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SHORT COMMUNICATION

Uncertainties of carbon emission from hydroelectric reservoirs

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Abstract Anthropogenic greenhouse gas (GHG) emissions have substantially contributed to intensification of heavy precipitation and thus the risk of flood occurrence, and this anthropogenic climate change is now likely to continue for many centuries. Thus, precise quantification of human-induced GHG emissions is urgently required for modeling future global warming and precipitation changes, which is strongly linked to flood disasters. Recently, GHG evasion from hydroelectric reservoirs was estimated to be 48 Tg C as CO_2 and 3 Tg C as CH_4 annually, lower than earlier estimate (published in *Nature Geoscience*; 2011). Here, we analyzed the uncertainties of GHG emissions from hydroelectric reservoirs, that is, reservoir surface area, data paucity and carbon emission relating to ecological zone, and argued that GHG evasion from global hydroelectric reservoirs has been largely under-estimated. Our study hopes to improve the quantification for future researches.

Keywords Greenhouse gas · Hydroelectric reservoir · Carbon emission

In the context of Cole's plumbed carbon cycling (Cole et al. 2007), the interest in carbon efflux from freshwaters has become greater and greater. Numerous studies have focused on carbon emissions from freshwaters particularly reservoirs (i.e., Bastviken et al. 2011; Barros et al. 2011). Barros et al. (2011) recently estimated the carbon emission from hydroelectric reservoirs (*Nature Geoscience*), downgrading the earlier estimate; however, there are a few uncertainties about data source and analyses, which are challenging the accurate quantification of carbon evasion. Researches have reported that anthropogenic greenhouse gas was directly linked to growing intensity of rain and substantially increased the risk of floods (Pall et al. 2011). Here, we analyze the common uncertainties for this

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topic and ultimately, we posit that obviously lower estimated greenhouse gases evasion is from hydroelectric reservoirs. This would help to improve global modeling on precipitation changes and flooding disasters.

First, the global reservoir area varies from 0.26 to 1.5 M km^2 (Downing et al. 2006), and a reliable area of reservoirs seems to be around 0.5 M km^2 on the basis of high-resolution mapping of Global Reservoir and Dam database (Lehner et al. 2011). The extremely large area (cf. 1.5 M km^2) obtained by St. Louis et al. (reference in Downing et al. 2006) was mainly due to the vague distinctions between impounded natural lakes and man-made reservoirs. Yet, this largest data were adopted by Barros et al. (2011). While the percentage of hydroelectric reservoirs (i.e., 25 %) before 1998 adopted by Barros and his colleagues (2011) is much lower than Varis et al. (2011) that hydropower reservoirs account for around 62 % of the total surface area of the world's reservoirs. The lower proportion is due to recently quick development of hydroelectric reservoirs, leading to yield lower GHG from hydroelectric reservoirs.

Second, current data are primarily from the Americas and Northern Europe and very little are from tropical Asia and Africa, especially from China and India where a large number of hydroelectric reservoirs exist and where more reservoirs will be constructed. Understandably, there is a lack of carbon emission measurements in this region, but there have been increasingly higher carbon emission reports (i.e., Chen et al. 2009; Wang et al. 2011; Zhao et al. 2011); Zheng et al. 2011). For instance, CO_2 degassing from the China's hydropower reservoirs reached as high as 2,070 mg/m^2/day with an average of 1,070 mg/m^2/day, and CH_4 emission ranged from 2.9 to 140 mg CH_4/m^2/d. These fluxes are, respectively, much higher than the CO_2 flux of 387 mg/m^2/day and CH_4 flux of 2.8 mg/m^2/day for temperate reservoirs (26°–50° N) (Barros et al. 2011). Consequently, the emissions could be much greater than those estimated by Barros et al. (2011). For example, Lima et al. (2008), in an estimate that included downstream degassing, estimated global methane emissions of 104 Tg/year from all large dams, as compared to the Barros et al. (2011) estimate of only 4 Tg/year from surface emissions of hydroelectric dams.

Third, the relations between the areal emission of carbon from hydroelectric reservoirs and reservoir age were observed (Barros et al. 2011), but these relations should be analyzed based on ecological zones, because catchment characteristics are extremely heterogeneous among varying ecological zones. Their relation demonstrating that carbon emission will be lower after a few years of installment requires further investigation. In fact, Fearnside (2006) demonstrated that carbon emission could remain at a higher level for many years, particularly in the drawdown areas (cf. Chen et al. 2009). This could be especially true for reservoirs in Asia and Africa where levels of sediment and its bound organic materials are very high, and the large amount of sediment trapped behind dams (Syvitski et al. 2005; Walling 2006) would have a potential of high carbon release.

Although there are still large uncertainties, the evidence suggests that the global emissions from hydropower are substantially greater than those estimated by Barros et al. (2011). Rapid hydropower development and increasing carbon emissions from hydro-electric reservoirs to the atmosphere (Li and Lu 2011) should not be downplayed.

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