Photography of Coral Reefs from ISS

Julie A. Robinson, Ph.D.
ISS Program Scientist
(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!

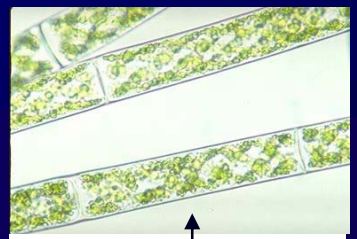
Threats to Reefs

- 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

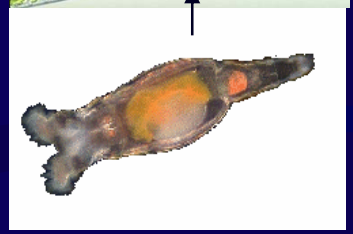
Reef Ecological Web

SUN

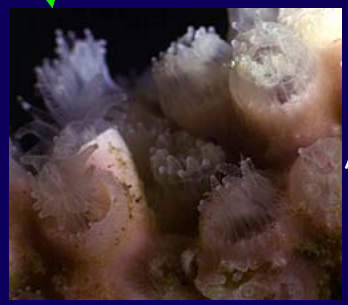
Zooxanthellae
(Symbiont)



Phytoplankton



Zooplankton



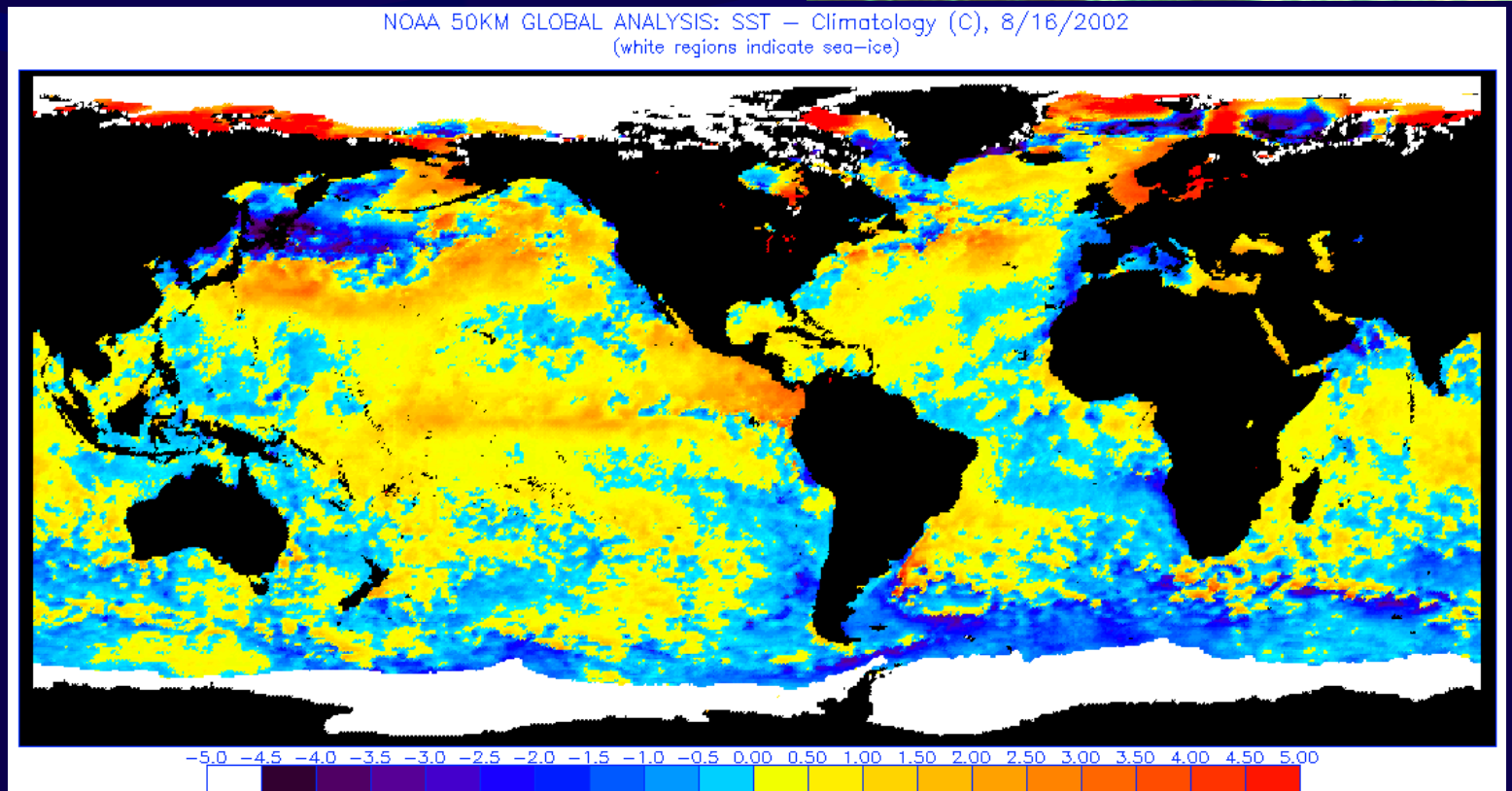
Corals

Predator

Top
Predator

Threats to Reefs

- Global climate change
  - coral bleaching
  - tropical storms and precipitation
  - sea level rise



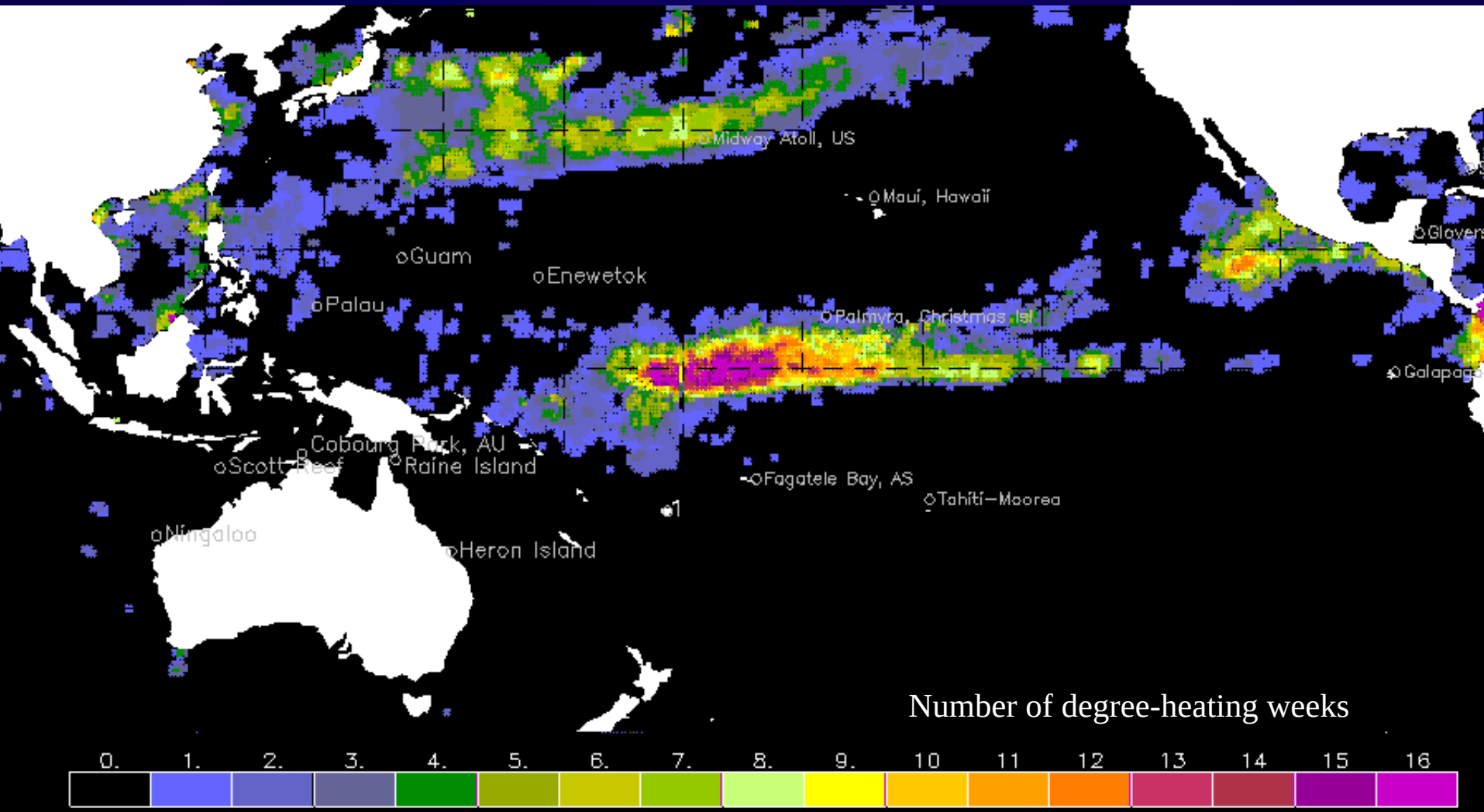
Degree-heating Weeks as Predictors of Coral Bleaching

Bermuda 32N 64W	
12wk accum today	2.6
Max 12wk*	3 (98)
Current temp (C)	27.5
Exp. max temp**	26.9

Midway Atoll, US 28.3N, 177.4W	
12wk accum today	5.4
Max 12wk*	2 (99)
Current temp (C)	28.2
Exp. max temp **	26.9

Enewetok 11N, 162E	
12wk accum today	0.0
Max 12wk*	0.0
Current temp (C)	29.1
Exp. max temp**	29.1

