We are very grateful to Reviewer 2 for the review we received. We present below our detailed answer to the discussed points. The reviewers' comments appear in black and our responses appear in brown. Quotes from the manuscript are in *brown italic*, modified parts from the revised version are ***in bold font***.

Review 2

Martin, Immerzeel and their colleagues conducted a study to understand recent ground thermo-hydrological changes in a Tibetan endorheic catchment and implications for lake level changes. The authors did a lot of work on using model to understand the cold region hydrology. I think this is a comprehensive modeling study. The conceptual hydrological framework includes precipitation downscaling, remote sensing glacier observation, catchment hydrology, lake evaporation and water balance. For land hydrology, the authors used the TopoSUB to delineate catchment into different units, and used CryoGrid to simulate the complicated frozen soil hydrology. The presentation is clear for most part, and the study has kind of novelty. But there are still some major issues the authors should address before considering for publication.

The definition of surface and subsurface flow. The authors defined the runoff from top 0.3m soil as surface runoff, and 0.3-2m as subsurface runoff. This definition might need more rigorous study.

We understand the reviewer's concern on the reader's understanding of the model. In the model, the distinction between surface and subsurface runoff is not based on the stratigraphy but on the balance between soil water content and new water input. We now provide further explanations on this matter in section 3.2.4 (Model setup and validation) as presented in the quotation responding to the next comment.

In hydrology, the separation of surface and subsurface flow is a grand challenge, which is still not well solved in moderate climate catchments (McDonnell, 2013), not to mention this data scarce permafrost region. Also the surface water and subsurface water have different behaviors in different topography (Seibert et al., 2003; Gao et al., 2014), e.g. on hillslope or riparian area. I did find how the CryoGrid model takes this into account.

We agree with the reviewer and to better acknowledge the relative simplicity of our approach compared to specific literature on this point, we modified section 3.2.4 (Model setup and validation). The following quotation of the revised manuscript thus answers this comment and the previous one.

"Regarding the processes implemented in the model (Sect. 3.2.3), infiltration according to Richards equation only occurs in the top and bottom soil units. The bedrock unit has a static water content. ***Unraveling surface from subsurface flow is an ongoing challenge in catchment-scale hydrology (McDonnell, 2013) and this distinction is important in mountain terrains where these two flows can behave differently due to the complex topography (Gao et al., 2014; Seibert et al., 2003). For this study, we rely on a simple approach that computes surface and subsurface flow as follows.***

On the one hand, surface runoff is computed relative to the saturation level of the soil column. When the entire soil column is saturated (WC = porosity), additional water input from precipitation or snowmelt is directly counted as surface runoff. On the other hand, subsurface runoff is computed relative to the field capacity of the ground, which is an input parameter of the model. When the water content (WC) of a ground cell exceeds this field capacity (FC), the amount of water corresponding to WC-FC is available to produce subsurface runoff. We use the lateral boundary condition LAT_WATER_RESERVOIR from the CryoGrid community model (Westermann et al., 2022) to account for this subsurface runoff. The speed at which this available water exits the soil column towards the lake is calculated with Darcy's law, using the hydrological conductivity of the ground and the mean slope of the catchment as hydraulic slope."

I did not see how the model takes the impacts of frozen soil on the connectivity between surface soil and groundwater. For example, in the early thawing seasons, although the top soil is thawed, but there is still frozen soil underneath, which inhibited the soil and groundwater connection. Also the impacts of frozen soil on groundwater discharge, i.e. the baseflow. These processes have huge impacts on catchment hydrology (Gao et al., 2022).

