The manuscript deals with hydrological modeling using a modified WEP-QTP distributed hydrological model, in its application to Niyang River basin in the named region.

In the Abstract, early in the MS text, the authors state that their main enhancements of the original model are, (a) separating gravel layer from the 'soil' layer, whatever the soil layer is, and (b) the addition of the overland snow cover on top of the soil layer during 'freeze-thaw period'. My overall impression is that this manuscript be rejected with encouragement to resubmit after substantial reworking.

Dear reviewer:

We appreciate your detailed and valuable comments, which have helped us to considerably improve the quality of the manuscript. Our point-by-point responses to the comments are provided below. We hope that the revisions will sufficiently address the shortcomings of the previous version of the manuscript.

Introduction is chaotically written and poorly referenced. Hydrological processes in permafrost environment are only vaguely explained, so that the readership might not adequately reflect on the correctness and scientific soundness of the proposed model formulation. In the future submissions, I would suggest better referencing sections concerning permafrost hydrology, show hydrology, and cold region hydrology modeling.

Reply: Thanks for the advice. It is indeed that the Qinghai-Tibet Plateau includes both permafrost and seasonally frozen soil areas. The water and heat transfer processes related to permafrost/seasonally frozen soil are important parts of the water cycle on the Qinghai-Tibet Plateau. Seasonally frozen soil thaws completely during the summer, while only the surface layer of permafrost thaws during the summer. The lower permafrost layer remains frozen year-round. Among them, seasonally frozen soil is directly related to the interactions between surface water and groundwater, and its freezing and thawing processes are affected considerably by the geological structure, which was the focus of this study. In regions with seasonally frozen soil, we considered the entire freezing and bidirectional thawing processes of the soil–gravel layer. For the permafrost regions, the surface layer freezing and thawing processes were considered, while the lower permafrost layer was used as the lower boundary condition. In permafrost areas, supra-permafrost water, an impermeable interlayer, or other conditions may also be present, thereby complicating the situation. For these areas, we simplified the simulation process to mainly address the hydrothermal transport in the active layer within 2 m of the surface layer.

We agree that in the introduction, the description of the impacts of seasonally frozen soil and permafrost on the water cycle on the Qinghai-Tibet Plateau wasn't adequate enough to explain the hydrological processes in the permafrost environment. In the revised version, emphasis will be paid to referencing sections concerning permafrost hydrology, show hydrology, and cold region hydrology in the region, and to further clarify the research objectives, and to highlight the impact of scientific issues in cold plateau regions.

It is unclear, quite early in the manuscript (MS), what are the 'freeze-thaw' and 'non-freeze-thaw' periods? This is unclear, because in seasonally frozen soils thaw period can be extended long into summer period, and in permafrost, phase state changes in the soil profile occur continuously.

Reply: Thank you for this comment. We will make it clearer that in this study, the division between the freeze–thaw and non-freeze–thaw periods was determined according to the soil and gravel temperatures in each calculation unit. Non-freeze–thaw period is defined as when all the soil/gravel layer temperatures were greater than 0 °C, and all of the water was a liquid. As long as a layer of soil or gravel had temperature below 0 °C, it is considered as freeze–thaw period. Due to the undulating terrain in the study area, the temperature range in the basin is large. Different regions may be in different periods at the same time. The freeze–thaw period may extend throughout the entire year in regions with lower average annual temperatures, while regions with higher average annual temperatures may have freeze–thaw periods that only occur during the winter and spring. We will add this information to the introduction.

The description of the Study region should be separated from the Materials and Methods section. In the Data description, some datasets seem to be irrelevant to the distributed model setting proposed in the MS.

Reply: Thank you for pointing this out. In the revised version, we will reorganize the structure of the manuscript accordingly, by dividing the Materials and Methods section into two sections: “Study area and data” and “Methodology”.

The Data description section will also be carefully revised to correctly and clearly present all the data used in the study, including their types, quality, resolutions, period, and sources.

Rainfall stations, as noted in the description, were all situated in the river valley. I would expect, here or later in the MS, that a typical rainfall distribution over the area would be given. Also, in principle, since the WEP-QTP is a distributed model, we would need to see the distribution of major hydrologically-relevant features across the watershed, and a sort of ‘hydrological response units’ distribution, or subcatchments having a meaning similar to HRU conceptually.

