Developing Ecological Forecasts and Applications Linked to the Great Lakes Operational Forecast System models

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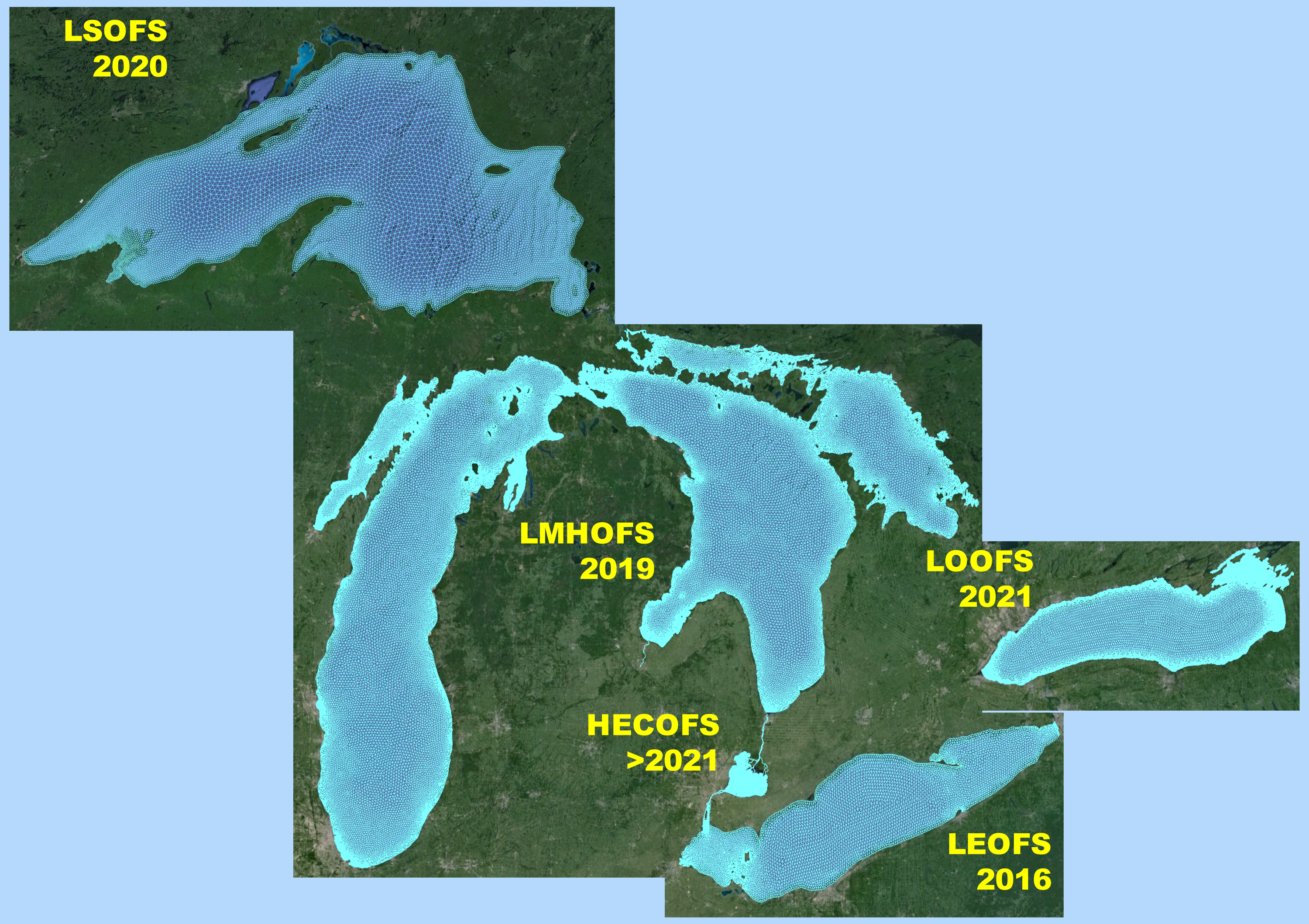
Great Lakes Operational Forecast System

