Coupling Lake, Estuarine, and Watershed Models to Elucidate Role of Freshwater Discharges in Driving HAB Severity, Location, and Timing

Lead: David Kaplan, University of Florida

USACE Harmful Algal Bloom Research & Development Initiative

Delivering scalable freshwater HAB prevention, detection, and management technologies through collaboration, partnership, and cutting-edge science.

Problem

Multiobjective management of Lake Okeechobee (Lake O) has been a "wicked problem" for USACE for nearly 100 years. The need to maintain in-lake storage for flood protection while meeting water quantity and quality requirements for flows to the Everglades has led to frequent discharges to the Caloosahatchee and St. Lucie Estuaries. While Lake O discharges have been associated with both freshwater and marine algal blooms, connections among lake management, watershed-derived nutrients, phytoplankton dynamics, and coastal hydrodynamics have not yet been fully resolved.

Objective

This project seeks to develop improved data- and model-driven guidance for Lake O releases and Caloosahatchee watershed management via four linked objectives: (1) adapting and coupling Lake O, Caloosahatchee watershed, and estuarine hydrodynamic models; (2) augmenting existing water quality data with real-time, monthly, and event-driven sampling; (3) quantifying estuarine residence times, nutrient concentrations, and phytoplankton communities in relation to environmental drivers; and (4) applying model and data synthesis to identify optimal conditions for Lake O discharge.

Approach

This project integrates multiple modeling, data collection, and analysis approaches. Modeling approaches include two Lake O models to simulate the effects of watershed loading and discharge decision-making on lake outflows and nutrient/algae loads; process- and machine learning-based models of Caloosahatchee River watershed flows and nutrient loads; and a coastal hydrodynamic model to understand how river discharge (including Lake O releases) affects estuarine residence times and water quality. Water quality monitoring and analyses include installation of real-time sensors and two years of discrete monthly sampling to

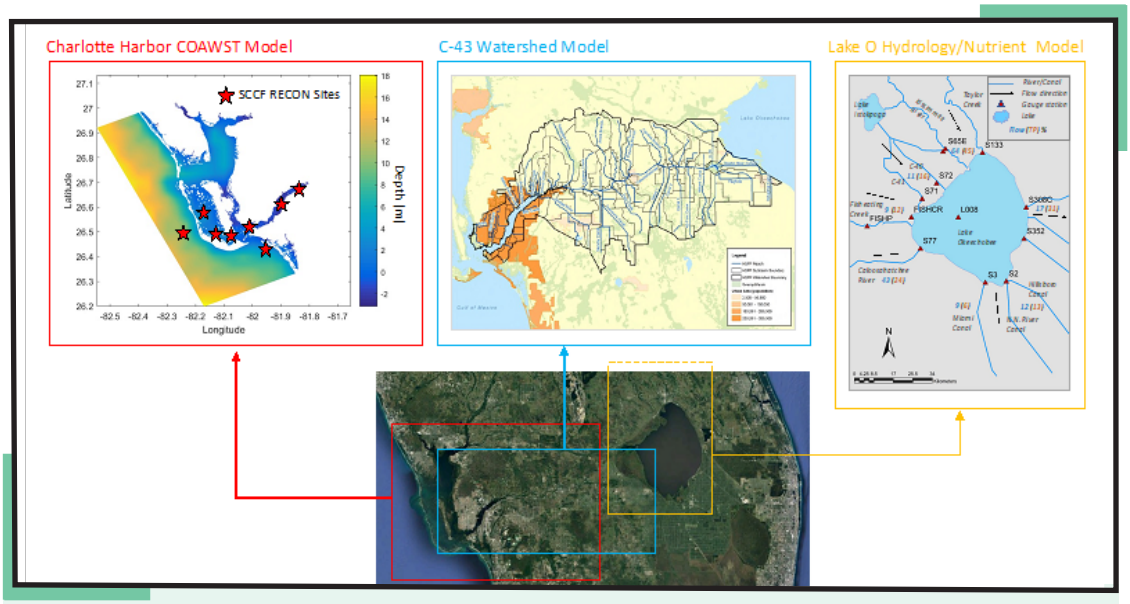

Figure 1. *To better understand the role freshwater discharge plays in HAB formation, researchers are combining data and models spanning from Lake Okeechobee to the Caloosahatchee River Estuary. The effort utilizes lake, watershed, and coastal hydrodynamic modeling to assess how lake operation decisions affect estuarine circulation, residence time, and water quality, including particle tracking within the Caloosahatchee River.*

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Approach (cont.)

characterize phytoplankton communities and track nutrient sources. Statistical analyses include trend and change analysis for Lake O discharges, development of concentration-discharge relationships for the lake and watershed, and predictive models for phytoplankton taxa as a function of environmental drivers.

