RC2:

The authors have the original idea of considering horizontal groundwater flow in the source/sink terms of the equation. While these are interesting results, I believe the paper could be improved by considering the following points.

About the equation

To clarify the difference between ELMlat and PFLOTRAN, it should be noted that the unsaturated horizontal flow is the results of one previous step.
Response: the lateral flux is based on pressure/theta values from the previous time step, we are using an explicit time integration for the lateral flux.

Equation 16 makes sense if flux includes the surface area of the terrain, but I can't determine that with the current description.
Response: In Section 2.1.1. of the revised manuscript, we have added more descriptions to illustrate this point and modify the equations accordingly. The volumetric flux is the dot product of the flux and the area, which either the flux can be adjusted by the cosine of the angle or the area that is normal to the direction of the flux should be used. We modified the area by using the projected area. Please see Equation (16) in the revised manuscript.

Equation 17 is correct in the equation itself, but does it not have to account for slope gradient as in equation 15? Need a description of why unsaturated horizontal flow is considered but saturation is not.

Response: The first reviewer also raised the same question, and we corrected the equation in the revised manuscript, as well as updated the code. The slope gradient is also considered in the saturated lateral flow calculation, please see Equation (17) in the revised manuscript. All simulations were rerun using the updated code. We found implementing the corrected Equation 17 improved the model performance of ELM_{lat} against PFLOTRAN for the three idealized benchmark problems, as shown in Figure 5.

Regarding the model benchmark

The authors mentioned that the moisture retention curves used in ELM and PFLOTRAN are different, but why not show how much they differ? Showing the results of the fitting would be helpful for the discussion.

Response: ELM uses the Clapp-Hornberger formula to parameterize the soil water retention curves while PFLOTRAN uses the Brooks-Corey formula. We have added the descriptions of the two formulas and how the parameters are transferred from one to the other in Appendix B. By assuming the residual soil water equals zero, the two formulas are actually very similar. In the revised manuscript, We don’t attribute the difference between ELM_{lat} and PFLOTRAN to the differences of retention curves.

Regarding the results

What is the reason for using top 5 layers in the comparison with PFLOTRAN as far as Figure 5 is concerned, I think it would be a fair assessment to include up to about top 10 layers. Also, what is the reason for using MAE? It tend to be small because the denominator is larger than the numerator. Why not present other indicators as well?

Response: The reason for choosing the top 5 layers for the comparison is because for some soils columns the layers 6-10 are saturated for both ELM_{lat} and PFLOTRAN during the simulation period. We now compare the top 10 years instead in the revised manuscript. Please see the updated Figure 5. Meanwhile, we have added the Root Mean Square Error as an evaluation metric in Figure A2.

I understand that Figures 6 and 7 are ELMlat-PFLOTRAN. If so, some discussion of the CH and DH soil moisture and groundwater table results is needed; ELMlat has less soil moisture on the down hill and more on the up hill than PFLOTRAN, even though the groundwater table is too flat compared to PFLOTRAN. Is this solely due to the water retention curve? Need to describe the difference in equations and the effect of the solution method.

Response: We added more details about the water retention curve formulas used in the two models. ELM_{lat} has less soil moisture on the downhill and more on the uphill than PFLOTRAN, and the groundwater table is actually steeper compared to PFLOTRAN which can be seen from Figure 7 (d-f). The Water Table Depth (WTD) is the distance between the groundwater table elevation and land surface elevation. ELM_{lat} has less soil moisture on the downhill and higher WTD values (lower groundwater table), but more soil moisture on the uphill and lower WTD values (higher groundwater table), which are consistent with previous discussions. Moreover, we also tested the sensitivities of the model results in response to different anisotropic ratios, as shown in Figure A5.

Regarding Figure 9, from Figure 8, the groundwater table is deeper near the watershed boundary, but even in such locations, does the soil temperature decrease, LH increase, and SH decrease? Are these results consistent? Results and discussion on whether horizontal unsaturated flow has an effect and how the seasonal planar distribution varies are needed.

Response: We made a mistake while adjusting the color map in Figure 9. In the revised manuscript, we replotted the figure with updated results using calibrated f_d values. At locations near the watershed boundary, the groundwater table is deep such that the effect of groundwater level change, which generally becomes deeper due to lateral flow, on land surface temperature and heat fluxes are relatively small, such that the energy fluxes change are approaching zeros at some of those grids.

The magnitude of unsaturated flow against saturated flow is small. Please see Figure 8 and Figure 14 .

The seasonal effect of lateral groundwater flow on the soil temperature and heat flux is dependent not only on the water movement and groundwater table change but also on the lateral heat flux and the groundwater temperature, for example,. However, ELM assumes no heat flux boundary at the soil bottom, and we do not have a lateral groundwater thermal transport model at this stage, seasonal analysis of the heat flux change may be biased. Since the main purpose of this study is developing the inter- grid cell lateral flow within ELM, we decided to focus more on the model development and validation. How the seasonal planar distribution varies will be discussed in the future study.

Minor comments

Line 127 may be clearer in Figure 1 than in Figure 2

Response: Thank you for this suggestion. We used the updated Figure 1 to illustrate Line 127 (now Line 128) instead.

I think (d) in Figure 10 is a mistake for A149.
Response: We have corrected this in the revised manuscript.

The equation numbers are not bracketed: lines 106, 116, 126, 128, 143.

Response: We have corrected this in the revised manuscript.

FigureA1 should be the result of all layers, not top 5 layers.

Response: We have modified Figure A1 with results of all the top 10 layers.

FigureA2 does not have results for (d), (e), (f).

Response: We have corrected the caption.

Figure A3 has all figures marked as (a).

Response: We corrected this, shown as Figure A4 in the revised manuscript.

Line 540 is Soil MoistureâBased (I noticed this by accident)

Response: Thank you for pointing this out. We corrected this.

References:

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