Authors' response to Comments of Reviewer 2

Review of hess-2024-250

In their manuscript, entitled "Hydrological Controls on Temporal Contributions of Three Nested Forested Subcatchments to DOC Export", Blaurock et al. analyzed DOC export across different hydrological periods. By the use of high-frequency data, they could show clear differences between the catchments in terms of the timing and magnitude of DOC export, which the authors could explain by differences in soil, topography, vegetation, and microclimate. The manuscript is well-written and contributes interesting insights into the drivers of riverine DOC export at the headwater catchment scale. My comments might be abundant, but they are largely of minor character. I do agree with the main points raised by reviewer 1. Furthermore, I did not agree with the author's repeated argumentation that the most important factor for DOC export was precipitation and, with that, discharge (see my detailed comment to lines 272-274). Furthermore, the authors should be careful in stating that certain catchments characteristic "control" DOC export, while not having directly tested this, but "only" having provided a sound explanation. Overall, studies like this one that get to the bottom of the drivers of DOC export from forested headwaters are highly valuable to the readers of HESS.

We really appreciate the constructive comments and the overall positive assessment of our study. Below we provide our responses to the reviewer's comments in italic font.

General (but still minor) comments:

I suggest highlighting the importance of high-frequency data to identify "hot moments" of DOC export that would be covered if low-frequency data were looked at alone. A comparison of how many % of DOC were exported within only % of the time would be cool, from my perspective. Within your framework, you could highlight that X% DOC was exported during the autumn period, while this period only covers X% of the entire year.

We agree that this information is interesting. However, only the flow-weighted values provide insight into mobilization processes as DOC is transported with water. We will insert a table in the SI that lists for each hydrological period the percentages of time, of runoff generated and of DOC export. We will also refer to this table in the results and discussion section and use the information provided there to support our interpretation.

I suggest you make it more explicit that increasing concentrations with increasing discharge make DOC export during high flow periods disproportionally high. Stagnant or even decreasing concentrations could still show higher exports during high flow, but not as pronounced.

We thank the reviewer for this suggestion and will express this point more explicitly in the first paragraph of chapter 4.1, before we discuss the flow-weighted DOC export values that disentangle the role of runoff generation for DOC export.

What about stream density? Is it higher in the upstream catchments? I could imagine that a network of (temporary) streams largely increases hydrological connectivity. If, with your knowledge of the catchments, you agree – I suggest you add stream density and this argumentation.

This is a good idea. However, we do not have data to include stream density in a quantitative way and would therefore prefer not to mention it.

Line-by-line comments:

L9: "paramount importance to understand *all* processes of the global carbon cycle" sounds overstated to me; could you please tone it down a little?

We will change the sentence as follows: "…is of vital importance to understand the global carbon cycle in detail".

L28-29: This doesn't read smoothly to me. If most of the carbon is inorganic, I miss the connection to organic carbon and the link to why organic carbon is also important. When you then, in L32-33, state that DOC is a major component of exported C, this appears contradictory to me.

We agree and will change the sentence in L 32 as follows: "However, especially in catchments with wetter and cooler…"

Generally, I am missing at least a little information on the role of DOC for nutrient cycling (i.e., important electron donor for denitrification) and its impact on aquatic ecosystems.

Thank you for pointing this out. We will add following sentence to this section: "DOC is linked to nutrient cycling as it acts as electron donor in anaerobic respiration processes, e.g., denitrification (Lovley et al., 1999; Pang and Wang, 2021)."

L60: have you looked at the TWI? It has often been found to correlate with DOC concentrations and could be interesting here as well. However, this is more a note than a comment that I want to see addressed.

For an earlier study, we calculated the TWI for the subcatchments and found that it did not differ much between the subcatchments. It was therefore, against first expectations, not helpful for explaining differences in DOC export and runoff generation behavior.

