Interactive comment on “Improvement of hydrological model calibration by selecting multiple parameter ranges” by Qiaofeng Wu et al.

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General comment:

We appreciate the comments from the reviewer and truly believe these comments can help us to improve our manuscript. We consider the corresponding changes can be included in the revised document to achieve publication status. We provide responses to the main and specific comments in sequential order as follows:

Responses to Referee #1

Main comment #1

"Probability distribution functions considered in the study. In this study, the authors propose a method to constrain parameter ranges for parameters that follow uniform, normal, and exponential probability distribution functions. These are the probability distribution functions that the case study model parameters reportedly follow. Some of the claims are debatable. For instance, parameters CI and Kc are reported to follow normal distributions (page 7, line 29) based on the following statement (page 7, line 25): "It is obvious that the box and whiskers are symmetrical and the length of whiskers is longer than that of the box [...].". Looking at Fig. 5, however, the whiskers are not symmetrical and, on the upper side, not longer than the box, suggesting that the ranges of these parameters do not follow a normal probability distribution. Therefore, the method used to constrain the ranges of these parameters might not be the optimal, potentially changing the results of the study."

Responses to main comment #1:

There are three types of distribution discussed in the investigation. In order to distinguish them, a simple method in section 3.2.2 was used based on shapes of the cumulative frequency curve and the histogram as well as the sizes of whiskers and box in the box-plot. Despite simplicity, it is subjective and unintelligible to readerships. For avoiding the confusion as described in this comment, a Kolmogorov-Smirnov (K-S) test will be employed to objectively identify each distribution type in the revised paper. Indeed, we carried out K-S tests to evaluate statistical distributions of all parameters in the hydrologic model. The results of K-S tests for parameters CI, Kc, and SM are listed in the following Table A. It is shown that both exponential and uniform distributions are rejected for the three parameters while normal distribution is not. It implies that the three parameters follow normal distributions. Therefore, the simple method used earlier does not change the results of the study, although it is subjective.

Table A. The results of K-S tests for parameters CI, Kc, and SM

	CI			Kc			SM		
	Normal	Exponential （2P）	Uniform	Normal	Exponential （2P）	Uniform	Normal	Exponential （2P）	Uniform
Statistic	0.0623	0.32805	0.1151	0.09199	0.37961	0.10694	0.05983	0.30392	0.10982
P-Value	0.80925	5.40E-10	0.1306	0.34466	3.08E-13	0.18882	0.84521	1.23E-08	0.16628
α	0.2	0.01	0.2	0.2	0.01	0.2	0.2	0.01	0.2
Reject?	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes

Main comment #2

"The authors report that parameter range selection has a direct impact on calibration efficiency and propose a new method to improve model calibration (page 1, line 12). The reported results, however, indicate that the improvement in the calibration efficiency by the proposed methodology is quite modest. For instance, in Fig. 9 different cases involving different combinations of parameters keeping the initial range and others having the "optimal" range are compared. The model efficiency different between case I (all the parameters set at the initial ranges) and any other of the considered cases is of the order of 0.002 at best. This suggests that the benefits of using the proposed technique are small."

Responses to main comment #2:

Notwithstanding a small increase in maximum E_{NS}, there is a significant improvement in minimum E_{NS} by using the proposed method. Comparing case 6 (using the optimal combination of ranges) with case 1 (using the initial ranges) in Fig. 9, we find that the maximum E_{NS} increases by 0.001 while the minimum E_{NS} (except outliers) increases by 0.01. The rising minimum E_{NS} with the fixed maximum contributes to the shrinkage of the range of the possible solutions. As a result, the uncertainty of the model performance can be effectively controlled. Moreover, the methodology can be used to analyze the parameter correlation and sensitivity by computing two indexes $R_{\mathrm{C\,Y,X}}$ and S_E. The paper presents the preliminary study of the proposed methodology. In the preliminary study, we adopt a Xinanjiang model with several parameters to evaluate the calibration efficiency of the methodology. Since the parameter Im having negative effect on other parameters is a little bit insensitive in a Xinanjiang model, a modest improvement in calibration efficiency is found after the application of the methodology. In future, we will consider using other complicated hydrologic models with more parameters to further study the application of the methodology.

