Authors' response to Editor's decision and comments from Reviewers

The most extreme rainfall erosivity event ever recorded in China up to 2022: The "7.20" storm in Henan province

Yuanyuan Xiao, Shuiqing Yin, Bofu Yu, Conghui Fan, Wenting Wang, Yun Xie

We would like to thank the editor and reviewers for their comments and suggestions. In the revised version, we have improved the text and figures, considered and addressed all the issues raised by the reviewers. We hope this revision is satisfactory for further processing of this manuscript.

Dear Editor,

Thank you very much for your feedback. We have revised the manuscript in detail, and responded to all the reviewers' comments. We would like to submit the revised version of our manuscript "The most extreme rainfall erosivity event ever recorded in China up to 2022: The "7.20" storm in Henan province" by Yuanyuan Xiao, Shuiqing Yin, Bofu Yu, Conghui Fan, Wenting Wang and Yun Xie.

We believe that we have considered and addressed all the suggestions from the reviewers and have substantially improved the manuscript. We look forward to hearing from you soon.

Below are our responses to reviewers. For clarity, each response is structured as follows: (1) RC# comments from Referees (black), (2) Authors' response (blue).

Thank you for your time and consideration.

Sincerely,

Yuanyuan Xiao

RC1: 'Comment on hess-2022-351', Anonymous Referee #1, REPLY

Comment: Regarding the maximum 1-minute intensity I do not agree with authors that this is not important if they used hourly data. I think this is very important since if there are errors in 1-minute data this is only aggregated to the hourly data. But if the same rainfall amount was measured using three different sensors then this is another thing that should definitely be mentioned in the manuscript. Hence, more details should be added regarding this verification using different sensors (which sensors, what was the difference, etc.).

Please, clarify this issue in the section on Materials and Methods, and if needed also in the section discussing the limitations of the study.

Response: We agree with the reviewer, Accuracy of the one-min rainfall intensity data is very important. Unfortunately, we are unable to obtain detailed information about the one-min data. In addition, we'd like to clarify that the three sensors, SL3-1, were used at each station, measurements with these sensos were used for verification purposes to ensure data quality. We have made the following changes in the revised manuscript.

Line 81-84: A multi-sensor system was used for precipitation measurement. The system consists of three separate SL3-1 tipping bucket rain sensors. Multi-sensor automatic weather stations detect abnormal or missing rainfall data caused by rain sensor failures to ensure precipitation data quality (He and Huang, 2015).

Comment: since you have applied only one KE-I equation, even though there are quite some presented in literature and you have not compared them, please, add this fact as a limitation to this study - also stating that when using another/different KE-I equation, the obtained results, such as the extremeness of this recorded event and therefore also its return period, may have been different as presented in this study.

Response: Different KE-I equations will lead to different results. It would be useful to acknowledge the uncertainty arising from the KE-I relationships. We have carefully compared the effects of using several KE-I equations including USLE, RUSLE, RUSLE2, van Dijk's, and found that different equations produced differences for this extreme event. We have added this as a supplement to this study, and included in the manuscript that when different KE-I equations were used, the erosivity value and return period of "7.20" storm were slightly different. At the same time, taking into account the concerns of several reviewers, we have added a discussion section in the manuscript to explain the uncertainty due to the KE-I equation, conversion factors, and frequency distributions. Please refer to the supplementary material for details. We have added the following content to the revised manuscript.

4 Discussion:

The above analysis shows that the "7.20" storm is the largest in terms of the rainfall erosivity among 2420 meteorological stations in mainland China up to 2022. However, there are limitations and uncertainties in our assessment due to KE-I equations, EI_{30} conversion factors, and probability distributions used.

Firstly, soil erosion processes are related to rainfall kinetic energy, which is a function of the size and fall-velocity of raindrops. Different KE-I relationships were recommended in different version of the USLE, and yet more location-specific KE-I relationships were noted for various regions around the world (van Dijk et al., 2002). Using different KE-I relationships, including those for the USLE, RUSLE, and from van Dijk et al. (2002), in addition to the RUSLE2 equation adopted for the study shows that other KE-I relationships would underestimate kinetic energy. Storm energy for the “7.20” storm using other KE-I relationships was 3.1% to 8.2% smaller than reported in the study, and the annual maximum event kinetic energy from 1951 to 2020 would differ by -16.9% to 28.7% from that reported in the study (Table S1.2). The uncertainty associated with different KE-I relationship does not increase with the magnitude of the rainfall event as shown in Fig. S1.1. Similarly, there are considerable differences in the estimated return periods of the event in terms of rainfall erosivity using different KE-I equations (Fig. S1.2). The return period of the “7.20” storm varied from about 20 thousand to more than 50 thousand years. The relatively small difference in event KE can lead to considerable differences in the return period for such an extreme event when the KE value of event exceeded all other KE values for the site by at least an order of magnitude. These large uncertainties associated with the return period of extreme precipitation have been noted in Germany (Grieser et al., 2007).

