Comments on **"Change in Frozen Soils and Its Effect on Regional Hydrology in the Upper Heihe Basin, on the Northeastern Qinghai-Tibetan Plateau"** by Gao et al. submitted to *The Cryospshere*

General comments

This paper reports a modelling study about the impacts of climate warming on frozen ground and hydrological processes for a large mountainous area containing permafrost and non-permafrost areas. The model reasonably captured the thermal and hydrological processes, especially the seasonal and long-term variations of river discharge and runoff. The results show changes in permafrost extent and thawing/freezing deaths, and associated changes in hydrological processes in this large area. The spatially distributed modelling approach is novel and efficient for such a large and cold region as well. This work is valuable to demonstrate the progress in high-resolution thermal-hydrological integrated spatial modelling for large cold regions and to understand the impacts of climate change on frozen ground and associated hydrological processes. Although I agree with some of the concerns indicated by the previous reviewer (see details below), I feel it is worthy to be published after a revision.

Specific comments

I agree with the concern of the previous reviewer that the almost exact simulation of ground temperatures at deep layers at the test sites (Figure 3, and Figure S1) probably is the results of calibration, i.e., setting the initial values. The paper should indicate that and probably needs to revise the phase "generally accurate" to a looser term. In addition, if there is no geothermal heat flux at the bottom, ground temperature profile in lower ground should not vary much with depth under equilibrium conditions (unless the 10-year climate force used to spin-up varied significantly from year to year). Most simulated and observed soil temperature increased with depth, indicating the existence of a geothermal gradient. The assumption of zero geothermal heat flux at the lower boundary (Line 279) seems not right.

The causal relationship between changes in frozen ground and runoff is an important issue and the paper tried to answer it. The high correlation between liquid soil moisture and runoff in freezing season is not enough to establish that causal relationship (Line 471-474). The modelling exercise of without frozen soil and Figure S2 are a direct way to show the effects of frozen ground and its thaw. More detailed explanation of the modelling exercise needs to be provided (e.g., how the model was modified to do that? is this a run for a grid or for the entire basin?). Figure 15 is interesting but not so clear for

me. An analysis from typical grids (permafrost and non-permafrost grids) and seasonal patters (e.g., Figure S2) might be helpful to understand it.

Minor points

Line 30: “active layer depth”. Using “active layer thickness” for consistency in the paper

Line 34: “large changes in runoff”, can you specify “change” as “increase”?

Line 38-39: “due to the degradation of permafrost in the study area”. Increase in precipitation probably also contributed to that change”.

Line 47: revise “regime” to “regimes”

Line 51: delete “the”.

Line 59: “…the frozen soil, and the long-term…”, separate it into two sentences.

Line 71: “…processes especially …”, add a comma after “processes”.

Lines 85-86. Unpack it into two sentences. “The Qinhai-Tibetan Plateau is characterized by… . Cryospheric processes have great impacts on its hydrological processes”.

Line 88: “permafrost thickness”, delete “thickness”

Line 91: delete “the”

Line 103-110: Agree with the previous reviewer, delete it.

Section 2: probably no needs for the sub-titles. Just describe the study area, field observations and spatial data. Try to focus on data description rather than how they are used (leave that in the next section).

Line 135-136: moving “provided by ..(CMA)” to the end of the sentence.

Line 141: revise “build” to “run”

Line 173-175: “in an integrated … 2016)” delete it.

Line 176: The approach of the model is very interesting. It is not a fully distributed model with lateral interactions but efficient in computation and handling water flows. I feel that is a important progress of spatial modelling. You may add some sentences about the feature of the model (not branding the project or funding) before “As…”.

Line 188 revise “used in” to “of”

Line281-285: You used thinner layers around 0.8m and from 1.7-3m, probably to capture the details of maximum thawing/freezing depths. You mad add some explanations about that.

Section 3.3: you may begin the section by “to initialize the model, we first estimated the soil temperature profiles based on the assumption that ….”. You may delete the sentence “For spin up run, the initial … this relationship”.

