

Geosci. Model Dev. Discuss., author comment AC4  
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## Reply on RC1

Jason A. Clark et al.

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Author comment on "Thermal modeling of three lakes within the continuous permafrost zone in Alaska using the LAKE 2.0 model" by Jason A. Clark et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2022-9-AC4>, 2022

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We thank both reviewers for their effort and insightful comments. These are two of the more keen and constructive reviews that we have received. Reviewers identified several key issues: model validation and performance, model temporal resolution, model vertical resolution, sediment temperatures, and Toolik lake inflow data. We addressed these issues by adding model evaluation metrics, adding new appendices for model resolution sensitivity, correcting errors, and updating manuscript text to address comments. We provide detailed responses to these issues below. As the GMD interactive comments do not allow us to submit a revised manuscript at this stage, we have attached excerpts from our revised manuscript that should be viewed along with our responses.

### Major comments:

Comment: "I have some issues with the study. Firstly, I think that the model baseline simulations were not correctly validated. I can't fully evaluate the model performance, and/or compare the model results with other model simulations (e.g. Guo et al., 2021, modeled Toolik lake) without a model evaluation metric such as: mean absolute error (MAE) or root mean square error (RMSE). Furthermore, I don't understand how the model was calibrated. What function were you trying to minimize in order to optimize the model performance?"

Response: Thank you for your effort and insightful comments. We have updated the manuscript with model evaluation metrics (including MAE and RMSE) as requested. Model performance was similar to Guo et al. 2021, with RMSE ~2C. However, it should be noted Guo et al. 2021 simulated Toolik lake only for the thawed seasons of 1983-1988. The LAKE model was minimally calibrated for each lake, as described in Section 2.2, to initialize water and sediment temperatures. A standard set of model parameters were applied to all lakes to demonstrate the applicability of the LAKE model in simulating Arctic lakes (Table 1).

Comment: "Secondly, why didn't you show the lakes sediment temperature obtained with the model as a function of water temperature? This kind of data is quite relevant for other researchers."

Response: We have added results showing sediment temperatures and new figures for water temperature profiles in addition the figures already present showing water

temperatures (Appendix C). As the focus of this paper was not directly on lake sediment temperatures we did not attempt to demonstrate sediment temperatures as a function of water temperatures.

**Specific comments:**

Comment: "L25: I think that the word "completes" is very strong."

Response: We changed it to 'is'.

Comment: "L26-L29: This sentence is unclear to me. You say that the model "is not highly sensitive to the weather data perturbations", and you conclude that "snow depth and lake ice strongly affect water temperatures during the frozen season"?"

Response: We have updated the text to clarify our point. "The sensitivity analysis shows us that lake water temperature is not highly sensitive to small changes in air temperature or precipitation, while changes in shortwave radiation and large changes in precipitation produced larger effects. Snow depth and lake ice strongly affect water temperatures during the frozen season which dominates the annual thermal regime. These findings suggest that reductions in lake ice thickness and duration could lead to more heat storage by lakes and enhanced permafrost degradation."

Comment: "L31: I suggest the following change to this sentence: "Approximately forty percent...""

Response: We have made this change.

Comment: "L70: **Description of the model:** I think that you need to improve the model description, namely, the multilayer snow and ice modules (Stepanenko and Lykossov, 2005; Stepanenko et al., 2011)."

Response: We have elaborated on this section to include a description of the snow and ice modules, including references.

Comment: "L85: **LAKE model setup:** Please describe the calibration procedure. Which parameters were calibrated in which ranges? Was calibration automatic? Please describe the parameters of the baseline simulation. The table 1 included in Stepanenko et al. (2016) is a very good example."

Response: Our calibration procedure simply involved the initialization of the soil and water temperature values as described in the Section 2.2. No other parameters were calibrated. The parameters of the baseline scenarios have been added as Table 1.

Comment: "L94: **Input data:** Please describe all meteorological variables. How did you characterize the inflow water temperature to lake Toolik? Please describe the initial water temperature and sediments values, before and after the 10 years simulation."

Response: We have added text to section 2.3 describing all met variables. Inflow water temperature was measured daily with discharge. Water temperature is included in the inflow input file. Discharge and temperature are described in section 2.7. Initial water temperature was taken from observed water temperature data. Initial and calibrated sediment temperatures are now reported in Table 1.

Comment: "L140: Please replace  $Wm^{-1}$  with  $Wm^{-2}$ ."

Response: Thanks, we made this change.

Comment: "L150: Do you have lake water level values? Do you think that neglecting the lake water level may lead to errors in surface heat flux predictions?"

