Modeling Carbon in the Coastal Zone

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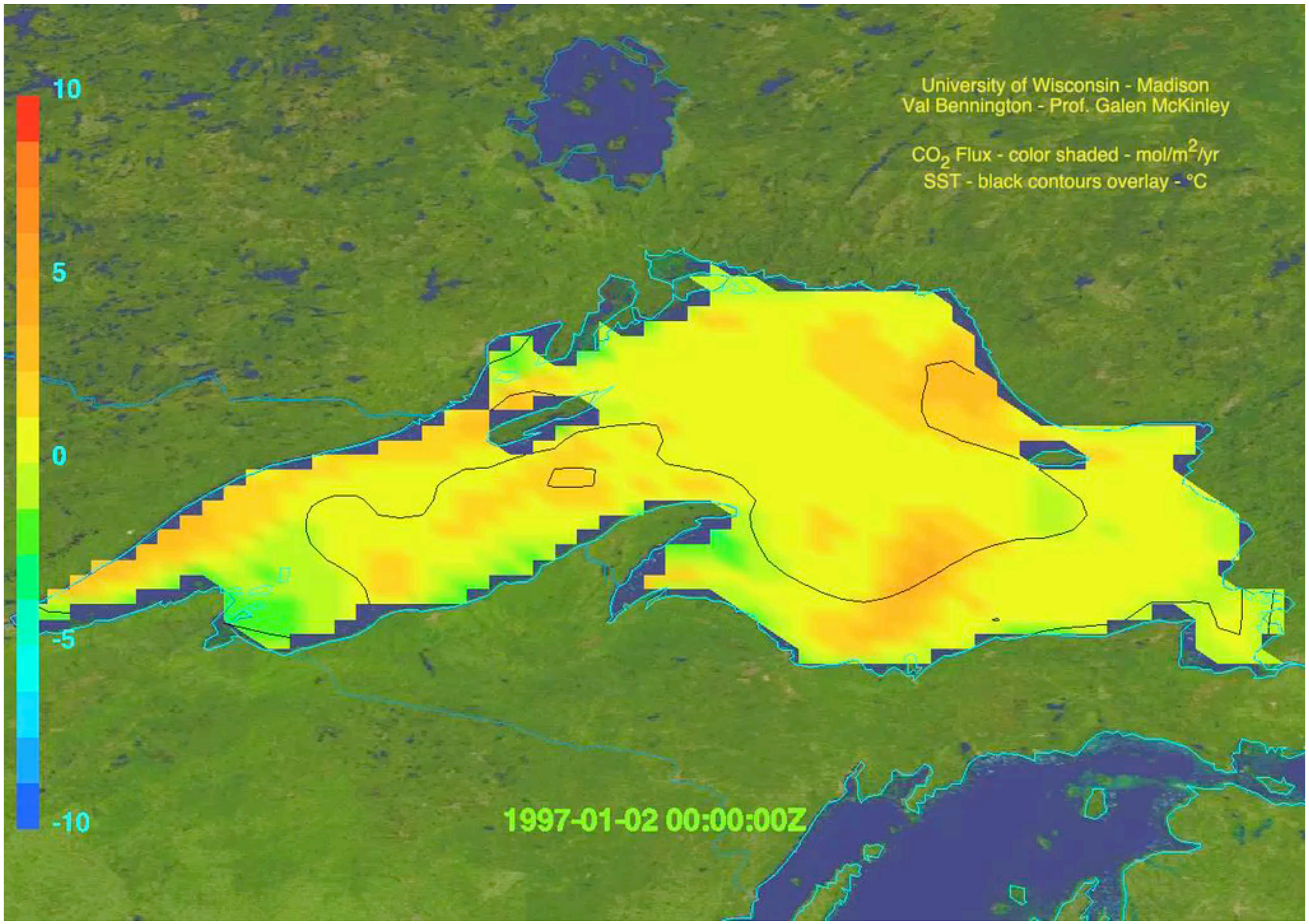


Why build a 3D coupled model?

- Assess impacts of spatio-temporal variability
- Generate new hypotheses
- A numerical laboratory
  - Sensitivity studies
  - Future scenarios
- Assist with management questions

- ….Data assimilation

But… many caveats…

- Model are only as good as the information we put into them…
- Many different "carbon cycles" can fit the same data

