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Comment on hess-2022-215

Anonymous Referee #3

Referee comment on "Application of an improved distributed hydrological model based on the soil–gravel structure in the Niyang River basin, Qinghai–Tibet Plateau" by Pengxiang Wang et al., Hydrol. Earth Syst. Sci. Discuss.,
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General comments

To tackle the question of the cryo-hydrology of Tibetan catchments under climate changes, the authors use an already publish cryo-hydrological model and improve it in two ways: they use a stratigraphy of a soil lying on a soil with more gravels that they identify as widespread across the QTP and they account for the yearly cycles of growth and melt of a snowpack both thermally and hydrologically.

I think overall that the study is interesting because it contributes to give visibility of catchment scale cryo-hydrological modeling which is a key approach, currently under development, to understand how climate change will impact the water cycle in high mountain regions. I also think that the field observations on the stratigraphy give an important added value to the paper and they should be presented with more details to better assess the characterization of this stratigraphy and its spatial distribution. The study also conveys the interesting message and demonstrates that the stratigraphy is important both regarding the hydrology and the thermal behavior of the model setup. The importance of representing the snowpack is also interesting but probably more obvious, as you cannot really model realistically the hydrology and thermal regime of a catchment with a significant seasonal snowpack without accounting for it.

So for me, this is where the added value of the article is: interesting field observations that motivate an interesting sensitivity test on stratigraphy. Even though visible, the improvements on the model outputs are not stunning on the provided graphs but I believe that if the authors could provide observations or something we could consider “reality” on figures 10 and 12 this feeling could be improved. I realize that this study represents an important amount of work, the objective is clear and I think the global structure of the article is relevant.

Yet the manuscript has important flaws that needs major modifications. I detail that below.

In the first place, according to me, the idea that the whole QTP, a region of millions of km^2 presents a more or less uniform stratigraphy with a layer of soil on top of a layer of gravels makes very little sense to me. I had a look at the studied catchment on Google Earth and I saw steep rock walls, colluvium, torrential streams, glacial valleys, all types of moraines, alluvial fans, braided fluvial systems… Meaning I saw the normal variety of landscape processes I could have expected and there is no reason they all produce this uniform stratigraphy at the scale of the catchment, not counting the whole QTP ! Not to mention that most of the sampling points are in the low lying parts of each valley. So the authors need to present better their field observations of the stratigraphy and discuss them in a much more cautious way.

L76-77 "The geological features of the QTP are generally thin soil layers above the thick gravel layers with clear boundaries between them." -> Any study supporting this at a large scale?

I also think mentioning "gravel" might be misleading. I think the authors should find a name to describe this type of formation (I see Wang et al. 2013 uses "soil-gravel mixtures" which sounds much more informative to me) because I think most readers reading "gravel" won't think about this unsorted slope deposits but rather to well sorted alluvial gravel formation that are highly conductive and then it might sound very counter intuitive. Especially when the author says "since gravel can neither conduct nor store water" and that it "hinders the movement of water".

Another big problem lies in the presentation of the models. Many points are unclear or don't make sense. I detail this below. A good example of this is the method used to calculate snow melt, which is first said to be based on a snow depth threshold between contour bands rather than on climatic variables (even though it is later the case, when the author mentions a PDD method). Not mentioning the so-called "snow sliding". I suspect the problem doesn't lie in the model itself since the output looks good, but rather in the description. I am happy to be shown I am wrong if it is the case, but from what I read and understand, there are major problems in the identifications of the processes and their representation as they are described (under the hypothesis that what is coded is different and correct).

Finally, I started correcting the English but I am not a native speaker and the task here is too important for a scientific reviewer. So I would recommend having the manuscript proofread by a native speaker because I think many formulations can be improved (see the examples I give below for the beginning).

Key specific comments

I had a look at Wang 2013 and, unless I am mistaken, one empirical parameter is missing in equation 1, where (1 - Wgravel) should be (1 – B x Wgravel) (Wang writes it B). Is this a mistake or is it me who missed a transformation of the equation ?

