Modeling the impacts of climate change on inland lakes in the Great Lakes Basin
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Background
Concerns about climate change and human impacts on the environment have increased in recent years, particularly the impacts on freshwater lakes and their ecosystems. This growing concern has elicited a need for models that predict changes in a lake’s physical, biological and chemical state in response to environmental stressors. Lakes in the Great Lakes Basin (GLB) are subject to large seasonal variations in temperature that result in stratification during the summer and winter and turnover or mixing in the spring and fall. Warmer winters will lead to shorter periods of ice cover in winter and longer periods of stratification in summer. These alterations in temperature can lead to increased eutrophication and algal blooms, resulting in decreased dissolved oxygen levels. These effects of climate change may interact with land use changes to produce even more severe impacts.

Objectives
Overall Objective:
Apply a lake model to determine the impacts of climate change on physical properties of inland lakes in the GLB including effects on:
• seasonal mixing regimes
• surface water temperature
• ice cover and thickness

Current Objective:
Determine the accuracy of a lake model for predicting temperature, given meteorological conditions, and quantify the sensitivity of the model to changes in input parameters.

Methods
We used Trout Lake, located in Vilas County, WI, to test the lake model ‘Flake’. The lake has a surface area of 3.875 acres, with a mean and maximum depth of 49 ft and 117 ft, respectively. Trout Lake is mesotrophic and the water is moderately clear.

Meteorological inputs and observed temperatures for the surface and at the mean depth for Trout Lake were obtained from North Temperate Lake-Long Term Ecological Research Network (NTL-LTER)4.

The surface and mean-depth temperatures were modeled using the meteorological data “average (x)” condition. The “average” input conditions were varied by 0.5x and 2x to determine model sensitivity. The groundwater temperature was 10°C for the “average” condition and tested at 4°C.

The root mean squared error (RMSE) for the “average” (actual) meteorological conditions model run was used to determine the fit of the modeled results to the observed data.

Results: Flake Model Testing

![Figure 1. The Great Lakes Basin](http://www.glerl.noaa.gov/pr/ourlakes/background.html)

Figure 2. Observed and modeled surface water temperatures. Actual meteorological conditions were used in the “average” model run. The “minimum” and “maximum” conditions were 0.5x and 2x the actual condition or the minimum and maximum of the available input range, respectively. Panels a-f show modeled surface temperature results for: a) solar radiation; b) air temperature; c) vapor pressure; d) wind speed; e) cloudiness; f) groundwater temperature.

Table 1. Root mean squared error (RMSE) comparing “average” model run (actual meteorological conditions), to observed water temperatures at the lake surface and mean water depth for Trout Lake.

<table>
<thead>
<tr>
<th>Surface Water Temp RMSE</th>
<th>Mean Depth Water Temp RMSE</th>
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<td>2.4 °C</td>
<td>3.6 °C</td>
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Conclusions
The main results of the sensitivity and overall model fit analyses are:
• lake model predictions are affected most by solar radiation, air temperature, vapor pressure, and wind speed inputs;
• the variance of the model predictions for surface and mean water temperature from the observed data are approximately 2.4 °C and 3.6 °C, respectively, and modeled mean depth water temperature responses to varied input parameters were similar to surface water temperature sensitivity results.

These results aid us in understanding which meteorological parameters drive the ‘Flake’ model and determining the suitability of the model to our project needs. Graphical comparisons suggest the model predictions using the “average (x)”, or actual, meteorological conditions satisfactorily replicate observed water temperatures; however, the RMSE results indicate otherwise and calls for further analysis to identify any systematic bias in the model predictions. Additionally, the sensitivity analysis shows that increasing the meteorological inputs has a larger impact on the model predictions than reducing them (Fig. 2 a-d).

References

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