Assessing Change in Coral Reef Ecosystems using ~~Hyperspectral Remote Sensing~~ Imaging Spectroscopy

J.A. Goodman [1], L. Guild [2], R. Armstrong [1], B. Lobitz [3],
F. Gilbes [1], R. Berthold [2], J. Kerr [4], Y. Detres [1]

[1] University of Puerto Rico at Mayagüez
[2] NASA Ames Research Center
[3] University Corporation at Monterey Bay
[4] California State University Monterey Bay

Science Objectives

- Assess the capacity for monitoring change in coral reef ecosystems using remote sensing.
- Explore spatial scaling relationships related to benthic habitat classification, from the field level to airborne and satellite analysis.
- Use NASA's 2004 and 2005 AVIRIS imagery over La Parguera, PR to map coral reef benthic types and 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 from remote sensing data.

Study Area


Isla Magueyes
Enrique
San Cristobal
Corral
Media Luna
Laurel
Turrumote

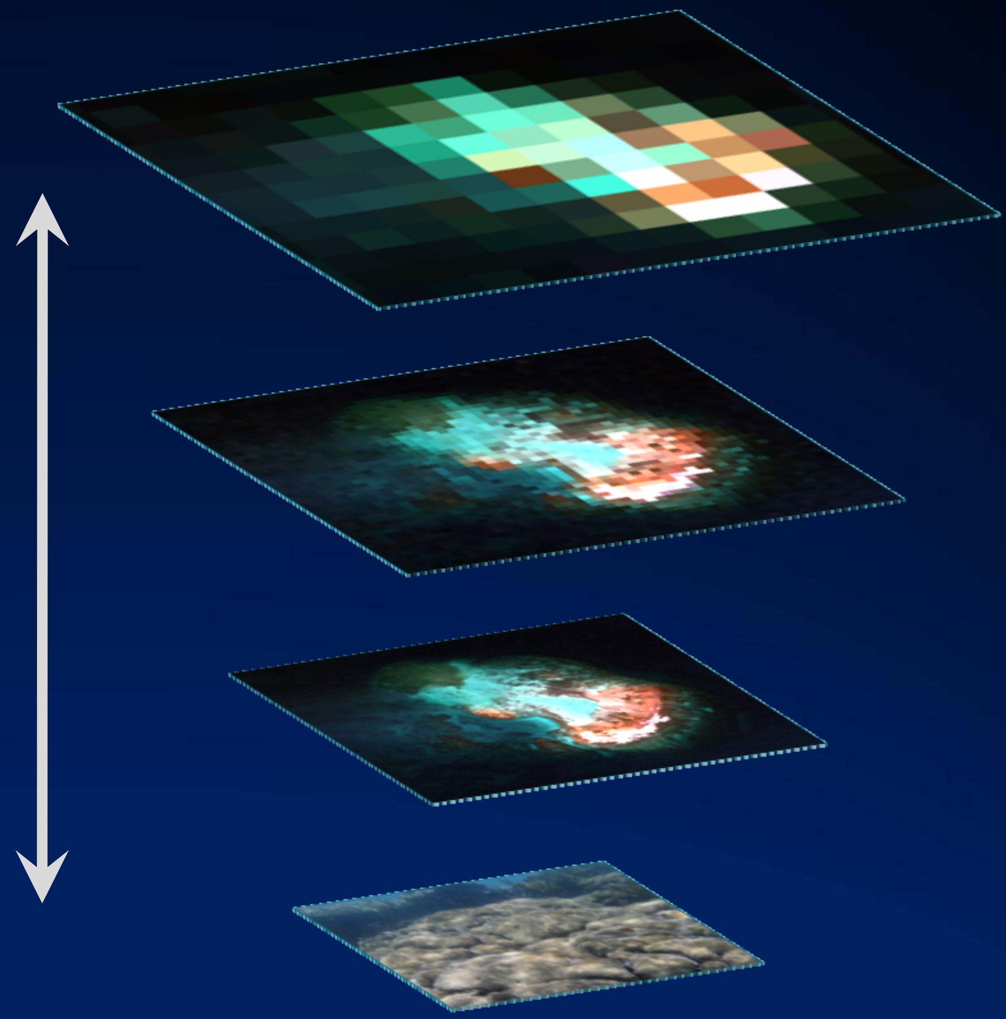
Assessment Across Spatial Scales

❖ Satellite Imagery
- Hyperion (30m spatial)
- HyspIRI (60m spatial)

❖ Airborne Imagery
- 2004 AVIRIS
- 16m Spatial Resolution

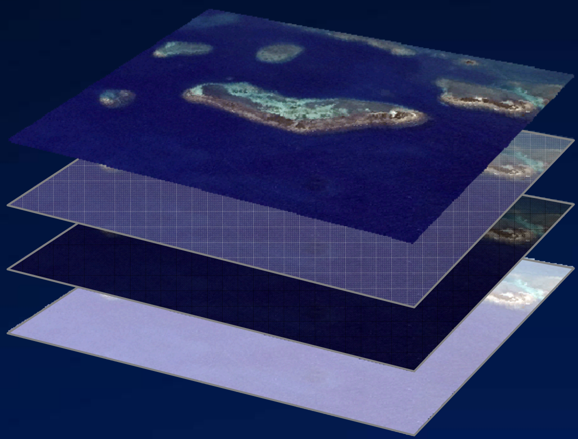
❖ Airborne Imagery
- 2005 AVIRIS
- 3m Spatial Resolution

❖ Fieldwork
- Benthic Reflectance
- Habitat Composition



SeaBED: Enrique Reef

CONCEPT : Assemble a multi-level array of field observations and remote sensing imagery describing a natural reef system



Hyperspectral Image Data
Surface Measurements
Water Column Measurements
Benthic Measurements

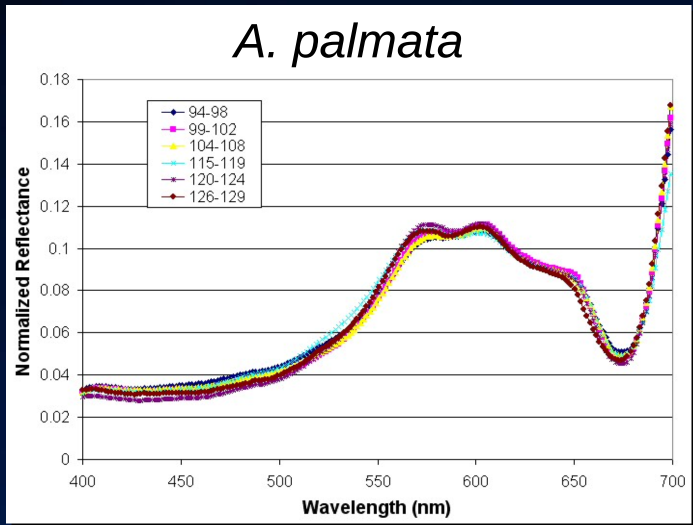
OBJECTIVE: Provide researchers with data from a fully-characterized test environment for the development and validation of subsurface aquatic remote sensing algorithms

