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## Reply on RC1

Xuejing Leng et al.

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Author comment on "The Spatiotemporal Regime of Glacier Runoff in Oases Indicates the Potential Climatic Risk in Dryland Areas of China" by Xuejing Leng et al., Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2021-377-AC1>, 2021

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Thank you very much for providing the insightful comments for our manuscript entitled "The Spatiotemporal Regime of Glacier Runoff in Oases Indicates the Potential Climatic Risk in Dryland Areas of China" (ID: HESS-2021-377). First of all, we realize that there were many unclear expressions and wrong marks of parameters in the manuscript which confused you. Following your comments, we have modified the corresponding sentence in responding to each specific comment. We will ask a well-established expert to polish our paper in the revised manuscript. According to your all comments, we think the main corrections in the paper are as follows:

- Correct the wrong variable expression in Method (such as ), and put discussion about precipitation dataset and mass balance dataset into supplementary materials and present it in figures or charts.
- For the socio-economic results of glacier runoff, a specific analysis of the impacts of glacier runoff on oases (e.g. using hydrological models) can be supplemented to increase the persuasiveness of this paper.

As for the method part, we think that adjusting the overall narrative structure is useful to express our method more systematically and explain each variable clearly. The revised method part will be *1. Reconciling High-altitude 2. Glacier Runoff and 3. Uncertainty analysis*. There are indeed some confusing parts in the method part, such as the comparison of mass balance datasets (lines 124-144). We may change this section into a figure in the supplementary materials attached to the manuscript. However, as precipitation is the most basic link in the water cycle and the most basic element in the whole calculation process, we believe that the reasons for selecting precipitation data need to be further explained and verified. Therefore, we only embellished the language in this part but did not delete the two paragraphs (lines 195-224). The confusing concluding paragraph (lines 251-254) should be deleted, and the methods section should now be clear and not short of details. Thank you again for your guidance.

As pointed in the introduction part (lines 61-68), energy balance models which commonly used in calculating glacier runoff are with low resolution and other physical models perform weak on regional scales. Most studies focus on single glacierized catchments or glacier, or develop corresponding glacier runoff modules in areas where terrestrial observations are abundant. In this paper, a high-resolution calculation method of glacier runoff is developed on a regional scale and be applied in oasis regions in drylands of China

to answer the hydrological consequences of glacier runoff, for example, the proportion of water withdrawn in oases due to glacier runoff including delayed runoff and meltwater runoff, in these vital basins in arid areas. Because of our unreasonable words' allocation in the introduction and application, you may not understand the meaning of this research. Highlight the gap that poor research about high-resolution glacier runoff calculating on regional scales may improve readers' recognition of this research.

For the doubt "missing a discussion how water from the glaciers reaches the agricultural areas", we obtained the catchment regions as shapefiles from the RESDC (Resource and Environment Science and Data Center of the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences) on public (lines 89-91). Basins with oases in our article are all originated from glaciers so glacier runoff is bound to affect those oases. While our article focuses on high-resolution glacier runoff calculating on regional scales but not the hydrological distribution model, the accurate value arrived at the oases (how water reached) is not our goal in this paper. We think that the changing proportion of water withdrawals due to glacier runoff under climate change is sufficient to illustrate the threat of glacier runoff to oases. However, following your comment, we think adding a case in one glacier basin to explain the socio-economic consequence caused by glacier runoff will make this paper more persuasive.

