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Interactive comment on "Are flood-driven turbidity currents hot-spots for priming effect in lakes?" *by* D. Bouffard et al.

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Replies to Reviewer 1's comments

R1-1- 'My first question deals with contradictory results between old observations of Meybeck et al. (1991) and those presented in the MS. Since in the present study measurements were made on a single date, could we expect that oxygen replenishment could be a transitory phenomenon? If oxygen profiles were measured throughout time, could we expect first an oxygen replenishment (in accordance with old observations) then followed by a decrease in O2 below initial values due to a stimulation of microbial respiration. For me, both results are not necessarily contradictory and this aspect could be discussed in the MS. '

About apparent inconsistencies with Meybeck et al's (1991) results : Meybeck et al.

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(1991) suggested, without yet no mean of proving it, that positive oxygen anomalies should be associated either with winter lake cooling and subsequent along slopes oxygen-rich density current, or with river intrusion. Year 1983 shows remarkable examples of anomalies near the bottom at the deepest point of the lake (their Figure 7 reproduced below).

However the correlation with river discharge from the Rhône or the Dranse remains unclear. Deep O2 anomalies may then occur even under normal discharge condition calling for an important role of lake surface cooling in deep O2 replenishment (Figure 1). For instance, Meybeck et al (1991) observed many positive anomalies in the first three months of 1983. Yet, the weak discharges observed in January to March 1983 should not provide enough momentum to the intrusion to reach the middle of the lake and instead a quickly mixed intrusion would have been expected. It is important to notice that the intrusion reported by Meybeck et al. (1991) are found at the lake bed while our observation from the 2015 floods indicates intrusion within the water column. Their dynamics are therefore different.

In any case, such phenomena are transitory and horizontal : vertical and horizontal diffusion will rapidly smooth any positive or negative oxygen anomaly.

About an oxygen replenishment followed by a consumption: As mentioned by the reviewer, the decrease in oxygen was certainly following an increase in oxygen in the intrusion. Our measurements were carried out 3 days after the discharge peak and an oxygen sensor moored at the depth of the intrusion (for instance at BP18) will likely have recorded first a slight increase of O2 and then an excess consumption compared to another O2 sensor moored outside the intrusion layer. However a detailed analysis of this temporal evolution is not possible with our measurements and would require interesting follow up.

A revised version of the manuscript (section 4.1) will discuss in more detail the apparent discrepancy between the anomalies found in Meybeck et al (1991) and our

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observations based on the above mentioned points.

R1-2 ‘ A second question related to the first one: Even if I believe that co-metabolism and/or priming effects arise, could O2 transported in river water be a primer of lake C mineralization? This question could perhaps be partly solved - and discussed- if initial O2 levels during dark bioassays were given. - I am not specialist at all of this question but would it be interesting to discuss of O2 concentrations both in terms of saturation levels and mg L-1? The related questions are : could higher river temperature lead to saturated but “low” O2 concentrations (in mg L-1) inputs in lake water, partly explaining O2 depletions in lake water measurements? ‘

Initial O2 concentrations were not different between incubations treatments. Overall, they ranged between 8-10 mg L-1. By the time that collected lake water was brought back to the lab and incubations started, DO had got close to equilibrium with the atmosphere. For the field data, the assumption made by the reviewer would imply that bacterial respiration/organic matter mineralization is stimulated by higher oxygen concentrations. Indeed there are some evidence of such a stimulating effect when shifting from anoxic to oxic conditions (Hulthe, G., S. Hulth, and P. O. J. Hall , 1998. Effect of oxygen on degradation rate of refractory and labile organic matter in continental margin sediments, Geochimica et Cosmochimica Acta, 62(8), 1319-1328). However, the stimulating effect has not been observed for varying oxygen concentrations within the oxic range. Whatever the considered lake depths, hypolimnetic water was always oxic, O2 being > 10 mg L-1 above 110 m and always > 4 mg L-1 even at greater depths. So priming by oxygen is unlikely to explain neither the bioassays, nor the field data. Regarding the second point, the Dranse water temperatures over the year ranges between 0 - 16°C, and more specifically 4 - 10 °C in spring. Close to oxygen saturation (see comment from rev 3, the Rhône and Dranse rivers shall be closer to 97

‘ Could observations differ if river floods come from ice melt or from (warmer) spring rainfalls? ‘

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This is likely the case since the organic matter carried by the hydrological flows shall be quite different between the two situations. A good reason to carry on research on that topic.

R1-3 ‘ And more minor questions/comments: - P8, L5: is it really 0.22mg L-1 m-1? I am probably wrong but this value seems huge since graphically, we can see variations between ca. 10-11mg L-1 and 5-6mg L-1 between 20 m and 200m deep. Such a decrease of 0.22mg O2 L-1 would lead to O2 levels of 0 mg L-1 on a 50m deep water column ‘

One decimal mistake : 0.022 mg L-1 m-1

R1-4 ‘ I find the results of the dark bioassays very interesting, especially when discussed in the light of priming effect and co-metabolism. It would certainly require further testing to understand in more depth the underlying mechanisms. However, as written, I find it might be a bit confusing for readers since both mechanisms are discussed in two distinct paragraphs. I suggest merging paragraphs 4.4 and 4.5 in a more integrated discussion’ This would be done in an amended version of the ms

R1-5 ‘ Why the 50% treatment was not tested with lake water coming from 200m deep? - Try to justify the selected % of river water introduced in the microcosms. Is 1% still high considering the size of Lake Geneva? Or is it what could be expected during the highest floods? Obviously this might differ as a function of the position in the Lake, but such calculation could render the bioassay more convincing for explaining results observed in May ‘.

