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Biogeosciences
Discussions

Interactive comment on "Long cold winters give higher stream water dissolved organic carbon (DOC) concentrations during snowmelt" *by* A. Ågren et al.

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We want to thank the anonymous referee for the comments which we believe have greatly improved our manuscript. We have now changed the scope of the manuscript, and performed additional analysis. The new analysis strengthens the previous results and also highlights the ecological significance of our study. Detailed answers to Referee comments are found below.

Referee #2 Comment: Agren and colleagues focused their study on dissolved organic carbon (DOC) dynamics during snow melt in a boreal catchment. They describe interesting results obtained from a long term hidro-biogeochemical monitoring coupled

to a pluri-annual riparian soil experiment. Undoubtedly, manuscript is of high scientific quality and the manuscript structure (text, tables and figures, cited literature) is excellent and, it constitutes a new contribution to the prolific scientific literature focused on DOC dynamic in northern regions. My concern is about the scientific relevance. The manuscript is similar to that published recently by some of the authors in another journal (Haei, M., et al. 2010). The similarity among the two works is palpable. Title, objectives, hypothesis, study site, data analysis and finally, conclusions are analogous. Therefore, it is my obligation to use all information from Haei paper to understand better your manuscript and to limit, as possible, redundancy among papers. Under this perspective, I understand that the present manuscript should be a step forward with respect to the Haei paper.

Answer: It should be clarified that we don't study the same study site, this is an entirely forest-covered subcatchment of the Haei study catchment (which also includes the influence of a mire).

But the similarity between the articles was still a valid point. We have now taken the analysis of this manuscript a step forward, by including new variables and analysis and expanding the discussion section to not only focus on the winter climate but on all processes controlling the DOC concentrations. We have now changed the title, objectives, hypothesis and data analysis to make it more clear that the this work is not a copy of the Haei et al (2010) work but instead a further step in understanding the role of winter climate for controlling DOC.

Comment: Therefore authors should use their published manuscript as starting point to reinforce (or refute, why not!) the relationship between winter severity and DOC concentration in stream/riparian strip, providing an alternative/complementary date analysis. In consequence, the hypothesis that drives the manuscript cannot be the same to that of Haei paper. A future potential reader of this paper will already know the answer.

Answer: Yes, we now use the Haei manuscript as a starting point.

Comment: Authors manage a huge quantity of DOC data (15 year record, with samples collected, at least, at weekly frequency: : :.that means a >750 samples!!). Nevertheless, they extracted, from the data base, only two samples obtained in two specific hydrobiogeochemical instants (DOCM and DOCF). Therefore, their entire statistical analysis is based on a set of 15 DOCM + 15 DOCF samples (<4% of the entire data set: : :.do I am wrong?). Obviously these samples are essentials to understand their catchment hydro-biogeochemical functioning. However, I believe that authors lost the opportunity to perform a more global analysis. For instance, it is excellent the initial analysis of the monthly variability of the logDOC-logQ slopes. It would be really interesting to explore the inter-annual slopes variability.: : :: : :These slope values might be an additional "Y variable" for PLS analysis: : :: : :.Perhaps, the logDOC-logQ slopes from data collected during snowmelts proceed by a "severe winters" are higher (i.e. severe flushing) than that collected after a "soft winters": : :: : :..Analysis and discussion of these results would be a substantial step forward with respect to the Haei paper.

Answer: We found that we could strengthen the results from this study by incorporating three more variables: the average concentration during snowmelt, the export of DOC during snowmelt and the slope of the Log Q - Log DOC relationship during snowmelt. The results from that are now shown in the new figure 5:[See fig 2]

Here is an extract from the results section: "The DOC concentrations during snowmelt (DOCM, DOCF and DOCAVERAGE) covaried and were explained with similar variables. When studying the Y's individually, the explaining variables could somewhat vary; for example, DOCF and DOCAVERAGE were more correlated to snowmelt variables while DOCM was more correlated to winter climate variables. Variables from all three groups of predictors (snowmelt, winter climate, antecedent conditions) were significant in explaining the inter-annual variation in stream concentrations during snowmelt (DOCM, DOCF and DOCAVERAGE) (Fig. 5, left panel [See fig 2 here]). The most important variable was the duration of the rising limb of the snowmelt hydrograph (Rising limb dur.), indicating that a short and intense snowmelt yielded higher DOC

concentrations in the stream. Discharge and DOC export during the antecedent summer and fall related negatively to spring flood DOC concentrations. There were three winter climate variables that related positively to the spring flood DOC concentrations (winter duration, number of days during winter with temperatures below zero, and the end of winter). These three variables covaried and should not be interpreted individually but rather as different measures of a long winter. A principal component analyses (PCA) of the entire dataset indicated no close correlation between rising limb duration and winter duration. This ensured that the relationship we found with long winter was not just an artifact, since a snowmelt following a long winter might eventually be more rapid and intense.

