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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.

Anonymous Referee #1

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General comments:

In this study the authors used a physically-based distributed model in combination with a particle tracking approach to determine groundwater travel times in the well-studied Kryklan catchment in northern Sweden. They compared the modeled mean travel times (MTTs) with average winter values of stable isotopes, pH, base cations and found significant correlations for all of them. Furthermore they tried to relate MTTs to certain catchment characteristics. The only strong and significant correlation they found was between MTTs and the fraction of low conductive sediments.

The use of particle tracking approaches to determine travel time distributions with nu-

merical models becomes more and more common in catchment hydrology. And although some of these approaches still suffer from certain simplifications (missing dispersion component, particles disappearing after temporary exfiltration, etc.) they can already shed light on general catchment dynamics. Having said that I am missing a more detailed description of both the model setup with Mike SHE and the particle tracking approach in particular (one or two additional figures would not hurt).

Language, style and structure throughout the manuscript are quite good and easy to follow.

In the introduction the authors present their hypotheses regarding the relationships between travel times and catchment characteristics. However, it seems that the review of relationships that have already been determined in former studies is a little short. I would like to point out that it is already quite well established that MTTs are time-variant and going along with this the strength of relationships between MTTs and certain physical catchment characteristics changes as well (this should be discussed at least in a little more depth than just mentioning it in line 49 once). Also research over at least the last 10 years has stressed the fact that it is in most cases a combination of multiple characteristics that control a catchment's MTTs. A comprehensive (short) summary of the state of art would be really helpful.

I am also missing a more detailed analysis of the modeled travel time distributions. I am especially intrigued by the very steep initial rise of the cumulative distributions. Given the fact that the TTDs are related to baseflow conditions, this seems particularly puzzling to me. Therefore I would like to see more explanation and discussion in this part. A figure of the modeled (not cumulative) TTDs would also be interesting/helpful.

The discussion and conclusion sections are straightforward and quite easy to comprehend. This may, unfortunately, be due to the fact that the results are not really new. Catchment size is not related to MTTs; hydraulic conductivity, slope and flow path length are related to MTTs. In the end I am left wondering whether there is enough novelty (maybe relating pH and base cations to MTTs?). A more in depth discussion of the modeled TTDs could help or maybe additional analyses on the interdependencies of how different catchment characteristics combined control MTTs. Still, I believe that in the end the authors will manage to add more analysis and discussion to justify a publication in HESS.

Specific comments:

Line 23: '…to investigate…'

Line 23: Better write: '…the travel time of the input to 14 […] sub-catchments via groundwater to the stream…'.

Line 30: Move this sentence up to Line 27 just after '…stream water.'.

Line 31: I would add whether these were positive or negative correlations.

Line 34: I would not call this a 'landscape characteristic'. Maybe better call it 'physical catchment characteristic'.

Line 35: '…to positively correlate with MTT.'

Line 50: These referenced papers deal mainly with mean travel times, not with travel time distributions. Appropriate references for variations in TTDs would be for example Botter et al. (2010), Heidbüchel et al. (2012), Hrachowitz et al., (2013).

Line 87: Again, I would not use 'landscape' factors since the term landscape refers to the visible landforms rather than to physical properties or subsurface features.

Introduction: This section lacks the mention/discussion of previous work that is very relevant to the study. Especially concerning research on the connection of travel time and catchment characteristics. Your hypothesis is that catchment size correlates with travel time, but what about any other catchment properties? So far travel times have been related to slope, flow path length, soil thickness, antecedent moisture content, hydraulic conductivity, just to name a few. I recommend expanding the short introduc-

tion a bit more to include a brief discussion of potential travel time controlling factors (Ameli et al., 2016; Birkel et al., 2016; Haitjema et al., 1995; Heidbüchel et al., 2013; Hrachowitz et al., 2010; McGuire et al., 2005; Yang et al., 2018).

Line 106: '…type OF regolith…'?

Line 123: I would like to see a figure of the stratigraphy and how it is displayed in the model.

