Dear Anonymous Referee #1,

Thanks very much for your constructive comments concerning our manuscript entitled "Responses of runoff to historical and future climate variability over China" (Manuscript No.: hess-2017-98). Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and here replied each comment below.

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Comments from Anonymous Referee #1:

This paper describes the projected effects of climate change on runoff and water availability in China using a framework based on runoff elasticity. In general the paper is well written and of sufficiently wide geographical scope to be interesting to a broad readership, but several key assumptions in the methodology, which are neither documented nor discussed, preclude a recommendation to publish without major revisions. These are:

1. More information on the parameters used in the hydrological modeling is necessary, especially those used with VIC to calculate runoff. These assumptions lie at the heart of the elasticities calculated, which will be heavily influenced by the structure and parametrisation of that model. [Section 2.1 Line 5]

Response: Thank you very much for your nice comments. In our study, the Budyko framework with an empirical parameter was used to calculate the climate elasticity of runoff, and this method has been proven to be robust to the calculation of climate elasticity (Yang et al., 2014). For the VIC model used for the calculation of runoff, the parameters include: the infiltration parameter *b*, the second and third soil layer depths (d_2 and d_3), and the three parameters in the base flow scheme. According to Zhang et al (2014), the VIC model was calibrated in the 11 major basins over China based on the best meteorological forcing data (derived by 756 meteorological stations over China). The model parameters were estimated by using an optimization algorithm of the multi-objective complex evolution of the University of Arizona (MOCOM-UA). The results indicated that the simulated runoff matches reasonably well with the observations at both seasonal and monthly timescales, with the Nash–Sutcliffe efficiency above 0.8. Our study conducted the analysis of climate elasticity of runoff at the long-term scale using annual data of runoff, which would be more accurate than that at the monthly scale. Therefore, the simulated annual runoff by the VIC model would show little influence on the calculation of elasticity. According to your good comments, we have added more information on the parameters in the VIC modeling in the revised manuscript.

Reference:

Yang, H., Qi, J., Xu, X., Yang, D., and Lv, H.: The regional variation in climate elasticity and climate contribution to runoff across China. J. hydrol., 517, 607-616, 2014.

Zhang, X., Tang, Q., Pan, M., Tang, Y.: A Long-Term Land Surface Hydrologic Fluxes and States Dataset for China, J. Hydrometeor., 15, 2067–2084, doi: 10.1175/JHM-D-13-0170.1, 2014.

2. There is some discussion of uncertainty in Section 4.3 but it is very general and not quantitative. In particular, the detailed choice of which formulation of the Budyko model used to compute elasticities is investigated but neither the runoff model nor the *PET* equation are examined in this regard.

Response: Thank you very much for your nice comments. We agree with you that the discussion section is lack of quantitative analysis, especially for the examination of the estimation of runoff or *PET*. The runoff simulated by the VIC model has been proven to be accurate at the long-term scale (Zhang et al., 2014). In our original version (i.e. initial submission), the *PET* of the 28 GCMs for the baseline 1971–2000 and the future period 2071–2100 was estimated by the Thornthwaite method. We noted that the Thornthwaite method is solely based on monthly temperature, which may tend to underestimate *PET* in the arid areas and overestimate *PET* in the humid areas. Therefore, we used a multiplicative correction for *PET* bias correction of the 28 GCMs:

$$PET_{cor,GCM,i} = PET_{Th,GCM,i} \times \frac{\overline{PET}_{Pen,obs,i}}{\overline{PET}_{Th,obs,i}} \tag{1}$$

where $PET_{Th,GCM,i}$ and $PET_{cor,GCM,i}$ are annual *PET* from the Thornthwaite method and the bias-corrected annual *PET*, respectively, for the *i*th grid point of the GCM data. $\overline{PET}_{Pen,obs,i}$ and $\overline{PET}_{Th,obs,i}$ are the 49-year averages of *PET* calculated from the Penman and Thornthwaite methods, respectively, for the *i*th grid point for the period 1960–2008.

