

Dear Editor and Reviewers,

We sincerely thank you for the time and effort you have devoted to reviewing our manuscript, as well as for the constructive comments and suggestions, which have been invaluable in guiding a major revision of this work. In response to the concerns raised, we have carefully reconsidered all comments and have undertaken a substantial and comprehensive revision, in which both the structure and the content of the manuscript have been extensively reworked rather than simply revised.

These revisions include a reorganization of the manuscript framework, clearer presentation of the methodology, and strengthened interpretation of the results, with the aim of improving the overall clarity, rigor, and logical consistency of the study.

In the following, we provide a detailed, point-by-point response to each comment, where the reviewers' comments are presented in italics and our responses are given below each comment.

*Comment 1: The consistent use of relative water level changes (defined as end-to-start level difference divided by initial level?) represents a methodological flaw. Since water levels are inherently relative to a datum plane, this secondary relativization lacks physical meaning and should be replaced with absolute variations.*

We thank the reviewer for the careful reading and the important comment. We understand the concern that the use of relative water-level changes may lack clear physical meaning. Upon re-examination, we consider that this issue mainly arises from insufficient clarity in the original description, which may have led to a misunderstanding of the variable definitions.

In the revised manuscript, the data sources and processing procedures have been explicitly clarified. It should be emphasized that the analysis of water levels at Hukou is based on the absolute variations in observed water levels, and that all discussions regarding hydrological regime shifts, water-level responses, and river-lake interactions are grounded in the original water-level records, without any further transformation into relative water-level variables. Therefore, the conclusions presented in this study retain clear physical interpretability. With respect to the references to "relative change" in the original manuscript, these have been revised and clarified. Specifically, relative change rates are applied only to the discharge series for the purpose of detecting abrupt variations and identifying hydrological events, where they serve as an auxiliary criterion to better capture the rapid changes in flow associated with backflow events. During the event identification process, both water-level trends and the absolute and relative variations in discharge are jointly considered, in order to improve the robustness of the classification. It is important to note that this relative metric is used solely for event identification and is not involved in the analysis of water-level processes or in the interpretation of physical mechanisms.

In addition, further clarification has been added regarding the sources and physical meaning of water-level data from both Hukou and Jiujiang stations, where it is emphasized that all water-level records are referenced to a consistent elevation datum, thereby ensuring comparability between stations and strengthening the physical basis for hydrodynamic interpretation.

Through these revisions, potential ambiguity associated with the expression of “relative water-level changes” has been eliminated, and the clarity of variable definitions and their physical meaning has been further improved. We again thank the reviewer for this helpful comment. The corresponding revisions can be found in Lines 118–146:

## 2.2 Data Sources and Processing

Hukou Station, which serves as the only outflow control section of Poyang Lake, provides an integrated representation of the combined effects of basin inflow and backwater influence from the Yangtze River, and therefore constitutes a key control point for analyzing the evolution of hydrological conditions in the lake and the mechanisms of river–lake interactions. This study is based on observed water level and discharge data collected at Hukou Hydrological Station.

Given that a pronounced regime shift in regional hydrological processes occurred around 2003, this year is selected as the dividing point, and the study period is divided into two stages, including the pre-operation period from 1970 to 2002 and the post-operation period from 2003 to 2022. On this basis, the variations in water level and discharge at the Hukou section are compared between the two periods in order to investigate the evolution of hydrological conditions in Poyang Lake and the associated river–lake relationships under the influence of the Three Gorges Project.

To represent upstream inflow conditions of the Yangtze River, water level data from Jiujiang Hydrological Station are also incorporated. Since the Yangtze River channel is wide and exhibits complex morphology with varying bed elevations along different reaches, observations from stations located far from Hukou may be strongly influenced by local channel geometry and may therefore fail to accurately reflect the backwater effect of the Yangtze River at Hukou. Jiujiang Station is located approximately 19 km upstream of the confluence between the lake and the river and is not directly affected by lake outflow, which enables it to provide hydrodynamic conditions of the Yangtze River that are representative of the Hukou section.

To quantify the hydrodynamic mechanisms, the SWAT model is employed to simulate hydrological processes in the Poyang Lake basin. The input data required for model simulation include daily precipitation, daily maximum and minimum temperature, daily relative humidity, daily average wind speed, monthly evapotranspiration, monthly precipitation, land use data, soil hydrological groups, a digital elevation model, biophysical parameters, and rainfall event data. During data preprocessing, land use is classified into six categories, including cropland, forest land, grassland, urban areas, and wetland types. Detailed information on the data sources is provided in Table 1, while

daily meteorological data are obtained from 23 meteorological stations within the Poyang Lake basin, as listed in Table 2.

