

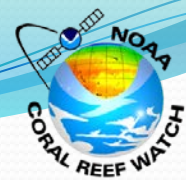


A Decision Support System for Ecosystem-Based Management of Tropical Coral Reef Environments

C. Mark Eakin, Frank Muller-Karger
L. Guild, M. Vega-Rodriguez, R. Nemani, G. Liu,
S. Heron, E. Geiger, J. Li, S. Lynds, R. Ressler, S. Cerdeira Estrada



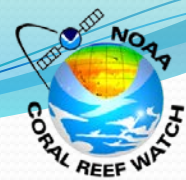
**NASA and Earth Science
Earth Science Division
Applied Sciences Program**



Partnerships

- U. South Florida (F. Muller-Karger, M. Vega-Rodriguez)
- NOAA NESDIS/CRW (M. Eakin, G. Liu, S. Heron, E. Geiger, J. Li)
- NASA Ames (L. Guild, R. Nemani, J. Torres-Perez)
- U. Colorado-CIRES (S. Lynds)
- CONABIO (R. Ressel, S. Cerdeira Estrada)
- UNEP-WCMC (L. Wood, C. Ravilious, C. Fitzgerald)





Acknowledgements

- Funding provided by:
 - NASA Applied Sciences Program
 - Woody Turner
 - 2008 Ecological Forecasting application area
 - 4-year program (2009-2013 + 2014 NCE)
 - NOAA
 - Coral Reef Conservation Program

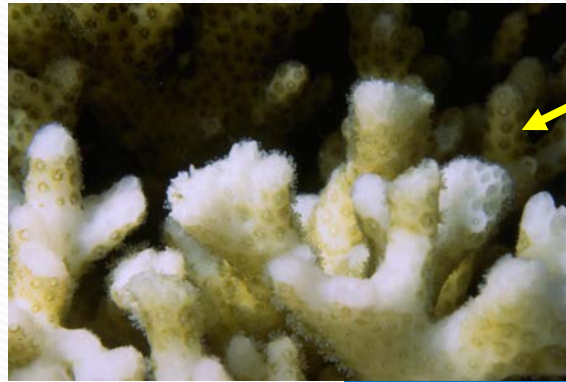




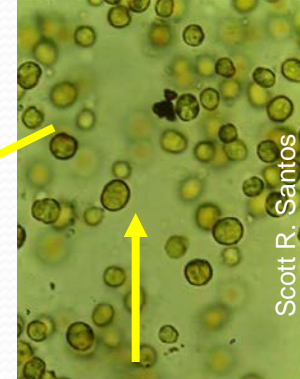
Coral Bleaching: Impact of Climate Change



- Most of corals' food comes from photosynthesis
- 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
 - Mass bleaching covers 100-1000 kms



zooxanthellae



Scott R. Santos

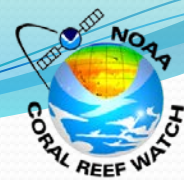
Symbiotic algae



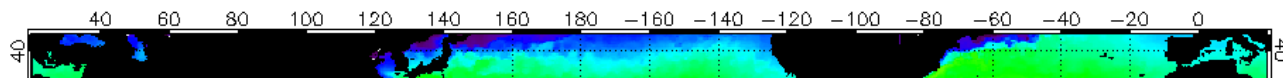


Coral Reef Watch

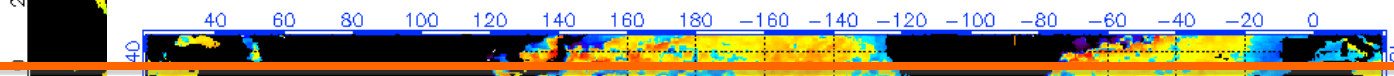
Satellite-Based Products



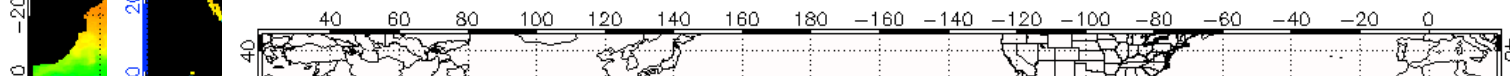
NOAA/NESDIS 50 km Nighttime Sea Surface Temperature (deg C), 2/2/2009



NOAA/NESDIS SST Anomaly (degrees C), 2/2/2009



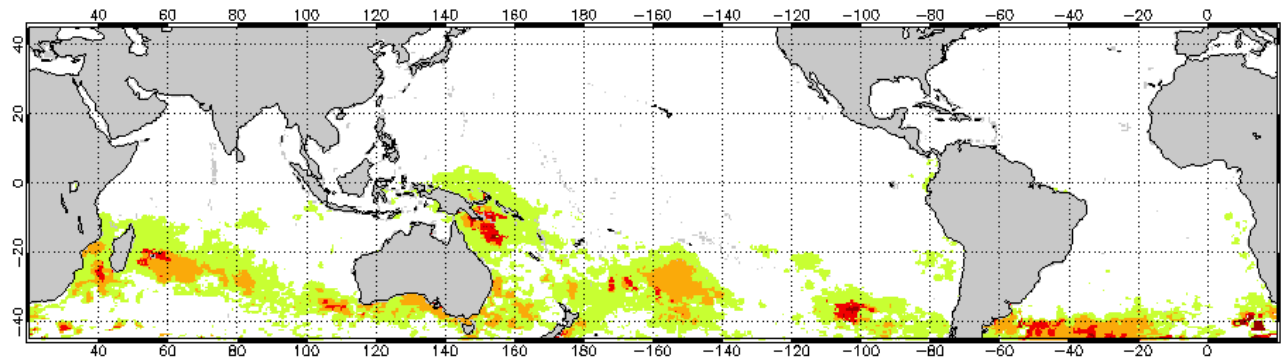
NOAA/NESDIS Coral Bleaching HotSpots, 2/2/2009



NOAA/NESDIS Degree Heating Weeks for last 12 Weeks - 2/2/2009



NOAA Coral Reef Watch Satellite Coral Bleaching Alert Area
02 Feb 2009



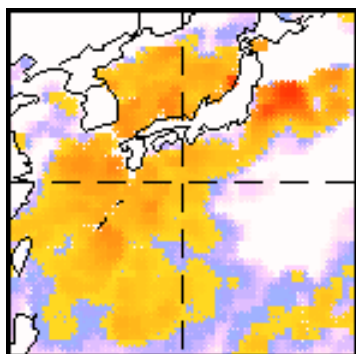
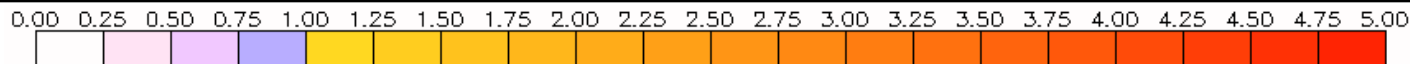
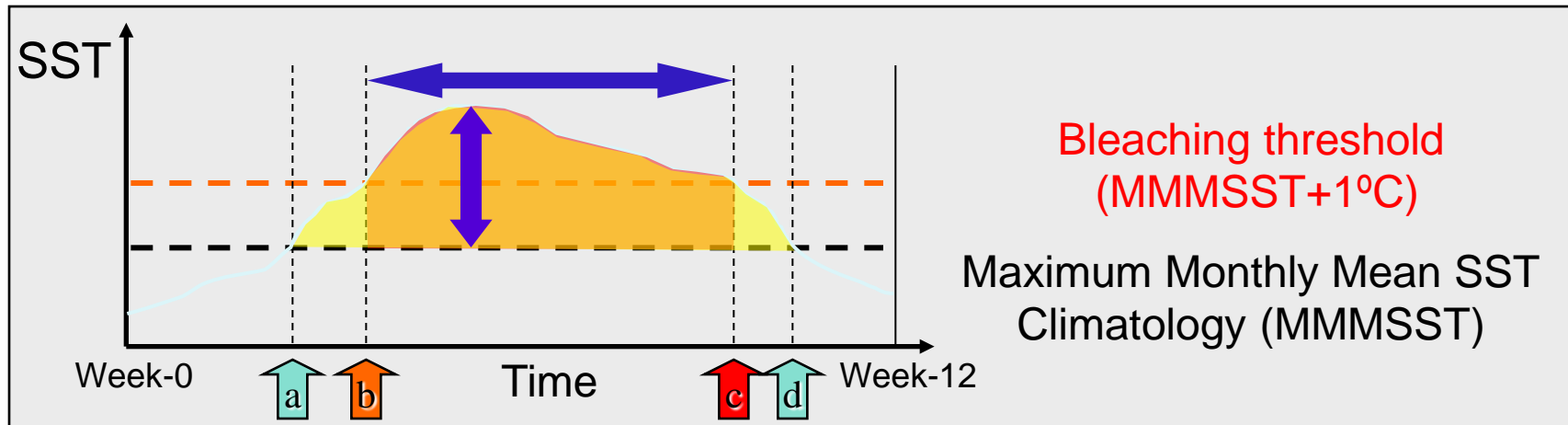
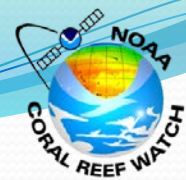
No Stress Watch Warning Alert Level 1 Alert Level 2

