Minor Revision

Comments to the Author:

Dear Elin and co-workers,

Congratulations for your last revisions. Thank you for all the efforts which went into your publication in our special issue. I have to apologise for the delay in handling your latest version, which was mainly due to my own uncertainty how to proceed. While in my view your paper is ready for publication in general, I came across a couple of unnecessarily sloppy details, which might be easy to resolve. Moreover, I am under the impression that your publication could be a very nice example for transparent science including the fundamental analysis code. Hence I decided to ask you once more for a quick feedback in a round of minor revisions before final acceptance.

I hope you find my comments helpful to fortify your paper and its outreach. I would be very happy if you can find a way to provide a more specific and complete reference to the data and at best even a condensate of your code.

All the best. Thank you again.

Conrad

Reply: Thank you for this positive response, your hard work and consideration of our manuscript. We have answered below each of your respective questions in brown. The major changes are also listed in the "Table of major changes". We removed all colors from the tables as instructed by the editorial support team of Copernicus Publications We also uploaded the model code and set up to Safe Deposit. Safe Deposit (managed at Svartberget research station) is a system for collection of forest research and materials, for past and ongoing projects. The intention is to have a long-term storage solution that is accessible for project colleagues and the public.

Table of major changes

- Data, including model inputs, model set up and main chemistry data was uploaded to Safe deposit
- Due to restrictions by HESS, colors were removed from all tables

Major comments

1. First of all the data and code: Your statement links to the Krycklan data website, which is fine. I made the effort to download the data and do some very quick plotting. What I could not find is data about the isotopic concentration in the precipitation. Further the adjusted 18O observations appear to be lacking.

Reply: We apologies that this data was missing from the Krycklan database (Krycklan Database, 2021). The website is undergoing updates, so all data are not re-uploaded there yet, but the data will be uploaded shortly. However, all chemistry data for this study can in the meantime be acquired from Safe Deposit (Jutebring Sterte et al., 2021).

The original ^{18}O data for all streams are available from the Krycklan database and Safe Deposit. ^{18}O data were adjusted in this study using the Fractionation Correction from Peralta-Tapia et al. 2015. Reviewers of earlier versions of the manuscript thought the equation was not necessary to include in the manuscript. However, we added the regression equation in the Appendix, Eq. A7.

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.

Krycklan Database, Hydrological Research at Krycklan Catchment Study, available at: https://www.slu.se/Krycklan, last access March 2021

DHI, Mike powered by DHI - MIKE software, available at: https://www.mikepoweredbydhi.com, last access March 2021

Jutebring Sterte, E., Johansson, E., Sjöberg, Y., Huseby Karlsen, R., and Laudon, H.: Krycklan Mike SHE 2020; Safe Deposit, available at: https://www.safedeposit.se/projects/166, last access March 2021.

2. Moreover, I do not see how I could possibly rework your results when starting MikeSHE from scratch and without the geo data. Since it is the year 2021 and since our special issue is also about transparency in data and code, I would like to persuade you to scope your options to publish some sort of repository alongside your paper. I simply see that your study is a very nice example of TTD and MTT analysis and people will hook to your work much more easily, when it is possible to really follow your calculations. I fully understand that the data policy of the Krycklan data explicitly seeks to avoid a copy of this data. This is fine. But for your further data and/or model setup/model results this could be easily feasible through github or any other DOI providing repository.

Reply: Thank you for this comment. We have now made all the model input data, including geological layers and input files, available at Safe Deposit (Jutebring Serte et al., 2021). The GIS, chemistry, and environmental data for Krycklan is available at the Krycklan database, under “Data service”, “Krycklan chemistry and environmental data” and “Krycklan GIS data” respectively (Krycklan Database, 2021). Chemistry data is also available through Safe Deposit. Note that licenses and software necessary to run the model can be acquired from DHI.

Krycklan Database, Hydrological Research at Krycklan Catchment Study, available at: https://www.slu.se/Krycklan, last access March 2021

DHI, Mike powered by DHI - MIKE software, available at: https://www.mikepoweredbydhi.com, last access March 2021

Jutebring Sterte, E., Johansson, E., Sjöberg, Y., Huseby Karlsen, R., and Laudon, H.: Krycklan Mike SHE 2020; Safe Deposit, available at: https://www.safedeposit.se/projects/166, last access March 2021.

