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GROWING SEASON DYNAMICS IN METHANE FLUXES AT A NORTHERN BOREAL SEDGE FEN

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SUMMARY

Methane (CH4) is a powerful greenhouse gas, one of its main natural sources being northern circumpolar wetlands. During the short growing season of northern mires, the temporal variation in CH4 emission is high, the flux increasing with the emergence of mire vegetation and the peat temperature. Still little is known about the more short-scale variations, e.g diurnal cycle, and the factors controlling the peat-atmosphere exchange. We have measured CH4 exchange in 2007–2010 in a northern boreal fen Lompolojänkkä (69 deg N, 24 deg E) with two automated chambers operating with closed dynamic principle. With these opaque chambers also carbon dioxide (CO2) flux, equalling the total ecosystem respiration, has been measured simultaneously. Concentrations of CH4 and CO2 in the peat have been monitored daily throughout the year, using a 50 m long tubing installed into the peat at a depth of 0.15 m. In this presentation we will study the driving factors behind the short-term temporal variation in CH4 flux, and discuss their relationship with the CH4 concentration in the peat. Comparison of different flux measurements (manual chambers, eddy covariance), offering information about the spatial variation, will be shown.

KEYWORDS: methane flux, automatic chamber, eddy covariance, methane concentration

INTRODUCTION

Methane (CH_4) is an intense greenhouse gas, one of its main natural sources being northern circumpolar wetlands. During the short growing season of northern mires, the dynamics of CH_4 emission is highly variable, the flux increasing along the growth of the mire vegetation and the peat temperature. However, little is known about the more short-scale variations, e.g diurnal cycle, and the factors controlling the peat-atmosphere exchange. Here we report measurements of CH_4 exchange in 2006-2010 in a northern boreal fen Lompolojänkkä. Measurements have been conducted with 1) the eddy covariance method, 2) two automated chambers operating with closed dynamic principle (since 2007) and 3) with manual chambers (since 2004). In addition, the concentration of CH_4 and CO_2 in the peat has been monitored daily since 2007.

In this presentation we will show snapshots of the most important driving factors behind the short-term temporal variation in CH_4 flux, and discuss the relationship between the CH_4 concentration in the peat and its flux into the atmosphere. We will also address the spatial variation of fluxes, which may have important implications when measuring fluxes concurrently with methods employing different spatial scales.

MATERIALS AND METHODS

Lompolojänkkä site is a nutrient-rich sedge fen located in the aapa mire region of north-western Finland (67°59.832'N, 24°12.551'E, 269 m above sea level). A one-sided leaf area index of 1.3, a maximum peat depth of 2 m and an average pH value of 5.5 (for the top peat layer) have been measured at the site. The long-term annual mean temperature and precipitation are -1.4 °C and 484 mm, respectively (1971-2000).

Fluxes of CH_4 have been measured bimonthly to monthly since autumn 2004 with manual closed static chambers (d=31.5 cm, h=30 cm) equipped with a fan. During the 35-min closure time, four samples were drawn from the chamber headspace and analyzed later with a gas chromatograph in the laboratory. Manual chamber fluxes were measured at three subsites located within a 50-m radius, each subsite consisting of four chamber plots (Lohila et al., 2010). Subsites 1 and 2 were slightly wetter than subsite 3, which also had higher vascular plant coverage. The amount of above-ground plant biomass (dry weight) was 130 g m^{-2} in subsites 1 and 2, and 550 g m^{-2} in subsite 3.

Since July 2007, hourly flux measurements of CO_2 and CH_4 have been done during the snowless period with two automated closed chambers (AC1 and AC2; h=70 cm, basal area 60 x 60 cm, volume approximately 0.24 m^3). The vegetation in AC 1 consisted of Carex spp (63% of the leaf area), *Equisetum fluviatile* (29%), *Vaccinium oxycoccos* (4%), *Andromeda polifolia* and *Salix* spp. In AC2, following species were found: *Carex* spp (65%), *Salix* spp (21%), *Betula nana* (6%), *Potentilla palustre* (6%), *Equisetum fluviatile*, and *Vaccinium oxycoccos*. The CO_2 concentration was analyzed with an LI-6262 (Licor, Inc.) infrared analyzer. For the CH_4 flux determination, gas samples were taken to a gas chromatograph just before the lid closing, and thrice during the 11-min closure time, and was analyzed with a flame ionization detector. The flux was calculated from the linear increase in the gas concentration using the last three concentration values. The chambers have been described in more detail by Lohila et al. (2010).