Tested ranges are based on bulk estimated values of river mixing in Lake Geneva. Details are provided below. The thickness of the intrusion provides information on the dilution of the riverine water by lake water. We assume first that horizontal dispersion, K_H, is of same order as vertical dispersion, K_z (e.g. conservative case as typically, $K_H > K_z$). The rate of dilution, Γ_δ, can be defined by $\Gamma_\delta = \delta_i/\delta_j$, with δ the thickness

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of the intrusion at the location defined by indices *i* and *j*. Taking $i = BP22$ or entrance of the river Dranse, respectively and $j = BP18$, gives $\Gamma_\delta = 46\%$ ($i = BP22$) and $\Gamma_\delta = 0.9\%$ ($i =$ entrance of river Dranse).

The rate of dilution within the intrusion can also be estimated, assuming negligible particle settling away from the plunging point, by comparing the averaged temperature anomaly in 2 profiles (e.g. BP22 and BP18). The intrusion density, ρ_I, is a function of temperature ρ_T, and particle concentration ρ_C with $\rho_I = \rho_T + \rho_C$ (Figure 2). ρ_I is calculated from the linearly interpolated temperature profile in the absence of intrusion. In so doing, we estimate $\Gamma_\rho = \rho_{C,BP18}/\rho_{C,BP22} = 29\%$ over the 4 km distance between BP22 and BP18. To have $\Gamma_\delta = \Gamma_\rho$, implies to have an horizontal dispersion 1.5 times larger than the vertical dispersion and will lead to a Dranse river fraction at BP18 of 0.4%.

These bulk estimates suggest that the river water is first efficiently mixed in the underflow stage (e.g. most of the dilution is done before the intrusion reaches BP22), then, the dilution rate becomes smaller allowing the intrusion to propagate over a long distance. For SHL2 (BP18), the riverine fraction is about $O(1\%)$ and, as shown above, river contribution increases as stations are closer to the river mouths. The 50% dilution treatment was therefore quite out of the range of possible dilution, we then focussed more attention on the functional consequences of river contrubution at low fractions.

We acknowledge that specifications about why such a range of concentrations has been chosen would be an helpful information to the reader and we would add it in an amended version of the ms (in an Appendix).

R1-6 'Changes that could have occurred between Dranse water entering Lake Geneva in May and Dranse water collected for the bioassays are well discussed in the MS. However, what could have occurred to lake water during the same period? Do we expect huge changes in lake water physico-chemistry between May and bioassays especially after the important spring river floods of 2015'

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Maybe such information could be better emphasized in a revised version of the ms, but hypolimnetic water residence time is very slow in deep Lake Geneva (a matter of decades, see p14, L 7-8) and indeed, N, P and OC concentrations and even temperatures were highly similar between May and October 2015. These specification were already present in the original version of the ms (L7-10, p10).

"Orthophosphate concentrations at 100 m and 200 m depth were very comparable to those recorded during the flood (13 and 29 μgP L-1 respectively at both dates) while nitrate concentrations were slightly lower (620 and 560 μgN L-1 in October, compared to 670 and 630 μgN L-1, in May 2015)."

The rest are minor comments and suggested improvements for the ms clarity that will be integrated in an amended version of the ms

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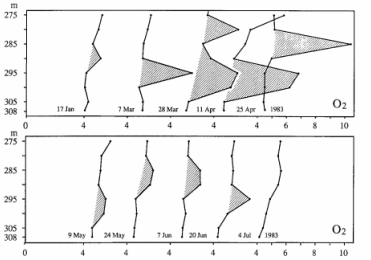

Figure 7. Evolution of dissolved oxygen ($mg \cdot l^{-1}$) at SHL 2 on 10 consecutive profiles from January to July 1983, showing persistence of lens anomalies during a partial overturn

Fig. 1.

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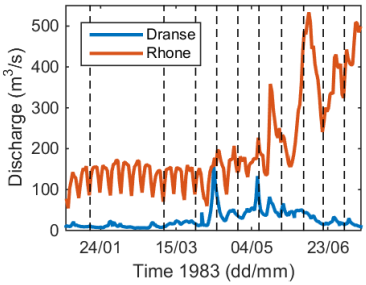

Figure 1R1. The Dranse and Rhône rivers discharges for a year of the Meybeck et al's (1991) study (see also their Figure 7). Dotted lines represent the dates at which positive anomalies had been detected by Meybeck et al (1991)

Fig. 2.

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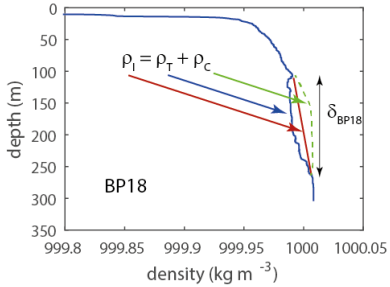

Figure 2R1. Density profile measured in BP18

Fig. 3.

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