

Coral Reef Ecosystems in a Changing Climate: Global Perspective and USCRTF Efforts

Dr. C. Mark Eakin
NOAA Coral Reef Watch

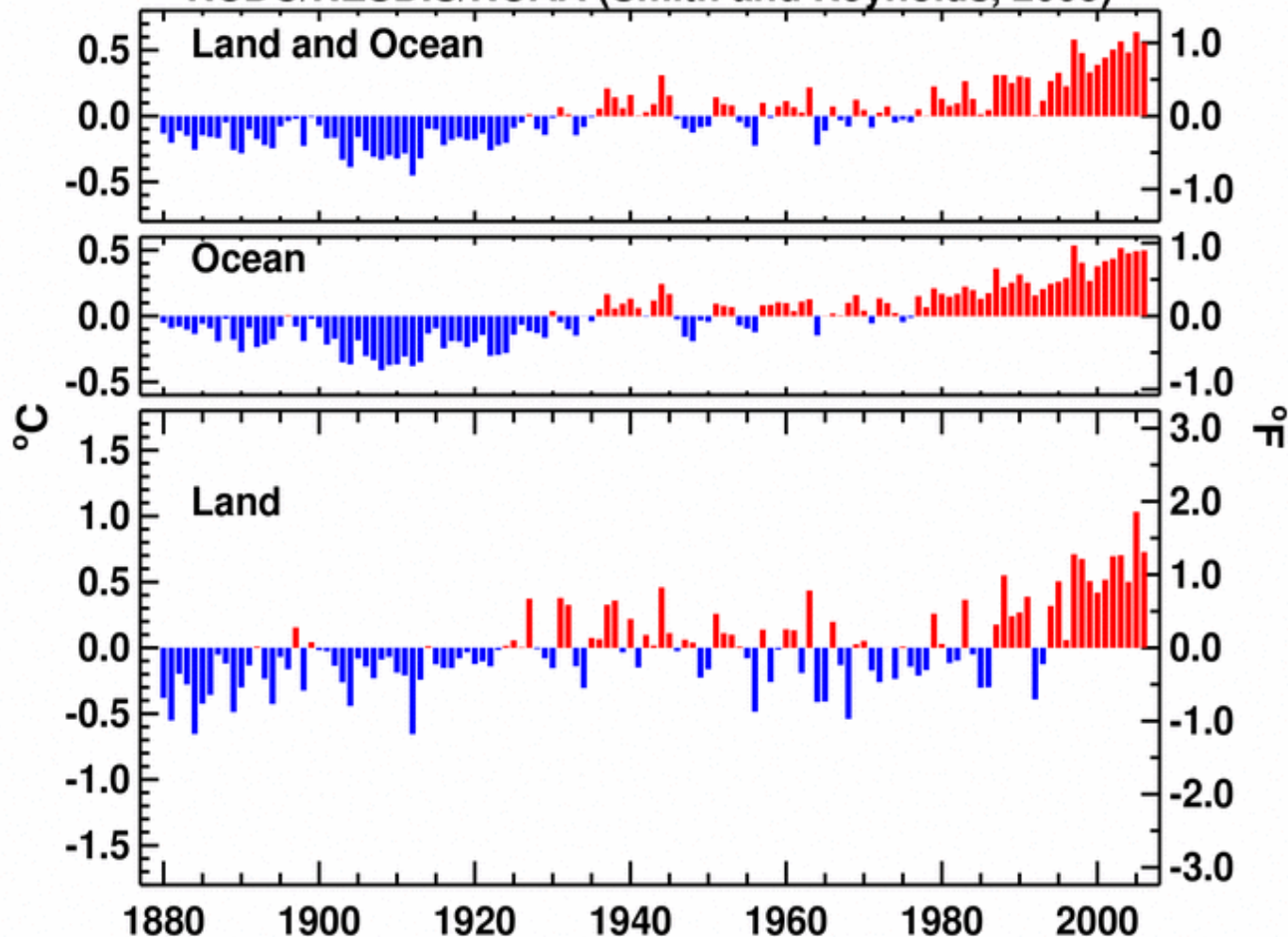


Outline

- **2 Major Climate Change Threats**
 - Rising Temperatures and Coral Bleaching
 - Rising CO₂ and Ocean Acidification
- **Actions Needed to Protect Coral Reefs**
 - Reduce Global Emissions
 - Reduce Local Stressors
- **The US CRTF Resolution on Corals and Climate Change**

Temperature Increases: Last Century

NCDC/NESDIS/NOAA (Smith and Reynolds, 2005)

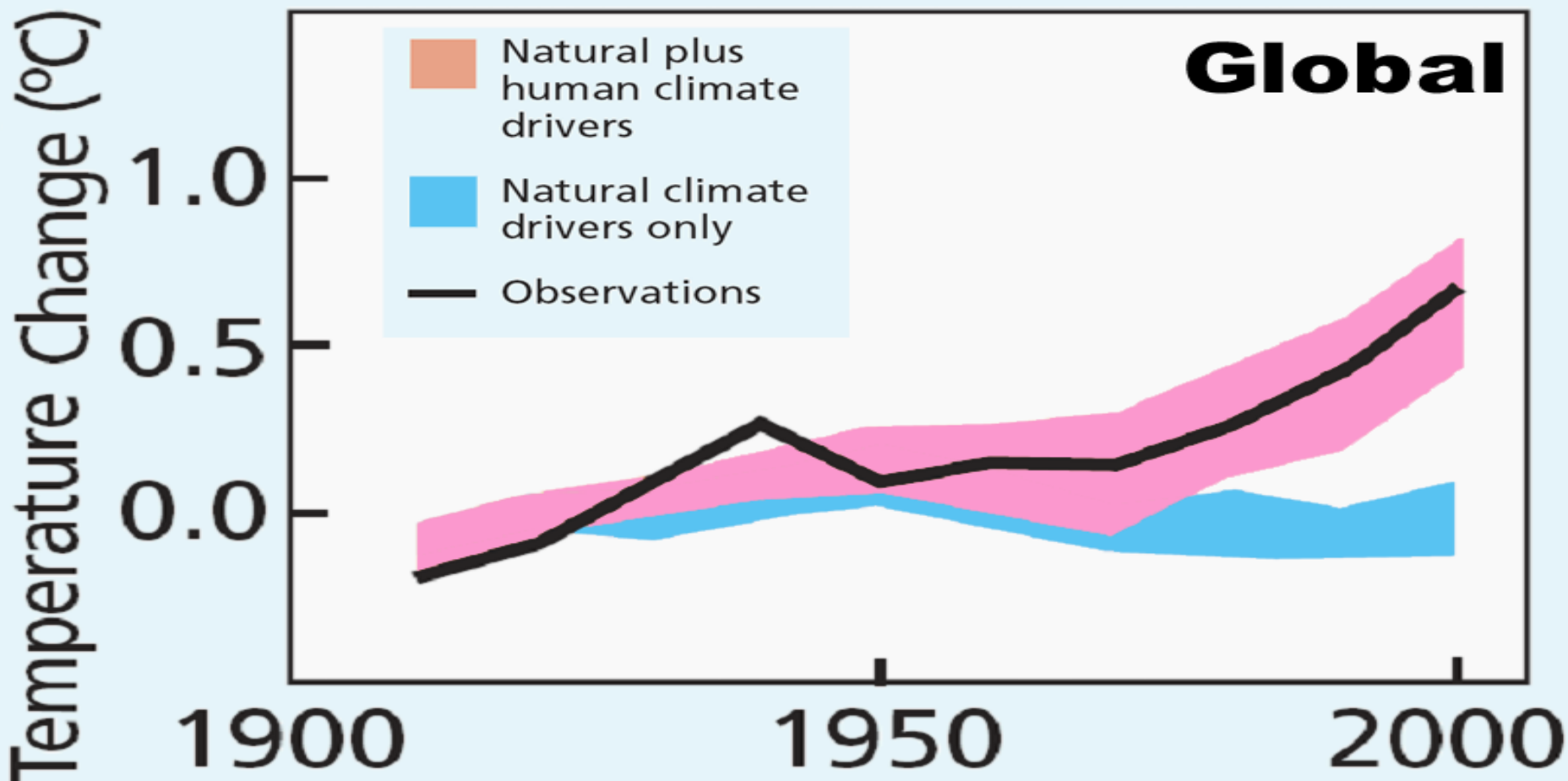


“Warming of
the climate
system is
unequivocal.”

- *IPPC 4th
Assessment Report,
Working Group 1*

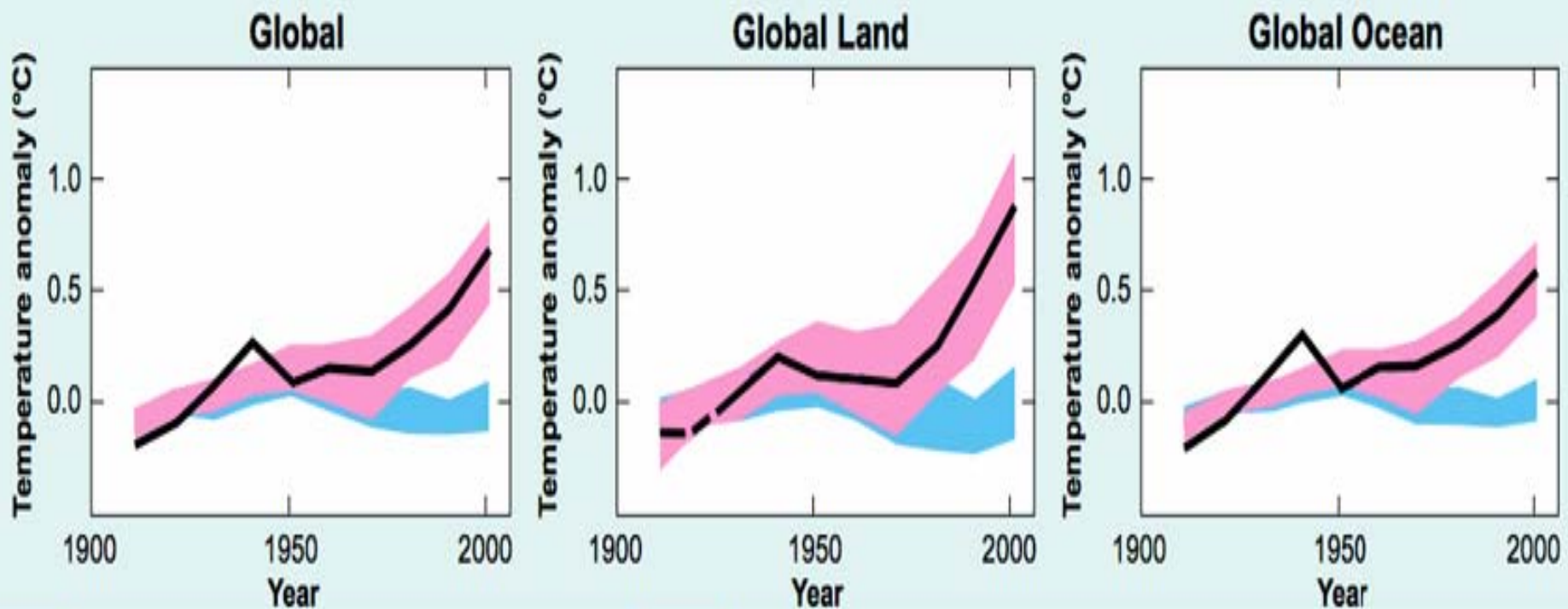
Temperature Increases: Last Century

“Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.” - *IPPC 4th Assessment Report, WG 1*



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From IPCC 2007 4AR WG-1

Natural + Human climate drivers

Natural climate drivers only

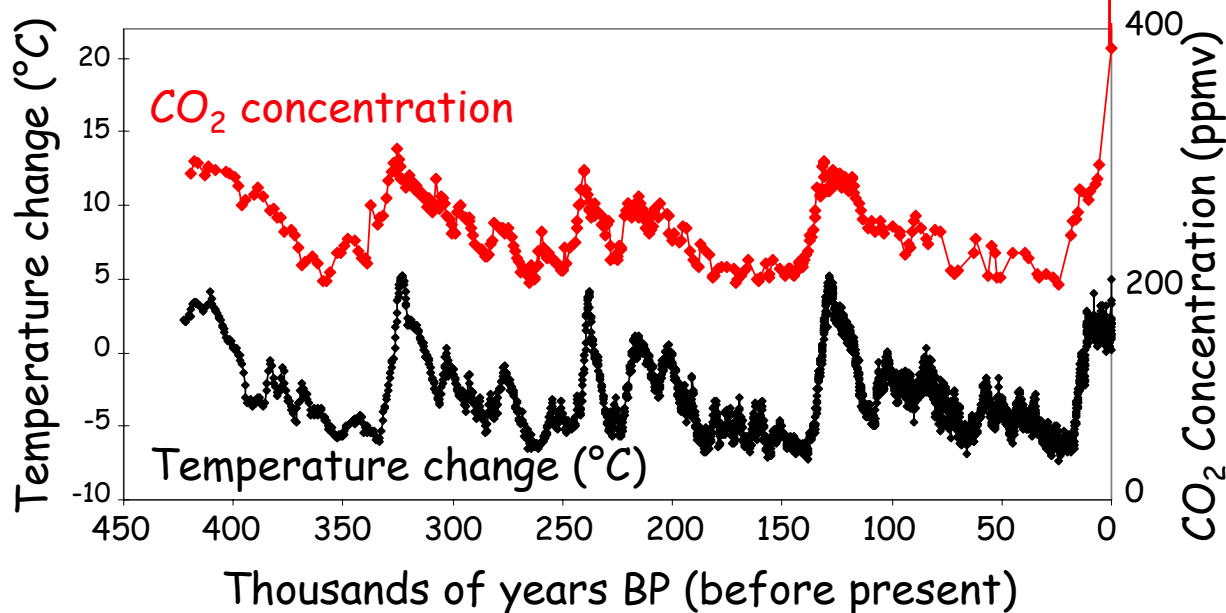
Observations

400,000 Years of CO₂ and Temperature Change from Antarctic Ice Cores

“It is very likely that [man-made] greenhouse gas increases caused most of the average temperature increase since the mid-20 century”
- *IPPC 4th Assessment Report*

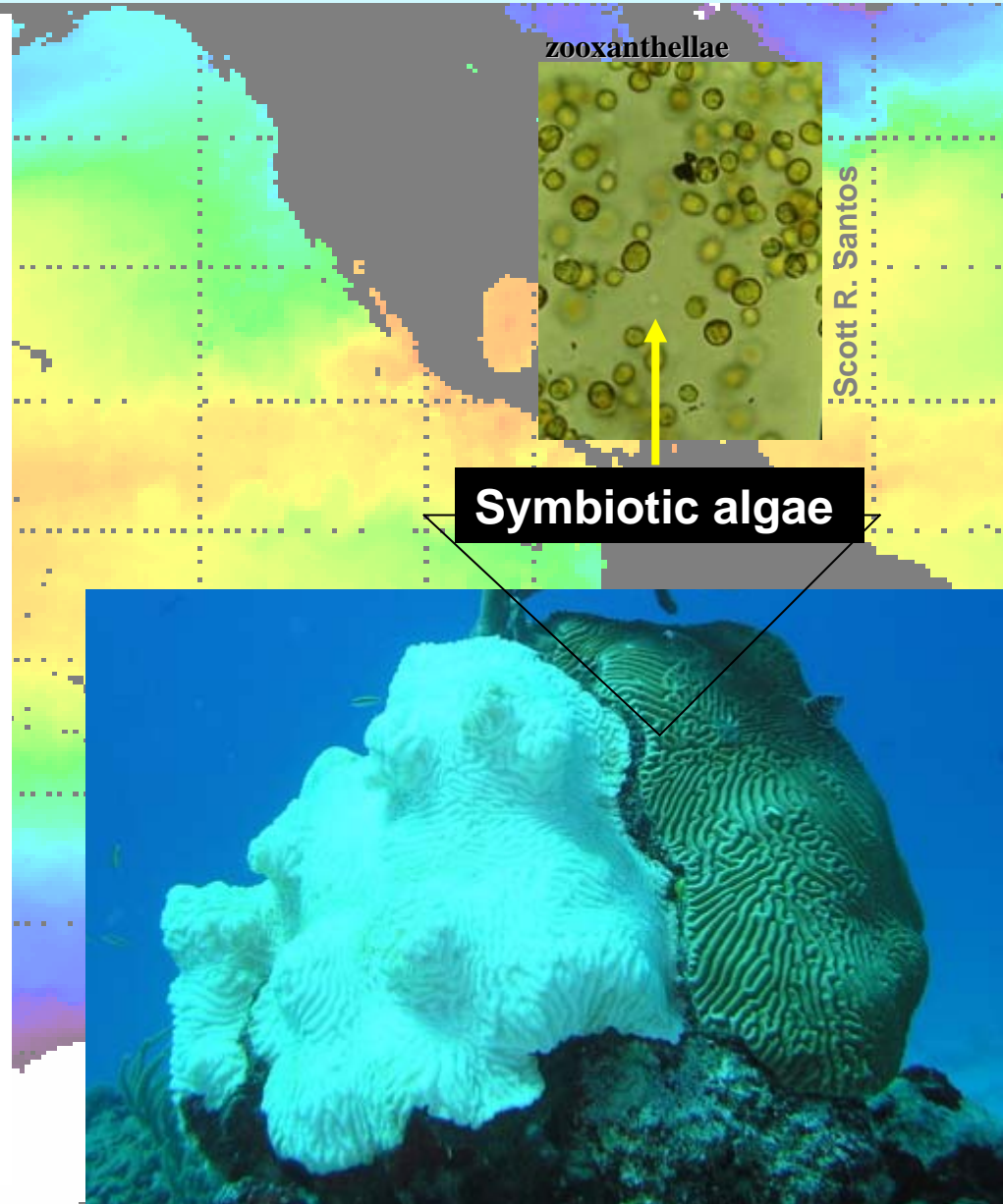
➤ Global Climate Change Processes

- Greenhouse gases including CO₂
- Increased global temperatures
- Sea level rise
- Loss of sea ice
- Loss of biodiversity
- Ocean acidification

