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Interactive comment on "Multimodel simulation of vertical gas transfer in a temperate lake" *by* Sofya Guseva et al.

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1. (1) Concerns arise however about the way one of the models - FLake - was treated in the study. The authors correctly state in the description of the model experiments that FLake "stands aside from the other 1-D models due to the . . . bulk-structure which employs the concept of <temperature profile> self-similarity. . . ". This high level of parameterization ensures computational efficiency of the model, which was primarily designed for prediction of surface temperatures in global/regional climate models and numerical weather prediction (NWP). On the other hand, the model parameterizations put some constraints on the model application to real lakes. One crucially important feature of FLake is that the model equations are derived in the assumption of preserving the heat capacity or volume of the lake. In this regard, the "baseline" configuration

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applied in this study with the maximum lake depth as model input is inappropriate for FLake and would produce a priori incorrect results. Another issue of the parameterized model refers to correct choice of the few “shape factor” parameters determining the stratification pattern. The latter is not resolved in FLake numerically, but parameterized via few “shape factor”-constants related to the spatial integrals over the stratified layer. Several recent publications, including co-authorship of one of the authors of the present study, (Shatwell et al., 2016; Kirillin et al., 2017; Shatwell et al., 2019; Su et al., 2019) discussed the appropriate choice of the shape factor constants in FLake and have demonstrated that the set of constants used in the NWP-version of the model should be amended if the vertical thermal structure is in question apart from the lake surface temperatures. In particular, the unrealistically weak deep stratification and the corresponding high depth of the surface mixed layer, as reported in the present study, are the results of applying the NWP-constants together with the maximum lake depth as the model lake depth. Hence, the FLake-outcomes discussed here are useless or even misleading for the potential FLake-users. I see two ways of possible modification of the study: (i) excluding FLake from the study completely, confining the set of tested models to four models; (ii) re-designing the FLake-experiments in the corrected way with corresponding changes in the results/discussion.

(2) We generally agree with these suggestions of the referee and have re-designed experiments with FLake model testing the sensitivity of the model to one of the constants determining "shape factor" – dimensionless relaxation constant C_{rc}. In the current study, we have got the best agreement with the measured temperature profile using the value $C_{rc} = 0.3$ (in comparison with the standard value of 0.003) and chose this setting for the baseline experiment RefSim. The model now reproduces the temperature profile much better and we conducted other experiments including the one with mean lake depth and varying light attenuation coefficient with $C_{rc} = 0.3$.

(3) Page 7 line 15: The concept of the self-similarity in the FLake model (Sect. 2.2) includes the "shape factor" coefficient C_θ, which determines the vertical temperature

profile below the mixed layer. Evolution of this parameter is controlled by a relaxation time scale t_{rc} (Mironov, 2008). This time scale includes the dimensionless relaxation constant C_{rc} having a default value of 0.003 in the model. This constant is a calibration parameter which is generally individual for each lake (Shatwell et al., 2016, Kirillin et al., 2017). We tested the sensitivity of the model to the variation of C_{rc} using values 0.03, 0.3, 0.5, 1, 2, 3, 30 and achieved the best agreement with the measured temperature profile using $C_{rc} = 0.3$ (for details, see Sect. 3.1). In the following sections, this C_{rc} setting is used in RefSim and other experiments with FLake model.

Page 10 line 11: In RefSim we test the model with different values of C_{rc} (see Sect. 2.3 above). The best agreement with observed temperature profile we get using $C_{rc} = 0.3$. In particular, the error ($RMSE_c$) for surface temperature reduces from 3.4 $^\circ$ C (using standard value of $c_{relax} = 0.003$) to 2.5 $^\circ$ and becomes close to other models. At the depth of $\sim$ 6-10 m $RMSE_c$ reduces from 5.7 $^\circ$ C (using standard value of $c_{relax} = 0.003$) to 5.2 $^\circ$. In addition, $RMSE_c$ reduces from 3.3-0.7 $^\circ$ C to 1.8-0.2 $^\circ$ C at the depths 20-27 m.

