HICO data: Life after level 1b

Curtiss O. Davis
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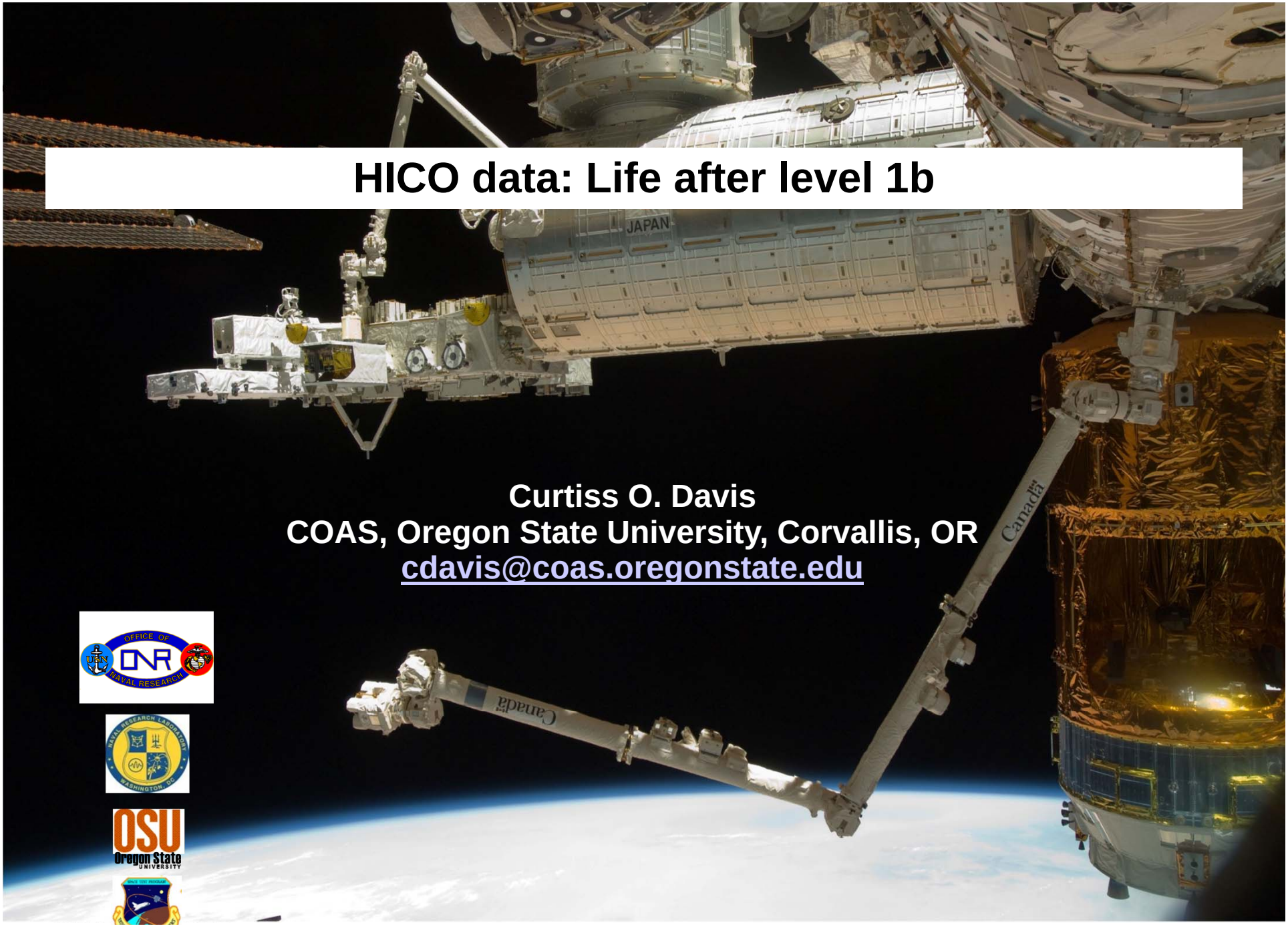
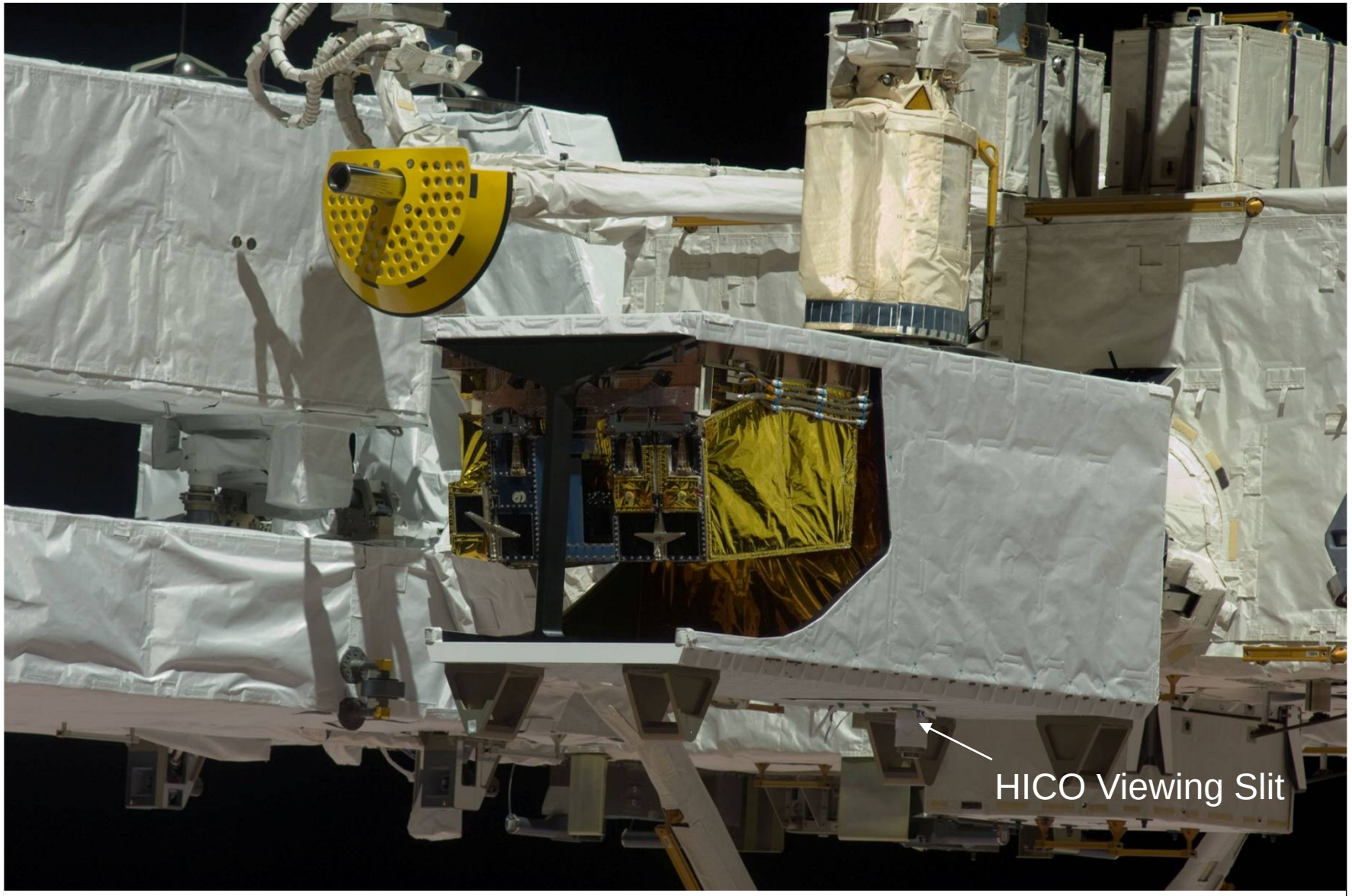


NASA Photo

HICO docked at ISS – Now What?