Coral –
specific

Bleaching Alert Areas

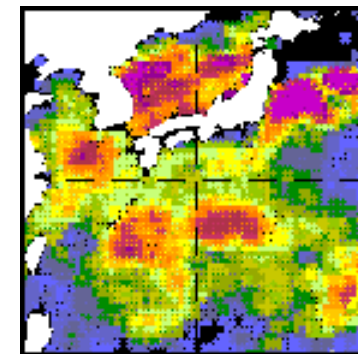


Degree Heating Week Product Algorithm

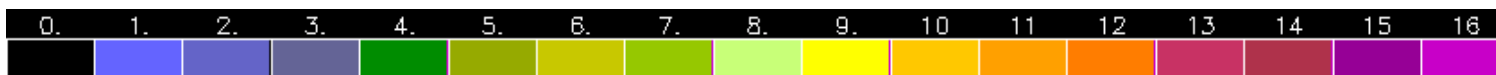


HotSpots

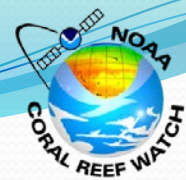
$$12 \text{ weeks} \sum (\text{HotSpot value} \times \text{duration}) \geq 1^\circ\text{C}$$



Degree Heating Weeks

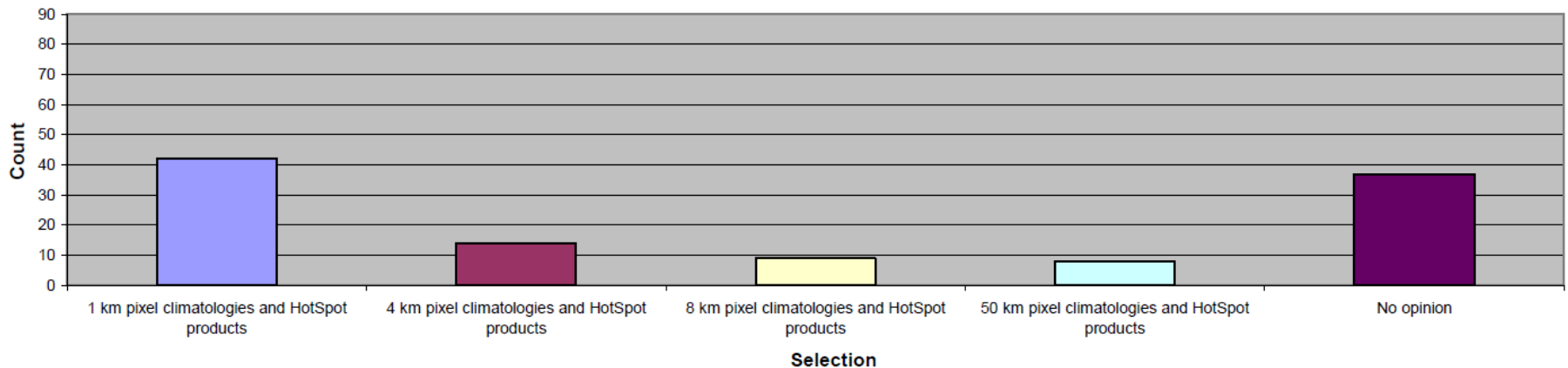


- ≥ 4 DHWs coral bleaching is expected
- ≥ 8 DHWs mass bleaching and mortality are expected

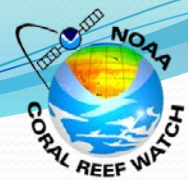


User surveys (S. Lynds / CIRES)

Considering enhancements for the products, which type of SST data would be the most valuable to you?
(Select all that apply if you would prefer a combination.) (n=90)



Users are interested in higher spatial resolution products



NOAA Coral Reef Watch: New Decision Support System

Approach:

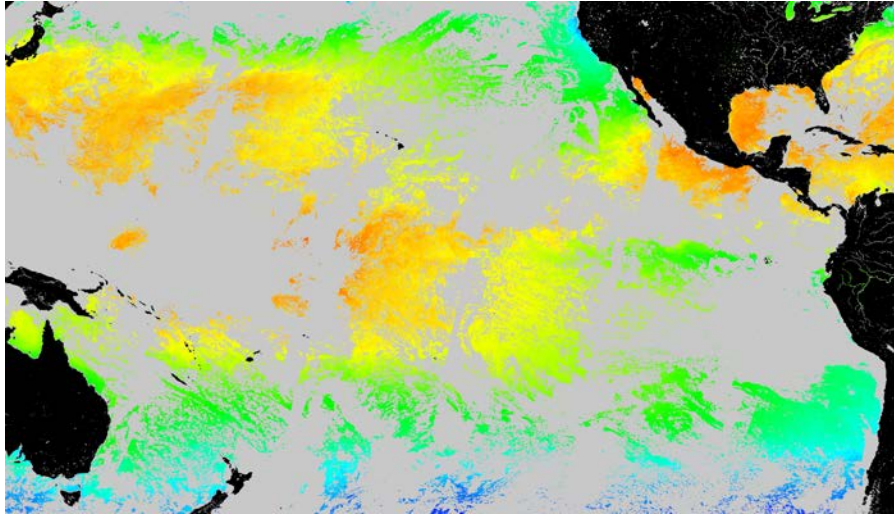
- Develop and test new, high-resolution climatologies
 - Global 4 km Pathfinder daily SST data
 - Application of NEX for handling large data volumes
- Develop 5 km global products (CRW)
- Develop 1 km regional products (USF)
- Develop full suite of high-resolution tools for coral reef managers



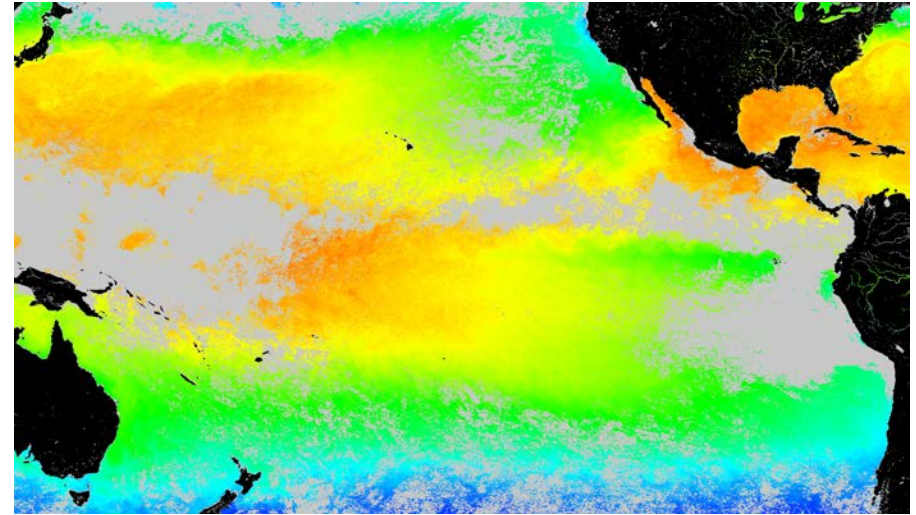
SST Coverage (August 10 2002)



