Assessing the Utility of Landsat 8 for Monitoring Cyanobacteria in the Great Lakes Region

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Landsat 8 image of Oneida Lake captured September 19, 2013

Outline

- Introduction
  - Landsat 8 improvements and takeaways
  - Quick background to water remote sensing
- Methods
  - Look-Up-Table approach
- Results
  - Modeled retrieval results
  - Preliminary imagery analysis
- Takeaways
  - Landsat 8 has the radiometric resolution and sensitivity to fully analyze standard water quality variables
  - Sensitivity plus 30 m spatial resolution provides unprecedented ability to work in inland waters and coastal areas

Landsat 8 improvements enable local water studies

- Added coastal band
- Improved signal-to-noise ratio (meeting minimum requirement)
- Increased radiometric resolution

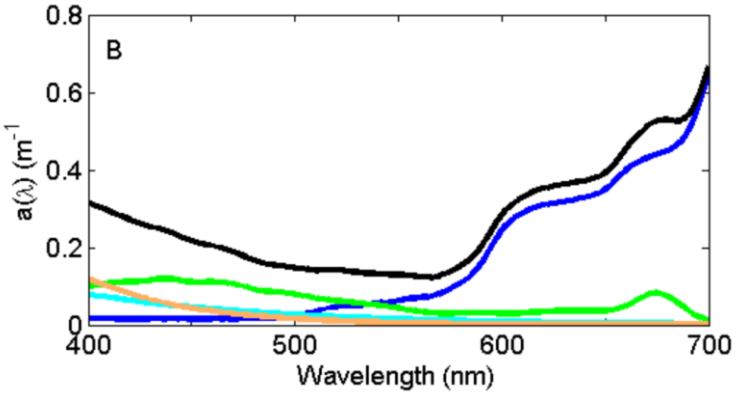
Combining Landsat 8 radiometric resolution and SNR with Landsat spatial resolution enables examining local water quality in small water bodies and coastal regions

Honeoye Lake, NY
Landsat 8 image
October 11, 2015

The red bar is 1 km

Quick background: Water remote sensing

- Primary constituent colorants (visible spectrum):
  - water
  - chlorophyll
  - suspended particles
  - colored dissolved organic matter
  - bottom reflectance



From Ocean Optics Web Book

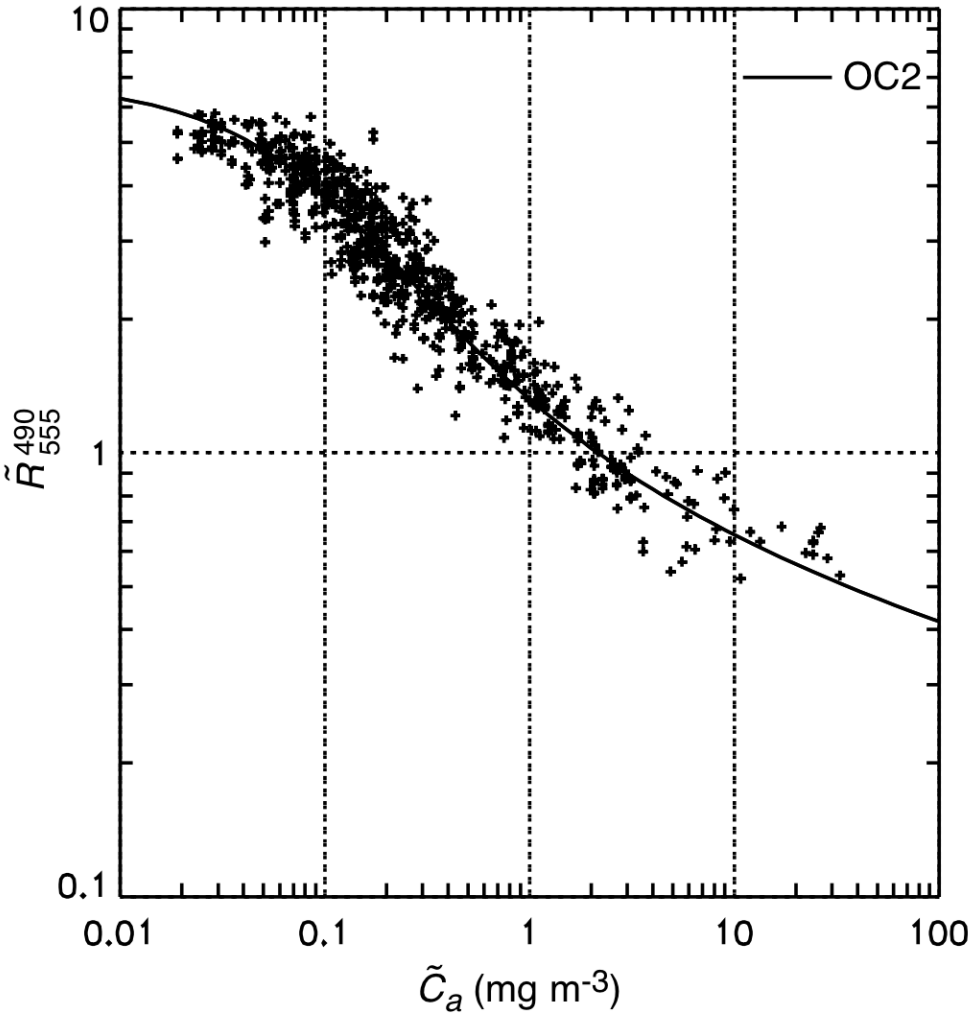
- Water color depends on absorption and scattering properties of the constituents
  - absorption and scattering are inherent optical properties (IOPs)
  - IOPs are variable (e.g. pigments, pigment packaging, particle size distributions, photobleaching)
  - IOPs are additive so determining constituents is an “unmixing” problem

Methods: The traditional ocean color algorithm approach

1. Reflectance ratios
2. Extensive reference data
3. Best fit curve
4. Similar approach for other variables

- Global empirical algorithms
- Nonlinear effects from multiple scattering and pigment packaging
- Variability treated as error?

