Reply to Referee #1 Comments

General Comments:

The current study is well thought out, while being presented and organized in a clear manner. The results are important for the scientific community and beyond (water managers and water users within the basin), and this study could play a role in initially quantifying of the types of changes that may occur in the future within the context of a warming climate. I would recommend the manuscript be published, after some minor concerns are addressed. The paper suffers from a lack of validation datasets at the relevant spatial and temporal scales. This is often the case with remote, data sparse, mountainous environments that are the subject of long-term snow research questions. The authors seem to creatively address those problems, but need to make some of the limitations of the validation datasets more clear. I will divide my comments into two categories: minor concerns and minor suggestions.

Reply: Many thanks for the positive comments and suggestions. For the limitations of the validation datasets used in this study, we will elaborate and supplement in detail.

Minor Concerns:

1. Line 148: This is the first time the SSP scenarios are mentioned. They are never defined and this is problematic for the study since it relies heavily on two of the SSP scenarios. Please briefly define the scenarios that are being used in this study and be clear about the differences between SSP126 and SSP585. This is important for readers that may be unfamiliar with these scenarios.

Reply: We have defined the SSP scenarios in the revised manuscript (Line 146–152): "SSP126: it is a combination of the low emission scenario RCP2.6 and the sustainable socioeconomic pathway SSP1, and it represents the low vulnerability, low mitigation pressure, and low radiative forcing (2.6 W m-2); SSP585: it is a combination of the high emission scenario RCP8.5 and the fossil-fueled development pathway SSP5, and it is the only shared socioeconomic pathway that can achieve an anthropogenic radiative forcing of 8.5 W m-2 by 2100, representing the worst development pathway."

2. Line 205: A limitation of this study is the model output resolution of 5km. In complex, mountainous terrain with high relief, a 5km grid cell introduces a huge amount of uncertainty and potential for inaccuracy, both for snow process modeling and for satellite snow remote sensing datasets. Can the authors address this scale

issue in the discussion and add some references to important snow scaling literature related to complex mountain environments? What do the authors think would change in the results if they could model at a significantly higher resolution?

Reply: We agree with the reviewer. The change of the model resolution will directly affect the terrain, that is, the slope, aspect, elevation, etc. will change accordingly, which will affect the model forcing variables that dependent on terrain. Following the suggestions, we further examined the performance of 3 km model resolution on the snow hydrological simulation based on the parameters of 5 km model resolution as follows (Lines 826-856):

"Here, the accuracy of snow hydrological simulation between the model resolution of 3 km and 5 km was compared. The NSE, R^2, KGE, RB and RMSE between the simulated and observed discharge at basin outlet during 1981-1987 based on the 3 km model resolution is 0.82, 0.8, 0.87, -7.93% and 346.12 $m^3 s^{-1}$, respectively (Fig. 8a). It shown that the accuracy of simulated discharge based on the 3 km resolution is slightly improved at basin outlet compared to that of the 5 km model resolution. Meanwhile, the 8d and monthly FSCA of former was slightly improved at basin-scale compared to that of the latter according to the R^2 that is improved from 0.73 (8d), 0.56 (monthly) to 0.74, 0.59, respectively (Figs. S9 b–c and Figs. 5 b–c). Overall, the improvement was not obvious between 3 km resolution and 5 km resolution, which may be caused by the following reasons: the model (WEB–DHM–sf) used in this study takes into account the sub–grid parameterizations, that is, a model grid consists of a set of geometrically symmetrical hillslopes that are the basic hydrological units (BHUs) of the model. The topography parameters (slope, length) of the hillslope in each model grid can be calculated by a fine DEM with 90m resolution (Wang et al., 2009a). The sub–grid parameterization scheme can enable more detailed characterization of basin topography information such as slope, aspect, sky view factor, elevation etc. (Etchevers et al., 2001), thereby retaining the important information of topography-induced spatial variation in forcing inputs (the solar radiation, albedo, precipitation, wind etc.), which would reduce simulation bias caused by model resolution (Winstral et al., 2014; Sohrabi et al., 2019). Furthermore, the original resolution of the forcing data input to the model was above 10 km. Downscaling from low resolution to high resolution (3 km and 5 km) through

interpolation can't improve the accuracy of these variables that affect the snow hydrological simulation, that is because coarse-scale data cannot transfer more effective information to the interpolated fine-scale data by downscaling scale (Sohrabi et al., 2019). However, this didn't mean that it is not important to improve the model resolution, but the model resolution suitable for a specific watershed should be selected according to the characteristics of the watershed, the snow hydrological model used, and the accuracy of the forcing data."

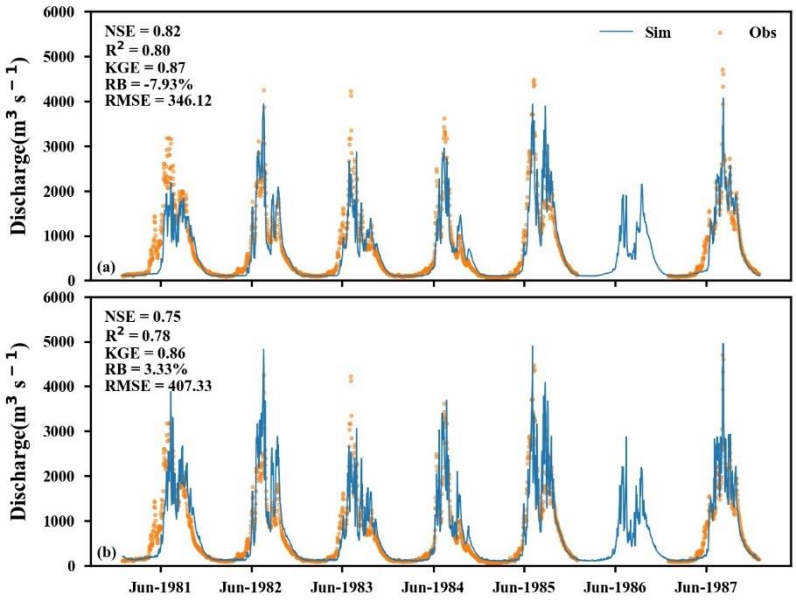

Figure. S8 Simulated and observed (a) 3 km and (b) 5km daily discharges at Jiayuqiao (JYQ) station from 1981 to 1987. The calibration and validation periods were 1981–1983 and 1984–1987, respectively.

