Review #3

The manuscript presents a valuable contribution toward improving the representation of canopy temperature in large-scale crop models while maintaining computational efficiency. The study is well structured and the proposed framework is clearly evaluated. However, there are several concerns need to be addressed before publishing:

Thank you very much for the positive assessment of our paper and the valuable suggestions. In the following we give a point by point response including suggested changes for improvement of the manuscript.

1. The manuscript demonstrates that the proposed emulator can reproduce canopy temperature reasonably well. However, it remains unclear whether the improved representation of canopy temperature translates into meaningful improvements in crop simulations. Since canopy temperature is introduced primarily to better represent crop physiological responses to heat stress. Stronger evidence may be needed about the improvement of crop simulations under current canopy temperatures setup.

Thank you for this valuable feedback. We agree that analyzing the effects of the new implementation, namely feeding heat sensitive processes with canopy temperature instead of 2 m air temperature, would be highly informative. That is why we are working on a separate study examining specifically these points. Incorporating the analysis regarding the effects of canopy temperatures on crop simulations into this work would stretch it too far, especially as it requires further model development. This paper is on how canopy temperature can be simulated in a global-scale crop model without introducing a significant computation time penalty (see also response to reviewer 1, point 2.)

2. The proposed framework introduces several additional components, including the emulator, boundary-condition estimation, water-stress scaling, and interpolation procedures. While the overall methodology is clearly described, it remains unclear whether the added complexity is justified by substantial improvements in model performance or crop-relevant outcomes. The manuscript would benefit from a more explicit assessment of the trade-off between model complexity and predictive gain. For example, comparisons against simpler empirical approaches or reduced-form implementations could help demonstrate the practical value of the proposed framework. Without such analysis, it is difficult to evaluate whether the additional methodological burden in your LPJML is warranted.

Thank you very much for your comment. Webber et al. (2017) have shown that empirical or simple energy balance approaches perform worse compared to complex energy balance approaches. Furthermore, the transferability of empirical approaches from specific regions to the global scale is limited. For these reasons, we decided to focus on the methodology development based on the complex energy balance approach. We will elaborate on the trade-offs between model complexity and predictive gain of the respective approaches based on the Webber et al. (2017) study in more detail in our revised manuscript. Certainly, we will assess the value of canopy temperatures in the implementation of heat damage in LPJmL. However, this will be part of a separate study (see response above).

3. The proposed workflow consists of multiple sequential steps, each of which may introduce uncertainty. However, the manuscript currently provides limited insight into how errors

accumulate throughout the workflow or which components contribute most strongly to the final prediction uncertainty. A quantitative error attribution or sensitivity analysis would substantially improve the methodological evaluation. Such an analysis could help identify the dominant sources of uncertainty and provide guidance for future model development efforts.

Thank you very much for the valuable comment. The first component, the EBSC model, is an independent model that computes the energy balance at the crop surface based on the inputs it receives. In this study, it is not embedded in a crop model, which is why it lacks any information on canopy conductance or transpiration rates. The same holds true for the emulators. Hence, neither of these two components can compute a water stress factor, which is needed to compute final canopy temperatures and to analyse the cumulative error throughout the model chain. That is why the workflow does not provide a basis to analyse how and when errors accumulate. Instead, we will evaluate the errors of the single components more comprehensively. Particularly, we will conduct a sensitivity analysis to challenge the assumptions we use to compute daily maximum canopy temperatures with the EBSC model (first component, see also response to reviewer 1, point 4.) and we will evaluate the water scaling factor K_WS in LPJmL (third component, see also response to reviewer 2, points 2. and 3.).

4. The evaluation relies primarily on ERA5 skin temperature as a reference dataset. However, ERA5 skin temperature is a reanalysis product rather than a direct observation of crop canopy temperature. The authors should acknowledge this limitation more explicitly and discuss its implications for the interpretation of model performance. Additional evaluation against independent canopy temperature observations or remotely sensed datasets, where available, would strengthen the validation.

Thank you very much for this comment. In the revised manuscript, we will discuss the limitations and implications of using a reanalysis product more comprehensively. Furthermore, we will provide a more elaborate and careful interpretation of the comparison. While we acknowledge that a comparison with earth observation data is a great opportunity to evaluate global model outputs, it lacks important data for our specific case. Both the computation of canopy temperatures and the evaluation of its accuracy need 2 m air temperature data, which is not provided by satellite data (see also response to reviewer 2, point 6.).

5. The introduction can benefit from an additional paragraph between the discussion of EBSC computational constraints and the study objectives (around line56). This paragraph can introduce the class of methods used in this study, briefly review their current development status, and explain why they offer a promising solution to the computational challenges outlined above. This would improve the overall flow and motivation of the Introduction.

Thank you very much for the helpful suggestion. We think such an additional paragraph will improve the readability and clarity of the article and we will include it in the revised manuscript.

Bibliography

Webber, H., Martre, P., Asseng, S., Kimball, B., White, J., Ottman, M., Wall, G. W., De Sanctis, G., Doltra, J., Grant, R., et al.: Canopy temperature for simulation of heat stress in irrigated wheat in a semi-arid environment: A multi-model comparison, Field Crops Research, 202, 21–35, 2017.