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MEASUREMENT OF METHANE AND NITROUS OXIDE EMISSIONS FROM THE PEATLANDS IN NORTHERN QUÉBEC, CANADA

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Abstract: Methane (CH_4) and nitrous oxide (N_2O) emissions were measured using a chamber (25×25 cm, 15 cm in height) in peatlands in northern Québec (57°45′N, 76°09′W) in the summer of 1991. The pH in the interstitial water was 4.4–5.6. Dissolved inorganic nitrogen was scarce; nitrate and nitrite concentrations were usually <0.01 mg NL^{-1} and ammonium concentrations were 0.02–0.30 mg NL^{-1}. Methane emission ranged from 0.1 to 18.9 mg CH_4-C m^{-2} d^{-1} in peat bogs. Nitrous oxide emission slightly exceeded our detectable threshold only in a peat bog (0.04 mg N_2O-N m^{-2} d^{-1}) and in a palsa top (0.02 mg N_2O-N m^{-2} d^{-1}).

1. Introduction

The effect of global warming is considered to be significant in the boreal regions (MITCHELL *et al.*, 1990). Increase in temperature will enhance rates or alter passes of material cycles in the area. In order to evaluate the effect of global warming, the present material cycles should be understood. We studied the material cycle in the boreal area, where tundra vegetation dominates and a tremendous amount of organic matter (peat) is buried in the permafrost. As a first step to understand the material cycles, gas (methane and nitrous oxide) fluxes from the soil surface to the atmosphere were measured. Both gases are considered to have a greenhouse effect on the earth. Global warming will enhance those gas fluxes, and in turn they will accelerate the global warming.

In the present study a portable top-separable open-bottom chamber was made, and some measurements were undertaken on methane and nitrous oxide emissions from peatlands in the tundra area in northern Québec, Canada.

2. Study Area

The study was conducted in the subarctic peatland region near Boniface River (57°45′N, 76°09′W) in northern Québec, Canada, in the summer (July 22–27) of 1991 (Fig. 1). The area lies at the northern limit of forest on the discontinuous permafrost zone. Three peat bogs, one black spruce forest, one palsa, and one bush area were selected for this study (Table 1). Peat bogs 1 and 2 were located on a hill near the Boniface River. Each bog was flat and spread over several hundred meters. The depth of the active layer in these sites was

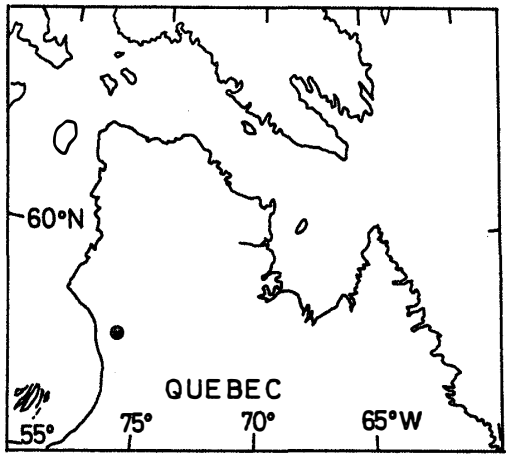

Fig. 1. Location of sampling site (closed circle) in northern Québec.

40–50 cm, and the water table was 0–5 cm from the peat surface. Sedges, many kinds of lichens, arctic cotton, willows, herbs, and dwarf shrubs dominated the area. Peat bog 3 was in a small valley located just north of the tree line. This sampling site was flooded slightly (water depth was <1 cm). The dominant vegetation was arctic cotton and sedges. The black spruce forest was located in the lowland site near the Boniface River, and extended over several hundred meters. The dominant vegetation was black spruce, dwarf birch and Labrador tea. The water table was 2–5 cm, and the forest floor was wet. In the study area, there were many palsas, which are peat frost mounds often developed in valleys. The palsa selected had an active layer of *ca.* 1 m on 3–5 m frozen peat. The palsa top was dry, and dwarf birch, many kinds of lichens, and Labrador tea dominated there. The bush site was on sandy soil near the Boniface River. The soil surface was dry, and dwarf birch and lichens dominated.

