Vicarious calibration and visible derivative spectroscopy to estimate the composition of the 2015 CyanoHAB in Sandusky Bay, Lake Erie

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CyanoHAB on Lake Erie September 3, 2011

(AGU Blogopshere)

Ortiz et al., (HyspIRI 2015)

Thanks to…

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Collaborators:

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Sea Grant

NASA

NATIONAL ESTUARINE RESEARCH RESERVE
OLD WOMAN CREEK
OHIO DIVISION OF WILDLIFE

Ortiz et al., (HyspIRI 2015)

Western Basin CyanoHAB during the 2014 Toledo Water Shutdown (1-3 Aug 2014)

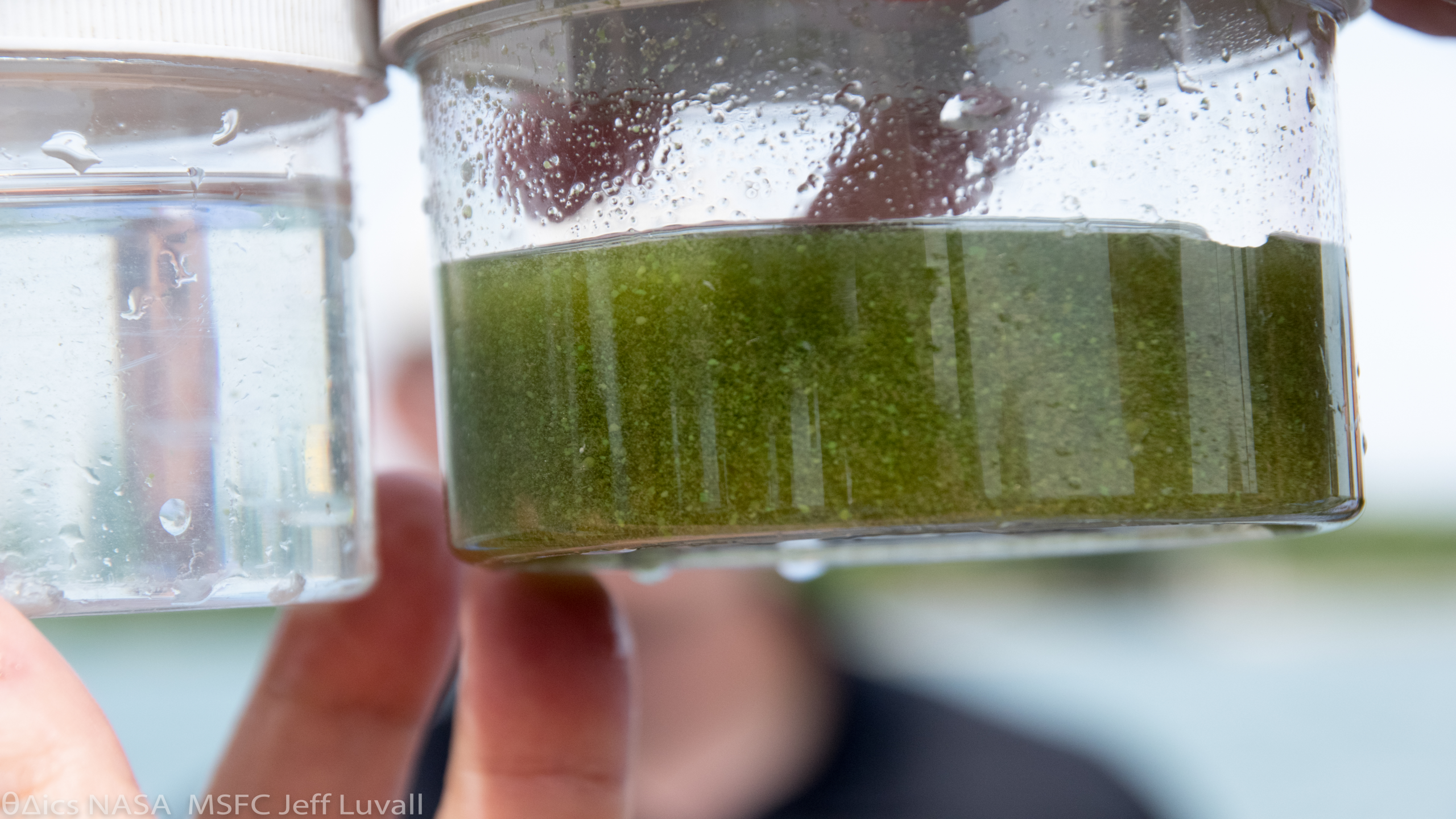
Algae surrounds Toledo's intake facility on Lake Erie on August 3.

People unload drinking water outside Waite High School in Toledo, Ohio, on August 3.

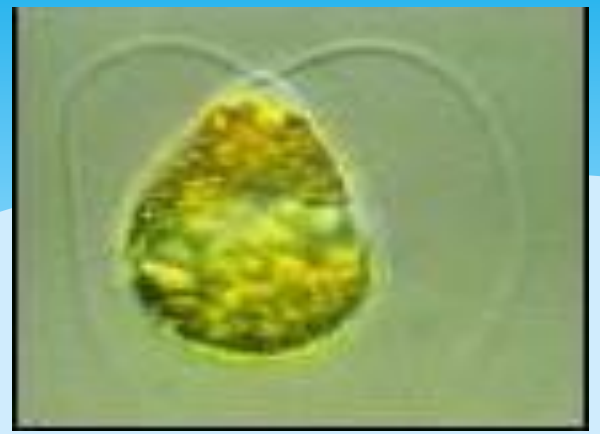
Source: Photos- P. Essick, National Geographic;
Related article: J.J. Lee, Aug 4, 2014 National Geographic News

Ortiz et al., (HyspIRI 2015)

θΔics NASA MSFC Jeff Luvall


θΔics NASA MSFC Jeff Luvall

Spectral identification of phytoplankton from space



- Different types of phytoplankton and cyanobacteria have different pigments.
- Pigments have specific absorption and reflectance patterns
- Spectral shapes can be used to identify different algal and cyanophyte phyla
- Capitalizes on all information available in hyperspectral-resolution spectra
- But, must unmix reflectance spectra

Graphics: Courtesy of NASA/GSFC.

Ortiz et al., (HyspIRI 2015)

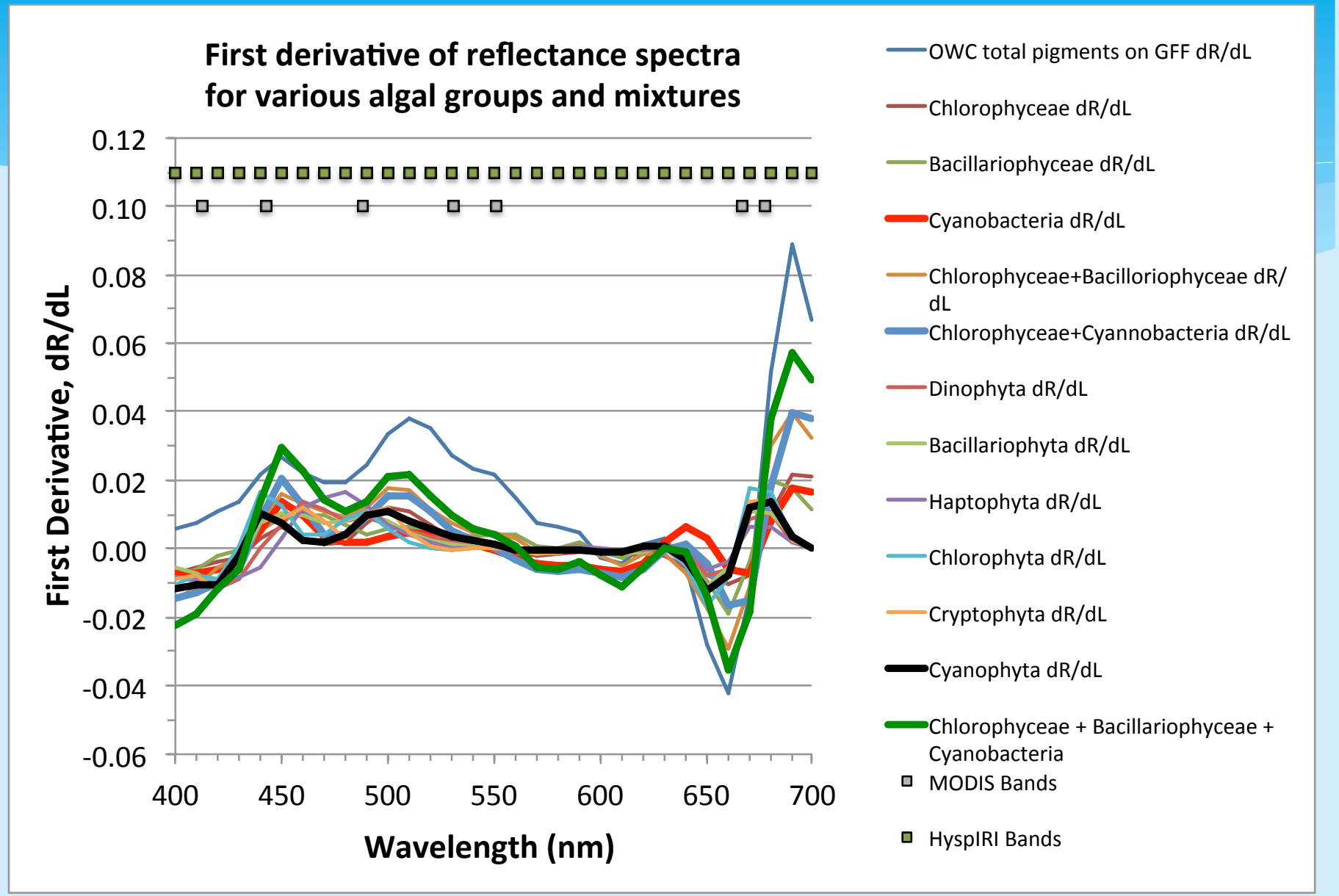
Monitoring by Remote Sensing? The problem…

- Remote sensing of lake color gives information on plant biomass, but…
- Lake water is a complex "organic soup"
  - Various types of phytoplankton
  - Colored dissolved organic matter
  - Suspended sediment
- Need a method to partition the variance
  - **Use VPCA Varimax-rotated Principal Component Analysis**

Ortiz et al., (HyspIRI 2015)

