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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

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Wind Sheltering: Response to Anonymous Referee #1

The referee points out that any estimate of the equilibrium surface stress based on a Rossby number would not be appropriate in a global model, even if it does work well for mid-latitude lakes as discussed here. In fact, on further analysis (including correcting a typo in the plotting programme) we now show that this estimate is not even appropriate for the mid-latitudes. Jensen's original notion was that equilibrium was reached when

the IBL filled the entire PBL, but it is easily shown that at the latitude of our study lake this would require fetches of several thousand km. However, plotting $\tau 0/\tau$- (new Fig. 2) it is easily seen that values for this ratio asymptote much sooner than this – generally for fetches of 5 km or less. New text describing this has been included starting around P5 L26 (marked-up text).

The new approach is not presented in terms of a final formula as suggested by the referee (which would not be easily expressed) but a simple algorithm is now outlined in the text near P6 L15 (marked-up text).

The full impact of wave state would add an enormous complexity to the current formulation, even if individual aspects could be incorporated. We have chosen simply to point out that this is a real issue, well beyond the scope of this study, and requires further research.

Response to Anonymous Referee #2

A more fulsome discussion on recent relevant wind tunnel, large eddy simulation, and field research is now presented (starting near P7 L24, marked-up text). The important phenomena of streamline displacement and flow reattachment in the lee of the forest edge is discussed, and it is noted that the empirical surface stress model of Markfort et al. (2014) appears similar to what is proposed here if the distance to flow reattachment is considered.

We have found that our results are not terribly sensitive to the choice of a (constant) water surface roughness of 10-3 m. Choosing values of 10-2 m or 10-4 m changes the mean surface stress reduction factor from 0.50 to 0.59 and 0.45 respectively, leading to quantitative but not qualitative differences (see P7 L37, marked-up text).

Fig. 3 now includes observed and simulated temperature profiles for a few days between 17-25 July capturing the impact of the wind mixing events. These clearly show differences in the simulated epilimnion temperatures and depths compared with ob-

served. Discussion has been added (starting near P7 L15, marked-up text).

Sediment Heat Flux: Response to Anonymous Referee #1

The boundary condition at the base of the sediment slab layer has been fixed isothermal at 6.0 oC for a layer 10 m thick. These values are somewhat arbitrary: there are few data beneath boreal lakes in our region to support these (nor have we been able to find any geothermal flux data below Canadian boreal lakes). Nevertheless our experience with lake L239 is that hypolimnion water temperatures rarely deviate from 4.0 oC throughout the year, so we assume the sediment base temperature should be close to this. Likens and Johnson (1969) found that data from Wisconsin (several hundred km to the south-east of our research area) show no seasonal variation in sediment temperatures below about 10 m in the lakes they examined, which motivates choosing our slab thickness. They found nearly isothermal conditions at this depth of around 6 – 8 oC. In this study, thermal properties of the sediment slab have been assumed the same as pure, dry sand, as noted in the text (P8 L26 marked-up text).

The statement "Since much of the sediment heat content arises from SW insolation . . ." was not meant to imply that SW forcing is the dominant mechanism here – only that it can be important. This statement has now been reworded to reflect this (P13 L7-8, marked-up text).

Minor Remarks: Response to Anonymous Referee #1

The noted references discussing the relationship between fetch and epilimnion depth are not intended to be comprehensive – merely indicative of the fact that it has long been known that a relationship exists (hence the older references).

Higher quality graphics can be provided at the production stage.

The issue of the overestimation of surface temperatures in both simulations during mid-day is indeed interesting and evidently little affected by a 50% reduction in surface stress. There is clearly information here indicating another process may be poorly

simulated, but we have so far been unable to track this down.

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