HICO OSU Website and Data Products

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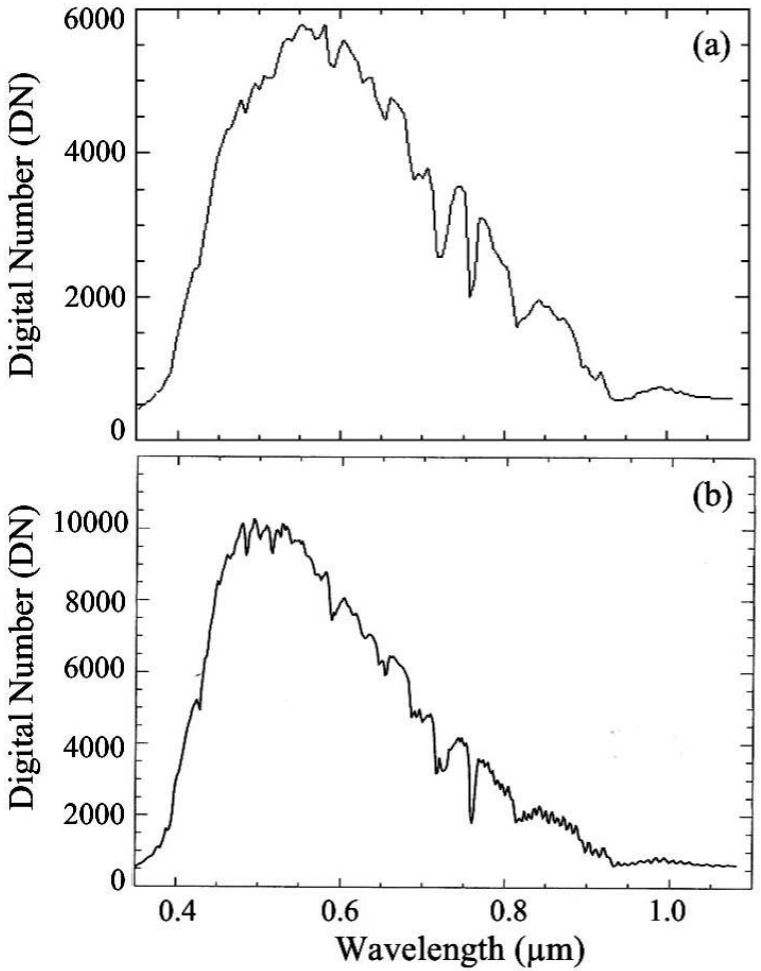
Introduction and Outline

- HICO calibrated radiances
- Atmospheric correction
- Derivative analysis at OSU
  - Products
  - Sites
- Access to HICO data via. CEOAS HICO website
- Summary and future directions

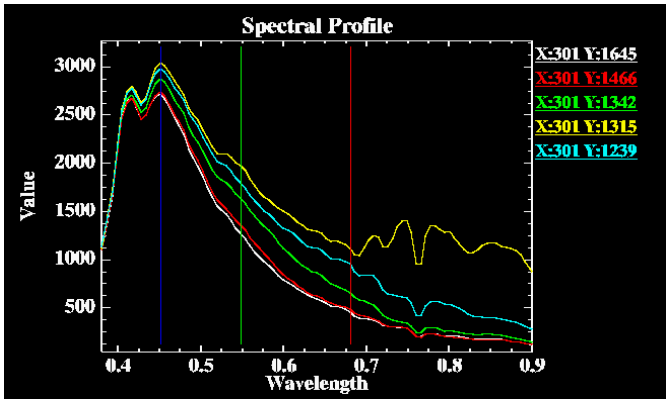
HICO On-Orbit Calibration

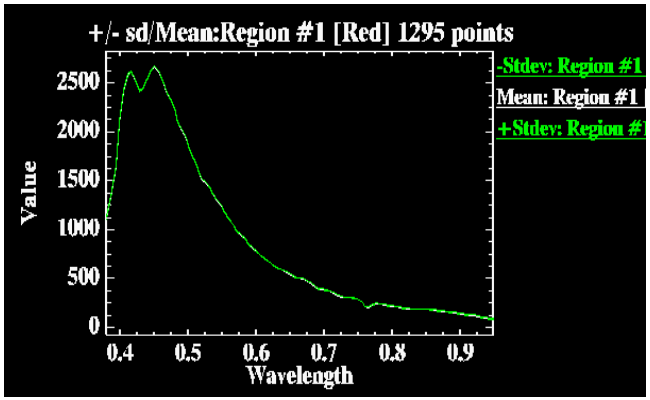
- HICO fully calibrated in the laboratory (Lucke et al, 2011)
  - Radiometric calibration
  - Spectral calibration
  - Dark current correction
  - Second Order correction
- HICO does not have a second order filter or an on-board calibrator.
- Cannot ask the ISS to rotate to point at the moon.
- On-orbit calibrations using natural scenes (Gao et al, 2012)
  - Spectral calibration using Fraunhofer lines and oxygen line
  - Radiometric calibration using land calibration targets
  - Second order correction using water scenes



HICO spectra a) normal (5.7 nm) resolution and b) at full (1.9 nm) resolution used for spectral calibrations.

Calibrated Spectral Radiances





Left: Spectra extracted from pixels along the east-west transect shown in yellow. Approximate locations of the spectra are indicated by same color Xs on the image. Spectra are scaled calibrated at-sensor radiances.

Right: Mean and standard deviation of 1295 pixels in the red Region of Interest. The SNR (μ/σ including all sensor and environmental variations) is >300:1 for much of the spectra. Spectra are scaled calibrated at-sensor radiances.

Radiometric Comparison of HICO to MODIS (Aqua)

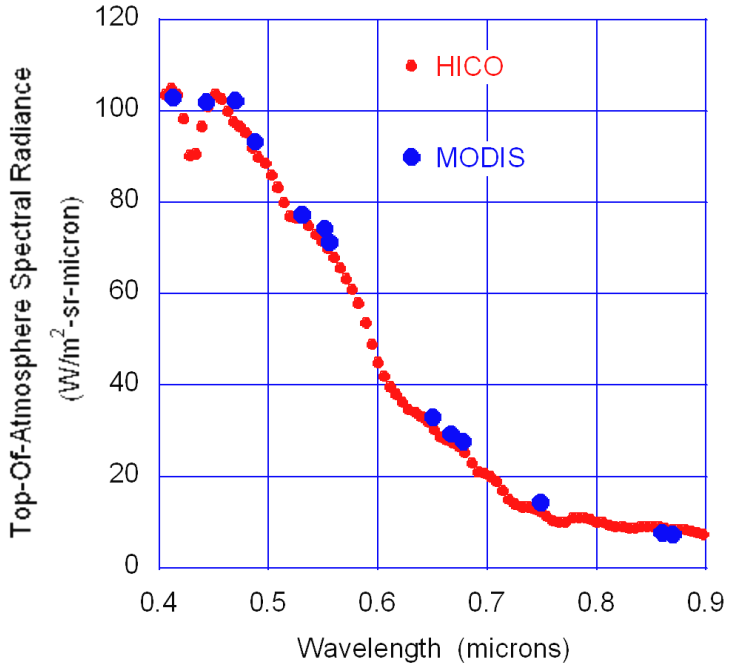
Nearly coincident HICO and MODIS images of turbid ocean off Shanghai, China demonstrates that HICO is well-calibrated

HICO	MODIS (Aqua)
Date: 18 January 2010	Date: 18 January 2010
Time: 04:40:35 UTC	Time: 05:00:00 UTC
Solar zenith angle: 53°	Solar zenith angle: 52°
Pixel size: 95 m	Pixel size: 1000 m