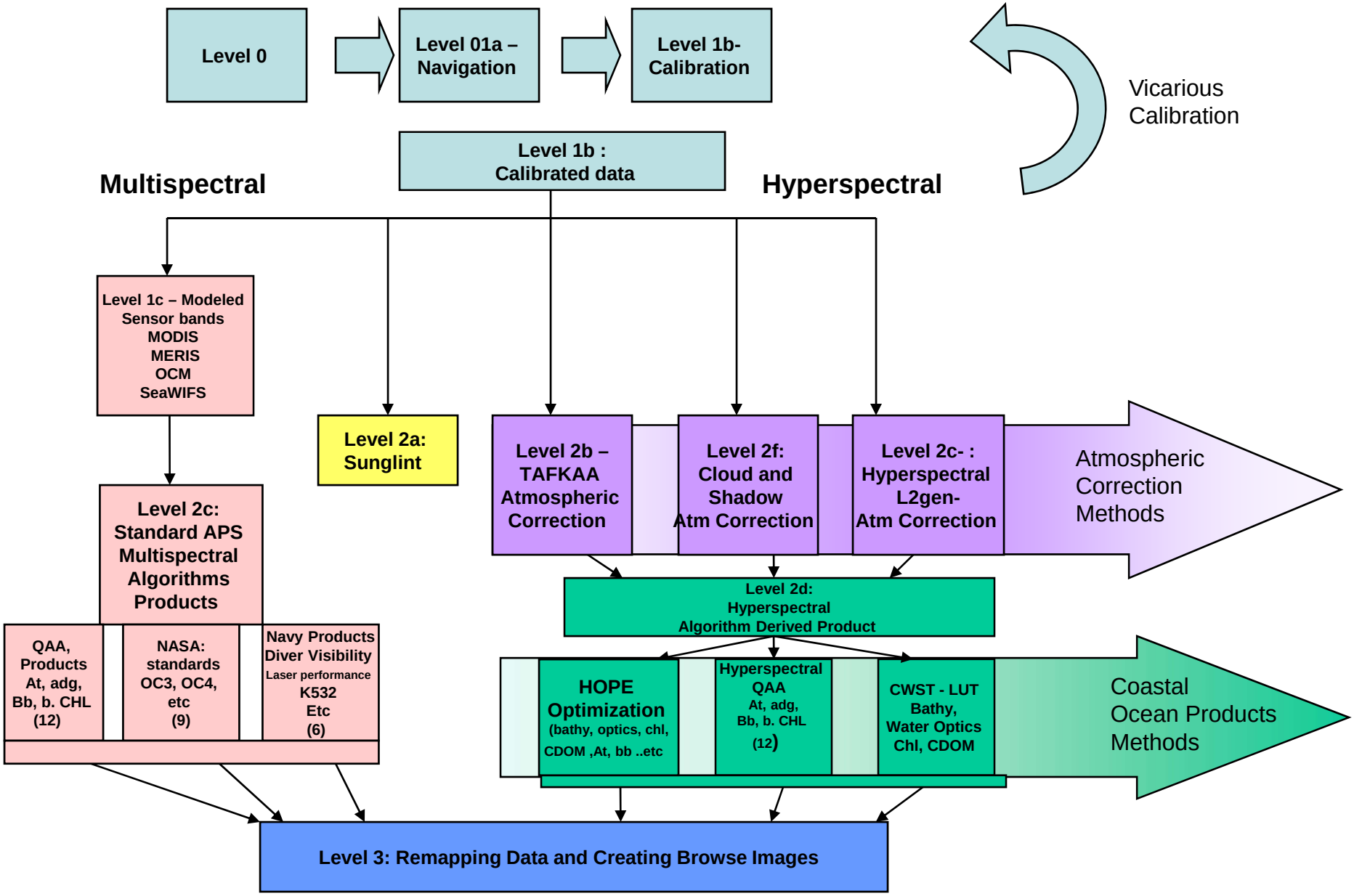


NASA Photo

Outline

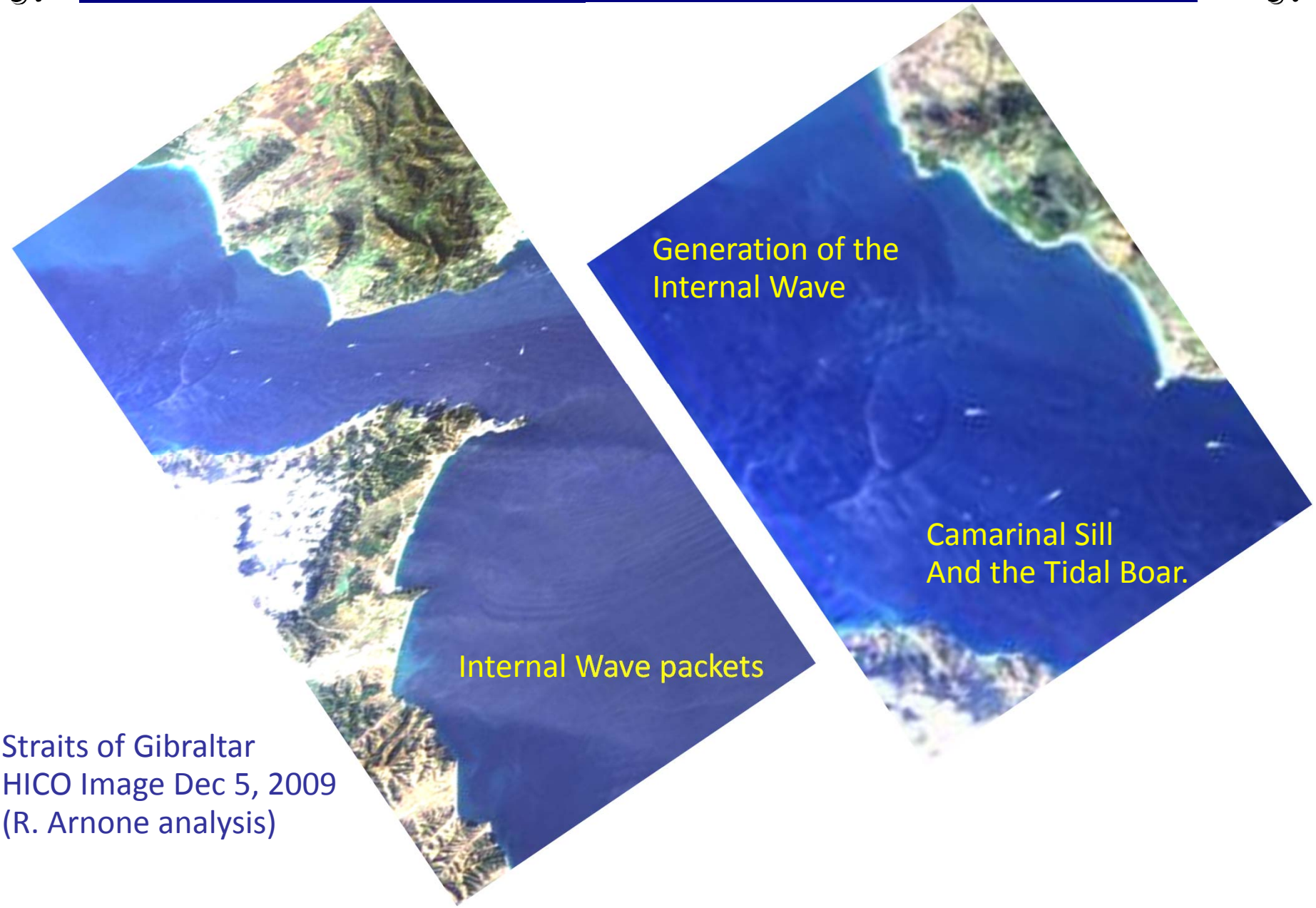
- 2500+ HICO images – How can we use them?
  - Level 1b products
  - Geolocation
  - Products using calibrated data
  - Comparison to MODIS and MERIS
  - Atmospheric correction
    - Overview
    - Tafkaa
    - Cloud-Shadow
  - APS MODIS like products
  - Hyperspectral products
- Access to HICO data via. COAS HICO website

HICO Processing Activity in APS



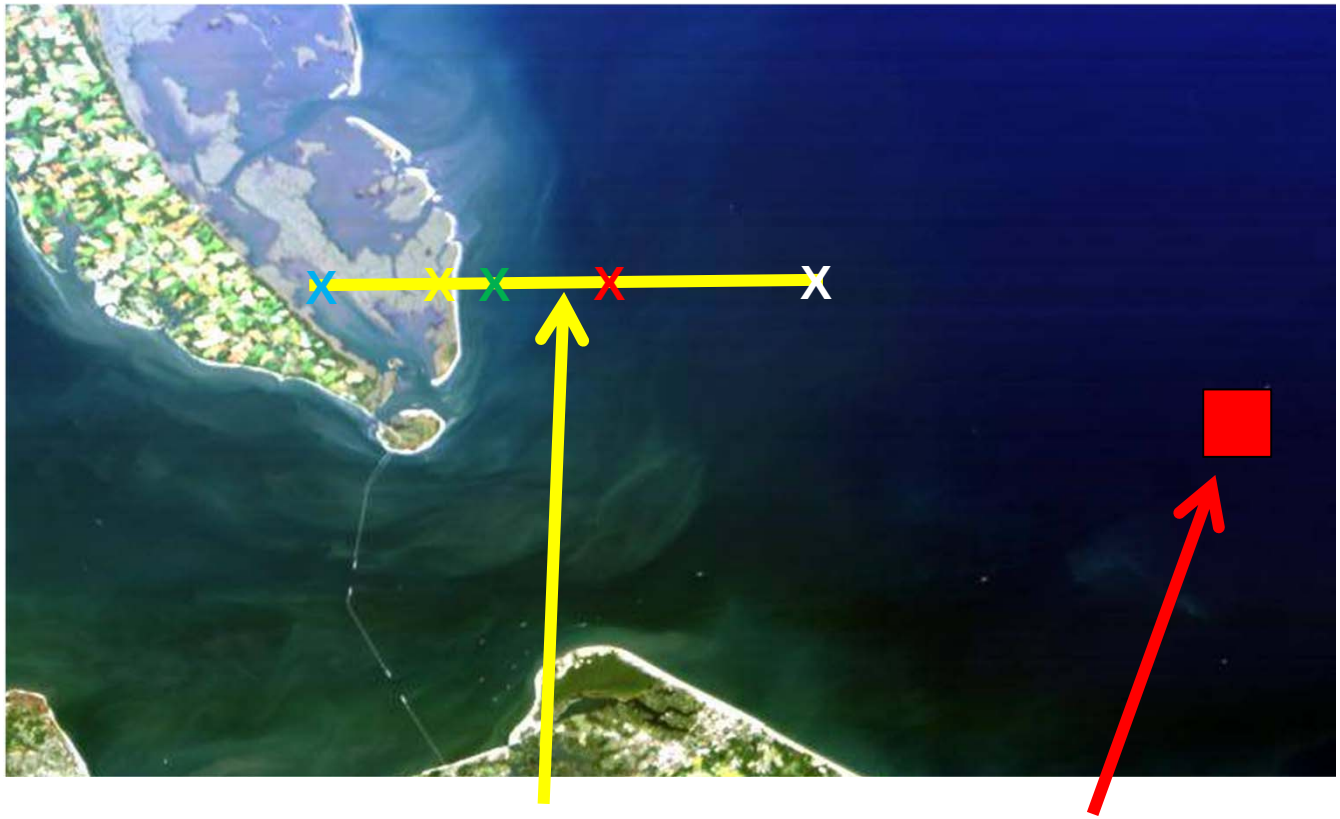
HICO Image
Pusan, South Korea: 11/18/09

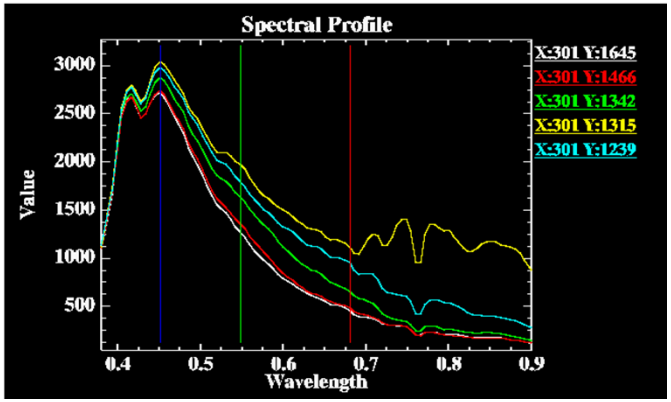
Internal waves at the Straits of Gibraltar