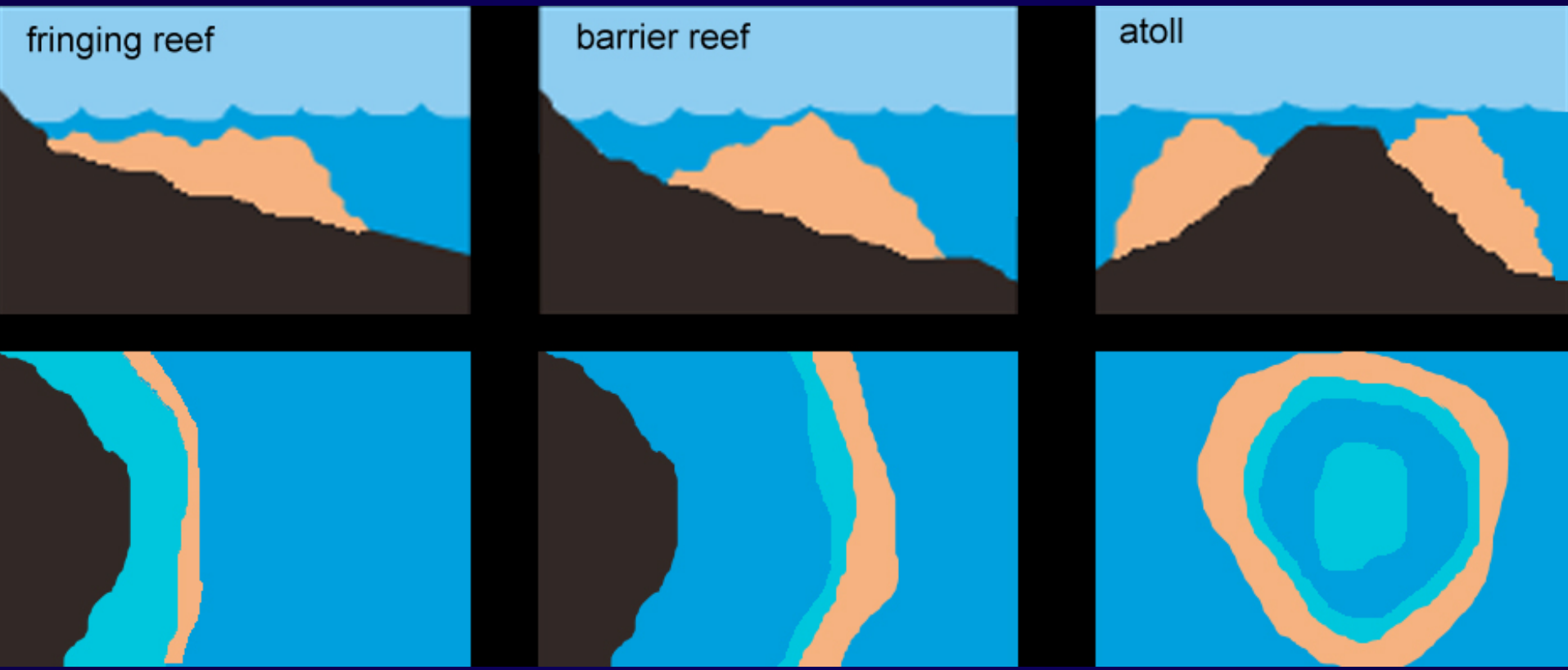
Oman - Muscat 23.7N, 58.6E	
12wk accum today	16.8
Max 12wk*	9 (90)
Current temp (C)	26.9
Exp. max temp**	30.1



