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Hydrology and Earth System Sciences Discussions

Interactive comment on "Influence of thermodynamic soil and vegetation parameterizations on the simulation of soil temperature states and surface fluxes by the Noah LSm over a Tibetan plateau site" *by* R. van der Velde et al.

R. van der Velde et al.

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We would like to thank the referee for his constructive comments. Below you will find our detailed responses and modifications to the text. Unfortunately, it is impossible to upload a revised version of manuscript and, therefore, the added equations, table and figure are not readable. A fully revised version of the manuscript is available upon request.

Comment 1: “The observed turbulent fluxes were derived from Bowen ratio.

As the accuracy of this method highly depends on the accuracy of air temperature and humidity profile, it is desirable to evaluate the Bowen-ratio derived fluxes agaist EC measurements if EC measurements were available during the simulated period or other periods.”

Authors’ response: Unfortunately, eddy correlation measurements are not available for the exact same period as we performed our simulations. However, as the referee suggested, we compare the Bowen Ratio method against EC measurements collected in another period (March 16- March 28, 2005) added the following to the manuscript:

P5: “Unfortunately, the turbulent heat fluxes measured by the eddy correlation (EC) instrumentation at Naqu station are not available for the selected period. Therefore,”

P6: “Since the reliability of BREB-method depends on the accuracy of the measured air temperature and humidity profile, the validity of its application to the Tibetan measurements is evaluated through comparison of the BREB-method and the measured EC heat fluxes, which are both available for the period March 16th and March 26th 2005. Figure 2 presents the BREB-method fluxes plotted against the EC measurements. The figure shows, despite a large scatter, that the general pattern of data points follows the 1:1 line resulting in a Root Mean Squared Difference (RMSD) of 31.14 W m-2. A similar agreement between the BREB-method and EC heat fluxes has previously been reported by Pauwels and Samson (2006). We, therefore, conclude that the BREB-method derived heat fluxes are representative for the EC measurement and can be used to evaluate Noah’s performance for the Tibetan site.”

Fig. 2: Comparison of the heat fluxes derived using the Bowen Ratio Energy Balance (BREB) method and from eddy correlation (EC) measurements for the period April 16th and April 26th 2005; the latent heat flux is shown in the left panel and the sensible heat flux in the right panel. The Root Mean Squared difference between the BREB and EC

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heat fluxes is found to be 31.14 W m-2.

Comment 2: “A formula to describe the relationship between quartz content (qtz) and kh is required. This formula is crucial for understanding the soil thermal parameterization; otherwise, the readers do not understand the range of qtz and how qtz affects kh. At least, it is difficult for the reviewer to understand the unit of qtz.”

Authors’ response: In Noah, the quartz content is an important in the kh formulation proposed by Peters-Lidard et al. (1998). We agree with referee that this should be a part of the manuscript and have included the following:

P8-9: “The G0 is calculated using Eq. 1 and the temperature gradient between surface and mid-point of the first soil-layer, whereby the κh is calculated (e.g. Johansen 1975, Peter-Lidard et al. 1998) as a weighted combination between the saturated (κsat) and dry thermal conductivity (κdry) depending on the degree of saturation according to,

(13) where Ke is the Kersten (1949) number representing the degree of saturation determined using, (14) with smsat as the saturated soil moisture content [m3 m-3] . κdry is calculated using a semi-empirical equation formulated by,

(15) where γd is the density of dry soil approximated by [kg m-3] and κsat depends on the volume fractions of the solid particles, frozen and unfrozen soil water in the matrix,

‘ (16) where κice and are the thermal conductivities for ice and liquid water [= 2.2 and 0.57 W m-1 K-1, respectively], smice and smliq are the frozen and liquid soil water contents [m3m-3] and κsoil is the thermal conductivity of the dry soil matrix calculated as a function of the volumetric quartz fraction (qtz),

(17) where κqtz and κo are the thermal conductivity of quartz and others soil particles, which are set to 7.7 and 2.0 W m-1 K-1, respectively.”

Comment 3: “The simulated period is a 7-day dry period (3-10 September

2005). This period is nearly post-monsoon and the vegetation greenness had decreased. You may need to consider this issue when setting vegetation parameters.”

