

## Response to referee #2's comments

### Major revisions:

- 1) In Section 2.1, a brief review of the “old” WEB-DHM has been given, including the general model structure and the soil model.
- 2) In Section 2.2, the frozen soil parameterization (particularly the soil thermal properties) has been better formulated and clarified.
- 3) In Section 3, the datasets descriptions have been improved.
- 4) In Section 4.1, all the parameters have been better optimized.

*First, by using the original WEB-DHM without the frozen scheme, the land surface parameters and two van Genuchten parameters were optimized using the observed surface radiation fluxes and the soil moistures at upper layers (5, 10 and 20 cm depths) at the DY station in July. Second, by using the WEB-DHM with the frozen scheme, the frozen soil parameters were calibrated using the observed soil temperature at 5 cm depth at the DY station from 21 November 2007 to 20 April 2008; while the other soil hydraulic parameters were optimized by the calibration of the discharges at the basin outlet in July and August that covers the annual largest flood peak in 2008.*

- 5) The Figure 2 (“soil model of WEB-DHM”) is added. The new calibration and validation results have been used to make/ update Figures 4-12.
- 6) The advantages and shortcomings of the implemented frozen soil parameterization with respect to different solutions available in the literature have been discussed in the conclusion part ([Lines 476-494 in the revised manuscript](#)).

### Responses to general comments:

#### 1) General model (description) comments

-Why is section 2.1 (surface radiation budget) and 2.2. Treatments of snow outlined in detail, but other model description just based on citing other papers (for example, Sellers et al. (1996) for formulation of land surface processes and Wang et al. (2009) for later flow, river routing)? Is section 2.2. (Treatments of snow) a new model addition and why this method by Yamazaki (2001) is chosen? My suggestion is to give a brief overview of parameters and

processes of the “old” WEB-DHM, including land cover, lateral and vertical flow in frozen and unfrozen soil, and distribution of fluxes in mountain terrain.

**Answer:** The surface radiation budget has been removed according to the 3<sup>rd</sup> referee’s comments. The descriptions about “treatments of snow” (including the method by Yamazaki (2001)) are also removed, because that the introduction of the Yamazaki method changes little on the simulated results (snow depth, soil temperature and moisture profiles, and river discharge), and the other snow descriptions can be found in Sellers et al. (1996a).

The processes of “old” WEB-DHM were briefly reviewed in Section 2.1 according to your suggestions, including the general model structure and the soil model.

*Sellers, P. J., Randall, D. A., Collatz, G. J., Berry, J. A., Field, C. B., Dazlich, D. A., Zhang, C., Collelo, G. D., Bounoua, L.: A revised land surface parameterization (SiB2) for atmospheric GCMs, Part I: Model Formulation, J. Climate, 9, 676-705, 1996a.*

*Yamazaki, T.: A one-dimensional land surface model adaptable to intensely cold regions and its applications in eastern Siberia, J. Meteorol. Soc. Jpn., 79(6), 1107-1118, 2001.*

2) -The authors use a simple empirical function to describe the freezing soil characteristics (formulas (7, 8)), but do not provide any material properties or measured data (for example, soil freezing characteristic curves).

**Answer:** Soil thawing curve for the DY station is added ([Figure 7 in the revised version](#)). The soil thawing curve is not measured directly, but determined by linearly interpolating soil temperature profile to find the thawing point. The deepest position at which temperature turns from above freezing to below freezing is considered to be the thaw depth.

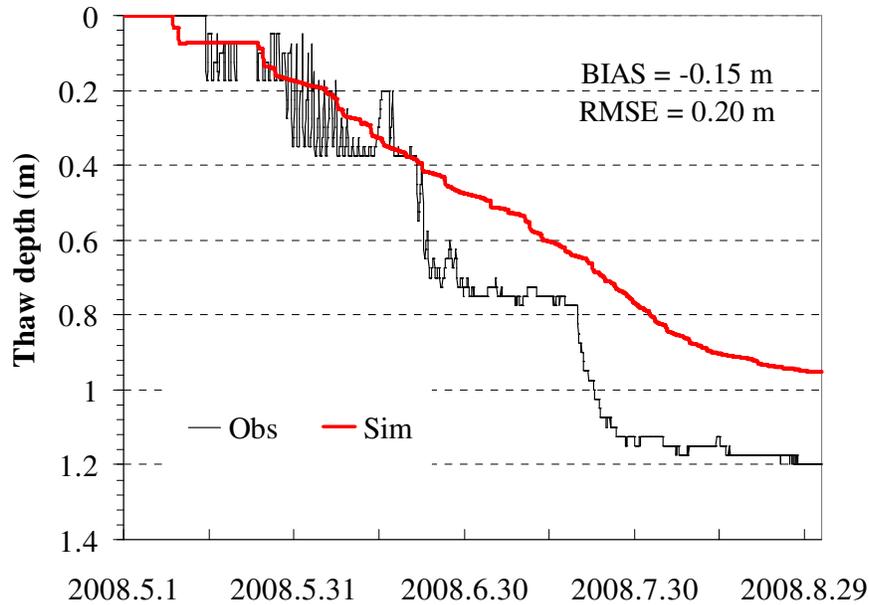


Figure 7. Hourly observed (interpolated from the observations of soil temperature profile) and simulated thaw depth at the DY station, from 1 May to 31 August 2008, by using the WEB-DHM with the frozen scheme.

Detailed comments

3) Page 6899, line 16: What is  $T_g$ ?

**Answer:**  $T_g$  is soil surface temperature (K) (Lines 168-169 in the revised manuscript).

4) Page 6900, line 1- this sentence is unclear- should this describe the infiltration into frozen soil?

**Answer:** It was an assumption by Sellers et al. (1996a), and describes the treatments of coexisting solid and liquid water at ground. In the revised manuscript, this part (treatments of snow) is removed.