There was an inter-annual variability in the Log-Log slope during snowmelt (0.10 - 0.44). The slope was negatively related to the number of days from the start of snowmelt to the date of DOCM and also to the duration of the rising limb (Fig. 5, right panel [See fig 2 here]). That means that the slope was steeper, i.e. the catchment exported higher concentrations per unit of discharge, in years when the snowmelt episode was short and intense. The slope was negatively related to the DOC export during the antecedent summer and fall and positively related to a delayed soil frost thaw, which in turn is correlated to a long winter. The results from the two analyses, shown in the left and right panels of Fig 5 [See fig 2], showed the same pattern; High DOC concentrations during spring flood were found in years with a short snowmelt episode, long antecedent winter, and low previous export."

Comment: With respect to the PLS, in this manuscript the predictors are more or less the same to that used by Haei (31 variables vs. 29). In consonance with my previous comment, in this manuscript the analysis should star by using at the beginning the significant 12 "X-variables" found by Haei.

Answer: Yes, it is basically the same predictors as in the other manuscript. But this study is conducted in a subcatchmnet (Västrabäcken) of the Haei et al study catchment (Nyänget/Svartberget/Gauging station in Fig 1 in the manuscript). The Haei study catchment drains both a wetland and forest, however this subcatchment is 100% forested and we wanted to investigate whether the same variables control also other catchment types. It is better to include all variables from the beginning and refine the model from that, rather than assume that the same predictors will fall out in this catchment. It is true that the result were similar between the studies, but we might have found other predictors for this catchment since the DOC patterns in streams draining forest and wetlands are very different.

Comment: Perhaps these significant X-variables might help to identify new and more specific predictors. For instance: variable "Number of days with below-zero air temperature in the preceding meteorological winter" is (after subtracting hydrology) the most significant predictor in Haei paper (and in the manuscript as well). With this previous information is it possible to attempt to dissect this predictor: For instance identifying the "Number of consecutive days with below-zero air temperature" (this is simply an example: : :.is possible to identify predictors ad infinitum: : :..).

Answer: Yes, it is true that we can identify even more predictors from such a rich data set. But, many of our variables covary and after constructing more than hundred PCA/PLS/MLR models we believe that one should be careful and not over interpret individual variables, but rather see the big picture. From our perspective we don't believe in more detailed variables.

Comment: Below I inserted some additional and more specific comments. Pag. 4861, line 9. The study site coordinates are different from that Haei et al.. check it!

Answer: Thank you, that was a typo. We have now corrected it.

Comment: Authors selected two "Y variables" (DOCM and DOCF) obtained during two keys moments. Nevertheless, authors should explain and justify in more details reasons that motivate their selection.

Answer: We now motivate the selection of DOCM and DOCF and have also added 3

variables that integrate DOC over the entire snowmelt period (DOC export, Average concentration and Log-Log slope).

Comment: In addition they should reveal if DOCM and DOCF covaried or not (from fig 4a I suppose that the relationship is not really consistent: : :..but it should be described and discussed).

Answer: Let's start with the issue of covariation. Yes, many variables in the dataset covary. That is why we choose to use PLS as the preferred statistical method, in favor of multiple linear regression. But with datasets like this one must be careful with the interpretation. We have made more than hundred PLS models using one or more Y variables, and in different combinations, with different degrees of refinement. In addition to that we have made PCA (principal component analysis), PCR (principal component regression), MLR (multiple linear regression (not statistically correct to use with many covariate variables, but still confirmed the major results in an easy way)). After all those analyses we have developed a good sense about the dataset, its boundaries and the level on which individual variables might be interpreted. In all our analyses individual variables might vary somewhat, however we also found consistent patterns and the major conclusion did not change. Unfortunately we cannot show all models in this manuscript, but, the ones we chose to show are representative.

Back to the issue of covariation between variables: To illustrate the covariation between variables we show a PCA of all variables [See fig 3]. The PCA creates 4 significant principal components, here we show the first two components from the PCA (explaining 27 and 20% of the variance in the dataset). In the lower right hand corner we can see that variables such as DOCAVERAGE and DOCF are correlated (lie lose to each other). Another example, the variables Winter duration and Winter End are closely correlated (not a surprise that a long winter ends later). In the study we showed using PLS (Fig 5 [See fig 2 here]) that snowmelt stream DOC concentrations were high if the snowmelt was short and intense. We had some concerns that perhaps the relationship we found with a long winter was just an artifact because after a long winter when the snowmelt eventually starts it is probably more rapid and intense. However, the PCA indicates no close correlation between Rising limb duration and Winter duration.