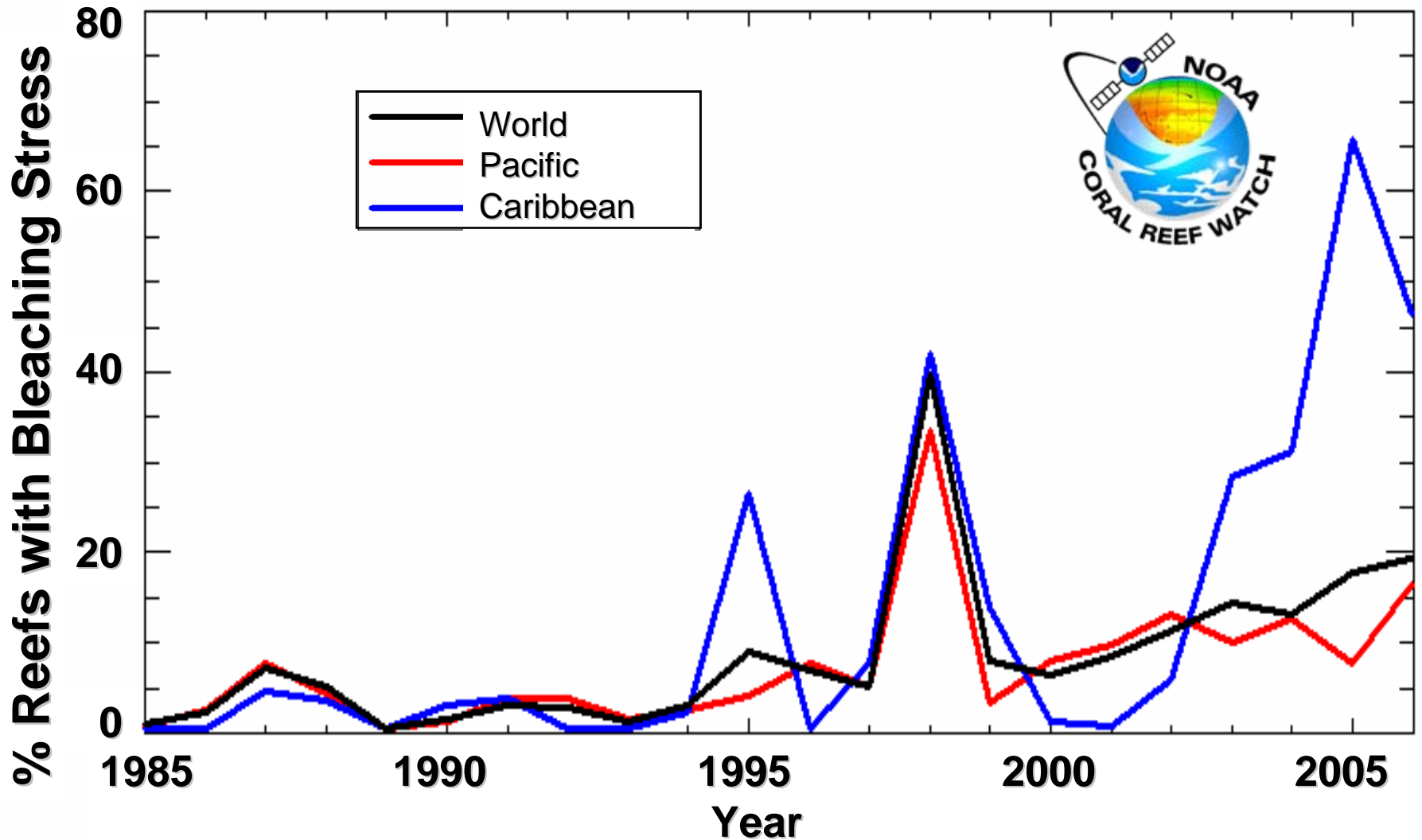


What is Coral Bleaching?

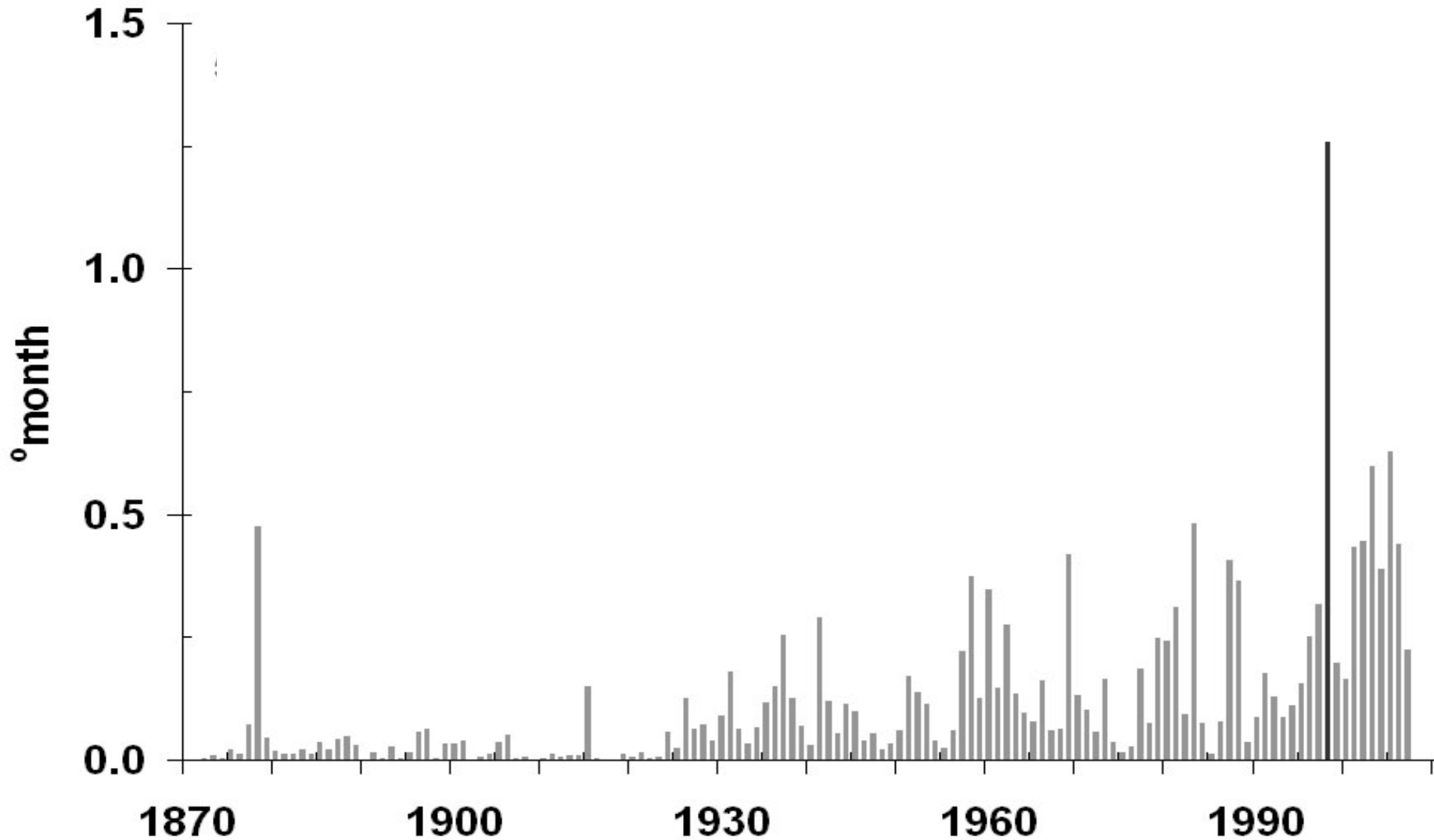
- Most of corals' food comes from photosynthesis
- Corals can “bleach” due to stress
- Corals exposed to high temperatures and/or high light become stressed
- Corals eject their algae; coral appears “bleached
- If stress is mild or brief, corals recover, otherwise they die



Highest Thermal Stress Recorded?



135 Years of Thermal Stress Increase



Wide Range of Coral Reef Threats

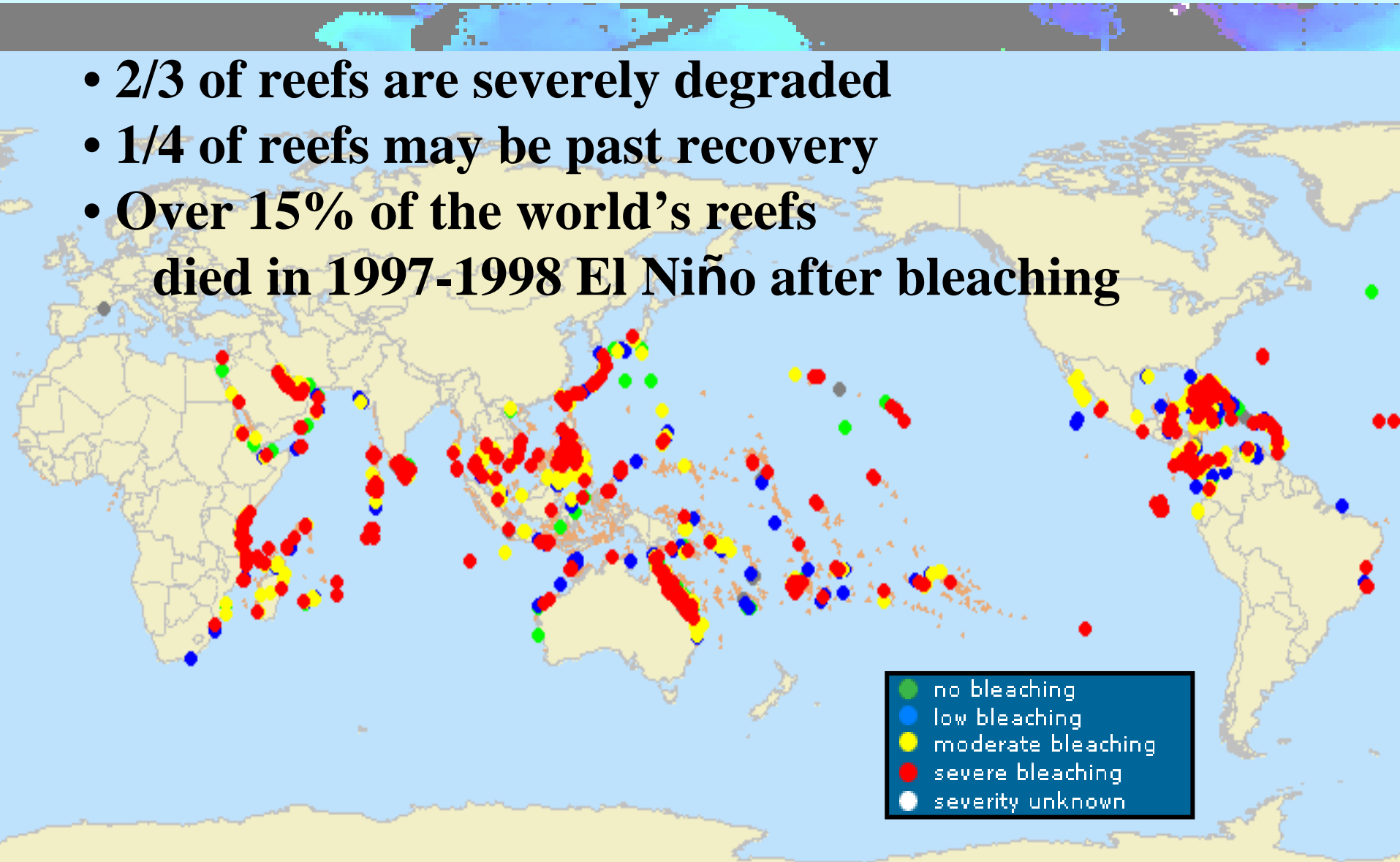
- **Human Population Growth**
- **Overfishing**
- **Coastal Development**
- **Lack of Laws / Enforcement**
- **Sedimentation (unnatural)**
- **Lack of Education**
- **Nutrient Enrichment**
- **Algal Competition**
- **Climate Change / Bleaching**
- **Habitat Destruction**
- **Tourism**

2004 Survey: 276 Coral Reef Scientists
Kleypas and Eakin (2007)





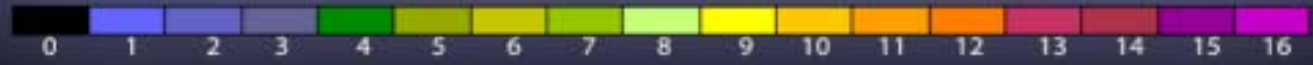
Worldwide Reef Deterioration

- 2/3 of reefs are severely degraded
- 1/4 of reefs may be past recovery
- Over 15% of the world's reefs died in 1997-1998 El Niño after bleaching

