

# Early Warning Systems: Predicting Mass Coral Bleaching



Britt Parker  
NOAA Coral Reef Watch

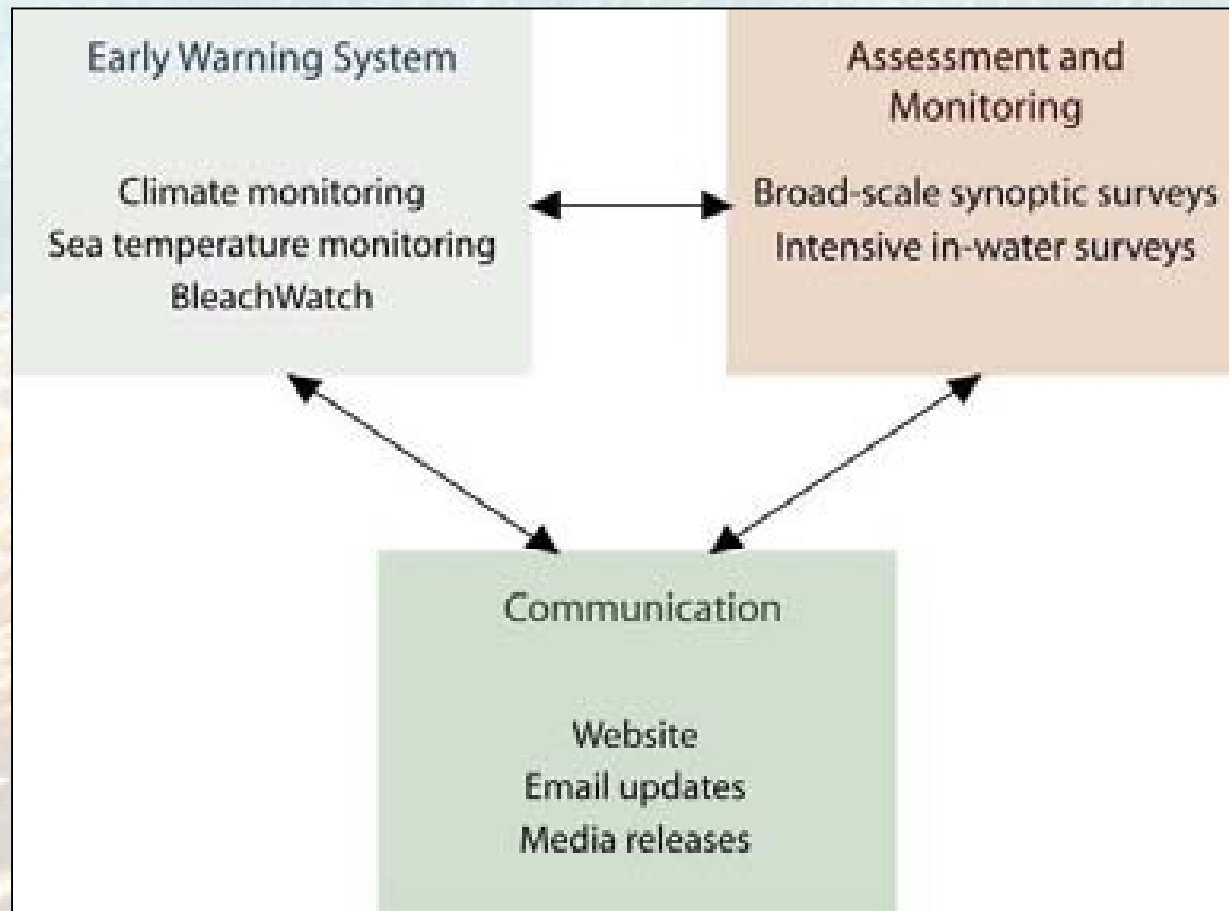
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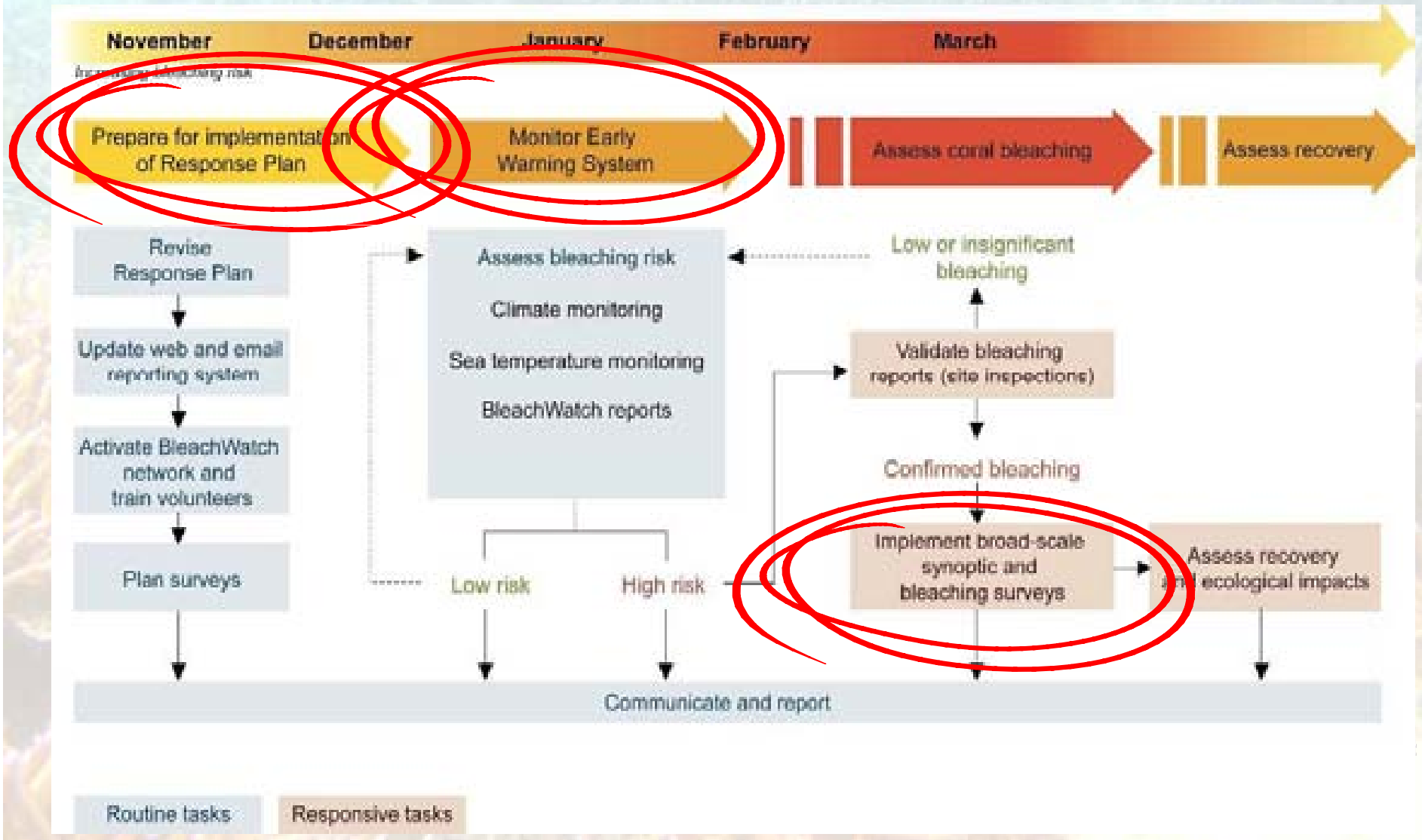
# Predicting Mass Bleaching: Section Outline

- Sources of “early warning” Information
- Satellites, Remote Sensing and Sea Surface Temperature
- Tools for Managers from NOAA Coral Reef Watch
- Activity: *You Make the Call!*

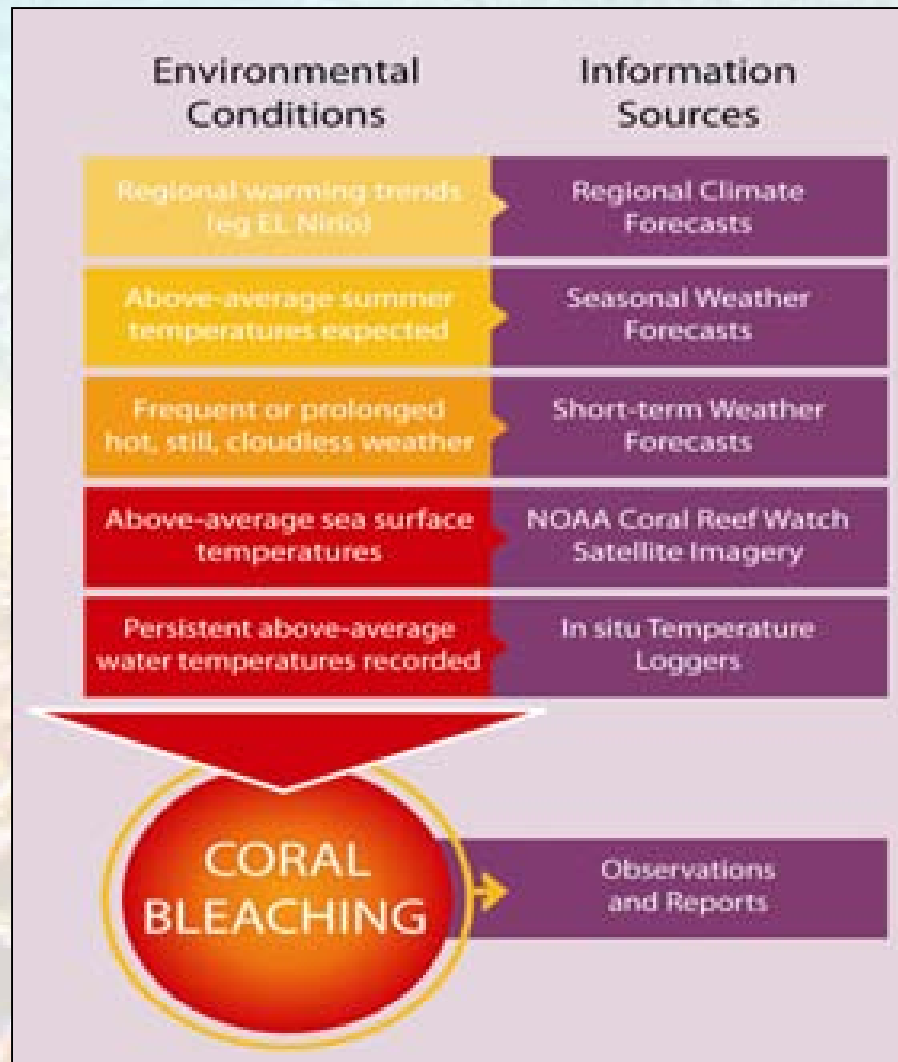
# Review: Elements of a BRP



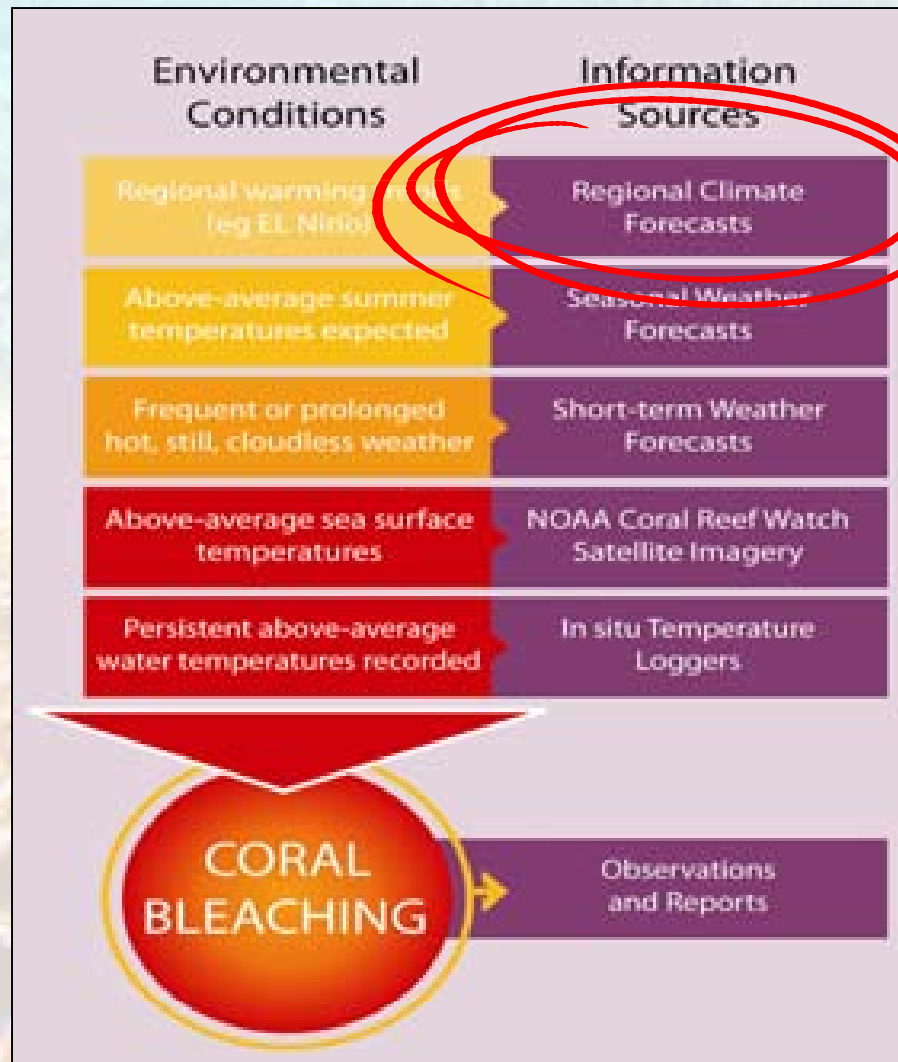
# The Role of Prediction in Bleaching Response



# Methods of Prediction



# Methods of Prediction



<http://www.elnino.noaa.gov/>

NOAA El Niño Page

Thursday, May 14, 2009

El Niño is a disruption of the ocean-atmosphere system in the Tropical Pacific having important consequences for weather and climate around the globe.

