Coral Reef Bleaching and Threats to Biodiversity in Puerto Rico

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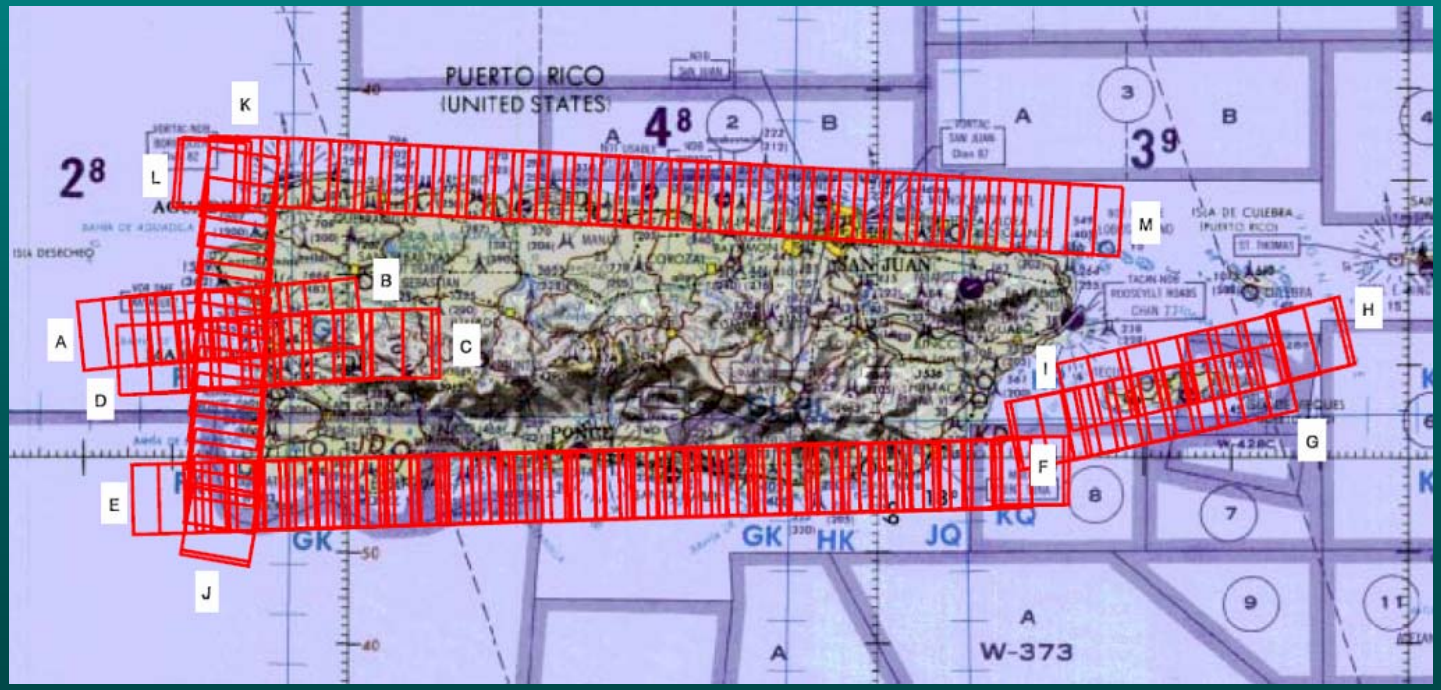
http://earthscience.arc.nasa.gov/sge/coral-health/

Science Objectives

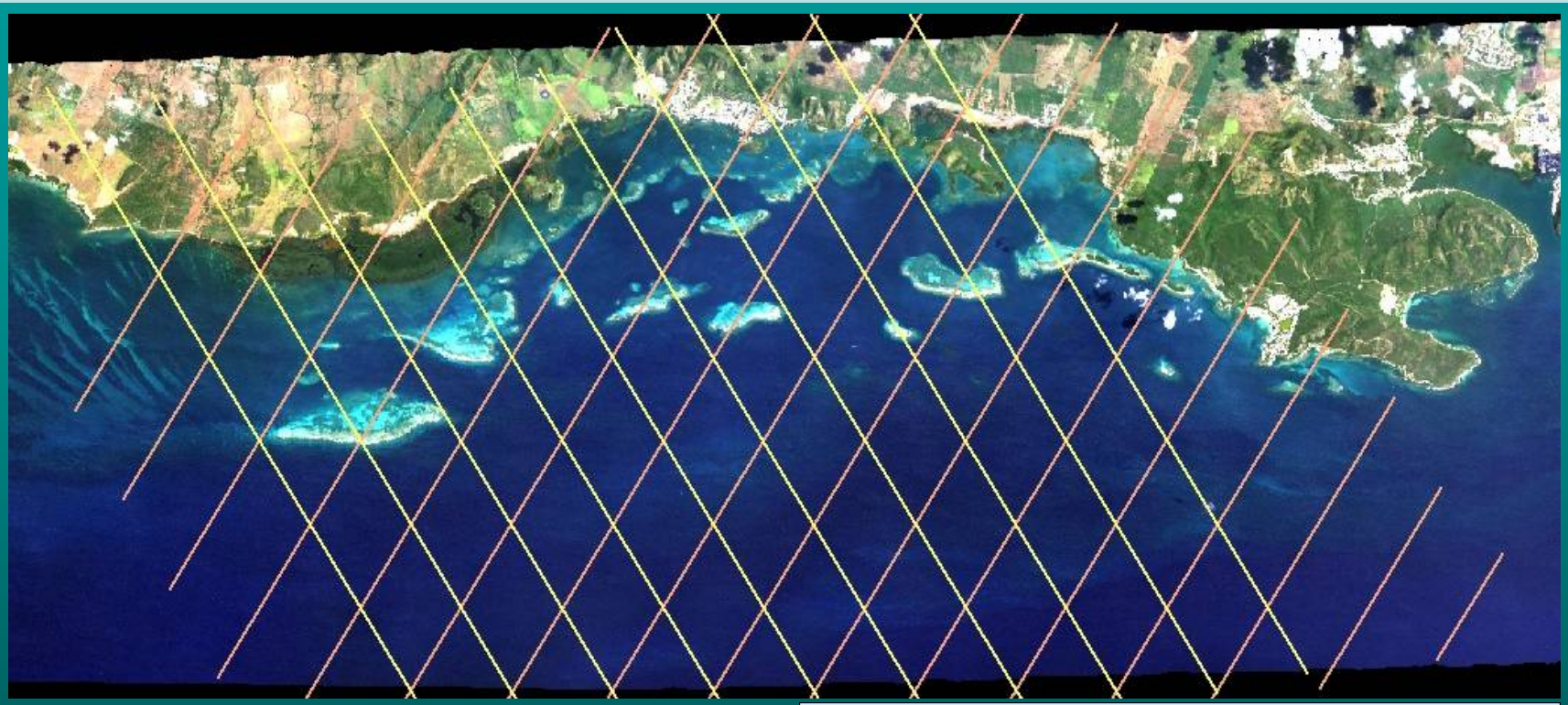
- Use NASA's 2004 and 2005 AVIRIS imagery over La Parguera, PR to map coral reef benthic types and change
- Map the distribution of the threatened *Acropora* species (elkhorn and staghorn corals) along bathymetric zones
- Establish permanent reef monitoring transects to track change
- Use AVIRIS data and field measurements to assess the ecological impact of the 2005 coral bleaching event in Southwestern Puerto Rico
- Improve the interpretation of reef habitat variability and biodiversity

