Югорский государственный университет, Ханты-Мансийск
Институт почвоведения и агрохимии СО РАН, Новосибирск
Сибирский научно-исследовательский и проектный институт природопользования
и охраны окружающей среды, Нижневартовск
Томский государственный университет
Департамент охраны окружающей среды и экологической безопасности
Ханты-Мансийского автономного округа – Югры

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WEST SIBERIAN PEATLANDS: COMPARATIVE STUDY OF GREENHOUSE GAS EMISSION IN MIDDLE TAIGA AND FOREST TUNDRA CLIMATIC CONDITIONS

A.V. Naumov[1], J.T. Huttunen[2], M.E. Repo[2], A.V. Chichulin[1], A.M. Peregon[1], I. Filippov[3], E.D. Lapshina[4], P.J. Martikainen[2], and W. Bleuten[5]

[1] **Institute of Soil Science and Agrochemistry SB RAS, Novosibirsk, Russia**
E-mail: naumov@issa.nsc.ru
[2] **University of Kuopio, Department of Environmental Science, Finland**
[3] **Tomsk State University, Tomsk, Russia**
[4] **Yugra State University, Khanty-Mansiysk, Russia**
[5] **Utrecht University, Department of Physical Geography, Utrecht, the Netherlands**

The study of CO_2 and CH_4 gas emission was carried out in two contrast bioclimatic sub-zones in the north provinces of Western Siberia. Three year measurements have shown the averaged summer fluxes to be equaled 81,6 ± 70,1 mg CH_4 m^{-2} d^{-1} (n = 190) and 7,56 ± 4,23 g CO_2 m^{-2} d^{-1} (n = 156) for middle taiga mires. The north peatland fluxes were substantively lower and ranged from 6,1 (in lake) up to 41,0 (oligotrophic hollow) mg CH_4 m^{-2} d^{-1} and 1,5 g CO_2 m^{-2} d^{-1} (lake) to 5,4 g CO_2 m^{-2} d^{-1} (palsa surface) during July-August 2005. Influence of peat temperature and water table level (WTL) were also searched on the methane and carbon dioxide fluxes. It was found statistically true regressive exponential relationship between CH_4 flux and WTL for middle taiga mire. The low temperature and permafrost impact were discussed.

Methane and carbon dioxide take the central place in problem of the global climatic and environmental change, since are straight connected with the biosphere carbon pools dynamics and human activity. The northern peatlands are considered as a global sink of atmospheric CO_2 and active source of biogenic methane. The mire area in West Siberia is almost 25 – 30% of the global peatlands cover. Estimates of carbon stocks for West Siberian peatlands are in range 50 – 70 Pg C (Sheng et al., 2004; Yefremov, Yefremova, 2001). Nevertheless clear global warming trend and increase of ambient CO_2 concentration may lead to change of the C-balance in the northern regions through melting the permafrost peaty soils and acceleration the decay processes (Billings, 1987; Camill, 1999). In addition, the question, whether peaty soils are sink or source for atmospheric CO_2, is actively debated on the local mire site hierarchy (Alm et al., 1999; Arneth et al., 2002; Borren, 2007). However one should too has the knowledge about C-balance controlling factors in diverse bioclimatic locations and large region.

OBJECTS AND METHODS

The study was carried out in two contrast bioclimatic subzones to find reliable discrepancy of gaseous emission and estimate the permafrost impact. We have used key site approach in the field measurements. The first (southern) key site was situated in middle taiga in 60 km from the city Khanty-Mansiysk (60° 59' N, 70° 10' E). The oligotrophic mire massif was chosen here for the study. Gas flux measurements were made during summer periods in 2004 – 2006 years. Four dominant bog ecosystems (oligotrophic hollow, pine-dwarf shrubs-Sphagnum bog – ryam, ridge-hollow complex and running-water fen), a peatland lake and a small wetland pond were under investigation.

The northern key site was situated in forest tundra subzone with a discontinuous permafrost layer in 20 km from the Pangody (65° 52' N, 74° 58' E). Two types of peat bogs (frozen palsa and oligotrophic hollow) and one secondary thermokarst lake were studied here during two field expeditions in early July and late August 2005.