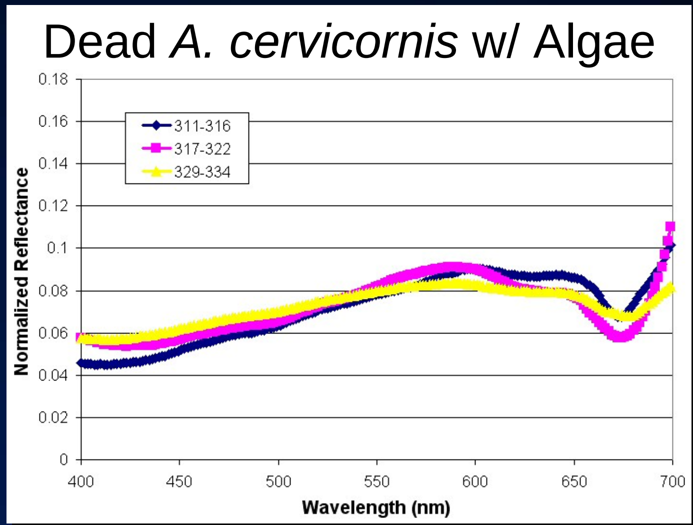
LEGACY: Utilize scientific publications and web-based distribution to establish Enrique Reef and its associated data as a lasting standard for algorithm assessment

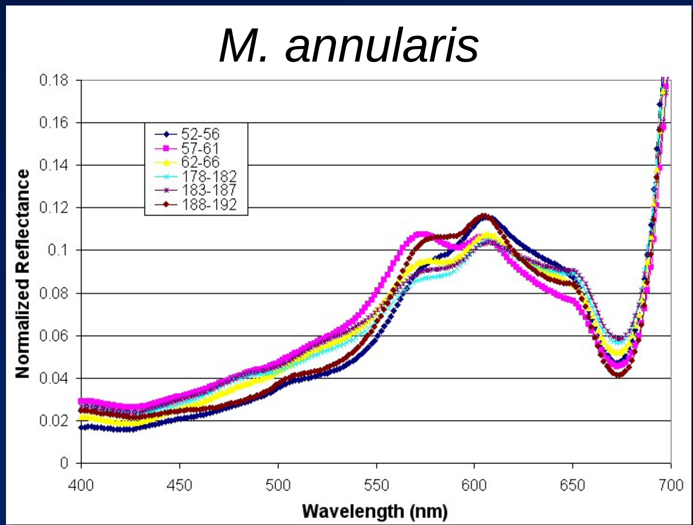
Field Measurements

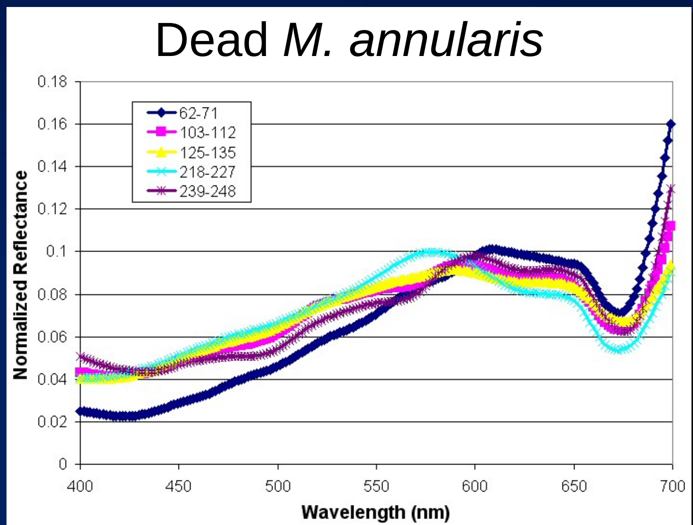
- Reef benthic spectra – species, substrate
- Photogrids - photographs
- GPS locations
- Spectra of calibration targets
- Aeronet station – atmospheric correction
- Water optical profiler – water correction

In Situ Reflectance









Habitat Components


Coral Rubble


A. cervicornis


A. palmata


M. annularis


S. siderea


Porites spp.


Gorgonians

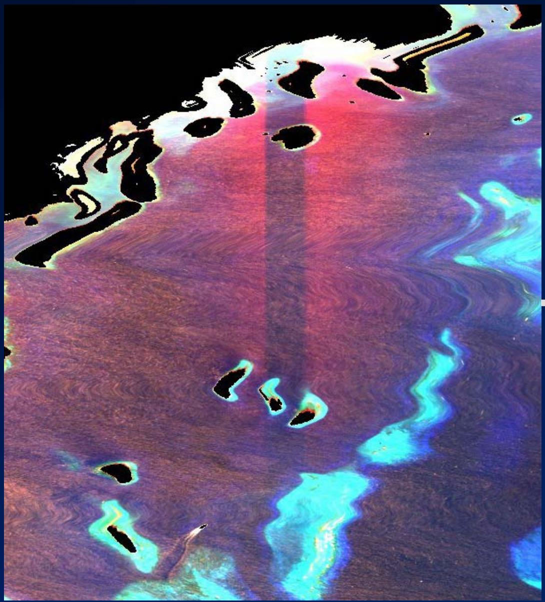

Dictyota spp.


