Outline

1. Setup: GLEON has never been able to identify THE science questions that the network should address; rather, GLEON provides the framework for bubble-up science.
2. With #1 in mind, I think it makes to frame this in terms of how science is done
3. Two slides on what GLEON is
4. Three slides on the current Lake Expedition, with science focus (Renato will give separate technology talk)
5. Nine slides on three GLEON Grand Challenges

Lake Expedition – Grand Challenges for the Global Lake Ecological Observatory Network (GLEON)

Paul C Hanson, Cayelan C Carey, Kathleen C Weathers

GLEON

Networked lake science

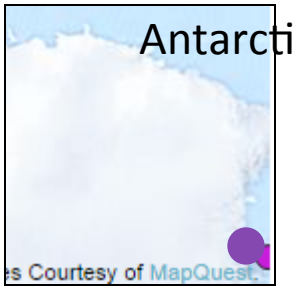
Global Lake Ecological Observatory Netwo

Mission: *GLEON conducts innovative science by sharing and interpreting high-resolution sensor data to understand, predict and communicate the role and response of lakes in a changing global environment*



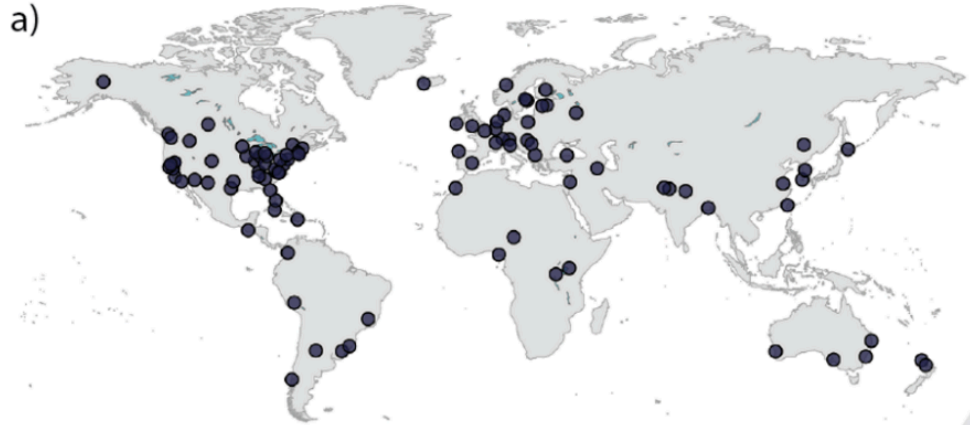
Argentina
Australia
Austria
Brazil
Canada
Chile
China
Colombia
Denmark
Estonia
Finland
Germany
Hungary
India
Ireland
Israel
Italy
Kenya
Netherlands
New Zealand
Nigeria
Pakistan
Poland
Puerto Rico
Russia
South Korea
Spain
Sweden
Switzerland
Taiwan
Turkey
United Kingdom

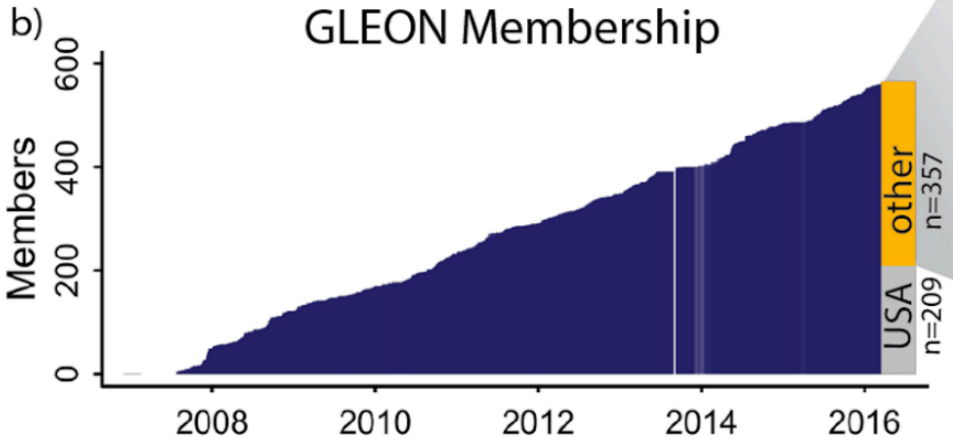
And most important a grassroots network of people…

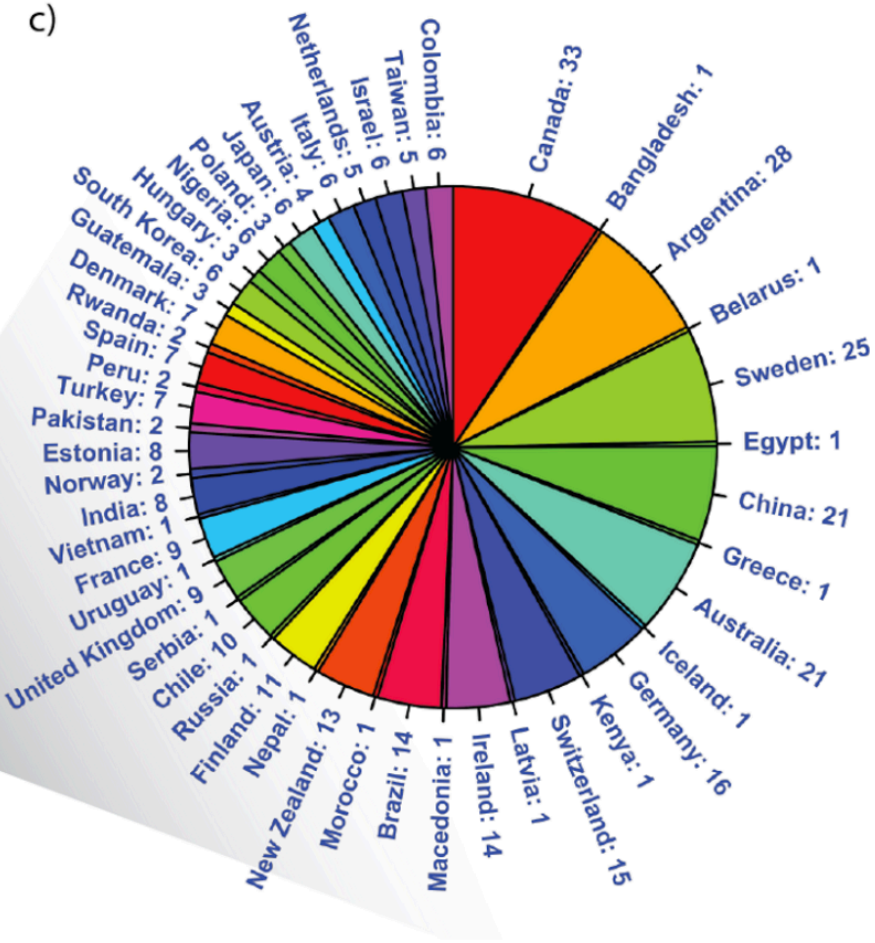


600 members (1/3 grad students)
52 countries

GLEON Demographics








Lake Sunapee, USA
LSPA
Ormajärven, Finland
Torrens Lake, Australia
Lake Mangueira, Brazil
Yuan Yang Lake, Taiwan
Crystal Bog, USA
Lake Annie, USA
Lake Plomo, Chile
Lake Rotorua, NZ
Lake Erken, Sweden

A new era of science is taking root

- *Tools, diverse data sets with new capacity*
- *Simulation capacity increased by orders of magnitude*
- *Building a group of people understand the science and have the skil*

PACIFIC RIM APPLICATIONS AND GRID MIDDLEWARE ASSEMBLY
PRAGMA

NYC Environmental Protection

AED Aquatic Eco Dynamics
THE UNIVERSITY OF WESTERN AUSTRALIA
Aquatic Ecodynamics Home
Aquatic Ecodynamics

