Dear Dr. Brunner,

We would like to thank you and the three reviewers for your reviews of our manuscript "The relative importance of antecedent soil moisture and precipitation in flood generation in the middle and lower Yangtze River basin". We appreciate these insightful inputs that have helped to improve the quality of this manuscript. In response to the comments, we have made substantial revisions. Our response to each comment is listed below in blue with the specific line numbers of the changes we have made. Again, we appreciate the time and inputs from you and the reviewers.

Best regards,
Sheng Ye,
Jin Wang,
Qihua Ran,
Xiuxiu Chen,
Lin Liu

Reviewer #1 (Comments to Author (shown to authors):

The authors aimed to reveal the dominant factor controlling flood generation in the middle and lower Yangtze River basin by calculating the ratio of the relative importance of antecedent soil moisture and daily rainfall (SPR). And they further analyzed the relationship of SPR with topographic wetness index to understand the linkage between the dominant flood generation mechanism and watershed characteristics. It is a valuable study and within the scope of this journal. However, there are several aspects that need to be clarified and improved.

Reply: We appreciate the reviewer's comments, we have made our efforts to address the concerns and made corresponding revisions. We have indicated the specific changes in the manuscript described in the following response. We hope the reviewer find this satisfactory.

Major concern:

1.In this manuscript, some conclusions were drawn based on correlation analysis but not casual analysis. For example, on the relationship of soil moisture with flood events in large catchments, due to long concentration time, it is possible that high soil moisture is the result of large rainfall, and at the same time the large rainfall leads to flood under the condition with low antecedent soil moisture. But when using correlation, the used soil moisture is not the soil moisture generating this flood but the one after rainfall. Therefore, I suggest that the authors add area information of the study catchments and calculate the concentration time. Based on the information, some further casual analysis should be taken.

Reply: It is possible that soil moisture at the day before the annual maximum flood (AMF) may not be the soil moisture before event in large catchments due to the long concentration time. We estimated the concentration time for 10 sites with largest drainage area (larger than 10^5km^2): the ones on the main stream and at the outlets of major tributaries following the USBR method (USBR 1973; Gericke & Smithers 2014). As we can see from Table A1-1, the concentration time is mostly within two days for main stream sites and is less than 24hr for sites at the outlets of major tributaries. Since these are the sites with largest drainage area, the rest of the sites are likely to have shorter concentration time. That is, for the sites we focused on, the concentration time is likely to be within one day. Thus, the soil moisture at the day before AMFs would contribute to the generation of AMFs.

We agree with the reviewer that, even for the soil moisture before AMFs, it could still be the results of rainfall. Since the AMFs in our study region all come during rainy season, when rainfall comes in most of the time. It could be difficult to separate individual rainfall events. Thus, we chose the daily scale instead of event scale to avoid the uncertainties. The goal of this study is to present a framework that examines the relative importance of soil moisture and single day rainfall in flood generation. Given the estimated concentration time for the largest watersheds, we believe the soil moisture of the day before the AMFs could represent the saturation ratio of soil before the occurring of AMFs. Besides, the seven days accumulated rainfall (Figure 4f) also represents similar correlation with drainage area, similar with Figure 3a. That is, the impact of antecedent soil moisture sustains with the consideration of concentration time.

It would be more rigorous to take the concentration time into consideration as the reviewer suggested, we are planning to do it with hourly data for further in-depth analysis. We have included these discussions in Section 4.4 Limitations (please see lines 431 – 441, 460 – 463). Hopefully the reviewer finds our explanation satisfactory.

Table A1-1: Estimated concentration time for sites on main stream (start with MS) and at the outlets of major tributaries (start with TR).

Site Name	Concentration Time (hr)	Drainage Area (km²)
TR-Hukou	17.9	161,979
TR-Chenglingji	18.8	261,986
MS-Zhutuo	32.7	668,661
MS-Cuntan	32.8	827,799
MS-Wanxian	37.6	948,524
MS-Yichang	41.5	982,948
MS-Jianli	45.2	1,014,690
MS-Luoshan	46.3	1,276,676
MS-Hankou	51.0	1,432,008
MS-Datong	54.3	1,657,604

Ockert J. Gericke & Jeff C. Smithers (2014) Review of methods used to estimate catchment response time for the purpose of peak discharge estimation, Hydrological Sciences Journal, 59:11, 1935-1971, DOI: 10.1080/02626667.2013.866712

USBR (United States Bureau of Reclamation), 1973. Design of small dams. 2nd ed. Washington, DC: Water Resources Technical Publications.

2. The analysis was based on the estimation of antecedent soil moisture, whose reliability was dependent on the water balance. However, there isn't enough description for the method to estimate soil moisture. (1) The authors simulated daily soil water storage using a water balance equation, in which there isn't the exchange of soil moisture with groundwater. It can lead to a large error in humid regions, such as Yangtze River basin.

Reply: We agree with the reviewer that there is exchange process between soil moisture and groundwater in our study region. Since the exchange with groundwater is more complicated and heterogenous: i.e., rivers could receive groundwater recharge in hilly area and recharge groundwater in lower land (Che et al 2021). According to Huang et al. (2021), the variation of groundwater level in the Yangtze River basin is relatively small, and the overall water resources will be in a balanced state. Thus, in this study, we estimated the soil moisture following Berhuijs et al. in 2019 with a simple water balance equation, and didn't consider the groundwater exchange. We agree that accurate estimation of soil moisture is important in our study, and we are using the reanalysis soil moisture for further analysis at event scale. We have included these discussions in Section 4.4 Limitations (please see lines 442 – 450). Hopefully the reviewer finds our explanation satisfactory.

Che, Q., Su, X., Zheng, S., Li, Y.: Interaction between surface water and groundwater in the Alluvial Plain (anqing section) of the lower Yangtze River Basin: environmental isotope evidence. Journal of Radioanalytical and Nuclear Chemistry, 329, 1331–1343.

Huang, C., Zhou, Y., Zhang, S., Wang, J., Liu, F., Gong, C., Yi, C., Li, L., Zhou, H., Wei, L., Pan, X., Shao, C., Li, Y., Han, W., Yin, Z., and Li, X.: Groundwater resources in the Yangtze River Basin and its current development and utilization[J]. Geology of China, 2021, 48(4):979-1000.

(2) Equation 6 was used to estimate the change in soil water storage, but it isn't clear how to determine the initial value.

Reply: Since our simulation starts from January, the relatively dry period in the study region, the initial value of soil water storage was set to 0. Due to the long term of simulation, the change of initial value wouldn't significantly affect the results. We have clarified this in Section 2.3 (please see lines 164 – 165), we hope the reviewer finds it clear now.

(3) There is lack of necessary assessment on the estimated soil moisture.

Reply: We have to admit that the estimation of soil moisture is highly simplified, and may not always represent the actual condition at event scale. However, due to the lack of observation, it is difficult for soil moisture assessment: local measurements could not provide representative observation of soil moisture at catchment scale for our study region while remote sensing images can only provide soil moisture at the top 5cm (Babaeian et al 2019). While sophisticated models could be applied for the soil moisture estimation, there are also substantial uncertainties (Zaherpour et al., 2018). In this study, we used the mean annual values of the soil moisture which is considered as less impacted by the inaccurate representations at the event scale (Berghuijs et al 2019).

To further reduce the biases that may be caused by this simplified estimation, we replaced the normalized soil moisture with percentile soil moisture following reviewer #2's comment. The percentile soil moisture represents the relative saturation, and would be less influenced by the inaccurate representations at the event scale (Berghuijs et al 2019). As we can see from Figure A1-1 – A1-6, all the trends sustain with the percentile presentation. More rigorous assessment would be necessary if we want to apply our findings to specific catchments. Indeed, we are planning to use reanalysis soil moisture data along with in-situ observations to further validate our results in experimental catchments at event scale, but it is beyond the scope of this study. We have included this discussion in Section 2.4 and 4.4 (please see lines 198 – 202, 422 – 430, 431 – 441, 460 – 463). Hopefully the reviewer finds our explanation satisfactory.

Babaeian, E., Sadeghi, M., Jones, S. B., Montzka, C., Vereecken, H., & Tuller, M. (2019). Ground, proximal, and satellite remote sensing of soil moisture. Reviews of Geophysics, 57, 530–616.

Zaherpour, J., Gosling, S. N., Mount, N., Schmied, H. M., Veldkamp, T. I., et al. (2018). Worldwide evaluation of mean and extreme runoff from six global - scale hydrological models that account for human impacts. Environmental Research Letters, 13(6), 065015.

Berghuijs, W. R., Harrigan, S., Molnar, P., Slater, L. J., & Kirchner, J. W. (2019). The relative importance of different flood - generating mechanisms across Europe. Water Resources Research, 55, 4582–4593.

Figure A1-1: The spatial distribution of (a) the percentile of antecedent soil moisture during annual maximum flood; (b) the percentile of daily precipitation during annual maximum flood.