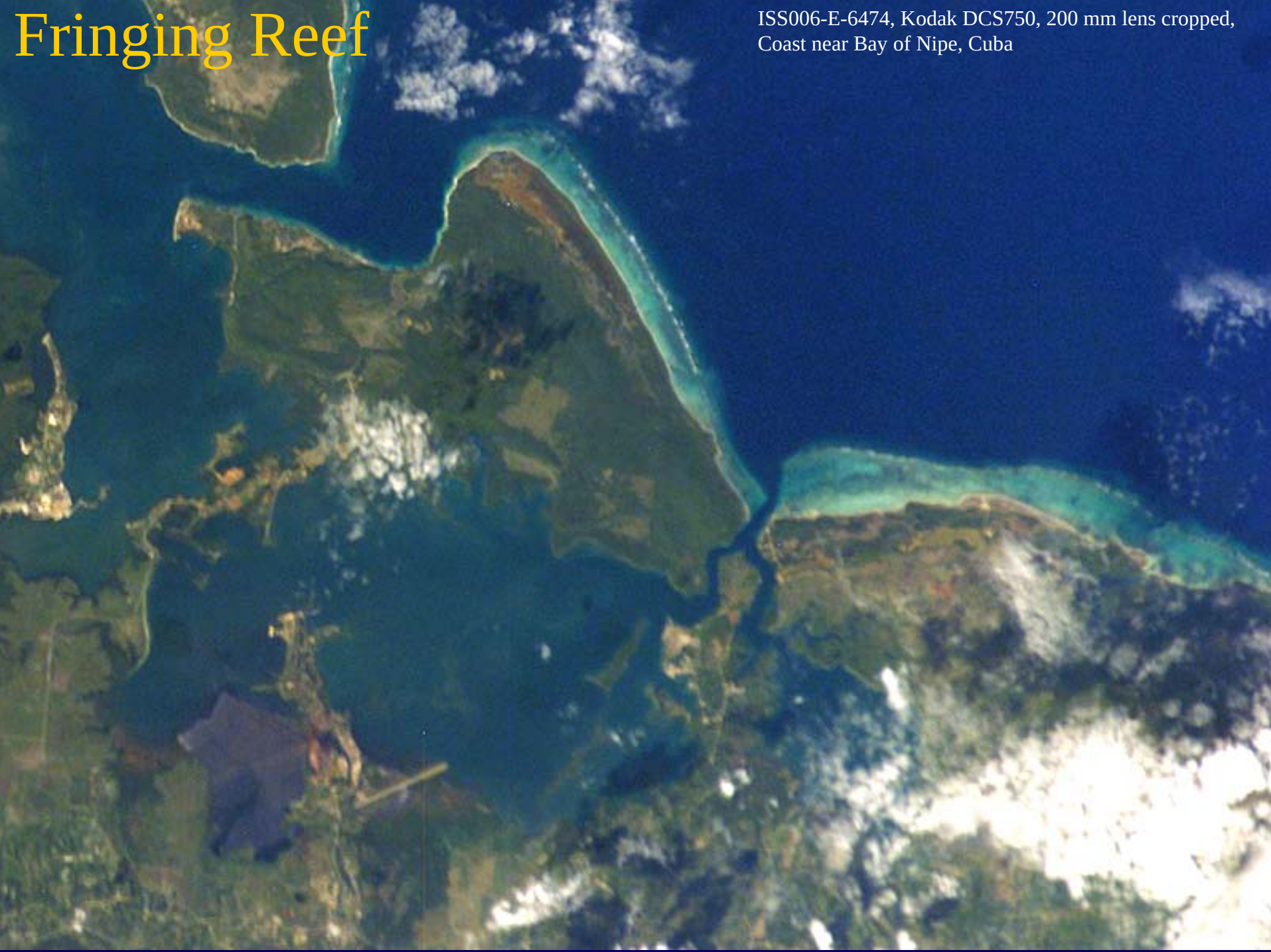
Observing Reefs from Orbit

1. Reef Morphology
2. Worldwide Reef Distribution

Reef Morphology

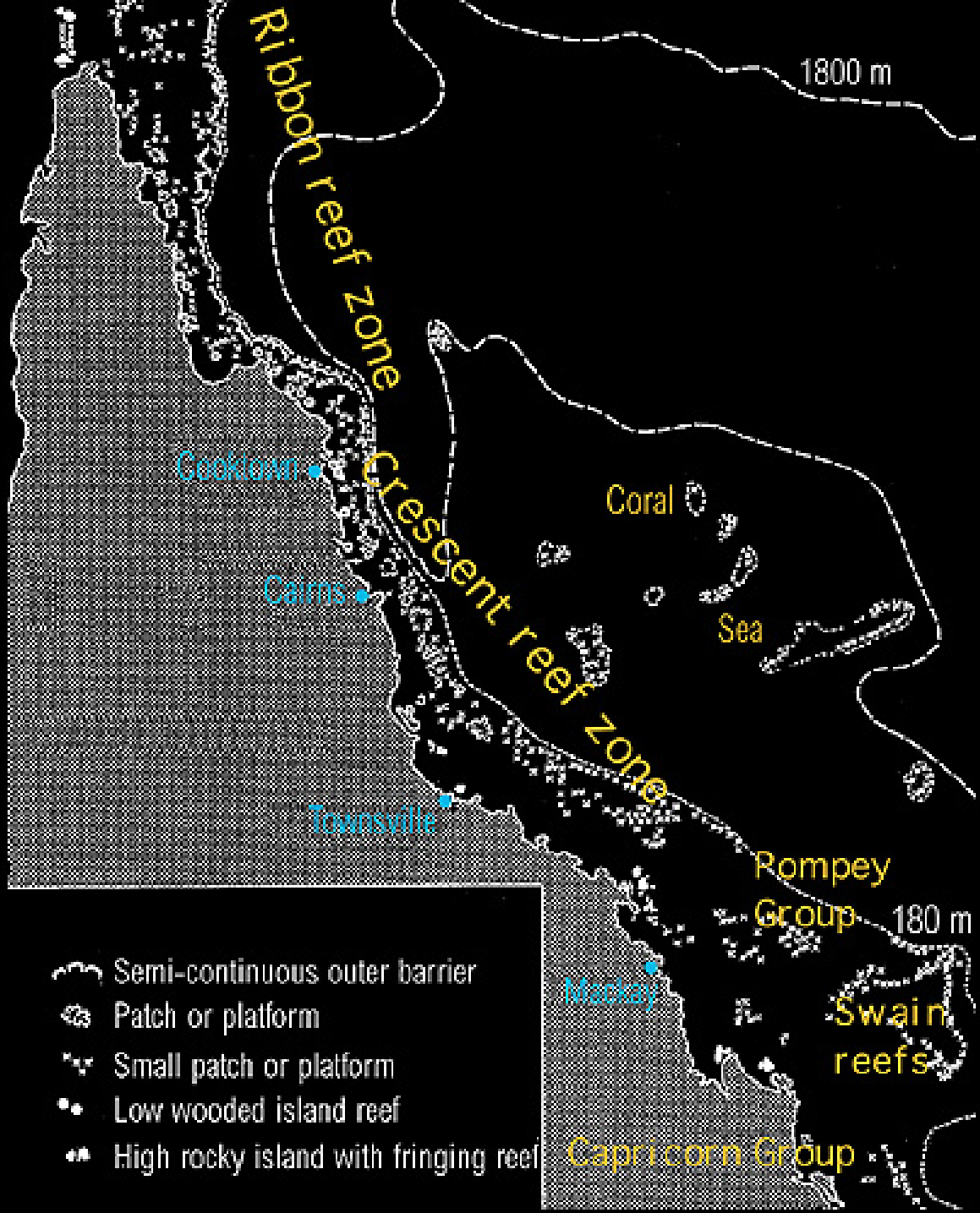


Fringing Reef



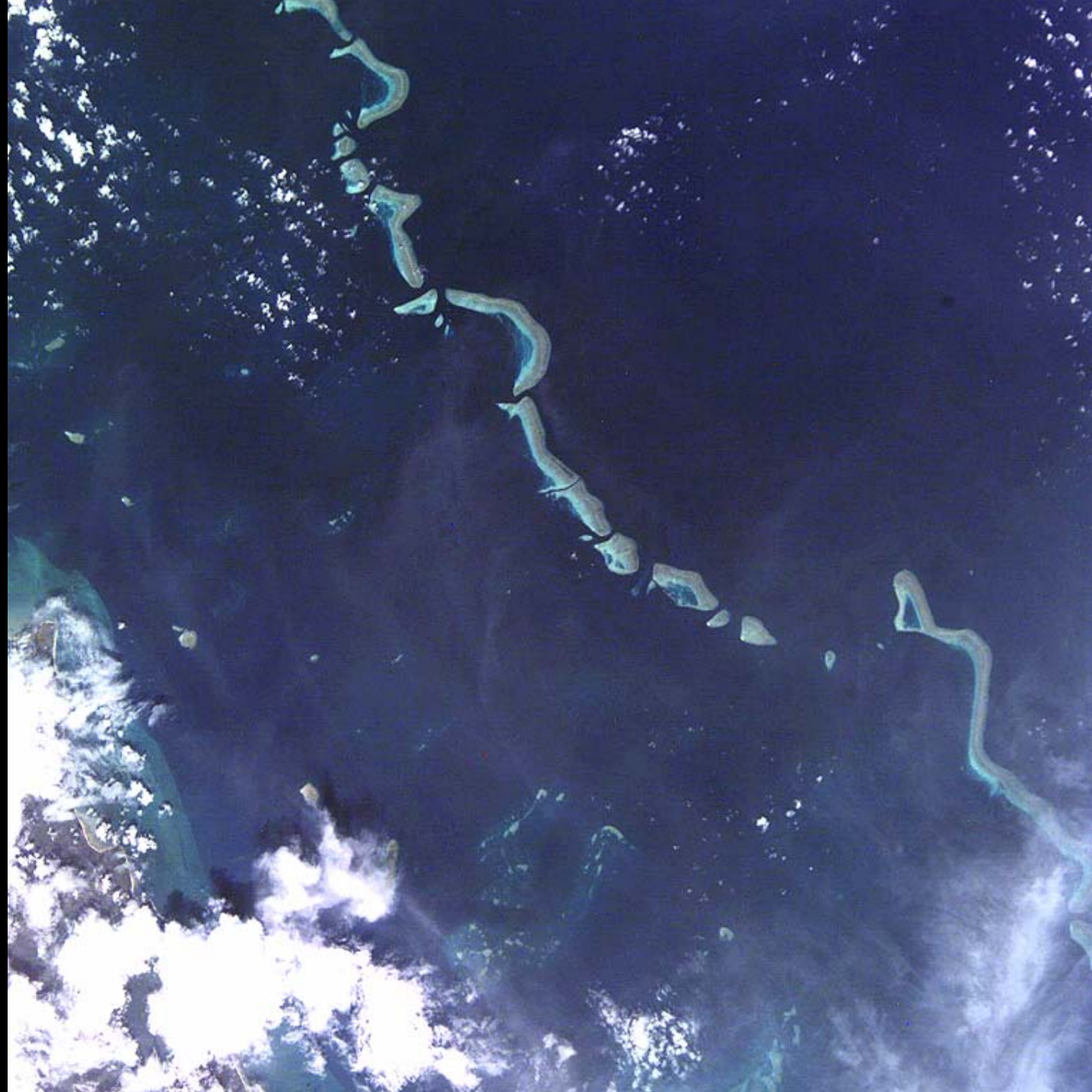
ISS006-E-6474, Kodak DCS750, 200 mm lens cropped,
Coast near Bay of Nipe, Cuba

Barrier 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

ISS002-713-19, Hasselblad, 350 mm lens, Cape Melville, Great Barrier Reef, Australia

Great Barrier Reef:
Southern Zone
Swain and Pompey
Reefs

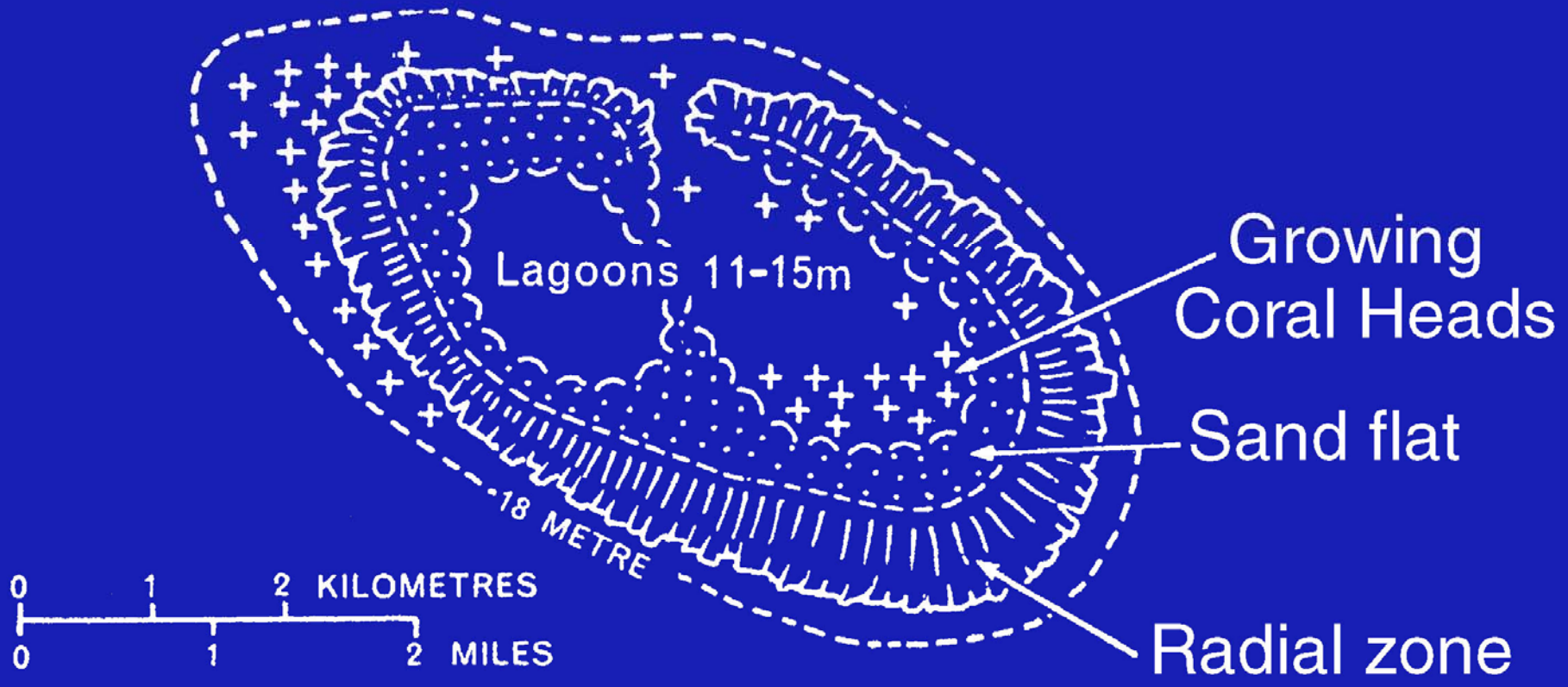
ISS005-E-15244,
Kodak DCS760, 80 mm lens

