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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Runoff simulation by SWAT model using high-resolution gridded precipitation in the upper Heihe River Basin, Northeastern Tibetan Plateau" *by* Hongwei Ruan et al.

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Thank you for your comments and suggestions. Those comments are all valuable and very helpful for revising and improving our paper, as well as important for further study of to our researches. We have studied comments carefully and have made correction which we hope meet with approval. The main corrections in the paper and the responds to comments are as flowing:

1) P2, L12-14: The following reference should be added here. Wang YH, Yang HB, et al. Spatial Interpolation of Daily Precipitation in a High Mountainous Watershed

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based on Gauge Observations and a Regional Climate Model Simulation. Journal of Hydrometeorology, 2016, DOI: 10.1175/JHM-D-16-0089.1 Answer: Thus, the gridded precipitation data based on the spatial interpolation of abundant gauged stations and RCM simulation can well depict its spatial heterogeneity, which is suitable for driving the hydrological model (Wang et al., 2017).

2) P2: Author should need to explain why select SWAT model in this study. What are the major advantages of SWAT comparing with many other distributed hydrological models? Answer: Soil and water assessment tool (SWAT) is a physical, semi-distributed hydrological model, which has some advantages in predicting climate change effects on water-related and hydrological processes over a continuous-time (Arnold et al., 2012).

3) P3: How are the glaciers in the study area? Do you consider the glacier melting runoff in the hydrological simulation? Answer: In this study, we did not consider the glacier melting runoff. The SWAT model lack the component of glacier melting runoff, but we simulated snow melting runoff and rainfall runoff on the glacier. Considering the glacier area and runoff contribution are low, and the glacier area changed little in recent years. Thus, ignoring the glacier melting runoff have little influence on the results. We discussed this question in Section 5. Revised in Section 2.1: The glacier area is approximately 34.8 km2, which accounts for 0.35% of the basin area and contributes 3% of the runoff (Kang et al., 1999).

4) P3: "Gridded precipitation data with daily resolutions of 3 km were used as precipitation forcing data downloaded from the Heihe Plan Science Data Centre (HPSD)." Please specify the original source or reference. Answer: Gridded precipitation data with daily resolutions of 3 km were used as precipitation forcing data downloaded from the Heihe Plan Science Data Centre (HPSD), which developed by Wang et al. (2017) .

5) P4: the gridded precipitation data: please refer the following paper. Wang YH, Yang HB, et al. Spatial Interpolation of Daily Precipitation in a High Mountainous Watershed based on Gauge Observations and a Regional Climate Model Simulation. Journal of

Hydrometeorology, 2016, DOI: 10.1175/JHM-D-16-0089.1 Answer: The gridded precipitation data with daily resolutions of 3 km for a time series were generated over the HRB (Yang, et al., 2015; Gao et al., 2015; Qin et al., 2016; Wang et al., 2017).

6) P5, Results: The general introduction about the gridded precipitation data should be moved to the Introduction section. The result section should contain the result mainly. Answer: We have removed this paragraph.

7) P8, Water balance component: Is this a long-term mean water balance at annual scale? Please specify the simulation period. The units of water balance components in Table should be mm/year for precipitation, evapotranspiration and runoff. Please check the units carefully. Answer: I'm so sorry for my careless, we have made correction according to your advice. Revised in section 4.5: The water balance components considered in this study include precipitation (PREC), evapotranspiration (ET), water yield (WYLD) and soil water content (SW), which is a long-term mean value at annual scale during the period of 2003-2014. Table 3 shows the mean annual values of the water balance components from 2003 to 2014 in different regions. For the entire basin, precipitation, evapotranspiration and water yield are 525.5, 318.1 and 194.4 mm/a, respectively. It indicates that the water balance components were relatively balanced. The mean annual precipitation is close to the original gridded precipitation (513 mm/a), indicating that the scale transformation and precipitation lapse rate calculation are reasonable. Evapotranspiration is similar to the remote sensing data (306 mm/a) (Wu et al., 2012). The differences of water balance components in different regions were determined by precipitation. The runoff coefficients in different regions are similar, and the coefficient of the entire basin is 0.37.

8) Section 4.5.1 and 4.5.2: You mentioned "The landscape follows a distinct vertical zonation and comprises the desert, steppe, shrub, coniferous forest, meadow, sparse vegetation, snow and glaciers" (P3). So what are the differences of results in the two sections? Answer: On the whole, the landscape follows a distinct vertical zonation. The distribution of landscape with a certain discontinuity and crumbliness, which may

be crossed several elevation bands. The area of various landscape types have great differences, and the same landscape in different elevation band has great difference. On contrary, the elevation band has obvious boundaries that may be comprised different landscape. Thus, the water balance features of landscape scale and elevation band scale are obviously different. It is necessary to analyze the spatial variability of water balance components, respectively. Revised in section 4.5.2: Elevation significantly affects the hydrological processes in alpine cold mountainous regions. Although the landscape follows a distinct a vertical elevation band, but the elevation band has obvious boundaries that may be comprised different landscape. There are obvious difference between of them. Thus, it is necessary to analyze the spatial variability of water balance components on elevation band scale.