T. testudinum

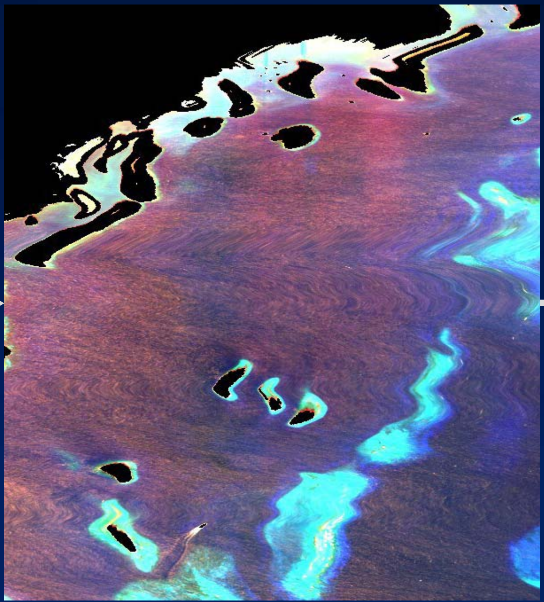
Pre-Processing Overview

Stray-Light Correction → **Sun Glint Removal** → **Atmospheric Correction**

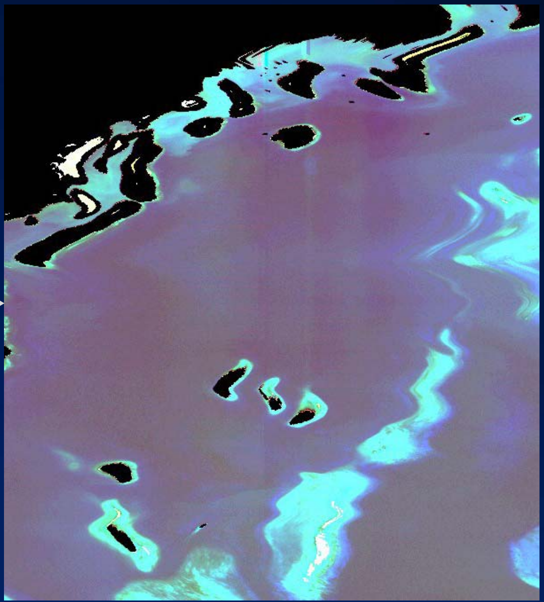
Example: AVIRIS 2005



Raw image



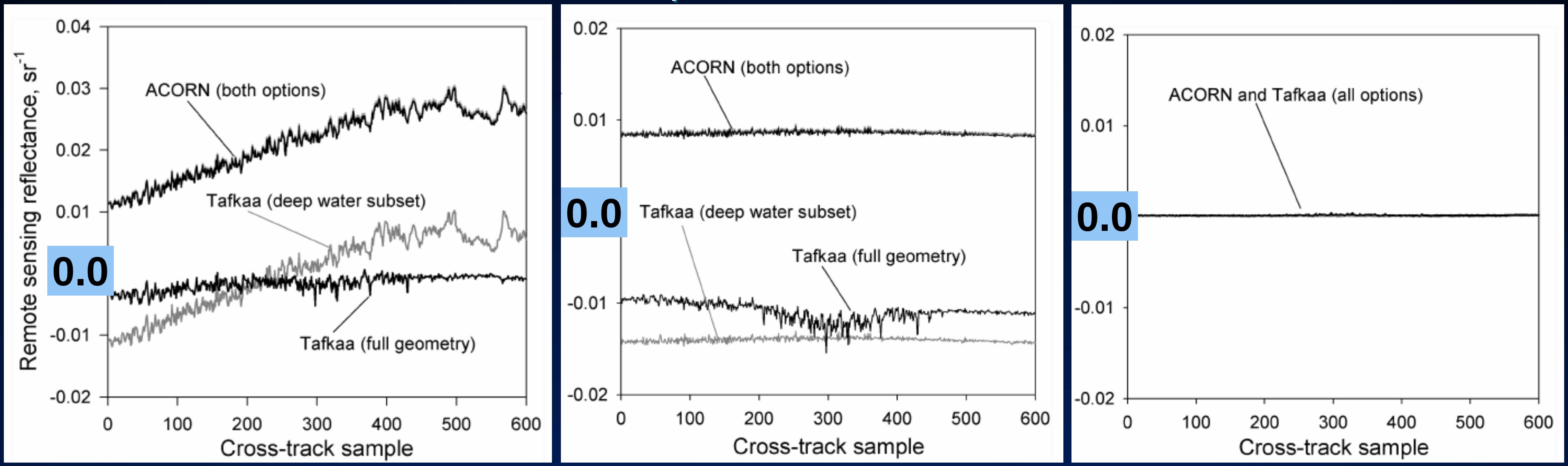
Stray-Light Correction



Sun Glint Removal

Sunglint Correction

No Sun Glint Correction | Incomplete Correction | Full Correction



* Cross-track reflectance at 750nm; 10 line average.

(Goodman et al. 2008, Applied Optics)

