Response to Review #2

Comment: The work by Xu et al. implemented a more trait-based model into FATES, and explored how the variation in traits may impact model simulations hence to test the models' sensitivity to those hydraulic traits. The manuscript is well written and well delivered. However, there are some major concerns over the manuscript given its positioning.

Response: Thank you for the time to review and we will revise the manuscript to address the concerns raised below.

Comment 1. It is not clear whether the manuscript is a model paper or validation paper. If the former, there were basically no details about the formulations; if the latter, the manuscript still lacks a fair amount of details for readers to understand how the traits are related to the modeling of vegetation processes. It seems that Lambert et al. (2022) GMD doi:10.5194/gmd-15-8809-2022 has more details on FATES-Hydro, but is not referenced in this study. I can see that the two studies have different aims, but this study should contain adequate details as Lambert et al. (2022).

Response: This manuscript mostly focused on the sensitivity analysis and the hydro code is based on Christoffersen et al.(2016). We did provide detailed implementation of the codes in FATES in the supplementary file [MODEL DESCRIPTION: updates made to TFS-HYDRO for FATES-HYDRO]. Per the suggestion from Review #1, in the revised manuscript, we will add key equations related to each parameter in the section of 2.1 and the supplementary file. We will add Lambert et al. (2022) GMD doi:10.5194/gmd-15-8809-2022 to our reference and the revised manuscript will provide as much detail as Lambert et al. (2022).

Comment 2. Following comment 1, these should be explicitly described in the manuscript:

How canopy RT is done
How canopy energy balance is done
How the key parameters like taper component, Kmax, P50, Gs50, and etc are related to stomatal control
How soil water balance is done, it is impacted by root distribution?
What is the hydraulic architecture, number of roots, branches, and leaves, is there a trunk?
How is sap area computed

Without these details, it is impossible to tell what is going on.

Response: Please see our response below specifically on different components. In the revised manuscript, we will provide a summary of each component and provide reference for the details to the reader of interest. Please see the details below:

- How canopy RT is done?

Canopy radiative transfer is calculated using a multi-layer scheme based on the iterative Norman radiation scheme. Leaf and stem area is binned into a matrix of canopy layer, leaf layer and plant functional types. Reflectance, abrogation and transmittance are calculated for each leaf layer. Between canopy layers, light streams are averaged between PFTs, such that all PFTs in the canopy layer below receive equal radiation on their top leaf layer. Fractional absorption of visible and near infra-red light is calculated separately for direct and diffuse light. For the direct stream, transmitted and reflected light is converted into diffuse fluxes. In FATES, the absorbed PAR is used to calculate photosynthesis rates for each of the canopy layer x leaf layer x PFT bins, after which rates across layers are re-aggregated into cohort level carbon fluxes. Please see the Supplementary file in Fisher et al. 2015 for details.

Fisher, R.A., Muszala, S., Verteinstein, M., Lawrence, P., Xu, C., McDowell, N.G., Knox, R.G., Koven, C., Holm, J., Rogers, B.M. and Spessa, A., 2015. Taking off the training wheels: the properties of a dynamic vegetation model without climate envelopes, CLM4. 5 (ED). *Geoscientific Model Development*, *8*(11), pp.3593-3619.

- How canopy energy balance is done

The energy balance is handled by the host land model. In this study, it is based on the land component of DOE's Exascale Energy Earth System Model (E3SM). The E3SM land model (ELM) is based on the Community Land Model 4.5 (Oleson et al 2013). Specifically, in ELM, the average canopy temperature is calculated based on the energy balance of latent heat, sensible heat, and absorbed radiation as determined by the radiative transfer model (above). The latent heat is determined by the transpiration, which is determined by the vapor pressure deficit from inside of leaf to the air, canopy stomatal conductance, and boundary layer constance. FATES calculated mean canopy stomatal conductance averaged across different cohorts, which is fed to ELM to calculate the energy balance. The Newton-Raphson numerical scheme is used to solve for the canopy temperature.

Oleson, K. W., Lawrence, D. M., Bonan, G. B., Drewniak, B., Huang, M., Koven, C. D., Levis, S., Li, F., Riley, W. J., Subin, Z. M., Swenson, S. C., Thornton, P. E., Bozbiyik, A., Fisher, R., Heald, C. L., Kluzek, E., Lamarque, J.-F., Lawrence, P. J., Leung, L. R., Lipscomb, W., Muszala, S., Ricciuto, D. M., Sacks, W., Sun, Y., Tang, J., & Yang, Z.-L. (2013). Technical description of version 4.5 of the Community Land Model (CLM) (*Tech. Rep. NCAR/TN-503+STR*). Boulder, Colorado, USA: National Center for Atmospheric Research.