Main comment #3

"The language should be improved to make the manuscript easier to understand and more compelling. More specifically, the following aspects should be revised: verb tenses (e.g. page 3, line 23-24: "single parameter is selected" - "correlation and sensitivity were estimated"; page 6, line 15: "The index *R*c was quantified" instead of "The index *R*c were quantified"), spelling errors (e.g. page 6, line 13: "contribute" instead of "contributes"; page 9, line 25: "of" instead of "pf"), and sentence structure (e.g. page 9, line 15 "[...] parameters [...] are of high sensitive to E_{ns}"). I would strongly recommend the article to be checked for language."

Responses to main comment #3:

We will revise the manuscript as it is suggested:
Page 3, line 23-24: "single parameter is selected" >> "single parameter was selected"
Page 6, line 15: "The index *R*c were quantified" >> "The index *R*c was quantified"
Page 6, line 13: "contributes" >> "contribute"
Page 9, line 25: "pf" >> "of"
Page 9, line25-26: "...when Case 4 compared with Case 1, Case 2 and Case 3 It can be explained..." >> "... when Case 4 is compared with Case 1, Case 2 and Case 3. It can be explained..."
Page 9, line 15: "… and CG are of high sensitive to E_{NS}" >> "... and CG are high sensitive to E_{NS}"

In addition, we will check the paper carefully and correct the other language errors. For example:
Page 1, line 3: "Qiaofeng." >> "Qiaofeng"
Page 1, line 14: "characteristics of single parameter value was analysed" >> "of single parameter value was analysed"
Page 1, line 17: "corresponding to the distribution" >> "corresponding to the distribution type"
Page 2, line 4: "mechanism of water cycle" >> "mechanism of the water cycle"
Page 2, line 9: "the streamflow at catchment outlet" >> "the streamflow at the catchment outlet"
Page 3, line 30: "in flood reason" >> "in flood season"
Page 4, line 18: "from observed streamflow" >> "from the observed streamflow"
Page 5, line 3: "which representing agreement between observed and simulated data" >> "which represents the agreement between observed and simulated data"
Page 5, line 11: "whisker to the box" >> "the whisker to the box"
Page 5, line 23: "…, the initial range of parameter is required adjusting properly" >> "…, the initial range of parameter requires adjusting properly"
Page 5, line 28: "represents the ranges" >> "represent the ranges"
Page 6, line 4: "in case of larger percentage" >> "in case of a larger percentage"
Page 6, line 5: "... values can transform and finally convert into..." >> "... values can be converted into..."
Page 6, line 11: "may more and less effect" >> "may affect"
Page 6, line 17: "the greater positive influence" >> "greater positive influence"
Page 7, line 2: "The statistic analysis" >> "The statistical analysis"
Page 7, line 6: "ranges is substituted" >> "ranges are substituted"
Page 7, line 8: "the selected one is adopted for calibration of multiple parameters." >>

"the selected ones are adopted for multi-parameters model calibration."
Page 7, line 16: "In stage 3 the ... " >> "In stage 3, the ..."
Page 7, line 26: "direction of Y axis" >> "direction of the Y axis"
Page 7, line 30-31: "The ratio of calibrated parameter range to initial one is less than 30% for parameters CI, SM, and Kc" >> "The ratios of the calibrated parameter range to the initial one are less than 30% of parameters CI, SM, and Kc"
Page 7, line 31: "It suggest that" >> "It suggests that"
Page 8, line 6: "To normal distribution" >> "For normal distribution"
Page 8, line 7: "different parameter range are selected" >> "different parameter ranges are selected"
Page 8, line 13: "concentrates at larger value zone" >> "concentrates at a higher value range"
Page 8, lien 24: "Because the parameter values in MINR indicate a high probability to be picked out to achieve high E_{NS}, vice versa." >> "It is because that the parameter values that may achieve a higher E_{NS} can be easily picked out from the MINR of higher probability density."
Page 8, line 33: "box-plot chart of E_{NS} for different ranges are shown in Fig. 8e" >> "box-plots for different ranges are shown in Fig. 8e"
Page 9, line 6: "value in columns" >> "values in columns"
Page 9, line 20: "penetrate" >> "penetrability"
Page 9, line 23: "there is contradiction owing to it" >> "there is a contradiction owing to it"
Page 10, line 13: "the extension range followed by" >> "the extended range followed by"
Page 10, line 17: "to adopted" >> "to be adopted"