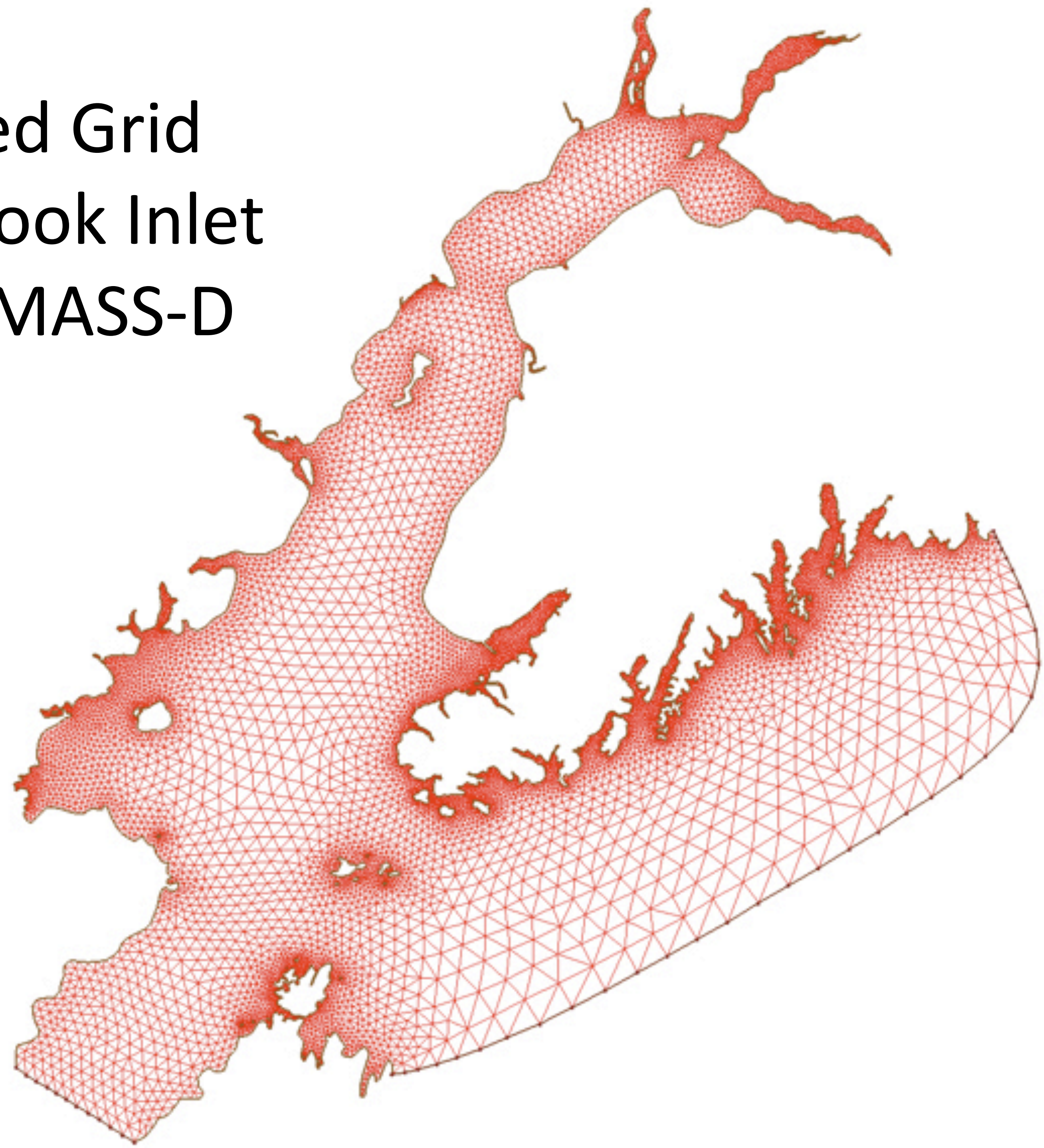
Requirements

- Physical model
- Biogeochemical module
- Computers
- People
  - Physical model
  - Physical data
  - Biogeochemical model
  - Biogeochemical data

Physical model

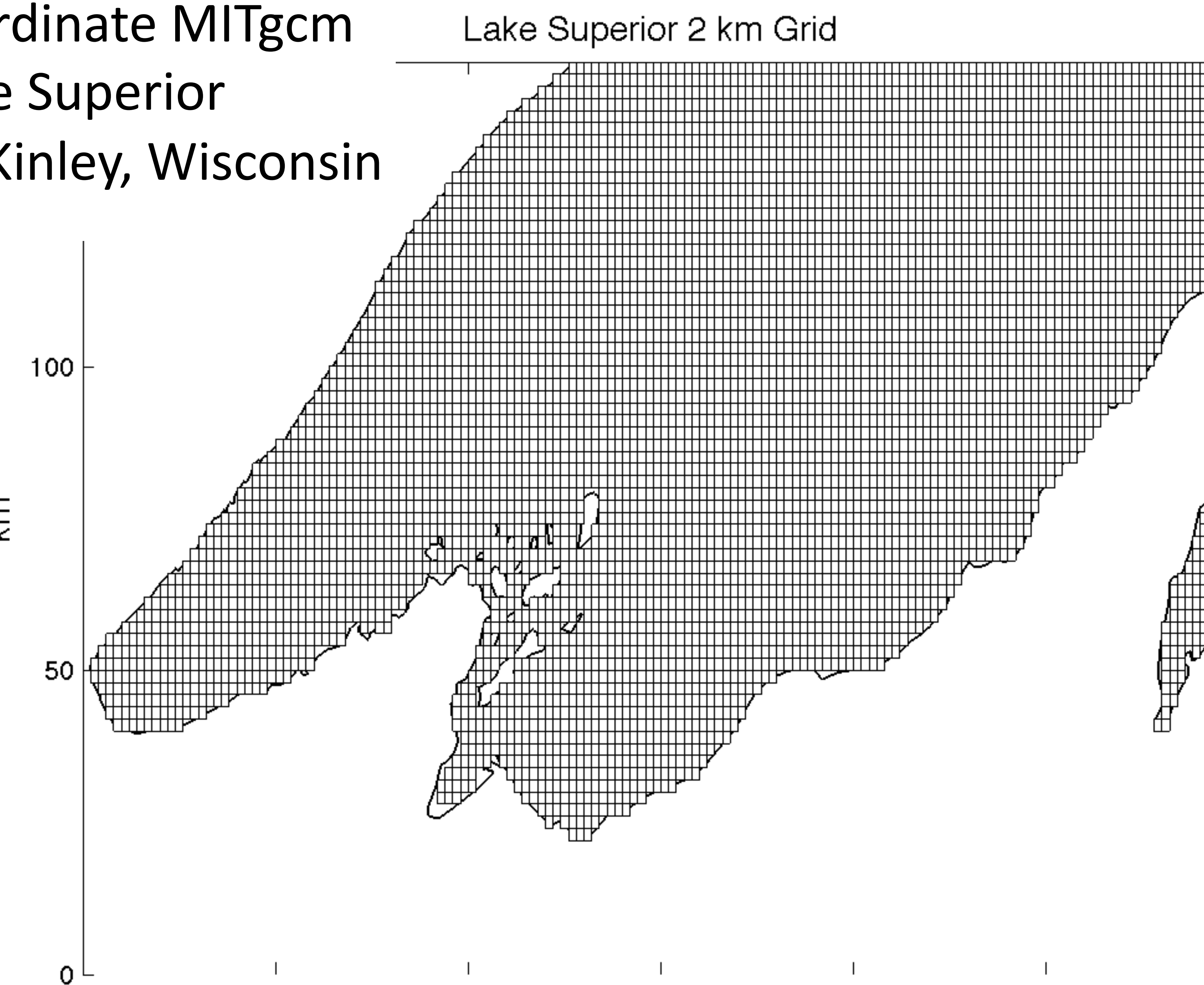
- Many codes out there, most free
  - ROMS, MITgcm, FVCOM, etc.
  - provided “as is”; support from discussion forum
- Some differences…
  1. Grid scheme – z-level, terrain following, unstructured
  2. Ability to run on parallel processors
- Developer familiarity is a big factor in choice

Unstructured Grid
- FVCOM, Cook Inlet
- Chen at UMASS-D



z-coordinate MITgcm

- Lake Superior
- McKinley, Wisconsin



Physical model

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Physical Data

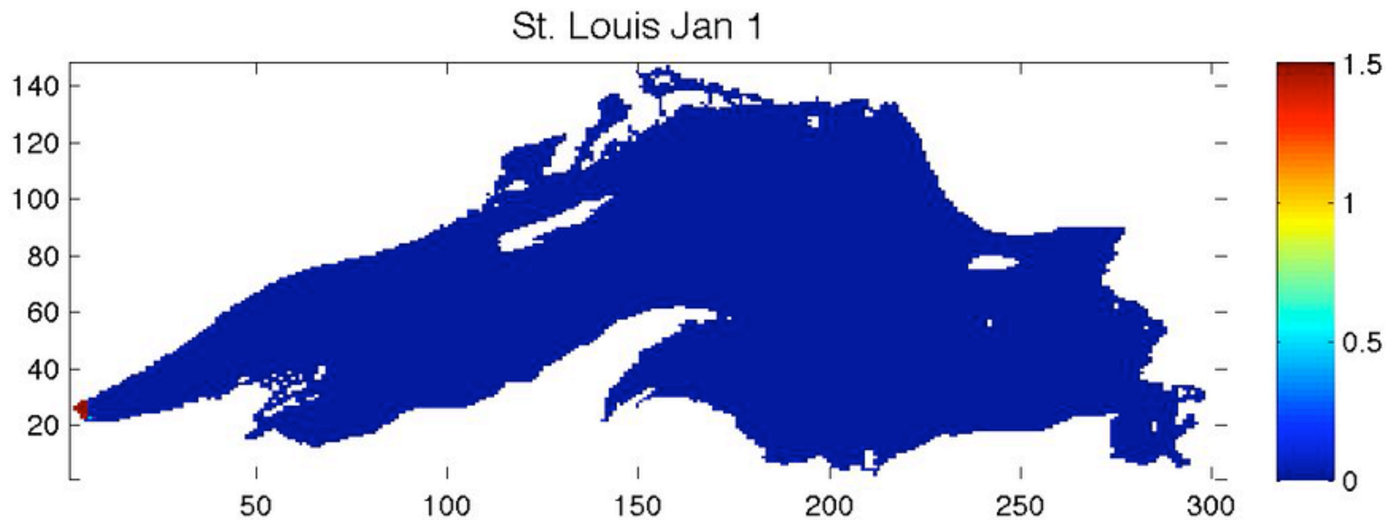
- To make it go
  - Bathymetry
  - Atmospheric forcing (NCEP Reanalysis, NARR)
  - Boundary conditions
    - A global model? A climatology?
  - Perhaps, data for assimilation
- To know if its right – Validation data
  - Currents, SSTs, T profiles
  - Coverage in all dimensions of space and time

