Response to Reviewer Comments

Reviewer #1:

Dear Reviewer:

Thank you for your thoughtful and detailed review of our manuscript. We greatly appreciate the time and effort you dedicated to providing feedback. We have carefully considered all your comments and suggestions and revised our manuscript accordingly. All revisions are marked in red in the revised manuscript. Point-to-point responses to your comments are listed below:

1. This paper investigates precipitation space-time characteristics (from IMERG, presumably primarily from GPM and TRMM satellite missions) for 623 flood-causing precipitation (FCP) events over China during the period 2000-2023. Their primary conclusion is that "despite the increase in 3D characteristics of FCP events over the past two decades, flood disasters have shown a significant reduction, except for the direct economic losses". Unfortunately, they never say what they mean by "3D characteristics – the term appears only three times in the paper, twice in the abstract and once in the discussion -- but from Figure 3 one might conclude that these are centroid, magnitude, area, lifespan, moving distance, and moving speed. Importantly, these are all attributes of FCP; none have to do with flood characteristics themselves (e.g., inundation extent, depth, peak discharge, and so on).

Response: We appreciate your constructive comments and suggestions. In the revised manuscript, we have added a detailed description of 3D characteristics in Lines 15-16 as "***accumulated magnitude, accumulated affected area, centroid, lifespan, moving direction, and moving distance***". In addition, to investigate flood characteristics, we used surface runoff from ERA5 datasets and river discharge from GloFAS-ERA5 to represent land-surface runoff generation and river flood characteristics during the flood-causing precipitation (FCP) period. Detailed descriptions of GloFAS-ERA5 river discharge and ERA5 precipitation and surface runoff datasets are provided in Sections 2.1 and 2.2 of the revised manuscript, respectively. The spatial-temporal variations of surface runoff and river discharge during FCP periods are analyzed in Section 4.3 of the revised manuscript. To clarify the flood characteristics, we have added the following paragraph in Section 4.3 of the revised manuscript:

"**4.3 Spatial-temporal variation of surface runoff and discharge during the FCP event periods**

The spatial and temporal variations of hydrological processes during the FCP event periods are analysed (Fig. 7 and Fig. 8). It can be seen from Fig. 7 that FCP events associated with low surface runoff are found mainly in Northwestern China (NWC) and the Qinghai-Tibetan Plateau (TP). At the same time, FCP events with low surface runoff are distributed in the western parts of SC and NC. By contrast, FCP events with high surface runoff are predominantly observed in central SC and NC and northeastern NC. A comparison between TC and non-TC events reveals that the average surface runoff of non-TC FCP events is 30.81 $\times 10^3\,mm$, which is higher than that of TC FCP events with average value of 23.34 $\times 10^3\,mm$. Fig. 7b presents a similar spatial variation of river discharge. FCP events with high river discharge are primarily concentrated in the central of SC, NC, and northeastern parts of NC. These findings indicate that areas with large surface runoff and river discharge in the central SC and NC face a higher probability of flood occurrence..

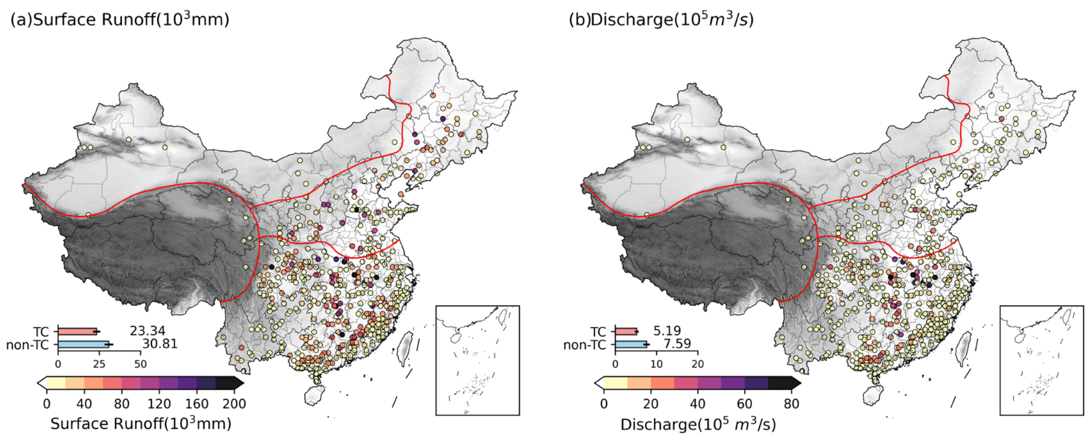

Figure 7. Spatial distribution of (a) surface runoff and (b) discharge during FCP event periods in China from 2000 to 2023. Bar chart illustrates the mean values of surface runoff and discharge of TC and non-TC FCP events. The shading indicates the terrain height.

