Science of the Total Environment 640–641 (2018) 908–920

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

CO_2 oversaturation and degassing using chambers and a new gas transfer velocity model from the Three Gorges Reservoir surface

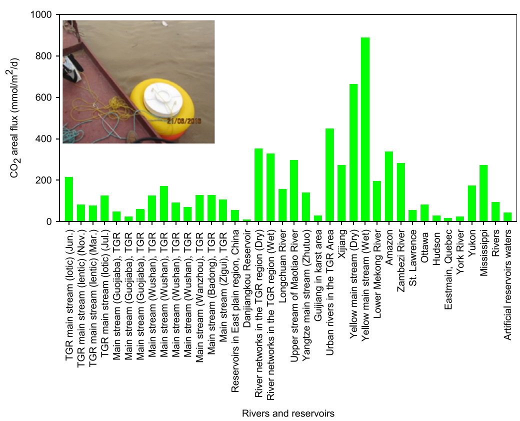
Siyue Li

Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences (CAS), Chongqing 400714, China

HIGHLIGHTS

- Aqueous pCO_2 averages 2511.6 ± 1721.3 μatm, 6.1fold higher than the ambient air pCO_2
- All samples are CO_2 sources and CO_2 efflux has pronounced spatial and monthly changes.
- Dam impoundment significantly alters CO_2 areal flux and controls of pCO_2.
- k model with reliable measurements is firstly developed in the Yangtze of TGR.
- k model and complete sampling create more reliable and higher CO_2 evasion estimate.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 15 April 2018
Received in revised form 27 May 2018
Accepted 27 May 2018
Available online xxxx

Editor: José Virgílio Cruz

Keywords:
CO_2 flux
Carbon source
Gas transfer velocity
Riverine carbon cycle
Spatial and temporal variability

ABSTRACT

Reservoirs are considered as important carbon source of the atmosphere, whilst, regional and global reservoir CO_2 quantification is hampered by data limitation and bias in spatial and temporal sampling. By deploying chamber measurements and employing the newly developed model of gas transfer velocity, CO_2 partial pressure (pCO_2) and evasion in the main stem of the Three Gorges Reservoir (TGR) were investigated. The pCO_2 ranged from 429 to 8668 μatm with an average of 2511.6 ± 1721.3 μatm, 6.1-fold higher than the ambient air pCO_2 (mean: 410 μatm). All the samples were net CO_2 sources via water-air interface, displaying pronounced spatial and monthly variability. The CO_2 areal flux averaged 212.5 ± 120.1 mmol/m^2/d in June, 123.3 ± 78.5 mmol/m^2/d in July in the lotic TGR main stream, much higher than its lentic system, i.e., 79.6 ± 41.3 mmol/m^2/d in November, and 76.3 ± 88.1 mmol/m^2/d in March. Much lower k levels in the lentic reservoir surface resulted in lower CO_2 evasion rates. Furthermore, dam impoundment considerably altered the riverine carbon cycle, as reflected by the changing magnitude of CO_2 efflux and environmental controls of dissolved CO_2. Precipitation and concurrent soil CO_2 influx exhibited a central role in controlling riverine pCO_2, and respiration of allochthonous organic carbon was a secondary factor in the TGR lotic system, whilst, both in-stream metabolism and terrestrial inputs played crucial roles in controlling aqueous CO_2 in the TGR lentic system. In comparison, we provided key findings of k model and more reliable CO_2 quantification with a consideration of water level shifts and a complete coverage of spatial sampling. Our higher CO_2 emission (1.47 (1.16–2.13) Tg CO_2/y) than previous studies called more field measurements to assess the resulting changes in CO_2 flux owing to dam operation and changing environment, and their implications for regional carbon budgets should be warranted.

E-mail address: syli2006@163.com.

https://doi.org/10.1016/j.scitotenv.2018.05.345

1. Introduction

Reservoirs and rivers that link the terrestrial and oceanic continuum, are now recognized to be significant net sources of atmospheric CO_2 (Cole et al., 2007; Tranvik et al., 2009; Butman and Raymond, 2011; Raymond et al., 2013; Li et al., 2015), and also act as key reactors of carbon (C) biogeochemical transformation (Cole and Caraco, 2001). Numerous studies reported that CO_2 emission from riverine-reservoir continuum is higher than or at least comparable to riverine delivery of C to the oceans (Richey et al., 2002; Li et al., 2012; Li et al., 2013b). As a consequence, rivers and reservoirs play a substantial role in the regional and global C cycle (Battin et al., 2009; Bastviken et al., 2011), and these ecosystems should be urgently included for reevaluating the continental C budgets (Bastviken et al., 2011).

A review of existing literature shows that estimates of total CO_2 evasion from global inland waters have been revised upwards over time from 0.75–1.4 Pg C/y (Cole et al., 2007; Tranvik et al., 2009) to 2.1–3.28 Pg C/y (Aufdenkampe et al., 2011; Raymond et al., 2013). However, estimates of CO_2 evasion from lakes and reservoirs combined show that the picture is more complex, for example, reservoirs annually emitted 0.28 Pg C-CO_2 (Tranvik et al., 2009), while Raymond et al. (2013) estimated the global combined lake + reservoir flux to be 0.3 Pg C/y in 2013, Deemer et al. (2016) estimated 0.037 Pg C-CO_2/y for global reservoirs alone, while a recent paper by Hastie et al. (2018) estimated the lake + reservoir flux to be almost 0.2 Pg C/y from the Boreal region alone (just 27% of global lake & reservoir area). This underscored the huge uncertainty of reservoir CO_2 estimation because of the data paucity and bias in data distribution of field measurements of CO_2 areal flux. Accurate quantification of CO_2 evasion with more completed coverage of spatially and temporally resolved CO_2 dataset would help refine reservoir carbon budgets over a regional and global scale, and their role in continental C budgets.

