Response to Reviewer 1 for the manuscript:

Assessing Soil and Potential Air Temperature Coupling Using PALM-4U: Implications for Idealized Scenarios

Manuscript number: egusphere-2024-1234

In the following text the original comments by the reviewers are given in black, our answers are blue. Line numbers refer to the unmarked manuscript (i.e., no tracked changes).

Reviewer #1 (Remarks to the Author):

This paper investigated the impact of varying soil temperatures on potential air temperatures in an idealized domain using a model for different scenarios. This is an interesting and certainly fits into the scope of the journal. The method presented is clear, and the results are also well discussed. However, some issues presented in this investigation need further exploration. Therefore, I suggest minor revisions before accepting the paper for publication. My comments are as follows:

Reply: Thank you very much for your constructive feedback. We implemented most of your suggestions which improved our research a lot. Please find detailed answers to all of your questions below.

1. My biggest concern is why the bottom layer air potential temperature generally had so huge differences with the topsoil temperature (0.005 m depth), as shown in Figs. 5 (b-e)? The difference between the bottom layer air temperature and topsoil temperature is up to about 15 ℃ in Fig.5c. Because of the continuity of temperature, I think the topsoil temperature should be same or much close to the bottom air temperature, as shown in the below figure.

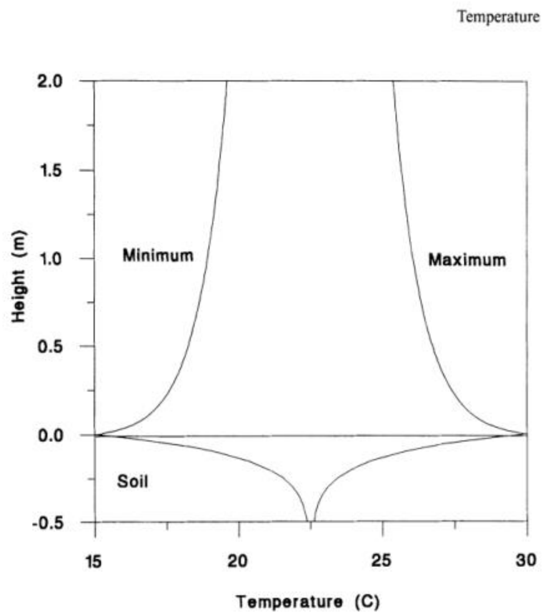

FIGURE 2.1. Hypothetical profiles of maximum and minimum temperature above and below soil surface on a clear, calm day.

(Reference of the figure: Campbell and Norman, 1998, An introduction to environmental biophysics, chapter 2, Page 16)

Reply: Unfortunately, we do not have access to the book you mention here. Based on the graphic it seems to describe a very idealized but unrealistic scenario. We know from many (experimental and theoretical) studies that the offset between near surface air temperatures is highly dependent on landcover but has an offset most of the time. One of the most well-known studies is Cermak et al. 2017; They conducted measurements of air, near-surface, and shallow ground temperatures under bare soil, sand, short-cut grass and asphalt. The shallow soil temperature was generally warmer than the near surface air temperature particularly under high solar radiation (as is the case in our model). We added the following text to the manuscript on page 19 after line 340:

"The modeled high difference between soil and air temperature is in line with existing literature. For example, Cermak et al. 2017 conducted measurements of air, near-surface, and shallow ground temperatures under bare soil, sand, short-cut grass and asphalt, and found that soil temperature was generally warmer than the near surface air temperature, particularly for high solar radiation. They also found different behavior for different land cover types showing the highest offsets in summer days under asphalt."

References:

Cermak, V., Bodri, L., Kresl, M., Dedecek, P., and Safanda, J.: Eleven years of ground–air temperature tracking over different land cover types, 37, https://doi.org/10.1002/joc.4764, publisher: John Wiley & Sons, Ltd, 2017.

2. Please define how "Δ Air temperature" in Figs. 5-7 a was calculated.

Reply: Thank you, we added this information in the caption of figure 5 (page 14). "… Δ Air temperature is the difference between the default scenario and the modified one. ..."

