Tomoko NAKAYAMA, Masami FUKUDA, Toshio SONE and Daisuke NAGAOKA 1993 : Measurement of methane flux in a tundra region near Tiksi, eastern Siberia in 1992. *Low Temperature Science, Ser. A, 52.*

Measurement of Methane Flux in a Tundra Region near Tiksi, Eastern Siberia in 1992*

Tomoko NAKAYAMA
(Graduate School of Science, Hokkaido University)
Masami FUKUDA, Toshio SONE
(Institute of Low Temperature Science, Hokkaido University)
and Daisuke NAGAOKA
(Graduate School of Earth Environ. Science, Hokkaido University)

(Accepted November, 1993)

Abstract : Methane is a significant greenhouse gas and the change of its concentration in atmosphere has an important effect on global climate. In order to ascertain the methane emission from tundra wetlands on permafrost area, the methane fluxes in the vicinity of Tiksi, eastern Siberia were measured in July, 1992. This study confirmed that methane gas is released from tundra wetlands in eastern Siberia. The values of fluxes were from 0 to 30.7 [mg CH_4 m^{-2} day^{-1}]

要旨：メタンは顕著な温室効果気体であり，その濃度の変化は気候に対し影響を与える。永久凍土地帯に広がるツンドラ湿地はメタンの発生源の一つと考えられる。そこで，高緯度のツンドラ湿地からメタンが発生していることを確認し，発生量の大きさを評価するために，1992年7月に東シベリアのチクシ近郊において，メタンフラックスの測定を行った。その結果，メタンの発生が確認され，フラックスの大きさは地点により，0－30.7 [mg CH_4 m^{-2} day^{-1}] であった。

Key words : Greenhouse gas, Methane flux, Permafrost, Siberia, Tundra wetland

キーワード：永久凍土，温室効果気体，シベリア，ツンドラ湿地，メタンフラックス

1. Introduction

Methane is a significant greenhouse gas. The methane concentration in the atmosphere has been rising for the past three centuries from about 0.7 to 1.7 ppmv (parts per million

* 北海道大学低温科学研究所業績　第3694号

by volume), although the global rate of methane accumulation actually decreased between 1983 and 1990[1]. Although the total methane flux is fairly well established, the contribution of the individual sources is far less certain. It is necessary to estimate the methane emission from each source in order to understand the global methane budget.

Tundra wetlands on permafrost areas are one of the most important sources of methane. Tundra wetlands are widely distributed in the arctic region (8.8×10^{12} m^2) and store large amounts of organic carbon as peat soil[2]. If the thickness of the active layer, which is denoted as the seasonal melting layer on a permafrost surface, will increase under a future warming, the production and emission of methane will probably increase as a result of the melting and decaying of the frozen soil. It is therefore important to investigate the methane flux from tundra wetlands and understand the mechanisms of its production in the ground and transportation to atmosphere. Recently, the methane fluxes from natural wetlands have been measured in high latitude regions of the northern hemisphere, mainly in North America[3~7]. However, there are few reports related to the methane emission in Siberian permafrost area. In this study, the methane flux, air and ground temperatures, and ground water level were measured in tundra wetlands near Tiksi, eastern Siberia in July, 1992. In this paper, we report the results of our measurements and evaluate the value of methane flux.

2. Study site and method of measurement

The measurements were carried out on the Bykovsky Peninsula (71°46'N, 129°30'E) from 19 to 23 July,1992 and Kalakhari Island (72°02'N, 128°45'E) on 29 July,1992 in the vicinity of Tiksi, Sakha Republic, Russia (Fig.1). These sites are located at the mouth of the Lena river. Mean annual air temperature is −14°C and annual precipitation is 240mm at Tiksi[8]. The region is continuously underlain by permafrost, the thickness of which has been estimated to be about 650m at Tiksi[9].

On the Bykovsky Peninsula, an ice complex of 40m thick is exposed on some parts of shoreline and ice-wedge polygons exist in alas. The term "alas" denotes a flat-floored depression formed by local melting of permafrost. The observations were performed in two locations; one was on the terrace of the ice complex (A) and the other was in an alas with ice-wedge polygons (B,C,D). The thawed layer on the terrace was about 15cm deep and the surface was moist, but not submerged under the water level. Conversely, the sediment near the surface in the alas was wet and the maximum thawed depth during the observational period was 40cm.

