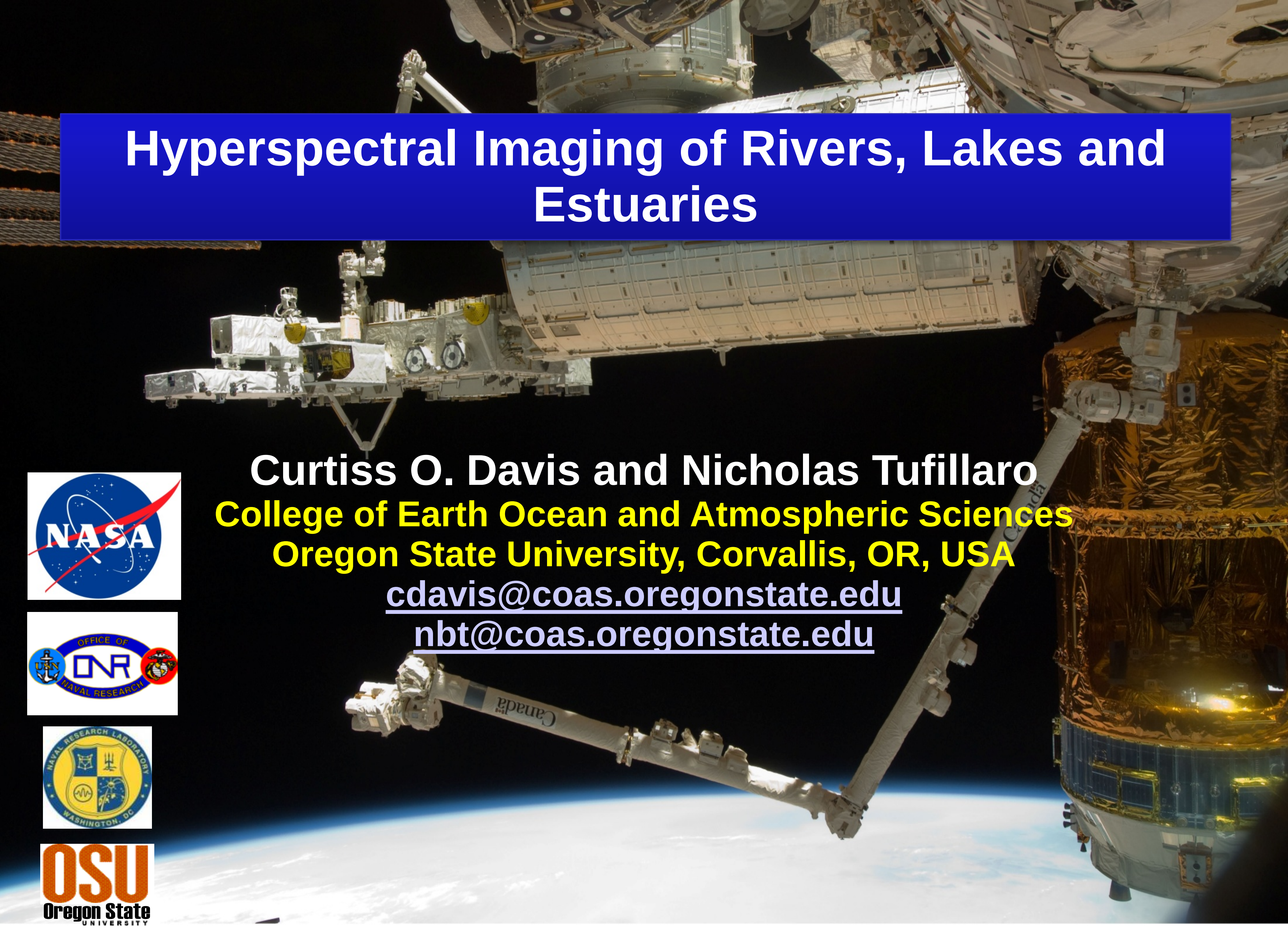
Hyperspectral Imaging of Rivers, Lakes and Estuaries



Curtiss O. Davis and Nicholas Tufillaro
College of Earth Ocean and Atmospheric Sciences
Oregon State University, Corvallis, OR, USA
cdavis@coas.oregonstate.edu
nbt@coas.oregonstate.edu

Introduction and Outline

- The Hyperspectral Imager for the Coastal Ocean (HICO)
- Derivative Analysis
  - The Elwha River Dam removal
  - Columbia River
  - Yangtze River
- Monterey Bay Phytoplankton blooms
- Phase Difference Function
  - San Francisco Bay
- Cyanobacteria blooms in lakes
- HICO Summary

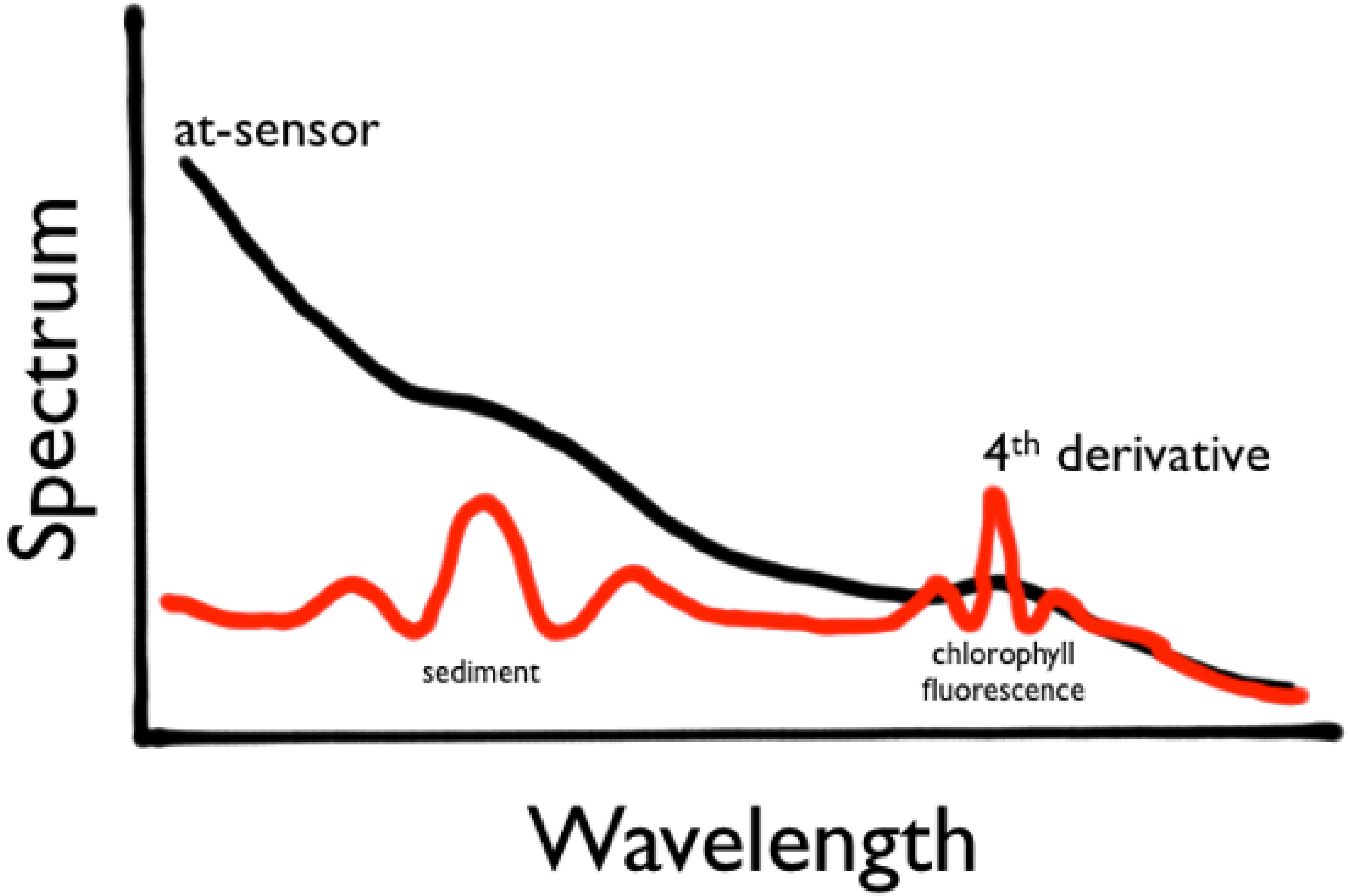
What is the Hyperspectral Imager for the Coastal Ocean (HICO)?

- HICO is an experiment to see what we gain by imaging the coastal ocean at higher resolution from space.
- The HICO sensor:
  - first spaceborne imaging spectrometer for coastal oceans
  - samples coastal regions at **<100 m (400 to 900 nm: at 5.7 nm)**
  - high signal-to-noise ratio to resolve the complexity of the coastal ocean
- Sponsored as an Innovative Naval Prototype (INP) by the Office of Naval Research: Goal to greatly reduce cost and shorten schedule.
  - Start of Project to Sensor Delivery in 16 months
  - Launched September 10, 2009; over 9000 scenes imaged to date

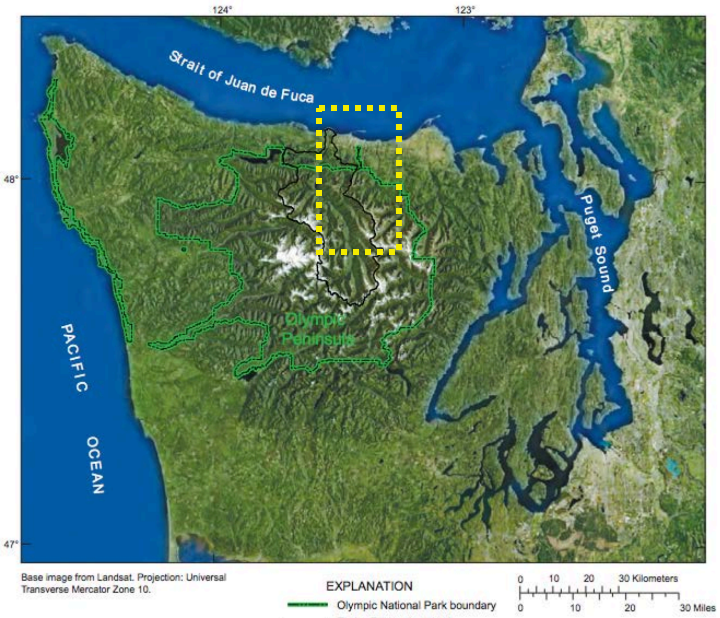
HICO image of Hong Kong, October 2, 2009.

