Comments in black and our response in blue

RC2: 'Comment on hess-2024-126', Anonymous Referee #2, 09 Jun 2024

Heterogeneities in meteorological and underlying surface conditions usually result in remarkable spatial and temporal variabilities of flood events. It is very beneficial to investigate comprehensive variation characteristics of flood events and their formation mechanisms by clustering massive homogeneous events into some representative classes. This manuscript made an interesting contribution to understand meteorological and physio-geographical controls of flood event variabilities at class scale across China. Over a thousand flood events were selected from most of river basins in China. The sizes of flood events, meteorological and physio-geographical factors were impressive, and the investigation was convincing because multiple statistical analysis methods were adopted, including the hierarchical and partitional clustering methods, constrained rank analysis and Monte Carlo permutation test. This topic fits well with the scope of HESS, and the study is original. I think that some moderate revisions are required for this manuscript before publication.

Response: Thank you very much for your careful review and constructive comments. We revised this manuscript substantially and provided point-by-point responses to all the comments and suggestions of reviewers accordingly.

Line 104, how to "assess" the potential meteorological and physio-geographical control factors of flood events?

Response: This sentence was revised to "*Meteorological, catchment and land cover data sources were collected together to calculate the potential meteorological and physio-geographical control factors and assess their contributions on the spatial and temporal variabilities of flood event classes*."

Line 123, the T_{bgn} is calculated using the circular variable. Please explain the reason.

Response: The circular variable is widely used to characterize the timing or seasonality of hydrological variables (e.g., flood and precipitation) (Fisher, 1993; Black and Werritty, 1997; Villarini, 2016; Hall and Blöschl, 2018). This method translates the calendar date into the polar coordinates on the circumference of a circle, which is beneficial to distinguish the seasonal pattern (Fisher, 1993; Dhakal et al., 2015). The explanation was given as follows:

"T_{bgn} is characterized using the circular statistical approach which translates the calendar date into the polar coordinates on the circumference of a circle, and is beneficial to distinguish the seasonal pattern (Fisher, 1993; Dhakal et al., 2015)."

References

Black, A.R., Werritty, A: Seasonality of flooding: a case study of North Britain, J. Hydrol.,195:1–25, https://doi.org/10.1016/S0022-1694(96)03264-7, 1997.

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Fisher, N.I.: Statistical Analysis of Circular Data. Cambridge University Press, Cambridge, UK, 1993.

Hall, J., and Blöschl, G.: Spatial patterns and characteristics of flood seasonality in Europe, Hydrol. Earth Syst. Sc., 22, 3883–3901, https://doi.org/10.5194/hess-22-3883-2018, 2018.

Villarini, G. On the seasonality of flooding across the continental United States, Adv. Water Resour., 87, 80-91, https://doi.org/10.1016/j.advwatres.2015.11.009, 2016.

In the section of methods, many of flood behavior metrics or control factors were not independent. Why were they selected? Please clarify specifically.

Response: We selected the flood response metrics or potential control factors as many as possible to fully characterize flood events and to comprehensively detect the control mechanisms according to the existing studies (Ali *et al*., 2012; Brunner *et al*., 2018;

Merz and Blöschl, 2003; Zhang *et al*., 2022). All the correlated metrics or factors were transformed into a few independent composite metrics without losing the metric or factor information using the principal component analysis and the constrained rank analysis, respectively.

For the flood response metrics, the magnitude, variability, timing, duration, and rate of changes were widely-accepted as the main five components to characterize the entire flood events. Thus, eight related metrics were selected including total flood volume, maximum flood peak, coefficient of variation, timings of flood event and maximum flood peak, flood event duration, and rates of positive and negative changes, which covered all the main five components. Additionally, flood peak number is one of the most important metrics for flood control, which was also selected to characterize the flood events.

For the potential control factors of meteorology and physio-geography, precipitation and evapotranspiration related factors were selected including the amounts and intensities in the antecedent period and during the events, all of which mainly affect the flood yield processes. The catchment attributes were selected including position (longitude and latitude), elevation, catchment area, slope and its length, river density and slope, ratio of river width to depth, all of which mainly affect the flood yield and routing processes. The area percentages of main land covers were also adopted, which mainly affect the flood yield and overland routing processes.

