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Reply on CC1

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Author comment on "Estimation of hydraulic conductivity functions in karst regions by particle swarm optimization with application to Lake Vrana, Croatia" by Vanja Travaš et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-253-AC1, 2023

REMARK: This paper presents an iterative method based on the application of particle swarm optimization for estimating the hydraulic conductivity functions associated with the semi-distributed lumped karts model in lake Vrana, Croatia. In my opinion, the topics of this paper might be of interest to the readers of this journal, but it cannot be considered acceptable for publication in its current state. I suggest that the authors consider a major revision of their work along the following comments.

ANSWER: We would like to thank the reviewer for all the remarks and comments, and we hope that with the answers given below and the changes made in the paper we managed to achieve the required quality for publication. We responded to all the comments and suggestions, and based on them, we believe that we have made appropriate corrections in the paper, which are marked by red text. Please note that we have made corrections and adaptations in the paper based also on the remarks and suggestions of other reviewers and so some corrections can overlap.

REMARK: An important concern is that the paper does not appear to be significantly innovative, but demonstrates a complex exercise that applies some approaches well established in the literature. The novelty of this paper should be reinforced to illustrate the scientific and academic findings in the study.

ANSWER: Please note that the model in consideration is represented by a system of two nonlinear ordinary differential equations with variable coefficients (i.e. three calibration functions). Since it cannot be classified as an LTI system, it was to be expected that the task of calibrating such a model would be very complex (note that the calibration functions and also their domains are unknown). The calibration of the model first started with the trial-and-error method, and we immediately established that there is an exceptional sensitivity of the model results to even the smallest changes in the calibration functions. For this reason, we started trying other calibration methods, and of all the ones we tried, the PSO method was convincingly the most effective. This paper was written in order to share our experiences. In this sense, we believe that the modest novelty of the paper can be recognized in the application of the PSO method to the calibration of this type of model. Namely, by reviewing the literature, we did not find the same use of the PSO method. Moreover, we came across only a few papers that use the keywords PSO and karst model (but not in the same context as in this paper). In order to highlight the modest scientific significance of the paper, we supplemented the introduction by elaborating the problem of multimodality (that is encountered in such problems) and brought it into connection with the application of the PSO method and the considered modeling approach by system of ODEs (i.e. lumped karst models).

REMARK: Another major concern relates to the estimate of the hydraulic conductivity functions of the karst aquifer. Although the mathematical model for simulating the exchange of fresh water and salt water is generally well calibrated, the uncertainty associated with precipitation recharge should be considered in model calibration. I strongly recommend authors investigate the sensitivity analysis regarding the inflow from precipitation recharge within the lake watershed.

ANSWER: We would like to recognize that the precipitation data are included in the groundwater flow component qkl,gw and the surface flow component qkl,sf which was obtained by field measurements (the same as the data of the flow component ql,pr from precipitation on the lake itself). In this way, these terms appear on the RHS as known functions in time and are not the subject of modeling. If the remark meant the model's sensitivity to these parameters, we would ask you to note that this was not the subject of the paper, but we focused on the problem of model calibration. Although we can equip the paper with a shorter sensitivity analysis, we believe that a complete sensitivity analysis would exceed the scope of this paper or would require writing a new paper. On the other hand, if the remark meant the sensitivity of the model with respect to the calibration functions, then we can state that the model result is extremely sensitive to a small change in the calibration functions (which was to be expected due to the nonlinearity of the model – note that the surface flow in Prosika channel is also modeled). For this very reason, it was necessary to apply the PSO method, which proved to be the best for global and local search of the domain of the objective function. The PSO method was used to search for the best solutions of the calibration functions, which will make the model solution the least sensitive to their change. Since the calibration functions are independent of time (model parameters), the obtained calibrated model represents the basis for further research, among which there will certainly be an analysis of the sensitivity of the model results to precipitations (we believe that this topic should be considered in another separate paper).

Fig. 7 should be explained in detail. Nowhere can be found the description of groundwater level in the domain of interest.

ANSWER: An additional description of the Figure in question is added in the paper (marked by red text). Namely, Fig. 7 shows the arrangement of the cross-section surface areas of cracks in the karst environment with respect to the elevation and thus includes the surfaces of conductors, caves, caverns, etc. Like hydraulic conductivity functions, this function is also unknown in advance and it is most often known that it decreases due to the dissolution process with the rise of the groundwater level (caverns and caves are usually located at deeper areas of the aquifer). On the other hand, as the groundwater level (variable hk) was one of the variables in the considered system of ODE, at the beginning of the time domain it was set as an initial condition (like the variable hl used to represent the water level in the lake). A description has been added for the interpretation of Figure 7, as well as a text related to the initial condition of groundwater level. “The initial conditions were given by the model variables hl(t0) and hk(t0) defined at time t0 i.e. at the beginning of the time domain. The initial condition hl(t0) was set to 0.81 m a.s.l. which is known by field measurements (as can be recognized in Fig. 3). On the other hand, the variable hk(t0) was set to 2.2 m a.s.l. and defined from model calibration so that a relatively rapid raise in water level hl, at the beginning of the time domain, is obtain (as evidenced by in situ measurements shown in Fig. 3).”

REMARK: If there are some measurement data of water salinity over time available, it’s better to consider the mass exchange of salinity between fresh water in karst aquifer and salt water in lake/sea coupled in the conceptual model.

ANSWER: Unfortunately, salinity measurements are only available for the lake and not in a continuous time series. On the other hand, it should be recognized that the lake is fed with fresh water from the karst aquifer, and therefore the flow in that part is only directed towards the lake (which is confirmed by the model i.e. sign of the flow component qgw,kl in Fig. 8 and Fig. 11). In this sense, there is no exchange of salt water between the lake and the karst aquifer.

REMARK: Some specific typos are below:

(1) Line 53, salt water instruction --> salt water intrusion

(2) Line 75, can by used to --> can be used to

(3) Line 312, is consider as --> is considered as

ANSWER: In accordance with the remarks, the necessary corrections were made.