GLEON-PRAGMA Science Expedition

0. Peter Arzberger

University of Wisconsin

5. Craig Snortheim

6. Renato Figueiredo

1. Paul Hanson

University of Florida

4. Youna Jung

2. Cayelan Carey

3. Ken Subratie

Virginia Tech

Agenda

- 8:30 – 9:00: Meet and greet
- 9:00 – 9:45: Motivation for the GLEON-PRAGMA Science Expedition
- 9:45 – 10:30: Technology overview
- 10:30 – 10:45: Break
- 10:45 – 11:15: Demonstration of the overlay at work
- 11:15 – 11:45: Discussion and next steps

Background

- Ecology has had a long tradition of empiricism and modeling – *but* the nature of those models is changing
  - We can't measure everything we want to know about, including the future
  - Models are a way of testing hypotheses *in silico*
- Certain questions benefit greatly from a modeling approach that couple physical, chemical, and biological processes, e.g., *What are the factors influencing the wax and wane of phytoplankton communities underlying blooms?*
- Making those models serve the needs of science can require lots of computing resources and specialized skill.
- Results can push the boundaries of science.

Eutrophication leads to…

- Poor water clarity
- Loss of macrophytes
- Bad smell
- Toxic water conditions
- Dead fish
- Reduced ecological and economic value

Can we predict the occurrence of cyanobacterial blooms in lakes?

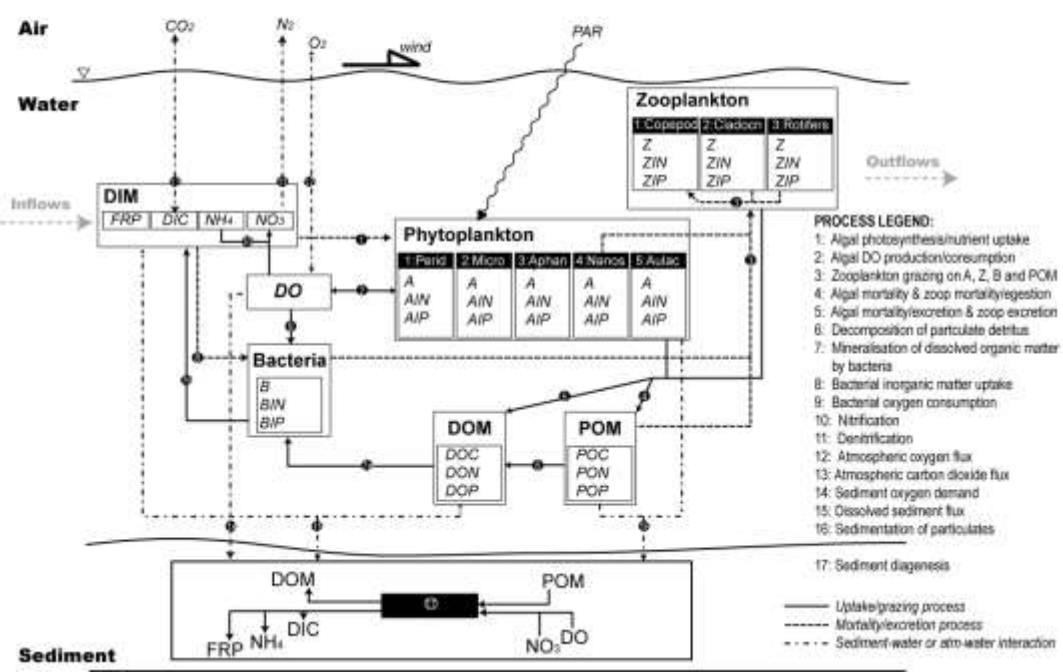
- Blooms are patchy both in space and time, problematic, and difficult to predict
- It is very difficult to collect continuous field data to track bloom development
- Can we use a modeling approach to better understand the factors driving their occurrence, magnitude, and duration?

