RC1**: ['Comment on hess-2023-233']**

General comment:

The paper has its value and represents a fair contribution to the scientific community mostly towards the discussion of the needed for adopting dynamic parameter optimisation in hydrological models by answering a so-far not completely answered scientific question. However there are many aspects of the manuscripts that ought to be corrected/included before the paper may pass through a peer-review process. After the completion of these corrections I will consider the paper for peer-review in HESS and personally I believe it would fit the journal.

General Reply:

Dear Reviewer, thank you very much for your efforts to review our paper, and gave us a positive comment. We have revised our paper based on your and another reviewer's comments, and a point-to-point response to your comments have been presented below. Please also note that the revised manuscript is attached in this end.

R1-C1. The paper requires substantial gramatical revisions. The structure is therefore confusing to the readers and need a proper revision in terms of the appropriate use of the English language.

AC1: We are very sorry about the English, please forgive us as we are not native English speakers. We have made substantial gramatical revisions, and have it proofreaded by a native speaker before it was sumbitted. We made further improvement once again, and hope the revised version is better to your satisfaction.

R1-C2. 1. INTRODUCTION: The paper aims mainly to answer an interesting research question regarding the need or not of optimising hydrological parameters after significant LUC changes at catchment level. I miss a proper cover of the current literature about the subject in the introduction. Remember that this part is needed to prepare the reader to what is gonna be mainly discussed in the paper. Therefore, the authors need to cover recent publications in the subject. Other studies where they considered the optimisation and got similar results? or not? Unless there is no literature about this topic (which I doubt) the authors should cover this more properly.

AC2: Thanks. During our study, we made a full literature review, and did not find literature covering the issue about parameter dynamics, the parameter updating, and parameter stationary. Most of the literatures derive model parameters from the terrain properties they obtained directly, and no parameter optimization in most cases. This is the main reason we hava made this study. Thank you for your reminder, we reveiwed the literatures again, and did not find new literature on this topic. So we are not able to expend the introduction.

We think this is partly because this kind of studies needs employing distributed hydrologcial model and huge hydrologicial data to simulate hydrological processes under difference LUCs conditions, it is always not easy and very time-consuming. We spent huge amount of times in more than 3 years to finish this study, it is really not easy. We fully understand that why there is not so much study in this topic.

R1-C3. 2.2. HYDROLOGICAL DATA: Remember to always cite the sources of the dataset used. Where is the source of the streamflow used? Is there an official government website? Where readers can obtain the same dataset in order to reproduce the present work?

AC3: Thank you for your reminder, I fully agree with you. But as the hydrological data used in this study is not from a public source, and we have promised to use this data only for this study (Hydrological data, like in many other countries, is not public data in China), so we are not able to publicize the data. But we add the data source in the paper: the administration of Songmushan Reservoir, and hope you understand our situation.

R1-C4. The methodology is confusing. You need to provide a proper and enjoyable workflow guiding the readers to what you did. what were your hypothesis and what they might expect. Think that your readers might want to reproduce this work in a coherent work and then write the most direct, and at the same time sufficient, as possible. Consider the use of flowcharts or framework figures to help the reader to understand the work-flow.

AC4: Thank you for your suggestion, very good suggestion. We rewrite the whole section 3, add a sub-section “3.1 Overview of the methodology”, and a technical roadmap figure is presented to ilustrate the methodology concisely, followed by detailed description to the important methods. As it is not allowed to submit the revised manuscript at this moment, so we attach the whole section 3 in the end with revision marks.

R1-C5 3.3. Dynamic parameter updating and parameter stationary: This entire section is very confusing, The authors do not make clear what they actually did here. Please consider restructuring this section since it is one of the most important of the manuscript.
AC5: Thank you very much. We rewrite the whole section 3. Please see the revised one in this end.

R1-C6. 5 Discussions: This part should still be part of the results and not of the discussion.
AC6: Thank you very much for your comment. We think this part can be partly results, and partly discussion also, so we merged the two parts as one part called results and discussions. As it is not allowed to submit the revised manuscript at this moment, so we attach the whole section 4 in the end with revision marks.

