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Interactive comment on "A General Lake Model (GLM 2.4) for linking with high-frequency sensor data from the Global Lake Ecological Observatory Network (GLEON)" *by* Matthew R. Hipsey et al.

Anonymous Referee #2

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Review of "A General Lake Model (GLM2.4) for linking with high-frequency sensor data from the Global Lake Ecological Observatory Network (GLEON)" by Matthew R. Hipsey et al.

This paper presents the formulation of a one-dimensional model of thermodynamics, mixing, and evaporative and momentum fluxes from lake surfaces, which conceptually should be applicable to a wide variety of lake morphologies. However, the manuscript achieves the paradox of simultaneously containing too much information and not enough information. It goes into great detail with many equations. However, in order to present this level of detail without losing the reader requires more care and at

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Discussion paper

least some additional details.

I have a few broad suggestions that I think might help.

Before anything, you need to have a clear idea of who is in your audience. You could even have an explicit statement of this very near the beginning, and direct users with a lower level of expertise toward a simpler users' guide. This reviewer has a background explicitly in meteorology, but significant exposure to lake dynamics as well, albeit mostly regarding very large lakes. Depending on your intended audience, you might have readers who will have difficulty with terms such as aliquot and even the intended understanding of "scalar concentrations" as used on p. 27, lines 2-3.

To reduce the length of a single paper, one option is to break it into multiple papers. Another is to move more of the detail to appendices. Since it is an online journal, there is probably not a large problem with overall page length. Things as detailed as conversion of area as a function of depth to volume in a layer (eq. 1) seem like they could be skipped in the main text and relegated to an appendix.

It would be useful to have a brief introduction to each sub-section. This should start out by stating the goal of that sub-section, i.e. what will be the final equation (or set of equations) derived in the section. Then state what elements will combine to get that final equation(s). One particularly glaring issue is that sub-section 2.5.2 ends with eq. 45, defining the variable f, but nowhere does it say how f relates to any other part of the model. It seems to be something that one would multiply by the difference in temperature (or another scalar) between layers) to get the exchange of that scalar between the two layers in a single time step. Whether this is exactly correct or not, the statement is missing from the manuscript.

A simple overall schematic would be good to have early on (Fig. 15 with less detail). This would make it less abrupt when "water quality model AED2" is mentioned on p. 27 (I may have missed it, but I don't think it was mentioned before.

Even if only for your own reference as author, Table 1 needs to be expanded to include every variable used in every equation! And in this expanded table, include every variant of each variable based on the use of different subscripts, prime, and circumflex ("hat"). With this many equations, it is rather inevitable that you also end up using the same symbol for different things (I noticed N in particular). Then, for each variant of each variable, put additional columns for: description, units, spatial type (defined at surface only, spatially continuous, or at discrete layers), and which equations it is used in. The reader needs to have all of these carefully defined.

My high school chemistry teacher is the one who taught me how to use units in equations, and the importance of doing so, hence the need for them in the big table above. Some examples of problems with units in the equations that may indicate that the equation is simply wrong: In eq. 52, Q seems like it should have units of m cubed per s, and h units of m, so the right-hand side does not have units of velocity.

I approached this manuscript with the immediate question of what makes this model better and more useful than the many others that are available. The introduction does a pretty good job of answering this, but it may be good to give some examples of uses that are not satisfied by other models. This could be introduced with a schematic of its components, options, and functions, at a lower level of detail than in Figs. 15 and 16.

Anything that can be done to bring the reader's intuition into play when introducing equations will improve comprehension of the manuscript. Eq. 27 isn't the most problematic one, but I'll use it as an example. You might introduce it by saying something like: "Shortwave radiation is absorbed and attenuates with different e-folding depths for snow, white ice, and blue ice, and these also depend on the light's wavelength. The overall effect is..." Eq. 47 has me very mystified about how a standard definition of Richardson's number translates into this equation in terms of the angles of inflow geometry (part of the problem may be that I don't feel like I understand the meaning of the angle labeled alpha in Fig. 10; the illustration isn't helping me). It also has me asking "Richardson number at what location?" At the interface of the river water and ambient lake water?