Line 318-319: the good agreement probably is due to calibration of initial values. A 500 year spin up run should change to a near constant ground temperature with depth. You need to check the model or whether the climate data from 1961-1970 vary significantly from year to year that prevent the establishment of equilibrium conditions.

Line 338-339. The value of RMSE and variation with depth is comparable with the study of Ou et al. (2016).

Line 353: revise “station” to “stations”

Line 366: “without the frozen soil scheme”. How the model was modified? and is the Figure S2 for the entire basin or just a grid? This is an important part of directly show the effects frozen ground on runoff. More description is needed, probably in the method section.

Section 4.2: It would be useful include the trends of air temperature (annual, thawing and freezing seasons) in the analysis.

Line 407: “In contrast”. Not a real contrast. It is expected. Delete it.

Line 434 “accurately reproduced” may be replace by “well reproduced”

Line 453: is increasing in precipitation a factor?

Line 455-469. It is easy to understand that the volume of soil liquid water increases with the increase in the volume of unfrozen soils. The sentences in these lines are long and complicated. You may simplify them.

Lines 471-474: You need more evidence to support the causal relations. The correlation is only one evidence. See the specific comments.

Line 482: From Table 2, the increase probably is mainly due to increase in snow run off in thaw season.

Line 484-485: revise “during the different seasons” to “between the two seasons”.

Line 499, 506, 512: “change in frozen soil”. You may specify it as “thaw of frozen soil”

Line 508: “was controlled by” the word probably is too strong. You may use “strongly affected by”

Line 512 revise “soil moisture” to “soil liquid moisture”

Line 540-522: “Different methods produce large differences in their estimates”. The following citations do not support such a statement since they are mainly for different areas. Actually, some of the estimates in Qinghai-Tibetan Plateau is comparable with your estimate, which is a support of your estimate.

Line 568: “especially in spring”, not clear for me.

The sediment thickness (depth from surface to bedrock), top organic layer thickness, and fraction of rock in soil are important to ground temperature and permafrost. You may add some sentences about them in sections of data, discussion or uncertainty. Active layer is thinner in valleys than in high slopes and on top of mountains due to differences in organic layer and vegetation conditions (Zhang et al., 2013). Temperature inversion and shading by surroundings may also keep the valley cooler than top of the mountains (O’Neil et al., 2015). You may comments on this in the discussions.

Figures: The font of words or numbers are too small in most figures.

Figure 3, S1: It is better to use a line with dots to represent the observations (so readers know the depths of observations). If you have annual averages, it is better to use annual averages rather than a specific date or month.

Figure 10b: revise “thaw depth” to “active layer thickness”

Figure 11d,e, Red curves are not necessary. For easy understanding, you may put elevation as Y axis, and percentage of permafrost to x axis.

References mentioned

Ou, C., B. Leblon, Y. Zhang, A. LaRocque, K. Webster, and J. McLaughlin (2016), Modelling and mapping permafrost at high spatial resolution using Landsat and RADARSAT images in northern Ontario, Canada: Part 1 - Model calibration, International Journal of Remote Sensing, doi: 10.1080/01431161.2016.1157642.

Zhang, Y., X. Wang, R. Fraser, I. Olthof, W. Chen, D. Mclennan, S. Ponomarenko, and W. Wu (2013), Modelling and mapping climate change impacts on permafrost at high spatial resolution for an Arctic region with complex terrain, The Cryosphere, 7, 1121–1137, doi:10.5194/tc-7-1121-2013. www.the-cryosphere.net/7/1121/2013/

O'Neill, H. B., Burn, C. R., Kokelj, S. V. & Lantz, T. C. ‘Warm’ tundra: atmospheric and near-surface ground temperature inversions across an alpine treeline in continuous permafrost, western arctic, Canada. Permafrost and Periglac. Process. 26, 103–118 (2015). doi: 10.1002/ppp.1838.