**No: NHESS-2021-218**
**JOURNAL: Natural Hazards and Earth System Sciences**
**MS TITLE: Spatiotemporal evolution and meteorological triggering conditions of hydrological drought in the Hun River basin, NE China**
**AUTHORS: S.P. Yue, F.T. Yang, X.D. Sheng**
**RESPONDENCE AUTHOR: Shupeng Yue (yuesp_123@163.com)**

**RESPONCES TO THE REVIEWERS' COMMENTS**

We do appreciate all useful comments and suggestions on our manuscript.

The MS was thoroughly revised, against all revision comments from the editors and reviewers. We have taken this opportunity also to read through and tried to perfect the analysis details, discuss the results more comprehensively and pick up any minor grammar, wording or format problem and made corrections accordingly so that it strictly follows the Journal formatting requirements. Detailed corrections and revisions are listed below point by point. And, all the revisions have been addressed in the reply.

***Reviewer # 1:***

**1.** ***Page 2 Line 12 Therefore and elsewhere***
[Authors' response]: We gratefully appreciate for your comment. We are very sorry for the mistakes in our manuscript and inconvenience they caused in your reading. We have changed 'Therefor' to 'Therefore' in our revised manuscript (Page 2 line 11).

**2.** ***Page 3 line 8 to make a link with the previous sentences it would be helpful to say that SPI is an index based on cumulative precipitation***
[Authors' response]: We gratefully appreciate for your comment. As suggested, we have optimized and adjusted this part in our revised manuscript combined with 3th comment.

**3.** ***Page 3 from line 9 to line 22 it is part of methodology and should be removed from there to the methodology section. However, the literature review about PTMH should be kept while adding a sentence concerning the advantages and eventually drawbacks of PTMH***
[Authors' response]: We gratefully appreciate for your comment. As suggested, the comments have been moved to the methodology section, and the literature review about PTMH has been retained in our revised manuscript (Page 2 line 24 to 27 and Page 4 line 11 to 23).

**4.** ***Page 4 line 14 data in place of dates***
[Authors' response]: We gratefully appreciate for your comment. As suggested, we have changed 'dates' to 'data' in our revised manuscript (Page 4 line 5).

**5.** ***Page 4 line 17 Thiessen with T not t***
[Authors' response]: We gratefully appreciate for your comment. As suggested, we have changed 'thiessen' to 'Thiessen' in our revised manuscript (Page 4 line 8).

**6.** ***Page 4 line 26 Gamma distributions***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have changed 'gamma distribution' to 'Gamma distributions' in our revised manuscript (Page 4 line 29).

**7.** ***Page 4 line 30 Authors need to test the normality of the SPIs and SRIs series. A normality test should be applied before accepting the Gamma.***

[Authors' response]: We gratefully appreciate for your comment. To calculate SPI, first, a monthly precipitation data set is prepared for a period of *m* months. A set of averaging periods are selected to determine a set of time scales of period *i* months. The data set is moving in the sense that each month a new value is determined from the previous *i* months. Then, each of the data sets are fitted to the Gamma function to define the relationship of probability to precipitation. Finally, the SPI value is obtained through equiprobability transforming the cumulative probabilities of the Gamma distribution to the standard normal distribution. Meanwhile, the standardization theory was also applied to runoff to obtain the SRI. Therefore, theoretically speaking, SPIs and SRIs series follow the standard normal distribution. In addition, the SPIs and SRIs series used in the study were normalized and the results showed that they obeyed normal distribution at 0.05 confidence level.

**8.** ***Page 6 line 2 to 16 in this work, the drought definition is more complex than using SRI. It is based on several criteria that are combined. Authors should put more light on this peculiarity in the body text and the abstract. The title of paragraph 3.3 should be changed consequently. A proposal for title is drought identification and copula estimation.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we added the introduction to the definition of drought based on optimized run theory in our revised manuscript, so that it could be more light in the article (Page 6 line 6 to 12).

[Authors' response]: We gratefully appreciate for your comment. As suggested, the title of paragraph 3.3 has been changed to 'Drought identification and copula Estimation' in our revised manuscript (Page 6 line 4).

**9.** ***Page 8 line 12 in Eq 6 Tp and D are not specified. Also, the relationship between period i and month m is not specified***

[Authors' response]: We gratefully appreciate for your comment. As suggested, a detailed description of $T_{pt}$ and $D$ in Eq 6 has been added in our revised manuscript. Meanwhile, the relationship between period *i* and month *m* has been explained (Page 8 line 10 to 16).

