Satellite Remote Sensing of Algal Blooms in the southcentral USA:

Landsat 8 based algal and turbidity indices in the Grand Lake watershed

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Growing concern over algal blooms in Grand Lake w/shed

News Headlines

Ada Evening News: July 21, 2011

Heat wave fosters toxic algae in touristy lakes

OKLAHOMA CITY (AP) — A prolonged heat wave in the central U.S. has fostered the growth of a dangerous form of algae in lakes and ponds, threatening swimmers and livestock and scaring away tourists during the busy summer season.

Blue-green algae are actually bacteria that produce toxins harmful to humans and livestock. It flourishes in warm, stagnant, sunlit water, and this year's heat wave combined with Oklahoma's worst drought since the Dust Bowl have created what one water official called a "perfect storm" for its growth.

Officials have issued a series of warnings, telling boaters and swimmers at lakes in northeast Oklahoma, southern Kansas and Nebraska to avoid contact with the toxic gunk. The issue attracted national attention earlier this month when Oklahoma Sen. James Inhofe blamed a respiratory illness on a swim in Grand Lake in Ketchum Hollow.

The bad publicity has had dire consequences for some businesses in Oklahoma, where tourism is the third largest industry with an estimated annual impact of $6.2 billion. Oklahoma's numerous lakes are a "huge economic engine" driving that industry, said Leslie Blair, a spokeswoman for the Department of Tourism and Recreation.

Problems on Grand Lake have subsided, the Grand River Dam Authority said. Advisories remained in effect Wednesday for portions of Keystone, Fort Gibson and Eufaula lakes in Oklahoma, Marion and Big Hill lakes in Kansas, and Willow Creek Lake in northeast Nebraska.

Durant Daily Democrat: July 3, 2011

Inhofe says swimming in Grand Lake made him ill

TULSA (AP) — Sen. James Inhofe says he believes a swim earlier this week in algae-laden Grand Lake made him ill.

Inhofe told the Tulsa World that he took a routine dive into the lake Monday morning and that night he was "deathly sick."

Oklahoma authorities warned people Friday against swimming in the lake, saying potentially toxic blue-green algae had been detected. They've also advised against water skiing and other activities that would bring people or pets in contact with the water.

Inhofe has had a home on the lake in Ketchum Hollow for decades.

He says he's never seen that kind of algae in the water before.

The 76-year-old Republican says he believes he's turned the corner on the respiratory illness and plans to return to Washington next week.

Dangerous algae plague Oklahoma's lakes, ponds

By Sean Murphy
Associated Press

OKLAHOMA CITY — A prolonged heat wave in the central U.S. has fostered the growth of a dangerous form of algae in lakes and ponds, threatening swimmers and livestock and scaring away tourists during the busy summer season.

"My friends at the marinas say their shops are full to the ceiling with beer that they haven't sold ... all because a senator went into a bad area in a cove and got a rash."
— Sam Williams

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"We took a beating from hell," said Sam Williams, who sells everything from water

Enid New and Eagle: July 21, 2011

News Headlines

Governor quick to respond to warning about Grand Lake

TULSA (AP) — Oklahoma officials said Friday they are discouraging swimming in Grand Lake because of potentially dangerous blue-green algae — a statement that drew a quick response from the governor, who was concerned about the effect on tourism over the holiday weekend.

Gov. Mary Fallin said she was extremely concerned about the economic damage that could result if people canceled trips to the northeastern Oklahoma lake at the last minute.

"There are still a lot of great things to do at the lake, even though there are concerns about the quality of the water," Fallin told The Associated Press.

Public pools are available for swimming, and there's golf courses, fireworks, an air show, free concerts, a carnival and numerous tourist attractions in the towns near the lake, including Grove, Pryor, Salina, Langley and Miami.

"I've had calls from businesses at the lake expressing concern about the effect on business and revenue," Fallin said. "Grand Lake is a wonderful tourism spot for Oklahoma. There's a lot of economic activity at the lake. We need to do all we can to support the lake."

Fallin's family had already planned a trip to Grand Lake over the Independence Day weekend and "we're still going," she said.

The GRDA is "strongly discouraging" swimming or other activities that would bring people into contact with the water, agency spokesman Justin Alberty said. The agency issue

THE TULSA WORLD, TOM GILBERT

This aerial photograph sh
Oklahoma officials said Fri
Grand Lake because of pote
statement that drew a quic
concerned about the effect

advisory because of ra
changing levels of
green algae in the lake
said.

The agency's board o
rectors scheduled an e
gency meeting in Tuls
Friday afternoon to dis
the situation.

Blue-green algae are
croscopic organisms
are naturally presen
lakes and streams, usu
in low numbers. Howe
the algae can become a
dant in shallow, warm w

Lawton Constitution: July 2, 2011

DEQ Issues Algae Alert

By CAREY HEAD
News Lifestyles Editor

OKLAHOMA CITY — An Oklahoma Department of Environmental Quality recommendation to temporarily avoid body contact with water at Sarrito State Park and a few other areas of Grand Lake is prompting the Grand River Dam Authority to remind lake enthusiasts to take extra precautions on Grand Lake this summer. The state park is putting up signage to notify the public.

Blue-green algae, or HA has been found in the waters near Bernice State Park, in portions of Horse Creek and the back of Duck Creek — all popular destinations for tourists enjoying the waters of Grand Lake. The DEQ made the recommendation to avoid body contact with water in those areas after BGA was found there.

Tests produced by BGA, or cyanobacteria, may cause allergic reactions, damage to the liver and other internal organs, as well as damage to the central nervous system and the brain.

According to Justin Alberty, corporate communications director with GRDA, the area on Duck Creek where the BGA was found was at the back of the creek beyond the popular Thunder Bay restaurant.

Alberty explained the biggest area of concern is Bernice State Park and Horse Creek. Tests conducted June 17 found the largest amounts were in Horse Creek, "but over the weekend, the strong southerly winds helped it dissipate."

Over a busy holiday weekend, such as the Fourth of July, the population of Grand Lake triples owing to the third largest in Oklahoma, according to Grand Lake Area Chambers of Commerce.

Visitors are advised to avoid areas where the water is shallow, still and warm. "We've not had this on Grand Lake before," Alberty said. "We don't want to panic anybody, but still advise everyone to swim in the main lake."

Three magnets attracting boaters are Woodruff Bay, Big Hollow and Dripping Springs.

IN THIS PHOTO provided by State of Washington Department of Ecology, a blue-green algae bloom washed up along the shoreline in Lenp Lake, Thurston County, Washington. The bluish-color means that some of the algae are starting to decompose leaving the blue pigment. Some forms of blue green algae, or BGA, are toxic to humans, pets and livestock. The Oklahoma Department of Environmental Quality and the Grand River Dam Authority have issued a warning to visitors to Grand Lake that BGA has been found in the waters of Bernice State Park, Horse Creek and Duck Creek on Grand Lake.