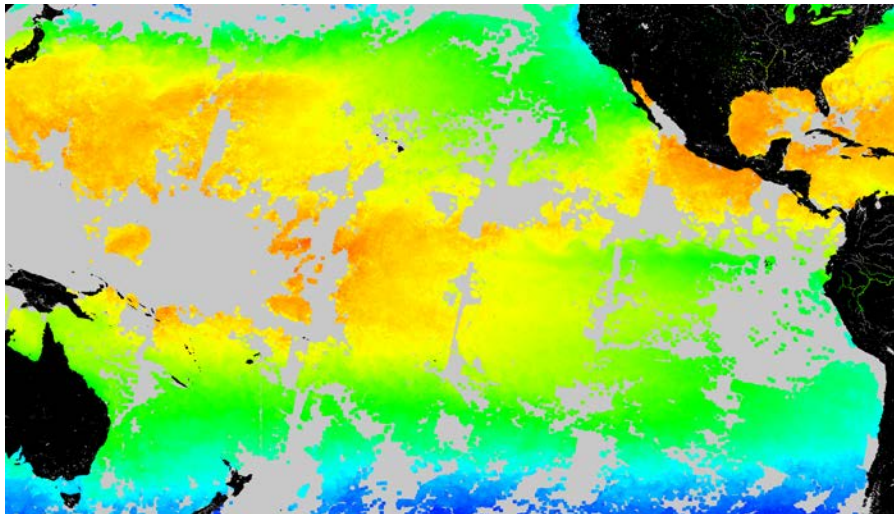
With Gap



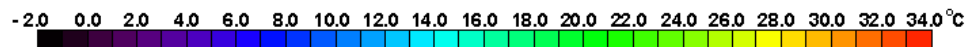
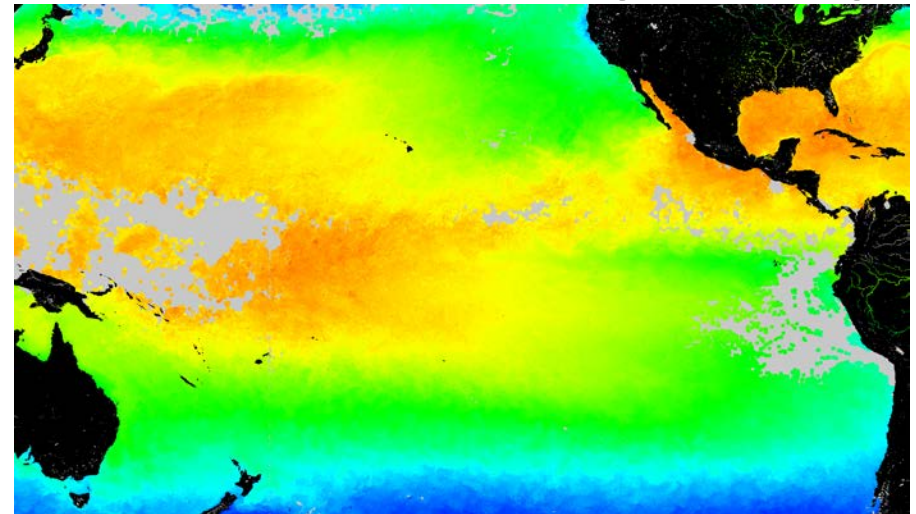
Temporal gap filling ($\leq 30d$)

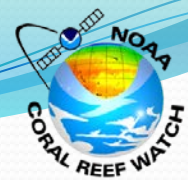


Spatial gap filling (≤ 50 km)



Temporal + spatial gap filling





5-km Resolution Global CRW

Products based on:

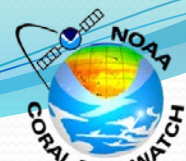
- Climatology: 4-km AVHRR Global Pathfinder – **completed April 2014**
- Data: 5-km Operational Blended
 - Polar-orbiters (2) + Geostationary (4)
 - Up to 28-100 scenes/day
 - 5th geostationary coming

<http://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php>

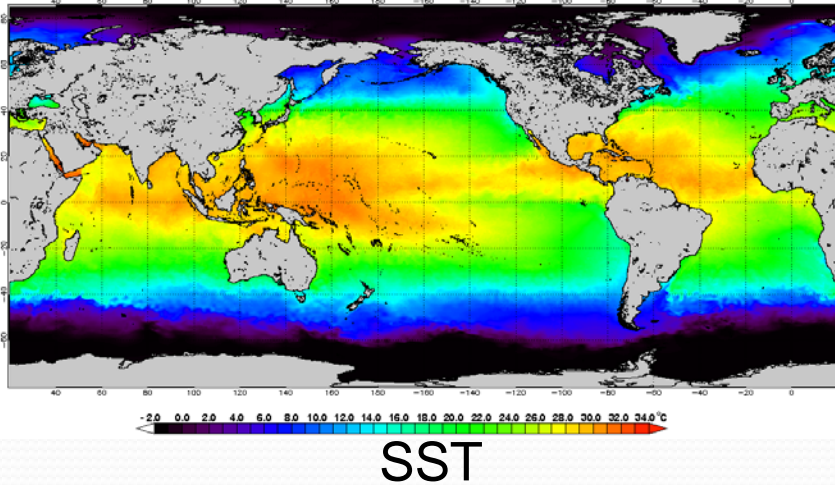


5 km – Resolution, Global Coral Thermal Stress Products – Now Live

Based on NOAA Operational GOES-POES SST, 10/03/13

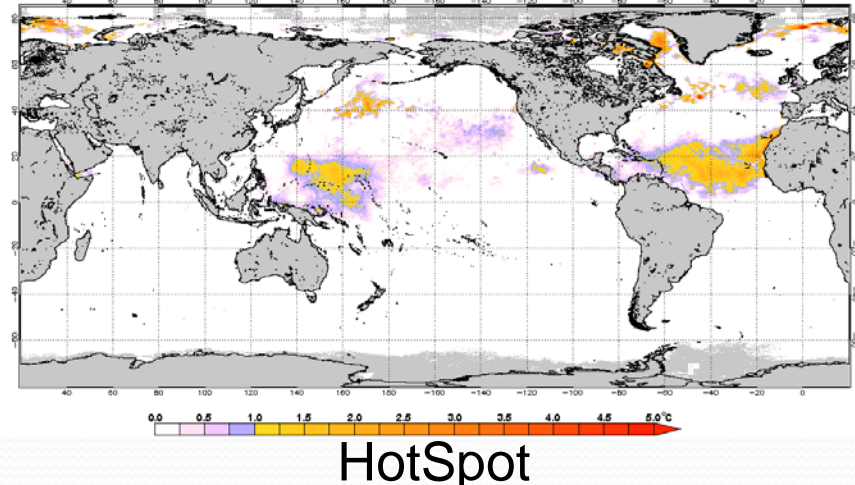


NOAA Coral Reef Watch Daily 5-km Blended Geo-Polar Nighttime Sea Surface Temperature 3 Oct 2013



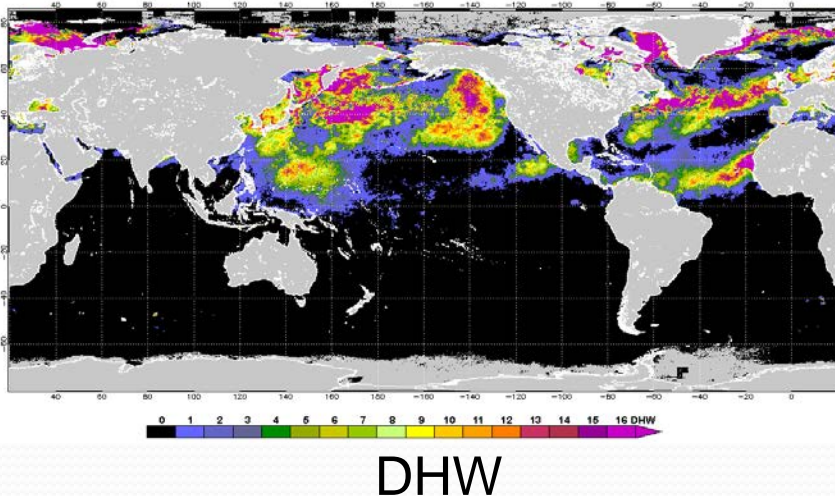
SST

NOAA Coral Reef Watch Daily 5-km Blended Geo-Polar Nighttime HotSpots 3 Oct 2013



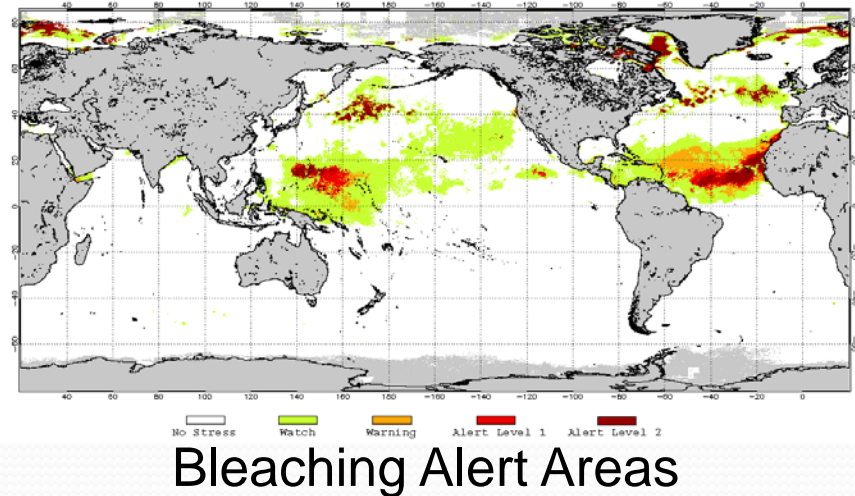
HotSpot

NOAA Coral Reef Watch Daily 5-km Blended Geo-Polar Nighttime Degree Heating Weeks 3 Oct 2013



DHW

NOAA Coral Reef Watch Daily 5-km Blended Geo-Polar Nighttime Bleaching Alert Area 3 Oct 2013