Kalakhari Island has a very flat surface (about 4m a.s.l.) composed of a Holocene peat layer. Ice-wedge polygons with an average diameter of about 15m are well developed.

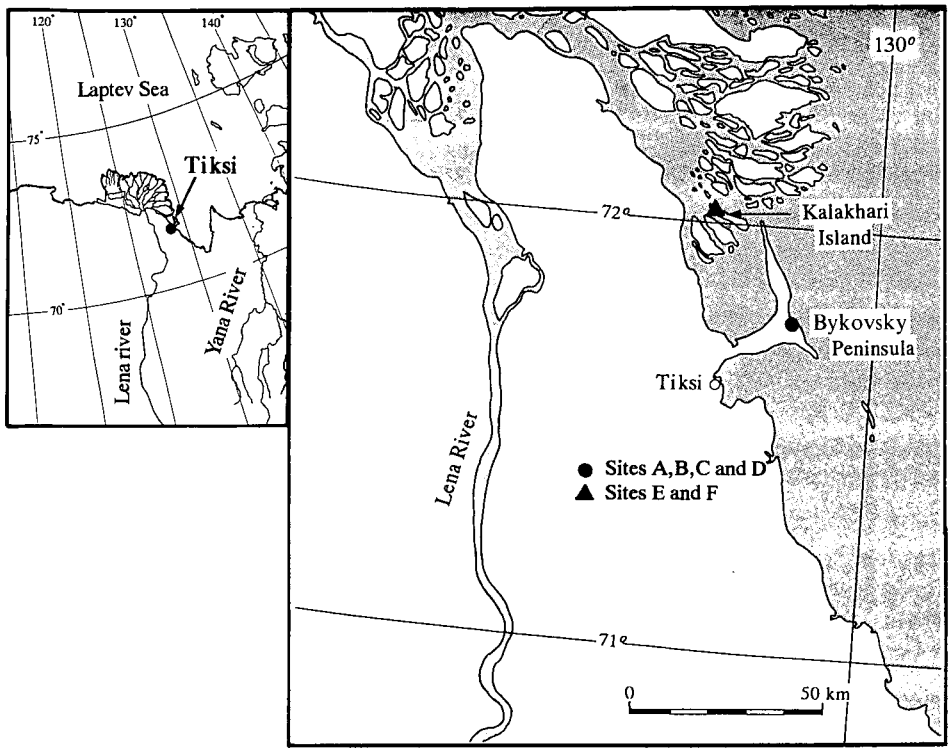

Fig.1 Locations of study sites

The methane fluxes were measured at the border (E) and center (F) of an ice-wedge.

On both the Bykovsky Peninsula and Kalakhari Island, the ice-wedge polygons are low-centered polygons. While its center is wet and covered with sedge, the border is relatively dry and covered with moss and small shrub (Fig.2). Thus ice-wedge polygons look like paddy fields and they form the landscape of typical tundra wetlands. A brief qualitative description of each site is given in Table 1.

The chamber technique, which is a common method for measuring the flux of atmospheric trace gas from soil to air, was employed for this research (Fig.3). An open bottomed aluminum chamber (dimensions $30 \times 30 \times 60$ cm) was inserted into the surface soil. Air in the chamber was removed by an air pump and stored in a sampling bag. Sampling at each site was conducted four times every 10 min over a 30 min period. The volume of each air sample was 500 ml. These samples were taken back to Japan and analyzed in the laboratory by gas chromatograph with a flame ionization detector. Methane fluxes were calculated from the gradient of the concentration change over time.

Meteorological observations (air temperature, ground temperature profile, wind velocity and direction, and insolation) were made automatically on the terrace of the Bykovsky Peninsula from 18 to 25 July, and at Kalakhari Island from 25 to 29 July.

