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Reply on RC1

Pengxiang Wang et al.

Author 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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The paper is interesting to read, which presented the development of Water and Energy transfer Processes model in the Qinghai–Tibet Plateau (WEP-QTP) that modified based on the original Water and Energy transfer Processes model in Cold Regions (WEP-COR). In the presented model, the vadose zone processes considered three strategies under different conditions: (1) a dualistic soil-gravel structure using the Richards equation under non-heavy rain in the nonfreeze–thaw period; (2) a multi-layer Green-Ampt model in a heavy rain scenario in the nonfreeze–thaw period; and (3) a hydrothermal coupling model based on the continuum of the snow-soil-gravel layer during the freeze–thaw period. The modified model was then verified with measured river discharge in Niyang River Basin by comparing the simulated groundwater.

The study adopted a new conceptualization of the water and energy transfer in Qinghai–Tibet Plateau, which is considered as novel. However, significant improvement is needed before the consideration of publication to Hydrology and Earth System Sciences.

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.

Major comments:

- ***Author stated in Line 52-62 that the existence of gravel in soil can significantly affect the soil water content and water transport. However, coupling of soil water and heat transport may be still not fully achieved in the***

modified version of WEP-QTP. When the dualistic soil-gravel structure was used in the nonfreeze–thaw period, the soil water transport may be decoupled with the thermal transport (see Line 296: "for soil and gravel layers, the average temperature was represented by the temperature of the middle layer"). It seems that the full coupling of water and heat transport can only be achieved for freeze–thaw period? Author should at least state whether the neglect of heat transport in nonfreeze–thaw period affect hydrological processes.

Reply: Thanks for the comment and suggestion. In the non-freeze–thaw period, all the water was in a liquid state, and the heat conduction had a minor effect on the water migration process. The model detected the non-freeze-thaw period based on ice content and temperature of each computing unit. In that period, only the moisture simulation was performed for simulation efficiency. We will make the supplementary modifications in Section 2.2 to address this point.

- ***During the nonfreeze–thaw period, the soil hydrology was simulated with either a dualistic soil-gravel model or a Green-Ampt equation, and the selection of the two options depend on whether the rainfall intensity exceeded 20 mm/day (Line 677). Why was such threshold selected? Would the dualistic model more suit to the high intensity rainfall?***

Reply: The runoff generation mechanism is different for the non-heavy and heavy rain scenarios: during non-heavy rain, there is saturation-excess, while during heavy rain, there is infiltration-excess. In heavy rain scenario, the Richards model is unstable for soil hydrology simulation while the Green-Ampt model is stable and has high computational efficiency. Therefore, in the WEP model, this threshold value was used to divide the simulations into two scenarios.

- ***In the schematic figure shown in Fig. 3 (a), the author proposed a dualistic soil-gravel model, it is not clear whether the dualistic model is similar to the dual-porosity model proposed by Greke and van Genuchten (1993). Moreover, author should clearly state how to separate the water flow in such dualistic pore system.***

Reply: Thanks for the insightful comment. In the dual-porosity model proposed by Greke and van Genuchten, the water transport medium is a mixture of soil and rock that is consistent from top to bottom; hence, the model generalized the medium into two systems: macropore and matrix pore. Our research object was the upper and lower layered medium with the thin soil layer and thick gravel layer in the Qinghai–Tibet Plateau. Based on this, we generalized the medium as an upper and lower dualistic soil–gravel structure to simulate the process of water and heat transport in different periods. In this model, the water flow is not separated like in the dual-porosity model. In future research, we will refer to the dual-porosity model to improve the mathematical description method of water transport in the gravel layer.

- ***The soil water retention curve was described with van Genuchten model in Eq. B2 (Line 685), while the soil hydraulic conductivity function adopted a power function $\theta^{\frac{1}{4}} \sim B_3 \theta^{\frac{1}{4}}$ which is similar to that was used in Brooks-Corey model. Besides, the parameter n in Eq.B3 also adopted Mualem's constant (Line 692).***

Such combination may be acceptable only if more cautions were taken for the parameterizations. Author should clarify why chosen to combine the selected soil water retention curve and soil hydraulic function, and how these soil hydraulic parameters were specified for distributed hydrological modeling.

Reply: We apologize for the unclearness on this part. The meanings of the two n values in Equation B2 and Equation B3 are different. In Equation B2, n and m are empirical parameters affecting the shape of the retention curve; $m = 1 - 1/n$. In Equation B3, n is Mualem's constant. In the revised version, we will replace letters to clearly explain the meanings of different variables in the equation.