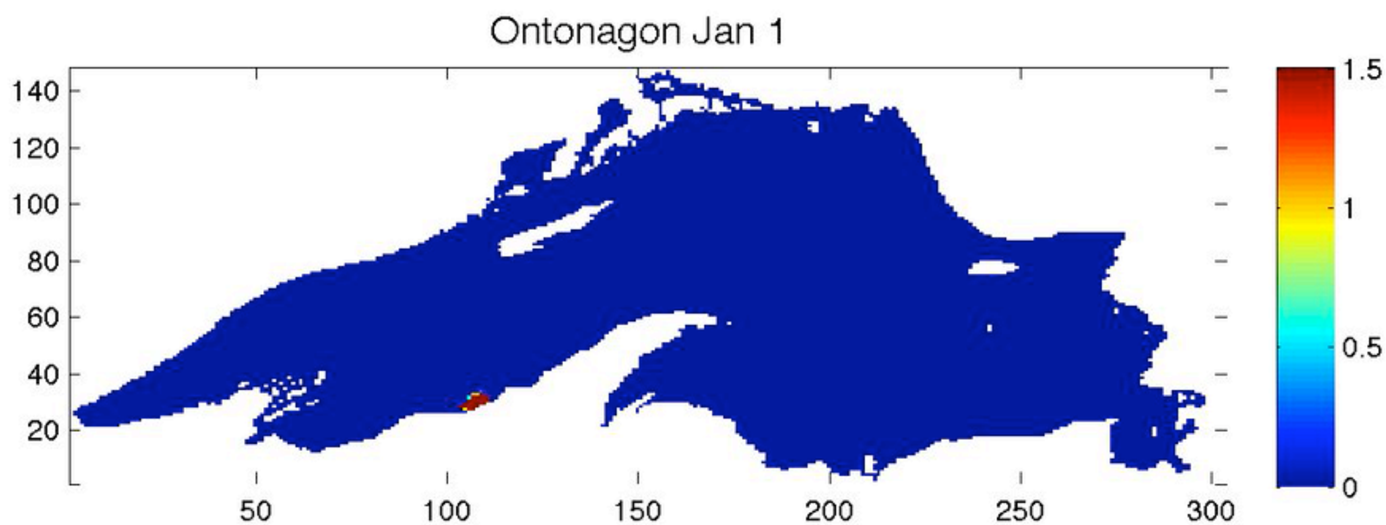
Who to build physical model?

- Ideally a physical oceanographer with modeling experience – or a lot of time to learn

- Or a good postdoc with modeling experience

Collaborate!

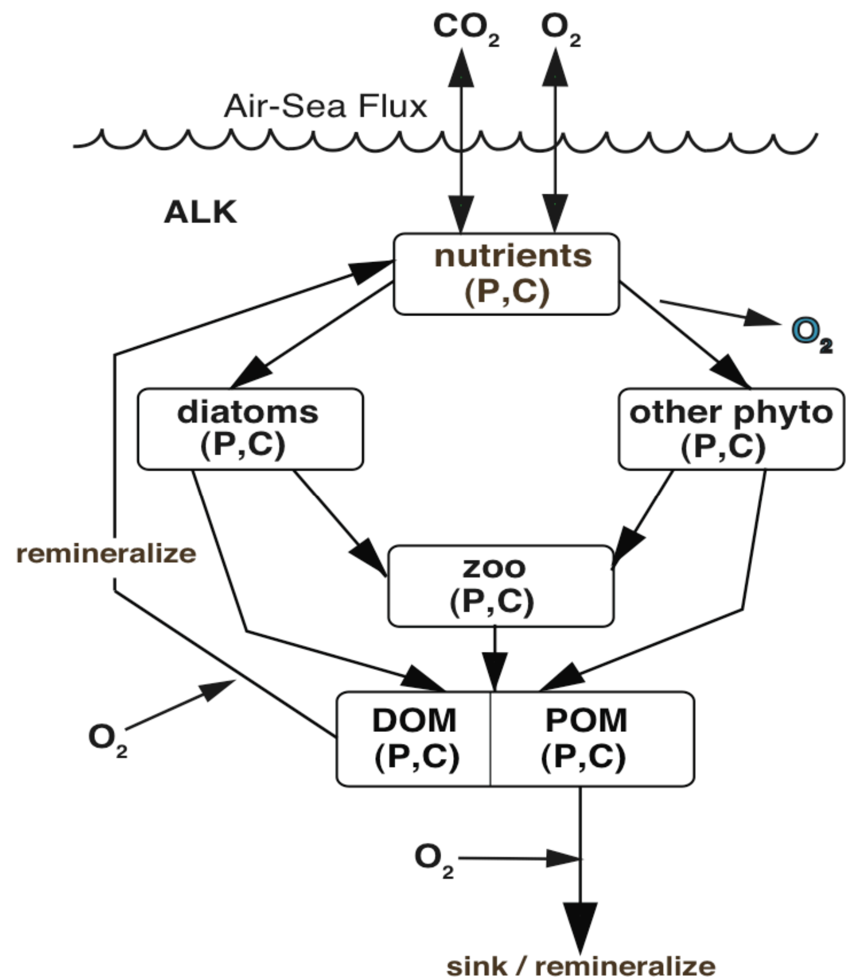




A passive tracer released Jan 1 with concentration ~$6x10^4$. When lake fully mixed, concentration=1 everywhere. 2 year animation.

Biogeochemical Module – Water Column

- Codes out there, but fewer
- Less support
- Maybe already coupled to physical model?
- Much "structural uncertainty" – i.e. are the equations you are using appropriate to your system?