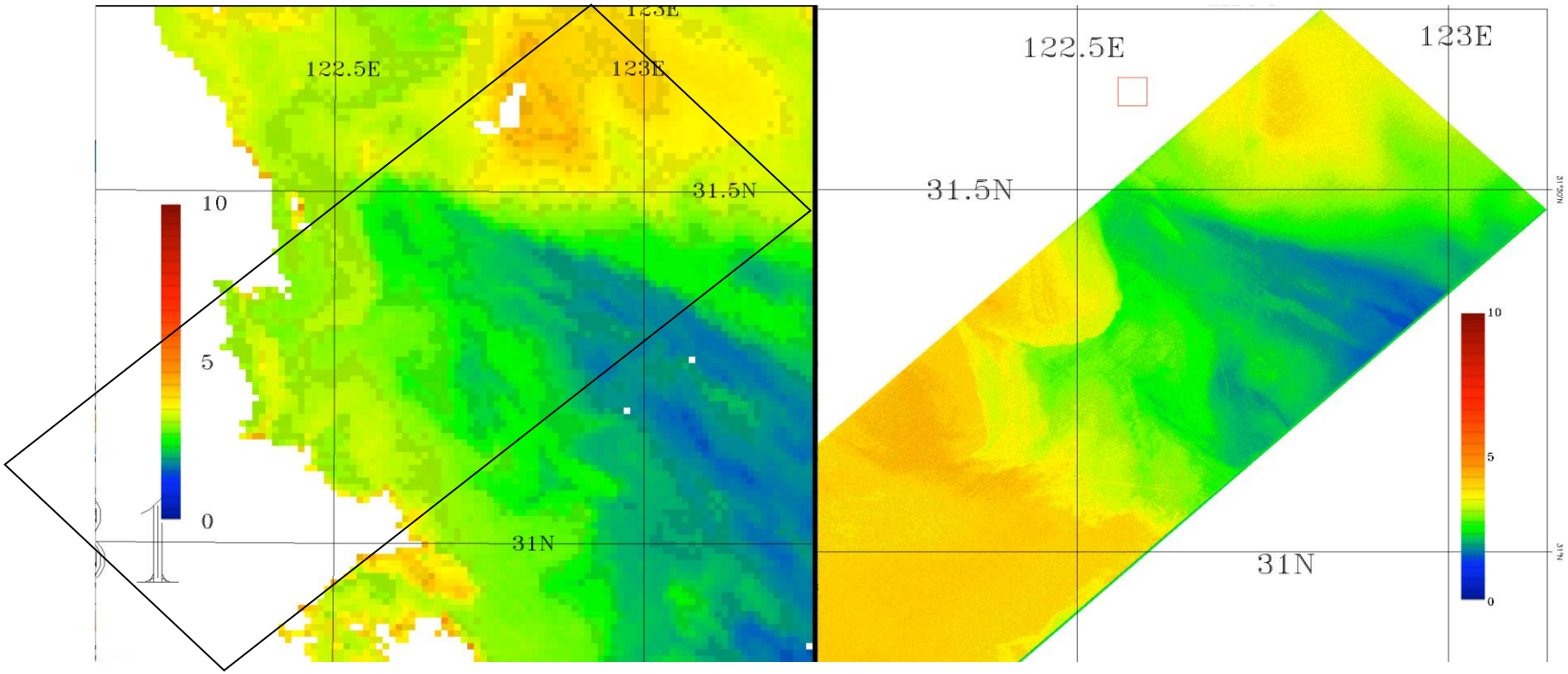
East China Sea off Shanghai

R.-R. Li, NRL

Top-Of-Atmosphere Spectral Radiance

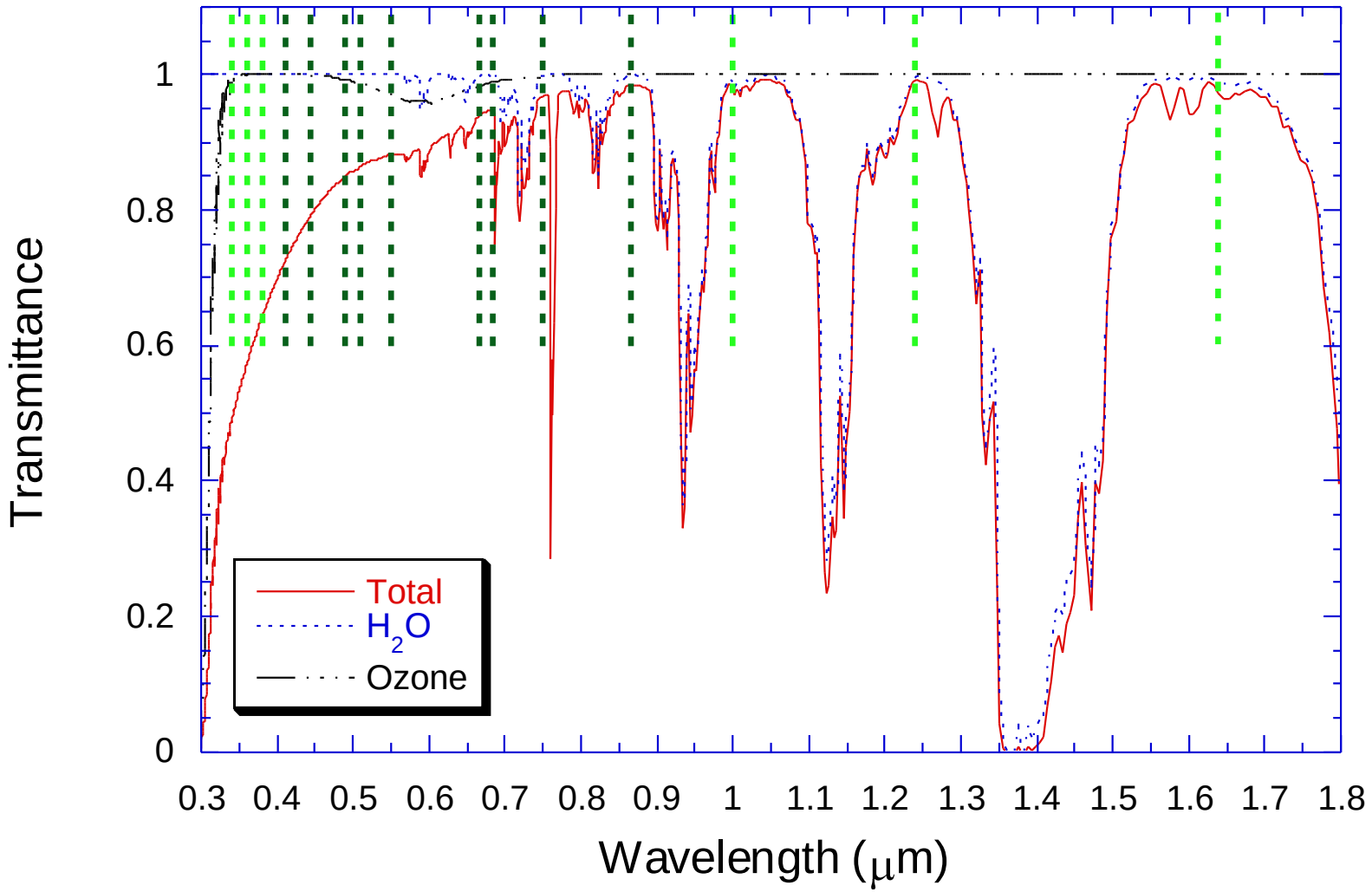


Chlorophyll Comparison of HICO to MODIS (Aqua)



Nearly coincident MODIS and HICO™ images of the Yangtze River, China taken on January 18, 2010. Left, MODIS image (0500 GMT) of Chlorophyll-a Concentration (mg/m3) standard product from GSFC. The box indicates the location of the HICO image relative to the MODIS image. Right, HICO™ image (0440 GMT) of Chlorophyll-a Concentration (mg/m3) from HICO™ data using ATREM atmospheric correction and a standard chlorophyll algorithm. (R-R Li and B-C Gao.)

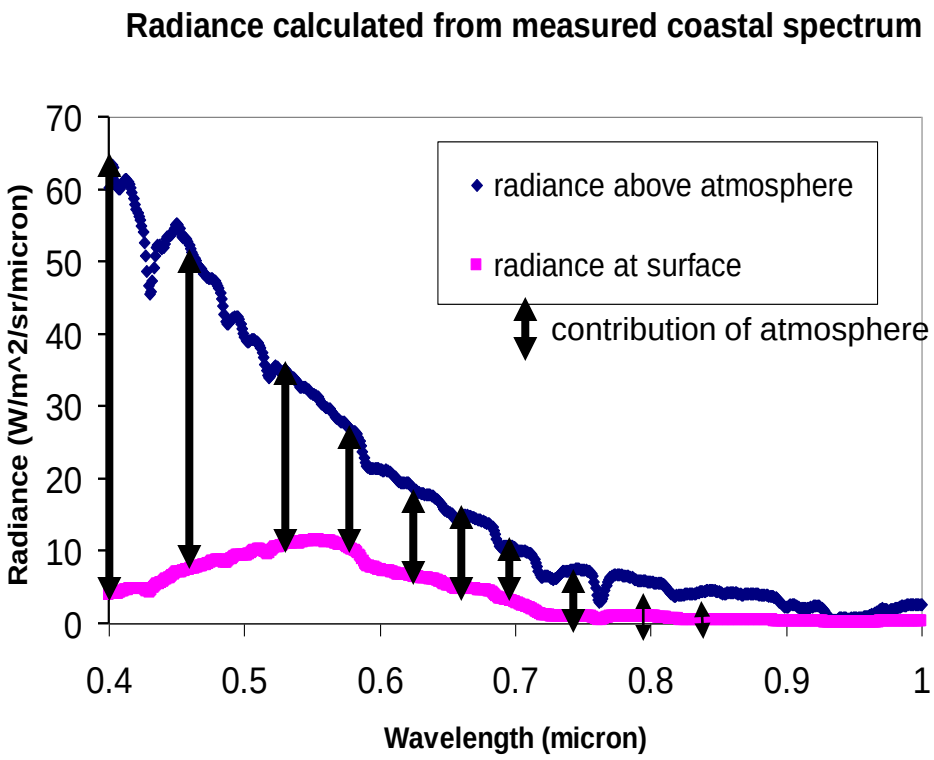
Full Spectral Atmospheric Correction



- Multispectral channels selected to avoid water vapor and other absorptions
- Must correct the full spectrum for hyperspectral data

Figure From Menghua Wang, NOAA/NESDIS/STAR

Difficulty of Atmospheric Removal over water



- Atmosphere most of signal
- Atmospheric gasses are well mixed, well understood
- Water is variable
- Aerosols variable in space & time
- Accurate aerosol models and radiative transfer necessary

Tafkaa Atmospheric Corrections

- Tafkaa-6-S
  - Based on ATREM (Gao & Davis 1997 PROC SPIE)
  - Uses 6-S atmospheric model
  - User selects aerosol model and optical depth
  - Handles data from all altitudes
  - Changes from ATREM include ability to parse image header file, improve speed, use larger set of aerosol models
- Tafkaa-Tabular
  - Much of the code based on ATREM (Gao & Davis 1997, PROC SPIE)
  - Changes as listed above plus:
  - Uses a large look-up table for the aerosol correction
    - Table created using Zia Ahmed's full vector radiative transfer model
    - Can use dark pixel assumption for open ocean scenes
  - Includes a correction for reflections off of the sea surface
  - Only works for near sea-level data
  - Originally described in (Gao, Montes, Ahmad, & Davis, Applied Optics 2000), modifications in several SPIE proceedings

Tafkaa Atmospheric Correction

The apparent reflectance ρ^*_{obs} at a hyperspectral sensor for a given wavelength is

$$\rho^*_{obs} = \pi L_{obs}/(\mu_o F_o) \qquad (1)$$

where L_{obs} is the radiance of the ocean–atmosphere system measured by the sensor, μ_o is the cosine of the solar zenith angle, and F_o is the extraterrestrial downward solar irradiance at the top of the atmosphere. Then ρ^*_{obs} can be expressed as:

$$\rho^*_{obs} = T_g\,[\rho^*_{atm+sfc} + \rho_w t_d t_u/(1 - s\rho_w)] \qquad (2)$$

where T_g is the total atmospheric gaseous transmittance on the sun-surface–sensor path, $\rho^*_{atm+sfc}$ is the reflectance resulting from scattering by the atmosphere and specular reflection by ocean surface facets, t_d is the downward transmittance (direct + diffuse), t_u is the upward transmittance, s is the spherical albedo that takes into account the reflectance of the atmosphere for isotropic radiance incident at its base, and ρ_w is the water- leaving reflectance. Solving (2) for ρ_w yields

$$\rho_w = \rho^*_{obs}/T_g - \rho^*_{atm+sfc}/[t_d t_u + s\,(\rho^*_{obs}/T_g - \rho^*_{atm+sfc})] \qquad (3)$$

Given L_{obs}, the water-leaving reflectance can be derived according to (1) and (3) and the other quantities in the right hand side of (3) modeled theoretically.

