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Geoscientific Model Development Discussions

Interactive comment on "Incorporating Wind Sheltering and Sediment Heat Flux into 1-D Models of Small Boreal Lakes: A Case Study with the Canadian Small Lake Model V2.0" *by* Murray D. MacKay

Anonymous Referee #1

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The study discusses possibilities of incorporating 2-d horizontal inhomogeneities into 1-dimensional vertical models of lake thermodynamics. Two numerically inexpensive parameterizations are developed by the author and tested in the framework of the Canadian Small Lake Model (CSLM): one dedicated to accounting of the surrounding roughness on the air-lake turbulent fluxes, the other one dealing with the heat storage by the lake sediments in lakes of different morphometry.

The first parameteization reproduces the sheltering effect of rough surroundings (e.g. forest) on small lakes, based on laboratory experiments data on turbulent stress tran-

sition from a rougher to a smoother surface. According to test model runs, the parameterization improves remarkably simulation of the surface mixed layer depth in a small Canadian lake and leads to a generally better simulation of lake surface temperatures. The approach is promising for modeling small boreal lakes, sheltered by forests, which are abundant in the northern latitudes. Since the approach does not need extensive calculations, it can be potentially incorporated in lake parameterization schemes of global/regional models. Some clarifications is nesessary here, before such global-scale implementation becomes possible:

(i) While using the Coriolis-scaling for the equilibrium surface stress (P5L20 Eq. 5) seems reasonable in high latitudes, it would apparently fail in tropics. A comment on possible ways of generalization or alternative scaling is needed; (ii) the algorithm proposed at P6L5-15 and Fig. 2 works fine for a single lake and provides a nice visual demonstration of the possible corrections. However, a final formula $\tau_0/\tau_+(fetch, G, z_+ \ldots)$ would allow the reader to directly test/incorporate the parameterization in other models avoiding diagrams and discrete choices of the landcover type; (iii) P6L16: if the wave aging produces the opposite effect to the sheltering on the surface stress, an estimation of the fetch length (lake size) at which the wave age becomes more important than the sheltering effect (land-lake transition) is needed.

The demonstrated effect of the second parameterization—incorporation of the solar heating of shallow sediment—on the model output is less obvious, being probably overwhelmed by other deficiencies of 1-d modeling approach. In the presented application, the CSLM seems to underestimate the verical mixing in the upper part of the ice-covered water column. As a result, a spurious convection is produced at the lake bottom, when the solar heating of the sediment surface is added. The mathematical framework is in turn well-developed and allows easy adaptation of the algorithm to a specific modeling task. In this sense, the approach offers a potentially effective way of incorporating lake morphometry into 1d horizontally-integrated models.

Below are questions on the second part of the study:

P7L21 “The boundary condition at the base of the slab is isothermal. . . which places a constraint on the minimum slab thickness” It sounds not very physical and numerically problematic. Why not using a constant (geothermal or zero) flux at the sediments' base or at an infinite depth instead?

P7L28 Do the conductivity and heat capacity values refer to dry or water-saturated sand?

P7L27-30 Why the sediment thickness 10 m and the lower boundary condition temperature of 6.0 °C are chosen?

P11L8 “Geothermal heating alone (X1) brings the mean heat flux into the column up to 0.08 W m^{-2} . . . ". Geothermal flux in this model formulation is not a result of simulations, but is artificially prescribed by setting the slab thickness and the temperature at its base. Does any evidence exist of geothermal flux of similar magnitudes in Canadian lakes?

P12L10 “Since much of the sediment heat content arises from SW insolation at the sediment – water interface . . . ” The statement needs some support. Contribution of turbulent heat transport from water to sediment can be at least as important as radiative heating.

minor/technical remarks:

P1L34 The references here seem slightly outdated. See Kirillin&Shatwell (2016 *Earth-Science Reviews*, 161, 179-190, https://doi.org/10.1016/j.earscirev.2016.08.008) for a discussion on the relationship between fetch/transparency and epilimnion depth.

Fig. 2: τ looks like T in the y-axis subscript.

Fig. 3: While surface stress correction resulted in generally better prediction of surface temperatures, it also produced a stronger overestimation of temperatures during daytime on 17, 21 and 23 July (calm and warm/sunny days?). Any comments on the background mechanisms?

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