Ponca City News: June 28, 2011

- The Grand River Dam Authority (GRDA) concerned over repeated bloom events
- Interested in new tools for near real time monitoring of algal blooms

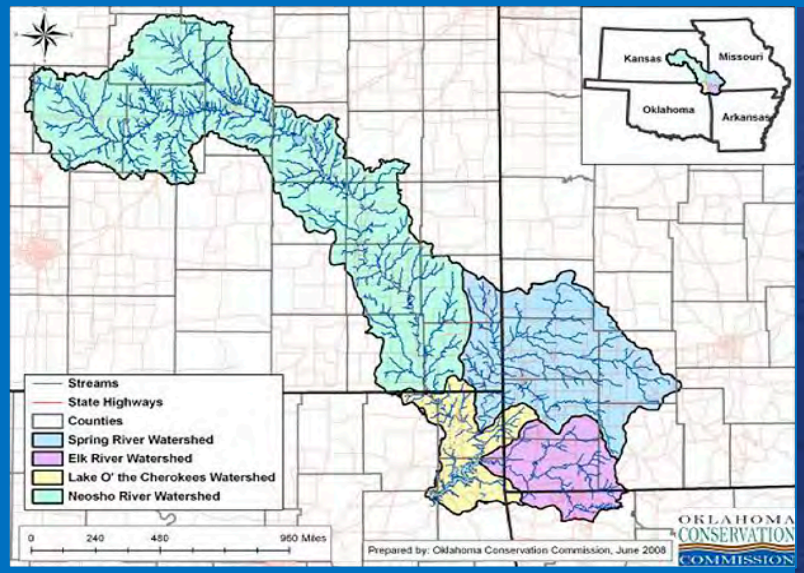
Algal bloom in the Grand Lake watershed

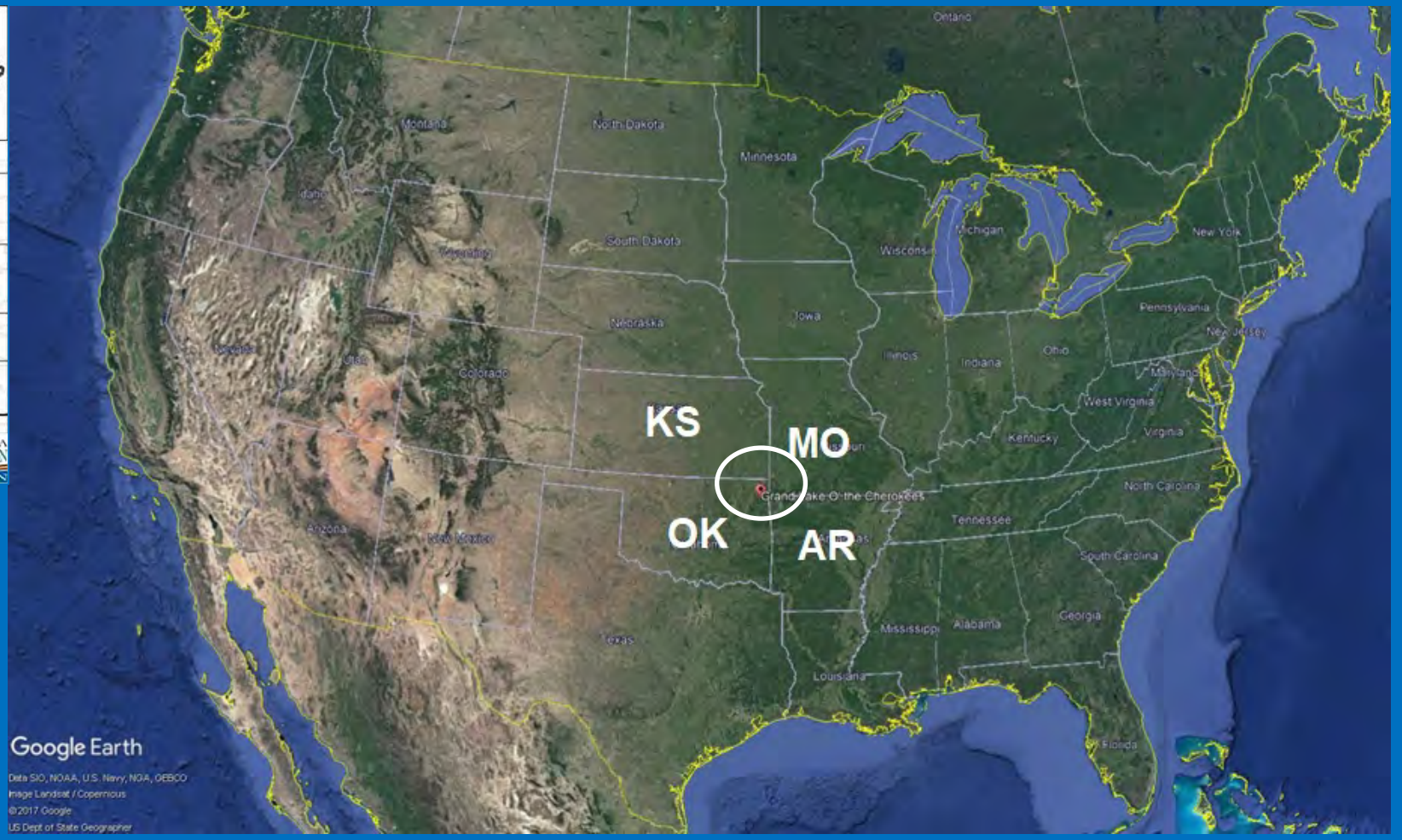
Grand Lake, Oklahoma. June-July 2011

Grand Lake, Oklahoma. June-July 2011

Marion Lake, Kansas. May 2004

Area of concern: The Grand Lake Watershed





Objective

In-situ Chl-a & BGA data

Landsat & Sentinel-2 data

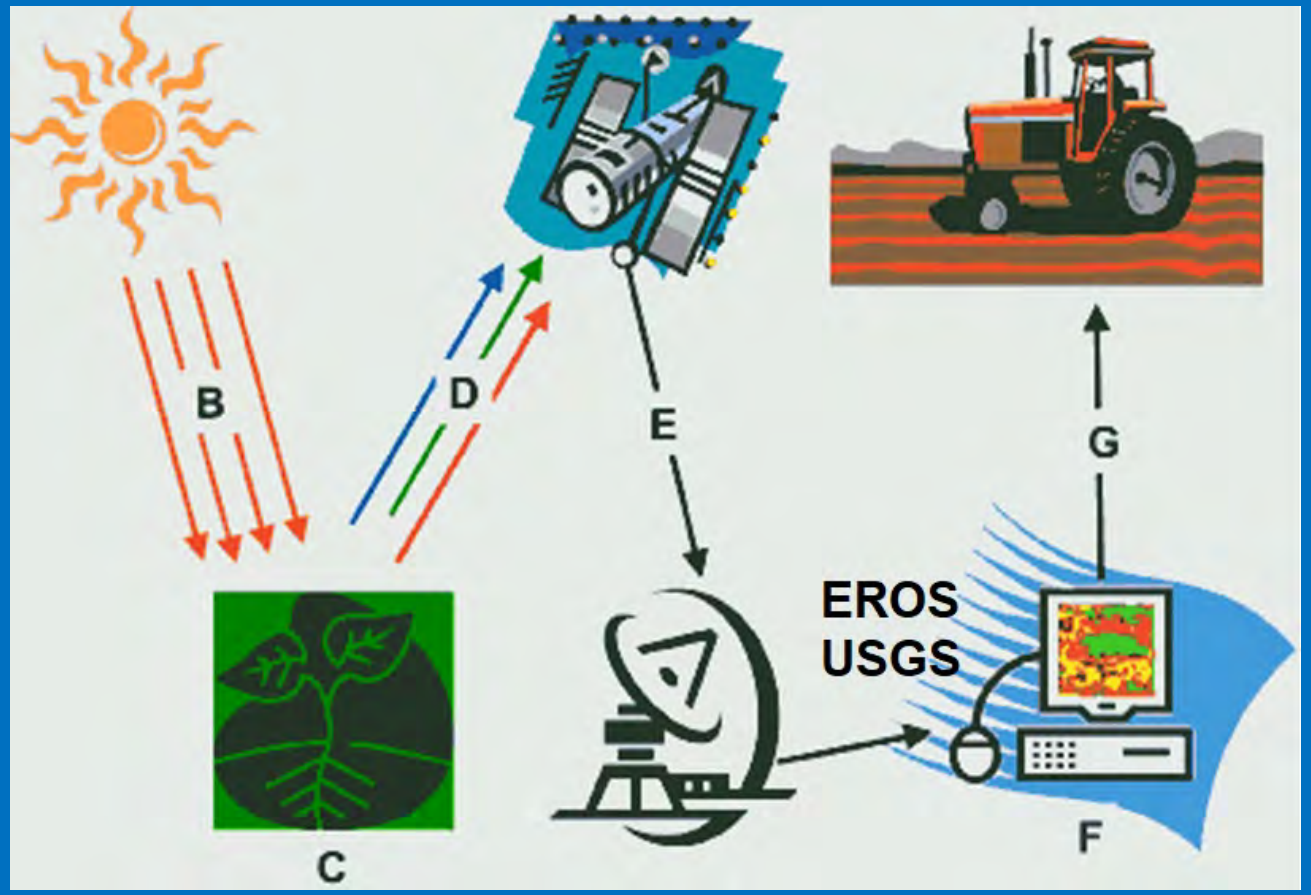
Develop indices for algae and turbidity

Validate indices

Develop a new monitoring tool and integrate into GRDA's existing monitoring routine

