From Satellite Remote Sensing to Coral Reef Management:

NOAA Coral Reef Watch's End-to-end Operational Decision Support System

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William Skirving, Scott Heron, Tim Burgess

NOAA Coral Reef Watch – NESDIS/STAR

NOAA CORAL REEF CONSERVATION PROGRAM

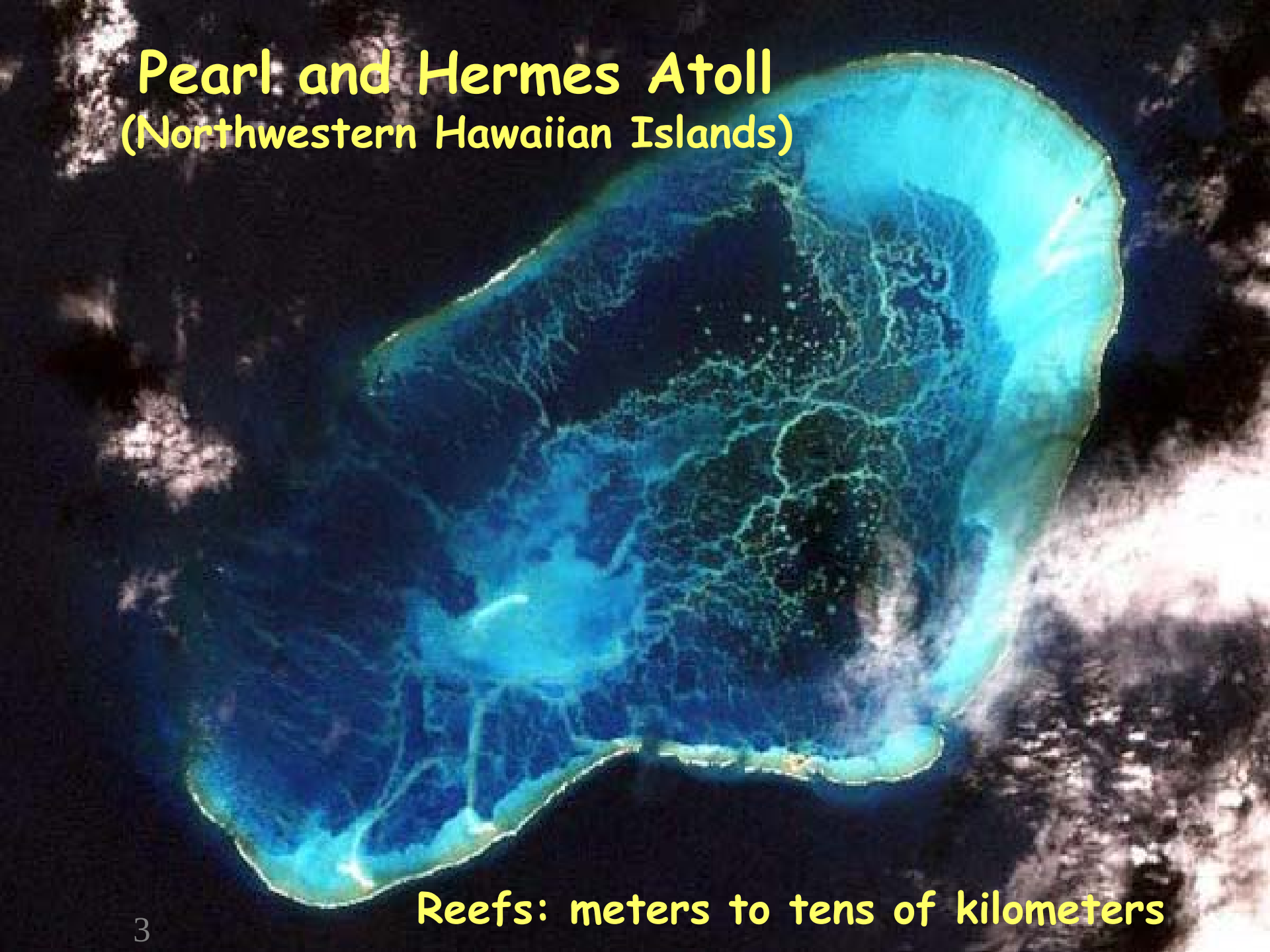
2015 STAR JPSS Annual Science Team Meeting
24-28 August 2015 · NCWCP · College Park, Maryland

Global Science & Technology, Inc.

Coral Reef

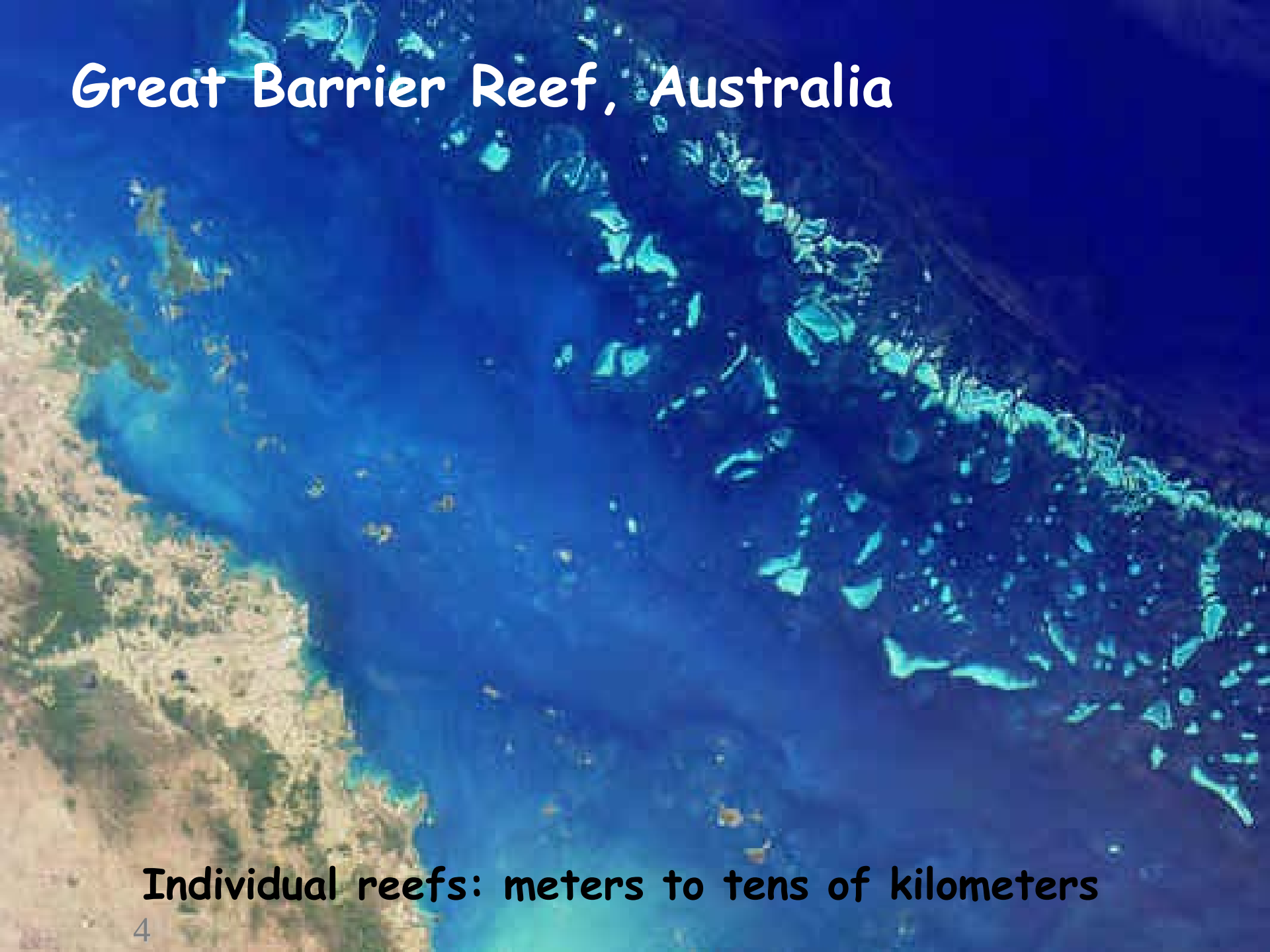


Pearl and Hermes Atoll
(Northwestern Hawaiian Islands)



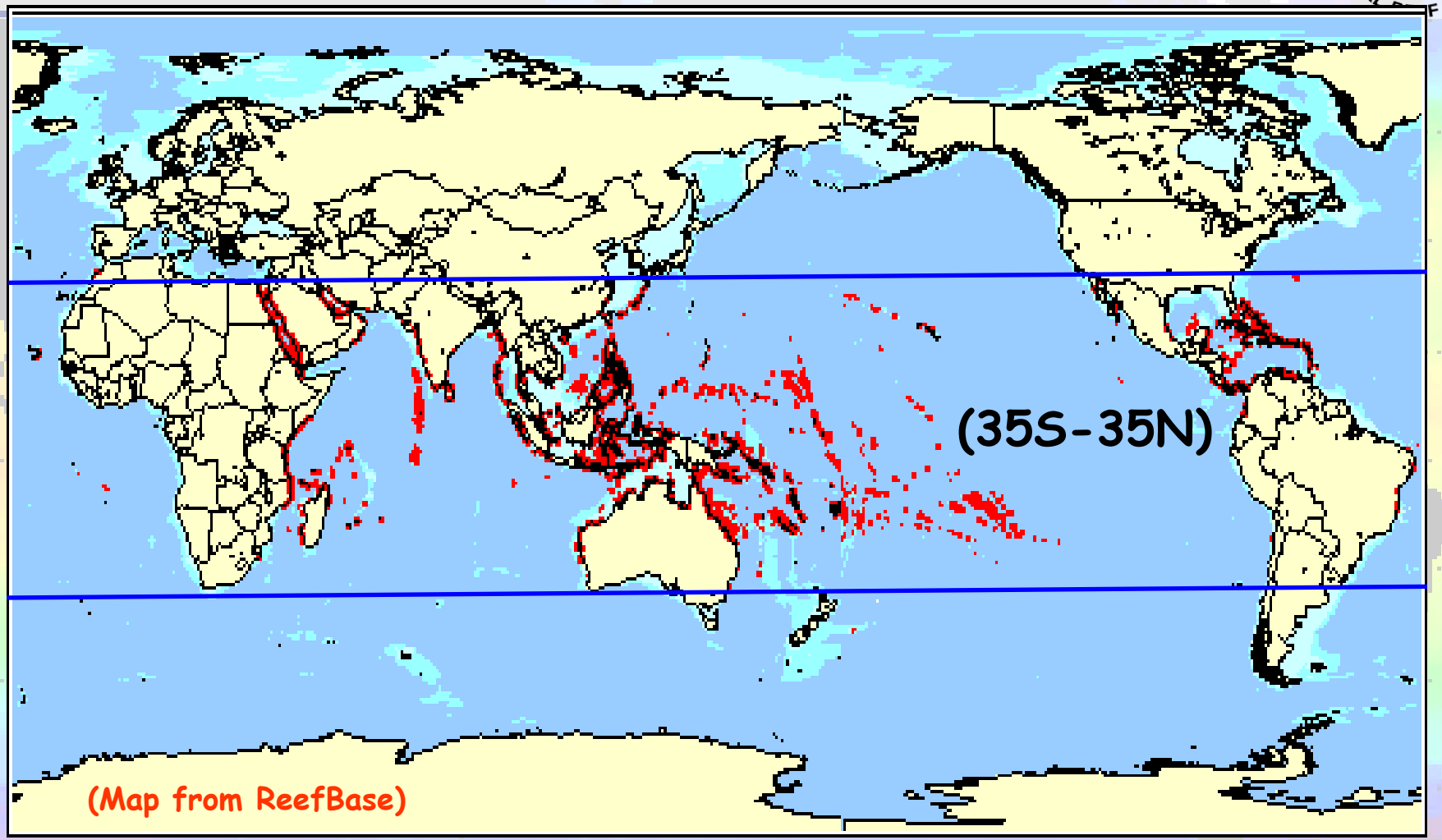
Reefs: meters to tens of kilometers

Great Barrier Reef, Australia



Individual reefs: meters to tens of kilometers

Distribution of World's Coral Reefs

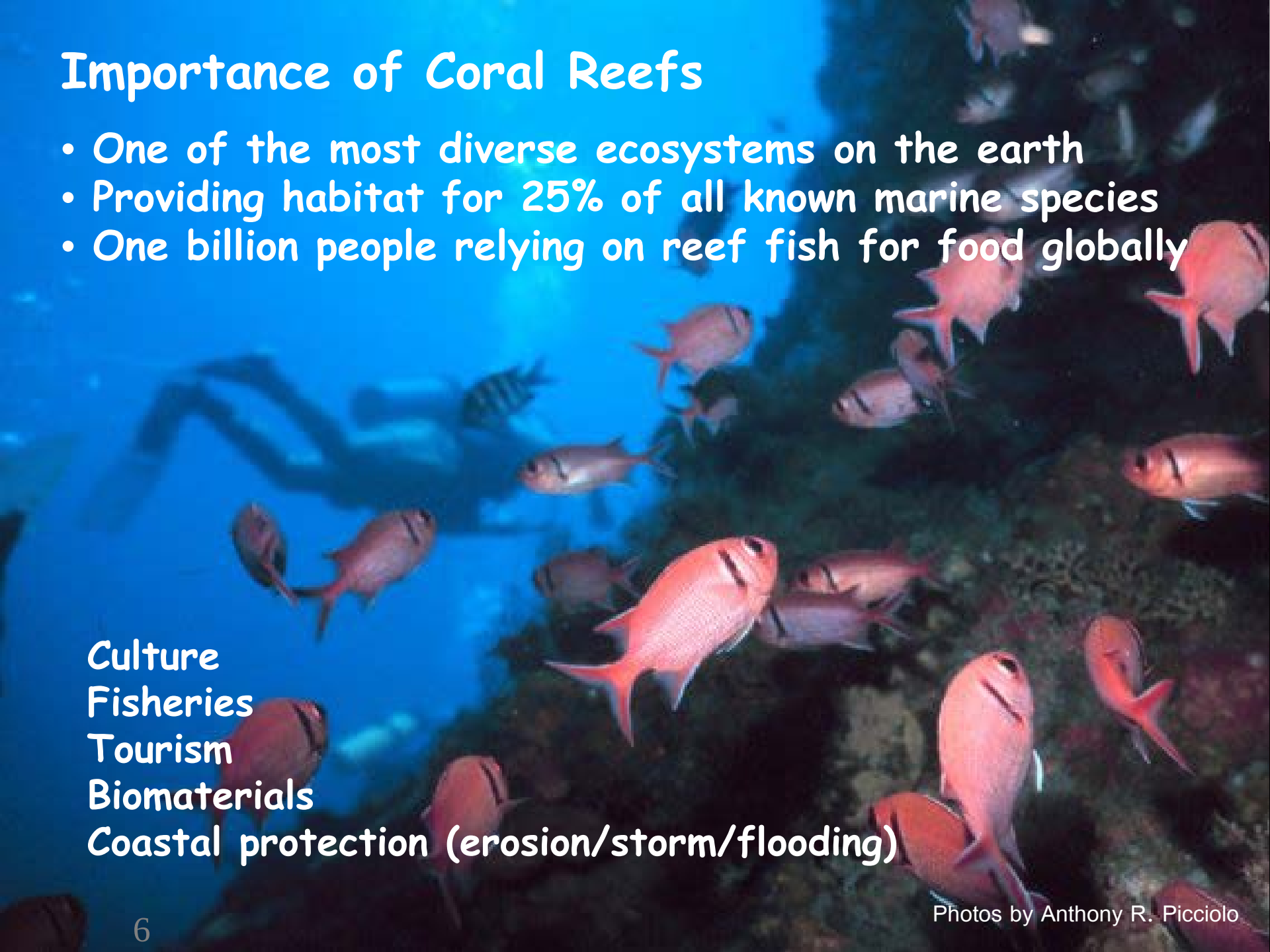


- Most in remote areas
- Covering only 1/10 of 1% of ocean floor

http://coralreefwatch.noaa.gov

Importance of Coral Reefs

- One of the most diverse ecosystems on the earth
- Providing habitat for 25% of all known marine species
- One billion people relying on reef fish for food globally



Culture
Fisheries
Tourism
Biomaterials
Coastal protection (erosion/storm/flooding)

Photos by Anthony R. Picciolo

Coral Bleaching


Bleached colony

A major threat
to the world's coral reefs

- Anomalously high water temperature induced mass bleaching
- Increasing in frequency & intensity over the past few decades

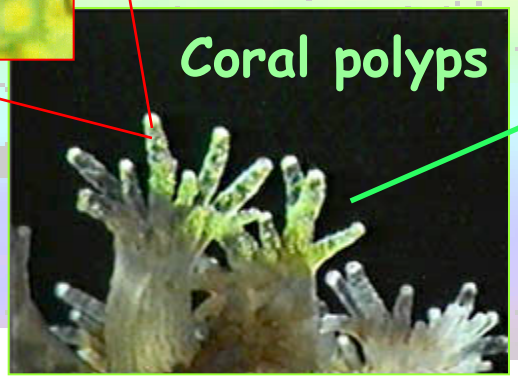
Coral and Symbiotic Algae

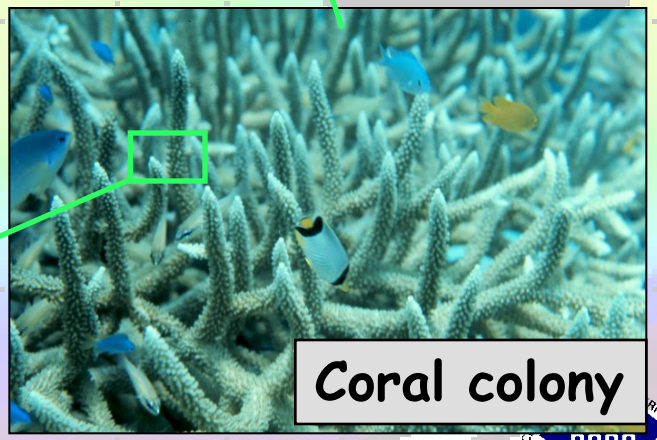
Symbiotic relationship
between algae and corals



Symbiotic algae
(Zooxanthallae)

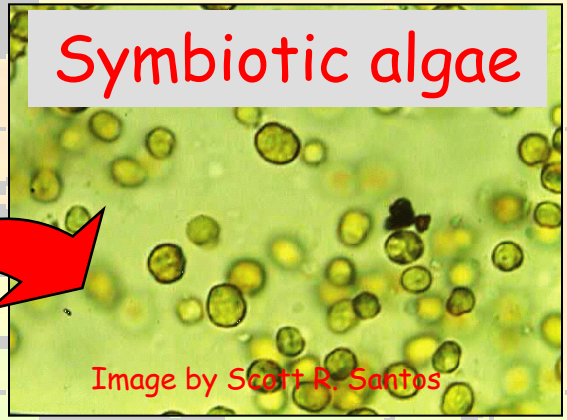




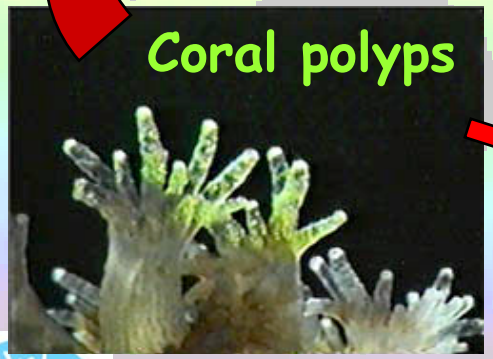


Coral Bleaching

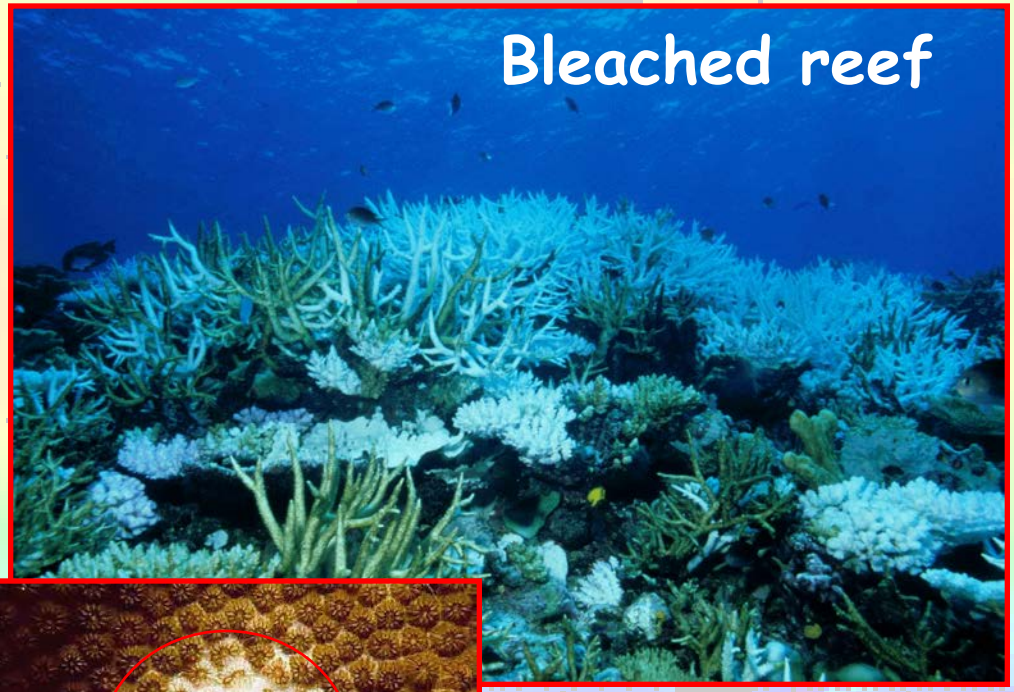
- Corals expel symbiotic algae under environmental stresses.
- White coral skeleton reveals through translucent coral tissue.
- Bleached colony becomes pale, even stark white.

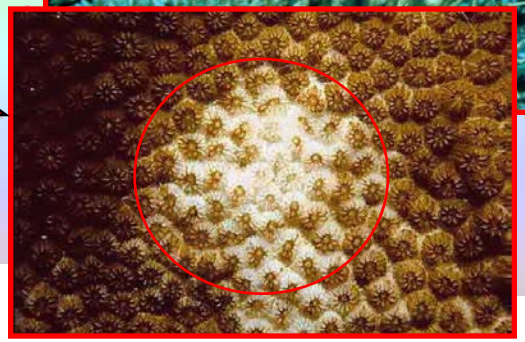


Expelling



Bleaching





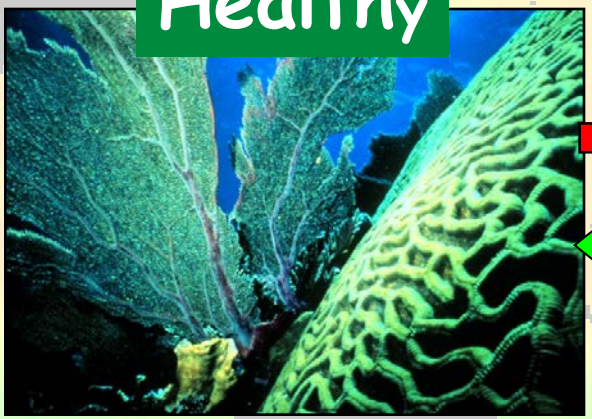
Bleached colony

Coral Bleaching & Coral Reefs in Crisis

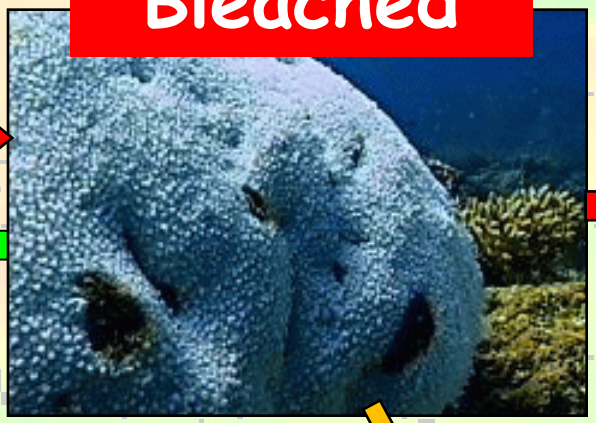
Dramatic long-term ecological and social consequences

??? (long time, favorable environmental conditions)

Healthy



Bleached



Dead



Bleaching increases the susceptibility of corals to disease

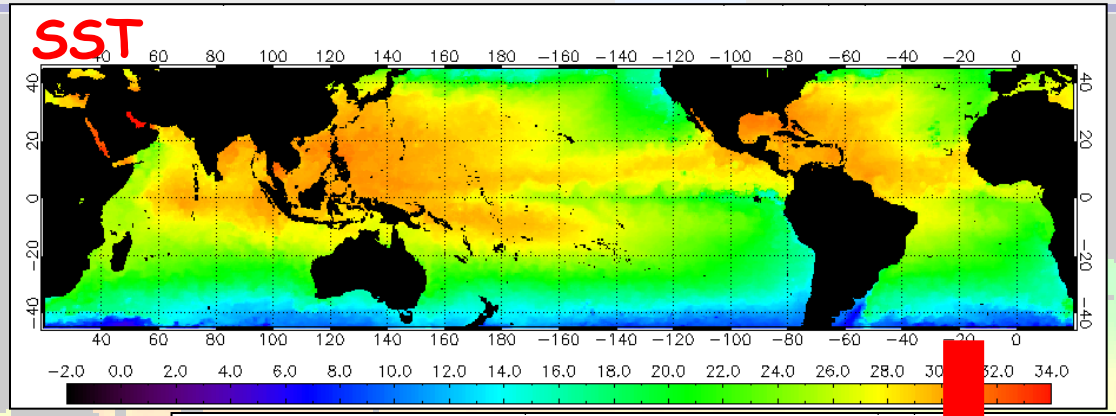
Disease

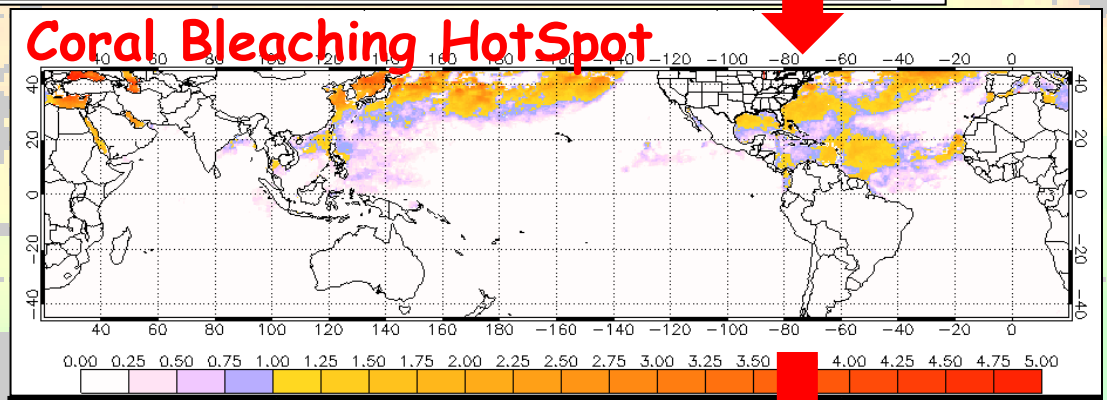


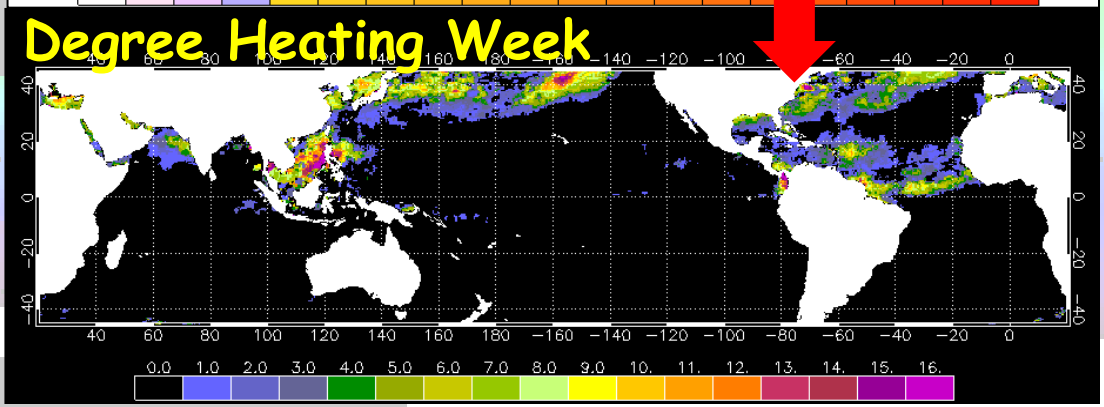
(Photo Credit: J.Lamb)