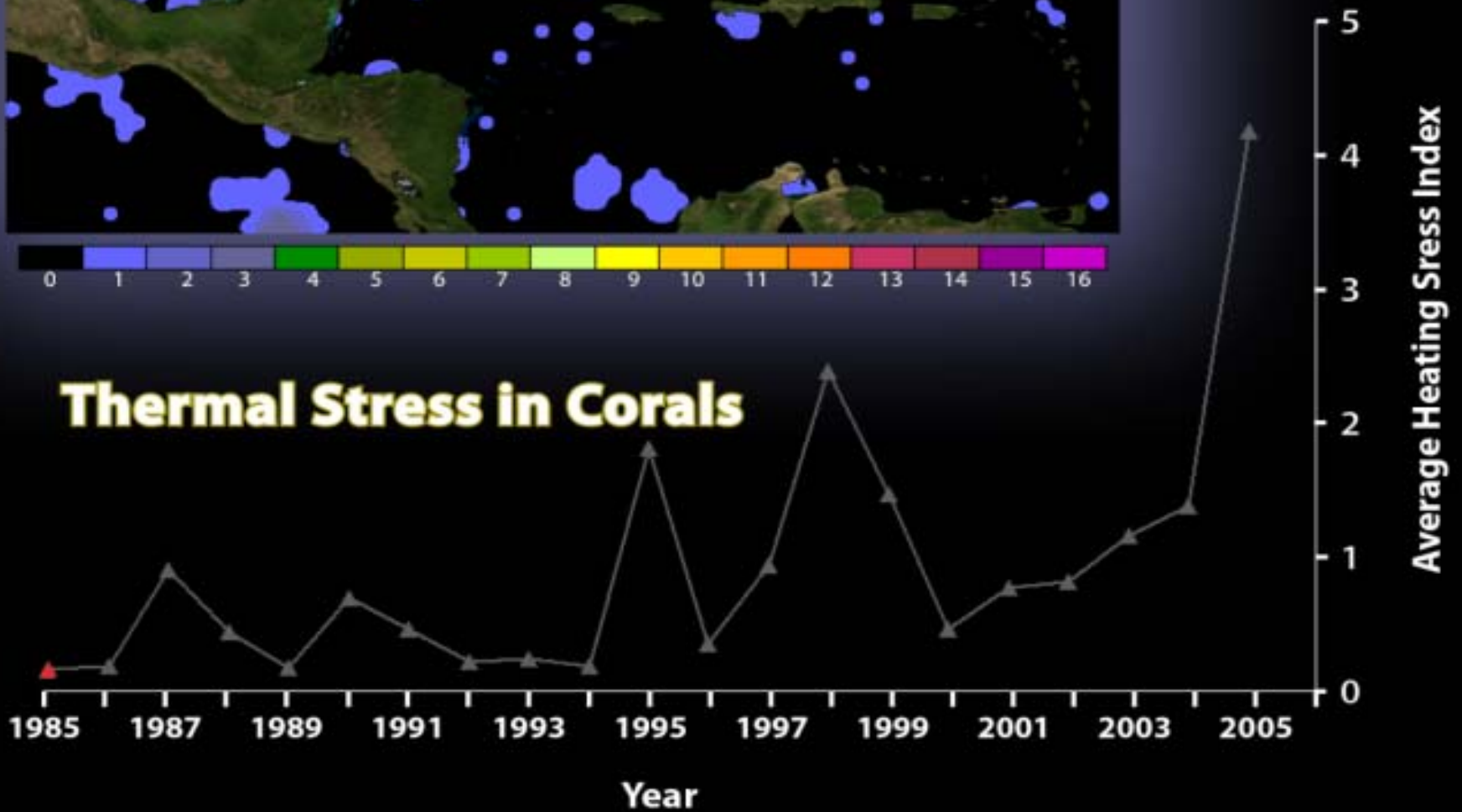


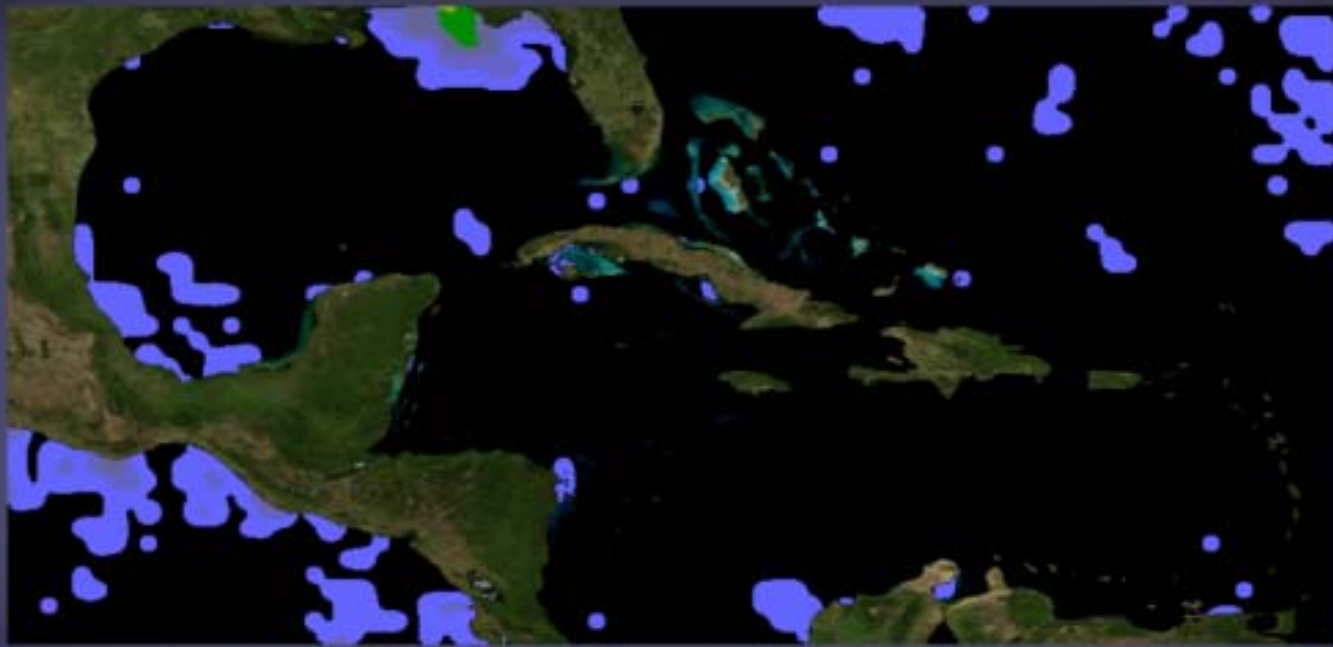


-  Bleaching Expected
-  Mass Bleaching and Mortality

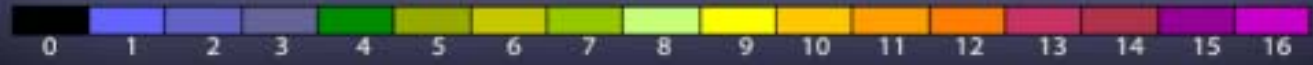


Thermal Stress in Corals

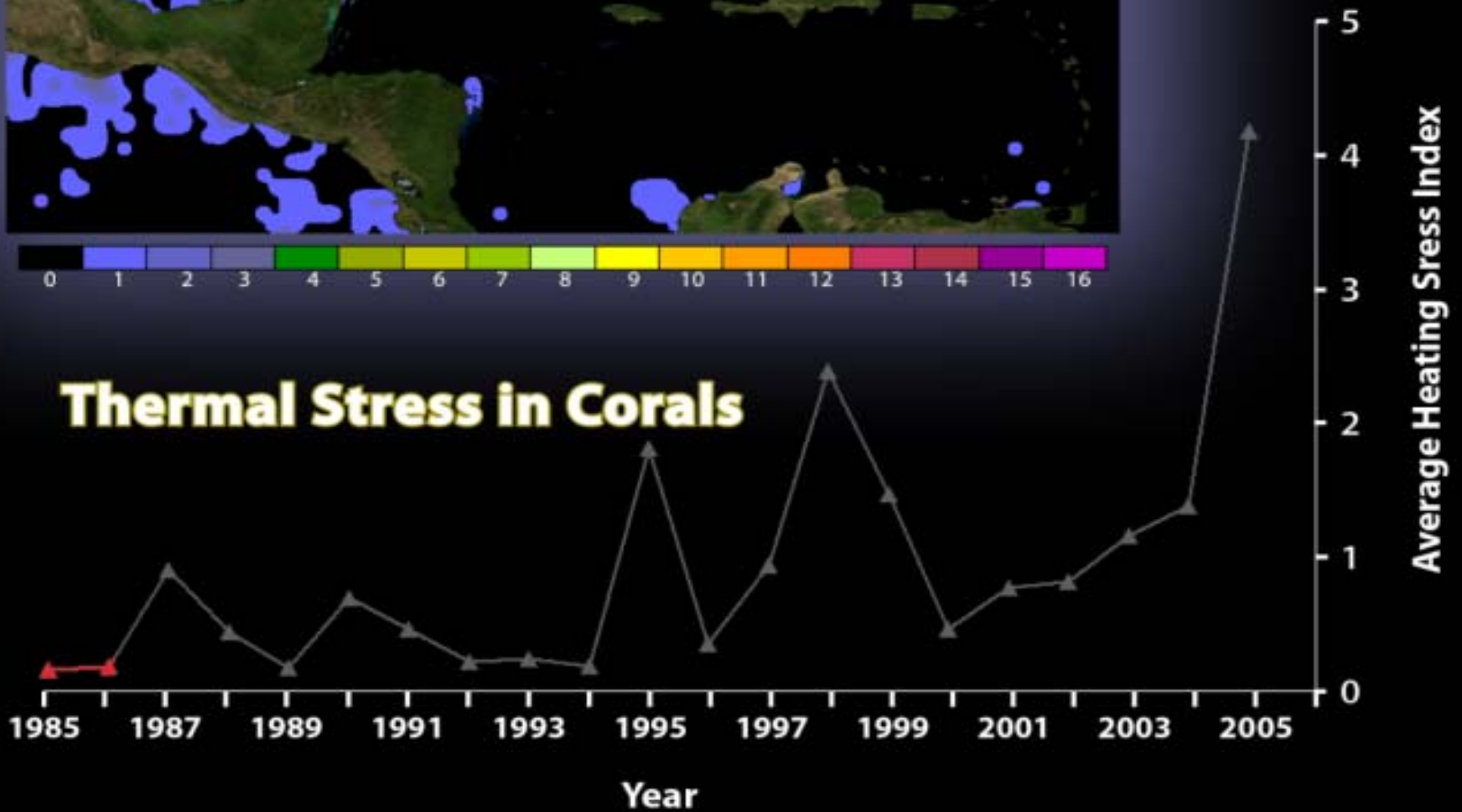


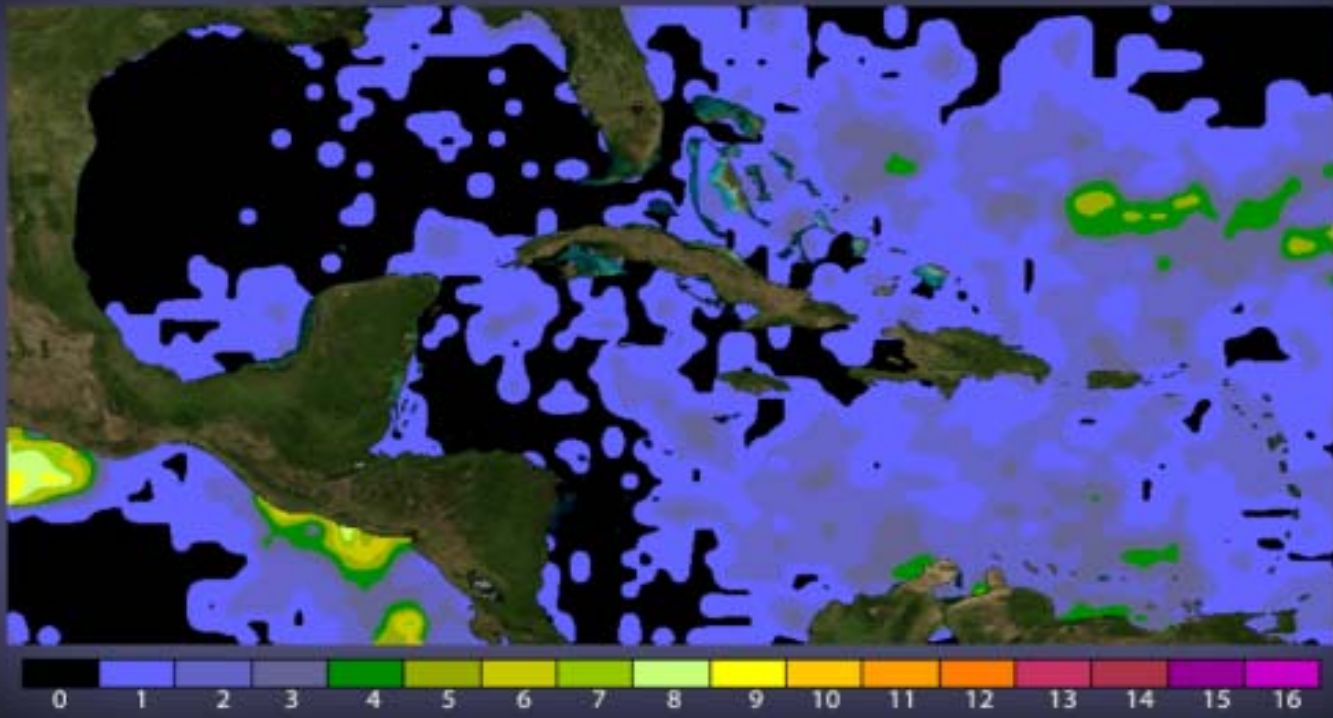




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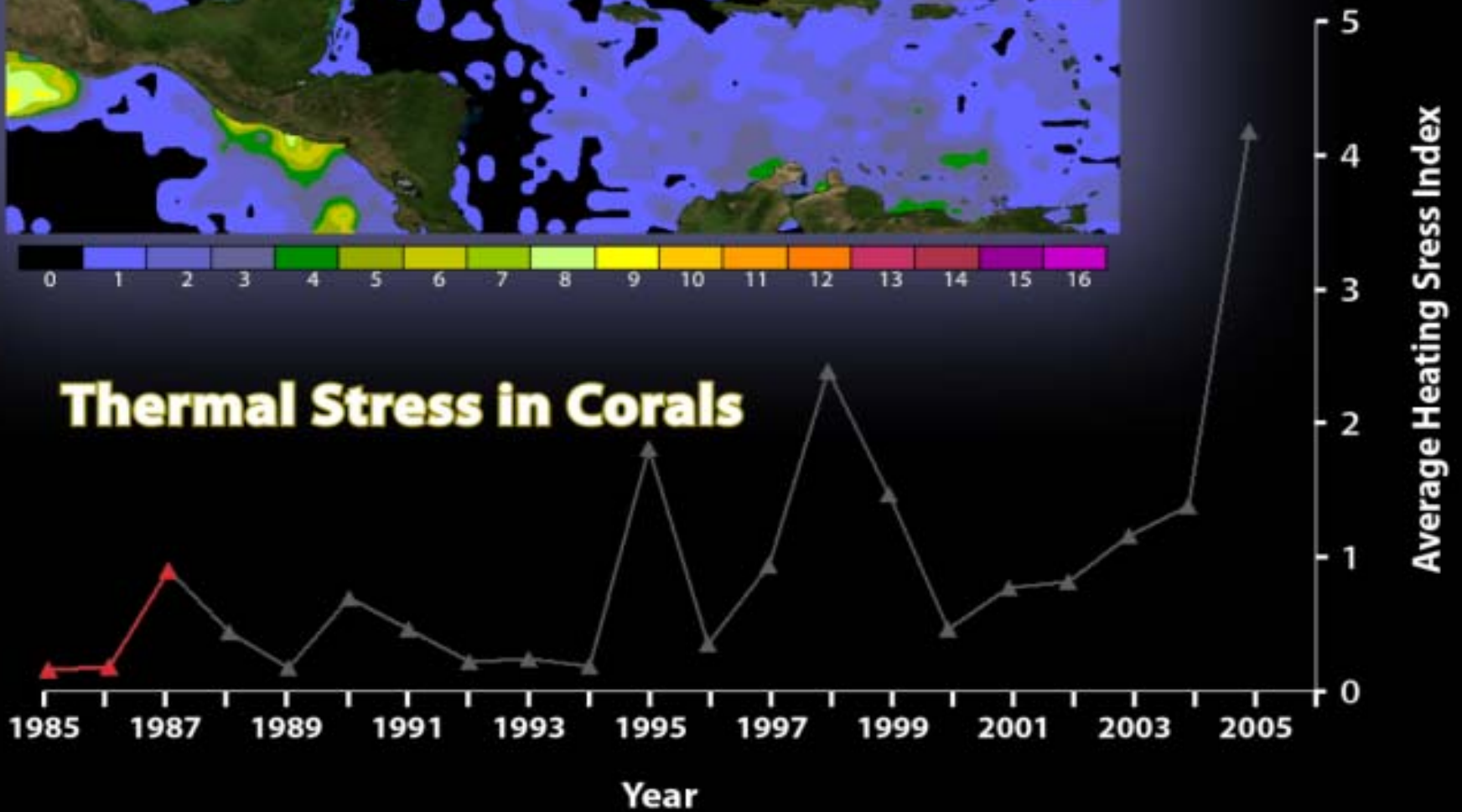
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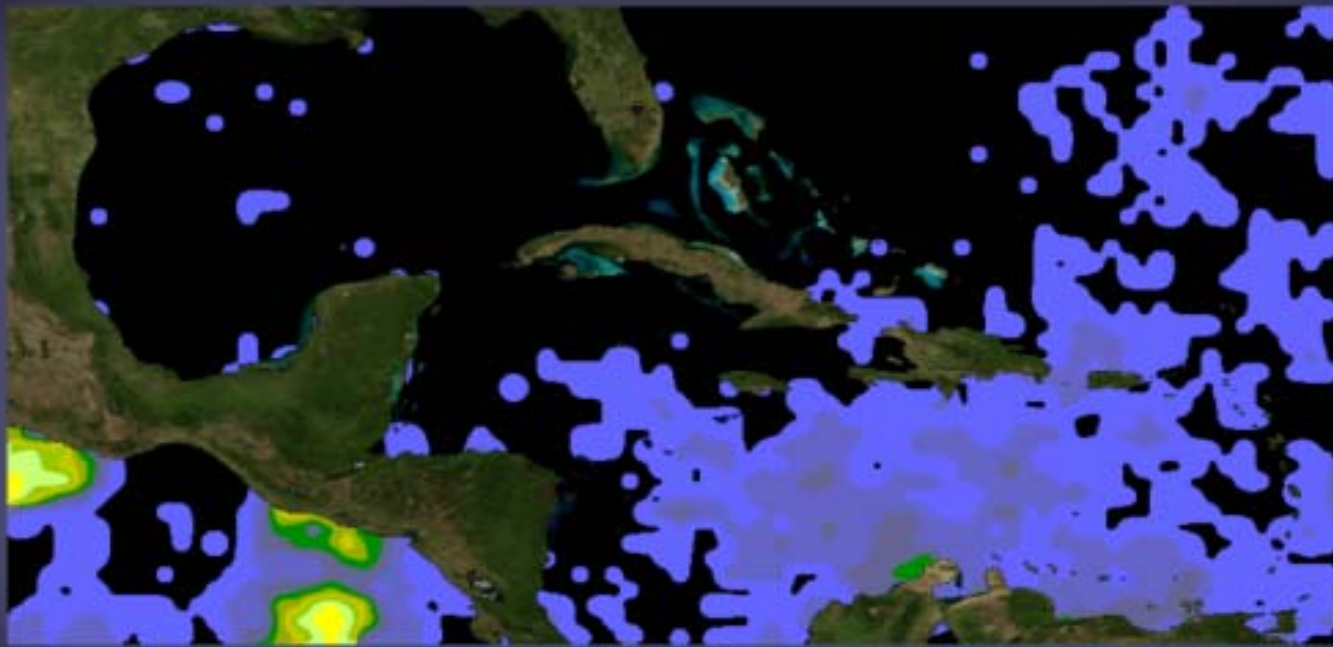






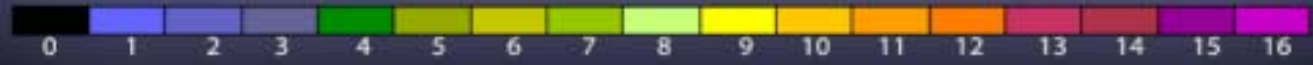
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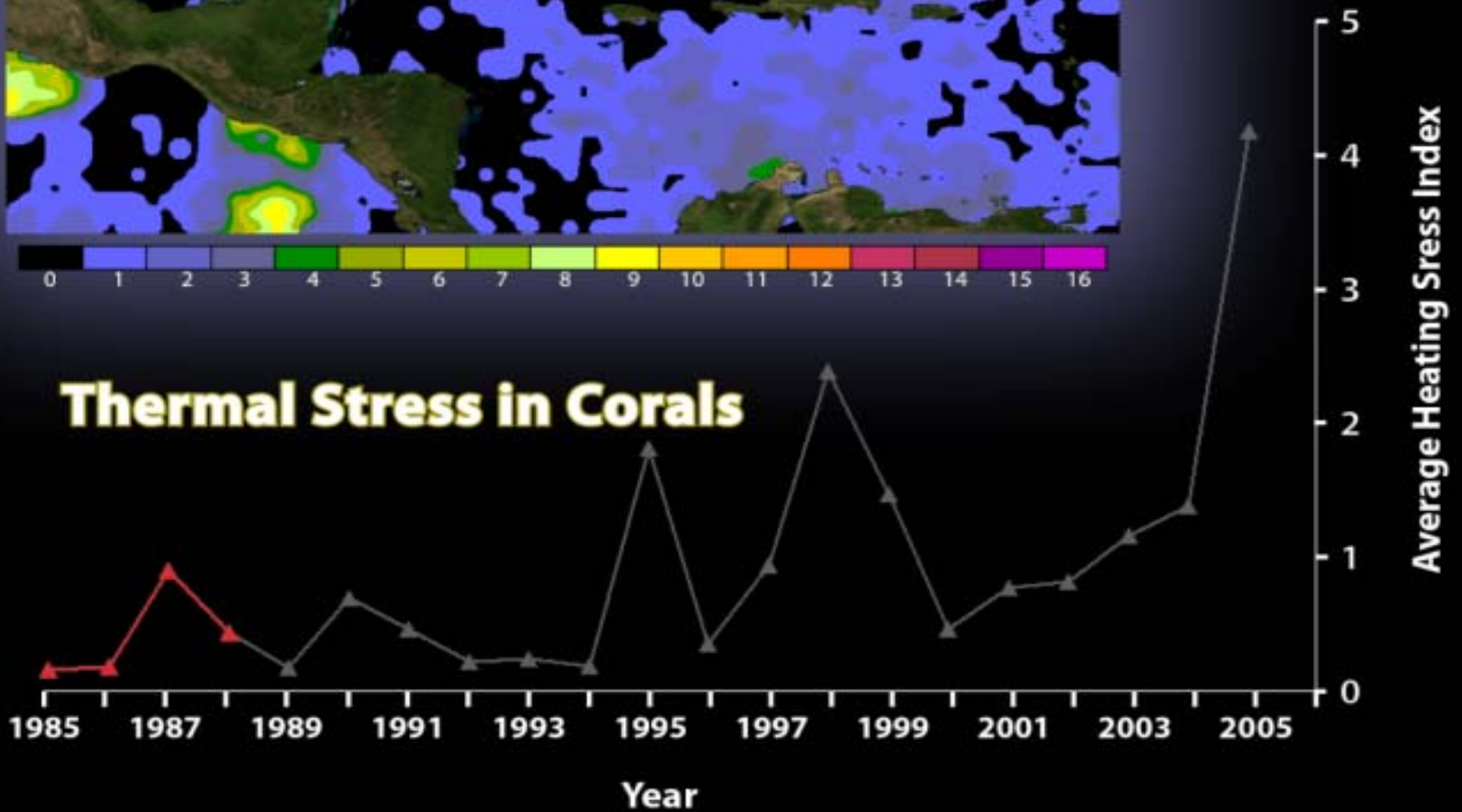