Chl-a = Chlorophyll a; BGA = Blue/Green Algae

Image acquisition



- EROS Center
  - Retrieves and pre-processes images
- USGS
  - Provide images via website
  - Free download

EROS: Earth Resources Observation and Science

USGS: United States Geological Surveys

Image processing

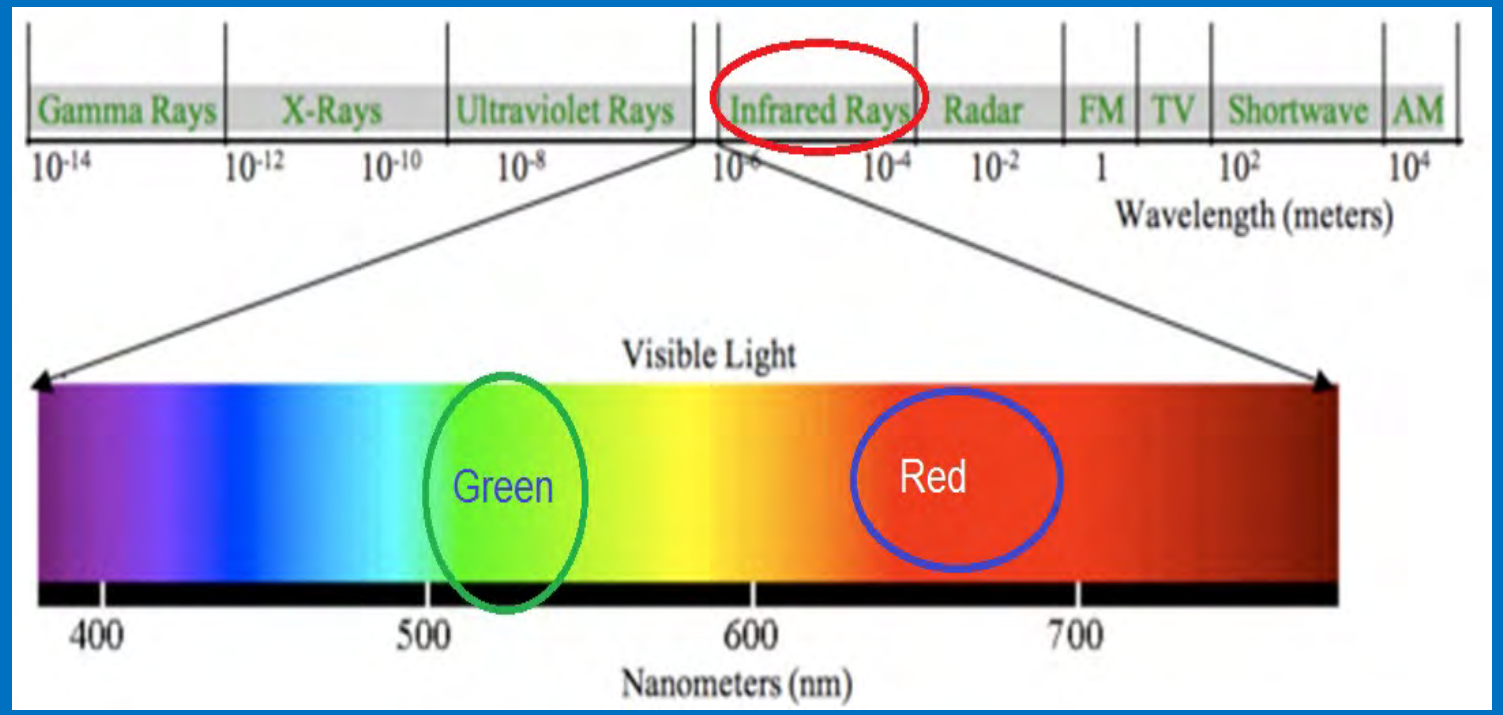
1. Geometric correction:
   - Making sure pixels are in their right geographic locations
   - Use ground control points (GCPs) or high resolution maps
   - The USGS does geometric correction

2. Radiometric correction:
   - Ensure senor is recording radiation coming from the right pixel

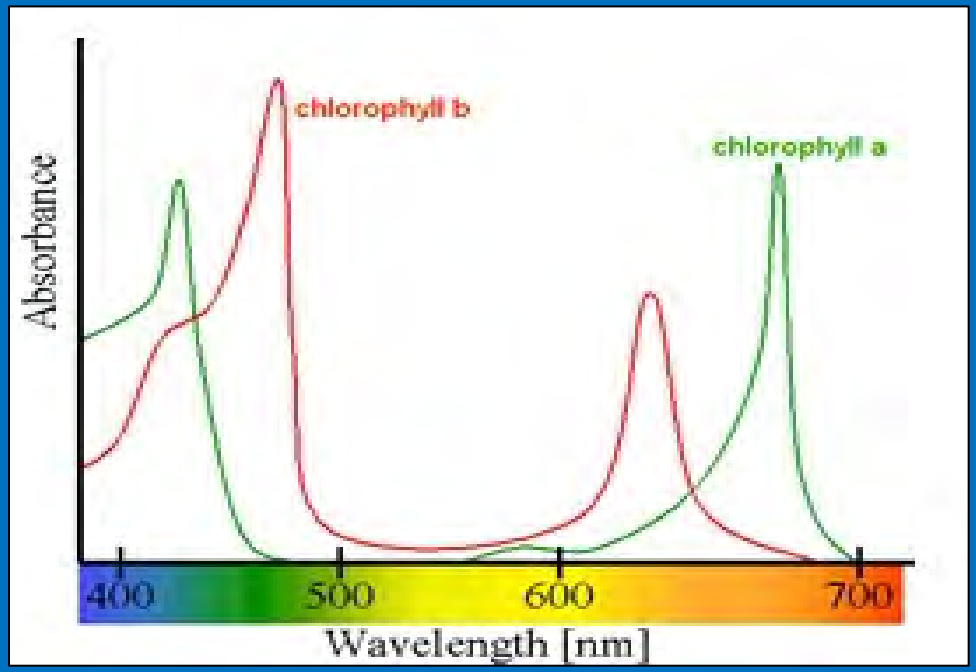
3. Atmospheric correction
   - Account for scattering by molecules, aerosols, and particles in the atmosphere

A pixel is the smallest angular or linear separation between two objects that can be resolved by a sensor

