List of Changes

1. Lines 135-174 of pages 7-9. Company names of instruments have been deleted, in response to Comment 3 of Reviewer #2.
2. Lines 167-168 of page 9 and Line 210 of page 11. “rainfall event” have been corrected as “rainfall-runoff event”, in response to Comment 2 and 5 of Reviewer #2.
3. Lines 170-171 of page 9. Simplified definitions of different events types have been added in Table 1, in response to Comment 2 of Reviewer #2.
4. Lines 221-225 of page 12. The method description of event separation has been added, in response to Comment 5 of Reviewer #2.
5. Lines 238-249 of pages 12-13. The definitions of different event types have been improved, in response to Comment 4 of Reviewer #1 and Comment 6 of Reviewer #2.
6. Line 256 of page 14. “t_{1p}” has been labelled in the Figure 2, in response to Comment 7 of Reviewer #2.
7. Line 268 of page 14. “Figure 3” in this sentence has been corrected as “Figure 2”, in response to Comment 5 of Reviewer #1 and Comment 8 of Reviewer #2.
8. Lines 329-332 of page 17. The explanation for the discrepancy between the patterns in Figure 4e and Figures 4f-h has been added, in response to Comment 9 of Reviewer #2.
9. Line 365 of page 20. The quantifier “three” has been deleted, in response to Comment 6 of Reviewer #1.
10. Line 398 of page 22. The explanation about identical response has been corrected, in response to Comment 9 of Reviewer #1.
11. Lines 400-409 of pages 23-24. Figure 6 has been improved, in response to Comment 10 of Reviewer #1 and Comment 10 of Reviewer #2.
12. Line 434 of page 26. “Figure 7c” in this sentence has been deleted, in response to Comment 11 of Reviewer #1 and Comment 11 of Reviewer #2.
13. Lines 479-481 of page 29. Figure 10 has been revised, in response to Comment 12 of Reviewer #2.
14. Lines 508-515 of page 31. The repeated paragraph has been deleted, in response to Comment 14 of Reviewer #1.
15. Lines 530-532 of page 32. More studies mentioning lag time of delayed peak have been supplemented, in response to Comment 13 of Reviewer #2.
16. Lines 805-812 of page 47. Figure A1 has been added in Appendix A, in response to Comment 6 of Reviewer #2.
17. One article has been cited as refs in response to Comment 5 of Reviewer #1, and three articles have been cited as refs in response to Comment 13 of Reviewer #1.

Note: The above changes are indicated using track changes in the marked-up revised manuscript.

Response to Reviewers' Comments

Dear Editor and Reviewers,

Thank you for the reviewers' useful comments and suggestions on our manuscript. We have meticulously read your comments, and modified the manuscript accordingly. The detailed corrections are listed below point by point:

Response to Reviewer #1:

Comment 1:

General comments:

The authors in this manuscript try to investigate the mechanism of how runoff generates in bimodal hydrographs under complex landscape structures. The study is based on over ten years observations, which provided consolidated field evidence for proving the dominance of shallow groundwater flow in the generation of delayed stormflow. The results of the manuscript are valuable to the science community of hydrology, and are important for improve hydrologic predictions in similar basins. English writing in the manuscript is good to follow, however some errors, e.g., figure numbers should be corrected. I only have some suggestions for the authors to improve their findings.

Response 1:

Thank you for your valuable feedback. Your comments have been instrumental in enhancing the manuscript's quality. We have diligently incorporated your suggestions into the revised version, denoted by changes highlighted in blue. Below, we provide a detailed response to each of your comments, along with the corresponding modifications in the revised manuscript. We sincerely hope that our responses and revisions meet your expectations, rendering the manuscript suitable for publication.

Comment 2:

As we know that the regolith is always thick in granite catchments especially in humid areas (Jia et al., 2021). So more subsurface flow was observed is not surprising here. However, not all catchments behave bimodal pattern for runoff generations. The reviewer believe that it may be relative dry climate conditions together with thick regolith have decided the bimodal phenomenon of runoff generation. So, the authors are required to provide more in-depth discussions and compare their results in XEW with many other catchments to tell why bimodal pattern has been observed in their study area.

Response 2:

Thanks for your comment. We agree with you that more subsurface flow was observed is not surprising here and not all catchments behave bimodal pattern for runoff generations. However, we don't think that the occurrence of the bimodal phenomenon is influenced by the relative dry climate conditions. Our review of previous studies reveals that bimodal patterns occur even in humid regions with annual precipitation exceeding 1000 mm, as evidenced by the studies listed in Table A1. Additionally, due to the limited availability of detailed information on geological structures in existing literature, it is challenging to ascertain whether thick regolith contributes to the appearance of bimodal peaks. Consequently, the underlying causes of the bimodal phenomenon are multifaceted and warrant further investigation in a separate article. We appreciate your insightful suggestion.

Considering that this manuscript primarily focuses on the characteristics and occurrence conditions of the bimodal phenomenon, we intend to develop a new manuscript to delve deeper into this issue.

Table A1 Summary of some studies that observed delayed peaks in relative humid climate regions.

Reference	Study site	Annual precipitation (mm)
Onda et al., 2001, 2006	Ina watershed (5.5/6.3 ha), Japan	1800
Padilla et al., 2014, 2015	EW watershed (1.5 ha), Japan	2669
Zillgens et al., 2007	Limberg catchment (0.07 km^2), Austria	1400
Masiyandima et al., 2003	M'b´e watershed (1.3 km^2), Côte d'Ivoire	1045
Kosugi et al., 2011	Nishi'otafuku-Yama Experimental Watershed (2.10 ha), Japan	1800

Specific comments:

Comment 3:

Lines 121-126: what is earth-rocky mountainous region? The saturated hydraulic conductivity provided by the authors is within the normal range of values like that of many other experimental catchments or hillslopes. In fact, soils mixed with unweathered small stones are normal thing in hilly areas, which may not help explain the enhanced functions of shallow aquifers in shaping hydrograph and why hydrograph here is characterized by bimodal peak.

