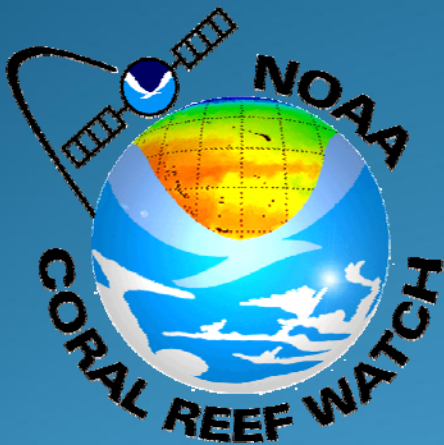


# A Decision Support System for Ecosystem-Based Management of Tropical Coral Reef Environments



F. Muller-Karger, M. Eakin, L. Guild,  
C. Hu, M. Vega, R. Nemani, T. Christensen, L. Wood, C. Ravillious,  
C. Nim, J. Li, C. Fitzgerald, J. Hendee, L. Gramer, S. Lynds

# Partnerships

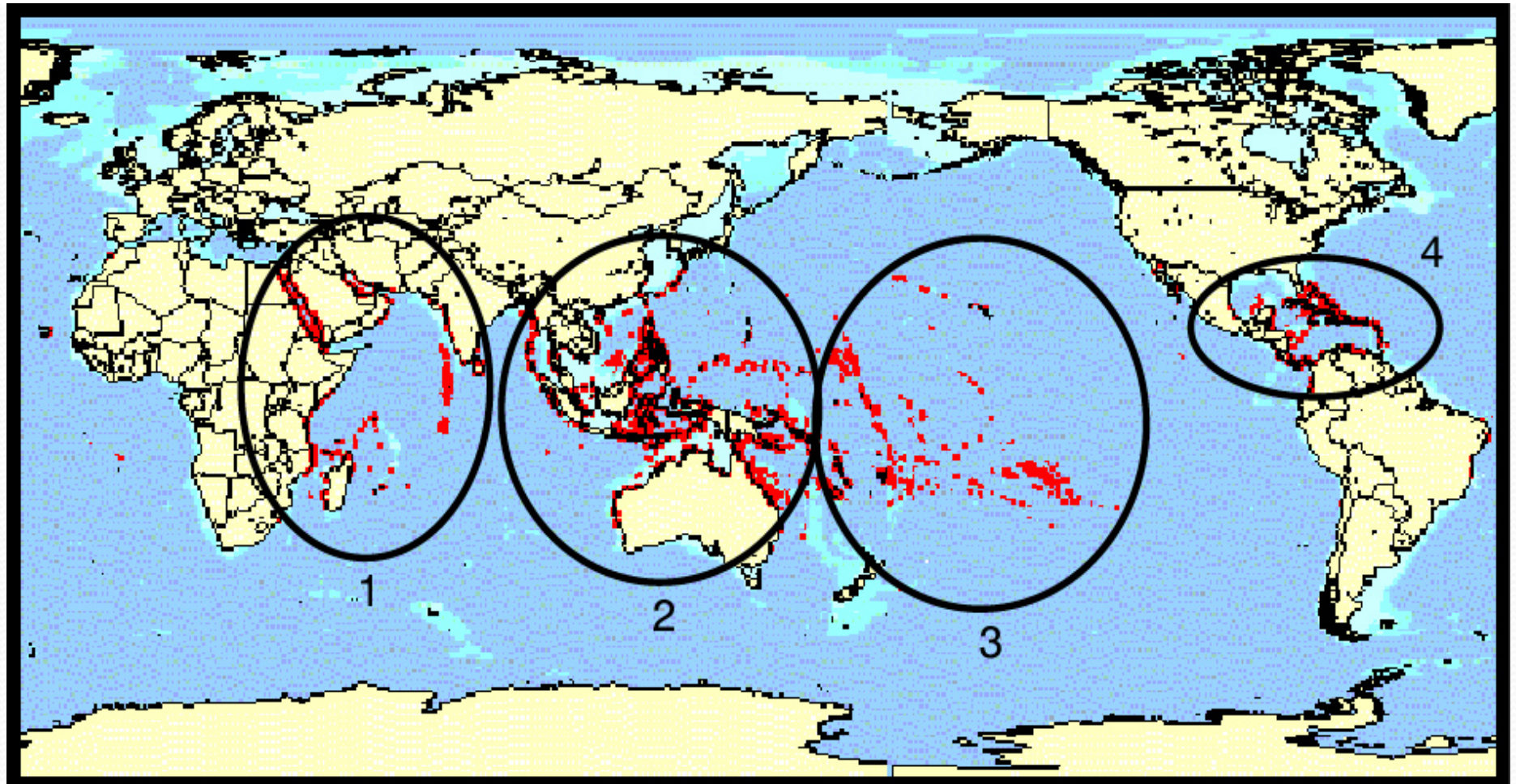


- NOAA NESDIS/CRW-CRCP (Mark Eakin, Tyler Christensen)
- NOAA AOML / ICON/CREWS-CRCP (James Hendee, L. Gramer)
- NASA Headquarters (Woody Turner, Paula Bontempi)
- NASA Ames (Liane Guild, Ramakrishna Nemani)
- UNEP-WCMC (Louisa Wood, Corinna Ravilious, Claire Fitzgerald)
- University of South Florida (Frank Muller-Karger, Chuanmin Hu, Maria Vega)
- And: Welcoming a partnership with Australia (William Skirving, Scott Heron / NOAA)

# Acknowledgements

- Funding provided by:
  - NASA Applications Program
    - Woody Turner
    - 2008 Ecological Forecasting application area
    - 4-year program (2009-2013)
  - NOAA
    - NESDIS Coral reef Watch

# Corals – a resource distributed sparsely and remotely, around the globe



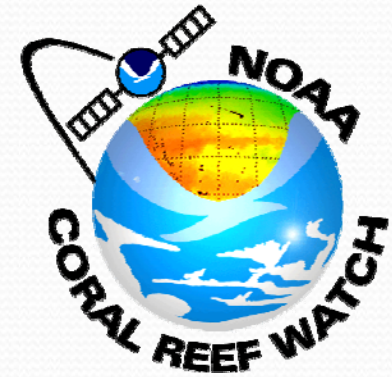
*Location of shallow tropical coral reef ecosystems (Source: ReefBase). The four coral reef biogeographic regions that are typically recognized by marine biogeographers are shown in circles: (1) Indian, (2) Indo-Pacific, (3) Pacific and (4) Caribbean.*



Research, monitoring, management of corals requires:

- Sampling a range of time and space scales
- Synoptic observing tools