The EC instrumentation for the CH_4 flux measurement consisted of a USA-1 (METEK) three-axis sonic anemometer/thermometer and a Fast Methane Analyser (Los Gatos Research). The details of this eddy covariance measurement system have been presented by Aurela et al. (2009).

RESULTS AND DISCUSSION

Annual CH_4 balances

Annual balances in 2005-2010, measured by the eddy covariance method, varied from 17 to 24 g CH_4 m^{-2} yr^{-1}, the 4-year average being 20 g. The annual emission was smallest during the year of 2006 with a dry summer and low water levels. The seasonal dynamics of the fluxes measured using the manual chambers followed closely that measured by the EC. However, the annual balances determined by manual chambers were significantly higher as compared to those determined by the EC method. This was most likely due to the different source areas: while the EC method was able to capture the fluxes from both the fen and the stream area, the chamber fluxes represented only the fen area outside the stream. This was probably attributed to the higher oxygen concentration in the stream and in the vicinity of it as compared to the areas further form the stream. In the presence of oxygen, microbial methane production is inhibited, and on the other hand, methane oxidation is enhanced.

Annual and seasonal cycle in the peat CH_4 concentration

Methane concentration at the depth of 15 cm in the peat showed a strong seasonal behaviour: peak concentrations were observed in spring just before the start of the snow melt and, on the other hand, in the late summer during the peak growing season. The concentration was at its lowest in the late autumn just before the freezing of the peat surface and started to grow along with the snow layer. Low concentrations were also observed immediately after the snow and ice melt, after which the concentration increased concurrently with the soil temperature increase and the start of the plant growth.

Flux vs. peat concentration during the growing season

During the snow-free period, there was a linear correlation between the CH_4 concentration measured at the depth of 15 cm in the peat, and the daily average CH_4 flux measured by the automatic chamber (Fig. 1). On average in 2007-2010, the relationship between the flux (F, g CH_4 m^{-2} d^{-1}) and concentration (C, ppm) followed the equation $F = -0.041+6.52*10^{-5}*C$ with some inter-annual variation. This indicates that the top layer of the peat, on average 10-20 cm, is the critical layer for the CH_4 production and oxidation at that site. It must be noted, however, that there were differences between the years, and for example in the wet summer of 2008 with slightly higher water tables, the relationship was much weaker, suggesting that the water level has an effect either on 1) the ratio of production/oxidation rate of CH_4 or 2) the route by which CH_4 is transported into the atmosphere.

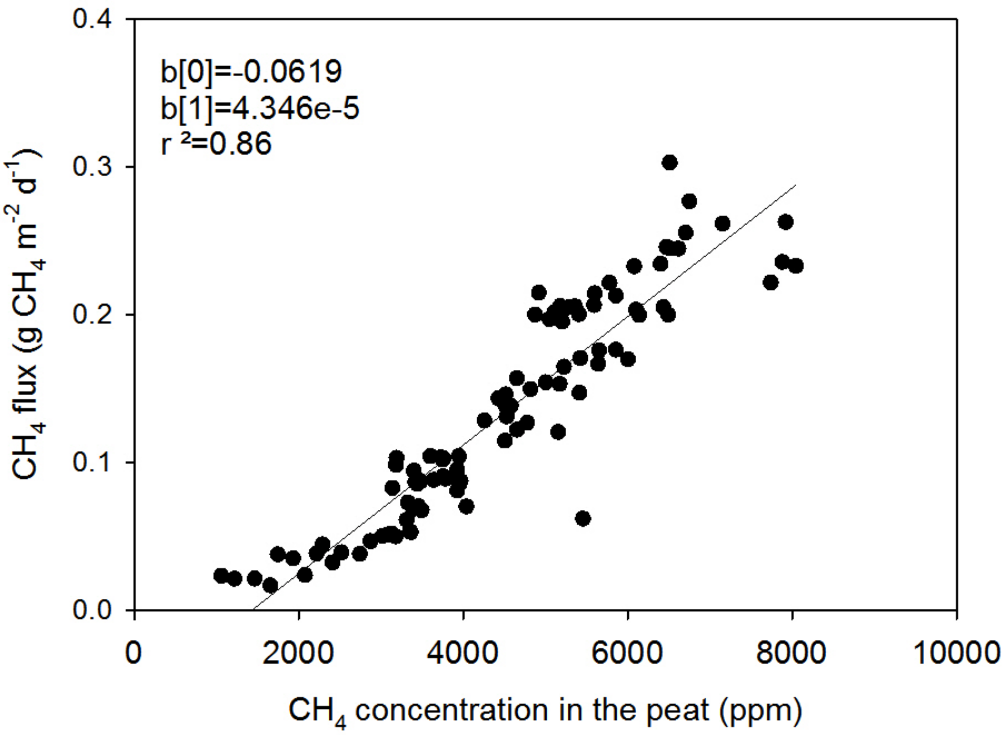

Figure 1. Daily average methane flux measured by an automatic chamber plotted against the CH_4 concentration at the depth of 15 cm in the peat at the Lompolojänkkä fen in summer 2009.

