Relationship Between Landsat 8 Spectral Reflectance and Chlorophyll-a in Grand Lake, Oklahoma

Presented by:

Abu Mansaray

Research Team

Dr. Andrew Dzialowski (PI), Oklahoma State University

Dr. Scott Stoodley (Co-PI), Oklahoma State University

Dr. Daniel Storm (Co-PI), Oklahoma State University

Dr. Nate Torbick (Co-PI), Applied Geosolutions

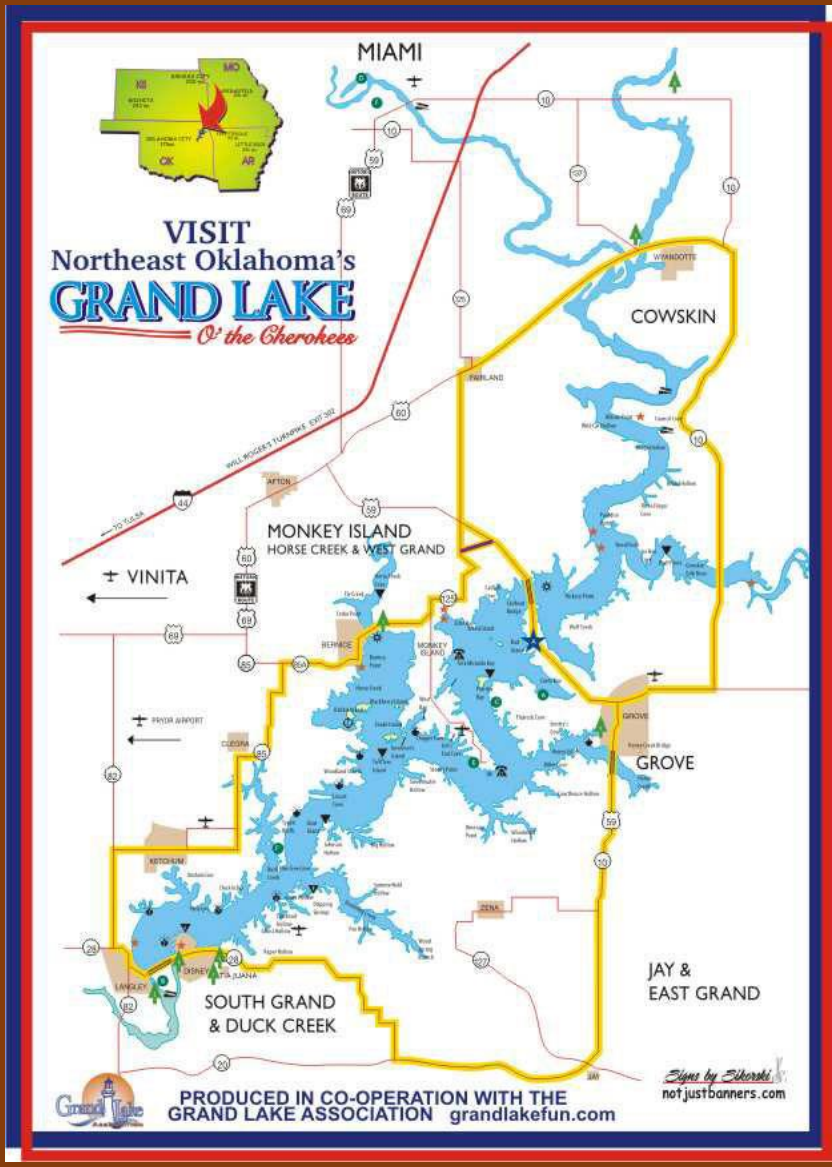
Abubakarr Mansaray (PhD Student), OSU, Environmental Science Graduate Program

Funding Provided by Grand River Dam Authority (GRDA)

Dr. Darrell Townsend, Steve Nikolai, and Dr. Rich Zamor

Grand Lake o' the Cherokees

- Located in Northeast Oklahoma in the foothills of the Ozark Mountain Range
- Administered by Grand River Dam Authority, an Oklahoma State Agency
- Pensacola Dam completed 1940
- 46,500 surface acres
- Designated Uses
  - Hydroelectric power
  - Flood control
  - Water supply
  - Recreation



http://mygrandlakehomes.com/

Grand Lake Water Quality Issues

- Blue-Green Algae Bloom, 2011
- Elevated Microsystin levels up to over 350 µg/l
- WHO – Adverse Health Effects when over >20 µg/l
- DEQ issued alert
- GRDA shut down the lake on July 4th 2011
- Monitoring Program has grown significantly (Townsend, OCLWA, 2014)

