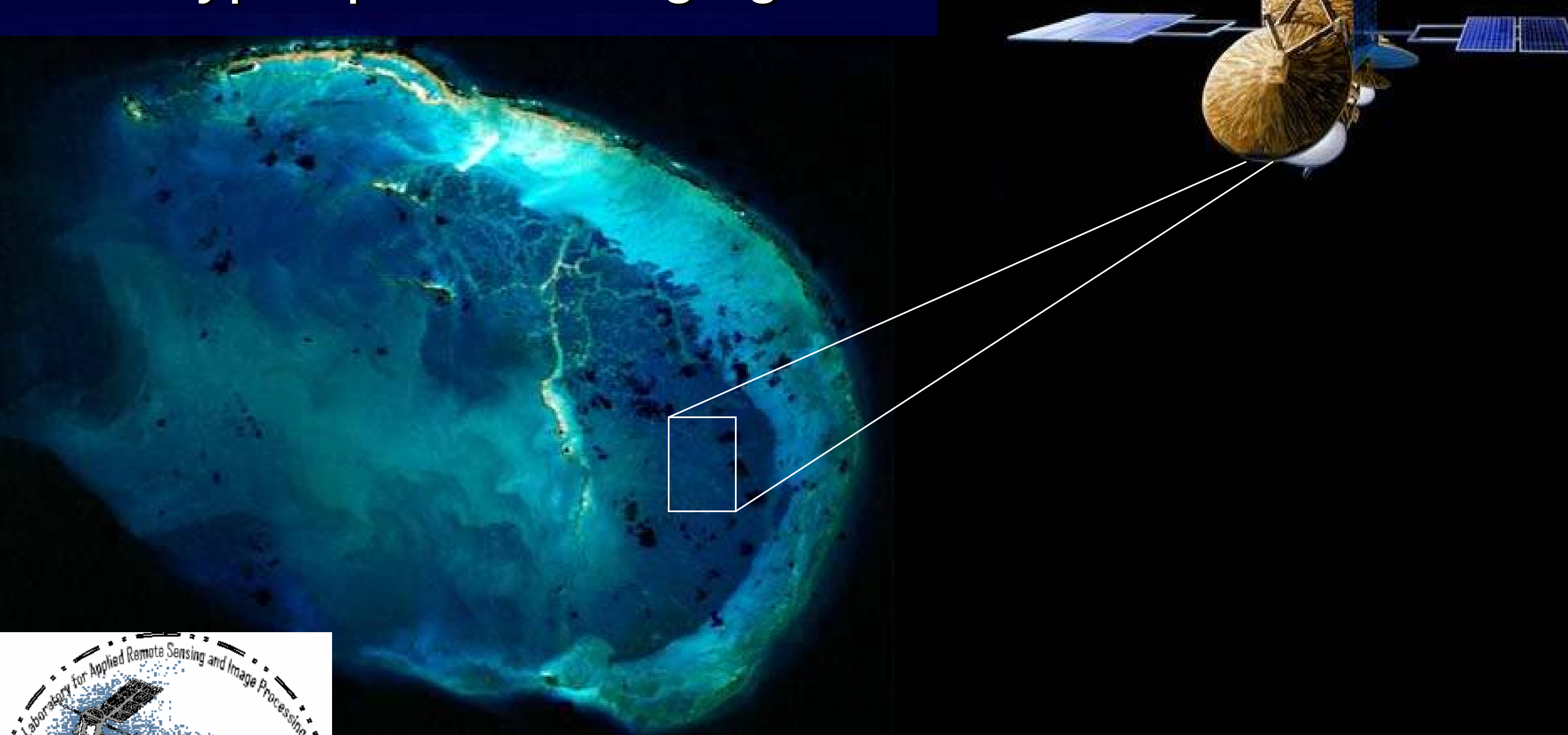
Quantitative Remote Sensing of Coastal Environments using Hyperspectral Imaging



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Overview

- Background on Spectral Imaging
  - Hyperspectral Imaging (HSI)
- Information Extraction from HSI
- Benthic Habitat Monitoring
- Examples using AVIRIS Imagery
- Final Remarks

What is Hyperspectral Imagery?

or Imaging Spectroscopy

Hyperspectral Imaging,

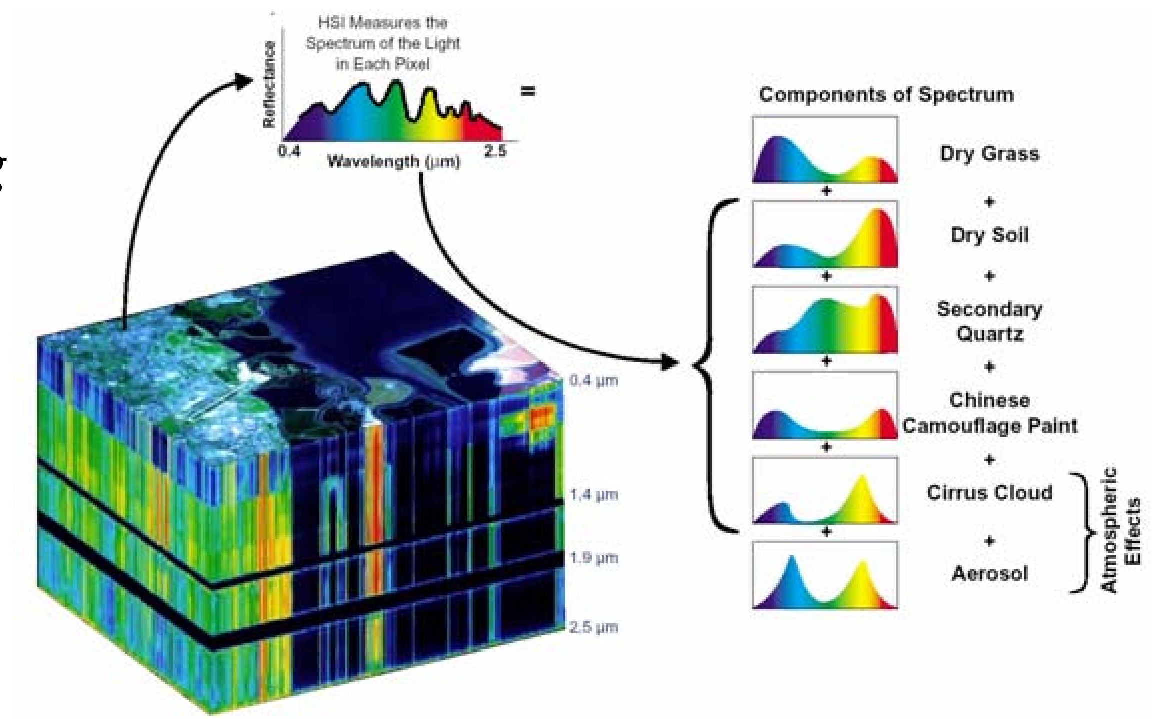
also referred to as *Imaging Spectrometry, combines:*