- Frequent and repeated observations
- Long-term observations
- Timely data delivery and easy access

# NOAA NESDIS *Coral Reef Watch* (Mark Eakin and team)



*Mission:*

*To provide remote sensing tools for the conservation of coral reef ecosystems.*

Coral Reef Watch aims to assist in the management, study, and assessment of impacts of environmental change on coral reef ecosystems.

# Objectives of the Program

- Assess and meet user needs
  - End-to-end evaluation and feedback mechanism
- Assess value of high-spatial resolution (1 km ) data
  - (MODIS, AVHRR, other)
- Link to higher-resolution geomorphological maps
  - Global Coral Reef Millennium Map
  - (Landsat – 30 m pixels, GIS layers)
- Link to real-time in situ observations
  - (ICON/CREWS, SeaKeys, Ocean observing system)
- Help design future remote sensing tools:
  - Hyperspectral and Infrared Imager (HyspIRI)
  - Landsat Data Continuity Mission (LDCM)
  - NPP, NPOESS, other environmental satellites
- Help managers/researchers communicate and



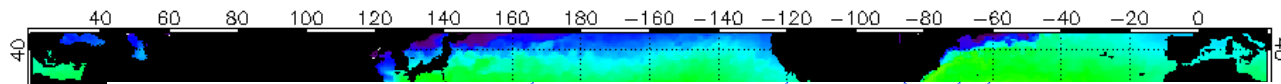
## Coral Reef Watch DSS (Decision-Support System)

- Near-real time suite of products to monitor and forecast thermal stress that may cause coral bleaching
- Empirical models and satellite data
- Open distribution via email/Internet/other
- Products:
  - night-time only 50 km SST anomaly,
  - coral bleaching HotSpots,
  - Degree Heating Weeks, and
  - Satellite Bleaching Alerts.
- <http://www.osdpd.noaa.gov/PSB/EPS/SST/methodology.ht>