Image Analysis: Development of indices

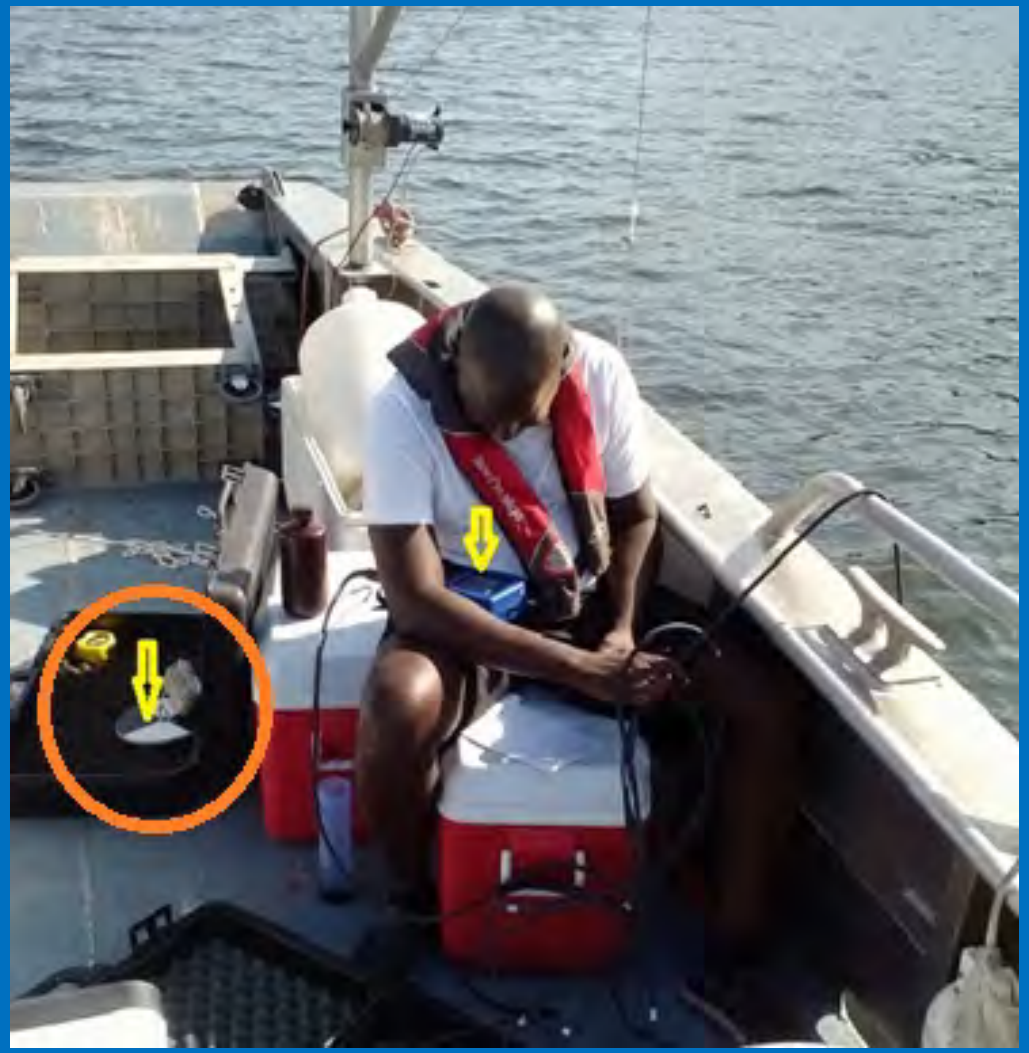


The electromagnetic spectrum (EMS)

