

Geosci. Model Dev. Discuss., author comment AC1  
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## Reply on RC1

Anthony Bernus and Catherine Ottlé

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Author comment on "Modeling subgrid lake energy balance in ORCHIDEE terrestrial scheme using the FLake lake model" by Anthony Bernus and Catherine Ottlé, Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-432-AC1>, 2022

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This article describes the implementation of the FLake lake model in ORCHIDEE. A subgrid approach has been adopted to represent lakes of different depths in the same model mesh. This ORCHIDEE-FLake coupling was evaluated with long offline simulations using reanalyses at resolutions of about 25 to 50 km. Thus, surface temperature and ice phenology have been evaluated on a thousand lakes. It is shown that the variability of atmospheric forcing has a strong impact on the dispersion of the results. Moreover, the tile approach for lakes of different depths has a significant effect on the ice formation date compared to a simulation where this subgrid approach is not activated. The impact of the lake tiling on the surface temperature is not significant.

This article describes a work to improve the representation of the surface and its processes by implementing a lake module. The work is based on work already done in other models and brings a novelty with the subgrid representation of lakes. This work can be tested in the LMDZ climate model and will undoubtedly help to explain or even reduce some of the temperature biases in high latitudes.

The article is well structured and clearly shows the contribution of the subgrid approach adopted to represent the lakes in this multi-tile system. However, some parts need to be clarified and my major comments concern the quality of the figures which is not sufficient for some of them and therefore deserves to be improved for a better reading of the manuscript. Data availability is not described.

Response: We thank you for reviewing our manuscript and sharing your suggestions and comments with us. We have thoroughly revised our paper following your advices and especially re-done and improved the quality of all the figures which are now all in the portrait mode in our revised version.

Major comments:

The figures need to be improved. In particular, the units of the plotted fields are often missing (Fig. 2,3,4,5,7,8,10). For some of them the size is too small for a correct reading.

P11: Figure 2 is not satisfactory. Reading in landscape mode is not comfortable for the reader. A portrait orientation would be better. Also, the legend is wrong. Then add a, b, c, d to each of the panels and refer to them in the legend and in the discussion. The size of

the thumbnails makes it almost impossible to read them: in my opinion we can remove the first map which lists all the lakes (depths from 1 to 500m) and be satisfied with the 3 classes, then choose the portrait mode and put 6 maps on the vertical: depth 1, fraction 1, depth 2, fraction 2...

Response: The new figure includes all these modifications. First, we have deleted the first case with all the lakes. Second, we have followed the recommendations on the figure layout. Third, we have corrected the legend.

P14: the figure 3 deserves to be improved. Units are missing on the longitudinal and latitudinal mean graphs. On the top right graph, 0, -10 and -20 appear: why this "-" sign? The legend is reversed (colors).

Response: In the new figure, we added all the label axes and the colorbar label. We have changed with a color more appropriated. We have added a vertical axis to take off the illusion of "-" in front of the 0, 10 and 20.

P19, L405-409: the errors cannot be read easily from figure 7, especially for small errors. A table containing the errors with in x the depths between 0 and 10m every 2m then between 10 and 20m every 5m and finally every 10m up to 50m, and in y the cumulative density function for 95, 90, 85, 80 and 50% the values of the errors as a function, would help in reading figure 7.

Response: The new figure 7 should be more readable with a new color scale and larger characters. We therefore, don't think that it is necessary to add a table besides.

p25: figure 10 is difficult to read because it is too small, and the maps are presented in landscape mode, which does not facilitate reading. You have to enlarge each thumbnail (you have to zoom in +400% to see something, and some readers still use the paper format to read the articles). Also, the units are missing on the color bars.

Response: We have added a title on the colorbar and have enlarged each thumbnail. The figure is now in portrait mode and the missing units have been added.

The data availability is mandatory in many journals and GMD attaches great importance to this aspect. In this manuscript, this section is missing and should be added.

Response: This section has been added in the revised version of the manuscript. All the data used are on open access and available online. The data of our simulations are available on request to the coauthors.

Minor comments:

P3, L60: MacKay's model did not participate in the LakeMIP intercomparison exercise.

Response: Yes, you are right, it is a mistake that was corrected in the revised manuscript.

