The manuscript modified the a distributed hydrological model based on soil–gravel structure, and applied it to a watershed in the QTP. The topic fell into the scope of this journal and there are some issues need to be addressed as shown below:

Dear reviewer:

We appreciate the detailed and valuable comments, which have considerably improved the quality of our manuscript. Our responses to the comments are provided below.

About the novelty of the study. Considering the soil layer and unconfined aquifer in the cold region and QTP have been test for some previous studies, the author need to compare the current study with some previous studies. For example:

Song L., Wang L., Li X., et al. Improving permafrost physics in a distributed cryosphere-hydrology model and its evaluations at the upper yellow river basin. Journal of Geophysical Research: Atmospheres, 2020, 125(18):1-22.

Sun, A., Yu, Z., Zhou, J., Kumud,A., Ju, Q., Xing, R, Huang, D, Wen, L., 2020. Quantified hydrological responses to permafrost degradation in the headwaters of the Yellow River (HWYR) in High Asia. Sci. Total Environ. 712, 135632.

Gao B., Yang D., Qin Y., et al. Change in frozen soils and its effect on regional hydrology, upper Heihe basin, northeastern Qinghai-Tibetan Plateau, Cryosphere, 2018, 12(8):657-673

Reply: Thanks for the comment and suggestion. We have carefully studied the previously published work on the influence of frozen soil on the hydrological cycle in the QTP including those introduced by reviewer. The survey revealed that most of those studies define the simulated object of hydrothermal coupled transport process as a one-dimensional homogeneous medium. However, the geological features of the QTP are generally thin soil layers above the thick gravel layers, and there are clear boundaries between them. Compared with soil, gravel layers have different porosity and density as well as water and thermal properties, which have a greater effect on hydraulic conductivity and water retention curve. Adjusting these parameters with the proportion of gravel can improve the hydrothermal simulation effect to a certain extent. However, owing to the generalization of soil into a one-dimensional homogeneous structure, it is difficult to reflect the influence of this region's obvious upper and lower layered geological structure on hydrothermal migration and watershed hydrological cycle only through parameter adjustment. Based on the general geological characteristics of the QTP, in this study, we generalized the hydrothermal coupling simulation object into the binary medium of soil and gravel. Combined with the characteristics of hydrothermal transport in different periods, two methods were used to simulate hydrothermal transport in freeze-thaw period and non-freeze-thaw period, which improved the accuracy of hydrothermal simulation. These details of theoretical and methodological differences from previous studies will be supplemented in the Introduction and Discussion in the revised version.

For the study area, the author need to describe the distribution of frozen soil. Where is the permafrost and seasonally frozen ground? For the experiment site, is it in permafrost region or seasonally frozen ground?

Reply: Thanks for the comment. The frozen soil in the study area is mainly seasonal. Permafrost accounts for approximately 23.65%, mainly distributed in the upper reaches of the basin and the high-altitude areas on both sides of the main stream. The annual average temperature of the experimental site is 5.28℃, which is a seasonally frozen soil area. In the revised manuscript, we will supplement these details in the section 2.1.1 Study area.

For figure 3, how do you determine the thickness of each soil layers? What is the maximum frozen depth of the study area? Do you consider the freezing front when you divide the soil layer?在永久冻土区，我们假设不透水层为

Reply: Thanks for professional questions, we will make it clearer here and in the revised manuscript. The division of soil layer thickness was mainly based on the convenience of accurately simulating the hydrothermal migration process. 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 depth from the surface to the impermeable layer was an adjustable parameter in the model that can be adjusted based on the actual basin conditions. Considering the active range of seasonal frozen soil, the depth of the hydrothermal numerical simulation in the model was set 2 m. When the groundwater depth was greater than 2 m, the excess comprised the transition layer. The maximum frozen soil depth was located in the permafrost regions. In these regions, the lower permafrost layer was used as the lower boundary condition of the model. The maximum frozen depth was the depth from the surface to the impermeable layer. The position of the freezing front was determined using the interpolation of the layer thickness and temperature at the center of the upper and lower layers. We have redrawn Figure 4 to ensure that the readers can better understand our model structure.

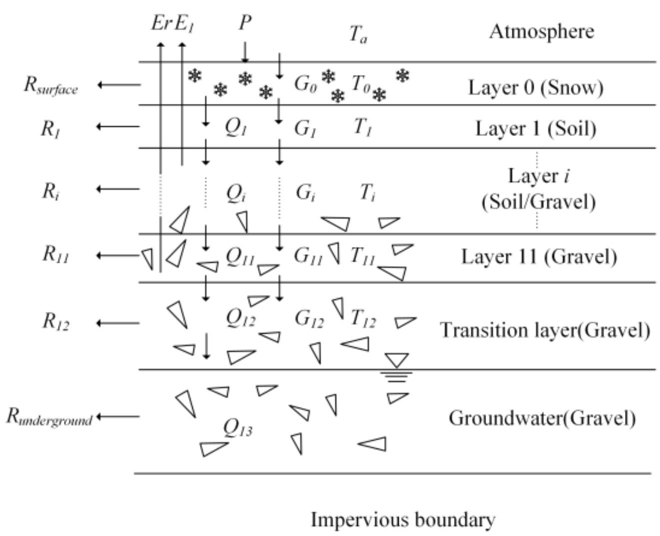

Figure 4. Layered structure of the dualistic "soil–gravel" structure

Eq 14, I suggest to give the equations about how to calculate LE and H.