NOAA is the National Oceanic and Atmospheric Administration, which has primary responsibilities for providing accurate information to the Nation, and a leadership role in sponsoring El Niño observations and research.

Today's El Niño status

What is El Niño? What is La Niña? What is ENSO?

NOAA Status: A comprehensive listing of NOAA El Niño sites

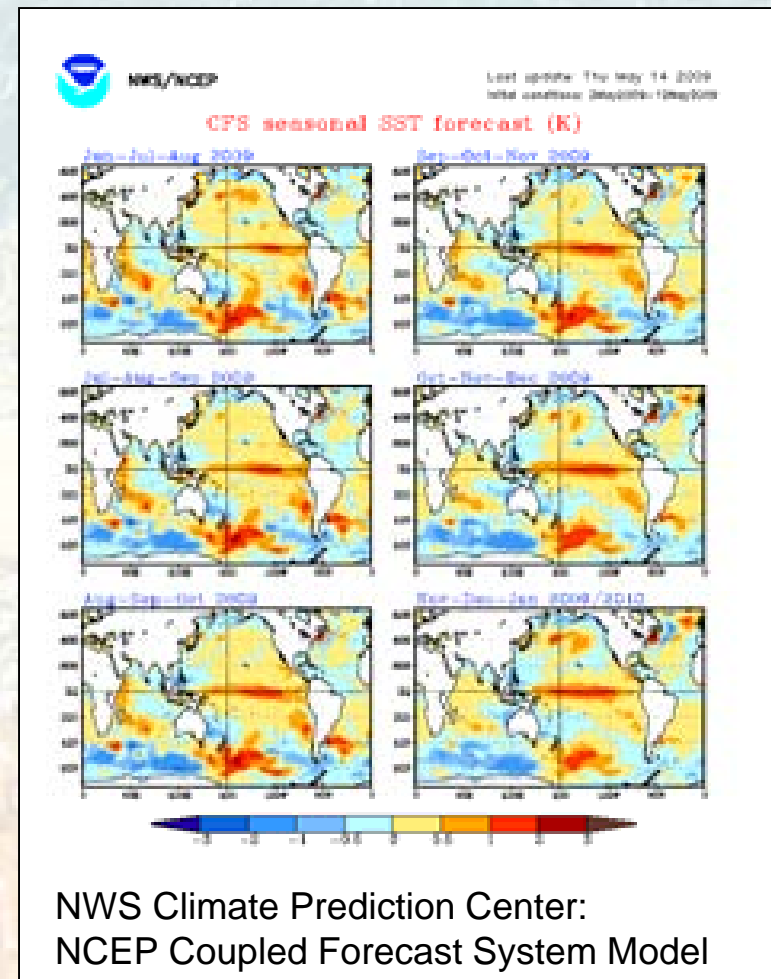
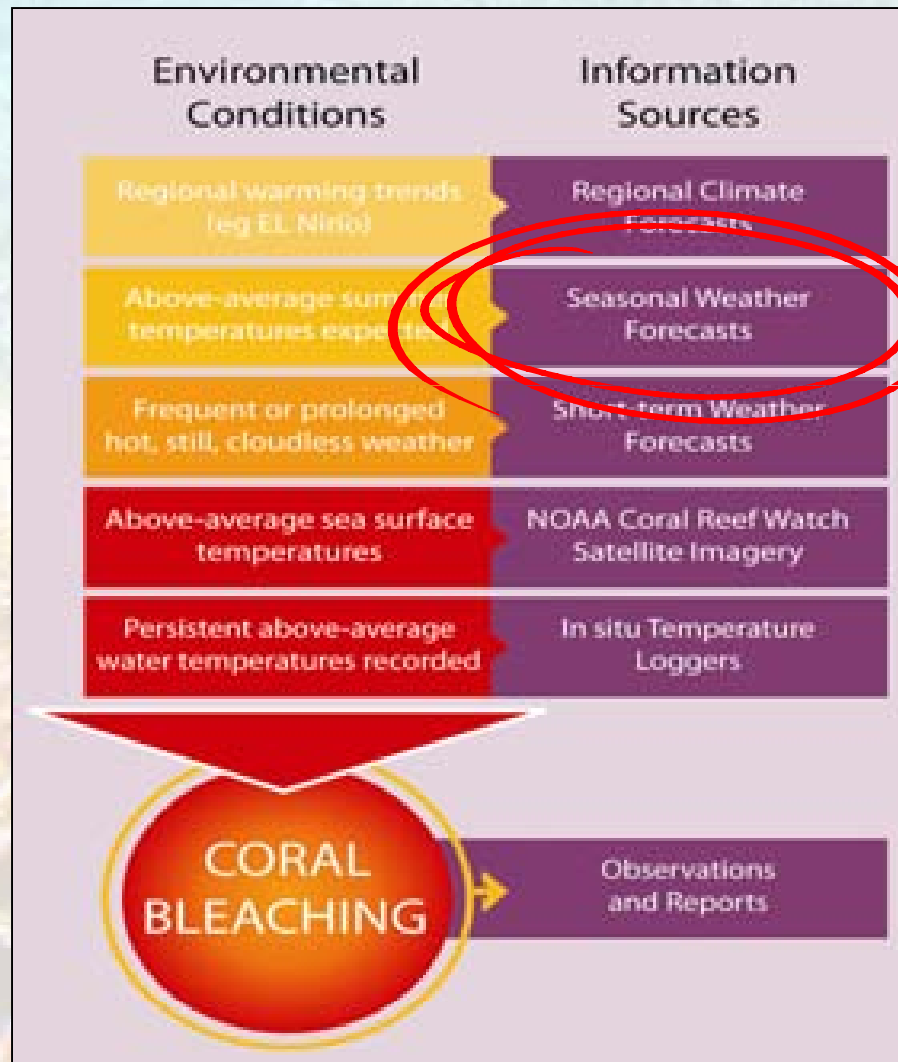
More about El Niño: Comprehensive index of more sites

La Niña: La Niña is associated with cooler than normal water temperatures in the Equatorial Pacific Ocean. Links on this page will have detailed information on processes involved in, and the status of, La Niña.

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Last updated: February 08, 2009

Current Status: ENSO-neutral conditions are expected to continue into the Northern Hemisphere Summer.

# Methods of Prediction





# Methods of Prediction

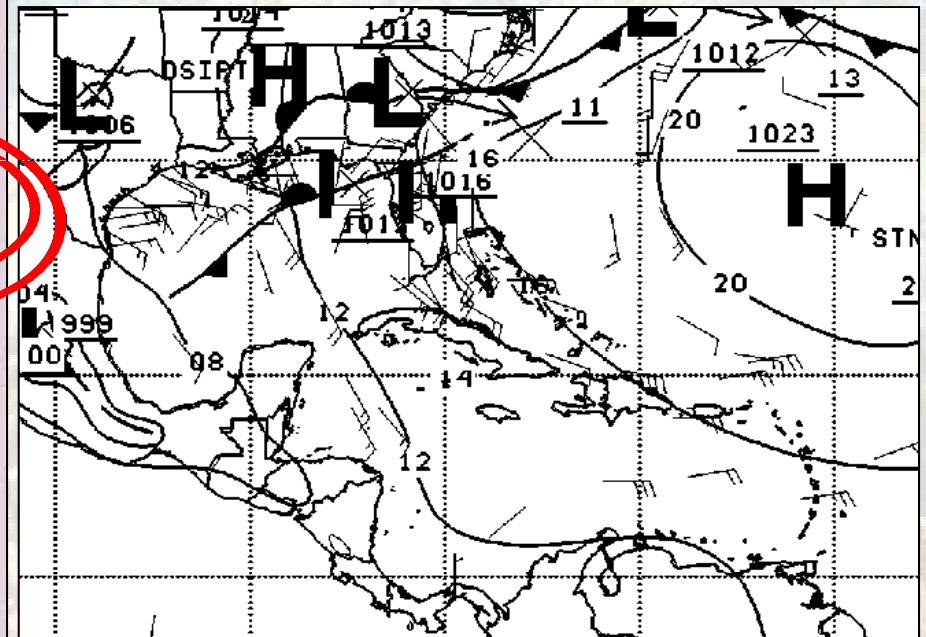
The diagram illustrates the methods of prediction for coral bleaching. It is organized into two main columns: 'Environmental Conditions' and 'Information Sources'. A red circle highlights the 'Short-term Weather Forecasts' section, which is linked to 'Frequent or prolonged hot, still, cloudless weather'.

Environmental Conditions	Information Sources
Regional warming trends (eg EL Nino)	Regional Climate Forecasts
Above-average summer temperatures expected	Seasonal Weather Forecasts
Frequent or prolonged hot, still, cloudless weather	Short-term Weather Forecasts
Above-average sea surface temperatures	NOAA Coral Reef Watch Satellite Imagery
Persistent above-average water temperatures recorded	In situ Temperature Loggers

A red arrow points from the 'Short-term Weather Forecasts' section to a red circle containing the text 'CORAL BLEACHING'. An arrow points from this circle to a box labeled 'Observations and Reports'.

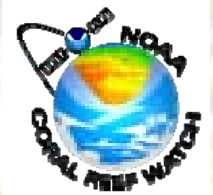
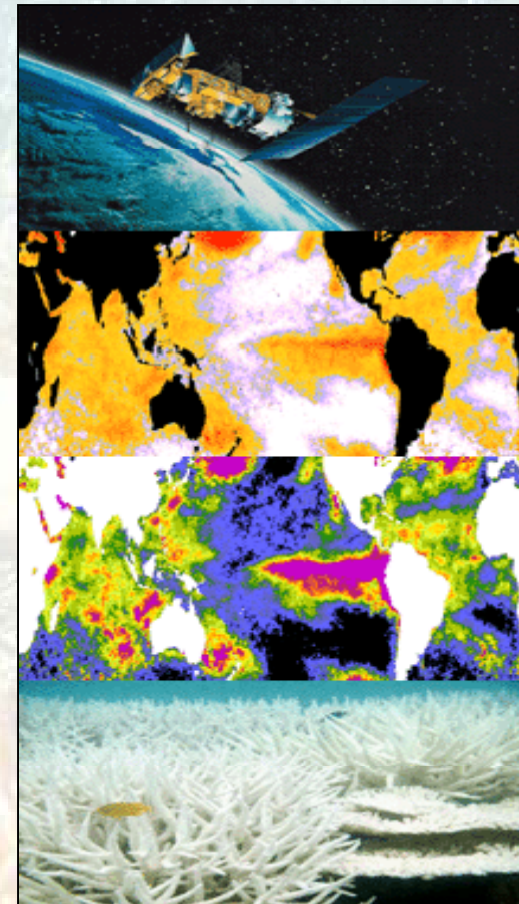
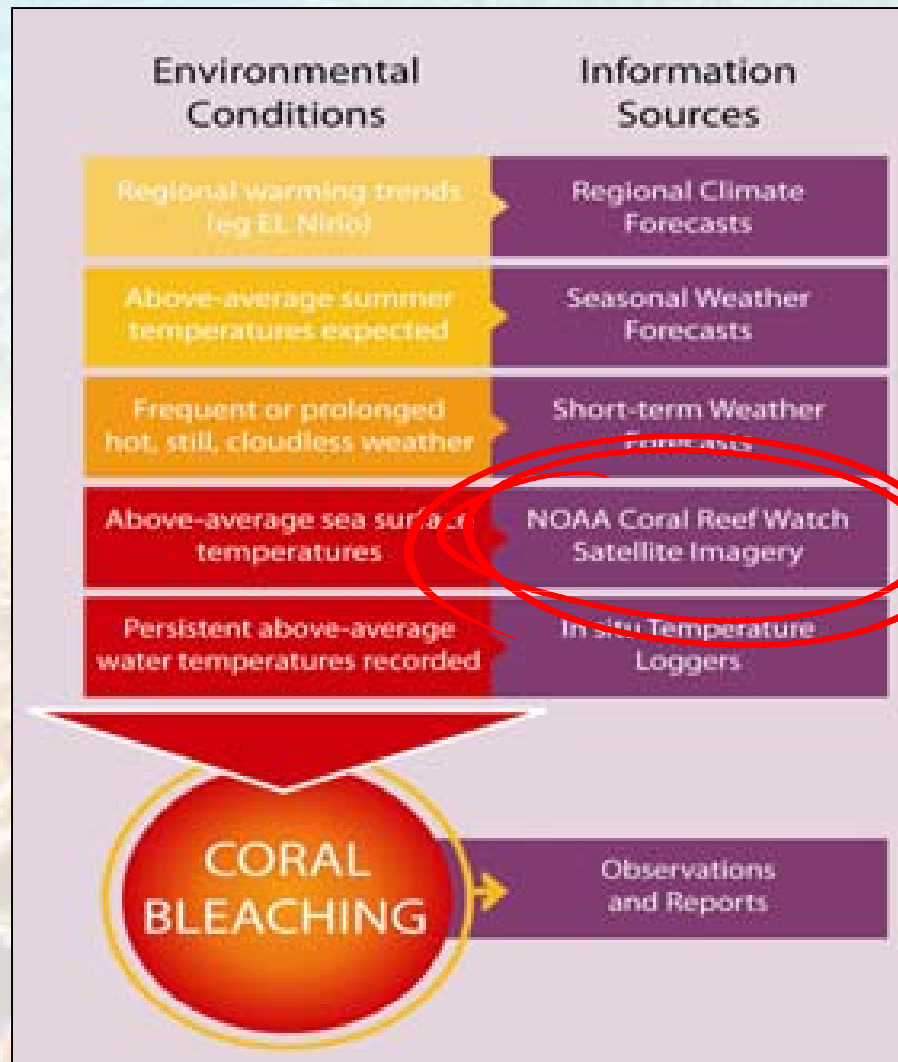
The map on the right shows the Pacific Ocean with various weather systems and pressure fronts. Key features include a high-pressure system (H) over the central Pacific, a low-pressure system (L) over the western Pacific, and a cold front (C) extending from the low-pressure system. Other features include a cold front (C) over the eastern Pacific, a cold front (C) over the southern Pacific, and a cold front (C) over the northern Pacific. The map also shows the equator and the Tropic of Cancer.

