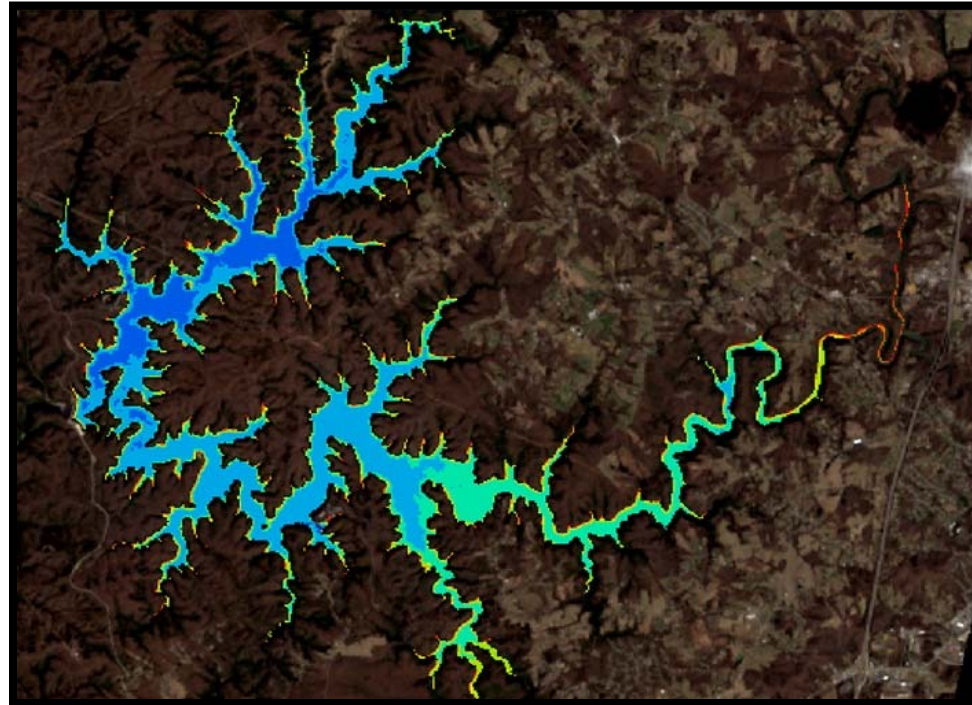


Predicting Water Quality In Kentucky Lakes Using Landsat Satellite Imagery

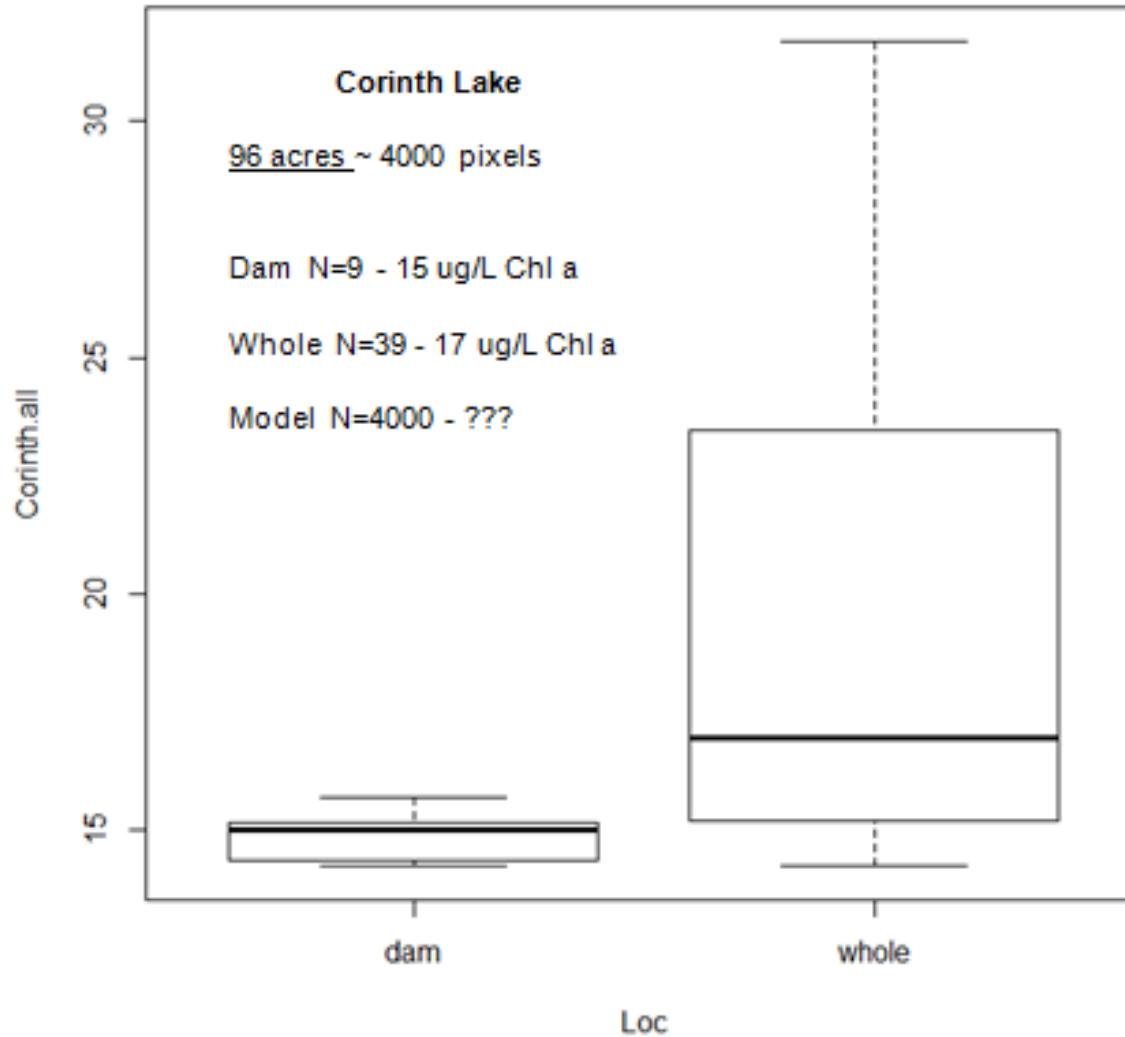


Garrett Stillings and Mark Martin
Kentucky Division of Water
Water Quality Branch



Limitations of Lake Sampling

- Over
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- High
 - Tr
- Ident
 - No
- Sam
 - (next



100 acres)

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imagery.

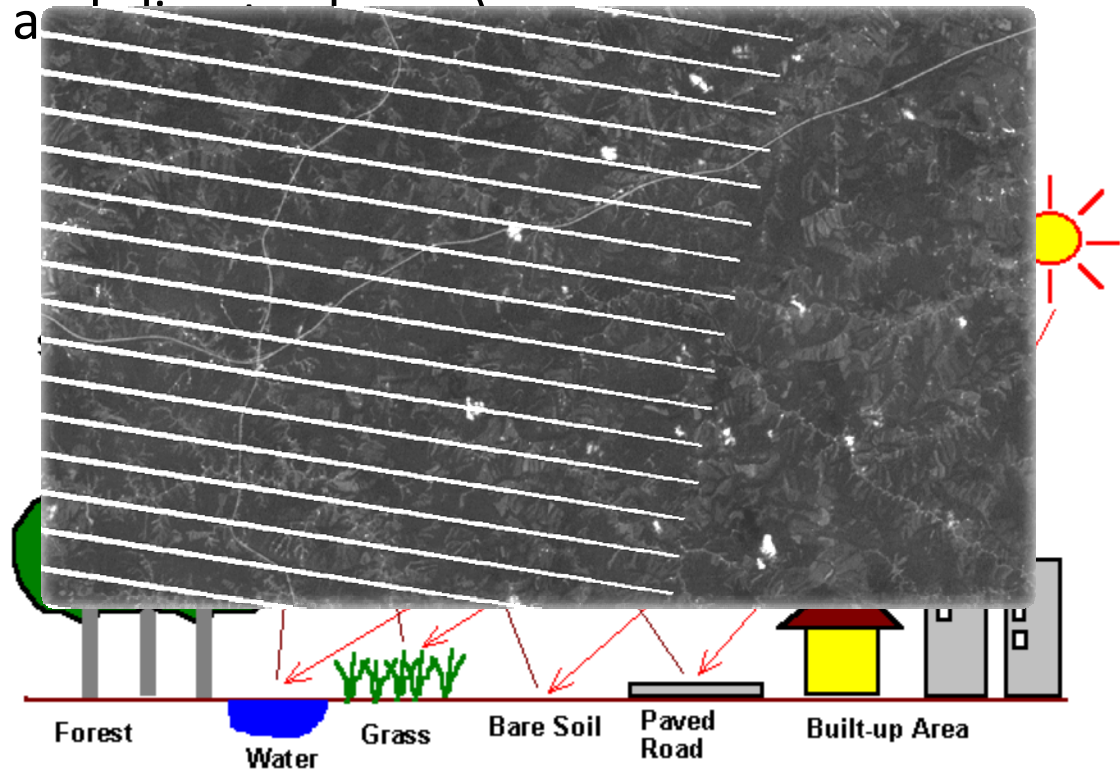
Remote Sensing using Landsat Imagery

- Acquiring information without the field work.
- Provides aerial data using different wavelengths of light.
- Used for monitoring in many disciplines (glacier and rain forest loss, population change and urban expansion)

