Answer to Editor

Comments to the Author:

Dear Elin and co-workers,

I have received a review for your manuscript, which I have little to add to. I have to agree with the referee that we are now actually on track to make it a decent publication and that the review process did cover quite a bit of the work that could be expected within your team, indeed. Please do not overlook the ironic tongue in some of the comments.

To avoid further complication I refrain from adding my own comments or a second review. Please carefully consider the referee's comments for another round of revisions including the overall logical coherence. I suspect some of the remaining confusion to be easily sorted when the respective logical lines of foci are strengthened.

I also encourage you, to really seek the expertise within your group of co-authors. I have full confidence that you will succeed and that your team has excellent capacities to make your paper a nice contribution to our science.

I look forward to receive your revised manuscript. All the best.

Conrad

Answer: Thank you for your consideration of our manuscript to Hydrology and Earth System Sciences (HESS). We have, as you suggested, gone through all the comments from the referee and especially looked into the comments regarding the structure and logical order of the text. We hope that the new version of the manuscript will be to your satisfaction. Our reply is structured as follows: answers and changes in brown and text from the original manuscript in blue**.**

List of major changes

The major changes to this version of the manuscript include:

- The title was changed to "How catchment characteristics influence hydrological pathways and travel times in a boreal landscape" based on the comments from the reviewer.
- Made several structural and clarifying changes of the text following comments from the reviewer
- Added information in the method section regarding the construction of the travel time distributions of Figure 5
- The order of catchments in the tables is now colour based.

Ref 1#

General comments:

The authors did a good job in improving the readability and overall quality of the manuscript in the last iteration. The authors' response was considerate and explained the reasoning behind all relevant changes and decisions. The fact that I still have a lot of questions and comments is not a bad sign because I see that my former comments were appreciated and helped in improving the paper. Therefore I am sure that the authors will also be able to use the new review to the benefit of the manuscript.

Reply: Thank you for your constructive criticism, suggestions, and questions. We are very thankful for the time and effort to read and comment on our manuscript, and we hope that you will be pleased with our changes and answers to the next version. We have answered all your questions in brown below. Blue text marked "Original text" was taken directly from the previous version of the manuscript. All reviewer and editor questions and comments are stated unbridged in black, and our reply and changes are stated below each question/comment.

Main question

My main questions that need attention concern the methods section. Some important details are still unclear to me:

1. For constructing the TTDs you show in Figure 5 do you take all the particles arriving in a stream at the catchment outlet over the entire modeling period? So these are not individual backward TTDs for a single moment in time? They are, however, similar to flow weighted averages of all individual backward TTDs, is that right? Accordingly, your annual and seasonal MTTs are flow-weighted, right? You take all the particles arriving in a stream within a certain period of time (e.g. spring) and take the average of the distribution.

Original text: Section 2.5 The time it took for particles to reach a stream or lake via groundwater (hereafter called 'travel time') was calculated for each sub-catchment both annually and for each season. The calculated travel time distributions were analysed using four statistical measurement tools, the arithmetic mean, the geometric mean, median, and the standard deviation (SD).

Original text: Figure 5: The figure shows the age of particles reaching sub-catchment outlets….

Reply: We like to answer these questions together because they handle the same issue**.** Figure 5 shows the distribution of all the particles exiting the model though a catchment stream over the entire modelling period. To clarify this, we changed the figure text to state that the statistics are based on all particles over the entire modelling period. We also added a part in section 2.5 to clarify the creation of the travel time distributions. It is correct that we take all the particles exiting a stream within a certain period of time and take the average of that distribution.

Text changed to: Section 2.5: The time it took for particles to reach a stream or lake via groundwater (hereafter called 'travel time') was calculated for each sub-catchment. The calculated travel time distributions were based on all particles arriving in a stream within a certain period of time, either annually or for a specific season, for the entire modelling period. The distributions were analysed using four statistical measurement tools, the arithmetic mean, the geometric mean, the median, and the standard deviation (SD).

Text changed to: Figure 5: The figure shows the distribution of all particles reaching the different streams for the entire modelling period….

2. How exactly do you account for the reduction of travel times due to overland flow? Please show the equation.

Reply: As we stated in the discussion and the method section, we reduced the age using the amount of overland flow as a scaling factor. We showed the equation in previous iterations of the manuscript, but we received comments that it was not necessary to show because it's such a simple equation. However, we agree that showing the amount of overland flow for different seasons would be a good addition. We added this in the Appendix, Table A1. We also added the equation in the Appendix (Eq. A6).

Text changed to: $\mathrm{MTT} = \mathrm{MTT}_{Particle\ tracking}\ (1 - \mathrm{fraction\ OL})$ Eq. A6

3. Please make sure to add all this relevant information to your methods section.

Reply: We hope that these additions to the method section and Appendix will clarify and remedy these concerns.

Specific comments:

Title

1. It includes everything. Maybe a focus on the most important issue would be better. Is isotopic composition not part of the stream chemistry? For example, a more logical title would be: How catchment characteristics influence flow pathways, travel times and stream chemistry in a boreal landscape

Reply: Thank you for this suggestion. We understand the title concern that it should be more focused, and we liked the suggestion. Therefore, we changed it, but we adjusted it a bit further to:

Text changed to: The title now reads "How catchment characteristics influence hydrological pathways and travel times in a boreal landscape"

Key points

1. The last key point is confusing. The greatest seasonality is observed in silty soils because they contribute a larger amount of old water during winter baseflow compared to other soils? And why do you mention the mires in the same key point? Are they also related to the seasonality in catchments with silty soils?

Original text: The greatest seasonality in mean travel times was found in sub-catchments dominated by silty soils contributing with old water during winter baseflow, while mires contributed the largest fraction young water during spring snowmelt.

Reply: We have changed this key point for clarification.

Text changed to: The greatest seasonality in mean travel times was found in catchments dominated by silty soils because of the long travel times in winter and relatively short in spring.

Abstract

1. Line 25: '…the pathways and associated travel times of water in 14 partly nested…'. First you use the model to investigate the pathways. Each of the pathways has an associated travel time. This is the logical order you could follow throughout the manuscript.

Original text: In this study, a particle tracking model approach in Mike SHE was used to investigate the travel time, and pathway of water in 14 partly nested, long-term monitored boreal sub-catchments.

Reply: We agree that this is the logical order to follow and changed the mentioned text accordingly, and we have also checked other parts of the manuscript for this logical error. Please see our change below:

Text changed to: In this study, a particle tracking model approach in Mike SHE was used to investigate the pathway and its associated travel time, of water in 14 partly nested, long-term monitored boreal sub-catchments (0.12-68 km2).

2. Line 29: Which seasonal changes? Meteorological changes?

Original text: The variations were found to be related to the distribution of different landscape types and their different response to seasonal changes.

Reply: We agree that this sentence should be clarified. We changed it to:

Text changed to: The variations were related to the distribution of different landscape types and their varying hydrological response during different seasons.

