



L E A P

Climate Data Science when data are sparse

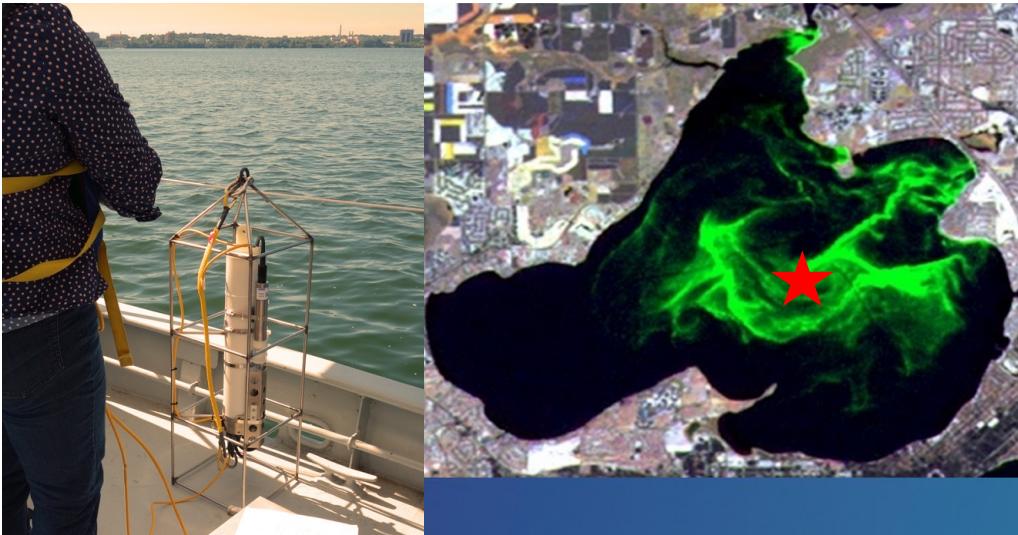
Professor Galen McKinley
Earth and Environmental Sciences

Climate Prediction Challenges
Spring 2022
Columbia University

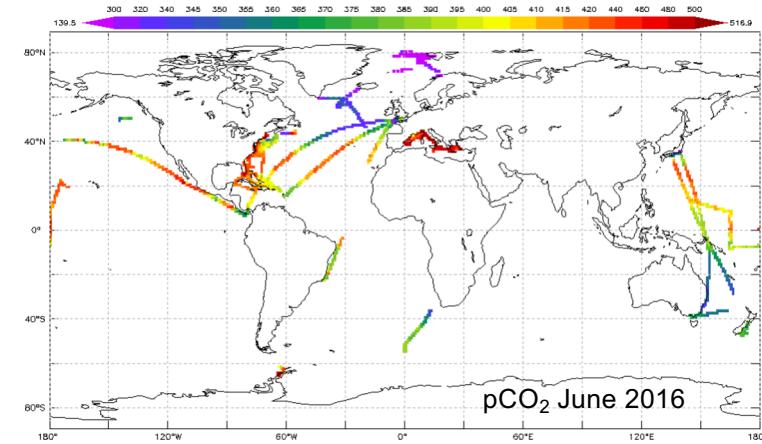
Understanding Earth system processes often complicated by sparse data

- Question: physical and ecological dynamics of lakes
- Data: a central buoy in only a few lakes
- PROJECT 2

Lake Mendota, Madison, WI

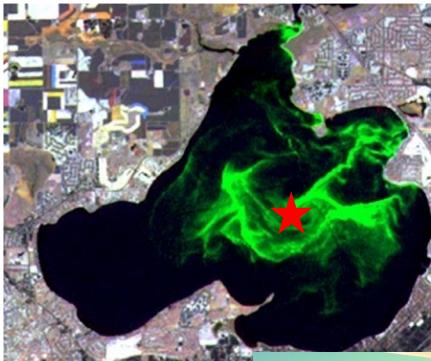


- Question: processes of variable ocean CO₂ fluxes
- Data: infrequent ship transects
- PROJECT 3