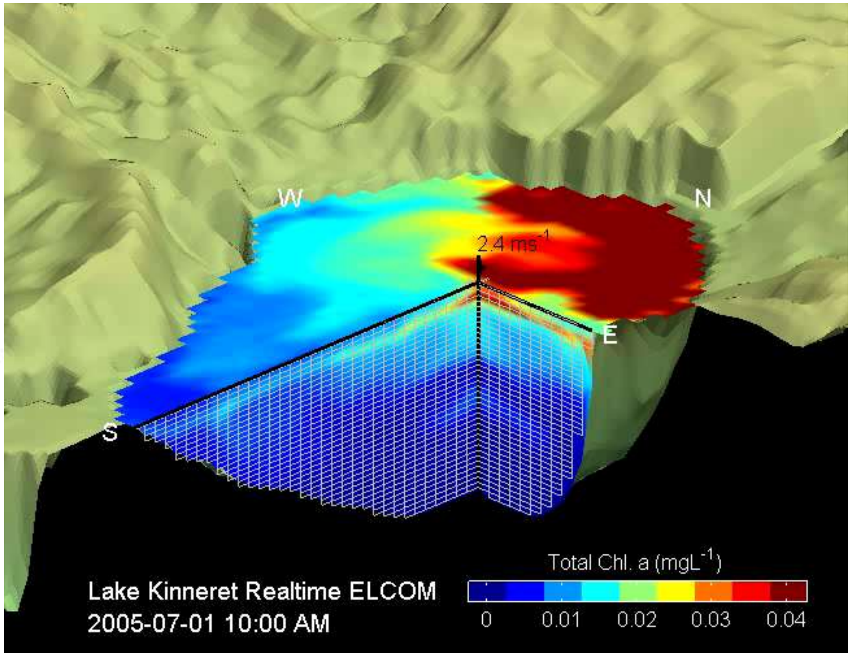
Recreating the phytoplankton dynamics underlying blooms is a major challenge because of the complex physical, chemical, and biological interactions