NASA AVIRIS 2004 Mission over Puerto Rico

- August 19, 2004
- ER-2 Platform, Altitude ~20.1 km
- 8 Flightlines
- Pixel Size ~17 m
- Total Area 8500 km^2



NASA Airborne Mission of the 2005 Caribbean Coral Reef Bleaching Event Using AVIRIS and DCS



AVIRIS flight lines over La Parguera, PR

- **December 12-13, 2005**
- **Twin Otter Platform, Altitude ~3.5 km**
- **Pixel Size ~3 m**

NASA Airborne Missions of Coral Reefs Using AVIRIS and DCS

AVIRIS (Airborne Visible Infrared Imaging Spectrometer):

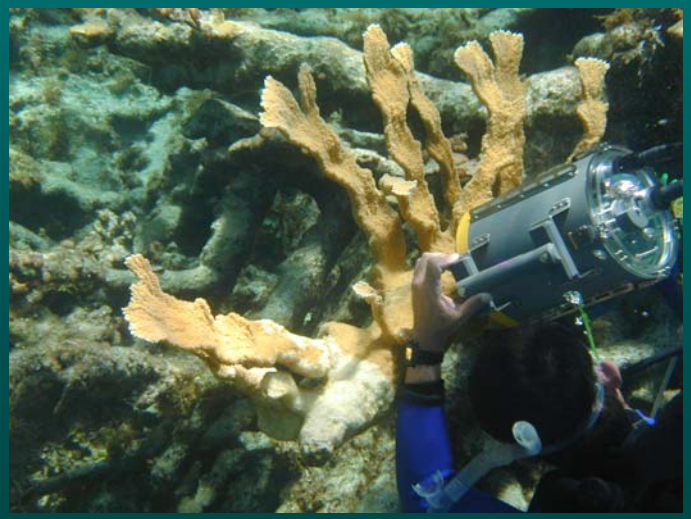
- Operated by NASA Jet Propulsion Lab
- NASA Wallops Twin Otter or ER-2 aircraft
- 224 contiguous spectral channels (370-2500 nm)
- Visible range: 410-700 nm (31 bands)
- 10 nm nominal channel bandwidth
- High signal to noise ratio
- Altitude: ~ 3.5 km (Twin Otter), ~14-20 km (ER-2)
- AVIRIS spatial resolution: ~ 3 m (Twin Otter), 13-17 m (ER-2)

Cirrus and Kodak DCS (Digital Camera System) on low altitude aircraft

- Cirrus: Operated by UC Santa Cruz Airborne Sensor Facility at NASA Ames
- Kodak: Operated by NASA Ames and Fireball Information Technologies
- Spatial resolution: <1 m

Field Measurements

- Water optical profiler (hyperspectral spectrometer– Satlantic Hyperpro)
  - Upwelling radiance
  - Downwelling irradiance
  - Backscattering coeff. at 400 and 700 nm
  - Spectral diffuse attenuation coefficients
- Spectra of calibration targets (GER 1500 spectroradiometer)
- Aeronet station – atmospheric correction
- Reef benthic type spectra (GER 1500)
- Photogrids
- GPS



Coral Reef Ecosystem Benthic Types

Coral Rubble

Acropora cervicornis

Acropora palmata

Montastraea annularis

Siderastrea siderea

Porites spp.