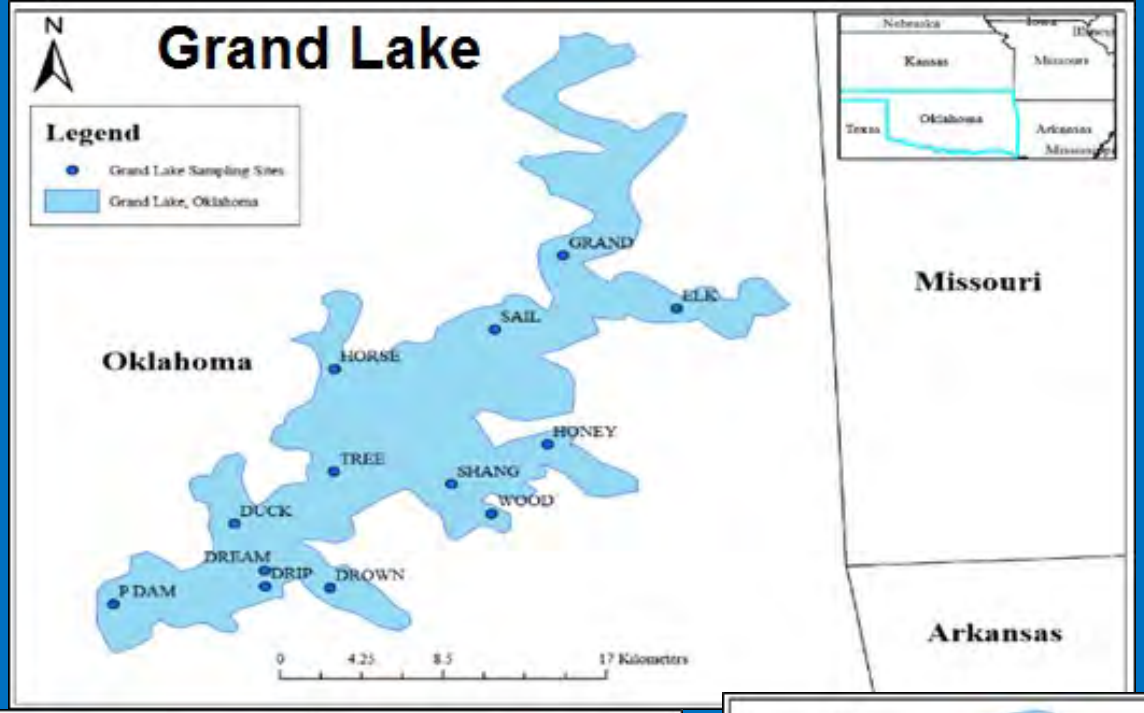


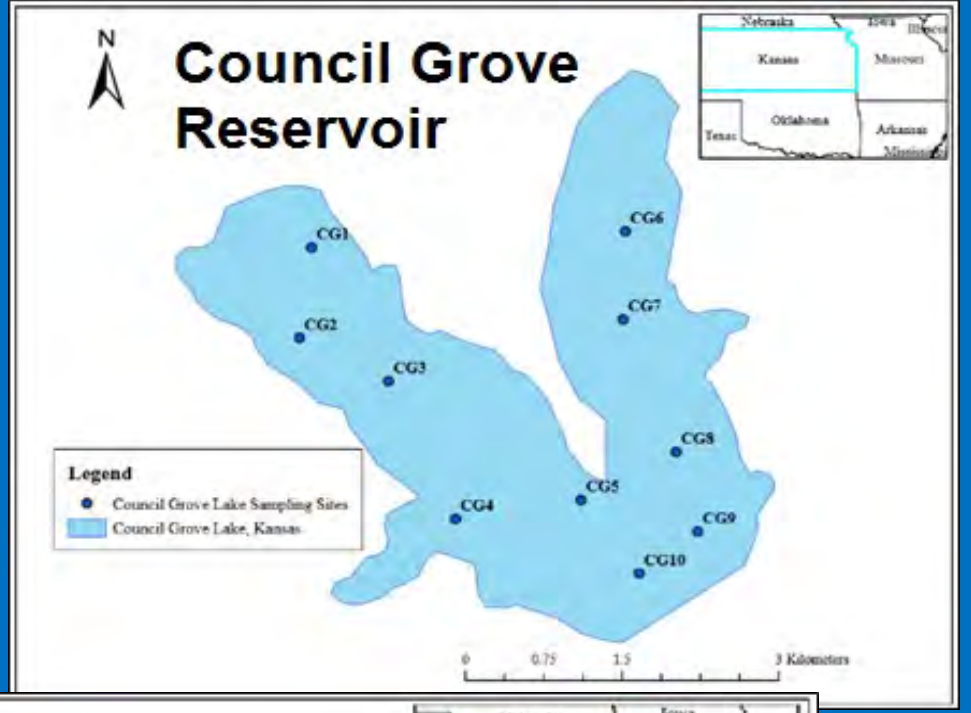
Spectral signatures of algal pigments

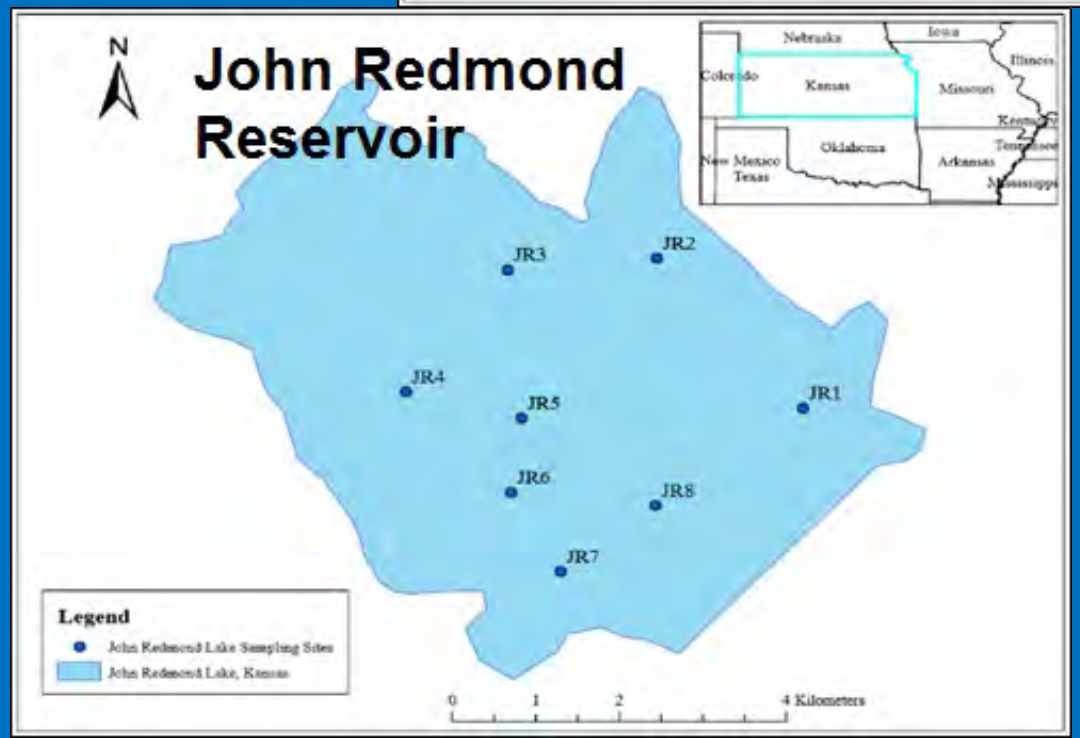
Ground based data

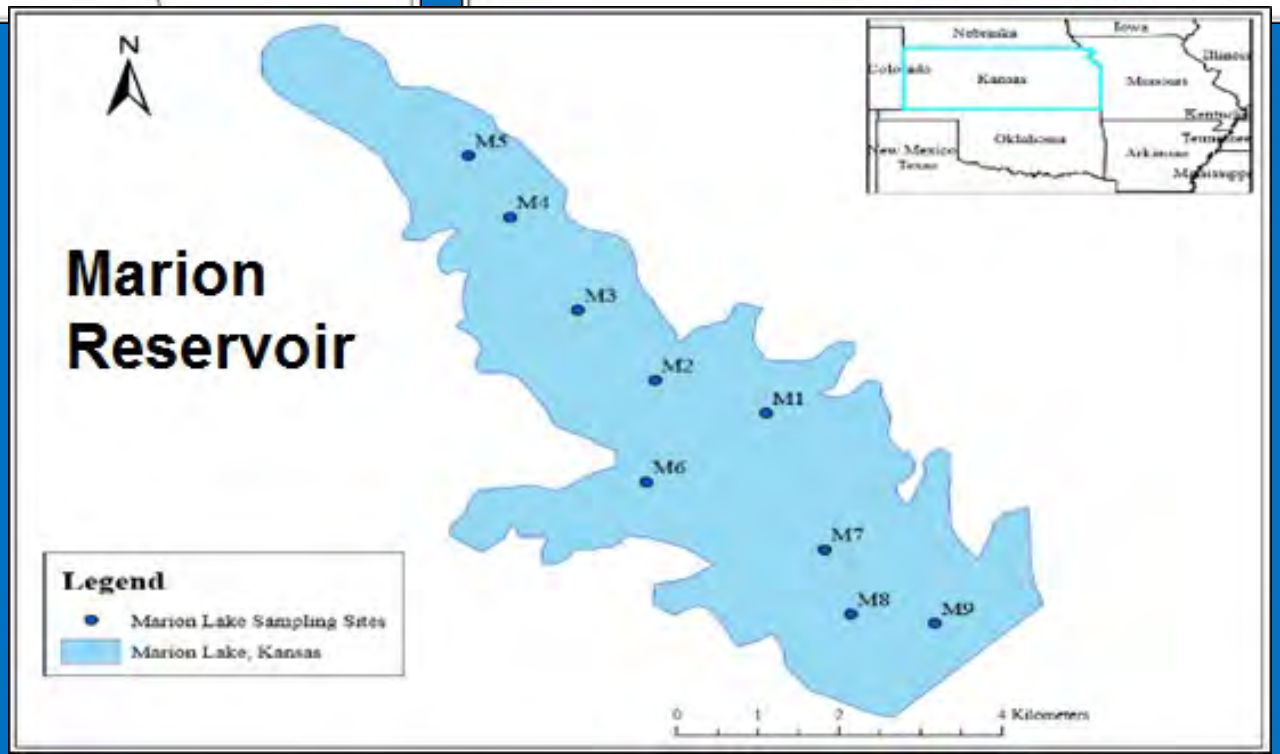


In Situ Sampling Sites



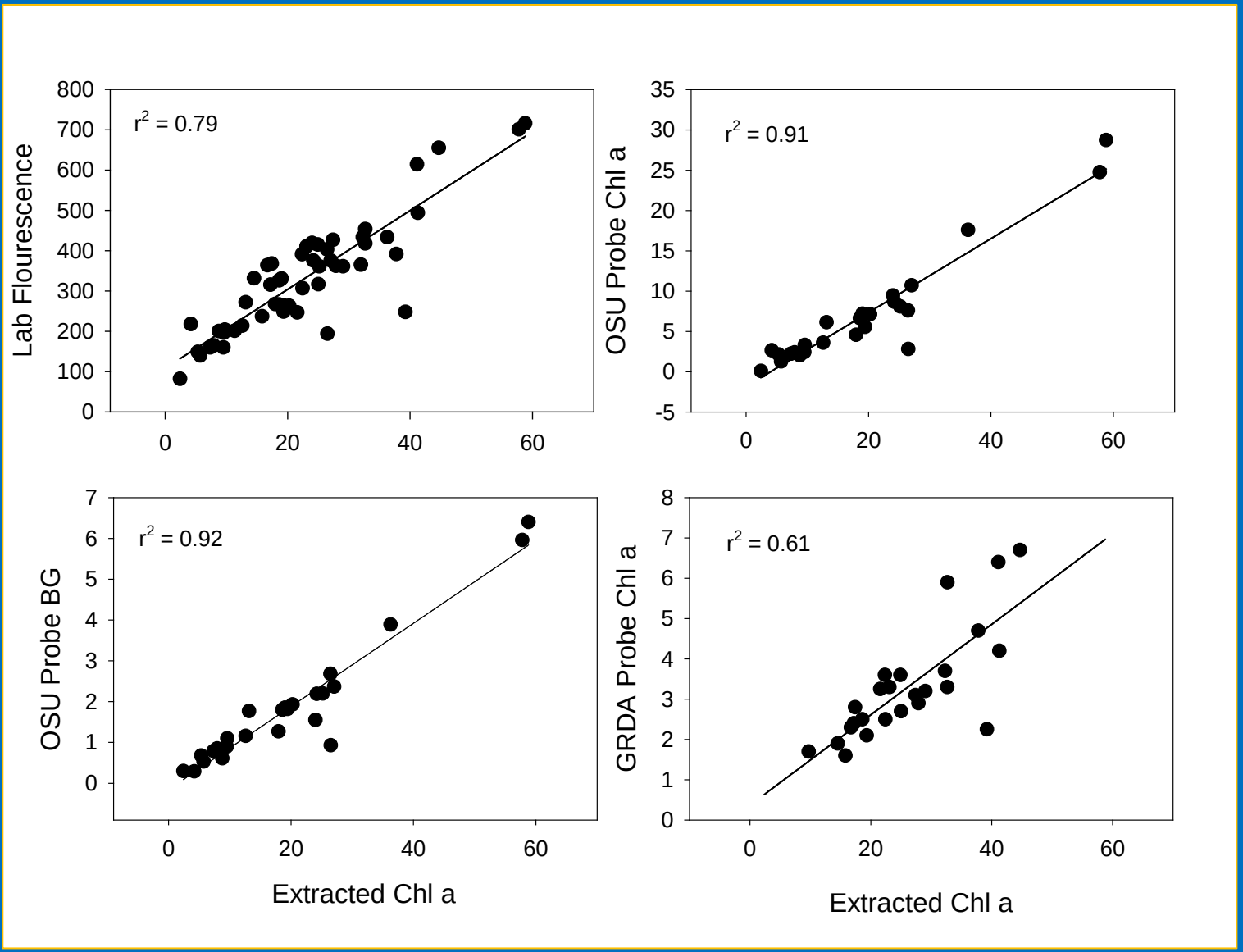






Validation and interpretation of Data