Lake Kinneret:
Physical-biological interaction

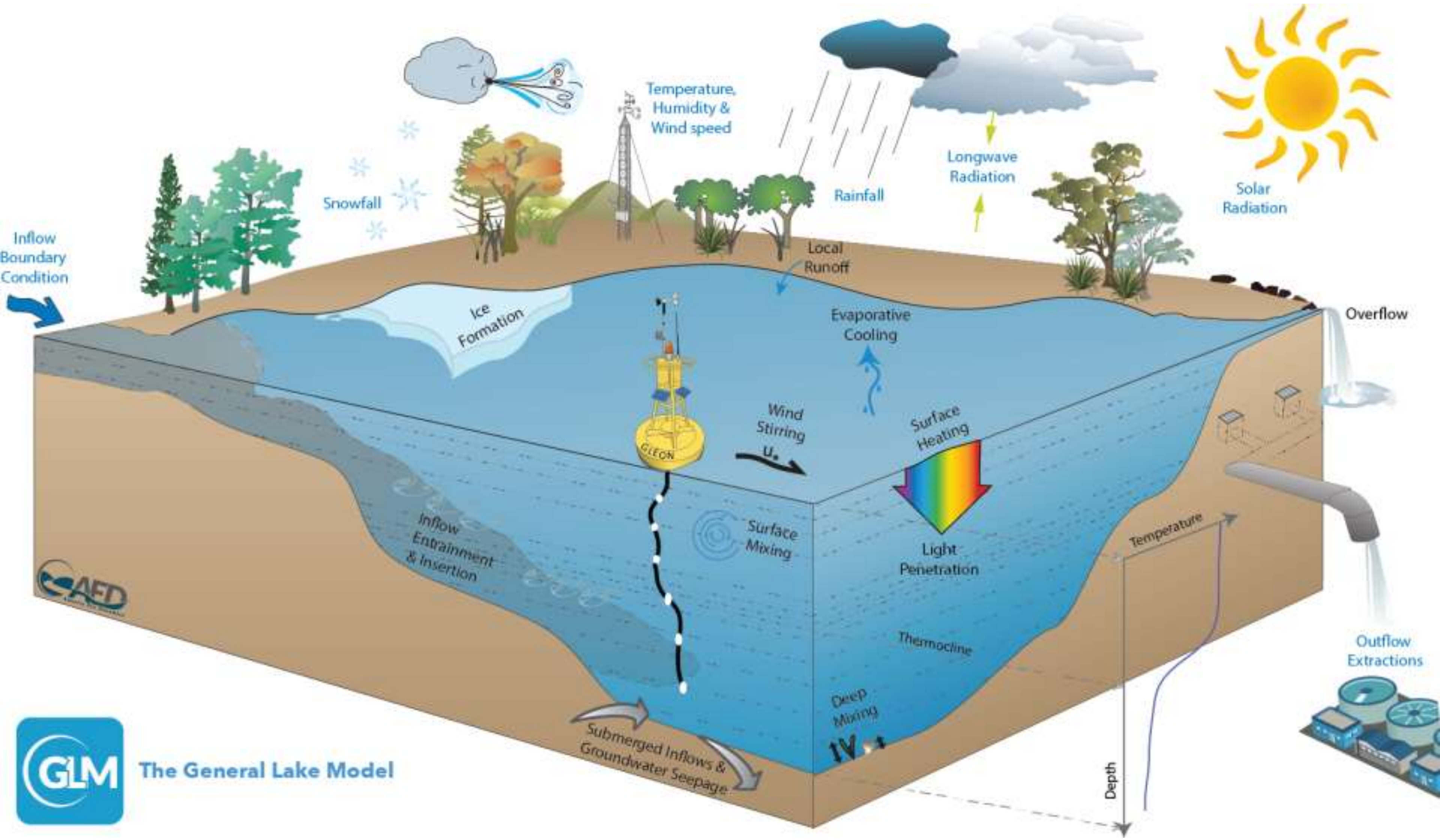
- Transport processes work in concert with biological dynamics to shape biomass concentrations and distribution

