Challenges and Opportunities of Remote Sensing in Caribbean Coastal Waters

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Objectives of this presentation

- Discuss the potential and limitations for remote sensing of ocean color and coral reefs monitoring in Caribbean coastal waters.
- Demonstrate the regional capabilities to develop very strong educational, research, and monitoring programs using remote sensing.
- Emphasize that new satellite sensors and image processing techniques are needed for the Caribbean.
- Show that a multi-sensor and multi-disciplinary approach is required to understand Caribbean coastal waters.
- Establish the importance of land-sea interactions studies using remote sensing and GIS.
Challenges for Ocean Color in Caribbean Coastal Waters
Global problems for ocean color remote sensing are also present in the Caribbean

- Better understanding of the temporal and spatial variability of inherent and apparent optical properties is needed.

- Site-specific bio-optical algorithms are required to better estimate the concentration of Chlorophyll-a and Suspended Sediments.

- CDOM and suspended sediments are seasonally produced by rivers discharge and their correlation controls the bio-optical variability.

- Photosynthetic picoplankton, like cyanobacteria, are competing with large phytoplankton for the quality and quantity of light.

- Current satellite sensors do not provide accurate estimates of water quality parameters in coastal areas due to all the above problems.
But, three unique challenges for remote sensing are also found in Caribbean coastal waters

1. **Small size of the coastal regions** - requires sensors with very high spatial resolution.

2. **Low concentration of the parameters** - requires sensors with very high S/N ratio.

3. **Short-term effects of dramatic seasonal events (like hurricanes) on land-sea interactions** - requires sensors with high temporal resolution.
PHYTOPLANKTON DYNAMICS AFFECTED BY LARGE REGIONAL RIVERS AS DETECTED BY SEAWIFS
But, SeaWiFS images fail in coastal waters with local rivers.
Bio-optical algorithms also fail
Low Chl for developing bio-optical algorithms
(also the number of data points are limited)

\[ y = -0.4212x + 1.8219 \]

\[ R^2 = 0.7436 \]
Low reflectance signal and no fluorescence peak
Effect of CDOM
Effect of Suspended Sediments
Opportunities for Ocean Color in Caribbean Coastal Waters
Easy access to coastal waters Mayaguez Bay at Western P.R.

- It is an accessible natural laboratory with large spatial and temporal variations.
- It is affected by rivers discharge and anthropogenic effects.
- Past and current research has provided excellent background information.
- It is an ideal place to develop and test remote sensing techniques for coastal waters.
Good sampling equipment for sensors validation and algorithms development
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Good laboratory equipment for sensors validation and algorithms development
New algorithms for MODIS

[Chlorophyll-a] = OC3 MODIS algorithm
1 km resolution

[Chlorophyll-a] = Empirical algorithm
500 m resolution
[Chl-a] = -42.12*(B3/B4) + 1.8219
Using MODIS for TSS

\[ y = 19.63x - 0.4768 \]

\[ R^2 = 0.8102 \]
SATELLITE DATA COLLECTION BY THE UPRM-TCESS SPACE INFORMATION LABORATORY
X-BAND ANTENNA

RADARSAT

LANDSAT-7

MODIS

AQUA TERRA

SAR

ETM+
PHYTOPLANKTON DYNAMICS AFFECTED BY HURRICANES

September 19

September 25

October 15
PHYTOPLANKTON DYNAMICS AFFECTED BY COASTAL UPWELLING

AVHRR Sea Surface Temperature

SeaWiFS Chlorophyll-a
MESOSCALE EDDIES AND FRONTS
Airborne Sensors

AOCl 90’s

ATLAS 2004

AVIRIS 2004
Sensors with high spatial resolution
HYPERSPECTRAL MISSION
NOV 28-DEC 21, 2007
AISA SENSOR

Data collected at:
1, 2, 4, 8 meters
128 bands
400-1000 nm
On-line Database

http://gersview.uprm.edu
Challenges for monitoring benthic habitats in Caribbean Coastal Waters
Issues in benthic habitat mapping

1. Sensor Characteristics:
   Signal to Noise (S/N) Ratio
   Spatial and Spectral Resolution

2. Atmospheric Conditions:
   Scattering and Absorption
   Gases and Aerosols

3. Signal from the Water Column:
   Surface Conditions
   Light Penetration
   Bio-Optical Properties

4. Signal from the Bottom:
   Water Depth
   Bottom Type
   Size of the Community

5. Signal Processing
Primary Study Area

Enrique Reef

Puerto Rico
WHAT IS THE BEST RESOLUTION?

EVALUATE THE SPECTRAL VS SPATIAL RESOLUTION

<table>
<thead>
<tr>
<th>SENSOR</th>
<th>BANDS</th>
<th>SPECTRAL RANGE (µm)</th>
<th>PIXEL SIZE (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKONOS</td>
<td>4 PAN</td>
<td>0.45-0.90</td>
<td>4</td>
</tr>
<tr>
<td>HYPERION</td>
<td>220</td>
<td>0.4-2.35</td>
<td>30</td>
</tr>
</tbody>
</table>
Image interpretation and classification

HYPERION

IKONOS
Change Detection

\[ B(x) = \begin{cases} 
1 & \text{if pixel } x \text{ has significant change from } I_1(x) \text{ to } I_2(x) \\
0 & \text{Otherwise} 
\end{cases} \]

Work by Vanessa Ortiz Rivera, UPRM
Spectral Unmixing

2002 HYPERION

Unconstrained
Non Negative
Sum To One

Unconstrained
Non Negative
Sum Less Than or Equal to One

Work by Samuel Rosario, UPRM
Opportunities for monitoring benthic habitats in Caribbean Coastal Waters
Field Data

Coral: Porites compressa

Field Measurements:
- Aquatic optical properties
- Georeferenced benthic reflectance
- Spectral library (species)
- Benthic Composition
- Detailed habitat map

Field Measurements:
- Pump
- CTD
- AC-9
- Battery Pack
- Data Logger
- Fluorometer
- OCR-200

Coral Rubble
A. cervicornis
M. annularis
Gorgonians
S. siderea
T. testudinum

Reflectance

Wavelength, nm

Coral: Porites compressa
Multi-Sensors Data

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

**Multi/Hyperspectral Data:**
- IKONOS
- HYPERION
- AVIRIS
- HyMap

**AVIRIS:** August 19, 2004

**IKONOS:**
- 2002
- 2004
- 2006
Spectral Unmixing

AVIRIS Color Composite

Benthic Habitat Composition

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

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

Sand

Coral

Algae

Work by James Goodman, UPRM
In summary... what are the major challenges?

- Higher spectral, spatial, temporal, and radiometric resolutions in future sensors.
- Multi-modalities approaches.
- More site-specific bio-optical algorithms instead of global algorithms.
- Integrate current diverse capabilities.
- Develop a better knowledge of land-sea interactions.
In summary...
what are the major opportunities?

• The region has the people with the appropriate expertise to overcome the challenges.

• Required infrastructure for remote sensing, like optical instruments and satellite receiving station, is already in place.

• Past and present data provide a good baseline for future work (modeling and satellite validation).

• Large interest of new collaborations.
Possible areas of Collaboration

✓ Biogeo-optical properties
✓ Ocean color of chlorophyll-a and suspended sediments
✓ Remote sensing of coral reefs
✓ GIS for land-sea interactions

➢ Modeling of coastal processes
➢ Seasonal extreme events, like hurricanes
➢ Bio-physical front detection
THANK YOU ... !

... QUESTIONS?