Hydrol. Earth Syst. Sci. Discuss., 12, C6238–C6249, 2016
www.hydrol-earth-syst-sci-discuss.net/12/C6238/2016/

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "HESS Opinions: Advocating process modeling and de-emphasizing parameter estimation" *by* A. Bahremand

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Received and published: 21 January 2016

Author's interactive reply to Prof. Schaefli's referee comment

I would like to thank Prof. Schaefli for her constructive comment. She has pointed out different shortcomings of the opinion paper. By making several important questions about parameter allocation, she obliged me to think deeper on parameter allocation and organize and clarify my opinion on the procedure. I really appreciate the referee's valuable questions and comments. I agree with the referee, therefore, I am going to include her suggestions and comments in the new version of manuscript (if I was given the permission to do so). Main part of the comment is on parameter allocation, so I discuss it at the end. Here comes all my plan how to address the referee's comments:

1. I agree with the referee where claims that I have cited some recent papers without mentioning what these papers actually propose or what the findings are (e.g. Gharari et al. 2014, Semenova and Beven 2015, and Bergstrom works). Since the opinion paper was originally an emailed comment to Prof. Hoshin Gupta so it was short, then later it was extended but some parts remained too concise. Therefore, I will write more about these papers in the final version. In particular, I am going to explain more about Beven and Semenova 2015. Because in this publication the authors have different opinions, so I better mention these two different opinions. Moreover, in search to address the referees' comments I have found several more significant publications that I am going to cite them too.

2. I agree with the referee about automatic optimization and uncertainty estimation. As I already mentioned in reply to Prof. Montanari's suggestion, I am going to write about the advantages of automatic optimization and also the importance of uncertainty estimation for hydrologic prediction. I must say although the nature of my argument is not in favor of automatic calibration but I have to discuss its advantages in the paper otherwise the reader might think that automatic calibration is useless, as pointed out by Montanari.

3. The referee has mentioned that the paper makes many statements without references (e.g. in pages 12380, 12388). All the mentioned statements are my own words. I do not know if any other author has also written such statements. I checked the manuscript several times for this reason. Yes, I see several statements without reference, but they are my own statements, just as an example I recall few of them here: the first 4 lines of page 12384, almost the entire pages 12385 and 12381, last sentence before conclusion (dealing with equifinality from different angles, this sentence will be explained later in this comment), all sentences in the conclusion (including the word equimodelity), and several more sentences. However, if I find out another person's statement similar to one of my statements, for sure I will give priority to cite the name of that author. The referee has asked about my statement in p. 12380 (it seems, in fact,

that it may often be possible. . ..), although this is my own statement, but I now realized that the entire paragraph might be a bit confusing. Because I have written this statement just after Semenova and Beven (2015), one might think the statement belongs to Semenova and Beven. I will correct this paragraph. Also, part of this paragraph is placed between quotation marks ". . ...", which should not be. I will drop the quotation marks (although that sentence was part of Prof. Beven's email to me in May 2015 but I think I better drop the quotation marks to avoid confusion). This will be corrected in the final version.

4. My reply to this referee's question (what do you mean by "P. 12388: Therefore, the equifinality should be dealt with from different angles to serve us to reach a better model"?): There is a clear explanation about this statement just in the last sentence before the statement: [Similar to the multi-objective criteria approach in model optimization, where a set of criteria is involved in order to reach a unique parameter set; accordingly from a different angle, if we take more physical processes into account into our model structure, it does a similar thing, i.e. it gives us more options to constrain parameter values and reach a rather unique parameter set. Therefore, the equifinality should be dealt with from different angles to serve us to reach a better model.] This is also one of the statements which there is no reference for it in the opinion paper because it was my own conclusion. However, this question is very important to me because it gives the opportunity for clarification and more explanation about one of the important opinions of this paper: By talking about dealing with equifinality from different angles, I mean tackling it from the head, the tail and the belly of the modeling process. In page 12380 and 12381 I have written about parameter allocation and its role in limiting the parameter range and parameter calibration and reducing the uncertainty (and also increasing the parameter consistency). Since the parameter allocation is kind of elaboration and sophistication on modeling process by the modeler, let us name this one (this angle) as working on the head (the mind of modeler as the head of our modeling process). Then, in page 12386, I have written about the improvement of our approach to model evaluation and then I have suggested several methods including