Scatterplot of reflectance ratio versus chlorophyll-a concentration for the original SeaBAM data set (N = 919). The curve represents the OC2 algorithm. [Taken from NASA Tech Memo 2000-206892, Volume 11]



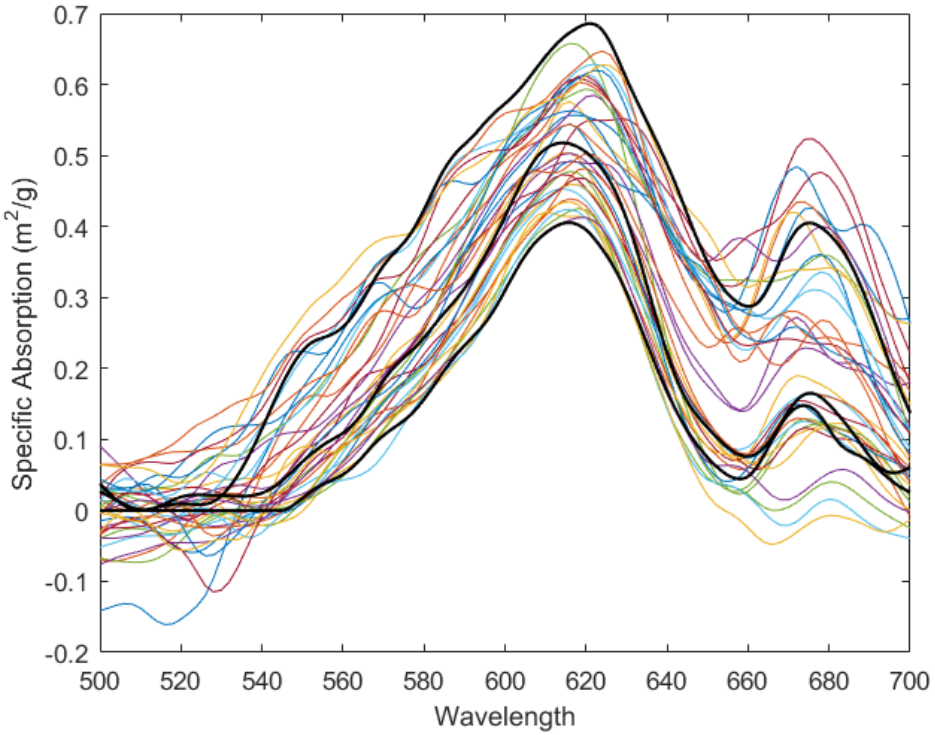
Methods: Look Up Table Approach

- Build a LUT by *forward modeling*
- Capture IOP variability in the LUT
- Retrieval is done with spectrum matching
- Caveats:
  - IOPs can be difficult to measure
  - garbage in, garbage out

Approach developed by C. Mobley and RIT

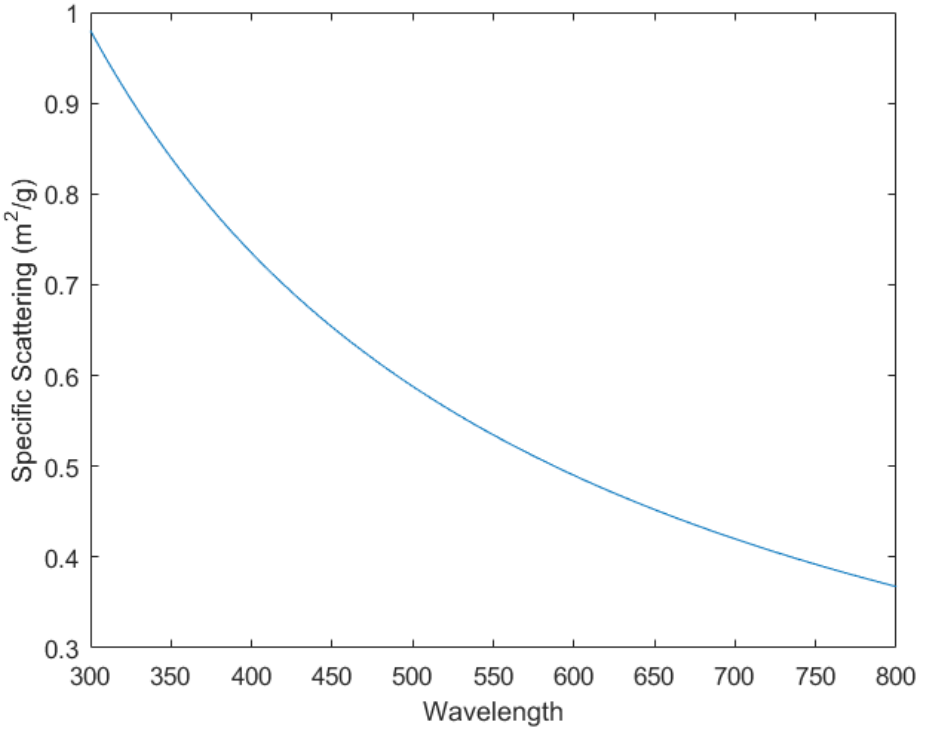
Methods: IOP variability example

Specific Absorption of Phycocyanin



Data from Nguy-Robertson et al. (2012)

Specific Scattering of Suspended Minerals



Data from Raqueño (2003)