5) Page 6900, section 2.3. Why is this approach chosen and not for example the approaches that have been published by others (Woo et al. 2004; Poutou et al. 2004; Bonan et al. 1996).

**Answer:** The approach by Li and Koike (2003) is chosen, because that both their study and our WEB-DHM hydrological model share the same land surface scheme (SiB2), which makes it easy to incorporate the frozen scheme into WEB-DHM. Furthermore, the empirical

approach is simple and fast with an acceptable accuracy as shown in Li and Koike (2003). For further discussions, please refer to [Lines 476-491 in the revised manuscript](#).

*Li, X., and Koike, T.: Frozen soil parameterization in SiB2 and its validation with GAME-Tibet observations, Cold Reg. Sci. Technol., 36, 165-182, 2003.*

6) Page 6901, line 5: How are the empirical parameters in van Genuchten's determined? How is  $f$  (hydraulic conductivity decay factor, line 15) determined?

**Answer:** We have added the text ([Lines 322-327](#)) in the revised manuscript as “The van Genuchten parameters  $\alpha$  and  $n$  regulate the soil hydraulic function which controls the soil water transport. They were optimized as 0.1 and 2.1 respectively, by comparing the simulated and observed soil moistures at the upper soil layers (5, 10, and 20 cm) in July 2008 at the DY station”.

The hydraulic conductivity decay factor ( $f$ ) determined the distribution of the magnitudes of the hydraulic conductivity in the soil profile, and was optimized by matching the simulated and observed discharges. (see [Lines 334-342](#) in the revised manuscript)

7) Page 6901, line 10:  $K_{sat,j}$  is represented using the assumption of an exponential decrease in hydraulic conductivity with increasing soil depth. Is this assumption valid for this landscape? For example, in some periglacial settings the opposite is true. Please provide details on soil material properties.

**Answer:** The DY station is located at a high altitude (4146.8m). In the region above 4000 m, there is mainly the non-vegetation's alpine desert, and the exposed decency rock debris quite grows having high water-permeability. (see [Lines 227-228](#) in the revised manuscript)

As you suggested, in the revised manuscript, an exponential increase (hydraulic conductivity decay factor  $f < 0$ ) in hydraulic conductivity with increasing soil depth is used in the WEB-DHM with the frozen scheme. (see [Lines 152-153](#) in the revised manuscript)

8) Page 6902, line 6: How is  $R_{ng}$  different to  $R_n$  in formula (1)?

**Answer:** In the WEB-DHM, each model grid is simplified as a mixture of vegetation and bare soil, and  $Rn$  is the total net radiation absorbed by the canopy ( $Rn_c$ ) and ground ( $Rn_g$ ). Therefore,  $Rn = Rn_c + Rn_g$ .

9) Page 6902, lines 5& 12: the physical basis and derivation from formula (14) to (15) are not clear.

**Answer:** In the old manuscript, the formula (15) just shows the modification of the effective heat capacity of surface soil ( $C_g$ ), to account for the latent heat of fusion in the surface layer. (see equations 13 and 14 in Li and Koike (2003)).

*Li, X., and Koike, T.: Frozen soil parameterization in SiB2 and its validation with GAME-Tibet observations, Cold Reg. Sci. Technol., 36, 165-182, 2003.*

10) Page 6903. Datasets for the study area. This section needs reorganization; cut out the section of general hydrological processes (lines 1-15) and move it to results. A new organization should include: description of study site (physical setting topography (altitudinal extent), surface characteristics (vegetation), soil/bedrock material, climate parameters such as annual air temperature, precipitation, snow water equivalent, permafrost/seasonally frozen ground distribution ..).

**Answer:** Thanks for the comments. We have moved “the general hydrological processes” (Lines 1-15 in p6903 in the old manuscript) to the beginning of Section 4. Furthermore, according to your requests, we have rewritten the site description ([Lines 222-238 in the revised version](#)), in which two references have been added.

*Yang, Z., Yang, Z., and Zhang, X.: Runoff and its generation model of cold region in Binggou Basin of Qilian Mountain, Memoirs of Lanzhou Institute of Glaciology and geocryology, Chinese Academy of Sciences, 7, 91-99, 1992. [In Chinese with English Abstract]*

*Zhang, X., and Yang, Z.: The primary analysis of water balance in in Binggou Basin of Qilian Mountains, Journal of Glaciology and Geocryology, 13(1), 35-42, 1991. [In Chinese with English Abstract]*

11) Page 6903, Line 25: Lower limit of permafrost coverage is about 3400 m- is this within the watershed? Please provide details on permafrost coverage, depth and thermal state and/or seasonally frozen soil.

**Answer:** They have been added (Lines 229-234 in the revised manuscript).

12) Page 6904, line 5 ff. Non quantitative phrases should be avoided, such as “drops a lot at night”; “runoff becomes very large/rather small”.

**Answer:** Thanks.

The text “drops a lot at night” has been changed to “drops to below 0 °C at night” (Line 281 in the revised manuscript).

Furthermore, we have rewritten the text as (Lines 283-286 in the revised manuscript) “Therefore, the snowmelt runoff in the early spring is rather small (around 15% of annual runoff; Zhang and Yang, 1991). From May to June (late spring), the air temperature increases to above 0 °C stably, and the snowmelt runoff becomes very large (greater than 25% of annual runoff; Zhang and Yang, 1991)” to show quantitative information of “runoff becomes very large/rather small”.

13) Page 6904, lines 1-22. This paragraph lacks a figure that describes the general hydrology of this basin, i.e. start/end of snowmelt, freeze/thaw in soil. Alternatively, numbers should be provided (i.e. percentage of annual runoff as springmelt; soil starts thawing around April and is completely thawed by August, etc.)

**Answer:** In Section 4 (Lines 273-286 in the revised manuscript), we have added the text:

“The spring snowmelt occupies about 30% of the annual runoff; while the residual comes from rainfall and groundwater (Zhang and Yang, 1991). In the lower area of the watershed, soil starts thawing around April and stops by August; while in the upper regions, soil starts thawing around late May. In the watershed, the thickness of the active frozen soil layer is about 1.0-1.5 m in the lower regions, and is greater than 3.0 m in the upper mountain regions (Yang et al., 1993).