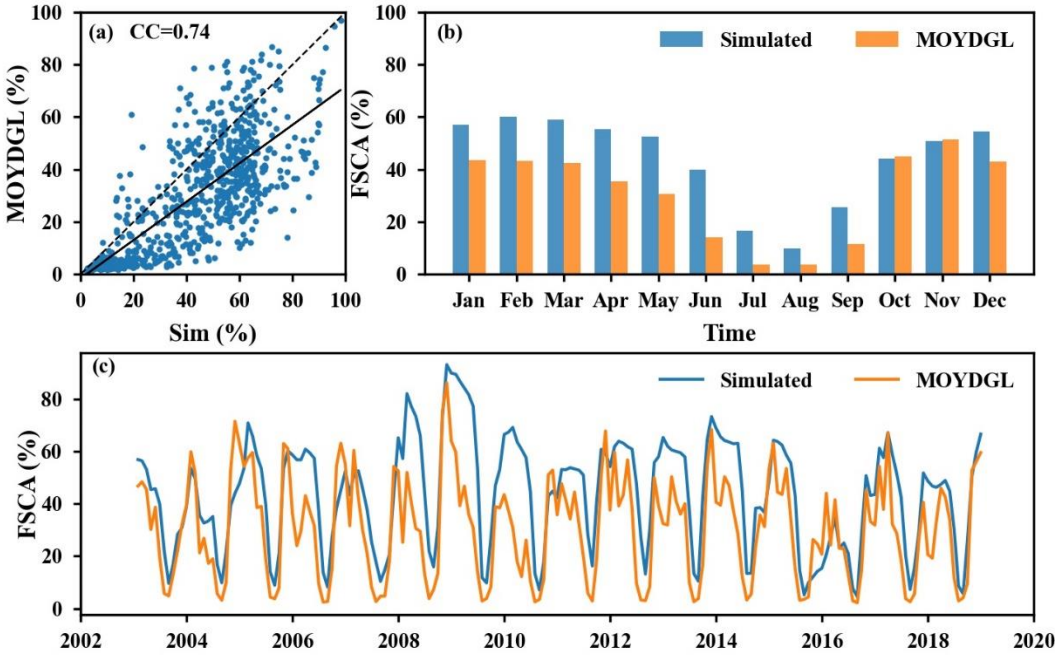

Figure. S9 Comparison of the simulated 3km fraction of the snow cover area (FSCA) and the MOYDGL06* time series in the USR basin. (a) 8-day FSCA; (b) multi-year mean monthly FSCA; and (c) variations in the monthly FSCA during 2003–2018.

3. Line 218-219: What type of evaluation did the authors conduct for the historical time period? How was the evaluation assessed and what metrics were used? They do not mention their methods in this paragraph (or anywhere in the publication?) and how they came to the conclusion that ERA5 was the best.

Reply: We thank the reviewer for pointing this out. We have made corresponding revisions as follows (Line 217-234):

"To better evaluate the applicability of four reanalysis precipitation products (ERA5, GLDAS, MERRA2, MSWEP) in the USR, here we mainly used several statistical indices to evaluate the products based on the meteorological observation data, including Correlation coefficients (CC), Mean error and Root mean square error (RMSE). Moreover, the probability of detection (POD), false alarm ratio (FAR), missing alarm rate (MAR), and Critical success index (CSI) were calculated to check the capture capability of rainfall events from reanalysis products (Ebert et al., 2007; Tian et al., 2009). It can be seen from Figs. S1 and S2 that, except for GLDAS, the statistical indicators of other precipitation products are relatively consistent, but if the international exchange station is excluded (Naqu and Dingqing), ERA5 and MSWEP have good performance (CC is about 0.5). In addition, ERA5 has higher POD (average

about 0.97) and lower FAR (average about 0.44) as a whole, which is also shown on CSI (average about 0.56), implying that ERA5 has better characterization of rainfall events."

Supplemental Figure

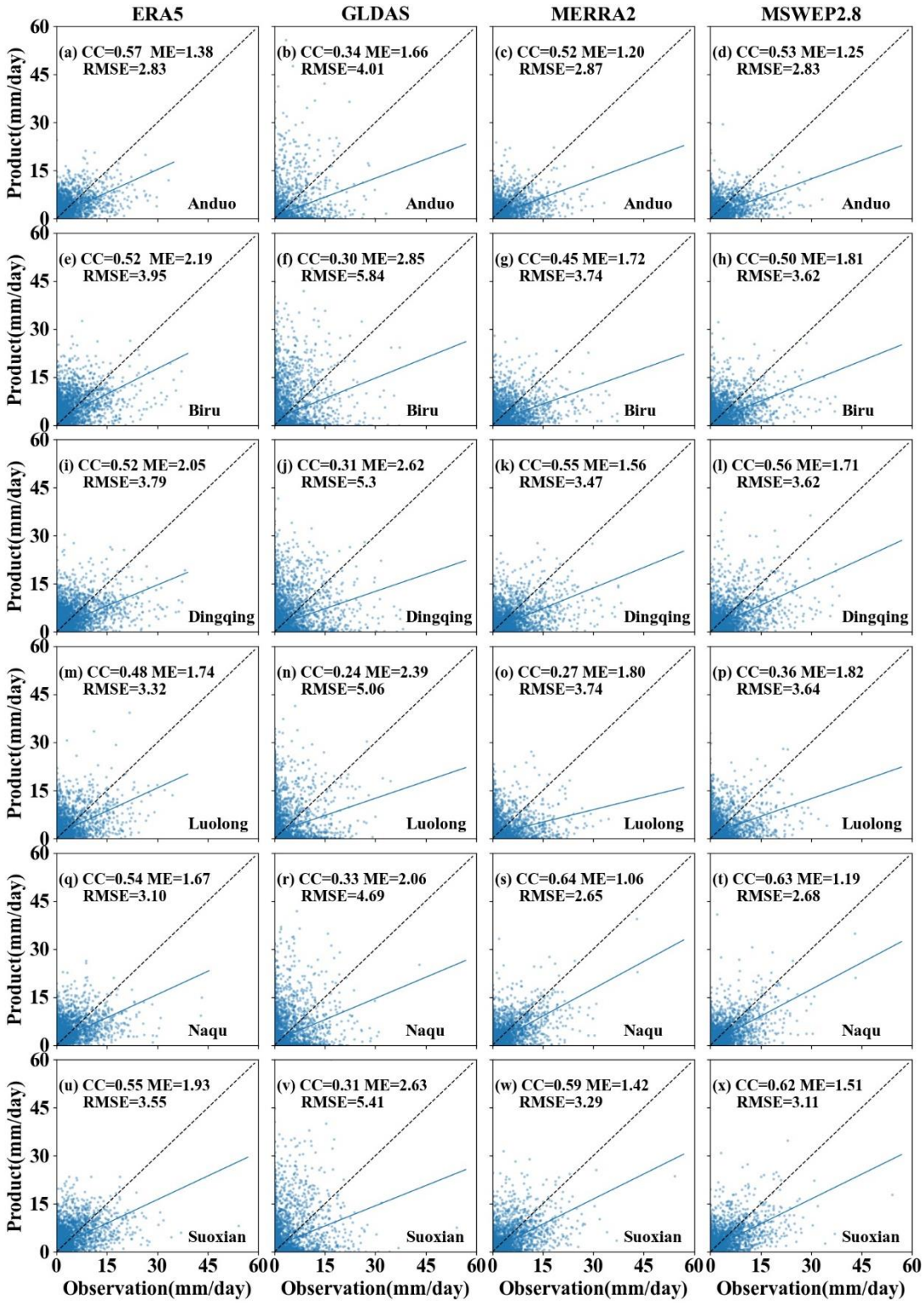

Fig. S1 Comparison of the daily precipitation values between the gauge observation and different operational global products during 2000-2019. The results of ERA5, GLDAS, MERRA2, and MSWEP2.8 are given from the first to the fourth column.

