

Point-by-Point Response to Review Comments

Manuscript Title: Increased Nonstationarity of Stormflow Threshold Behaviors in a Forested Watershed Due to Abrupt Earthquake Disturbance

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(**C** and **R** denotes Comment and Reply, respectively)

Response to Reviewer #1 Comments:

C1: Summary: Increased Nonstationarity of Stormflow Threshold Behaviors in a Forested Watershed Due to Abrupt Earthquake Disturbance assessed changes in hydrologic response of a forested experimental watershed in the eastern Tibet Plateau following an earthquake. The authors characterized longer-term changes in threshold behavior in the watershed and introduced a new metric to quantitatively express thresholds for watersheds with areas of disparate land use, ecology, and physiography. The authors found that lower threshold values were observed in disturbed landslide regions and that non-stationarity in thresholds was mainly controlled by changes to the dominant runoff generation mechanisms of subsurface stormflow and the variable source area.

Significance: This work is significant in several ways:

It contributes to our growing understanding of threshold-mediated hydrologic response. It contributes to the further advancement of a unified threshold-based

hydrologic theory. It assesses longer-term trends in threshold behavior following an environmental disturbance. It introduced a new metric to quantify and compare thresholds.

R1: We are very grateful for having the summary of your positive assessments and appreciation of our work. The point-by-point comments have been addressed below. We also hope that this study with the interconnection of hydrological sciences and flash flood disasters could be considered for publication in the “*Hydrology and Earth System Sciences*”.

C2: I found the abstract difficult to digest. Multiple results are communicated, but there is little context for the reader, making it difficult to understand the methodology or the jargon used in the abstract. Consider revising the abstract to be more general to start and highlighting only key results.

R2: Thanks for your comment. The abstract has been revised to “Extreme earthquake disturbances to local and regional landscape vegetation could rapidly impair former hydrologic functioning, significantly increasing the hydrologic complexity and temporal nonstationarity in the estimation of threshold behaviors of rainfall-runoff processes. It is still unclear how alternating catchment hydrologic behaviors under an ongoing large earthquake disruption are mediated by long-term interactions of landslides and vegetation evolutions. In the present study, the nonlinear hydrologic behavior related to the Wenchuan earthquake having two thresholds with intervening linear segments was analyzed. A lower rising threshold (T_r) value (210.48) observed in post-earthquake local landslide regions exhibited a stormflow response faster than that in undisturbed forest and grass-shrub regions, easily triggering huge flash flood disasters. To characterize longer-term changes in hydrologic threshold behavior pre- and post-earthquake at the watershed scale, an integrated response metric pair (integrated watershed average generation threshold T_{g-IWA} and rising threshold T_{r-IWA}) with areas of disparate land use, ecology, and physiography was proposed and efficiently applied to identify catchment hydrologic emergent behaviors. The interannual variations of two hydrologic thresholds pre- and post-earthquake were assessed to detect the temporal nonstationarity in hydrologic extremes and nonlinear runoff”

response. The year 2011 was a turning point in the unsteady recovery process, as post-earthquake landslides evolutions reached a state of extreme heterogeneity in space. At that time, the T_{r-IWA} value decreased by ~ 9 mm compared to the pre-earthquake level. This is closely related to the fast expansion of landslides leading to a larger extension of variable source area from channel to neighboring hillslopes and a faster subsurface stormflow contribution to flash floods. Finally, we present a conceptual model interpreting how the short- and long-term interactions of earthquake-induced landslides and vegetation affect flood hydrographs at event timescale that generated an increased nonstationary hydrologic behavior. This study expands our current knowledge about threshold-based hydrological behavior and nonstationary stormflow threshold behaviors in response to abrupt earthquake disturbance for the prediction of future flood regimes.”.

C3: Starting at the end of Line 50 the authors suggest that most threshold behavior in rainfall-runoff relationships reported in the literature has been of the hockey-stick diagnostic shape. I think it is notable that most of the listed studies had an identification procedure only compatible with this shape of a threshold. Otherwise, the wording is somewhat ambiguous and may lead to readers assuming that the dominance of the hockey-stick shape is process-driven or a reflection of some common element in watershed behavior.