1st derivative

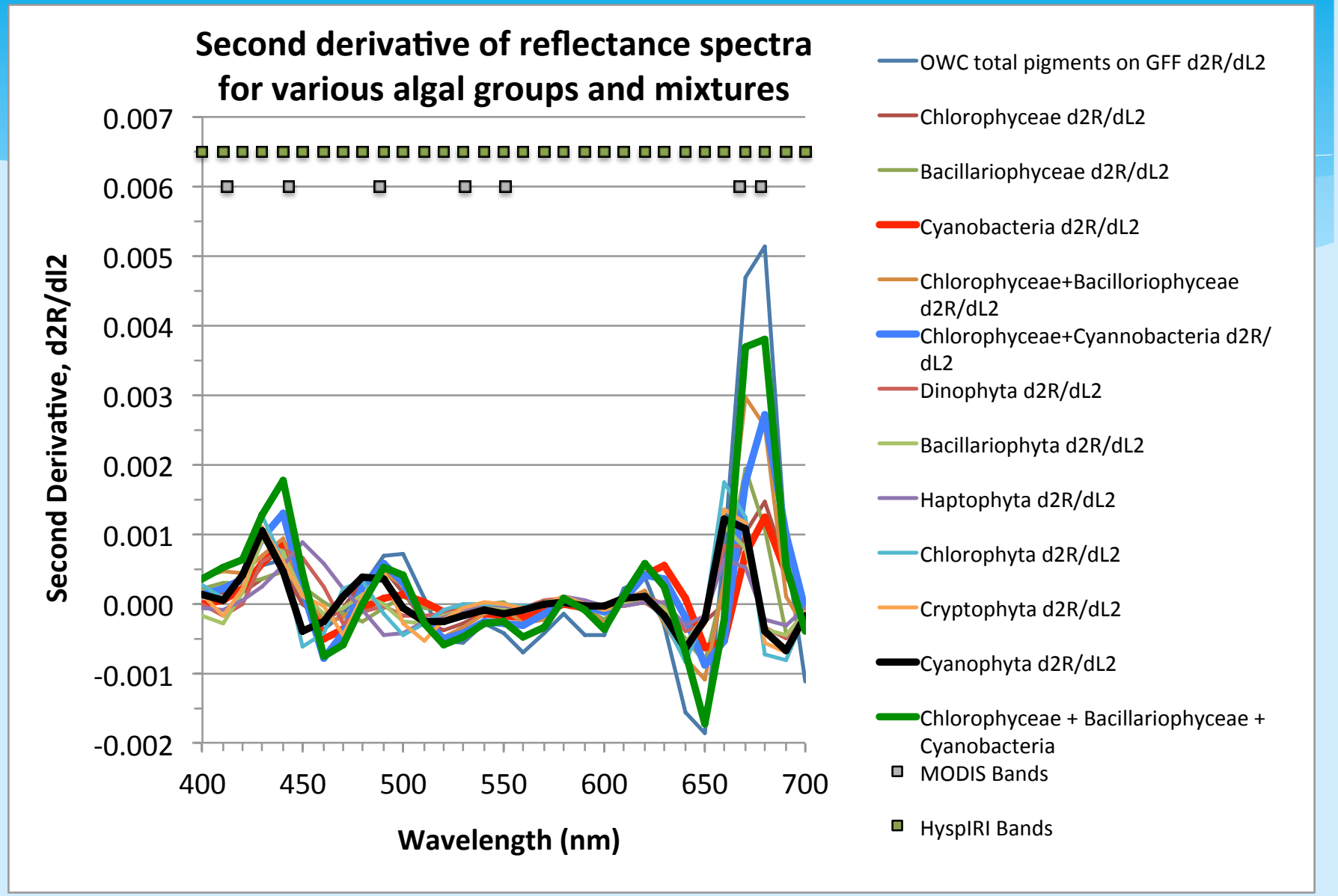
Provides information on different pigments and thus algal and cyanophyte composition



Ortiz et al., (HyspIRI 2015)

2nd derivative

Red Edge 2nd derivative provides information on algal and cyanophyte concentration and thus bloom intensity



Ortiz et al., (HyspIRI 2015)

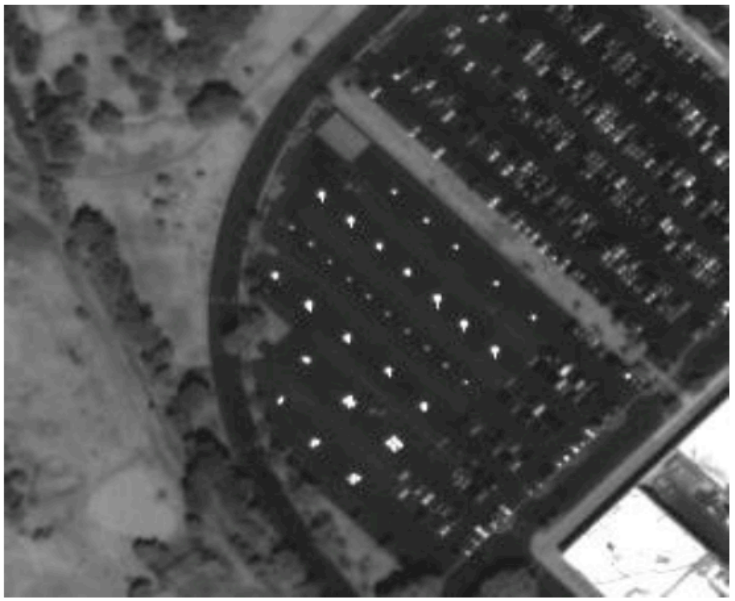
Mirror Based Atmospheric Correction or "White Reference" Calibration

- Provides information about atmospheric aerosol composition when used with MODTRAN or other radiative transfer code
- Provides basis for empirical calibration of radiance measurement from air-borne or space-borne assets
- Advantages that you obtain synchronous measurements of downwelling irradiance and upwelling radiance with the same sensor

Ortiz et al., (HyspIRI 2015)

SPARC Targets Isolate Direct Solar Signal From Background

po_365283



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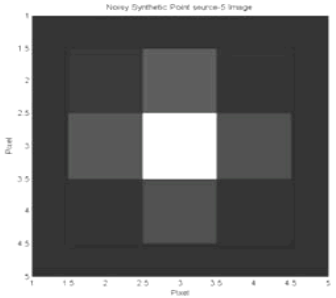
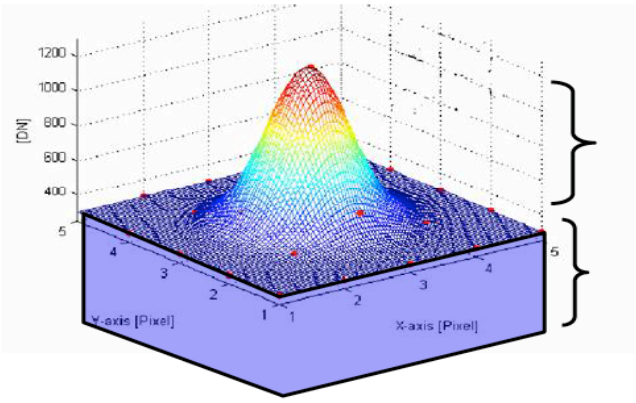


Image of target



Signal from specular target

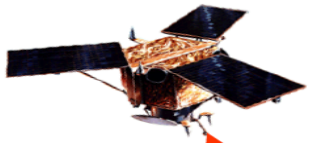
Signal from background surface, sky path radiance, adjacency effect, stray light, etc.

Limited direction of illumination causes SPARC targets to “turn off” when viewed outside the field-of-regard revealing background contribution

This reveals the potential to isolate the direct solar signal reflected by the SPARC target from the background based on image data alone

Schiller 2011

Transmittance Is The Only Atmospheric Component Affecting The Sensor Response To The Reflected Direct Solar Signal



Zenith

E_o – Top-of-atmosphere solar spectral irradiance

$\tau_{\downarrow}$ – Sun to target transmittance

$\tau_{\uparrow}$ – Target to sensor transmittance

θ_{sen}

θ_{sun}

ρ– Specular Reflectance

Total Transmittance

$$\tau = \tau_{\downarrow}\tau_{\uparrow} = \tau_{oz}\tau_{aero}\tau_{H_2O}\tau_{Rayleigh}$$

For spectral bands in which the extinction law applies

$$\tau_{\downarrow} = e^{-\delta \sec\theta_{sun}} \qquad \tau_{\uparrow} = e^{-\delta \sec\theta_{sen}}$$

or

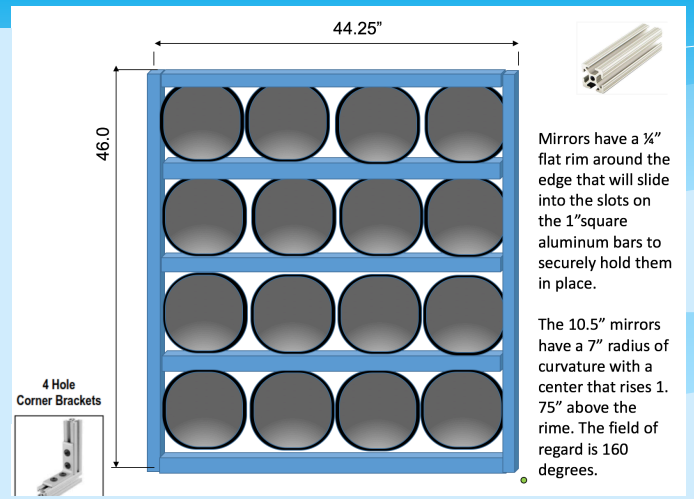
$$\tau = e^{-\delta(\sec\theta_{sun} + \sec\theta_{sen})}$$

δ = Vertical Optical Depth in a uniform atmosphere

Outcome is the potential for the satellite to emulate a sun photometer/radiometer using SPARC reflectors

Schiller 2011

Radiometric Calibration and Atmospheric Corrections of the Glenn Hyperspectral Sensor Using the Specular Array Calibration (SPARC) Method



Sampling Design

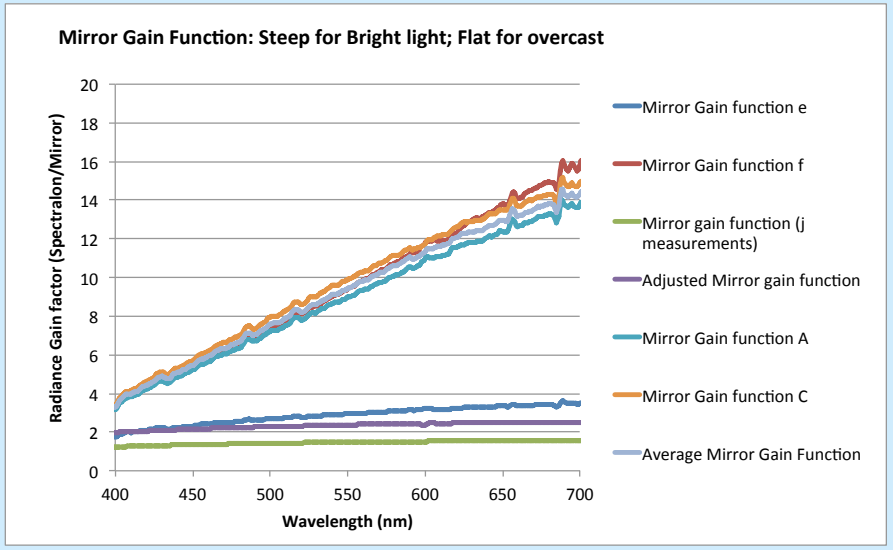
Maumee Bay State Park (Aug 10)- inter-calibration using all mirrors & shadow bands along with other researcher's calibration equipment & techniques.