P3, L74: Mlake was not developed in SURFEX but in the SURFEX environment to allow for water exchange between lakes, rivers and land surfaces.

Response: Corrected.

P5, L127: the different forcing are presented and later it is said that their variability is large and that they have a strong impact in particular on the surface temperature. To clarify this point it would be good to show how the forcing differ: for example, by showing

average annual cycles of air temperature, radiation...

Response: It is difficult to map the variability of all the forcings at the global scale, since the differences/biases vary in time (seasonally) and spatially for all the variables. We have seen that depending on the lakes and on the climate encountered, the differences can be explained mostly by the air temperature or the longwave radiation. We have added this information in the discussion of the results, where the impact of the atmospheric forcing variables was already discussed .

P5, L140: the methodology is not explicitly presented under this link. Please give more details on the methodology.

Response: This sentence was misleading and it is better to remove the link, the methodology is described in Viovy (2018) and we added another reference (Wei et al., 2014) which better describes the methodology : Wei, Y., Liu, S., Huntzinger, D. N., Michalak, A. M., Viovy, N., Post, W. M., Schwalm, C. R., Schaefer, K., Jacobson, A. R., Lu, C., Tian, H., Ricciuto, D. M., Cook, R. B., Mao, J., and Shi, X.: The North American Carbon Program Multi-scale Synthesis and Terrestrial Model Intercomparison Project – Part 2: Environmental driver data, *Geosci. Model Dev.*, 7, 2875–2893, <https://doi.org/10.5194/gmd-7-2875-2014>, 2014.

P6, L163: missing precipitation forcing that play a primary role when the snow module is activated.

Response: Sorry, precipitation is indeed playing a key role in freezing conditions when snow can accumulate. It was forgotten in the list of the forcing variables and has been added in our revised document.

P7, L178: the snow depth is calculated through an evolution equation that considers the snow precipitation rate in the time step.

Response: Sentence corrected.

P9, L236: "time split": how is this effect implemented in the coupled model? Is it in FLake, in the ORCHIDEE driver, or in a call interface to FLake? Please give details on this aspect, maybe proposing an appendix that describes it if it is justified.

Response: The time split was implemented in FLake (only on the snow module) and not in the ORCHIDEE driver with a simple loop. We added it in the revised version.

P10, L255: the permanent water surfaces come from ESA-CCI? If so, please specify.

Response: The permanent water surfaces of the CCI-Land Cover database has been removed from the ORCHIDEE PFT maps. The lake fraction in the grid cell was derived from the HydroLAKES database which provides the depth of the water bodies at the same time. In order to have the sum of the various land cover fractions equal exactly to unity, we have imposed the HydroLAKES fractions and rescale the other grid fractions coming from CCI. We have reformulated this sentence in order to be clearer.

P12, L276: The Caspian Sea is treated as a lake: what motivated this choice?

Response: In the ORCHIDEE land surface model when coupled to the other modules of the Earth System Model, the Caspian sea is simulated thanks to the ocean model NEMO. When ORCHIDEE is run offline, we have chosen to apply the FLake model, which is better than to consider that the Caspian sea is a bare soil, like it is done in the previous version of the code. We can note that in some ESMs, the Caspian sea is simulated with a lake model

instead of an ocean model and has shown to give better results (see paper of Choulga et al., 2019 for example )

P15, A329: the comparisons presented in this section refer to the year 2012 with no reason given. How does 2012 compare to other years? Do we see the same annual cycles? How do they differ? The results would have been more robust if Figure 4 had presented the results of the average annual cycle calculated over 2000-2016 as for 4.2.

Response: In figure 4, we present the comparison of LWST simulations to observations. Because of the interannual variability of the forcing data and of the observations, a mean average seasonal cycle over a number of years is certainly interesting to highlight systematic biases but less to discuss the model-data discrepancies given the observations uncertainties (better assessed by looking at daily variability). It is difficult to plot more than one year, and we chose 2012 as an example. The biases that we have highlighted are present in other years. In the revised version, we have finally switched to 2010, because there were more data available on lake Victoria, but the conclusions were pretty the same as you will see.

P15, 341: there are no continuous observations on Lake VICTORIA: any explanation? Is this the case for other years between 2000 and 2016 and how does it affect the statistical results?