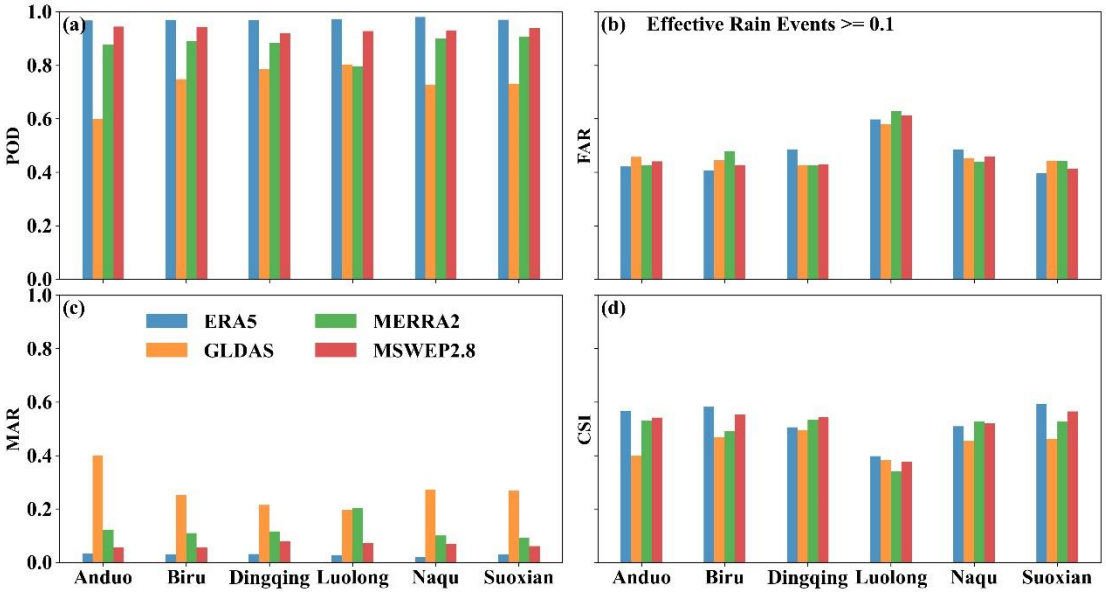

Fig. S2 Evaluation of capturing ability of different global operational products to precipitation events. Effective precipitation is defined as daily precipitation greater than or equal to 0.1 mm. (a) POD (probability of detection); (b) FAR (false alarm ratio); (c) MAR (missing alarm rate), and (d) CSI (critical success index).

4. Line 235: The delta method is mentioned here (and later in the publication) but never described. Please briefly describe this method for readers who are unfamiliar.

Reply: We have supplemented the delta method as follows (Line 247):

"The delta method (it is a simple linear bias correction method, see bias correction methods in Supplementary Material for details).

Supplemental Methodology:

Bias correction methodology for future scenario meteorological data

Using the delta method to correct the future monthly data of GCM needs to calculate the monthly correction factor that is the differences and fraction between monthly mean of historical observations and the monthly mean of GCM historical simulations (1995-2014). The correction factor is then multiplied or added to the future simulated data of the GCM for the corresponding month (Gleick et al., 1986; Hay et al., 2000). The calculation formula is as follows,

$$T_{fut,cor} = T_{fut,GCM} + \left(\bar{T}_{his,obs} - \bar{T}_{his,GCM,}\right) \quad (1)$$

$$P_{fut,\mathrm{cor}} = P_{fut,GCM} \times \left(\frac{\bar{p}_{his,obs}}{\bar{P}_{his,GCM}}\right) \quad (2)$$

Where $T_{fut,cor}$ is the bias-corrected GCM future air temperature, near-surface air pressure, long-wave radiation and short-wave radiation for the 2021-2100; $P_{fut,cor}$ is the bias-corrected GCM future precipitation, wind speed, and specific humidity for the 2021–2100; $\bar{T}_{his,obs}$ and $\bar{p}_{his,obs}$ is the monthly mean of the observation of historical period (1995–2014); $\bar{T}_{his,GCM}$ and $\bar{P}_{his,GCM}$ is the monthly mean of the GCM simulation of historical period (1995–2014)."

5. Line 303: I've never seen a remotely sensed satellite temperature dataset used for validation in a snow modeling study. This does not mean using this dataset is invalid and please correct me if I'm wrong (and add some publication citations for clarity). The need for this validation dataset is likely due to the lack of other spatially extensive snowpack observational datasets, however it still seems a bit odd to me. I'm left wondering how this validation method/dataset performs at elevations in the Upper Salween River watershed where temperatures are most likely to influence snow processes? Also, how does this validation method/dataset perform during the months of the year that snowpack is accumulating and melting, rather than just looking over the entire 18-year time period?

Reply: LST is a key parameter in land-atmosphere interactions because it is the main factor controlling the surface-atmosphere sensible and latent heat fluxes (Wang et al., 2009). Assessment of the LST can be used to evaluate model performance in representing basin-wide energy processes. Due to the lack of heat flux observations, there is no energy-related analysis in this region. However, Satellite remote sensing offered the most feasible, consistent, and accurate means of global fields of land surface parameters (Sellers et al., 1997). In recent years, Moderate Resolution Imaging Spectroradiometers (MODIS) datasets with global coverage and high resolution, were widely used for model evaluations in geophysical studies (Sheng et al., 2009; Shrestha

et al., 2012; Corbariet al., 2014; Zhong et al., 2020; Zhang et al., 2020). The MOD11A2 has shown good agreement with the ground-based LST measurements on the western TP with mean difference of 0.27 K (Wang et al., 2007), and it provides us with a viable option to improve water and energy budget studies at the watershed scale. Therefore, we use MODIS LST to evaluate the performance of the model in the characterization of energy processes. This evaluation method is widely used in high mountain regions, such as Yangtze River (Qi et al., 2019), Nam Co Lake (Zhong et al., 2020), Selin Co Lake (Zhou et al., 2015), etc.

Following the reviewer's suggestion, we further verified the basin-averaged LST from the different elevations (Fig. AC2), and those in snow accumulation and ablation periods (Fig. AC1) during 2001-2018. From the point of view of snow accumulation and ablation period, the simulated LST during the snow accumulation period is better than that in the ablation period compared to MODIS LST. The daytime and nighttime LST simulated during the snow accumulation period are in good agreement with the MODIS LST ($R^2 > 0.7$), but the simulated LST in the daytime is generally lower (MB = -3.87K) and that in the nighttime is slightly higher (MB = 1.64K). While the accuracy of simulated LST has a difference between daytime and nighttime during the snow ablation period, the simulated daytime LST don't reproduce the MODIS daytime LST well ($R^2 = 0.21$, MB = -3.93K) compared to that in the nighttime ($R^2 = 0.67$, MB = 1.01K).

The simulated daytime and nighttime LST can generally better characterize the variation trend of the LST at different elevations in the USR basin, and also have good consistency. The simulated daytime and nighttime LST in high-elevation areas (> 5000m) are better than those in low-elevation areas (< 4500 m) based on the determining coefficient and mean bias. Moreover, the simulated nighttime LST at each elevation is better than those in daytime compared with MODIS LST. The simulated daytime LST at each elevation and nighttime LST at low elevation are lower than MODIS LST, while the nighttime LST at mid-high elevations is slightly higher.

We find that the accuracy of the simulated daytime LST is generally lower than that of the simulated nighttime LST regardless of that perspective. Overestimation for

the daytime was greater than the nighttime mainly due to the complex interactions of the surface energy balance during daytime. The LST is controlled by solar radiation absorbed by the surface canopy and the ground during daytime, and these factors lead to greater uncertainty in the simulated daytime LST in the USR basin with complex terrain, while the solar radiation can be ignored at nighttime, and the LST is mainly affected by the downward long wave radiation (Xue et al., 2013; Zhou et al., 2015).