3. Methods

Gas flux measurements were made during the daytime (between 0830 and 1700). Emissions of gases from the soil surface were measured using a top-separable open-bottom chamber (25×25 cm, 15 cm in height, Fig. 2). The top of the chamber is made of transparent acrylic resin covered with thin aluminum film (0.1 mm thick), fitted with an air sample port and a thermistor probe port. The bottom part is made of stainless-steel. Water was used to seal the top to the bottom part, as described in LINDAU *et al.* (1988). At each site three chambers were placed on the peat surface with their bottom rims approximately 5 cm deep in the soil. The top cover was placed on the bottom part 15 min after the chamber insertion. This procedure might eliminate the artificial enhancement of gas flux caused by insertion of chambers into the soil (*cf.* MATTHIAS *et al.*, 1980). A series of six 10 m*l* air samples was taken for each chamber at intervals of 30–60 min using preevacuated glass vials with butyl rubber (Nichiden SVF-10). Soil temperature at 1 cm depth was measured on each air sampling, and the head space height on the soil in the chamber was recorded after measurement.

The air samples were brought to Japan, and analyzed within 3 months after

Table 1. Vegetation, temperature, pH, and dissolved inorganic nitrogen in interstitial water at the study sites in northern Québec.

Site	Vegetation	Depth in soil	Temp. (°C)	pH	NO_3-N	NO_2-N	NH_4-N
					(mg NL^{-1})		
Peat bog 1	sedge: *Carex bigelowii*	(surface water)	–	5.6	<0.01	<0.01	0.02
	dwarf shrubs: *Vaccinium uliginosum*	2 cm	12.2	–	–	–	–
	lichen: many species	5 cm	7.2	4.6	<0.01	<0.01	0.05
		10 cm	3.4	4.5	<0.01	<0.01	0.10
Peat bog 2	arctic cotton: *Eriophorum spissum*	2 cm	12.5	–	–	–	–
	willows; *Salix planifolia*	5 cm	10.7	5.5	<0.01	<0.01	0.09
	herb: *Calamagrostis canadensis* and many sedge species	10 cm	8.4	5.1	<0.01	<0.01	0.21
Peat bog 3 (north of tree line)	arctic cotton: *Eriophorum angustifolium*? and sedge species	2 cm	9.8	–	–	–	–
		5 cm	8.6	5.5	<0.01	<0.01	0.05
		15 cm	7.3	5.5	<0.01	<0.01	0.05
Black spruce forest	horsetail: *Equistum sylvaticum*	2 cm	12.8	–	–	–	–
	Labrador tea: *Ledum groenlandicum*	5 cm	8.1	4.4	<0.01	0.02	0.12
	dwarf birch: *Betula glandulosa*	10 cm	4.8	4.5	<0.01	<0.01	0.30
	mosses: *Sphagnum* and other species						
Palsa	lichen: many species	2 cm	16.5	–	–	–	–
	dwarf birch: *Betula glandulosa*	5 cm	11.7	–	–	–	–
	labrador tea: *Ledum groenlandicum*	10 cm	7.7	–	–	–	–
	sedge: *Carex bigelowii*						
Bush	dwarf birch: *Betula glandulosa*	2 cm	23.1	–	–	–	–
	lichen: *Cladina stellaris*	5 cm	10.4	–	–	–	–
		10 cm	7.4	–	–	–	–

–: no measurement.