Line 172: Are these winter GW travel times travel times of particles that entered the catchment during the winter or exited the catchment during the winter (are they from 'forward' or from 'backward' TTDs)? This is a very important and interesting question since it could be very different catchment characteristics that control forward or backward travel times.

Line 215: According to this equation a mire coverage of 100% would result in an infinitely large adjusted cation concentration which is quite unrealistic (this is equivalent to a scenario where mires do not contribute any cations whatsoever). How do you justify this relationship?

Line 220: What exactly do you mean by this ('…less impacted…', '…also considered.')?

Line 239: But the simulated specific baseflow is not included in Table 4.

Line 243: Again it would be important to know whether these are forward or backward times.

Line 243: I would somehow indicate that the means are geometric instead of arithmetic when you write MTT (maybe something like 'gMTT'?). Because one will automatically assume that MTT is the arithmetic mean of the travel times.

Line 245: This is not a complete sentence (verb missing).

Line 248: 'Over the course of a year…'; '…may enrich or dilute…'

Line 259: Winter baseflow or winter groundwater fraction?

Line 272: Instead of 'decreased' I would rather write '. . .became more negative/became more enriched in the lighter isotope. . .'

Line 277: '. . .averageS. . .'

Line 292-294: It would be good to add 'positive' or 'negative' before 'correlations', so you immediately know the direction of the relationship.

Line 297: How do these equations show that LCS is the most significant parameter?

Line 304: 'Percentage of low conductive sediments. . .'

Line 314: '. . .on the other. . .'?

Line 318: '. . .and a gamma distribution transfer function (convolution) method. . .'

Line 318: 'In a conceptual, non-distributed modeling study. . .'

Line 319: Some more details would be helpful ('another travel time distribution technique').

Line 361: This section is a bit unstructured. You start out by stating that slope and hydraulic conductivity are the main factors controlling MTTs, then you state that the fraction of LCS is the most important factor adding travel distance to the mix before arguing that the steeper small C20 behaves differently maybe also because of the fluvial deposits fraction. . . Since these are some of your main findings it would be good to clarify the section.

Also, what about the fact that you released the particles at the top of the transient groundwater table? That means that depending on the groundwater table a larger or smaller part of the regolith was not taken into account for the MTT calculations. If the water table was high a larger proportion of the regolith was considered, if it was low the particles started somewhere else in the profile. What are the implications of this?

Would that influence your results?

Line 380: It would be good to point out more the novel aspects of your work. What did you find out that was really new? The fact that Darcy's law works? Catchment size has been ruled out as a MTT control since quite a while now. Or is it mainly a study that confirms the applicability of the particle tracking of your model by comparing results to time series of pH, base cations and stable isotopes?

Figures:

Figure 1: Why do you call the sub-catchments subareas in this figure? Also, all sub-catchments (not only the green ones) connect before reaching the main outlet at C16.

Figure 2: I am confused by the y axis label. Why does it start with 100% and then decrease to 0%? Isn't this a cumulative TTD (that should start with 0%)? Also, you never mention how you construct this TTD. Do you record the time the particles that arrive in the stream in the winter needed to travel through the catchment (backward TTD) or do you record the time that particles that are released during winter need to travel through the catchment (forward TTD)? I am curious since the cumulative TTDs exhibit a shape I would not have expected since the initial rise is very steep although you use a logarithmic x axis. For a groundwater TTDs in particular, this extremely high initial values are quite unusual. How do you explain this?

Figure 3: So if you replace the geometric MTT with the commonly used arithmetic MTT, how does that change the correlations? In case they become weaker you could argue for the general use of the geometric MTT.

Supplements

S1: Check again for typos and misuse of words throughout the supplement (in particular in the table captions and the table foot notes).

S1, line 3: What does that mean that the table includes both non-transformed and log-normal transformed data? Which is which?

S1, line 4: What happened to the other 44% of particles?

S1, line 8: ‘Artesian’ mean? And why ‘back-transformed’?

S1, line 19: ‘. . .as well as the precipitation (P)’

S2, line 3: What does ‘The statistics are based on. . .’ mean?

S2: The tables are not that helpful. Many of the abbreviations are not explained.

Literature

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