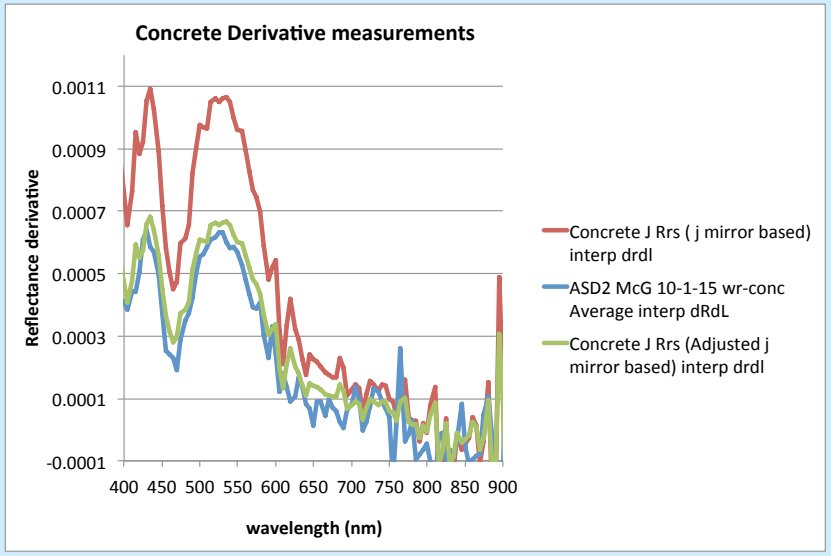
Paired shadow band radiometer with mirror array(s)
- Sandusky-Central & Eastern Basin
- Stone Laboratory – Western Basin

"Floating" mirror with each boat.
- ODNR Sandusky Bay Vessel with Ortiz
- ODNR Central Basin Coastal Transect Vessel with Ortiz student
- UT Maumee Bay vessel with Ricky Becker

Empirical mirror based "white referencing"

- Simultaneous measurements of spectralon plate and concave mirror under differing light conditions enables development of mirror gain functions to convert radiance to reflectance
- Derivative spectra can be then be calculated





Ortiz et al., (HyspIRI 2015)

θΔics NASA MSFC Jeff Luvall

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2015 SPARC Mirror Calibration in Sandusky Bay

- Deployed arrays of concave mirrors on floats or from land stations (Derived from Schiller's SPARC method)
- Concave mirrors reflect irradiance signature back to sensor without saturation
- Embeds a signal related to scene downwelling irradiance into the image

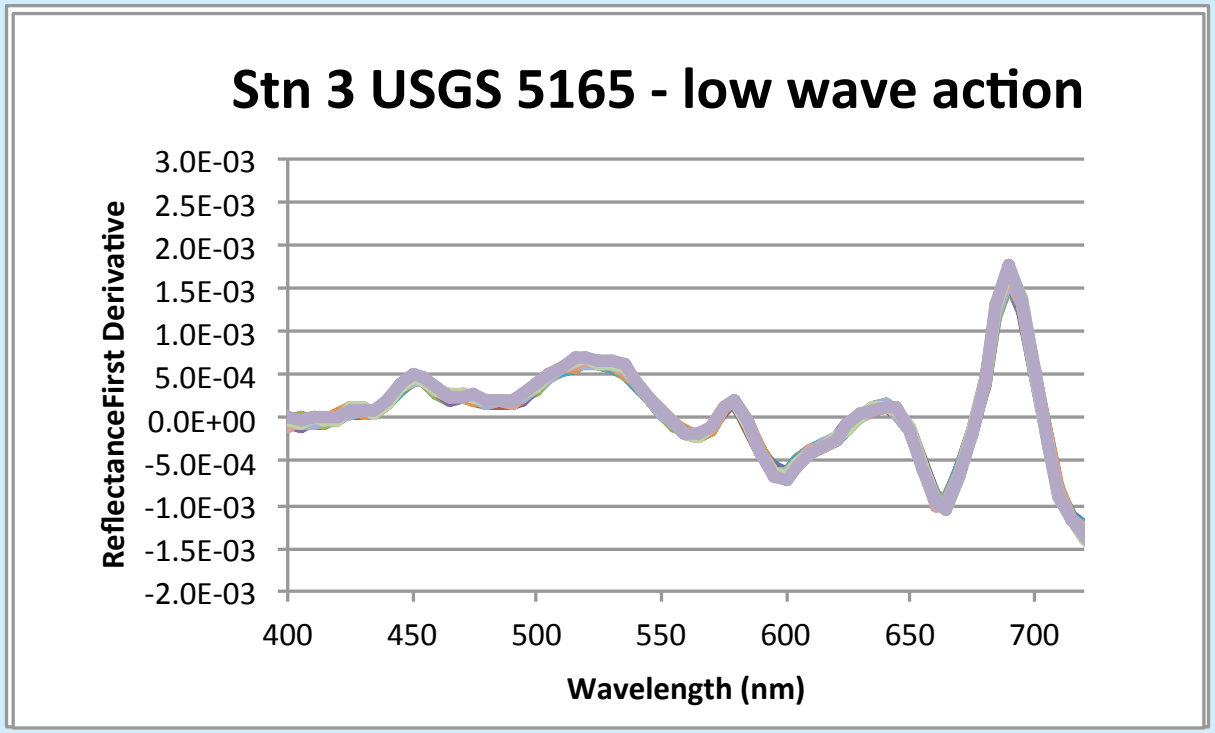
Ortiz et al., (HyspIRI 2015)

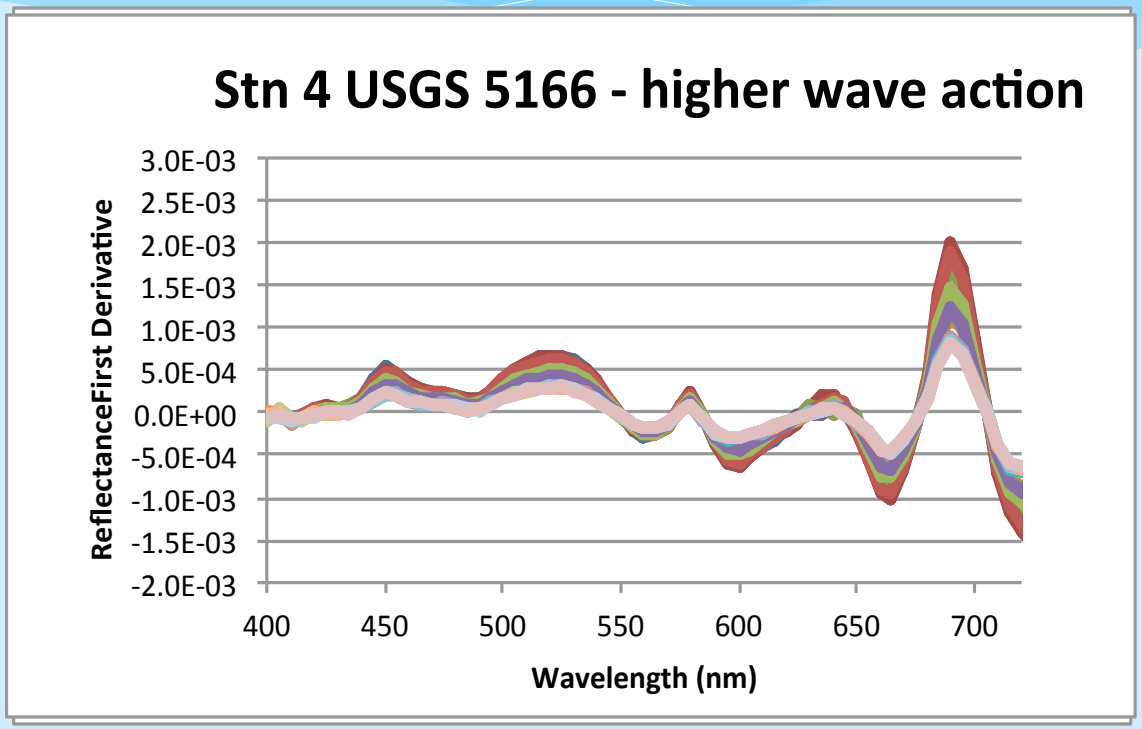
Example data: 8-12-14 USGS CSMI sampling

- Samples collected from 24’ Boston Whaler
- Winds 10-15 NW, overcast with scattered rain showers
- Samples collected at three paired stations in Maumee Bay

Ortiz et al., (HyspIRI 2015)

