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Comment

Interactive comment on “Greenhouse gas emissions (CO₂, CH₄ and N₂O) from perialpine and alpine hydropower reservoirs” by T. Diem et al.

Anonymous Referee #1

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Reviewer comments on "Greenhouse gas emissions from perialpine and alpine hydropower reservoirs" by T. Diem et al. submitted for publication to Biogeosciences

This paper reports on greenhouse gas (GHG) emissions (CO₂, CH₄ and N₂O) from 11 hydroelectric reservoirs located in Switzerland and the authors focused mainly on CH₄ and tried to propose a CH₄ mass balance. The global significance of GHG emissions from man-made lakes is still unclear and therefore, this work is of great importance for the field, especially since data from temperate reservoirs are sparse. Besides the quantification of atmospheric emissions, three important points are still under debate: (1) the identification of the GHG pathways and particularly the significance of emissions

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just below the dam and emissions from the rivers downstream of the dam [see Abril et al., 2005; Guérin et al., 2006; Roehm and Tremblay, 2006; Kemenes et al., 2007 and the debate between P. Fearnside and the P. Rosa Team], (2) the sources of carbon leading to emissions [see Huttunen et al., 2002; St. Louis et al., 2003; Guérin et al., 2008a], and (3) the significance of the global warming potential of nitrous oxide (N₂O) emissions from reservoirs [Huttunen et al., 2002; Hendzel et al., 2005; Guérin et al., 2008b].

In this paper, the authors present (1) CO₂, CH₄ and N₂O diffusive emissions from the reservoir surfaces calculated from surface concentrations and gas transfer velocities depending on wind speed; (2) CH₄ bubbling emissions data obtained on one reservoir by direct measurements with funnels and (3) they estimated the CH₄ loss after the water passes through the turbines of 6 reservoirs under study. Also, they measured CH₄ concentration in the rivers feeding 6 of the reservoirs under study and in the sediments of one reservoir. The carbon isotopic signature of CH₄ (d¹³C-CH₄) was determined for all the vertical profiles of CH₄ in the water column in all the reservoirs and in the sediments they sampled. Based on this material, they attempt to identify the potential sources of CH₄ emissions from these reservoirs.

In that respect, this study could provide new insights on this very topical subject which fits well in the subject areas of Biogeosciences. However, in its present form, it is very difficult to evaluate the quality of the work as it is presented in this MS. I think that the dataset is highly valuable; therefore, I recommend resubmission of this MS after major revisions.

General/Major comments

1-The introduction does not provide all information needed to understand the context of the present study. The actual questions on this hot topic are not listed here (see my general comments) whereas the sampling strategy proves that, in some ways, they aimed to provide new information about these three points. In addition, the introduction

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is not well organized; in particular, the paragraph P3701 L6-11 should be at the end of the introduction.

2-No information is provided about the number of replicates for individual measurements (for water and sediment samples), nor the number of stations for each campaign on each lake.

3-For the loss at the turbines, where were the samples representing the water entering the turbines sampled? Usually, the water column is partially mixed before entering the turbines and this makes the quantification of the loss at the turbine difficult to estimate accurately from vertical profiles. Ideally, the samples have to be taken at the intake. How far from the dam the river water sampled? This latter information is important to know if the so-called "loss at the turbines" is only the loss at the turbines or if it also includes the efflux from the river downstream of the dam.

4-A classification of the lakes is given based on the shape of CH₄ vertical profiles (P3709). Based on the figures provided in the MS and the figures in additional material, this classification is not relevant since the shape of the profiles changes significantly at each sampling date (see Figure 3a, 4, A1, A2a and b, A3a and b, A5, A7). This section has to be rewritten.

The shapes of the vertical profiles of CH₄ concentration in the reservoirs in Switzerland vary seasonally and are very different from those from reservoirs in Finland (Huttunen et al., 2002) and from tropical reservoirs (see Guérin et al., 2006, Guérin and Abril, 2007; Kemenes et al., 2007) which both show, whatever the period of the year, a CH₄ rich hypolimnion and a CH₄-"depleted" epilimnion. These differences have to be discussed taking into account the physics of the reservoirs: temperature of the water from the inflow, temperature profiles in the reservoirs, information about river discharge in the reservoir and from the reservoir (unfortunately, this information is not shown or discussed in the MS whereas they are available). Also, the differences in the carbon cycle between temperate and the tropical reservoirs studied so far have to be

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considered (source of organic matter driving the emissions, age of the reservoir). For this latter point the author should refer to Huttunen et al. (2002), St. Louis et al. (2003) and to Guérin et al. (2008a). The classification is given in the results section, but this dataset is not discussed.