Significant Cross-Track Sun Glint

Raw AVIRIS Imagery

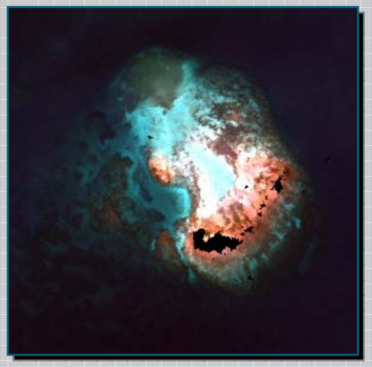


Image Pre-Processing

Correct Stray Light Anomaly

Hedley Glint Removal

Tafkaa Atmospheric Correction

Spectral Input Parameters

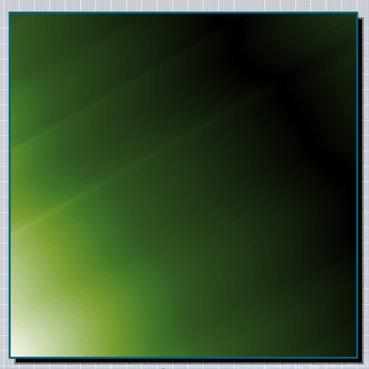
Aquatic Absorption Properties

Generic Bottom Reflectance

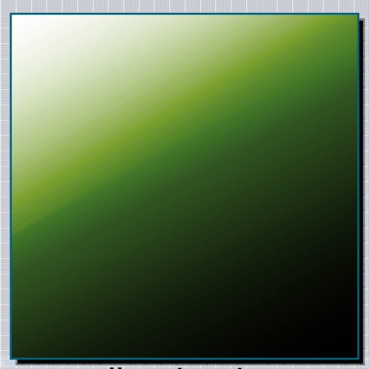
Inversion Model

Image Geometry

Explicit pixel by pixel subsurface angles



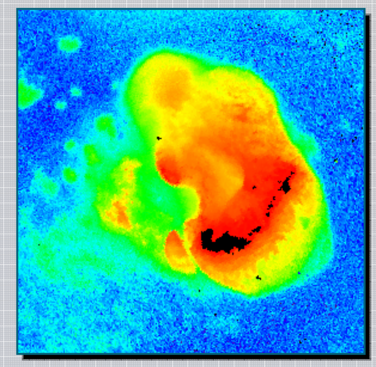
View



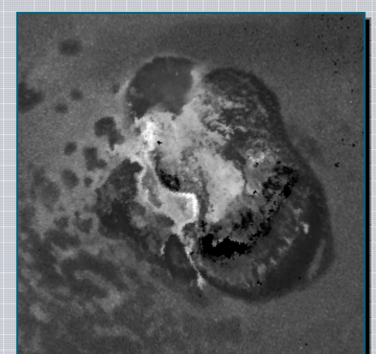
Illumination

Inversion Output

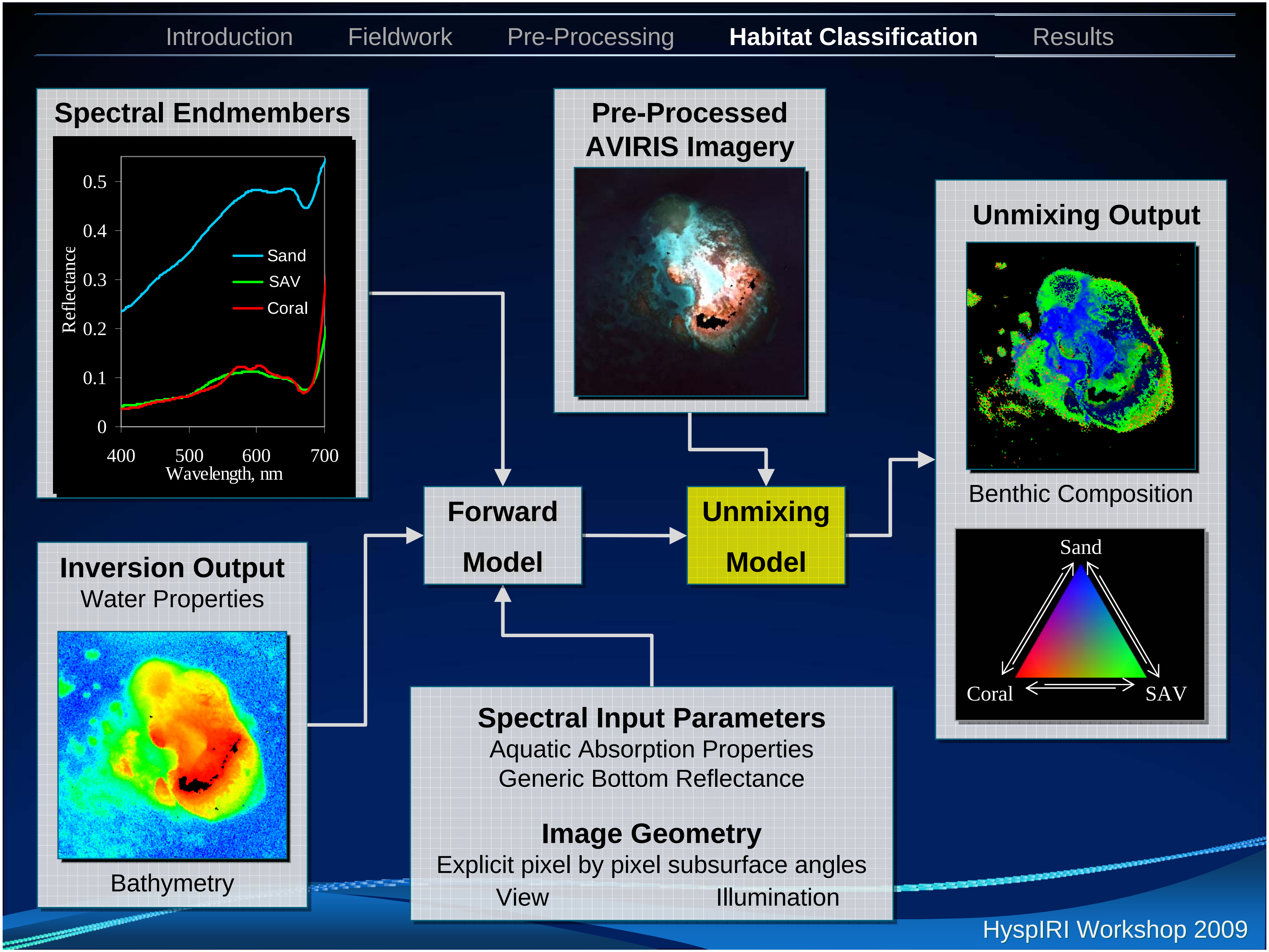
Water Properties



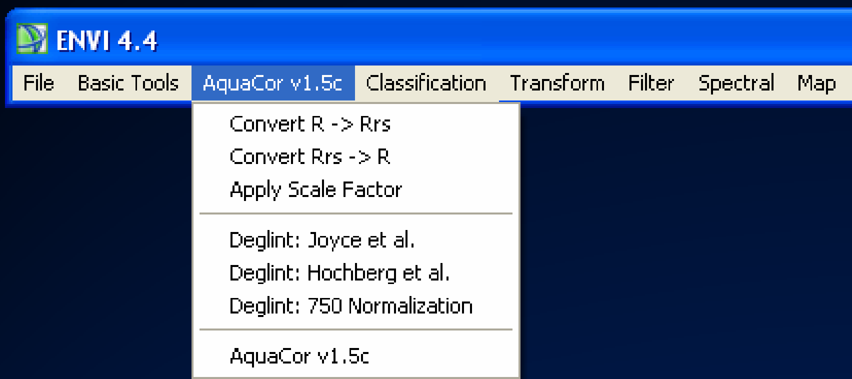
Bathymetry



Bottom Albedo (550 nm)


Introduction
Fieldwork
Pre-Processing
Habitat Classification
Results
Spectral Endmembers
0.5
0.4
0.3
0.2
0.1
0
Reflectance
Sand
SAV
Coral
400
500
600
700
Wavelength, nm
Pre-Processed AVIRIS Imagery
Unmixing Output
Benthic Composition
Sand
Coral
SAV
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
Illumination
HyspIRI Workshop 2009