Minor comments

Abstract:

1. Why is the "Krycklan" catchment name avoided until L112? I suggest to include it in the abstract near L25, since it is a well known experimental catchment. This could also strengthen the reference of the third sentence. It will also help meta analyses.

Reply: We agree to this change and "Krycklan" was added to L25.

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 of the Krycklan catchment (0.12-68 km^2).

2. L31ff. The sentence was modified and is fragmented now. Maybe: Catchments with mixed soil landscape settings typically displayed larger variability in seasonal MTTgeo, as contrasting hydrological responses between different soils (e.g., mires, till and silty sediments) are integrated. One more detail: I am not sure if mires and till can count as "soil types" (which may be a matter of languages used in the different classifications). Maybe simply "soils" would solve the issue?

Reply: We agree to the suggestion and have applied it to the new version of the manuscript accordingly.

We also agree that "mire" is not a soil type – or even a soil. Peat would be the appropriate term to describe the soil type in mires so this has been changed. However, we believe that "soil type" is a better and more specific word than just "soil" to describe the relevant differences in the landscape. Soil would rather refer to, for example, spodosol, histosol etc., which is not what we mean. Soil type is the appropriate term in soil science to describe the texture and composition of a soil. It was also a classification of soil types (and not soils) that was used to parameterize the model.

There are several national and international systems that are used to classify soil types, but most (if not all) in some way recognize the difference between sorted and unsorted soils. Especially in areas like Scandinavia, where there has been profound glacial influence on formation of soils, the perhaps most important distinction between different types mineral soils is that between unsorted glacial sediments (i.e. till) and sorted fluvial or glaciofluvial sediments. This is therefore how soil types are named and classified at least in a Swedish context, and that includes the maps from the Swedish Geological Survey that were used to set up the model. The soil type can then be described in more detail as, for example, sandy till or clay till, but in the available data they were just classified as till. Accordingly, we believe that till is the adequate way to describe the soil type in this case.

Main Document:

3. L135f. Maybe: the characteristic VEGETATION of this boreal landscape are Scots pine and Norway spruce… I would not see the vegetation as characteristic features.

Reply: We agree, this is a great improvement

4. L141 Why is the hydraulic conductivity given here? 5e-5 m/s is not coherent with table 3. Moreover it is difficult to refer to, when the other soil landscape characteristics are left for sec 2.3. Further a decreasing hydraulic conductivity is nothing specifically rare… I suggest to check again, what information is really characterising the different soil landscapes.

Reply: We agree to give a specific number here was confusing and have changed this sentence accordingly. However, the decreasing hydraulic conductivity is characteristic for glacial till compared to other soil types, and we believe that this is the key parameter that can explain much of the variation in transit times in the landscape. The other soil types in the catchment, such as the sandy and silty sediments have mainly been compacted by their own weight. This is probably true also for the upper part of the glacial till, which is so-called ablation till. However, beneath the top layer of the glacial till, there is basal till. The basal till was deposited underneath the glacier, which in turn gives the deeper till a significant compaction with soil depth compared to other soil types. We changed this section to clarify this.

Change to: Krycklan has a landscape distinctively formed by the last ice age (Ivarsson and Johnsson, 1988; Lidman et al., 2016). At the higher elevations to the northwest, located above the highest postglacial coastline, the soils can reach up to 15-20 m in thickness. Here, the soil primarily consists of glacial till, and the landscape is intertwined with lakes and peatlands. The deeper soils consist of basal till, which was deposited and compacted under the moving ice. In contrast, the shallower till layers, consist primarily of ablation till, which is less compact, since it mainly has been compacted by its own weight (Goldthwait, 1971). This causes a decreasing hydraulic conductivity with depth, which is characteristic for glacial till in northern Sweden (Bishop et al., 2011; Nyberg, 1995; Seibert et al., 2009). At lower elevations, the soils consist of fluvial and glaciofluvial deposits of primarily sandy and silty sediments. Compared to the soil at higher elevations in the catchment, these deposits can reach thicknesses up to approximately 40 to 50 m and have a hydrological conductivity that is more constant with depth because these soil types mainly been compacted only by their own weight.

