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Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "Coupling a groundwater model with a land surface model to improve water and energy cycle simulation" *by* W. Tian et al.

**W. Tian et al.**

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We would like to thank the anonymous Referee #2 for his time and effort for this manuscript. His critical reading and valuable comments will help us to improve this manuscript. Every comment was replied as follows.

**RC2:** Major comments:
1. One deficiency of the paper is insufficient validation. I understand that the authors only select three typical sites due to limited access to data over western China (Yuan et al. 2008a) and computation resources. To complement it, I suggest the authors conduct a set of experiments with original AquiferFlow model, and compare the simulated soil moisture and ET (could be obtained by simple algorithm based on



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soil moisture and potential ET, P1169) with SiB2 and the coupled model. In fact, sometimes empirical ET formulation is not bad if there is strong coupling between shallow groundwater and surface fluxes (Yeh and Famiglietti, 2009).

**Response:** Like most of the groundwater models, AquiferFlow model uses an empirical formula to simulate evapotranspiration.

$$ET_a(\psi, t) = R_E(\psi)E_0(t)$$

Where $ET_a$ is the mass of evapotranspiration; $\psi$ is the soil moisture potential; $R_E$is relative coefficient, and it is a empirical parameters, depending on the $\psi$; $E_0$ is potential evapotranspiration, that changes with time.
From the evapotranspiration formula of AquiferFlow, it can be found that real evapotranspiration is strongly influenced by $R_E$, but it as a empirical parameters has a great uncertainty. This make the evapotranspiration error of AquiferFlow calculation is larger. Yeh and Famiglietti (2009) calculated evapotranspiration using the water balance method, there are also many factors that can not be identified, such as runoff, the best correlation coefficient of runoff calculated by the empirical formula is just reach to 0.668 according to their article. Because there are large errors when using the empirical formulation calculate the evapotranspiration, it is not credible to validate the model using an empirical ET formulation because of the large errors brought about by the empirical formulation for calculation evapotranspiration.

**RC2:** 2. The authors offer two time coupling schemes: concurrent with land surface model and daily time step. They use the second one due to computational limitation, however, they do notice that the step change of soil moisture at the beginning of a day will affect the groundwater recharge to the surface soil, and lead to the underestimation of ET if upper soil is not wet enough. To investigate the effects of diurnal cycle of groundwater recharge on ET, I suggest the authors to select a small subdomain where water table is not too shallow or too deep within the study area, and conduct a sensitiv-



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ity experiment by using two different time steps for the groundwater model. The lateral boundary conditions could be provided by the large-area groundwater simulation that has been done in this study.

**Response:** In general, the soil moisture calculated by AquiferFlow has higher accuracy than that calculated by SiB2 Because the AquiferFlow is a three-dimensional unsaturatedsaturated zone groundwater model and takes more groundwater processes into account, such as the water uptake from the saturated zone by the capillary action or the soil moisture exchange between the grid cells. The soil moisture simulated by the land surface model at the beginning of a day is corrected according to the calculation of the groundwater model, which makes the result more accurate. Compared with the first coupling method (concurrent with land surface model), the second coupling method (daily time) leads to more errors (e.g. the underestimated evapotranspiration), but the errors will not be accumulated continuously because of the correction for soil moisture at every morning The sensitivity of the time coupling scheme is affected by many factors and this is a complex issue We plan to conduct a comprehensive sensitivity analysis of the model in another article.

**RC2:** 3. The spin-up process is important for land surface modeling, especially for the deep soil hydrology. The authors only spin-up the model for four years. Is it enough to obtain the equilibrium of soil moisture and groundwater especially if the water table is deep (Fan et al., 2007; Yuan et al., 2008b)? How about repeatedly using the four year data for spin-up?

**Response:** It is very important that the measured value of 2003 rather than a guess value was used as the initial groundwater table in this work. In addition, in the study area of this paper, the annual variation of groundwater is not very intense. So the spin-up period of four year is sufficient for our study. It was proved by the comparison between the model simulation and the measurements in December 2008 Soil moisture is mainly affected by the ground water level, weather conditions, and soil structure.



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If these factors can be determined, the soil moisture will be rapidly converged to an equilibrium situation. So the four-year spin-up can keep the soil moisture of the study area in a reasonable range.
Because of data limitations, the 2008 meteorological data were also used as the forcing in the spin-up period. Because the purpose of this spin-up is to make the model state to an equilibrium situation, this treatment will not cause a problem The groundwater-related data used the measured value of year from 2003 to 2007.

**RC2:** 4. Please do not overstate your conclusions. For instance, 1) Fig. 4 could not support the authors' argument in P1182 "Furthermore, the GWSiB simulation could provide a more stable relationship between precipitation and soil moisture than the SiB2 simulation: : :"; 2) there is no "diurnal variation" (P1183) information in Fig. 5, and discussing about diurnal cycle does not make sense since GWSiB uses a daily step for groundwater in this study; 3) the attribution of underestimation of ET in YK station to the daily time step of groundwater model is questionable. The water table depth is over 70m, how can we expect groundwater could contribute to surface soil moisture and heat flux?