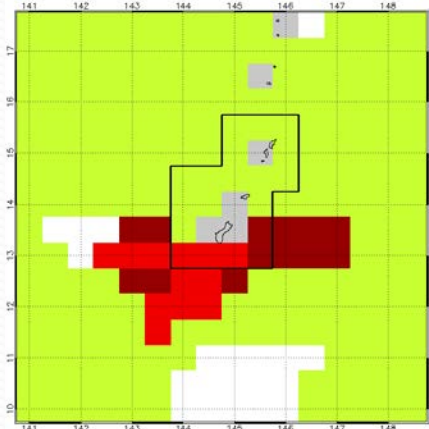
Bleaching Alert Areas



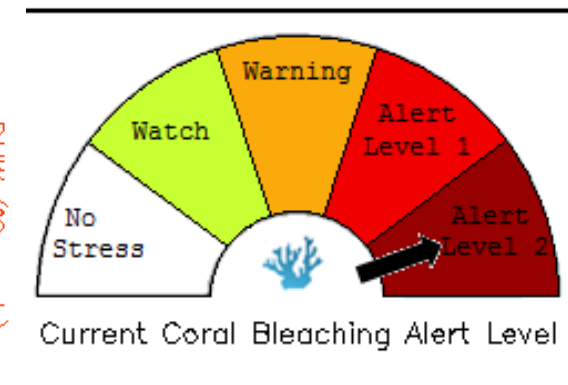
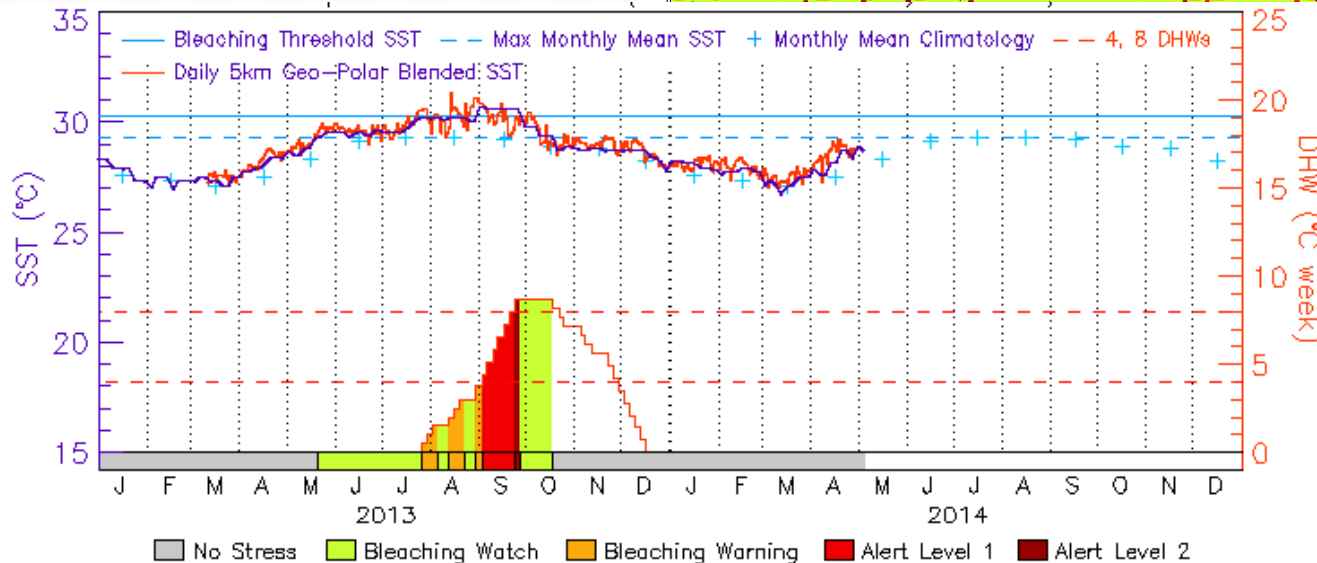
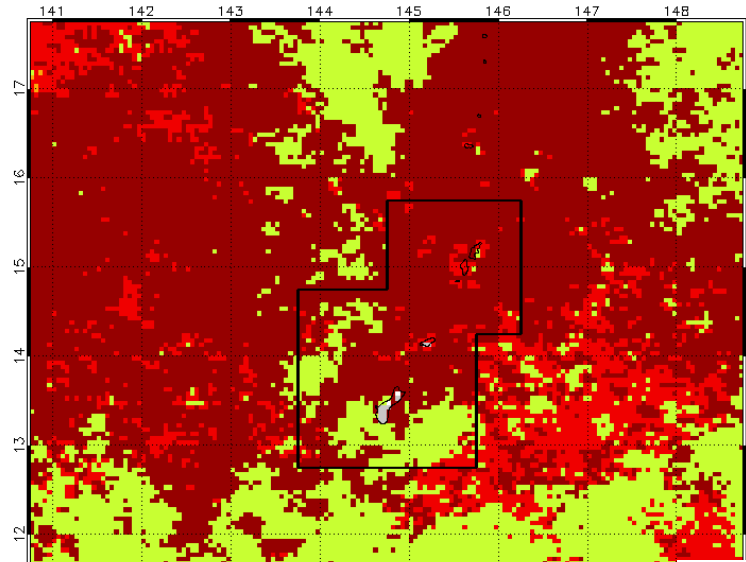
Prototype Regional Alert Products for Guam and Marianas Islands



50-km, 3 Oct 2013

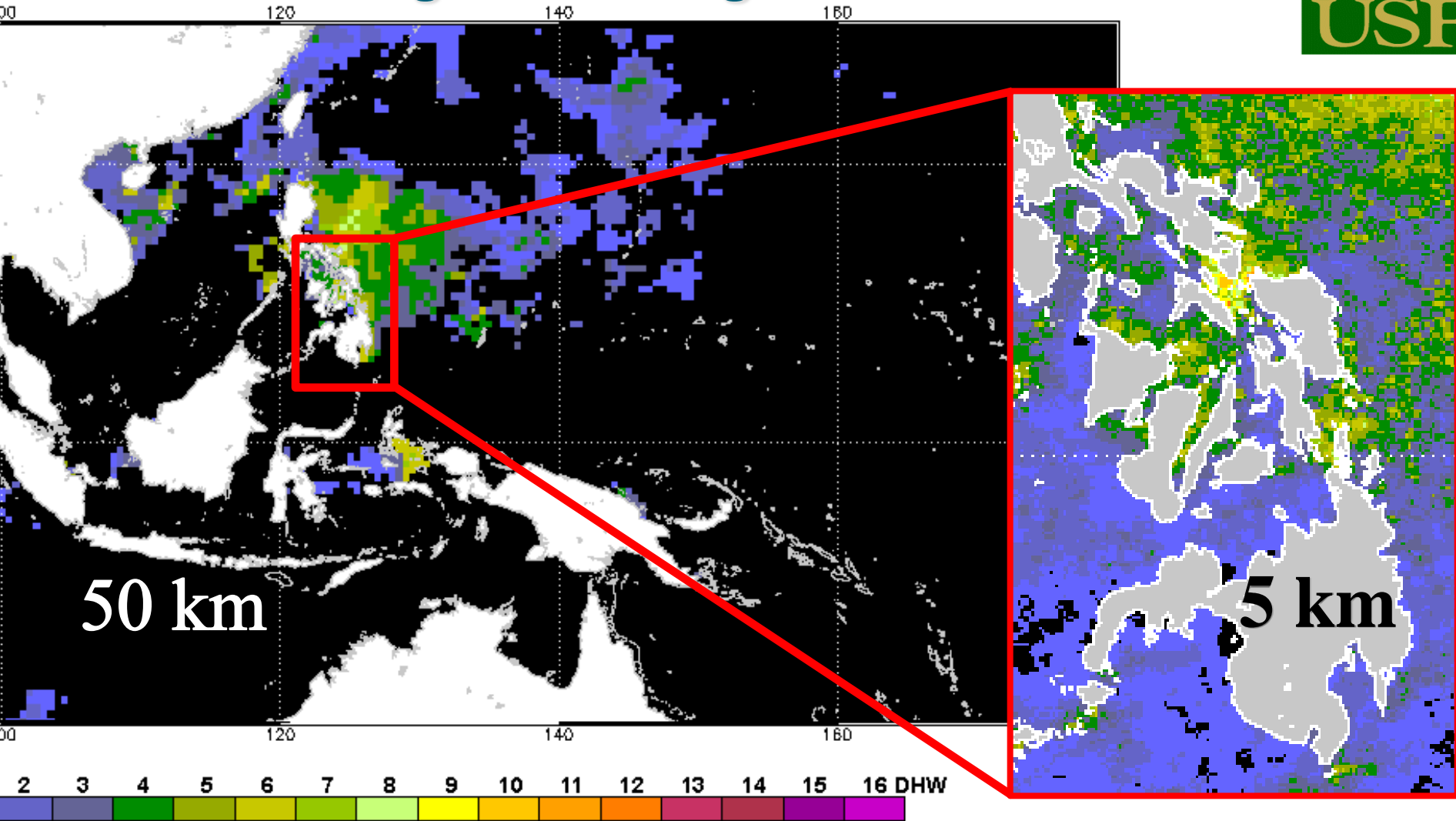
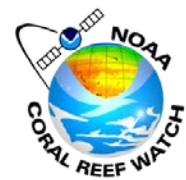