The suspicion "the usefulness of calculating trends if changes in glacier extent are not considered" appeared is because the scarce introduction of the glacier extent datasets (lines 87-88, Information about glacier outlines, elevations, and areas was derived from the Randolph Glacier Inventory (version 6.0, [https://www.glims.org/RGI/rgi60\\_dl.html](https://www.glims.org/RGI/rgi60_dl.html))). Randolph Glacier Inventory, a multisource glacier inventory (lines 145-148), was obtained by overlaying outlines on modern satellite imagery and aggregating the World Glacier Inventory. All glacier extents were obtained started in the 1990s and finished in 2014 which is consistent with our research time. Two methods are to use widely to identify changes in glacier extent. One is used the MOD10A1 Snow Cover Daily Global 500m product based on a snow mapping algorithm employing the NDSI (Normalized Difference Snow Index) to obtain the changing of glacier extents (Hall et al., 2016; Muhammad and Thapa, 2021). However, we think that glacier extents changes over the past 55 years cannot be accurately expressed by a 500m product. The other is using satellite imageries in a resolution of 30 m and also the NDSI (Wang et al., 2020; Tak and Keshari, 2020). But the extent is not be as of accurate as the glacier inventory like RGI because of the difficulties to select the least-cloudy scenes. So, we chose the multisource glacier inventory RGI for our research. In addition, we verified our glacier runoff in section 3.2 *Glacier Runoff validation* testifying our trends over Aksu River Basin (1961-1986, lines 402-405) and Ebinur Lake Drainage Systems (the 1980s, lines 406-407) to be usable even if before 1990. Based on the former uncertainties about obtaining changing glacier extents, we think RGI is the most appropriate while the calculation results are proved to be consistent even in the time before the inventory was constructed (1961-1990), so trends can also be used to indicate changes in local glacier runoff.

Overall, thank you for your doubts and suggestions on our language, method structure, and some narrative details, which make great progress on our research. We still insist that the research is valuable. As oases' special impacts supporting agriculture, industry, and municipality in arid areas, how much relative stable water is provided by glaciers is a vital problem to be solved. This paper can fill in the gap of glacier runoff calculation on regional scales lack of local terrestrial observations. However, a case of how much glacier runoff arrived oases is needed to add to the discussion section.

Through the above explanation, I hope you can understand the purpose and hope to dispel your doubts.

A detailed point-by-point response to each comment is shown followed and we think the

article will be more persuasive after our discussion.

*[Reviewer #1 Specific Comment 1] P2: 'Under current climatic conditions, warming causes glaciers to melt and sea level to rise, creating negative feedback between the two' -- what is the negative feedback here?*

[Response] Following this comment, we apologize for our unclear expression. What we want to point is that warming expedites glaciers to melt and then speeds up raising sea levels under current climatic conditions. The increase in meltwater can alleviate drought in the river basins originated from glaciers like the drylands of China, but sea level rise poses risks to coastal areas, meaning that the meltwater of glaciers is not only a result of climate change but also contributing to the consequences of climate change such as rising sea levels. So, we think we could change the sentence as follows:

"Under current climatic conditions, warming expedites glaciers to melt and meltwater speeds rising sea levels, which is why glaciers are both the result of and contributor to climate change."

*[Reviewer #1 Specific Comment 2] P3: 'Semi-distributed hydrological models semi-quantitatively calculated the proportion of meltwater runoff to total runoff without time series' -- what is meant with 'without time series'?*

[Response] The semi-distributed hydrological models used in the previous study only semi-quantitatively calculated the proportion of meltwater runoff to the total runoff. For example, Wang et al. (2019) calculated that glacier runoff accounted for 24.4% of the total runoff in combination with the hydrological data of the outlet in the Ebinur Lake Drainage System. Gao et al. (2008) calculated that glacier runoff in the Kai-Kong River Basin accounted for 21.1% in the 1980s and 22.1% in 2000 or the total runoff, respectively. What these researches showed are ratios over time and but not illustrating complete glacier runoff time series, so we say they are 'without time series'. Perhaps the expression in the original text is not clear enough, we think adding some examples at the end of this sentence for further modification to explain can solve the problem. The corrected sentence is as follows:

"Semi-distributed hydrological models semi-quantitatively calculated the mean proportion of glacier runoff to total runoff rather than a time series, such as 21.1% in the Kai-Kong River Basin in the 1980s (Gao et al., 2008) and 24.4% in the Ebinur Drainage System (Wang et al., 2019)."