**Response:**
1) This content will be removed
2) This is a language error, it should be "daily variation", and we will corrected it.
3) The "groundwater" here is a general concept, which refers to all the water below the land surface including the saturated zone and unsaturated zone. The deeper soil moisture which came from the irrigation or precipitation can affect the surface soil moisture by capillary action, then contribute to the heat flux of land surface We will replaced "the deep groundwater" by "the soil moisture of deeper layer" to make the description more clearly in the revise manuscript.

**RC2:** 5. I do not think the irrigation experiment at YK station is fair to SiB2 model. Why



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do not the authors simply add the irrigation amount to the term “precipitation reaching the ground surface (Pg)” and then compare with GWSiB? Again, for all three sites, do the authors carry out similar spin-up procedure for SiB2 model before comparisons?

**Response:** That there are many ways to take the irrigation process into the land surface model. Adding the irrigation amount into soil moisture as a source term or into the term of “precipitation reaching the ground surface (Pg)” are two methods with a same essence which is expressed as the increase of soil moisture due to the irrigation process. In this paper, we mainly tried to show that the GWSiB that considers more groundwater processes can easily express the irrigation process in simulation. Compared to original SiB2, GWSiB has an improvement in the water and energy cycle simulation. The comparison of the different irrigation simulation schemes is not the aim of this article. For other sites, there are no irrigation, so they does not have this problem.

**RC2:** 6. Since the authors are doing three-dimensional groundwater modeling, a plot showing spatial distributions of baseflow and groundwater recharge rate (flux between the third and fourth soil layer) would be helpful to identify the contributions of lateral and vertical groundwater fluxes. These could be incorporated into Fig. 10.

**Response:** It is a good suggestion We will add these contents in the revise manuscript

**RC2:** Specific comments:
7. The introduction includes a nearly full literature review for the coupling of groundwater model with land surface models, which indicates that the authors are very familiar with this field. However, it misses some work in China. For instance, Tian et al. (2006) implemented a subsurface runoff scheme with variable water table into CLM2; Yuan et al. (2008b) coupled a groundwater model with BATS and regional climate model RegCM3, and investigated the local and remote effects of water table dynamics on



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regional climate.

**Response:** The literatures of groundwater model coupling with the land surface model in china will be added as references in the revised manuscript.

**RC2:** 8. Please move the information of the thickness of three soil layers in SiB2 from section 3.2 to model description section 2.2.

**Response:** It will be revised.

**RC2:** 9. To be consistent with SiB2 model, the authors specify the depths of the first three layers in the coupled model as 0.02, 0.48 and 1.5m (Section 2.3). However, the numerical 3-dimensinal groundwater model usually has fine vertical resolution. Is there any numerical instability in the application? The authors also mentioned in section 3.2 that the thicknesses of the lower three layers of the coupled model are determined by the aquifer information. This is reasonable and sometimes critical to land surface hydrology modeling. Yuan and Liang (2011) show the importance of bedrock data to soil moisture and water table modeling. So my question is: what if the bedrock depth is shallower than 2m? Are the specifications of three soil layer depths still valid? Perhaps it is not a problem in current study, but it will affect the application of the coupled model at large scales.

**Response:** Yes, the thickness of soil layer is a key factor for the stability of the groundwater three-dimensional model. By adjusting the iteration number, the relaxation factor, and the convergence standards of the model, we make the model converge. For bedrock depth shallower than 2 m, because the study area is located in the middle reaches of Heihe River basin and belongs to the alluvial and diluvial fan where always has the thicker soil there are no such cases in our study area. When the model is applied to a larger area, The regional average soil thickness will bring the simulation error. To reduce this error, it need specially treated the thickness of soil layer on some



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situation, such as phreatophytes and bedrock. we plan to finish the work by modifying the code of the coupled model in the next step.

**RC2:** P1174, “Runoff is not the key hydrological process in this region; thus, the coupled model can be used here.” Usually runoff consists of surface and subsurface runoff (baseflow); I guess the “runoff” in the paper only means surface runoff since the coupled model considers lateral groundwater flow which is part of subsurface runoff. So please revise it to “surface runoff” throughout the paper.

**Response:** Yes, the “runoff” here means surface runoff, we will replace the “runoff” by the “surface runoff”

**RC2:** 11. Fig. 1, please make the text in the flowchart more clearly.

**Response:** The text will be set to bold, and the clear flowchart will be sent to the editor in together with the revise manuscript.

**RC2:** 12. Fig. 2, when validating the simulation of water table, it is better to use water table depth since the absolute value of water level is too large and it is difficult to see the difference between observation and simulation.

**Response:** There is other information that was described in the manuscript in the groundwater table map (FiG.2). We will add the observed groundwater depth to FiG.3 to validated the groundwater table.

**RC2:** 13. P1180, L3, it is better to use “spin-up” instead of “calibration” P1183, L5, add “the” before “same period : : :” P1186, L16, “supply” should be “supplied”

**Response:** These will be modified.



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## References

Yeh, P. J. F., and Famiglietti, J. S.: Regional Groundwater Evapotranspiration in Illinois, Journal of Hydrometeorology, 10, 464-478, 2009.



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