1972-Present

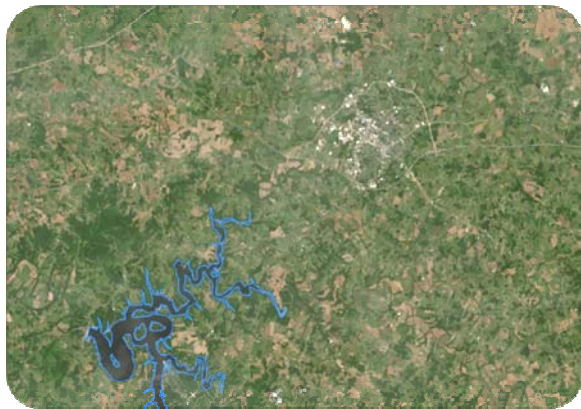
Landsat 7- Still functioning, but with faulty scan line corrector (2003).

Landsat 8- Launched Feb 2013.



Landsat Imagery

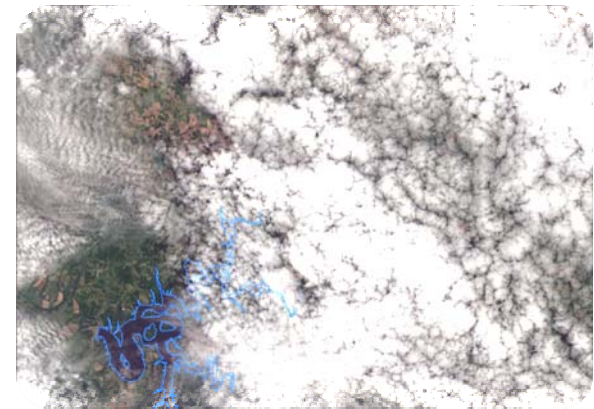
1.) Landsat imagery provides well calibrated data collected every 16 days.



Aug 30, 2013



June 11, 2013



May 26, 2013

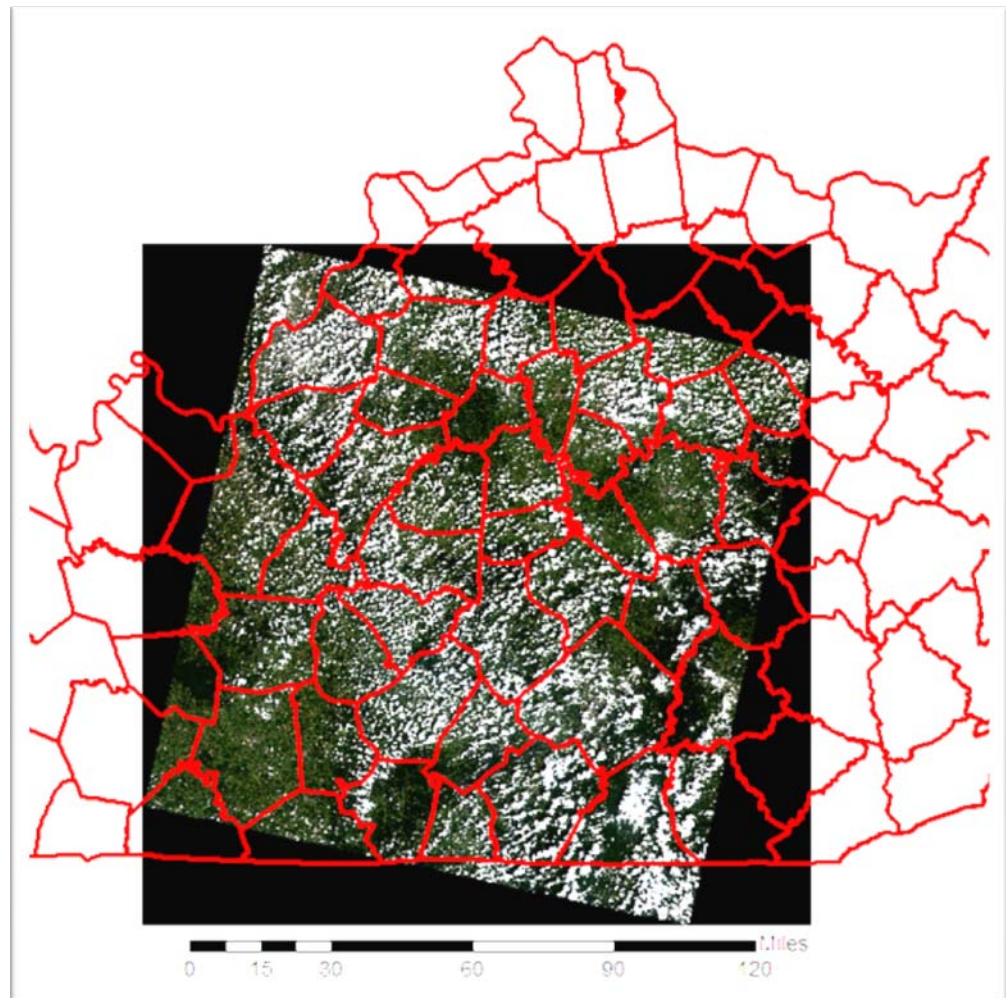
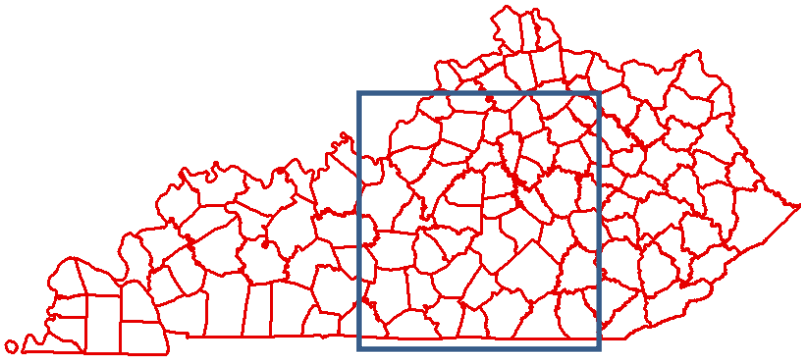


-Atmosphere has to be clear to obtain good data (~10% Cloud Cover).

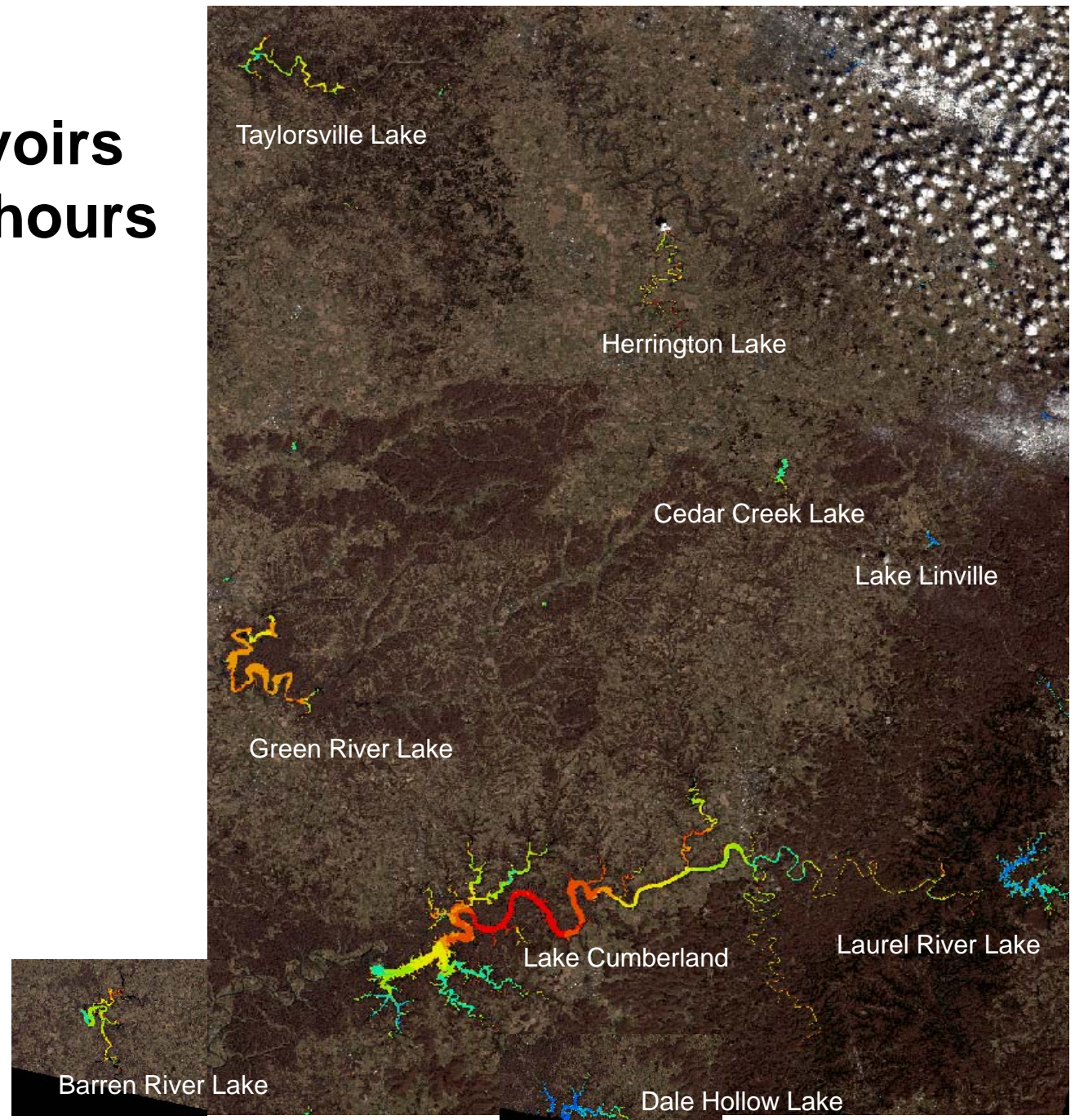
-New QA Band.

