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Seasonal variation of CO_2 diffusion flux from a large subtropical reservoir in East China

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HIGHLIGHTS

- We report the CO_2 emission from a subtropical large reservoir.
- Reservoir surface can absorb large amount of atmospheric CO_2 in warm seasons.
- Downstream the dam has the similar contribution of CO_2 emission to reservoir surface.

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ABSTRACT

The Xinanjiang Reservoir (E118°42′–E118°59′, N29°28′–N29°58′), has a surface area of 567 km^2, with a mean water depth of 34 m, and is in an oligotrophic state at present. In this study, five cruises were carried out in April, June, August and November 2010, and January 2011, to understand the seasonal variation of CO_2 emission and to estimate the annual diffusion flux of CO_2 from this reservoir. The partial pressure of CO_2 (pCO_2) in surface water was determined using a continuous measurement system (equilibrator-infrared system) from upstream to central reservoir, and pCO_2 along the water column in central reservoir and in downstream of the dam was also determined. Results showed that pCO_2 in reservoir surface water varied significantly in different seasons, ranging from 5 μatm in August to 1700 μatm in January; while in downstream of the dam, it ranged from 1400 μatm in April to 3800 μatm in August. Along the water column in central reservoir, pCO_2 also showed significantly variations seasonally, and a water mass with quite high pCO_2 (>4000 μatm) formed below water depth of 20 m in warm seasons. The highest diffusion flux of CO_2 (F–CO_2) appeared in January, with values of 20.9 mmol m^{-2} d^{-1} at river reach and 25.2 mmol m^{-2} d^{-1} at central reservoir, while the lowest values of F–CO_2 were −10.0 at river reach and −10.8 mmol m^{-2} d^{-1} at central reservoir in August. Downstream of the dam had quite high positive F–CO_2 during the whole year, with a range of 129.1 in April to 381.5 mmol m^{-2} d^{-1} in August. In total, about 88.9 kton a^{-1} CO_2 was emitted to the atmosphere from the Xinanjiang Reservoir surface, while 39% of it (35.1 kton a^{-1}) was absorbed by surface water in warm seasons. Downstream and turbine had a comparable CO_2 outgas flux of 61.5 kton a^{-1}. When taking the whole reservoir surface, turbine and downstream into account, the Xinanjiang Reservoir system had a net CO_2 emission flux of 115.3 kton a^{-1}.

1. Introduction

Currently, carbon dioxide (CO_2) emission accounts for the largest share of greenhouse gases (GHGs) equivalent of 80–85% of the emissions (Tremblay et al., 2005). Since the industrial revolution, atmospheric CO_2 concentration has increased from 280 ppm to 389.85 ppm in 2010 (http://www.esrl.noaa.gov). Among the major anthropogenic sources of CO_2, fossil fuel burning has always been considered as the highest contributing factor. In order to alleviate the CO_2 emissions, clean energy development and utilization, especially hydropower exploitation, have been vigorously promoted (Chamberland and Levesque, 1996; Victor, 1998). As a result, large numbers of artificial hydropower reservoirs have been

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constructed worldwide, with the estimation that “some 40,000 large dams (defined as more than 15 m in height) and more than 800,000 smaller ones are in operation, and more are still being constructed” (Humborg et al., 2002), and references therein.

However, recent researches showed that artificial reservoirs might also be a potential CO_2 contributors to the atmosphere (Kelly et al., 1997; Duchemin et al., 1995; St Louis et al., 2000; Fearnside, 2002; Dos Santos et al., 2006; Huttunen et al., 2002; Teodoru et al., 2012; Raymond et al., 2013) and have called the green credentials of hydropower into question (Giles, 2006). For example, some hydroelectric reservoirs in tropical regions were reported emitting more CO_2 per unit generating capacity than thermal power did (Dos Santos et al., 2006; Fearnside, 2002). The decomposition of flooded biomass and autogenetic organic matter is the major mechanism that produces GHG, which is composed of CO_2 and CH_4. Thus, the quantity of organic matter and the depositional environment in the reservoirs become determining factors for the production of GHG. In boreal and tropical reservoirs, flooded area generally has a higher density of soil organic carbon (OC), which will gradually be mineralized to CO_2 or CH_4 under oxygen-deficient condition after impounding. In addition, submerged vegetative cover in tropical area also provides abundant biomass to sedimentary OC in reservoir. These factors together made reservoirs in boreal and tropical area become the hotspots for GHG emission research (Abril et al., 2005; Demarty et al., 2009; Roland et al., 2010).

