Lake Photic Zone Temperature Across the Conterminous United States

Shivers, S.D.[1], Kreakie, B.J.[2], Milstead, W. Bryan[2], and Hollister, J.W.[2]

[1] ORISE Fellow, EPA Office of Research and Development, ACESD
[2] US EPA Office of Research and Development, ACESD

NALMS, November 14, 2019

Introduction – Warming Lakes

- Summer surface temperatures of lakes are increasing (0.34 °C/decade between 1985 and 2009)
- Spatial heterogeneity in warming
- Summer air temperature most important and consistent predictor

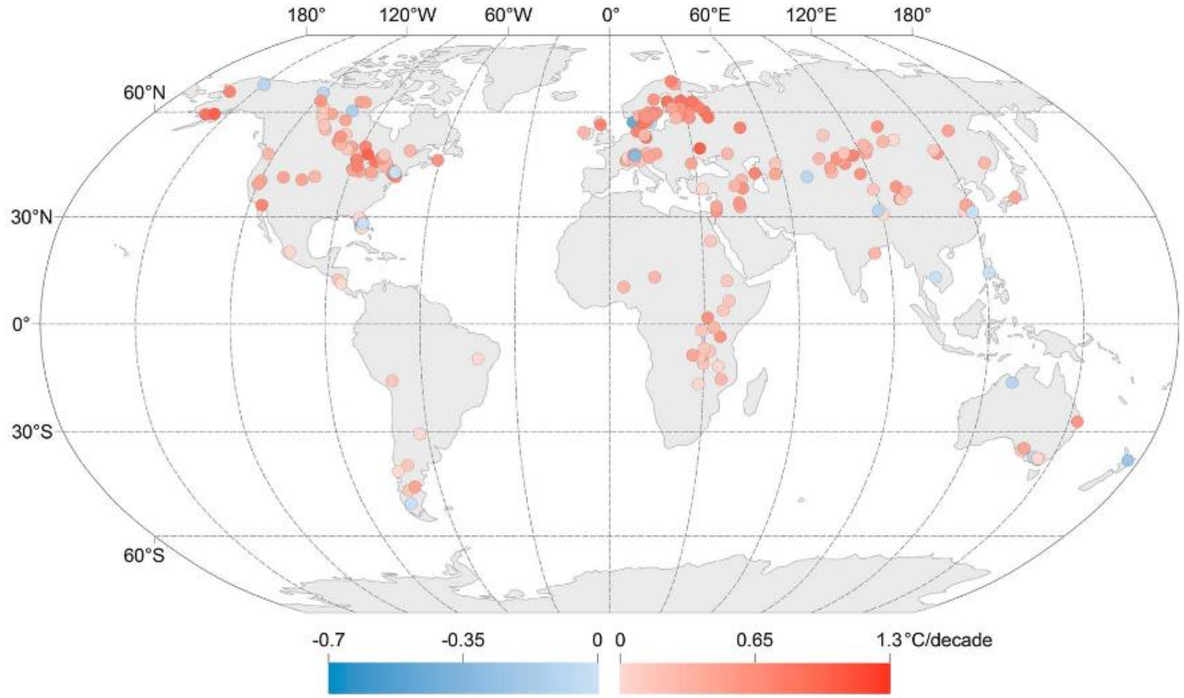


Figure 1. Map of trends in lake summer surface temperatures from 1985 to 2009. Most lakes are warming, and there is large spatial heterogeneity in lake trends. Note that the magnitudes of cooling and warming are not the same.

O'Reilly et al. 2015. Rapid and highly variable warming of lake surface waters around the globe. Geophysical Research Letters 42:10773-10781

Introduction – Implications of Warming

- Increasing temperature will affect both abiotic and biotic components of ecosystems
- Warmer lake temperatures will likely cause cyanobacterial blooms to increase
- Accurate lake temperature forecasting will be needed to protect human and environmental health

Previous Modeling Efforts

- Most studies use single or small number of lakes
- Models can be complex
- Many of these studies yielded good results
- Small lakes may be underrepresented

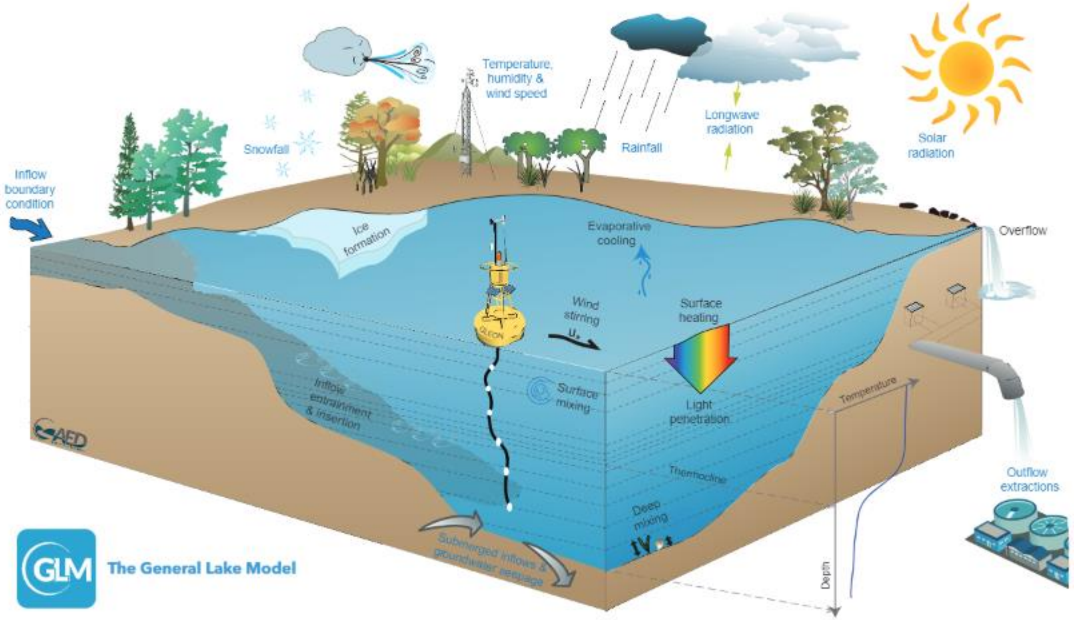


Figure 1. Schematic of a GLM simulation domain, input information (blue text), and key simulated processes (black text).

Hipsey et al. 2019. A General Lake Model (GLM 3.0) for linking with high-frequency sensor data from the Global Lake Ecological Observatory Network (GLEON). Geosci. Model Dev. 12:473-523.

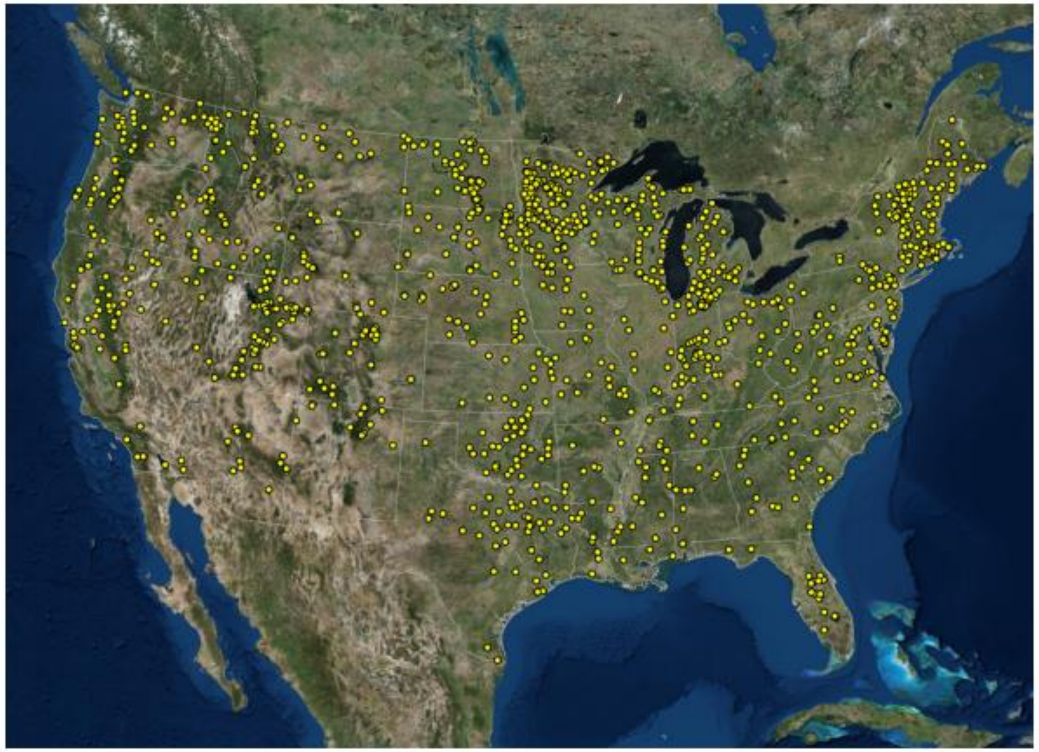
Project Goals

- To develop a simple, robust photic zone temperature model for all lakes in the conterminous US
- To create a data product of continental scale air temperatures from PRISM and make the product and all R code publicly available

Methods – Water Temperature from NLA

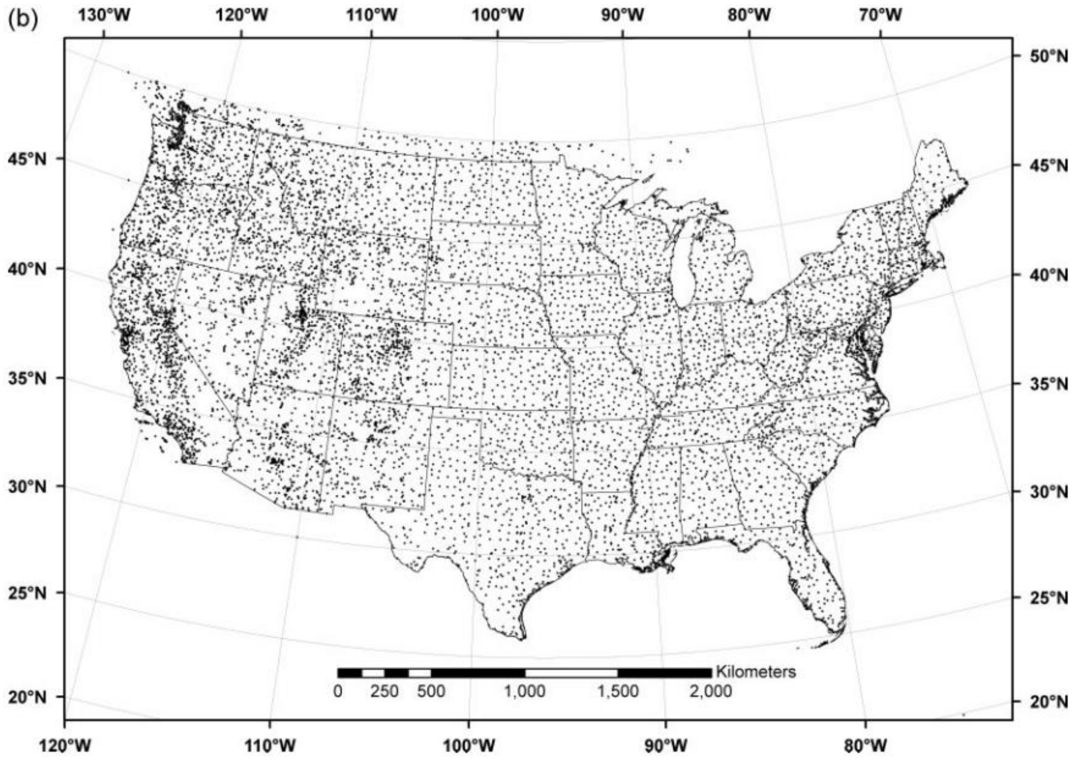
- 2007 and 2012 NLA used
- Over 1000 lakes across the conterminous US excluding the Great Lakes
- Mean temperature for all sampled depths less than 2m
- Small lakes well represented

NLA 2012 Sampled Sites



Methods – Air Temperature from PRISM

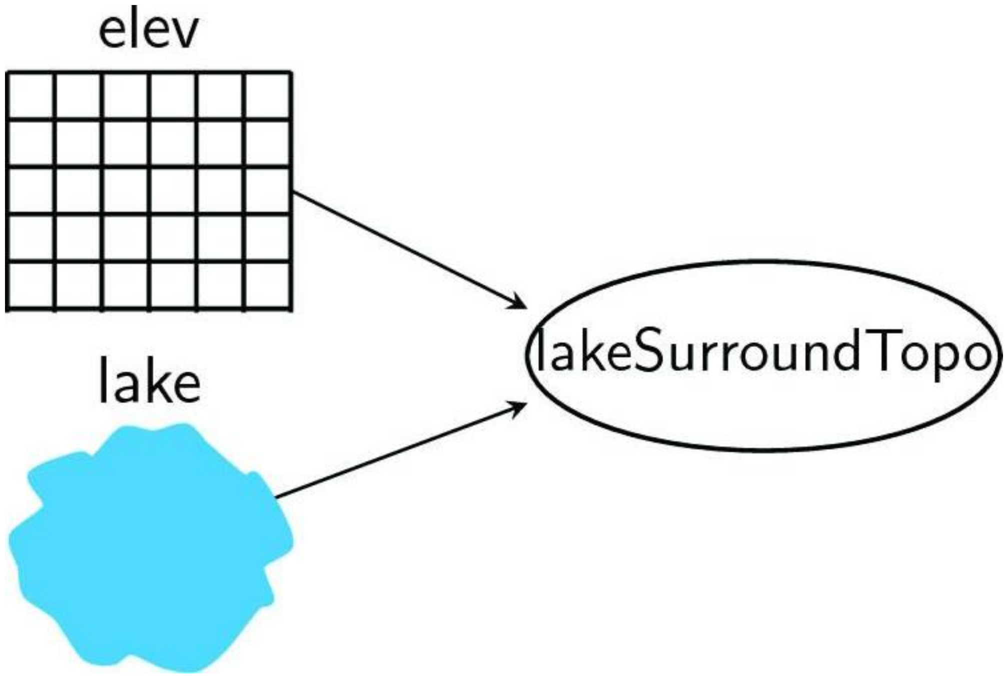
- Daily temperature estimates (4 km grids)
- 1981-present
- prism R package used to download mean daily temperature for centroids of NLA lakes
- Temperature variables for model (day of, day before, 3, 7, and 30 days prior to NLA sampling date)



Daly et al. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. Int. J. Climatol. 28:2031-2064

Methods – Other Variables

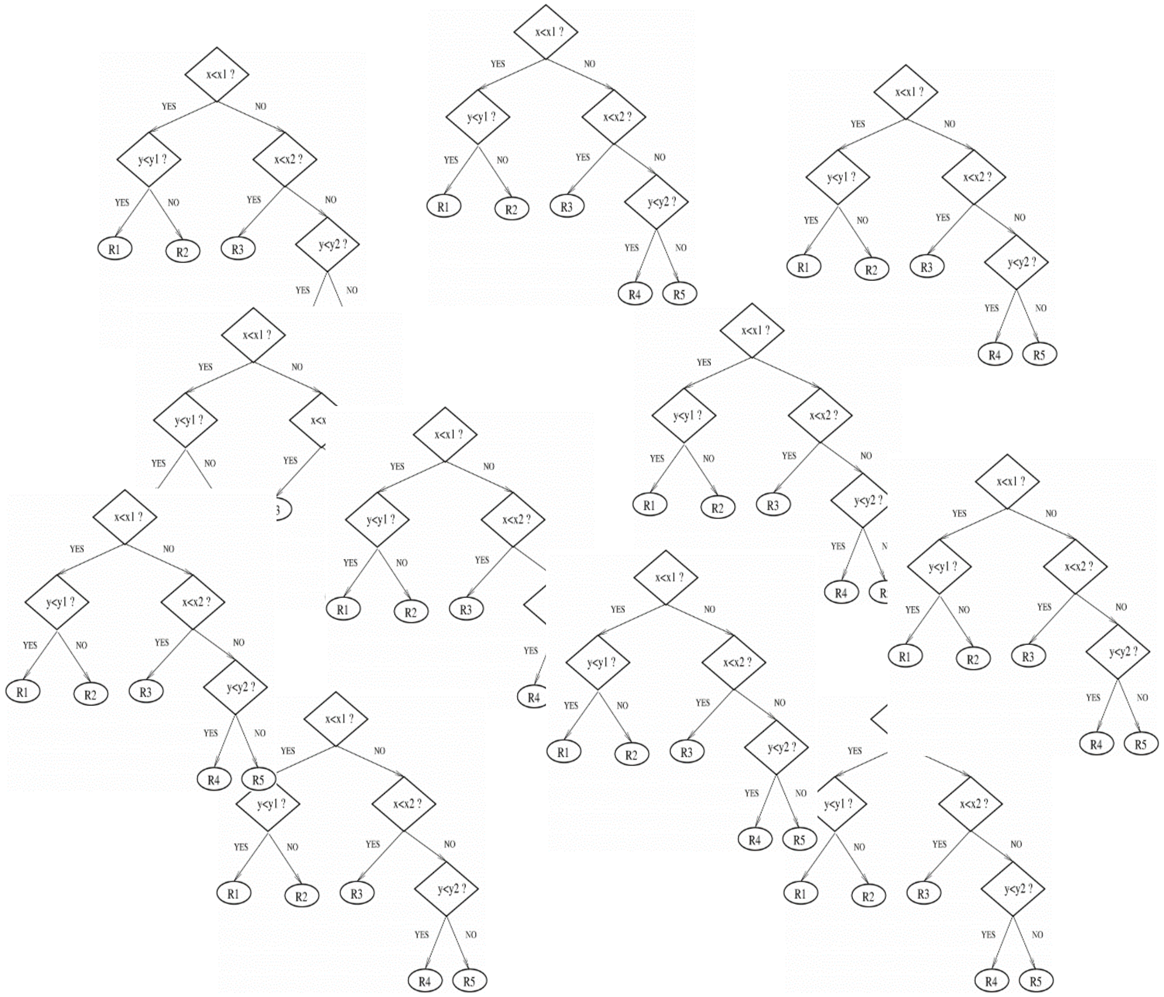
- Other variables impact lake temperature (e.g., land use, lake depth, size, and elevation)
- lakemorpho and elevatr R packages used to incorporate these variables
- Landcover data from National Land Cover Database (NLCD)



Methods – Random Forest

Random Forests

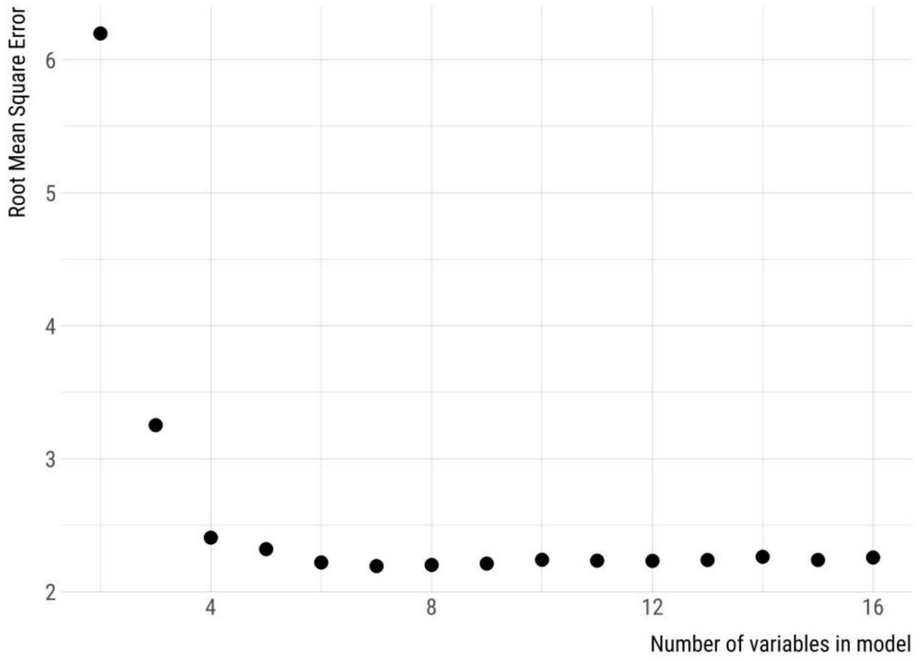
- Machine Learning Approach
- Based on trees
    - Classification
    - Regression
- Very few assumptions
- Predictions
    - Accurate
    - Less biased
- Used to predict:
    - Chlorophyll *a*
    - Trophic state



https://www.otexts.org/1512

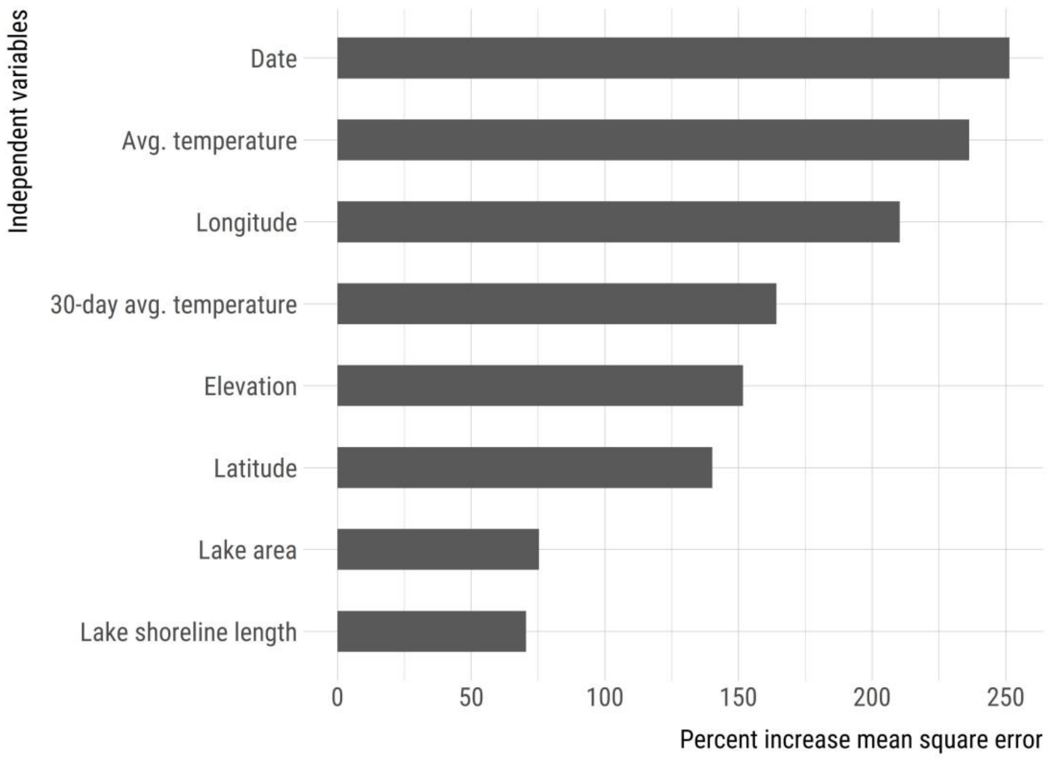
Results – Variable Selection

- Average photic zone temperature was response variable
- Began with 16 predictor variables
- Variable selection identified 8 variables (avg. sample day temp, sample date, longitude, avg. 30 day prior temp., elevation, latitude, shoreline length, and lake surface area

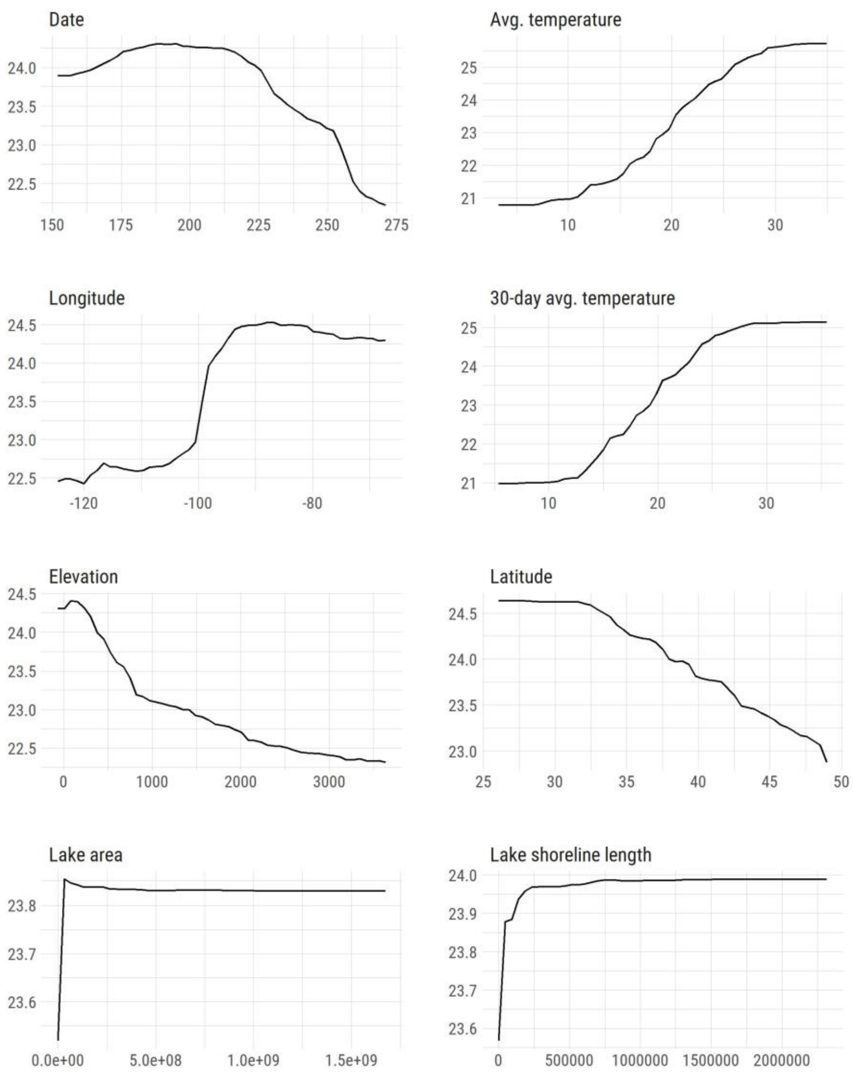


Results – Final model

- Final model has mean-squared error of 2.19 °C and adjusted r^2 of 0.88
- Variables ranked in order of importance: date, avg. temp., longitude, avg. 30 day temp, elevation, latitude, lake surface area, and shoreline length



Results – Partial Dependency Plots



Conclusions and Future Work

- A simple, yet robust, model was created capable of predicting photic zone temperature in any lake within the continental US
- We are currently backcasting lake temperature for all lakes (>300,000) in NHDplus to investigate spatial and temporal trends (1981-2018)
- Next, we plan on forecasting??

Questions?