

Thank you for providing us with an opportunity to improve our manuscript further. We provided clarifications and edited a figure in line with the referees' suggestions. Referee 2 does not believe this manuscript is novel, which we do not agree with. As we explain in our responses, there is – to the best of our knowledge – no literature yet that explicitly examines effects on leaf or canopy temperatures during different-type heat waves. Our opinion on novelty is reinforced by the responses we received when presenting the results from this paper at ESA 2016 (“Plants and extreme events: Environmental buffers and amplifiers of heat extremes”), which were positive and surprised. We are therefore confident that the paper will be useful to many researchers, especially with the extensive background information presented. We suggest to make the model (Matlab code) available as free-to-use (the URL, if provided by Biogeosciences, can be filled in on p 2 li 32).

We respond to each comment (*italics*) below. Line numbers refer to the clean version of the document.

Sincerely,

Hans De Boeck & co-authors

Referee 1:

Thank you for the revisions and the comprehensive answers to my earlier comments. I appreciate the changes made, in particular the contour plots that were added to the appendix.

The comparison between model and data has improved somewhat, but is still a weak point of the manuscript. Although the model has indeed been evaluated in De Boeck et al. (2012), the conditions in this earlier study were considerably more moderate (up to 20 C), and did not reflect heat stress. The relationship with relative humidity (Fig. 2) explains 13% of the variance, so there is a lot more to be explained by the other factors. Also, if relative humidity appears to be correlated with any of the other factors (which seems likely, e.g. when considering the diurnal pattern of several of these parameters), the relationship found in the regression may be flawed. This should at least be discussed.

→ Response: We are happy that our prior changes were well received by the referee. We agree that the model results are not explicitly validated for the high temperatures addressed in the manuscript. Apart from practical concerns (heat waves are rare and we would need multiple types, lab data are not an option since the environment is incomparable to outside), it is important to note that energy balance calculations have been used in hundreds of scientific papers and are widely accepted to yield good approximations of reality. Indeed, they are based on longstanding physical equations rather than on equations trying to grasp the complexity of biological processes. The solution of the equations for T_l is part of many textbooks and at the heart of the environmental biophysics and meteorology disciplines. For this reason we do not agree that a lack of explicit comparisons between model and data is a weak point of the manuscript. We seem to have ended up between a rock and a hard place as Referee 1 would like to have some more certainty about the results, while Referee 2 considers them as obvious (which is opposite to uncertain). We now more explicitly mention the reliability of energy balance modelling on p 2 li 15, also in accordance with Referee 2's suggestion to refer to the relevant standard works.

The fact that the relationship with relative humidity (Fig. 2) explains only 13% of the variance was to be expected. Our simulations demonstrate that several other factors than RH also strongly determine T_l at $T_a = 40$ °C, notably radiation, wind speed and stomatal conductance, and these all vary (as noted in the caption of Fig. 2). The relationship in Fig. 2 is not a validation of the model as it explicitly considers only one of the variables of the model, but rather an illustration of a general trend predicted by the model and also observed in reality. We state as such on p 4 li 16-17: the natural heat wave "provided us with an opportunity to test whether increasing air humidity diminishes the cooling capacity of leaves". The relevance here is that we indeed found a trend that was in line with the model's predictions regarding the effect of relative humidity on leaf cooling.

As the referee notes, RH indeed changes depending on other variables, notably air temperature. However, our simulations consider different situations at one temperature (40 °C), rather than the ramp up towards or the cooling down afterwards, exactly in order to obtain clean comparisons at the same peak air temperature. We agree that we did not explicitly mention the fact that the regression in Fig. 2 includes air temperatures before and after the peak, which is not the same as in the simulations with constant T_a . This has now been clarified (legend of Fig. 2).

Fig. S8 gives a glimpse of other factors that could play a role, but it could differentiate the other factors varied better, e.g. by making separate regression lines, or by colouring the circles by SW radiation and/or wind speed.

- Response: We edited the figure, making a visual distinction between the different radiation levels used in the simulation and explaining in the legend that “lower wind speed leads to lower T_I-T_a at identical other environmental conditions”. This should give the readers an improved idea of ‘noise’ in the relationship between relative humidity and T_I-T_a caused by wind and radiation (cf. Figs. S2-S7).

