Biogeosciences

Discussions

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Interactive comment on "Organic carbon characteristics in yedoma and thermokarst deposits on Baldwin Peninsula, West-Alaska" *by* Loeka L. Jongejans et al.

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Authors reply by Loeka Jongejans, on behalf of all authors (loeka.jongejans@awi.de)

We thank this referee for the valuable feedback on our manuscript. We will go through the discussion section and incorporate their suggestions. For now, we hope to clarify the central theme of our manuscript in our replies to their open questions.

Referee Comment (RC): Permafrost affected soils and sediments of the Northern hemisphere are a major terrestrial C reservoir, highly vulnerable to climate change. A better knowledge on the amount and composition of organic matter is thus crucial (e.g. to

improve earth system models). Thus the authors report on a very important topic in biogeochemical research. However, the authors miss to get a clear central theme. It seems the group of authors tried to include a bit of everything in a very descriptive manner rather than providing a synthesis of the extensive data set. Another major drawback is the rather one-sided citation of studies either from the co-author list or affiliated colleagues. Especially with respect to organic matter quantity and quality a growing number of biogeochemical basic research is going on in the Arctic. For instance Gentsch et al. worked on the bioavailability of specific OM in Siberia, or Mueller et al. worked rather "close by" on OM quantity and quality on thaw lake basins in the Alaskan North slope region.

Authors Reply (AR): In our study, we aim to characterize the OC properties in permafrost deposits in order to assess the vulnerability of the permafrost to climate change and contribute to a better estimate of the terrestrial C reservoir in this part of the Arctic. We will better highlight this theme in the revised version of the manuscript. Regarding the comment on one-sided citation, in particular the OC quantity, we compared our OC budget estimates to other studies that studied similar deposits (yedoma or DTLB) and were expressed in the same units ($kg/m3$). In the revised manuscript we will add the suggested study of Mueller et al. (2015). Regarding the OC quality, we will elaborate on bioavailability of OC in high-latitude soils and include more studies such as the suggested study of Gentsch et al. (2015), and Vonk et al. (2010).

RC: line 21 Volumetric OC content in your case is OC stock. With giving soil OC stocks you are closer to what gets reported for soils.

AR: With volumetric OC content we mean the OC density, as the values are expressed per unit weight over unit volume. The carbon stock, however, is expressed per unit weight, which we report in megaton (Mt).

RC: page 3 line 6, To which OC pool do you refer here? Are you aiming to model specific OC pools with respect to decomposability, or are you just aiming to differentiate

OC stocks with respect to different research sites?

AR: We here refer to the OC pool in the yedoma, DTLB and thermokarst lake sediments. We aim to estimate the stocks and decomposability, i.e. size and quality of OC pools. We will clarify this in the revised version of the manuscript.

RC: page 3, line 7 The used biomarkers only represent a minor portion of the organic matter. Although useful for reconstruction of OM origin, these proxies are lower in explanatory power for the bioavailability of the sequestered OM. So I would not speak of "molecular composition of each OC pool and its quality" as it only represents a minor part of the bulk OC.

AR: We agree with the reviewer and will rephrase this throughout the manuscript.

RC: page 3, line 10-23 - What was the reason to go to this site? How representative is it for Arctic permafrost soil landscapes with respect to the studied OC distribution and composition?

AR: This is the first time yedoma deposits on Baldwin Peninsula were described. Therefore, this study contributes to a better and more precise approximation of the OC of yedoma deposits for this part of the Arctic. We will make this clearer in the revised version of the manuscript. The yedoma deposits were discovered on the coast of the peninsula during a reconnaissance campaign, after which this coastal bluff and those of the drained thermokarst lake basin deposits were sampled. We show that the total organic carbon content of the yedoma deposits is in the range of other yedoma studies in Siberia and Alaska. Also, the higher quality of yedoma OC compared to that in DTLB deposits was shown before. We will address the representativity of our study site in the revised manuscript.

RC: page 3 line 28 - What do you mean by representative? How did you test representativity? How are the five locations connected to each other with respect to the choice of sampling spots?

AR: With representative, we mean that we tried to cover the whole yedoma exposure. Due to the difficult terrain and the fact that the samples were taken in summer – the fast thawing of the deposits limits the accessibility – it was not possible to sample the whole exposure in one straight profile. Therefore, we sampled different portions of the exposure wherever accessible and compiled a composite profile. We will add this explanation to the manuscript.

RC: page 5 line 2 - How were the samples pre-treated? Did the authors test for Carbonates in the samples, or is the TC representing OC and IC?

AR: We did not pre-treat the samples. We measure the TC and TOC in different devices. To measure the TOC, the samples are combusted at a much lower temperature compared to the TC measurements, so that the inorganic part of the sample is not combusted, and hence not measured in the device. The total carbon (TC) represents the sum of the organic (TOC) and inorganic carbon (TIC).

RC: page 5 line 8 - Was it not possible to increase the sample amount to get into the measurement range?

AR: The sensitivity of the Elementar Vario Max C is 0.1 wt%. This means that with a large sample amount, the weight percentage would be similar and therefore also below the detection limit of the device. We measured two aliquots per sample where we allowed a standard deviation of <5%; we measured multiple times when this criterion was not met.

RC: page 5 line 15-28 - You are extracting free lipids, and thus you can make assumptions about the composition of the extractable lipid fraction of your samples. You cannot draw conclusions about the "molecular composition of the OC" in general as proposed. Please be more precise in the writing.

AR: You are right, we rephrased as suggested.