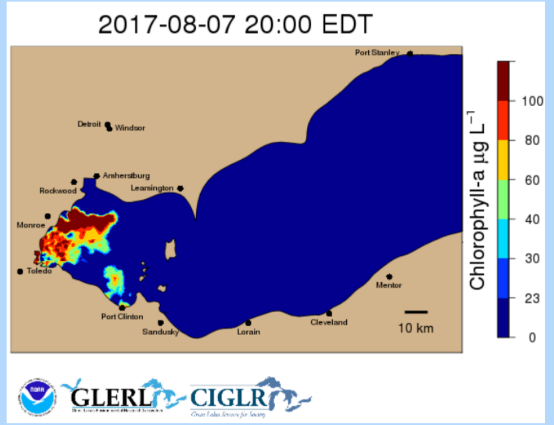
GLERL is working with NOS/CO-OPS and NOS/OCS/CSDL to upgrade the Great Lakes Operational Forecasting System (GLOFS), based on the Finite Volume Community Ocean Model (FVCOM). With greater spatial resolution and more realistic depiction of shoreline morphology than the previous generation of models, this new generation of models promises more realistic representation of coastal and transport processes that are important drivers of ecological processes.



Experimental Lake Erie Harmful Algal Bloom Forecast

The Lake Erie Operational Forecast System (LEOFS) model was linked to a Lagrangian particle tracking model to provide a daily nowcast and five-day forecast of harmful algal bloom distribution, called the Lake Erie HAB Tracker. The HAB Tracker is initialized using satellite-derived cyanobacterial index, produced by CO-OPS. The HAB Tracker has provided daily updates of location and predicted movement of HABs to drinking water systems, anglers, and recreational boaters on an experimental basis for 2014-2018, and is on a path to transition to operations at NOS/CO-OPS.

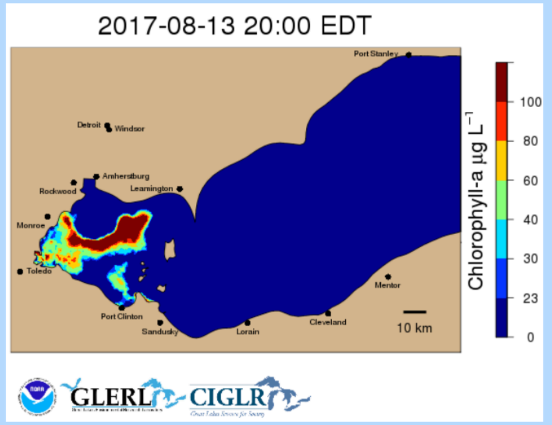
Nowcast



Initialize bloom location and intensity in a Lagrangian particle tracking model based on satellite remote sensing imagery

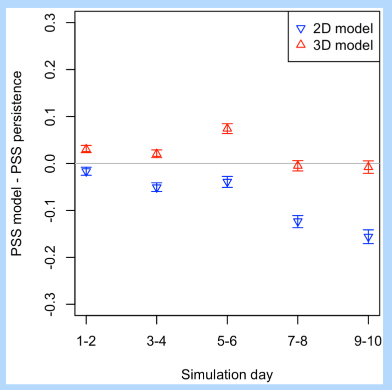
www.glerl.noaa.gov/res/HABs_and_Hypoxia/habTracker.html

Five-day forecast



Five-day forecast of bloom intensity and location based on

1. Currents from Lake Erie Operational Forecast System model (LEOFS)
2. Lagrangian particle tracking model incorporating simulation of *Microcystis* colony vertical distribution, combining turbulent diffusivity from LEOFS with measurements of *Microcystis* colony buoyancy and size distribution in a random-walk turbulence model