R1-C7. The authors need to include a proper discussion in the paper. The current discussion part is actually part of the results and cannot be considered a discussion. For the discussion the authors need to explore the current literature and how close/different are the results found by other authors to the results presented here. This paper conclusions have a big potential for the subject, but to be properly effective they need to be as much as possible discussed in view of what has been done/ is being done by others.
AC7: Thanks. As mentioned above, there is no this kind of study, so we are not able to compare something as you suggested. We think this part can be partly results, and partly discussion also, so we merged the two parts as one part called results and discussions.

Attachment: revised section 3 and section 4

type data in Fig. 3(b) needs to be adjusted based on this definition. Besides, the urban land data in Fig. 3(b) was prepared by FAO in 1990, ~~so~~ it is out of date, and ~~have been~~was updated with the results of Fig. 2 in this study. The final soil types of SRW, inclusive of the newly introduced urban land soil type, are illustrated in Fig. 4. Notably, the soil types for the years 2018, 2011, 2013, and 2015 exhibit variations~~adding the urban land soil type, is produced and shown in Fig. 4, the soil types in 2018, 2011, 2013 and 2015 are different~~.

Fig. 4 is here

3 Methodology

3.1 Overview of the methodology

The methodology proposed in this study has three major steps, including preparation, model set up, and flood simulation, which are briefly introduced below, and a technical roadmap depicting the whole precedure is presented in Figure 5. For some important methods, they are explained in more details in the following sub-sections.

Figure 5 is here

1. Preparation

In the preparation step, two things need to be done. Firstly, a physically based, distributed hydrologic model needs to be selected as the flood processes simulation tool, and the one selected for this study needs to be able to simulate the flood processes as accurate as possible in the urbanizing watersheds, and to be able to relate its parameters with the LUCs changes. As mentioned in the introduction section, there are already many PBDHMs, and Liuxihe model is selected as the PBDHM in this study, which will

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be introduced in more detail in the following sub-section. But some other PBDHMs may also be employed as the hydrological model if they satisfy the above requirements.

Secondly, a watershed needs to be selected as the study case which should be an urbanizing watershed, i.e., significant LUC changes should be observed in the study period. There should be hydrological data observation during this period, data for model set up and flood processes simulation should also be available. As introduced in section 2, the Songmushan Watershed has been selected as the study watershed, which has appropriate data for this study, it is an ideal study case.

2. Model set up

The second step is to set up the selected hydrological model in the selected watershed, which includes several jobs. Firstly, to set up the model structure with available terrain property data. Different from lumped hydrological model, which has the same model structure in different watersheds, PBDHMs have different model sturctures in different watershed, which could be set up by using terrain property data, including DEM, soil types, LUCs, different PBDHMs have different model structures also.

Secondly, the initial model parameters need to be determined, usually PBDHMs derive their initial model parameters from the terrain properties, different model usually has its own ways to do this job. For Liuxihe model, the parameterization method is introduced in the following sub-section.

Thirdly, to optimize model parameters. As mentioned in the introduction section, initial model parameters ususlly have high uncertainty, and parameter optimization is an effective way to control this uncertainty. For Liuxihe model, it has proposed effective parameter optimization methodology, which will be introduced in more details in the following sub-section.

3.Flood simulation

The last step is to simulate the flood events observed in the study watershed during the LUCs changing period, and based on these simulation results with different LUCs and parameter combination scenarios, conclusions could be proposed. In this study, three kinds of simulations need to be done. Firstly, the flood simulation with optimized model parameters, so to prove the model employed in this study is rational, and can simulate the urbanizing watershed flood processes effective. While at the same time, to prove that parameter optimization is needed even for PBDHMs, which could improve the model performance, and is feasible computationally.

The second simulation is about the parameter's dynamics and parameter updating method proposed in this study. This could be done by simulating flood events with and without parameter updating, then comparing the two simulation results to find the conclusion on parameter dynamics and parameter updating. This simulation is described in more details in the following sub-section.

The third simulation is about parameters LUCs stationary. These simulations simulate flood processes with dynamic parameter optimization and updating, and with only parameter updating. By comparing these results, if parameters are LUCs stationary can be proposed. These simulations are described in more details in the following sub-section.