The CryoGrid community model aims at coupling the heat and water fluxes in the ground. In this regard, the hydraulic conductivity of each cell of the soil column during the simulation accounts for both the saturation of water and ice following Dall'Amico et al. (2011). In this approach, we first calculate the hydraulic conductivity based on liquid water saturation according to Mualem (1976) and then reduce the obtained value with an impedance factor equal to $10^{-\omega q}$ with ω being an empirical factor (that equals 7, following Zhao et al., 1997 and Hansson et al., 2004) and with q being the ice saturation. We now provide a short presentation of this approach in section 3.2.3 (The CryoGrid community model) of the revised manuscript :

"The soil matric potential and hydraulic conductivity follow van Genuchten, (1980) and Mualem (1976). **Additionally, to represent the obstruction of connected porosity by ice formation, the hydraulic conductivity is reduced by a factor dependent on the local ice content, following Dall'Amico et al. (2011).**".

Additionally, we want to clarify the fact that, consistently with the conceptual hydrological framework of our study (Fig. 2 of the revised and former manuscript), our setup does not include other groundwater components than the subsurface runoff. As such, the temperature-and-water-dependent calculation of the hydraulic conductivity applies for all the hydrologically active ground cells and drives variations in connectivity in response to variations of temperature around 0°C.

"physics-based approaches at the catchment scale aiming to connect the ground thermo-hydrological regime and the observed hydrological changes on the QTP changes remain scarce." "To our best knowledge, our study represents to date the most complete effort to include the variety of coupled climatological, surface and subsurface processes characterizing the climate, hydrology and ground thermal regime of high-mountain catchments in Tibet at a small scale with a high spatial resolution." These might be true when the authors wrote the paper, but I would like to recommend this new paper (Gao et al., 2022) for the authors' reference.

We agree with the reviewer, we re-phrased this sentence to the following:

*"To our best knowledge, **along with Gao et al. (2022)** our study represents to date the most complete effort to include the variety of coupled climatological, surface and subsurface processes characterizing the climate, hydrology and ground thermal regime of high-mountain catchments in Tibet at a small scale with a high spatial resolution."*

I did not find how the soil evaporation and plant transpiration were estimated. These processes are very important for water balance, especially for this basin, with only 10% precipitation generates runoff (as mentioned by the authors), and 90% goes back to atmosphere.

Potential evapotranspiration is derived from the latent heat fluxes in the frame of the surface energy balance calculation (using the latent heat of evaporation). This potential evaporation is then scaled to the available water in the ground . It occurs in the first grid cell only, but water can be drawn upwards due to matric potential differences We clarified this point in section 3.2.3 (The CryoGrid community model):

"At the surface, the model uses a surface energy balance module to calculate the ground surface temperature and water content. The turbulent fluxes of sensible and latent heat are calculated using a Monin–Obukhov approach (Monin and Obukhov, 1954). Evaporation is derived from the latent heat fluxes using the latent heat of evaporation and is adjusted to the available water in the soil. It occurs in the first grid cell only, but water can be drawn upwards due to matric potential differences."

Regarding the unraveling of evaporation and transpiration, we acknowledge that it is an important question in most hydrological studies, yet in the case of the Paiku catchment, vegetation is extremely scarce. During our field trip, we noted that most of the catchment corresponds to barren lands and that vegetation is limited to very sporadic herbaceous cover. Therefore, we do not expect transpiration to have a strong imprint on evapotranspiration in the catchment. For this reason, our approach does not separate evaporation from transpiration in our calculations. To include these considerations in the manuscript, we added the following sentence to the precedent quote:

"***Because vegetation is very scarce in the catchment, we do not expect transpiration to have a strong imprint on evapotranspiration and our calculations do not unravel evaporation from transpiration.***"

We present below a photo to show the type of land cover we found on the field that supports this assumption.

Figure R2.1 Ground photo in the Paiku catchment (Credit: Fanny Brun).

Some terms need to be improved. For example, in Figure 5D, the y-axis should be changed to "Runoff depth (mm/y)".

We changed the label of the y-axis according to the reviewer's suggestion.

Gao, H., Hrachowitz, M., Fenicia, F., Gharari, S., and Savenije, H. H. G. (2014) Testing the realism of a topography-driven model (flex-topo) in the nested catchments of the upper Heihe, china, Hydrology and Earth System Sciences, 18, 1895-1915, 10.5194/hess-18-1895-2014.