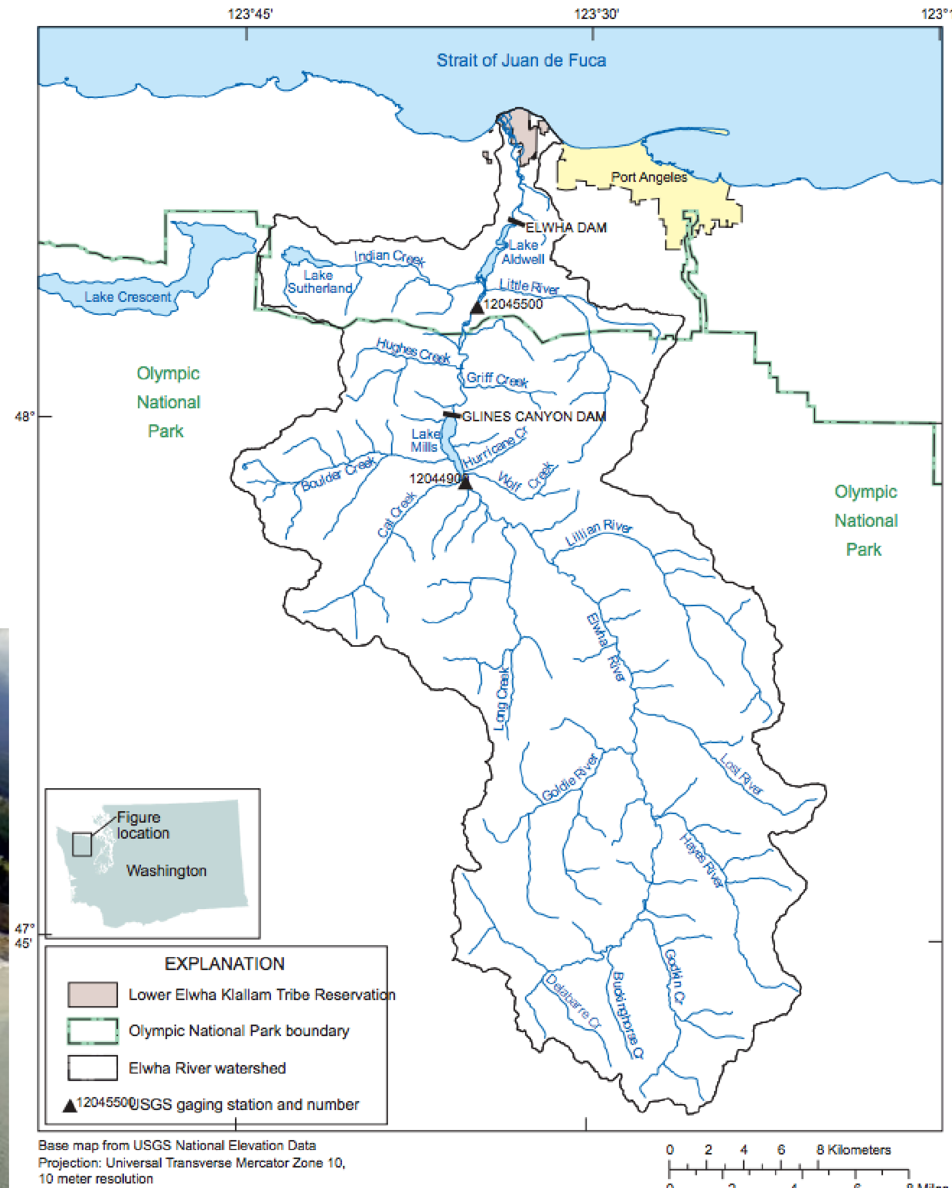
HICO is integrated and flown under the direction of DoD's Space Test Program

Derivative Spectroscopy



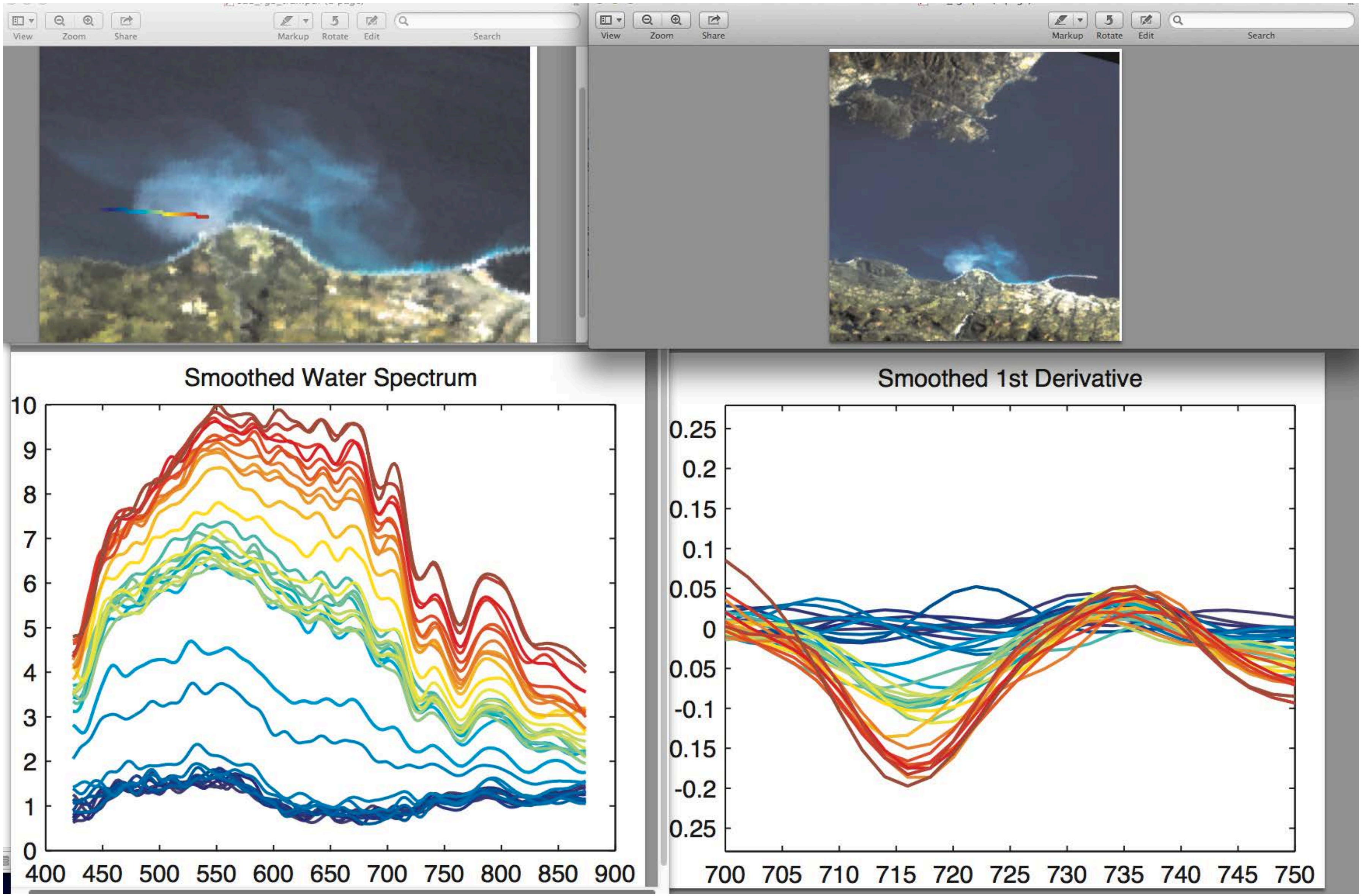
Removing Dams from the Elwha River, Washington