5- Bubbling fluxes were measured where they were observed (P3710 L13-22). Bubbling is episodic and thus it is difficult to accurately quantify it. The author should clearly mention that bubbling was probably less important at the other lakes but they can not assume that it does not occur. Even if CH₄ bubbles can dissolve into the water column on their way to the atmosphere, it was shown that this is not significant in shallow aquatic environment like lakes and reservoirs (McGinnis et al., 2006). Therefore, the authors cannot consider the fact that they observe low CH₄ concentrations in some reservoirs to speculate that there is no bubbling in these reservoirs (P3717 L17-18).

6-Illustrations are not of well presented.

Rather than showing only CH₄ and d13C-CH₄ vertical profiles in the water column of different reservoirs on separate graphs, the authors should merge graphs showing O₂, pH, temperature, CH₄, d13C-CH₄ and N₂O in one figure with several panels for several representative reservoirs. Oxygen, pH and temperature could help (1) the reader to understand the variations in CH₄, d13C-CH₄ and N₂O showed in the different figures and (2) to shorten and clarify the section 4.3 (P3708-3712). This should allow the graphs to show all the data already included in the MS and most of those presented in the supplementary material.

The CH₄ core profile should be in the MS.

Table 3 is not comprehensive and not precise enough. The name of the reservoirs should be given as well as the gas pathway taken into account. It seems that the authors want to compare only diffusion at the air water interface but, for instance, the average taken from St Louis et al. (2000) includes bubbling. Sometimes, the ranges are given in the original publications but not reported in the table. Why are natural

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lakes from temperate regions included in the table whereas the title of the table is emissions from reservoirs? Why did the authors exclude four lakes studied by Soumis et al. (2004)? The average CO₂ and CH₄ emissions from tropical reservoirs given by St Louis et al. (2000) does not provide a credible estimate since they "first averaged the 1 to 2-year-old reservoirs before taking an overall average" (see St Louis et al., 2000, Table 1). N₂O emissions from the tropical reservoirs (Guérin et al., 2008b) are missing as well as CO₂ and CH₄ emissions from reservoirs in Brazil reported in Guérin et al. (2006).

7-The authors attempted to propose a CH₄ mass balance for some of the reservoirs under study. Even if these individual mass balances will be incomplete (all pathways and sources were not estimated on each reservoir), the authors should add an additional table showing the amount of CH₄ entering the reservoirs (in gC.d⁻¹), the contribution of the different pathways of CH₄ to the atmosphere integrating the surface area changes between the different sampling dates (in gC.d⁻¹) and the amount of CH₄ exported downstream (in gC.d⁻¹). This will clarify the MS and allow the reader to evaluate a surprising assumption. The authors claim here that the sediments are not a CH₄ source for the sediment but based on their discussion, it is not difficult to estimate the validity of their assumption.

8-Quite often, the references are not cited for what they show

9-The MS suffers from problems of organization and errors in grammar, word choice, and sentence construction and poor illustrations (figures and tables).

Specific comments:

P3700 L6: In the framework of emissions from reservoirs, "net emissions" refers to the difference between the dam emissions (gross emissions) and the pre-dam emissions (Guérin et al., 2008b). Net should be removed.

P3700 L20: A comparison of GHG emissions between a hydroelectric reservoir and

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other thermal alternatives over 100 years was given by Delmas et al. (2001).

P3701 L2-5: This assumption is wrong for tropical reservoirs (Guérin et al., 2008b) which emit proportionally more CH₄ than boreal and temperate reservoirs.

P3701 L21-23: Abril et al. (2006) does not give CH₄ concentrations in natural rivers. Upstill-Goddard et al. (2000) reviewed CH₄ concentration in non dam-impacted rivers. High CH₄ concentration below dams were reported by Lilley et al. (1996) and Upstill-Goddard et al. (2000) for temperate ecosystems and by Guérin et al. (2006) and Kemenes et al. (2007) for tropical ecosystems.

P3702 L17-20: Is the water taken from the epilimnion or the hypolimnion?

P3702 L21-27: The authors should refer to table 2 for the description of the sampling frequency and dates

P3703 section "Hydrographic data". This section describes mainly the sampling strategy. The authors should refer to tables 1 to inform the reader about which parameters were measured in which lakes.

P3703 L15-22: No information is provided about pH and Alkalinity measurements that were used to determine pCO₂. Were they performed on filtered or non-filtered samples? As mentioned in the MS, the determination of pH was sometimes problematic with the equipment used (P3708 L5-7), it would be useful to give the specification of the pHmeter, the pH probe and the buffers used for this study. The detection limit and the accuracy obtained with the equipment must be mentioned in order to evaluate the quality of the pCO₂ dataset.

P3705 L13-P3706 L15: As described page 3715 the emissions calculated from surface partial pressure can vary significantly depending on the gas transfer velocities vs. wind speed relationships used. I would recommend the authors to calculate their diffusive fluxes with 2 different relationships in order to give a range for the diffusive fluxes. In addition to Crucius and Wanninkhof (2003), Upstill-goddard et al. (1990) and Frost

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and Upstill-goddard (2002) determined the gas transfer velocities in temperate environments. Cole and Caraco (1998) provided a compilation of relationships obtained in several lakes.