R3: Thanks for your serious comment. I agree with you, and the sentence has been revised as “In the literature, the runoff behaviors with Hockey stick shape were found at the hillslope (Tromp-Van Meerveld and McDonnell, 2006; Fu et al., 2013a; Wang et al., 2022) and watershed scales (Wei et al., 2020; Farrick and Branfireun, 2014; Scaife and Band, 2017; Buttle et al., 2019; Zhang et al., 2021b).”

C4: In L58-59 I see that the authors have referenced Wei et al. (2020) and the proposed three-linear hydrologic behaviors. I find this wording hard to follow, which I also address in comments about the abstract. I think it might make more sense to describe this form of rainfall-runoff relationship as having multiple inflections/thresholds with intervening linear segments.

R4: Thanks for your valuable and logical suggestion. The three-linear hydrologic behaviors could be well expressed by the rainfall-runoff relationship as having multiple thresholds with intervening linear segments. In the revised manuscript, the sentence has been revised as “Wei et al. (2020) proposed a rainfall-runoff relationship as having multiple thresholds with intervening linear segments to reflect the initial streamflow activation and larger flood response.”

C5: The paragraph spanning L62-89 was very clear and informative. It contrasted with the writing style of earlier paragraphs. I hope that a revised version of the manuscript more broadly applies the tone and writing quality of this section.

R5 Thanks for your serious comment and good suggestion. This Section has been modified and improved in the revised version of the manuscript.

C6: L109-112: I am unsure if this information is a study area description or is an early interpretation of results. Perhaps, it is just the wording, particularly “let to an unstable trend of the disturbance-response-recovery...” that is confusing me.

R6: Thanks for you pointing it out. It is an early interpretation of our results in the study area, and has been marked by the reference of Zhang et al., 2021a. The sentence has been revised “After the earthquake, the forest land had a 19.9% shrinkage percentage (Zhang et al., 2021a)”. Additionally, the unclear sentence has been changed as “The post-earthquake hydro-geohazards, such as landslides and debris flows, could lead to an unstable recovery trend of landscape vegetation (Figure 1), significantly influencing the stability of hydrologic function and stormflow behaviors of the watershed from rainfall to runoff (Zhang et al., 2021a).”.

References:

Zhang, G., et al. (2021). "Changes in hydrological behaviours triggered by earthquake disturbance in a mountainous watershed." *Science of the Total Environment* 760: 143349.

C7: In L123-125, the authors mention the disturbance recovery process of vegetation

and how analyzing this might help better understand runoff generation. I think that this information is critical, and a more detailed process-based description of these relationships would be a welcome addition to the introduction.

R7: Thanks for your suggestion. It is indeed critical for us to reasonably describe the effects of the disturbance-recovery process of vegetation on runoff generation.

The sentence has been revised as “After the abrupt disturbance, the exposed bedrock in the trailing edge of the landslides easily induced the Horton overland flow, and the generated loose deposition in the lower part of the landslides generally increased the subsurface stormflow with the microporous flow (Mirus et al., 2017a; Zhang et al., 2018). Such hydrological behaviors are related to the quick runoff generation mechanism with short lag time, resulting in higher runoff potential (Figure 1)” and has been added to the Introduction.

The sentence has been revised as “During the recovery processes, the earthquake-derived amounts of geohazards affected by large rainstorms led to unstable forest shrinkages and landslide expansions (Figure 1) at long-term timescales in a forest-dominated mountainous watershed. The unstable disturbances from endogenous (earthquake) and exogenous (rainstorms and concomitant hydro-geohazards) origins remarkably increased the uncertainty in the assessment of the hydrological regime from disturbance to recovery and flood risk management (Seidl et al., 2017)”

C8: In section 2.4, I was hoping for more details rationalizing the proposed integrated watershed average index for the thresholds. In the discussion, I think that a section should be added to further elaborate on the efficacy of this metric and some introspection about how this metric may or may not be well suited for other environments/conditions where the control factors on the threshold behaviors differ.

