Reviewer3:

Review of “Climate Projections over the Great Lakes Region: Using Twoway Coupling of a Regional Climate Model with a 3-D Lake Model”, by Xue et al.

In this study, the authors present and analyze climate projections over the Laurentian Great Lakes regions using an RCM coupled to a 3D lake model. The authors discover that the model setup substantially reduces model biases relative to the driving GCMs, and that future GHG emissions may lead to substantial changes in the near-surface climate in the region. The paper uses model simulations to assess climate change in a robust way (given computational constraints) over a region where many people live and depend on the lakes for their livelihood. The selection of the driving GCM using an objective method is appreciated, though I’m not sure a penalty for distance from the ensemble mean is appropriate. Moreover, the manuscript is well written, and the figures are generally clear. Also, the abstract and introduction reads very well. This study thus overall demonstrates the potential to make a substantial contribution to the scientific literature. However, I have some concerns, which require minor revisions of the manuscript. In general, I could recommend publication of this study if the comments specified below are sufficiently addressed.

General Comments

1. As a general comment, there seem to be several inconsistencies in the naming of experiments, evaluation products, variable names etc. throughout the manuscript, figure labels and figure captions. See specific comments for examples, but please carefully check the entire manuscript for other inconsistencies.

Response: Thanks! We’ve gone through the paper in the revision and ensured the consistency of experiments, names, labels, captions, etc.

2. Difference between using the small and large domain is only briefly discussed for precipitation, though I feel this is important information to share. Does model performance and/or climate sensitivity differ between the two domains? Or do both domains yield very similar results (e.g., for T and LST)? And which domain approach do the authors recommend for future research in this region? Such information could be covered in the discussion section.

Response: This is a good question and was a concern of one of our co-authors. We carefully discussed among co-authors (and another senior researcher at MIT) on the concern of whether or not we should combine these 3 GLARM-large domain model results and 3 GLARM-small domain model results. We have agreed that a simple ensemble average seems questionable because these results are from two sampling groups that can possess different uncertainty distributions. We decided just to use one of the domains for simplicity. We

selected the small domain GLARM, which is similar to other RCM configurations for the Great Lakes climate studies, to represent the uncertainty inherited from different GCMs and enhance the computational efficiency. Nonetheless, please note that the results (GLARM-EA3) are similar to our previous 6-member ensemble results (GLARM-EA6), and all conclusions remain unchanged. Still, we did update the results (including numbers, figures, and tables) throughout the manuscript.

Specific comments

1. L1: No need to reply to this comment, but I am a little surprised that the authors choose GMD as a journal to publish their work. Given that the focus of the study is on the results of the future projections, I believe that a content-journals like for example ESD could have been a better fit for this work. That said, I respect the author's choice of GMD and do not suggest transferring this manuscript to a different journal.

2. L51: does this statement refer to an area or temporal change? Please clarify.

Response: this is corrected as "The overall ice coverage on the five Great Lakes has reduced by 71% from 1973 through 2010" (Wang et al. 2012).

3. L79-82: In this context, it could be interesting to check what the recent scientific results obtained as part of the ISIMIP lake sector tell for the Laurentian Great Lakes. See https://www.isimip.org/outcomes/publications-overview-page/

Response: in ISIMIP lake sector, we checked five relevant papers (listed below) (we already cited Woolway and Merchant 2019.) and we believe the most relevant one is the one we have cited (i.e. Woolway & Merchant, Worldwide alteration of lake mixing regimes in response to climate change, Nature Geoscience (2019) and second-most relevant one is Woolway et al., 2021 Phenological shifts in lake stratification under climate change Nature Communications, 12, 2318 (2021). It has been added to the reference in the revision.

The relevant findings in Woolway and Merchant 2019: By forcing the Flake model with four GCMs under two RCPs, Woolway and Merchant modeled and predicted the changes in the mixing regime of 635 lake around the world. Many lakes around the world are predicted to experience a reduction in mixing events such as the transition of monomictic lake to permanently stratified lakes and dimictic lakes to monomictic lakes. These future changes are expected to be driven by increase in lake surface temperature and significant decrease in winter ice cover duration.
In Woolway et al. (2021) they predicted the changes in the mixing regime of Northern Hemisphere lakes by forcing a four independently developed lake models with four GCMs,

each under three different RCP scenarios. They predict a longer thermally stratified season duration with earlier onset and later break-up, particularly for lakes situated at higher latitudes. The largest change in stratification phenology are projected under RCP 8.5 with stratification onset and break-up, respectively, occurring 22.0 ± 7.0 days earlier and 11.3 ± 4.7 days later, on average across the Northern Hemisphere.

Other papers:

Guo M., et al., Validation and Sensitivity Analysis of a 1-D Lake Model across Global Lakes, Journal of Geophysical Research: Atmospheres, 126, e2020JD033417 (2021)

Luke Grant et al. Attribution of global lake systems change to anthropogenic forcing Nature Geoscience 14, pages 849–854 (2021) (2021)

Iestyn Woolway, et al. Lake heatwaves under climate change. Nature 589, 402–407 (2021)

4. L109: Importantly, RCP8.5 is not to be considered 'business as usual', but a 'high-end emission scenario'. And I suggest referring to RCP4.5 as a 'moderate mitigation scenario'

Response: Corrected as suggested.