Tafkaa-Tabular Look-up Table Generation

We use a modified version of the Ahmad and Fraser code to generate lookup tables for retrieving the required atmospheric parameters. This code includes an atmospheric layering structure that allows for the proper mixing of aerosol particles with atmospheric molecules and the treatment of wind-roughened water surfaces. The lookup table quantities $\rho^*_{atm+sfc}$, t_d, t_u, and s are functions of wavelength (λ), solar zenith angle (θ_o), view zenith angle (θ), relative azimuth angle ($\varphi - \varphi_o$), aerosol model, optical depth (τ_a), and surface wind speed (W). The values of $\rho^*_{atm+sfc}$. In our lookup table are obtained for a total of 25 aerosol models, 16 MODIS channels, and for the following values of independent variables:

τ_a 0, 0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.3, 1.6, and 2.0 at 0.55 μm;

θ_o 1.5 , 12 , 24 , 36 , 48 , 54 , 60 , 66 , and 72 ; 193

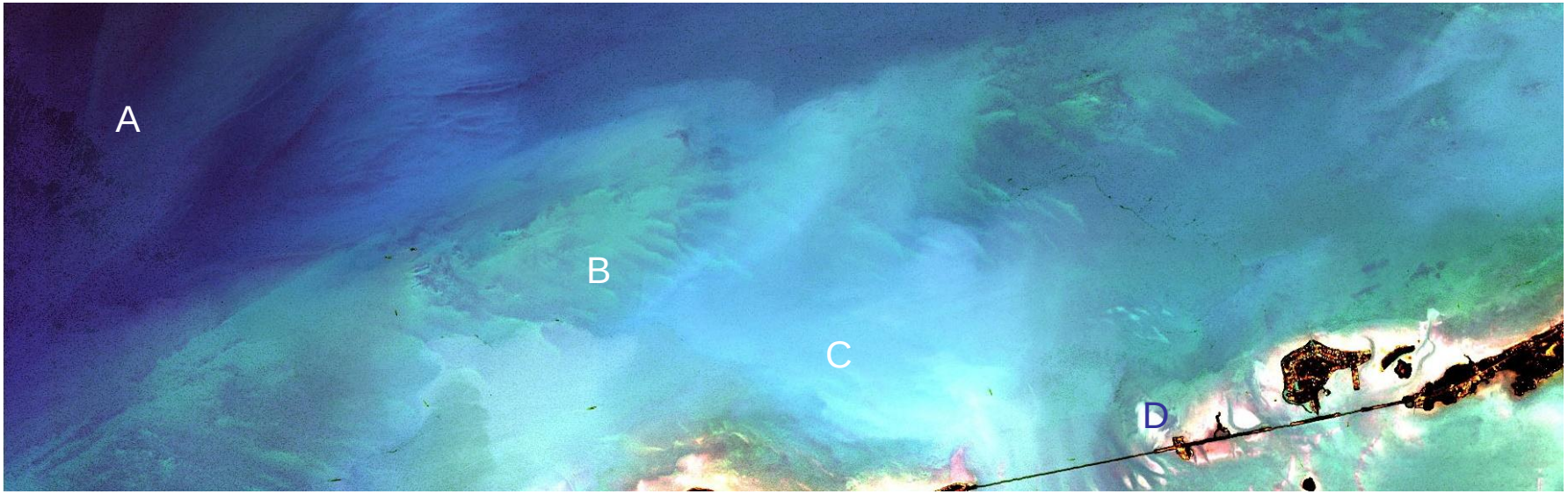
θ 0 , 1.5 , 6 , 12 , 18 , 24 , 30 , 36 , 42 , 48 , 54 , 60 , 66 , 72 , 78 , 84 , and 88.5 ;

φ_o 0;

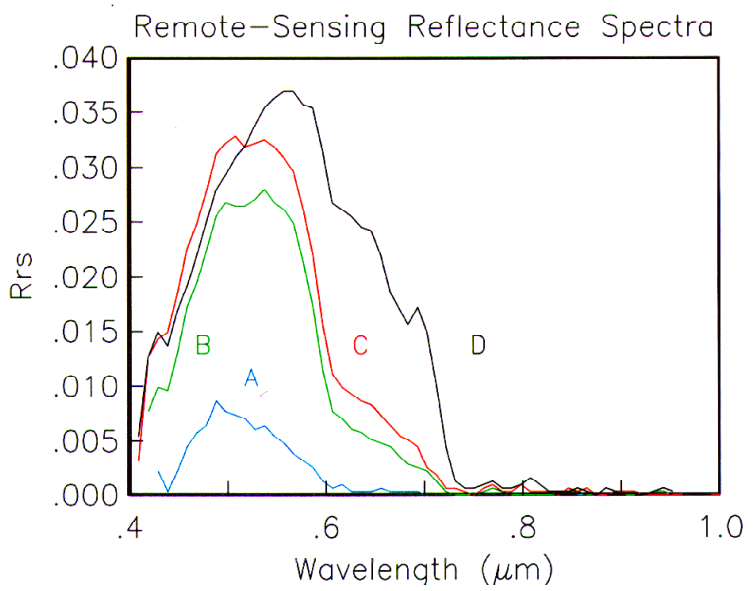
φ 0 , 12 , 24 , 36 , 48 , 60 , 72 , 84 , 90 , 96 , 108 , 120 ,
132 , 144 , 156 , 168 , and 180 ;

W 2, 6, and 10 m/s;

Tafkaa Tabular Including Surface Glint Correction for Ocean Scenes



AVIRIS data were atmospherically corrected using the Tafkaa Tabular algorithm for ocean scenes. The data are corrected for skylight reflected off the sea surface and then it is assumed that the water leaving radiance is 0 for wavelengths greater than 1.0 micron. (Gao, et al., *Appl. Opt.* 39, 887-896, 2000)



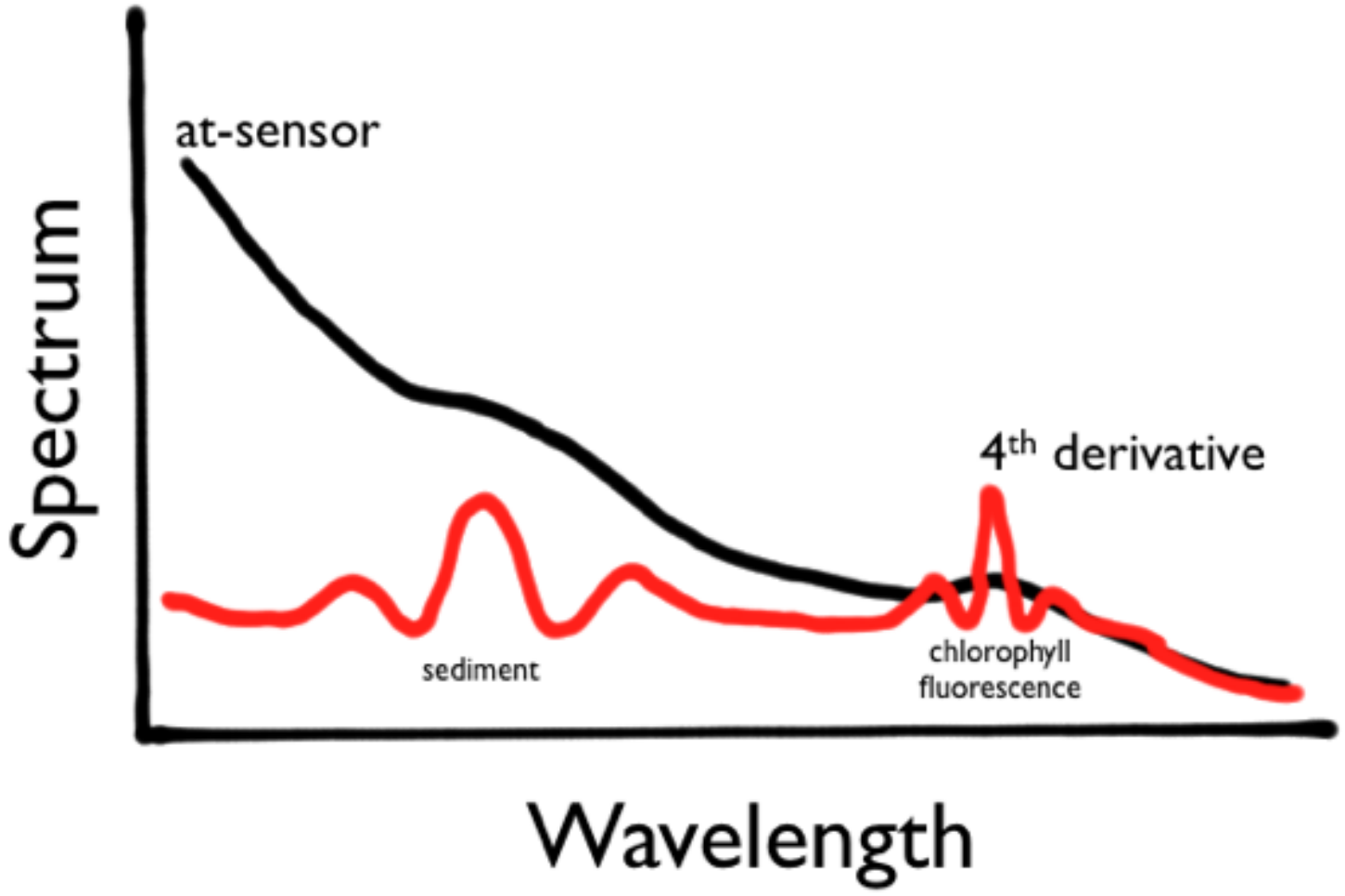
Derivative Spectroscopy at OSU

What is derivative spectroscopy?
Applications
- Pigment ID
- Product Indicator Maps

Where are we looking with HICO?
- Lake Erie (with Joe Ortiz, Kent State U)
- Columbia River
- Yangtze River
- San Francisco Bay
- Monterey Bay (with John Ryan, MBARI)

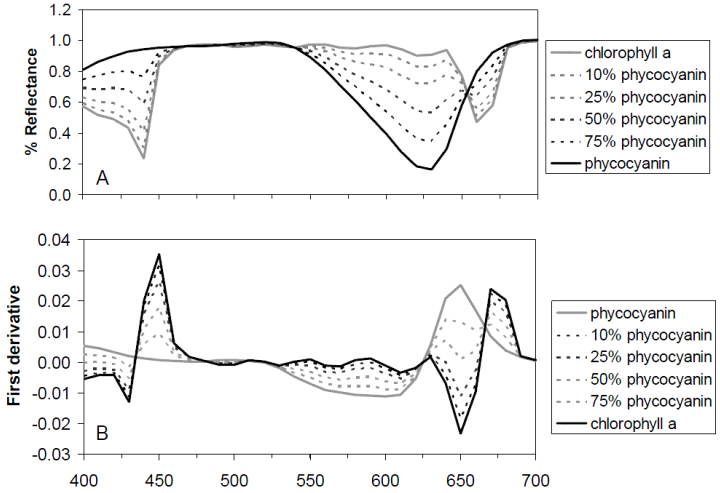
[Preliminary work by Nick Tufillaro]