3. Line 97, please add additional text to state how these variables are automatically prompted (or estimated).

Reply: We added this to the manuscript (after line 97):

"Variables like roughness lengths, emissivity, and leaf area index are automatically prompted by the model and are summarized following look-up tables: https://palm.muk.uni-hannover.de/trac/wiki/doc/app/iofiles/pids/static/tables (Static tables) and https://palm.muk.uni-hannover.de/trac/wiki/doc/app/land_surface_parameters (Land Surface Parameters)."

4. In Table 2, the vertical humidity gradient is shown for the given heights. The air humidity and temperature are coupled. It would be interesting if the results of humidity profile are shown and discussed for different scenarios. How did humidity profile change for different scenarios? what the potential roles of humidity on the air temperature changes?

Reply: It is indeed a valuable point you mentioned. We also considered to investigate this question but have decided against focusing on it in this study. We are aware that there is a link between temperature and humidity. It is not within the scope of this study to look at the interaction with humidity. But, since we have no saturated zone, we assume that our results will not change much. The careful investigation of latent heat energy flux components is one of our future objectives.

5. Lines 341-342, why deep soil temperature modifications impact the potential air temperature differently? Please add some potential reasons.

Reply: We added the following explanation to the manuscript (line 341 ff.).

“Furthermore, comparing all three land cover types, deep soil temperature modifications impact the potential air temperature differently, although, in a small magnitude ((Fig. 5 (a), Fig. 6 (a), Fig.7 (a)) due to the e.g., different surface properties like heat conductivity, heat capacity, soil moisture, different surfaces energy balances and the dependent influence of the ground heat flux etc.”

6. Lines 339-341, “The highest absolute temperature and the highest offset between … the lack of vegetation and thus evapotranspiration (Brunsell et al., 2011)”. It seems that there is an assumption that the soil moisture of bare soil is less than that of grass soil. It is highly recommended to add additional text to clarify some assumptions.

Reply: Thank you, we clarified that in the manuscript (line 339 ff.).

“This can be explained by lack of vegetation, resulting in less evapotranspiration and an decreased latent heat flux. This in turn leads to an increased ground heat flux as well as decreased soil moisture and a low heat capacity of bare soils.”

7. Line 346, “when temperature are cooler” -> “when soil temperature are cooler”.

Reply: 7. We changed it to overall temperatures, because we refer to both, air and soil.

Line 346: “In winter, when overall temperatures are cooler, the potential air temperature increases with height i.e., the atmosphere is stable.”

8. Line 355, explain why “The atmosphere responds more to colder temperature”.

Reply: We added the following information in the manuscript (after line 355):

“In addition, the response to colder temperatures is greater because the energy difference is distributed over a smaller volume in the cold scenario due to the mixing depth in the boundary layer. Due to increases in mixing layer heights with seasonal changes in stability and solar irradiance, the same energy differences are distributed over a comparably larger volume during summer, resulting in local air temperature differences being less pronounced.”

Format:

9. Line 71, there is an edit error. Change “PALM-4U?;” ->“PALM-4U;”

Reply: We apologize for the misunderstanding and reformatted our text to make things more clear

“Accordingly, we set out to conduct a sensitivity analysis and address three distinct questions:

- (a) how to depict a realistic but idealized domain in PALM-4U?
- (b) … “

10. Please maintain consistency of potential temperature units in Figures 2, 5-7. In Fig.2, the x-label is “Θ Air temperature [℃]”, while the x-label is “Potential temperature [℃]” in Figs. 5-7 b-e.

Reply: Thank you for drawing this to our attention. We adapted all figures accordingly and now use the term Potential air temperature.

11. In Figs. 5-7 b-e, the x-label is for air potential temperature and soil temperature. It is not strict by using “Potential temperature [℃]” for both soil temperature and air potential temperature.

Reply: 11. Very good point. We changed it to Soil- and potential air temperatures. As an example, see the following figure: