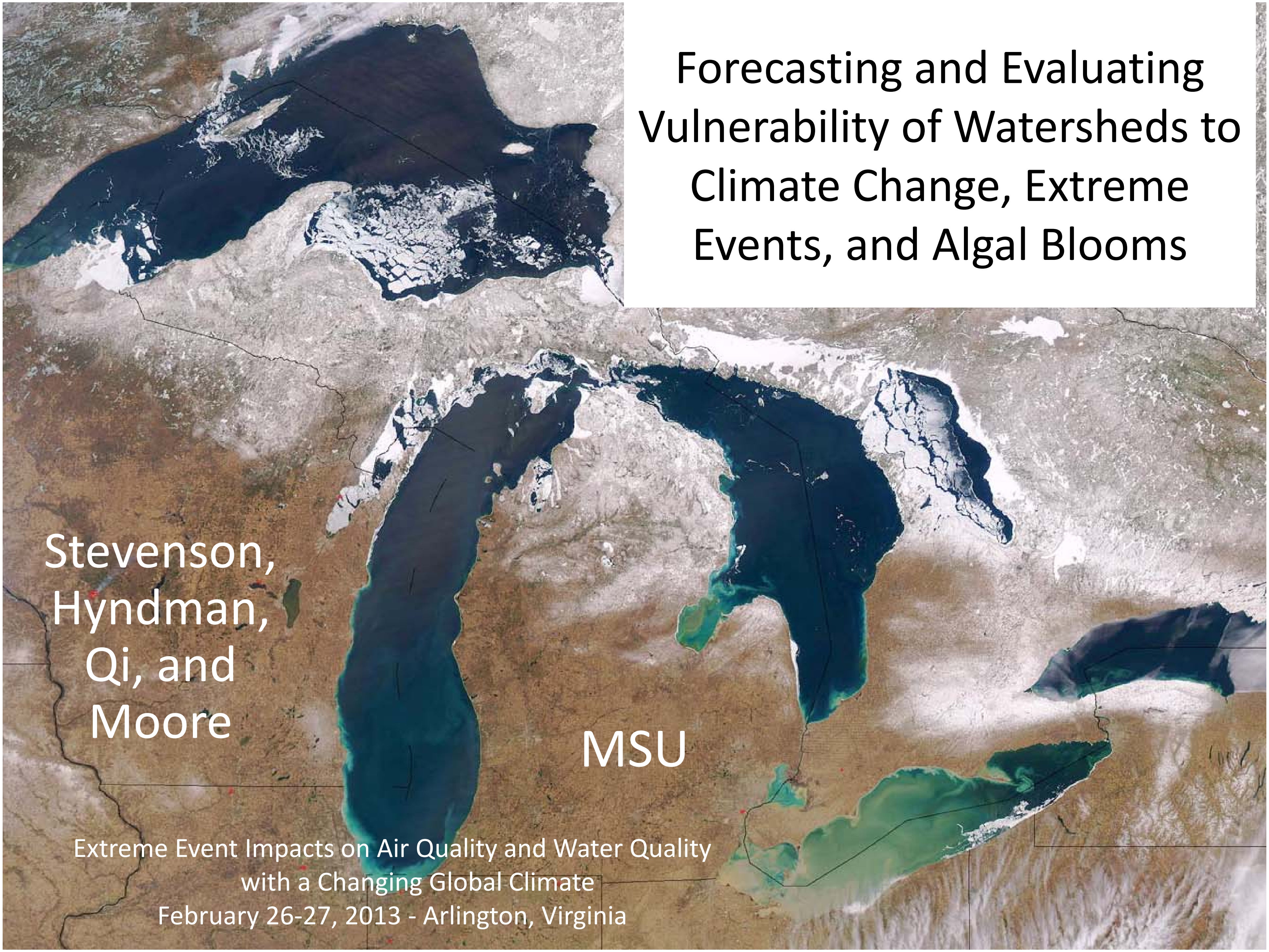


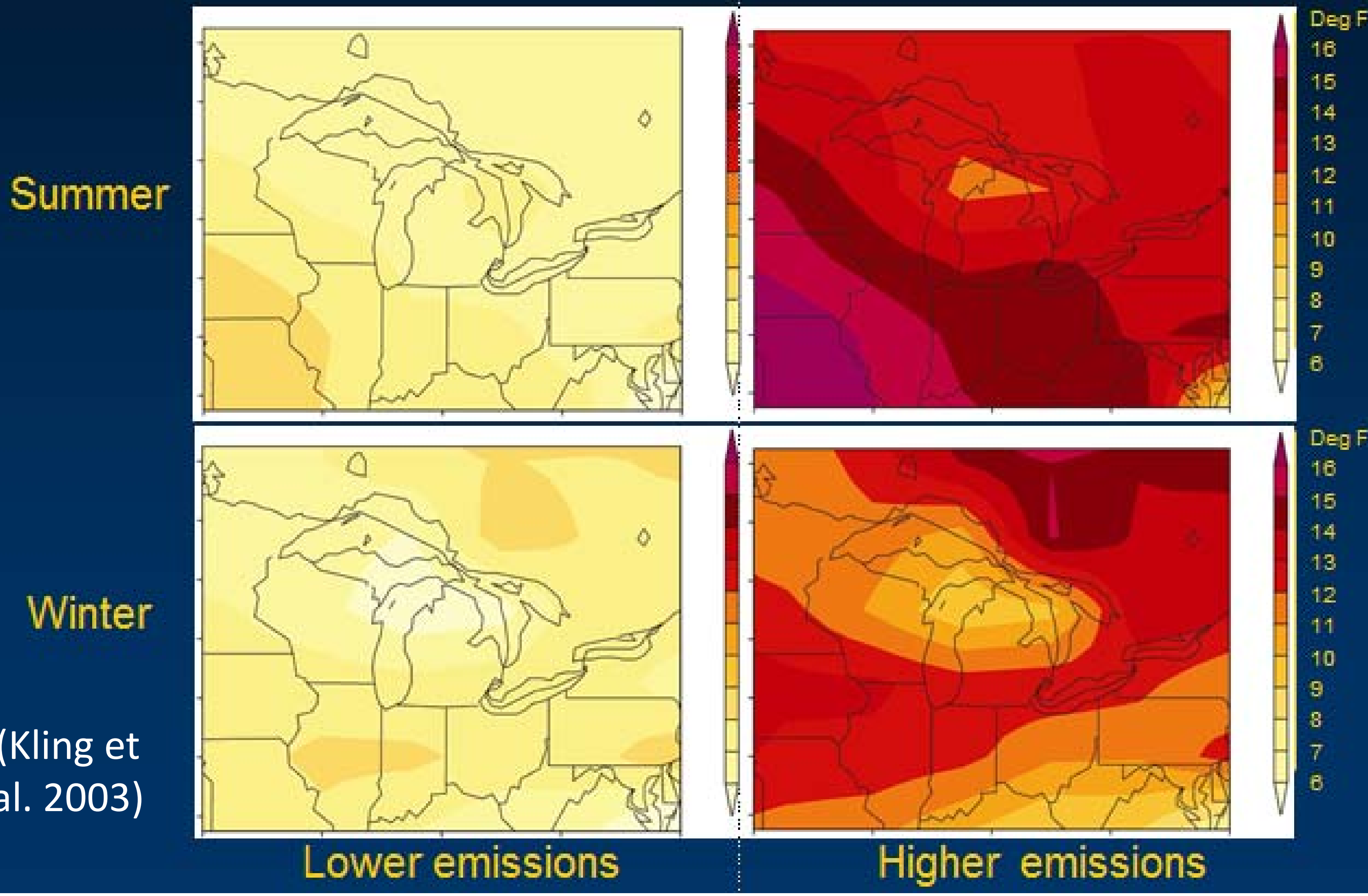
Forecasting and Evaluating Vulnerability of Watersheds to Climate Change, Extreme Events, and Algal Blooms

Stevenson, Hyndman, Qi, and Moore

MSU

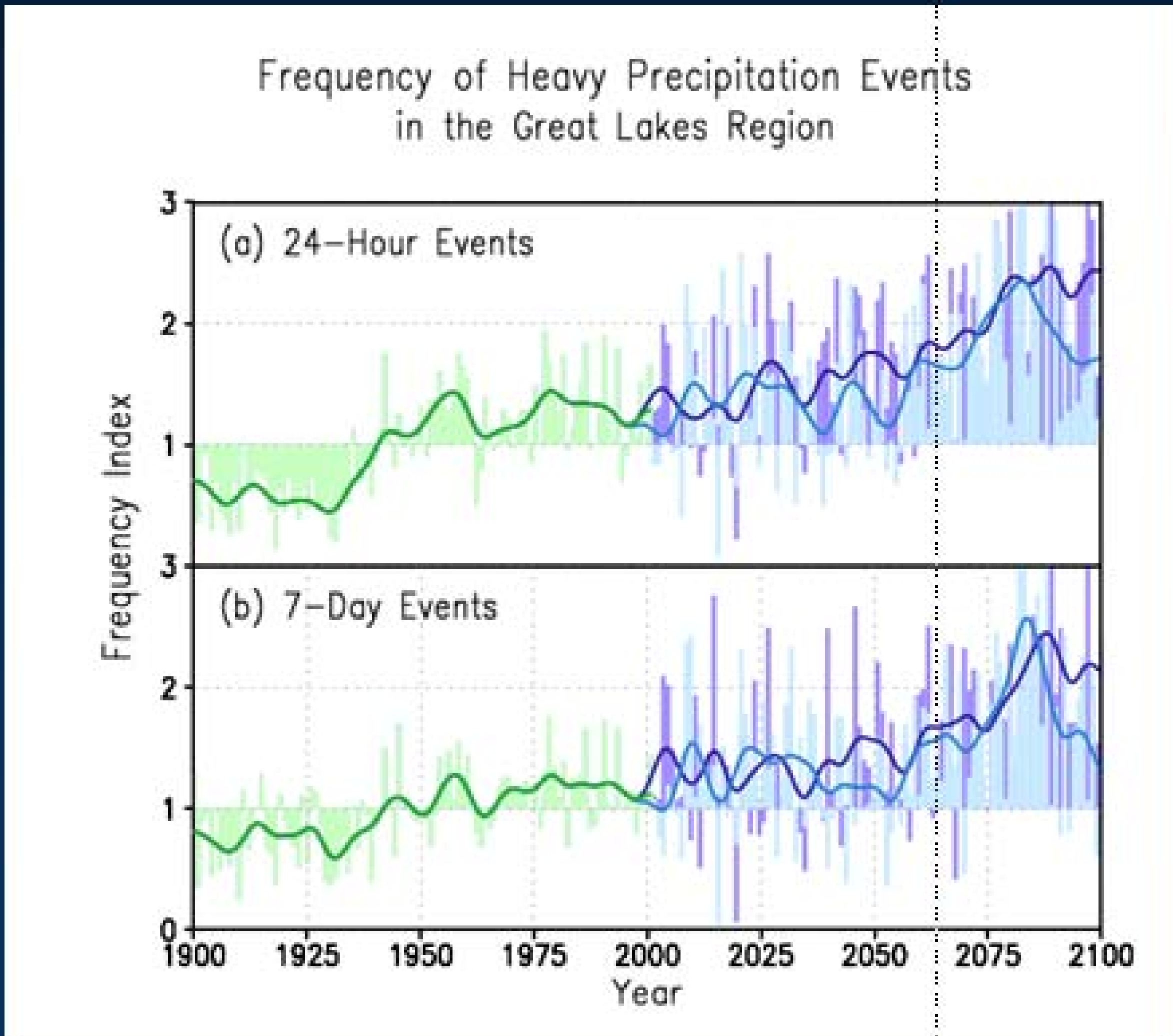
Extreme Event Impacts on Air Quality and Water Quality with a Changing Global Climate
February 26-27, 2013 - Arlington, Virginia

Projected Temperature Increase in the Great Lakes Region (by 2070-99)



(Kling et al. 2003)

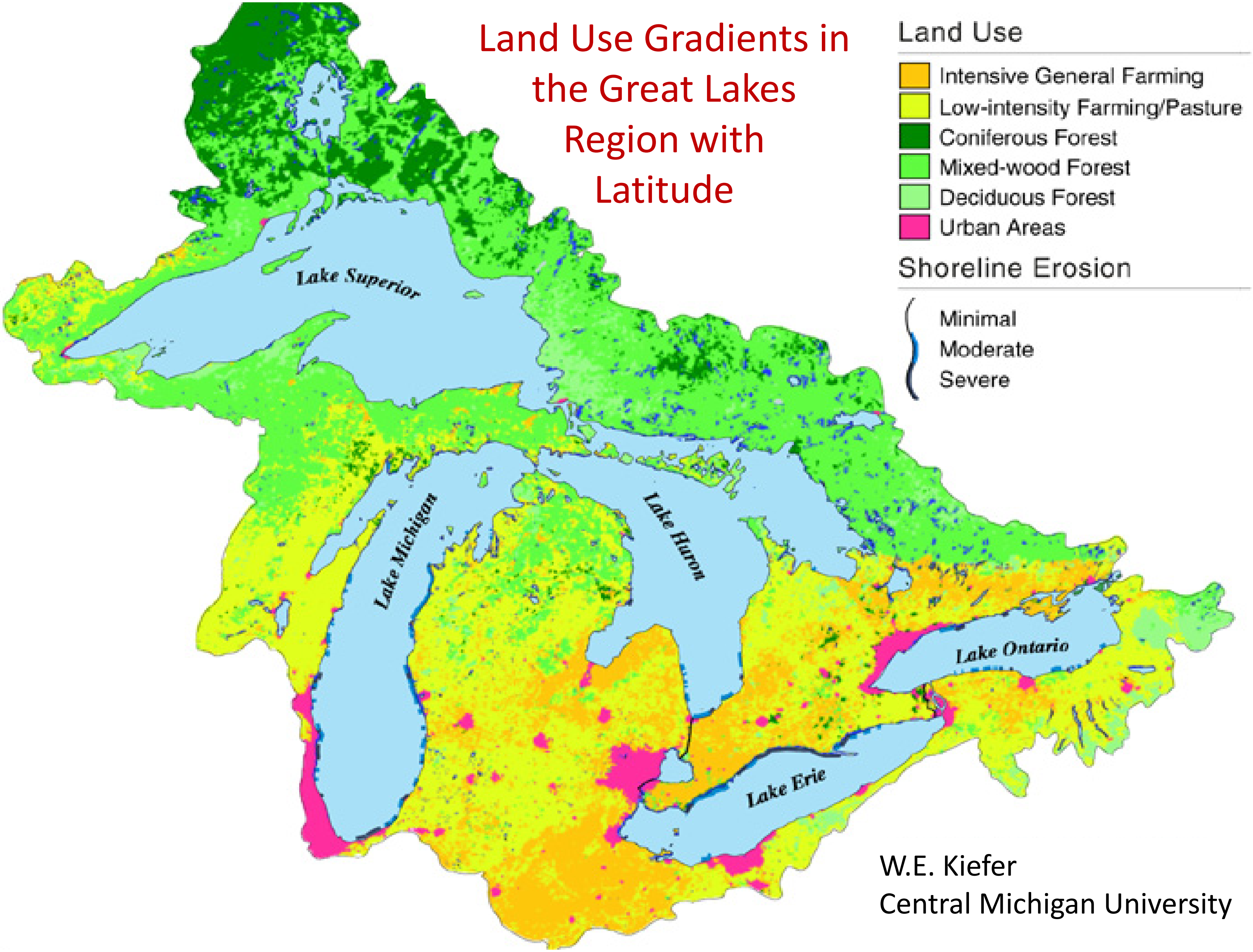
Projected Precipitation Changes in the Great Lakes Region (by 2070-99)



- Doubling of heavy precipitation events
- Seasonal shifts in precipitation --
  - * More rain in winter and spring (planting season)
  - * Less rain during the summer and fall growing seasons

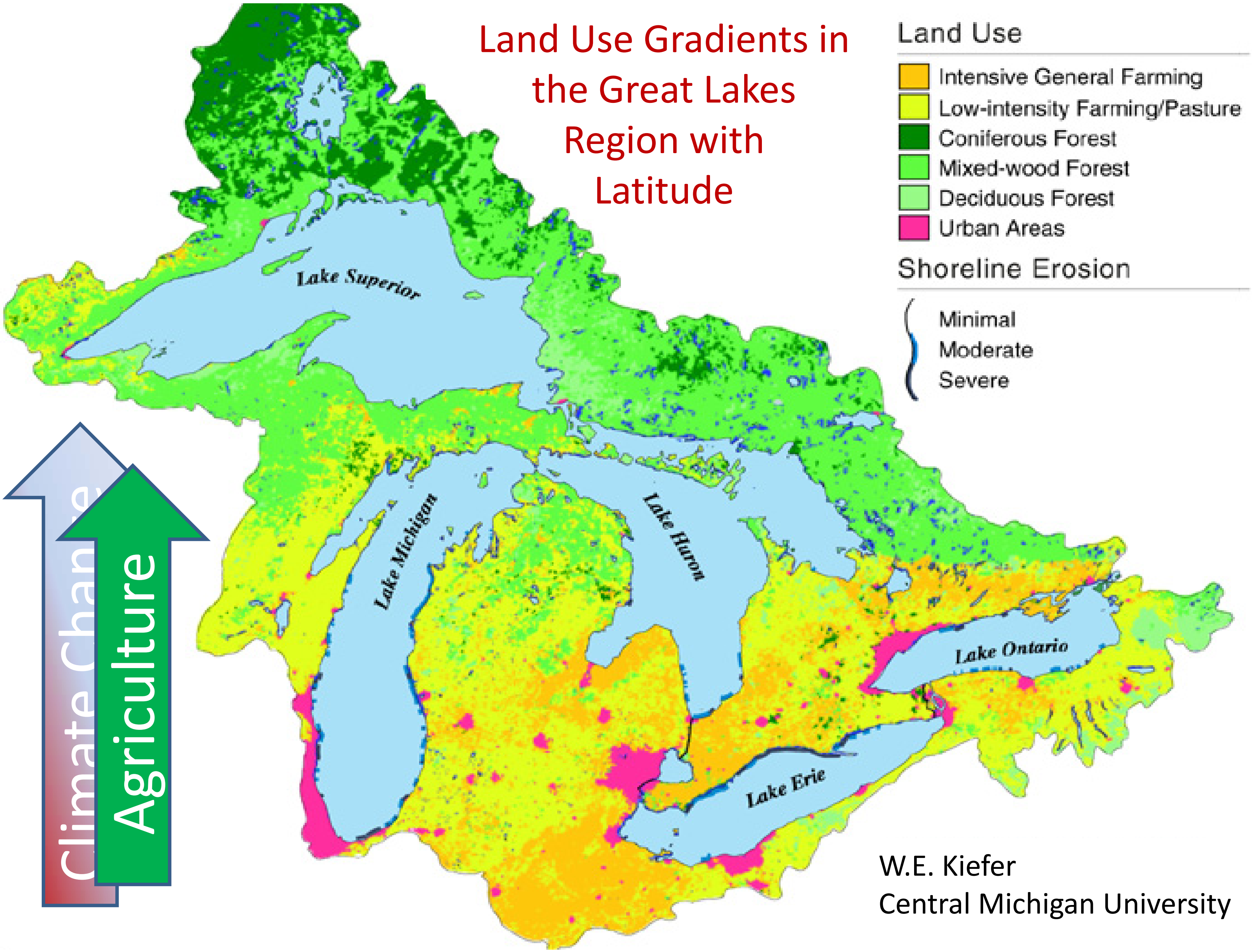
(Kling et al. 2003)

Land Use Gradients in the Great Lakes Region with Latitude



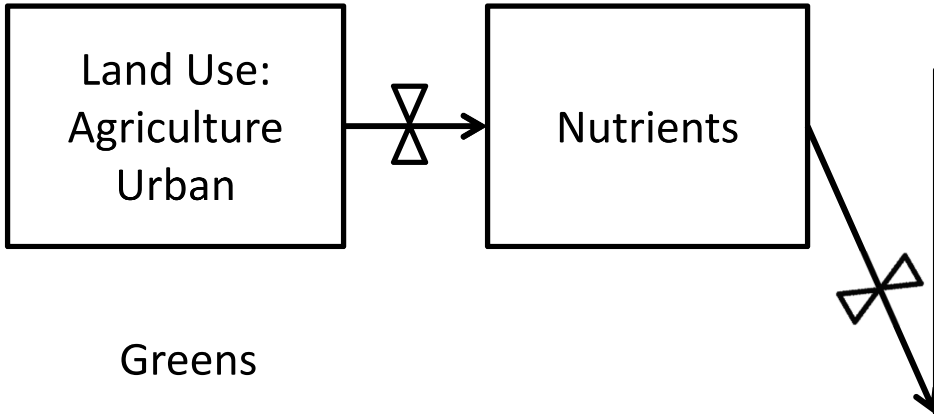
W.E. Kiefer
Central Michigan University

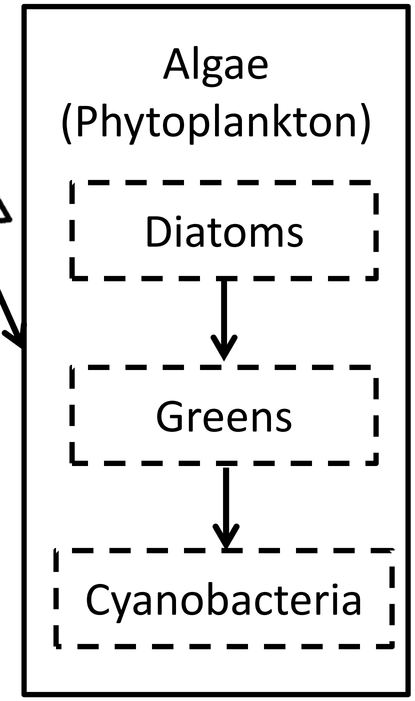
Land Use Gradients in the Great Lakes Region with Latitude