Extensive efforts have been made on CO_2 evasion estimates from reservoirs particularly in tropical and temperate biomes (Barros et al., 2011; Deemer et al., 2016). Tropical reservoirs were reported to have extremely high C areal flux (Guerin et al., 2006; Kemenes et al., 2011) and thus the "green" credentials of hydropower were balanced (dos Santos et al., 2006). This put the hydroelectric reservoirs to the centre of the debate, and research on reservoir greenhouse gases (GHGs) emission is progressively increasing (Hertwich, 2013; Li and Zhang, 2014a; Li et al., 2015). China's hydropower reservoirs also receive increasing concerns because of high GHGs emission in the TGR (i.e., 170 ± 150 mmol $CO_2/m^2/d$) (Zhao et al., 2013) and in its littoral zone (i.e., −1.0–156.5 mmol $CO_2/m^2/d$) (Chen et al., 2009) produced by dam operation in particular. Studies on reservoirs GHGs emissions in China have focused on large hydropower reservoirs (Li et al., 2015; Wen et al., 2017), for example, Danjiangkou Reservoir (Li and Zhang, 2014b), reservoirs Ertan, Wan'an, Hongfeng and Hongjiadu (Li et al., 2015), as well as The Three Gorges Reservoir (TGR) in particular. There are rapidly increasing studies on GHG effluxes from the TGR, for instance, methane areal flux from mainstream (Chen et al., 2011), drawdown area (Chen et al., 2009; Lu et al., 2011; Yang et al., 2012) and backwaters (Xiao et al., 2013a; Wang et al., 2014), and N_2O efflux from the TGR (Chen et al., 2010; Zhu et al., 2013). However, CO_2 evasion from the TGR region are constrained by spatially resolved sampling, i.e., limited field measurements in the mainstream (Xiao et al., 2013b; Zhao et al., 2013), as well as tributaries (Wang et al., 2017). Our earlier work quantified CO_2 evasion from TGR river networks from a high spatial resolution investigation (Li et al., 2018). As such, there are several key knowledge gaps on the TGR main stem to be addressed as follows: (1) aquatic CO_2 emission is quantified without consideration of water area shift because of dam operation, (2) gas transfer velocity is a key parameter for GHG estimation over the entire reservoir scale, whilst is not measured, (3) comparative CO_2 evasion from "river" (lotic) and "lake" (lentic) status of the TGR mainstream remains to be quantified, which would help evaluate the magnitude of CO_2 evasion from the TGR with a transition from the dominance of "river" to "lake" as water level fluctuated from 145 to 175 m.

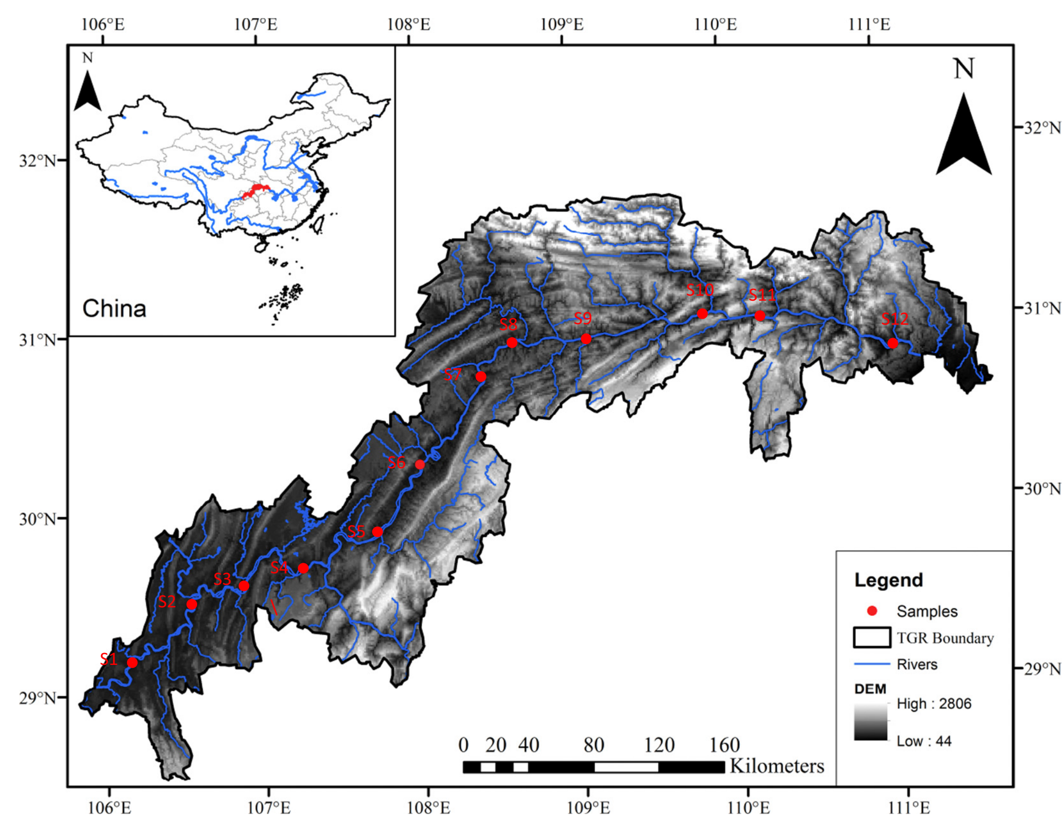


Fig. 1. Sampling sites in the main stream of the TGR.