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Interactive comment on "A multi-layer land surface energy budget model for implicit coupling with global atmospheric simulations" *by* J. Ryder et al.

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The authors motivate this manuscript with a very important point: that land surface models give highly divergent responses to land-cover change; that this relates to outdated and poorly documented parameterizations of canopy processes; and that multi-layer canopy models that explicitly resolve non-linearities within the plant canopy are a necessary step forward to improve the models and better represent the consequences of land-cover change. I strongly agree with this view. However the paper, as currently written, does not represent that step forward.

1. The advantage of multi-layer canopy models over big-leaf models is that they resolve gradients of radiation, leaf temperature, stomatal conductance, and energy fluxes within the canopy. These models emphasize radiative transfer, distinguishing visible and near-infrared wavebands, scattering within the canopy, the different absorption of

direct beam and diffuse radiation, and the differences between sunlit and shaded leafs. There is no discussion of these key features of multi-layer canopy models, so when I see model biases I am left to wonder how much is due to the radiative transfer. Similarly, the authors use a very outdated stomatal conductance model. Would a better stomatal conductance model have improved the simulations?

2. Instead of discussing the critical features of a multi-layer canopy model and how that class of models is an improvement over big-leaf models, this manuscript instead emphasizes the numerical implementation of an implicit temperature calculation. There is no emphasis on physiological and micrometeorological processes in the canopy. Much of the text and equations derive and justify the implicit temperature calculation. Again, when I see biases in the simulations I cannot judge whether these are due to process details or to the numerical scheme.

3. The longwave radiative transfer seems to be separate from the implicit temperature calculation. This is very poorly explained and the few details provided are buried in the supplementary materials. Again, this is one of the key features of a multi-layer canopy: how do you couple longwave radiative transfer (which depends on leaf temperature) to the leaf temperature calculation.

4. Some additional key details are missing: a description of soil fluxes (net radiation, latent heat, sensible heat, heat storage); there is no mention of canopy interception and evaporation.

5. The presentation of the model is confusing. The fundamental equations being solved are (13), (24), and (28). These are given very deep into the manuscript. Instead, the initial description of the model emphasizes calculation of specific humidity (Eq. 2-10) and its linearization with respect to temperature. This is not the key feature of the model. It would be better to first present the leaf temperature, canopy air temperature, and canopy specific humidity equations. Then describe these, their derivation, and their numerical implementation in more detail.

6. The description of the model, equations, and variables is sloppy. Here are some examples, and there are many more: (i) Eq. (11) has the variable Dz but the following text refers to Ds; df(z) is unexplained. (ii) Eq. (20) introduces R(τ) to calculate the eddy diffusivity in the canopy. I immediately wonder how the parameter τ is defined. Only much later in the manuscript do I find that Eq. (20) is not used at all; instead R(τ) is set to a constant. (iii) Table 1 is not a complete list of model variables. (iv) Some variables have the same notation; e.g., TL represents both leaf temperature and the Lagrangian timescale. (v) R'i is called stomatal resistance in section 3.2, whereas Ri is the leaf boundary layer resistance. However, the use of R'i in Eq. (13) to calculate latent heat flux implies that this also includes the leaf boundary layer resistance for water vapor. Or is the leaf boundary layer resistance not included in the latent heat flux equation? Table 1 does not help explain, because both Ri and R'i are called "stomatal resistance for sensible and latent heat flux, respectively". What is "stomatal resistance for sensible heat"?

7. How would a more advanced stomatal model that couple photosynthesis (Farquhar model) and stomatal conductance (Ball-Berry) work in the implicit temperature calculation? That model requires leaf temperature to calculate photosynthetic parameters (e.g., Vcmax) and vapor pressure deficit. This can be easily done in an iterative leaf temperature calculation. How would it be done in an implicit temperature calculation?

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