R8: Thanks for your valuable suggestions. The *IWA* index mainly considers the processes of runoff generation in the watershed's underlying surface based on the principle and framework of runoff potential for curve numbers (Deshmukh et al., 2013). The underlying surface mainly encompasses the land use types, the shallow

storage capacity as well as the physical properties of soils and bedrock at different locations. These factors play vital roles in the runoff generation processes. Another dominant water source of event precipitation amounts in the atmosphere was also taken into account. Therefore, the index is mainly calculated from the area contribution ratio of different land use types (R_i), the shallow water storage capacity at different locations ($DASI_i$), and event precipitation amounts (P). The corresponding sentences have been added.

Additionally, we also presented the applicability and limitations of the proposed detailed metric in the results and discussion Sections. The index was presented and verified through the applications of the magnitudes in two threshold values during the flood hydrograph with 5-min intervals (Figure 5). Meanwhile, in this experimental watershed (Figure 4) a significant negative correlation relationship ($p < 0.05$) between hydrologic thresholds and peak discharges derived from runoff potential was found. Their hydrologic signatures were observed simultaneously, providing an efficient verification of the application of the index in the interannual hydrological variations. Of course, we also acknowledged as a limitation that only the dominant hydrological process of runoff generation was considered while the important confluence flow was mostly ignored. In a future study, such a metric will be involved in the runoff generation and confluence flow to more efficiently reflect the watershed's hydrologic behavior.

Therefore, the sentence “The threshold index was efficiently verified through the applications of the magnitudes in two threshold values during the flood hydrograph (Figure 5) and their concomitant hydrological variations with the discharges derived from runoff potential (Figure 4). However, we also acknowledge as a limitation that only the dominant hydrological process of runoff generation was considered while the important confluence flow was mostly ignored. In a future study, the such metric will be involved in the runoff generation and confluence flow to more efficiently reflect the watershed's hydrologic behavior.” have been added.

C9: In the discussion, I think some attention should be given to uncertainty in the actual threshold values. I understand that the use of PRA in this context is to characterize the relationship shape rather than to be used in prediction. Still, how robust was the PRA, and are there any concerns about the unequal distribution of events and leverage from particularly large events?

R9: Thanks for your good comments. It is very important to exploit the uncertainty in the actual threshold values at the watershed scale. For example, the threshold values with large uncertainty could be affected by seasonal and interannual forest transpiration (Scaife et al., 2017). In the revised manuscript, a total of 47 large events in this experimental watershed were identified during periods of June ~ August from 2018 to 2020, possibly filtering out the uncertainty in assessing hydrological behaviors from seasonal variations of the vegetation forest canopy (Hwang et al., 2018). We mainly used the potential mean values of our measured hydrological thresholds from 2018 to 2020 to identify their past long-term changes before and after the Wenchuan earthquake. The changes or uncertainty in thresholds triggered by the earthquake disturbance were mainly considered rather than other factors.

The catchment threshold behaviors were quantitatively assessed using piecewise regression analysis (*PRA*) combined with the Levenberg-Marquardt method and global search optimization algorithm. The standard error of estimate (*SEE*) in multiple regression was estimated considering different locations of the forest, grass-shrub, and landslide lands. These *SEE* values are listed in Table 2. We acknowledge the existence of nonlinear and complex stormflow generation, but automatic searching and calculating the breakpoints and slope parameters using *PRA* with top-down approaches and maximum likelihood approach (Muggeo, 2003) could relatively efficiently determine the emergent hydrological behavior.

The Sentence “A total of 47 events in this experimental watershed were identified during periods of June ~ August from 2018 to 2020, possibly filtering out the uncertainty in assessing hydrological behaviors from seasonal variations of the vegetation forest canopy (Hwang et al., 2018)” was revised.

