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METHANE EMISSION FROM MIDDLE TAIGA OLIGOTROPHIC HOLLOWS OF WESTERN SIBERIA

The paper presents experimental data on the methane emissions from West Siberian middle taiga oligotrophic hollows. Studied fluxes vary considerably from –0.08 to 58 mgC·m^{-2}·h^{-1} (median is 2.76 mgC·m^{-2}·h^{-1}). Received data are consolidated in the scope of «standard model» Bc8 conception of methane emission. The model contains medians of CH_4 flux distributions on seven different microlandscape types depending on their area and duration of methane emission in the respective zones. The total flux from the middle taiga oligotrophic hollows is 0.37 TgC or approximately 70 % of CH_4 total flux from middle taiga mires. Version Bc8 of this model estimates the value of yearly CH_4 emission from mires of whole Western Siberia as 2.93 TgC·yr^{-1} that accounts for around 2.4 % of the total mire methane emission.

Key words: *methane emission, mires, oligotrophic hollows, middle taiga, West Siberia.*

Introduction

Methane is an important greenhouse gas contributing as much as 20 % of the anthropogenic radiative forcing in the contemporary atmosphere [1]. Therefore estimation of the relative contribution of different methane sources to the atmosphere is a crucial task in addressing the problem of global warming.

Wetlands comprise the largest and most variable natural source of CH_4 released to the atmosphere (estimations of emission are varied from 100 to 231 $TgCH_4$·yr^{-1} [2]. West Siberia gains the especial importance in this respect as one of the most paludified regions in the world with the mire area of 68.5 Mha or 27 % of this region area [3]. However the question about regional methane flux from this territory remains open: the previously published estimations varied considerably from 2 to 22 $MtCH_4$·yr^{-1} [4–6]. Thereby the goal of this research was to evaluate the contribution of mire landscapes to the regional Western Siberia CH_4 emission. The middle taiga oligotrophic hollows were chosen as the case study of present research. The objectives of the study were:

– to define the values of specific methane fluxes from middle taiga oligotrophic hollows of Western Siberia;

– to evaluate the relative contribution of different middle taiga microlandscapes to the regional flux from this zone.

Research methods

The field experiments were carried out during 2007–2010 summer-autumn periods. Primarily the variety of wetland types was reduced to 8 microlandscape types: palsas, ryams (pine-shrub-sphagnum communities), ridges, fens, poor fens, oligotrophic hollows, peat mats (lakeside quagmires) and wetland ponds. Further the measurements were concentrated on oligotrophic hollows of Western Siberia middle taiga zone. Key sites in a quantity of 6 were investigated over such period of time [7–9].

Measurements were made by a static chamber method. The chamber consisted of two parts: i) a permanent stainless steel square collar (40 × 40 cm) with a channel for water seal, and ii) a removable plexiglas box (30 or 40 cm height). To minimize the changes of chamber temperature, the plexiglas box was covered with reflecting aluminum fabric. Mechanical disturbances of peat layer were prevented by using of the portable or permanent footbridges.

The air inside the chamber was circulated by the battery-operated internal fen. The bottom of the collar was inserted into the soil at the depth of 10 cm at the time of about 15 minutes before the starts of measurements. Gas were sampled at the times $t_o = 0$, t_1, t_2 and t_3 to the nylon syringes («SFM», Germany). Exposition time ($\Delta t = t_3 - t_0$) were chosen correspondingly with the microlandscape type and usually varied from 30 to 60 min on the sites with a probably high and low fluxes respectively. Syringes were sealed by rubber stoppers and delivered to the laboratory. The leakage from syringes also was tested in a special experiment: as it turned out an initial CH_4 concentration of 5 ppm was decreased with the rate of 0.02 % per hour.

Methane concentrations were measured by a gas chromatographs “KhPM-4” (“Hromatograf” Co., Moscow, Russia) and “Crystal-5000” (“Chromatec” Co., Yoshkar-Ola, Russia) with a flame-ionization detectors.

At each site following environmental characteristics were measured: air and peat temperatures (at the depths of 0, 5, 15, 45 cm) by temperature sensors “TERMOCHRON” iButton DS 1921–1922 (DALLAS Semiconductor, USA), pH and electroconductivity by Combo “Hanna 98129” and concentration of dissolved oxygen by “Ecotest-2000” (“ECONYX”, Russia). Botanical descriptions also were made.

The intensity of methane emissions was calculated from linear regression with weights [10]. Nonparametric estimations of the density functions for methane flux probability were obtained by **equal-probability interval histograms method**.

Received data are consolidated in the scope of “standard model” Bc8 conception of methane emission. The model contains medians of CH_4 flux distributions on 8 different microlandscape types depending on their area (by [3]) and duration of methane emission in the respective zones [11].

Results and discussion

Up to the present moment only a few measurements of methane emissions in oligotrophic hollows were made in West Siberian middle taiga zone [8]. The main data array about CH_4 fluxes was received over the last four years during the current research (see Tables 1–8).

Generally CH_4 fluxes vary considerably from –0.08 to 58 mgC·m^{-2}·h^{-1}. Probability density distribution of

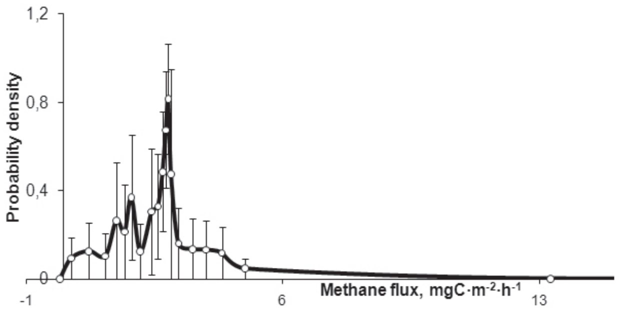

Fig. 1. Probability density distribution of methane fluxes from middle taiga oligotrophic hollows

CH_4 emission values (see Fig. 1) has several peaks though the only one is significant having a regard to accuracy. The figure 1 shows the most probable values of emission at 2.87 mgC·m^{-2}·h^{-1} while the median is 2.76 mgC·m^{-2}·h^{-1}.

