Photography of Coral Reefs from ISS

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(Background: biology, ecology, conservation biology, remote sensing of Earth)

January 2009
Coral Reef Remote Sensing

• The global environmental crisis
• Observing Reefs from orbit
  – Basic reef morphology and appearance from orbit
  – Reef distribution around the world
• Applying astronaut photography to reef mapping
  – Photographic techniques
Global Coral Reef Crisis

- High biological diversity
- Resources that sustain local and national economies (fisheries, coastal protection, tourism)
- Lack of data for management
  - locations
  - spatial extent
  - Health
- Up to 60% declining!
Threats to Reefs

• Development
  – Human run-off (fertilizers, pollution, sewage)
  – Sedimentation from development or deforestation

• Over-exploitation of reef resources
  – overfishing disrupts food chain
  – blast fishing
  – cyanide poisoning
  – collection of dead coral
  – heavy tourism
Reef Ecological Web

Zooxanthellae (Symbiont)

SUN

Corals

Phytoplankton

Zooplankton

Predator

Top Predator
Threats to Reefs

- Global climate change
  - coral bleaching
  - tropical storms and precipitation
  - sea level rise
### Degree-heating Weeks as Predictors of Coral Bleaching

<table>
<thead>
<tr>
<th>Location</th>
<th>12wk accr sum today</th>
<th>Max 12wk*</th>
<th>Current temp (°C)</th>
<th>Exp. max temp**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermuda</td>
<td>2.6</td>
<td>3 (98)</td>
<td>27.5</td>
<td>26.9</td>
</tr>
<tr>
<td>Midway Atoll, US</td>
<td>5.4</td>
<td>2 (99)</td>
<td>28.2</td>
<td>26.9</td>
</tr>
<tr>
<td>Enewetok</td>
<td>0.0</td>
<td>0.0</td>
<td>29.1</td>
<td>29.1</td>
</tr>
<tr>
<td>Oman - Muscat</td>
<td>16.8</td>
<td>9 (90)</td>
<td>26.9</td>
<td>30.1</td>
</tr>
</tbody>
</table>

**Note:**
- 12wk accr sum today: Summation of degree-heating weeks over 12 weeks.
- Max 12wk*: Maximum degree-heating weeks over 12 weeks.
- Current temp (°C): Current temperature in °C.
- Exp. max temp**: Expected maximum temperature.
Observing Reefs from Orbit

1. Reef Morphology
2. Worldwide Reef Distribution
Reef Morphology

- Fringing reef
- Barrier reef
- Atoll
Fringing Reef

ISS006-E-6474, Kodak DCS750, 200 mm lens cropped,
Coast near Bay of Nipe, Cuba
Barrier Reef

- Semi-continuous outer barrier
- Patch or platform
- Small patch or platform
- Low wooded island reef
- High rocky island with fringing reef
Barrier Reef

Great Barrier Reef: Ribbon Reef Zone with deltaic channels cutting through the “ribbon”

ISS004-E-5726, Kodak DCS760, 800 mm lens, Bigh Reef, Northern Great Barrier Reef, Australia
GBR Crescent Reef Zone

*Continental Shelf is Narrow*
Great Barrier Reef: Southern Zone
Swain and Pompey Reefs

ISS005-E-15244,
Kodak DCS760, 80 mm lens
Presence of sediments and pollution

- River mouths with heavy sediments do not have fringing reefs
  - Ameliorated by mangroves and seagrasses
- Coral cover and diversity declines as you get closer to cities
Atolls

- Lagoons 11-15m
- Growing Coral Heads
- Sand flat
- Radial zone

Scale: 18 METRE
0 1 2 KILOMETRES
0 1 2 MILES
Global distribution of coral reefs may surprise you!