CSILIMNOLOGY
Team

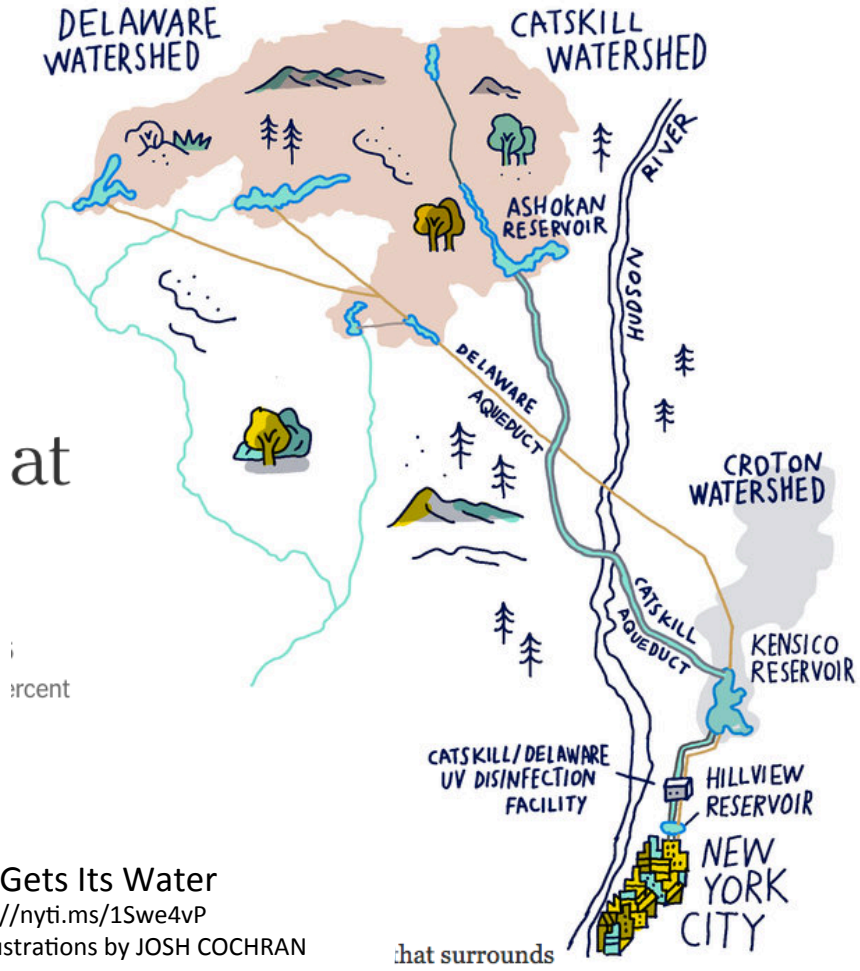
CZO CRITICAL ZONE OBSERVATORIES
U.S. NSF NATIONAL PROGRAM

The Long Term Ecological Research Network

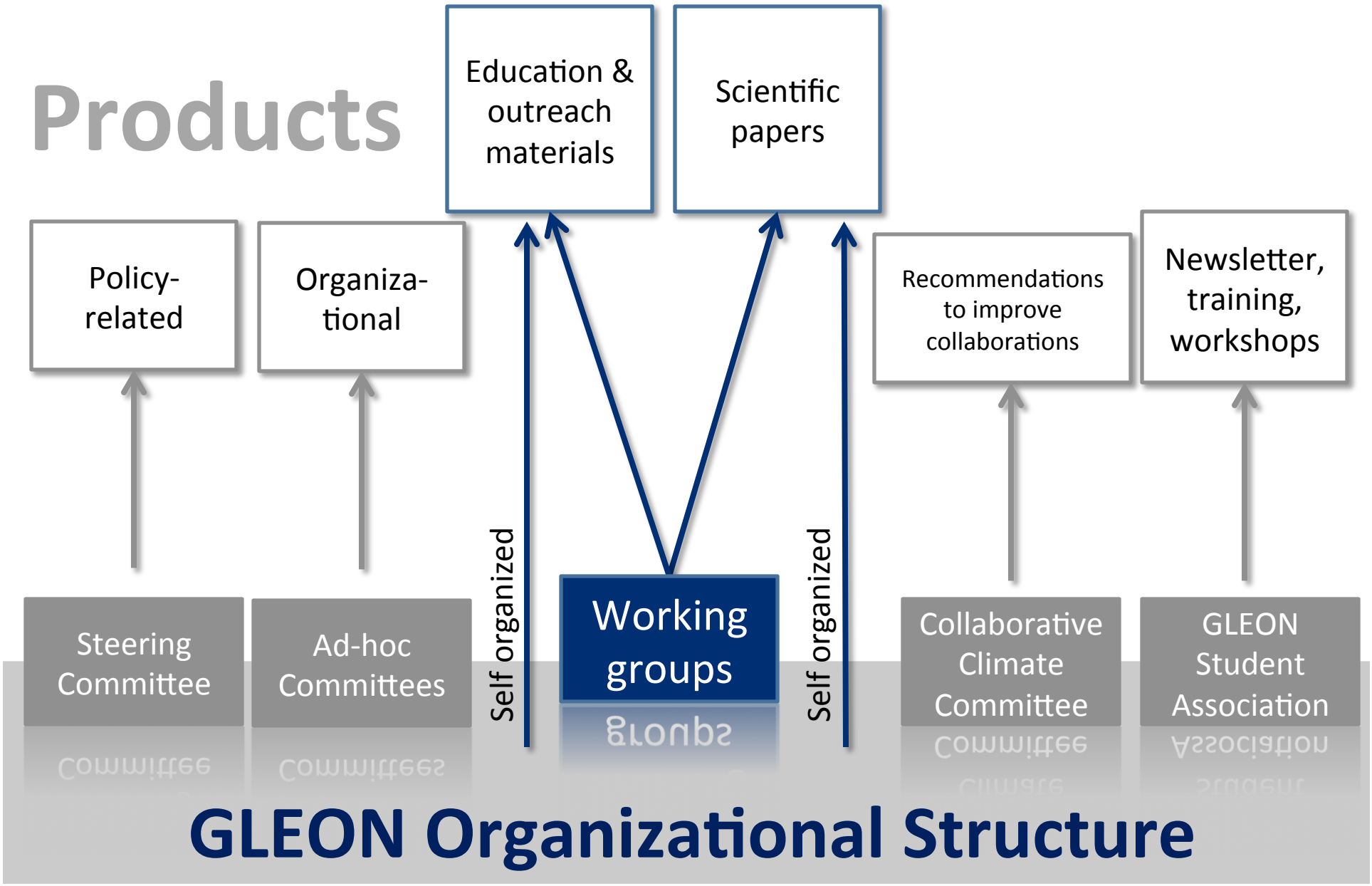
CNH

LSPA
Devoted to the Environmental Quality of the Lake Sunapee Watershed
FOUNDED 1898

CLEAN LAKES ALLIANCE



How New York Gets Its Water
NY Times, 2016, http://nyti.ms/1Swe4vP
By EMILY S. RUEB; Illustrations by JOSH COCHRAN



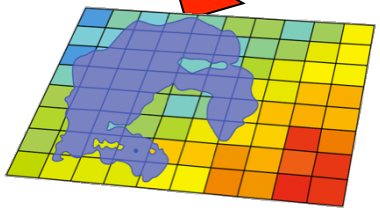
GLEON Organizational Structure

PRAGMA+GLEON = GRAPLE Lake Expedition

Lake ecology science questions

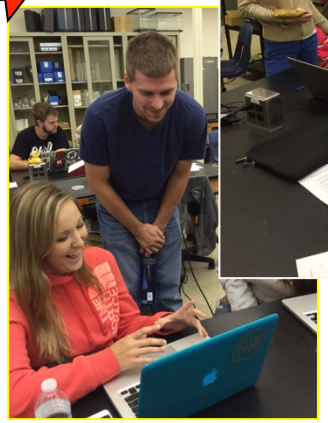
Identify and iterate problems, requirements