Response 3:

Thanks for your comment. We agree with you that the presence of soils mixed with unweathered small stones is common in hilly areas, and this may not help explain the enhanced functions of shallow aquifers in shaping hydrograph. We referred to the Earth-rocky mountainous region to describe the study area, as it is a commonly used term in China for areas characterized by a mixture of stones and soil. However, it's important to note that China encompasses various regions with diverse soil compositions and geological features. While some regions have well-developed soil and fewer exposed rocks, others may exhibit weaker weathering, thinner surface soil layers, and more prominent rocks. The soil layer thickness in the Earth-rocky mountainous region is intermediate and relatively stable, distinguishing it from other types of mountainous areas in China. And this study does not specifically address the effect of this soil structure characteristic on the bimodal phenomenon. We appreciate your insightful questions and comments.

Comment 4:

Lines 243-246: how do you recognize the so-called hybrid bimodal event? In Fig.2c, I cannot see the difference between fig.2a and 2c, and both of them seems to be unimodal? It seems that unimodal, bimodal and hybrid events are classified according to rainfall or discharge volume.

Response 4:

Yes, we classified events as unimodal, bimodal, or hybrid bimodal based on the shape of the hydrograph, considering not only the number of runoff peaks but also the discharge volume and lag time of the peaks. The size of the graphs in Fig. 3 partly reflects the magnitude of these runoff processes. For instance, the discharge volume and lag time of the stormflow peak in Fig. 3c are significantly greater than those in Fig. 3a. We apologize for any confusion caused by the schematic. We have improved the explanations of different event type as follows:

'A unimodal event has a single peak generates during or shortly after the cessation of rain impulse (refer to Figure 2a). While a bimodal event features two peaks as a response to the same rain impulse, of which the direct peak (also called the first peak) corresponds to a fast catchment response to rainfall and occurs synchronously with the rainfall or shortly after its onset. Additionally, we referred those events has a similarly shaped hydrograph to unimodal event, but the water yield and peak delay time are significantly greater, as hybrid bimodal events. Hybrid bimodal events can be distinguished from unimodal events by their extremely high streamflow volume, longer duration, and delayed response time (Figure 2c). The hydrographs of bimodal and hybrid bimodal events can refer to Figures 12 and 13'. **(Lines 238-249, pages 12-13)**

Comment 5:

Line 263: Should Fig.3 be Fig.2?

Response 5:

Yes, Fig. 3 here should be Fig. 2, thanks for your correction, we apologize for this mistake, and we have corrected it in the revised manuscript. **(Line 268, page 14)**

Comment 6:

Line 357: which three unimodal events?

Response 6:

These three unimodal events are those represented by the three points in Fig. 5 that fall approximately on the ASI_0+P=200 mm threshold line. Due to the overlapping points representing these three events in Figure 5, discerning them becomes challenging. Consequently, we eliminated this quantifier to uphold the rigor of the quantitative formulation in revised manuscript. **(Line 365, page 20)**

Comment 7:

Lines 357-359: Does it mean that all the flood hydrographs are bimodal when the watershed was sufficiently humid?

Response 7:

Thank you for your comment. Based on the available data, we observed that all bimodal events occurred under wet conditions with ASI_0+P>200mm, indicating a necessary condition for the bimodal phenomenon. However, it remains unclear whether this condition alone is sufficient to guarantee the occurrence of bimodal hydrographs. Further analysis is needed to explore the underlying mechanisms of the bimodal phenomenon and determine if all flood hydrographs are bimodal under sufficiently humid watershed conditions.

Comment 8:

Lines 361-362: Based on these findings that no discernible relationship observed, you posit that the stormflow generation process may be dominated by groundwater or SWC. Why? I do not understand how did the authors draw the conclusions. We know totally the relationship between rainfall-runoff is like a "hockey-stick" (e.g., Ross et al., 2021). Does it mean the selected events were not large enough to show the linear relationship on the "hockey handle"?

Response 8:

Thank you for your comment. We will address the two questions sequentially. Firstly, we apologize for any imprecise speculation or expressions in the manuscript. Without further analysis supported by subsequent sections of the manuscript, we are indeed unable to draw this conclusion. We will review the entire text to ensure removal of similarly uncritical statements and imprecise expressions. Secondly, we regret our current inability to explain why the rainfall-runoff relationship does not exhibit a hockey-stick pattern akin to Ross's proposal. It is possible that the number of events is insufficient or that a different pattern exists from previous studies. While we have been observing continuously for 10 years, there is a limit to the number of storm-runoff events. A longer observation period may be necessary to fully elucidate this phenomenon. We appreciate your valuable comments and questions, which contribute significantly to improving our manuscript.

Comment 9:

Lines 387-390: Identical response timing. Isn't it indicating that whole catchment or critical zone contributes to runoff due to heavy rainstorms rather than groundwater be the major contribution.

Response 9:

Thanks for your comment. We agree with you that the identical response timing between soil water, groundwater, and stormflow indicates whole catchment or critical zone contributes to runoff due to heavy rainstorms. Our previous assertion that groundwater is the primary contributor may not be sufficiently rigorous. We have revised this statement as 'Identical response timing or groundwater rising and peaking just before the stream suggest that whole catchment or critical zone contributed to delayed stormflow.' **(Line 398, page22)**.

Comment 10

Line 392: in figure 6, what is SP1?