At the present time methodology of the "standard model" use an approach under which measurements have been provided in a number of individual wetlands to determine typical CH_4 flux values. It is opposed to another approach supposing that the detail stationary measurements of the sole wetland are sufficient for a quite good estimation of spatial emission variability within the zone.

Such robust estimator as interquartile range was used for analysis of methodology correctness. It was found that the interquartile ranges were 1.81, 1.74 and 2.14 mgC·m^{-2}·h^{-1} for all wetlands, the sole wetland ("Mukhrino" mire) and the wetlands without "Mukhrino" mire, respectively. Data set of "Mukhrino" mire has the lowest interquartile range of CH_4 fluxes, so the natural variability of fluxes in this data set is shown worst. It confirms that even the detail stationary measurements can not be an alternative to numerous investigations of the individual wetlands and methodology is quite correct.

A general result of the study is a statistical modeling on a base of the "standard model" conception which gives a logical picture of contribution of different microlandscapes to the regional CH_4 flux from Western Siberia mires (see Fig. 2).

Table 1

CH_4 emission from middle taiga oligotrophic hollows of Western Siberia (further – CH_4 emission) in 2007

№ of point	Date	Temperature, °C					WTL, cm[a)]	pH	Botanical descriptions[b)]	CH_4 fluxes, mgC·m^{-2}·h^{-1}	
		Air	Soil on depth h (cm)							Mean	STD
			0	5	15	45					
T.Su. – N61.4 E73.3, 2007											
1.H	16.08	12.1	–	15.0	12.3	11.4	2	3.9	*Sch, And, Oxy*	0.73	0.05
1.H	16.08	12.1	–	15.0	12.3	11.4	2	3.9	*Sch, And, Oxy*	0.66	0.09
2.H	18.08	19.7	–	14.5	12.8	11.2	0	4.1	*Eri, Car, Sha*	0.79	0.13
2.H	18.08	19.7	–	14.5	12.8	11.2	3	4.1	*Eri, Car, Sha*	1.56	0.14
2.H	18.08	21.7	–	15.0	13.3	11.3	0	4.1	*Eri, Car, Sha*	0.95	0.17
2.H	18.08	21.7	–	15.0	13.3	11.3	0	4.1	*Eri, Car, Sha*	0.25	0.32
3.H	18.08	20.3	–	21.3	16.0	11.8	–6	4.6	*Car, Sha*	0.86	0.16
3.H	18.08	20.3	–	21.3	16.0	11.8	–5	4.6	*Car, Sha*	0.88	0.19
3.H	18.08	18.9	–	20.7	16.0	11.8	3	4.6	*Car, Sha*	0.52	0.11
3.H	18.08	18.9	–	20.7	16.0	11.8	4	4.6	*Car, Sha*	1.35	0.35
T.Lem.GMK.H (11–13) – N60.903 E71.326, 2008											
11	1.09	19.5	19.2	16.4	13.6	11.7	10	3.6	*And, Ros, Bal*	1.95	0.12
12	1.09	19.5	19.2	16.4	13.6	11.7	8	3.6	*And, Ros, Bal*	1.36	0.06
13	1.09	19.5	19.2	16.4	13.6	11.7	12	3.6	*And, Ros, Bal*	1.90	0.09
T.Dem.GMK.H (14–16) – N59.677 E69.976, 2008											
14	4.09	8.7	9.6	12.8	14.2	14.0	10	3.9	*Sch, Lim, Sph*	1.78	0.07
15	4.09	8.7	9.6	12.8	14.2	14.0	10	3.9	*Sch, Lim, Sph*	3.70	0.15
16	4.09	8.7	9.6	12.8	14.2	14.0	10	3.9	*Sch, Lim, Sph*	1.87	0.08

[a)] *And* – Andromeda polifolia; *Ang* – Sphagnum angustifolium; *Bal* – Sphagnum balticum; *Car* – Carex sp.; *Cha* – Chamaedaphne calcylata; *Eri* – Eriophorum sp.; *Jen* – Sphagnum jensenii; *Las* – Carex lasiocarpa; *Lim* – Carex limosa; *Lin* – Sphagnum lindbergii; *Maj* – Sphagnum majus; Oxy – Oxycoccus microcarpus; *Pap* – Sphagnum papillosum; *Ros* – Carex rostrata; *Sch* – Scheuchzeria palustris; *Vag* – Eriophorum vaginatum.

[b)] Positive and negative values mean situations, when water table level (WTL) is lower and higher than mean level of moss surface respectively.

Table 2

CH_4 emission in 2008 (without "Mukhrino" mire)