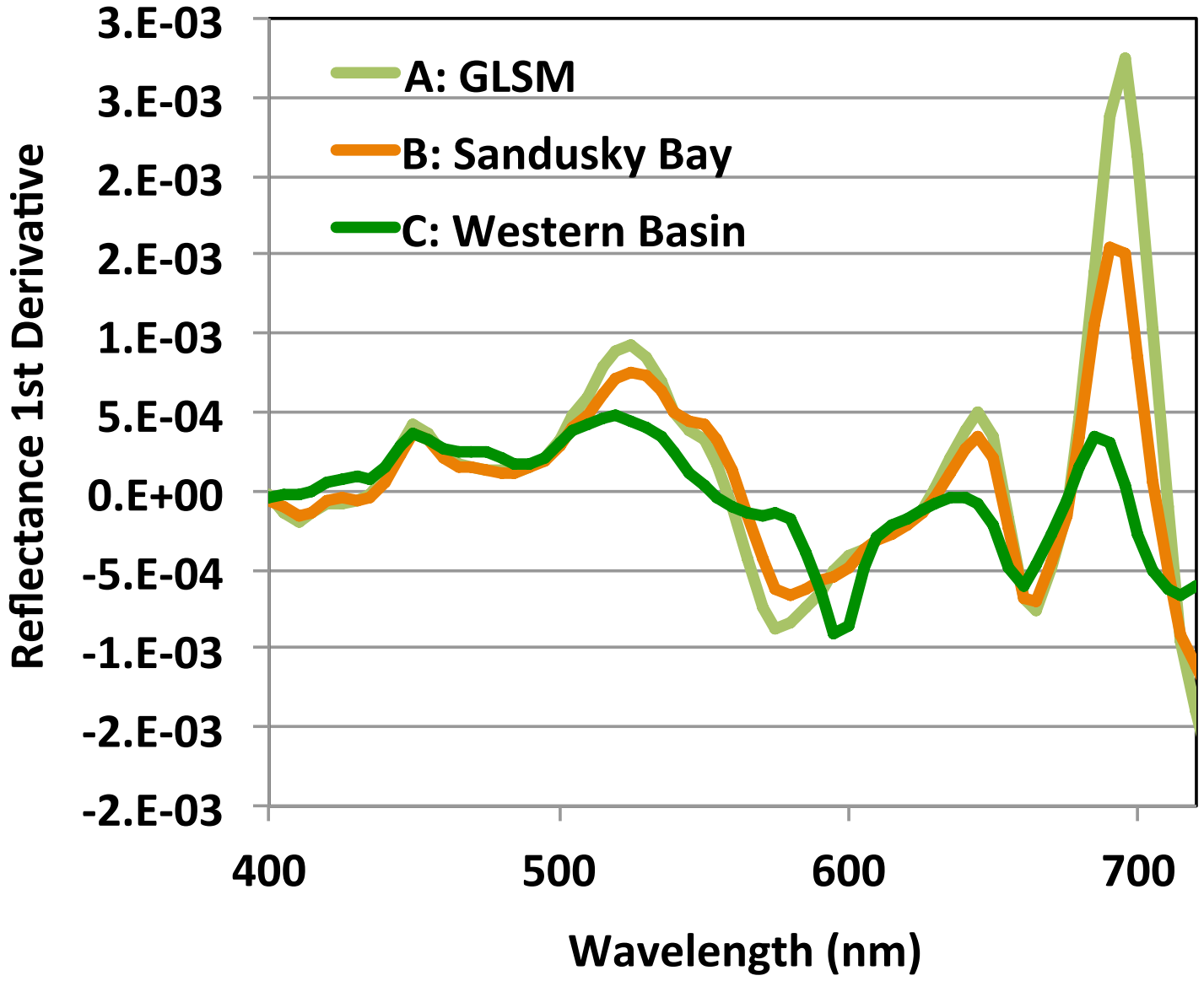
1st derivative spectra removes influence of wave action on reflectance spectra





At each site averaged 2-3 sets of 10 replicates with 30 spectra per replicate
Integration time at 10's of milliseconds

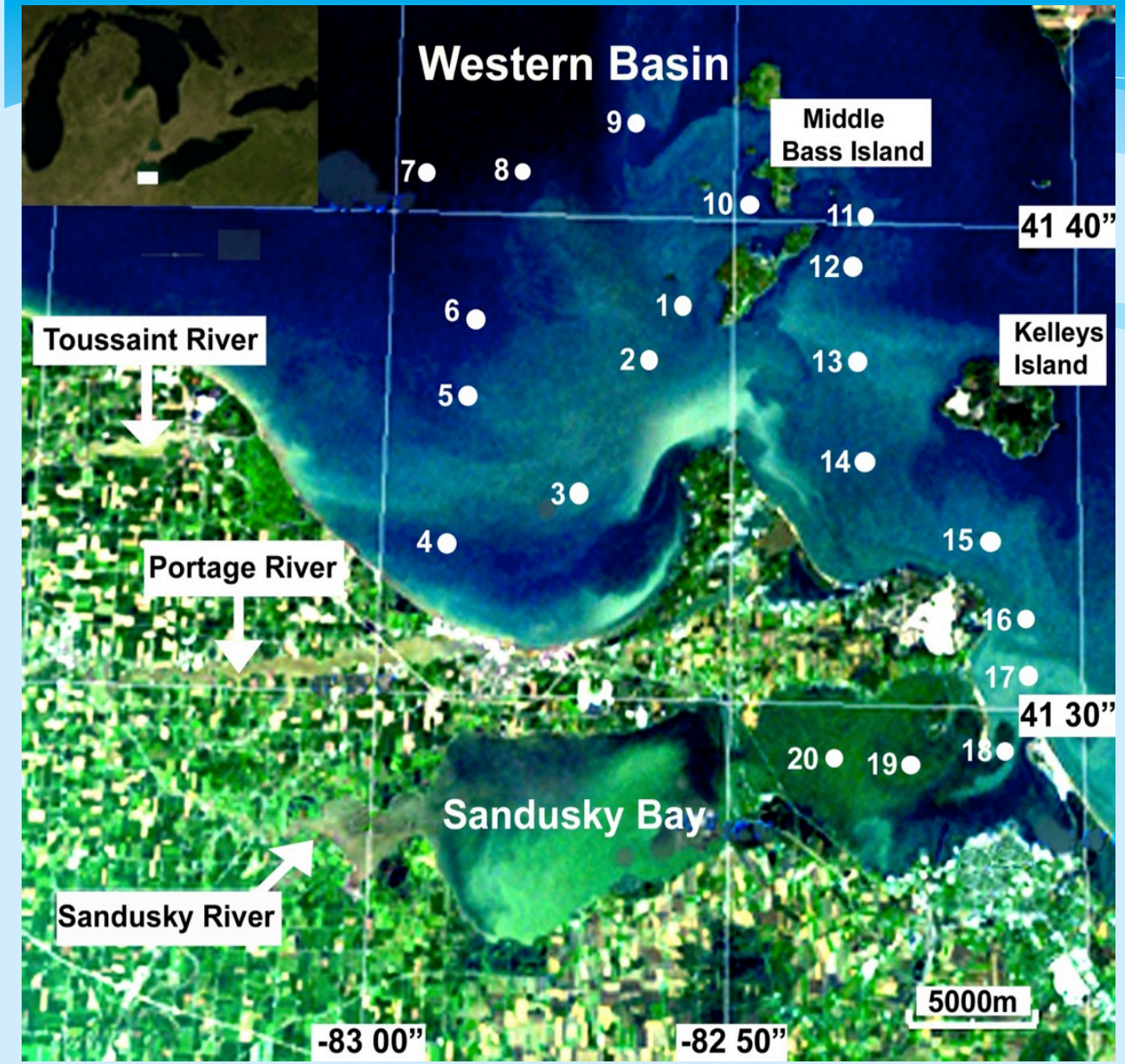
Ortiz et al., (HyspIRI 2015)



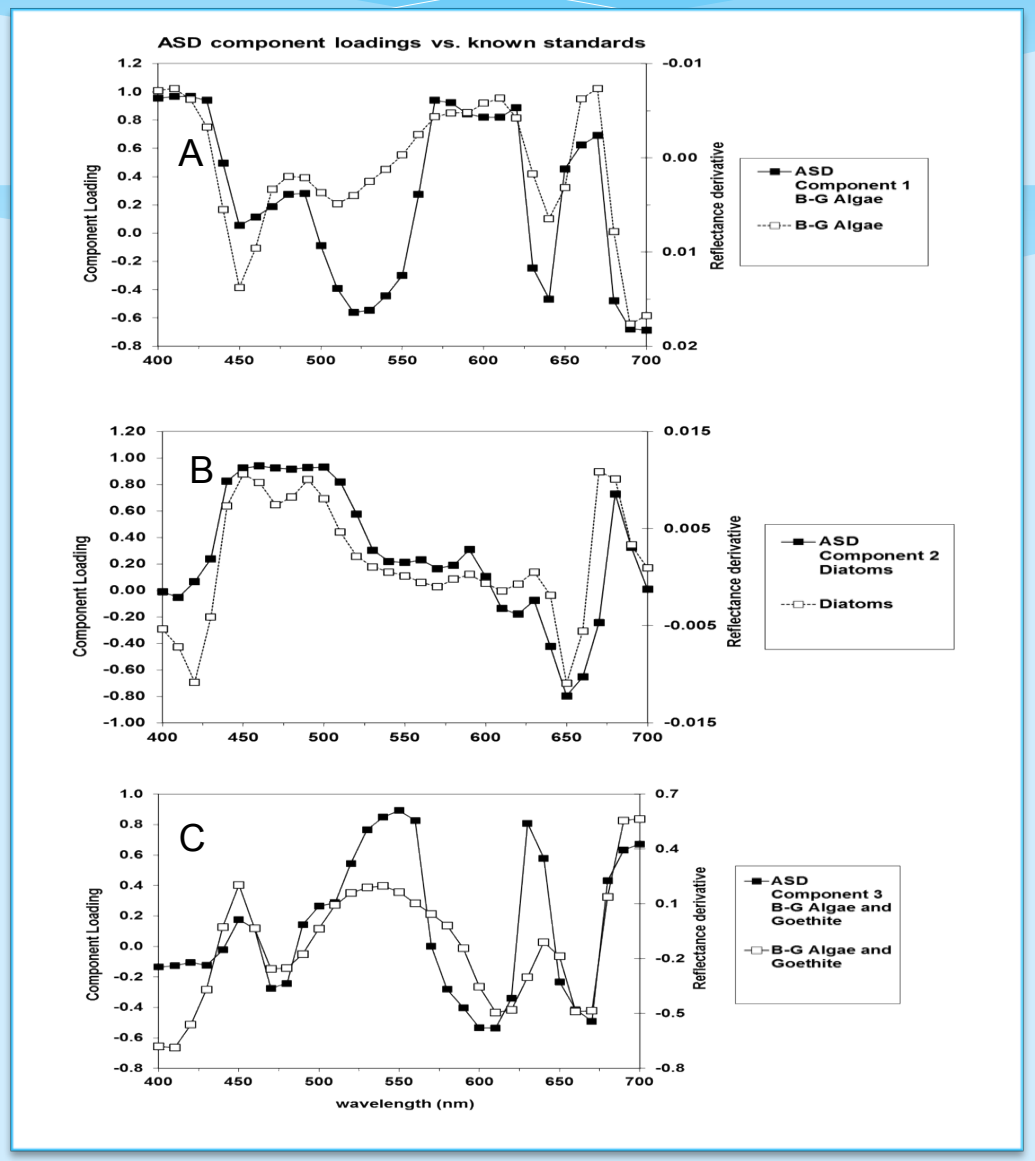
Ortiz et al., (HyspIRI 2015)

