NOAA Operational Satellite SST for Monitoring Coral Bleaching Thermal Stress

NOAA Coral Reef Watch's Decision Support System for Coral Reef Managers

NOAA Coral Reef Watch

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
2013
SATELLITE CONFERENCE
for Direct Readout, GOES/POES, and GOES-R/JPSS Users

NOAA CORAL REEF CONSERVATION PROGRAM

http://coralreefwatch.noaa.gov

GLOBAL SCIENCE & TECHNOLOGY, INC.

Presentation Outline

- Introduction to corals, coral reefs, and bleaching
- Satellite remote sensing for coral reef monitoring
- NOAA Coral Reef Watch (CRW)'s current operational near-real-time satellite coral bleaching monitoring products
- Demonstration: CRW near-real-time monitoring of major coral bleaching events
- New CRW satellite products for monitoring coral health

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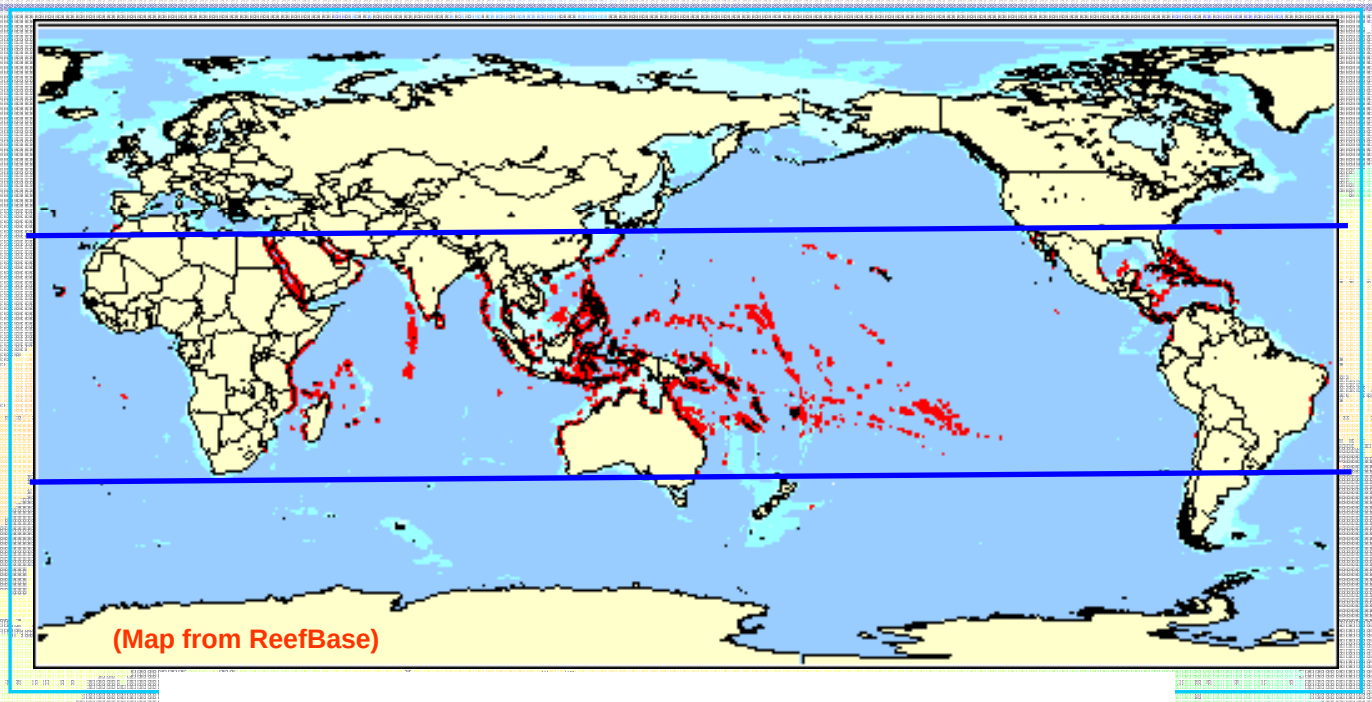
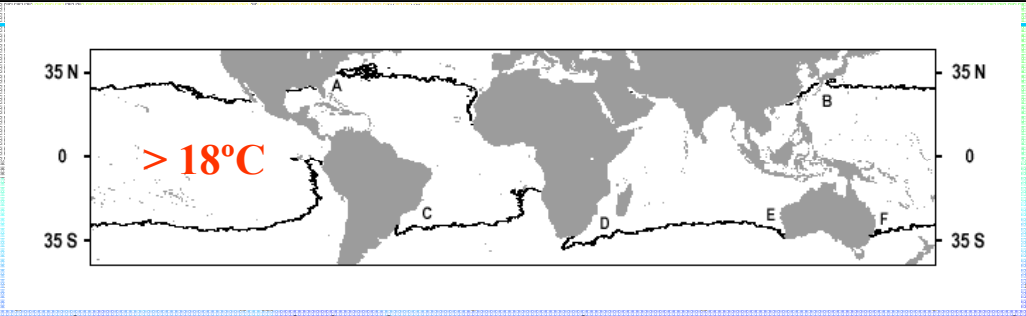
Distribution of world's coral reefs



(35S-35N)



- Coral reefs thrive in global tropical regions: >18°C (35S-35N)
  - covering less than 1% of the Earth's surface
  - providing habitat for 25% of all known marine species

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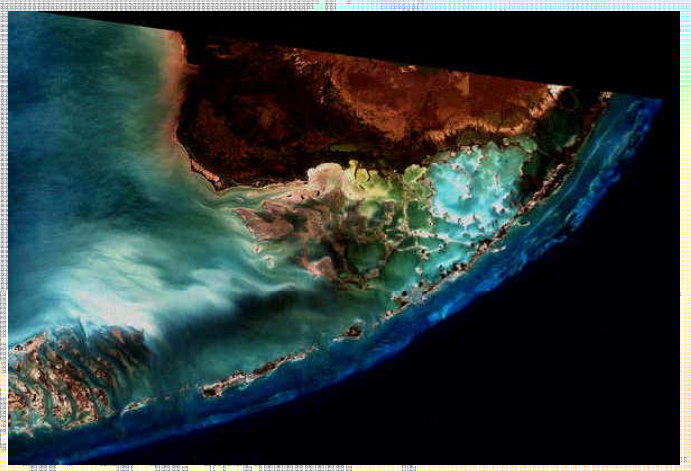
Coral Reefs As Seen from Space

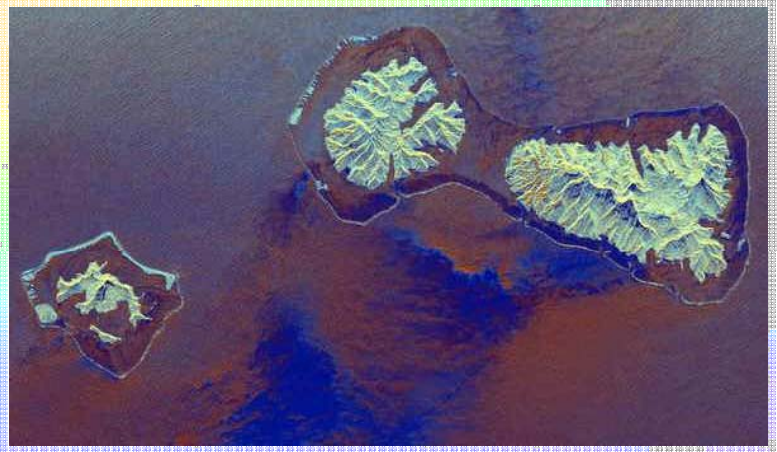


Florida Keys

GBR, Australia

Midway Atoll

Maldives-atolls



Raiatea and Taha'a, French Polynesia

Spatial scale of individual reefs: meters to tens of kilometers

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Coral Reefs As Seen from Airplanes

Rose Atoll, American Samoa

Molokini

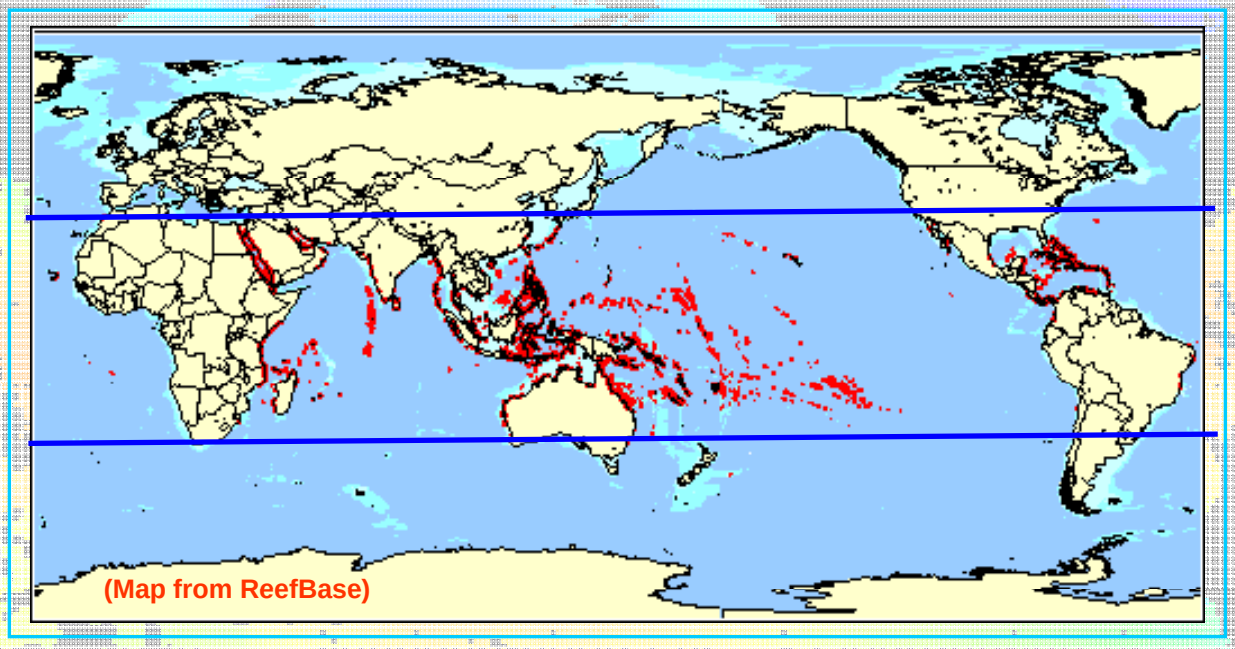
Midway Atoll

Cayman Island

Johnston Atoll

Spatial scale of individual reefs: meters to tens of kilometers

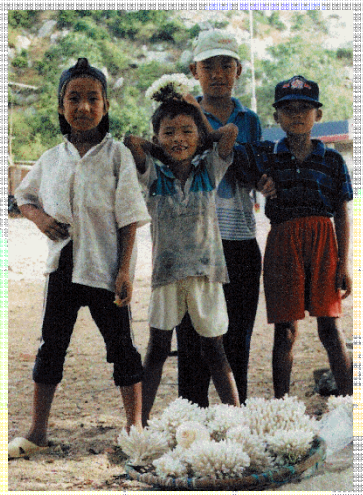
Why Satellite Remote Sensing for Coral Reef Monitoring?



(35S-35N)

- Offshore, around remote islands, and covering large areas
- Need:
  - Global monitoring
  - Reaching remote areas
  - Synoptic view of large area
  - Real-time or near-real-time monitoring

Importance of Coral Reefs



Photos by Anthony R. Picciolo (left) and Heidi Schuttenberg (right)

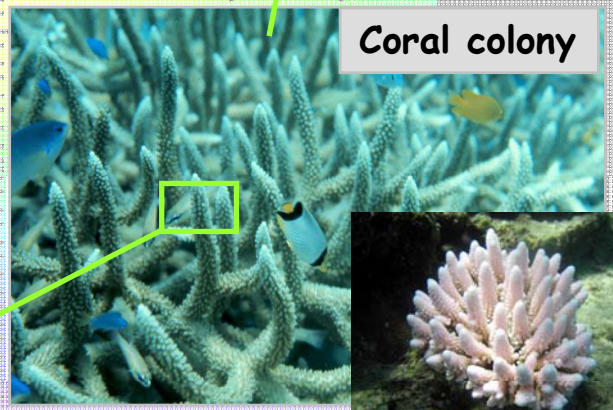
Coral Reefs cover less than 1% of the Earth's surface, but

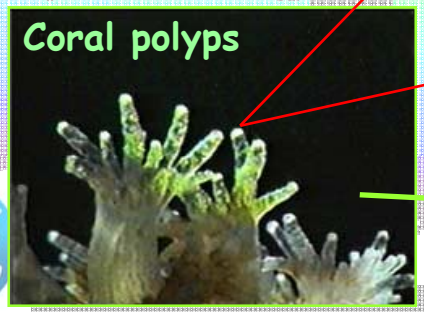
- -- provide habitat for 25% of all known marine species
- -- support approximately 500 million people
  - -- support culture
  - -- provide food security and support fishing industry
  - -- protect coastal areas from erosion, storm damage, and flooding
  - -- attract tourists and tourism dollars
  - -- provide biomaterials, bioactive compounds, potential medicines

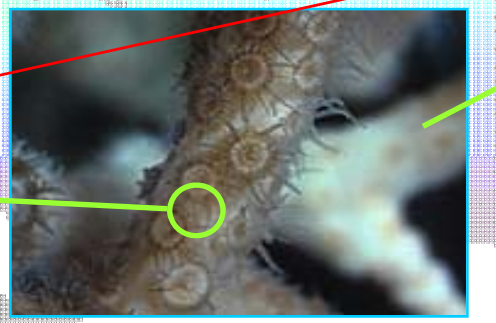
Coral Reef, Coral, and Symbiotic Algae

- Symbiotic relationship between algae (zooxanthallae) and their host corals
- Healthy coral tissue shows various symbiotic algae colors ranging from yellow to brownish
- Most of coral's food comes from photosynthesis of its symbiotic algae
- Algae use and remove waste produced by host corals

Symbiotic algae
(Zooxanthallae)







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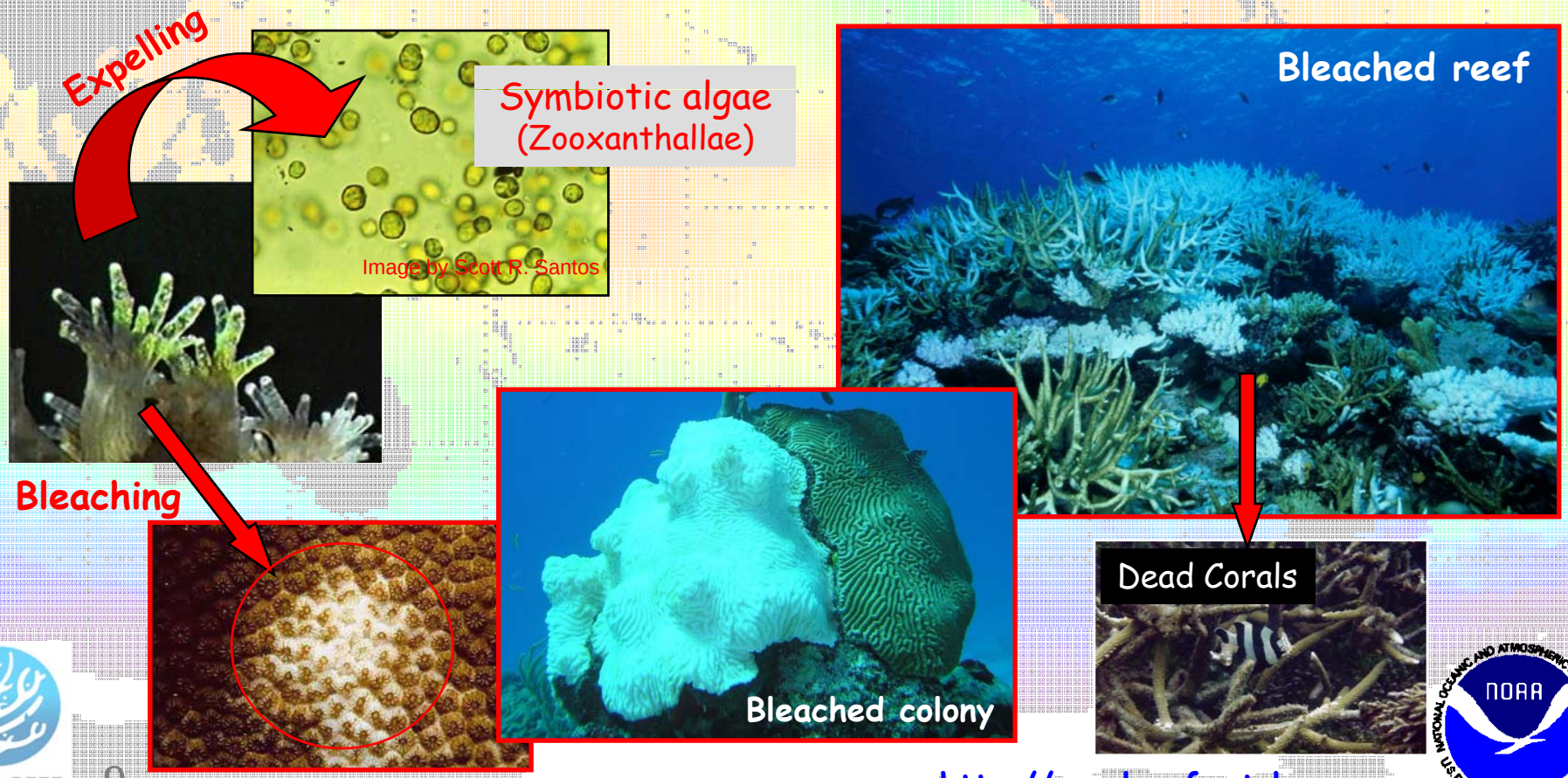
Coral and Coral Bleaching

-- Under certain environmental stresses, the symbiotic relationship may break down and the algae can be expelled by the host corals

-- Bleached colony becomes pale, even stark white, revealing its underlying white calcium carbonate skeleton through translucent coral tissue