3D: hydrodynamic-ecological model



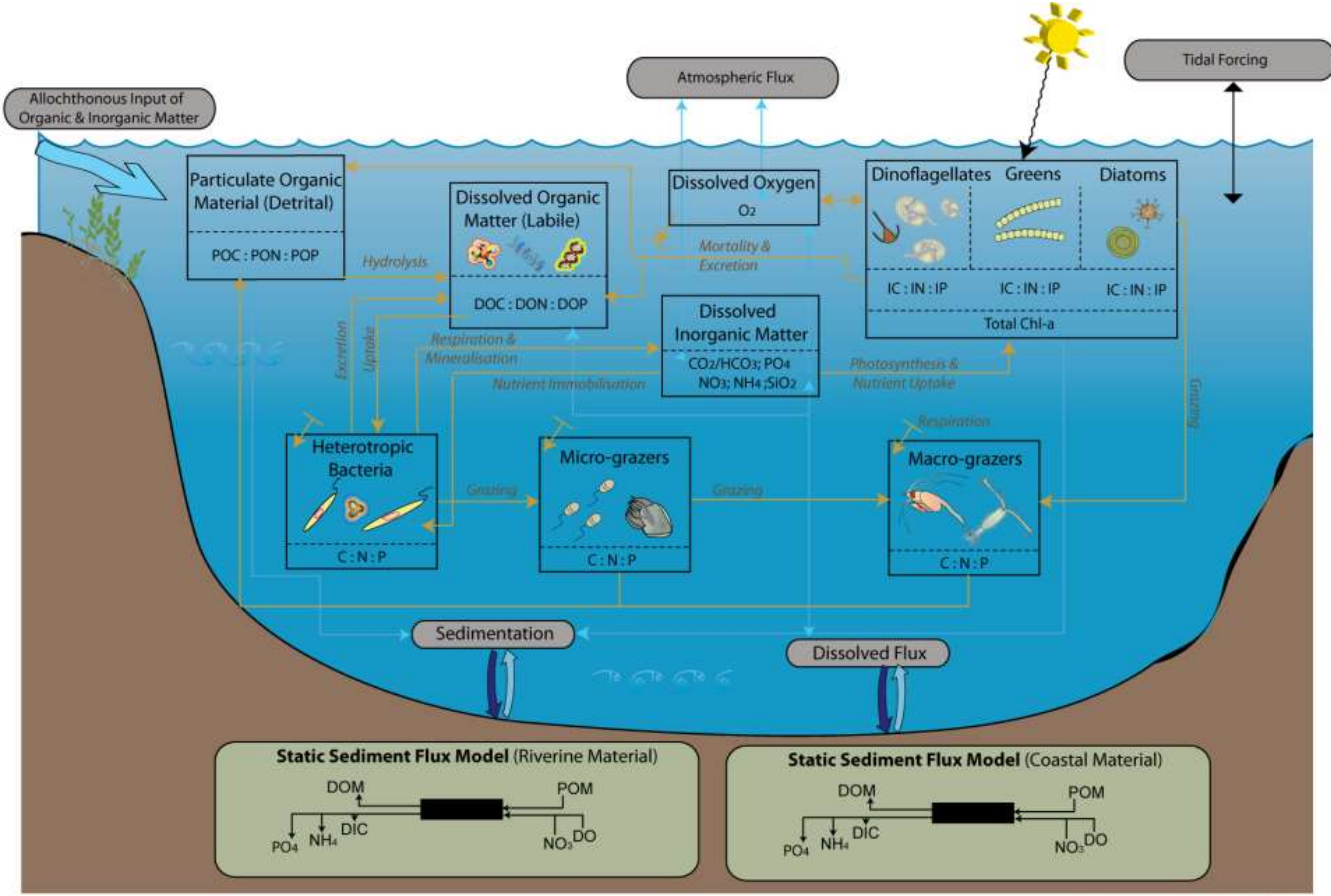


Modelling Lakes & Reservoirs with GLM



1D – laterally averaged models: assume most variability is vertical

A more complex model structure…



Workflow within the context of numerical simulation of phyto communities:

1. Setup a numerical simulation
    1. Data that setup and drive the model
    2. Data to evaluate the model predictions
    3. Simulation software
2. Calibrate the simulation: Adjust parameters until predictions of lake physics/WQ show some agreement with observations of physics/WQ
3. Run scenarios with the calibrated simulation to better understand the controls over phytoplankton

Setup

1. e.g., hypsometry, initial conditions,
2. Defines how a simulation represents a particular lake

Drivers

1. e.g., Meteorology, Inflow/outflow, nutrient loads
2. Drive the changes in ecosystem dynamics

$$\frac{\partial Chl}{\partial t} = (\mu - L) * Chl - (s - w)\frac{\partial Chl}{\partial z} + \frac{\partial \left[K(\partial Chl / \partial z)\right]}{\partial z}$$

$$\frac{\partial PON}{\partial t} = v * Chl - (s - w)\frac{\partial PON}{\partial z} + \frac{\partial \left[K(\partial PON / \partial z)\right]}{\partial z} - L * PON$$

$$\frac{\partial N}{\partial t} = -v * Chl + w\frac{\partial N}{\partial z} + \frac{\partial \left[K(\partial N / \partial z)\right]}{\partial z} + r * L * PON$$

The equations represent the processes (or "rules")

Predictions

Lake physics, chem, bio

Observations

Lake physics, chem, bio =phytoplankton!

