VARIABLE REGIME OF METHANE EMISSION IN PERIODICALLY FLOODED FOREST

A.I. Churkina[1], M.V. Glagolev[1,2,3,4], D.V. Il'yasov[2], I.E. Terentieva[3], A.F. Sabrekov[2,3,4], S.S. Maksyutov[3,5]*

[1]Moscow State University, Moscow, Russia
[2]Institute of Forest Science Russian Academy of Sciences, Moscow region, Russia
[3]Tomsk State University, Tomsk, Russia
[4]Yugra State University, Khanty-Mansiysk, Russia
[5]National Institute for Environmental Studies, Tsukuba, Japan
* m_glagolev@mail.ru

Because of the methane having greenhouse effect, the wetlands have been studied rather intensively as sources of methane as well as forests have been studied like methane sinks (Glagolev et al., 2012; Fedorov et al., 2015; Sabrekov et al., 2015). The ecosystems of periodically flooded forests have been studied substantially less, although there arises more questions. The major question is what the periodically flooded forests are: sources or sinks of methane. Currently the Standard Model doesn't consider the flooded forest at all for the calculation of the methane flux from the Western Siberia territory (Глаголев, 2008). If the flooded forests periodically produce methane it may sufficiently change the regional flux estimation In connection with this, the aim of our study

Table 1 Site description

Point	Coordinates		Characeristics		
	Latitude	Longitude	pH	EC	The most abundant woody species[2]
Wet Forest near the river Polynanka					
fp_2	56.96188	82.51528	–	–	*B.p.*
fp_3	56.96180	82.51528	7.22[1]	115–132[1]	*B.p.*
fp_4	56.96195	82.51555	7.38–7.54	467–599	*B.p.*
Wet Forest near the Bakcharskoe bog					
Tr.PWF	56.83113	82.85278	–	–	*B.p., P.s.*
Tr.PWF_2	56.83128	82.85150	6.25–6.65	93–235	*B.p.*
Tr.WF/RB_2.1	56.83148	82.85133	5.47 – 6.05	85 – 223	*B.p., P.s.*
Tr.WF/RB_2.2	56.83150	82.85133	5.47 – 6.05	85 – 223	*B.p., P.s.*
Tr.WF/RB_1	56.83169	82.85122	4.27 – 4.76	51 – 90	*B.p., P.s.*
Bakcharskoe bog					
D35	56.82047	82.85555	4.09 – 4.23	56–62	*C.c., A.p., E.v.*
D375	56.82008	82.85555	–	–	*C.c., A.p., E.v.*
D.Oz1	56.81333	82.85337	5.63–5.87	17 – 22	–

[1] - For 26.07.2016 [2] - *B.p. - Betula pendula*, *P.s. - Pinus sylvestris*, *C.c. - Chamaedaphne calyculata*, *A.p. - Andromeda polifolia*, *E.v. - Eriophorum vaginatum*

Table 2 The soil moisture

Depth, cm	Moisture, %			
	Wet Forest_Polynanka, 21.07.16		Wet Forest, 24.07.2016	Wet Forest_Polynanka, 26.07.16
	fp_2, elevated	fp_3, depressed	Tr.PWF	fp_2, elevated
0	59.3±0.33	53.0±13.46	44.6±15.47	75.2±4.04
5	59.4±0.30	53.7±1.51	22.2±4.35	73.9±1.61
10	54.1±0.35	45.0±0.89	17.1±1.32	61.7± n.d.
15	45.5±10.68	26.6±10.43	16.9±0.38	66.2± n.d.