3. Line 31: By 'groundwater age' you mean what exactly? The residence time of the groundwater, the travel time of the groundwater to the stream? The age of the fraction of streamflow fed by groundwater?

Original text: The groundwater age was positively correlated to the areal coverage of low conductive silty sediments

Reply: We agree that the use of groundwater age was confusing here. We changed this sentence accordingly.

Text changed to: The travel time of water to streams was positively correlated to the area coverage of low conductive silty sediments

Introduction

1. Line 41-45: Here you introduce the terms 'age', 'residence time' and 'travel time' somewhat interchangeably and without proper explanation. Also, I would mention flow pathways first (they cause/control the travel times and not the other way around). For example: 'The pathways of water through the terrestrial landscape to stream networks and associated age is a…'.

Original text: The age and pathway of water through the terrestrial landscape to stream networks is a widely discussed topic in contemporary hydrology.

Reply: We agree with the suggestion and have changed the sentence accordingly. This was also mentioned in point 7 of the method questions, where we answered more thoroughly and checked the whole manuscript for these types of inaccuracies.

Text changed to: The pathways and associated travel times of water through the terrestrial landscape to stream networks is a widely discussed topic in contemporary hydrology.

2. Line 55: Only if you assume that the groundwater is fully mixed. If not, even groundwater can still be associated with certain hydrologic events.

Original text: Stream water consists of a blend of overland flow and groundwater of different ages. The mean travel time (MTT) to streams is calculated as the average age of this mix (McGuire et al., 2006). The baseflow is the part of stream groundwater contribution that is not linked to a specific hydrological episode.

Reply: We agree the sentence was a bit unclear. We changed it as follows:

Text changed to: Stream water consists of a blend of overland flow and groundwater of different ages. The mean travel time (MTT) to streams is calculated as the average age of this mix (McGuire et al., 2006). The baseflow is the part of stream groundwater contribution that generally has travelled the furthest and is the oldest (Klaus et al., 2013; Hrachowitz et al., 2016). Specific hydrological episodes become harder to distinguish the older and the more well-mixed the baseflow is. In contrast, young stream water is typically connected to overland flow or fast and shallow groundwater pathways, which mainly can be seen at times with large rain or snowmelt inputs…

3. Line 56-57: You should at least mention that a large fraction of young stream water can also be derived from shallow subsurface flow in the soil or at the soil bedrock interface (some call this 'interflow').

Original text: In contrast, young stream water is typically connected to overland flow or fast and shallow groundwater, which mainly can be seen at times with large rain or snowmelt inputs

Reply: We do not understand this question, since we believe we already mentioned shallow groundwater flow paths, but we tried to make the text clearer.

Text changed to: In contrast, young stream water is typically connected to overland flow or shallow subsurface pathways, which mainly can be seen at times with large rain or snowmelt inputs.

4. Line 65: It is the dampening of the isotopic tracer signal that provides MTT estimates.

Original text: Isotopic tracer dampening can provide an estimate of MTT

Reply: We changed this sentence to make it clearer.

Text changed to: Isotopic tracer signal dampening can provide an estimate of MTT

5. Line 68: Precipitation-discharge relationships are not similar to the mentioned gamma distribution transfer functions. I would leave them out of this argument.

Original text: Theoretical transfer functions, such as the gamma distribution model, can also be used by relating input and output signals of isotopes, such as precipitation-discharge relationships

Reply: We agree to leave it out of the argument and decided on removing the sentence completely.

6. Line 86: How are 'isotope models' a method to calculate travel times? I understand how particle tracking can be used to calculate TTDs but 'isotope models'? Maybe you are talking about models that use solute transport routines (assuming conservative non-reactive tracers) to trace water pulses through a catchment system? Fitting references would include Remondi et al. (2018) and Heidbüchel et al. (2020).

Original text: Two common methods to calculate travel times using numerical methods includes isotope models and particle tracking (Hrachowitz et al., 2013; Ameli et al., 2016; Kaandorp et al., 2018, Yang et al., 2018).

Reply: Thank you for the reference suggestions. Using your advice, this sentence was changed to:

Text changed to: Common methods to calculate travel times using numerical methods includes models using solute transport routines, and particle tracking (Hrachowitz et al., 2013; Ameli et al., 2016; Kaandorp et al., 2018; Remondi et al., 2018; Yang et al., 2018; Heidbüchel et al. 2020).

7. Line 117: Age distributions or travel time distributions? Please be consistent in your terminology.

Original text: The main objective of this study was to quantify annual and seasonal travel time distributions and calculate MTT of water runoff to streams of the Krycklan sub-catchments to disentangle how these are related to physical landscape characteristics and seasonality.

Reply: For clarification, this sentence was changed to:

Text changed to: The main objective of this study was to quantify annual and seasonal (winter, spring, and summer) travel time distributions and calculate MTT of water runoff to streams of the Krycklan sub-catchments to disentangle how these are related to physical landscape characteristics and seasonal variation of groundwater recharge…

8. Line 118: Seasonality in what? Temperature? Precipitation amount? Weather in general?

Original text: The main objective of this study was to quantify annual and seasonal travel time distributions and calculate MTT of water runoff to streams of the Krycklan sub-catchments to disentangle how these are related to physical landscape characteristics and seasonality.

Answer: We changed this sentence to include an explanation to your question:

Text changed to: The main objective of this study was to quantify annual and seasonal (winter, spring, and summer) travel time distributions and calculate MTT of water runoff to streams of the Krycklan sub-catchments to disentangle how these are related to physical landscape characteristics and seasonal variation of groundwater recharge…

9. Line 119: How do you compare calculated travel times to 10-year seasonal isotope signatures? Do you compare the relative damping of the signatures for different years to the calculated travel times?

Original text: Firstly, the credibility of the model results was tested by comparing calculated travel times for the 14 sub-catchments to ten-year seasonal isotope signatures and base cation concentrations record from the Krycklan network.

Reply: We changed this sentence slightly to be more precise but kept it short since this part belongs to the introduction.

Text changed to: Firstly, the credibility of the model results was tested by comparing calculated travel times for the 14 sub-catchments to ten-year observational records from Krycklan, including average seasonal changes of stream isotope signatures and base cation concentrations

Method

1. Line 169: What is a 'rapid transition in hydrology'?

Original text: Similarly, we defined spring by the rapid transition in hydrology and biogeochemistry in April-May

Reply: We changed this sentence for clarification

Text changed to: Similarly, we defined spring as the hydrological period directly influenced by the snowmelt, in April-May.

2. Line 177: 'measurements' instead of 'results'.

Original text: Ten years of δ18O results for 13 of the 14 sub-catchments.

Reply: Thank you for noticing this error, we have corrected it.

Text changed to: Ten years of $\delta^{18}O$ measurements for 13 of the 14 sub-catchments

3. Line 177-179: Comprehensibility would benefit enormously from a more concise writing style. This sentence is a good example: Instead of writing a long and convoluted sentence like this one: 'Some of the sub-catchments are affected by evaporation from lake surfaces that result in isotopic fractionation that, consequently, affected the signal (Leach and Laudon, 2019)'. Better write: 'Isotopic fractionation caused by lake surface evaporation affects the isotopic signal of some of the sub-catchments (Leach and Laudon, 2019).

