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We would like to thank the editor's decision regarding the revision of our manuscript. We are greatly thankful for the insightful and constructive comments from the anonymous reviewer. We have carefully studied them and revised the manuscript accordingly. This document contains our specific responses to the comments.

Responses to Anonymous Referee #1's Comments:

This manuscript reviews the present status, limitations and future challenges of hydrological modelling in glacierized, data-scarce Central Asia. It is a comprehensive review on recent development in hydrological modeling in glacierized catchments of Central Asia. The authors summarized hydrological responses to climate change during the past few decades and for the future period in literatures. Importantly, the limitations of hydrological modeling in the glacierized regions are summarized and discussed in terms of model inputs, model structure and model calibration. This is an interesting and important study, in particular, to discuss the specific module (glacier melt) and its limitations in hydrological modeling in Central Asia. I believe that the manuscript shed light on data-sharing and multi-objective calibration that should be effective to help us understand the hydrological processes in data-scarce Central Asia. I believe this manuscript has provided a comprehensive and timely review and deserves to be published in Hydrology and Earth System Sciences. However, the following major comments should be addressed in the further revision processes.

(1) Studies on fieldwork, e.g., glacier retreat monitoring, glacier melt modeling, should be additionally reviewed and discussed.

Response: Thanks for your advice. We have added the general glacier retreat monitoring in Section 1 (Page 1 Lines 26-29) in the revised version.

The glacier melt modeling, e.g., hydrological modelling of single glacier, was additionally reviewed and added in Table 2. For example, the hydrological modelling of test site "Abramov" in Syr Darya and "Oigaing" in Amu Darya were added. This study focuses on the glacio-hydrological modeling, e.g., conclusions, limitations and directions, in the Tienshan Mountains. To make this clear, we added the explanation in our manuscript in Section 3.2.

Page 1 Lines 26-29: According to Farinotti et al. (2015), the overall decrease in total glacier area and mass from 1961 to 2012 to be 18±6% and 27±15%, respectively. These values correspond to a total area loss of 2,960±1,030 km^2, and an average glacier mass change rate of 5.4±2.8 Gt yr^{-1}.

Page 8 Line 14: This paper focuses primarily on glacier melt modules. It does not include the individual glacier dynamics.

(2) Line 161-209: The glacier melt model (Lines 183-192) should come first in section 3.2, and then its coupling with hydrological models (for example, distributed hydrological models).

Response: Thanks for your comment. We have revised accordingly in the revised version.

3.2 Glacier melt modelling

~~Glacier models that are physical-based (e.g., mass-energy fluxes and glacier flow dynamics) depend heavily on detailed knowledge of local topography and hydrometeorological data, which are generally limited in high mountain regions (Michlmayr et al., The temperature-index method (or its variants), which only requires temperature for meteorological input, is widely used to calculate glacier melt (Konz and Seibert, 2010). In recent years, hydrologists were trying to add other meteorological variables into the calculations of glacier melt, e.g., Zhang et al. (2007b), included potential clear sky direct solar radiation in the degree-day model, and Yu et al. (2013) stated that accumulated temperature is more effective than daily average temperature for calculating the snowmelt runoff model. Using degree-day calculation is much simpler than using energy balance approaches and could actually produce comparable or better model performance when applied in mountainous basins (Ohmura, 2001).~~

~~Several limitations could be concluded in the glacier process modeling in the previous studies.~~

Glacier melt accounts for a large part of the discharge for the alpine basins in Central Asia as discussed above. However, most hydrological modeling does not include glacier melt and accumulation processes. For example, Liu et al. (2010) failed to account for the glacier processes ~~through~~in VIC model in the Tarim river; Peng and Xu (2010) missed the glacier module in Xin'anjiang and Topmodel; Fang et al. (2015a) failed to account for glacier processes though the glacier melt could contribute up to 10% of discharge of the Kaidu River Basin. Similarly, in their research on the Yarkant River Basin, Liu et al. (2016a) neglected to include the influence of glacier melt in the SWAT and MIKE-SHE model, even though the glacier covered an area of 5574 km^2. The most widely used hydrological models, such as the distributed SWAT, the MIKE-SHE model and the conceptual SRM model, do not as a rule calculate glacier melt processes, despite the fact that excluding the glacier processes could induce large errors when evaluating future climate change impact. Glacier processes are complex, in that glacier melt will at first increase due to the rise in ablation and lowering of glacier elevation, and then, after reaching its peak, will decrease due to the shrinking in glacier area (Xie et al., 2006). Moreover, simulation errors can be re-categorized as precipitation or glacier melt water and consequently result in a greater uncertainty in the water balance in high mountain areas (Mayr et al., 2013).