Derivative Spectroscopy

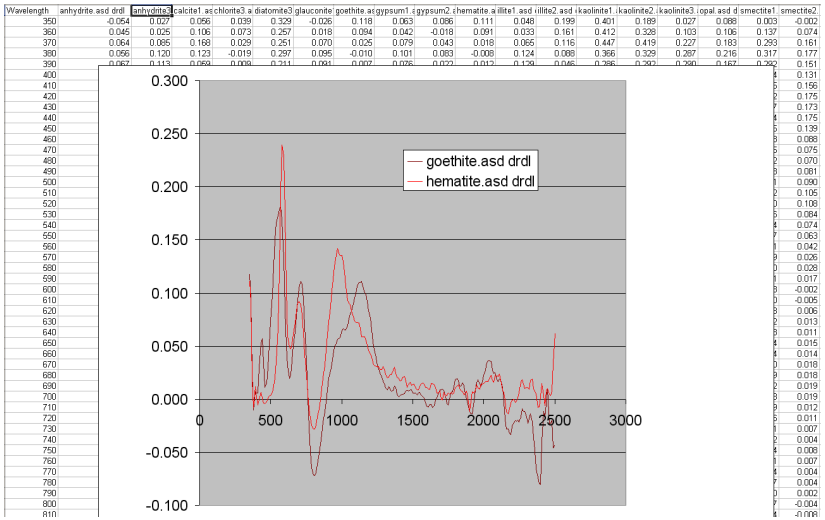


Relating derivatives to spectral features

Biology

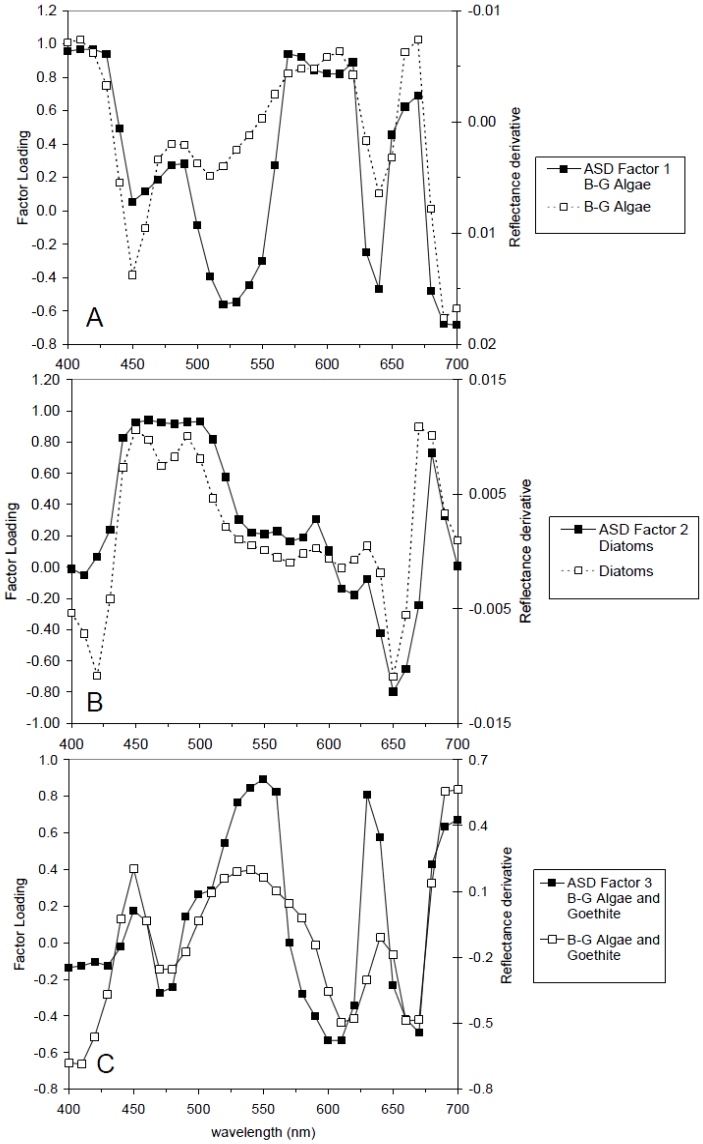


Minerals



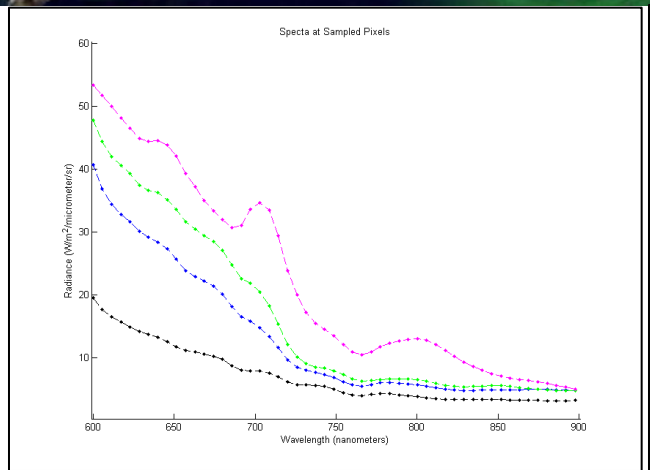
Data from Joe Ortiz, Kent State University

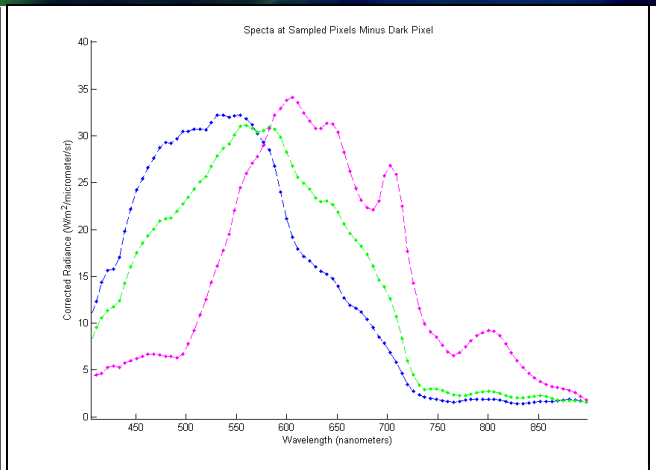
PCA to develop signatures



Microcystis bloom in Lake Erie

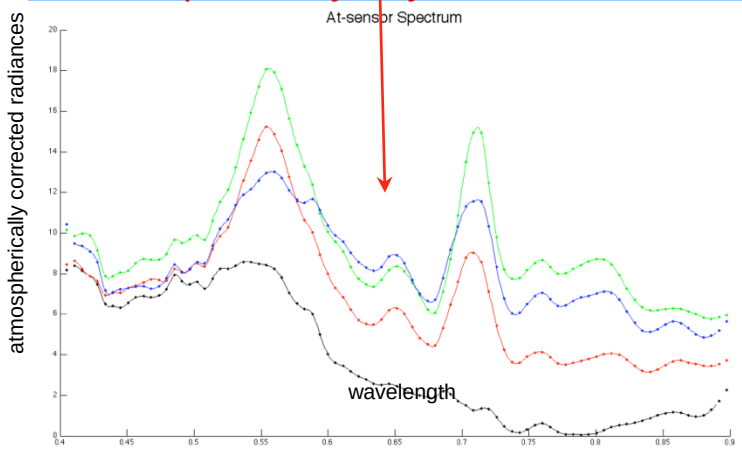
HICO Image of a massive *Microcystis* bloom in western Lake Erie, September 3, 2011 as confirmed by spectral analysis.