**Table 1 Data sources**

Raster Data	References	Data scale	Time
Hukou water level and discharge	Hukou Hydrological Station	Daily	1970-2020
Jiujiang water level	Jiujiang Hydrological Station	Daily	1970-1986/2005-2020
Waizhou, Meigang, Lijiadu, Dufengkeng, and Wanjiabu discharge	Hydrological Station	Daily and monthly	1970-1986/2005-2020
Digital Elevation Model	www.data.tpsc.ac.cn	annual	1990/2010
Landuse	www.resdc.cn	annual	1990/2010
Soil Hydrologic Group	www.data.tpsc.ac.cn	annual	1990/2010
Daily meteorological data	weather stations (www.data.cma.cn)	daily	1970-2020

**Table 2 Weather Stations**

Meteorological station	Longitude	Latitude	Meteorological station	Longitude	Latitude
Boyang	29.01	116.4	Lianhua	27.08	113.56
Dexing	28.51	117.34	Lushan	29.35	115.59
Ganxian	22.5	114.5	Nanchang	28.4	115.58
Guangchang	26.48	116.11	Nancheng	27.33	116.36
Guixi	28.17	117.06	Nanfeng	27.12	116.23
Ji'an	27.05	114.55	Nanlong	24.53	114.46
Jiang'an	28.51	115.22	Ningdu	26.22	115.5
Yifeng	28.25	114.47	Shangrao	28.27	117.59
Yongfeng	27.21	115.25	Wuning	29.16	115.06
Yushan	28.4	118.15	Xiuhui	29.02	114.34
Zhangshu	28.05	115.31	Xunwu	24.57	115.29
Yichun	27.48	114.23			

*Comment 2: The application of data-driven LightGBM model to characterize outflow-inflow relationships under normalflow events exhibits some limitations. The exclusion of critical influencing factors (e.g., mainstream-tributary water levels) compromises the model's*

*representation of river-lake system regulation. The training dataset's restriction to normalflow events raises concerns about generalizability to nonlinear scenarios (flood, drought, backflow events), evidenced by poor flood flow predictions in Figure 3.*

We thank the reviewer for the insightful comments regarding the model applicability and variable selection. We understand the concern that the LightGBM model may omit key hydrodynamic variables and may have limited generalization ability under nonlinear extreme conditions.

In the revised manuscript, the purpose and scope of the model have been further clarified. It should be emphasized that this study does not aim to develop a universal predictive model applicable to all hydrological conditions. Instead, training data are deliberately selected from normal-flow events, during which hydrodynamic conditions are relatively stable and the influence of mainstream backwater is weak, so that a response relationship at Hukou can be established that is primarily driven by basin inflow under conditions of limited mainstream interference. This relationship is then used as a reference baseline to represent the natural response of the lake system in the absence of strong mainstream forcing.

Consistent with this objective, variables that directly reflect mainstream hydrodynamic effects, such as mainstream water levels, are intentionally excluded from the model inputs. This simplification is introduced to prevent the model from implicitly learning backwater effects, thereby ensuring that the simulated discharge represents a quasi-natural outflow response. Subsequently, inflow from the five tributaries under different hydrological scenarios is input into the model to reconstruct the corresponding theoretical discharge, which is then compared with observed discharge at Hukou, so that the systematic deviation between the two can be interpreted as the influence of mainstream hydrodynamic processes.

With regard to the relatively lower model performance in the high-flow range, this issue has also been clarified in the revised manuscript. It mainly arises from the fact that extreme conditions are intentionally excluded from the training dataset, which inevitably limits the model's extrapolation capability in high-flow regimes. However, the focus of this study is not on the precise prediction of extreme discharge values, but rather on identifying the relative response characteristics of the system under different hydrological conditions and their underlying driving mechanisms. Moreover, the model demonstrates high accuracy under baseline conditions, with NSE values of approximately 0.94 and PBIAS close to zero, and the deviations identified in typical events exhibit consistent directional behavior and physical plausibility, which supports its suitability for subsequent attribution analysis.

In the revised manuscript, the applicability of the model has been more clearly defined in the Methods section, and additional discussion on extrapolation uncertainty has been included, where it is emphasized that such uncertainty may affect the magnitude of quantitative estimates but does not alter the main conclusions regarding the mechanisms of river-lake interactions.

We again thank the reviewer for raising this important point, which has helped us to more clearly define the physical meaning and application boundaries of the model. The corresponding revisions can be found in Lines 169–209 and 489–512:

## 2.4 Basin Inflow Simulation and Quantification of Influencing Factors

To establish a unified reference for analyzing hydrological processes in the lake and to separate the effects of basin inflow from those of mainstream hydrodynamics, a sequential modeling framework is constructed, which consists of a Hukou discharge response model and a basin inflow simulation model.

### (1) Hukou Discharge Response Model

In order to characterize the natural response of the lake system to basin inflow under conditions of weak mainstream influence, a Hukou discharge response model is developed using the LightGBM machine learning approach. Training data are selected from normal-flow hydrological conditions during which hydrodynamic conditions are relatively stable, the influence of the Yangtze River mainstream is weak, and no backflow occurs. Based on daily observations of inflow from the five tributaries and outflow at Hukou, a mapping relationship is established in which discharge at Hukou is controlled solely by basin inflow.

The model is trained and tested using a time series split in which 80% of the data are used for training and 20% for testing. Model performance is optimized by adjusting the number of trees, learning rate, and sampling parameters, while early stopping is introduced to prevent overfitting. In addition, segmented modeling is conducted using 2003 as a breakpoint in order to capture stage-dependent variations in the discharge response relationship. Model performance is evaluated using percentage bias (PBIAS), root mean square error (RMSE), and Nash–Sutcliffe efficiency (NSE).

After model validation, two types of applications are conducted. First, observed inflow from the five tributaries during backflow events is used as model input to reconstruct the discharge process at Hukou under the assumption of no strong mainstream influence, and the reconstructed discharge is compared with observed discharge in order to quantify the contribution of backflow effects. Second, basin inflow under different scenarios is input into the model to reconstruct discharge at Hukou under a unified reference condition, which enables comparison of hydrological processes across different scenarios.

