

## ***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 #3**

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### General Comments

This paper describes the detailed functioning of the 1D physical lake model GLM 2.4 and its application potential. The model incorporates a broad range of physical processes as surface heat exchange, snow and ice dynamics, in- and outflow, submerged inflow and groundwater seepage and can be coupled with or embedded into other models. The authors explain how GLM 2.4 has emerged as a response to the need of standardized, yet flexible and computationally effective community lake model to interpret environmental data from a broad range of lakes collected within the Global Lake Ecological Observatory Network (GLEON). The model has been formulated as a new

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code in 2012, whereas layer structure, mixing algorithms and physical formulae are based on earlier peer reviewed work. The authors state that the code is computationally efficient and well suited for embedding in larger scale modelling frameworks. The authors present also an overview of pre- and post-processing utilities as well as an innovative cloud computing environment. Lastly, they elaborate on the educational use and gained experience in the classroom.

I realized that this manuscript is for a major part equivalent to an earlier manual of GLM (V2 Manual, October 2014, accessed on the 08.01.2017 from <http://aed.see.uwa.edu.au/research/models/GLM/Pages/documentation.html>). I think the authors should mention this.

The model in this paper represents with no doubt a tremendous effort in lake modelling and is of interest for modelers in various fields of environmental research. The publication of this model is a step towards better model documentation and contributes to the general scientific discussion and better lake model development. As such it falls within the scope of this journal. The paper is well written and the language is easily comprehensible. Unfortunately, this manuscript has some structural problems and there are quite a few mistakes in equations and figures. After dealing with these issues, the manuscript should be good for publishing. The main problem of this very long manuscript is that it is missing an instant overview of what is in the paper and what not. Scanning through, the reader gets lost easily in the large chapter 2 ‘model overview’ and might miss the subsequent chapters that elaborate more on the possibilities and significance of this model for the scientific community.

I think that this problem can be fixed with some changes in the introduction: I suggest using subtitles in the introduction. (In the introduction, the authors describe the importance of the study of lakes, the importance of GLEON, the importance of lake models, the advantages of simple models, applications and features of 1D models, the need for a flexible open-source model, how GLM 2.4 answers this need and finally an overview of the paper) I suggest creating a new paragraph starting at p. 3 Line 19

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“Nonetheless, there ...”. The need of an open source and flexible community model that can be applied to various lakes should be highlighted better. Another additional paragraph could explain how GLM 2.4 responds to this need. As I understand, GLM 2.4 is filling the gap because it provides a standard middle complexity physics ‘shell’ (simple yet enough complex to be applied for various lakes) that can be connected individually to or implemented into various other models (e.g. water quality or land-climate models). I think this point could be emphasized. A figure could be helpful to draw attention to the significance of this model in the scientific community. This could also be combined with schematic overview of the model functioning (I agree with R2 that anything that gives an overview helps). The specific limitations of GLM 2.4 (not of 1D models in general) should be mentioned in the introduction. Like this, the reader may have a quick idea whether GLM is suitable for him/her. What are the key features of this model that set it apart from other models? On p. 4 lines 5-9, the authors explain the aims of the paper and in which of chapter 2-6 these aims are met. I think these lines are important and should be extended to a paragraph by itself to make sure the reader is fully aware what to expect from the paper. In the same paragraph, I would also expect some more information regarding what this paper is not about and mention that a companion paper by Bruce et al. (2017) is assessing the model’s error structure against 31 GLEON lakes.

I think the authors did not carefully go through the complete manuscript. Many of the empirical equations are missing the definition of units for used variables. On other occasions variables were poorly described (see the examples listed below, as well as listed by R1 and R2). On several figures elevation and not the labeled depth is shown on y axis. The references are not formatted coherently. Like R2, I am of the opinion that many variable symbols are confusingly similar and that they should all be listed in a table. I also agree with R2 that all the subchapters of chapter 2 should have a small introduction paragraph. Further, I agree with the comments of R1 on the equations 1, 2, 3, 5, 9c, 12, 16 and with the comments of R2 on the equations 4, 7, 14, 26, 31, 52.