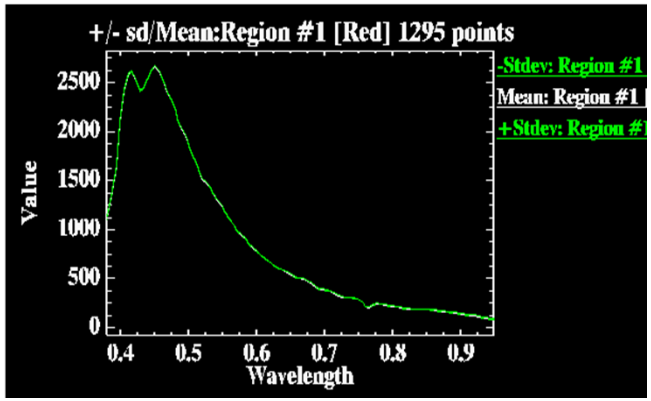


Straits of Gibraltar
HICO Image Dec 5, 2009
(R. Arnone analysis)

Spectral Properties







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.

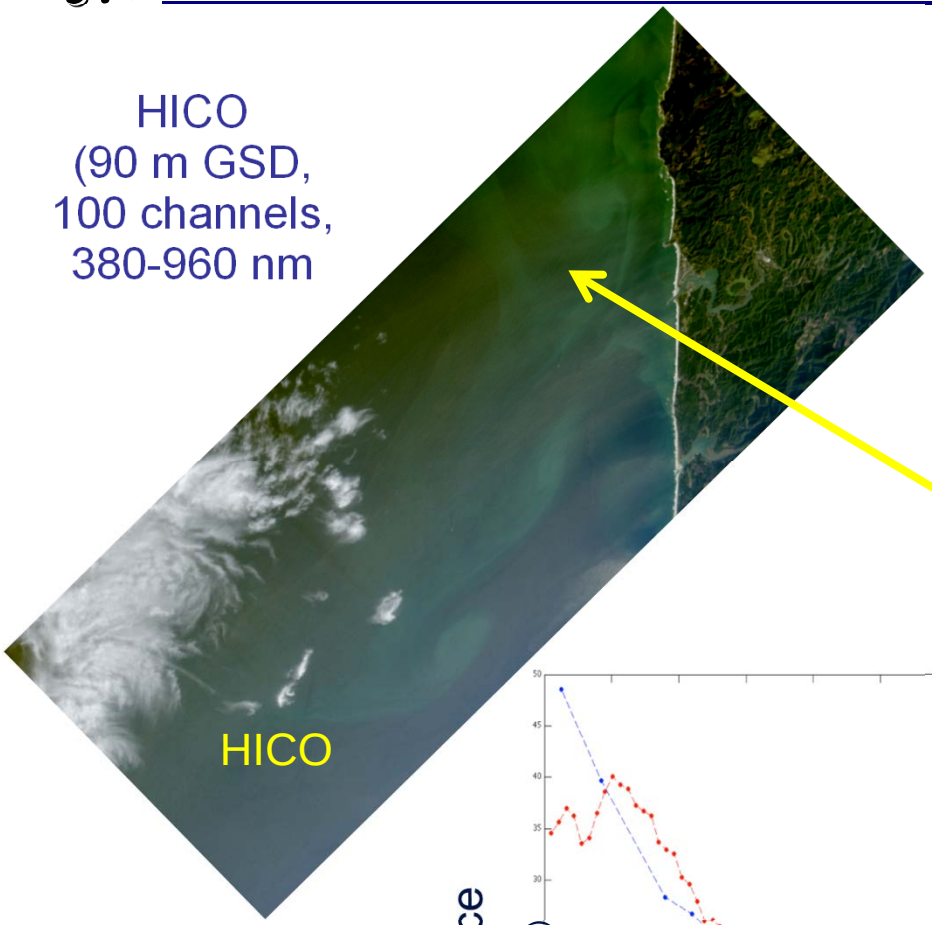
Right: Mean and standard deviation of 1295 pixels in the red Region of Interest. The SNR (μ/σ including all sensor and environmental variations) is >300:1 for much of the spectra. Spectra are scaled calibrated at-sensor radiances.

Targeting and Geolocation

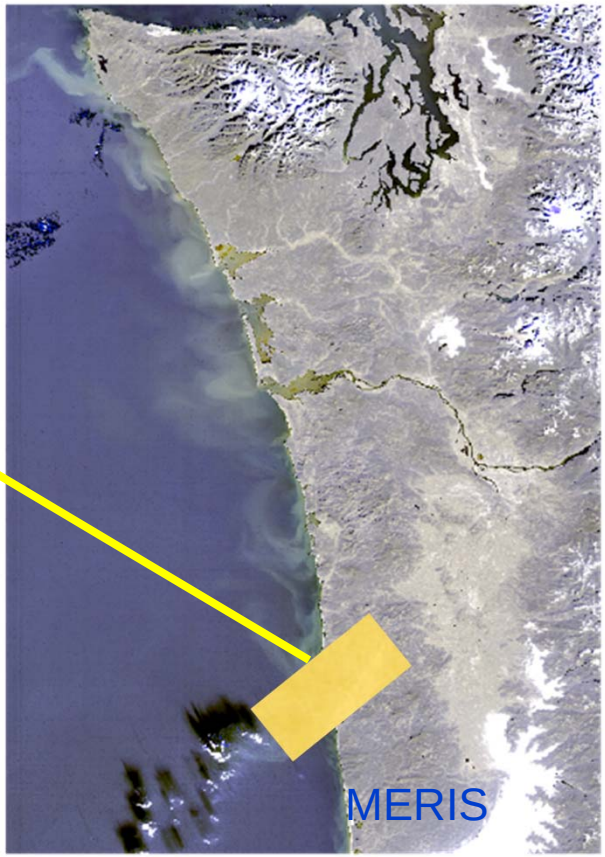
- **Targeting** is done using a predicted ISS Ephemeris and Torque Equilibrium Attitude (TEA) models several days in advance
  - These can change with ISS maneuvers, shuttle docking, etc.
  - Targeting can be of by a few to 10 km
- **Geolocation** proves challenging from the ISS
  - We provide two geolocation files:
    - **Rad_geom** provided immediately with the data (accurate to a few km)
    - **LonLatViewAngles** files provided about a week alter; more accurate, use these if available (accurate to about 1 km)
    - Directions for using these files for geolocation in ENVI Provided on HICO website under "**Working with the Data**"
  - For greater accuracy match ground control points to a reference image.
    - Directions for doing this in ENVI are Provided on HICO website under "**Working with the Data**"

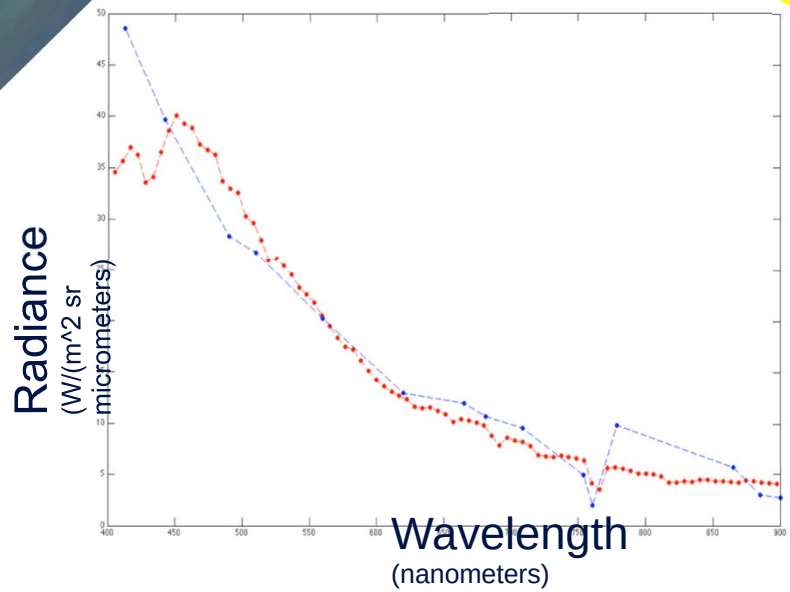
HICO-MERIS Matchup (Lt)
Newport, OR 2 December 2009

HICO
(90 m GSD,
100 channels,
380-960 nm



MERIS
(300 m GSD,
15 channels)