Short-term variation in the CH_4 fluxes during the growing season

Highest CH_4 flux was observed in the end of July and the beginning of August in both AC1 and AC2. Considerable short-term fluctuation was found in the flux pattern, related to water level variations. Typically, there was a sudden decrease in the methane flux in AC1, and a concurrent increase in the flux of AC2, the one with more plant biomass in general, and also above the water level (Fig 2). However, deviation from this pattern occurred in the dry years of 2007, when both chambers showed the same behaviour, and of 2009, when such peaks were practically not taking place at all. The rapid water level rise affected not only the fluxes, but also the CH_4 concentration in the peat dropped simultaneously. This may be attributed to the fact that water, coming either from precipitation or as a discharge from the surrounding mineral soil, brings along oxygen, which enhances the microbial methane oxidation and reduces its production. On the other hand, increasing water table induces a pressure peak in the underlying peat, which may liberate CH_4 gas from the water and peat into the atmosphere.

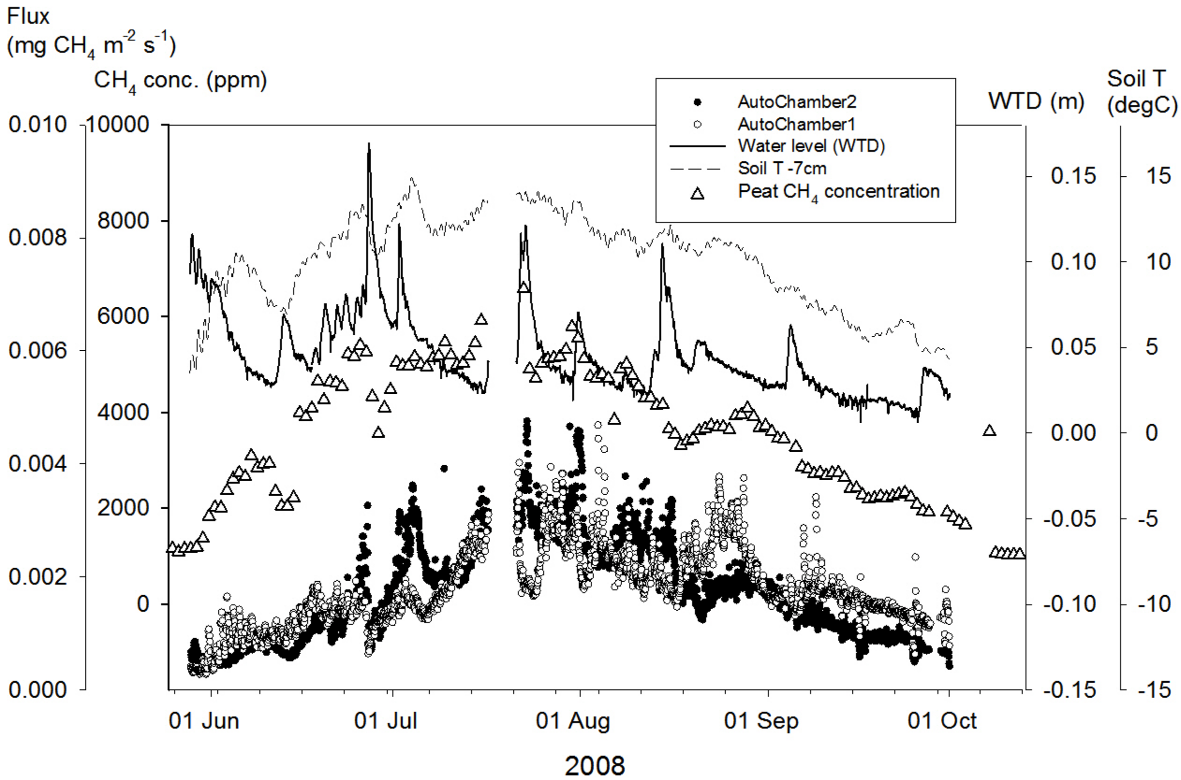

Figure 2. Hourly values of methane flux measured by the two autochambers (AC1-2), water table depth (WTD), and soil temperature (SoilT -7cm), together with the daily CH_4 concentration at the depth of 15 cm in the peat in summer 2008 at the Lompolojänkkä fen.