№ of point	Date	Temperature, °C					WTL, cm	pH	Botanical descriptions	CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$	
		Air	Soil on depth h (cm)							Mean	STD
			0	5	15	45					
T.Sh – N61.06 E69.46, 2008											
07a	15.08	19.1	14.6	14.1	14.0	12.3	8	3.9	*Cha, Vag, Ang*	0.80	0.05
07b	15.08	21.1	16.3	14.7	14.0	12.3	5	3.9	*Cha, Vag, Ang*	58.00	19.4
07	12.08	23.3	19.5	15.0	14.3	13.3	35	4.0	*Cha, Vag, Ang*	0.22	0.09
08	15.08	19.0	16.2	14.8	13.8	12.7	4	3.6	*Cha, Vag, Ang*	13.88	9.91
08	12.08	22.8	18.2	16.3	14.3	12.8	25	3.5	*Cha, Vag, Ang*	34.44	14.2
09a	15.08	20.2	16.3	16.1	15.3	13.5	1.5	4.2	*Cha, Vag, Ang*	2.61	0.28
09b	15.08	19.4	16.2	16.0	15.3	13.4	0	4.2	*Cha, Vag, Ang*	1.49	0.07
09	12.08	24.4	18.2	16.3	14.7	13.8	15	3.9	*Cha, Vag, Ang*	7.20	2.22
10	14.08	13.8	14.2	15.3	15.0	15.4	0	4.0	*Maj*	44.10	4.31
10	15.08	16.8	18.2	18.1	16.4	14.5	–10	4.2	*Maj*	0.37	0.03
11	14.08	13.4	14.9	14.9	14.7	14.1	0	3.8	*Maj*	2.98	0.70
11	15.08	16.8	18.2	18.1	16.4	14.5	–20	3.9	*Maj*	43.02	3.78
12	14.08	12.7	14.1	14.1	14.1	13.6	0	3.9	*Maj*	0.92	0.09
12	15.08	17.9	17.1	17.0	15.8	14.4	–2	4.2	*Maj*	1.22	0.43
13	15.08	18.0	17.0	16.8	15.8	14.4	–10	4.0	*Maj*	1.64	0.10
14a	16.08	28.1	21.2	15.9	13.7	11.3	7	4.0	*Cha, Vag, Bal*	0.19	0.02
14b	16.08	27.4	23.9	21.9	13.2	11.7	12	4.0	*Cha, Vag, Bal*	0.31	0.02
14	16.08	28.7	22.3	17.7	13.7	11.3	7	4.0	*Cha, Vag, Bal*	2.47	0.15
15	16.08	25.2	21.5	17.6	14.0	11.5	9	3.5	*Cha, Las, Ang*	0.21	0.07
15	16.08	26.6	22.2	18.4	14.0	11.5	8	3.8	*Cha, Las, Ang*	0.55	0.03
16	16.08	24.2	20.6	16.6	15.1	12.1	14	3.8	*Vag, Bal*	1.49	0.80
16	16.08	24.9	19.8	17.2	15.1	12.1	8	3.8	*Vag, Bal*	1.88	0.12
11	16.08	19.3	16.2	12.9	11.2	11.9	–4	3.9	*Maj*	0.56	0.04
11	09.09	20.3	17.0	13.6	11.1	11.8	–6	3.9	*Maj*	0.36	0.04
11	09.09	21.5	17.3	14.6	11.2	11.8	–3	3.9	*Maj*	16.80	1.80
11	09.09	13.0	17.1	15.5	11.4	11.8	–5	3.9	*Maj*	10.21	11.3
09	09.09	12.0	11.5	11.9	11.5	11.3	10	4.2	*Cha, Vag, Ang*	11.50	2.87
09	09.09	11.9	14.4	12.5	11.3	10.6	6	4.2	*Cha, Vag, Ang*	2.28	0.14
T.Sh - N61.06 E69.46, 2009											
8.1	26.08	24.7	20.1	14.9	13.7	10.5	2.5	3.9	*Cha, Vag, Ang*	1.06	0.03
8.2	26.08	32.3	26.4	22.2	15.7	12.7	25	3.9	*Cha, Vag, Ang*	3.55	2.06
17	26.08	38.6	19.2	13.7	12.3	9.0	7	3.9	*Sch, Sph*	1.37	1.91
17	26.08	28.0	25.3	21.9	14.4	10.5	37	3.9	*Sch, Sph*	3.23	2.38

a), b): see table 1.

Table 3

CH4 emission in 2008 on "Mukhrino" mire (N60.89 E68.68)

№ of point	Date	Temperature, °C					WTL, cm[a)]	pH	Botanical descriptions[b)]	CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$	
		Air	Soil on depth h (cm)							Mean	STD
			0	5	15	45					
T.Mu.GMK.H; 2009											
1	30.06	12.2	10.2	–	–	–	10	3.9	*Sch, Lim, Sph*	2.36	0.13
1	30.06	11.2	10.0	–	–	–	10	3.9	*Sch, Lim, Sph*	2.86	0.18
2	10.07	41.1	31.6	26.3	18.2	12.7	4	3.8	*Sch, Lim, Sph*	1.85	0.12
2	10.07	28.2	30.0	27.2	18.4	12.7	5	3.8	*Sch, Lim, Sph*	4.55	0.90
2	10.07	28.7	23.7	23.8	19.9	12.8	–3	3.8	*Sch, Lim, Sph*	1.01	0.33
2	11.07	28.7	26.9	26.8	19.6	13.2	5	3.8	*Sch, Lim, Sph*	3.56	0.22
2	11.07	33.5	27.0	26.7	19.8	13.2	12	3.8	*Sch, Lim, Sph*	1.44	0.12
2.1	11.07	33.7	27.0	26.7	19.9	13.2	–5	3.9	*Sch, Lim, Sph*	0.80	0.05
2.1	11.07	29.5	26.2	26.3	20.0	13.2	0	3.9	*Sch, Lim, Sph*	1.88	0.12
2.1	12.07	17.0	19.1	19.3	18.7	13.6	–10	3.9	*Sch, Lim, Sph*	11.33	3.01
2.1	12.07	16.3	18.8	19.1	18.7	13.6	10	3.9	*Sch, Lim, Sph*	5.72	0.41
2.1	12.07	15.9	18.6	18.9	18.7	13.7	–10	3.9	*Sch, Lim, Sph*	5.87	0.37
2.2	12.07	15.4	17.9	18.2	18.4	13.7	–10	4.1	*Sch, Lim, Sph*	13.38	1.64
2.2	13.07	20.3	18.4	17.5	16.0	14.6	–10	4.1	*Sch, Lim, Sph*	10.01	4.47
2.2	13.07	20.9	18.9	17.9	15.6	14.2	5	4.1	*Sch, Lim, Sph*	2.65	0.28
2.2	13.07	20.8	19.3	18.3	15.7	14.1	10	4.1	*Sch, Lim, Sph*	3.51	0.48
2.2	13.07	21.6	19.6	18.6	15.8	14.1	13	4.1	*Sch, Lim, Sph*	0.70	0.04

