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Discussions

Interactive comment on "Methane emissions from a sediment-deposited island in a Lancang-Mekong reservoir" *by* Wenqing Shi et al.

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General comments: Thank you for providing your responses to the two referee reports. As the two reviewers mentioned, your manuscript reports on a very novel aspect of CH4 dynamics in a sediment-deposited island formed within a hydroelectric reservoir. However, both reviewers raised some critical issues about the rarely reported sink of CH4 at the water-sediment interface and potential flaws in measuring CH4 fluxes using chambers as described in the previous version. Given the importance of these issues and many additional uncertainties I myself found in reading the revised manuscript (please note that Biogeosciences require authors to provide the revised manuscript after this stage of editorial decision, not in writing your responses to reviewer comments), a major revision would be required to reconsider your manuscript for publication in

Biogeosciences. The revised manuscript may be resent to the reviewers to double check whether you have adequately addressed all the raised issues and minor corrections. I would like to ask you to make all the changes easily identifiable in a marked-up manuscript and a point-by-point reply to the reviewers' and my own comments to facilitate the second round of review. I would suggest you to specify the line numbers of the revised parts when you respond to the reviewer comments, and my comments and suggestions as follows:

- We are indeed grateful to the editor for the valuable comments that have enabled us to improve the manuscript. We seriously considered all the comments and made a thorough revision. The changes made were shown with a red color font in the marked-up manuscript and supplements. Detailed point-to-point responses are presented below. The marked-up manuscript and supplements are listed in the attachment.

Question 1: The CH4 sink along the island edge and accuracy of chamber measurements. Both reviewers were concerned about potential errors involved in your chamber measurements. Though you provided more detailed descriptions about the chamber system, there might be some lingering uncertainties about the repeated gas sampling in low-concentration chambers and potential gas leakage during storage of evacuation vials. I would suggest you to provide more details on sampling and gas analysis including QC measures to guarantee analytical accuracy so that the reviewers could assess the accuracy of CH4 measurements. You may also include the original CH4 measurements (as shown in your response to the reviewer 2) as a supplementary table. Lastly, you can also cite available literature information about very low to negative CH4 fluxes in reservoir sediment systems similar to yours. Your discussion in L256-267 is too general to explain specific conditions you encountered in your sediment island.

- Thanks for the editor's valuable comments. For gas sampling, static chambers have been widely used in the low-to-negative CH4 flux analyses (Veldkamp et al., 2013; Wang et al., 2013), and yielded a good linear regression based on CH4 concentration changes over time in this study (Table S1 in the supplements). For gas storage, Exetainer® vials have been evaluated for storage of gas samples and they can limit sample loss to insignificant amounts for at least 3 months (Glatzel and Well, 2008; Van Dam et al., 2018). Nevertheless, we have presented more details on CH4 flux analysis and added the original CH4 data as a supplementary table according to the editor's suggestion. Please see line 148-151, 153-154, 160 on page 8, line 165, 166-168 on page 9, and the updated supplements.

- We have cited the literature information about very low-to-negative CH4 fluxes similar to this study. Please see line 151 on page 8, line 480-481 on page 23, and line 485-488 on page 24 in the revised manuscript.

- We have updated the discussion in Line 256-267 in the previous version to focus on specific conditions in the studied island. Please see line 277-283 on page 14 in the revised manuscript.

Wang, J. M., Murphy, J. G., Geddes, J. A., Winsborough, C. L., Basiliko, N., & Thomas, S. C. (2013). Methane fluxes measured by eddy covariance and static chamber techniques at a temperate forest in central Ontario, Canada. Biogeosciences, 10(6), 4371-4382.

Veldkamp, E., Koehler, B., & Corre, M. D. (2013). Indications of nitrogen-limited methane uptake in tropical forest soils. Biogeosciences, 10(8), 5367-5379.

Glatzel, S., & Well, R. (2008). Evaluation of septum-capped vials for storage of gas samples during air transport. Environmental Monitoring and Assessment, 136(1-3), 307-311.