Table 3 Summary of the measured fluxes and ecosystem parameters

Point	Date	Micro Land-scape[3]	CH_4 flux, mg C $m^{-2}h^{-1}$			CO_2 flux, mg C $m^{-2}h^{-1}$			Temperature CH_4/CO_2, °C					WTL
			Mean	Err	Error Code[4]	Mean	Err	Error Code[4]	of air	of soil at depth, cm				
										0	5	15	45	
fp_2	21.07.2016	E	-0.083	0.084	95	553	40	4	34.5/35.6	21.8/22.0	17.8/17.5	14.5/14.6	12.0/12.0	-
			-0.013	0.260	95	376	98	4	28.6/32.0	21.5/21.5	18.0/18.0	14.5/14.5	12.0/12.0	-
			0.044	0.039	4	634	28	4	25.9/26.7	21.5/21.5	18.5/18.5	14.6/14.5	12.0/12.0	-
	26.07.2016	E	-0.045	0.059	95	45	6	6	16.4/16.3	16.7/16.5	17.0/17.0	16.0/16.0	13.5/13.5	25
			-0.058	0.036	95	170	226	4	16.2/15.9	16.9/16.5	17.0/17.0	16.0/15.8	13.5/13.5	25
			-0.024	0.095	95	689	29	4	15.8/15.0	16.5/16.5	17.0/16.8	15.8/15.6	13.5/13.5	25
			0.010	0.064	6	57	4	4	15.0/15.0	16.3/16.5	16.6/16.7	15.5/15.5	13.5/13.5	25
fp_3	21.07.2016	D	-0.025	0.118	95	275	78	4	34.5/35.6	21.8/22.0	17.8/17.5	14.5/14.6	12.0/12.0	30
			-0.002	0.140	95	409	123	4	28.6/32.0	21.5/21.5	18.0/18.0	14.5/14.6	12.0/12.0	30
			0.035	0.075	6	333	11	4	25.9/26.7	21.5/21.5	18.5/18.5	14.6/14.5	12.0/12.0	30
	26.07.2016	D	0.052	0.069	6	443	5	4	16.4/16.2	16.7/16.5	17.0/17.0	16.0/16.0	13.5/13.5	-7
			0.037	0.024	4	372	48	4	16.2/16.5	16.9/17.0	17.0/17.0	16.0/16.0	13.5/13.5	-7
			0.048	0.083	6	38	19	4	15.7/16.5	16.5/17.0	17.0/17.0	15.8/16.0	13.5/13.5	-7
			0.059	0.110	6	713	78	4	15.0/15.9	16.3/16.5	16.6/17.0	15.5/15.8	13.5/13.5	-7
	07.08.2016	D	3.692	0.692	4	n.d.	n.d.	n.d.	40.1/ -	28.2/ -	19.2/ -	17.5 / - [1]	16.1/ - [2]	15
			1.907	0.382	4	n.d.	n.d.	n.d.	28.3/ -	25.5/ -	19.8/ -	17.6 / - [1]	16.0/ - [2]	15
fp_4	30.07.2016	D	0.800	0.045	4	72	22	4	24.3/25.9	18.0/17.0	16.5/15.7	15.5/15.3	14.1/15.3	-5
			0.705	0.099	6	52	11	4	26.2/28.4	17.6/17.5	16.0/16.0	15.0/15.0	15.0/15.0	-5
			0.715	0.057	4	67	5	4	24.3/24.5	18.0/18.0	16.4/16.3	15.4/15.3	15.0/15.0	-5
	04.08.2016	D	0.996	0.131	4	179	36	4	28.0/27.5	19.5/19.7	17.0/17.1	16.1/16.4[1]	15.4/15.6[2]	-3
			1.227	0.084	4	189	66	4	29.0/27.1	19.8/19.7	17.0/17.0	16.0/16.0[1]	15.1/15.0[2]	-3
			1.159	0.128	4	199	41	4	25.9/26.4	19.2/19.5	17.0/17.0	16.0/16.0[1]	15.1/15.1[2]	-3
			0.830	0.220	6	209	36	4	23.7/23.9	18.9/18.8	17.0/17.0	16.0/16.0[1]	15.5/15.5[2]	-3
Tr.PWF	24.07.2016	-	-0.006	0.064	95	224	97	4	26.3/26.5	23.4/24.0	19.4/20.1	15.8/16.3	12.5/12.7	25
			0.027	0.025	4	162	90	4	26.3/26.5	23.4/23.8	19.4/19.9	15.8/16.2	12.5/12.6	25
			-0.007	0.099	95	278	138	4	26.3/26.0	23.0/23.0	19.0/19.0	15.5/15.5	12.0/12.0	25
			0.053	0.119	6	269	29	4	26.3/26.0	23.0/23.0	19.0/19.0	15.5/15.5	12.0/12.0	25
			0.005	0.053	6	406	179	4	24.3/27.0	22.2/23.0	19.0/19.0	15.5/15.5	12.0/12.0	25
			-0.041	0.034	95	270	40	4	24.0/26.9	22.1/23.0	19.0/19.0	15.5/15.5	12.0/12.0	25

Table 3 (continuation)

