Response to Reviewer 2

- The authors use an extensive dataset on water temperatures from three neighboring lakes to test and validate a one-dimensional lake temperature model. The model is subsequently used for reconstruction of the thermal and stratification regime of the lakes during the last century and for sensitivity studies exploring the lake response to changes in mean annuals of air temperature and wind speed. The idea behind the sensitivity experiments is to elucidate the dissimilarity in the response of lakes with different depths and surface areas subject to identical external atmospheric forcing. The problem statement is clear. The methods are generally relevant to the questions stated in the study (except the application of a 1d time-depth model to investigation of the effects of horizontal extensions on lake thermics, which requires additional justification, see below).

  The authors thank Reviewer 2 for taking the time to review and provide detailed and insightful comments on the manuscript. These point-by-point comments or questions will be carefully addressed in a revised version of the manuscript.

- My major concern is the analysis of the results, which looks superficial, and representation of the outcomes, which is lengthy and poorly structured. The analysis is confined to descriptive presentation of model outcomes without an insight into the physical mechanisms producing the observed effects.

  We appreciate the comment concerning the analysis of results and structure of the paper. We will restructure the manuscript and revise analysis to address the points raised and provide insight of physical mechanisms producing the observed effects.

- Verbal presentation of trends in lake thermal characteristics covering several paragraphs is exhausting and not really informative.

  The authors thank the reviewer for this comment. We have reduced the presentation of trends and related thermal characteristics within the text by removing those that are extraneous to addressing the problem statement. These information have been incorporated into the figures and tables.

- The manuscript presents a nice set of data and numerical results, which can serve as a basis for a well-thought study, but has little value for the reader in its present form.

  The authors thank the reviewer for the positive comments. We restructure the presentation and put careful thoughts into the manuscript to improve the value of the paper for readers.

- The manuscript requires a more detailed description of the model and discussion on its uncertainties and relevance to the real lake processes; the discussion should be rethought, moving the accent from the descriptive listing of the model responses to varying inputs to the discussion on the physical mechanisms producing the responses.

  The authors thank the Reviewer 2 for this suggestion. We restructure the discussion by moving Sections 4.2 and 4.3 to the Results section; emphasize the results in terms of physical mechanisms that are influencing the simulated and observed responses; and discuss the results in context of ecological and chemical processes within the lakes. Detailed description of the model will be provided without repeating in the papers (Magee and Wu, 2016 in *Hydrological Processes* doi/10.1002/hyp.10996/full, Magee et al, 2016 in *Hydrology and Earth System Sciences*, DOI:10.5194, 20(5), 1681-1702. In this manuscript, we will improve description of physical processes and address parameterization of horizontal processes. Furthermore, we will improve discussion on how the model parameterizations affect the results of our study and how they differ from real lake processes.

Here are some major critical points:

- Effects of lake surface area on the response to the atmospheric forcing are continuously mentioned throughout the manuscript and are among the main subjects of the model sensitivity runs. However, the entire discussion is based on the outputs of a one-dimensional model, i.e. none of the physical processes depending on the horizontal dimensions are modeled directly, but parameterized in the model. Hence, the response of the model outcomes to varying surface area does not necessarily coincide with the response of real lakes to the same perturbations. To analyze properly the modeling results the authors need to (i) present the details on the model parameterizations related to the effects of horizontal advection, wind fetch, horizontally varying depth, and other horizontal processes, such as mixing by internal waves and upwelling of hypolimnetic waters in near-shore areas of the lake; (ii) when discussing the modeling results state clearly which of them can be extrapolated on the real lakes, which horizontal processes are missed by the model, and how it can affect the real situations; (iii) differentiate between the effects produced by increase of the wind energy input due to larger surface area from those produced by increase of the thermal inertia due to larger lake volume, like, in particular, timing of the stratification onset (Section 4.3.1).

  The authors thank the reviewer for this comment. We will present additional details of the model, especially concerning horizontal parameterizations in the text to detail how the model may differ from real lakes and how that difference impacts results concerning the response of lakes to perturbations. As suggested by the reviewer, we will clearly state which horizontal processes are missed by the model and which can clearly be extrapolated onto three-dimensional lakes. Additionally, we will discuss the effects of increased wind energy input due to larger surface area compared to changes caused by increase of thermal inertia as suggested by the reviewer here. This is a particularly important point to investigate when attempting to extrapolate results presented here to a larger variety of lakes.

- Do the lakes have ice cover in winter? The ice model is repeatedly mentioned in the MS, but no results on the ice regime are presented/discussed. Duration of the ice-covered period directly affects timing of the summer stratification onset and summer hypolimnetic temperatures. Any discussion on these variables is incomplete without considering the ice regime.

  These lakes do have ice cover in winter. A paper, Magee and Wu (2016) is in press and details both the ice model and results of changes to the ice regime in the three lakes. As a result, we do not include the same ice cover changes in this manuscript. We agree with the reviewer that timing of ice-off does influence the timing of stratification onset and the duration of mixing in the spring. We will summarize the results on the ice regime in Magee and Wu (2016). We also will add a section in the discussion that describes this interaction and its influence on the results presented here while not reproducing content already presented in Magee and Wu (2016).

  Reference:

  Magee, MR and Wu, CH (2016) Effects of changing climate on ice cover in three morphometrically different lakes. *Hydrological Processes*. DOI: 10.1002/hyp.10996

- Section 4.3 Sensitivity runs can be shortened, at least, to a half and moved from 'Discussion' to 'Results'. The actual discussion should be added, considering the reasons for the observed dependencies, their relevance to the processes in real lakes and novelty of the results compared to the state-of-the-art in this area of research.