-- If stress is mild or brief, bleached corals recover, otherwise they can die



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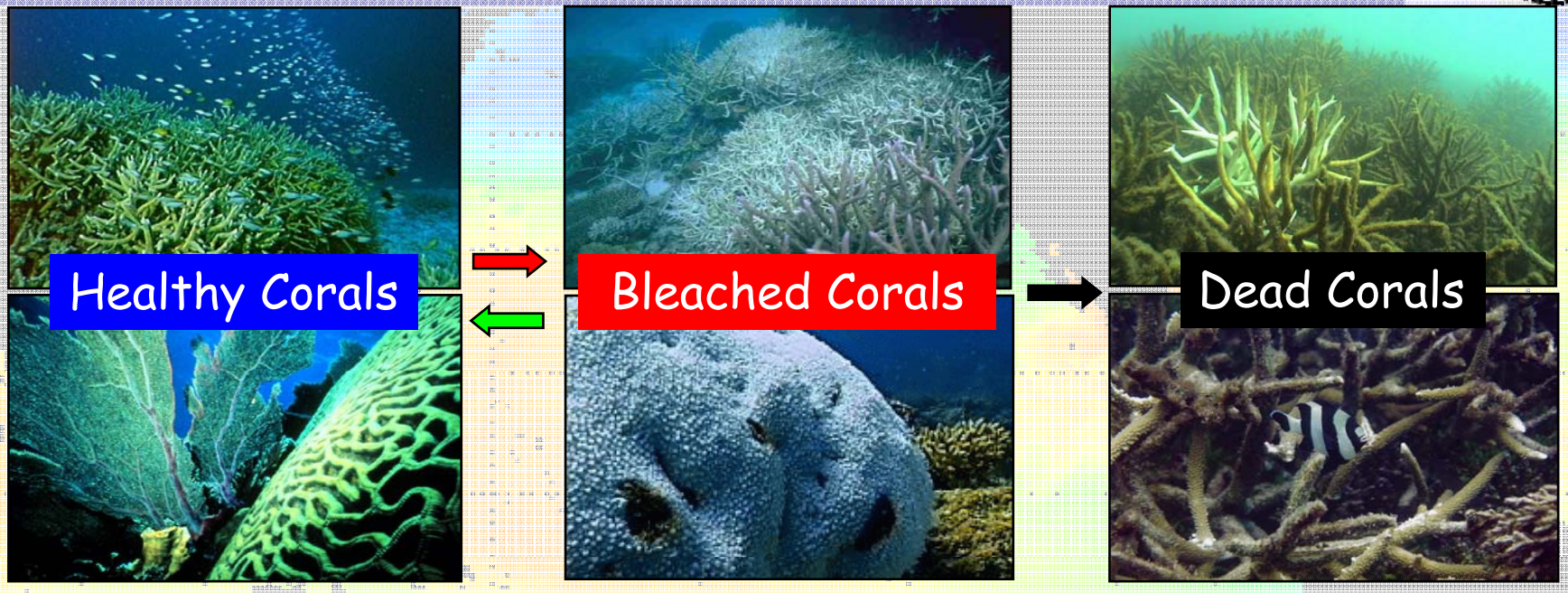
Coral Bleaching & Coral Reefs in Crisis



- Dramatic long-term ecological and social consequences
- The world has effectively lost 19% of the existing area of coral reefs in recent decades; 15% are seriously threatened with loss within the next 10–20 years; 20% are under threat of loss in 20–40 years

  --- *(Status of Coral Reefs of the World 2008)*
- High-temperature induced bleaching has increased in frequency & intensity over the past few decades – a major threat to the world's coral reefs

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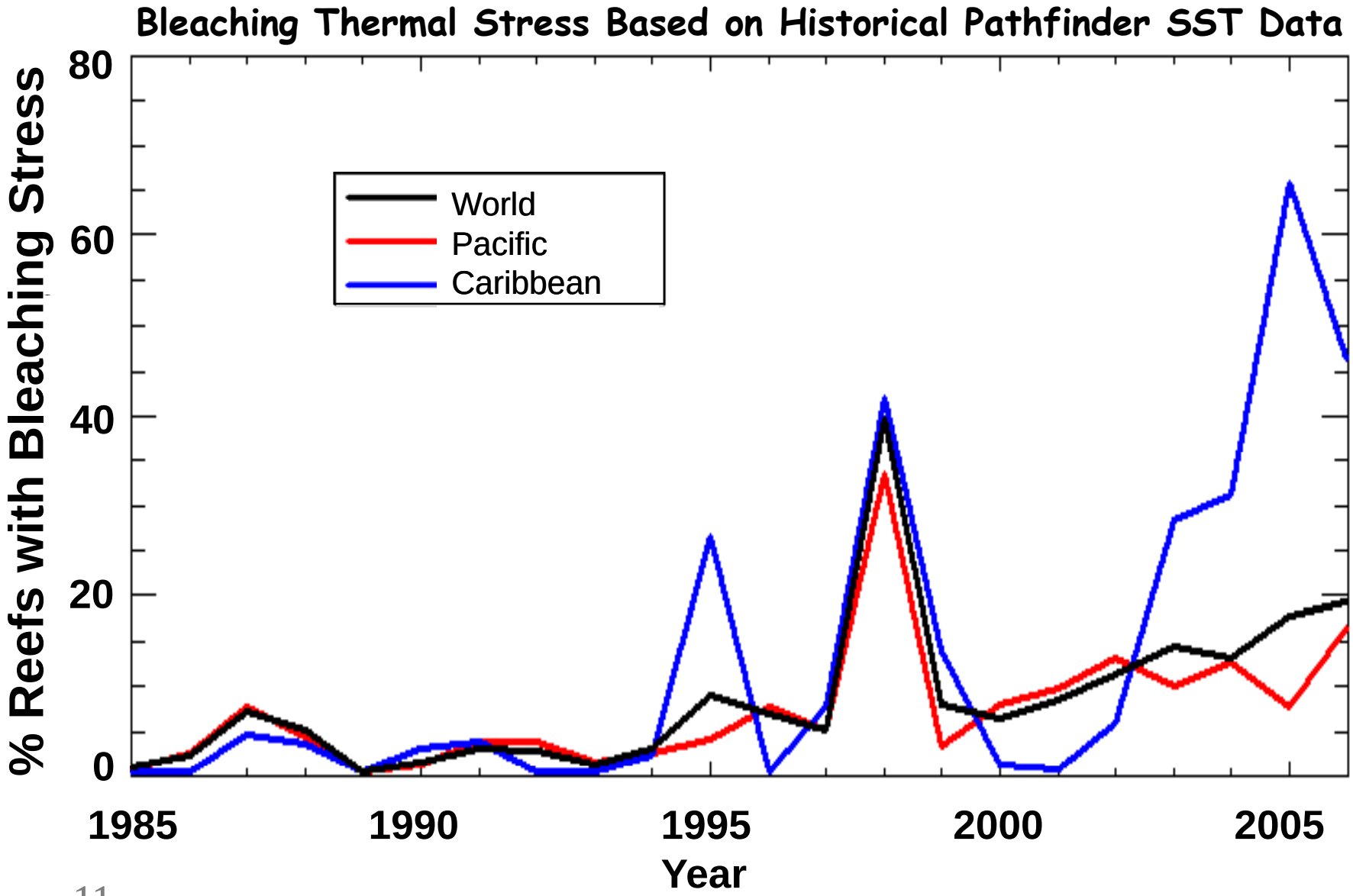
Increasing Bleaching Thermal Stress



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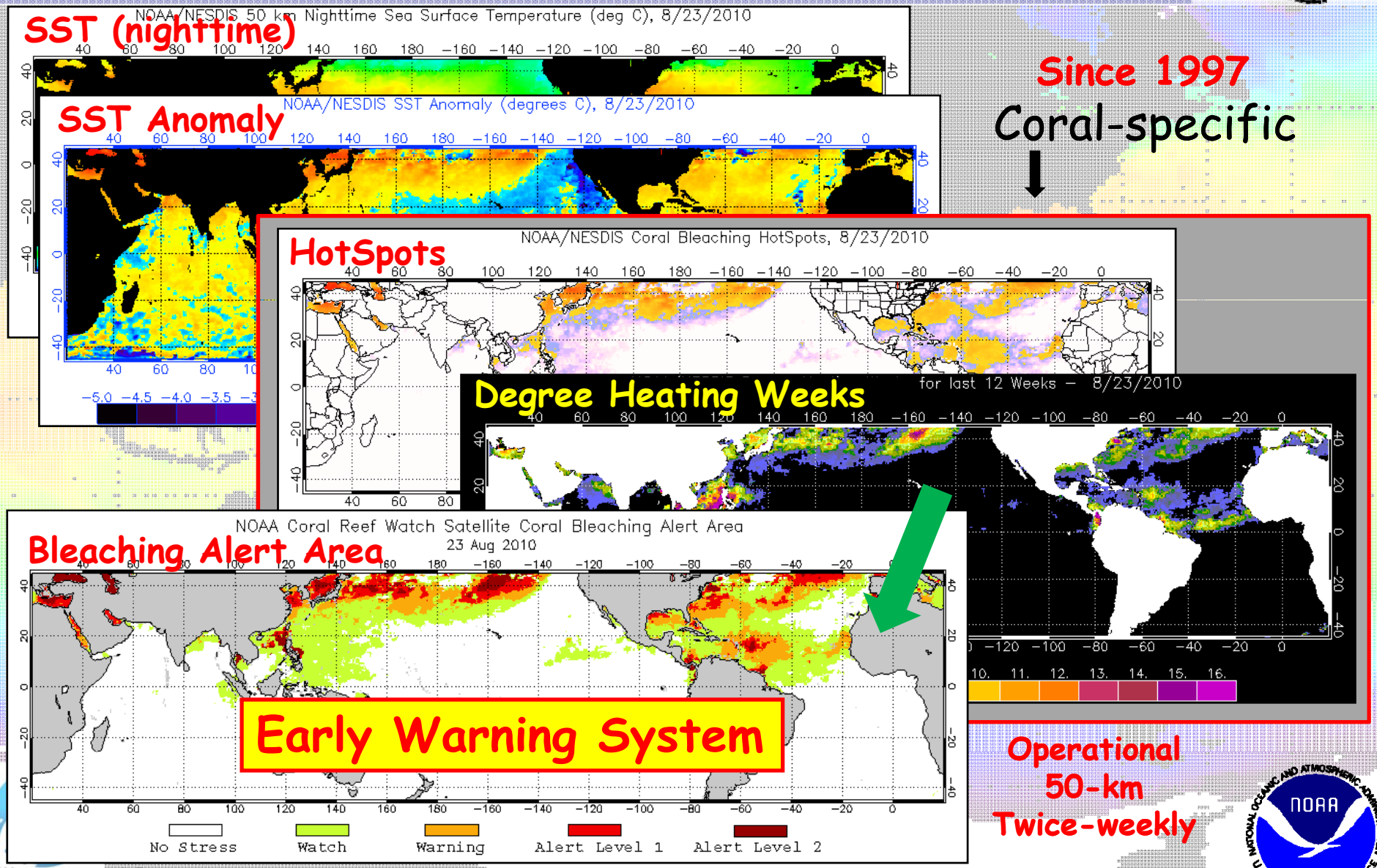
Satellite Bleaching Thermal Stress Monitoring



Since 1997

Coral-specific

Early Warning System

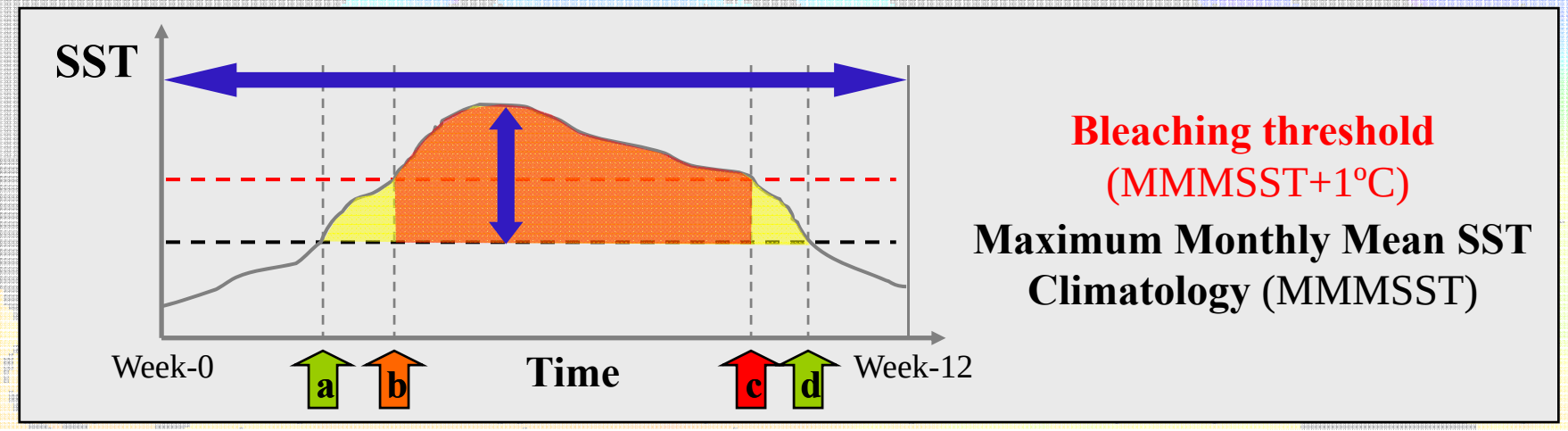
Operational

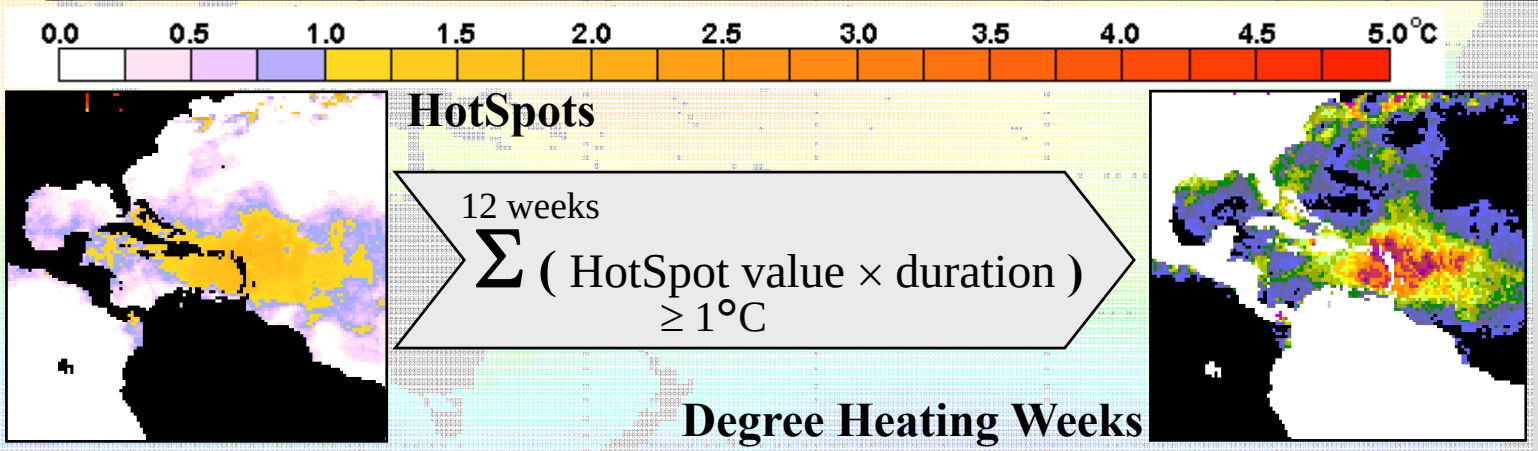
50-km

Twice-weekly

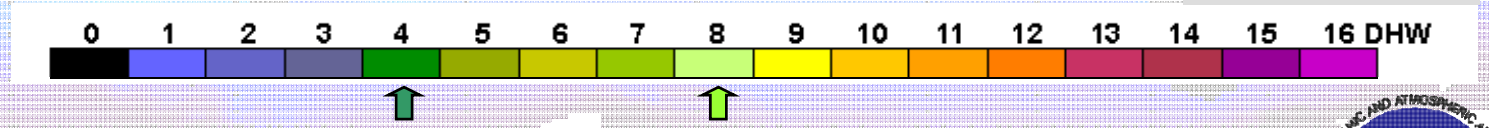
NOAA Coral Reef Watch

Satellite Bleaching Thermal Stress Monitoring





DHW: cumulative measure of thermal stress intensity and duration during the most-recent 12-week period