Continuation of table 3

№ of point	Date	Temperature, °C					WTL, cm[a)]	pH	Botanical descriptions[b)]	CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$	
		Air	Soil on depth h (cm)							Mean	STD
			0	5	15	45					
T.Mu.GMK.Hb; 2009											
4	11.08	10.9	13.0	12.5	12.9	12.0	5	3.8	*She, Lim, Sph*	1.55	0.22
4	11.08	10.9	13.0	12.5	12.9	12.0	5	3.8	*She, Lim, Sph*	1.71	0.08
4	11.08	12.6	13.4	12.5	12.9	12.0	5	3.8	*She, Lim, Sph*	0.83	0.08
4	11.08	12.6	13.4	12.5	12.9	12.0	5	3.8	*She, Lim, Sph*	1.76	0.09
4	11.08	16.4	14.4	12.5	12.9	12.0	5	3.8	*She, Lim, Sph*	0.71	0.04
4	11.08	16.4	14.4	12.5	12.9	12.0	5	3.8	*She, Lim, Sph*	1.76	0.09
4	11.08	19.1	15.1	12.6	12.9	12.0	5	3.8	*She, Lim, Sph*	0.15	0.06
4	11.08	19.1	15.1	12.6	12.9	12.0	5	3.8	*She, Lim, Sph*	1.89	0.10
4	11.08	17.6	15.4	12.7	12.9	12.0	5	3.8	*She, Lim, Sph*	0.39	0.13
4	11.08	17.6	15.4	12.7	12.9	12.0	5	3.8	*She, Lim, Sph*	1.83	0.09
4	11.08	12.7	14.6	13.6	12.9	12.0	5	3.8	*She, Lim, Sph*	1.94	0.10
4	11.08	12.7	14.6	13.6	12.9	12.0	5	3.8	*She, Lim, Sph*	1.53	0.35
4	11.08	11.6	14.4	13.6	12.9	12.0	5	3.8	*She, Lim, Sph*	1.86	0.09
4	11.08	11.6	14.4	13.6	12.9	12.0	5	3.8	*She, Lim, Sph*	0.64	0.03
4	11.08	11.1	14.1	13.8	13.0	12.0	5	3.8	*She, Lim, Sph*	1.91	0.10
4	11.08	11.1	14.1	13.8	13.0	12.0	5	3.8	*She, Lim, Sph*	1.39	0.07
4	11.08	11.9	14.1	13.8	13.0	12.0	5	3.8	*She, Lim, Sph*	1.83	0.09

[a), b)]: see table 1.

Table 4

CH_4 emission in 2009 on “Mukhrino” mire (N60.89 E68.68)

Temperature, °C				CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$		Temperature, °C				CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$	
Air	Soil on depth h (cm)			Mean	STD	Air	Soil on depth h (cm)			Mean	STD
	0	5	15				0	5	15		
T.Mu.GMK.Hb.4; 11.08.2009; WTL = 5 cm; pH = 3.8; T(soil on depth 45 cm) = 12.0 °C; botanical description: *Sch, Lim, Sph.*											
11.9	14.1	13.8	13.0	–0.04	0.01	10.9	14.0	13.7	13.0	0.70	0.07
10.9	14.0	13.7	13.0	1.77	0.11						
T.Mu.GMK.Hb.6; 14.08.2009; WTL = 5 cm; pH = 4.0; T(soil on depth 45 cm) = 12.5 °C; botanical description: *Sch, Lim, Sph.*											
24.4	22.3	14.7	14.1	1.56	0.08	28.2	26.1	16.2	13.5	1.28	0.06
24.8	22.3	14.8	13.8	–0.08	0.01	27.4	21.2	16.9	13.9	1.43	0.11
24.9	22.5	14.9	13.7	1.28	0.08	25.9	20.5	16.9	13.9	0.41	0.02
25.4	22.9	15.3	13.5	1.26	0.06	25.9	20.3	16.9	13.9	1.48	0.07
25.5	23.0	15.3	13.5	0.05	0.03	25.9	19.8	16.8	14.0	1.37	0.07
26.1	23.8	15.6	13.5	1.37	0.07	25.9	19.6	16.8	14.0	0.33	0.02
27.3	24.8	15.9	13.5	0.41	0.04	25.1	19.2	16.7	14.0	1.42	0.07
27.6	25.1	16.0	13.5	1.27	0.06	19.3	18.3	16.6	14.1	1.35	0.07
28.4	26.1	16.2	13.5	0.08	0.04	19.1	18.3	16.5	14.1	0.76	0.04
T.Mu.GMK.Hb.7; 15.08.2009; WTL = 15 cm; pH = 4.1; T(soil on depth 45 cm) = 11.5 °C; botanical description: *Sch, Lim, Sph.*											
26.3	18.1	13.6	13.6	7.50	0.59	30.1	18.8	14.8	13.2	2.69	0.14
26.6	18.4	13.6	13.4	1.00	0.06	29.3	18.5	14.8	13.3	2.04	0.14
26.8	18.4	13.7	13.4	6.39	0.60	29.0	18.4	14.8	13.3	2.63	0.16
27.8	18.9	13.8	13.3	6.42	0.59	26.4	18.1	14.8	13.3	2.39	0.13
28.5	19.1	13.9	13.3	1.26	0.26	25.4	18.0	14.8	13.3	1.70	0.08
28.9	19.2	13.9	13.3	5.24	0.26	21.8	17.6	14.8	13.3	3.51	0.18
29.8	19.4	14.1	13.3	4.44	0.34	19.5	17.2	14.8	13.3	3.98	0.36
29.9	19.5	14.1	13.3	0.41	0.15	18.9	17.2	14.8	13.3	1.78	0.09
30.4	19.5	14.2	13.2	3.23	0.17	14.7	16.7	14.8	13.3	2.92	0.29
30.5	19.6	14.3	13.2	0.67	0.06						

[a), b)]: see table 1.