Reply: We checked the text for more example like this and tried to remedy as many as we could find. In this specific case, we used the suggested sentence in the new manuscript.

4. Line 179: '…was corrected by accounting for the percentage…'

Original text: …was corrected for the percentage of …

Reply: We agree with this change.

Text changed to: …was corrected by accounting for the percentage…

5. Line 183: This is not a logical conclusion. Just because there is no groundwater recharge during winter this does not mean automatically that the stream is only fed by groundwater only. It could still be fed by overland flow from meltwater or from rain on snow...

Original text: The comparison of the modelling results to observations of δ18O was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). Because there is no or very little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow, we assume the stream isotopic signature originates from groundwater only (Laudon et al., 2007). Hence, we assumed that δ18O during winter baseflow should be statistically related to the average travel time of the groundwater to the streams (up until the point where full mixing is reached)

Reply: It is true that meltwater or rain on snow could still feed the streams with water. However, we chose the winter season, specifically when the temperature is below zero, resulting in very little to no meltwater and unfrozen precipitation. We have tried, unconvincingly till now, to make the argument that the setting of this site with long and cold winter without much mid-winter melting and rain on snow allows making the case we have made. The text was changed as follows:

Text changed to: The comparison of the modelling results to observations of δ18O was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). The precipitation signal varies on a seasonal basis, creating an amplitude difference. This amplitude is reduced due to groundwater mixing until complete mixing is reached and the groundwater receives the same signal as the long-term precipitation average. There is no or little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow. Hence, we assume that the stream isotopic signature originates from groundwater only (Laudon et al., 2007; Peralta et al., 2015). Consequently, the closer the stream signature comes to the long-term precipitation average, the more the groundwater has been mixed. The groundwater isotopic signature, in turn, should be correlated to the travel time to stream until full mixing of the precipitation signal is reached.

6. Line 184: What aspect of the isotope (measurements? time series?) should be statistically related to average age of the groundwater?

Original text: The comparison of the modelling results to observations of $\delta^{18}O$ was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). Because there is no or very little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow, we assume the stream isotopic signature originates from groundwater only (Laudon et al., 2007). Hence, we assumed that $\delta^{18}O$ during winter baseflow should be statistically related to the average travel time of the groundwater to the streams (up until the point where full mixing is reached)

Answer: We have changed this section to include an answer to this question. The closer stream signature during winter baseflow comes to the long-term precipitation average, the more the groundwater has been mixed and should be correlated groundwater travel time to streams. This assumption is also supported by that the long-term isotopic signature is very close to the signature of the deep groundwater (old water) in Krycklan.

Text changed to: The comparison of the modelling results to observations of δ18O was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). The precipitation signal varies on a seasonal basis, creating an amplitude difference. This amplitude is reduced due to groundwater mixing until complete mixing is reached and the groundwater receives the same signal as the long-term precipitation average. There is no or little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow. Hence, we assume that the stream isotopic signature originates from groundwater only (Laudon et al., 2007; Peralta et al., 2015). Consequently, the closer the stream signature comes to the long-term precipitation average, the more the groundwater has been mixed. The groundwater isotopic signature, in turn, should be correlated to the travel time to stream until full mixing of the precipitation signal is reached.

7. Line 184: Are you aware of the fact that the average age of the groundwater is the mean residence time and not the mean travel time of the water reaching the stream? They can be very different. You need to be very careful with the terminology you are using. Please go through the manuscript and check each occurrence of the words 'age', 'MTT', 'travel time', 'residence time'. Don't use two terms for one and the same concept – like 'average streamflow age' and 'MTT' or 'average groundwater age' and 'mean residence time'.

Reply: We agree that these concepts were mixed up at some places in the text. We searched for them and corrected the issues we found. This is how we used the concepts:

- MTT – mean travel time, the mean of the travel time distribution based on the model ages of all the released particles reaching the stream. Particles are "born" when introduced into the model and receive an increasing age with time.
- Travel time – in this manuscript, it is the time it takes a particle to reach a stream, i.e., equal to the end age of a particle. This could also be water soil contact time of water discharging to streams
- Residence time – the average time a particle (or in this case water molecule) spends within a system. We only look at the water that exits the system via streamflow. Therefore, residence time should not be used in our case. We have removed the instances where this have been used.
- Streamflow and groundwater age – We agree that the use of these in the text is misleading. We do not look at the age of stream water, nor the age of the groundwater. We look at the travel time of water to the streams. We have checked the manuscript for such errors and removed them.

8. Line 185: Up until the point where full mixing is reached. Full mixing of what?

Original text: The comparison of the modelling results to observations of δ18O was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). Because there is no or very little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow, we assume the stream isotopic signature originates from groundwater only (Laudon et al., 2007). Hence, we assumed that $\delta^{18}O$ during winter baseflow should be statistically related to the average travel time of the groundwater to the streams (up until the point where full mixing is reached)

Answer: The precipitation signal varies on a seasonal basis, creating an amplitude difference. This amplitude reduces due to mixing until complete mixing is reached and the groundwater gets the same signal as the long-term precipitation average (which also is the same as the old and deep groundwater). The difference in $\delta^{18}O$ between winter baseflow and the long-term average of the precipitation should therefore be linked to the groundwater travel time to streams.

Text changed to: The comparison of the modelling results to observations of δ18O was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). The precipitation signal varies on a seasonal basis, creating an amplitude difference. This amplitude is reduced due to groundwater mixing until complete mixing is reached and the groundwater receives the same signal as the long-term precipitation average. There is no or little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow. Hence, we assume that the stream isotopic signature originates from groundwater only (Laudon et al., 2007; Peralta et al., 2015). Consequently, the closer the stream signature comes to the long-term precipitation average, the more the groundwater has been mixed. The groundwater isotopic signature, in turn, should be correlated to the travel time to stream until full mixing of the precipitation signal is reached.

9. Line 187: But now imagine a year where the average input signal is equal to the average annual precipitation signal (that can also be found in the deeper groundwater). In this case you cannot draw a conclusion about how old the winter groundwater signal is because it will be close to the long-term average no matter if there is more young recently recharged or more old groundwater in the mix. Maybe you can use the variability in the winter stream isotope signal. But I would like to see a better explanation on why this method would work.

Reply: In Krycklan we have approximately six months of accumulating snowpack during winter and only a few instances of precipitation falling as rain nor snowpack melting. Of course, it can occur, but it’s rare, and one can assume that during these months no recharge occurs to the groundwater. We hope that the changed text below will better describe our conceptual model (Peralta et al., 2015). Our concept builds on:

1. We know from empirical evidence that deep groundwater (< 10 m soil depth) is equal to long-term average precipitation inputs.

2. All recharge that has occurred the month after the last spring snowmelt and before the winter is isotopically heavier.