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3.~~1~~ 2 Liuxihe model and structures

The PBDHM employed in this study is the Liuxihe model, which is a physically based, distributed hydrological model proposed for watershed flood forecasting (Chen, 2009; Chen et al., 2011; Chen, 2017). ~~But any PBDHMs which could relate its parameters with LUCs could be employed.~~

Liuxihe model divides the watershed surface into grid cells, which are categorized as hill slope cells, river channel cells and reservoir cells. For river channel cells and reservoir cells, the watershed surface is water, runoff produced in these cells are equal to the net precipitation. The surfaces of hill slope cells are covered with different land use/cover (LUC) types, so each hill slope cell has its unique LUC. Currently in Liuxihe model, there is no urban land LUC type, only vegetated LUCs. Each hill slope cell also has its own soil type and elevation. LUC type, soil type and elevation are called watershed terrain properties in Liuxihe model. Runoff is produced first on cells, and then routed to the watershed outlet via a routing network. Runoff production is governed by the infiltration, and the soil type is the controlling terrain property for runoff production. Runoff routing is categorized as hill slope routing, river channel routing and reservoir routing. The kinematical wave approximation is employed for hill slope routing, while the diffusive wave approximation for river channel routing.

For Liuxihe model, there is no way to make runoff production and routing calculation for the urban land grid cells, so in this study, a module that can make this calculation is added. The urban land surface is impervious, the precipitation falls to this ground surface is regarded as completely converted into surface runoff, and no precipitation is infiltrated to the soil beneath it. Runoff produced on cells with urban land surface is equal to precipitation fallen to the surface. The approach used to calculate runoff production is as below.

$$R_{i,t}=P_{i,t}-E_{i,t} \quad (1)$$

Where $R_{i,t}$, $P_{i,t}$ and $E_{i,t}$ are surface runoff, precipitation and actual evaporation produced on cell i at time t respectively, and the evaporation could be regarded as water surface evaporation if there is surface runoff, otherwise it is zero.

As only the hill slope cell may have urban land surface, so the runoff routing on urban land cell is hill slope routing. In Liuxihe model, hill slope routing is solved by using kinematic wave approximation. For hill slope routing, the governing factors are the slope of the cell and the roughness coefficient of the surface. For the hill slope routing on urban land surface, the same approach is used but using different roughness coefficient. The above approaches for runoff production and routing on urban land cell has been developed and embedded into the currently used Liuxihe model software tool.

Liuxihe model structure includes dividing the whole watershed terrain into grids, classifying grid types, i.e., hill slope cell, river channle cell and reservoir cell, then to divide the river channel into virtual channel, and measuring the virtual channel's sizes, which could be done based on the satellite remote sensing imagies. The detailed method could be referred to the Liuxihe model references (Chen, 2009; Chen et al., 2011; Chen, 2017).

3.~~2~~ 3 Liuxihe model parameter look-up table and parameter determination

Liuxihe model is a distributed hydrological model, so each grid cell has its own parameters, i.e., 13 parameters (Chen et. al, 2011). The parameters in each grid cell are divided into 4 categories, including climate-based parameters, topography-based parameters, vegetation-based parameters and soil-based parameters (Chen et. al, 2016). The parameters' values are related to only one category terrain property of its grid cell, i. e., climate-based parameters are only related to the climate condition, the topography-based parameters are only related to the topography, vegetation-based parameters are only related to the land use/cover types, and the soil-based parameters are only related to the soil types. There is only one climate-related parameter, i.e., the reference evaporation which is regarded as the same for all grid cells. There are two topography-based parameters, including flow directions and slopes for hill slope cells and river channel cells. There are also two vegetation-based parameters, the evaporation coefficient and roughness. There are 8 soil-based parameters, including soil prorosityperty coefficient, soil thickness, hydraulic conductivity under saturated condition, soil water contents under saturated condition, field condition, and wilting condition. There is one parameter for underground water routing which is regarded as the same for all grid cells, and is also a soil-based parameter.

