CHNEP Watershed Summit
June 21-22, 2023

Synthesizing Monitoring Data With a 1D Model for Water Quality Conditions in the Caloosahatchee Estuary

Detong Sun, PhD
Lead Scientist
Coastal Ecosystems Section

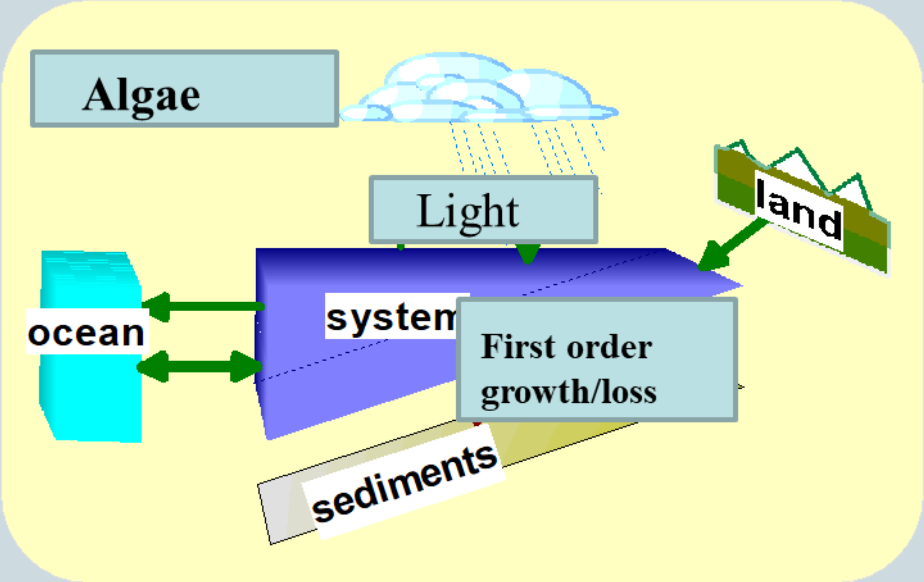
Background and Objectives

Kinetic rates are the major uncertainty, obstacles for water quality modeling

$$\frac{dC}{dt} = diffusion + \mu C$$

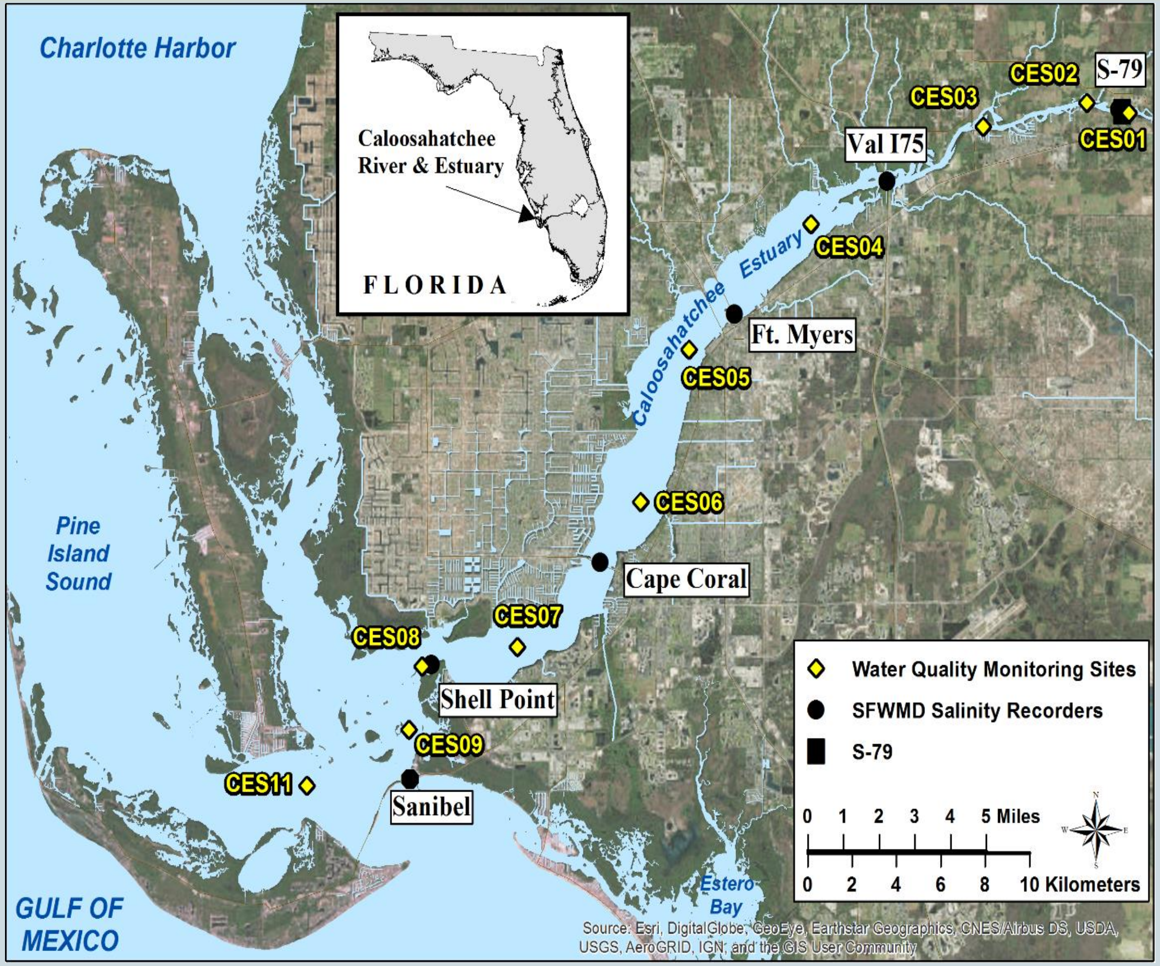
$$\mu = G - R - M$$

- *C* phytoplankton concentration