The revisions were provided as follows: *"The magnitude, variability, timing, duration, and rate of changes are widely-accepted as the main five components to characterize the entire flood events (Poff et al., 2007) and thus…,nine metrics are used to fully characterize the response of flood events"*

"The potential control factors are selected as many as possible to investigate the control mechanisms on the variability of flood event classes according to the existing studies and the total number is 34 meteorological, catchment and land cover factors in all the catchments. In the meteorological category, 17 factors related to precipitation, potential evapotranspiration and aridity index are selected, including the amounts, intensities and timing factors during flood events, in the antecedent period and at annual scale. .... All of these factors mainly affect the flood yield processes (Merz and Blöschl, 2003; Aristeidis et al., 2010; Zhang et al., 2022).

For the physio-geographical factors, the 10 catchment attributes are selected, including catchment location, area, elevation and slope, river density and slope. All these factors mainly affect the flood yield and routing processes (Ali et al., 2012; Kuentz et al., 2017). Seven land cover factors are selected, including the area fractions of paddy, dryland, forest, grassland, water, urban and rural area to the total catchment, respectively for the seven land cover periods. All of these factors mainly affect the flood yield and overland routing processes (Kuentz et al., 2017; Zhai et al., 2021)."

References

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Kuentz, A., Arheimer, B., Hundecha, Y., and Wagener, T.: Understanding hydrologic variability across Europe through catchment classification, Hydrol. Earth Syst. Sc., 21, 2863–2879. https://doi.org/10.5194/hess-21-2863-2017, 2017.

Merz, R., and Blöschl, G.: A process typology of regional floods, Water Resour. Res., 39(12), 1340, https://doi.org/10.1029/2002WR001952, 2003.

Poff, N. L., Olden, J. D., Merritt, D., and Pepin, D.: Homogenization of regional river dynamics by dams and global biodiversity implications, P. Natl. Acad. Sci. USA, 104, 5732–5737, https://doi.org/10.1073/pnas.0609812104, 2007.

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Zhang, S.L., Zhou, L.M., Zhang, L., Yang, Y.T., Wei, Z.W., Zhou, S., Yang, D.W., Yang, X. F., Wu, X.C., Zhang, Y.Q., and Dai, Y.J.: Reconciling disagreement on global river flood changes in a warming climate, Nat. Clim. Change, 12, 1160–1167, https://doi.org/10.1038/s41558-022-01539-7, 2022.

Lines 142-147, 22 criteria were used to assess the classification performance and determine the best number of clusters. I agreed that it would be a robust way to select an optimal class number. However, most of the criteria were given as an abbreviation. Could you please give a detailed explanation about these criteria including full names, equations and units in the supplementary material?

Response: All the criteria were explained clearly, which was provided in the Supplement.