Reply: Thank you for this comment. Contour maps of annual precipitation (Fig. a) and annual mean temperature (Fig. b) in the Niyang River Basin are given below. Figures of other data, including land type and vegetation coverage, among others, will be added to the supplementary materials in the revised manuscript.

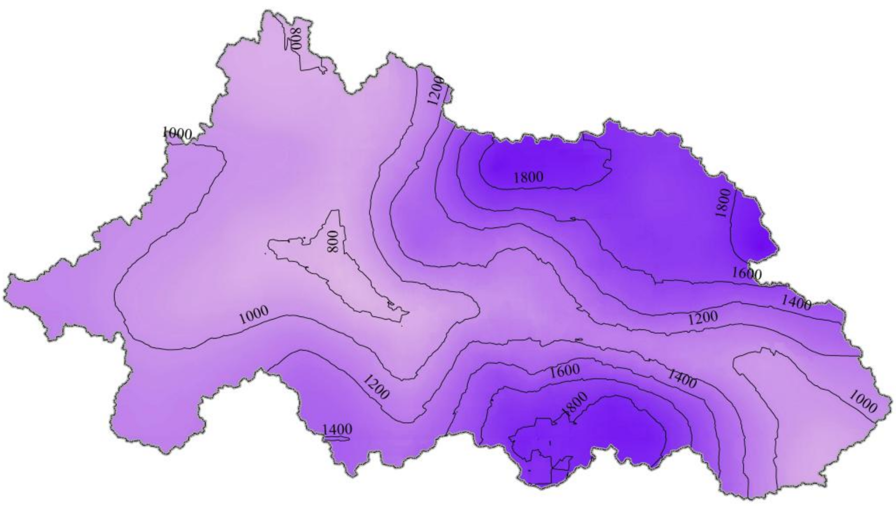

Figure a. Annual precipitation contour map (mm/year).

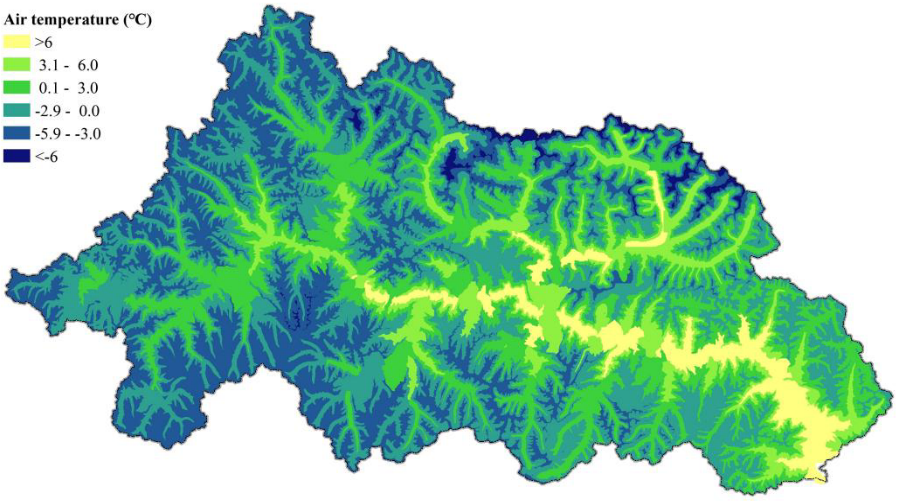

Figure b. Mean annual temperature (°C).

We would need to understand how the daily precipitation signal processes across the catchment, especially where only one downstream weather station is operational in the catchment.

Reply: Two weather stations were used for the spatial interpolation of precipitation: Nyingchi station (in the downstream area) and Jiali station (outside the upstream basin) (Fig. 1 in the MS). In addition, we also obtained precipitation data from six rainfall stations (Fig. 1 in the MS) in the basin from 2013 to 2015, and used the annual precipitation contour map data in the Tibet Water Resources Bulletin (2012–2017).

First, the precipitation data from these eight stations were interpolated using the reversed distance squared method. Then, we considered the precipitation–elevation relationship and the topographic effect of the plateau mountainous area, particularly the blocking effect of the mountains on water vapor transport. The watershed was divided into five sub-regions (Fig. c) according to the precipitation contour map, and the vertical precipitation gradient in each sub-region was calculated. Finally, the precipitation was corrected using the elevation and the vertical precipitation gradient to obtain the precipitation data for the entire basin.