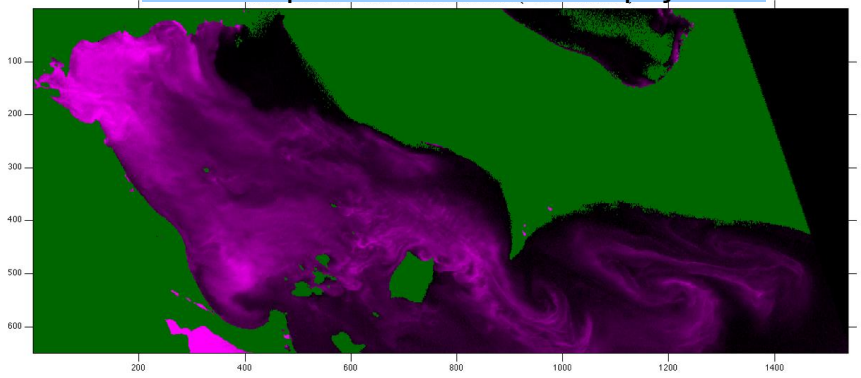


HICO L2 Spectra for Western Lake Erie 2011 09 03

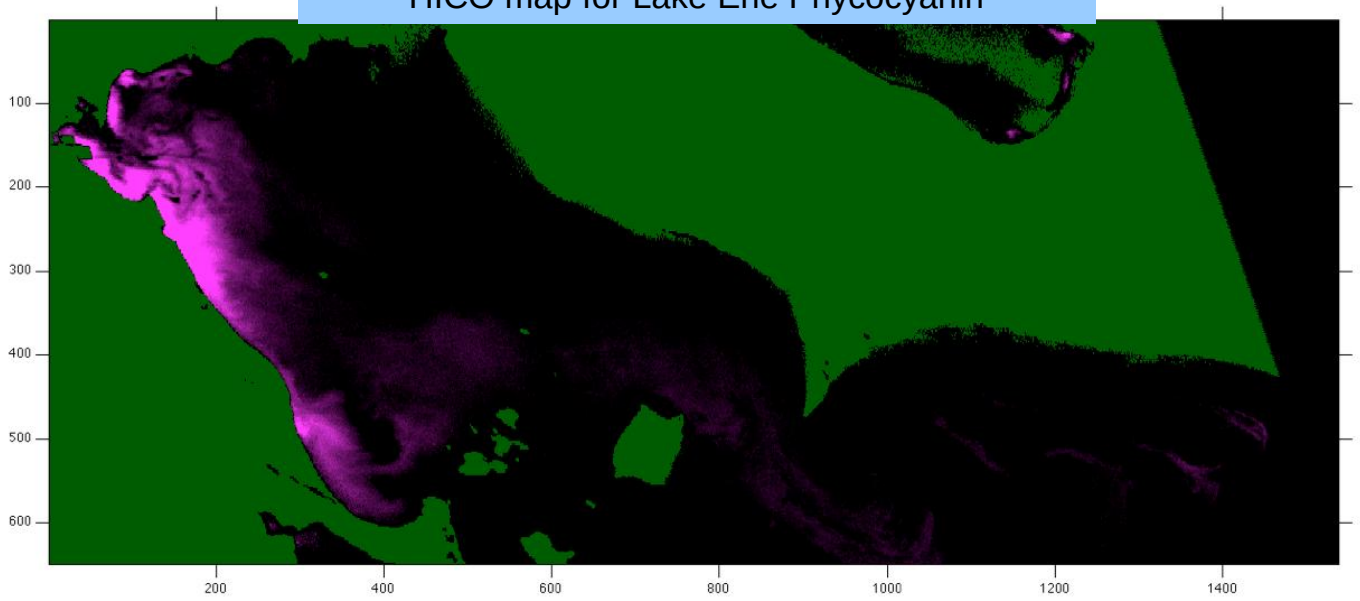
~650 nm peak, Phycocyanin Fluorescence



HICO map for Lake Erie Chlorophyll

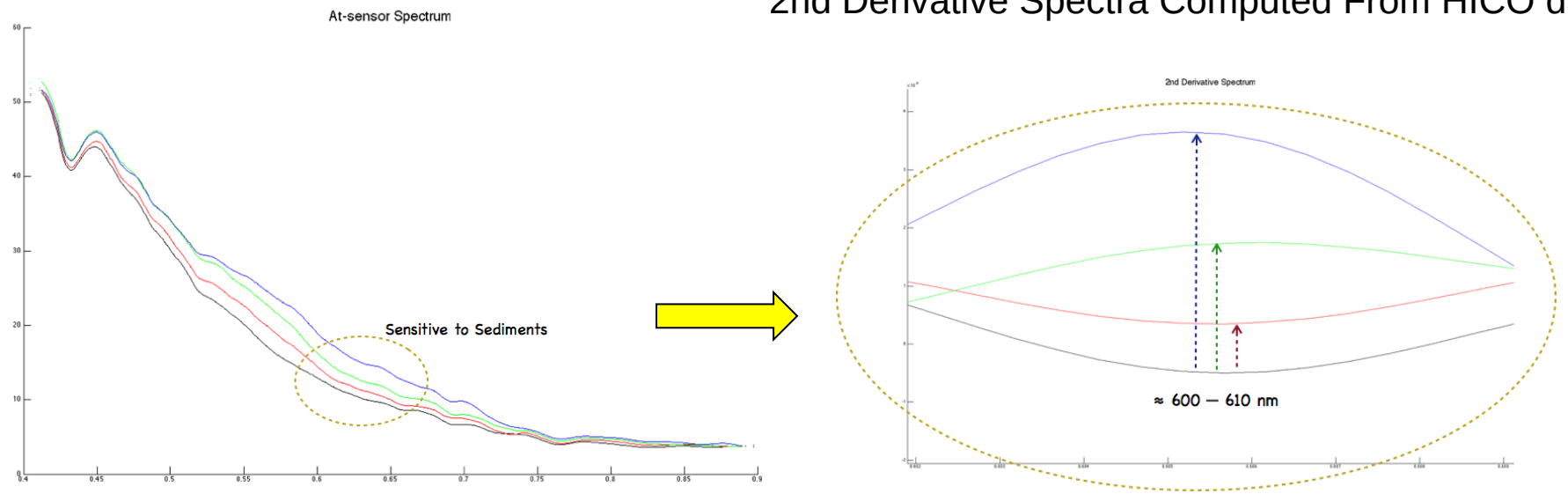


HICO map for Lake Erie Phycocyanin

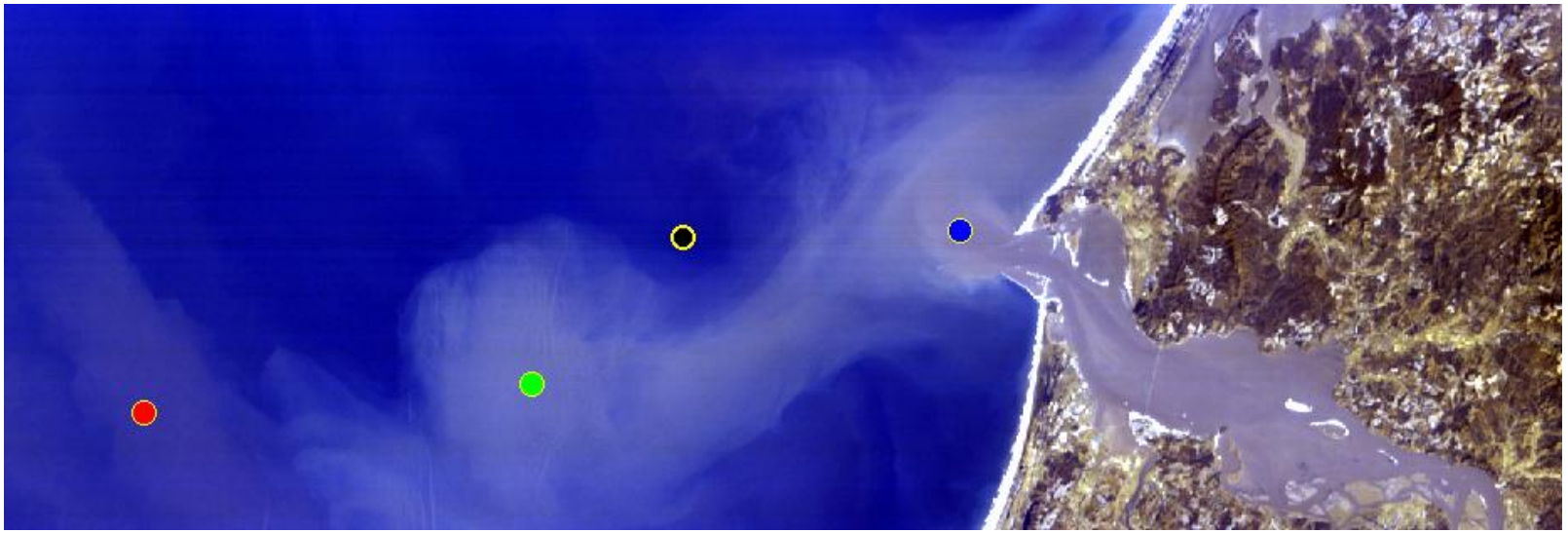


Columbia River Plume Derivative Analysis

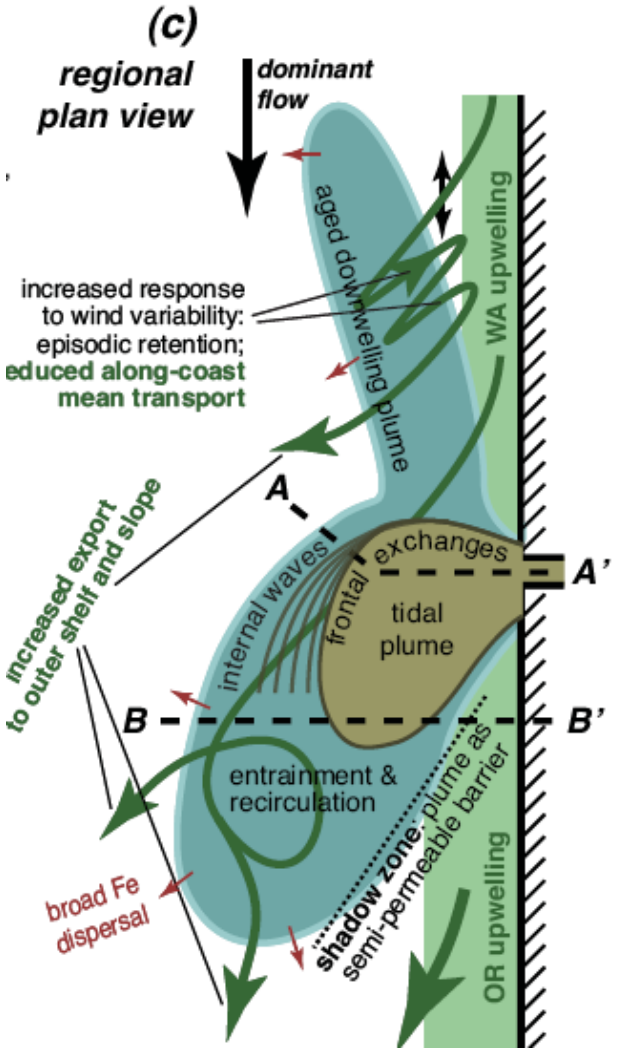
2nd Derivative Spectra Computed From HICO data