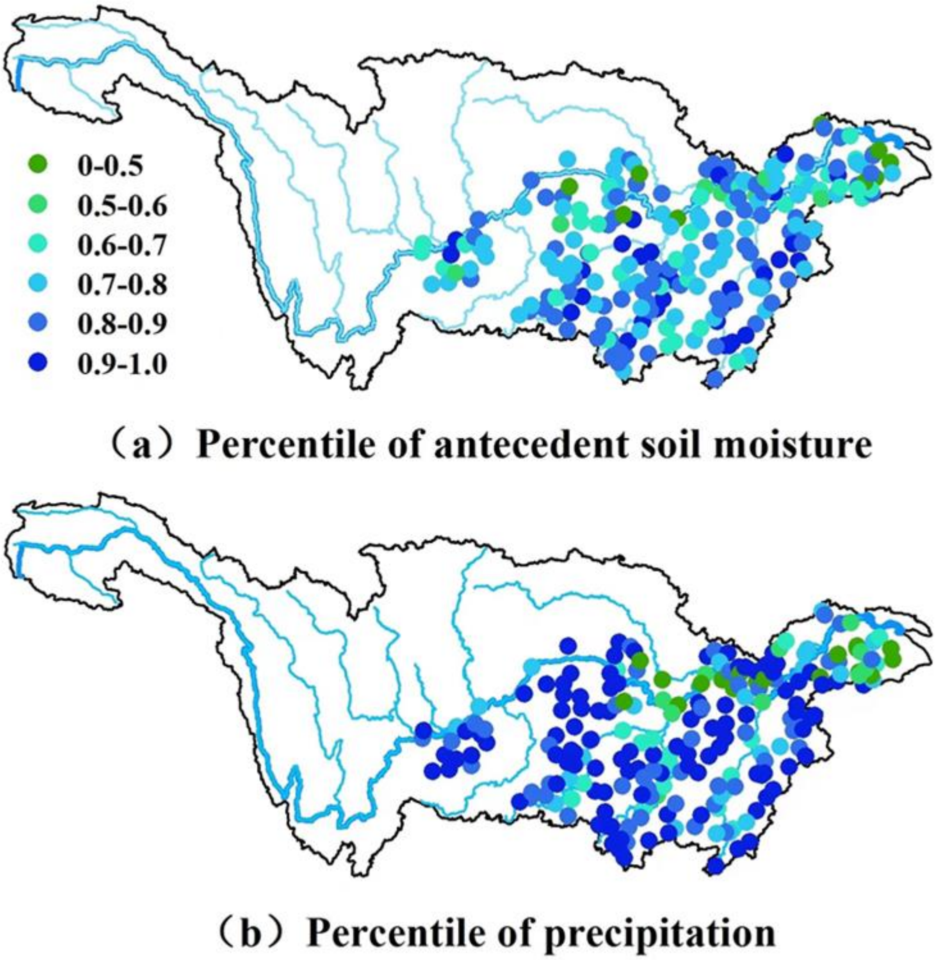


Figure A1-2: Scatterplot between the drainage area and (a) the percentile of antecedent soil moisture of AMF events (the linear regression for blue dots: $R^2 = 0.46$, p-value<0.001); (b) the percentile of precipitation at the day of AMF events (the linear regression for blue dots: $R^2 = 0.61$, p-value<0.001). The green dots represent the regulated watershed, the cyan dots represent the sites on the main stream, and the rest sites are shown in blue.

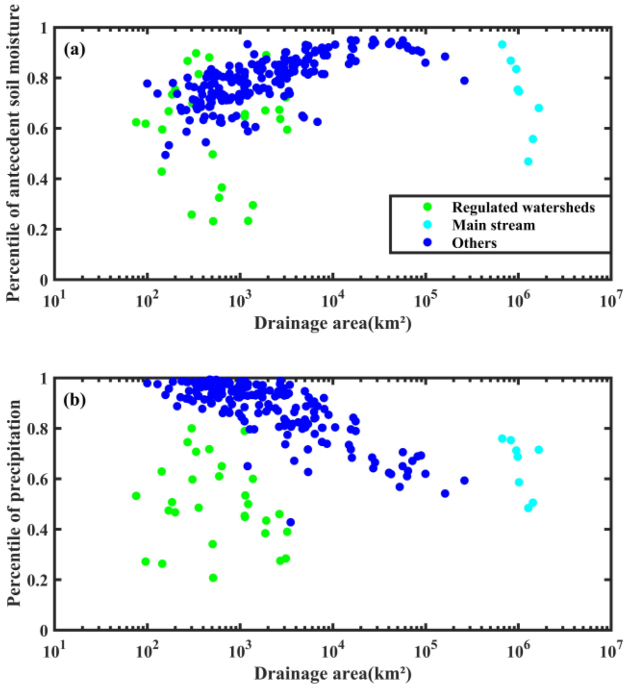


Figure A1-3: Scatterplot between the drainage area and the percentile of accumulated rainfall of (a) two days; (b) three days; (c) four days; (d) five days; (e) six days; and (f) seven days on AMF events.

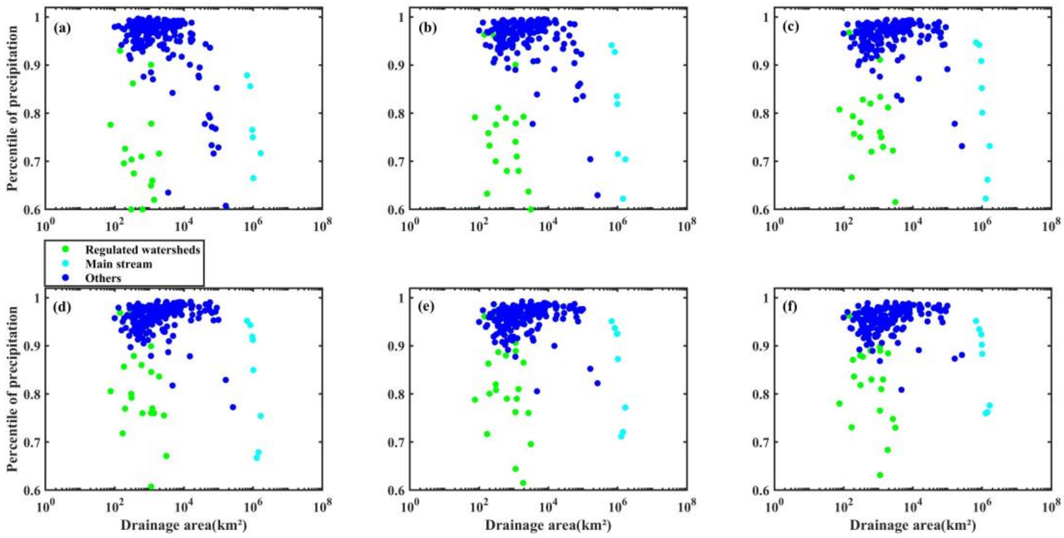


Figure A1-4: Scatterplot of the percentile of precipitation and antecedent soil moisture, the color represents topographic gradient and the size of circles is scaled by drainage area.

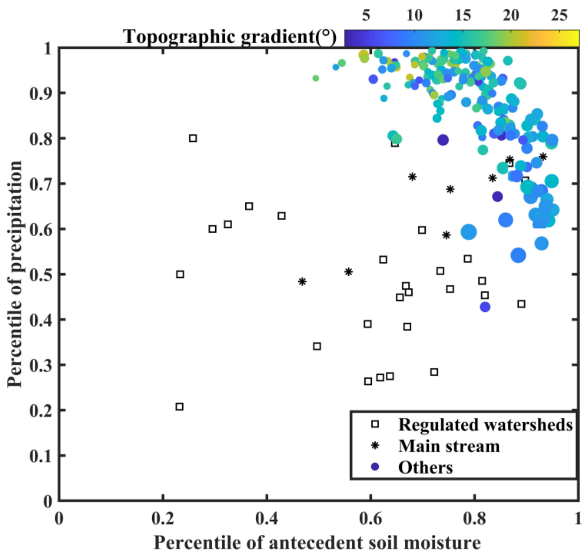


Figure A1-5: Scatterplots between the ratio of the percentile of antecedent soil moisture and precipitation (SPR) and (a) drainage area; (b) slope; and (c) topographic wetness index (TWI).

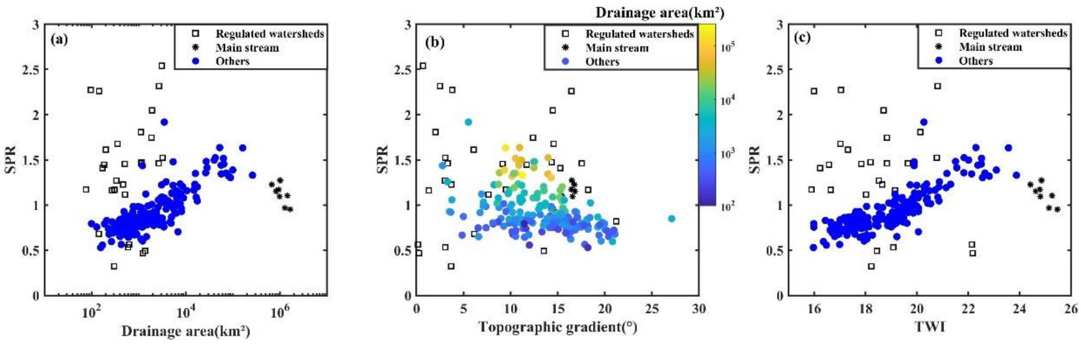
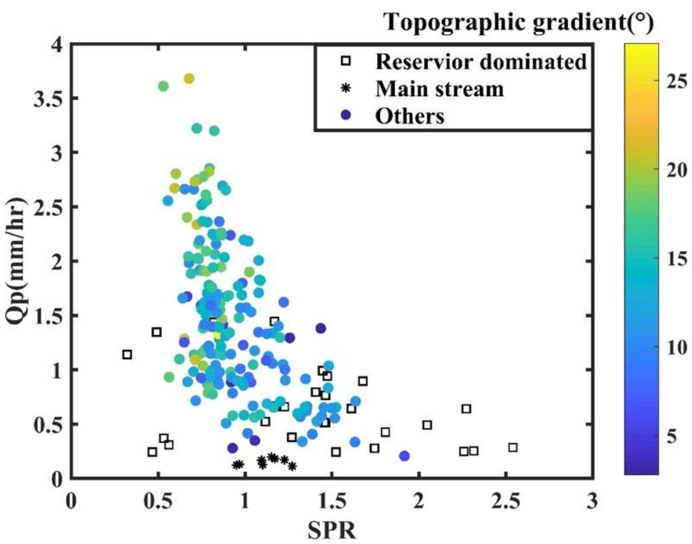


Figure A1-6: Scatterplot between the ratio of antecedent soil moisture and precipitation (SPR) and area weighted annual maximum discharge (Q_P), the color represents topographic gradient.



