bg-2018-278

Author response to RC4 (3^{rd} reviewer's comments)

Jin and co-authors present an extensive dataset of greenhouse gas (GHG) measurements along a human-impacted river in Korea. The river is divided in three sections: the upper reach which is characterised by forest and agricultural land use, the middle reach which is impacted by multi-purpose dams and the lower reach which is influenced by wastewater discharge of the city of Seoul. Significant discontinuities in the GHG concentrations were found in the dam and sewage impacted reaches. Although the conclusions are not very surprising, the importance of this manuscript is the comprehensive dataset created by the authors, which provides a lot of quantitative information for larger-scale overview articles.

General comments

In the introduction, you often mention that previous studies looked at only a single anthropogenic factor. It took me a second reading before I distinguished the two anthropogenic factors, dams and sewage, as spatially distinct along the river (middle and lower reach). Even though it might be a slight over-simplification, it might help the reader if you make it more explicit (similar to the second sentence of previous paragraph). Your many sites and tributaries can become confusing, but framing it as 'natural', 'dams' and 'urban/sewage' would help to keep track.

<Response> As you indicated, the suggested framing is difficult to apply considering within-reach spatial heterogeneity. To follow your suggestion, we have added some additional sentences to specify the dominant anthropogenic perturbation of each reach in Introduction (Lines 104-105: The primary objective was to examine the effects of dams and urban wastewater**) and Methods (L 138-141:** Compared to the upper reach (HR1 – HR4) located in a heavily forested watershed with some scattered agricultural areas, the impounded middle reach (HR5 – HR11) and the lower reach receiving heavy loads of urban sewage (HR12 – HR15) are subject to stronger anthropogenic perturbations; **L 145-146:** The 8 sites were selected to cover the spatial pattern of land use, ranging from the forested upper reach to the increasingly urbanized downstream reaches (Fig. S1).**).**

You have a tendency to make complicated sentences because you want to include all your reasoning or justifications in one sentence. While these sentences were grammatically correct, they are really hard to read. Be critical to sentences which are more than 4 lines and consider splitting them up. I will indicate a few of those sentences in the detailed comments.

<Response> We have reformulated the long sentences you pointed out, as detailed in our responses to specific comments below. In addition, we have thoroughly revised many parts of the manuscript to improve the readability by minimizing long sentences.

Specific comments

L. 16: I have difficulties with calling the dams and sewage primary controls, because I perceive the term 'primary' as the 'first', while the human impact is actually superimposed on the natural dynamics. I would suggests changing it to "major controls". Also, the effects are not the controlling the GHG dynamics. "... to investigate the influence of dams and urban water pollution on GHG dynamics ..."

<Response> The phrase has been changed to "to investigate dams and urban water pollution as major controls**" in L 16.**

L. 28 : might (without e at the end)

<Response> Corrected.

L. 112: Add the length of the river

<Response> The length, together with a reference, has been added in L 116-117.

L. 115-118: Split over two sentences. One about major land use, one about the metropolitan area.

<Response> Split into two sentences (L 119-122: Major land uses in the basin include forests (73.6%), croplands (14.1%), urban and industrial areas (2.6%), and other uses (9.7%) (Fig. S1). The highly urbanized metropolitan area along the lower reach has a large impermeable surface regarded as urban land use, accounting for 58% of the total city area of Seoul (Seoul Metropolitan Government, 2017).**).**

L.127: What is the treatment level of the three WWTPs.

<Response> Information available for the largest WWTP has been provided in L 133-134 (which employs tertiary treatments including modified Ludzack Ettinger (MLE) and anaerobic-anoxic/oxic process (A_2O)**).**

L. 138-140: What are the observation dates/month & year?

<Response> DMY (10 June 2016**) has been added in L 149.**

L. 219: It was not clear to me where the agricultural stream and forested headwater stream belong to. Are they both part of the upper reach? Also the submerged weirs is not clear to which section they belong. It felt like you are jumping up and down along the river in the description of the longitudinal variations. Try to be consistent in describing each parameter from upper reach over middle reach to lower reach.

<Response> The paragraph has been rearranged and added with site information so that the longitudinal variations are described in the order of upper-middle- lower reaches.

L 230-239: The concentrations of three GHGs were relatively low along the upper reach, although small, but noticeable increases occurred in the agricultural stream (HR2) compared to the generally low values found in the forested headwater stream (HR1) (Fig. 2; Table 1). Levels of $p\mathrm{CO_2}$ in the middle reach (HR5 – HR11; 51 – 761 μatm) tended be lowest when compared with upper and lower reaches and were particularly low at sites within a few km upstream or downstream of the cascade dams. In contrast, N_2O and CH_4 concentrations were higher at one (HR6; 212 nM N_2O L^{-1}) or three dam sites (HR6, HR7, and HR10; 693 – 748 nM CH_4 L^{-1}), respectively, compared to the upstream or downstream reaches of the dam sites (Table 1). For all three GHGs, large downstream increases were found along the lower reach flanked by two submerged weirs (HR12 – HR14). Gas concentrations at some lower-reach sites approached or exceeded the levels found in three tributaries draining the urban sub-catchments located in Seoul and surrounding suburban areas (Fig. 2).

L. 225: replace "less impacted upstream or downstream reaches" with "compared to the upper and lower reaches". All of the reaches are impacted, just in a different way.

<Response> Here upstream and downstream do not refer to upper and lower, respectively. They literally mean upstream and downstream reaches of the dam sites. The phrase has been changed to "compared to the upstream or downstream reaches of the dam sites**" (L 236).**

L. 225-227: This is a complicated sentence. Consider splitting it up (especially the explanation for sites HR8 and HR11).