The bottom right corner features logos for 'The Nature Conservancy' and 'NOAA'.

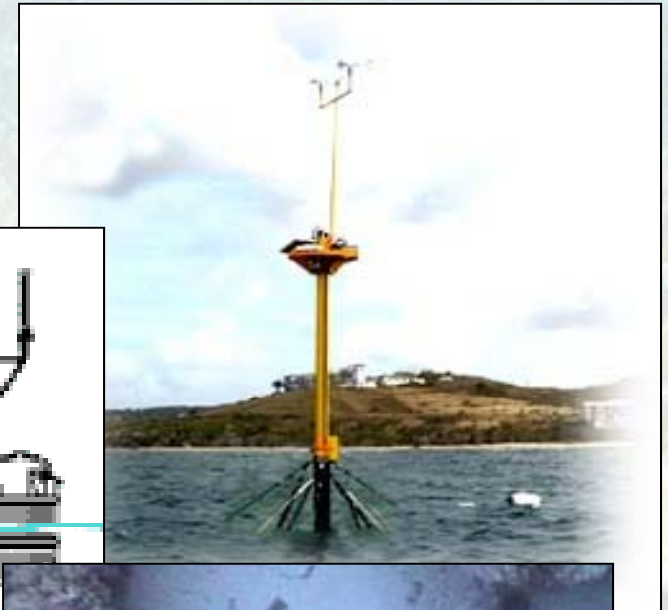
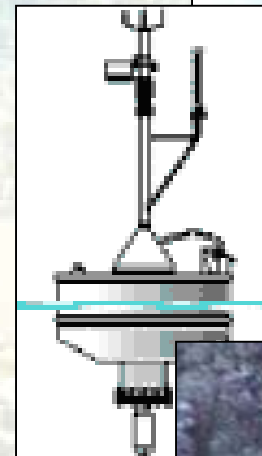
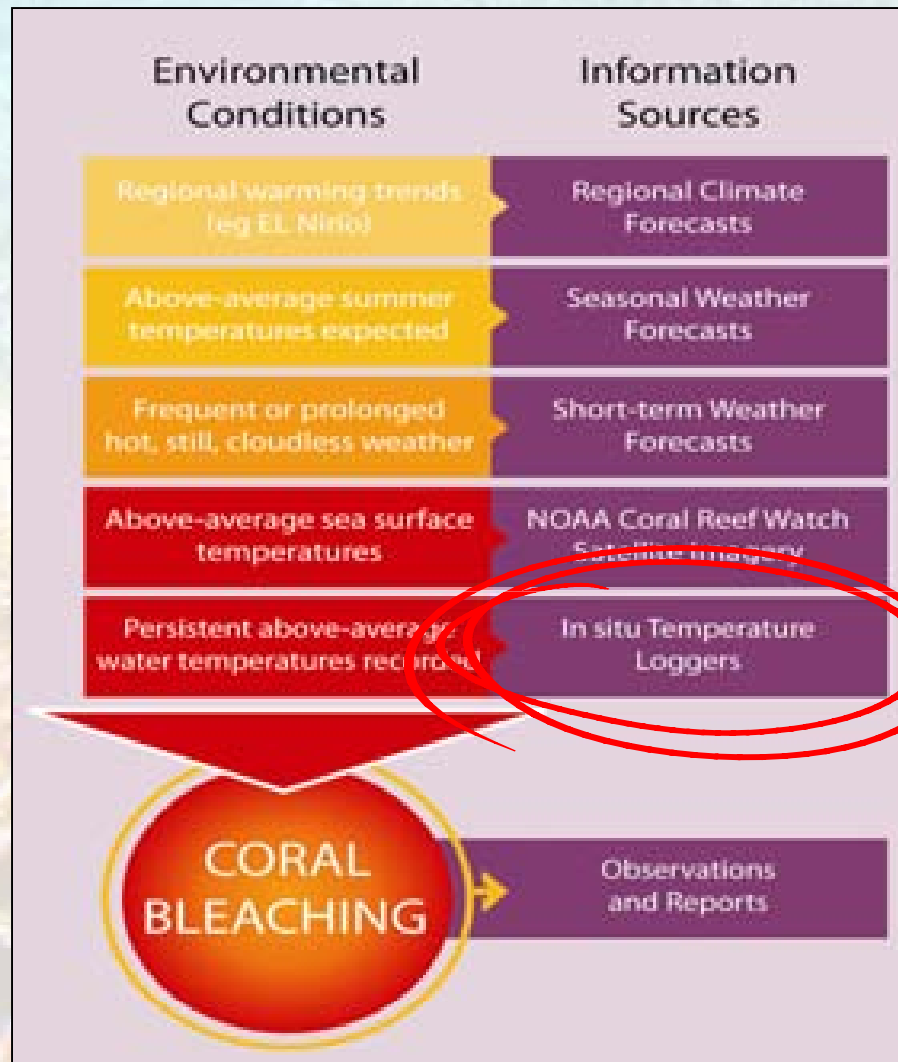




# Methods of Prediction

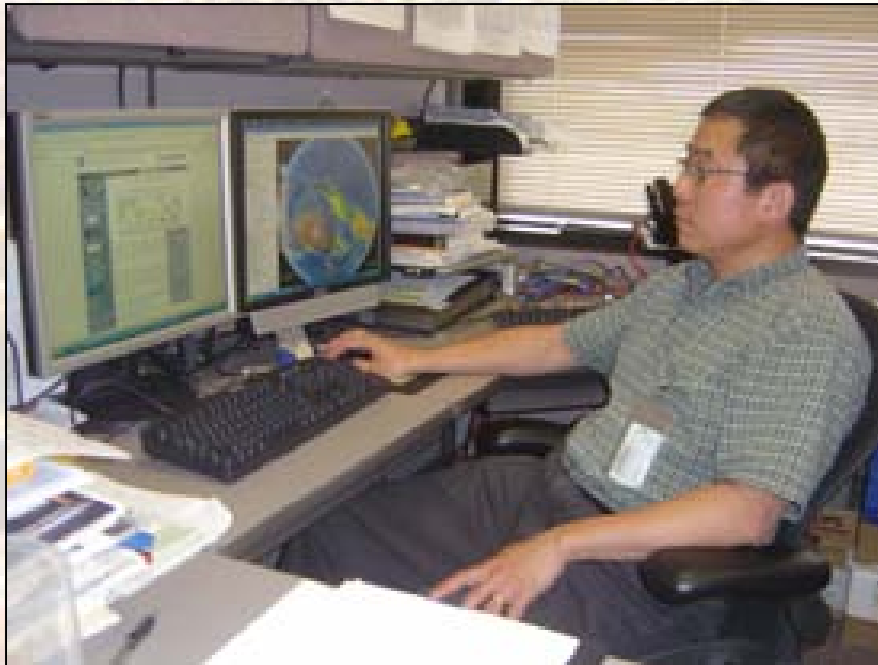


# Methods of Prediction



# NOAA Coral Reef Watch

Using satellite data to provide current reef environmental conditions, quickly identifying areas at risk for coral bleaching

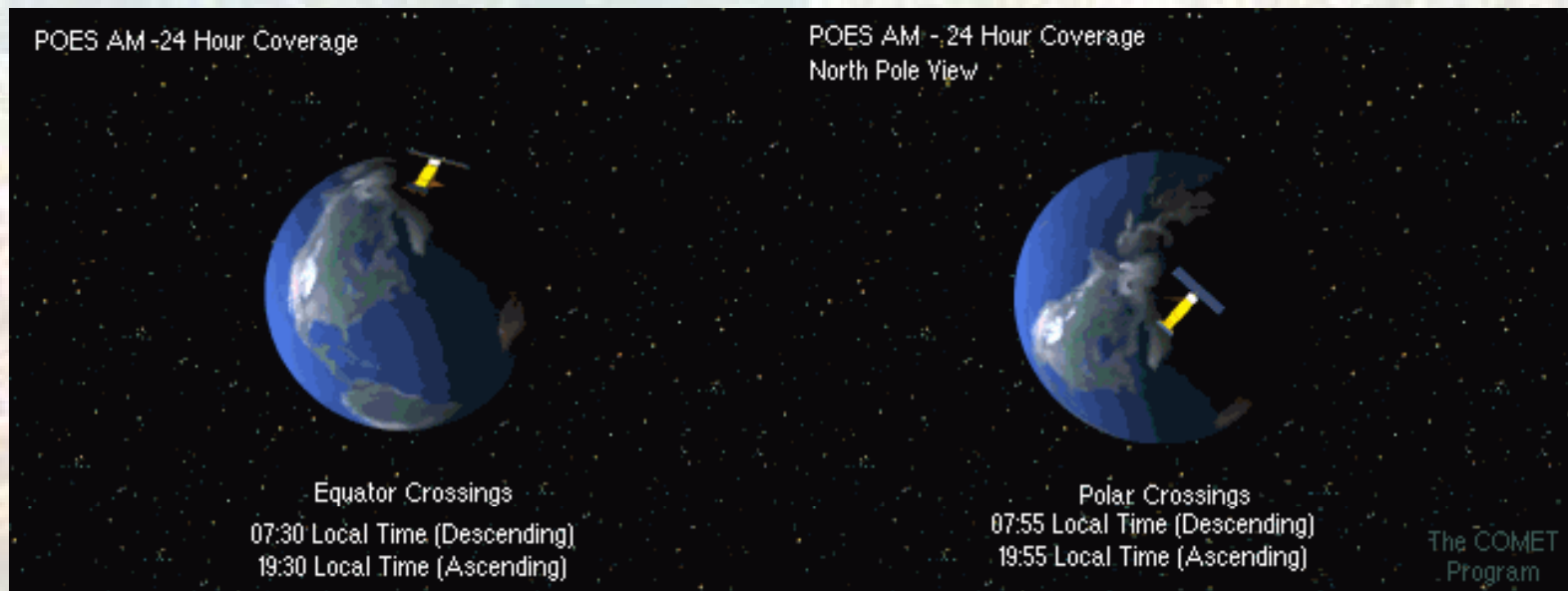


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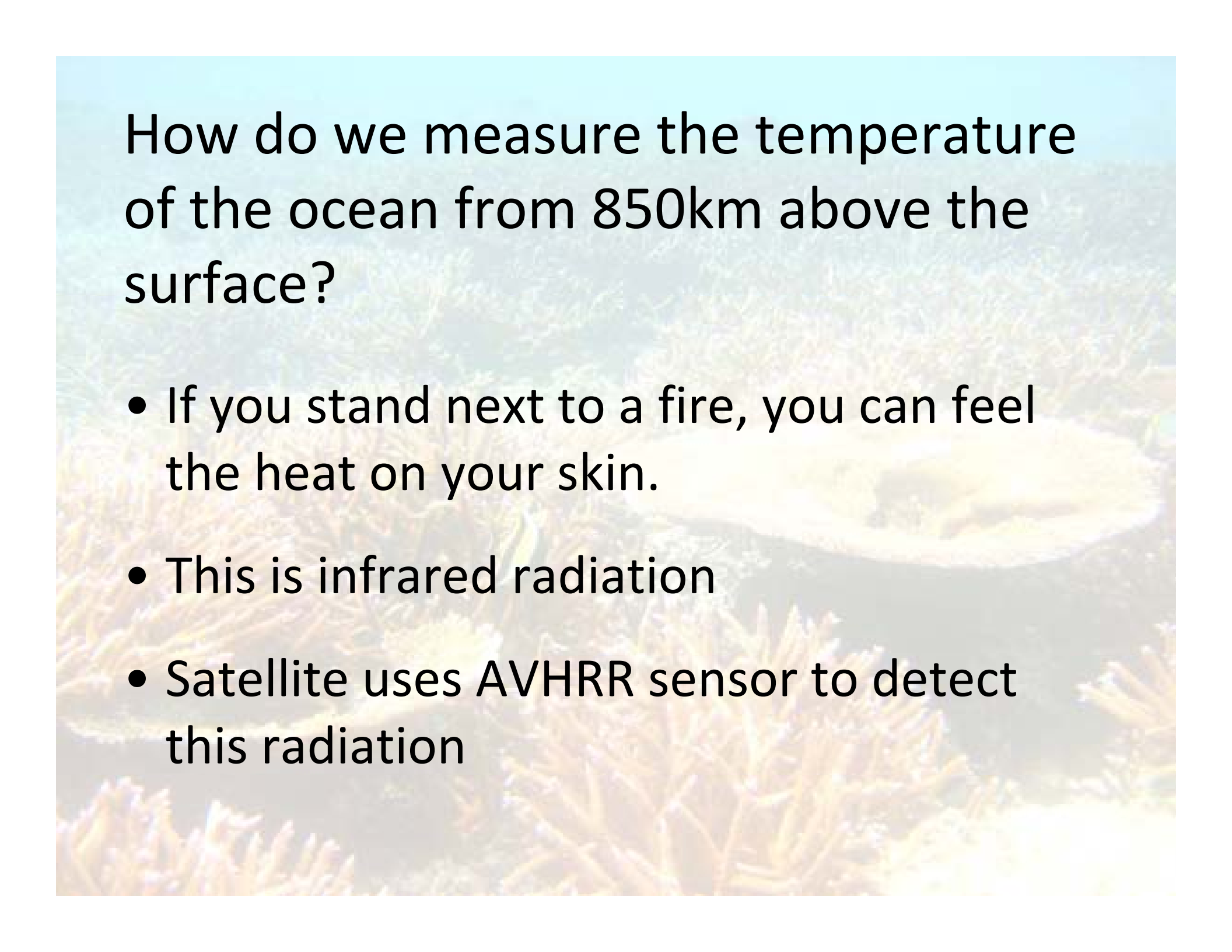


# What satellites do we use?

NOAA's polar-orbiting POES satellites view most of the earth's surface every day.