The specific methods will be introduced in the supplementary materials in the next MS.

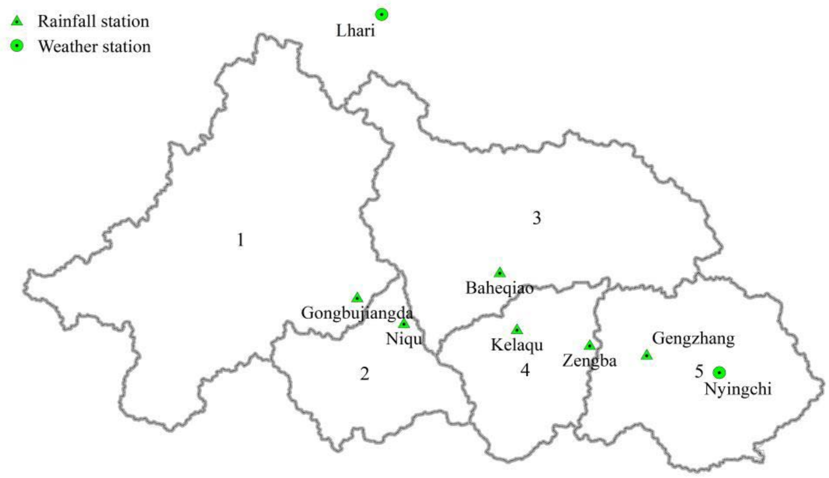

Figure c. Sub-region divisions used for precipitation elevation interpolation.

Since the introduction of snow layer was done in the distributed model setting, we would like to know how the snow cover distribution was estimated, and how snow meltdown was assessed (in spatial terms). Typical snow cover thickness in different parts of the catchment must also be presented.

Reply: Thank you for pointing this out. We apologize for any confusion. We will make it clearer that the precipitation and temperatures of all calculation units are different, and the model can calculate the snowfall amount according to the meteorological data. Based on the mass balance of snow (Equation 16), the amount of snow cover in each calculation unit can be calculated, from which the snow cover distribution in the basin can be obtained.

The basic calculation unit in the model was the contour band. The differences in temperature and precipitation due to altitude difference cause the calculation units at higher altitudes to accumulate more snow and undergo less melting. Units with lower elevations accumulate less snow and undergo more melting. In the model, we established a thickness threshold. When the snow thickness difference between two calculation units exceeded this threshold, snow meltdown occurred. The snow in the higher-altitude calculation unit slides into the next unit until the two units had the same snow thickness.

The temporal and spatial variations in snow thickness are shown in Figure d.