"Table S2. Criteria of classification performance assessment

ID	*Criteria name*	*Abbreviation*	*Equation*	*Reference*
1	*Krzanowski-Lai*	*KL*	$\mathrm{KL}(q) = \left\lvert \frac{\mathrm{DIEF}_q}{\mathrm{DIEF}_{q+1}} \right\rvert$	*Krzanowski and Lai 1988*
2	*Calinski-Harabasz*	*CH*	$\mathrm{CH}(q) = \frac{\mathrm{trace}(B_q)/(q-1)}{\mathrm{trace}(W_q)/(n-q)}$	*Calinski and Harabasz 1974*
3	*Hartigan*	*Hartigan*	$\mathrm{Hartigan} = \left(\frac{\mathrm{trace}(W_q)}{\mathrm{trace}(W_{q+1})} - 1 \right)(n-q-1)$	*Hartigan 1975*
4	*Cubic Clustering Criterion*	*CCC*	$\mathrm{CCC} = \ln\left[\frac{1-\mathrm{E}(R^2)}{1-R^2} \right] \frac{\sqrt{\frac{np^*}{2}}}{(0.001+\mathrm{E}(R^2))^{1.2}}$	*Sarle 1983*
5	*Scott*	*Scott*	$\mathrm{Scott} = n\log \frac{\det(T)}{\det(W_q)}$	*Scott and Symons 1971*
6	*Marriot*	*Marriot*	$\mathrm{Marriot} = q^2 \det(W_q)$	*Marriot 1971*
7	*Trcovw*	*TrCovW*	$\mathrm{Trcovw} = \mathrm{trace}(\mathrm{COV}(W_q))$	*Milligan and Cooper 1985*
8	*Tracew*	*TraceW*	$\mathrm{Tracew} = \mathrm{trace}(W_q)$	*Milligan and Cooper 1985*
9	*Friedman*	*Friedman*	$\mathrm{Friedman} = \mathrm{trace}(W_q^{-1} B_q)$	*Friedman and Rubin 1967*
10	*Silhouette*	*Silhouette*	$\mathrm{Silhouette} = \frac{\sum_{i=1}^{n} S(i)}{n}, \mathrm{Silhouette} \in [-1,1]$	*Rousseeuw 1987*
11	*Ratkowsky-Lance*	*Ratkowsky*	$\mathrm{Ratkowsky} = \frac{\bar{S}}{q^{1/2}}$	*Ratkowsky and Lance 1978*
12	*Ball*	*Ball*	$\mathrm{Ball} = \frac{W_q}{q}$	*Ball and Hall 1965*
13	*Ptbiserial*	*Ptbiserial*	$\mathrm{Ptbiserial} = \frac{[\bar{S}_b - \bar{S}_w][N_w N_b / N_t^2]^{1/2}}{s_d}$	*Milligan 1980, 1981*
14	*Dunn*	*Dunn*	$\mathrm{Dunn} = \frac{\min_{1 \le i < j \le q} (C_i, C_j)}{\max_{1 \le k \le q} \mathrm{diam}(C_k)}$	*Dunn 1974*

15	*Rubin*	*Rubin*	$\text{Rubin} = \frac{\det(T)}{\det(W_q)}$	*Friedman and Rubin 1967*
16	*C-Index*	*Cindex*	$\text{Cindex} = \frac{S_w - S_{\min}}{S_{\max} - S_{\min}}, S_{\min} \neq S_{\max}, \text{Cindex} \in (0,1)$	*Hubert and Levin 1976*
17	*Davies-Bouldin*	*DB*	$\text{DB}(q) = \frac{1}{q} \sum_{k=1}^{q} \max_{k \neq l} (\frac{\delta_k + \delta_l}{d_{kl}})$	*Davies and Bouldin 1979*
18	*Duda*	*Duda*	$\text{Duda} \geq 1 - \frac{2}{\pi p} - \sqrt{\frac{2(1-\frac{8}{\pi^2 p})}{n_m p}} = critValue\_Duda$	*Duda and Hart 1973*
19	*Pseudo t^2*	*Pseudot2*	$\text{Pseudot2} = \frac{V_{kl}}{\frac{W_k + W_l}{n_k + n_k - 2}}$	*Duda and Hart 1973*
20	*McClain-Rao*	*McClain*	$\text{McClain} = \frac{\bar{S}_w}{\bar{S}_b} = \frac{S_w / N_w}{S_b / N_b}$	*McClain and Rao 1975*
21	*SD validity*	*SDindex*	$\text{SDindex}(q) = \alpha \text{Scat}(q) + \text{Dis}(q)$	*Halkidi et al. 2000*
22	*SDbw validity*	*SDbw*	$\text{SDbw}(q) = \text{Scat}(q) + \text{Density.bw}(q)$	*Halkidi and Vazirgiannis 2001*

Note: q is the number of clusters; n is the number of observations; p is the number of variables; B_q is the between-group dispersion matrix for data clustered into q clusters; W_q is the within-group dispersion matrix for data clustered into q clusters; R^2 is the coefficient of determination; T is the total sum of squares; S_b is the sum of the between-cluster distances; S_w is the sum of the within-cluster distances; $\bar{S}_b$ is the ratio of the S_b and N_b; $\bar{S}_w$ is the ratio of the S_w and N_w; N_w is the total number of pairs of observations belonging to the same cluster; N_b is the total number of pairs of observations belonging to different clusters; N_t is the total number of pairs of observations in the data set; S_{max} is the sum of the N_w largest distances between all the pairs of points in the entire data set; S_{min} is the sum of the N_w smallest distances between all the pairs of points in the entire data set (there are N_t such pairs); S_d is the standard deviation of all distances; $\bar{S}$ is the average of the ratios of sum and total sum of squares between the clusters for each variable; i is the number ranges from 1 to n; j is the number ranges from 1 to p; k, l and m is the cluster number ranges from 1 to q; C_i; C_j and C_k are the different clusters; n_k, n_l and n_m are the number of objects in cluster C_k, C_l and C_m, respectively; W_k, W_l and W_m are the squared errors of the different clusters; V_{kl} equals W_m minus W_k and then minus W_l; d_{kl} is the distance between centroids of clusters C_k and C_l; δ_k and δ_l are the standard deviation of the distance of objects in cluster C_k and C_l, respectively."