The background of the slide is a photograph of a coral reef. The water is clear, and the coral is a mix of brown and orange colors. In the center-right, there is a white sandy patch where a small, dark object, possibly a person or a boat, is visible. The text is overlaid on the top left of the image.

# How do we measure the temperature of the ocean from 850km above the surface?

- If you stand next to a fire, you can feel the heat on your skin.
- This is infrared radiation
- Satellite uses AVHRR sensor to detect this radiation

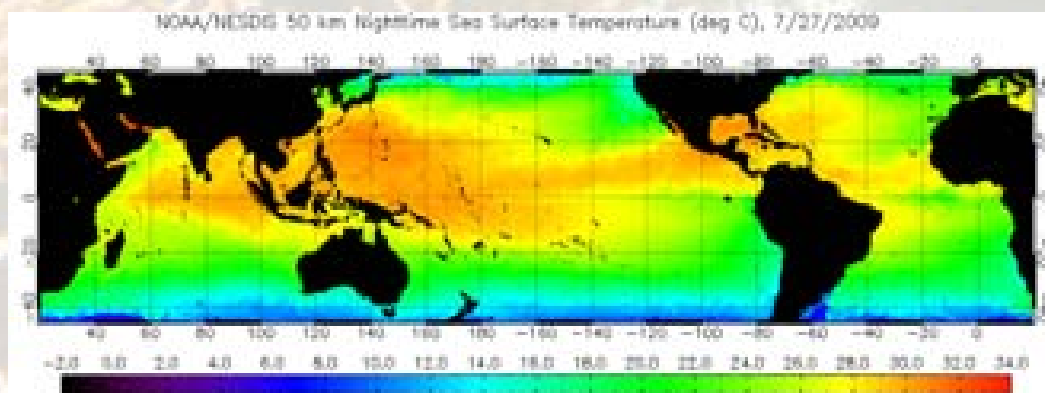
# Challenges to SST Measurements

- Diel variation
- Skin Effect – Surface cooling
- Clouds



# Basis of all Coral Reef Watch Products

- Semi-weekly data on a 0.5-degree (~50km) grid
  - Partly to account for cloud gaps
- Night-time only
- Tuned to buoy data (at 1m depth)



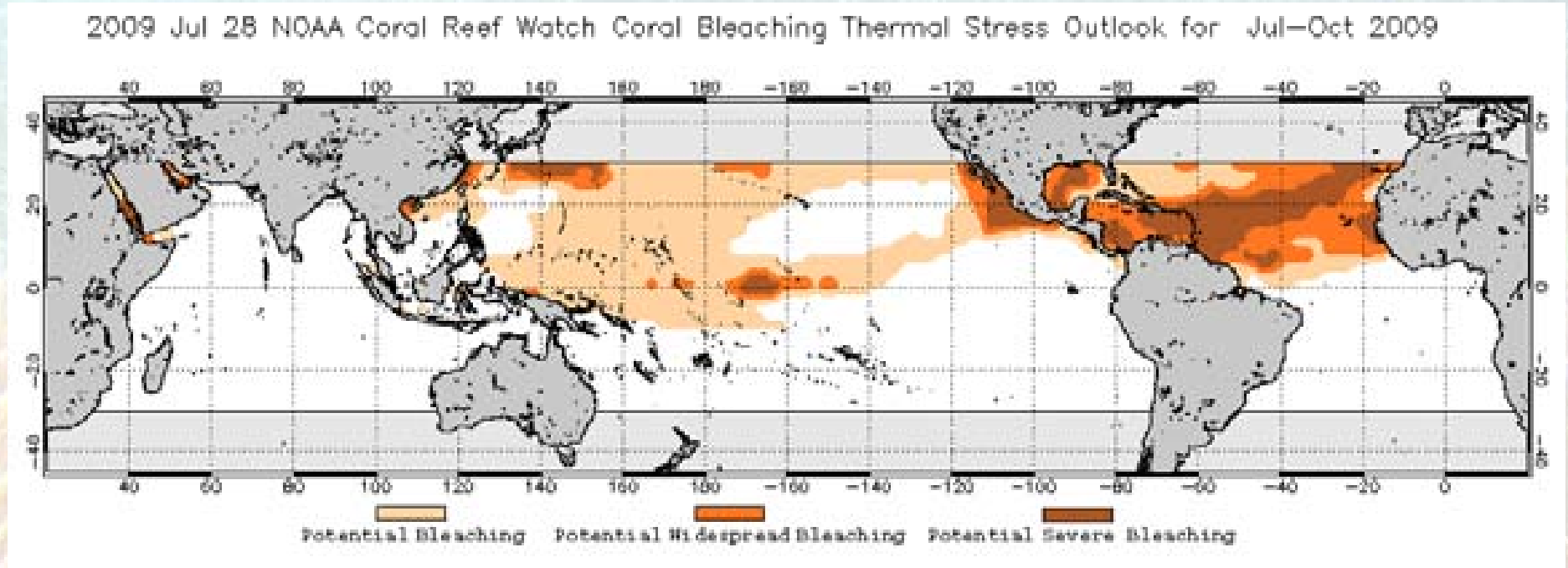
[www.coralreefwatch.noaa.gov](http://www.coralreefwatch.noaa.gov)

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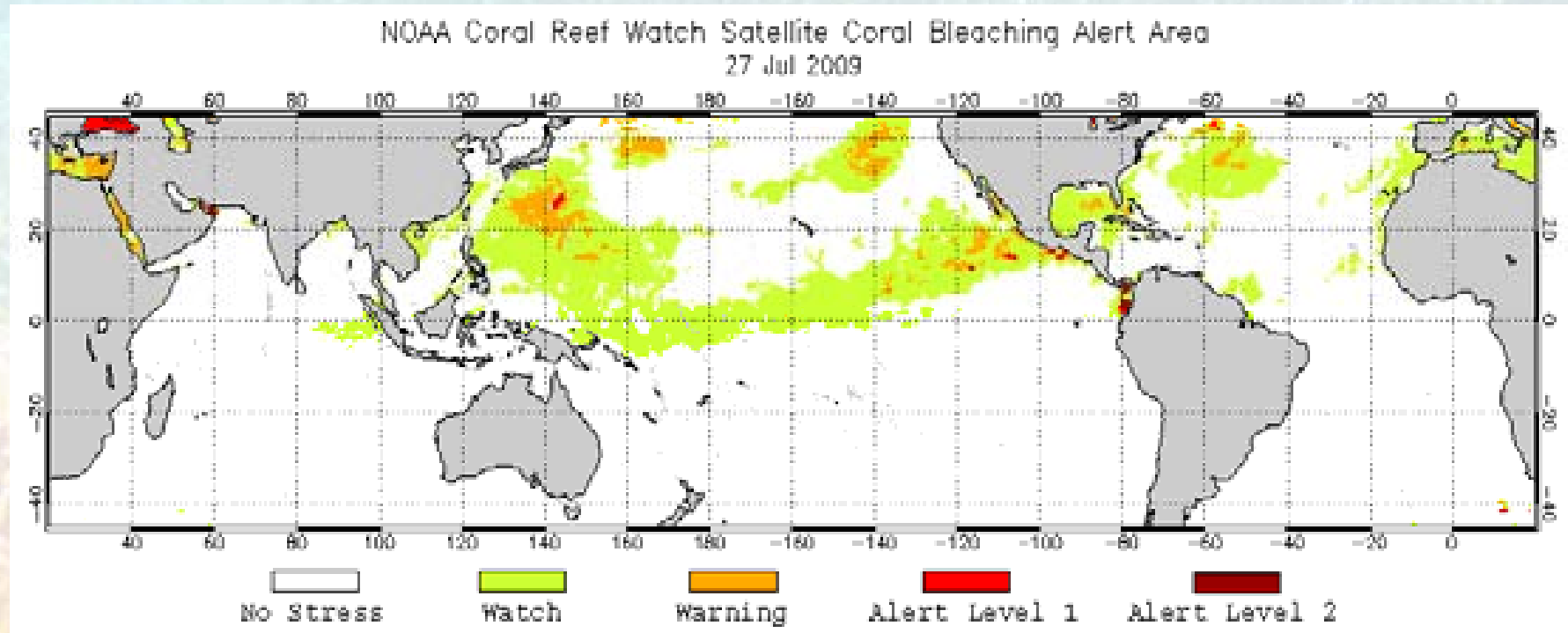


# Bottom Line for Managers



Is my reef at risk for bleaching in the future?

# Bottom Line for Managers



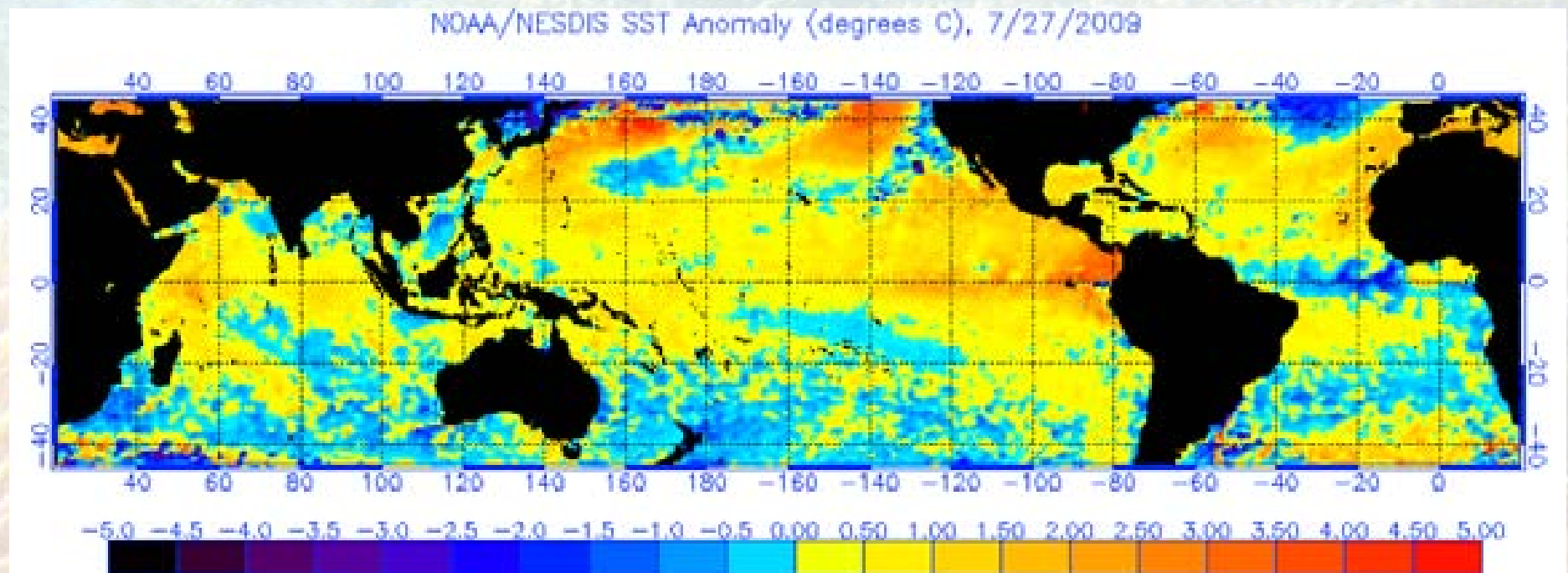
Is my reef currently at risk for bleaching?