Liuxihe model takes two steps to determine model parameters, firstly deriving initial parameter look-up tables from the watershed terrain property data, and then optimizing them. For a specific watershed studied, Liuxihe model first proposes parameter look-up tables, which are two-dimensional tables referring the values of parameters with the terrain properties, for example, with soil type Ferric Acrisols, the parameter value of soil water content under saturated conditions is referred to as 46.1%. Based on these parameter look-up tables, the parameters of each grid cell could be determined according to the grid cell's terrain properties, including DEM, LUCs and soil types. As climate-based parameters take the same value for all grid cell, so there is no need for a look-up table for the climate-based parameters. While the topography-based parameters are calculated directly based on the DEM using the D8 method (O'Callaghan et al., 1984; Jensen et al., 1988), so there is no need for a look-up table for the topography-based parameters also. Therefor there are two parameter look-up tables, one is for vegetation-based parameters, and another is for soil-based parameters.

Liuxihe model proposed ways for determining the two parameter look-up tables (Chen et al, 2011; Chen et al, 2016). For the vegetation-based parameters look-up table, the referring values are decided from laboratory experiments and local experiences, or even from references or results from other watersheds. There are two vegetation-based parameters, the evaporation coefficient and roughness. For the soil-based parameters look-up table, Liuxihe model employs the Soil Water Characteristics Hydraulic Properties Calculator (Arya et al., 1981) to calculate the referring values based on the soil texture, organic matter, gravel content, salinity and compaction. With these parameters look-up table, based on its terrain properties, the initial parameters for each grid cell could be derived. With this way, if the terrain properties of each grid cell are available, then the initial parameters could be proposed.

As the initial parameters derived with the above method are highly experience-based, and current parameterization experiences are very limited, so the initial parameters have uncertainty, thus model performance could not be secured. To improve model performance, Liuxihe model optimizes the initial parameters by using optimization algorithm, this is the second step of Liuxihe model parameters determination. From past experiences of Liuxihe model parameterization, it has been found that parameter optimization could largely improve the model's performance. Besides, in optimizing model parameters, hydrological data from only one flood events is enough, not like lumped hydrological mode, series of hydrological data is requirred. This is very important for an urbanizing watershed as it usually has limited hydrological data, no long series of hydrological data.

Currently two algorithms have been proposed for Liuxihe model parameter optimization, one is SCE-UA algorithm (Xu et al., 2012), another is Particle Swarm Optimization (PSO) algorithm (Chen et al., 2016). In optimizing parameters, Liuxihe model does not optimize all parameters of each grid cells, but optimizes the parameters look-up tables. I.e., an adjusting coefficient for each terrain property is proposed, so the optimized variables are limited, which makes the calculation practical, otherwise, even with the fastest computers in the world, the optimization is not feasible.

3.~~3~~ 4 P~~Dynamic p~~arameter dynamics and parameter updating ~~and parameter stationary~~

In this study, parameter dynamics is defined as when LUCs change, the model parameters should change also with the LUCs changing. This is an assumption proposed by the authors. Further, if the parameter dynamics assumption is correct, then the model parameters should be updated with the changing LUCs. As f~~F~~or an urbanizing watershed, the terrain properties, particularly the LUCs are in constant changes, so after parameter look-up table is optimized based on hydrological data from one specific flood event and terrian properties at a specific date, model parameters should be updated if the terrain properties change~~s~~ based on the parameter dynamics assumption. I~~, i~~t is called ~~in this study,~~ dynamic parameter updating in this study, this~~it~~ is also the core concept of this study~~, that the model parameters are dynamically changing with terrain property changes~~. Only with ~~this~~ dynamic parameter updating, can the model performance ~~can~~ be secured.

It seems the parameter dynamics assumption is obviously correct based on human's direct response or experiences, but we must prove this assumption scientifically. In this study, we use the simulation results to validate this assumption. We first simulate flood processes of observed flood events with the optimized hydrological model parameters, and also simulate the same flood events with updated model parameters, then compare these simulated flood processes. If both the simulated flood processes are the same, it implies that the model parameters do not change with the LUCs change. If there is significant difference between these two results, it implies that the model parameters changed due to LUCs change. Further, if the simulated flood processes with updated parameters fits the observation better, then it can be concluded that parameter updating is necessity, and model performance can be improved with parameter updating. In this study, the above assumption will be validated in the case study.