Grand Lake Project Objectives

- Relate *in situ* water quality data to spectral reflectance data
- Develop algorithms to predict water quality parameters based on an empirical model and semi-analytical shape derivative approach
- Spectral Data
  - Temporally and spatially corresponding Landsat satellite imagery
  - Landsat 8 OLI (Operational Land Imager) and historical Landsat 5 TM (Thematic Mapper) 30-meter resolution multispectral satellite imagery.
  - Proba CHRIS satellite observations
  - Develop semi-analytical algorithms for hyperspectral instruments

Water Quality Data — Remotely Sensed Data

Temporally & Spatially Coincident

Presentation Objective

- **Determine which Landsat 8 Surface Reflectance (SR) bands better predict CHL-a in Grand Lake, using the following datasets**
  - **8 bands of Landsat 8 SR values for Aug. 14th and Sept. 15th 2015**
  - **Temporally coincident *In situ* CHL-a data from 13 sampling points in the Grand Lake, Oklahoma**

Literature Review

- **Han & Rundquist (1997)**
  - NIR/RED (Band 5/Band 4) comparison
  - NIR/Red ratio not an effective algal-chlorophyll concentration predictor
- **Arenz Jr. & Saunders III (1996)**
  - NIR/Green (Band 5/Band 3) comparison
  - Strong relationship ($R^2 = 0.98$)
- **Pattiaratchi, Wyllie & Hick (2007)**
  - Combined Band 1 & Band 3
  - High predictive confidence
- **Torbick et al. (2013)**
  - Lake water Quality Mapping
  - Band ratio radiance models performed well ($R^2 = 0.65\text{-}0.81$)

Data Acquisition

- USGS Earth Explorer – downloaded Landsat 8 images in GeoTIFF format
- Created ArcMap project
- ESRI Image Classification tool
  - Created polygons at Sampling sites
  - Calculated mean reflectance per selected pixel
- Export analysis to MS Excel and combine with In-situ CHL-a data

Landsat Download Bands

Bands	Wavelength (nm)	Resolution (m)
Band 1 - Coastal aerosol	430 - 450	30
Band 2 - Blue	450 - 510	30
Band 3 - Green	530 - 590	30
Band 4 - Red	640 - 670	30
Band 5 - Near Infrared (NIR)	850 - 880	30
Band 6 - SWIR 1	1570 - 1650	30
Band 7 - SWIR 2	2110 - 2290	30
Band 8 - Panchromatic	0.50 - 0.68	15

http://landsat.usgs.gov/band_designations_landsat_satellites.php

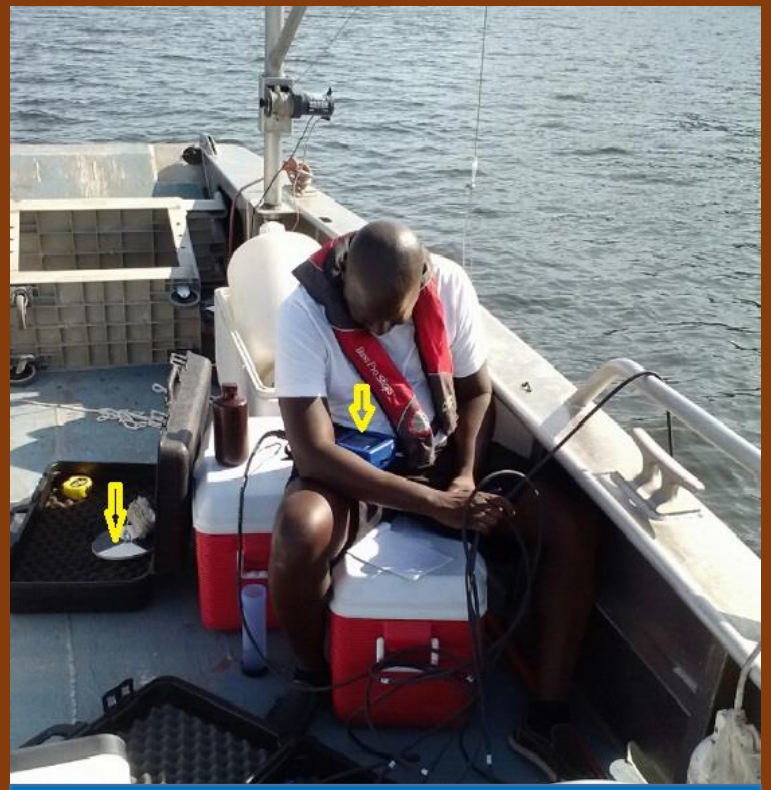
Water Quality Sampling: 2015 & 2016

1. Seasons
   - Spring, Summer, Fall
   - Capture spatial and temporal variability in water quality
2. Sample dates
   - Temporally coincident satellite overpass
   - Sampling begins just prior to satellite overpass and continues for a short period after
3. Alternative
   - +/- 2 days of individual satellite overpasses (acceptable)
   - Assumes no rainfall/runoff event

