Update on Great Lakes Hyperspectral Water Quality Instrument Suite for Airborne Monitoring of Algal Blooms

Authors: John Lekki[1], George Leshkevich[2], Quang-Viet Nguyen[1], Joseph Flatico[3], Norman Prokop[1], Jun Kojima[3], Robert Anderson[1], James Demers[1], Michael Krasowski[1]

NASA Glenn Research Center and NOAA Great Lakes Environmental Research Lab have continued their collaboration to utilize an airborne hyperspectral imaging sensor suite to monitor algal blooms in the western basin of Lake Erie and Saginaw Bay. The development of a bloom is a very dynamic event because the bloom can form, spread and then disappear within a 4 to 8 week time period in late summer. They are a concern for human health, fish and wildlife because they can contain blue green toxic algae. This situation is well suited for aircraft based monitoring because the blooms are such a dynamic event and they can spread over a large area. A second generation custom designed hyperspectral imager and a point spectrometer mounted in a Lear 25 aircraft have been used to obtain data of multiple areas in western basin of Lake Erie during September 2007. Water samples have been taken of these same areas concurrently by NOAA and the EPA. The correlation of the water samples with the hyperspectral measurements will help to determine the efficacy of hyperspectral monitoring of harmful algal blooms in the Great Lakes. The sensor suite and operations will be described and preliminary hyperspectral data of this event will be presented.

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3. Ohio Aerospace Institute, Cleveland, Ohio.

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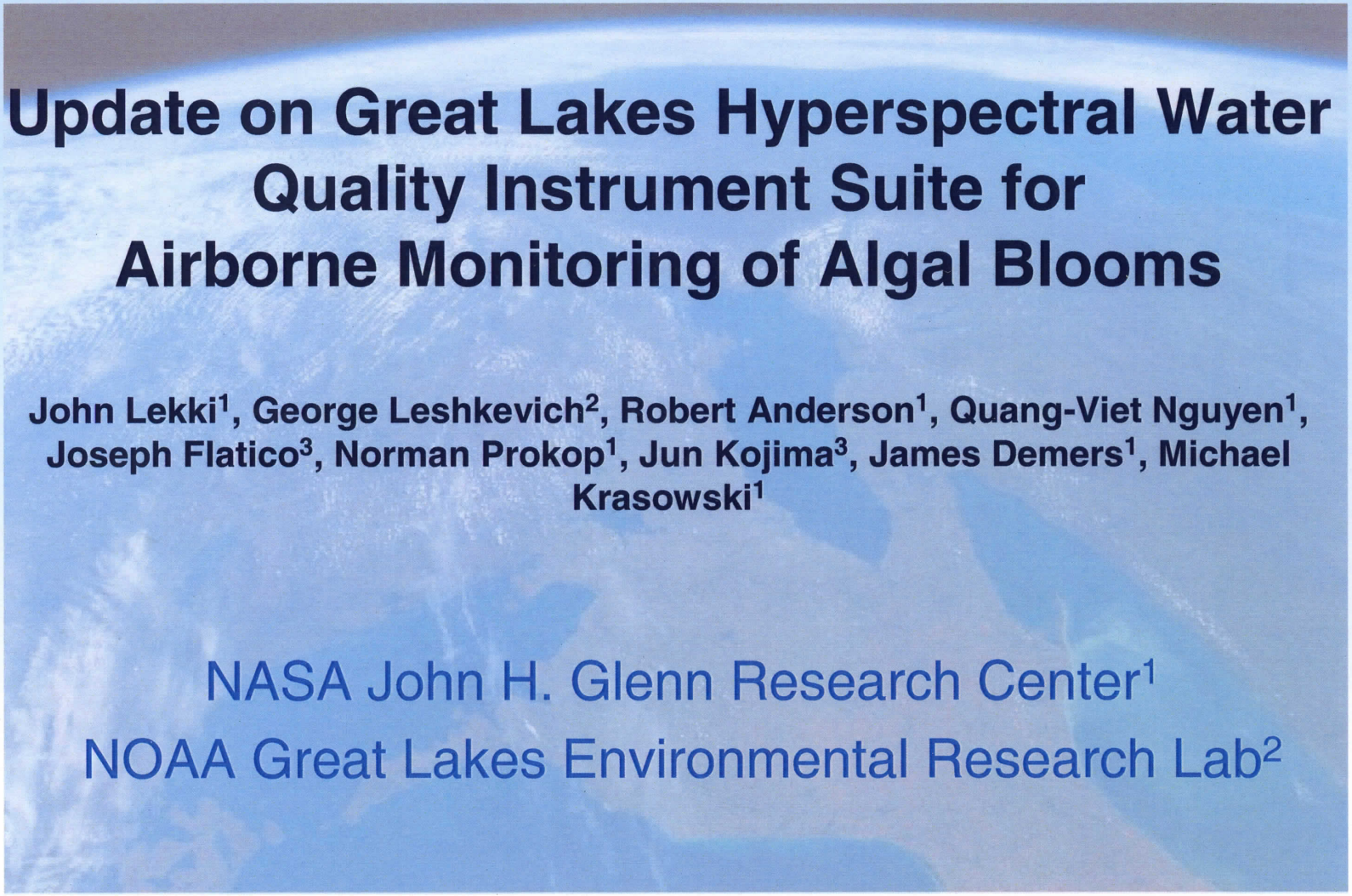

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How aerial monitoring fits with other measurement capabilities

- In Situ – many physical measurements at a point
- Satellite – Measurements over a large area
- Aerial Monitoring is Complementary
  - More frequent measurement opportunities to understand rapidly changing blooms
  - Lower concentrations potentially detectable because of higher spatial and spectral resolution
  - Can quickly locate areas of interest and guide NOAA in situ measurements
  - Easily tailor instrumentation to suit the problem