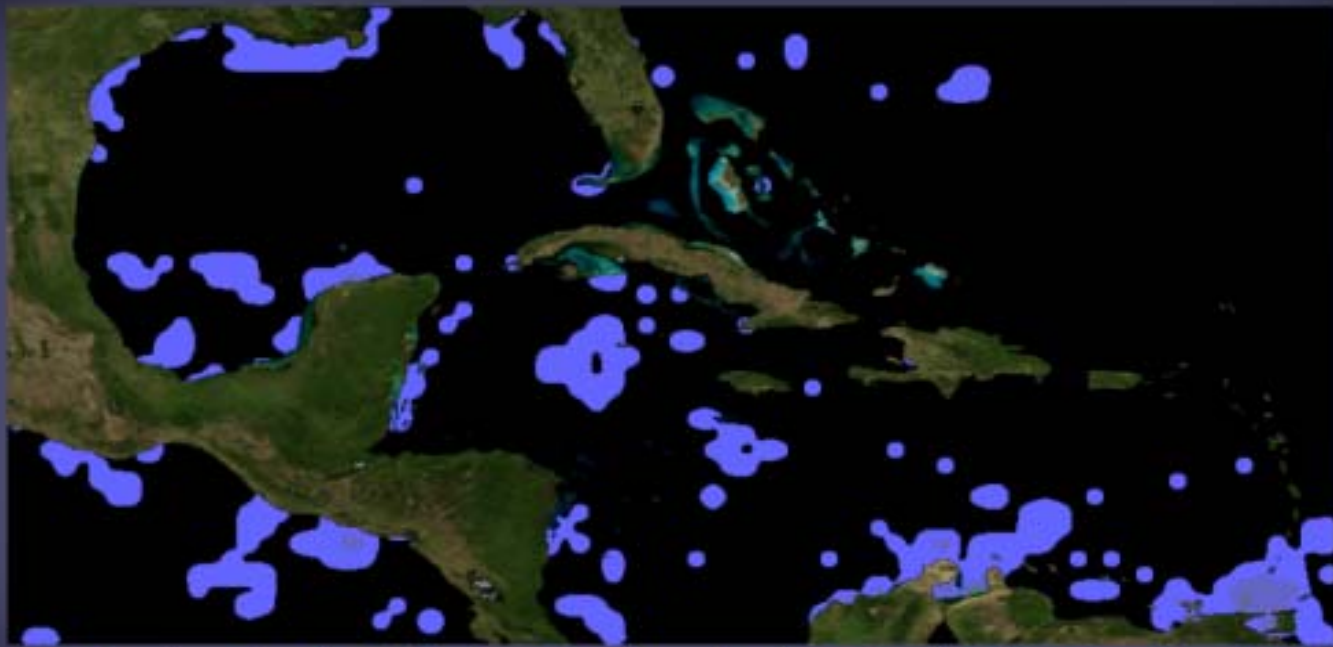




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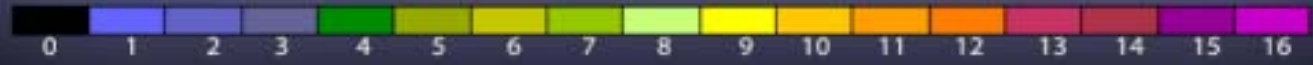


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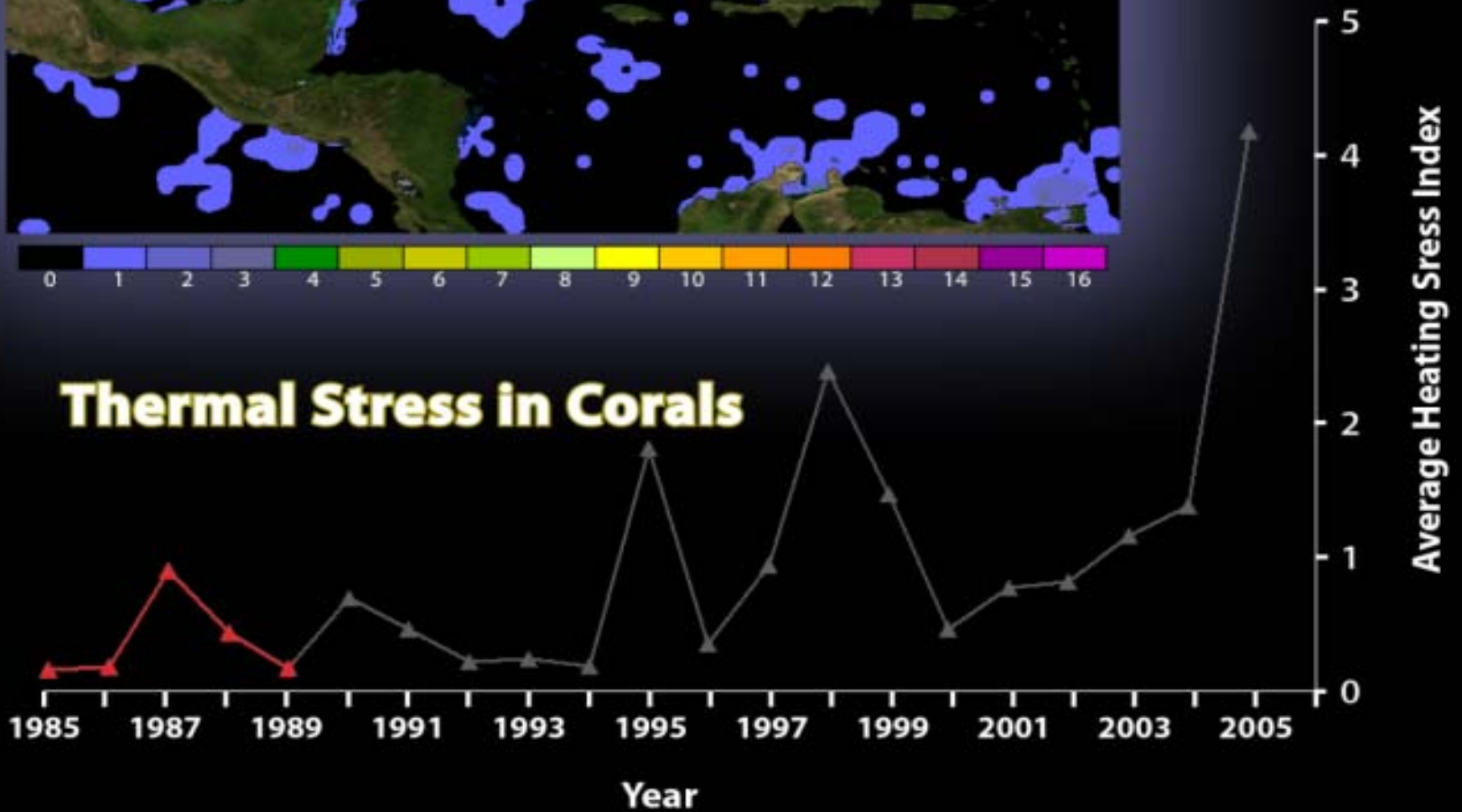


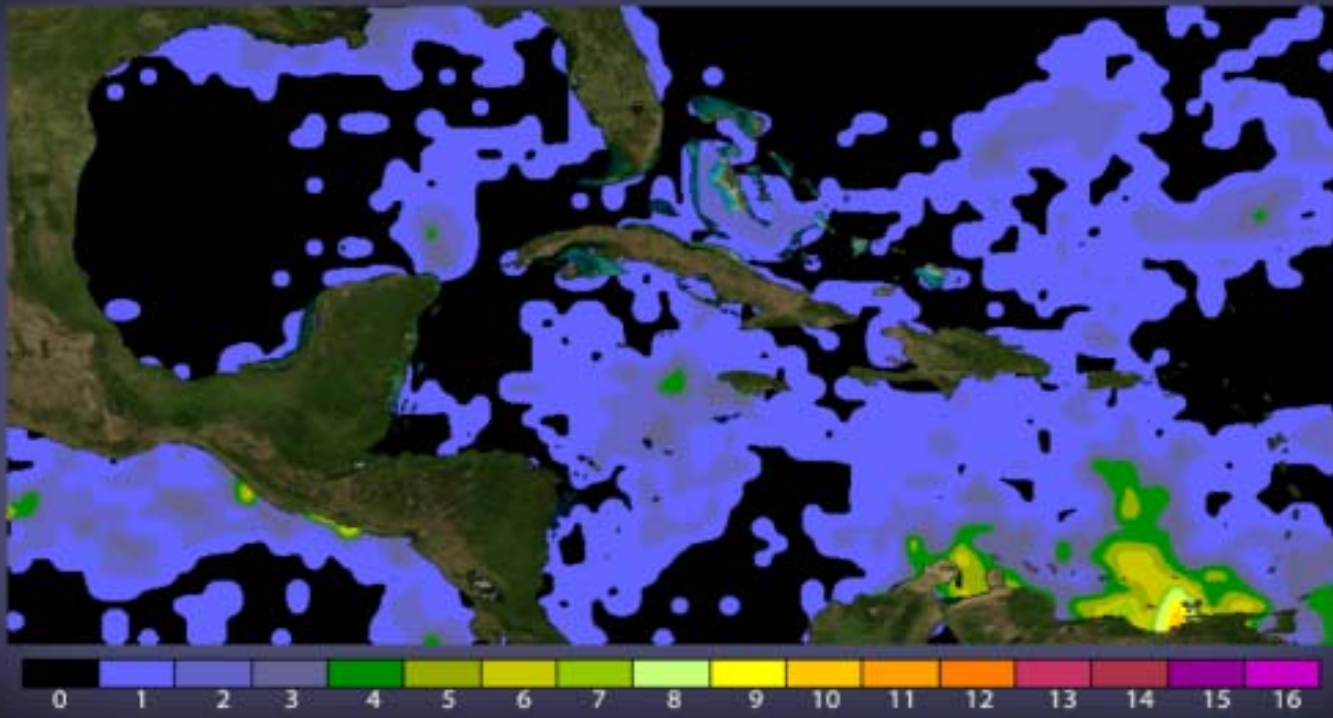


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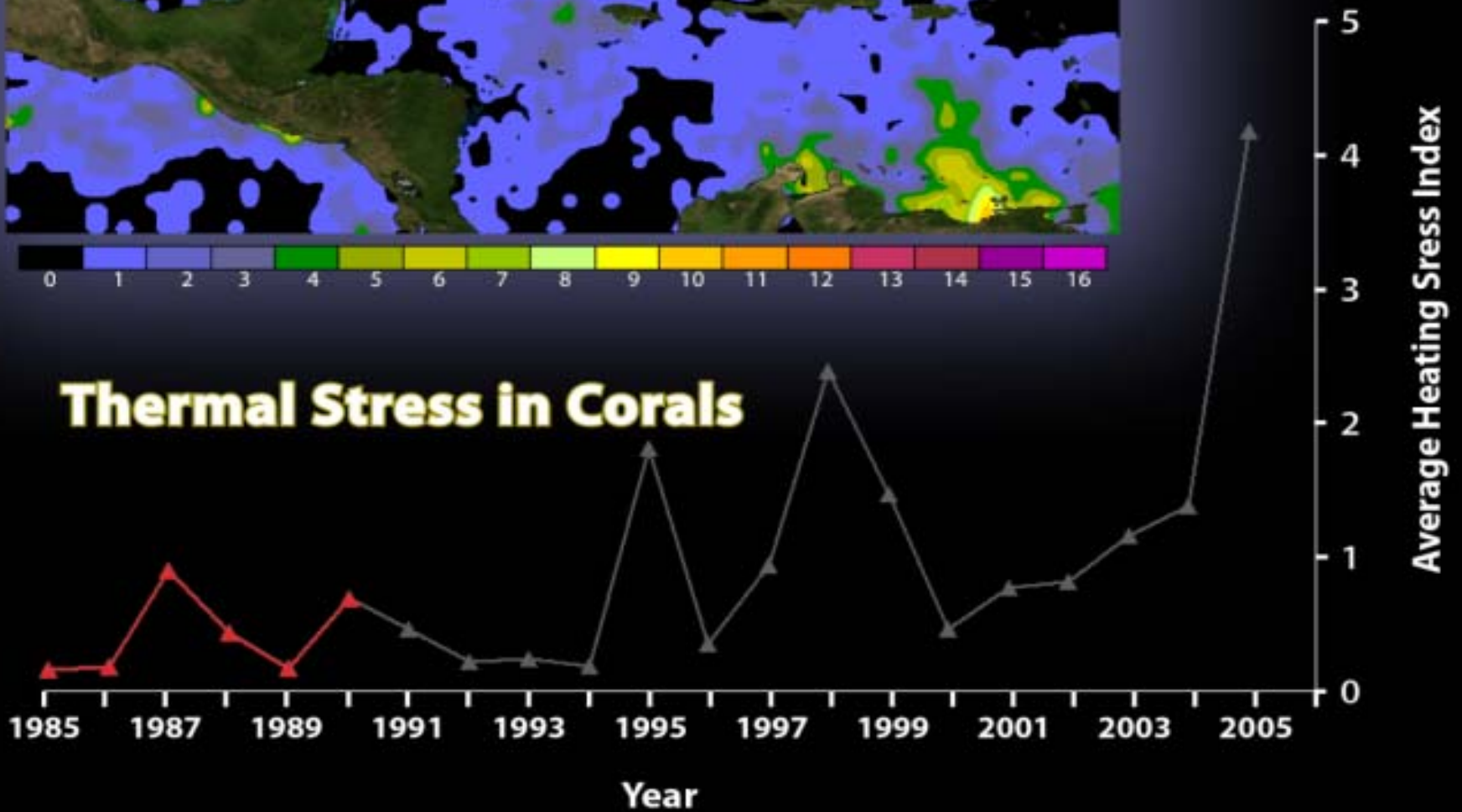
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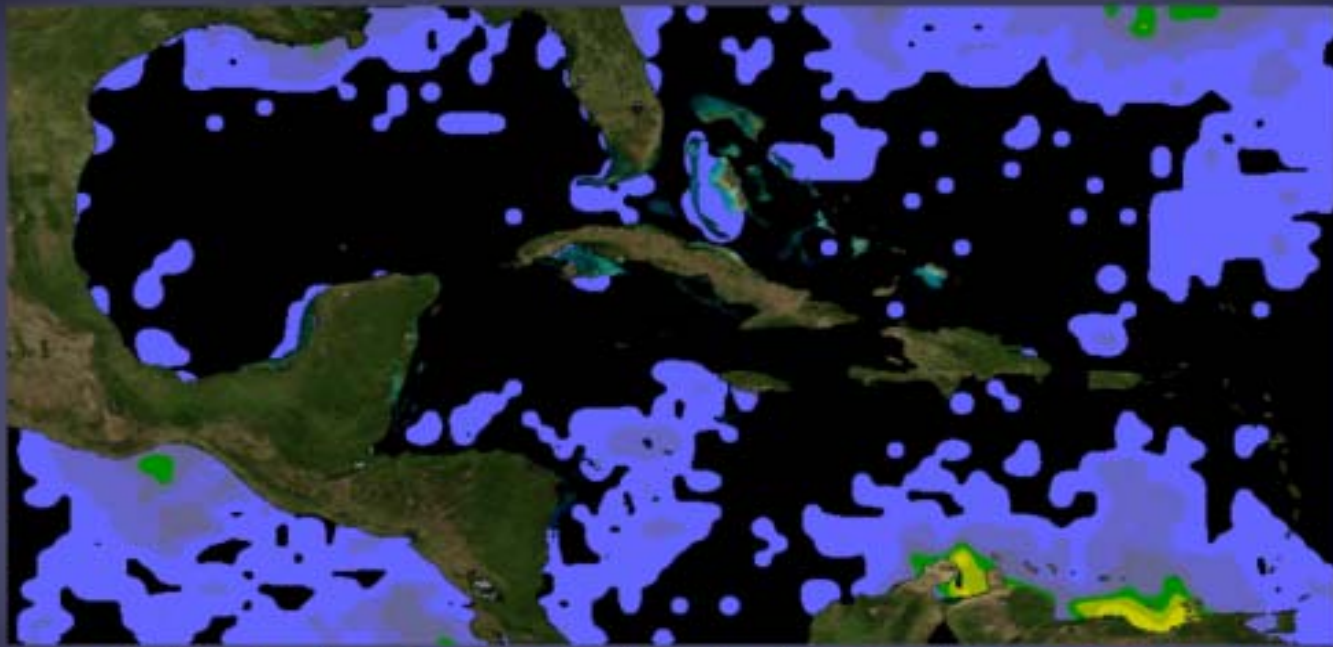