GRDA Designated 13 Sampling Sites

http://www.oclwa.org/pdf/2015Presentations

Field Sampling



YSI multi-parameter Sampler
Secchi Disc

Boat (GPS enhanced, bathymetry)

Van Dorn Sampler

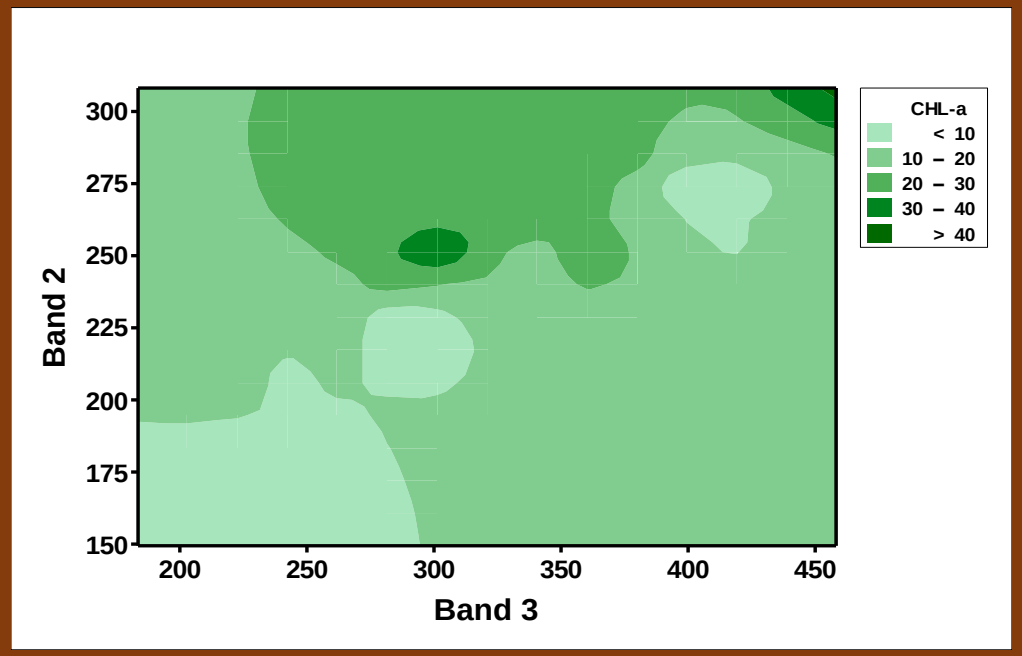
Sample bottles & Ice Chest
Water sampling Hose