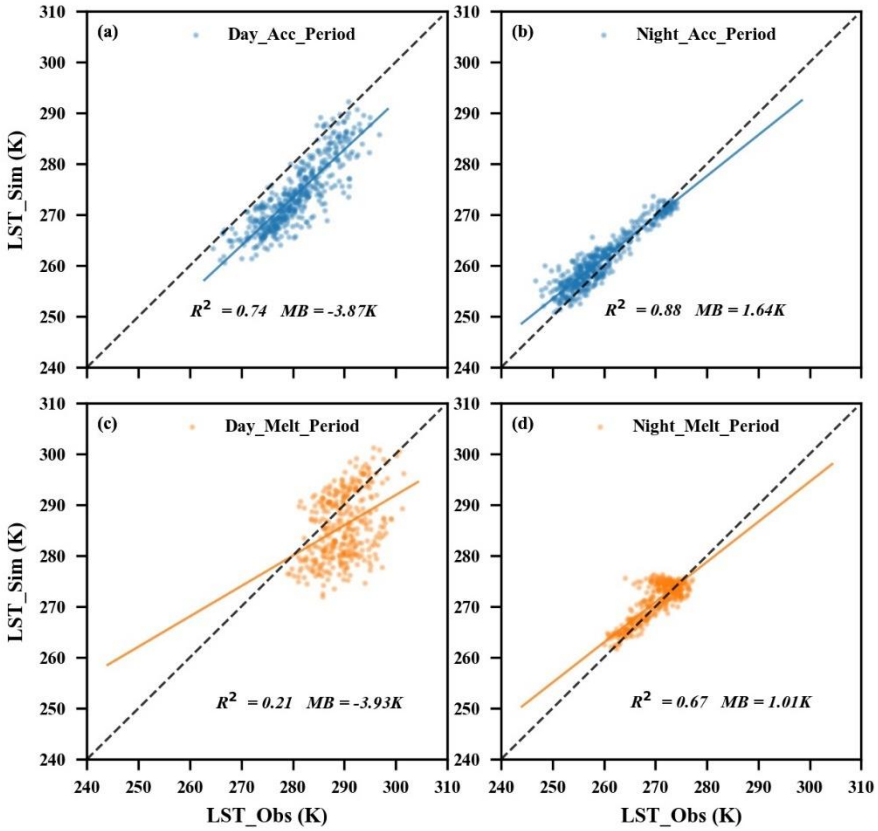

Figure. AC1 Validation of simulated 8-day daytime and nighttime land surface temperatures in accumulation (a, b) and ablation periods (c, d) compared to MODIS 8-day satellite observations, averaged over the USR basin during 2001–2018.

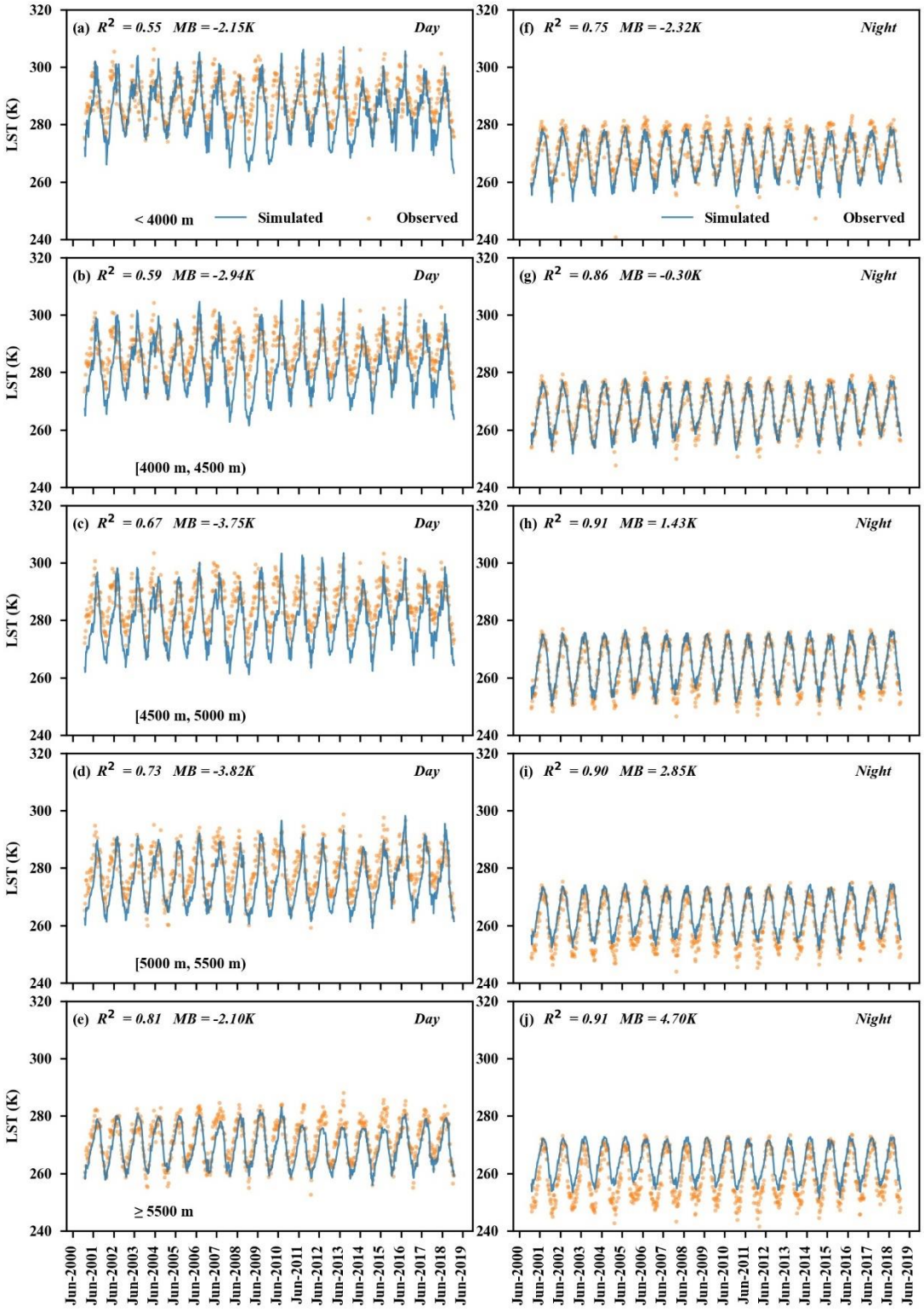

Figure. AC2 Change in the 8-day simulated land surface temperature (day and night) in the different elevation bands compared to MODIS 8-day observations, averaged over the USR basin during 2001–2018.

Minor Suggestions:

1. The title is awkward and a little unclear. I would suggest something more along the lines of "Hydrological changes to runoff in the Upper Salween River from forecast changes to snowpack under climate warming scenarios". This is just a suggestion.

Reply: The main objective of this study is to simulate the changes in the snow-related hydrological processes in the USR. We used the WEB-DHM-sf driven by global climate model (GCM) in CMIP6 to predict the changes in the snowfall, snow cover, snow water equivalent (SWE), total snowmelt, snowmelt runoff during different periods (near-term: 2021-2040; Mid-term: 2041-2060; Long-term: 2081-2100) under different shared socioeconomic pathway scenarios (SSP126 and SSP585), and we further analyzed the impact of the snow changes on the runoff. Therefore, although the reviewer gives a good suggestion, the original title of the manuscript may be more in line with the major contents of the study.

2. Line 19: The authors chose to abbreviate Upper Salween to US but this may be confusing for readers based in the United States, which is also often abbreviated to US. Consider USR for Upper Salween River using instead of US?

Reply: Following the reviewer's suggestion, we have changed the abbreviation of Upper Salween River to "USR" in the revised manuscript.

3. Line 22: I would encourage the authors not to assume that everyone reading the abstract knows what these abbreviations (SSP126 and SSP585) mean without context or the full spelling

Reply: We have supplemented the abbreviations as follows (Lines 18–20):

"In this study, we aimed to project future snow changes and their impacts on the hydrology in the upstream region of Salween (USR) under two shared socioeconomic pathway scenarios (SSP126 and SSP585) using a physically-based cryosphere–hydrology model."

4. Line 51: I'm unsure what 'all walks of life' means in this context.

Reply: For this unclear expression, we have revised it as follows (Line 51):

"Accordingly, it not only has a strong effect on the regional hydrological cycle, but also provides abundant water resources for the industry, agriculture and residents in basins and supports about one-sixth of the world's population."