the use of multi objective criteria and evaluation on multiple variables. Let us name this improvement as working on the tail (evaluation as the end of our modelling process). Then, later, in page 12388, it is mentioned if we take more physical processes into account into our model structure, it gives us more options to constrain parameter values and reach a rather unique parameter set. Let us name this one as working on the belly (physical processes and model structure as the main body of our modelling process). This is the reason that the opinion paper comes to sentence: "Therefore the equifinality should be dealt with from different angles to serve us to reach a better model". And "hopefully then, we will move past equifinality to achieve equimodellity, reaching at last one fulfilling model that is a "model that is so physically correct that it does not need calibration at all" (the third aforementioned solution of Bergstrom). Explanation about this comes here:

5. Response to these questions (what do you mean by equimodellity? Why would a single fulfilling model be useful? What do you mean by fulfilling here?): I made this word humorously just imitating the equifinality. We know over the past few decades that physicists have considered seeking a final theory, ultimate theory or master theory. They often talk about a single fundamental force. So, analogous to that I believe it is possible to think about a hypothetical single model which is fully based on coherent formulas of physics. Such model is white box with all processes are taken into account. It is the model of everywhere. The ultimate practical mathematical framework by which all hydrological processes are simulated precisely hopefully with no parameterization and calibration. Such model is fulfilling because it works everywhere. Even if not reachable or possible but such single model is very useful. It could at lease act as a beacon for hydrologists.

6. Acknowledging knowledge based optimizations: Two of the referees have commented that I better acknowledge some researches practicing knowledge based optimizations and attempts to incorporate the physical knowledge into hydrological practice. Later, in the final version of the paper, I am going to fill this gap by discussing some

recent publications, e.g. Merz and Bloesch (2008a, 2008b), Viglione et al. (2013), Schaefli and Zehe (2009), Hingray et al. (2010), Schaefli and Huss (2011), Hrachowitz et al. (2014).

Parameter allocation

Regarding this opinion, the referee, Prof. Schaefli has mentioned several valuable questions which directed me to write down more about parameter allocation. I just would like to say that the following text still has to be refined and hopefully some parts of the rough ideas will be presented concisely in a proper scientific language in the final text. Here, I am going to write each question and then few lines as a primary response.

A. Where the term allocation comes from? While trying to explain a kind of calibration in which the modeler reaches a certain value for a parameter based on logic and reasoning, I used the term "allocation" just out of my limited English vocabulary. But later, after the referee's enquiry I searched in the internet, and I could not find this word in the combination with the word "parameter". I could just find the term "regional parameter allocation" in Bosshard and Zappa (2008) with different meaning. In their work they had only a gauge downstream and had to calibrate a really big area, therefore, they decided to calibrate in one sub-basin and transfer all parameters to the whole region. Since they could neither use parameter calibration nor parameter regionalization, so they opt for the term "regional parameter allocation".