Methods: R_{rs} Look-Up-Table (LUT) Generation

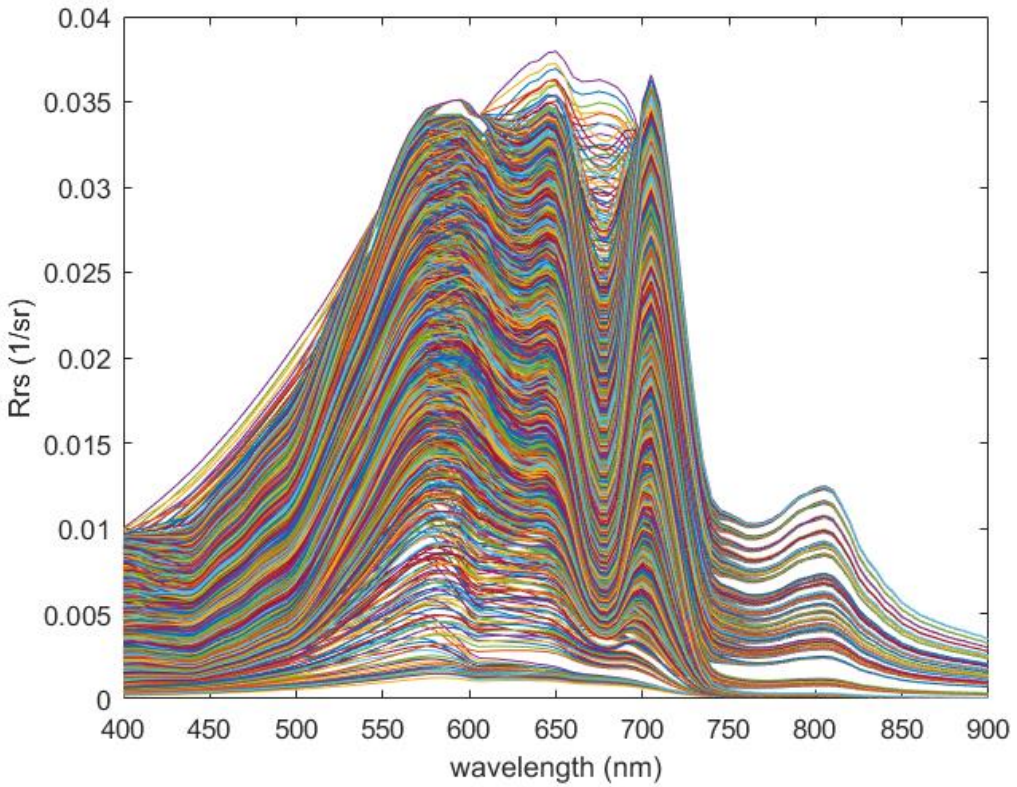
water, Chl-a, phycocyanin
suspended sediment, CDOM