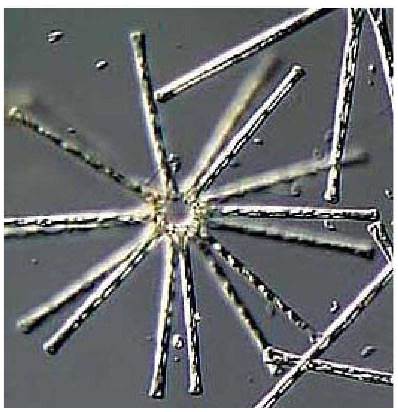
W.E. Kiefer
Central Michigan University

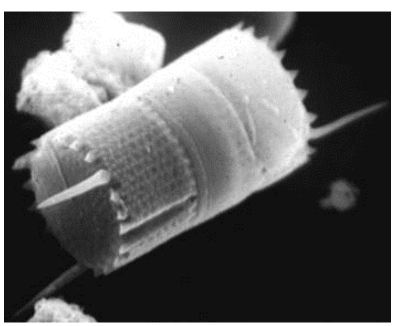
Algal-Nutrient-LandUse Relationships



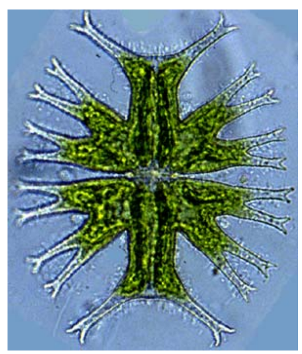


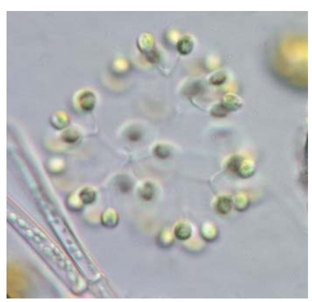
Diatoms



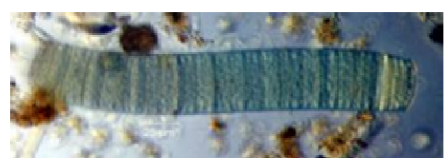


Greens

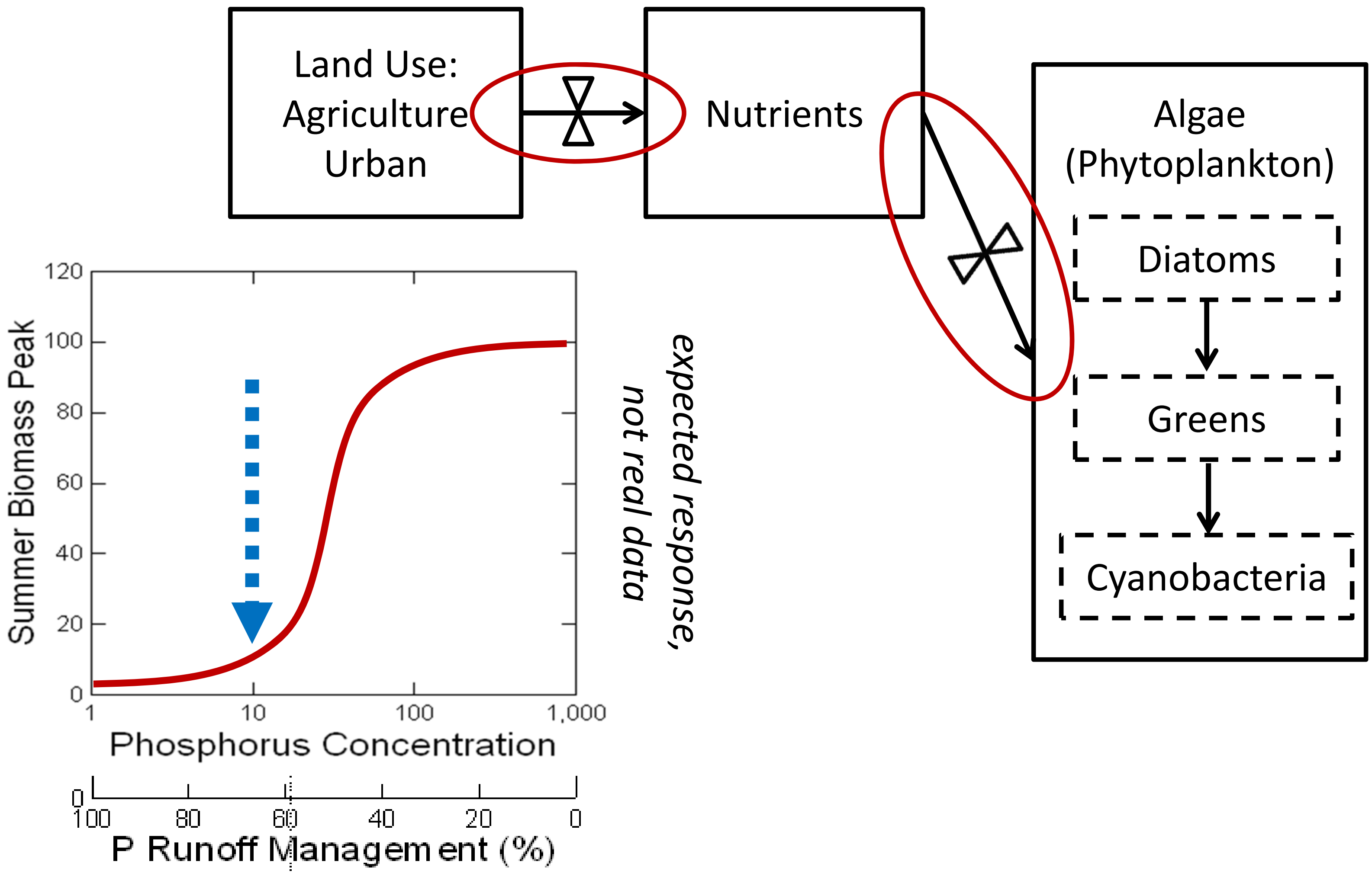


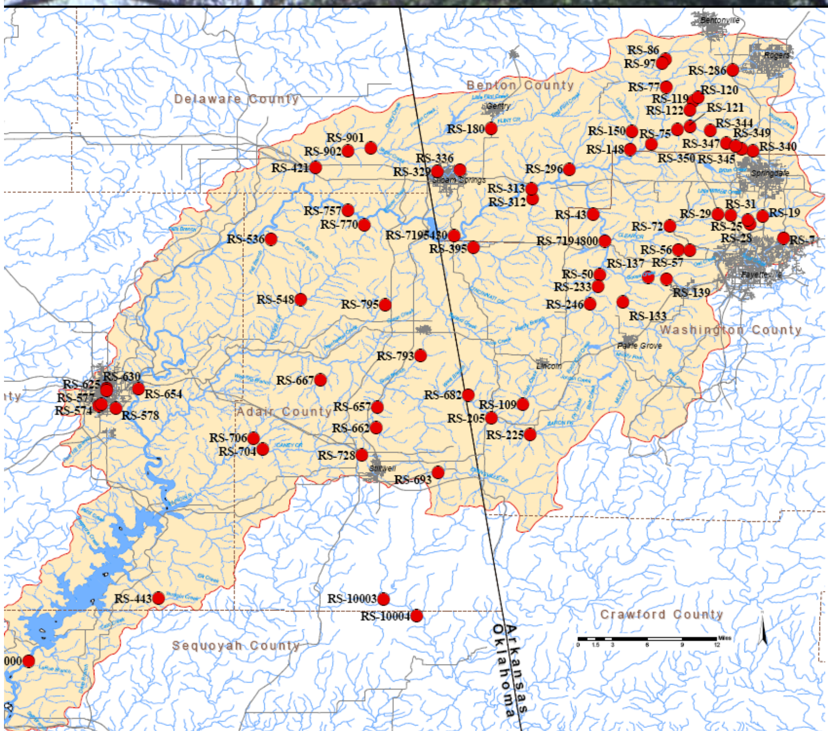


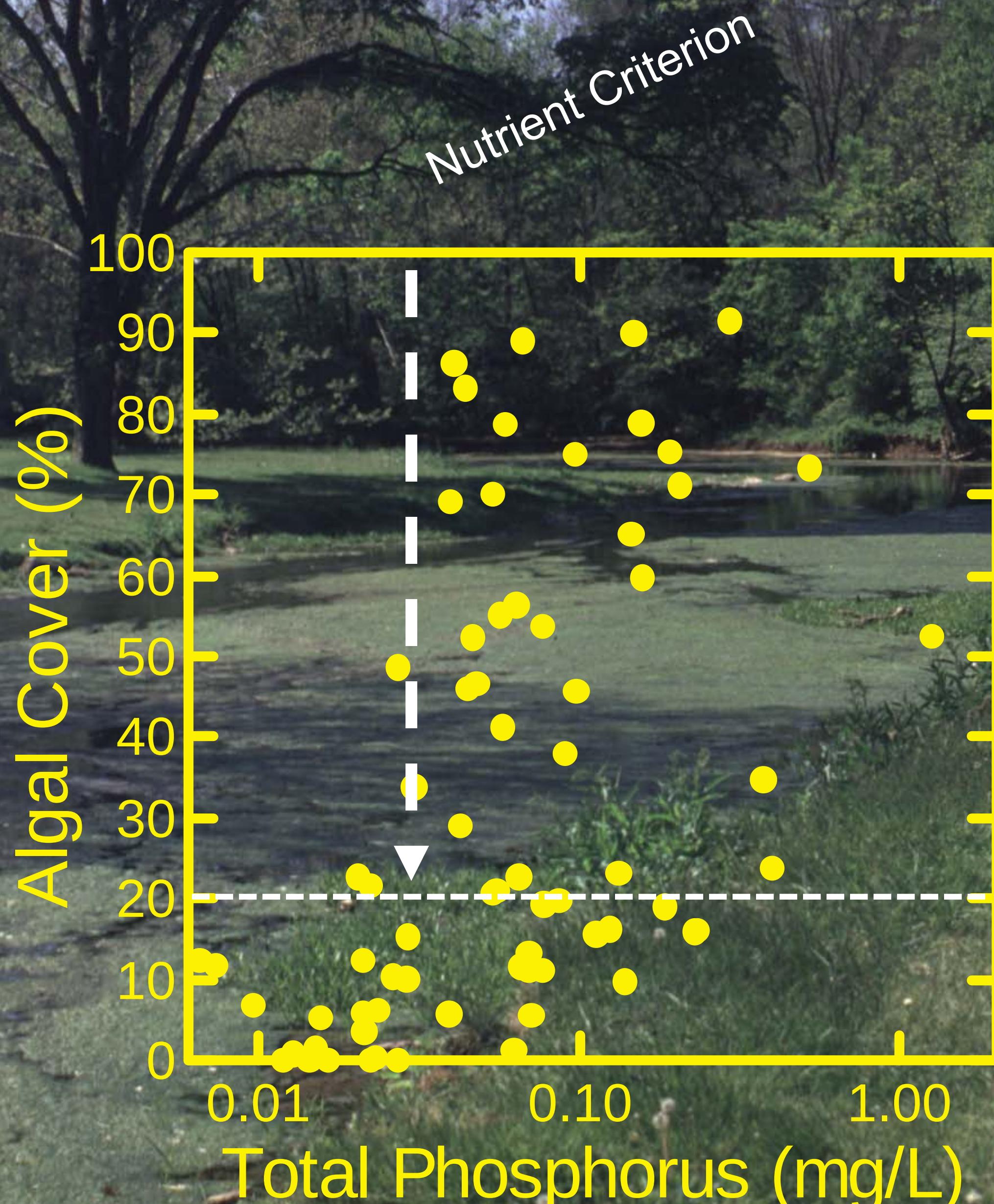
Cyanobacteria



Algal-Nutrient-LandUse Relationships and Management with Nutrient Criteria



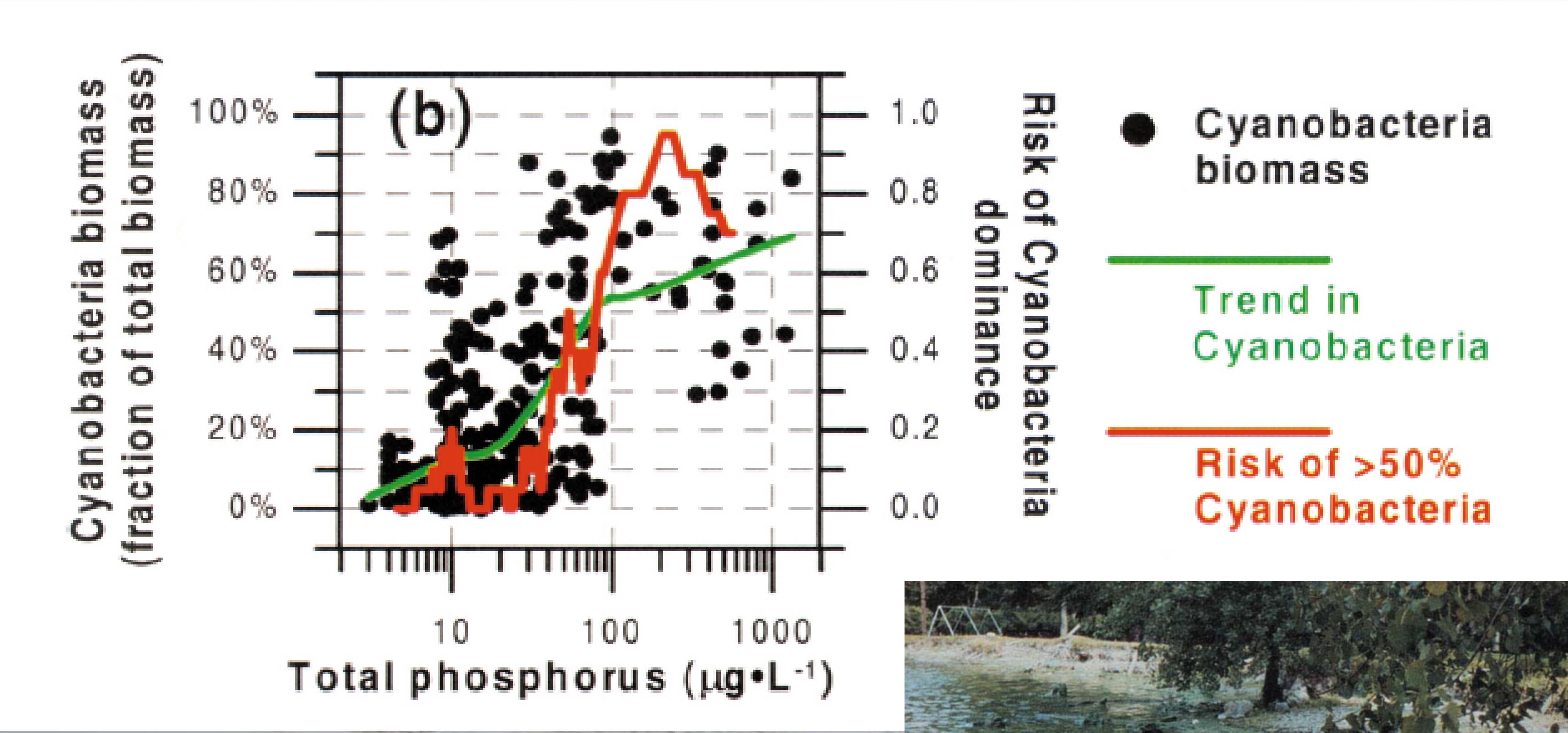




Threshold: Response of Filamentous Algal Blooms in Streams

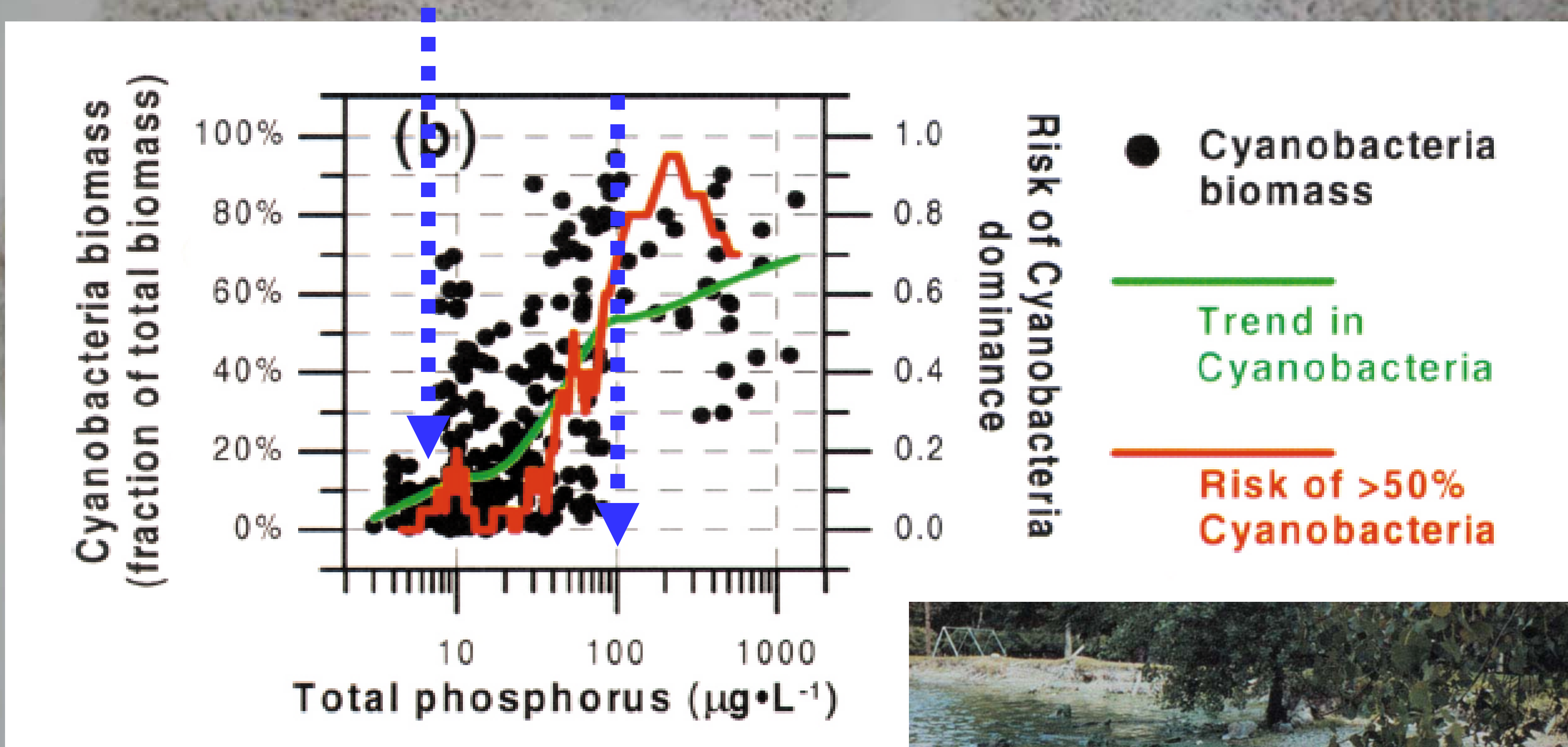
(Stevenson et al. 2012)

Cyanobacteria in Lakes = f(TP)



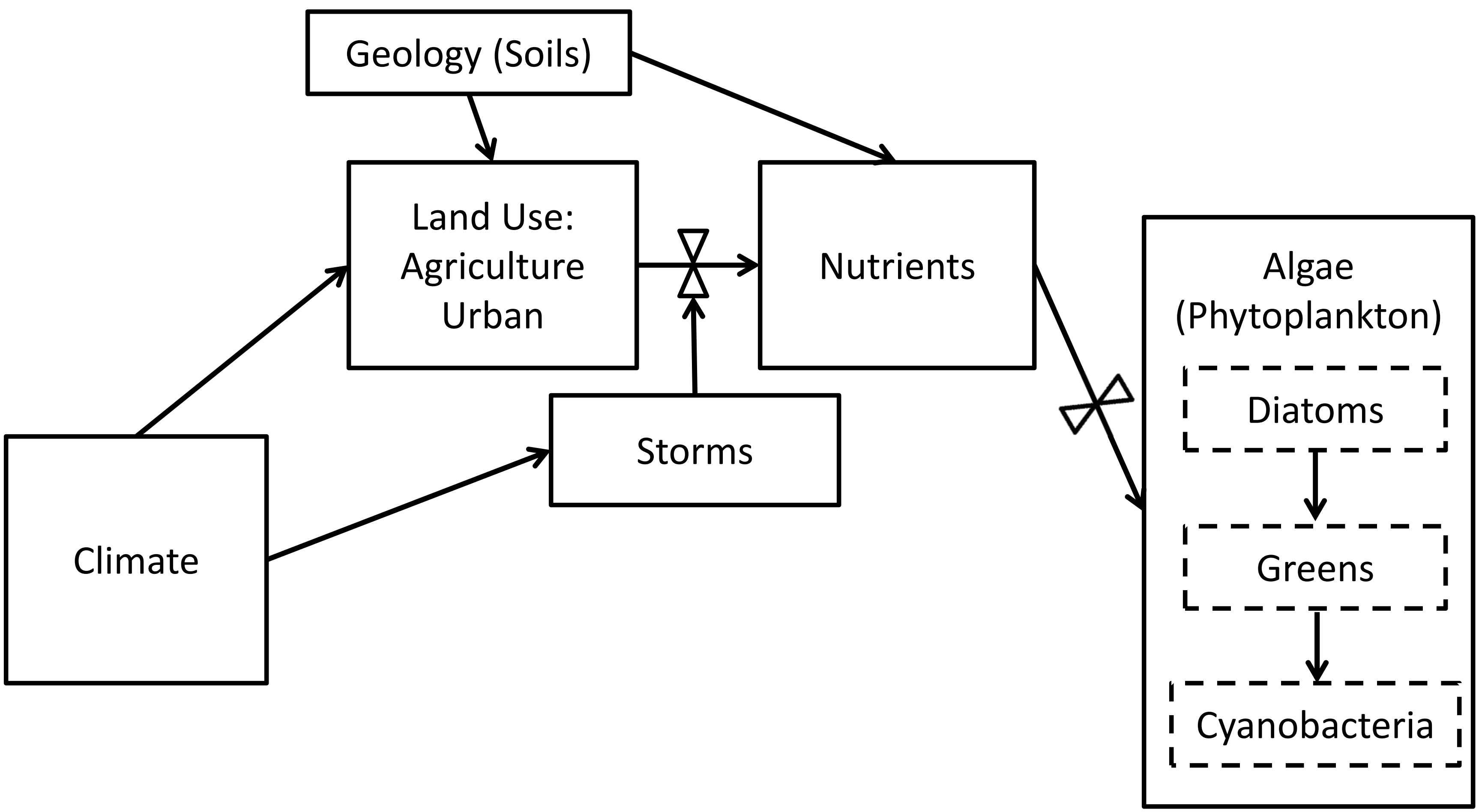
Downing et al. 2001, CJFAS

Thresholds Identify Management Targets

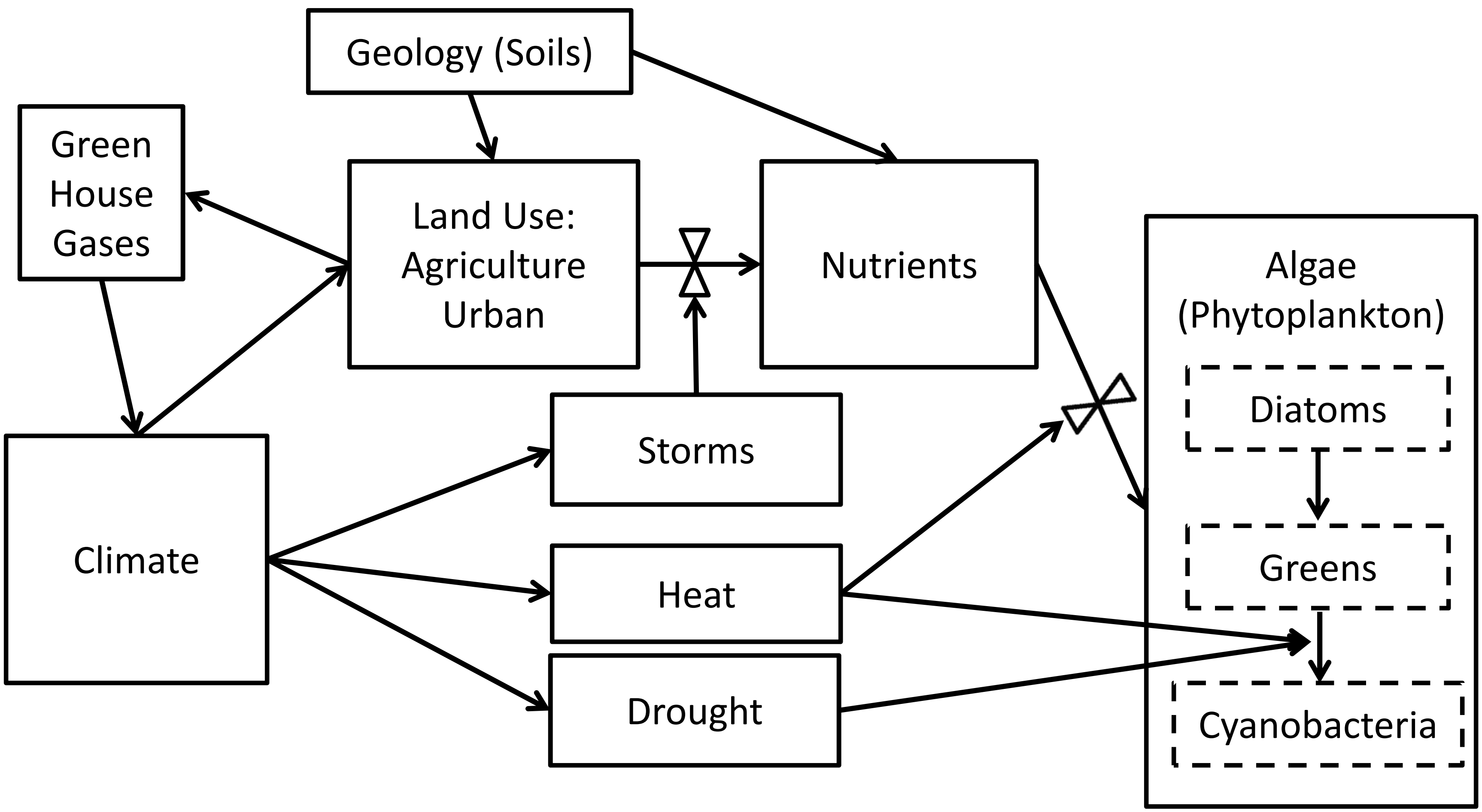


Downing et al. 2001, CJFAS

Algal-Nutrient-LandUse Relationships Vary with Naturally with Climate & Landscape



"Perfect Storm Model"



Project Objectives

- Relate *historical patterns in algal blooms* to storm flows and droughts (i.e. “extreme events”) using *satellite imagery* for 12 to 40 years.
- Relate changes in *storm flows* and resulting algal blooms to climate change.
- Determine *vulnerability of watersheds* to algal blooms and changing climate based on natural variation in *hydrology and soils*.
- Develop models that quantify algal bloom risk under different management and climate change scenarios across a national range of hydrologic variability and soil conditions.

Research Team

- R. Jan Stevenson
  - algal ecology, bioassessment, nutrient criteria
- Dave Hyndman
  - hydrologic and watershed modeling
- Jiaguo Qi
  - remote sensing
- Nathan Moore
  - regional climate modeling
- Post-docs and Graduate Students
  - Esselman, Lawawirojwong, Lin, Luscz, Kendall, Martin, Novitski, Suepa

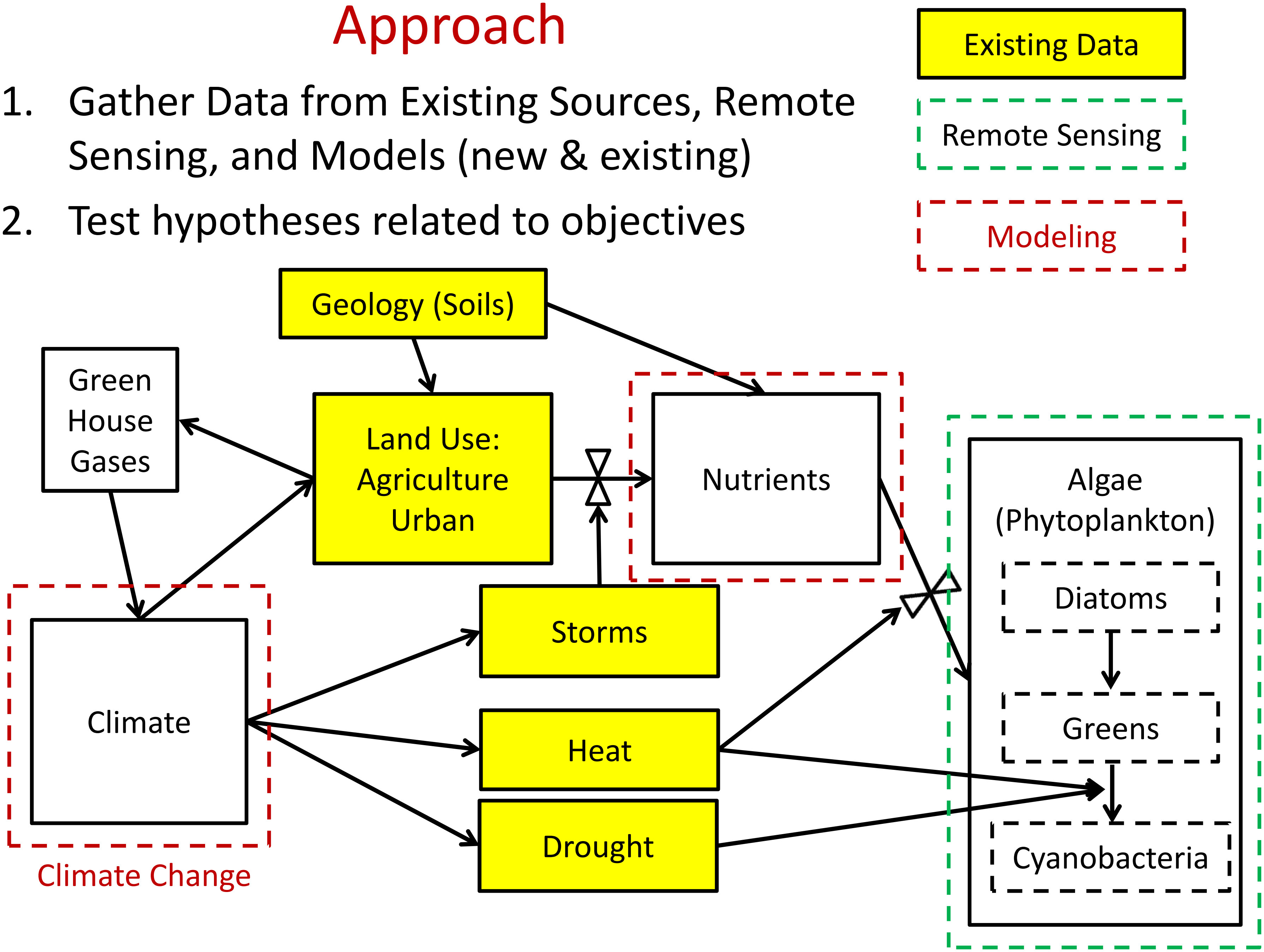
Funded by: USEPA - Great Lakes Restoration Initiative: “Nutrient Management Models to Constrain Harmful Algal Blooms”

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program

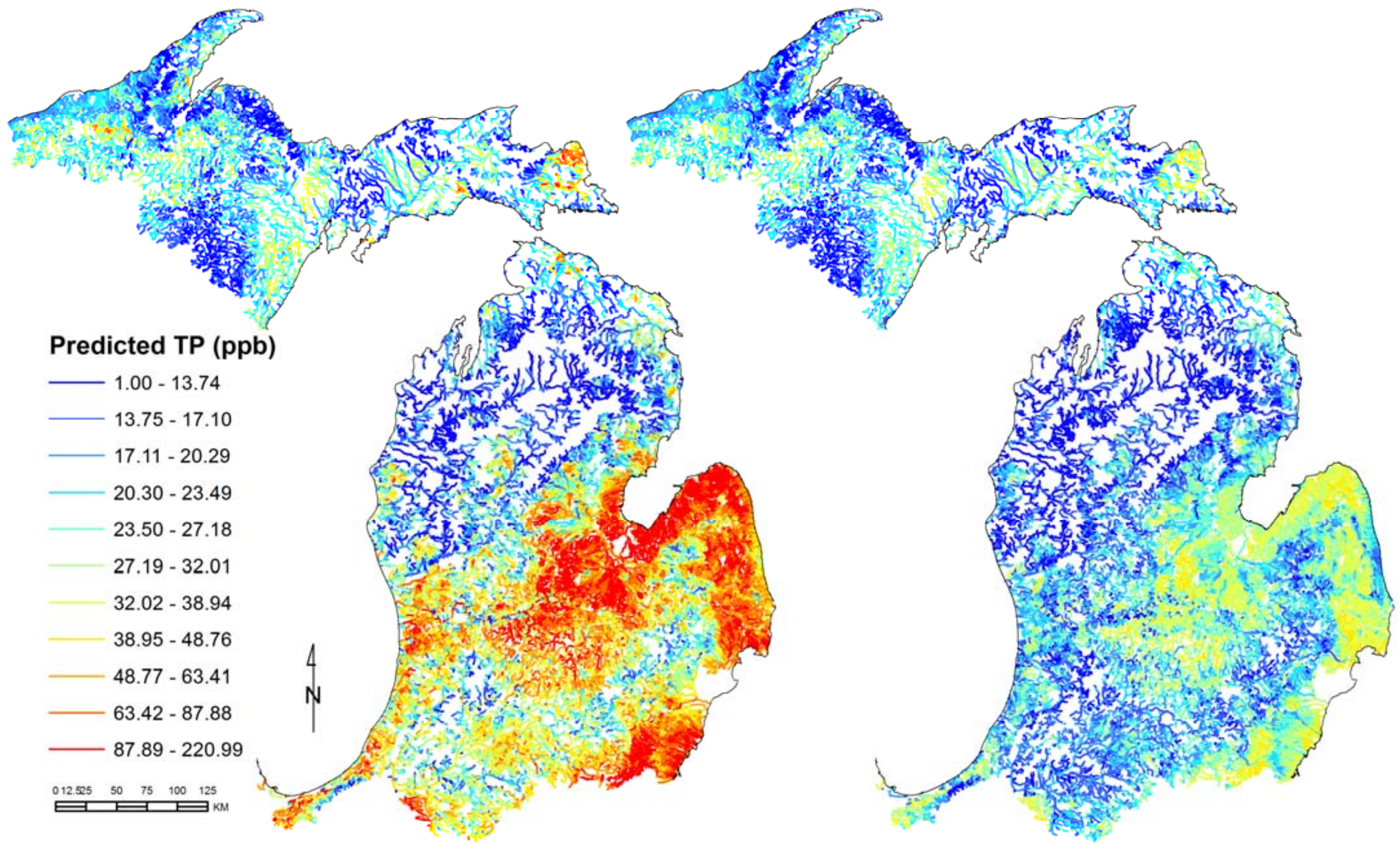
Grant # RD835203010

Approach

1. Gather Data from Existing Sources, Remote Sensing, and Models (new & existing)
2. Test hypotheses related to objectives