3. The stream mix we measure during winter is hence primarily a combination of deep groundwater and more recent summer/autumn precipitation water. Hence, we can assume that the deviation between long-term average precipitation and winter streamflow is a good proxy for the travel time.

Text changed to: The comparison of the modelling results to observations of $\delta^{18}O$ was based on a conceptual model of the seasonal variability and differences between precipitation and runoff (Fig. 2a). The precipitation signal varies on a seasonal basis, creating an amplitude difference. This amplitude is reduced due to groundwater mixing until complete mixing is reached and the groundwater receives the same signal as the long-term precipitation average. There is no or little groundwater recharge during winter because almost all precipitation inputs arrive and accumulates as snow. Hence, we assume that the stream isotopic signature originates from groundwater only (Laudon et al., 2007; Peralta et al., 2015). Consequently, the closer the stream signature comes to the long-term precipitation average, the more the groundwater has been mixed. The groundwater isotopic signature, in turn, should be correlated to the travel time to stream until full mixing of the precipitation signal is reached.

Peralta-Tapia, A., Sponseller, R. A., Ågren, A., Tetzlaff, D., Soulsby, C., and Laudon, H.: Scale-dependent groundwater contributions influence patterns of winter baseflow stream chemistry in boreal catchments. Journal of Geophysical Research: Biogeosciences, 120(5), 847–858. https://doi.org/10.1002/2014JG002878, 2015.

10. Line 191: But does the preceding spring not influence the summer signature also? So how can you assume that the difference between winter and summer signature gives you the young water fraction in the summer if there is another overlaying signal from the spring? Somehow you have to take this into account.

Reply: What you state is true and is a weakness with this concept. To account for this as much as possible, we use the relative change, the ratio between the winter/spring and winter/summer, that gives a relatively good proxy of change. We also excluded June from the summer evaluation, because according to stream chemistry observations at the site, one can still see the impact of the spring snowmelt in most streams during this month. However, we added a section regarding the summer season issue in the discussion section 4.2.

Text changed to: Similar to the conditions in spring, the conceptual model predicted that the difference in stream isotopic signature between winter baseflow and summer flow, $\Delta\delta^{18}O_{summer}$, should be correlated to the young water fraction in summer, but with the opposite sign, due to isotopically heavier summer rains (Fig. 2). A larger inter-annual variation in precipitation and high ET likely caused the relationship to be less evident compared to the spring results as the snowmelt conditions are more consistent from year to year. The groundwater signal reaching the streams during the summer season may also be affected by a lingering signal from the snowmelt. However, although less evident than compared to the $\Delta\delta 18O_{spring}$, there was still a significant correlation between the average $\Delta\delta^{18}O_{summer}$ and the modelled young water fraction (Fig. 7e).

11. Line 253: Why are the UZ processes only active in the SZ? Should they not be active first and foremost in the UZ?

Original text: The ET and UZ processes are only fully active in the uppermost SZ-CL, and here the ET and UZ are calculated at a finer resolution, leading to a detailed calculation of the groundwater table level. If the groundwater table falls below the first SZ-CL, a more simplistic method, not taking capillary rise and all ET-processes into account, was applied

Reply: Apart from the UZ itself, the interaction between UZ and SZ processes (including influence from ET) is only fully active in the uppermost SZ calculation layer. If the groundwater table falls below the lower level of the uppermost calculation layer, a more simplistic method is used. The main result of this simplification is that capillary rise is not accounted for when the groundwater table falls below the uppermost SZ calculation layer.

Text changed to: The SZ-CLs vary with depth and are thinner closer to the soil surface; the first CLs extend to 2.5 m, 3 m, 4 m, and 5 m, respectively, below the ground surface, with the soil properties and depth extension following the stratigraphy (Table 3). The UZ and SZ interact throughout the soil. If the soil is unsaturated, the UZ discretisation and equations are used. The influence from ET and UZ processes on the SZ is only fully active to the depth of the uppermost SZ-CL. Here, the ET and UZ are calculated at a finer resolution, leading to a detailed calculation of the groundwater table level.

12. Line 259: Do you mean all ‘soil layers’ not deeper than 2.5 m below the ground surface being average into one soil type?

Original text: The thickness of the first SZ-CL in the Krycklan model results in all soils shallower than 2.5 meters being averaged into one soil type.

Reply: Yes, you are correct, and we, therefore, changed the sentence for clarification.

Text changed to: Following the thickness of the SZ-CL in the Krycklan model, all soils above 2.5 m depth are prescribed as one soil type with hydraulic properties being an average of all the soil types throughout the vertical profile from the ground surface to 2.5 m depth.

13. Line 259-265: You used ‘In the Krycklan model…’ at the start of sentences three times in this short paragraph.

Reply: Thank you for noticing it. We have changed this paragraph to remedy this.

14. Line 276: Streamflow accumulated of what period of time? It makes a big difference if it is accumulated over a day or a year. So I would write ‘…able to reproduce daily accumulated discharge…’.

Original text: The Krycklan flow model was able to reproduce observed stream accumulated discharge, groundwater levels, and timing of precipitation events

Reply: We agree with this change.

Text changed to: The Krycklan flow model was able to reproduce daily accumulated stream discharge, groundwater levels, and timing of precipitation events

15. Line 306: Numerical constraints restricted the number of particles released to 0.5 particles/10 mm modelled groundwater recharge PER GRID CELL, which corresponds to a total of approximately 0.6 million particles FOR THE ENTIRE MODELED AREA IN THE FIRST YEAR.

Original text: Numerical constraints restricted the number of particles released to 0.5 particles/10 mm modelled groundwater recharge, which corresponds to a total of approximately 0.6 million particles. This number of particles was assumed to be enough to capture the timing of recharge patterns (Fig. 4).

Reply: We agree with this change.

Text changed to: Numerical constraints restricted the number of particles released to 0.5 particles/10 mm modelled groundwater recharge per grid cell, which corresponds to a total of approximately 0.6 million particles for the entire modelled area in the first year. This number of particles was assumed to be enough to capture the timing of recharge patterns (Fig. 4).

16. Line 318: However, that does not mean that the distribution is significantly skewed if the SD is larger than half of the average. I think what you want to express is that if the SD is smaller than half of the average, the distribution is not significantly skewed.

Original text: If the distribution is significantly skewed, the SD is larger than half of the average

Reply: Thank you for the suggested correction. The text was changed accordingly.

Text changed to: If the distribution is not significantly skewed, the SD is smaller than half of the average

17. Line 324: Good job explaining why you chose to use the geometric mean. Makes sense to me.

Reply: Thank you, we hoped that our choice would make more sense with this addition to the text.

Result

1. Line 354-355: Be more consistent in the way you describe the catchments (size, soil, landuse). For example you say that C20 and C16 are both silt-dominated, yet in the parentheses you only repeat this for C20.