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

ISS005-E-10354, Kodak DCS 760, 80 mm, Jakarta and Kepulauan Seribu

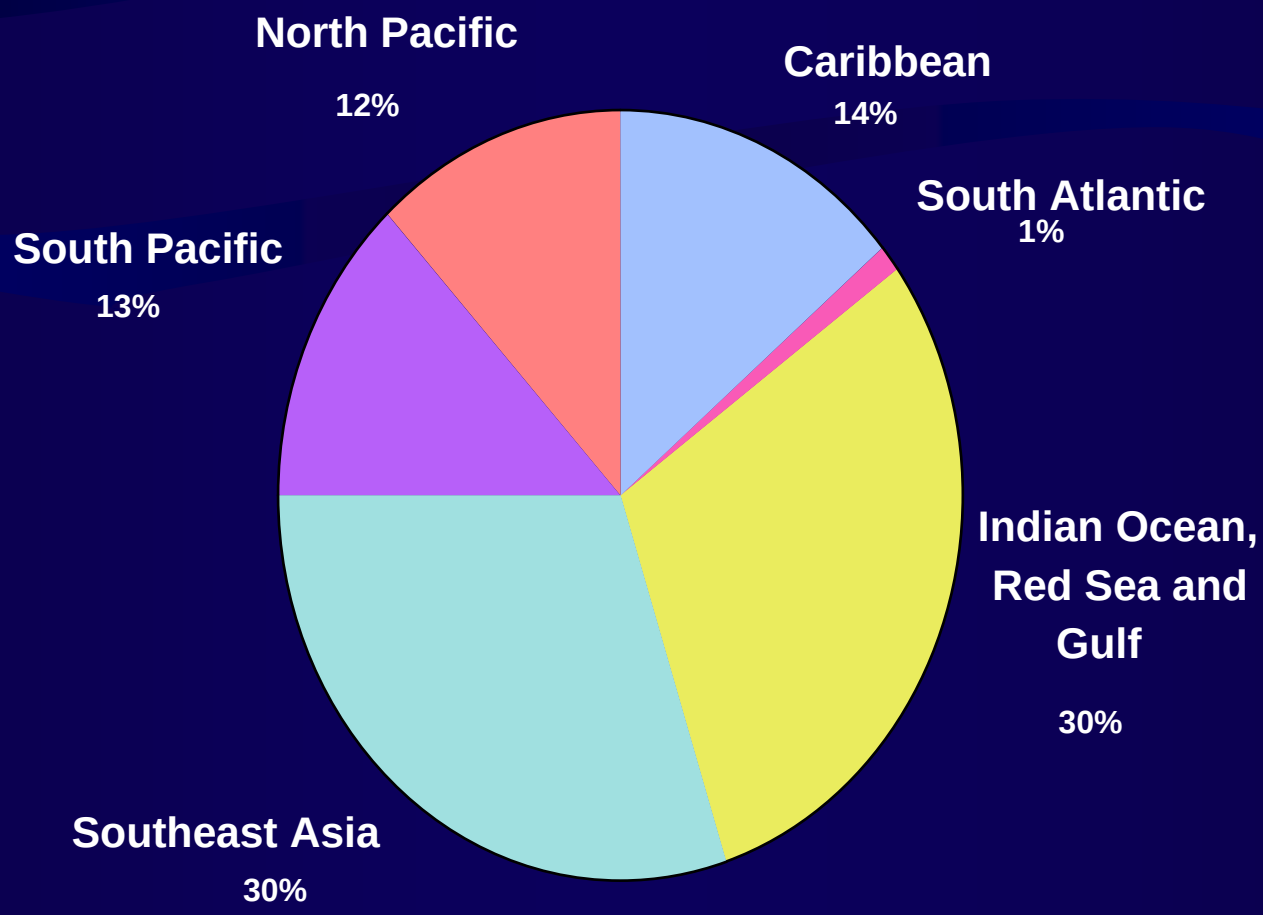
Atolls


Lagoons 11-15m
18 METRE
Growing Coral Heads
Sand flat
Radial zone
0 1 2 KILOMETRES
0 1 2 MILES


ISS006-E-22132, Kodak DCS760, 85 mm,
Tupai, Bora-Bora, Raiatea, Huahine


ISS005-E-13931, Kodak DCS760, 400 mm lens
Lisianski Shoal, NWHI

Global distribution of coral reefs may surprise you!



ISS007-E-13145, Kodak DCS760,
180 mm, Mashabih Island, Saudi Arabia

STS067-728A-62, HB 250 mm, Saudi Arabia

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

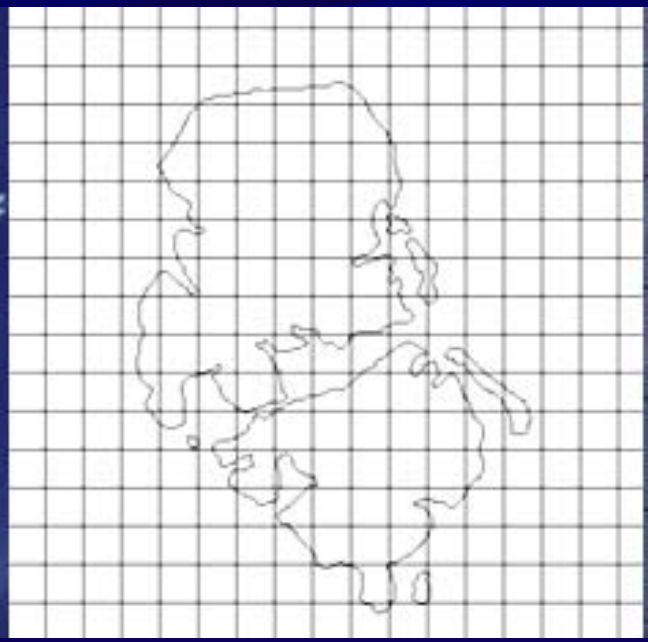
STS038-85-103, HB 250 mm, Key West, FL

Astronaut photography continues to provide one-of-a-kind images of remote reefs

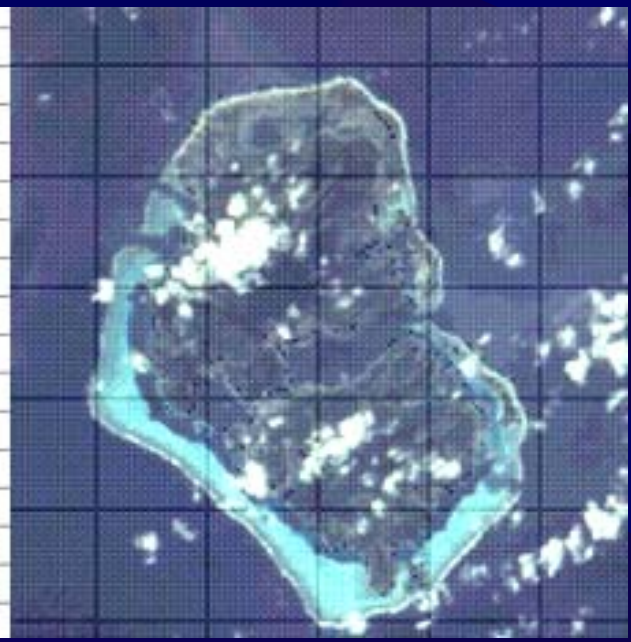
Moruroa, Tuamotu Archipelago
Not successfully imaged to date by Landsat or SPOT!

Using Photographs to Make Reef Maps

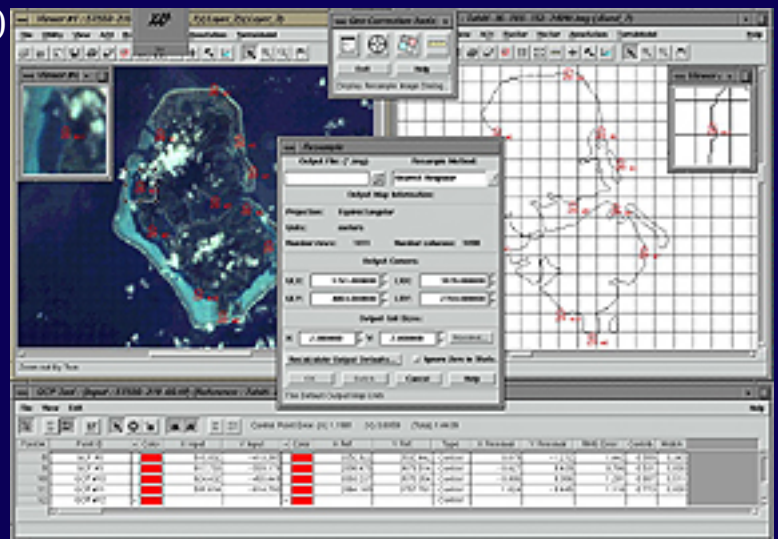
Source image: Huahine, Society Islands (STS059-219-69, HB, 250 mm)