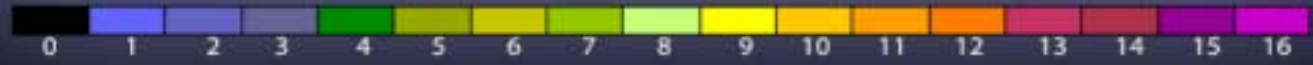
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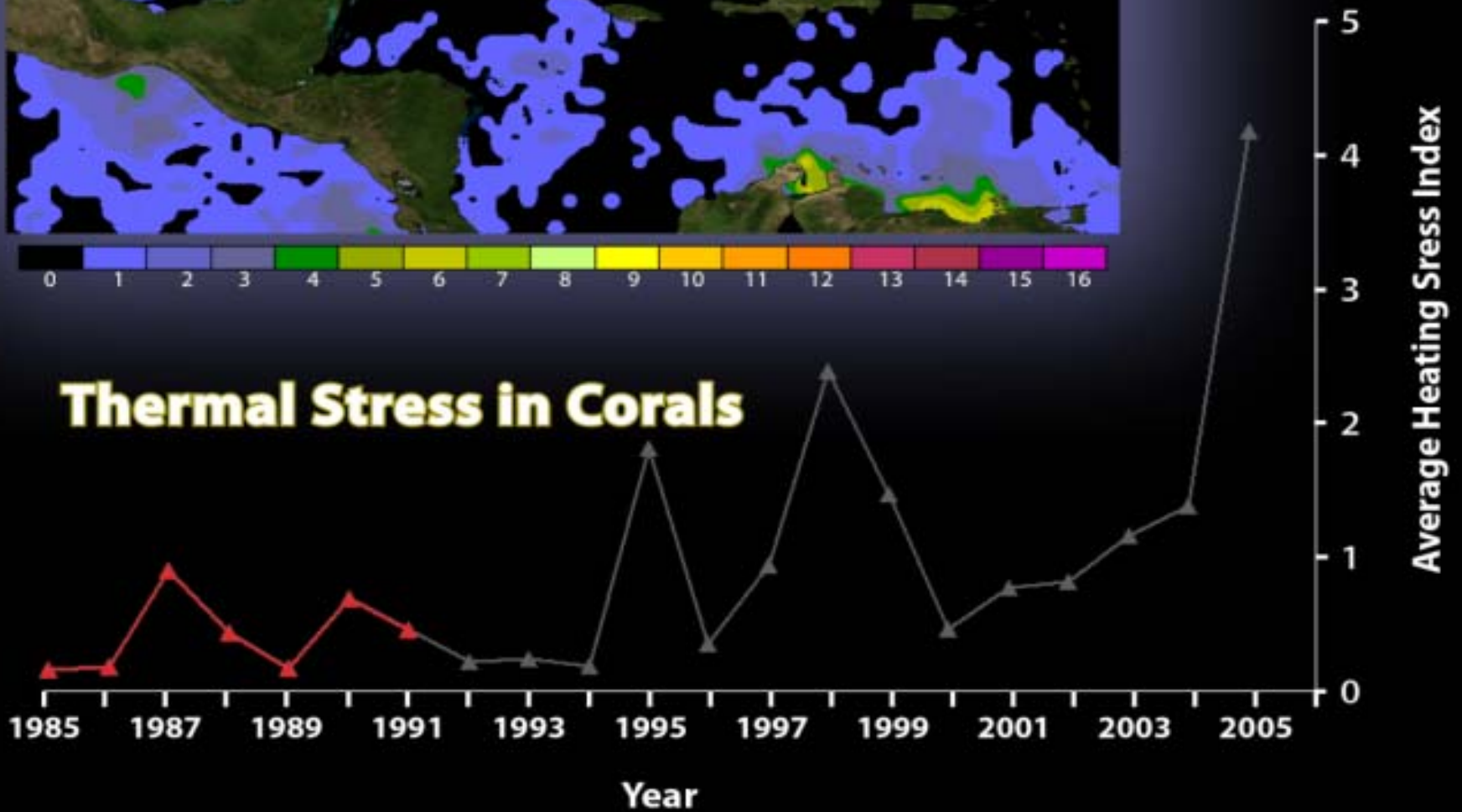


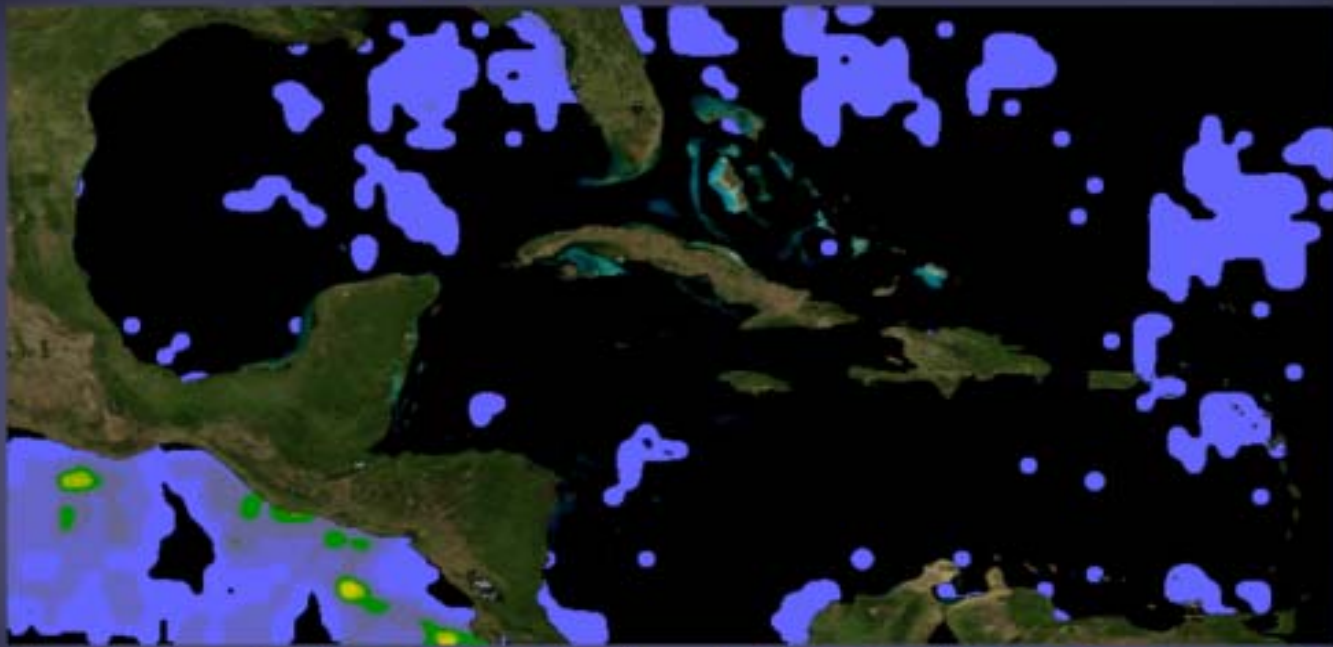


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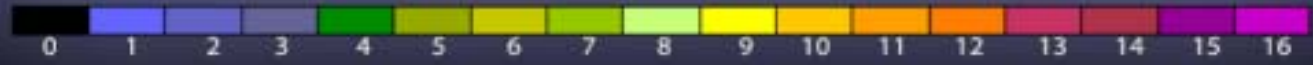


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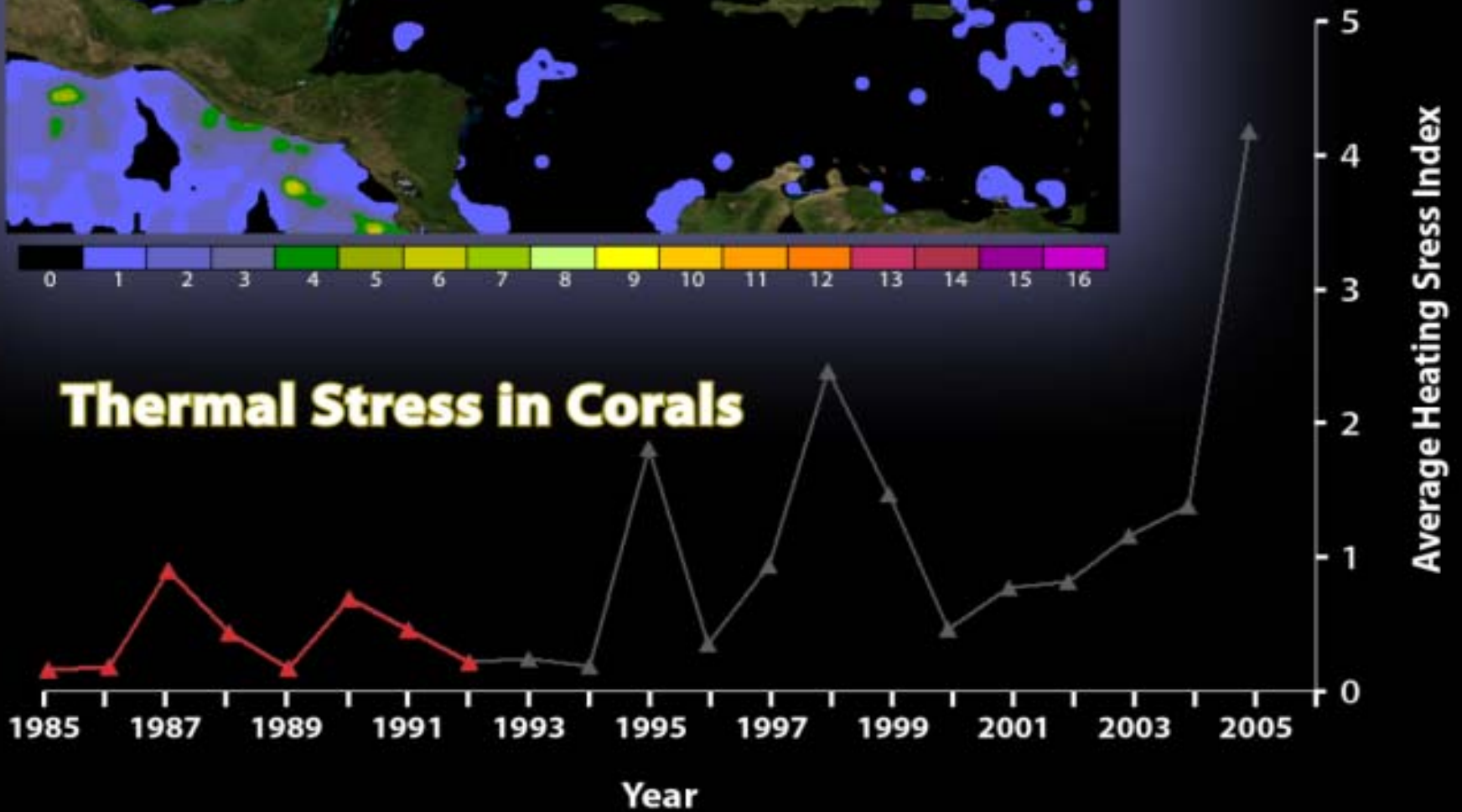




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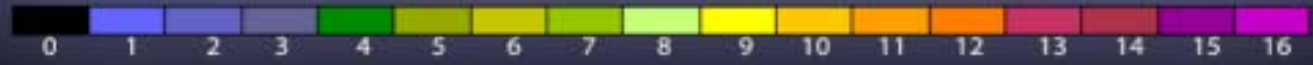


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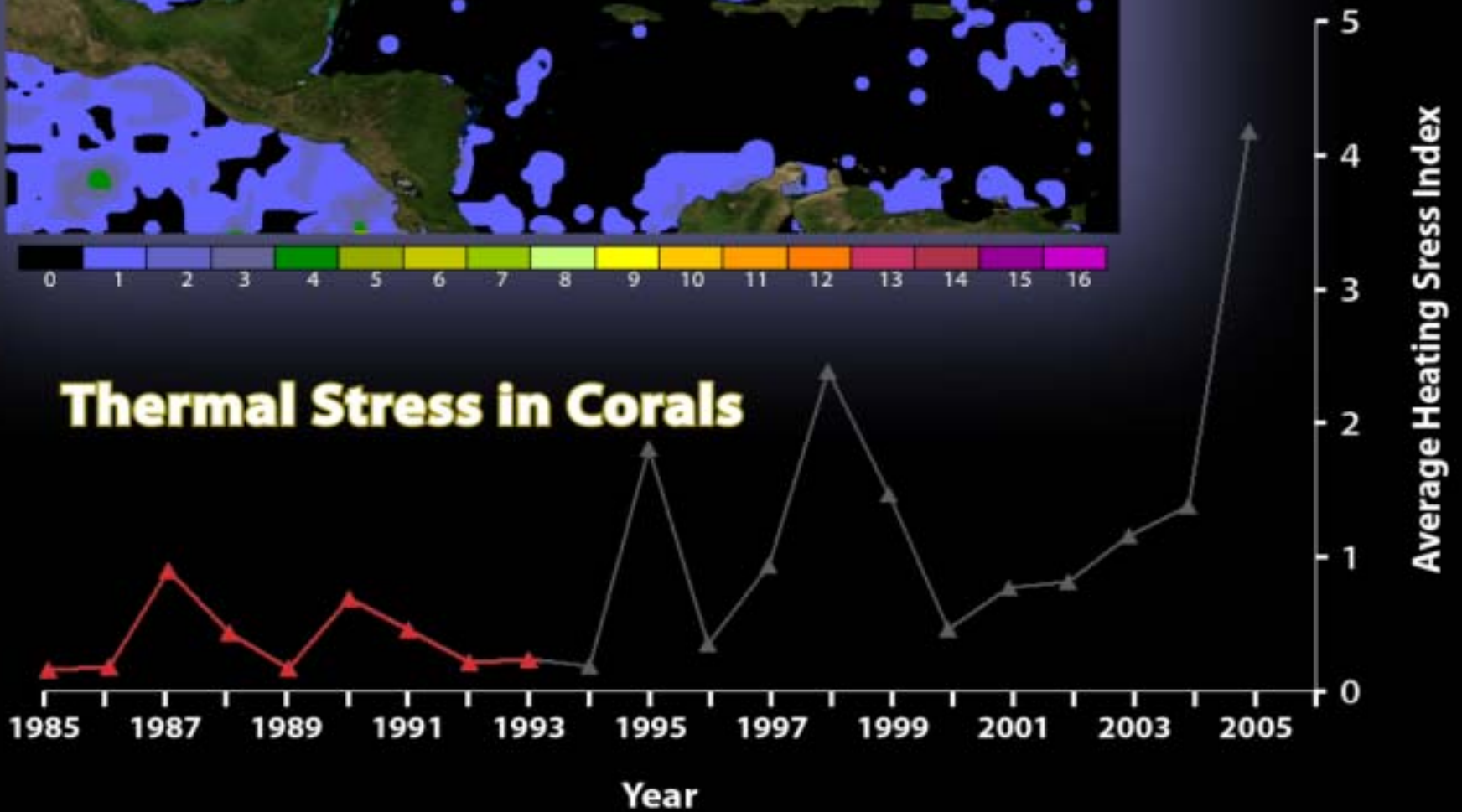


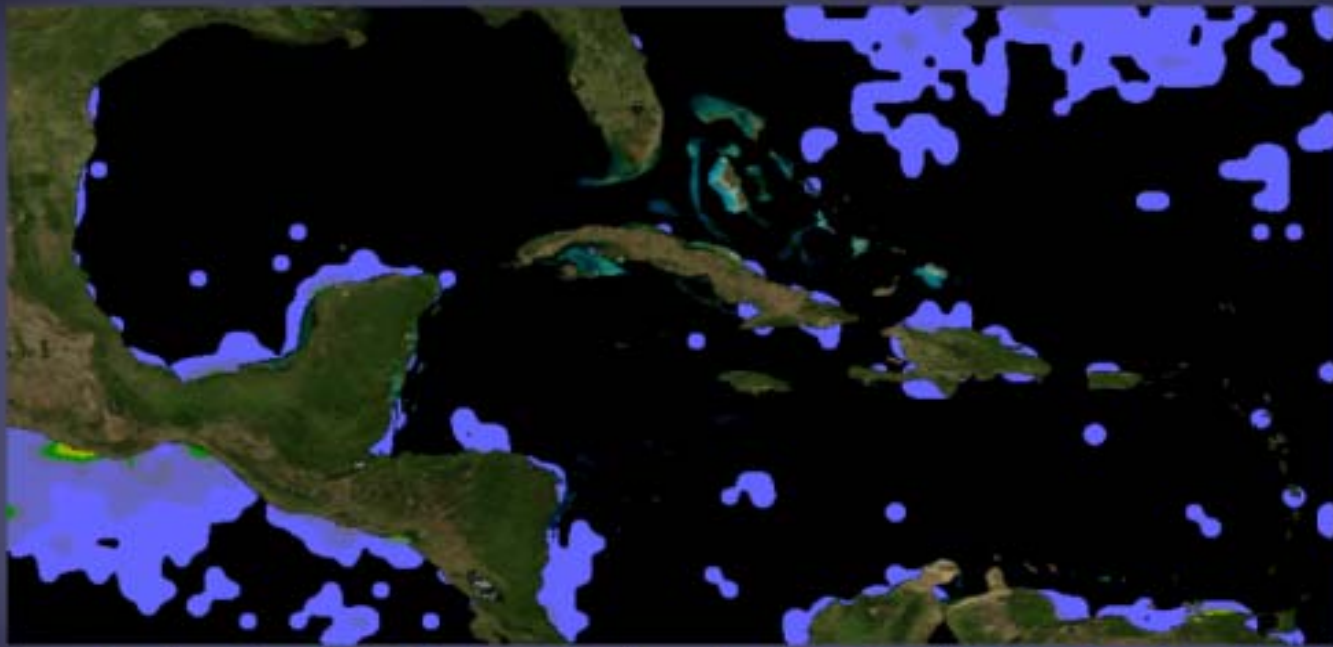




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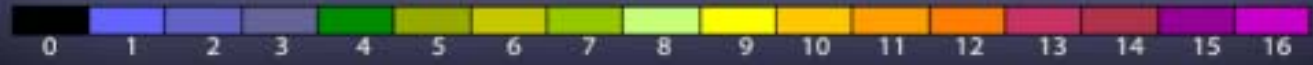


