Development of a coupled hydrodynamic-biogeochemical-*Microcystis* model for the St. Lucie estuary, FL

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Background

The St. Lucie estuary (Fig. 1) has recently experienced significant deterioration in water quality and *Microcystis* blooms. Freshwater discharges from Lake Okeechobee carry significant nutrients and cells of cyanobacteria *Microcystis aeruginosa* that may lead to phytoplankton blooms and reduced dissolved oxygen, among other effects. More importantly, *Microcystis* may produce *Microcystin* that affects human health. It remains unclear what controls the water quality and *Microcystis* blooms remain unclear. Here we use a numerical model along with available observation to study the dynamic mechanisms and spatial-temporal patterns of key water quality parameters. The ultimate goal of this project is to develop an operational forecast model that can be used to assist in water management decision.

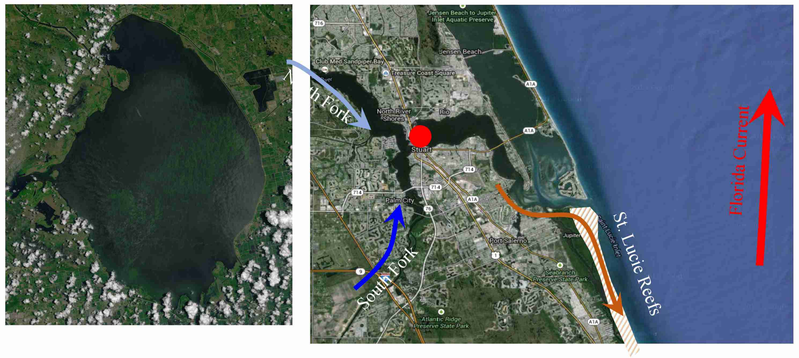


Figure 1. (Left) *Microcystis* blooms in Lake Okeechobee on July 16, 2016, and a diagram for St. Lucie estuary (right). Freshwater waters are exported to the coastal areas through St. Lucie inlet. Red dot indicates a mid-estuary station.

Model Description

The numerical model is based on the Regional Ocean Modeling System (ROMS), which includes a hydrodynamic module that solves the hydrostatic equations of ocean motions, and a biogeochemical model that describes nutrient cycles and phytoplankton blooms with seven NPZD functional groups (Fennel et al. 2006). The model is forced by river discharges, atmospheric forcing, and open boundary forcing incl. tides. Nutrients inputs include river and watershed discharges, atmospheric loading, and sediment inputs. One year (2018) simulation has been conducted and the results calibrated with available data.

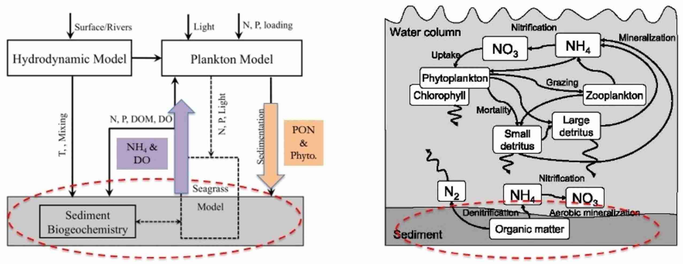


Figure 3. (left) a diagram of the coupled physical-biogeochemical model and (right) the biogeochemical model (Fennel et al. 2006). Note sediment processes are not directly simulated.

Model Domain and Bathymetry

Model domain includes St. Lucie estuary, southern part of Indian River Lagoon, and a portion of eastern Florida shelf. The model resolution is ~60 m within main channels and inlets. Yet there remains significant uncertainty in water depth.

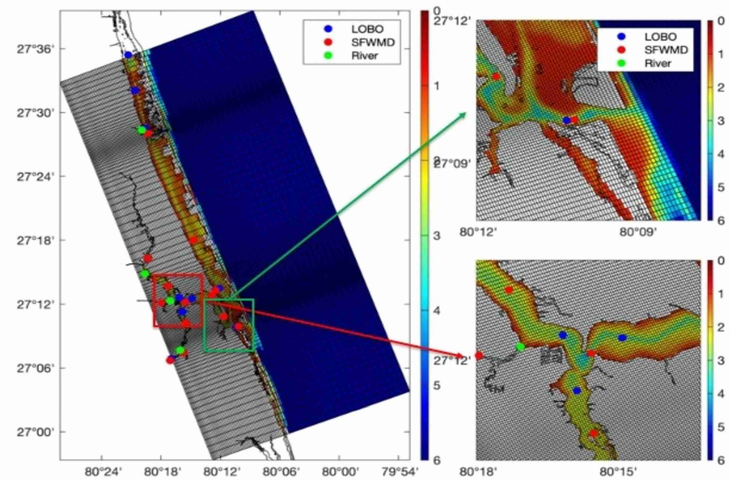
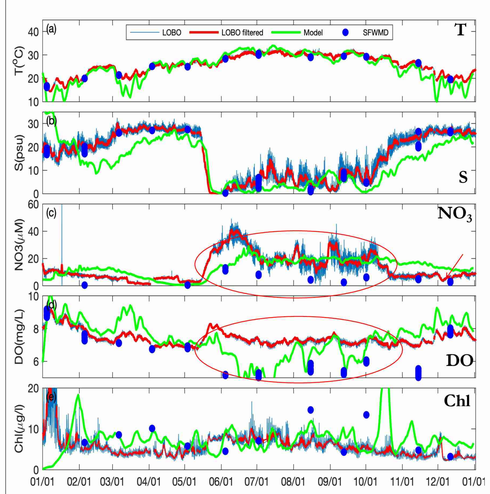


Figure 2. Model domain and bathymetry (left), and the details in St. Lucie inlet (top right), and mid-estuary (bottom right). Dots indicate stations for in situ observations (red), IRLON time-series (blue) and input entry points (green).