Bennington 2010;
Dutkiewicz et al. 2005

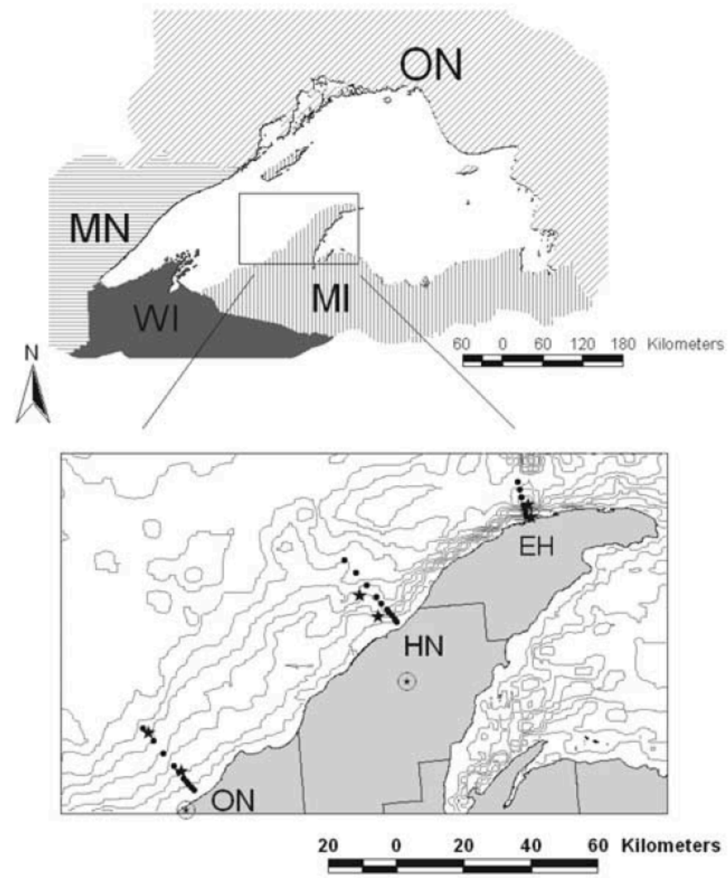
Depending on system, other modules

- Sedimentation
- Benthic processing
- Rivers
- Estuaries
- Coastal Vegetation
- Other..

Biogeochemical Data

- Initialization
- Boundary Conditions
- Validation and/or formal optimization

- Nutrients, DIC, DOC
- Chl – satellite, if algorithm OK
- Observed rates most helpful, but scarce

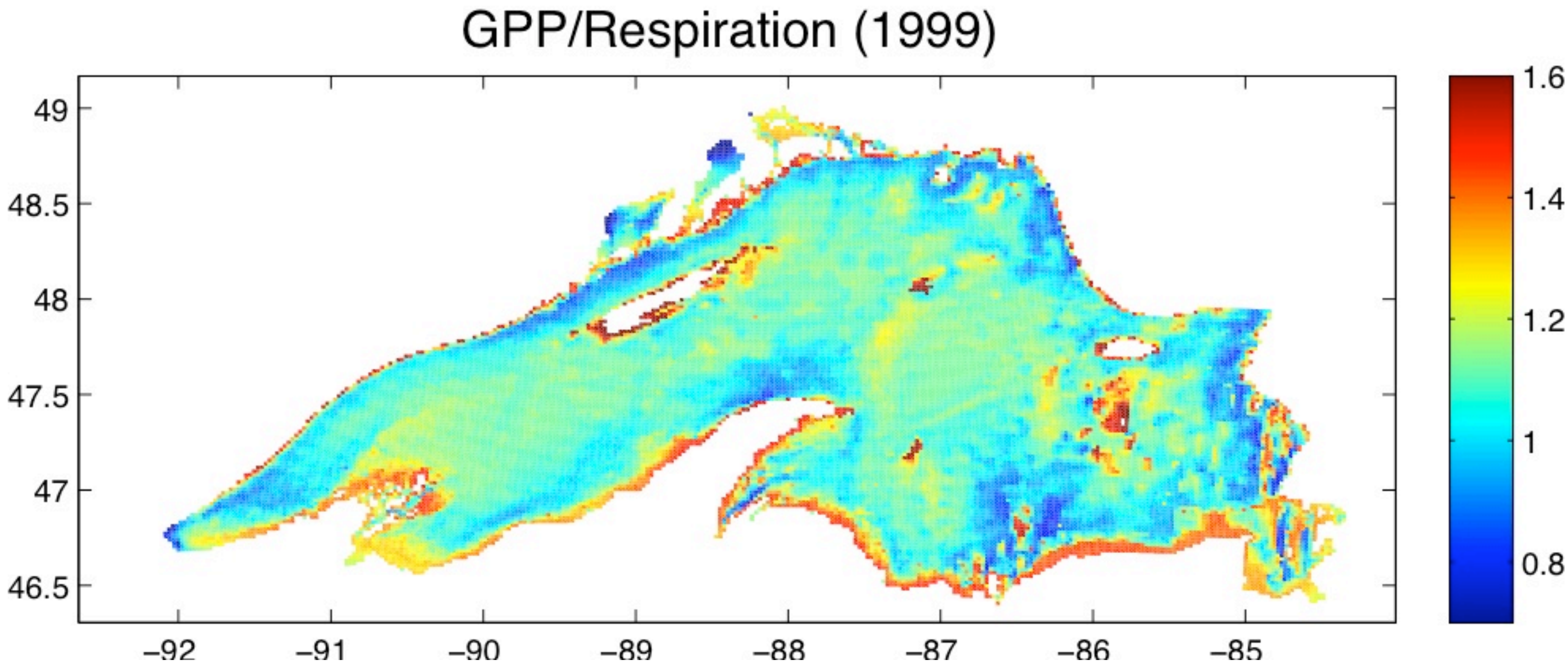


Computers:
Lots of processors and lots of disk space

- Your lab?
- Your institution?
- NCAR
- NASA

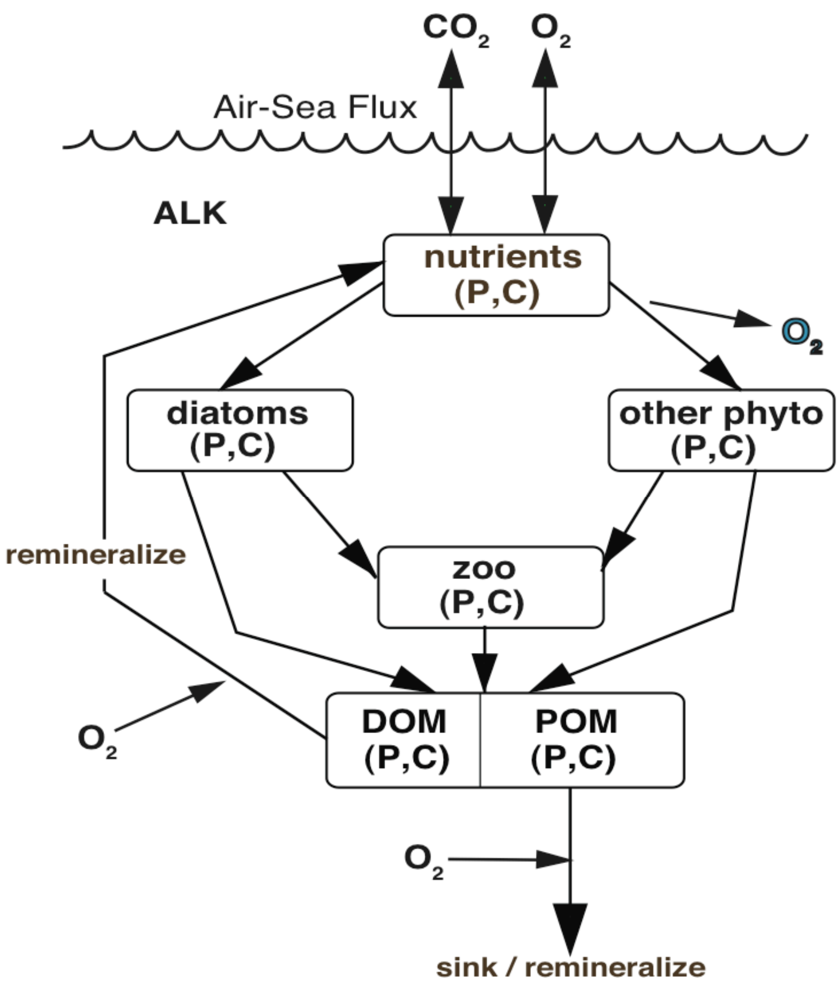
- Biogeochemistry typically makes computation 10x's larger than physical only
- Terrabytes of output