Landsat Imagery

2.) One Landsat 8 image covers $\sim 12,000$ mi²
(115 mi x 105 mi).



- **9 major reservoirs**
- **24 personnel hours**

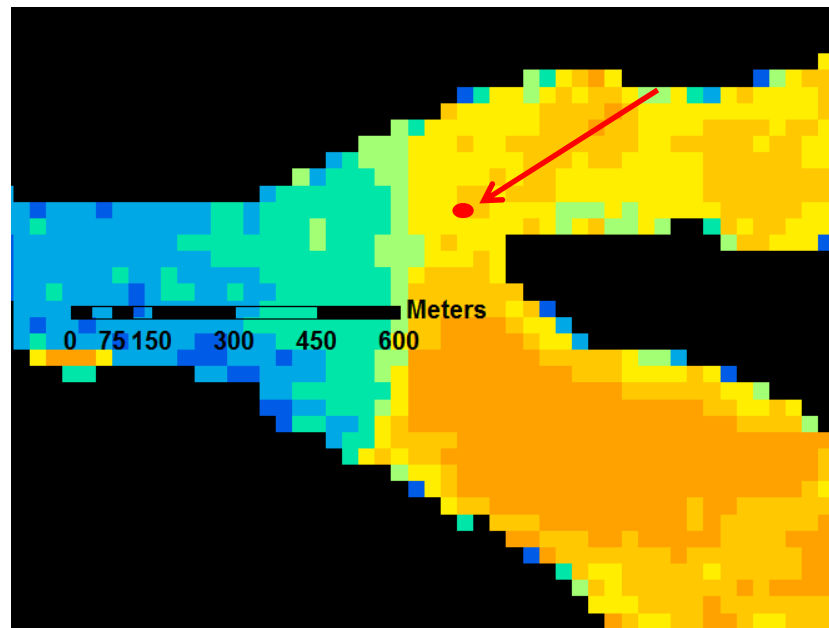


Landsat Imagery

3.) Landsat imagery provides digital numbers in a 30 m x 30 m pixel size.

-Thousands of sample locations.

-Identify problem areas easily at fine scales.



Digital Numbers

Band 1=10779

Band 2=9726

Band 3=8728

Band 4=7395

Band 5=7341

Band 6=5564

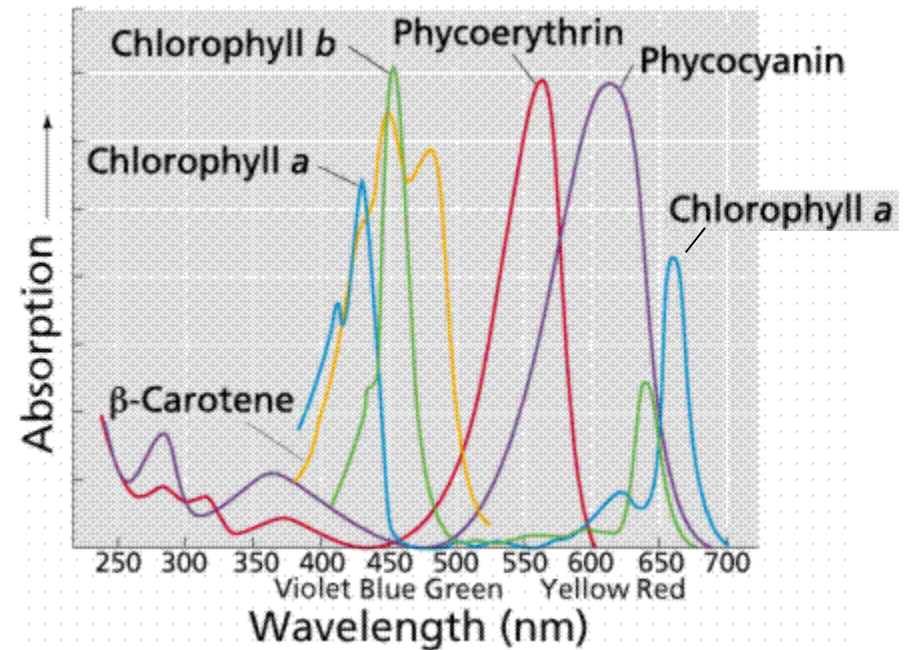
Band 7=5333

Landsat Imagery

4.) Able to analyze many water quality variables using different band wavelengths.

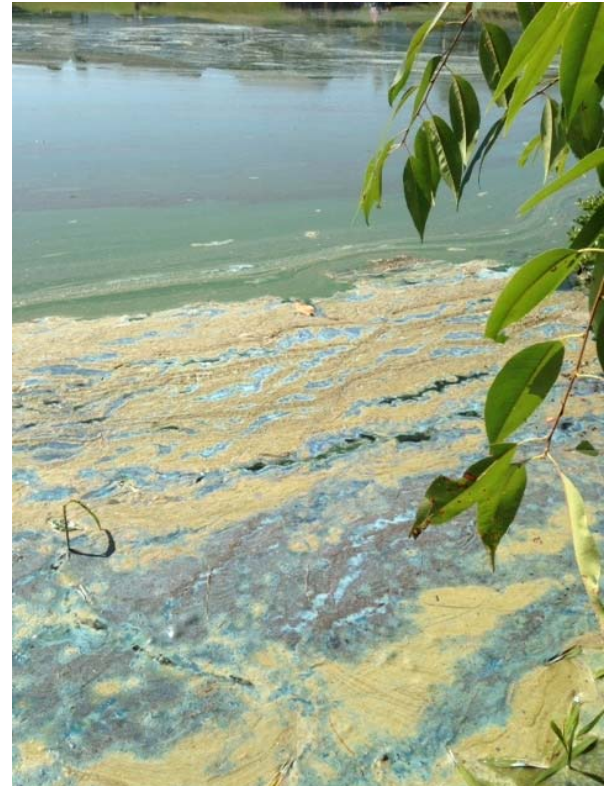
Spectral Band	Wavelength
Band 1 - Coastal / Aerosol	0.433 - 0.453 μm
Band 2 - Blue	0.450 - 0.515 μm
Band 3 - Green	0.525 - 0.600 μm
Band 4 - Red	0.630 - 0.680 μm
Band 5 - Near Infrared	0.845 - 0.885 μm

www.landsat.usgs.gov



- Each band explains a different story
- Helps in differentiating HABs and Chlorophyll (next.)

