Response to Interactive comment by Anonymous Referee #1

Comments from the referee are printed in black. Authors' responses are printed in red.

The authors perform a set of numerical experiments to investigate the shape of the transit time distribution for a watershed under different catchment and climate characteristics. They focused mainly the role of soil depth, soil hydraulic conductivity, antecedent soil moisture content and subsequent precipitation amount, but other runs explored also soil porosity, bedrock hydraulic conductivity, depth dependence of the soil hydraulic conductivity and precipitation frequency. The ambitious goal of the article is to relate the shape (i.e., parameters) of common probability density functions (the AD, Gamma, and Beta distributions) to the variability of catchment and climate characteristics.
Exactly.

The paper is well written, with a simple structure that makes it easy to follow. Of course, they authors could not explore the role of all parameters, but the analysis is yet very inclusive overall. All the details that necessary to reproduce the work are explained in detail, and the presentation and discussion of the results are comprehensive.
We want to thank referee #1 for the assessment of our manuscript and a thoughtful review that led to a significant improvement of the study.

However, I have both some major and minor questions that I would ask the authors.

The major question is mostly conceptual. The authors aim at finding general results about the TTD shape variability across locations with different characteristics. I like their systematic approach as an attempt to quantify this variability, e.g. by linking alpha to F. However, I am not surprised that they could only partly achieve their goal.
The issue is that the authors assume a given distribution (e.g., the gamma) for each run. This is analogous to assume that the discharge depends only on the residence time of the water, and not on the water storage. In other words, the authors do not move away from the assumptions behind the instantaneous unit hydrograph approach. From a mathematical standpoint, other authors introduced this assumption by stating that the storage selection function or the loss function (e.g., Botter, 2011; Calabrese and Porporato, 2015) depend on only the residence time (or age). This, however, is the simplest scenario and the farthest from reality. It is very likely, in fact, that if the authors injected the tracer later in the simulation, the TTDs would again differ.
As an example, a more realistic assumption would be to somewhat include a dependence of the TTDs on the overall water storage, or some proxy for it. I think it would be very instructive to explore the dependence of time dependent TTDs parameters on the time dependent water storage. As I mentioned earlier, I still believe that their analysis is very insightful. It is only that, in my opinion, this work could be even more impactful. I wonder whether the authors have comments on this.
This is a very valid point that we hope to address by examining the influence of antecedent moisture content on the shape of TTDs. We believe that the antecedent moisture content of the soil is a proxy for the water storage of the catchment (the bedrock is almost permanently fully saturated). We agree that a tracer injection at a different point in time would cause the TTD shape to differ (depending to a much higher

degree on the current antecedent soil moisture content than on the pattern of following precipitation). In section 3.2 (figure 6, panel in the upper left corner) we analyze the dependence of time dependent TTD parameters on the time dependent water storage. You can see that, e.g., for situations when the water storage is high, K_S has a higher influence on TTDs than when water storage is low, while the relative influence of P_{sub} is larger when the initial water storage is low. In the revised manuscript we will clarify figure 6 and improve its discussion in the text.

I also have some minor questions/comments.

-It seems that boundary conditions, mainly I am referring to the shape of control volume, may have a big effect on TTDs, perhaps that could partly overwhelm the effect of the parameters studied by the authors. Have the authors tested this (e.g., with a non-elliptical shape)?
Again, a valid point that we had not tested yet. Catchment shape was one of the properties we also thought could potentially influence the TTD shape but chose to investigate at a later point in a different study (like, e.g., catchment size or slope). However, after your remarks we decided to try out two additional catchment shapes to get an idea whether it would have a significant impact on the results. So we tested one catchment with the center of gravity located farther away from the outlet and another catchment with the center of gravity located closer to the outlet (catchment size and slope staying the same in all cases). We found that changing the catchment shape had substantially less influence on the TTD shape than we expected. We will add this analysis to the manuscript.

-I don't agree with repeating the one year precipitation time series in loop 32 times. First, it is not realistic, and second it might cause some statistical bias. Why not using a Poisson generator throughout the analysis? It would certainly be more consistent. On a different note, there are numerous references that introduced Poisson rainfall/storm. One of the first was Cox and Isham (1988).
Thanks for the additional reference, we will add it to the manuscript. In order to erase your worries about looping the time series we did what you suggested and created a 33 year time series with a Poisson generator. The resulting TTDs did not differ significantly from the ones we derived from the looped time series. We will add a comment on this to the manuscript and a figure to the supplement.

-The authors believe that a truncated Gamma or a lognormal distribution may work better over the all range of ages. Why not trying it?
Ok, following your suggestion we conducted this analysis. The truncated lognormal distribution did indeed capture almost all of the TTD shapes better. Additionally we also tested the regular (i.e. not truncated) lognormal distribution and found that it is a better representation for the shape of TTDs in catchments with high K_S than the advection-dispersion distribution. That means we will modify our results and discussion sections accordingly in the revised manuscript.

Hoping that these comments may help improve the manuscript, I suggest major revisions.
Thanks again for the valuable input that helped to improve our paper.