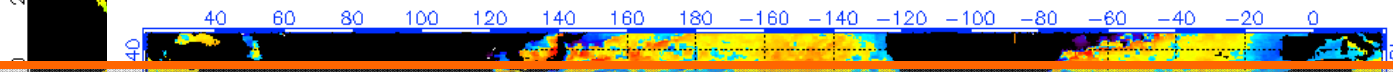
# CRW-Operational SST-based products

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



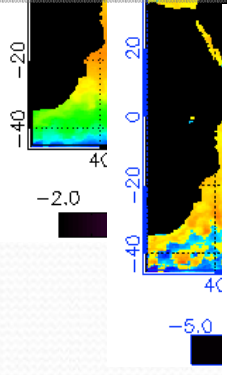
**Operational 2002**

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



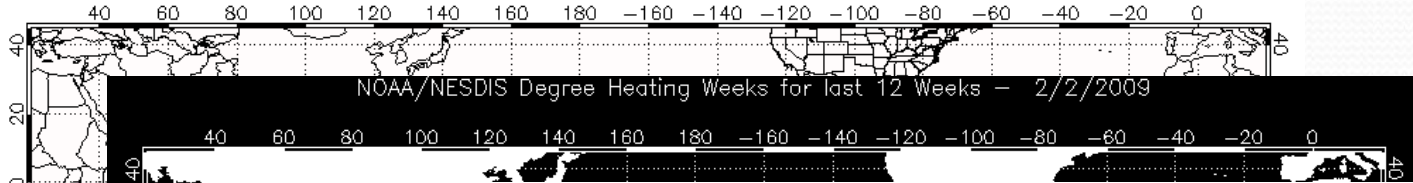
**2002**

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



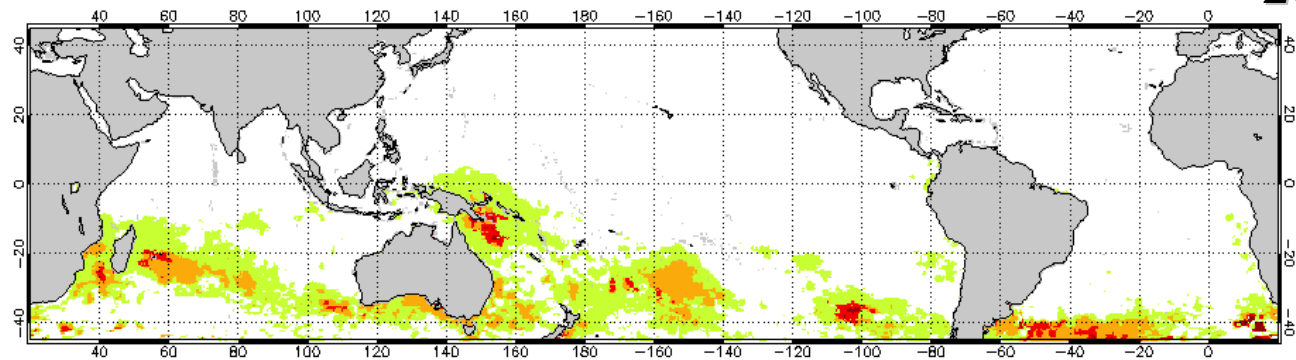
**2002**

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



**2003**

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



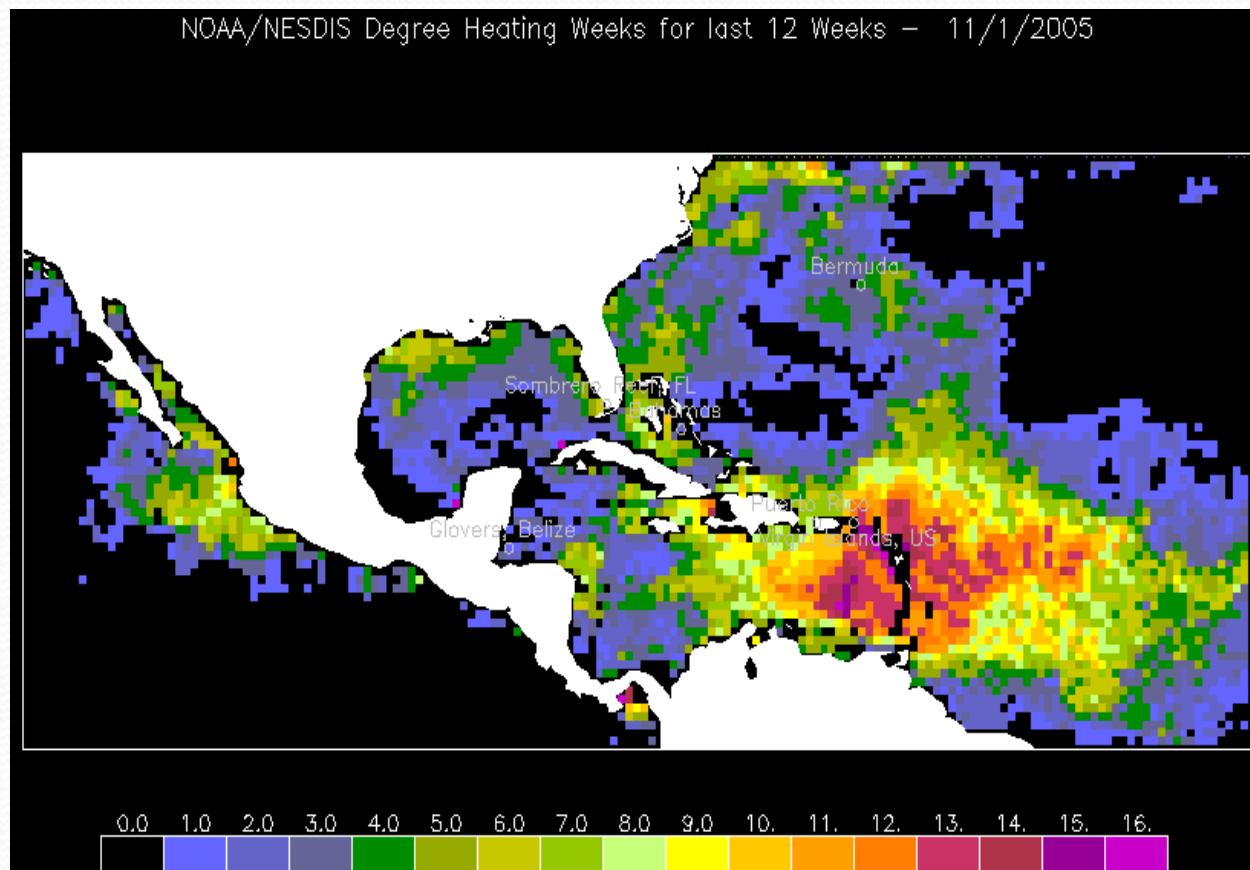
**2009**

No Stress    Watch    Warning    Alert Level 1    Alert Level 2

