Introduction to Remote Sensing for Ocean and Coastal Applications

Week 4: Coral Reefs
Course Structure

• One lecture per week – every Wednesday July 6 – July 27
• 1:00 – 2:00 PM EDT (UTC-4)
  – Lectures
  – In-class demonstration
  – Homework exercises, due August 10th
• Webinar recordings, presentations, and homework assignments can be found after each session at:
• Q/A: Following each lecture and/or by email (sherry.l.palacios@nasa.gov)
Accessing Course Materials


Course Agenda:

- **Agenda.pdf**

**Session One: Overview of Satellite Remote Sensing of Aquatic Environments**

**July 6, 2016**

An overview of themes in coastal and ocean applied science, how remote sensing is used for coastal and ocean applied science, fundamentals of remote sensing (spatial, temporal, spectral resolutions), and the advantages and limitations of remote sensing in aquatic environments. View the recording »

- Presentation Slides »

**Session Two: Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools**

**July 13, 2016**

Satellites and sensors for coastal and ocean applications, satellite data processing levels, NASA satellite data access tools and data processing tools. View the recording »

- Presentation Slides »
Your Course Instructors

- Sherry Palacios: sherry.l.palacios@nasa.gov
- Amber McCullum: amberjean.mccullum@nasa.gov
- Cindy Schmidt: cynthia.l.schmidt@nasa.gov

Guest Speakers:
- Mitchell Roffer, Roffer’s Ocean Fishing Forecast Service (Week 3)
- Mark Eakin, NOAA Coral Reef Watch (Week 4)

General ARSET Inquiries
- Ana Prados: aprados@umbc.edu
Course Objectives

• Overview of NASA Earth Observation resources available for open ocean and coastal applications including:
  – A basic understanding of remote sensing of aquatic systems
  – How to access and visualize NASA Earth science data
  – How to use NASA Earth science data, tools, and products for ocean and coastal applied science issues

• Conduct live demonstrations of useful ocean and coastal applied science tools
Course Outline

Week 1
Overview of Satellite Remote Sensing

Week 2
Platforms and Sensors for Ocean Observations

Week 3
Animal Movement

Week 4
Coral Reefs
Week 4 Agenda

• Overview of coral biology
• Threats to coral reefs
  – Local
  – Global
• Remote sensing of coral reefs
• Examples of remote sensing tools for understanding coral reef systems
• Live Demo:
  – Dr. Mark Eakin: NOAA Coral Reef Watch

Credit: XL Catlin Seaview Survey, Osprey Reef, Great Barrier Reef
Overview of Coral Biology
Worldwide Distribution of Coral Reefs

Reefs at Risk Revisited (2011)

Credit: Reefs at Risk Revisited
Worldwide Distribution of Coral Reefs

Reefs at Risk Revisited (2011)

Credit: Reefs at Risk Revisited
The Tropical Coral Reef and its Allies

- Scleractinian “stony” corals
- Mangroves
- Seagrasses
- Upland watersheds
- Open ocean

Credits: The Bahamas Trust, P. Selvaggio, B. Ross
Scleractinian Coral Biology

• Hundreds of thousands of tiny (1-3mm diameter) polyps make up a coral colony

• Secretes calcium carbonate skeleton that makes the coral “stony”

• Stings prey with tiny stinging cells called nematocysts

• Part of a mutually symbiotic relationship with dinoflagellate (commonly known as zooxanthellae)

Credit: NR Fuller, Sayo Studio
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Coral Reef Systems

• Ecosystem engineers
• Oases of biodiversity in the tropical ocean
• Nursery grounds for many animal species
• Hotspots of productivity

Credit: Reefs at Risk Revisited
Coral Reef Systems

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<tr>
<th>Biome</th>
<th>Productivity (kg C/ m²/yr)</th>
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<tbody>
<tr>
<td>Average Oceanic Areas</td>
<td>0.1</td>
</tr>
<tr>
<td>Temperate Grassland</td>
<td>1</td>
</tr>
<tr>
<td>Rainforest</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Kelp Forest</td>
<td>2</td>
</tr>
<tr>
<td>Intensive Alfalfa Crop</td>
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<td>Coral Reef</td>
<td>1.5 - 5</td>
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Threats to Coral Reefs
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Reefs at Risk – Revisited (2011)