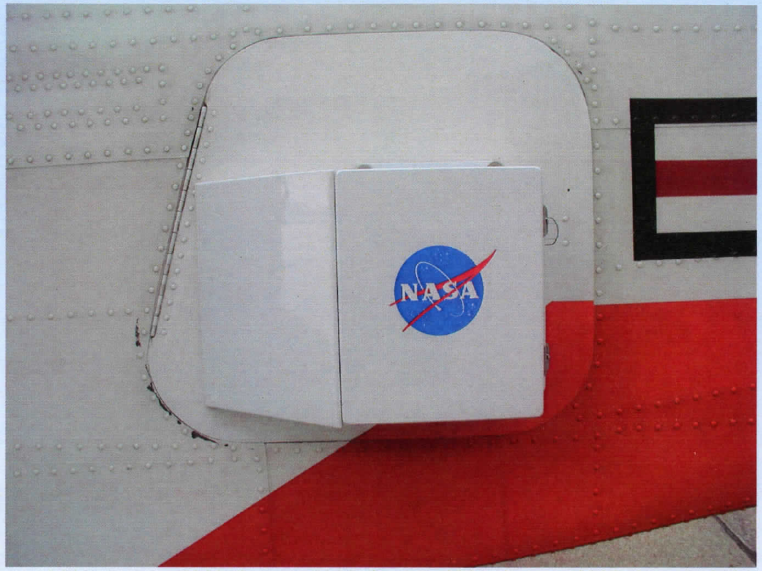
Method	Observation Frequency	Resolution
Satellite Landsat TM	Once every 8 days	30 meter
Satellite MODIS	2/day	1km
Satellite AVHRR	3/day	1km
Satellite SeaWiFS	1/day	1km
In Situ	Flexible	Point
Aerial Monitoring	**Hourly**	**1- 5 m**

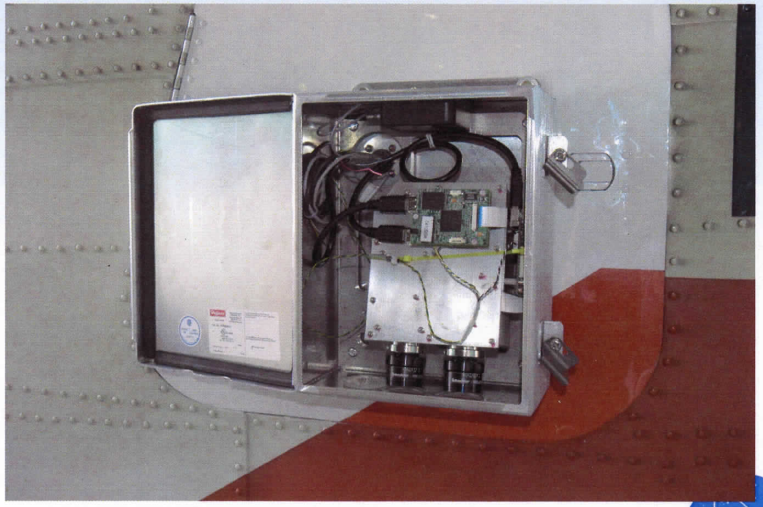
Brief History of NOAA / NASA Collaboration in Hyperspectral Imaging for the

- In 2006 Developed Generation I miniature Hyperspectral Imager (HIS). Weighed less than 4 kg and size was about 11 cm x 16 cm x 3 cm
- Acquired HSI data of Algal blooms in Lake Erie and Grand River sediment plume in Lake Michigan with concurrent water sampling conducted by GLERL and others (2006)
- In 2007 Developed 2nd generation hyperspectral imager suite that is about twice the size of the Gen I instrument
- Acquired HSI data of Algal blooms in Lake Erie and Saginaw bay with concurrent water sampling conducted by GLERL and others. (2007)