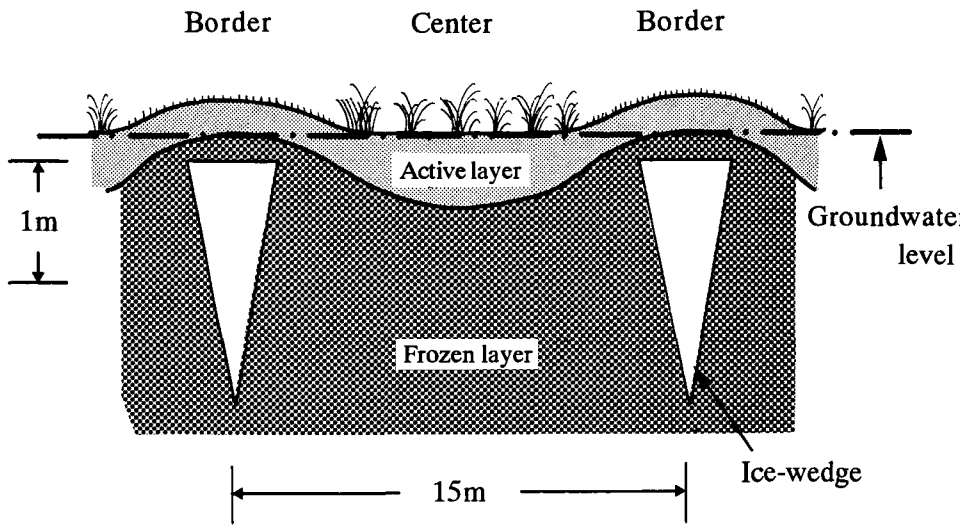

Fig.2 Scheme of a profile of an ice-wedge polygon

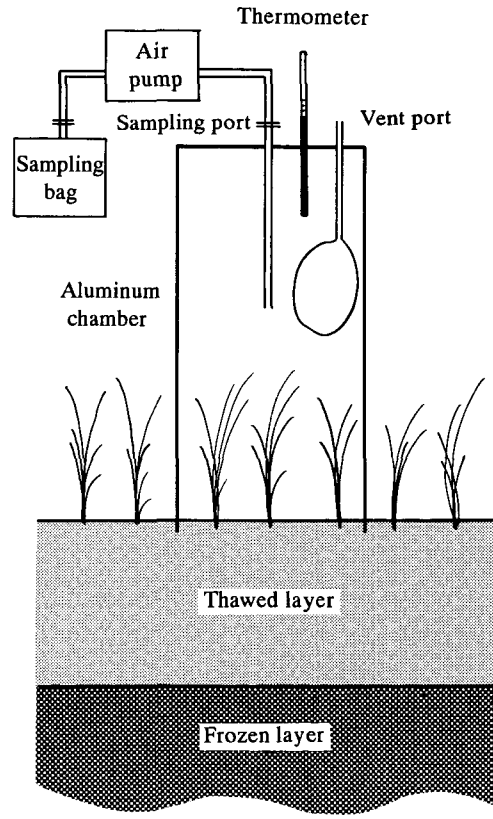

Fig.3 Chamber technique for the measurement of methane flux

Table 1 Description of field sites

Site	Condition and Vegetation
A	Bykovsky Peninsula. The terrace of the ice complex was covered with moss and very small shrubs
B	Bykovsky Peninsula. The center part of ice-wedge polygon in the alas was wet and covered with sedge
C	Bykovsky Peninsula. The border part of the ice-wedge polygon in the alas was covered with moss and small shrubs
D	Bykovsky Peninsula. Similar to site B
E	Kalakhari Island. Similar to site C
F	Kalakhari Island. Similar to site B

3. Results and discussion

The results of the methane flux measurements and the ground temperature profiles at the time of air-sampling are shown in Table 2 and Fig.4. The methane emission was obtained at all the sites that were wet and covered with sedge (B,D,F) and only one of the three sites that were moist and covered with moss (C). The average values of flux at the sedge sites and the moss sites are 22.3 (12.2 - 30.7) and 8.6 (0 - 25.9) [mg CH_4 m^{-2} day^{-1}] , respectively. It was confirmed that methane gas was released from tundra wetland in eastern Siberia, especially from those sites covered with sedge.