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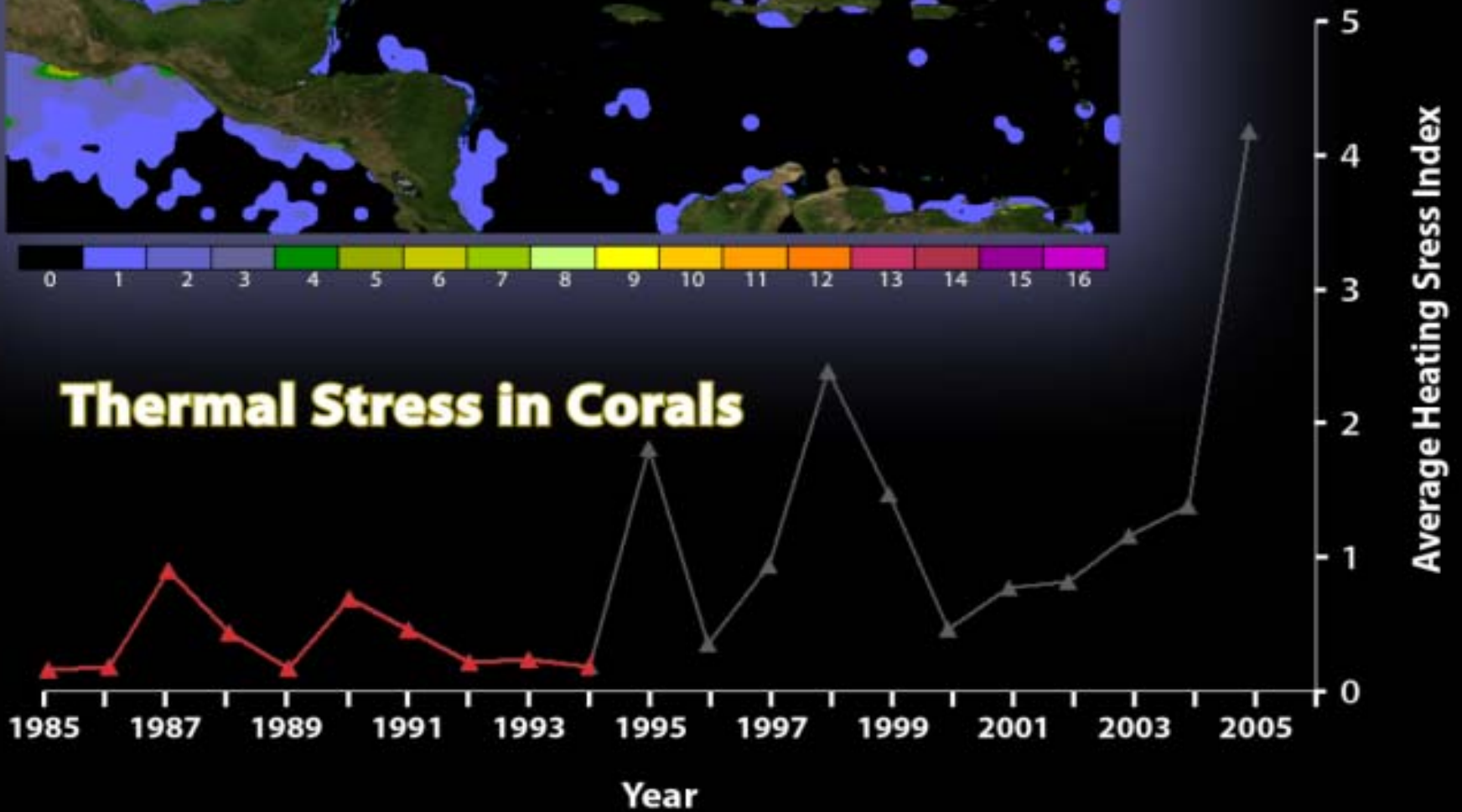


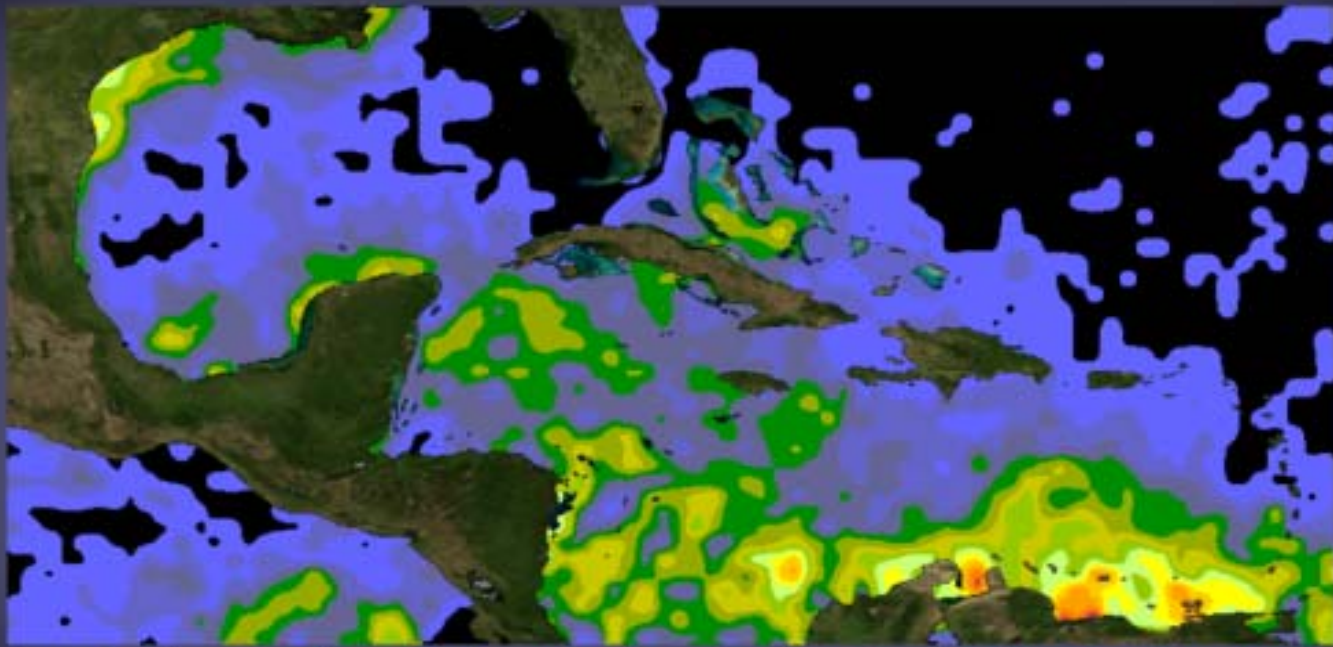


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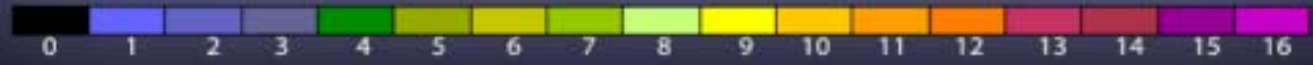


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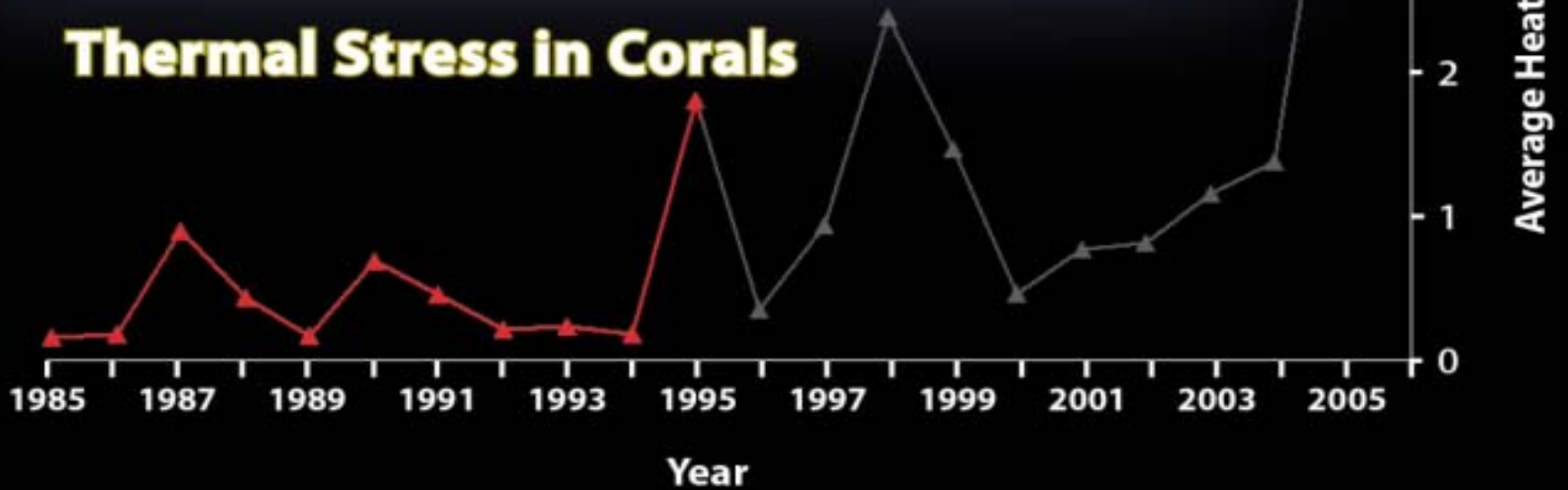






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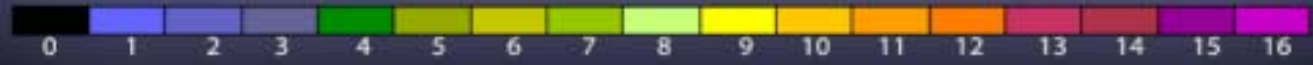


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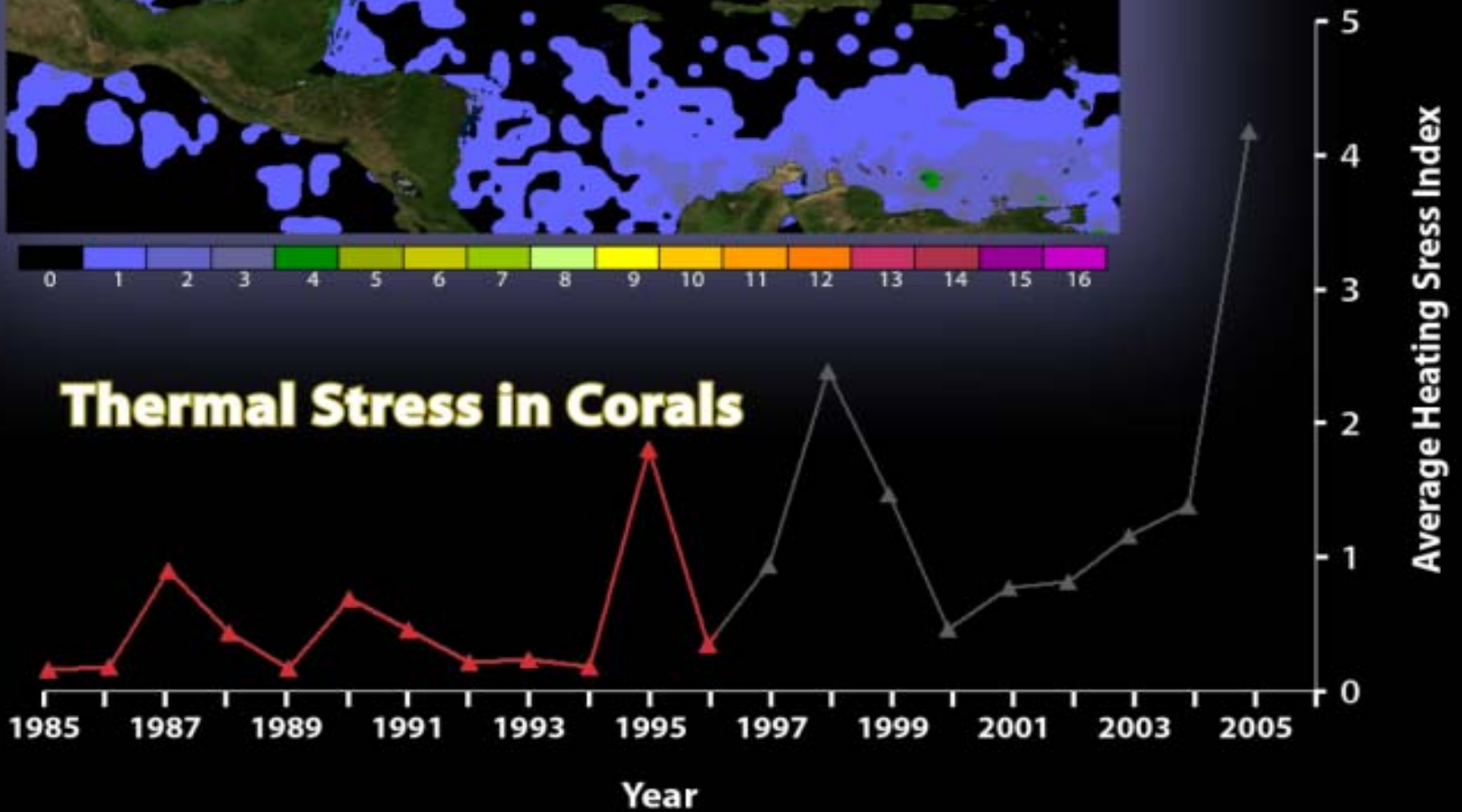


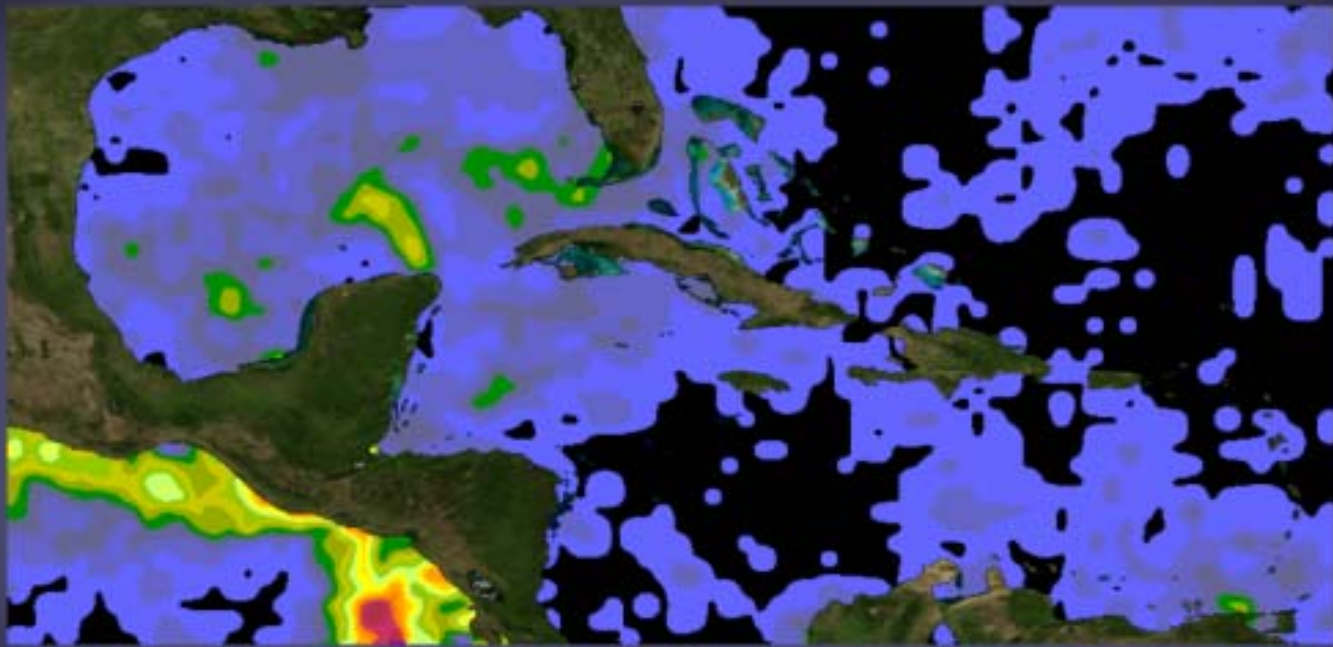




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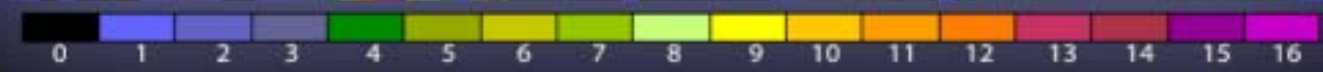