Specific comment #1

"Page 4, line 28 and page 6, line 2: "plenty of tests". The text suggests that the authors defined their sampling size and cumulative frequency value through a process of trial and error. Since this might affect the subsequent results I think that evidence should be provided to support the authors' claims."

Responses to specific comment #1:

Before defining sampling size and cumulative frequency value, we performed a lot of trial tests. Figure A shows the variation curves of maximum and minimum E_{NS} with sample size. It is indicated that both maximum and minimum E_{NS} keep stable when sampling size is greater than 100. Avoiding the time-consuming computation, we assigned sampling size for the study as 100. Figure B gives the variation curves of maximum and minimum E_{NS} with cumulative frequency value. It is found that the maximum E_{NS} keeps constant despite a cumulative frequency value varying, while the minimum E_{NS} approaches the peak value of 0.881 when the cumulative frequency value is equal to 50%. Considering that higher minimum E_{NS} contributes to more efficient calibration, we selected the fixed cumulative frequency value of 50% to determine the ranges of maximum and minimum probability density (i.e. MINR and MAXR) for each parameter.

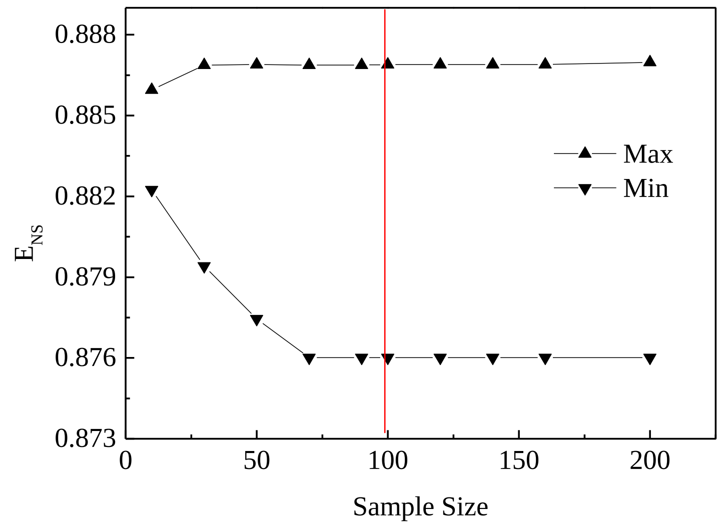

Figure A. Variation curves of maximum and minimum E_{NS} with sample size

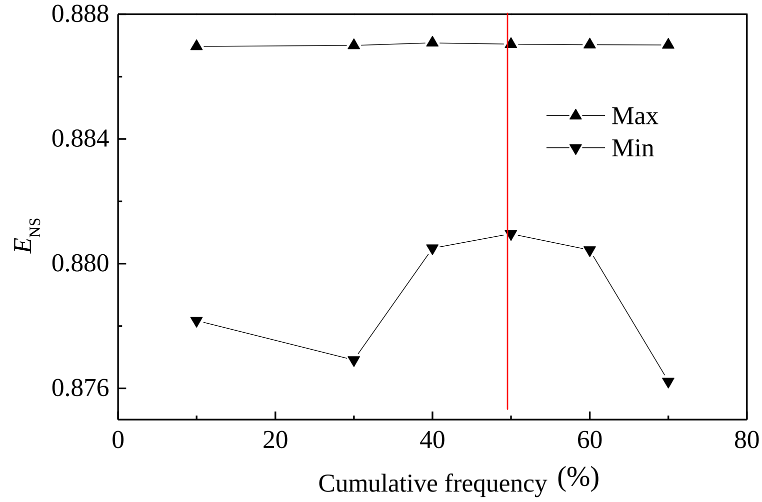

Figure B. Variation curves of maximum and minimum E_{NS} with cumulative frequency value

Specific comment #2

"Page 8, line 34: "[...] there is considerable improvement [...]". "Considerable" is a vague word, please provide a quantitative measure of the improvement. Similar problem in page 8, line 12. Please revise the results section to ensure that no vague words are used."