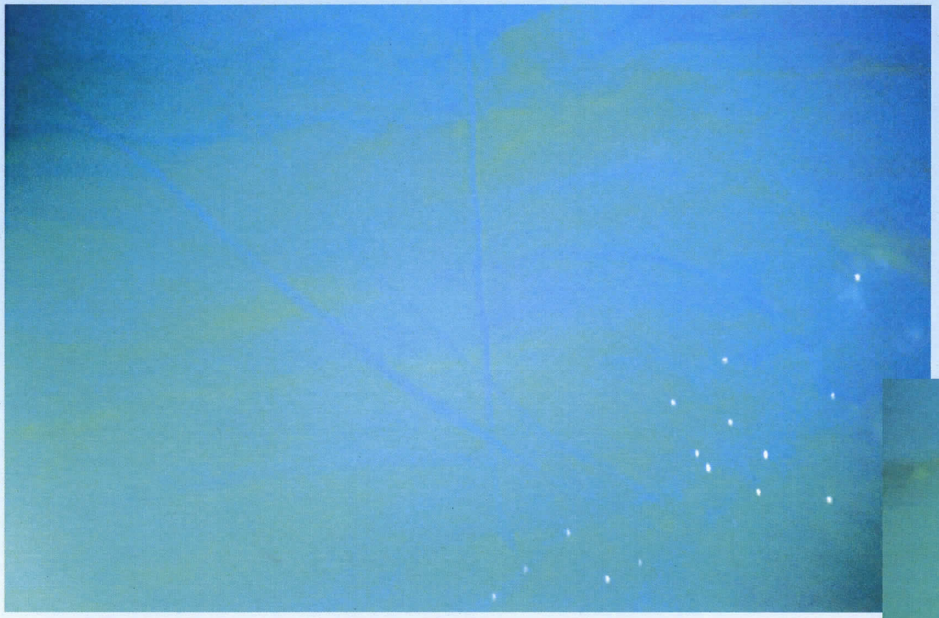
Hyperspectral Imager Mounted to T-34

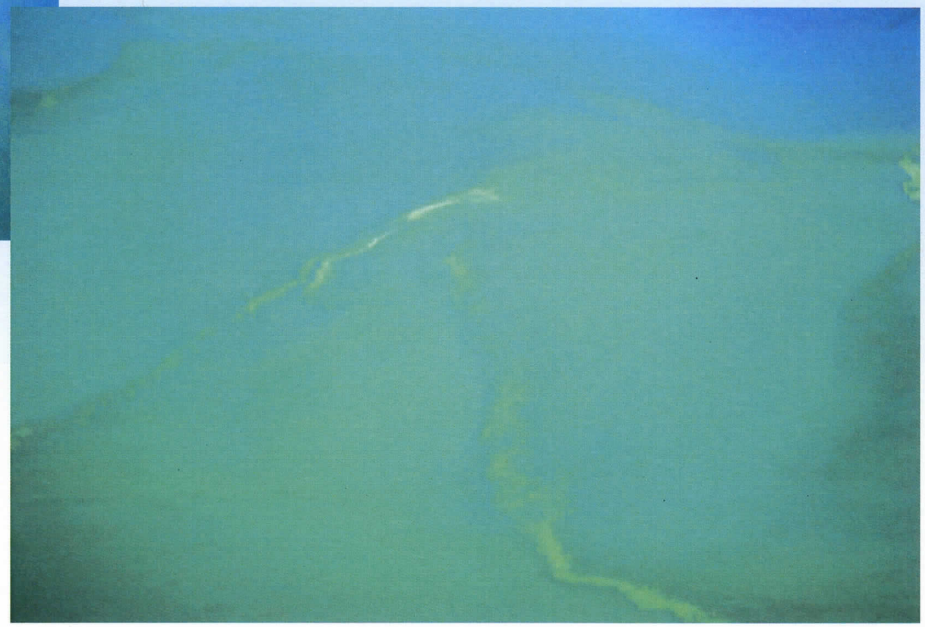
All 2006 Great Lakes operations carried out on T-34





Operations
Algal bloom visible on surface – Western Lake Erie
September 5, 2006



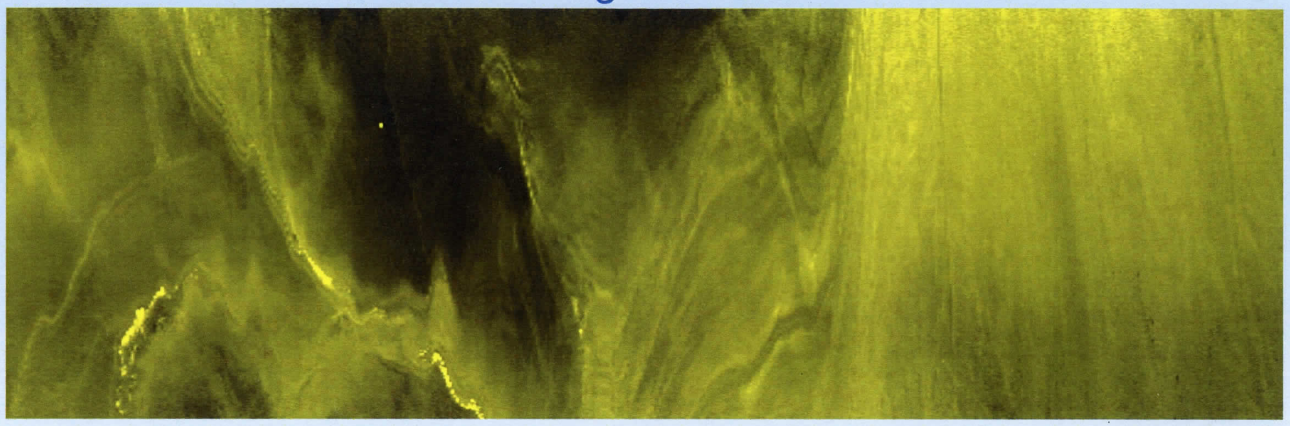


On this day the bloom has developed so that mats are visible on the surface and tracks can be seen from boats traveling through the algae

Hyperspectral images of Algal Bloom from Gen I instrument 2006

These results indicate Hyperspectral data is very promising for remotely identifying Harmful Algal Blooms as well as determining concentrations