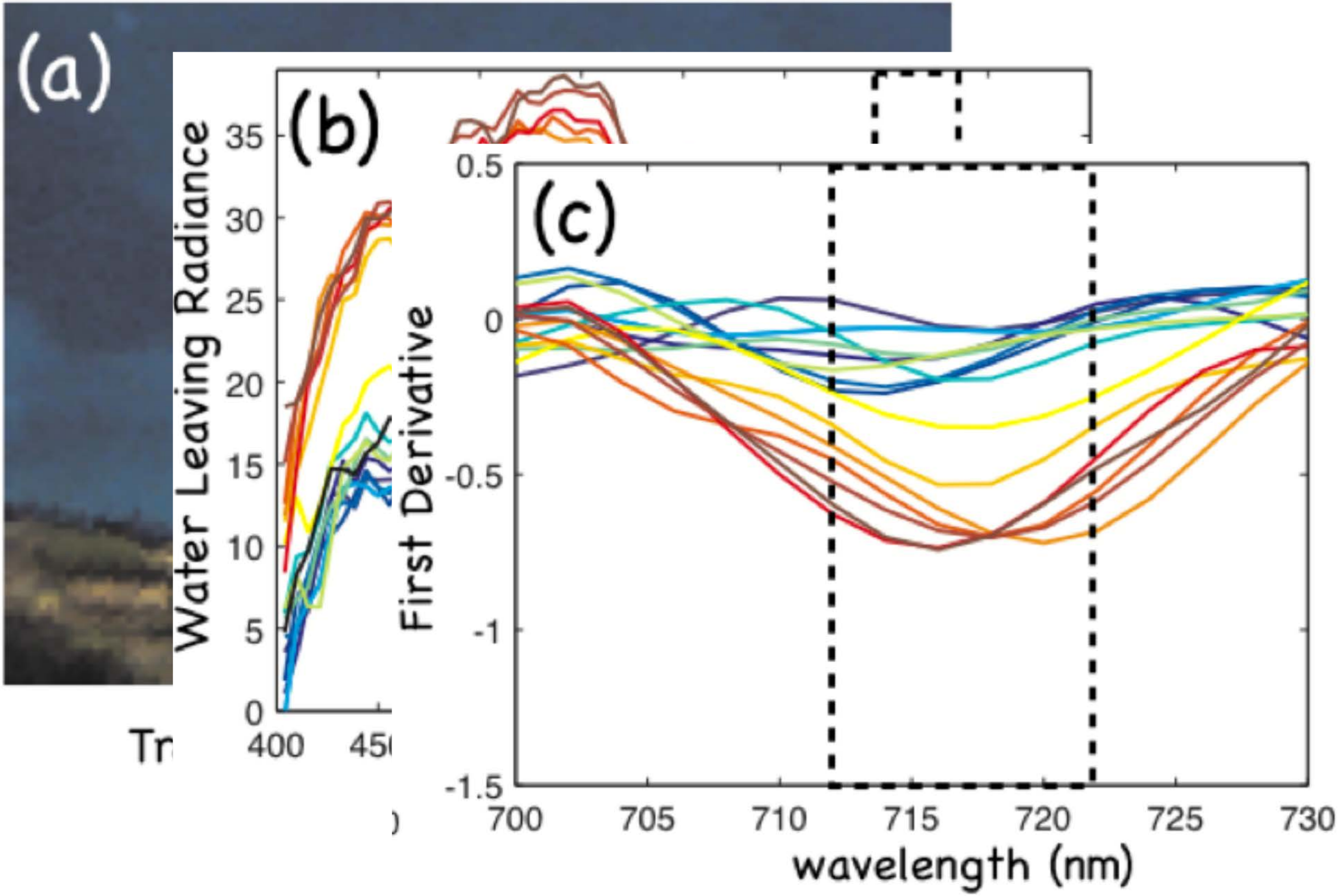


Lake Aldwell after dam removal

HICO Image of Elwha River, Washington

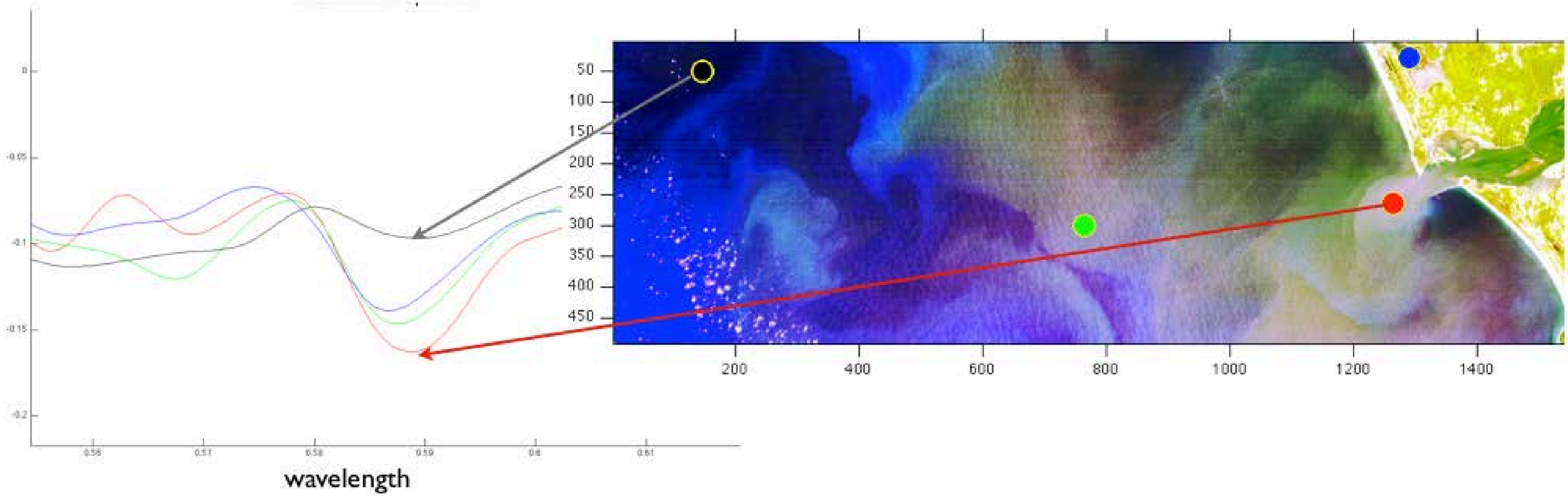


Elwha River Plume Derivative analysis

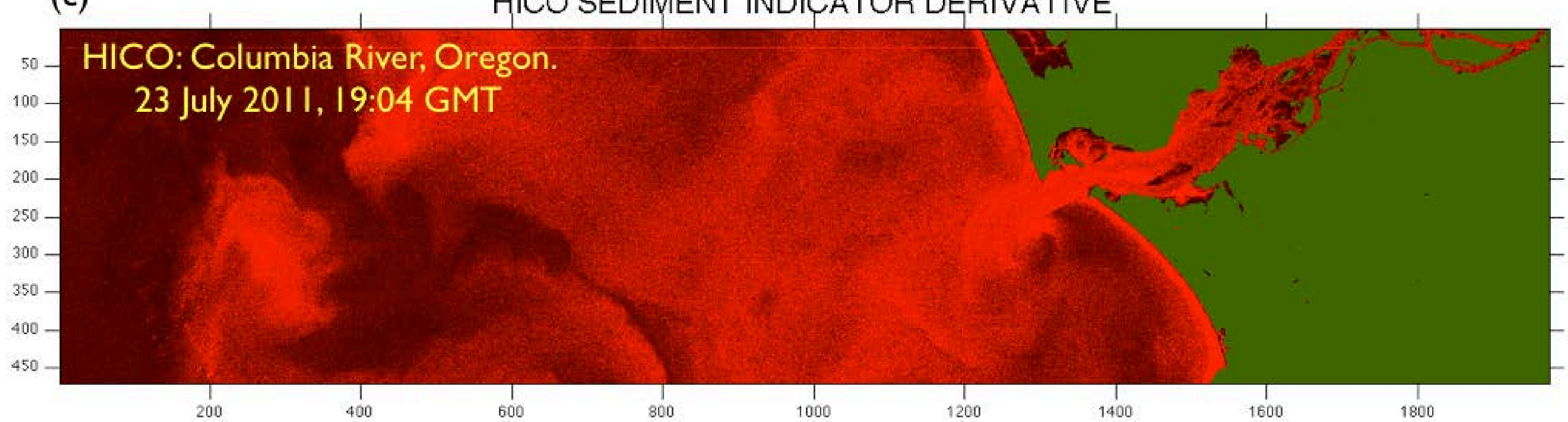


Columbia River Plume Derivative Analysis

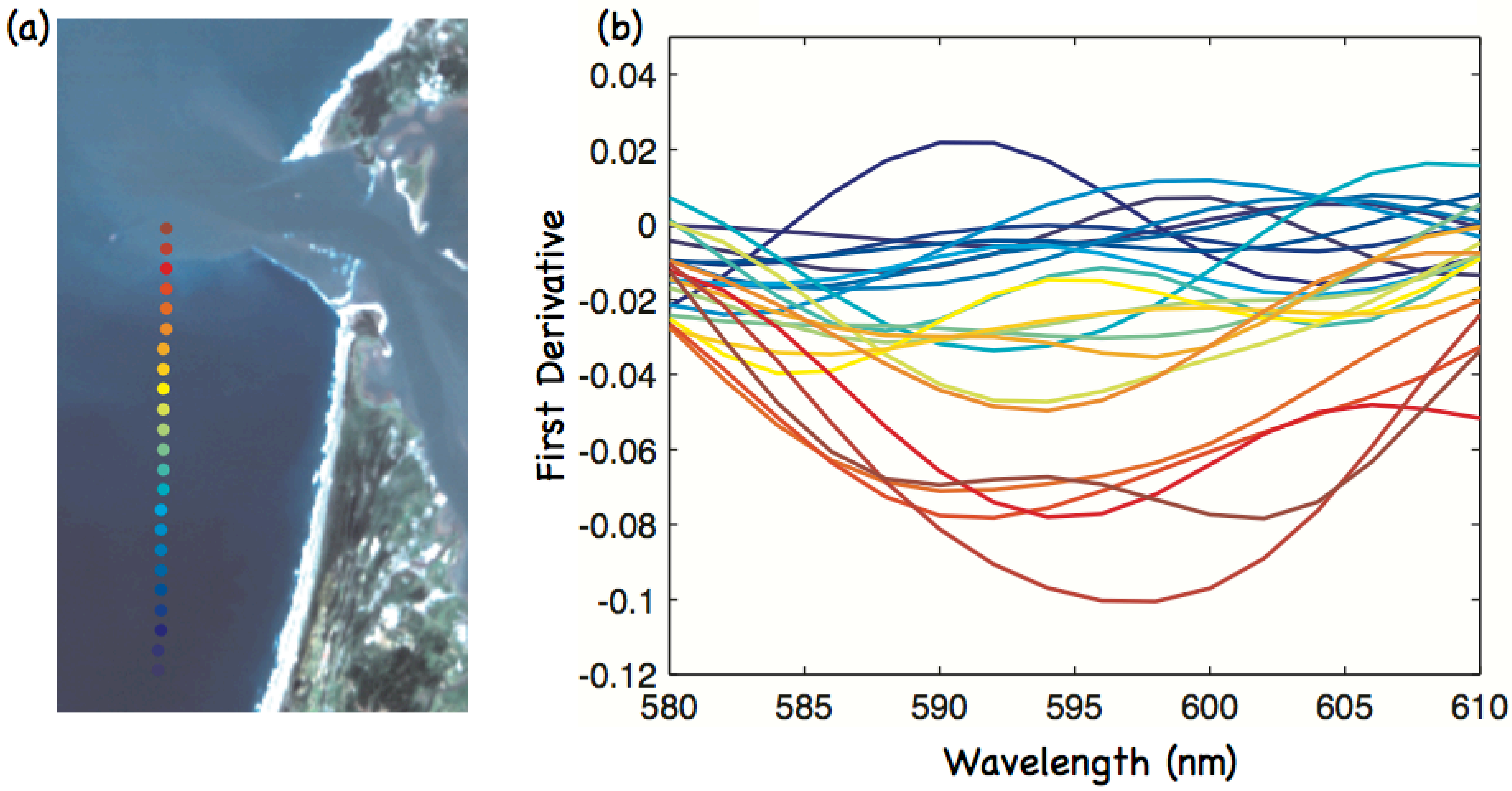
(a) Derivative of HICO Spectra (b) HICO Columbia River Swath 23 July 2011