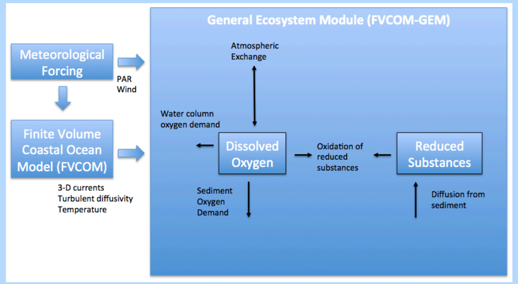


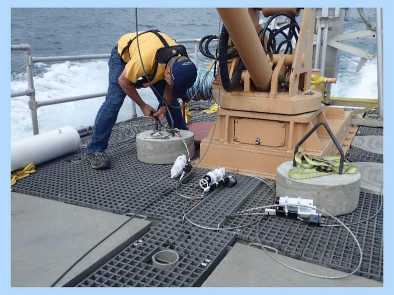
A hindcast skill assessment showed improved skill of the new 3D model relative to the current operational model that assumed the bloom was always on the surface. The Pierce Skill Score (PSS) quantifies the probability of detection minus the probability of false detection for HAB presence. As a benchmark, PSS was compared to a "persistence" forecast, or assumption of no change from the most recent satellite image, which represents the best available alternative to the forecast model.

Rowe et al. 2016. J. Geophys. Res. doi:10.1002/2016JC011720

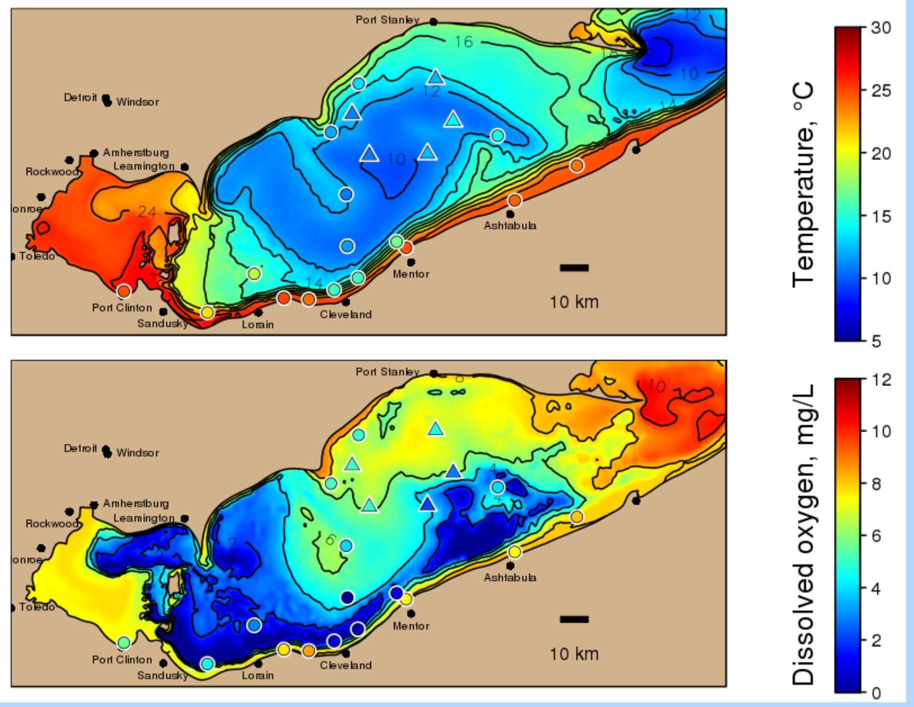
Experimental Lake Erie Hypoxia Forecast

In a project funded by NCCOS, the LEOFS model was extended to predict dissolved oxygen, and is being used to provide a daily nowcast and five-day forecast of spatial patterns of hypoxia in Lake Erie. The experimental LEOFS-hypoxia model is used to give drinking water systems advance notice of upwelling events that can bring hypoxic water into nearshore water intakes. A project goal is to transition the LEOFS-hypoxia model to operations in 2021.