What can you get?

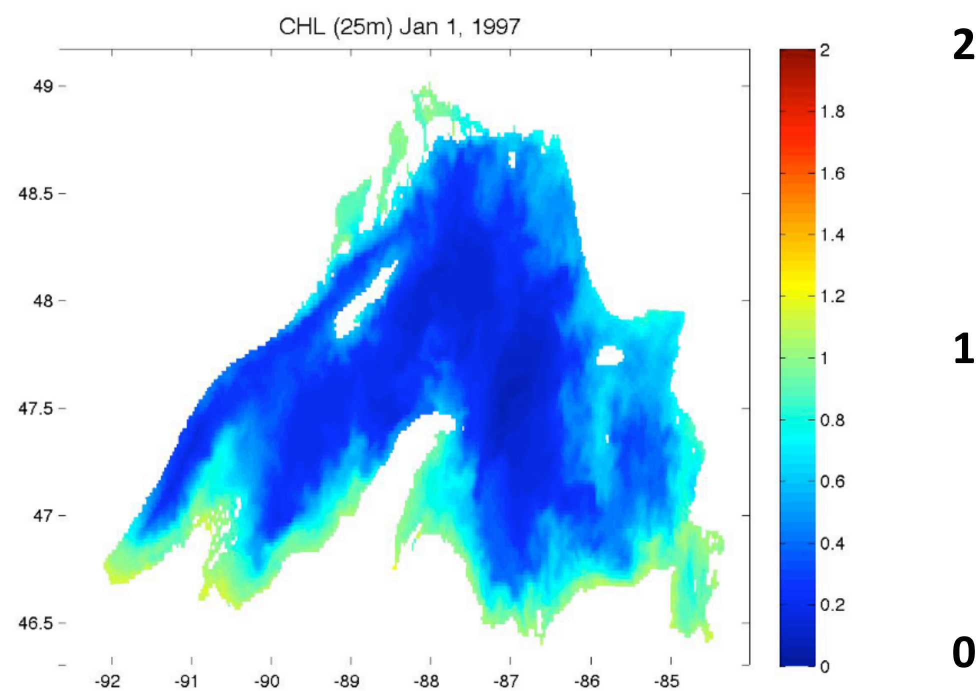


Lake Superior's Multiple "realities"