(c) HICO SEDIMENT INDICATOR DERIVATIVE

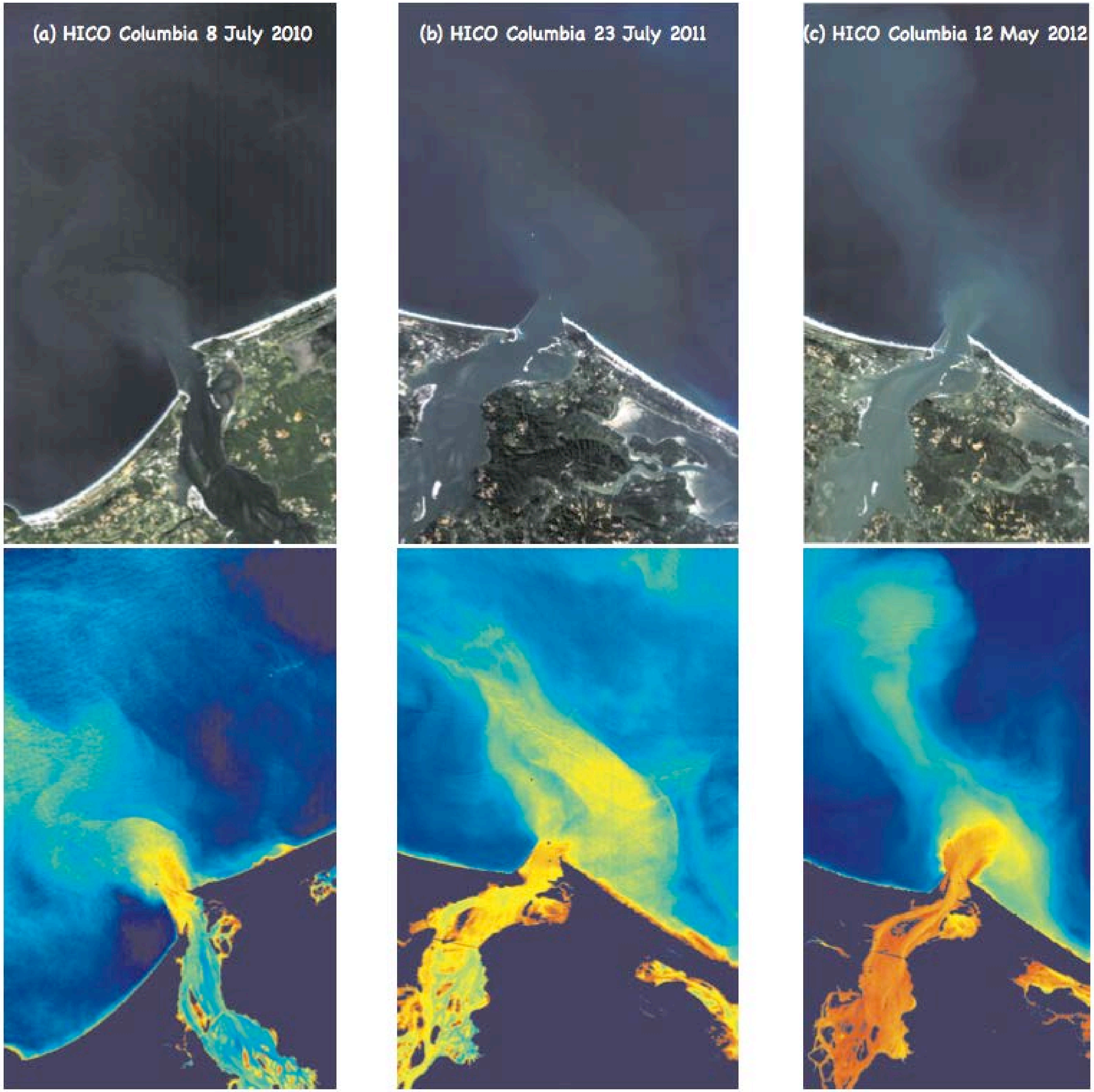


Columbia River Plume Derivative Analysis



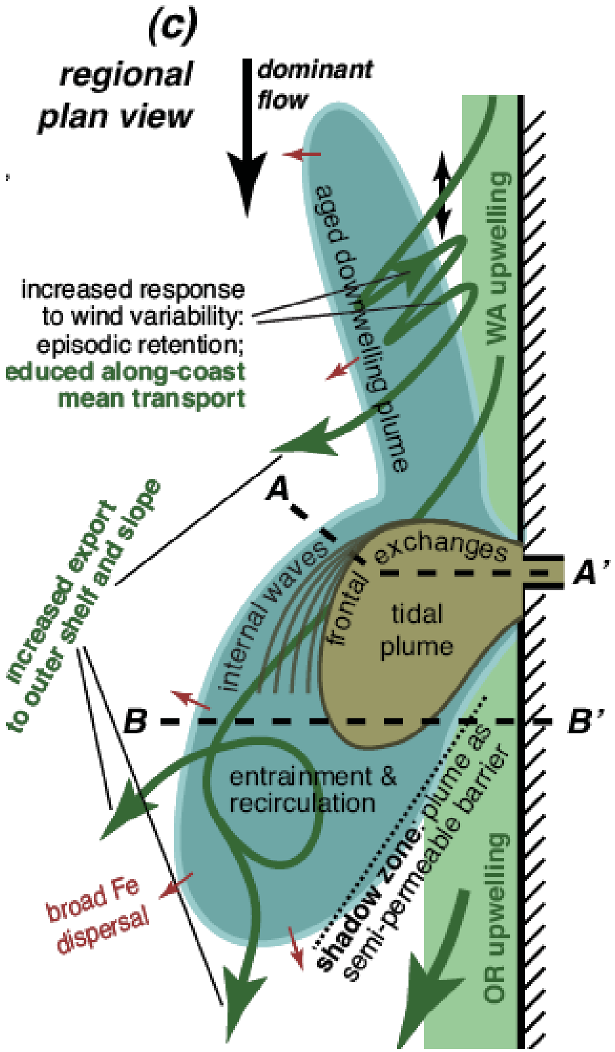
(a) HICO 12 May 2012 image of the Columbia River Mouth showing transect used for selecting spectra. (b) The first derivative of the spectrum shows (negative) extrema around 595 nm for sediment-laden waters.