5. Fig. 2: I still struggle to read this conceptual figure – not because it was too complex but rather not really in touch with the data. As mentioned, I tried to catch up with your approach by downloading some data from the database. I see your point in using the difference from the ∂18O winter. But what I could not really trace back is if the winter streamflow covers a range and the difference is calculated to either upper and lower bounds of this range, as the figure suggests. Your text does refer to the averages without any distribution. When checking in with the data, I could see the spring event as very pronounced signal while the summer is far less depicted. I was wondering if this figure might benefit from using real data or at least a curve for an idealised streamflow? Could you please clarify the winter streamflow range reference? Did I understand correctly that the isotopic concentration "raw data" from the Krycklan data base was adjusted (L179) and that the final merged product of 18O concentrations was used as reported in Table 2?

Reply: We tried to make the figure clearer by including the streamflow data of the sub-catchment C4, see figure below. Displayed in Table 2 are the average annual winter signatures (∂^{18}O winter). For example, on average C4 signature is approximately -13.1 ‰, for the years 2008-2018. The closer this average is to the long-term precipitation the older the winter baseflow is.

Every year, there is a change from winter baseflow to spring flood, i.e., winter -spring. The values listed in table 2 are the mean of the difference between the average spring signature and average winter signature for all years (2008-2018). I.e., on average, the change from winter to spring signature is -1.1 for C4. The same method was used for summer, but here the difference is made from winter and summer signature averages. The fact that the difference between winter and summer is less distinct than winter and spring, is also reflected in the results (Fig. 7c and e).

We also clarified the lengths of the winter, spring, and summer seasons. The winter season occurs early December to late February, from negative air temperatures, until increasing temperatures causes small snowmelt events. The spring season is the period of the main spring flood. The isotopic signal is more sensitive than the BC data. Even though the BC data is less affected by early snowmelt in March and small precipitation inputs in November, we decided to use the same dates for evaluation of 18O and BC for clarification. We also added these dates in a table (now called A1) in Appendix.

Table A1: Dates used for chemistry investigation. The dates are start and end dates for observations within the seasons classified as winter, spring, and summer respectively. Note that BC only includes dates from 2008-2016.

	Season - Winter		Season - Spring		Season - summer	
Year	**Start date (year-month-day)**	**End date (year-month-day)**	**Start date (month-day)**	**End date (month-day)**	**Start date (month-day)**	**End date (month-day)**
2008	2008-01-16	2008-02-13	04-18	05-12	07-01	09-28
2009	2008-12-09	2009-02-12	04-20	05-12	07-08	09-15
2010	2009-12-15	2010-02-10	04-15	05-14	07-06	09-28
2011	2010-12-16	2011-02-21	04-18	05-09	07-04	09-28
2012	2011-12-20	2012-02-14	04-17	05-14	07-03	09-25
2013	2012-12-18	2013-02-20	04-17	05-10	07-04	09-20
2014	2013-12-17	2014-02-25	04-22	05-13	07-08	09-29
2015	2014-12-16	2015-02-17	04-17	05-12	07-14	09-22
2016	2015-12-15	2016-02-15	04-18	05-12	07-12	09-20
2017	2016-12-06	2017-02-08	04-18	05-09	07-11	09-21
2018	2017-12-05	2018-02-13	04-17	05-07	-	-