NOAA Coral Reef Watch

Decision Support System for Coral Reef Management







Since 1997

50-km

Twice-weekly

1997

2000

Workshops, Outreach, and Trainings

2000-present: Bring managers, scientists, and stakeholders together



American Samoa, 2007



Pigeon Key, Florida, 2008



Maui, Hawaii, 2008



Thailand and Indonesia, 2013





American Samoa, 2014



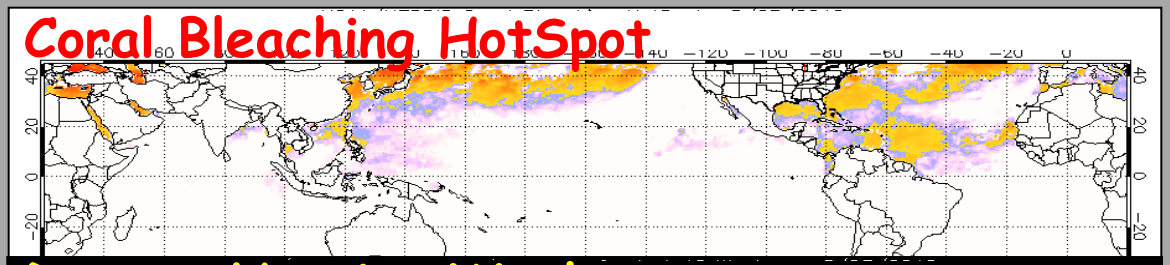


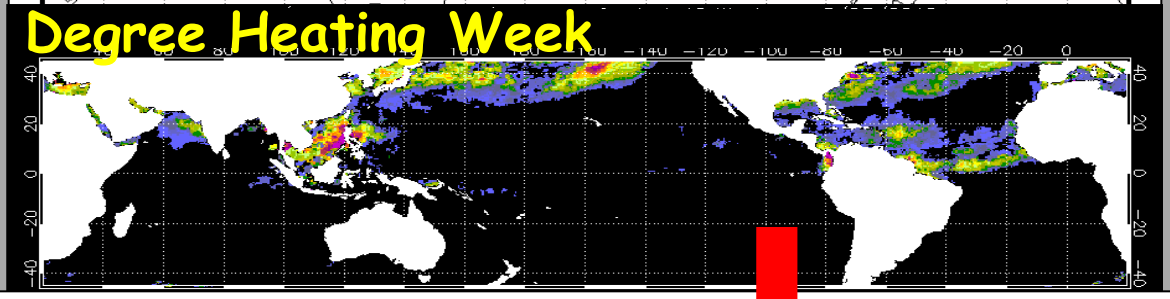
St. Lucia, 2015



NOAA Coral Reef Watch

Decision Support System for Coral Reef Management





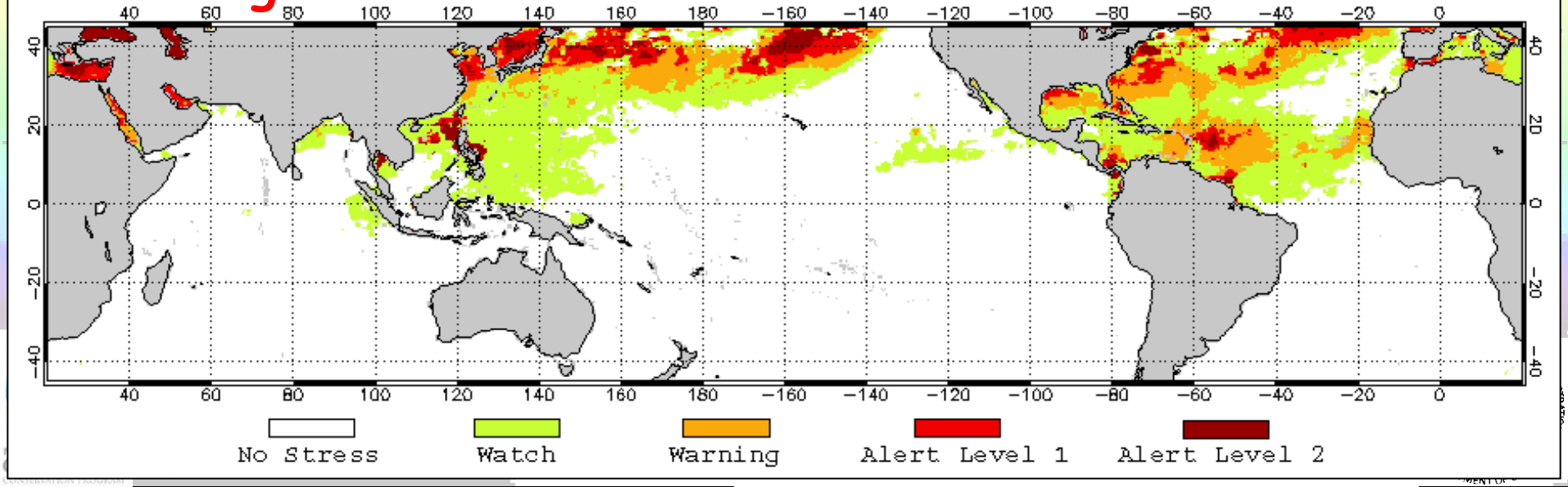
Since 1997

50-km

Twice-weekly

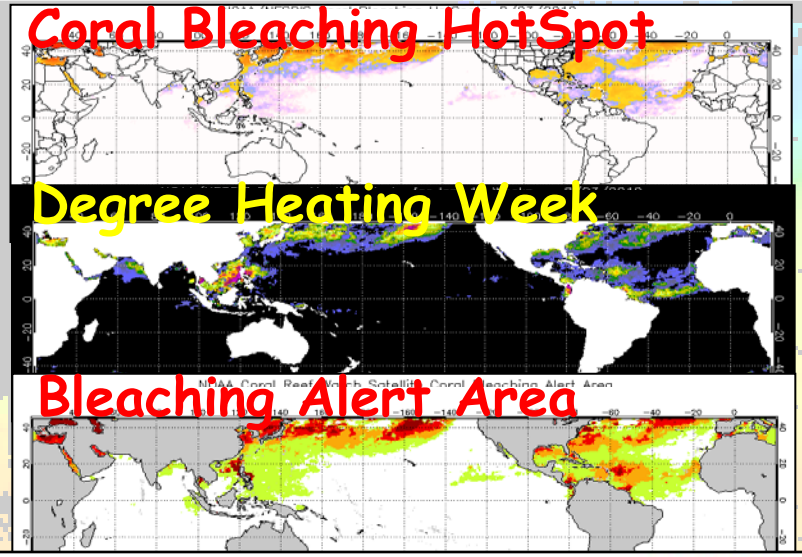
2009

Bleaching Alert Area



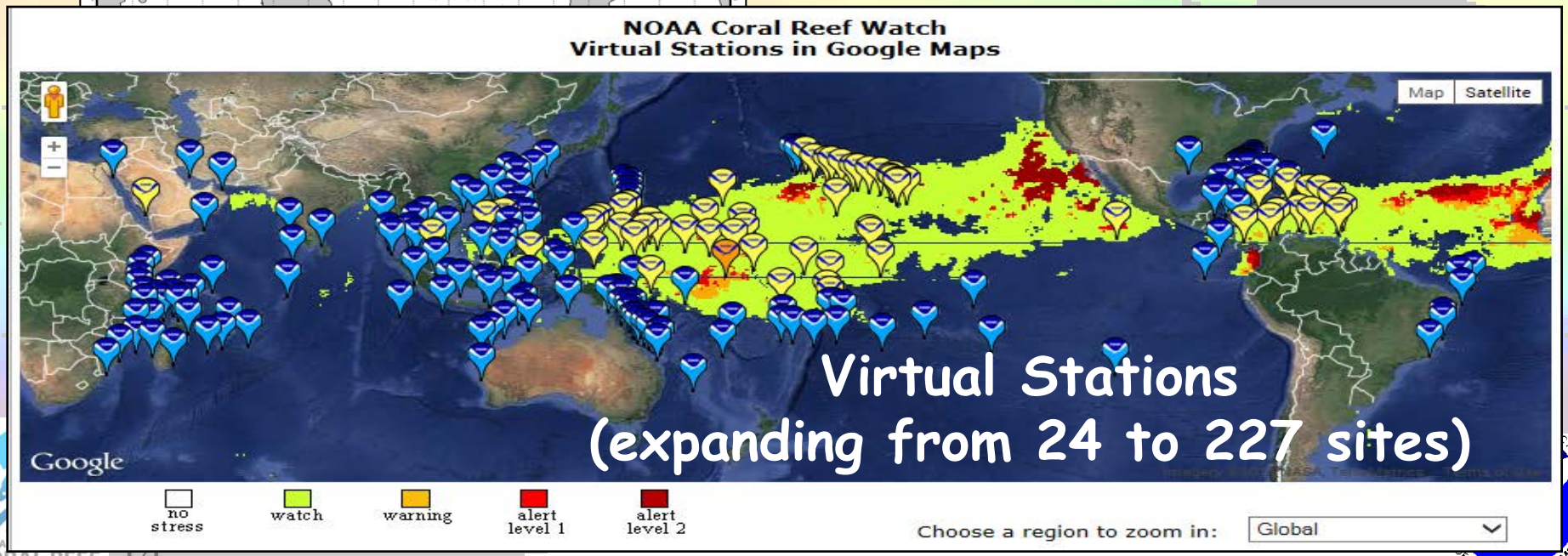
NOAA Coral Reef Watch

Decision Support System for Coral Reef Management



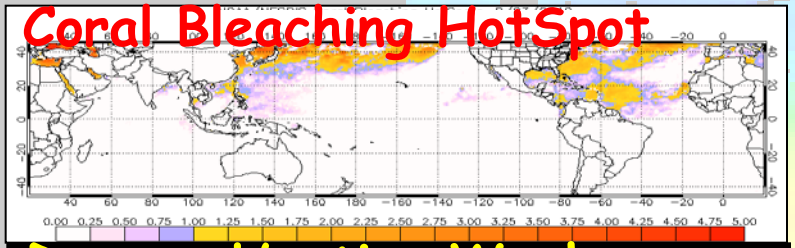
50-km
Twice-weekly

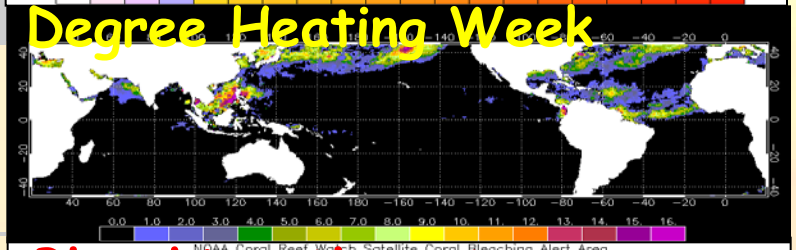
2000-2011

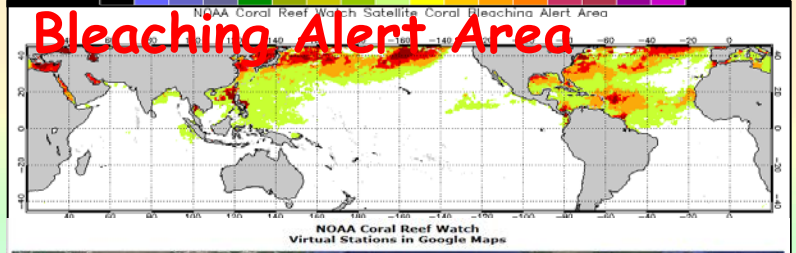


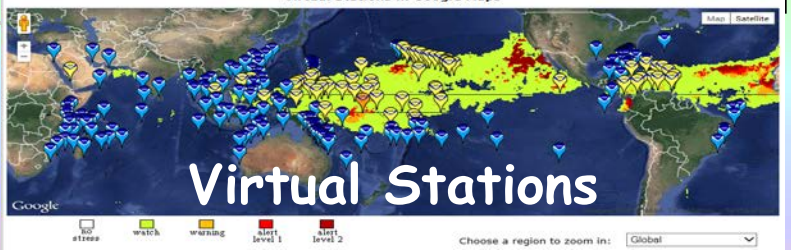
NOAA Coral Reef Watch

Decision Support System for Coral Reef Management









50-km, twice-weekly

2005

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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

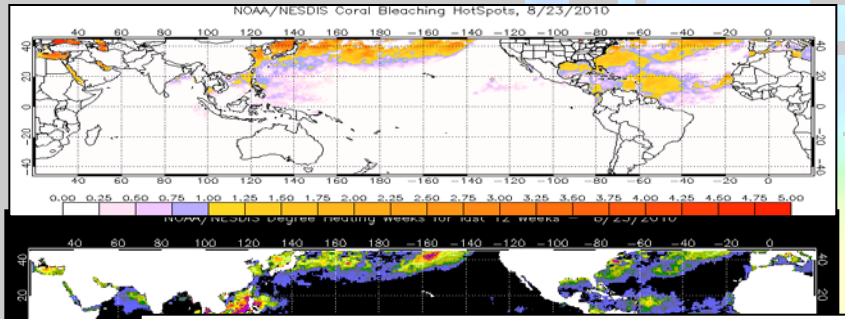
** Polynesia

-- Funafuti, Tuvalu	(+) Bleaching Watch

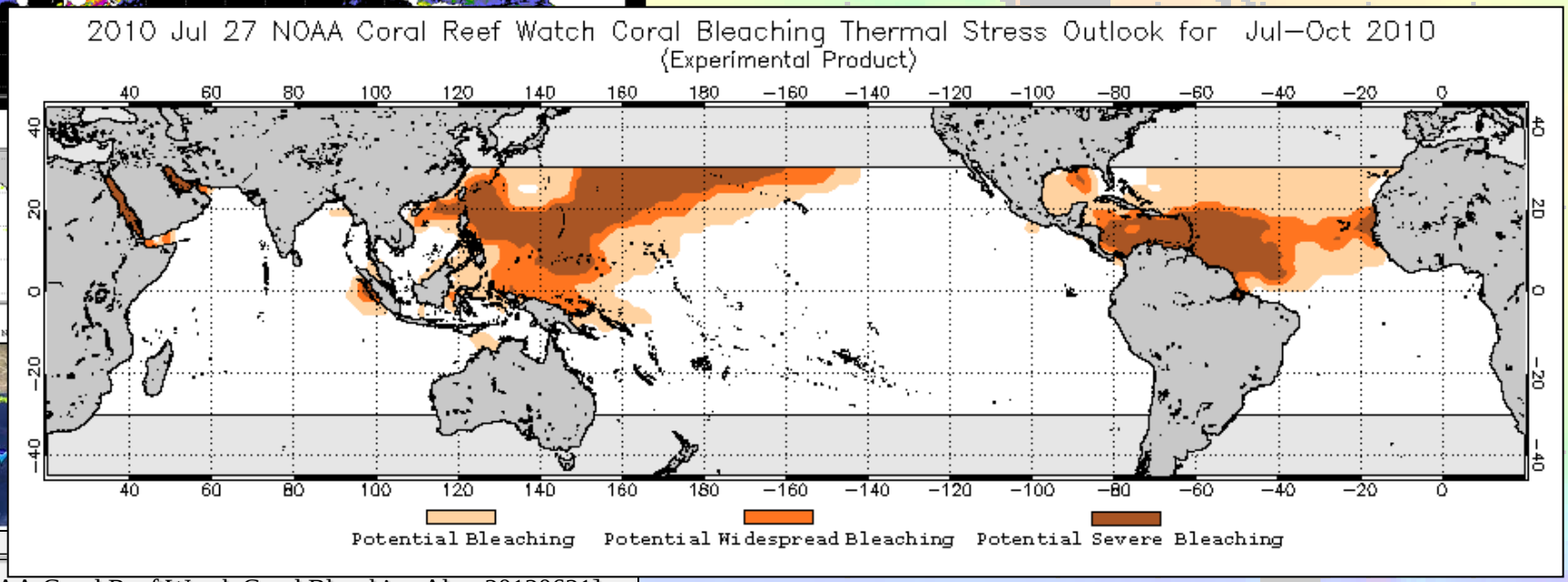
Automated email alert for Virtual Stations

NOAA Coral Reef Watch

Decision Support System for Coral Reef Management



2008





[NOAA Coral Reef Watch Coral Bleaching Alert 20120621]

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Atlantic Ocean

** Caribbean

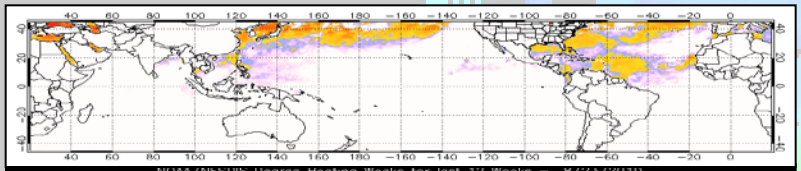
-- Bocas del Toro, Panama (+) Bleaching Watch

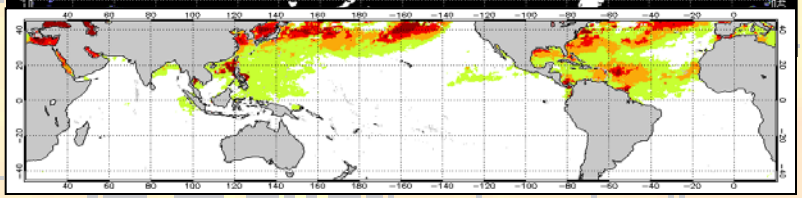
-- Cayos Miskitos, Nicaragua (+) Bleaching Watch

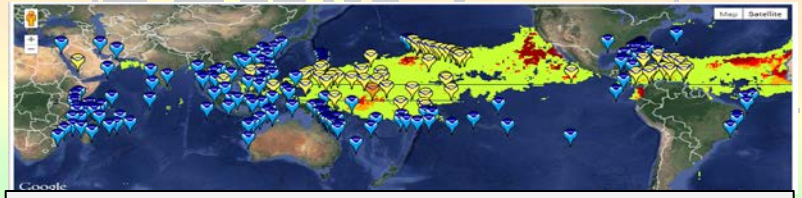
Seasonal Bleaching Outlook

NOAA Coral Reef Watch

Decision Support System for Coral Reef Management







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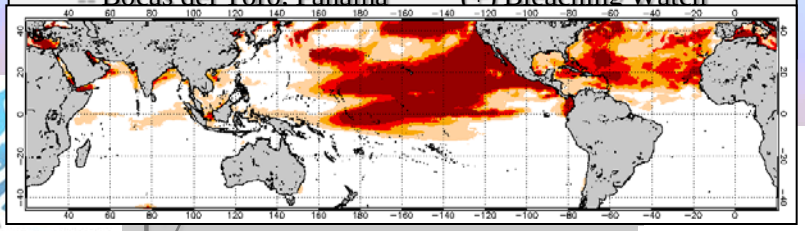
[NOAA Coral Reef Watch Coral Bleaching Alert 20120621]

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Atlantic Ocean

** Caribbean

-- Bocas del Toro, Panama (+) Bleaching Watch



Bleaching Thermal Stress Analysis/Seasonal Guidance

Pacific Climate Update
Coral Bleaching Thermal Stress Analysis and
Seasonal Guidance through August 2015

(Released May 3, 2015)

NOAA Coral Reef Watch's near-real-time satellite monitoring has shown significant and persistent elevation of sea surface temperature (SST) throughout the equatorial Pacific Ocean. High SST anomalies are now well-developed in the eastern equatorial Pacific Ocean and along the coast of South America, consistent with a conventional El Niño (Figure 1). Meanwhile, a significantly high anomaly in the central equatorial Pacific Ocean that started early last year has persisted, consistent with an atypical El Niño Modoki or central Pacific El Niño event (Figure 1). SST anomalies in the western equatorial Pacific Ocean also remain higher than normal.