Responses to specific comment #2:

According to the review comments, we will revise the corresponding parts as follows:

Page 8, line 34: "It is indicated that there is a considerable improvement of both maximum and minimum E_{NS} when extension-MINR is used for calibration." >> "It is shown from Fig. 8e that there is little improvement in maximum E_{NS} when MINR is used for calibration instead of the initial range. There is an increase of 0.0003 in maximum E_{NS} if the initial range is replaced with the extension range or extension-MINR. As for minimum E_{NS} (except outliers), an increase of 0.001 in the case of MINR, a decrease of 0.003 in case of the extension range and an increase of 0.003 in the case of extension-MINR are found when the initial range is substituted with the three ranges respectively."

Page 8, line 12: "It is found that the minimum E_{NS} except extreme outliers rises convincingly and E_{NS} concentrates at larger value zone when MINR is used instead of the initial range." >> "It is found that the minimum E_{NS} except extreme outliers rises from 0.8805 to 0.8842 and E_{NS} concentrates at a higher value range when MINR is used instead of the initial range."

Page 9, line 29-30: "As for the cases of multi-parameter range selection (i.e. Case 5, Case 6 and Case 7), the results are much better than of Case 1-4." >> "As for the cases with multi-parameter range selection (i.e. Cases 5-7), the results are much better than those of cases with initial range or single-parameter range selections (i.e. Cases 1-4). There is approximately an increase of 0.001 in maximum E_{NS} and an increase of 0.01 in minimum E_{NS} when the multi-parameter range selection is performed. "

Specific comment #3

"Page 9, line 24: Seven cases are investigated with different combinations of parameter ranges. What is the rationale behind the chosen combinations? Please specify."

Responses to specific comment #3:

The seven cases were set to demonstrate three primary results. Firstly, the multi-parameter optimal range selection method is superior to the single-parameter one for calibrating hydrologic models with multiple parameters. It can be deduced from higher E_{NS} values of Cases 5-7 than those of Cases 1-4. Secondly, merely using the optimal range of the parameter of relatively higher sensitivity contributes to more efficient calibration when the two parameters have negative effect on each other. It can be concluded by comparing the E_{NS} values of Cases 2-4 referring to the two parameters EX and Im. Thirdly, the combination of optimal ranges of all parameters is not the optimum inasmuch as some parameters like Im have negative effects on other parameters. It can be inferred through analyzing the E_{NS} values of Cases 5-7. The analysis of sensitivity and correlation between parameters is, therefore, very important to determine the optimum ranges combination of all parameters for model calibration.

Specific comment #4

"Figure 1: The chosen color scale makes the figure difficult to read in black and white. Please consider modifying it to facilitate reading the figure in printed form. The elevation units should be "m a.s.l." instead of "m". The lowest elevation in the catchment is reported to be 19 m below the sea level; is that so?"

Responses to specific comment #4:

We will use the gray ribbon for DEM rendering to make Figure 1 easy to read in printed form. The unit "m a.s.l." will be used instead of "m" in revised Figure 1. In addition, there exist dolines (known as sinkholes) in the catchment. It is the reason why the lowest elevation in the catchment is 19 m below the sea level.

Specific comment #5

"Figure 2: Please correct "cure" in the figure caption."

Responses to specific comment #5:

We will change "cure" to "curve" in the caption of Figure 2.

Specific comment #6

"Figure 5: Since the figure represents normalized parameter values on the y-axis, it would be more informative to constrain this axis between 0 and 1."