Van Dam, B. R., Tobias, C., Holbach, A., Paerl, H. W., & Zhu, G. (2018). CO2 limited conditions favor cyanobacteria in a hypereutrophic lake: An empirical and theoretical stable isotope study. Limnology and Oceanography. https://doi.org/10.1002/lno.10798

Question 2: The quantitative importance of CH4 emissions from the anaerobic inner area of islands (spatial extent and seasonally) As you mentioned in the revised

manuscript (L302-303) – "studies should assess the quantitative relationship between methane emissions from the drawdown area and hydropower operation scenarios", the information about hydropower operation and its effects on water levels and island flooding would be critical in assessing the quantitative significance of CH4 emissions from sediment-deposited islands. The revised manuscript still lacks this critical information. Please provide more details about the dam operation affecting reservoir and island water levels and dam discharge. If you want to argue for any enhancement or mitigation of CH4 emissions caused by fluctuating water levels and O2 availability, you also need to provide some estimates for the total area of islands affected by the processes you report in your manuscript and discuss their implications for the total reservoir CH4 emission.

- Thanks for the comments. The objective of this study is to explore spatial patterns of CH4 emissions from the sediment-deposited island and the underlying mechanisms. We found the spatial heterogeneity of methane emissions from the island and attributed it to the shift of oxygen availability in sediments under water level fluctuation induced by reservoir operation. The descriptions had been presented in the manuscript. Please see line 78-84 on page 5, line 284-300 on page 14-15, and line 324-335 on page 16. It is very interesting to further establish the quantitative relationship between methane emissions and water level fluctuation (or hydropower operation) and assess the mitigation of CH4 emissions from all the islands in these cascade reservoirs, however, this is a much more complex and difficult task that is beyond the aims of our current study. We can study it separately in the future with the help of China Huaneng Group Co., Ltd, who runs these cascade reservoirs. Here, the limited descriptions of "Prospective studies should assess the quantitative relationship between methane emissions from the drawdown area and hydropower operation scenarios" and "mitigation of CH4 emissions" are the implications based on the results of this study. To avoid confusion, we have deleted these descriptions.

Question 3: L56, L61: Please provide definitions of "sidebays" and "forebays".

- The forebay is an artificial pool of water in front of a larger body of water, which refers to the waters in front of the dam in reservoirs (Wikipedia). The sidebay is formed by abrupt variations in channel width (Jenkins et al., 1981), which refers to the corner of the reservoir here. Based on the definition of sidebays, we updated the number of sediment deposited islands in sidebays. Please see line 94 on page 5 in the revised manuscript and the updated supplements.

https://en.wikipedia.org/wiki/Forebay_(reservoir).

Jenkins, B. S. (1981). Effects of channel geometry on exchange processes in river side-bays. In Conference on Hydraulics in Civil Engineering 1981: Preprints of Papers (p. 156). Institution of Engineers, Australia.

Question 4: L64: What do you mean by “following hydropower production demands”?

- In reservoirs, the water level decreases during hydropower production, and increases with the inputs from inflows during the stagnant hydropower production. Hence, the water level frequently fluctuates following hydropower production demands. Here, we updated the description to make it clearer. Please see line 64-66 on page 4 in the revised manuscript.

Question 5: L67 & L71-73: It is difficult to understand why this happens - “This may lead to changes of oxygen conditions in the interior of the drawdown area”. You need to provide more relevant background information about anaerobic conditions developing in sediment-deposited islands, not the very general description – “oxygen conditions in sediments may affect the microbial processes”. I would suggest you to cite more relevant studies so that readers can understand better how anaerobic conditions in sediment systems similar to your study site affect methanogens and their competitive balance over methanotrophs.

- Many thanks for the valuable comments for improving the manuscript. As for the relevant background information about anaerobic conditions developing in deposited

sediment, we had presented it in the paragraph ahead. Please see line 47-49 on page 3.

- As for the effects of oxygen conditions in sediments on the microbial processes, we have rewritten it and cited more relevant studies. Please see line 71-77 on page 3-4 in the revised manuscript.

Question 6: L79-81: Please be more specific in providing your study objective. I expected that you would examine how changing hydrologic conditions and oxygen-dependent metabolic processes affect CH4 production and consumption.

