Hydrol. Earth Syst. Sci. Discuss., 9, C5362–C5370, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C5362/2012/


Hydrology and Earth System Sciences Discussions

# *Interactive comment on* "What can flux tracking teach us about water age distributions and their temporal dynamics?" *by* M. Hrachowitz et al.

**M. Hrachowitz et al.**

m.hrachowitz@tudelft.nl

Received and published: 22 November 2012

General Comments

Comment: This manuscript is an important contribution to the field of water age distribution modelling in more than one way. To begin with, the authors provide an excellent summary and review of transit time modeling in hydrology. The summary includes basics as well as the newest developments in the field. It also tackles questions that have not been discussed in detail yet (e.g. the differences of age distributions of water and solutes). Furthermore, the presented results on the effects of complete vs. partial mixing on transit time modeling is a welcome and necessary contribution to hydrologic catchment response research. Finally, relating the individual properties (e.g. shapes,



breaks) of the water age distributions to specific runoff processes and storage mixing assumptions is a step forward on the way to determining hydrologic response controls, enhancing our process understanding and process analysis capabilities and thereby making hydrologic prediction easier.

Reply: We highly appreciate the reviewer's positive evaluation of our manuscript and want to thank him/her very much.

Comment: Some parts of the manuscript need clarification though. Especially helpful would be more consistency in terminology as we find it in other recent papers. For example the definition of the three different age distributions (resident water, water in flux, transient water): Why not use the names that have been established before (residence time, reverse transit time, transit time (cf. van der Velde et al. 2010))? Also, when describing the age distributions in figures 6 and 8 there is no proper explanation on what they actually are. I suppose the age distributions are variable in time. Then what are the distributions that are shown in these figures? You say they are median distributions, so how did you compute the median values? Are they comparable to 'master transit time distributions'? Is there weighting involved? Please give some more details.

Reply: Please find detailed replies below in the "Specific Comments" section.

Comment: The manuscript is dense and full of information. The review section alone can make a good paper. The authors proceed to investigate the influence of a) different mixing assumptions, b) different dominant catchment processes represented by different model configurations and c) different wetness conditions on 1) transit time distributions 2) residence time distributions and 3) reverse transit time distributions in both streamflow and evapotranspiration. Other authors would split the research that went into this paper and write four papers instead of one. On the one hand splitting up the paper would make the results more easily digestible (smaller bites). On the other hand one could argue that all this information belongs in one paper to make it a more

or less complete overview of the field of water age distributions. I agree with the latter argument and would like to see the paper published in the current format.

Reply: We agree with the reviewer that this is a long manuscript and we initially shared the same concerns. However, after lengthy discussions with many colleagues from the catchment hydrology community and careful deliberation we also came to the conclusion that the presented information can only be fully appreciated if it is shown in the full context. This is especially important as much of the literature on water age is quite scattered, which also contributed to the fact that some important aspects of the topic (as highlighted in the manuscript) were simply forgotten or, when seen out of context, not considered relevant by wide parts of the community over the past 3 decades or so. As the presented information further does not offer a clear splitting point for providing 2 papers (i.e. which part would go into which paper?) as the information is very interwoven, we would thus strongly prefer to present the information in one single manuscript instead of splitting it up into 2 papers.

Comment: The order of the presentation of the results might be enhanced if the authors first presented the variation of pF, pR and pT in the different catchments before proceeding to discuss the differences of pF due to variations in wetness conditions.

Reply: We agree with the reviewer and we will rearrange the sections accordingly.

Specific Comments

Comment: p. 11368, l. 19: The difference between flux and transient water is not clear. I know you mean water at the outlet with 'flux' and water on the way to the outlet with 'transient', but you explain the concept only later in the paper.

Reply: Although an short explanation is given on p.11366, l.26ff. in the original manuscript, we agree with the reviewer that it is not entirely clear. We will change this accordingly.

Comment: p. 11368, l. 23: 'changes in the hydrological regime'. Can you be a little



more specific here? Dominant flow paths, antecedent conditions, storage dynamics?

Reply: This will be rephrased to be more specific.

Comment: p. 11372, l. 7: Why not report the Nash Sutcliffe Efficiencies and the AIC for the three best models?

Reply: We agree with the reviewer and will provide NSE and AIC for the three best models for comparative reasons in Table 4.

Comment: p. 11378, l. 2: Would be nice to see a figure of that relationship of soil moisture and mixing coefficient.

Reply: This figure will be added to Figure 3.

Comment: p. 11378, l. 3-21: very interesting conceptual model that connects mixing dynamics with new-old water

Reply: We appreciate this comment. We think it is, also in catchment hydrology, really necessary to start moving away from static mixing descriptions.

Comment: p. 11379, l. 14: What do you mean by saying that they were chosen to be comparably simplistic? Would you rather have used a more complicated approach because it would have given you better results in terms of NSE?

Reply: This sentence was merely meant to avoid misunderstandings and to make clear that we are aware of the presence of more physically based and more detailed mixing representations, which however are not warranted here by the available data. As also reviewer 2 found this sentence confusing we will remove it.

Comment: p. 11382, l. 3: Thanks for the nice clarification on these issues. It was high time that someone wrote it down.

Reply: We again highly appreciate this comment and fully agree with the reviewer.

Comment: p. 11382, l. 9-20: Your definition of the three different age distributions

(resident water, water in flux, transient water): Why not use the names that have been established before (residence time, reverse transit time and transit time)?