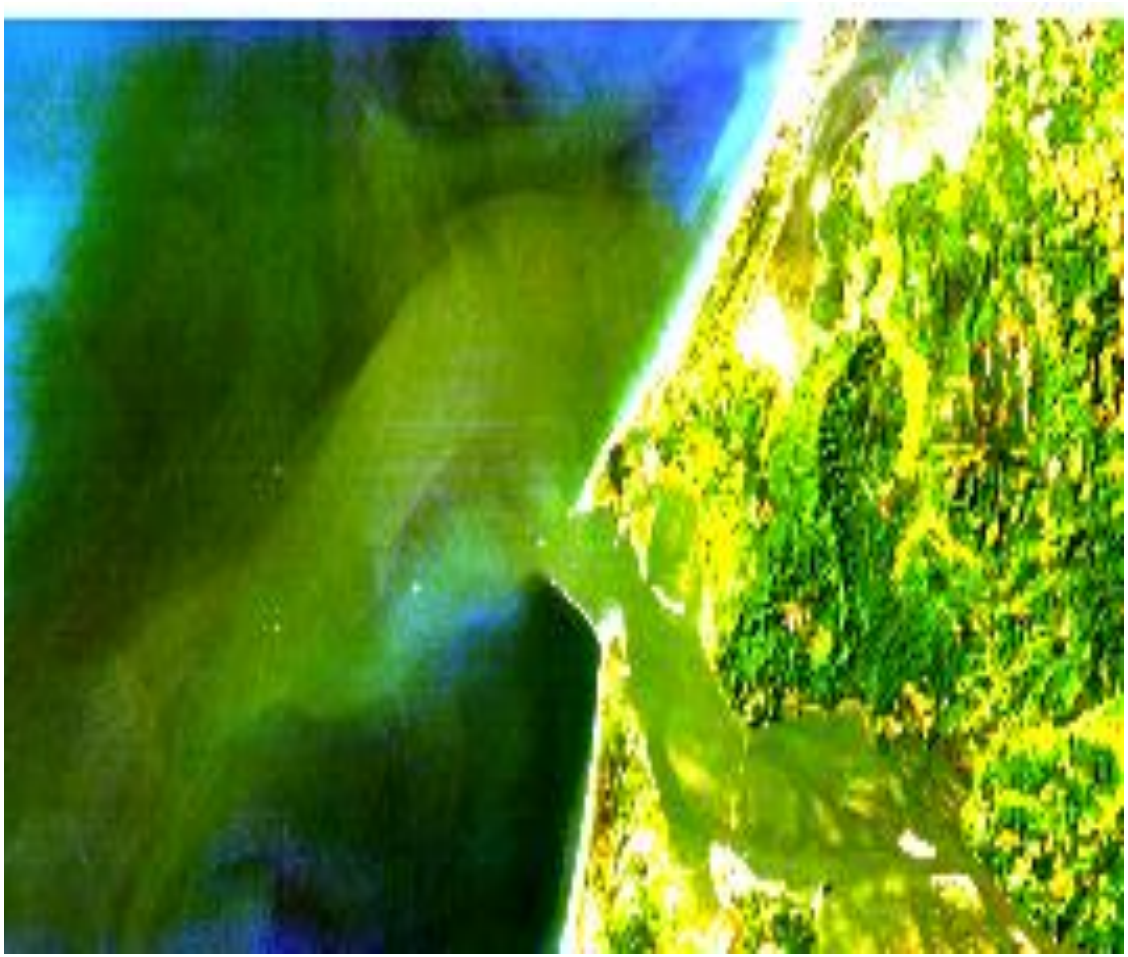


HICO image of Columbia River 2012-05-12



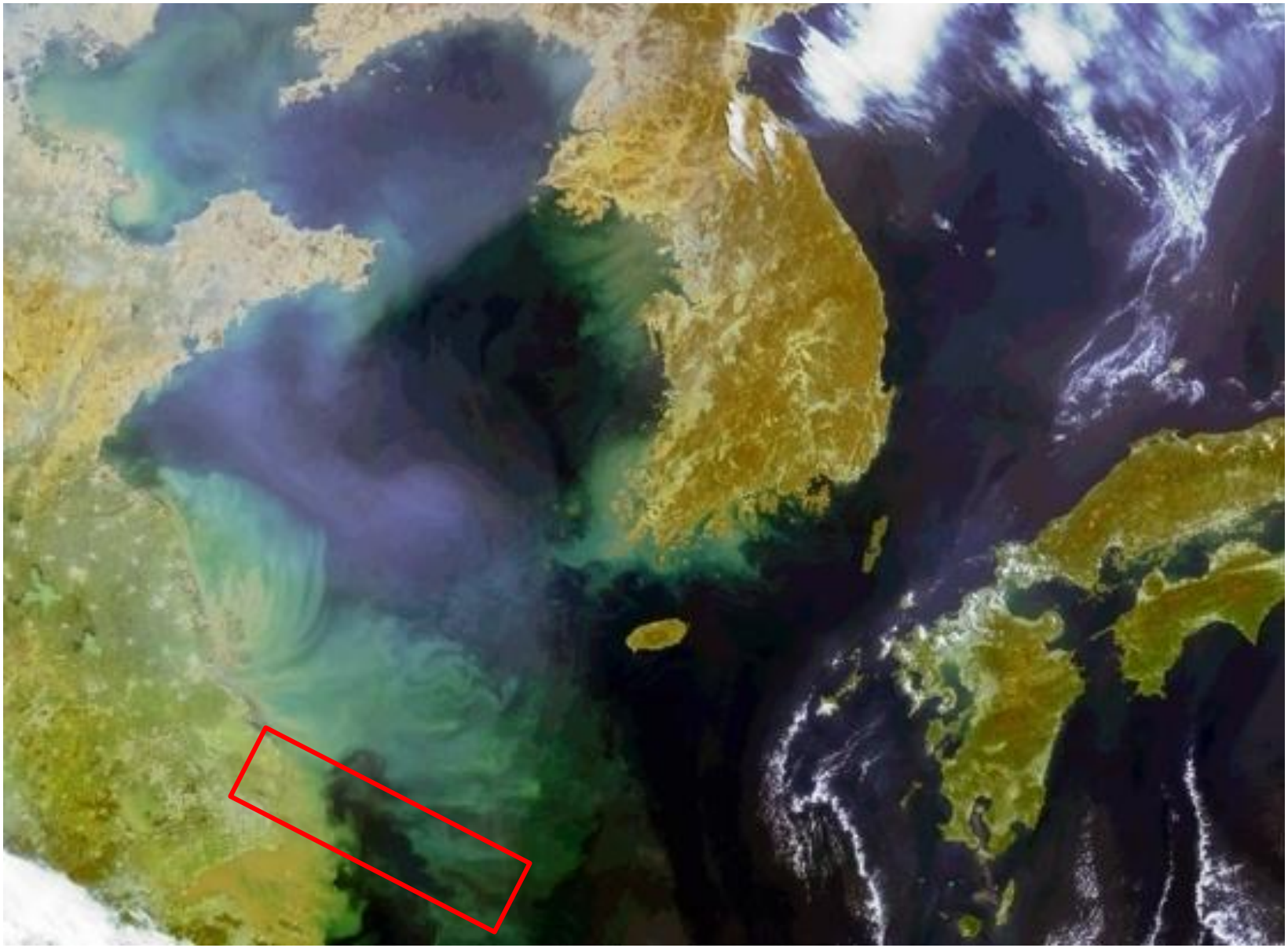
Derivative Spectroscopy with HICO



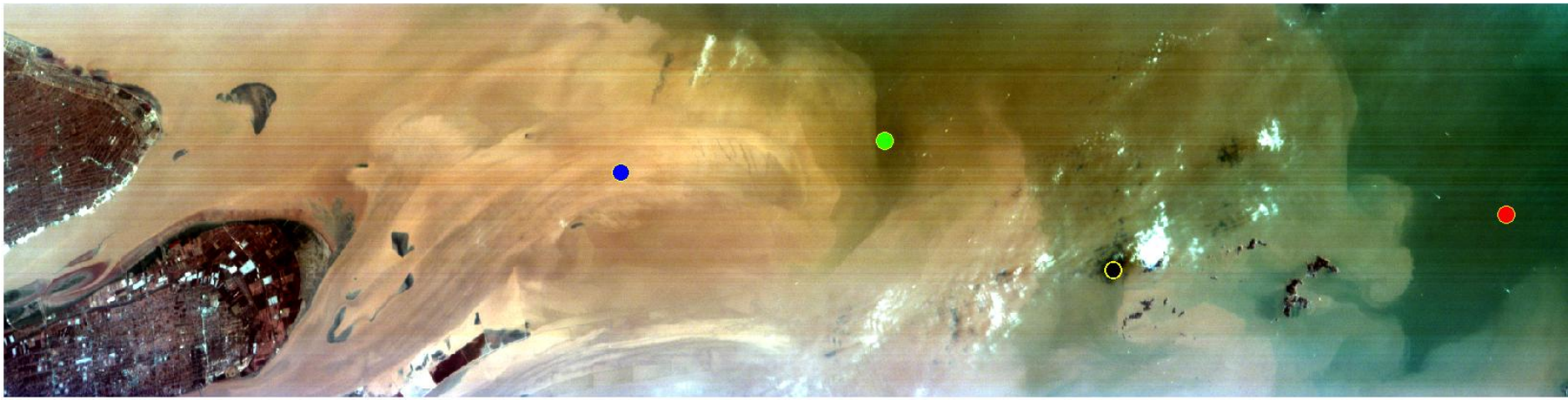


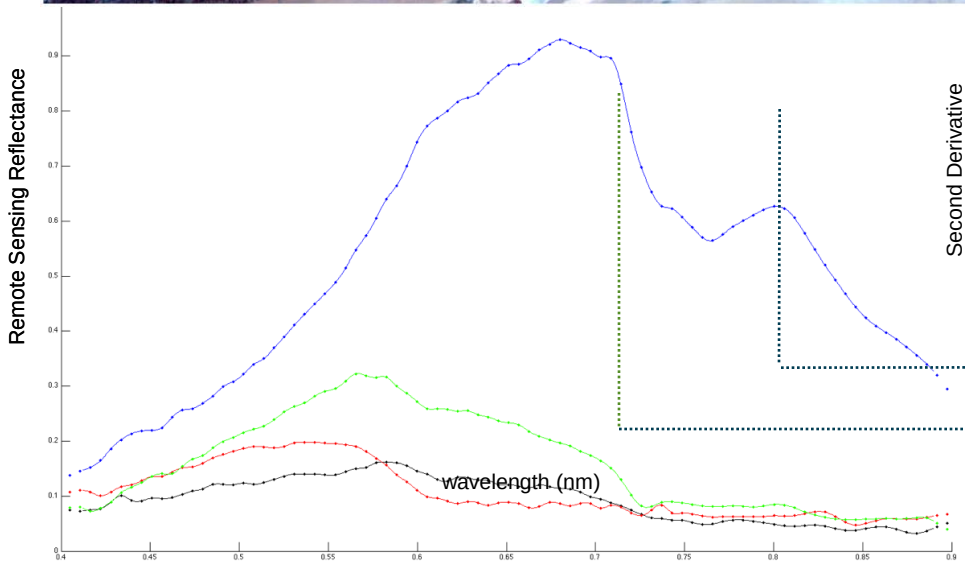
Comparing RISE Synthesis view of the plume (Hickey, et al, 2010, JGR 115: C00B17) and Columbia River 13 July 2010 HICO sediment product using Derivative Analysis (N. B. Tufillaro, preliminary results)

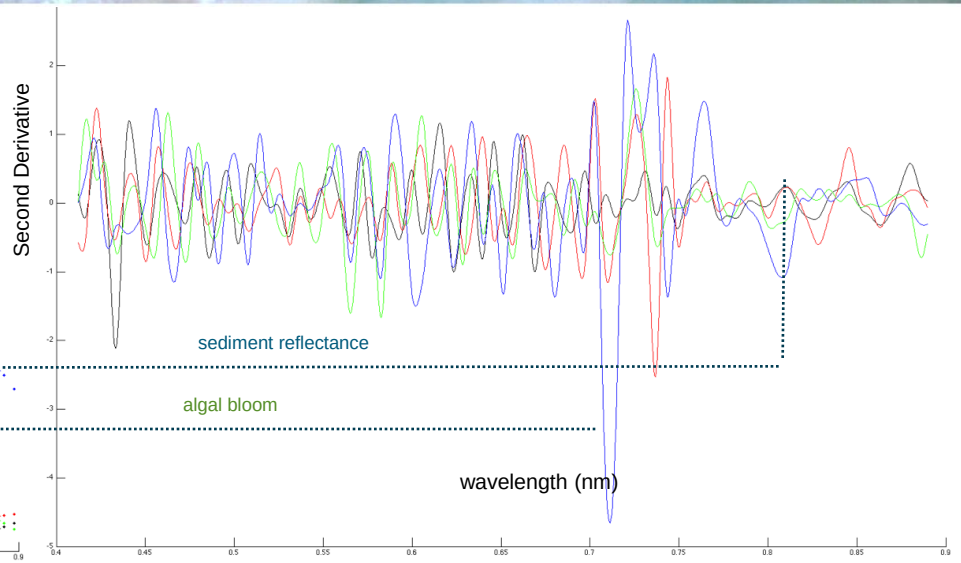
GOCI image of the Waters around Korea



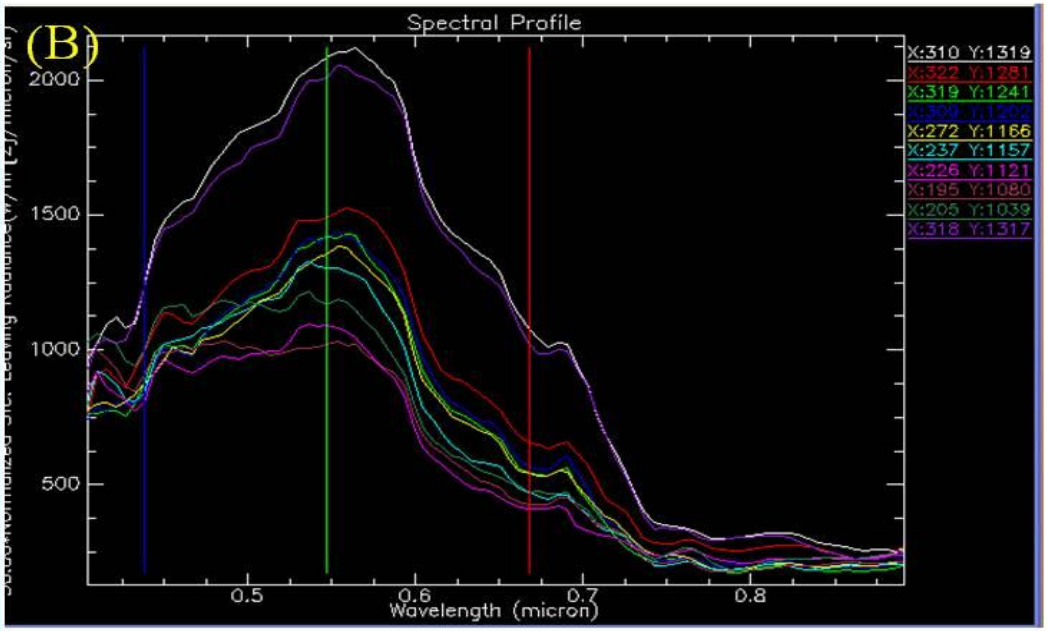
Coincident HICO image of the Yangtze River