According to your good suggestions, we compared four different *PET* calculation equations (i.e., the Penman method, the Thornthwaite method, the FAO-56 Penman–Monteith method, and the Thornthwaite method corrected by equation (1)) over the 14 river basins of China, and conducted a quantitative analysis of the impacts of the *PET* calculations on the *PET* elasticity calculations (as shown in Figure R1 below). The results showed that the mean annual *PET* by the Penman method, the FAO-56 Penman–Monteith method, and the Thornthwaite method corrected by equation (1) are quite consistent, and the *PET* elasticity calculations from these three methods give very similar results in all 14 basins. In summary, our study suggests that the estimation of *PET* elasticity is robust to the *PET* estimated from the Penman method, the FAO-56 method, and the Thornthwaite method corrected by equation (1), but is not robust to the Thornthwaite method.

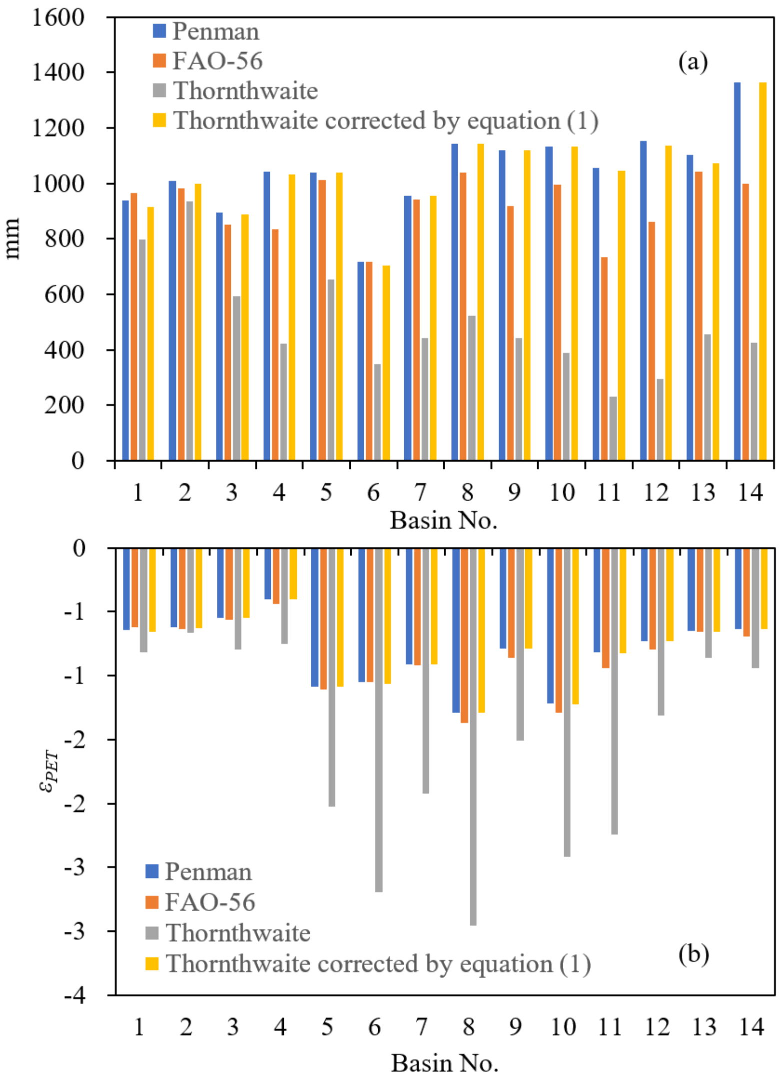

Figure R1. (a) Mean annual *PET* calculated from the four methods for the 14 river basins of China during the period 1960–2008. (b) *PET* elasticity calculated based on the four *PET* data for the 14 river basins of China during the period 1960–2008. The basin number is as follows: 1, Southeast Drainage; 2, Pearl River; 3, Yangtze River; 4, Southwest Drainage; 5, Huaihe River; 6, Heilongjiang River; 7, Liaohe River; 8, Haihe River; 9, Yellow River; 10, Inner Mongolia River; 11, Qiangtang River; 12, Qinghai River; 13, Xinjiang River, 14, Hexi River.

Reference:

Zhang, X., Tang, Q., Pan, M., Tang, Y.: A Long-Term Land Surface Hydrologic Fluxes and States Dataset for China, J. Hydrometeor., 15, 2067–2084, doi: 10.1175/JHM-D-13-0170.1, 2014.

