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Interactive comment on "Catchment-scale carbon exports across a subarctic landscape gradient" *by* R. Giesler et al.

R. Giesler et al.

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Response to referee #3

We greatly appreciate the comments given by the reviewer and have addressed the questions raised by referee#1 below.

Specific comments

Specific comments P7954 L25: I thought that CH4 release in relation to global warming is of potentially higher importance than CO2 in the northern latitude ecosystems. It is worth mentioning the CH4 at least.

We agree and have added CH4 as suggested

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P7955 L26: What is the reference period of the decrease in summer DOC export in the Yukon River?

They compare the periods of 78-80 with 01-03, we have added this information in the text.

P7956, paragraph starting at L13: not clear who is an important sink for terrestrial C.

This is now re-worded.

P7958 L8: Perhaps a short description of major geological formations in the region would be useful.

We agree and have added this information in the text

P7958 L17: The irregularity in the sampling frequency (from couple of times per week to weekly and monthly) could results in large errors associated with latter flux calculation and/or seasonal patterns which will incorporate additional errors associated with a lot of assumptions used to estimate individual flow rates (P7959 L9). Perhaps an additional paragraph describing the relationship between water levels and rating curves, etc would give the reader better inside.

We agree. To address this, we have added a paragraph explaining the general rating curve fitting results. As such, power law relationships were fit (as is the norm for natural cross sections) at each site based on 4 to 6 observations. Fits for the power law rating curves to the flow observations had R2 values between 0.86 and 0.99 (this has been highlighted in the text). Further, the potential impact of errors in the flow estimates on flux estimates has been better addressed in the revision. See also comment on sampling frequency below.

P7959 L12: Even the 7 months period where flow rates were estimated may account for only 10% of the annual flow, the influence of those potential errors would be mostly reflected in the annual DIC loads as DIC concentrations over this period are highest compare to DOC.

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We agree and have also avoided to discuss seasonal differences in fluxes across the streams. Our ambition is to get better flow estimates from streams in the research area in the future to enable us to do more accurate flux estimates. There will, however, always remain an uncertainty for winter flow estimates since all streams generally are ice-covered in the witch which makes monitoring more difficult.

P7960 L6: Same as discussed above: 1. potentially large errors associated with estimates of daily concentrations (interpolation) from real measurements at 2/3 times per week frequency to weekly and monthly; 2. large potential errors resulting from daily flow rate estimates. So, estimated DOC and DIC loads would carry all those errors which should be at least discussed appropriately if not presented somewhere is the main text or in tables.

We agree and have thus done as follows: firstly we have added a figure comparing daily measures for DIC and grab samples showing that the sampling intensity is not critical for the load estimates. Secondly, as the largest error is likely to come from the flow estimates, we have used a conservative estimate of the error in flow estimates and also added the error related to uncertainties in the chemical analyses to give a total error for the loads.

7960 L13: Where are those weighted average concentrations displayed? Which table, graph? How different/similar are those values compared to normal averages?

We are unclear with this comment. The concentrations are listed in Table 3. Further, we have expanded our consideration of literature reported values for DOC and DIC from permafrost affected areas in high-latitude areas. This addition helps put these values in context with “normal” values.

P7962 L21: Either or not using /yr when referring to annual load or flux, unit should be g/m2 (or g m-2) and not g x m2 (g m2) here and everywhere else in the main text, tables and graphs.

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We agree and have changed it accordingly.

P7963 L1: Would be more interesting and perhaps more appropriate to see the relation between those predicting variables and DOC and DIC concentrations and not DOC and DIC fluxes for reasons discussed above.

We have elected to keep the originally reported relationships. We do agree that more could be done looking into the relationships between concentrations and landscape characteristics (and we are in the process of following up on that topic). However, we have decided to keep focus in this revision on the dynamics of the C concentrations across the six streams and the long-term chemistry data.

P7963 L5, L8: I don't think anyone would consider $p<0.1$ as a significant level.

We agree and have changed the text accordingly.

P7964 L14-15: not a strong relationship of increasing DOC export with higher flow." While this seems to be true for long-term data, a good and positive relation exist for the 6 catchments as shown in Figure 6. How do you explain the difference?

The difference is a central point of this work. Given one catchment (e.g., stream 6) over time, there is much variability in annual flow relative to the variability in DOC export. Given several catchments in one year (e.g., across all 6 catchments), there is an increasing relationship between flow and load (as expected and highlighted by previous comment from this reviewer); however, it is not consistent with the relationship over time. Thus, we would not expect all catchments to vary along the same linear relationship over time (compare to the DIC where we would expect this). We have clarified this in the text to highlight that by relationship we intend increasing linear trend with flow.

P7964 L18: I think the authors must be careful with the interpretation of data and the use of strong words such as "substantial component" since both DOC and DIC are very low, even for subarctic or boreal ecosystems. DOC and DIC values are rather

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comparable despite that the relative contribution of DIC to the total C flux seems slightly higher. Data need error range.