Inter-disciplinary collaboration



Engage the community
Research, education

GLEON

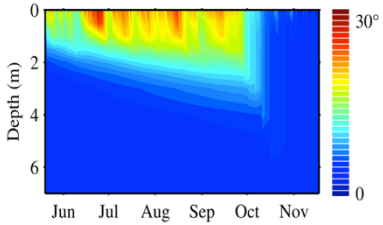


IPOP

HTCondor
High Throughput Computing

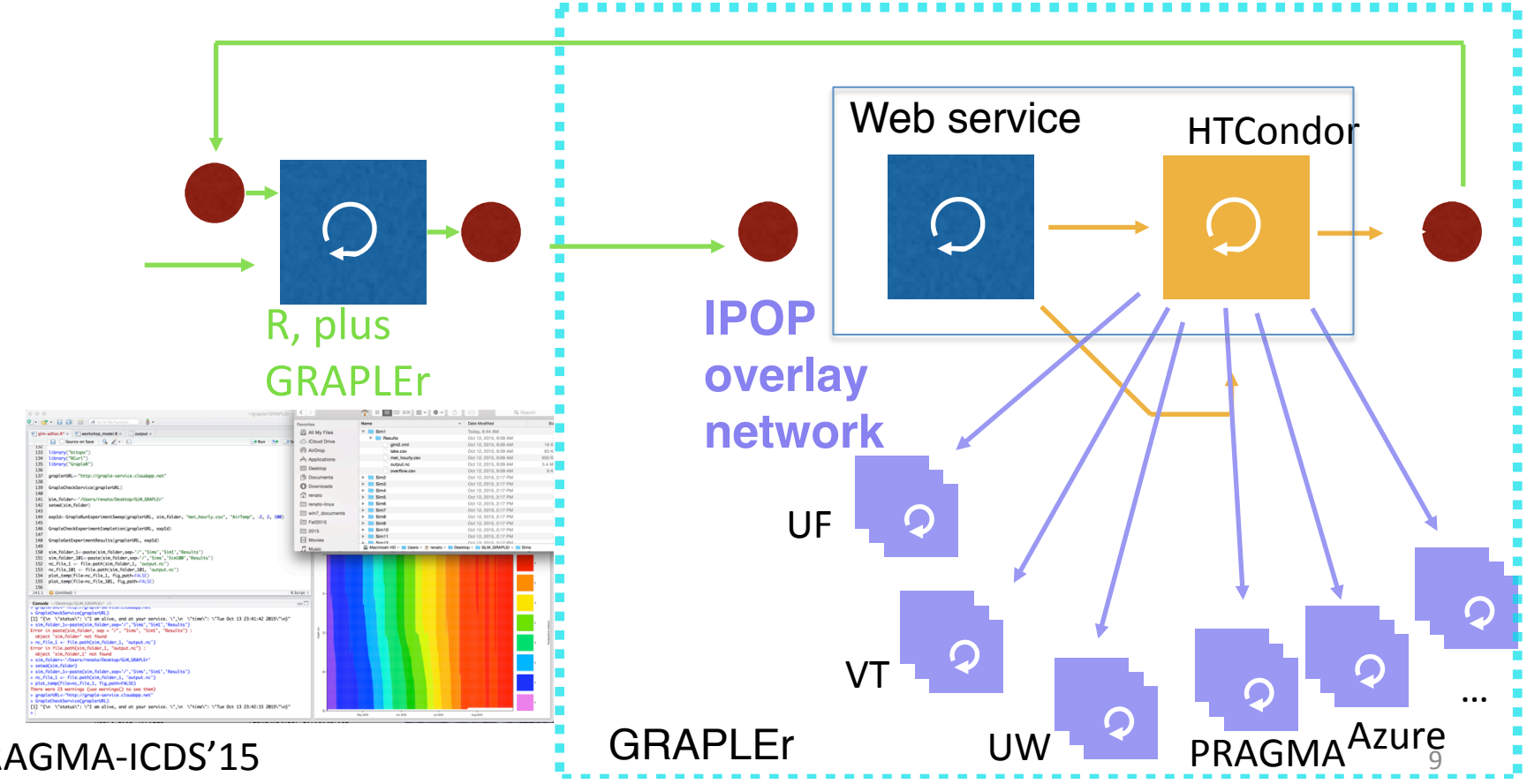
R GLM

GRAPLEr



GRAPLEr framework

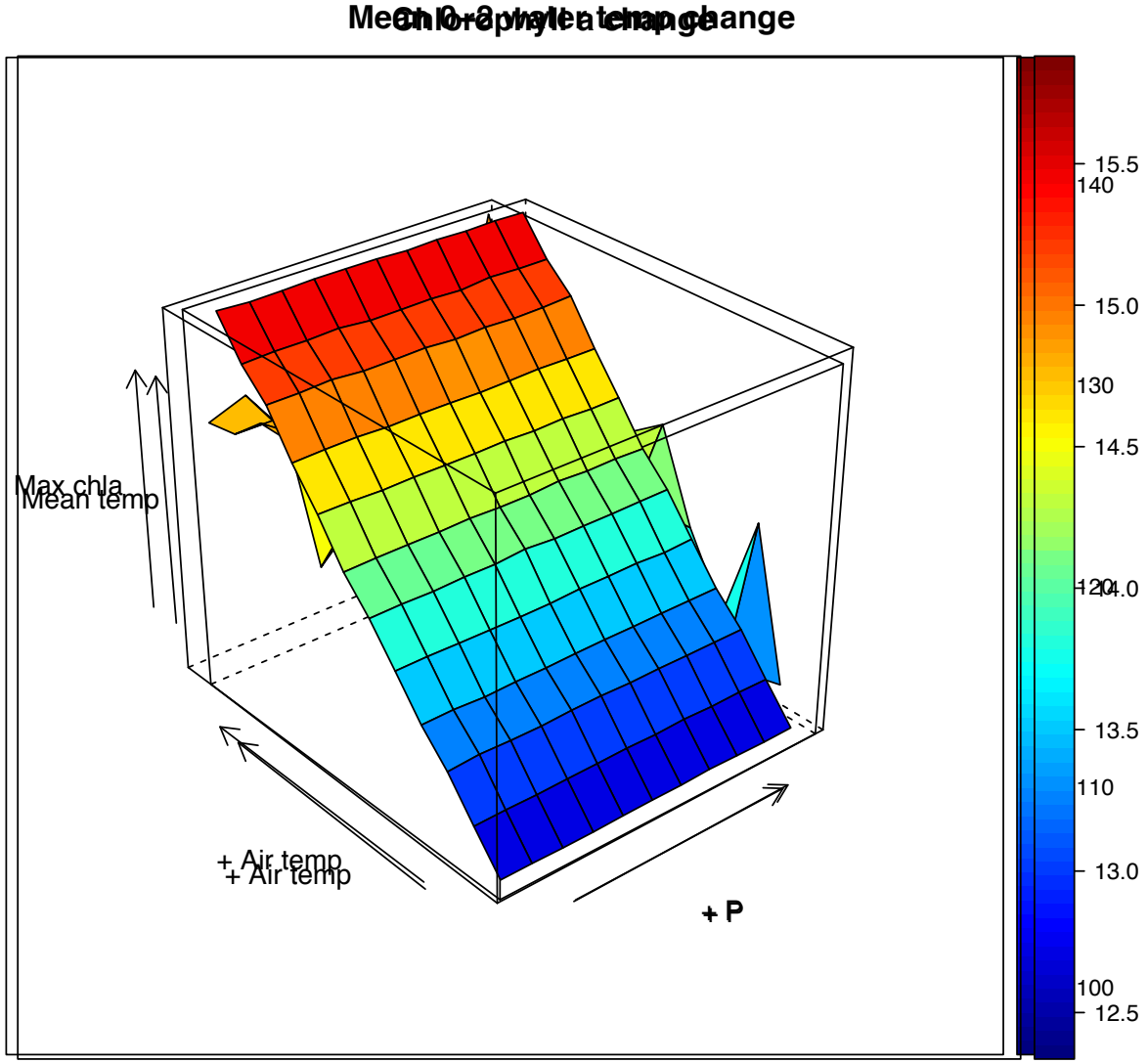
- Expose simple R desktop interface to users; handle packaging of multiple simulations into Condor job, compression, job submission, post-processing
- Applications for science working groups + students