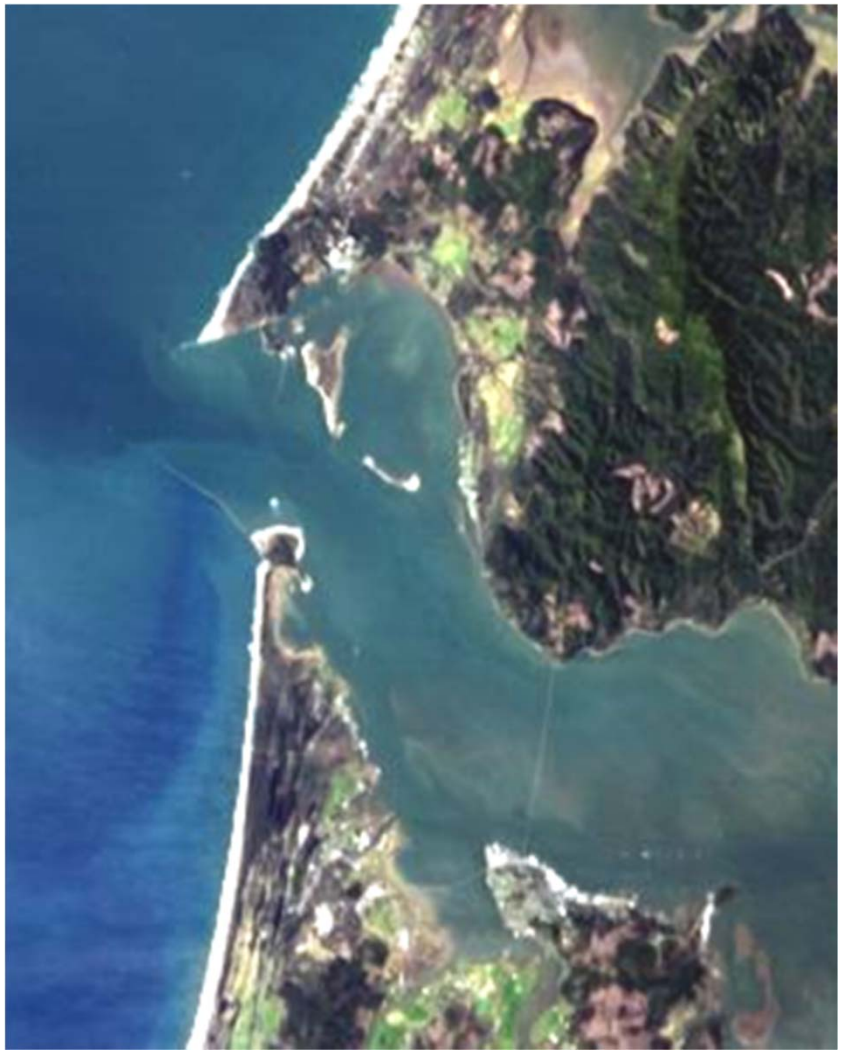




MERIS (300 m) Columbia River March 19, 2010

HICO Images of the Columbia River

March 17, 2010

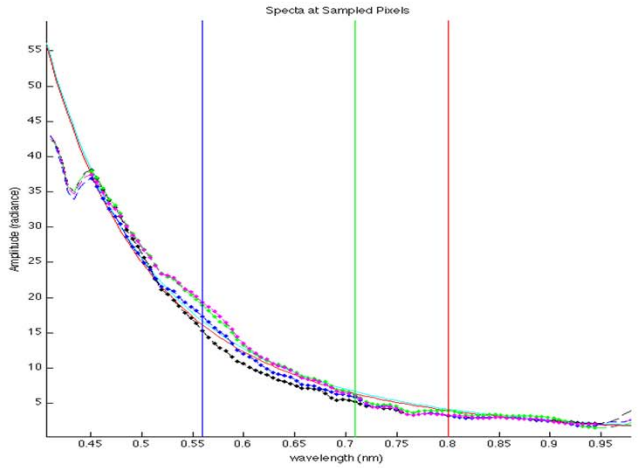


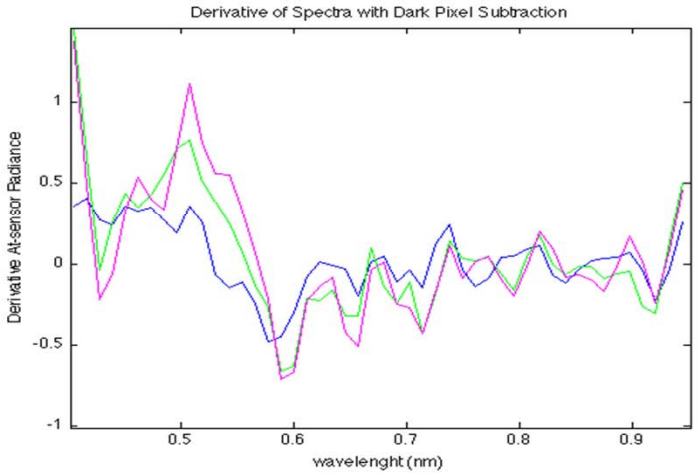
March 19, 2010

Derivative Spectroscopy with HICO

Spectrum at-sensor

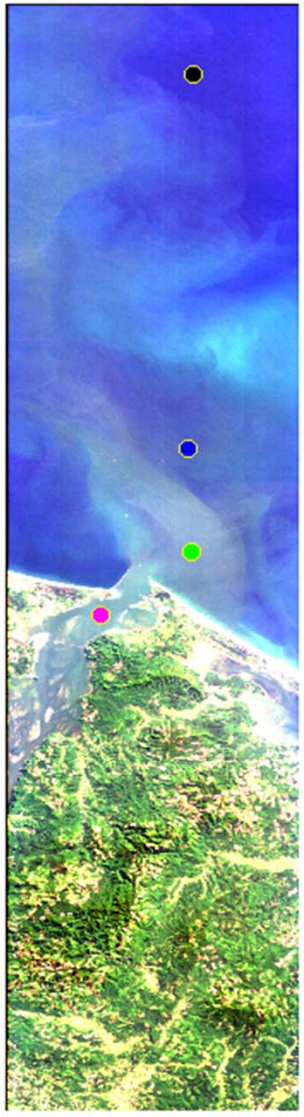
(pixel locations shown in RGB)