During the last few decades, a large variety of melt models have been developed (Hock, 2005). Previous studies have investigated glacier dynamics for the mountainous regions. Among these studies, Hock (2005) reviewed glacier melt related processes at the surface-atmosphere interface ranging from simple temperature-index to sophisticated energy-balance models. Glacier models that are physical-based (e.g., mass-energy fluxes and glacier flow dynamics) depend heavily on detailed knowledge of local topography and hydrometeorological data, which are generally limited in high mountain regions (Michlmayr et al., 2008). Hence, they mostly applied to well-documented glaciers and have few applications in basin-scale hydrological models.

The temperature-index method (or its variants), which only requires temperature for meteorological input, is widely used to calculate glacier melt (Konz and Seibert, 2010). As is illustrated by Oerlemans and Reichert (2000), glaciers can be reconstructed from long-term meteorological record, e.g., summer temperature is the dominant factor for glaciers in a dry climate (e.g., Abramov glacier). In recent years, hydrologists were trying to add other meteorological variables into the calculations of glacier melt, e.g., Zhang et al. (2007b), included potential clear sky direct solar radiation in the degree-day model, and Yu et al. (2013) stated that accumulated temperature is more effective than daily average temperature for calculating the snowmelt runoff model. Using degree-day calculation is much simpler than using energy balance approaches and could actually produce comparable or better model performance when applied in mountainous basins (Ohmura, 2001).

More recently, the melt module has been incorporated into different kinds of hydrological models. Zhao et al. (2015) integrated a degree-day glacier melt algorithm into a macroscale hydrologic Variable Infiltration Capacity model (VIC) and indicated that annual and summer river runoff volumes would decrease by 9.3% and 10.4%, respectively, for reductions in glacier areas of 13.2% in the Kumalike River Basin. Hagg et al. (2013) analyzed anticipated glacier and runoff changes in the Rukhk catchment's upper Amu-Darya basin up to 2050 using the HBV-ETH model by including glacier and snow melt processes. Their results showed that with temperature increases of 2.2 ℃ and 3.1 ℃, the current glacier extent of 431 km^2 will reduce by 36% and 45%, respectively. Luo et al. (2013) taking the Manas River Basin as a case study, investigated the glacier melt processes by including the algorithm of glacier melt, sublimation/evaporation, accumulation, mass balance and retreat in a SWAT model. The results showed that glacier melt contributed 25% to streamflow, although the glacier area makes up only 14% of the catchment drainage area.

~~Glacier models that are physical-based (e.g., mass-energy fluxes and glacier flow dynamics) depend heavily on detailed knowledge of local topography and hydrometeorological data, which are generally limited in high mountain regions (Michlmayr et al., 2008). Hence, they have few applications in basin-scale hydrological models. The temperature-index method (or its variants), which only requires temperature for meteorological input, is widely used to calculate glacier melt (Konz and Seibert, 2010). In recent years, hydrologists were trying to add other meteorological variables into the calculations of glacier melt, e.g., Zhang et al. (2007b), included potential clear sky direct solar radiation in the degree-day model, and Yu et al. (2013) stated that accumulated temperature is more effective than daily average temperature for calculating the snowmelt runoff model. Using degree-day calculation is much simpler than using energy balance approaches and could actually produce comparable or better model performance when applied in mountainous basins (Ohmura, 2001).~~

~~Several limitations could be concluded in the glacier process modeling in the previous studies.~~

(3) If one want to quantify the hydrologic responses to climate change in central Asia (section 2.1), it would be interesting to compare researches on other parts of the world (e.g., the Alps, the Andes, the Himalayas, etc.). That would be more relevant to a general expectation in glacierized catchments.

Response: According to the reviewer's comment, we added Section 2.3 to compare hydrological responses for different glacierized regions worldwide including the responses of glacier runoff to climate change. Their common characteristics and differences are also addressed.