Using GRAPLEr to study drivers of algal blooms in response to global change

Dr. Amy Hetherington, Virginia Tech

CNH-Lakes



Grand Challenge 1

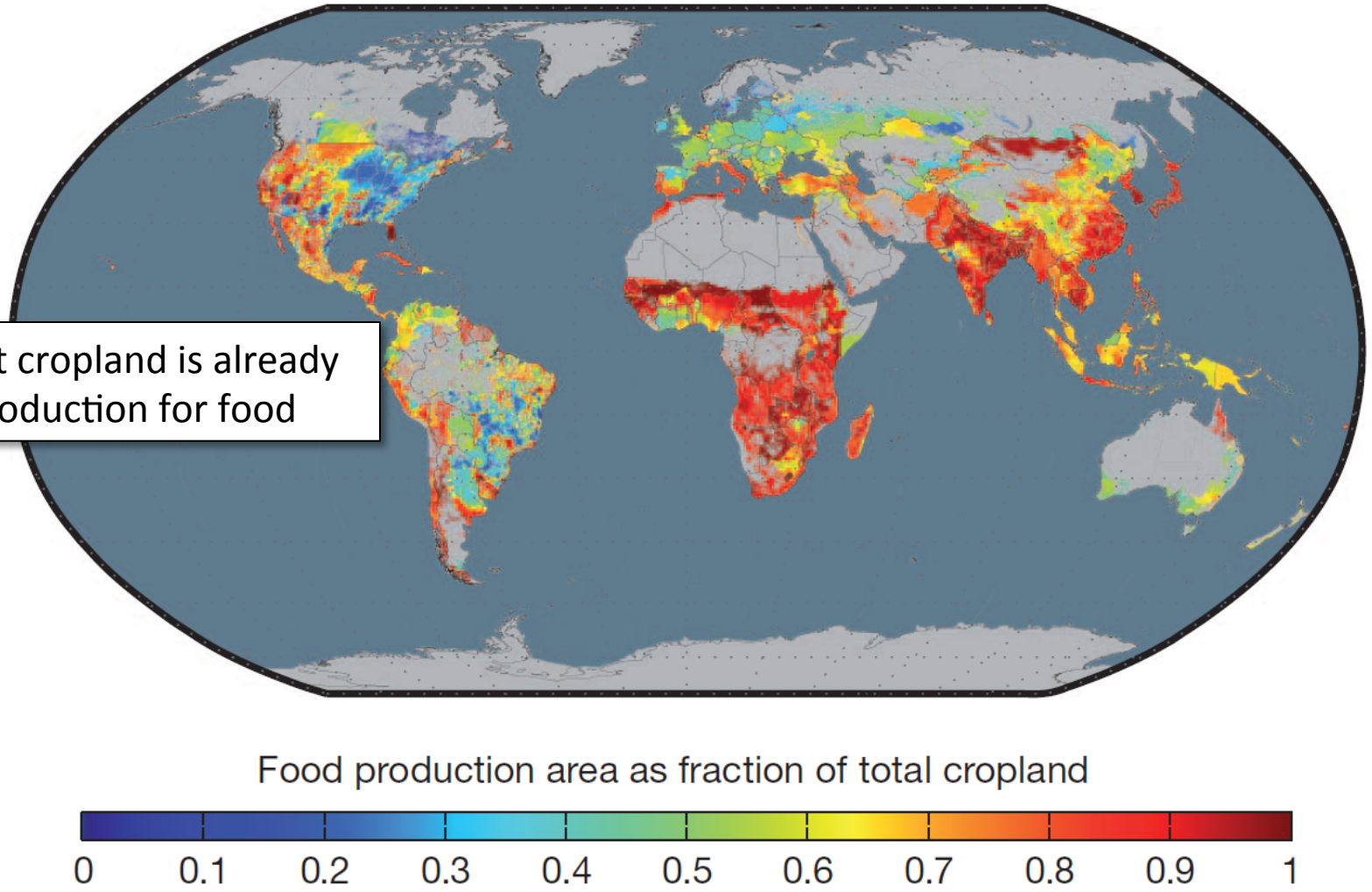
Challenge: A globally relevant assessment of lake and reservoir water quality

Why this matters: The ability of Earth to support the projected human population depends on the availability of fresh water.

Why it is a challenge: Data exist, but are in different systems/ structures/languages in different countries.

What we will learn: Determine current conditions and their uncertainty; map use/need onto available resources; understand better the drivers of water quality globally

Most cropland is already in production for food



Solutions for a cultivated planet

Jonathan A. Foley[1], Navin Ramankutty[2], Kate A. Brauman[1], Emily S. Cassidy[1], James S. Gerber[1], Matt Johnston[1], Nathaniel D. Mueller[1], Christine O'Connell[1], Deepak K. Ray[1], Paul C. West[1], Christian Balzer[3], Elena M. Bennett[4], Stephen R. Carpenter[5], Jason Hill[1,6], Chad Monfreda[7], Stephen Polasky[1,8], Johan Rockström[9], John Sheehan[1], Stefan Siebert[10], David Tilman[1,11] & David P. M. Zaks[12]

20 OCTOBER 2011 | VOL 478 | NATURE | 337

Grand Challenge 2

Challenge: On-demand model predictions for any lake in the GLEON network

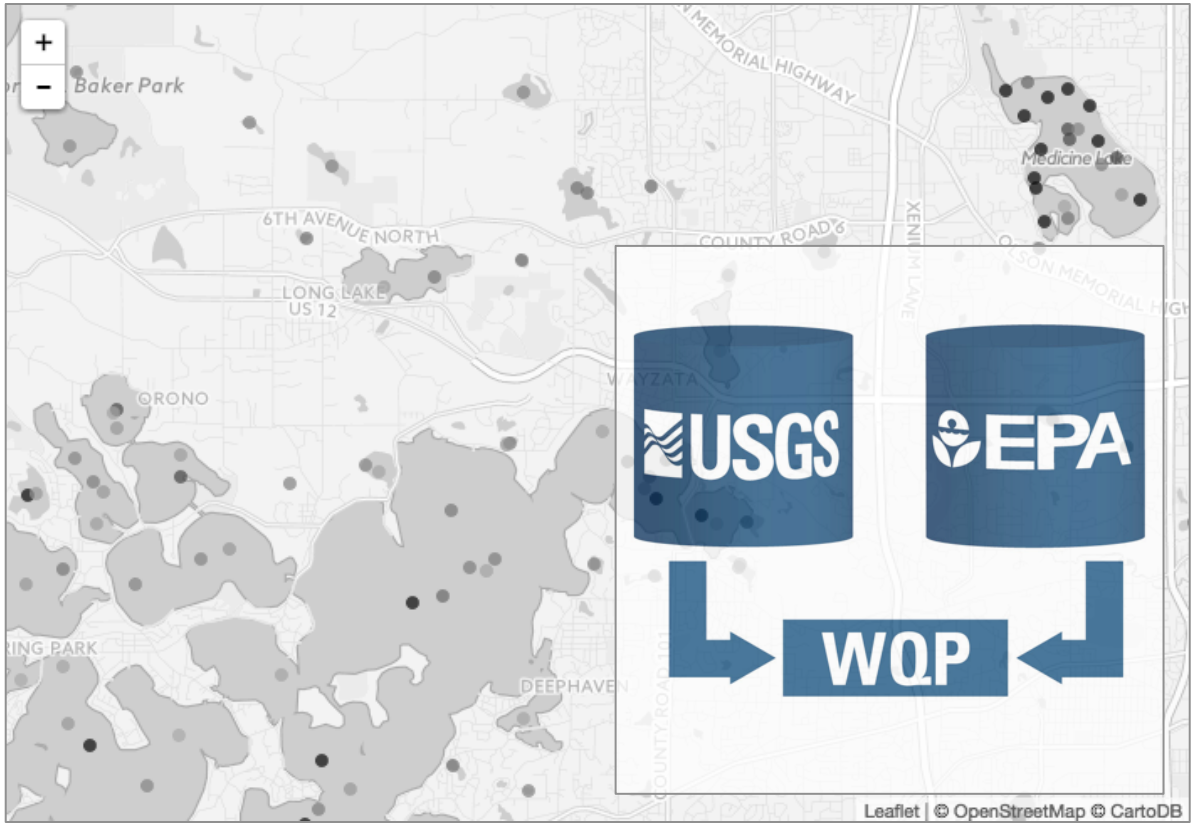
Why it matters: Predicting future changes to water quality in different change scenarios requires coupled bio-physical models grounded in observational data.

Why it is a challenge: Rapid access to climate data and lake observations is challenging; we need compute infrastructure to support millions of simulations for global-scale predictions.

