# Authors' response to review

Antoine Pelletier, on behalf of co-authors

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## 1 Response to anonymous referee #2

We would like to thank Anonymous referee #2 for their careful and useful review. The answers to their specific comments and technical corrections can be found below.

### 1.1 Specific comments

*I read through the replies to reviewers' comments, and the revised manuscript and found the authors made efforts to improve their manuscript. However, I am afraid I have the impression my major concerns/comments have not been adequately addressed. More specifically, the main aim of using additional data, not only streamflow, to calibrate a hydrological model (regardless whether it is a physically based or conceptual one) is to make the model more capable of reproducing reality, i.e. to simulate runoff well for the right reasons, to simulate not only runoff but other fluxes and model states more efficiently/realistically, to improve process consistency, etc. Now if the authors argue that their model "The GR6J model which is used in the study is a macro-scale conceptual model, describes macro-scale hydrological processes but does not intend to reproduce the meso-scale or laboratory-scale physical processes. Thus, it does not enable us to know what happens in reality in the catchments of the test dataset, in particular regarding the local river-aquifer interactions." – then I am confused why piezometer data measured at one single or a few points within a catchment are used in the study to calibrate their model? I find this contradictory. The study seems to lack any hydrological reasoning based conclusions (e.g. physically based reasoning, understanding what happens in each catchment, why the streamflow and groundwater level simulations are satisfactory or not on certain catchments, etc.). The main point of using additional data is to avoid calibrating hydrological models machinelike, without knowing what is happening in the models (and in the catchments).*

We are responsible for your confusion: in our answer, we tried to avoid a long philosophical discussion on what represents really a model. It is not because we did not want to defend our opinions on modelling, but because we thought that the philosophical discussions would make this paper too long. But your remark shows that such a discussion was in fact needed.

We wrote that *"the GR6J model which is used in the study is a macro-scale conceptual model, describes macro-scale hydrological processes but does not intend to reproduce the meso-scale or laboratory-scale physical processes"* : we meant that this model (like many – if not all – models) does pose a challenge for a process-based interpretation or validation. Because the physical processes are understood and defined based on small-scale observations, a meso-scale model cannot be (most of the time) directly confronted to these small-scale observations, because of what we call a "scale-gap". Because of this gap, the very question of "being right for the right reason" becomes less evident to discuss: what is right at the scale of a few square meters is not necessary right (or meaningful) at the scale of a few hundred km$^2$. If we go back to Klemeš (1986), who seems to have been the first to popularize the expression *"right for the right reason"* in hydrology, most of his critics were on the arbitrary choice of statistical distributions in flood design, the separation of hydrographs, and the lure of what he names

(after Box, 1976) *"mathematistry"*. He wrote *"for a good mathematical model it is not enough to work well. It must work well for the right reasons. It must reflect, even if only in a simplified form, the essential features of the physical prototype"*. Basically, we believe that the model we use, even if it remains simplified and parsimonious, follows Klemeš's injunction. Kirchner too published (Kirchner, 2006) a paper entitled *"Getting the right answers for the right reasons"*: in his modeling suggestions, he advocated replacing the linear black-box approaches with nonlinear gray box approaches, as well as developing macroscale hydrological laws (at the catchment or hillslope scale) to replace the microscale equations describing small-scale physics, and also developing ways to test models more comprehensively and incisively (particularly in extrapolation mode). Kirchner (2006) also underlined the necessity of keeping models parsimonious: *"in order to know whether we are getting the right answers for the right reasons, we will need to develop reduced-form models with very few free parameters"*, and we would argue that this is precisely what we have been trying to do since the last 40 years in our group (Michel, Claude, 1983): parsimony is not a goal in itself, but it is a means for keeping a model analysable, open to criticism. In our case, this is certainly what helped us identifying the state of the model where the assimilation of piezometric levels would be the better indicated.

When you mention that *"the main point of using additional data is to avoid calibrating hydrological models machinelike, without knowing what is happening in the models (and in the catchments)"*, we must say that we cannot agree entirely: this is our ultimate objective, one that we very often do not reach. If the scale-gap between what is observed and what is measured was not too big, then we would be able to identify in the model a physically-explicit representation of the process in question, and the issue of data assimilation would be straightforward, without any possible hesitation. But at the catchment scale, the scale-gap is huge, we had to first explore the model states in order to identify which state offered the best opportunity for data assimilation. And obviously, the available piezometric time series only perform a sampling of the aquifer level, none of the piezometers can be considered to represent in an exhaustive way the behaviour of the aquifer: this is an additional challenge to assimilate this information.

A clearer explanation of the scope of the paper was added to section 1.4 to take into account this specific comment.

## 1.2 Technical corrections

Technical corrections that are not listed below were addressed in the revised version of the manuscript and no comment is needed.

- *Generally: please shorten and simplify sentences, e.g. splitting very long sentences into more, shorter ones – it is hard to follow and understand very long sentences (i.e. several lines long).*
- *The manuscript could be potentially shortened.*
- *Please avoid mixing past and present tense (in methods, results, etc.).*

A native English speaker will have a final look at the paper to improve its readability.

- *Line 123: "observation function"? Objective function?*

This was replaced with "observation operator", as said for data assimilation.

- *Line 125: "in-field measurements are often used", please add what are often used?*

Several examples of in-fields measurements that are used in hydrological models are given in the same paragraph, after this sentence.

- *Figure 4: please move this figure to Appendix A considering that all the variables are explained there – or move the model description to the main text from the appendix.*

We think that it is crucial to show the model structure in the main text, since it is one of the main points of the article. Therefore, we would not like to move this figure to the appendix.

## 2 List of changes in manuscript

Table 1: List of changes made by authors in the manuscript. Page and line numbers refer to the latexdiff version of the manuscript, attached to this document.

| **Page** | **Lines** | **Description** |
|---|---|---|
| 1 | 13 | Rephrasing |
| 1 | 16 | Rephrasing |
| 2 | 27 | Rephrasing |
| 3 | 64 | Rephrasing |
| 4 | 123 | Terminology correction |
| 5 | 142 | Clarification |
| 6 | 169-171 | Clearer explanation of the scope of the paper |
| 8 | 212 | Rephrasing |
| 8 | 222-223 | Clarification of the sentence |
| 11 | 244-245 | Clarification of the sentence |
| 11 | 261 | Redundant information removed |
| 11-12 | 272-274 | Supererogatory information removed |
| 13 | 286 | Sentence split |
| 16 | 359 | Terminology correction |
| 16 | 374 | Redundant information removed |
| 27 | 467 | Rephrasing |
| 27 | 469 | Rephrasing |
| 27 | 473 | Grammar |

## References


Box, G. E. P.: Science and Statistics, Journal of the American Statistical Association, 71, 791–799, https://doi.org/10.1080/01621459.1976.10480949, 1976.

Kirchner, J. W.: Getting the right answers for the right reasons: Linking measurements, analyses, and models to advance the science of hydrology, Water Resources Research, 42, https://doi.org/ https://doi.org/10.1029/2005WR004362, 2006.

Klemeš, V.: Dilettantism in hydrology: Transition or destiny?, Water Resources Research, 22, 177S–188S, https://doi.org/https://doi.org/10.1029/WR022i09Sp0177S, 1986.

Michel, Claude: Que peut-on faire en hydrologie avec modèle conceptuel à un seul paramètre ?, La Houille Blanche, pp. 39–44, https://doi.org/10.1051/lhb/1983004, 1983.