2.3 Glacio-hydrological responses to climate change: a comparison

The hydrological responses to climate change of several major glacierized mountainous regions are also discussed to make a comparison to that in the glacierized Tienshan Mountains. For the Himalaya–Hindu Kush region, investigations suggested that a regression of the maximum spring streamflow period in the annual cycle by about 30 days, and annual runoff decreased by about 18% for the snow-fed basin, while increased by about 33% for the glacier-fed basin using the Satluj Basin as a typical region (Singh et al., 2005). For the Tibetan Plateau, the glacier retreat could lead to expansion of lakes, e.g., glacier mass loss between 1999 and 2010 contributed to about 11.4% ~ 28.7% of three glacier-fed lakes, Siling Co, Nam Co and Pung Co (Lei et al., 2013). Analysis from groundwater storage indicated that the groundwater for the major basins in the Tibetan Plateau has increased during 2003-2009 with a trend rate of +1.86 ±1.69 Gt yr^{-1} for the Yangtze River Source Region, +1.14 ±1.39 Gt yr^{-1} for the Yellow River Source Region (Xiang et al., 2016).

For the South American Andes, the melting at the glacier summit has been occurred. With the continually increased temperature, though glacier melt was dominated by maybe other processes in some regions, the probability seems high that the current glacier melting will continue. As the loss of glacier water, the current dry-season water resources will be heavily depleted once the glaciers have disappeared (Barnett et al., 2005).

For the Alps Mountains, many investigations have been implemented, ranging from glacier scale modelling to large basin scale or region scale modelling (Finger et al., 2015; Abbaspour et al., 2015). Glacier melt water provided about 5.28±0.48 km^3 a^{-1} of freshwater during 1980–2009. About 75% of this volume occurred during July–September, providing water for large low-lying rivers including the Po, the Rhine and the Rhône (Farinotti et al., 2016). Under the context of climate change, decreases in both annual and summer runoff contributions are anticipated. For example, annual runoff contributions from presently glacierized surfaces are expected to decrease by 16% by 2070–2099, despite of nearly unchanged contributions from precipitation under RCP 4.5 (Farinotti et al., 2016).

For the glacierized regions, they have something in common. The annual runoff is likely to reduce in a warming climate with high spatial-temporal variation at the middle or end of the 21st century. Seasonally, increased snowmelt runoff and water shortage of summer runoff with the disappearing glaciers are expected. However, there are also differences in the responses of hydrological processes to climate change. For example, the contrasting climate change impact on river flows from glacierized catchments in the Himalayan and Andes Mountains (Ragettli et al., 2016). In the Langtang catchment in Nepal, increased runoff is expected with limited shifts between seasons while for the Juncal catchment in Chile, the runoff has already been decreasing. These qualitative or quantitative differences are mainly caused by glaciation ratio, regional weather pattern and glacier property (Hagg & Braun, 2005).

However, for many glacierized catchment in the Tienshan Mountains, currently or for the next several decades, the runoff appears to be normal or even increasing trend, making an illusion of better prospect. What worth particularly mentioning is that, once the glacier storage (fossil water) melts away, the water system is likely to go from plenty to want, leading to water crisis given the increasing water demand.

(4) Line 82-84: need references on that.

Response: According to the reviewer's comment, we added the reference in the revised manuscript. For example, the runoff of the Kumalike river (glaciation being 16.2%) has increased 26.2% compared to 14.9% of the Toxkan River (glaciation being 4.2%) (Duethmann et al., 2015). This is also supported by the Karatal river (Kaldybayev et al., 2016) and the Toudao Gou river.

The added reference:

Kaldybayev, A., Chen, Y., Issanova, G., Wang, H., and Mahmudova, L.: Runoff response to the glacier shrinkage in the Karatal river basin, Kazakhstan, Arabian Journal of Geosciences, 9, 1-8, doi:10.1007/s12517-015-2106-y, 2016.

(5) Line 85: Reorganize this sentence "glacier inflection points will or have already appeared, the amount of surface water will probably decline or remain at a high state of fluctuation".

Response: This sentence has been revised to "With further warming and the resulted acceleration of glacier retreat, glacier inflection points will or have already appeared. The amount of surface water will probably decline or keep high volatility due to glacial retreat and reduced storage capacity of glaciers (Chen et al., 2015)."

(6) Line 100: Section 3.1 should be "Meteorological input in hydrologic .. " instead of "Input in hydrologic: : :". Only the meteorological inputs are discussed here and other inputs (soil, snow cover, landuse) are not well described.

Response: We have updated it accordingly.