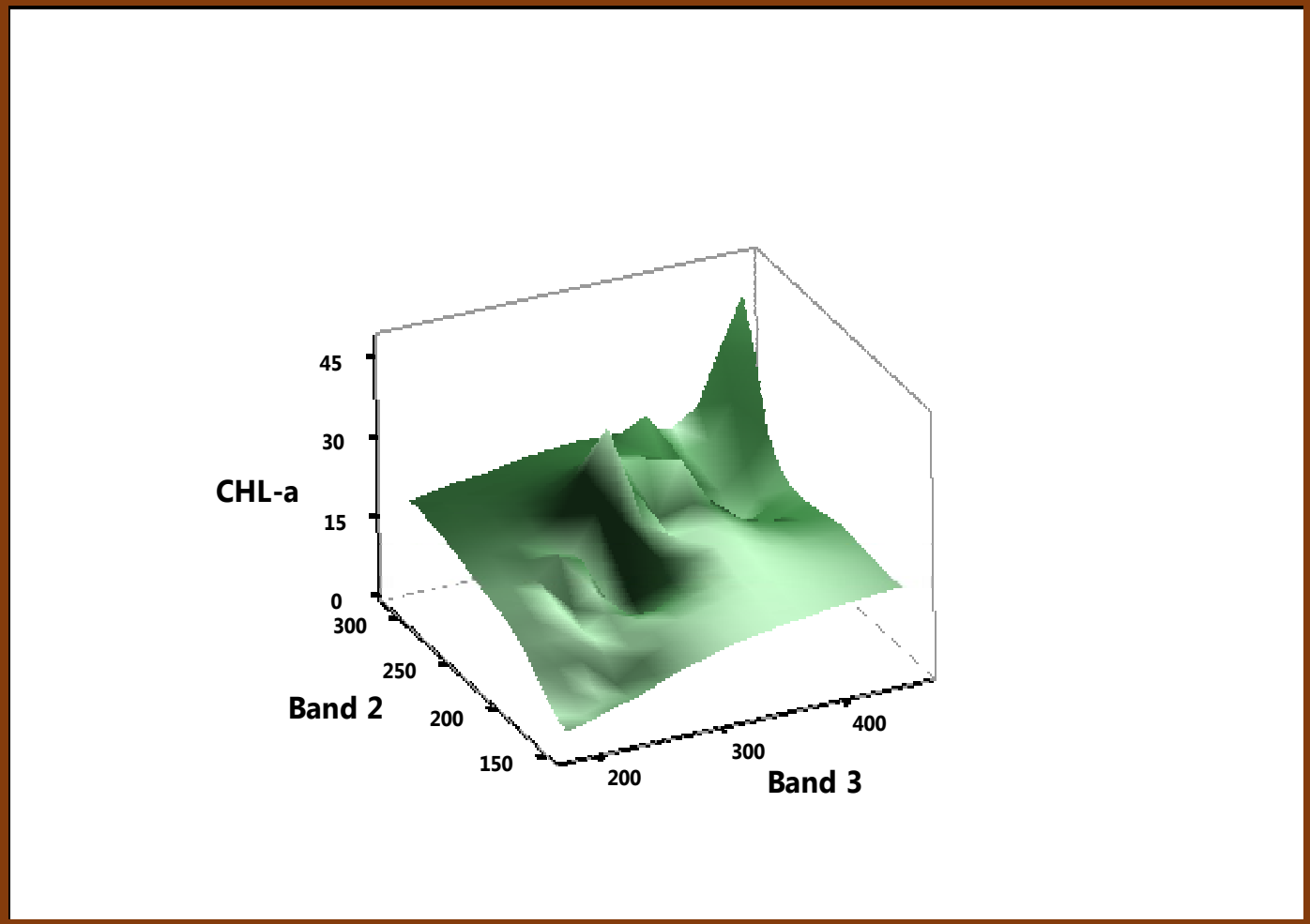
Laboratory Analysis for QA/QC Conducted

Statistical Analysis of Data

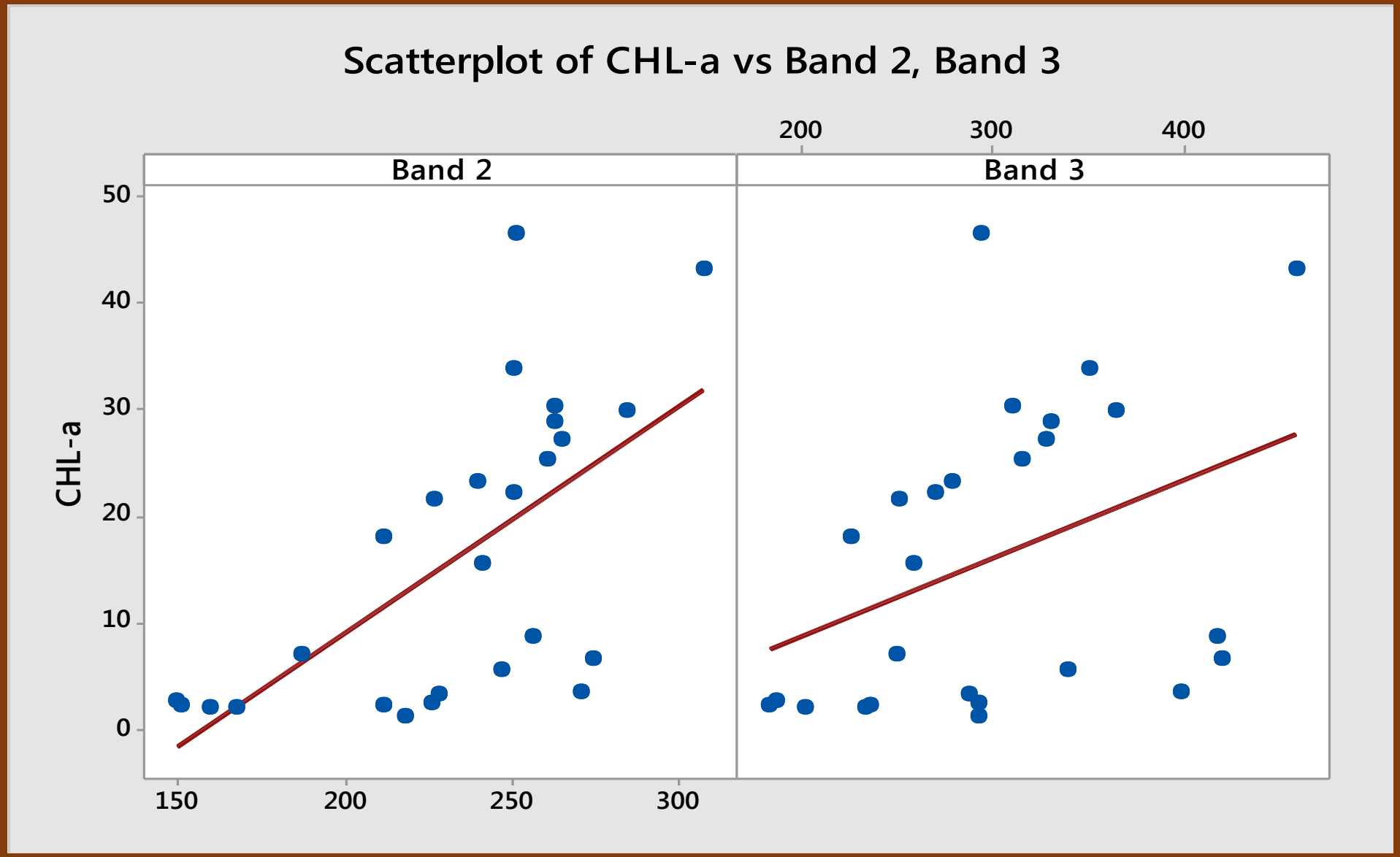
- **Regression**
  - **Chlorophyll *a* vs spectral bands**
  - **Stepwise elimination of bands**
  - **Band 2 (Blue) and Band 3 (Green) linear relationship**
  - **Equations**
    1. **CHL-a = 0.05456 Band 3**
    2. **CHL-a = -33.1 + 0.2105 Band 2**
    3. **CHL-a = -40.1 + 0.4138 Band 2 - 0.1349 Band 3**
    4. **CHL-a = 20.32 Band2/Band3**
- **ANOVA**
  - **Different combinations of Bands 2 and 3 with CHL-a**

Plot of CHL-a vs. Band 2, Band 3





Plot of CHL-a vs. Band 2, Band 3



Hypothesis

- **Null Hypothesis (Ho): Selected bands cannot be used to predict CHL-a (non-significant relationship)**
- **Alternative Hypothesis (Ha): Selected bands are good predictors of CHL-a (significant relationship)**
- **Test: Reject Ho if P–Value < 0.05**

Results of Regression Analysis

Equation	R^2 (%)	RMSE	b_0	b_1	b_2
Chl a = b_0 + b_1Band 2	40.00	11.05	33.10	0.211	-
Chl a = b_0 + b_1Band 3	63.40	12.99	0	0.055	-
Chl a = b_0 + b_1Band 2 + b_2Band 3	51.83	10.10	-40.1	0.414	-0.135
Chl a = b_0 + b_1Band 2 / Band 3	57.57	13.72	0	12.16	-

RMSE: Root Mean Square Error

Desired outcome: High R-squared, Low RMSE