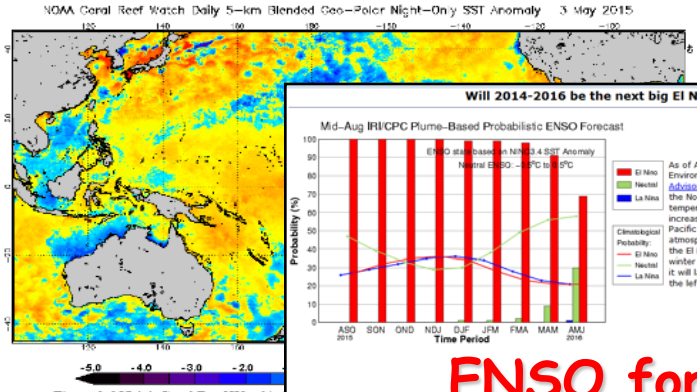
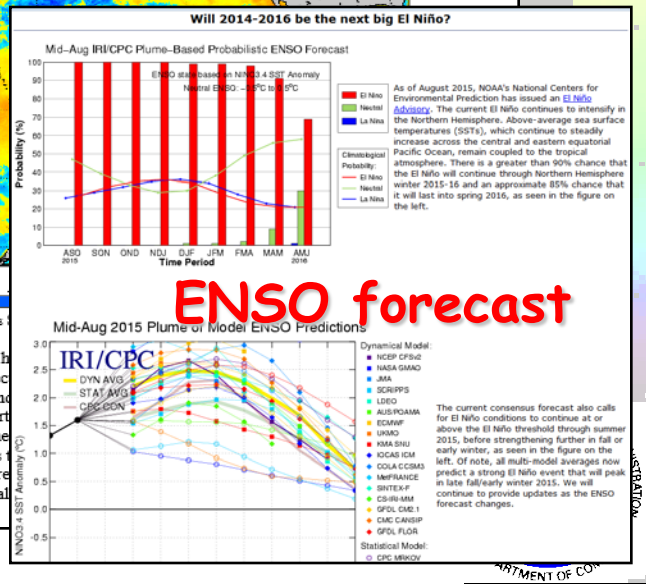


Figure 1. NOAA Coral Reef Watch's

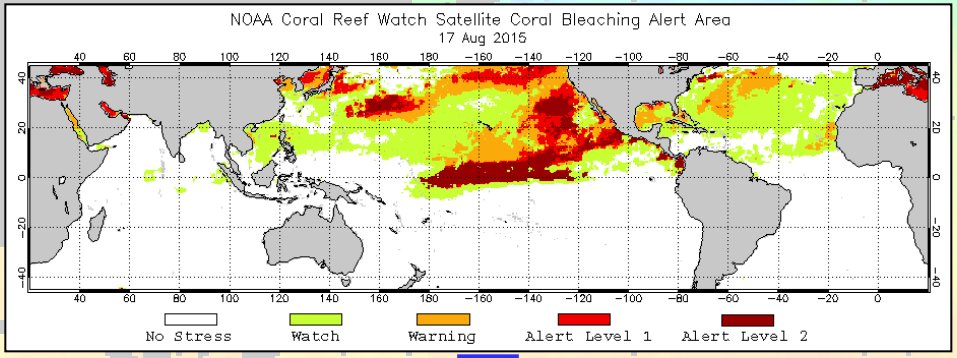
As a result, Coral Bleaching HotSpots h
equatorial Pacific Ocean (Figure 2), acc
(Figure 3). Bleaching Alert Levels 1 and
soon bleach on reefs in Kiribati (Gilbert
west, and the Galapagos Islands and the
western South Pacific has decreased as t
thermal stress still can be seen in Figure
come from regions such as Fiji and Wal



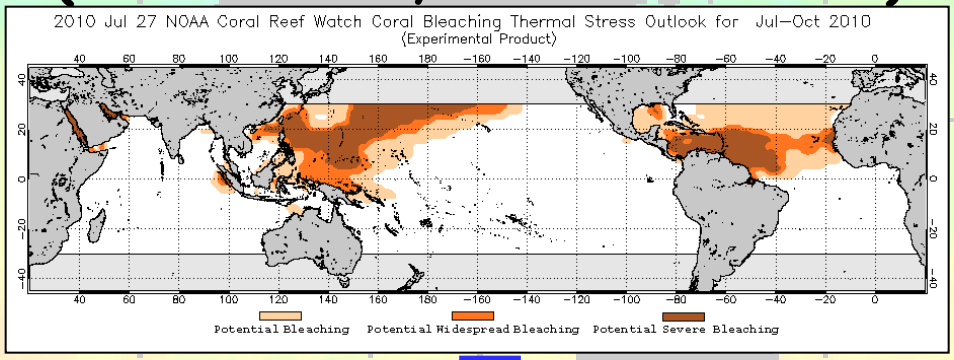
ENSO forecast

Next-Generation Products

50 km Twice-weekly Satellite Products



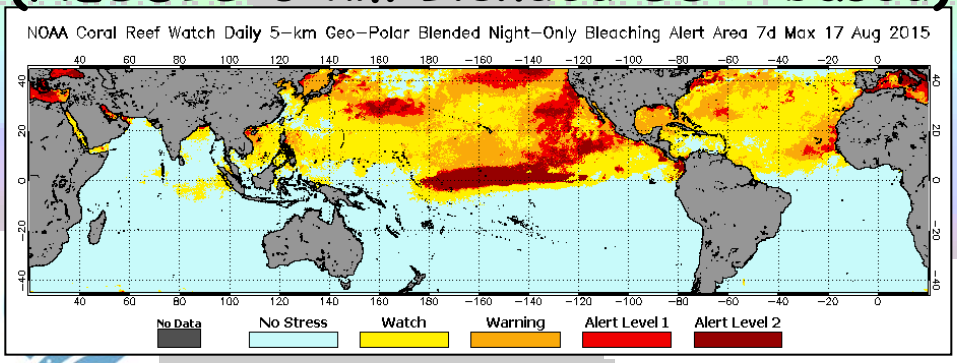
2 degree 4-Month Outlook (deterministic, OAR/LIM-based)



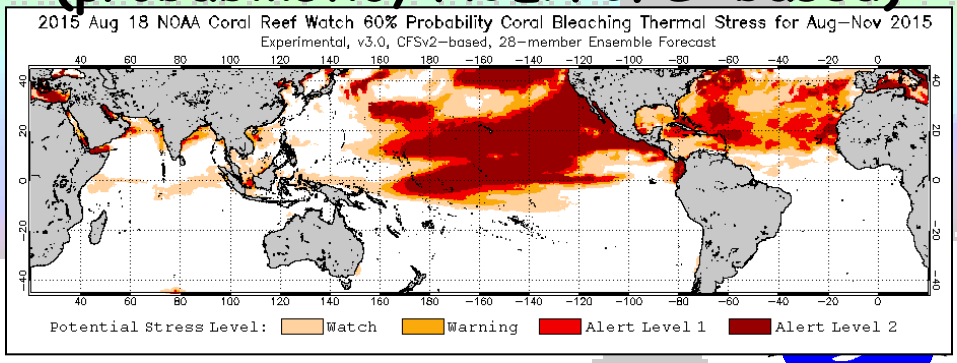
2012 2015

2012 2015

5 km Daily Satellite Products (NESDIS 5 km Blended SST-based)



0.5 degree 4-Month Outlook (probabilistic, NCEP/CFS-based)

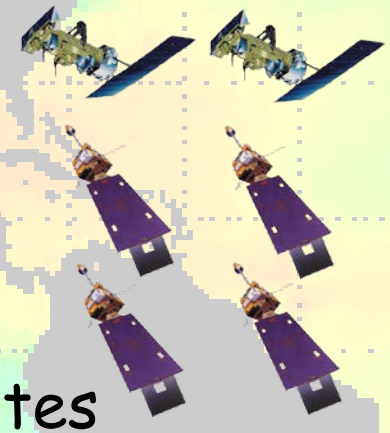


Next-Generation Satellite Products

NESDIS Geo-Polar Blended Night-Only SST Analysis

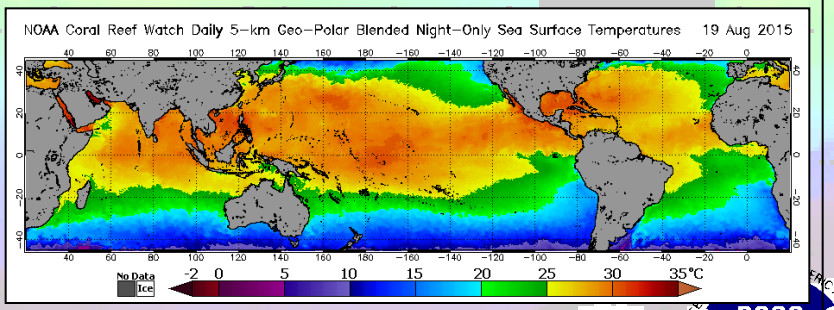
Heritage		Next Generation
50 km	➔	5 km
twice-weekly	➔	daily
one polar-orbiter only	➔	blended data from polar-orbiting & geostationary satellites





Polar-orbiting satellites: **Suomi-NPP (VIIRS: highest spatial res.)**
MetOp-B

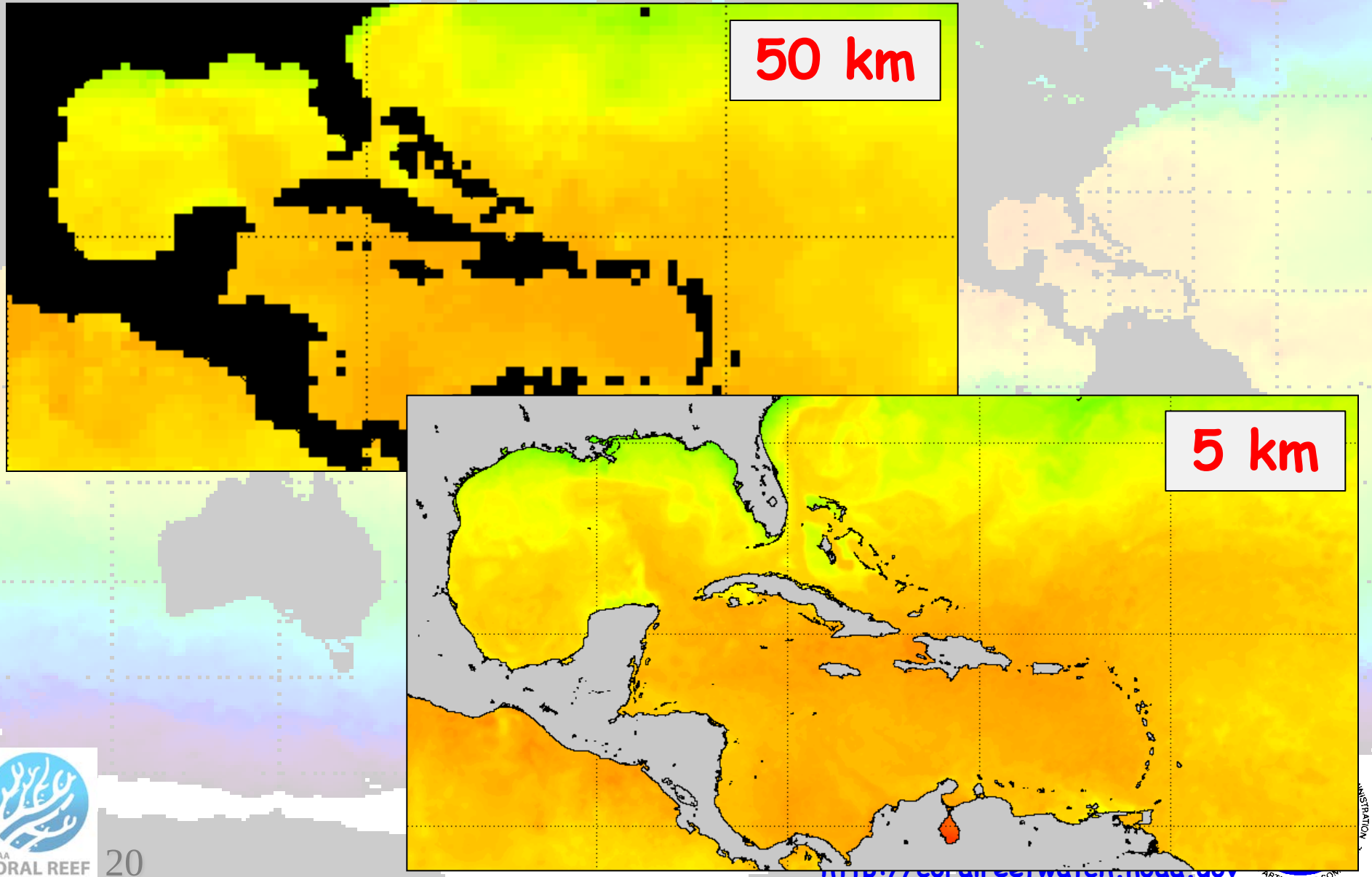
Geostationary satellites: **GOES-E**
GOES-W
MTSAT-2
MSG-3



http://coralreefwatch.noaa.gov

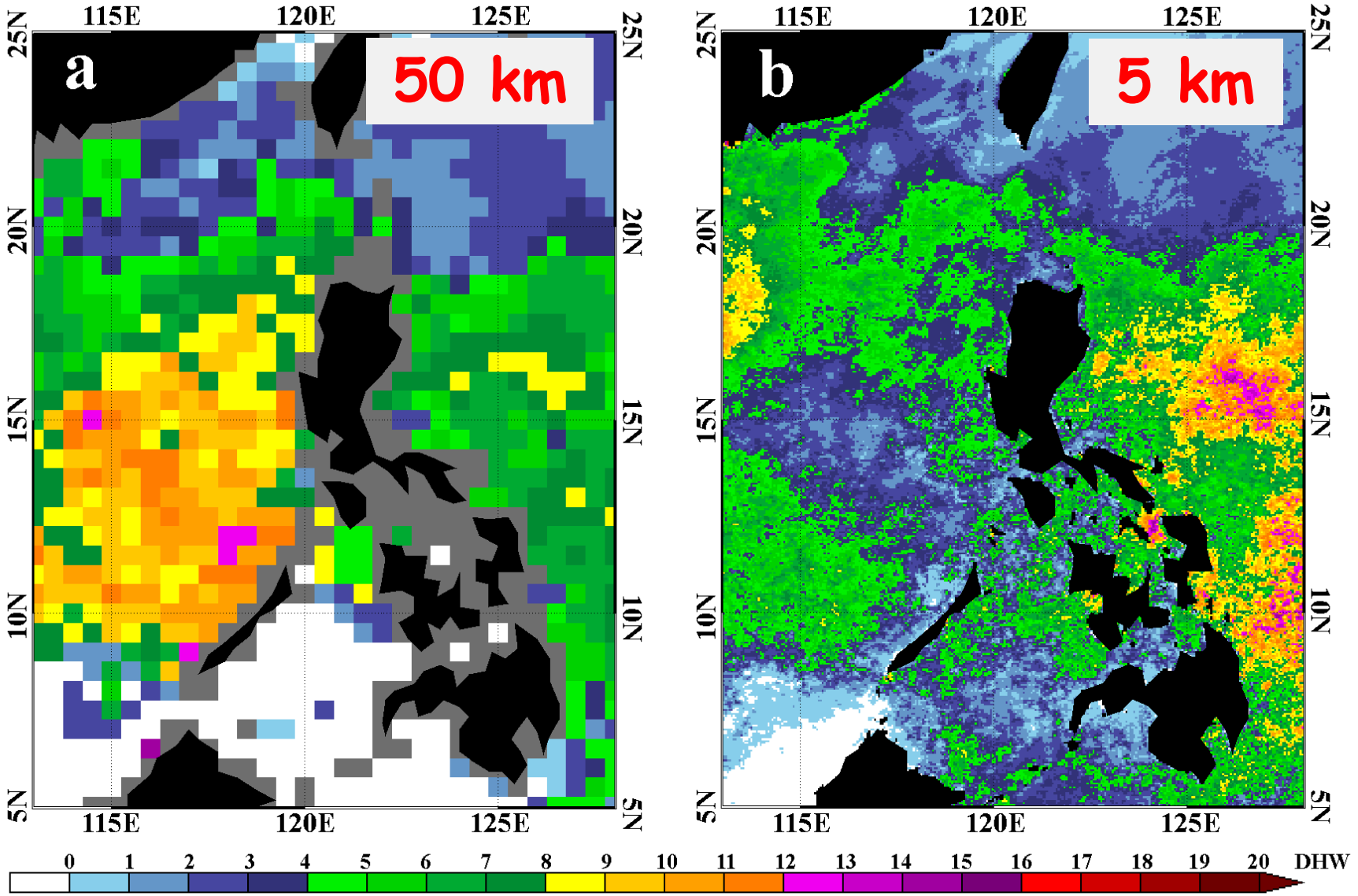
NOAA Coral Reef Watch

Sea Surface Temperature (Input)