L65: this section should be concretized. Why did you specifically want to go beyond the event scale (or low-frequency data)? What were your expectations? It reads a little listless.

We will adjust the section as follows: "The objective of this study was to improve our understanding of the temporal and spatial patterns of DOC export from a forested headwater catchment beyond the event timescale to assess the importance of seasons with differing hydrological conditions including low-flow periods for DOC export."

L78: I assume HSsub should be HS_{sub}?

Yes, we will change it accordingly.

L85: I would prefer you do not repeat exactly what is already given in the table. Either rephrase or take it out. And check this throughout the manuscript, please.

Thank you for this suggestion. We will rephrase this section as follows: ~~Elevation in the entire catchment ranges from 771 m to 1373 m with a mean slope of 12.0°.~~ MG and KS represent

the upper part of the catchment with ~~a mean slope of 15.8° and 14.5° and~~ incised streams and HS_{sub} represents the lower part of the catchment with a wide riparian zone. The geology of the Hinterer Schachtenbach catchment (HStot) is dominated by biotite granite ~~(81 %)~~ and cordierite–sillimanite gneiss ~~(14 %).~~

We will also check all other instances throughout the manuscript and make changes accordingly.

L132: I very much appreciate this sound method section. However, I would like to see the fit between grab samples and sensor measurement as a scatterplot in the SI.

We show this fit in Figures S3-S5 for the different devices.

Table 3: I would like to have average discharge and DOC concentration included here as well to be able to tell if high loads are mainly due to high C or Q.

We would like to not include this information in Table 3 as average values are not very meaningful, in our opinion. We rather refer to the new Table S1 in the SI where the relations of percentages of runoff and DOC export point to this aspect raised by the reviewer. Together with Figure 2 (time series) and Figure 4 (cumulative Q and DOC export for HStot), this demonstrates if high loads are due to high C, high Q or both.

Figure 3 & Figure 6: I am a little confused with your unit of (flow-weighted) DOC export. According to your equation, DOC export is C [mg/L] * Q [L/min] * t [min], so the unit should be mg, right? How do you get mg /L*d in Figure 3 then and in Figure 6b mg/L…? What is it exactly that you define as flow-weighted DOC export, and how does it differ from DOC export and from concentrations? Please clarify.

We either refer to absolute values of DOC export (kg) for a hydrological period with a certain length or to daily DOC export per day (kg/d). The daily values were derived by dividing the DOC export by the number of days of the specific hydrological period.

Flow-weighted DOC export is calculated as the total absolute DOC export value for a hydrological period (kg) divided by the cumulative absolute discharge of this period (L). By dividing this value by the number of days of the specific hydrological period, we get the daily flow-weighted DOC.

The concentration and the flow-weighted DOC export do have the same unit (weight/volume) but refer to two different aspects. Concentrations refer to a certain amount of C in the water column at a specific moment. DOC export is the total amount of DOC that was transported during a certain period, i.e. the load. Flow-weighted DOC export is the total amount of DOC that was transported during a certain period normalized by the total amount of water that was transported during the same period.

Figure 5: Would it get too messy to add lines for cumulative Q here as well? Maybe as thin or transparent lines? I really liked being able to compare that to the export in the previous figure. But I leave that up to your discretion.

We did consider a figure like that in the beginning but concluded that calculating cumulative values of discharge in 15 min resolution for HSsub (where we obtain values by calculating the differences between HStot on one hand and MG + KS on the other hand) is difficult. We would need to assume a certain time lag between the discharge values upstream

and downstream to account for the time it takes for water to travel from MG and KS to the outlet at HStot. However, this would be a very arbitrary decision, and therefore we decided to not do it.

Figure 6a, b: What about the green (a) and black (b) columns reaching the limit of the y-axis? Are the values beyond the y-axis limit? Could you please change the limit or indicate these specific values somewhere in the figure?

We will modify the plots for a revised version of the manuscript, extending the y-axes and also removing the "all" columns.