### (2) Basin Inflow Simulation Using SWAT

To quantitatively attribute the mechanisms through which basin hydrological changes influence discharge at Hukou, the SWAT model is used to generate basin inflow series under multiple scenarios, which allows assessment of how variations in basin runoff regulate hydrodynamic responses at Hukou. During model calibration and sensitivity analysis, key parameters are selected and optimized, including those at the basin scale, HRU scale, soil properties,

groundwater processes, and channel characteristics. Model parameters are iteratively adjusted to ensure good agreement between simulated and observed discharge.

Since the period from 1990 to 2010 represents the most significant stage of land use change in the Poyang Lake basin, while changes become relatively stable after 2010, the years 1990 and 2010 are selected as representative scenarios for comparison. After calibration, meteorological and land use data under different scenarios are input into the model to simulate basin inflow processes, which serve as the basis for discharge simulation at Hukou.

It should be noted that SWAT produces monthly runoff series for the five tributaries, whereas the Hukou discharge response model is constructed at a daily scale. To ensure consistency between the two models, monthly runoff is uniformly distributed according to the number of days in each month under the constraint of mass conservation, thereby converting it into daily inflow series for use as model input. Although this approach may smooth short-term fluctuations at the daily scale, the primary objective of this study is to analyse relative changes and stage-dependent characteristics under different scenarios rather than to reproduce daily extremes, and therefore the impact of this temporal transformation on the results is limited.

489-512:

#### 4.3 Limitations and Implications for Future Management

This study develops an integrated analytical framework that combines observational data, machine learning, and hydrological modeling to quantify the evolution of hydrological conditions in Poyang Lake under the influence of the Three Gorges Project. The approach can be regarded as an observation-driven counterfactual framework, in which a reference condition without mainstream interference is constructed to quantify deviations in the actual system, thereby indirectly identifying the influence of mainstream hydrodynamics. Based on this framework, a set of evaluation indicators is established to systematically analyze lake regulation mechanisms under different hydrological conditions from the perspectives of basin inflow and mainstream constraints. The discharge response model constructed under normal-flow conditions shows high accuracy under baseline conditions, and the deviations identified in typical events exhibit consistent directionality and physical plausibility, which indicates that the method is capable of capturing system responses and provides a feasible approach for mechanism identification under complex river-lake interaction conditions where high-resolution hydrodynamic boundary data are unavailable.

Despite these advantages, several sources of uncertainty should be acknowledged. First, basin inflow simulation is based on the SWAT model, and differences in simulation accuracy among tributaries may introduce uncertainty in the magnitude of inflow. However, since this study focuses on relative changes and stage-dependent characteristics,

the influence of this uncertainty on the overall conclusions is limited. Second, the discharge response model is constructed based on normal-flow conditions, and its application to backflow and low-flow events may introduce some extrapolation error. Nevertheless, the model shows high accuracy under baseline conditions, and the identified deviations exhibit consistent directional behavior in typical events, which suggests that the results primarily reflect systematic responses rather than random error. In terms of attribution, the counterfactual framework identifies the influence of mainstream hydrodynamics through systematic deviations between theoretical and observed discharge, which provides a degree of robustness against random uncertainty. Although these uncertainties may affect specific numerical estimates, they have limited influence on the qualitative conclusions regarding the restructuring of hydrological regimes and their driving mechanisms.

*Comment 3: Methodological issues in the SWAT simulation require clarification. The handling of temporal inconsistencies among meteorological, hydrological, and land use datasets remains undocumented. The conversion methodology from monthly river discharge to lake outflow lacks sufficient detail, casting doubt on the quantification of Three Gorges impacts.*

We thank the reviewer for the careful attention to the methodological details. We understand the concern regarding temporal consistency of the data and the runoff conversion process. Upon re-examination, we consider that this issue mainly arises from insufficient description in the original manuscript, which may have led to a misunderstanding of the modeling workflow.

First, with respect to temporal consistency, all meteorological data, basin runoff data, and hydrological observations at Hukou are processed into daily time series, and are subjected to temporal alignment and completeness checks prior to model development, so that consistency across datasets in the time dimension is ensured. Therefore, no direct mixing of data with different temporal resolutions is involved.

Second, it should be clarified that no direct “conversion” from monthly runoff to discharge at Hukou is performed in this study. The SWAT model is used to simulate basin inflow processes under different scenarios, specifically the inflow from the five tributaries, which serves as input to the subsequent discharge response model at Hukou. The discharge at Hukou is not directly estimated by SWAT, but is instead simulated using a LightGBM-based response model. Accordingly, the study adopts a sequential modeling framework, in which basin inflow simulation and lake response modeling are conducted in sequence, rather than a direct runoff transformation approach. The Hukou discharge response model is constructed using daily data and is designed to capture the statistical relationship between inflow and outflow.

During application, the SWAT model provides basin inflow at a monthly scale. In order to ensure consistency of model inputs, the simulated monthly runoff is evenly distributed into daily values under the constraint of monthly water balance conservation, and is then used as input to the response model.

It should be noted that this treatment may, to some extent, smooth short-term variability at the daily scale. However, since the focus of this study is on the relative changes and stage-dependent characteristics of system responses under different scenarios, rather than on the detailed representation of daily extremes, the influence of this temporal disaggregation on the main conclusions is considered to be limited.