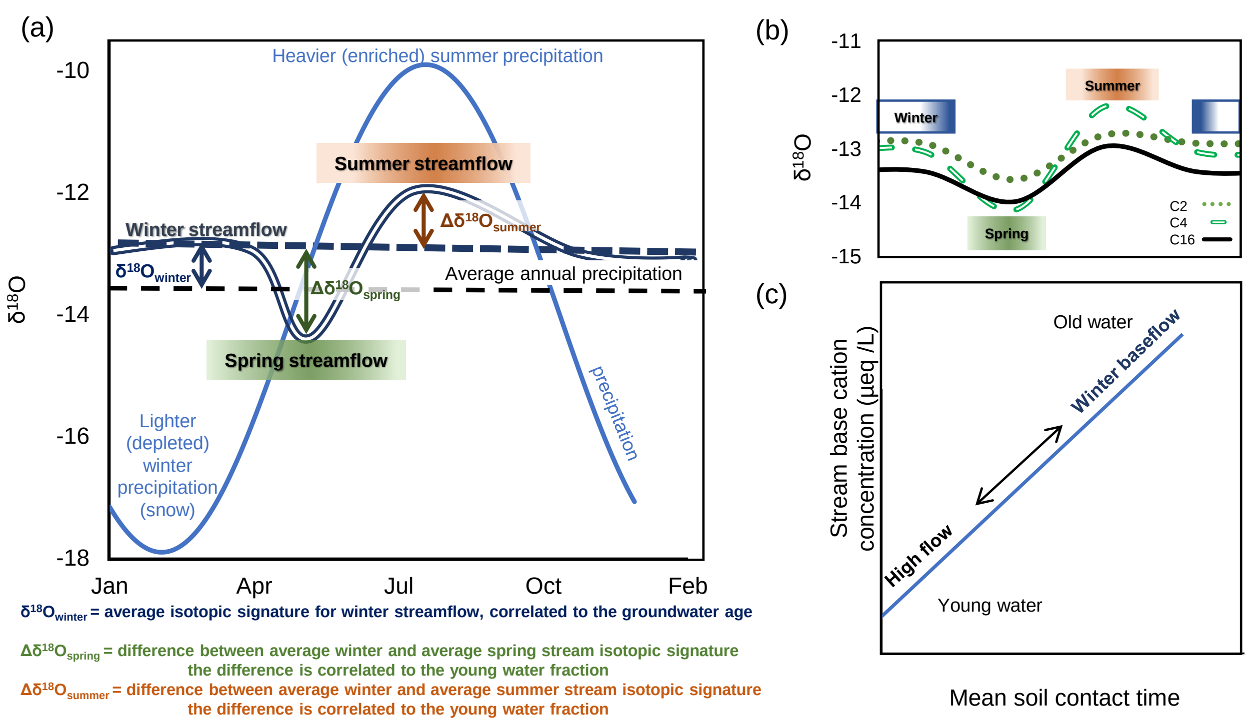


Figure 2: Conceptual figure of travel time to stream vs stream isotopic signature (a and b), and stream base cation concentration (c). (a) The connection between $\delta^{18}O$ and travel time to stream, where the sine curve shows the annual variations of $\delta^{18}O$ in precipitation, and approximate seasonal winter, spring, and summer stream compositions are marked and exemplified by the average annual changes of C4. In winter, the travel times are related to the average deviation in the isotopic signature between the winter baseflow and the long-term precipitation. In spring, the fraction of young water is correlated to the difference between the average spring stream signature and the average winter baseflow. In summer, the fraction of young water is correlated to the difference between the average summer stream signature and average winter baseflow. (b) Seasonal $\delta^{18}O$ averages for three example streams: C2, C4 and C16. (c) The connection between base cation (BC) concentration and soil contact time. The longer time the water spent in the mineral soil, the higher the stream concentrations of BCs will be due to soil weathering.

Table 2: I could not see any isotopic concentration records of the precipitation in the Krycklan database.