Response: Interesting point. We do not have observations of lake water level values. The water level change may affect surface fluxes via the thickness of the mixed (or active) layer of a lake, the latter is a layer which total heat capacity interacts with the atmosphere. If not limited by lake depth, the typical summertime ML thickness in mid- and high latitudes is 3-5 m (see e.g. simulated/observed temperature profiles in LakeMIP papers). Thus, there are two situations with respect to the lake level effects on ML depth and thus the surface fluxes. First, the lake is shallower than 3-5 m, then the ML is a lake depth. In this case, the water level may affect fluxes, if it varies significantly retaining the depth below 3-5 m. In the case where the lake depth much exceeds 3-5 m (Toolik lake), the level variations do not change ML depth and thus the fluxes.

Comment: "L156: I suggest adding a new section, "Evaluation metrics" for the "new" evaluation metrics (e.g. RMSE). The Z-score equation can also be included here. You don't need to apply the "new" metrics to the sensitivity analysis."

Response: We have added this section, now section 2.8.

Comment: "L169: "During the frozen season, the modeled temperatures underestimate cooling in the lake." By how much?"

Response: We have added Table 2 which shows model error (MAE, RMSE, Bias) for the entire time series, and split by frozen and thawed season. For this particular sentence the error for Atqasuk over the frozen period was 5.8 (RMSE).

Comment: "L189-190: "For 2013 and 2014 the modeled shallow (0, 3 m) water temperature was overestimated while for 2015 and 2016 shallow water temperature was underestimated, though it tracked observed temperature." By how much?"

Response: We have added Table 2 which shows model error (MAE, RMSE, Bias) for the entire time series, and split by frozen and thawed season. The Toolik model simulations have been updated based on corrected discharge data. This sentence and interpretation of the Toolik water temperatures have been changed. Thawed and frozen season errors are presented in Table 2.

Comment: "L192: I can't see the step-like dip in figures B1 and B2 can this fact be related with inflow water temperature?"

Response: We thank the keen reviewer who caught this error. We were able to trace the 'dips' to a formatting error in the inflow data file. This has been corrected. All Toolik simulations have been repeated and figures updated (Section 3.3). The 'dips' were an artifact of the erroneous inflow data and are no longer present (Figs. 3 & 4).

Comment: "L200: The datasets length (x values) shown in figures 3 and 4 is smaller than the datasets length shown in figures B1 and B2."

Response: These have been corrected to show the same length of data.

Comment: "L210: "shallow depth water temperatures (1, 3, and 5 m 210 depth, -0.13 to 0.34)". I can't find the value -0.13 in Figure 5."

Response: This was an error. The text has been updated to reflect the data in the figure.

Please note this figure and data have been updated to reflect the new simulations for Fox Den (now hourly) and Toolik (with corrected inflow data)(Fig. 5).

Comment: "L246: "Modeled shallow water (1 m) temperature exceeded the observed temperatures" After the incorporation of inflows/outflows, the water temperature (1 m) in 2013 and 2014, still exceeds observed water temperatures. This kind of analysis would be easier with a model evaluation metric."

Response: Error metrics have been added and are included in Table 2, B1, & B2 for this sentence.

Comment: "L270: I think that this entire section "Modeling Lake thermal effects in permafrost" must be in the introduction."

Response: We have moved this section to the Introduction.

Comment: "L286: "The "dips" of water temperature in LAKE model results for Toolik lake down to depths of 10 m prior to ice-off can be explained". I can see the dip at 19 m (Figure 4, 2014-07)."

Response: We thank the keen reviewer who caught this error. We were able to trace the 'dips' to a formatting error in the inflow data file. This has been corrected. All Toolik simulations have been repeated and figures updated (Section 3.3). The 'dips' were an artifact of the erroneous inflow data and are no longer present (Figs. 3 & 4).

Comment: "L287: "can be explained by convective instability under the ice, where this instability can be caused by the under-ice penetration of solar radiation" As I said previously, I can't see the "dips" in figures B1 and B2. Can this be related with the effect of lake inflow?"

Response: We thank the keen reviewer who caught this error. We were able to trace the 'dips' to a formatting error in the inflow data file. This has been corrected. All Toolik simulations have been repeated and figures updated (Section 3.3). The 'dips' were an artifact of the erroneous inflow data and are no longer present (Figs. 3 & 4).

Please also note the supplement to this comment:

<https://gmd.copernicus.org/preprints/gmd-2022-9/gmd-2022-9-AC4-supplement.pdf>