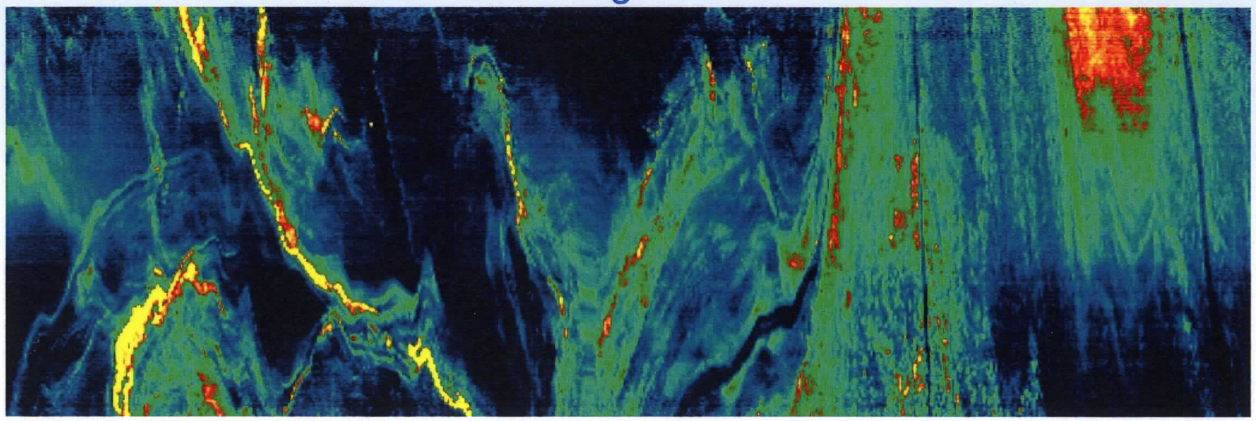
Bloom imaged at 532 nm



1 Km

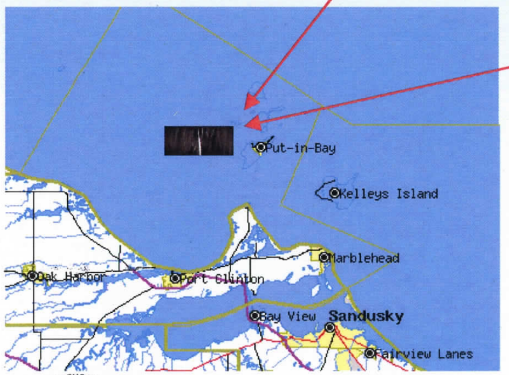
5 Km

Bloom imaged at 723 nm

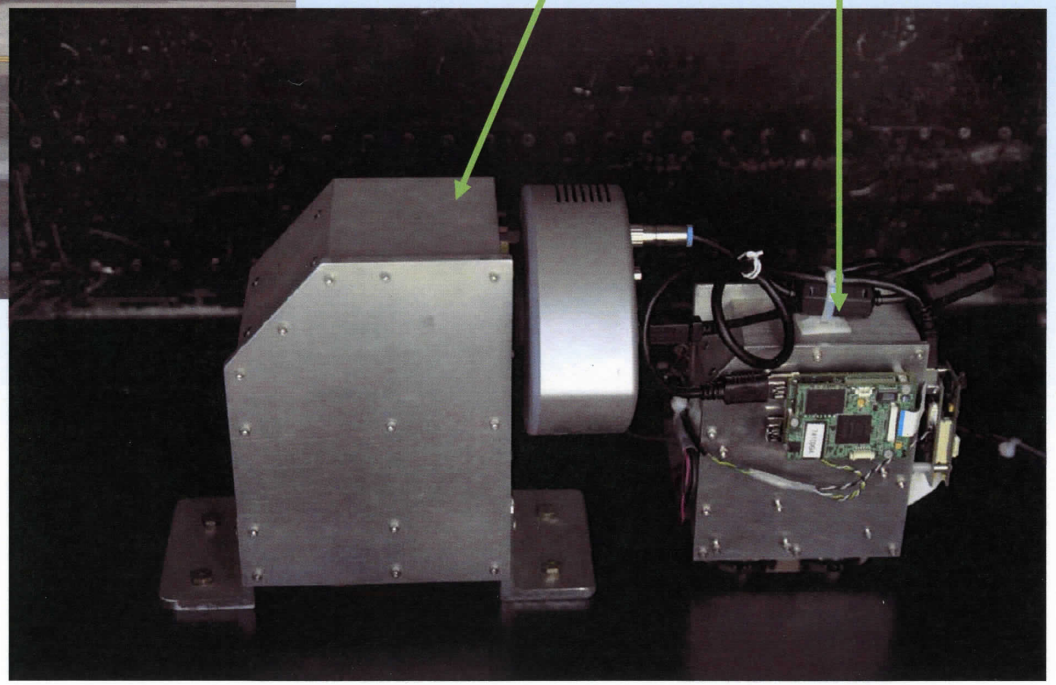


1 Km

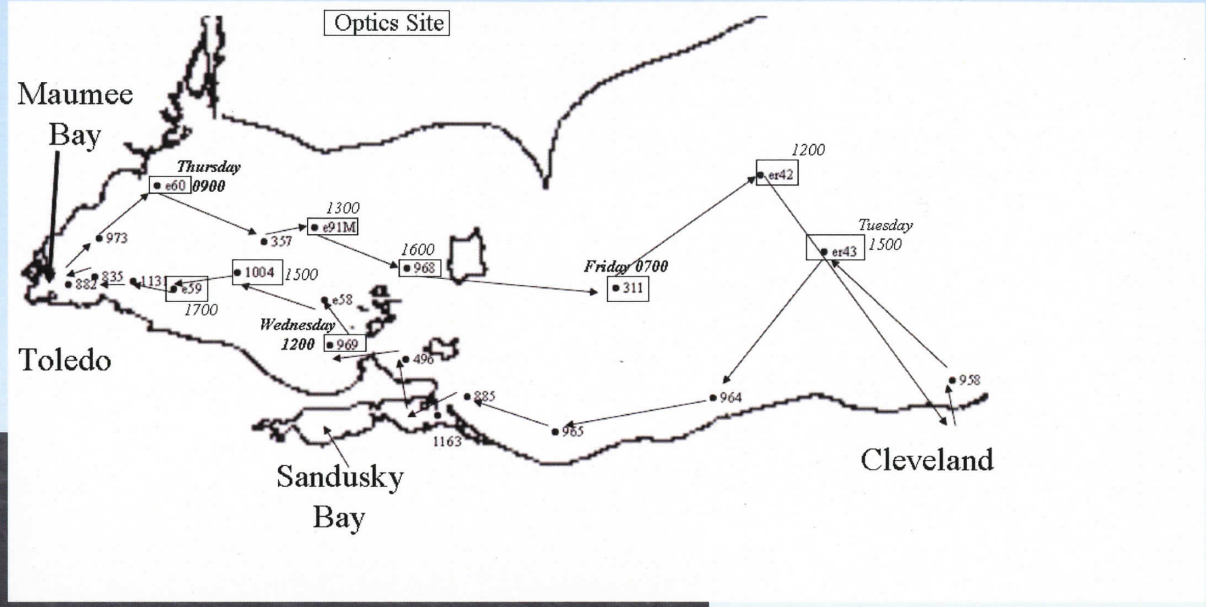
5 Km

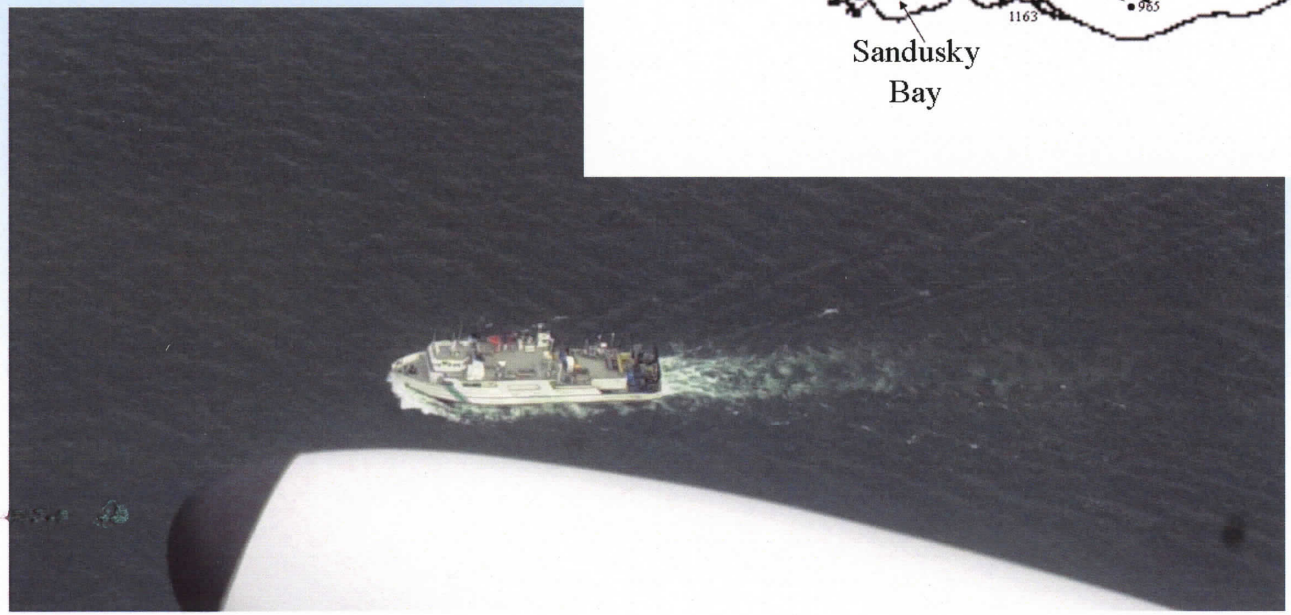


2007 Operations Utilizing GRC Lear jet



HSI Data Acquisition Occurred at the same time as the EPA Lake Guardian Cruise – Sept 12th Thru 14th

