Detailed review replies of

First Pan-Arctic Assessment of Dissolved Organic Carbon in Permafrost-Region Lakes

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Interactive comment on

"First Pan-Arctic Assessment of Dissolved Organic Carbon in Permafrost-Region Lakes" *by* Lydia Stolpmann et al.

Anonymous Referee #1

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General Comments:

The authors have presented a synthesis of a very large data set of DOC concentrations from permafrost affected lakes spanning the entire Arctic and a straight forward, but yet effective regional scale analysis of the landscape controls on the DOC concentrations in these lake.

The authors have identified the data gap and clearly spelled out the objectives of the study. They have done a commendable job at gathering this very impressive and novel data set, they have provided a detailed summary of the temporal and spatial nature of the data, and have applied valid statistical tools to investigate and identify the role that a range of landscape variables play in controlling the DOC concentrations in Arctic/permafrost lakes. The authors have also done a very good job at addressing the uncertainties and challenges with the data in the discussion.

Thank you very much for acknowledging the importance of the data presented in our paper. We are grateful for the review and acknowledge the reviewer's comments, which improved and strengthened the paper.

On it's own the act of gathering and describing this data set constitutes a valuable contribution, and the analyses conducted and conclusions drawn add significantly the value of that contribution. The research presented is well within the scope of the journal and should be of interest to a wide audience. As such I believe the work is definetly worthy of publication. I do feel that the data have been under-utilized in a few respects, and/or there are some analyses that could be added to address some of the issues of uncertainty and the variability in the data and strengthen the paper. I detail the suggestions in the specific comments below. I view these as minor to moderate revisions, as they require some additional analyses or description of the data, but I do not believe they will change the outcomes or conclusions that are reached.

Thank you very much for the appreciation of our dataset. The dataset we presented here will be basis for further analyses and we intend to use it for further detailed investigations.

Specific Comments:

Title – I suggest a couple minor changes. First I would remove "-Region" from the title - simply state Permafrost Lakes. Second I would advise the authors to consider editing the title slightly to specify the nature of the "Assessment" conducted. Perhaps: "First Pan-Arctic Assessment of landscape characteristics as controls on Dissolved organic carbon in Permafrost Lakes" Or "First Pan-Arctic Assessment of environmental parameters as drivers for Dissolved organic carbon concentrations in Permafrost Lakes" Or along these lines.

We like the idea of specifying the title and thank you very much for concrete suggestions. Since the term "permafrost lakes" might be confusing to other readers with respect to the well-known "glacial lakes" or "thermokarst lakes" in the existing literature we adjusted the title accordingly to "First Pan-Arctic Assessment of Dissolved Organic Carbon in Lakes of the Permafrost Region".

Study Area: The authors spend several paragraphs on pages 3-5 describing the percentages of the lakes that are from the different Arctic regions and the different ecozones etc. Although the authors do provide the lake/sample numbers as n values in Table 2 and Figure 3, because there is a strong spatial bias (with more than half the lakes in Alaska) I suggest that a histogram be included, to better illustrate the geographical distribution of the lakes. This could be included as an insert for example in Figure 1 (using this regional description).

We agree that the overview of the lakes in the several study areas with n-values in figures and tables and percentages within the text can be confusing. The suggested histogram is indeed a

nice way to better illustrate the lake geographical distribution in our synthesis dataset. We included such a histogram in figure 1 as subfigure 1b) and 1c) see below.