≥ 4 DHWs → coral bleaching is expected

≥ 8 DHWs → widespread bleaching and mortality are expected

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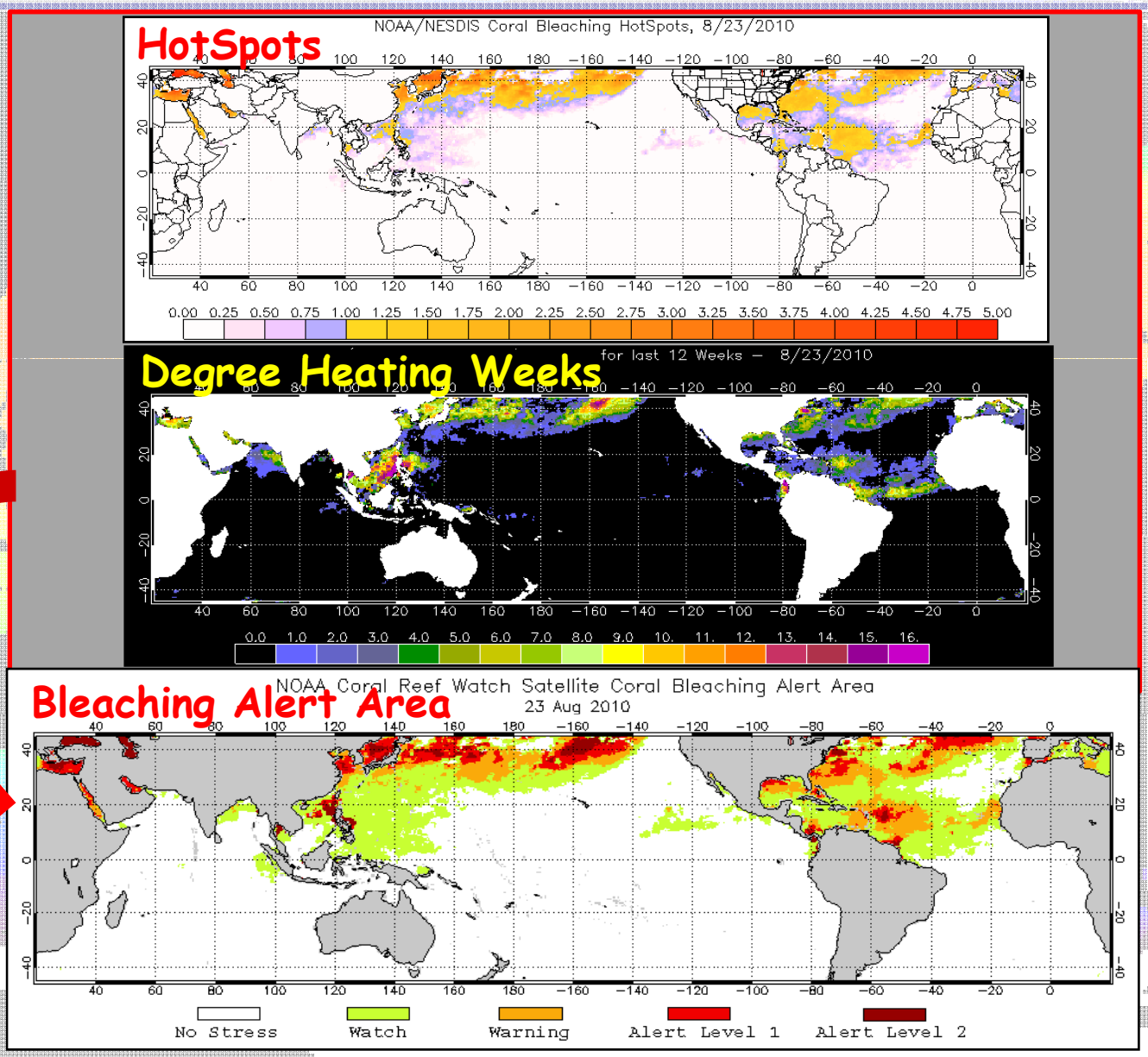
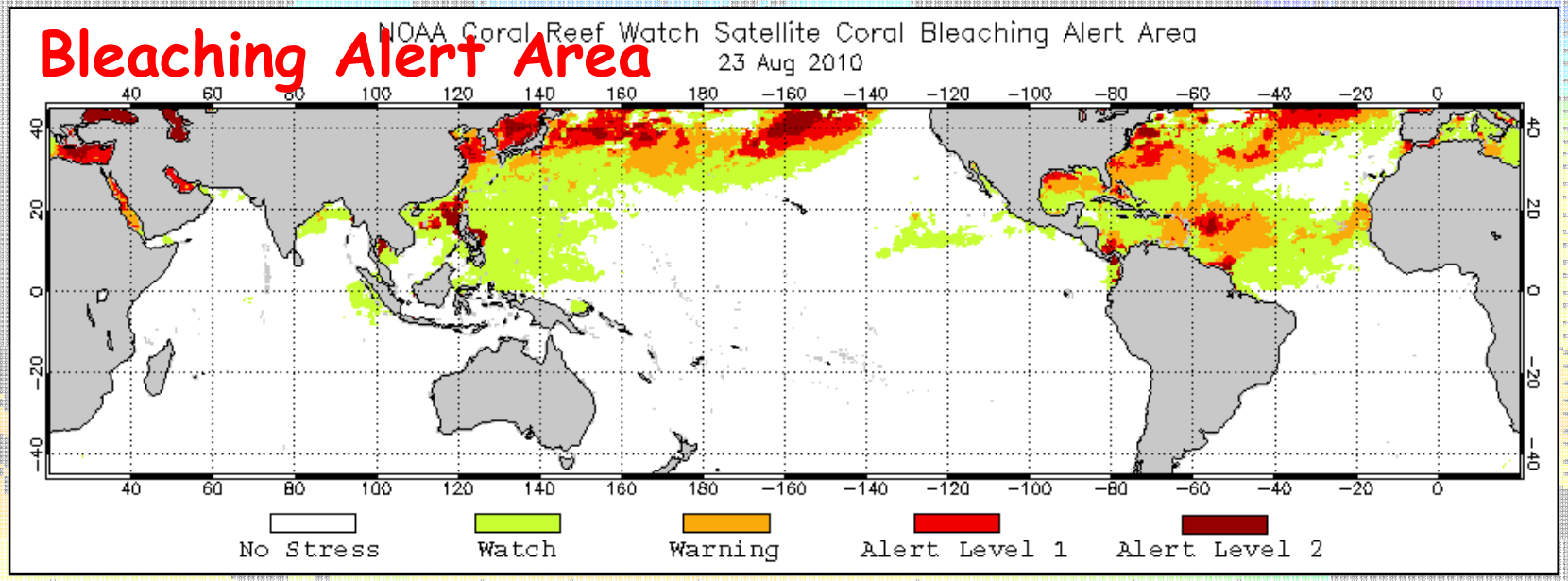
Satellite Bleaching Thermal Stress Monitoring



NOAA Coral Reef Watch

Satellite Bleaching Thermal Stress Monitoring



Stress Level	Definition	Potential Bleaching Intensity
No Stress	HotSpot ≤ 0	No Bleaching
Bleaching Watch	0 < HotSpot < 1	
Bleaching Warning	1 ≤ HotSpot and 0 < DHW < 4	Possible Bleaching
Bleaching Alert Level 1	1 ≤ HotSpot and 4 ≤ DHW < 8	Bleaching Likely
Bleaching Alert Level 2	1 ≤ HotSpot and 8 ≤ DHW	Mortality Likely

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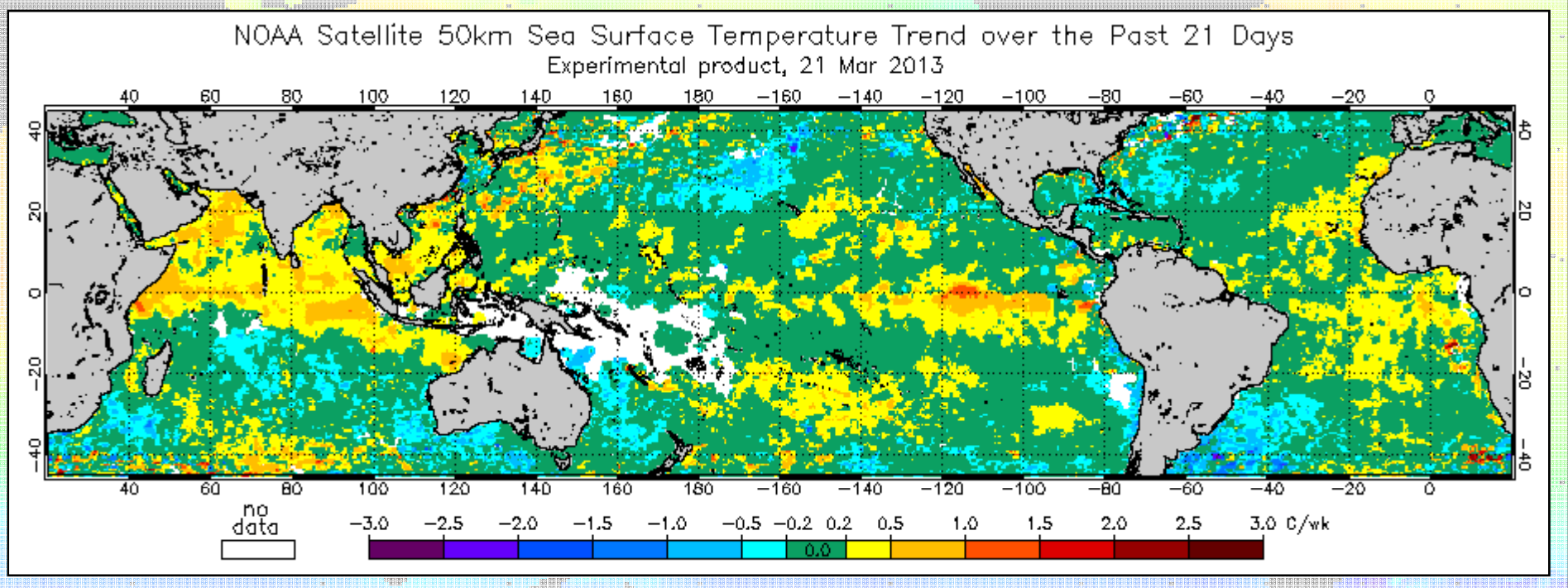
Satellite Bleaching Thermal Stress Monitoring

Short-term SST Trend (over three weeks)



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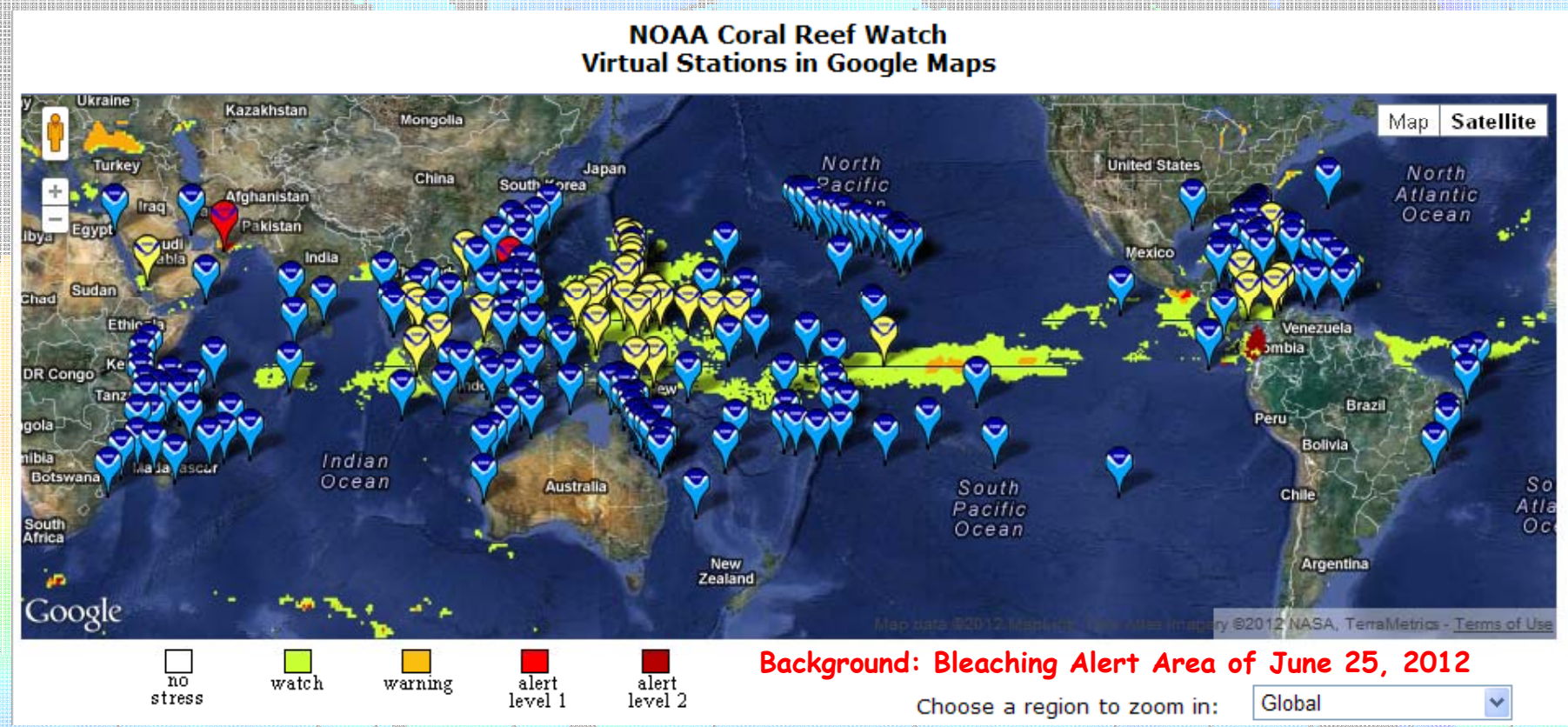
Satellite Bleaching Virtual Stations (50-km)

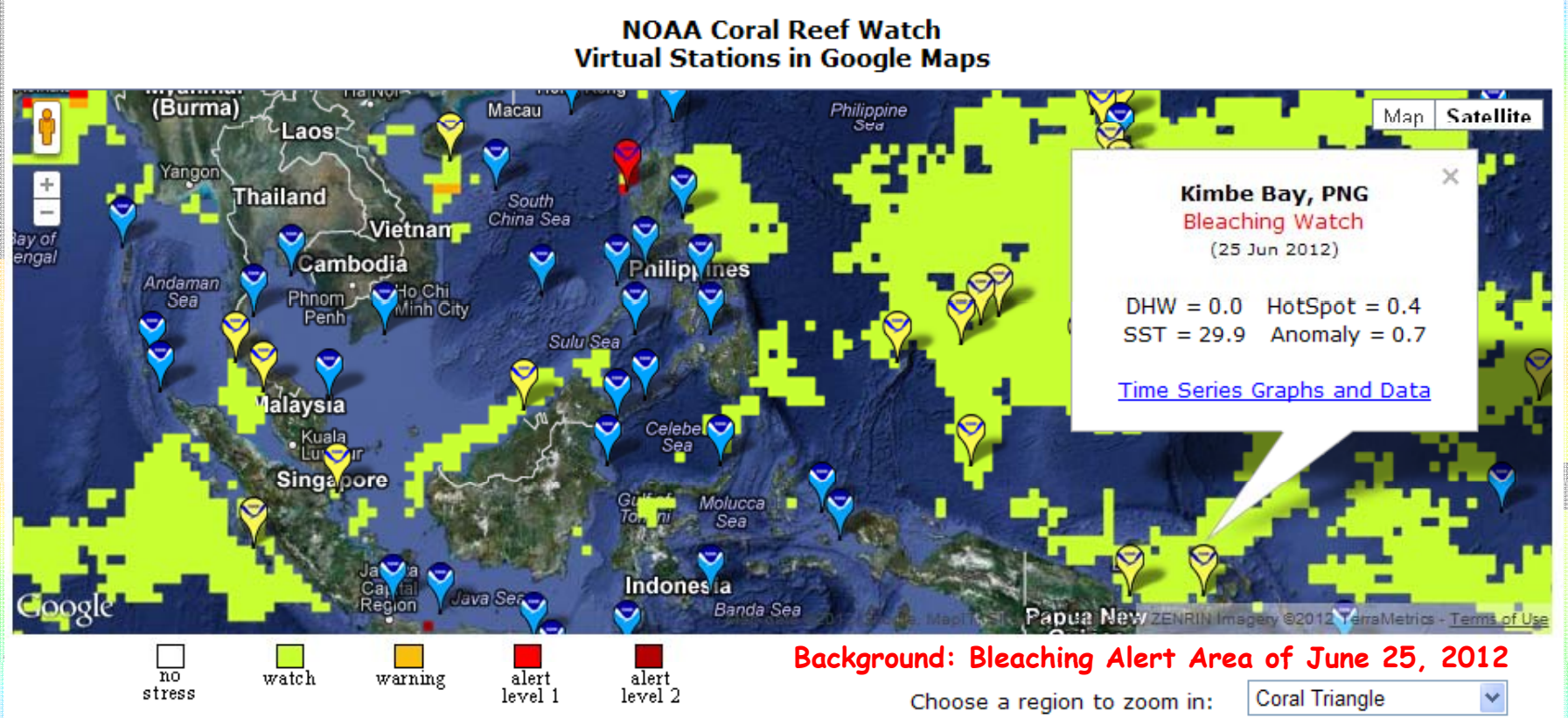


227 Virtual Stations

http://coralreefwatch.noaa.gov

NOAA Coral Reef Watch

Satellite Bleaching Virtual Stations (50-km)



no stress | watch | warning | alert level 1 | alert level 2

Background: Bleaching Alert Area of June 25, 2012

Choose a region to zoom in: Coral Triangle

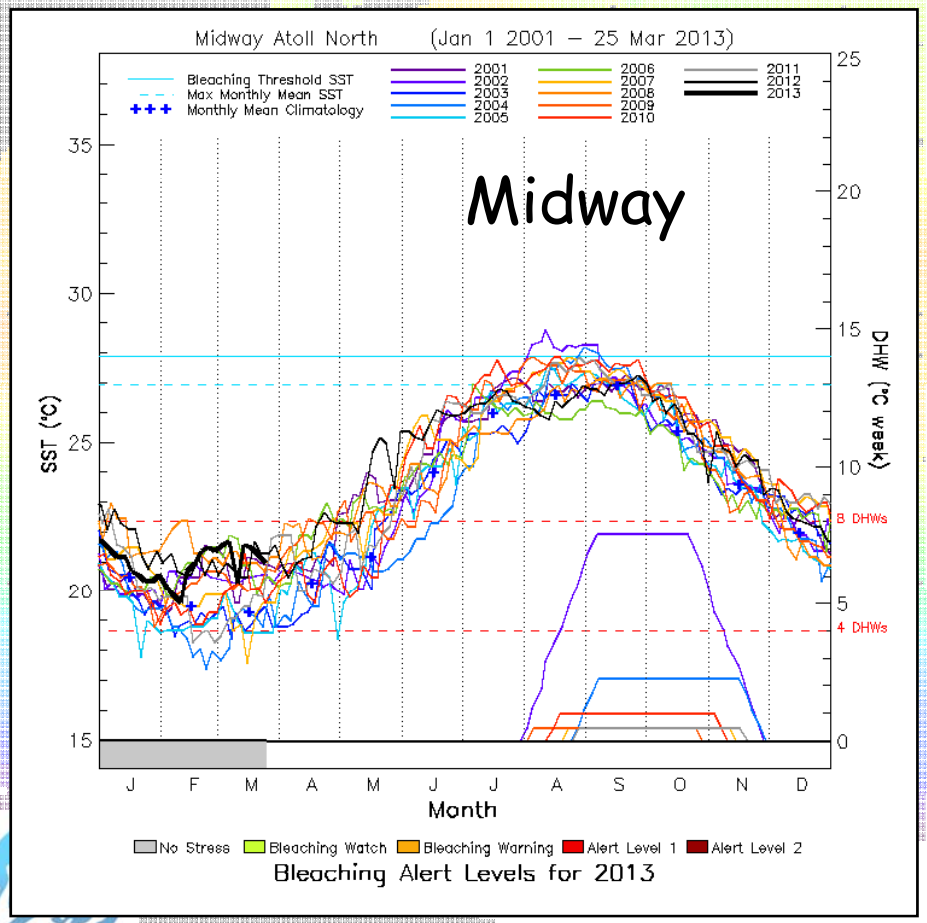
227 Virtual Stations

http://coralreefwatch.noaa.gov

NOAA Coral Reef Watch

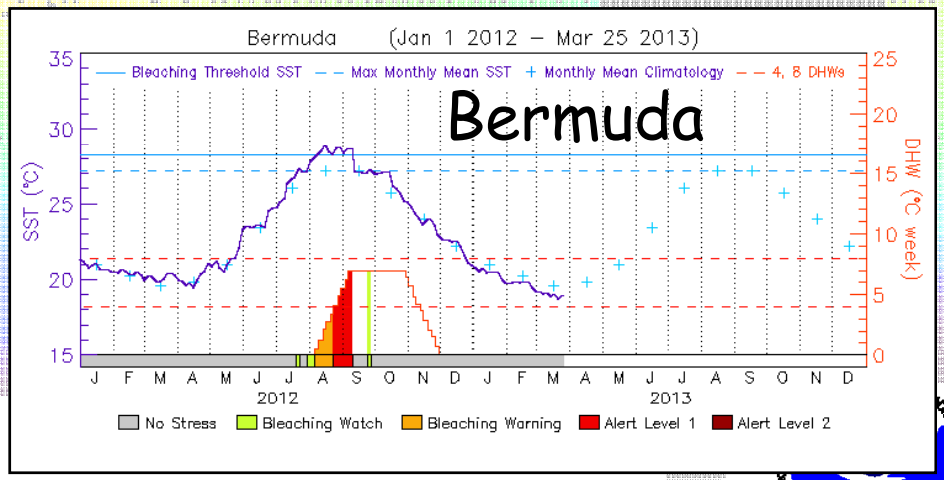
Satellite Bleaching Virtual Stations (50-km)