Model-data Comparison

The model results agree with data in general but also show significant mismatches. An example is shown below. However, the relatively stable chlorophyll concentration indicate this is largely a chemostat system where sufficient nutrients flow through the estuary, and lead to relatively steady phytoplankton responses, which biomass are controlled by temperature and losses (grazing & mortality). This raises questions on how *Microcystis* may behave when the cells are introduced into the estuary from the lake?



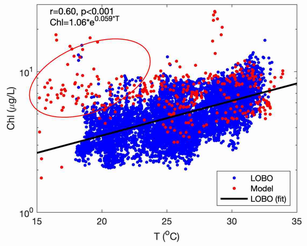


Figure 5. Left: A comparison with IRLON and *in situ* bottle data at a mid-estuary station (Fig. 1). Top: Observed chlorophyll in the estuary is strongly correlated with water temperature. Model did not fully re-produce this relationship.

River and Watershed Inputs

The nutrients and freshwater are from Lake Okeechobee and local watershed through 4 main canals and runoffs, largely during the wet seasons. About 60-80% of nutrient inputs are in the forms of organics.

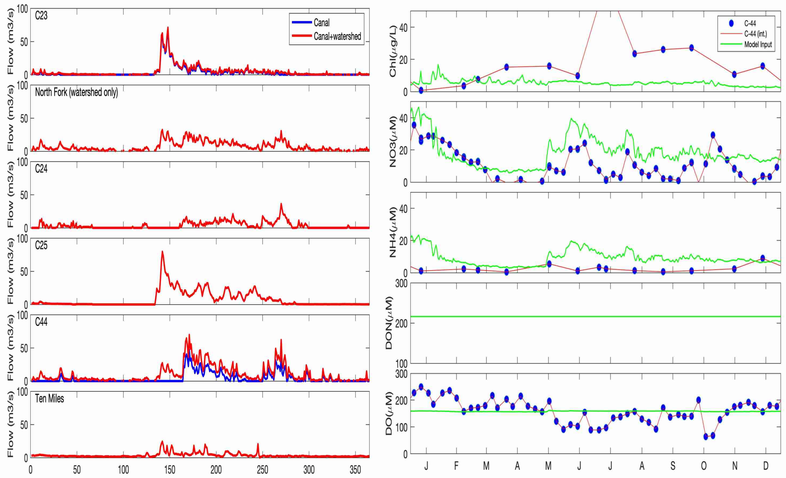


Figure 4. Left: River discharges from all of the main canals and watershed. Right: Phytoplankton (top), NO3 & NH4 (2nd & 3rd panels), DON (4th panel) and dissolved oxygen (bottom) concentrations measured at C-44 canal (source: SFWMD), and the actual model inputs largely based on IRLON SF2 station data.

Individual-based Modeling for *Microcystis*

An individual-based model for tracking Microcystis is being developed to simulate *Microcystis* cells as passive particles that can adjust density based on light condition and oxygen bubbles produced by photosynthesis, which allow them to stay afloat at the surface. Preliminary results suggest that passive particles favor west and north shore but the patterns with the biological behaviors of the *Microcystis* cells are complex.

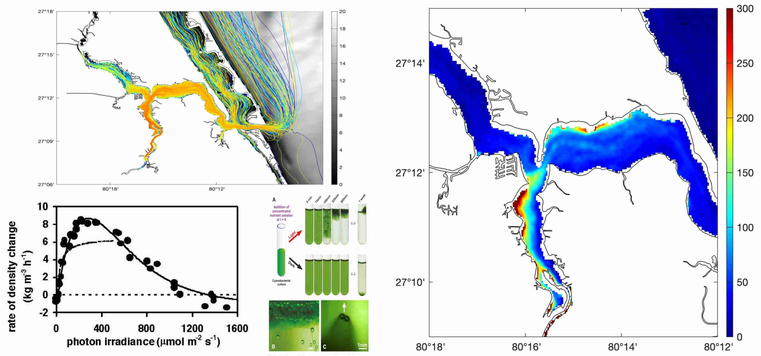


Figure 6. Top left: Trajectories of particles released from South Fork (for 1 month and track another month). Bottom left: Two biological mechanisms that allow *Microcystis* colony to stay afloat: Density changes with light and bubbles trapped in colonies (bottom). Right: Mean particles distribution 2 weeks after release.

Acknowledgements

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