References

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Lines 285-297, the comparisons of flood events among different classes are largely based on percentages, but the flood event numbers at many stations were not the same. Please give the detailed introductions about the spatial and temporal distributions of flood event classes.

Response: This paragraph and Figure 6 were revised and the flood event numbers in all the classes and basins were added according to your comments. The revised paragraph was provided as follows:

"According to the interannual distributions of individual classes (Figure 6), all the classes are evenly distributed, whose annual mean percentages are 24.0±5.9%, 21.2±6.4%, 13.5±7.7%, 25.9±6.2%, and 15.4±12.5%, respectively. However, the interannual distributions of individual classes are quite distinct at different stations, particularly in the Songliao River Basin. In the headstream stations of Songliao River Basin, the dominant class is Class 4 with the annual mean percentage of 26.1±38.3% (n=32) though flood events are missed in several years due to the dry period. In the headstream stations of Yellow River Basin, the Class 4 is also dominant across the whole period with the annual mean percentage of 58.1±33.9% (n=67), particularly in 1994-1996, 1999 and 2007. In the headstream stations of Huaihe River Basin, the Class 5 gradually prevail with the annual mean percentage of 41.5±23.7% (n=102), particularly after 2007, whose percentage reaches 63.2±15.8% (n=79). The event numbers of both Classes 1 and 2 gradually decrease, accounting for 33.1±24.4% (n=11) and 8.7±7.1% (n=5) of annual flood events in the period of 1993-1999 and 2011-2015 for the Class 1, respectively, and 20.3±20.9%

(n=9) and 2.7±1.3% (n=1) in the period of 1993-1999 and 2011-2015 for the Class 2, respectively. The explanations are that the total precipitation amount and duration probably increase due to the climate change (Dong et al, 2011; Jin et al., 2024). In the headstream stations of Yangtze River Basin, the Classes 1, 2 and 4 are dominant, accounting for 29.3±9.6% (n=251), 23.0±11.5% (n=197) and 21.1±7.0% (n=181) of annual mean flood events, respectively. Although the interannual changes of event numbers of Classes 1 (n=1–21), 2 (n=1–14) and 4 (n=1–16) are considerable, those of class percentages are relatively uniform except 2015. In the headstream stations of Southeast River Basin, the Class 3 gradually prevail after 2000 with the annual mean percentage of 46.2±32.5% (n=39). In the headstream stations of Pearl River Basin, the Class 1 is dominant with the annual mean percentage of 36.0±24.0% (n=52), but gradually shifts to Class 2 which accounts for 30.0±25.2% of annual mean flood events (n=40), particularly after 2008. "

References:

Dong, Q., Chen, X., and Chen, T.: 2011. Characteristics and changes of extreme precipitation in the Yellow-Huaihe and Yangtze-Huaihe Rivers Basins, China, J. Climate, 24(14), 3781-3795, https://doi.org/10.1175/2010JCLI3653.1, 2011.

Jin, H., Chen, X., and Adamowski, J. H. S.: Determination of duration, threshold and spatiotemporal distribution of extreme continuous precipitation in nine major river basins in China, Atmos Res, 300, 107217, https://doi.org/10.1016/j.atmosres.2023.107217, 2024.

In Figure 1, the main river names should be replaced by the river basin names.

Response: It was revised accordingly.