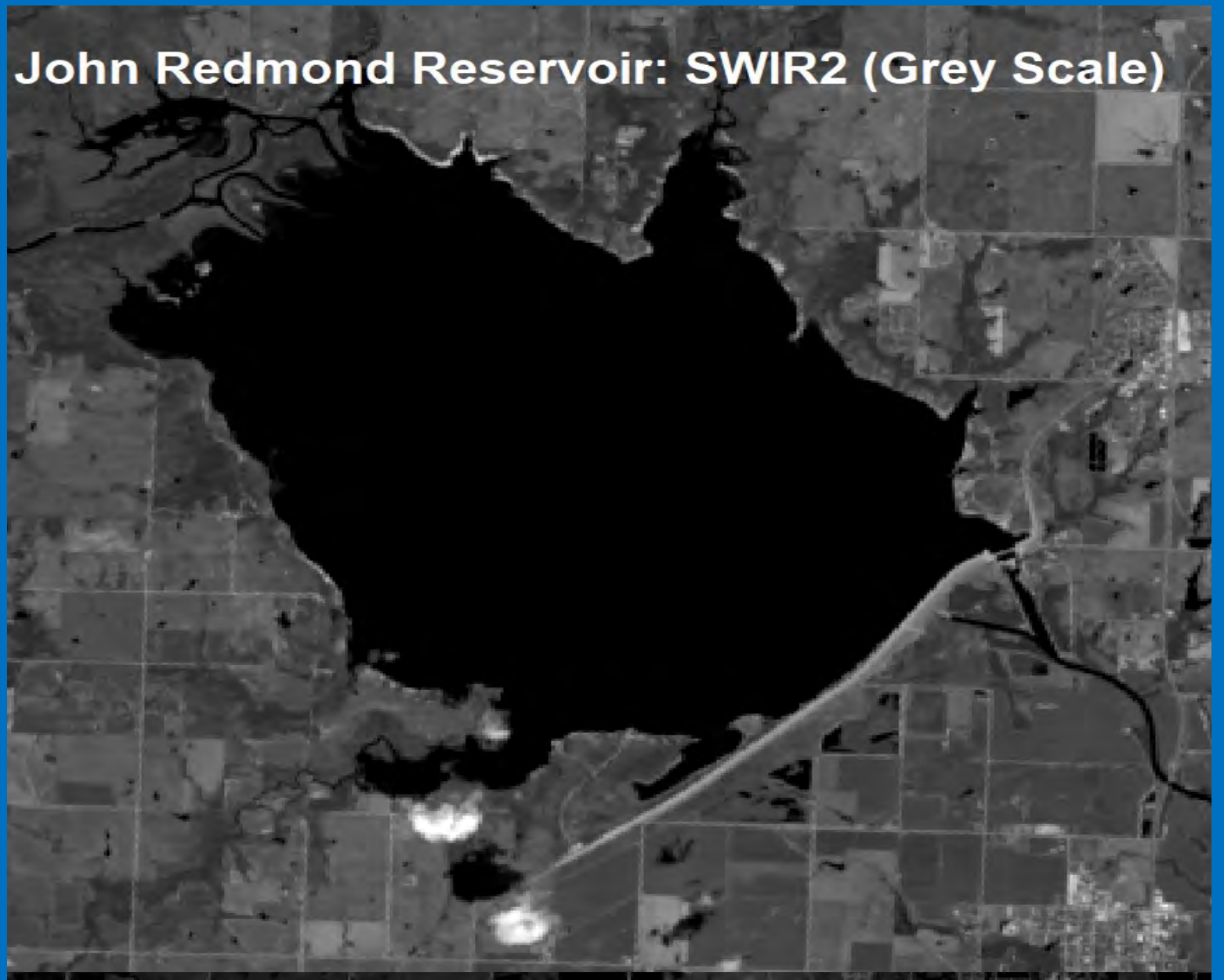
Data validation – Lab & Probe Comparisons



- All measures of algal biomass were correlated
  - Extracted chlorophyll, laboratory fluorescence, probe fluorescence

Image interpretation

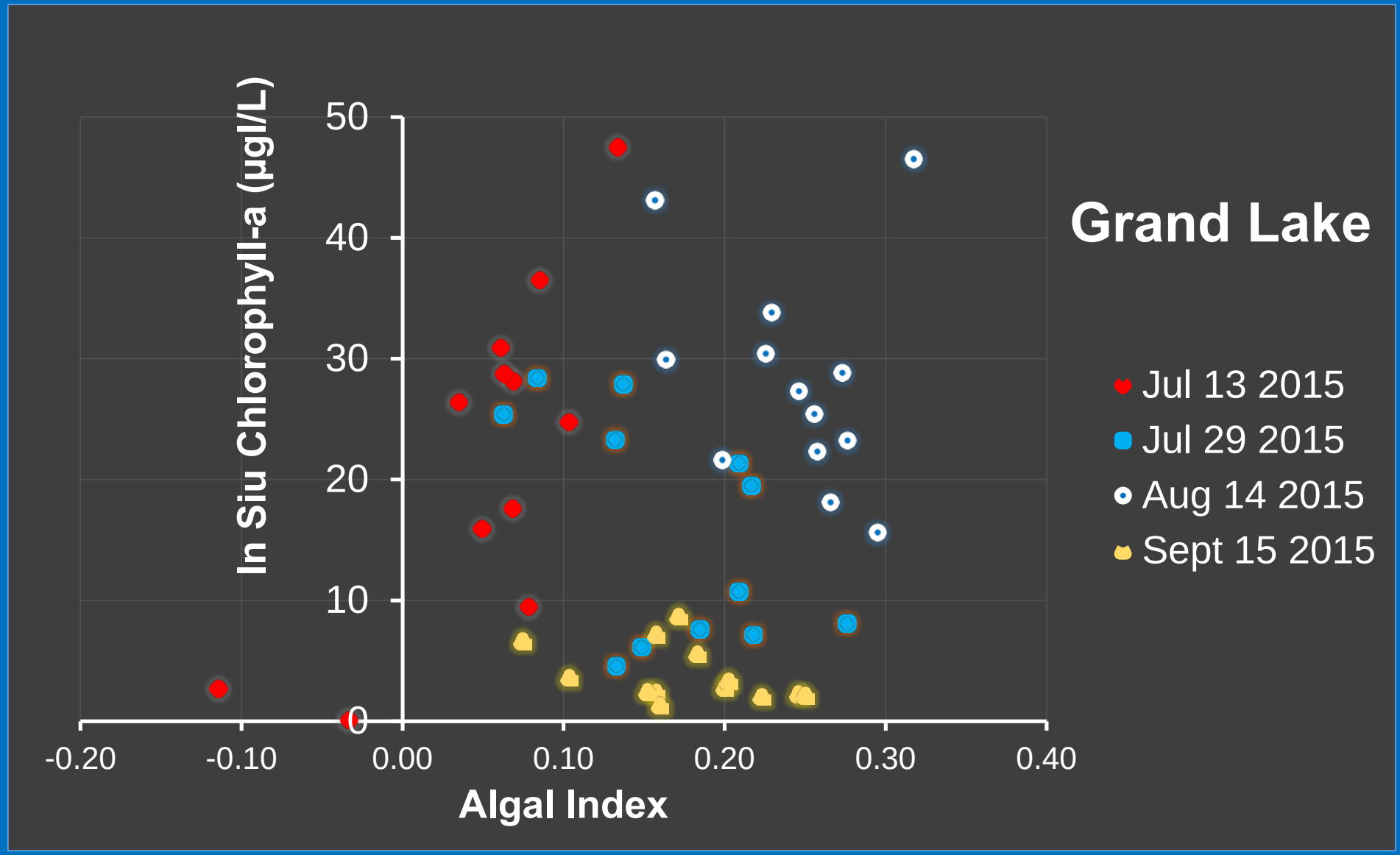
Example: John Redmond Reservoir 08/26/2017