~~But this parameter updating is based on the assumption that the parameter look-up tables are LUCs stationary, i.e., the look-up tables are not changed with the terrain property changing. Otherwise, the updated parameters could not improve the model performance, or the parameter look-up table needs to be optimized again with the changed LUCs and new observed hydrological data.~~

3.5 Parameter stationary

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~~But this~~The parameter updating method proposed in this study is based on the a~~a~~ssumption that the parameter look-up tables are LUCs stationary, i.e., the look-up tables ~~are~~do not change~~d~~ with the terrain property changing, including LUCs change, otherwise, the parameter look-up tables need to be optimized again after there is significant LUCs change. So, if parameters are LUCs stationary, then there is no need to optimize the parameter look-up tables very often, ~~O~~otherwise, they need to be optimized again and again. The authors assume that thethe updated parameters are LUCs stationary, which will be proved in this study. could not improve the model performance, or the parameter look-up table needs to be optimized again with the changed LUCs and new observed hydrological data.

Parameters LUCs stationary is a science question that has not been answered and seldom studied by the world scientific communities. In this study, our approach to address this question involves simulating flood processes and conducting comparisons. We introduce a methodology termed "dynamic parameter optimization and updating." This process entails optimizing the parameter look-up tables when significant LUCs changes occur and subsequently updating model parameters with the newly optimized parameter look-up tables. Then flood processes are simulated under two conditions: dynamic parameter optimization and updating, and solely parameter updating. In the latter condition, the parameter look-up tables remain unaltered post-initial optimization and persist unchanged despite substantial land use/cover (LUC) modifications. Comparing these two results, if the simulation results are almost the same or very close, it can be inferred that the parameter look-up tables remain consistent despite significant LUC changes. This inference supports the assumption that the model parameters are LUC stationarity

Do the parameter look-up tables change with the watershed terrain property changing, it is a science question that has not been answered and fully studied by the scientific communities. The authors assume that the parameter look-up tables of Liuxihe model are LUC stationary, otherwise, we can not validate this assumption. and the simulation results in the case study will validate this assumption.

4 Results and discussions

4.1 Liuxihe model set up

The DEM produced in this study with spatial resolution of 30 m is used to divide the studied watershed into 62942 grid cells, which are further divided into 658 river cells, 53435 hill slope cells and 8849 reservoir cells, based on the method employed in Liuxihe model. A 3-order river network is derived using the D8 method (O'Callaghan et al., 1984; Jensen et al., 1988) and Strahler river ordering method (Strahler, 1957) based on the DEM. The river network is further divided into 24 virtual sections based on 4 virtual nodes. In the Liuxihe model, the virtual river cross section shape is assumed trapezoidal, and the river size is estimated based on satellite remote sensing images. The structure of the Liuxihe model for SRW set up in this study is shown in Fig. 56. The time resolution of the Liuxihe model set up in SRW is 1 hour, the same with that of the observed hydrological data. Precipitation from rain gauges is interpolated to the grid cells by using the Thiesson Polygon method (Thiessen, 1911).

Fig. 5 6 is here

Flow directions and slopes are derived using the D8 method (O'Callaghan et al., 1984, Jensen et al., 1988) based on the DEM. The climate-based parameter, i.e., the potential evaporation is estimated as 5 mm/day for each grid cell according to daily evaporation observations in this region. According to previous studies of Liuxihe model parameterization and references (Chen et al., 1995; Zhang et al., 2006, 2007; Guo et al., 2010; Li et al., 2013), the initial look-up table for vegetation-based parameters is proposed and listed in Table 2.

Table 2 is here

Based on past modeling studies (Zaradny, 1993; Anderson et al., 1996; Shen et al., 2007; Zhang et al., 2015), the soil water content under wilting conditions takes 30% of the soil water content under field conditions, and the soil porosity coefficient takes the value of 2.5. Based on local experiences, the estimated soil layer thickness is listed in Table 3. The Soil Water Characteristics Hydraulic Properties Calculator proposed by Arya et al. (1981) is employed to calculate the soil water contents under saturation condition and field condition, and the hydraulic conductivity under saturation conditions, as listed in Table 3.

Table 3 is here

For grid cells with urban land soil type, all the soil-based parameters are set to zero. This reflects the hydrological response of urban land soil type, i.e., the precipitation falling onto urban land will be converted into surface runoff completely, no precipitation will be infiltrated to the soil or stored on the surface.

