Response to Referee #2

[Comment 1] This study developed a process-based vegetation phenology module and coupled it with the SWAT-Carbon model. This modified model demonstrates improved performance in simulating both vegetation dynamics and runoff in the upper reaches of the Jinsha River watershed, and it is applied to investigate the vegetation effects on runoff. This study shows the strong influence of vegetation phenology on hydrological processes and highlights the importance of integrating a phenology module into hydrological models. The manuscript is well-written and improves the SWAT-Carbon model for historical and future ecohydrological simulation under climate change, though some details need to be further explained and modified. Some detailed suggestions and comments are listed below:

[Response 1] We thank the referee for the supportive and constructive comments. Please find below our point-by-point response to each comment raised.

[Comment 2] Introduction: The manuscript does not emphasize the significance of choosing the Jinsha River watershed as the study area for applying the modified model. It would be better to clarify the importance of this study area in light of its ecohydrological characteristics.

[Response 2] Following the referee's comment, we emphasized the significance of choosing the upper reaches of the Jinsha River watershed as our study area in the revised manuscript as: "*The upper reaches of the Jinsha River watershed, originating from the Tibetan Plateau and forming the upper reach of Yangtze River, is recognized as one of the ecologically fragile regions in China. In recent years, the upper reaches of the Jinsha River watershed experienced seriously climate change, greatly influencing vegetation dynamics and regional water cycles (Wu et al., 2020; Jiang et al., 2022; Li et al., 2022). Enhancing our understanding and simulation of ecohydrological processes in the upper reaches of the Jinsha River watershed is critical for securing water resources and maintaining ecological stability.*"

[Comment 3] Line 100: Why are these four CMIP6 models chosen for prediction? Some models, such as CanESMs, have coarse spatial resolution especially when applied at the watershed scale. The authors should clarify the considerations for their selection of these climate models.

[Response 3] We thank the referee for this suggestion. We selected the four CMIP6 models based on two main criteria. The first is that these models provide daily time outputs of mean temperature, maximum temperature, minimum temperature, and precipitation, which were used to drive phenology models and SWAT-Carbon model. The second is that these models were commonly used in studies of Yangtze River (Zhang et al., 2023; He et al., 2024). To reduce the effect of resolution differences, we downscaled the spatial resolution of climate data from the four CMIP6 models to match the observation data, and further corrected systematic biases using the empirical quantile mapping technique.

Following the referee's comment, we clarified this in the method section of the manuscript as: "*CMIP6 outputs were used to predict vegetation phenology and future runoff. We selected four CMIP6 models, i.e., CanESM5, FGOALS-g3, MPI-ESM1-2-HR, and MRI-ESM2-0, which were commonly used in studies of Yangtze River (Zhang et al., 2023; He et al., 2024). The daily time series of mean temperature, maximum temperature, minimum temperature, and precipitation under three emission scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5) were acquired from the CMIP6 website (https://esgf-node.llnl.gov/search/cmip6/).*"

[Comment 4] Line 250: Future runoff changes simulated by the modified SWAT-Carbon model could be compared not only with those simulated by the original SWAT-Carbon model but also with runoff directly provided by CMIP6.

[Response 4] Following the referee's comment, we added a comparison of future runoff simulated by the modified SWAT-Carbon model with those directly provided by CMIP6. We found that the average future runoff obtained from CMIP6 models were larger than those simulated by the modified SWAT-Carbon model (please see the Fig. S3 below and the revised manuscript). In the revised manuscript, we incorporated these findings in the results as:

"*Monthly total runoff outputs were obtained from CMIP6 models and aggregated to annual runoff from 2030 to 2100. We calculated the watershed-scale future runoff from CMIP6 using the area-weighted mean method and found that the future runoff from CMIP6 models were larger than that simulated by the modified SWAT-Carbon model (Figure S3).*"

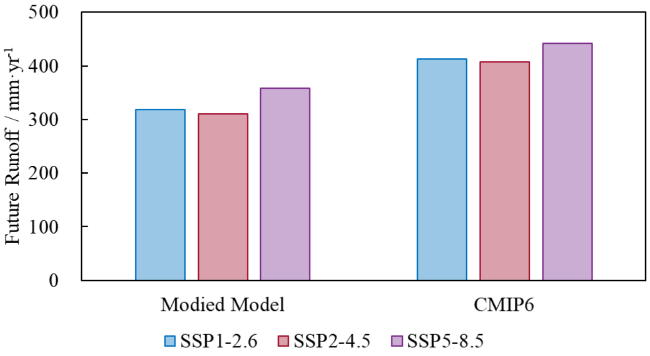

Figure S3: Projection of average future runoff from 2030 to 2100 under each emission scenario simulated by the modified SWAT-Carbon model and CMIP6.

[Comment 5] Figure 2: The information (e.g., abbreviations) in the figures should be clearly interpreted in the figure caption.

[Response 5] Following the referee's comment, we improved the caption of Figure 2.