(i) *conventional imaging,*

(ii) *spectroscopy, and*

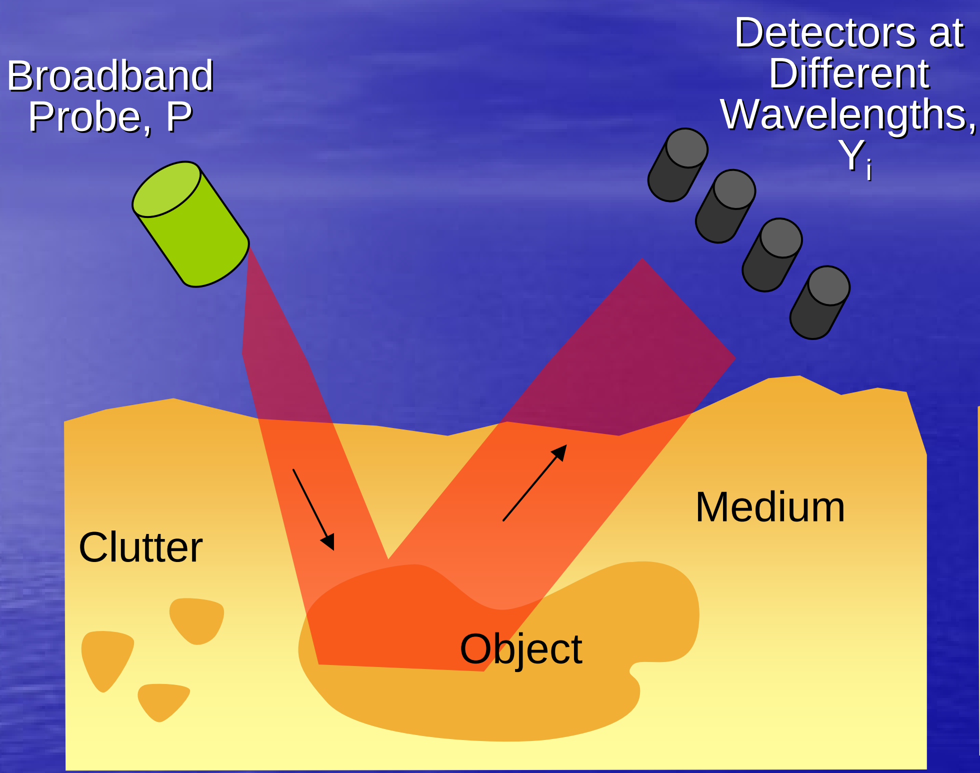
(iii) *radiometry*

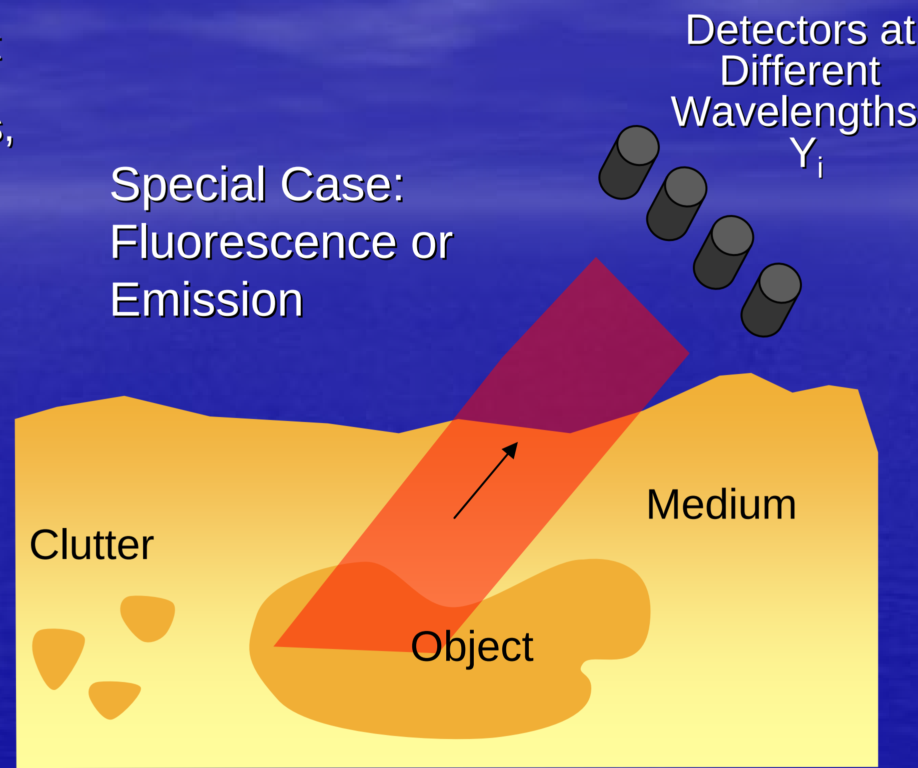
to produce images for which a spectral signature is associated with each spatial resolution element (pixel).



Information Extraction Algorithms for HSI should take advantage of spatial and spectral information contained in the data.