What we will learn: Understand how lakes respond to changes; identify how best to do simulations most efficiently; develop new ways to visualize changes in water quality

Lake science at scale: **Data**

Unified water quality database

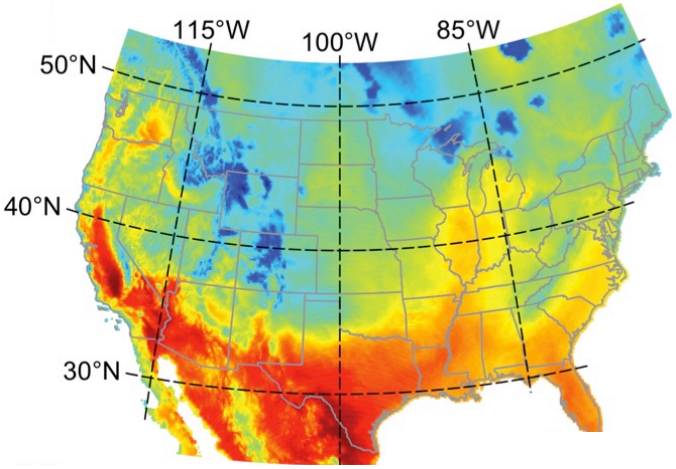


http://www.waterqualitydata.us

U.S. hydrolayer

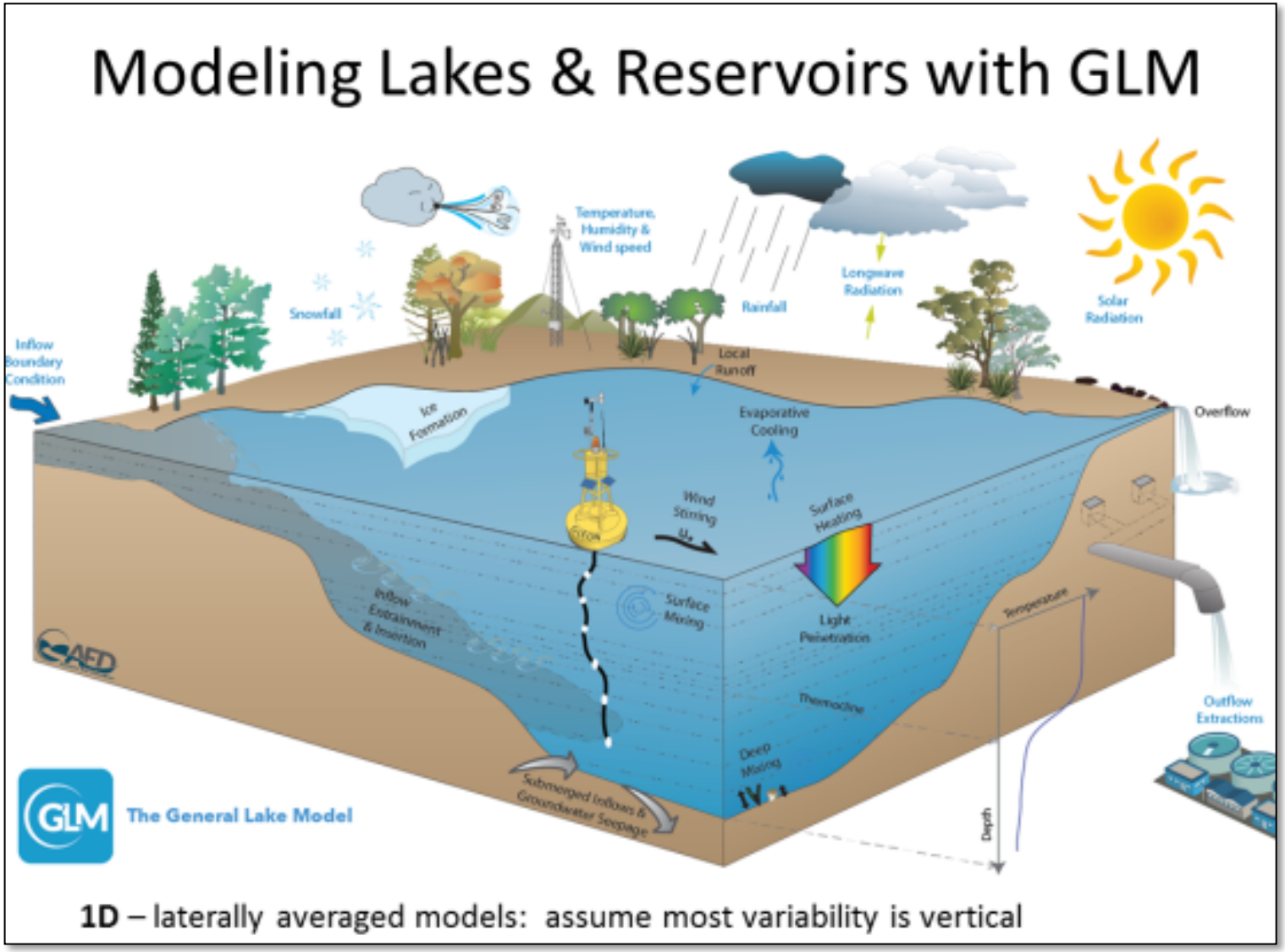
http://nhd.usgs.gov/

Climate and land-use



http://cida.usgs.gov/gdp/

Lake science at scale: **Modeling tools**



Grand Challenge 3

Challenge: Understand the importance of lakes and reservoirs and the risks they face for different stakeholder groups

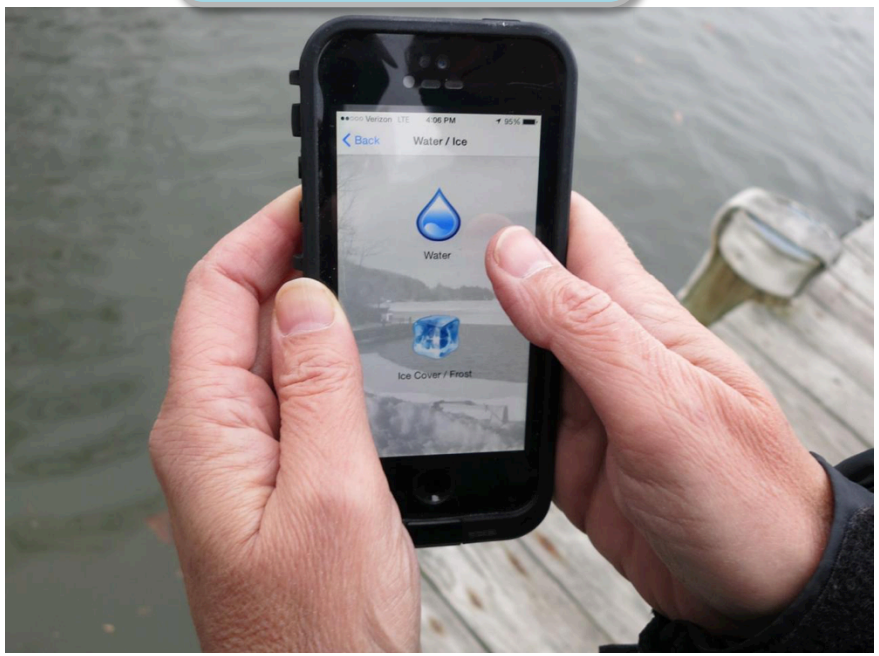
Why it matters: Our science needs to be relevant and informed by the people who have a stake in the lakes.

Why it is a challenge: Translating science and public priorities into a common language requires time, effort, resources, and training

What we will learn: What citizens value and how we can form meaningful partnerships; develop effective strategies for working with the public at a large scale

GLEON Lake Observer App
www.lakeobserver.org

Citizens & science



A mobile application for recording lake and water observations across the globe by citizens and scientists.

Weathers, Chiu, Ewing Borre, Mihalko, Chrobot

- President Obama's **US Climate Data Initiative (CDI) Partnership** with Cary Institute **(GLEON Team App)**, private sector, & USGS
- **Crowd-sourced data**
  - Citizen scientists
  - Research scientists
- **Geographically referenced and accessed**
- **Data publicly available**
- **Visualization tools**

How can PRAGMA & GLEON work together to address these challenges?

- Expand upon our existing GRAPLEr framework for lake modeling
- Develop new compute strategies/ infrastructure to aid modeling in service of the science
- Collaborate with GLEON scientists for managing and visualizing diverse datasets (e.g., citizen science app data)
- And in multiple other ways…

PRAGMA Lake Expedition Publications: to date!