San Francisco, San Pablo and Suisun Bays



San Francisco Bay Estuary, June 24, 2011

Entrance to San Francisco Bay, California

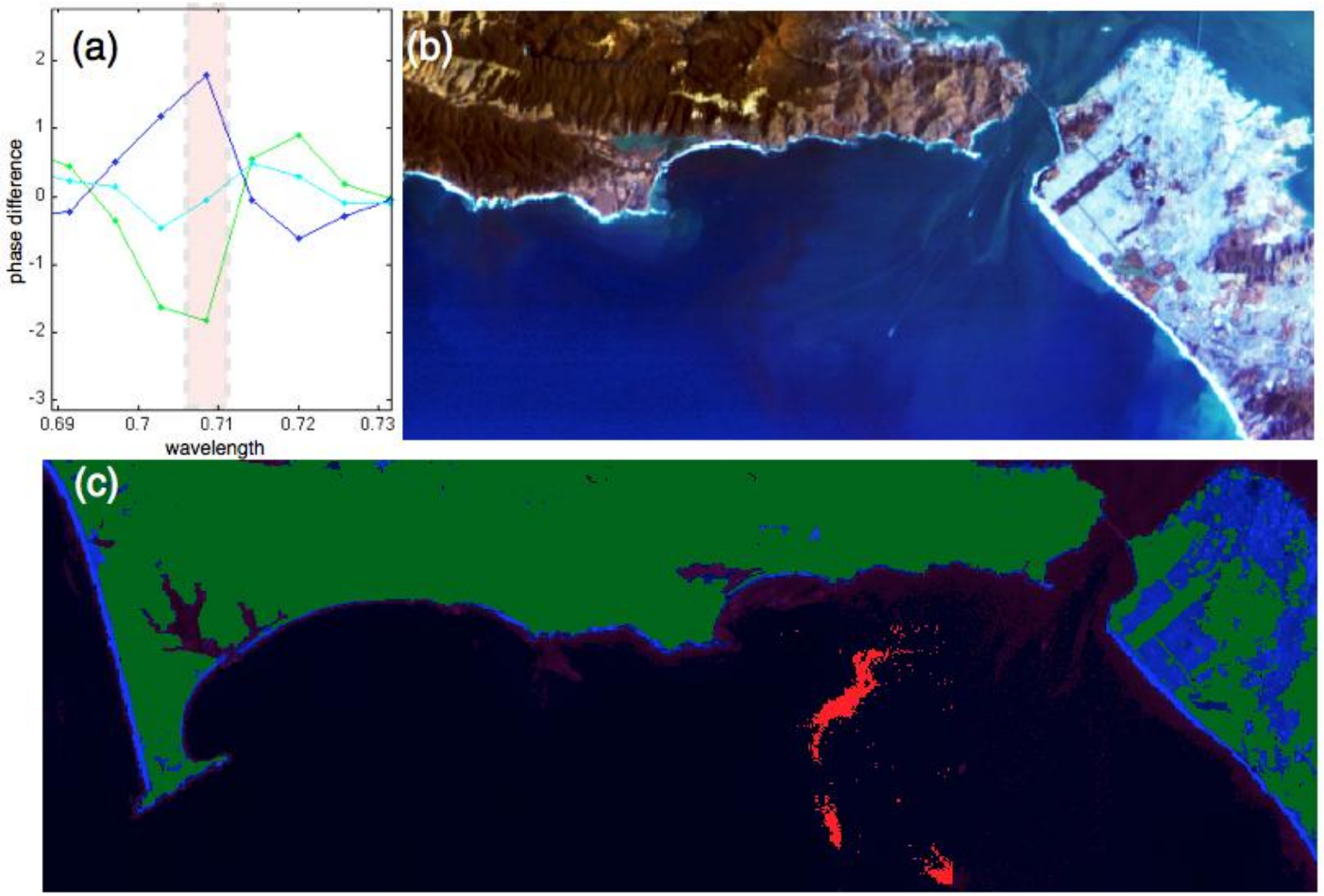
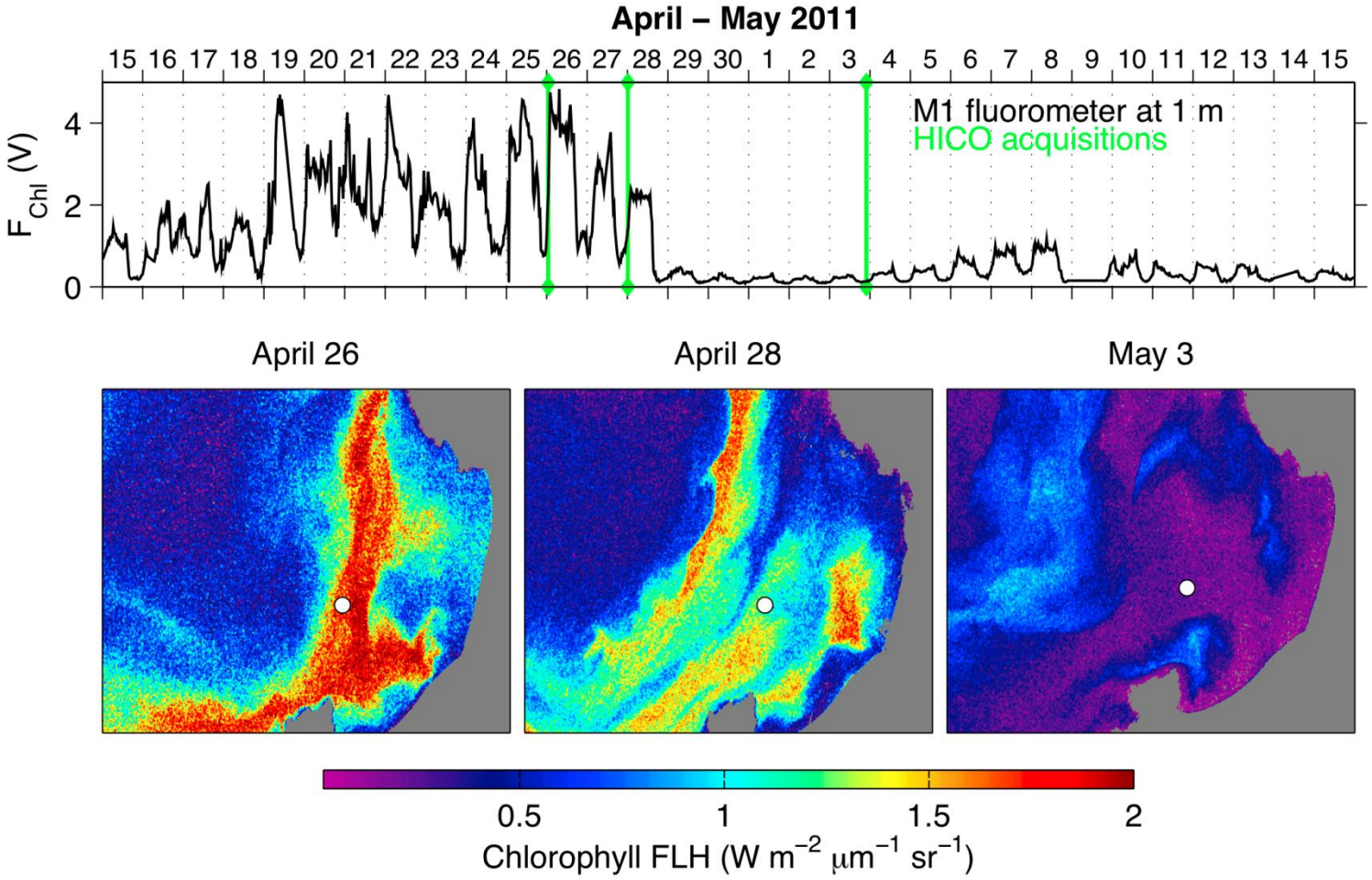


Fig. 14. (a) The phase difference function using the 709 nm HICO channel to indicate chlorophyll rich water. (b) HICO image of the mouth of San Francisco Bay, 28 September 2011. (c) Indicator function for high chlorophyll levels which shows a high concentration of chlorophyll at the interface of bay water and sea water. (N.B. Tufillaro preliminary results)

Monterey Bay, California

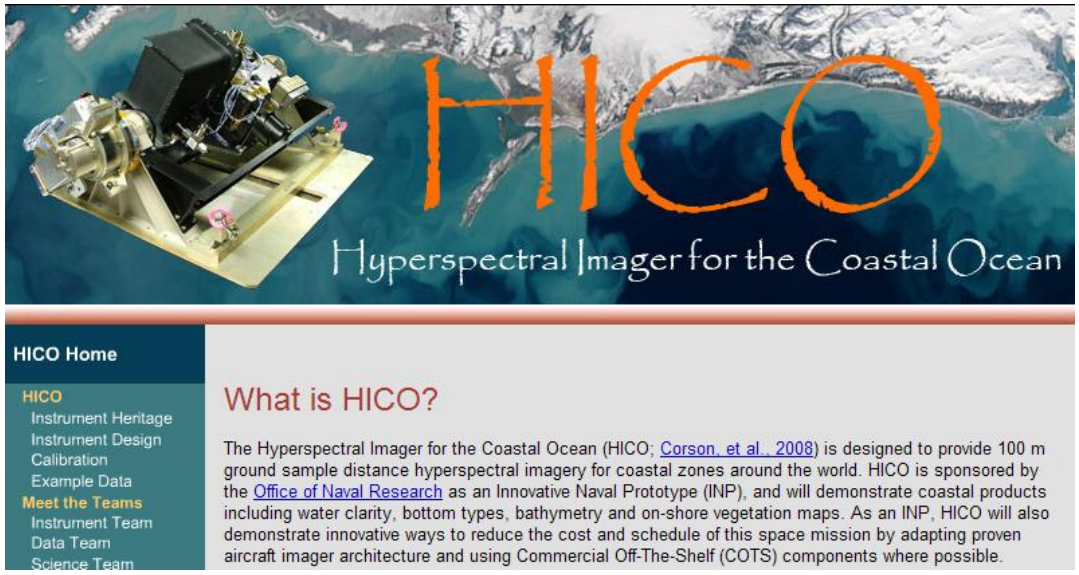
With John Ryan



Time series of In situ chlorophyll fluorescence data from Mooring M1 and corresponding HICO images of Fluorescence Line Height (FLH) for the three times indicated in the time series. The location of M1 is indicated by the dot in the HICO images.