Local Threats
- Coastal Development
- Watershed-Based Pollution
- Marine-Based Pollution and Damage
- Overfishing and Destructive Fishing

Global Threats
- Past Thermal Stress
- Future Thermal Stress
- Ocean Acidification

Credit: Reefs at Risk Revisited (http://www.wri.org/publication/reefs-risk-revisited), NASA JPL
Local Threats by Region

Middle East

Credit: Reefs at Risk Revisited
Local Threats by Region

Indian Ocean

Credit: Reefs at Risk Revisited
Local Threats by Region
Southeast Asia

Overfishing

Credit: Reefs at Risk Revisited
Local Threats by Region
Australia

Integrated Global Threats: Climate Change

Credit: Reefs at Risk Revisited
Local Threats by Region

Pacific Ocean

Credit: Reefs at Risk Revisited
Local Threats by Region
Caribbean Sea/Atlantic Ocean

Credit: Reefs at Risk Revisited

Overfishing & Mechanical Destruction
Global Threats
Rising Ocean Temperature

- Ocean temperatures are rising with climate change
- Extended periods of above normal temperatures result in coral expelling zooxanthellae, pigment loss, or both. Also called coral bleaching
- 2014 – 2016 has been an unprecedented bleaching event
- Elevated temperature makes corals susceptible to disease

Credit: Reefs at Risk Revisited
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Credit: XL Catlin Seaview Survey/Underwater Earth
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Ocean Acidification

- Atmospheric CO₂ equilibrates with seawater resulting in rising ocean pCO₂
- CO₂ reacts with seawater causing a decrease in pH: it becomes more acidic
- Low pH water ‘dissolves’ calcium carbonate
- Coral skeletons are made of a particularly vulnerable crystal form of calcium carbonate known as aragonite
- Ocean acidification threatens the growth and sustainability of coral reef systems

Credit: Reefs at Risk Revisited
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Credit: Modified from Feeley 2008
Characteristics of Degraded Coral Reefs

- Reduced habitat complexity
- Phase shifts from stony corals to fleshy macroalgae, soft corals, and sponges
- Reduced numbers of grazing fish
- Coral bleaching
- Physical destruction (e.g., from blast fishing)

Credit: XL Catlin Seaview Survey
Socio-Economic Consequences of Degraded Coral Reefs

Reef Dependence & Adaptive Capacity Govern Vulnerability

Credit: Reefs at Risk Revisited
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Reef Dependence & Adaptive Capacity Govern Vulnerability

Credit: Reefs at Risk Revisited
Conservation

- Efforts are underway to ‘re-seed’ reefs after major bleaching events
- Marine protected areas (MPAs) and locally managed marine fisheries are being used to lessen the impact on top predators or grazers
- Remote sensing can be used to monitor reef condition
Remote Sensing of Coral Reefs
Remote Sensing for Coral Reef Monitoring
S. Phinn & C. Roelfsema, Editors

- Used to measure benthic type, reef structure, water quality, sea surface temperature
- Spatial, temporal, and spectral scale have large impact on the types of questions that can be asked
- Deriving coral productivity from imagery is in its early stages of development

Hedley et al. 2016
Remote Sensing for Coral Reef Monitoring

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Hedley et al. 2016
# Observing Environmental Factors with Remote Sensing

Hedley et al. 2016

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# Remote Sensing Technologies for Coral Reef Mapping

**Hedley et al. 2016**

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National Aeronautics and Space Administration

Applied Remote Sensing Training Program
Spatial Scale Needed for Imagery Varies by Question

Example: Heron Island, Australia

Example Question:

Hedley et al. 2016
• CORal Reef Airborne Laboratory (CORAL)

• Question: What is the relationship between coral reef condition and biogeophysical forcing parameters?
  – Measure condition of corals: proportion of coral, algae, and sand, calcification, and primary productivity
  – Establish empirical models (some using remote sensing inputs) to assess coral condition

• Sensor: Portable Remote Imaging SpectroMeter (PRISM)
Examples of Remote Sensing Tools for Understanding Coral Reef Systems
Australia’s eReefs

ReefTemp

- ReefTemp is a web interface to view sea surface temperature data for the Great Barrier Reef
- It is a data portal that provides near real-time access to water temperature data
- It is freely available