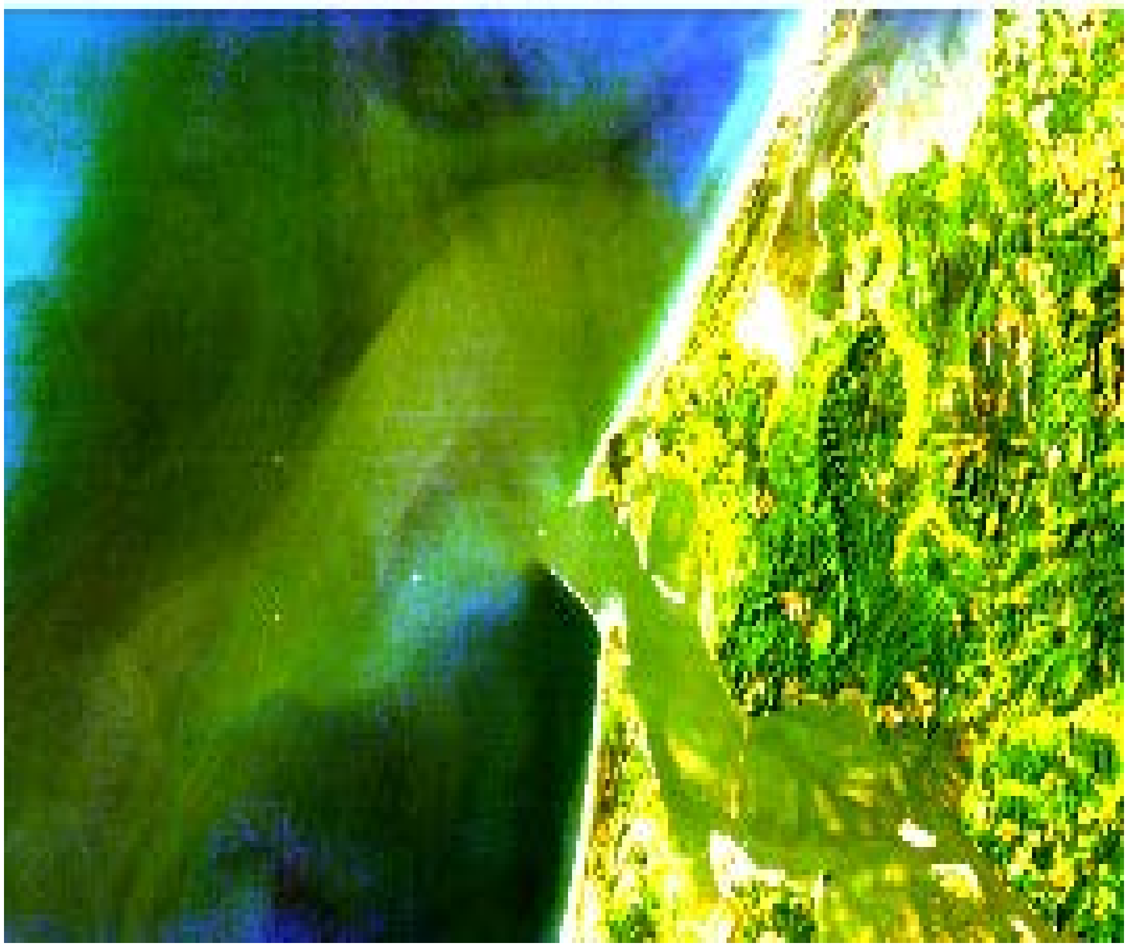
Columbia River Plume identification



HICO images of the Columbia River Mouth. The top images show RGB for the indicated dates. The bottom images are river plume sediment maps based on derivative analysis.

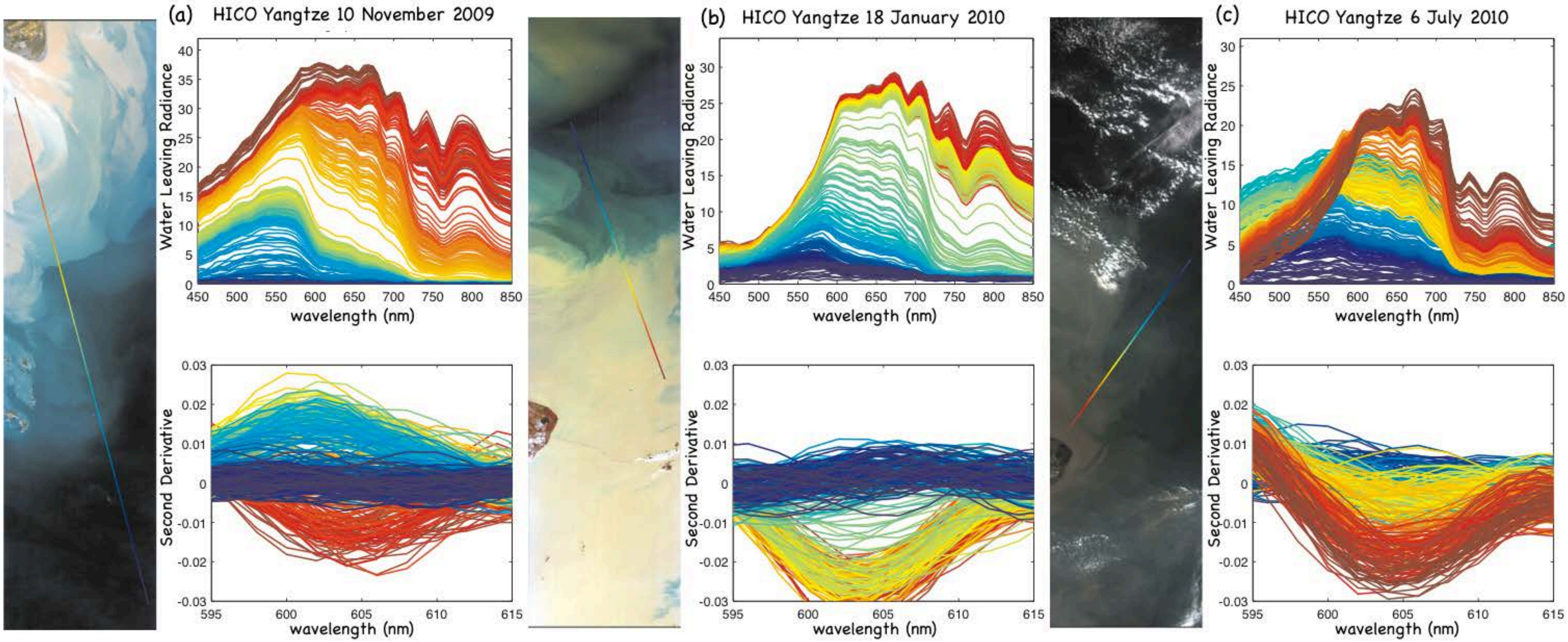
HICO data shows plume complexity





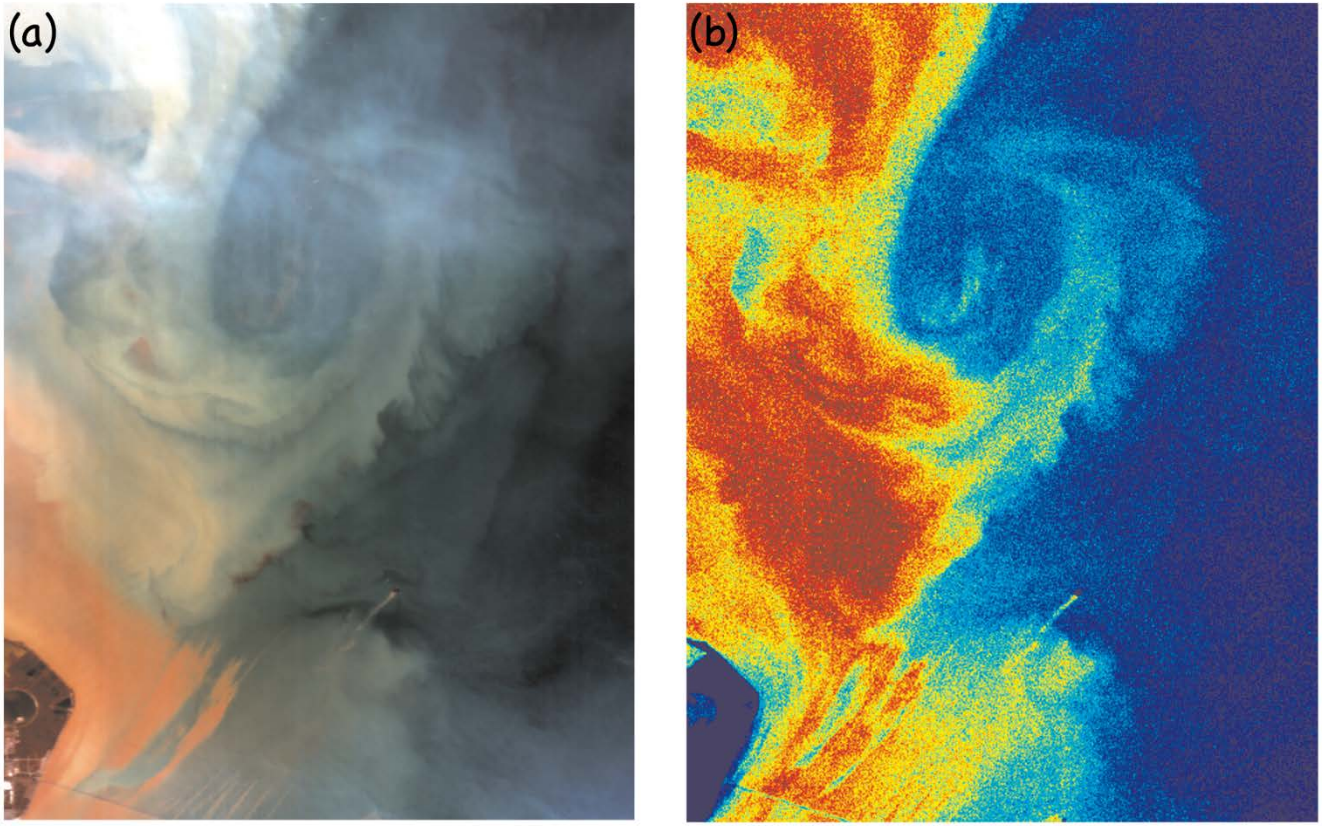
Comparing RISE Synthesis view of the plume (Hickey, et al, 2010, JGR 115: C00B17) and Columbia River 13 July 2010 HICO sediment product using Derivative Analysis (N. B. Tufillaro, preliminary results)