CO_2 and CH_4 measurements were made by closed dark chamber method with permanently stated collars of 40 × 40 cm in size on the peat soils and floating plexiglass chamber of 60 × 60 cm in size on the lakes and pools. Four samples of chamber headspace air were taken by syringes every 7 min. Carbon dioxide and methane concentrations were analyzed with GC-FID module (Crystal 5000, Russia), served with methanizer. Carbon dioxide data were corrected, using EGM-4 (PP-System, UK) and Testo-435 (Germany) gas analyzers measurements. The intensity of gas emission was calculated from linear regression for the chamber headspace concentration vs. measuring time. In the course of flux measurements the air and peat temperature and water table level were registered.

Estimations of the key site emission were based on the GIS-technique, botanical descriptions of plant communities and peatlands classification.

RESULTS AND DISCUSSION

The measurements on mires of the south key area have revealed high spatial and temporal variability in the carbon dioxide and methane emission. The diversity of the peatland types is a typical particularity of peat-forming process in middle taiga. Inter-annual differences for greenhouse gas flows were not statistically significant, when one compared the average July values. It was an exception of the lower methane emission from the oligotrophic hollows at July 2004 (25.9 ± 26.2 $mgCH_4\ m^{-2}\ d^{-1}$, $n = 14$) through the lower rainfall and water table level in peat. In the long run the averaged fluxes of methane and carbon dioxide were equaled 81.6 ± 70.1 $mgCH_4\ m^{-2}\ d^{-1}$ ($n = 190$) and 7.56 ± 4.23 $gCO_2\ m^{-2}\ d^{-1}$ ($n = 156$) during summer time in 2004 – 2006.

Intensive measurement campaigns were made on the southern key site in summer 2005. Average emissions, observed here, have formed from 18 to 180 $mgCH_4\ m^{-2}\ d^{-1}$ and 5.6 to 11 $gCO_2\ m^{-2}\ d^{-1}$ in different mire ecosystems. In the north key site the corresponding flows were vastly below: 8 – 41 $mgCH_4\ m^{-2}\ d^{-1}$ and 4.6 – 5.4 $gCO_2\ m^{-2}\ d^{-1}$.

There was negative relationship between average fluxes of methane and carbon dioxide: the CO_2 flux was higher, the methane emission was lower and contrary. The wet ecosystems such as fen and hollow had higher rate of methane emission then ryam in south and palsa in north key site (Fig. 1).

In the course of the field measurements the meteorological and ecological factors were registered. Statistically significant relationship for CO_2 flux and water table level was found for northern oligotrophic hollow: $F = 31.172e^{0,1489WTL}$; $R^2 = 0.85$, $n = 15$. Other significant correlations were not found in the north.