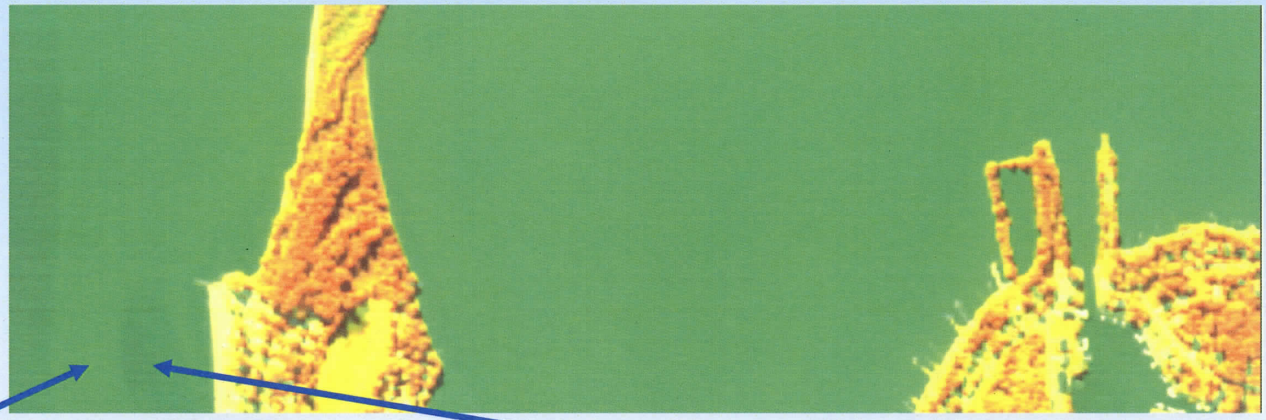


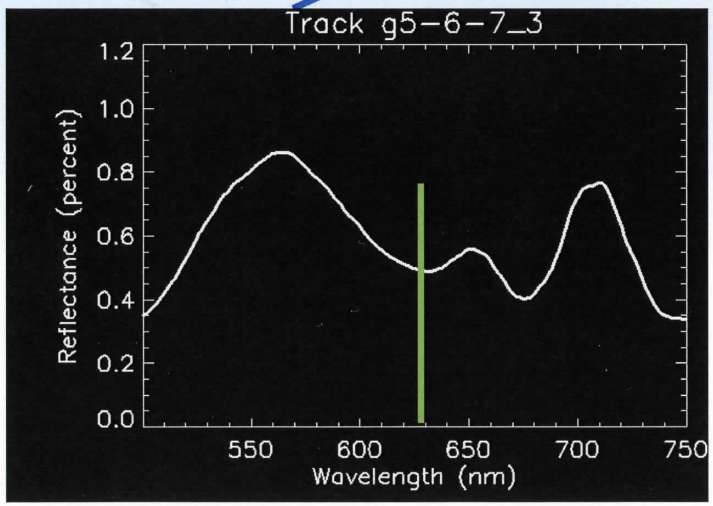


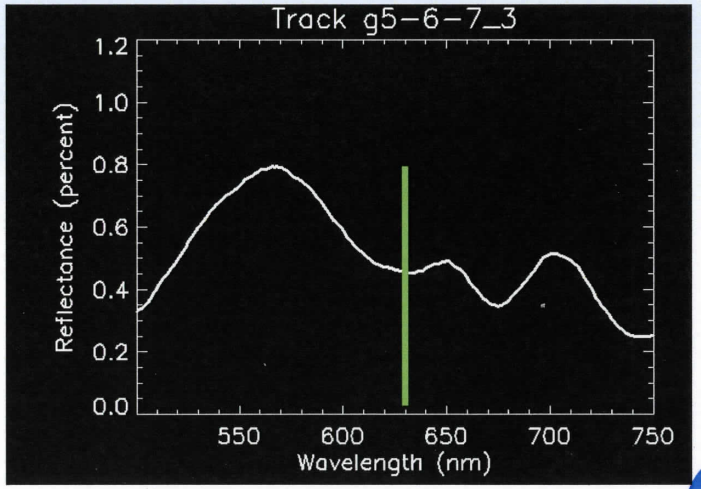
Sandusky Bay HSI

Spectrum indicates presence of Phycocyanin – green mark indicates Phycocyanin absorption peak