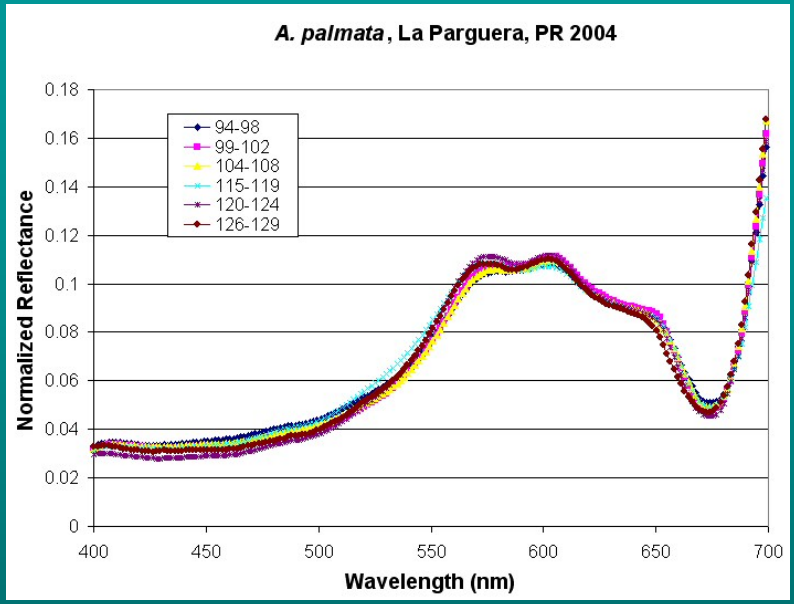
Gorgonians

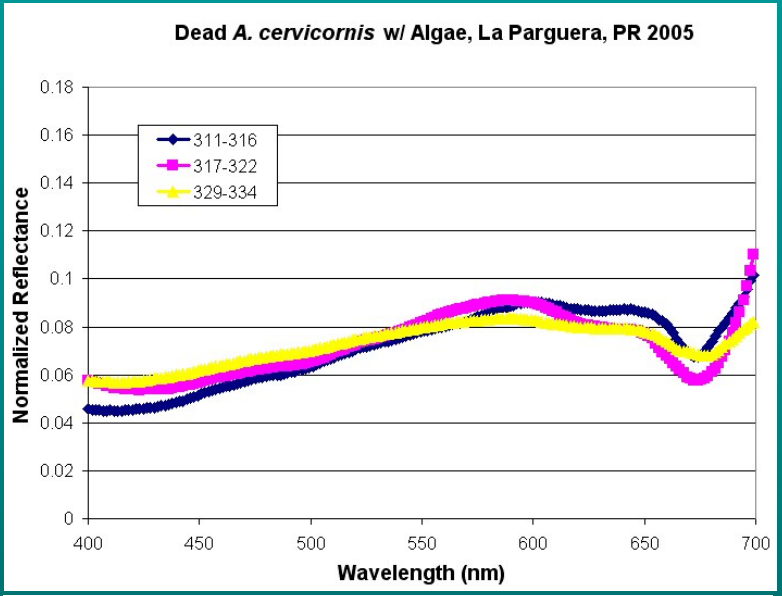
Dictyota spp.

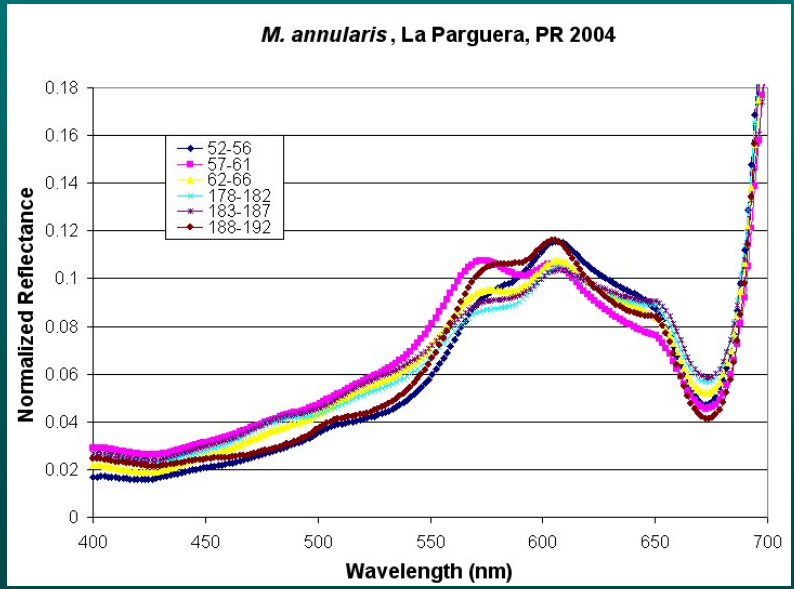
Thalassia testudinum

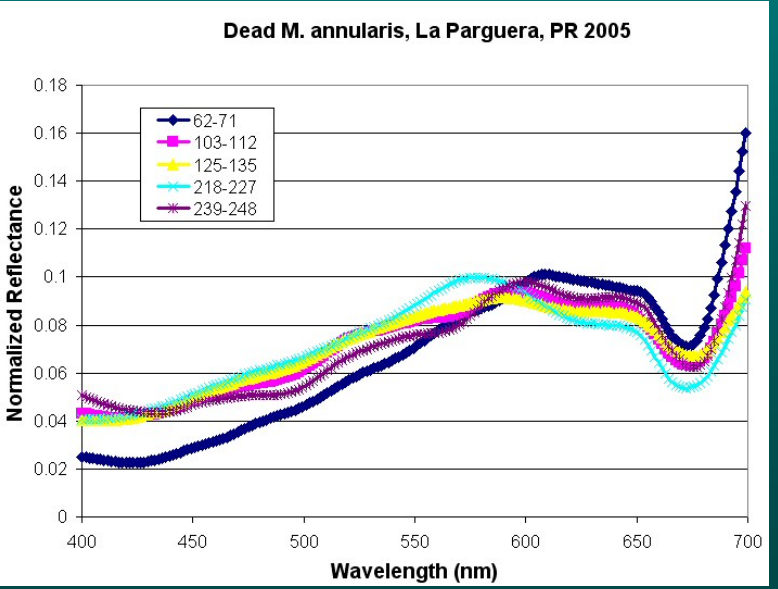
Acropora cervicornis (staghorn coral) Transects 2004-2007