# NOAA Coral Reef Watch Satellite Coral Bleaching Products

- Satellite Sea Surface Temperature (SST)
- SST Anomaly
- Coral Bleaching HotSpot
- Degree Heating Weeks
- Bleaching Area Alert Product
- “Virtual Stations” & Satellite Bleaching Alerts
- Experimental Products



# Satellite Sea Surface Temperature (SST)

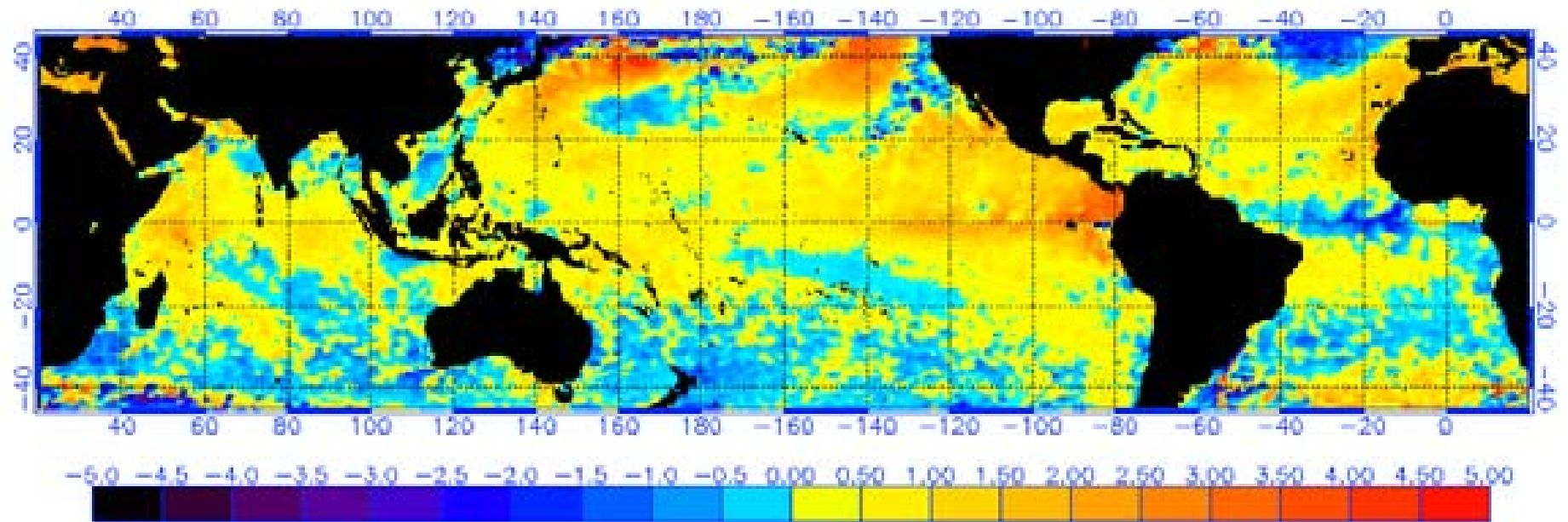


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# Sea Surface Temperature Anomaly

NOAA/NESDIS SST Anomaly (degrees C), 7/27/2009

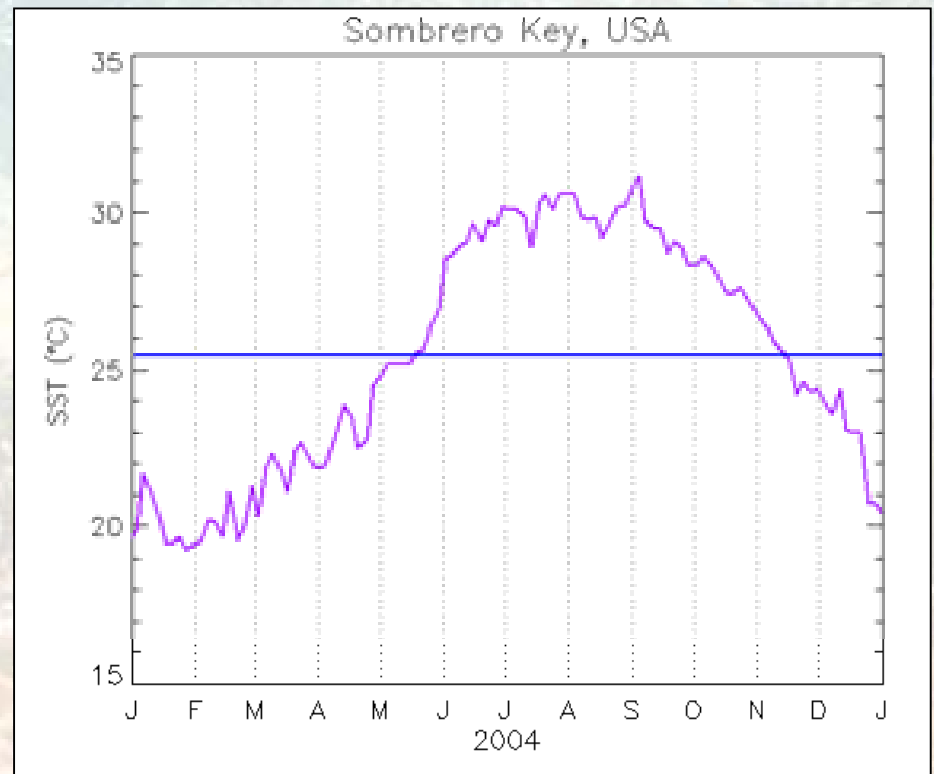
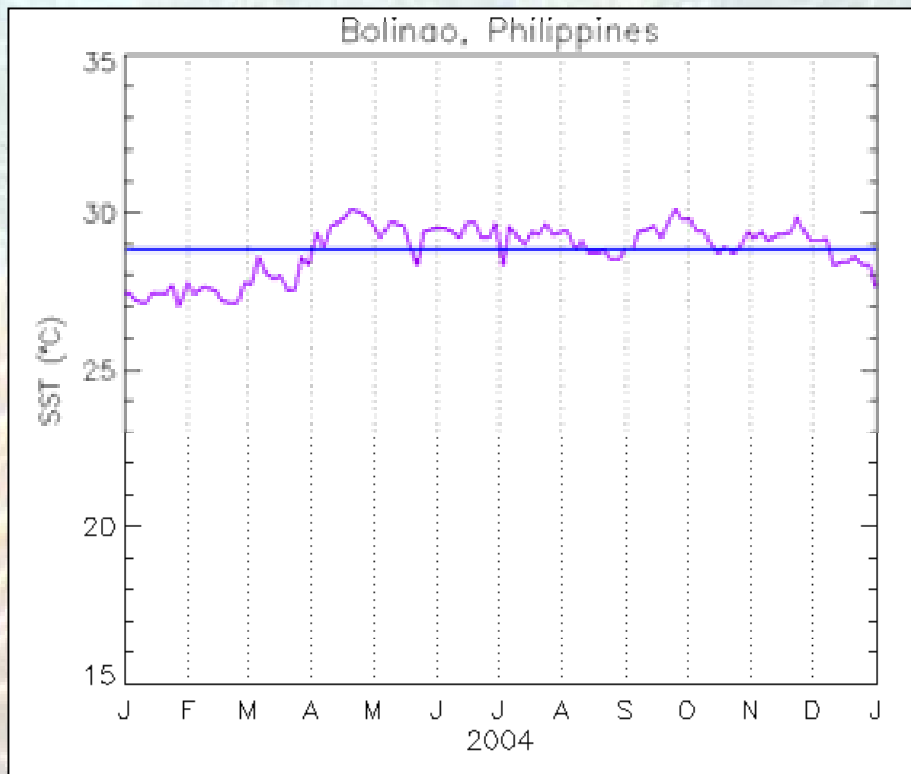


Is today's temperature above or below average  
for this location at this time of year?



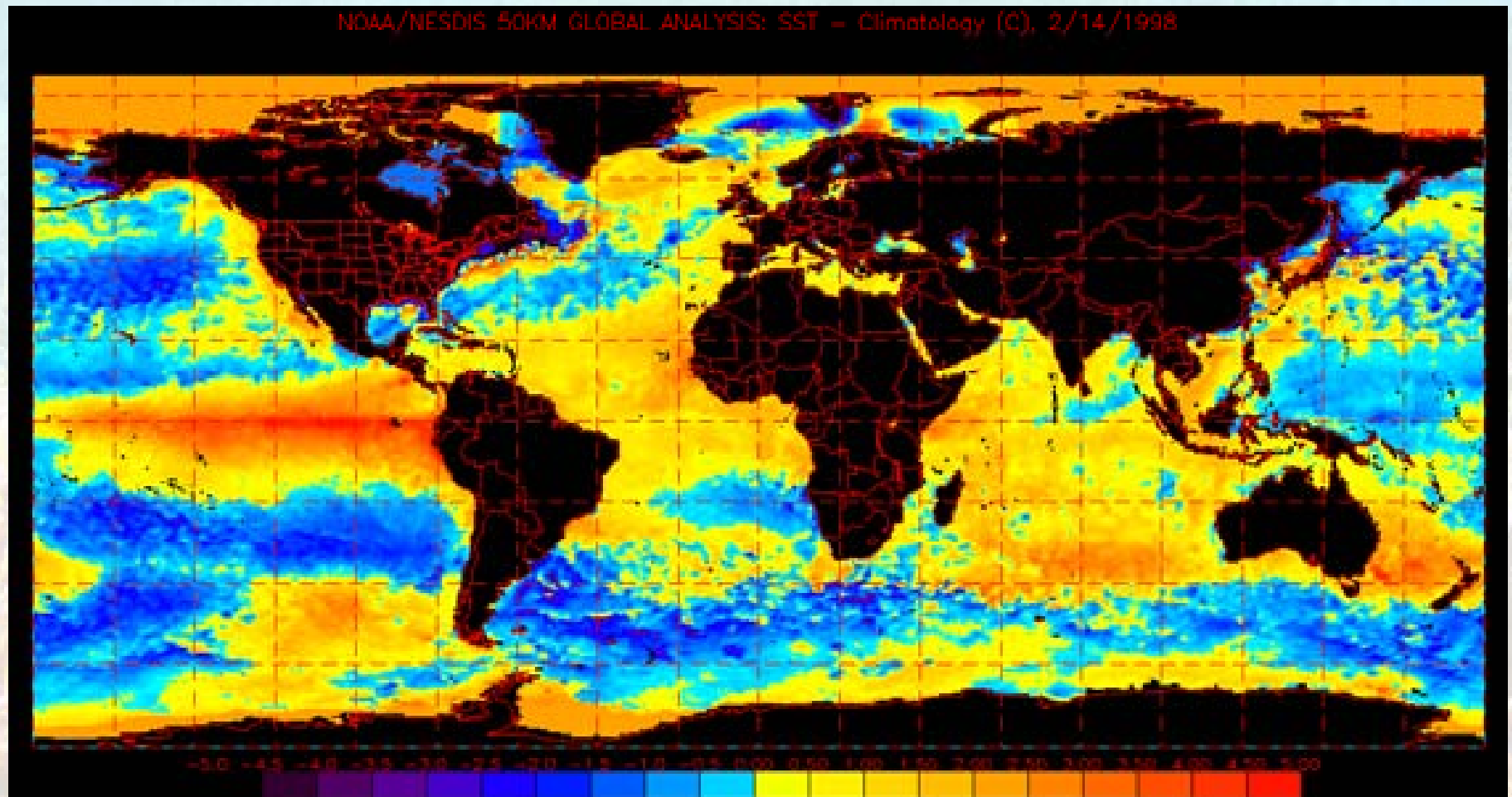
# Why use an anomaly?

## Let's Look at Two Sites





# 1998 El Niño - Feb



Climate-scale temperature features visible





# Coral Bleaching

- Reef-building corals live near their thermal limit
- Stressed corals “bleach” expelling symbiotic algae
- Thermal threshold is around 1°C above summer time maximum
- Prolonged stress leads to mortality
- Pollution and other stresses can also cause bleaching and mortality



# Bleaching Threshold Temperature: When do Corals Bleach?

Corals will bleach when experiencing anomalously high levels of light and water temperature

**Coles et al. (1976) & Glynn & D'Croz (1990)**

Threshold Temperature for Coral Bleaching is 1-2°C above the Summer-Time Max Temperature



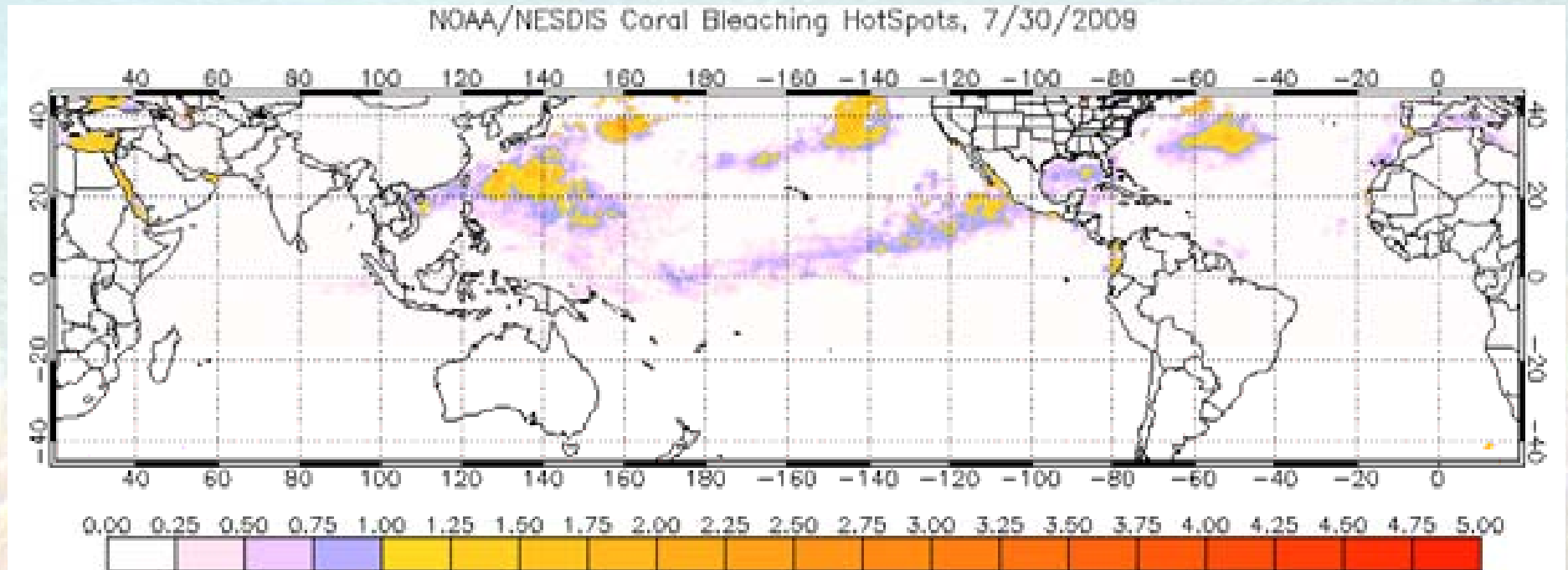
# Coral Reef Watch MMM Climatology

(Maximum Monthly Mean Climatology)

- For each pixel, average all years to derive 12 monthly SST averages
- Pick the hottest month
- HotSpots are: degrees  $>$  MMM (i.e., the positive anomaly)



# Coral Bleaching HotSpot



HS = 0

$0 < HS < 1$

$HS \geq 1$

No Thermal Stress

Temperatures above  
maximum summer value  
Thermal Stress on corals



# Degree Heating Weeks (DHW)

HotSpots are degrees > MMM



Corals bleach when conditions get  
hot and stay hot

DHW are accumulated HotSpots  $\geq 1$   
for the preceding 12 weeks



# Degree Heating Weeks (DHW)

How much thermal stress has built up  
over the past three months?