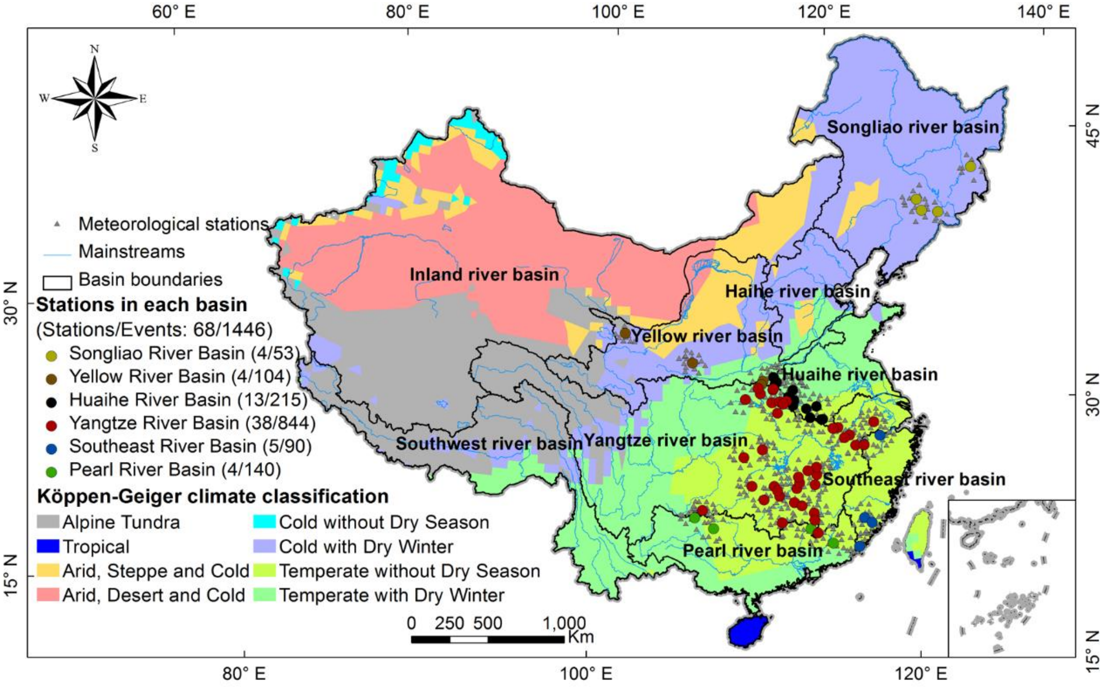

Figure 1. Spatial distributions of all the selected flood events and their corresponding climate types

In Figure 5, the legend "Flood classes" should be changed to "Flood event classes". Please remove shading from the stacked bars. That adds no information.

Response: It was revised accordingly.