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#### Specific comments

I think it is not very clear how the amalgamating, expanding, contracting or splitting and adding of layers works. For example, in p. 23 L 21 it is not obvious what the mentioned ‘numerical criteria within the model’ are. I would explain these in detail somewhere in the beginning of chapter 2.

p. 6 eq 2 and eq 3: It seems odd that the interpolation of values between levels  $b-1$ ,  $b$  and  $b+1$  and not only on  $b-1$  and  $b$ .

p. 10 Line 5-8:  $\varphi_{SWS}$  is defined only in text form and not as an equation, yet it is used in equation 6. There is the danger that  $\varphi_{SW}$  defined in eq 10 will be confused with  $\varphi_{SWS}$ . I suggest mentioning early on in this subchapter how you approach calculating  $\varphi_{SWS}$ .

p. 12 eq 17: formula only for forced convection? Wind speed at what height? What are the units? I would introduce first the concepts of sensible heat (free and forced convection) and latent heat (evaporation and condensation) before showing the equations.

p. 18 L10: An intro with possible conceptual options to reproduce a surface mixed layer would be good. I would like to know how the chosen approach of a bulk mixed layer depth compares to other approaches in other models (e.g. k-epsilon turbulence closure with Fickian diffusion) and what the consequences of this approach are.

p. 22 L 15 and eq 44 and eq 45: I think an explanation of the concept behind this numerical scheme is necessary

p. 24. Figure 10: This figure is not enough self-explanatory to me.

p. 28 eq 60: Shouldn’t  $G$  not just be another term in eq 4 for all cases?

p. 40 lines 21-24: move this sentence to the intro

p. 40 L 24 – 26: This needs to be better explained.

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## List of Corrections

- p. 1 lines 31-32. Consider splitting sentence as it contains different ideas.
- p. 2. Line 1: write only 'standing' as this word is comprehensible and you don't use lentic in the rest of the text.
- p. 5 Line 17. Write the definite instead of the indefinite integral or otherwise phrase it in a sentence.
- p.6 eq 1: could be simplified
- p.6. Line 11-18: Should this go in the introduction?
- p. 9 eq 9b: Contrary to R1, I managed to get the peak at 80°SZA. The equation seems to be the same as used in fig 3.
- p. 9 eq 9c: Specify units, also see comments of R1.
- p. 9. L 6:  $U_x$  is wind speed at which height?
- p.9 figure 3: Specify the values of relative humidity, wind speed and atmospheric diffusive radiation used for eq 9c. I agree with R1 that the label is wrong, but I think it should be  $SZA = 360^\circ \Phi_{zen}/(2\pi) = 180^\circ \Phi_{zen}/\pi$
- p. 11 eq 16 a-d: Use either only °C or only K in equations, now they are mixed. I found eq 16 c in Henderson-Sellers (1986) but strangely I couldn't find this equation in Brutseart (1975).
- p. 12 L 12: no units specified for latent heat of vaporization
- p. 13 L 9 and L 13: I guess the authors meant eq 17 -18 and not eq 16-17?
- p. 16 L 6: 'penetrating the surface', which surface?
- p. 20 eq 35: What is  $u_0$ ?
- p. 22 eq 39: Please explain the variables in this equation.

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- p. 22 L 10. Should be eq 38, not 42
  - p. 22 eq 43: check index, should be  $h_l$  not  $h_i$
  - p. 23 L 17: typo: entrain (not entrains)
  - p. 23 L 18: typo: the (not th)
  - p. 34 figure 17: increase font size and size of arrows.
  - p. 34 L 19: Insert the references into the place holder
  - p. 35 L 26: Who is testing these 'Wrappers' and examples? What is a wrapper?
  - p. 37 L 13: What is HTCondor?
  - p. 27 L 16: Start a new paragraph at 'GRAPLER's Web service ...' to highlight this idea.
  - p. 40 L 24 – 26: Explain better.
- References Formatting: Some parts are underlined, remove it. Change all to coherent formatting.
- P. 49 L 23, 25 same author, write same initials.
  - P. 51 L 13, is there a translation of this Japanese paper? Check the year (2014 in text, here 2015)

## Appendix:

Table 1: If there is no default variable, can you give a range for snow density, compaction coefficient, and thermal conductivity of snow?

Table 1: Latent heat of fusion: remove the trailing zero 334

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Interactive comment on Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2017-257>, 2017.

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