- Carey, C.C. and R.D. Gougis. *In press*. ***Simulation modeling of lakes in undergraduate and graduate classrooms increases comprehension of climate change concepts and experience in computational tools***. Journal of Science Education and Technology.
- Gerling, A.B. 2015***. Hypolimnetic oxygenation mitigates the effects of nutrient loading on water quality in a eutrophic reservoir***. Masters Thesis. Virginia Tech.
- GRAPLE GitHub repository: https://github.com/GRAPLE/GRAPLEr
- GRAPLE Web Site: http://graple.org/GRAPLEr/
- Hanson, P.C., C.C. Carey, M. Hipsey. *In prep.* ***Tail of two distributions: the probability of harmful algal blooms in model simulations***.
- Ruan, G, PC Hanson, HA Dugan, and B Plale. *In review*. ***Mining lake time series using symbolic representation***. Ecological Informatics.
- Snortheim, CA. 2015. ***Meteorological drivers of oxygen depletion in Lake Mendota***. Masters Thesis. University of Wisconsin.
- Snortheim CA, PC Hanson, KD McMahon, JS Read, CC Carey, HA Dugan. *In revision*. ***Meteorological drivers of hypolimnetic anoxia in a eutrophic, north temperate lake***. Ecological Modeling.
- Subratie K, Aditya S, Figueiredo R, Carey CC, Hanson PC. 2015. GRAPLEr: ***A distributed collaborative environment for lake ecosystem modeling that integrates overlay networks, high-throughput computing, and Web services.*** PRAGMA Workshop on International Clouds for Data Science (PRAGMA-ICDS'15). arXiv:1509.08955 [cs.DC]

Acknowledgements

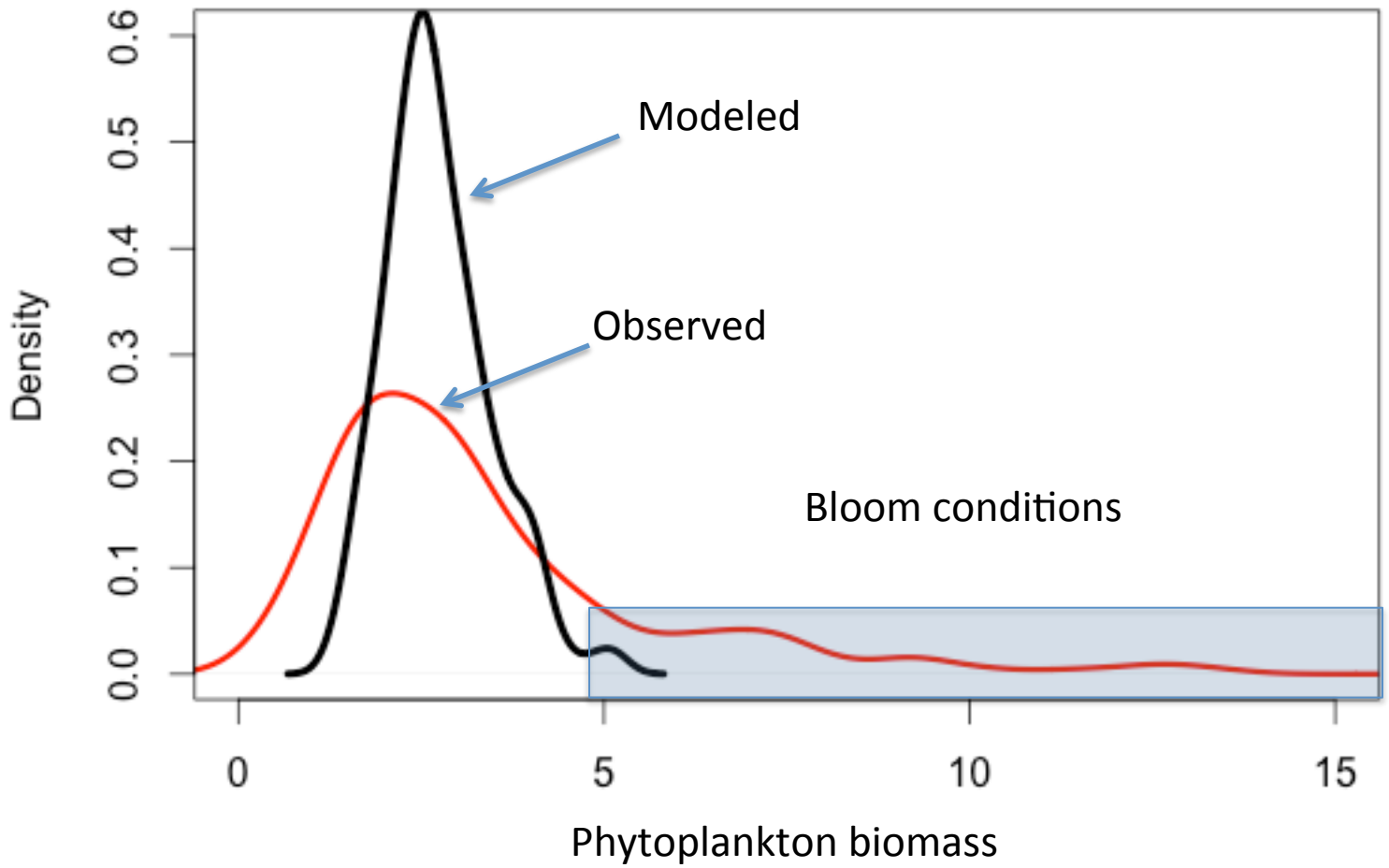
GLEON
global lake ecological observatory network

NSF

PACIFIC RIM APPLICATIONS AND GRID MIDDLEWARE ASSEMBLY
PRAGMA

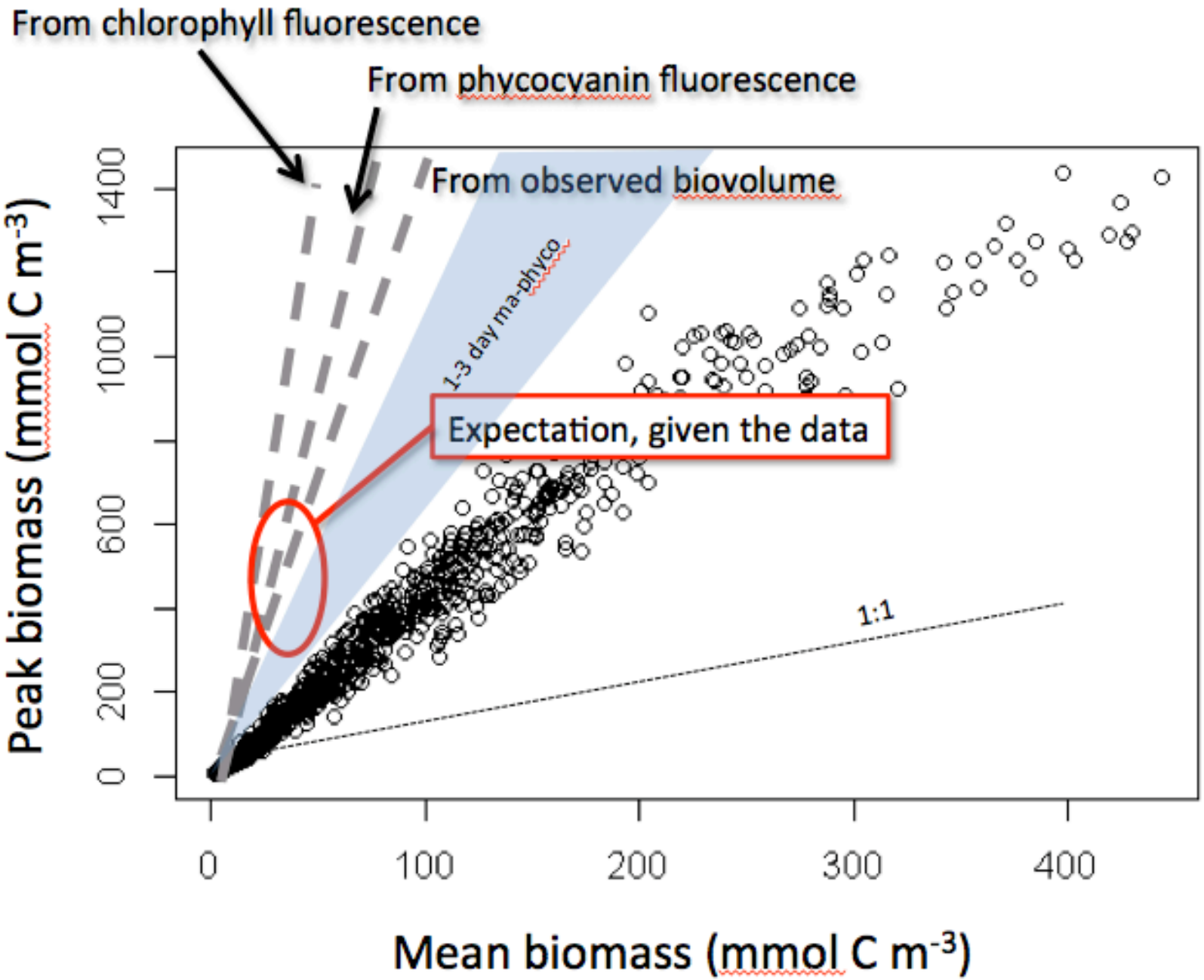
Work to date on the PRAGMA Lake Expedition: Developing the cyberinfrastructure necessary to run thousands of simulations on a few lakes and reservoirs

