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Interactive comment

Interactive comment on "Frequency and magnitude variability of Yalu River flooding: Numerical analyses for the last 1000 years" *by* Hui Sheng et al.

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The paper coupled HYDROTREND with the ECHO-G model to reconstruct and investigate the impacts of climate change and human activity on the flooding frequency and magnitude for the Yalu River over the past 1000 years. The results indicated that the frequency trends of flooding were dominated (increased) by climate variability, i.e., intensity and frequency of rainfall events. The also found that deforestation increased the magnitude of floods by 19.2-20.3 percent while the construction of cascade reservoirs significantly reduced their magnitude by 36.7-41.7 percent. In general, the paper presents some useful analyses and can potentially make a useful contribution to the field. However, there are some critical issues need to be addressed. All the major and minor issues I found are included in the detailed review below.

Dear review: We greatly appreciate for your positive summary on our study, your comments and valuable suggestions are helpful for us to improve the manuscript. The manuscript has been carefully revised and point-by-point responses are listed as below.

Major comments:

Q1: (1) According to section 3.2, the climate model ECHOG was used to simulate monthly precipitation and temperature of Yalu River over last millennium. How to calibrate by meteorological station data? The accuracy of the simulated precipitation and temperature would have an important impact on flood simulation by HYDROTREND model. If there are large biases in ECHOG simulation, a bias correction is necessary before coupled with HYDROTREND model. But there is no relevant information in the paper.

Response: I agree that in order to convince readers for availability of simulated stream flow values, clarifying accuracy of climate data over the last 1000 years is essential. In response to review's comments, Fig.3 has been added and the processes of calibration and bias corrections for climate data in past 1000 years have been clarified based on meteorological station data.

Line 232-246 in revised manuscript: As shown in Fig. 3, ECHO-G can accurately predict the actual variations in temperatures of the Yalu River, and additionally, it can accurately capture the inter-annual seasonal precipitation distribution. However, there was a certain bias in the observed and simulated annual precipitation when comparing the ranked multi-year precipitations, where data were significantly dominated by the simulated precipitation. The calibrated and validated relationship between simulations and bias of precipitation during 1957–1990 was applied to modify the annual simulated precipitation over the last millennium, where amplitudes of simulated precipitation during 1957–1990 basically covered the whole simulated period (Fig. 3). The climate data for the Ai River over the past millennium were also modified through the monthly relationship of the Yalu's and Ai's temperature and precipitation during 1957–2012.

Q2: On the other hand, the HYDROTREND model was run at the daily scale (as shown in Figures 3d and 4d), whereas the precipitation and temperature of ECHOG are simulated at the monthly scaled. How the authors downscaled monthly-scale climate data to daily scale. The authors should provide relevant information in detail.

Response: Thank you for your professional comments. Similar to most of Downscaled Global Climate Model (GCM) forced with a variety of emissions scenarios generates daily resolution outputs based on Monte Carlo analysis, the rainfall event module and degree-day module in HYDROTREND downscaled monthly precipitation and temperature to daily scale through the same methods. In order to help reader effectively understand how monthly-scale climate data downscaled, we first add the summary of solution in first pages and given some details in method descriptions (Line 86-89 and Line 199-210 in revised manuscript).

Q3: (2) The authors used the GEV distribution to calculate the return interval flood values. How to estimate the parameters of the GEV when fitting the data of peak flows? There is no any information about it. In addition, I am not sure if the GEV is the best distribution for the study basin, which raises another key question: why not use other distribution functions such as P-3, since the P-3 is widely used for the frequency analysis of floods in Chinese basins. Or, why not use multiple probability distributions and find the optimal distribution to analyze flood frequency? The authors need to carefully clarify this.

Response: We have followed your suggestion. In the new manuscript, the reasons for why use GEV distribution combined with block maxima method were clarified. For frequency analysis of floods in Yalu River, the GEV distribution combined with block maxima method and P-III distribution (widely used in Chinese basins) were compared to study the impact of the two methods on research targets of the paper, parameters of distributions were estimated by L-moments method. In addition, we also gave some descriptions for the block maxima method, which was applied in this paper to reduce the uncertainties of simulations. Response to the suggestion Appendix A4 has been added and this section has been revised as follow :

Line 304-317 in revised manuscript:The generalized extreme-value distribution (GEV) and Pearson type three distribution (P-III) combined with the L-moments method have been widely used to investigate flood characteristics, of which P-III has been widely adopted for the frequency analysis of floods in many Chinese rivers (Xu et al., 2016). For this study region, GEV based on the block maxima method and P-III showed significant differences for flood estimations on return periods larger than the observed time periods (1958–2012 for 55 years)(Appendix A4.a-b). However, two methods have a little difference for investigating the impact of climate change and human activities on 100-, 50-, 20- and 10-year floods when samples increased to 1000 years generated by model (Appendix A4.c). In addition, the block maxima method in GEV, which divides the estimations period into non-overlapping periods of equal size and restricts attention to the maximum estimations in each period, can reduce the uncertainties of simulations (Ferreira and Laurens, 2015). Therefore, here the L-moments method for parameter estimation of the GEV was applied to study the flood frequency in the Yalu River based on simulated annual peak discharges in Yalu River, combined with the block maxima method.