NOAA Coral Reef Watch

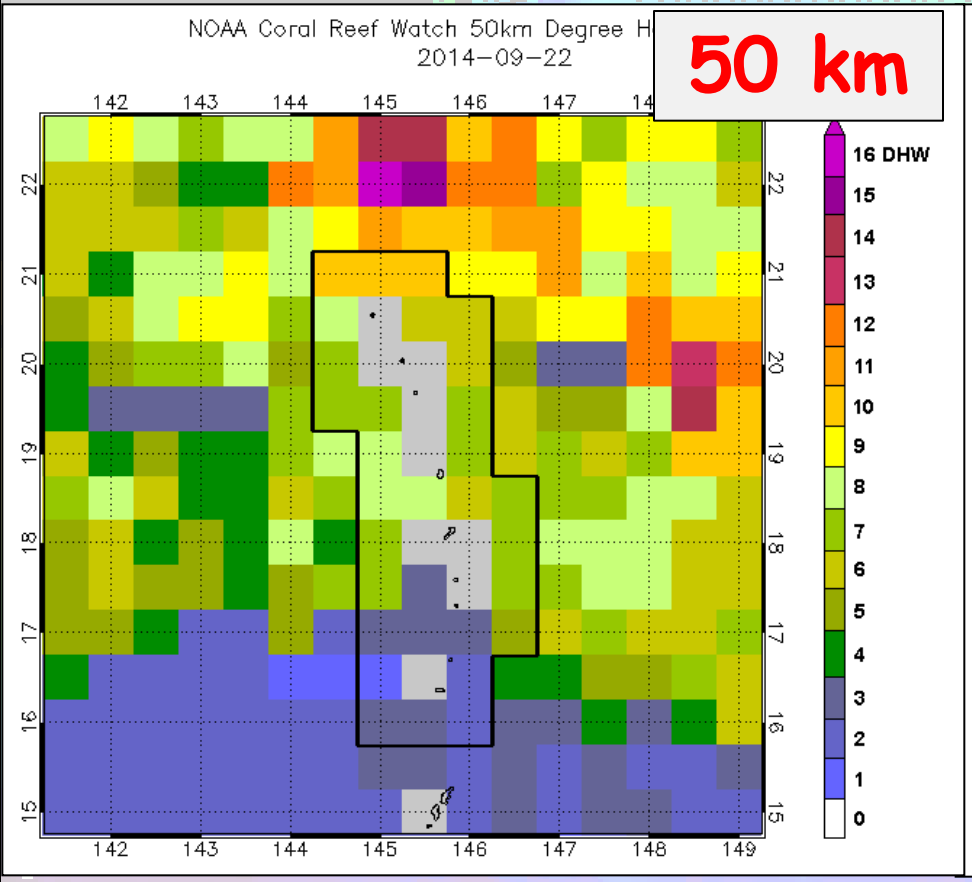
Degree Heating Weeks

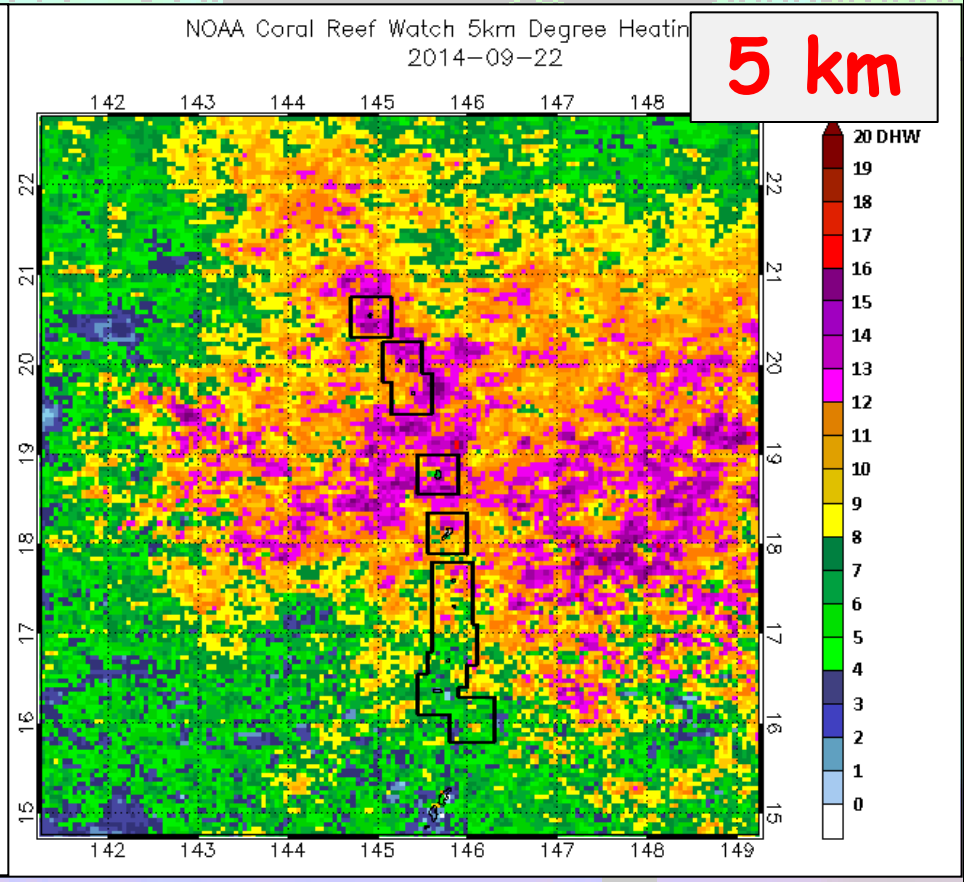


NOAA Coral Reef Watch

Degree Heating Weeks

2014 bleaching event in CNMI

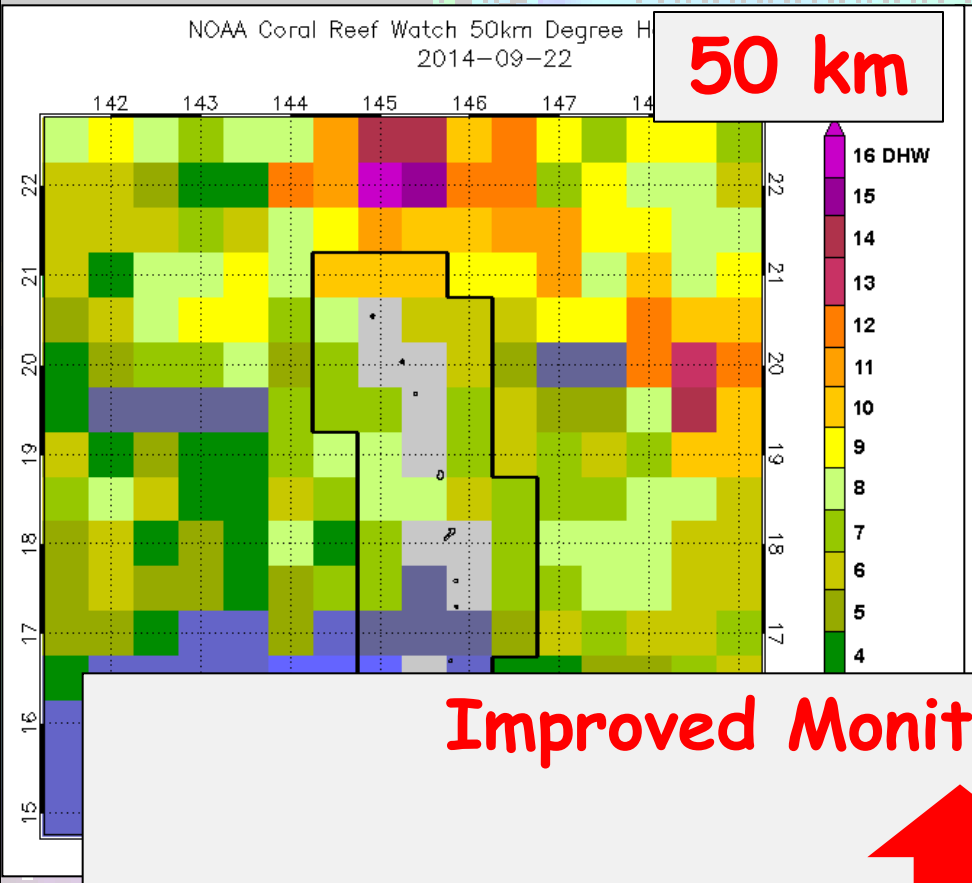


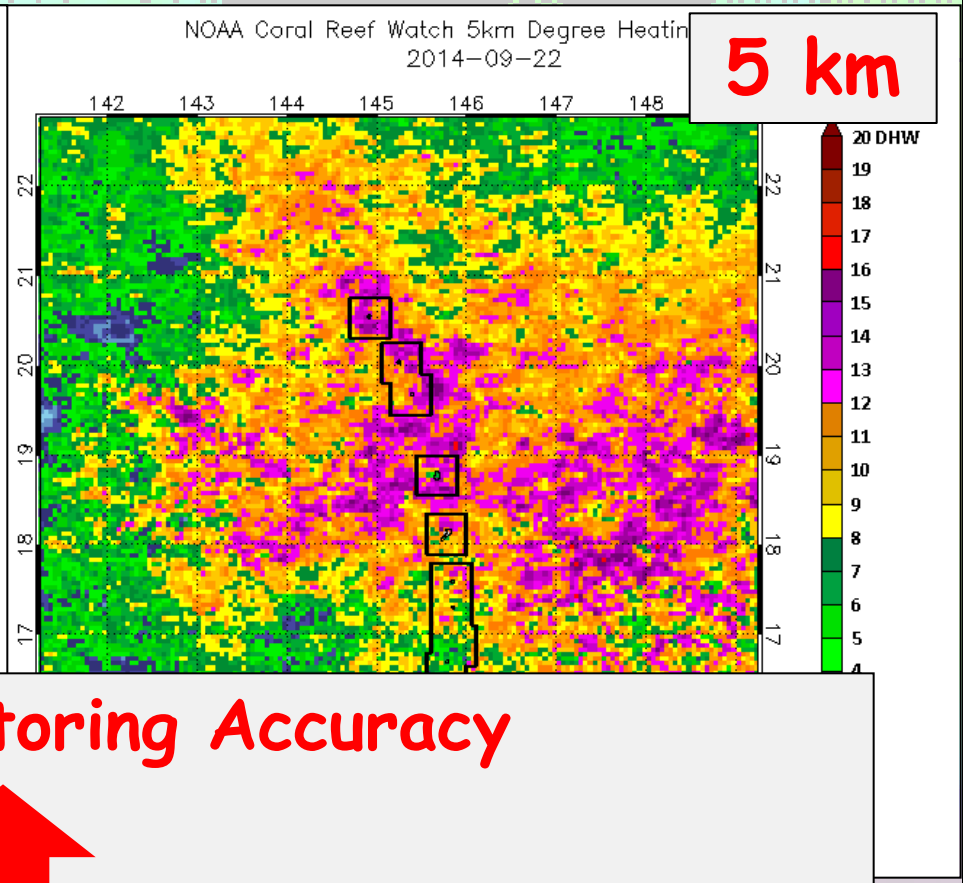


(CNMI: Commonwealth of the Northern Mariana Islands)

Degree Heating Weeks

2014 bleaching event in CNMI

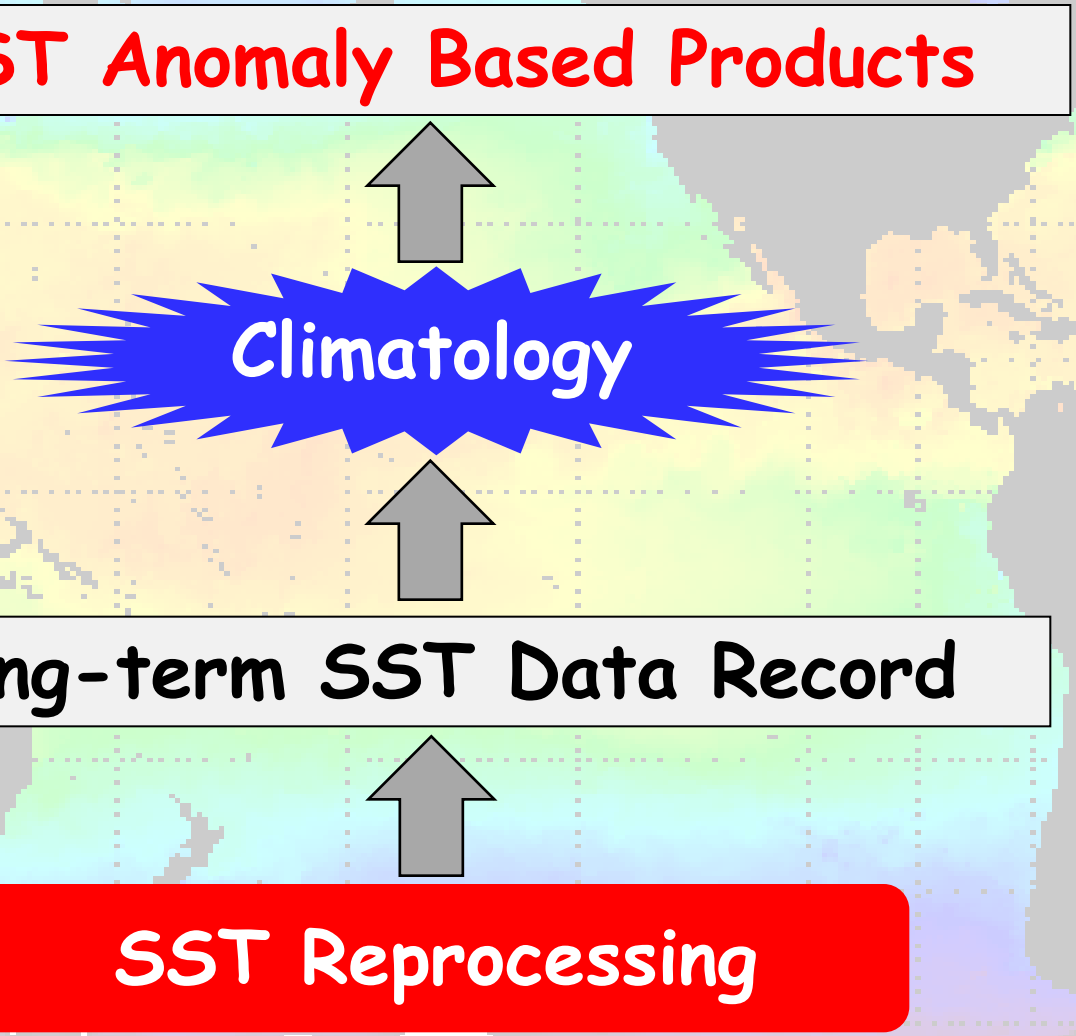




Improved Monitoring Accuracy

Improved SST quality / Improved Climatology

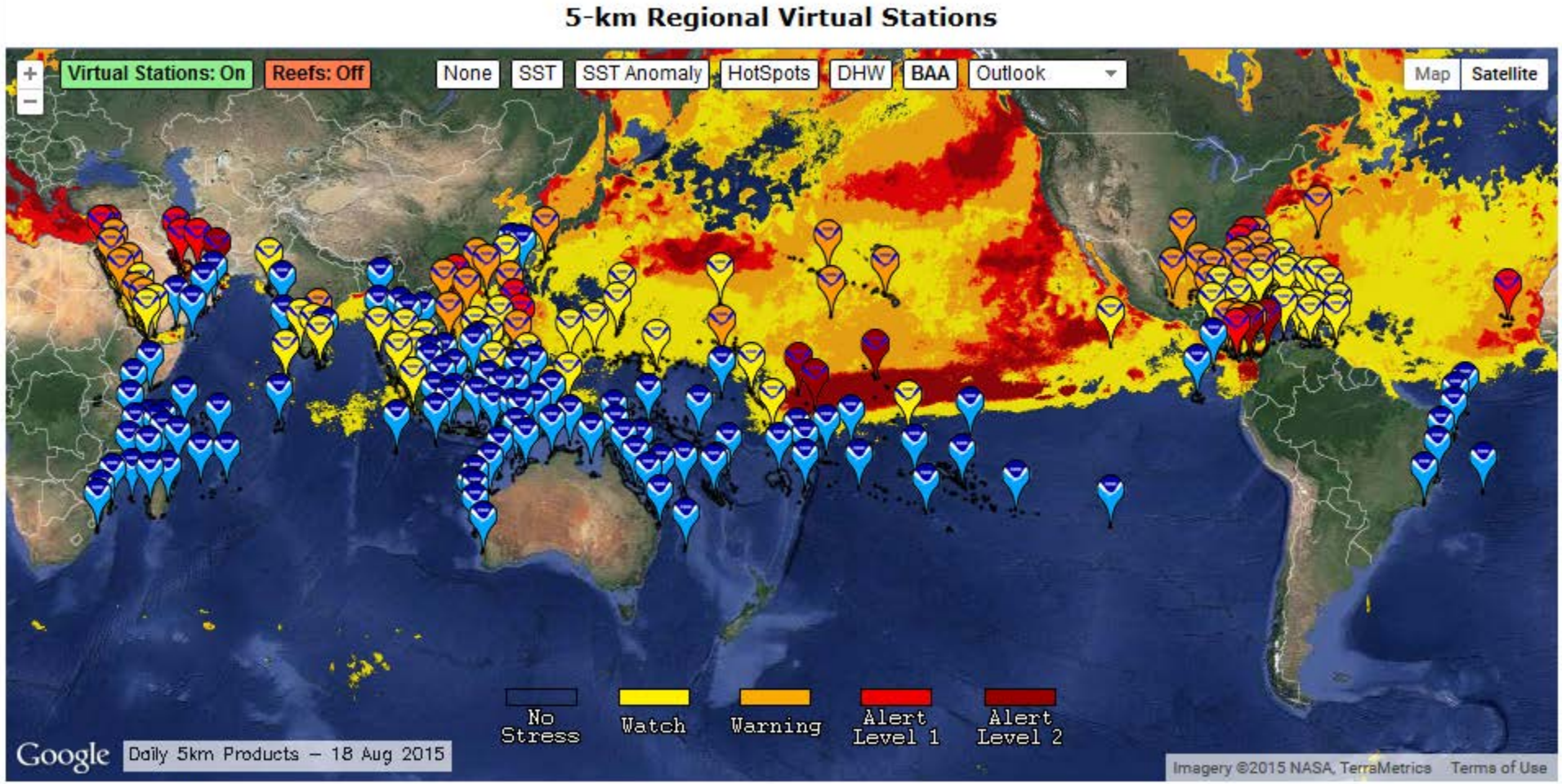
SST Reprocessing and Climatology



(STAR SST teams)

NOAA Coral Reef Watch

Satellite Bleaching Regional Virtual Stations (5-km)



View this map full screen.

