S4: Coral Reef Monitoring

Why Coral Reefs?

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UPRM

CenSSIS Site Visit
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The Importance of Coral Reefs

• Coral reefs are highly productive coastal ecosystems that are often described as the marine equivalent of rainforests in terms of biodiversity.

• For many tropical countries coral reefs are a major or principal source of income from fisheries, tourism, and recreation.

• It has been estimated that coral reefs provide nearly US$30 billion annually in net benefits in goods and services globally.
The Status of Coral Reefs

- Coral reefs are among the most threatened coastal ecosystems worldwide.
- Coral reef ecosystems have been subject to unprecedented degradation over the past few decades.
- Recent accelerated coral reef decline is mostly related to anthropogenic impacts such as increased sedimentation, nutrient overloading and overfishing.
The Status of Coral Reefs

- Severe impacts to coral reefs can also result from hurricane disturbances, flooding (low salinities), high and low temperature extremes, and diseases.
- Coral reef bleaching is a common stress response of corals and other reef organisms to many of the various disturbances mentioned above.
Challenges: Exponential Attenuation of Light in the Aquatic Medium and Heterogeneity of the Habitat

Problems of the medium:

- High variability of IOPs (scattering, absorption) and AOPs (Lu, Ed, Kd)
- Surface reflection, refraction and wave action
- Variable bathymetry
- Variable water column bio-optical properties (chlorophyll, CDOM, suspended sediments)

Problems of the reef habitat:

- Spatially and structurally variable
- Coral reefs are a heterogeneous mixture of corals, sponges, gorgonians, algae, sand, etc.
What is the Extent and Condition of Coral Reefs in the US Caribbean?

Bathymetry of Puerto Rico -Virgin Islands Geological Platform Potential Reef Habitat
Remote Sensing Platforms and Sensor Requirements for Coral Reef Assessments

• **Insular Shelf (0-20 m) Shallow-water Reefs**
  – Satellite Sensors – HYPERION, IKONOS, Landsat TM, SPOT
  – Airborne Sensors – AVIRIS

• **Upper Insular Slope (30 – 100 m) Deep Reefs**
  – Seabed Autonomous Underwater Vehicle (AUV)
    • Optical and Acoustic Imaging
Spatial Resolution Requirements for Coral Reef Studies

- Landsat TM – 30 m
- HYPERION
- SPOT – 20 m
- CASI – 5 m
- IKONOS – 1 m
- HYPERION
Coral Reef Bleaching

Photos courtesy of Hector Ruiz and Juan Torres
Coral Bleaching Spectral Response

Normal versus a bleached colony of *D. clivosa*
# AVIRIS 2004 and 2005 Hyperspectral Missions

**Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) 224 spectral bands**

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<th>Location</th>
<th>Date(s)</th>
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<td>8</td>
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<td>2005</td>
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<td>December 12-20, 2005</td>
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<td>12,000'</td>
<td>~3.5 m</td>
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Field Sampling in Support of the AVIRIS Missions

- **Mayaguez Bay (2004)**
  - Apparent and Inherent water optical properties
- **La Parguera Reefs – NASA and UPRM researchers**
  - Remote sensing reflectance (Rrs) of corals and other benthic communities
  - Spectral water attenuation coefficients
  - Chlorophyll, turbidity, Rrs at 13 stations
- **Calibration Targets (La Parguera)**
  - Flat fields – Rrs
  - Sunphotometer measurements (AOT)
Why Study Deep Coral Reefs?

• In shallow waters (< 20 m) of the Caribbean Region, a coral decline of 80% over the last 30 years has been documented (Gardner et al. 2003).
• Deeper reefs (> 30 m) are largely unknown.
• They appear to be healthier than shallow water reefs.
• Habitats of commercially important fish species.
• Source of coral larvae for recruitment and potential recovery of the shallower reef areas.
• There could be several times as much reef habitat deep as there is shallow.
Why Study Deep Coral Reefs With AUVs?

- Effective airborne or satellite remote sensing of coral reefs is limited to shallow, optically clear water.
- The deep hermatypic corals (30 to 100 m) lie beyond the range of safe diving operations.
- The Seabed AUV is an ideal platform for large scale benthic imaging.
- AUVs can be configured to carry a wide variety of imaging sensors and other instruments such as CTDs, side scan sonars, multi-beam and pencil beam sonar sonars, chemical sensors, video plankton recorder recorders, and others.
- We developed the use of pencil beam sonar data from the AUV to derive the rugosity index of coral reefs.
Coral Reef Habitat at 40 m

Hind Bank Marine Conservation District, St. Thomas, USVI
Major Science Accomplishments

- Pioneer work on AUV characterization of deep coral reef habitats.

- The AUV data provided, for the first time, a quantitative assessment of a unique coral reef habitat present in deeper insular shelf areas.
• Developed a methodology to derive the rugosity index of coral reefs from the Seabed AUV.

• CenSSIS investigators participated in a multi-agency effort to assess the impact of the 2005 massive bleaching events in the US Caribbean using hyperspectral AVIRIS data.

• Unprecedented database of coral reef spectral signatures, water optical properties, and state-of-the-art hyperspectral data to map and assess the condition of shallow-water coral reefs.
<table>
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<tr>
<th>Grant Title</th>
<th>Characterization of deep hermatypic coral reef biodiversity in Puerto Rico and the US Virgin Islands using Autonomous Underwater Vehicles (AUV) and advanced diving technology</th>
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<tr>
<td>PI:</td>
<td>R. Armstrong (UPRM)</td>
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<tr>
<td>Co-PI’s:</td>
<td>J. García, Y. Detres, H. Singh (WHOI), R. Camilli (WHOI)</td>
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<td>Evaluation of Spatial and Spectral Scale for Remote Sensing of Biodiversity in Coral Reefs and Associated Biotopes</td>
</tr>
<tr>
<td>PI:</td>
<td>Liane Guild (NASA)</td>
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| Amount:                                       | $405,963