**Coral –  
specific**

**Bleaching Alert Areas**

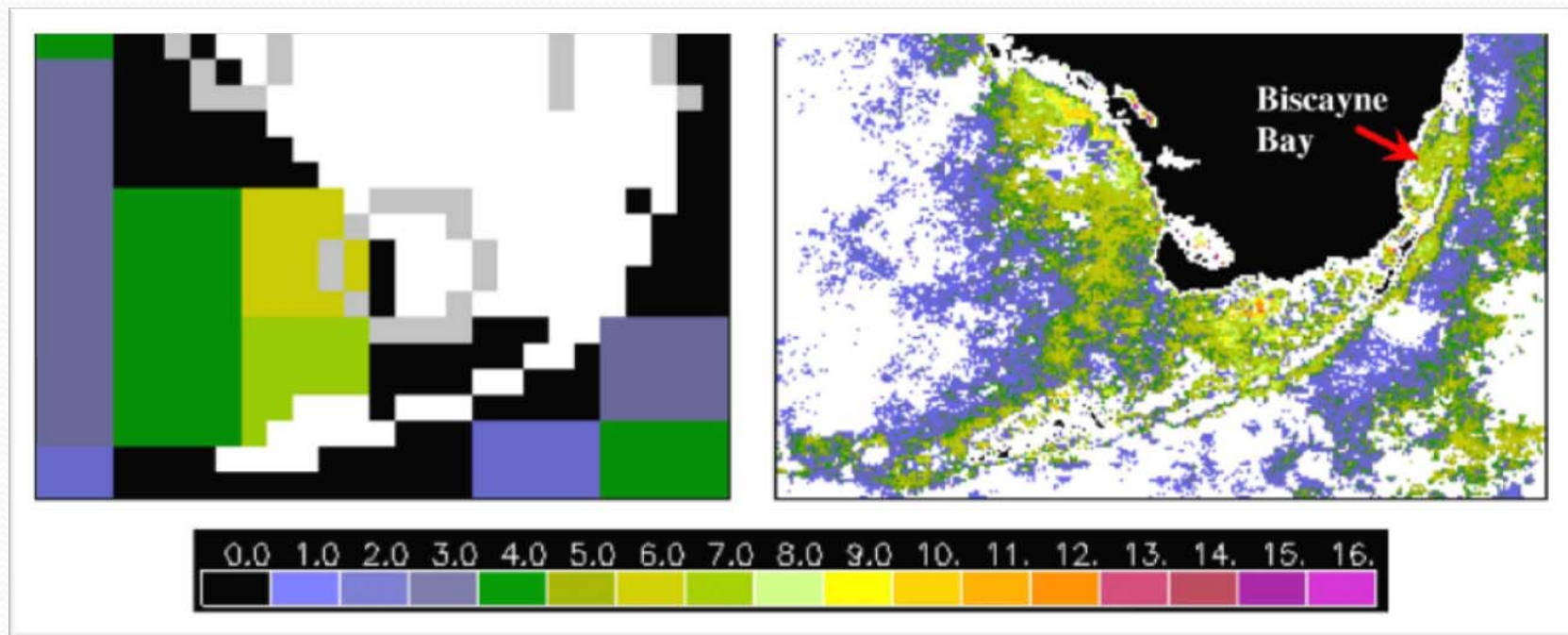
# NOAA CRW Degree-Heating Weeks



DHW corresponds to one week of SST exceeding the maximum summer SST by one °C. A value of two DHWs indicates two hot weeks, but is also equivalent to one entire week of SST exceeding the maximum summer SST by two °C.

**The 2005 Bleaching Event in the Western Hemisphere. The image shows the Degree-Heating Weeks (DHW) accumulated through 1 November, 2005. Note high DHW (yellow-orange colors) in the eastern Caribbean Sea. Significant bleaching took place in the U.S. Territories and adjacent islands.**