Reference image GMT Vector Coastline Map

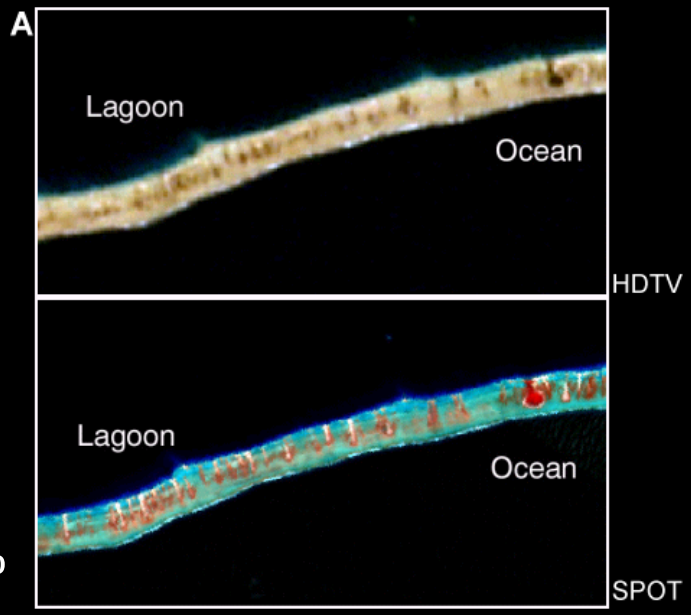


Georeferenced image



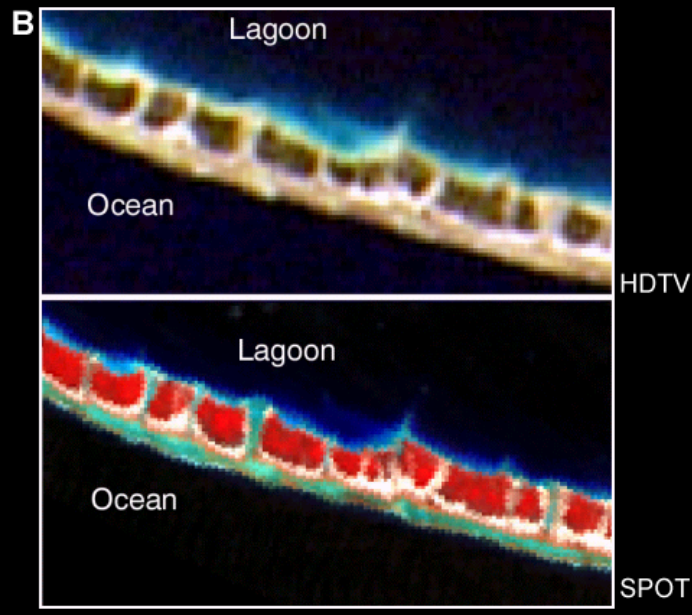
Georeferencing

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



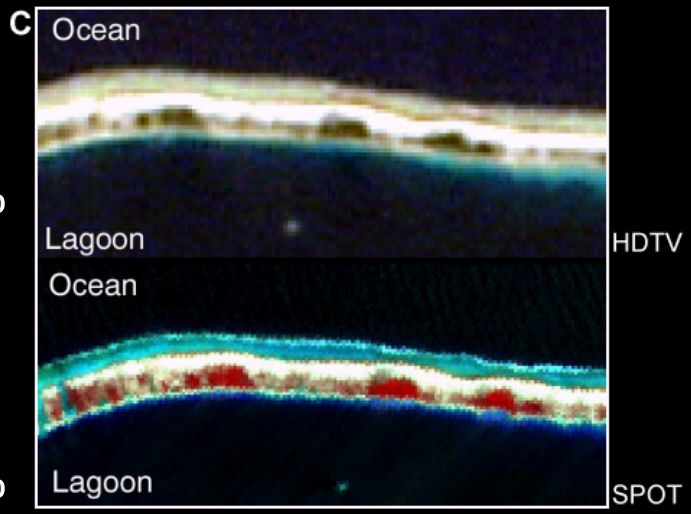
89.4%

90.1%



72.5%

62.0%



82.0%

73.5%

Overall classification accuracies:

- shallow water*
- conglomerate/rubble*
- intertidal*
- vegetation*
- deep water

* Is mean of class % accuracies

Andréfouët, Robinson, Hu, Feldman, Salvat, Payri, Muller-Karger, 2003, Influence of the spatial resolution of SeaWiFS, Landsat 7, SPOT and International Space Station data on landscape parameters of Pacific Ocean atolls, *Canadian Journal of Remote Sensing*, 29(2):210-218.

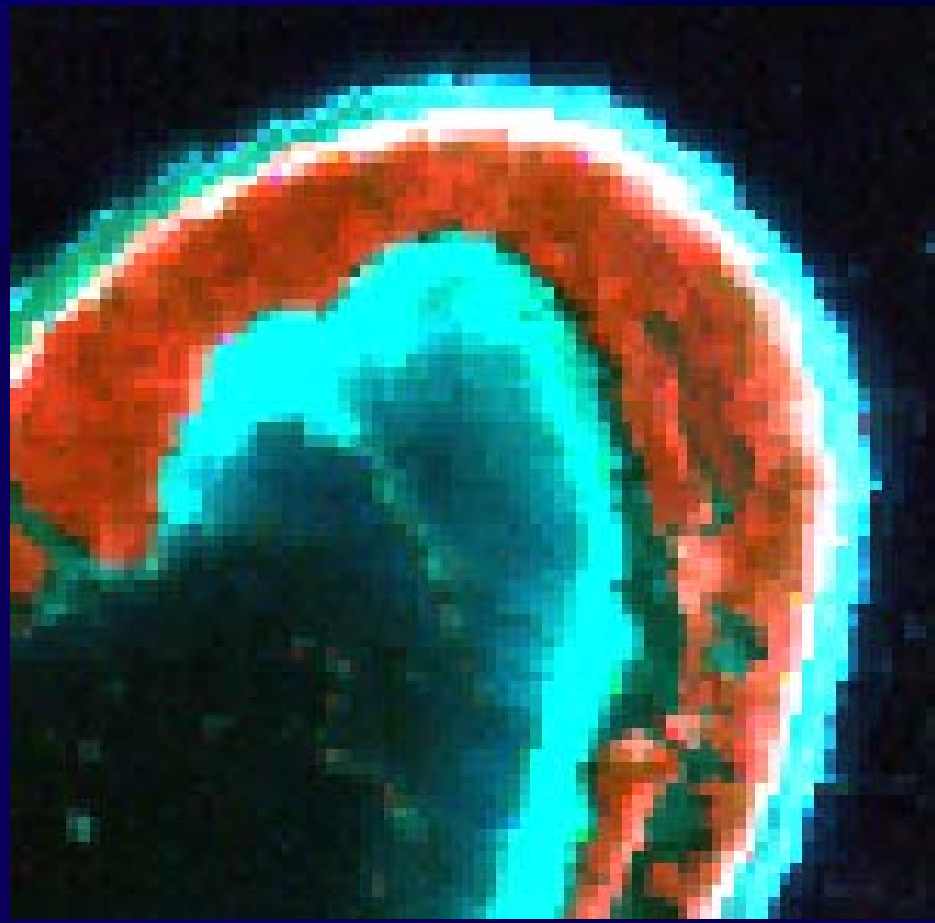
Detailed Spatial Resolution Photography

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

Adding spatial resolution

Digital photo from ISS, 5.6 m

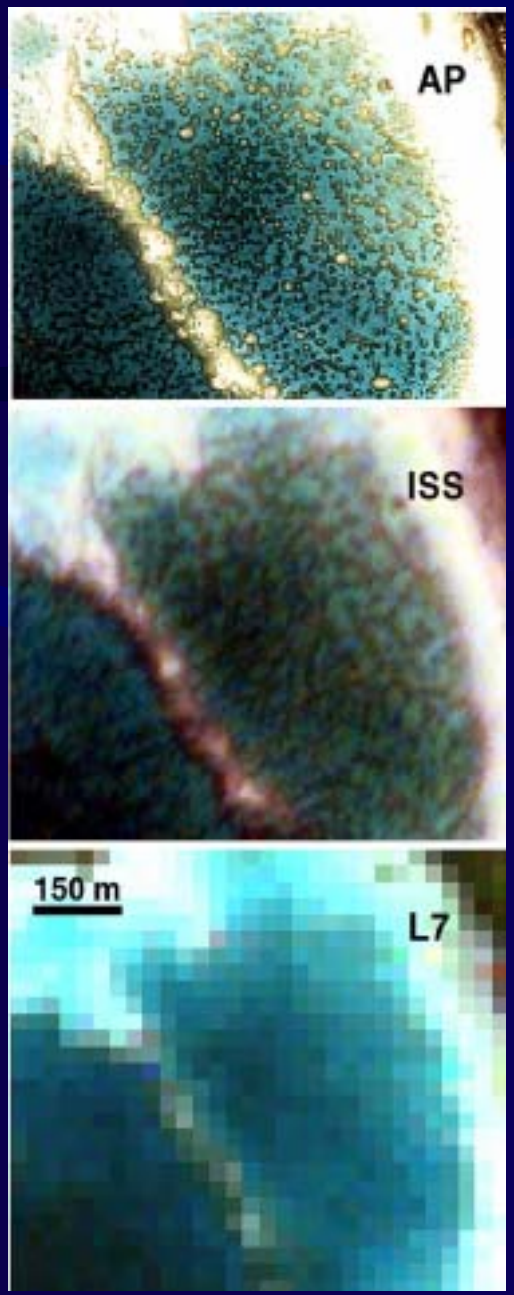
Landsat 7, 30 m

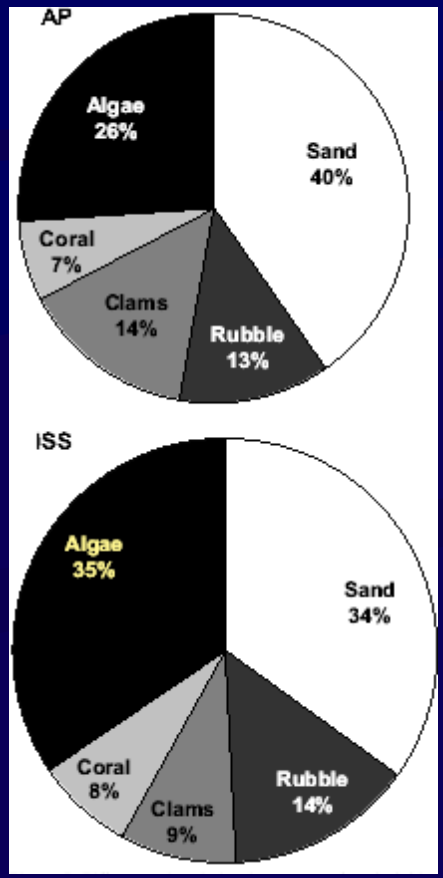


Fangatau, French Polynesia

Endangered Small Giant Clam (*Tridacna maxima*)

4 tons of clam meat (50,000 individuals) harvested per year. Sustainable?