Identify Harmful Algal Blooms



These are obvious



It might look like this



Landsat Imagery

5.) It's Free!

www.earthexplorer.usgs.gov

The screenshot shows the USGS EarthExplorer website. At the top left is the USGS logo with the tagline "science for a changing world". Below it is the "EarthExplorer" header. The main content area is divided into several sections: "Search Criteria" with a "1. Enter Search Criteria" instruction, "Data Sets", "Additional Criteria", and "Results". The "Search Criteria" section includes a search box with "Denver" entered, a "Show" button, and a "Clear" button. Below this is the "Area Selected" section with a "Degree/Minute/Second" radio button selected and "Decimal" selected. The coordinates "1. Lat: 39° 44' 21" N, Lon: 104° 59' 05" W" are entered. Below that is the "Date Selected" section with "Search from: 01/01/1920" and "to: 03/13/2011" and "Search months: (all)". At the bottom of the search criteria section is "Number of records to return: 100". To the right of the search criteria is a "Search Criteria Summary (Show)" section with a "Clear Criteria" button. Below this is a map of the United States with a red pin on Colorado. The map shows state boundaries and names. At the bottom of the map is a "Google" logo and a disclaimer: "Map data ©2011 Europe Technologies, INEGI, MapLink, Tele Atlas, Mapbox, ©2011 NASA, TerraMetrics, Terra of US".

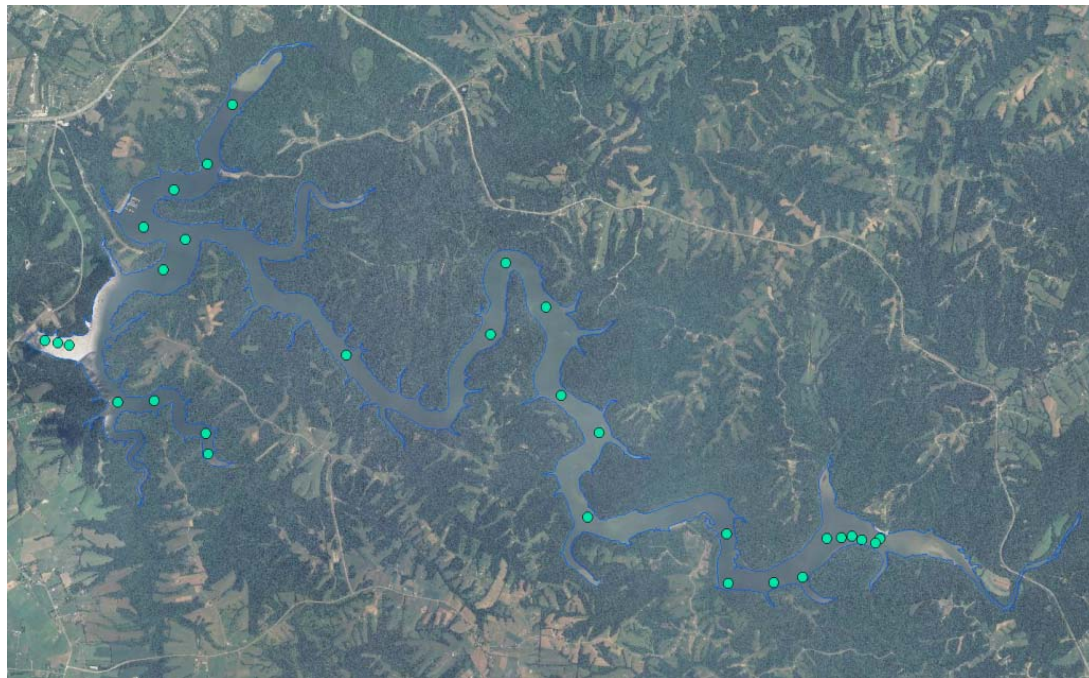
www.glovis.usgs.gov

The screenshot shows the USGS Global Visualization Viewer website. At the top is the USGS logo and the tagline "science for a changing world". Below it is the "Earth Resources Observation and Science Center (EROS)" header. The main content area is divided into several sections: "USGS Global Visualization Viewer" and "System Notices (2)". Below this is a "Collection Resolution Map Layers Tools File Help" menu. The "Downloadable" section is highlighted. Below this is a map of the United States with a yellow box on Colorado. To the right of the map is a "Scene Information" section with the following details: "ID: LT50260292011183PAC01", "Cloud Cover: 0%", "Qty: 9", "Date: 2011/7/2". Below this is a "Prev Scene" and "Next Scene" button. At the bottom of the scene information section is a "Landsat 4-5 TM Scene List" section with "Add", "Delete", and "Send to Cart" buttons. Below this is a "1000m No Limits Set" section. At the bottom of the page is a navigation bar with links: "Quick Start Guide", "User Guide", "What's New!", "Browser Requirements", "Download Source Code", "About Browse Images", "DOI", "USGS HOME", "Biology", "Geography", "Geology", and "Water".

Field Methods

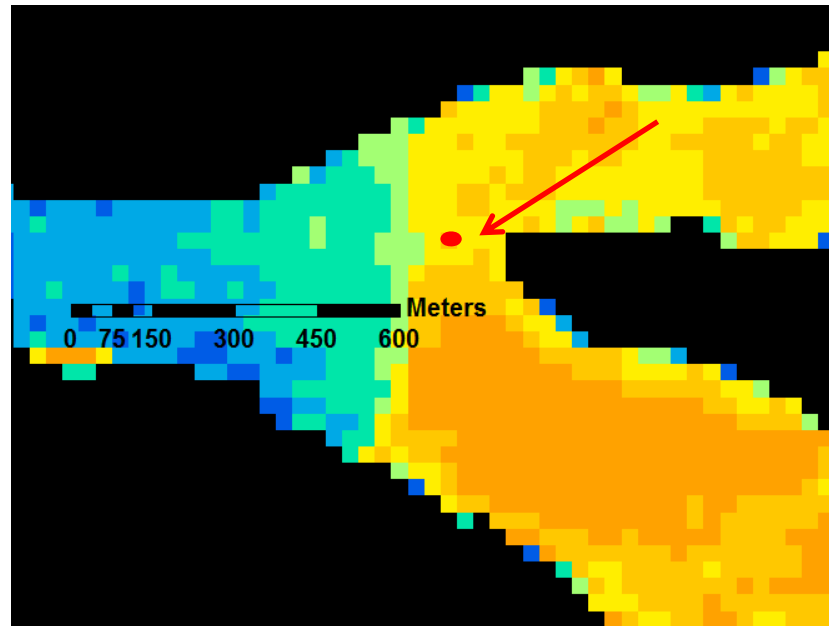
- Taylorsville Lake was sampled from georeferenced locations.
- *In situ* **chlorophyll a** and **secchi depth** samples were collected on the same day as the satellite fly over (± 3 days).

- 2014 – Phycocyanin samples to model cyanobacteria density



Remote Sensing

- Digital numbers were extracted at georeferenced sites using seven bands of Landsat 8 imagery data.



Digital Numbers

Band 1=10779
Band 2=9726
Band 3=8728
Band 4=7395
Band 5=7341
Band 6=5564
Band 7=5333

MLR Models

- **Employed Stepwise Multiple Linear Regression**

- Water quality variables as the dependent variable (chl a and total P)
- Bands 1-7 as the independent variables.

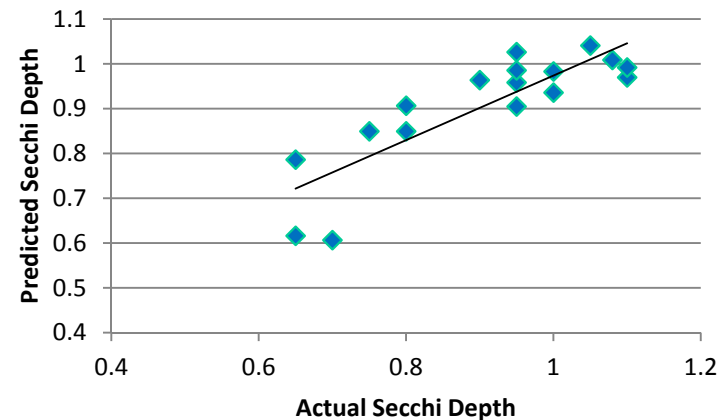
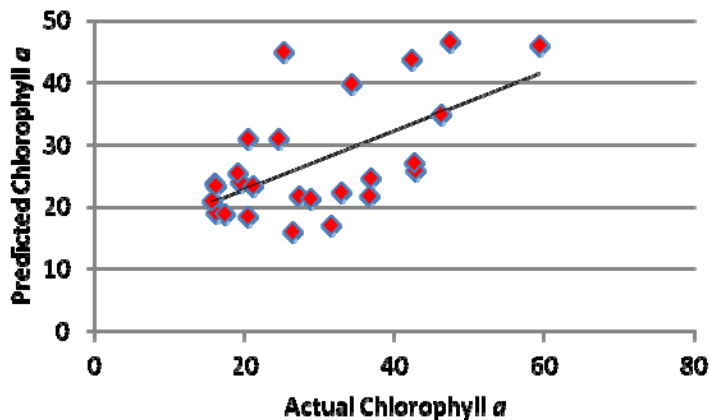
- **Used stepwise comparison of single bands and ratio of bands to find model with the best fit**

