Methane Flux from a Subtropical Rice Field

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Abstract. It has been confirmed that rice fields contribute a lot to atmospheric methane. The object of this research was to analyse the diurnal changes of CH_4 fluxes from a rice field in southern subtropical China in early rice season. The measuring device was a modification of a closed static chamber and gas chromatography. Samples of CH_4 were collected from treatments with rice crop plot and bare soil plot at the same time. The results indicated that there are two peaks of variation in diurnal CH_4 emissions during the growing season of rice. The average CH_4 fluxes in the field appeared in the order of maturity stage (1.96 ± 0.33), booting stage (0.13 ± 0.01) and post-harvest stage (-0.01 ± 0.02) ($mg \cdot m^{-2} \cdot h^{-1}$). At booting stage, average flux of CH_4 was much higher in the plot with rice plants than that of bare soil plot ($p<0.01$). Soil temperature had no significant effect on CH_4 emissions at any stage in this study. The results showed that soil moisture and rice plants significantly affected CH_4 flux in rice field.

1 Introduction

The atmospheric greenhouse gas concentration of methane in 2011 was 1803 ppb, 150% higher than before the beginning of industrialization in the mid-18th century, reaching the highest level in the past 800,000 years [1]. CH_4 is only second to CO_2 as one of the main greenhouse gas. Irrigated rice fields are important sources of atmospheric CH_4 emissions, accounting for about 9%-19% of the total source of atmospheric methane [2]. China is a big rice planting country. At the beginning of the 21st century, the planting area and yield accounted for 22% and 34% of the world respectively [2]. The total CH_4 emission from rice fields in China is about 6-10 Tg/y [3]. CH_4 release from double cropping rice fields in southern China is relatively high [4]. The main factors affecting CH_4 emissions from paddy fields include soil temperature, soil pH, water management, fertilizer application, different types of rice crop management, etc [5]. The CH_4 fluxes from rice fields are the results of the production, oxidation and transportation of CH_4 from the soil to the atmosphere. The purpose of this research was to study the diurnal changes of CH_4 flux of crops of the first season on subtropical rice fields in southern China and the relationship between CH_4 flux and temperature and rice plants.

2 Methods

2.1 Natural geography of the study site

The study site is located in Heshan, Guangdong Province (112° 54' north latitude and 22° 41' east longitude). The subtropical monsoon climate in this area has an average precipitation of 1700 mm and a total annual evaporation of 1600 mm. The annual mean temperature is 21.7 °C, the monthly mean temperature is 28.7 °C (absolute maximum temperature is 37.5°C). The soil type in this area is latosolic red soil.

The local conventional rice was planted in tested field. After rice planting, rice fields were exposed to sunlight within 7 to 10 days for aeration after a month long submergence. The field was flooded again and then turned to intermittent watering. Before the rice transplanting, ammonium bicarbonate and compound fertilizer were used to rice field at a rate of 750 kg hm^{-2} separately. Before the water in the paddy field was drained, urea was used at booting stage and panicle stage at a rate of 75 kg of nitrogen per hectare.

2.2 Methane sampling and analysis

Six closed static chambers for greenhouse gas exchange were located in rice fields, half of which were randomly assigned to measure the effects of rice plants in the field (i.e. plots with rice plants) and half of which were for comparison (i.e. plots without rice plants). No plants were permitted to exist during all the studying time in the bare soil treatment area. Appropriate solutions were taken to guarantee that environmental conditions and soil state in the static-chambers were the same as those in the outside experimental area. The early rice season lasted from April to July. Diurnal variations were measured on fine and cloudless days every two hour in the daytime and every three hour in the nighttime. Measurements of CH_4 fluxes were taken by closed chamber and gas-chromatography technological methods [6]. Units of closed chambers were made up by a perpetual fixed foundation support of stainless steel. The

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unit of static chamber were made up by a perpetual fixed foundation support of stainless steel (50 centimeters long × 50 centimeters wide × 10 centimeters high). The foundation support was attached to the U-shaped groove on the upper rim to secure the removable stainless steel case lid (50 centimeters long × 50 centimeters wide × 50 centimeters high). After the case lid was installed on the base, the water depth in the groove would be 2 cm which could serve as a gas seal. The homogenization of air in the box was by using two battery-powered fans in the static chamber. The lid was equipped with 1 three-way sampling turncock and 3 temperature sensors. Outside of the stainless steel lids were covered with white heat shields to minimize the direct sun radiant heat effect while the experiment lasted.

Samples of methane were taken by 100-milliliter plastic injectors at a 10-minute collection interval. The analysis of gas sample was conducted by means of gas chromatography not beyond twenty-four hours [6]. The basis of calculation of methane emission was by methane concentration change rate in the box, which calculated as the concentrations-time linear regression slope. In this study, all linear regression coefficients (r^2) were bigger than 0.95.

At the sampling time, measurement of five centimetres of soil temperature underground was conducted with a portable digital thermometer (JM624, JinMing instrument CO., Ltd., China). The soil volumetric humidity was measured by a soil hygrometer (ICT Australia) at a five-centimeter depth at the same time. Climatic data (air temperature and precipitation) were acquired from the meteorological station of the experimental station in the hilly area of Heshan.