In the early spring (April to May), with the increase of air temperature, snowmelt occurs from the lower regions to the mountain areas. However, during this period (April to May), the air temperature exceeds 0 °C only at noon, but drops to below 0 °C at night. Consequently, much of the snowmelt water freezes again at night before its departure from snowpack.

Therefore, the snowmelt runoff in the early spring is small (around 15% of annual runoff; Zhang and Yang, 1991). From May to June (late spring), the air temperature increases to above 0 °C stably, and the snowmelt runoff becomes very large (greater than 25% of annual runoff; Zhang and Yang, 1991).”

Zhang, X., and Yang, Z.: *The primary analysis of water balance in in Binggou Basin of Qilian Mountains, Journal of Glaciology and Geocryology, 13(1), 35-42, 1991. [In Chinese with English Abstract]*

Yang, Z., Yang, Z., Liang, F., and Wang, Q.: *Permafrost hydrological processes in Binggou Basin of Qilian Mountains, Journal of Glaciology and Geocryology, 15(2), 235-241, 1993. [In Chinese]*

14) Page 6904, lines 19 ff: Rock and gravel soils are classified as agriculture/grassland soils?  
**Answer:** No, the land use type “Rock and gravel” is reclassified as “broadleaf shrubs with bare soil”, which defines the vegetation cover fraction as 0.1.

15) Page 6904, lines 22: What is a “typical frost desert soil”?

**Answer:** This sentence has been removed, and we have rewritten the land cover and soil characteristics in the site description (Lines 225-228 in the revised manuscript): “In the altitude from 3440 to 4000 m, there is mainly alpine meadow; while in the altitude from 3440 to 3700 m, the shrubs and the fish-scale shape sod coexist. In the region above 4000 m, there is mainly the non-vegetation's alpine desert, and the exposed decency rock debris quite grows having high water-permeability”.

16) Page 6904, lines 29: Forcing data- what are the errors for radiation and humidity by not correction for elevation and topography? According to Figure 2, the climate station is located on a high altitude location and thus not representative for the entire basin.

**Answer:** The relative humidity of an air-water mixture is defined as the ratio of the partial pressure of water vapor ( $e_w$ ) in the mixture to the saturated vapor pressure of water ( $e_w^*$ ) at a prescribed temperature. Where,  $e_w^*$  is a function of dry bulb temperature (or air temperature, which is affected by elevation). The calculation of incident radiations at the land surface within a basin, is influenced by both topography (e.g., slope inclination, slope orientation and topography of surroundings) and elevation (mainly through air temperature, air pressure). For

simplificity, the above factors are not considered in the current study; while only the air temperature is modified according to the elevation difference between the DY site and each model grid. Because the air temperature is a critical factor that controls the frozen soil process in the basin.

Although the DY station is located on a high altitude location (4146.8m), but the basin is very small (30.48 km<sup>2</sup>) and the mean altitude is 3900 m. Through the consideration of altitude effect of air temperature for all the model grids in the basin, the simulated discharges at the basin outlet are generally in acceptable accuracies.

17) Page 6905, lines 6 ff. This and further information should be merged into one section on model parameters.

**Answer:** The text “[The vegetation static parameters including morphological, optical and physiological properties were initially defined following Sellers et al. \(1996b\)](#)” has been moved to the beginning of Section 4.1 in the revised manuscript ([Lines 294-295](#)).

18) Page 6906, line 2: You mean reflectance.

**Answer:** Revised.

19) Page 6906, line 5: what is “top soil depth”?

**Answer:** The WEB-DHM includes a lumped unconfined aquifer model to describe groundwater dynamics, and the “top soil” represents the soil column above the unconfined aquifer. As shown in [Figure 2 of the revised manuscript](#),  $D_s$  represents the top soil depth; while  $D_g$  refers to the thickness of the groundwater aquifer.

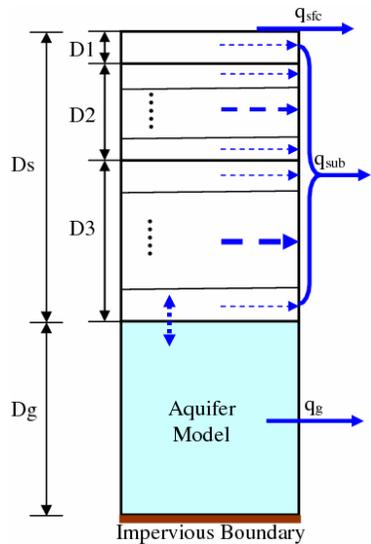


Figure 2. Soil model of the WEB-DHM.

20) Page 6906, line 12: moisture set to 0.58 and 0.017 for one entire year- are these average values? The year includes seasonal freezing and thawing, thus a seasonal range of soil moisture is expected.

**Answer:** In the yearlong simulation, although the seasonal freezing/thawing along with the phase changes will alter the solid and liquid soil moistures, but the total soil moisture (solid plus liquid water contents) is set as no greater than 0.585 and no less than 0.017. They are just boundary values used in the hydrological simulations. For simplicity, in the study, the fixed values (0.58 and 0.017) are used without considering seasonal change.

21) Page 6906, lines 10 ff: This section warrants further analysis; what is the “trial and error” method by which the optimization was done? Do these parameters make any physical sense (table 2)? A sensitivity analysis should be performed to quantify the importance of the model parameters.

**Answer:** Trial and error, or trial by error, is a general method of problem solving, fixing things, or for obtaining knowledge. “Learning doesn't happen from failure itself but rather from analyzing the failure, making a change, and then trying again.” (Source: [http://en.wikipedia.org/wiki/Trial\\_and\\_error](http://en.wikipedia.org/wiki/Trial_and_error)).