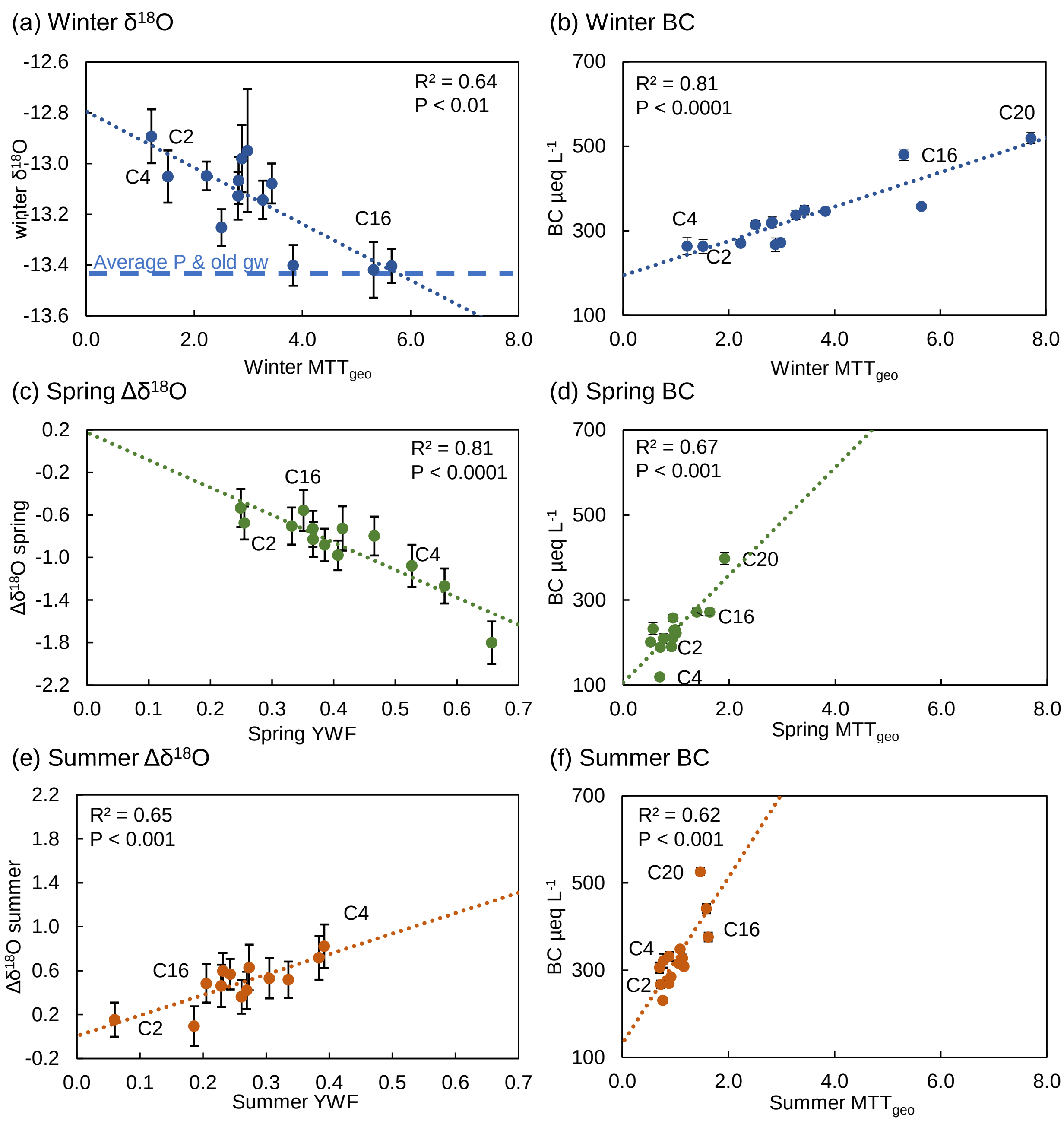
Reply: We apologies that this data was missing from the Krycklan database. However, as previously stated, all data can in the meantime be acquired from Safe Deposit. Here, we also added the specific chemistry data used in this study in a zip-folder together with the model set up and input files.

L285f. Did I understand correctly that until here, MikeSHE was setup based on common rainfall, runoff and groundwater dynamics but without information about the isotopic concentration dynamics or BC? Maybe referring to "all available data" is sparking some confusion?

Reply: We understand the confusion. We removed the "all available data" comment in the description of the Mike SHE model. No chemistry data was used to drive the Mike SHE flow or particle tracking. The chemistry data was only used to evaluate the model results.

Fig. 7: Here the concept explained in Fig. 2 is applied to evaluate the model performance. Referring to the last comment, 18O and BC are only used as evaluation reference, correct? I suggest to either include the Δ in the subfigure titles in c and e. Or even more easy to digest why not printing ∂18O Winter – ∂18O Summer?

Reply: You are correct. No chemistry data was used to drive the Mike SHE flow or particle tracking. The chemistry data was only used to evaluate the model results. We liked your first suggestion and added Δ in the subfigures c and e, see figure below.



L476f.: Did I understand correctly that MikeSHE simply adds a particle for every 20 mm recharge but that the isotopic concentration dynamics of the precipitation was not used? Does this imply that the percolation is actually neglected? In addition I find your argument slightly self-fulfilling: Since you focus your analysis on groundwater dynamics you can only retrieve dominance of the groundwater domain. All interpretation whether percolation and unsaturated zone water is negligible or not is actually just reiterating your assumption. I think this could be formulated more clearly here.

Reply: The chemistry data was only used for model evaluation. It was not used as a driver of the model.

Yes, the percolation is neglected. However, as stated in section 2.5 we do account for the overland flow when assessing MTT. Furthermore, the uncertainty of the time spent in the unsaturated zone is reduced whenever the groundwater table and recharge rates are high, which is when most particles are placed in the groundwater.

L542: I suspect “this" refers to the finding about catchment size. Maybe something like this is more clear? “However, a correlation of travel times to catchment size appears to be a spurious relationship.”

Reply: We liked the suggested change and have applied it to the new version of the manuscript.

L602: why is there a dot after IPCC?

Reply: Thank you for noticing this error, it has been fixed and the dot was removed.