(4) As an important element of water balance, ET was calculated according to Equation 7, which needs being re-considered. First, the dimension of ET0 and ET is mm/d, while that of S is mm. Second, why the upper limit of ET is 0.75*ET0?

Reply: ET was calculated following Berhuijs et al. (2019). *S* was used as the upper limit of daily ET to make sure that daily ET flux would not exceed the soil water storage. The ET was scaled as 0.75*ET_0 following Berhuijs et al. (2019) to make sure it is smaller than the potential evaporation. This is a highly simplified estimation of ET; more sophisticated method should be used in further analysis on specific catchments at event scale. For this study, we used this as an illustration for the framework that differentiate the contribution of precipitation and soil moisture in flood generation. We have included this explanation and discussed in Section 2.3 and 4.4 Limitations (please see lines 170 – 173, 418 – 421, 422 – 430). Hopefully the reviewer finds our explanation satisfactory.

(5) It isn't clear whether the soil moisture has an upper limit.

Reply: Since we used the observed streamflow data for the water balance estimation, we didn't set an upper limit in the estimation of soil moisture. We calculated the Smax for our study catchments, they are mostly between 100mm and 300mm (Figure A1-7). According to the Harmonized World Soil Database (Nachtergaele, van Velthuizen, & Verelst, 2009), most of our study catchments belong to AWC (available water storage) class 1, that is 150mm/m (Figure A1-8). The soil depth usually varies between one and three meters; thus, the total soil water storage would be between 150mm and 450mm. Our estimated Smax is within the range. To further reduce the bias in soil moisture estimation, we replaced the normalized soil moisture with percentile soil moisture following reviewer #2's comment (Figure A1-A6). The percentile soil moisture represents the relative saturation, and would be less influenced by the inaccurate representations at the event scale. We have included the discussed in Section 4.4 Limitations (please see lines 422 – 430, 431 – 441). Hopefully the reviewer finds our explanation satisfactory.

Figure A1-7: Histogram of Smax across the study watersheds

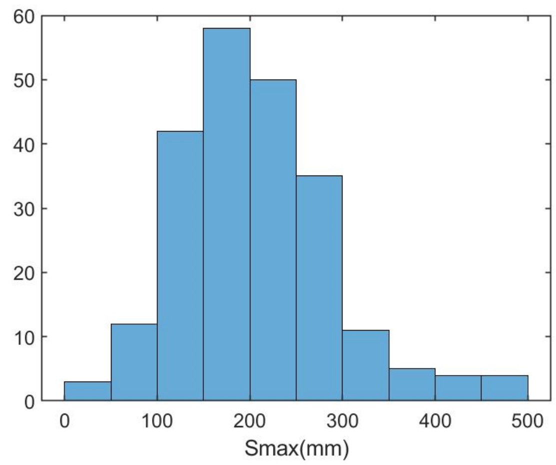
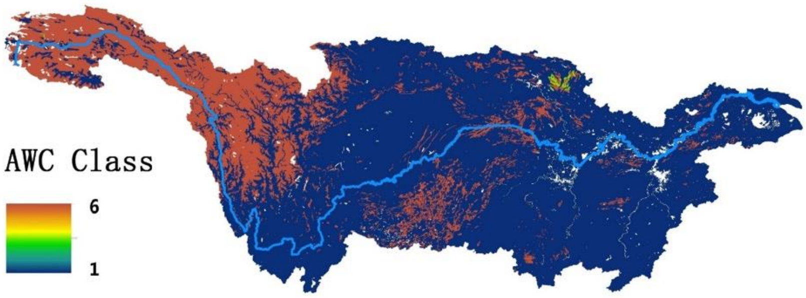


Figure A1-8: The available water capacity (AWC) class in the middle and lower Yangtze River basin.



Nachtergaele, F., van Velthuizen, H., & Verelst, L. (2009). Harmonized world soil database, Version 1.1. Rome: FAO/IIASA/ISRIC/ISSCAS/JRC.

3. The authors assumed that "When SPR is larger than 1, floods at those sites are more dominated by antecedent soil moisture; when SPR is less than 1, rainfall is the primary driver of floods." Why it is 1, not any other value? More explanations on its rationality are required.

Reply: SPR was calculated as the ratio between the saturation rate (*S'*) and the relative intensity (*P'*), both were normalized by the maximum values. In our revision, we have replaced the normalized soil moisture and daily rainfall with percentile soil moisture (*S'*) and percentile rainfall (*P'*) following reviewer #2's comment (Figure A1-1~A1-6). That is, both of them were ranks indicating how extreme they are. If *S'* is close to 1 and *P'* is small, then SPR would be larger than 1, that is, the soil moisture is close to the maximum while the rainfall is a relatively small rainfall comparing among the time series. Thus, the generation of runoff would be more dominated by soil saturation. Instead, if the soil is relatively dry (*S'* << 1) while *P'* is close to 1, then SPR would be smaller than 1. That is, the rainfall is close to the annual maximum rainfall while the soil moisture is relatively low. Thus, the generation of floods would be more dominated by extreme rainfall. That is, the larger the SPR is, the more dominant the soil moisture is in runoff generation, and vice versa. When SPR equals 1, the relative rank of soil moisture and rainfall are similar. Thus, we used 1 as the divide.

We agree that the demarcation on 1 could be a bit arbitrary, we have included these explanations in the introduction of SPR in Section 2.4, and changed it to focus on the trend instead of the divide: 'When SPR is large, the antecedent soil moisture is much closer to the maximum, floods are more affected by the antecedent soil moisture; while a smaller SPR indicates relatively larger magnitude of rainfall comparing with antecedent soil moisture, that is, rainfall is more extreme and influential in flood generation' (please see lines 205 – 209). Hopefully the reviewer finds our explanation clear now.

Detailed comment:

1. Line 60-61, it states that "Little work has been conducted on the flood generation mechanisms in China (except Yang et al., 2019)". It isn't correct. I notice that Yang et al. (2020) has been

listed in the reference. In fact, based on casual analysis, Yang et al. (2020) explored the flood generation mechanism and the dominant factors (antecedent soil moisture, rainfall, snow melt and etc.) in the Eastern Monsoon Region of China, including most of the Yangtze River basin.

Reply: Thank you so much for pointing out this, we have now included Yang et al. 2020 and rephrased the sentence: 'Such researches were just conducted in China recently, though still limited (Yang et al 2019; Yang et al 2020)' (please see lines 61 – 62). We hope the reviewer finds our revision appropriate now.

2. Line 76-77, a comment is similar to the above one.

Reply: Thank you for pointing this out. What we intended to say is that 'a quantitative evaluation of the relative contribution of rainfall and antecedent soil moisture and its change across watersheds is currently unavailable in China.' We are sorry about the confusion and have rephrased this sentence (please see lines 77 – 82), hopefully the reviewer finds our revision appropriate.

3. Line 171, maximum daily discharge?

Reply: Yes, it is maximum daily discharge, we have added daily in the sentence (please see line 187). Thank you.

4. Line 179, it isn't clear how to obtain Smax. Which data was used?

Reply: The Smax was obtained from the soil moisture estimated from Equation 6. Since we have replaced the normalized soil moisture with percentile soil moisture, we have removed Smax in the manuscript (please see lines 198 – 199)).

5. Line 181, it isn't clear how to define Pmax, the maximum in one year, or the maximum in all the years.

Reply: The Pmax is the maximum in each year and averaged for all the records to minimized the uncertainties. Again, since we have replaced the normalized rainfall with percentile rainfall, we have removed Pmax in the manuscript (please see lines 199 – 201).

Reviewer #2 (Comments to Author (shown to authors):

The authors analyse the relative importance of soil moisture and precipitation for the generation of the average annual flood in the Yangtze river basin. This is achieved by comparing the ratios of precipitation and soil moisture before the flood event with recorded maximum of the respective variable. The relative ratio of both variables shows a positive correlation with topographic wetness index and a negative correlation with magnitude.

Overall, I think the authors present a very thoughtful analysis which addresses some important drawbacks in our current approach to flood generating processes. Instead of annually averaged results I would have liked some more event-based results. Other recommended improvements are detailed below. I encourage the authors to take them into account for a great and improved article.

Reply: We appreciate the reviewer's comments, these insightful inputs have helped to improve the quality of this manuscript. We have made our efforts to address the concerns and made corresponding revisions. We have indicated the specific changes in the manuscript described in the following response. We hope the reviewer find this satisfactory.

Soil moisture estimation

The authors quote two sources upon which the soil moisture routine is based on: Berghuijs et al, (2016) and Deb et al (2019). Deb et al (2019) use a water balance equation, however they did not use it to calculate soil moisture. I do not see any relevance of this reference at this point. I would recommend following the simple bucket model by Berghuijs et al (2016) to calculate soil moisture, the update version in Stein et al (2020) or to consider a modelled soil moisture product, such as ERA5. They are less prone to water balance errors.