General Spectral Sensing

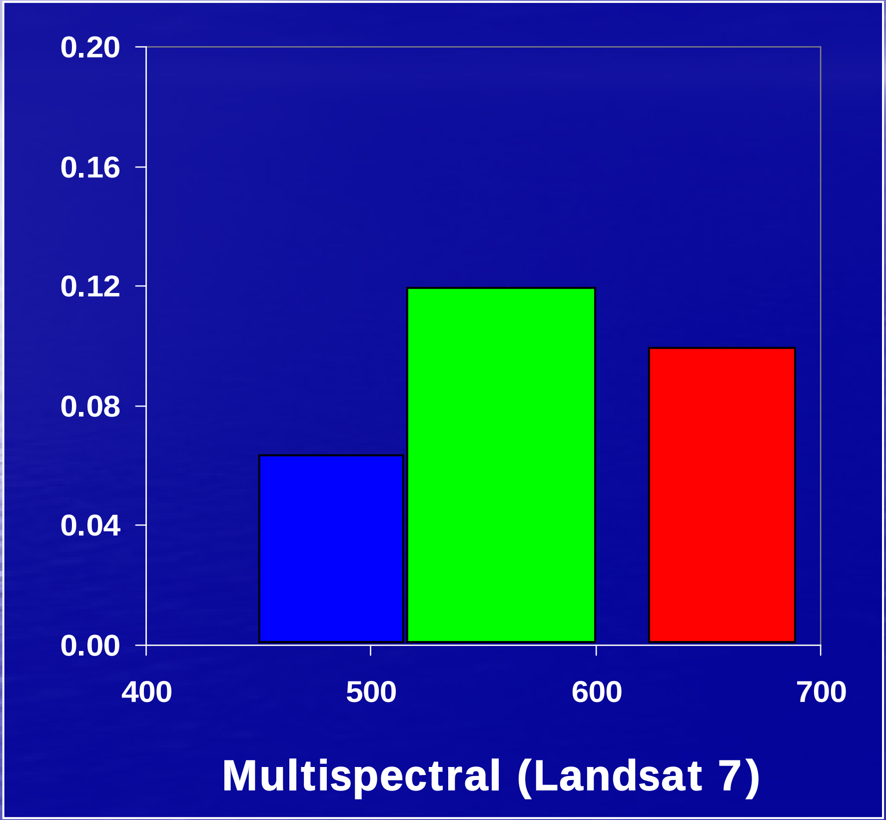


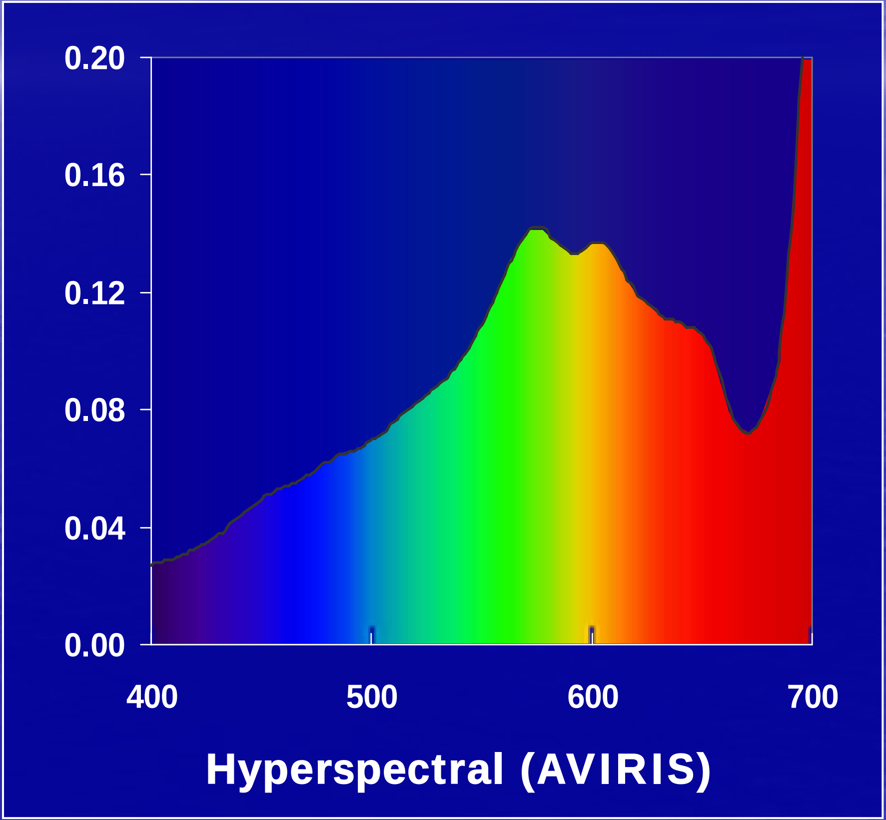


$$
\begin{aligned}
Y_i &= \mathcal{T}(\alpha_i, S_i, \gamma_i) + \omega_i \\
S_i &= \text{sensing parameters including } P_i \\
\gamma_i &= \text{unknown nuisance parameters} \\
\omega_i &= \text{measurement errors} \\
\mathcal{T} &= \text{measurement operator}
\end{aligned}
$$

α_i= probed spectral signature

Hyperspectral vs. Multispectral





Representative Coral Reflectance Spectra

Spectral Sensing Information Extraction Goals

- **Estimate**: probed spectral signature $\{\alpha(x,y,\lambda)\}$

  physical parameter to be estimated $\{\beta(x,y,\lambda)\}$

Examples of β	Crop health Chemical composition, pH, CO_2 Metabolic information Ion concentration Physiological changes (e.g., oxygenation) Extrinsic markers (dyes, chemical tags)

- **Detect**: presence of a target characterized by its spectral features α or β

- **Classify**: objects based on features exhibited in α or β

- Or **Understand**: object information, e.g., spectral signature, shape or other features based on α or β

Benthic Habitat Assessment

Estimate:

{ β }

- Atmospheric constituents
- Aquatic optical properties
- Aquatic constituents
- Benthic composition
- Bathymetry (water depth)

Detect:

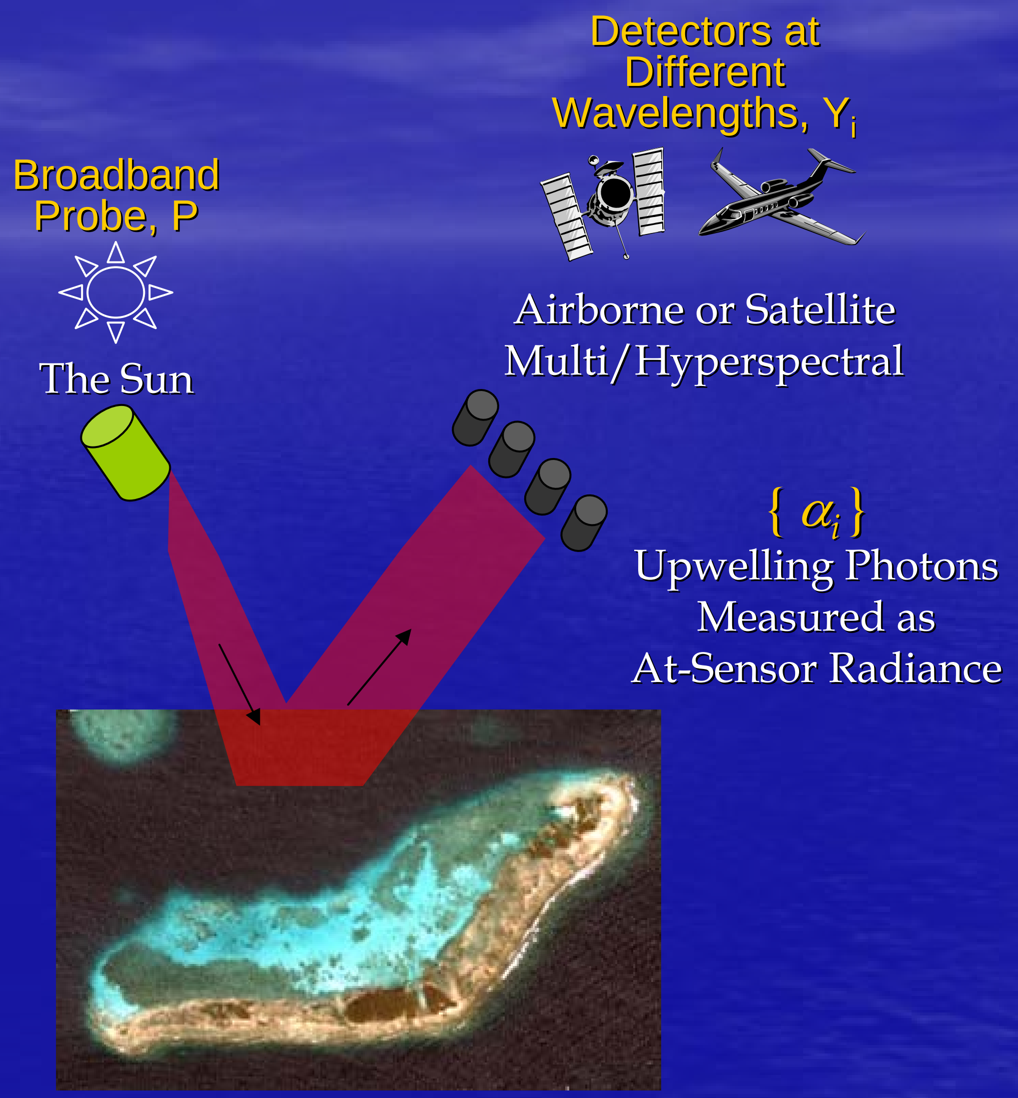
- Healthy/unhealthy coral
- Unexploded ordinance
- Human induced changes

Classify:

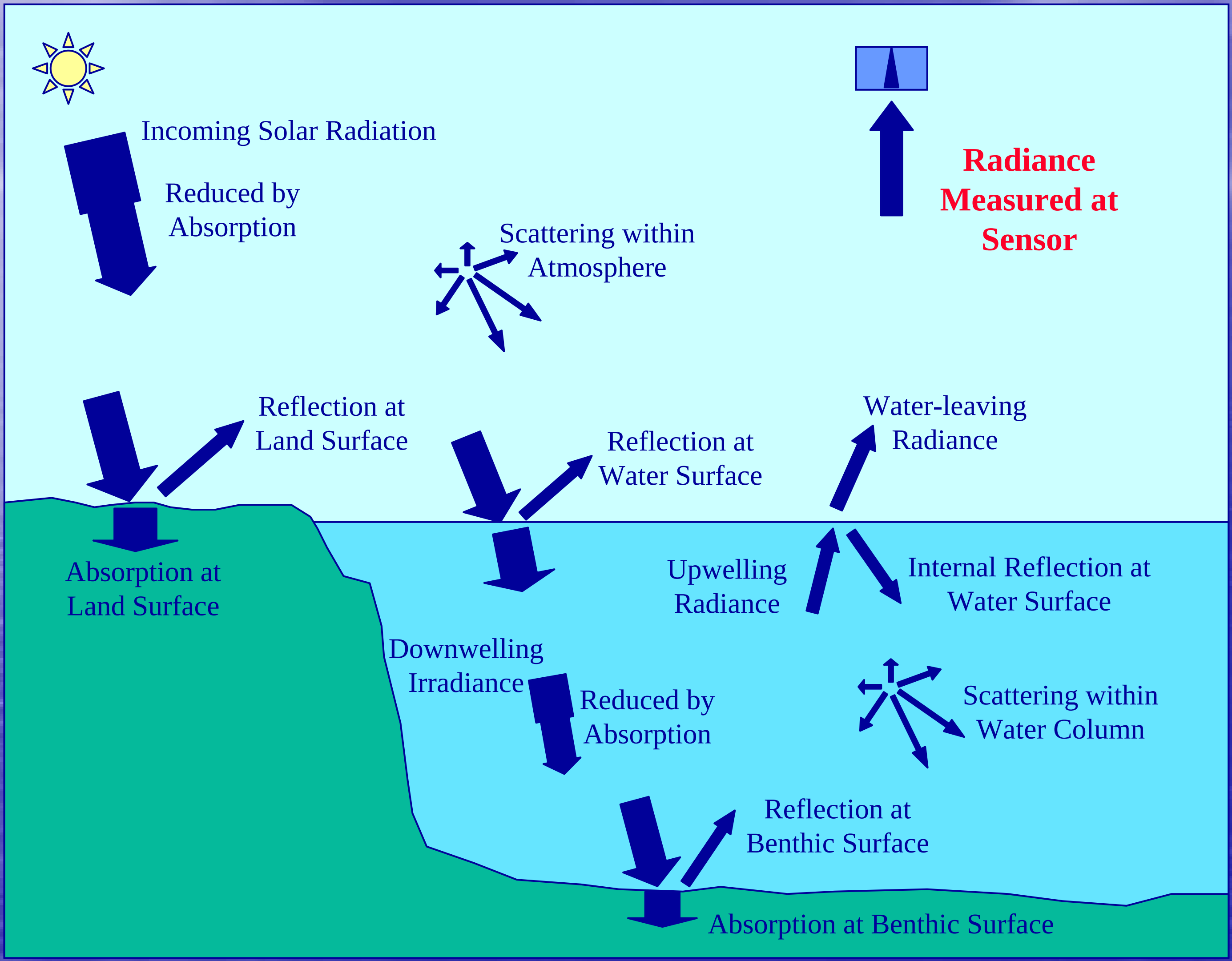
- Coral distribution
- Seagrass density
- Benthic habitat maps

Understand:

- Environmental stressors
- Seasonal/annual changes
- System productivity



Energy Interactions



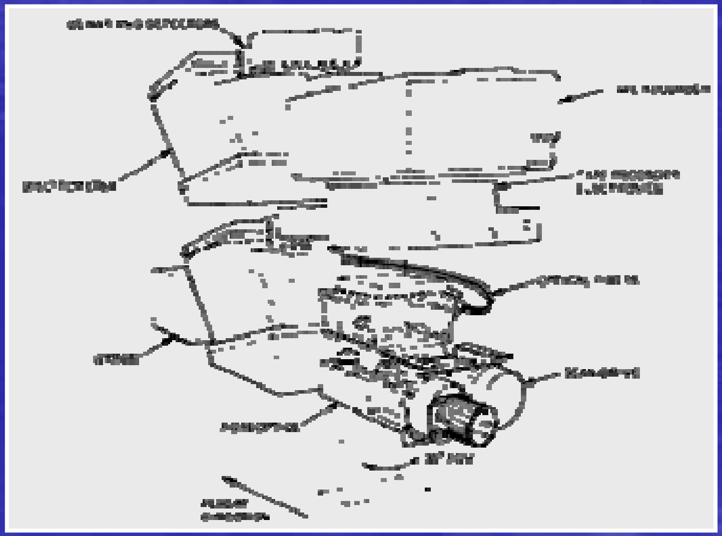
Power of Hyperspectral

- The continuous high resolution sampling of the spectrum allows us to separate atmospheric, and water contribution by means of atmospheric correction algorithms.
- Furthermore we can decompose the water signature into its contributions by the different elements in the water column and the contribution of the sea floor.
  - Combination of inversion procedures and analytical models

Examples Over Enrique Reef in Parguera

AVIRIS 2004 Mission Over PR

- NASA's Jet Propulsion Laboratory
- 224 Spectral Bands, 400-2500 nm
- Spectral Resolution 10 nm
- ER-2 Platform, 20 km Altitude
- Spatial Resolution 17x17 m pixels



Mission Overview

Puerto Rico:

- August 19, 2004
- 8 Flightlines
- Altitude ~20.1 km
- Pixel Size ~17 m
- Total Length 750 km
- Total Area 8500 km^2

Florida:

- August 17, 2004
- 6 Flightlines
- Altitude ~14.3 km
- Pixel Size ~13 m
- Total Length 350 km
- Total Area 3000 km^2

AVIRIS Deployment:

- Robins AFB, Georgia
- ER-2 Platform

Imaging Data

■ (red)	Completed Collection
■ (yellow)	Planned/Ongoing Collection

HYPERION:
- **August 15, 2002**
- **January 15, 2003**
- **March 13, 2004**
- **March 29, 2004**
- **September 5, 2004**

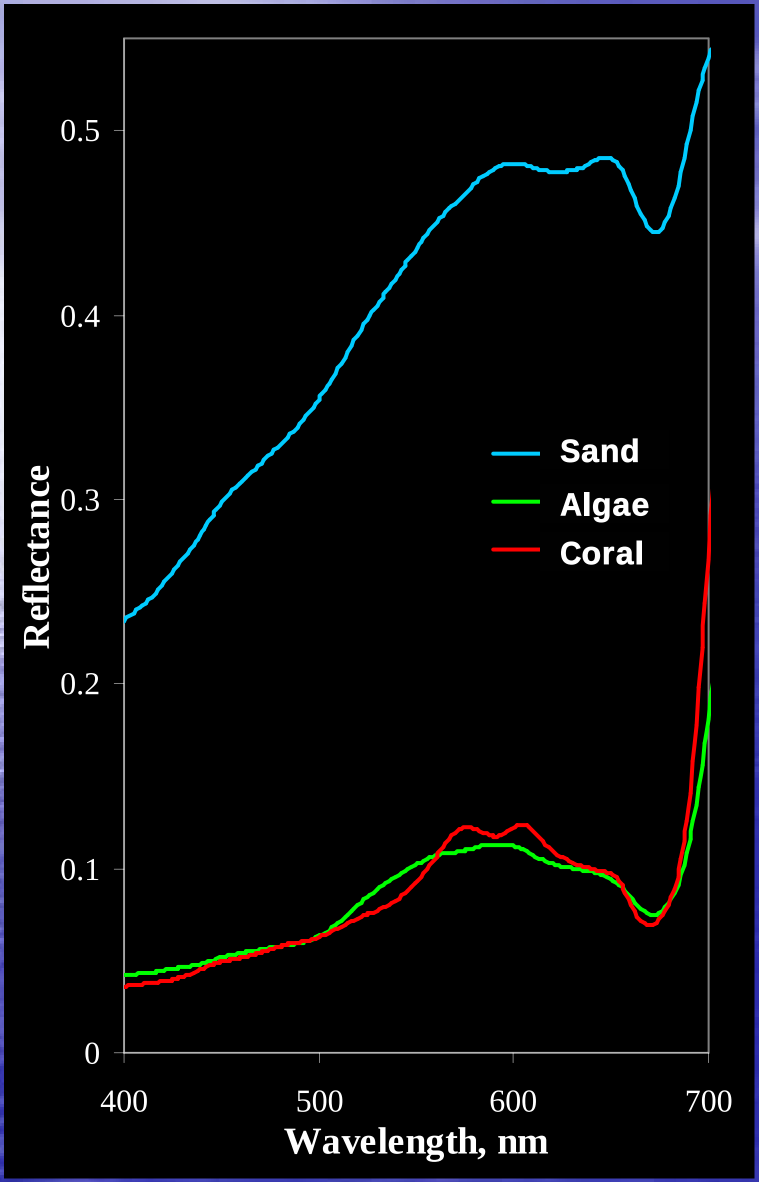
Multi/Hyperspectral Data:

Completed	Planned/Ongoing	Sensor
■	■	IKONOS
■	■	HYPERION
■	■	AVIRIS
	■	Spectra Vista
	■	Optech

IKONOS:
- **2002 Composite**

AVIRIS: August 19, 2004

Spectral Data

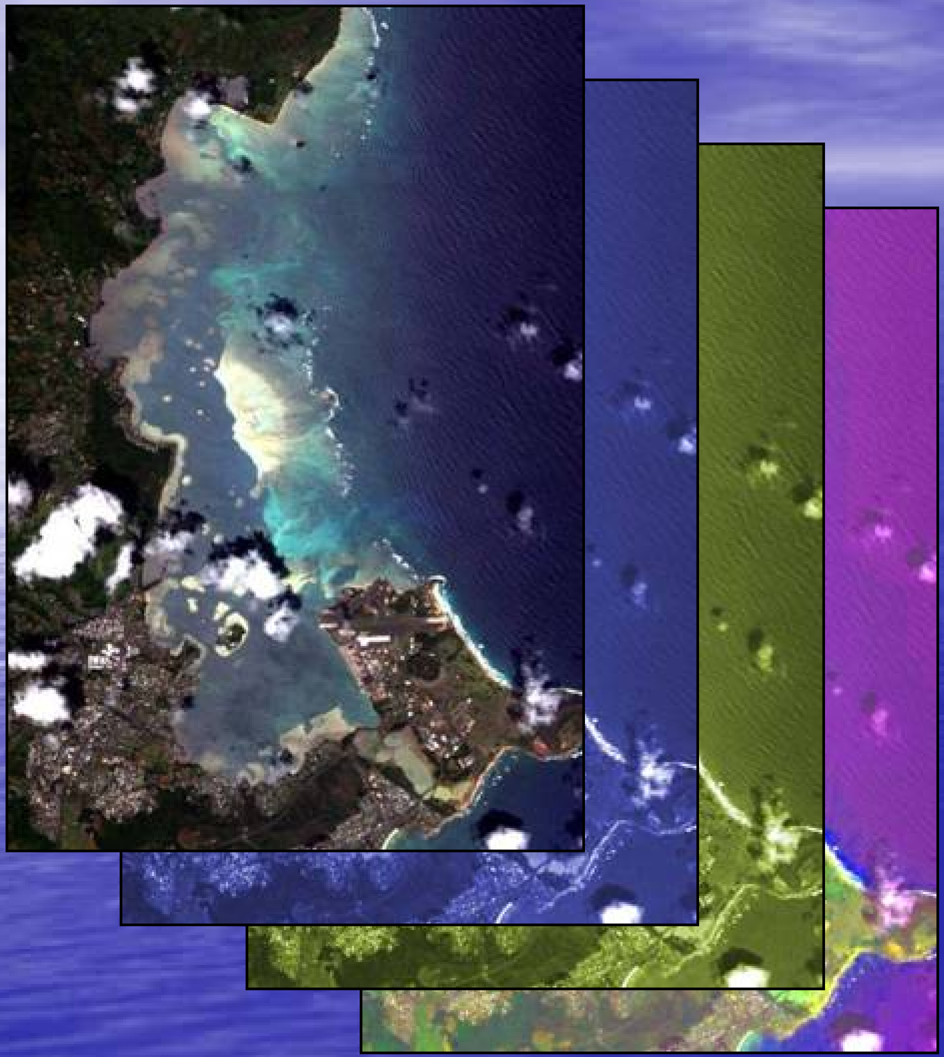


Sand

Algae

Coral

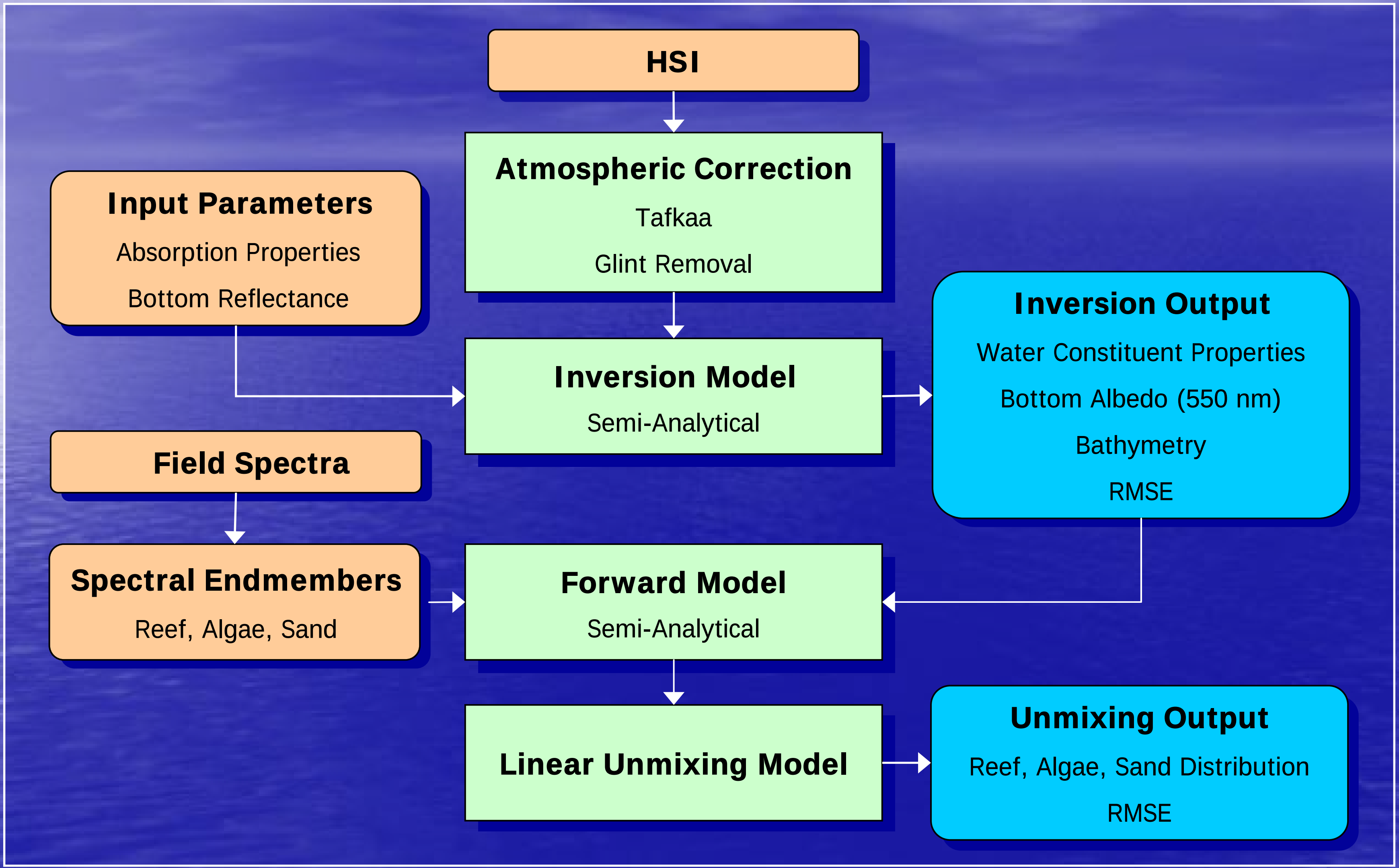
Analysis Overview



- Field Measurements
- Atmospheric Correction
- Water Column Inversion
- Endmember Selection
- Linear Unmixing
- Benthic Classification

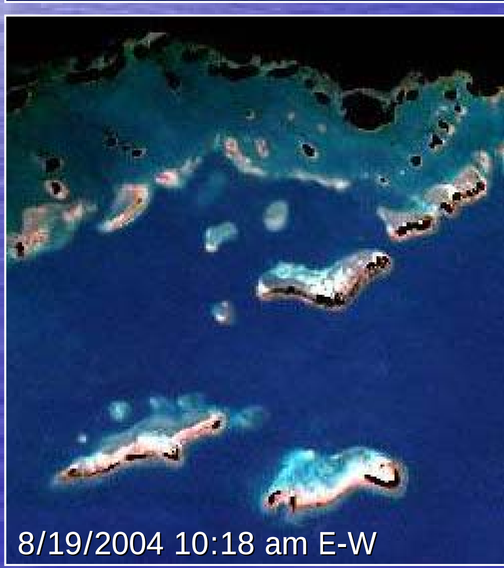
Analysis Procedure for Benthic Habitat Mapping