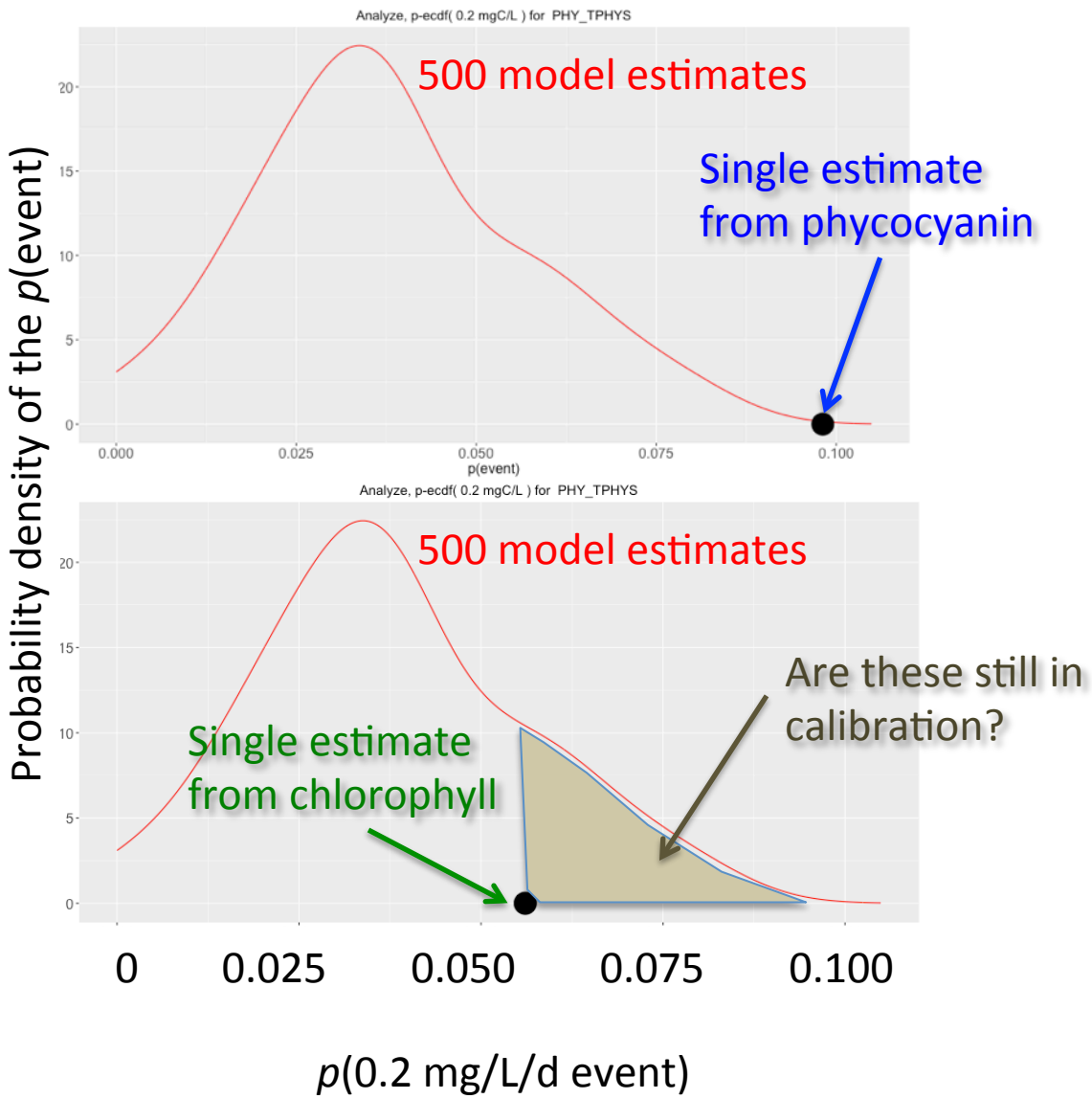
- Collaborative capacity outcomes:
  - Close interactions between PRAGMA CS and GLEON lake ecologists
- Technological outcomes:
  - GRAPLEr R package and tools; Application of iPOP and HTCondor in service of millions of lake simulations
- Science outcomes:
  - Changing meteorological conditions alter ***anoxic conditions*** in eutrophic lakes, potentially transforming water quality
  - Probability of surprise blooms in observational data is ***higher*** than predictions from our best simulations
  - Land use and climate change may interact ***synergistically*** to increase toxic algal blooms
- Educational outcomes:
  - Lake simulation teaching modules developed and delivered to hundreds(?) of undergraduate and graduate students
  - Improved understanding of ecological concepts:
    climate change effects on lakes



Conceptual Figure: figure caption- need to call out how means can be dead-on but the tails are not, and the tails represent the p(bloom-days)- some simple math about X% higher likelihood of bloom-days for the different distributions (HF vs observed vs. model)

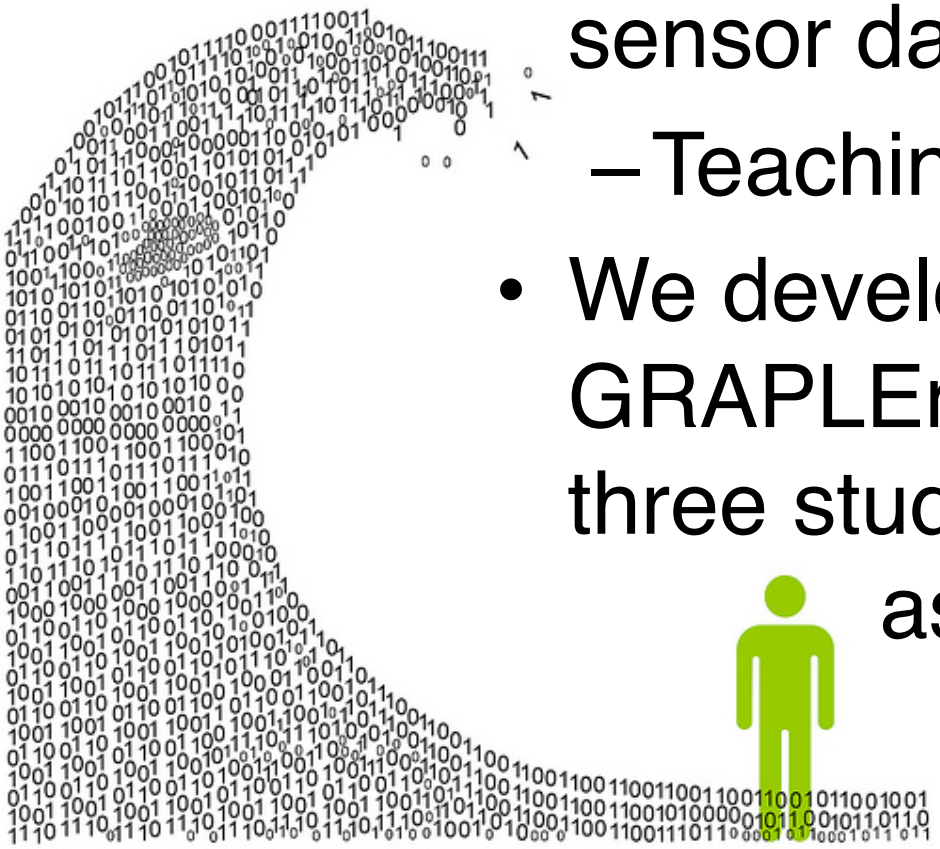
R code adapted from FitDistributions.R – see slide below for code sample.