Since the model uses different types of equations depending on a threshold for rain, what happens at the transition between normal and heavy rain ? What if during a rain event the threshold is crossed, how smooth is the model in this regard ? Are there some data processing methods to smooth a potentially sharp transition ?

L242

"The large portion of gravel in the gravel layer causes the formation of macropores, which are connected to form a fast channel for transporting water during heavy rains"
I am totally confused here. As I said earlier, it is indeed the general way gravel formations are treated (as a conductive layer). But before the authors wrote :
"However, since gravel can neither conduct nor store water, the gravel […] hinders the movement of water and affects the water retention curves"
So how does all of this work together? The authors have been, since the beginning, using studies on soils containing rock fragments to support a certain type of behavior from their bottom layer and now they argue towards another behavior because they have been calling these fragments "gravels". And at this stage I am confused. Maybe I missed something here but if so, there is a lack of pedagogy/clarity in the way this model and stratigraphy works together.

L255

"(the contour bands)"
The authors need to explain more clearly how the model works in the main text. I had to read the appendix to get a clearer idea of how this works. It is an unusual approach so it needs to be commented on. What decides the shape and extension of a band ? And it also needs some statistics: How many bands ? Average size of a band ? Average elevation range within a band ? I would also like to see a map with all these bands to see how all this looks like. Otherwise, what is done here remains very abstract.

L256-259

"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 daily variation of snow water equivalent was calculated as follows"
Why is melt based on thickness difference ? Melt should be based on the climate input. All this makes very little sense, but I suspect these problems lie in the model description and not in the model itself.

L262-263

"when the difference in snow thickness between contour bands in the same sub-basin exceeds the threshold, the snow slides downwards until the snow thickness"
What is snow sliding ? I never heard of that and found nothing relevant on the net. The 2 important redistribution mechanisms I can think of are wind drift and avalanche. Snow

creep also exists but is marginal in comparison. So what is the process here ?

L290-292
"G is the heat flux (MJ/m2/d) conducted into the snow or soil, which was determined by the temperature difference between the soil or snow and the atmosphere near the surface. The above equation was combined with the ground heat conduction and energy balance equations"
I think this is wrong. G is the energy input in the ground that is used to drive heat conduction after the surface energy balance equation has been applied. So G is not derived from the atmosphere temperature near the surface, but H is. G is what you get when you sum the energy fluxes from the radiations and turbulent fluxes. Another problem is that the end of the sentence talks about heat conduction and energy balance equations. Conduction has not been introduced but energy balance is actually equation 7.

L294
"We […] simplified the calculation by solving the H according to the energy balance equation after calculating the LE"
Well that is not what the authors say before. Equation 9 is clearly a way to calculate H from temperature inputs. It is impossible to deduce H from the energy balance equation because you deduce G from this equation knowing all the other terms.

L297
"The temperature difference between the atmosphere and the surface is the source of heat conduction"
Why say this after calculating the surface energy balance ? The surface energy balance enables to calculate the energy change of the top cell, to work with temperature, the authors can then do $\Delta T = \Delta E/Cp$. Saying what I quote here after detailing an SEB module is more than confusing.

I don't have this level of problematic issues with the rest of the paper. Yet I think that in general, the text of the result and discussion section could be lighter and more concise.

Specific comments

I don't know where to put it so I write it here: to be able to understand what the new stratigraphy brings we need to have access to the WEP-COR stratigraphy, on Figure 3 for

example.

L16
"The Qinghai-Tibet Plateau has a thin soil layer on top of a thick gravel layer"
I have 2 problems with this abstract opening:
Problem 1: See my previous comments, this cannot be true at the scale of a region as large as the QTP where one can find mountain peaks, peatlands, moraines, alluvial fans, blocky terrain… I suggest writing something like "For hydrological purposes, simplifying the representation of the QTP subsurface conditions to a thin soil layer on top of a thick gravel layer…" but this needs to be either demonstrated in a previous paper or in the present paper.
Problem 2: I guess this is just a matter of personal preference, but I would recommend to start the abstract with a bit of context on what big question this study works with. Hydrology in mountainous cold regions and climate change…

L41-42
"plays an important role in ensuring the security of water resources in China and Southeast Asia"
Needs to be supported by a reference.