Reply: Thank you so much for the suggestion. We are sorry about the confusion caused by the citation of Deb et al 2019, we have removed it now. Actually, we did follow the simple bucket model of Berghuijs et al. (2016) to calculate soil moisture. We removed the snowmelt component as it has little impact on flood generation in our study region, where the climate is warm and AMFs occur in summer (Yang et al 2020). We have to admit that the estimation of soil moisture is highly simplified, and may not always represent the catchment condition accurately. Thus, we normalized it with maximum to reduce the impact of the biases in the estimation but keep the seasonal trend and calculated the multi-year mean to reduce the uncertainties. In this revision, we have replaced the normalized soil moisture with percentile soil moisture following the reviewer's comment (Figure A2-1 ~ A2-6). The percentile soil moisture represents the relative saturation, and would be less influenced by the inaccurate representations at the event scale.

We agree with the reviewer that reanalysis data like ERA5 are less prone to water balance errors and could provide more event-based results with its high accuracy. The goal of this study is to present a framework to evaluate the relative contribution of rainfall and soil moisture in flood generation, we mainly focused on mean annual scale, more detailed data with high resolution would be used for validation at specific catchment in our future work. Indeed, we have collected climate data with high resolution and reanalysis data to do further analysis at event scale, but this is beyond the scope of this study. We have included these discussions in Section 2.3 and 4.4 (please see lines 161 – 162, 170 – 173, 422 – 430, 460 – 463). Hopefully the reviewer finds our explanation satisfactory.

Yang, W., Yang, H., and Yang, D.: Classifying floods by quantifying driver contributions in the Eastern Monsoon Region of China, Journal of Hydrology, 585, 124767, 2020.

Normalizing precipitation/soil moisture

Precipitation has more of an extreme tail than soil moisture. This is due to the fact that soil moisture has an upper limit, e.g. when the soil is completely saturated. Although this is not currently reflected in the equation used for soil storage calculation, this difference should still be taken into account. Another problem with the current normalisation approach is that some catchments in the study period will have experienced more extreme precipitation events than others, simply due to the small time period. If catchment A has experienced a 100-year precipitation event in the observed time period, but catchment B has not, then the values of catchment B will generally be higher than in catchment A. An approach to reduce this uncertainty is to use percentile values as a form of normalisation instead which is more robust (though still not perfect) to this error.

Reply: We agree with the reviewer that precipitation could have more of an extreme tail than soil moisture. We drew the figures with percentile values following the reviewer's suggestion (Figure A2-1 ~ A2-6). As we can see, the trends seen in figures with normalized values also sustains with percentiles values: i.e., the positive correlation between antecedent soil moisture and drainage area, the negative correlation between antecedent soil moisture and drainage area, as well as the correlation between SPR and TWI which are less scatter in percentile plot. We have replaced these figures (Figure 2 – 7) in the manuscript with Figure A2-1 ~ A2-6.

Figure A2-1: the spatial distribution of (a) the percentile of antecedent soil moisture during annual maximum flood; (b) the percentile of daily precipitation during annual maximum flood.

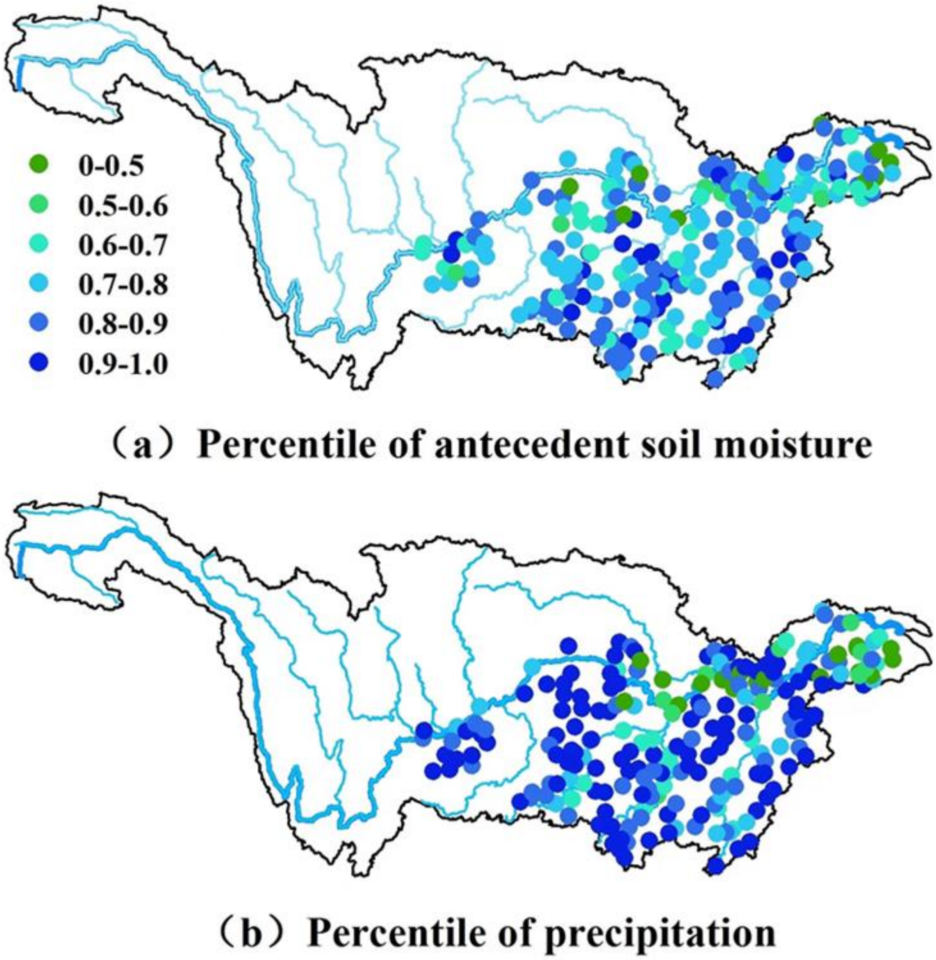


Figure A2-2: Scatterplot between the drainage area and (a) the percentile of antecedent soil moisture of AMF events (the linear regression for blue dots: $R^2 = 0.46$, p-value<0.001); (b) the percentile of precipitation at the day of AMF events (the linear regression for blue dots: $R^2 = 0.61$, p-value<0.001). The green dots represent the regulated watershed, the cyan dots represent the sites on the main stream, and the rest sites are shown in blue.

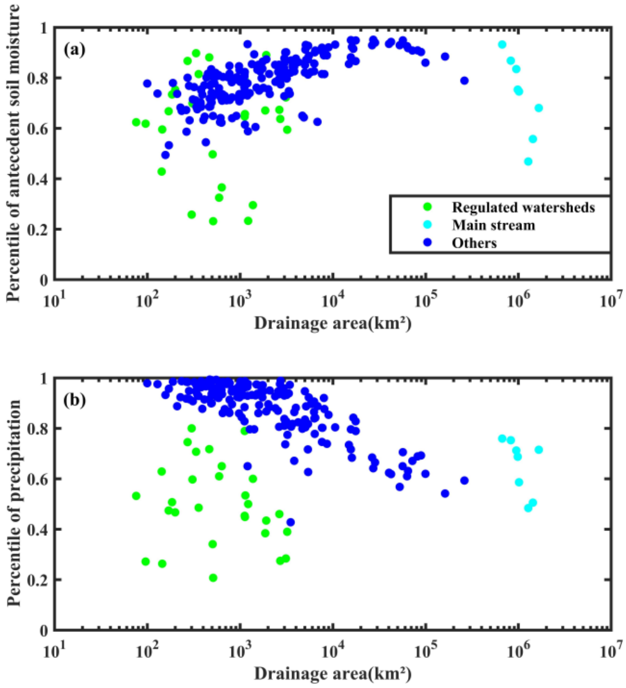


Figure A2-3: Scatterplot between the drainage area and the percentile of accumulated rainfall of (a) two days; (b) three days; (c) four days; (d) five days; (e) six days; and (f) seven days on AMF events.

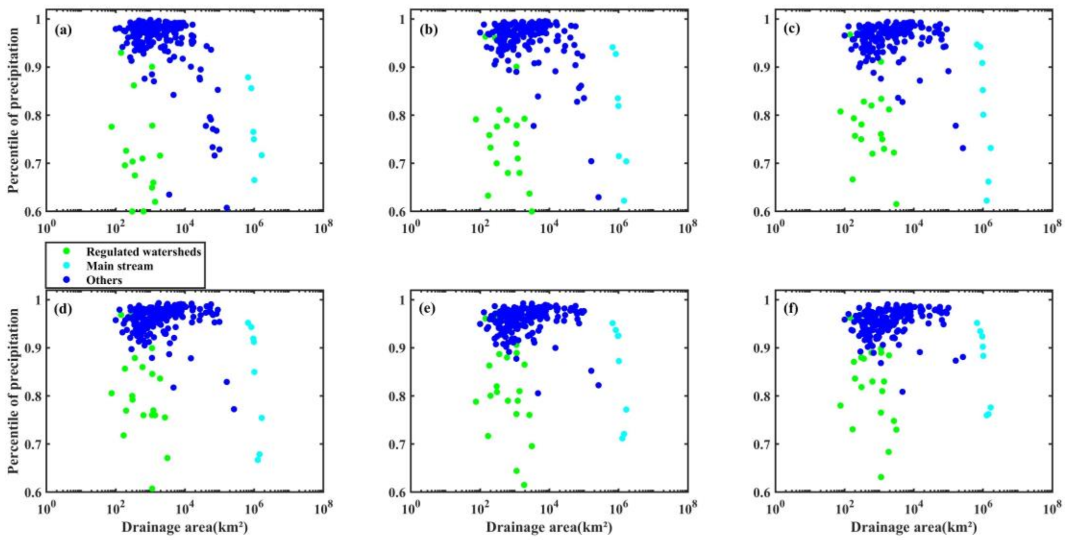


Figure A2-4: Scatterplot of the percentile of precipitation and antecedent soil moisture, the color represents topographic gradient and the size of circles is scaled by drainage area.