2001-2013 time series
SST, SST Anomaly, HotSpots, DHW, and Bleaching Alert Area Level (data and graphs)



Multi-year graph

Two-year graph



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Satellite Bleaching Alert E-mails

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[NOAA Coral Reef Watch Coral Bleaching Alert 20120621]

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Atlantic Ocean

** Caribbean

-- Bocas del Toro, Panama	(+) Bleaching Watch
-- Cayos Miskitos, Nicaragua	(+) Bleaching Watch
-- San Bernardo, Colombia	(+) Bleaching Watch
-- Santa Marta, Colombia	(+) Bleaching Watch

** Florida

-- Gulf Sloughsway, Florida	(-) No Stress
-- SW FL Shelf Inshore, Florida	(-) No Stress

Pacific Ocean

** Eastern Pacific

-- Clipperton Island, France	(-) No Stress

** Micronesia

== Federated States of Micronesia

-- Chuuk, FSM	(+) Bleaching Watch
-- Pisaras, FSM	(+) Bleaching Watch

** Polynesia

-- Funafuti, Tuvalu	(+) Bleaching Watch

Southeast Asia

** Coral Triangle

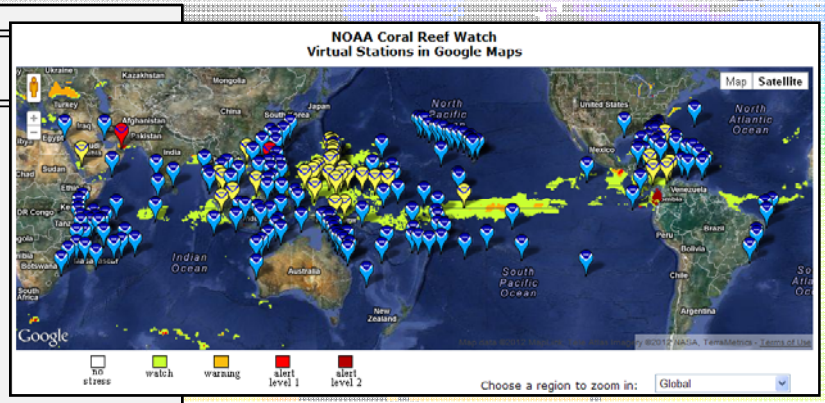
== Philippines

-- Polillo Islands, Philippines	(-) No Stress
-- Visayan Sea, Philippines	(-) No Stress

Indian Ocean

** Middle East

-- Farasan Bank, Saudi Arabia	(+) Bleaching Watch
-- Muscat, Oman (+) Bleaching Alert Level 1	



Free subscription for 227 Virtual Stations

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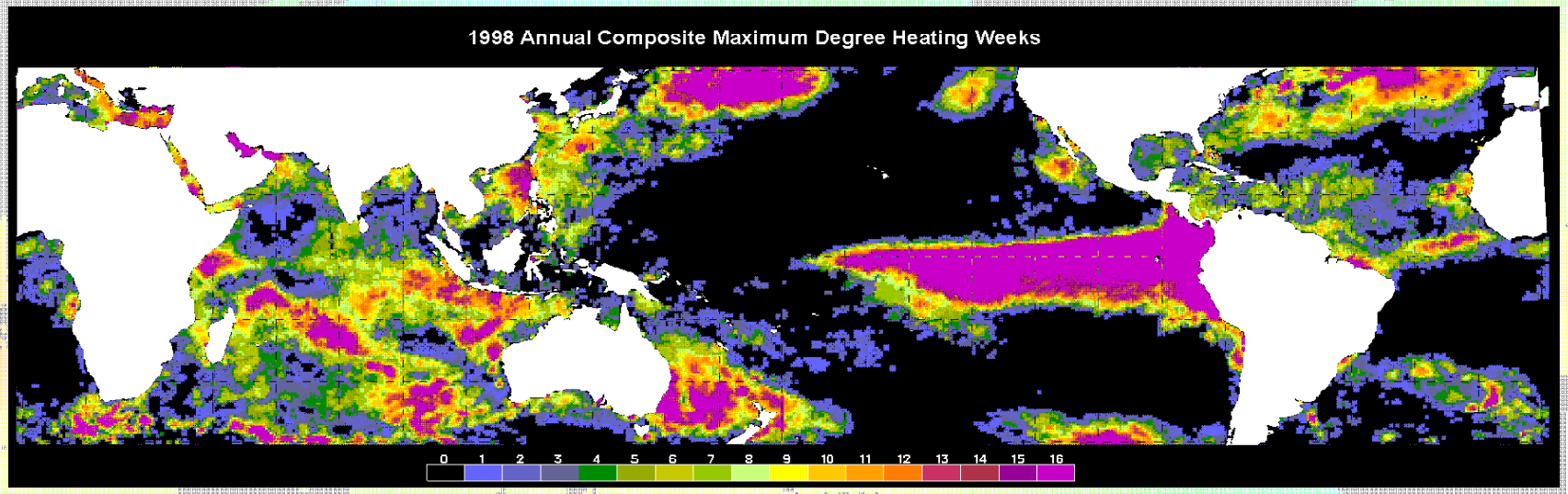
Major Bleaching Events

1997-1998: Unprecedented Global Mass Bleaching Event
(during a strong ENSO event)



A large El Niño event, immediately switching over to a strong La Niña

Globally the most extensive bleaching event in the modern record for most of the affected regions

- Indian Ocean
- West Pacific Ocean
- East Pacific Ocean
- The Caribbean
- The Greater Atlantic Ocean

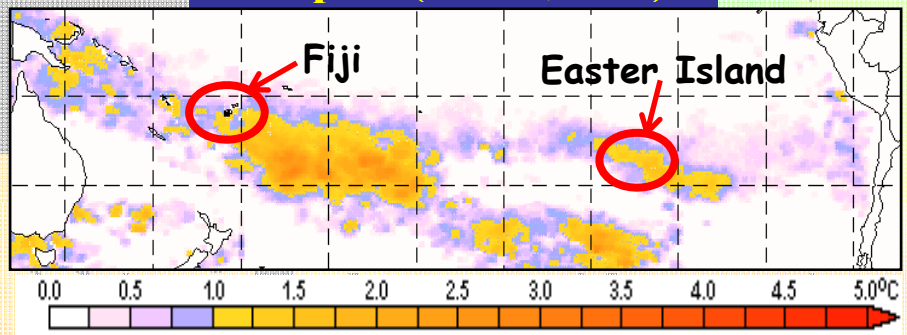
16% of the world's reefs were destroyed

NOAA Coral Reef Watch

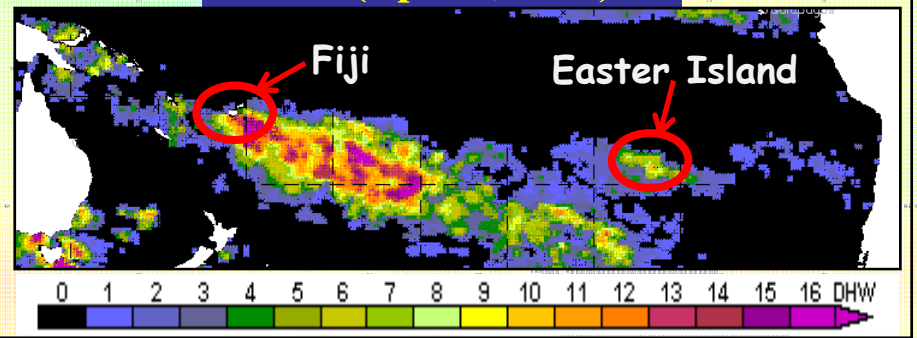
Major Bleaching Events

2000: Easter Island and Fiji

HotSpots (Feb 29, 2000)

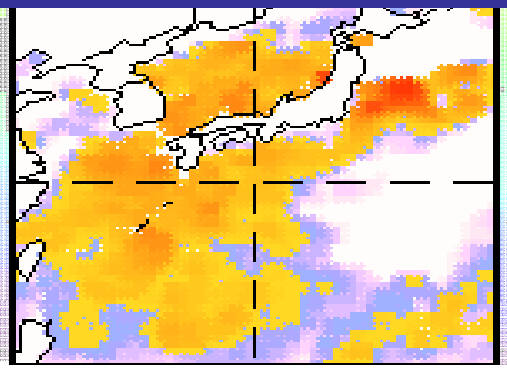


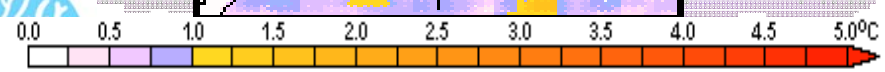
DHW (Apr 15, 2000)



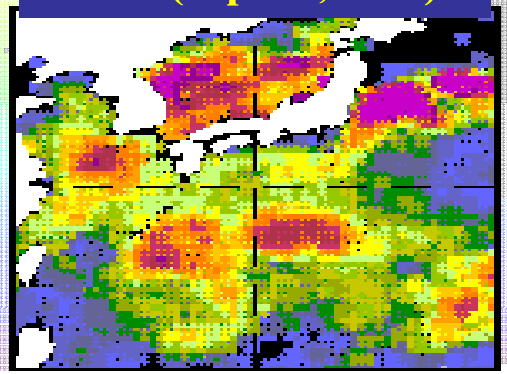
2001: Ryukyu Islands, Japan

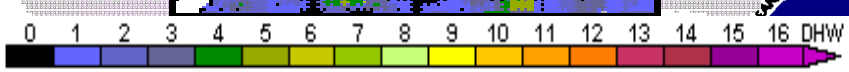
HotSpots (Aug 13, 2001)





DHW (Sept 31, 2002)

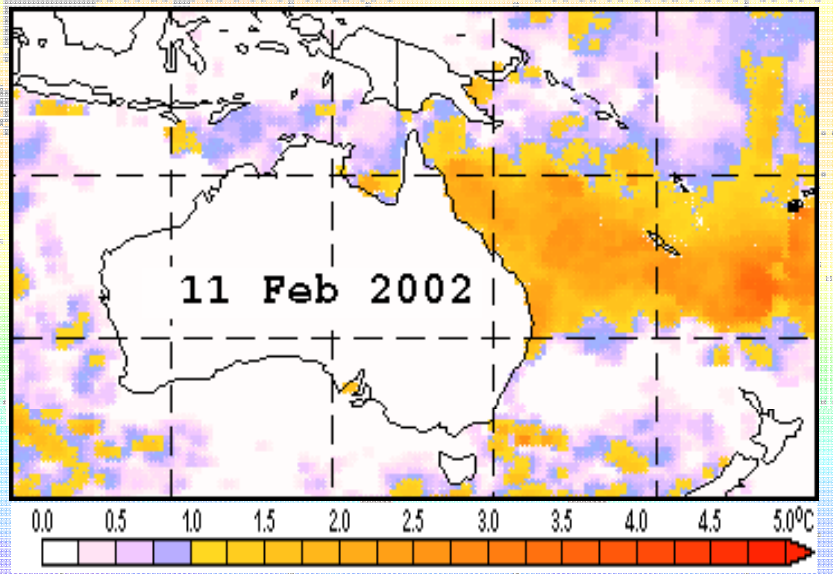




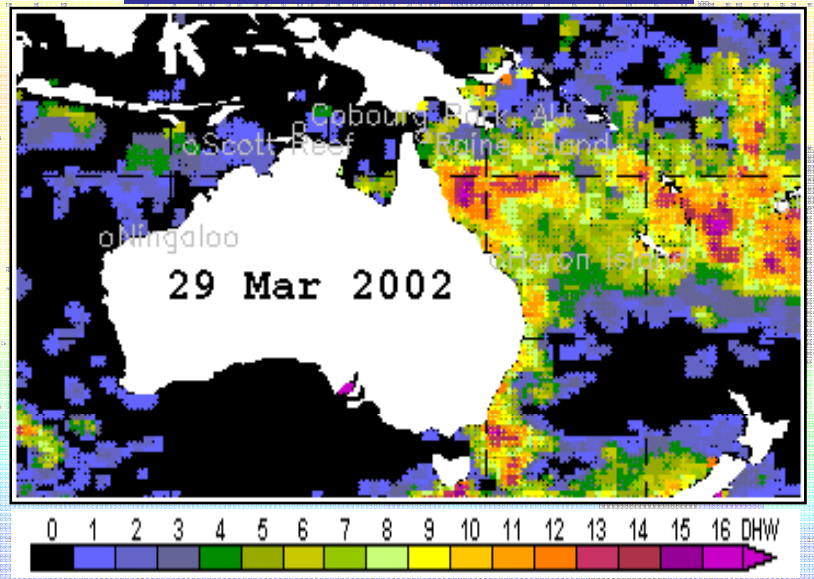
Major Bleaching Events

2002: Great Barrier Reef, Australia (Unprecedented)

HotSpots (Feb 11, 2002)



DHW (Mar 29, 2002)



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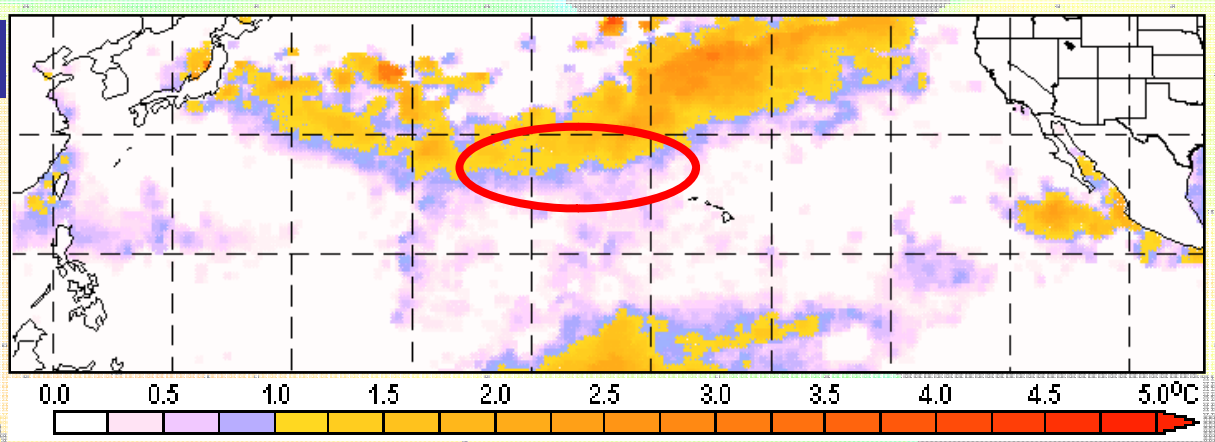
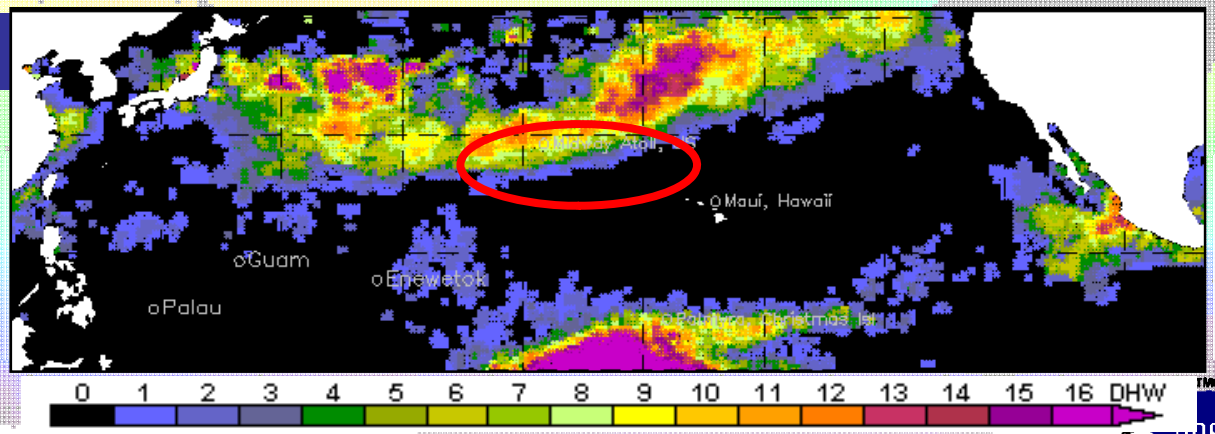
Major Bleaching Events