Several of the figures have characters that are so small as to be illegible.

What about modularity of the model? Can other schemes for pieces of the model be plugged in? The details of how may be an appendix or even another paper or guide.

Some particular examples of the general problems above are among the specific comments below.

Specific comments:

1. In nearly every review that I do, I refer to the rules of hyphens found at http://www.grammarbook.com/punctuation/hyphens.asp particularly Rule 1 on that page. Your manuscript is actually better than most, but here are the problems that I found: P. 2, line 23 should have "system scale" (no hyphen). "Time-scale" is sort of borderline; I tend to use it without a hyphen when it doesn't modify another noun. P. 4, line 15 and some figure captions: "time series". P. 13, lines 22 and 24: "Wind sheltering". P. 24, line 3: "user-specified".

2. P. 2, line 33: Change "spatial" to "vertical", to contrast with horizontal from earlier in the sentence.

3. P. 3, line 10: Stepanenko is misspelled.

4. P. 3, lines 17-18: Do you have any comment on use in small vs. large lakes? Both in terms of area and depth? There might also be considerations in terms of morphological complexity.

5. P. 3, lines 30-31 specifically mention temperature, salinity, and density. Later on, there is mention of the broader category of "scalars". Are you unnecessarily limiting yourself here? I am thinking of such things as dissolved oxygen (mentioned later) and concentrations of nutrients and contaminants.

6. P. 3, line 32: I think many readers will object to the use of "hydrodynamic" here,

since it does not explicitly represent advection of water. Continuity equations say that dynamics requires at least two dimensions.

7. P. 4, lines 31-32: “user-defined” and “set by the user” are redundant.

8. P. 5, line 8: This model doesn’t include it, but in reality, vertical advection of heat can be important along with vertical mixing. Again this may depend on the size of the lake, but this factor should be acknowledged here.

9. Eq. 4 has issues with sign conventions, units, and possible missing terms depending on how one understands it. It is strange to have a positive sign on E in the right-hand sideâĂŤthis means that E is ordinarily a negative number. The units need to be very explicitâĂŤlength per time, such as mm per day. Because of these units, E should not be called “mass flux”. E multiplied by lake area should be considered a volume flux. For practical purposes these can be considered equivalent, but there would be another term for water density to convert between mass flux and volume flux. Are the evaporation, snowfall, and rainfall defined as being specifically over the area of the lake itself, or over the drainage basin? If over the lake, how is the Q term for runoff optional? I have a hard time imagining many cases of lakes in which it is not a major term in the water balance. If these variables are defined over the whole basin, is there an issue with agreement in timing between P – E and runoff?

10. P. 7, line 21: “However” is an interjection, not a conjunction. Here, it stands between two independent clauses, so preceded with either a semicolon or period. Also p. 33, line 10 and p. 35, line 11.

11. Eq. 7 is a place where I started to distinctly feel the problem of definition of variables. I had to really think through what had happened to the subscript S from eq. 6 and why the “hats” were there in eq. 7.

12. Eq. 9a has a strange step function in space. Can you justify this not being a smooth function, but rather one value for all of the northern hemisphere, another for the equator

(an infinitesimal amount of space), and another for the southern hemisphere?

13. P. 9, line 6: What makes the different formulas oceanic and lacustrine? Is there anything to help the reader's intuition for why these formulas should be different?

14. Audience issue: P. 10, line 14 departs from the main conceptual theme to give a specific file name. Detailed mathematical formulation and detailed user information don't mix very well.

15. Eq. 14: Are you using a different temperature at the skin (interfacial layer) or bulk temperature a little deeper? Specify how deep.

16. P. 11, line 10: Air temperature at how high above the surface? Standard is 2 m, but there may be adjustment needed if measurements are at a different height than that intended in the formulation.