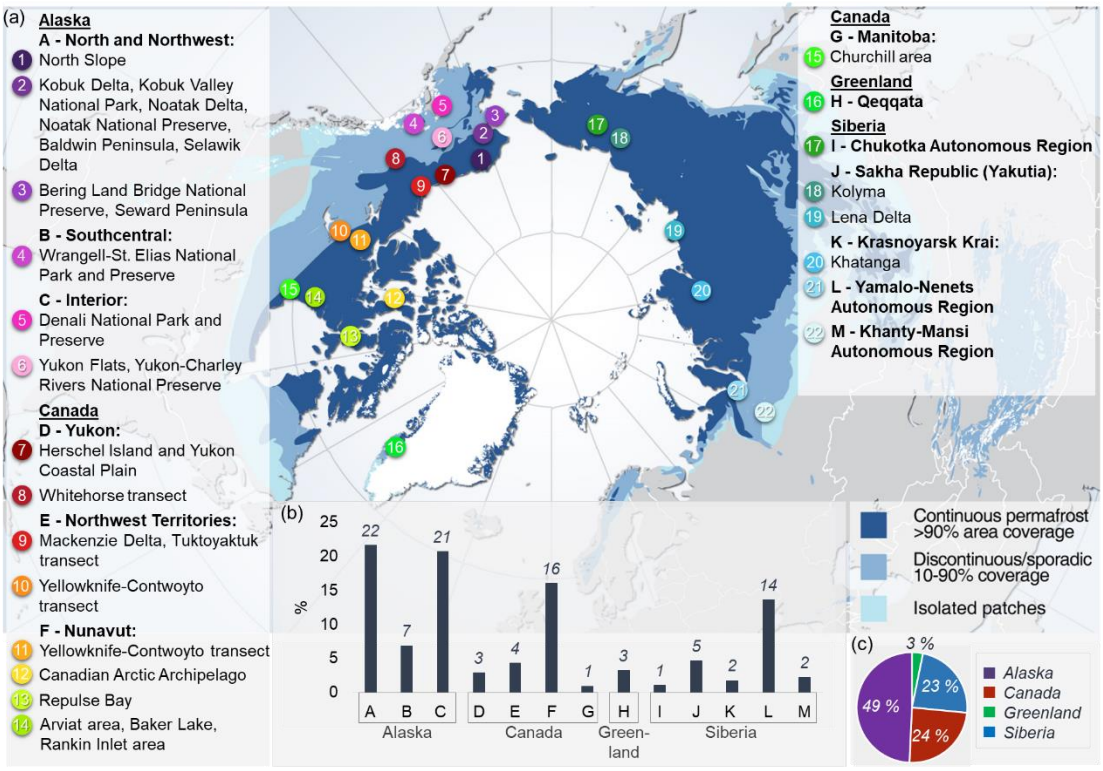

Figure 1: Overview of study regions (underlined bold font), study areas (bold font) and sites overlain of the map of permafrost zones (a), and histogram of the number of lakes in percentage by study area in our synthesis dataset (b) and pie chart of lake distribution in the dataset by overarching regions (c) (Background map: after Brown et al., 1997).

The other aspect of the data that is not clearly illustrated is the timeframe of collection. It would help the reader understand the data, if there was some illustration of the number of samples/lakes that were taken from the various years (e.g. how many samples are from 1979-1985 in Nunavut?). I do not think it would require much effort to generate a temporal histogram (with the number of samples from the various years and quarters).

Indeed, the number of samples from the various year is very informative for the reader. So, we added the number of samples in brackets after each year in Table 1. Additionally, we added a histogram of numbers of samples per decade per study area to the Appendix as Figure A1, see below. The figure illustrate that there are only a few samples collected in the 90s and two third of the samples were collected since 2009. More information can be found in the dataset itself, which we will publish in the open access data archive PANGAEA soon (doi will be provided with this paper).