AquaCor v1.5c

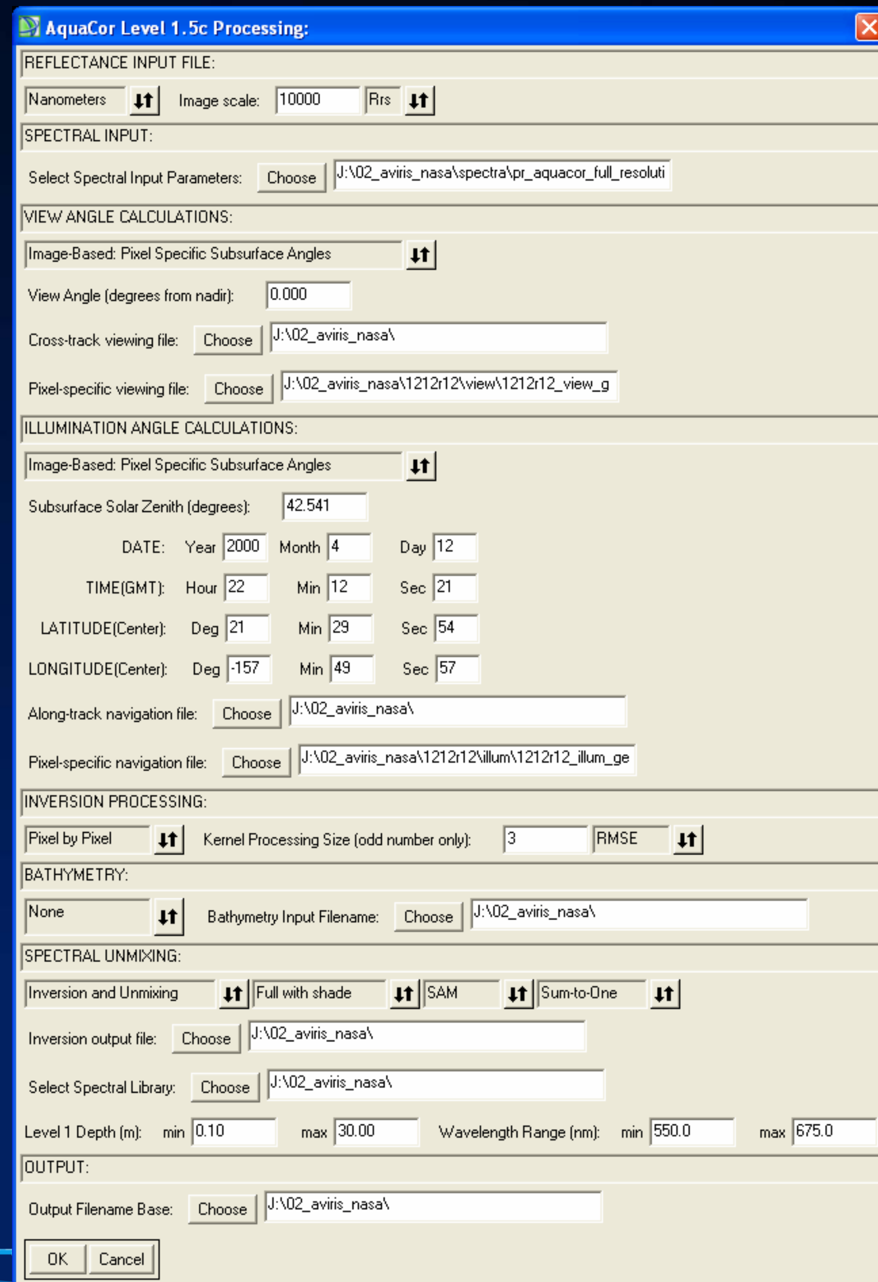


View and Illumination Angles

Pixel-by-Pixel vs. Kernel Processing

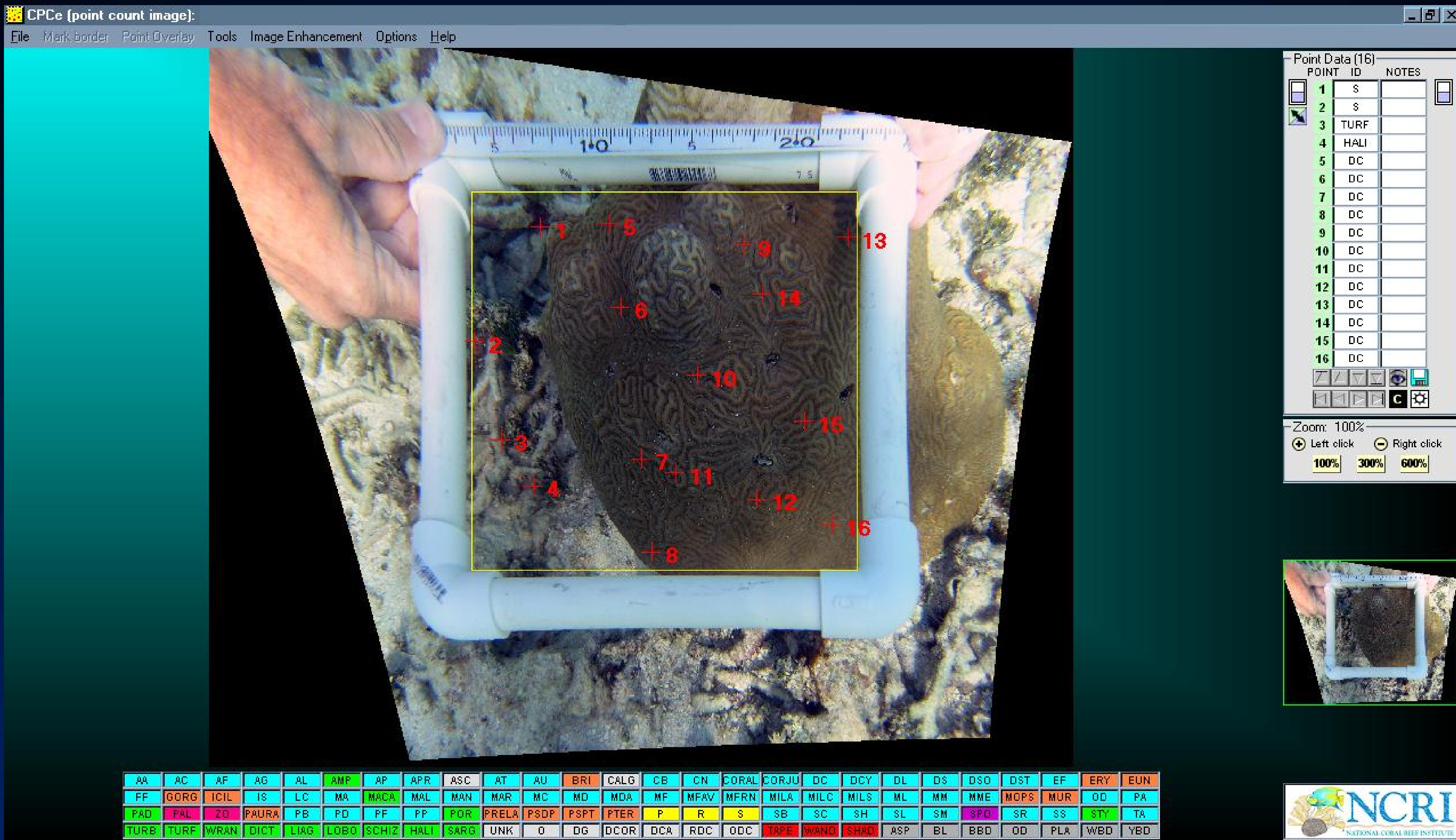
Optional Bathymetry Input

Spectral Unmixing Options

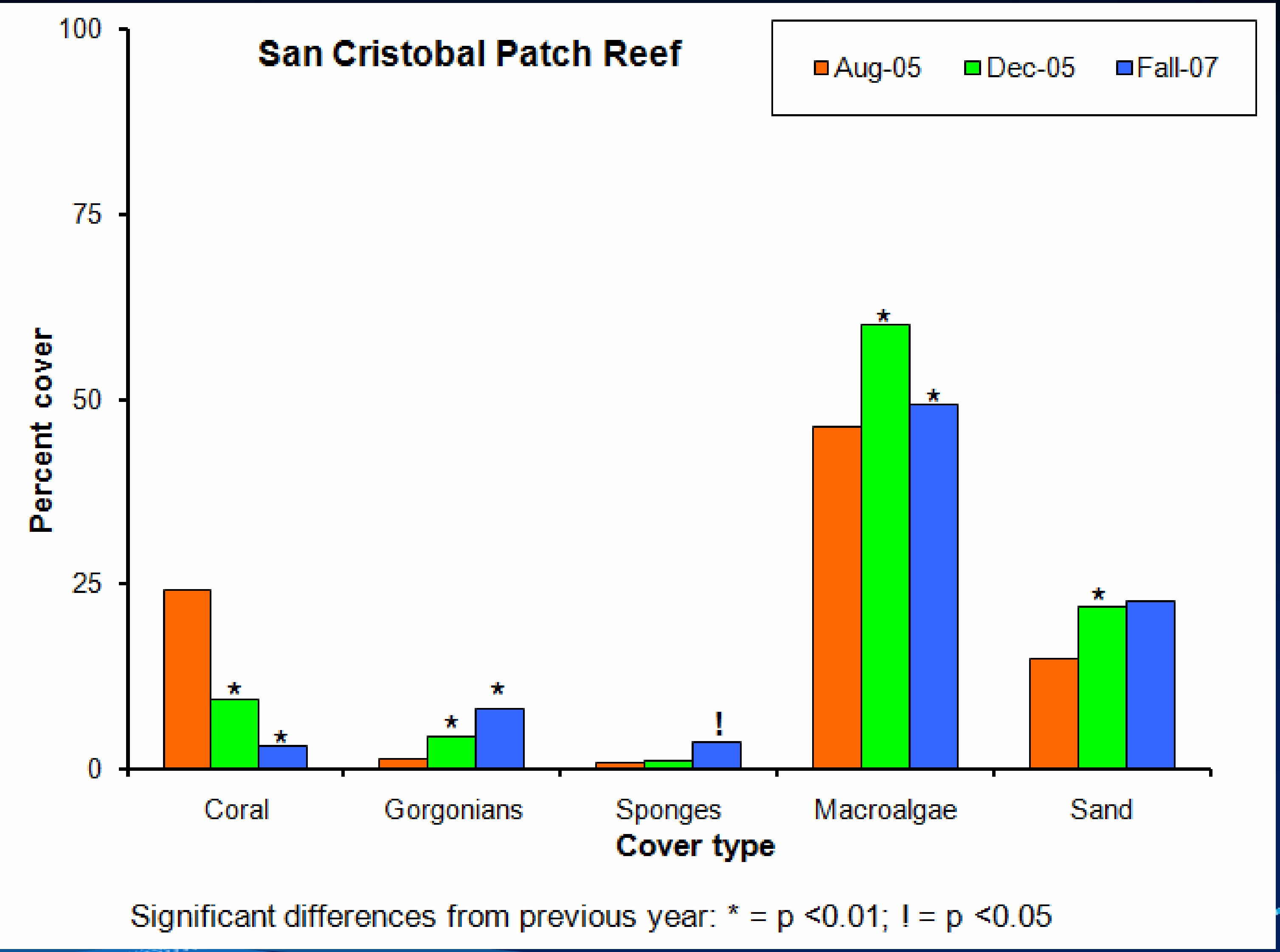


Habitat Change

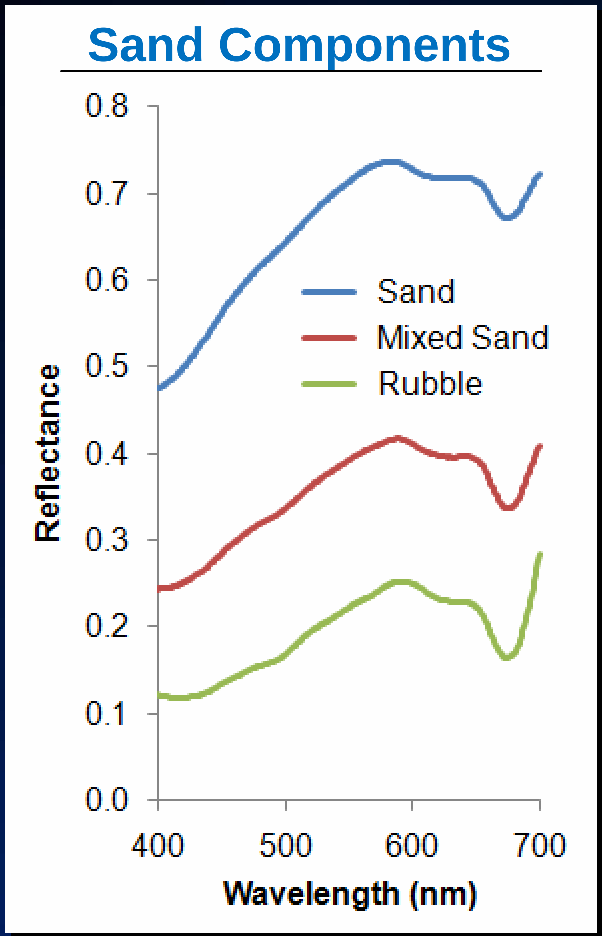
Coral Point Count (CPCe)

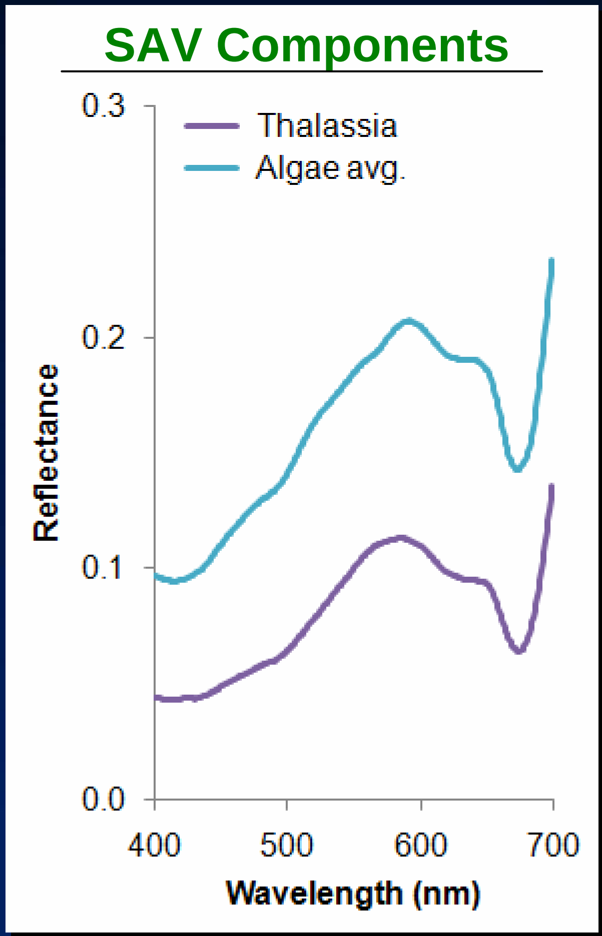


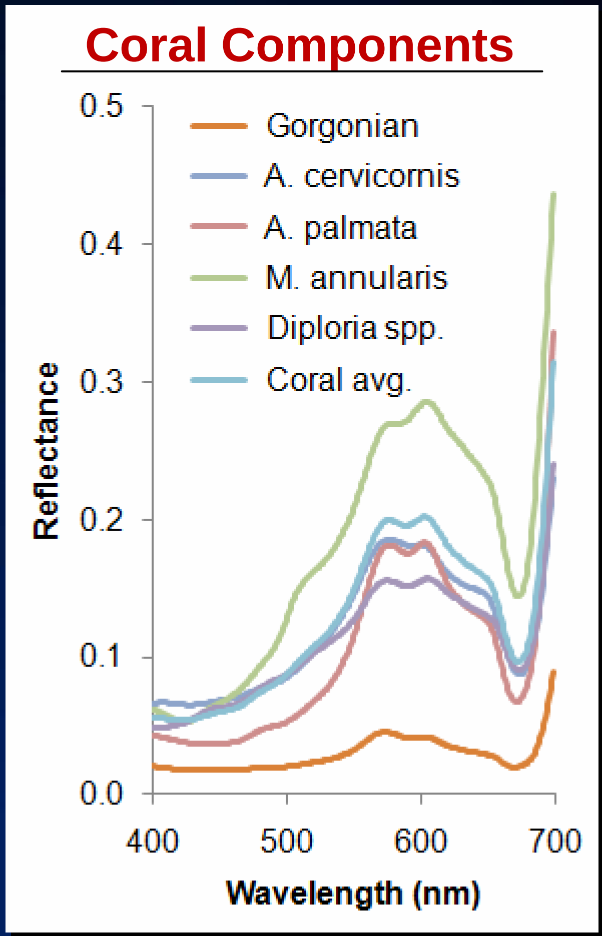
Habitat Change



Field Spectra







Spectral Separability @ 0m

	Sand Components			SAV Components		Coral Components					
	Sand	Mixed Sand	Rubble	Thalassia	Algae avg.	Gorgonian	A. cervicornis	A. palmata	M . annularis	Diploria spp.	Coral avg.