- Previous studies have mainly focused on CH4 emissions from dam forebays, while the understandings of CH4 emissions from sediments deposited in sidebays remain poor (Line 60-63, Page 4). The objective of this study is to explore spatial patterns of CH4 emissions from the sediment-deposited island in sidebays and the underlying mechanisms. The changing hydrologic conditions and oxygen-dependent metabolic processes were studied here to explore the mechanisms of CH4 emission spatial patterns across the sediment-deposited island. We have updated our study objective in line 83-84 on page 5 in the revised manuscript.

Question 7: L86-88: The basin information is quite different from other reported values. Please double check and provide more official (or common) values (e.g., Mekong River Commission reports or Milliman, J. D., Farnsworth, K. L.: River Discharge to the Coastal Ocean: A Global Synthesis, Cambridge University Press, Cambridge, UK, 2011.)

- Thanks for the editor’s careful correction. The previous basin information was cited from Li et al. (2013). To be more official, we have updated this information from the Mekong River Commission according to the editor’s suggestion. Please see line 88-92 on page 5 in the revised manuscript.

Li, J. P., Dong, S. K., Liu, S. L., Yang, Z. F., Peng, M. C., and Zhao, C.: Effects of cascading hydropower dams on the composition, biomass and biological integrity of phytoplankton assemblages in the middle Lancang-Mekong River, Ecol Eng, 60, 316-324, 10.1016/j.ecoleng.2013.07.029, 2013.

Question 8: L92-94: Please describe here key information about the dam.

- Thanks for the valuable comments. We have moved the key information about the Manwan dam from the supplements to the manuscript. Please see line 100-103 on page 6 in the revised manuscript.

Question 9: L95-100: This short site description lacks many important details about the studied island (How “typical” is it? How many those islands in the sidebay vs. forebay? Total areas of those islands and the study site’s area?„„), local climates (What is plateau monsoon climate? Rainfall and discharge regimes? Temperature?„,), and reservoir operation?

- The forebay is in front of the dam in the reservoir, where sediment accumulation can not form islands but build up cohesive sediment layers at the bottom because of the deep water and the high flow rate near the hydropower stations within the dam. We had presented the description of “sediment accumulates in forebays and sidebay islands” in line 39-40 on page 3 in the revised manuscript. In the upstream section of the Lancang-Mekong River in China, there were about 33 sediment-deposited islands in the reservoir sidebay, of which 81.8% are located at the convex bank, and 18.2% at the concave bank. Hence, we selected the widely distributed type of island at the convex bank for investigation, which the “typical” island refers to in this study. To make it clearer, we have revised the description to “This study selected the widely distributed type of island at the convex bank for investigation, which is located in the Manwan Reservoir ”. Please see line 93-98 on page 5-6 in the revised manuscript. The studied island has a surface area of 1.3 $\times$ 104 m2, and the total area of the 33 sediment-deposited islands was estimated to about 4.3 $\times$ 105 m2. The information has been also updated in line 94 on page 5, line 99 on page 6 in the revised manuscript.

- The subtropical plateau monsoon climate refers to that the air temperature features no distinct seasons. This sentence has been revised to “Manwan has a subtropical plateau monsoon climate, and the temperature features no distinct seasons”. Please see line 103-104 on page 6 in the revised manuscript.

- The “reservoir operation” means “water level fluctuation induced by reservoir operation”, which has been corrected to make it clearer. Please see line 105 on page 6 in the revised manuscript.

Question 10: L104: Your site map needs to distinguish clearly the locations and labels of groundwater wells from those for sediment sampling. It is now very confusing. Please think about showing some key site labels on the site map (Fig. 1), and providing more details in the supplementary information, like Fig. S3 or Fig. 3 in your response to the second reviewer comments.

- We thank for the editor’s comments. The groundwater wells/sediment sampling sites and gas sampling sites were indicated in red and yellow dots, respectively, in Fig. 1b, and the labels were showed in Fig. 1a. To make it clearer, we have modified Fig. 1, and provided more details in the supplementary information. Please see Fig. 1 and the updated supplements.

Question 11: L122: Please describe how you kept the collected samples to prevent sample exposure to air.

- The samples were kept in the plastic ziplock bag to prevent exposure to air. This information has been updated, and please see line 130-131 on page 7 in the revised manuscript.

Question 12: L130: I wondered how you could measure DO in situ using the 6600 sonde. Was it possible to put in in the well with 9 cm diameter?

