Response to the interactive comments on "Dissolved and particulate organic carbon in Icelandic proglacial streams" by Peter Chifflard et al.

Response to anonymous Referee #2 (Received and published: 6 May 2018)

We thank the anonymous referee #2 for careful reviewing our manuscript and for his constructive and interesting comments. We found these most helpful and have revised the manuscript accordingly. We are aware that there exist specific methodological uncertainties which have an impact especially on POC concentration and export estimations, but we would like to highlight, that this is an interesting pilot study for DOC and POC in Icelandic proglacial streams where none currently exists. We would like to point out that this study is an initial stepping stone that raises interesting questions from the observations and highlight the need to further investigations based on these initial studies.

Major comments:

(1) The POC measurement method. I think the authors did a very good job in DOC measurement. But for POC measurement, the method seems too old. As stated in the manuscript, there should be some interference (sometimes it may be very big) due to this old method. I think an elemental analyzer should be used, with inorganic carbon being removed (e.g., via HCl) first. As POC data is widely presented and discussed in this manuscript, so I think this becomes a very clear flaw of the work. In addition, authors reported that POC flux in Iceland is very large in this work and take this as one of the key findings. Given the POC method problem, I think their suggestions (about the big POC flux) are not that convincing.

Response:

The authors agree that the applied method for POC measurement (loss on ignition) is an older method and that it may be possible to eliminate several of the mentioned uncertainties by using an elemental analyzer. However, we are confident that we can account for the major sources of uncertainty in our current calculations. We are aware that clay minerals, present in volcanic ash and soils, may contain water of hydration, which is expelled at ~300° (Lagaly 1993). The dehydration of typical volcanic ash hydrated clay minerals such as allophane may result in a weight loss of up to 36%, with most of the water of hydration lost at temperatures ~ 110°C (Hensen and Smit 2002, Kitagawa 1972), similar to temperatures used for oven drying sediment. Other clay minerals such as kaolinite and montmorillonite show weight losses of about 14% and 15% respectively, losing most of their water of hydration at higher temperatures (Hensen and Smit 2002). Thus, accounting for the water of hydration within the respective sediment composition of our samples would allow for correction of current POC "over-estimates". Furthermore, other accepted methods for the determination of POC concentration can be used e.g., Federer et al. (2008) and Skidmore et al. (2000) detected POC concentration by subtracting the DOC content of filtered water samples from the TOC content may be used to correct for uncertainties.

References:

Federer, U., Kaufmann, P. R., Hutterli, M. A., Schüpbach, S., & Stocker, T. F. (2008). Continuous flow analysis of total organic carbon in polar ice cores. Environmental Science & Technology, 42(21), 8039-8043.

Hensen, E. J., & Smit, B. (2002). Why clays swell. The Journal of Physical Chemistry B, 106(49), 12664-12667.

Kitagawa, Y. (1972): An aspect of the water in clay minerals: An application of nuclear magnetic resonance spectrometry to clay mineralogy. American Mineralogist 57:751-764

Skidmore, M. L., Foght, J. M. & Sharp, M. J. Microbial life beneath a high Arctic glacier. Appl. Environ. Microbiol. 66, 3214–3220 (2000).

(2) OC flux. In this manuscript, organic carbon flux is presented in the conclusion part, which is very strange. I think the flux estimate should be in a separate section, and with all the uncertainties presented and discussed.

Response:

Thank you for pointing this out and for your suggestion. We have now added a separate paragraph to discuss DOC and POC fluxes and uncertainties.

(3) Organic matter process in the glacier meltwaters. I got confused by the authors. At line 5 of page 7, authors suggest that the DOC concentration decrease is likely due to influence of seawater, as indicated by higher electrical conductivity. I went to Table 2, and check for the data of HV (ie. HV01-HV11). When I plot the conductivity against DOC concentration for all the HV station (ie. HV01-HV11), I found no such supporting relationship between conductivity and DOC concentration. Instead, DOC concentration seems slightly increase with increasing conductivity. This is in contrast with the authors words in line 5 of page 7. I have no idea if this is due to my mistake as I am not that familiar with the data as the authors are, but I think anyway the authors explanation here needs more attention.

Response:

Thank you for highlighting the unclear wording. We have changed the wording to highlight the fact that we refer to the observed higher electrical conductivity as an indicator of streamwater-seawater mixing and the transition from stream to estuary, where other processes may influence DOC concentration at this sampling point.

"At the sampling point HV01, located at the end of the lagoon Ölfusá, in the estuary of the river Hvitá, the DOC concentration decreased, possibly as a result of the influence of incoming seawater, indicated by the substantially higher electrical conductivity at this location (Table 2)."

(4) POC decrease at line 7 page 8. I think authors should present stronger evidence to support their idea that the POC decrease may be due to direct use and reworking by benthic organisms, instead of

citing a literature. Did they have evidence of benthic organisms in the sampling site? We indeed observed mosquito-like winged insect in some of the glacier meltwaters in the field. Sometimes there can be some other insects in some of the glacier meltwaters (benthic like). Is that the case in this current work? Are these insects being removed in the membranes before the sample was measured?