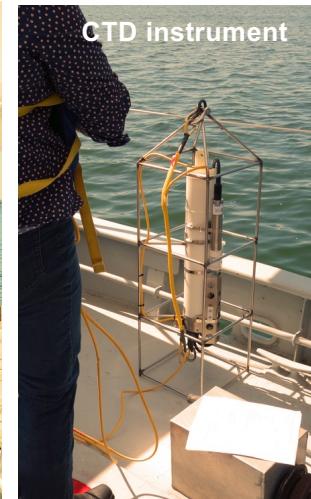


Observing Lake Mendota, Madison WI

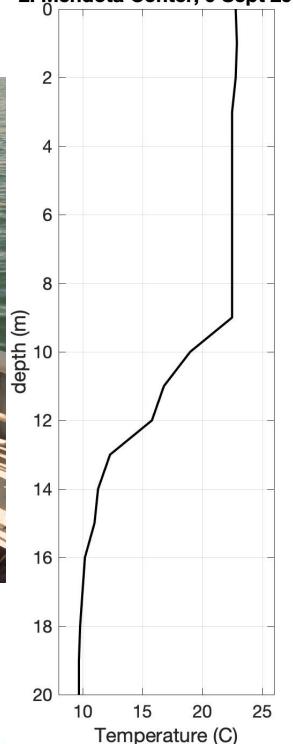
Lake Mendota, Madison, WI



Intro to Physical Oceanography, Wisconsin, Fall 2014

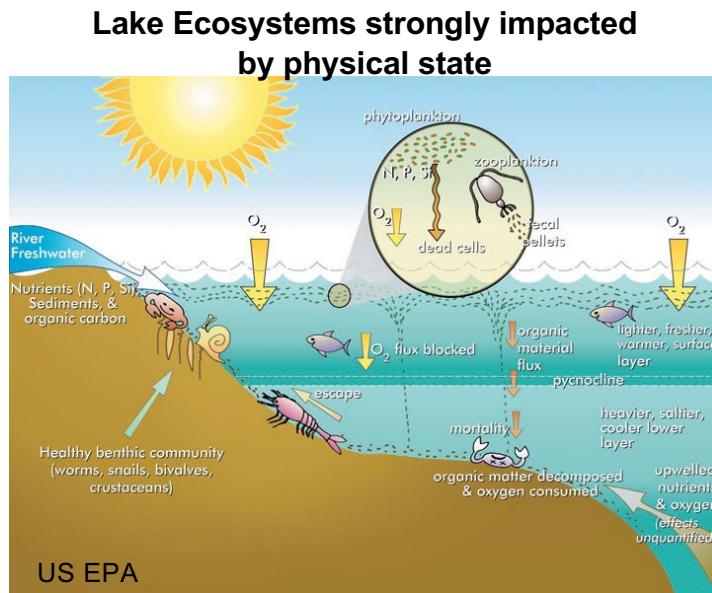


L. Mendota Center, 9 Sept 2014

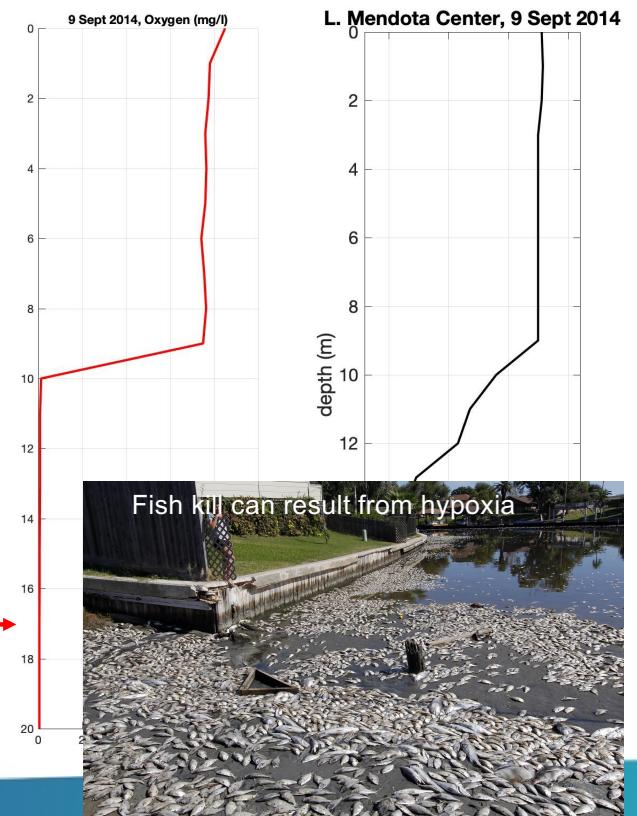


LEAP

Why do we care about lake temperatures?