Original text: The longest stream MTTs were connected to silt dominated catchments such as C16 and C20. We used some sub-catchments for result representation, but all results are provided in Table 5 and Appendix A1. The displayed sub-catchments were: C2 (small till and forest dominated catchment), C4 (small mire dominated catchment), C20 (small silt dominated catchment), and C16 (the full-scale Krycklan catchment).

Reply: Thank you for noticing this error. C16 was supposed to be an example of a larger catchment, while C20 was supposed to be an example of a silt-dominated catchment. We changed the text accordingly.

Text changed to: The longest stream MTTs were connected to the larger catchments, such as C16, and the silt dominated catchments such as C20. We used some sub-catchments for result representation, but all results are provided in Table 5 and Appendix A1. The displayed sub-catchments were: C2 (small till and forest dominated catchment), C4 (small mire dominated catchment), C20 (small silt dominated catchment), and C16 (the full-scale Krycklan catchment).

Line 371: However, the groundwater MTT of mire-dominated catchments supposedly showed less variation due to the smaller amount of groundwater recharge in your (not-overland-flow-corrected) particle tracking model. Is that the case?

Original from text from the discussion: The lack of synchronicity between mire and silt areas caused greater annual MTTgeo variation for sub-catchments with both features. For example, the MTTgeo for C4, dominated by mires, decreased from 1.5 years to 0.7 years from winter to spring. In contrast, winter MTTgeo for the C20 catchment dominated by silt was 7.7 years, which decreased to 1.5 years in spring. The results also show that groundwater recharge is affected by the soil frost in mires. For example, C4 showed more variations in its seasonal MTTgeo, although C2 (dominated by forest and till) and C4 (dominated by mires) had almost an equal annual MTTgeo (Table 5). In spring, the MTTgeo was shorter in C4 than in C2 due to the surface runoff from the frozen mire. Comparatively, in winter, the MTTgeo of C4 was longer than C2 due to the lower recharge and displacement of older water during the spring. Besides the slightly higher specific discharge from mires (Karlsen et al. 2016), empirical-based studies suggest that the soil frost on mires causes a large fraction of overland flow (Laudon et al. 2007; 2011).

Reply: True. For example, in C4, $MTT_{geo,}$ including OL, goes from 1.5 to 0.7 years from winter to spring, while C2 goes from 1.2 to 0.7 years. Only looking at the particle tracking, the MTT_{geo} goes from 1.5 to 1.2 years, i.e., less variation due to smaller amount of groundwater recharge. These results can be found in the Appendix, Table A1. However, C4 shows more variation than C2 in both cases due to an older age in winter, due to less groundwater renewal in spring. Previously the result text got confusing by introducing both OL adjusted and not OL adjusted in the text. We will, however, add a part about this in the discussion section.

Change in discussion: The effect of the areal coverage of silty sediments was especially prominent in winter when the range in MTTgeo is between one and almost eight years. The change in seasonal MTTgeo from winter to spring was also largest for the silt dominated catchments. For example, there was a six-year difference for C20 compared to two-year difference for the similar-sized till dominated sub-catchment C6. These intra-annual variations can also be linked to another landscape feature, namely the areal coverage of mires. Mires affected the young water fraction only when new precipitation or snowmelt input into the system occurred in spring and summer. The contrasting hydrological response of mire and silt areas, respectively, caused greater annual MTTgeo variation for sub-catchments with both features. For example, the MTTgeo for C4, dominated by mires, decreased from 1.5 years to 0.7 years from winter to spring. In contrast, winter MTTgeo for the C20 catchment dominated by silt was 7.7 years, which decreased to 1.5 years in spring. The results also show that groundwater recharge is affected by the soil frost in mires. For example, C4 showed more variations in its seasonal MTTgeo, although C2 (dominated by forest and till) and C4 (dominated by mires) had almost an equal annual MTTgeo (Table 5). In spring, the MTTgeo was shorter in C4 than in C2 due to the surface runoff from the frozen mire. Besides the slightly higher specific discharge from mires (Karlsen et al. 2016), empirical studies suggest that the soil frost on mires causes a large fraction of overland flow (Laudon et al. 2007; 2011). Looking only at the part of runoff originating from groundwater (Appendix, Table A1), the MTTgeo for C4 decreases from 1.5 years to 1.2 years. However, C4 still showed more variation than C2, due to longer travel times in winter. The results suggest that the longer MTTgeo in winter was caused by the reduced groundwater renewal of mires in spring, because the main difference between the two being the mire soil frost of C4.

Line 393: How are the annual and seasonal MTTgeo values computed? Are they flow weighted or simple time averages?

Reply: We hope that the clarification of the method text 2.5 will suffice. MTTgeo values are calculated from the travel time distributions. The calculated travel time distributions were based on all particles arriving in a stream within a certain period of time, either annually or a specific season, for the entire modelling period. Since the particles are released with the rate of groundwater recharge, these become flow weighted in turn.

Discussion

1. Line 445: What do you mean by 'gamma transformation method'?

Original text: …years using long-term isotopic data and a gamma transformation method…

Reply: This sentence was changed to make it clearer.

Text changed to: … by applying a mathematical method for isotopic dampening to fit a model to the observed stream isotopic response.

2. Line 453: Do you show this scaling function anywhere? Would be good to see it written out.

Original text: Therefore, to allow for actual MTTgeo estimates, we corrected the results by reducing the estimated MTTgeo using the overland flow from the flow model as a scaling factor

Reply: We answer this question in The main question 2: As we stated in the discussion and the method section, we reduced the age using the amount of overland flow as a scaling factor. We showed the equation in previous iterations of the manuscript, but we received comments that it was not necessary to show because it's such a simple equation. However, we agree that showing the amount of overland flow for different seasons would be a good addition. We added this in the Appendix, Table A1. We also added the equation in the Appendix.

Text changed to: $\mathrm{MTT} = \mathrm{MTT}_{Particle\ tracking}\ (1 - \mathrm{fraction\ OL})$ Eq. A6

3. Line 483-484: These theoretical consideration strengthen the results of a winter MTTgeo being LONGER OR EQUAL TO four years. Are they also telling you that winter MTTgeo is BETWEEN four AND SIX years?

Original text: At an average water travel time older than four years, it can be expected that the groundwater has reached full mixing. Hence, older water can no longer be accurately quantified using water isotopes only due to amplitude loss (Kirchner., 2016). These theoretical considerations strengthen the results of a winter MTTgeo between four and six years for the larger sub-catchments as their stream isotopic signatures were close to the long-term precipitation average and, therefore, should have reached complete mixing.

Reply: Reading the text again, it might have been misleading. What we are trying to say is that the mix of the isotopes suggests that the water is older or equal to four years and that this is consistent with the calculated MTT, because they are equal to or older than four years.

Text changed to: At an average water travel time older than four years, it can be expected that the groundwater has reached full mixing. Hence, older water can no longer be accurately quantified using amplitude dampening of the water isotope signal (Kirchner., 2016). These theoretical considerations strengthen the results of a winter MTTgeo older than four years for some sub-catchments, since their stream isotopic signatures were close to the long-term precipitation average and, therefore, should have reached complete mixing.