Goodman 2005

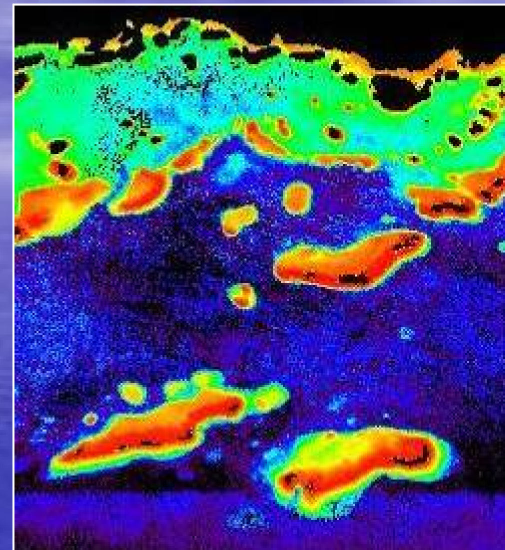


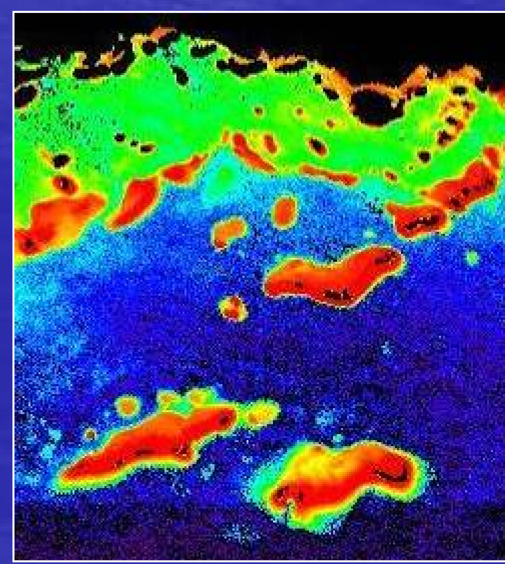
AVIRIS Derived Bathymetry

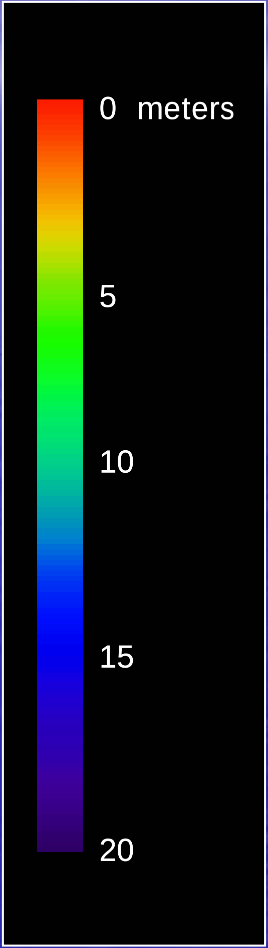
AVIRIS Color Composite



Bathymetry

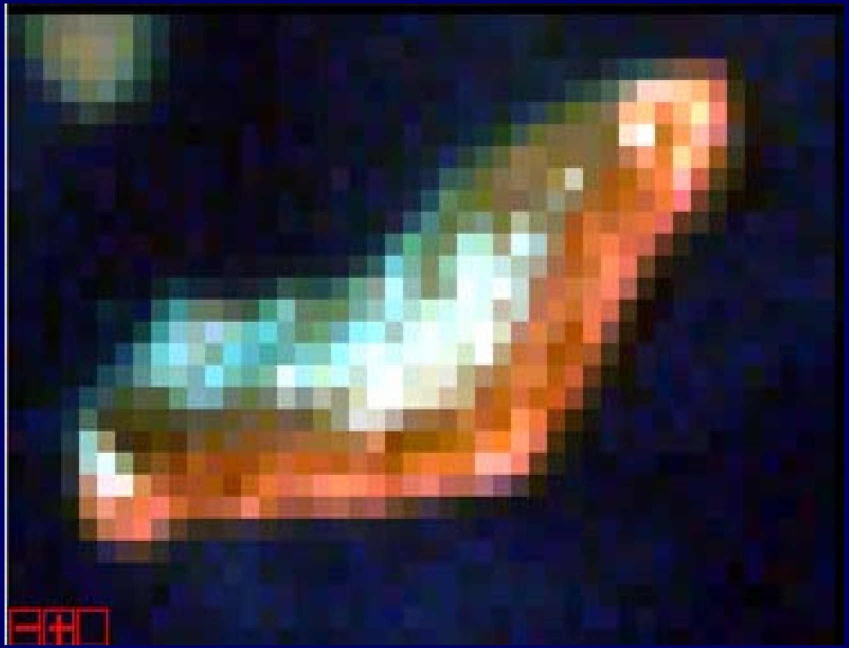






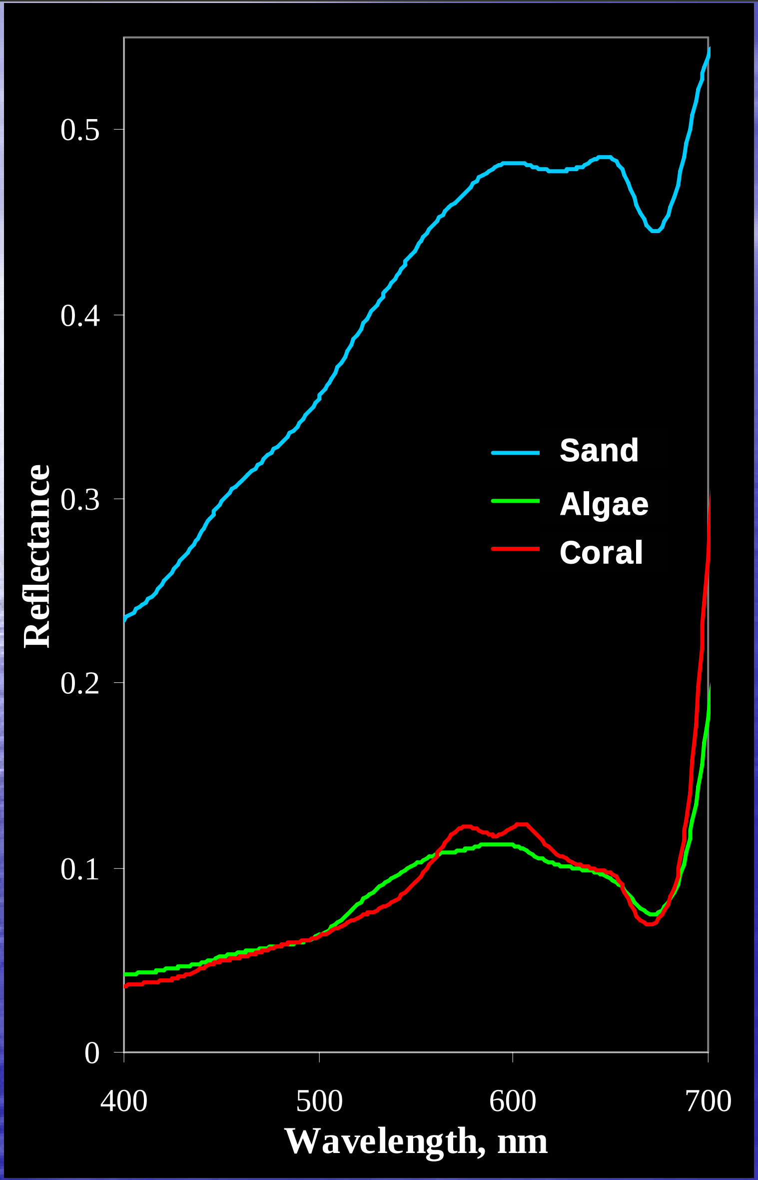
Another Problem: Low Spatial Resolution in Hyperspectral Environmental RS

IKONOS Image
Multispectral Sensor
1 meter, 4 bands



Hyperion Image
Hyperspectral Sensor
30 meters, 192 bands

Endmembers: Pixels in the Image are Modelled as Linear Combinations of this Basis Signatures