5-km Bleaching Alert 3 Oct 2013

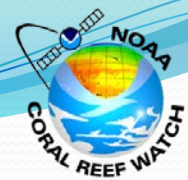




NOAA Coral Reef Watch 5-km Degree Heating Weeks Product



<http://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php>



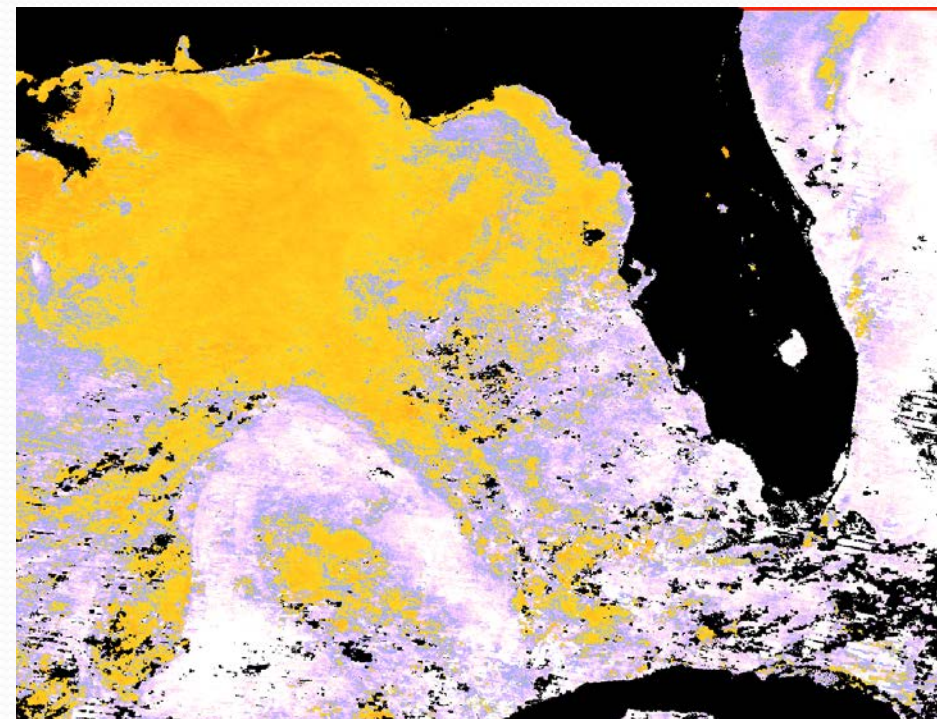
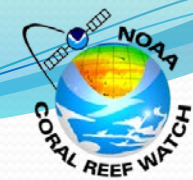
1-km Prototype Products based on:

- 4 km AVHRR Global Pathfinder Climatology
- 1 km MODIS and AVHRR
 - Test area: Florida Keys National Marine Sanctuary
 - Being operationalized by CONABIO

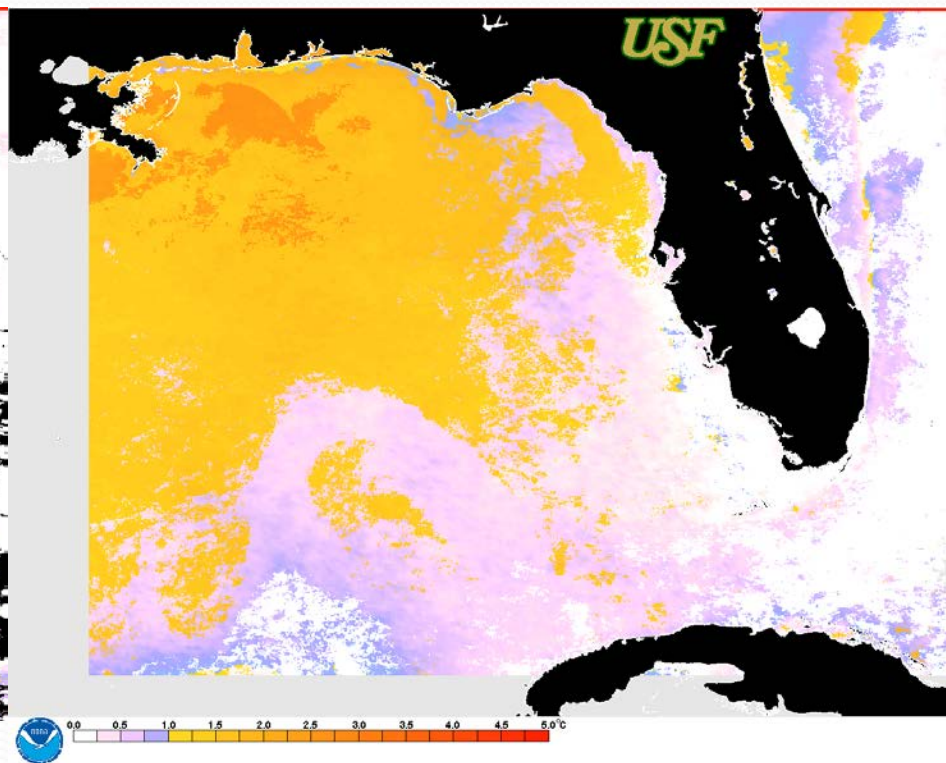


USF 1-km HotSpot products for the West Florida Shelf

(August 29, 2011)



NASA MODIS HotSpot
Climatology from Pathfinder 4km MMM



USF AVHRR HotSpot
Climatology from Pathfinder 4km MMM

<http://imars.marine.usf.edu/crw-dss/crw-dss-description>

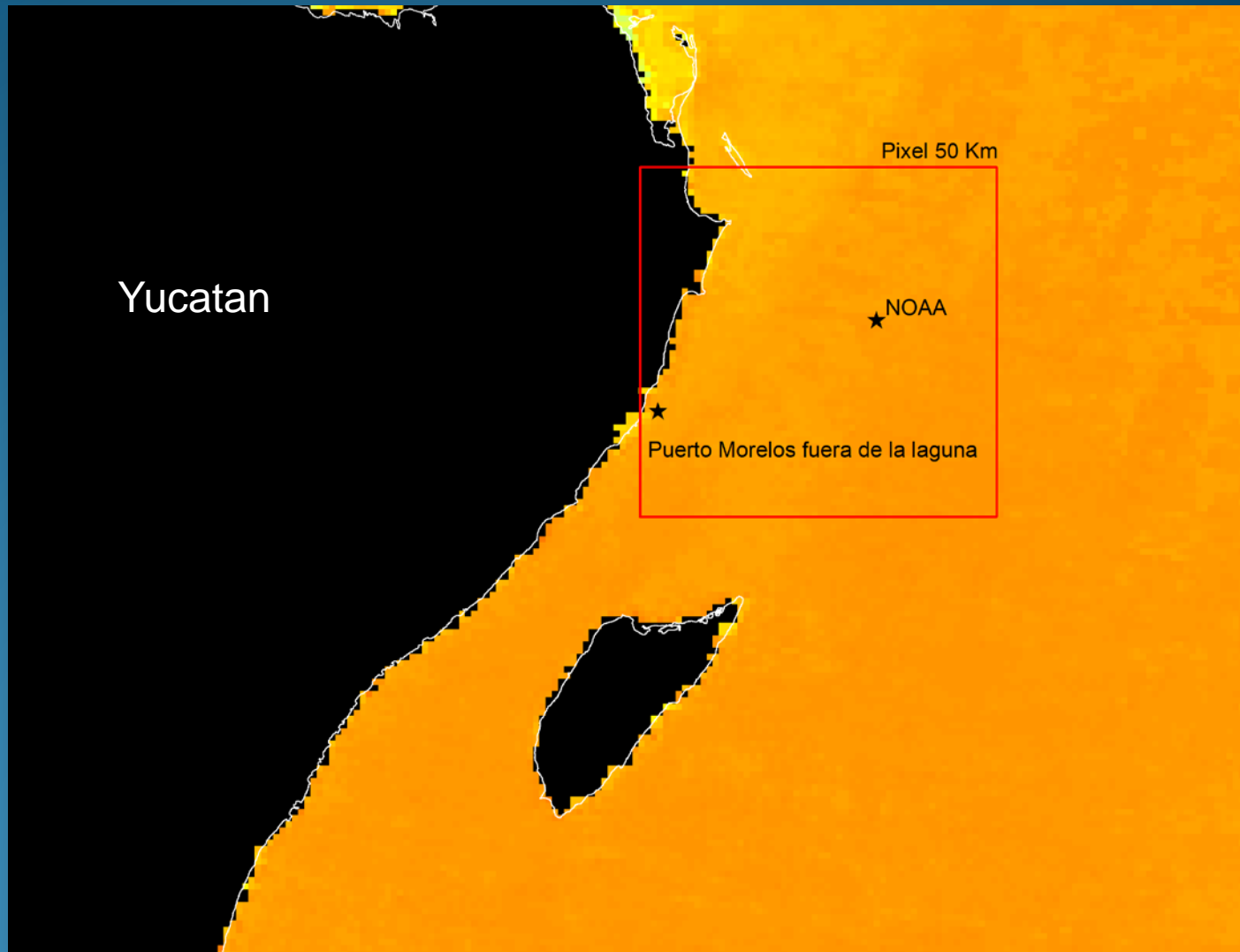


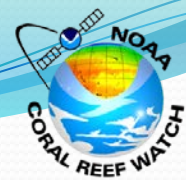
Satellite-derived Bleaching Coral Reef Early Warning System (SATcoral)