For Liuxihe model, hydrological data from only one flood event is needed for parameter optimization, and Particle Swarm Optimization~~(PSO)~~ is the official optimization algorithm, which has been tested and proven to be effective. In this study, hydrological data from flood event 20080625 is used for parameter optimization, and PSO algorithm is employed to optimize the parameters, while LUCs in 2008 is used. The optimized parameter look-up tables are called parameter-20080625-2008 to distinguish parameters optimized with different hydrological data and LUCs in different year. In parameter-20080625-2008, the first number is the flood event number with its hydrological data being used for parameter optimization, while the second one is the year of the LUCs which is used in the parameter optimization. I.e., Parameter-20080625-2008 is the optimized parameters by using hydrological data from flood event 20080625 and LUCs in 2008. Fig. ~~6~~ 7 shows the evolution results of parameters, adaptive values and evaluation indices during the parameter optimization process.

Fig. ~~6~~ 7 is here

With 9 evolution, the model parameters approached their optimal values, and the simulated hydrograph with optimized parameters fits the observed flood event well as shown in Fig ~~6~~7(d), this means the PSO algorithm has good performance for Liuxihe model parameter optimization.

From the result of Fig ~~6~~7(a), it has been found that the initial value of soil p~~r~~orosity~~perty~~ coefficient is quite different from its optimized value, but with the optimization of PSO algorithm, its optimized value is obtained, this implies that the PSO algorithm has good convergence even the initial values is far from its optimal one, and well suits Liuxihe model parameter optimization. From these resutls, it also found that Liuxihe model well suits the flood simulation of urbanized watershed, and could relate its parameters with the LUCs, and the parameters could be optimized with the initial values.

4.2 Flood simulation for parameter dynamics and dynamic updating

1. Flood simulation with Parameter-20080625-2008

Using the above optimized parameter-20080625-2008, simulations were conducted for the remaining 12 flood events. Notably, in this simulation, the LUCs data for the year

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2018 was employed consistently across all 12 flood events. This approach assumes that the parameters remain constant throughout the watershed's urbanization process, indicating that the model parameters are not dynamically updated in response to changing LUC conditions.~~With the above optimized Parameter 20080625 2008, the other 12 flood events were simulated, while in this sumulation, the LUCs in 2018 are used for all the 12 flood events, that means the parameters are regarded not changed during the watereshed urbanization, and the model parameters are not updated dynamically with the LUC changing.~~ Four evaluation indices, including Nash-Sutcliffe coefficient, mean relative error, peak flow error and peak flow timing error, has been calculated and listed in Table 4, the simulated hydrographs are shown in Fig. ~~7~~8.

Table 4 is here

Fig. ~~7~~ 8 is here

From the results shown in Table 4 and Fig. ~~7~~8, it has been found that for all the 12 flood events, the simulated hydrographs are similar with the observations in shape. In average for all the 12 flood events, the Nash-Sutcliffe coefficient is 0.79, the mean relative error is 63.91%, the peak flow error is 19.47%, while the peak flow timing error is -0.58 hour. From these results, the flood processes of SRW have been simulated ~~reasonabl~~reasonably~~e~~ by Liuxihe model set up in this study.

From the above results, we also find that the four evaluation indices get worse with time goes. For example, the average peak flow error for flood events in 2008 and 2009 is 6.7%, 35.88% in 2011, 17.15% in 2013 and 2014, and 27.87% in 2015, in general, the average peak flow error gets bigger as time goes. For the Nash-Sutcliffe coefficient, those in 2008 and 2009, in 2011, in 2013 and 2014, and in 2015 are 0.835, 0.775, 0.753 and 0.76, a similar trend with peak flow error. Based on these results, it can be proposed that the model parameters should have changed with time going, i.e., with LUCs change~~s~~, ~~and~~ the model parameters need to be adjusted with the changing LUCs. To verify this opinion, the dynamical parameter updating is tested in the follow~~-up sectioning~~ing paragraph.

42.~~3~~ Flood simulation with dynamic updating to parameter-20080625-2008

Based on the dynamic parameter updating method proposed in this study, parameters used for simulating flood events in 2011, in 2013 and 2014, in 2015 are updated with the LUCs in 2011, 2013 and 2015 respectively based on parameter-20080625-2008. The dynamically updated model parameters in 2011, 2013 and 2015 are different from each other, so are from parameter-20080625-2008, which is called parameter-20080625-2008-updated. With these parameters, 8 flood events (parameters for the flood events in 2008 and 2009 are not updated) are simulated again, the four evaluation indices have been calculated and listed in Table 5, the simulated hydrographs are shown in Fig. ~~7~~ 8 also to make comparison with those results simulated with no parameter updating.