We added new figures with new results for FLake model to the main manuscript: Fig. 2, Fig. 3, Fig. 4 ; add new figures to SI: Fig. S2; changed metrics for FLake model performance in Tables: S2, S3, S4.

2. (1) Regarding the biogeochemical part, the study would benefit from an extension of the discussion on possible ways of improving the representation of biogeochemistry, in particular, the deep oxygen (chlorophyll) maximum in oligotrophic lakes, and the vertical distribution of carbon dioxide across the water column.

(2)-(3) Page 19 line 34: Successful representation of maximal O_2 content below mixed layer during summer may be an important modelling skill for simulating correctly CH_4 in a lake because the former acts as a sink region for the latter. Furthermore, realistic oxygen concentration reduction during periods of stable stratification means that the respective CO_2 production from aerobic organic matter decomposition is reproduced reasonably as well.

Page 21 line 21: As stated in the previous section, a realistic decay of oxygen content during stratified periods in ALBM and LAKE models suggests that CO_2 amount produced by aerobic decomposition of organic matter both in water column and in the top part of sediments is reasonably simulated as well. Satisfactory agreement of computed oxygen in the mixed layer and below with observations implies that photosynthesis minus respiration rate is fairly captured as well, and so do the models for CO_2 gain or loss due to these processes. Hence, the primary drawback of the models used in respect to DIC simulation is likely to be not explicitly simulating transport of carbon species from catchment to a water body. Thus, modelling approaches coupling the catchment and a lake presented recently (Futter et al., 2008; Duffy et al., 2018; McCullough et al., 2018) should be elaborated and wider used.

3. (1) Note also that the temperature profile within the ice cover in FLake is not assumed to be linear, but parameterized via a time-varying shape-function with a linear asymptotic.

(2) Yes, that is correct.

(3) Page 5 line 20: In FLake model, the temperature profile within the ice cover is parameterized via a time-varying shape-function having a linear asymptotic.

References: 1. Duffy C.J., Dugan H.A., Hanson P.C.: The age of water and carbon in lake-catchments: A simple dynamical model, Limnol. Oceanogr. Lett.,Vol. 3, No. 3, pp. 236–245, https://doi.org/10.1002/lol2.10070, 2018.

2. Futter M.N., Starr M., Forsius M., Holmberg M.: Modelling the effects of climate on long-term patterns of dissolved organic carbon concentrations in the surface waters of a boreal catchment, Hydrol. Earth Syst. Sci., Vol. 12, No. 2, pp. 437–447, https://doi.org/10.5194/hess-12-437-2008, 2008.

3. Kirillin, G., Wen, L., Shatwell, T.: Seasonal thermal regime and climatic trends

in lakes of the Tibetan highlands, Hydrol. Earth Syst. Sci.,21(4), 1895-1909, https://doi.org/10.5194/hess-21-1895-2017, 2017.

4. McCullough I.M., Dugan H.A., Farrell K.J., Morales-Williams A.M., Ouyang Z., Roberts D., Scordo F., Bartlett S.L., Burke S.M., DoubekJ.P., Krivak-Tetley F.E., Skaff N.K., Summers J.C., Weathers K.C., Hanson P.C.: Dynamic modeling of organiccarbon fates in lake ecosystems, Ecol. Modell. Vol. 386. pp. 71–82, https://doi.org/10.1016/j.ecolmodel.2018.08.009, 2018.

5. Mironov, D. V.: Parameterisation of lakes in numerical weather prediction. Description of a lake model, COSMO Technical Report 11,Deutscher Wetterdienst, Offenbach am Main, Germany, 2008. 6. Shatwell, T., Adrian, R., and Kirillin, G.: Planktonic events may cause polymictic-dimictic regime shifts in temperate lakes., Sci. Rep.-UK,256, 24361, https://doi.org/10.1038/srep24361, 2016.

Additional comment: Attached file contains all changes in the manuscript and SI mentioned above.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-146/hess-2019-146-AC1-supplement.zip

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