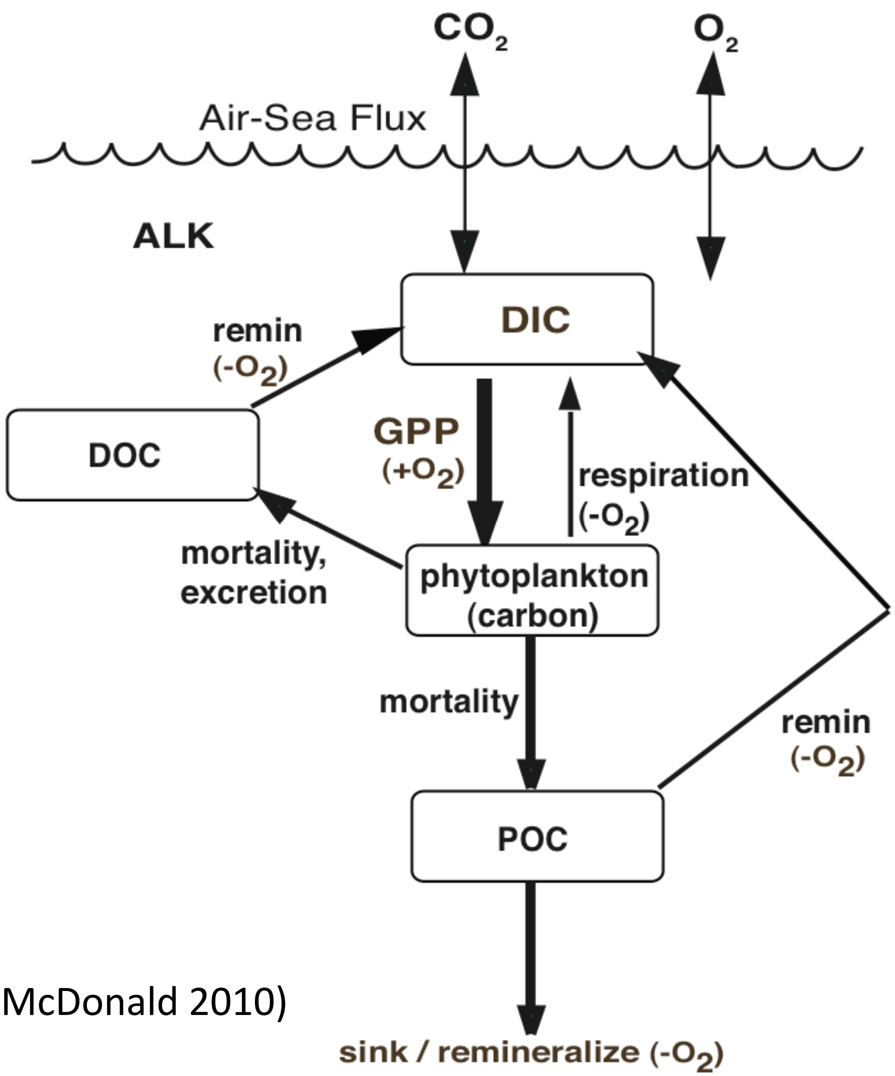
Phosphorous Model



Hand-tuned to best fit available data

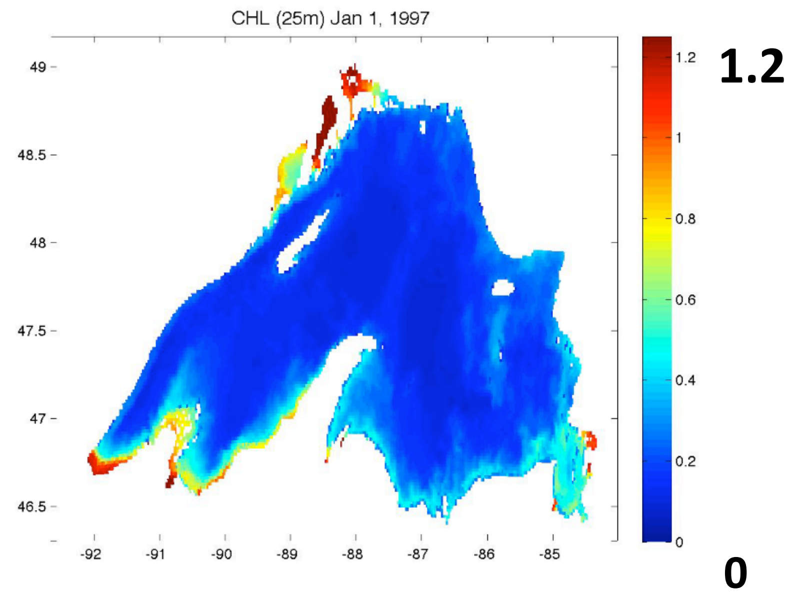


No Phosphorous Model

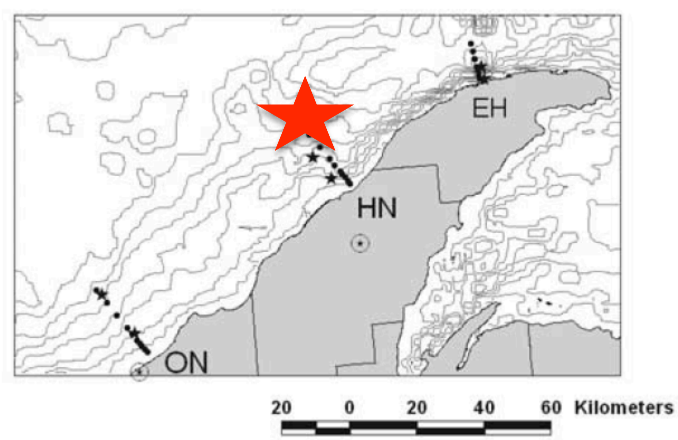


(McDonald 2010)

GPP from T, PAR (Sterner 2010)