Concentration Ranges

Absorption Ranges

Scattering Ranges

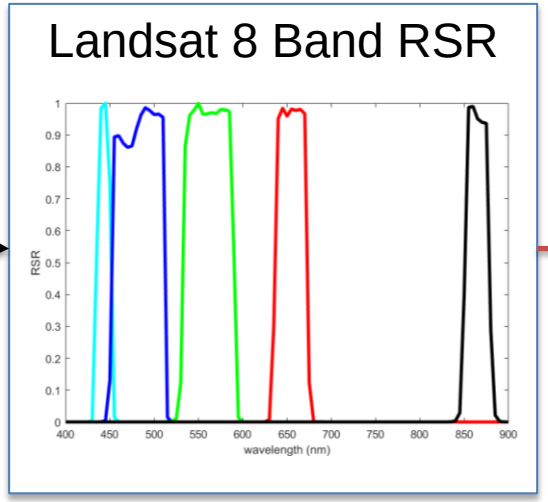
Phase Scattering Range

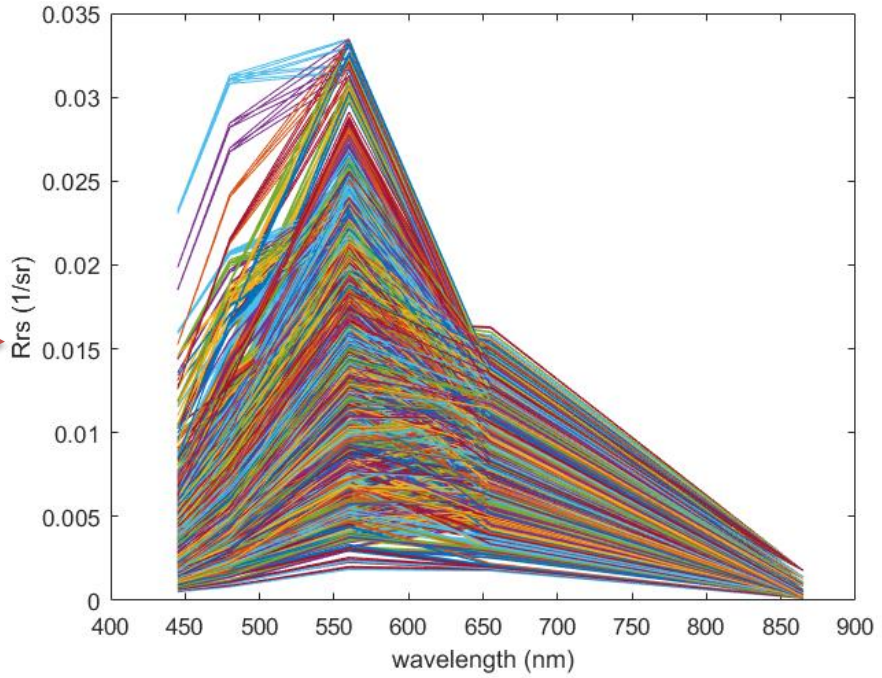


LUT size: 21,870 Runs

Methods: Resample spectral LUT

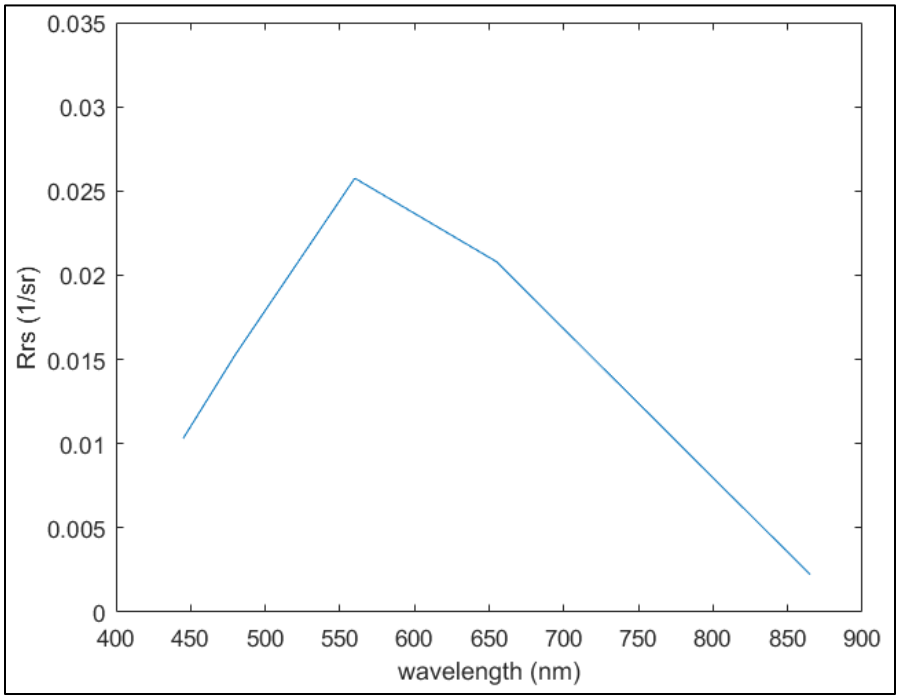
LUT Generation