Statistical Models (BRTs) of N&P =f(Land Use, Sources, Natural Factors)



Existing Condition

Minimally Disturbed Condition

Esselman et al. (in prep)

BRT=Boosted Regression Trees

e.g. Stats Models: P = (Land Use)

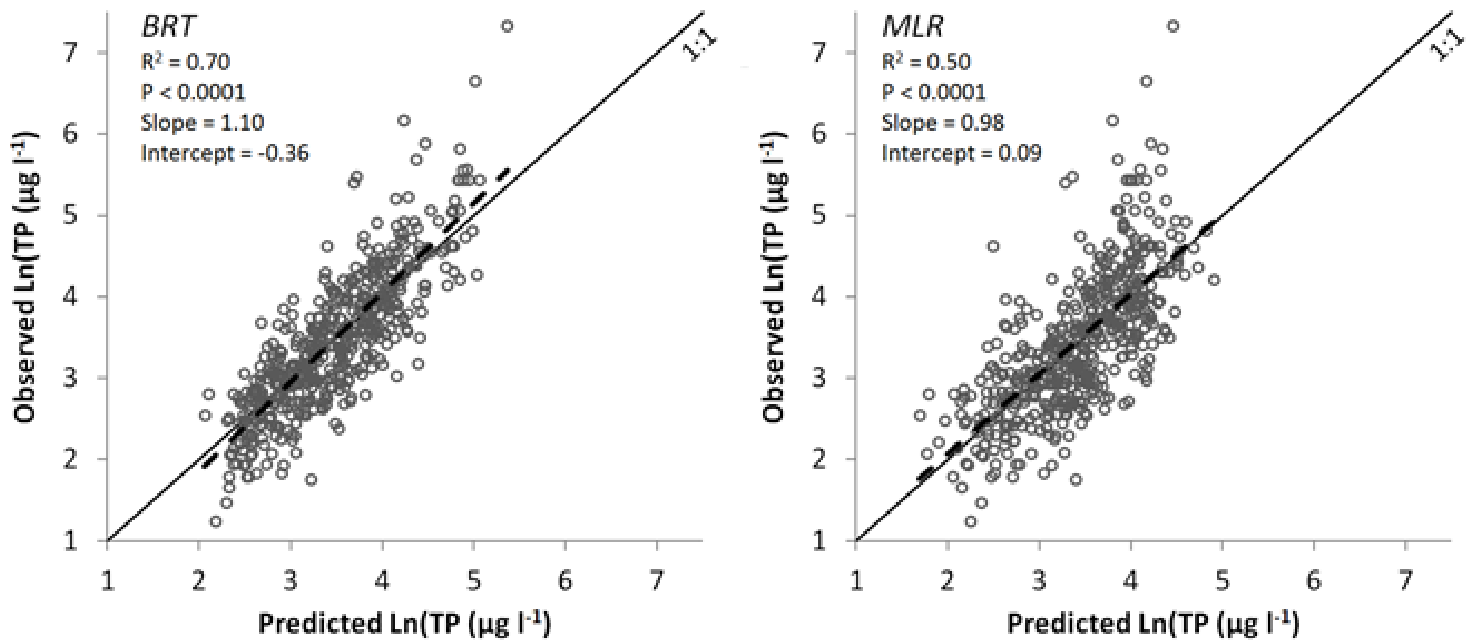
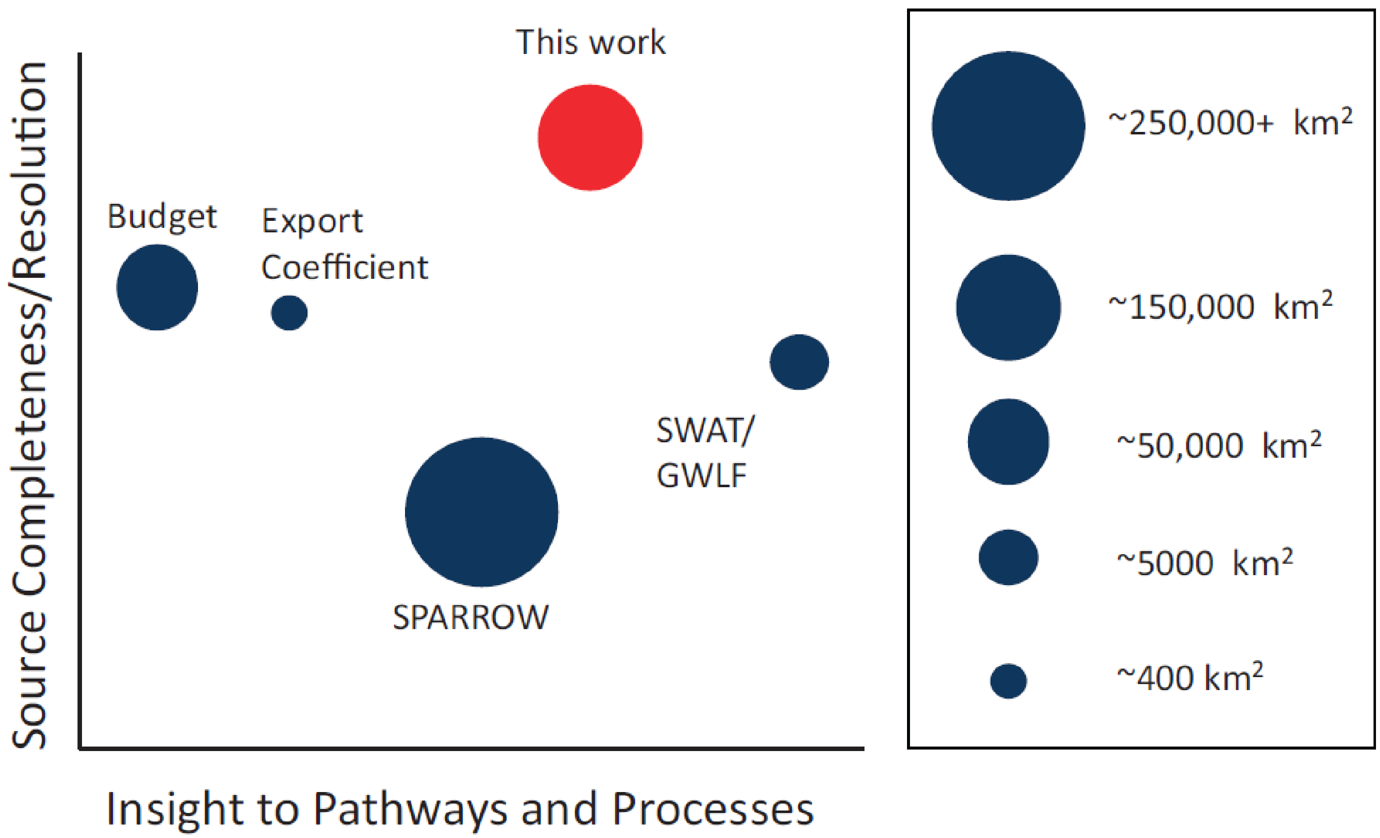


Figure 3. Comparison of observed versus predicted TP levels between boosted regression tree (left) and multiple linear regression (right) models. The solid line shows the perfect fit (1:1) and the dashed line is the best fit line through each scatter plot.

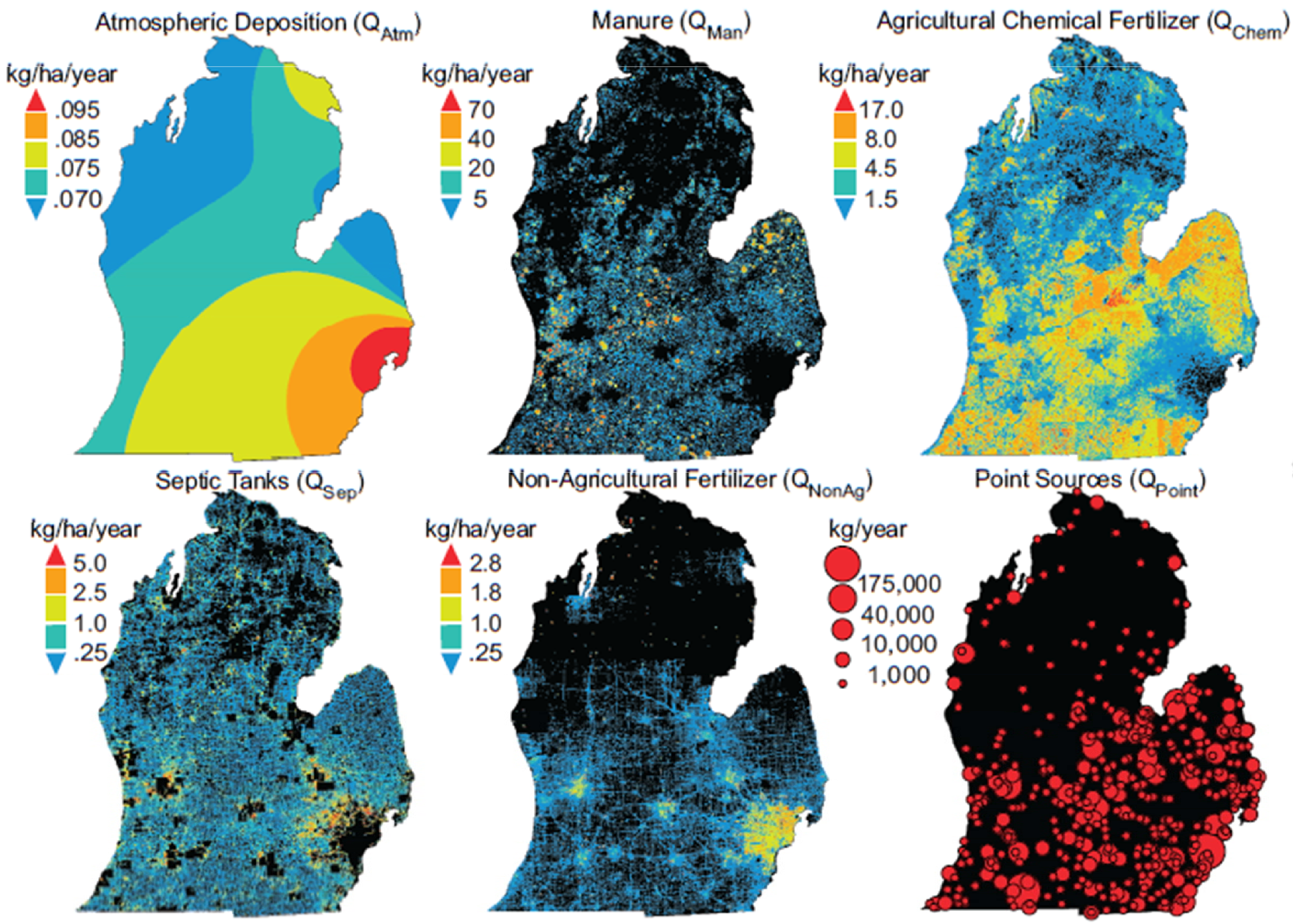
Esselman et al. (in prep)

New Nutrient Loading & Hydrologic Models (Integrated Hydrologic and Landscape Model + Nutrient Source & Loading Model)



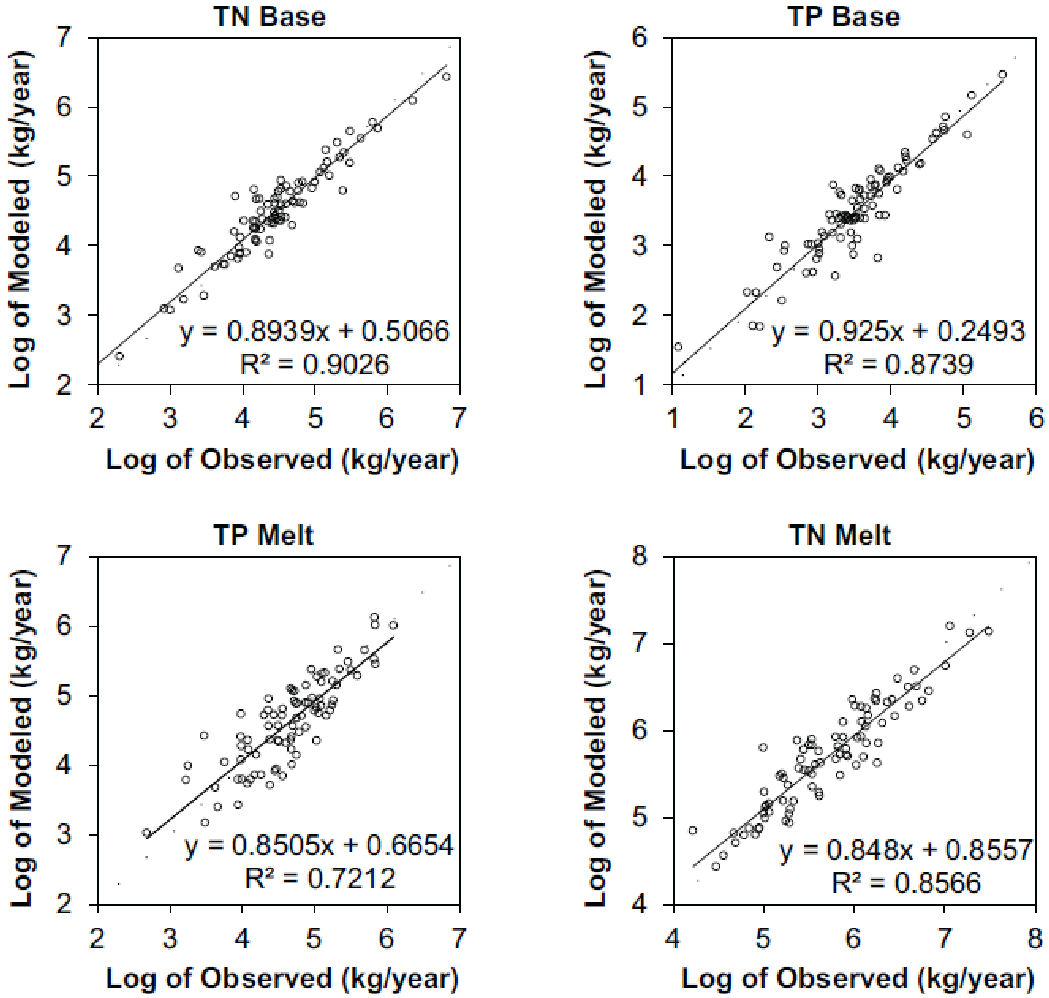
Luscz et al. (in prep)

Detailed Source Load Maps



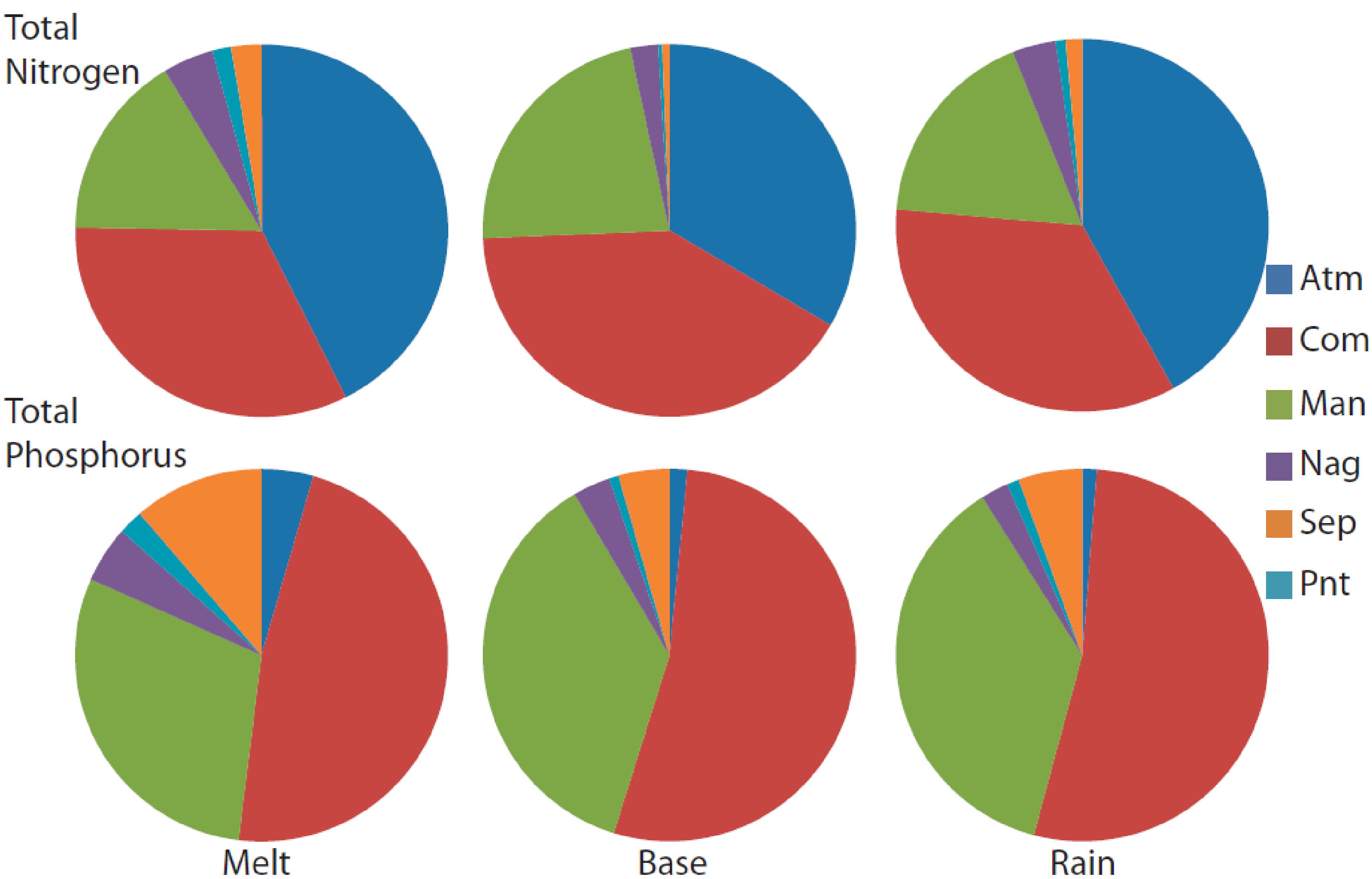
Luscz et al. (in prep)

Model Nutrient Loading Performance at Baseflow and Storm Flow



Luscz et al. (in prep)