Gao, H., Han, C., Chen, R., Feng, Z., Wang, K., Fenicia, F., and Savenije, H.: Frozen soil hydrological modeling for a mountainous catchment northeast of the Qinghai–Tibet Plateau, Hydrol. Earth Syst. Sci., 26, 4187–4208, https://doi.org/10.5194/hess-26-4187-2022, 2022.

McDonnell, J.J., Are all runoff processes the same? Hydrol. Process. 27, 4103–4111 (2013)

Seibert, J. Rodhe, A., and Bishop, K. Simulating interactions between saturated and unsaturated storage in a conceptual runoff model. Hydrol. Process. 17, 379–390 (2003)

References

Dall'Amico, M., Endrizzi, S., Gruber, S. and Rigon, R.: A robust and energy-conserving model of freezing variably-saturated soil, Cryosph., 5(2), 469–484, doi:10.5194/tc-5-469-2011, 2011.

Gao, H., Hrachowitz, M., Fenicia, F., Gharari, S. and Savenije, H. H. G.: Testing the realism of a topography-driven model (FLEX-Topo) in the nested catchments of the Upper Heihe, China, Hydrol. Earth Syst. Sci., 18(5), 1895–1915, doi:10.5194/hess-18-1895-2014, 2014.

Gao, H., Han, C., Chen, R., Feng, Z., Wang, K., Fenicia, F. and Savenije, H.: Frozen soil hydrological modeling for a mountainous catchment northeast of the Qinghai–Tibet Plateau, Hydrol. Earth Syst. Sci., 26(15), 4187–4208, doi:10.5194/hess-26-4187-2022, 2022.

van Genuchten, M. T.: A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils, Soil Sci. Soc. Am. J., 44(5), 892–898, doi:10.2136/sssaj1980.03615995004400050002x, 1980.

Hansson, K., Šimůnek, J., Mizoguchi, M., Lundin, L. and Genuchten, M. T.: Water Flow and Heat Transport in Frozen Soil: Numerical Solution and Freeze–Thaw Applications, Vadose Zo. J., 3(2), 693–704, doi:10.2136/vzj2004.0693, 2004.

McDonnell, J. J.: Are all runoff processes the same?, Hydrol. Process., 27(26), 4103–4111, doi:10.1002/hyp.10076, 2013.

Monin, A. S. and Obukhov, A. M.: Basic laws of turbulent mixing in the surface layer of the atmosphere, Contrib. Geophys. Inst. Acad. Sci. USSR, 151, 163–187, 1954.

Mualem, Y.: A new model for predicting the hydraulic conductivity of unsaturated porous media, Water Resour. Res., 12(3), 513–522, doi:10.1029/WR012i003p00513, 1976.

Seibert, J., Rodhe, A. and Bishop, K.: Simulating interactions between saturated and unsaturated storage in a conceptual runoff model, Hydrol. Process., 17(2), 379–390, doi:10.1002/hyp.1130, 2003.

Westermann, S., Ingeman-Nielsen, T., Scheer, J., Aalstad, K., Aga, J., Chaudhary, N., Etzelmüller, B., Filhol, S., Kääb, A., Renette, C., Schmidt, L. S., Schuler, T. V, Zweigel, R. B., Martin, L., Morard, S., Ben-Asher, M., Angelopoulos, M., Boike, J., Groenke, B., Miesner, F., Nitzbon, J., Overduin, P., Stuenzi, S. M. and Langer, M.: The CryoGrid community model (version 1.0) -- a multi-physics toolbox for climate-driven simulations in the terrestrial cryosphere, Geosci. Model Dev. Discuss., 2022, 1–61, doi:10.5194/gmd-2022-127, 2022.

Zhao, L., Gray, D. M. and Male, D. H.: During Infiltration Into Frozen Ground, J. Hydrol., 200, 345–363, 1997.