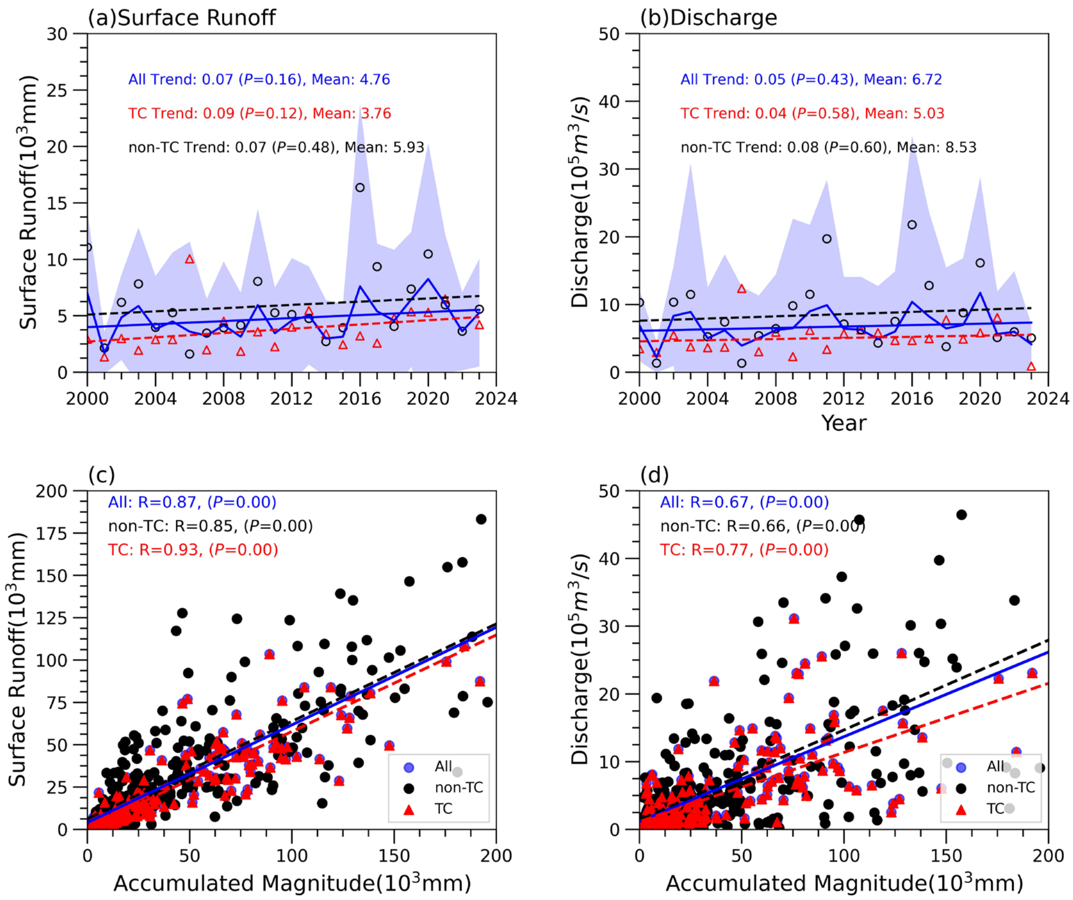

Figure 8. Time series of annual mean values of surface runoff (a) and discharge (b) during FCP periods in China from 2000 to 2023. The blue solid line and straight line indicate the time evolution and trend of mean values of surface runoff and discharge during 2000-2023, respectively. The blue shading indicates the ± standard deviation across the evolution of surface runoff and discharge during FCP events. The black dots and dashed line represent the annual mean values and trend of surface runoff and discharge during the non-TC FCP periods events from 2000 to 2023. The red triangles and dashed line represent the annually mean values and trend of surface runoff and discharge during the TC FCP periods events from 2000 to 2023. The relationships between surface

runoff and accumulated magnitude, and between discharge and accumulated magnitude are shown in (c) and (d), respectively. Black dots represent non-TC events, red triangles represent TC events, and the regression lines indicate the correlation trends (solid blue line for all events, dashed red line for TC events, and dashed black line for non-TC events). The Pearson correlation coefficient (R) and significance level (P) are provided for each category, showing significant positive correlations between the hydrological variables and accumulated magnitude at the 99% confidence level.