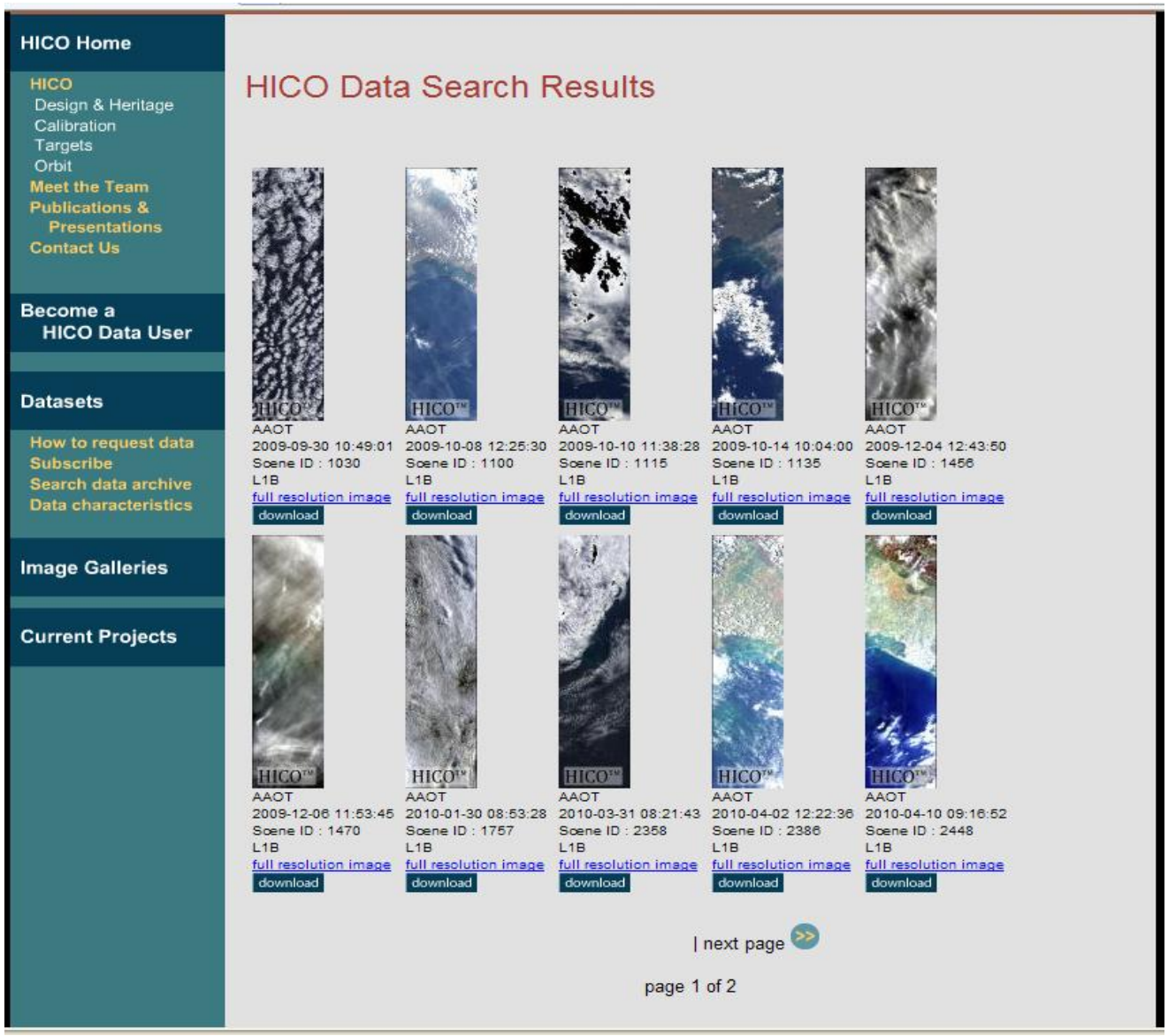
HICO Data Distribution at OSU

- **Developed HICO Public Website at OSU for distribution data, publications and presentations.**
- **Includes some example HICO data that are approved for distribution.**
- **OSU HICO Web site is the portal for data requests and distribution**
  - **Data requests require a short proposal and data agreement**
- **http://hico.coas.oregonstate.edu**
- **Full description of the data and directions for use on the website**

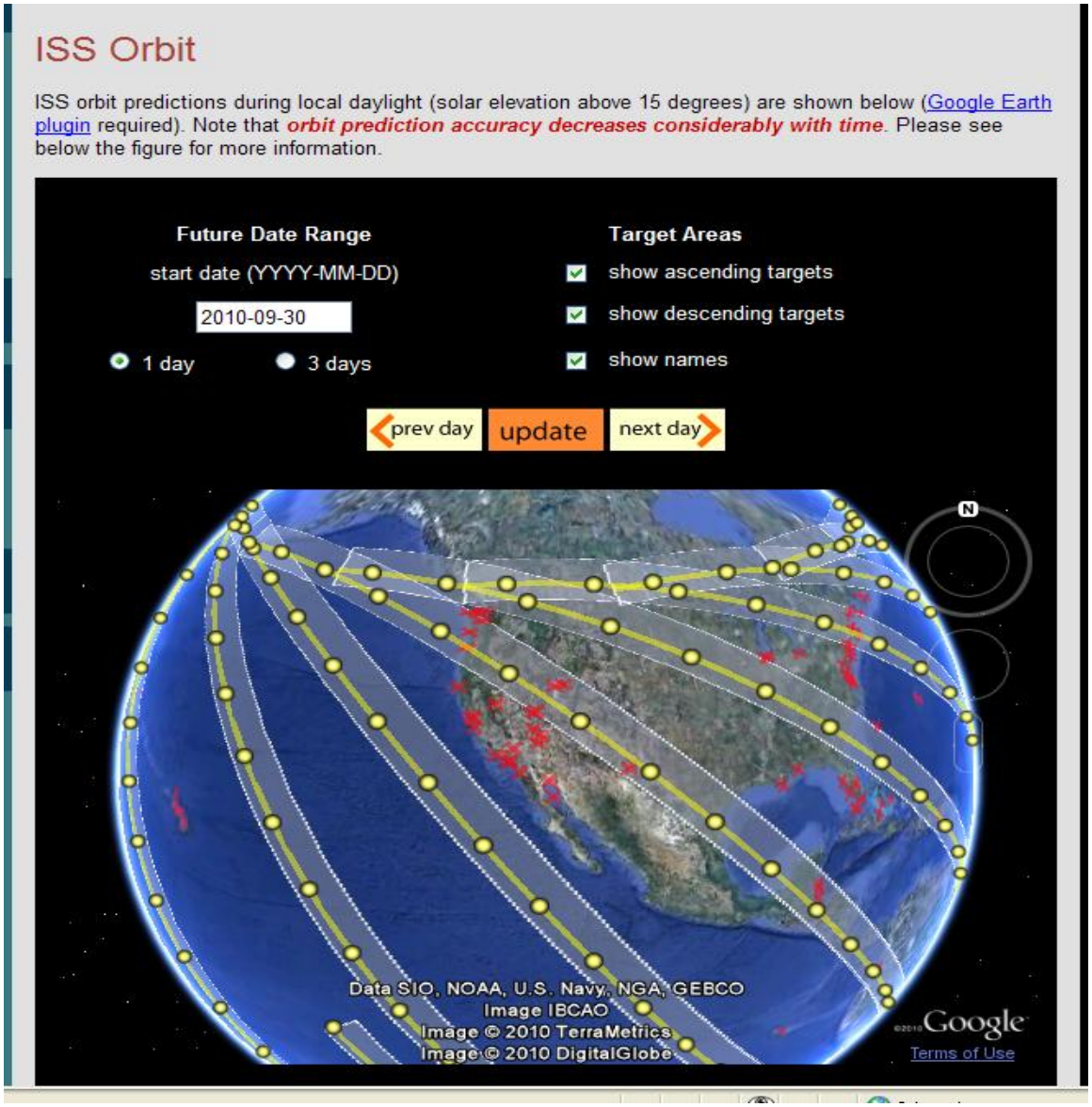


OSU HICO Website: Search Archive

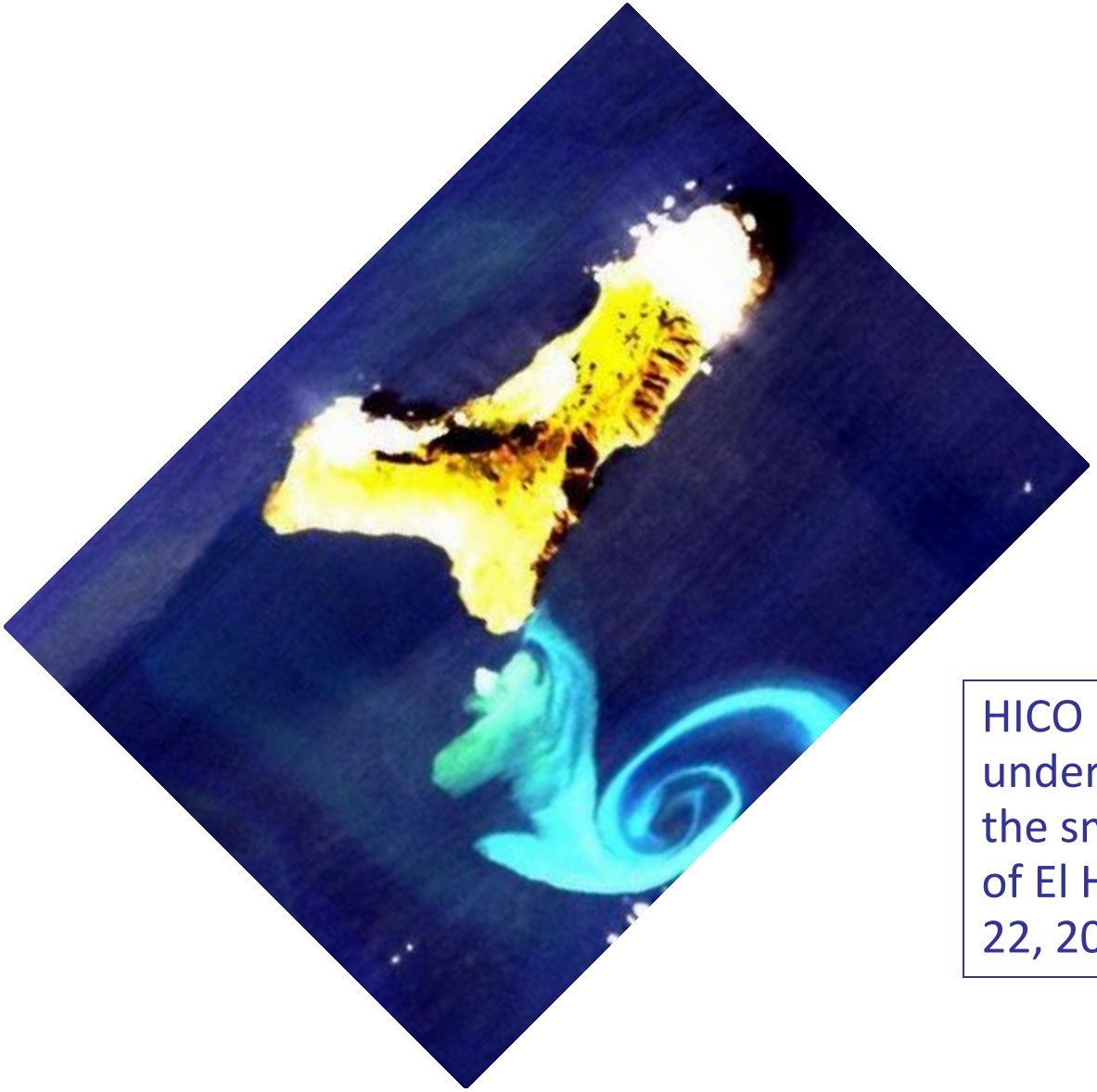
OSU HICO Website: Select Data



OSU HICO Website: Experiment Planning



Birth of a New Island, Canary Islands



HICO Image of the new underwater volcano off the small Canary Island of El Hierro, December 22, 2011.

HICO Summary (HICO Docked on the ISS)

- HICO operating for three years
- Over 6000 scenes collected
- Slot on ISS until July 2014
- Data from OSU HICO website
- http://hico.coas.oregonstate.edu