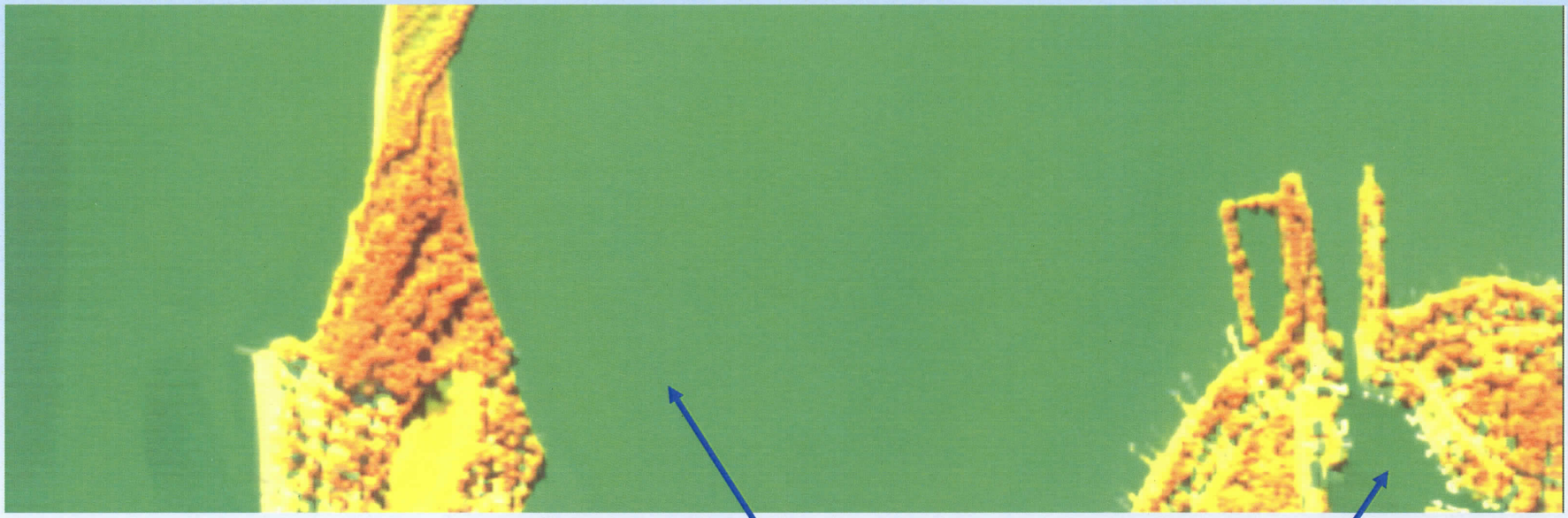
Note: Large local spectral reflectance differences



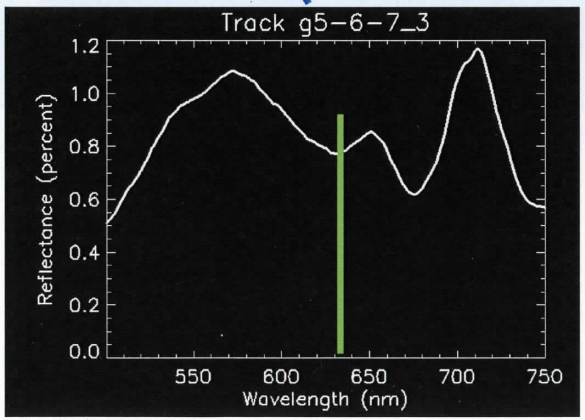


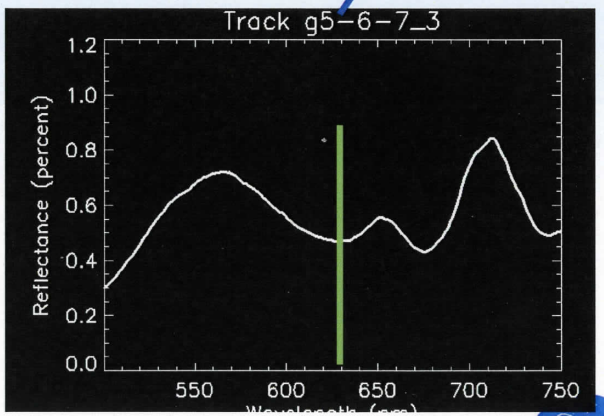


Sandusky Bay HSI – Sept. 13, 2007

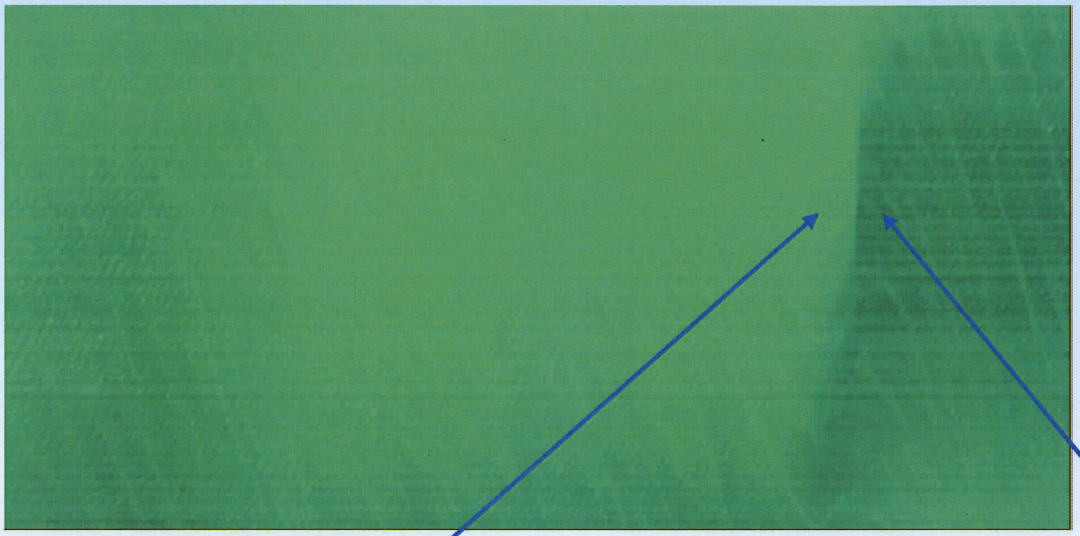


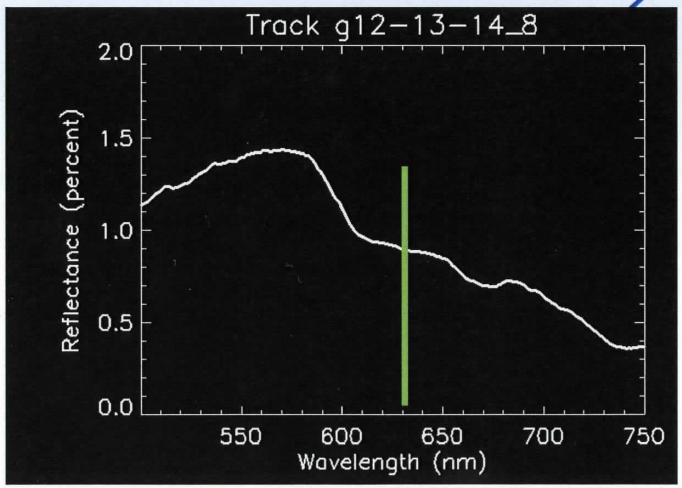
Note: Large spectral reflectance differences throughout the bay and presence of phycocyanin is indicated