2002: Northwestern Hawaiian Islands (Unprecedented)

HotSpots (Sept 2, 2002)



DHW (Oct 5, 2002)



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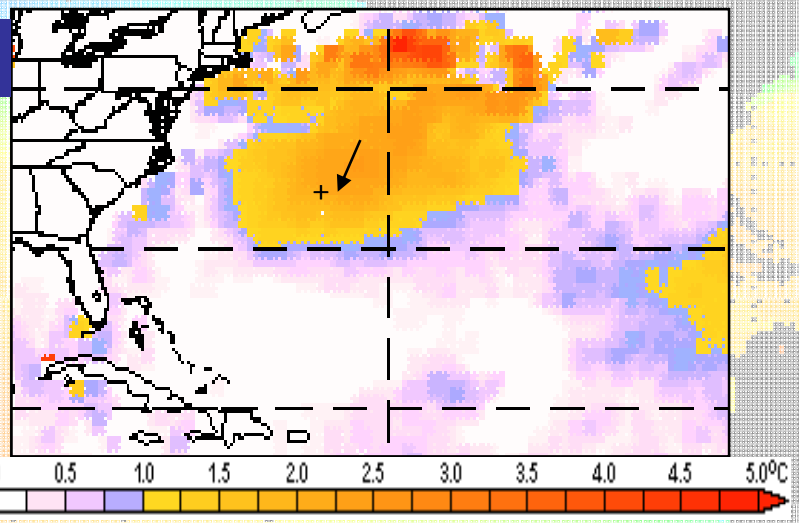
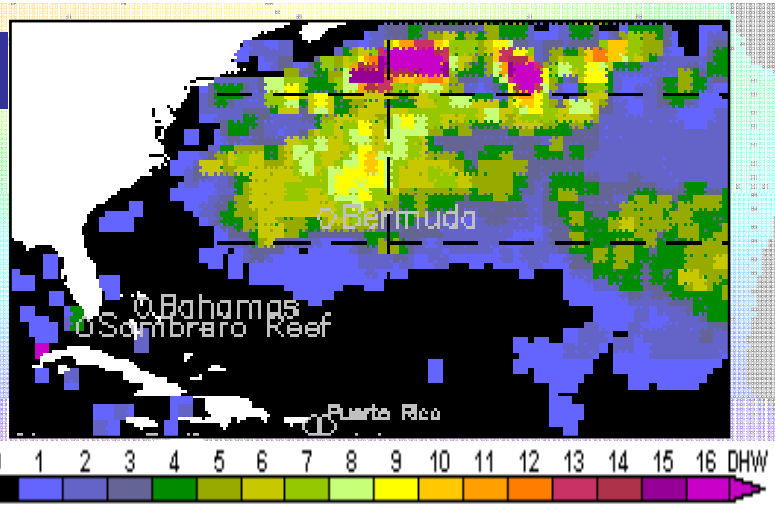
Major Bleaching Events

2003 : Bermuda

HotSpots (Aug 16, 2003)



DHW (Sept 6, 2003)



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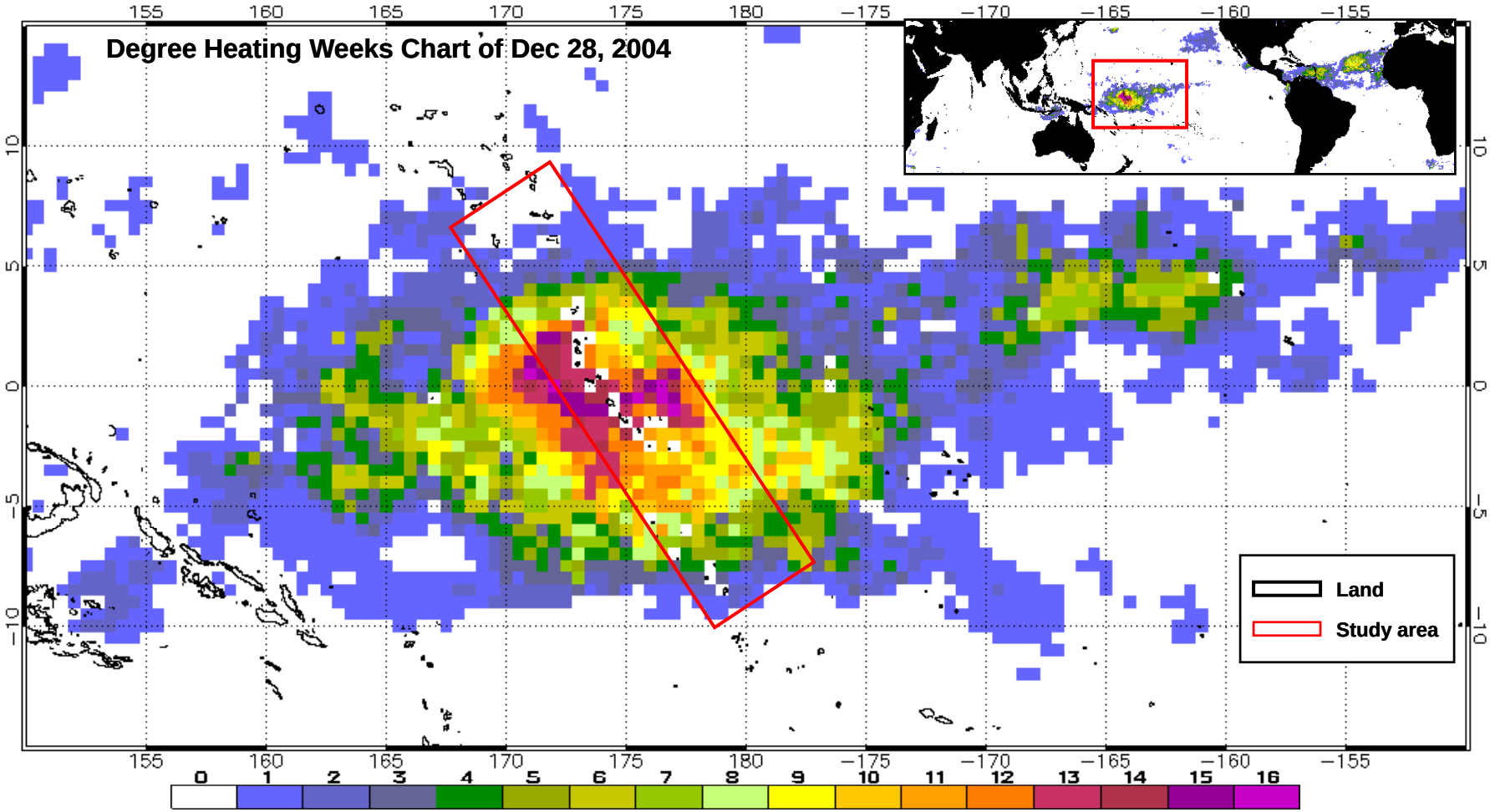
Major Bleaching Events

2004: Kiribati -- unprecedented bleaching



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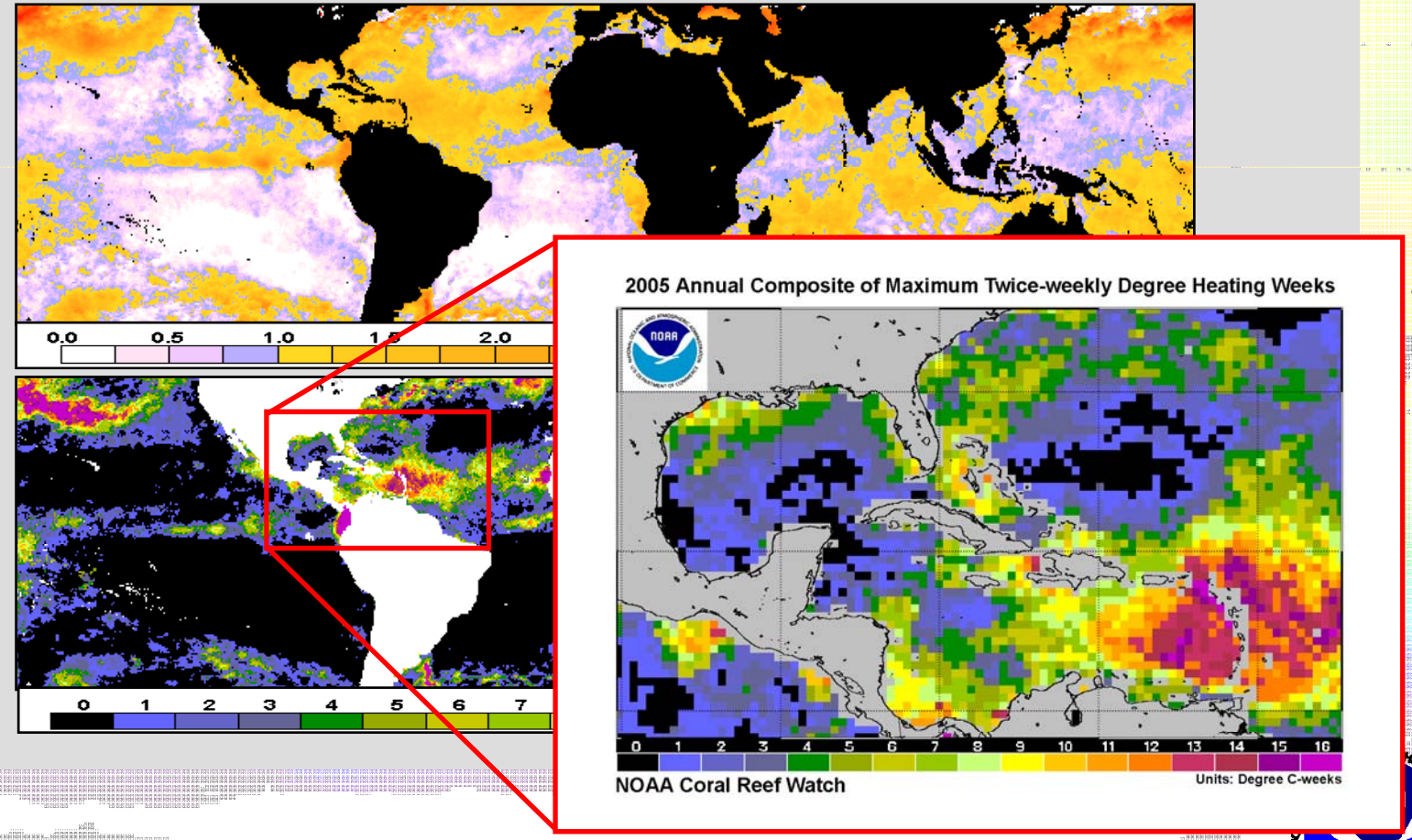
Major Bleaching Events

2005: Caribbean (unprecedented)

Coral Reef Watch's 2005 Annual Maximum HotSpot and Degree Heating Weeks



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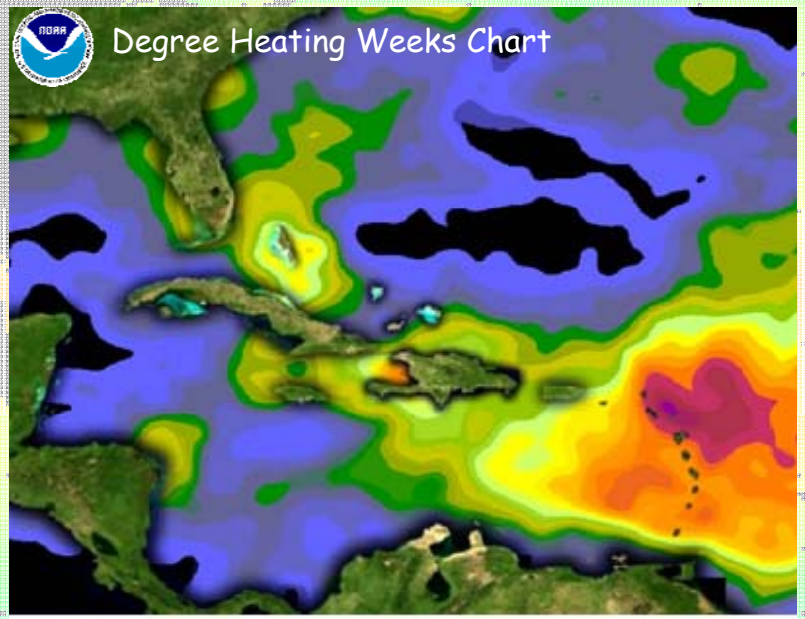
Major Bleaching Events

2005: Caribbean (unprecedented)



NBC NIGHTLY NEWS WITH BRIAN WILLIAMS

National Oceanic & Atmospheric Administration, 2005

ABC News, CBS News, NBC News, MSNBC, CNN News, USA today, National Geographic, Newsweek, Washington Post …

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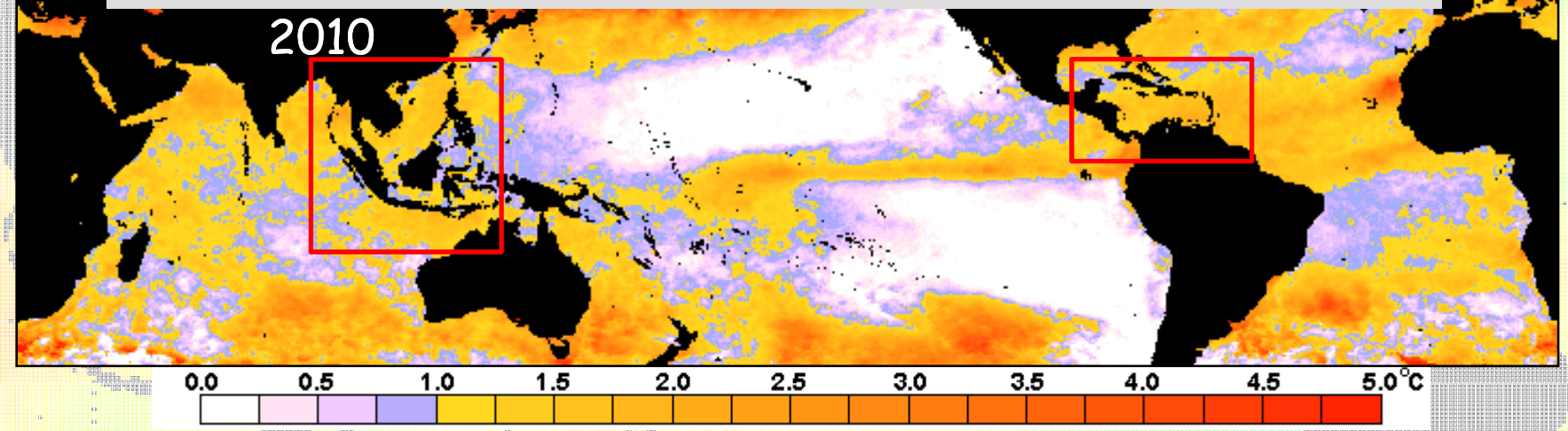
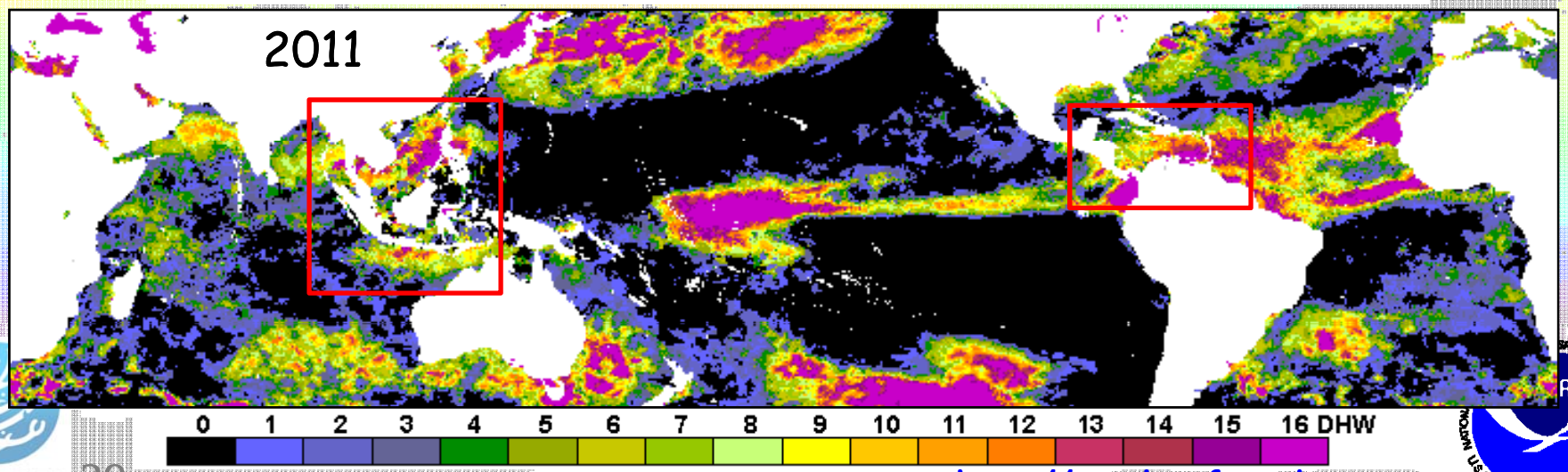
Major Bleaching Events