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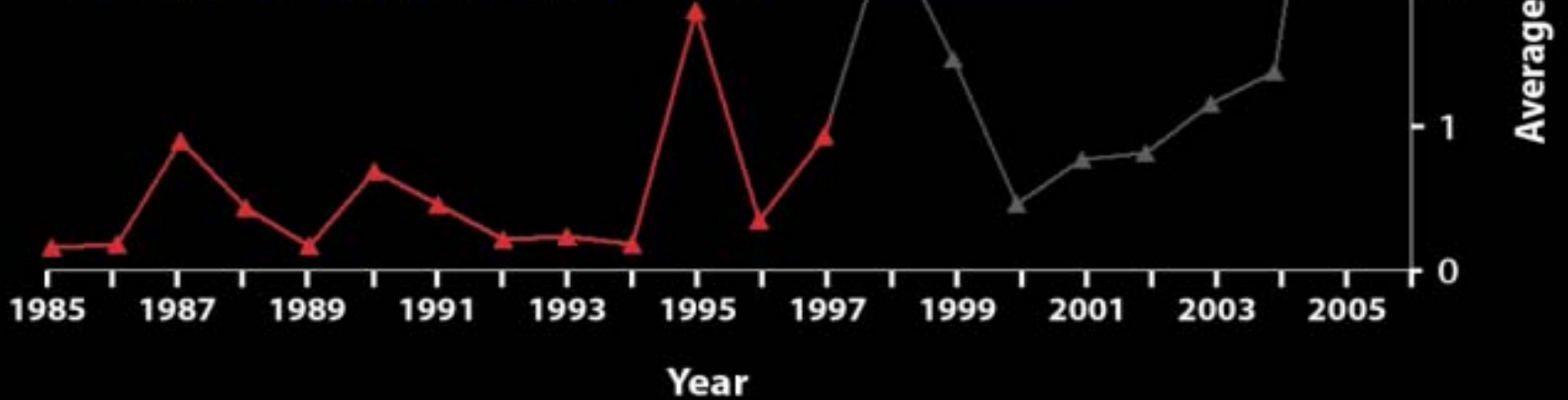


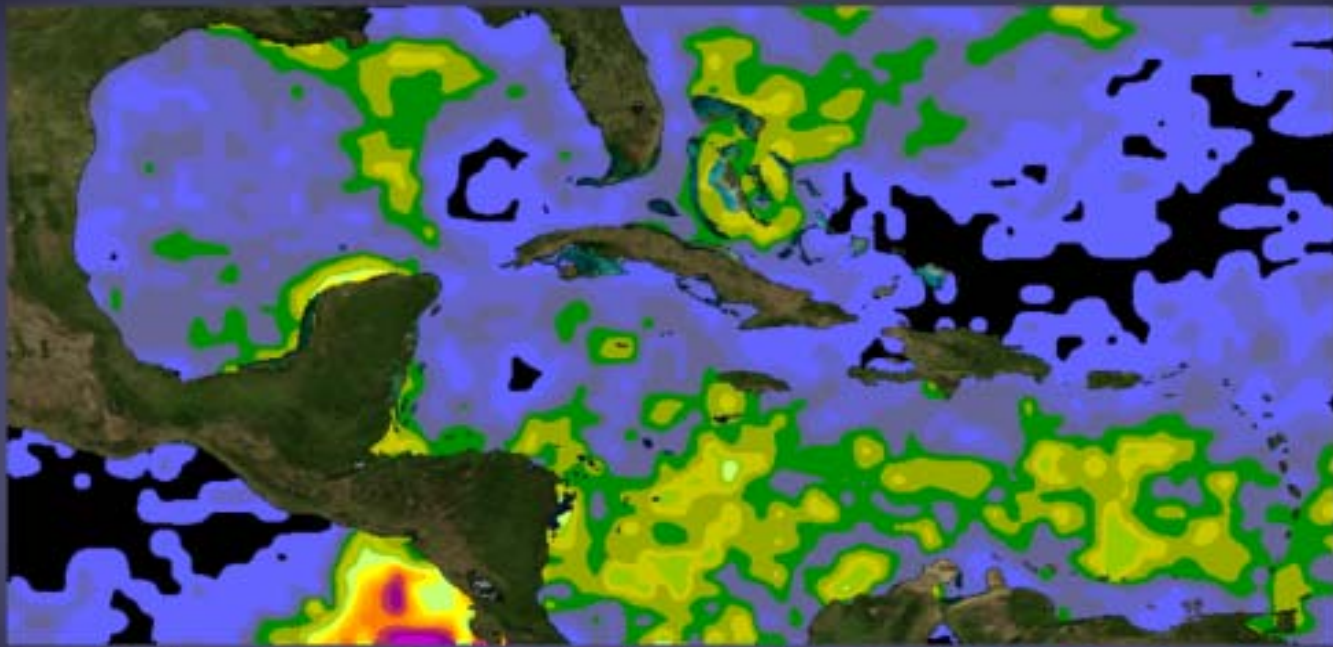




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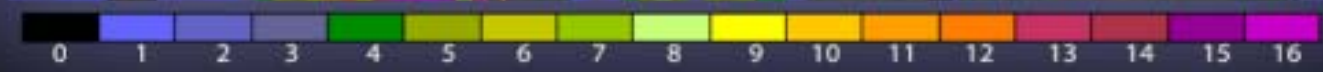


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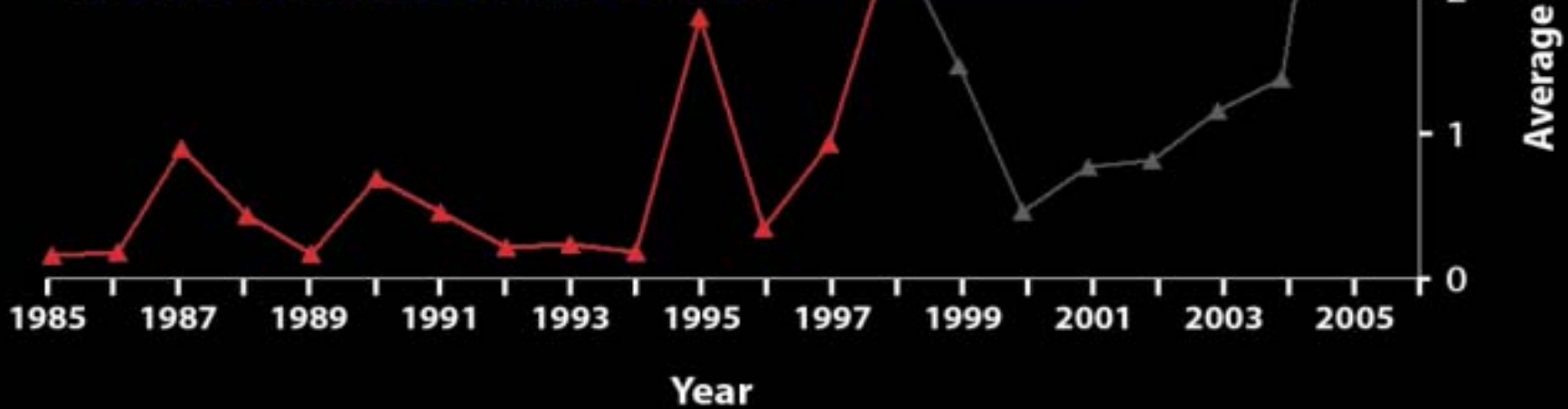


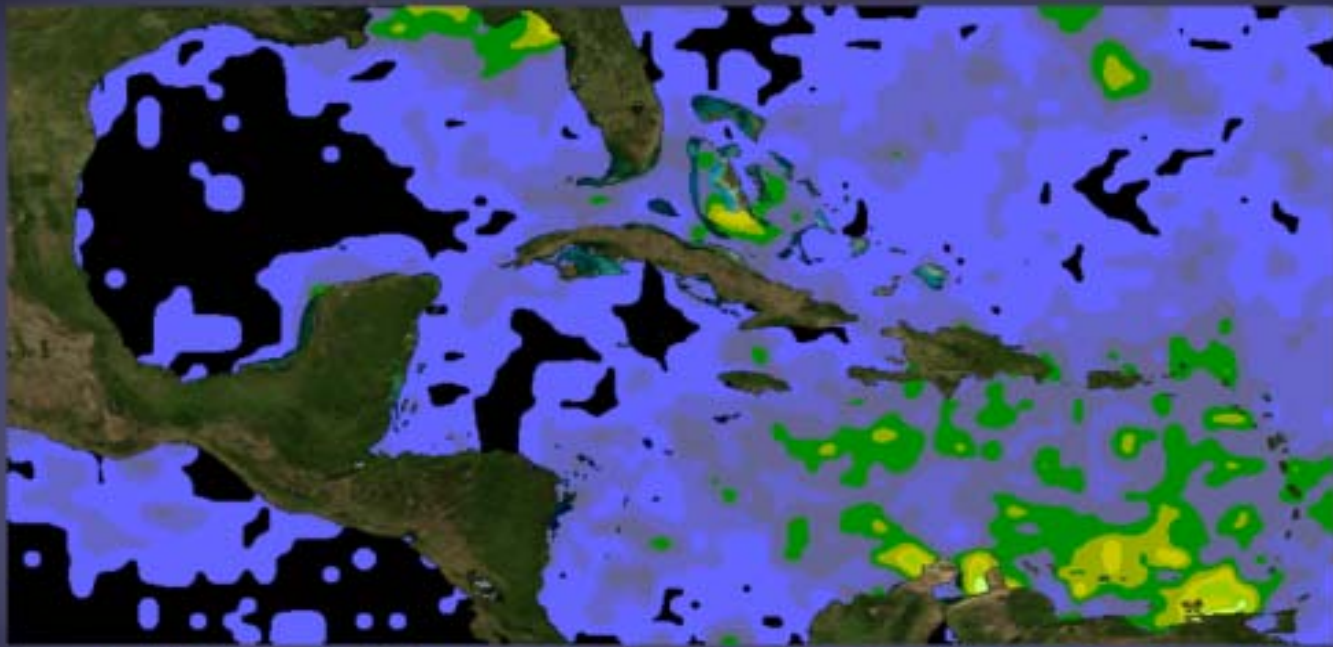




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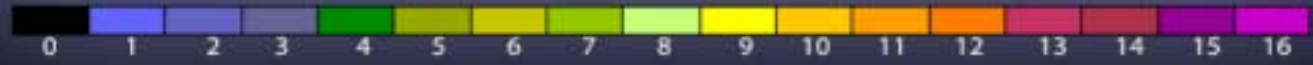


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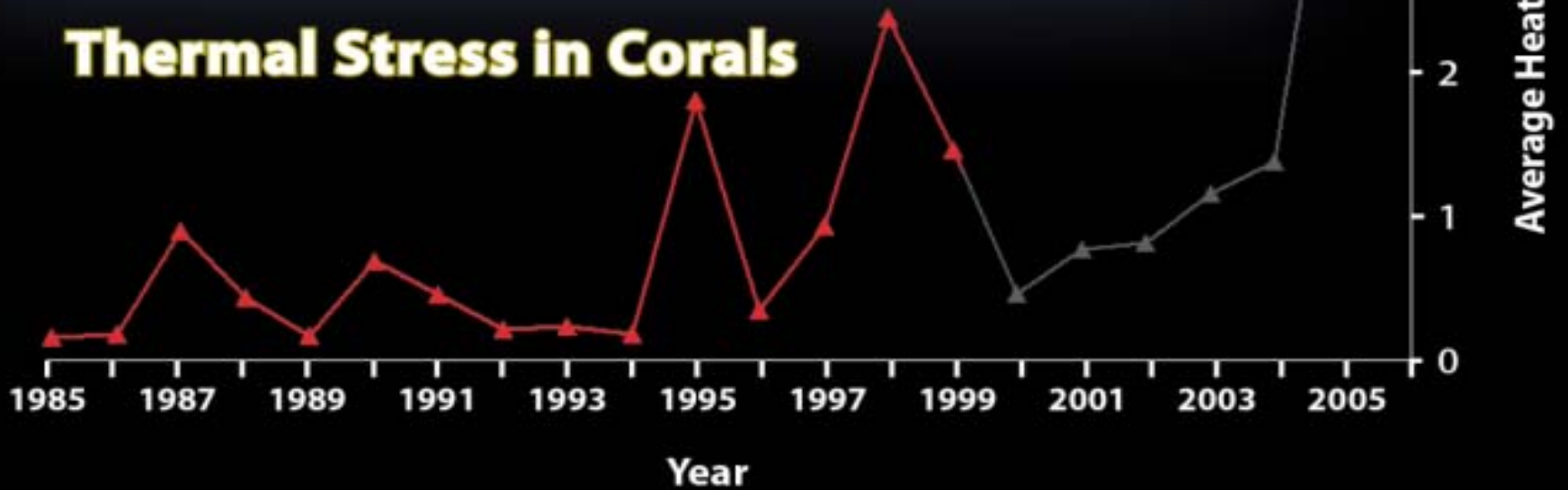






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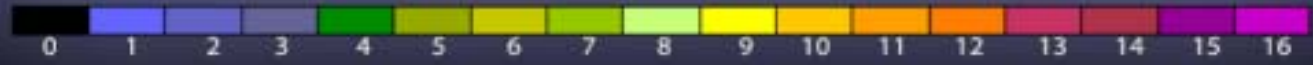


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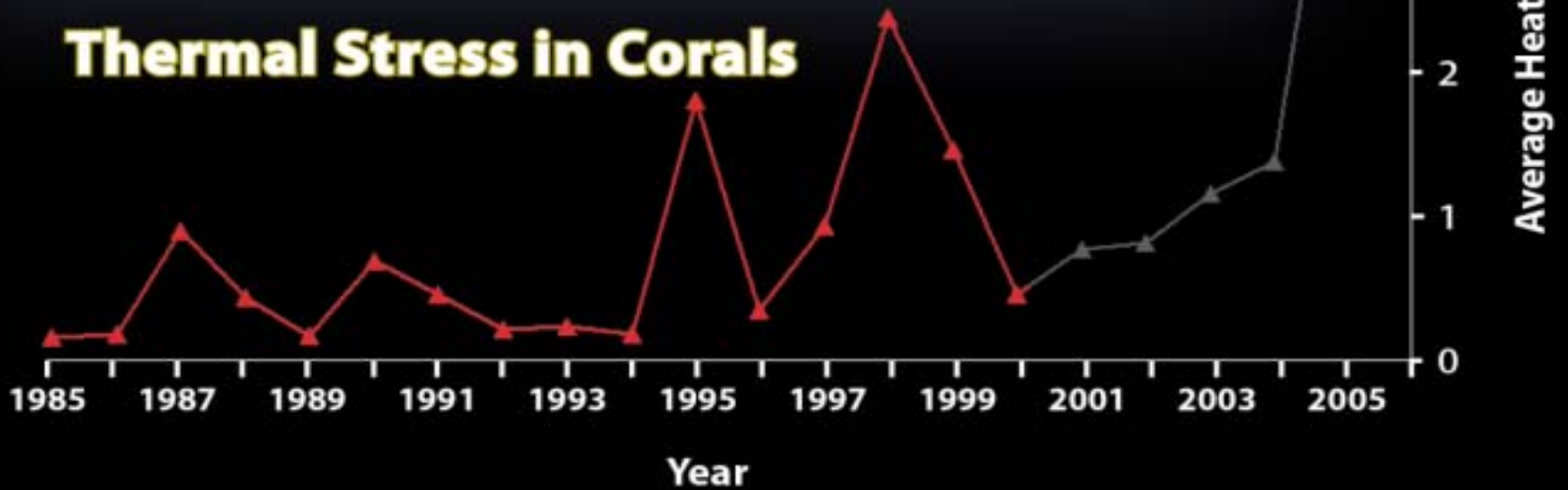


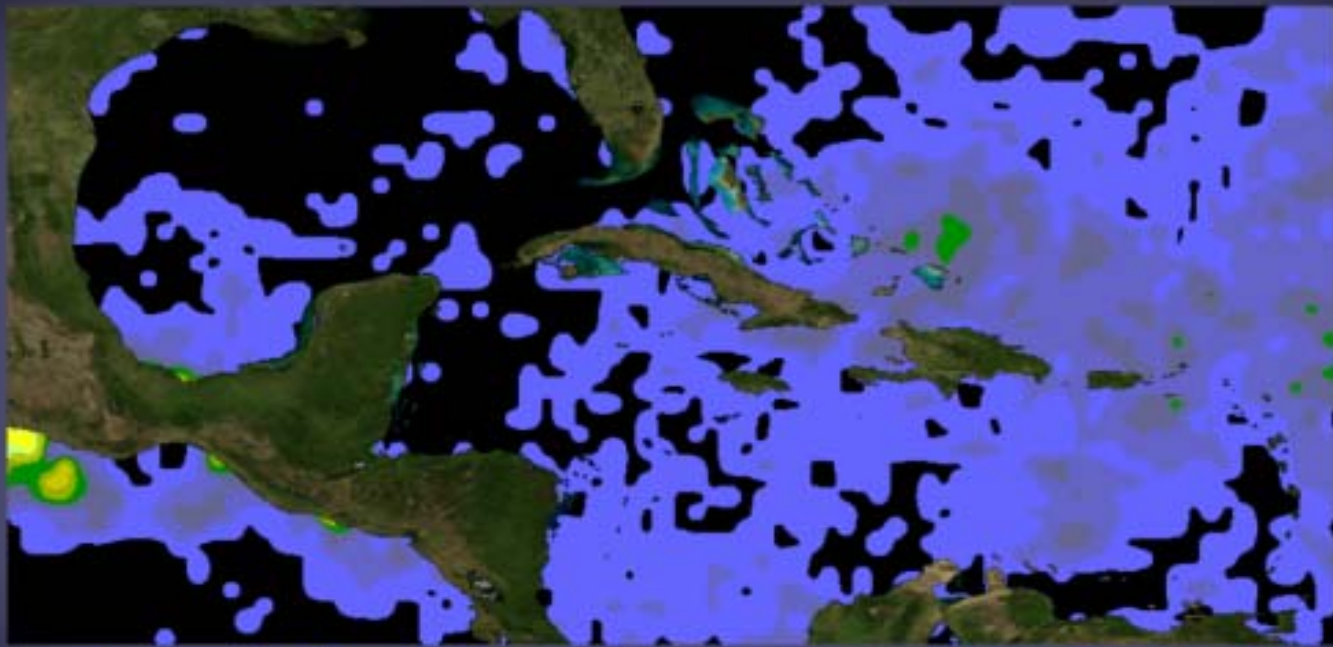


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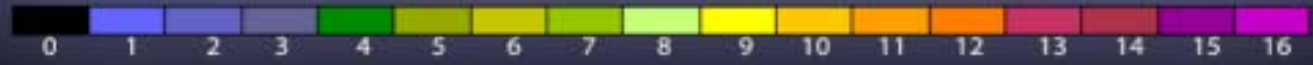