Comparable products being produced and distributed by CONABIO (Mexico)

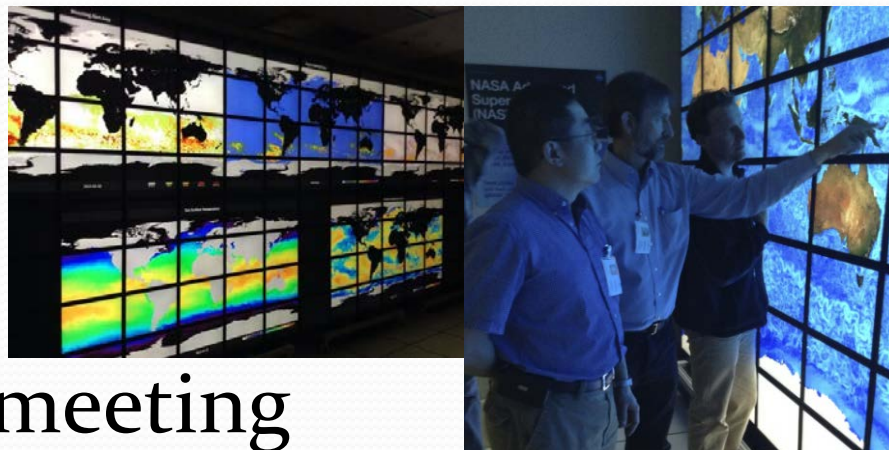
1-km products from MODIS/Aqua





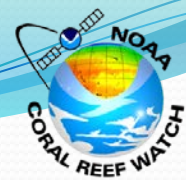
Display and Testing on Hyperwall

- CRW-DSS Team examines data on Ames Hyperwall during March 2014 meeting
- Planned analysis at Ames August 2014
- Talk using mini-Hyperwall at Ocean Sciences, February 2014