L51-52: The information in the last sentence could also very well be integrated into Table 4, which would be more consistent, from my point of view.

We assume that you refer to L251-252; we agree and will add this information to Table 4.

L269-270: I would appreciate it if you could name these ranges briefly.

We will add the ranges to the manuscript:

Agren et al., 2007: 14.8 to 99.1 kg ha^{-1} yr^{-1} (1490 to 9910 kg km^{-2})
Bernal & Sabater, 2012: 1.8 ± 1 kg C ha^{-1} yr^{-1} (1800 kg km^{-2})
Strohmeier et al., 2013: 84 kg C ha^{-1} yr^{-1} (8400 kg km^{-2})
As the exact values are not stated in Tittel et al., 2013, we will remove this source.

L272-274: I partly disagree here. Precipitation is not simply equal to discharge… besides being driven by precipitation, discharge is further driven by catchment wetness that also relates to temperature controlling snowmelt and evapotranspiration, vegetation, and soil type – all of which control how much water is stored in the catchment and enable hydrological connectivity and transport. From your analysis and results, I would rather see a direct link to discharge than to precipitation alone.

Moreover, to me, "the most important factor" implies you have run some kind of statistic to rank the importance of factors.

Please rephrase your argument.

We agree that precipitation is not simply equal to discharge and that catchment wetness plays undoubtedly an important role, too. Depending on antecedent wetness and season, equally sized precipitation events may cause different runoff responses. However, in general, runoff events are caused by precipitation events (or snowmelt, which can be seen as an event as well), and this is what was meant here. We will rephrase the statements to avoid the impression of a simple relationship between precipitation and resulting discharge (beginning and end of section 4.1).

L275: In your figures, you show the average daily DOC export, where can I see the absolute solute export? If it's a "new" result it should not appear here in the discussion for the first time.

The absolute DOC export can be found in Table 3 in the column "Total DOC Export (kg)".

L298: Again, some numbers would help me here. What is the 'typical base flow concentration'?

We will add the numbers from Da Silva et al., 2021 (2.6 mg L^{-1}).

L319: See my argument above. I agree that a lack of precipitation events can limit DOC flushing. However, especially in summer, there is not only a lack of precipitation but also higher evapotranspiration, reducing catchment wetness and connectivity and thus discharge.

We will change the sentence as follows: "Moreover, it is possible that DOC had accumulated in the soils during summer due to 1) the warm temperatures, which enhance biological activity ***as well as evapotranspiration****, and 2) the lack of precipitation events* ***and a low hydrological connectivity****, therefore limiting DOC flushing (Dawson et al., 2008; Kawasaki et al., 2005; Seybold et al., 2019; Wei et al., 2021).*

L320-326: I might be mistaken here. But is freshly fallen leaf litter directly turned into DOC? Doesn't it take some time to decay until it is **D**OC?

According to Hongve (1999), fresh deciduous litter has very high potential for production of DOC in the short term. This study also observed a high leaching rate for fresh litter from leaf fall to early spring.

L370: Good point! If not the entire area is connected, catchment area can be misleading.

L329: P ≠ Q; see my argumentation above

We will adjust this section as follows: "Hence, precipitation regime and catchment wetness, both governing hydrological connectivity and runoff responses, were important factors for DOC export. Resulting runoff events contributed…"

L410-414: You discuss this, and it sounds very reasonable to me, but you do not directly prove this. Thus, you should be careful with phrases like "is controlled by". Instead, "can be explained by", or "we argue that…" would be more appropriate.

We will tone down the statements as suggested. We will change the sentences mentioned as follows: "…hydrological connectivity, which is influenced by topographical position…. We argue that these hydrological processes control the DOC export…".

L419-431: This is not really a conclusion, rather than an Outlook. Thus, I suggest calling this section "Conclusion and Outlook"

We agree to changing the name of this section to "Conclusions and Outlook.