*[Reviewer #1 Specific Comment 3] P4: 'Dataset of spatial distribution of degree day factors for glaciers' -- since this dataset is so central for the calculations in this study, just giving a link to this data is not acceptable*

[Response] Following this comment, we think that the explanation of this dataset is not obvious enough that we just describe how the dataset is established in our manuscript (Lines 153-155, 'This paper used the spatial distribution of snowmelt data with a resolution of 0.5° based on a formula built by investigations and observations of 40 different glaciers in the HMA, and the dataset verified the accuracy (Zhang et al., 2006).'). We will correct the unclear sentence and add validation about this dataset in the corrected manuscript as follows:

"This paper used the spatial distribution of degree-day factors (DDFs) for glaciers with a resolution of 0.5° based on a formula built by investigations and observations of 40 different glaciers in the HMA. Map of isolines for the DDFs shows the factors increase gradually from northwest to southeast in western China which is consistent with the varied climatic environment from cold-dry to warm-wet (Zhang et al., 2006)."

*[Reviewer #1 Specific Comment 4] P5: The table shows the area of the oases in each watershed. Apart from expecting here instead the relative area of OAA and glacier cover, the amount of rain in mm does not give a lot of information on the importance of glacier runoff. Why is glacier runoff not calculated as mm/y?*

[Response] The average annual precipitation (mm/y) for each basin of dryland areas of China is listed in Table 1 to show the spatial precipitation heterogeneity between basins. The intention is to illustrate the scarcity and instability of precipitation in the arid zone and to highlight the importance of glacier runoff providing a relatively stable water amount. The table only provides the average annual precipitation as mm/y, but following this comment, we think we should add the coefficients of variation of precipitation to indicate different water conditions in the study area. Explaining the heterogeneity then readers could understand the effects of glacial runoff on mitigation of water scarcity in arid areas. We used mm/y as the unit of precipitation under the description of precipitation in previous studies, while m<sup>3</sup> is used as the unit of glacier runoff to highlight the amount of glacier runoff and facilitate numerical comparison with the amount of agricultural, industrial, and municipal water consumption. According to AQUASTAT (FAO's Global Information System on Water and Agriculture, <https://www.fao.org/aquastat/en/>), the unit of water withdrawal by sector in different countries is m<sup>3</sup>. However, we apologize for the lack of pointing out the water withdrawal source. We will add the part as follows:

"The data used in our manuscript is from AQUASTAT (<https://www.fao.org/aquastat/en/>), The agricultural water consumption at the watershed scale was obtained by averaging the agricultural water consumption statistical data to the land use types of agricultural land and then ranged regional statistics, which was the same with industrial and municipal water consumption."

*[Reviewer #1 Specific Comment 5] P7-15 Methods: Methods:*

*A whole page is used to describe different studies and data sources of geodetic mass balances, first describing those two datasets will be compared (Brun and Shean), to later read only the 'Shean estimation' is used.*

[Response] In section 2.3.1 *Reconciling High-altitude Precipitation*, we first compare the calculation results of mass balance by Brun et al. and Shean et al. using ASTER DEMs and by IceSat-1 (Ice, Cloud, and land Elevation Satellite) in High-mountain Asia. The comparisons are shown in Lines 126 to 131. Since the IceSat-1 datasets were used to calculate the elevation changes of glaciers larger than 5 km<sup>2</sup> not reflecting smaller glaciers and ended providing data in 2009, we choose not to use this dataset in our research (Lines 131-134). Excluding IceSat-1 dataset, this paper focused on comparing the Shean Estimation and Brun Estimation to handle a more appropriate dataset. We compare these two datasets in each region of glaciers in dryland areas of China, and point out the main estimates between the two datasets were relatively consistent, but there was a big difference between the uncertainties (Lines 137-145). This is because the Brun Estimation was a mass balance raster dataset with a spatial resolution of 30 m while Shean Estimation calculated the mass balance of each glacier in the RGI (Randolph Glacier Inventory) and for the above reasons, we select Shean Estimation (Lines 145-148). Since the glacier mass balance dataset is a key dataset for this paper's input data, we thought it should take a whole page to explain why we chose this dataset (Shean Estimation) over others (IceSat-1 or Brun Estimation). We apologize for the confusion in this paragraph and for not giving the reader a clear understanding of why we chose Shean Estimation. To explain more clearly why we choose Shean Estimate, we can change this part into a graphic description in the supplementary materials attached to the manuscript, and simplify the description of the mass balance dataset comparisons.