Field Spectra







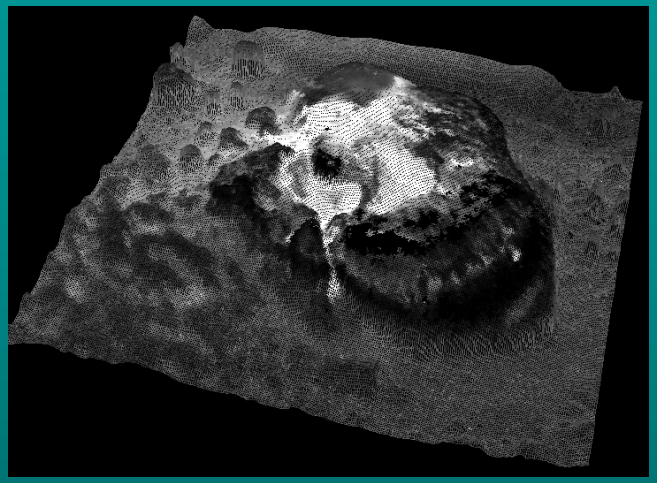


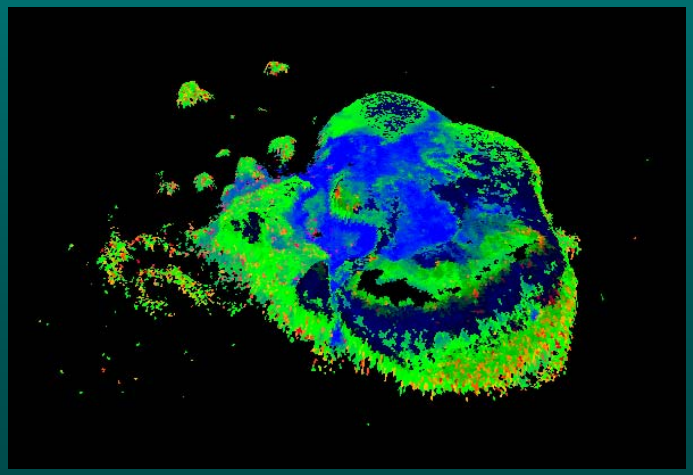
AVIRIS Dec. 2005
(3 m Resolution)
Mosaic of La Parguera, PR

J. Goodman (UPRM)

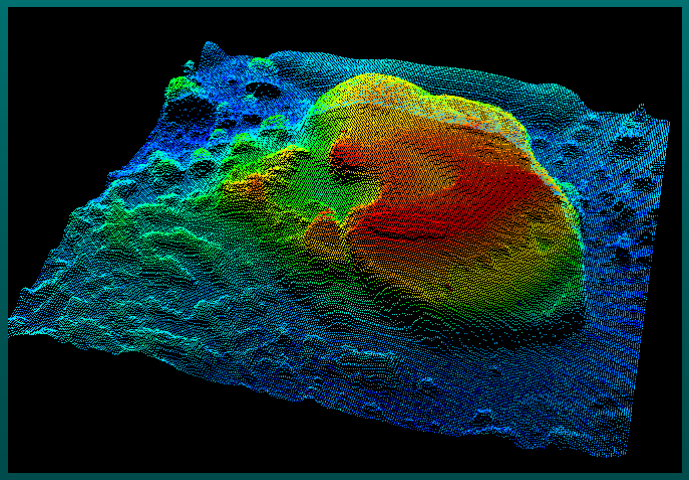
2005 AVIRIS: From Imagery to Information