Point	Date	Micro Land-scape[3]	CH_4 flux, mg C $m^{-2}h^{-1}$			CO_2 flux, mg C $m^{-2}h^{-1}$			Temperature CH_4/CO_2, °C					WTL
			Mean	Err	Error Code[4]	Mean	Err	Error Code[4]	of air	of soil at depth, cm				
										0	5	15	45	
Tr.PWF_2	04.08.2016	D	1.415	0.321	4	n.d.	n.d.	n.d.	24.5/ -	22.8/ -	18.3/ -	17.5/ -	14.9/ -	0
			1.809	0.218	4	n.d.	n.d.	n.d.	24.7/ -	20.5/ -	15.5/ -	14.3/ -	12.0/ -	0
			0.425	0.360	4	n.d.	n.d.	n.d.	23.8/ -	19.7/ -	15.4/ -	14.0/ -	12.0/ -	0
			1.718	0.057	4	n.d.	n.d.	n.d.	23.8/ -	19.4/ -	15.3/ -	14.0/ -	12.0/ -	0
		E	3.941	0.852	4	n.d.	n.d.	n.d.	25.9/ -	20.9/ -	17.4/ -	14.5/ -	13.0/ -	20
			3.207	1.258	4	n.d.	n.d.	n.d.	25.2/ -	22.7/ -	20.7/ -	16.5/ -	15.3/ -	20
			7.623	2.404	4	n.d.	n.d.	n.d.	24.2/ -	20.1/ -	17.0/ -	14.5/ -	12.6/ -	20
Tr.WF/ RB_2.1	30.07.2016	D	0.602	0.133	6	182	5	4	22.0/22.3	n.d.	n.d.	n.d.	n.d.	5
			0.354	0.140	6	154	20	4	21.2/21.5	n.d.	n.d.	n.d.	n.d.	5
			0.401	0.088	6	65	22	4	19.8/20.5	18.4/19.2	17.4/18.3	15.7/16.4	13.3/13.6	5
Tr.WF/RB_2.2	30.07.2016	E	0.152	0.103	4	216	148	4	22.0/22.0	n.d.	n.d.	n.d.	n.d.	7
			0.508	0.150	4	132	22	4	22.0/22.1	n.d.	n.d.	n.d.	n.d.	7
			0.154	0.081	4	185	26	4	22.1/21.5	n.d.	n.d.	n.d.	n.d.	7
			0.188	0.122	6	107	23	4	22.1/21.5	n.d.	n.d.	n.d.	n.d.	7
			0.070	0.094	4	330	67	4	19.6/20.5	18.3/19.0	17.3/17.8	15.6/16.0	13.2/13.5	7
			0.434	0.061	6	199	38	4	19.7/20.5	18.2/18.9	17.2/17.7	15.6/15.9	13.2/13.5	7
Tr.WF/RB_1	01.08.2016	E	0.370	0.183	4	155	53	4	23.9/23.5	18.9/18.8	17.0/17.0	16.0/16.0	15.5/15.5	10
			4.145	1.419	4	120	9	4	24.0/23.6	19.0/18.9	17.0/17.0	16.0/16.0	15.5/15.5	10
			9.641	3.083	4	247	31	4	24.0/23.8	19.0/19.0	17.0/17.0	16.0/16.0	15.5/15.5	10
			0.158	0.097	6	122	43	4	25.3/24.8	19.7/19.5	17.5/17.4	15.9/16.0	15.5/15.5	10
			8.180	5.669	4	108	17	4	25.5/24.9	19.8/19.5	17.5/17.5	15.9/16.0	15.5/15.5	10
			3.060	1.427	4	100	29	4	25.6/24.9	19.8/19.5	17.5/17.5	15.9/16.0	15.5/15.5	10
			15.946	4.811	4	184	41	4	27.7/27.3	20.8/20.6	17.8/17.5	16.0/16.0	15.5/15.5	10
			9.833	4.515	4	76	15	4	27.7/27.6	20.8/20.7	17.8/17.5	16.0/16.0	15.5/15.5	10
			3.269	0.824	4	146	112	4	27.8/26.8	20.9/21.3	17.8/18.0	16.0/16.0	15.5/15.5	10
			1.285	0.609	4	290	123	4	25.6/26.6	21.0/21.3	18.0/18.0	16.0/16.0	15.5/15.5	10
			2.565	1.021	4	94	34	4	25.5/26.5	21.0/21.3	18.0/18.0	16.0/16.0	15.5/15.5	10
			16.169	9.983	4	120	16	4	25.4/22.7	20.9/20.5	18.0/19.3	16.0/17.8	15.5/17.1	10
			2.630	1.033	4	87	11	4	22.0/22.5	20.8/20.8	19.7/19.4	18.6/17.9	17.6/17.3	10
			2.248	0.759	4	122	18	4	22.0/22.3	20.8/20.9	19.7/19.4	18.6/17.9	17.6/17.3	10
			0.356	0.137	6	n.d.	n.d.	n.d.	21.9/ -	20.9/ -	19.8/ -	18.7/ -	17.6/ -	10

Table 3 (continuation)