Response:

The authors agree that insects which are released on the filters can influence the measurements of POC concentration. To avoid such impacts, the authors checked every GF/F filter directly after the sampling and proceeding measurements with no indication of insects on the filters. Additionally, water samples were taken in the upper part of the water column reducing the likelihood of capturing benthic organisms during sampling. Furthermore, POC retention is strongly correlated with macroinvertebrate abundances, particularly with respect to detritivorous invertebrates which utilize POC as source of nutrition (Dangles et al. 2001; Monaghan et al. 2001). POC will be directly used by a variety of invertebrates and so may represent a more direct pathway of carbon transfer than the "microbial loop" with its inherent respiratory losses (Findlay 1995). The findings of Gislason et al. (2001) and Lods-Crozet et al. (2001) support the idea that the observed POC decrease may be due to direct use and reworking by benthic organisms. Here, filter-feeders (especially Simulidae, blackflies) of POC only occur in downstream reaches of the glacial river, while the most upper river sections are only inhabited by algae scrapping chironomid larvae due to the harsh environmental conditions.

Dangles, O., Guerold, F., Usseglio-Polatera, P. (2001). Role of transported particulate organic matter in the macroinvertebrate colonization of litter bags in streams. Freshwater Biology, 46(5), 575-586.

Monaghan, M. T., Thomas, S. A., Minshall, G. W., Newbold, J. D., Cushing, C. E. (2001). The influence of filter-feeding benthic macroinvertebrates on the transport and deposition of particulate organic matter and diatoms in two streams. Limnology and Oceanography, 46(5), 1091-1099.

Findlay, S. (1995). Importance of surface-subsurface exchange in stream ecosystems: The hyporheic zone. Limnology and oceanography, 40(1), 159-164.

Gíslason, G. M., Adalsteinsson, H., Hansen, I., Ólafsson, J. S., Svavarsdóttir, K. (2001). Longitudinal changes in macroinvertebrate assemblages along a glacial river system in central Iceland. Freshwater Biology, 46(12), 1737-1751.

Lods-Crozet, B., Lencioni, V., Olafsson, J. S., Snook, D. L., Velle, G., Brittain, J. E. & Rossaro, B. (2001). Chironomid (Diptera: Chironomidae) communities in six European glacier-fed streams. Freshwater Biology, 46(12), 1791-1809.

(5) *On another aspect, authors would need evidence to prove that how significantly these author-mentioned microbial can contribute to modifying POC, given the short distance (and hence short time) and low temperature (and hence low rate) environment. I see that DOC in glacier meltwater may be highly labile, but for POC, the condition can be quite different. I suggest the authors check if the POC variation is partly due to increasing conductivity or not. In addition, to present and discuss POC% data (POC in mg/L divided by TSM in mg/L) may be helpful too.*

Response:

Thank you for your suggestion. We agree, that microbes may not rework such high amounts of POC within such a short distance, but rather DOC. Presently, in the Icelandic glacier-fed streams, microbial reworking of POC is but a first attempt to explain the decrease of POC concentration. This aquatic process has been already identified in similar environments. In fact, POC has been shown to be directly used by a variety of invertebrates and thus may represent a more direct pathway of carbon transfer than the "microbial loop" with its inherent respiratory losses (Findlay 1995). As mentioned above, the results by Gíslason et al. (2001) and Lods-Crozet et al. (2001) supporting the evidence of the idea that the POC decrease may be due to direct use and reworking by benthic organisms. Here, filter-feeders (especially Simulidae, black flys) of POC only occur in downstream reaches of the glacial river and the most upper parts are only inhabited by algae scrapping chironomid larvae due to the harsh environmental conditions. Thus, the authors suggest this to be a first possible explanation with the recommendation for further future research in these glacial-fed streams. We will re-word the text to clarify this point.

"As a first hypothesis, we suggest that the observed decrease in POC may be due to direct use and reworking by benthic organisms (Findlay, 1995) and recommend further investigation into the rapid decrease in POC over relatively short river lengths in Icelandic streams. At the same time, DOM composition changed from relatively more allochthonous to autochthonous DOM."

Minor comments:

(1) About the length of the streams. In line 34 page 3 authors suggest that the streams are long. But later in line 20 page 6, authors suggest that the streams is short. I got confused.

Response:

Thank you for you for highlighting this. In line 20 of page 6, the length of the proglacial streams refer exclusively to the proglacial streams draining the southern parts of the glaciers Mýrdalsjökull and Vatnajökull. At page 3, line 34, the authors mention that in comparison to Greenland and additionally to the proglacial streams in the southern part of the two glaciers, there exist several longer proglacial streams which are draining e.g., the northern parts of Hofsjökull and Vatnajökull. Thus, both possibilities are given in Iceland. The manuscript text will be adjusted to further clarify these.

"Such elevated concentrations may have implications for biogeochemical processes in the ocean, due to the relatively short distance from the glacier terminus of the Mýrdalsjökull and Vatnajökull glaciers to the North Atlantic Ocean compared to the other glaciers (Bhatia et al., 2013)"

(2) From line 10-20, page 3. The result from model predictions come with uncertainties. And so I suggest authors shorten the discussion and comparison for the glacier future changes.

Response:

Thank you for your comment. We agree that model predictions always come with specific uncertainties. In this section we aimed to highlight the common future development of the shrinking of Icelandic glaciers and not in reference to the estimation of the DOC and POC export. We believe that the present text is required to stress this point of importance of the study given current predictions for the various Icelandic glaciers.

(3) The OC flux should be discussed with care. For example, OC may vary in both concentration and composition among different months within a melting season.

Response:

Thank you for your comment. We agree that there may be considerable variation in OC concentration and composition within the melting period and thus our estimates taken during peak melt season may lead to high OC fluxes. Therefore, we now discuss the seasonal variation in OC and that the amount of both dissolved and particulate organic carbon may be in fact, on average, lower than we estimate from our study during peak melt.

(4) Figure 1. Please indicate the north direction.

Response:

Thank you for highlighting this omission. We have now inserted a north arrow as suggested.