These soil hydraulic parameters have their physical meaning defined in Table 2, except the two empirical parameters used in van Genuchten equation. And the van Genuchten equation is widely used as the soil hydraulic function in the hydrology community.

The sensitivity analyses have been performed for the 6 soil hydraulic parameters ( $K_{surface}$ ,  $f$ ,  $\alpha$ ,  $n$ ,  $anik$ ,  $K_{G0}$ ) using the flood hydrograph from 21 July to 7 August 2008 as follows.

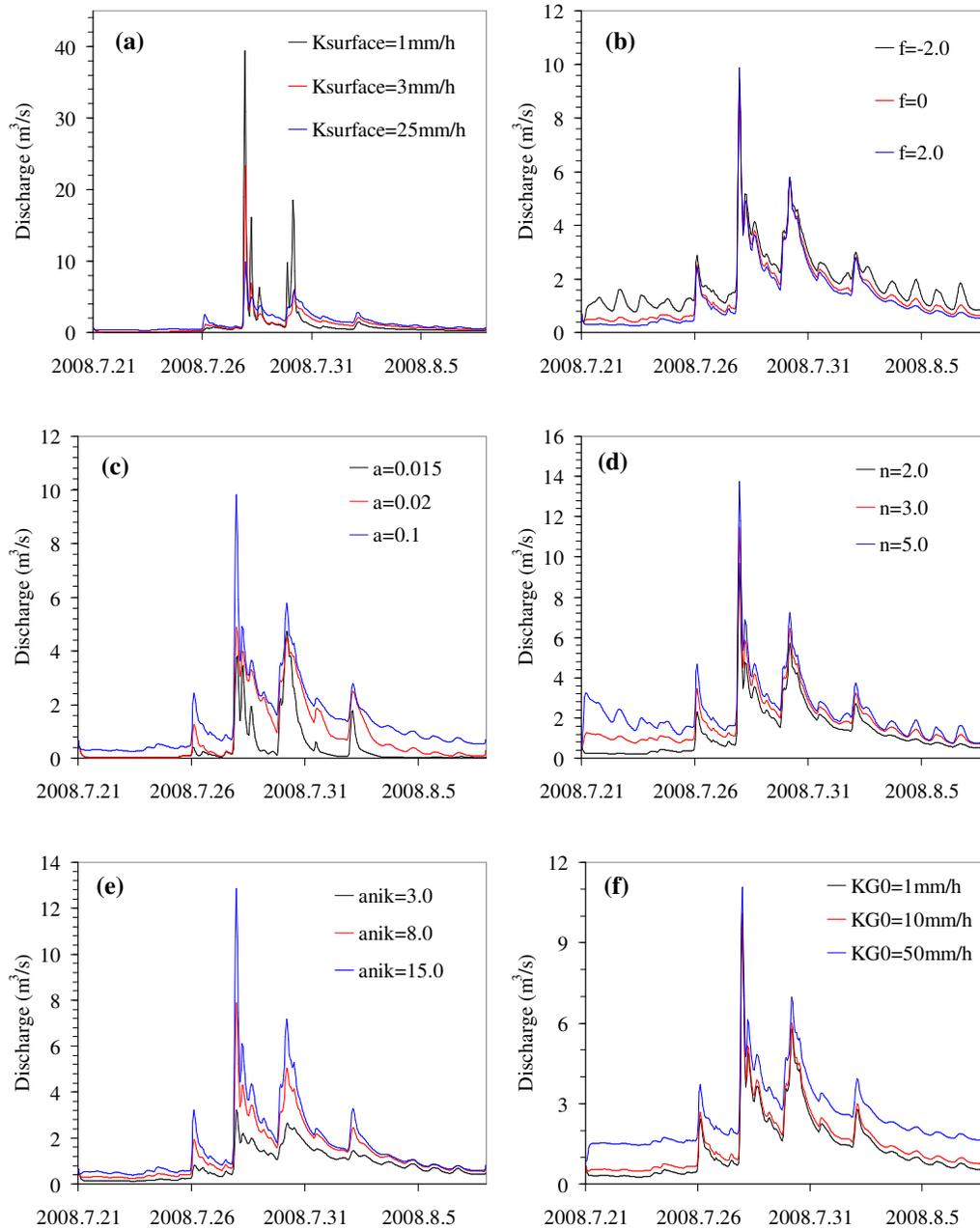


Figure. Sensitivity of the flood hydrograph from 21 July to 7 August 2008 in the Binggou Watershed, to different parameters: (a)  $K_{surface}$ , (b)  $f$ , (c)  $\alpha$ , (d)  $n$ , (e)  $anik$ , and (f)  $K_{G0}$ , simulated by using the WEB-DHM with the frozen scheme.

As expected,  $K_{surface}$  and  $anik$  are most sensitive parameters in streamflow simulations with WEB-DHM.  $K_{surface}$  controls the peak flow; while  $anik$  contributes to both peak and recession flows.  $K_{G0}$  determines the base flows; while  $\alpha$  and  $n$  regulate the soil hydraulic function which controls the soil water transport, and thus affect the shape of the flood hydrograph.

In the study, at first, by using the WEB-DHM without the frozen scheme,  $\alpha$  and  $n$  were optimized with the calibration of the soil moistures at upper layers (5, 10 and 20 cm depths) at the DY station in July, while keeping the original values of  $K_{surface}$  obtained from FAO (2003). Second, by using the WEB-DHM with the frozen scheme, according to the shape of the flood hydrograph in the basin, after defining the values of  $K_{G0}$  and  $f$ , we carefully calibrated  $K_{surface}$  and  $anik$  with the initial conditions obtained from a previous hydrological simulation starting from 21 November 2007.

*FAO: Digital soil map of the world and derived soil properties, Land and Water Digital Media Series Rev. 1, United Nations Food and Agriculture Organization, CD-ROM, 2003.*

22) Page 6906, lines 25 ff: Define BIAS?