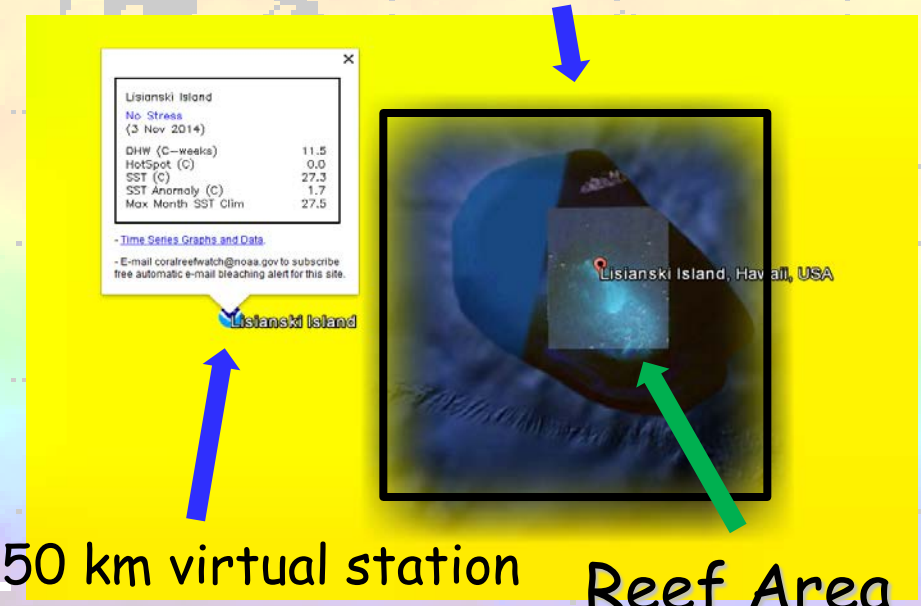
Select a region to zoom in: Global

http://coralreefwatch.noaa.gov

Satellite Bleaching Virtual Stations

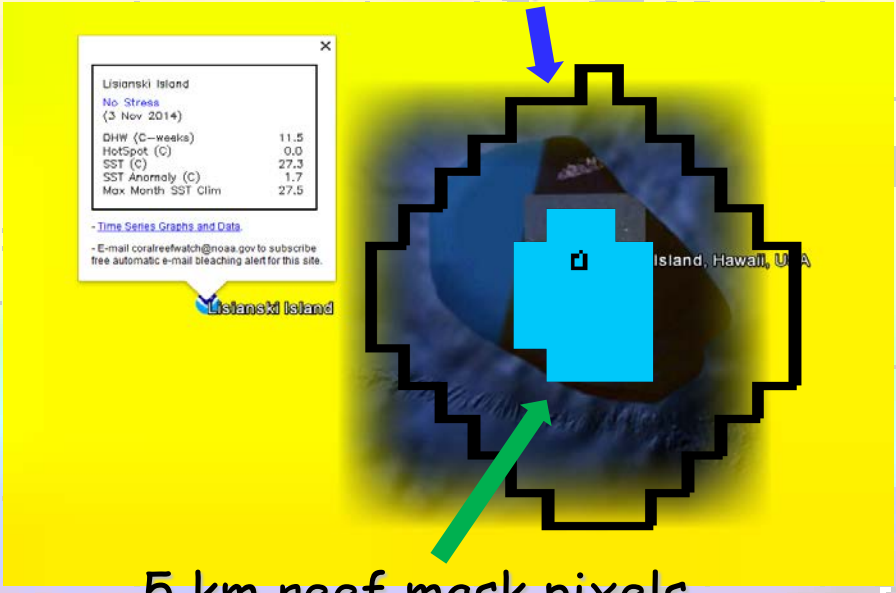
50 km virtual station
(a single 50-km pixel near reef)

Approx. 50 km pixel size

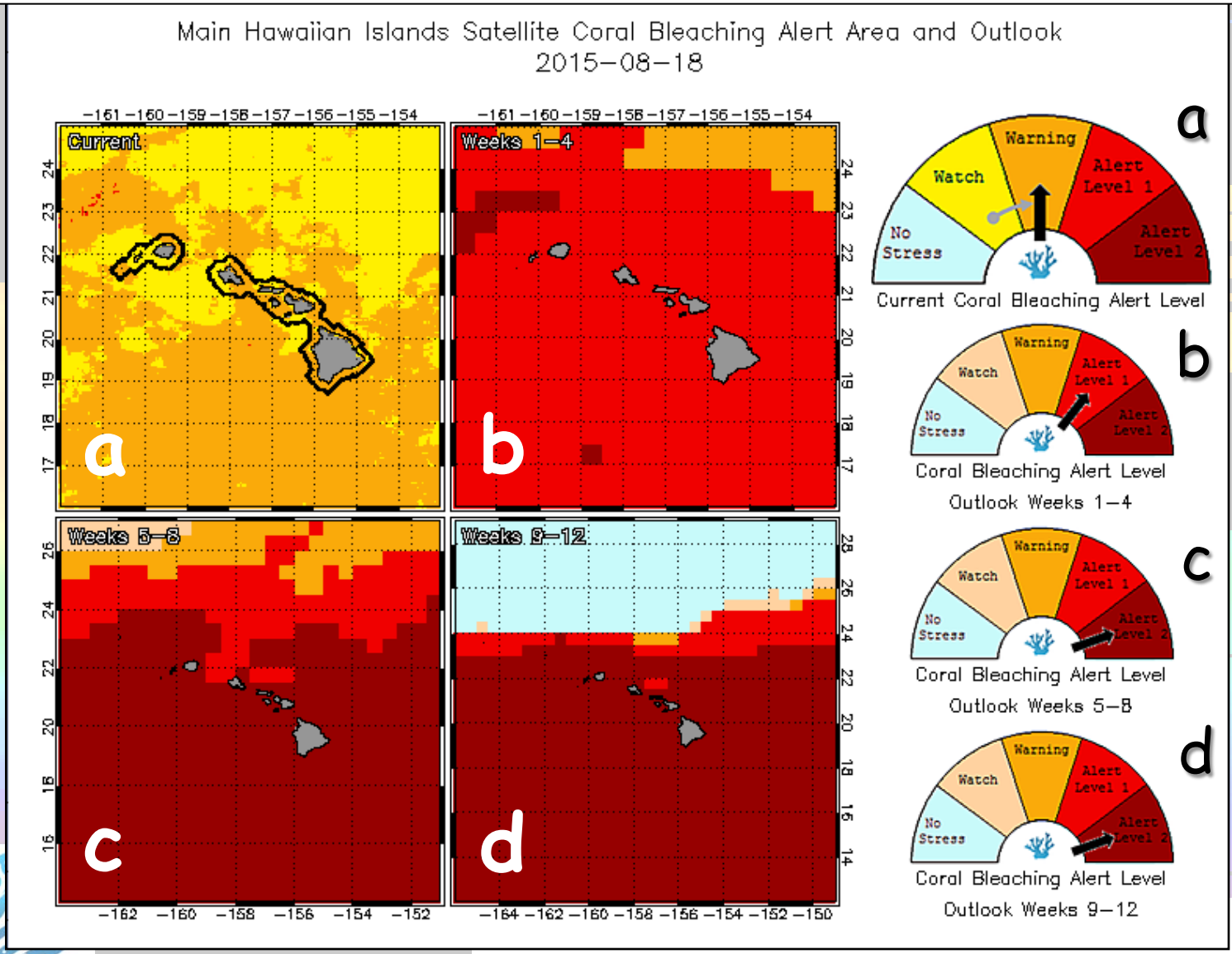


5 km regional virtual station
(a multi-pixel region of at reef)

20-km buffer around reef pixels



Main Hawaiian Islands Regional Virtual Station 5-km Bleaching Thermal Stress Gauges

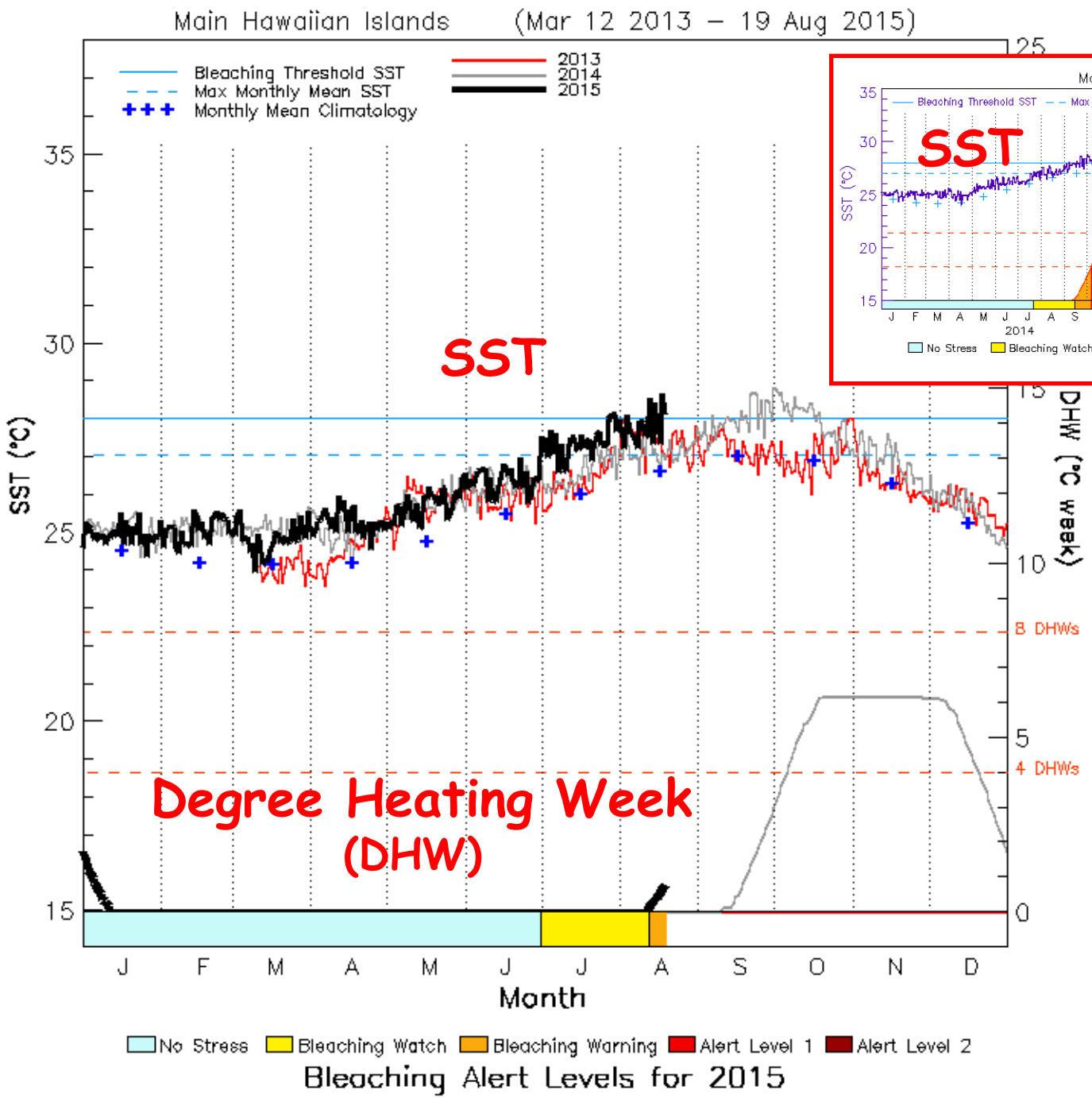


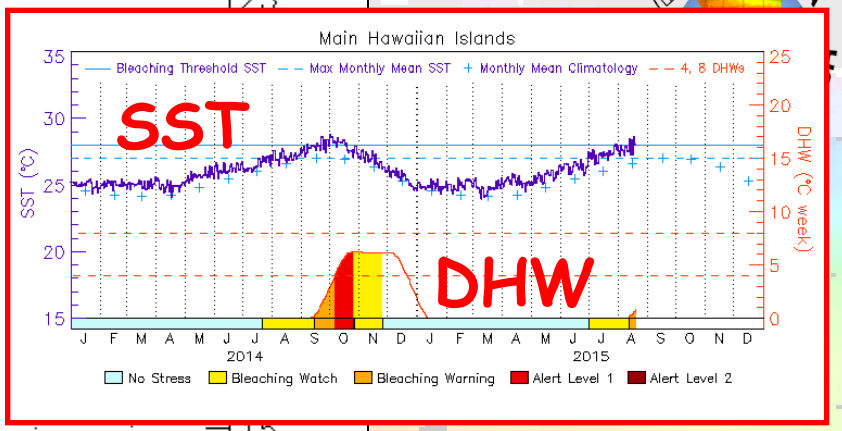
Current Satellite Bleaching Alert

Outlook (1-4 weeks)

Outlook (5-8 weeks)

Outlook (9-12 weeks)





SST and DHW time series for the Main Hawaiian Islands Regional Virtual Station

fwatch.noaa.gov

NOAA Coral Reef Watch

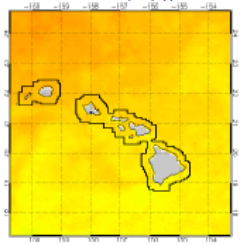
CRW's Products in Users' Newsletters/Bulletins

UPDATE: CORAL BLEACHING DATA

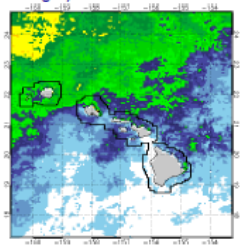
10/13/2014

NOAA CORAL REEF WATCH DATA (http://coralreefwatch.noaa.gov)

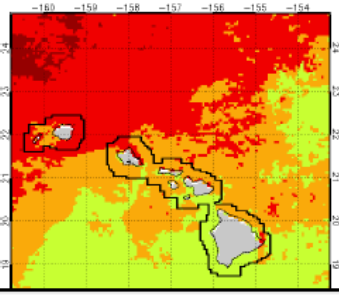
The NOAA Coral Reef Watch Sea Surface Temperature (SST) Anomaly map (top left) shows the difference between today's temperature and the long-term average. The Degree Heating Week map (top right) shows accumulated thermal stress, which can lead to coral bleaching. Significant coral bleaching usually occurs when DHW values reach 4 °C-weeks. At 8 °C-weeks, widespread bleaching is likely and significant mortality can be expected.

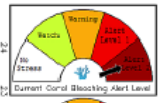


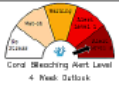
Sea Surface Temperature Anomaly—10/13/2014

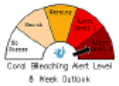


Degree Heating Week- 10/13/2014











NOAA Potential Bleaching Intensity Levels

No Stress	No bleaching
Bleaching Watch	Possible bleaching
Bleaching Warning	Possible bleaching
Alert Level 1	Bleaching Likely
Alert Level 2	Coral Mortality Likely

This experimental map product provides a summary of current satellite data as well as forecaste bleaching reflect the and forecas coral bleach

Mote Marine Laboratory / Florida Keys National Marine Sanctuary

Coral Bleaching Early Warning Network

Current Conditions Report #20150701

Updated July 1, 2015

Summary: Based on climate predictions, current conditions, and field observations, the threat for mass coral bleaching within the FKNMS is currently **MODERATE**.

NOAA Coral Reef Watch Current and 60% Probability Coral Bleaching Alert Outlook June 29, 2015 (experimental)

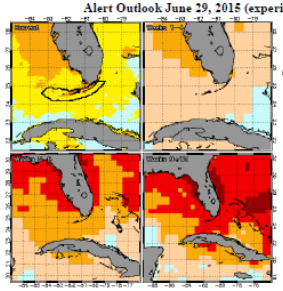


Figure 1. . NOAA's 5 km Experimental Current and 60% Probability Coral Bleaching Alert Outlook Areas through September 2015. Updated June 29, 2015.
http://coralreefwatch.noaa.gov/vs/gauges/florida_keys.php

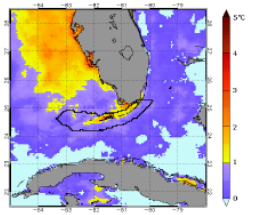
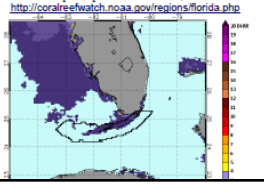


Figure 2. NOAA's Experimental 5km Coral Bleaching HotSpot Map for Florida June 29, 2015.
http://coralreefwatch.noaa.gov/regions/florida.php



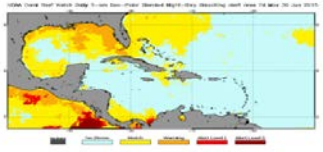
Weather and Sea Temperatures

According to the newly released NOAA Coral Reef Watch (CRW)

CARIBBEAN CORAL REEF WATCH

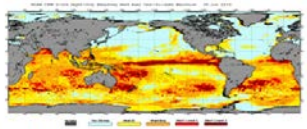
Notable Observations

- El Niño moderate in strength and intensifying.
- Southwestern Caribbean region already unusually warm with early bleaching watches and warnings.
- Bleaching Warning issued for Florida.



