Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2020-121-AC2, 2020

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Linking groundwater travel times to stream chemistry, isotopic composition and catchment characteristics" *by* Elin Jutebring Sterte et al.

Elin Jutebring Sterte et al.

eljs@dhigroup.com

Received and published: 9 July 2020

Introduction comment from reviewer #2 In the manuscript "Linking groundwater travel times to stream chemistry, isotopic composition and catchment characteristics," Sterte et al. analyze the drivers of catchment travel times across catchments in norther Sweden. They use a physical hydrology model combined with particle tracking to generate transit time distributions and compare this to isotopic and stream chemistry observations. Overall, I think that the study is well done and the manuscript is well written and easy to follow.

- Authors response: We would like to thank reviewer #2 for his/her constructive criticism

and suggestions, which we believe will help to improve the manuscript. The main concern seemed to be the introduction and hypothesis, which we, having read the reviewer's comments, agree should be re-worked to progress the manuscript further. Our explanations and responses to all the reviewer's comments and questions are listed below.

However, I do have some signiïňĄcant concerns about the manuscript in its present form. My most serious concern is that it's not clear what the novelty of this study is that would warrant publication in HESS. All of the methods used here are well established and the idea that catchment travel time distributions are driven by catchment characteristics is not new. The authors start from the hypothesis that catchment area is the main driver, however previous research has already indicated that many drivers will be important, so disproving this hypothesis does not seem to be the best angle to take here. I would suggest the authors consider what portions of their ïňĄndings are the most novel addition to the body of literature in this area and organize the manuscript around this rather than the area hypothesis.

- Authors response: Thank you for this comment, it will help to make a better manuscript. We received a similar comment from reviewer #1. Based on these comments, we will re-focus the manuscript, and in the new version, better highlight the novel aspects of this study. This includes emphasizing the implication of processes in the northern landscape setting where the hydrology is dominated by prolonged winter conditions followed by snowmelt. We do that by studying one of the most well-investigated and well-instrumented catchment systems in the boreal region. Both reviewers have pointed out that the hypothesis that the catchment area is the main factor controlling the travel time distributions is obsolete and that the manuscript, therefore, should not be organized around this idea. Having considered the remarks of the reviewers and studied the literature thoroughly, we feel inclined to agree that this was a mistake and that the manuscript would benefit from a revision where this idea does not have such a central place. As Reviewer #2 remarks below, this should not be the storyline of the manuscript, particularly as neither the modelling results nor the observations supported the area hypothesis. Therefore, we see that there are possibilities to improve the manuscript by emphasizing and developing other aspects of the results, for instance, the role of base flow in these boreal systems as this will make the novel contributions of this study clearer.

Even if the area hypothesis is what guided the study in the ïňĄrst place, this does not need to be the storyline of the manuscript. Along the same lines as my ïňĄrst comment I think the introduction could use significant revision. As it stands it is a very broad overview of the topic but I would like to see a more thorough review of previous ïňĄnding directly relevant to this work that can clearly motivate the novelty of this study and the gap it is ïňĄlling. Similarly I think the discussion section would be more powerful if it provides a better evaluation of how and where results form this study add new information/disagree or provide additional corroboration to existing studies.

- Authors response: Thank you for your comment. We understand that the introduction needs to be extended with at least a section regarding relevant works related to this study. We received some very helpful reference suggestions from reviewer #1, which we will incorporate to change and extend the introduction with regards to relevant research. We also agree that the catchment size hypothesis used in the original version of the manuscript is not the best way to present the results of this study. Both the introduction and the discussion would, therefore, have to be changed accordingly. We will focus the study on the connection between baseflow travel times and stream chemistry (base cations and isotopes). There is a unique opportunity to distinguish the baseflow in the streams due to the prolonged winter, which gives little to no new input of water to the system. The baseflow, in turn, can be a very important signature for the amount and quality of groundwater. The boreal systems are sensitive to climate change, and to have as much of a base understanding of these systems as possible is important to be able to evaluate changes in the future. Shorter snow seasons and changes in the amount of precipitation can change travel times in the future, which can

have an impact on weathering and biological processes. We have in this study show a strong relationship between isotope mixing and base cation concentrations, on the one hand, and groundwater travel times on the other. We have already seen changes in the climate in the last couple of years, making this a pressing issue.