Nevertheless, little research has been devoted to the GHG emission from subtropical reservoirs. In fact, large numbers of reservoirs are operating in subtropical areas. Such as, over 40,000 reservoirs have been constructed in the Yangtze River basin, which is the longest river in Asia and the third-longest in the world. Furthermore, the characteristics of the reservoirs, including capacity, retention time, and the geological background, are diverse in different climate regions, which might induce different GHG emission flux. Consequently, it is potentially inaccurate to apply a uniform model to extrapolate the global reservoir GHG emission from different types of reservoirs. Therefore, investigating representative reservoirs in different climate areas is crucial to the estimation of the global GHG emission from reservoirs. In this study, the Xinanjiang Reservoir, a large subtropical reservoir, was investigated through five cruises carried out from 2010 to 2011. The main objectives were to understand the seasonal patterns of the pCO_2 in the Xinanjiang Reservoir, and to estimate the annual CO_2 diffusion flux contribution to the atmosphere. Moreover, the impact of deep-water discharge from the hydropower reservoir on the downstream CO_2 emission was also discussed in this study.

2. Study area and methodology

The Xinanjiang River is the mainstream of the Qiantang River, the largest river in Zhejiang Provence, East China, and has a length of 589 km and drains an area of 55,600 km^2. The Xinanjiang Reservoir (E118°42′–E118°59′, N29°28′–N29°58′), located in the Chun'an County, Zhejiang Province, was constructed in 1959, also known as the Qiandao Lake. It has a surface area of 567 km^2, with the mean and maximum water depths of 34 m and 117 m, respectively. The climate is typically subtropical monsoon climate with air temperature ranging from −5 °C to 36 °C (annual average value of 17 °C) and the annual precipitation of 1429.9 mm on average. The air humidity here is about 76% and forest coverage rate of the drainage area reaches 83%.

Cruise route began from the upstream (site A) to middle reach (site B), and finished at the central reservoir (site C) (Fig. 1). Five cruises were carried out during April, June, August and November 2010, and January 2011. In each cruise, surface water (0.3 m below water surface) was pumped (by a self-priming pump. Model: IZDB-

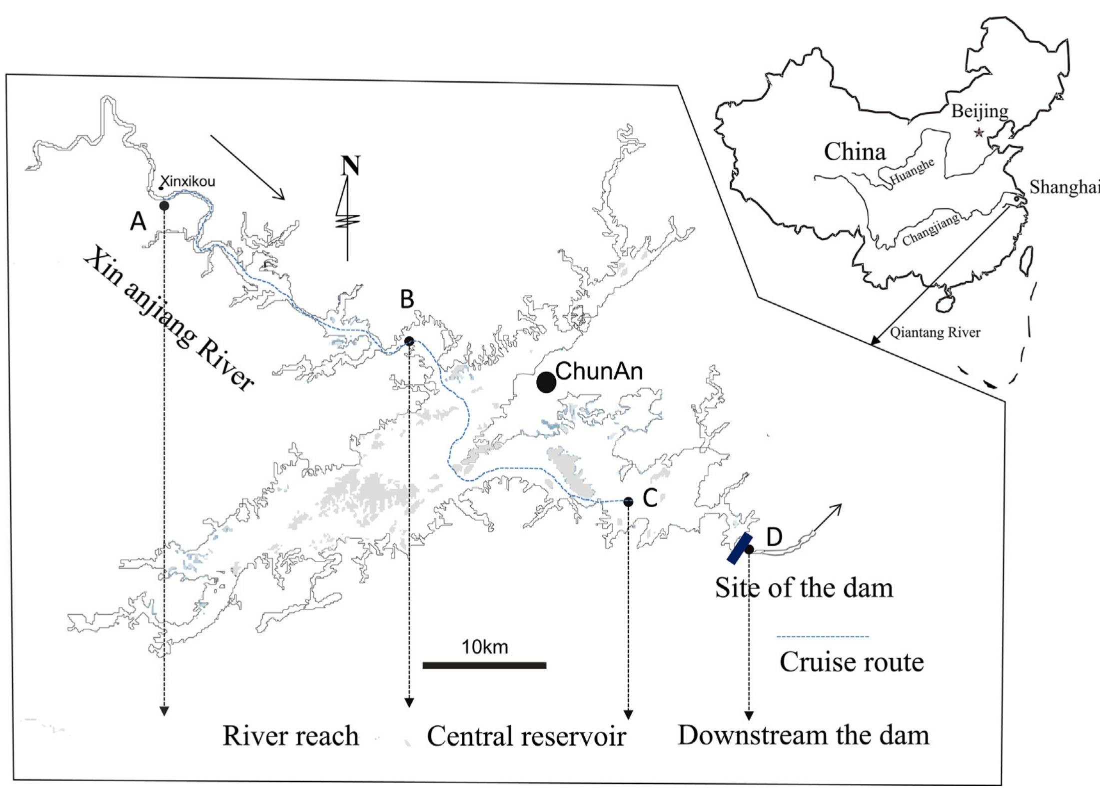

Fig. 1. Geographic location of the study area and the sampling sites.