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Interactive comment on “Identification and analysis of low molecular weight dissolved organic carbon in subglacial basal ice ecosystems by ion chromatography” by E. C. Lawson et al.

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The authors have indeed conducted an interesting and novel study of low molecular weight dissolved organic carbon (LMW-DOC) in basal ice. The text is well written and suitable for Biogeosciences. The authors have good control on the biological and biogeochemical aspects of the study. Therefore, I have focused my review mainly on the glaciological and sedimentological aspects.

My main concern is the lack of information about the sampling sites and character of the basal ice (i.e. the basal ice facies). This makes it difficult to know how the basal ice was formed (regelation, adfreezing, trusting) and to assess whether the authors make

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appropriate comparisons, interpretations and conclusions. I will like to see a better description of the basal ice at each sampling site, including a figure showing close-up photos of the basal ice.

I am also concerned about the coupling between LMW-DOC and debris concentration in basal ice because debris concentration is a poor proxy for the surface area of the debris within a sample. I would have liked to see some data on particle size distributions. Again, this makes me skeptical to some of the interpretations and conclusions.

Overall, this study is a step forward in the understanding subglacial biogeochemistry and I look forward to read the revised paper.

Abstract 14141, L2-4: It seems awkward to start the Abstract by talking about glacial runoff, when the focus of this paper is on basal ice and the subglacial environment. I suggest that you delete the first 2-3 sentences and direct the reader's attention towards the lack of knowledge about DOC in basal ice.

14141, L7-8: I certainly don't like this definition of basal ice. Several other processes than basal adfreezing may form basal ice, and basal ice may contain incorporated segregation ice or intermixed glacier ice. Here in the Abstract there is no need to define basal ice, but you must present a proper definition of basal ice in the Introduction section.

14141, L11: It is unclear what is meant by "basal debris type".

14141, L13: Make it clear to the wide readership of Biogeosciences that FAA refers free amino acids.

Introduction 14142, L2-21: In my opinion, the Introduction section needs to be rewritten. You use 20 lines to talk about glacial runoff, and a single sentence to give a wrong definition of basal ice, which is the environment that you are actually examining. I cannot follow the leap from "Thus, further knowledge is needed to accurately assess the source of LMW-DOC in glacial runoff..." to "... and determine the abundance and com-

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position of potentially bioavailable LMW-DOC in basal ice at the base of glaciers and ice sheets". This paper does not accurately assess the source of LMW-DOC in glacial runoff. What is the link between subglacial meltwater runoff and basal ice? At three of the four glaciers that you are studying I will assume that the basal ice is primarily formed at cold-based conditions; at temperate Engabreen, I will assume that the basal ice consists of glacier ice and ice formed by regelation.

I recommend that you focus the first paragraph on basal ice. For example, use the definition of basal ice by Hubbard et al. (2009) and inform the readers about metamorphose of glacier ice into basal ice (Sharp et al., 1994) and post-formational tectonic deformation of basal ice causing intermixing of glacier ice and basal ice (Waller et al., 2000), in addition to basal ice formation by adfreezing and regelation. Then, you may continue by describing subglacial entrainment of LMW-DOC into basal ice.

14142, L22-25: The subglacial environment and the basal ice environment are not synonymous. The basal ice environment is a part of the subglacial environment. Here, it is unclear to me whether you make this distinction.

14143, L1: Introduce the abbreviation of free amino acids here.

14144, L1-3: You mention that the four glaciers have distinct temperature regimes, but you only list the four glaciers with their assumed substrates. It will be informative to include the temperature regimes in the list.

Sample sites and basal ice sample collection 14144, L9: What does the reference refer to? It seems superfluous.

14144, L17: I would say west margin rather than southwest margin.

14144, L21: I think that you mean Archaean, not Achaean.

14144, L21-22: A more correct reference to the local geology will be Escher and Watt (1976).

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14145, L2-8: It is relevant to mention that Finsterwalderbreen last surged between 1898 and 1910 (Liestøl, 1969) because the formation of the basal ice is very likely linked to the surge event, as it has been shown at Variegated Glacier (Sharp et al., 1994) and Kuannersuit Glacier.

14145, L10: Better use the term temperate than warm-based.

14145, L16-14146, L2: The description of the sampling sites is very cursory. It will be difficult for others to find the sampling sites in the field based on these few sentences, and even if they manage to find the sampling sites they will not know which basal ice facies they should sample to replicate your sampling. It is important with a more detailed site description and a characterization of the basal ice in order to get an idea of the differences in the formation processes of the basal ice, as these processes may influence the abundance and composition of LMW-DOC (the aim of this paper). A figure showing photos of the basal ice at each sampling site (both the BI and PR for Finsterwalderbreen) will give an impression of the character of the basal ice. This may also be helpful to readers of Biogeochemistry, who are not familiar with basal ice.

14145, L16-17: Is this actually basal ice or is it in fact subglacial frozen lacustrine sediment? If it is basal ice, it must have distinct physical or chemical characteristics different from frozen lacustrine sediments (see definition of basal ice by Hubbard et al., 2009). From this single sentence I am unable to assess whether you have actually sampled frozen lacustrine sediment.

14145, L16-19: A characterization of the sampled basal ice beneath Engabreen will be useful (see Jansson et al., 1996), as the formation of basal ice at Engabreen may differ from the other three glaciers because of its temperate basal regime.