Oligotrophic hollows of middle taiga are found to be the most significant methane source with the annually emission rate at 0.37 TgC when the total flux from this zone is 0.53 TgC. It is attributed to the great area covering for about 17 % of whole mire area in this region by [3] as well as to the high flux values (1^{st} quartile/median/3^{rd} quartile = 1.78/2.76/3.59 $mgC \cdot m^{-2} \cdot h^{-1}$).

Table 5

CH_4 emission in 2009 on "Mukhrino" mire (continuation)

Temperature, °C				CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$		Temperature, °C				CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$	
Air	Soil on depth h (cm)			Mean	STD	Air	Soil on depth h (cm)			Mean	STD
	0	5	15				0	5	15		
T.Mu.GMK.Hb.5.1; 11.08.2009; WTL = 6 cm; pH = 3.6; T(soil on depth 45 cm) = 12.5 °C; botanical description: *Sch, Lim, Sph*.											
13.6	13.6	12.9	13.0	2.75	0.06	17.3	16.0	13.3	13.0	2.79	0.06
14.1	13.5	12.9	13.0	2.72	0.06	18.9	16.6	13.5	13.0	2.86	0.06
14.9	13.7	12.9	13.0	2.80	0.06	17.2	16.6	13.8	13.0	2.91	0.07
13.3	13.1	13.0	13.0	2.79	0.06	15.8	15.3	14.0	13.0	2.85	0.09
11.6	12.5	13.0	13.0	2.73	0.06	12.8	13.5	14.0	13.0	2.77	0.06
10.6	12.0	13.0	13.0	2.91	0.07	13.7	13.4	14.0	13.0	2.79	0.06
10.9	12.0	13.0	13.0	2.76	0.06	15.6	14.3	14.0	13.0	2.68	0.06
10.5	11.9	13.0	13.0	2.85	0.06	15.6	14.7	14.1	13.0	2.74	0.06
11.9	12.3	13.0	13.0	2.79	0.06	12.9	13.2	14.1	13.0	2.82	0.06
15.1	14.2	13.1	13.0	2.70	0.06	11.9	12.6	14.1	13.0	2.76	0.06
10.9	12.1	14.0	13.0	2.70	0.06	10.6	11.7	13.8	13.0	2.61	0.06
11.1	12.2	13.9	13.0	2.52	0.16	10.3	11.4	13.7	13.0	2.69	0.06
11.4	12.3	13.9	13.0	2.67	0.06						
T.Mu.GMK.Hb.5.2; 11.08.2009; WTL = 7 cm; pH = 3.6; T(soil on depth 45 cm) = 12.5 °C; botanical description: *Sch, Lim, Sph*.											
13.6	13.6	12.9	13.0	3.27	0.12	17.3	16.0	13.3	13.0	2.91	0.07
14.1	13.5	12.9	13.0	2.79	0.06	18.9	16.8	13.6	13.0	2.96	0.07
14.9	13.7	12.9	13.0	2.96	0.07	17.0	16.4	13.9	13.0	2.96	0.07
13.2	13.1	13.0	13.0	2.92	0.07	15.8	15.3	14.0	13.0	2.99	0.07
11.6	12.5	13.0	13.0	2.91	0.07	12.8	13.5	14.0	13.0	2.86	0.06
10.6	12.0	13.0	13.0	2.86	0.06	13.7	13.4	14.0	13.0	2.86	0.06
10.9	12.0	13.0	13.0	2.89	0.07	15.6	14.7	14.1	13.0	2.97	0.07
10.6	11.9	13.0	13.0	2.85	0.06	15.6	14.3	14.0	13.0	3.03	0.07
11.9	12.3	13.0	13.0	2.82	0.06	12.9	13.2	14.1	13.0	2.88	0.06
15.1	14.2	13.1	13.0	2.88	0.06	11.9	12.6	14.1	13.0	2.96	0.07
10.7	12.0	14.0	13.0	2.90	0.07	10.6	11.7	13.8	13.0	2.73	0.06
11.1	12.2	13.9	13.0	2.90	0.07	10.2	11.3	13.5	13.0	2.85	0.06
11.4	12.3	13.9	13.0	2.88	0.06						
T.Mu.GMK.Hb.8; 16.08.2009; WTL = 5 cm; pH = 4.3; T(soil on depth 45 cm) = 8.0 °C; botanical description: *Sch, Lim, Sph*.											
22.0	16.4	12.3	11.0	4.91	0.25	25.5	17.4	12.6	10.2	2.45	0.13
22.7	16.5	12.3	10.7	3.87	0.20	25.6	17.5	12.7	10.1	4.98	0.26
22.9	16.7	12.3	10.6	5.07	0.26	25.7	17.5	12.8	10.1	2.90	0.82
23.7	17.0	12.3	10.4	4.40	0.23	25.2	17.6	12.9	10.1	4.01	0.20
24.1	17.0	12.4	10.4	2.84	0.14	24.8	17.6	12.9	10.0	2.76	0.14
24.7	17.0	12.4	10.3	4.75	0.24	24.5	17.5	13.0	10.0	4.92	0.26
25.4	17.3	12.5	10.2	6.11	0.31						

[a), b)]: see table 1.