*[Reviewer #1 Specific Comment 6] P7-15 Methods: Methods:*

*The resolution is 100 m. What does this mean? How does the DDF vary in space? Are the PDD or PDDm calculated for each glacier, for each 100 m, for each basin?*

[Response] We apologize for the unclear sentence "Considering that the spatial resolution of this paper was 100 m, monthly positive-degree days ( ) were chosen instead of absolute (Braithwaite & Olesen, 1993), and they were the summed positive daily average temperatures." (Lines 155-157). Map of isolines for the DDFs shows the factors increase gradually from northwest to southeast in western China which is consistent with the varied climatic environment from cold-dry to warm-wet (<http://www.sciencedb.cn/dataSet/handle/747>). The spatial pattern of DDF in High-mountain Asia will be added later (see the response for Specific Comment 3). The PDD is calculated at a spatial resolution consistent with other variables on the 100 m grid scale. The temperature of PDD is calculated according to the APHRODITE data corrected by DEM data, that is, the temperature decreases by 0.65 degrees for every 100 m rise. So, the corrected sentence reads as:

"Monthly positive-degree days ( ) were chosen instead of absolute (Braithwaite & Olesen, 1993) while the calculation method was still summing positive daily average

temperatures, on the 100 m grid scale. The temperature was obtained according to the APHRODITE data corrected by DEM data, that is, the temperature decreases by 0.65 degrees for every 100 m rise."

*[Reviewer #1 Specific Comment 7] P7-15 Methods: Methods:*

*How was the maximum rainfall height determined?*

[Response] As the name suggests, the height where rainfall is the largest in the whole section is generally called the maximum rainfall height. A detailed discussion of the maximum rainfall height is presented in section 4.1 *Precipitation Correction at High-altitudes* (lines 495-543). In the part, we compare the debate between glaciologists and meteorologists about the maximum rainfall height. There has always been controversy over whether there are one or two maximum altitudes in the mountains. Even in the same region, there are different results due to the limitations of the discipline, purpose, method, time, or initial conditions of the study. About this controversy, we have introduced it in detail in the discussion section (lines 495-543).

*[Reviewer #1 Specific Comment 8] P7-15 Methods: Methods:*

*From the description in the manuscript, it is also unclear how the precipitation gradient was optimized. Was the ablation calculated based on the same period as the Shean mass balance estimation?*

[Response] The ablation was calculated by the product of and as shown in lines 157-158. The original sentence reads as:

"The monthly spatial distribution of ablation, (m), was calculated by the product of and when the sum of the twelve months was the yearly spatial distribution of ablation, it is (m)."

*[Reviewer #1 Specific Comment 9] P7-15 Methods: Methods:*

*And what is 'H', the mean elevation of the glacier?*

[Response] The variable 'H' is the terrain elevation for each glacier described in line 169

meaning the mean terrain elevation calculated by DEM for each glacier.

*[Reviewer #1 Specific Comment 10] P7-15 Methods: Methods:*

*In the current formula (equation 4), the elevation between and are taken twice into account? Or did I understand something wrong? Should it not be (- delta H)□*

[Response] We must apologize for the mistakes in Equation (3) and Equation (4). The correct equations are:

$$\Delta H = H - H_{rmd} \quad (3)$$

$$P(\text{cor},d) = P(\text{rmd},d) \cdot \{1 + [\Delta H + (H - H_{map})]\} \quad (4)$$

□H was calculated by the mean terrain elevation from DEM minus DEM aggregated into the same scales as the APHRODITE dataset,  $H_{rmd}$  (m), for each glacier affecting the DAC. And the corrected precipitation,  $P(\text{cor},d)$  (m), was calculated as a function of original precipitation data from APHRODIE\_MA\_v1101\_EXR1,  $P(\text{rmd},d)$  (m), the vertical precipitation gradient,  $PG$  ( $\% \text{ m}^{-1}$ ), at a daily time step with the maximum rainfall height,  $H_{map}$  (m) and mean terrain elevation from DEM,  $H$  (m), for each glacier.