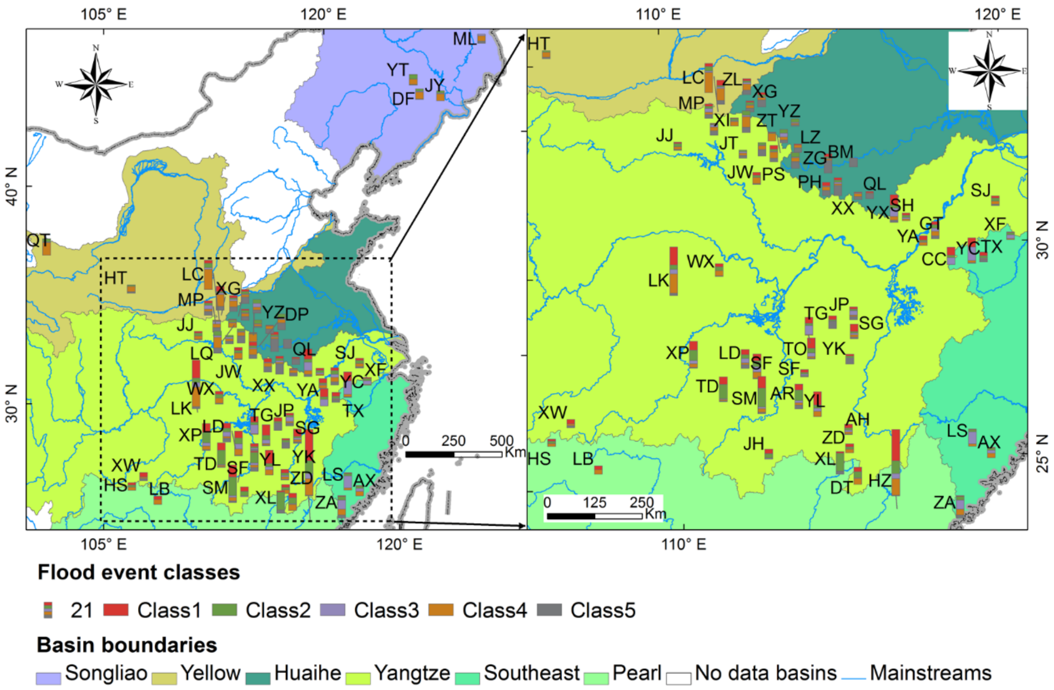

Figure 5. Spatial variabilities of individual flood event classes in major river basins

What are the means of 21 in Figure 5 and 0.46 in Figure 8?

Response: The number in the figure means the measuring scale of the bar, which is the number of flood event classes at each station. Figure 5 was revised following the comments of Reviewer 1 and Figure 8 was changed to Table 4.

In Figure 6, I suggested that the flood event numbers could be given for every year in all the basins.

Response: It was revised accordingly.