In response to this comment, additional clarification on data temporal scales has been incorporated into Section 2.2 of the revised manuscript, and the input–output relationships between the SWAT model and the Hukou discharge response model have been further clarified, so as to avoid potential misunderstanding of the modeling framework.

We again thank the reviewer for the careful review and valuable suggestion. The corresponding revisions can be found in Lines 119–146 and 489–512:

119–146:

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Waizhou, Meigang, Lijiadu, Dufengkeng, and Wanjiabu discharge	Hydrological Station	Daily and monthly	1970-1986/2005-2020
Digital Elevation Model	www.data.tpdc.ac.cn	annual	1990/2010
Landuse	www.resdc.cn	annual	1990/2010
Soil Hydrologic Group	www.data.tpdc.ac.cn	annual	1990/2010
Daily meteorological data	weather stations (www.data.cma.cn)	daily	1970-2020

**Table 2 Weather Stations**

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169-209:

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Since the period from 1990 to 2010 represents the most significant stage of land use change in the Poyang Lake basin, while changes become relatively stable after 2010, the years 1990 and 2010 are selected as representative scenarios for comparison. After calibration, meteorological and land use data under different scenarios are input into the model to simulate basin inflow processes, which serve as the basis for discharge simulation at Hukou.

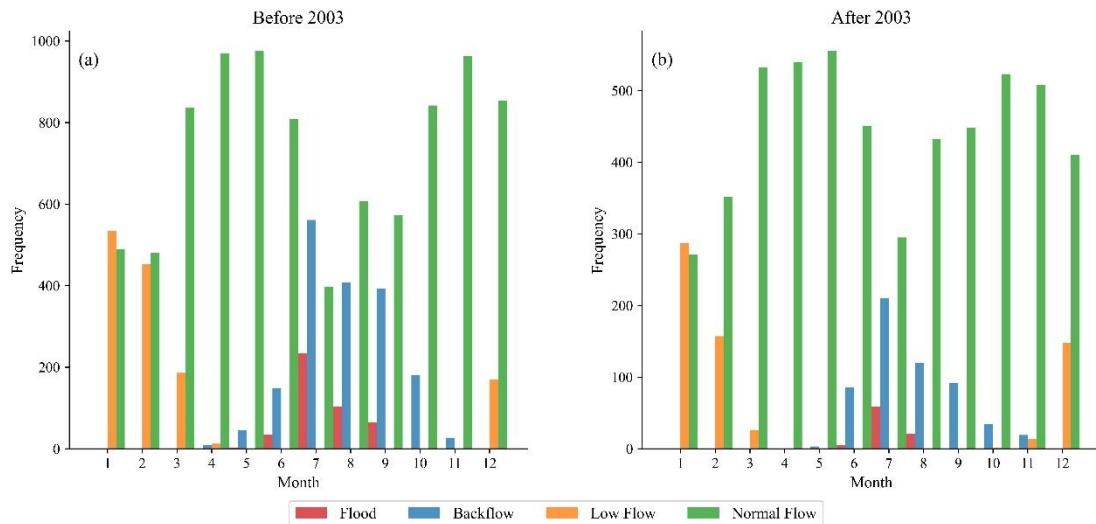
It should be noted that SWAT produces monthly runoff series for the five tributaries, whereas the Hukou discharge response model is constructed at a daily scale. To ensure consistency between the two models, monthly runoff is uniformly distributed according to the number of days in each month under the constraint of mass conservation, thereby converting it into daily inflow series for use as model input. Although this approach may smooth short-term fluctuations at the daily scale, the primary objective of this study is to analyse relative changes and stage-dependent characteristics under different scenarios rather than to reproduce daily extremes, and therefore the impact of this temporal transformation on the results is limited.

*Comment 4:* What do the colored maps in Figure 6 represent? Please note to explain.

We thank the reviewer for the valuable comment. We acknowledge that, in the original manuscript, the physical meaning represented by the color scheme was not sufficiently clarified, which may have increased the difficulty of interpretation.

In the revised manuscript, Figure 6 has been completely redrawn, and the results are now presented in the form of bar charts, through which the statistical characteristics of different hydrological events can be illustrated more clearly and directly. In particular, in response to the difficulty in interpreting the distribution differences of backflow events (previously shown as blue points) across subplots, a classification-based statistical approach has been adopted, by which different hydrological scenarios are compared in a more structured manner, so that the variation patterns of backflow events across scenarios become clearer and more directly comparable.

Through these revisions, the logical structure and readability of Figure 6 have been substantially improved. The corresponding modifications can be found in Lines 273–274.