  The authors agree with this suggestion from the reviewer. We have moved Section 4.3 to the Results section, shortened the presentation of the results. We will add discussion of the reasons for the observed relationships and their relevance to ecological and chemical processes within the lakes.

Minor comments:

- P3L16 What is 'thermocline shifts'? Please, explain.

  The authors thank Reviewer 2 for pointing out confusion due to our choice of word. 'Thermocline shifts' refers to changes in thermocline depth in response to a driver such as changes in climate. We have changed the line to read "changes in thermocline depth from warming air temperatures may be dampened…" to remove some of this confusion due to previous word choice.

- P6L29 Provide model parameters and simulation specifications here.

  We will provide addition parameters and simulation specifications as suggested within the text.

- P9L7 Add 'summer epilimnetic' to 'temperatures'

  Done, as requested by the reviewer.

- P10L13 and other appearances: replace '0.067 days earlier decade− 1 ' to '+0.067 days decade− 1 '

  Following the suggestion by the reviewer, the authors have made this change to improve readability of the manuscript.

- P10L28 onwards: 'J m^{-2}' are not correct units for heat flux. Provide flux values in understandable units.

  The authors thank the Reviewer 2 for pointing out this error in units. Indeed, the units should be W m^{-2}, and the error occurred by inadvertently carrying over units from the previous sections of text). The units are correct in the corresponding figure. We have addressed the incorrect units in the text.

- P11L17 How lake morphometry can affect the shortwave flux of solar radiation??

  The shortwave flux is the net flux at the surface of each lake. The shortwave flux is controlled in part by albedo of the surface water, by snow ice cover in the lake. Each lake may have slightly different net shortwave radiative flux for each day and average for the year.

- P14L12 and at other places: Schmidt stability is irrelevant to non-stratified lakes and cannot be used for comparison.

  P17L9 See above

  Lake Wingra does stratify on daily or weekly timescales during the summer months (Kimura et al, 2016). Summer Schmidt stability was calculated at daily timescales, and then averaged for each year before comparing coherence among the lake pairs. Higher average stability for one year on Lake Wingra would indicate that the lake experienced more days of stratification during the period. This phenomenon can be coherent with changes in stability for the other two lakes.

  Reference:

  Kimura, N., Wu, C.H., Hoopes, J.A., and Tai, A. 2016, Diurnal thermal dynamic processes in a small and shallow lake under non-uniform wind and weak stratification, Journal of Hydraulic Engineering-ASCE, 142(11), 04016047,

- P17L18 Evaporation depends on surface temperatures, not the deep water temperatures. Explain what do you mean in this sentence, or remove it and find another explanation for the phenomenon.

  Evaporation does depend on surface temperature. Lakes with cooler bottom waters will have more heat transfer from the surface waters to lower levels in the water column compared to lakes that have warmer bottom waters. This heat flux in turn affects the surface temperature of the lake, and consequently affect the evaporation.

- P17L2529 Actually, the main driver for epilimnetic temperatures is solar radiation not air temperature. If air temperature is the 'main driver', what do you mean under 'wind. . . a more dominant mechanism'?

  The authors agree that solar radiation is the main driver for epilimnion temperatures and the driver is not included in this analysis. What we mean is that the main driver of between air temperature and wind speed is air temperature. Wind mixing is a more dominant mechanism to transfer heat from upper layers of the water column to bottom waters, in comparison with molecular diffusion of heat. While air temperature is a main driver to directly influence surface water temperatures, wind speed changes are the main mechanism for dissipating heat to the lower water levels. Both can act to change the response of epilimnion temperatures to air temperature changes. Based on the comments from the reviewer, this section is confusing and unclear for the readers. We will carefully revise the manuscript and also cite references. Overall, we will make it clear the main mechanisms and how they interact with one another..

- P18L14-15 Explain, why stronger winds should produce higher spatial variability in wind stress. How did you estimate changes in turbulence and why do you think they are nonlinear?

  The authors will provide the explanation and address the questions raised by the reviewer. First of all, we do not mean to imply that there is higher spatial variability in wind stress within the lakes themselves. Rather, increases and/or decreases in wind speed in general will result in nonlinear changes in wind stress and turbulence in all lakes. Specifically, wind stress varies with the square of wind speed. As a result, changes in wind speed directly result in non-linear changes in wind stress on the water surface. The DYRESM model parameterizes mixing within the model by estimating the turbulent kinetic energy (TKE) and mixing layers when a potential energy threshold is exceeded. TKE in the model is introduced through convective mixing, wind stirring, and shear mixing using parameterizations that are all non-linear equations and influenced non-linearly either directly or indirectly by wind speed. In other words, linear changes in wind speed yield non-linear changes in the turbulence estimation in the model. This explanation will be made in the revised manuscript both through restructuring and rewording that section and by providing details of model equations and parameterizations. We will make more clear to the readers how the nonlinear response occurs.

- Table 2, Fig. 3: The model seems to produce consistently a positive bias in lake temperatures. Any explanation for this?

  The model results under predict slightly water temperatures. This under prediction is from a combination of averaging meteorological inputs over the day and comparing temperatures output on a daily timestep with observations collected typically during the afternoon when water temperatures are slightly higher than daily averages.

Typos:

- P4L12 Capitalize ‘Secchi’
- P5L29 remove second appearance of ‘Lake Mendota’
- P8L15 replace ‘decreased’ with ‘decrease’
- P12L13 replace ‘difficulty’ with ‘difficult’

All the typos have been fixed within the manuscript. We extend our many thanks to the reviewer for pointing out these mistakes to the authors. Furthermore, we will review and re-review the manuscript carefully for typographical errors before resubmitting a revised manuscript.