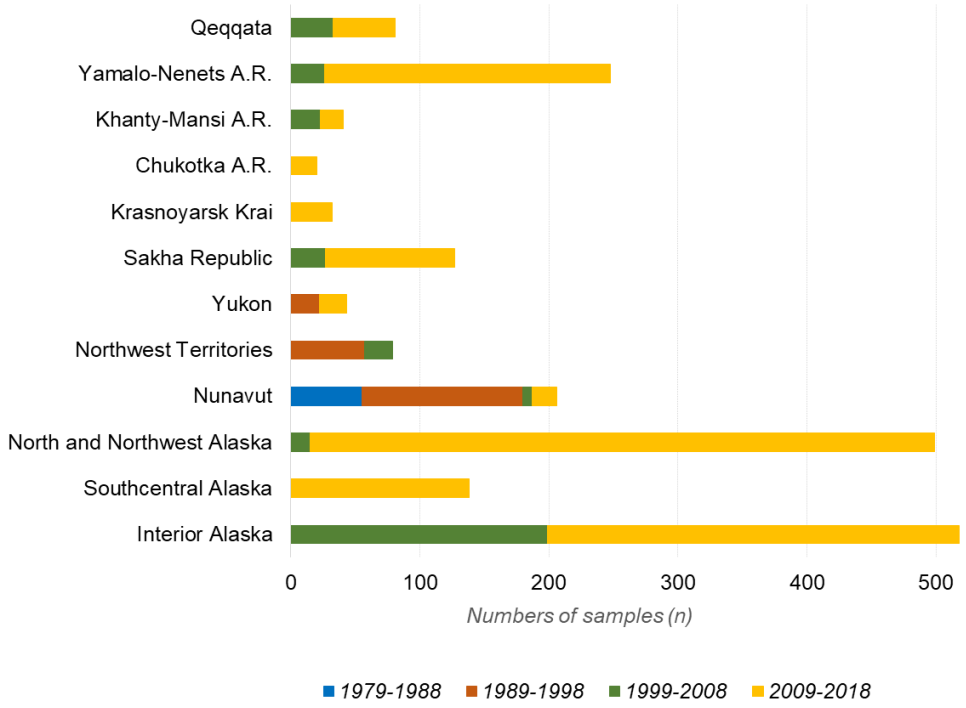

Figure A1: Histogram of numbers of samples in each study area per decade of sample collection. Since an exact allocation of the sampling year was not possible for 113 samples, these are missing in this figure for study areas Nunavut and Manitoba, Canada. The study area Manitoba, Canada, is not included.

The authors need to address the potential impact of including samples from nearly 40yr span of time could have on the analyses, especially given that climate and permafrost has been changing dramatically (and at different rates) across these ecoregions during this time. For example this long time frame of the sample period could play a role in the relationship between DOC and latitude. Is it possible the relationships might be more robust if the authors limited themselves to data from the last decade or two? The temporal histogram suggested above would provide a means to speak to this issue.

Thank you very much for this constructive comment. We included this topic in the discussion. In the past 40 years, the study areas may of course have changed due to the accelerating climate change. Thermokarst lakes in particular are very active. Some lakes that were sampled 30-40 years ago may by now be completely drained and thus no longer exist, for others environmental characteristics in catchments such as permafrost, vegetation cover, or runoff dynamics may have changed over time thereby also affecting lake DOC. The goal of our first synthesis step was not to quantify change in DOC over time but to look a broad spatial patterns on a hemispheric scale. In addition, our dataset shows that more than two thirds of the samples were collected since 1999 (see Table 1, which was modified after the reviewer's comments, and the histogram added to the appendix Figure A1). Hence, analyses with data from the last two decades already form the majority (89 %) of our data set. We agree, however, that continued efforts to expand the dataset in the future should certainly look into the temporal dynamics of northern lake DOC as well.

Results: Temporal Variability of the data set. I like that the authors indicate the nature of the seasonality of the sampling. Althought section 4.1 breaksdown how many lakes were sampled multiple times, and how the DOC concentrations varied in terms of the overal range and trends in concentrations of DOC (i.e. across all lakes) through different seasons, I feel what is lacking is an assessment of the degree to which DOC concentrations vary in individual lakes over the year or seasons. i.e. is the range of variability within a year/season in a given lake greater than the variability between lakes for this subset? I suspect this seasonal variability is minimal, however if seasonality is important then the authors would need to consider limiting the data set to lakes sample from a consistent time of the year? Although the temporal subset is small relative to the whole data set, there are 81 lakes and 266 samples, which is by most any measure still a substantial data set. There is likely sufficient data within this to provide some assessment of the relative impact of both the seasonality on the data.

We agree that the DOC seasonality of our dataset provides an opportunity to assess the degree to which DOC concentrations vary in individual lakes over the year or season. We now address this in the results and discussion. We added Table A2 to the Appendix and the following to subchapter 4.1:

"In our dataset we found six lakes that were sampled three times over the same period. These six lakes are located in Qeqqata on Greenland and were sampled in April, June and August. For five of these six lakes, the highest DOC concentration of the respective sampling series was found for April samples. Then, the DOC concentration decreased in June and increased in August (Tab. 2). For these lakes, we observed a 30 % to 45 % higher DOC concentration in April and up to 25 % higher DOC concentration in August in comparison to the June sampling and therefore shows a seasonal variability. We have also checked for seasonal variability in a larger dataset. Therefore, we used data from the study areas Southcentral and Interior Alaska since samples in these areas were available for each month from May to September. However, these samples include all samples of these study areas and not a sample series of a single lake. We focused on the median DOC concentration for each month for each of the two study areas. For Southcentral Alaska we found a pattern similar to that in the lakes in Qeqqata. We found a 17% higher DOC concentration in May and September compared to July. However, the same pattern cannot be seen for Interior Alaska (Table A2).
In order to make a more precise comparison with the Qeqqata lakes, we compared samples of the whole dataset from the months June and August. For these months, in addition to the Qeqqata samples, samples from the study areas Yamalo-Nenets A.R., North and Northwest Alaska, Southcentral and Interior Alaska were available. In three of the four study areas we also found higher DOC concentrations in August than in June, comparable to the Qeqqata lakes."

Table 1: DOC concentration of six lakes (Qeqqata, Greenland) sampled three times in one year.

Lake name	DOC concentration [mg L^{-1}]		
	April	June	August
SS906	8	5.2	5.8
SS1381	39.2	24	31.3
SS2	35.1	23.8	27.7
SS8	52.5	28.7	38.3
SS904	8.1	5.2	5.8
SS1590	31.1	36.6	25

Table A2: Overview of median DOC concentration according to sampling months, where sampling month could be clearly identified.

	Study area	Median DOC concentration [mg L^{-1}]						
		April	May	June	July	August	September	October
Greenland	Qeqqata	33.1		10.2		25		
Siberia	Yamalo-Nenets Autonomous Region			18.1	29.6	13.9		
	Khanty-Mansi Autonomous Region				14.1	10.9		
	Chukotka Autonomous Region				9.6			
	Krasnoyarsk Krai				8.3	9.8		
	Sakha Republic (Yakutia)				8.1	10.2	7.8	15.3
Canada	Yukon				12.9			
	Northwest Territories				8.5		13	
	Nunavut				2.2	3.8	2.6	
Alaska	North and Northwest			4.5	9.1	8.2	8.1	
	Southcentral		15	13.6	12.5	16.3	15	
	Interior		12.7	18.4	12.6	20.3	21.3	

To clarify, that we didn't use under-ice samples for our statistical analysis but here to investigate seasonality of our data, we added the following sentence to subchapter 3.3 Statistical analysis:

"Our dataset contains six samples from Qeqqata on Greenland that were collected in April and are under-ice samples. For the sake of comparability, these data have not been included in the statistical analysis."

We also added this point to the discussion subchapter 5.4 Challenges of a pan-Arctic assessment, describing possible causes of the seasonal variability found in a small scale single lake analysis and similar patterns analyzing multiple lakes per month. Additionally, we highlight the lack of seasonal data to emphasize that seasonal variability and that continuous sampling during the ice-free period is needed.

I didn't see a data availability statement. Even if this is not a requirement of the journal, it is critical and needs to be included – perhaps in the results or cited as a data archive? Readers are going to want to know how or where they might be able to access this valuable data set.

Thank you for the comment. We are currently preparing the dataset for publication in PANGAEA and will provide the DOI soon.

Technical corrections:

*P1 L29 Edit: Our synthesis shows a significant relationship of lake DOC concentration and ecoregion of the lake. *cut "of" insert "between" , insert "lake" ahead of "ecoregion" and cut "of the lake"*

We changed this accordingly.

*P1L32 Compared to previous studies we found a weak significant relationship of soil organic carbon content. . .. *cut "of" insert "between"*

We changed this accordingly.

P7 Line 21 - add "data" to the end of the section title

We changed this accordingly.

P13 L16 change "with a surface are " to ". . .surface area"

We changed this accordingly.

P.21 L20 – check reference volume number "Limnol. Oceanogr., 9999"?

Thank you very much. We corrected it into: Johnston, S. E., Striegl, R. G., Bogard, M. J., Dornblaser, M. M., Butman, D. E., Kellerman, A. M., Wickland, K. P., Podgorski, D. C., and

Spencer, R. G. M.: Hydrologic connectivity determines dissolved organic matter biogeochemistry in northern high-latitude lakes, Limnol. Oceanogr., 65(8), 1764-1780, doi: 10.1002/lno.11417, 2020.