Table 2: Comparison of parameters in assessing the three-linear threshold behaviors of $DASI+P$ and Q_q relationships at the confidence level of 95%

Location	Period	Parameters						
		T_g (mm)	T_r (mm)	m_{i1}	m_{i2}	m_{i3}	r^2	SEE
Forest land	Pre-earthquake [#]	111.2	260.7	0.28	0.33	2.36	0.88**	17.17
Grass-shrub land		130.4	247.9	0.21	0.49	1.12	0.84**	15.65
Landslide land	Post-earthquake	91.98	210.48	0.24	0.36	1.04	0.87**	16.54

Note:

m_{ij} indicates the values in the slope parameter of PRA equations from the j_{th} phase at the i land (i =forest, grass-shrub, and landslide lands, $j=1, 2, 3$ shown in Figure 3).

[#] denotes the collected data in a row, reported by Zhang et al. (2021b).

** indicates that correlation is significant at the 0.01 level (two-tailed).

SEE is the standard error of estimate in multiple regressions.

C10: In Section 3.2, especially in later parts, interpretation and discussion begin to creep in a bit.

R10: Thanks for your pointing it out. Some text **has been removed and revised**, such as the sentence “Two thresholds had the opposite trends for these simulated interannual variations in peak discharge and flood volume (Figure 4b), as reported by observed data combined with a hydrological model from Zhang et al. (2021a) in this experimental watershed”, and “This revealed that the lower values in generation and rising thresholds after the earthquake require a lower watershed storage capacity (rainfall and antecedent soil content) input to readily trigger the observed huge flash flood.”.

C11: I think that a stronger definition of threshold is needed to maintain clarity throughout the manuscript. On the first introduction of the tipping points, I also feel that a clear distinction should be made so that the reader can more readily determine that different patterns are being assessed.

R11: Thanks for your valuable and logical suggestions. The meanings of the words “threshold” and “tipping point” are very similar, and are not easy for the reader to recognize. We refer to the interpretation from Ali et al., 2013 and some hydrologists you suggest, and characterized the hydrologic threshold as follows.

The observed hillslope- or catchment-scale threshold runoff response (Zehe and Sivapalan, 2009; Fu et al., 2013b; Ross et al., 2021; Wang et al., 2022) shows a hydrologic emergent pattern, which could be used to identify key hydrologic signatures across spatiotemporal scales. The hydrologic threshold is the critical point in time or space at which abrupt changes in stormflow response are observed (Ali et al., 2013). Below the hydrologic threshold, small generated stormflow enters the adjacent channel, but significantly higher runoff magnitudes generally occur above the threshold (Tromp-Van Meerveld and McDonnell, 2006; Zehe et al., 2007; Wei et al., 2020). The corresponding sentences have been added in the introduction part.

In this manuscript, the word “tipping point” is ambiguous, and should be a critical or turning point in time (2011) from 2008 to 2018. It is completely different from the meaning of “threshold” from the words “stormflow threshold behaviors”. We redefined the term “tipping point”, and changed it to “turning time” in the revised manuscript. Therefore, some details in the revised manuscript were revised.

C12:L237-230: The authors describe bedrock depression storage and soil moisture deficit as the main factors controlling a runoff initiation threshold. How do the environments of the referenced studies compare to that of the area in the current study? Are there common characteristics that make this process-based interpretation transferable to this study environment? Figures 6 and 7: I like figures 6 and 7! They were a nice conceptual addition to the manuscript.

R12: Thanks for your appreciation of our work and some good suggestions. Some common characteristics allow transferring such process-based interpretation to different future studies (Tromp-Van Meerveld and McDonnell, 2006; Fu et al., 2013b; Farrick and Branfireun, 2014; Scaife and Band, 2017; Zhang et al., 2021b; Ross

2021; McDonnell et al., 2021). Firstly, the low permeability of bedrock such as granite and basalt. Secondly, the hillslope is characterized by steep slopes and highly permeable soils. These properties generally lead to a significant soil-rock interface, readily triggering the subsurface stormflow on the interface under heavy rainfall conditions. In the future, it is expected to prepare a reasonably generalized ecohydrological zoning based upon some organizing principles. Such ecohydrological zoning is closely related to climate zones, vegetation types, lithology types, and soil-to-rock depths in the subsurface, topography, landforms, etc. By extending the physical processes which affect the formation and development of flash floods, several dimensionless parameters associated with ecohydrological processes as new metrics could be proposed to characterize the ecohydrological zoning. The corresponding sentences have been added.

