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## SeaBED: A Laboratory and Field Test Environment for the Validation of Coastal Hyperspectral Image Analysis Algorithms

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# SeaBED: A Laboratory and Field Test Environment for the Validation of Coastal Hyperspectral Image Analysis Algorithms

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## SeaBED Facilities and Accomplishments

### SeaBED Overview

#### Objective

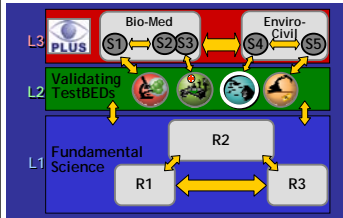
To Remotely Assess Coral Reef Conditions and Distribution.

#### Abstract

The University of Puerto Rico at Mayagüez (UPRM), one of the core academic partners in the NSF sponsored Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems (Gordon-CenSSIS), is developing algorithms using hyperspectral, multispectral and other sensing modalities to extract subsurface information in aquatic environments. As part of this effort, UPRM has created SeaBED, an algorithm validation testbed which is composed of three different analysis systems: a small laboratory based tank, a larger outdoor tank and a field site located on a nearby reef in southwest Puerto Rico. The main objective of SeaBED is to collect multiple levels of image, field and laboratory data with which to validate physical models, inversion algorithms, feature extraction tools and classification methods for subsurface aquatic sensing. Furthermore, in its role as an open testbed facility, SeaBED also provides academic, governmental and industrial collaborators access to both facilities and data for the development and validation of new instrumentation. Data produced from the testbed environment currently includes: airborne, satellite and field-level hyperspectral and multispectral images; and *in situ* measurements of spectral signatures, habitat composition and water properties (temperature, salinity, chlorophyll fluorescence, absorption coefficient, beam attenuation coefficient, backscattering coefficients, downwelling irradiance and upwelling radiance). We present the latest results from SeaBED, illustrate new and evolving industrial collaborations and discuss ongoing development.

#### Overview of Strategic Research Plan

SeaBED is one of the primary Validating TestBEDs in L2.



SeaBED provides critical data for validating subsurface aquatic remote sensing information extraction algorithms (S4 and R2).

#### SeaBED Multi-Level Validation Data

Control Test Facilities (Indoor and Outdoor Tanks)  
Field Study Area (Enrique Reef)

#### Algorithm Development and Validation

Image Calibration: Atmospheric and Water Column Correction  
Preprocessing: Resolution Enhancement and Registration  
Image Classification and Target Detection Algorithms  
Accuracy Assessments Using Ground Truth Data

#### Image Analysis Products

Benthic Composition, Distribution and Relative Health  
Bathymetry and Water Properties  
Temporal Change Detection

#### State of the Art

Remote sensing is increasingly being used as a tool to quantitatively assess the location and relative health of coral reefs and other shallow aquatic ecosystems. These assessments are provided by scientists and managers important spatial information on not only habitat distribution but also on the proximity of environmental stressors. It is expected that as image analysis procedures and detector capabilities continue to improve, so too will the effectiveness and efficiency of aquatic remote sensing applications. For instance, recent advances in the field of hyperspectral technology are demonstrating an enhanced ability to extract multiple levels of information from a complex optical environment as well as facilitating a progression in the level of questions that can be addressed. As the use of subsurface aquatic remote sensing continues to grow and the analysis products become more sophisticated, there is an increasing need for comprehensive ground truth data as a means to assess the algorithms being developed, particularly in the field of hyperspectral remote sensing. However, there is a lack of a readily available, comprehensive data from one test facility or from one field site that can be utilized for testing the full range of processing levels involved in this analysis. Thus, to address this need for validation data, we have developed SeaBED, a multi-level aquatic testbed for evaluating remote sensing information extraction algorithms.

#### Acknowledgement

This work was supported in part by Gordon-CenSSIS, the Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems, under the Engineering Research Centers Program of the National Science Foundation (Award Number EEC-9986821).

### Control Test Facilities

#### Indoor Tank: SeaBED Level 1

**Purpose:** Small indoor control test environment for data collection under artificial illumination conditions.



#### Control Options:

Water Depth and Properties  
View and Illumination Geometry  
Target/Bottom Composition

#### System Design:

0.7m-W x 0.3m-D x 0.5m-H Black Tank  
Halogen-Quartz Light Sources  
Hyperspectral Imaging Camera (400-1100nm)  
Field Spectrometer (350-1050nm)

#### Outdoor Tank: SeaBED Level 2

**Purpose:** Large outdoor control test environment for data collection under natural illumination conditions.



#### Control Options:

Water Depth and Properties  
View Geometry  
Target/Bottom Composition

#### System Design:

2m-D x 1.5m-H Black Tank  
Hyperspectral Imaging Camera (400-900nm)  
Field Spectrometer (350-1050nm)

### Field Study Area

#### Enrique Reef: SeaBED Level 3

**Purpose:** Study area for data collection under natural conditions.

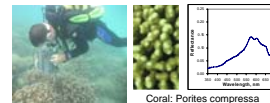


#### Enrique Reef Study Area Description:

Located in southwestern Puerto Rico  
Close to UPRM Maguayes Island Field Station  
Included Habitats: Coral, Sand, Seagrass, Algae, Mangrove  
Varying Depth: Shallow (< 0.5m) → Deep (> 20m)

#### Spectral Data Collection

**Purpose:** Location specific spectral data for assessment of image calibrations; and spectral library for unmixing and classification analysis.

