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Interactive comment on "Parameter sensitivity analysis of a 1-D cold region lake model for land-surface schemes" *by* José-Luis Guerrero et al.

Anonymous Referee #2

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Review of 'Parameters sensitivity analysis of a 1-D cold region lake model for land-surface schemes' by Guerrero et al.

General comments This is a reasonably written paper describing an interesting topic in environmental modeling and numerical weather prediction: 'How do lakes interact with their overlying atmosphere and to what extent can lakes modify their surrounding climate, and the uncertainties in these interactions'. A number of previous papers have addressed similar topics in the past (e.g. Dutra et al. 2010; Balsamo et al. 2012), but the strength of this current paper is the uncertainty estimation that it provides. Specifically, the authors introduce a third-party toolbox and the GLUE methodology to perform a sensitivity and uncertainty analysis of the different surface heat fluxes

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simulated by the Canadian Small Lake Model (CSLM), a one-dimensional integral lake model. The authors focus their study on a small lake in northern Canada, which is a good study site as small lakes are the most abundant at the global scale (see further my notes in the specific comments below). Within their sensitivity analysis, the authors find that the light attenuation coefficient, Kd, is the most important parameter controlling model performance and that variable Kd provides the highest uncertainty in surface flux estimates. I don't particularly find this surprising, as others have found that water clarity can have a considerable influence on lake stratification and the turbulent heat fluxes (see Heiskanen et al. 2015) and can also considerably influence the diurnal cycles of heating and cooling in lakes (Woolway et al. 2016), but I do find this an important point to highlight and one that deserves some attention. While I think this paper will be of interest to those who focus on the integration of lakes within the climate system and for Numerical Weather Prediction, I strongly believe that the paper would be improved if there were more focus on the analysis and the results were put into context of the published literature. Often I found some of the most relevant literature being ignored and/or overlooked and some references, which were included in the text, seem inappropriate or irrelevant. One of my main criticisms is that a thorough literature review is needed to strengthen the introduction and discussion of the results. I provide some examples of relevant studies in this review, but there are many others which the authors should also look into. I strongly suggest a thorough review of the current literature prior to publication. I find it surprising that the authors specify that Kd is the most important parameter controlling model performance, but do not include any detailed measurements of Kd. In particular, it is very likely that the lake has a different Kd to that estimated from the model sensitivity analysis. Overall, I think there is some potential for this paper to be revised sufficiently to make it a valuable contribution to the scientific literature. However, addressing all of the points raised below are needed, in my opinion, prior to this paper being considered for publication in HESS.

Specific Comments Unfortunately the Downing et al. (2006) estimates of global lake size and abundance are no longer supported. Many studies have since shown that

the Pareto distribution does not adequately describe the global distribution of lakes. For example, see Seekell and Pace (2011) and McDonald et al. (2012). A more detailed description of the global abundance and size distribution of lakes are provided by Verpoorter et al. (2014) and more recently by Cael and Seekell (2016). Granted that these recent studies to do not consider the smallest lakes of the world (for example, Verpoorter et al. only consider lakes larger than 0.002 km2), but still the authors should read up on these papers and include the relevant citations.

'They also provide a more immediate feedback through mass and energy exchanges with the atmosphere' - you need some reference for this. As I'm sure you're aware, these fluxes are quite difficult to calculate (see Woolway et al. 2015a). Further information on these fluxes is needed, in my opinion. Additional information here will allow others who are not experts in the field to understand better the kind of interactions you are talking bout.

Tanentzap et al. (2008) did not consider the influence of variations in thermocline depth on fluxes to the atmosphere, thus I don't think this reference is appropriate.

'Rinke et al. (2010) illustrate the feedback between phytoplankton and thermal structure...' - There are other studies which you could also cite. For example, Mazumder et al. (1990) showed this over two decades ago. There are many other studies since then which I think the authors should read up on.

It may also be worth mentioning that, on a regional scale, Samuelsson et al. (2010) found that the presence of lakes induces a warming on the European climate, and an observational study by Rouse et al. (2005) found that high-latitude lakes strongly enhance evapotranspiration when added to a landscape. A useful study, which I think the authors should cite, is Heiskanen et al. (2015). The authors should also look at the papers cited by Heiskanen et al. (2015) as these will be of direct relevant to this study. In addition, a paper by Rose et al. (2016) describes that water clarity can either amplify or suppress lake surface water temperatures, which in turn will influence their

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interaction with the atmosphere. Please read the Rose et al. (2016) paper and look at the references within.

A lake depth sensitivity analysis was undertaken by Balsamo et al. (2010) and might be worth mentioning also.

P2L26 - What is a small lake? How do you characterize a lake as small?

P3L24 - Water clarity can have numerous other influences on lake temperatures. I think this section needs to be expanded. A few examples include its influence on the thermal structure of lakes (e.g. Persson and Jones 2008), its influence on the absorption of heat during the day and greater release in the evening leading to larger diurnal cycles (Woolway et al. 2015b) and influencing the likelihood of diurnal stratification as well as seasonal stratification. Also, studies have shown that surface waters have been browning over the last few decades (Roulet and Moore 2006). All of these points should be included and expanded.

Italics aren't needed for the description of all units.

P12L30 - The authors state that Kd is not often measured and measuring Kd for every lake might be a practical impossibility. In my opinion, this is one of the largest uncertainties in the inclusion of lakes in NWP. For example, in ECMWF's IFS Kd is assumed equal to 3 for all lakes, which could result in numerous biases in the turbulent heat fluxes. While I somewhat agree with the author's statements here, it may also be worth mentioning that satellites can estimate Kd, so there are possibilities in improving lake surface water temperature simulations. For more information, see Torbick et al. (2013) for information on how satellites can potentially be used to estimate secchi depth, which can be used as an indicator of Kd.

P13L3 - 'this kind of monitoring has never been performed' - This isn't true. Lake monitoring stations now often have light sensors above and below the water surface and are thus used to determine water clarity and Secchi depth observations are tradition-

ally recorded. I suggest the authors look through the literature to find examples of where they've been used. I'm almost certain that this information has not been used in NWP or climate modeling, but I hope in the future meteorologists and limnologists will work closer to address this and similar issues. A literature search on this topic is also needed in my opinion.

P13L9 - I don't think this can be a main conclusion as unfortunately it is not unknown. For example, see Heiskanen et al. (2015).

There doesn't appear to be much discussion in this paper. I would recommend restructuring the paper to include separate 'Results' and 'Discussion' sections and perhaps reduce the conclusion to one or two paragraphs. This, in my opinion, would make the paper easier to digest.

I don't find many of the figures presented in the paper very informative. They seem to all show similar results. Much of this information could be shown in 1 or 2 figures, in my opinion.

Figure 1 needs more information. For example, can the authors add a smaller inset map to show where the lake is? Also, the figure would need a 'scale ruler' so that the reader can easily interpret the size of the lake.

At first glance, I don't particularly understand Fig. 8. It isn't clear what the grey regions represent as one would expect the grey area to be an envelope that surrounds the main (blue) line?

Fig. 9 - Isn't irradiance a term often used to describe solar irradiance and not the turbulent fluxes? Also, why isn't there an x-label on the bottom panels?

Fig. 10 - I'm not sure how to interpret this figure. Can you please provide a better description of what we're seeing? I think a more detailed discussion of this figure should be given in the text.

Table 1 - The square brackets appear the wrong way round in the fourth column.

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