- *G* gross production
- *R* respiration
- M mortality/predation
- μ net growth rate



Background and Objectives

- Kinetic rates are critical for assessment of water quality conditions and algal bloom risks
- Monitoring data may provide indirect way for the estimates of net rates



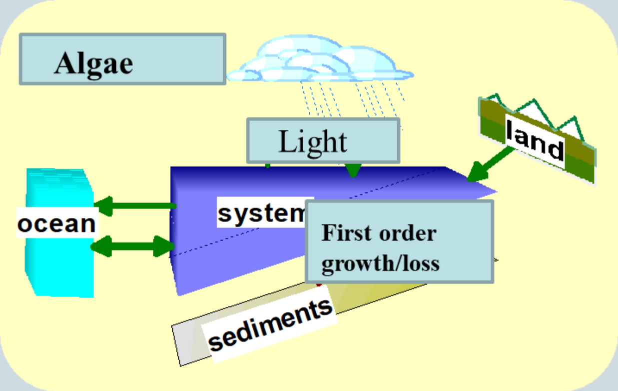
1D Mathematical Model

$$\frac{\partial Ac}{\partial t} + \frac{\partial Qc}{\partial x} = \frac{\partial}{\partial x}\left(AE\frac{\partial c}{\partial x}\right) + \mu Ac$$