*[Reviewer #1 Specific Comment 11] P7-15 Methods: Methods:*

*Why were the vertical gradients interpolated if they are already calculated for each individual glacier?*

[Response] As the spatial resolution of temperature and precipitation dataset from APHRODITE is  $0.25^\circ$ , which is quite different from the area of glaciers, the vertical precipitation gradient between nearby glaciers may be quite different. Interpolating each glacier's precipitation gradient could smooth the errors caused by the boundary of the raster data.

*[Reviewer #1 Specific Comment 12] P7-15 Methods: Methods:*

*Like in other parts of the paper, also here discussion parts are mixed up with the methods part and it is confusing to read again about the precipitation gradients in section 2.3.2.*

[Response] In section 2.3.1 Reconciling High-altitude Precipitation, we introduce how to calibrate precipitation data through glacier mass balance dataset. We compare the IceSat-1, Brun Estimation, and Shean Estimation to select a more appropriate dataset for our paper (lines 124-148). The degree-day model is used to calculate glacier ablation (lines 150-158). The way to calculate glacier accumulation (corrected precipitation in this paper) is shown in Equation (2) on each glacier is calculated according to the corrected temperature data based on altitude. Then put the result of Equation (2) in Equation (3) and Equation (4), the vertical rainfall gradient could be calculated. And interpolate precipitation gradient to reduce the error caused by grid edge mutation.

*[Reviewer #1 Specific Comment 13] P7-15 Methods: Methods:*

*Regarding the uncertainty analyses, what is meant with 'the PG of each single glacier around the DAC was obtained with geographical simulation'? In a few paragraphs before I read that PG was obtained by fitting the accumulation to the geodetic mass balance and estimated ablation?*

[Response] As mentioned before, we use interpolation to reduce the uncertainty caused by data mutation at a spatial resolution of 0.25 degrees. So, the geographical simulation here refers to the interpolation method. We apologize for our unclear statement. The sentence needs to be corrected as follows:

"The PG of every glacier around the DAC was obtained by combining the accumulation of mass balance and ablation calculated by degree-day factor model, and geographical simulation was used to reduce the impact of data mutations."

*[Reviewer #1 Specific Comment 14] P7-15 Methods: Methods:*

*And why is only the uncertainty in the Shean mass balance estimation considered? What is the uncertainty in the DDF? These can have a large effect also on the accumulation estimates.*

[Response] According to the individual glacier uncertainty (including random error and systematic error) calculated in the Shean Estimation, we calculated the uncertainty of mass balance. We agree that the uncertainty in the DDF can also bring a large effect on the results. However, previous studies used degree-day factors as a constant value, which means, degree-day factor for glaciers was  $(2 \pm 2)$  ( $\text{mm } ^\circ\text{C}^{-1} \text{ d}^{-1}$ ). The DDF we used in this



paper is from the map of degree-day factors for glaciers in High-mountain Asia which was built by investigations and observations of 40 different glaciers. This distribution of DDF has improved the accuracy when DDF is just a constant value ( $2\pm 2$ ) ( $\text{mm } ^\circ\text{C}^{-1} \text{ d}^{-1}$ ), so the uncertainty of DDF is not considered as a calculation in this paper.

*[Reviewer #1 Specific Comment 15] P7-15 Methods: Methods:*

*For the calculation of glacier runoff and consequently the trend analyses, I do not understand what is meant with the 100 m resolution of this study and how changing glacier area is considered. Are precipitation and temperature calculated for fixed grid cells containing the glacier?*

[Response] The spatial resolution with 100 m was chosen because of the spatial resolution of DEM (version 4.1, <http://srtm.csi.cgiar.org>). We uniformly resampled the precipitation, temperature, and DDF to the spatial resolution of 100 m using the nearest neighbor method before all the calculations in this paper.