Reply: We will add that the LE is related to the sublimation and evaporation rates and can be obtained as follows:

$$LE = L_{vi}E_{subl} + L_{vl}E_{evap} \approx L_{vi}E$$

where, L_{vi} is the latent heat of sublimation of ice (2.838×10^6 J/kg at 0°C); L_{vl} is the latent heat of evaporation of water (2.505 × 10^6 J/kg at 0 °C); E is the sum of the surface sublimation and evaporation rates.

H:

$$H = \frac{\rho_a C_P (T_s - T_a)}{r_a}$$

where, ρ_a is the air density; C_P is the constant pressure specific heat of the air; T_s is the surface temperature; T_a is the air temperature; and r_a is the aerodynamic impedance.

The above formula was combined with the ground heat conduction equation and energy balance equation and solved using the iterative method, which requires extensive calculations. Therefore, in this study, we approximately deduced the heat into the ground according to the daily temperature change, and simplified the calculation by solving the *H* according to the energy balance equation after calculating the *LE*.

Are Supra-permafrost water and Sub-permafrost water both exit in the study area?

Reply: The supra-permafrost water and sub-permafrost water are important components of the hydrological cycle in the cold region. We will make it clearer in the revision that the sub-permafrost water is generally confined, and the interaction between the sub-permafrost water and the hydrological process is weak owing to the impermeability of the permafrost layer. In this study, for the permafrost, the freezing and thawing processes of the surface layer were considered, and the lower permafrost layer was used as the lower boundary condition. We simplified this process and only considered the exit of supra-permafrost water.

The radiation transfer in the snow layer are ignored in this study, the author may discuss the uncertainty from this? Another question, how do you estimate the snow albedo to get the net radiation of snow surface?

Reply: Thanks for the insightful comment. Radiation will get into the snow and participate in the water phase transition and heat transfer process. However, owing to the high reflectivity of the snow to short-wave radiation, the short-wave radiation into the snow is much less than long-wave radiation into the snow. Considering that the main factors affecting the long-wave radiation are the temperature of the atmosphere and snow cover, in this study, we used the temperature index method to simplify the simulation of the snowmelting process. The value of the temperature index was determined by parameter calibration to characterize the effect of temperature and radiation on the snowmelting process. In this model, the snow albedo was fixed at 0.8. We will clarify it better in the revised version.

How do you calibrate the parameters of the hydrological model? And what are the major parameters you calibrated?

Reply: Sorry for the unclearness on this part. We will make it clearer here as well as in the revised version that the parameters of the model were divided into four categories: underlying surface parameters, vegetation parameters, soil parameters, and aquifer parameters. All parameters have physical meaning and can be estimated based on observational experimental data or remote sensing data. The sensitivity of the above four types of parameters was analyzed, and the sensitivity of these parameters was divided into three levels: high, medium, and low. Only the high-sensitive parameters, i.e. soil thickness, soil saturated hydraulic conductivity, and riverbed material permeability coefficient were calibrated using the daily flow process data of Duobu stations from 2013 to 2015 with Nash Sutcliffe efficiency (NSE) and relative error (RE) as the objective functions..

There seems an underestimation of river discharge by the WEP-QTP in the freeze season, why?

Reply: We will make it clearer that the underestimation of river discharge in the freeze season can be attributed to the following two reasons: the geological conditions in the cold plateau region are complex, and the runoff process was not fully reflected by the model because the model simplifies the groundwater simulation. In addition, the main focus of this study was the aquifer above the impervious boundary. The outflow of sub-permafrost water was not explicitly considered, and this part of water can also supplement the river discharge in the freeze season through the macropores in the bedrock fracture zone.

It seems that at 20 cm, the variation of soil temperature of WEP-QTP is reduced and the variation is lower than observations and WEP-COR, why?

Reply: Considering the heat preservation effect of the snow, the soil temperature variation of WEP-QTP in the 20 cm soil layer was less than that of WEP-COR.

The thermodynamic parameters of snow cover in this study were a function of snow density. In the model, the snow density increases with the decrease of temperature, unlike the snow density in the physical model, which only increases with snow thickness and degree of melting. The thermal conductivity of snow decreases with decreasing temperature during soil freezing, resulting in the smaller variation of soil temperature of WEP-QTP, which needs to be further improved.

I suggest to show the comparison of long term changes in the simulated runoff in the winter and summer and spring by different models and observations.

Reply: We thank you for your valuable suggestion; we are also working on a long-term runoff evolution analysis. However, owing to the limited space, in this study we mainly considered the influence of snow and gravel on hydrothermal transport in the freeze-thaw period and the non-freeze-thaw period to construct a hydrothermal multi-structure simulation method for the underlying surface of the plateau cold region. The effects of the special underlying surface conditions of the plateau on the main water cycle processes such as direct surface runoff, groundwater recharge, and groundwater recharge channels were analyzed. In the ongoing work, we will analyze the evolution law of long-term variation of seasonal runoff and its components in the basin from various elements such as meteorology and vegetation.