**Answer:** We have added the text in the revised manuscript (Lines 346-351):

“The bias error ( *BIAS* ) and root mean squared error ( *RMSE* ) are used as evaluation criterion for the simulated results, where *BIAS* and *RMSE* are defined as

$$BIAS = \sum_{i=1}^N (x_{si} - x_{oi}) / N , \quad (19)$$

$$RMSE = \sqrt{\sum_{i=1}^N (x_{si} - x_{oi})^2 / N} , \quad (20)$$

where  $x_{oi}$  is the observation,  $x_{si}$  is the simulation, and  $N$  is the total number of time series for comparison.”

23) Page 6907, line 2 ff: “after calibration of a few land surface parameters” is too vague.

**Answer:** This sentence has been rewritten in the revised manuscript (Lines 356-359):

“After the calibration of the soil reflectance to visible radiation, the diurnal cycles of the upward solar radiation is well represented by the calibrated WEB-DHM without the frozen scheme.”

24) Page 6907, lines 8 ff: Using the soil temperature at 5 cm depth (where the signal is clearly dampened) as surrogate surface longwave radiation from the surface introduces a large error! It is not clear why the authors are using this approach.

**Answer:** Sorry for the mistake. I did this comparison since we have not monitored the soil surface temperature in the DY station.

In the revised manuscript, I have deleted the comparison of radiations except for the shortwave radiation, and rewritten the relevant text in the revised manuscript (Lines 359-362) as: “The *BIAS* and *RMSE* for the simulated upward shortwave radiation at the DY station are  $-3.8 \text{ W m}^{-2}$  and  $32.6 \text{ W m}^{-2}$ , respectively. It should be mentioned that the measurements of upward longwave radiation in the station were found erroneous for all periods, and was not used for model evaluation in the study.”

25) Page 6908, line 3: Timing and magnitudes of peak flows of measured vs. model discharge are different- why?

**Answer:** For the Figure 6b in the revised manuscript, by using the WEB-DHM with the frozen scheme, the hydrograph in July and August has shown that the simulated discharge (including the peak flows) well responds to the observed precipitation. The difference of timing and magnitudes between the observed and simulated peak flows is possibly attributed to the sparse density of the meteorological sites used in this study (only the DY station).

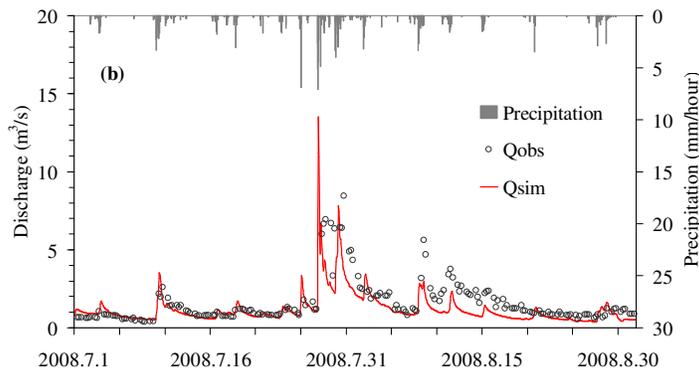


Figure 6. The hourly simulated and observed soil temperature at 5 cm in the DY station from 21 December 2007 to 20 April 2008 (a), and the calibrated hydrograph at the Binggou gauge in July and August 2008 (b), by using the WEB-DHM with the frozen scheme.

26) Page 6908, line 1 ff: Information about the method of discharge measurements should be provided in the method section.

**Answer:** We have added the following text to describe the discharge measurements in the revised manuscript (Lines 256-261): “The method of discharge measurements is briefly described as follows. First, a rectangle cross section was built using concrete at the selected point. Second, the water depth (which was used to derive the area of the cross section) and the flow velocity at the cross section were measured by the local staff several times a day (not hourly). Third, the flow velocity and the area of the cross-section were used to calculate the discharge at the cross-section.”

27) Page 6908, lines 17 ff: The high RMSE numbers actually show that the soil temperatures are not reproduced “well”.

**Answer:** In the revised manuscript, the soil temperatures are in general well simulated (see Figure 8 in the revised manuscript).

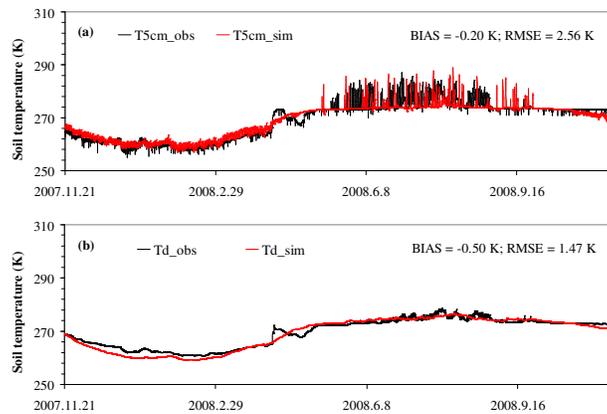


Figure 8. Hourly observed and simulated temperature at 5 cm  $T_{5cm}$  (a) and temperature of deep soil  $T_d$  (b) at the DY station, from 21 November 2007 to 20 November 2008 by using the WEB-DHM with the frozen scheme.