Current Conditions

- Reports on extensive bleaching have come from the British Indian Ocean Territory the Maldives, and western Indonesia in the Indian Ocean and from Kiribati in the Central Pacific.
- These observations are consistent with near-record high sea surface temperatures and with a moderate El Niño.



CARIBBEANCORAL REEF WATCH

Florida Department of Environmental Protection
Coral Reef Conservation Program

SEAFAN BleachWatch Program

Current Conditions Report #20130604

June 4, 2013

Summary: Based on climate predictions and field observations, the threat for mass coral bleaching in southeast Florida is LOW.

Environmental Monitoring

Climate predictions for this current conditions report are based on NOAA's Coral Reef Watch (CRW) satellite imagery products, which summarize sea surface temperature data and provide an indication as to when conditions are favorable for coral bleaching. Current CRW experimental 5 kilometer (km) Daily Coral Bleaching Alert Area indicates that the southeast Florida region is presently experiencing no thermal stress (Figure 1):

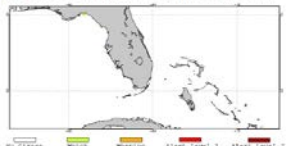


Figure 1. NOAA Coral Reef Watch Experimental 5 km Daily Geo-Polar Day-Night Blended Bleaching Alert Area; June 2, 2013.
http://coralreefwatch.noaa.gov/satellite/bleaching5km_index.html

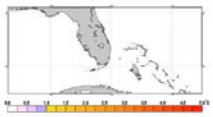


Figure 2. NOAA CRW Experimental 5km Daily Geo-Polar Day-Night Blended Hotspot Map for June 2, 2013.
http://coralreefwatch.noaa.gov/satellite/bleaching5km_index.html



Figure 3. NOAA CRW Experimental 5km Daily Geo-Polar Day-Night Blended Degree Heating Weeks; June 2, 2013.
http://coralreefwatch.noaa.gov/satellite/bleaching5km_index.html

WESTERN INDIAN OCEAN – Regional coral bleaching alert

DATE OF THIS ALERT: 22 April 2014

Contact: bleaching@cordioea.net; David Obura & Majambo Jarumani





22 April 2014 – Coral bleaching forecast – Western Indian Ocean

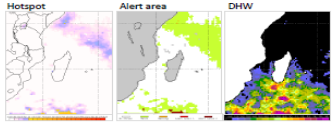
Area	Region	Alert	Bleaching observations
S Moz/S Africa	Cool, south (D1)	End	
SWIO/E Madag	Cool, south (D2)	End	Moderate bleaching, Reunion
SW Madagascar	Hot, south (A1)	End	Moderate bleaching, SW Mad
South Equat Curr	Moderate, central (C)	End	
East Moz Cha/Comoros	Hot, central (A2)	End	
NW Moz Cha /C Tanz	Warm, central (B)	End	Minor bleaching, Chumbe
NW Seychelles	Hot, north (A3)	End	
Kenya-Somalia	Variable, north (E)	End	Minor bleaching, C Kenya

Current conditions

The southeast monsoon winds are already in place, with warm SST moving northwards towards Somalia and out of the WIO region.

NOAA Products – 17 April 2014

Hotspot | Alert area | DHW



While thermal stress over most part of the WIO region has subsided, the CRW's satellite monitoring products show thermal stress has moved further north along the Somalia coast. Continuous monitoring of near real time satellite observations during the coming weeks will give a clear picture if this is the end of bleaching season in the region.

Virtual stations summary

NOAA's Coral Reef Watch program is issuing a bleaching warning to:

- Mahe, Seychelles

Tropical Cyclones

None currently.

Doldrums

The chart show mean wind speeds of less than 3m/s in Seychelles for four days ending 31 March.



Bleaching observations

20 April/Bazaruto Isbambane, Mozambique, no signs of bleaching – David Obura

Climate Impacts and Outlook

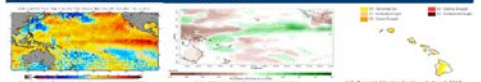
Hawaii and U.S. Pacific Islands Region

3rd Quarter 2015

Significant Events and Impacts for 2nd Quarter 2015



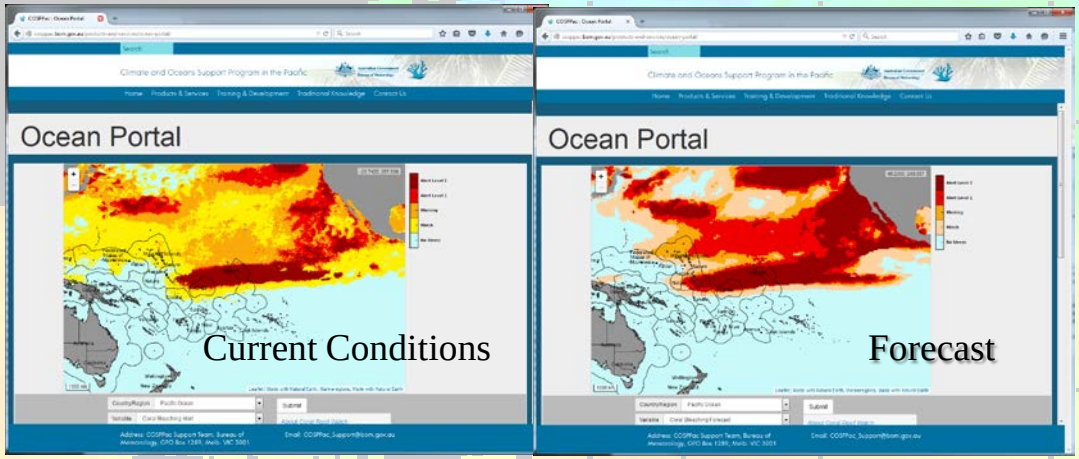
Regional Climate Overview for 2nd Quarter 2015



CRW's Products in Users' Online GIS

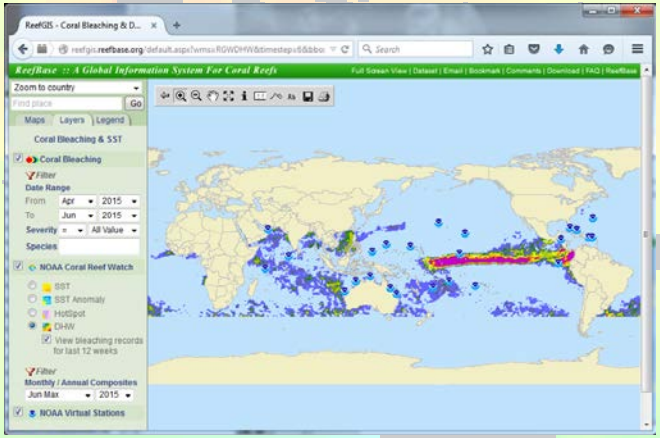
Climate and Oceans Support Program in the Pacific (COSPPac)

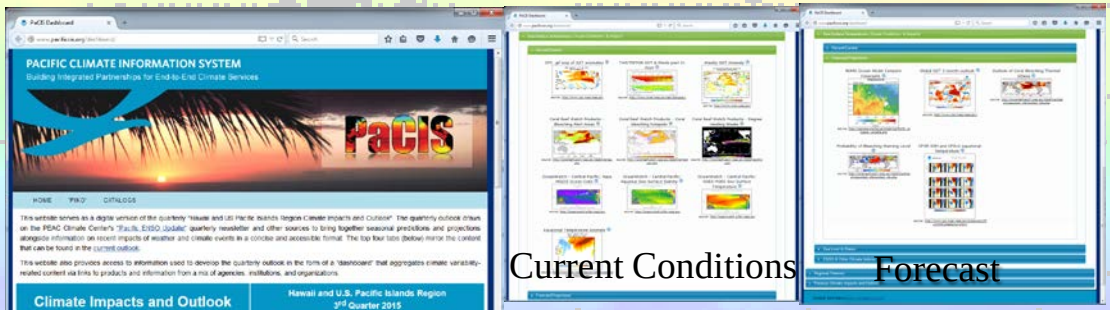
http://cosppac.bom.gov.au/products-and-services/ocean-portal/



ReefBase ReefGIS

http://www.reefbase.org





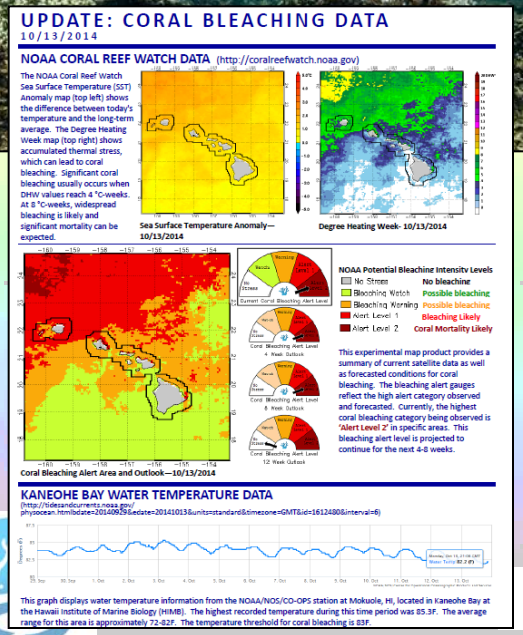
Pacific Climate Information System (PcCIS)

http://www.pacificcis.org/dashboard

NOAA Coral Reef Watch

Information for Local Bleaching Responses





UPDATE: CORAL BLEACHING DATA
10/13/2014

NOAA CORAL REEF WATCH DATA (http://coralreefwatch.noaa.gov)

The NOAA Coral Reef Watch Sea Surface Temperature (SST) Anomaly map (top left) shows the difference between today's temperature and the long-term average. The Degree Heating Week map (top right) shows accumulated thermal stress, which can lead to coral bleaching. Significant coral bleaching usually occurs when DHW values reach 4 °C-weeks. At 8 °C-weeks, widespread bleaching is likely and significant mortality can be expected.

Sea Surface Temperature Anomaly— 10/13/2014

Degree Heating Week- 10/13/2014

Coral Bleaching Alert Area and Outlook—10/13/2014

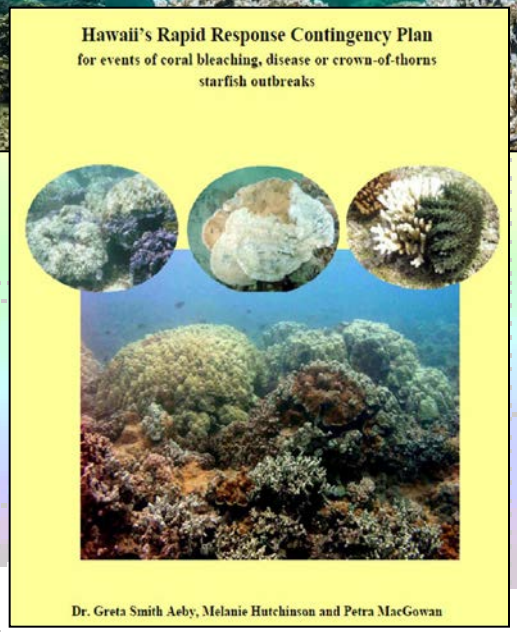
NOAA Potential Bleaching Intensity Levels

No Stress	No bleaching
Bleaching Watch	Possible bleaching
Bleaching Warning	Possible bleaching
Alert Level 1	Bleaching Likely
Alert Level 2	Coral Mortality Likely

This experimental map product provides a summary of current satellite data as well as forecasted conditions for coral bleaching. The bleaching alert gauges reflect the high alert category observed and forecasted. Currently, the highest coral bleaching category being observed is 'Alert Level 2' in specific areas. This bleaching alert level is projected to continue for the next 4-8 weeks.

KANEOHE BAY WATER TEMPERATURE DATA

This graph displays water temperature information from the NOAA/NOS/CO-OPS station at Mokuole, HI, located in Kaneohe Bay at the Hawaii Institute of Marine Biology (HIMB). The highest recorded temperature during this time period was 85.3F. The average range for this area is approximately 72-82F. The temperature threshold for coral bleaching is 83F.



Hawaii's Rapid Response Contingency Plan

for events of coral bleaching, disease or crown-of-thorns starfish outbreaks

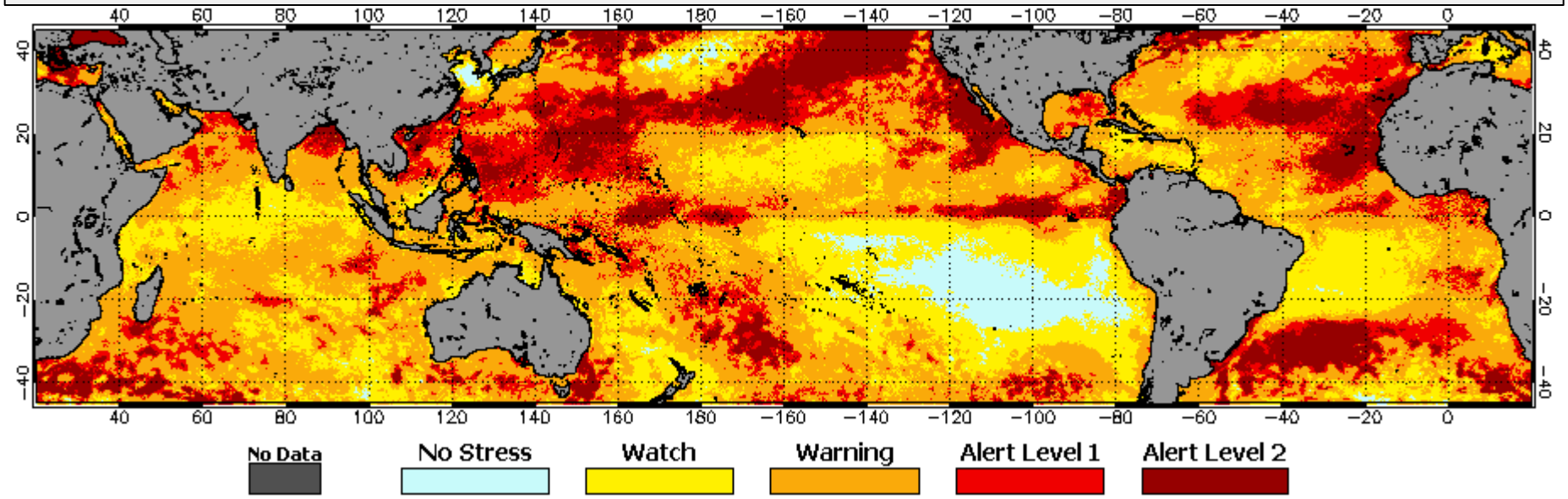
Dr. Greta Smith Aeby, Melanie Hutchinson and Petra MacGowan

Hawaii Division of Aquatic Resources (DAR)