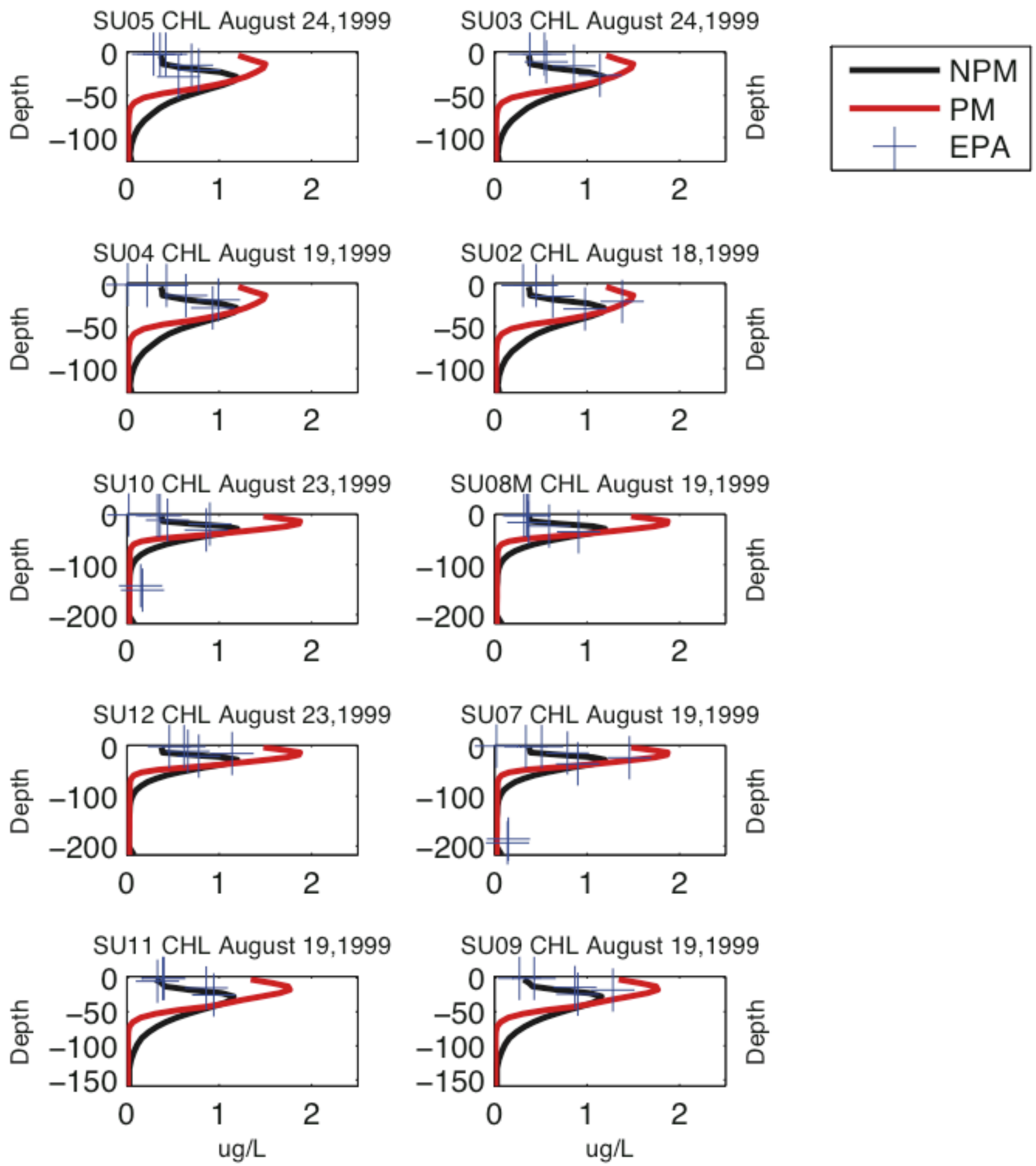


Formal Optimization in 1-D

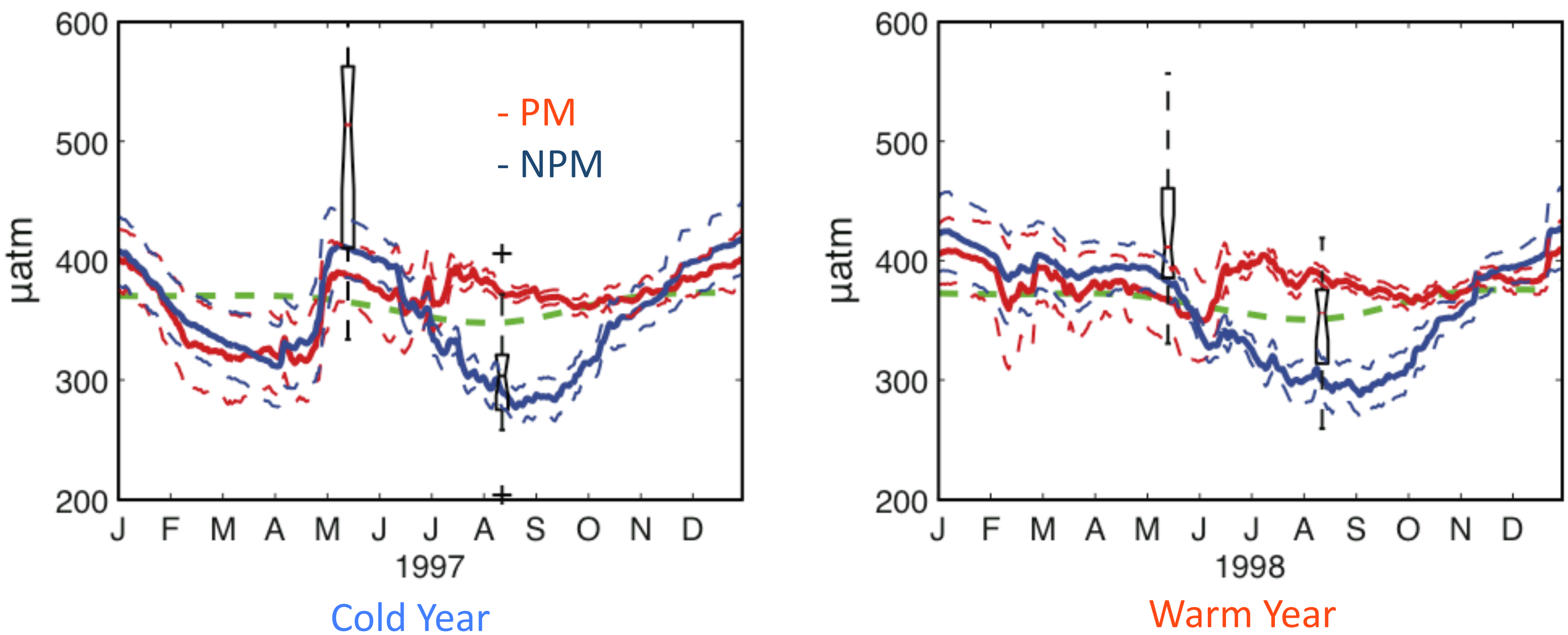


Model - Observation Comparisons

Data not used in NoPhos optimization

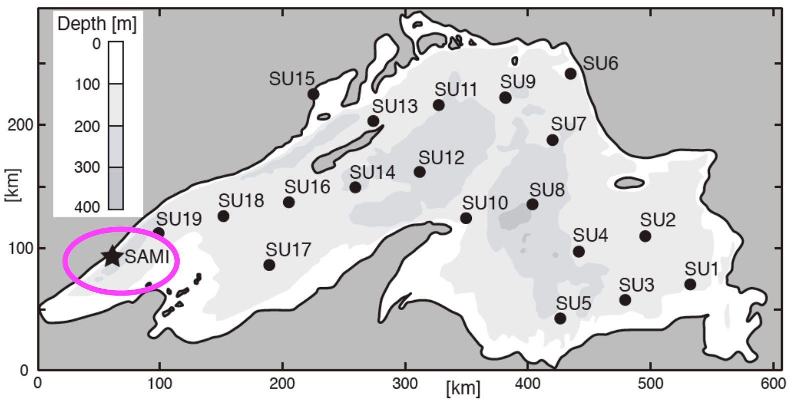

SU05 CHL August 24,1999
SU03 CHL August 24,1999
SU04 CHL August 19,1999
SU02 CHL August 18,1999
SU10 CHL August 23,1999
SU08M CHL August 19,1999
SU12 CHL August 23,1999
SU07 CHL August 19,1999
SU11 CHL August 19,1999
SU09 CHL August 19,1999
Depth
ug/L
NPM
PM
EPA

