Referee Report

Development and evaluation of a variably saturated flow model in the global E3SM Land Model (ELM) Version 1.0

In this paper, the authors intended to unify the treatment of subsurface water movement using variably saturated Richards' equation and to demonstrate its performance in predicting groundwater level and other hydrologic components. However, the results do not fully support the motivation shown, and the needed validations are not provided. In order to substantiate the authors' claim, I think some issues below should be addressed.

1. The authors tried to demonstrate the robustness of ELMv1-VSFM by conducting several experimental simulations. However, there may be inaccuracies in numerical solutions due to differences in the size of spatial and temporal mesh (El-Kadi & Ling, 1993). The authors used outputs from simulations with different configurations (e.g. spatial resolution of grid-cell, soil column depth, spatial discretization) to support the robustness of global analysis. Moreover, temporal resolutions used in the experimental simulations are not indicated in the paper. Since information required for ensuring numerical stability of the model is not indicated, I am not sure whether or not ELMv1-VSFM converges well at a spatial-temporal resolution of 1.90 (latitude) × 2.50 (longitude) with a 30 [min] time-step.

2. The authors mentioned that there are advantages to using variably-saturated flow model (variably saturated Richards' equation) rather than applying different governing equations for each flow domain noted in the previous work. However, they did not specify what the relative strengths of using variably saturated Richards' equation are compared to adapting different equations (e.g., computational cost). The reason why they intended to unify the treatment of soil hydrologic processes should be stated.

3.The authors used ILAMB package to show additional consideration of saturated zone does not degrade the model's predictive capabilities in other hydrologic processes. However, without any explanation of the interaction between groundwater and other components (e.g., streamflow, LH/SH), it is difficult to accept the author's claim saying further consideration about groundwater-surface water interaction does not degrade other predictions.

4. The authors mentioned this work has a focus on representing groundwater-surface water interactions but all the outputs appear to be related addressing subsurface hydrology using VSFM. The authors may want to specify what they did to emphasize their focus on groundwater-surface water interactions by adding more results regarding that (e.g., interactive effect between runoff and groundwater level)

I would like to note some recommendations for this paper: 1) how the authors determine the robustness of the model based on the results of the experimental simulations should be specified. 2) the authors may need to perform experimental simulations with the same configuration used for global analysis in order to show the numerical stability of the model. 3) the authors may want to demonstrate the numerical stability of the model by providing some indexes (e.g., Peclet number). 4) the authors can demonstrate the benefits of applying variably-saturated flow model compared to outputs derived from different physics application, especially in terms of computational cost. 5)

the authors may want to add some description about the modeling scheme used for representing the interactions between stream and groundwater and between evapotranspiration and groundwater.
6) To emphasize their motivation for groundwater-surface water interaction, the authors may want to indicate how runoff simulation is correlated groundwater level.

Bibliography

El-Kadi, A. I., & Ling, G. (1993). The Courant and Peclet Number criteria for the numerical solution of the Richards Equation. *Water Resources Research*.