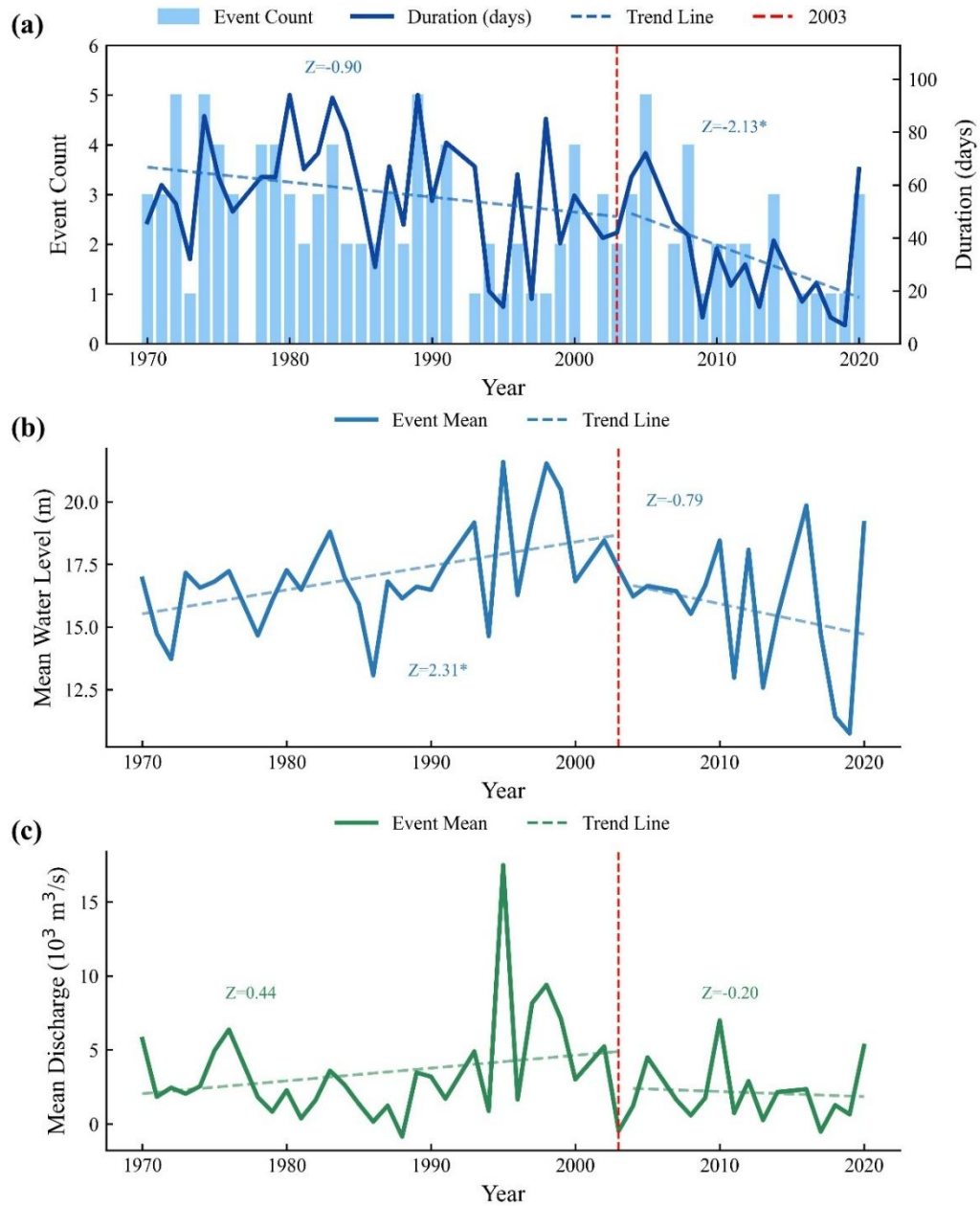
**Figure 4 Intra-annual Distribution Characteristics of Different Hydrological Events**

*Comment 5: Table 1 is incomplete, resulting in unclear meanings of many data.*

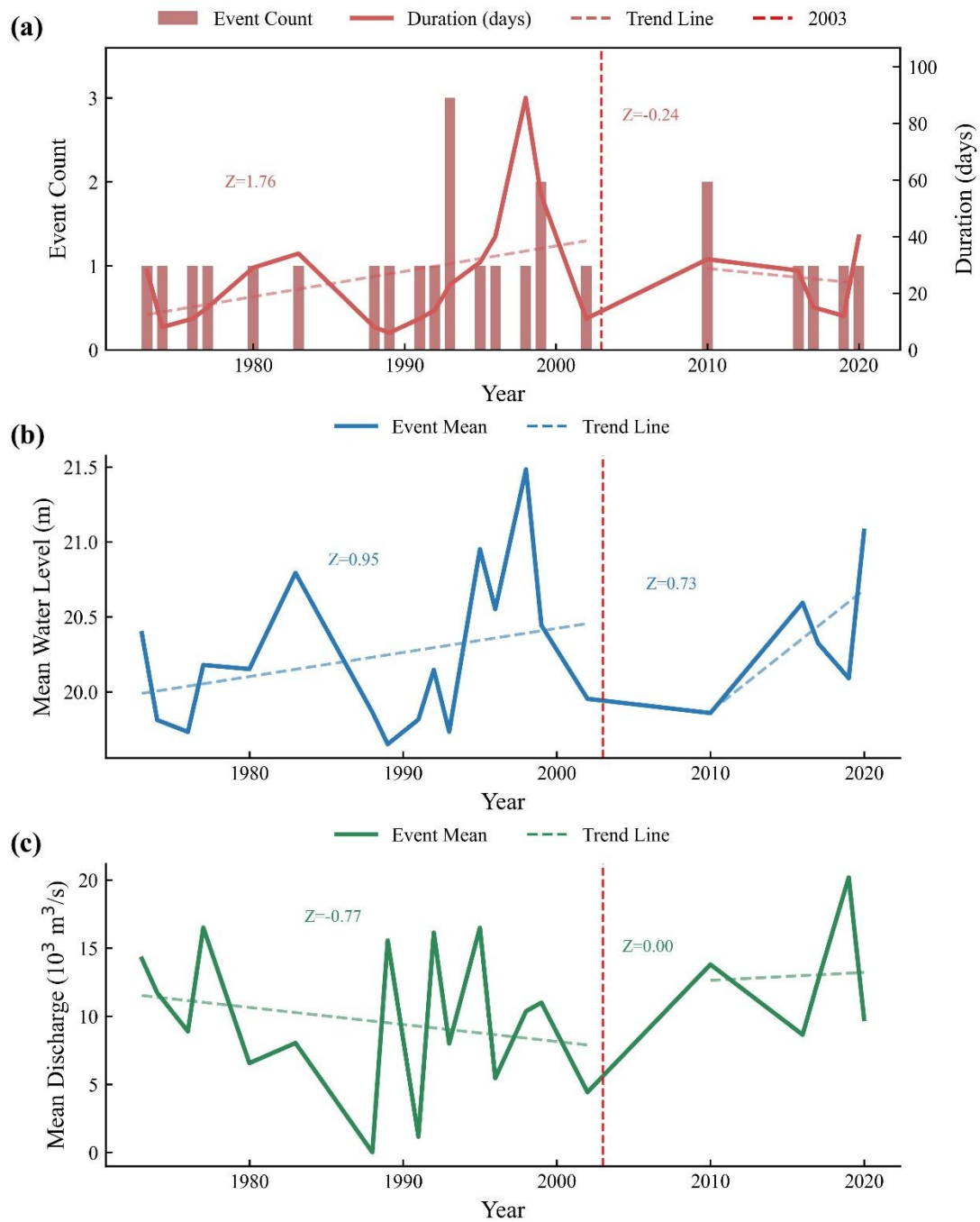
We thank the reviewer for the valuable comment. We agree that the information presented in Table 1 in the original manuscript was incomplete, and that the explanation of certain variables was not sufficiently clear, which affected the readability and interpretability of the results.