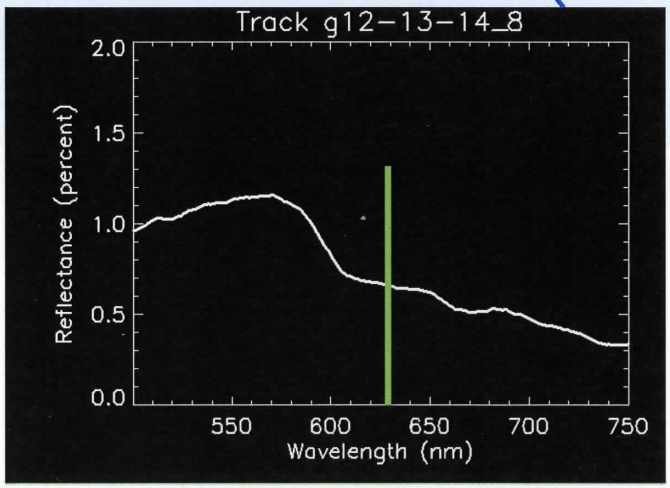




Lake Erie HSI at Point E59 – Sept. 13, 2007
No indication of Phycocyanin



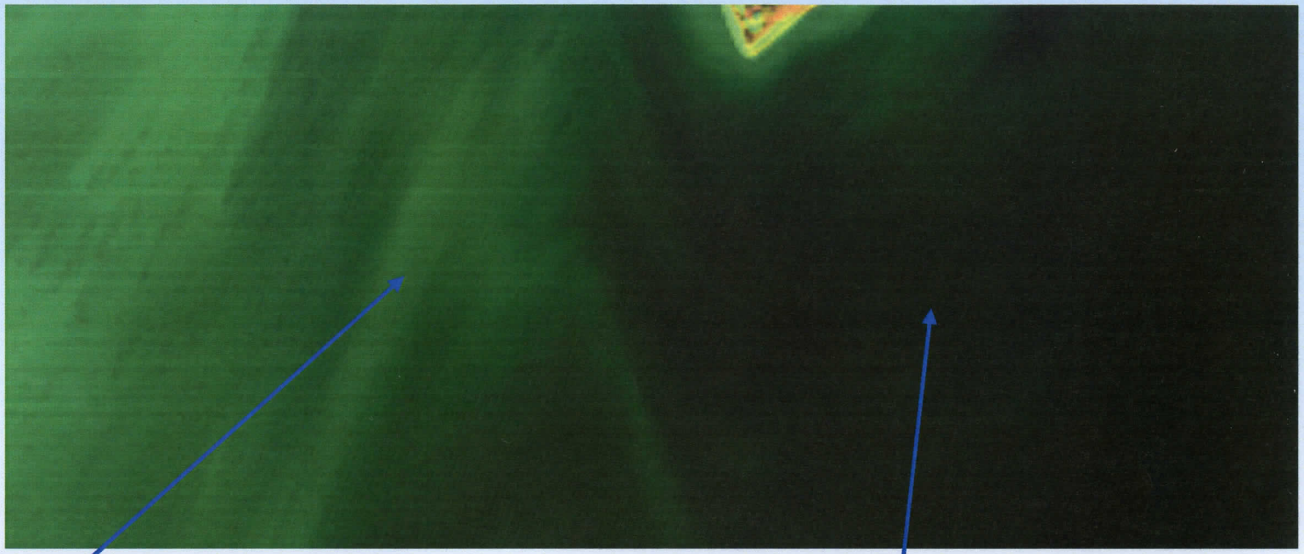


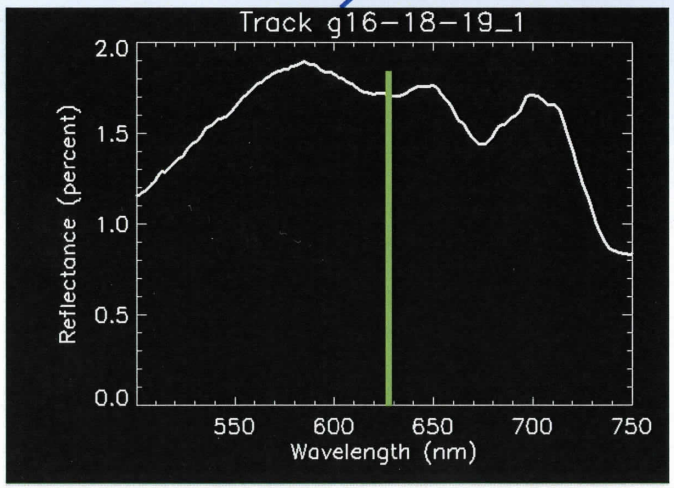


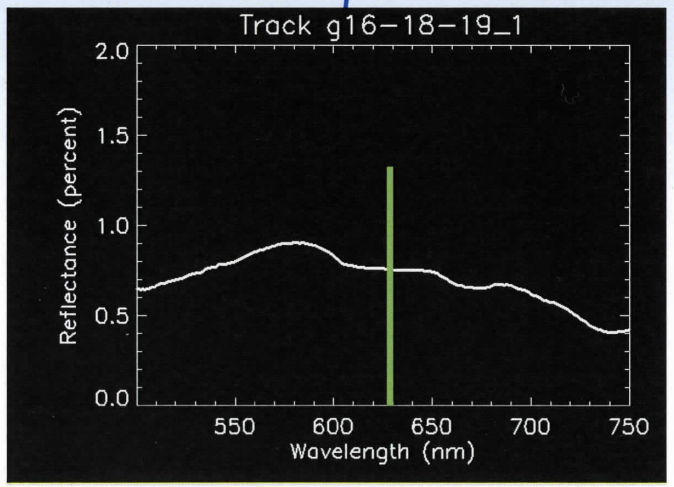
Lake Erie HSI – Maumee Bay September 13, 2007

Slight indication of Phycocyanin in bay (left)

No indication further out (right)