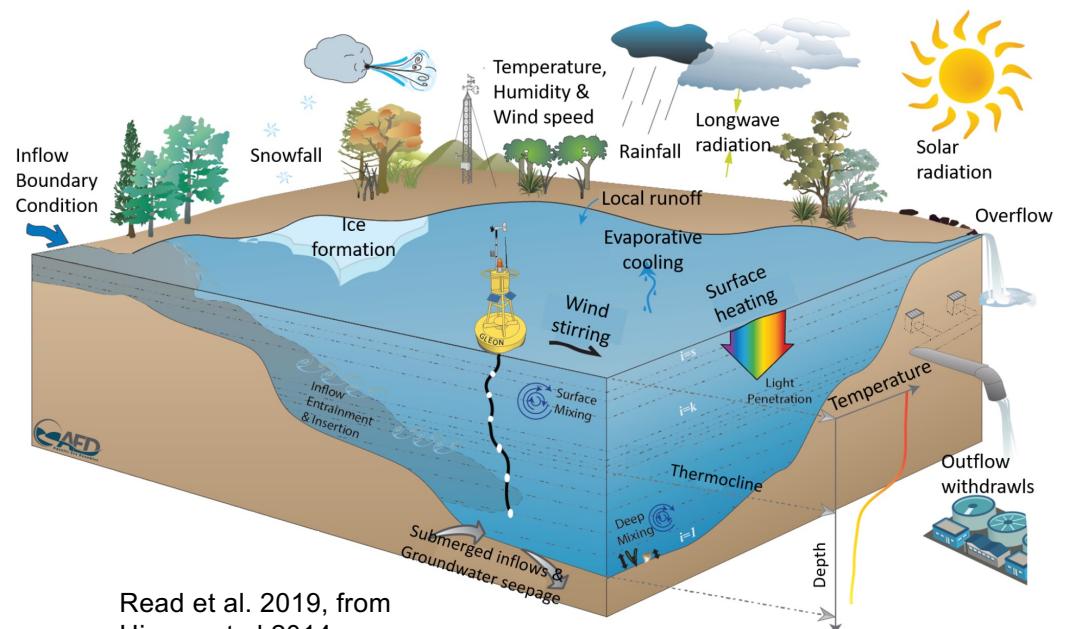
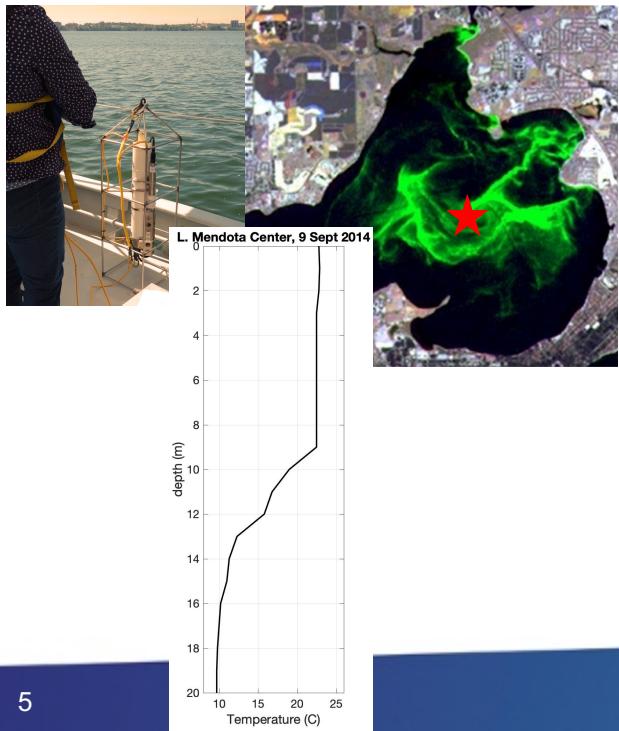


- Stratification encourages low O₂ at depth, reduces habitability for fish →
- Humans make this problem worse by adding excess nutrients to lakes (eutrophication).
- Excess nutrients and warmer surface encourages harmful algal bloom (image at left)
- Surface temperatures increase and the length of the stratified season grows with climate change (O'Reilly et al. 2015 GRL, Sharma 2014)



Observation are sparse and labor-intensive, but we do know a lot about the physics