Open Lake pCO_2

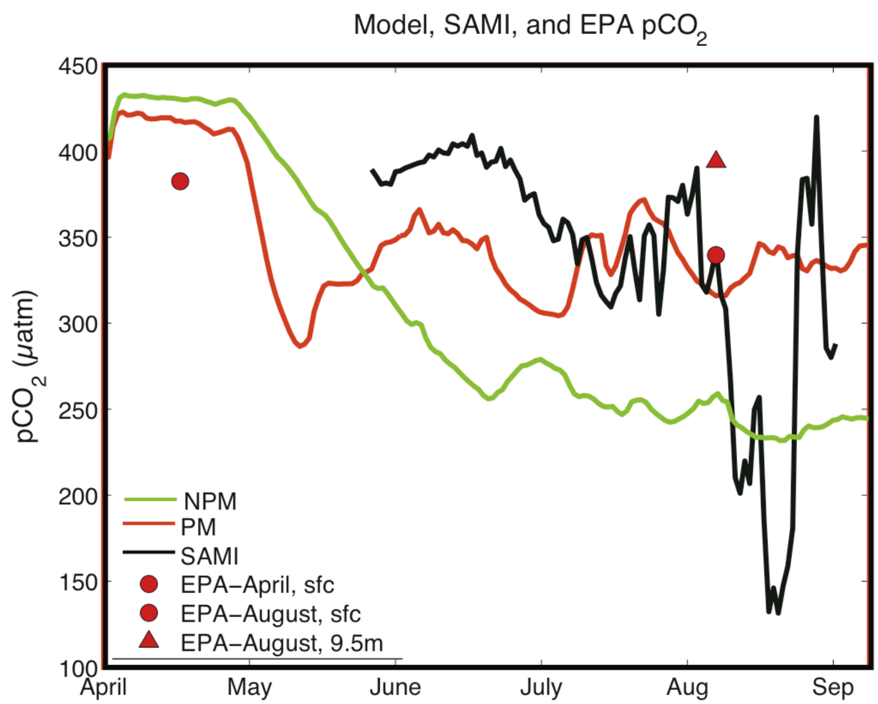


- Both models capture spring and summer open lake pCO_2 within reason

SAMI pCO_2 Time Series



- No phosphorous model misses effects of internal mixing to and from P



2001

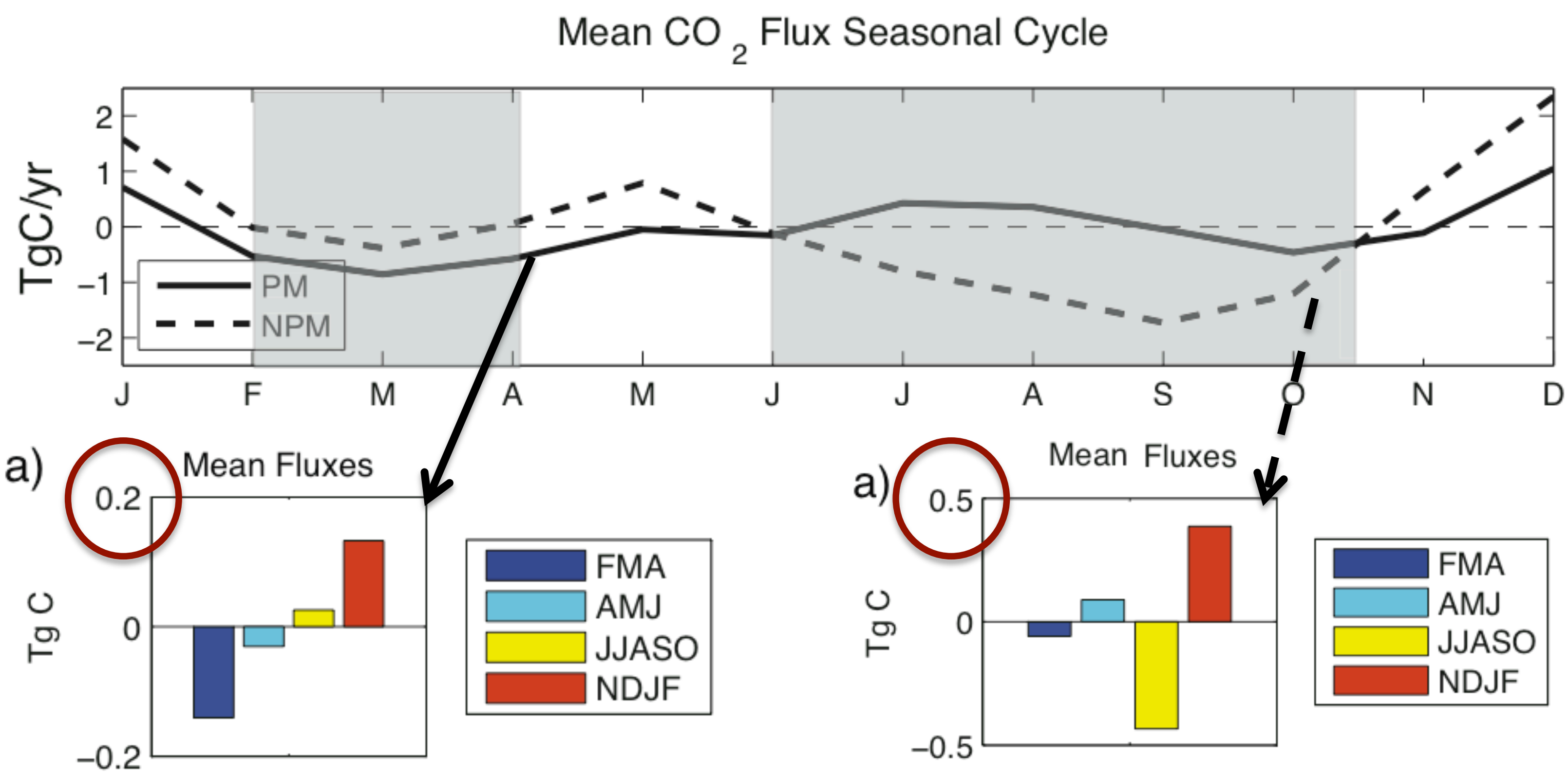
Model Summary

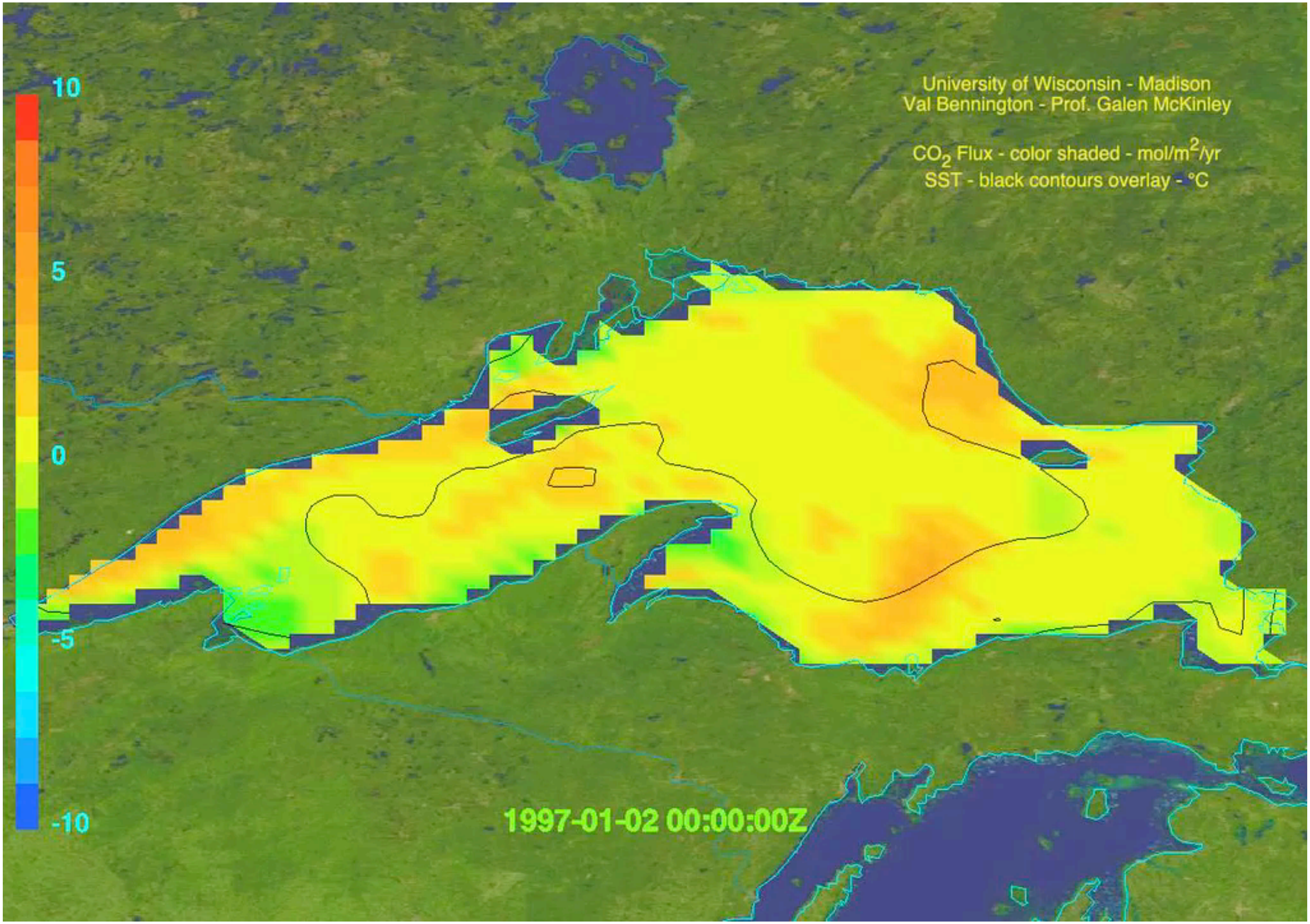
	Phosphorous Model	No P Model
Chlorophyll		Better
Open Lake pCO_2 (EPA)	Okay	Okay
High frequency pCO_2	Better	

Given the lack of data constraints, these models only begin to cover the potential ecosystem / carbon cycle realities of Lake Superior.

Nevertheless, the models do begin to cover the state space and so are reasonable tools for further carbon cycle analysis.

Seasonal cycle of air-lake CO_2 flux remains poorly constrained





10
5
0
-5
-10
University of Wisconsin - Madison
Val Bennington - Prof. Galen McKinley
CO_2 Flux - color shaded - mol/m^2/yr
SST - black contours overlay - °C
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