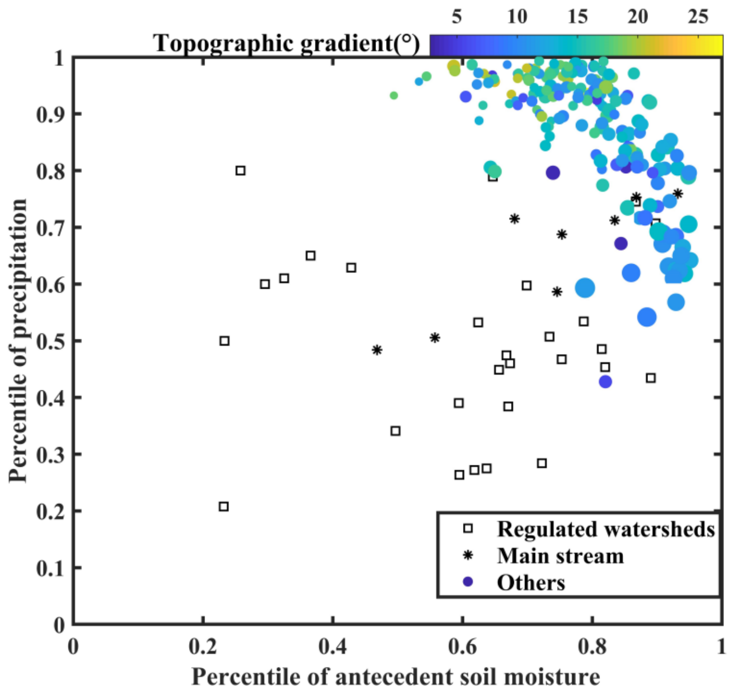


Figure A2-5: Scatterplots between the ratio of the percentile of antecedent soil moisture and precipitation (SPR) and (a) drainage area; (b) slope; and (c) topographic wetness index (TWI).

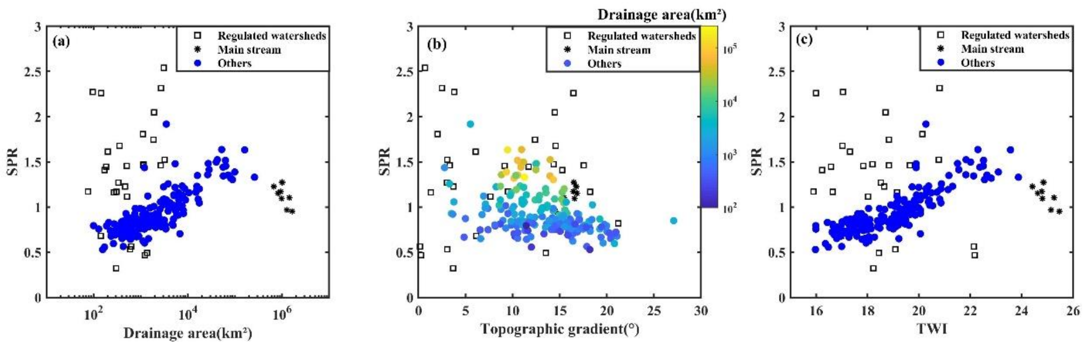
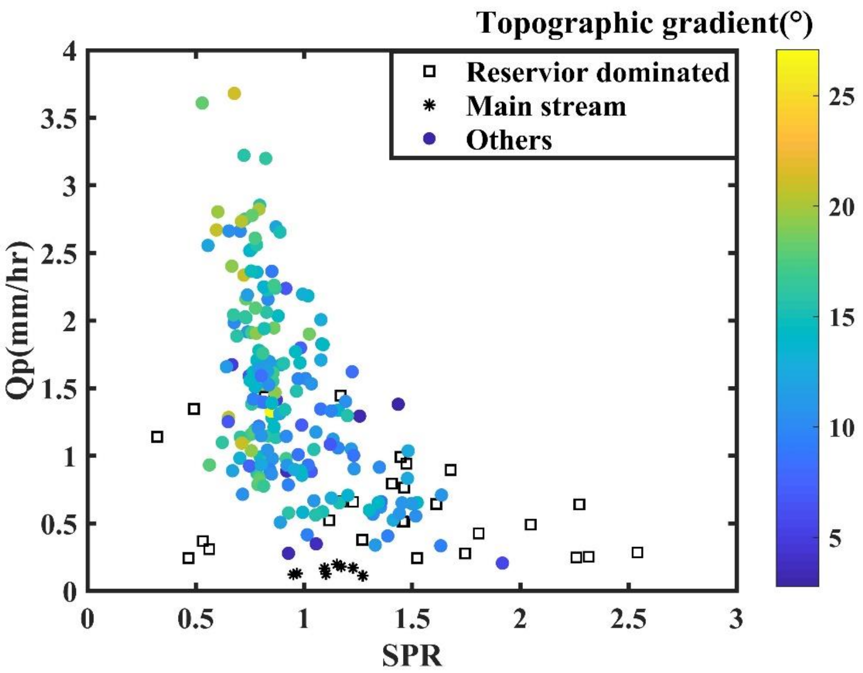


Figure A2-6: Scatterplot between the ratio of antecedent soil moisture and precipitation (SPR) and area weighted annual maximum discharge (Q_P), the color represents topographic gradient.



Section 4.3.

Being able to predict average annual flood magnitude for ungauged catchments would be a valuable discovery. This should certainly be explored further in another study. However, since all results are presented at an average and not event scale, I am not convinced that these approaches would work for flood early warning. For that the diversity of flood generating processes (Stein et al, 2020) is too high and the interplay between soil moisture and precipitation too diverse (e.g. Figure 5b, Saffapour et al, 2016). Just because a catchment is dominated by soil moisture, does not mean that an extreme precipitation event will not cause a flood. I would therefore recommend removing the discussion around early warning system and focus on predicting mean annual flood for ungauged catchments.

Reply: We agree with the reviewer that given the diversity of flood generation, the SPR we derived at an average not event scale is not sufficient for flood early warning. This study is to present a framework to quantitatively evaluate the relative contribution of rainfall and antecedent soil moisture at mean annual scale, the potential application on flood early warning would need more detailed analysis at event scale. We have removed the discussion about early warning and focused on predicting mean annual flood for ungauged catchments as the reviewer suggested (please see lines 488-495). Thank you again for your insightful suggestions. We hope the reviewer find our revision satisfactory now.

Minor comments

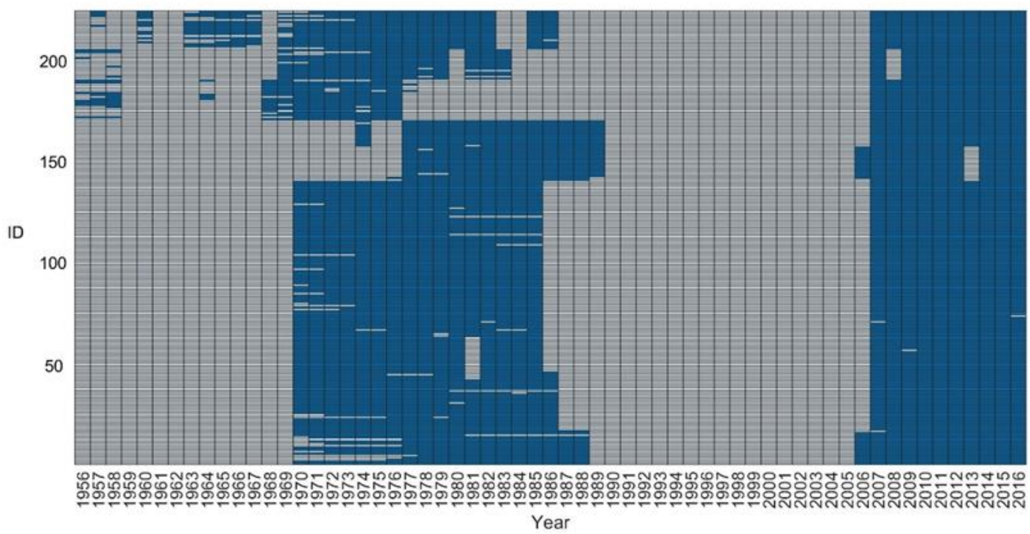
L61: Yang et al, 2020 presented an analysis on flood generating mechanisms in China.

Reply: Thank you for pointing this out, we have included Yang et al 2020 and changed this into: "Such researches were just conducted in China recently, though still limited (Yang et al 2019; Yang et al 2020)" (please see lines 61 – 62). Thank you.

L132: “with at least 20 years records from 1970 to 1990 and from 2007 to 2016 were selected”. Unclear. Does that mean that some of the stations only have data between 1970 and 1990, while others only have data between 2007 and 2016? These time periods have likely different climatic conditions and the older ones might have since had dams added to their catchment. Please clarify if my understanding is correct. If yes, please discuss the implications for your analysis and add a Figure to the supplement indicating data ranges for the stations.