Major Milestones

Deliverable	Description
Journal Articles	Hewageegana, V. H., M. Olabarrieta, and J. M. Gonzalez-Ondina. 2023. "Main Physical Processes Affecting the Residence Times of a Micro-Tidal Estuary." *Journal of Marine Science and Engineering* 11 (7): 1333. https://doi.org/10.3390/jmse11071333. Phlips, E. J., S. Badylak, A. L. Mathews, E. C Milbrandt, L. R. Montefiore, E. S. Morrison, N. Nelson, and B. Stelling. 2023. "Algal Blooms in a River-Dominated Estuary and Nearshore Region of Florida, USA: The Influence of Regulated Discharges from Water Control Structures on Hydrologic and Nutrient Conditions." *Hydrobiologia* 850:4385–4411. https://doi.org/10.1007/s10750-022-05135-w. Shi, L., C. Ortals, A. Valle-Levinson, and M. Olabarrieta. 2023. "Influence of River Discharge on Tidal and Subtidal Flows in a Microtidal Estuary: Implication on Velocity Asymmetries." *Advances in Water Resources* 177:104446. https://doi.org/10.1016/j.advwatres.2023.104446. Tarabih, O. M., T. D. Dang, R. Paudel, and M. E. Arias. 2023. "Lake Operation Optimization of Nutrient Exports: Application of Phosphorus Control in the Largest Subtropical Lake in the United States." *Environmental Modelling & Software* 160:105603. https://doi.org/10.1016/j.envsoft.2022.105603. Montefiore, L. R., D. Kaplan, E. J. Phlips, E. C. Milbrandt, M. Arias, E. Morrison, and N. G. Nelson. In review. "Relative Contributions of Reservoir Releases and Basin Inputs on Downstream Water Quality in a Highly Engineered Watershed." *Water Resources Research.* Orozco-Lopez, E., and D. Kaplan. In review. "Interpretable Transformer Neural Network Prediction of Diverse Environmental Time Series Using Weather Forecasts." *Water Resources Research.*
Tech Reports	Kaplan, D., M. Arias, E. Milbrandt, E. Morrison, N. Nelson, M. Olabarrieta, E. Phlips, et al. 2022. *Year 1 Annual Report (October 1, 2021 – September 30, 2022): Coupling Lake, Watershed, and Estuarine Models to Better Understand the Role of Engineered Freshwater Discharges in Driving the Severity, Location, and Timing of Harmful Algal Blooms.* Technical report to the US Army Corps of Engineers Engineering Research Development Center, Aquatic Nuisance Species Research Program, Gainesville, FL. Olson, L. 2023. "Assessing Annual Changes in Water Quality in the Caloosahatchee River and Estuary." Undergraduate thesis, University of Florida.

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Major Milestones (cont.)

Deliverable	Description
Products	One-page "Fact Sheets" summarizing the key findings and take-home messages from each of the journal publications listed above are currently in development.

Partnership/Leveraging Opportunities

Project outcomes are being leveraged by the new project "Integrating Modeling Tools and Observations for Prediction and Management of Harmful Algal Blooms in the St. Lucie Estuary and Watershed." End-user workshops and scenario development efforts are being coordinated among the two projects. A kickoff meeting was held in February 2023 and included the project team and representatives from the Florida Department of Environmental Protection, US Army Corps of Engineers Jacksonville District, and the South Florida Water Management District (which is also a direct project partner).

Value to USACE Mission

Understanding how lake, estuarine, and watershed operations influence the severity, location, and timing of HABs in and around Lake Okeechobee would give valuable insight for project managers that can guide more stratetgic operational decisions. This fundamental knowledge has the potential to inform novel prevention and management strategies in Lake Okeechobee and cyanoHAB research in freshwaters across the nation.