Australia’s eReefs

eReefs Marine Water Quality Dashboard

- The transparency of the water column has a big impact on coral health
- The dashboard is a data portal that provides near real-time access to water quality data for different reef regions of Australia
- The tool permits viewing, statistics, and the download of data
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Special Guest: Dr. Mark Eakin

NOAA Coral Reef Watch: http://coralreefwatch.noaa.gov/satellite/index.php

http://coralreefwatch.noaa.gov/satellite/education/tutorial/crw29_exercises.php
Live Demo: NOAA Coral Reef Watch
NOAA Coral Reef Watch:
Coral Bleaching Products and the Biggest Bleaching Event in History

Dr. C. Mark Eakin
NOAA Coral Reef Watch
http://coralreefwatch.noaa.gov
2015 Coral Bleaching: American Samoa

December 2014

http://coralreefwatch.noaa.gov
2015 Coral Bleaching: American Samoa

February 2015

http://coralreefwatch.noaa.gov
2015 Coral Bleaching: American Samoa

August 2015

http://coralreefwatch.noaa.gov
What is Coral Bleaching?

- Most of corals’ food comes from photosynthesis
- Corals can “bleach” due to stress
- Corals exposed to high temperatures and/or high light become stressed
- Corals eject their algae; coral appears “bleached”
  - If stress is mild or brief, corals recover, otherwise they die
Coral Reef Watch
5-km Satellite-Based Products

Sea Surface Temperature

http://coralreefwatch.noaa.gov
Coral Reef Watch
5-km Satellite-Based Products

NOAA Coral Reef Watch Daily 5-km Blended Geo-Polar Nighttime SST Anomaly 17 Oct 2014

SST Anomaly

http://coralreefwatch.noaa.gov
Coral Reef Watch
5-km Satellite-Based Products

Degree Heating Week

http://coralreefwatch.noaa.gov
Coral Reef Watch
5-km Satellite-Based Products

Bleaching Alert Area

http://coralreefwatch.noaa.gov
Coral Reef Watch: Product Comparison

5 km Geostationary-Polar Blend

- **Climatology:** 22 year, 4 km (Pathfinder AVHRR)
- **Data:**
  - 5 km Operational Blended, night only
  - Polar-orbiters (2) + Geostationary (4)
  - Up to 50 scenes/day

50 km Polar-only (Operational)

- **Climatology:** 7 year, 50 km (AVHRR)
- **Data:**
  - 50 km Operational, night only
  - Polar-orbiter (1)
  - Max 1 scene/day
2014-5: New Coral Reef Watch
5-km Product Suite for Coral Bleaching

http://coralreefwatch.noaa.gov
Local Use of 5-km products

**Coral Bleaching**

One coral bleaching report was received through the Eyes of the Reef Network in June and July 2014. There was Bleaching "Watch" alert issued for Oahu through NOAA Coral Reef Watch. No Rapid Responses were initiated.

- NOAA (National Oceanographic and Atmospheric Administration)
- Local Use of 5-km products
- June/July 2014 EOR Report Summary

**Florida Department of Environmental Protection**

Coral Reef Conservation Program
SEAFAN BleachWatch Program

Current Conditions Report 20140902

**September 2, 2014**

**Environmental Monitoring**

The latest CRW experimental 5 kilometer (km) Daily Coral Bleaching Alert Area (Figure 1) indicates that southeast Florida is presently experiencing a moderate to high level of thermal stress, with an Alert Level 1 or Bleaching Warning present throughout the region. This indicates that bleaching is likely in southeast Florida and additional alerts are possible if current conditions continue or worsen.

- NOAA's Bleaching Hotspot Map compares current SST to the maximum monthly mean, which is the average temperature during the month.

**Notable Observations**

- Sea surface temperature (SST) anomalies have decreased significantly across most of the equatorial Pacific. La Nina is favored to develop during the Northern Hemisphere summer with a high chance that it will evolve through fall and winter 2014-2015... read more...
- Warn SST on the Caribbean but no significant thermal stress expected outside the southwestern Caribbean at this time.
- Bleaching warnings issued for the Florida Keys, N Bahamas, NW & SW Cuba, Bleaching notches in TCI, Brit, Cayman Is., Jamaica & Hispaniola.