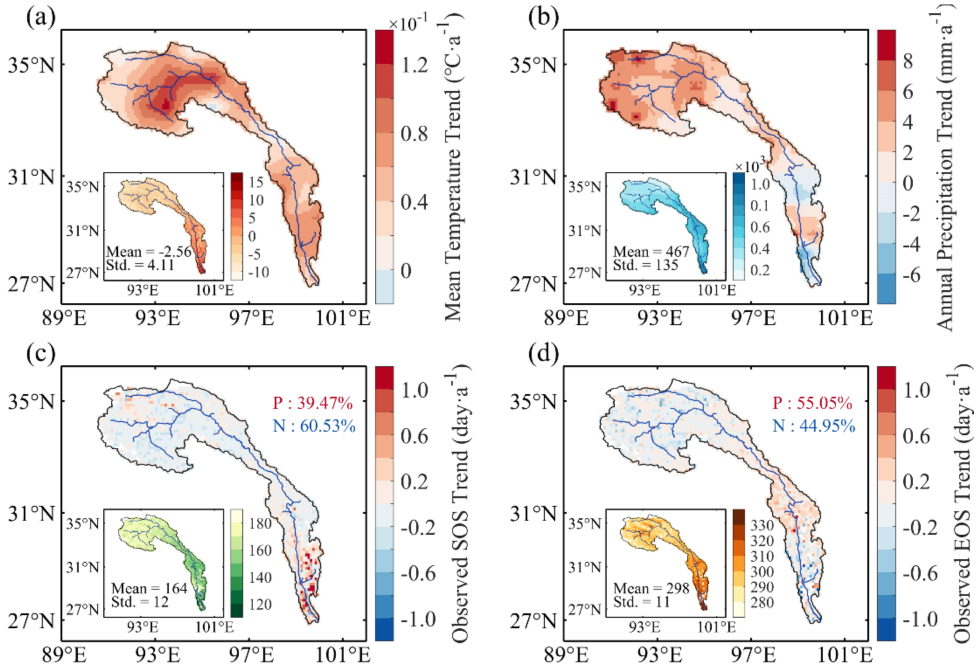

Figure 2: Spatial and temporal variations of climatic variables and vegetation phenology during 1982–2018. Temporal variations of mean annual temperature (a), accumulated annual precipitation (b), start-of-season (SOS, c) and end-of-season (EOS, d). The inner plot of each subfigure depicts the spatial pattern of the multi-year means of each variable. P, percentage of pixels showing a positive trend, indicates increased temperature and precipitation, or delayed SOS and EOS; N, percentage of pixels showing a negative trend, indicates decreased temperature and precipitation, or advanced SOS and EOS.

[Comment 6] Figure 6: These times series should include shading to represent the uncertainty, as shown in Figure 5?

[Response 6] Following the referee's comment, we incorporated shading into Figure 6 to represent the uncertainty across the four CMIP6 models under each emission scenario.

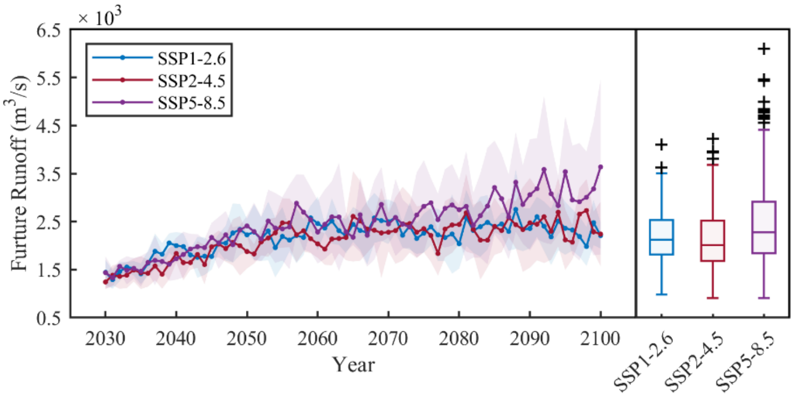

Figure 6: Projection of future runoff during 2030–2100 using the modified SWAT-Carbon model. Colored lines and shading in the right subplot represent the mean and one standard deviation across the four Coupled Model Intercomparison Project Phase 6 (CMIP6) models. The scenarios SSP1-2.6, SSP2-4.5 and SSP5-5.8 refer to low emission, moderate and high emissions, respectively.

[Comment 7] Abbreviations in the text need to be consistent to enhance readability.

[Response 7] Following the referee's comment, we reviewed and corrected abbreviations throughout the manuscript to ensure consistency.

Additional references cited in our response to Referee #2 as:

He, K., Chen, X., Zhou, J., Zhao, D., and Yu, X.: Compound successive dry-hot and wet extremes in China with global warming and urbanization, J. Hydrol., 636, 131332, https://doi.org/10.1016/j.jhydrol.2024.131332, 2024.

Jiang, Q., Yuan, Z., Yin, J., Yao, M., Qin, T., Lü, X., and Wu, G.: Response of vegetation phenology to climate factors in the source region of the Yangtze and Yellow Rivers, J. Plant Ecol., 17, rtae046, https://doi.org/10.1093/jpe/rtae046, 2024.

Wu Y., Fang H., Huang L., and Ouyang W.: Changing runoff due to temperature and precipitation variations in the dammed Jinsha River, J. Hydrol., 582, 124500, https://doi.org/10.1016/j.jhydrol.2019.124500, 2020.

Zhang, C., Sun, F., Sharma, S., Zeng, P., Mejia, A., Lyu, Y., Gao, J., Zhou, R., and Che, Y.: Projecting multi-attribute flood regime changes for the Yangtze River basin, J. Hydrol., 617, 128846, https://doi.org/10.1016/j.jhydrol.2022.128846, 2023.