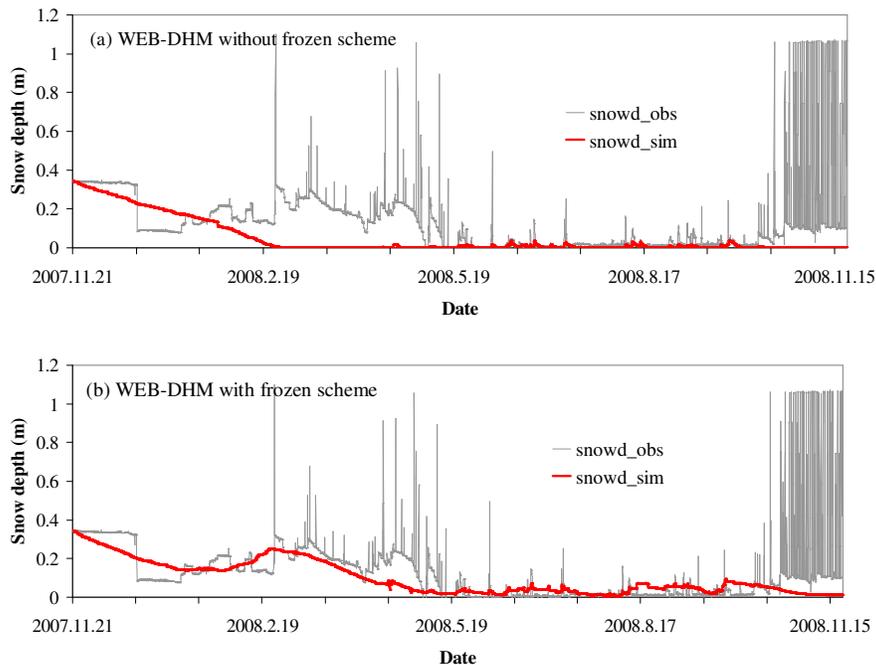
28) Page 6908, line 19: Not clear what was done with the heat flux transducer data (they measure flux, not temperatures).

**Answer:** Sorry for the mistake. The “heat flux transducer” should be “soil temperature sensors”. (Line 246 in the revised manuscript)

29) Page 6908, line 20: Model evaluation should be done for the snow (depth and snow water equivalent).

**Answer:**

At the DY station, only snow depth was measured, and the large fluctuations of the observed snow depth were caused by strong wind blowing. By assuming that the snow depth is five times of the snow-water equivalent, the simulated snow water equivalent was converted into snow depth, and then compared with the measured snow depth (see [Figure 9 in the revised manuscript](#)). Result shows that the WEB-DHM with the frozen scheme generally reproduces the snow depth with an acceptable accuracy.



*Figure 9. Hourly snow depth at the DY station from 21 November 2007 to 20 November 2008, simulated by the WEB-DHM without and with the frozen scheme.*

Comments about the figures:

30) Fig. 5 e,f,g Why does the simulated soil moisture show a diurnal signal? Fig. 5 f shows clearly that the model does not match the actual field data during the process of thawing, indicating that the parameterization needs improvement. This is critical for accurate discharge predictions.

**Answer:**

In the old manuscript, by using the WEB-DHM with the frozen scheme, the diurnal signal of soil moisture at the deeper layers is attributed to the wrong parameterization of soil temperature profile.

In the revised manuscript, the parameter calibration in summer is done for the original WEB-DHM without the frozen scheme (see Figure 5 in the revised version). The simulated soil moistures do not show a diurnal signal in Figures 5e-5g. Due to a lack of frozen soil physics, the thawing process at deeper layers (around 80 cm) is missed by the original WEB-DHM. It also reveals that it is necessary to incorporate a frozen soil scheme.

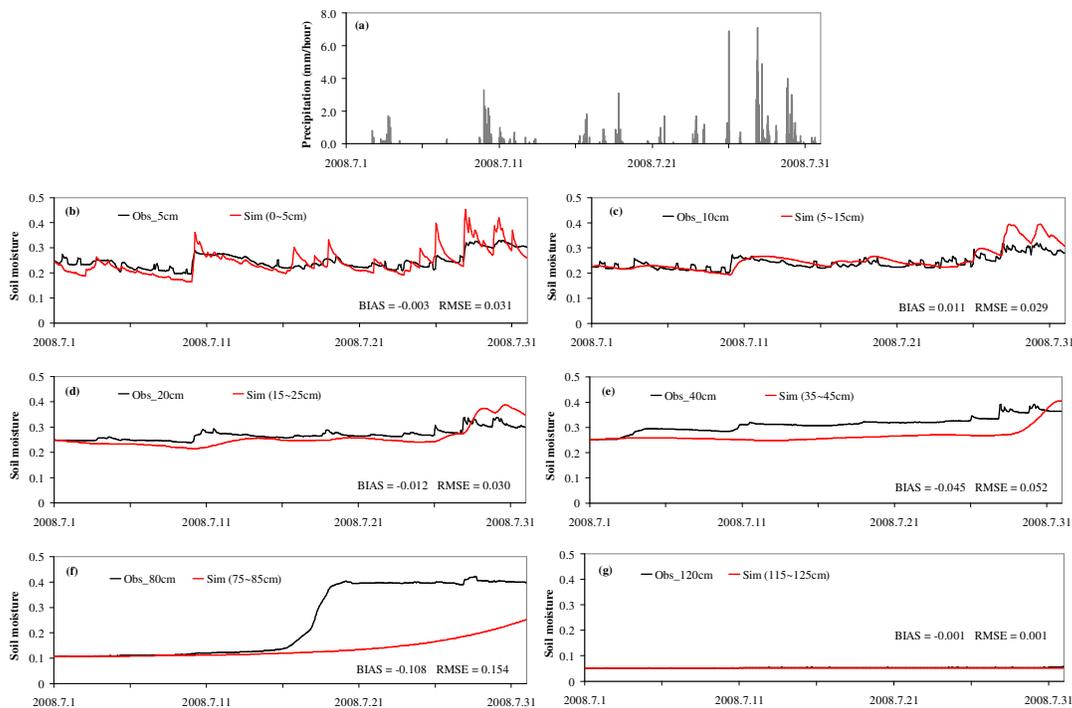


Figure 5. Hourly precipitation (a), and the simulated and observed hourly volumetric liquid soil moisture at 5, 10, 20, 40, 80, and 120 cm (b-g) at the DY station in July 2008, by using the WEB-DHM without the frozen scheme.

31) Fig 6. The high measured discharges are not matched with the simulation.