*[Reviewer #1 Specific Comment 16] P7-15 Methods: Methods:*

*Which of the parameters are changing over time to calculate a trend in the glacier runoff? Changes in P and T can affect the total glacier runoff and the partitioning between balanced and imbalanced contributions, but also the changes in glacier extent play a role for the amount of glacier runoff.*

[Response] The variables needed to calculate glacier runoff include altitude, precipitation, degree-day factor, and temperature, and of which precipitation and temperature are two major variables over time. The altitude is from DEM and the DDF is from the map of degree-factor in HMA which was built by 40 observations rather than a constant value. Randolph Glacier Inventory, a multisource glacier inventory (lines 145-148), was obtained by overlaying outlines on modern satellite imagery and aggregating the World Glacier Inventory. All glacier extents were obtained started in the 1990s and finished in 2014 which is consistent with our research time. Two methods are to use widely to identify changes in glacier extent. One is used the MOD10A1 Snow Cover Daily Global 500m product based on a snow mapping algorithm employing the NDSI (Normalized Difference Snow Index) to obtain the changing of glacier extents (Hall et al., 2016; Muhammad and Thapa, 2021). However, we think that glacier extents changes over the past 55 years cannot be accurately expressed by a 500m product. The other is using satellite imageries in a resolution of 30 m and also the NDSI (Wang et al., 2020; Tak and Keshari, 2020). But the extent is not as accurate as of the glacier inventory like RGI because of the difficulties to select the least-cloudy scenes. So, we chose the multisource glacier inventory RGI for our research. In addition, we verified our glacier runoff in section 3.2 Glacier Runoff validation testifying our trends over Aksu River Basin (1961-1986, lines 402-405) and Ebinur Lake Drainage Systems (the 1980s, lines 406-407) to be usable even if before 1990. Based on the former uncertainties about obtaining changing glacier extents, we

think RGI is the most appropriate while the calculation results are proved to be consistent even in the time before the inventory was constructed (1961-1990), so trends can also be used to indicate changes in local glacier runoff.

*[Reviewer #1 Specific Comment 17] P15: 'The creeks of the Kriya Rivers basin were the most unique, with 93.67% of the components (glacier runoff) coming from delayed runoff; therefore, more attention should be paid to glacier disasters in this basin. What is meant here?'*

[Response] The composition of glacier runoff in the Kriya Rivers basin is special compared with other river basins where 93.67% of glacier runoff comes from delayed runoff. Delayed runoff is the part runoff stored in glacial areas during cold seasons and then is released in the warm season. It could be said that delayed runoff is basically determined by rainfall and temperature, which is distinguished from meltwater runoff. Therefore, when extreme precipitation climate occurs, it is easy to cause geologic hazards such as flash floods which should be paid more attention to (Kaltenborn et al., 2010; Shen et al., 2007).

*[Reviewer #1 Specific Comment 18] Why is 3.2 a results section? It rather discusses the results? the 3.2 on P18, there is also a 3.2 on P23.*

[Response] We apologize for the wrong subheadings in Section 3 *Results*. The correct subheadings are 3.1 *Glacier Runoff* during 1961-2015 on P15, 3.2 *Glacier Runoff validation* on P18, 3.3 *Glacier Classification Based on Potential Climatic Risks* on P23, and 3.4 *The Spatiotemporal Change in Glacier Runoff* on P24. We first show the calculated glacier runoff values in the Results, and then verify the calculated glacier runoff. As the data are reliable, we explain the climate risk and the temporal and spatial characteristics of glacier runoff including delayed runoff and meltwater runoff. The discussion section includes some detailed discussions of calculating methods and supplements of the socio-economic impact of glacial runoff on oases.