- $\text{Chl } a = 46.399 - (0.068 * \underline{\text{B3}}) + (0.108 * \underline{\text{B4}}) - (0.042 * \underline{\text{B6}})$

- (Adj R² = 0.60 p < 0.001 n = 27)

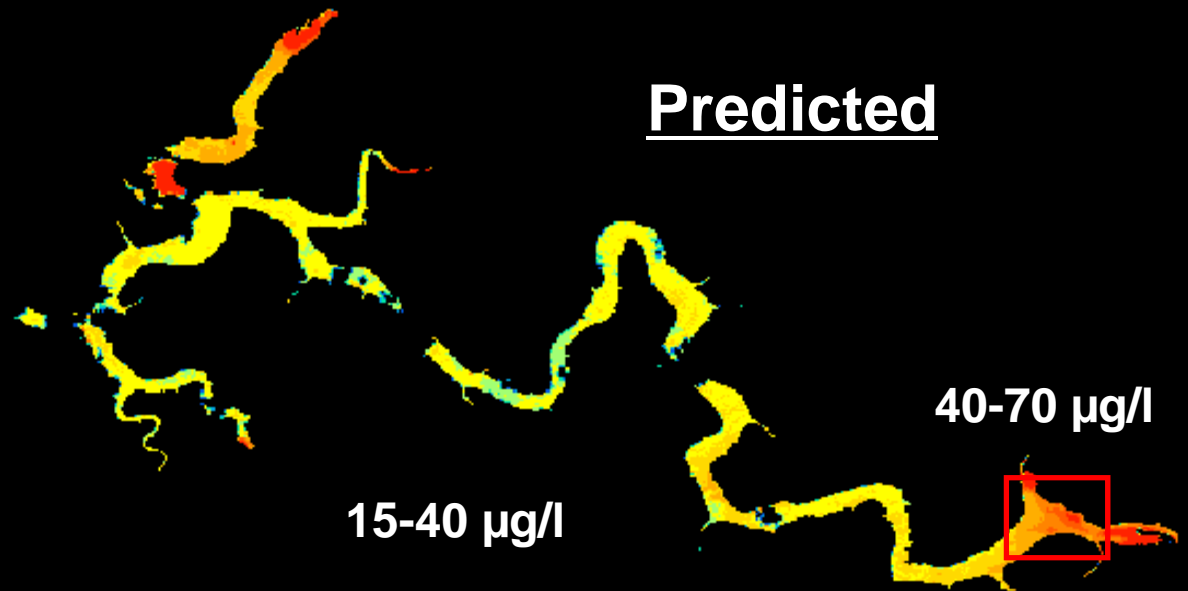
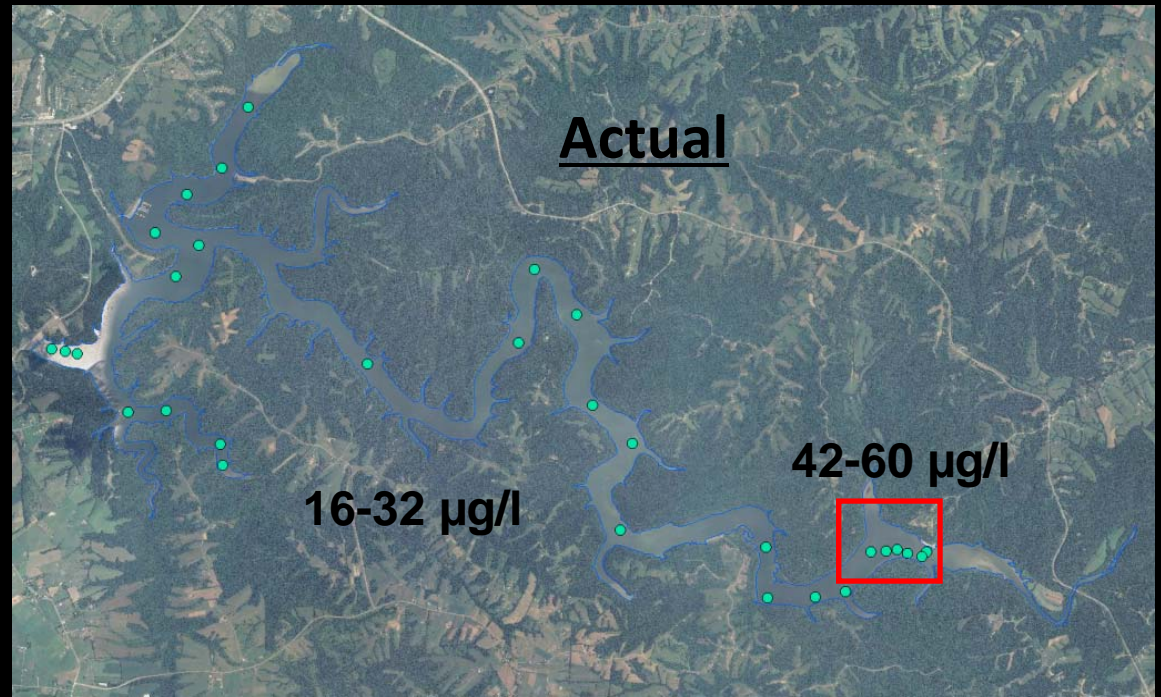
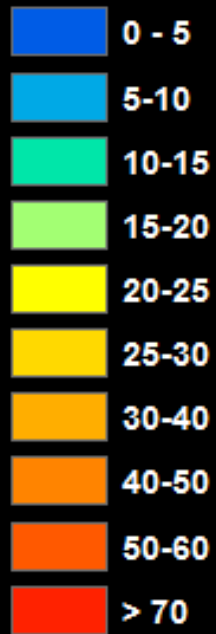
- $\text{Secchi Depth} = -3.4815 + (0.0021 * \underline{\text{B2}}) - (0.00157 * \underline{\text{B3}}) - (0.0004 * \underline{\text{B7}})$

- (Adj R² = 0.66 p < 0.001 n = 17)



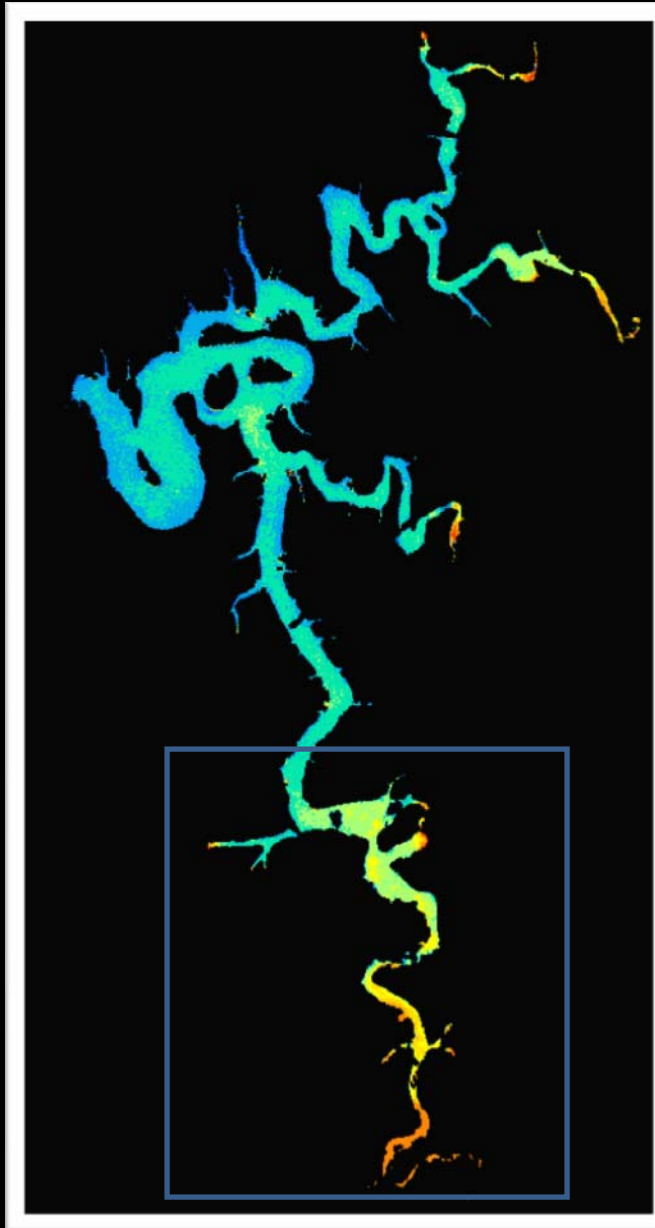
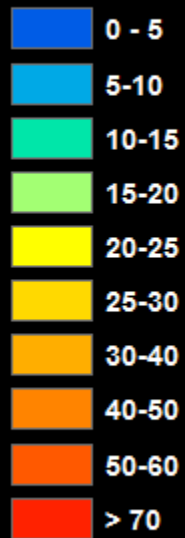
Taylorville Lake

