2019 ASLO, Puerto Rico

Title (160 char limit with spaces): Improved understanding and prediction of 37 years of surface water phosphorus dynamics using theory guided machine learning

Authors: Paul C. Hanson[1], Aviah B. Stillman[1], Cayelan C. Carey[3], Xiaowei Jia[2], and Vipin Kumar[2]

[1]University of Wisconsin-Madison, Center for Limnology
[2]University of Minnesota, Department of Computer Science and Engineering
[3]Virginia Tech, Department of Biological Sciences

Abstract (1600 char limit): Surface water concentration of phosphorus (P) is a determinant of lake water quality through its control over growth of primary producers. In dimictic lakes, accurate predictions of epilimnetic P are important for evaluating water usability and safety. Equally important is building the contextual understanding for those predictions, including the mechanisms that control ecosystem-scale P budgets. However, improving mechanistic understanding while improving prediction accuracy can be challenging because of the contrasting philosophies of process-based and empirical approaches to modeling lake P.

We use 37 years of data from Lake Mendota, Wisconsin, to both improve our understanding of lake P cycling and improve our accuracy of summertime surface P predictions. We use theory-guided machine learning (ML) to constrain the problem space for ML algorithms with a process-based model of lake P mass balance. As a consequence, we are able to reproduce monthly to decadal patterns in surface water P, determine which external drivers and internal controls modulate the observed patterns, and learn how to improve our process-based model. ML indicates bias in the process-based model, even though it is relatively simple and fitted through well-accepted optimization techniques. Inclusion of missing processes related to temperature and thermocline depth would significantly improve prediction accuracy for surface water P. Over decadal scales, a roughly 70% reduction in load would reduce surface water P from eutrophic to mesotrophic levels.