2.3 Statistical analysis of data

The values of soil moisture, temperatures and gas emission at both two experiment plots were averaged on three repeated samples. We analysed all the data by applying SPSS 19.0 software package. ANOVA was used to check the difference of normal distribution data. The Kolmogorov-Smirnov test was used to check normal distribution of data.

3 Results and discussion

3.1 Diurnal characteristics of methane flux

The Irrigated paddy fields are the main source of CH_4 from paddy fields [7]. The result in this study showed that the diurnal change of CH_4 flux was regular with the participation of rice plants and water cover in the field in sunny days during the first crop season (Fig. 1). Two crest values of the diurnal curves appeared on May 30 (booting stage) and June 30 (maturity stage) (Fig. 1). The first high peak appeared at twenty-one PM and the second high peak at eight AM at booting stage. The maximum appeared at 6 AM and the second at 21 PM at maturity stage (Fig. 1). Three crest values appeared at 8 AM, 16 PM, 0 AM at post-harvest stage (Fig. 1). The diurnal change range of CH_4 flux from bare soil was not large. In addition to the peaks at different times, the daily average trend of CH_4 emission from the plot with rice plants was basically the same at booting stage and post-harvest stage. Both plots appeared negative CH_4 emission moments On July 30 (Fig. 1).

Diurnal variations of CH_4 flux are mainly due to growth characteristics of rice and temperature. Three types of day and night changes in CH_4 flux exists: random state, night maximum and day maximum. It belonged to the second and third categories in this study. A different pattern at post-harvest stage could be caused by the temporary drainage time before the successive crop season at both plots. Different peak time showing (daytime or nighttime) may be related to different emission paths (bubble, liquid phase diffusion, rice aeration tissue) and rice eco-physiological characteristics of rice [8].

3.2 Influence of temperature on methane flux

CH_4 emission from soil is the consequence of combination of processes such as CH_4 oxidation and CH_4 production. Therefore, CH_4 emission could be affected by factors under field conditions，such as the weather conditions， the water regime, the soil characteristics and the type and amount of applied fertilizers through influencing the process of CH_4 oxidation or CH_4 production [9]. Research has shown that diurnal emissions of CH_4 are greatly affected by temperature. In this study, it showed a different result. CH_4 emission either from plot with rice plants or contrastive plot had not significantly related to soil temperature or air temperature (Fig. 1). When the temperature changed, the accumulated paddy water might play a buffering role, so the effect of temperature on CH_4 emissions was weakened [10].Control mechanisms remain to be elucidated and may be more complicated since factors such as upper soil temperature and oxygen concentration at flood boundaries and soil-water change during the vegetation period [7].With the increase of organic matter, the basic level of methane emissions and the range of change increase [7].

3.3 Influence of rice plants on methane flux

The mean value of diurnal CH_4 emission from paddy field was much bigger than that of the contrast at booting stage (Table 1). It was also bigger at maturity stage but no significant differences was detected (Table 1). There was not much difference between the two groups at post-harvest stage (Table 1). The mean value of diurnal CH_4 emission from paddy plots was with the order of maturity stage > booting stage > post-harvest stage (Table 1). Rice plant is important for the release of CH_4 due to its involvement in the generation, oxidation and transport processes of CH_4 in rice fields [11]. Rice plants provide substrates for methanogenes in the form of root exudates and litters and provides aerobic environment for methanothrophs by transporting oxygen from aeration tissue to rhizosphere [12]. Studies show that 60%~90% of methane generated in rice field soil is

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released into the atmosphere through plant aeration tissues [13]. Rice plant has different effects on CH_4 release at different growing phases. CH_4 flux is greatly affected by rice growth characteristics and phenology [14]. Due to the part of rice plants playing in CH_4 release from soil into atmosphere during the tillering or panicle initiation period, CH_4 flux from plot with vegetation was greater than that of without vegetation. The CH_4 flux in the tillering period was greater than the panicle initiation period was because of less oxidation of CH_4 and more efficient transportation by rice vegetation [13].

The results of this study indicated that, in addition to water flooding, the amplitude of diurnal change of CH_4 emissions could be dependent on the ability of transportation through rice gas delivery system. The reason could also be used to explain the highest diurnal change at the maturity phase. The main period of CH_4 emission usually occurred at booting stage in paddy field. In this study, CH_4 emissions at the booting stage were lower than at maturity, probably because the paddy fields were during the drainage time. The negative CH_4 value at post-harvest stage showed the rice field soil could even absorb CH_4 from atmosphere when it drained after harvest. It means proper water management could lower the amount of CH_4 release from rice field.