Proportions of In-Stream Nutrients Vary Among Sources



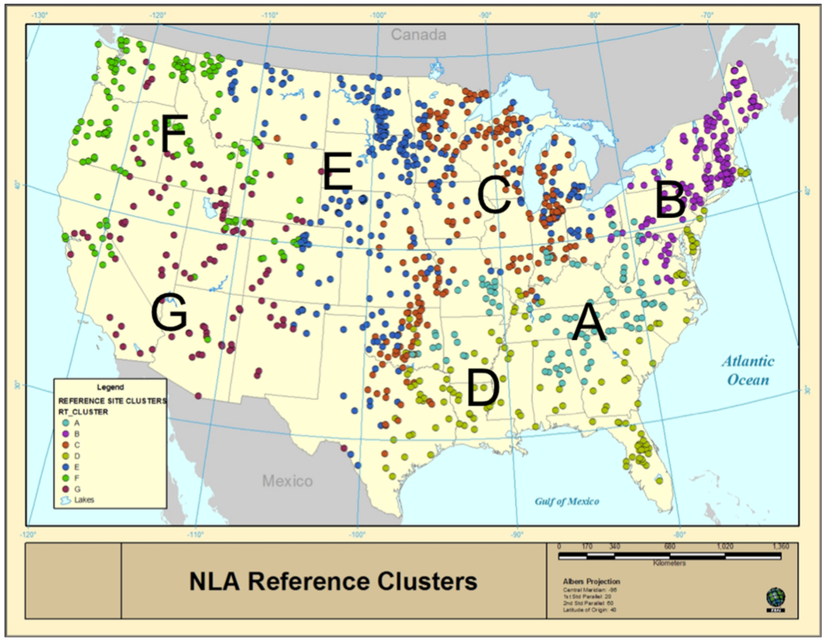
Luscz et al. (in prep)

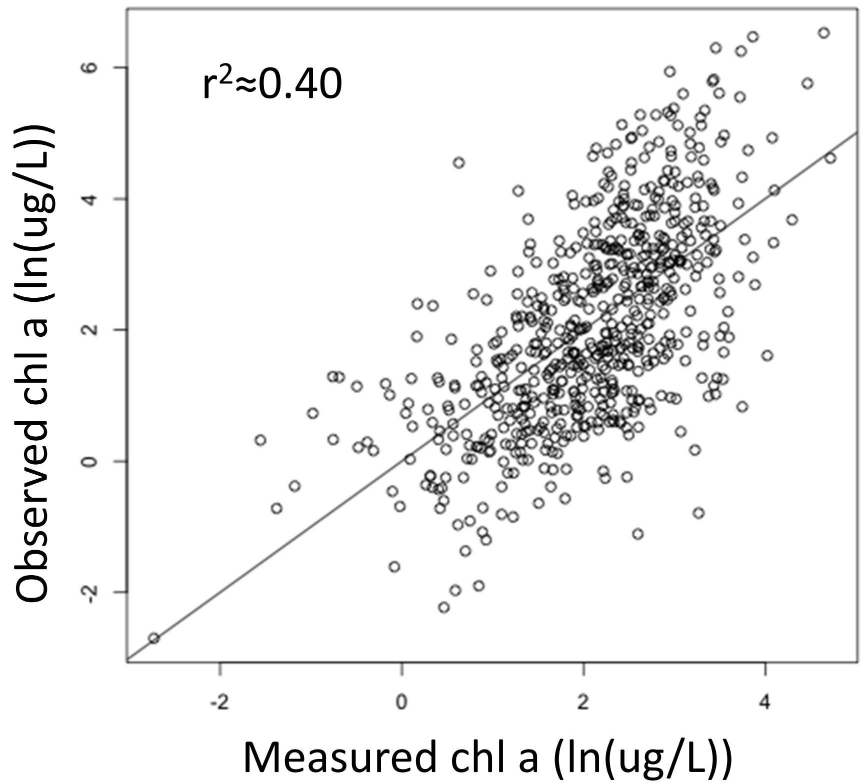
Remote Sensing Models

- MODIS and Landsat
  - MODIS > 2000
    - Narrow band width, large pixels, daily
  - Landsat >1972
    - MSS, ETM, ETM+
    - Broader band width, small pixels, /8 days
- Land Use
- Chlorophyll a
- Sediments
- Different kinds of algae
  - cyanobacteria, greens, and diatoms

National Model:
Chlorophyll a = f(Landsat ETM+, MLR)

USEPA's
National Lakes Assessment



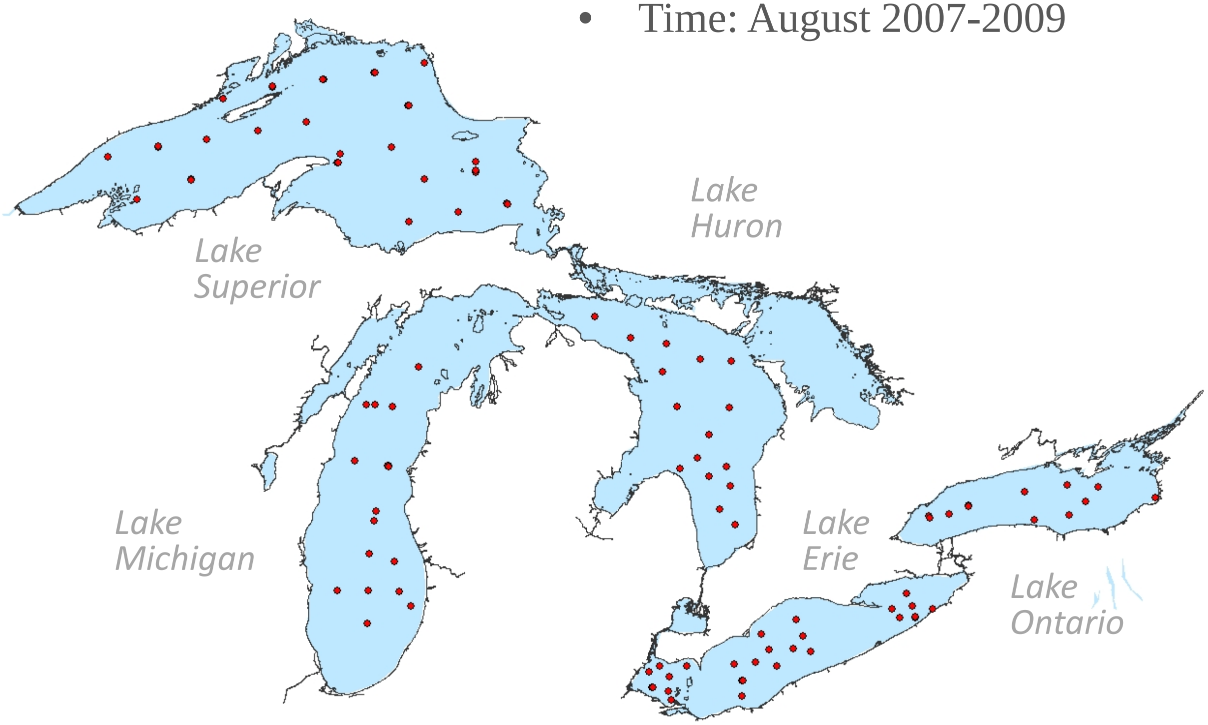


Novitski et al. (in prep)

Chlorophyll and MODIS datasets

Sample data:

- Number of station: 77
- Number of sample: 226
- Time: August 2007-2009



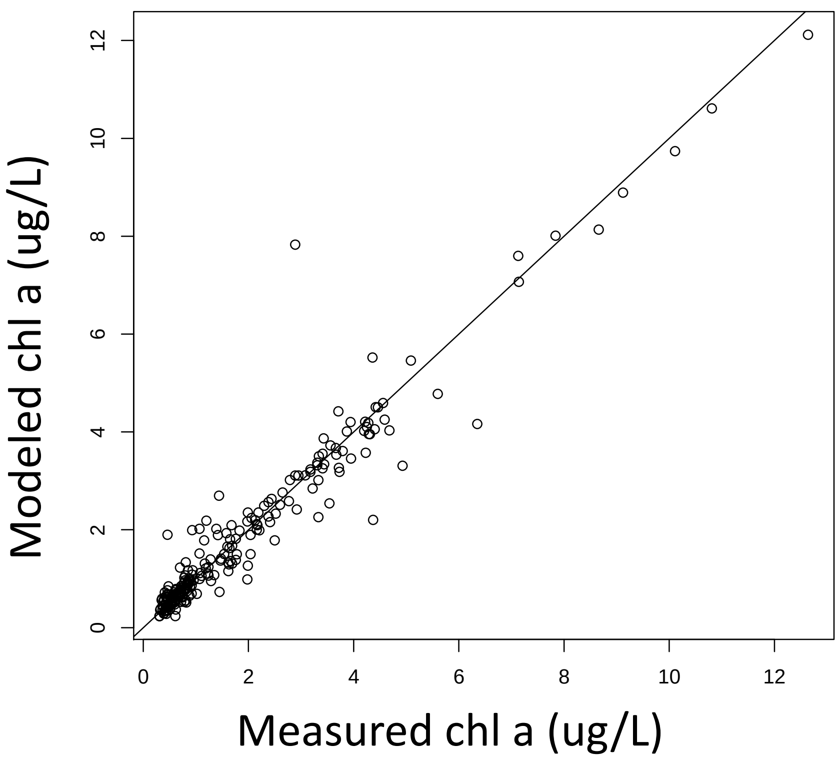
MOD02 Bands: (1Km)

Band	Wavelength (nm)	
1	620-670	R
2	841-876	NIR
3	459-479	B
4	545-565	G
5	1230-1250	T
6	1628-1652	T
7	2105-2155	T
8	405-420	B
9	438-448	B
10	483-493	B
11	526-536	G
12	546-556	G
13	662-672	R
14	673-683	R
15	743-753	NIR
16	862-877	NIR

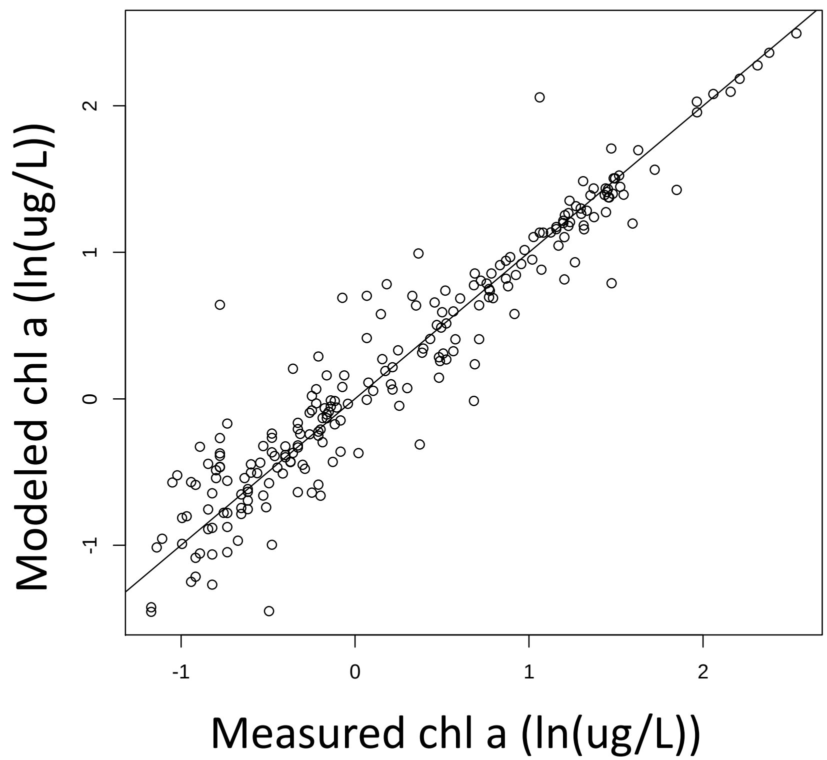
Daily

Great Lakes Model: Chlorophyll a = f(MODIS, BRTs)

Developed with Untransformed Data



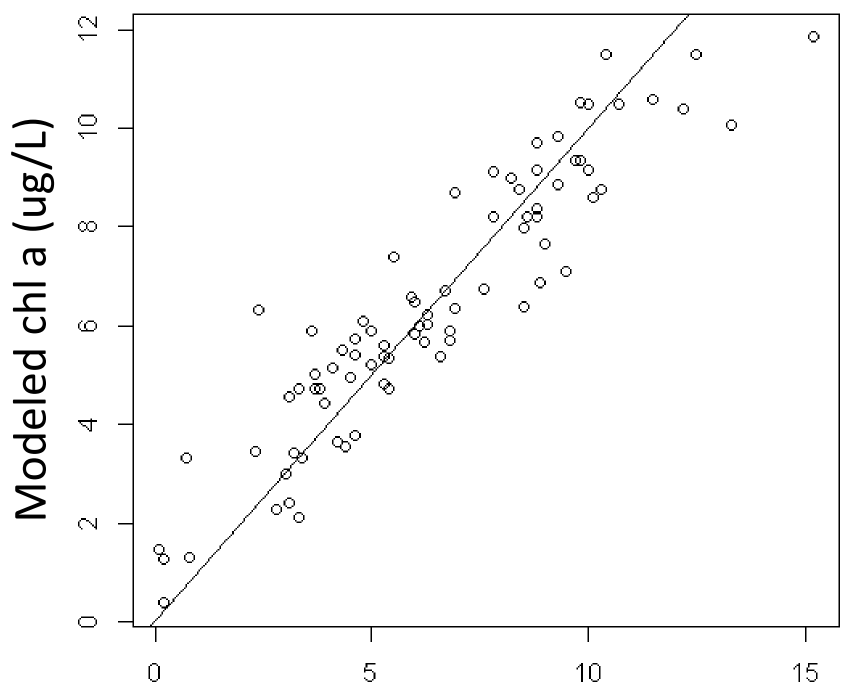
Checked with Ln Untransformed Data



Novitski et al. (in prep)

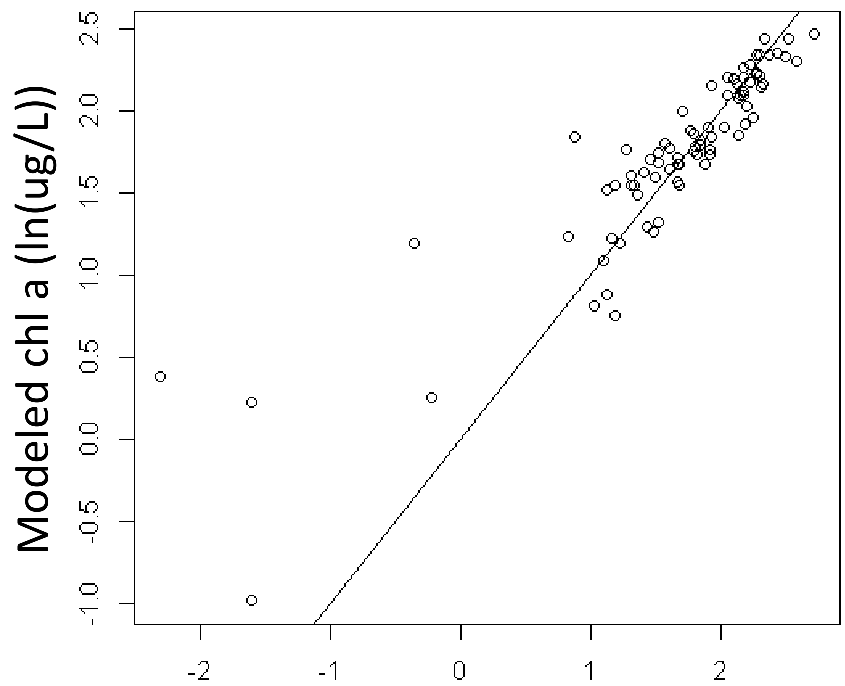
Great Lakes Model:
Chlorophyll a = f (Landsat ETM+, BRT)

Developed with Untransformed Data



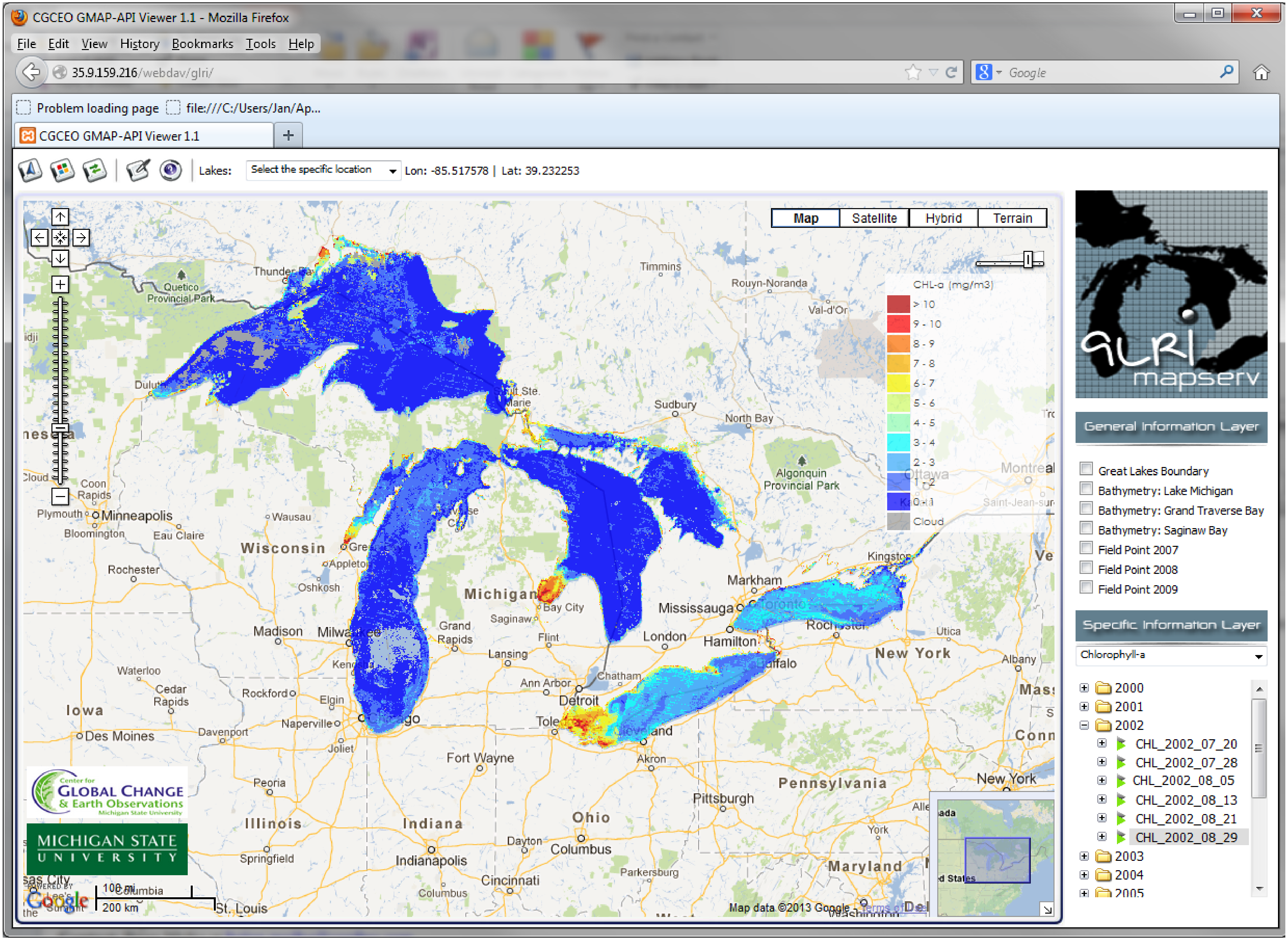
Measured chl a (ug/L)