The combined application of the two models has been verified in the previous WEP COR model (Li 2019), which performs well in simulating water transport in frozen soil. These two models are mainly used to calculate the unsaturated soil hydraulic diffusivity $D(\theta)$ and the hydraulic conductivity $K(\theta)$ in Equation B1. Equation B1 was used to calculate the vertical movement of water in unsaturated soils.

- ***In Page 20, Fig.8, why the simulated soil moisture differed between the two models in a freeze-thaw period (Line 414)? Modification in the proposed model may be solely focused on the nonfreeze-thaw period.***

Reply: Differences in simulated soil moisture were caused by different model structures. The WEP-COR model did not consider the layered geological features of Qinghai-Tibet Plateau; the simulation object was homogeneous soil. Therefore, the simulated moisture of the WEP-COR model changed gradually in the vertical direction, and a large difference between simulated and measured values occurred below 40 cm (the soil layer thickness at the experimental site is 40 cm, with gravel layer below 40 cm.). The WEP-QTP model took this geological structure into account. Gravel layer has higher hydraulic conductivity and lower water-retention capacity, which is manifested in the simulated difference in the water content of the gravel layer. The simulated results from the improved WEP-QTP model were closer to the measured values.

The model improved in both the freeze-thaw period and non-freeze-thaw period. Like in the non-freeze-thaw period, the revised formula for water retention properties of the soil-gravel mixture was used to describe water retention curves for the lower gravel layer during the freeze-thaw period (Equation 1). The saturated hydraulic conductivity (K_s) of the soil or gravel layer was corrected by temperature (Equation 6). There are also improvements to the heat transport calculations; please see Section 2.2.2 for details.

- ***All the figures have poor resolution. Please consider replacing all of them.***

Reply: Thank you for your suggestion. In the revised version, we will replace all the figures with high-quality figures and improve figure layout.

Minor comments:

- ***Line 132: "Temperature" should be "temperature"***

Reply: Thanks, we will correct it and check for other potential errors.

- **Line 154: The "0" may be redundant.**

Reply: Sorry for this mistake, we will correct it and check for other potential errors.

- **Line 164: The citation of MODIS data should be added.**

Reply: The citation of MODIS data is: <https://ladsweb.modaps.eosdis.nasa.gov/search/>

- **Line 166: The citation China's second glacier inventory data set should be added.**

Reply: Line 169 shows this citation (<http://westdc.westgis.ac.cn/>).

- **Line 167: add the citation of Water and Energy transfer Processes in Cold Regions (WEP-COR) model.**

Reply: Thanks, we will add this citation in the revised version.

- **Line 267: The unit of saturated hydraulic conductivity K_s and snow water equivalent S should be consistent.**

Reply: S is the daily variation of snow water equivalent (mm/d), which is consistent with the unit of daily precipitation. K_s is the saturated hydraulic conductivity, which was used for the calculation of water transport in Equation B1. Unit conversion was considered in the calculation process of the model.

- **Line 289: The unit of $E_{\text{sub}}/E_{\text{evap}}$, c_p , and r_a should be added.**

Reply: We apologize for these omissions. We will supplement these contents as follows: is the sum of the surface sublimation and evaporation rates (mm/day); is the air density (kg/m^3); is the constant pressure specific heat of the air ($\text{MJ/kg/}^\circ\text{C}$); is the aerodynamic resistance (day/m).

- **Line 290: r_a is aerodynamic resistance?**

Reply: Yes, we will supplement its definition in the revised version.

- **Line 340: where can we found the calibrated parameters?**

Reply: The calibrated parameters were in Line 344-354.

- ***Line 454: Figure 10 In order to prove the conclusion in this paper that WEP-QTP can better simulate the measured runoff, it was suggested to plot the measured runoff data in the figure.***

Reply: The simulated and measured runoff data are compared in Figures 5 and 9. Due to the limitations of the experimental site conditions, the hydrological cycle fluxes in Figure 10 have no measured values. Figure 10 was provided to compare the effect of model improvement on the runoff process. We will supplement this in the revised version.

- ***Figure11 Legend and the scale is too small to read; It is recommended to mark the location of the three stations. What the source of the plotted data, measured snow thickness or the model simulation? If it is a map of measured snow, it is recommended to put it in the appendix. If it is a map of modeled results, suggest making a comparison with the actual measurement.***

Reply: We apologize for the unclearness on this part. Figure 11 shows the snow thickness simulated by the model. The measured snow thickness was calibrated at the experimental site (Figure 6). We will modify this map as you suggested and supplement the site location.

References

Li J, Zhou Z, Wang H, et al. Development of WEP-COR model to simulate land surface water and energy budgets in a cold region [J]. Hydrology Research, 2019, 50(1): 99-116.

Please also note the supplement to this comment:

<https://hess.copernicus.org/preprints/hess-2022-215/hess-2022-215-AC1-supplement.pdf>