Q4: (3) The flooding frequency analysis is based on the hydrological model coupled with the climate model. In my opinion, there would be large uncertainties throughout the process of modeling and frequency function analysis as well as the data used, especially for such long-term (1000 years) hydrological simulations. The authors should make a discussion to emphasize this point.

Response: HYDROTREND have limitations for simulating annual peak flows over the last 1000 years due to the uncertainties of input boundary conditions and model as-

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sumptions. In the revised manuscript, we firstly discussed limitations induced by model assumptions, uncertainties of climate data input and limitations caused by simplistic anthropogenic impacts, respectively, and then some descriptions are given to clarify how to reduce the uncertainty of simulation results in this paper.

Specific comments:

Q5:Line 15: what' s the meaning of "AD"? Please give it full name.

Response: A.D. is a Latin abbreviation for Anno Domini, in the year of our Lord. A.D. is used with dates in the current era, corresponding to B.C (before Christ indicates that a date is before the Christian era). When there is no A.D or B.C mark before the era, the time means current era. In the revised manuscript, all A.D marks before the year were removed.

Q6:Line 21: what' s the meaning of "larger floods"? please clarify it.

Response: We have added specific designed floods (100- and 50-year) for "larger floods".

Q7: Lines 228-230: Please provide information about the spatial resolution of the ECHO-G model.

Response: We have been followed this suggestion in revised manuscript.

Q8: Line 250: How to identify wet years, average years and dry years? please clarify it.

Response: In this paper, different rainfall periods (wet, average and dry years) in Yalu and Ai rivers were defined based on observed climate data during 1958-2012. Classified total rainfall patterns were applied to calibrate rainfall event distribution coefficients and exponents which are significant model input parameters strongly correlated with the simulated daily rainfall events. The results of calibration were used to reconstruct the annual maximum water discharge over the last 1000 years, combining with

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long-term input boundaries. The Appendix A3 was added for in response to review's suggestion.

Q9: Line 255: Why use 14 years as the period of wet and dry years for the Yalu River basin?

Response: The period of wet and dry years for the Yalu River basin obtained from Yi et al., 2014. The results of this paper indicated that Yalu River and its adjacent rivers (Liaohe River, small and medium-sized rivers along the east coast of Liaodong peninsula, Songhua River, etc.) have periodic of 14 year for wet years and dry years based on analysis of multi-years monitoring hydrological data. Periodic of 14 years as the time unit of simulation can effectively improve the accuracy of daily rainfall events simulation, combing with different rainfall conditions. In the process of model simulation, the estimated precipitation over the last 1000 years was first divided into multiple consecutive 14 years, and then model input parameters, strongly correlated with the simulated daily rainfall events, were adjusted according to the classification criteria of rainfall patterns and rainfall data for 14 years. This process can reduce the uncertainties of simulations induced by climate data. Multiple input files of modeling are generated by R Programming Language, and multiple simulation process were conducted through script editing.

Q10: Table 1: Which basin's error results are summarized in Table 1? Ai River or Yalu River? please clarify it.

Response: This question is reply together with the next one. The summary of error for design floods in Table1 is from Yalu River in original manuscript. However, in the revised manuscript Table1 was replaced by figure of Appendix A4. As shown in Appendix A4.a-b, flood frequency analysis was conducted in Yalu and Ai rivers based on simulated and observed peak discharges during 1958-2012, combined with GEV and P-III distribution. The results show that the model can simulate the changes of flood frequencies in Yalu and Ai rivers. Although the simulation results of Ai River are slightly inferior to those of Yalu River, it has no significant difference for investigating the impact of climate change and human activities on flood frequencies (100-, 50-, 20-year, etc.).

Q11: Figure 3: the performance of model seems not well for daily peak flows in the Ai River, how would this affect the flood frequency analysis?

Response: Please refer to above reply for this question.

Q12: Figures 3 and 4: I suggest the x-axis of (e), (f), (g) in Figures 3 and 4 be marked with the actual year.

Response: We have followed your suggestion to make changes for figures.

Q13: Section 4.3: wavelet analysis is conducted based on continuous (flood) data over a certain period. How to compute the long-term (1000-2012) series of the designed floods with different return intervals? As I know, for a specific time series there is only one value for a certain return period fitted by the GEV distribution. How to generate a long-term data of the designed floods used for wavelet analysis? please clarify it.