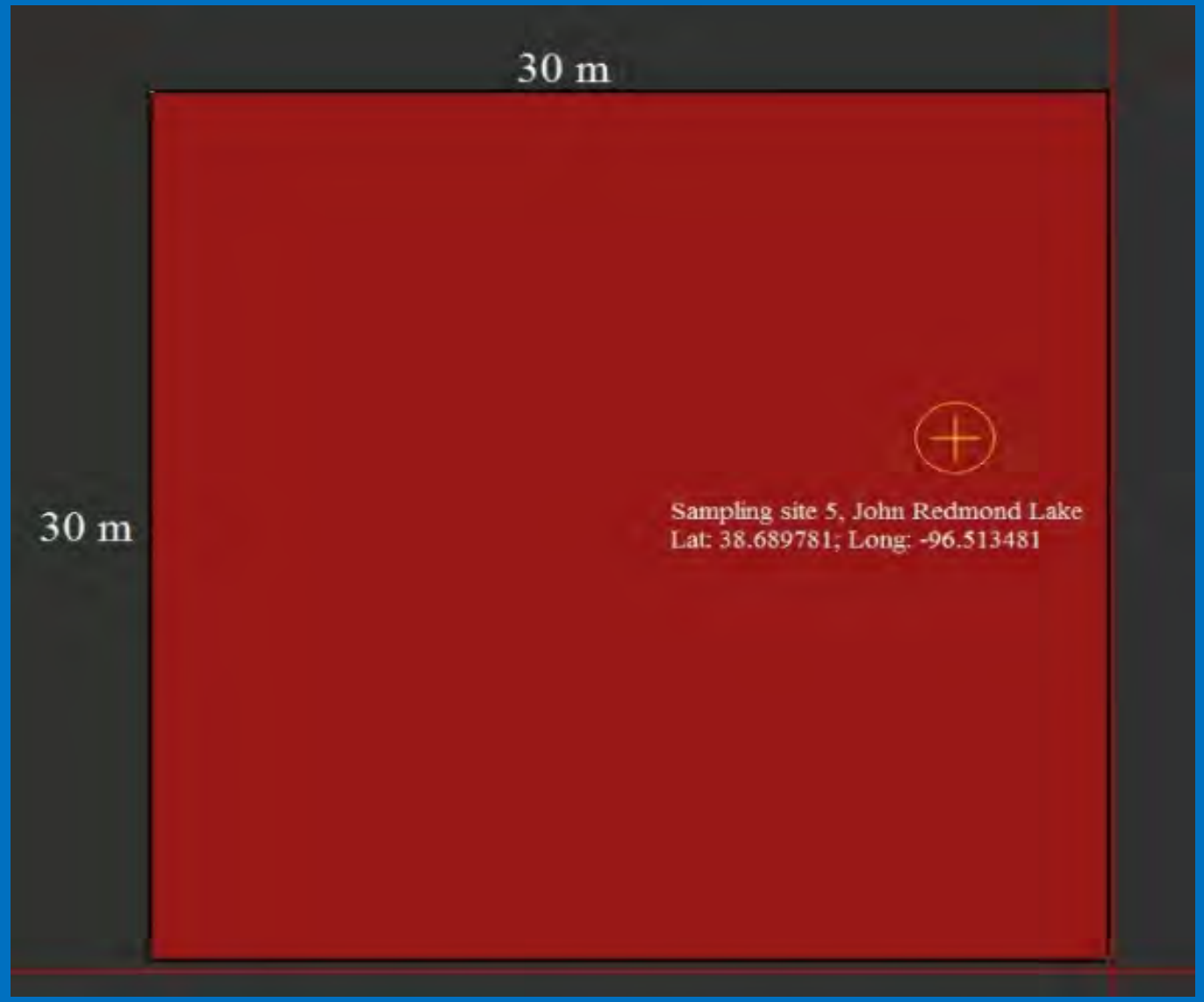
Test for correlation (Example: Grand Lake, Summer 2015)

No linear relationships

Why not?