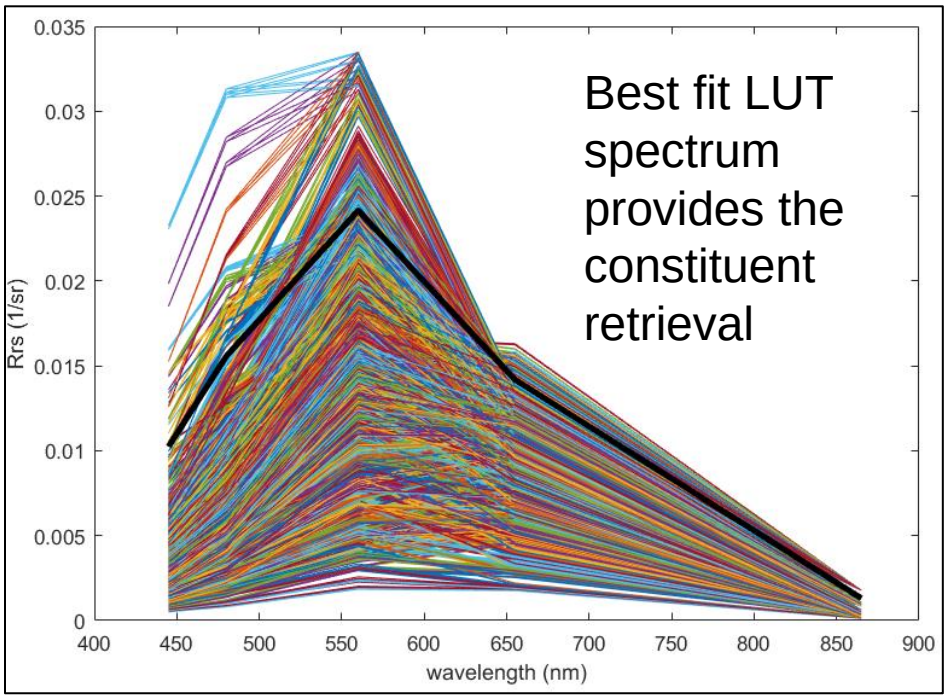


Methods: Matching Data to LUT

Test Pixel from Imagery

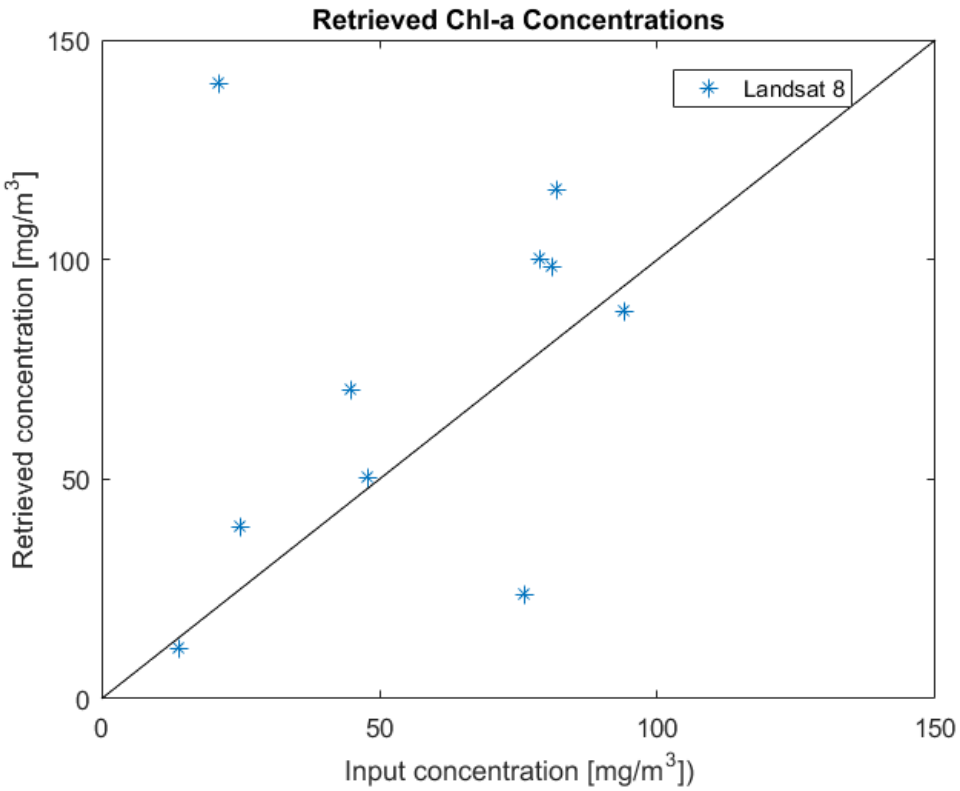


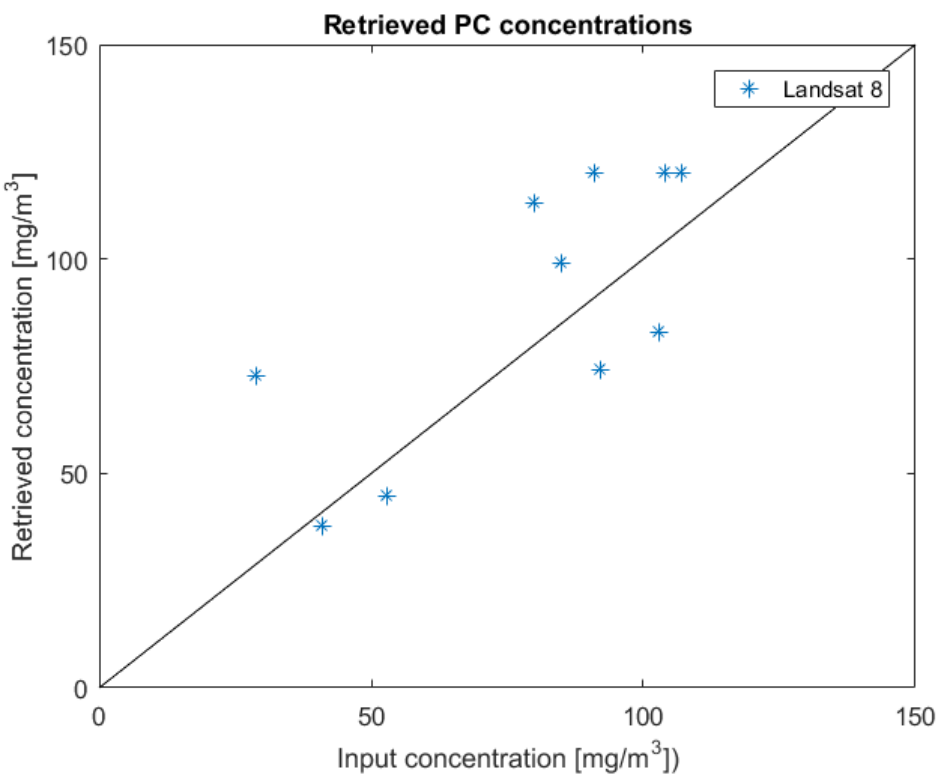
Best Fit Spectrum on LUT



RESULTS

Results: Constituent Retrievals (model to model)