In Alaskan permafrost regions, similar measurements were conducted previously. Sebacher et al.(1986)[4] obtained the value of 119 (34 - 266) [mg CH_4 m^{-2} day^{-1}] as flux from the North Slope coastal tundra near Prudhoe Bay (70°30'N) in August 1984. Whalen and Reeburgh (1990)[7] made methane flux measurements during the summer of 1987 at 10km intervals from Prudhoe Bay to the Arctic Circle (66°33'N). The mean methane flux from arctic tundra was 52 (33 - 82) [mg CH_4 m^{-2} day^{-1}] . The results of our study are comparable with these values. On the contrary, methane fluxes from mid-latitude wetlands during summer were reported to be on the order of 10^2 - 10^3 [mg CH_4 m^{-2} day^{-1}][10~12]. The flux values of tundra wetland are significantly smaller than those of mid-latitude wetland. However, total methane emission from tundra region can not be negligible, since tundra wetlands are widely distributed in the arctic permafrost area.

The methane flux is determined by various factors, for example, ground temperature, soil moisture, substrate quality and quantity, pH, and transport processes[13]. The air temperature, ground temperatures at the surface and a depth of 10 cm, groundwater level

Table 2 Results of the methane flux and other factors

Site	A	B	C	D	E	F
Date	92.7.19	92.7.20	92.7.20	92.7.23	92.7.29	92.7.29
Time	16:15	12:03	14:23	11:27	11:07	12:10
Methane flux(mg/m2/d)	-	30.7	25.9	24.0	-	12.2
Air temp.(°C)	12.8	19.8	10.3	10.6	7.0	10.5
Surface temp.(°C)	13.2	16.5	9.6	7.7	7.5	12.1
10cm ground temp.(°C)	2.6	5.2	5.6	6.2	1.7	5.5
Groundwater level(cm)	-	5.0	-	2.0	-	5.0
Thawing depth(cm)	14.0	27.0	16.5	40.0	25.0	40.0
The average of the 24 hours before measurement (*)						
Air temp.(°C)	5.3	13.2	13.2	6.5	6.1	6.1
Surface temp.(°C)	4.8	9.7	9.7	8.4	6.5	6.5
10cm ground temp.(°C)	3.0	6.8	6.8	4.7	2.9	2.9

(*) at the point of meteorological observation

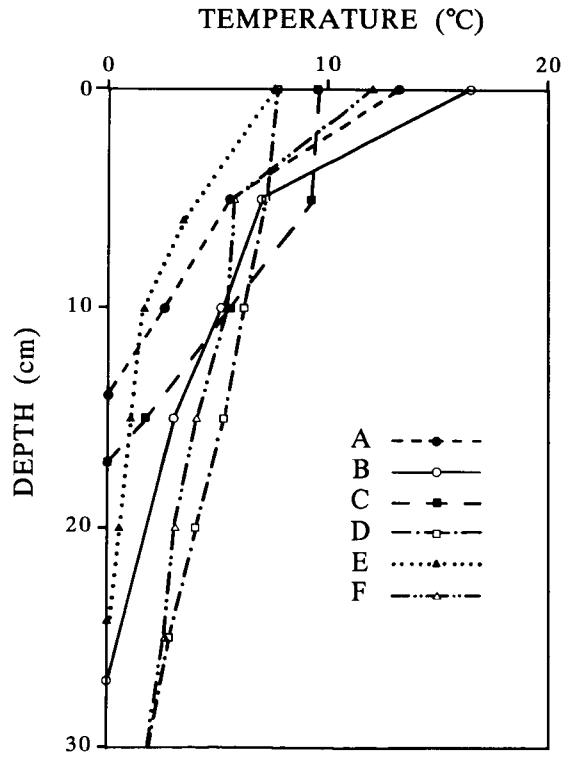

Fig.4 Ground temperature profiles at the time of methane flux measurement

and thawed depth at the time of air-sampling, and 24-hour mean temperatures before the air sampling are listed in Table 2. The ground temperatures of the 10cm depth at four sites where the methane emission was obtained (B,C,D,F) were higher than 5°C, while those at two other sites where no methane emission was obtained (A,E) were lower than 2.6°C and groundwater was not observed. On the three sedge sites (B,D,F), the higher the 24-hour mean air and ground temperatures are, the greater is the amount of methane released. In general, more methane is released from soil with a high temperature[11] and high moisture[13]. Our results are in agreement with this statement.