4. Line 529: What exactly do you mean by 'synchronicity'? The seasonal patterns? Do you mean that the changes occur at exactly the same time during a year?

Original text: All sub-catchments showed similar synchronicity in the seasonal patterns in MTTgeo and young water fraction, but catchment characteristics influenced the magnitude of the seasonal patterns across the landscape. On a landscape level, the main causal mechanism determining the annual MTTgeo was the areal coverage of silt, which overshadowed the importance of other catchment characteristics (Fig. 8, Table 6). This finding stands in contrast to earlier studies in Krycklan by Peralta-Tapia et al. (2015) and Tiwari et al. (2017) that suggested that the groundwater travel times are nonlinearly linked to the catchment size. We found that the small silt dominated C20 catchment was a distinct outlier to such a scale-dependent pattern, indicating that catchment size may not be the primary factor determining the variability (Fig. 6).

Reply: The text was re-written to include the answer to your question. What we mean is that all sub-catchment had their shortest MTT_{geo} during the spring snowmelt and the longest in winter. We removed the word "synchronicity" for clarification.

Text changed to: All sub-catchments showed similar seasonal patterns in MTTgeo and young water fraction, manifested as water with shorter travel times discharging in spring and water with longer travel times discharging in winter. Some of the catchment characteristics influenced the magnitude of these seasonal patterns across the landscape. On a landscape level, the main causal mechanism determining the annual MTTgeo was the areal coverage of silty sediments (Table 1), which largely overshadowed the importance of other catchment characteristics (Fig. 8, Table 6).

5. Line 531: ‘the areal coverage of silt’? Do you mean ‘the spatially averaged silt content of the soil layer’? Or ‘the areal fraction of soils with a certain silt content’?

Original text: On a landscape level, the main causal mechanism determining the annual MTTgeo was the areal coverage of silt, which overshadowed the importance of other catchment characteristics (Fig. 8, Table 6).

Reply: What we meant by “the areal coverage of silt”, was the areal proportion covered by silt soils, referring to the silty sediment column in Table 1. We have tried to clarify this in the text.

Text changed to: On a landscape level, the main causal mechanism determining the annual MTTgeo was the areal coverage of silty sediments (Table 1), which largely overshadowed the importance of other catchment characteristics (Fig. 8, Table 6).

6. Line 535: The variability of what?

Original text: We found that the small silt dominated C20 catchment was a distinct outlier to such a scale-dependent pattern, indicating that catchment size may not be the primary factor determining the variability

Reply: Thank you for noticing that something was missing in this sentence. We have changed it accordingly.

Text changed to: The importance of the silt, rather than the catchment area, for the groundwater travel time is most clearly illustrated by the small silt dominated C20 catchment, which was a distinct outlier to such a scale-dependent pattern.

7. Line 532-543: I would also mention the correlation between catchment size and silt content you observed when discussing this issue.

Reply: We had a discussion regarding this topic in an earlier version of the manuscript, but it was removed for clarity purposes. We added this section again, in section 4.4., however, we re-wrote the section to work better with the new text.

Text changed to: However, it seems that this a spurious relationship, since there is a correlation between the catchment size and the areal coverage of silty sediments (Table 6). The reason is that the silty sediments are located in the lower parts of the Krycklan catchment, which implies that all large catchments contain at least some proportion of silty sediments. The importance of the silt, rather than the catchment area, for the groundwater travel time is most clearly illustrated by the small silt dominated C20 catchment, which was a distinct outlier to such a scale-dependent pattern. This indicates that catchment size may not be the primary factor determining the variability of travel times of different catchments (Fig. 6). Instead, the long travel times in C20 suggest that the groundwater flow velocity is slower in the silt areas than elsewhere in Krycklan, even though the average catchment slope is steeper than comparably sized sub-catchments in till areas (Table 1 and Fig. 1).owever, we found a correlation between the catchment size and the areal coverage of silty sediments. The reason is that the silty sediments are located in the lower parts of the Krycklan catchment, resulting in that all large catchments contain at least some proportion of silty sediments. However, we found that the small silt dominated C20 catchment was a distinct outlier to such a scale-dependent pattern, indicating that catchment size may not be the primary factor determining the variability of travel times of different catchments (Fig. 6). Hence, the long travel times in C20 suggest that the groundwater flow velocity is slower than elsewhere in Krycklan, even though the average catchment slope is steeper than comparably sized sub-catchments in till areas (Table 1 and Fig. 1). The areal coverage of silty sediments may also explain the relatively long travel times of other catchments such as C14. Although C14 is smaller than C15, it still has longer MTT.

8. Line 545: ‘Silt fraction effect’ is unprecise wording. What fraction? In the soil? Across the landscape?

Reply: This section was changed to:

Text changed to: The effect of the areal coverage of silty sediments

Line 570: What do you mean by '…silt dominated areas, that have more consistent hydrological conductive with soil depth…'?

Reply: The till soils show a greater decrease in hydraulic conductivity than other soils in the area, with fast-flowing water in the shallow part of the soil and slow-moving water in the deeper parts of the soil. This sentence was re-written to:

Text changed to: Consistent with this explanation, silt dominated areas had much longer MTTs than comparatively sized sub-catchments underlain by till soils, because till soils have a greater decline in hydrologic conductivity with soil depth (Fig 6, Fig. 8 and Appendix Fig. A1).

Conclusions

Line 583-585: This is interesting and you should explain what this would entail. Where and in which way would transit times change in a warmer climate?

Original text: In contrast, mires lead to increased fractions of young water, and hence shorter travel times, but mainly in spring when the soil was frozen. As a result of the lower groundwater recharge during the snowmelt, however, the MTTs in mires were, in turn, longer than in forests during the winter. In a warmer climate with reduced soil frost and decreased snowmelt input, we would expect the effect of mires to be reduced while the impact of till and silty sediment soils likely will remain relatively unaffected.

Reply: We believe that the section covers part of your question, but it was a bit "wordy" and we hope our changes make the statement clearer. We also extended the discussion regarding climate change.

Text changed to: In contrast, mires led to increased fractions of young water, and hence shorter travel times, but mainly in spring when the soil was frozen. However, mire dominated catchments experience longer travel times than similar-sized forested catchments in winter. Generally, for the boreal landscape, a warmer climate is predicted with reduced snow cover and snow duration, accompanied by increases in the frequency of winter thawing episodes and reduction in soil frost (IPCC., 2014; Jungqvist et al., 2014; Brown et al.,2017; Lyon et al., 2018). Our results suggest that these changes would reduce the intra-annual variations of MTT created by the freezing of mires, while the impact on other parts of the landscape would remain relatively low.

Ref: IPCC: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151 pp, 2014.

Jungqvist G., Oni S. K., Teutschbein C., and Futter M. N.: Effect of Climate Change on Soil Temperature in Swedish Boreal Forests. PLoS ONE 9(4): e93957. https://doi.org/10.1371/journal.pone.0093957, 2014.