Response 10:

We apologize for missing the necessary explanations for the variables in Figure 6. In the figure, SP1 represents the soil water content on the hillslope. We have enhanced Figure 6 by incorporating axis titles and providing essential explanations for the variables within the figure's caption in the revised manuscript. The revised figure as follow **(Lines 400-409, pages 23-24)**:

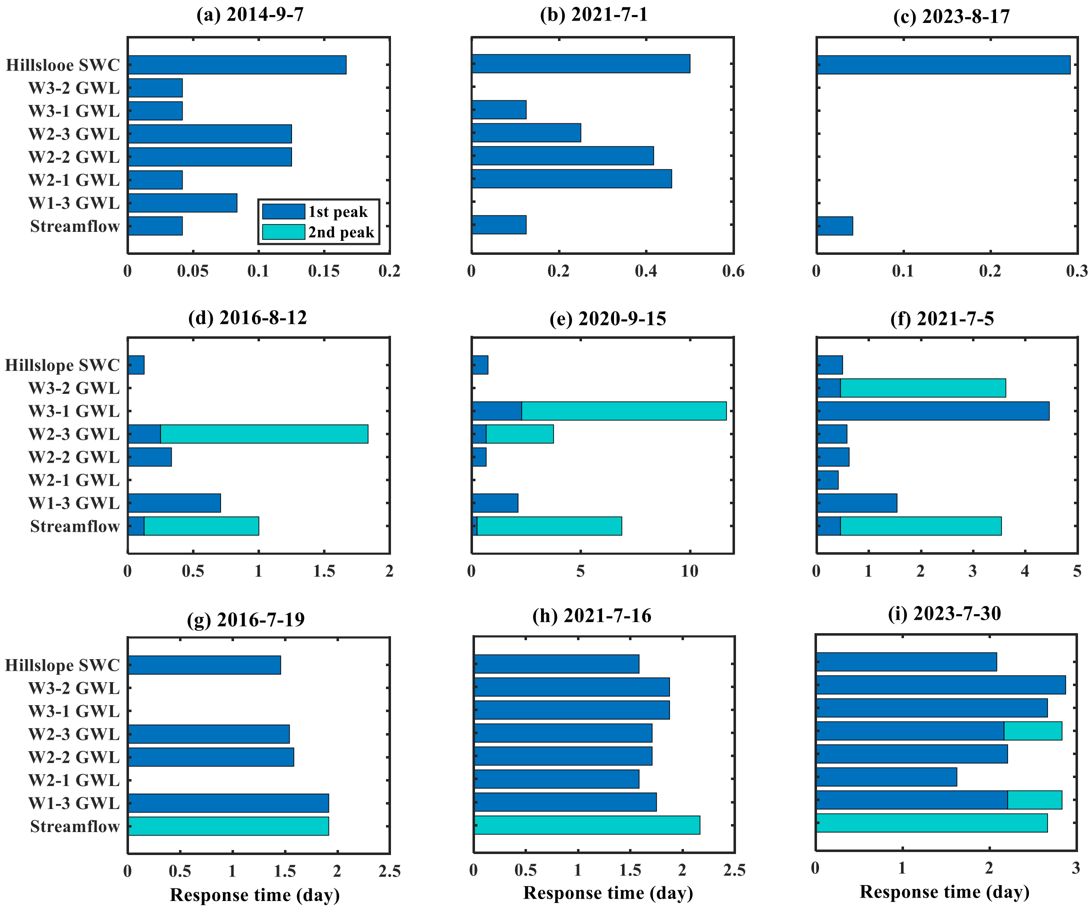

Figure 6. Response time of streamflow, groundwater level and soil water content in nine events. The horizontal axis illustrates the lag time from the onset of rainfall (days). The bar lengths depict the time taken for volumetric water content and groundwater level to reach their respective maximums from the onset of rainfall. GWL is groundwater level, and SWC is soil water content. Each row and column chart shares identical vertical and horizontal axis titles.

Comment 11:

Line 418: where figure 7c?

Response 11:

Thanks for your comment. Figure 7c here should be Figure 7. We apologize for the mistake and deleted it in the revised manuscript. **(Line 434, page 26)**

Comment 12:

Lines 440-448: I wonder if return flow due to the rising of groundwater levels dominants the quick response of so-called delayed stormflow in XEW catchment?

Response 12:

Thanks for your comment. We agree with your opinion that return flow due to the rising of groundwater levels dominants the quick response of so-called delayed stormflow in XEW catchment. Regarding the internal mechanisms governing groundwater level rise and drainage, we plan to address these in a separate paper for a more detailed analysis.

Comment 13:

Lines 490-497: the authors argue that the direct peaks were generated by bypass flow via macropores, fractures or soil-bedrock interface. In fact, in many humid catchments, runoff is just like what you have described for the direct peaks, however, there are no bimodal pattern. So why? I wonder if there are many naked rocks in XEW for infiltrated-excess flow? Or are there always dry with lower levels in saprolites? I suggest the authors add more essential explanation.

Response 13:

Thank you for your valuable comment. Firstly, we agree with you that in many humid catchments, runoff generated through bypass flow mechanisms such as macropores, fractures, or soil-bedrock interfaces does not exhibit a bimodal pattern. However, after reviewing relevant literature dating back to 1960, we have noted instances of bimodal phenomena observed in humid catchments, as indicated in our response to your comment 2. Additionally, in XEW, exposed bedrock is minimal, and both on-site observations and prior numerical analyses suggest limited infiltrated-excess flow. Furthermore, XEW experiences fluctuations in groundwater levels, with levels varying significantly across different locations and even rising to 0.2 meters below the surface during periods of abundant rainfall, as demonstrated in Table A2. Therefore, the occurrence of the bimodal phenomenon in XEW is multifaceted. Based on our current analysis, we speculate that the appearance of delayed runoff peaks may be linked to soil water storage capacity, a topic we plan to explore further in a separate article.

Table A2. Depths and groundwater levels of boreholes.

Borehole	Borehole depth (m)	Shallowest GWL (m)	Deepest GWL (m)
W1-3	10	2.8	10[a]
W2-1	5	0.2	2.2
W2-2	10	4.8	10[a]
W2-3	26	6.4	12.2
W3-1	10	0.8	3.9
W3-2	10	6.1	9.9

Note: All values indicate depths (in meters) from the ground surface; GWL represents groundwater level; 'a' indicates the groundwater level dropped below the bottom of the borehole.

Comment 14:

Lines 498-507: repeated Lines 490-497!!!