Summary of Regression Results

- **Band 3 is a good predictor of CHL-a (p-Value < 0.05).**
  - **The equation accounts for 63% of the data**
- **Band 2 is a good predictor of CHL-a (P-Value < 0.05)**
  - **The equation accounts for 40% of the data**
- **Combining them gives a predictive potential in-between, with less RMSE**

Results of the ANOVA

Response variable	Treatment	Significant	p-value (α = 0.05)	
CHL-a (µg/L)	Date	Yes	<0.001	√
	Sample site	No	0.997	√
	Date, Sample site	No	<0.001, 0.077	
Band 2 (nm)	Date	Yes	0.005	√
	Sample site	No	0.274	√
Band 3 (nm)	Date	No	0.437	?
	Sample site	Yes	<0.001	?

Desired trend: change in SR values reflects change in CHL-a conc.

Conclusions

- Different Combinations of Landsat 8 SR values in Bands 2 and 3 enhance prediction of CHL-a in Grand Lake, Oklahoma
- The predictive equations account for at least 40% of the data
- Few data points were utilized, relationships will change with more data points
- No processing of SR data was done; relationships might improve with pre-processing

Next steps

- Collect more *in situ* data in 2016
- Pre-process spectral data and combine with *in situ* data
- Re-run the tests using more data points, with a more robust software
- Build predictive models

Thank you!