C13: For Section 4.1, controls on threshold behaviors, I found that the author's rationalization of the controls was detailed. With that said, it did read as a mere explanation of different runoff generation mechanisms, and I found there to be a lack of synthesis connecting the experimental observations and analysis results to these more processed-based interpretations. It would be nice if the authors could add some checkpoints in the theoretical explanations to better articulate how their interpretations are supported by their data and how these observations differ from or parallel other studies.

R13: Thanks for your valuable suggestions. It is very important to closely connect the experimental observations and analysis results to those more processed-based interpretations. In Section 4.1, we analyzed and examined whether the thresholds could separate the initial runoff generation and the flood response using the observed data, including rainfall intensity ($I_{5\text{min}}$), event accumulative precipitation (EAP), and discharge (Q) at a 5-min interval. Additionally, below and above the two thresholds, we attempted to estimate and analyze the changes in minimum contributing area (MCA), stormflow discharge (Q_q), and soil water in different depths at hillslopes

based on our collected data (Zhang et al., 2021b). The corresponding sentences were revised as “Below and above the generation and rising thresholds, the changes in minimum contributing area (MCA , with the mean value of 13.79 km², 22.52 km², and 34.43 km², respectively) and stormflow discharge (Q_g , with the mean value of 3.14 mm, 22.5 mm, and 138.3 mm, respectively) are significant (Zhang et al., 2021b; Dickinson and Whiteley, 1970). Higher values of MCA above the rising threshold exceeded 60% of the watershed area (Zhang et al., 2021b), significantly increasing the hydrological connectivity of hillslope riparian-stream and readily triggering catastrophic flash floods (Figure 6e-f).”.

In a future study, the indoor potential scaled model test or runoff plots with bedrock depression could be applied to further parse the potential constitutive relationship of rainfall-runoff in different scenarios.

References:

Zhang, G., Cui, P., Gualtieri, C., Zhang, J., Ahmed Bazai, N., Zhang, Z., Wang, J., Tang, J., Chen, R., and Lei, M.: Stormflow generation in a humid forest watershed controlled by antecedent wetness and rainfall amounts, *Journal of Hydrology*, 603, 127107, <https://doi.org/10.1016/j.jhydrol.2021.127107>, 2021b.

Dickinson, W. and H. Whiteley (1970). "Watershed areas contributing to runoff." *IAHS publ* 96: 12-26.

C14: For Section 4.3 point 3. I think that this is an interesting recommendation. Can the authors provide an example of how this could be done? It is a little ambiguous, but I think that this could be a potentially appealing avenue for future work.

R14: Thanks for your good comment and appreciation for future recommendations. We think that a reasonably generalized ecohydrological zoning with some organizing principles is very necessary. The eco-hydrological zoning is closely related to climate zones, vegetation types, lithology types, and soil-to-rock depths in the subsurface, topography, landforms, etc. By extending the physical processes which affect the formation and development of flash floods, it is expected to propose several dimensionless parameters associated with ecohydrological processes as new metrics to characterize such ecohydrological zoning. If possible, we could better describe

region heterogeneity in runoff processes related to flash floods.

C15: Abstract L12: Consider “former hydrologic functioning” rather than “original hydrologic functioning”.

R15: Thanks for your suggestion. The words “original hydrologic functioning” have been changed into “former hydrologic functioning”.

C16: Abstract L16: I am confused by “three-linear stormflow threshold behaviors are examined”, as graphical representations of threshold behaviors are nonlinear. Also, the following segment refers to “both thresholds”, which I also find confusing.