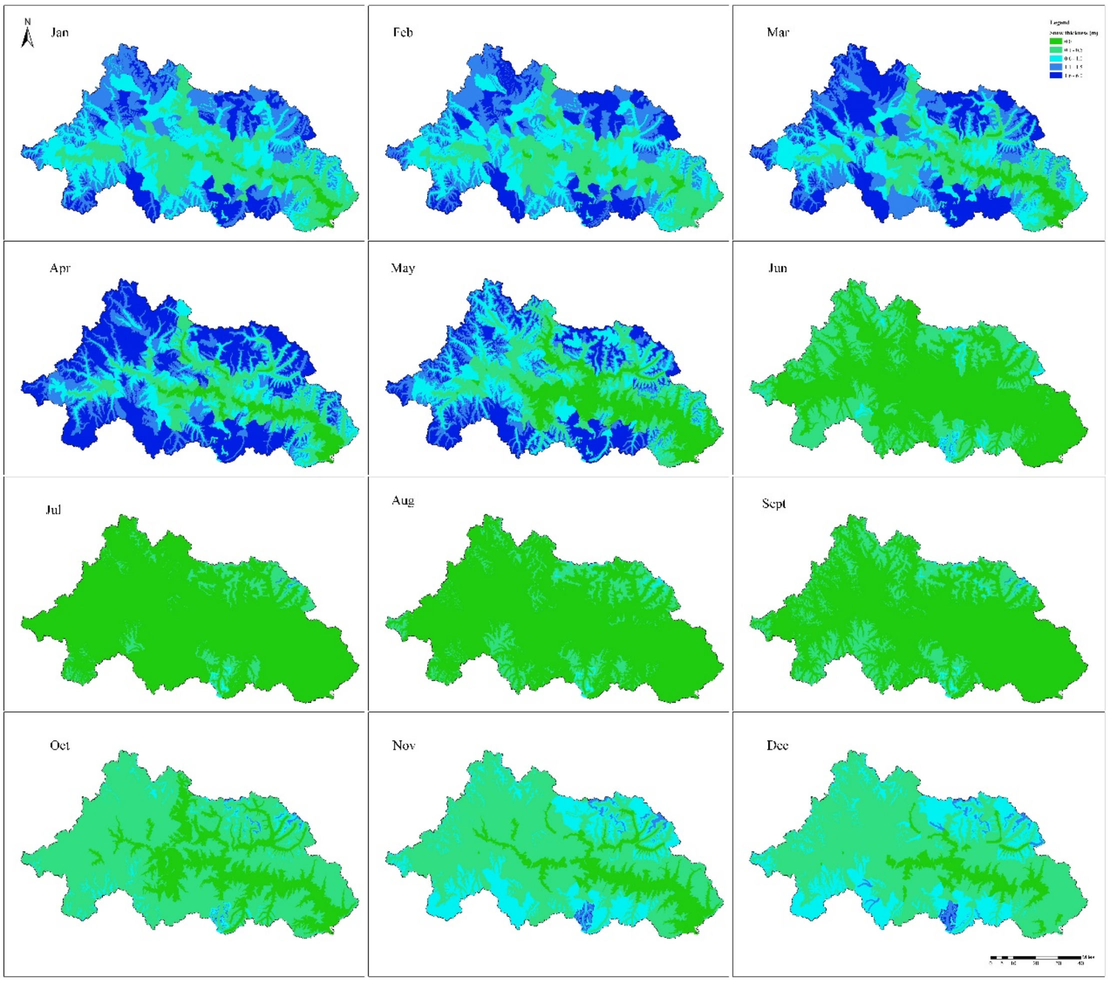

Figure d. Temporal and spatial variations in snow thickness.

Permafrost/seasonal frost distribution in the catchment is essential since it was already presented in the Introduction that permafrost affects the hydrological processes at the QTP, and it needs to be presented on a separate figure along with glacier distribution.

Reply: Thank you for pointing this out. Permafrost accounts for ~23.65% and is mainly distributed in the upper reaches of the basin and in high-altitude areas on both sides of the main stream. The glacier coverage in the basin accounts for ~8.55%, which is mainly distributed above 5000 m a.s.l (Fig. e). We will add these details in the “Study area” section of the revised manuscript.

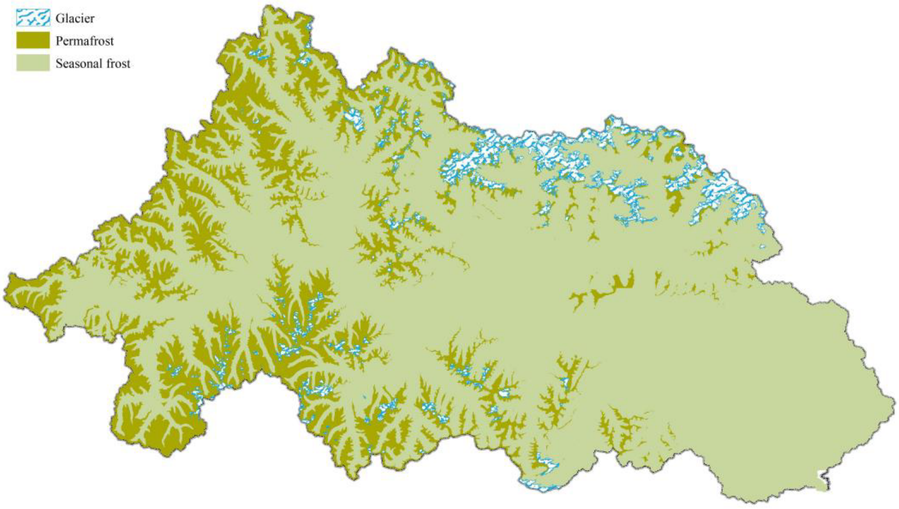

Figure e. Glacier and permafrost distributions.