<Response> The sentence has been split and rephrased in L 239-242 ($p$$CO_2$ tended to be higher in summer than in other seasons at all monthly monitoring sites except HR8 and HR 11, which are subject to direct or indirect influences of the cascade dams along the middle reach. There was no clear seasonality in CH_4 and N_2O across the sites, but at the lower-reach site HR14 the concentrations of two gases tended to be higher in spring and summer than in fall and winter (Fig. S2).**).**

L. 233: What is the water discharge ratio between the tributary and the main river?

<Response> Discharge ratios have been provided in the rephrased sentence in L 249-253 (The comparison of monthly water quality measurements between the six sites and the urban tributary (HR12), together with the proportion of tributary discharge in the mainstem flow ranging from 5% in the monsoon period to 12% in dry seasons, points to the disproportionate influence of urban tributary inputs on the downstream increases in concentrations of DOC and nutrients observed in the lower reach (Fig. 3).**).**

L. 238: This is a complicated sentence. "When we pooled the measurements for the whole river basin, at least two of the GHG's exhibited significant ..."

<Response> The sentence has been rephrased in L 257 (When all measurements of three GHGs and water quality were pooled for the whole river basin,…**).**

L. 260: How can the WTTP effluents and tributary reach values of the upstream river. Consider rephrasing.

<Response> The sentence has been rephrased in L 283-285 (In contrast, CH_4 concentrations exhibited relatively large fluctuations along the middle reach, ending up at the intermediate levels observed for the upper to middle reaches in the WWTP effluents and the tributary outlet.**).**

L. 261: the large scatter (without s)

<Response> Corrected.

L. 273: "though" doesn't seem the correct word.

<Response> Corrected ("through"**).**

L. 304-309: Very long and complicated sentence with lots of subsentences.

<Response> Reformulated in L 329-334 (It would be very challenging to tease out multiple, interrelated factors as shown by previous studies of GHG dynamics in urbanized river systems (Smith et al., 2017; Wang et al., 2017b). However, the observed longitudinal patterns of three GHGs (Figs. 2–4), along with their correlations with specific sets of water quality components (Fig. 5), make one thing clear. The primary factors and mechanisms for the production and consumption of three GHGs may change in response to longitudinal variations in dominant anthropogenic perturbations, often abruptly as shown by the localized pulses of GHGs downstream of urban tributary inflows (Figs. 2, 8)**).**

L. 408: Could the composition of the respired organic material be responsible for the variation in $\delta^{13}C$? I expect very little C4 plants in Canada, which is consistent with the very low δ13C values. If you have more variation in C3-C4 plants throughout your catchment, then you would expect to see that change reflected in the riverine C.

<Response> We understand your point, but the lower reach is in the Seoul metropolitan area with little agricultural area, suggesting that variations in C3/C4 plants cannot explain spatial variations in δ13C in CO2 along the lower reach mig. To provide more coherent explanations, the entire paragraph has been revised as follows (L 439-456):

"The longitudinal increase in $\delta^{13}C_{CO2}$ from −20.9‰ at 76 km from the river mouth to −16.7‰ at 50 km from the river mouth in Fig. 8 might be related to a complex array of interacting processes such as organic matter degradation, photosynthesis by phytoplankton, and atmospheric gas exchange, which have usually been investigated as determinants of the isotopic composition of riverine DIC consisting of dissolved CO_2, bicarbonate, and carbonate (Barth et al., 2003; Schulte et al., 2011; Zeng et al., 2011; Deirmendjian and Abril, 2018). The observed values of $\delta^{13}C_{CO2}$ fall within the reported ranges of $\delta^{13}C$ measured for CO_2 dissolved in riverine and estuarine waters (−25 – −15‰) (Longinelli and Edmond, 1983; Maher et al., 2013). However, the values reported here are less negative than the ranges of $\delta^{13}C$ measured directly for CO_2 respired by bacteria consuming organic matter of terrestrial and algal origin in two streams and eight lakes in Canada (−32.5 – −28.4‰) (McCallister and del Giorgio, 2008).When the observed values of $\delta^{13}C_{CO2}$ are compared with the low range of $\delta^{13}C_{CO2}$ reported by McCallister and del Giorgio (2008) and the usual ranges of $\delta^{13}C$ in plant and algal biomass as two primary biological sources of riverine CO_2 (Fig. 7), it follows then that other riverine processes than bacterial degradation of plant (predominantly C3 in the studied basin) and algal biomass might be involved in the upward shift of $\delta^{13}C_{CO2}$. It has been reported that $\delta^{13}C$ in riverine DIC derived from carbonate dissolution and bacterial respiration ranges from −15 – −5‰, reflecting the balance between the concurrent processes that can either enrich or deplete DIC in ^{13}C (Telmer and Veizer et al., 1999; Barth et al., 2003; Schulte et al., 2011; Zeng et al., 2011). In contrast to the preferential use of the lighter organic C by heterotrophic bacteria depleting ^{13}C in the respired CO_2, photosynthesis and atmospheric gas exchange can result in an enrichment of ^{13}C in remaining riverine CO_2 through preferential phytoplankton uptake of the lighter $^{12}CO_2$ and dissolution of atmospheric CO_2 enriched in ^{13}C, respectively (Schulte et al., 2011)."

Figure 2: Could you indicate the three different reaches in the graphs?

<Response> Three reaches have been indicated at the top of the graphs.