# New: High-resolution Degree Heating Weeks



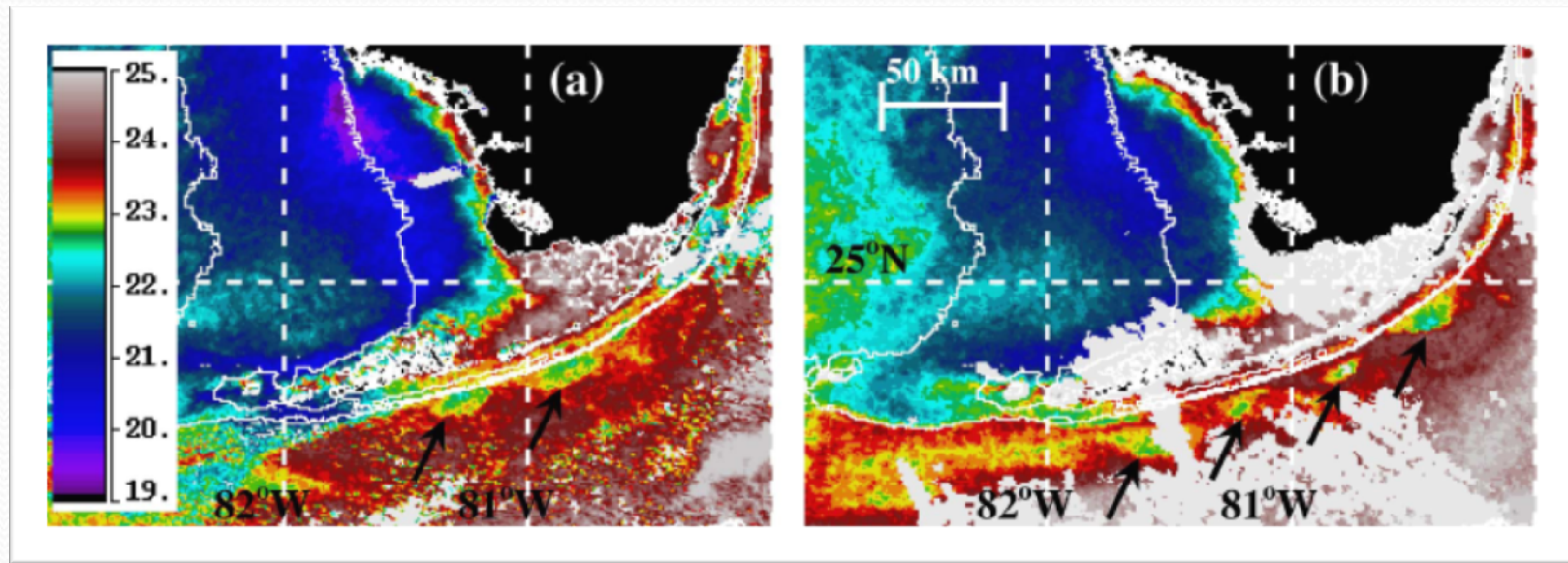
Left: 50-km DHW product

Right: Equivalent 1-km DHW product  
for 3-day period ending on August 20, 2005

Land mask colors are reversed between the images with zero DHW shown as black in the NOAA image and white in the USF image.

Reference: Building an Automated Integrated Observing System to Detect Sea Surface Temperature Anomaly Events in the Florida Keys. 2009. Chuanmin Hu, Frank Muller-Karger, Brock Murch, Douglas Myhre, Judd Taylor, Remy Luerssen, Christopher Moses, Caiyun Zhang, Lew Gramer, and James Hendee. IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 47, NO. 6, JUNE 2009