Lake Mendota, Madison, WI

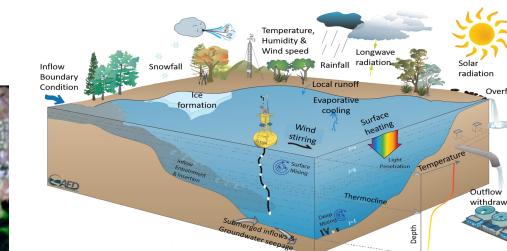
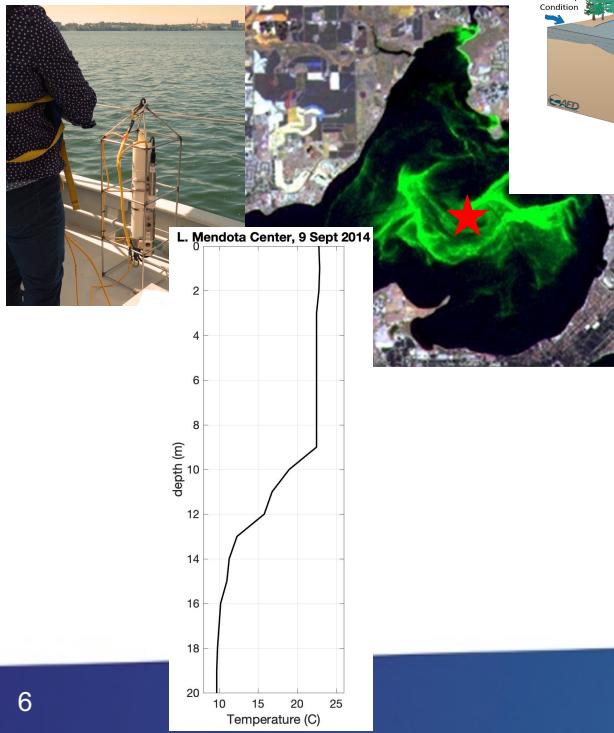


