GRAPLEr Platform Accelerates Whole-Ecosystem Simulation Modeling to Increase Understanding of Climate Change Impacts on Lake Nutrient Cycling

Kaitlin J. Farrell[1,*], Cayelan C. Carey[1], Arianna I. Krinos[1], Nicole K. Ward[1], Paul C. Hanson[2], Renato J. Figueiredo[3], Vahid Daneshmand[3], and Kensworth Subratie[3]

[1]Department of Biological Sciences, Virginia Tech, USA; [2]Center for Limnology, University of Wisconsin, USA; [3]Advanced Computing and Information Systems Laboratory, University of Florida, USA; *Email: farrellk@vt.edu, @farrellkj2

Ecology in the Era of Rapid Global Change

- Ecologists use simulation models to predict how climate warming will affect lake ecosystem processes like nitrogen and phosphorus cycling
- Lake responses to climate warming may depend on historical climate and land use
- Comparing lakes with different land use can provide insights into importance of local (land use) vs. regional (climate) drivers

Lake Mendota (Wisconsin, USA)

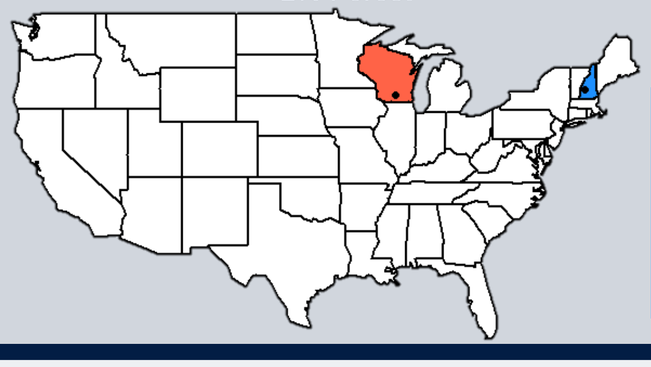
Eutrophic
- High nitrogen
- High phosphorus

Main land uses:
- 55% Agriculture
- 20% Urban
- 1% Forest

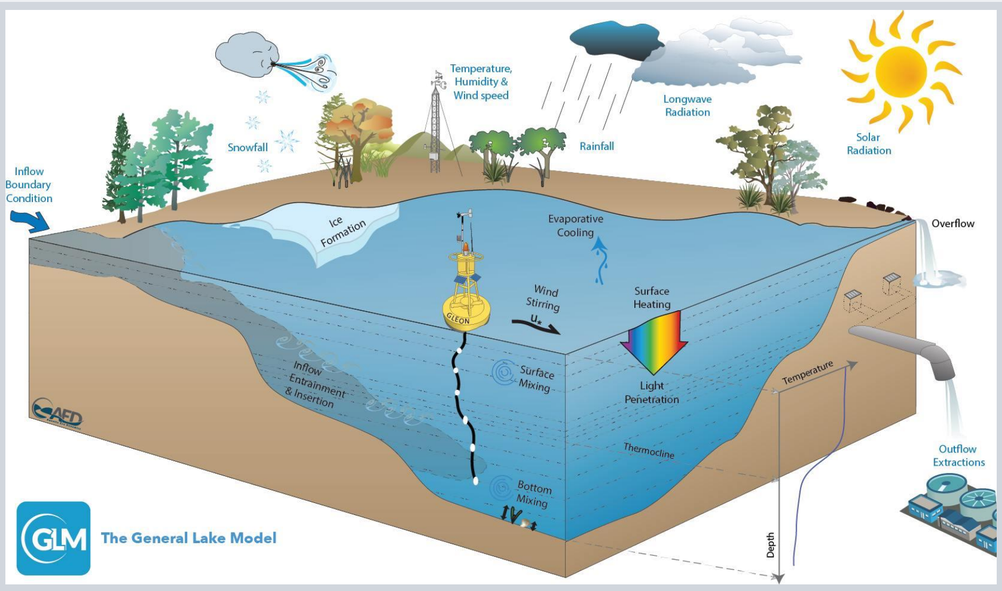
Lake Sunapee (New Hampshire, USA)

