RC3:

This manuscript gives a good description of the parameterization scheme of Inter-Grid Cell Lateral Unsaturated and Saturated Flow Model, and evaluates the simulation performance of this scheme. But I think there are still some things that need to be improved to make it better. My detailed comments are as follows:

About the parametric scheme

1. Line 94. For soil water movement, k is an important parameter. Is the description of equation 3a accurate? I noticed that ELM originated from CESM1.3, and the calculation of k in CESM1.3 is divided into two parts according to soil layer (for details, please refer to Oleson et al., 2013, equation 7.89). Why did this paper modify this? Will such modification have a significant impact on the results?

   Response: We did not modify the calculation of vertical hydraulic conductivity. Equation 3a (Equation 10a in revised manuscript) is a general form of the Clapp-Hornberger equation used by CESM1.3. We just didn't specify the usage of this equation for specific layers.

   Line 100. The modification of equation 4 can be confusing. I recommend the author can cite "Yan Yu, Zhenghui Xie, XubinZeng, Impacts of modified Richards equation on climate simulation in the regional climate model RegCM4, Geophys. Res. Atmos., 119, 12,642–12,659, doi:10.1002/2014JD021872, 2014.". It would be more appropriate to explain the reasons for the changes.

   Response: Thank you for sharing this reference, which is very helpful. We have included this reference in the revised manuscript. Please see line 160

2. Line 130. Equation 14, does the direct modification of the tridiagonal equation mean that soil water lateral flow is carried out firstly and then vertical flow is carried out in 3D soil water flow? In fact, however, they happen at the same time. Will this have a significant impact on the results?

Response: The lateral and vertical flows in the unsaturated zone are carried out simultaneously within a single tridiagonal equation. However, it should be noted that the vertical fluxes use an implicit time integration method, while the lateral fluxes are solved using an explicit time integration method. The coupling between the unsaturated and unsaturated is calculated sequentially. This could be one of the factors that contribute to the errors benchmarked against the PFLOTRAN. Nevertheless,results show that the errors are small as shown in Fig. 5 and Fig. A5 Fig with different anisotropic ratios.

3. Line 137. I am confused about the expression of equation 15. Generally speaking, the soil water lateral flow is driven by soil matrix potential, but the gravitational potential (z) is obviously included in equation 15. Clarify please.

Response: The detailed derivation of equation 15 is described in Childs (1971) and was used by PARFLOW, please see equation (7) of Maxwell (2013). The gravitational potential (z) is for referring the elevation gradient.

4. Line 137. I think the parametric scheme of soil water lateral flow is the focus of this paper, but this part is too simple in this paper. It is important to give a detailed process of the derivation of equations rather than simply referenced. Moreover, it seems that the final parametric equation is not given in equation 14. I suggest: 1) First introduce the soil flow scheme in ELM; 2) Then introduce the soil water lateral flow scheme and your improvement; 3) Finally, the tridiagonal equation including soil water lateral flow is given. Or switch step 1 and step 2.

Response: As suggested by the reviewer, we have reformatted the equation section to describe the general 3-D soil water movement equations first, then introduced the simplified 1-D equation used by ELM/CLM, followed by the new lateral flux term in equation 14. We added more descriptions about the equation derivations.

5. Line 149. The description of equation 17 is simplistic. In fact, in my opinion, equation 17 is just as important as equation 15, so the derivation of 17 should be detailed rather than simply quoted, because I have noticed there are differences between equation 17 and the equation in Fan (2007).

Response: equation 17 is the Darcy's equation based on the extended form of the Dupuit-Forchheimer assumption. This is also cited and used by Parflow, so we decided not to put the detailed derivation in the manuscript since the derivation is long. Instead, we cite the original reference, please see equation (8) of Childs (1971) and equation (17) of Henderson and Woodinq (1964). Moreover, we added the details of transmissivity calculation in Appendix A.