# High resolution preserves spatial patterns of importance to reefs

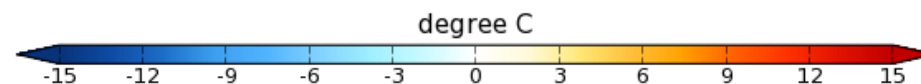
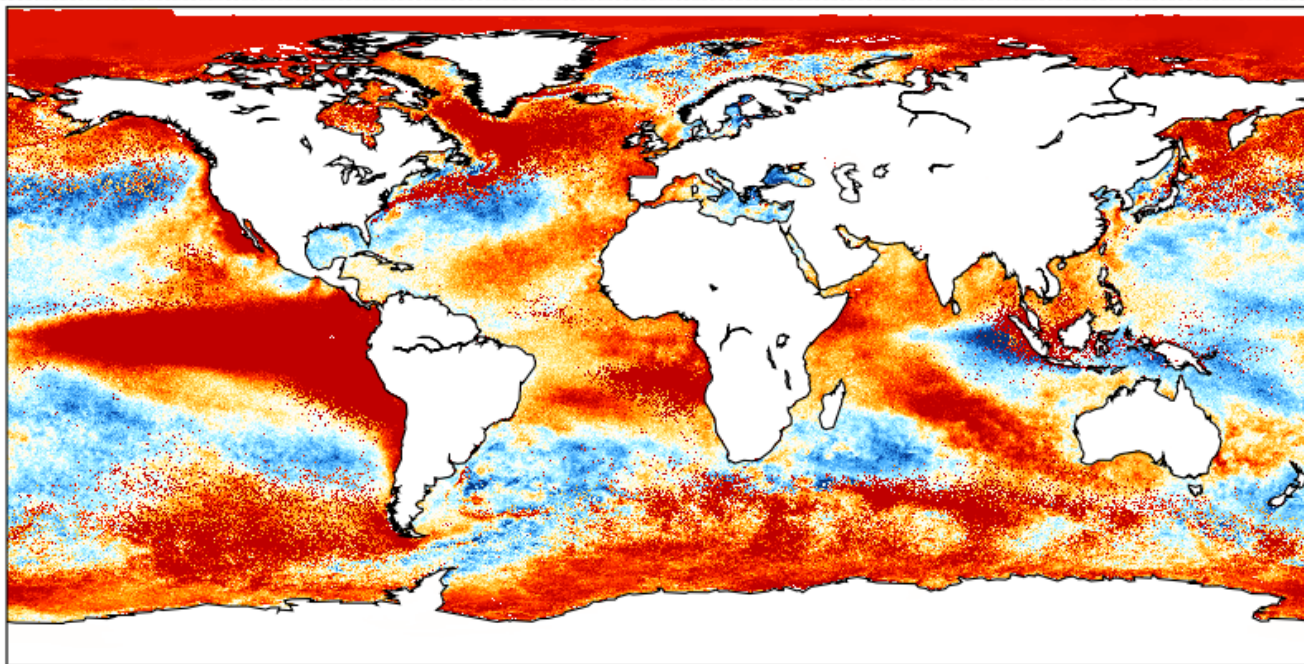


- High-resolution (1-km) AVHRR SST imagery (NOAA-16 satellite) showing small-scale ( $\approx 10$  km,  $\Delta < 1$  °C) frontal eddies (annotated with black arrows) along the shallow isobaths in the Florida Straits
- January 22, 2002 at 7:36 GMT and January 23, 2002 at 18:45 GMT.
- Eddies are due to shelf wave dynamics, and they cannot be detected by other coarser resolution data (4 km or lower).