Response: Thank you for your suggestions. This section was used to indicate the qualitative impact of climate change and human activities on flood frequency. We first set standards based on design floods estimated by simulated annual peak discharges during 1000-2012. And then, thresholding process was conducted to produces new data sets (over standards for 1, otherwise for 0), based on times series of peak discharges over the last 1000 years and standards. Next, wavelet analysis was conducted for new data sets to produce times series of the occurrence frequencies of floods exceeding different return period standards. Eventually, the results were applied to qualitative analysis the impact of climate change and human activities on flood frequency. The descriptions for this section are insufficient in original manuscript, which led to the confusion. This section has been rewritten in response to review's suggestions (Line 492-525 in revised manuscript).

Q14: Table 3: how to calculate the frequency of flood occurrence for different recurrence intervals? More explanations are needed.

Response: In the original manuscript, the ratio of the number of simulated flood peaks exceeding the standards to the statistical years is defined as ‘frequency of flood occurrence’, and designed floods of different recurrence intervals estimated by simulated annual peak discharges during 1000-2012 were applied for the standards. In the revised manuscript, Table3 and the Sections related to ‘frequency of flood occurrence’ were removed. The reasons are as follows: 1): Distinction between the frequency of floods and ‘frequency of flood occurrence’ cause confusions of readers. 2) The impacts of climate change and human activities on floods are able to clarify through discussing the changes of frequencies of floods or magnitudes of design floods. 3) The manuscript is more shortened and clear by removing related redundancies.

Q15: Line 485: decreased corrected to increased

Response: Line 553: Revised.

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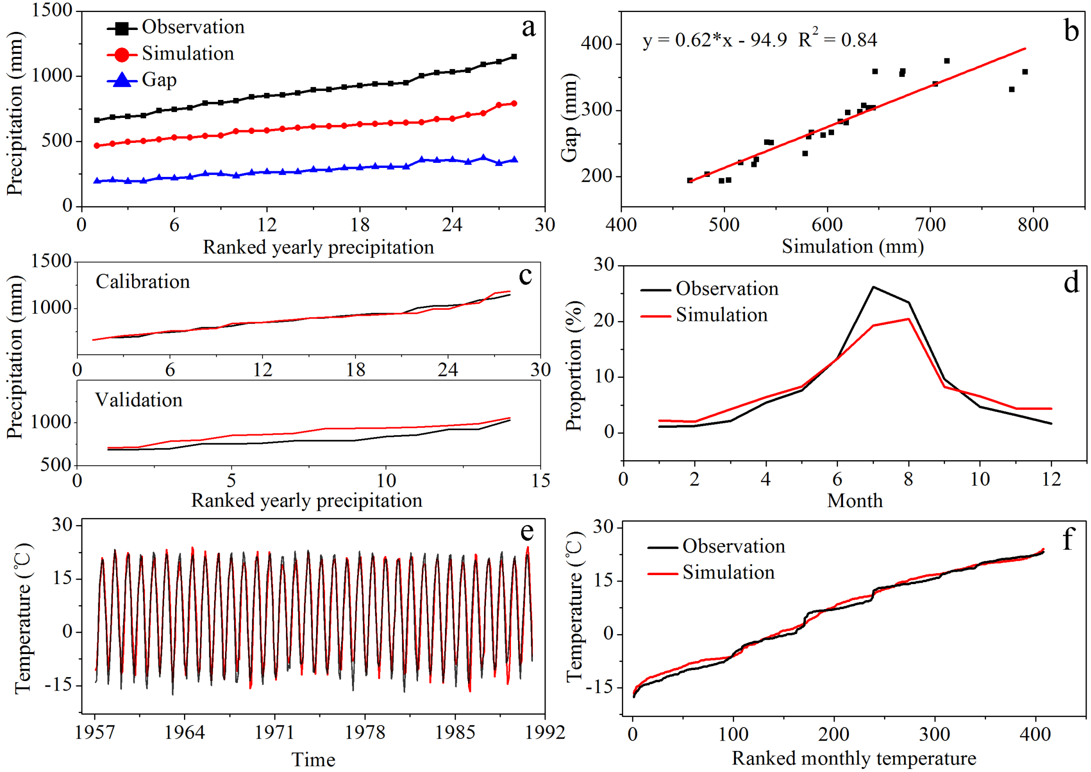

Fig. 1. Figure 3. Correction of the simulated climate data from the ECHO-G model based on observations during 1957–1990: (a) annual ranked precipitation distribution of observations, simulations, and the gap;