Chlorophyll a ($\mu\text{g/l}$)

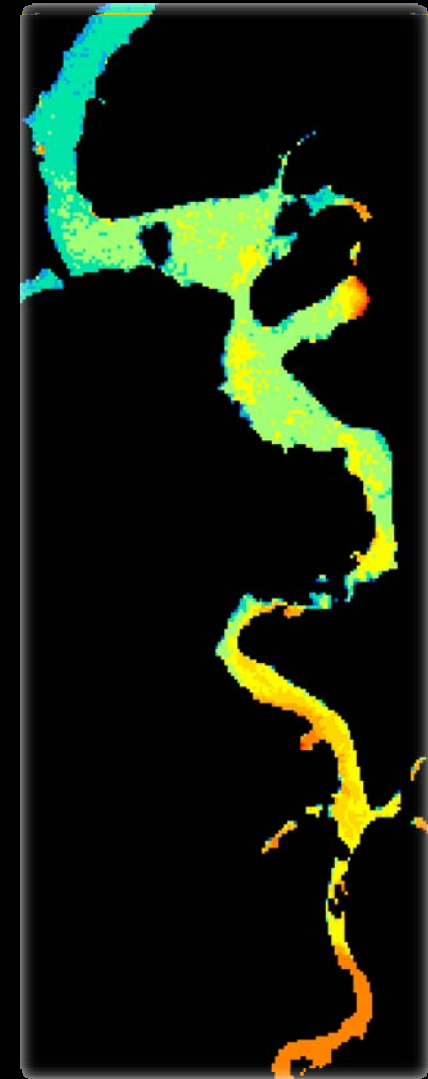


Barren River Lake

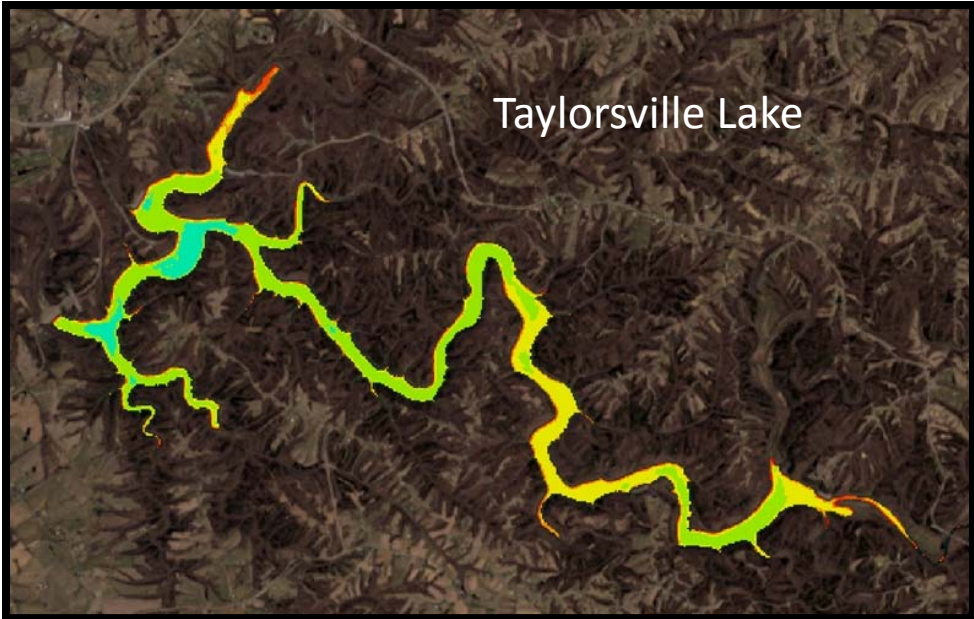
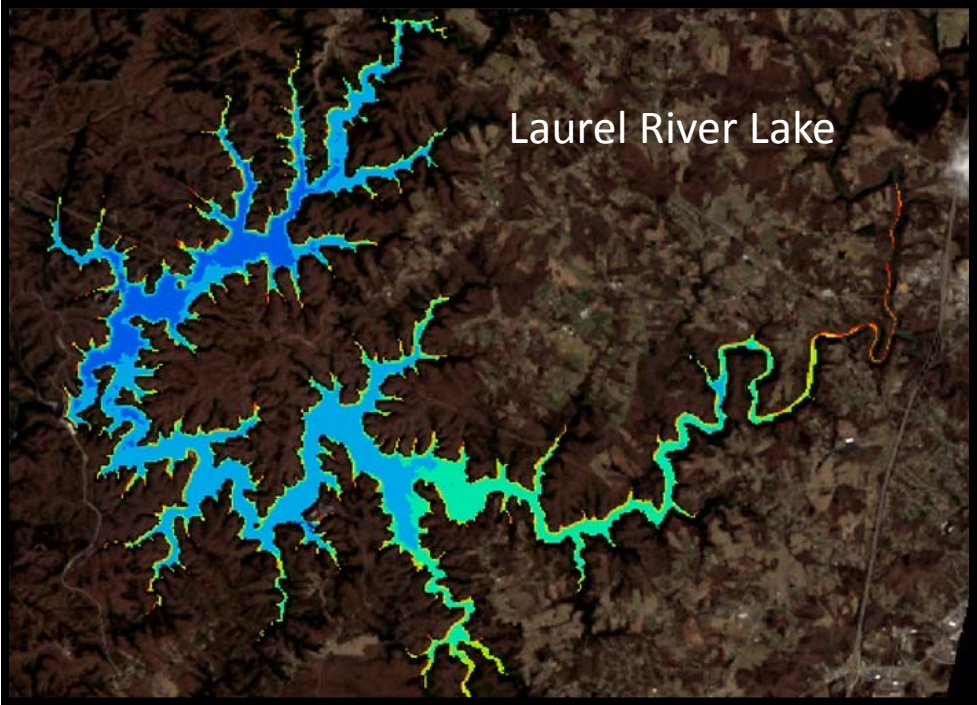
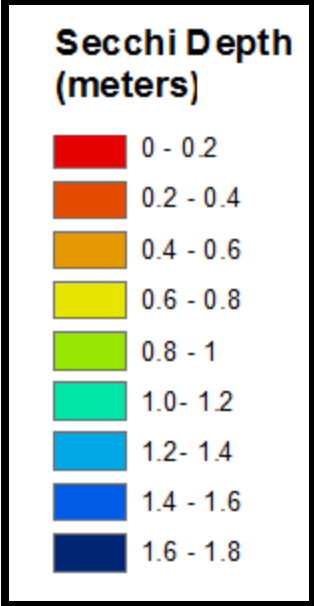
Chlorophyll a ($\mu\text{g/l}$)



-Geographic Differences
-Identifying Sources



Secchi Depth Model

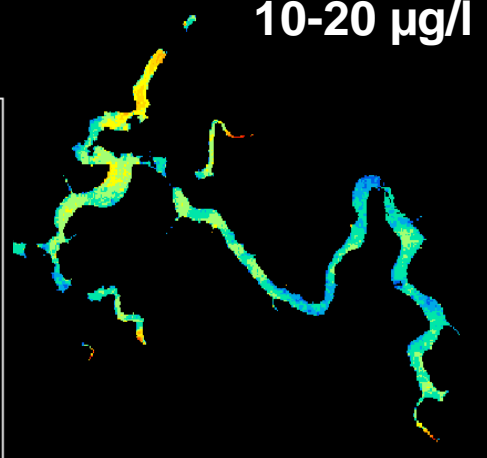
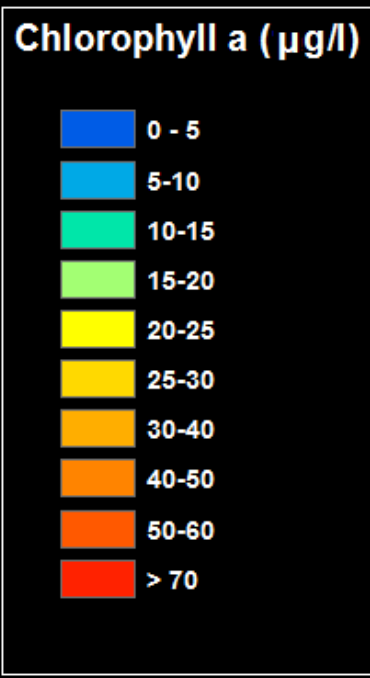


