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Methane emissions from temperate herbaceous peatland in the Sanjiang Plain of Northeast China

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HIGHLIGHTS

- Rapid precipitation events might have no immediate influence on CH_4 emissions.
- Accurate predictions depend on the long-term observation of various wetland types.
- The peatlands in the Sanjiang Plain are the substantial source of atmospheric CH_4.

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ABSTRACT

Peatlands are the significant source of atmospheric methane (CH_4), which is produced during peat accumulation. In this study, we investigated CH_4 emissions over two growing seasons from a *Carex lasiocarpa*-dominated peatland in the Sanjiang Plain in China using the static chamber technique. We also investigated the environmental factors controlling emissions during the two years of study, 2012 and 2013. CH_4 emissions ranged from 0.07 to 56.01 mg CH_4–C m^{-2} h^{-1} with mean values of 7.33 $\pm$ 1.65 mg C m^{-2} h^{-1}, showing significant temporal patterns in both years with peak values in early June and middle August respectively. Variations in water table, soil temperature at 25 cm depth and soil's water-filled pore space together explained 66.7% of the observed temporal variation of CH_4 fluxes by the step-wise regression. Rapid and short-lived precipitation events might have no immediate influence on CH_4 emissions, which primarily depended on the actual soil aeration and moisture conditions. A simple relationship between single parameter and CH_4 fluxes would be overruled once the water table dropped below the critical threshold for CH_4 release. The amount of CH_4 emitted from the herbaceous peatland in the Sanjiang Plain during the growing season was about 6.93 $\times$ 10^{12} mg C. Our results suggested that the herbaceous peatland in the Sanjiang Plain is an important source of atmospheric CH_4.

1. Introduction

Methane (CH_4), a potent greenhouse gas, contributes about 22% to the radiative force driving global climate change despite its short atmospheric residence time of approximately 10 years (IPCC, 2007). Peatlands, which extend over vast areas in the northern hemisphere, are considered as one of the most important biological CH_4 sources to the atmosphere, accounting for approximately 25–30% of total CH_4 released to the atmosphere each year (Cicerone and Oremland, 1988; Gorham, 1991). There are many studies on CH_4 emissions in various types of peatlands around the world, especially in European and Canada (e.g. Bubier and Moore, 1993; Bellisario et al., 1999; Laine et al., 2007; Danevcic et al., 2010; Liebner et al., 2012). However, owing to the complex interactions among CH_4 production, oxidation and transportation, the magnitude and patterns of CH_4 fluxes are not uniform within and between peatland ecosystems (Huttunen et al., 2003). Estimates of CH_4 emissions from northern peatlands ranged widely, from 20 to 60 $\times$ 10^{12} g CH_4 yr^{-1} (Matthews, 1993). A comprehensive knowledge of CH_4 emissions from the various wetland types is necessary to accurately predict global atmospheric CH_4 concentrations in the future due to the large variability within and between different

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habitats (Moore and Roulet, 1993; Hans et al., 2001; Teh et al., 2011).

The commonly accepted natural wetland taxonomy in China reported by Liu (2005) was gley marsh and peatlands, which differ in the existence of peat. The peatlands in the Sanjiang Plain formed in the initial stage of the early Holocene period, remaining at a low eutrophic stage of development for a long time and they all belong to herbaceous peatlands (Yang, 1989; Ma et al., 1988). To date, research on CH_4 emissions in the Sanjiang Plain has been focused gley wetlands (Ding et al., 2002; Song et al., 2003, 2009; Sun et al., 2012), whereas less information is available regarding the dynamics and magnitude of greenhouse gases (GHG) emissions from herbaceous peatlands in this region. Although these do not occupy a relatively large area, peatlands may exert great influence on the regional and global greenhouse gas balance (Schäfer et al., 2012). An investigation into the magnitude and processes of CH_4 emissions from these temperate peatlands is needed to more accurately estimate GHG fluxes from the Sanjiang Plain. Temperate peatlands likely emitted more GHG than their boreal counterparts because they experience warmer conditions and much longer growing seasons (Jungkunst and Fiedler, 2007; Teh et al., 2011). Increased emphasis on CH_4 emissions in temperate peatlands will improve our basic understanding of environmental controls on CH_4 emissions (Whalen, 2005) and provide more accurate current source strength to estimate of GHG emissions which will help constrain models in the Sanjiang Plain. The goals of this study were to provide a first dataset of CH_4 emissions from herbaceous peatland in the Sanjiang Plain and to investigate the factors controlling the temporal CH_4 fluxes. Using the static opaque chamber method, we observed CH_4 fluxes from the temperate, herbaceous peatlands during the growing seasons in 2012 and 2013.

