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Characteristics of CH_4 and CO_2 emissions and influence of water and salinity in the Yellow River delta wetland, China

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ABSTRACT

Due to the severe degradation and environmental pollution of coastal wetlands by human activities, they have gradually become an important source of greenhouse gases (GHGs) emissions, so exploring the characteristics of their emission is important to reduce greenhouse gas emissions from coastal wetlands. In this study, the dynamics of methane (CH_4) and carbon dioxide (CO_2) emissions were investigated in five kinds of typical tidal flats from the Yellow River delta wetland during the years 2011–2013, and the influences of water level and salinity on their emissions were explored in laboratory experiments. The mean fluxes of CO_2 and CH_4 were −20.98 to 68.12 mg m^{-2} h^{-1} and −0.12 to 0.44 mg m^{-2} h^{-1} across all seasons in the five kinds of representative tidal flats. The highest and lowest mean fluxes of CO_2 were mainly observed during summer and winter, respectively, whereas the seasons with the highest and lowest mean fluxes of CH_4 varied according to the type of tidal flat. The results showed that the summer season and the mud flat environment had the largest contributions to greenhouse gas emissions. In laboratory experiments, the largest sequestration fluxes of CO_2 and CH_4 were observed with +4/+2 cm and −4 cm water levels, respectively, indicating that a moderately high water level was beneficial for CO_2 sequestration but led to the increase of CH_4 emission. In the study of salinity, we found that the largest sequestration fluxes of CO_2 and CH_4 were both detected at 24 g L^{-1} salinity, indicating that high salinity level was advantageous for CO_2 and CH_4 sequestration in the five simulation devices. Furthermore, a carbon cycle pathway of coastal wetlands was proposed, which could have a vital significance for research into the global carbon cycle. We can reduce GHG emissions by protecting the coastal wetlands and lessening human activities.

1. Introduction

The period from 1983 to 2012 was likely the warmest 30 years during the last 1400 years in the Northern Hemisphere. The globally averaged combined land and ocean surface temperature data as represented by a linear trend show a warming of 0.85 °C (0.65 °C–1.06 °C) over the period 1880 to 2012 (Barros et al., 2014). Climate scientists have reached an overwhelming consensus that the global warming in recent decades has been caused primarily by human activities that have increased the amount of active greenhouse gases (GHGs) in the atmosphere (Van Groenigen et al., 2011; Zhang et al., 2013). A warming climate could cause a gradual increase in the rate of sea level, which would cause saltwater to intrude on soils, and a significant change in the dynamics of carbon cycling (Kirwan and Megonigal, 2013; Neubauer, 2013; Solomon, 2007).

Carbon dioxide (CO_2) and methane (CH_4) are key GHGs, which make substantial contributions to global warming (Stocker et al., 2013). CO_2 concentrations increased at the rapid rate of 2.0 ± 0.1 ppm/y during the years 2002–2011 (Barros et al., 2014); the CH_4 concentration increased from 715 ppb in 1750–1774 ppb in 2005 (Solomon, 2007), and increased by 8.3 ± 0.6 ppb in 2007 and 4.4 ± 0.6 ppb in 2008 (Dlugokencky et al., 2009). To mitigate the serious impacts of the greenhouse effect, it is necessary to lower atmospheric CO_2 and CH_4 concentrations.

Coastal wetlands have been recognized as the most vulnerable and sensitive ecosystems, because they act as the ecotone between terrestrial and aquatic ecosystems (Kirwan and Megonigal, 2013; Liu et al., 2012). However, they play an important role in the global carbon cycle as natural carbon pools (Han et al., 2014; Page

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et al., 2011), and at least 430 Tg of C is stored in the upper 50 cm of tidal salt marsh soils (Chmura et al., 2003). Coastal wetlands can act as greenhouse gas sinks via peat formation, sediment deposition, and plant biomass accumulation, and also as greenhouse gas sources through the release of CO_2 and CH_4 produced by deposition of organic matter (Page et al., 2011; Poffenbarger et al., 2011), so they are important in governing the atmospheric concentrations of CO_2 and CH_4 (Song et al., 2009). However, due to the severe degradation and environmental pollution of coastal wetlands by human activities, they have gradually become an important source of GHG emissions. In order to lower emission fluxes of CH_4 and CO_2 produced by coastal wetlands, the first and most important thing to do is to explore the characteristics of CH_4 and CO_2 emissions.

It has been reported that the temporal and spatial variations in the CO_2 and CH_4 fluxes differed greatly in various wetlands, and they were strongly influenced by salinity, water level and so on (Cheng et al., 2010; Sun et al., 2013). Salinity can control the distribution pattern of particular organisms, and the content and distribution of soil nutrients (*i.e.*, N and P) can also be influenced by salinity (Cheng et al., 2010; Neubauer, 2013). Water level was also a key factor influencing wetland ecosystems, which could considerably influence the concentrations, forms, and transformation of soil nutrients as well as the plant productivity in wetland ecosystems (Bai et al., 2005; Hirota et al., 2007). Therefore, a better understanding of the effects of water level and salinity on CO_2 and CH_4 emission fluxes would contribute to coastal wetland management and conservation.