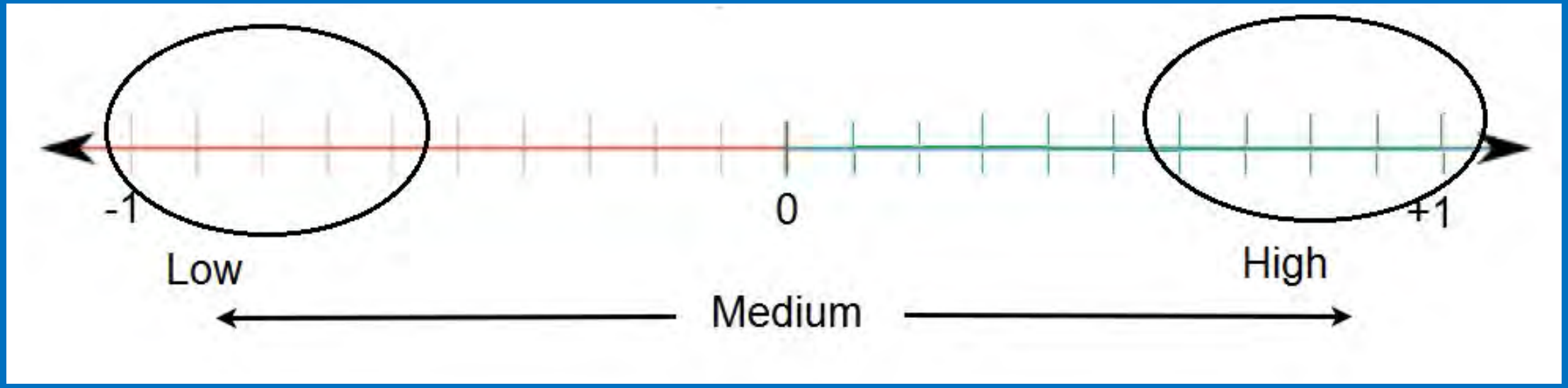
Pixel size vs Sample point



Correlation:
in-situ conc. from a single point vs algal index from a whole pixel

We may, however, use the index to explain algal activity at that point

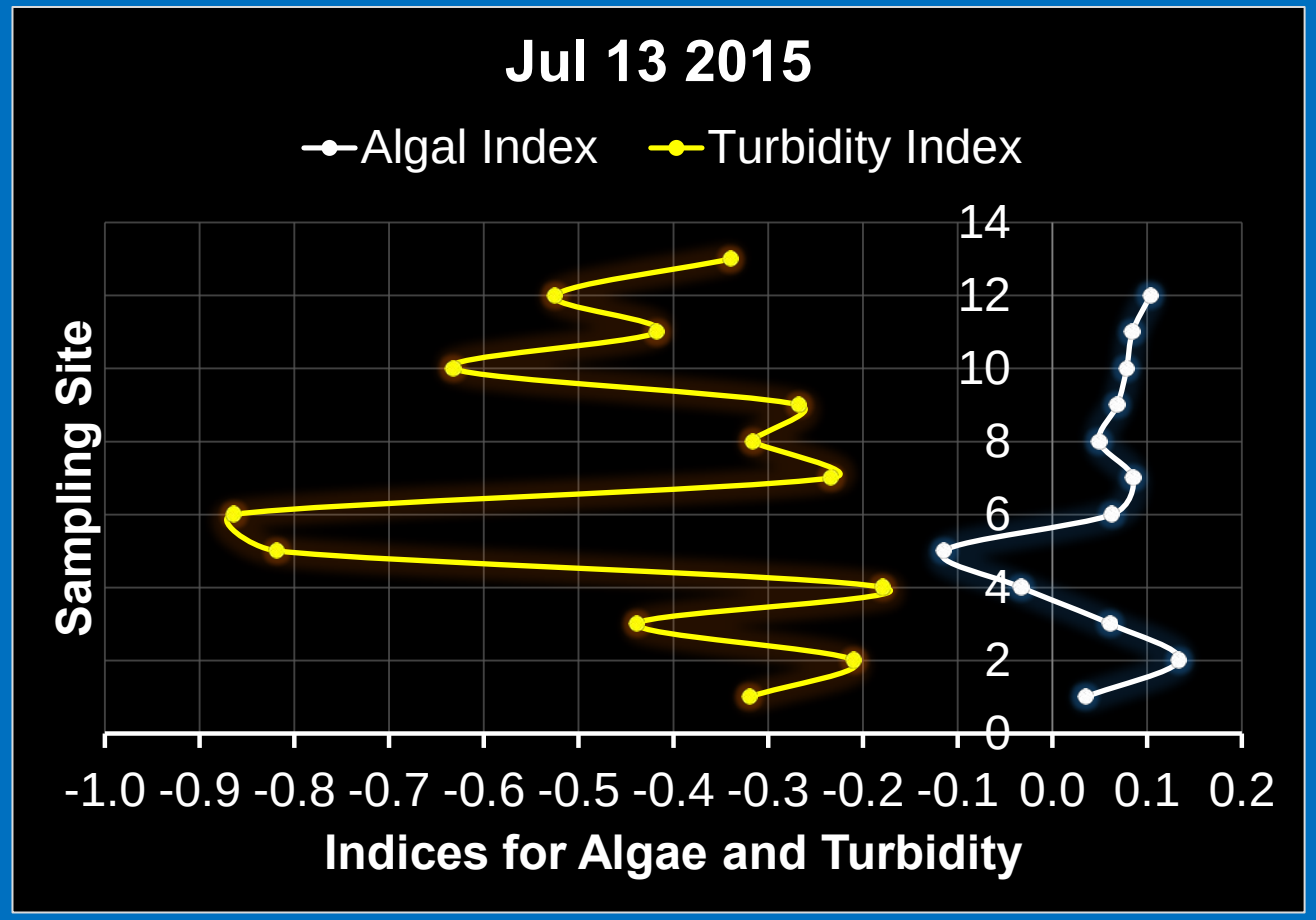
Rule of Thumb: Normalize the index (-1≤x≤1)

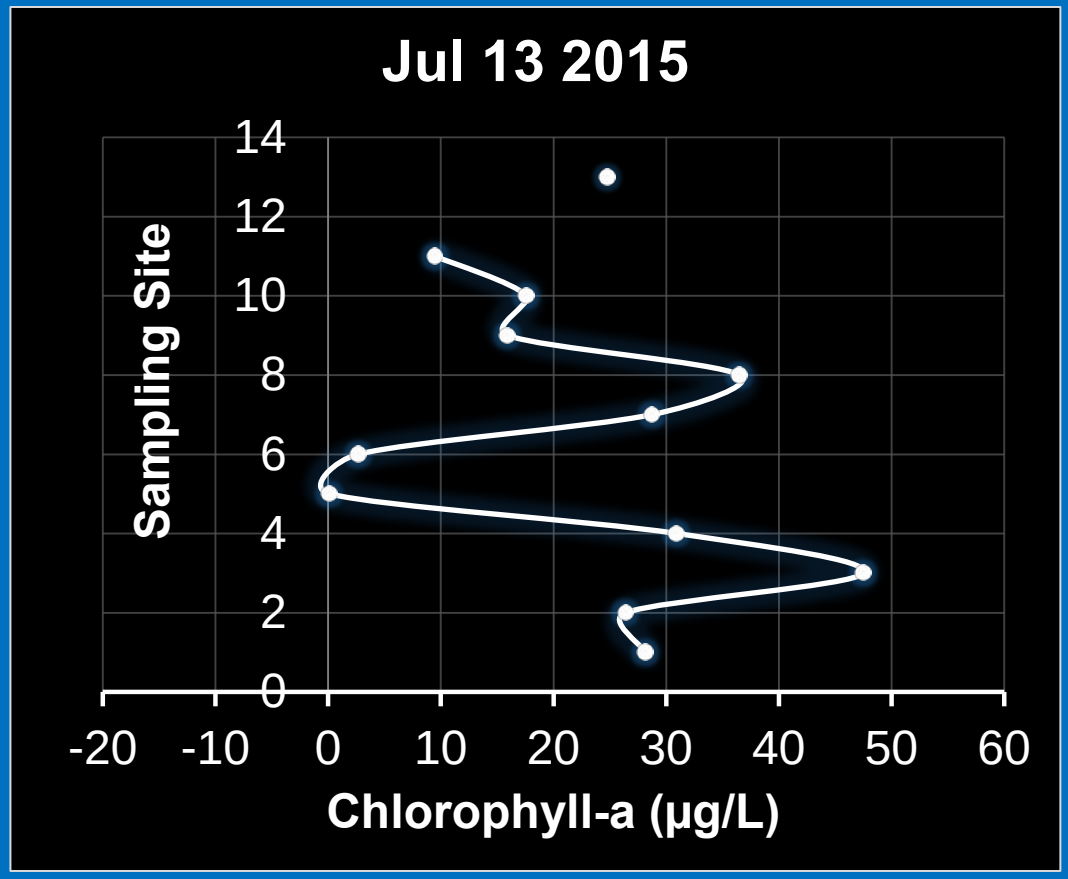


Rule of Thumb: Set thematic standards

Turbidity index	Algal index	Interpretation	Scenario
Low	**High**	Low IR ref.; high vis. Ref.	Algal bloom
Medium	**High**	Some IR ref.; high vis. Ref.	Probable algal bloom
Medium	**Medium**	Several scenarios	Ground based monitoring required
Low	**Medium**	Low IR ref.; some vis. Ref.	A different IOP
High	**Medium**	High IR ref.; some vis. Ref.	Probable muddy water
High	**Low**	High IR ref.; low vis. Ref.	Muddy water

Example: Grand Lake





No algal bloom. A different inherent optical property (IOP)?

Even though algal concentration is high at some points, the sensor may not "see" that single point at that resolution

Next steps

Validate and calibrate the indices

- **Use spatial statistics to address correlation issue**
- **Lab based confirmatory test of spectral signatures used to develop indices**
- **Set cut off points for the high-medium-low ranges**

Research team

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Thank you!