For the most part I think the paper is very clearly written, however the description of the modeling approach is a bit confusing and could use some more details. For example the term simulation is used to refer to both the hydrology model and the particle tracking portion which can be confusing. This section could be helped by a ïňĄgure or a schematic to illustrate the approach I think.

- Authors response: Reviewer #1 also requested a schematic figure, and we agree with the reviewers and like the suggestion to better describe the modeling procedure, see a preliminary figure 2. We will also give more distinctive terms to the hydrology modelling part and the particle tracking part of the manuscript. One reason for the confusion is probably that much of the hydrological model was described in a previous paper. Although this paper was cited, we realize that we need to explain the model setup in more detail also in this manuscript so that potential readers can grasp the general idea of what has been done without reading the previous paper.

SpeciïňĄc comments from reviewer #2

Authors' disclosure: We agree with the most specific suggestions and comments from reviewer #2. However, some sections of the introduction and discussion will be rewritten whit the help of this input, and some sentences might end up being different in the revised manuscript.

I think the catchment numbering could be done in a more intuitive way so its easier to separate unique outlets (i.e C12-15). I would suggest giving each of these outlets their own letter and then numbering points within them potentially by drainage area, that way itis easier to compare when points are within the same drainage or not.

- Authors response: We understand the concern regarding this comment. However, we hesitate to change the names of the sub-catchment since they all have been included in many previous peer-reviewed papers, which argues against introducing new names in this manuscript. It would make all comparisons with previous papers from the Krycklan catchment unnecessarily difficult and confusing. We hoped that the colors of figure 1 will help to distinguish which sub-catchments were connected. However, we will also add a color code in table 1, which will further connect the different sub-catchments in figure and text.

Line 138-140: This is confusing are you trying to say that the hydrologic model is run ïňĄrst and then the particle tracking is applied to the outputs of that model?

- Authors response: Yes, the model flow field is run first and, then one year of the flow field is cycled for 1000 years with particle tracking applied to the flow field results. We will add the schematic figure (see figure 2) to clarify these steps and be more direct that the hydrology model output used are the results from the model is used in Jutebring et al. 2018. We will also add a more in-depth description of the water movement model in the revised manuscript.

Section 2.3 – this is really more a description of scenario design than numerical methods. I would consider renaming.

- Authors response: We appreciate this suggestion from the reviewer and will incorporate the suggestion and change the name from numerical methods to scenario design.

Line 148: 'several years' is very vague can you be more precise.

- Authors response: We agree with the reviewer and will be more precise. It is one year of the Mike SHE flow results that has been cycled for 1000 years in order to allow for long-term particle tracking. We will clarify this throughout the manuscript.

Line 154: at what time frequency were particles injected into the model? Just at the start of each year?

- Authors response: We will clarify this section of the text. The particles are only introduced in the first year. The Mike SHE flow results of that year are then cycled 1000 times to let the particles travel for a longer period (1000 years).

Line 159: I think the more standard reference for this would be heavy tailed rather than long tailed.

- Authors response: A distribution with a long tail means that there is a large proportion of the distributions is far away from the main central tendency. A long-tailed distribution can also be heavy tailed, meaning that a distribution goes towards zero slower than an exponential distribution. In the section in question, we are talking about the use of the geometric mean instead of the arithmetic mean for long-tailed distributions because the geometric mean is less bias to the long tail and describes the central tendency more effectively.

The term simulation is used to refer to both the hydrology model and the particle tracking model and this can make the methods confusing when you are talking about run times for example.

- Authors response: We will look through the manuscript and try to be more distinct when using the term simulation so that it becomes clearer when we talk about the flow model or the particle tracking.

At the beginning of section 2.3 you say that you used several years of simulation but actually it looks like you use only one year of the hydrologic simulation but repeated it 1000 times (i.e. more than several). This description is confusing.