Checked with Ln Untransformed Data



Measured chl a (ln(ug/L))

Novitski et al. (in prep)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File Edit View History Bookmarks Tools Help
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file:///C:/Users/Jan/Ap...
CGCEO GMAP-API Viewer 1.1
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Select the specific location
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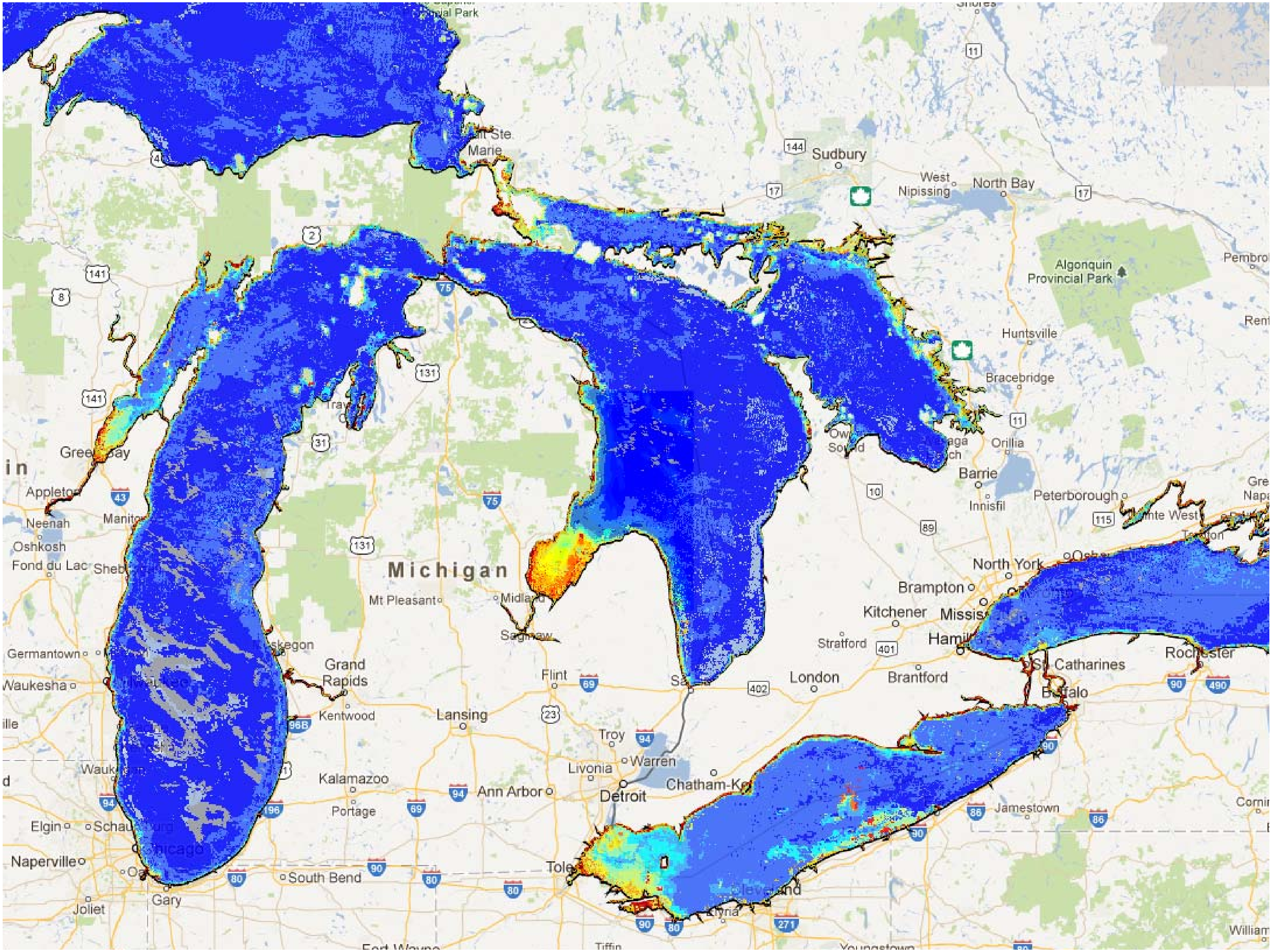
Satellite
Hybrid
Terrain
CHL-a (mg/m3)
> 10
9 - 10
8 - 9
7 - 8
6 - 7
5 - 6
4 - 5
3 - 4
2 - 3
1 - 2
0 - 1
Cloud
glri mapserv
General Information Layer
Great Lakes Boundary
Bathymetry: Lake Michigan
Bathymetry: Grand Traverse Bay
Bathymetry: Saginaw Bay
Field Point 2007
Field Point 2008
Field Point 2009
Specific Information Layer
Chlorophyll-a
2000
2001
2002
CHL_2002_07_20
CHL_2002_07_28
CHL_2002_08_05
CHL_2002_08_13
CHL_2002_08_21
CHL_2002_08_29
2003
2004
2005
Center for Global Change & Earth Observations
Michigan State University
MICHIGAN STATE UNIVERSITY
Map data ©2013 Google
100 mi
200 km



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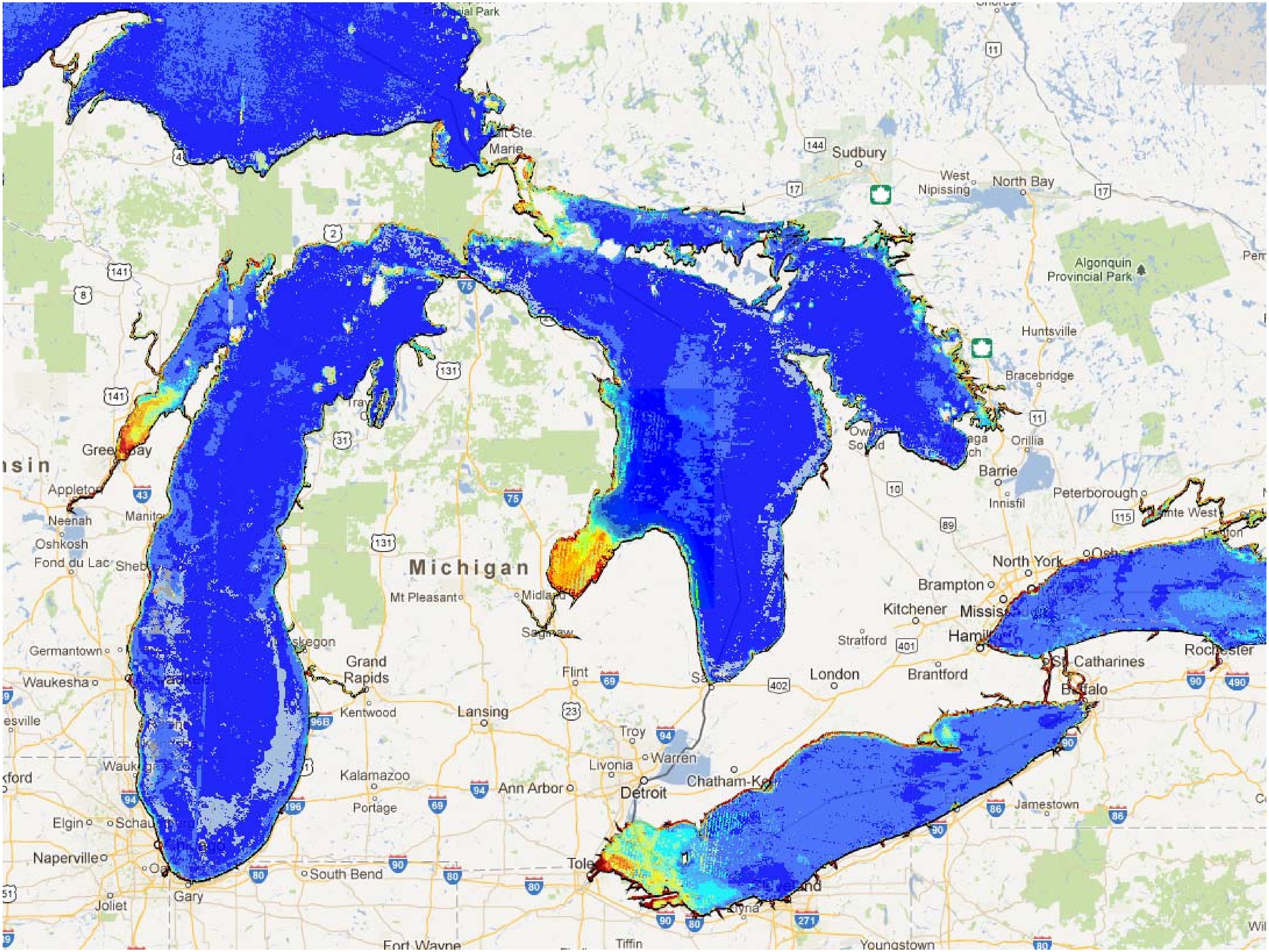

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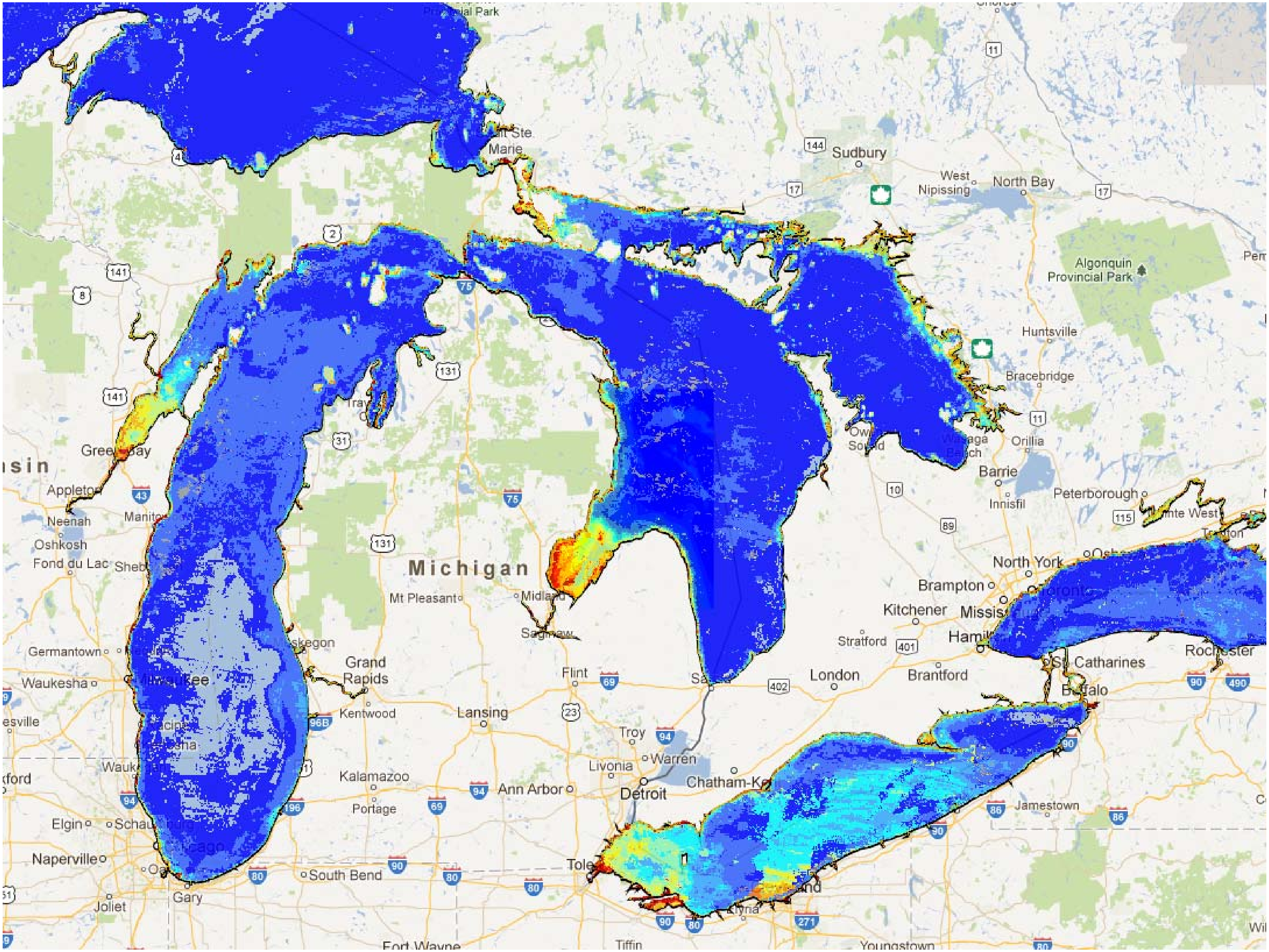

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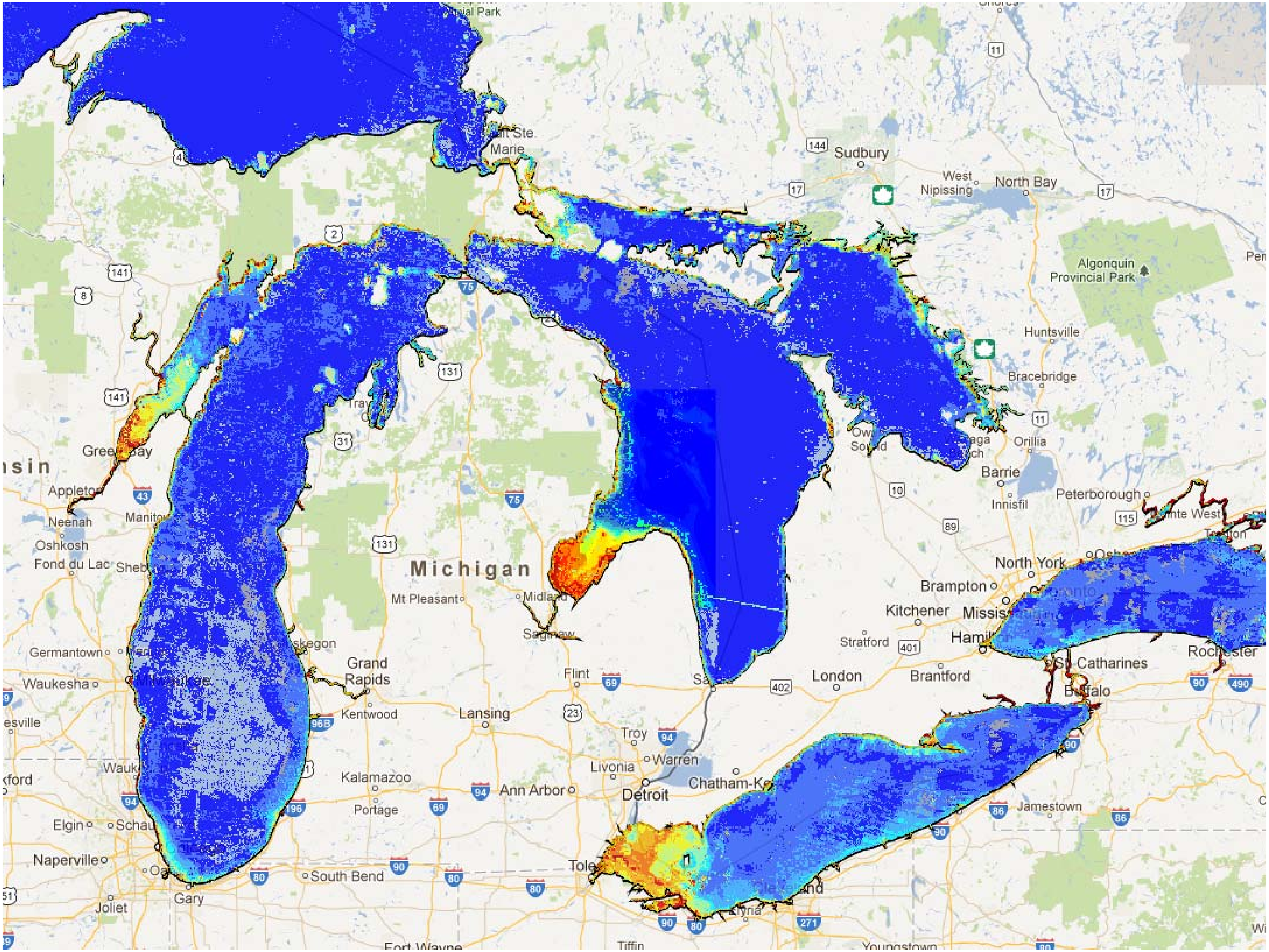