2. Materials and methods

2.1. Study site

This study was conducted in a *Carex lasiocarpa*-dominated peatland (47° 29′ N, 133° 21′ E, 56 m a.s.l.) (Fig. 1), which belongs to seasonal frozen zone where the water and soil are completely frozen from late October to early in the following April (Ding et al., 2002). The mean annual temperature and precipitation are approximately 2.52 °C and 558 mm, and characterized with substantial inter-annual variations (Song et al., 2009). The depth of the peat is more than 30 cm. The *Carex* community is composed of the dominant *C. lasiocarpa* species with cover of 75%–95%; the second dominant is *Glyceria spiculosa*. The non-dominant species have less than 1% cover and include *C. meyeriana*, *Nymphaea tetragona*, *Caltha palustris*, *Iris tectorum* and *Bryophyte* spp. The soil profile is composed of the brown and fiber-like root layer, the spongy peat layer and the pale yellow and sticky gley soil layer. Detailed data on soil characteristics is given in Table 1.

2.2. CH_4 flux measurements

CH_4 fluxes were measured in four plots using the static opaque chamber and gas chromatography techniques every 5 days starting in May in 2012 and in April in 2013, and continuing to October in both years. In each plot, a 50 × 50 × 20 cm stainless steel base for measurements was permanently installed. The opaque chambers (50 × 50 × 50 cm) were made by stainless steel and fitted with rubber stoppers for head-space sampling. The chambers were shaded with Styrofoam to minimize temperature changes within the system when sampling and equipped with two battery-operated fans to keep the air mixed. Water was poured into the channel groove of the collars as sealer during the measurements.

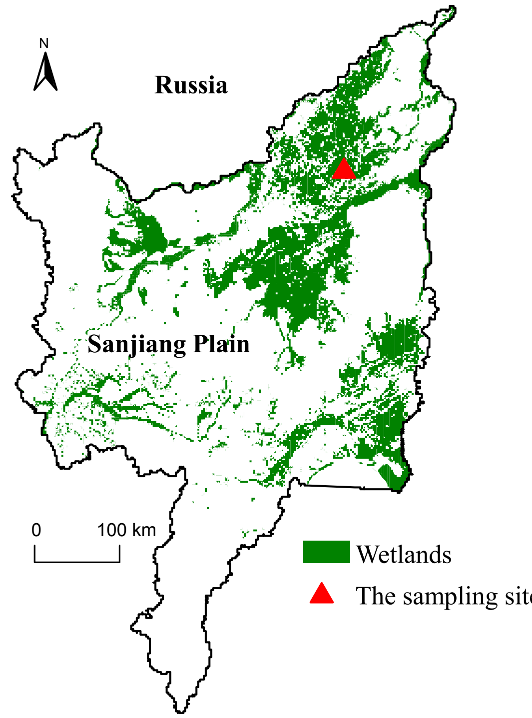

Fig. 1. The location of the sampling site in the Sanjiang Plain.

We built trestles to minimize disturbance on the plant and soil microenvironments around collars during the measurements. A vent on the chamber roof to make sure pressure equilibration was used, which was sealed with a septum plug when sampling was not conducted (Leppälä et al., 2011). The gas sampling process was carried out five times with an 8 min interval using syringes equipped with three-way stopcocks, rather than four times as in previous studies (e.g. Ding et al., 2002; Song et al., 2007, 2009; Sun et al., 2012).

The gas samples were stored in syringes for less than 4 h before being measured using a gas chromatograph (Agilent 4890D, Agilent Co., Santa Clara, CA, USA) (Song et al., 2009). CH_4 fluxes were calculated from changes in the initial rate of concentration within the chambers headspace; this was calculated from the initial slope of a non-linear regression of concentration against time (Zheng et al., 2008). Fluxes were discarded if initial chamber CH_4 concentration exceeded ambient levels two times or the regression coefficient was under 0.87 ($n = 5$), 0.94 ($n = 4$) or 0.996 ($n = 3$).

2.3. Auxiliary measurements

When sampling gas, we measured air temperature inside and outside of the chambers, soil temperature, depth of melting layer, soil moisture and water table. Air temperature was measured with a portable digital thermometer (JM624, Jinming Instrument CO.,

Table 1
Soil characteristics in the herbaceous peatland, in the Sanjiang Plain.

Depth (cm)	pH	Total N (g/kg)	Total organic C (g/kg)	C/N	Bulk density (g/cm^3)
0–20	6.1 ± 0.2	18.3 ± 0.8	280.1 ± 9.7	15.3 ± 0.2	0.1 ± 0.0
20–40	6.2 ± 0.1	8.8 ± 0.5	84.5 ± 3.8	9.6 ± 0.1	1.0 ± 0.1
40–60	6.3 ± 0.1	2.8 ± 0.1	7.5 ± 2.4	2.7 ± 0.9	1.3 ± 0.1

The unit g/kg indicates gram C/N per kilogram dry mass.