In addition to this day-to-day variation, significant diurnal variation was found in CH_4 flux in both automatic chambers. It did not, however, occur regularly, and showed opposing directions for the different chambers and even for the same chambers during in the course of the summer. For example, in June 2009, the CH_4 flux in AC1 had a clear diurnal pattern with the minimum in day-time and maximum in night, whereas the total ecosystem respiration in the same chamber followed the air temperature, with a maximum in afternoon. At the same time, the CH_4 flux in AC2 showed a very small diurnal variation with an opposing pattern as compared to AC1, i.e., highest emission in the afternoon (Fig.3). These differences probably results from differences in methane oxidation: the lower methane emission in daytime in AC2 imply that the higher surface peat temperature is more favoured by the methane oxidation than production. A typical phenomenon seen in Fig. 3 and observed almost throughout the data is that the total ecosystem is smaller in the chamber where the CH_4 emission is higher.

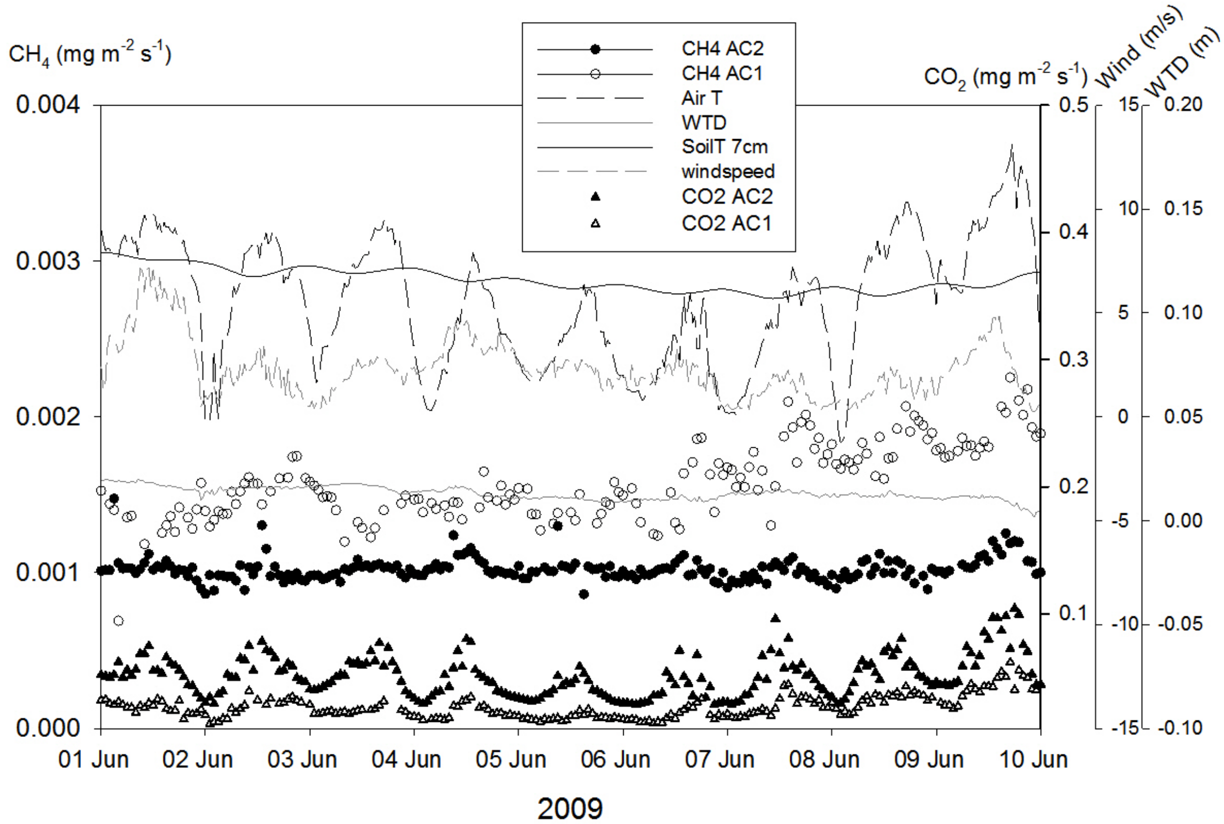

Figure 3. CH_4 and CO_2 fluxes in automatic chambers AC1 and AC2 during ten days in June 2009, when different diurnal patterns for CH_4 fluxes were observed. Also shown are the air and soil temperature, WTD and wind speed.

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