

Review of Guerin et al.

Effect of sporadic destratification, seasonal overturn and artificial mixing on CH<sub>4</sub> emissions from a subtropical hydroelectric reservoir

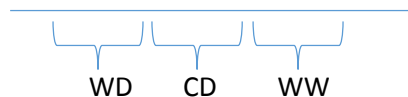
This manuscript discusses 3.5 years of diffusive CH<sub>4</sub> data measured every two weeks at nine stations at a subtropical hydropower reservoir in Laos. The authors present temperature, oxygen and CH<sub>4</sub> profile data and discuss the spatiotemporal variability of CH<sub>4</sub> emission dynamics of the reservoir. They found that occasional destratification and seasonal overturn impact the temporal dynamics of emissions, while mixing induced by a water intake created an emission hot spot. There is an impressive amount of data included in this study that resulted in novel conclusions regarding the relationship between the spatiotemporal variability of CH<sub>4</sub> dynamics and reservoir hydrodynamics that has implications for gas dynamics in both natural and man-made water bodies. The methods are technically sound, although some more details are necessary for a more thorough understanding. The results are well presented, but a few modifications to figures would help the reader follow the text better. The discussion covers the main conclusions, but the writing could be clearer in some sections for the reader to absorb them more efficiently. Ultimately, I feel this manuscript contains an excellent dataset with unique conclusions that will be useful to the field and thus recommend it for publication following minor revisions that I have outlined below.

General comments:

1. For the most part, the English is good throughout the paper. It does require some grammatical corrections, of which a few I will suggest to look out for (but this is likely not an exhaustive list).
  - a. The word 'a' should be used in certain situations. For example, lines 27 and 54 where it should read 'recognized as a source' and 'known to be a source', respectively.
  - b. While 'fortnightly' does mean 'every two weeks', it is not the most commonly used word and I would recommend the authors avoid using it as many readers may not know its meaning. In many instances, it can be replaced with 'every two weeks' and in some instances there does not necessarily need to be a mention of the sampling resolution (see specific comments).
  - c. There are many places in the text where the authors could replace the phrasing 'X of Y' with simply 'Y X'. For example, on line 171 it now reads 'vertical profiles of O<sub>2</sub> and CH<sub>4</sub>', but this could be changed to 'vertical O<sub>2</sub> and CH<sub>4</sub> profiles'. This is an easy fix that works in the majority of cases and sounds more eloquent.
  - d. Some words are pluralized incorrectly. For example, on line 69 'overturns' is incorrect.
  - e. In some places, words are incorrectly ordered. For example, on line 72 it should read 'of annual CH<sub>4</sub> emissions'
2. I believe I did not see anywhere in the text the words 'artificial mixing' as stated in the title of the manuscript. I am torn on the use of the word 'artificial' here. It is artificial in the sense that it is not brought on naturally by way of convection or wind, for example; however, it is still mixing and I would rather say it is simply 'mixing induced by the water intakes'. While you cannot say all of that in the title then it is fair to say 'artificial mixing' but this must be defined in the abstract and again early on in the discussion.
3. I believe that the water level changes and consequent seasonal surface area changes must be important to CH<sub>4</sub> storage and emissions. The surface area increases threefold from dry to wet seasons. That must have an impact on total emissions. In fact, this is also very important in terms of storage values if the increase in depth also increases storage volume. This is never

explicitly discussed in the paper in terms of the results. I would like to see a bit more discussion of this.

4. The authors do not report much about the k600 values that they estimated, which are crucial for estimating diffusive emissions. I would like to see more details about the values and variability of k600 over the years and seasons and across stations.
5. Section 4.2 – The first two paragraphs (lines 438-476) cover both sporadic destratification due to river inflows and seasonal overturn. It is too confusing to have them combined in this discussion. Separate them out for the reader.
6. The authors should be careful with the sampling resolution recommendations that they make on lines 553-572. Their resolution was only 2 weeks and there was ample time between samplings for events to occur and to be missed. See specific comments for more details.
7. Table 1 – I would like to see depth ranges for these sites
8. Table 3 – the left column descriptions are not easy to understand – make these much more specific. For example, ‘total emissions from reservoir’ includes ebullition and diffusion, correct? Then put that in parentheses
9. Figure 2 – the CH<sub>4</sub> scale should be reduced in any panel in which necessary to see the trend of the line. They all don’t have to be the same scale. State in the caption that the reader should note the changing CH<sub>4</sub> scale.
10. Figures 3, 6, and 7 – Instead of color coding the seasons on these figures, I think it would be easier for the reader to see labels depicting the length of the seasons, like this:



#### Specific comments:

1. Line 30 – delete ‘fortnightly’ and ‘parameters’. Add ‘every 2 weeks for 3.5 years’ after ‘concentrations’
2. Line 35 – why parentheses around the reference?
3. Line 37 – ‘dependent on the thermal’ – watching spelling of ‘dependent’ and ‘on’ instead of ‘of’
4. Line 39 – avoid using ‘They’ to start a sentence. Here you can say ‘Concentration and storage’
5. Line 40 – delete ‘the’ in ‘decreases of the CH<sub>4</sub> storage’
6. Line 41 – delete ‘sporadic’ here – it’s not necessary
7. Line 41-42 – here you can say ‘These sporadic emissions occurred...’
8. Line 42-43 – you do not need to say ‘the overturn’, you can simply say ‘overturn’
9. Line 44 – should read ‘these extreme CH<sub>4</sub> emissions’
10. Line 46 – it sounds better to say ‘...WW seasons, an emission hotspot was identified...’
11. Line 46-52 – it’s confusing that you are saying the water intake area is a hot spot but during CD that that location is where the lowest emissions are observed. I recommend deleting the sentence about CD season – it’s not necessary. I also recommend that you explicitly state here that the reason this location is a hot spot is because of the ‘artificial’ mixing induced by the water intake. Otherwise, the reader is left wondering why and whether or not you actually know the answer.
12. Line 64 – before discussing that diffusive fluxes are usually highest when stratification weakens, the authors should mention that CH<sub>4</sub> builds up in anoxic hypolimnions of stratified water bodies
13. Line 66 – doesn’t ‘amictic’ refer to lakes that freeze?
14. Line 69 – delete ‘the reservoir’ and don’t make ‘overturn’ plural

15. Line 72 – ‘of annual CH<sub>4</sub> emissions’ instead of ‘of CH<sub>4</sub> annual emissions’
16. Line 77-81 – I recommend re-writing this sentence: ‘The spatial variability of diffusion in reservoirs is less prominent with a few exceptions of higher emissions (1) in areas where dense forest is flooded (Abril), (2) at shallow sites (Zheng.), and (3) at river inflows (Musenze).’ Also, be more specific with shallow sites. Were these simply littoral areas or just because of depth no matter the location? What would be a depth range?
17. Line 83 – in what way does the spatiotemporal variability ‘significantly affect carbon budgets and emission factors’? In a negative or positive way?
18. Line 85 – add ‘reservoir’ after ‘subtropical’
19. Line 85-86 – define ‘Lao PDR’ here instead of line 99
20. Line 86 – add ‘previously’ before ‘studied’
21. Line 89 – ‘in previously published CH<sub>4</sub> budgets due....’ Does this refer to previously published CH<sub>4</sub> budgets of NT2R? I guess so but be specific and cite papers.
22. Line 90 – extra period
23. Line 91-92 – you state that data was taken over a ‘three and half year period (May 2010 to December 2012)’ however this is only 2.5 years. Then you finish the sentence talking about concentrations that started in June 2009. This is confusing.
24. Line 101 – should read ‘in April 2008 with full water level reached by October 2009 and the power plant commissioned in April 2010.’
25. Line 102 – I believe ‘commissioned’ here means that the turbines were officially turned on. If this is the case, please specify that here as it directly relates to your results regarding Res9 hot spot.
26. Line 104 – is 2 m<sup>3</sup>/s the real flow? That seems quite low.
27. Line 106-107 – Most people would expect a hydroelectric reservoir to have the intakes and power station be at the dam itself, but I believe that NT2R is set up slightly differently with the intake and power station at another end of the reservoir. While you have other papers describing this, you should state that explicitly here. It also lets the reader know why you state that the water used for electricity is delivered from the water intake to the powerhouse, which is a sentence that I, at first, thought was unnecessary.
28. Line 116-117 – here you have more dates about water level and the study period that don’t exactly match the dates on lines 91-92. This is all confusing, especially here where you say that the reservoir water level was constant til April 2010, which was after your measurements started (June 2009?). Water level started to change in April 2010 when the turbines were put to use but online line 116 you say ‘After the commissioning during the studied period (June 2009 to Dec 2012),’ of which then June 2009 to April 2010 is not technically after commissioning.
29. Line 118 – the authors should explicitly state (1) that the surface area triples from dry to wet seasons, (2) that the depth increases by X meters at most locations, and (3) what the volumetric changes of the reservoir are over a season. These are important values related to your results.
30. Line 122 – this has already been stated twice before (nine stations monitored fortnightly)
31. Line 124 – what characteristics are in the table?
32. Table 1 should also contain depth ranges at each site
33. Line 129 – here you should state the depth of the intake relative to depth of water column seasonally
34. Line 139 – using the words ‘since January 2009’ implies constantly measured. Is that the case?
35. Line 144 – is it a custom-built water sampler? If so, state that.
36. Line 146 – water samples were stored air free, correct? Please state that