Comment: Furthermore, in Fig. 4b it appears (more or less..) that DOCF residuals are typically negative, while that of DOCM are typically positive: : : Why?.....Is it coherent this tendency?

Answer: Yes it is true that DOCF residuals are typically negative (average -5 mg/L) and DOCM are typically positive (average +2 mg/L) [See fig 1]. This is because we choose not to optimize the f-factor in the RIM model but instead choose to use a constant (average) f-factor during May. We could have optimized the f-factor so DOCF and DOCM were both centered on 0. However, our selected approach is valid because we are only interested in the interannual variation and absolute numbers does not matter. Besides, all variables were converted to z-scores before statistical analysis.

Comment: Pag. 4894 eq. 2: In my opinion the formula is wrong and it should be rewritten. The model is the derivation of a simply exponential decay (dC/dy=-f C0) and its analytic solution is: Cy= C0eËĘ(-f y) where "y" is the depth and C0 is the solute concentration at y=0.

Answer: Thank you, that was an embarrassing typo.

Comment: Pag 4867 line 14: It is difficult to individuate clearly the variables "length of the spring flood (days >1mm) and the "amounts of discharge (mm) during the rising limb" in table 1: "amounts of discharge (mm) during the rising limb"=" Discharge from the onset of snowmelt until the peak-flow (mm)" ? "length of the spring flood (days >1mm)" = ?? What does "days >1mm" mean?

Answer: This has now been clarified.

Comment: Pag. 4867 line 25 (and table 1) the term "metrological" sound to me unusual. What does mean?

Answer: We choose to remove the term.

Comment: In any case, the variables "Length of the metrological winter" and "Number of days with below-zero air temperature in the preceding meteorological winter" appear describe a similar variable: : :..do they covaried? Due to the relevance of length and severity of winter in this study it should be explained in detail difference and/or similarity among the two variables. Furthermore, the facts that the "delayed soil frost thaw" is the third most important variable appear obvious because is a consequence of a long and severe winter (i.e. "Number of days with below-zero air temperature: : :").

Answer: Yes, these variables covary (Winter dur. and Winter days <0°C are both found in the lower right hand corner of the PCA-graph [See fig 3]). In the discussion we now write about the covariation between variables and how it is important not to over interpret individual variables, but look at the consistent general patterns that we found.

Comment: Fig. 5. In the PLS weight plot the label "w*c[1] appears on both axes. Is it correct? The data cross perfectly a hypothetical 1:1 line: : :: : :.therefore a x-y plot is unnecessary and it should replaced by a histogram or a table.

Answer: Yes, we have now changed that to a bar chart [See fig 2].

Comment: On the other hand, I strongly miss a plot illustrating the relationship between long severe winters and DOMM (or DOMF) concentrations (or residual after subtracting the RIM output).

Answer:Good idea, we have now added a linear regression between the variables with highest weights (Residual DOCM and Winter days < 0°C) as a new panel [See fig 4].

Comment: Table 1: what is the difference between "Start soil frost thaw" and "start data of snowmelt"?

Answer: As with many of our variables they are similar variables but not the same. Start soil frost thaw was defined as the date when liquid water was found in the soil (measured by sending an electrical current through a gypsum block in the soil, when water is available the circuit closes), there may still be ice present. Start snowmelt is defined using the hydrograph from the stream and is the date (Julian date) when discharge overrides 1 mm day-1. This has now been clarified in the table.

Detailed figure captions:

Fig. 2. PLS weight plot, showing that high DOCM, DOCF and DOCAVERAGE correlate positively to long winters and negatively to previous export during summer/fall and low intensity snowmelts with much water (R2X=0.46, R2Y=0.41, Q2=0.29) (Left panel). PLS weight plot, showing that high Log-Log slope correlates positively to delayed soil frost thaw and negatively to low intensity snowmelts and high previous export (R2X=0.50, R2Y=0.38, Q2=0.21) (Right panel). Y variables are marked in grey and significant (95% confidence level) X variables in white.

Fig. 3. PCA score plot for the first two components, showing all X and Y variables.

Fig. 4. Left panel: PLS weight plot (R2X=0.54, R2Y=0.38, Q2=0.23), showing that high soil water DOC concentrations, inferred from stream DOC, (indicated by the Residual DOC concentrations) correlates positively to long cold winters and negatively to a high previous DOC export during winter. This means higher soil water DOC concentrations after long winters with low export. The Y variables are marked in grey and the six significant (90% significance level) X variables in white. Right panel: Linear regression between Residual DOCM and Winter days < 0 °C (the variables with the highest weights), illustrating the relationship between long severe winters and spring flood DOC concentrations.