Temperature and duration combined: °C – weeks

10 DHWs could be:

1 degree above MMM for 10 weeks

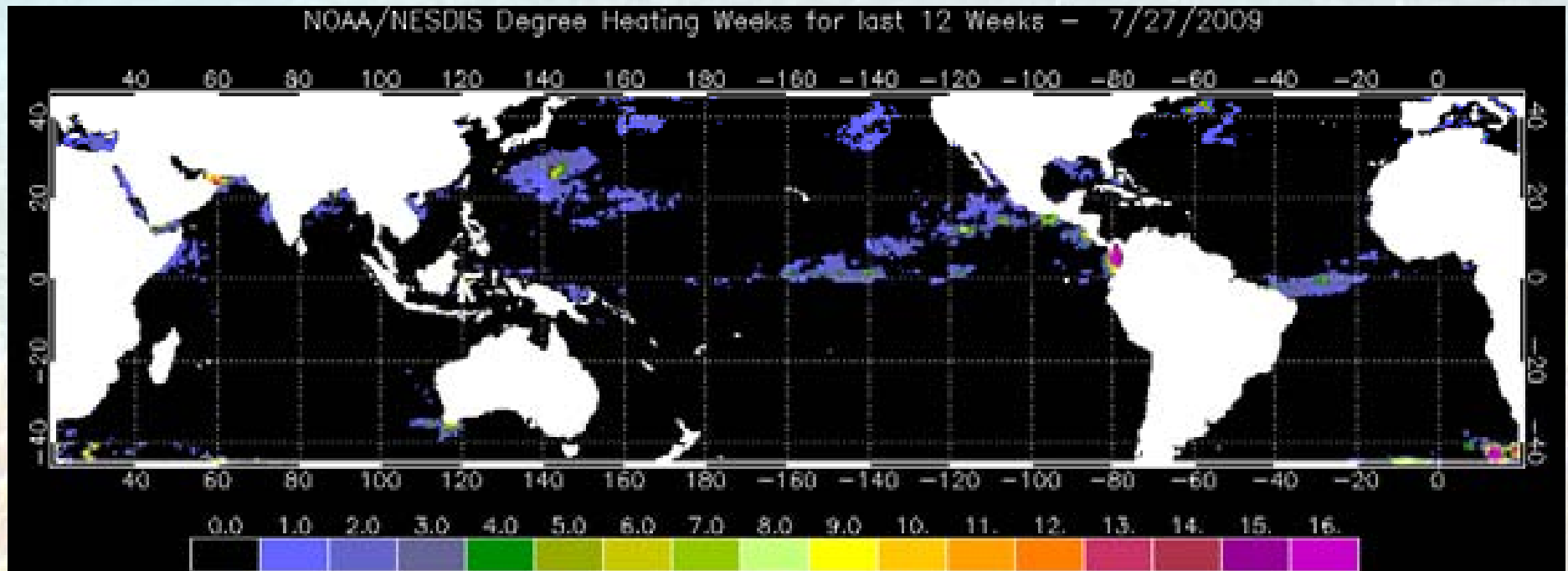
2 degrees above for 5 weeks

2.5 degrees above for 4 weeks





# Degree Heating Weeks (DHW)

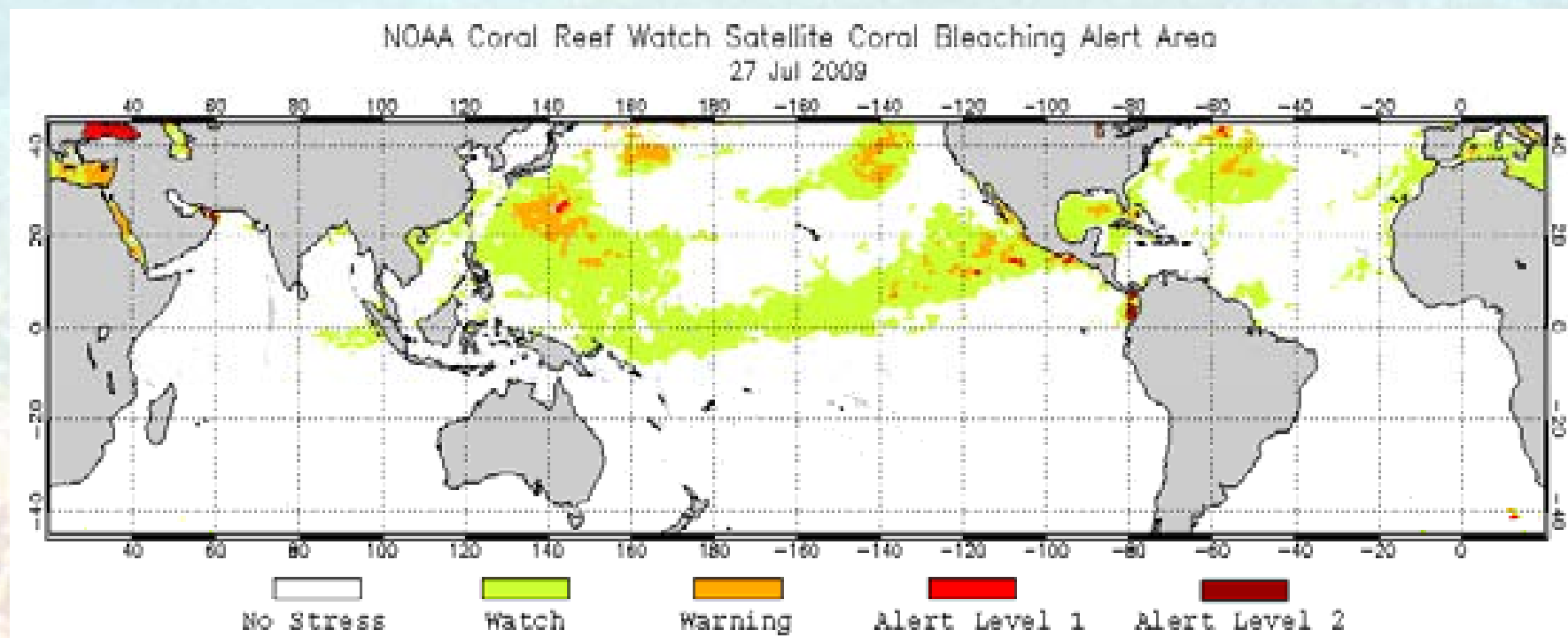


DHW = 0	No Thermal Stress
DHW $\geq$ 4	Thermal Stress leading to significant bleaching
DHW $\geq$ 8	Thermal Stress leading to wide spread bleaching and significant mortality





# Bottom Line for Managers



Stress Level	Definition	Potential Bleaching Intensity
No Stress	HotSpot = 0	No Bleaching
<b>Bleaching Watch</b>	$0 < \text{HotSpot} < 1$	
<b>Bleaching Warning</b>	$1 \leq \text{HotSpot} \ \& \ 0 < \text{DHW} < 4$	<b>Possible Bleaching</b>
<b>Bleaching Alert Level 1</b>	$1 \leq \text{HotSpot} \ \& \ 4 \leq \text{DHW} < 8$	<b>Bleaching Likely</b>
<b>Bleaching Alert Level 2</b>	$1 \leq \text{HotSpot} \ \& \ 8 \leq \text{DHW}$	<b>Mortality Likely</b>

# “Virtual Stations” & SBA’s

- Like data buoys in the water without the cost or the headache!
- Everything is satellite based
- ~200 stations available globally



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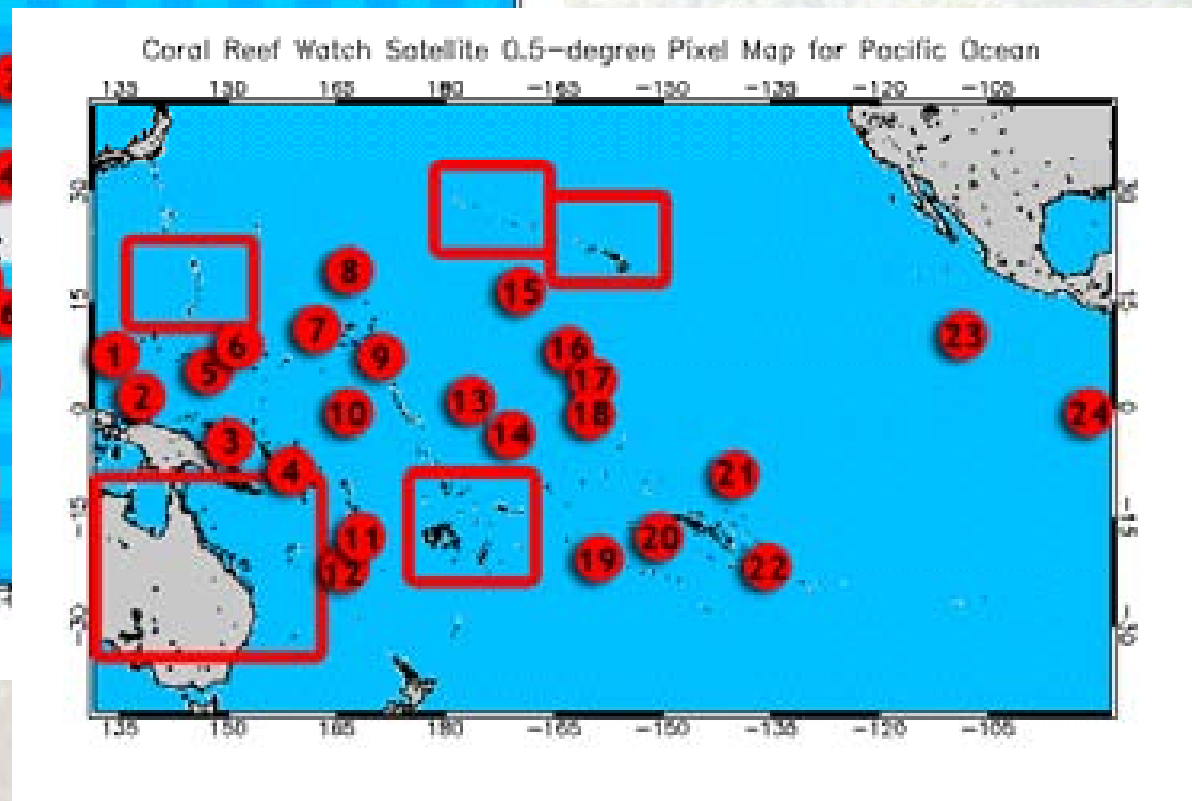
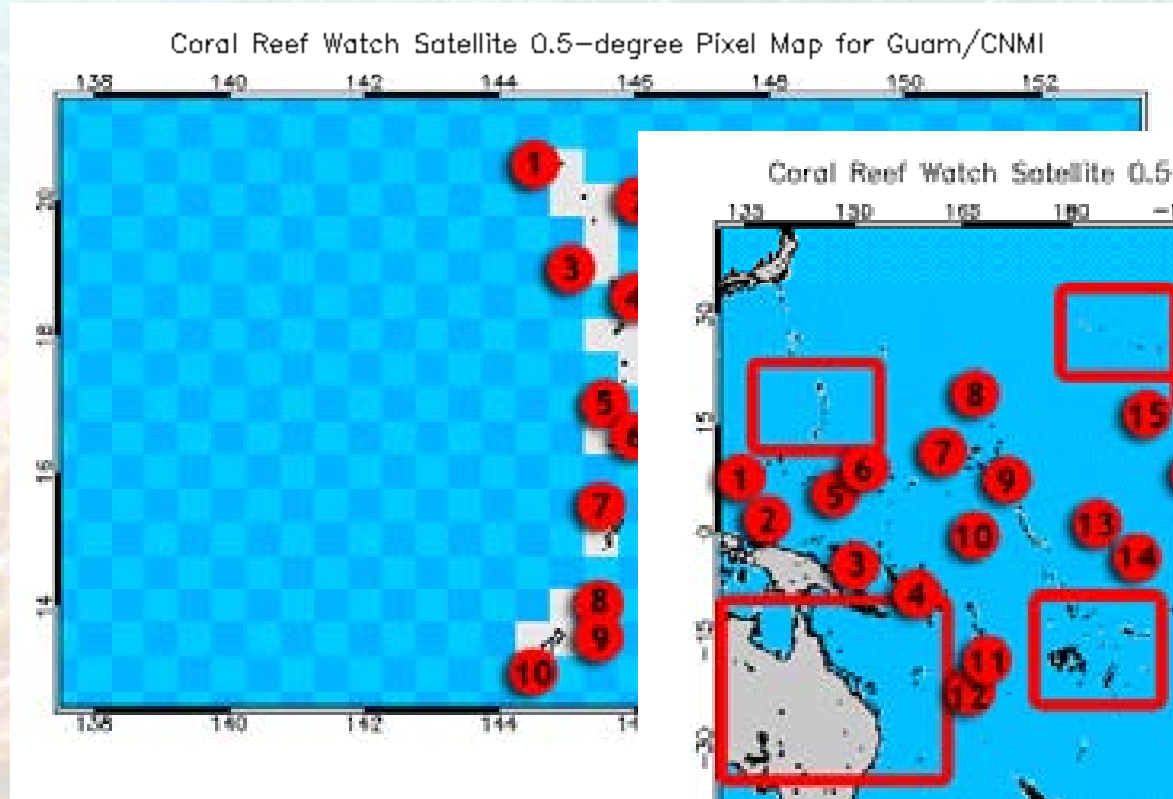