Bottom Albedo



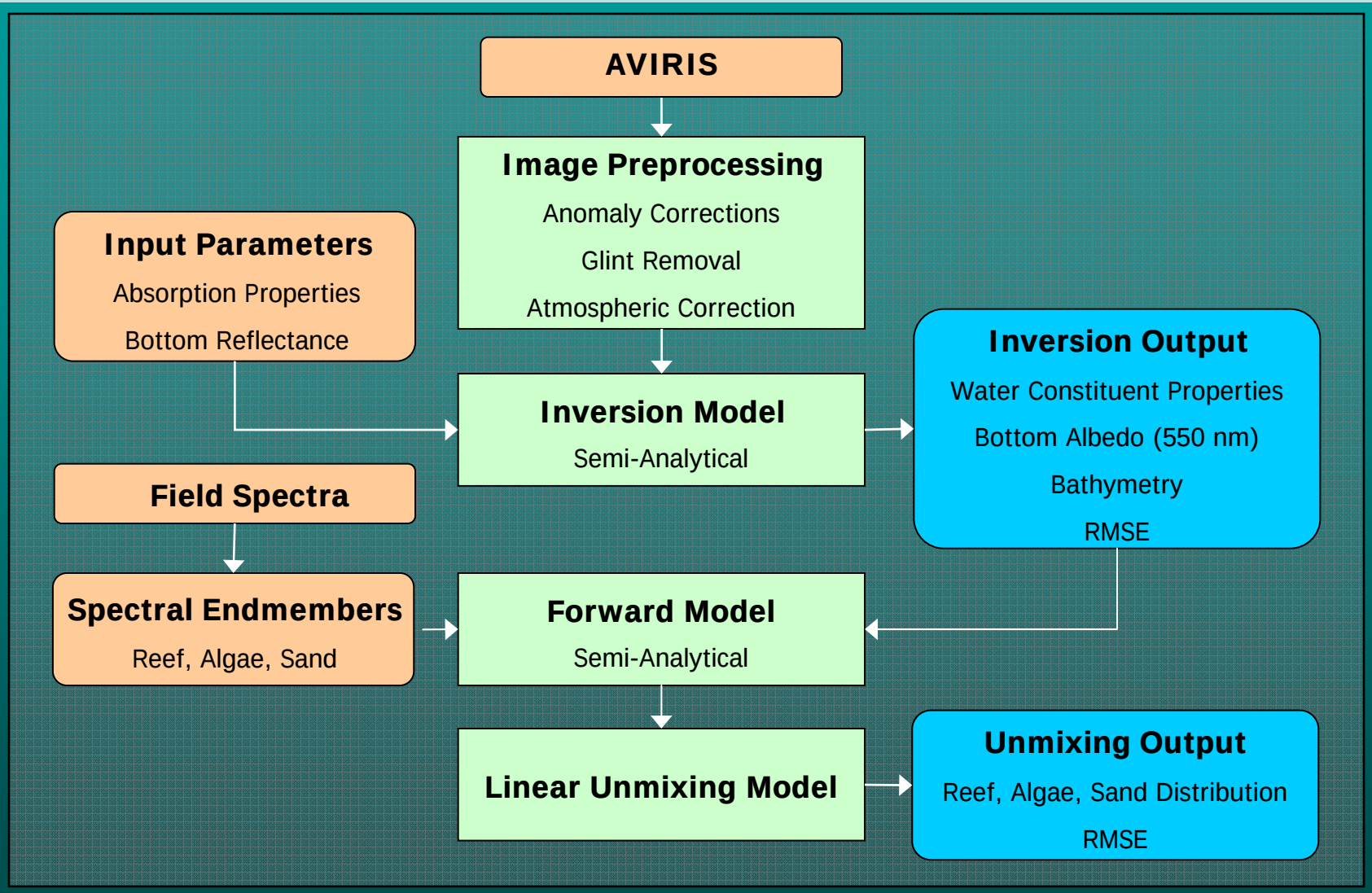


Benthic Composition



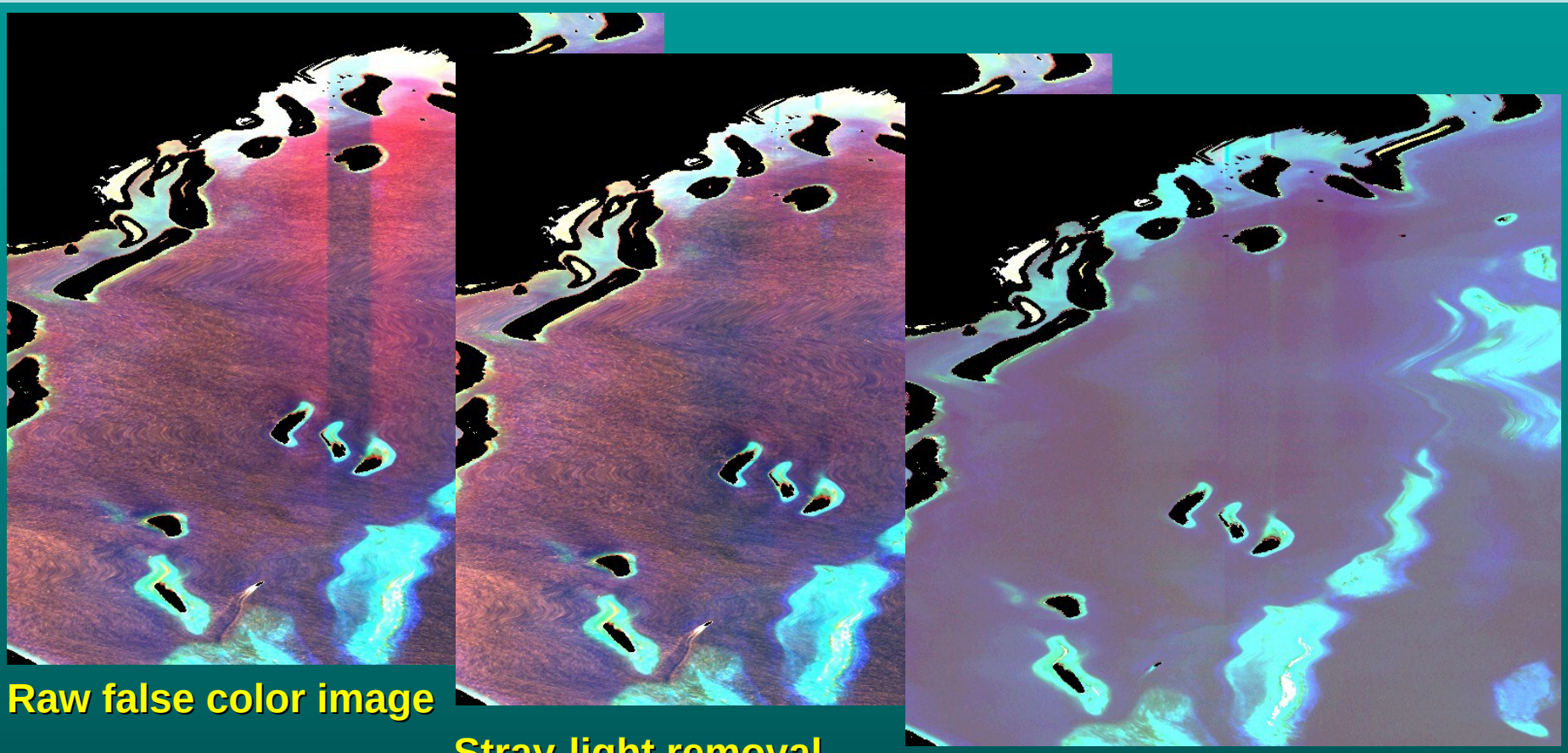
Bathymetry

Processing Steps



- Atmospheric correction (Gao et al. 2000, Montes et al. 2001, 2003)
- Sun glint removal (Hedley et al. 2005)
- Semi-analytical model (Lee et al. 1996, 1998, 1999)

Preprocessing



Raw false color image

Stray-light removal

Sun glint removal

Steps:

1) The difference between the central stripe of data and the halo pixel values is calculated, then halo values are reduced based on this difference and the halo's cross-track profile.