L43-44
"cannot be ignored"
Needs also a reference. The sentence is also surprising. The authors could start the sentence by "The extensive glacier…" list the items and end the sentence with "have a major impact on the water cycle…"

L44-45
"On the surface of seasonal frozen soil and permafrost, seasonal thaw layers alternately freeze and thaw as seasons change."
This is a convoluted way to say that both in permafrost and permafrost free areas, the ground undergoes seasonal freezing.

L63-67
My expertise on the topic is limited but this section on the links between tectonics, sedimentology and granulometry of the Quaternary sediments could be better phrased and states obvious things that don't show particular relevance for the study. I don't understand the message the authors want to convey that is important for the paper.

L105
"8 °C"
Add the average elevation associated to this mean temperature

L111-112
"Permafrost accounts for approximately 23.65%, mainly distributed in the upper reaches ofthe basin and the high-altitude areas on both sides of the mainstream."
Reference for this value ? Also I doubt one can reach such a precision in the significant numbers of the percentage.

L113-114
"The annual average temperature of the experimental site is 5.28 â□□, which is a seasonally frozen soil area."
It is the first time the authors mention this site, maybe introduce it first.

Caption of Fig 2
Indicate where this is located on the map of Fig. 1

L172-173
"The volume of the glacier was calculated by the area-volume empirical formula (Grinsted, 2013; RadiÄ□ and Hock, 2010)."
Does this give access to volume changes along time ?

L188-189
"According to the geological characteristics of the QTP, this study improved the hydrothermal simulation methods of the non-freeze–thaw period and the freeze–thaw period."
This is a conclusion, it should not be part of the methods.

L193-196
"In the non-freeze–thaw period, the calculation object of water movement was defined as the dualistic soil–gravel structure (Fig. 3a). The upper layer is soil whose thickness and number of layers are determined by the location of the calculation unit; the thickness of the soil layer gradually decreases from the foot to the peak of the mountain. The lower layer is the gravel layer (mixed layer of soil and gravel)."
This is really hard to read/understand, rephrase, with examples and tangible elements.

L233-234
"Until the water has the same potential energy in the soil and the gravel, the INF breaks through the critical surface, and then the infiltration rate stabilizes (Fig. 4)."
I don't understand this part. First I am unsure that potential energy is the good terminology (i.e. potential energy of the water in a dam), I assume it is the pressure head. And if it is so, the Green-Ampt model does not calculate the pressure head, it calculates the volume of infiltrated water or the depth of the infiltration front. So I don't understand this sentence. Maybe I did not understand the situation correctly but then please clarify this point.

Figure 4: Cumulative infiltration process of the WEP-QTP model
I don't understand this figure. Please give an explanation in the caption. Re-explain the letters. Why are there 2 dashed lines, are they different scenarios ? I see now that this part of the figure is modified from Jia et al. (2001). I think that it should be cited as a source element of the figure. Also, now that I found this image from Jia, I understand that what is represented are the successive wetting fronts. Yet what I don't understand is why we see these dashed curves. In the Green-Ampt model, the wetting front is horizontal.

Eq2 and L233-241
Here again it is hard to understand what the authors are doing. Where does this equation come from? Classically, the infiltration rate tends towards K because F(t) is at the place of Fitf here. But Fitf is hard to understand as it is a finite quantity and not a variable (i.e. the cumulative infiltration when the front breaks through). Also why ksoil when working with the "gravel" layers ? And What are "error caused by the different soil moisture content of the soil above the interface". I think this paragraph needs more pedagogy to avoid giving the feeling that the authors are doing their own cooking with some well-established equations.

L253
"determined by the snow water equivalent and snow density"
What is the approach ? Constant values ? Values derived from climate forcing data?

Equation 7
"RN = LE + H + G"
A more comprehensive way to write it is G=… because it shows how what the authors derive from the climate forcing data is used as an input from the model. Also what about this equation when there is snow ? Is it also applied ?

Equation 10
How is the ice content linked to the temperature ? I assume the authors also use a soil freezing curve.