5. Line 84: The sentence beginning on this line is long and complex, consider splitting apart for clarity.

Reply: We shall do this as follows (Line 84):

"Previous studies have assessed several snow variables (e.g., snowfall, snow storage, SC, and snowmelt) and the hydrological processes related to snow under climate change on the TP based on in-situ observations and land surface snow/hydrological models. However, the impact of future snow changes on runoff is still unclear due to a lack of reliable data."

6. Line 99-100: Consider 'study area' instead of 'research object.'

Reply: We have made revisions as follows (Line 95–97):

"To better understand the effect of snow changes on the TP on runoff under climate change, in this study, the upstream region of Salween (USR) was selected as the study area."

7. Line 101: This is vague, I am not sure what the authors mean by 'complex underlying surface.' Same with line 105 'underlying surface.'

Reply: The meaning of 'complex underlying surface' mentioned in the text is the same as 'the underlying surface', both refer to the diverse and complex surface environment in the basin. In order to avoid ambiguity, we unified the two expressions, using 'complex underlying surface'.

8. Line 144: Use 'observational' instead of 'observation'

Reply: Revised.

9. Line 322: Are there any stats that can quantify the 'very close' and 'slightly overestimated' claims here, thus bolstering your argument?

Reply: The 'very close' and 'slightly overestimated' mentioned here both refer to the comparison between the simulated LST and the MODIS LST during the daytime and nighttime at the basin-average values. We can see the basin-average value of different seasons LST from Figure 4. We have revised it as follows (Line 336):

"The basin-average value of simulated seasonal LST during the nighttime was closer to the MODIS LST (DJF: MB = -2.25 K; MB = JJA: -1.07 K; MAM: MB = -1.5 K; SON: MB = -0.66 K) than that in daytime, and the simulated seasonal LST during the daytime was underestimated in winter (MB = -5.38 K), spring (MB = -7.24 K), and autumn (MB = -2.76 K) and was slightly overestimated in summer (MB = 0.86 K)."

10. Line 365, Figure 6: Using the off-white color to represent no snow and the blue color to represent snow is not easy to interpret here. Anytime white is used in a snow study it is often interpreted as the presence of snow.

Reply: We have made revisions as follows (Line 385):

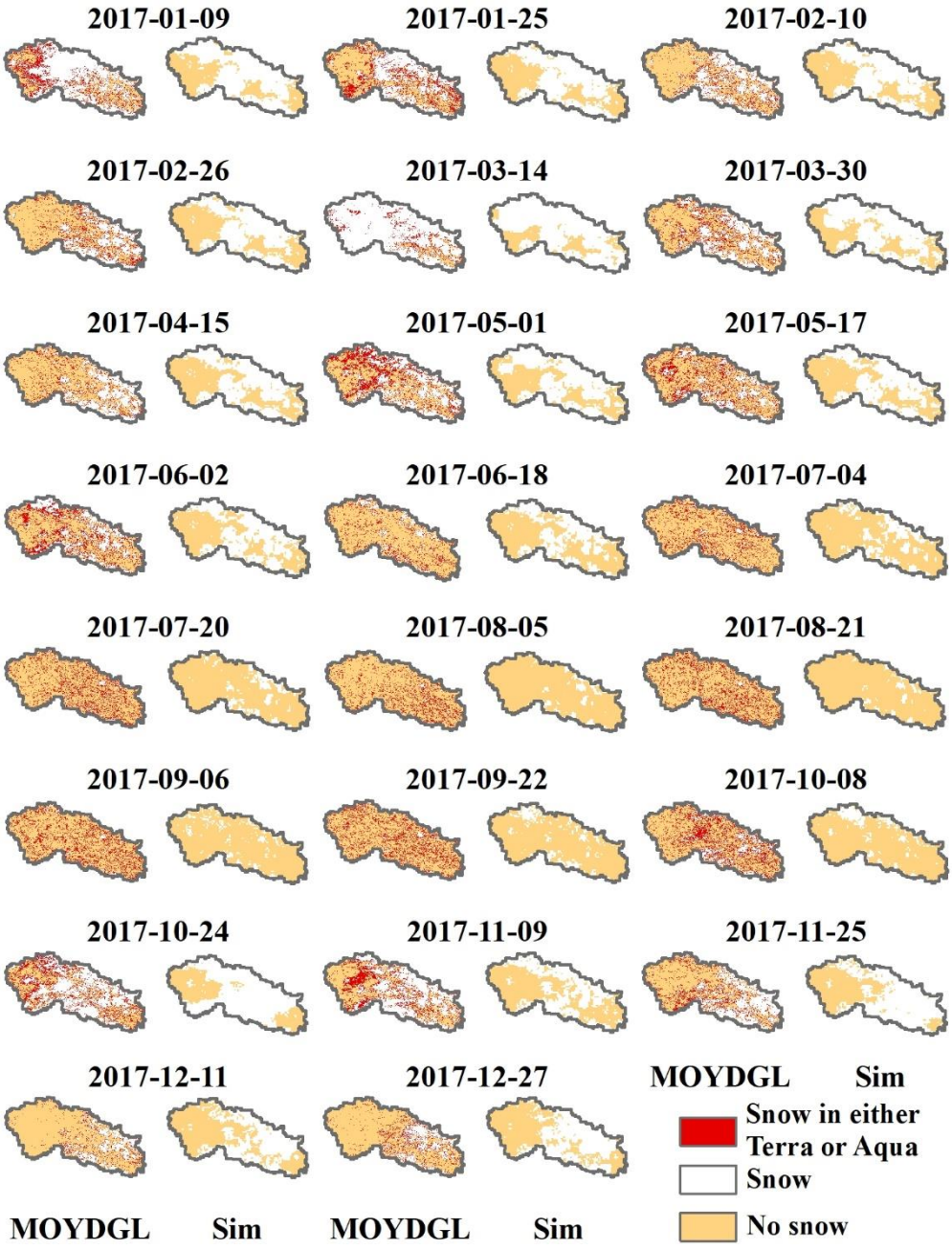

Figure. 6 Comparison of the MODIS 8-day snow cover product (MOYDGL06*) and the simulated 8-day snow cover in the USR basin in 2017. The time interval is 16 days

11. Line 415, Figure 8: These figures are excellent and easy to interpret. However, the SSP585 line becomes difficult to see during the long-term portion of the figure in both (a) and (b). Consider changing the color of the trend line to clarify.

Reply: We have made changes as follows (Line 437):

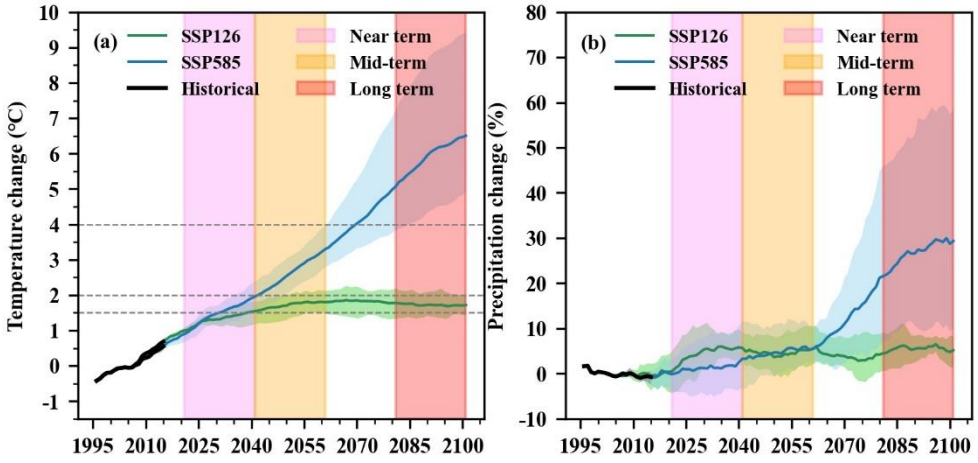

Figure. 8 Relative changes in the annual precipitation and mean annual temperature from 1995 to 2100. The black, bule, and green lines represent the precipitation and temperature during the reference period (1995–2014) and under CMIP6 SSP585 (2015–2100) and SSP126 (2015–2100), respectively. The rectangular shaded areas are the near-term (pink: 2021–2040), mid-term (yellow: 2041–2060), and long-term (red: 2081–2100) periods. The shading around the lines represents the fluctuation range of the data, and the upper and lower ranges are 95% and 5%.