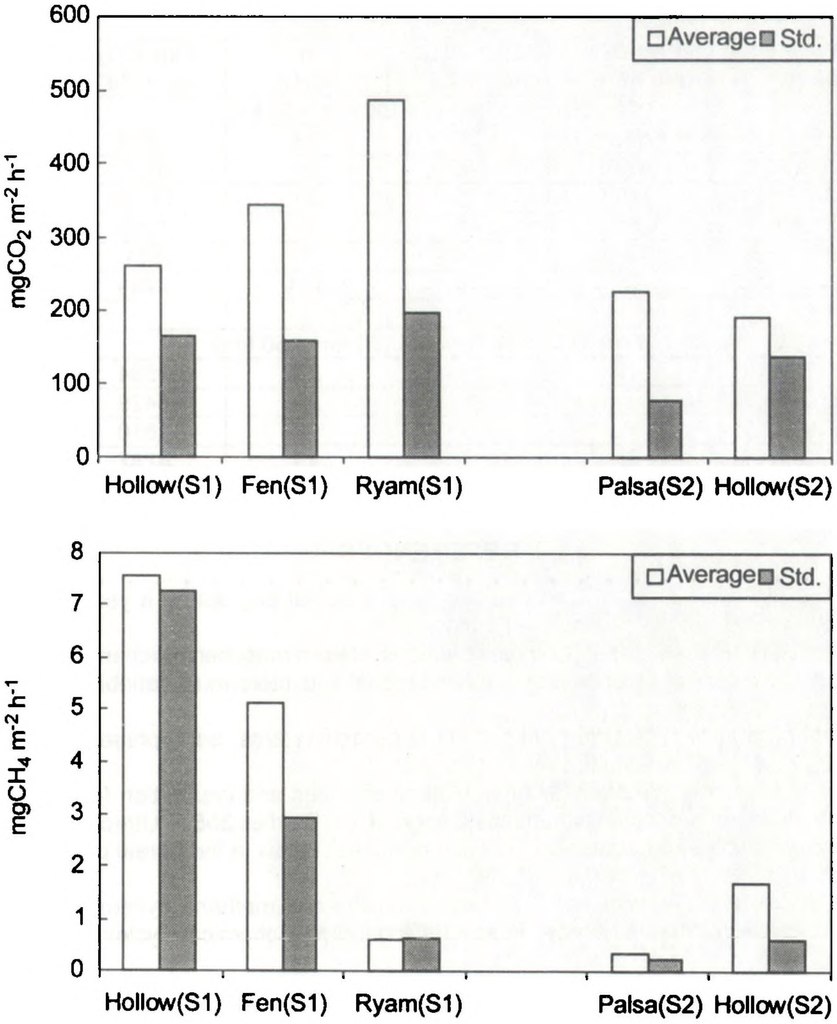

Fig. 1. Averaged CO_2 and CH_4 summer fluxes in the north and south key sites (2005).

Functional links for methane emission rate (F) and water table level (WTL) were also inspected in middle taiga. The stable regressive exponential function of view $F = 7.1066e^{-0,0879WTL}$ ($R^2 = 0.61$, $n = 112$) between ones was found. The searched out relationship was just right for bog massif level and couldn't been prove for separate ecosystems. Strong positive correlation ($r = 0.79$ and $t > t_{0.001}$) was found for total CO_2 flux and air temperature in poor fen. Q_{10} was predictably close to 2.

The results of gas flux measurements in aquatic objects, wetland lakes and pond, have been discussed in the earlier work (Naumov et al., 2006). Here we demonstrate the average area weighted fluxes for the contrast bioclimatic zones (table 1). These data explain functional distance between northern and southern types of mire landscape in West Siberia. The differences were very sharp because of limiting influence of permafrost. Total respiration was almost two times higher in middle taiga key site versus forest tundra mire. And methane emission in south exceeded the north flux little less threefold. Like so, it is implied the decreasing flux trend toward the north (Naumov, 2004). In comparison with other regions, the searched estimates of carbon dioxide and methane fluxes in middle taiga and forest tundra mires were accordingly in similar range as that in boreal peatlands of Finland (Nykänen et al., 1998) and Russian tundra (Nakano et al., 2000; Heikkinen et al., 2002). The same consistent patterns of greenhouse gas emission were reported for mires in discontinuous permafrost zone in Canada (Turetsky et al., 2002). Evidently, the low temperatures and permafrost are critical factors, decreasing total ecosystem metabolism and limiting the wetland expansion.

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The area weighted methane and carbon dioxide (total respiration) fluxes on the north and south key sites (n – number of individual chamber measurements)

Ecosystem	Peatland area, ha (%)	Flux CH_4, mg $m^{-2}d^{-1}$	StD. CH_4, mg $m^{-2}d^{-1}$	*n* (CH_4)	Flux CO_2, mg $m^{-2}d^{-1}$	StD. CO_2, mg $m^{-2}d^{-1}$	*n* (CO_2)
Middle taiga key site (50 km × 50 km)							
Fen	4318 (3,8)	123	74	33	7898	3595	33
Hollow	29476 (26,0)	180	182	34	5597	3734	33
Ryam	71800 (63,3)	18	30	21	11050	4824	24
Pond	790 (0,7)	41	41	6	1650	903	5
Lake	7097 (6,3)	8	9	7	511	442	7
South flux	**113482 (100)**	**63**	**70**	**101**	**8789**	**4193**	**102**
St. Er.			**13**			**847**	
Forest tundra key site (50 km × 50 km)							
Hollow	64727 (41,9)	41	14	23	4594	3310	16
Palsa	78316 (50,7)	8	6	22	5429	1848	27
Lake	11539 (7,5)	6	3	4	1510	915	4
North flux	**154582 (100)**	**22**	**9**	**49**	**4787**	**2390**	**47**
St. Er.			**2**			**581**	

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