14145, L20: It sounds a bit dangerous to collect basal ice samples at the calving terminus of Russell Glacier. If you collected the samples at the northern corner of the terminus, you have to be aware that before the 1990s there were some small lakes here, dammed between the moraine and the glacier. When the glacier advanced during

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the 1990s the lakes were overridden and the glaciolacustrine sediment may have been incorporated into the basal ice. At the southern corner, the glacier advanced into a dune. Detailed information about the location and character of the sampling site is therefore very important, as it may have significant impact on LMW-DOC.

14145, L20: Also, it is relevant to mention whether you sampled the solid or banded basal ice facies at Russell Glacier. You make a distinction between two ice facies at Finsterwalderbreen, but the same argument can be used for Russell Glacier. It is okay that you just sampled one ice facies at Russell Glacier, but the readers need to know which one. I will encourage you to do a follow-up study on the horizontal distribution of LMW-DOC in basal ice to examine potential links between genetic basal ice facies and the abundance and character of LMW-DOC.

14145, L21-22: Again, it will be nice with information about which basal ice facies was sampled.

14145, L22: Insert the word glacier in front of surface, and delete the word frozen unless you actually mean that the subglacial material was frozen when it was entrained into the shear planes.

14145, L23-24: To me the term Pressure Ridge is related to sea ice, making this sentence rather confusing. A more appropriate term could be debris layer, thrust band or shear plane (I am guessing a bit here, as it is unclear to me what you sampled). No matter what you sampled I am pretty sure that the thrusting did not happen “during cycles of (glacier) advance and retreat”. As Finsterwalderbreen is a polythermal surge-type glacier, my guess is that primary thrusting occurred during the early surge phase in the subglacial zone between temperate ice and cold ice, and secondary thrusting may have occurred during surge termination due to ice flow compression. This is at least how it is envisaged at the polythermal surge-type Kuannersuit Glacier (Larsen et al., 2010). All this is relevant because it may indicate that the PR debris derives from further upglacier than the BI debris, and that the PR debris may have been glacier-covered for

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a much longer period than the BI debris.

14145, L23-24: It is also unclear to me whether the debris-rich ice in the pressure ridges is in fact basal ice. Maybe it is glacier ice with discrete debris layers (although the debris may derive from the glacier bed).

14146, L1 and elsewhere: It is more scientifically correct to write (by mass) rather than (by weight).

14146, L6-7: Maybe debris-rich basal ice is a better term than “dirty basal ice”. This sentence is awkward because your Finsterwalderbreen BI samples had a debris concentration of 20 +/- 27% and thereby not meet the criteria of having a debris concentration >20%. I suggest that you delete the sentence.

14147, L22-28: Basal ice debris concentrations are not very useful, as basal ice often contains boulders, stones and sorted gravel lamina. Therefore, the basal ice debris concentration depends on whether you choose to collect you samples in places without large boulders or stones. It will be meaningful to present the basal ice debris concentration for particle sizes <2 mm and preferably in combination with data on particle size distribution <2 mm.

14151, L17 and L21: Here, you use the abbreviations FPR and FBI rather than PR and BI.

14153, L16-23 (and section 5.2): I am not sure how robust this hypothesis between DOC (and LMW-DOC) and debris concentrations really is, as long as you do not present any data on particle size distributions <2 mm. Assuming that DOC is leached from sediments, the controlling variable will be the surface area of the debris rather than debris concentration. I think that you need to rethink this part of the paper. It is important to present information about debris concentration in the basal ice because it tells something about the material, but it is probably not appropriate to test a hypothesis between DOC and debris content unless you have the appropriate data to do it. As

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I am skeptical to your hypothesis, I am also skeptical to your use of this hypothesis in the Discussion section.

14153, L23: Where is the presentation of the major ion concentrations in basal ice that you mention in the Methodology section? If you have these data, please show them.

14154, L5: To my knowledge this is the first study to quantify LMW-DOC in basal ice. If not, insert references to other studies.

14154, L15: Specify what you mean by “type of overridden material”? Do you mean differences in lithology or unconsolidated vs. consolidated substrata or differences between pre-entrainment sedimentary types (till, glaciofluvial, lacustrine, soil)?

14154, L17: This is slightly confusing, as one will expect the values in brackets to be the mean values, not maximum limits.

14154, L18: Not sure what you mean by comparable. Most things are comparable. Rephrase this sentence.

14155, L25-26: I am not convinced that the GrIS debris in basal ice derives from a soil origin. It all depends on where you collected your samples along the margin of Russell Glacier. It could be of glaciofluvial, glaciolacustrine or aeolian origin, or derive from subglacial erosion.

14155, L29 and Table 2: These ages are only relevant if you have collected the samples at the exact same site as Stibal et al. (2012). If you did so, mention it in the text.

14156, L4: No reason to mention again that the Russell Glacier samples were collected from the GrIS margin.

14156, L17-20: Could the lack of organic biomarkers at Engabreen be due to debris entrainment by regelation rather than adfreezing?

14156, L21: It seems relevant to distinguish between glacial (ice-contact) lakes and other lake types.

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14157, L7: Again, I miss information about the chemistry of your basal ice.

14157, L9-10: These are not the only sources of parent water. Refreezing of water from pressure melting during the regelation process is important.

14157, L20: But you do not have age data from Joyce Glacier and Engabreen, so how do you know that age is a controlling parameter? How can you exclude that other parameters at Russell Glacier are less important?

L14159, L19-21: In a warming climate the tendency is that temperate/polythermal glaciers become cold-based as the ice thickness decreases, not the other way around.

L14159, L19-21: Why is a change in basal thermal regime needed? Cold-based glaciers may have discrete subglacial channels where water is in contact with the substrate (e.g. at Longyearbreen).

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