Sand	0.00	0.04	0.13	0.20	0.12	0.31	0.26	0.45	0.36	0.25	0.33
Mixed Sand	0.04	0.00	0.09	0.16	0.09	0.29	0.23	0.42	0.32	0.21	0.29
Rubble	0.13	0.09	0.00	0.07	0.01	0.22	0.14	0.33	0.24	0.13	0.21
Thalassia	0.20	0.16	0.07	0.00	0.08	0.19	0.08	0.27	0.19	0.08	0.15
Algae avg.	0.12	0.09	0.01	0.08	0.00	0.23	0.15	0.34	0.24	0.13	0.21
Gorgonian	0.31	0.29	0.22	0.19	0.23	0.00	0.15	0.19	0.19	0.15	0.14
A. cervicornis	0.26	0.23	0.14	0.08	0.15	0.15	0.00	0.20	0.14	0.08	0.09
A. palmata	0.45	0.42	0.33	0.27	0.34	0.19	0.20	0.00	0.14	0.21	0.13
M. annularis	0.36	0.32	0.24	0.19	0.24	0.19	0.14	0.14	0.00	0.12	0.07
Diploria spp.	0.25	0.21	0.13	0.08	0.13	0.15	0.08	0.21	0.12	0.00	0.09
Coral avg.	0.33	0.29	0.21	0.15	0.21	0.14	0.09	0.13	0.07	0.09	0.00