From chlorophyll fluorescence
From phycocyanin fluorescence
From observed biovolume
1-3 day ma-phyco
Expectation, given the data
1:1
Peak biomass (mmol C m-3)
Mean biomass (mmol C m-3)
0
200
600
1000
1400
0
100
200
300
400

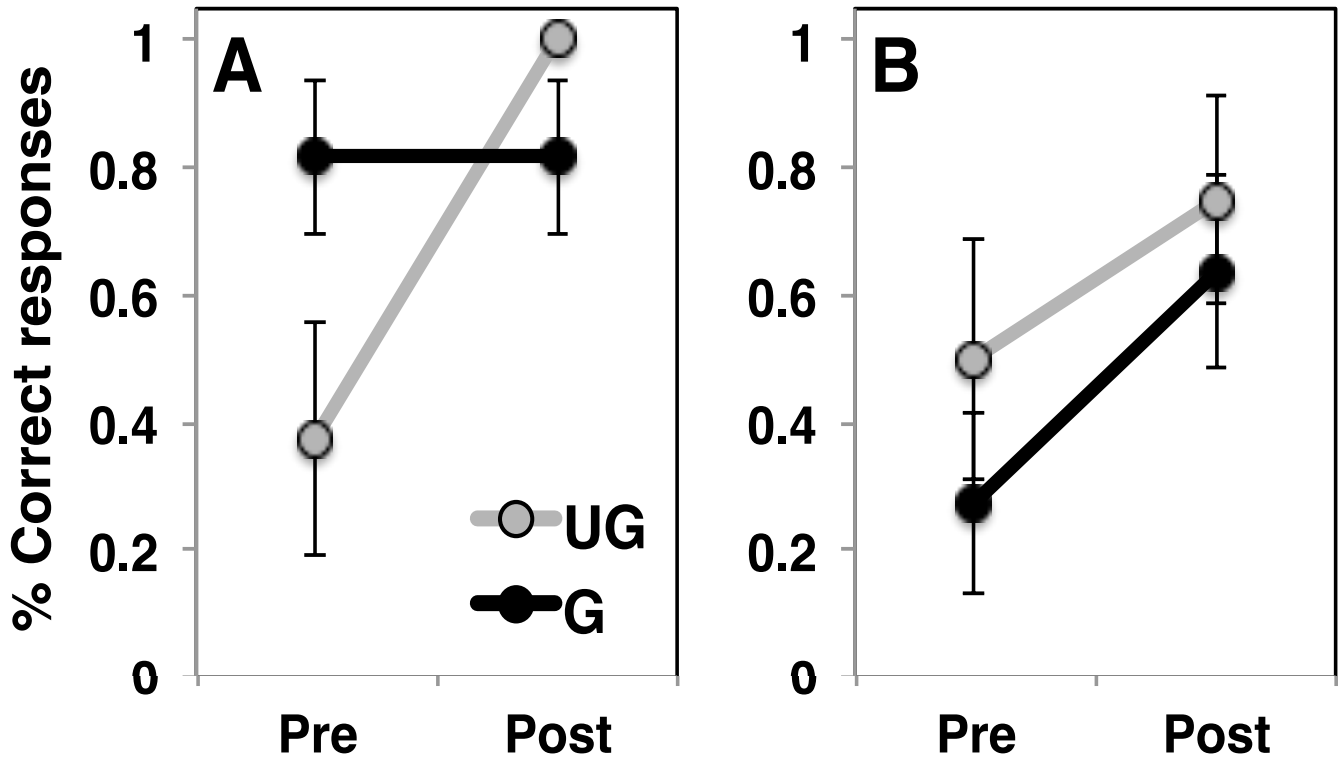

Analyze, p-ecdf(0.2 mgC/L) for PHY_TPHYS
500 model estimates
Single estimate
from phycocyanin
20
15
10
5
0
0.000
0.025
0.050
0.075
0.100
p(event)
Analyze, p-ecdf(0.2 mgC/L) for PHY_TPHYS
500 model estimates
Are these still in
calibration?
Single estimate
from chlorophyll
Probability density of the p(event)
0
0.025
0.050
0.075
0.100
p(0.2 mg/L/d event)

Integrating the GRAPLEr into classrooms

- How best can we prepare ecology students to understand and use computer modeling and big sensor datasets?
  - Teaching modules!
- We developed and tested new GRAPLEr teaching materials in three student workshops/classes as part of Project EDDIE



Improved understanding of ecological concepts: climate change effects on lakes



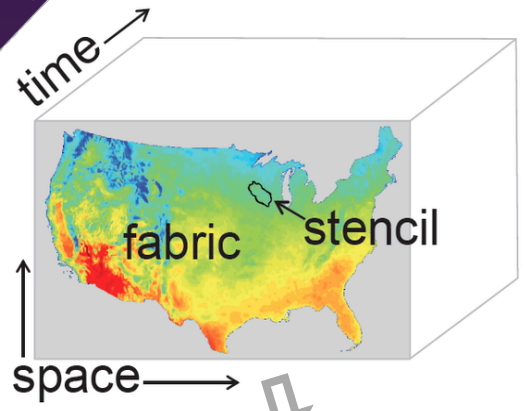
A. How do mixing events alter thermal stratification?

B. How will modeled air temperatures affect water temperatures?

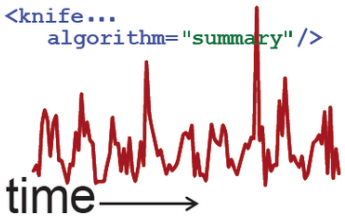
Carey & Darner, *in revision*

Lake science at scale: **Modeling tools**

Data Access

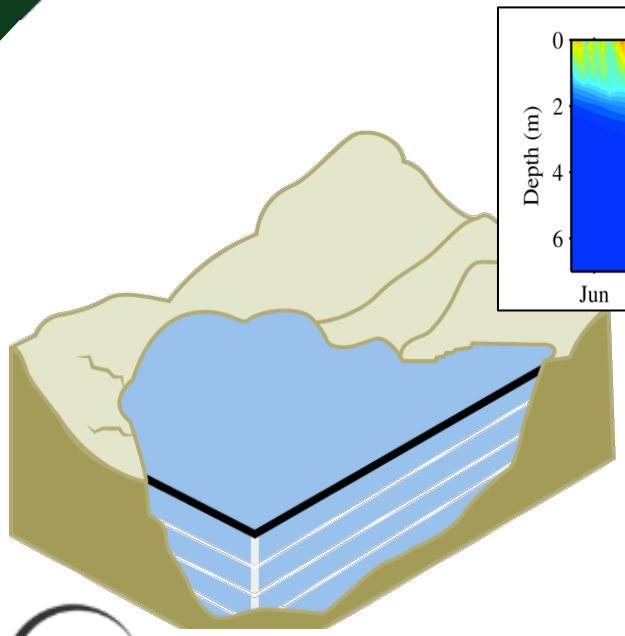


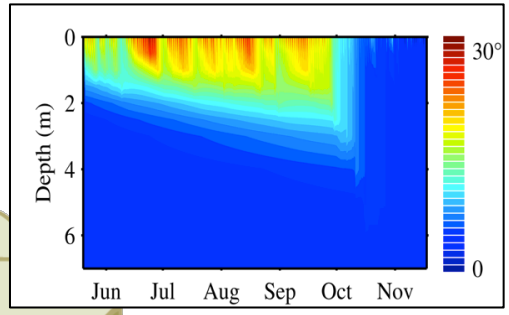

```
<knife...
   algorithm="summary"/>
```



USGS

Modeling and Data Analysis





AED Aquatic Eco Dynamics

USGS