R16: Thanks for your comment. The term “three-linear stormflow threshold behaviors” denotes a nonlinear hydrologic behavior as having two thresholds with intervening linear segments. According to your suggestion from **C3**, the corresponding sentence has been revised as “the nonlinear hydrologic behavior as having two thresholds with intervening linear segments was analyzed, where the thresholds were identified as a diagnostic tool to characterize variations in hydrologic emergent patterns pre- and post-earthquake”.

C17: L38-40: This sentence was confusing to me. I interpret these thresholds as emergent patterns or hydrologic signatures that are an integrated representation of processes spanning spatiotemporal scales. If I have correctly interpreted what the authors were aiming for, I do not believe that this is conveyed in their writing.

R17: Thanks for your comment. The sentence has been revised as “The observed hillslope- or catchment-scale threshold runoff response (Zehe and Sivapalan, 2009; Fu et al., 2013b; Ross et al., 2021; Wang et al., 2022) shows a hydrologic emergent pattern, and could be used to identify key hydrologic signatures across spatiotemporal scales (Ali et al., 2013). The hydrologic threshold behavior is the critical point in time or space at which abrupt changes in stormflow response are observed (Ali et al., 2013). Below the hydrologic threshold, a small”

generated stormflow enters the adjacent channel, but significantly higher runoff magnitudes generally are observed above the threshold (Tromp-Van Meerveld and McDonnell, 2006; Zehe et al., 2007; Wei et al., 2020)."

C18:L40-44: I understand the intent of this sentence, but I found the wording unusual. Consider revising for clarity.

R18: Thanks for your suggestion. The sentence has **been revised to** "A unified threshold-based hydrological theory that possibly advanced catchment hydrology was extensively discussed during the AGU 2011 Fall Meeting (Ali et al., 2013), and later was continuously developed (Ross et al., 2021; Ross, 2021; Ali et al., 2015; Scaife et al., 2020). Theoretical advancements in hydrology can support the development of appropriate algorithms for more efficient predictive models."

References:

- Ross, C. A. (2021). *Moving towards a unified threshold-based hydrological theory through inter-comparison and modelling*.
- Ross, C. A., et al. (2021). "Evaluating the Ubiquity of Thresholds in Rainfall-Runoff Response Across Contrasting Environments." *Water Resources Research* 57(1).
- Scaife, C. I., et al. (2020). "Non-linear quickflow response as indicators of runoff generation mechanisms." *Hydrological Processes* 34(13): 2949-2964.
- Ali, G., et al. (2015). "Comparison of threshold hydrologic response across northern catchments." *Hydrological Processes* 29(16): 3575-3591.
- Ali, G., et al. (2013). "Towards a unified threshold-based hydrological theory: necessary components and recurring challenges." *Hydrological Processes* 27(2): 313-318.

C19:L44-46: Ambiguous wording. I suggest providing a concise definition of the threshold behavior in the runoff response being referred to. The Ali et al., 2013 reference provided, offers one such definition.

R19: Thanks for your logical suggestion. According to the research from Ali et al., 2013 and some hydrologists, we have analyzed and defined the threshold behavior in the runoff response. The following sentences **have been revised and added** as "The observed hillslope- or catchment-scale threshold runoff response (Zehe and Sivapalan, 2009; Fu

et al., 2013b; Ross et al., 2021; Wang et al., 2022) shows a hydrologic emergent pattern, and could be used to identify key hydrologic signatures across different spatiotemporal scales (Ali et al., 2013). The hydrologic threshold behavior is the critical point in time or space at which abrupt changes in stormflow response occur (Ali et al., 2013). Below the hydrologic threshold, a small stormflow enters the adjacent channel, but significantly higher runoff magnitudes generally are observed above the threshold (Tromp-Van Meerveld and McDonnell, 2006; Zehe et al., 2007; Wei et al., 2020).”