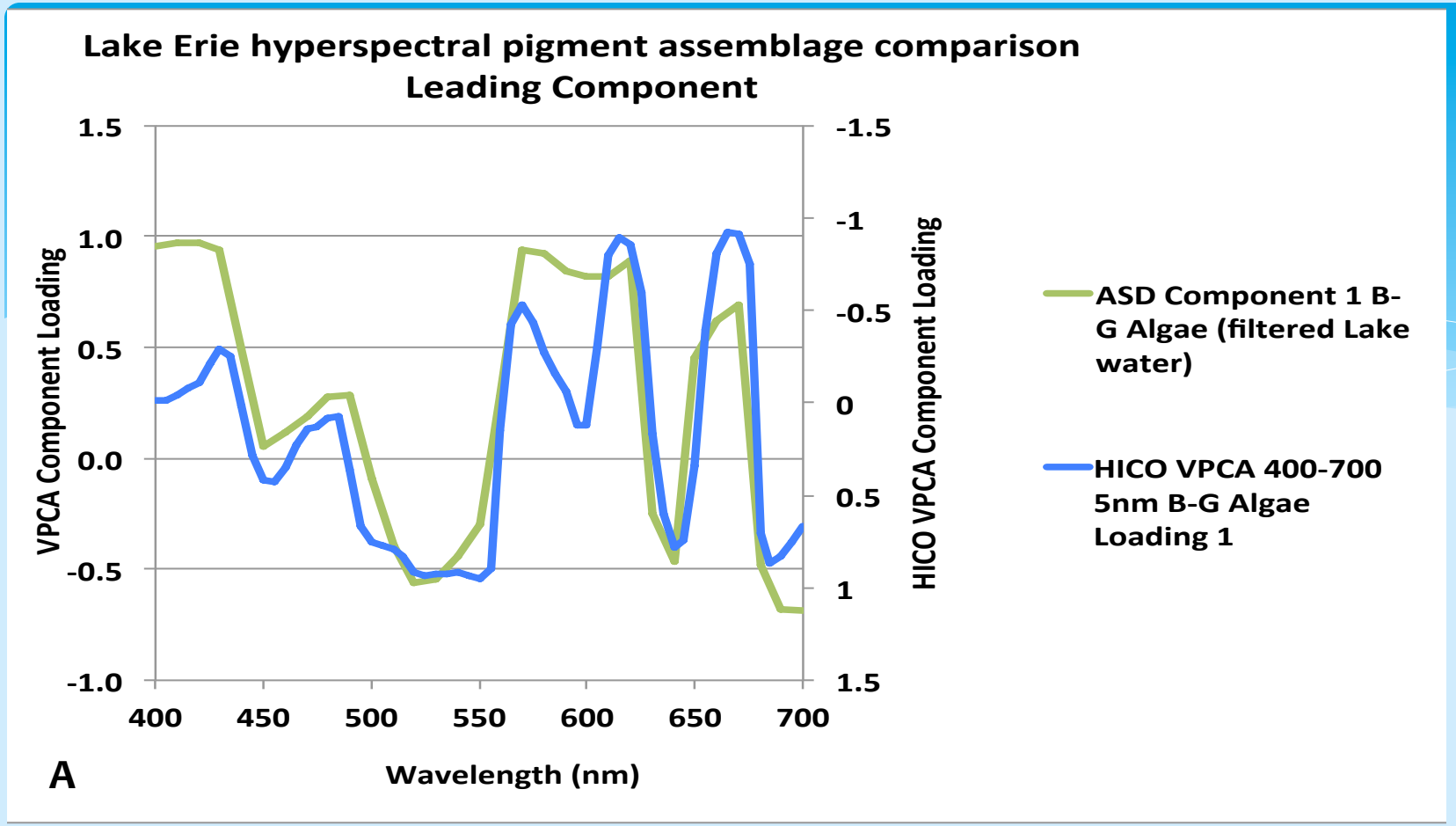
Photos: J. Ortiz

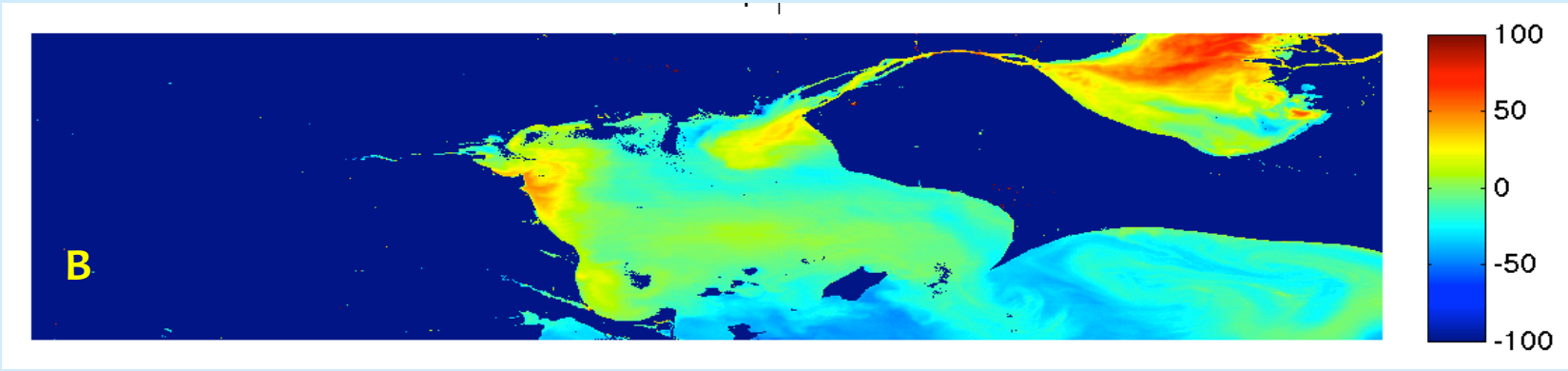
VPCA Unmixed Lab Measurements from 2007 Field Samples



Ortiz et al. 2013







2007 field VPCA results (green) vs. HAB-forming Cyanophyte (Leading Component) extracted from HICO image 9-3-11

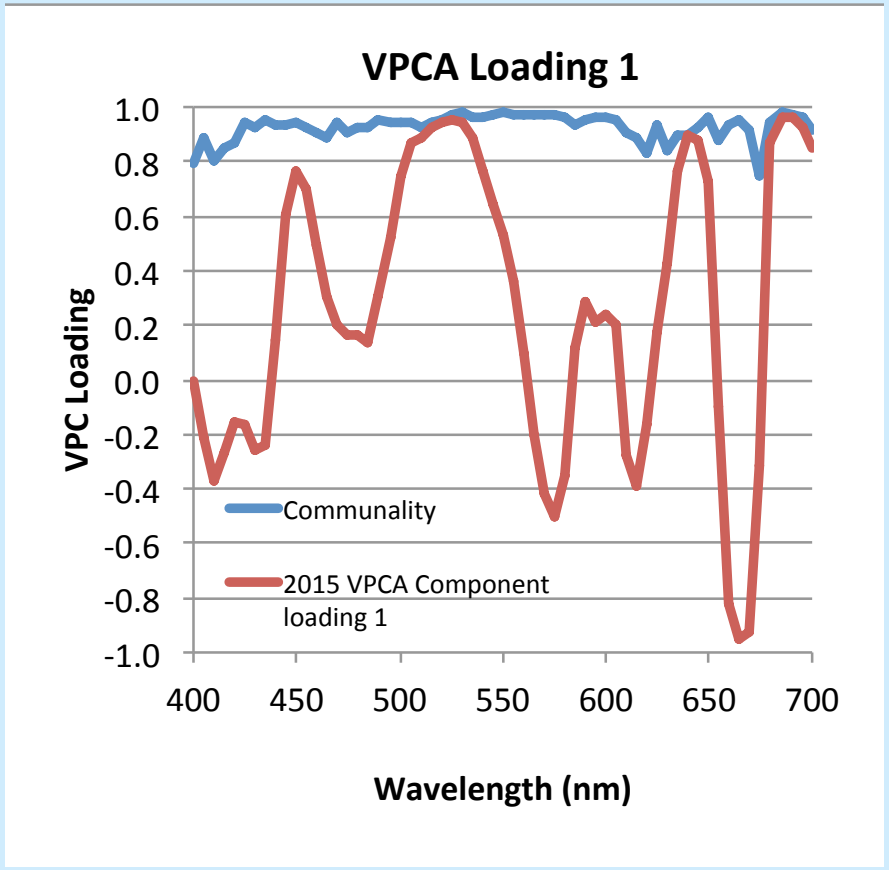
Ortiz et al., (HyspIRI 2015)

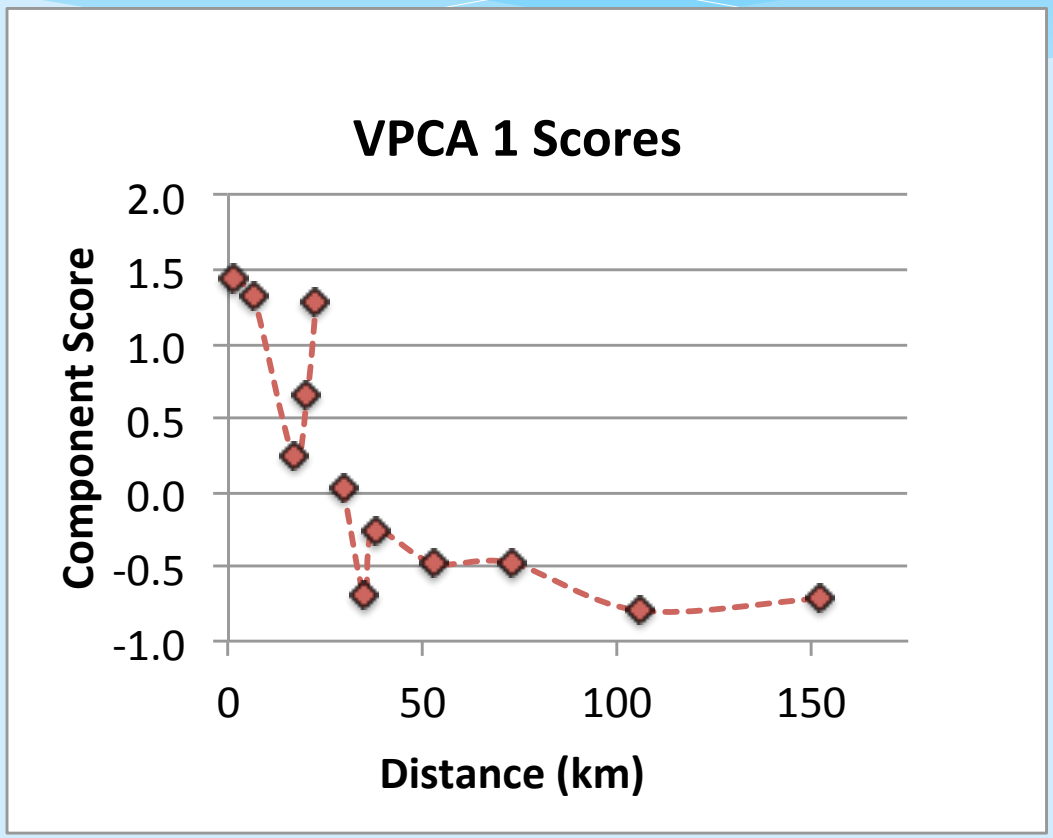
2015 ASD Spectroradiometer Field Data Presented: Weekly 6-8-15 to 7-20-15 Additional samples until 10-9-15