- How the key parameters like taper component, Kmax, P50, Gs50, and etc are related to stomatal control

The means by which plant hydraulic traits and leaf water potential interact to influence stomatal control remains unchanged from Christoffersen et al. (2016), by replacing the default stomatal closure parameter with a prediction based on leaf water potential. At each 30-minute timestep, the model solves for updated water potentials throughout the tree (leaf, stem, transporting and absorbing roots) based on the current timestep individual tree transpiration rate. The new leaf water potential is then used in the next time step to update a dimensionless stomatal closure parameter (beta; 0=fully closed;1=fully open), which impacts host land model (HLM) canopy energy balance in the standard way, and thus the simulated transpiration by the combined FATES canopy energy balance solution (see above).

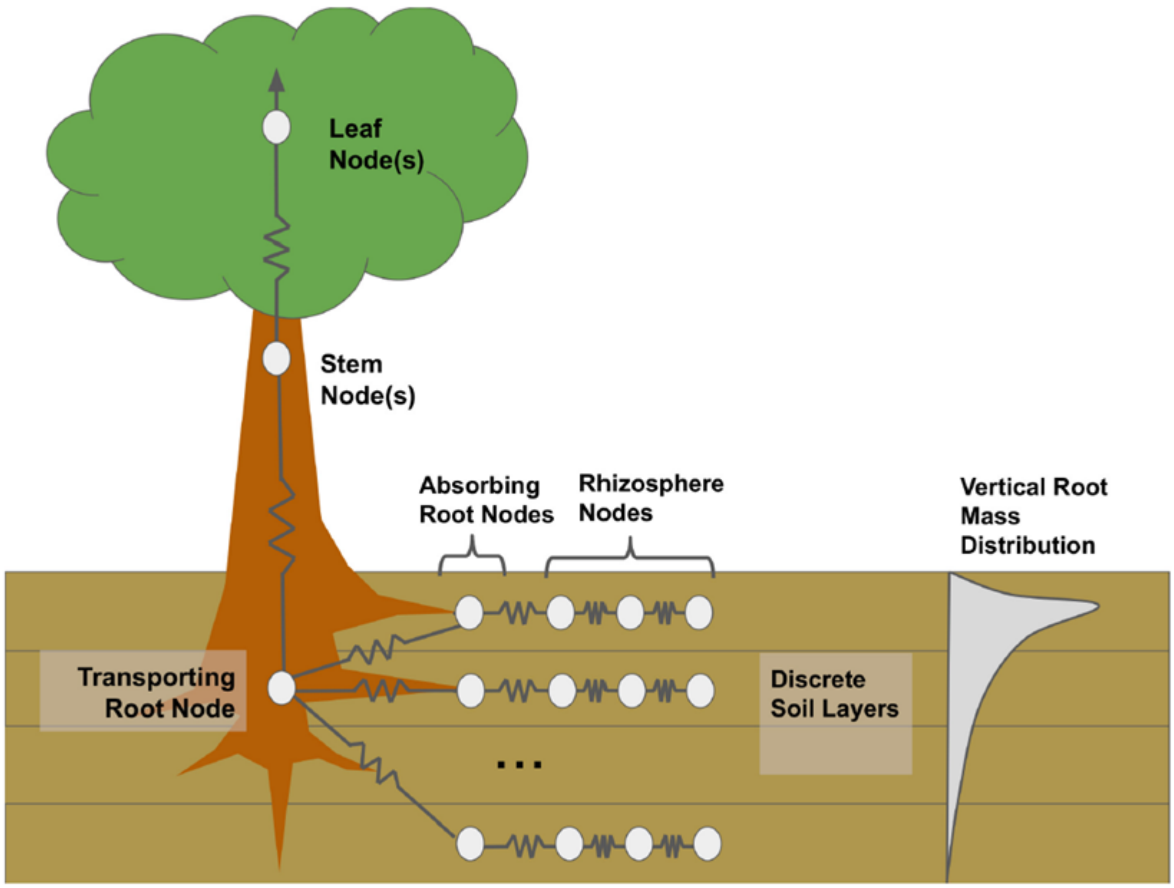
- How soil water balance is done, it is impacted by root distribution?

  All aspects of soil water balance (infiltration, water transfer among soil layers, and drainage) happen at the 'column' scale at 30-min timesteps and are handled within the Host Land Model (see Oleson et al. 2013 for a detailed description of hydrology in CLM4.5, the parent model of ELM, which is used in this manuscript). FATES-HYDRO handles soil water operations at the patch and cohort scales. It simulates root water uptake and changes in plant water potential from roots to leaves based on current timestep transpiration. The belowground conductance for each soil layer is weighted by root biomass with an exponential vertical distribution. Sections 2 and 3 in the Supplement of this manuscript provide full details on boundary conditions, sequence of operations among HYDRO and the HLM, downscaling of soil moisture to rhizosphere shells, and downscaling of transpiration from the patch to individual scale.