Yangtze River, China



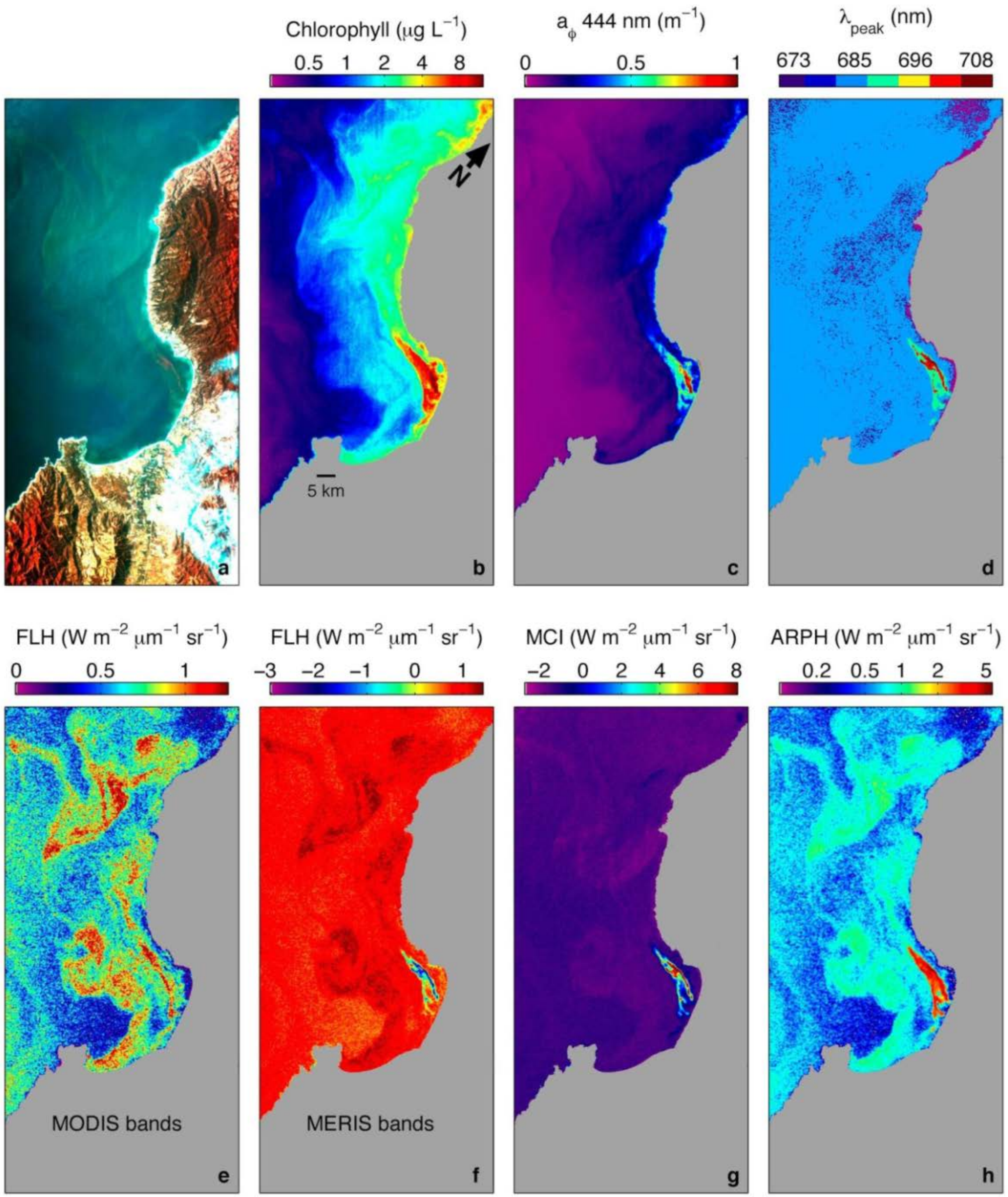
HICO images and derivative spectra of the Yangtze River in China. Using collections of images we are building up signatures to distinguish the constituents of the water column for this region. This sequence of images and spectra illustrates a consistent (negative) extrema for Yangtze River sediments in the second derivative around 605 nm. The spectra are taken from the rainbow-colored transect indicated in each image.

Yangtze River, China sediment map



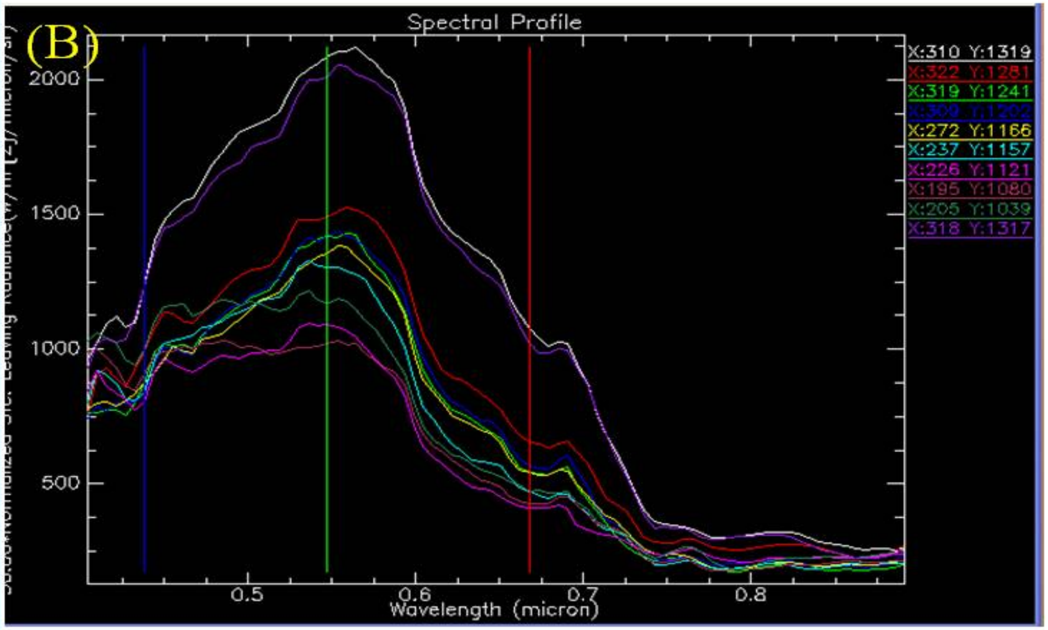
HICO RGB image and (b) sediment product map for Yangtze River, China on 6 July 2010. Fig. 2 (c) shows the second derivative of the spectrum around 605 nm, which is more sensitive to sediment concentration than the 620 nm MERIS band 6. Our HICO product algorithm automatically optimizes the product algorithm to weight data more heavily around 605 nm when trained on Yangtze regional historical data, like those presented in the previous slide.

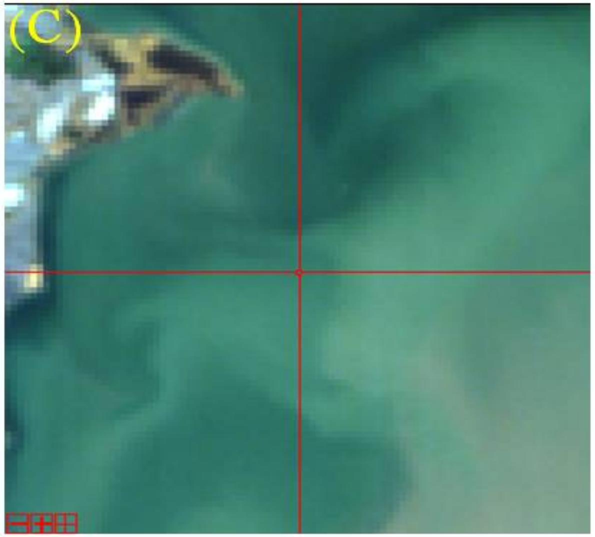
Monterey Bay, CA HICO Data
(6 November 2012)



Characterization of phytoplankton in Monterey Bay from a suite of algorithms. The enhanced color image (a) used bands centered at the 466 nm (blue), 554 nm (green), and 708 nm (near infrared, to emphasize signal of the red tide). The continuous spectral from HICO allows the evaluation of existing algorithms and testing of a new algorithm (ARPH) using the same data set for all the products. (Ryan, et al., Remote Sens. 2014, 6, 1007-1025)