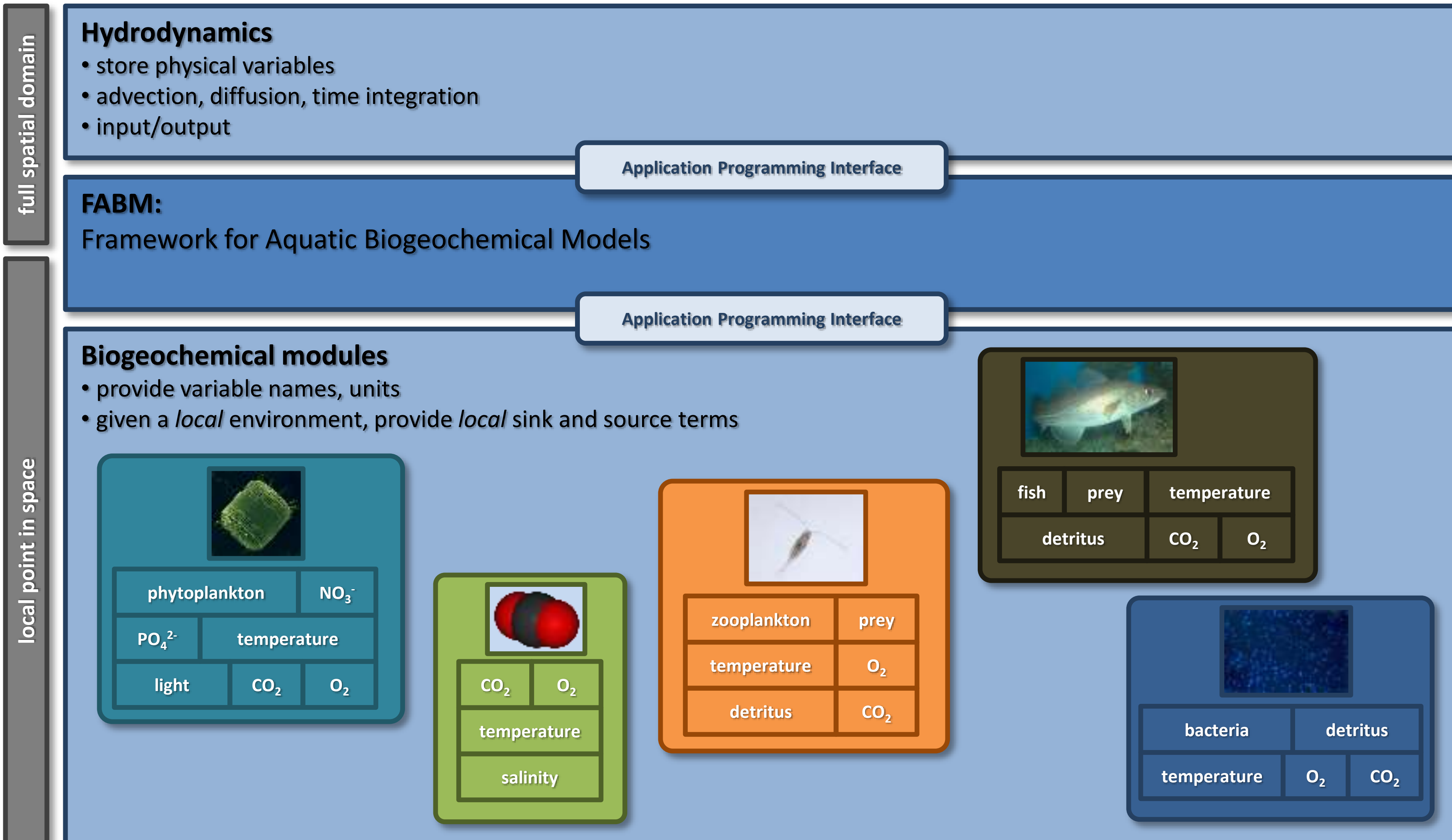
Parameters in the equations

1. e.g., P uptake rate, OC degradation rate, P
2. Determine how driver data are expressed in the predictions, given the equations ("rules")

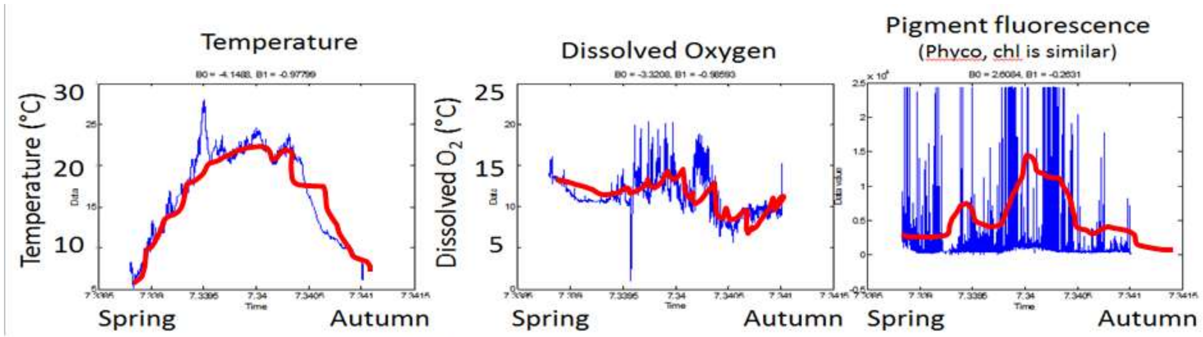
Drivers are changed to simulate scenarios of, e.g., land use and climate change

