RH: Dissolved oxygen prediction in reservoirs

Title: Do polymictic mixing regimes complicate prediction of dissolved oxygen in lakes and reservoirs?

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**Significance Statement**

Our manuscript focuses on predictability of dissolved oxygen across four different reservoirs in the south-Central US – two polymictic and two monomictic. High frequency (here, ~2 hourly) water chemistry profiling is an emerging technology, and these time series are particularly rare in polymictic systems. The novelty of this manuscript lies in 1) comparing predictability at daily-to-seasonal timescales of such time series, 2) across environmental conditions in 4 reservoirs with different mixing regimes (whereas ‘classical paradigms’ of lakes and reservoirs were generated in dimictic systems), 3) with a focus on dissolved oxygen rather than water temperature, which has been the main subject of recent forecasting efforts elsewhere, 4) while highlighting surprising dynamics in the dissolved oxygen time series themselves. Our argument is that such predictive modeling across environmental gradients sets expectations for how freshwater ecosystems might be managed under scenarios of global change, which are widely predicted to include shifts in both lake mixing regimes and trophic status.

This work is appropriate for L&O and particularly the special issue on Autonomous Instrumentation (Dr. Steeve Comeau, *pers. comm*)because it highlights the relevance of high temporal resolution data to both basic biogeochemistry and management objectives (e.g., in a forecasting context), across conditions considered fundamental to lake and reservoir water quality and ecological function.

**Author Contribution Statement**

**Anders Nielsen**: Conceptualization (supporting), Methodology (equal), Writing – review and editing (equal); **Caleb Robbins**: Conceptualization (lead), Data curation (lead), Formal analysis (lead), Methodology (equal), Writing – original draft (lead); **Jeffrey Sadler**: Methodology (equal), Writing – review and editing (equal); **J. Thad Scott**: Conceptualization (supporting), Data curation (supporting), Project administration (lead), Resources (lead), Writing – review and editing (equal); **Dennis Trolle**: Conceptualization (supporting), Methodology (equal), Writing – review and editing (equal); **Nicole Wagner**: Data curation (supporting), Writing – review and editing (equal).

**Abstract**

As lake and reservoir ecosystems transition across major regimes resulting from anthropogenic change, setting predictive expectations is imperative. Mixing regimes are shifting in many lakes and reservoirs and can strongly control dissolved oxygen (DO) dynamics, a major control on biogeochemistry, fauna, and general water quality for ecosystem services. We tested the hypothesis that DO is more predictable in monomictic reservoirs that thermally stratify throughout the summer, warm season compared to polymictic reservoirs that stratify intermittently. We compared daily-aggregated errors of DO predictions from random forests across two monomictic and two polymictic reservoirs in the South-Central (subtropical) USA. Although one monomictic reservoir was typically more predictable than the polymictic reservoirs, the hypereutrophic, small monomictic reservoir had surprising DO patterns potentially related to rapid oxygen cycling and intrusions of oxygenated waters in the hypolimnion without mixing. Daily mixing did not relate strongly to model errors. Water temperature, depth, and wind were the most important predictors, but were not clearly related to season or mixing. Lastly, we compared multiple model types (regression, neural network, and process-based) in one polymictic reservoir, finding that the models generally agreed, except the process-based model poorly predicted DO at the middle depth, where most models performed poorly due to a temporally unstable, vacillating metalimnion. Predicting reservoir DO dynamics may be easier in stratified reservoirs with a stably anoxic hypolimnion and consistent diel swings in the epilimnion, but we hypothesize that eutrophication and complex hydrodynamics may cause forecasting surprises for those who use or manage reservoir water resources.

**Key Words**: recurrent neural network, forecasting, Shapley Additive exPlanation (SHAP), variable importance, LASSO, GOTM-WET