San Francisco, San Pablo and Suisun Bays





San Francisco Bay Estuary, June 24, 2011

Adapting Signal-Processing Techniques

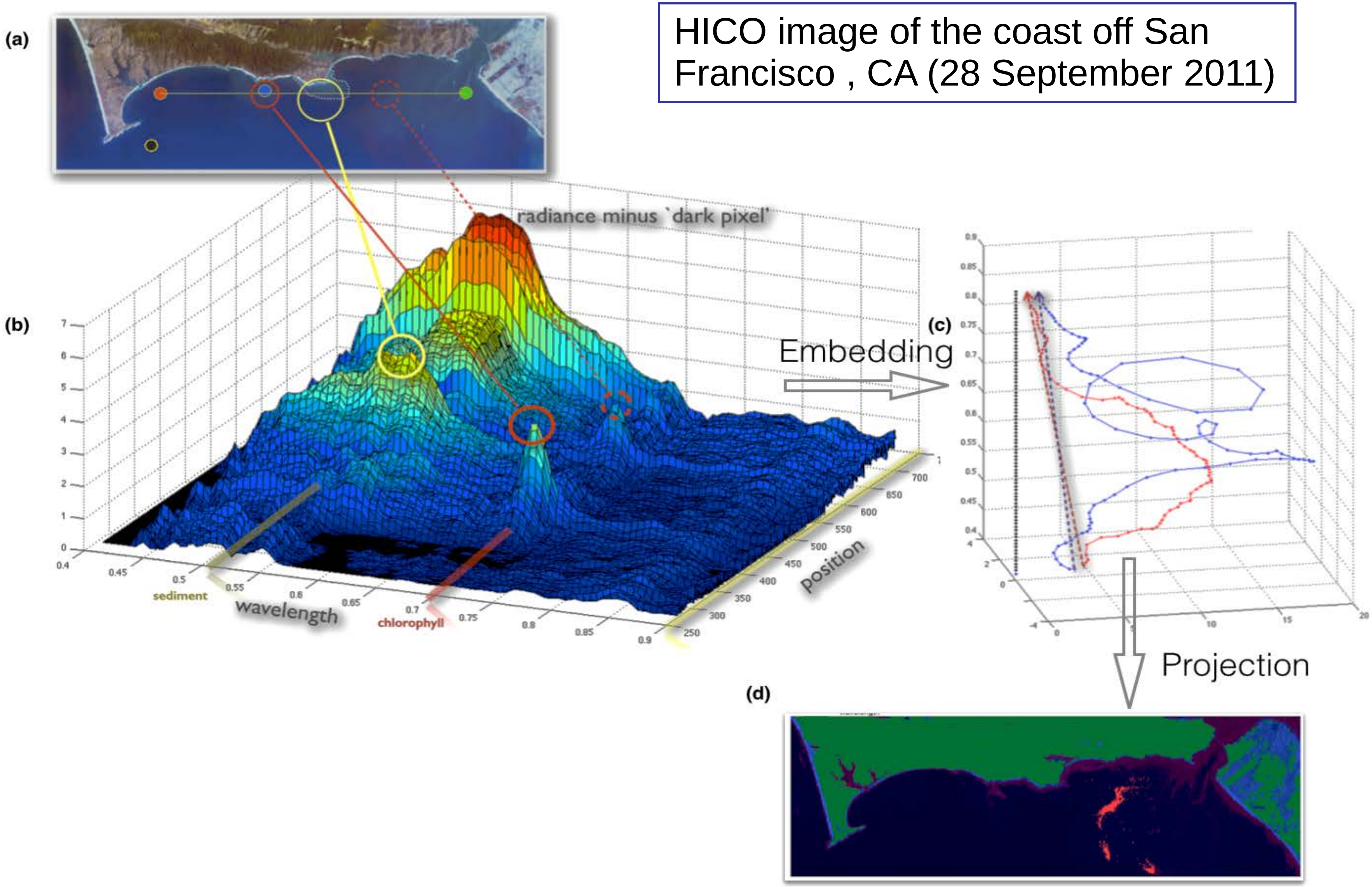
We are investigating combining a number of signal processing techniques for analysis of HICO data. Though the methods might appear distinct, in fact, each one implements one step in our paradigm for embedding, manifold reconstruction, and projection. For instance 'derivative spectroscopy' essentially is the method for 'embedding'. 'Sparse signal processing' contributes a (run-time) computationally effective method for 'manifold reconstruction'. Our example algorithm using nonlinear optimization illustrates an efficient method for projecting which can preserve clustering separation.

Topic	Application in Manifold Framework for Target Generation
Derivative Spectroscopy	Embedding
Sparse Signal Processing	Global Manifold Reconstruction and Projections
Nonlinear Optimization (Peak Finding)	Projections

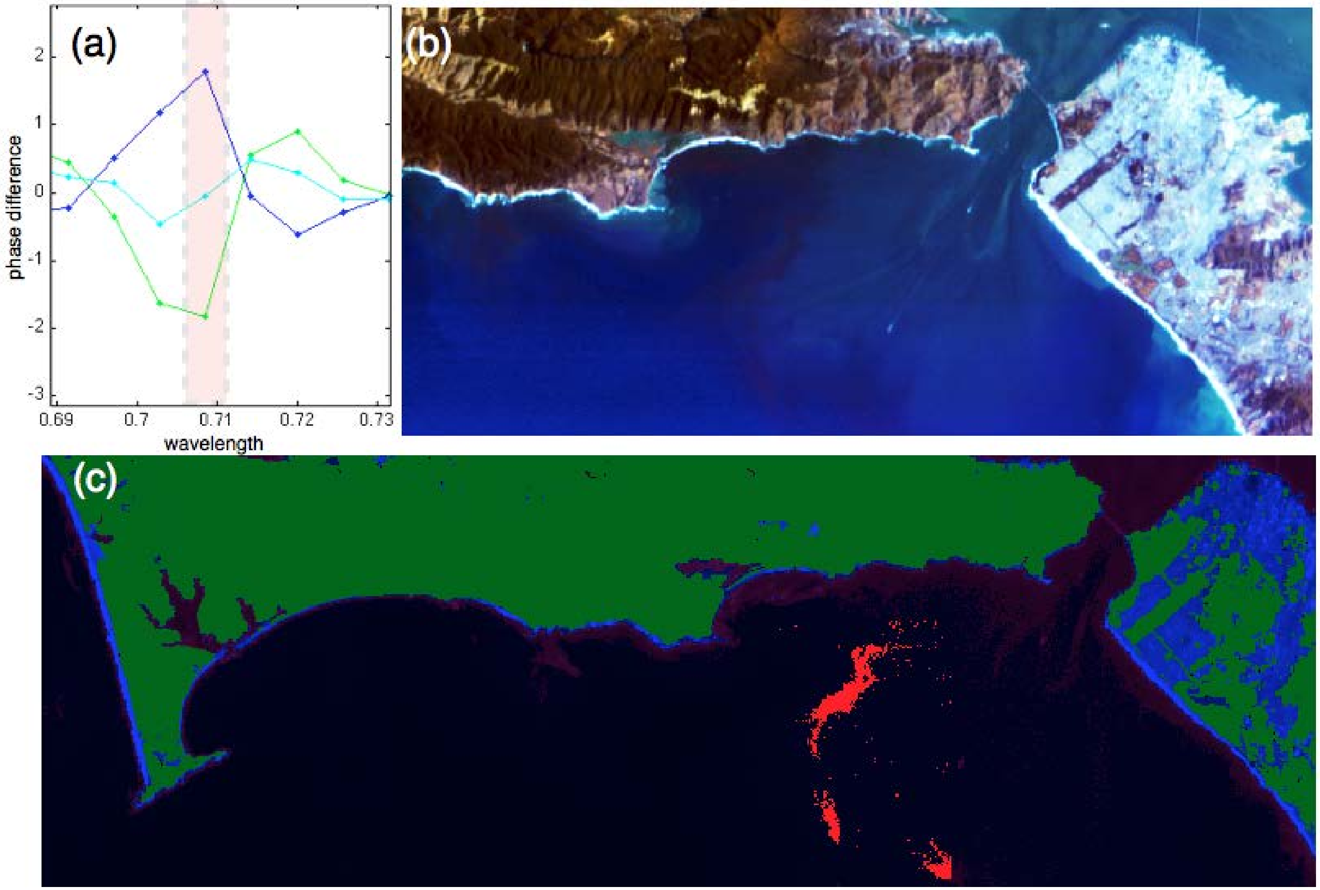
Tufillaro, N., 2012, "The shape of ocean color," book chapter in From Laser Dynamics to the Topology of Chaos, R. Gilmore and C. Letellier eds., World Scientific

Using embedded nonlinear manifold

HICO image of the coast off San Francisco , CA (28 September 2011)

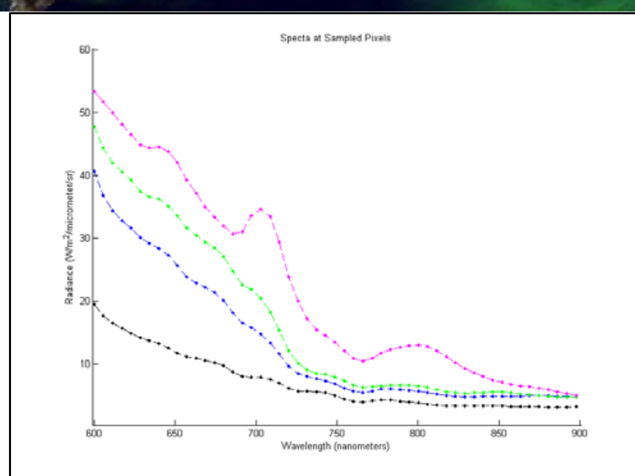


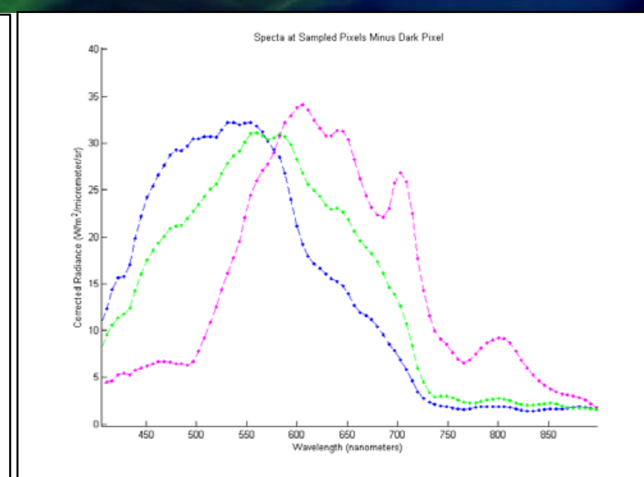
San Francisco Bay Phase Difference Function



(a) The phase difference function for spectra at the mouth of the San Francisco Bay showing that the 709 nm HICO channel can be used to indicate chlorophyll rich water. (b) HICO image of the mouth of San Francisco Bay, 28 September 2011. (c) Indicator function for high chlorophyll levels which show a high concentration of chlorophyll at the interface of bay water and sea water apparently in response to large amounts of nutrients being exported from SFE.

