Reply to Reviewers' comments (Reviewer#2)

This paper integrates the runoff generation and flow routing principles of the Xinanjiang model into a recurrent neural network framework, proposing the XAJRNN layer and constructing an EDL model. This approach enhances the physical interpretability of deep learning-based flood forecasting. Using the Lushui River and Qingjiang River basins as case studies, the EDL model is compared with benchmark models, demonstrating superior performance in flood simulation. The study is well-structured, data-driven, and methodologically rigorous, offering a novel perspective and valuable tool for explainable deep learning in hydrology. However, improvements in clarity, graphical details, and language are needed.

Response: We thank the reviewer for his/her time in reviewing our manuscript and providing comprehensive suggestions for further improvements. Below is our detailed response to the reviewers' comments and suggestions.

(1) Line 128: Please provide additional explanation on why the runoff generation and flow routing principles of the Xinanjiang model were chosen to construct an explainable deep learning model, specifically elaborating on its advantages and applicability.

Response: Thank you for providing this comprehensive review. We chose the runoff generation and flow routing principles of the Xinanjiang (XAJ) model as the foundation for constructing an explainable deep learning model based on the following considerations. First, the XAJ model has demonstrated excellent performance in hydrological simulation and forecasting across various watersheds. Its hydrological principles have been extensively validated over time, ensuring high reliability and maturity. Second, our study area is located in the Yangtze River Basin, which falls within a typical humid and semi-humid climate zone. The XAJ model's saturation excess runoff mechanism effectively captures the nonlinear runoff response under such climatic conditions. This mechanism is particularly suitable for depicting the runoff response of our study area under varying rainfall intensities, thereby providing a solid theoretical foundation for both the interpretability and accuracy of our model.

(2) Line 131: Please further explain the rationale for using LSTM neural network layers to construct the model, highlighting its superiority.

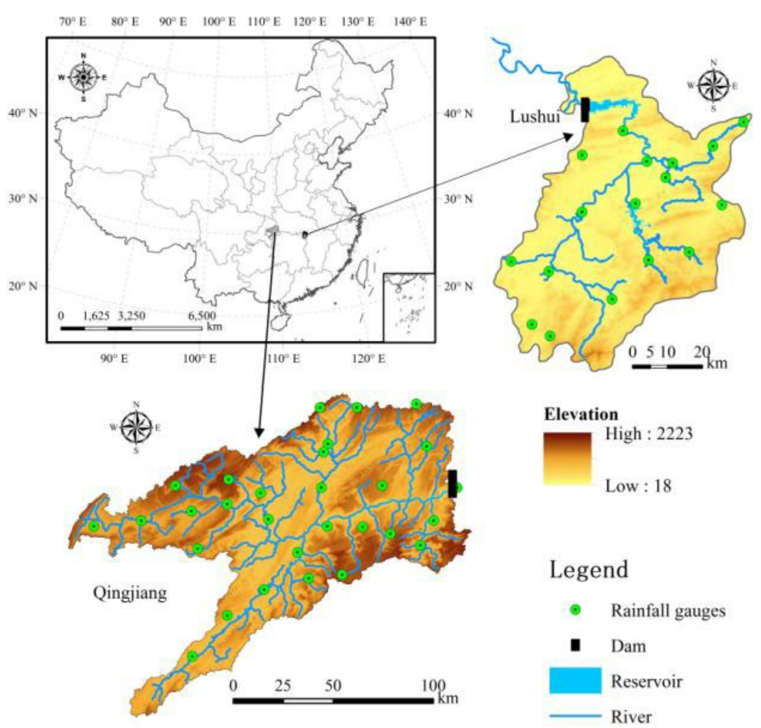
Response: Thank you very much for the notice. We chose LSTM as a component of the explainable deep learning model primarily based on two considerations. First, LSTM's memory units can store hydrological information over long periods, enabling it to effectively model the temporal dependencies in the rainfall-runoff process and enhance flood prediction accuracy. Second, flood evolution involves multiple dynamic processes, including precipitation, evapotranspiration, surface runoff, and groundwater recharge. LSTM can adaptively learn the nonlinear relationships among these variables.

(3) Lines 154-166: To enhance the completeness of the research background, it is recommended that information on the magnitude and frequency of historical floods in the study area be supplemented.

Response: Thank you very much for the notice. We agree with your viewpoint, and we will add information on the magnitude and frequency of historical floods in the background section of the study area. For example, the Qingjiang River Basin experienced major floods in 2016 and 2017, with peak inflow discharge into the Shuibuya Reservoir reaching 13,100 m^3/s and 6,710 m^3/s, respectively.

(4) Line 168: Please adjust the scale of the river curves in Figure 1 to improve the aesthetic quality and clarity of the illustration.

Response: Thank you very much for the notice. We revise the scale of the river curves in Figure 1 to improve the aesthetic quality and clarity. As shown below.