In the revised manuscript, Table 1 has been removed and the relevant information has been re-presented in a graphical format. Specifically, newly added figures illustrate the hydrological characteristics of backflow events, including (a) the interannual variation and trends in event frequency and duration, (b) the interannual variation in mean water level, and (c) the interannual variation in mean discharge.

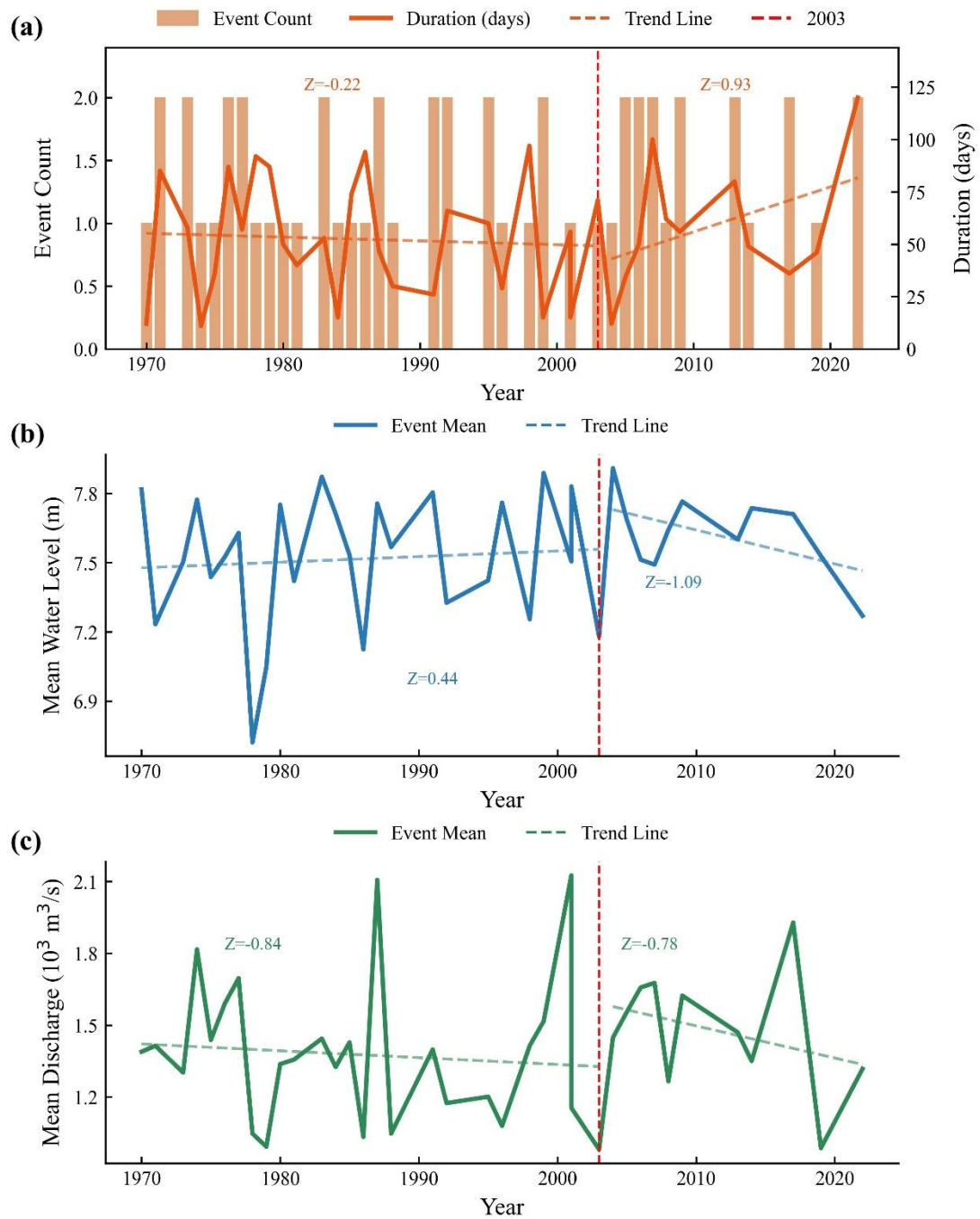
Through these revisions, the presentation of the results has become more complete and clearer, which also facilitates subsequent analysis and discussion. The corresponding modifications can be found in Lines 281–284 and 292–304.