Experimental data were used in this research (see cf. Lines 160-166). Experimental monitoring site, program, methods and data description need to be explained, if these data are used in the MS.

Reply: Thank you for pointing this out. We are sorry that we failed to make this clear enough in the earlier MS. We will make it clearer in the revised version that the coordinates of the experimental site are 29°27′12″ N, 94°21′45″ E, and the altitude is 4607 m a.s.l (Fig. 1). Before the field experiment, nuclear magnetic resonance was used to calibrate the water and heat transport monitoring instruments under seasonal freezing and thawing soil conditions on the plateau. A working area with a length of 1.0 m, a width of 1.0 m, and a depth of 2.0 m was excavated at the experimental site. A time-domain reflectometry sensor was used to monitor the contents of the liquid water, a PT100 sensor was used to measure the temperature, and a TensionMark sensor was used to measure the potential of the substrate, which were installed every 10 cm vertically in the experimental pit to a depth of 1.6 m. After the instrumental installation was completed, the pit was backfilled with undisturbed soil and the data were collected automatically.

In the Introduction to WEP-COR section, it is unclear whether this version of the model has already had a permafrost hydrology routine implemented or not.

Reply: Thank you for this comment. We will make it clearer that the WEP-COR model already considers both seasonally frozen soil and permafrost. In regions of seasonally frozen soil, the model considered the entire freezing and bidirectional thawing processes of the soil. For permafrost regions, the surface layer freezing and thawing processes were considered, and the lower permafrost layer was used as the lower boundary condition. In permafrost areas, supra-permafrost water, an impermeable interlayer, or other conditions may also be present, thereby complicating the situation. For these areas, we modified the simulation process to mainly address the hydrothermal transport in the active layer within 2 m of the surface layer.

From Lines 190- 193, I can assume this, but it is unclear how phase state transitions control water distribution across the soil layers: when soil surface is all frozen; when the residual frozen layer separates surficial soils from groundwater (seasonal frost situation).

Reply: Thank you for pointing this out. We will make it clearer that the soil moisture and temperature during the freeze–thaw period were calculated iteratively using finite differences. First, the heat conduction was calculated (Equation 15), and then the soil moisture migration process was calculated (Equation 18). The effects of the phase transition on moisture (Equation 19) and saturated hydraulic conductivity (Equation 27) were considered in this process.

When winter began, the surface layer froze first, thereby minimizing the moisture content and saturated hydraulic conductivity. Below the surface, water transport was still calculated according to Equation 18, but the water flux from the surface to the soil was zero. When a residual frozen layer was present during thawing, the soil moisture transport processes above and below the residual frozen layer were calculated according to Equation 18. If the surface layer is supplemented by snowmelt at this time, a saturated soil layer may be generated above the frozen layer.

In the Model Improvement section, 'the widespread dualistic soil–gravel structure' is once again being referred, though neither geological sections were presented nor spatial distribution of gravel thickness was given. Overall soil thickness down to transitional layer was 200 cm, first two layers were 10 cm thick and lower lying layers, 20 cm thick. What was then the transitional layer thickness? Is it constant or variable? It can be imagined from the

Figure 2 that gravel layer thickness above the groundwater table could easily exceed 2 m, and reach or even exceed 5 m. No information is given in the MS concerning this particularity of the vertical model structure. Still, no explanations on how permafrost is affecting lateral routing in the subsurface.

Reply: Thank you for these valuable comments. During the continuous uplift of the QTP, a series of ascending areas (denuded areas) and descending areas (deposited areas) have formed. Quaternary deposits are generally thinner in the denuded areas and thicker in the depositional areas (valleys and plains). The thicknesses of the Quaternary deposits vary widely at the transition between the denuded and depositional areas controlled by the fault zone. Soil formation in Quaternary deposits on the QTP is frequently interrupted by the influence of surface uplift. In addition, under strong freeze–thaw conditions in the cold plateau region, herbaceous plant humus accumulation is slow, and the decomposition of minerals is weak, resulting in slow soil development and a thin soil layer. This phenomenon is prevalent throughout the QTP.