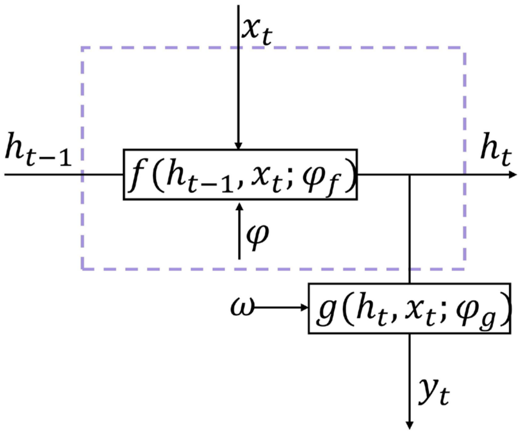
(5) Line 224: The author mentions "a similar structure"; please specify in which aspects this similarity is reflected to improve clarity.

Response: Thank you very much for your suggestion. In our manuscript, we mention "a similar structure", which is primarily reflected in the composition of Equations (2) and (3). Both equations consist of two parts: an ordinary differential equation and an output equation, and they share a highly similar structure. Specifically, in the ordinary differential equation part, both equations include the state variable from the previous time step (h(t-1)), the state variable at the current time step (h(t)), the input (x), and the parameters ((φ, W, b)). In the output equation part, both equations rely on the current state variable (h(t)), the output (y), and the same set of parameters ((φ, W, b)).

(6) Equations (1) and (2) and Figure 3 (b): The parameter symbols in the equations do not match those used in Figure 3 (b). Please carefully verify and ensure consistency.

Response: Thank you very much for your suggestion. We have reviewed the manuscript and found a minor error. We revise the parameter symbols in Figure 3(b) to ensure consistency with Equations (1) and (2). As shown below.

$$\begin{cases} h(t) = f(h(t-1), x(t); \varphi_f) \\ y(t) = g(h(t), x(t); \varphi_g) \end{cases} \quad (2)$$



(7) Lines 258-260: The XAJRNN layer outputs four physical variables of interest. Please explain why these four variables were selected as outputs instead of others.

Response: Thank you very much for your suggestion. We chose actual evapotranspiration (E_t), areal mean free water storage (S_0), areal mean tension water storage (W), and outflow discharge (Q) as the output variables of the XAJRNN layer, primarily based on their high hydrological relevance to flood forecasting. Actual evapotranspiration (E_t) is a key component of the hydrological cycle, directly affecting water availability and being crucial for runoff processes and flood simulation. Areal mean free water storage (S_0) and tension water storage (W) represent the states of free water and water under tension in the watershed, reflecting the watershed's storage capacity, which in turn influences flood occurrence and intensity. Outflow discharge (Q), as the direct output of the basin system, is a core indicator for flood simulating and can directly reflect downstream flood risk. The selection of these variables fully considers their physical significance and practical application value in flood simulation.

(8) Lines 274-280: The paper mentions that a genetic algorithm was used to optimize the parameters of the Xinanjiang model. Please provide the obtained optimal parameter values and include them in the relevant section.

Response: Thank you very much for your suggestion. Below are the calibrated parameter values of the Xinanjiang model.

Parameter	Value range	Lushui River basin	Qingjiang River basin
K_c	[0.6,1.5]	0.95	0.85
c	[0.01,0.2]	0.18	0.19
W_{um}	[5,30]	28.75	23.15
W_{lm}	[60,90]	84.36	64.47
W_{dm}	[15,60]	23.19	15.60
A_{imp}	[0.01,0.2]	0.02	0.01
b	[0.1,0.4]	0.40	0.35
S_m	[10,50]	49.97	39.86
ex	[1,1.5]	1.08	1.06
K_i	[0.1,0.55]	0.19	0.37
K_g	[0.7-K_i]	0.51	0.33
c_i	[0.1,0.9]	0.87	0.89
c_g	[0.9,0.988]	0.98	0.97
K_f	[0.1,10]	3.99	1.58

(9) Figure 8 (d): The simulation performance of the EDL and the benchmark models appears to be poor. Please analyze the potential reasons for this issue.

Response: Thank you very much for your suggestion. By analyzing the simulation performance of the EDL model and the benchmark model in Figure 8(d), we identified two major influencing factors: First, the location of the heavy rainfall center has a significant impact on the simulation results. Since the model input uses areal average rainfall, it fails to fully account for the spatial distribution characteristics of rainfall. As shown in Figure 8(d), when the heavy rainfall center is close to the Shuibuya Reservoir, the shortened routing time leads to a significant decline in the model's simulation performance. Second, the impact of upstream reservoir regulation cannot be ignored. During multiple flood events in the Qingjiang River Basin in 2020, the upstream reservoirs of Shuibuya increased their outflow to cope with the severe flood control situation. Combined with the effects of rainfall, this further reduced the model's simulation accuracy.

(10) Language expression: Some parts of the paper contain repetitive phrasing. It is recommended to refine the text to improve fluency and conciseness.

Response: Thank you very much for your suggestion. We will carefully review and refine the language in the manuscript.

(11) Reference formatting: Please carefully check the reference formatting to ensure compliance with the journal's requirements, including the correct spelling of author names, publication year format, DOI, and page ranges.

Response: Thank you very much for your suggestion. We will carefully check the reference format in the manuscript according to the journal's requirements, including names, spelling, and publication years.