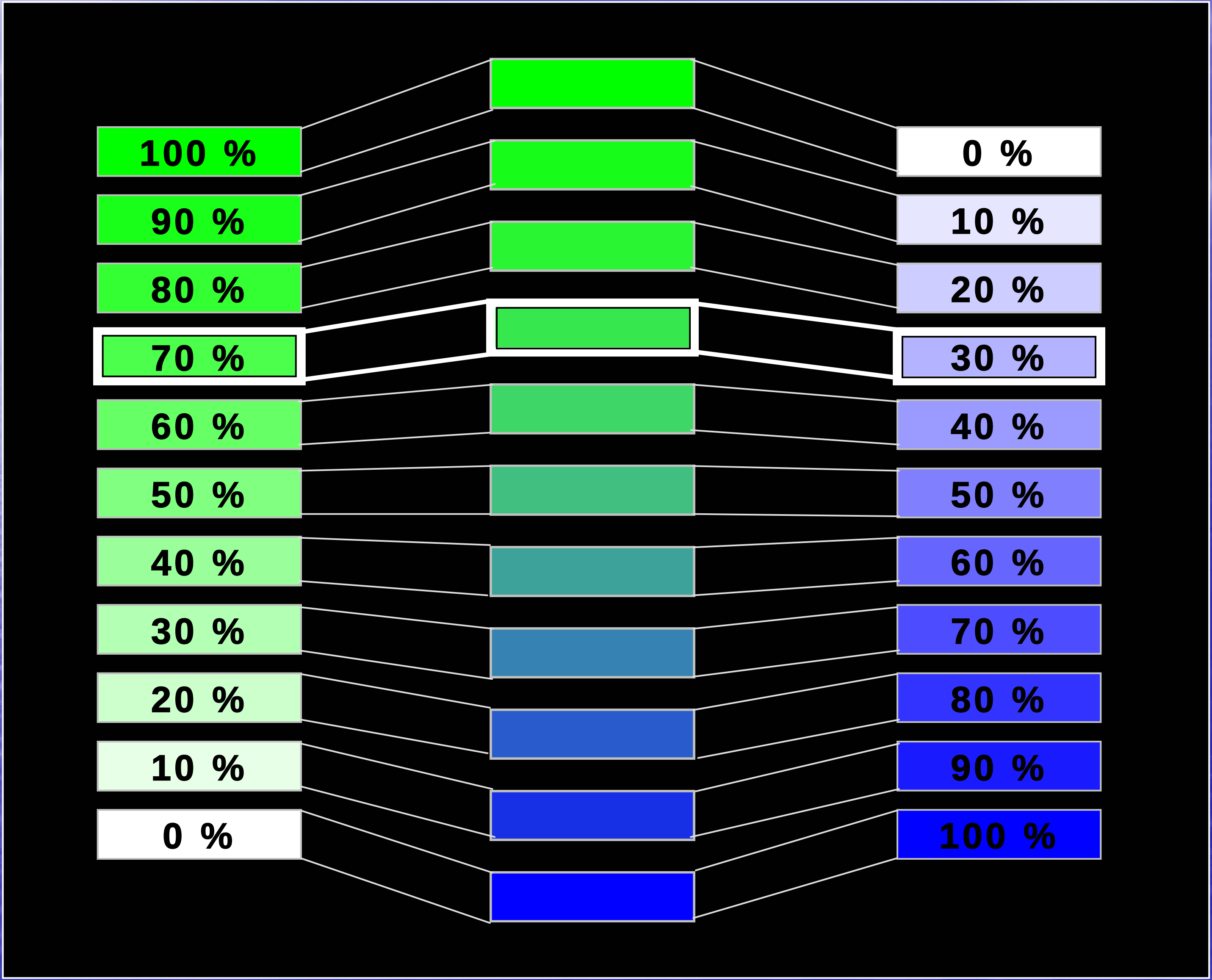


Sand

Algae

Coral

Linear Spectral Mixing Model in One Slide



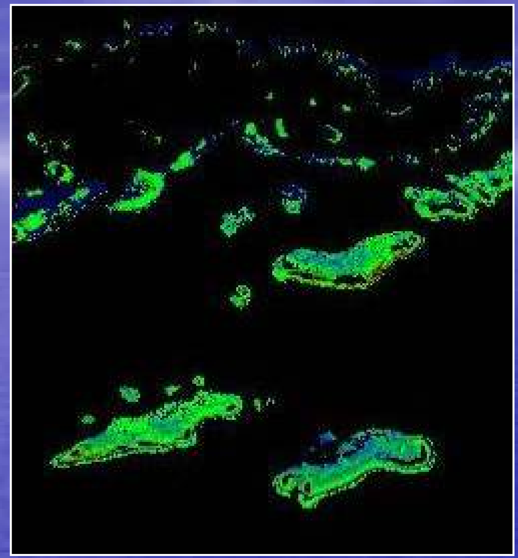
AVIRIS Linear Unmixing

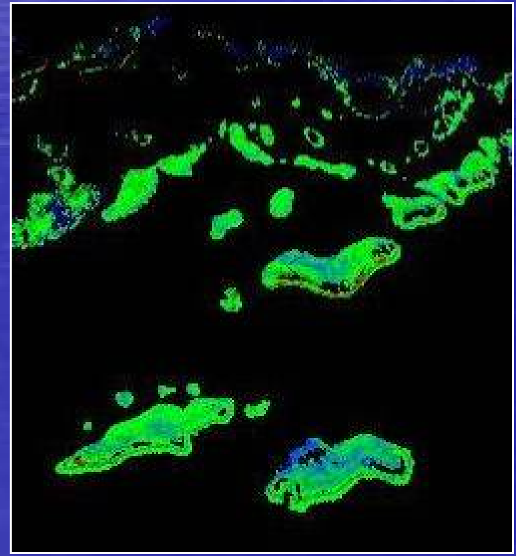
AVIRIS Color Composite

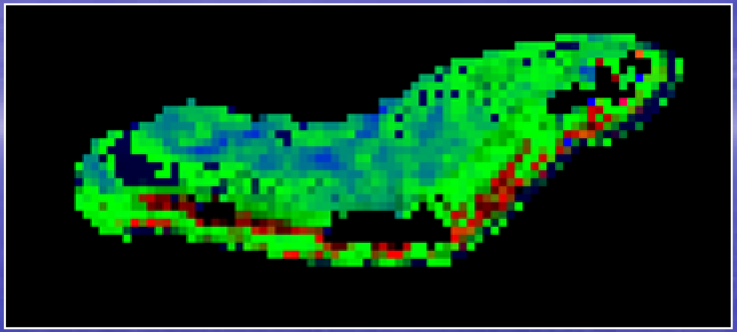
8/19/2004 9:36 am W-E

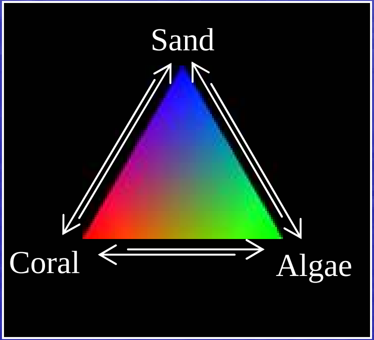
8/19/2004 10:18 am E-W

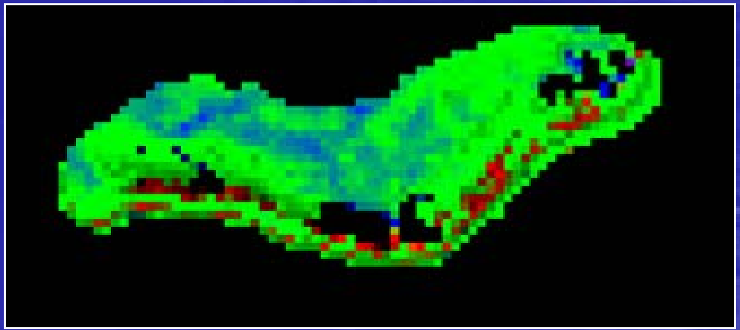
Benthic Habitat Composition









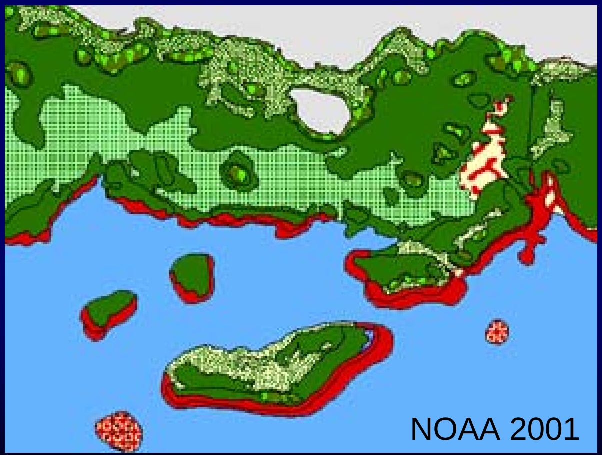