37. Line 160 – should read ‘Between sampling depths of the vertical CH<sub>4</sub> profiles, concentrations were assumed to change linearly...’ But what was the sampling resolution for the profiles? Be specific.
38. Line 171 – ‘since the resolution of the vertical O<sub>2</sub> and CH<sub>4</sub> profiles was not high enough in 2009’... we don’t know the resolution at all
39. Line 179 – you need to define Km too
40. Line 182 – ‘limit of oxygen penetration’
41. Line 184 – delete ‘fortnightly’
42. Line 190-193- since you need to define kt, you should move that to the end of this paragraph (after delta C) and then go right into the equation for kt
43. Line 198-210 – in general here, this paragraph is very confusing. First, you say used both k600s determined by wind and rain and the Macintyre 2010 equation, but how? Did you average them for each station? Next, I believe you are trying to validate the use of these two k600 equations by stating that the fluxes calculated with them agreed with chambers and eddy fluxes. If this is true then it needs to be stated clearer. Also, I don’t understand how the eddy covariance system would have impacted buoyancy fluxes. Then for wind speed and rainfall, did you use both met stations data? How did you split them amongst stations? I am guessing you used a k600 for each station on each sampling, but you never state that. Then you report an average k600, which confuses the reader more. Please be more specific as to what you used.
44. Line 206-207 – delete ‘for calculation purpose’
45. Line 218-220 – how exactly did you determine the k600 here? With chambers? These measurements that are not shown, are they in another paper?
46. Line 226 – ‘it has been shown’
47. Line 264 – reference Figure 3a after ‘temperature was defined.’
48. Line 267 – ‘oxycline’ and not ‘oxicleine’
49. Line 277-278 – ‘After the commissioning of the reservoir and the turbines were powered on in April 2010, the water column located near the intake (RES9) completely mixed as indicated by the homogeneous temperature and oxygen profiles with depth in every season’.
50. Line 283 – ‘on average’
51. Line 291-294 – You are reporting two averages here and it’s a bit confusing. Maybe separate this into two sentences and be explicit. Is the 215 uM the highest recorded average of a single day (including all stations)? And then the other averages are seasonal averages, which includes all stations and all days within a single season?
52. Line 301 – delete ‘the reservoir’
53. Line 301-313 – I am very curious about how much of the CH<sub>4</sub> storage is due to CH<sub>4</sub> accumulation and how much to any volumetric changes of the hypolimnion. The oxycline must move throughout the year, which will impact the hypolimnetic volume. Also, do the large changes in surface area and water level impact the hypolimnetic volume? I think these numbers would be interesting to see for each season too.
54. Line 324 – was it the single highest aerobic oxidation rate observed in CD of 2012? If so, make sure to put the word ‘single’ as you just state earlier in that sentence that WW and WD have higher rates than CD.
55. Line 333 – why do you cite supplemental figure S3 before S1 and S2? Change the order of the figures if there is no mistake here.
56. Line 337 – ‘in all seasons’
57. Line 346 – delete ‘at’ before ‘all stations’
58. Line 349 – delete ‘the’ in the beginning of the line
59. In table 2, you also report ‘% Fch4 < 1’ but you don’t say anything about it in the text