- Temporal Change
- Different Models

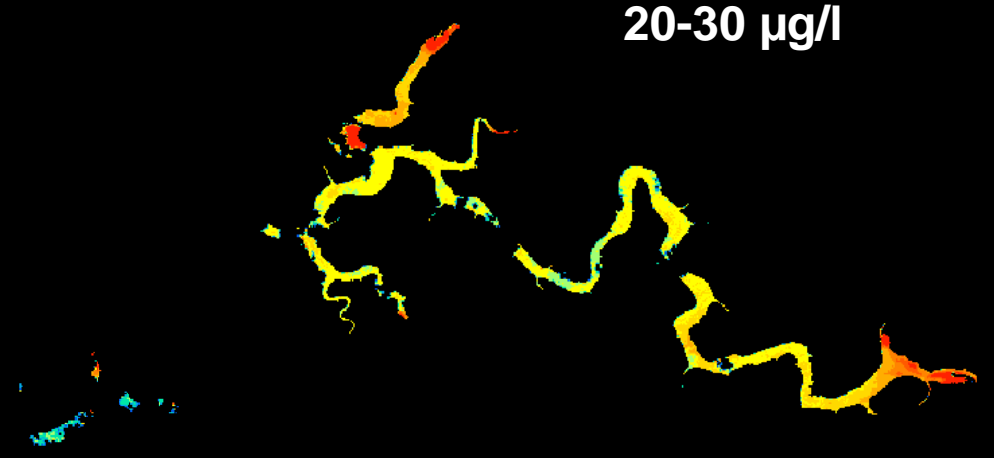
Taylorville Lake

10-20 $\mu\text{g/l}$

20-30 $\mu\text{g/l}$



July 29, 2013

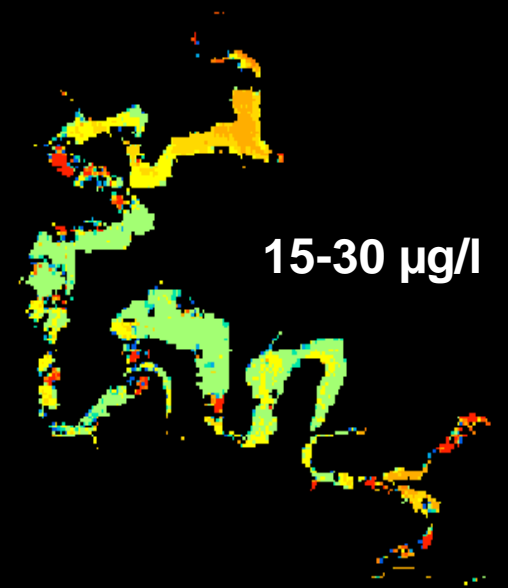
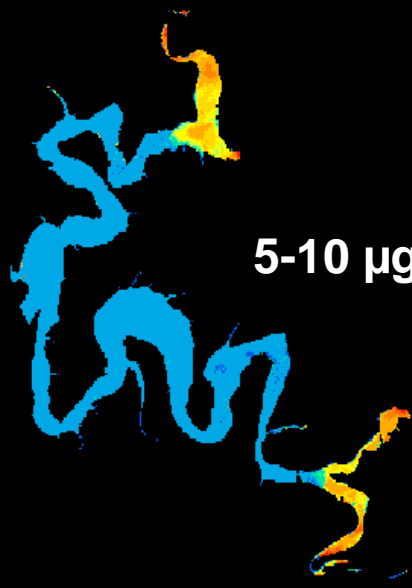


Aug 30, 2013

Green River Lake

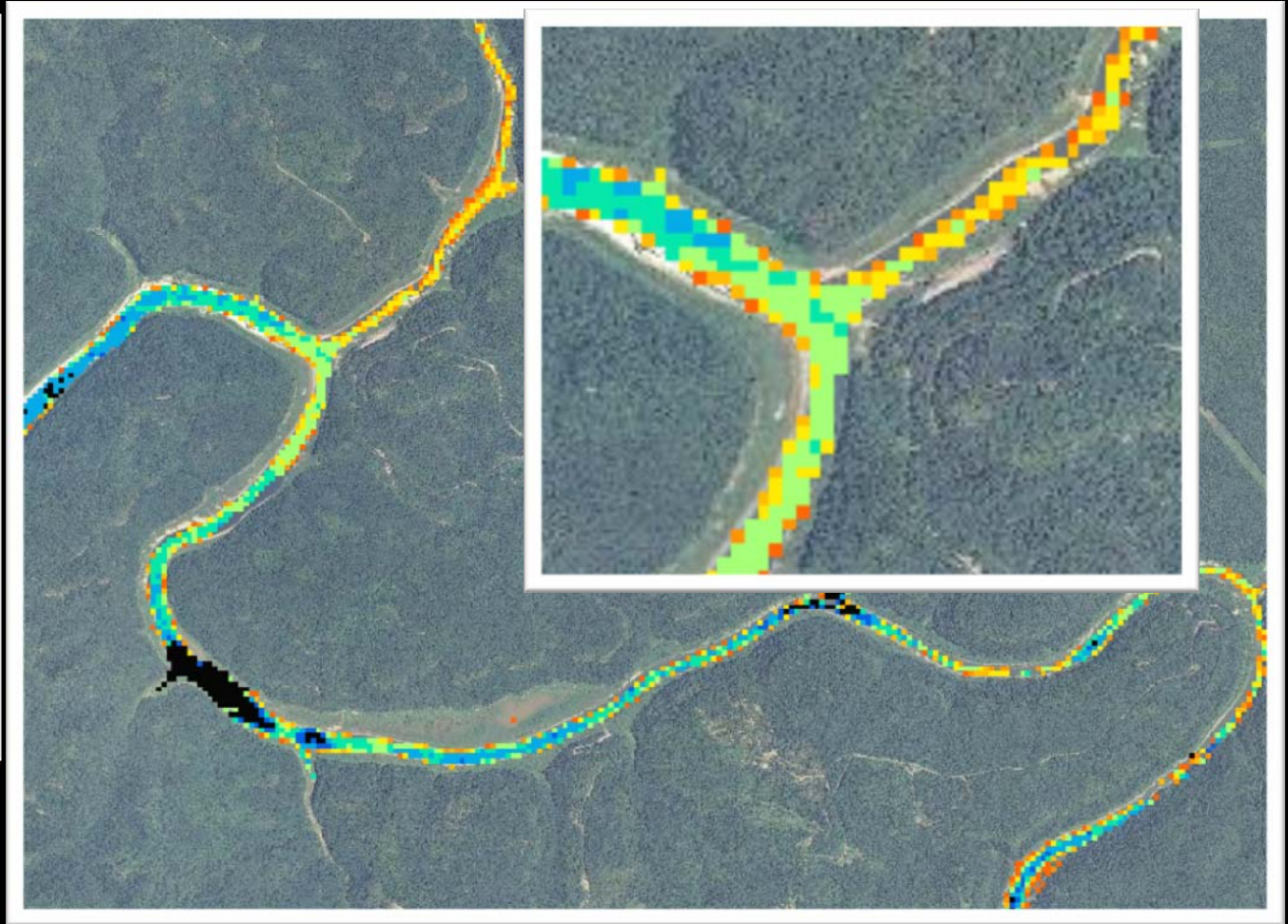
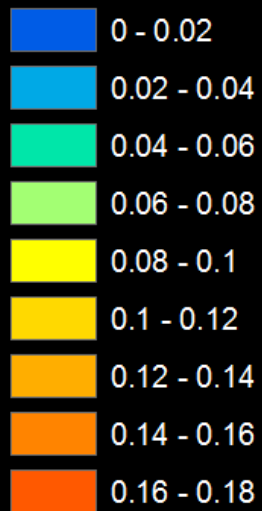
5-10 $\mu\text{g/l}$

15-30 $\mu\text{g/l}$



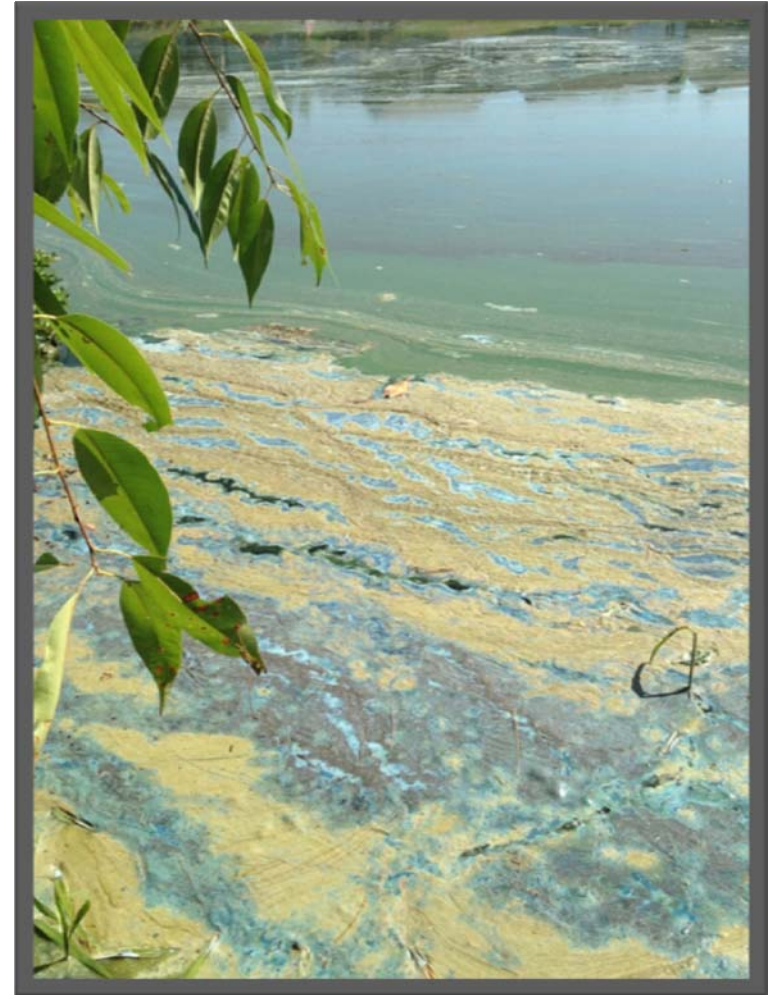
Cumberland River

Total Phosphorus (mg/l)