**10.** ***Page 9 line 7 and 8 this sentence belongs to methodology. It should be removed.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, the content mentioned in the comment has been removed.

**11.** ***Page 13 line 20 Periodicity should be replaced by return period***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have changed 'periodicity' to 'return period' in our revised manuscript (Page 14 line 5).

**12.** ***Page 14 line 13 and 14 this sentence should be in methodology section***

[Authors' response]: We gratefully appreciate for your comment. As suggested, the content mentioned in the comment has been moved to the methodology section (Page 7 line 11 to 14).

**13.** ***Page 14 line 16 the median corresponds to 0.5 only in case of normality. That is why it is important to check for normality. In the paper of McKee et al 1993 on page 3, they insist on the fact that SPI is normally distributed. So it is***

***needed to check for normality for SPI and SRI. Did authors verify using their samples that the median is 0.5?***
[Authors' response]: We gratefully appreciate for your comment. In this study, according to the univariate empirical frequency of drought duration (D) and severity (S), three typical drought scenarios were selected to analyze the return periods. The scenarios corresponding to the empirical frequency of 0.50, 0.25 and 0.05 of the univariate were defined as moderate, severe and extreme drought (i.e. Moderate drought is defined as the drought whose duration and intensity are greater than their corresponding values at univariate frequency equal to 0.5). The optimal distributions of drought duration and drought intensity have been listed in Table 3 of our revised manuscript (Page 14 line14).

**14.** ***Page 15 line 13 how did authors computed the uncertainty of the correlation coefficient? The uncertainty of sample correlation coefficient depends mainly on the sample size and the value of the correlation coefficient.***
[Authors' response]: We gratefully appreciate for your comment. The determination of the uncertainty of correlation coefficient is based on the theory of set pair analysis (Zhao, 2000; Wang et al., 2010). Based on the theory of set pair analysis, the relation degree of $X$ and $Y$ is established by the identical-discrepant-contrary analysis of dependent variable $X$ and independent variable $Y$. $S$, $F$ and $P$ represent the number of identical, discrepant and contrary subsets in $X$ and $Y$ sets. When $X$ and $Y$ are positively correlated in general, that is, the correlation coefficient $r$ is positive, $S$ of N samples are certain, and $F+P$ is uncertain, which can be expressed by the correlation degree $\mu$:

$$\mu = \frac{S}{N} + \frac{(F+P)}{N} \times i \; or \; (\mu = a + b \times i)$$

The larger $a$ is, the stronger the positive correlation trend of the two sets is. Therefore, $r$ can be decomposed into positive correlation of $r_a$ part and uncertain correlation of $r_b$ part. When $X$ and $Y$ are negatively correlated in general, that is, the correlation coefficient $r$ is negative, $P$ of N samples are certain, and $S+F$ is uncertain, which can be expressed by the correlation degree $\mu$:

$$\mu = \frac{(S+F)}{N} \times \; i - \frac{P}{N} \; or \; (\mu = b \times i - c)$$

The larger $c$ is, the stronger the negative correlation trend of the two sets is. Therefore, $r$ can be decomposed into negative correlation of $r_c$ part and uncertain correlation of $r_b$ part.
If the uncertainty of the correlation coefficient (expressed by $f_s$) represents the proportion of the uncertain part in the correlation coefficient, $f_s = r_b/r = b = 1-a$, $r < 0$, $f_s = r_b/r = b = 1-c$, $r < 0$. Therefore, when the correlation coefficient is positive, the larger $a$ is, it indicates that the larger the certainty part of the correlation coefficient takes up, the smaller its uncertainty is. On the contrary, when the correlation is negative, the larger $c$ is, the larger the certainty part of the correlation coefficient takes up, the smaller its uncertainty is. In correlation analysis, only when the correlation coefficient reaches the significant level and the uncertainty is low, can the correlation be more authentic and credible.

*Zhao Keqin. Set Pair Analysis and Its Preliminary Application [M], Hangzhou, Zhejiang Science and Technology Press, 2000.*
*Wang Wensheng, Li Yueqing, Jin Juliang and Ding Jing. Set Pair Analysis of Hydrology and Water Resources [M], Beijing, Science Press, 2010:1-180.*

**15.** ***Page 17 line 3 please check the grammar***
[Authors' response]: We gratefully appreciate for your comment. We are very sorry for the mistakes in our manuscript and inconvenience they caused in your reading. We have corrected the relevant sentences in our revised manuscript (Page 18 line 13 to 14).