- We are very sorry for the wrong description here. The YSI 6600 was applied to the DO measurements in the reservoir, and another portable DO meter was used to measure the DO at each well by directly putting the probe to the well. This mistake has been corrected. Please see line 136-139 on page 7 in the revised manuscript.

Question 13: L160: What do you mean by "the range of the uncertain"?

- In this study, we used simple spline interpolation to interpolate the methane emissions from the island and adjacent reservoir based on several measured values. This method is valid, but there exist the range of uncertain, which is similar to error margin.

Question 14: L178: pomA?

- The pmoA gene is the most commonly used functional markers of methanotrophs, which encodes a subunit of the particulate methane monooxygenase (Nauer et al., 2012; Sheng et al., 2016).

Nauer, P. A., Dam, B., Liesack, W., Zeyer, J., & Schroth, M. H. (2012). Activity and diversity of methane-oxidizing bacteria in glacier forefields on siliceous and calcareous bedrock. Biogeosciences, 9(6), 2259-2274.

Sheng, R., Chen, A., Zhang, M., Whiteley, A. S., Kumaresan, D., & Wei, W. (2016). Transcriptional activities of methanogens and methanotrophs vary with methane emission flux in rice soils under chronic nutrient constraints of phosphorus and potassium. Biogeosciences, 13(23), 6507-6518.

Question 15: L198: Please also provide % DO values to allow for a better assessment of O2 availability.

- Thanks for the valuable suggestion. We have changed DO concentrations to % DO values. Please see line 211 on page 11 and Figure 2 in the revised manuscript.

Question 16: L220: At which "island sites"?

- Here, it means that high CH4 emissions were observed at the sites on the island other than the reservoir. To avoid confusion, we have revised this sentence to "High methane emission rates were observed at the island center, with a maximum of 10.4

mg h-1m-2." Please see line 233-234 on page 11 in the revised manuscript.

Question 17: L220-227: Please describe the proportions represented by the edge sink, the low-emission ring, and the core source in the total island emission.

- The total island emission contained the emission from the low emission ring and the core source, which was estimated to 8.3 and 5.4 g h-1, accounting for 60.6% and 39.4%, respectively. This information has been updated in line 239-240 on page 12 in the revised manuscript. However, we are not sure how to get the proportions represented by the edge sink in the total island emission.

Question 18: L243 (and L206-207): Please describe how "hysteretic response" occurred. Delays in the response of islands water levels to rising reservoir levels appear only slight during the initial rising phase, and almost negligible on the descending limb of the water level.

- The hysteretic response occurred in presence of head gradients and sediment resistance (Gerecht et al., 2011). The information has been updated in the revised manuscript. Please see line 258-259 on page 13.

- Since the water permeability was high for sands, the hysteretic response is slight in the sand-deposited island. Data from the automated water level recorders indicated that the water level responses in the island lagged the reservoir stage by 20–30 min (line 222-224 on page 11). The delays on the descending limb of the water level become negligible due to the water conservation of sediments in the island.

Gerecht, K. E., Cardenas, M. B., Guswa, A. J., Sawyer, A. H., Nowinski, J. D., & Swanson, T. E. (2011). Dynamics of hyporheic flow and heat transport across a bedâĂŘtoâĂŘbank continuum in a large regulated river. Water Resources Research, 47(3).

Question 19: L297: Under which reservoir operation? Do you mean under the conditions of fluctuating water levels?

- Yes, it refers to 'under the conditions of fluctuating water levels'. We have checked the similar descriptions throughout the manuscript and revised them to "under water level fluctuation induced by reservoir operation" to make them clearer. Please see line 105 on page 6, line 308-309 on page 15 and line 318-319 on page 16 in the revised manuscript.

Question 20: L298: Please provide the range reported for other reservoir banks.

- The range is -0.08–0.66 mg h-1m-2. This information has been updated in line 309-310 on page 15 in the revised manuscript.

Question 21: L301: Quantitatively the magnitude of "concern"? This statement is contradictory to what you suggested in the previous section (L286-289).

- Thanks for the careful corrections. We have deleted this inappropriate description here.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-380/bg-2018-380-AC4-supplement.pdf

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