

Response to S. Gharari (Referee)  
Received and published: 20 September 2017

*Shervan Gharari (SG): The manuscript has improved significantly from the initial submission. However I am still struggling to get the main message of the paper.*

Simon Höllering et al. (SH): We sincerely thank Shervan Gharari for reviewing also our revised submission. We think we are able to overcome many of his concerns together with the revisions on the basis of the detailed comments of the first reviewer, Björn Guse. In summary, we will especially direct our efforts to a clearer presentation of the main contributions of the present study.

The detailed answers on the comments are collected below.

*SG: The title looks very broad. It is hard to predict what the reader should expect from the current title.*

SH: Thank you for your opinion and perception on the title. We have decided to choose a comparably brief title, which nevertheless points out the main features of our study. Admittedly, it does not summarize the contents of the paper in full detail. We would, however, prefer not to add more details to the title, as it probably would only be longer and not much clearer. Instead, we would invite the reader interested in “Regional sensitivity analysis” and “Hydrological fingerprints” to consult the abstract - and then hopefully the entire paper – for further information.

*SG: The objectives and research questions are not answered in the conclusions.*

**SH:** In this point we do not fully agree with the reviewer. We admit that the detailed answers to the research questions are contained in the discussion section, and that in the conclusions only short reference to the three questions is made.

Research question 1 (“Which parameters can be identified as sensitive with regard to specific hydrological response characteristics?”) and research question 2 (“How does parameter sensitivity change with different hydrological objectives (response targets) applied in global sensitivity analysis?”) are referred to in the first paragraph of the conclusions, while research question 3 (“How does parameter sensitivity change in different catchments under slightly distinct physiographic and hydroclimatic conditions?”) is answered in the second paragraph.

We regard this structure to address the research question in the discussion and to summarize the main findings in the conclusion section as instructive and in line with many manuscripts, but would nevertheless happily consider any propositions on improvements of this issue.

*SG: I still cannot easily summarize the manuscript scope and aim into one paragraph for myself!*

**SH:** We will revisit the abstract and the short summary of our study once more to further optimize it for the reader. In this respect, reviewer 1 came up with a concise description that we will incorporate into the short summary: “In this manuscript, hydrological fingerprints are introduced as target

variable for a sensitivity analysis and compared with a classical approach using streamflow data for a temporally resolved sensitivity analysis. The joint benefit of both approaches is presented for several headwater catchments.”

In addition to that, we will take care to point out more clearly the contribution of the study in our revisions of the introduction, discussion and conclusions as pointed out in our answers to reviewer 1.

*SG: The organization of the paper is still far from being perfect. For example figure 1 is explained twice and in between there figure 2 is mentioned (I really do not get what the point of figure 2 is).*

SH: Thank you for this comment. We are not sure if this is a major point; however, we will check the references to Fig. 1 (map of the study area) and delete any references which should not be needed to guide the reader to this map.

Figure 2 illustrates the variation of parameter values with different, independent frequencies along the number of simulation runs, which is at the heart of the FAST method. In our case, 243 (x-axis) different combinations of values for the eight parameters were obtained. Each parameter was varied in its specified ranges (y-axes). The parameter variations are displayed in three subplots for reasons of legibility.

243 model runs were performed and the same number of simulated streamflow time series was obtained. These 243 hydrographs are then used for TEDPAS and for the calculation of the fingerprint metrics for INDPAS.

We will add more explanation to the caption of Fig. 2 for clarification. But we still think that the figure is helpful and necessary, particularly for readers who are not familiar with FAST, to understand the essence of the method. We thus prefer to keep Fig. 2 in the revised manuscript.

*SG: The discussion part is too wordy and contains many repetition from the earlier sections as well as literature review.*

SH: Thank you for the comment. We will double check and optionally streamline the discussion.

For reasons of clarity, we structured the discussion in two parts. The first part addressed the complementary merits of TEDPAS and INDPAS. The second part focuses on the regional differences in parameter sensitivity among the headwaters and possible reasons for this, which are the specific findings for this hydrological system. While the latter might change when moving to a different study area, the former part is generic to the application of the proposed framework. Though one might choose other fingerprints in a different study, this does not change the philosophy of the approach. We will better stress why we structure the discussion that way in the revised manuscript.

*SG: One more point which I am missing in the manuscript is, how the sensitivity was carried out on the fingering indices? Did the authors used the value of these indices and see how sensitive they are comparably? If this is the case how did the authors compare the sensitivities? The range of values for these indices might vary from one to the other.*

SH: Maybe the reviewer missed the description of how the sensitivity analyses were carried out (Sections 2.2 and 2.5.2)? If anything should be unclear about these paragraphs, we would appreciate any hints.

The sensitivity analyses were performed with the Fourier Amplitude Sensitivity Test (FAST, section 2.2 in the manuscript). The general idea of FAST is to vary parameters of interest with independent frequencies, and then perform a Fourier analysis of the simulated target variable across the ensemble of model runs to determine the first-order sensitivities of the parameters as a function of time, hence obtaining a power spectrum for each simulation time step. The variance  $\sigma_i^2$  that is explained by a parameter  $i$  is determined by normalizing the corresponding power with the total power in the spectrum, which corresponds to the total variance  $\sigma^2$  within the model ensemble (see the cited paper by Reusser et al. 2011). The sensitivity of model output on parameter  $i$  is then calculated as the partial variance, which is the ratio  $\sigma_i^2/\sigma^2$ .

We tested different model results (hydrograph and fingerprint metrics, i.e. single value indices and FDCs) in our analyses, which yielded parameter sensitivities with respect to each of these target variables. The fingerprint metrics were calculated from each of the 243 simulated streamflow hydrographs, and each one was individually analyzed with FAST. This analysis directed to fingerprint metrics is essentially the same procedure as for TEDPAS. The resulting partial variance for each fingerprint are comparable because they portray the relative influence of the parameters on the variation of the target, regardless of the concrete values of the targets, which might indeed be quite different.

The range of model results, for example in single value fingerprints, might influence the sensitivity analyses as discussed in section 4.1 with the example of the autocorrelation time (ACT). Following the recommendation of the first reviewer, we will add some more explanation in the discussion on this topic. We could also try to further clarify the explanation of the INDPAS method, if not already sufficiently explained.