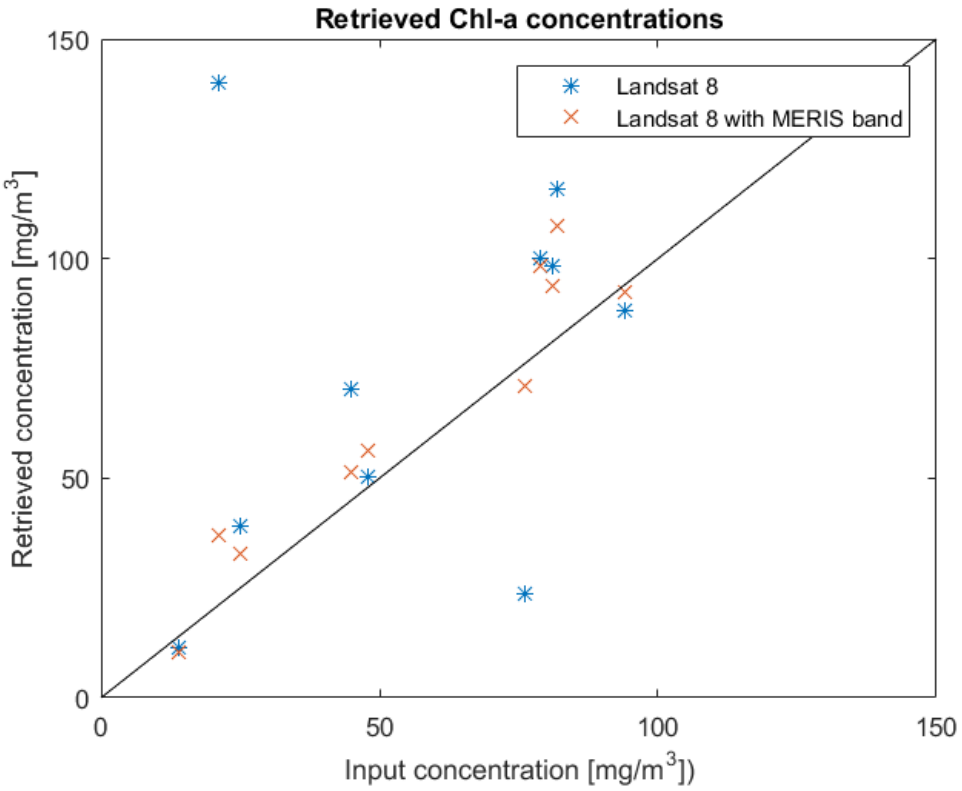


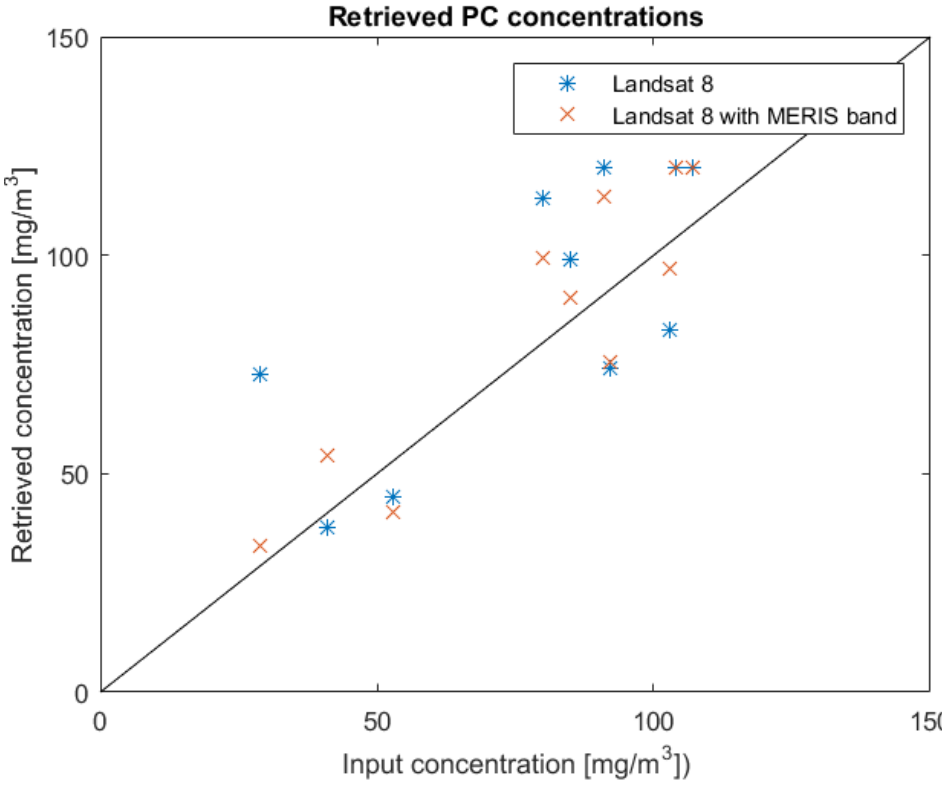
RMSE: 44.34

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{N}[C_{ret}(n) - C_{in}(n)]^2}$$

RMSE: 22.88

Results: Constituent Retrievals w/ MERIS Band (model to model)