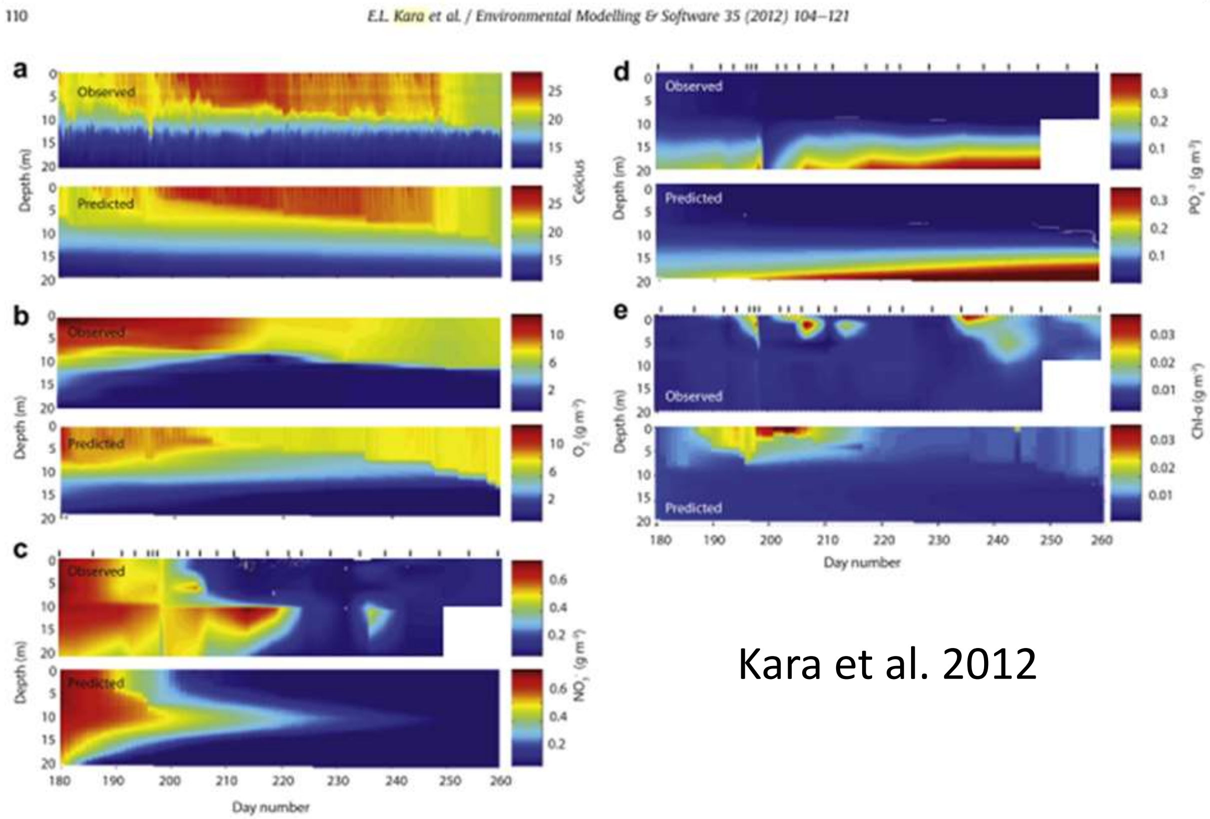
To calibrate the model, parameters are adjusted to make predictions ~= observations