Interactive comment on Biogeosciences Discuss., 7, 4857, 2010.

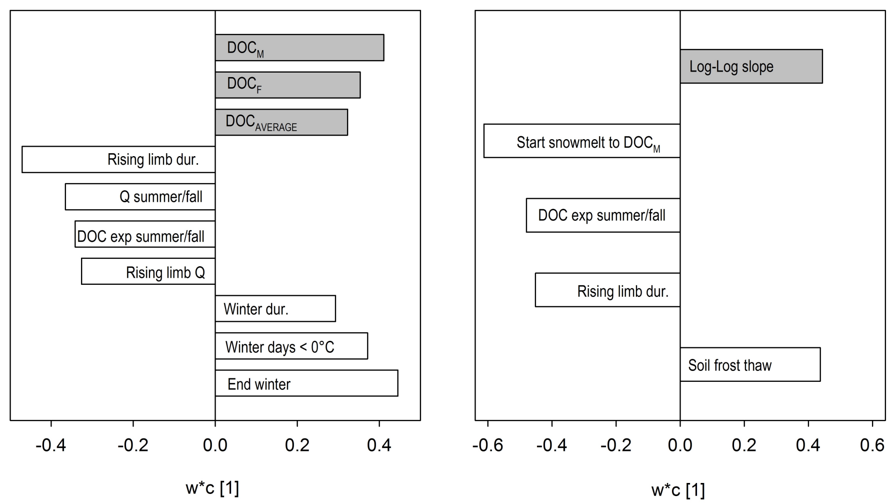

Fig. 1. Fig 2

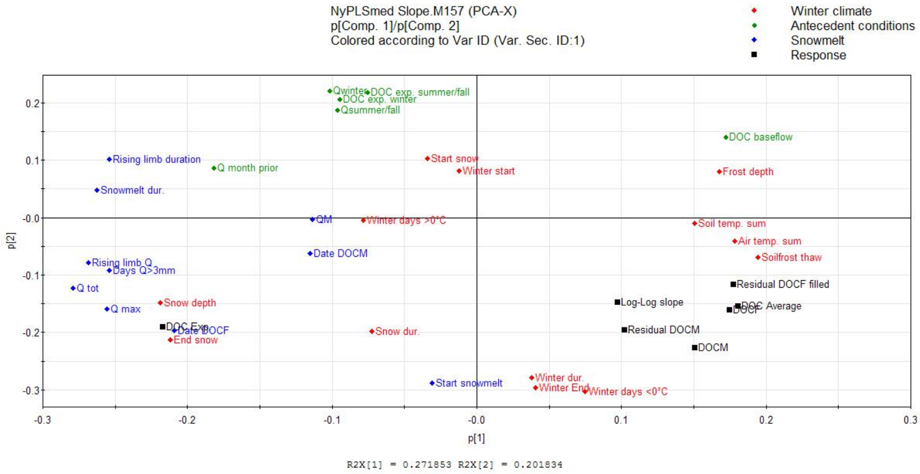

Fig. 2. Fig 3

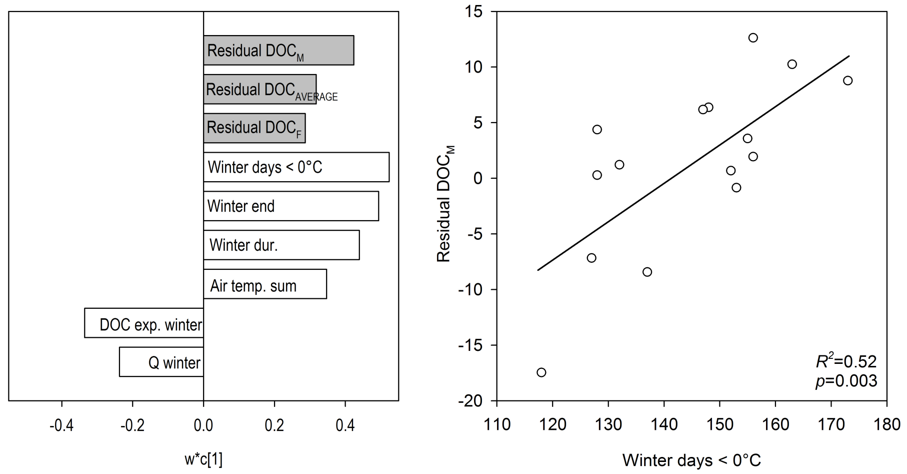

Fig. 3. Fig 4