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Short communication

Summer fluxes of atmospheric greenhouse gases N_2O, CH_4 and CO_2 from mangrove soil in South China

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ABSTRACT

The atmospheric fluxes of N_2O, CH_4 and CO_2 from the soil in four mangrove swamps in Shenzhen and Hong Kong, South China were investigated in the summer of 2008. The fluxes ranged from 0.14 to 23.83 μmol m^{-2} h^{-1}, 11.9 to 5168.6 μmol m^{-2} h^{-1} and 0.69 to 20.56 mmol m^{-2} h^{-1} for N_2O, CH_4 and CO_2, respectively. Futian mangrove swamp in Shenzhen had the highest greenhouse gas fluxes, followed by Mai Po mangrove in Hong Kong. Sha Kong Tsuen and Yung Shue O mangroves in Hong Kong had similar, low fluxes. The differences in both N_2O and CH_4 fluxes among different tidal positions, the landward, seaward and bare mudflat, in each swamp were insignificant. The N_2O and CO_2 fluxes were positively correlated with the soil organic carbon, total nitrogen, total phosphate, total iron and NH_4^+-N contents, as well as the soil porosity. However, only soil NH_4^+-N concentration had significant effects on CH_4 fluxes.

1. Introduction

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are key radiatively active greenhouse gases (GHGs) contributing to global warming (IPCC, 2001). The production and emission of these greenhouse gases have increased continuously since the pre-industrial era. For CH_4, the recent growth could be due to a decrease in concentration of the hydroxyl radical which is the largest CH_4 sink or an increase in CH_4 emission rate (Rigby et al., 2008). Extra emissions of CH_4 from the wetland at northern latitudes in 2007 and at tropical regions in 2008 have been reported (Dlugokencky et al., 2009). Different from some forest soils which serve as net N_2O sink (Billings, 2008), the wetlands are considered as a source of N_2O gas (Allen et al., 2007). Coastal wetlands such as mangroves in tropical and subtropical regions have also been recognized as major marine contributors to atmospheric greenhouse gas emission but the atmospheric N_2O and CH_4 fluxes are poorly characterized (Nevisson et al., 1995; Bange et al., 1996). Being intertidal, mangrove ecosystems are regularly flooded by incoming tides, and mangrove soils, which are anoxic and reduced, favor denitrification and methanogenesis (Rivera-Monroy and Twilley, 1996; Tam and Yao, 2002; Krithika et al., 2008). Some mangrove soil emitted a significant amount of greenhouse gases (e.g. Mukhopadhyay et al., 2002; Allen et al., 2007). Moreover, mangroves also receive nutrient input from human activities (e.g. Tam and Wong, 2000; Trott and Alongi, 2000; Lovelock et al., 2004), which enhanced soil microbial metabolism, leading to more emissions of N_2O and CH_4 from mangrove soil into the atmosphere (Mosier, 1994; Purvaja and Ramesh, 2001; Kreuzwieser et al., 2003; Alongi et al., 2005; Wang et al., 2009). The potential of greenhouse gas emission from mangrove ecosystems to atmosphere cannot be neglected.

The mangroves in South China are under severe human disturbance, particularly pollution due to rapid urbanization, industrialization and reclamation, which may further change the greenhouse gas emission from mangrove soils. The present study aims to (i) quantify the greenhouse gas fluxes in different mangrove swamps in Shenzhen and Hong Kong; and (ii) examine the relationships between soil characteristics and the greenhouse gas fluxes.

2. Materials and methods

2.1. Description of mangrove swamps and sampling sites

The present study was carried out in summer (July and August) 2008 in four mangrove swamps in South China (Fig. 1). Futian Mangrove Nature Reserve (FT) is in the Shenzhen Special Economic Zone and the other three are in Hong Kong Special Administrative Region, namely Mai Po (MP), Sha Kong Tsuen (SKT) and Yung Shue O (YSO). FT, MP and SKT are located in the Deep Bay region receiving discharges from the Pearl River Delta and nearby polluted rivers in Shenzhen and Hong Kong (Ong Che, 1999); while the last mangrove swamp in the eastern side of Hong Kong is more oceanic and has less human disturbance (Tam and Wong, 2000). In all four mangrove swamps, *Kandelia obovata* is the most dominant plant species.

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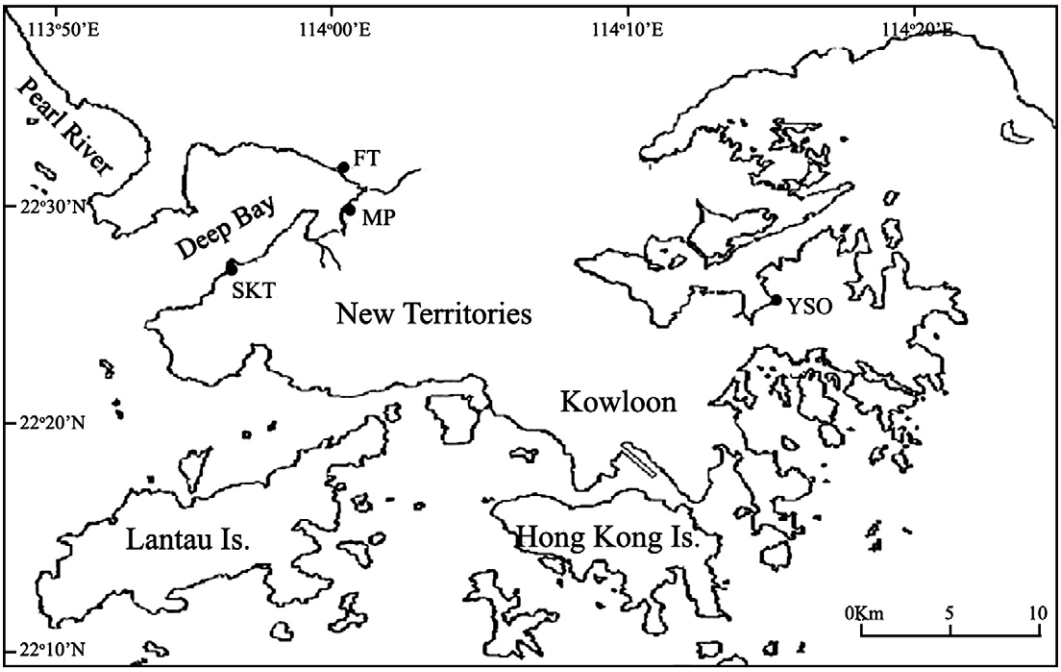