  Oleson, K. W., Lawrence, D. M., Bonan, G. B., Drewniak, B., Huang, M., Koven, C. D., Levis, S., Li, F., Riley, W. J., Subin, Z. M., Swenson, S. C., Thornton, P. E., Bozbiyik, A., Fisher, R., Heald, C. L., Kluzek, E., Lamarque, J.-F., Lawrence, P. J., Leung, L. R., Lipscomb, W., Muszala, S., Ricciuto, D. M., Sacks, W., Sun, Y., Tang, J., & Yang, Z.-L. (2013). Technical description of version 4.5 of the Community Land Model (CLM) (*Tech. Rep. NCAR/TN-503+STR*). Boulder, Colorado, USA: National Center for Atmospheric Research.

- What is the hydraulic architecture, number of roots, branches, and leaves, is there a trunk?

  The model is based on a beam approximation for each tree according to the Shinozaki pipe model (Shinozaki et al. 1964), in which the hydraulic path length from the trunk base to each leaf is assumed constant. A tree is approximated with single pools of water separately for each of leaves, stem (includes trunk and branches), transporting and absorbing roots with connecting resistors . This is shown in Figure S1 below. To better help the reader to better understand the structure, we will move this S1 figure to the main text.



Shinozaki, K., Yoda, K., Hozumi, K. and Kira, T., 1964. A quantitative analysis of plant form-the pipe model theory: I. Basic analyses. *Japanese Journal of Ecology*, *14*(3), pp.97-105.

- How is sap area computed

  The sapwood area is calculated based on the product of the leaf area and the ratio of leaf area to sapwood area, which is an input parameter in Table 1.

Minor comments:

Comment: Line 2: (FATES-HYDRO V1.0) or using FATE-HYDRO v1.0?

Response: it should be FATES-HYDRO V1.0

Comment: Line 39: P50 for xylem or stomata? Need to be consistent, say P50x, P50gs

Response: We will make them consistent in the revised manuscript.

Comment: Line 41: top 5 traits? I can only found 4 from the text…

Response: Thanks for pointing this out. The sentence will be updated in the revised manuscript as follows:

“The taper component determining hydraulic conductivity tapering from trunk to branch, the water potential leading to 50% loss of stomatal conductance, the maximum hydraulic conductivity for the stem, the fraction of total hydraulic resistance in the above ground section, and the water potential leading to 50% loss of xylem conductance are the top 5 traits determining the simulated leaf water potential.”

Comment: Line 86: such water limitation functions (based on soil moisture? to be more explicit)

Comment: Lines 138-139: a function of the tissue water content? Why water content? Shouldn't it be xylem pressure?

Comment: Line 203: Sensitivyt or Sensitivity?

Response: It should be Sensitivity.

Comment: Line 245: branches are most vulnerable... How about leaves? Does this branch mean stem and leaf?

Response: Here, ‘branch’ includes to the tip of the leaf petiole; the model does not explicitly consider xylary or extraxylary resistance within and outside the leaf midrib. Thus, the vulnerability of leaf conductance is not explicitly simulated in the model. We will point this out in the revised manuscript.

Comment: Line 280: How is p50_gs used? Does it mean gs is always a function of Pleaf? Regardless of variations in PAR, CO2, VPD, and Psoil?

Response: The stomatal conductance (gs) is estimated based on the Ball-Berry model, with a slope (g1) and intercept (g0) to link g_s to humidity (RH), CO2 and photosynthetic rate (A) . A is determined by PAR and CO2 based on the Farquhar photosynthesis model. Namely,

$$gs=g0+g1\ A\ RH/[CO2].$$

p50_gs is used to calculate a water limitation factor (Btran) based on leaf water potential, which is resulted from water loss from leaf and root water uptake as determined by soil water potential and plant as follows,

$$Btran = 1/\ (\ 1+ (Pleaf/p50\_gs)^a).$$

Btran is then applied to both gs and g0 to estimate its impact on gs. We will add this detail with equations to the revised manuscript to clarify this confusion.

Comment: Line 311: epsil_node, you need to be consistent with ths symbols (you provided two for the same parameter in Table 1)

Response: We will update the symbol so that they are consistent.

Comment: Fig. 1 is too crowded, consider use fewer curves

Response: Agreed and in the revised manuscript, we will only plot every 10th percentile.

Comment: Fig. 2 Xylem cavitation can fully recover?

Response: In this version of code, we assume that xylem cavitation can fully recover.