- Authors response: We have taken one year and repeated it 1000 times. We will be more distinct and not use the word several for better clarity in the revised manuscript.

I think some of the tables could be converted to ïňĄgures to better present the information. For example Table 4 could be presented as a series of maps.

- Authors response: We do not understand exactly what the reviewer is asking for. Most of the information in Table 4 are shown in the figure 2 in the manuscript. We attempted to make maps at the onset of this study, but the information was not clearly visible. However, we will add travel time distribution per month for each sub-catchment to visualize the impact of various fractions of travel times. See an example of C16, Figure 6.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2020-121/hess-2020-121-AC2-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-121, 2020.

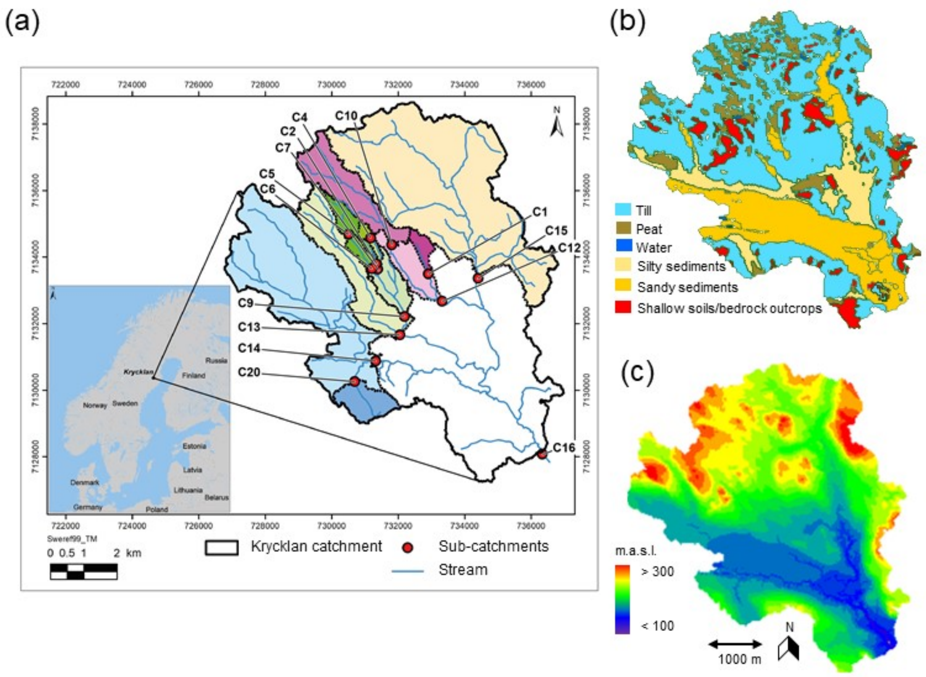

Fig. 1. The Krycklan catchment

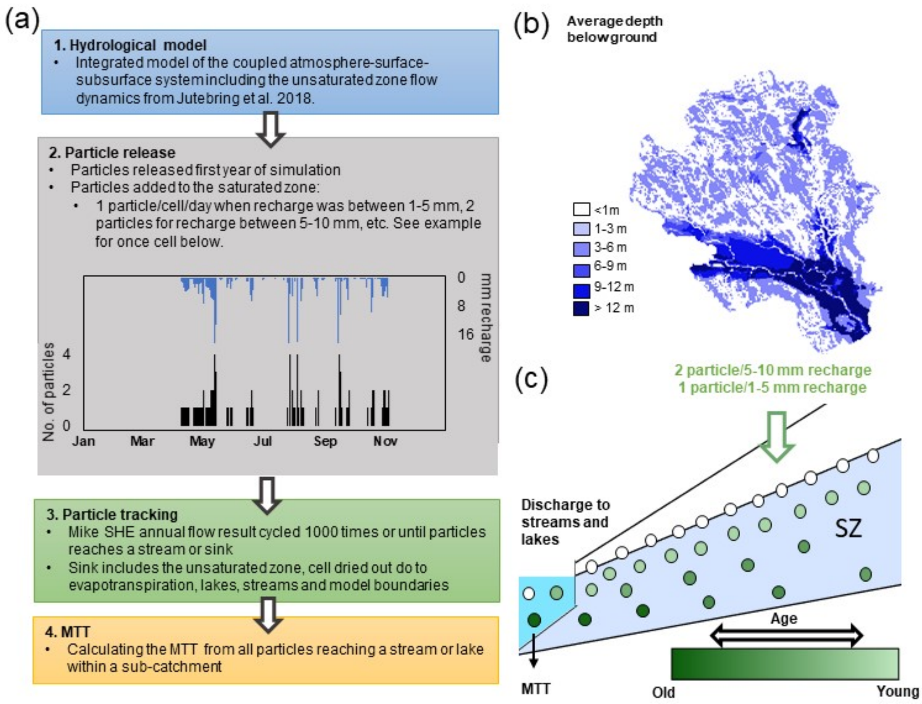

Fig. 2. Model setup

C16

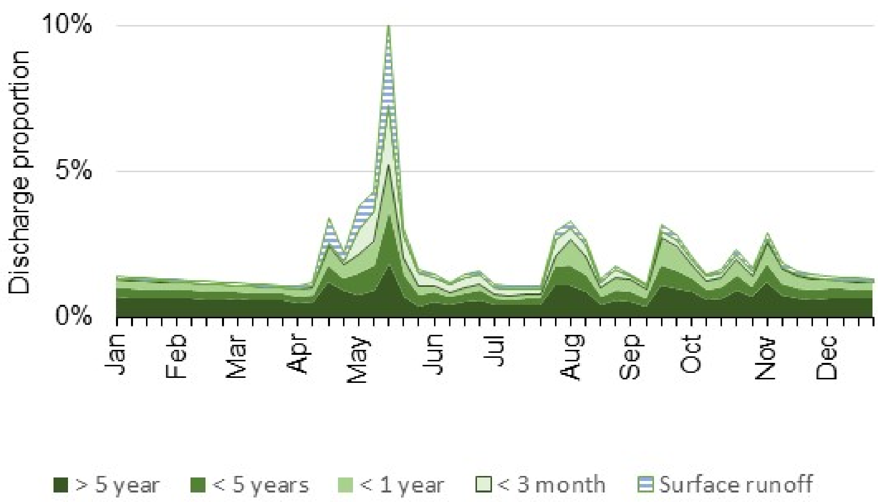

Fig. 3. Discharge distribution

Figure text

Figure 1: The Krycklan catchment

(a) Location of sub-catchment and their outlets (red circles). The areas are color-coded based on their stream network connections, e.g., all sub-catchments of one color connect before reaching the white area. For further details of the catchment characteristics, see Table 1.