Reply: We are sorry about the confusion. Each of the stations used have data from both periods. As we can see from Figure A2-7, All the stations have at least 9-year data from 2007 to 2016, and at least 11-year data from 1970 to 1990, that is, at least 20-year records in total. We have included Figure A2-7 in the supplementary and rewritten this sentence as: “with at least 20 years records from both the period from 1970 to 1990 and the period from 2007 to 2016 were selected (see Figure S1 for data availability).” (Please see lines 134 – 136).

Figure A2-7: The data availability of each station, each column indicates each year while each row is corresponding to each station, blue grid indicates there is record of this year.



L190-193: Can be removed since it repeats information from the Introduction.

Reply: We have removed these two sentences as the reviewer suggested (please see line 212). Thank you.

L200-203, 237-242, 256-266: Please ensure that you are not mixing results and discussion.

Reply: These are brief explanation for the results, which we discussed further in the discussion section. But as the reviewer indicated, it is better to differentiate results and discussion. We have moved most of these discussions in Section 4.1 now (please see lines 330 – 355).

L220: There are no red dots on the colour scale in Figure 2. Please clarify.

Reply: It should be 'blue dots', we have corrected it now (please see line 224). Thank you.

L308: Can you explain why the fact that smaller watersheds more easily reach saturation supports that they are less soil moisture dominated? They way the results by Sharma et al (2018) are mentioned might confuse some readers otherwise.

Reply: We are sorry about the confusion. What we want to say is that due to the relatively small drainage area, the heterogeneity would be small, and the hydrologic connectivity would be developed quickly, it would be easier to reach saturation in more parts of the catchment. As the reviewer mentioned, this sentence could cause some confusion, we have removed the citation of Sharma and rephrased this sentence as: "This contrast correlation with watershed size indicates a shift of dominance in AMFs generation, which may be attributed to the longer confluence time in the large watersheds and less heterogeneity in small watersheds." (Please see lines 327 – 329). Hopefully the reviewer finds our explanation clear.

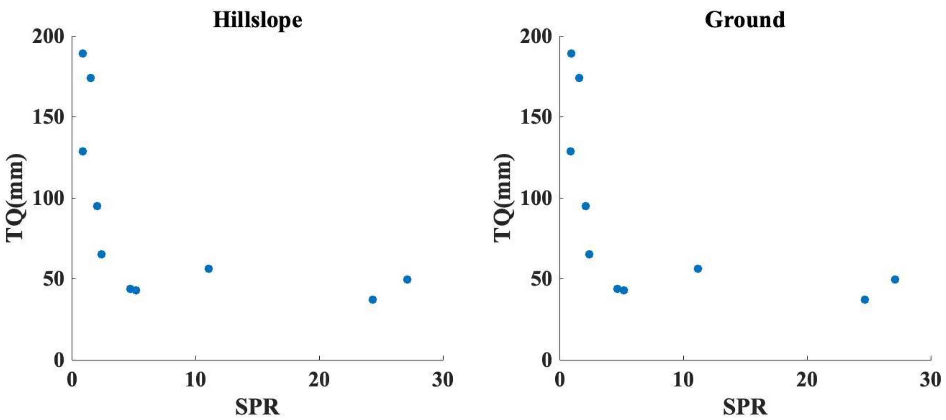
L321-322: The correlation between TWI and SPR is much weaker in the regulated watershed. It will most likely not be sufficient for any form of prediction in those catchments.

Reply: We agree with the reviewer that this correlation between TWI and SPR should only be applied to the 'natural watersheds' not the regulated ones or the ones on the main stream. We have changed it into: "That is, we could derive the relative dominance of soil moisture and rainfall in flood generation in specific watershed from its TWI for the natural watersheds without significant human intervention." (Please see lines 359-361).

L333-336: Where are the event scale results presented? It would be most interesting to see event scale results as well. Currently, I do not see any evidence that the results can easily be transferred to event scale.

Reply: It was from the field observation in a small mountainous catchment. We had soil moisture measurements at two spots, one on upslope and the other at the bottom, as Figure A2-8 presents, the SPR at both spots have negative correlation with total event discharge. Since this is a very preliminary results, we just want to say that there is possibility of application of this framework. We agree with the reviewer that so far, we don't have convincing evidence that the results can easily transferred to event scale. We have removed the discussion about early warning at event scale and focused on predicting mean annual flood for ungauged catchments as the reviewer suggested (please see lines 376 – 381).

Figure A2-8: The scatter plot between total event discharge and SPR at two observation spots.



Figures:

Please try to avoid the use of red and green together when they are the only distinguishing feature. People with colour vision deficiency will not be able to differentiate them. For alternatives, please check Stoelzle & Stein (2021).

Reply: Thank you very much for your kind reminder, we have replaced all the red dots with cyan ones in all the figures.

Figure 5: The scaling of point size according to drainage area is barely visible. Since drainage area is covered in Figure 6b as well, I would suggest to remove this scaling.

Reply: We agree that the size of the points representing the drainage area is not distinct. Since in this figure we also want to discuss the impact of drainage area, so it might be better to include the scaling here. We have amplified the difference of drainage area (please see Figure 5), hopefully it is clear now.

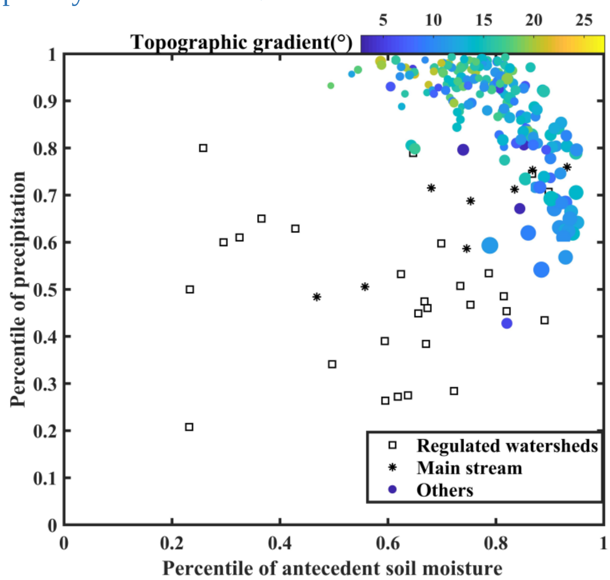


Figure 5: It is unclear what the dashed lines indicate.

Reply: The dashed line is used as illustration of the three groups of catchments: the relatively large and flat catchments on the bottom right that are more dominated by soil moisture, the relatively small and steep catchments on the upper left that are more rainfall dependent, and the rest of the catchments having floods with heavy rainfall on near saturated soil. But this is just a qualitative illustration, so we have removed the dashed line to avoid further confusion and focused more on the declining trend between the percentile of rainfall and percentile of antecedent soil moisture (please see Figure 5).

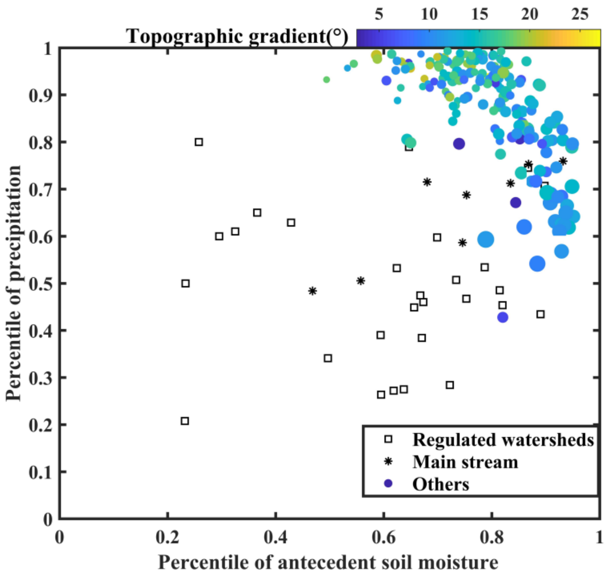
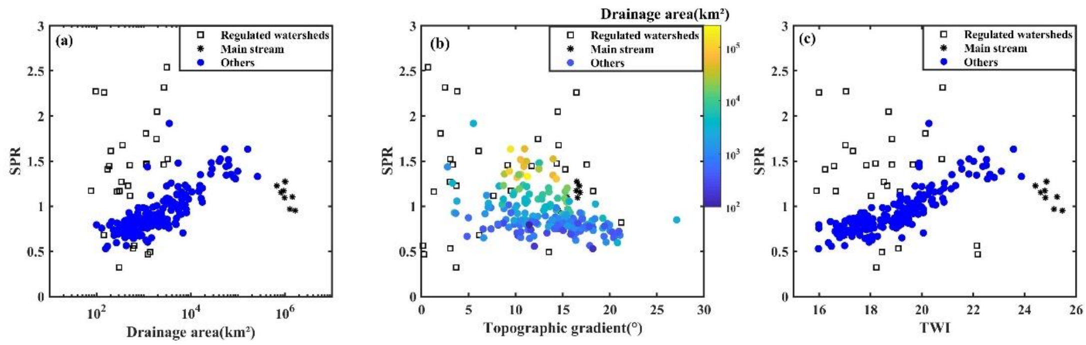
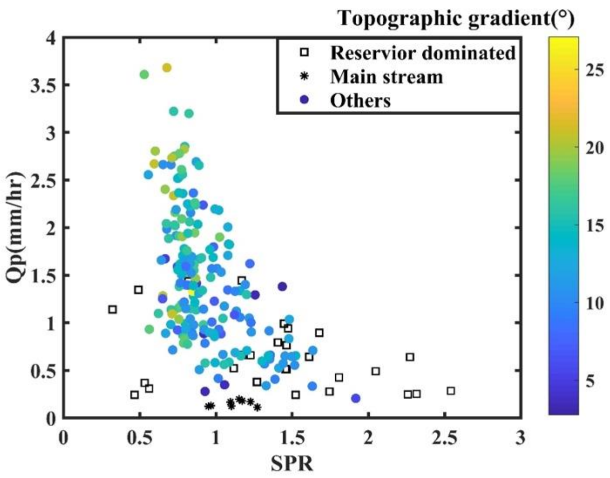


Figure 6b and 7: Since the text talks only about topographic gradient and not slope I would recommend using the same terminology in the Figures.