Reply: We understand the reviewers concerns as we also found it difficult to find meaningful, intuitive and in the same time short terms expressing the quintessence of the 3 different distributions. We thus adopted the terms resident and flux water age distributions from a recent paper of Van der Velde et al. (2012) based on Kreft and Zuber (1978). However, we found the term "reverse transit time" as suggested by Botter et al. (2011) not very intuitive. But we agree with the reviewer that "age distribution of transient water" is quite an awkward expression. We will thus follow the reviewers suggestion and use "transit time distribution" instead.

Comment: p. 11384, l. 11-18: I recommend mentioning the fact that if you are interested in the actual hydrologic catchment response you should only use the N components (flow generating processes) when assembling your time distributions. Adding the M components (evaporative processes) is very likely to skew your distributions towards the faster responses.

Reply: That is a very important point and we will add this aspect.

Comment: p. 11387, l. 21: You presented three mixing model hypotheses (complete, static partial, dynamic partial) and you should stick with these distinctions.

Reply: We thank the reviewer for pointing this out. Here "two mixing model hypotheses" should actually read "two mixing model scenarios". As outlined on p.11379, l.3-9 of the original manuscript, two SCENARIOS were tested: the first one with complete mixing in all model components and the second one with complete mixing in the interception and fast reservoirs, static partial mixing in the slow reservoir and dynamic partial mixing in the unsaturated reservoir. We will rephrase it to "scenario" and emphasize this stronger to avoid future misunderstandings.

Comment: p. 11389, l. 10: What exactly are you showing here? Is it a snapshot of



one flux water age distribution? Is it an average distribution assembled from all the individual distributions? Weighted or unweighted? Is it a master distribution for the specific wetting scenario? This is important, please give more details.

Reply: The reviewer is right that we did not properly explain what is shown in Figure 6. In fact it is the unweighted median distribution constructed from the respective median values for every transit time during the four individual wetness conditions (dry, wetting-up, wet, drying-up). This will be better explained in the revised manuscript.

Comment: p. 11394, l. 14: This is the first time that you mention that figure 6 shows median distributions. How do you define a median distribution? Do you select for every transit time the median probability value? Do you weight the individual distributions by mass or volume? These are important aspects that should be explained.

Reply: Please see previous reply

Comment: p. 11400, l. 10: Terminology: to enhance clarity I recommend calling 'transient age distribution of water conditional on runoff' simply 'water transit time distribution to runoff' to differentiate it from 'water transit time distribution to evapotranspiration' or from 'solute transit time distribution to runoff'. Vice versa the terminology would be e.g. 'reverse water transit time distribution from overland flow' or 'reverse solute transit time distribution from baseflow'...

Reply: We agree and we will change this accordingly.

Comment: p. 11400, l. 27: : : :'transit' times of water: : :

Reply: Ok

Comment: p. 11403, l. 15: 'higher' or 'larger'?

Reply: Probably "larger" is more suitable here

Comment: p. 11404, l. 10: : : :shorter 'transit' times: : :

Reply: Ok

Comment: Figure 2: It is very difficult to compare modeled to observed runoff in these figures. You probably want to show the whole time series for completeness, but I would select one (or five) years of data so that an actual comparison becomes possible.

Reply: This will be changed accordingly

Comment: Figure 4: Very important figure. I would also fill the first 4 time steps with numbers, so that the selection aspect (of runoff vertical and event horizontal) becomes more obvious.

Reply: This will be changed accordingly

Comment: Figures 6: the y-axis goes to 10-5, in figures 8 it's only 10-4 (comparability?).

Reply: We played around quite a bit with the figures and came up with the present version as the best alternative. The problem being that if in Fig.6 y-axis was to be reduced to 10-4, much of the tail information will be lost, and if in Fig.8 the y-axis was extended to 10-5, the PDF will shift upwards and in most panels interfere with the respective figure insets (CDF). We would thus prefer to keep it the way it is.

Comment: Figures 6, 8, 11 and maybe 12: General recommendation: If you convert the figure to a log-log plot then it is easier to see the variations in fast response behavior.

Reply: In our first internal draft we used log-log plots, we however decided to change it to semi-log as the log-log plots were intuitively very difficult to read/interpret. We would thus prefer to keep the present version.

Comment: p. 11364, l. 4: flow path(s) distributions

Reply: Ok

Comment: p. 11368, l. 16: do you mean 'modeled' internal fluxes?



Reply: No we actually meant internal fluxes of the model.

Comment: p. 11368, l. 25: : : :a summary 'of' their: : :

Reply: Ok

Comment: p. 11372, l. 1: It should be 'DYNAmic MIxing Tank'.

Reply: Ok

Comment: p. 11380, l. 25: : : :as 'a' free calibration parameter: : :

Reply: Ok

Comment: p. 11381, l. 20: Better write: 'On the one hand this can be: : :'

Reply: Ok

Comment: p. 11384, l. 13: Delete one 'further'.

Reply: Ok

Comment: p. 11391, l. 5: : : :a break 'in' at: : :?

Reply: Ok

Comment: p. 11392, l. 8: : : :as 'an' individual process: : :

Reply: Ok

Comment: p. 11394, l. 27: : : :with the only major difference 'being' that: : :

Reply: Ok

Comment: p. 11399, l. 17: : : :in 'a' modeled average: : :

Reply: Ok

Comment: p. 11399, l. 28: delete ',' before could.

Reply: Ok

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 11363, 2012.