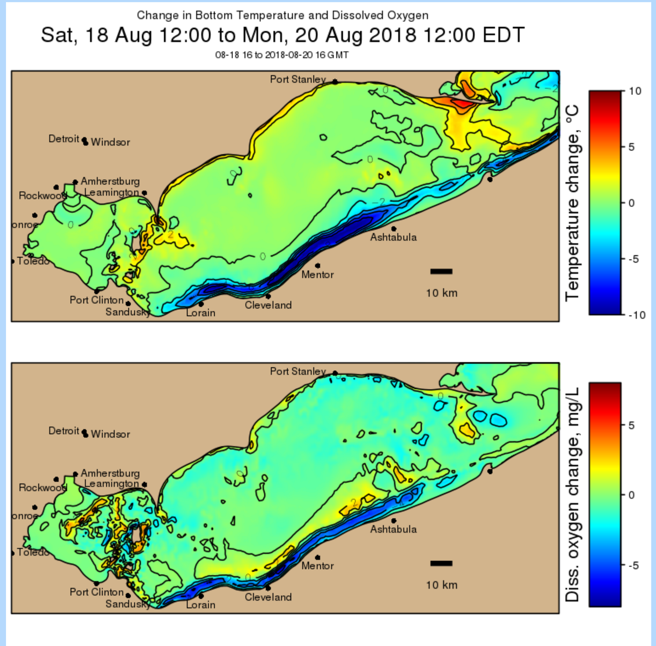




The FVCOM General Ecological Module was adapted to include simulation of dissolved oxygen and reduced substances in the water column and sediment fluxes of oxygen and reduced substances. We deployed an array of moored sensors to collect data on rapid changes in temperature and dissolved oxygen that occur in nearshore Lake Erie in response to upwelling events.



Observations from our sensor array combined with those of other agencies and universities were used to conduct a hindcast skill assessment. The figure above shows observations (symbols) plotted over model data on the same color scale. The model shows the complex spatial pattern of bottom dissolved oxygen, which is largely driven by the thickness of the hypolimnion and the location where the thermocline intersects the bottom.

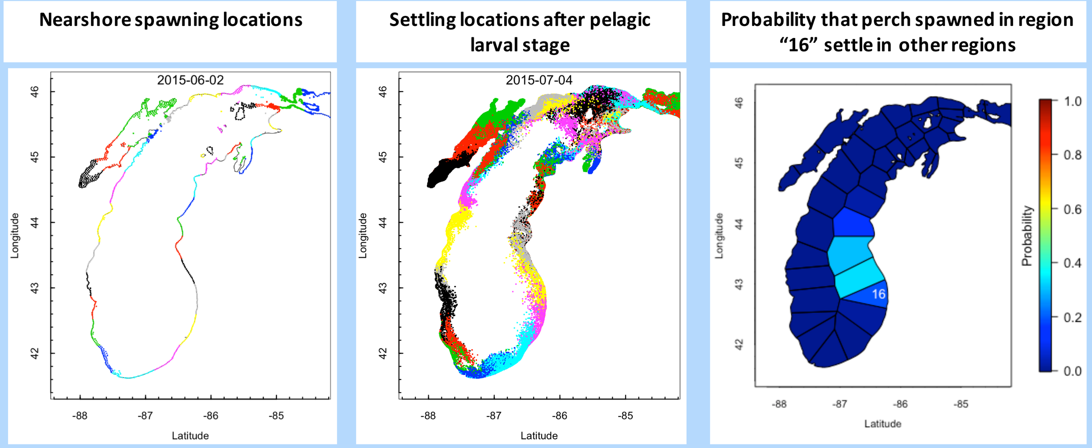


Forecast graphics were developed with feedback from a focus group study involving drinking water plant operators. The graphic above shows the predicted change in bottom water temperature an dissolved oxygen. On August 18-20, 2018, the model predicted an upwelling event that caused a rapid decrease in temperature and dissolved oxygen (blue color) along the Ohio coast from Lorain to Ashtabula, requiring operators at several drinking water plants to make adjustments to treatment operations to maintain high quality treated water.

The forecast website is updated daily during the summer hypoxia season:
www.glerl.noaa.gov/res/HABs_and_Hypoxia/hypoxiaWarningSystem.html