Table 6

CH_4 emission in 2009 on "Mukhrino" mire (continuation)

Temperature, °C				CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$		Temperature, °C				CH_4 fluxes, $mgC \cdot m^{-2} \cdot h^{-1}$	
Air	Soil on depth h (cm)			Mean	STD	Air	Soil on depth h (cm)			Mean	STD
	0	5	15				0	5	15		
T.Mu.GMK.Hb.3.1; 28–29.08.2009; WTL = 2 cm; pH = 4.0; T(soil on depth 45 cm) = 14.5 °C; botanical description: *Sch, Lim, Sph*.											
35.5	19.1	17.2	17.8	6.75	0.97	22.6	16.9	17.0	17.5	2.64	0.08
37.8	19.4	17.3	17.6	3.39	0.10	20.0	17.3	17.0	17.5	2.64	0.08
39.3	19.8	17.4	17.4	3.22	0.10	20.5	17.5	17.0	17.5	2.51	0.08
40.4	20.1	17.5	17.4	3.50	0.10	21.4	17.7	17.1	17.4	2.51	0.08
40.8	20.3	17.8	17.3	3.70	0.11	21.3	17.9	17.1	17.4	2.80	0.12
40.3	20.5	17.9	17.3	3.85	0.12	28.3	18.4	17.2	17.4	3.03	0.09
33.4	20.4	18.3	17.3	2.71	0.08	25.9	18.5	17.4	17.3	4.95	0.15
29.1	20.1	18.5	17.3	3.51	0.26	34.7	19.1	17.5	17.3	5.91	0.18
23.4	19.9	18.6	17.3	1.94	0.38	11.7	17.9	18.3	17.6	4.21	0.13
19.4	19.7	18.8	17.4	2.21	0.07	12.3	17.8	18.2	17.6	4.28	0.13
15.4	19.4	18.8	17.4	3.05	0.09	12.4	17.7	18.1	17.6	4.29	0.13
13.0	19.1	18.9	17.4	3.86	0.43	12.0	17.6	17.9	17.6	4.38	0.13
12.0	18.8	18.8	17.5	3.95	0.32	11.9	17.4	17.8	17.6	4.46	0.13
11.8	18.5	18.8	17.5	7.18	2.71	12.1	17.3	17.7	17.6	4.61	0.14

Continuation of table 6

Temperature, °C				CH_4 fluxes, $mgC·m^{-2}·h^{-1}$		Temperature, °C				CH_4 fluxes, $mgC·m^{-2}·h^{-1}$	
Air	Soil on depth h (cm)			Mean	STD	Air	Soil on depth h (cm)			Mean	STD
	0	5	15				0	5	15		
13.5	18.4	18.5	17.6	4.08	0.12	11.3	16.9	17.3	17.6	4.50	0.23
12.9	18.3	18.5	17.6	4.36	0.13	12.5	16.7	17.2	17.6	3.22	0.10
11.6	18.1	18.4	17.6	4.31	0.45	17.3	16.8	17.1	17.6	3.20	0.10
T.Mu.GMK.Hb.3.2; 28–29.08.2009; WTL = 5 cm; pH = 4.0; T(soil on depth 45 cm) = 14.5 °C; botanical description: *Sch, Lim, Sph*.											
35.5	19.1	17.2	17.8	3.23	0.81	15.4	19.4	18.8	17.4	1.86	0.13
37.8	19.4	17.3	17.6	3.51	0.11	13.0	19.1	18.9	17.4	1.91	0.11
39.3	19.8	17.4	17.4	3.36	0.10	12.0	18.8	18.8	17.5	1.93	0.07
40.4	20.1	17.5	17.4	3.36	0.10	11.8	18.5	18.8	17.5	2.41	0.37
40.8	20.3	17.8	17.3	3.71	0.11	12.9	18.3	18.5	17.6	3.59	0.33
40.3	20.5	17.9	17.3	3.68	0.11	11.6	18.1	18.4	17.6	4.32	0.13
33.4	20.4	18.3	17.3	2.64	0.31	11.7	17.9	18.3	17.6	3.73	0.11
29.1	20.1	18.5	17.3	3.32	0.10	12.3	17.8	18.2	17.6	4.04	0.12
23.4	19.9	18.6	17.3	1.90	0.50	12.4	17.7	18.1	17.6	3.88	0.12
19.4	19.7	18.8	17.4	1.97	0.08	12.0	17.6	17.9	17.6	3.77	0.17
11.9	17.4	17.8	17.6	3.72	0.11	20.0	17.3	17.0	17.5	2.70	0.11
12.1	17.3	17.7	17.6	3.59	0.11	20.5	17.5	17.0	17.5	2.97	0.15
11.3	16.9	17.3	17.6	2.97	0.14	21.4	17.7	17.1	17.4	2.83	0.30
12.5	16.7	17.2	17.6	3.03	0.09	21.3	17.9	17.1	17.4	2.32	0.18
17.3	16.8	17.1	17.6	2.13	0.09	28.3	18.4	17.2	17.4	2.93	0.34
22.6	16.9	17.0	17.5	2.53	0.13	25.9	18.5	17.4	17.3	3.88	0.12
34.7	19.1	17.5	17.3	4.11	0.12						

[a), b)]: see table 1.