9) P10: Uncertainty of the hydrological simulation should be discussed. Answer: We discussed uncertainty of the hydrological simulation in Section 5. Revised as follows: To some extent, these methods can be used to optimise the precipitation input parameters for the SWAT model effectively and maximise the horizontal and vertical distribution superiorities of the high-resolution gridded precipitation. However, the 1,113 grids were converted into 97 virtual stations, which simplified the spatial distribution of precipitation. Thus, further studies should focus on the optimal drainage threshold area of the sub-basin division. Based on basin climate and terrain, the division into the sub-basin with a large amount, and then the building of virtual station with a high density is necessary. Previous studies showed that precipitation and elevation may be best described by log-linear or exponential functions (Daly et al., 1994). In the present study, liner regression functions were selected because the precipitation lapse rate is considered the mean annual value on the sub-basin scale in the SWAT model. Although this method simplified the vertical variability of precipitation with elevation, a linear regression function is suitable for calculating the precipitation lapse rate for the SWAT model. The upper HRB is a typical high cold mountainous region. The process of glacier and permafrost are ignored by SWAT model. Considering the glacier area and runoff contribution are low and the glacier area changed little in recent years (Guo

et al., 2014), ignoring the glacier melting runoff have little influence on the results. After the analysis of parameter sensitivity by SWAT-CUP, the 10 most sensitive parameters are achieved. The range of parameter calibration was controlled within in ±20%. The precipitation event has great uncertainty and randomness, and gridded data have a certain boundedness to present daily precipitation. We concentrated on monthly runoff simulation and annual scale analysis, in order to reduce the uncertainty that brought by daily precipitation. The SWAT model achieved a good monthly runoff simulation on the large scale and long-term series, which is sufficient to support the study on the water balance component characteristics on the mean annual scale. This result can provide a credibility reference for basin water resource assessment and management. And most hydrological models are simulated monthly runoff in this study area, our research can be used to compare with the previous study. However, the monthly simulation hardly reflects the superiority of the gridded precipitation in spatial distribution. Thus, the further study on the water balance component characteristics on the inner-annual and small catchment scale is necessary. The hydrological model is widely used in the upper HRB to study hydrological processes, which NSEs are usually higher than 0.85 (Li et al. 2009, 2010, 2011; Lu et al. 2015). Compared with these studies using gauged precipitation, the simulation accuracy derived in the present study has yet to be improved. However, this study using high-resolution gridded precipitation, which is obviously superior to a few gauged station. The model calibration not only rely on hydrographs but also refer to basin features, such as base flow coefficient, evapotranspiration, snow melting runoff. Although the statistical evaluation criteria of simulation is not perfect, but the hydrological process and distribution of water balance components are more reasonable. The accuracy of the spatial distribution of water balance components has been improved. The 15 years simulation has a certain limitation to analysis water balance component changing trend. In this region, the meteorology and hydrology researches are plentiful and mature in historical period. Based on previous studies (Liu et al., 2012; Zang et al., 2013; Deng et al., 2015; Lu et al., 2015), we concentrated on the period of recent years, there few studies on this period. The un-

derlying surface data used by SWAT model released in recent years, which is more credible for meteorology and hydrology changing trend analysis in recent years. For model climate forcing, only precipitation inputs used high-resolution gridded data; the temperature, wind speed, solar ration and relative humidity still used gauged data, which were scarce and unevenly distributed. The high-resolution gridded data of other climate elements should be applied in the SWAT model. For validation data, the precipitation lapse rate, soil water content and evapotranspiration lack gauged data match with the resolution of simulation, which is difficult to reflects the superiority of this study. These factors influence the accuracy of the model simulation. The runoff coefficient of the coniferous forest is relatively higher than those reported in previous studies; improvement of the calibration model is necessary (Gao et al., 2015; He et al., 2012; Yin et al., 2016). On the whole, the model parameters setting are empirical, the accuracy and resolution of validation data are too low and the study period is not long enough, which increases the uncertainty of model simulation. Future studies should focus on these limitations to investigate the SWAT model driven by high-resolution gridded data and to improve the model performance.

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Table 3. Water balance components for different regions.

Region	Area (km^2)	PREC (mm/a)	ET (mm/a)	WYLD (mm/a)	SW (mm/a)	Runoff coefficient	Runoff contribution (%)
East tributary	2,504	609.8	364.4	229.9	63.5	0.37	29
West tributary	5,032	522.8	310.3	199.5	58.5	0.38	52
Main stream	2,482	446.2	287.4	148.3	27.7	0.33	19
Entire basin	10,018	525.5	318.1	194.4	52.1	0.37	100

Fig. 1. Table 3. Water balance components for different regions