Response 14:

Thank you for your comment. We sincerely apologize for the oversight, and we have removed the duplicated content in the revised manuscript. **(Lines 508-515, page 31)**

Comment 15:

Lines 586-595: move field observation into section 4.1 as field verifications.

Response 15:

However, considering the manuscript's content structure, we think it is more logically coherent to retain this section in its original position. The main reasons for this decision are as follows: Section 4.1 analyzes and discusses the water source composition of stormflow based on lag time, while sections 4.2-4.3 further explore this using hysteresis relationships and isotopic signatures. Therefore, sections 4.1-4.3 collectively address the water source composition using different methodologies. And then section 4.4 provides direct observational evidence that corroborates the conclusions drawn in the preceding sections.

References:
Onda, Y., Komatsu, Y., Tsujimura, M., & Fujihara, J. (2001). The role of subsurface runoff through bedrock on storm flow generation. Hydrological Processes, 15(10), 1693–1706.
Onda Y, Tsujimura M, Fujihara J, et al. (2006). Runoff generation mechanisms in high-relief mountainous watersheds with different underlying geology. Journal of Hydrology, 331(3-4): 659-673.
Padilla, C., Onda, Y., Iida, T., Takahashi, S., & Uchida, T. (2014). Characterization of the groundwater response to rainfall on a hillslope with fractured bedrock by creep deformation and its implication for the generation of deep-seated landslides on Mt. Wanitsuka, Kyushu Island. Geomorphology, 204, 444–458.
Padilla, C., Onda, Y., & Iida, T. (2015). Interaction between runoff-bedrock groundwater in a steep headwater catchment underlain by sedimentary bedrock fractured by gravitational deformation. Hydrological Processes, 29(20), 4398–4412.
Zillgens, B., Merz, B., Kirnbauer, R., & Tilch, N. (2007). Analysis of the runoff response of an alpine catchment at different scales. Hydrology and Earth System Sciences, 11(4), 1441–1454.
Masiyandima, M. C., van de Giesen, N., Diatta, S., Windmeijer, P. N., & Steenhuis, T. S. (2003). The hydrology of inland valleys in the sub-humid zone of West Africa: rainfall-runoff processes in the M'be experimental watershed. Hydrological Processes, 17(6), 1213–1225.
Kosugi, K., Fujimoto, M., Katsura, S., Kato, H., Sando, Y., & Mizuyama, T. (2011). Localized bedrock aquifer distribution explains discharge from a headwater catchment. Water Resources Research, 47(7).

Response to Reviewer #2:

Comment 1:
The study from Cui et al. explore why runoff hydrographs exhibit the bimodal patterns. They performed the event-scale analysis investigating different drivers on the streamflow hydrographs based on the data from a catchment in North China. The topic is interesting and important to the hydrology community. However, some notable figure number errors and repeated sentences in the discussion needs to be carefully checked and corrected. In addition, the event identification method described in the paper is quite simple and subjective.

Response 1:
Thank you for your valuable suggestions and questions. Your feedback has greatly contributed to enhancing the quality of our manuscript. We have thoroughly revised the manuscript based on your comments, with changes highlighted in blue. Below, we address each of your comments individually and outline the corresponding revisions made in the revised manuscript. We sincerely hope that you find our responses and modifications satisfactory and that the manuscript is now acceptable for publication.

Detailed comments:

Comment 2:

Table1: what's the definition of hybrid bimodal event? Can you add or move your hybrid bimodal event definition from line 244 to here? In addition, the bimodal event should refer to the shape of hydrographs rather than the rainfall event. The name in the table caption should at least be 'Rainfall-runoff event'.

Response 2:

Thank you for your suggestion. The bimodal phenomenon is characterized by two runoff peaks in response to the same rain impulse. When the delayed peak rapidly merges with the direct peak into a single peak, the event is termed a hybrid bimodal event. Although hybrid bimodal events may share a similar hydrograph shape with unimodal events, they can be distinguished by their significantly higher streamflow volume, longer duration, and delayed response time. As you mentioned, the classification of unimodal, bimodal, and hybrid bimodal events is based on the shape of hydrographs. Therefore, it is more appropriate to refer to rainfall-runoff events rather than rainfall events. We have changed "rainfall event" to "rainfall-runoff event" throughout the manuscript. **(Lines 167-168, page 9 and Line 210, page 11).**

Additionally, to improve the article's readability, we have included brief descriptions of different event types in Table 1 in the revised manuscript, the revised Table 1 as follow **(Lines 167-170, page 9)**:

Table 1. Rainfall-runoff event classification and counts by year. This table provides a breakdown of the number of rainfall-runoff events categorized as unimodal, bimodal, and hybrid bimodal for each year, along with the corresponding time periods. The total counts are summarized at the bottom.

Year	Unimodal event	Bimodal event	Hybrid bimodal event	Time period
Characteristics	A needle-shaped peak which responds immediately to the rainfall impulse	A delayed damped arch-shaped peak responding to the same rainfall impulse in addition to the direct peak	The delayed peak increased rapidly and merged with the direct peak, generating extremely high streamflow volume	
2014	7	-	-	Jul 25 - Sep 25
2015	12	2	-	Jun 1 - Oct 1
2016	2	2	1	Jul 10 - Aug 20
2017	-	2	-	Jun 20 - Jul 10
2020	14	2	-	Jul 1 - Oct 10
2021	15	5	2	Jun1 - Oct 10
2022	18	1	-	Apr 1 - Nov 1
2023	9	-	1	Apr 1 - Nov 1
Total	77	14	4	

Comment 3:

In the section of Meteorology and runoff measurements, there are too many company names for different weather, streamflow, water level logger etc. measurements stations in the main text. These are not necessary and less interested to the readers. Please remove those names from the main paper and record those in a table for the supporting information.