L350
"the riverbed conductivity was approximately 5.184 m/d"
Where is this value used ? I feel some part of the model description is missing. From what I understood there is the soil and the gravel layers, now it seems there is a riverbed layer. I just looked for the word riverbed, it does not appear before part 3. I have the hardest time understanding how this model works and I am trying hard.

L350-351
"The thickness of the soil layer at the mountaintop, mountainside, and foot of the mountain was 0.4 m, 0.6 m, and 1.0 m, respectively."
Was there an attempt to characterize the stratigraphy based on the topography/morphology ? If so it is not mentioned in the method. And it is more than

necessary for the message this study wants to convey. So if this effort has been made, please explain it in the methods. Also as I said before, the stratigraphic observations should be presented in detail somewhere. They really contribute to the added-value of the paper.

Figure 11
The legend is so small, with the resolution I got for the figure (which is low) I cannot read it.

L429-424
"There might have been a soil interlayer at cm, and the measured water content was between the simulated values of the WEP-QTP and WEP-COR. The average RE of WEP-COR was 33.74%, and that of WEP-QTP was smaller at -12.11%. WEP-QTP could reflect the influence of gravel on the vertical migration of water."
This discussion is really hard to follow. How speculative is the existence of this interlayer ? What is the physical process that makes it a relevant hypothesis ? I think if this suggestion is important it needs to be explained in more detail.

Figure 10 and L453-454
"was inconsistent with the measured value"
If possible the authors should add observations on figure 10. Since the main message of the study is to show the benefits of the new stratigraphy, these benefits are visible only when compared to observations.

L455
"In addition, snow cover significantly contributed to the inconsistencies between the temporal and spatial changes of the frozen soil in the two models, which in turn caused variations in the groundwater recharge and discharge process."
What supports these results ? Can the author provide a number or a graph that supports this ?

L656
"water body, soil–vegetation, irrigated farmland, non-irrigated farmland, and impervious area"
What about mountain bare lands above the tree line ? Which type was used?

Technical corrections

L16
"while"
I don't see the point of this "while", it is not putting 2 ideas in parallel. It is possible to end the first sentence before the while and restart with "This unique…"

L17
"To investigate the mechanism of the underlying surface structure on the…"
The sentence reads weird. The structure does not have mechanisms. And "to investigate" misses something like "the effect", "the consequences"… I would rephrase it to something like "To understand the impacts of this subsurface structure on the water cycle of QTP catchments…"

L17
"hydrothermal migration"
Is this term correct ? I googled it and found papers about the motion of magma. Which makes more sense because heat can trigger density gradients and thus motion. I do not really see it with fresh water on the continent.

L22
"the single soil"
I think "single" is not useful here.

L23-24
"In the non-freeze–thaw period"
When no phase change occurs in the ground

L35
"the "tailing" process after October"
the observed "tailing" process after October (it if is indeed what the authors mean)

L40
"typical"
This world carries little meaning. I would write "major"

L45-46
"Almost all ecological, hydrological, soil, and biological activities in the soil in cold regions occur here, hence it has been the focus of hydrological research in cold regions"
This sentence could be improved because of the "Almost all", "soil in the soil" etc. I would rephrase "This region has received a lot of attention regarding hydrological research because of the great variety of biological and physical processes occurring at the surface and subsurface…".

L84-85
"during the non-freeze–thaw period"
Under fully thawed conditions

L86
"develop a hydrothermal coupling method"
This is unclear according to me, I would say "develop a modeling framework representing coupled heat and water transfers in the ground"

L102
"litharenitewith"

L144-143
"stations. Avoid"

L153-154
"from the foot to the peak of the mountain"
decrease with elevation. I guess it gets to 0 even before the peaks.

L154
"and0"

L279
"the upper boundary energy"
"energy fluxes"

L279
"calculated by meteorological elements"
"calculated based on the climate forcing"

L289
"specific heat"
"specific heat capacity"

L293
"the iterative method"
There are a few of them, be more specific.

L389-390
"the heat preservation effect of the snow"

I guess the authors refer to the insulation effect of snow

L400
“the thermodynamic properties”
Are the author talking about the temperature ? I am confused.

L429-430
“the unstable water-holding capacity”
I don’t understand why it is unstable.