Oligotrophic
- Low nitrogen
- Low phosphorus

Main land uses:
- 81% Forest
- 8% Urban
- 4% Agriculture



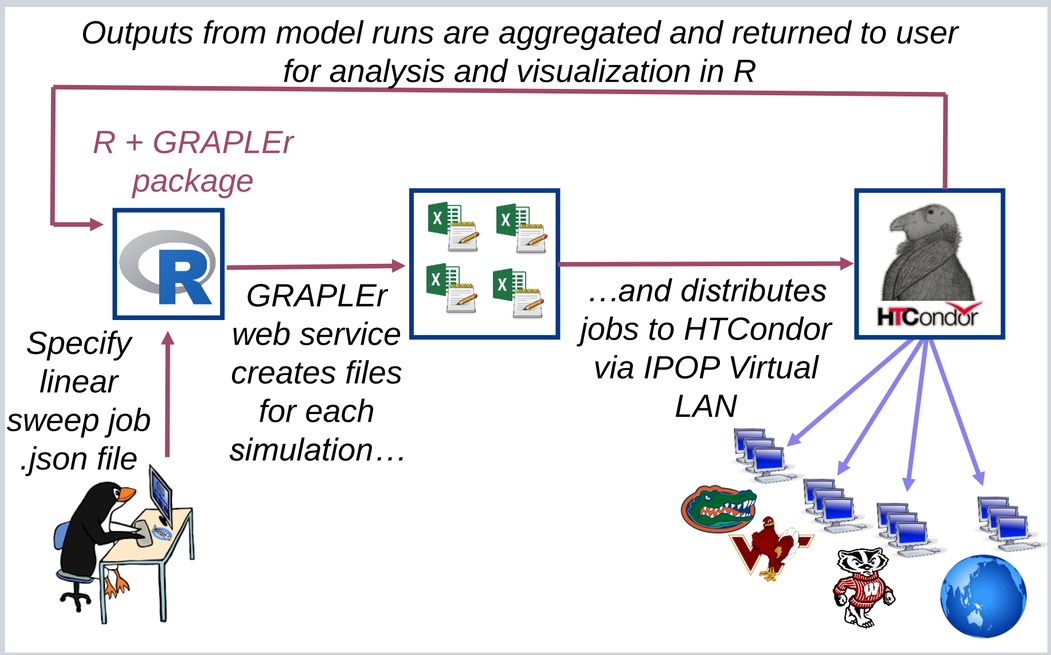
General Lake Model for Whole-Ecosystem Simulation Modeling



Schematic of the General Lake Model showing data inputs (blue text) and simulated processes (black text; Hipsey et al. 2014).