According to the geological features of the QTP, we generalized the hydrothermal coupling simulation object as a binary "soil–gravel" structure and assumed that all above the impermeable layer is dualistic soil–gravel structure (Fig. f). As the surface soil is more sensitive to changes in atmospheric temperature, the thicknesses of the first and second layers were set to 10 cm each, and the third through eleventh layers were divided evenly, each with a thickness of 20 cm. The groundwater depth was calculated using water infiltration and groundwater movement. When the groundwater depth was greater than 2 m, the excess comprised the twelfth layer (transition layer). Beneath the groundwater was an impermeable layer, and the distance from the impermeable layer to the surface was an adjustable parameter in the model that can be adjusted based on the actual basin conditions. The thickness gradually increased from the top to the foot of the mountain (Fig. g). In the permafrost area, we assumed that the permafrost layer was located under the dualistic soil–gravel structure. The permafrost layer was generalized as an impermeable boundary with a constant temperature of less than 0 °C. When a saturated aquifer formed on this boundary, the water moved laterally. We will rewrite this section in the revised version to further clarify the model structure used in the study.

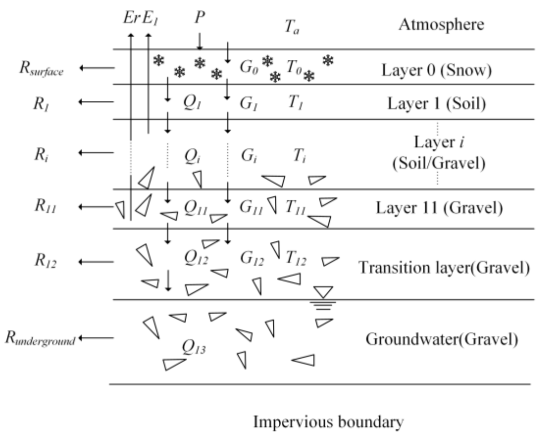

Figure f. Layered structure of the dualistic "soil–gravel" structure.

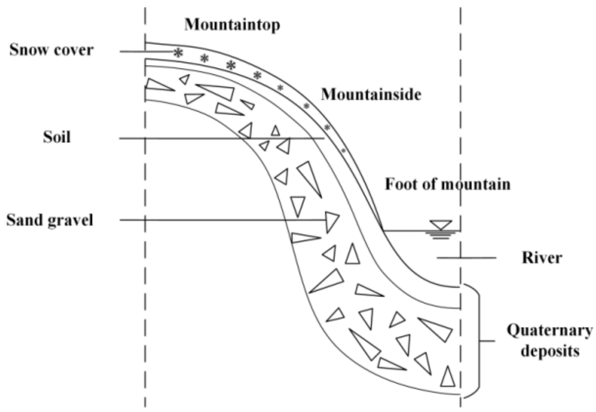

Figure g. Snow–soil–gravel layered structure.

If at one point, e.g., ground temperatures were observed, these data could be presented in the respective MS section to explain permafrost/seasonal frost dynamics.

Reply: Thank you for this suggestion. The soil temperature and moisture differed at different locations in the basin. The experimental site is located in the lower reaches of the Niyang River (Figure 1), which is within a region of seasonally frozen soil. We monitored the air temperature, soil temperature, and soil moisture at the experimental site, the results of which are shown in Figures 7–9 in the MS. Based on these results, the dynamic changes in water and heat transport in the region of seasonally frozen soil were analyzed, and the model simulation was verified (Section 3.2).

It is known that clastic sediments are mostly cryotic, i.e., with low temperature and low ice content. Also, since the presence of permafrost/seasonal frost is implied, I would like to

know how the convective heat exchange in gravels affects the ground temperature in the model.

Reply: Thank you for this professional question. We will make it clearer that the model divided the soil–gravel structure into 11 layers. First, the thermodynamic parameters of each layer were calculated using Equations 23–25, and heat conduction was calculated using Equation 15, which determined the temperature of each layer. The influence of gravel on ground heat conduction was reflected by the thermodynamic parameters, which were dynamically affected by the proportion of gravel, the water content, and the ice content.

In an unfrozen state, there is little difference in heat capacity between soil and gravel due to the higher moisture content of the soil. However, when frozen, the heat capacity of the soil layers is substantially reduced as the water becomes ice, which has a lower heat capacity. The gravel layers underwent minimal heat capacity changes due to their low water contents. At this time, the heat capacity of the gravel layers was larger than that of the soil layers. When the heat flux into the ground is constant, the presence of gravel slows down ground temperature changes.