Table 1. The mean values of diurnal ch4 emission at plots with rice plants and bare soil plots

Period	**CH_4($mg \cdot m^{-2} \cdot h^{-1}$)**	
	Plot with rice plant	Bare soil plot
Booting stage	0.13±0.01**	0.06±0.02**
Maturity stage	1.96±0.33	1.32±0.23
Post-harvest stage	-0.01±0.02	0.04±0.02

**P < 0.001.

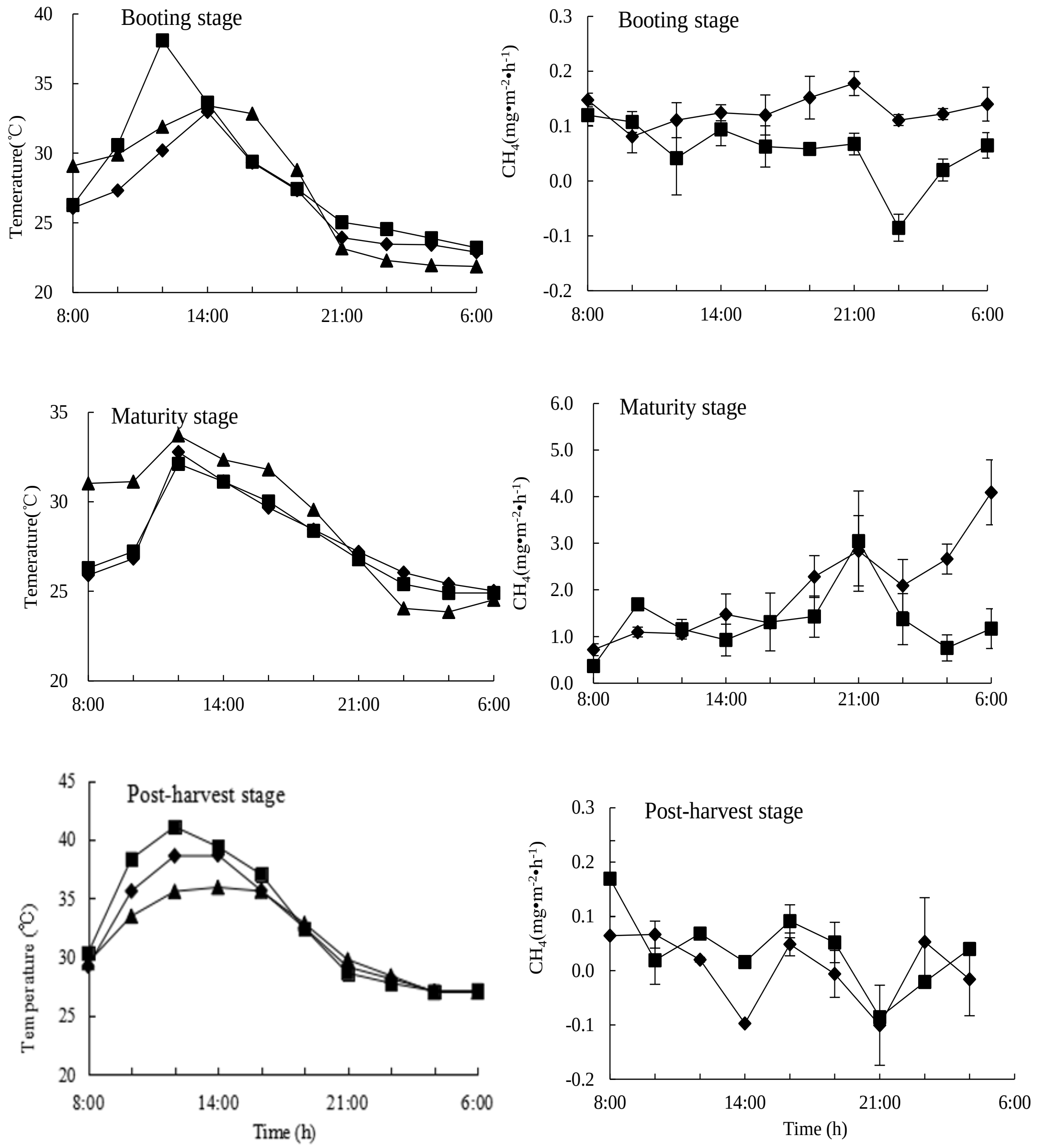

Fig.1. Diurnal variations of temperatures and CH_4 emission from rice field.

Temperature: − ▲ − Air temperature; − ■ − Above-ground temperature; − ◆ − 5-centimeter soil temperature

CH_4: − ■ − Bare soil plot ; − ◆ − Plot with rice plant

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4 Conclusions

CH_4 fluxes showed obvious diurnal changes during the crop growing season. Diurnal variations of CH_4 fluxes had two peak values at booting stage and maturity stage. Diurnal CH_4 flux was not significantly correlated to air or soil temperature. Rice plants had different effects on CH_4 release at different growing period. The amount of CH_4 release from rice field at maturity stage was bigger than that of booting stage and post-harvest stage. The mean value of diurnal CH_4 emission from paddy plots was with the order of maturity stage > booting stage > post-harvest stage. The smallest amount CH_4 flux appeared at post-harvest stage was because of no plants and the drainage time in the rice field which could reduce CH_4 emission from soil.

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