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# Using a machine learning to model dead zones in lakes

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The waters of Lake Erie seem to glow green in this image taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite. Credit: NASA image courtesy LANCE/EOSDIS MODIS Rapid Response Team at NASA GSFC

Aquatic ecosystems are complex environments that can be affected by many variables, including weather, the biological activities of the organisms living within them, and anthropogenic nutrient pollution. The influence these variables may have on aquatic ecosystems can also depend on the characteristics of the water body, such as temperature and depth. These interconnected processes can be tipped out of balance with devastating consequences.

To help anticipate these consequences, a group of UConn researchers have developed a versatile computer modeling method using machine learning to enhance existing efforts to monitor and predict lake water quality. The method was recently published in *Environmental Modelling & Software*.

Department of Civil & Environmental Engineering and Head of the Atmospheric and Air Quality Modeling Group Associate Professor Marina Astitha explains the research was five years in the making and is a collaboration with a former student, Christina Feng Chang '22 Ph.D. as part of her dissertation, and Department of Marine Sciences and Head of the Environmental Chemistry and Geochemistry research group, Professor Penny Vlahos.

Aquatic environments are susceptible to eutrophication, a process triggered by excess nutrients, most prominently tied to fertilizer runoff from agricultural activities, that make their way to water ecosystems and lead to algae blooms. The increase in growth and eventual decomposition of these plant-like materials consume much or all of the available oxygen, to the detriment of other organisms in the environment.

Oxygen-deprived or hypoxic areas are dubbed "dead zones" and can lead to fish mortality, water quality issues, and other harmful environmental and economic impacts. Astitha explains that these eutrophication events are expected to intensify with climate change, and that models like this will become more important for monitoring and prediction purposes.

The researchers focused their study on Lake Erie's central basin, which has experienced seasonal algal blooms and eutrophication events for decades. The lake's proximity to large agricultural areas, where fertilizers are used, and metropolitan centers, where air pollution is a concern, presents a unique set of challenges that the team aimed to study.

With millions of people relying on Lake Erie for their water, modeling has been and continues to be instrumental in monitoring water quality, says Astitha.

"Right now, predictive models do day-to-day forecasts, which is very important, especially for the people living in these areas because they're big population hubs. Water is not just for recreational purposes; people use it in their daily lives."

However, Astitha says no single model can account for all the variables that impact water quality. To address this, they started building machine learning models to integrate data from different sources and train machine learning algorithms with observations in the lake.

Astitha says their first publication using this method focused on machine learning modeling of chlorophyll a, an indicator of algal biomass and eutrophication, and a second paper used the same methodology but looked at nutrient pollution from rivers and streams. This most recent paper looks at physical and biological processes confined within a physics-based model to understand the dynamic processes involved in eutrophication events.

Astitha says they must start the model building from scratch for each of the processes they are studying, but it is necessary to assess the different physical, biological, weather-related, and human processes that impact eutrophication.

Chang explains that eutrophication processes start in the spring when fertilizer applications on agricultural lands followed by rain events can flush the nutrients into the lake. During the summer, Lake Erie's waters form three layers, a warmer one closer to the surface called the epilimnion, an intermediate layer that experiences the most drastic water temperature change called the metalimnion, and a deeper, cooler one called the hypolimnion.

The metalimnion layer houses the thermocline, where the temperature changes abruptly. In summer during stratification, there is little to no mixing between the epilimnion and hypolimnion layers, which means that the deepest waters become increasingly oxygen-deprived throughout the summer.

The lake's central basin is prone to the most severe hypoxic events, and to study these events and understand what is driving them, Astitha explains the model was designed to predict dissolved oxygen (DO), which is a proxy for hypoxia in the water, and apparent oxygen utilization (AOU), which is a proxy for biological activity in the aquatic ecosystem. They used 15 years of data collected between 2002 to 2017 to train the model.

The results were good, says Astitha, and the model accurately predicted the observed DO and AOU conditions. The model also identified that thermal stratification, or the separate temperature layers in the water column, was the most impactful variable driving eutrophication in their study area.

"It was a good proof of concept because there are scarce data points in the lake," says Astitha. "Ideally, any model would need a more extensive lake coverage, which is not there. It's not feasible with the point observations we have. Nevertheless, the model worked very well."

Models like this will become increasingly important for water quality monitoring and support decision making as the climate continues to change. Astitha says they expect conditions, such as temperature increases, to intensify stratification, while potentially exacerbating the amount of nutrients entering the lake with extreme precipitation events caused by climate change.

"What happens with hypoxia is that in this natural system, they have nitrogen and phosphorus in them anyway, but when hundreds of acres of land are fertilized, some of that fertilizer leeches into the water. It depends on the mixing or stratification of the lake, and weather conditions influence these. Conceptually, we think climate change will make things worse, and we can now entertain hypothetical future scenarios with the model within the conditions of climate simulations."

Astitha says future research includes applying the methodology to other freshwater or marine ecosystems and a more thorough analysis using different climate change projection data to investigate the impact of climate change scenarios on water quality of those systems.

"From my point of view, we wanted to build a tool that complements the models already doing this important prediction and monitoring. In the era of machine learning and artificial intelligence, we are trying to bring that piece in and see how helpful it is, which motivated me to start and continue this work."

**More information:** C. Feng Chang et al, Assessing physical and biological lake oxygen indicators using simulated environmental variables and machine learning algorithms, *Environmental Modelling & Software* (2024). DOI: 10.1016/j.envsoft.2024.106024

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