Response 3:

Thanks for your valuable suggestion. We agree with you that including these company names is unnecessary and does not contribute to the understanding of the study; rather, it detracts from the readability of the main text. Therefore, we have eliminated this information from the revised manuscript. **(Lines 135-174, pages 7-9)**

Comment 4:

Line 189: What do you mean by 'bgs'?

Response 4:

In this manuscript, fluctuations in groundwater level were represented as the groundwater depth below the ground surface. Since this differs from the commonly used term "groundwater level," we have abbreviated "below the ground surface" to "bgs" and noted it in the figures and tables in the main text when expressing groundwater levels and their units.

Comment 5:

Line 214-232: Should this section called as 'Separation of rainfall-runoff events'? Not only rainfall events but also the runoff events is separated. Moreover, the separation of rainfall runoff events described here is too subjective and especially not clear how author identify the runoff events. Also, only straight-line separation method is used here. The accurate event separation is critical to the analysis results. There are lots of event separation toolbox available, i.e., HydRun Tang and Carey (2017) (10.1002/hyp.11185),Giani et al. 2022 (doi.org/10.1029/2021WR031283), TOSSH toolbox Sebastian et al. (2021) (doi.org/10.1016/j.envsoft.2021.104983), which can identify the events automatically and objectively. The comparison of analysis for using different event identification methods should be presented to avoid inaccurate event separation.

Response 5:

Thank you for your insightful comment and suggestion. "Separation of rainfall-runoff events" is indeed a more precise term than "Separation of rainfall events" and accurately conveys its meaning. We will incorporate this change in the revised text. We agree with you that the critical importance of accurate event separation in the analysis results and appreciate your recommendation of valuable event separation toolboxes. In our analysis, we utilized the HYSEP computer program (Sloto & Crouse, 1996) to automatically separate a streamflow hydrograph into baseflow and stormflow components. Subsequently, we manually verified and adjusted the results based on actual observations to enhance accuracy, considering the limited number of bimodal events. We sincerely appreciate your suggestions and intend to leverage the tools you recommended for future analyses. Moreover, we have modified the related expression as "The computer program HYSEP (Sloto & Crouse, 1996) was employed to automatically partition a streamflow hydrograph into baseflow and stormflow components. Subsequently, the automated separation outcomes underwent manual verification and adjustment, aligning with observed data and widely accepted straight-line separation principles." in the revised manuscript. **(Lines 221-225, page 12)**

Comment 6:

Line 242-246 and Figure2: The definition of hybrid bimodal event is quite unclear and vague. To be specific, how to distinguish the direct peak and delayed peak? In the Figure 2c, there is no first peak (i.e., direct peak) in this case, so why this peak is called as delayed peak? According to your results, there are only 4 hybrid bimodal events. It would be better to provide their hydrographs and also some of the bimodal hydrographs at least in the supporting information to help readers better understand this concept.

Response 6:

Thank you for your comment and suggestion. We classify events with hydrographs similar to unimodal events but with significantly greater water yield and peak delay time as hybrid bimodal events. Our analysis reveals that during unimodal events, runoff responds rapidly to rainfall, peaking within one hour, with a stormflow yield of less than 0.25 mm. However, despite the hydrograph shape of hybrid bimodal events closely resembling that of unimodal events, characterized by a single runoff peak, they produce stormflow volumes exceeding 26 mm and have longer durations, ranging from 5 hours to nearly one day. Consequently, hybrid bimodal events are distinguished by their higher streamflow volume, longer duration, and delayed response time.

Considering their substantial stormflow volume and prolonged delayed response time, we propose that this type of hydrograph results from the fusion of delayed and direct peaks, a hypothesis confirmed in our manuscript analysis. The dominance of the delayed peak in the stormflow process is evident, although the direct runoff peak cannot be discerned from the delayed peak due to their complete coincidence. Additionally, hydrographs of some bimodal and hybrid bimodal events in XEW are available in Figures 12 and 13 in the main text of manuscript, and in the revised manuscript, we have also provided hydrographs of all hybrid bimodal and bimodal events in the supporting information. Thank you once again for your suggestion.

The revised definition of different event types and Figure 2 as follows:

"The hydrograph served as a valuable tool for characterizing the timing, magnitude, and duration of runoff responses to rainfall. Two primary response types were identified based on the number and shape of streamflow peaks: unimodal and bimodal events. Schematic diagrams illustrating these three types of events are presented in Figure 2.

A unimodal event has a single peak generates during or shortly after the cessation of rain impulse (refer to Figure 2a). While a bimodal event features two peaks as a response to the same rain impulse, of which the direct peak (also called the first peak) corresponds to a fast catchment response to rainfall and occurs synchronously with the rainfall or shortly after its onset. Additionally, we referred those events has a similarly shaped hydrograph to unimodal event, but the water yield and peak delay time are significantly greater, as hybrid bimodal events. Hybrid bimodal events can be distinguished from unimodal events by their extremely high streamflow volume, longer duration, and delayed response time (Figure 2c)." **(Lines 234-249, pages 12-13)**

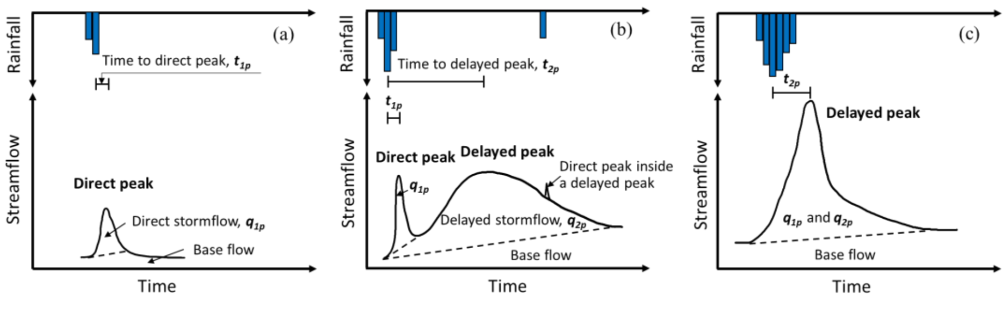

Figure 2. Schematic diagrams of the hydrographs of an (a) unimodal event, (b) typical bimodal events, and (c) hybrid bimodal event (modified from Zillgens *et al.*, 2007).