12. Line 436, Figure 9: Again, excellent and intuitive figure. The only thing that needs clarification is the dashed vertical lines, I'm not sure what they represent.

Reply: The dotted line is just a hint that means that the precipitation in April and October during future period (near term, mid-term, long term) is higher than that in the reference period (1995-2014).

Line 457:

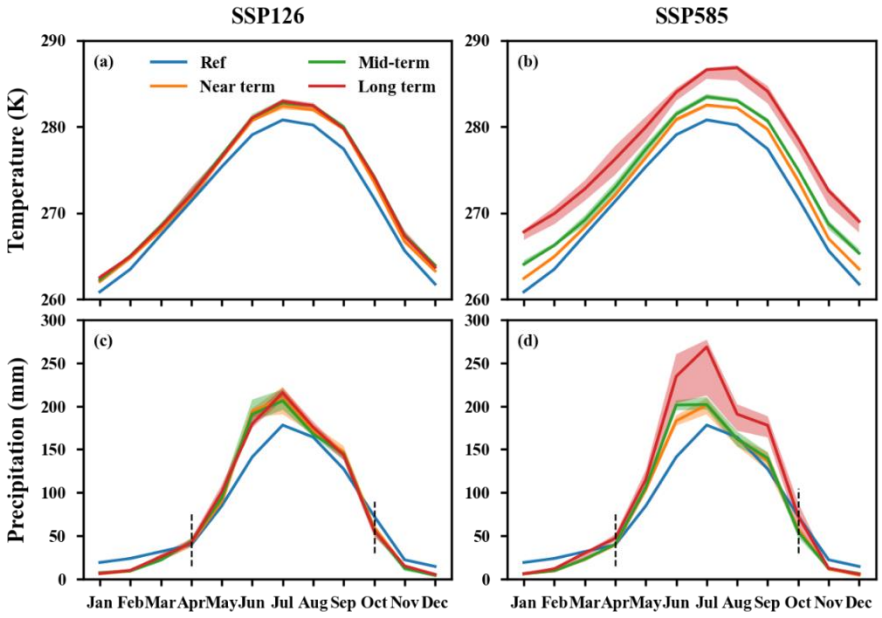

Figure. 9 Seasonal changes in the temperature and precipitation in the reference period, the near term, the mid-term, and the long term under (a, c) SSP126 and (b, d) SSP585. The shading around the lines represents the fluctuation range of the data, and the upper and lower ranges are 95% and 5%. The dotted line of figure b and d means that the precipitation in April and October during future periods higher than that in the reference period.

13. Line 474, Figure 10: In figure 10 (c) and (d) does the solid line represent snowfall? If so, that is not clear from the legend.

Reply: This solid line does represent snow, and we have modified the legend for this figure.

Line 498:

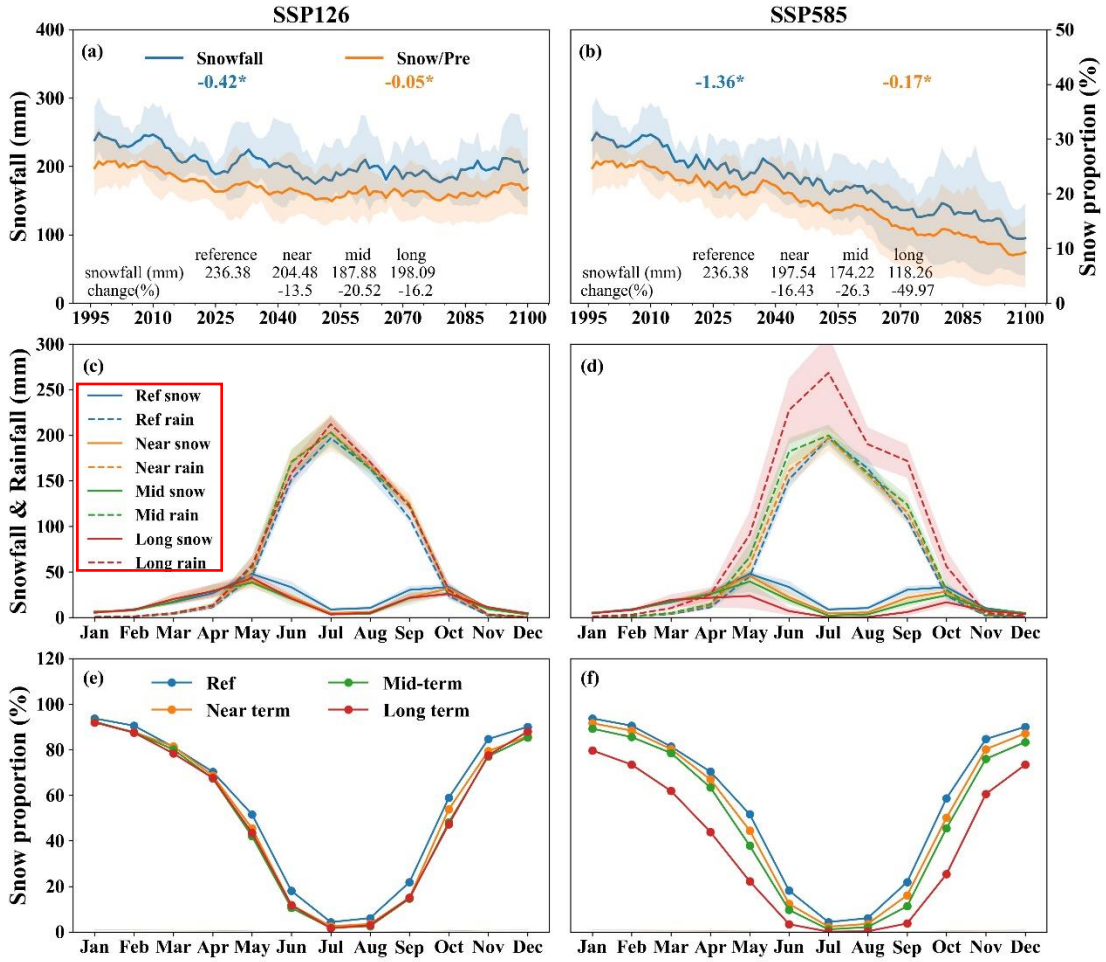

Figure. 10 Snowfall changes and the ratio of snowfall to total precipitation (TP). (a, b) Annual changes in and proportion of snowfall, (c, d) seasonal changes in snowfall and rainfall, and (e, f) the ratio of snowfall to total precipitation on the seasonal scales in the USR basin during different periods under SSP126 and SSP585 compared to the reference period. The shading around the lines represents the fluctuation range of the data, and the upper and lower ranges are 95% and 5%.