Lake Expedition: Using GRAPLEr to Accelerate Discovery in Limnology

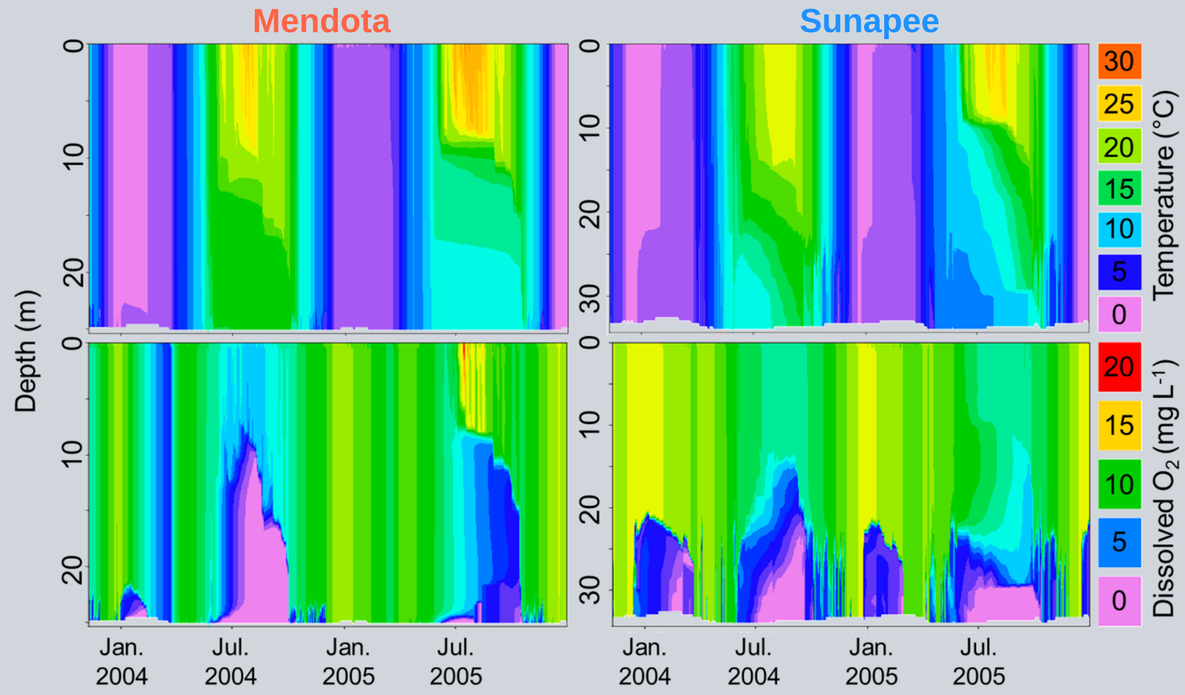
- The Lake Expedition is an interdisciplinary collaboration between PRAGMA and GLEON (Global Lakes Ecological Observatory Network) researchers
- GRAPLEr distributed computing platform brings power of distributed computing to the fingertips of lake ecology modelers
- Lake simulations distributed across 100's of processing nodes that are aggregated into a peer-to-peer overlay virtual private network, dramatically reducing computation time



For more details, see Subratie et al. 2017 or visit the GRAPLEr website (www.graple.org or snap this QR code)

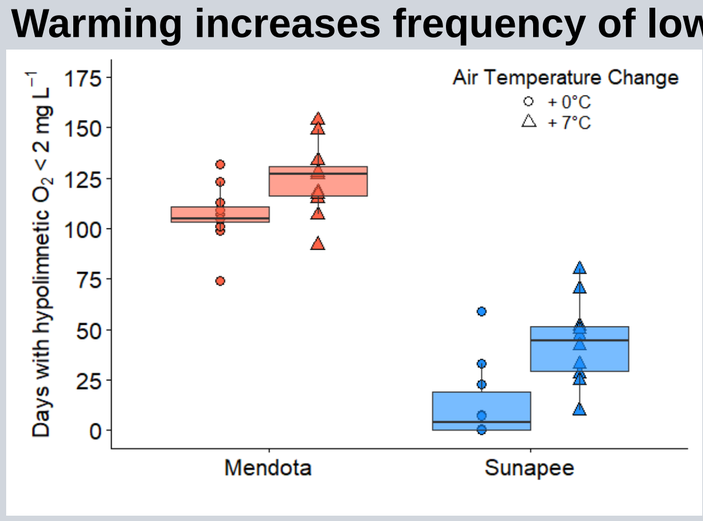
Warming Effects Depend on Initial Lake Water Quality