17. Eq. 163: "Brutsaert" is misspelled.

18. P. 11, line 13: The range of octals should be 0 to 8.

19. P. 12, line 11: This should specify molecular weight of dry air, and it might be better to say mass rather than weight.

20. P. 13, lines 5 and 9: I think these should reference eqs. 17-18 rather than 16-17.

21. Eq. 23: The Latin v and Greek nu are somewhat difficult to distinguish here, and are even more difficult to distinguish in the text following.

22. P. 13, lines 16-18: Thanks for explicitly using units here. Am I correct in understanding that molecular heat conductivity is molecular heat diffusivity multiplied by heat capacity? I think it would be better not to use heat conductivity, but use diffusivity and capacity.

23. P. 13, line 22: "may be" should be two words.

24. P. 15, line 13: This use of "conductive heat flux from the ice or snow cover to the at-

mosphere” particularly triggers my thought bias as a meteorologist. That bias prompts me to assume that this means flux through the atmosphere’s interfacial layer, where molecular diffusion dominates. But I also wonder whether it means heat conduction through the ice. These are not equal in general, and need to be distinguished from each other.

25. Eq. 26: Why isn’t shortwave radiation here?

26. P. 16, lines 11 and 12: These are very wide ranges of albedo. Please describe the conditions under which different parts of this range manifest.

27. P. 18, line 10: The idea of energy required for mixing needs to be introduced more carefully. If you think of the water column as continuous in space, mixing is also a continuum. But the concept here is based on discrete layers, and this indicates how much energy is required to outright include a model layer in the mixed layer.

28. Eq. 31: C sub T seems completely undefined.

29. P. 20, line 14: This cannot be reproduced unless your definition of “epilimnion” and “hypolimnion” are precisely stated.

30. P. 20, line 20: Is K sub epsilon eddy diffusivity.

31. Since the vertical axis in Fig. 8 has zero at the bottom, it appears to be height above the bottom, not depth. It might be worth explaining that the varying top height of the color fill is due to varying overall depth (assuming that this is correct).

32. P. 22, line 13 and eq. 43: This seems to say that sigma should have units of inverse seconds squared, which implies that the square-bracketed part of eq. 43 has units of (m/s) squared, but exponential operations can only be performed on unitless numbers.

33. P. 24, line 5: Slope is usually defined as a ratio of rise divide by run, not an angle. I would say that the slop is the tangent of the angle.

34. The inset in Fig. 10 does not help me understand the meaning of the angle alpha,

and it could use larger lettering.

35. Equation 52 seems messed up. Units-wise, it seems to make more sense if h squared is in the denominator instead, but I also wonder why there is no dependence on width of inflow.

36. P. 26, line 16: In standard usage, dz represents an infinitesimal difference in z in continuous space, but here it is used to indicate a finite distance in discretely sectioned space.

37. P. 26, lines 16-17: It is difficult to understand the distinction between “height of withdrawal” and “edge of the withdrawal layer”.

38. P. 26, line 19: Why say “fluid” rather than “water”?

39. A formatting problem put some labels that belong to Fig. 12 on p. 27, while the rest of the figure is on p. 28.

40. P. 28, lines 10-11: Removing no more than half of a layer’s mass per time step seems like a reasonable way to ensure numerical stability, but it would be good to remind the reader here of the layer merging scheme that is likely to kick in. This merging and disaggregation scheme, also mentioned on p. 34, is never really described well.

41. P. 29, line 3 says “wind speed and fetch. . .calculated as”, while eq. 61 only shows the formula for fetch.

42. To help solve the problem of small print in Fig. 16, it may be useful to transfer some of the information to a table instead.

43. P. 34, line 19 has a placeholder for a citation. This is evidence of a poor final edit on the part of the authors.

44. P. 34, line 23: If you mention calibration, it would be well to describe this process more fully, in particular which parameters you consider adjustable for purposes of calibration. Where p. 35, line 10 mentions “compare”, I wonder whether this might also

imply calibration.

45. P. 48, line 12: “Anneville” misspelled?

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