14. Line 479: I am not sure what is meant by 'fluctuation range of the data'.

Reply: The fluctuation range of the data indicates the spread in projections for the

future period when forced with the ensemble of 4 GCMs which can also be understood as the very likely range of simulations and the uncertainty range (IPCC, 2021). The shaded band around the line denotes the interquartile range, and the upper and lower ranges are 95% and 5%.

15. Line 497: I think FSAC should be FSCA here.

Reply: Revised.

16. Line 500: I think 'ere' needs to be deleted.

Reply: We have removed this misspelling in the revised manuscript.

17. Line 605 (Fig14) and line 626 (Fig15): These figures are very informative while also being a little complicated to understand. My suggestion is to: 1) remove the seasonal average percentage stats from the figures and put them in a table and 2) separate out the third column as a separate figure that is reported alongside the new table. Then, the authors could group the SSP126 runoff figs and the SSP585 runoff figs into the same figure. In other words, Fig14 column 1 & 2 would be beside Fig 15 column 1 & 2 in a new Figure14. Likewise, Figure14 column 3 would be beside Figure15 column 3 in a new Figure 15. I think this would help simplify the experience for the readers.

Reply: Following the reviewer's suggestions, we have removed the seasonal average percentage stats from the figures 14 and 15, and put them into a table in the supplement file (Tables S7 and S8). we have modified Figures 14 and 15 in the revised manuscript, specifically as follows,

Supplementary information:

Tab. S7 Change and proportion of future seasonal snow runoff to total runoff comparing to the reference period.

SSP	Period	Spring(mm)			Summer(mm)			Autumn(mm)			Winter(mm)		
		TR	SR	%	TR	SR	%	TR	SR	%	TR	SR	%
SSP126	Near term	15.7	4.1	25.9	214.4	53.9	25.1	103.0	8.7	8.5	11.6	0.01	0.09
	Mid-term	17.8	4.3	24.2	232.4	37.9	16.3	113.2	5.5	4.9	13.1	0.01	0.08
	Long term	18.4	4.7	25.6	216.5	55.4	25.3	106.3	8.7	8.2	12.9	0.01	0.09
SSP585	Near term	18.1	4.1	22.5	210.7	43.7	20.7	104.3	6.4	6.1	12.6	0.007	0.05
	Mid-term	21.7	4.8	22.0	257.6	31.8	12.3	125.2	4.5	3.6	14.5	0.01	0.1
	Long term	38.5	3.0	7.6	433.0	9.9	2.3	228.8	2.1	0.9	23.6	0.02	0.09

Reference	20.1	2.9	14.3	199.8	51.1	25.6	104.7	5.9	5.6	16.4	0.01	0.05

Tab. S8 Change and proportion of future seasonal snow runoff to total snowmelt (TM) comparing to the reference period.

SSP	Period	Spring(mm)			Summer(mm)			Autumn(mm)			Winter(mm)		
		TM	SR	%	TM	SR	%	TM	SR	%	TM	SR	%
SSP126	Near term	13.1	4.1	31.0	144.2	53.9	37.4	28.6	8.7	30.5	0.08	0.01	13.2
	Mid-term	14.5	4.3	29.7	134.0	37.9	28.3	27.2	5.5	20.3	0.11	0.01	9.6
	Long term	13.4	4.7	35.2	139.1	55.4	39.8	27.2	8.7	32.1	0.09	0.01	12.4
SSP585	Near term	14.1	4.1	28.9	139.6	43.7	31.3	26.8	6.4	23.9	0.09	0.007	8.0
	Mid-term	17.8	4.8	26.8	125.7	31.8	25.3	24.3	4.5	18.7	0.16	0.014	9.1
	Long term	25.2	3.0	11.6	77.7	9.9	12.7	20.1	2.1	10.3	0.59	0.02	3.6
Reference		11.4	2.9	25.1	170.7	51.1	29.9	34.6	5.9	17.1	0.07	0.01	12.3

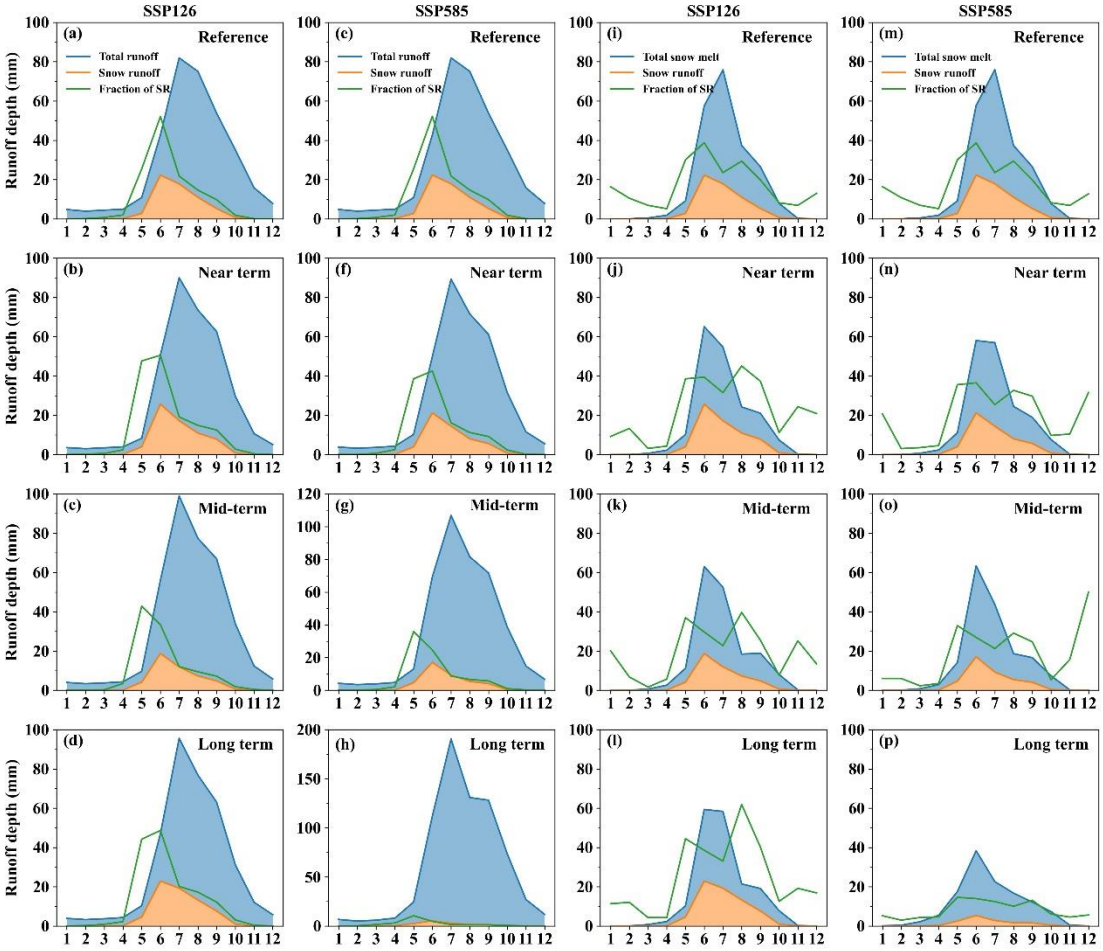

Figure. 14 Changes in the snowmelt in the USR basin during the different periods under SSP126 and SSP585, compared to the reference period; (SSP126: a–e; SSP585: e–h) Comparison of snowmelt runoff (SR) and total runoff at the basin outlet; (SSP126: i–l; SSP585: m–p) Comparison of snowmelt runoff and total melt (snowmelt runoff plus snowmelt that seeps into the soil).