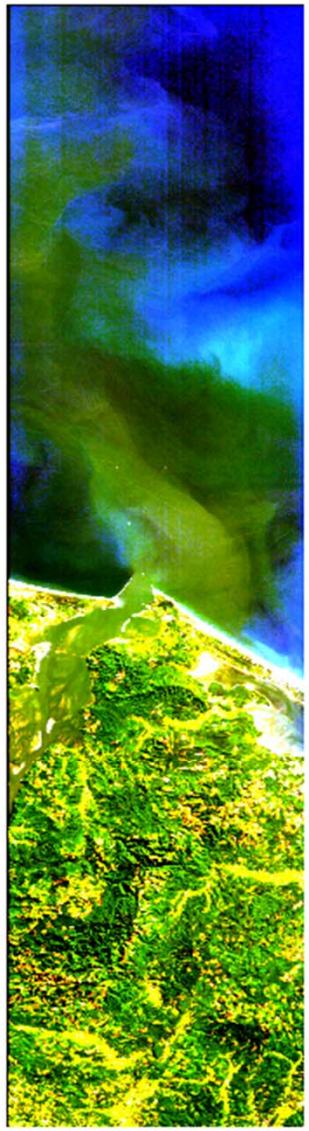




N. B. Tufillaro, preliminary results

Columbia River 13 July 2010

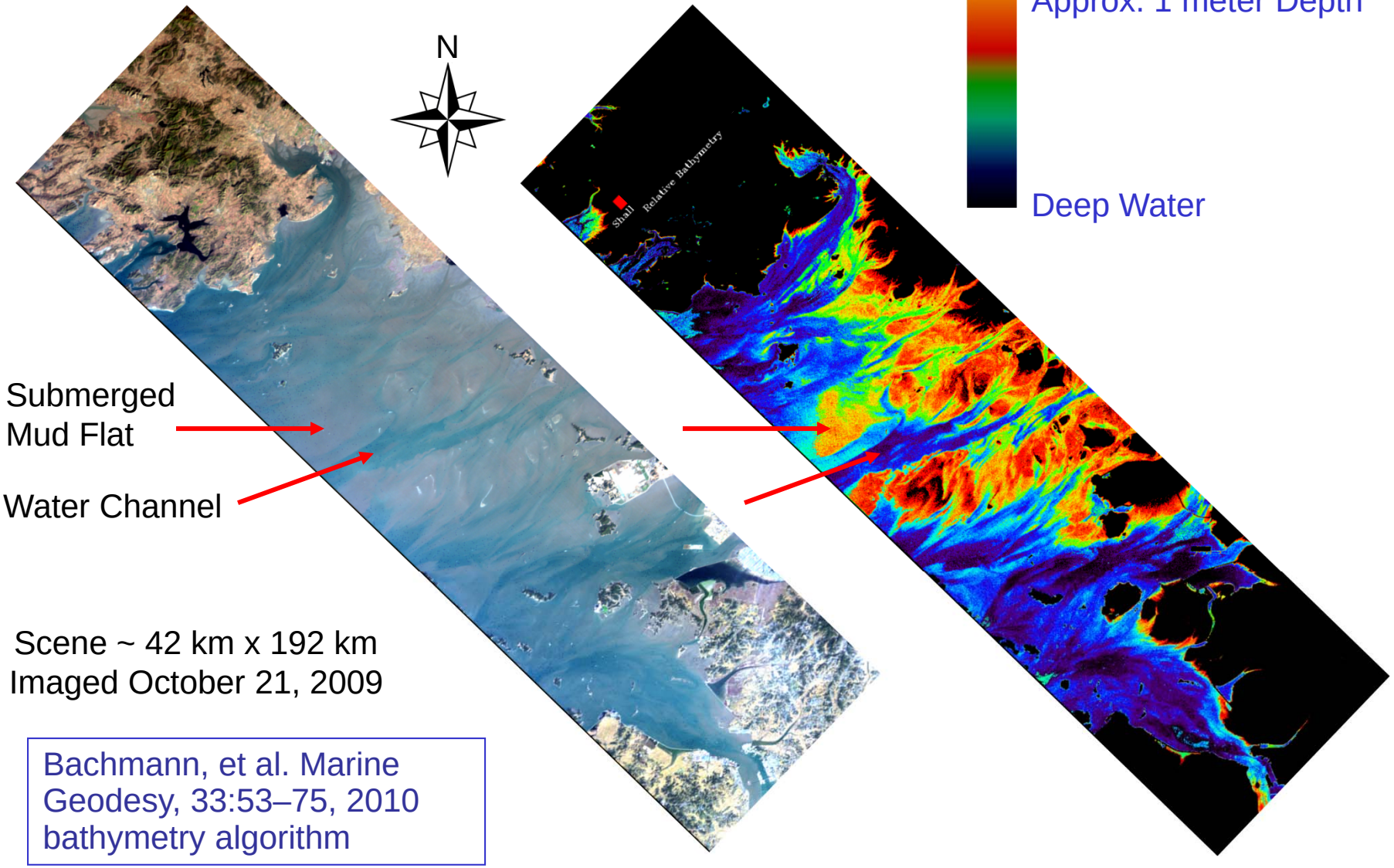




Relative Bathymetry of Han River Area Mud Flats

HICO Image off Korean Peninsula

Relative Bathymetry Map Retrieved from HICO Image



Scene ~ 42 km x 192 km
Imaged October 21, 2009

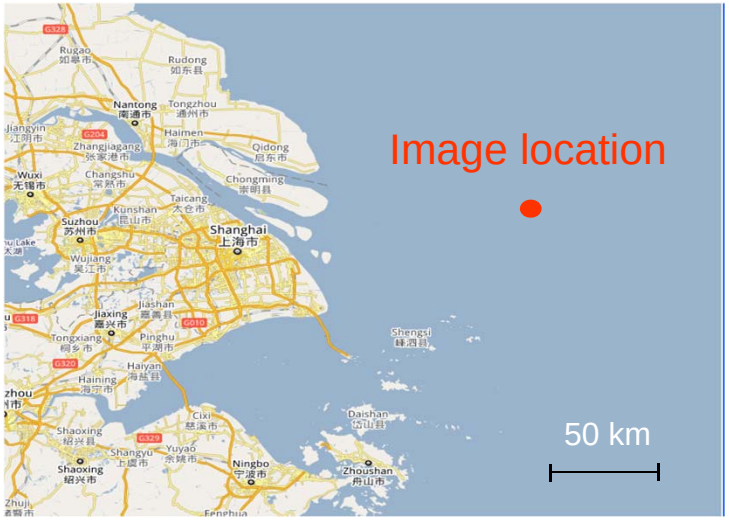
Bachmann, et al. Marine Geodesy, 33:53–75, 2010 bathymetry algorithm

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

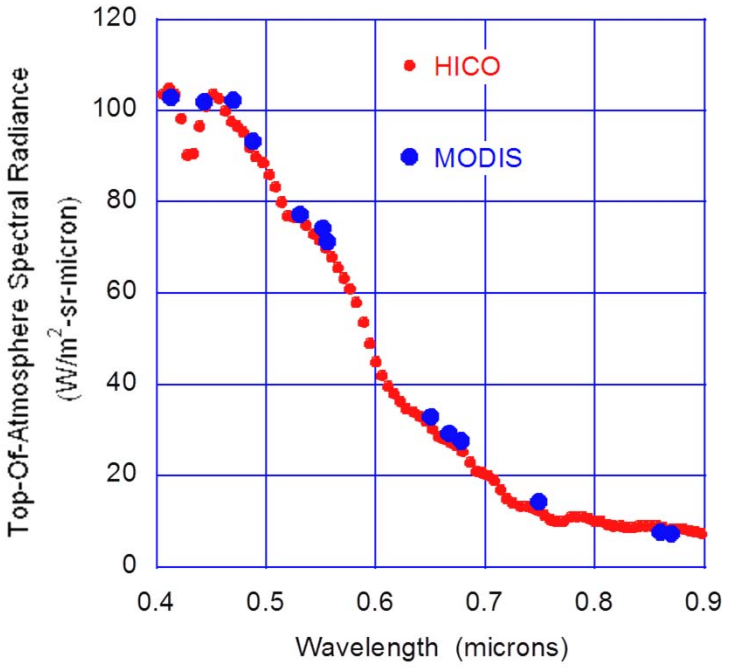
HICO	MODIS (Aqua)
Date: 18 January 2010	Date: 18 January 2010
Time: 04:40:35 UTC	Time: 05:00:00 UTC
Solar zenith angle: 53°	Solar zenith angle: 52°
Pixel size: 95 m	Pixel size: 1000 m

East China Sea off Shanghai

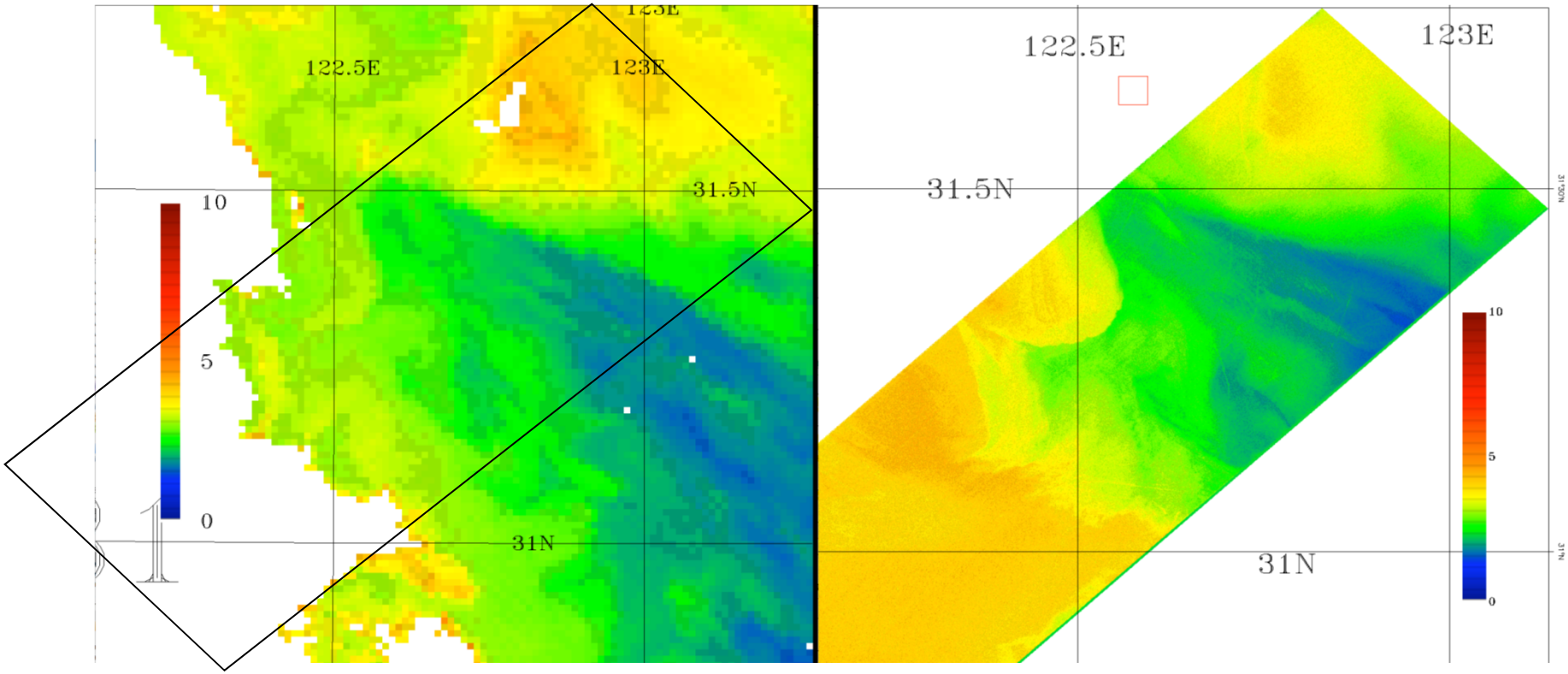


R.-R. Li, NRL

Top-Of-Atmosphere Spectral Radiance

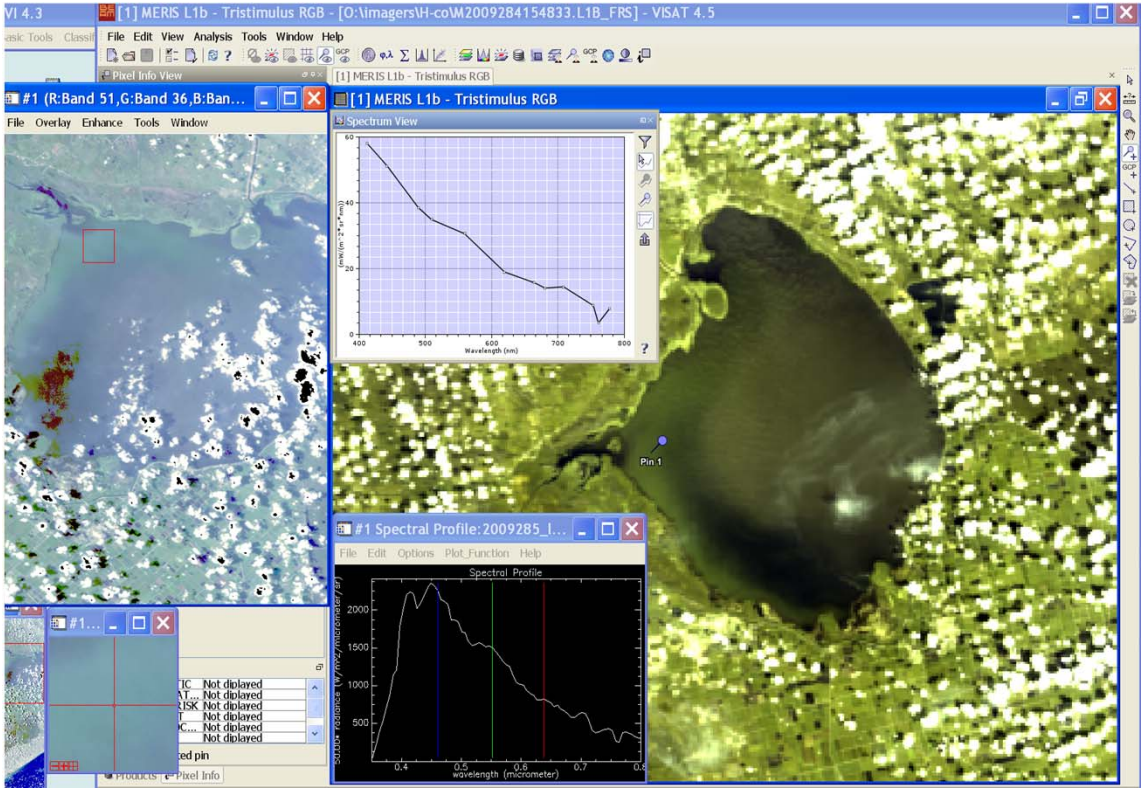


Chlorophyll Comparison of HICO to MODIS (Aqua)