The contour plots are very nice and illustrative, I would suggest to extract the explanatory lines from each of the captions (“Generally, ...”) of S2-S7, and incorporate these in the main text (in some cases, these effects are already discussed there and can simply be removed from the captions).

- Response: The problem is that variables here are compared in pairs, which is not the way the text in the manuscript is structured (figures relate to multiple paragraphs). We would therefore prefer to keep the explanations in the captions, where they directly relate to the figure in question. If the editor wishes to have this implemented in the main text nevertheless, we will of course do so.

Referee 2:

The revised manuscript addresses some of the raised concerns but the use of an inappropriately complex model in favor of a thorough theoretical reasoning remains the fundamental flaw of the paper.

- Here we disagree. If the model would be overly complex, it would not be part of many textbooks as the referee mentions below. Moreover, no part of the model can be omitted because all processes of energy exchange (sensible heat transport, latent heat transport, shortwave radiation fluxes and longwave radiation fluxes) have to be defined to be able to calculate leaf temperature. We also do not understand why using a model would constitute a fundamental flaw, nor can we see how the results in the figures (including their magnitudes for all combinations of factors) could be derived through theoretical reasoning.

In their response, the authors justify the use of their model by claiming that the calculation of leaf temperature “requires iterative computation and decision schemes.” This alone wouldn’t justify the replacement of theory by numerical simulations. But it is not even true. An excellent example of a concise theoretical discussion of the topic including an explicit equation to determine leaf temperature from air temperature, radiation, wind speed, and vapor deficit can be found in Campbell and Norman (1998). It is not the only example. In fact, the issue is a standard topic covered by almost every textbook on the matter. Further examples include Geiger (1950), Oke (1987), Lambers, Chapin III, and Pons (2008), Monteith and Unsworth (2009), and Jones (2013), to name just a few.

- Response: We agree that T_l can also be calculated by an explicit equation (using approximation through linearization, as mentioned in Campbell & Norman 1998) instead of iterative computing, but the two are equivalent as both techniques calculate steady state by making the energy gains equal to the energy losses. We do therefore not understand how this would invalidate the results, especially as the referee does not claim that the iterative procedure would be wrong.

Given the fact that knowledge about the difference between leaf and air temperature and its importance is so well established, it is indeed surprising that leaf temperature is not routinely used when assessing plant responses to heat waves and environmental conditions in general.

- Response: This is exactly our point. Moreover, the emerging literature on extreme event ecology does not take into account that T_l can be extremely different from T_a during a heatwave, which is why we made the calculations at 40 °C. We presented the results discussed in the paper at the 2016 ESA meeting in Florida, and we received many positive and surprised responses from the ecologists present, which reinforces our view that – in spite of the established background knowledge on energy exchange – our simulations and discussion thereof are relevant and timely.

One probable reason might be that leaf temperature is not a standard meteorological variable and cannot be easily measured on the landscape scale. On the other hand, estimation of leaf temperature from standard climate variables is data intensive and entails potentially large uncertainties. Additional problems arise from temperature gradients within canopies leading to non-uniform distribution of heat stress. Practical guidance on how to address these problems is required to lower the barrier for including leaf temperature in ecological and agronomic studies.

- ➔ Response: Infrared imaging has now sufficiently advanced to make measurements of T_l feasible both from a practical and financial point of view. We hope this paper will stimulate researchers to fill the gap and start making such measurements. Practical guidance is now added in a new paragraph on p 4 li 30 – p 5 li 5.

In my view, the manuscript by De Boeck et al. fails to provide any new ideas and perspectives on the issue of leaf temperature and heat stress. It merely states that using air temperature instead of leaf temperature as a measure for heat stress is inappropriate. The attempt to identify the drivers for leaf temperature remains superficial and consequently ignores the vast body of literature on the topic. The paper does not provide any practical suggestions for improving studies on heat waves nor does it line out a way towards addressing the problem more appropriately in the future.

- ➔ Response: We do not understand why the characterisation of T_l in many different heatwave conditions would be superficial. To our knowledge there is no body on leaf temperature during extreme temperature events (cf. p 1 li 10-11), and the referee does not list any existing publications on the subject. We believe that our assessment is important and novel with regards to extreme event ecology, as also emerges from contacts with colleagues (see above). We do agree that we failed to implement practical suggestions and ways forward. This has now been amended (p 4 li 30 – p 5 li 5).