Point	Date	Micro Land-scape[3]	CH_4 flux, mg C $m^{-2}h^{-1}$			CO_2 flux, mg C $m^{-2}h^{-1}$			Temperature CH_4/CO_2, °C					WTL
			Mean	Err	Error Code[4]	Mean	Err	Error Code[4]	of air	of soil at depth, cm				
										0	5	15	45	
D35	09.08.2016	-	5.094	0.654	4	n.d.	n.d.	n.d.	27.0/ -	20.2/ -	15.6/ -	15.6/ -	12.5/ -	n.d.
			5.449	0.195	6	n.d.	n.d.	n.d.	27.5/ -	23.13/ -	16.7/ -	16.7/ -	12.7/ -	n.d.
D375	09.08.2016		1.95	2.384	4	n.d.	n.d.	n.d.	39.0/ -	21.53/ -	16.5/ -	16.0/ -	14.0/ -	n.d.
			0.275	0.068	4	n.d.	n.d.	n.d.	41.2/ -	21.31/ -	16.6/ -	16.0/ -	14.5/ -	n.d.
D.Oz1	09.08.2016	Ls	11.673	1.221	4	n.d.	n.d.	n.d.	28.3/ -	22.44/ -	21.4/ -	20.7/ -	19.2/ -	-
			12.317	2.828	4	n.d.	n.d.	n.d.	30.7/ -	23.17/ -	21.5/ -	20.5/ -	18.4/ -	-
			60.400	22.141	4	n.d.	n.d.	n.d.	26.9/ -	22.56/ -	21.2/ -	20.4/ -	18.0/ -	-
			62.943	14.905	4	n.d.	n.d.	n.d.	27.6/ -	22.50/ -	21.7/ -	20.5/ -	18.0/ -	-
			25.172	2.343	4	n.d.	n.d.	n.d.	27.8/ -	23.06/ -	22.2/ -	21.0/ -	18.0/ -	-
			14.891	1.207	4	n.d.	n.d.	n.d.	28.3/ -	24.38/ -	22.9/ -	21.4/ -	18.5/ -	-
			21.831	2.460	4	n.d.	n.d.	n.d.	29.4/ -	24.44/ -	23.0/ -	21.5/ -	18.5/ -	-

[1] - The temperature is measured at depth 10 cm.
[2] - The temperature is measured at depth 15 cm.
[3] - Microlandscape: D - depressed element; E - elevated element; Ls – small lake.
[4] - ErrorCode: 4 - standard deviation, 6 – error derived from solving linear programming problem, 95 - confidence interval is 95%

was to determine CO_2 and CH_4 fluxes originated from the periodically flooded forests in different conditions of moistening.

Our study was carried out in July-August 2016 at 3 key sites in the southern taiga of Western Siberia (Table 1). The measurements were conducted by the static chamber method as described in (Sabrekov et al., 2015).

The results of the individual measurements are shown in the Table 2, 3. The obtained medians of the methane fluxes was 0.048 $mgC \cdot m^{-2} \cdot h^{-1}$ for wetland forest near the river Polynanka and 0.602 $mgC \cdot m^{-2} \cdot h^{-1}$ for wetland forest near the Bakcharskoe bog. The typical fluxes of the Bakcharskoe bog were 0.275 ë 5.449 $mgC \cdot m^{-2} \cdot h^{-1}$ in the open bog and 11.673 ë 62.943 $mgC \cdot m^{-2} \cdot h^{-1}$ in the paludal lake. It is shown that a huge rain causes a significant increase of the water table level which may turn soil methane uptake (usually relatively dry conditions) into emission (typical for wetlands) rather fast (time ~ hours÷day). Most probably it can be explained by the hypothesis that increasing of soil moisture observed after rain (intensification of anaerobiosis) not so much activates the methanogenic archaea as cuts off the methane-consuming "filter" supplied by the activity of the methanotrophic bacteria.

1. Глаголев М.В. 2008. Эмиссия метана: идеология и методология «стандартной модели» для Западной Сибири // Динамика окружающей среды и глобальные изменения климата. № S1. С. 176-190.
2. Fedorov Y.A., Shipkova G.V., Gar'kusha D.N. Methane emission from peat deposits of raised bogs in Pscov oblast // Geography and Natural Resources. 2015. V. 36. No. 1 P. 70-78.
3. Glagolev M.V., Sabrekov A.F., Kleptsova I.E., Filippov I.V., Lapshina E.D., Machida T., Maksyutov S.S. Methane Emission from Bogs in the Subtaiga of Western Siberia: The Development of Standard Model // Eurasian Soil Science. 2012. V. 45. No. 10. P. 947-957.
4. Sabrekov A.F., Glagolev M.V., Fastovets I.A., Smolentsev B.A., Il'yasov D.V., Maksyutov S.S. Relationship of Methane Consumption with the Respiration of Soil and Grass–Moss Layers in Forest Ecosystems of the Southern Taiga in Western Siberia // Eurasian Soil Science. 2015. V. 48. No. 8. P. 841–851.