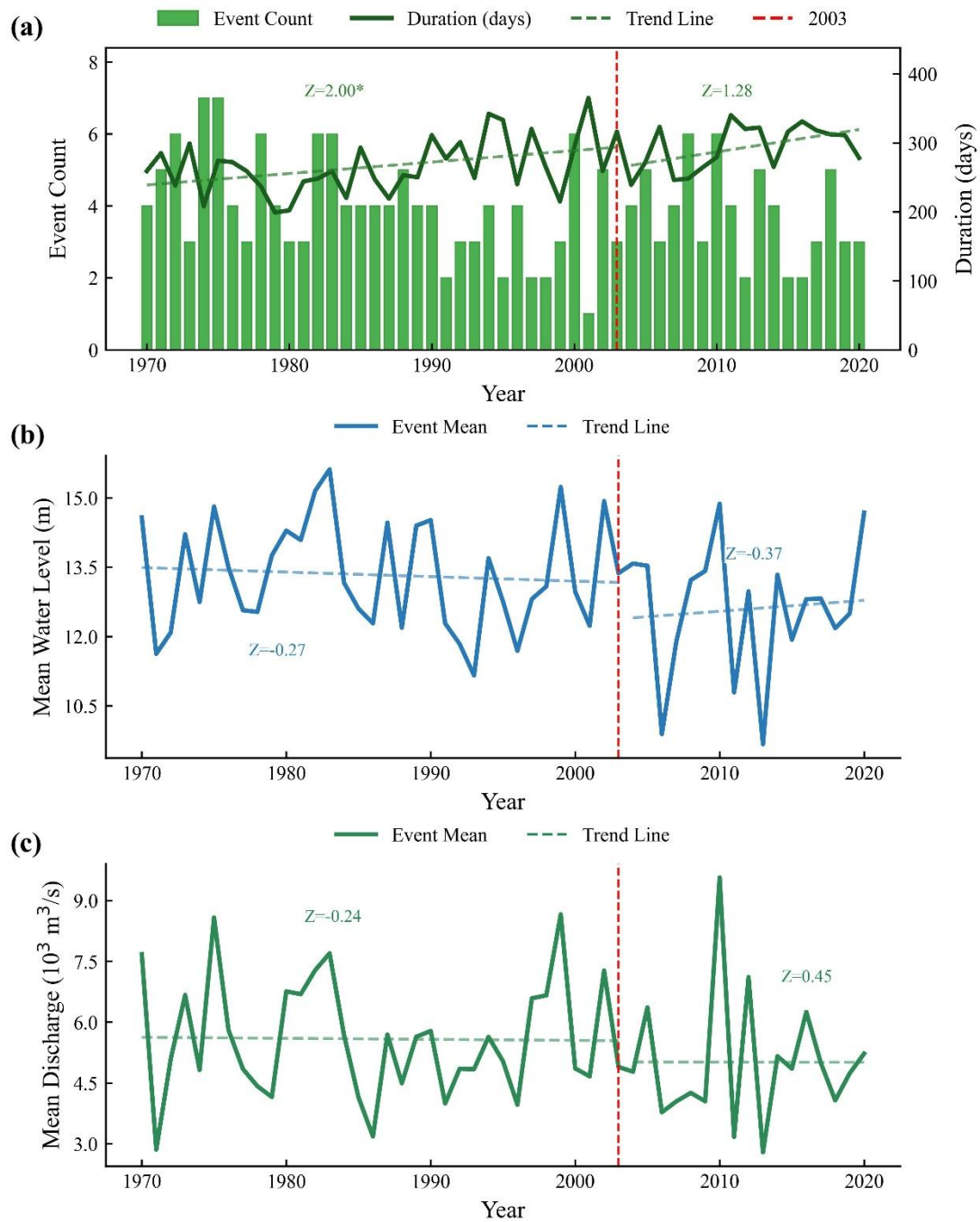
**Figure 5 Hydrological characteristics of backflow events: (a) Interannual variations and trends of event frequency and duration (b) Interannual variation of mean water level (c) Interannual variation of mean discharge**



**Figure 6 Hydrological characteristics of flood events: (a) Interannual variations and trends of event frequency and duration. (b) Interannual variation of mean water level. (c) Interannual variation of mean discharge.**



**Figure 7 Hydrological characteristics of low-flow events: (a) Interannual variations and trends of event frequency and duration (b) Interannual variation of mean water level (c) Interannual variation of mean discharge**



**Figure 8 Hydrological characteristics of normal-flow events: (a) Interannual variations and trends of event frequency and duration (b) Interannual variation of mean water level (c) Interannual variation of mean discharge**

*Comment 6: The author uses the relationship between the water level difference between Jiujiang and Hukou and the flow at Hukou to illustrate the dominant position of the main stream and tributaries in the river-lake hydrological system. There is a lack of a clear physical mechanism behind this. Given the modest correlation coefficients ( $r=-0.24$  or  $0.34$ ), visual evidence (e.g., scatterplots with regression lines) should supplement the statistical analysis.*

We thank the reviewer for this valuable comment. We agree that interpreting river–lake interactions based solely on correlation coefficients is insufficient in terms of physical explanation, and that a more cautious interpretation supported by more intuitive evidence is necessary. In response, several improvements have been made in the revised manuscript.