It is predicted that future warming will be greater in the arctic region than in the temperate and tropical regions[14]. An increase of ground temperature and active layer thickness on permafrost with such climatic warming will likely cause an increase in methane emission. It is therefore essential to measure the methane flux and the factors such as ground temperature and soil moisture in tundra wetlands for a long time period and establish the relationships between the methane flux and the contributing factors.

4. Conclusion

In this study, it was first confirmed that methane gas was released from tundra wetlands in eastern Siberia. The values of fluxes were from 0 to 30.7 [mg CH_4 m^{-2} day^{-1}] . This result is comparable with the methane flux values which were observed in Alaskan tundra wetlands. It is indicated that the methane flux is related to the ground temperature at a depth of 10cm at the time of air-sampling, the presence of groundwater, and the 24-hour mean air and ground temperatures before sampling.

Acknowledgements

We wish to thank Dr.V.V.Kunitsky, Permafrost Institute, Siberian Branch, Russia Academy of Science, Yakutsk, Russia for helping in the field and Dr.S.Ohta and Mr.T. Fukasawa, Dept. of Sanitary and Environmental Engineering, Hokkaido University, Japan for useful advice and for giving us facilities for analysis in their laboratory. This field work was financially supported by a Grand-in-Aid for Overseas Scientific Research Fund from Ministry of Education, Science and Culture, Japan.

References

1) Steele, L.P., E.J. Dlugokencky, P.M. Lang, P.P. Tans, R.C. Martin and K.A. Masarie, 1992, Slowing down of the global accumulation of atmospheric methane during the 1980s, *Nature*, **358**, 313-316.

2) Post, R.M., W.R. Emanuel, P.J. Zinke, and A.G. Stangenberger, 1982, Soil carbon pools and world life

zones, *Nature*, **298**, 156-159.

3) Svensson, B. and T. Rosswall, 1984, In situ methane production from acid peat in plant communities with different moisture regimes in a subarctic mire, *Oikos*, **43**, 341-350.
4) Sebacher, D.I., R.C. Harriss, K.B. Bartlett, S.M. Sebacher, and S.S. Grice, 1986, Atmospheric methane sources: Alaskan tundra bogs, an alpine fen, and a subarctic boreal marsh, *Tellus*, **38**, 1-10.
5) Moore, T.R. and R. Knowles, 1987, Methane and carbon dioxide evolution from subarctic fens, *Can.J. Soil Sci.*, **67**, 77-81.
6) Whalen, S.C. and W.S. Reeburgh, 1988, A methane flux time series for tundra environments, *Global Biogeochem. Cycles*, **2**, 399-409.
7) Whalen, S.C. and W.S. Reeburgh, 1990, A methane flux transect along the trans-Alaska pipeline haul road, *Tellus*, **42B**, 237-249.
8) Kunitsky, V.V., 1989, Cryolithology in estuary of the Lena, Permafrost Institute, Yakutsk, pp.162.(in Russian)
9) Katasonov, E.M., 1969, General facts on Yakutia and permanently frozen rock, in Guide to trip round central Yakutia, Intl. symp. on paleogeography and periglacial phenomena of Pleistocene, 4-10, ed. by E.M.Katasonov and P.A.Solov'ev, Yakutsk, pp.87.
10) Harriss, R.C., E. Gorham, D.I. Sebacher, K.B. Bartlett, and P.A. Flebbe, 1985, Methane flux from northern peatlands, *Nature*, **315**, 652-653.
11) Crill, P.M., K.B. Bartlett, R.C. Harriss, E. Gorham, E.S. Verry, D.I. Sebacher, and L. Madzer, 1988, Methane flux from Minnesota peatlands, *Global Biogeochem. Cycles*, **2**, 371-384.
12) Dise, N.B., 1993, Methane emission from Minnesota peatlands: spatial and seasonal variability, *Global Biogeochem. Cycles*, **7**, 123-142.
13) Crill, P.M., R.C. Harriss and K.B. Bartlett, 1991, Methane fluxes from terrestrial wetlands environments, in Microbial production and consumption of GREENHOUSE GASES, Chapter 6, 91-109, ed. by J.E.Rogers and W.B.Whitman, American Society for Microbiology, pp.298.
14) IPCC, 1990, Climate change: The IPCC scientific assessment, Cambridge University Press, pp.365.