Thank you very much to the reviewer for their thoughtful review and commentary. It has lead to several substantial improvements to the manuscript. We have responded to each of your comments in bold below.

Reviewer 3:

The manuscript analyses the water level variations for 117 globally-distributed lakes and surface air temperature in order to disentangle the effects of climate variation and anthropogenic activities on lake variations. The authors use boosted regression trees (BRTs) to model water level as a function of time and the PCs of temperature. Then those most influential PCs are correlated with climate indices. The topic is highly relevant and will provide important contributions to current climate and anthropogenic impacts on inland water bodies, e.g. lakes.

We are grateful for these comments summarizing the manuscript.

General Comments

In general, the manuscript is generally well organized and easy to read. But the method section is a bit redundant and needs to be clarified. The main assumption is that the pattern of global lake changes is somehow driven by global patterns of earth surface air temperature. But the results (27% of water level variation was associated with background climate variation) do not support this assumption very well. In my opinion, a better re-designation of the study objectives is needed.

Thanks to the reviewer for this suggestion on how to clarify and improve the methods section. 27% of the variability was, in fact, attributable to the the PCs representing de-seasonalized and de-trended global variation in earth surface temperatures. However, the seasonal component of the model explained an additional 5%, and the long-term trends component explained an additional 13% of the variation. So, in sum, we were able to explain 45% of the variation in water levels on average across lakes. In this context, the importance of the PCs is more apparent because they explained more than 5 times the amount of lake level variation than background seasonality (27% > 5 x 5%). This has now been clarified in the results section and in the abstract with the following text:

In the abstract: "On average, 27% of water level variation in individual lakes was associated with background climate variation with an additional 18% explained by seasonal variation and the long-term trend."

In the results section: "Together, the PCs selected for each lake explained an average of 27% of the variance in water levels (interquartile range: 4-44%) compared to 5% explained by seasonality and 13% explained by the long-term trend."

The authors stressed that a novel statistic method BRT is used, but in my opinion, more details are needed. On top of that, some justifications and clarifications are needed as pointed out below. I hope my comments are useful for authors to improve the manuscript.

Thanks very much for the comments below on how to further clarify the methods section. Our responses are detailed below.

Specific comments

P4L6: ". . . based on average annual water level. . ." why and how is annual water level used?

Thanks for pointing out the need to clarify here. We have added the following text to the manuscript: methods section:

"Annual water levels were used in the trend analysis instead of raw water levels so that the trend residuals would not be serially autocorrelated."

P4L13-21: Does this consider the nonstationary of time series induced by climate?

Yes it does. All effects in the model including the effects of the PCs and the effects of season are allowed to change from year to year. For example, the effect of PCenso on water level variation might be very important in driving water levels in some years for a specific lake but not in others. We have added the following text to the manuscript: methods section:

"The main advantages of BRTs over other statistical models is that they have higher predictive performance, do not require data transformation or outlier elimination, automatically handle complex nonlinear relationships and interactions, and allow for many types of predictor variables and partial missing data. Through these interactions, the BRT allows for non-stationarity of the timeseries (e.g. the effect of each PC is allowed to change over time)."

P4L15: Here the climate indices should be renamed or clarified to be distinguishable from those called climate index, e.g. ENSO, IOD, NAO, etc. It is a bit confusing.

Thanks for pointing out the need to clarify here. We have added the following text to the methods section:

"In cases where a PC is highly correlated to one of the major climate indices (PCs), we renamed it with a subscript (e.g., PC_{ENSO}) to facilitate interpretation. In all remaining cases, PCs were named with a numeric subscript which matched their order in the PCA (e.g. "PC1")

P4L22-31: Why are the PCs detrended instead of temperature detrended? How can detrended PCs remove anthropogenic effect?

Thanks for this insightful comment. In our revision, we detrended the temperature data prior to the PCA as suggested by the reviewer. Detrending the temperature data also removed the long-term trends from the PCs. We would also add that detrending in this way as suggested by the reviewer predominantly removed the effect of anthropogenic climate change. However, the broader "anthropogenic effect" which includes water extractions and

reservoir construction have not been removed from the PCs. We have now clarified this throughout our revision of the methods section and the discussion section.

P4-P5: I think the overview of method should be simplified and move some of the description to specific methodologies.

Thanks for this suggestion. In our revision, we have moved much of the text from the "overview" section to the subsequent relevant topic sections.