ASD Field Spec HH measurement were collected along two 5-6 station transects

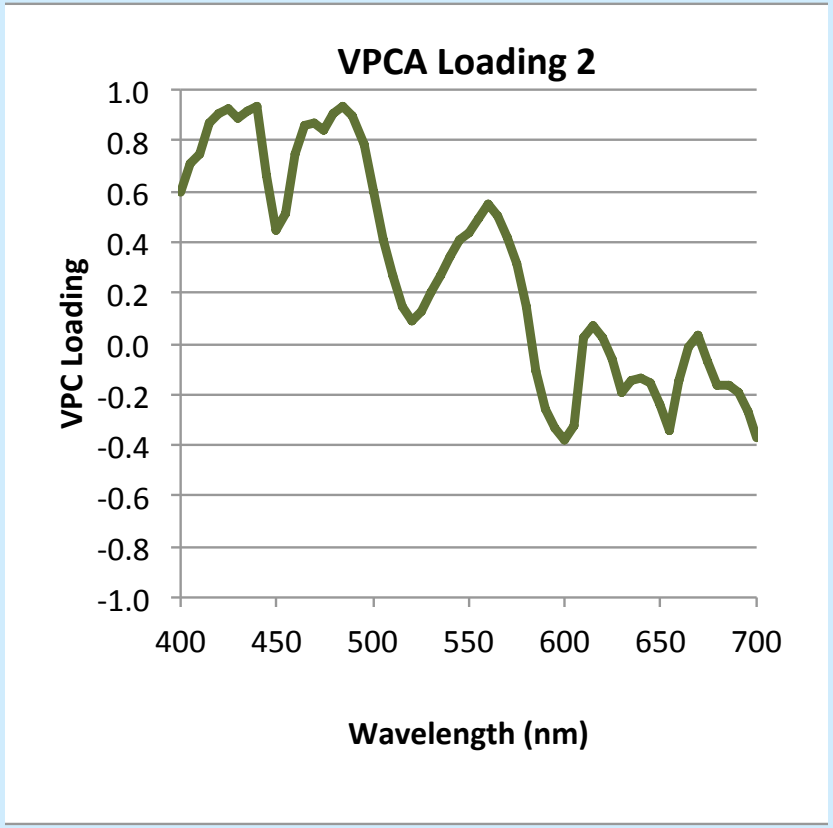
- Sandusky Transect
  - Inner bay from Muddy Creek to Outer Bay near mouth of Sandusky Bay
  - 0-25 km from Muddy Creek
- Central Basin Coastal Transect
  - Coastal samples generally <250 m offshore from Sandusky Bells toward Avon Point
  - 25- 150 km from Muddy Creek

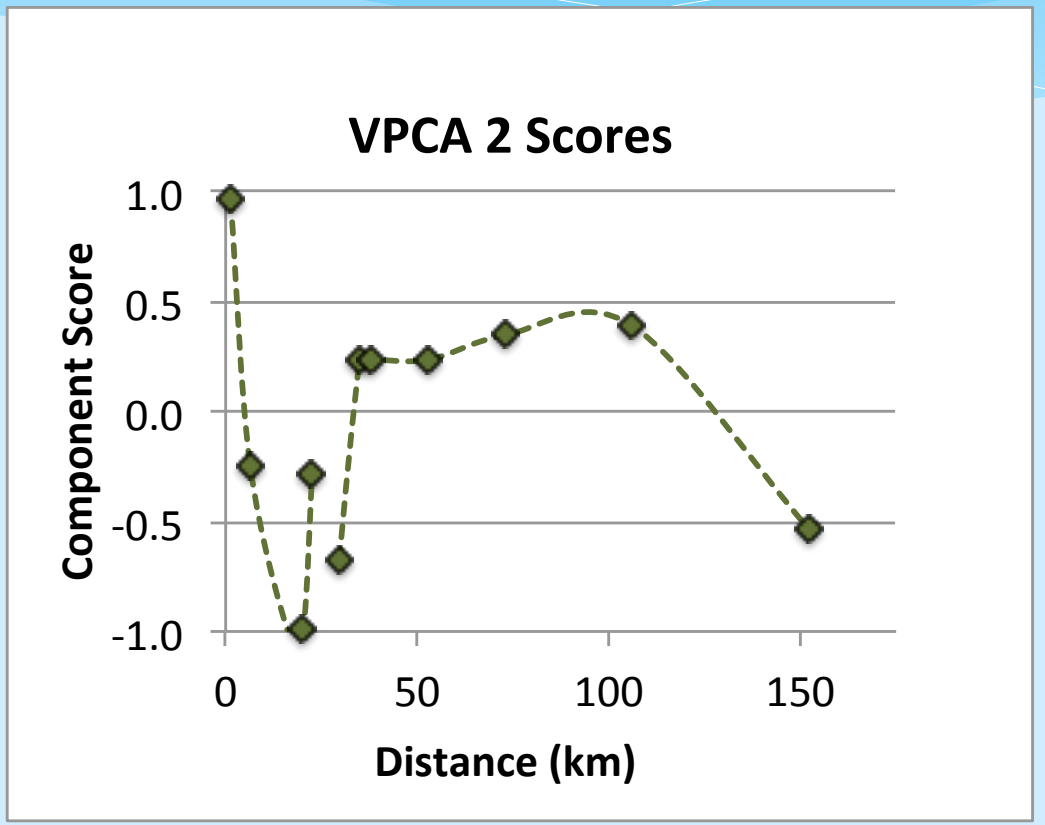
2015 ASD Spectroradiometer VPCA Components CyanoHAB algae



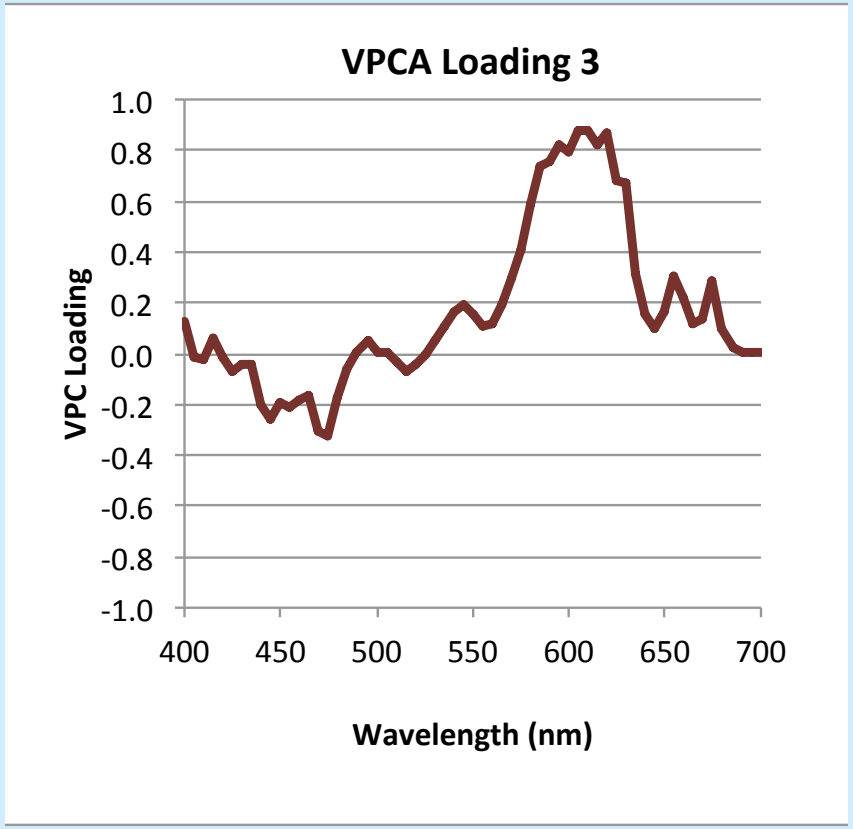


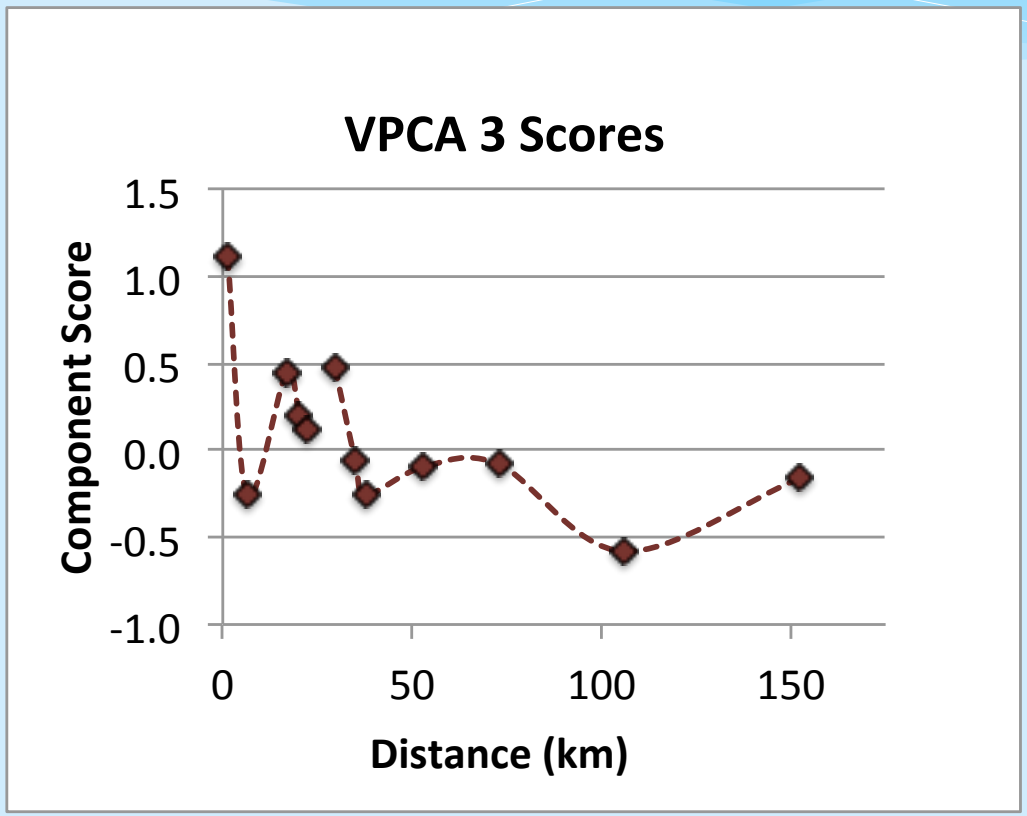
2015 ASD Spectroradiometer VPCA Components Diatoms and suspended sediment