*[Reviewer #1 Specific Comment 19] What is the point that the study tries to make in Section 4.1 and 4.2? From the methods section the calculation of the precipitation gradient was already unclear, but the discussion section does not clarify any of these concerns. Hmap and Href are the same? Could the 'believing' in one or two maximum rainfall heights not be demonstrated here?*

[Response] Our intention in section 4.1 is to discuss the concept of maximum rainfall height and the different maximum rainfall heights for each region, as well as the debate among meteorologists (lines 507-513) and glaciologists (lines 496-503) about maximum rainfall height. And because of different data or observing methods used, the maximum rainfall height would be different even in the same district (lines 515-529). After these descriptions, Table 2 shows the maximum rainfall height for each region used in this paper. In 4.2 of the discussion section, we want to illustrate the calculated distribution of

precipitation gradient (PG) in seven glacier regions (Eastern Tien Shan, Western Tien Shan, Eastern Kunlun, Western Kunlun, Pamir, Qilian Shan, and Karakoram) and the statistical results of PG at different elevation ranges ( $\Delta H + (H - H_{map})$ , where  $\Delta H = H - H_{rmd}$ ). We apologize for the misrepresentation of Equation (3) and Equation (4) again. As a result of this error, the abscissa heading on the left-hand chart in Figure 8 is also incorrect. There is no Href variable in the paper, only maximum rainfall height, Hmap.

As for the debate about whether there are one or two rainfall heights, this paper cannot demonstrate. Equation (3) and Equation (4) in this paper are based on the hypothesis that there is only one maximum rainfall height in a mountain. Corrected high-altitude precipitation decreases with a certain precipitation gradient (PG) corresponding to the height above the only maximum rainfall height. While we have chosen "one rainfall height" as the calculation basis, we think the basis cannot be verified by the conclusions generated on this basis.

*[Reviewer #1 Specific Comment 20] Section 4.3 does in my point of view not add anything to the study.*

[Response] Our intention in section 4.3 is to explain the rationality of selecting precipitation and temperature as input variables for the calculation of glacier runoff as mentioned in lines 570-572. While glaciers in High-mountain Asia are all continental glaciers, precipitation and temperature are the two major factors of glacier runoff change. Frontal ablation is not considered because glaciers regions in this paper are all continental glaciers. Section 4.3 also shows that, compared with precipitation, the temperature is a more dominant influencing factor in the glacier regions studied in this paper (Azam & Srivastava, 2020; Ban et al., 2020; Huai, 2020; Noël et al., 2020).

*[Reviewer #1 Specific Comment 21] Regarding section 4.4, it is described that oases in the DAC rely most on glacier runoff and that it maintains soil moisture, vegetation growth and groundwater replenishment. However, without comparing glacier runoff to other sources of water and without describing the pathways of glacier runoff (how does glacier melt become soil moisture?), such conclusions cannot be drawn.*

[Response] The text in the article is that "OAA in the DAC relied most on glacier delayed runoff and meltwater runoff to irrigate and maintain agriculture as well as to maintain soil moisture, vegetation growth, and groundwater replenishment to maintain food security" in lines 579-581. The conclusion that oases are most dependent on glacier runoff was concluded from previous research (Bury et al., 2013; Clouse et al., 2016; Rasul & Molden, 2019). In this part, we compare meltwater runoff and delayed runoff, two components of glacier runoff, with the domestic, industrial, and irrigation consumption water in oases of DAC, in order to show the relative importance of glacier runoff. So hydrological processes are not taken into account in the original text. However, following your comments, we also think that adding a one-year description of the whole hydrological process of glacier runoff to the oases would make our study more convincing. We hope that we can have the opportunity to add an example to illustrate it later.