B. What role might play expert-knowledge based parameter allocation? As the referee has mentioned in her comment "what the author calls parameter allocation indeed plays a certain role in hydrological modeling and it might well be something that experienced modelers do in any modeling study but lacks some up-to-date discussion", I also believe it needed to be emphasized because it is in the direction of more understanding of the hydrological processes, the way they are represented in the model, and the link between model parameters and catchment characteristics (this understanding can be extended to conformity with organizing principles mentioned in Schaefli et al.,

2011). Expert-knowledge based parameter allocation gives us reasonable parameter values, a narrower uncertainty range for each parameter. It supports our basic conceptual understanding of the system. In such framework, models with least number of parameters-subjected-to-calibration (lumped parameters) gain more support and popularity. Parameter allocation makes parameter estimation to be a learning process. It is the product of our emphasis on understanding rather than solely acquiring good results. In such framework less accurate results with reasonable parameter values are more desirable than more accurate results with unreasonable parameters. It allows to make a tradeoff between accuracy and reasonability (e.g. the accuracy of the simulated hydrograph in tradeoff with hydrologic reasonability of the model processes and parameters). This step of modeling (parameter allocation) can become the link between the two modeling approaches (bottom-up and top-down). I mean, the modeler can change her/his view position frequently using this allocation procedure. Each of the mentioned modeling approaches have advantages and disadvantages. The experienced modeler continuously applies both approaches, and the allocation of parameter values is the outcome of the commute between the two approaches. Parameter allocation can act as the link between physics based distributed modeling and behavioral modeling described by Schaefli et al. (2011). Schaefli et al. discuss about "using organizing principle to constrain models" and propose the behavioral modeling framework. My opinion paper partly talks about using expert-knowledge to constrain models. It suggests a limited calibration. It mentions that with constraints and relational rules we can find out/reason out a proper value for the parameter, or make the range of possible value narrower. This range can even become narrower using optimality principle or organizing principles. Therefore, the parameter must be reasonable according to organizing principles too (or in the language of Schaefli et al., 2011:"adjusting the model structure and parameters so as to respect this organizing principle"). It must satisfy the rules of a higher level of organization. The expert can make connection between the rules of different levels.

C. What makes it different from parameter calibration and how it completes it? We may see parameter allocation as part of (or kind of) parameter calibration procedure. Whether calibrating the parameters manually or automatically, the modeler can do it rationally and logically (based on hydrologic reasoning, mostly). The procedure can be controlled using some constraints and relational rules between parameters and simultaneously in accord with organizing principles (this need to be elaborated in future modeling researches). Such constraints and relational rules can be applied manually or by computer using mathematical algorithms. The difference between parameter allocation and parameter calibration is the extent of prior knowledge applied by the modeler. In parameter calibration, the prior knowledge is mostly the range of parameter. While in parameter allocation the modeler based on experience knows some relational rules between parameters, and how some certain parameters can follow certain principles. In parameter allocation procedure the modeler does her/his best to allocate some values for some parameters, and few parameters still remain for some trial and error. The point is to take most use of the prior knowledge to allocate parameters and the modeler applies the blind trial and error only for some certain parameters. By blind trial and error or automatic calibration the modeler lets the parameter uncertainty come to the results in its full extent, while by what I call white-box calibration or parameter allocation, the modeler is determined to minimize the uncertainty. If we can eliminate the uncertainty of only one parameter by specifying a value to that parameter then it is already a progress in reducing the total uncertainty. Besides, I believe there likely exist certain organizing principle regarding the uncertainty of a natural system. Who knows maybe the optimality principle results in an outcome principle for uncertainty as well, a limiting one!

D. Why parameter allocation is useful for hydrologic prediction and for model coupling? Parameter allocation is important for model prediction because that prediction is less uncertain and the decision on such results is easier. Also using the results as the input into another model is easier. Perhaps the desirable outcome of parameter allocation is to limit equifinality. Parameter allocation implies that we can have models with limited calibration or perhaps uncalibrated models. This illustrates the potential value of the

combined use of physic/process based models and relational constraints and “organizing principles” (Schaefli et al., 2011) for prediction in ungauged basins, where no time series are available for model calibration. Gharari et al. 2014, while assessing the effects of imposing semi-quantitate, relational inequality constraints based on expert knowledge for model development and parameter specification, states “imposing constraints prevents the model from over fitting on calibration time series and therefore enables the model to more reliably perform outside the calibration period”. Let’s use the term allocated parameter set as analogous to calibrated parameter set. I believe there are other parameter sets which give the same results but those sets might not be different values statistically (like the parameter sets reported in Bahremand and De Smedt, 2010). The equifinality extent in such modeling practice is much narrower. Although the equifinality always exists but still we can reject some of equifinal models by hydrologic reasoning. No need to accept all eqifinal parameter sets, we can reject some with allocation.