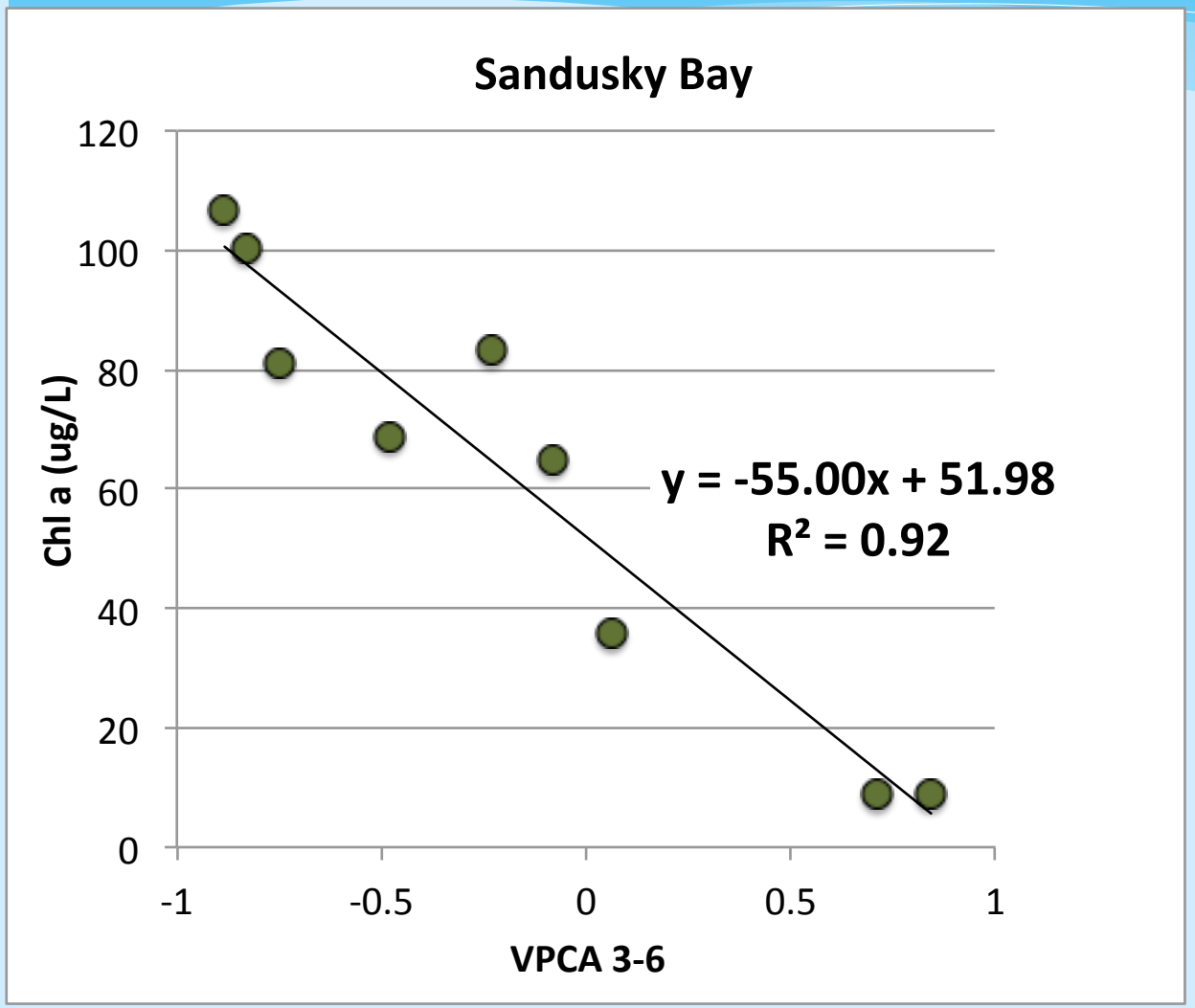


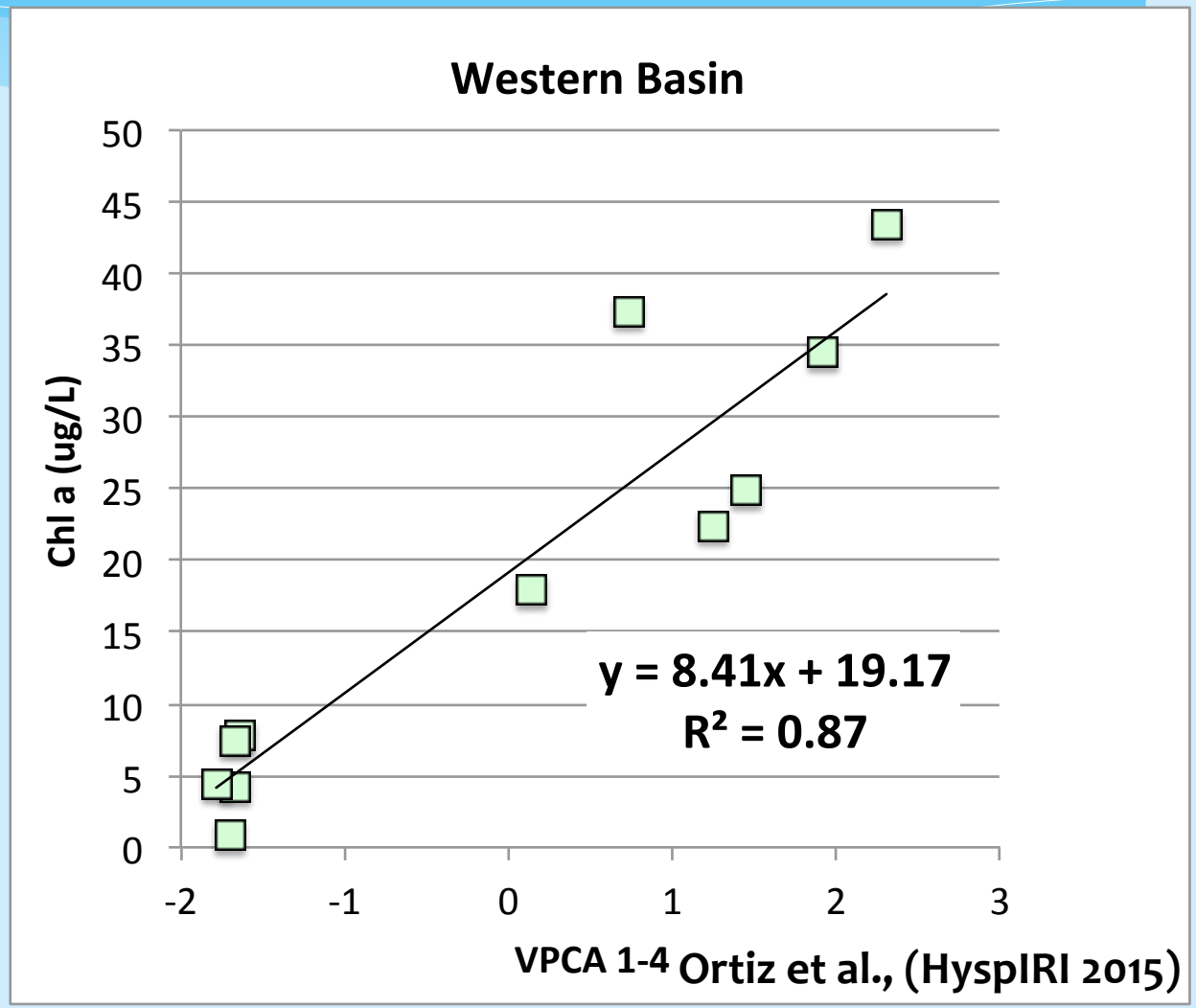
2015 ASD Spectroradiometer VPCA Components Hematite (Iron-Oxide) suspended sediment