Impact: Taking Coastal Mapping to a New Level

NOAA State-of-the-Art

Aerial Photo-Mosaic

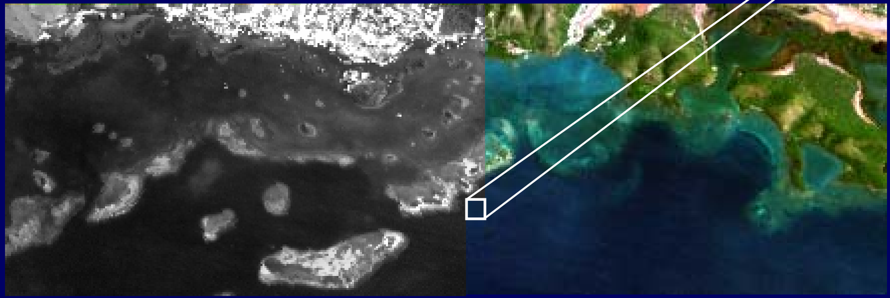
Manual Classification



CenSSIS: Automated Approach

AIVRIS: Hyperspectral

- 2004 Puerto Rico

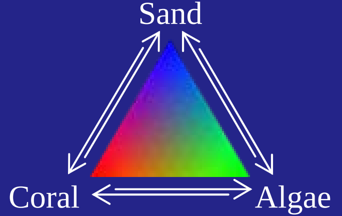


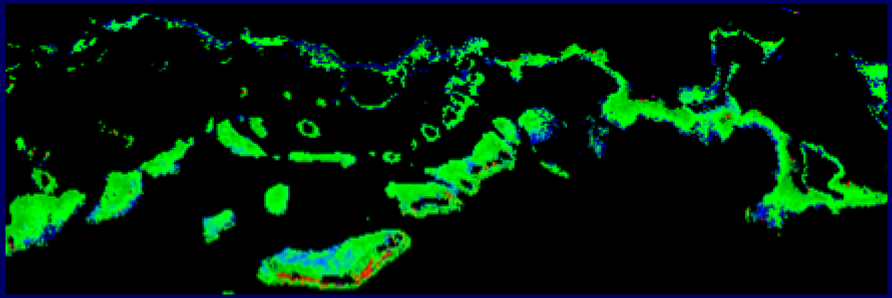
224 Bands

10 nm Spectral

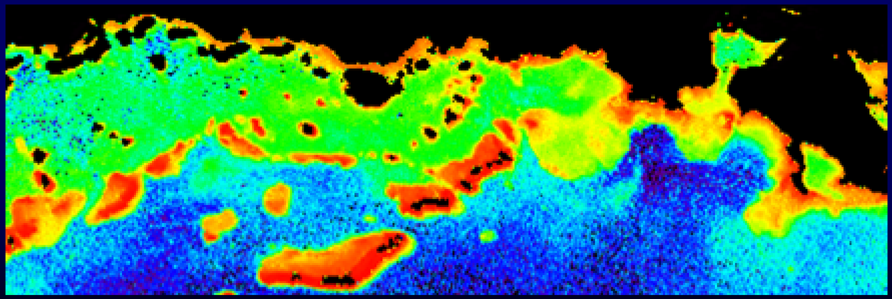
17 m Spatial

Habitat Map





Water Depth



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