**Answer:** Please see the reply to the comment 25).

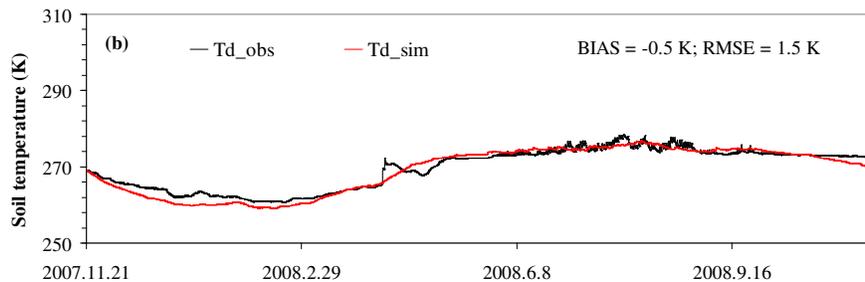
32) Fig 7. What is “deep soil”? The simulated diurnal fluctuations are much higher compared to measured data; furthermore, there should be almost none in the deeper soil zone.

**Answer:**

As shown in [Figure 2 \(“The soil model”\)](#) in the revised manuscript, D1 is the surface soil layer (0~5 cm); D2 is the root zone (5~25 cm in the study); and D3 is the deep soil (25~125 cm in the study). The deep soil (D3) can provide water for the upper root zone and receive water from the groundwater aquifer.

The Figure 7 in the old manuscript has been removed, since it makes readers confused between the temperature averaged at the deep soil layer (25-125 cm;  $T_{d,ave}$ ) and the deep soil temperature ( $T_d$ ) obtained by the force-restore method.

In the revised manuscript, the observed and simulated temperature at deep soil ( $T_d$ ) are shown in [Figure 8b](#), where observed  $T_d$  is obtained by averaging the soil temperatures at 20 cm, 40 cm, and 80 cm in the study, and simulated  $T_d$  is obtained by the force-restore method (see Sellers et al. (1996a)).



*Figure 8*

33) Fig 8 b. What is the reason for the moisture increase (without frozen scheme) in February? Comparing the frozen and without frozen simulations to the real measured data, I do not see a better performance of the new model, since neither one of them reproduces the seasonal freeze thaw! For some depths, the old model even performs better than the new model (see Fig. 8 g).

**Answer:** In the revised manuscript, the simulated liquid soil moisture by the WEB-DHM without and with the frozen scheme is shown in [Figure 10](#). The WEB-DHM with the frozen scheme has demonstrated better performance than the original WEB-DHM.

The soil moisture increase (in surface layer and root zone) by the WEB-DHM without the frozen scheme, is caused by the simulated earlier snowmelt (see [Figure 9a in the revised version](#)). The simulated earlier snowmelt is attributed to the overestimation of the soil surface temperature fluctuations (see below) caused by without treatments of latent heat fusion in the surface layer, in the WEB-DHM without the frozen scheme.

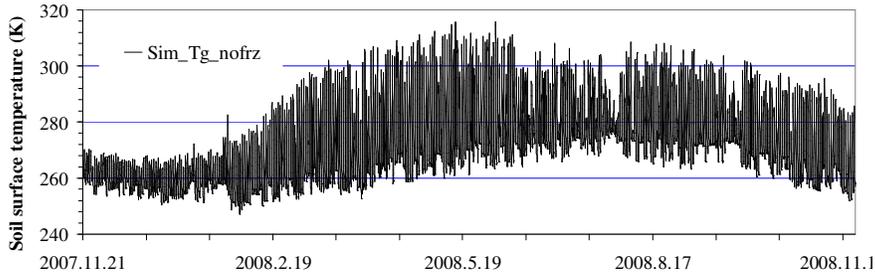


Figure. Simulated soil surface temperature by the WEB-DHM without frozen scheme.

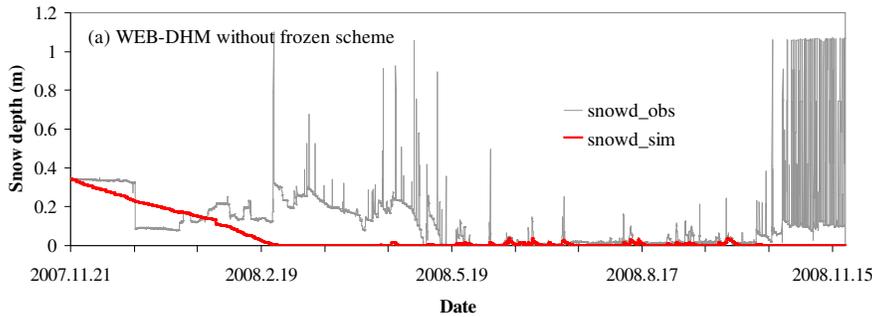


Figure 9a Hourly snow depth at the DY station from 21 November 2007 to 20 November 2008, simulated by the WEB-DHM without the frozen scheme.