Authors’ response: We would like to thank referee for reminding us. For our simulation we have, however, set the greenness fraction to 0.3, which is in our opinion a reasonable value, given an NDVI of appr. 0.5 [-].

Comment 4: “In the Noah LSM, the Reynolds number dependent methodology proposed by Zilintinkevich (1995) is employed for the determination of the kB-1. Yang et al. (2008) shows it is the Zilintinkevich (1995) scheme among seven schemes that produces the largest under-estimates of heat transfer resistance and over-estimates of heat flux. This should be one reason why Noah over-estimates heat flux while under-estimates Tskin.”

Authors’ response: In the discussion, we acknowledge that the parameterization of surface exchange coefficient for heat is one of the reasons for the overestimation of the sensible heat flux and the underestimation of the Tskin. This is further clarified in this section by referring more directly to the results of Yang et al. (2008). The text has been modified as follows:

First, the surface exchange coefficient for heat (Ch) may not be properly parameterized for the Tibetan conditions. Noah uses the Reynolds number dependent method proposed by Zilintinkevich (1995) to determine the kB-1. However, Yang et al. (2008) showed for bare soil surfaces that Reynolds number dependent kB-1 methods, in general, tend to underestimate the strong diurnal kB-1 variations observed over the Tibetan Plateau (e.g. Ma et al. 2005 and Yang et al. 2003). A kB-1 underestimation during daytime results in more efficient heat transfer between the soil surface and the atmosphere, which causes an H overestimation and explains also the discrepancy between the measured and simulated Tskin. Other kB-1 methods (e.g. Su et al. 2001 and Yang et al. 2002) that are able to capture this diurnal kB-1 variation would further improve

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Noah’s overall performance over the Tibetan Plateau. This reaches, however, beyond the scope of this investigation. For evaluations of the available kB-1 methods readers are referred to Liu et al. (2007) and Yang et al. (2008).

Comment 5: “Linear correlation of Eq.(2) can be applied only when soil moisture did not change much during the simulated period. This should be clarified.”

Authors’ response: We use the soil heat flux at 10-cm and the temperature gradient over this depth to determine a “reference” kh. Then, using this reference and soil moisture measurements, the kh is calculated over the study period. We agree with the referee that this was not clear in the original manuscript and we have revised the manuscript as follows:

“Using this “reference” kh, the kh is calculated for following time steps using soil moisture measurements according to”

Comment 6: “LAI is a very sensitive parameter, and this study used its default value. As LAI is a measurable parameter through remote sensing (e.g. MODIS), it would be better to use a realistic value. At least, the default value of 5 m2/m2 is too large for the site of interest. This will, then, contaminate the calibrations of soil and vegetation parameters.”

Authors’ response: We agree with the referee that it is somewhat hard to understand with the availability of LAI products from different satellite platforms, but the leaf area index (LAI) in Noah is a fixed parameter. This is the case for the community version available from the NCEP webpage and we found also a LAI of 5 m2m-2 in the Noah component of the Land Information System v4.2. Moreover, previous reports on this fixed LAI value has also been made by Hogue et al. (2005). Since we evaluate Noah’s performance for our Tibetan site as it is applied at a global scale, we would like to maintain the simulations with LAI of 5.0 m2m-2. However in the discussion we added a several paragraphs, in which we describe the results from calibrating the Noah qtz, Rc,min and Topt parameters using a LAI of 1.2 m2m-2 (derived from

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the MODIS LAI product). We find that the value of the qtz parameter decreases, Topt remains fairly the same and Rc,min decreased by a factor more than two. Overall the simulation of soil temperature improves somewhat, but this results in a general decrease in Noah’s ability to reproduce the surface fluxes. In general, we may conclude that if we would have used a LAI of 1.2 m2m-2 the calibrated qtz and Rc,min parameters would have been lower. For the qtz parameter this leads to values closer to one, but the resulting values are still unrealistically high. Further, an even lower Rc,min value deviates more from the default values. Moreover, these parameter values do not change the model performance significantly and would not have affected conclusions from this study. To address this LAI issue, the following text is added to section 3.4:

“Somewhat peculiar is that the Leaf Area Index (LAI) is held constant at a value of 5.0 m2m-2 (see also Hogue et al. 2005) instead of using other data sources, such as the ones available from satellite platforms. In this investigation, we evaluate the Noah as it is applied at a global scale and, therefore, the default LAI value is used. The impact of this large LAI values on the results is addressed in the discussion via Noah simulations performed with a more realistic LAI, which is found to be 1.2 m2m-2 for the study site based on Moderate Resolution Imaging Spectroradiometer (MODIS) LAI product.”

and this text is added to the discussion:

Another issue in the default Noah configuration that has not been addressed in the text above is the LAI value, which is fixed at a value of 5.0 m2m-2. To evaluate the influence of this LAI value on the results presented in this study, the optimization of the qtz parameter has been performed using a LAI of 1.2 m2m-2 (obtained from the MODIS LAI product) for the Noah 4- and 5-layer configurations with 2 STL’s, whereby for the 5-layer configuration a top soil thickness of 0.5 cm was used. This optimization results in qtz values 0.66 and 1.45 for the 4- and 5-layer discretization, respectively. The optimized qtz parameters are lower and, thus, in the case of the 5-layer configuration closer to a value that is realistically possible, but is still far too high. Using the qtz value of 1.45 and 5-layer discretization with a 0.5 cm top layer, the vegetation parameters, Rc,min and Topt, have also been recalibrated with a LAI of 1.2 m2m-2, which results in values of 20.89 s m-1 and 9.73 oC, respectively. Compared to the vegetation parameter presented above, the Rc,min has decreased by more than a factor two, while the Topt has increased only slightly. This large reduction in Rc,min follows directly from Eq. 24, in which the Rc,min and LAI have an opposite effect on the calculation of the Rc. Thus, the decrease in LAI is for a large part compensated within the model calibration by decreasing the Rc,min. As to determine whether using the MODIS LAI improves Noah’s performance, RMSD values between the measured and simulated soil temperatures and heat fluxes have been computed for the three additional Noah simulations and are presented in Table 10. Comparison of the RMSD values of Table 10 with the results presented previously shows that the simulation of the temperatures across the soil profile improves somewhat. However, Noah’s overall ability to simulate the heat fluxes decreases when using the MODIS LAI. Apparently, Noah has been tuned to perform optimally using LAI of 5.0 m2m-2, which is probably the reason for using a fixed value for large-scale Noah applications.

Comment 7: “The soil parameterization is discussed before the vegetation parameterization. As the output of temperature and land fluxes are affected by both soil processes and vegetation processes, please clarify whether you have used the improved soil model structure and parameters presented in Section 5.1 when you discussed the vegetation parameterization in Section 5.2.”

Authors’ response: We thank the referee for his comment. However, in section 5.2 (p474 L24-25) we state “For this optimization procedure, the 5-layer Noah model configuration is utilized with a 0.5 cm top soil layer.” To be complete we have the quartz content used. Now the text is modified as follows:

“For this optimization procedure, the 5-layer Noah model configuration is utilized with a 0.5 cm top soil layer and a qtz value of 1.58 [-].”

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Minor comment 1 "LSM" instead of "LSm"

Authors’ response: We have replace “LSm” by “LSM”

Minor comment 2 P460: "The soils can be classified as sandy loam (70% sand and 10% silt) with a high saturated hydraulic conductivity (Ksat=1.2md-1) on top of an impermeable rock formation. Due to the high root density from the short grasses, organic matter content in the top-soils is relatively high (14.2%)"; Please clarify these data were observed or default values.

Authors’ response: Soil samples collected during a field campaign in 2006 have been analyzed in the laboratory for their soil textural properties and soil hydraulic characteristics. The results from these analyses are presented in section 2.1. The text has been modified as follows:

“Based on soil textural and hydraulic characterizations performed in the laboratory, soils can be classified as sandy loam (70% sand and 10% silt) with a high saturated hydraulic conductivity (Ksat = 1.2 m d-1) on top of an impermeable rock formation.”

Minor comment 3 It is not necessary to list all soil types and vegetation types. Table 2 and Table 3 can be merged and only show the relevant information.

Authors’ response: We would like to thank the referee for his comment. However, on this point we do not agree. We think that the Table 2 and Table 3 give the readers an idea on range of parameter values that are used for Noah simulations at a global scale. For that reason we would like maintain Tables 2 and 3.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 455, 2009.