2010 Mass Coral Bleaching in Southeast Asia and the Caribbean

Coral Reef Watch's 2010 Annual Maximum HotSpot and Degree Heating Weeks





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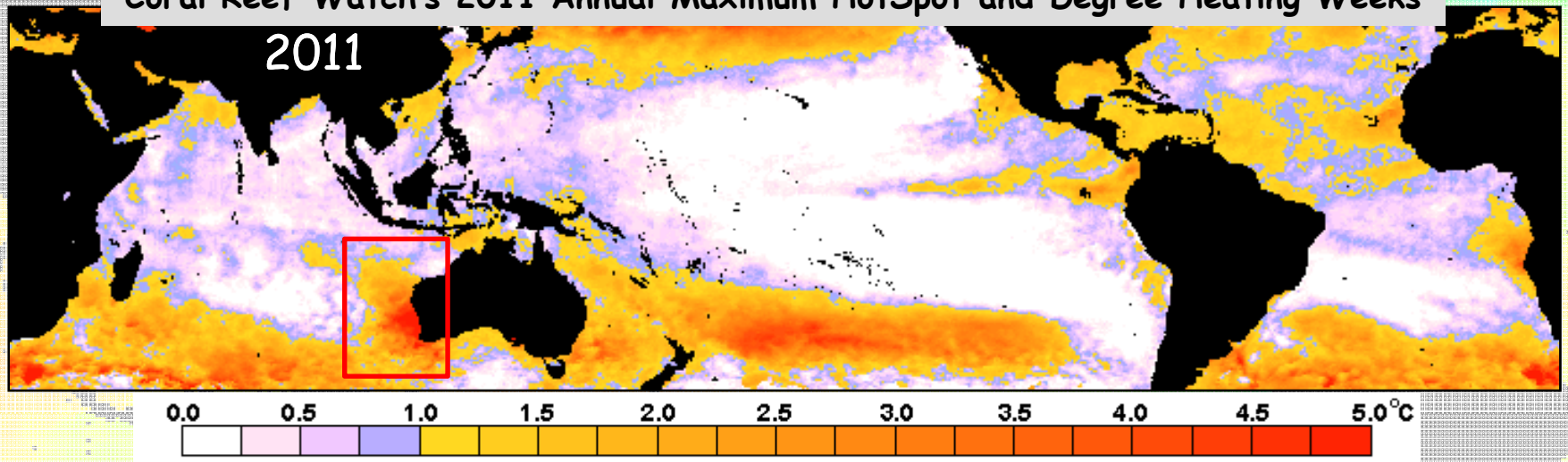
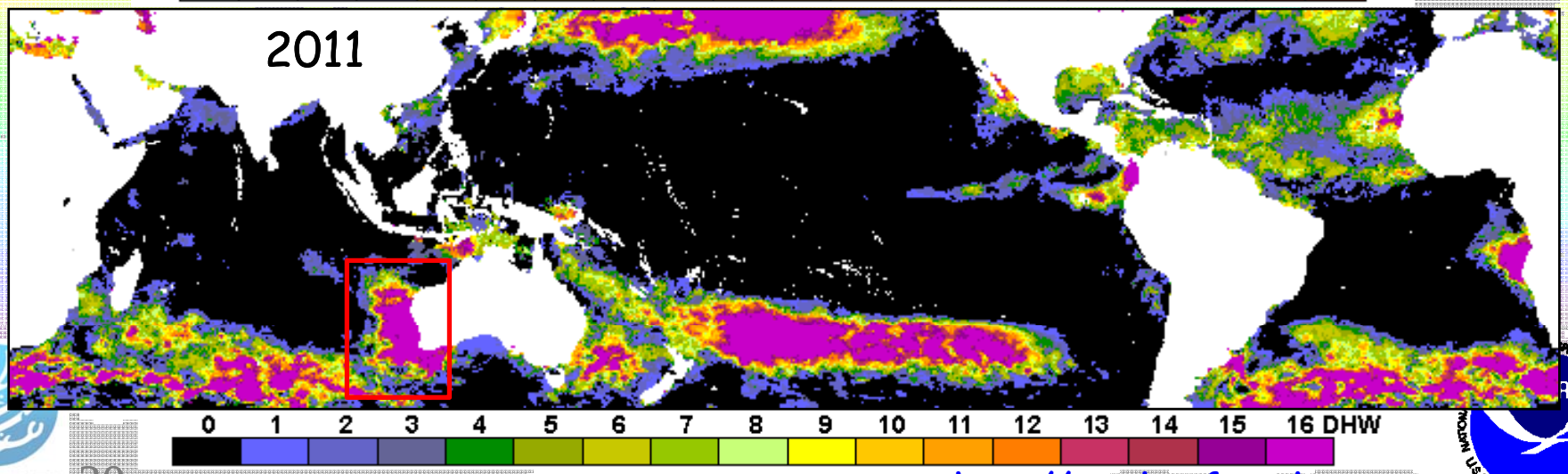
NOAA Coral Reef Watch

Major Bleaching Events

2011: Unprecedented Mass Coral Bleaching in Western Australia

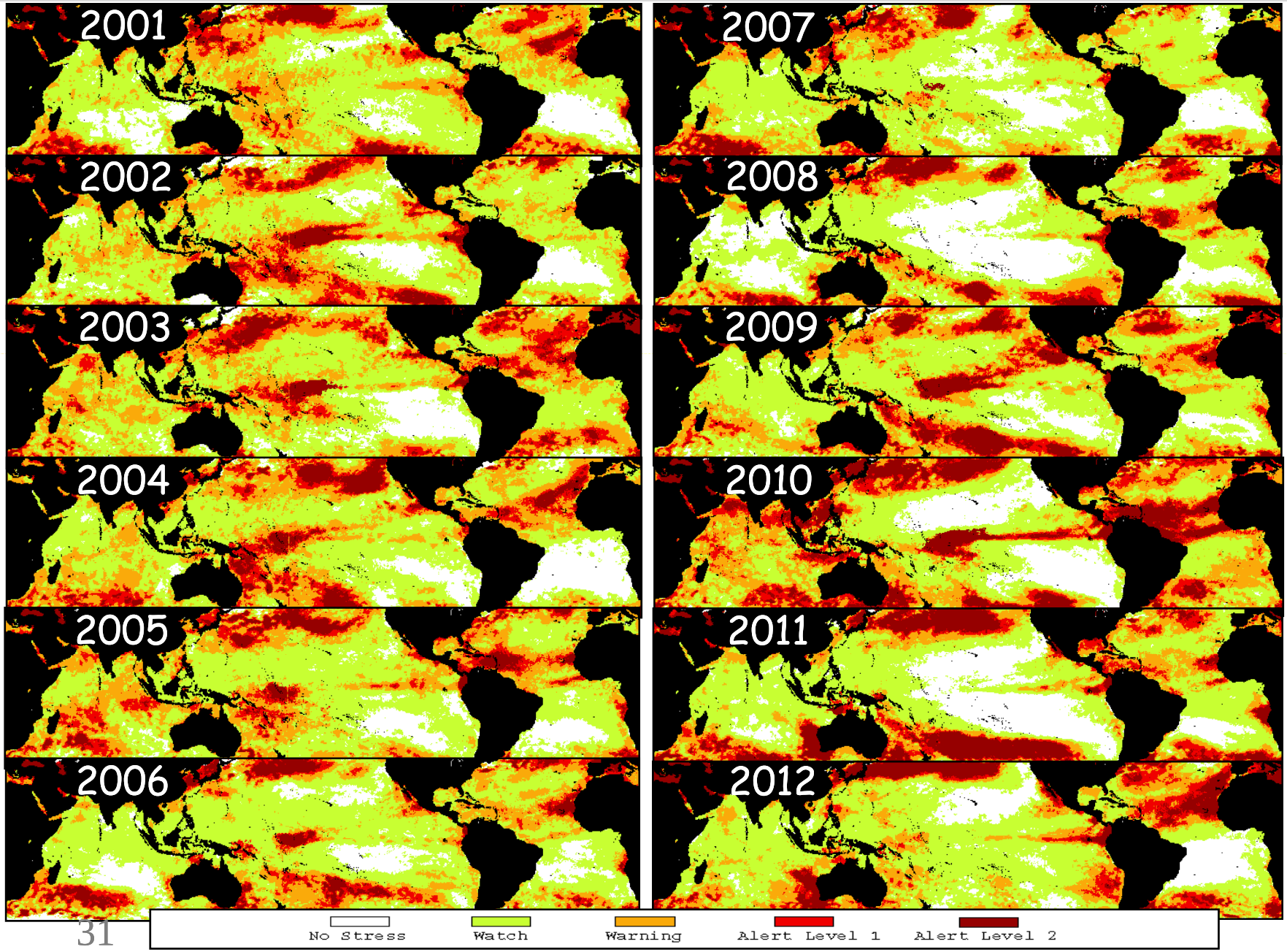
Coral Reef Watch's 2011 Annual Maximum HotSpot and Degree Heating Weeks

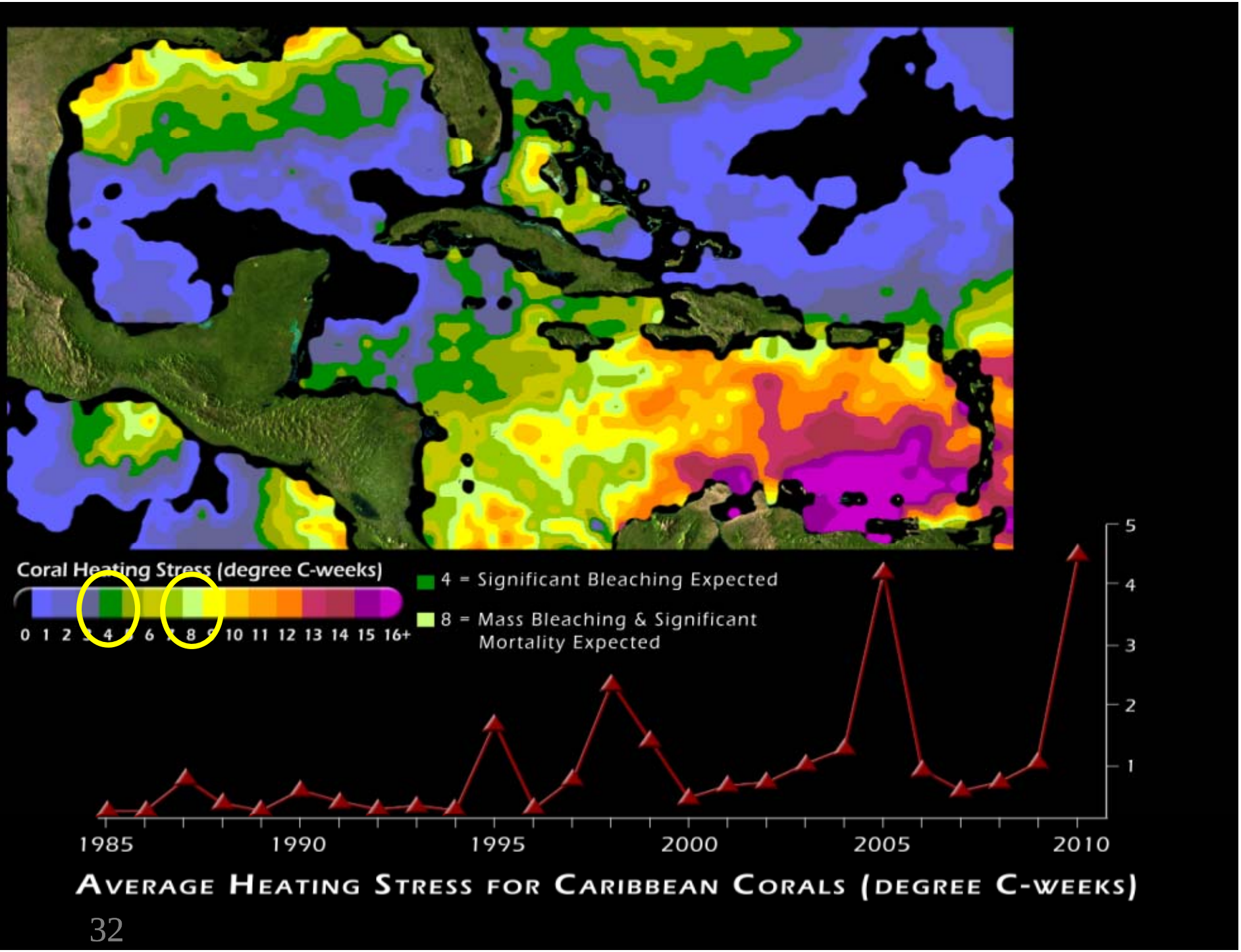




http://coralreefwatch.noaa.gov

2001-2012 Annual Composites (Bleaching Alert Area)



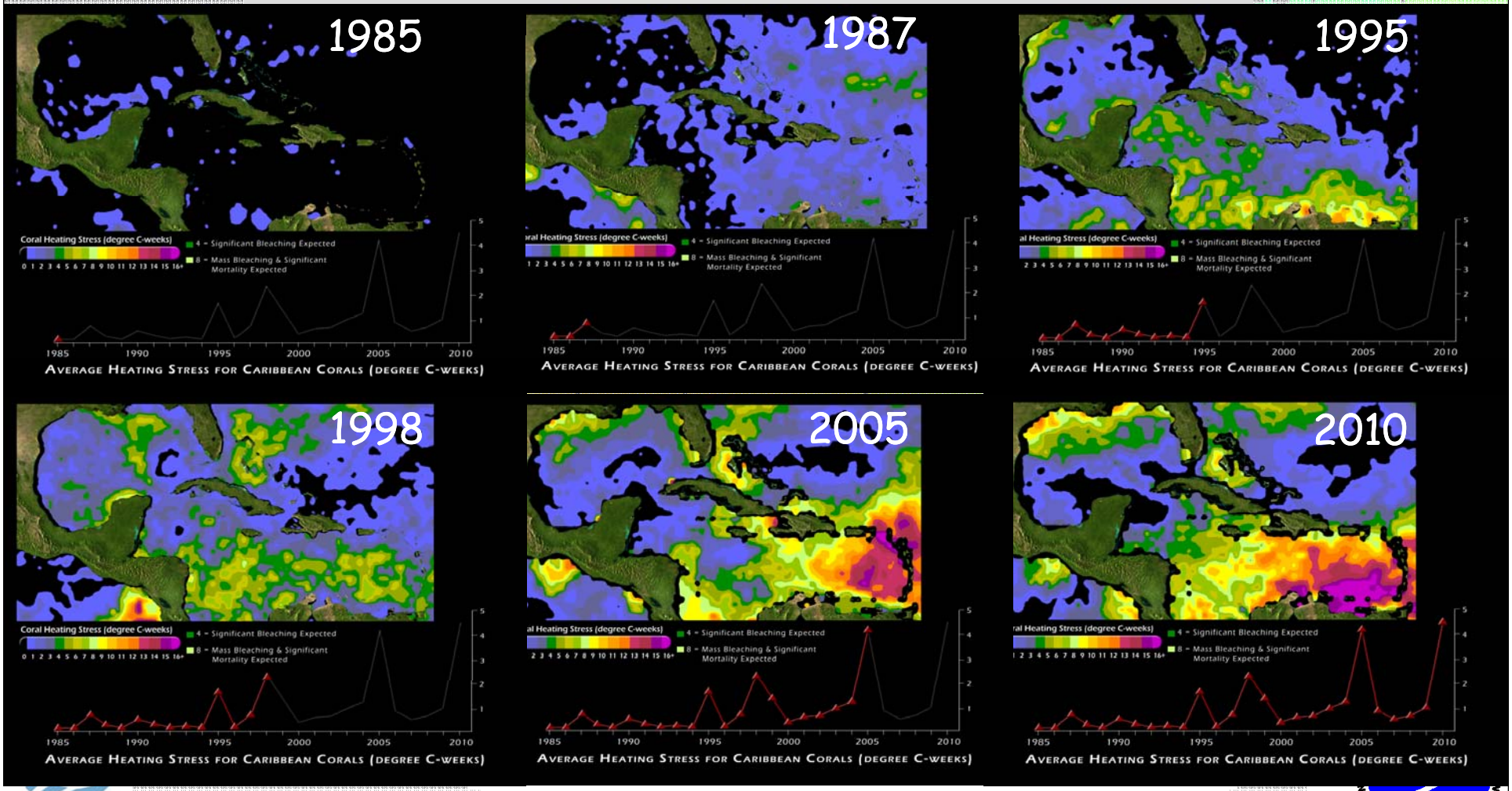

Coral Heating Stress (degree C-weeks)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16+
4 = Significant Bleaching Expected
8 = Mass Bleaching & Significant Mortality Expected
5
4
3
2
1
1985
1990
1995
2000
2005
2010
Average Heating Stress for Caribbean Corals (degree C-weeks)

NOAA Coral Reef Watch

Change in Bleaching thermal Stress in the Caribbean

1985-2010 Annual Maximum Degree Heating Weeks

(Based on historical Pathfinder SST and CRW near-real-time SST)