P3706 section 3.5. This section is useless in its actual form and should be at the end of the “Methods” as all carbon pathways must be taken in the carbon mass balance. See also the major comment #7.

P3706 L20-25: Was the water content of the sediment taken into account for CH₄ concentration in the sediments? How many replicates?

P3707 L15: Where was the "spill-water" sampled?

P3707 L23: Data from Abril et al. (2006) were obtained during a unique 24h experiment. In addition, data are given in ppmv, thus they cannot be given in μM without giving the conversion factor and temperature considered for this conversion. It would be better to refer to Abril et al. (2005). The data should also be compared with data from boreal reservoirs (e.g., Huttunen et al., 2002).

P3708 L5-7: this should be mentioned and discussed in the methods section

P3712 L7-11: The specific situation described for Lake Lungern would better fit in the Site description.

P3713 L4-22: Seasonality of emissions must be studied by statistical test but not by correlation. As mention by the authors, the correlations between CO₂ fluxes and pH and Alkalinity does not make any sense since the fluxes were calculated using these two parameters.

P3713 L24-P3714 L26: Unfortunately, the results about N₂O emissions from the littoral zones of the reservoirs are not shown in the tables or figures.

P3713 L6: Why do the authors consider that the N₂O fluxes are "probably overestimated"?

P3714 L11: The fact that the global warming potential of N₂O emissions of lowland reservoirs is a surprising result that should be highlighted.

P3715 L5-23: The gas transfer velocities are site specific (Kremer et al., 2003; Borges et al., 2004; Guerin et al., 2006). Depending on the k-wind speed relationship used and the specificities of the site under study, it can be found that the TBL under or overestimates the fluxes. Ideally, fluxes have to be measured on site. Matthews et al. (2003) compared SF₆ and chamber measurements. They used inappropriate chambers without wall extending below the water surface. As mentioned in their paper, this lead to an overestimation of the fluxes by a factor 3 to 5. Therefore, their comparison is not valid. Soumis et al. (2004) did not compare different methods for the estimation of fluxes. Guerin et al. (2006) compared fluxes obtained by the floating chamber and Eddy Covariance methods. Also, see my comments on flux calculations.

P3716 L2: Abril et al. (2005) did not show that emissions from the Petit Saut Reservoir reach a steady state, the emissions were still decreasing.

P3716 L4-9: Guérin et al. (2008a) showed that the flooded soils were still the main carbon source in a 10 y old reservoir that has not yet reach its steady state whereas Huttunen et al. (2002) suggest that observed emissions in two 20 y old boreal reservoirs are due to the spiraling of autochthonous and allochthonous carbon.

P3717 L14-16: How can a short water residence time cause a high supply of organic matter to the reservoir?

P3717-3719 Section 5.3: This section is hard to follow without a suitable table to illustrate their argumentation (see major comment #7)

Table 1: It would be useful for the reader to provide average rainfall rate and air temperature (or the ranges) and, if available, amount of carbon that were flooded in the reservoirs.

Table 2: The authors should give the number of samples, separate data from open

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waters and data from the littoral zone and give the average.

Table 3: see major comment #6

Same as above for the graphs in the MS and the graphs in additional material.

REFERENCES cited in the review and not cited in the MS.

Borges et al., 2004, *Limnol. Oceanogr.*, 49:1630-1641

Delmas et al., 2001, *Global Biogeochem. Cycles*, 15, 993-1003

Frost and Upstill-Goddard, 2002, *Limnol. Oceanogr.* 47, 1165-1174.

Guérin and Abril, 2007, *J. Geophys. Res. (Biogeoscience)*, G03006, doi:10.1029/2006JG000393

Guérin et al., 2008a, *Appl. Geochem.*, 23, 2272-2283

Guérin et al., 2006, *Geophys. Res. Lett.*, 33, L21407, doi:10.1029/2006GL027929

Guérin et al., 2008b, *Geophys. Res. Lett.*, 35, L06404, doi: 10.1029/2007GL033057

Hendzel et al., 2005, *Environ. Sci. Technol.*, 39, 4353-4360

Kremer et al., 2003, *Estuaries* 26, 829-836

Lilley et al., 1996, *Mitt. Int. Ver. Limnol.*, 25, 187-196.

McGinnis et al., 2006, *J. Geophys. Res.-Oceans*, 111, C9, C09007

Roehm and Tremblay, 2006, *J. Geophys. Res.*, 111, doi:10.1029/2006JD007292

St. Louis et al., 2003, *Biogeochem.*, 64: 97-100

Upstill-Goddard et al., 1990, *Tellus* 1990, 42B, 364-377

Upstill-Goddard et al., 2000, *Global Biogeochem. Cycles*, 14, 1205-1217.

Interactive comment on *Biogeosciences Discuss.*, 5, 3699, 2008.

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