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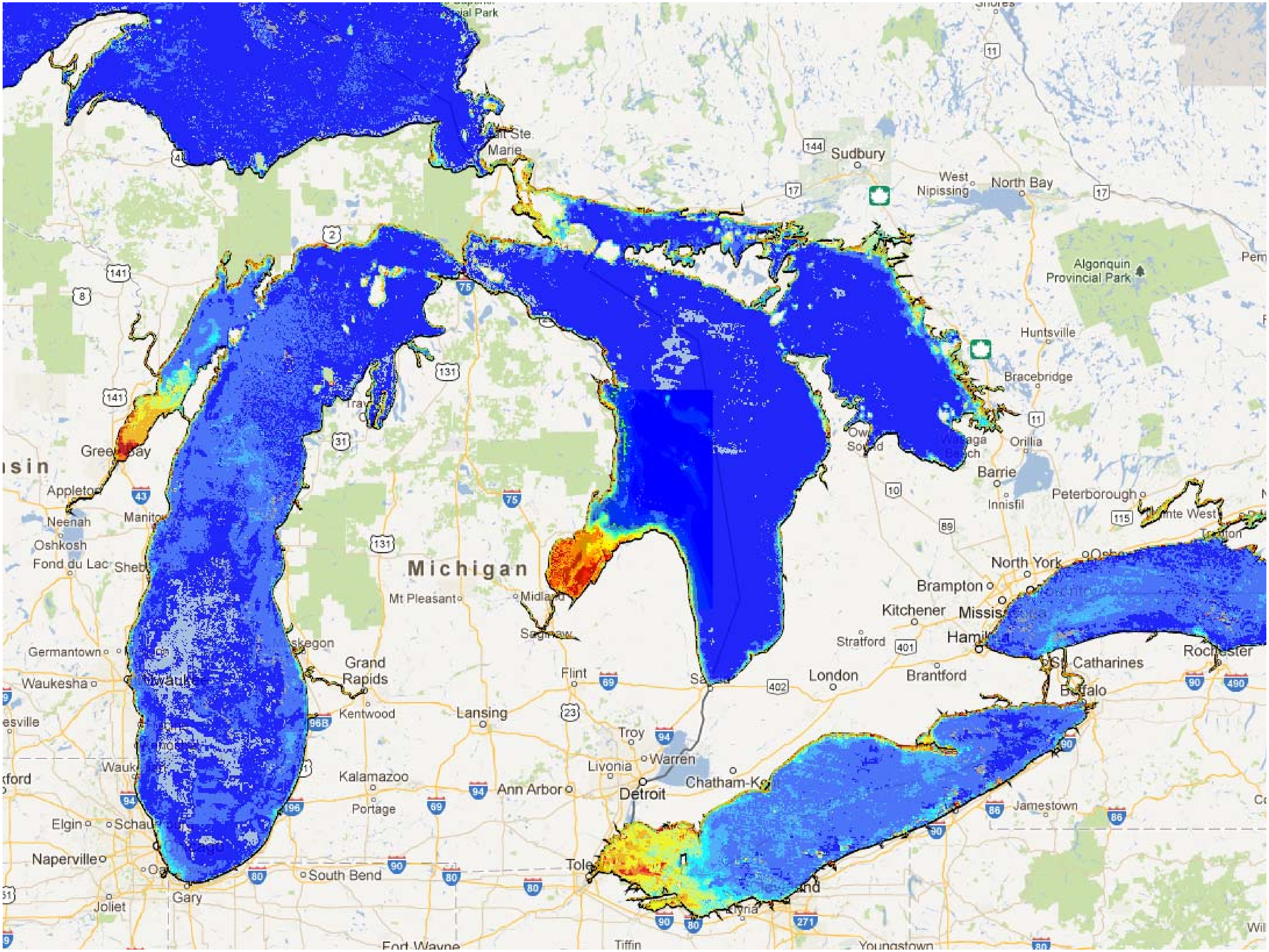
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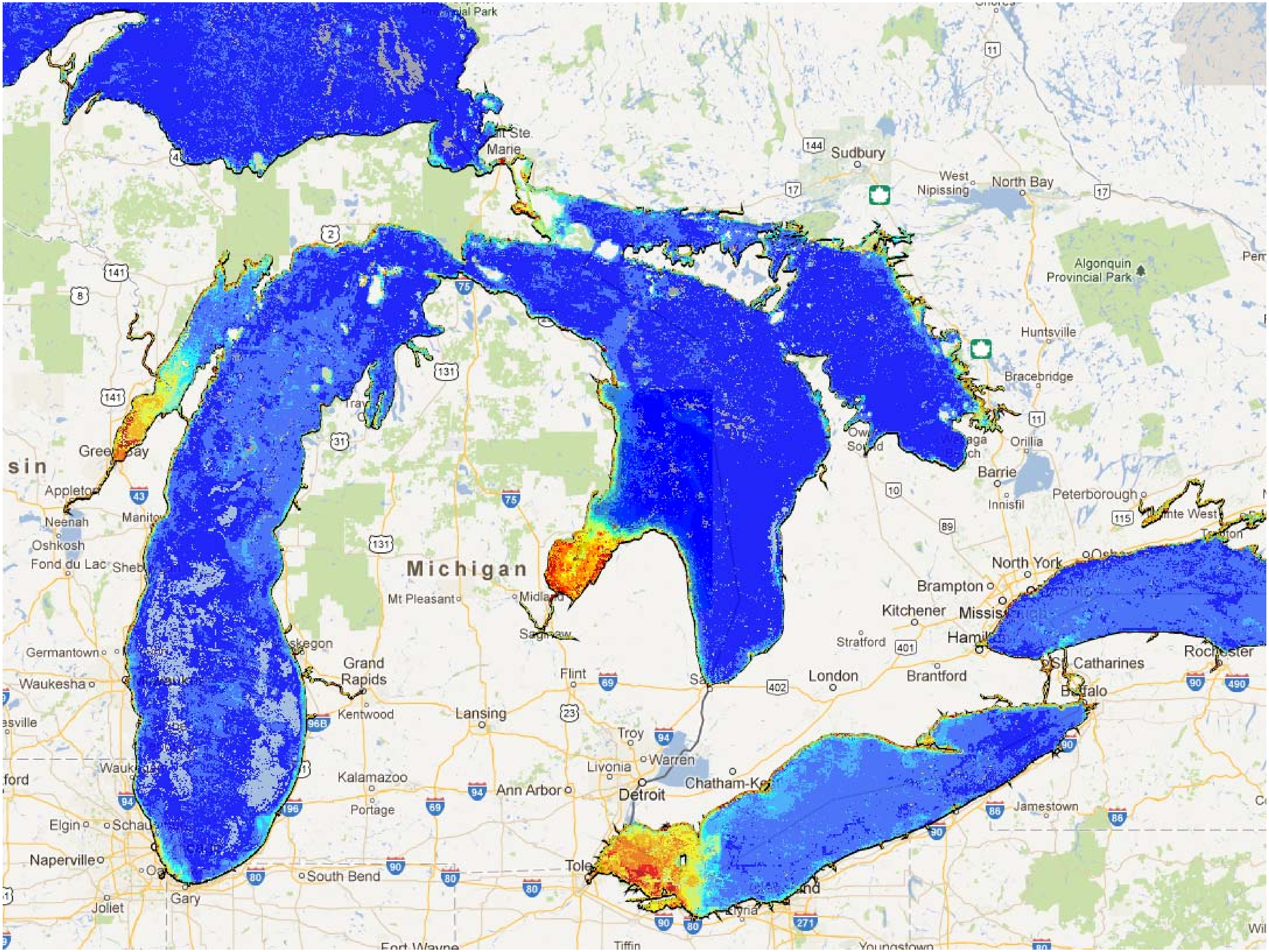

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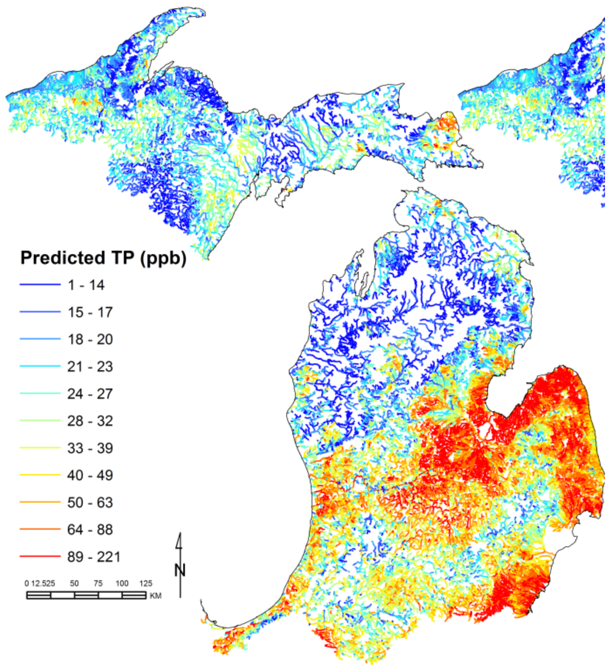
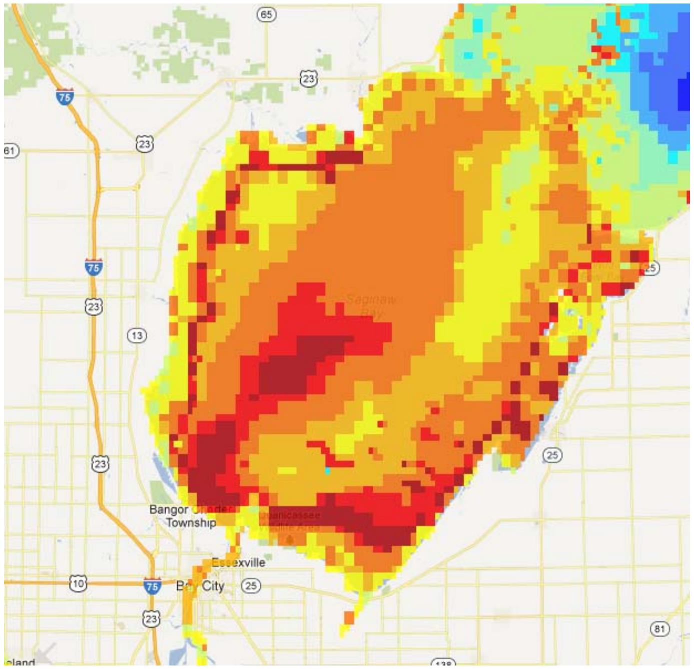
Conclusions to Date



TP Baseflow, Michigan Rivers



Saginaw Bay – August 29, 2008

Good models for nutrient concentrations and loads in rivers

=f(land use, weather).

Good RS models for algae over relatively broad range of conditions using MODIS and Landsat

Data Generated

- For six 8-d periods: mid-July thru August
- Average nutrient concentrations and loads for rivers of:
  - US watersheds of the Great Lakes from 2000-2012
  - Four targeted watersheds of GL from 1972-2012
- Average algal biomass per pixel:
  - Great Lakes from 2000-2012 using Modis
  - Four Targeted watersheds from 1972-2012 using Landsat MSS, ETM, and ETM+

Next Steps

- Analyze current data to achieve 4 objectives:
  1. Relate historical patterns in algal blooms to storm flows and droughts (i.e. “extreme events”) using satellite imagery for 12 to 40 years.
  2. Relate changes in storm flows and resulting algal blooms to climate change.
  3. Determine vulnerability of watersheds to algal blooms and changing climate based on natural variation in hydrology and soils.
  4. Develop models that quantify algal bloom risk under different management and climate change scenarios across a national range of hydrologic variability and soil conditions.
- Expand analysis to other regions of the US with a range of hydrologic and soils conditions expected to greatly affect relationships between climate, storm flows, droughts, temperature, and algal blooms

Vulnerability to Climate Change Varies with Hydrologic Regime and Soil Erodibility

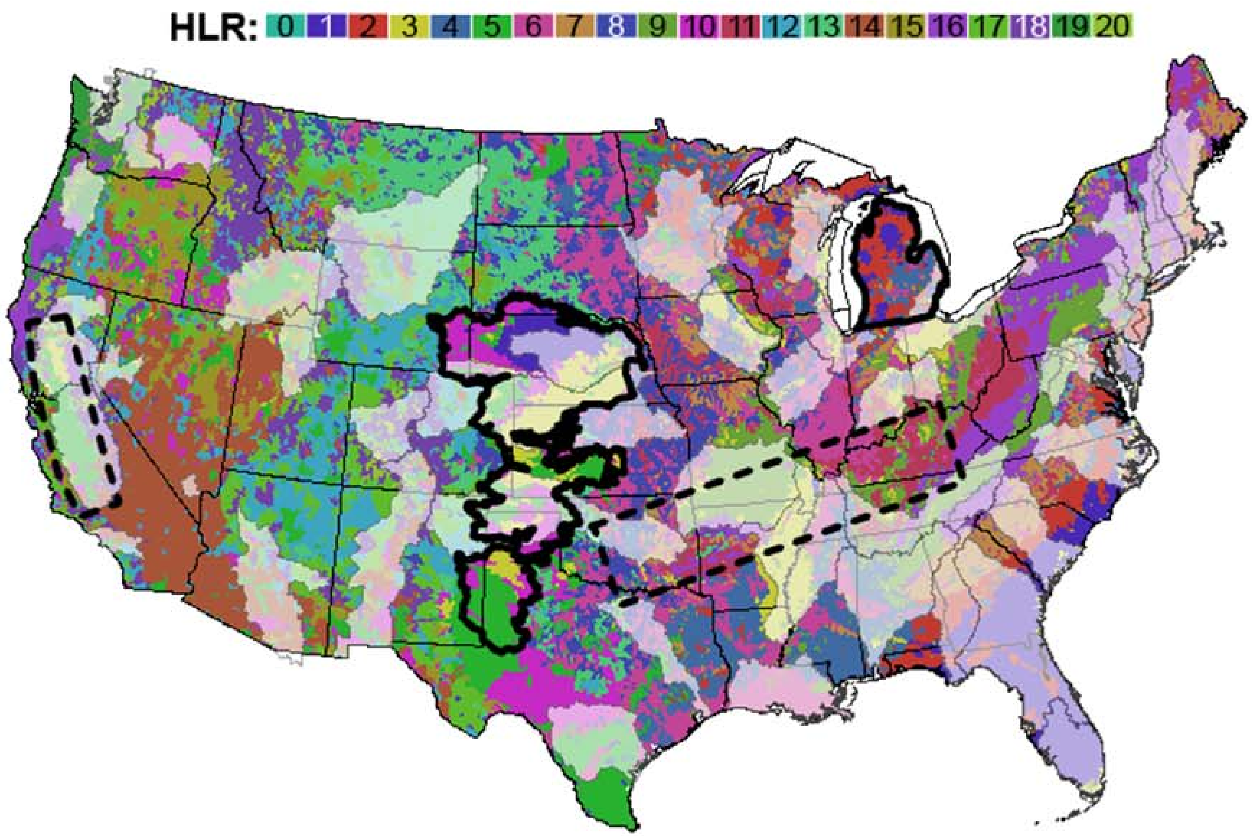
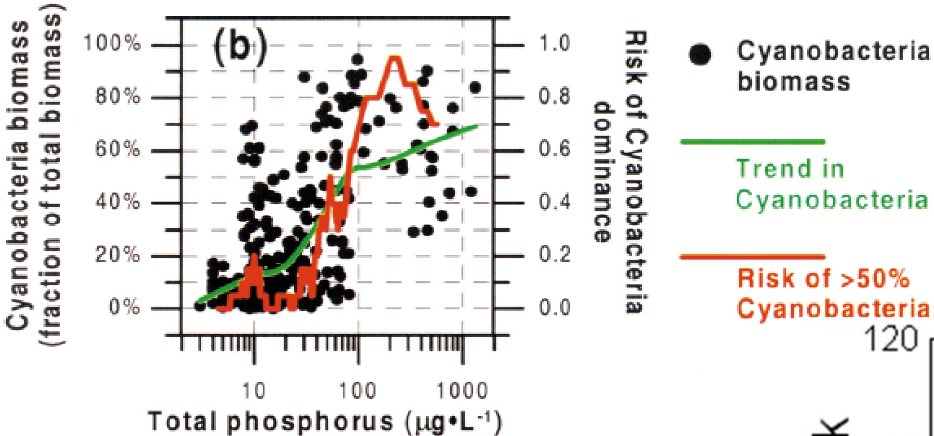
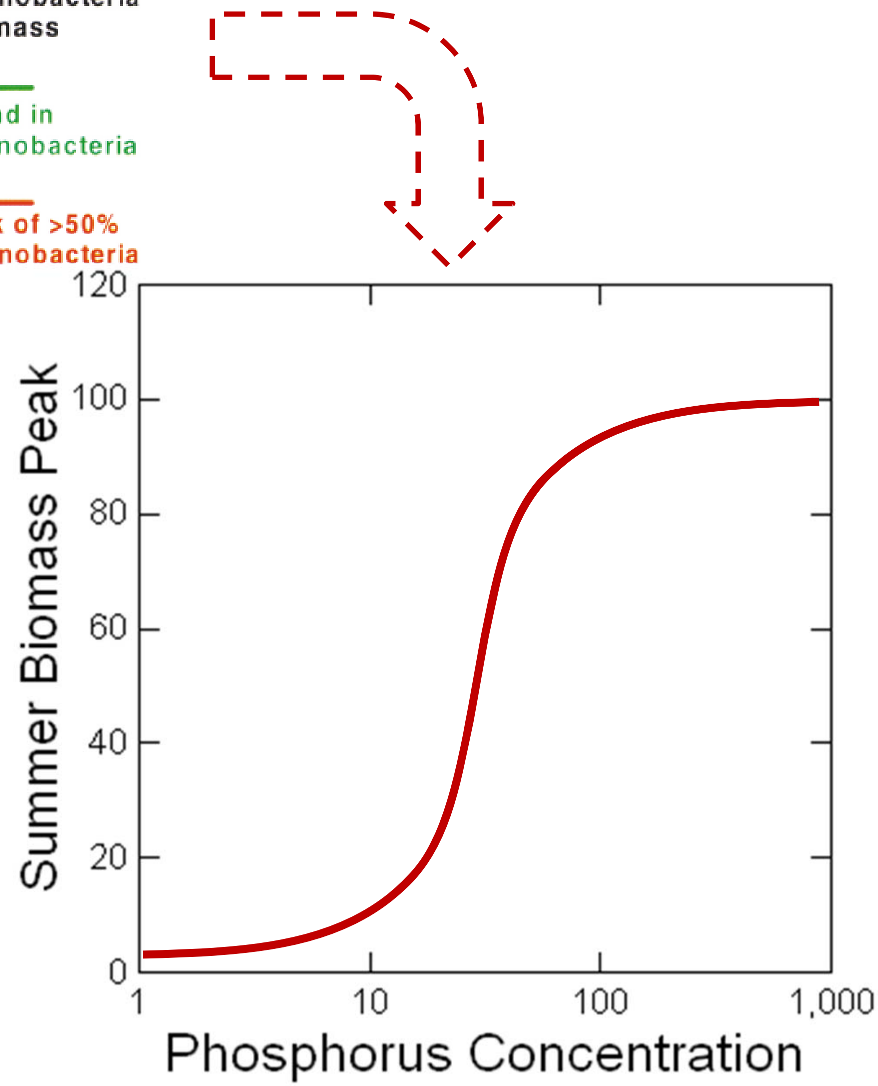


Figure 2. USGS Hydrologic Landscape Regions (HLRs) for the lower 48, showing where we have developed ILHM models for Tier 1 watersheds (solid lines around MI and the High Plains), and where we expect to develop additional models (dashed lines, OK-KY and CA). Highlighted areas in white indicate NAWQA cycle 2 studied watersheds.

