Replies to Referee #2

Title: Dynamics of hydrological model parameters: mechanisms, problems, and solution

General comments:

The manuscript identifies the problem of finding the global optimum for dynamic hydrological model parameters and proposes an approach involving the investigation of their evolutionary processes. The study was performed for data from three river basins: Hanzhong, Mumahe and Xunhe. The Authors used hydrological and climatic data from the period 1980-1990. Two clustering operations have been performed on this data. Additionally, both data groups were divided into 4 sub-periods: dry period and three wet periods. The data were analyzed using maximal information coefficient (MIC) and the Principal Component Analysis (PCA). The HYMOD model was used. The parameters used in this model were analyzed in the paper (5 parameters). The model has been calibrated. Moreover, the Authors used the Shuffled Complex Evolution algorithm from the University of Arizona (SCE-UA) as an evolutionary algorithm for dynamic parameters. The combination of the Nash-Sutcliffe Efficiency index (NSE) and its logarithmic transformation (LNSE) was used as the function of the object. The simulation performance with dynamic parameters was assessed using seven performance metrics including NSE, LNSE, a five-segment flow duration curve (5FDC) with the Root Mean Square Error (RMSE). A fitness landscape was used to visualize the evolutionary processes, and violin plots were used to visualize the distribution parameters. The Authors collected a large number of results that are presented in the charts. These charts are clear and interesting. Such studies are undoubtedly needed because finding the global optimum for dynamic hydrological model parameters is an important practical issue. In my opinion, the novelty of this work is in the developed framework for the dynamic operation of parameters. The Authors might also consider expanding the discussion to the case of single- and multi-parameter spaces. In my opinion, the supplement (Supporting Information), could contain: equations, codes, details of used parameters or the names of used programs. I am interested in how the data were prepared for the determination of distributions and for the MIC and PCA analyzes. Were the data logged in the PCA analysis?

Reply: We thank Dr. Łukasz Gruss for reviewing our paper and for your positive evaluation and encouragement. All your comments and suggestions will be fully considered in making revisions. All codes of methods and data in this study will be opened and attached in Supporting Information.

Specific comments:

Line 17, page 2: The concept of an evolutionary process described in the introduction is not very clear. Please consider a more detailed description.

Reply: Thanks for the referee's reminding. The more detailed description will be added in the Introduction section. The specific information is as follows:

“Evolutionary algorithms (EAs) are the most well-established class of global optimization algorithms for solving water resources problems (Maier et al., 2014). In each evolutionary process, four steps, including evaluation, fitness assignment, selection and reproduction, are performed. The parameter set with the best objective function value in each evolutionary process loop is recorded in the "evolutionary processes". The evolutionary process evolves toward minimizing the objective function values. The final optimum is obtained at the end of the run while satisfying the stopping criteria."

Line 22, page 3: Please consider using "hydrological and climatic data" instead of "daily streamflow and climatic data". Have the authors considered including water temperature and air temperature in the analyzes?
Reply: Thanks for the Referee's suggestion. Revised will be completed, as suggested. We did not use water temperature and air temperature in the analyzes.

Line 6, page 4: I suggest that the methodology for performing PCA and MIC analyzes should be described.
Reply: We agree with the Referee on this point. The methodology for performing PCA and MIC analyzes will be described in the revised manuscript. The detailed information is as follows:

"A set of climatic-land surface indices was provided and preprocessed using the maximal information coefficient (MIC) and principal components analysis (PCA). Actually, the indices are specified based on dynamic characteristics on a catchment. The climate and land-surface indices were selected just as examples in this study. The selected climatic indices included total precipitation, maximum 1-day precipitation, maximum five-day precipitation, moderate precipitation days, heavy precipitation days, total pan evaporation, maximum 1-day pan evaporation and minimum 1-day pan evaporation. The land-surface indices included antecedent streamflow and runoff coefficient. The definition of the indices is provided in Table A1. Indeed, the indices that are independent with streamflow may damage the extraction of dynamic catchment characteristics. Hence, the selected indices should be screened first by identifying the degree of correlation between the indices and streamflow. The MIC, as a statistical metric, can indicate the linear and nonlinear correlation between the variables (Zhang et al., 2014) and is used to screen the indices in this study. The detailed introduction of the MIC metric is provided in the Supporting Information. It is assumed that the indices have a significant effect on streamflow and are picked up while the MIC value is larger than 0.35. In addition, a large amount of redundant information still exists among the screened indices and damages the availability of the extracted information. Hence, PCA is applied to further eliminate the multicollinearity of indices (Ho et al., 2017)."