3. *PET* is calculated using the Thornthwaite method, which is a surprise since with the data available there is information to justify the use of more physically accurate *PET* calculations. Justification for the use of the temperature-based Thornthwaite method is required, especially given that it may oversimplify (and artificially constrain) the results of the Budyko calculation which features subsequently. [P5 line 5]

Response: Thank you very much for your nice comments. In the original version (i.e. initial submitted manuscript), the *PET* data used for the calculation of climate elasticity are derived from the CRU TS3.22 dataset as produced by the Climatic Research Unit (CRU) at the University of East Anglia (Harris et al., 2014). In this dataset, the *PET* is calculated from the FAO Penman-Monteith method. In contrast, the *PET* of the 28 GCMs is estimated by the Thornthwaite method. We fully agree with you that the temperature-based Thornthwaite method is lack of physical basis, and it is necessary to justify the use of the temperature-based Thornthwaite method and the use of more physically *PET* calculation methods.

In the revised manuscript, we used a more physically *PET* data that estimated by the Penman method (during the period 1960–2008 provided by the Hydroclimatology Group of Princeton University) to calculate the climate elasticity (i.e. *PET* elasticity) over China instead of the *PET* data from the FAO Penman-Monteith method. The related results of the study and some figures and tables have been updated in the revised manuscript. We believe the new climate elasticity coefficients would be more accurate compared with that in the original version. Meanwhile, the *PET* of GCMs calculated by the Thornthwaite method was corrected by the equation (1) above. We compared the corrected annual *PET* with the *PET* calculated from the Penman method at both basin and grid scales (Figure R2). The results indicated the Thornthwaite method corrected by the equation (1) significantly improves the accuracy of *PET* and can be acceptable for the *PET* calculation of the 28 GCMs. In future work, we are going to compute the Penman *PET* using the meteorological data from the CMIP5 output and make a comparative analysis to fully understand the *PET* calculation uncertainties in the projections of climate change.

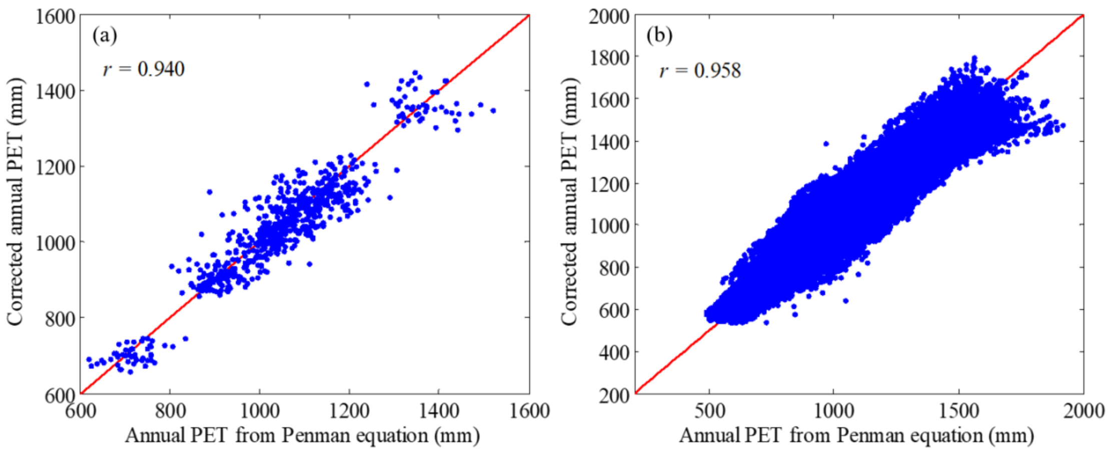

Figure R2. Comparison of annual *PET* calculated from the Penman method and the Thornthwaite method corrected by Equation (1) during the period 1960–2008 for (a) the 14 river basins and (b) all 0.5° grid points over China.

Reference:

Harris, I., Jones, P. D., Osborna, T. J., Lister, D. H.: Updated high-resolution grids of monthly climatic observations–the CRU TS3.10 Dataset, Int. J. Climatol., 34(3), 623–642, 2014.