Refine Existing Relationships: Algae=f(TP)

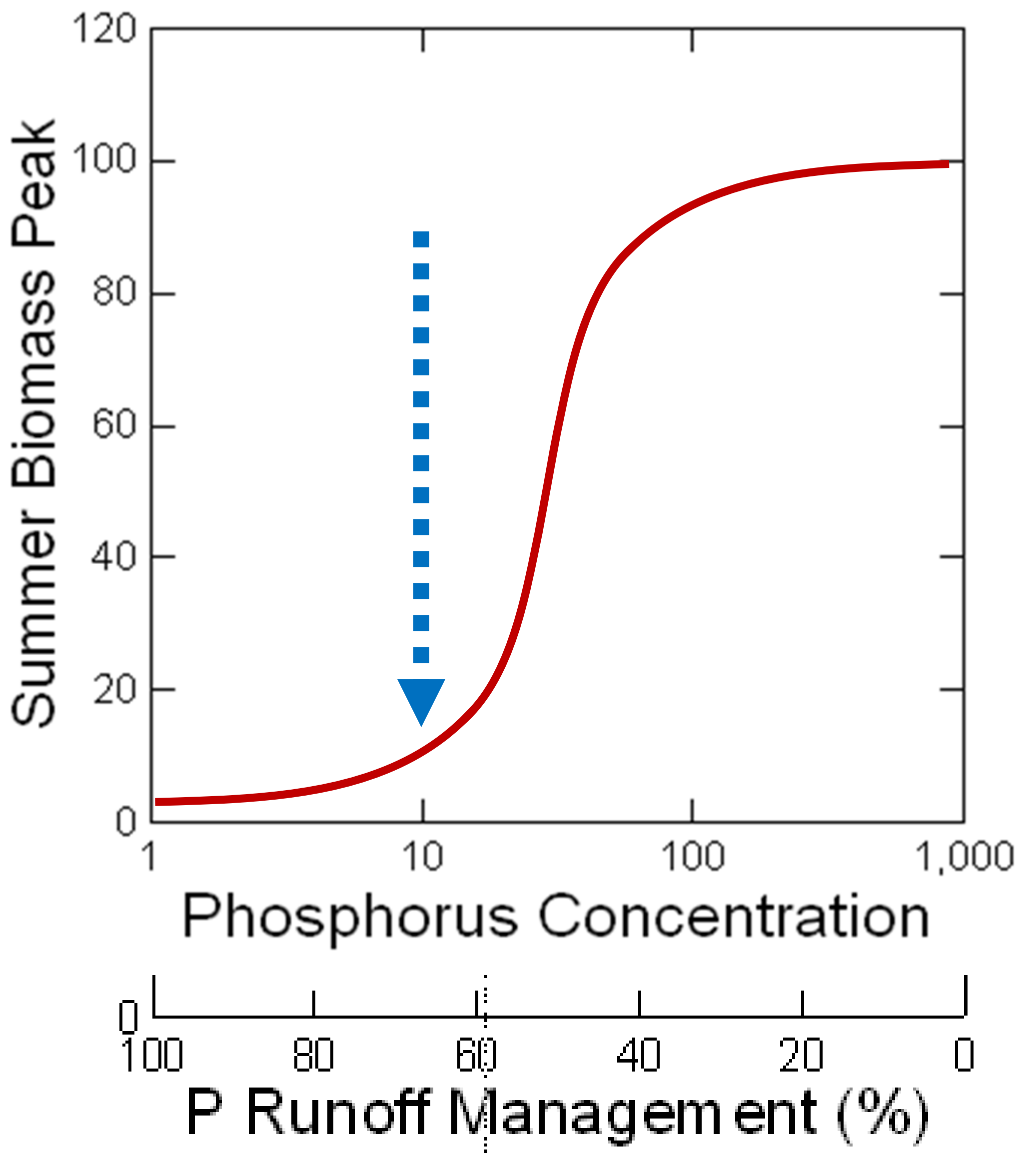


Downing et al. 2001, CJFAS



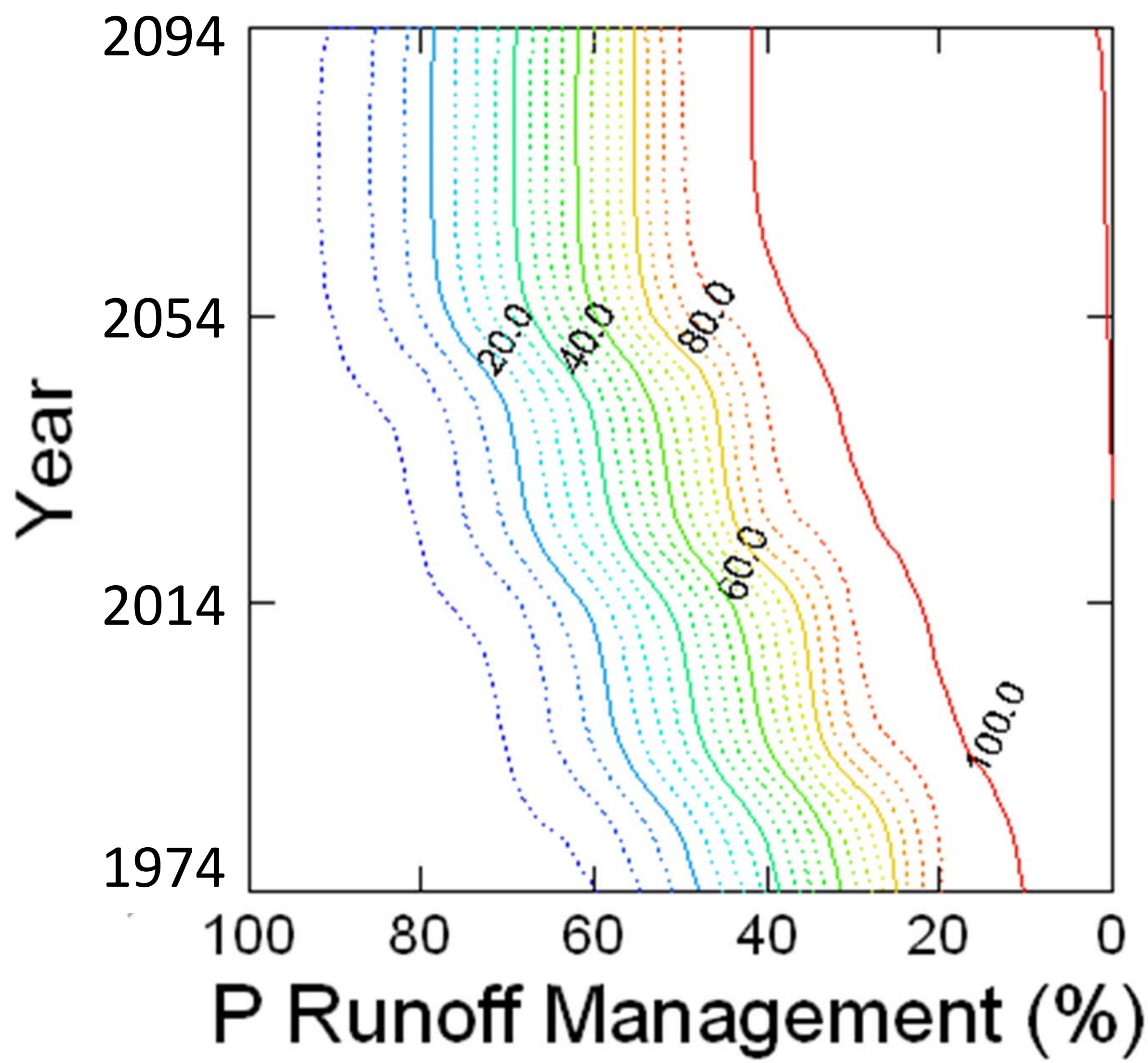
- Summer Peak Biomass (ug chl a/L)(measured with from bi-weekly satellite images)
- Phosphorus concentration inferred from refined nutrient loading model

Relate Algal Blooms to P Management Efforts

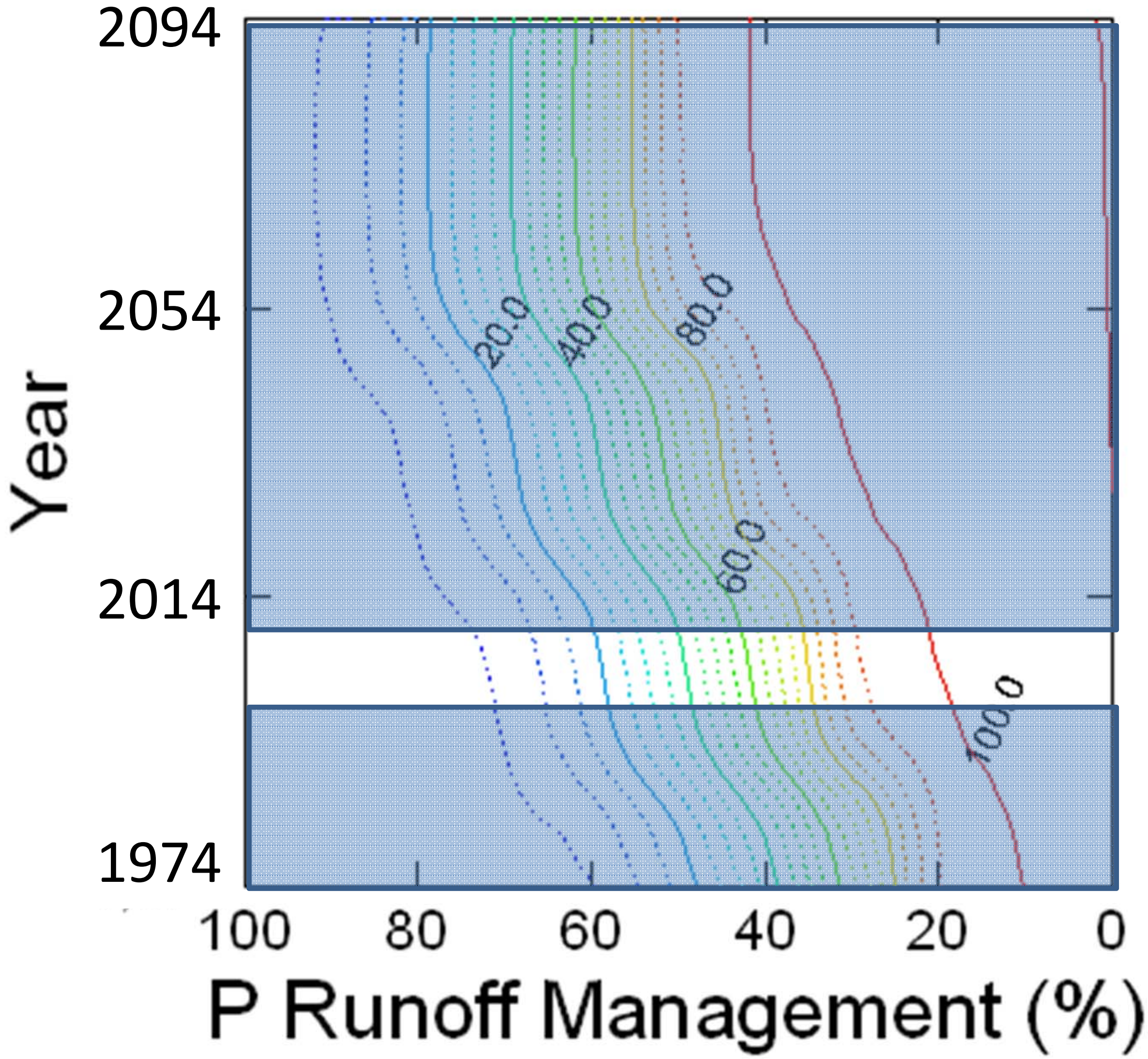


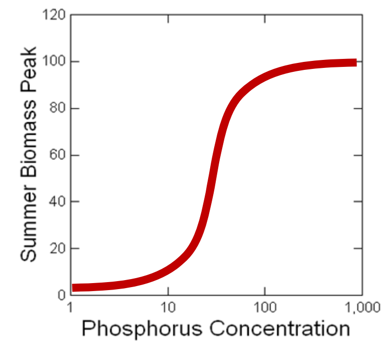
- Relate Phosphorus concentration in lakes (coastal zones) to P sources and watershed runoff
- Problem – P runoff increases with storm severity (climate change)

Relate Peak Coastal Algal Biomass to Land Use over 30 years with Landsat Images



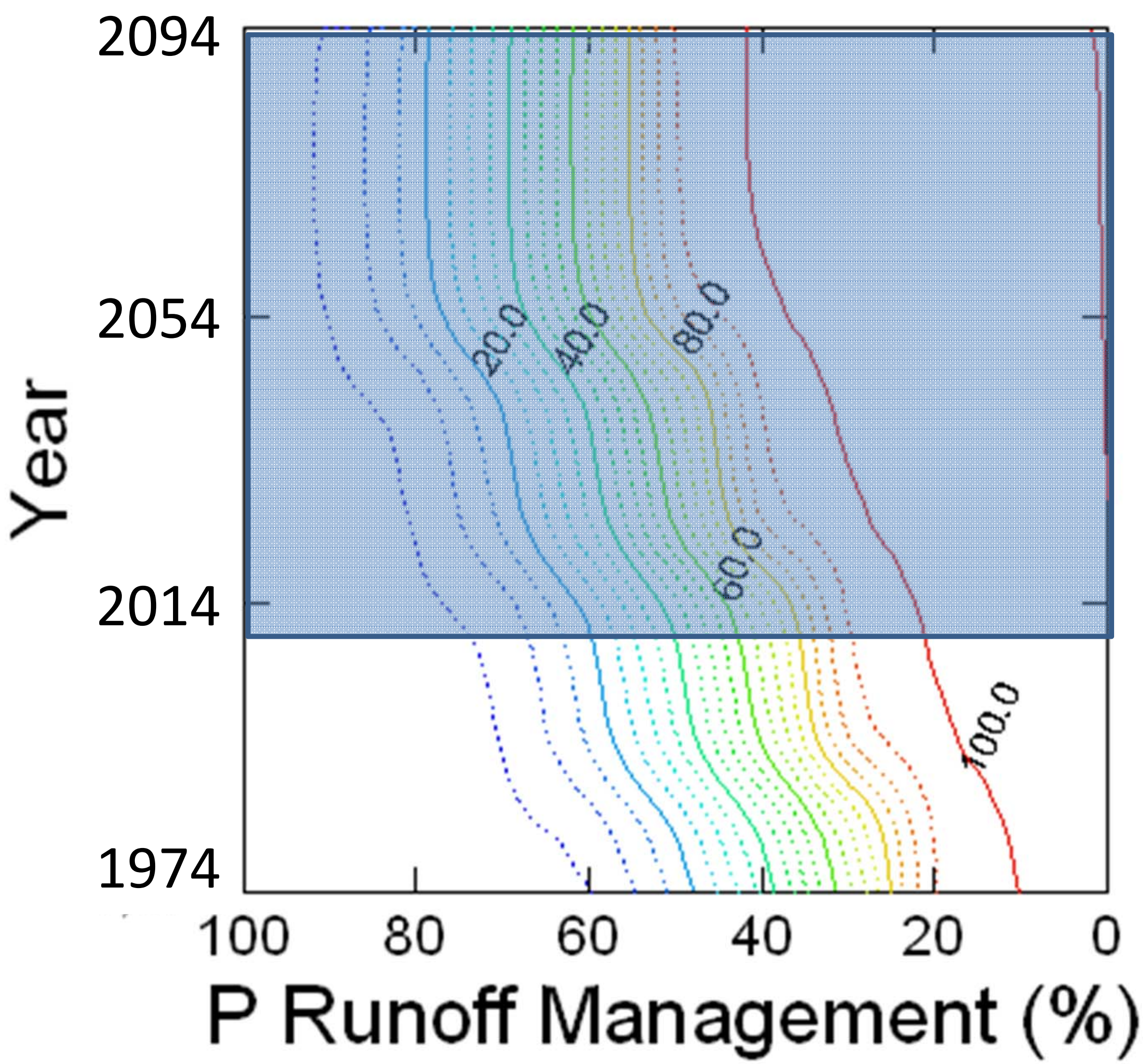
Relate Peak Coastal Algal Biomass to Land Use over 30 years with Landsat Images





Currently, we only know the present relationship.

Relate Peak Coastal Algal Biomass to Land Use over 30 years with Landsat Images



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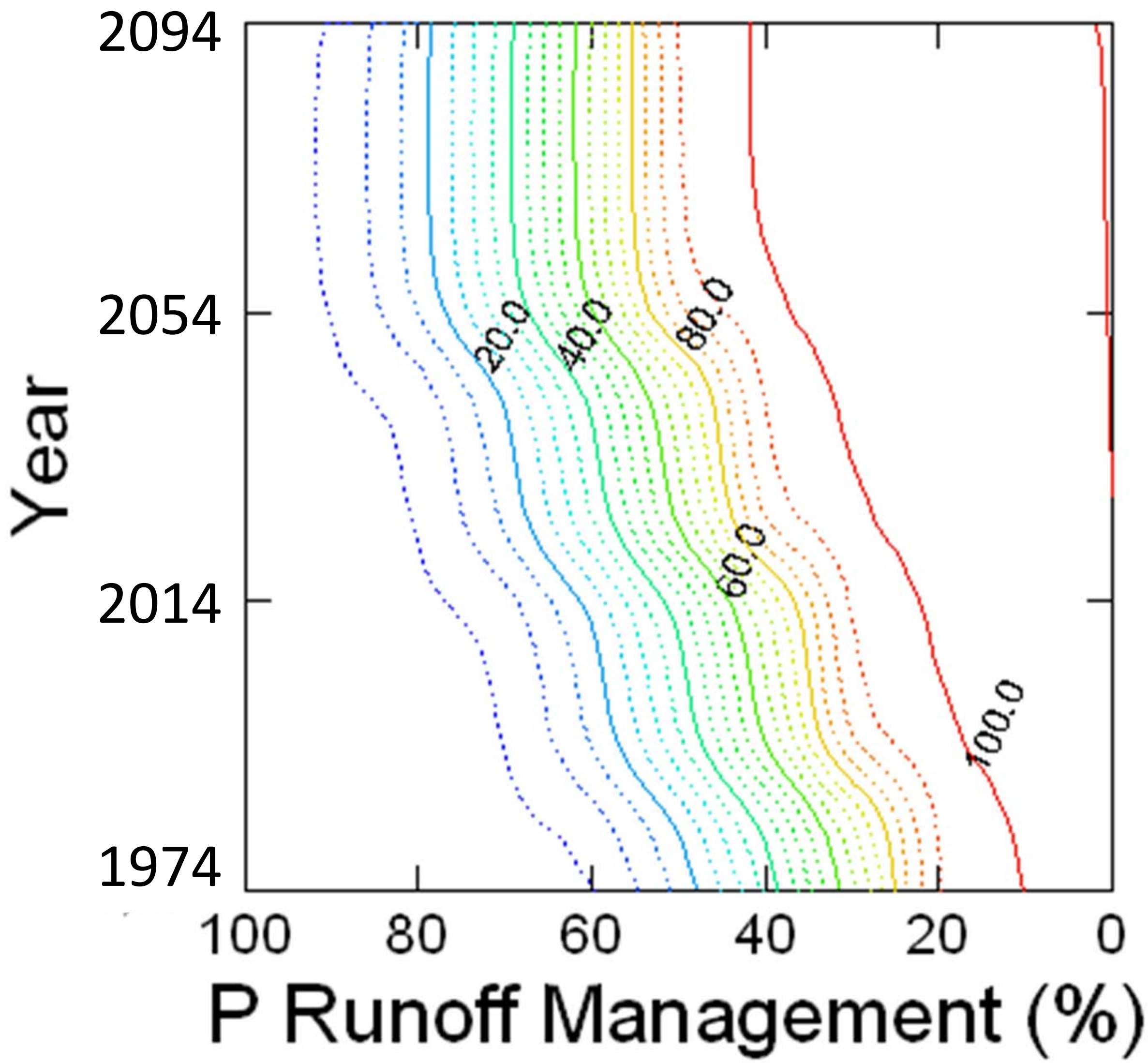
(historical)

- Land Sat Inferred Algal Biomass to 1972-1974
- P Runoff modeled with land use and weather records

Relate Peak Coastal Algal Biomass to Land Use over 30 years with Landsat Images



Managing P Runoff w Climate Change