Table 5 is here

From the results shown in Fig. ~~7~~ 8 and Tabel 5, it has been found that the model performance has been improved with dynamic parameter updating. For example, for all the 8 flood events, the simulated hydrographs fit those of the observations better than

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those simulated with no parameter updating. The Nash-Sutcliffe coefficients of all the simulated flood events with updated parameters gets higher, except those of flood event no. 20150520 and 20150720. The average Nash-Sutcliffe coefficient increasing is 0.764, a 0.3% increasing. While for the peak flow error, all flood events have observed decreasing, the average decreasing is 66.81%, a very significant model performance impro~~r~~vement.

The above ~~se~~ results imply that with dynamical parameter updating, Liuxihe model has a much better performance in simulating the flood events of SRW, i.e., model parameters are in dynamic changing with ~~the~~ LUC changing, and dynamical parameter updating with the LUC changing is needed. This confirms the parameter dynamics assumption proposed in this study, and prove that the parameter updating method proposed in this study is effective. ~~characteristics of model parameters.~~

~~5 Discussions~~

~~5~~4.~~1~~3 Effect of parameter optimization on model performance

To assess the efficacy of parameter optimization, simulations for the 12 flood events were conducted using the initial parameters, and the corresponding results are presented in Fig. 9. For comparative purposes, hydrographs obtained through simulations with dynamic parameter updating are also included. ~~To test the effectiveness of parameter optimization, the 12 flood events are simulated with the initial parameters, and the results are shown in Fig 8, to make comparision, the simulated hydrographs with dynamically updated parameters are also shown.~~ From the results, it could be found that the simulation results with initial and dynamic parameter updating ~~dynamically updated parameters~~ are quite different. Though both the simulated hydrographs have similar patterns, but the flows simulated with the initial parameters are generally much lower than the observations, and those simulated with dynamic parameter updating the dynamically updated parameters well fit the observation well.

Fig. 8 9 is here

The four evaluation indices of the 12 flood events is calculated and listed in Table 6. Compared with the simulation with initial parameter, the simulation with dynamic parameter updating dynamically updated parameters has been improved much based on these evaluation indices. Among them, the average Nash-Sutcliffe coefficient increased 68.2%, correlation coefficient increased 3.2%, peak flow error reduced 86.4%, water balance coefficient increased 45.8%. These results show that parameter optimization is needed and feasible even for distributed hydrological model.

Table 6 is here

54.2 4 Flood simulation for Pparameter stationary

In above sections, the dynamic parameter updating was based on the optimized parameter look-up tables with LUCs in 20182008. There appears a question, should the look-up tables be optimized with the latest LUCs, not the LUCs at a specific time? I.e., is are the look-up tables no-stationary to LUCs during urbanization. If yes, then the look-up tables needss to be optimized with the latest LUCs, and done again when there is significant LUCs change. Otherwise, the look-up tables can be optimized with LUCs at any given time, alleviating the need for frequent re-optimizationtime, and there is no need to optimize it very often. To answer this question, in this study, the parameters were optimized with LUCs in 2011, 2013 and 2015~~ also~~, and the hydrological data used for parameter optimization were from flood events 20110516, 20130815 and 20150520 respectively. T~~, t~~hese parameters are called parameter-20110516-2011, parameter-20130815-2013, and parameter-20150520-2015 respectively. Then the parameters are dynamically updated with latest LUCs, and are called parameter-20110516-2011-updated and parameter-20130815-2013-updated respectively. Notable, there is not parameter-20150520-2015-updated. In other words, dynamic parameter updating process in a forward temporal manner and not backward~~I. e., dynamical parameter updating is time forward, not time backward~~. For example, parameter-20110516-2011-updated only update parameters with LUCs in 2013 and 2015, not in 2008 and 2011; parameter-20130815-2013-updated only update parameters with LUCs in 2015, not in 2008, 2011 and 2013, so there is not parameter-20150520-2015-updated. The dynamically optimized and updated parameters are then employed to simulate the flood events, and the results are shown in Fig. ~~9~~10. The four evaluation indices are calculated and listed in table 7.