Scale	
0.50	**High Separability**
0.45	
0.40	
0.35	
0.30	
0.25	
0.20	
0.15	
0.10	
0.05	
0.00	**No Separability**

Spectral Separability - Spectal Angle

Spectral Separability @ 1m

	Sand Components			SAV Components		Coral Components					
	Sand	Mixed Sand	Rubble	Thalassia	Algae avg.	Gorgonian	A. cervicornis	A. palmata	M . annularis	Diploria spp.	Coral avg.
Sand	0.00	0.04	0.12	0.16	0.11	0.20	0.25	0.42	0.35	0.21	0.31
Mixed Sand	0.04	0.00	0.08	0.13	0.07	0.17	0.22	0.39	0.32	0.17	0.27
Rubble	0.12	0.08	0.00	0.05	0.01	0.14	0.14	0.31	0.24	0.10	0.20
Thalassia	0.16	0.13	0.05	0.00	0.06	0.13	0.10	0.27	0.20	0.07	0.15
Algae avg.	0.11	0.07	0.01	0.06	0.00	0.15	0.15	0.32	0.25	0.11	0.21
Gorgonian	0.20	0.17	0.14	0.13	0.15	0.00	0.15	0.28	0.27	0.15	0.20
A. cervicornis	0.25	0.22	0.14	0.10	0.15	0.15	0.00	0.18	0.14	0.07	0.07
A. palmata	0.42	0.39	0.31	0.27	0.32	0.28	0.18	0.00	0.14	0.22	0.12
M. annularis	0.35	0.32	0.24	0.20	0.25	0.27	0.14	0.14	0.00	0.15	0.08
Diploria spp.	0.21	0.17	0.10	0.07	0.11	0.15	0.07	0.22	0.15	0.00	0.10
Coral avg.	0.31	0.27	0.20	0.15	0.21	0.20	0.07	0.12	0.08	0.10	0.00

0.50	**High Separability**
0.45	
0.40	
0.35	
0.30	
0.25	
0.20	
0.15	
0.10	
0.05	
0.00	**No Separability**

Spectral Separability - Spectal Angle

Spectral Separability @ 10m

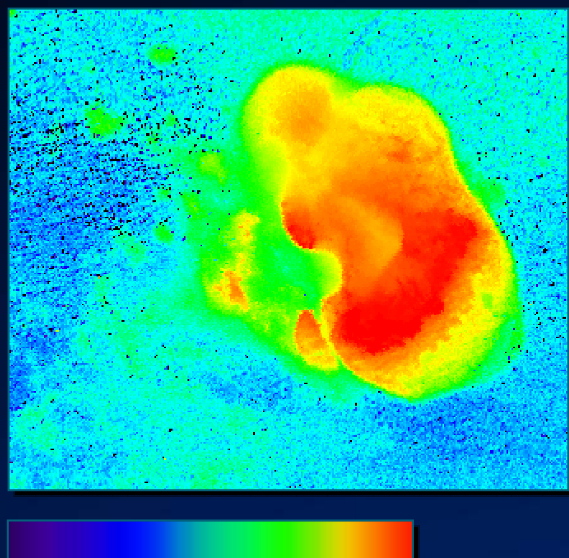
	Sand Components			SAV Components		Coral Components					
	Sand	Mixed Sand	Rubble	Thalassia	Algae avg.	Gorgonian	A. cervicornis	A. palmata	M. annularis	Diploria spp.	Coral avg.
Sand	0.00	0.06	0.12	0.21	0.14	0.29	0.18	0.21	0.13	0.18	0.17
Mixed Sand	0.06	0.00	0.06	0.15	0.08	0.24	0.13	0.16	0.09	0.12	0.12
Rubble	0.12	0.06	0.00	0.09	0.02	0.18	0.07	0.10	0.07	0.06	0.06
Thalassia	0.21	0.15	0.09	0.00	0.07	0.09	0.06	0.08	0.13	0.04	0.07
Algae avg.	0.14	0.08	0.02	0.07	0.00	0.16	0.06	0.10	0.09	0.04	0.06
Gorgonian	0.29	0.24	0.18	0.09	0.16	0.00	0.14	0.14	0.22	0.12	0.15
A. cervicornis	0.18	0.13	0.07	0.06	0.06	0.14	0.00	0.04	0.08	0.03	0.02
A. palmata	0.21	0.16	0.10	0.08	0.10	0.14	0.04	0.00	0.10	0.06	0.04
M. annularis	0.13	0.09	0.07	0.13	0.09	0.22	0.08	0.10	0.00	0.10	0.07
Diploria spp.	0.18	0.12	0.06	0.04	0.04	0.12	0.03	0.06	0.10	0.00	0.04
Coral avg.	0.17	0.12	0.06	0.07	0.06	0.15	0.02	0.04	0.07	0.04	0.00

Scale	
0.50	High Separability
0.45	
0.40	
0.35	
0.30	
0.25	
0.20	
0.15	
0.10	
0.05	
0.00	No Separability

Spectral Separability - Spectal Angle

Estimated Bathymetry

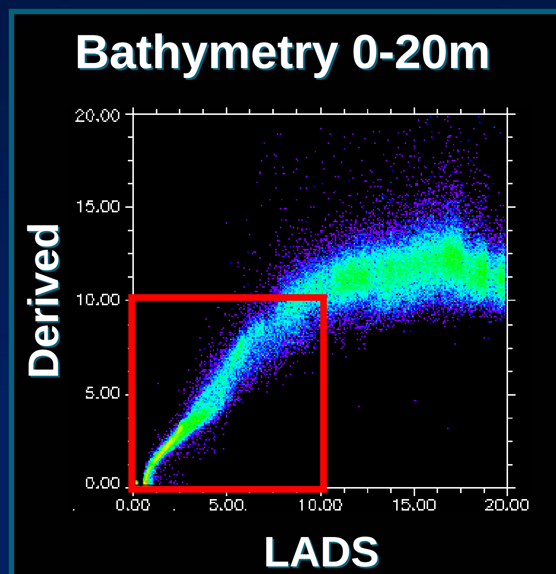
Model Derived Bathymetry



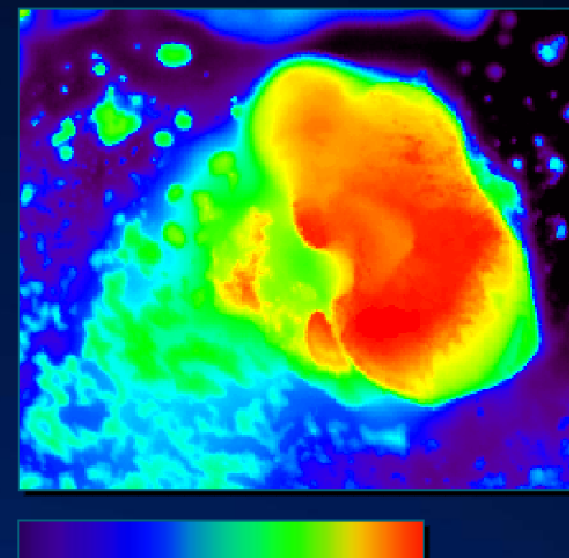
20 10 0 meters

San Cristobal Regression (0-10m)