**CARIBBEAN CORAL REEF WATCH**

**Western Indian Ocean – Regional coral bleaching alert**

**DATE OF THIS ALERT: 4 January 2016**

http://www.cordio.noaa.gov/bleachingalert/

**NOAA Products – 2 January**

**Current CRW Data 2 January 2016**

- Bleaching Alertread high values at all virtual NOAA stations, with only the 3 closest locations showing no stress (Somalia, Maputo and South Africa), 11 at Bleaching Watch and 7 at Bleaching Warning level.
- Tropical Cyclones
- Bleaching observations

**Grande Comores**: Initial observations indicate bleaching is already starting on Grande Comores, at a “moderate” level. Read Alarms/NOAA Comoros
Global Bleaching: Last Half of 2014

NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2014

- No Stress
- Watch
- Warning
- Alert Level 1
- Alert Level 2

Florida

Marshall Islands

Guam & Marianas

Hawaii

http://coralreefwatch.noaa.gov
Global Bleaching: 2015

NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2015

http://coralreefwatch.noaa.gov
Global Bleaching: First Half of 2016

NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area 1 Jan – 19 July 2016

Western India
Seychelles
Kenya/Tanzania
Mozambique
Maldives
Réunion
Mauritius
Madagascar
Taiwan
Philippines
New Caledonia
Fiji
Kiribati
E. Australia
French Polynesia
93% of reefs with bleaching

Far Northern GBR with 95% severe bleaching & 50% dead
Great Barrier Reef Bleaching: 2016

Justin Marshall, Coral Watch
The lack of fish was an indication that there was “complete ecosystem collapse”
Justin Marshall, Univ. of Queensland
The Guardian 21 July 2016
Global Bleaching: Early 2016

- 80% dead
- 15% bleached
- 5% “normal”
Global Bleaching: Early 2016

- 95% dead
- 4% bleached
- <1% “normal”
June 2014-June 2016 Thermal Stress

Global Reefs:
- > 40% @ Alert Level 1 or 2
- Level 2 Area > Massachusetts
- Over ½ exposed twice
- ~100% stressed

US Reefs:
- 72% Alert Level 1 or 2
- Over ½ exposed twice
- 100% stressed
Bleaching Risk Through October 2016

- Severe bleaching likely in NE Philippines, Micronesia, Guam/CNMI, Marshall Islands
- Bleaching likely in Hawai'i, Caribbean

2016 July 19 NOAA Coral Reef Watch 60% Probability Coral Bleaching Thermal Stress for July - Oct 2016

Potential Stress Level:  
- Watch  
- Warning  
- Alert Level 1  
- Alert Level 2
Management Responses: Thailand Reef Closures

NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area YTD
18 June 2016

[Map showing coral bleaching alert areas with Thailand highlighted]
Thailand closes dive sites over coral bleaching crisis

In a rare move to shun tourism profits for environmental protection, 10 popular dive sites have been shut down in a bid to slow a coral bleaching crisis.
Management Responses: 2015 Hawai’i Bleaching – DAR “Ark”
Key Messages

New 5-km product suite
- Just in time for 2014 bleaching
- Higher resolution, better regional products
- Excellent use by community

2014-17? Bleaching:
- Longest, most widespread, often repeated bleaching
- > 40% of global reefs affected
- 72% of U.S. reefs affected

@CoralReefWatch  CoralReefWatch

CoralReefWatch.NOAA.Gov
Questions?

Dr. C. Mark Eakin
NOAA Coral Reef Watch

http://coralreefwatch.noaa.gov

Facebook Coral Reef Watch Twitter @CoralReefWatch
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Week 4 Agenda

• Overview of coral biology
• Threats to coral reefs
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• Remote sensing of coral reefs
• Examples of remote sensing tools for understanding coral reef systems
• Live Demo:
  – Dr. Mark Eakin: NOAA Coral Reef Watch

Credit: XL Catlin Seaview Survey, Osprey Reef, Great Barrier Reef
Course Summary

• A basic understanding of remote sensing of aquatic systems

• How to access and use NASA Earth science data, tools, and products for ocean and coastal applied science issues

• Demonstrations of Applied Science tools developed in partnership with NASA
  – animal movement
  – coral reefs

Eye of an Algal Storm
Cyanobacteria Bloom in the Baltic Sea

http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/Sentinel-2_catches_eye_of_algal_storm
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