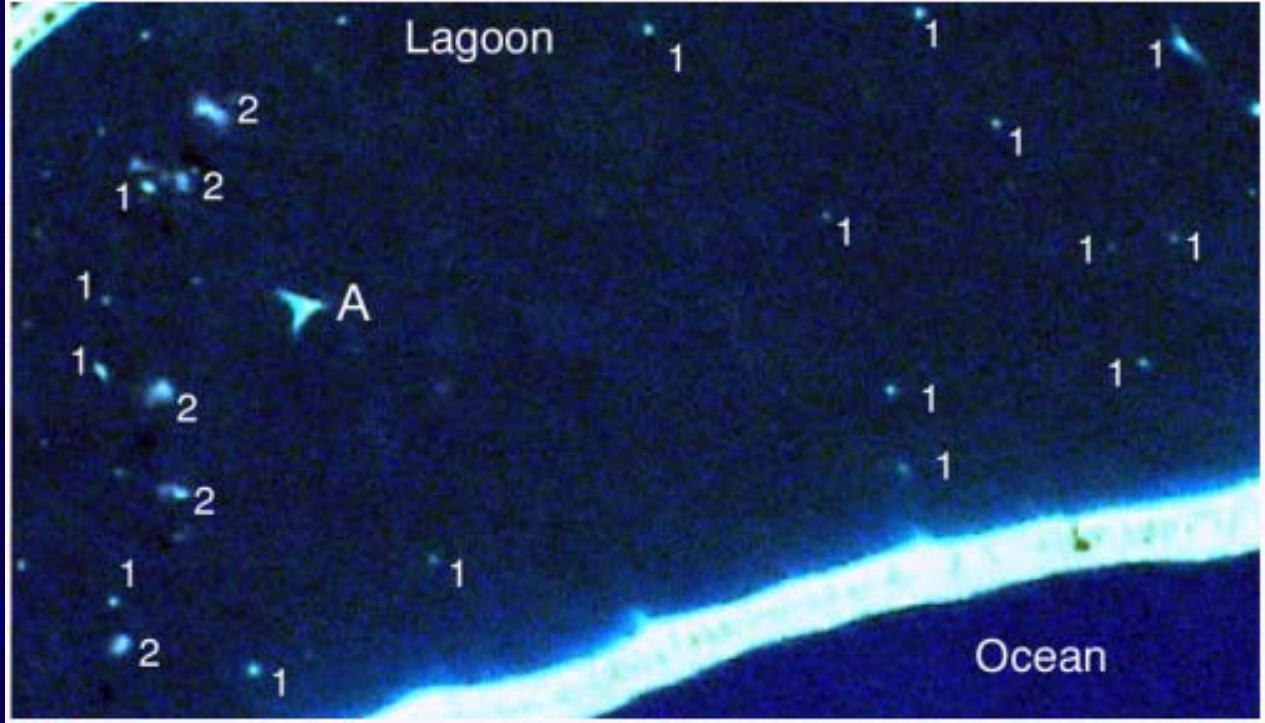
- Clam population estimates:
  - AP: 23.65±5.33 million clams
  - ISS: 21.90±5.48 million clams
- Both lack NIR band for glint correction and must be georectified
- Extremely useful alternative for remote areas
  - IKONOS or Quickbird (commercial options) better if money is not an object
  - Logistics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

ISS photography provides nearly equivalent population estimates to aerial photography

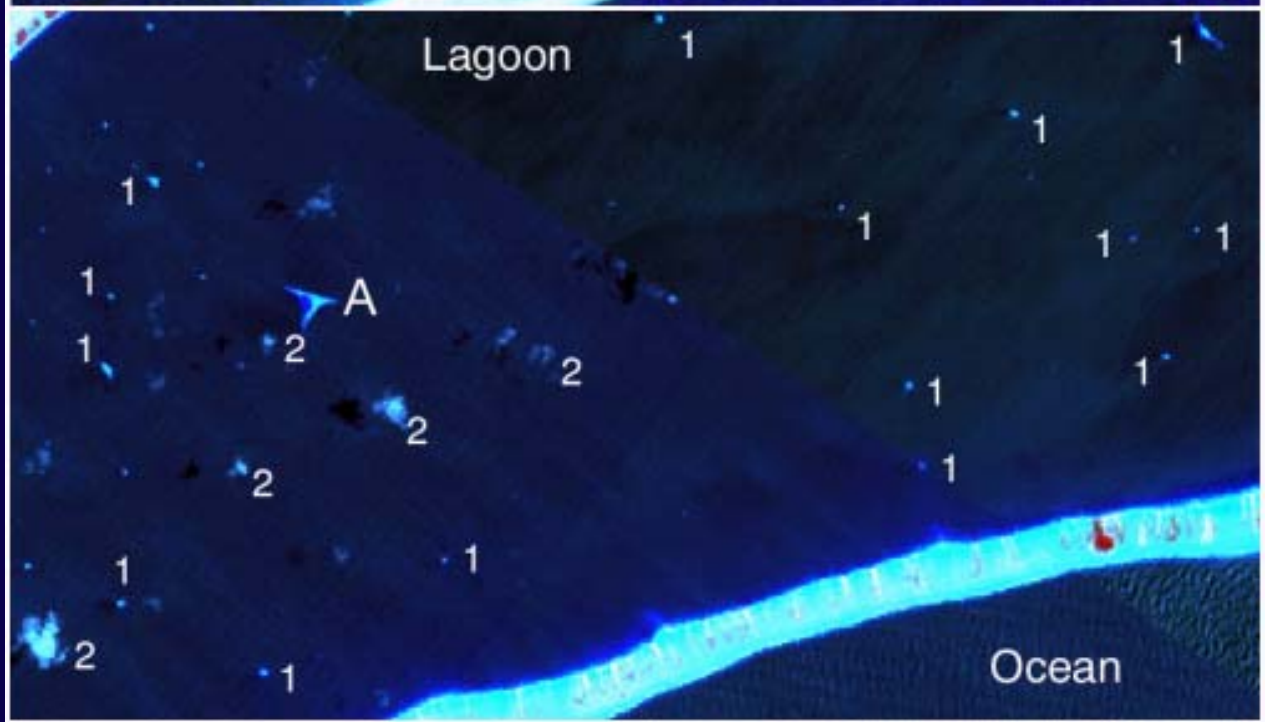
Andrefouët, Gilbert, Yan, Remoissenet, Payri and Chancerelle, The remarkable population size of the endangered clam *Tridacna maxima* assessed in Fangatau Atoll using *in situ* and remote sensing data, In press, *J. Marine Science*.

Cloud Removal

Astronaut photographs supplement SPOT data to distinguish reef pinnacles



HDTV digital still image (STS-93)



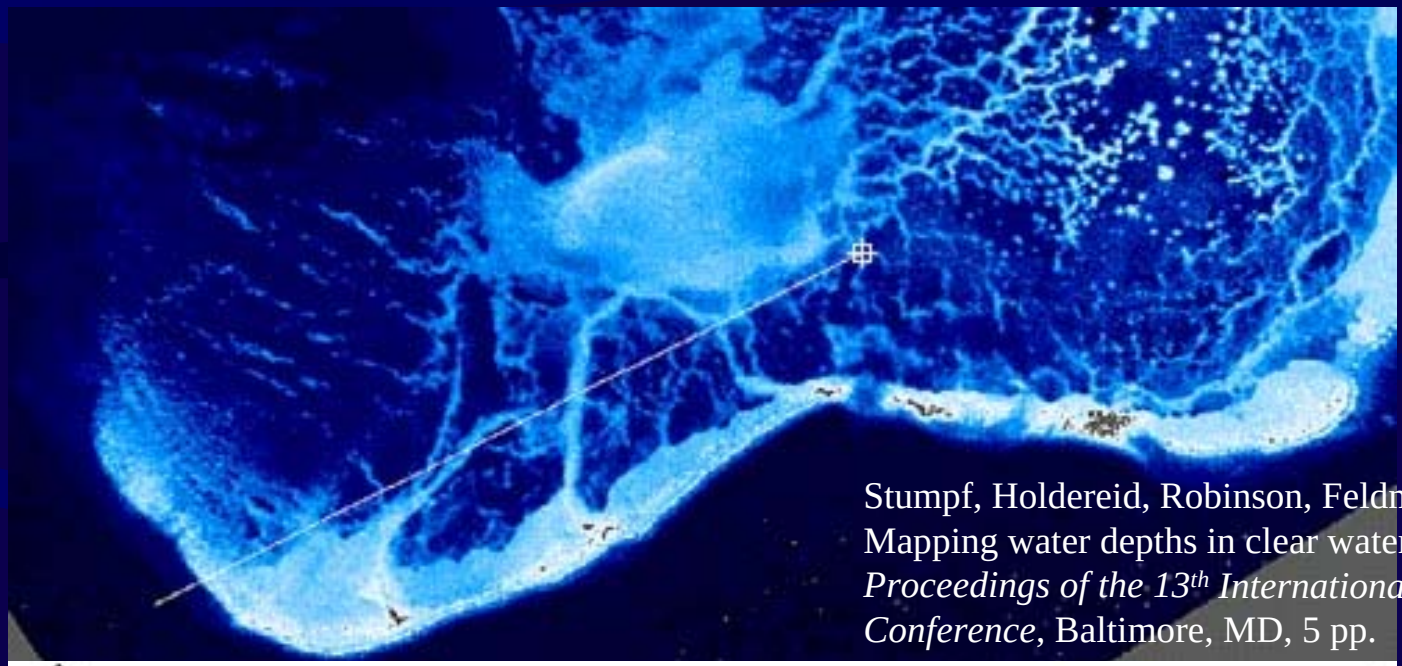
SPOT satellite image

Andréfouët, S., and J. A. Robinson. 2003. The use of Space Shuttle images to improve cloud detection in mapping of tropical coral reef environments. *International Journal of Remote Sensing* 24(1):143-149.