*[Reviewer #1 Specific Comment 22] P33: 'For example, due to increased temperature and reduced glacier runoff, California, in the United States, experienced a severe drought from 2011 to 2015 where hydroelectric power decreased by two-thirds' -- I think such a statement requires a reference. Moreover, a lack of precipitation and snowmelt and increased evaporation caused a severe drought, rather than the small 'reduced glacier runoff' contribution.*

[Response] We apologize for missing reference to this sentence "For example, due to increased temperature and reduced glacier runoff, California, in the United States, experienced a severe drought from 2011 to 2015 where hydroelectric power decreased by two-thirds". Based on your comment and the references, we will revise the sentence as follows:

"For example, due to increased temperature and reduced snowmelt or precipitation, California, in the United States, experienced a severe drought from 2011 to 2015 where hydroelectric power decreased by two-thirds due to declining runoff, including glacier runoff (Gonzalez et al., 2018; Rasul & Molden, 2019)."

*[Reviewer #1 Specific Comment 23] P33: 'In the future, glacier runoff will reach its peak when glacier tourism disappears' -- What is the connection between these two processes?*

[Response] We apologize for the unclear statement. The sentence should be corrected as follows:

"Under climate change, the reliability of the natural snow on the traditional glaciers has decreased and the ski season has shortened, posing a certain risk to the ski tourism industry (Falk, 2016; Rasul & Molden, 2019). For example, the ski season in Ontario and Quebec was shortened between 2000 and 2010, and the recent record warm winter resulted in a 10-15% drop in visitors (Scott et al., 2012a). At the same time, considering the human influence could accelerate the melting of the glaciers, some glacier tourism has been canceled, such as Tien Shan in Xinjiang of China. Appropriate human activities in glacial areas, especially on the surface of glaciers, such as hiking, skiing, etc., will not be the main cause of glacier loss, these activities can be carried out. However, authorities in Xinjiang have stopped glacier tourism in Tien Shan, arguing that the loss of glaciers will be far greater than glacier tourism. In the past decade, glacier tourism revenue in Xinjiang was less than 1 billion yuan, but the loss caused by glacier collapse or melting was incalculable (Liu, 2016). Similarly, at Yulong Snow Mountain, the local government is considering stopping glacier tourism as the glacier is also shrinking at an accelerating rate. So, as glacier runoff increases, glacier tourism in many regions may stop for balance melting purposes."

*[Reviewer #1 Specific Comment 24] P34: The linear regression is only introduced in the conclusion (I could not find it elsewhere in the manuscript). Apart from that, how does the study deal with the non-linear change in glacier runoff (peakwater)?*

[Response] The linear regression was introduced in line 441. We used the function FORECAST.LINEAR in Microsoft Excel to predict glacier runoff in the next decade simply as the annual data of glacier runoff obtained are non-stationary series. The results of prediction are compared with the previous 55 years of calculated glacier runoff data to determine whether the glacier is "Increase continuously", "Decrease continuously" or is "Reach the peak soon". The changing slope can be calculated using the mean value of each decade. If the slope is larger than 0.005%, it means increasing continuously, while decreasing continuously happens when the slope is smaller than -0.005%. If the slope is in the range of  $\pm 0.005\%$ , it is considered to be reaching the peak of glacier runoff soon (except Karakoram). We apologize for missing the description of this part and will add it to the paper.

*[Reviewer #1 Specific Comment 25] P34: Nothing that is mentioned at point three in the conclusion I can find in the results section. Where do these conclusions come from?*

[Response] The first sentence in the third conclusion "as a continental glacier, the glacier runoff studied in this paper was mainly regulated by hydrothermal regulation, in which temperature was the dominant factor, followed by precipitation" was from lines 575-577 in section 4.3 *Impact factors*. We apologize for the wrong number in the second sentence "since the water source of the oases in the DAC was mostly glaciers and the total GDP of the OAAs accounted for 76.92% of that of the northwestern DAC, glacier runoff had a greater impact on local agriculture, animal husbandry, and economy" from lines 584-585, the correct proportion is 79.86%. And the third sentence "in the future, it is necessary to quantify the impact of each change in the cryosphere on social production factors more precisely" is a summary statement based on the impact factors of glacier runoff and its socio-economic consequences.

Please also note the supplement to this comment:

<https://hess.copernicus.org/preprints/hess-2021-377/hess-2021-377-AC1-supplement.pdf>