Reply: Thank you for the comment. We have replaced slope with topographic gradient in Figure 6b and Figure 7.





Saffarpour, S., Western, A. W., Adams, R., and McDonnell, J. J.: Multiple runoff processes and multiple thresholds control agricultural runoff generation, Hydrol. Earth Syst. Sci., 20, 4525–4545, https://doi.org/10.5194/hess-20-4525-2016, 2016.

Stein, L., Pianosi, F. and Woods, R., 2020. Event-based classification for global study of river flood generating processes. Hydrological Processes, 34(7), pp.1514-1529.

Stoelzle, M., & Stein, L. (2021). Rainbow color map distorts and misleads research in hydrology–guidance for better visualizations and science communication. Hydrology and Earth System Sciences, 25(8), 4549-4565.

Reply: Thank you for the literature input. We have included these in our manuscript now, thank you!

Reviewer #3 (Comments to Author (shown to authors):

I enjoyed reading this manuscript and believe the results presented here are very convincing – showing the dependence between soil moisture, rainfall, catchment area and flood magnitude. Although previous studies have attempted in parts to show this interplay (e.g. looking at trends), I feel this manuscript probably shows the most convincing and comprehensive results to date.

Reply: We appreciate the reviewer's comments, these insightful inputs have helped to improve the quality of this manuscript. We have made our efforts to address the concerns and made corresponding revisions.

Some general comments:
Line 178-187: I must admit I am having a bit of trouble with the S'/P' ratio. Maybe the wording could be changed a little bit; in line 181 it isn't the contribution of rainfall but really just the relative magnitude; in Line 186 it is not that one is more dominant than the other, it is just a relative measure. The demarcation on "1" is arbitrary and not helpful.

Reply: We agree with the reviewer that the S'/P' ratio is just the relative magnitude, and the demarcation on "1" could be arbitrary, we have rephrased this as: "When SPR is large, the antecedent soil moisture is much closer to the maximum, floods are more affected by the antecedent soil moisture; while a smaller SPR indicates relatively larger magnitude of rainfall comparing with antecedent soil moisture, that is, rainfall is more extreme and influential in flood generation." (Please see line 205 - 209). We hope the reviewer finds our revision appropriate now.

I am not convinced by Section 4.3 or Lines 411-423 for the flood warning because any SPR (low or high) could cause a flood because it is just a relative measure and has no measure of magnitude. You could have low rainfall and low soil moisture and get the same SPR as a high rainfall and high soil moisture. I don't think this can be used for forecasting.

Reply: We agree with the reviewer that SPR is just a relative measure, and given the diversity of flood generation, the SPR we derived at an average not event scale is not sufficient for flood early warning. This study is to present a framework to quantitatively evaluate the relative contribution of rainfall and antecedent soil moisture at mean annual scale, the potential application on flood early warning would need more detailed analysis at event scale. We have removed the discussion about early warning now (please see lines 395 – 406, 488 – 495). Hopefully the reviewer finds our revision appropriate now.

Also, I would concur with the other reviewer on the colour choice

Reply: Thank you for the suggestion, we have replaced the red dots with cyan dots for all the figures now.

Line by line comments:

Line 42: “frequency and intensity”?

Reply: Yes, extreme rainfall events are becoming more frequent and intense. We have included “intensity” in the sentence (please see line 42). Thank you!

Line 43: And hence understanding the drivers of change becomes more and more important Villarini, G., Wasko, C., 2021. Humans, climate and streamflow. Nat. Clim. Chang. 11, 725–726. https://doi.org/10.1038/s41558-021-01137-z

Reply: We have included this citation in the manuscript: “which requires better understanding of the underlying mechanism of flood generation as well as the drivers of change (Villarini & Wasko 2021).” (Please see line 45 - 46). Thank you so much for your input.

Line 61: remove “except Yang et al 2019” because in the next paragraph you demonstrate there are more studies than just this one.

Reply: Thank you for pointing this out. We have rephrased this sentence as: “Such researches were just conducted in China recently, though still limited (Yang et al 2019; Yang et al 2020).” (Please see line 61 – 62).

Line 76: I think there is an opportunity here to state what has been performed in terms of understanding the balance between soil moisture and rainfall as flood drivers (e.g. dependence on magnitude, catchment size, region etc). I appreciate these papers are quite recent and may not have come to the authors attention when writing their manuscript. Examples include:
Brunner, M.I., Swain, D.L., Wood, R.R. et al. An extremeness threshold determines the regional response of floods to changes in rainfall extremes. Commun Earth Environ 2, 173 (2021). https://doi.org/10.1038/s43247-021-00248-x
Wasko, C., Nathan, R., Stein, L., O’Shea, D., 2021. Evidence of shorter more extreme rainfalls and increased flood variability under climate change. J. Hydrol. 603, 126994. https://doi.org/10.1016/j.jhydrol.2021.126994
Bennett, B., Leonard, M., Deng, Y., Westra, S., 2018. An empirical investigation into the effect of antecedent precipitation on flood volume. J. Hydrol. 567, 435–445. https://doi.org/10.1016/j.jhydrol.2018.10.025
Bertola, M., Viglione, A., Vorogushyn, S., Lun, D., Merz, B., Blöschl, G., 2021. Do small and large floods have the same drivers of change? A regional attribution analysis in Europe. Hydrol. Earth Syst. Sci. 25, 1347–1364. https://doi.org/10.5194/hess-25-1347-2021

Reply: Thank you very much for your recommendation. These studies about the threshold effect, the elasticity of flow to antecedent precipitation relative to flood-producing precipitation are inspiring for our work. We have included these citations in the manuscript and rephrased this sentence to: “Recently, studies started to examines the relative importance of rainfall and antecedent soil moisture in flood generation (Brunner et al., 2021; Wasko et al., 2021; Bennett et al., 2018; Bertola et al., 2021). A quantitative evaluation of the relative contribution of rainfall and antecedent soil moisture and its change across watersheds is still limited and currently unavailable in China (Liu et al., 2021; Wu et al., 2015).” (Please see line 77 – 82). Hopefully the reviewer finds our revision satisfactory.

Line 93: “The Yangtze River”

Reply: We have made the suggested change (please see line 96), thank you!

Line 106: The ‘s’ is a typo.

Reply: Sorry about the typo, we have deleted it now (please see line 109), thank you.

Section 2: I am not sure Figure 1 was referenced anywhere? The caption says: “climate stations and hydrological”, the legend “hydrological and precipitation stations” and the text in Section 2.2 “meteorological and streamflow”. As a result, I am not actually sure what stations have what data.

Reply: Thank you for pointing this out. We have referred Figure 1 in Section 2.2, and changed it to “hydrological stations and meteorological stations” in the manuscript (please see line 133), figure caption as well as on Figure 1. Sorry about the confusion.

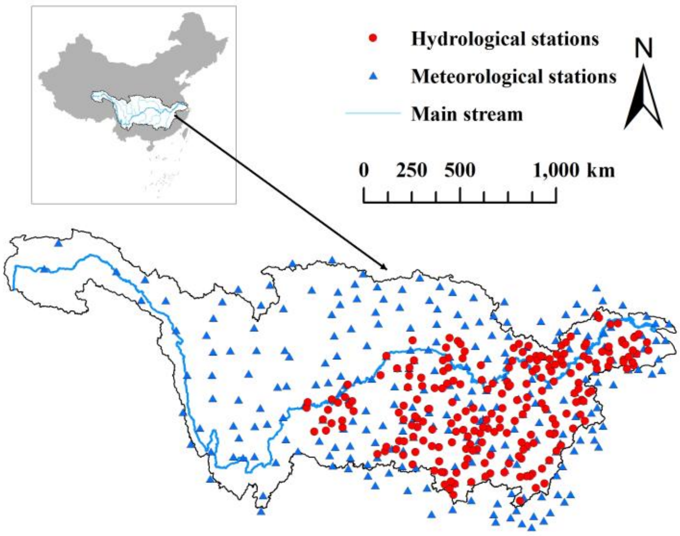


Figure 3 caption: Rather than saying “the green ones” you could say “the green circles” or “the green dots”

Reply: We have changed “the green ones” to “the green dots”, and “the red ones” to “the cyan dots” now (please see Figure 3 caption). Thank you.

Line 231: “Dominant driver” – again, this is subjective and I would remove this sentence altogether.

Reply: We have deleted this sentence as the reviewer suggested (please see lines 245 – 247), thank you.

Figure 4 y-axis: please label with normalized precipitation like you did in Figure 3.

Reply: Since we have replaced the normalized values with percentile values following reviewer #2's comment, we have changed the y-axis label to "Percentile of Precipitation" in Figure 4.