Moreover, we have added Figure A1 in Appendix A in the revised manuscript to provide hydrographs of bimodal and hybrid bimodal events. **(Lines 805-812, page 47)**

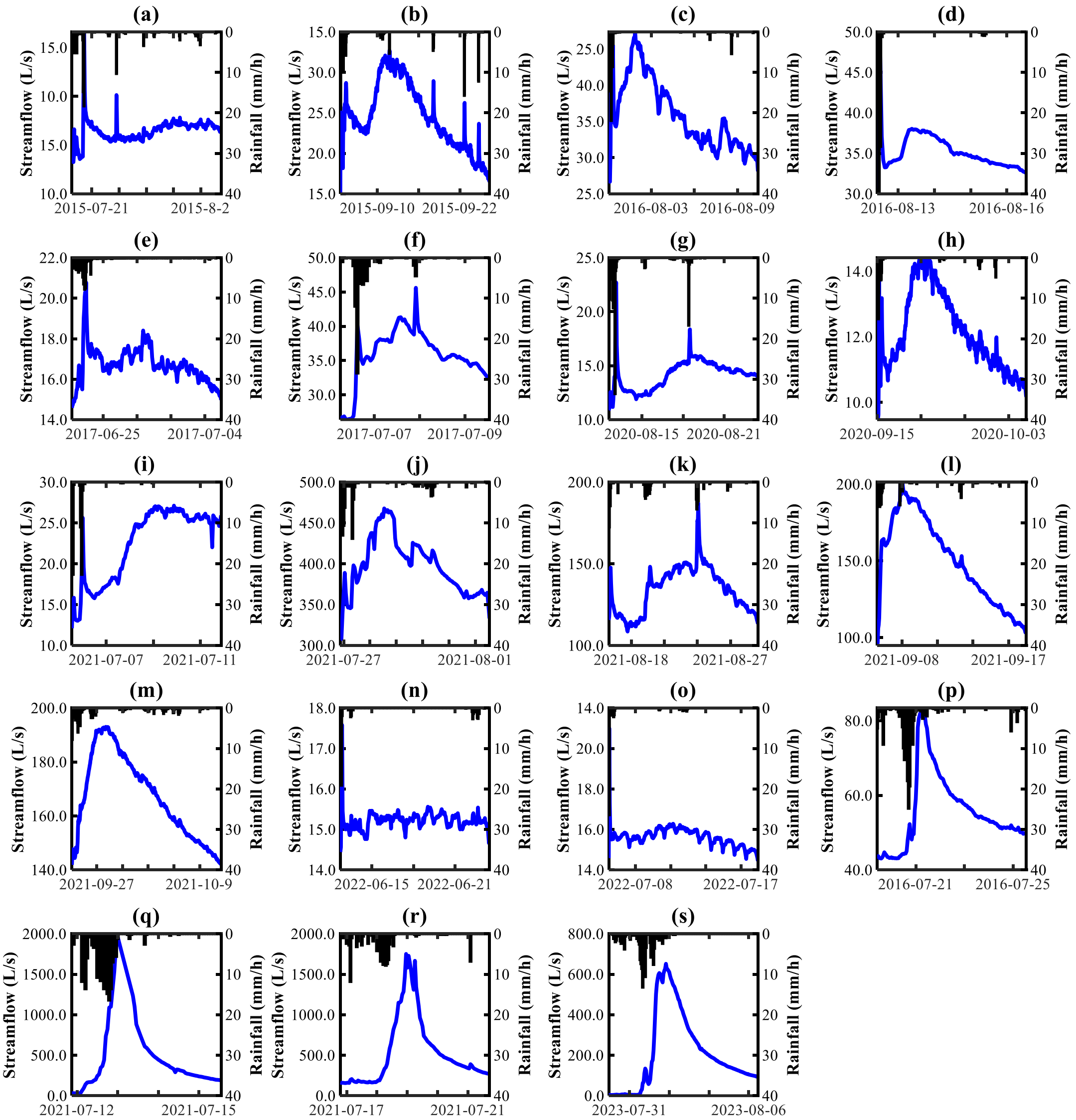

Figure A1. Rainfall and streamflow hydrograph for (a-o) 15 bimodal and (p-s) 4 hybrid bimodal events.

Comment 7:

Line 261-262: There is no variable called 't1p' labelled in the Figure 2. Should be added in the figure.

Response 7:

Thanks for your comment. We regret the oversight. We have now added the label "t_{1p}" to Figure 2 in the revised manuscript, and the revised figure is **(Line 256, page 14)**:

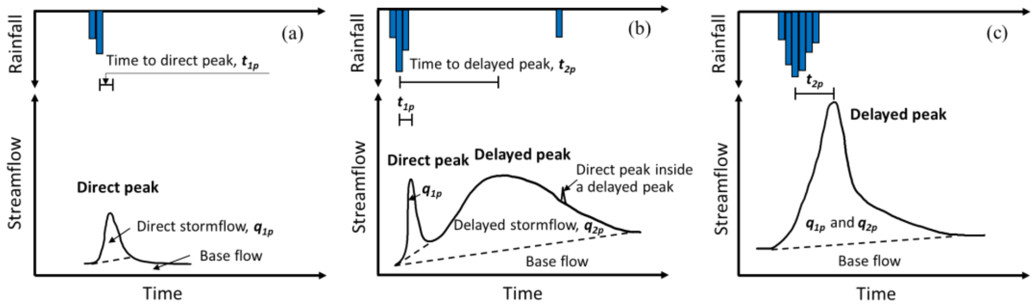

Figure 2. Schematic diagrams of the hydrographs of an (a) unimodal event, (b) typical bimodal events, and (c) hybrid bimodal event.

Comment 8:

Line 263: It should be 'as illustrated in Figure 2' rather than Figure 3.