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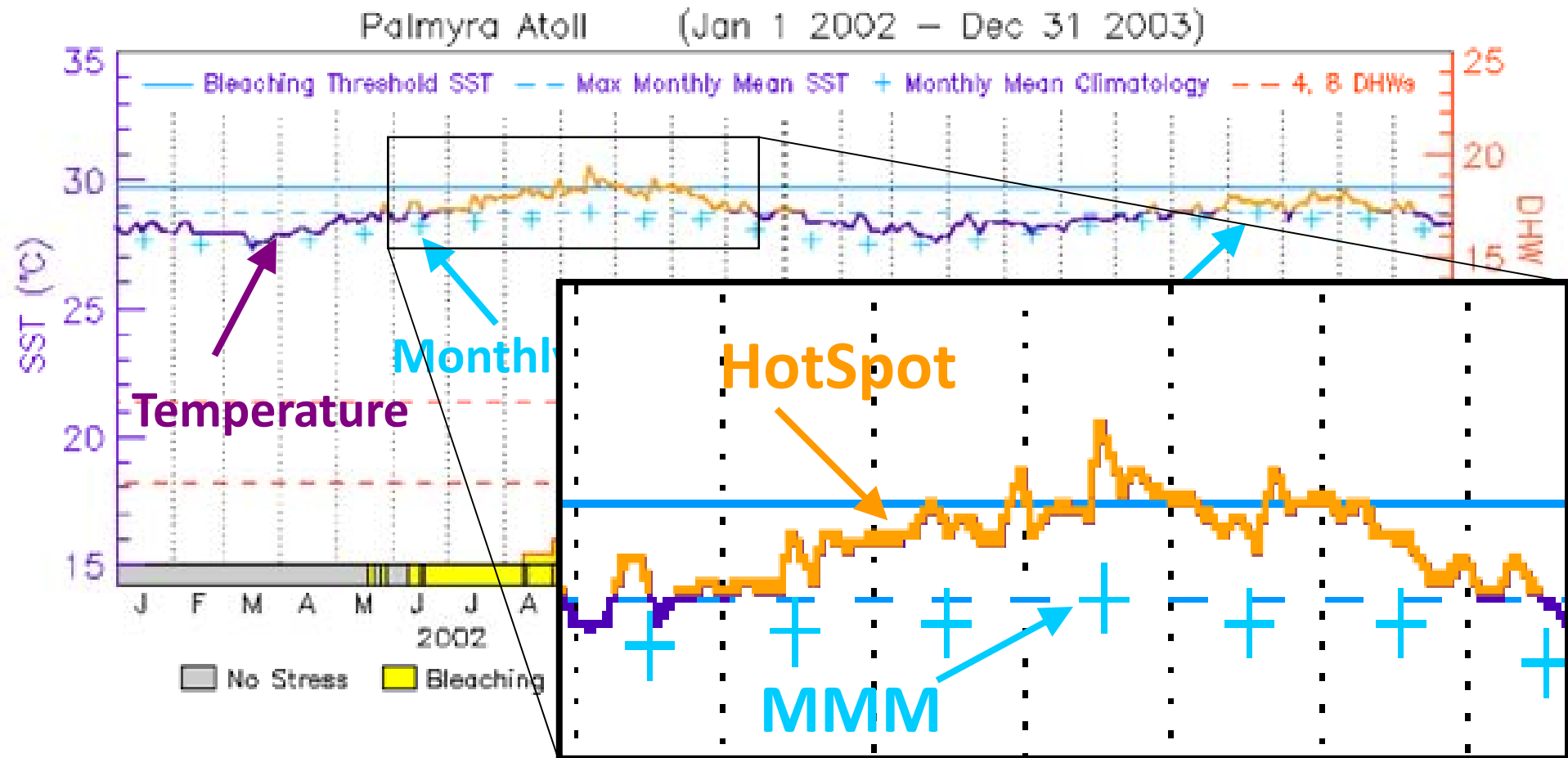
# Experimental “Virtual Stations”

Available for 10 pixels across Guam and CNMI

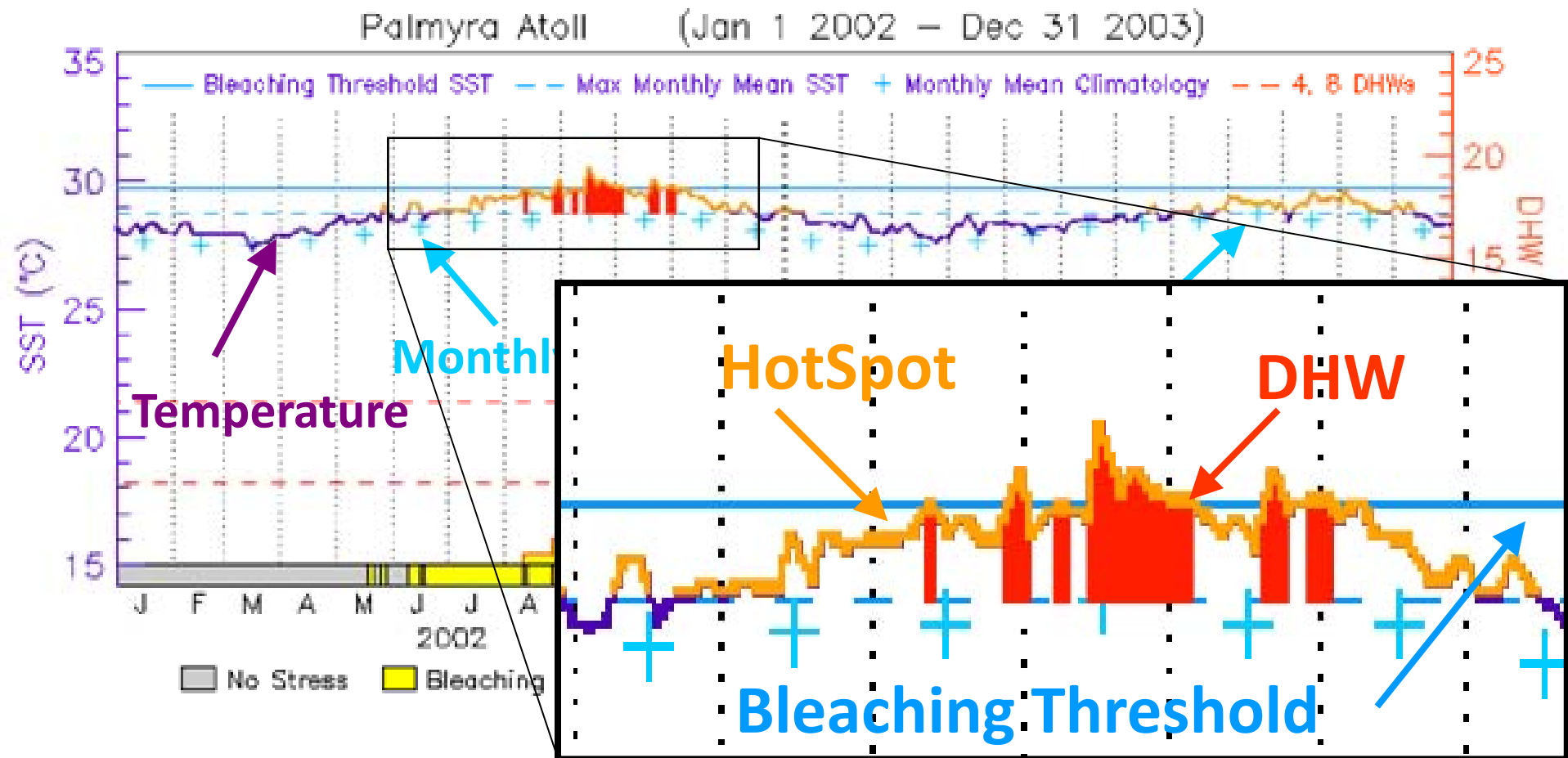


Available for 24 pixels across the Pacific

# Coral Bleaching HotSpot



# Degree Heating Weeks (DHW)



# Satellite Bleaching Alerts

- Automated emails for managers are sent when the alert status changes
- Provides current satellite data and alert status
- Helps managers to plan response efforts



# Satellite Bleaching Alerts

<http://coralreefwatch-satops.noaa.gov/SBA.html30>

\*\*\*\*\*  
\*\* [CRW Alert 20070711] Sombrero Reef: Bleaching Warning  
\*\*\*\*\*

Satellite observations: 9 July 2007 - 11 July 2007

- Bleaching Degree Heating Weeks : 0.5 Deg C-week
- Historical Maximum Degree Heating Weeks : 9.2 Deg C-week (2005)
- Coral bleaching HotSpot : 1.0 Deg C
- Sea surface temperature : 30.3 Deg C
- Maximum Monthly Mean SST at site : 29.3 Deg C

Previous Three Alerts for Sombrero Reef:

- 06/25/2007 Bleaching Watch
- 10/07/2006 No Stress
- 09/11/2006 Bleaching Watch

Reef site name: Sombrero Reef

SST Pixel latitude: 25.0

SST Pixel longitude: -81.5

Current Status: **Bleaching Warning**





# SBA Components

## Date, Location, Status

=====

\*\* [CRW Alert 20070711] Sombrero Reef: Bleaching Warning

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# SBA Components

## Current DHW, HotSpot, SST

=====

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# SBA Components

## Alert History

```
=====
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Current Status: **Bleaching Warning**



# SBA Components

## Alert Definitions

### =====

#### Definitions of Alert Levels:

--No Stress:           No thermal stress  
(HotSpot  $\leq 0$ )

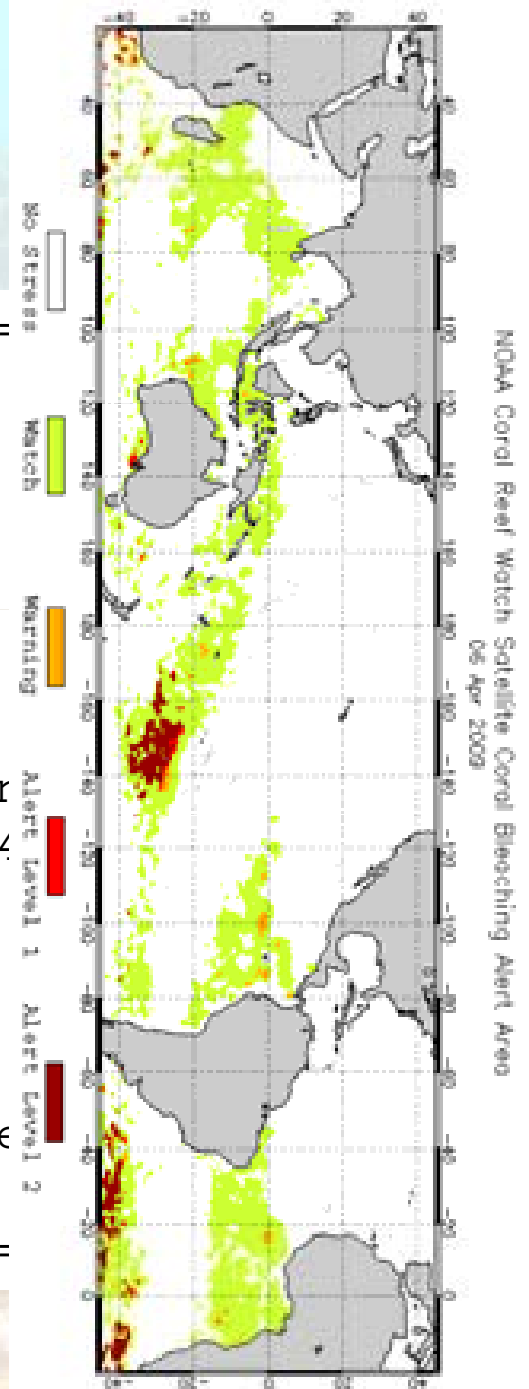
--Watch:               Low-level thermal stress  
( $0 < \text{HotSpot} < 1$ )

--Warning:            Thermal stress is accumulating  
(HotSpot  $\geq 1$  and  $0 < \text{DHW} < 4$ )

--Alert Level 1: Bleaching expected  
(HotSpot  $\geq 1$  and  $4 \leq \text{DHW} < 8$ )

--Alert Level 2: Significant bleaching expected  
(HotSpot  $\geq 1$  and  $\text{DHW} \geq 8$ )

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The background of the slide is an underwater photograph of a coral reef. It shows various types of coral, including branching and table corals, in shades of brown, tan, and green. The water is clear, and the lighting is bright, suggesting a sunny day. The text is overlaid on this background.

## How to sign up:

Contact us at  
[coralreefwatch@noaa.gov](mailto:coralreefwatch@noaa.gov)  
to subscribe!

absolutely free  
updated twice a week

# NOAA Experimental Products

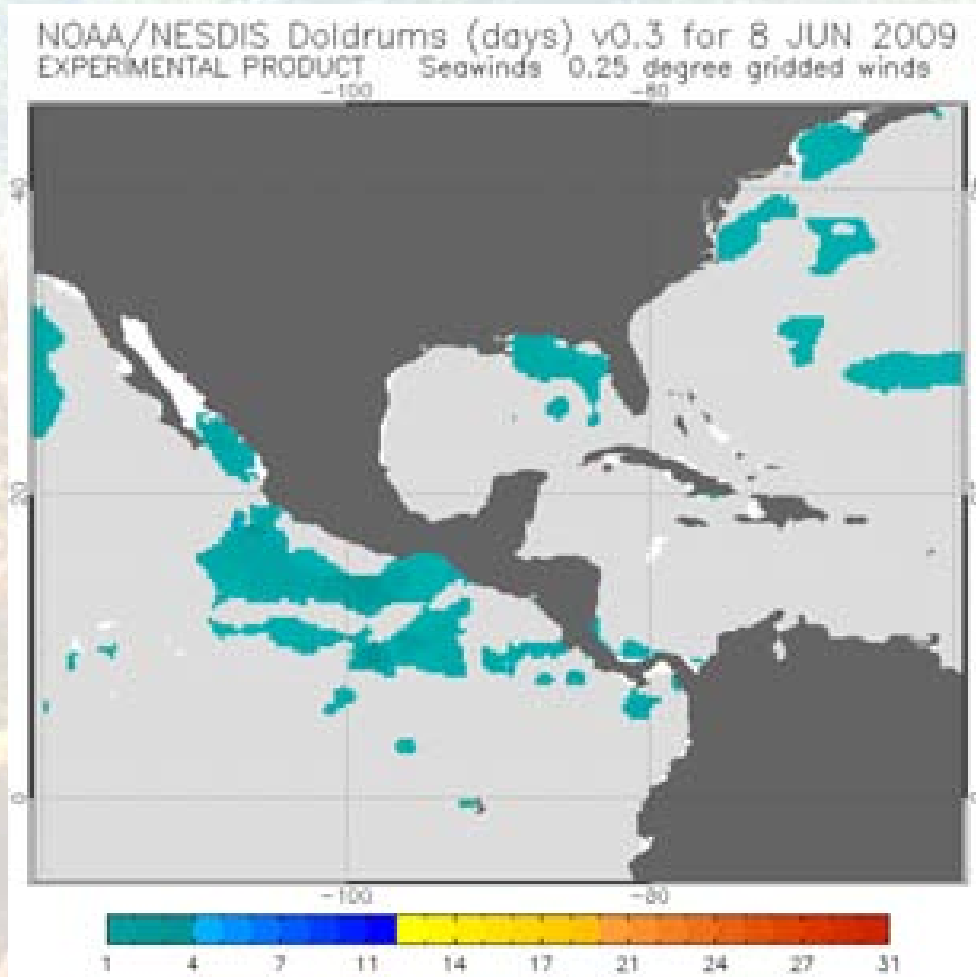
- Doldrums
- Coral Disease
- Improved Landmask
- High Resolution SST Product
- Seasonal Bleaching Outlooks





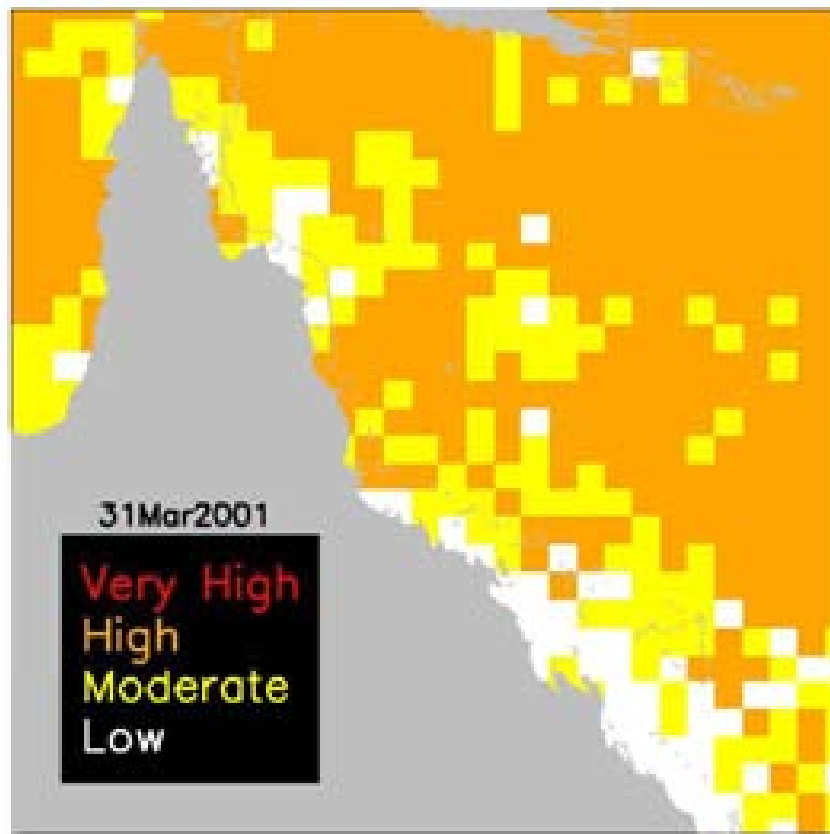
# Doldrums

**Wind causes vertical mixing and sea surface roughness.  
These can mitigate coral bleaching.**



# Coral Disease Outbreak Risk

Coral disease abundance has been linked to environmental conditions of high coral cover, warm summers and mild winters. Coral Reef Watch is leading the development an Outbreak Risk product.



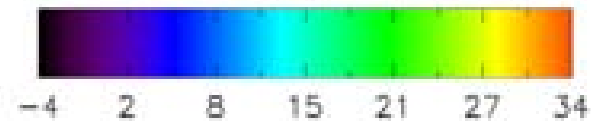
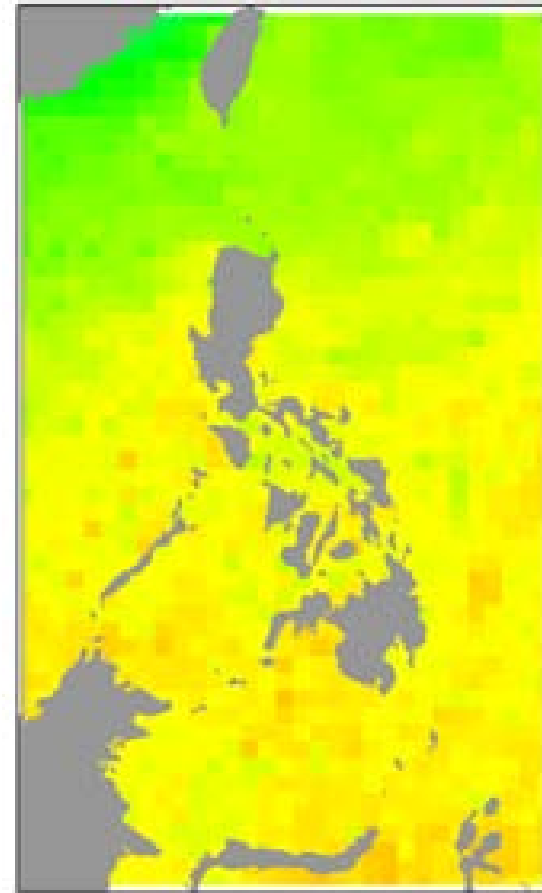
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# Improved Landmask

Coral Reef Watch has developed a new landmask that includes coastal pixels, previously masked as land.

Temperatures in the new coastal pixels are produced using only over-water satellite retrievals.

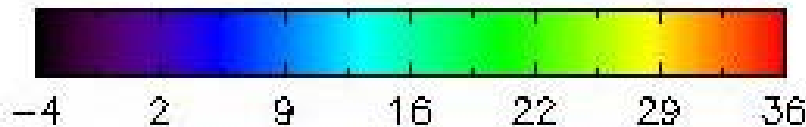
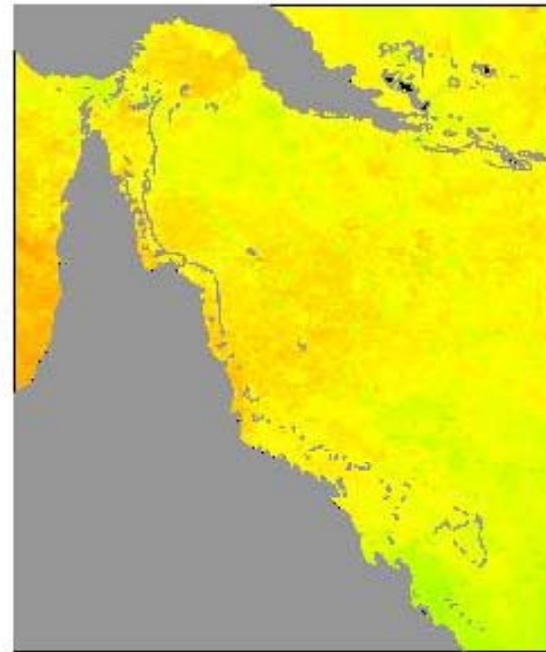
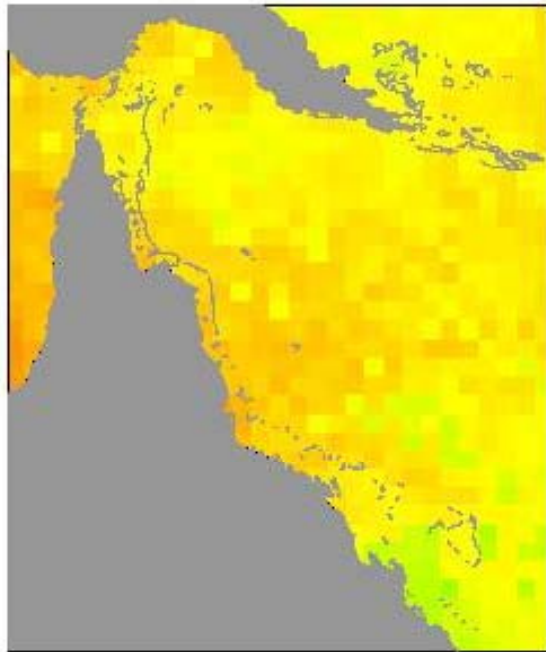


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# High Resolution Products

Coral Reef Watch has initiated development of high-resolution, near real-time SST products. These products will likely incorporate temperature data from geosynchronous satellites.

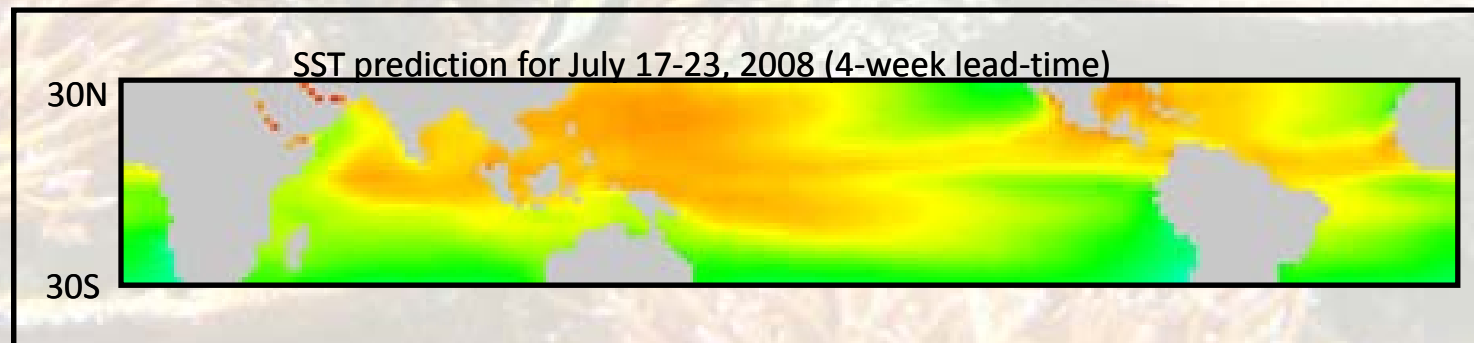


# Seasonal Bleaching Outlook

A Bleaching prediction tool is currently in the final stages of development

Based on the SST forecast model developed by the NOAA Earth System Research Laboratory (ESRL)

Shows areas predicted to be at risk for bleaching, up to 4 months in advance



# Bleaching Outlook

Prediction for July 17-23, 2008 (4-week lead-time)

HotSpot forecast

DHW forecast

level 1: HotSpot prediction > 0

level 2: HotSpot prediction > 0.5

level 3: HotSpot prediction > 0.5 and DHW prediction > 4

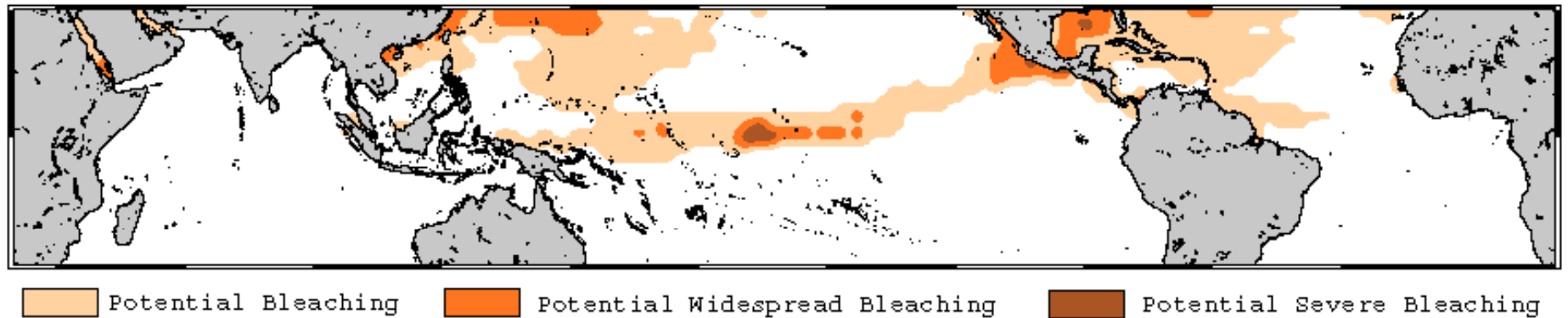
Bleaching Outlook

Potential Bleaching    Potential Widespread Bleaching    Potential Severe Bleaching



# Current Bleaching Outlook Animation

NOAA Coral Reef Watch Coral Bleaching Thermal Stress Outlook: 2-Week forecast for Aug 02 2009



The Outlook is based on a composite of forecasts for all weeks included in the time period.

Purpose is to provide general patterns of bleaching potential



# Activity

## ***You Make the Call!***



# Predicting coral bleaching

HotSpot = 0

No Thermal Stress

$0 < \text{HotSpot} < 1$

Above Maximum Monthly Mean

$\text{HotSpot} \geq 1$

Accumulating Thermal Stress

$\text{DHW} \geq 4$

Thermal Stress leading to significant bleaching

$\text{DHW} \geq 8$

Thermal Stress leading to wide spread bleaching and significant mortality