Sandusky and Maumee Bay VPCA Relationships to Chl a



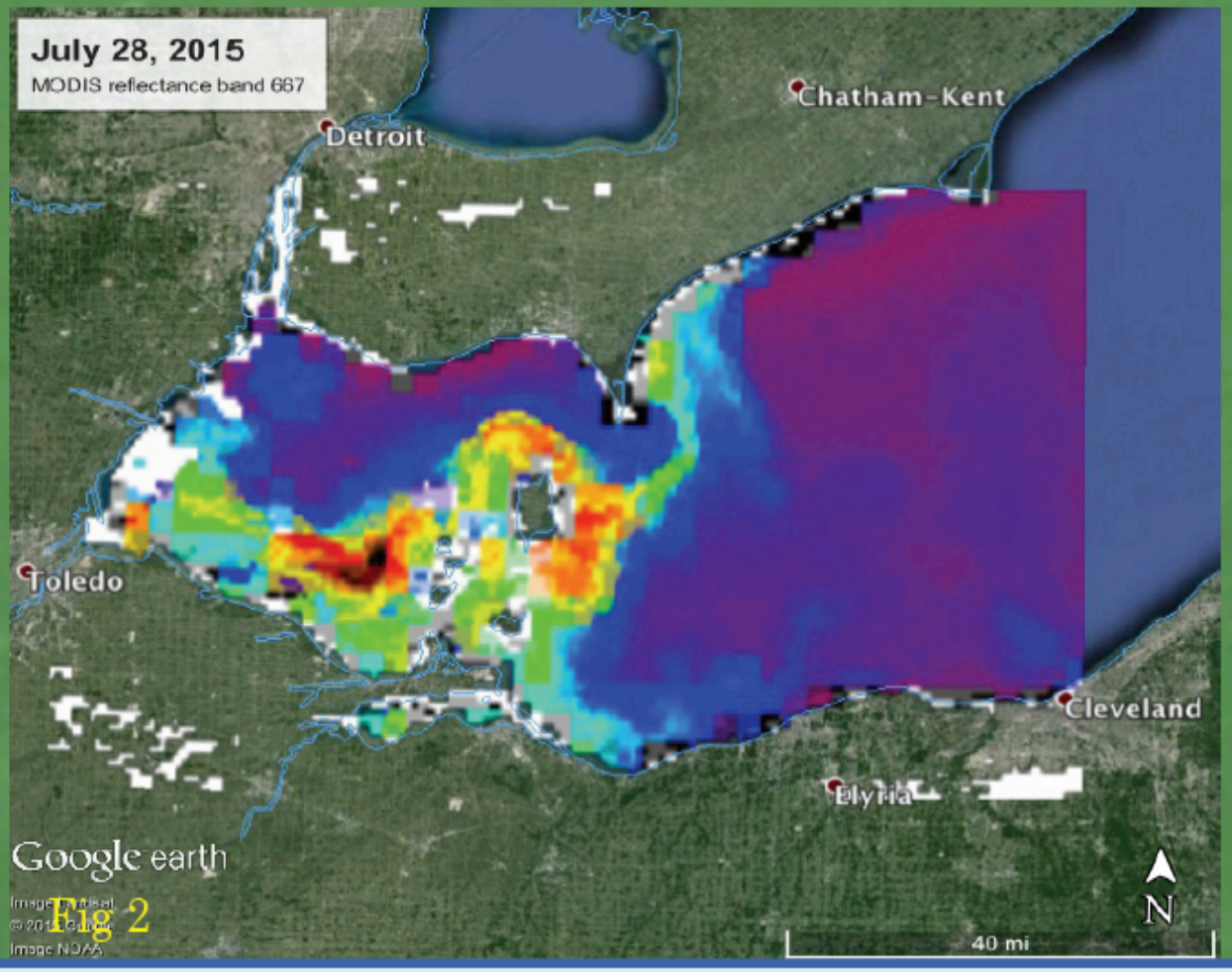


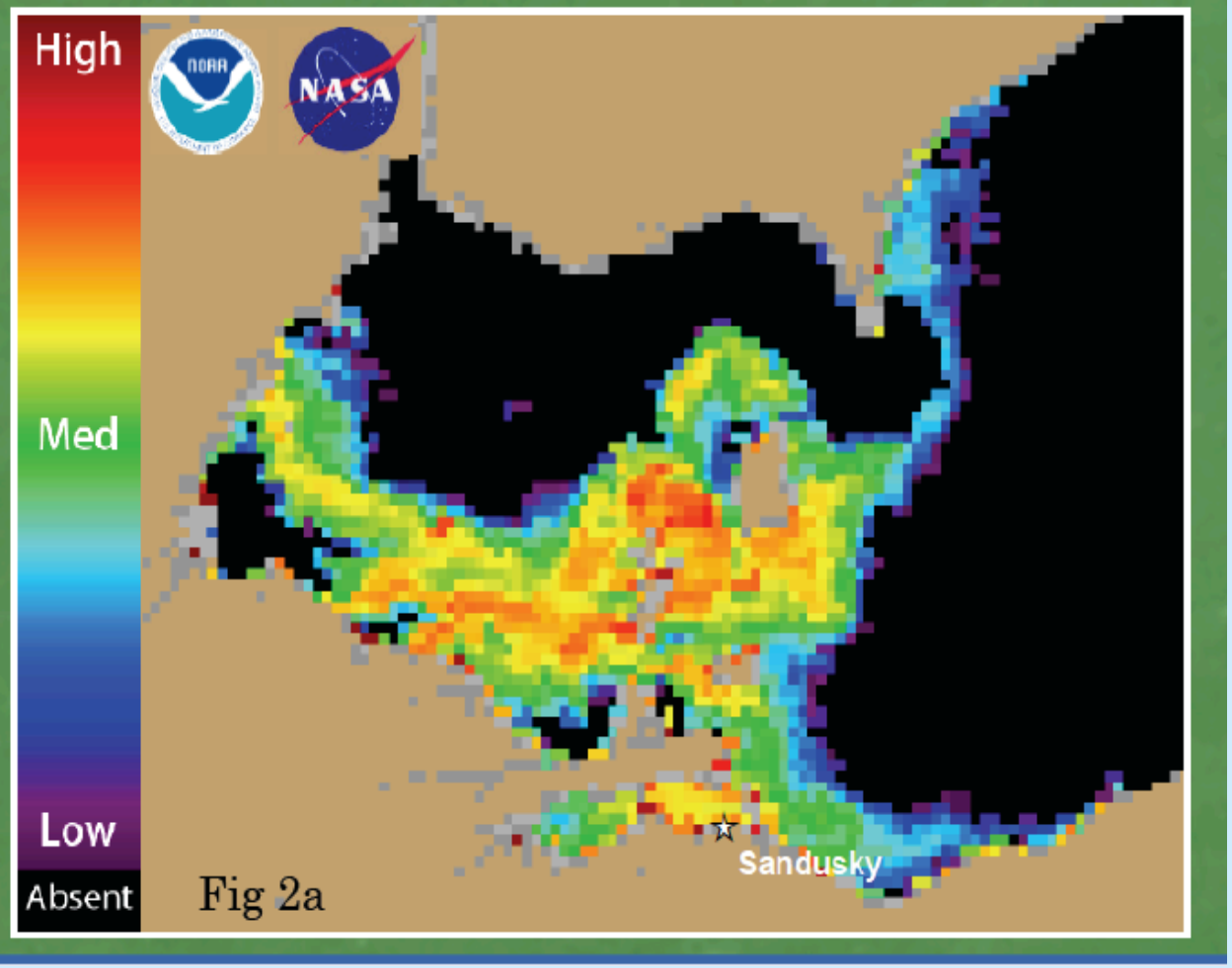
Summary

- VNIR derivative spectroscopy quantifies plant pigment assemblages in Case 2 aquatic systems (Akron Reservoirs, Lake Erie, OWC, Sandusky Bay, GLSM)
- VNIR derivative spectroscopy helps address non-Lambertian scattering effects
- Ties optical assemblages to phytoplankton and cyanophyte phyla
- Method can be applied to lab samples, field-based spectroradiometers, Remote Sensing data
- Well suited for application to Sentinel-3, HyspIRI, PACE: Makes use of all information present in hyperspectral spectra

Ortiz et al., (HyspIRI 2015)

MODIS Monitoring Lake Erie Algal Blooms: Derivative Spectroscopy analysis of field and satellite data to identify color-producing agents in Western Lake Erie





Derivative spectra were analyzed with Varimax-Rotated Principal Component Analysis (VPCA)

The chlorophyll index (C.I.) image from the NOAA HAB bulleting for July 29 demonstrates the close correlation of MODIS band 667 and chlorophyll.

Avouris et al, (2015)

VPCA of Derivative Reflectance Spectra
MOSIA vs ASD

Fig 5

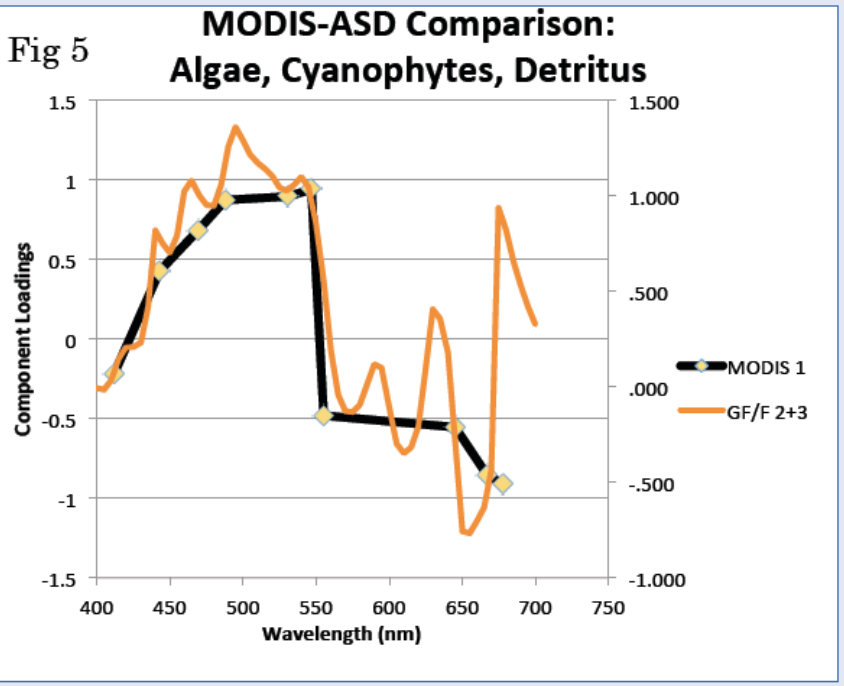


Fig 4

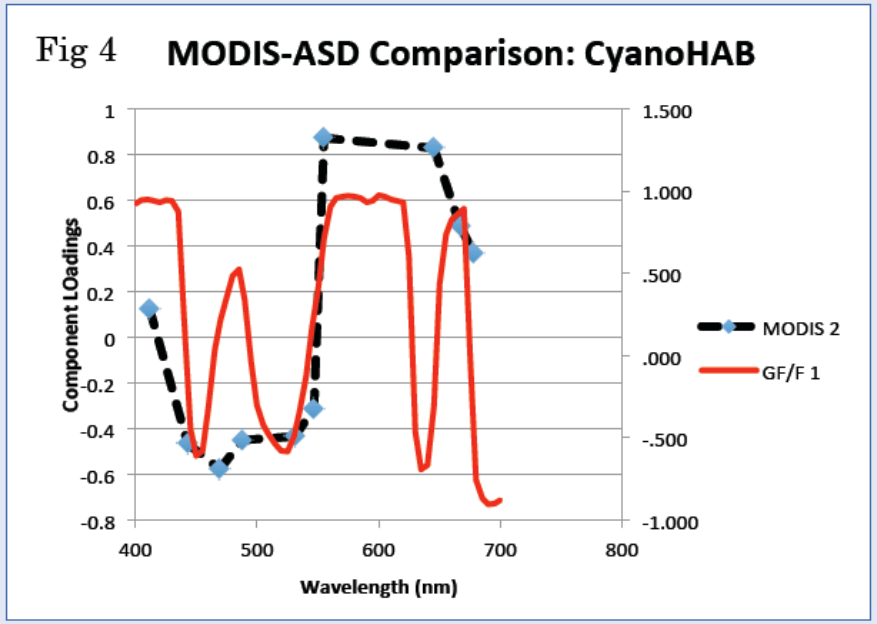
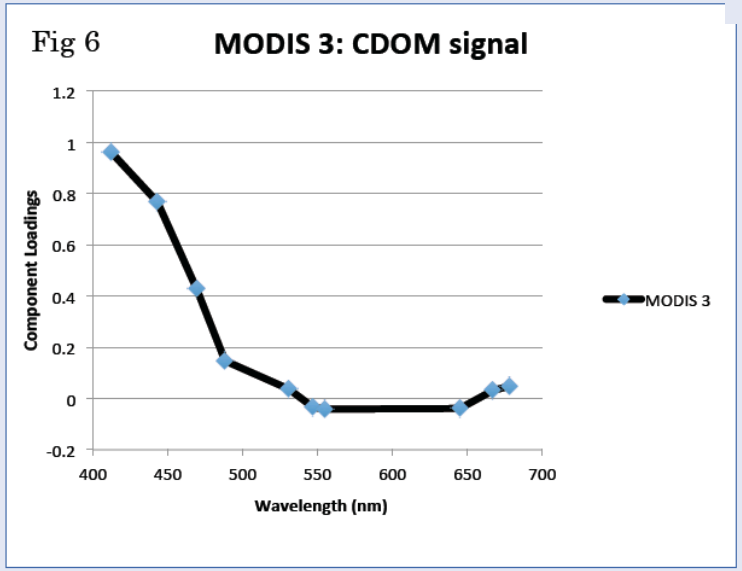


Fig 6



Avouris et al, (2015)