Geoscientific Model Development Discussions

Geosci. Model Dev. Discuss., author comment AC5
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Reply on RC2

Jason A. Clark et al.

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-AC5, 2022

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.

Comment: "Modeling of lake thermodynamics in polar regions is a highly relevant topic with regard to the response of the Arctic permafrost to the global change. The model LAKE has been intensively applied in recent studies on lake dynamics and air-lake interaction. Therefore, a study on the LAKE model abilities to simulate thermal properties of lakes in the permafrost zone falls into the scope of the GMD and is of interest for its readership. Comparison of the model performance for three Arctic lakes of different morphometry provides a necessary background for future analysis of the atmosphere-lake-permafrost interaction. Herewith, the study is a valuable contribution to modeling of lakes as components of the climate system. The methods, presentation of results, and discussion are generally adequate to the problem statement, however contain some gaps, related, in particular, to the effects of the spatial and temporal resolution on the modeling results and to the simulation of the water-sediment interaction as a crucial aspect of lake modeling in the permafrost zone. I recommend extending the study with relevant details providing the reader with a necessary overview of the model performance beyond the sensitivity to variations in the input forcing, which is currently the major focus of the manuscript."

Response: Thank you for your comments. We have added several new sections to the manuscript and to the Appendix that we believe add more detail and aid in understanding the spatial resolution an temporal resolution on modeling results as well as results of the water-sediment interaction.

Comment: "As it was pointed out by the previous reviewer, the model validation is presented in a rather qualitative way, and some numerical scores of the model performance, like bias, absolute error, RMSE etc., will be useful here."

Response: We have updated the manuscript with model evaluation metrics (including MAE and RMSE) as requested. Please see Table 2 and the Appendix.

Comment: "The temporal resolution of the model input was different for three different lakes: 1 day for one of them and 1 hour for the two others. It is unclear how the diurnal cycle of the atmospheric forcing and radiation was treated in the model. Were the daily data interpolated on sub-diurnal scales? If yes, how the interpolation was performed? How does the neglect of the sub-daily variations in the input data affect the model output? The question could be answered by comparison of model runs with daily and hourly inputs for the lakes where sub-diurnal data on forcing are available."

Response: We have updated the simulations to use the same temporal resolution (1 hour) for all lakes. Additionally we have added a section to the Appendix that shows the effect of temporal resolution on model performance (Appendix F). Daily data are linearly interpolated to finer temporal scales within LAKE.

Comment: "The vertical resolution for both water column and sediment was set to 1 meter and did not vary between lakes. What were the criteria for the choice of the resolution? One can assume that for the vertical diffusion rates within the sediment of 10^{-6} m^2 s^{-1}, the vertical resolution of 1 m will capture the processes with typical time scales of >10 days. Is it sufficient? How many vertical grid points did Fox Den have, whose depth is 1.5 m? Can you perform sensitivity runs demonstrating the effect of the vertical resolution on the model output?"

Comment: "L316, Section 5.4 The details on the sediment layer modeling results are crucial for discussion on the model applicability to permafrost lakes. The information is missing in the ms. How did the soil temperatures under the lake bottom vary during the modeling period? What are the values of the bottom heat flux and how do they depend on the model configuration, initial and boundary conditions?"

Response: We have added new figures and a new section in the results to show the sediment temperatures and heat flux during simulations (Appendix C). Soil temperatures responded differently in each lake. In general, shallow sediment showed warming in the thaw period and deeper sediments remained constant over the simulation period.

Some minor remarks:

Comment: " "It is a large lake (2,732,050 m2)..." why 2 km^2 area is large for a lake?"

Response: It is large relative to our study lakes. We have updated the text reflect this comparison.

Comment: " " 30 cm and 250 cm" better use meters here for consistency."

Response: We have made this change.

Comment: "In Fox Den the model calculated up to 1.0 m thick ice cover in a 1.5 m deep lake. Was the water volume/depth adjusted during the ice-covered period? Was 1 m vertical resolution sufficient for simulation?"

Response: All frozen water (which formed the ice layer) is subtracted from the lake water volume. The water depth is adjusted accordingly. As to resolution, the grid spacing in water and ice is automatically adjusted in the model to keep the predefined number of numerical layers in each physical layer. In the manuscript you reviewed, we misstated the vertical resolution used for the simulations (Table 1). We have corrected these errors. For Fox Den the vertical resolution was 0.0375m which we believe was sufficient for simulation.

Comment: “L286: “The “dips” of water temperature in the LAKE model results for Toolik lake…” How did the vertical model resolution affect the representation of free convection? The 1 m resolution seems to be crude for the typical values of the convective layer entrainment rates of < 1 m/day (e.g. Kirillin et al. 2012).”

Response: The statement of 1m resolution was incorrect. We have corrected the text to reflect the vertical resolution used in each Lake (Table 1). For Toolik the resolution was 0.65m. We have added an appendix to look at the effects of increasing model water vertical resolution. Using 1m, 0.5m, and 0.25m vertical resolutions we found minimal effects on lake water temperatures and model performance. Kirillin et al. 2012 report rates of 0.5 m per day increasing to several meters per day in deep lakes. We simulated lakes with vertical resolutions of 0.0635m, 0.0375m, and 0.65m (for Atqasuk, Fox Den, and Toolik respectively) and tested vertical resolutions down to 0.25m for Toolik and 0.025m for Atqasuk (Appendix D). We did not see evidence that the vertical resolutions used in the manuscript was too coarse.

Please also note the supplement to this comment:
https://gmd.copernicus.org/preprints/gmd-2022-9/gmd-2022-9-AC5-supplement.pdf