Baseline water temperatures & dissolved oxygen differ between lakes



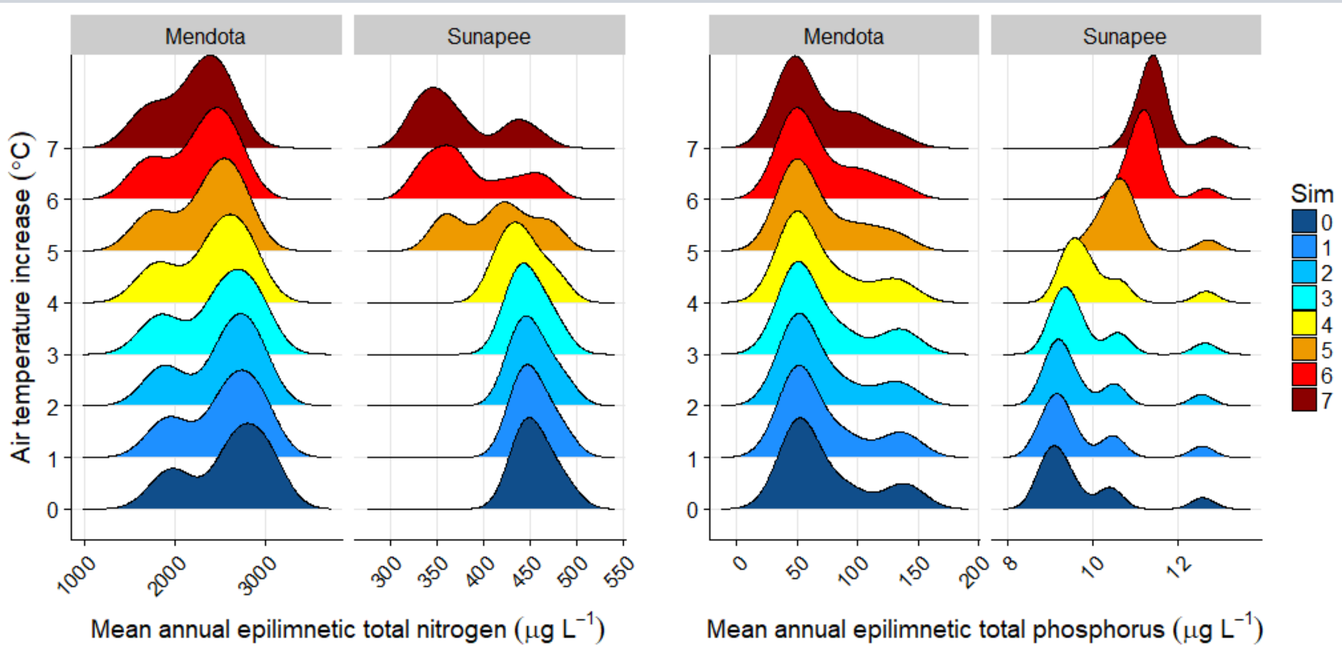
- Mendota tends to be warmer, lower oxygen than Sunapee under baseline conditions

Warming increases frequency of low-oxygen bottom-water conditions



- Hypoxia (< 2 mg L-1 dissolved O_2) contributes to N and P release from lake sediments
- Bottom-waters (25 m) in both lakes experienced more days of hypoxia under +7°C air temperature scenario
- Median increase of 22 more days of hypoxia in Mendota; 41 more days in Sunapee

Surface nitrogen and phosphorus responses differ by lake



- Mean annual total nitrogen concentrations in epilimnion (0-6 m) decreased in both lakes
  - 15% ⬇ in Mendota; 18% ⬇ in Sunapee between baseline and +7°C air temperature scenarios
- Mean annual total phosphorus concentrations in epilimnion (0-6 m) increased in both lakes
  - 9% ⬆ in Mendota; 19% ⬆ in Sunapee between baseline and +7°C air temperature scenarios

Implications and Next Steps

Ecologically

- Nutrient concentrations in Sunapee changed more in response to warming than Mendota → this suggests that **oligotrophic (low-nutrient) lakes are more sensitive to climate warming** than eutrophic (high-nutrient) lakes

Computationally

- Distributed computing resources like the GRAPLEr platform accelerate whole-ecosystem simulation modeling, which allows ecologists to more effectively predict ecological responses to climate change

Acknowledgements

This work is supported by funding from United States National Science Foundation grants #ACI-1234983, EF-1702506, and ICER-1517823. We appreciate feedback from Carey Lab members Jon Doubek, Ryan McClure, and Mary Lofton during the preparation of this presentation.