Microcystis bloom in Lake Erie

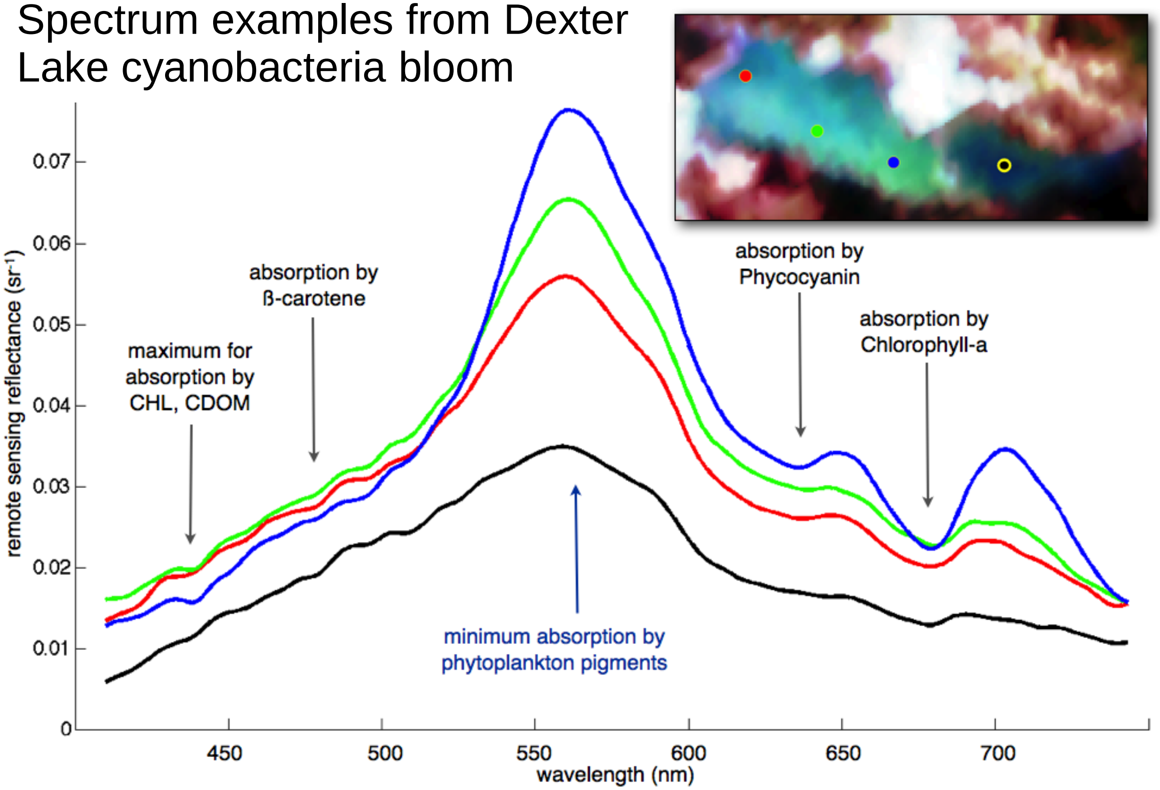


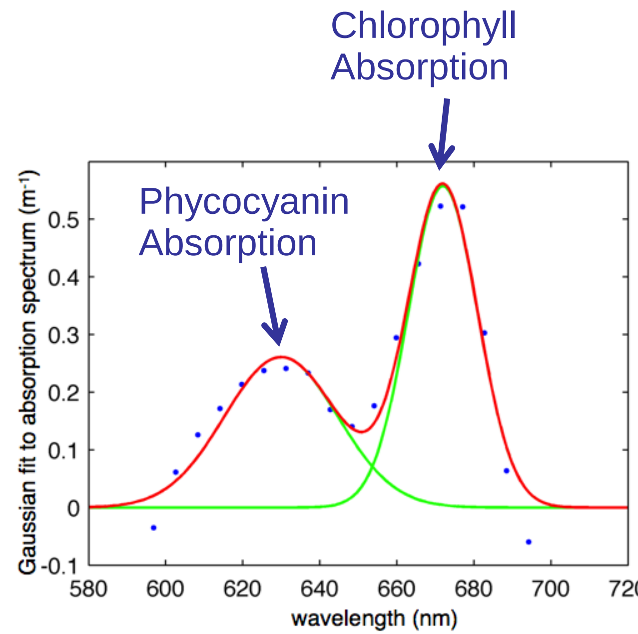


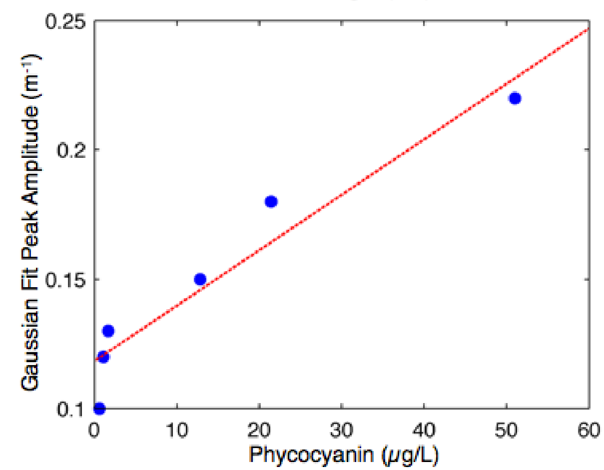
HICO Image of a massive *Microcystis* bloom in western Lake Erie, September 3, 2011 as confirmed by spectral analysis.

Using HICO Data and spectral peak detection to monitor the Health of Lakes and Reservoirs

Spectrum examples from Dexter Lake cyanobacteria bloom

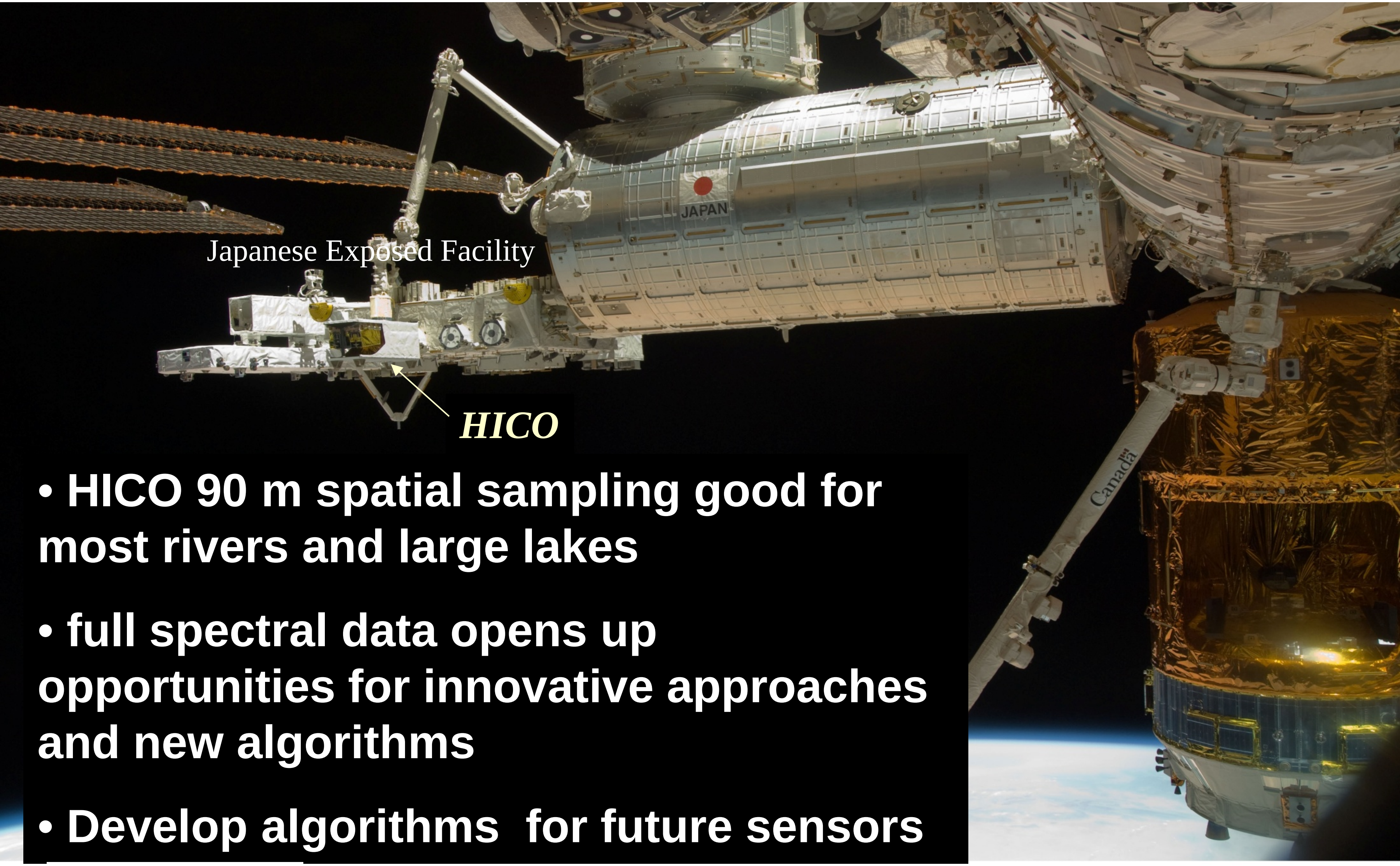






HICO data is being used to track a cyanobacteria bloom in Dexter Reservoir, July 2013. The bloom is quantified using the absorption peaks. Phycocyanin absorption identifies it as a Cyanobacteria bloom.

HICO Summary: 4.5 Years and Counting



- HICO 90 m spatial sampling good for most rivers and large lakes
- full spectral data opens up opportunities for innovative approaches and new algorithms
- Develop algorithms for future sensors