P6, 2.3: Regarding PCA, a bit more details maybe help to reproduce the results presented in the manuscript. Why 100 PCs are used? Personally, I think those beyond 20 are very weak and probably mainly noises. Is a constant number of PCs used in the BRT for all lakes? I think that not all PCs are statistically significant in the regression. Does BRT take this into consideration?

We used an excess number of PCs in the model fitting to ensure that we captured all of the important background climate drivers. But with that said, in our revision, we removed all PCs which were indistinguishable from random noise using a Box-Ljung test (alpha = 0.01). Based on the Box-Ljung test, we eliminated 5 PCs from our BRT model selection procedure. We also include a rigorous evaluation of the importance of each of the PCs in the model through a model selection process. Through the model selection process, if the inclusion of a PC in the BRT did not lead to an improvement in the model's performance during cross validation, it was removed from the model. This is a more rigorous way to exclude variables than exclusion based on "statistical significance."

P6L3: "the longest and highest resolution time series". How long are they? Do they vary for different lakes? What does it mean when you say "highest resolution"? Be specific.

We are grateful to the reviewer for bringing up these needed clarifications. In our revision, we have updated the time series for each lake so that it begins in 1992 and ends in 2020. We have included the exact number of observations for each lake in the supplementary Table S3. By "longest" we mean greater than 27 years, and by "highest resolution," we mean, "the greatest number of observations per unit time." This has been clarified in the line referenced by the reviewer. In our revision, the sentence reads,

"The lakes in this study comprise the 117 lakes with the longest (>28 years) and highest temporal resolution time series (greatest number of samples per year)."

P6L5: ". . . is typically ∼3 cm for large lakes. . .". This is a bit overstated. The best case is around 3 cm. Please double check and revise.

Thanks for this comment. This has been updated to "~5 cm for large lakes" based on the USDA G-REALM website.

P6L9: ". . .linearly-interpolated each lake's time series. . .". Why not use a model considering annual and semi-annual variations given that you have quite long time series? I suggest using the approach used in previous studies, e.g. (Kleinherenbrink et al., 2015; Villadsen et al., 2014).

Thanks for this suggestion. In our revision, we have interpolated the time series using ARMA time series modelling with a Kalman filter. The reveiewer is correct that this is a much more robust and accepted way to interpolate the time series.

P7 2.4: The description of statistical method, BRT should be expanded instead of just saying some R packages are used given that you state this method is novel in your study.

We are grateful to the reviewer for pointing out this key area for improvement. In our revision we have included the following description of BRTs:

"A BRT is an ensemble machine learning approach that differs from conventional statistical techniques which use a single parsimonious model. Instead, BRTs combine the strengths of standard regression trees and boosting—a method for aggregating many models to improve the predictive capacity. The main advantages of BRTs over other statistical models is that they have higher predictive performance, do not require data transformation or outlier elimination, automatically handle complex nonlinear relationships and interactions, and allow for many types of predictor variables and partial missing data."

P9L26: Lake water level definitely is an integrative metrics of regional water budget. I think this sentence should be rephrased.

This sentence has been rephrased. Our revised sentence states, "This contrast highlights how global analyses of waterbody surface level variation can enhance our ability to detect hydrological changes."

P9L26: "significant effects . . . in most lakes", is this overstated?

Thanks for pointing out our misuse of the term "significant." We have replaced the phrase, "had significant effects on " with the phrase "substantially influenced."

P11L28-29: As pointed above, I doubt that detrending the PCs helps to separate background climate indices from ongoing climate change. Instead, I would first detrend the time series of temperature, and the perform PCA.

In our revised manuscript, we have detrended the temperature data prior to the PCA as suggested by the reviewer.

References

Kleinherenbrink, M., Lindenbergh, R. C. and Ditmar, P. G.: Monitoring of lake level changes on the Tibetan Plateau and Tian Shan by retracking Cryosat SARIn waveforms, J. Hydrol., 521, 119–131, doi:10.1016/j.jhydrol.2014.11.063, 2015.

Villadsen, H., Andersen, O. B. and Stenseng, L.: Annual cycle in lakes and rivers from CryoSat-2 altimetry - The Brahmaputra river, Int. Geosci. Remote Sens. Symp., 894–897, doi:10.1109/IGARSS.2014.6946569, 2014.