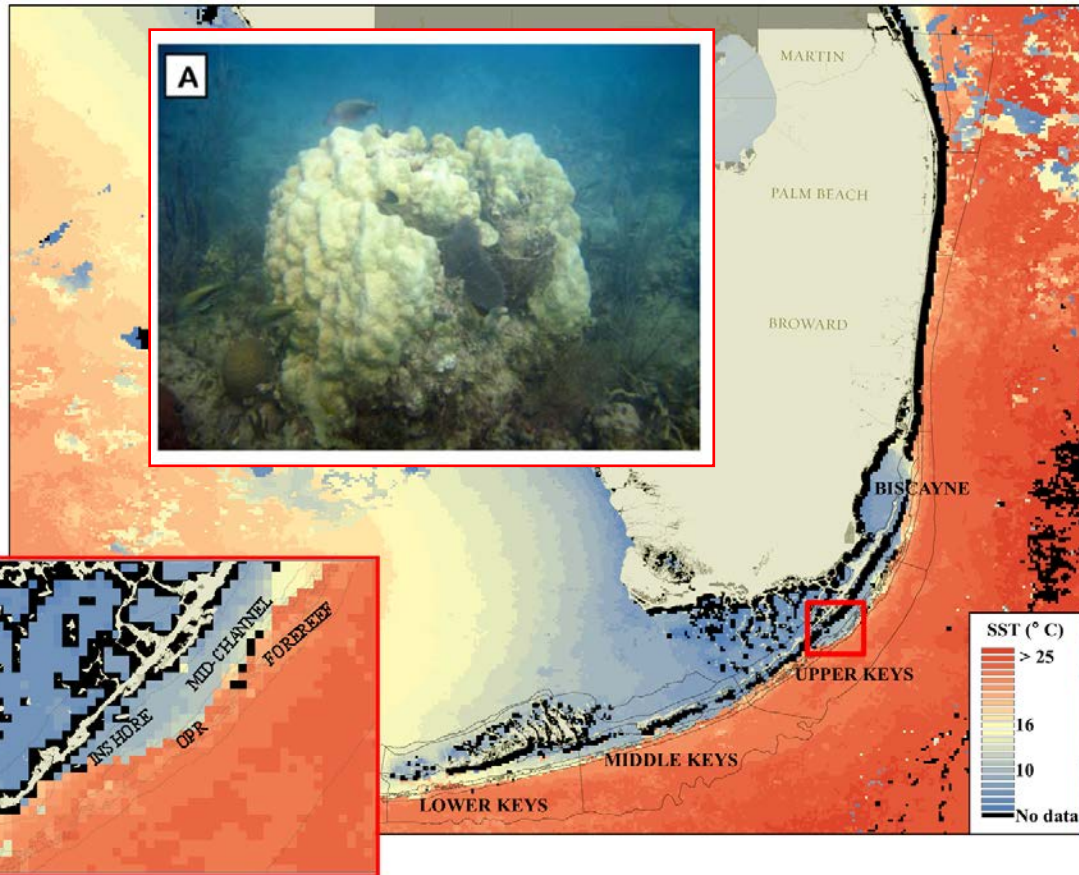


Cold Stress Index

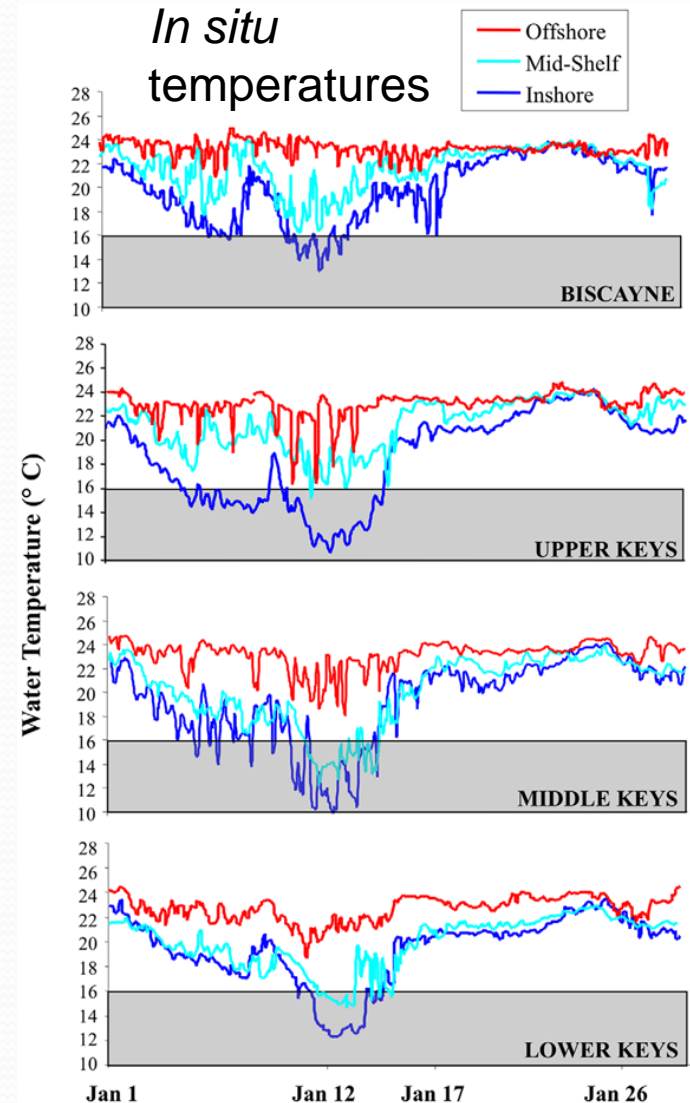


Corals susceptible to low temperature stress and death

- January 2010 corals in Florida suffered severe mortality from cold



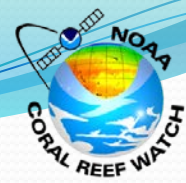
In situ temperatures



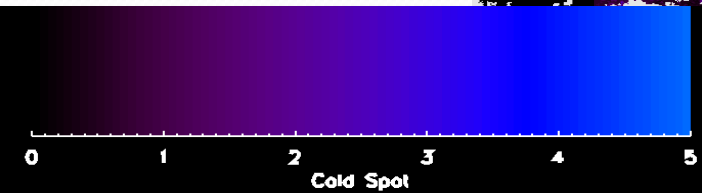
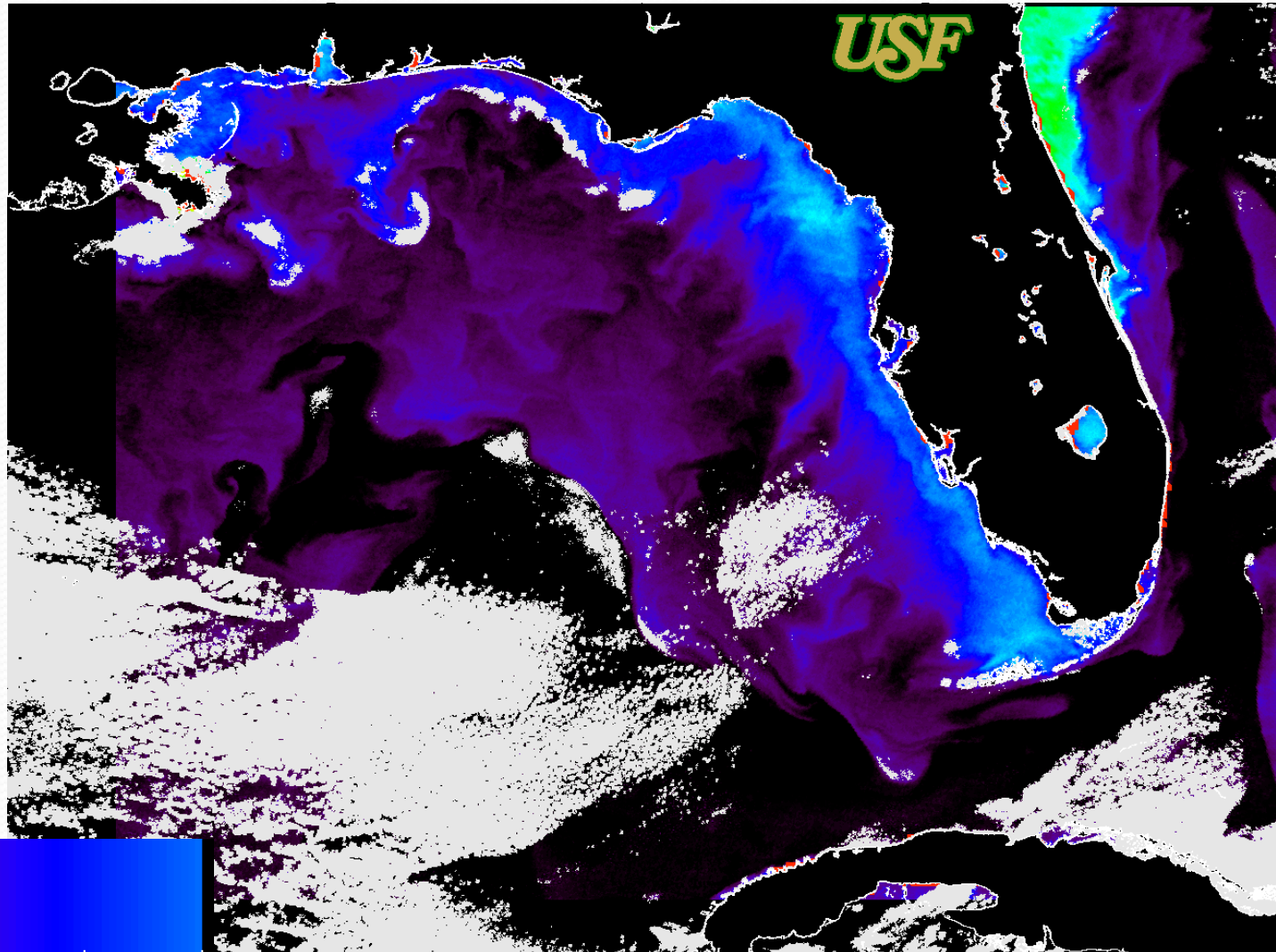


ColdSpot

January 27, 2010



Similar to the Hotspot, except using minimum monthly means of the JAN-MAR seasonal climatology.





'So what?'



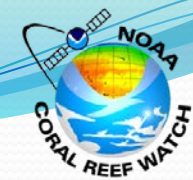
Linking science and management



- Goal: To improve our ability to alert reef managers around the world of bleaching-level stress, so they can take appropriate actions.
- In the Florida Keys, the CRW products have helped:
 - Guide Rapid Response efforts to assess reef conditions (BleachWatch)
 - Inform the public about what may be happening on the reef when corals are visibly stressed
 - Restrict access to a reef during thermal stress and disease
 - Increase confidence in management decisions



'So what?'



Linking science and management



Florida Department of Environmental Protection Coral Reef Conservation Program **SEAFAN BleachWatch Program** Current Conditions Report #20130903 September 4, 2013

Summary: Based on climate predictions and field observations, the threat for Florida, between Miami-Dade and Martin County, remains **LOW**.

Environmental Monitoring

According to NOAA's Coral Reef Watch (CRW) satellite imagery products, there is low thermal stress in the southeast Florida, indicating that the region is experiencing a low level of thermal stress.

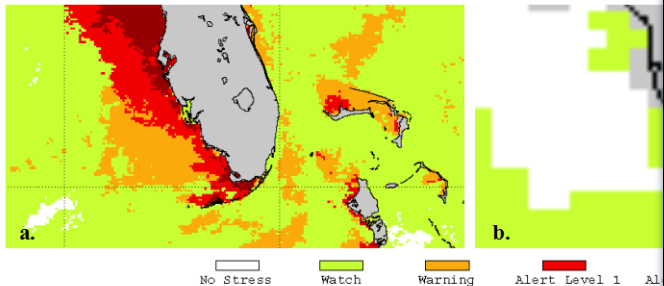


Figure 1. NOAA CRW Experimental 5 km Daily Geo-Polar Day-Night Blended Bleaching Alert Satellite Coral Bleaching Area (a); September 1, 2013. (b) September 2, 2013.

(a) <http://coralreefwatch.noaa.gov/satellite/bleaching5km/index.html>, (b) <http://coralreefwatch.noaa.gov/satellite/index.php>



Mote Marine Laboratory / Florida Keys National Marine Sanctuary **Coral Bleaching Early Warning Network** Current Conditions Report #20130903



Updated September 3, 2013

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

NOAA Coral Reef Watch Coral Bleaching Alert Area September 1, 2013 (experimental)

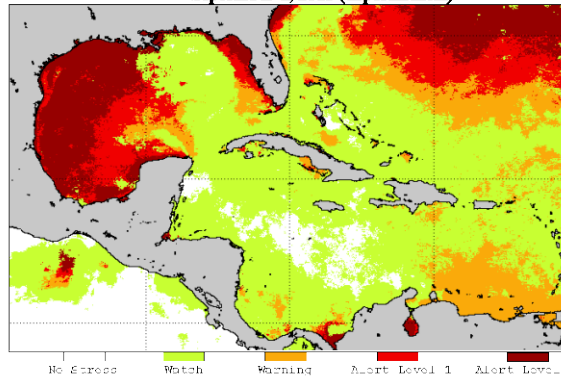


Figure 1. NOAA's 5 km Experimental Coral Bleaching Alert Areas for September 1, 2013. <http://coralreefwatch.noaa.gov/satellite/bleaching5km>

Weather and Sea Temperatures

According to the latest NOAA Coral Reef Watch (CRW) experimental 5 kilometer (km) Satellite Coral Bleaching Alert Area, there is currently a bleaching watch for the Atlantic side of the Florida Keys, with the potential for bleaching warnings and alerts if temperatures in the Gulf continue to increase (Fig. 1).