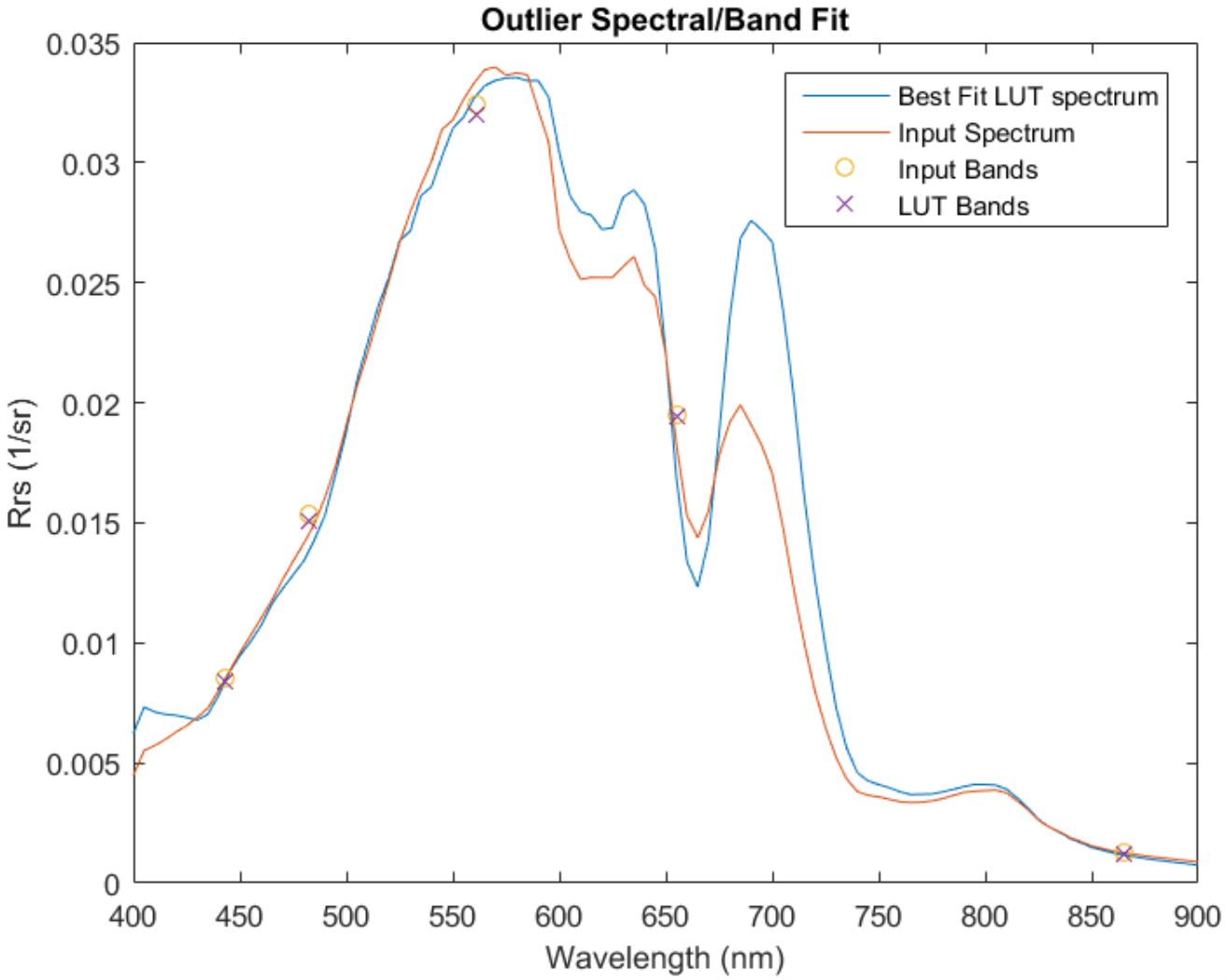


RMSE: 44.34
RMSE MERIS: 12.84

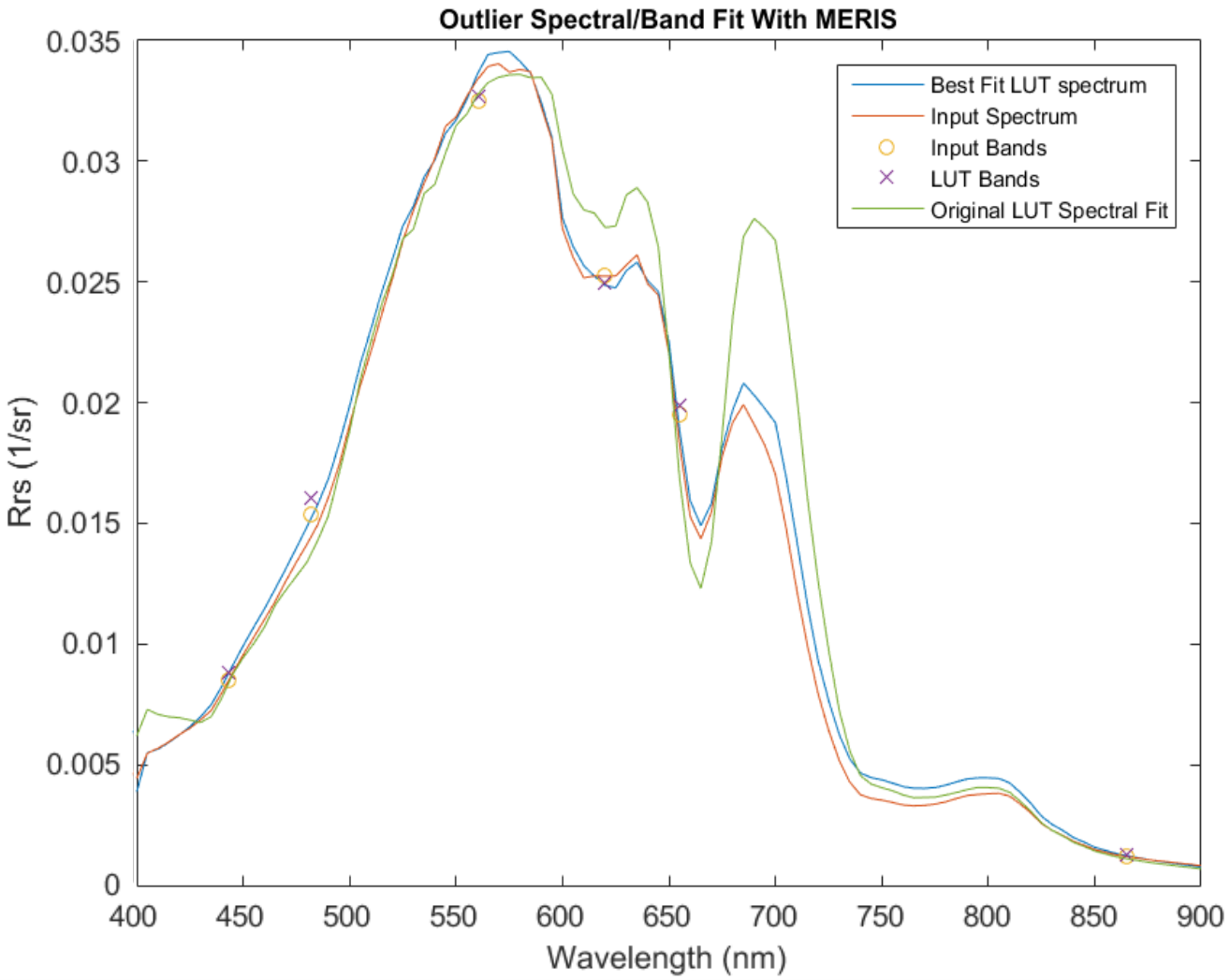
$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{N}[C_{ret}(n) - C_{in}(n)]^2}$$

RMSE: 22.88
RMSE MERIS: 14.03

Results: Outlier Chl-a Point (model to model)



Results: Outlier Point, w/MERIS (model to model)



