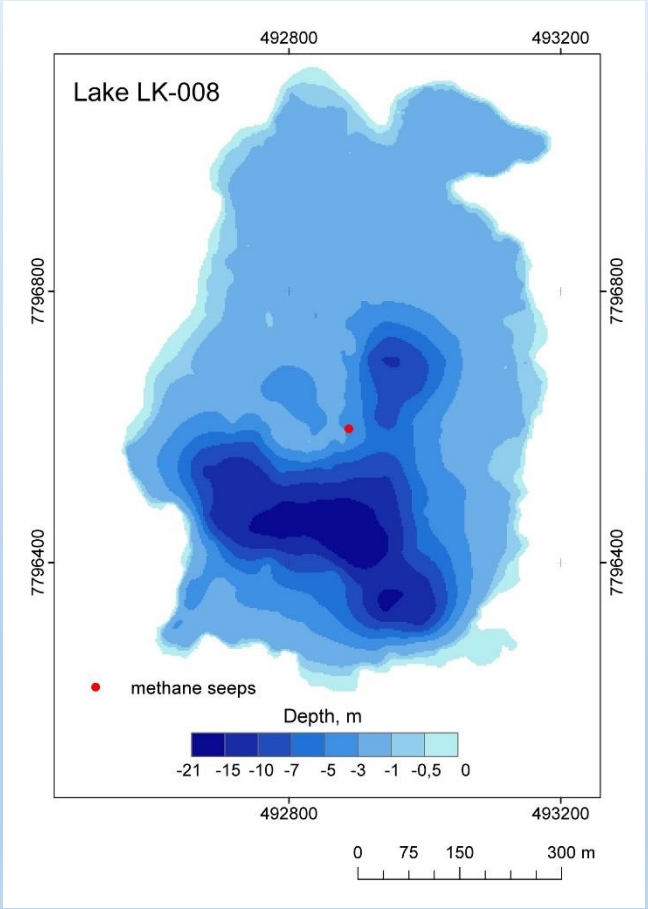
Site location

Central part of the Yamal Peninsula (Western Siberia, Russia), typical tundra zone. Territory near “Vaskiny Dachi” research station.

Object

Studied gas seeps were found during field campaign of 2019 yr. within the lake LK-008 (70.2754°N, 68.8112°E) at the distance of ≈2 m between each other.

Lake with seeps



Bathymetric map of lake

Methods

- Gas samples were collected by a bubble trap of the original design. CH_4 concentrations with tenfold air dilution were determined by gas chromatograph Crystal 5000.2 with a flame ionization detector.
- Analysis of the $\delta^{13}C$ and δD isotope content in CH_4 was conducted by isotope mass spectrometer Delta V Plus with GC Isolink modules and elemental analyzer Flash HT plus.
- Annual CH_4 emission from seep to the atmosphere was calculated as a multiplication of the CH_4 concentration, mean gas flux (intensity of seep ebullition) and the emission time.

Seepage gas sampling

Gas chromatography

Results

Statistical characteristics of gas emission from seeps at lake LK-008.

Seep №	Number of samples	Seep gas flux, ml min^{-1}			
		I quartile	Median	III quartile	Mean with 95% CI
1	10	160	175	203	182±19
2	10	122	127	137	127±7

Methane content in gas seeps and its isotopic composition.

Seep №	Concentration, %		$\delta^{13}C$ vs VPDB, ‰		δD vs VSMOW, ‰	
	Min	Max	Mean	STD	Mean	STD
1	96.2	100	−75.73	0.25	−226.68	3.46
2	94.2	100	−76.97	0.11	−222.31	0.83

Estimation of annual methane emissions.

Seep №	Annual emission values with 95% CI, $kgCH_4\ yr^{-1}$		
	Min	Mean	Max
1	65.8±2.6	67.1±3.8	68.5±7.1
2	44.8±2.5	46.1±1.9	47.5±2.7

Possible origin of the seep gas

According to the CD-diagram of the methane genesis classification from [Whiticar, 1999], isotopic composition corresponds to the biogenic origin of methane. The initial CH_4 source can be in the form of a meta-stable methane-hydrate or free gas which is widely described for Central Yamal. Presumably, gas migrates through sub-lake talik and further through the water column into the atmosphere.

Conclusions

- Studied gas seeps are obviously direct channels of methane emission from permafrost to the atmosphere.
- The sampled gas is of biogenic origin.
- The intensity of methane emission from gas seep №1 is estimated as 65.8–68.5 $kg*yr^{-1}$ given the methane concentration 96.2–100%; from seep №2: 44.8–47.5 $kg*yr^{-1}$ given the methane concentration 94.2–100%.