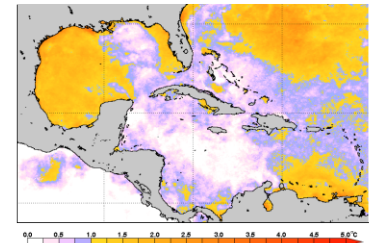


Figure 2. NOAA's Experimental 5km Coral Bleaching HotSpot Map for September 1, 2013. <http://coralreefwatch.noaa.gov/satellite/bleaching5km>

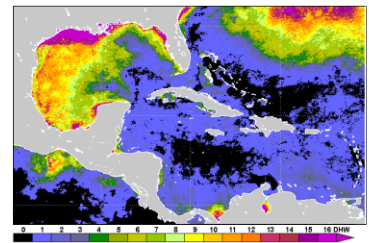
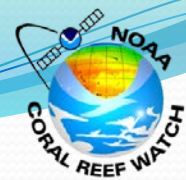


Figure 3. NOAA's Experimental 5km Degree Heating Weeks Map for September 1, 2013. <http://coralreefwatch.noaa.gov/satellite/bleaching5km>

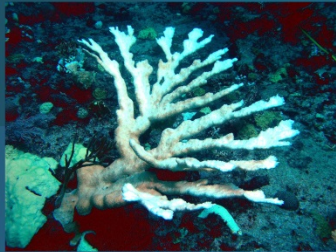


User Evaluation Still Underway



Coral Reefs in Hot Water: Monitoring Sea Surface Temperature Anomalies from Space

Explore NOAA Coral Reef Watch



Next-Generation Tools for Management, Research, Education, Youth, and Public Awareness

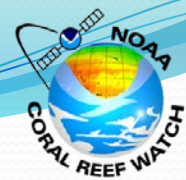
- In-person and online interviews continue
- Interviews at meetings
 - Ocean Sciences Feb 2014
 - Florida Marine Science Educators Assoc. April 2014
 - National Marine Educators Assoc. July 2014





Web Analytics—

NOAA CRW 5 km Products



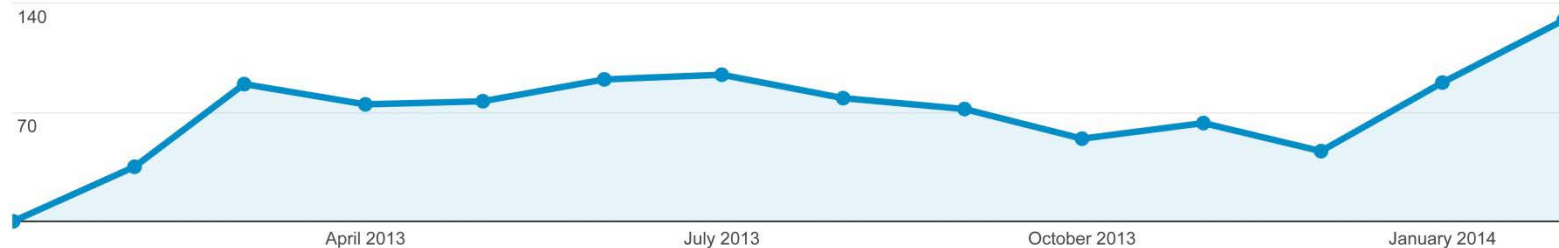
Audience Overview

Jan 1, 2013 - Feb 28, 2014

CRW5km
2.87%

Overview

● Visits



Visits

CRW5km

990



Unique Visitors

CRW5km

491



Pageviews

CRW5km

9,848



Pages / Visit

CRW5km

9.95



Avg. Visit Duration

CRW5km

00:10:08



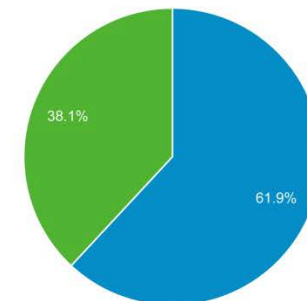
Bounce Rate

CRW5km

11.01%



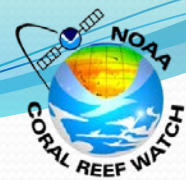
■ Returning Visitor ■ New Visitor





Ocean Sciences 2014

Interview and Survey Results

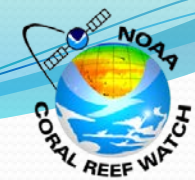


User applications of new Coral Reef Watch high resolution products?

- Education (students/public)
- Monitoring bleaching
- Integrating with mapping/modeling
- Fish distributions
- Ecosystem indicators
- Work on coral reef recovery
- Forecasting coral disease outbreak risk
- Microbial diversity associated with stressed coral communities

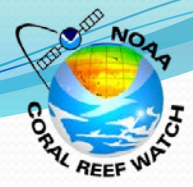


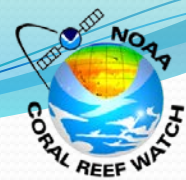
Accomplishments: 2010-2014



Visit our [Poster](#) for more information

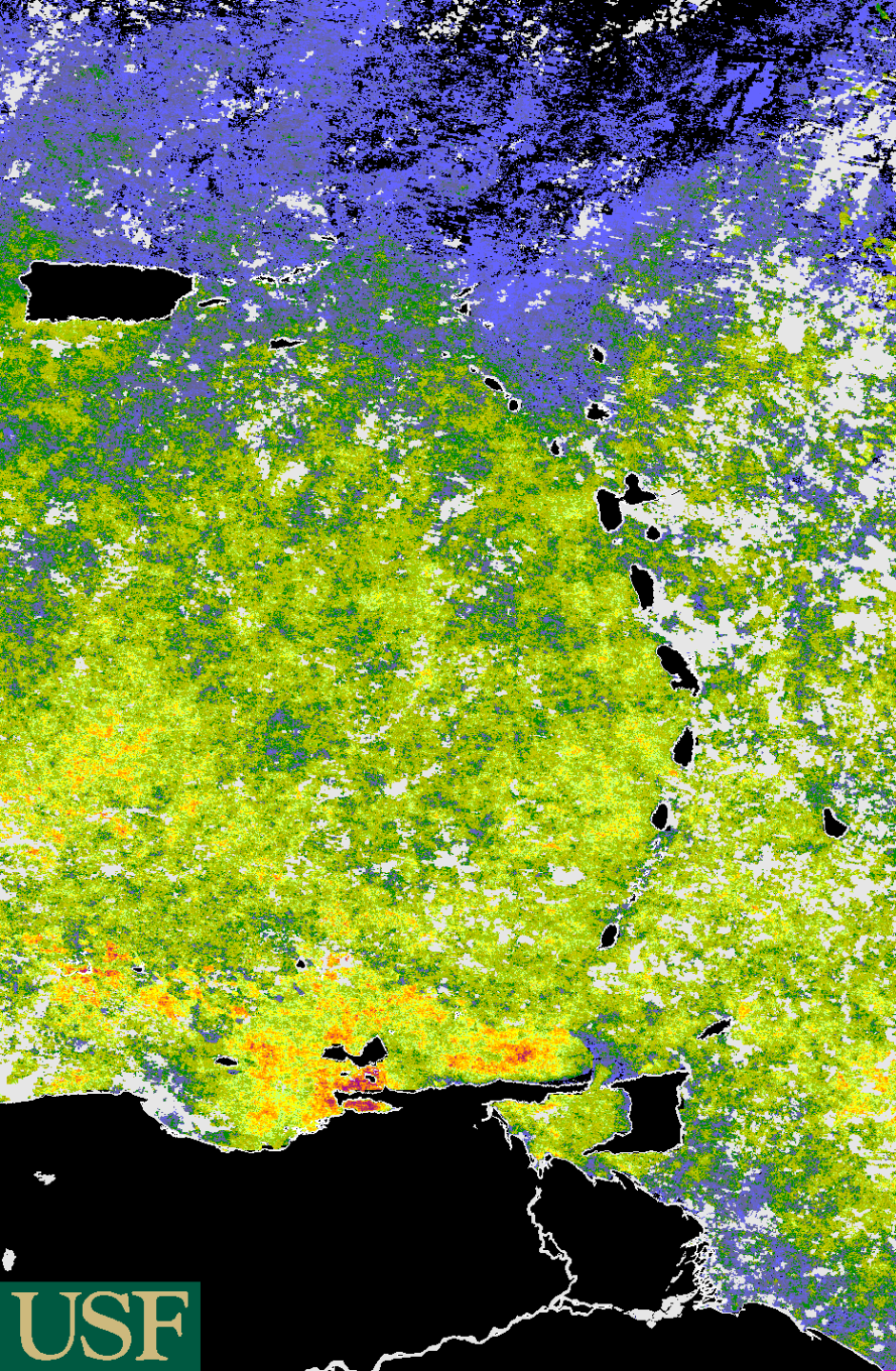
- Completed user surveys for NOAA Coral Reef Watch products.
- Just completed global high-resolution SST climatology from Pathfinder; final testing and application to 1-5 km products being done in 2014
- NOAA deployed 5-km global Coral Reef Watch (CRW) products – **Global products now live**, regional product under development
- USF and CONABIO deployed websites with 1 km Coral Reef Watch (CRW) products for the Gulf of Mexico, Florida Keys and Caribbean Sea using AVHRR and MODIS
- Developed prototype cold water stress index (cold spot) for the Florida Keys.
- UNEP WCMC integrated the NASA Coral Reef Millennium Map into their online Map servers (<http://data.unep-wcmc.org/datasets/13>).





Objectives of the Program

- Assess and meet needs in coral reef research, management, education
- Assess value of high-resolution (1-5 km) data
 - (MODIS, AVHRR, Geo-Polar Blended)
- Develop higher-resolution decision support tools
 - Link to higher-resolution maps
 - Satisfy user needs



USF 1-km DHW product for the Southern Eastern Caribbean

Based on MODIS Aqua (11um)
nighttime only SST & PF (v5.0)
gap-filled climatology

<http://imars.marine.usf.edu/crw-dss/crw-dss-description>