References:

- Zehe, E. and M. Sivapalan (2009). "Threshold behaviour in hydrological systems as (human) geo-ecosystems: manifestations, controls, implications." *Hydrology and Earth System Sciences* 13(7): 1273-1297.
- Fu, C., et al. (2013). "Threshold behavior in a fissured granitic catchment in southern China: 1. Analysis of field monitoring results." *Water Resources Research* 49(5): 2519-2535.
- Ross, C. A., et al. (2021). "Evaluating the Ubiquity of Thresholds in Rainfall-Runoff Response Across Contrasting Environments." *Water Resources Research* 57(1).
- Wang, S., et al. (2022). "Rainfall-runoff characteristics and their threshold behaviors on a karst hillslope in a peak-cluster depression region." *Journal of Hydrology* 605.
- Ali, G., et al. (2013). "Towards a unified threshold-based hydrological theory: necessary components and recurring challenges." *Hydrological Processes* 27(2): 313-318.
- Tromp-van Meerveld, H. J. and McDonnell, J. J.: Threshold relations in subsurface stormflow: 1. A 147-storm analysis of the Panola hillslope, *Water Resources Research*, 42, 336-336, 10.1029/2004WR003778, 2006.
- Zehe, E., Elsenbeer, H., Lindenmaier, F., Schulz, K., and Blöschl, G.: Patterns of predictability in hydrological threshold systems, *Water Resources Research*, 43, 10.1029/2006wr005589, 2007.
- Wei, L., Qiu, Z., Zhou, G., Kinouchi, T., and Liu, Y.: Stormflow threshold behaviour in a subtropical mountainous headwater catchment during forest recovery period, *Hydrological Processes*, 34, 1728-1740, 10.1002/hyp.13658, 2020.

C20:L46-48: It is unclear to me why threshold is plural in this sentence – I also think that this information can be incorporated into the former sentence where I have suggested clearly defining the author’s operational definition of threshold behavior.

R20: Thanks for your serious comment. The word “threshold” has been revised to be singular. Additionally, the clear interpretation and definition of threshold behavior were illustrated in the fore-mentioned **R19**. Additionally, the information can be

incorporated into the former sentence (Please see R19).

C21:L50: “They might indicate...” is vague. Are the authors referring to the different diagnostic shapes or the transition from pre-threshold to post-threshold behavior?

R21: Thanks for your serious comment. The word “They” is the transition from below-threshold to above-threshold behavior for different diagnostic shapes. Therefore, the sentence **has been revised** as “The transition from below-threshold to above-threshold behavior for different diagnostic shapes suggests several water retention and release mechanisms in the watershed”.

C22:L50: “The runoff behaviors...”. Are the authors referring to the thresholds in the cited literature or in the current study?

R22: Thanks for your logical comment. These thresholds are from the cited literature. The sentence **has been revised** as “In the literature, the runoff behaviors with Hockey stick shape were found at the hillslope (Tromp-Van Meerveld and McDonnell, 2006; Fu et al., 2013a; Wang et al., 2022) and watershed scales (Wei et al., 2020; Farrick and Branfireun, 2014; Scaife and Band, 2017; Buttle et al., 2019; Zhang et al., 2021b)..”.

C23:L78-L79: I found this hard to follow and after reading it multiple times am not sure about the intended messaging.

R23: Actually, the exposed bedrock in the trailing edge of the landslides easily stimulated the occurrence of the Horton overland flow, and the generated loose deposition in the lower part of the landslides generally motivated more subsurface stormflow with the microporous flow. The two hydrological behaviors are related to the quick runoff generation mechanism with short confluence time, resulting in higher runoff potential. Therefore, the corresponding sentences have been revised as “After the abrupt disturbance, the exposed bedrock in the trailing edge of the landslides easily induced the Horton overland flow, and the generated loose deposition in the lower part of the

landslides generally increased the subsurface stormflow with the microporous flow (Mirus et al., 2017a; Zhang et al., 2018). Such two hydrological behaviors are related to the quick runoff generation mechanism with short confluence time, resulting in higher runoff potential”.

References:

Mirus, B. B., et al. (2017). "Hydrologic Impacts of Landslide Disturbances: Implications for Remobilization and Hazard Persistence." *Water Resources Research* 53(10): 8250-8265.