E. What is the outcome of parameter allocation (a single model? Transferable in space?) The outcome of parameter allocation should be a single model, but I prefer to say that in allocation practice the extent of equifinality is much lesser. If we could constrain our models to specify all parameters without using the observed data then we could confidently apply it to ungauged basins (of course a new parameter set for the new catchment is needed). Safari et al. 2012 published the uncalibrated simulations of the WetSpa model for ungauged basin. The performance of the uncalibrated model with reasonable accuracy is encouraging. Schymanski et al. (2009) presents a good example of how optimality may be a useful way of approaching the prediction and estimation of some vegetation characteristics and fluxes in ungauged basins without calibration.

F. How would a typical parameter allocation procedure look like? Parameter allocation procedure: Parameter allocation is suggested for process based models where parameters are meaningful with physical and rational explanation. With some degree of practice, and after gaining some understanding about how the hydrological processes are represented in the model and how the parameters relate to observable or conceptual catchment characteristics, the modeler can specify the parameters values in a logic based manner. Of course for some parameters few trial and error attempts might be needed. It is still a heuristic technique, a kind of ansatz, an educated guess on parameter set that is later verified by its results. Few steps for a parameter allocation can be mentioned:

I) Preliminary rough test on parameters sensitivity (the parameter set of a previous study in a different catchment can be a good choice to start with). The modeler is supposed to know the parameter behavior so by this test the behavior is checked for the new study area.

II) To collect and to list all the relational inequality constraints between parameters, the conceptual relations between parameters and catchment characteristics, (as well as organizing principles).

III) Allocating those parameters which the modeler can easily fix them on an approximate value with rules of thumb.

IV) If there is an insensitive parameter among the parameters that should be fixed on a certain value too (I believe normally this is not the case for the physic based distributed models because their parameters are all sensitive usually).

V) Parameters with consistent relational behavior with catchment characteristics are approximated.

VI) Inequality conditions between some parameters are applied. Those parameters with constraint and relational rules are allocated together. The constraints are either implemented manually or using simple computer codes in case of automatic procedure.

VII) Some parameters or processes have to conform with some organizing principles (like, the optimality principle, landscape evolution equations, and Horton's laws

of stream networks, e.g. Horton number of bifurcation). This is quite rough idea and needs elaboration and perhaps revision.

VIII) For some parameters the modeler might come up with a narrow range rather than a certain value.

IX) Always some manual trial and error would be helpful to decide on the final set.

X) Trust the allocated set and be confident with the outcome.

G. What examples support it? Apart from my own experience with the WetSpa model, some publication like Gharari et al. (2014), Hrachowitz et al. (2014), Antonetti et al. (2015) are in support of expert knowledge in limiting calibration. In the final version they will be cited properly.

H. What further work is needed to improve it? I would suggest some researches to be carried out by different modelers using different physics based models in different catchments (or same catchment). Each of the modelers has to have enough experience with their model. Their study catchment has to be new in order to perform an honest test, and they should not have applied their model to the given catchment before. By just forgetting about discharge they impose their expert knowledge on the model parameter ranges, model simulated state and fluxes if they can come up with any. They would try to use any information from topography to soil to any which they need (except discharge time series). They would perform their model and see how their simulations are compared with the observed discharge finally. I think this will help of more in understanding of our model even more.

At the end, again, I thank Prof. Schaefli for her constructive comments. The referee's valuable comments will surely improve the final version of the paper. I apologize for my answers being lengthy and repetitive, therefore, they will be edited and shortened later.

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