Response 8:

Thank you for your correction. We apologize for the mistake, which has been rectified in the revised manuscript. **(Line 268, page 14)**

Comment 9:

Figure 4: Antecedent precipitation index is often used to represent and indicate the soil water content. Yet, in your results, the pattern of Figure 4e and Figure 4f-h is quite different. Please add the explanation for this.

Response 9:

Thank you for your comment. As you mentioned, the antecedent precipitation index is commonly employed as an indicator of soil wetness. However, since the delayed peak typically occurs after rainfall cessation, we utilized soil water content data at the end of rainfall to analyze its impact on delayed stormflow occurrence, as depicted in Figure 4e. Conversely, Figures 4f-h utilize rainfall data preceding the event rainfall. This discrepancy in data usage likely explains the distinct patterns observed in Figure 4e compared to Figures 4f-h. In the revised manuscript, we have clarified the varying data sources utilized for these figures, and the content we added is:

'It is noteworthy that the soil water content (SWC) and groundwater level index (IG) presented in Figure 4 represent data recorded at the end of rainfall events, considering that delayed streamflow peaks typically manifest subsequent to the cessation of rainfall events.' **(Lines 329-332, page 17)**

Comment 10:

Figure 6: What's the meaning of the labels 'SP1, W32, W31.' on the y-axis? Can you add labels for both x and y axis on this figure?

Response 10:

Thank you for your comment and suggestion. In Figure 6, the y-axis represents the soil water content of the hillslope (SP1), groundwater levels in various observation wells (W13, W21, W22, W23, W31, and W32), and streamflow, while the x-axis denotes the response timing of these variables. We have improved the axis labels to Figure 6 and provided additional explanations for each variable in the figure caption, and the revised figure is **(Lines 400-409, pages 23-24)**:

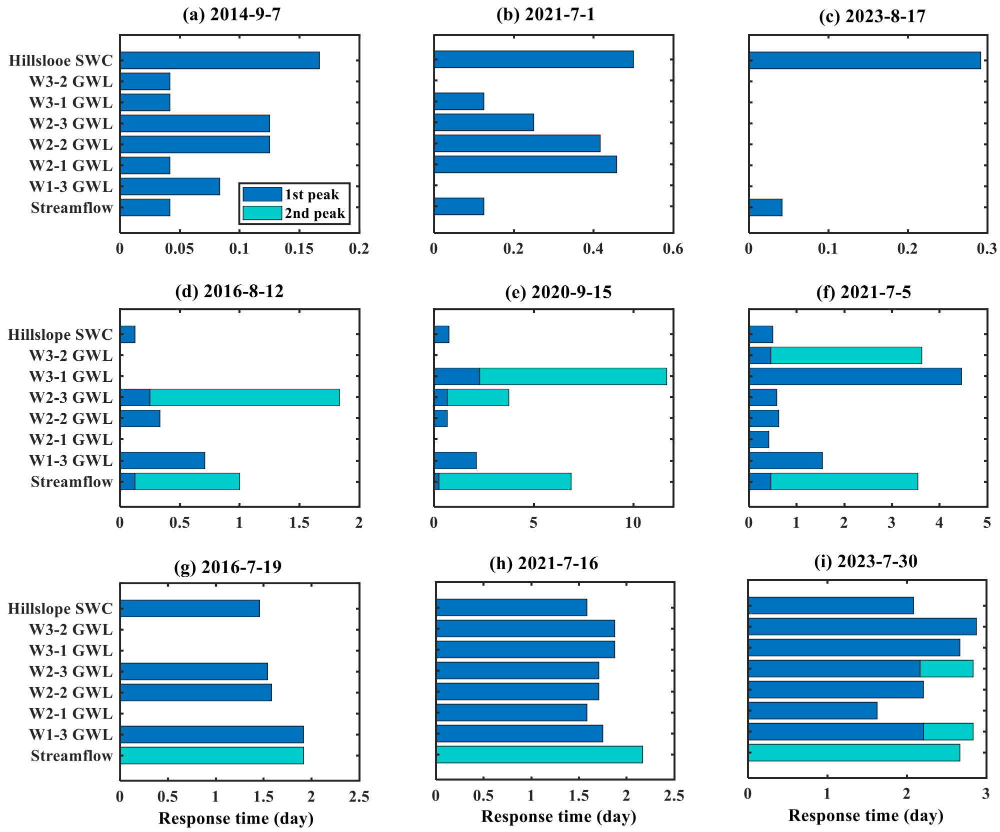

Figure 6. Response time of streamflow, groundwater level and soil water content in nine events. The horizontal axis illustrates the lag time from the onset of rainfall. The bar lengths depict the time taken for volumetric water content and groundwater level to reach their respective maximums from the onset of rainfall. GWL is groundwater level, and SWC is soil water content. Each row and column chart shares identical vertical and horizontal axis titles.

Comment 11:

Line 418: Where is Figure 7c?

Response 11:

Thanks for your comment. Figure 7c here should be Figure 7. We apologize for the mistake and we have deleted it in the revised manuscript. **(Line 434, page 26)**

Comment 12:

Figure 10: The light blue rainfall timeseries shows strange patterns in this figure. Can you plot the rainfall timeseries as a separate bar plot on the top of this figure?