Table 7

CH_4 emission in 2009 on "Mukhrino" mire (continuation)

Temperature, °C				CH_4 fluxes, $mgC·m^{-2}·h^{-1}$		Temperature, °C				CH_4 fluxes, $mgC·m^{-2}·h^{-1}$	
Air	Soil on depth h (cm)			Mean	STD	Air	Soil on depth h (cm)			Mean	STD
	0	5	15				0	5	15		
T.Mu.GMK.Hb.3.3; 28–29.08.2009; WTL = 10 cm; pH = 4.1; T(soil on depth 45 cm) = 14.5 °C; botanical description: *Sch, Lim, Sph*.											
35.5	19.1	17.2	17.8	1.98	0.06	15.4	19.4	18.8	17.4	2.86	0.09
37.8	19.4	17.3	17.6	1.89	0.06	13.0	19.1	18.9	17.4	2.40	0.29
39.3	19.8	17.4	17.4	1.85	0.06	12.0	18.8	18.8	17.5	2.39	0.23
40.4	20.1	17.5	17.4	1.67	0.05	11.8	18.5	18.8	17.5	2.81	0.27
40.8	20.3	17.8	17.3	1.73	0.06	13.5	18.4	18.5	17.6	1.47	0.04
40.3	20.5	17.9	17.3	1.81	0.05	12.9	18.3	18.5	17.6	2.29	0.38
33.4	20.4	18.3	17.3	2.44	0.07	11.6	18.1	18.4	17.6	1.50	0.14
29.1	20.1	18.5	17.3	1.14	0.11	11.7	17.9	18.3	17.6	1.59	0.06
23.4	19.9	18.6	17.3	0.73	0.02	12.3	17.8	18.2	17.6	1.63	0.09
19.4	19.7	18.8	17.4	2.51	0.08	12.4	17.7	18.1	17.6	1.58	0.15
12.0	17.6	17.9	17.6	1.71	0.12	20.0	17.3	17.0	17.5	2.78	0.08
11.9	17.4	17.8	17.6	1.48	0.13	20.5	17.5	17.0	17.5	2.58	0.08
12.1	17.3	17.7	17.6	1.51	0.05	21.4	17.7	17.1	17.4	2.52	0.08
11.3	16.9	17.3	17.6	3.35	0.14	21.3	17.9	17.1	17.4	3.12	0.09
12.5	16.7	17.2	17.6	2.96	0.26	28.3	18.4	17.2	17.4	2.33	0.11
17.3	16.8	17.1	17.6	2.60	0.08	25.9	18.5	17.4	17.3	2.46	0.29
22.6	16.9	17.0	17.5	2.68	0.08	34.7	19.1	17.5	17.3	2.19	0.23
T.Mu.GMK.Hb.3.4; 28–29.08.2009; WTL = 0 cm; pH = 4.1; T(soil on depth 45 cm) = 14.5 °C; botanical description: *Sch, Lim, Sph*.											
35.5	19.1	17.2	17.8	2.53	0.12	15.4	19.4	18.8	17.4	3.72	0.24
37.8	19.4	17.3	17.6	2.51	0.11	13.0	19.1	18.9	17.4	4.01	0.15
39.3	19.8	17.4	17.4	2.38	0.07	12.0	18.8	18.8	17.5	4.46	0.57
40.4	20.1	17.5	17.4	2.55	0.09	11.8	18.5	18.8	17.5	3.68	0.58
40.8	20.3	17.8	17.3	2.62	0.08	13.5	18.4	18.5	17.6	6.33	0.63
40.3	20.5	17.9	17.3	2.66	0.08	12.9	18.3	18.5	17.6	6.62	0.20
33.4	20.4	18.3	17.3	4.12	0.12	11.6	18.1	18.4	17.6	7.44	0.39
29.1	20.1	18.5	17.3	3.20	0.30	11.7	17.9	18.3	17.6	7.35	0.38
23.4	19.9	18.6	17.3	1.48	0.04	12.3	17.8	18.2	17.6	7.09	0.21
19.4	19.7	18.8	17.4	2.79	0.13	12.4	17.7	18.1	17.6	6.80	0.20
12.0	17.6	17.9	17.6	6.31	0.19	20.0	17.3	17.0	17.5	4.40	0.13
11.9	17.4	17.8	17.6	6.29	0.19	20.5	17.5	17.0	17.5	4.93	0.15

Continuation of table 7

Temperature, °C				CH$_4$ fluxes, mgC·m^{-2}·h^{-1}		Temperature, °C				CH$_4$ fluxes, mgC·m^{-2}·h^{-1}	
Air	Soil on depth h (cm)			Mean	STD	Air	Soil on depth h (cm)			Mean	STD
	0	5	15				0	5	15		
12.1	17.3	17.7	17.6	5.41	0.26	21.4	17.7	17.1	17.4	4.57	0.14
11.3	16.9	17.3	17.6	4.29	0.13	21.3	17.9	17.1	17.4	4.97	0.52
12.5	16.7	17.2	17.6	4.35	0.13	28.3	18.4	17.2	17.4	4.56	0.29
17.3	16.8	17.1	17.6	4.06	0.27	25.9	18.5	17.4	17.3	2.89	0.11
22.6	16.9	17.0	17.5	5.20	0.25	34.7	19.1	17.5	17.3	2.78	0.08

a), b): see table 1.

Table 8

CH$_4$ emission in 2010 on "Mukhrino" mire (continuation)