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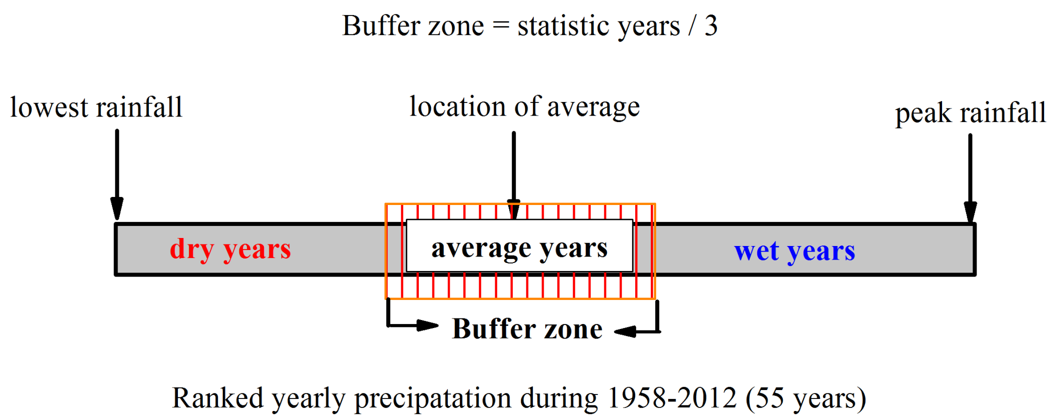

Fig. 2. Appendix A3.The classification method for different rainfall conditions (wet, average and dry years) in Yalu and Ai rivers

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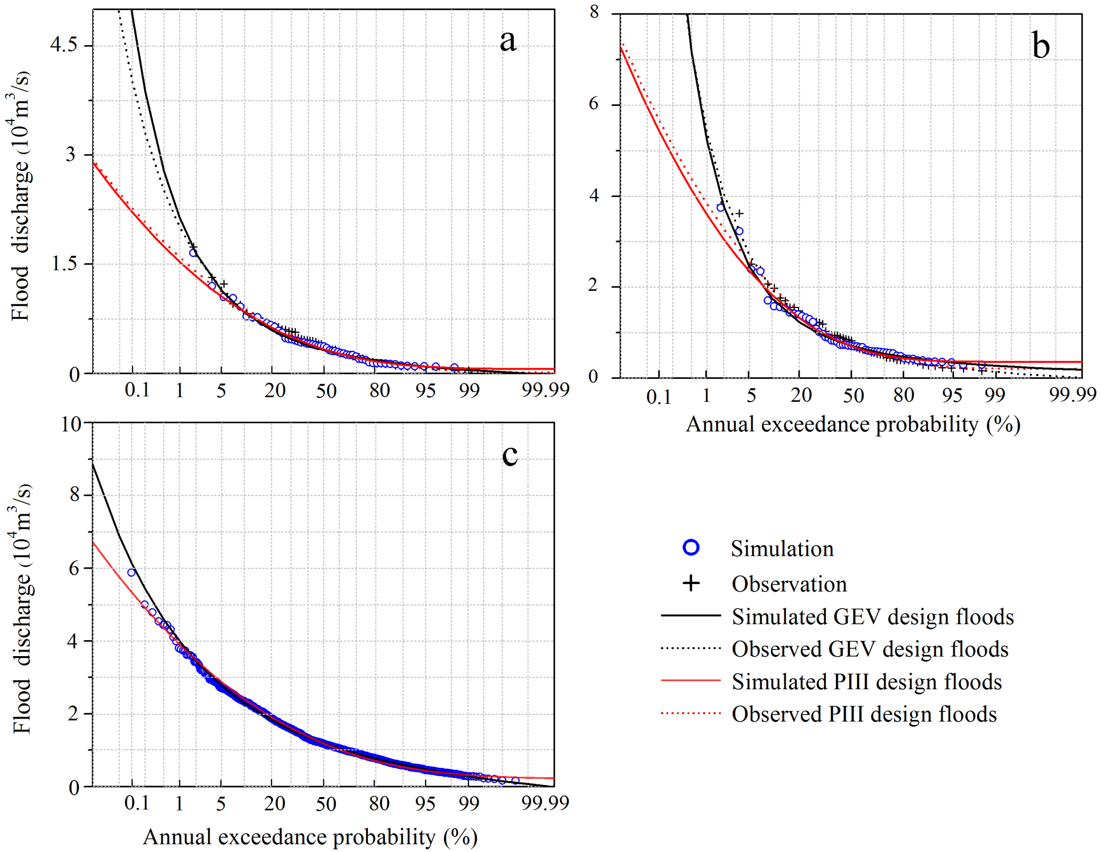

Fig. 3. Appendix A4. Comparison between the observed and simulated return interval peak discharges in the Ai River and Yalu River based on the GEV and P-III methods. The design floods for the period 1958–2012