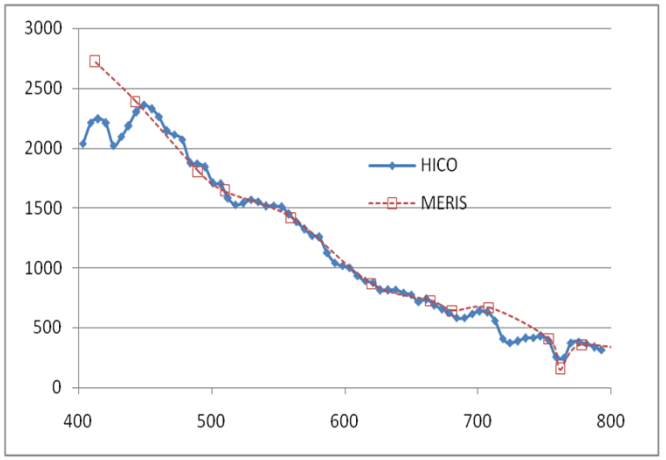


Nearly coincident MODIS and HICO™ images of the Yangtze River, China taken on January 18, 2010. Left, MODIS image (0500 GMT) of Chlorophyll-a Concentration (mg/m3) standard product from GSFC. The box indicates the location of the HICO image relative to the MODIS image. Right, HICO™ image (0440 GMT) of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

Comparison of HICO and MERIS



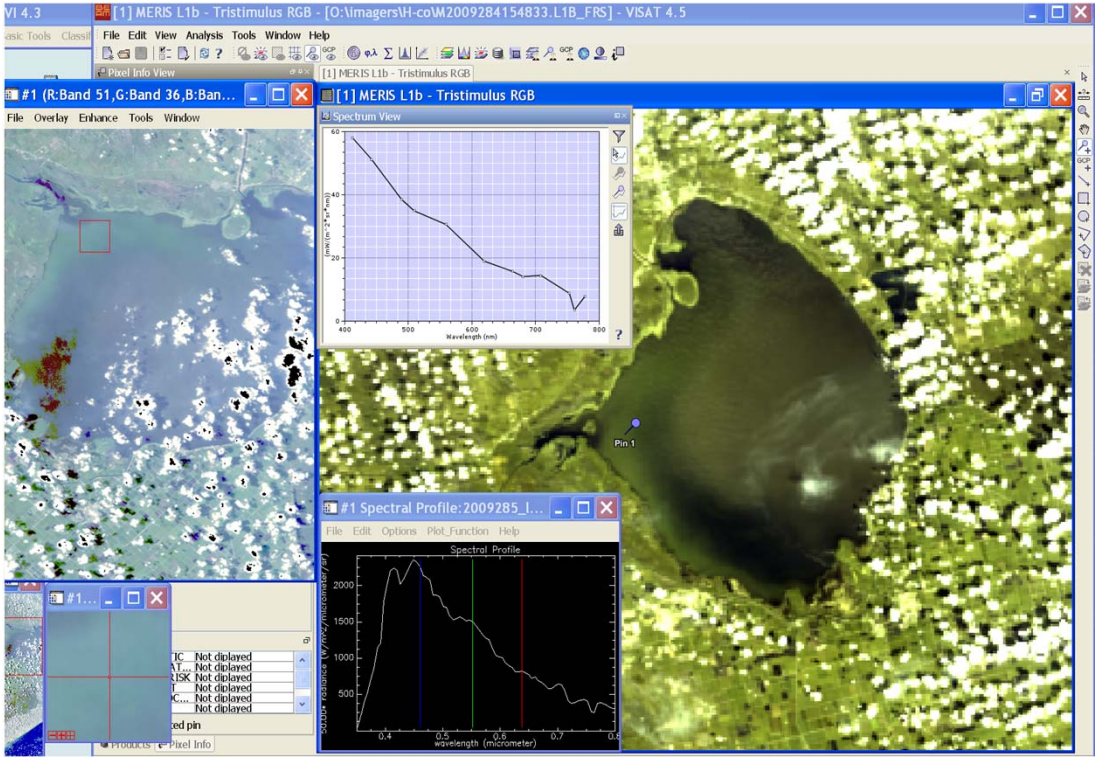
Lake Okeechobee



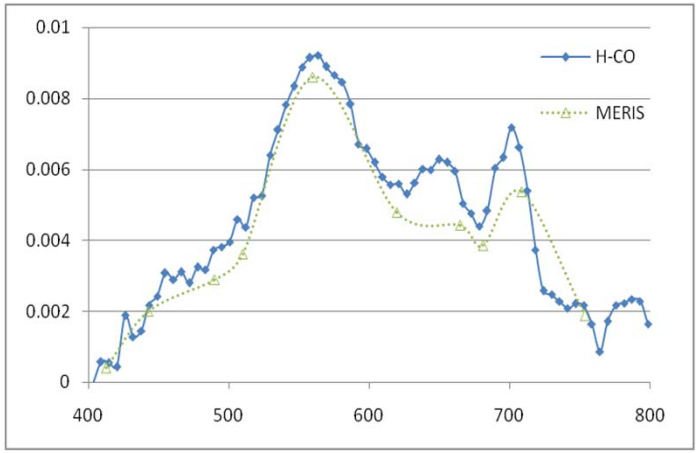
At Sensor Spectra Comparison

Ping Lee Cloud/Shadow and HOPE algorithms

Comparison of HICO and MERIS



Lake Okeechobee



Reflectance Spectra Comparison

Ping Lee Cloud/Shadow and HOPE algorithms

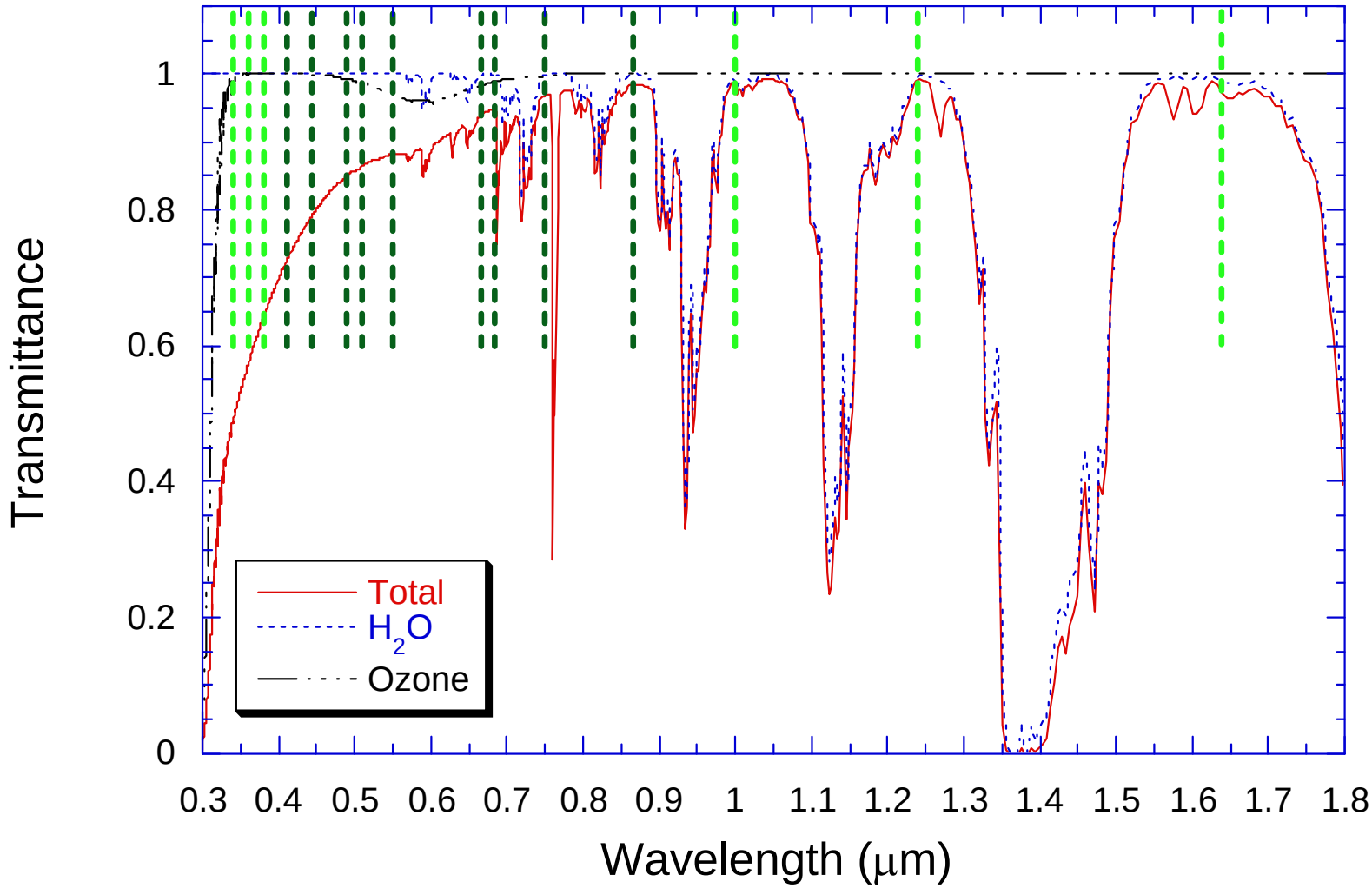
SeaWiFS and MODIS Atmospheric Correction

SeaWiFS and MODIS algorithm (Gordon and Wang 1994)

$$\rho_t = \rho_r + \rho_A + t\rho_{wc} + T\rho_g + t\rho_w, \quad \rho = \pi L / \mu_0 F_0$$

- ρ_w is the desired quantity in ocean color remote sensing.
- $T\rho_g$ is the sun glint contribution—avoided/masked and residual contamination is corrected.
- $t\rho_{wc}$ is the whitecap reflectance—computed from wind speed.
- ρ_r is the scattering from molecules—computed using the Rayleigh lookup tables.
- $\rho_A = \rho_a + \rho_{ra}$ is the aerosol and Rayleigh-aerosol contributions — estimated using aerosol models.
- For Case-1 waters in the open ocean, ρ_w is usually negligible at 765 & 865 nm. ρ_A can be estimated using these two NIR bands.