-More dynamic than lakes (flow and seasonal characteristics play a factor)

- **Able to monitor many environmental variables.**
- **Time and cost efficient.**
- **A useful tool to identify geographic and temporal water quality trends in lakes and some rivers.**
 - Regular observation.



Advances

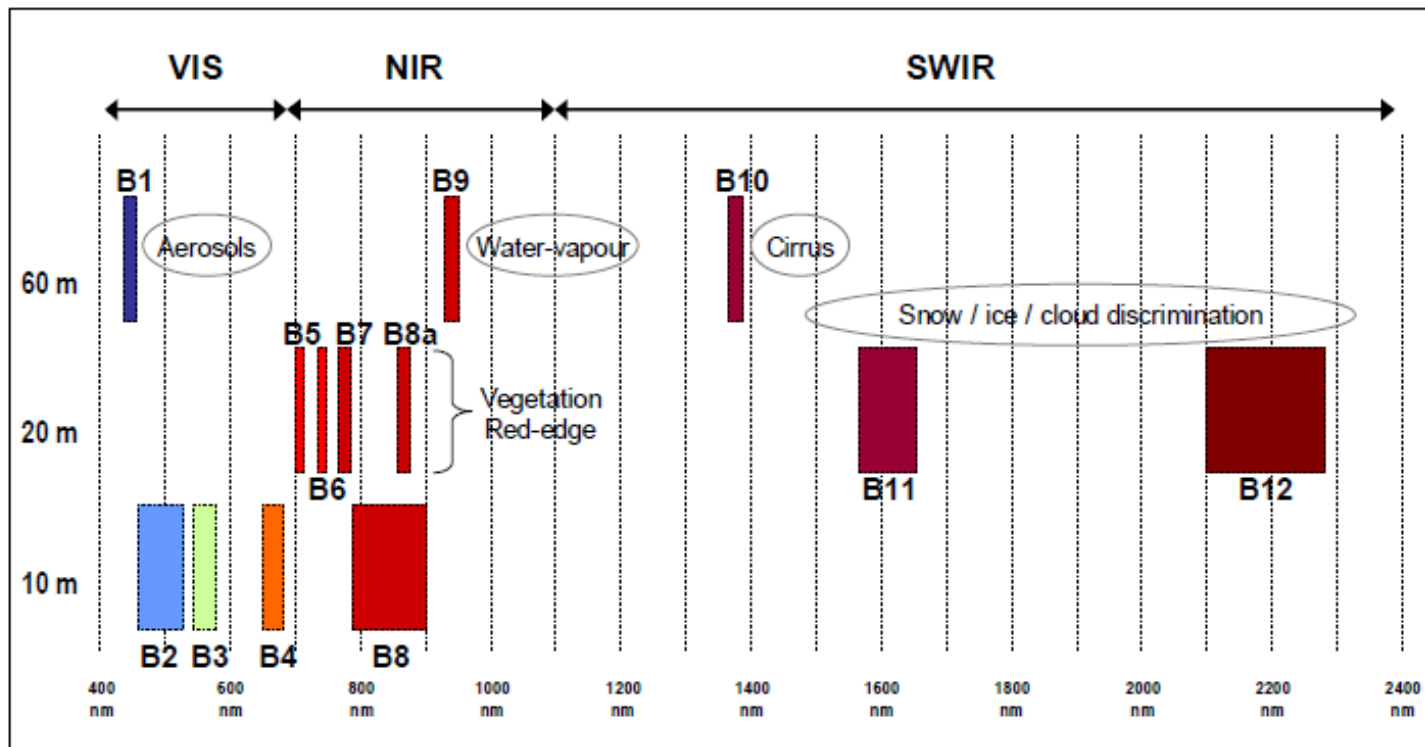


Un-manned Aerial Vehicles



Advances ESA Sentinel 2

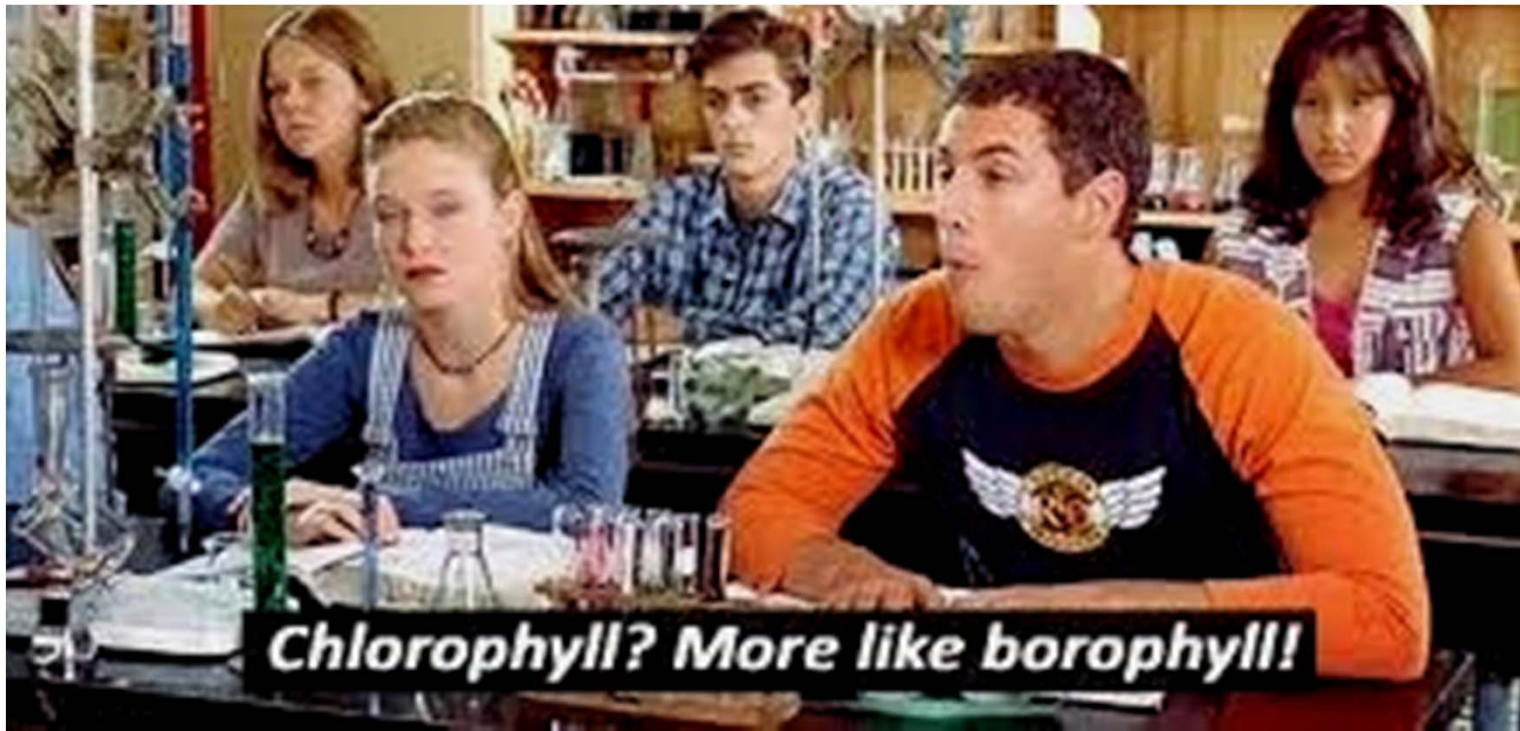
*Launches in 2015



Every 2-3 days



Thank You.



Questions?