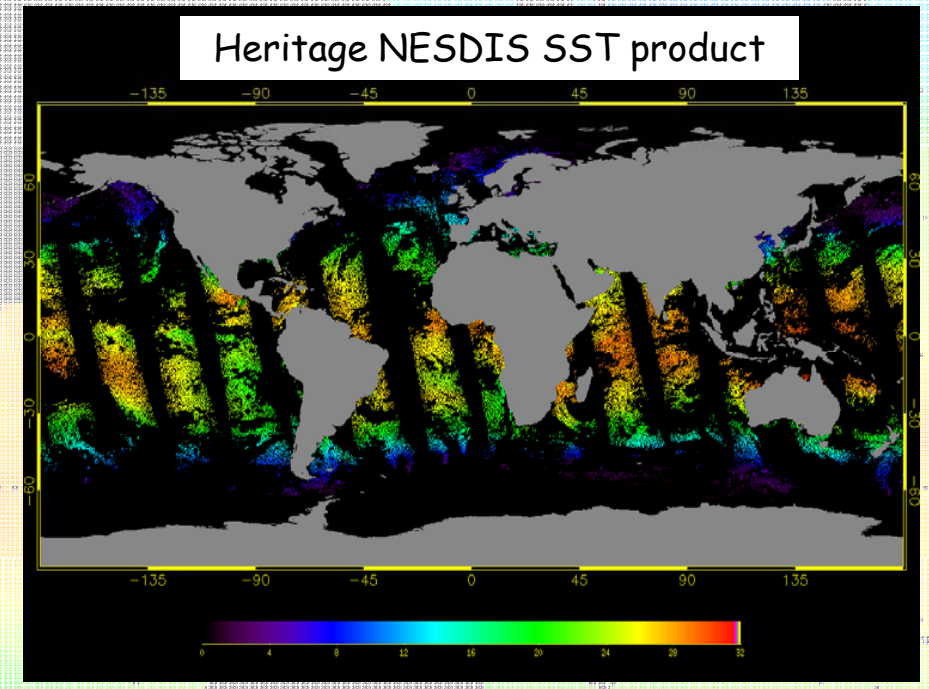
Next-Generation NOAA SST-based Products

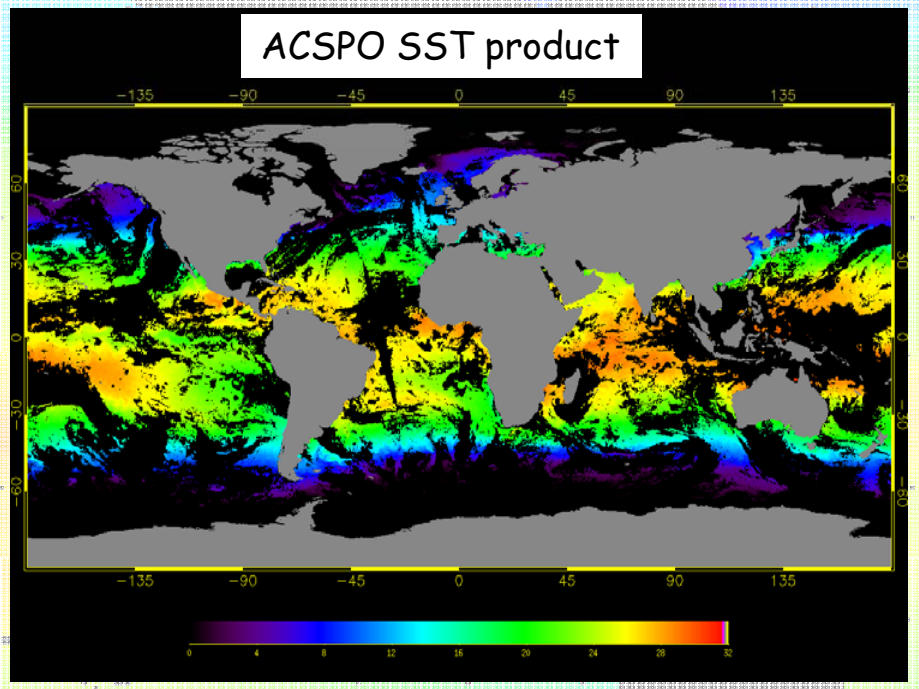
NESDIS GOES-POES Blended Nighttime SST Analyses

Current		Next Generation
50-km	➔	5-km
twice-weekly	➔	daily
one polar-orbiter only	➔	blended data from polar-orbiting & geostationary satellites

Polar-orbiting satellites:	NOAA-19, METOP-A
Geostationary satellites:	GOES-E & GOES-W (NOAA) MTSAT (Japan), MSG (Europe)

NESDIS Advanced Clear-Sky Processor for Oceans (ACSPO) SST (from Polar-Orbiting Satellites)



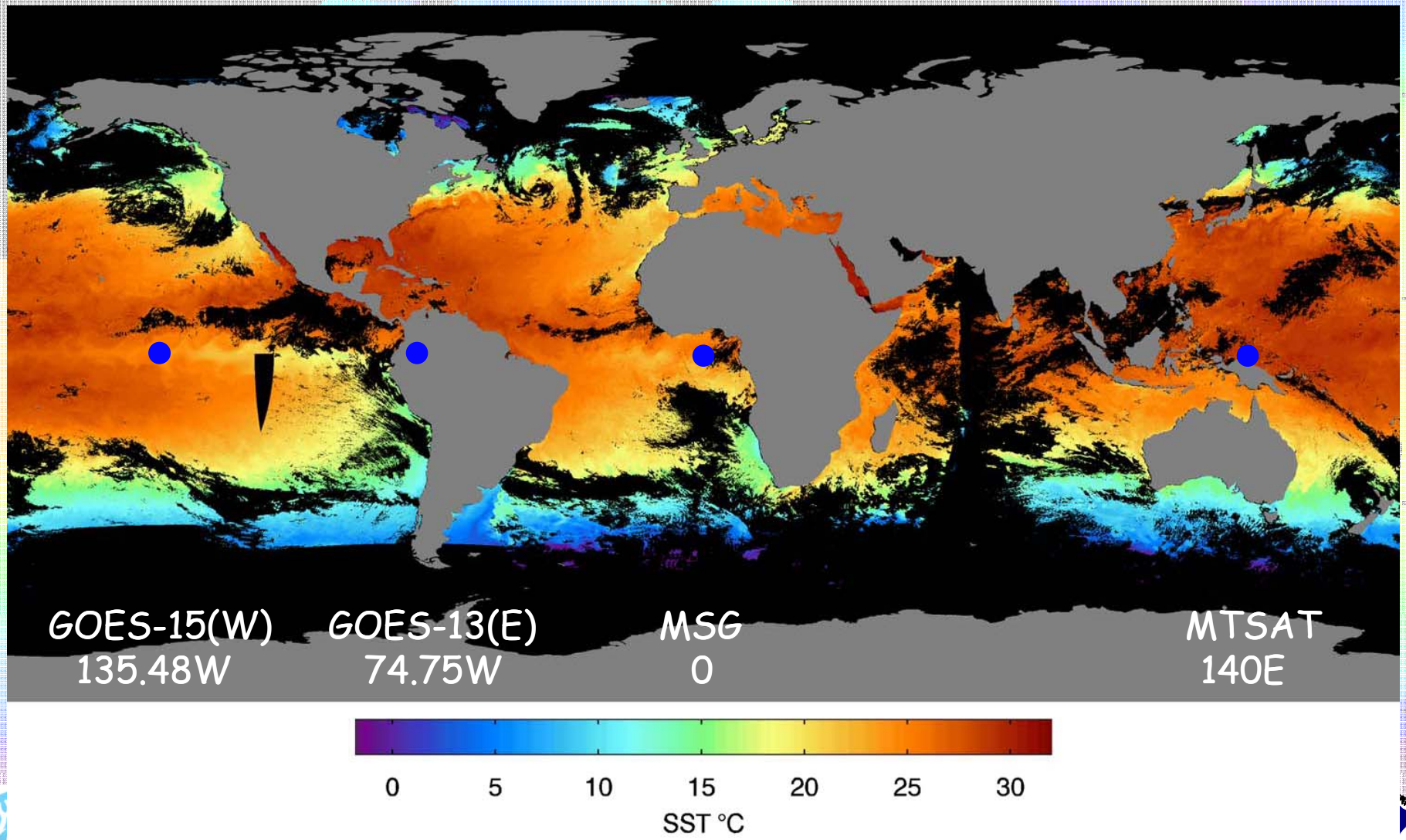


- Native pixel resolution 8 km
- 5.3×10^4 SST pixels
- 12.8% ocean covered daily at 0.3° resolution
- 1 satellite

- Native pixel resolution 4 km
- 2.8×10^6 SST pixels
- 35.9% ocean covered daily at 0.3° resolution
- 2 satellites
- new algorithm using more observations

http://coralreefwatch.noaa.gov

Geostationary Satellite Coverage



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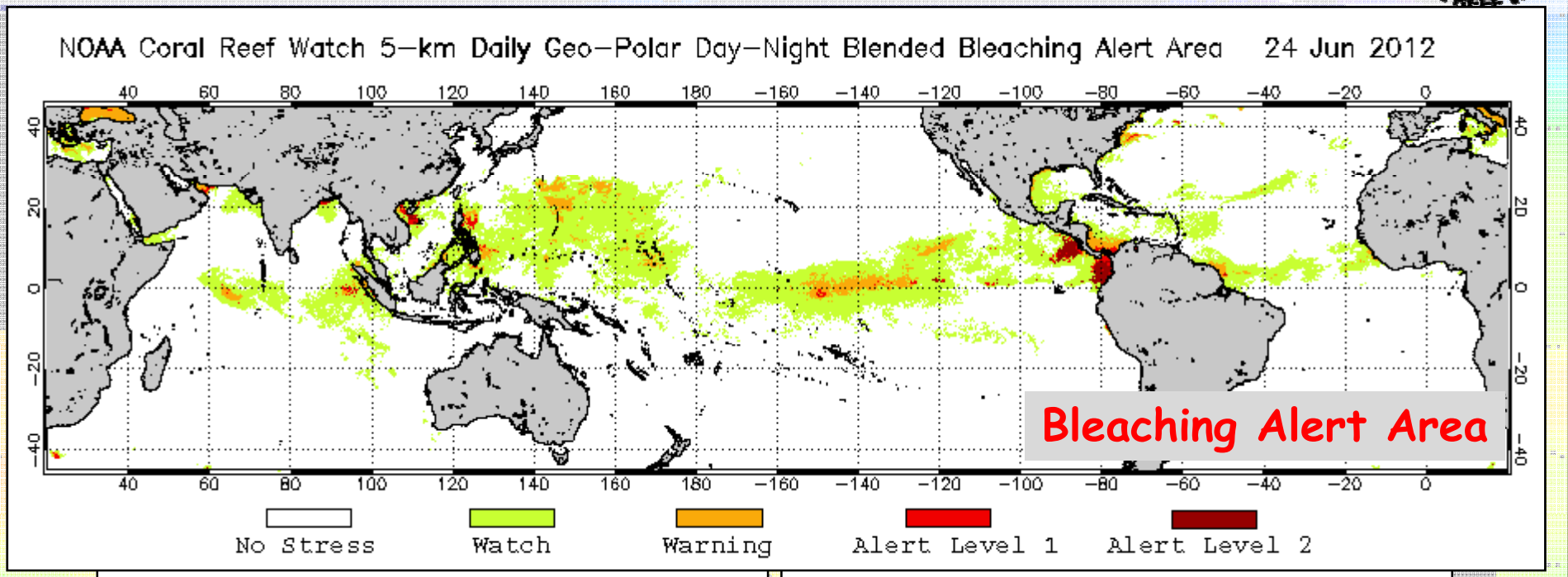
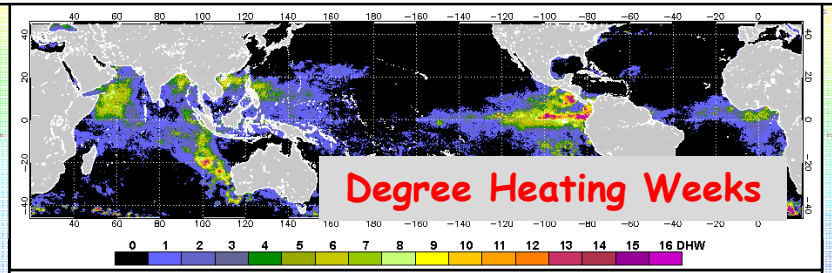
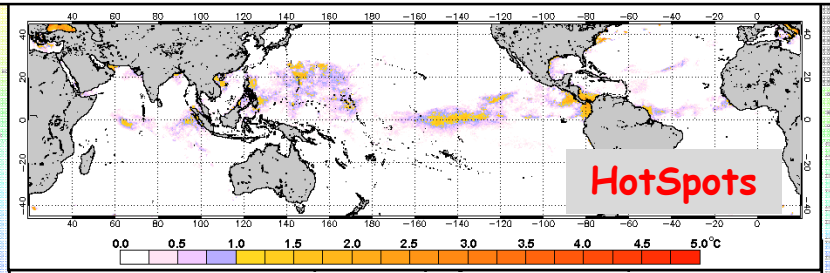
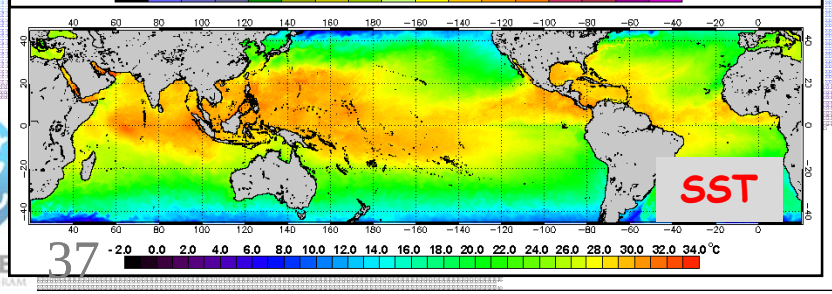
NOAA Coral Reef Watch

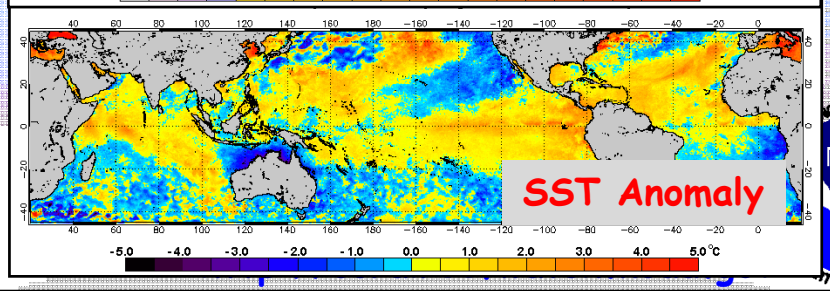
5-km Satellite Bleaching Thermal Stress Monitoring