- x coordinate
- C estuary concentration
- μ net growth rate

$\mu = G - R - M$

$\mu = P_M f(I) f(T) - M$

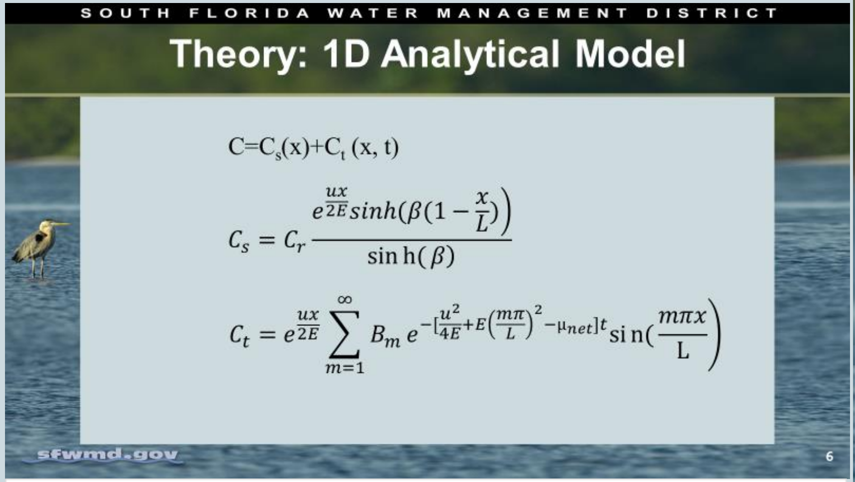


- E mixing coefficient
- Q river discharge
- A cross section area
- t time

Theoretical Solutions

Analytical solutions for idealized condition:

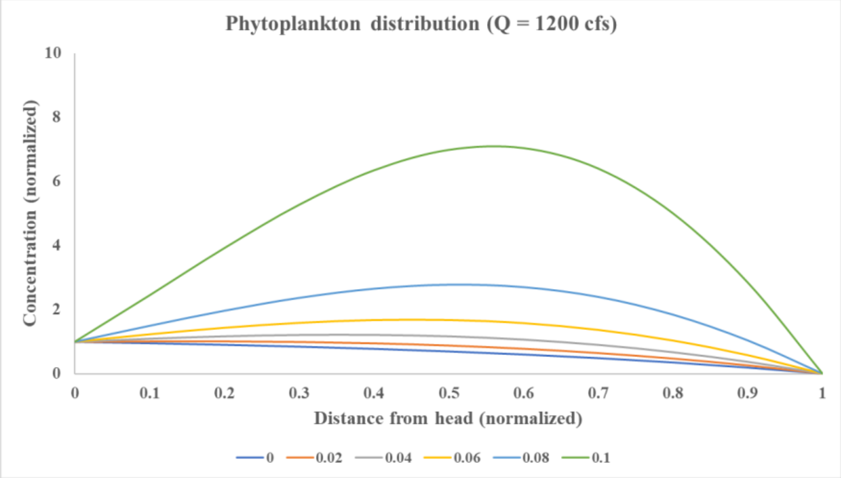
- Upstream boundary conditions have a controlling effect on downstream estuary for both nutrients and phytoplankton
- Residence time is critical for algal bloom: when µ >f, potential algal bloom may develop
- Higher µ leads to higher chlorophyll maximum, the location of which moves downstream with increasing discharge



$$C=C_s(x)+C_t(x, t)$$

$$C_s = C_r \frac{e^{\frac{ux}{2E}} \sinh(\beta(1-\frac{x}{L}))}{\sinh(\beta)}$$

$$C_t = e^{\frac{ux}{2E}} \sum_{m=1}^{\infty} B_m e^{-[\frac{u^2}{4E}+E(\frac{m\pi}{L})^2-\mu_{net}]t} \sin(\frac{m\pi x}{L})$$