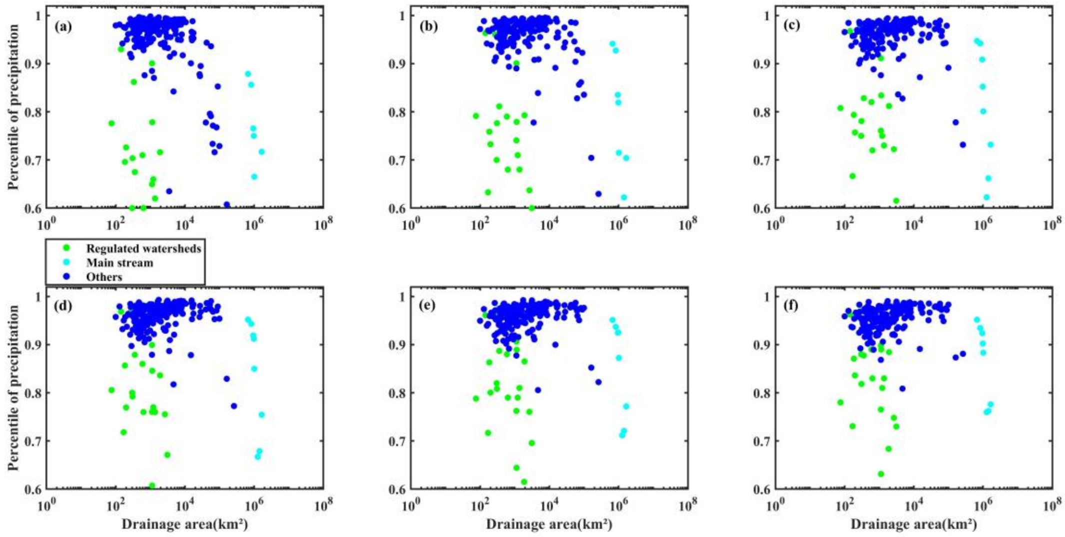
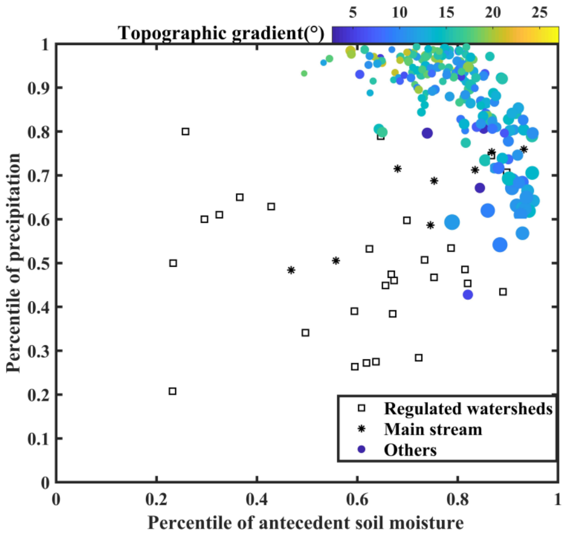


Figure 5: What are the slope units? The size of the dots needs a scale too. Figure 5 needs more explanation in the text to justify its place in the paper.

Reply: The unit of slope is (°). We have added it in Figure 5 and rescaled the size of dots to make it more distinct (following the comment of reviewer #2, we have also replaced the normalized soil moisture and rainfall with percentile values). We have also removed the dash lines as Reviewer #2 suggested. This figure is used for an illustration that we may divided the watersheds into three groups: the relatively large and flat catchments on the bottom right that are more dominated by soil moisture, the relatively small and steep catchments on the upper left that are more rainfall dependent, and the rest of the catchments having floods with heavy rainfall on near saturated soil. This could then lead to the derivation of TWI in Figure 6. We have included this discussion of Figure 5 and focused more on the declining trend between the percentile of rainfall and percentile of antecedent soil moisture in the manuscript now (please see lines 278 – 290). We hope the reviewer finds our revision and explanation sufficient now.

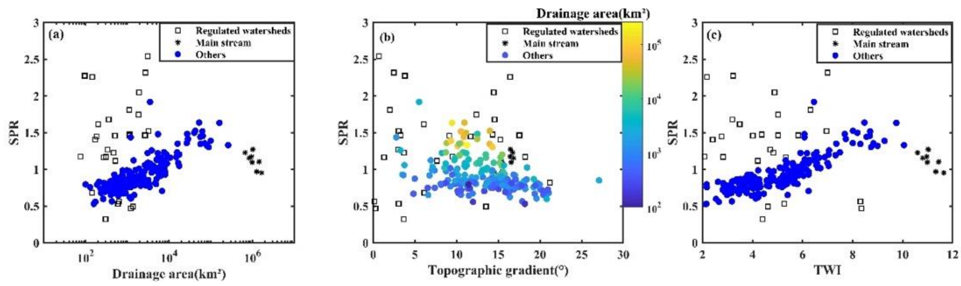


Line 275: Remove "the influential factors of"

Reply: We have removed "the influential factors of" as the reviewer suggested (please see line 291), thank you.

Figure 6: Units of drainage area?

Reply: The unit of drainage area is (km^2), we have added it in Figure 6 now. We have also replaced the SPR calculated from normalized values with percentile values following reviewer #2's comments.



Line 286: What is the practical implication of the TWI? Is it just dominated by the area? Not sure about the value or physical interpretation of Figure 6c. Okay – this comes in the discussion – but I think more should be mentioned in the results to point to this.

Reply: TWI is the ratio between drainage area and topographic gradient, it is influenced by both factors. Its correlation with SPR is similar with Figure 6a, but less scatter. That is, the inclusion of topographic gradient could help improve the prediction of SPR. TWI represents the propensity of subsurface flow accumulation and frequency of saturated conditions, and thus can be used to predict relative surface wetness and hydrological responses (Meles et al 2020). It is widely used to quantify topographic impact on hydrological processes: i.e., spatial scale effects, hydrological flow path, etc. It has also been used in land surface models for hydrological, biogeochemical as well as ecological processes (Sørensen et al 2006). Thus, the correlation between SPR and TWI is consistent with the physical representation of TWI, the relative surface wetness (TWI) could be used as indicator of the flood generation SPR. We have added brief description of TWI in Section 2.3 and this brief discussion in Section 3.4 as well (please see lines 178 - 184, 302 – 305). Hopefully the reviewer finds our addition sufficient now.

Sørensen, R., Zinko, U., and Seibert, J.: On the calculation of the topographic wetness index: evaluation of different methods based on field observations, Hydrology and Earth System Sciences, 10, 101–112, 2006.

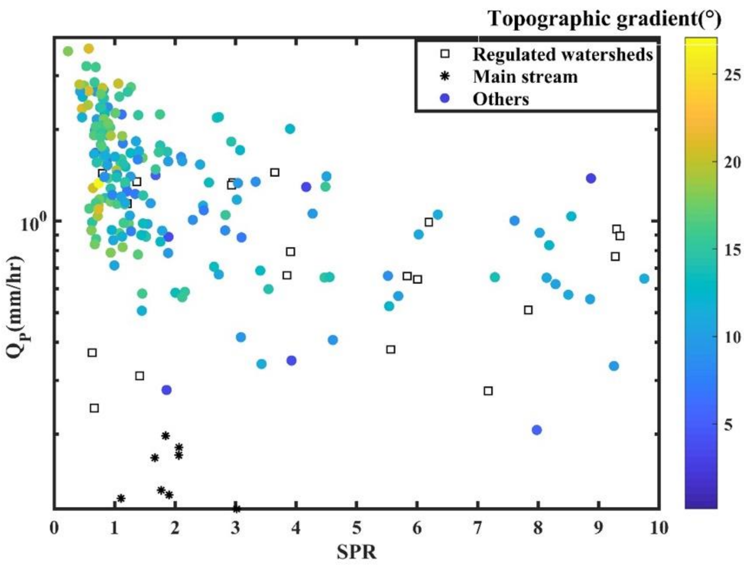
Meles, M.B., Younger, S.E., Jackson, C.R., Du, E., Drover, D.: Wetness index based on landscape position and topography (WILT): Modifying TWI to reflect landscape position, Journal of Environmental Management 255, 109863, 2020.

Figure 7: Again, more discussion is needed in the text, the authors may consider a log scale for the y-axis.

Reply: We agree with the reviewer that more discussion is needed for Figure 7. Following the other reviewer's comment, we have toned down the discussion on the event scale application and focused more on the discussion of mean annual scale. We have added the following discussion about Figure 7 in the discussion section (Section 4.2):

"Meanwhile, the SPR also present a negative correlation with the magnitude of AMFs (Figure 7). That is, we could infer the average AMFs based on SPR for each watershed. Since the characteristic SPR could be estimated from TWI, we could derive qualitative estimation of the mean AMFs from topographic characteristics that are easy to measure. This would be helpful for flood control management in ungauged watersheds, especially the mountainous watersheds with small SPR and flush floods. Similar correlation was also found in the observations from our experimental watershed, a headwater of Yangtze River (Liu et al 2021). The ratio of observed antecedent soil moisture and event precipitation also presents similar decline trend with total discharge at event scale. However, the correlation between SPR and discharge at event scale is preliminary, more observation data with higher resolution and detailed analysis are needed for validation at event scale. For this study, the goal is to present the framework of flood generation SPR that could be derived from topographic characteristics and used to provide information of mean AMFs." (Please see line 367 – 381).

We tried a log scale for the y-axis, as shown following, we think it may be better to keep the linear scale for the y-axis.



Line 375: Remove “for sure”

Reply: We have removed “for sure” now (please see line 422), thank you.

Line 377: “be used”

Reply: We have revised this paragraph corresponding to the change from normalized soil moisture to the percentile now (please see lines 422 – 430). Hopefully the reviewer finds it appropriate now, thank you.