# Sample product: Global 8 km resolution

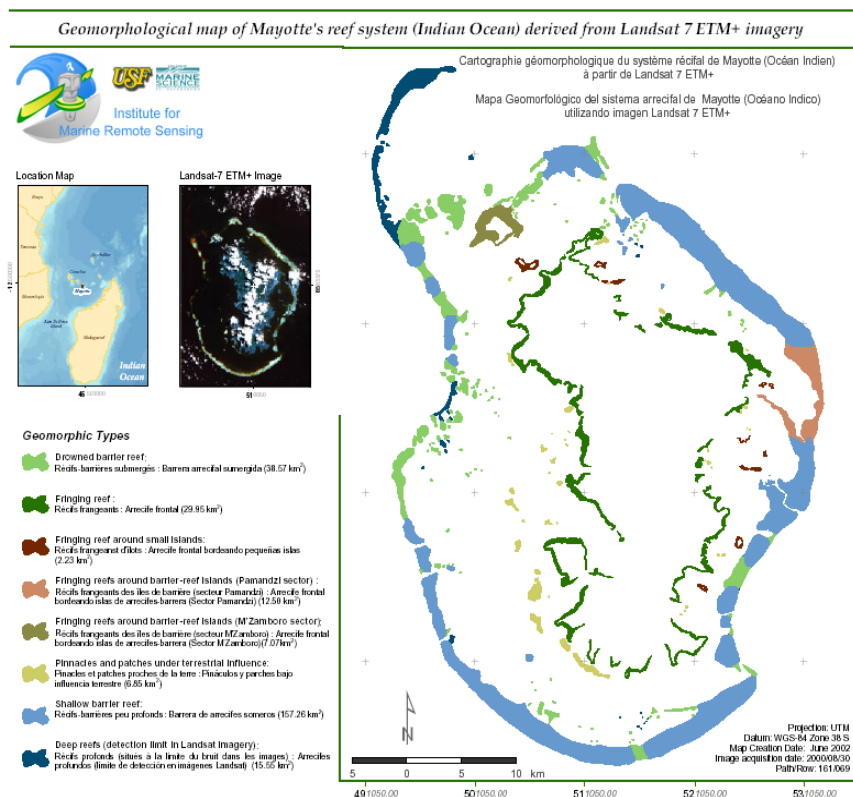
DHW

\* Rama Nemani and NASA Ames supercomputer



Accumulation of 12 weeks of hotspots by the first week of January 2008  
at moderate (8 km) resolution.