Responses to specific comment #6:

We will constrain the y-axis of Figure 5 between 0 and 1 in the revised paper. The Fig. 5 modified is presented as follows.

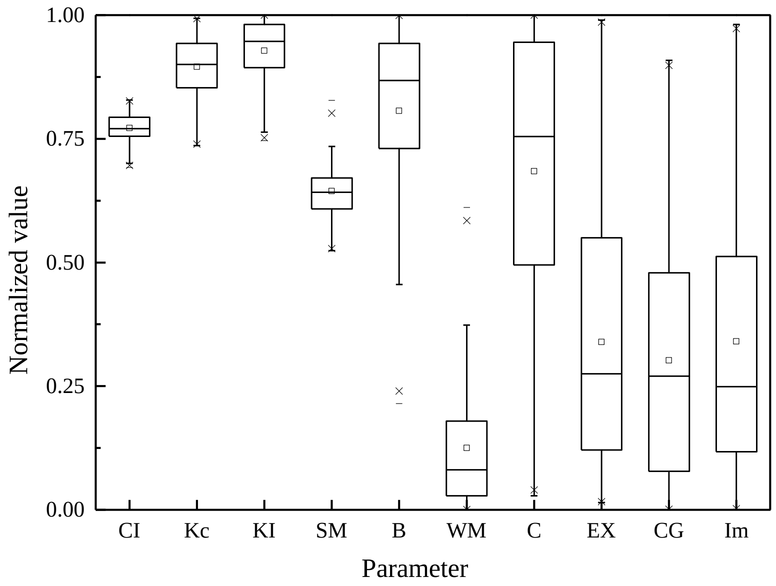

Fig. 5. The box-plot chart of normalized calibrated values for parameters of Xinanjiang model

Specific comment #7

"Table 2: please provide units for all the parameters. In the case of dimensionless parameters indicate so."

Responses to specific comment #7:

We will give units for parameters in a Xinanjiang model, as it is shown in Table 2 below.

Specific comment #8

"Table 2, 3, 4: In order to facilitate the readability of the different tables it might be convenient to order the parameters in the same way in all the tables."

Responses to specific comment #8:

We will modify Tables 2, 5 so that the parameters are ordered in the same way in the related tables. Moreover, the column "range" of Table 2 will be changed as column "Units" because the ranges for parameters are reported in Table 3.

Table 2. Parameters of Xinanjiang model

Parameter	Definition	Units
CI	Recession constants of the lower interflow storage	dimensionless
Kc	Ratio of potential evapotranspiration to pan evaporation	dimensionless
KI	Outflow coefficients of the free water storage to interflow	dimensionless
SM	Areal mean free water capacity of the surface soil layer, which represents the maximum possible deficit of free water storage	mm
B	Exponential parameter with a single parabolic curve, which represents the non-uniformity of the spatial	dimensionless
WM	Averaged soil moisture storage capacity of the whole layer	mm
C	Coefficient of the deep layer, that depends on the proportion of the basin area covered by vegetation with deep roots	dimensionless
EX	Exponent of the free water capacity curve influencing the development of the saturated area	dimensionless
CG	Recession constants of the groundwater storage relationships	dimensionless
KG*	Outflow coefficients of the free water storage to groundwater relationships	dimensionless
Im	Percentage of impervious and saturated areas in the catchment	dimensionless

* the value of KG is calculated by the function 0.7-KI

Table 5. Parameter ranges setting for different cases

Case	Range setting of parameter									
	CI	Kc	KI	SM	B	WM	C	EX	CG	Im
1	I	I	I	I	I	I	I	I	I	I
2	I	I	I	I	I	I	I	I	I	O
3	I	I	I	I	I	I	I	O	I	I
4	I	I	I	I	I	I	I	O	I	O
5	O	O	O	O	O	O	O	O	I	I
6	O	O	O	O	O	O	O	O	O	I
7	O	O	O	O	O	O	O	O	O	O

The symbol 'I' represents the initial range of the parameter in Table 3, and 'O' the optimal range of the parameter in Table 4.