RC: page 6/7 line 30 and following - You are taking some samples at one small edge

of the Island and estimate based on this the OC stocks for the whole Island? Do you have any data on the representativity of the sampled locations for the rest of the Island? And what is the aim of such a very vague approximation? I miss a consequent central theme in the manuscript. Is it the quantification of OC stocks in a permafrost affected landscape? If yes, you clearly miss representivity (e.g. just one lake core!). Or is it the study of the composition of the extractable lipids in concert with C and N contents? If yes, you could possibly dig deeper into that by looking for correlations between all the measured data.

AR: Arctic fieldwork is expensive and it is difficult to get to the remote places for sampling. Therefore, we sampled the three main landscape units of the peninsula to get an initial overview of the thermokarst processes influencing the topography and the organic carbon characteristics. The sample sites are exposed at the coast, allowing us to study OC characteristics of deep permafrost deposits. Sampling sites on top of the deposits, however, would require drilling. This was not possible as no drilling rig was available during the fieldwork. Using the stratigraphical land cover classification map that we made and remote sensing, we indeed generated a first estimate of the characteristics and size of the OC pool in this part of the Arctic.

RC: Results - How are all the single proxies/data correlated? You are just reporting every single measured proxy, but how are things related to each other?

AR: Our aim is to characterize the OC pool in the different landscape units on Baldwin Peninsula by assessing the OC pool size and quality. In order to assess the organic carbon quantity, we analyzed the total organic carbon content and – using the stratigraphical landcover classification map we made and bootstrapping techniques – we estimated the OC stock of the different landscape units (based on the wedge-ice volume, bulk density, total organic carbon content and the coverage and thickness of the deposits). In order to assess the OC decomposability, i.e. the quality, we analyzed the carbon-nitrogen ratio and stable carbon isotopes. Using the differences between the landscape units, we show that the C/N ratio and d13C show both OC source as well as

quality. We used the n-alkane derived ACL index to distinguish between terrestrial land plants, algae and bacteria, and the CPI index as an indicator for OC decomposability, where a higher CPI suggests well preserved material. We will clarify the link between the parameters in the revised manuscript. However, we would like to keep the results section as it is to keep it factual.

RC: page 9 line 7 - What is the uncertainty based on the spatial heterogeneity of sediment and soil properties including BD, C content, horizon depths etc.? How did you account for the spatial heterogeneity on the Island with respect to only 5 sampling spots at the edge of the research area?

AR: This study represents the first characterization of permafrost deposits on Baldwin Peninsula, including newly discovered yedoma. Even though spatial heterogeneity exists both between and within landscape units (e.g. Zona et al., 2011), we were able collect a total of 91 samples at 5 different locations that we used for all analyses. We believe that this is sufficient for an initial characterization of the OC pool in this part of the Arctic, and the objective of our study. The uncertainties of the estimations are included by repeated artificial subsampling for the OC stock calculation using bootstrapping. A detailed assessment of potential spatial heterogeneity is beyond the scope of this paper. However, following the suggestions of the reviewers, we will sharpen the existing focus of the paper in the revised manuscript.

RC: page 9 line 20 and following - What does this paragraph in its extensive form have to do with "organic carbon characteristics" as proposed in the title? I recomend to at least shorten the "origin of the material" section, or put very reduced parts of it into the site description in the M&M section. The parts with 14C and 13C etc. should go into a condensed discussion of the OM composition in the subsequent section.

AR: This section describes the depositional environment of the island to provide a framework for the interpretation of the OC data. In order to assess the vulnerability of carbon in permafrost deposits on Baldwin Peninsula, it is crucial to know the source

and properties of the deposits in which this OC is stored. Especially for OC in old, deep permafrost deposits like yedoma, it is highly important to report on sedimentary origin as well as the ages of the deposits. These both describe the regional geological context of the deposits, as well as it gives an insight in the origin of the material. Hence, we prefer to keep the content of this paragraph as it is.

RC: page 11 line 2 - So if it is comparable, why should one keep on reading? Put your data first and get the central theme out of it, not just repeat other peoples work at a new fancy sampling location.

AR: Thank you for the suggestion. We will restructure the paragraph.

RC: page 11 line 8 - "a significant OC pool is expected" - do you have data to prove it? Otherwise stay away from vaque approximations.

AR: We wanted to stress the importance of the volume of the yedoma deposits compared to the relatively shallow thermokarst deposits, after which we report on the absolute numbers. To avoid further confusion, we will rephrase this sentence as suggested.

RC: page 13 line 13-27 - This whole paragraph is purely hypothetical. You have no data on OC vulnerability to climate warming nor for OC bioavailability. What is the central theme of your work? It reads like the authors wanted to have a bit of everything in it, paleo reconstruction, large scale OC estimates and OC composition. It would be great to get a synthesis of these parts rather than a descriptive manuscript.

AR: Giving a synthesis of the OC pool size and composition in permafrost on Baldwin Peninsula is exactly what we tried to do in the first part of the discussion, where we report on the quantity and quality of OC based on organic geochemical, sedimentological and also palaeoecological methods. The paragraph following this is meant as an outlook and to put the study and also the study area in a larger perspective. We will put more stress on the actual data rather than on the more hypothetical part in the revised version of our manuscript.

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RC: Conclusions – This is just a summary of your findings, but what are the take home messages and especially the implications of your work?

AR: We agree with the reviewer: we indeed summarized our findings in the conclusion. With these main findings, we show the answer to our research question and our main message: the first estimate of the total OC pool on Baldwin Peninsula, the relative contribution of the different landscape units (answer to our first research question), as well as the finding that OC in yedoma is most vulnerable to decomposition (answer to our second research question).