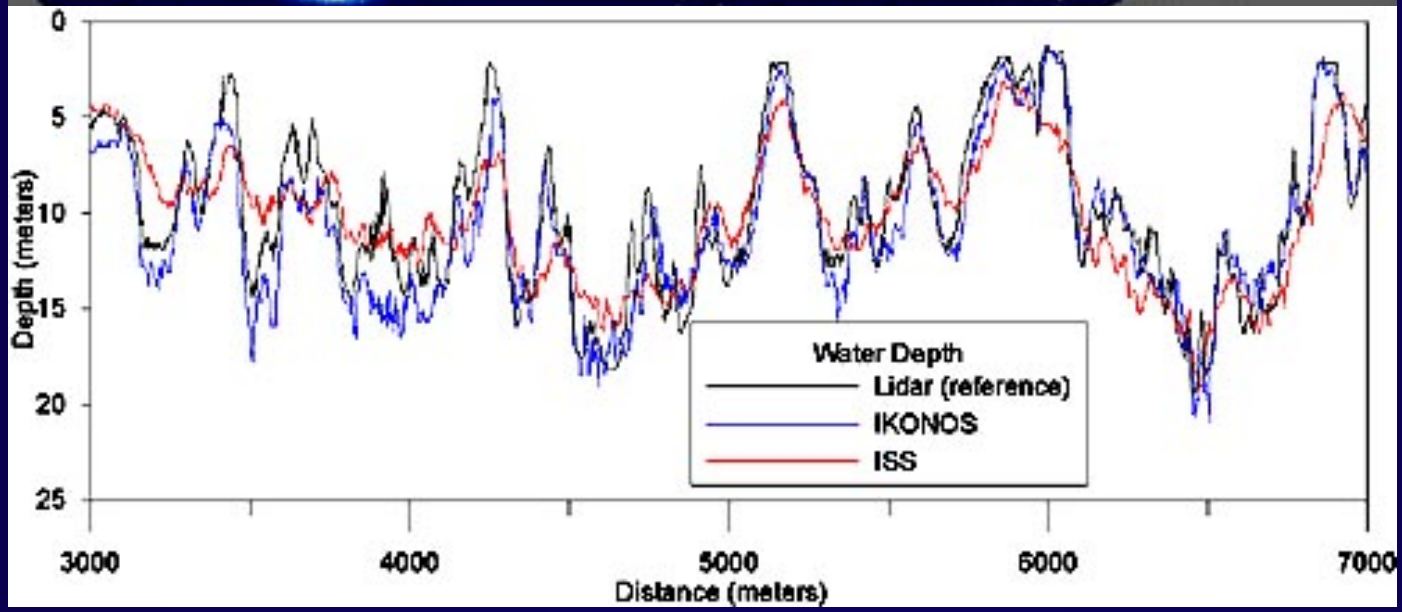
Bathymetry from Digital Photographs

- 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

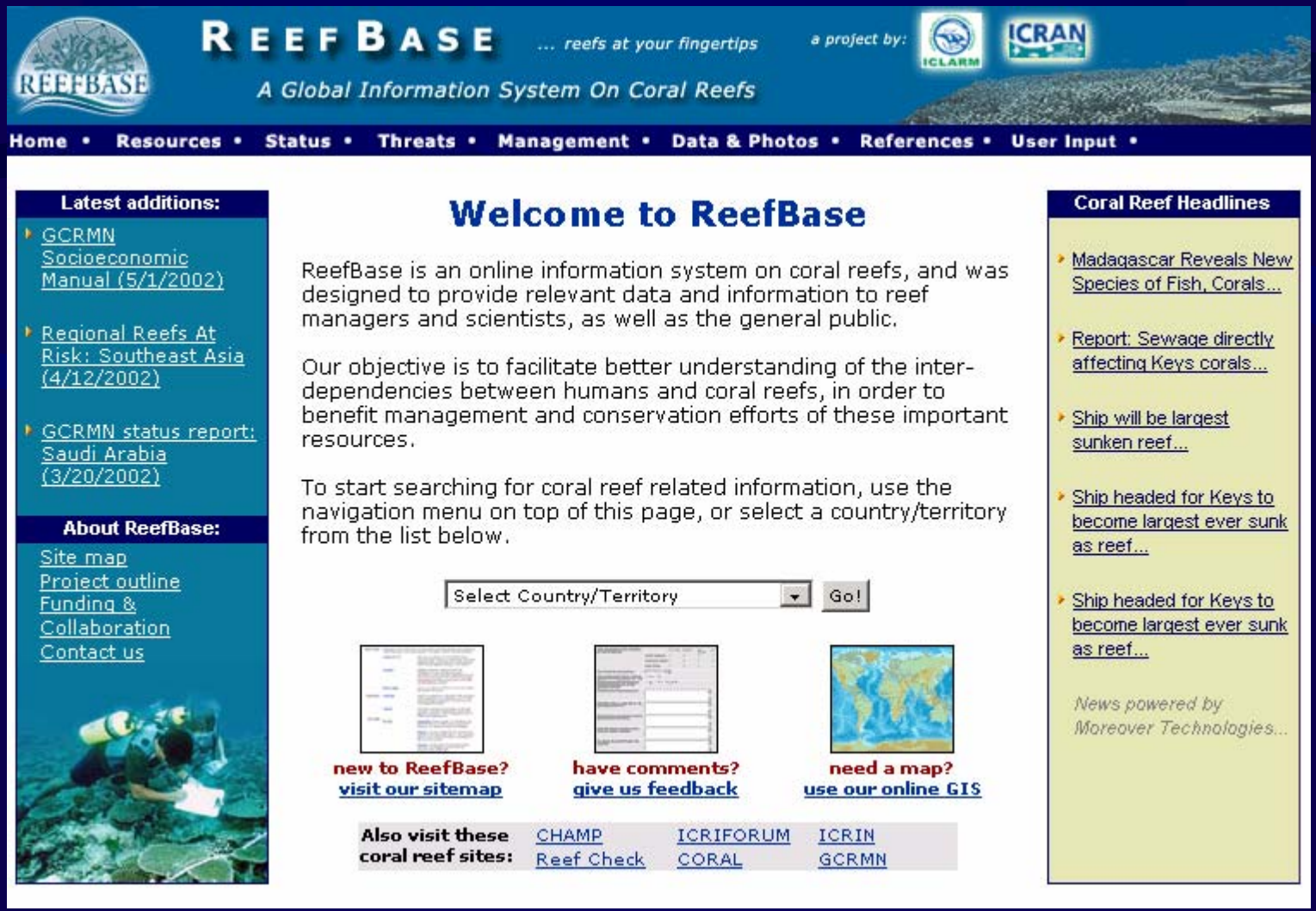
Bathymetry from Digital Photographs



Stumpf, Holdereid, Robinson, Feldman and Kuring, 2003, Mapping water depths in clear water from space. *Proceedings of the 13th International Coastal Zone Conference*, Baltimore, MD, 5 pp.