5. L160-162: please add one or more refs to back this statement.

Response: Added : 1) Giorgi, F.: Thirty years of regional climate modeling: where are we and where are we going next?, Journal of Geophysical Research: Atmospheres, 124, 5696–5723, 2019. 2) Feser, F., Rockel, B., von Storch, H., Winterfeldt, J., Zahn, M., Feser, F., Rockel, B., Storch, H. v., Winterfeldt, J., and Zahn, M.: Regional climate models add value to global model data: a review and selected examples, B. Am. Meteorol. Soc., 92, 1181–1192, 2011.

6. Table 2: I suggest marking the selected GCMs in bold in this table

Response: Good suggestion. The selected GCMS are highlighted in bold.

7. Figure 3: caption and figure labels say 'GCM' but manuscript says 'AOGCM'. Please make this consistent (I think GCM is used more often nowadays).

Response: GCM is now used throughout the manuscript. AOGCM is removed.

8. Figure 4: Are the wintertime LSTs water temperatures taken only during the ice-free period or the average of the whole season (i.e., combined snow/ice/open water)? Please clarify. Also, caption says 'GLICD' but title of panel e says GLSEA. Also, has the acronym AICE (title panels e1-2) been introduced?

Response: the winter LSTs are the average for the whole season (combined snow/ice/open water), this is added in the caption. The panel legend is corrected as GLICD. AICE is removed and replaced with "ice cover" (AICE is the variable name in the model for Ice cover).

9. Figure 5: legend: GLARM(6MA), while text and other figures use GLARM-EA6. Also, spell out lake names (acronyms are not introduced in paper and they add no value, see also figure 12 and elsewhere)

Response: Lake names have been explicitly added to all applicable figures. And the typo of 6MA is corrected.

10. Figure 7 & 10: is this the standard deviation of the change (future minus past) or of the future state? Please clarify in the manuscript and/or caption

Response: they are the standard deviation of the change. (now the legend is revised as Std of T2 Change and Std of Precip Change), the caption is also updated as: The standard deviation of the projected ensemble changes in the annual mean surface air temperature over the Great Lakes basin during the mid-century (2030-2049) and the late century (2080-2099) in RCP 4.5 and RCP 8.5 scenarios, relative to the present-day climate (2000-2019)."

11. L327-328 & L332-333: I wonder if these changes (4 and 6%) are sufficiently different to say that RCP4.5 gives a stronger wetting than RCP8.5 for mid-century. Probably the uncertainty bands are largely overlapping? In that case I would rather say that they project a similar wetting.

Response: Agree. It is revised as "The projected mid-century increase in precipitation is similar in RCP 4.5 (6.5%) and RCP 8.5 (5.6%) with relatively similar atmospheric GHG concentrations over the period."

12. Fig. 14: to better understand the change, it would be more useful to also plot the present-day ice cover, or to plot the change in ice cover (future – present)

Response: Agree, we have added the present-day ice cover.

Textual comments

1. L26, ‘are’ > ‘is’.

Response: corrected.

2. L61: ‘will’ > ‘could’.

Response: corrected.

3. L72: ‘predicted’ > ‘projected’ (always use projections in the context of future climate) and ‘atmospheric greenhouse gasses (GHGs)’ > ‘greenhouse gas (GHG) emissions’.

Response: corrected as suggested.

4. L89 and elsewhere: I’d suggest specifying ‘Great Lakes’ to ‘Laurentian Great Lakes’ throughout the manuscript, to avoid confusion with the African Great Lakes.

Response: The Laurentian Great Lakes are used at the beginning of abstract, Introduction and conclusion .

5. L101: FVCOM, this acronym hasn’t been introduced yet

Response: Finite Volume Community Ocean Model (FVCOM) is defined in the revision.

6. L106: ‘a RCM’ > ‘an RCM’

Response: corrected.

7. L116: ‘LakesAtmosphere’ > ‘Lakes Atmosphere’

Response: corrected.

8. L116: ‘iceatmosphere’ > ‘ice-atmosphere’

Response: corrected.

9. L155: ‘projections’ > ‘assessment reports’

Response: corrected as suggested.

10. L233: ‘predictions’ > ‘projections’ (check elsewhere, predicted>projected) .

Response: corrected. We use projections in the context of future climate throughout the manuscript in the revision.

11. L252: remove space before ‘.’ Check elsewhere for double or missing spaces.

Response: corrected.

12. L306: ‘much more substantial’ > ‘more pronounced’

Response: corrected as suggested.

13. L309: ‘cooling’ > ‘buffering’

Response: corrected as suggested.

14. L310: ‘overlake’ > ‘over-lake’

Response: corrected as suggested.

15. L429: check punctuation

Response: corrected as suggested.

16. L428: check sentence (drop ‘changes’?)
Response: This sentence is removed in the revision.

We hope we have addressed your questions satisfactorily. Thank you again for your time and efforts in reviewing our manuscript!