Read et al. 2019, from
Hipsey et al 2014

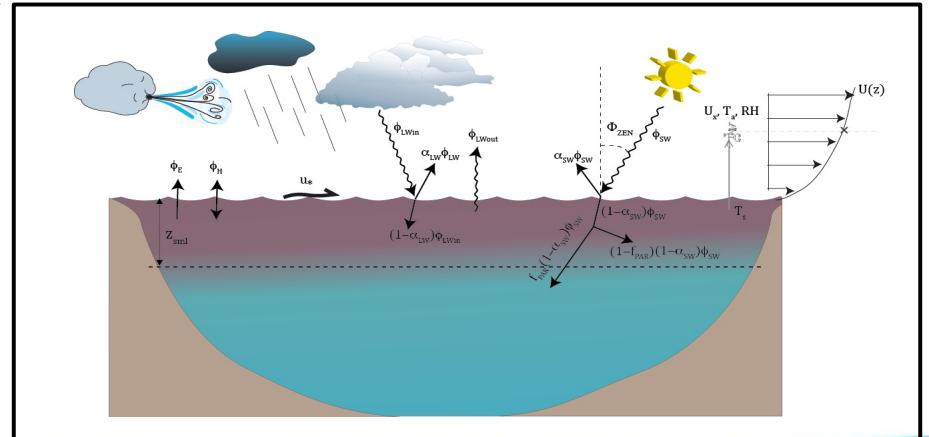


These physics can be embodied in a process model

Lake Mendota, Madison, WI

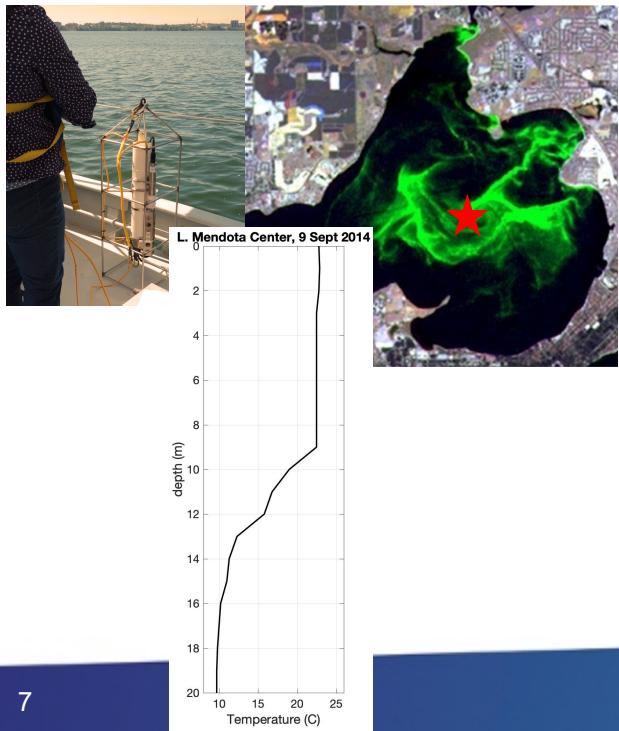


Process Model for 1D lake hydrodynamics

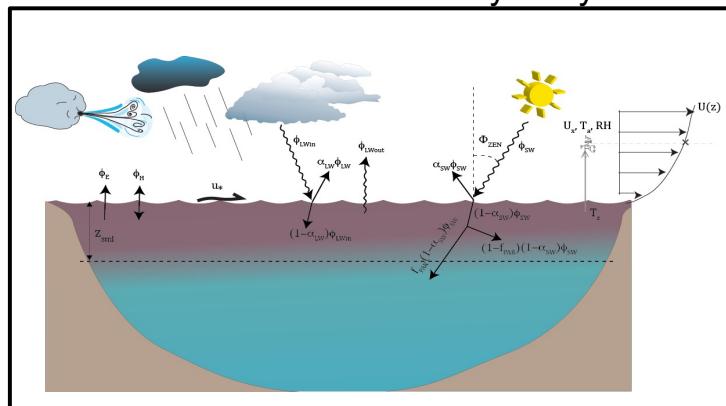


Process model to predict lake 1D temperatures

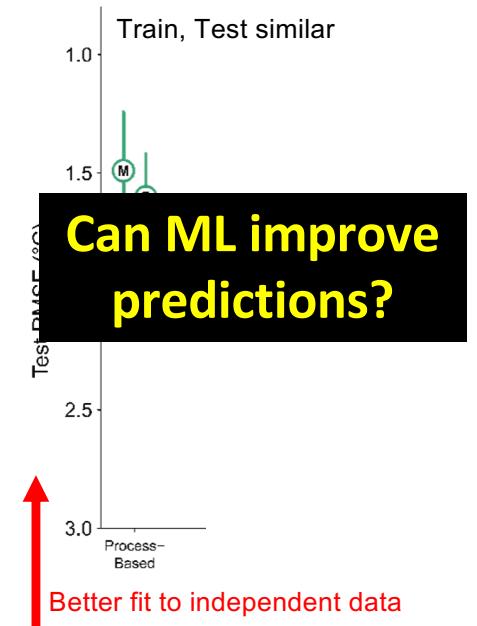
Lake Mendota, Madison, WI



Process Model for 1D lake hydrodynamics



Results



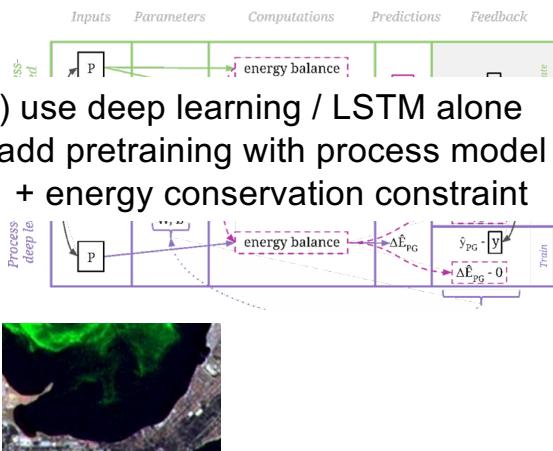
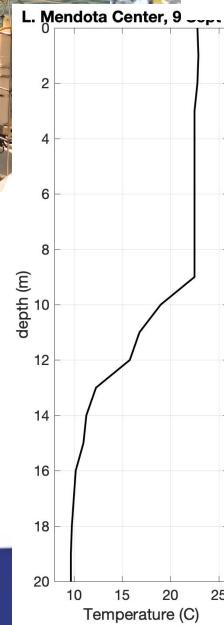
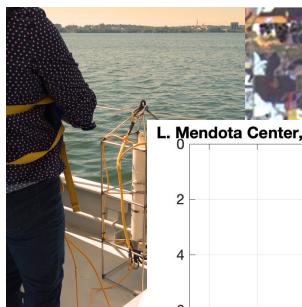
Read, Kumar et al. 2019, *Water Resour. Res.*



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Physics-Guided ML blends process knowledge and deep learning for more robust predictions

Lake Mendota, Madison,



Read, Kumar et al. 2019, *Water Resour. Res.*



Next steps: estimate temperatures for 1000's of unobserved lakes, from surface data only



Next steps: extend to multiple interacting processes and spatial scales; other domains

