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Interactive comment on "Future projections of temperature and mixing regime of European temperate lakes" *by* Tom Shatwell et al.

Anonymous Referee #2

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Future projections of temperature and mixing regime of European temperate lakes by Tom Shatwell, Wim Thiery and Georgiy Kirillin is dedicated to qualify the role of individual lake characteristics, like water temperature, vertical mixing, ice formation, and water transparency, in their response to regionally homogeneous 2 meter air temperature warming. This study is designed to analyse the effects of seasonality on the response of northern temperate lakes to projected future warming. Changes in lake mixing regime reflect climate change impact on lakes, understanding how the seasonality of warming interacts with lake stratification and ice cover is vital to interpret differences in future lake warming trends. Four intensively studied German lakes of varying morphology and mixing regime (two shallow and two deep lakes, where each pair is similar in terms of morphology but different in terms of water transparency and/or

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Discussion paper

mixing regime) situated within a distance of $\leq$ 150 km from each other were modelled with a one-dimensional lake model FLake, which is based on a two-layer parametric representation of the vertical temperature structure. The upper layer is treated as well-mixed and vertically homogeneous. The structure of the lower stably-stratified layer (lake thermocline), upper layer of the bottom sediments and the ice cover are parameterized using a self-similar representation of the temperature profile. For each lake FLake model was forced with an ensemble of 12 climate projections (RCP4.5) from 2006 up to 2100. The ensemble was assembled from different downscaled global climate models (MPI-ESM-LR, EC-EARTH, CanESM2, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-ESM2M, MIROC5, NorESM1-M) each providing lateral boundary conditions to the RCA4 regional climate model. All simulations were performed at a horizontal resolution of 0.44°. Main results are: (i) lakes warming at 0.10 – 0.11 °C decade-1, which is 75 – 90% of the projected air temperature trend; (ii) advanced ice thaw and summer stratification by 1.5–2.2 and 1.4–1.8 d decade-1 respectively, less sensitivity of autumn turnover and winter freeze timing; (iii) summer mixed layer depth not affected by warming but sensitive to changes in water transparency; (iv) transparency decrease dampens the effect of warming on mean temperature but amplifies its effect on stratification; (v) heat store and lake respond to climate warming is determined not only by lake morphology, but also by mixing regime. Altogether this study suggests that warming over the next century will gradually shift many temperate dimictic lakes towards a predominantly monomictic regime, particularly since projected warming rates are highest in winter and spring, with deeper lakes shifting before shallower ones. On the other hand, shifts from polymixis to dimixis are more likely to occur due to a change in transparency or depth than due to climate warming alone.

General comments Paper addresses relevant scientific questions within the scope of HESS, namely internal physical mechanisms determining the response of lakes to a future warmer climate. It presents new analysis of northern temperate lakes variables in a projected moderate climate warming scenario (Radiative Concentration Pathway 4.5, RCP4.5). In addition, all lakes used in this study have different combination of morphology and mixing regime, yet they all are situated rather close to each other, what makes analysis even more interesting and relevant. Paper reaches substantial conclusions on lake vertical mixing, ice formation dates and water transparency behaviour according to the projected climate change. Methods and assumptions are valid and rather clearly outlined, the only clarification is needed for light extinction constant for Arendsee. Paper results are sufficient to support the interpretations and conclusions presented. Model experiment description and explanations of result calculation methodology are sufficiently complete and precise to allow their reproduction by fellow scientists (good traceability of results). Also, authors give possibility to download initial data or model output. They give proper credit to related work and clearly indicate their own new/original contribution to the analysis of lake main variables in future warming climate and indicate each authors input. Paper title clearly reflects the contents of the manuscript, abstract provides a concise and complete summary of the research done. Overall presentation of the paper is well structured and clear, language fluent and precise, all mathematical formulae, symbols, abbreviations, and units are correctly defined and used, number and quality of references are appropriate.

Specific comments Although paper gives an impression of a proper well-written, well-referenced and well-structured manuscript, I think that following clarifications/additions should be done prior publication: 1. p4, l13 - could you add some explanation how constant 2.17 was derived? 2. p6, l5 - could you specify on the technique used to detect lake variable changes for rather small lakes (lake water surface area vary between 0.3-7.3 km2) if simulations were performed at a horizontal resolution 0.44°? Or this is only atmospheric forcing resolution? 3. p6, l17 - what period of data was used to empirically determine the value? 4. p27, Fig.5 - Stechlinsee and Arendsee patterns look very similar, horizontal and vertical grids would help to better see if any difference is present. 5. p28, Fig.6 - mixed layer depth values especially for Stechlinsee and Arendsee are not visible (as well as winter and autumn periods for all 4 lakes), as it was mentioned that there are 58% and 75% respectively that these lakes are ice-free is it possible to show values on the graph (extending y and x axis)? Or an explanation why it shouldn't be done? 6. p30, Fig.8 - could you explain an interesting behaviour pattern of Heiligensee in annual mean temperature graph? 7. p32, Table1 - could extra line with ice duration in days be added? 8. p33, Table2 - some correction with table rows is needed.

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