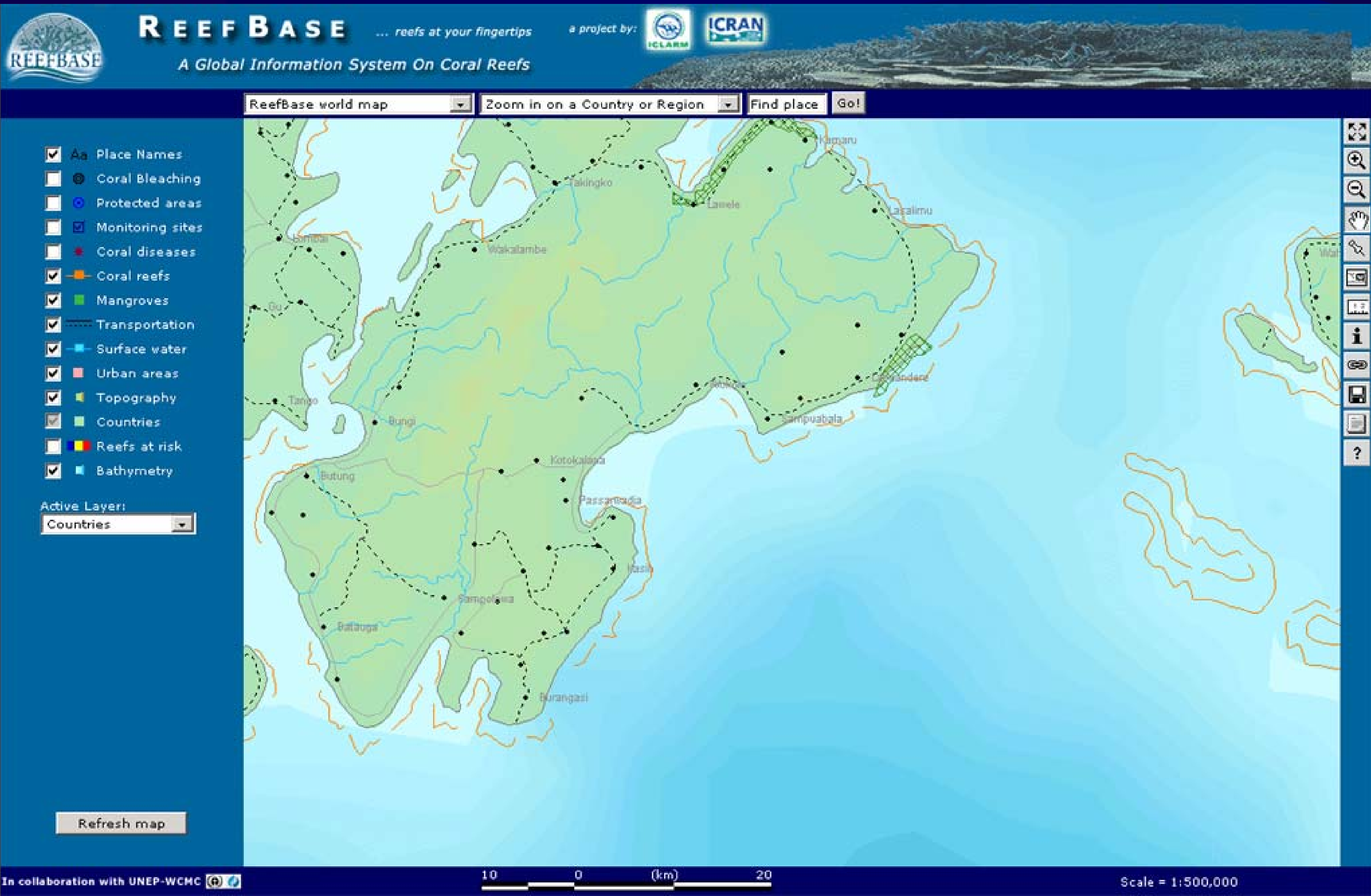


Reef Map and Image Distribution: ReefBase



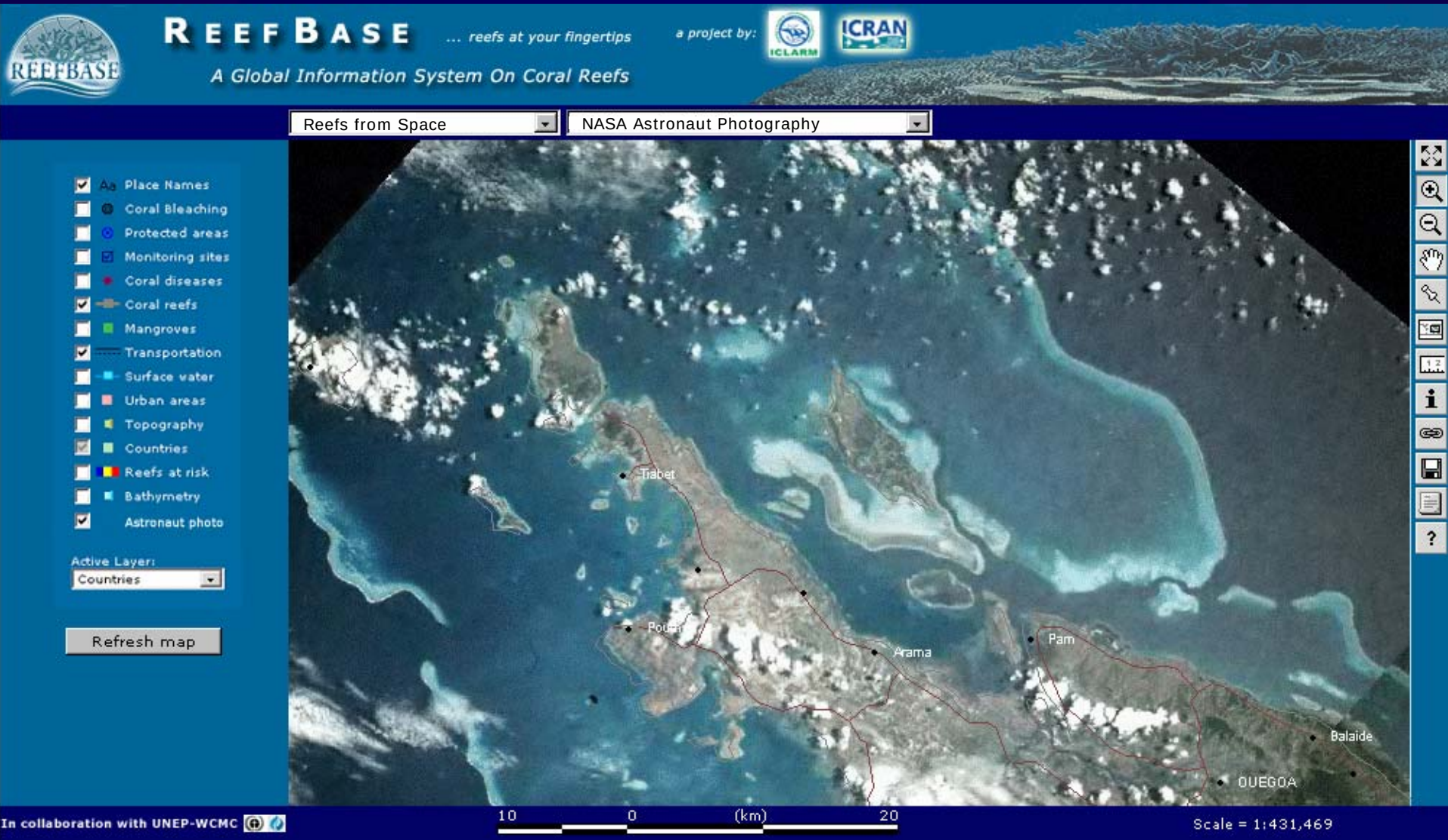
http://www.reefbase.org/

Went public April 2002



REEFBASE
REEF BASE
... reefs at your fingertips
a project by:
ICLARM
ICRAN
A Global Information System On Coral Reefs
ReefBase world map
Zoom in on a Country or Region
Find place
Go!
Place Names
Coral Bleaching
Protected areas
Monitoring sites
Coral diseases
Coral reefs
Mangroves
Transportation
Surface water
Urban areas
Topography
Countries
Reefs at risk
Bathymetry
Active Layer:
Countries
Refresh map
Kamaru
Takingko
Lawele
Lasalimu
Wakalambe
Tango
Bungi
Butung
Sampolawa
Batauga
Burangasi
In collaboration with UNEP-WCMC
10
0
(km)
20
Scale = 1:500,000

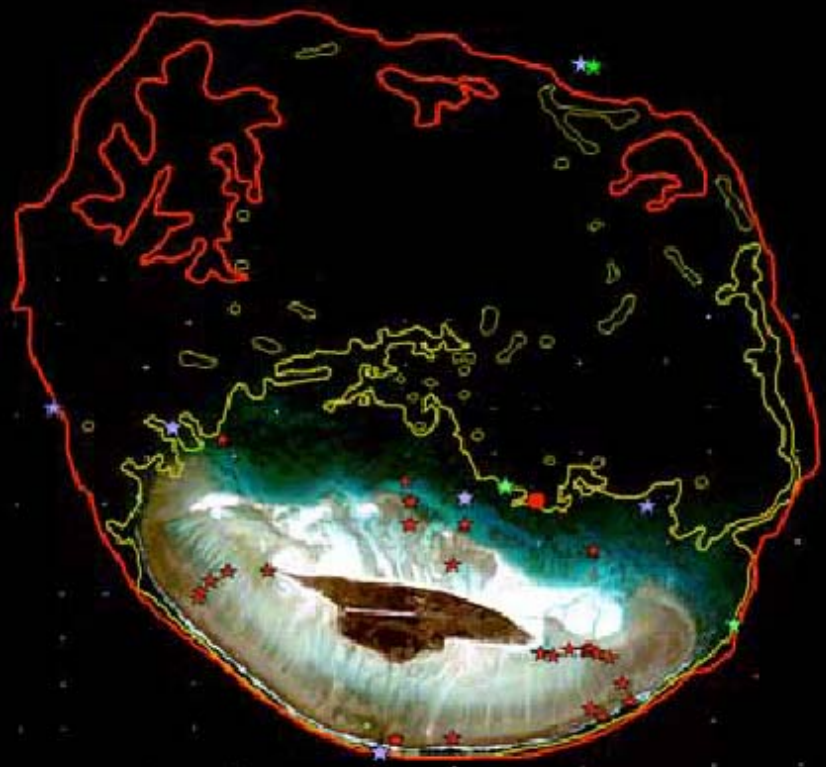
Astronaut Photography in ReefBase

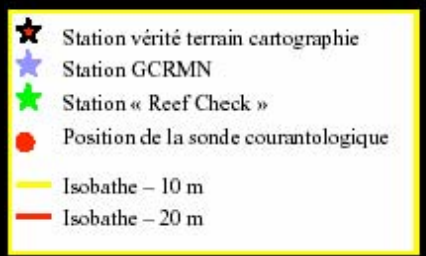


Public by end of 2002

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