2) Sun glint is removed by using the relative difference between sun glint in one NIR channel and each of the other channels (Hedley et al. 2005).

3) Atmospheric correction using Tafkaa (Montes et al. 2003).

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2005 AVIRIS: Preprocessing and Inversion Model

Raw AVIRIS Imagery

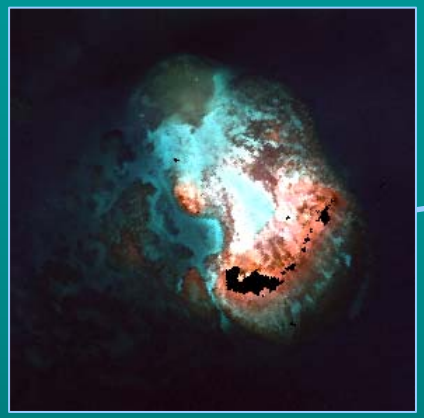


Image Preprocessing

Correct Stray Light Anomaly

Hedley Glint Removal

Tafkaa Atmospheric Correction

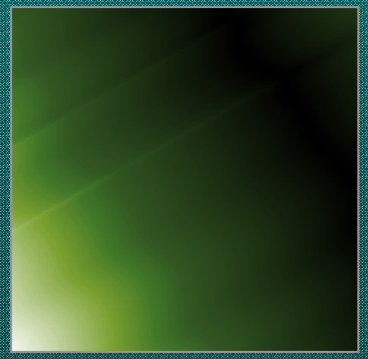
Spectral Input Parameters

Aquatic Absorption Properties

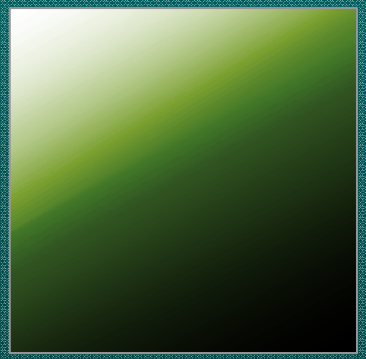
Generic Bottom Reflectance

Image Geometry

Explicit pixel by pixel subsurface angles



View (AVIRIS)

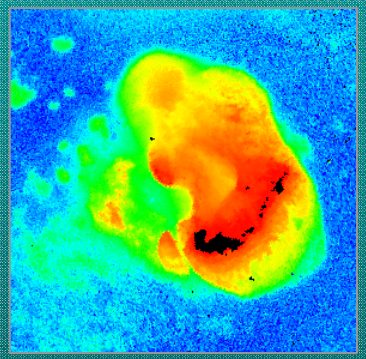


Illumination (solar)

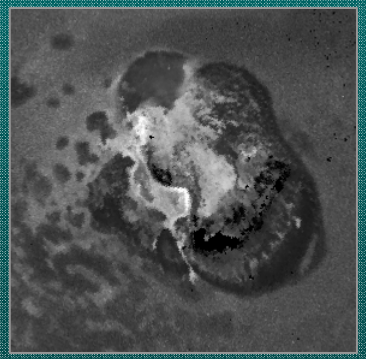
Inversion Model

Inversion Output

Water Properties



Bathymetry



Bottom Albedo (550 nm)

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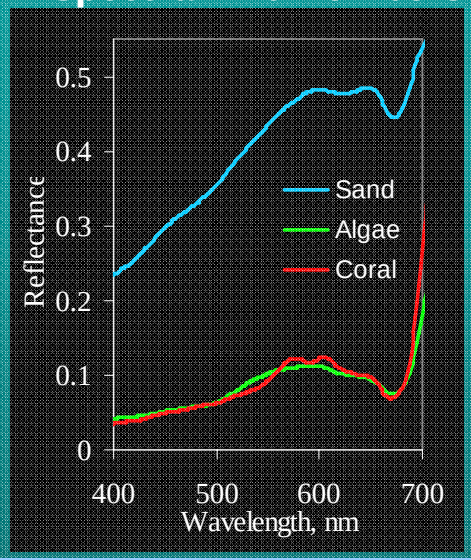
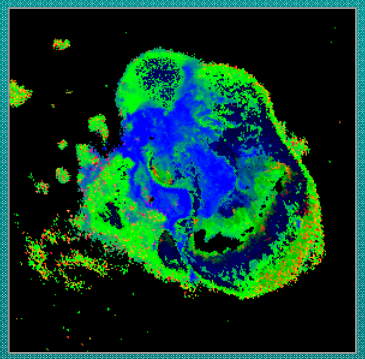
2005 AVIRIS: Unmixing Model