(b) Soil map used in the hydrology model is based on the quaternary deposits map (1:100,000) and depth to bedrock map from the Swedish Geological Survey (2014), combined with field investigations.
(c) Catchment topography, shown as meter above sea level (m.a.s.l.).

Figure 2: Model setup

(a) Step by step of the particle tracking procedure.
(b) Average depth to groundwater table. The main part of the model area has a calculated depth to the groundwater table between 0-3 m. Note that the top vertical layering of the saturated zone is 2.5 m at the soil surface and the thickness thereafter follows the soil layers (thickness increasing with depth) while the horizontal grid-size is 50x50 m.
(c) Schematic illustration of particle tracking set up. Particles are added in each cell at the depth varying and transient groundwater table. The age of these particles is zero at the time of recharge. The particles then follow the groundwater flow while increasing in age. All particles that reaches a stream or lake receives an end age which is equal to time from recharge to discharge in the stream. MTT is calculated for each stream using these particles.

Figure 3 – Yearly discharge distribution of C16 (full-catchment). The discharge is divided into different source fractions, ranging from surface runoff to groundwater flow. The groundwater has been further divided into age groups which been calculated through the particle distribution for each month. The groundwater categories shown are; less than 3 months, less than 1 year, less than 5 years and more than 5 years.

Fig. 4. Figure Text