Figures 8a and 8b illustrate the temporal variations of surface runoff and river discharge during FCP event periods, respectively. Both surface runoff and river discharge show increasing trends, yet the trend is not significant at the 0.05 level. The mean surface runoff and river discharge for non-TC FCP events are higher than that of TC events. This finding can be attributed to increase of precipitation features in China, as shown in Fig. 5. According to the correlation analysis between the accumulated magnitude of FCP events, surface runoff, and river discharge, we find that surface runoff exhibits a significant correlation with accumulated magnitude (R=0.87, P<0.001). The correlation coefficients between the accumulated magnitude and surface runoff are 0.85 for non-TC and 0.93 for TC FCP events, both of which are statistically significant at the 0.01 level (Fig. 8c). By contrast, the correlation between accumulated magnitude and river discharge is relatively weaker, with the mean correlation coefficient greater than 0.67 and statistically significant at the 0.01 level. Consequently, enhanced 3D characteristics of FCP events across China drive increases in surface runoff and river discharge. Particularly, flood disasters are more prominent in central SC and NC."

2. Their primary source of flood information is something called the China Meteorological Disaster Yearbook. Exactly what is in this publication (or data base) I can't tell for sure as it's In Chinese, but it appears that it's only high-level attributes such as what one might find in NOAA's Billion Dollar Natural Disasters. So, they've managed to sidestep the entire field of flood hydrology, as well as what arguably is one of the current grand challenges facing the hydrologic community, specifically, if extreme precipitation is increasing, why aren't floods? (they do cite a 2018 WRR paper with that title). There in fact is reasonably conclusive observational evidence that extreme precipitation is increasing, and they cite some key papers along that line. But, they also note that "… despite the observed and projected increase in extreme precipitation, the flood magnitude and frequency exhibit mixed trend patterns. Several global scale flood trend detection studies have found that more stations exhibit significant decreasing trends in flood magnitude than increasing ones … These inconsistencies highlight the nonlinear relationship between precipitation intensity and flood disasters" What is widely acknowledged is that flood damages (but not necessarily deaths, especially in the developed world) have been increasing. Tanoue et al. (2016) have a pretty good paper on this, showing that increasing flood damages are strongly linked to increased development on flood plains. Surely this must be the case in China, especially during their study period. But that's hardly a new finding.

Response: Thank you for your note and suggestions. As you pointed out, flood disasters data used in this study is derived from the *China Meteorological Disaster Yearbook*, similar to NOAA's Disasters dataset. In this study, we systematically investigated the three-dimensional (3D) characteristics of FCP events, surface runoff, river discharge, and associated flood disasters from a 3D event-based perspective based on flood disaster data to improve our understanding of the characteristics and evolution process of rainstorms and floods. To further improve the analysis of flood processes, we introduced surface runoff (from ERA5) and river discharge (from

GloFAS-ERA5) in the revised manuscript. Our results show that evolution characteristics of FCP events have increased (not significant at the 0.05 level), and surface runoff and river discharge also show non-significant increasing trends. This finding indicates that the variations in rainstorms and floods in China are consistent, which is inconsistent with previous studies that found more stations exhibit significant decreasing trends in flood magnitude (e.g., Sharma et al. 2018). In addition, it is widely acknowledged that rising flood economic losses are closely linked to population growth and socioeconomic development in floodplains (Xie et al., 2018; Feng et al., 2023). In our study, we extracted and analyzed the 3D rainfall features, surface runoff, river discharge, and disaster impact of FCP events from 2000 to 2023 at the event-based scale. This event-oriented 3D framework effectively captures the spatiotemporal evolution of rainstorms and hazard impacts of flood disasters, providing more robust evidence for the relationships between flood hazards and changes in population and socioeconomic conditions, as illustrated in Figure 12 of the revised manuscript.

Reference:

Feng, J., Li, D., Li, Y., and Zhao, L.: Analysis of compound floods from storm surge and extreme precipitation in China. J. Hydrol. 627, 130402, https://doi.org/10.1016/j.jhydrol.2023.130402, 2023.

Sharma, A., Wasko, C., and Lettenmaier, D.P.: If precipitation extremes are increasing, why aren't floods? Water Resour. Res. 54, 8545-8551, https://doi.org/10.1029/2018WR023749, 2018.