Channels and Atmospheric Transmission Windows



- UV channels can be used for detecting the absorbing aerosol cases
- Two long NIR channels (1000 & 1240 nm) are useful for of the Case-2 waters

Menghua Wang, NOAA/NESDIS/ORA

Atmospheric Correction of HICO data

- Atmospheric Correction with ATREM (Gao & Davis 1997 Proc. SPIE; Bo-Cai and Rong-Rong)
- Marcos will discuss Tafkaa Atmospheric Correction in detail
  - 6S version derived from ATREM
    - Currently implemented using 820-nm water vapor band and 720-nm band for water vapor correction (820-nm feature is used if ρ_t(800 nm) > 0.05; otherwise 720-nm feature is used)
    - We produce a standard product with this version at OSU.
  - Tabular Tafkaa (Gao et al. 2000, Appl. Opt.)
    - Scattering effects via lookup-tables calculated with Ahmad & Fraser vector radiative transfer code
    - Includes surface reflections correction (Cox & Munk)
    - Water vapor correction described above (720-nm and 820-nm switch) will be implemented
  - Gordon and Wang Atm. Corr. implemented in APS (David will present)
- Cloud-Shadow method (Lee, et al. 2007,JARS)
  - Ruhul Amin to present results with this method
- Dark Pixel subtraction to show coastal features (Tufillaro and Davis)
- Other methods from users?

ATREM Atmospheric Correction Over Land

The measured radiance at the satellite level can be expressed as:

$$L_{obs} = L_a + L_{sun}\, t\, \rho \qquad (1)$$

L_a: path radiance;
ρ : surface reflectance;
L_{sun}: solar radiance above the atmosphere;
t: *2-way transmittance for the Sun-surface-sensor path*

Define the satellite apparent reflectance as

$$\rho^*_{obs} = \pi\, L_{obs} / (\mu_0\, E_0) \qquad (2)$$

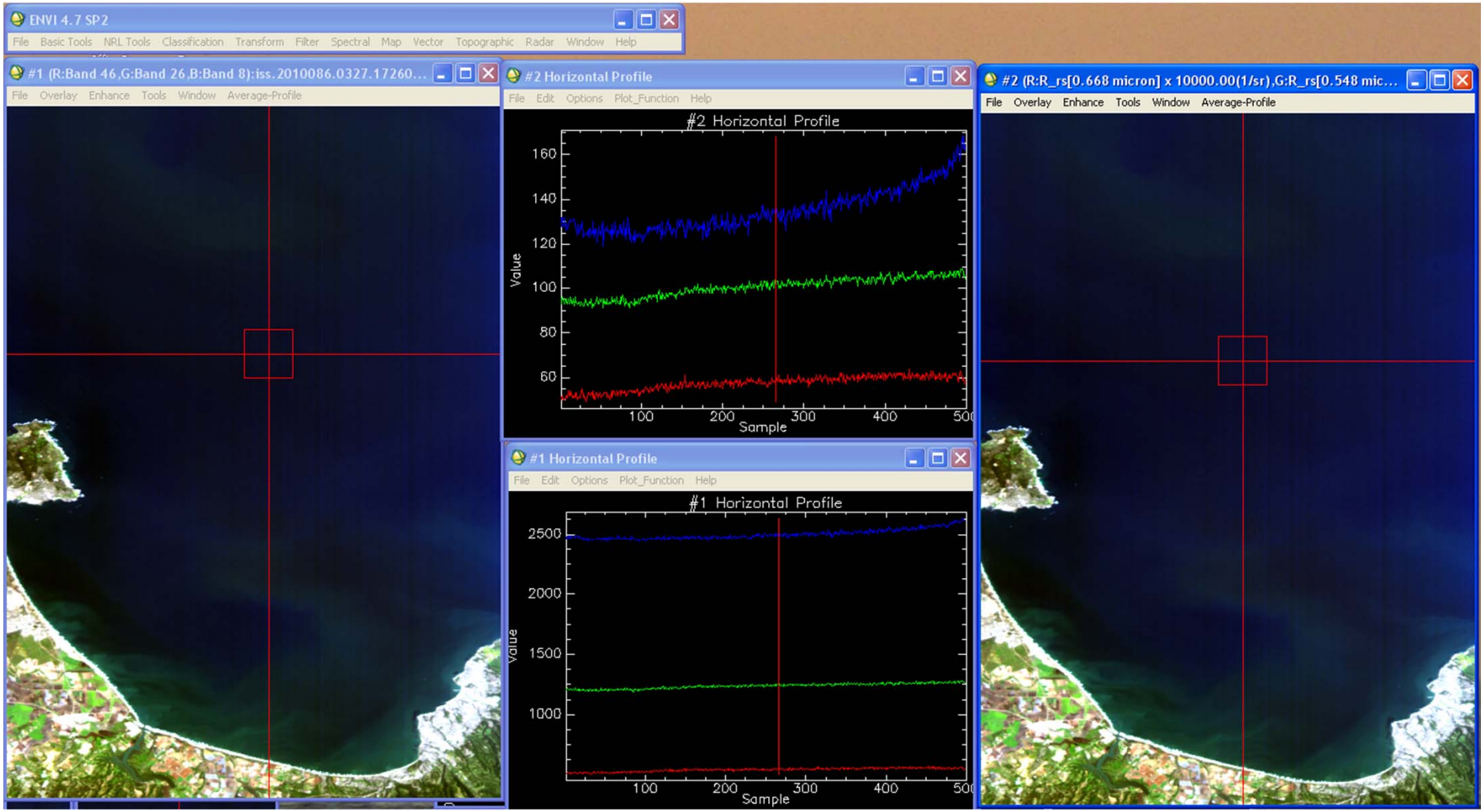
$$\rho^*_{obs} = T_g\, [\, \rho_a + t\, \rho / (1 - \rho\, s)\,] \qquad (3)$$

By inverting Eq. (3) for ρ, we get:

$$\rho = (\rho^*_{obs}/T_g - \rho^*_a) / [t + s\, (\rho^*_{obs}/T_g - \rho^*_a)\,] \qquad (4)$$

Gao, B.-C., K. H. Heidebrecht, and A. F. H. Goetz, Derivation of scaled surface reflectances from AVIRIS data, *Remote Sens. Env., 44*, 165-178, 1993.

Residual Cross track signal in the blue?



HICO Image of Monterey Bay, CA 3/27/2010; Left level 1B, right Rrs from Tafkaa 6S.

Coastal CAL/VAL

SeaPRISMs

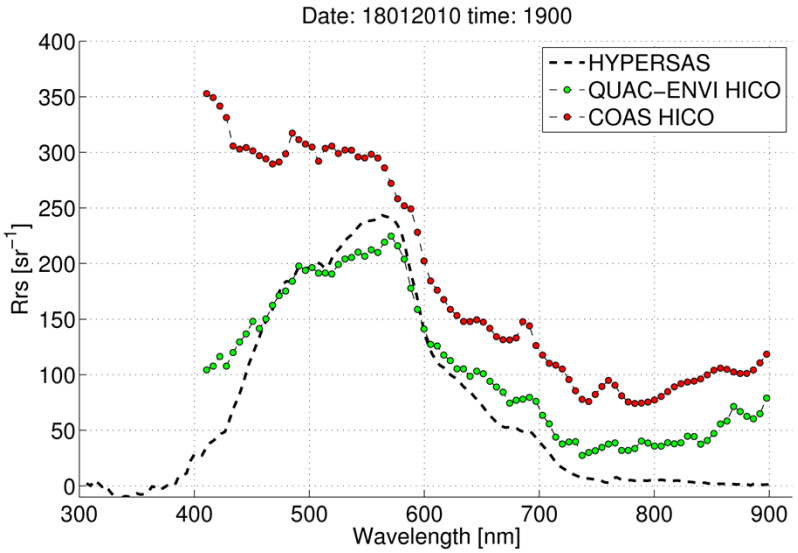
PLATFORM EUREKA, CCNY, AAOT, …

CRUISES

OREGON (MILOCO, MOCHA)