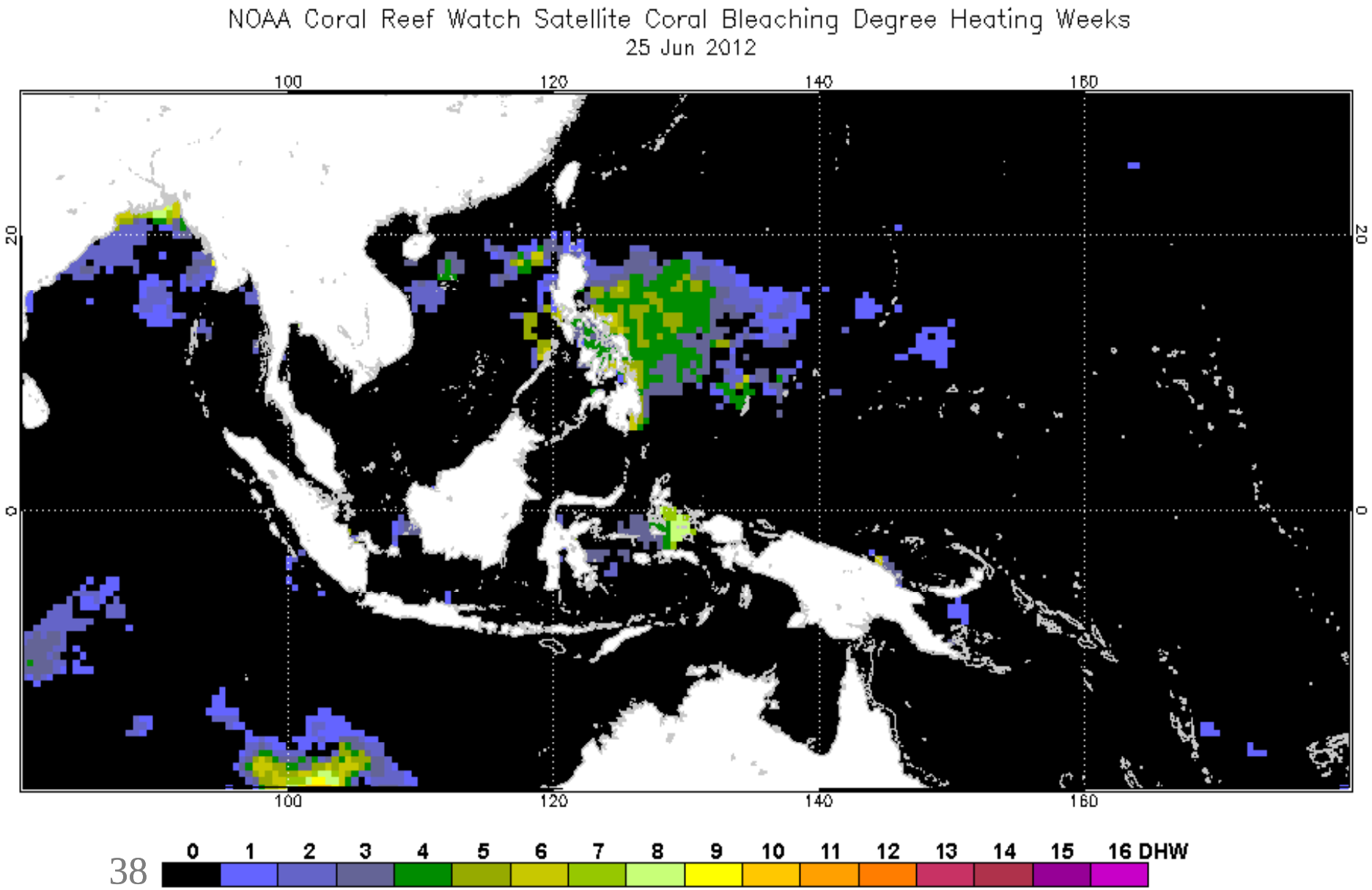






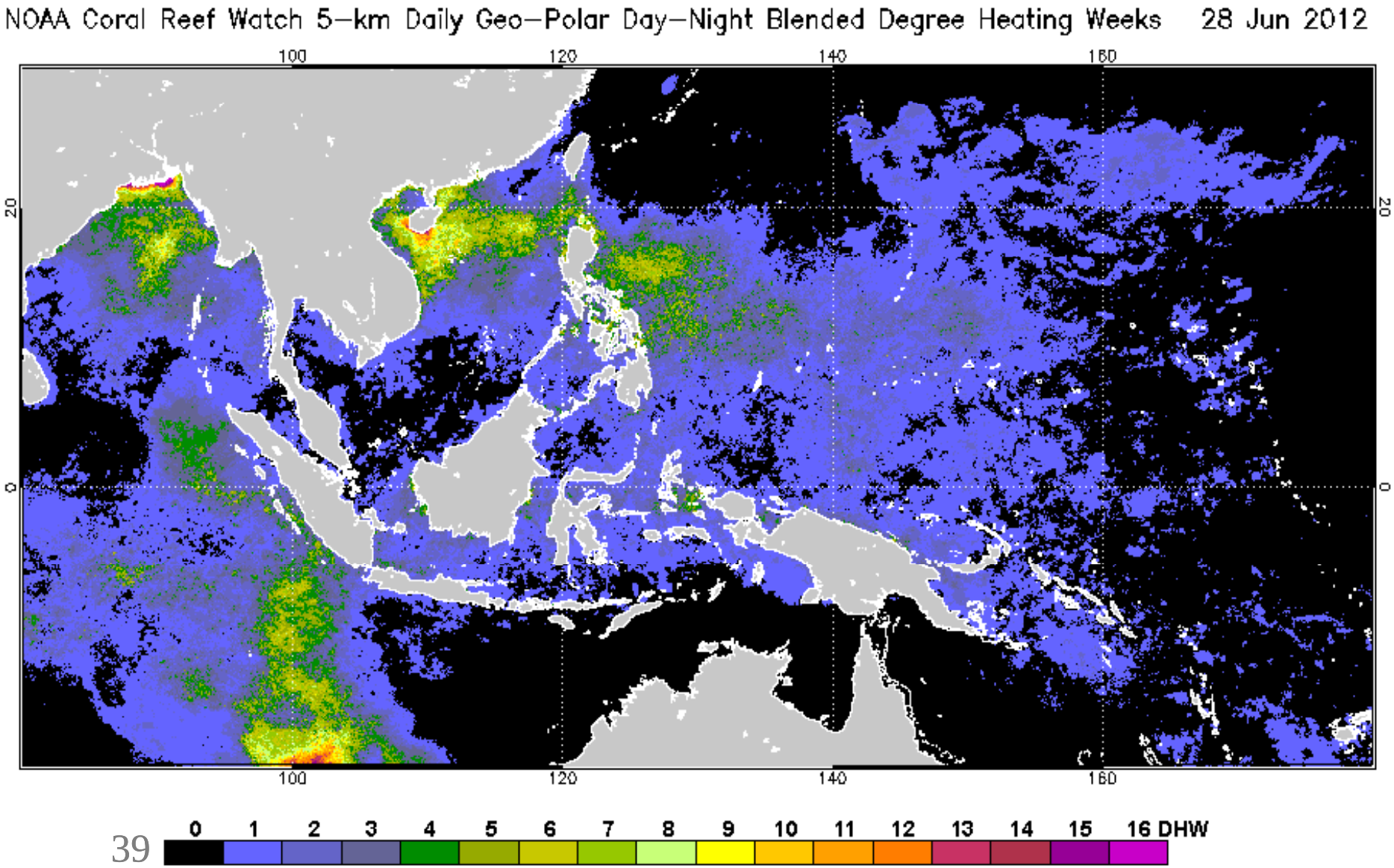
NOAA Coral Reef Watch

Current 50-km Degree Heating Weeks



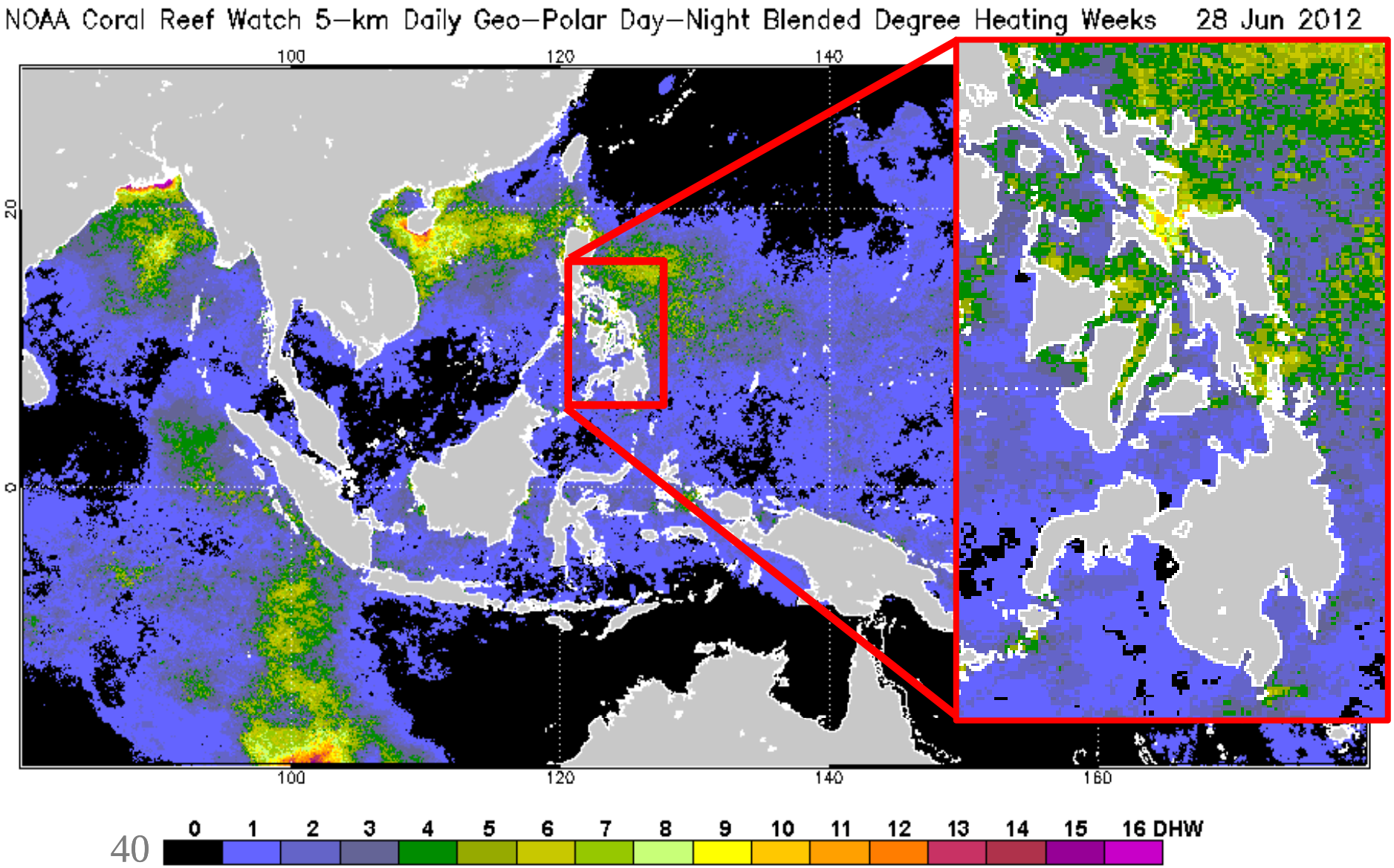
NOAA Coral Reef Watch

Next-Generation 5-km Degree Heating Weeks



NOAA Coral Reef Watch

Next-Generation 5-km Degree Heating Weeks

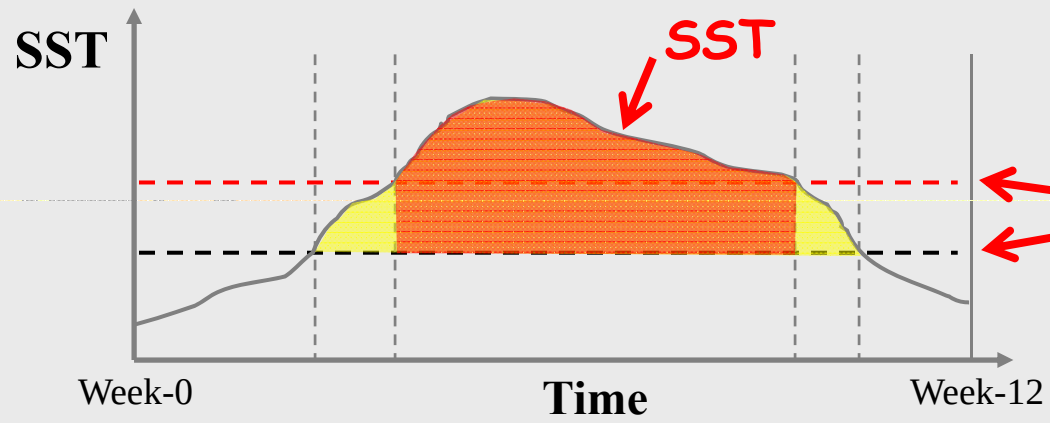


NOAA Coral Reef Watch

Next-Generation 5-km Products

Currently under testing and evaluation

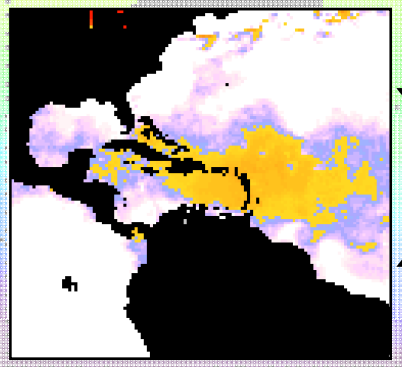
Anomaly based products



Climatology

Bleaching threshold
(MMMSST+1ºC)

Maximum Monthly Mean SST Climatology (MMMSST)

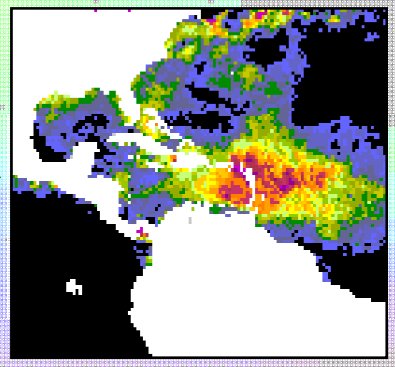


HotSpots

12 weeks

$$\sum_{\geq 1^\circ C} (\text{HotSpot value} \times \text{duration})$$

Degree Heating Weeks



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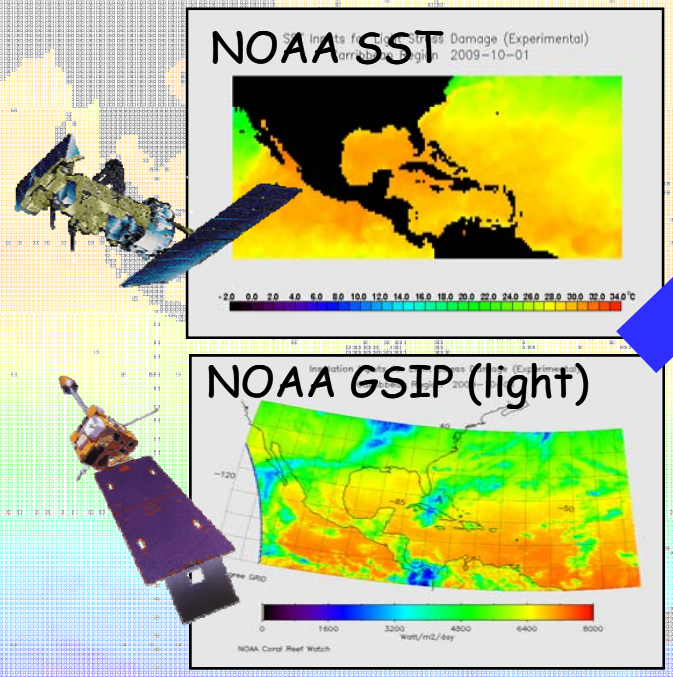
NOAA Coral Reef Watch

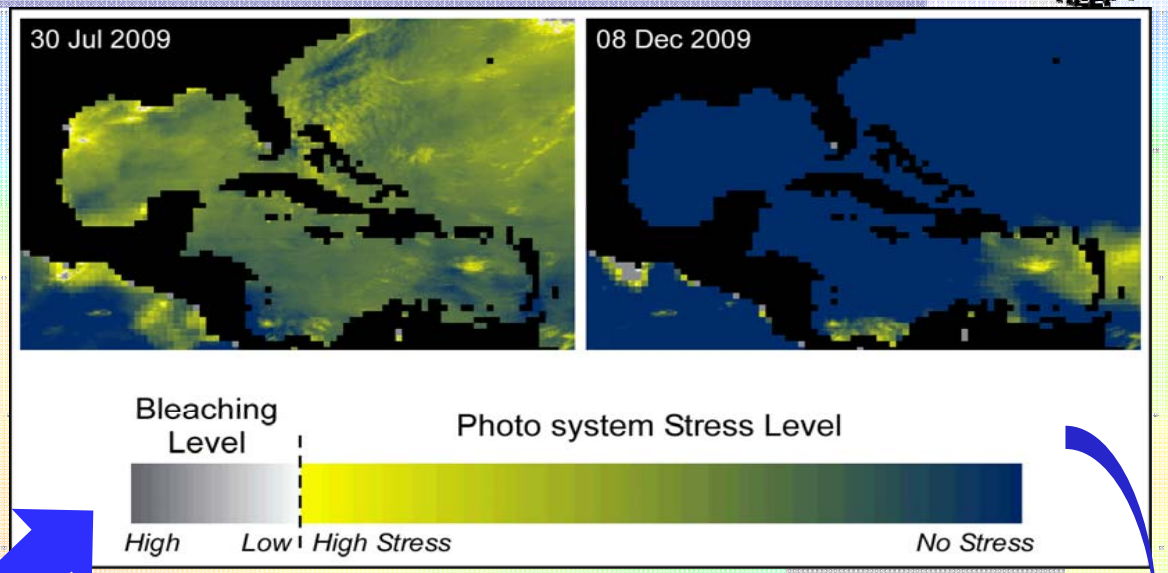
Regional Daily Light Stress Damage (LSD) Product

(Experimental)

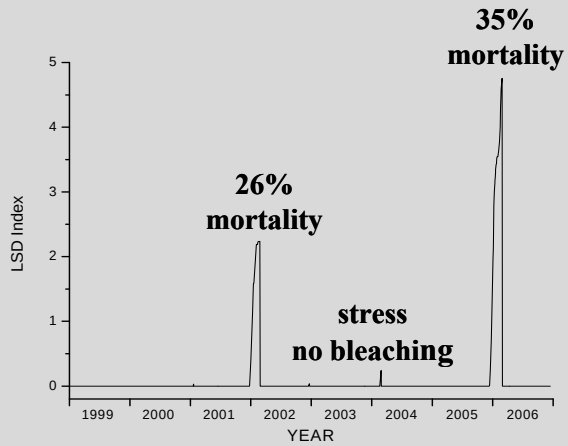
Coral physiology-based product for monitoring coral bleaching stress



GOES Surface and Insolation Products
1/8 degree



A case study at the Keppel Islands, Great Barrier Reef



(Collaboration with the Universidad Nacional Autónoma de México (UNAM), the University of Queensland, and the University of Exeter) http://coralreefwatch.noaa.gov

NOAA Coral Reef Watch

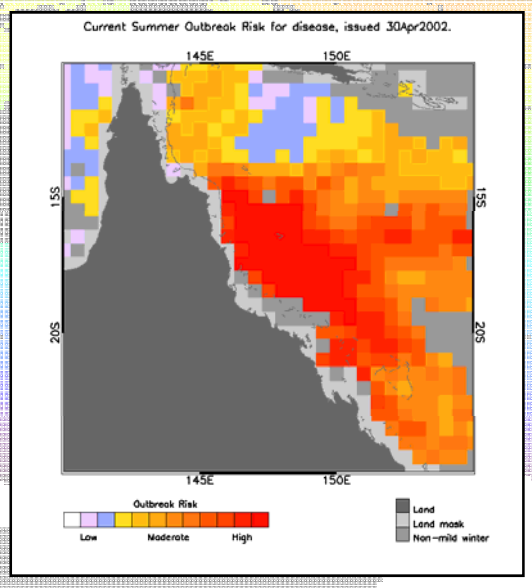
Regional Coral Disease Outlook Product

WARM WINTER + HOT SUMMER → DISEASE OUTBREAK

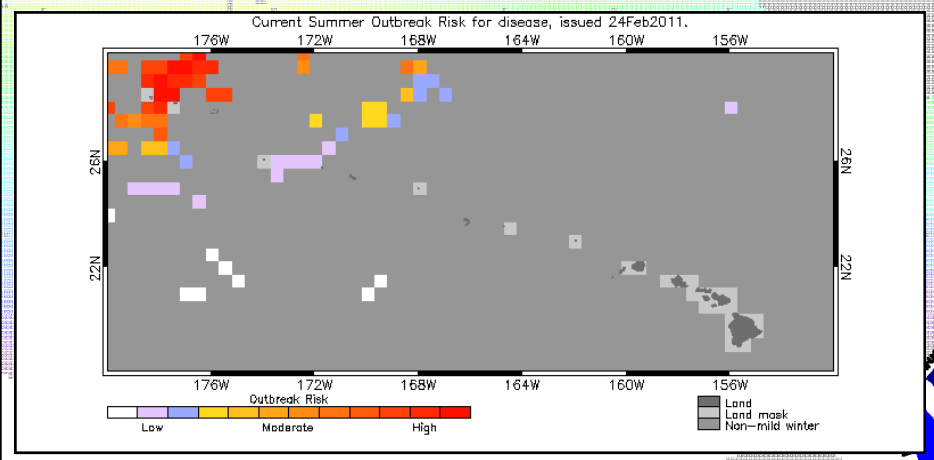
A pilot expert system is being tested and evaluated to use satellite SST data to predict coral disease outbreak risk

Experimental Neal-Real-Time Summer Outbreak Risk Product

2002 Austral Summer Season



2010 Boreal Summer Season



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Future CRW Satellite Product Development

Purposes:
- **To adapt to new satellite technology, and**
- **To address new environmental threats**

Strong et al. (2012) suggests the following top non-SST product development areas:

Ocean Color:
Ocean color will directly address land-based sources of pollution (LBSP) and other water quality issues.

Synthetic Aperture Radar (SAR) and **Ocean Surface Vector Winds (OSVW)**:
Surface wind speed and direction will contribute toward understanding and monitoring LBSP transportation, oil and chemical spill detection, biological connectivity, climate change resilience via wind generated cooling effects, and possible detection of large-scale spawning events.

Summary

- **CRW operates a near-real-time Decision Support System (DSS) for coral reef management**
  - U.S. and global coral reef communities
- **CRW develops new products to address ever-growing coral reef management needs in a changing climate**
  - Applying advances in satellite technology and coral research
- **CRW continues to work with reef managers directly throughout product development, validation and improvement, based on management needs**

http://coralreefwatch.noaa.gov

Coral Reef Watch: a NOAA/NESDIS program, funded predominantly by the NOAA Coral Reef Conservation Program (CRCP), integrates scientists from the Center for Satellite Applications and the Research (STAR) and Office of Satellite and Product Operations (OSPO).