In snow cover model description, was snow sublimation assessed? What was the phase separation temperature, or air temperature at which precipitation falls as snow or rain? This parameter is important for the catchment in question, since owing to the great difference in altitude, precipitation may fall as rain at lower altitudes but as snow at higher altitudes. If the model does not account for this effect, it must be stated explicitly.

Reply: Thank you for these comments. The sublimation of snow was not considered in the current version of the model. The threshold temperature for separation of precipitation into rainfall and snowfall was fixed as 2°C to simplify the model (line 309), as there are many important components and parameters have been considered. Correspondingly, the atmospheric temperatures at different altitudes were corrected for altitude in the model, as higher altitudes were colder, and more precipitation was converted to snow.

For the model, it is useful to show explicitly the number of calibrated parameters, and their values: either calibrated from the model runs/sensitivity analysis or taken from the literature.

Reply: Thank you for pointing this out. We apologize for any confusion. Using the Nash Sutcliffe efficiency (NSE) and relative error (RE) as the objective functions, the model parameters were calibrated using the Duobu station daily flow data from 2013 to 2015. The model parameters were divided into four categories: underlying surface, vegetation, soil, and aquifer parameters. Most model parameters did not require calibration; however, the highly sensitive parameters were adjusted by comparing the simulated discharge with observed values during the selected calibration period. Model parameter sensitivity analysis was previously conducted by Jia et al. (2006). Highly sensitive parameters included soil thickness, soil saturated hydraulic conductivity, and the riverbed material permeability coefficient. The values of the sensitive parameters are shown in lines 374–381. We will supplement this in the manuscript accordingly.

In the experimental data analysis, I am particularly surprised to see no signs of the 'zero curtain' effect during phase transitions in soils. Does this mean that soil moisture content finally is low enough to not affect the ground temperature dynamics?

Reply: Thank you for this professional question. We will make it clearer that for gravel layers below 40 cm, their water contents were indeed small. The water content of the top (10 cm) soil layer also decreased to a lower level of 0.25 before refreezing (due to evapotranspiration), which is also small. For the 20 cm soil layer, since its water retention capacity was greater than that of the lower gravel layer and the evaporation influence was less than that of the 10 cm soil layer, the water content was the largest in the vertical profile. Therefore, the 'zero curtain' effect was only observed in the 20 cm layer from March 9 to March 15.

Also, from the experimental site data I would assume there is no permafrost, but only seasonal ground freezing, which has only limited effect on cold regions hydrology. In the same lines, I has started wondering how exactly the model treats phase state changes and latent heat release/absorbtion.

Reply: Thank you for these comments. The experimental site is located in the lower reaches of the Niyang River (Figure 1), which has an average annual temperature of 5.28 °C and is within a region of seasonally frozen soil. The terrain of the Niyang River Basin fluctuates widely, and the temperatures at different altitudes also vary widely. Regions of seasonally frozen soil and permafrost are both located in the basin. The model considered both seasonally and permanently frozen soil in the simulation. In regions of seasonally frozen soil, the model considered the entire freezing and bidirectional thawing processes of the soil–gravel layer. For the permafrost regions, the freezing and thawing processes of the surface layer were considered, and the lower permafrost layer was used as the lower boundary condition. In the permafrost regions, supra-permafrost water, an impermeable interlayer, or other conditions may also be present, thereby complicating the situation. For these areas, we simplified the simulation process to mainly address the hydrothermal transport in the active layer within 2 m of the surface layer.

Changes in liquid water content due to temperature phase transition were calculated using Equation 19. Phase changes and latent heat release/absorption were described by Equation 18. This process was calculated iteratively using finite differences during the coupled hydrothermal simulation. This will be further clarified in the revised version.

There are numerous other remarks along the text flow which I preferred to not pick up all, but rather generalize as a poor English usage, and lack of explanations/references. I do not believe the manuscript can be published in HESS in the present form.

Reply: Your comments have been very useful to us. We will revise the whole manuscript based on your comments and add relevant explanations/references where appropriate, and revised manuscript will undergo proofreading by native English speakers before submission.