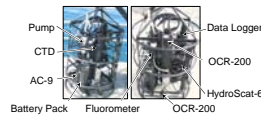


#### System Design:

Field Spectrometer (GER-1500, 350-1050nm)  
Custom Underwater Housing for Subsurface Acquisitions

#### Water Properties

**Purpose:** Data for validating image water quality estimates and for testing water column inversion/correction algorithms.

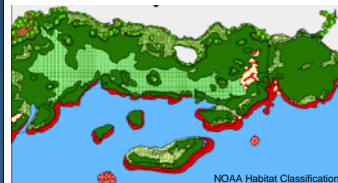


#### System Design:

Instrument Rosette Measures Profiles of: Temperature, Salinity, Chlorophyll Fluorescence, Beam Attenuation Coefficient, Backscattering Coefficients, Downwelling Irradiance and Upwelling Irradiance.

#### Ancillary Geospatial Data

**Purpose:** Additional data for algorithm validation, particularly for comparison against other benthic habitat maps.



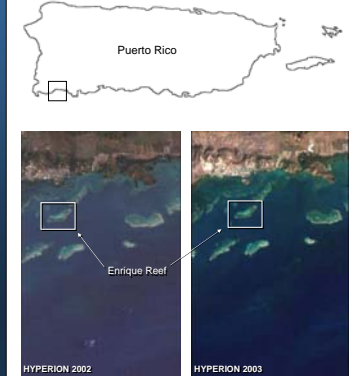
#### Available Data:

NOAA Coastal Services Center Digital Bathymetry Data Collected From Traditional Ship Soundings and More Recently From SHOALS, an Airborne Lidar System.  
NOAA Biogeography Program Digital Benthic Habitat Maps of Puerto Rico.

### Remote Sensing Data

#### Airborne/Satellite Imagery

**Purpose:** Large scale remote sensing imagery for testing and validation of image information extraction algorithms.



#### Sensor Specifications:

Hyperion (satellite, 196 bands, 400-2500nm, 30m pixels)  
AVIRIS (ER-2, 224 bands, 400-2500nm, 17m pixels)  
AVIRIS (Twin Otter, 224 bands, 400-2500nm, 4m pixels)  
Optech (airborne, 288 bands, 400-1050nm, 3-4m pixels, fused with SHOALS Laser Bathymeter)  
SpectraVista (airborne, under development, 3-4m pixels)  
Ikonos (satellite, 5 bands, 3 VIS and 1 NIR at 4m pixels, 1 Pan at 1m pixels)

#### Acquired Data:

Hyperion Images in 2002, 2003, 2004, 2005 and 2006  
Ikonos Image in 2002  
AVIRIS Images in 2004 (ER-2) and 2005 (Twin Otter)

#### Future Acquisitions:

SpectraVista and Optech in Planning Stages  
High Spatial Resolution Imagery Currently Scheduled

### Planned Hyperspectral Mission

#### High Spatial Resolution Imagery

##### Overall Acquisition Area

Total area = 2000 km<sup>2</sup>  
Ground sampling distance = 4 m resolution  
Coverage includes:  
Enrique Reef and entire southwest Puerto Rico reef system  
La Parguera Bioluminescent bay  
Guánica dry forest (International Biosphere Reserve)  
Diverse coastal ecosystems

##### Multi-Resolution Science Areas

Total area = 100 km<sup>2</sup>  
Ground sampling distance = 1, 2, 4 and 8 m resolution  
Unique opportunity for multi-resolution algorithm assessment  
Coverage includes:  
Enrique Reef and two other western reef areas

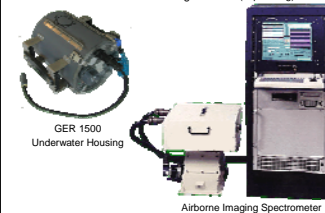
##### Acquisition Scheduled for May/June 2007



### New Industrial Collaborations

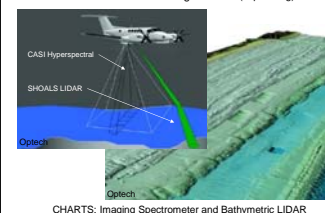
#### Spectra Vista Corporation

**CenSSIS Involvement:**  
Development of Improved Field Spectrometer Capabilities  
Airborne Data Validation Using SeaBED (in planning)



#### Optech International, Inc.

**CenSSIS Involvement:**  
Field Data Collection for Algorithm Validation  
Airborne Data Validation Using SeaBED (in planning)



CHARTS: Imaging Spectrometer and Bathymetric LIDAR