Accelerated Warming of Lakes Worldwide: Evidence of Global Brightening and Climate Change

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Abstract

Increasing surface water temperatures have been demonstrated to affect the distribution of fish species, primary productivity rates, and food web dynamics of aquatic systems. It is important to understand how lake surface water temperatures (SWT) are changing globally, and what drivers are influencing these changes. Changes in lake surface water temperatures of 78 globally distributed lakes were assessed between 1985 and 2009. Ninety percent of the lakes studied experienced increasing SWT trends over the 25-year period. We used a regression tree to investigate the drivers of SWT trends. Mean surface water temperatures increase with increasing summer solar radiation and summer air temperatures, with little variation explained by lake morphology. This is the first study to provide limnological evidence for the importance of two large-scale phenomena, global brightening/dimming and global climate change, for lakes worldwide.

Background Information

- Increases in air temperatures average at approximately 0.02° C/year globally over the past 20-30 years (1)
- Rising global air temperatures are anticipated to increase the heat uptake of lakes, followed by increases in epilimnetic temperatures (2)
- Water temperatures are influenced by multiple drivers including: climate and lake morphology (3,4)

Research Questions

1. How have lake surface water temperatures (SWT) been changing globally between 1985-2009?
2. How have the SWTs of Ontario lakes changed compared to global lakes?
3. Which drivers are important in predicting SWTs globally?

Methods

- Lake surface water temperatures and lake morphology data acquired from 80 collaborators within the Global Lake Temperature Collaboration
- Climate (air temperature and solar radiation)
- Time period: 1985-2009
- 78 lakes analyzed ≥15 years of data
- Data Analysis: i) Trends: Sen slope estimator, ii) Comparison of Ontario vs. Global: Mann-Whitney U & iii) Importance of Drivers: Regression Tree Analysis (5)

Figures

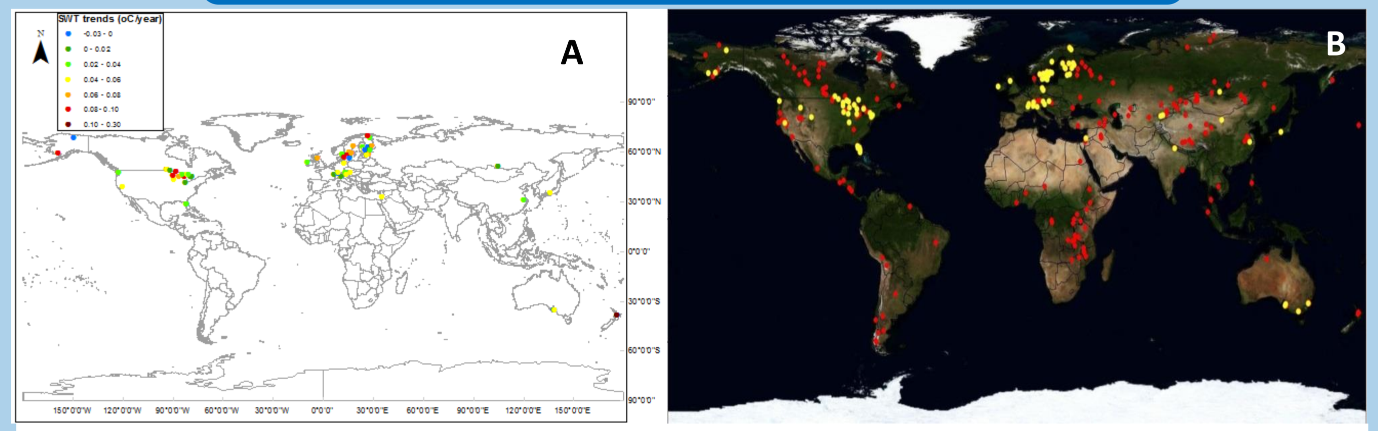


Figure 1. A) Global distribution of lakes used in our analysis (n=78). B) In-situ (yellow dots) and satellite lakes (red dots) used in the larger project.

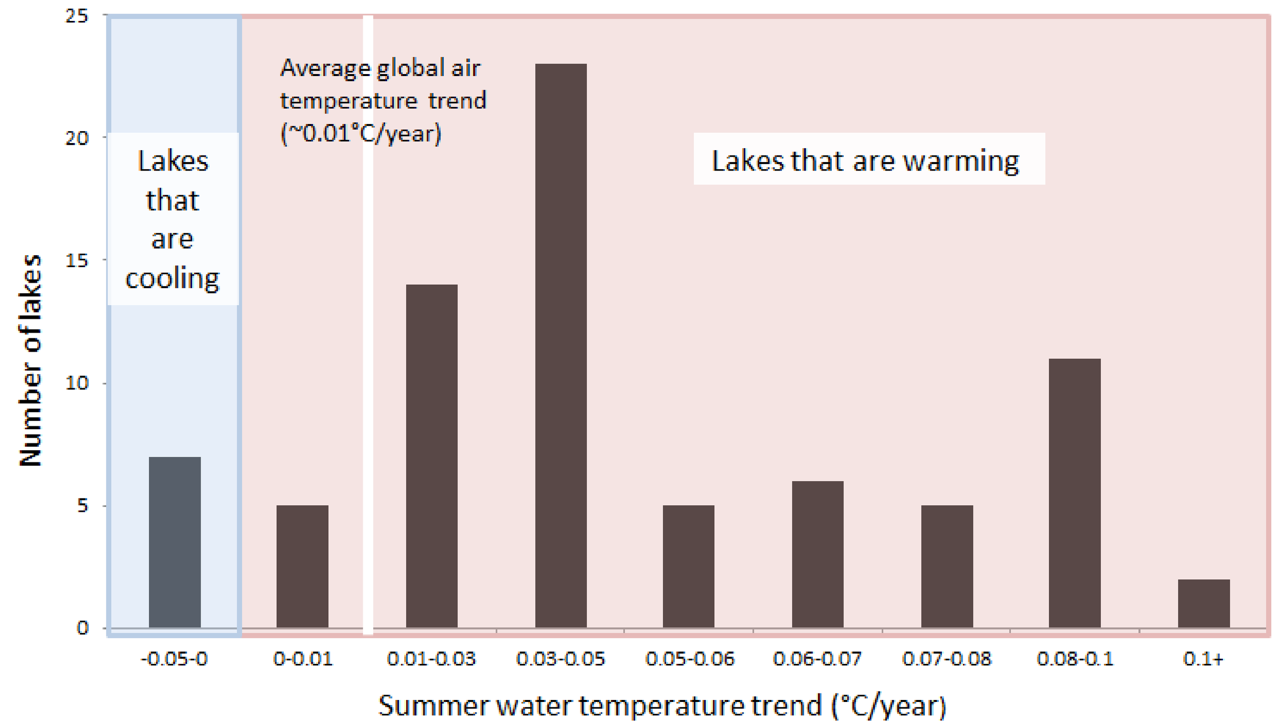


Figure 2. Histogram of summer lake surface water temperature trends. Blue regions indicate lakes that are cooling and red regions indicate lakes that are warming over the 1985-2009 study period.

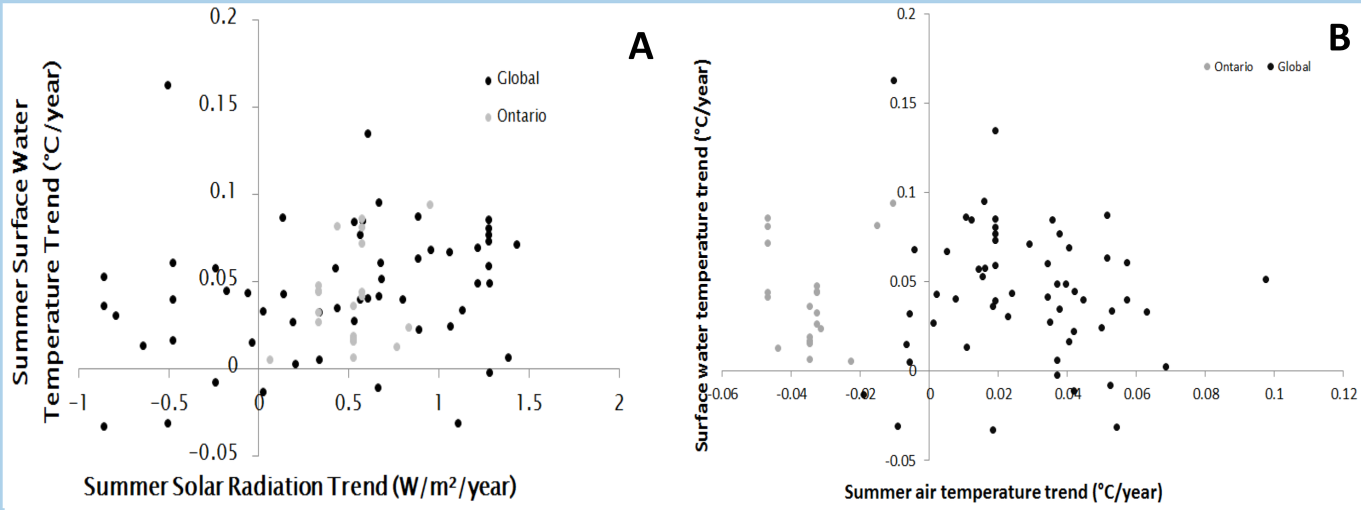


Figure 3. Trends in A) summer solar radiation changes, and B) summer air temperature changes of all 78 study lakes from both the Ontario and global datasets and their corresponding trends in summer surface water temperature.

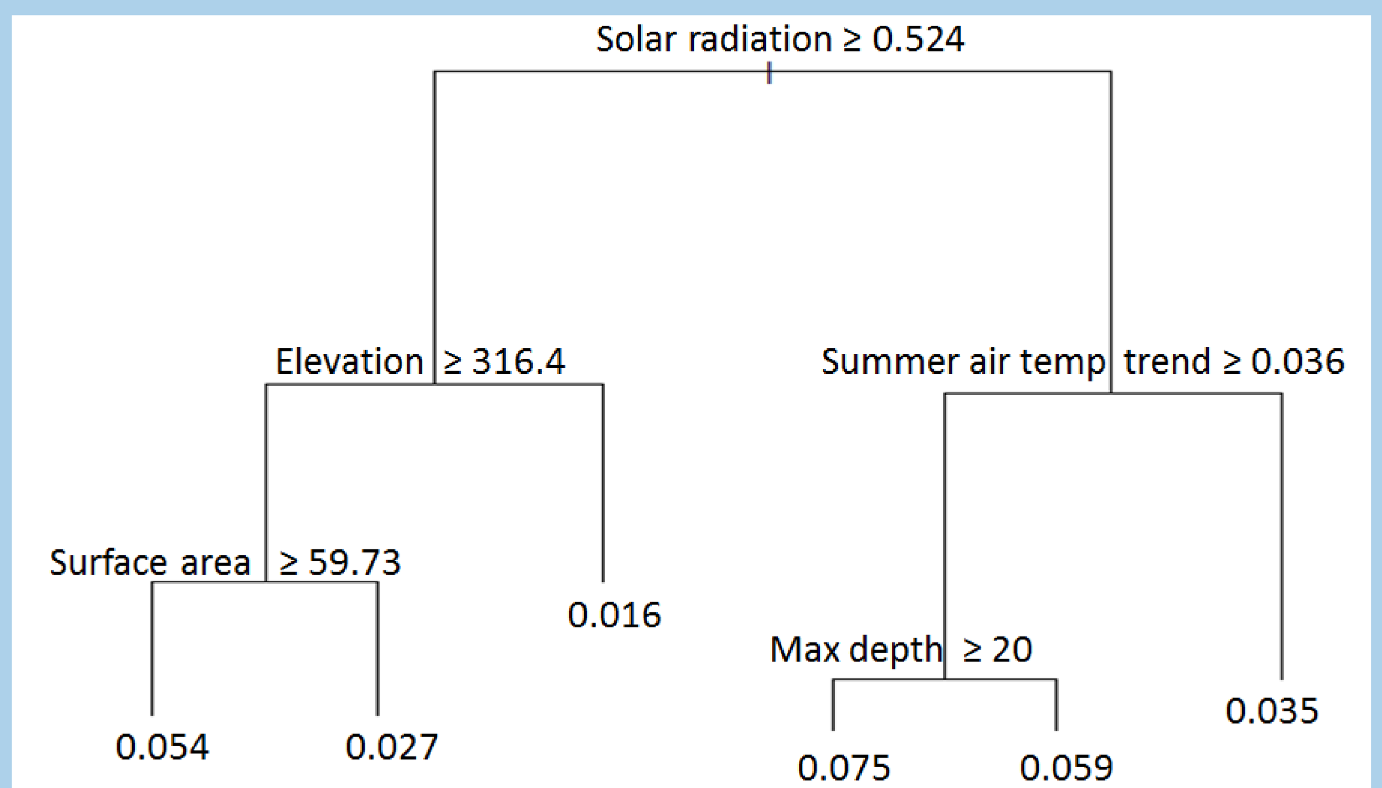
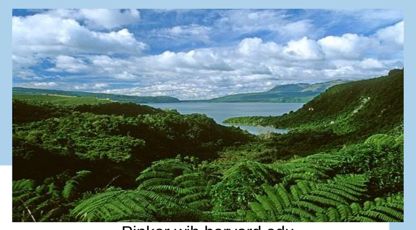


Figure 4. Regression tree summarizing the drivers explaining global lake surface water temperatures. The most important predictor of SWT trends is solar radiation. The overall variation explained by this tree was 32%. SWT trend units: °C/year.



Results

- 90% of lakes are warming
- There is no significant difference between Ontario and global lakes (Mann-Whitney U; p-value=0.558)
- SWTs are warming faster than air temperatures
- Regression tree analysis explained 32% of the variation in SWTs globally
- Solar radiation was the most important predictor of SWT trends
- Air temperatures and lake morphology explain remaining variation in SWTs
- Intra-annual air temperatures were well-correlated with summer SWT

Discussion

- This study provides limnological evidence for two interacting global phenomena: global brightening/dimming and climate change
- SWT plays a major role in lake biology (6)
- Increasing SWTs will have serious ecological implications (7), with changes in:
  - lake primary productivity (8)
  - fish species range shifts (9)
  - food web dynamics (10)

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Future Directions

As part of a collaborative project with the GLTC, I am assisting with the larger project which involves identifying the drivers contributing to changes in lake surface water temperatures for lakes collected *in situ* and by satellites, in order to encompass a greater number of lakes distributed globally.