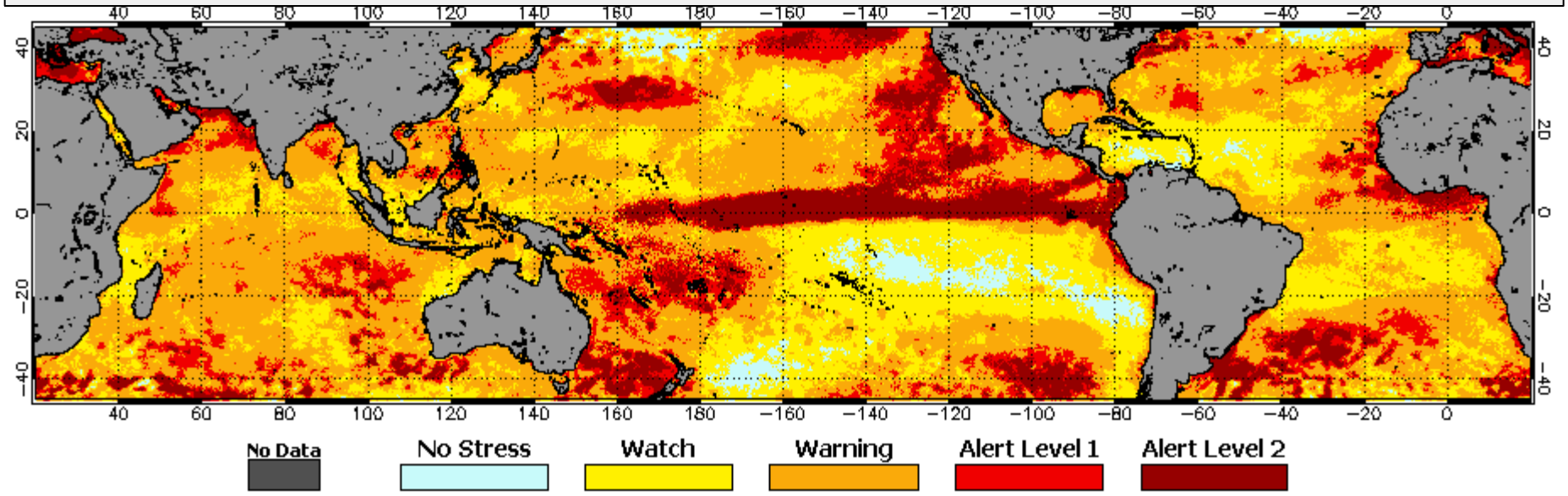
Hawaii Division of Aquatic Resources

http://coralreefwatch.noaa.gov

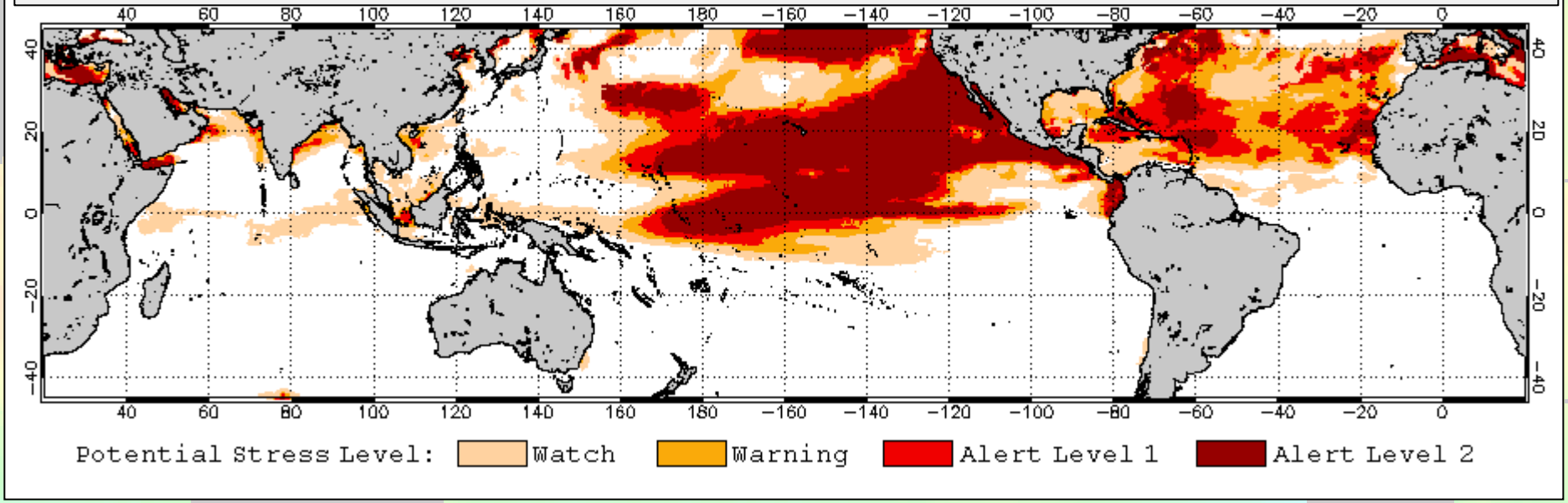
Bleaching Alert Area (Maximum) 2014



Bleaching Alert Area (year-to-date max) 2015



Four-month Outlook for Aug-Nov 2015



http://coralreefwatch.noaa.gov

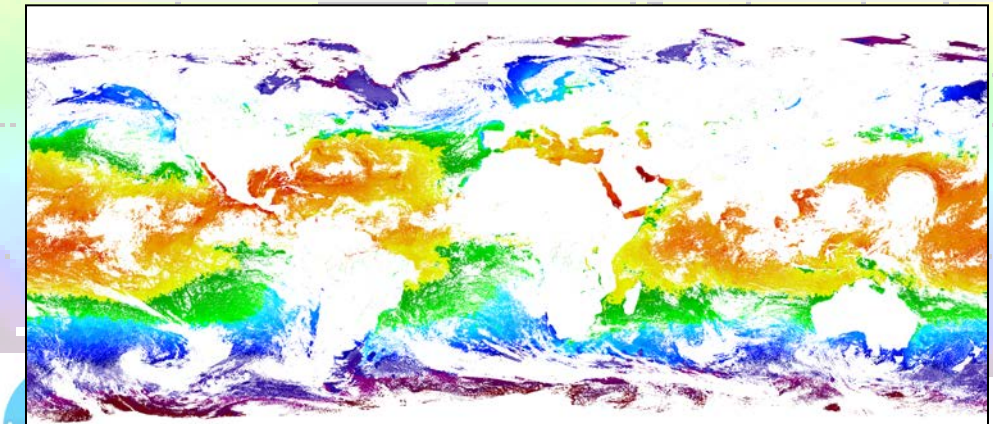
2015: American Samoa before and after: Flower Pot Island in Dec. 2014 & Feb. 2015

CATLIN SEAVIEW SURVEY

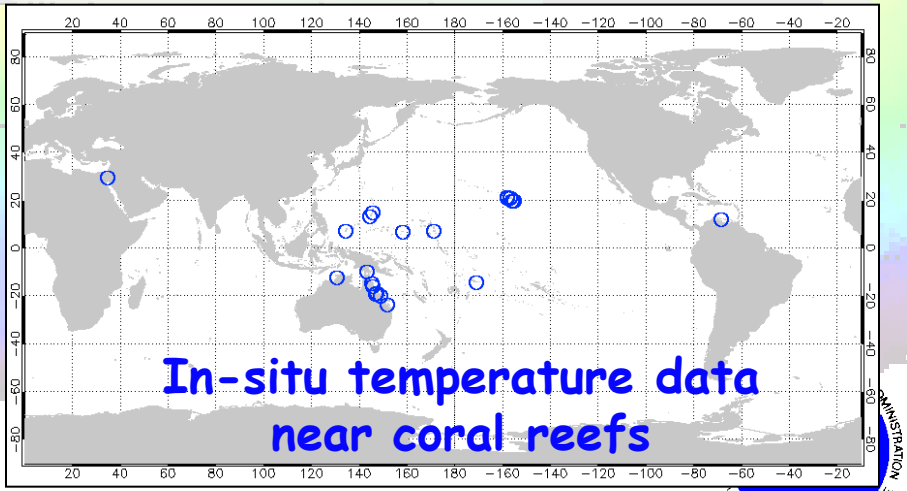


VIIRS SST for Higher Resolution CRW Products

- **JPSS funded collaboration with STAR's Polar SST team:**
  - -- Develop 0.02-deg gridded VIIRS SST for CRW applications.
  - -- Set up *in situ* dataset in near-shore, coral-specific regions for calibrating and improving VIIRS SST (as well as other SSTs).
- **Proposals in collaboration with STAR's Blended SST team:**
  - -- Develop 1-2 km geo-polar blended SST analysis using VIIRS SST as main global data source.



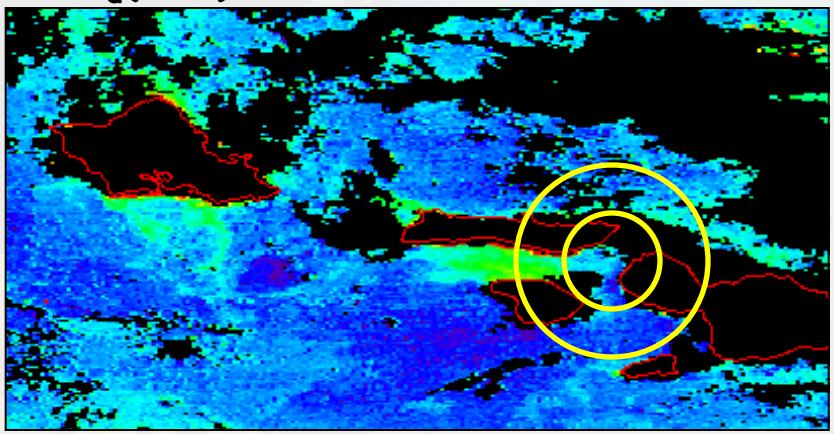
ACSPO L3 VIIRS 0.02-deg SST-skin



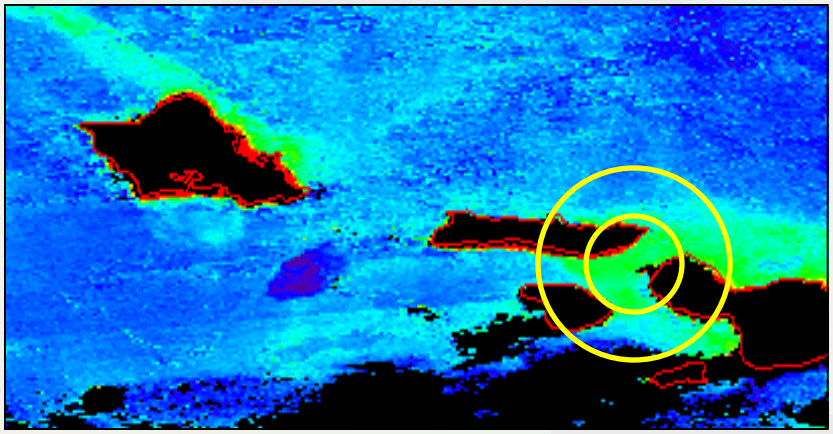
Ocean Color Product (Land Based Sources of Pollution)

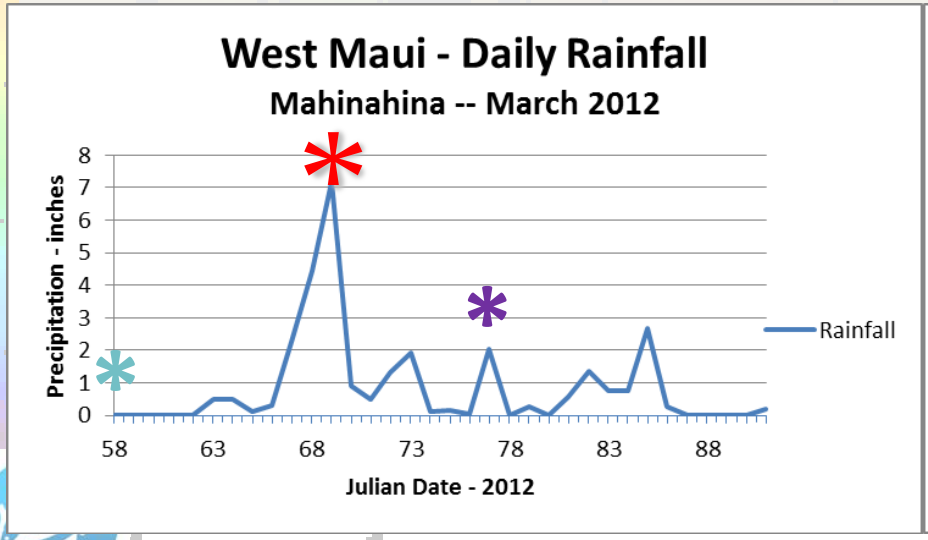
RECORD MAUI FLOODS – 8 MARCH 2012*

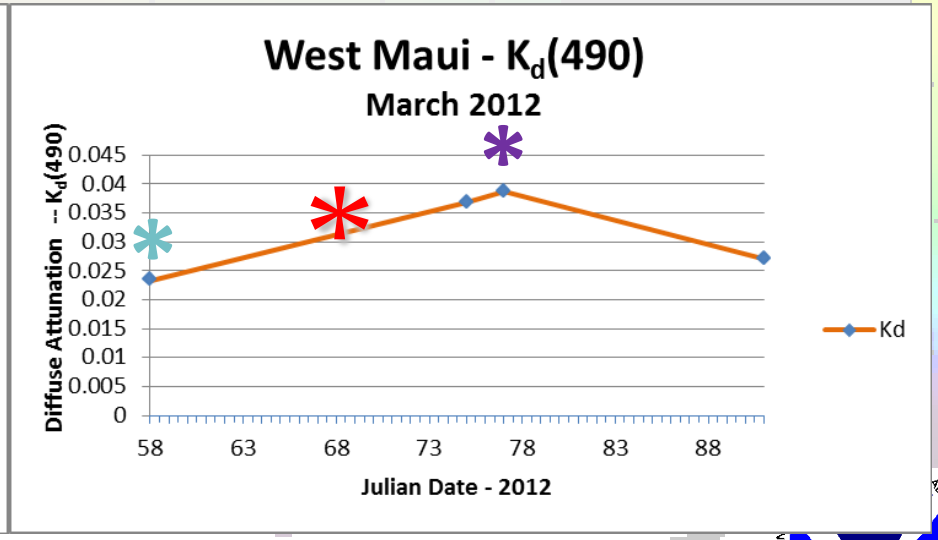
K_d(490): Before – 27 Feb *



K_d(490): After – 17 Mar *

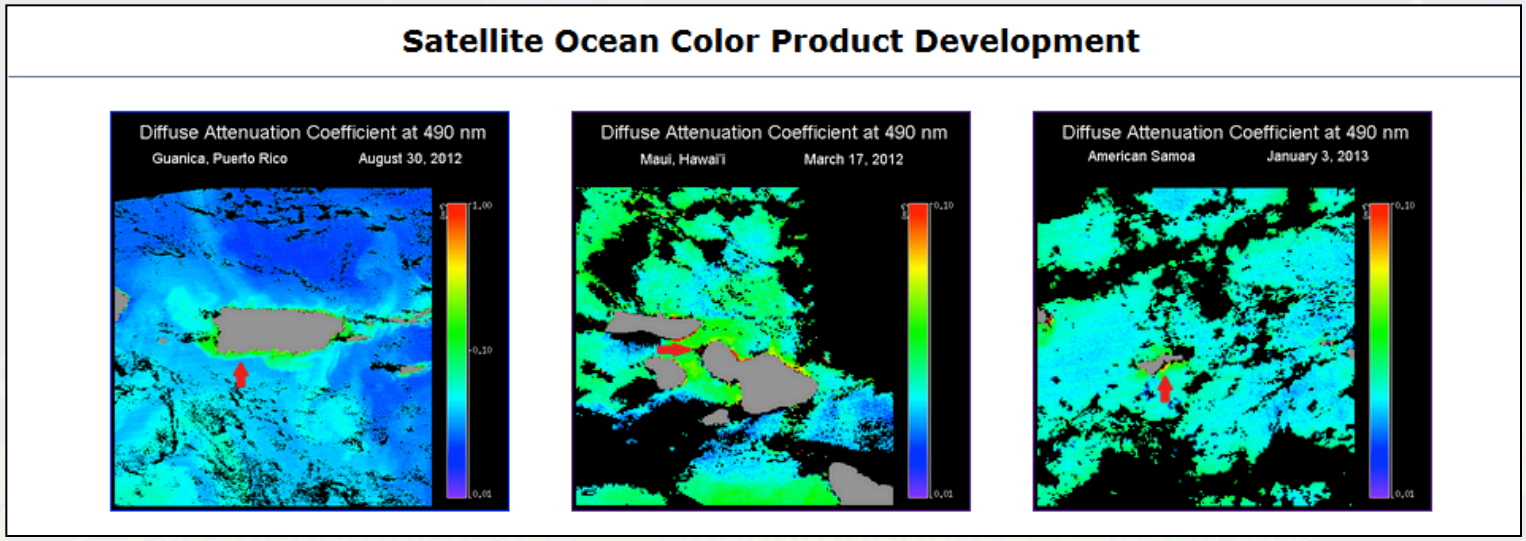






In collaboration with STAR's Ocean Color Team

Ocean Color Product (Land Based Sources of Pollution)



- Based on STAR's 2 km VIIRS ocean color data
- Developing climatology for anomaly detection
- Focusing on USCRTF's 3 "priority" watersheds:
  - Southern Puerto Rico (Guánica)
  - W. Maui (Ka'anapali)
  - American Samoa (Faga'alu)
- Collaboration with STAR's Ocean Color Team

Summary

- CRW operates the only near-real-time global Decision Support System (DSS) for coral reef management.

- CRW develops new products to address ever-growing coral reef management needs in a changing climate.

- CRW's end-to-end DSS engages reef managers and scientists throughout product development, validation, and improvement.

- Data from next generation satellites such as JPSS and GOES-R/Himawari-8 are critical for CRW's DSS to support U.S. and international coral reef conservation.

http://coralreefwatch.noaa.gov