Zhang, J., van Meerveld, H. J., Tripoli, R., and Bruijnzeel, L. A.: Runoff response and sediment yield of a landslide-affected fire-climax grassland micro-catchment (Leyte, the Philippines) before and after passage of typhoon Haiyan, *Journal of Hydrology*, 565, 524-537, 10.1016/j.jhydrol.2018.08.016, 2018.

C24:L119-L120: Please clarify.

R24: Thanks for your suggestion. The unclear sentence has been revised to “Subsurface stormflow generated on the soil-bedrock interface under heavy rainfall conditions is one of the dominant runoff sources contributing to flash flooding”.

C25:L129: why is volumetric soil moisture content italicized?

R25: Thanks for your suggestion. The font “volumetric soil moisture content” is not italicized, and has been revised.

C26:L129-131: this sentence is unclear/ hard to follow.

R26: Thanks for your suggestion. The sentence has been revised to “Each probe equipped with eight sensors at a 10 cm depth interval was installed 80 cm in soil profiles below the surface (Figure 2a).”.

C27:L132-134: tense changes from rest of paragraph.

R27: Thanks for your pointing it out. It is revised to be simple past tense and is consistent with the tense from the above sentences.

C28:L139-140: please include in-text which method of baseflow-stormflow

separation was used.

R28: Thanks for your serious comment. The two-parameter recursive digital filter method was used to separate the quick flow (i.e. stormflow) and delayed flow (i.e. base flow) from total discharge for the storm runoff events (Eckhardt, 2005). The method has been illustrated in the revised manuscript.

References:

Eckhardt, K., 2005. How to construct recursive digital filters for baseflow separation. Hydrol. Process. 19 (2), 507–515

C29:L193: “non-stationary” rather than “non-stationarity”.

R29: The word “non-stationarity” has been revised to “non-stationary”.

C30:L203-205: I found the first half of this sentence difficult to understand/follow.

R30: The unclear sentence has been removed, and changed to “A significant negative correlation relationship ($p < 0.05$) between hydrologic thresholds and peak discharges was observed in this experimental watershed (Figure 4b)”.

C31:L271: “severally” rather than “several”?

R31: The word “several” has been revised to “severally”.

C32:L274-277: I am not sure what the authors are saying in this sentence.

R32: It was really unclear. The sentence mainly introduced that earthquake disturbance induced spatially uneven distribution and dynamic nonstationarity at timescales of landslide patches at watershed scales, such as the back-slope effect, hanging wall effect, etc. These processes generally have a large limitation in accurately assessing runoff generation and the dynamic evolution of catastrophic flash flood disasters. In the revised manuscript, the paragraph has been revised to be “This highlighted the importance of spatially uneven distribution and dynamic nonstationarity at

timescales of earthquake-induced landslide patches for an accurate assessment of the runoff generation and the dynamic evolution of catastrophic flash flood.”.

C33:L305: “from2011” missing space.

R33: Thanks for your reminder. It has been revised.

C34:L306: “It triggered...” what are the authors referring to as “it” in this context?

R34: Thanks for your comments. The paragraph “It triggered...” was unclear, and **has been revised to be** “During the period, the RP and VSA zones rapidly expended while the hydrological threshold behaviors were quickly recovered and improved”.

C35:L310: I do not understand the messaging of the Section 4.3 title.

R35: The title in Section 4.3 has been revised to “Limitations and Challenges in the identification of Nonunique Threshold Behaviors during Large Disaster Events”.

C36: L320: The spatial patchiness of which characteristics?

R36: Herein, the spatial patchiness within the watershed is mainly triggered by sudden disaster events. It possesses these characteristics. The landscape vegetation could be impaired. The forest canopy and vegetation-soil system generally could be destroyed, facilitating the reduction of the canopy interception and shallow soil water storage capacity. With the expansion of the broken patchiness, the structural hydrological connectivity is rapidly enhanced, accelerating the confluence process and stormflow generation. The words “spatial patchiness” have been revised into “spatially broken patchiness”.