About model benchmarking

In the benchmarking model, I am more interested in the comparison among ELM, ELMlat and PFLOTRAN. This comparison may be important to reveal the importance of soil water lateral flow. and can more directly show the improvement of this paper.

Response: in the benchmarking model, the water table depths in ELM have no spatial changes since homogeneous surface data and forcing is used and there are no connections among the grid cells. Therefore, we only performed comparison between ELMlat and PFLOTRAN

1. Is the lateral flow of unsaturated and saturated soil water equally important? Or is one of them dominant? How much do they contribute to soil water movement?

Response: The saturated lateral flow plays a more dominant role in the benchmarking model simulations. We present the results of the magnitude of the two fluxes in Figure 8 for the benchmarking problems and also for the LWW case in Figure 14. Additionally, we evaluated the change of energy flux results after turning off the unsaturated lateral flux through a rainfall event, please see Figure A8.

About LWW

1. Line 297. Why did this paper focus on the summer soil temperature?

Response: The reason for focusing on summer soil temperature is because it is more influenced by the lateral flow. We clarified this in the revised manuscript and also showed annual soil temperature results in the new Figure 12 and zoomed in the summer temperature for better viewing the difference.

2. For LWW case, authors only verified soil moisture for shallow soils (25cm), but I think the results below 1m are just as important. I think more soil moisture data (such as ERA5-land or satellite inversion data) can be used to verify the simulated soil moisture, soil temperature and other results, rather than just using two stations data. This is important to illustrate the importance of soil water lateral flow.

Response: Thank you for this suggestion. The ERA5-Land dataset, as any other reanalysis dataset, provides estimates which have some degrees of uncertainty. The land-surface model , HTESSEL (Tiled ECMWF Scheme for Surface Exchanges over Land, Balsamo et al., 2009), used by ERA-5 dataset has no groundwater lateral flow component. The comparison may be biased due to this mismatch. In addition, the resolution of ERA-5 is 9km, the whole domain will only occupy 3x5 grid cells, the impacts of lateral groundwater flow may be small at this scale.Therefore, we did not compare the model results with reanalysis data like ERA5 considering the above reasons. We will consider including intercomparison with other land surface models with lateral groundwater flow included in a much larger domain in the future work.

3. Figure 8. In addition to the differences between Figure b and Figure c, the resolution of Figure b seems to be lower. Is this related to the modification of the depth of the soil layer? If yes, can more reasonable soil depth distribution be considered in future work?

Response: Thank you for this suggestion. The resolutions of Figure b and Figure c are the same. The modification of the soil layer depth could be one of the reasons resulting in the lower resolution of Figure 8 (b). Heterogeneous and reasonable distributions of soil and aquifer depth will be considered in the future work which are stated in the 'Caveats and future work' section. Other reasons for the low resolution of Figure 8 (b) may include the homogeneous fd value used which is closely related to the subsurface runoff and coarser resolution (1/8 degree) of the NLDAS forcing data than the horizontal model resolution (1 km) resolution. In the revised manuscript, we calibrated the fd values which significantly improved the spatial groundwater table depth simulations against Fan's results, as shown in Figure 9.

Minor comments

1. Is line 138 and line142 duplicated?

Response: they are different. Line 138 is explaining the angle of slope at the horizontal direction at the land surface cell center, while Line 142 is explaining the angle between the surface of two neighboring cell centers and the horizontal direction. They can be different if the terrain has non-uniform slopes for different cells. We modified the text to make them clearer. Please see line 138 and line 143

2. Line 146. The unit of is m3/s, but the unit of q in line 124 is mm/s. There is an obvious difference between the two. Whether this is a clerical error, if not, please explain.

Response: The saturated flow is volumetric flux with unit m^3/s, while the unsaturated flow is rate flux with unit mm/s. We underscored this in the revised manuscript and use Q instead of q for the saturated flux.

3. It will be better to label (a) (b) (c) in Figure 12.

Response: As suggested, we have added the labels in the revised manuscript.