№ of point	Date	Temperature, °C					WTL, cm	pH	Botanical descriptions	CH$_4$ fluxes, mgC·m^{-2}·h^{-1}	
		Air	Soil on depth h (cm)							Mean	STD
			0	5	15	45					
1	14.07	–	–	–	–	–	10	4.1	*Sch, Lim, Sph*	3.05	0.21
2	15.07	–	–	–	–	–	10	4.1	*Sch, Lim, Sph*	3.22	0.19
3	15.07	–	–	–	–	–	10	4.1	*Sch, Lim, Sph*	4.26	0.23
4	15.07	–	–	–	–	–	10	4.1	*Sch, Lim, Sph*	3.15	0.30
5	19.07	–	–	–	–	–	10	4.1	*Sch, Lim, Sph*	2.59	0.08
6	7.08	15.9	16.9	16.7	16.1	13.0	15	4.0	*And, Pap, Bal*	1.02	0.04
7	7.08	15.8	16.4	16.7	16.1	13.0	15	4.0	*And, Pap, Bal*	2.87	0.09
8	7.08	14.9	15.6	16.2	16.3	13.0	15	4.0	*And, Pap, Bal*	1.96	0.10
9	7.08	14.3	14.8	15.9	16.3	13.0	15	4.0	*And, Pap, Bal*	1.42	0.05
10	7.08	15.8	15.5	15.5	16.1	13.0	3.5	4.0	*Sch, Lin, Maj*	4.82	0.17
11	7.08	17.4	16.3	16.2	16.1	13.0	3.5	4.0	*Sch, Lin, Maj*	4.02	0.12
12	7.08	16.7	16.8	16.8	17.5	14.5	3.5	4.0	*Sch, Lin, Maj*	6.83	0.60
13	7.08	16.9	17.3	16.9	17.5	14.5	3.5	4.0	*Sch, Lin, Maj*	7.05	2.09
14	8.08	17.0	16.5	16.5	16.6	13.2	5	4.0	*Sch, Lim, Lin*	4.02	0.12
15	8.08	16.9	16.5	16.5	16.5	13.1	5	4.0	*Sch, Lim, Lin*	4.04	0.12
16	8.08	16.3	16.1	16.5	16.5	13.0	5	4.0	*Sch, Lim, Lin*	2.15	0.18
17	8.08	16.3	16.0	16.5	16.5	13.0	5	4.0	*Sch, Lim, Lin*	3.79	0.13
18	8.08	15.9	16.1	16.5	16.5	13.4	1	4.1	*Sch, Lin, Maj*	3.93	0.15
19	8.08	15.6	16.3	16.5	16.5	13.5	1	4.1	*Sch, Lin, Maj*	3.17	0.21
20	8.08	15.8	16.8	16.5	16.1	13.3	1	4.1	*Sch, Lin, Maj*	4.21	0.17
21	8.08	15.9	16.9	16.5	16.0	13.2	1	4.1	*Sch, Lin, Maj*	2.87	0.14
22	8.08	15.8	16.4	16.5	16.0	13.0	13	4.1	*Sch, Lin, Maj*	2.87	0.29
23	8.08	14.9	15.6	16.2	16.0	13.0	13	4.1	*Sch, Lin, Maj*	3.19	0.15
24	8.08	14.3	14.8	15.9	16.0	13.0	1	4.1	*Sch, Pap, Maj*	3.48	0.10
25	8.08	15.8	15.5	15.5	15.6	15.4	1	4.1	*Sch, Pap, Maj*	5.85	0.18
26	9.08	17.2	17.1	16.2	16.1	15.6	1	4.0	*Sch, Lim, Maj*	2.75	0.18
27	9.08	15.8	16.7	15.8	16.0	15.6	1	4.0	*Sch, Lim, Maj*	3.18	0.10
28	9.08	15.5	16.3	15.5	16.0	15.6	0	4.0	*Sch, Lin, Maj*	1.62	0.26
29	9.08	16.2	16.9	15.1	15.3	15.7	0	4.0	*Sch, Lin, Maj*	2.39	0.11
30	9.08	15.6	16.4	15.1	14.5	15.3	0	4.0	*Sch, Maj, Jen*	5.39	0.16
31	9.08	14.6	15.3	14.4	13.8	14.2	0	4.0	*Sch, Maj, Jen*	7.36	0.70

a), b): see table 1.

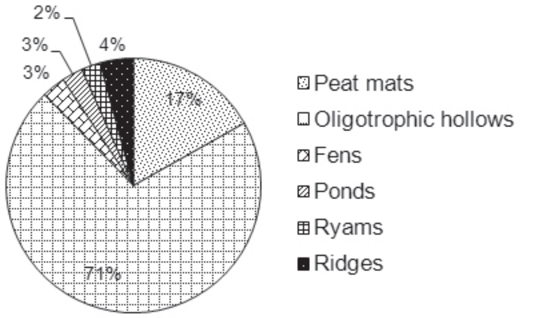

Fig. 2. Contribution of different microlandscape types to the regional CH$_4$ flux from Western Siberia mires

The latest version Bc8 of emission model estimates the total flux from all Western Siberia mires at 2.93 TgC·yr^{-1}. It accounts for about 2.4 % of emission from all mires or 0.7 % of global methane emission from all CH$_4$ sources (calculated using results from [2]).

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ЭМИССИЯ МЕТАНА ИЗ ОЛИГОТРОФНЫХ МОЧАЖИН СРЕДНЕЙ ТАЙГИ ЗАПАДНОЙ СИБИРИ

Представлены экспериментальные данные об эмиссии метана из олиготрофных мочажин средней тайги Западной Сибири. Измеренные значения удельного потока CH_4 варьируют в широких пределах от 0.08 до 58 мгС·м$^{-2}$·ч$^{-1}$ (медиана – 2.76 мгС·м$^{-2}$·ч$^{-1}$). Полученные данные рассматриваются в контексте «стандартной модели» эмиссии метана (версия Bc8). Эта модель содержит медианы распределений удельного потока метана для семи различных микроландшафтов, их площади и продолжительность периода эмиссии метана для каждой из 7 географических зон. Суммарный поток метана из олиготрофных мочажин равен 0.37 ТгС·год$^{-1}$, что составляет примерно 70 % от общего потока метана из болот средней тайги Западной Сибири. Версия Bc8 этой модели оценивает значение потока метана со всех болот Западной Сибири в 2.93 ТгС·год$^{-1}$, что составляет около 2.4 % потока метана в атмосферу со всех болот мира.

Ключевые слова: *эмиссия метана, болота, олиготрофные мочажины, средняя тайга, Западная Сибирь.*

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