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***Reviewer # 2:***

**1.** ***Sect. 3.2. The SRI and SPI series are autocorrelated: a modified version of the Mann Kendall test should be applied. Results of Tab. 2 may be affected (significance of trends) by this issue. For instance, check https://nhess.copernicus.org/articles/21/2181/2021/nhess-21-2181-2021.pdf***

[Authors' response]: We thank you for reminding us this importing. We have replaced MK method with MMK method in our revised manuscript (Page 5 line 7 to 12 and Page 6 line 1 to 3). Meanwhile, the conclusions related to MMK test have also been revised.

**2.** ***Equations 2 and 3 should be better explained and a reference should be added.***

[Authors' response]: We gratefully appreciate for your comment. We have better explained Equations 2 and 3 and added relevant reference in our revised manuscript (Page 7 line 19 to 26).

**3.** ***Sect 3.5 The aim of the Bayesian network analysis remains quite unclear.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have optimized the content in Section 3.5 in our revised manuscript (Page 8 line 4 to 30 and Page 9 line 1 to 16), making the purpose of Bayesian network analysis clearer.

**4.** ***Conclusions focus only on results valid for the analyzed case study: what are the broader implications of your work?***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have added a summary and a description of the broader implications and applications of the research in our revised manuscript (Page 24 line 10 to 15).

**5.** ***Minor comments. Please see corrections in the attached annotated PDF. The manuscript still presents some issues with spelling and grammar that limit its clarity.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have optimized these issues in our revised manuscript, as follows:

(a) Meteorological in place of meteorological (Page 1 line 1).

(b) were in place of was (Page 1 line 14).

(c) ‘SY showed the highest drought propagation threshold at moderate and severe drought scenarios, while XJWP at extreme drought scenario’ in place of ‘midstream showed the highest drought propagation threshold at moderate and severe drought scenarios, while downstream at extreme drought scenario’ (Page 1 line 24 to 25).

(d) Change ‘..., which has a grievous fatal effects...’ to ‘..., which can have serious effects...’ (Page 1 line 27 to 28).

(e) Change ‘Hydrological drought, mainly lagged the occurrence of meteorological drought, ...’ to ‘Hydrological drought, mainly lagged the occurrence of meteorological drought, ...’ (Page 2 line 5).

(f) Change ‘... can reveal the hydrological drought status of the basin well...’ to ‘... can rellably reveal the hydrological drought status of the basin...’ (Page 2 line 7 to 8).

(g) Change ‘Therefor, based on the SRI, the spatio-temporal evolution of drought events can be quantitatively revealed’ to ‘Therefore, based on the SRI, the spatio-temporal evolution of drought events can be analyzed quantitatively’ (Page 2 line 11 to 12).

(h) Change ‘The copula function can combine multiple drought characteristic variables well, which provides an effective method for multivariate frequency analysis (Lee et al., 2013; Vyver and Bergh 2018; Dash et al., 2019; Lindenschmidt and Rokaya, 2019). Thus, the copula function with the highest goodness of fit would be selected to establish the joint distribution of drought duration and drought severity, and calculate the return period of hydrological drought, ’ to ‘The copula function can be suitable to combine multiple drought characteristic variables, and provides an effective method for multivariate frequency analysis (Lee et al., 2013; Vyver and Bergh 2018; Dash et al., 2019; Lindenschmidt and Rokaya, 2019). Thus, once a suitable copula function is filted to model the joint distriution of drought duration and drought severity, the return period of hydrological drought can be estimated’ (Page 2 line 14 to 18).

(i) ‘results from’ in place of ‘is a response to’ (Page 2 line 20).

(j) As suggested, we have added the definition of drought propagation time in our revised manuscript (Page 2 line 24 to 27).

(k) Change ‘... were used as the detection values to trigger hydrological drought’ to ‘... were used to characterize the drought propagation threshold’ (Page 2 line 30 to 31).

(l) ‘determinate’ in place of ‘determine’ (Page 3 line 14).

(m) ‘implied’ in place of ‘employed’ (Page 4 line 11).

(n) As suggested, we have added the original references in our revised manuscript (Page 6 line 6).

(o) ‘characteristics’ in place of ‘factors’ (Page 6 line 11).

(p) ‘determined’ in place of ‘believe’ (Page 6 line 15).