We agree and have been more careful in our phrasing. We have also added more information on literature data from permafrost affected and high-latitude streams to put our concentrations and flux estimates in a larger context. This indicates that our DOC values are comparable to other streams in other streams (still low compared to forested or wetland influenced streams) while our DIC concentrations probably are in the lower range. We have added errors to our load estimates.

P7964 L20: Perhaps the geology may explain part of the discrepancy.

Both our and the more intense studied Krycklan catchment lacks strong influence of calcareous bedrock. A likely explanation is that higher DOC concentrations leads to higher proportion of CO2 in the boreal streams. Since these streams also have a lower pH degassing is probably important which will reduce the DIC concentration.

P7965 L6-10: The paragraph needs some brushing/re-writing

This paragraph is deleted since we have excluded the space-for-time discussion in the paper as suggested by referee #2

P7965 L10-13: There is a repetition of the message suggested in the first paragraph of the page (L1-4).

This is reformulated in the revised text.

P7965 L10: The biogenic vs geogenic origin of DIC could be settled by looking at stable isotope data. Any _13C measurements?

First, we have re-worded the phrasing since we cannot separate between biogenic and geogenic sources. We have published data on 13C-DIC from the six streams and from a larger survey of streams in the Abisko area. Our conclusion from that specific study is that 13C-DIC (unfortunately) cannot help us in separating the two sources.

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P7965 L27: Positive trends in relation to what?

It should be positive trends in relation to time. This has been clarified.

P7966 P17-23: Perfectly true.

P7970 L7-18: P7970 L7-18: Instead of creating hypothesis around the source/fate of CO2, a great exercise would have been to quantify the CO2 emissions from the 6 studied streams since pCO2 has been measured anyway, and compare CO2 fluxes with the total C export. the CO2 emissions from the 6 studied streams since pCO2 has been measured anyway, and compare CO2 fluxes with the total C export.

We agree that estimating CO2 fluxes would be interesting but we think that our CO2 data are not sufficiently strong for this exercise due to several reasons. A major issue is that there still is a lack of good estimates of the k-value (gas diffusion coefficient) for these type of streams. To do a proper estimate of gas exchange for the various streams we also need a good estimate on stream velocity (V) along the streams. To estimate the velocity we would need a detailed stream geometry, data that are unfortunately not hand. Only a detailed estimate on V may allow an estimate on the k-value; the latter can be empirically linked to V and the catchment slope (Raymond, P. A. et al. Scaling the gas transfer velocity and hydraulic geometry in streams and small rivers. Limnology and Oceanography Fluids and Environments 2, 41-53 (2012).) Still, it is definitely on the agenda for coming studies and will include determinations of k-values for the streams.

Tables: Table 1. It should be specified in the table capture if not in the table itself that Total Flow is in fact Total Annual Flow with the unit expressed as m3 yr-1 and that Daily Flow represent the Average Daily Flow

We agree and have changed it accordingly.

I believe that Table 2 should go first as it describe more general catchment characteristics. Also it should be specified in the table caption that Area represent Catchment

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Area, while Elevation, Slope, Aspect, etc, represent average values as mentioned in the text.

We agree and have changed the order of the tables and given the requested information.

Table 3. Concentrations should be better expressed in mg L-1 instead of mg dm-3. Similarly, I believe that “Mass Fluxes” refer here to annual fluxes so the unit should be gC m-2 yr-1 and not g C m2. Also, values should be followed by error range (_) as beside being small, they are rather comparable with each other (DOC with DIC, both concentrations and fluxes). The need of error range is even more evident as one of the major conclusion of the study (DIC export is higher than DOC) is based on these small differences.

We agree fully and have changed the units accordingly and also included error estimates on the fluxes.

Table 4. I don’t agree that p<0.1 is significant. Overall, I don’t know how much novelty this table brings. Perhaps it can better go to Supplementary Material to save space if necessary. Same for Table 6.

We agree and have also excluded table 4 and 6.

Figures: Figure 1 has no coordinates system. The Torne River should be indicated on the map rather than Road E10.

We have now changed figure 1 so that Torne river and coordinates are included.

Figure 2 should specified if displayed concentrations are directly measured values or the figure show also estimated data based on interpolation. Same for the other figures displaying concentrations to create a separation between measured and assumed values.

There are no data based on interpolations in any figures so maybe the clarification is

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not necessary.

Not sure what is the main message of Figure 4. Perhaps it can better go to Supplementary Material

We have excluded this figure and instead presented the data in the text.

Figure 6. kg is unit of mass not of a flux. Similarly, annual discharge – m3 yr-1 (or m3/yr), not m3. Overall, one may expect such positive correlations between discharge and loads. Why the relation between DOC load and discharge for the six catchments (filled triangles) has only 2 points?

The figure has been corrected accordingly. Also, the "missing" points were hidden behind solid symbols (which has been corrected).

Editing comments: 7955 L20, comma after "ecosystems"

Changed

Figure 4. Delete "other" after "during" in the 2nd line.

Figure 4 is excluded.

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