FABM: A flexible approach to disentangle physics and biology



Example Simulation Result

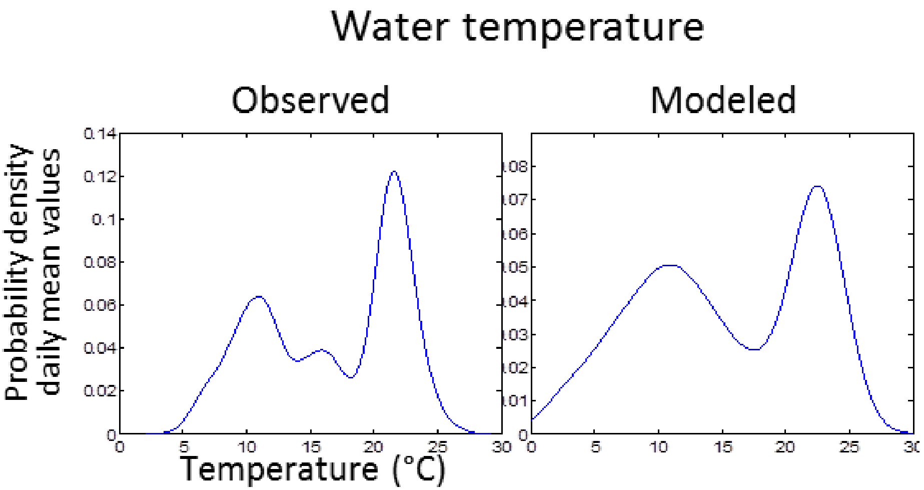




Kara et al. 2012

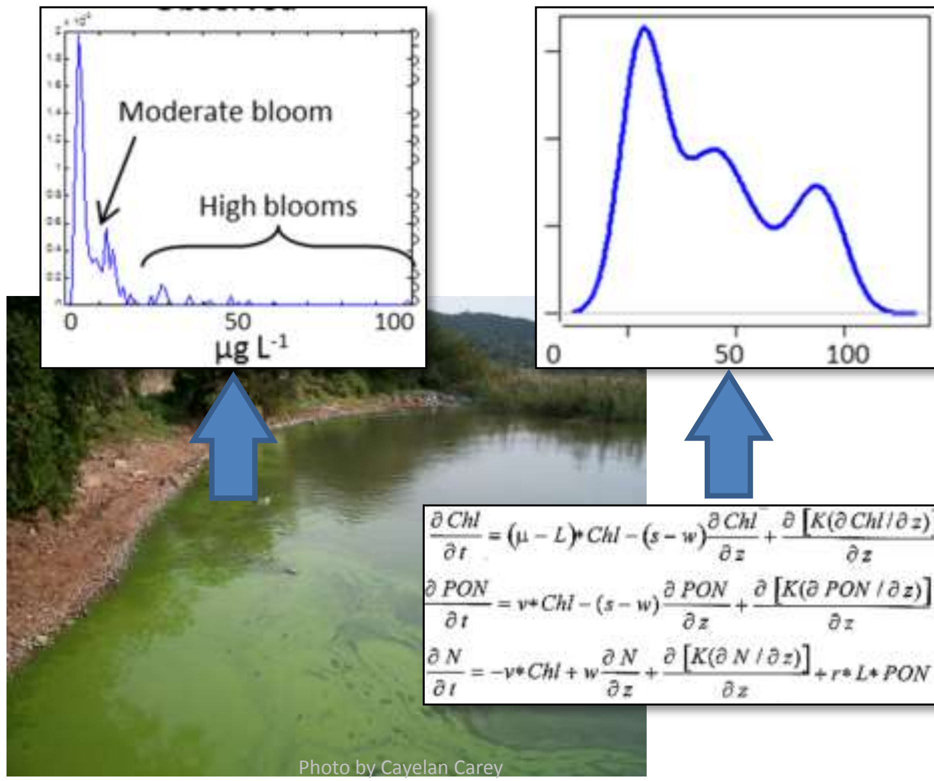
L. Mendota 2009 daily values

one day moving window, no overlap, bits=5, alphabet=3



PaulsSAX3.m, plot(ksdensity(AllStd))

Although we predict the mean well, and we can predict seasonal succession, we have a problem…



$$\frac{\partial Chl}{\partial t} = (\mu - L)*Chl - (s-w)\frac{\partial Chl}{\partial z} + \frac{\partial\left[K(\partial Chl/\partial z)\right]}{\partial z}$$

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Two approaches to solving this problem: (1) Search parameters for combinations that reproduce the features we want; (2) If #1 doesn't work, play with rules.

Break to Run Simulation

Scaling up. What if…

- What is the fate of allochthonous OC loads to lakes, and how certain are we about those predictions? (Hanson et al. 2011)
- How do the thermal regimes of all lakes in a region respond to changing climate? (Read et al. 2014)
- **Do the current models governing phytoplankton community dynamics allow us to recreate blooms? (PRAGMA-GLEON expedition)**

1. Generate community

(throw the dice for some of the parameters, e.g., T-opt, MaxGrowth, Respiration)

Parameter database

P_NAME	DESCR
p_initial	Initial concentration of phytoplankton
p0	Minimum concentration of phytoplankton
w_p	Sedimentation rate
Ycc	Carbon:chlorophyll ratio
Pmax	Phyto max growth rate @20C
fT_Method	Specifies temperature limitation function of growth (0 = no temperature limitation; 1= CAEDYM style)

(47 total parameters)

Community
2 species of cyanophytes
2 species of N-fixing cyano
2 species of chlorophytes
2 species of diatoms