Spectral Endmembers

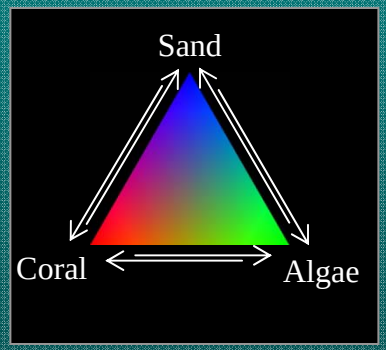


Preprocessed AVIRIS Imagery

Unmixing Output



Benthic Composition

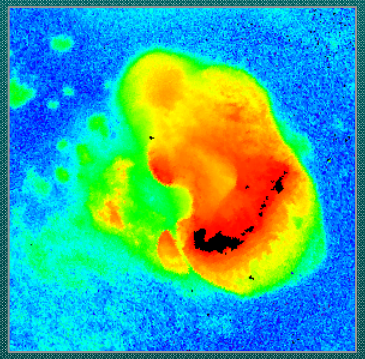


Forward Model

Unmixing Model

Inversion Output

Water Properties



Bathymetry

Spectral Input Parameters

Aquatic Absorption Properties

Generic Bottom Reflectance

Image Geometry

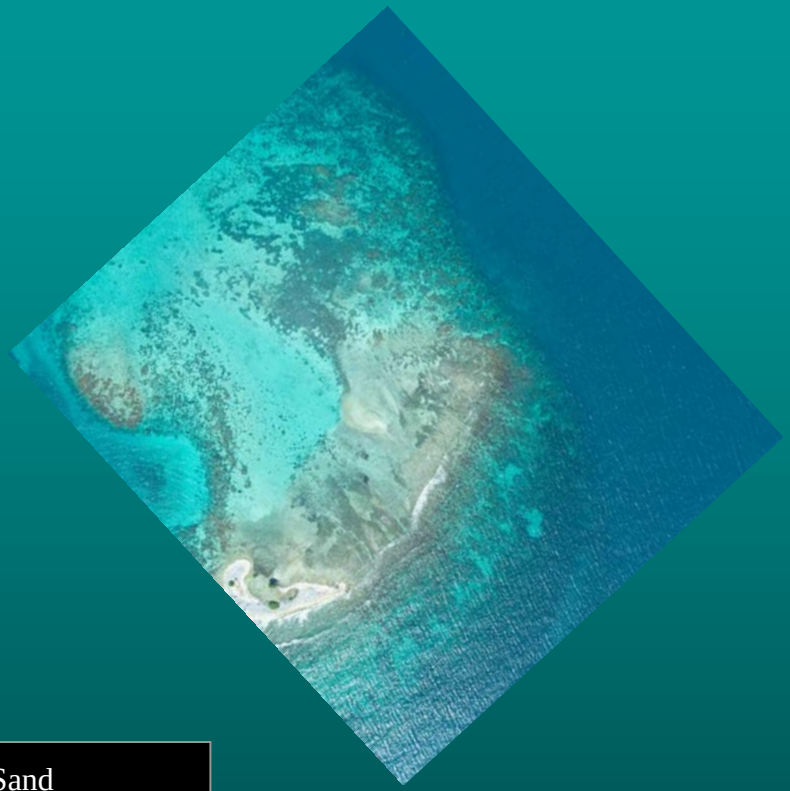
Explicit pixel by pixel subsurface angles

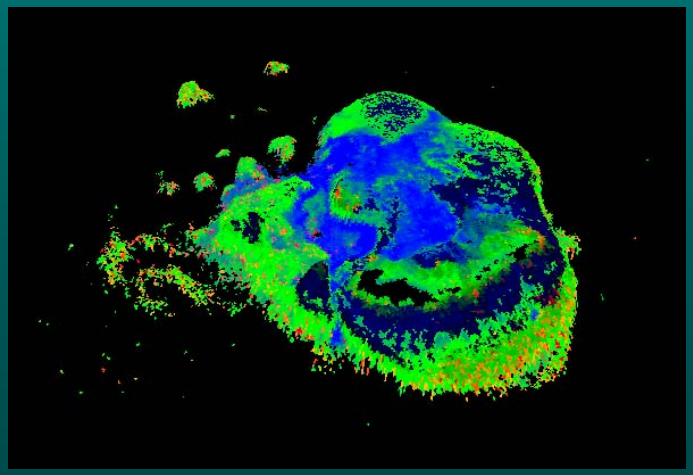
View (AVIRIS) Illumination (solar)

J. Goodman (UPRM)

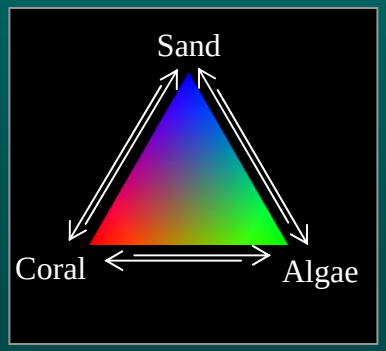
2005 AVIRIS: From Imagery to Information

AVIRIS Data





Benthic Composition



Summary

- Pre-processing steps:
  - Stray-light anomaly suppression, removal of sun glint, and atmospheric correction
- Preliminary unmixing analysis:
  - Using generic spectral endmembers of coral, sand, and algae
  - Spectral endmembers do not differenciate between algae and seagrass
  - Analysis performed for depth range 0-10m
- Next steps for processing:
  - Incorporate additional spectral endmembers from Puerto Rico
  - Identify viable depth range for unmixing analysis
  - Use MESMA for unmixing and compare results
  - Evaluating other algorithms for water column correction
    - •Spectral attenuation coefficients and Lidar bathymetry
    - •Underwater flat fields calibration

      -> Use spectral matching approach (field and AVIRIS) for benthic classification
  - Identify best processing options for benthic composition classification