- Caribbean: 14%
- South Atlantic: 1%
- Indian Ocean, Red Sea and Gulf: 30%
- Southeast Asia: 30%
- South Pacific: 13%
- North Pacific: 12%
Astronaut Photography of Reefs

- Makes multiple contributions to global mapping efforts
  - There are still locations where an astronaut photograph is the only orbital data available (cloud cover obscures coverage from other satellites)
    - Shuttle Archive of primarily 70-mm color positive film with 15 to 40 m resolution (28,000 frames suitable for reef remote sensing near-nadir look angle)
    - ISS Imagery Archive with 5-8 m resolution for a growing number of locales
  - Spatial resolution now being acquired from ISS is revolutionary
  - Can be combined with sub-optimal quality satellite data to get the best of both worlds
    - Spatial positioning accuracy from satellite
    - Cloud removal
    - Enhances spatial resolution
  - Many users still want image rather than map
Astronaut photography continues to provide one-of-a-kind images of remote reefs

Moruroa, Tuamotu Archipelago
Not successfully imaged to date by Landsat or SPOT!
Using Photographs to Make Reef Maps

Source image: Huahine, Society Islands (STS059-219-69, HB, 250 mm)

Reference image GMT Vector Coastline Map

Georeferenced image

Georeferencing
Multi-band satellite data vs. 3-band digital photo

Overall classification accuracies:
- shallow water*
- conglomerate/rubble*
- intertidal*
- vegetation*
- deep water

* Is mean of class % accuracies

Detailed Spatial Resolution Photography

Fangatau, Tuamotu Archipelago
22 km² atoll
Including 9.9 km² lagoon
150 inhabitants

ISS002-E-6372, Kodak DCS 760, 400 mm lens, 2X extender
Adding spatial resolution

Digital photo from ISS, 5.6 m  
Landsat 7, 30 m

Fangatau, French Polynesia
Endangered Small Giant Clam (*Tridacna maxima*)

4 tons of clam meat (50,000 individuals) harvested per year. Sustainable?
ISS photography provides nearly equivalent population estimates to aerial photography.

- Clam population estimates:
  - AP: 23.65±5.33 million clams
  - ISS: 21.90±5.48 million clams
- Both lack NIR band for glint correction and must be georectified
- Extremely useful alternative for remote areas
  - IKONOS or Quickbird (commercial options) better if money is not an object
  - Logistics of aerial photography not always possible

Andrefouët, Gilbert, Yan, Remoissenet, Payri and Chancerelle, The remarkable population size of the endangered clam *Tridacna maxima* assessed in Fangatau Atoll using *in situ* and remote sensing data, In press, *J. Marine Science.*
Cloud Removal

Astronaut photographs supplement SPOT data to distinguish reef pinnacles

HDTV digital still image (STS-93)

SPOT satellite image

Bathymetry from Digital Photographs

- A new algorithm for depth determination can be applied to any sensor with blue and green bands
- Works with Landsat-7, IKONOS, and Digital Astronaut Photography
Bathymetry from Digital Photographs

Welcome to ReefBase

ReefBase is an online information system on coral reefs, and was designed to provide relevant data and information to reef managers and scientists, as well as the general public.

Our objective is to facilitate better understanding of the inter-dependencies between humans and coral reefs, in order to benefit management and conservation efforts of these important resources.

To start searching for coral reef related information, use the navigation menu on top of this page, or select a country/territory from the list below.

http://www.reefbase.org/

Went public April 2002
Astronaut Photography in ReefBase

Reefs from Space NASA Astronaut Photography

Public by end of 2002
Use of ISS Imagery in Field Mapping

ISS005-E-9412, Juan de Nova, Iles Eparses, Indian Ocean

Quod, Research and monitoring of the coral reefs of the French islands of the Indian Ocean. 2004 Annual Report. IFRECOR (l'Initiative Française pour les Récifs Corallines), 2004
SUMMARY:
Astronaut photography of coral reefs

• Relevance
  – Visible and beautiful from space
  – Important global environmental issue

• Scientific Uses
  – NASA Mapping Initiatives
  – ReefBase distribution worldwide
  – Use of images by biologists in the field