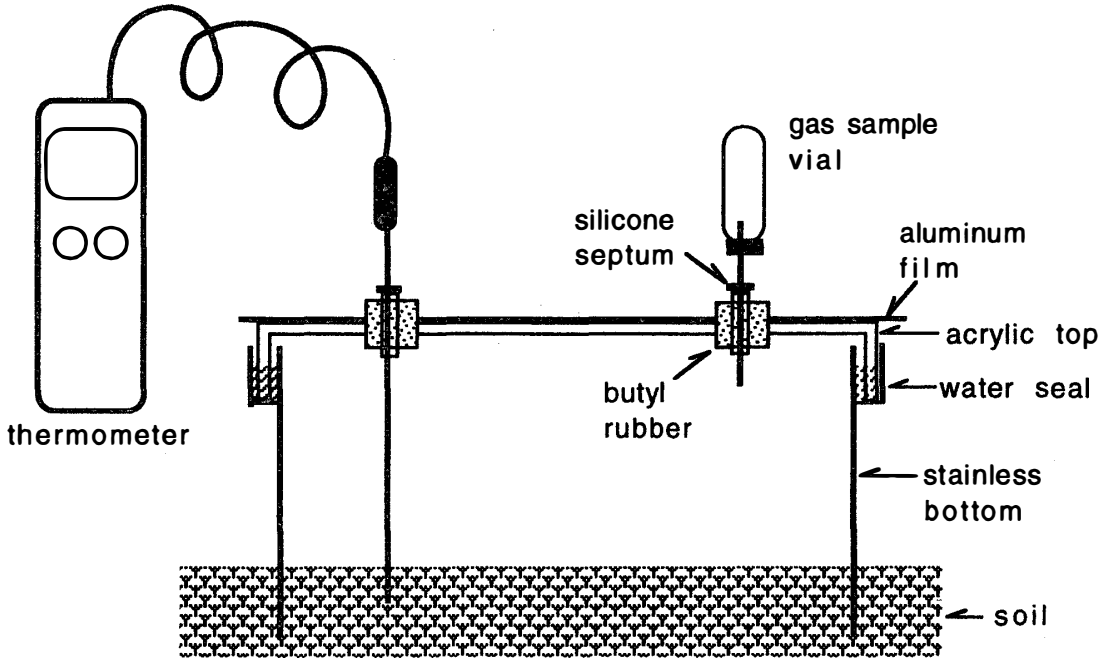

Fig. 2. Chamber used for measurement of methane and nitrous oxide emissions.

sampling. The CH_4 concentrations were determined by using a gas chromatograph (Shimadzu GC-12A) equipped with a flame ionization detector and a molecular sieve 5A column (2.6 mm i.d. × 2.0 m) under N_2 (40 m*l* min^{-1}) as a carrier gas at 70°C (YAGI and MINAMI, 1990). The peak areas of CH_4 were calibrated by using CH_4 standard gas at concentrations of 2.48 and 49.9 ppmv (Takachiho Co., Ltd.). The N_2O concentrations were determined by using a gas chromatograph (Shimadzu GC-14A) equipped with an electron capture detector and a stainless column (3.0 mm i.d. × 3.0 m) packed with Porapak Q (50/80 mesh). N_2 was used as a carrier gas (25 m*l* min^{-1}). The detector was set at 340°C and the oven at 70°C. The peak areas of N_2O were calibrated by using a N_2O standard gas at the concentration of 2.62 ppmv (Takachiho Co., Ltd.).

Interstitial water was sampled using a stainless pipe (0.7 mm i.d. × 20 cm) and a 20 m*l* plastic syringe (Terumo Co., Ltd.), filtered through a 0.22 μm filter (Millipore Co., Ltd.), and stored in a 15 m*l* plastic tube. Dissolved inorganic nitrogen was determined colorimetrically by using a Technichon AutoAnalyzer II. Soil temperature was measured by using a digital thermometer (Yokogawa model 2455), and pH using an electric pH meter (Horiba Twin B-112).

4. Results and Discussion

Soil surface temperature (2 cm depth) varied from 9.8°C to 23.1°C depending on the sampling site and date (Table 1). Soil temperature decreased sharply with depth. The pH in the interstitial water was 4.4–5.6. The concentrations of nitrate and nitrite were less than 0.01 mg NL^{-1} in most water samples. The ammonium concentrations were 0.02–0.30 mg NL^{-1}.

The insulation by the thin aluminum film was effective in minimizing the increase of temperature in the chamber during measurements. The change in soil temperature at 1 cm depth in the chamber was within 2°C, except for one case (Peat bog 1) where the soil temperature increased 4.4°C.