Table 7 is here

Fig. ~~9~~ 10 is here

The simulated flood hydrographs, both with and without dynamic parameter optimization and updating, exhibit no significant differences. Drawing from the methods and results presented above, it can be concluded that the parameters demonstrate LUC stationarity during urbanization progress.~~Both the simulated flood hydrographs with and without dynamic parameters optimizing and updating have no obvious differences, so based on the above methods and results, it can be concluded~~

that the parameters are stationary during the urbanization, i.e., during the LUC changing period. There is no need to optimize the look-up tables frequentlyvery often with rapid LUC changing. Instead, the focus should be on optimizing and updating of parameters, which emerges as the crucial aspect in response to dynamic LUCs conditions., parameter optimization and updating is most important.

54.3 5 Impact of LUC changes on flood responses

Based on the above results, it could be found that with due to the LUCs changes, the flood response changes also. To quantitatively analysis this effect, the peak flow and urban land area rate of flood events from 2011 to 2015 are extracted from the above results and listed in Table 8. The values with no-update are the simulated values with parameter-20080625-2008, while the ones with update are the simulated values with parameter-20080625-2008-update.

Table 8 is here

From the results, it could be found that from 2008 to 2011, the SRW observed an urban land rate change from 18.62% to 23.4%, a 25.67% increasing. For flood event 20110516, with the same precipitation, the peak flow will change from 87.08 m^3/s to 99.42 m^3/s, having with a 14.2% increasing. While for flood event 201100808, the peak flow changinge is from 103.68 m^3/s to 117.21 m^3/s, having a 13.1% increasing. Both these events are light flood, the peak flow increasing has similar magnitude.

But from 2008 to 2013, the SRW observed an urban land rate increasing of 40.92%. For flood event 20130815, which is regarded as a heavy flood event, the peak flow increasing is 9.0%, while for flood event 20140511, the peak flow increasing is 12.8%, for flood event 20140819, this is 14.6%. The latter two flood events are regarded as medium. With these results, it can be concluded that the much heavier of the flood magnitude, the ~~more~~ less increasing of peak flow.

From 2008 to 2015, the SRW observed an urban land rate increasing of 63.10%. For flood event 20150520, which is regarded as a light flood event, and flood events 20150523 and 20150720, which are regarded as a medium flood event, the peak flow increasing are 56.3%, 18.5%, and 12.2% respectively. This implies that for the light flood event, the peak flow increases much more. Based on this analysis, with the increasing of the urban land area rate, the peak flow of a flood event will increase, and the light flood event has the most peak flow increasing, while the heavy one has the least peak flow increasing.

~~6~~ 5 Conclusions

In this study, a method is proposed for accurately simulating flood processes of urbanizing watersheds that appear during the world urbanization process, which employs the Liuxihe model, a physically based distributed hydrological model as the flood simulation tool. This method first derives initial parameter look-up tables, and then optimizes ~~it~~them, and dynamically updates the parameters with the changing LUCs to improve the model performance. A case study has been carried out in the Songmushan Reservoir Watershed, a highly urbanizing watershed in the Pearl River Delta Area in southern China which experienced rapid urbanization in the past decade. Based on the results, following conclusions have been proposed.

1. The methodology proposed in this study could be used for simulating and forecasting urbanizing watershed flood processes with good model performance.

2. For an urbanizing watershed, terrain properties are in changing, and model parameters are in changing also due to terrain properties changing, this is called model parameter dynamics. Model parameters should be updated with the LUC changes.

3. Parameter look-up tables of physically ~~-~~based distributed hydrological model ~~is~~ are LUCs stationary, i.e., the parameter look-up tables only need~~s~~ to be determined once during the watershed urbanization.

4. With same precipitation, flood peak flow will increase due to urban land rate increases. The much heavier the precipitation, the less increasing of the peak flow.

5. This study provides more evidence to prove that ~~P~~parameter optimization is effective and needed in controlling parameter uncertainty for physically based distributed hydrological model.

Competing interests: The contact author has declared that none of the authors has any competing interests.