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Interactive comment

Interactive comment on "Aggregation effects on tritium-based mean transit times and young water fractions in spatially heterogeneous catchments and groundwater systems, and implications for past and future applications of tritium" *by* M. K. Stewart et al.

Anonymous Referee #1

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The paper builds on the publications by Kirchner (2016) analyzing the effects of aggregation of transit times distributions on estimating the MTT from 2 systems using tritium as a tracer. In addition, the paper also discusses the effects for a couple of examples from the literature. The paper is well written, however, it could be improved when better linking the examples with the analysis of the aggregation effects, considering from the beginning the use of compound LPMs and improving the readability and celerity of the figures. The list of comments and ideas below should help to improve the paper to be

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Discussion paper

published in HESS.

General comments:

1) The definition of heterogeneity needs to be clearer in this paper. Most LPMs assume a certain heterogeneity in the system, otherwise there would not be a transit time distribution – the specific effect considered in this paper regarding the aggregation effects are two distinctly different systems, each heterogeneous, but usually separate flow systems resulting in the investigated effects – this could be – as nicely shown in the examples, a shallow and deep GW system, a confined or unconfined system etc. So, it would help to make this clear, heterogeneity is everywhere, but you are only analyzing a specific set of heterogeneity with you analysis.

2) As you mention at some locations in the paper, a compound LPR usually addresses the possible effects of the aggregation error – at least this is how you define it in the example section. Hence, there is no aggregation effect if we would always use compound LPRs – you partly propose this in section 4, but in my opinion, this is not strong enough. If we apply a compound LPR and the two compounds are quite similar, we could also use a simple LPM (maybe simple is not a good phrase, I would prefer single – and there will be no aggregation effect. However, if the two compounds are different, a single LPR would result in a strong bias. Hence, we should propose to always use compound LPRs and then analyze the results in order to deal with the aggregation effect.

3) Why are you only using the standard deviation as your objective function. This considers only part of the fit – maybe you should consider the paper of Kling and Gupta or others to better select an appropriate function to be used, in particular when comparing the different models in Table 1.

4) The definition of the young water fraction is problematic. Why should the threshold (ty) change with changing alpha. So, we would always need to define this ty and then apply it differently to the different sets or models etc. If we use something like the young

water fraction, we should define it based on a fixed value that is related to the analysis and the question behind, However, for me the young water fraction is just another measure in order to avoid displaying the whole transit time distribution – this is what we need (as done nicely in Fig 10 – this should be repeated for the other examples as well) and not another factor in addition to the MTT. It would be helpful to discuss this and also to better clarify what the assumption of a non-constant ty would mean with respect to the whole analysis.

5) The whole section 3.3 is not necessary and should be removed including the figure. It is sufficient if you discuss without showing a similar analysis as already done in Kirchner (2016).

6) as already mention in some other points, you should make the examples better comparable in terms of defining the compounds LPRs, but also in respect to the figures and results shown. I think you should at least do the following: a) use the most common single LPRs (EPM, EM, GM, DM) and the best compound (or even better also a reference compound model) model and fit it to the observed TU showing the resulting fit (including a quantification of the fit) and the resulting TTD of each model. b) based on these figures, discuss the possible aggregation effects based on the models and the objective functions. c) define MTT, young water fraction for all model combination (in figure or table).

7) In the discussion, you should clearly differentiate what is necessary or problematic when using single LPRs or when using compound LPRs. For example, section 4.1 is only relevant when applying single LPRs.

8) the statement in section 4.3 that individual tritium measurement can/should be used to estimate a series of TTDs for one system is in my opinion not helpful. We should rather use the series of tritium measurements to apply the best possible compound LPRs that is necessary to describe the heterogeneity of the system as nicely presented in several of the examples. A single tritium measurement is not helpful at all, as there

is too much ambiguity. This could only be solved when combining the single tritium measurement with other tracers to identify the individual systems (multi components) and hence the complexity of the system studied. Hence, the whole issue of aggregation error will be solved to begin with.

Specific comments:

1) The title is very long and awkward – it would be helpful to focus on the implications and less on the different ideas of aggregation – please shorten considerable.

2) P2/L32 – the tritium method does not only depend on the radioactive decay, but still also on the bomb peak. . ..

3) P5: The list of LPMs should be more consistent and maybe best in a table listing all used LPMs and possible compound LPMs. In the moment, this section is incomplete, as there are additional compound LPMs in the result section not introduced in the method. You should also consider a systematic use of the compound LPMs – 2P_EM, 2S_EM, or EM_P-EM, EM_S_EM, PFM_P_DM etc, I think this would generally help to get a better understanding how the compound LPMs are set up, in particular the one introduced in the example section.

4) P7: why did you select 3 and 197 years for the analysis of the aggregation effect. It would be better the select a more realistic difference, which is commonly observed in the tritium analysis. In addition, you could also use TU/TU of Input as a relative measure in order to avoid defining the constant 2 TU for the analysis.

5) P8/L21: it is not clear to me how the "error of fitting" was determined – please define this in the method section and do not only show it for one selected combination but for all.

6) P8/L25-30. The discussed small difference between the northern and southern Hemisphere are very difficult to see, as the results are shown in separate figures – either combine the figure to see the effects or use only the figure from one location

and mention that the results are similar for the other site (maybe with some kind of quantification).

6) P9/L4: I assume you mean 197 years.

7) P9/L19: mention that alpha is from the Gamma model – not directly clear in this context.

8) P12/L3: The assumption that the old water component includes a zero tritium concentration is not clear for at all – is this possible at all?

9) The figure should be improved considerably – the layout is changing, the borders are annoying, the arrangement is not consistent, points cannot be seen (e.g. Fig 6 and 7), style is changing in the paper (Fig 1-9 and 10-end).

10) Please describe the different lines in Fig 3 in a legend.

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