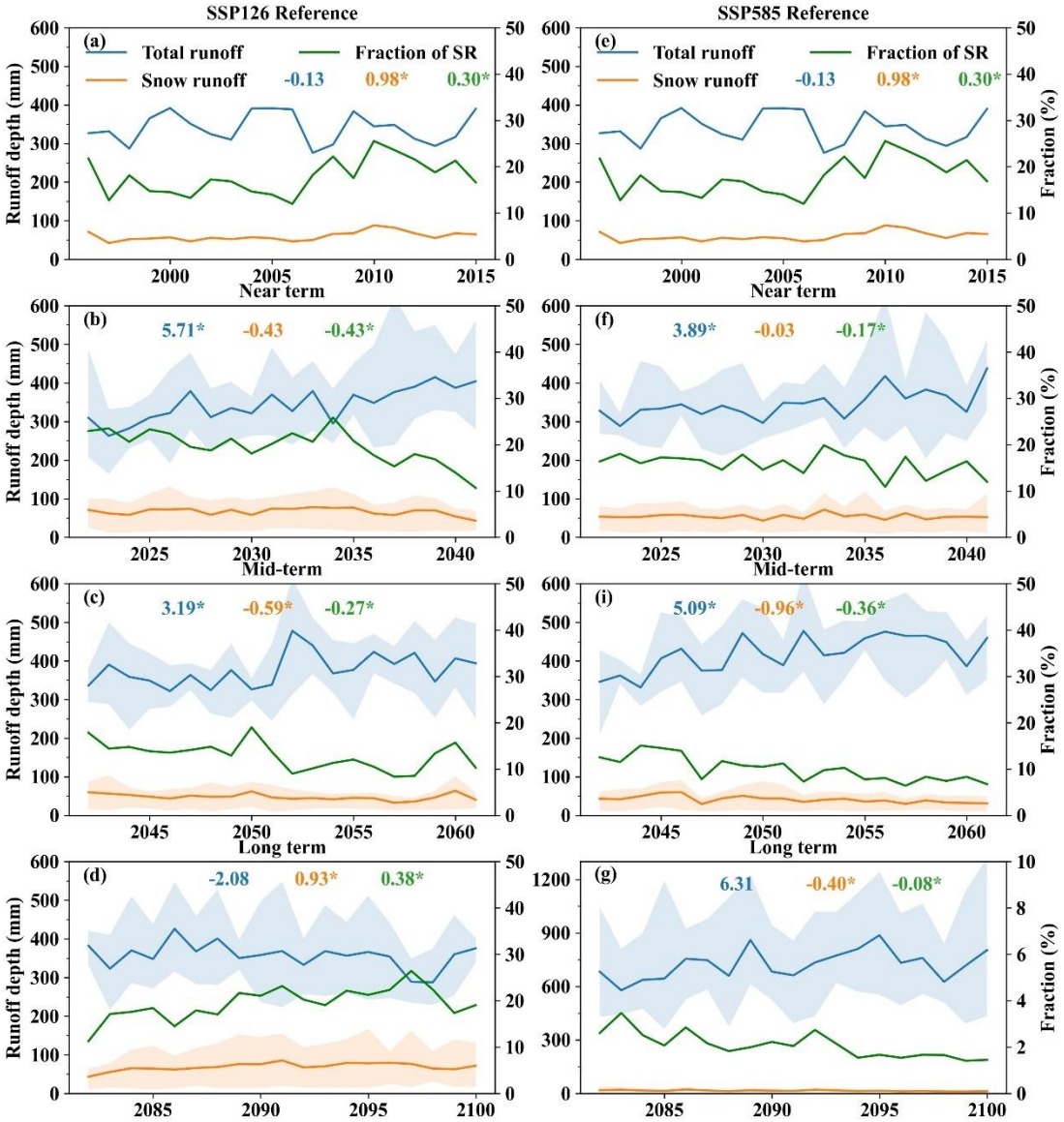

Figure. 15 Changes in the total runoff (blue line) and snowmelt runoff (orange line) during the different periods under SSP126 (a–b) and SSP585 (e–g). The green line is the percentage of snowmelt runoff in total runoff; The number represents the trend of the corresponding line (the same color), and * indicates a significant trend. The shaded band around the line denotes the interquartile range, and the upper and lower ranges are 95% and 5%.

18. Lines 628–675: These paragraphs could be condensed for clarity and ease for the readers.

Reply: We have made revisions as follows (Line 656–686):

"The intra-annual changes in the total runoff would be very similar to those of the precipitation, and the hydrograph would remain largely consistent in all periods under SSP126 and SSP585, with 60% of the annual total runoff occurring in summer and the peak flow occurring in July (Fig. 14a–h). There would be a very obvious change in the total snowmelt, that is, the peak snowmelt would shift from July to June after the

reference period (Fig. 14i–p). The snowmelt runoff in summer is the largest than that in other seasons, accounting for about 65%~85% of the annual snowmelt runoff, and it would sharply increase in May, and peak in June (Fig. 14i–p). From the Table 3, compared to the reference period, there would be a consistent decrease of the spring and winter total runoff in the future periods under all of the SSPs except in the long term of SSP585, while it would increase in summer and autumn in all of the periods. The snowmelt would consistently increase in winter and spring in the future periods under all of the SSPs, while it would markedly decrease in summer and autumn. Similarly, the snowmelt runoff in spring was projected to increase in all of the periods under all of the SSPs, while it would decrease in summer and autumn, except in the near term and long term under SSP126.

Table S6 and Fig. 15 shown the contributions of the multi-year average and seasonal snowmelt runoff to the annual total runoff (SR/TR) in all of the periods under SSP126 and SSP585. The SR/TR was about 17.6% in the reference period, and this value would reach about 19% by the end of the century under SSP126. However, the SR/TR would constantly decrease in all periods under SSP585, with only about 2% by the end of this century. Compared to the reference period, the SR/TR in spring was projected to increase in all of the periods, except in the long term under SSP585. Although the SR in summer would contribute the most to the annual TR at annual scale, the spring SR contributed the most to the spring TR at seasonal scale, which would more obvious after the mid-term under all of the SSPs due to climate warming. (Table S7). From the monthly scale (Fig. 14a–h), the SR/TR was the largest in June during the reference period, while it would gradually shift to May after the near term under SSP585 and SSP126. In short, the above results indicated that the changes in the SR under all of the SSPs would not be the primary reason for the increase in the annual total runoff, but its contribution cannot be ignored."

19. Line 746: I am unsure what 'a lot' means in this context, consider quantifying it or maybe remove?

Reply: We have removed it in the revised manuscript.

20. Line 766: I am confused by the term 'at the edge' here, please clarify.

Reply: The 'at the edge' indicates the lower elevation areas. The changes of snowpack at lower elevation regions are more strongly than that at mid-high elevation regions, since the effects of climate change on the shallow snowpacks at low elevations can be relatively immediate. Eventually, these reductions in snow may translate to shorter snow seasons and a rapid associated decrease in albedo, which contributes to elevation-dependent warming feedbacks. We replaced it in the revised manuscript with at low

elevation regions.

21. Line 839: I am unsure of what is meant by 'massive continued snow melting' here.

Reply: What we want to express here is that a large amount of snowpack is melting in the USR, which further lead to a continuous reduction in snow storage. We have revised it as below (Line 880):

"A large amount of snowpack is melting in the USR, which further lead to a continuous reduction in snow storage."

22. Line 857: I am unsure of what is meant by 'result in a weak balance' here.

Reply: We have made the following modifications (Line 897):

"The snowmelt runoff would significantly decrease, except the long term of the SSP126, and the meltwater peak would advance to June, with the largest proportion would occur in May."

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