Response: It was the case for Year 2012 but not for all the years. So, we have switched to 2010 presenting more observations in the revised figure to show longer time series.

P16, L359: it would be interesting to add a comment on Baikal which is not frozen until mid-December while the model has a very cold temperature and therefore a strong negative bias.

Response: The comment was added in the revised version. The differences are probably linked to the limits of FLake 1D freezing model which do not account for fractional ice cover. This point is also more deeply discussed in the discussion part of the revised manuscript.

P16, L364: the decomposition of the RMSE into SB, SDSD and LCS should be better highlighted in the appendix. What is the relationship between the 3 and how to interpret them should be added?

Response: The sum of the 3 components is equal to the MSE, we have modified in the appendix the presentation of the decomposition and hope that it is more clear in the revised version.

P16, L365: comparison to the ensemble mean is not clear: what I understand is that each point is the RMSE (e.g.) calculated for each forcing for the 1000 selected lakes. But the ensemble mean is the average of the RMSEs of the 5 simulations, right? It should be clarified in the text. The units on the y-axis should be added.

Response: We have better explained what is plotted in this figure in the revised version. The figure was redone and the units were added

P16, A375-378: the explanation is not clear: what shows that LCS and SB explain 50% of the bias? The reader should be guided.

Response: This part was rewritten to better explain what is plotted (see lines 400-403).

P16, L381: "the bias is mostly positive": this conclusion is not obvious when reading figure

5: the signed bias varies from -1 to +1 and on the right it is SB2 which is plotted, thus positive.

Response: The figure has been revised to better show the differences between the simulations. We hope that it is more clear in the revised version

P19, L390: Why does the E2OFD forcing have better scores than the others? Which component of the forcing plays the most?

Response: We can not give a clear answer, we guess that the better scores obtained by the 2 best resolution forcings are the result of their higher spatial resolution which allows to represent the atmospheric conditions above the lake surfaces in a more realistic way. But since we do not have any in situ atmospheric data to evaluate the forcings, it is difficult to be more affirmative.

P19, L403: it is more a histogram than a PDF for which the sum of the values is 1.

Response: Agree, it has been corrected in the manuscript.

P23, L432: CRJ and CRJ3med do not analyze water budgets, but rather surface energy balances (latent heat flux is an energy flux).

Response: Sorry, the sentence was misleading and was corrected in the revised version.

P27, L495: "used in this process": to be reworded to clarify the point

Response: Will be corrected

P27, L512: and so do LWST and ice phenology

Response: Agree and corrected

P29: add the link between RMSE and the other components discussed in the manuscript; the superscript "F" appears in the LCS formulation and has not been defined

Response: Corrected

Technical comments:

P3, L62: models instead of Models

Response: The change has been done

P5, L118: the ARC-Lake database

"project" was changed into "database"

P5, L120: extra parenthesis after 0.7 K; bias instead of biase; "for day" and "for night" could be replaced by "during daytime" and "at night"

Response: The parenthesis has been taken off, the "e" has been removed and for day and for night has been replaced

P5, L132: a space is missing before WFDEI

Response: The space has been added

P7, L185: units should be homogenized throughout the manuscript (degrees Kelvin and not Celsius, superscript notation, italics...)

Response: Done

P10, L263: use etc. or ... but not etc...

Response: "etc" has been removed

P12, L279: FLake instead of Flake

Response: "l" has been replaced by "L"

P12, L298: CNC3med appears twice.

Response: The second occurrence has been deleted

P14, A324: put a "-" sign in front of 11 days

Response: the sign has been added

P15, L331: eight instead of height

Response: "h" has been removed

P15, L334: year instead of Year

Response: The capital letter has been removed

P16, L362: corresponding instead of correct?

Response: "corresponding" is more suitable, so it has been changed

P16, A369: extra parenthesis before between; 3.16 and 2.82 shall be followed by K

Response: The parenthesis has been taken off and the units have been added

P19, L384: missing units for RMSE

Response: The units have been added

P19, L402: median depth

Response: "depth" and "median" have been swapped

P23, L453: 30°N

Response: "N" has been added

P23, L459 Lake Superior

Response: It has been changed

P27, L495: techniques instead of technics

Response: It has been corrected