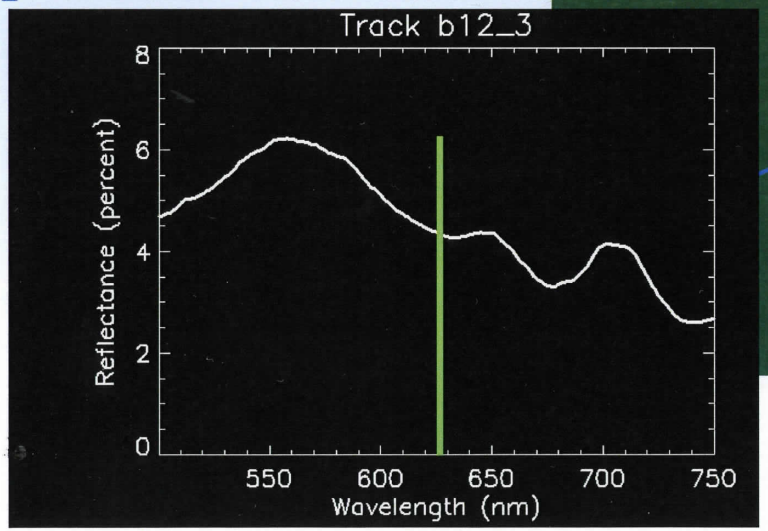


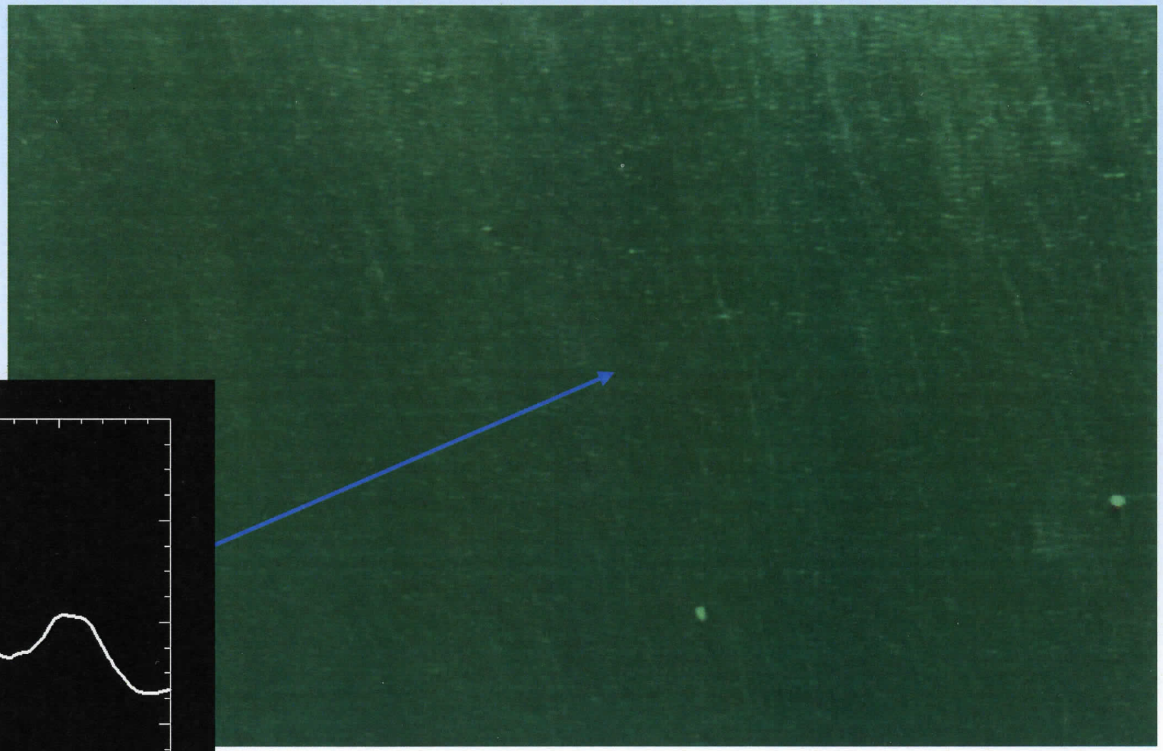




Hyperspectral Data Saginaw Bay – Sept. 13, 2007

Little or no indication of Phycocyanin absorption in HSI spectrum





Summary

- Two generations of hyperspectral imagers have been built and tested the past two years
- Both were built primarily for water quality studies and were intended for flexibility in deployment – they were made lightweight, compact and durable
- Data has been acquired in 2006 and 2007 with concurrent water sampling
- Data from Gen II HSI looks very promising for the remote identification of Microcystis
- Next step is to compare aerial hyperspectral measurements of each sampling point to the water samples that were obtained at those points on the same day
- Future plan is to deploy the Gen II instrument on a tethered balloon on the southern shore of Lake Erie for time lapse study in late 2008

Project Team

- **Instrument Team**
  - Robert Anderson, Image Processing
  - Jerry Anschuetz, Quality Assurance
  - Jim Demers, Research Pilot
  - Al Mickelright, Research Pilot
  - Mike Ernst, Aircraft Engineering
  - Joe Flatico, Software and Electronics
  - Steve Hayes, Crew Chief - T 34
  - Steven Hughel, Crew Chief - Lear 25
  - Don Hilderman, former Project Manager
  - Michael Krasowski, Lead Electronics Engineer
  - Dr. Jun Kojima, Instrumentation Calibration
  - George Leshkevich, Project Scientist (NOAA GLERL)
  - John Lekki, Primary Investigator
  - Dr. Quang-Viet Nguyen, Hyperspectral Imager Development
  - Norman Prokop, Electronics
  - Danny Spina, Electronics Technician
  - Larry Liou, Research Test Support Supervisor
  - Trevor John, Engineering Technician
  - Nathaniel Doy, Electrical Engineering Coop
  - Floyd Truskot, Electrical Engineering Technician
  - Tim Ubienski, Mechanical Technician

- **Center Management Support**
  - Dr. Jih-fen Lei, Director of Research and Technology Directorate
  - Anita Liang, Deputy Director of Facilities
  - Sandy Reehorst, Chief Advanced Flight Projects Office
  - Dr. Mary Zeller, Chief of Instrumentation and Controls Division
  - Dr. George Baaklini, Chief of Optical Instrumentation and Non Destructive Evaluation Branch
  - Alan Micklewright, Chief of Aircraft Operations Office