The Yellow River delta wetland, one of the youngest wetlands, is the most complete and extensive wetland in the warm temperate areas of China with high water salinity (5–30 g L^{-1}) and ground water levels (1–3 m) (Fan et al., 2011; Yang et al., 2009). It is ecologically important due to its hydrological attributes and its role as an ecotone between terrestrial and aquatic ecosystems (Qin et al., 2010). However, there were few studies on the characteristics of CH_4 and CO_2 emissions, as well as the environmental controlling factors. In our study, we investigated the dynamics of CH_4 and CO_2 emission in five kinds of typical tidal flats from the Yellow River delta wetland, and the influences of water level and salinity on their emissions were quantified in laboratory experiments. This work has a vital significance for exploring the carbon cycle model and reducing greenhouse gas emissions of coastal wetlands.

2. Materials and methods

2.1. Study area

The field experiments were conducted in the Yellow River delta wetland (N37° 43′ 04″–N37° 46′ 02", E118° 55′ 38″–E119° 13′ 45") in Shandong Province, China (Fig. 1). The soil types of the study area had high salinity, including tidal soil, saline tidal soil and coastal tidal soil. The gradually increasing ground water table and salinity from inland to coast resulted in a vegetation gradient (Fan et al., 2011). Five kinds of representative tidal flats (YW1, YW2, YW3, YW4, YW5) were used for field experiments, and their characteristics are shown Table 1.

2.2. Experiments

The field experiments were conducted to explore the seasonal and spatial variations of CO_2 and CH_4 fluxes in the Yellow River delta wetland during the years 2011–2013. The fluxes of CH_4 and CO_2 were simultaneously measured in a closed static opaque chamber (100 cm × 100 cm × 60 cm) (Hoffmann et al., 2015). Three sampling points were selected in each research area. The gas sampling campaigns were conducted thrice in each quarter, with durations of 2 h at a time. Contemporaneously the temperature and air pressure were measured in the static opaque chamber. Gas samples were transported to the laboratory and analyzed by gas chromatography (GC). The method of assessing the degree of vegetation coverage was quadrat sampling, and the size of quadrat was 100 cm × 100 cm.

To study the effects of water and salinity on CO_2 and CH_4 fluxes in different tidal flats, we designed different water levels (+4 cm, +2 cm, 0 cm, −2 cm and −4 cm) and salinity treatments (0.6 g L^{-1}, 1.2 g L^{-1}, 6 g L^{-1}, 12 g $L^{-1}$and 24 g L^{-1}) in laboratory experiments. Salinity was adjusted with sodium chloride. The volume of the simulation experiment device was 0.25 m^3, with an inner diameter of 40 cm. The soil samples and plant communities were collected from the five kinds of typical tidal flats from the Yellow River delta wetland, and the depth of sampling was 80 cm. All the soils in the simulation devices were pre-incubated for 2 months in order to avoid the disturbance of initial salt contents in the wetland soils. The fluxes of CH_4 and CO_2 were obtained from June to September in 2013 and measured by the static opaque chamber–GC technique. The gas samples were collected at 9:00,

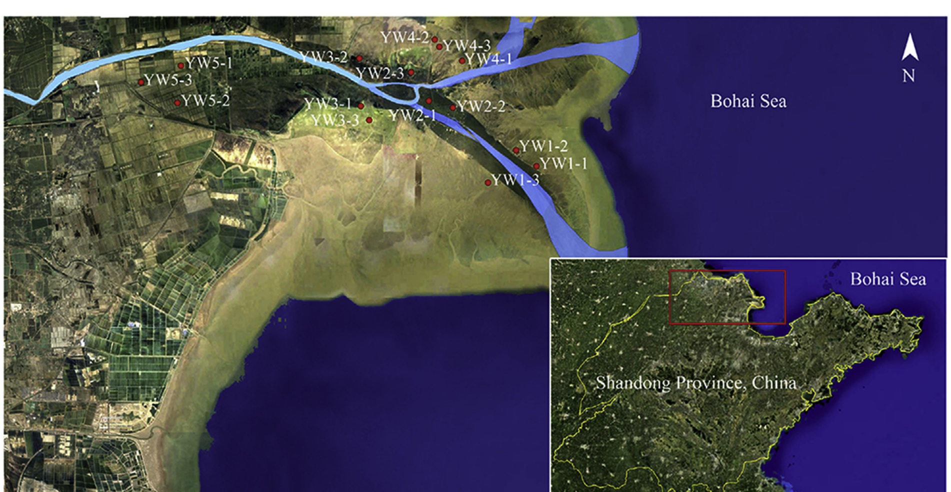

Fig. 1. The monitoring sites in the Yellow River delta wetland. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)