, CHILE, HAWAII, OTAGO, NOUMEA,

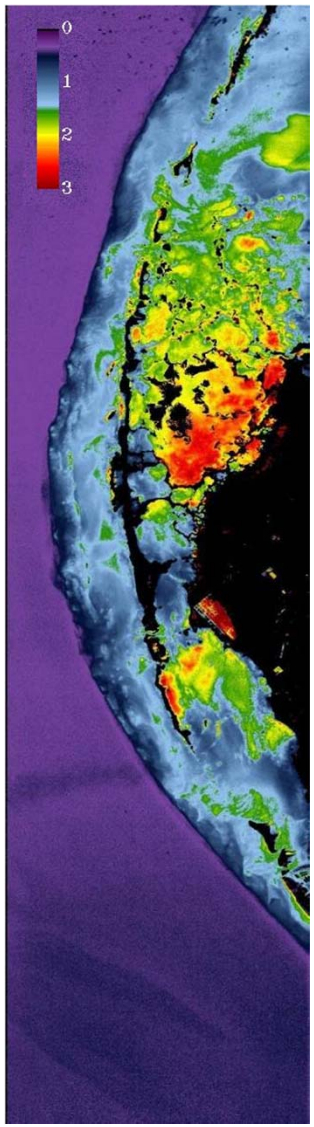
CCNY HyperSAS



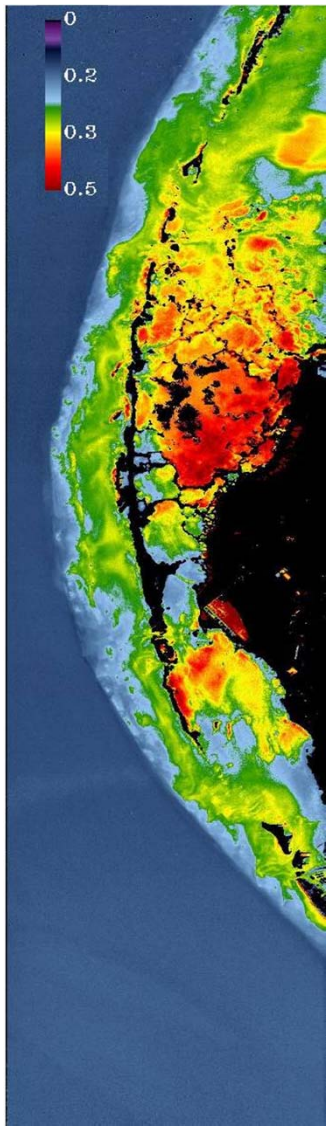
Plot from Tristan Harmel and Alex Gilerson, CCNY

Selected HICO APS Data Products
Key Largo, Florida

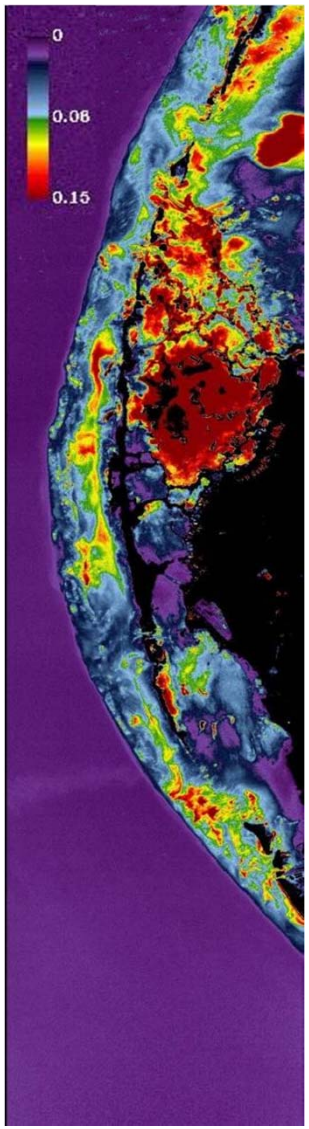
Radiance



chl_02



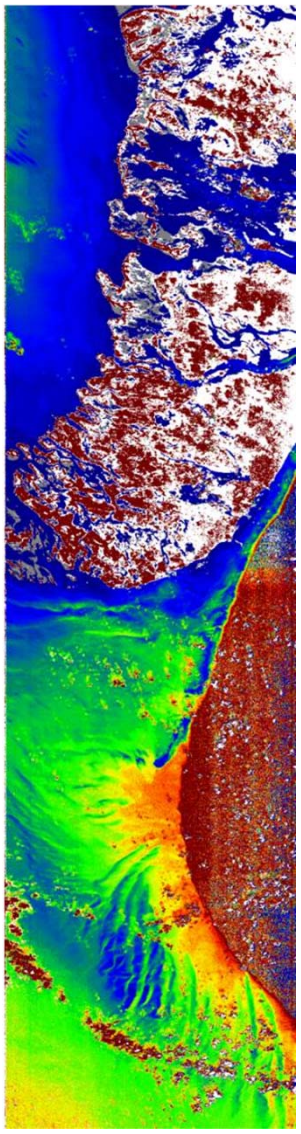
Kd_490



bb_551

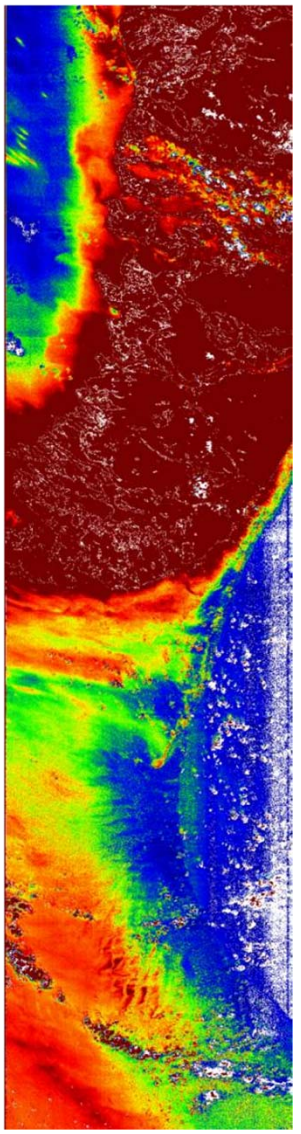
HICO Image
Bahamas: 10/22/09

Radiance



Bathymetry

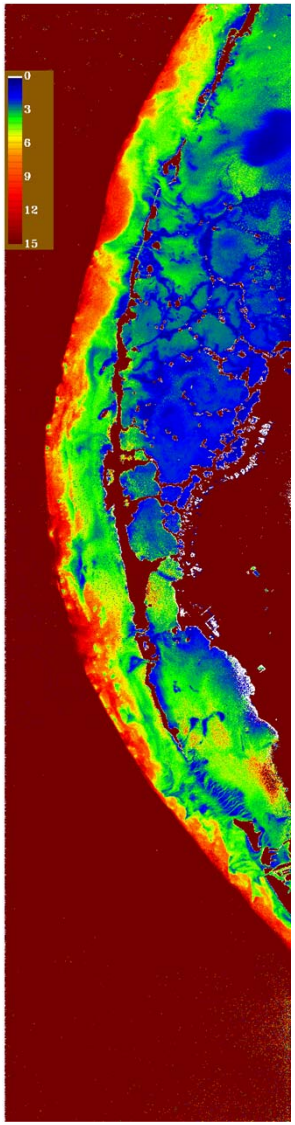
Ping Lee
HOPE
Algorithm



Absorption

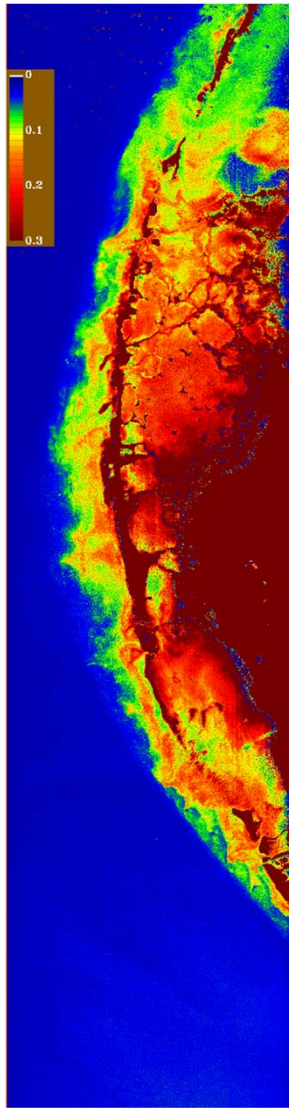
HICO Image
Key Largo, Florida: 11/13/09

Radiance



Bathymetry

Ping Lee
HOPE
Algorithm



Absorption

Planned HICO Data Distribution at OSU

- **HICO Public Website at OSU including published and approved for distribution data, publications and presentations.**
  - **Currently Password protected working with a test group of users**
- **Will include some example HICO data (e.g. Columbia River) that is approved for distribution.**
- **OSU HICO Web site will be portal for data requests and distribution**
  - **Data requests require proposal and data agreement signed by the requestor and their institution and approved by NRL.**
- **Example data and data requested by that user will be available to them.**
- **http://hico.coas.oregonstate.edu/login/login.shtml**

NRL – HICO Team

NRL – DC

- Michael Corson, PI
- Robert Lucke, Lead Engineer
- Bo-Cai Gao
- Charles Bachmann
- Ellen Bennert
- Karen Patterson
- Dan Korwan
- Marcos Montes
- Robert Fusina
- Rong-Rong Li
- William Snyder

NRL – SSC

- Bob Arnone
- Rick Gould
- Paul Martinolich
- Will Hou
- David Lewis
- Ronnie Vaughn
- Adam Lawson
- Alan Weidemann
- Ruhul Amin

Academic

- Curt Davis, OSU, Project Scientist
- Jasmine Nahorniak, OSU
- Nick Tufillaro, OSU
- Curt Vandetta, OSU
- Ricardo Letelier, OSU
- Zhong-Ping Lee, MSU

Special thanks to our sponsors the Office of Naval Research, the Space Test Program, and to NASA and JAXA who made this program possible.

Summary (HICO Docked on the Space Station)

- **Built and launched in 28 months**
- **Over 1700 scenes in first year**
- **Two more years of operations**
- **Data from OSU HICO website**