Results: Honeoye Lake, NY 2015 cyanobacteria bloom

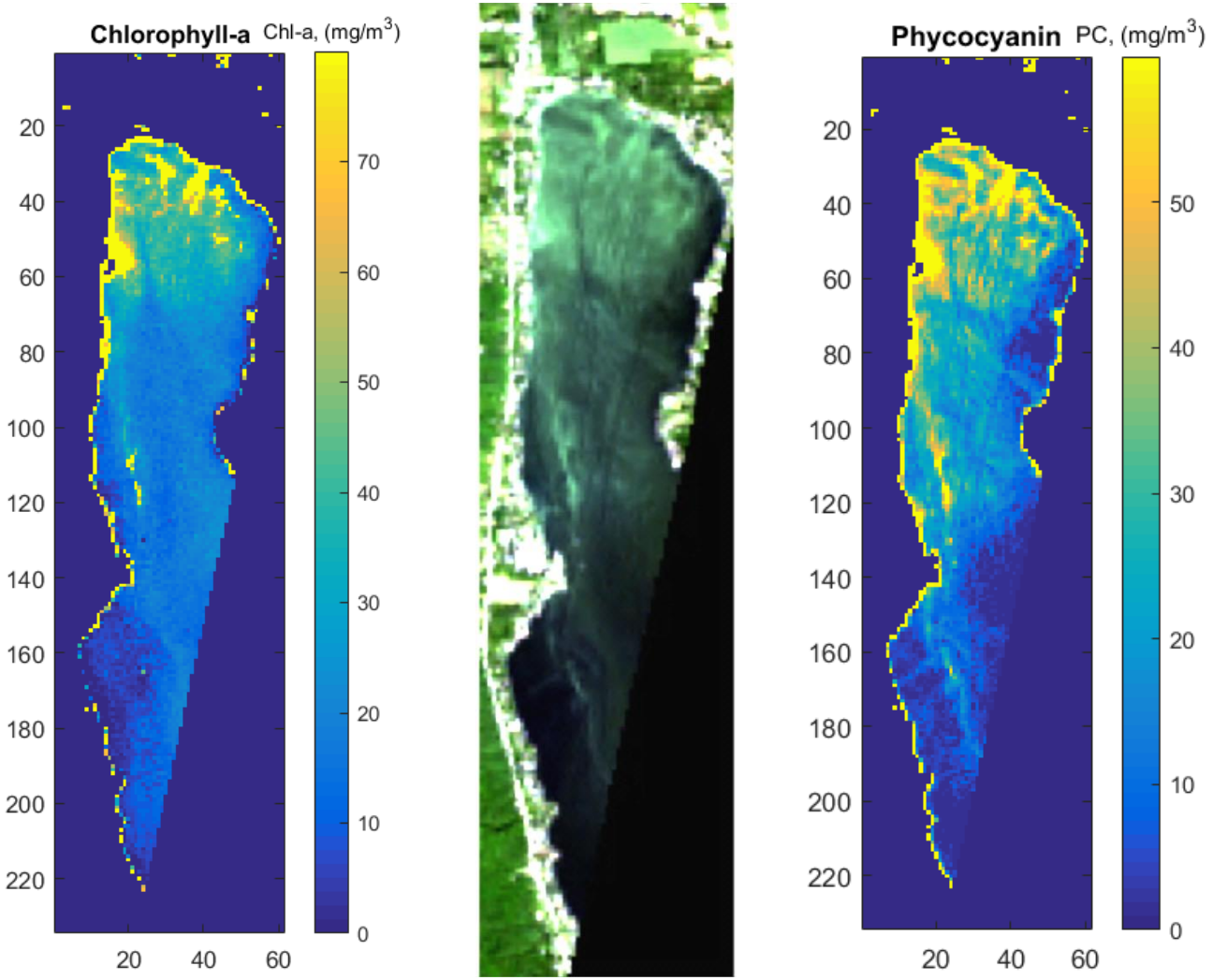
DEC Bloom Reported in Honeoye Lake from:

August 21, 2015
To
October 9, 2015

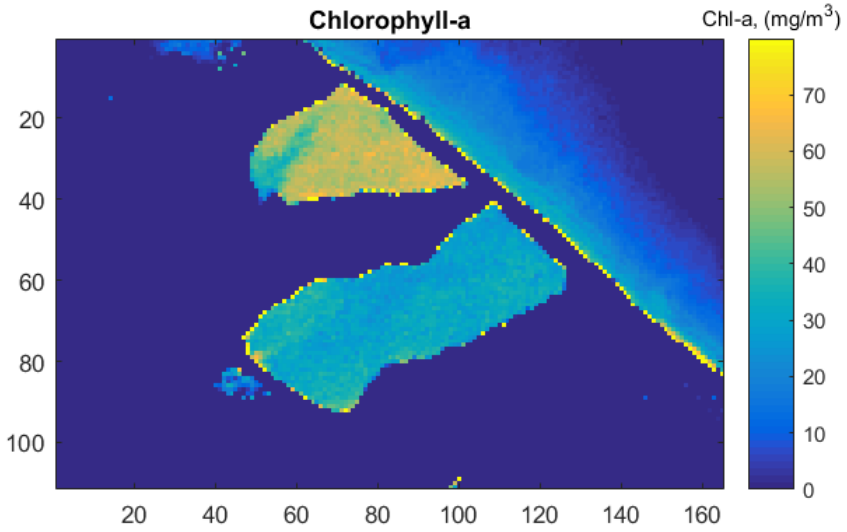
Left image is from Landsat 8 captured September 16, 2015

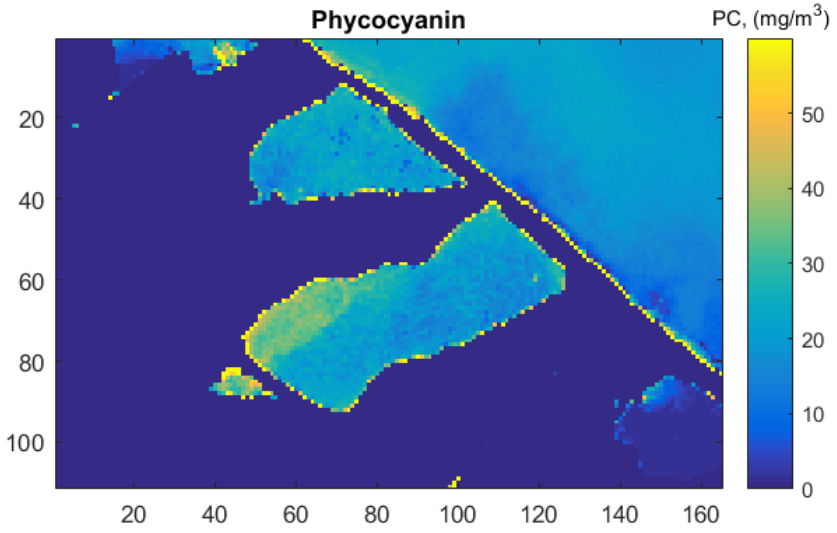
Right image is from Landsat 8 captured October 11, 2015

Results: Honeoye Lake, NY Chl-a and PC retrievals



Results: Long Pond/Cranberry Pond, NY Chl-a and PC retrievals





Takeaways

Current Status

- The combined Landsat 8 spatial and radiometric resolution is an enabler for inland and coastal water applications
- ESPA On Demand Interface is an enabler for local use

Ongoing Needs

- Adequate atmospheric compensation over water
- A yellow band at a minimum, spectrometer is better
- Better SNR will allow better retrievals
- More frequent imaging