Brown, R., Vikhamar-Schuler, D., Bulygina, O., Derksen, C., Luojus, K., Mudryk, L., Wang, L., and Yang, D.: Arctic terrestrial snow cover. Chapter 3 in: Snow, water, ice and permafrost in the arctic (SWIPA) 2017, pp. 25–64, Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, 2017

Lyon, S.W., Ploum, S.W., van der Velde, Y., Rocher-Ros, G., Mörth, C.-M., and Giesler, R.: Lessons learned from monitoring the stable water isotopic variability in precipitation and streamflow across a snow-dominated subarctic catchment. Arctic, Antarct. Alp. Res. 50, e1454778. https://doi.org/10.1080/15230430.2018.1454778, 2018.

Figures:

1. Figure 1: In the caption you use strange sentences ('(b) The soil map used in the Mike SHE flow model and is based on the soil map…', '(c) Depth to bedrock from the Swedish Geological Survey (2014) is shown in meters…').

Original text: Figure 1: The Krycklan catchment. (a) Location of sub-catchment and their outlets. The areas are color-coded based on their stream network connections, e.g., all sub-catchments of one colour connect before reaching the white area. For further details of the catchment characteristics, see Table 1. (b) The soil map used in the Mike SHE flow model and is based on the soil map (1:100,000) from the Swedish Geological Survey (2014), combined with field investigations. (c) Depth to bedrock from the Swedish Geological Survey (2014) is shown in meters below the ground surface. (d) Catchment topography, shown as meters above sea level (m.a.s.l.).

Reply: Thank you for noticing this error. We have changed this text to:

Text changed to: Figure 1: The Krycklan catchment. (a) Location of sub-catchment and their outlets. The areas are colour-coded based on their stream network connections, e.g., all sub-catchments of one colour connect before reaching the white area. For further details of the catchment characteristics, see Table 1. (b) The figure shows the soil map used in the Mike SHE flow model which is based on data from the Swedish Geological Survey soil map (1:100,000), 2014 and field investigations. (c) Soil depth to bedrock map taken from the Swedish Geological Survey, 2014, and is shown in meters below the ground surface (m.b.g.s.). (d) Catchment topography, shown as meters above sea level (m.a.s.l.).

2. Figure 3: There are no labels on the graphic. Where is the UZ, the SZ? I don't see the ten calculation layers either.

Reply: The figure is a schematic figure and not adapted to the specific model for the Krycklan catchment and its associated calculation layers. The ten calculations layer would not be possible to illustrate in a figure at this scale since they are so thin in comparison to the total soil depth. The purpose of the figure is to show the main interactions between the different parts of the system (ET, snow, precipitation, surface water and groundwater. Since the groundwater table is allowed to fluctuate from totally saturated and ponded conditions to large depth, the boundary between the UZ and SZ is not defined. However, as suggested, we added some labels to the figure describing the main parts of the model. See figure below.

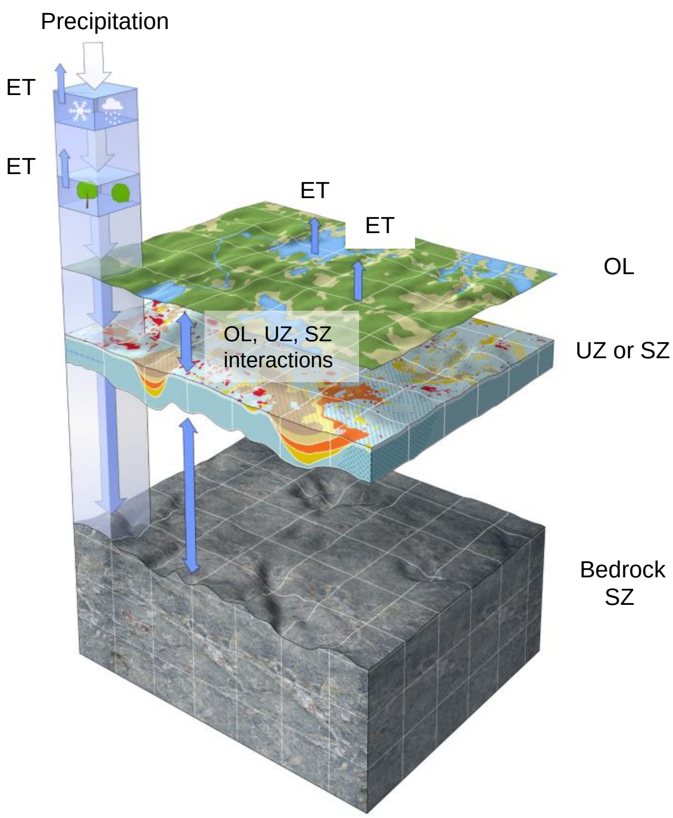


Figure 3 Schematic of a general Mike SHE model set up. Precipitation falls on the ground as rain or snow. Evapotranspiration (ET) processes include canopy interception, open surface evaporation, root uptake, and soil evaporation from the unsaturated zone (UZ). The overland flow (OL), saturated zone (SZ), and UZ interact depending on the saturation level. The SZ is divided into ten calculation layers (CL), while the UZ has a much finer description. Streamflow is modelled through Mike 11 and is not restricted to the Mike SHE resolution. The figure is used on the courtesy of SKB. Figure illustrator: LAJ.

3. Figure 5: Are these TTDs specific for a certain point in time? Are they forward or backward TTDs? Are they weighted averages of multiple TTDs (master distributions)?

Reply: Please see the answer to Question 1 of the Main questions: We like to answer these questions together because they handle the same issue. Figure 5 shows the distribution of all the particles exiting the model though a catchment stream over the entire modelling period. To clarify this, we changed the figure text to state that the statistics are based on all particles over the entire modelling period. We also added a part in section 2.5 to clarify the creation of the travel time distributions. It is correct that we take all the particles exiting a stream within a certain period of time and take the average of that distribution.