The concentrations of CH_4 and N_2O in the chambers increased linearly with time in some cases. An example obtained at Peat bog 2 was shown in Fig. 3. The flux of a trace gas species across the soil-atmosphere interface was calculated using a least squares fit to the time series of linearly increasing concentrations within the chamber.

The emission of CH_4 was detected in the peat bogs, ranging from 0.1 to 18.9 mg CH_4-C m^{-2} d^{-1} with a large variation within each site (Table 2). The CH_4 emission was scarce in the black spruce forest floor, and negative (absorbed) in the dry palsa top. The CH_4 emission rates obtained by the present study were relatively low, compared with the values of 27–94 mg CH_4-C m^{-2} d^{-1} obtained in the fens in Schefferville, subarctic Québec (54°48′N, 66°49′W, southeast of the present site) by Moore *et al.* (1990).

The emission of N_2O was very scarce, and significantly exceeded our detectable threshold (*ca.* 0.01 mg N_2O-N m^{-2} d^{-1}) only in Peat bog 2 (0.04 mg N_2O-N m^{-2} d^{-1}) and in the palsa top (0.02 mg N_2O-N m^{-2} d^{-1}, Table 2). The N_2O emitted from soil is produced by nitrifying microorganisms during oxidation of ammonium to nitrate (Bremner and Blackmer, 1981) or by denitrifying microorganisms during anaerobic reduction of nitrate (Payne, 1981). The extremely low level of nitrous oxide emission indicates that neither nitrification nor denitrification take place in the study area. The low availability of inorganic nitrogen, low pH, and/or low temperature (Table 1), may restrict such activity by microorganisms.

The procedure for measuring fluxes of trace gas species across the soil-atmosphere interface in a remote area was established by the present study, and some measurements were obtained in a subarctic region in northern Québec, Canada. In order to cover spatial and temporal variations in gas fluxes, and to

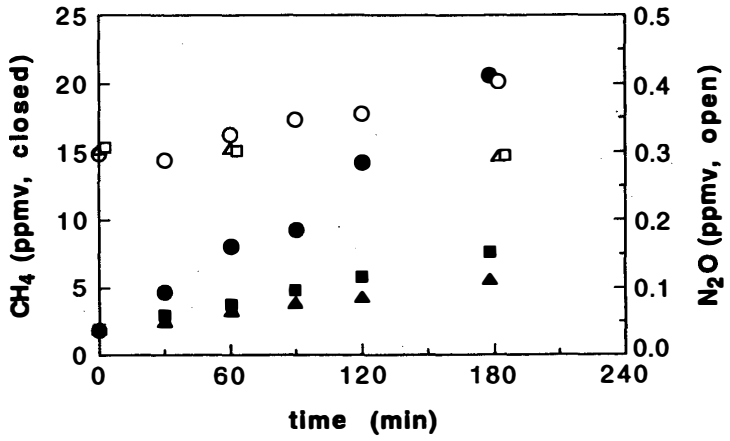

Fig. 3. An example of gas flux measurement. Change in concentrations of methane (closed symbols) and nitrous oxide (open symbols) in each chamber (shown by different symbol shape) at the Peat bog 2.

Table 2. Methane and nitrous oxide emissions from peatlands in northern Québec.

Site	Date	CH_4 emission		N_2O emission	
		average	sd	average	sd
		(mg CH_4-C m^{-2} d^{-1})		(mg N_2O-Nm^{-2} d^{-1})	
Peat bog 1	July 22 '91	0.14	0.23	0.00	0.00
Peat bog 2	July 23 '91	4.90	4.05	0.04	0.09
Peat bog 3	July 24 '91	18.85	15.62	0.01	0.01
Black spruce forest	July 25 '91	0.01	0.01	0.00	0.00
palsa-a*	July 26 '91	−0.22	0.11	0.02	0.02
palsa-b*	July 26 '91	–	–	0.01	0.03
Bush	July 27 '91	–	–	0.01	0.01

* : measured at two places in a palsa.
– : no measurement.

relate those rates to environmental factors such as soil temperature, redox potential, organic and water content, and pH, or net primary production, more extensive and intensive measurements are required in the future.

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