First, additional visual evidence has been provided. A scatter plot with regression lines showing the relationship between water-level difference ( $\Delta H$ ) and discharge at Hukou has been added (see revised Figure 18), and, when combined with the results of lagged correlation analysis, it allows the relationship and its evolution across different stages to be more directly visualized, thereby improving the interpretability of the statistical analysis.

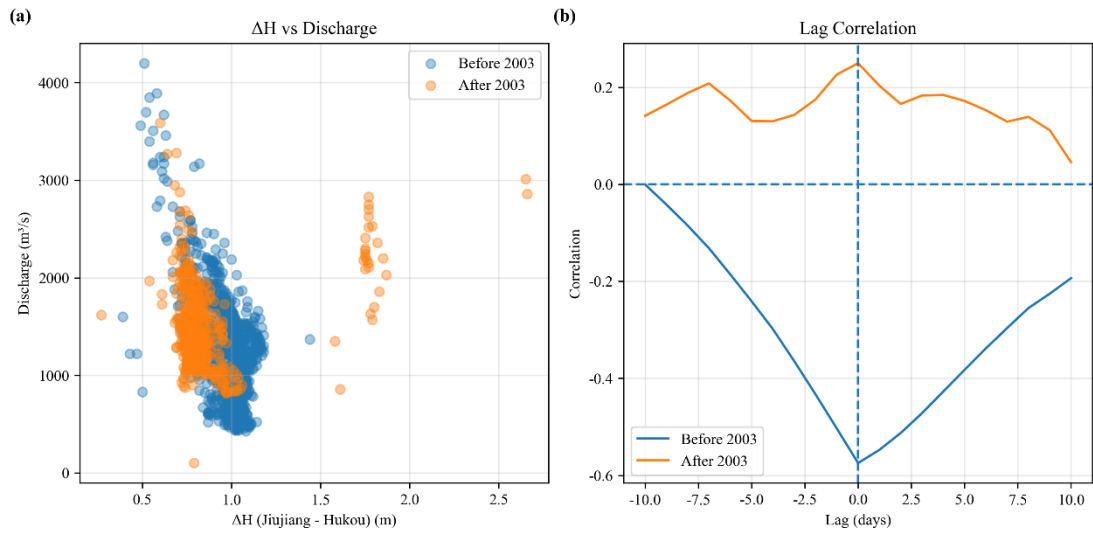
Second, the physical meaning of  $\Delta H$  has been further clarified. The water-level difference, defined as the difference between water levels at Jiujiang and Hukou, is interpreted as an approximate indicator of the hydraulic gradient between the river and the lake, which is used to reflect the potential modulation of discharge at Hukou by mainstream water levels, rather than being used to directly diagnose backflow or to establish a strict causal relationship.

Third, the interpretation of the results has been adjusted. Correlation results are no longer treated as direct evidence of a dominant controlling relationship, but are instead interpreted as statistical response characteristics, with emphasis placed on stage-dependent trends and on the transition in system regulation mechanisms reflected by these trends.

Finally, greater caution has been incorporated into the interpretation. It is explicitly stated in the manuscript that, because  $\Delta H$  and its relationship with discharge are influenced by multiple factors, including channel morphology, hydrodynamic conditions, and local hydrological processes, a certain degree of uncertainty is inherent in this metric, and that it is primarily used to reveal trends and modulation directions rather than to provide a precise representation of physical processes.

Through these revisions, the analysis has been strengthened in terms of both physical consistency and interpretive rigor, thereby improving the overall reliability of the results. We again thank the reviewer for this constructive suggestion. The corresponding revisions can be found in Lines 411–424:

Further analysis introduces the water level difference between Jiujiang Station and Hukou Station, denoted as  $\Delta H$ , to represent the hydraulic gradient between the river and the lake. The results show that  $\Delta H$  is generally negatively correlated with discharge at Hukou in both periods, which indicates that outflow is constrained as  $\Delta H$  increases. However, after 2003, discharge at Hukou is consistently lower under comparable  $\Delta H$  conditions, which suggests that the degree of outflow obstruction is enhanced. Lagged correlation analysis further reveals that before 2003,  $\Delta H$  and discharge at Hukou exhibit a negative correlation near zero lag, which indicates that lake outflow responds rapidly to variations in mainstream water level. After 2003, this relationship weakens and shifts toward a positive correlation, while the lag structure becomes more gradual, which suggests that the response of discharge at Hukou to changes in water level difference has been adjusted and that the constraining effect of mainstream water level on outflow is reduced (Fig. 18).



**Figure 18 Relationship between water level difference ( $\Delta H$ ) and discharge at Hukou and their lagged correlation (a)  $\Delta H$ -discharge relationship at Hukou (b) Lagged correlation between  $\Delta H$  and discharge**