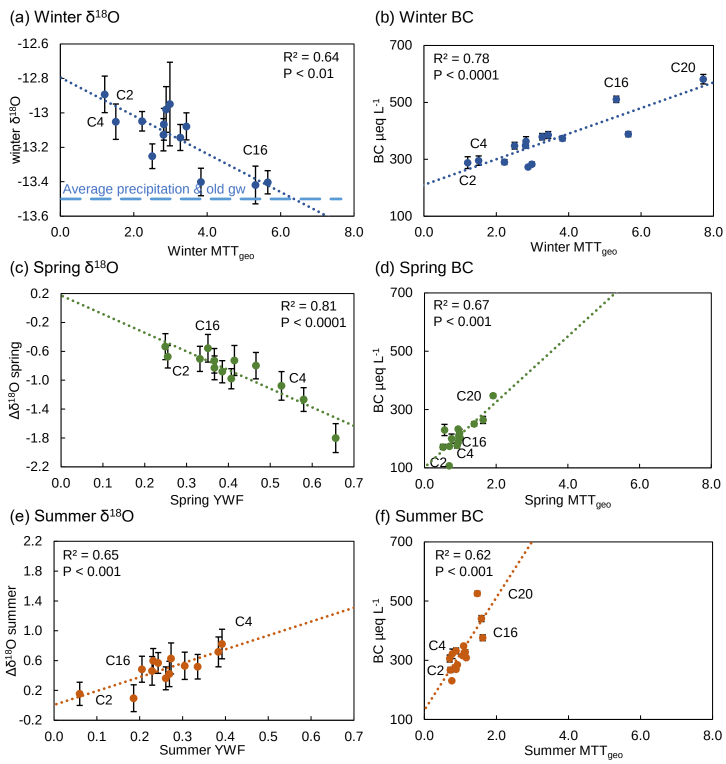
Text changed to: Section 2.5: The time it took for particles to reach a stream or lake via groundwater (hereafter called 'travel time') was calculated for each sub-catchment. The calculated travel time distributions were based on all particles arriving in a stream within a certain period of time, either annually or for a specific season, for the entire modelling period. The distributions were analysed using four statistical measurement tools, the arithmetic mean, the geometric mean, the median, and the standard deviation (SD).

4. Figure 6: The blue outline of the surface runoff gives the impression that there is surface runoff happening constantly in b), c) and d). Rather make it a blue fill without an outline (like the green fill for the groundwater contributions).

Reply: We agree with this change and believe that removing the blue outline made the figure easier to understand.

5. Figure 7: I recommend using the same scale for MTT, BC and YWF for all axes. This way the different relationships (as well as the season-specific variabilities) become much clearer.

Reply: We understand the reviewer's point of view, and we have changed the figure accordingly. Although the individual point was easier to see in the original plot, this version shows better the seasonal changes.



6. In the caption better write something along the lines of 'Relationships of seasonal MTTgeo and young water fractions with seasonal stream isotopic composition and base cation concentration'.

Original text: Figure 7: Results of seasonal young water fraction (YWF) and MTTgeo compared to stream isotopic composition and base cation concentration. Note that δ18O results are for 13 sites, while the BC record comprises all 14. The sub-plots (a) to (f) show the δ18O (winter) or Δδ18Ospring/summer and BC concentrations as a function of the MTTgeo in winter, spring, and summer, respectively. The standard error of the mean (SEM) shown as whiskers denotes variations in field observations.

Reply: We agree to the suggested changed and the new figure text is written as:

Text changed to: Relationships of seasonal MTT_{geo} and young water fractions (YWF) with seasonal stream isotopic composition and base cation concentration. Note that $\delta^{18}O$ results are for 13 sites, while the BC record comprises all 14. The sub-plots (a) to (f) show the $\delta^{18}O$ (winter) or $\Delta\delta^{18}O$spring/summer and BC concentrations as a function of the MTT_{geo} in winter, spring, and summer, respectively. The standard error of the mean (SEM) shown as whiskers denotes variations in field observations.

Tables

1. Table 1 and 2: Just a suggestion: Why not grouping the catchments and nested sub-catchments instead of listing by catchment number (so all the green catchments together and all the red and blue catchments together as well)? The numbering is somehow arbitrary.

Reply: This has changed from iteration to iteration because some people want the tables in name order, others in size order and yet others in colour order. We do agree to collect them in colour order is the neatest version, so we changed the tables to firstly be ordered in colour order, thereafter in name order. The numbering may indeed come across as somewhat arbitrary, but they are long-established in publications from Krycklan.

2. Table 5: I would rearrange the order in all the tables and group the catchments as mentioned earlier. In the caption rather write '…that is younger than three months…' instead of '…that is less than three months…'.

Original text: The geometric mean of the travel time distribution (MTT_{geo}) is adjusted for the overland flow. The young water fraction (YWF) includes overland flow and groundwater that is less than three months (%). An extended version of the results, including arithmetic mean, median, and SD, is included in the Appendix, Table A1.

Reply: We agree with this change and we changed the text accordingly. See our answer regarding colour order for table 1 and 2. The tables were changed to order of colour.

Text changed to: The geometric mean of the travel time distribution (MTT_{geo}) is adjusted for the overland flow. The young water fraction (YWF) includes overland flow and groundwater younger than three months (%). An extended version of the results, including arithmetic mean, median, and SD, is included in the Appendix, Table A1.

3. Table 6: Why did you remove the values that are smaller than 0.5? Please add them again - in the caption you are still mentioning the darker colors. Otherwise I like the new design (just make sure you either close all or none of the boxes around the seasons).

Reply: Thank you for this comment. We agree that the new design works better. In the new design, we tried to make the table smaller, yet with all the necessary information. However, we agree that we should add all values again, and we changed the table accordingly. We noticed an error in the table as well, and this error was also corrected.

Table 6: Correlation matrix – young water fraction (YWF), geometric mean travel time (MTT_{geo}), and catchment characteristics. The catchment characteristics include the log catchment size (Log A), the areal coverage of mires (Mire), and the areal coverage of silt (Silt). The table includes annual (grey), winter (blue), spring (green), and summer (orange) results. Darker colours show |r| > 0.5 with the connected p-value according to [a] p<0.05 and [b] p>0.05.

		Winter season					Summer season			
	Log A (km^2)	**Mire (%)**	**Silt (%)**	**MTT_{geo} (year)**	**YWF (%)**	**Log A (km^2)**	**Mire (%)**	**Silt (%)**	**MTT_{geo} (year)**	**YWF (%)**
Log A (km^2)	1	0.02	0.58 [a]	0.64 [a]	-0.08	1	0.02	0.58 [a]	0.68 [a]	0.20
Mire (%)	0.02	1	-0.37	-0.34	-0.14	0.02	1	.0.37	-0.50 [b]	0.91 [a]
Silt (%)	0.58 [a]	-0.37	1	0.92 [a]	-0.43	0.58 [a]	-0.37	1	0.80 [a]	-0.20
MTT_{geo} (year)	0.63 [b]	-0.51 [b]	0.90 [a]	1	-0.21	0.55 [a]	-0.55 [a]	0.92 [a]	1	-0.28
YWF (%)	-0.02	0.96 [a]	-0.39	-0.53 [b]	1	0.11	0.95 [a]	-0.29	-0.52 [b]	1
	Annual					Spring season				

Appendix

Line 869-870: ‘whereas’?

Reply: This word was left from an earlier iteration but is not necessary in the text as it stand now. This word war removed.

References

Remondi, F., Kirchner, J. W., Burlando, P., & Fatichi, S. (2018). Water flux tracking with a distributed hydrological model to quantify controls on the spatio-temporal variability of transit time distributions. Water Resources Research, 54(4), 3081-3099.

Heidbüchel, I., Yang, J., Musolff, A., Troch, P., Ferré, T., & Fleckenstein, J. H. (2020). On the shape of forward transit time distributions in low-order catchments. Hydrology and Earth System Sciences, 24(6), 2895-2920.

Reply: Thank you for the suggested references. These have been used in the introduction and added to the reference list.