Response 12:

Thank you for your comment. We apologize for the oversight regarding the accurate annotations in Figure 10, which may have led to confusion. The blue line in Figure 10 actually represents the isotopic content ($\delta^{18}O$) of rainfall, not the rainfall amount time series. To maintain consistency with the graphical style of isotopic data for other water bodies, we will present the rainwater isotopic data as a scatter plot. Furthermore, we have improved the description of this variable in the legend and caption of Figure 10 within the revised manuscript, and the revised figure is **(Lines 479-481, page 29)**:

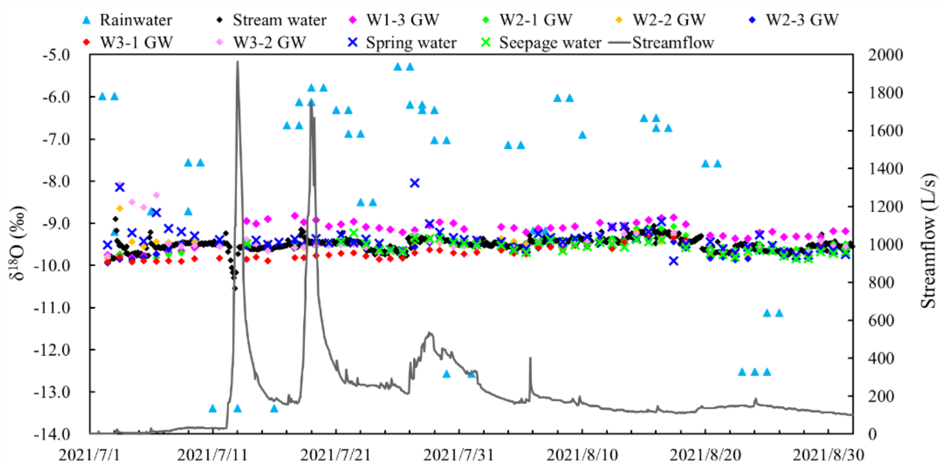

Figure. 10. Stable isotope $\delta^{18}O$ time series of rainwater, stream water and groundwater.

Comment 13:

Table 3: Can you add comparisons with more recent studies within last 5-8 years?

Response 13:

Thanks for your comment and suggestion. We appreciate the reviewer's suggestion to include comparisons with more recent studies. However, despite our diligent efforts, we were unable to locate relevant literature published within the past 5-8 years. The articles we retrieved regarding bimodal streamflow phenomena and the delay in the second peak were predominantly published before 2016. Therefore, in the latest revision of this manuscript, we have supplemented the available literature up to 2016. Additionally, we will continue to expand our search across databases and remain vigilant for relevant studies. Should we obtain more recent research findings, we commit to promptly incorporating them into the manuscript. Thank you for your understanding and valuable feedback.

Table R1 Previous studies of bimodal phenomenon and characterization of the study area.

Reference	Lag time of delayed peak	The source of the delayed peak
Anderson & Burt (1978)	About one day	Subsurface flow
Onda *et al.* (2001)	Ten hours to one week	Subsurface flow and bedrock groundwater
Masiyandima *et al.* (2003)	Several hours	Subsurface flow
Becker (2005)	A day to several weeks	Subsurface stormflow
Zillgens *et al.* (2007)	Three to five days	Subsurface flow
Birkinshaw (2008)	Several tens of hours to a few days	Subsurface stormflow
Kosugi et al. (2011)	Two to three days	Bedrock groundwater

Fenicia et al. (2014)	Several hours or days	Subsurface flow
Padilla *et al.* (2014, 2015)	Within four days	Bedrock groundwater
Yang et al. (2015)	Several hours	Subsurface flow
This study	5 hours to 9.9 days	Subsurface flow (groundwater flow)

References:

Anderson, M. G., & Burt, T. R. (1978). The role of topography in controlling throughflow generation. Earth Surface Processes, 3(4), 331–334.

Becker, A. (2005). Runoff processes in mountain headwater catchments: recent understanding and research challenges. Global Change and Mountain Regions: An Overview of Current Knowledge, 283-295.

Birkinshaw, S. J. (2008). Physically-based modelling of double-peak discharge responses at Slapton Wood catchment. Hydrological Processes: An International Journal, 22(10), 1419–1430.

Fenicia, F., Kavetski, D., Savenije, H. H., Clark, M. P., Schoups, G., Pfister, L., & Freer, J. (2014). Catchment properties, function, and conceptual model representation: Is there a correspondence? Hydrological Processes, 28, 2451-2467.

Kosugi, K. I., Fujimoto, M., Katsura, S. Y., Kato, H., Sando, Y., & Mizuyama, T. (2011). Localized bedrock aquifer distribution explains discharge from a headwater catchment. Water Resources Research, 47(7).

Masiyandima, M. C., van de Giesen, N., Diatta, S., Windmeijer, P. N., & Steenhuis, T. S. (2003). The hydrology of inland valleys in the sub-humid zone of West Africa: rainfall-runoff processes in the M'be experimental watershed. Hydrological Processes, 17(6), 1213–1225.

Onda, Y., Komatsu, Y., Tsujimura, M., & Fujihara, J. (2001). The role of subsurface runoff through bedrock on storm flow generation. Hydrological Processes, 15(10), 1693–1706.

Padilla, C., Onda, Y., & Iida, T. (2015). Interaction between runoff-bedrock groundwater in a steep headwater catchment underlain by sedimentary bedrock fractured by gravitational deformation. Hydrological Processes, 29(20), 4398–4412.

Padilla, C., Onda, Y., Iida, T., Takahashi, S., & Uchida, T. (2014). Characterization of the groundwater response to rainfall on a hillslope with fractured bedrock by creep deformation and its implication for the generation of deep-seated landslides on Mt. Wanitsuka, Kyushu Island. Geomorphology, 204, 444–458.

Sloto, R. A., & Crouse, M. Y. (1996). HYSEP: A computer program for streamflow hydrograph separation and analysis (No. 96-4040). US Geological Survey.

Yang, Y., Endreny, T. A., & Nowak, D. J. (2015). Simulating double-peak hydrographs from single storms over mixed-use watersheds. Journal of hydrologic engineering, 20(11), 06015003.

Zillgens, B., Merz, B., Kirnbauer, R., & Tilch, N. (2007). Analysis of the runoff response of an alpine catchment at different scales. Hydrology and Earth System Sciences, 11(4), 1441–1454.

All the authors express their gratitude for the reviewers' kindness and helpful suggestions aimed at enhancing our manuscript. The revised version has been submitted to your esteemed journal, and we eagerly anticipate your favorable response.

Yours

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