Fig. 1. Geographical location of the mangrove swamps in the present study. FT: Futian mangrove; MP: Mai Po mangrove; SKT: Sha Kong Tsuen mangrove; YSO: Yung Shue O mangrove.

However, *Acanthus ilicifolius* is the co-dominant species in FT and MP; while in YSO, the co-dominant species is *Bruguiera gymnorrhiza*.

In each mangrove swamp, three tidal positions, landward (LW), seaward (SW) and foreshore bare mudflat (BF, without any mangrove plants), were selected, and triplicate samples were collected at each position. Tides in Hong Kong are mixed and mainly semi-diurnal with two high and two low tides a day. The average tidal range during sampling dates was around 2.7 m. The gas samplings were carried out at low tides during day time. The samplings were all done 2 h before the time reaching the lowest ebb tide according to Hong Kong Observatory's tidal prediction. The tidal range, tidal flooding and exposure duration were comparable among sampling days and four mangrove swamps.

2.2. Greenhouse gas samplings and flux measurements

Gas flux was quantified using the static (closed) chamber technique (Ye et al., 2000). Each chamber covered a soil area of 0.025 m^2 and had an internal volume of 1.25 L. The open end of the chamber was inserted 3 cm into the soil. The deployment time was set to 45–60 min with sampling at 15–20 min intervals. At each sampling time, a 5 ml gas sample was collected by passing a hypodermic needle attached to a 10 ml glass syringe through the air sampling port. All samples were stored in a dark cool box, transported to the laboratory and analyzed within 24 h using the gas chromatography (GC) technique.

N_2O concentration was determined by Hewlett Packard 6890A GC equipped with a 63Ni electron capture detector (μECD) and a RT-QPlot column (Restek), and helium gas was used as the carrier gas at a flow rate of 6.5 ml min^{-1}. The temperature of the injector, column and detector were 100, 70 and 320 °C, respectively. CO_2 and CH_4-concentrations were determined by the Hewlett Packard 5890 GC equipped with a thermal conductivity detector (TCD) and a Poropak-Q column. The carrier gas was nitrogen with a flow rate of 20 ml min^{-1}. The temperature of the injector, column and detector were 80, 50 and 80 °C, respectively.

Standard curves were obtained by injecting various volumes of pure N_2O (99.5%, HKO Co Ltd), CH_4 (99.992%, HKO Co Ltd) and CO_2 (99.999%, HKO Co Ltd) in high purity N_2 (99.999%, HKO Co Ltd). The range of the standard curve was 0–39.4 ppm, 0–118 ppm, and 0–2% by volume for N_2O, CH_4 and CO_2, respectively. The greenhouse gas concentrations were quantified by comparing the peak areas of samples against the standard curves, a similar method used by Chang and Yang (2003). During the gas measurement, standards (2.5 ppm N_2O, 39.4 ppm CH_4 and 1000 ppm CO_2) were analyzed every 15–20 samples of determination to ensure the data quality. The relative standard deviations (RSD) of replicate standard measurements were 2.4%, 2.7% and 2.8% for N_2O, CH_4 and CO_2, respectively.

2.3. Sampling and analyses of soil

After the gas sampling, the redox potential (E_h) of soil under the chamber was measured using a pH/Eh meter (WP-81, TPS) by inserting the platinum probe directly into the soil at a depth of 5 cm from the surface prior to soil collection. This depth was chosen according to a previous study by Bauza et al. (2002) who reported the redox potential (E_h) at a depth between 4 and 6 cm in a Puerto Rico mangrove represented the medium value of the E_h value-gradient which decreased from surface to 10 cm. Allen et al. (2007) also made the measurement at 5 cm depth. The salinity of porewater was measured using a pocket refractometer (0–100 parts per thousands, Atago PAL-06 S, Japan). Three soil cores (0–15 cm) were then collected using hand-held PVC corers. The samples were air-dried and sieved through a 2 mm sieve. Soil conductivity ($Ec_{1:5}$) and pH (1:5 soil: distilled water, w/v) were determined by a hand-held Conductivity/TDS-pH/mV-Temperature Meter (WP-81, TPS), and a soil pH meter (Hanna HI 9025), respectively. The concentration of organic carbon (OC) was determined based on the loss on ignition at 550 °C. Total Kjeldahl nitrogen (TKN) and total phosphorus (TP) contents were measured by the Flow Injection Analyzer (FIA, Lachat Quik-Chem-8000, Lachat Instruments, USA) after Kjeldahl digestion. The NH_4^+-N and NO_3^--N contents in the KCl (2 M) extracts were also determined by FIA. All soil analyses were based on the standard methods for soil analyses described by Page et al. (1982), and data were expressed in terms of 105 °C oven-dried weight.