(q) As suggested, we have added the references about Kolmogorov-Smirnov (K-S), Root mean square error (RMSE) and Akaike information criteria (AIC) test methods in our revised manuscript (Page 7 line 3-5).

(r) ‘denoted’ in place of ‘symbolize’ (Page 8 line 3).

(s) Change ‘... of hydrological drought were similar in SY and XJWP, showed alternate characteristics of drought and flood’ to ‘... of hydrological drought were similar without obvious trend characteristics in SY and XJWP’ (Page 10 line 3 to 4).

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***Reviewer # 3:***

**1.** ***The manuscript is investigating the propagation of meteorological drought towards hydrological drought in a river basin in China that has a major reservoir. It uses 4 stream gauges to derive the SRI and SPI for each one of them. There is a significant improvement of the structure between initial submission and R1 version. My main concern is the authors are attempting the propagation estimation in a basin that has a major reservoir. I mean that this estimation for the stations downstream to the reservoir include the combined effect of precipitation deficit and the effect of the reservoir operation policies. The DHF reservoir was built in 1958 and your study period is 1967-2019, resulting to a record that does not have information prior to the dam's construction. Please comment to the above as to how you take into account the reservoir operation in the estimation of the propagation.***

[Authors' response]: We thank you for reminding us this importing. We strongly agree with you that the propagation estimation in the downstream of the reservoir is influenced by a combination of precipitation deficit and reservoir operation polices. DHF reservoir plays an important role in flood control, water supply, power generation and fish farming, among which the functions of water supply and flood control can affect the runoff downstream of the reservoir. When a major flood occurs in the basin, the flood control function of the reservoir mainly achieves the effect of peak clipping and flood detention through pre-discharge and interception, and then drains the flood to the downstream after the flood peak. The flood control mechanism of the reservoir has a limited influence on the monthly runoff used in our analysis and only occurs in July and August. Reservoir water supply includes urban domestic, irrigation and ecological water supply. Urban domestic water supply is transported by pipeline, which has no impact on downstream runoff. However, the fixed allocation of irrigation and ecological water supply is mainly concentrated from May to August every year and the time is relatively fixed, with little change under normal circumstances. Taking the above two points into consideration, the estimation of the propagation in this study is carried out under the condition of the current operation of the reservoir.

**2.** ***The DHF station is upstream of the reservoir, right? Please make this more clear in your text.***

[Authors' response]: We gratefully appreciate for your comment. DHF reservoir and DHF station are in the same location, and the runoff data of DHF station is the inflow runoff of DHF reservoir. We have revised it in our revised manuscript to make this more clear (Page 3 line 28 to 30 and Page 4 line 1 to 8).

**3.** ***The authors don't mention in the "study area" section the Beikouqouian (BKQ) station. It is just appearing at the results section. It should be included. I would like to ask if there is another available station why not show the BKQ results alongside with the rest? Why the results are presented only for some of the analysis? I would have liked to see results for BKQ station as well so you have the whole basin.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have added an introduction to Beikouqouian (BKQ) station in the "Study region and data" section (Page 3 line 28 to 30 and Page 4 line 1 to 5).

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have added the discussion on the spatiotemporal evolution characteristics and return period of hydrological drought at BKQ station in sections 4.1 and 4.2.

**4.** ***Despite the improvement from the initial submission, the manuscript's structure and presentation of results could be further improved. While you present some results based on the reservoir operation periods (storage and release) in section 4.3 (fig 9), on other parts you only present seasonal results. More specifically in figure 5, it would be useful to see the operation periods as well instead only of the SRI-3 for the ending month of the season. Especially for the stations downstream of the DHF reservoir.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have added corresponding results in Figure 5 and Table 2 during the operation and storage periods of the reservoir and discussed them (Page 11 line 9 to 13 and line 28 to 30 and Page 12 line 1 to 2).

**5.** ***In Figure 4 and Figure 5 please indicate the scale of the index.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have added the scale of the SRI index in Figure 4. SRI in Figure 5 has multiple scales, so it is not easy to mark clearly in the figure. We have explained it in detail in our revised manuscript (Page 10 line 8 to 18).

**6.** ***Section 4.1 lacks discussion of the spatial dimension, in other words, upstream and downstream of the reservoir.***

[Authors' response]: We gratefully appreciate for your comment. As suggested, we have added the discussion on the characteristics of hydrologic drought in the upstream and downstream of the reservoir in our revised manuscript (Page 12 line 6 to 20).