60. Line 363-364 – you say ‘NT2’ and then the next sentence ‘NT2R Reservoir’ ... be consistent throughout the paper. Check them all
61. Line 365 – ‘lower than those at Petit Saut’
62. Line 367 – ‘for reservoirs ~ 10 to 18 years older’
63. Line 373-374 – should read ‘Following the commissioning of the reservoir and powering of the turbines, CH<sub>4</sub> concentrations at station RES9, which was located at the water intake, were up to 30 times higher than at the other stations (36.6....)’
64. Line 375-376 – delete ‘that is’ and put the rest of the sentence in parentheses
65. Line 377 – how are concentrations in WW higher than those in WW? Something strange here
66. Line 390-393 – this is a discussion point and not for results
67. Line 408-416 – I understand your point here but it is a bit convoluted. You should explicitly state that you ‘did not see a significant increase in methane oxidation during overturn in the CD season except for in the year 2012 when hypolimnetic CH<sub>4</sub> concentrations were still quite high’. I believe you need to state here too that in fact the turnover in this reservoir is gradual and doesn’t just occur in a few short days as observed in other systems. You say that later but I think it’s fair to put that point here now.
68. Line 411 – delete ‘already’
69. Line 418 – delete ‘ in the reservoir’
70. Line 426-427 – ‘storage in the dry year of 2012 was twice that of the wet year of 2011, likely due to a 25% increase in residence time’ - why did the residence time increase?
71. Line 428 – why is the warming of surface waters less efficient? Simply because of the inflows? I agree with this point but the sentence needs to be a bit clearer
72. Line 430 – what I don’t agree with is how a sharper decrease and larger range of temperature from top to bottom means a less stable stratification. A more pronounced thermocline actually induces a more stable water column. Something is confused in your writing here.
73. Line 433 – ‘Therefore, our results suggest that hydrology...’
74. Line 435 – you state that hydrology ultimately influences emissions too but you don’t make that connection here directly. Add one more sentence about this.
75. Line 438 – delete the first ‘the’ and start with ‘Figure 7’
76. Line 443 – ‘and were usually’ .... Everything should be in past tense
77. Line 445 – if these CH<sub>4</sub> bursts were during CD does that mean they were during overturn?
78. Line 447-452 – ‘together with the CH<sub>4</sub> storage in the water column but remained less than 20 mmol m<sup>-2</sup> d<sup>-1</sup>. Sporadic high fluxes occurred in the WD season at Res3,7, and 8 and were usually associated with dT variations less than 2C. The CH<sub>4</sub> storage decreases associated with these fluxes, however, were not as sharp as those observed during other seasons.’ But what is the 20 mmol/m<sup>2</sup>/d all about? Why is this relevant?
79. Line 465 – ‘in a reservoir older than’
80. Line 471-475 – this sentence is a bit long and wordy. You can separate it into two or put in numbers (1) and (2) for the two different points. Delete ‘mostly’ both times. The second half could read as follows: ‘an in areas away from inflows during overturn’. Why does ‘riverbed’ matter here?
81. Line 484 – you finally state here that NT2R destratifies progressively rather than quickly. This should have been stated earlier!
82. Line 485 – ‘when the water body finally overturns as was observed’
83. Line 489-492 – ‘Therefore, during overturn in the CD season, a significant amount of CH<sub>4</sub> is oxidized, but the removal of CH<sub>4</sub> during overturn is not as efficient as...’ Why are the references in the middle of the sentence here? I don’t think they are necessary here.

84. Line 517 – I do not understand the description of this channel. Perhaps a figure would be useful, like an inset on Figure 1.
85. Line 532 – the 18-27% estimate includes hot spots and moments then?
86. Line 536-539 – you need to be explicit here that it was the powered on of the reservoirs that made the difference between 2009 and 2010. Also, you don't have measurements for many months of 2009 so that could also influence the difference between these years, although it was more the hotspot of RES9 following commissioning.
87. Line 541 – I believe you are reporting values only for 2010, 2011 and 2012 here. You should state that you are disregarding 2009 data as it was prior to commissioning of the reservoir.
88. Line 545 – shouldn't it be between 3 and 7 %?
89. Line 547 – delete 'very'.. avoid using this word altogether. It's informal and not necessary usually.
90. Line 547-549 – these locale perturbations and how much they influence mixing are also dependent on depth, however
91. Line 553 – you are talking about total daily emissions here, right? Add the word 'daily' if so
92. Line 562-567 – can you really make any recommendations on sampling frequency when your data was only at a 2 week resolution? You do not know what happened in the two weeks between samplings. Even if you saw high emissions in two consecutive samplings that doesn't mean that it was occurring consistently between samplings. I think you need to be careful here. Clearly, your resolution is better than only seasonally or monthly, but that is likely as much as you can say. Also, if overturn happens quickly in a water body, sometimes just two or three days, then you would definitely miss those emissions if you were not there during those days. This should also be stated here. Your resolution worked only because of the gradual destratification.
93. Line 580 – 'areas far from inflows'
94. Line 583-587 – these lines can be moved to the paragraph before describing sampling resolutions