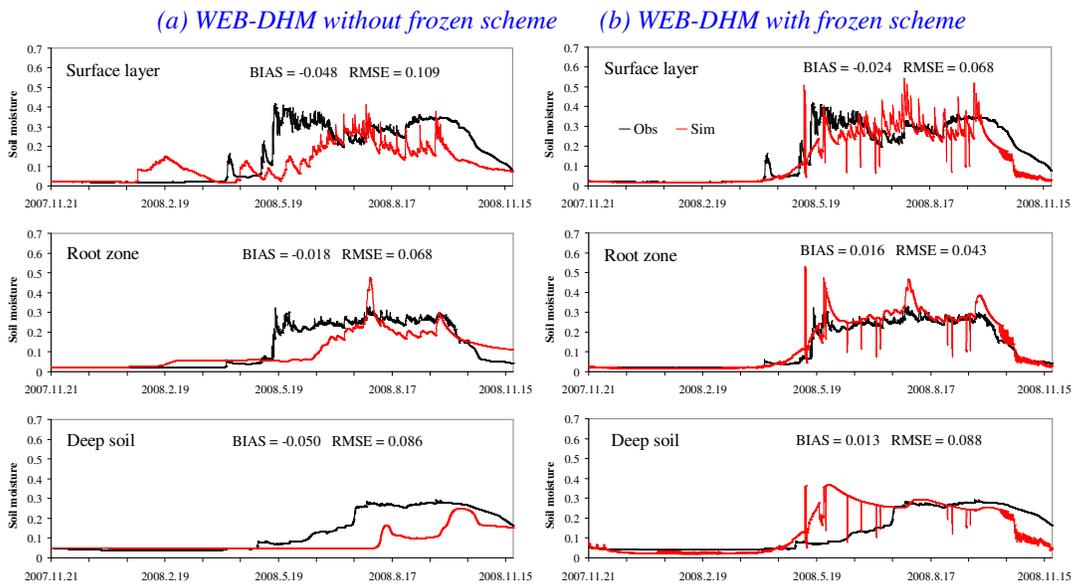


Figure 10. Hourly volumetric liquid soil moisture averaged at surface layer (0-5 cm), root zone (5-25 cm), and deep soil layer (25-125 cm) at the DY station from 21 November 2007 to 20 November 2008, simulated by the WEB-DHM without and with the frozen scheme.

34) Fig. 9. Why is there winter discharge? It is hard to interpret this figure; the y-scale should be enlarged; for measured discharge, I would prefer a line, not symbol plot.

**Answer:** Groundwater flows from the unconfined aquifer contributed to the discharges, even in winter. To clearly show the small values in y-scale, the logarithmic hourly hydrograph has been given for the WEB-DHM with the frozen scheme in [Figure 12b in the revised manuscript](#)).

The measured discharges at the remote stream gauge (Binggou) were discontinuous and irregular, which were measured with the frequency of several times a day by a local staff. Therefore, if all the measured data points were connected with a line, then the line does not represent the actual hourly discharges. Due to this reason, the observed discharges were displayed as discontinuous plots other than a line.

35) Fig 10 a. What is the reason for the peak in simulated discharge in January? I do not agree that “a constant  $K_G$ ” (Fig. B) improves the model. What is the source of base flow during winter?

**Answer:**

[In the revised manuscript](#), there is no peak in the simulated discharge in January (see below).

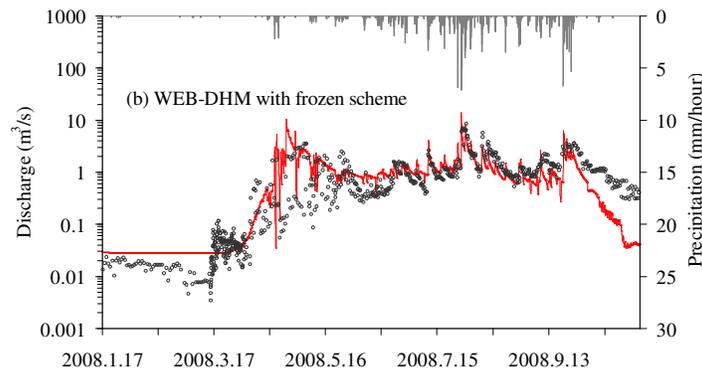


Figure 12b. Logarithmic hourly hydrographs simulated by using the WEB-DHM with the frozen scheme.

We have changed the order of (a) and (b), and put the results simulated by the WEB-DHM with the frozen scheme into [Figure 12 \(b\)](#). In fact, we want to demonstrate that “a variable  $K_G$ ” considering frozen soil effect is necessary, and performs better than “a constant  $K_G$ ”.

Base flows during winter come from the groundwater aquifer.

### 36) References:

Page 6913, line 26, Stefan, 1889. This must be a wrong citation. The Stefan formula for determining of the depth of seasonal and perennial freezing thawing should be cited, for example, by Yershov, E.D. (1990).

**Answer:** The citation “Stefan, 1889” has been changed to “[Yershov, 1990](#)” (Line 196 in the revised manuscript). The following reference is also added.

*Yershov, E. D.: General geocryology, Cambridge University press, 1990.*

### Style/technical comments

37) -The presentation of the paper is rather chaotic and requires serious organization (suggestions are provided below). -Figures are partly duplicated, for example Fig 6. is partly shown in Fig. 9 again. - The English is sometimes hard to understand; there is switching between past and present tenses; - I suggest a nomenclature in the appendix for clarification of symbols.

### Answer:

In the revised manuscript, [Figure 6b](#) shows the calibrated hydrograph in July and August, initialized from a previous simulation starting from 21 November 2007, by using the WEB-DHM with the frozen scheme; while [Figure 11b](#) illustrates the hydrograph from 17 January to 20 November 2008, also initialized from a previous simulation starting from 21 November 2007. As a result, the two hydrographs are quite similar to each other in the summer parts from July to August 2008.

The English has been carefully checked again, with a focus on the past and present tenses.

A [nomenclature](#) is also added in the [Appendix](#) for the clarification of symbols.

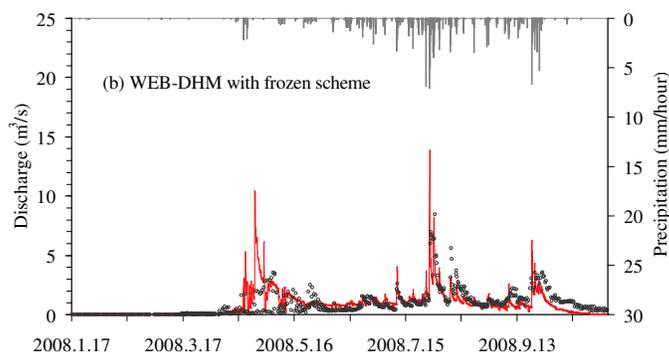


Figure 11.