Semi-analytical Solutions

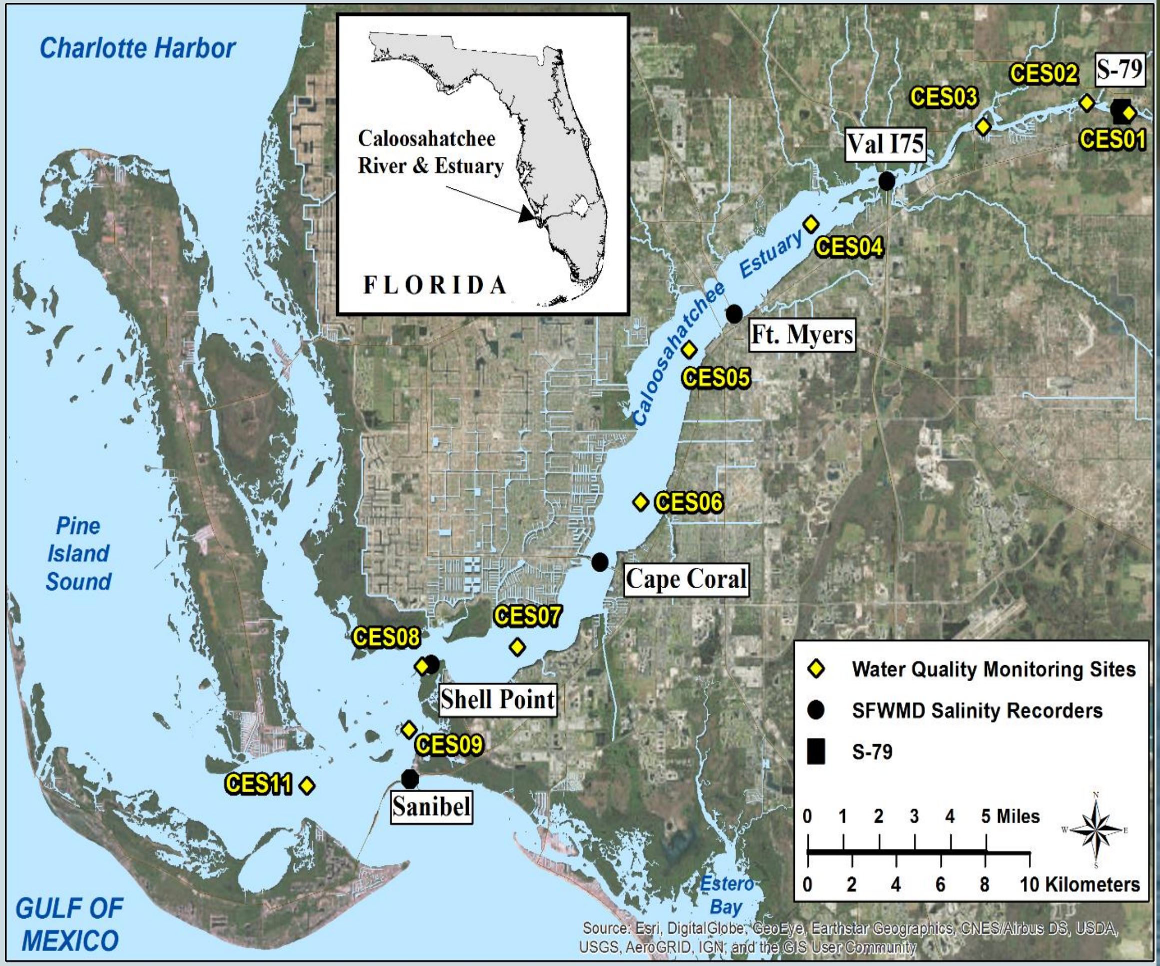
Semi-analytical solutions for a real estuary:

- Salt-balance approach
- Salinity from monitoring or a hydrodynamic model
- Green function constructed to compute nutrient and phytoplankton concentrations
- Iterations are needed