r = 0.97
m = 1.08
avg. diff. = 0.68m
n = 32,600 pixels

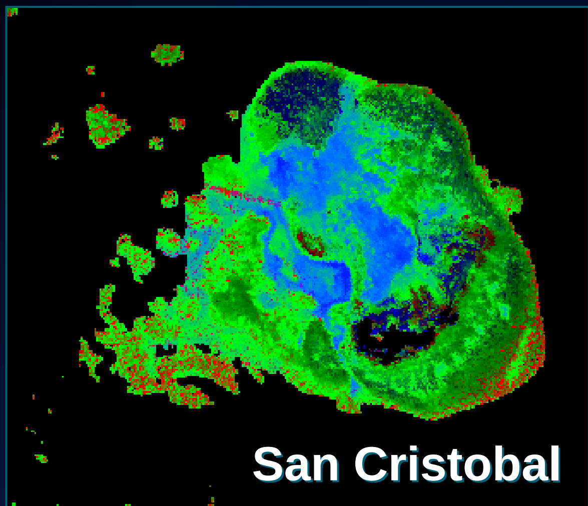


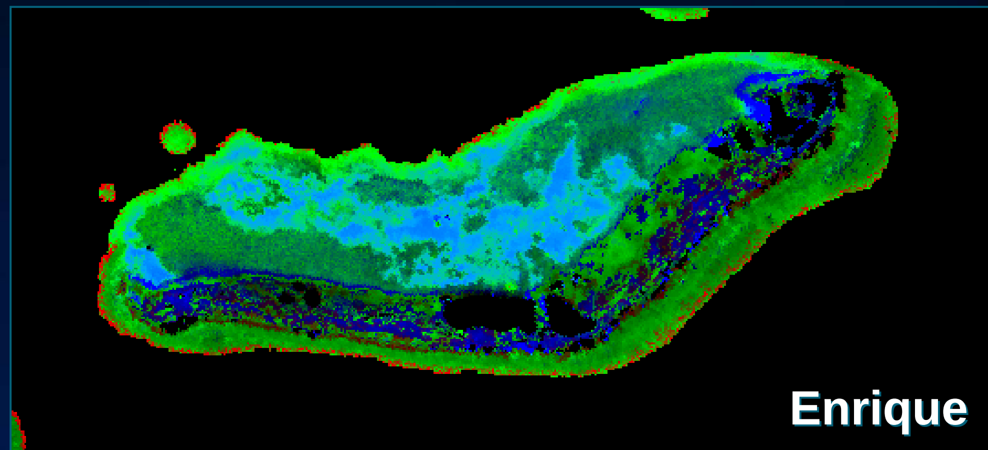
LADS Bathymetry

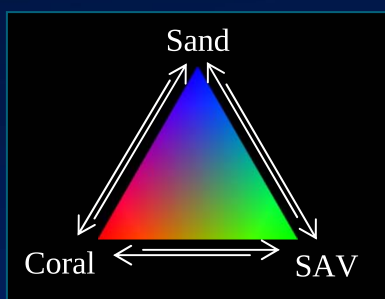


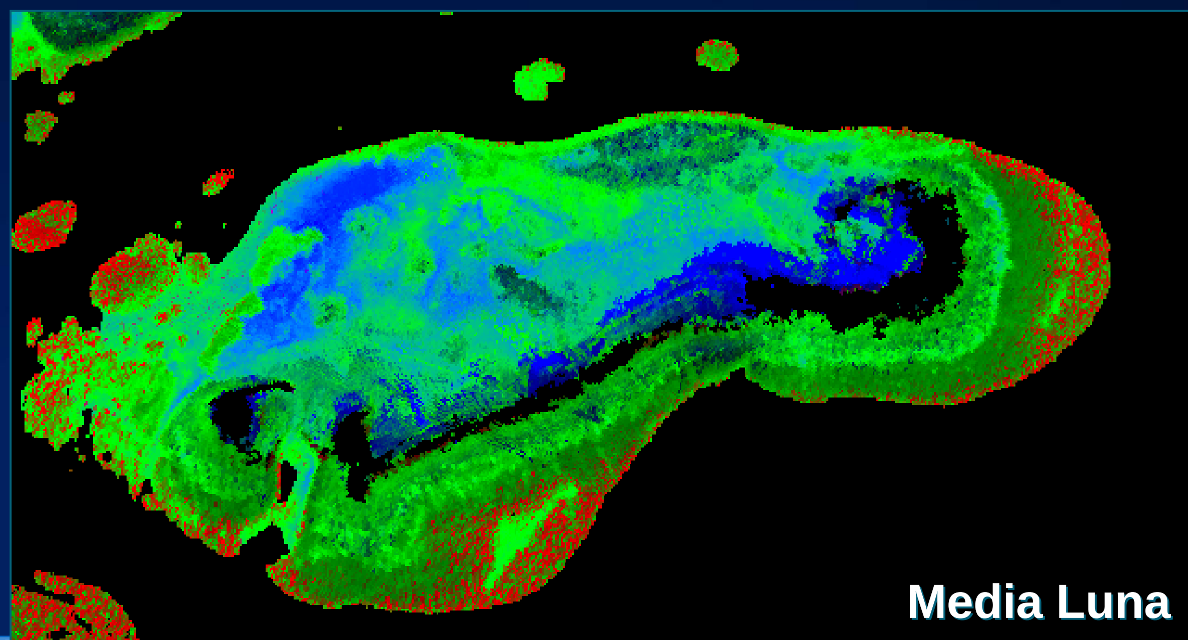
20 10 0 meters

Habitat Classification









Observations

- Difficult to achieve spectral separability at the species level, and even at the level of general reef classes, particularly when you add the overlying water column.
- General reef classes are composed of a variety of actual habitat components.
- Image spectral classification techniques can effectively differentiate general reef classes.
- Image classification is correlated with field observations.
- Accurate pre-processing is essential for effective classification.
- The strength of these classification maps, particularly at the scale of satellite observations, is the capacity to identify and track large-scale ecosystem change.

Project Contacts

James Goodman	james.goodman1@upr.edu
Liane Guild	liane.s.guild@nasa.gov
Roy Armstrong	roy.armstrong@upr.edu
Brad Lobitz	bradley.m.lobitz@nasa.gov