Secondly, rainfall erosivity is usually calculated using long term precipitation records from rain gauges, and depends strongly on the temporal resolution of the precipitation data used. Data at higher temporal resolution would be higher desirable to compute rainfall erosivity is high temporal resolution. However, such data are in short supply, short in length and sparse in spatial coverage. R-factor values decrease with decreasing temporal resolution because intensities are reduced when precipitation amount is aggregated over longer time intervals (Fischer et al., 2018). Therefore, it is necessary to use conversion factors to adjust the computed EI_{30} value using data of low temporal resolution. The conversion factor for the 1-in-10-year EI_{30} computed with the one-min resolution rainfall data is 1.489, which was appropriate for evaluating extreme rainfall erosivity in this study. To allay the reviewer’s concerned, we collected one-min temporal resolution rainfall data from Zhengzhou Meteorological Station from 2005 to 2016, The annual maximum EI_{30} values estimated using one-min and one-hour data were compared (Fig. S2.2). The conversion factor for the annual maximum EI_{30} at Zhengzhou meteorological station is 1.974, which is very close to the conversion factor of 1-in-10-year EI_{30} is 2.029.

Finally, the estimated return period depends on the selected probability distribution function. Different probability distribution functions can produce quite different estimates for large return periods (Laio et al., 2011). Three frequency distributions were considered and tested, including Generalized extreme value (GEV), P-III, and LP-III was found to be the most appropriate (Table S3.1). All the three distributions fitted the observations well, and performance indicator values do not suggest a single distribution that consistently and significantly superior to others (Table S3.2). The return period estimated by the three probability distributions are quite different. The average recurrence intervals of the maximum event rainfall erosivity of GEV and P-III for “7.20” storm exceeds 340,600 years, which is far greater than reported in the study. The estimated return period of around 20,000 years for the “7.20” storm is conservative. The estimated return period would be much higher if we use other KE-I equations and other probability distributions. Given LP-III was widely recommended for extreme precipitation and flood events in China (Chen et al., 2012), LP-III was used to assess the return period of this “7.20” storm. Estimating return periods comes with large uncertainties, especially for return periods exceeding the length of the observational record (Bloemendaal et al., 2020).

RC2: 'Comment on hess-2022-351', Anonymous Referee #2, REPLY

Comment: the title and the text are using the expression "the most extreme rainfall erosivity event ever recorded in China" - which is fine, but you must the date, e.g. till 2022, so that possibly more extreme events in future will be regarded as a new extreme - this is quite easy to incorporate into the title and the text.

Response: We have changed the title “The most extreme rainfall erosivity event ever recorded in China: The “7.20” storm in Henan province” to “The most extreme rainfall erosivity event ever recorded in China **up to 2022**: The “7.20” storm in Henan province”. In addition, we have added “up to 2022” in the following position of the manuscript.

Line 20: “and these were the maximum rainfall erosivity ever recorded among 2420 meteorological stations in mainland China **up to 2022**”

Line 65: “The maximum hourly rainfall between 16:00 and 17:00 on 20 July reached 201.9 mm at Zhengzhou meteorological station, the highest ever recorded in China **up to 2022**”

Line 265: “geographical distribution of the maximum daily rainfall erosivity ever recorded at each of 2420 meteorological stations in China **up to 2022** is shown as a function of the latitude in Fig. 9.”

Line 279: “Geographical distribution of the maximum event rainfall erosivity ever recorded at each of 2420 meteorological stations in China **up to 2022** is shown as a function of the latitude in Fig. 10.”

In addition, we have revised and updated the manuscript because we found that there was a calculation error in the rainfall erosivity used for frequency analysis. Using a conversion factor of 1.489 consistently, we updated the relevant results in the manuscript.