Larval Fish Dispersion

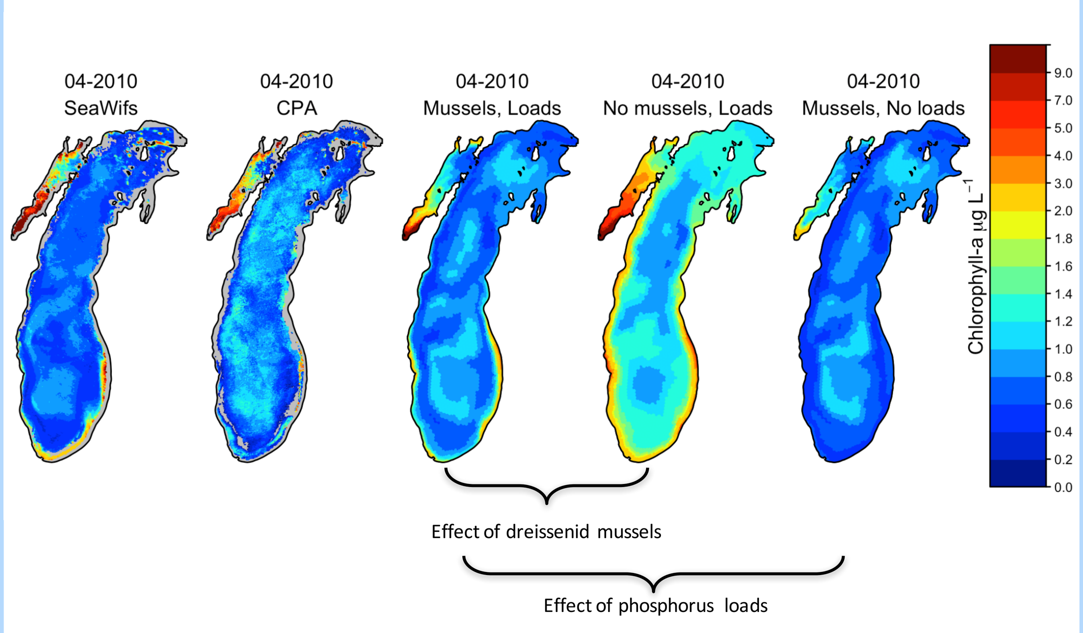
Lake Michigan has historically supported an economically important yellow perch fishery, but numbers have declined in recent years. CIGLR and Purdue University are collaborating in a project funded by the Great Lakes Fisheries Commission to delineate separate breeding populations of yellow perch in Lake Michigan. A Lagrangian particle dispersion model driven by currents from the new FVCOM-based Michigan-Huron Operational Forecast System model will be used to estimate the probability that larval perch originating in one spawning region will settle in another region after their month-long pelagic phase. The resulting transport connectivity matrix will be combined with genetic data to develop an eco-genetic agent based model.



Points color-coded by their starting location in nearshore spawning areas for larval perch were tracked for the month of July using a Lagrangian particle dispersion model driven by currents from the Michigan-Huron OFS to estimate the probability of larval perch spawned in one location to settle in another.

Lower Food Web Models

Lake Michigan supports an economically-important salmon fishery. Prey fish abundance has been declining since the 1980s. Predation by salmonids is likely the main driver, but nutrient loads have declined over the same time period and invasive filter feeders (quagga mussels) became established in large numbers after 2004. A nutrient-phytoplankton-zooplankton model was developed using the FVCOM General Ecological Module to help disentangle competing effects of declining nutrients, invasive filter feeders, and inter-annual changes in meteorology on primary production. It was found that invasive filter feeders changed spatial and temporal patterns of productivity, while declining nutrient concentrations reduced annual, lake-wide productivity. Results contributed to a study by the Great Lakes Fisheries Commission on potential lower food web impacts on the Lake Michigan fishery.



Scenarions simulated with an FVCOM-GEM nutrient-phytoplankton-zooplankton model of Lake Michigan reproduced patterns seen in remote sensing imagery and showed the separate effects of nutrient loads and invasive filter feeders on phytoplankton abundance (as chlorophyll-a).

Rowe et al. 2017. Limnol. Oceanogr., 62:2629-2649

Bunnel et al. 2018. Are Changes in Lower Trophic Levels Limiting Prey-Fish Biomass and Production in Lake Michigan? Great Lakes Fishery Commission report 2018-01, http://glfc.org/pubs/misc/2018-01.pdf

Food Web Models

We are using food web models of varying complexity to evaluate the potential effects of stressors (potential species invasions, climate, nutrients) on the food web and fisheries in the Great Lakes. These models range from tracking individuals across space and time to linking food web and habitat models with 3-D hydrodynamic models.