Xie, Z., Du, Y., Zeng, Y., and Miao, Q.: Classification of yearly extreme precipitation events and associated flood risk in the Yangtze-Huaihe River Valley. Sci. China Earth Sci. 61, 1341-1356, https://doi.org/10.1007/s11430-017-9212-8, 2018.

3. Given the above, the contribution of this paper isn't clear to me. Certainly, "mining" the meteorological disaster yearbook, along with the precipitation data base, could yield some interesting insights, but I don't see how much that's very interesting could come from that without closely investigating the hydrological aspects of the floods. This clearly would involve some filtering to remove (or account for) the effects of flood regulation by dams and other means. There also is a question in my mind as to whether the length of the database (24 years) is sufficient, although perhaps they could make an argument for space for time substitution. In any event, the absence of any flood hydrology in the current version is, in my view, a fatal flaw, and I think the authors need to go back to the drawing board (and perhaps augment the author group with some flood hydrology expertise).

Response: We sincerely appreciate your valuable comments. In response to the core deficiencies in our manuscript, we have conducted in-depth reviews and improvements. We introduced river discharge reanalysis data from GloFAS-ERA5 to systematically evaluate the spatiotemporal variations of flood within regions affected by FCP events, thereby revealing the evolution of floods. Meanwhile, in order to be consistent with the GloFAS-ERA5 river discharge, we adopted ERA5 precipitation and surface runoff datasets that have the same source as GloFAS-ERA5, to systematically analyze the 3D spatiotemporal evolution of FCP and changes in land-surface runoff generation. Our results indicate that metrics of FCP events in China, including accumulated magnitude, accumulated affected area, centroid, lifespan, moving direction, and moving distance, all show increasing trends (insignificant at the 0.05 level). Correspondingly, surface runoff and river discharge also exhibit nonsignificant increasing trends.

Constrained by available datasets, this study cannot quantitatively assess the flood regulation effects of dams and other hydraulic projects. Nevertheless, based on the temporal and spatial distribution of dam construction in China shown in Fig. 1, the role of hydraulic projects in flood mitigation cannot be ignored. Although both flood-causing rainstorms and runoff display increasing trends, the hazard severity of floods in China have decreased. This implies that dams and hydraulic infrastructures play a critical role in national flood prevention and disaster reduction. Accordingly, we have explicitly acknowledged this limitation and discussed the impacts of hydraulic projects on rainstorm-flood hazards in the Discussion section (Lines 554-558 of the revised manuscript).

In addition, limited by the availability of historical disaster records, we have collected the most complete rainstorm-flood disaster data for this study, and we sincerely appreciate your understanding.

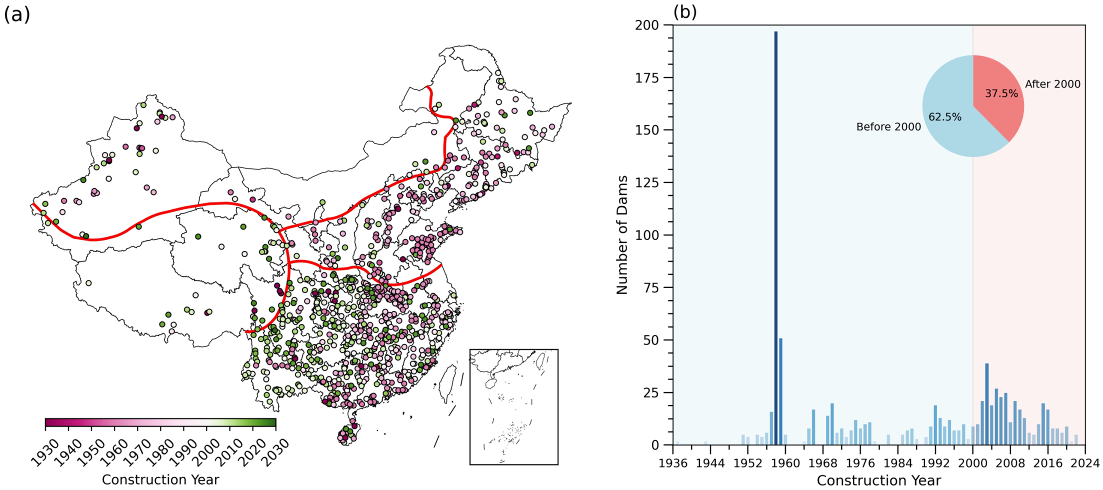

Fig. 1 (a) Spatial distribution of major dams and (b) the annual construction numbers of dams in China during 1930–2024