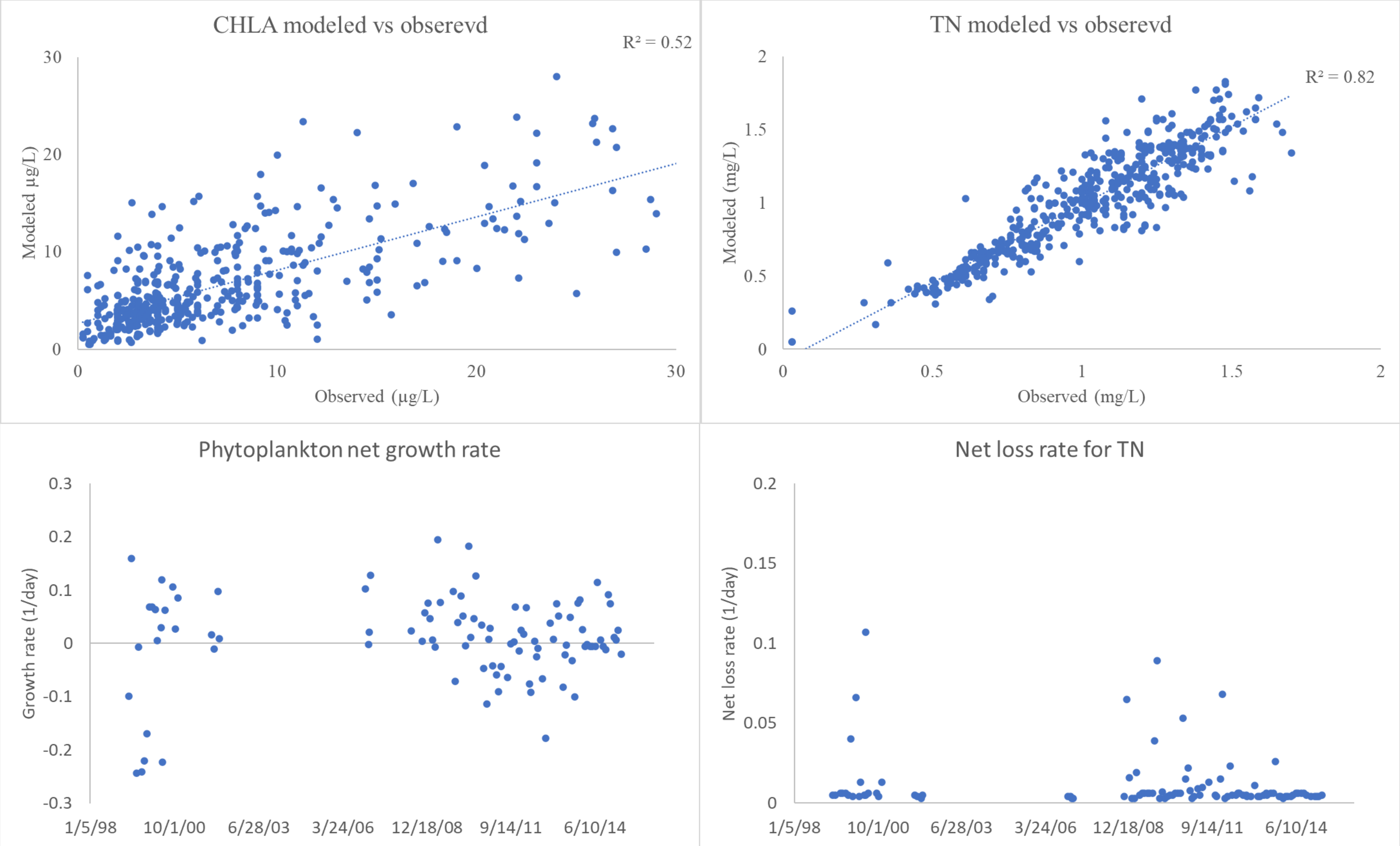
Semi-analytical Solutions

Application to monthly surveys of the Caloosahatchee River Estuary:

- Discharge at S-79
- Salinity from the CH3D hydrodynamic model
- Boundary conditions from survey at S-79 and CES09
- A modified BZI model used to compute phytoplankton growth rate as a function of temperature, light. color, turbidity
- Empirical parameters determined through calibration for each survey



Application to Monthly Survey



What Does the 1D Model Tell Us?

- Net growth rate μ is the key to forecast algal bloom
- Higher μ, higher concentration, higher discharge to stop algal bloom
- The experiment suggests it is possible to infer net growth rate from survey data
- External input can be important sources, upstream algal bloom risk poses threat to the downstream estuary

Challenges

- Net growth rate μ seems to be very small compared to G or GPP (order of magnitude difference, e.g., 0.05/day vs 0.5/day)
- Predation is a wild card
- What happens in the Lake and canals means a lot for CRE

Algae Growth Model

- Algae growth:

$$\frac{\partial B}{\partial t} = (G - R - M)B = \mu B$$

$$G = G_M f(N) f(I) f(T)$$

- Gross production

$$GPP = GB$$

- Net production

$$NPP = (G - R)B$$