Line 9, page 4: What do the Authors understand by total precipitation? Is it the annual rainfall?
Reply: The definitions of climatic-land surface indices will be supplemented in the Appendix as follows:

Table A1. Climatic-land surface indices.

Indices	Descriptive names	Definitions	Units
R_T	Total precipitation	Current half-monthly total precipitation	mm
RX1day	Maximum 1-day precipitation	Half-monthly highest 1-day precipitation	mm
RX5day	Maximum five-day precipitation	Half-monthly highest consecutive 5-day precipitation	mm
R25pday	Moderate precipitation	Count of days where RR (daily precipitation amount) <	days

	days	25th percentile	
R75pday	Heavy precipitation days	Count of days where RR ≥75th percentile	days
PE_T	Total pan evaporation	Current half-monthly total pan evaporation	mm
PE_x	Maximum 1-day pan evaporation	Half-monthly highest 1-day pan evaporation	mm
PE_n	Minimum 1-day pan evaporation	Half-monthly lowest 1-day pan evaporation	mm
Q_{T-1}	Antecedent streamflow	Antecedent half-monthly average streamflow	m^3/s
C	Runoff coefficient	Ratio of runoff volume to rainfall volume	

Line 4, page 5: if the code is open, please consider making it available in a supplement.

Reply: All codes of methods and data will be opened and attached in Supporting Information of the revised manuscript.

Line 12, page 5: A description or explanation of the 5 parameters mentioned would be desirable. [reference to the supplement]

Reply: The definitions of parameters, state variables and fluxes used in the HYMOD model will be supplemented in the Appendix as follows:

Table A2. Definitions of parameters, state variables and fluxes used in the HYMOD model (Wagener et al., 2001).

Label	Property	Range	Description
H_{uz}	Parameter	0-1000 [mm]	Maximum height of soil moisture accounting tank
B	Parameter	0-1.99	Scaled distribution function shape
alpha	Parameter	0-0.99	Quick/slow split
K_q	Parameter	0-0.99	Quick-flow routing tanks' rate
K_s	Parameter	0-0.99	Slow-flow routing tank's rate
XH_{uz}	State variable	[mm]	Upper zone soil moisture tank state height
XC_{uz}	State variable	[mm]	Upper zone soil moisture tank state contents
X_q	State variable	[mm]	Quick-flow tank states contents
X_s	State variable	[mm]	Slow-flow tank state contents
AE	Fluxes	[mm/day]	Actual evapotranspiration flux
OV	Fluxes	[mm/day]	Precipitation excess flux
Q_q	Fluxes	[mm/day]	Quick-flow flux
Q_s	Fluxes	[mm/day]	Slow-flow flux
Q_{sim}	Fluxes	[mm/day]	Total streamflow flux

Line 2, page 20: The use of the CDF (cumulative distribution function) is mentioned. If these results are not presented in the article, I suggest that they should not appear in the conclusions.

Reply: The use of the CDF will be removed, as suggested.

References:

Gomez, J.: Stochastic global optimization algorithms: A systematic formal approach, Information Sciences, 472, 53-76, https://doi.org/10.1016/j.ins.2018.09.021, 2019.

Ho, M., Lall, U., Sun, X., and Cook, E. R.: Multiscale temporal variability and regional patterns in 555 years of conterminous U.S. streamflow, 53, 3047-3066, 10.1002/2016wr019632, 2017.

Maier, H. R., Kapelan, Z., Kasprzyk, J., Kollat, J., Matott, L. S., Cunha, M. C., Dandy, G. C., Gibbs, M. S., Keedwell, E., Marchi, A., Ostfeld, A., Savic, D., Solomatine, D. P., Vrugt, J. A., Zecchin, A. C., Minsker, B. S., Barbour, E. J., Kuczera, G., Pasha, F., Castelletti, A., Giuliani, M., and Reed, P. M.: Evolutionary algorithms and other metaheuristics in water resources: Current status, research challenges and future directions, Environ Modell Softw, 62, 271-299, 10.1016/j.envsoft.2014.09.013, 2014.

Wagener, T., Boyle, D. P., Lees, M. J., Wheater, H. S., Gupta, H. V., and Sorooshian, S.: A framework for development and application of hydrological models, Hydrol. Earth Syst. Sci., 5, 13-26, 10.5194/hess-5-13-2001, 2001.

Zhang, Y., Jia, S., Huang, H., Qiu, J., and Zhou, C.: A novel algorithm for the precise calculation of the maximal information coefficient, Sci Rep, 4, 6662, 10.1038/srep06662, 2014.