# Sample product: Millennium Map



**Figure 4.** Sample Millennium Coral Reef Map geomorphological classification, based on Landsat-7 data.

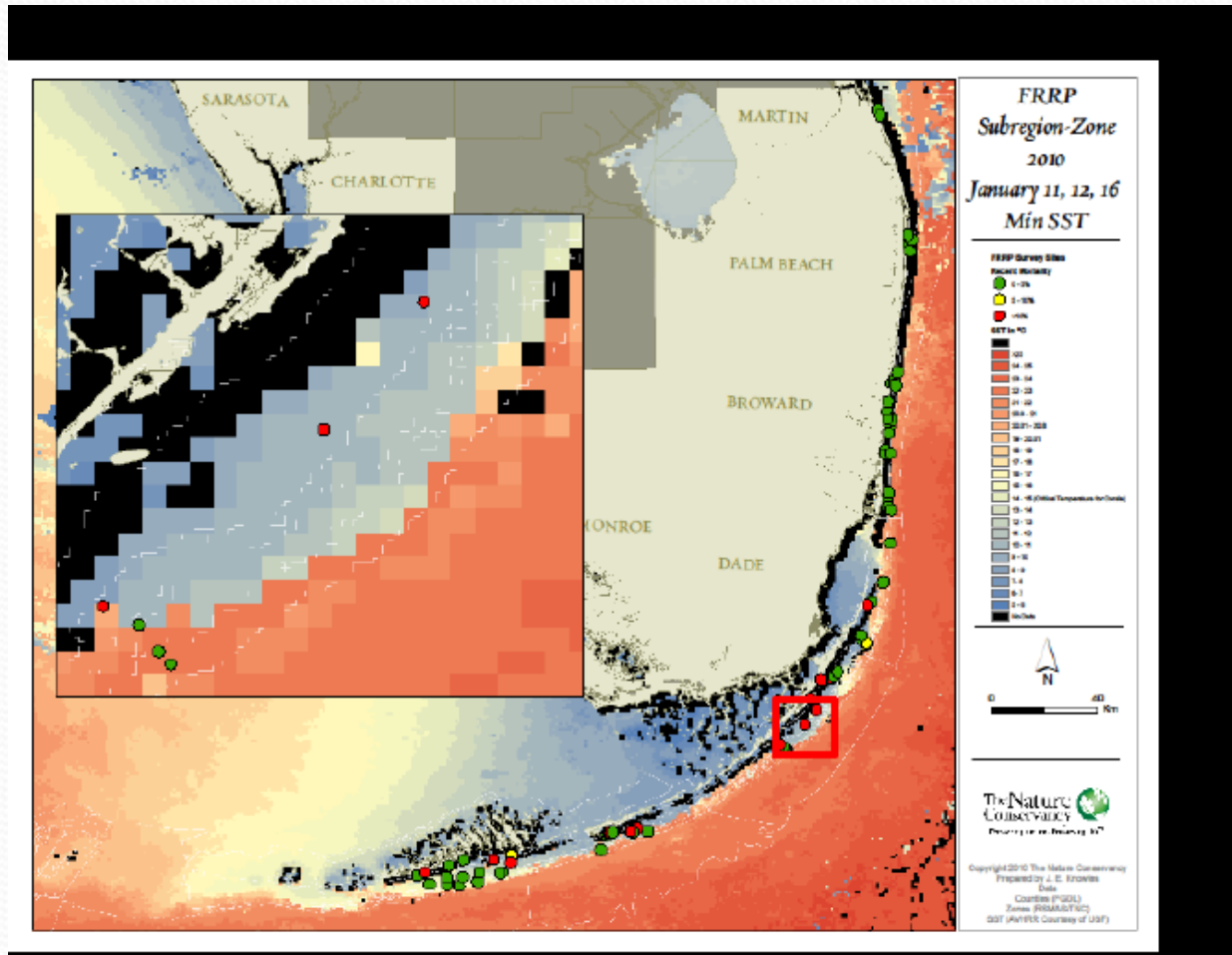


**Figure 5.** Sample Millennium Map products for the Florida Keys displayed on Google Earth.

## Other possible “enhancements”

- Cold water stress index
- Marine Spatial Planning support via CRW
  - Variables: SST, CHL, SSH, other?
  - Generating monthly, weekly climatologies
  - Anomalies
  - Long-term time series
  - Trends in variables
  - Plotting and data extraction capabilities

# Florida Reef Tract



SST between  
10° C – 21° C

**Critical low SST temperature threshold is ~ 13° C:  
mass mortality in scleractinian coral communities**

Dr. Tianran Chen, South China Sea Institute of Oceanology, Guangzhou, China



# Summary

- Survey sent to users, now waiting for returns
- Improve 'bleaching early-warning system' by moving to higher spatial resolution satellite images to better monitor local-scale conditions that the current 50km global products may miss
- Improve data delivery, using formats and online tools that enhance decision-making
- Integrate with global reef maps from the Coral Reef Millennium Map (30 m resolution)
- Integrate with real-time in situ obs. (ICON/CREWS, SeaKeys, etc.)
- Assist in defining education objectives (formal, informal)

*'So what?'*

## *Linking science and management*

- Ultimately, the goal is to improve our ability to alert reef managers around the world of bleaching-level stress, so they can take appropriate actions. Specifically, this will help them to better:
  - Communicate with stakeholder groups
  - Deploy targeted monitoring of bleaching events
  - Focus research on reef resilience
  - Reduce other stresses during bleaching
  - Design/employ experimental mitigation techniques