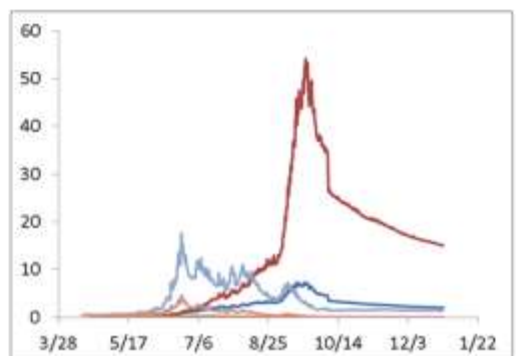
8 spp total

Repeat Cycle 1,000x

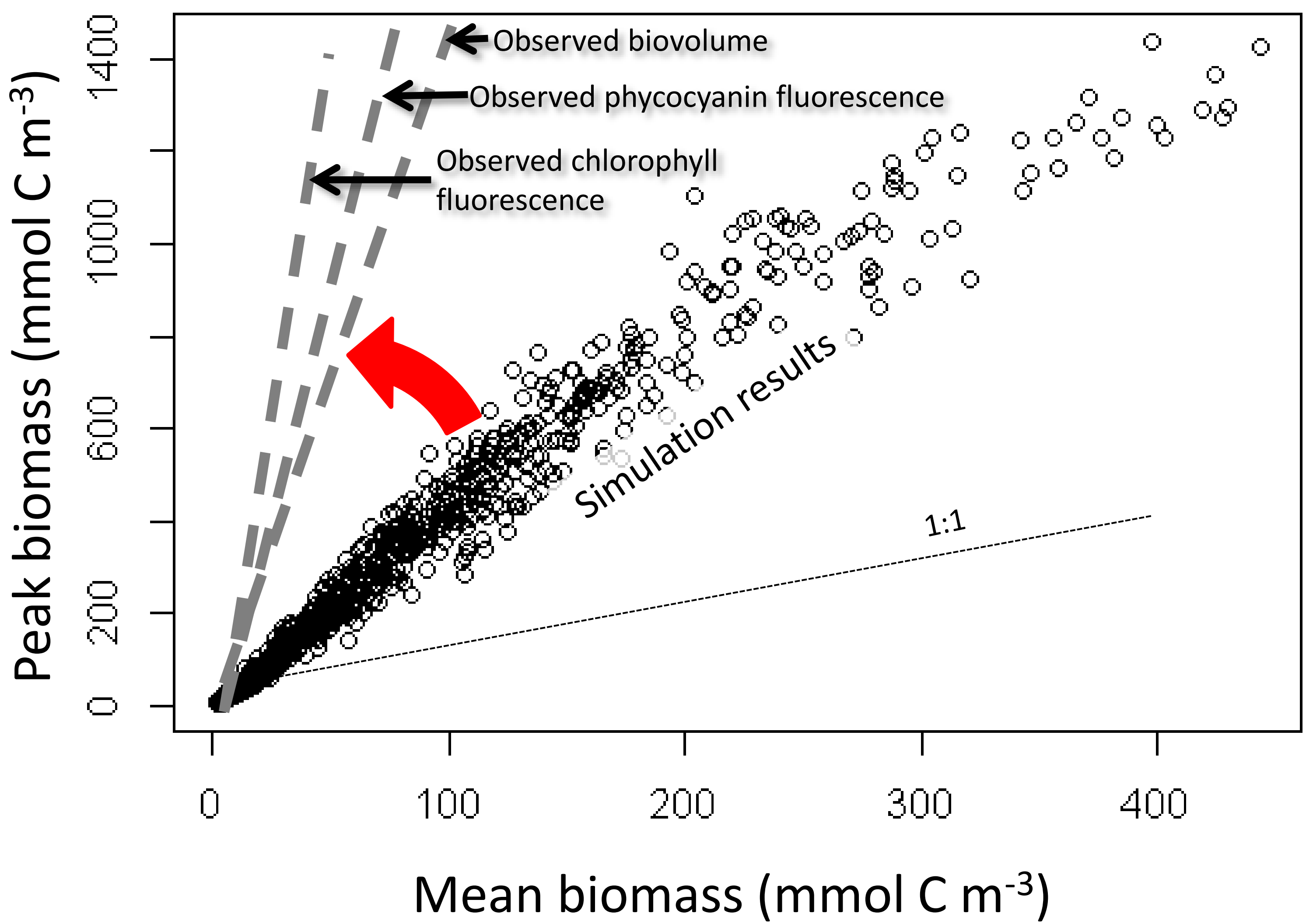
Simulation

Feature	*1*	*2 =>*	*1000*
Mean	*57*	*33*	
Max	*410*	*127*	
Peak timing	*185*	*177*	
Shape	*-0.2*	*-0.15*	

2. Simulate one year



3. Store features



Observed biovolume
Observed phycocyanin fluorescence
Observed chlorophyll fluorescence
Simulation results
1:1
Peak biomass (mmol C m-3)
0
200
600
1000
1400
0
100
200
300
400
Mean biomass (mmol C m-3)

PRAGMA-GLEON Expedition:

Mission: (1) Discover the rules controlling phytoplankton community dynamics; (2) Expand opportunities for GLEONites to use HTC resources to enable the science; (3) Build an interdisciplinary community