Water Column Corrections

- **Lyzenga's "depth invariant" bands**

$Y_{i,j} = X_i - (K_i/K_j)X_j$ where $X_i = \ln(L_i - L_{i\infty})$

- **Benthic Reflectance Model**

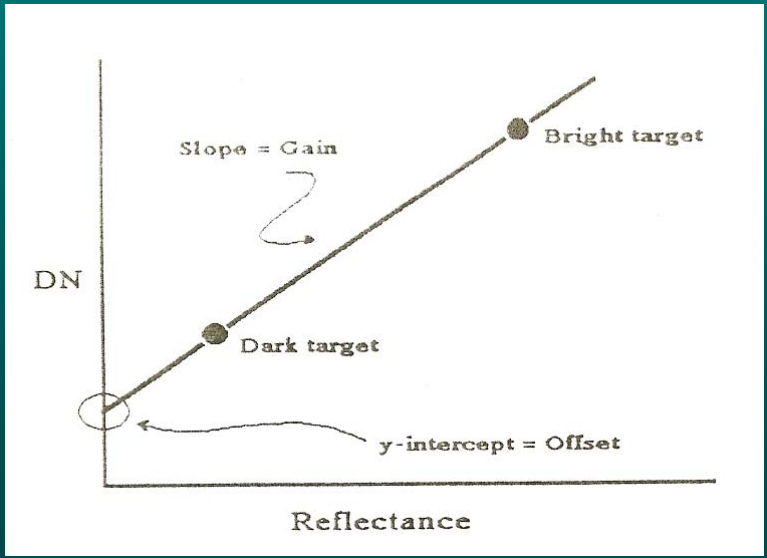
$$R_b = \frac{\frac{1}{0.54}R_{rs}(z=a) - \left(1 - e^{-2kz}\right)R_w}{e^{-2kz}}$$

- **Empirical Line Method**

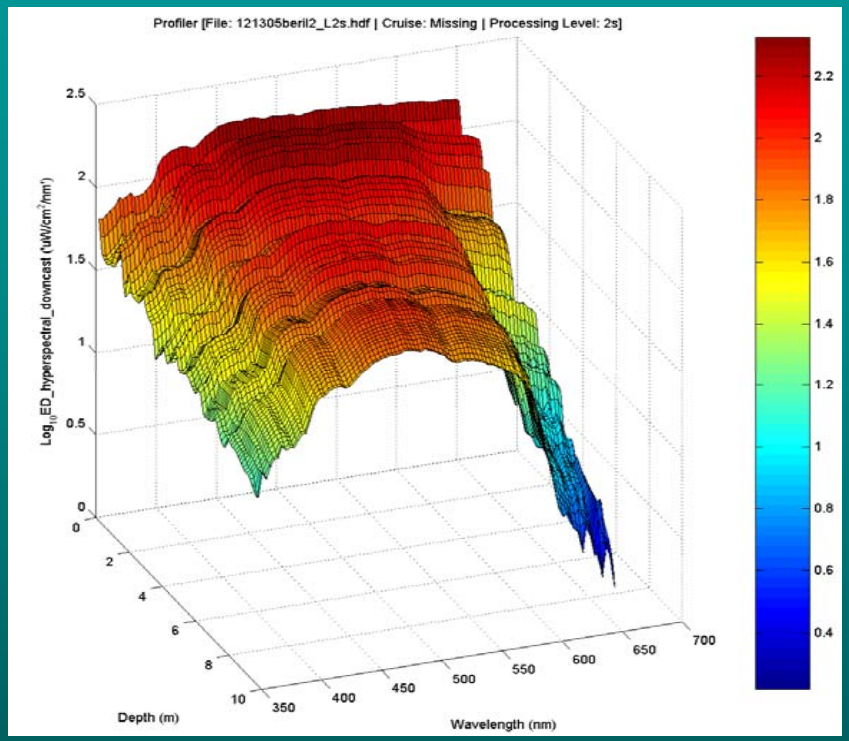
Relies on field measurements of homogeneous area or "flat fields"

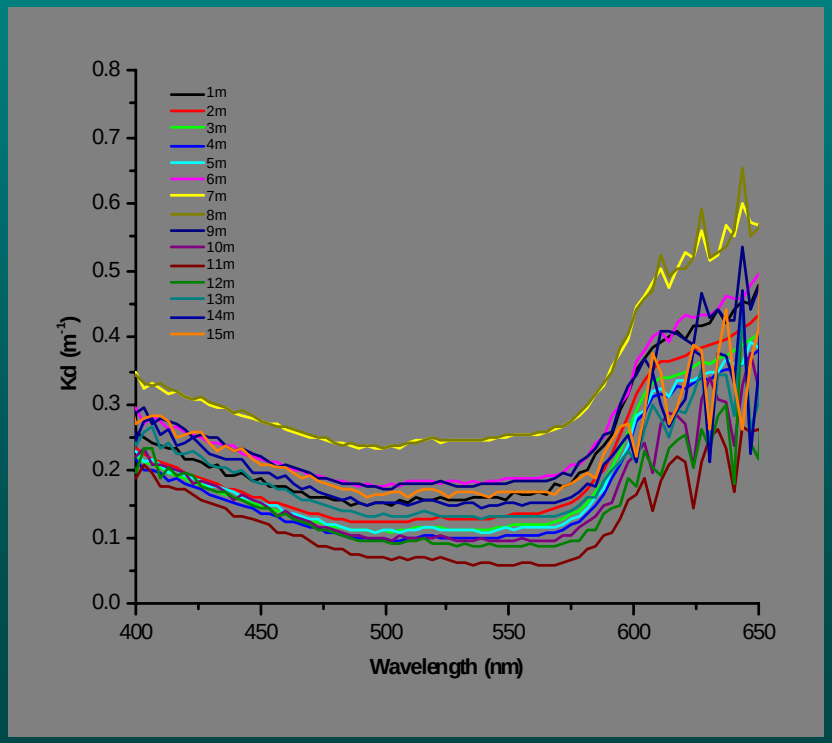
DN(b) = ρ(b)A(b) + B(b)

ρ = reflectance of surface material
A = multiplicative term, B = additive term



Water Column Corrections



Spectral attenuation coefficients can be determined by using Satlantic Hyperpro Ed profiles.

These measurements can be expressed as a function of depth.