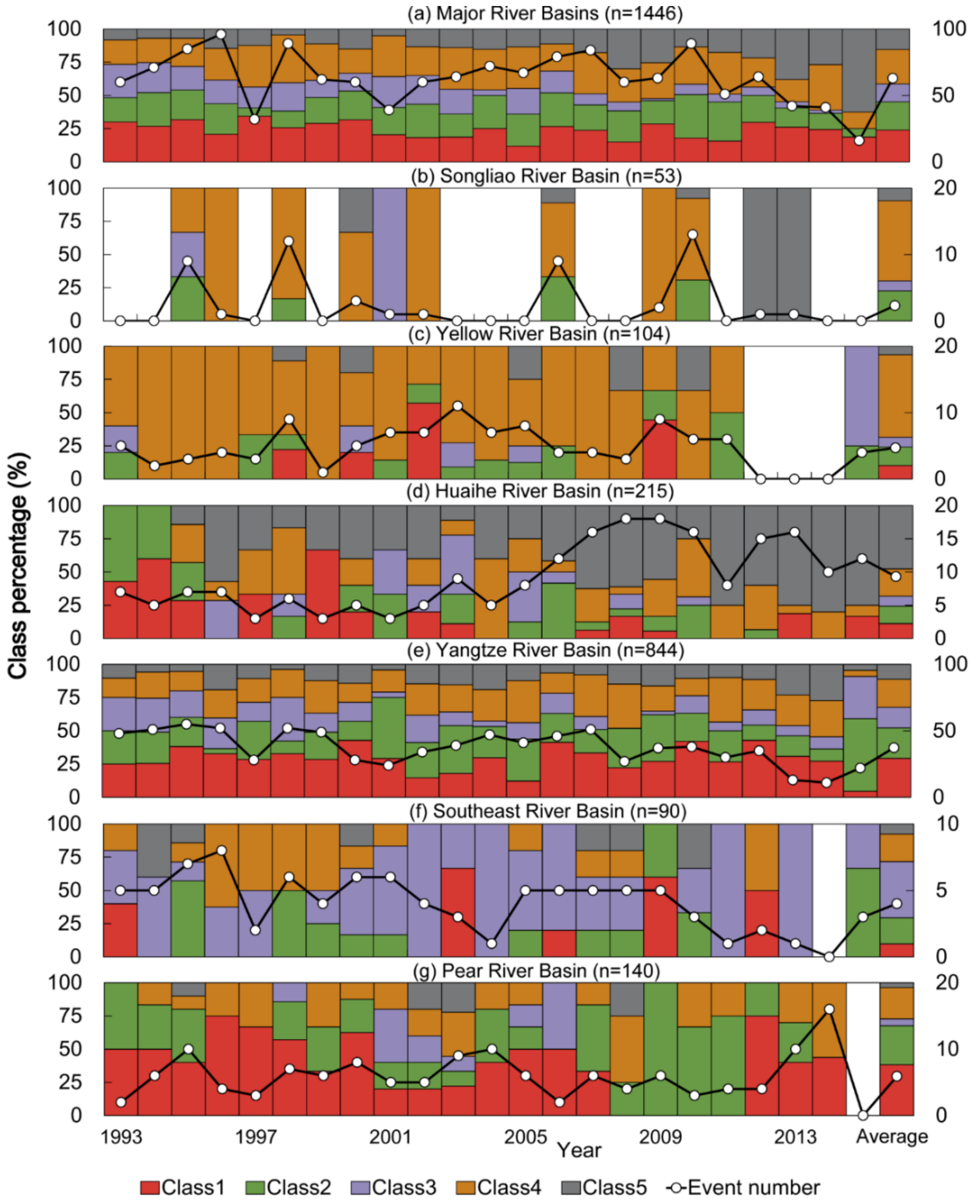

Figure 6. Interannual variabilities of individual flood event classes and their percentages in major river basins

In Figure 7, it should be changed to a single column of the five cases. The coefficients should be "correlation coefficients".

Response: This figure was revised following the comments of you and Reviewer 1.

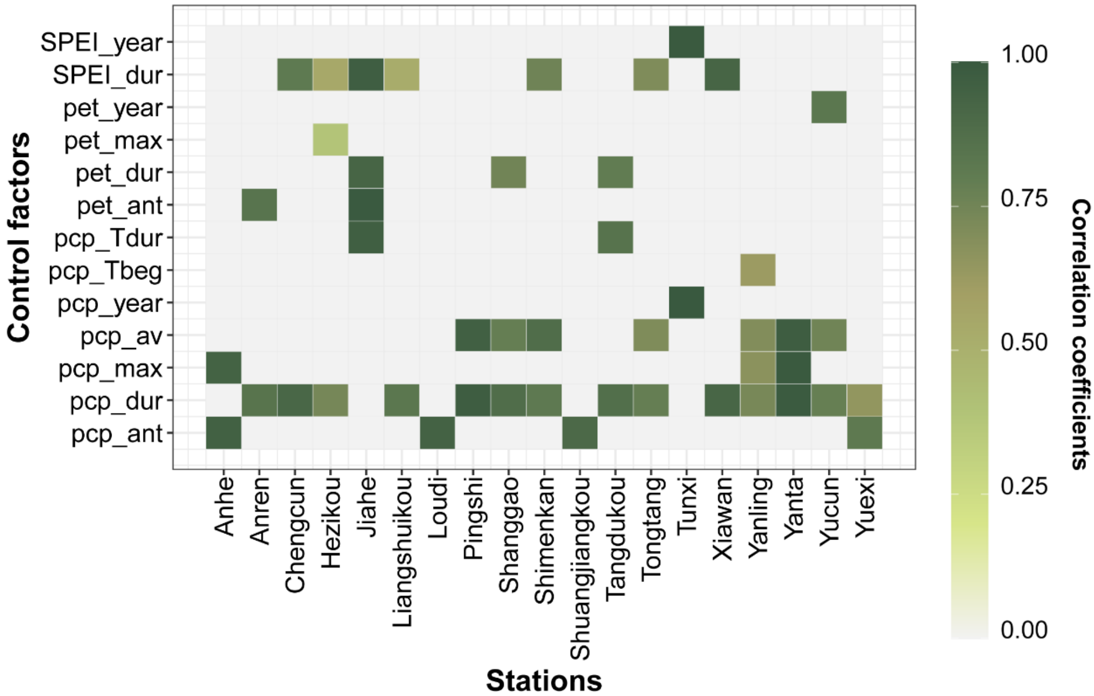

Figure 7. Significant control factors and their correlation coefficients for the temporal variabilities of flood event class 1 in the individual catchments. The gray color means the control factor without statistical significance.

Note: Anhe, Anren, Chengcun, Jiahe, Liangshuikou, Loudi, Pingshi, Shanggao, Shimenkan, Shuangjiangkou, Tangdukou, Tongtang, Xiawan, Yanling, Yanta, Yucun and Yuexi catchments are from the Yangtze River Basin; Tunxi catchment is from Southeast River Basin; Hezikou catchment is from Pearl River Basin.