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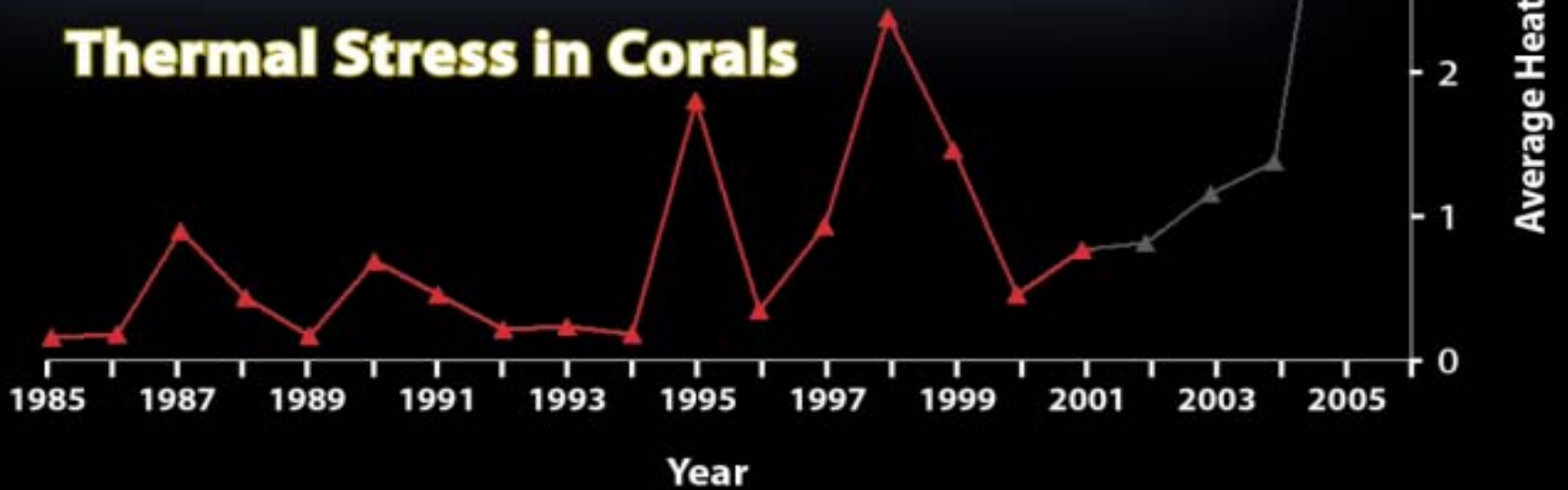


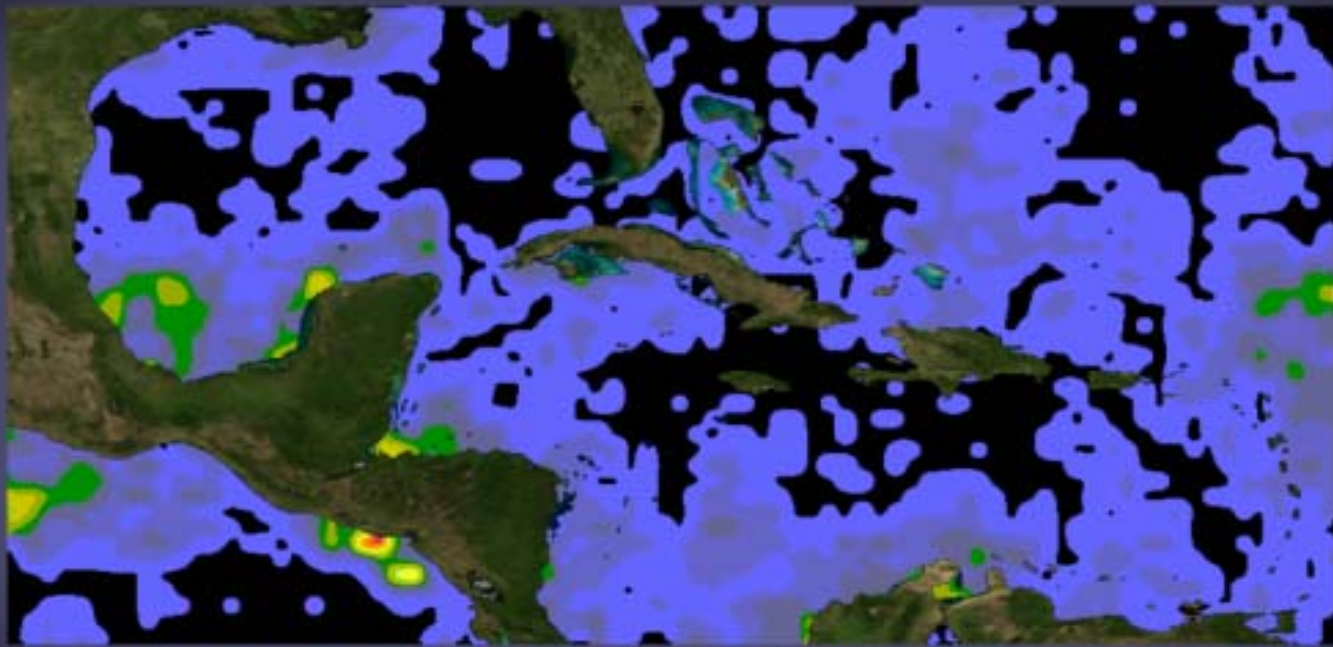




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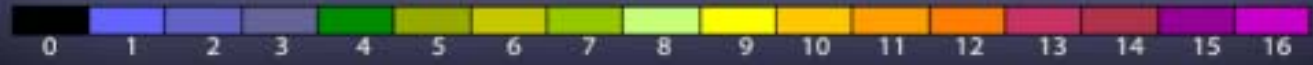


Thermal Stress in Corals

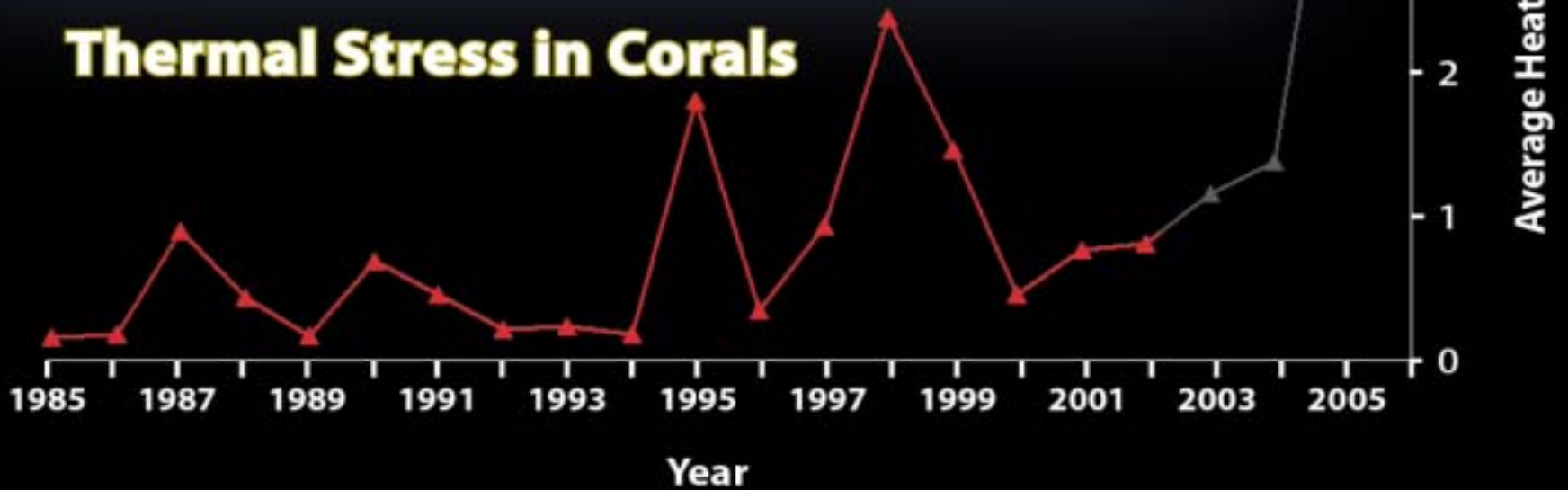


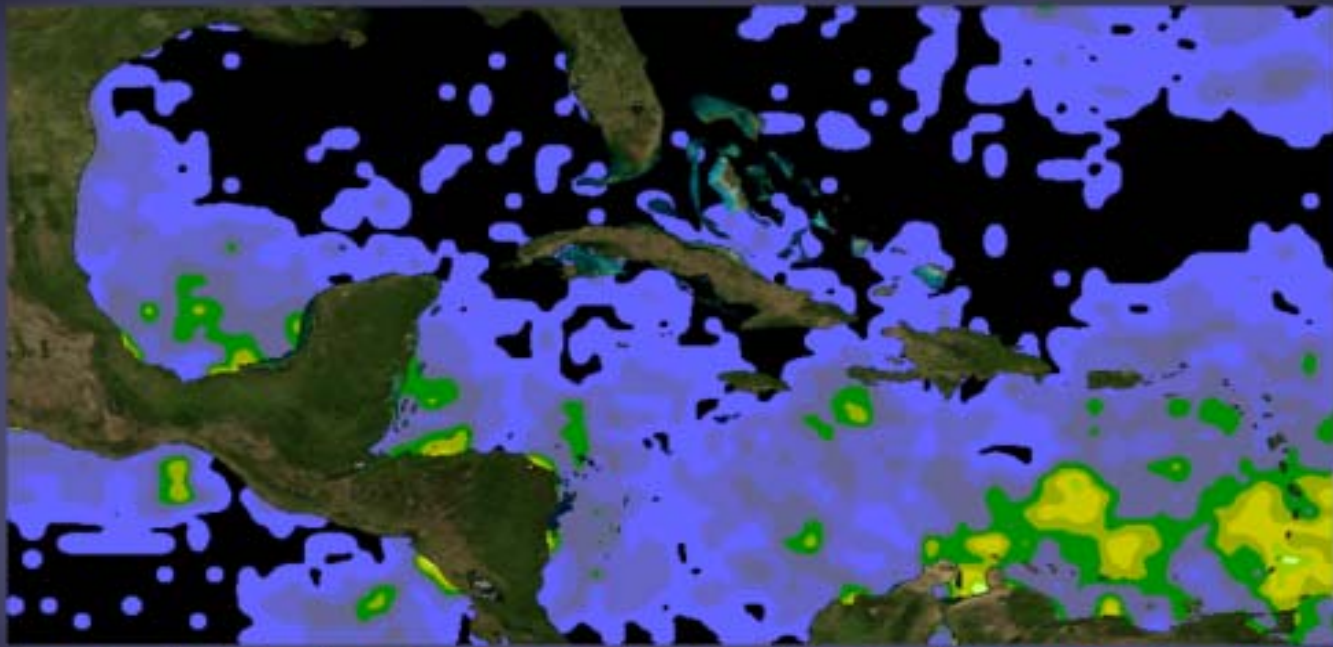


-  Bleaching Expected
-  Mass Bleaching and Mortality

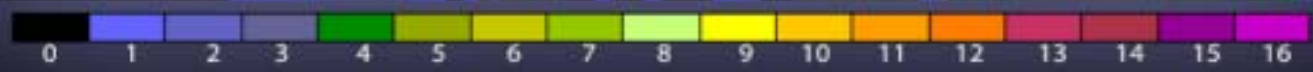


Thermal Stress in Corals

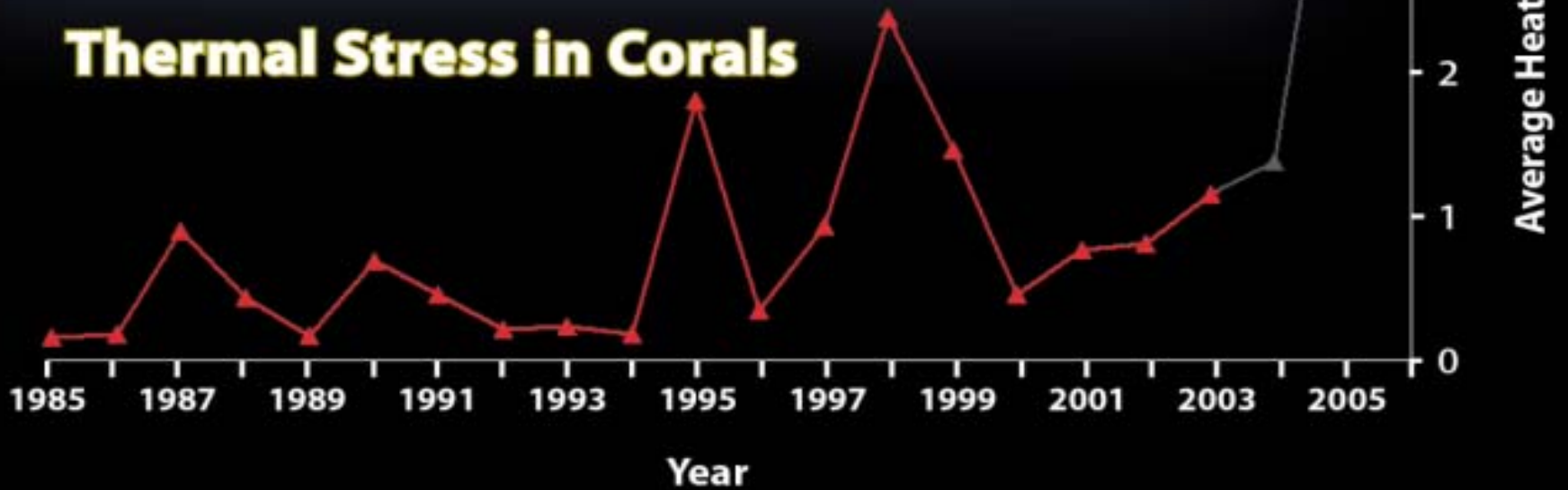


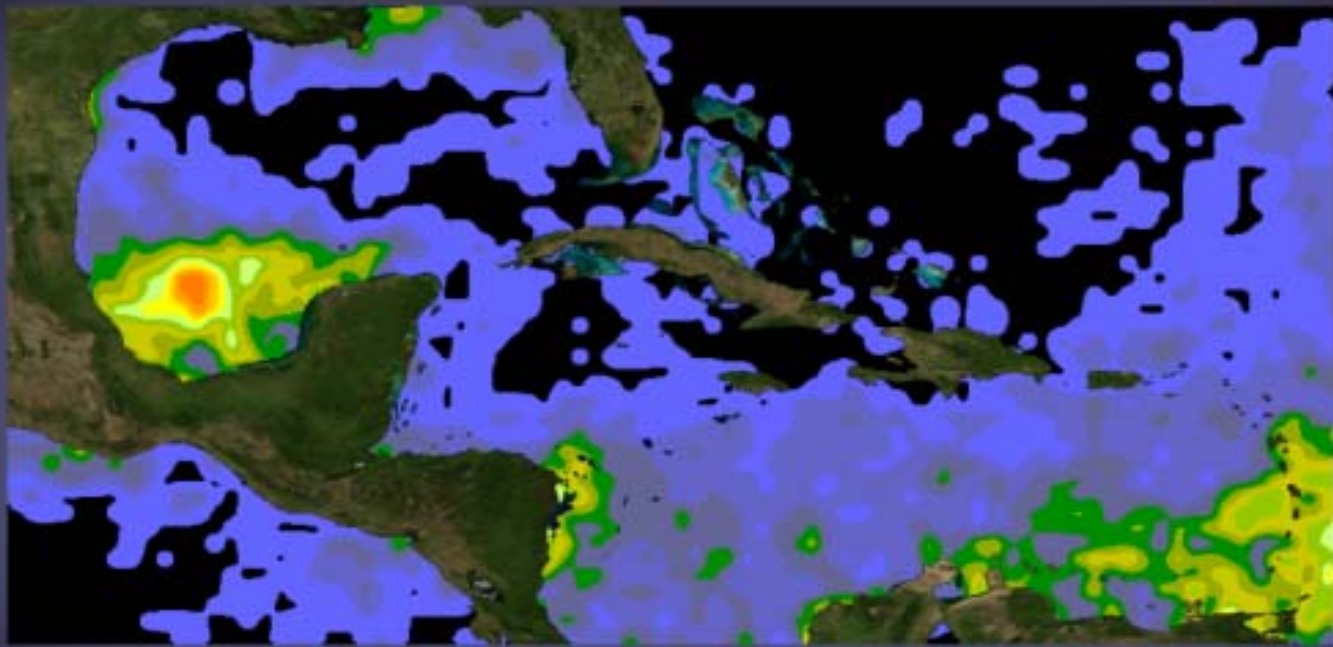




- Bleaching Expected
- Mass Bleaching and Mortality

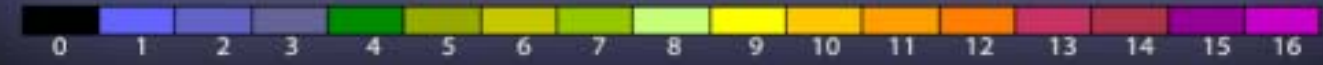


Thermal Stress in Corals

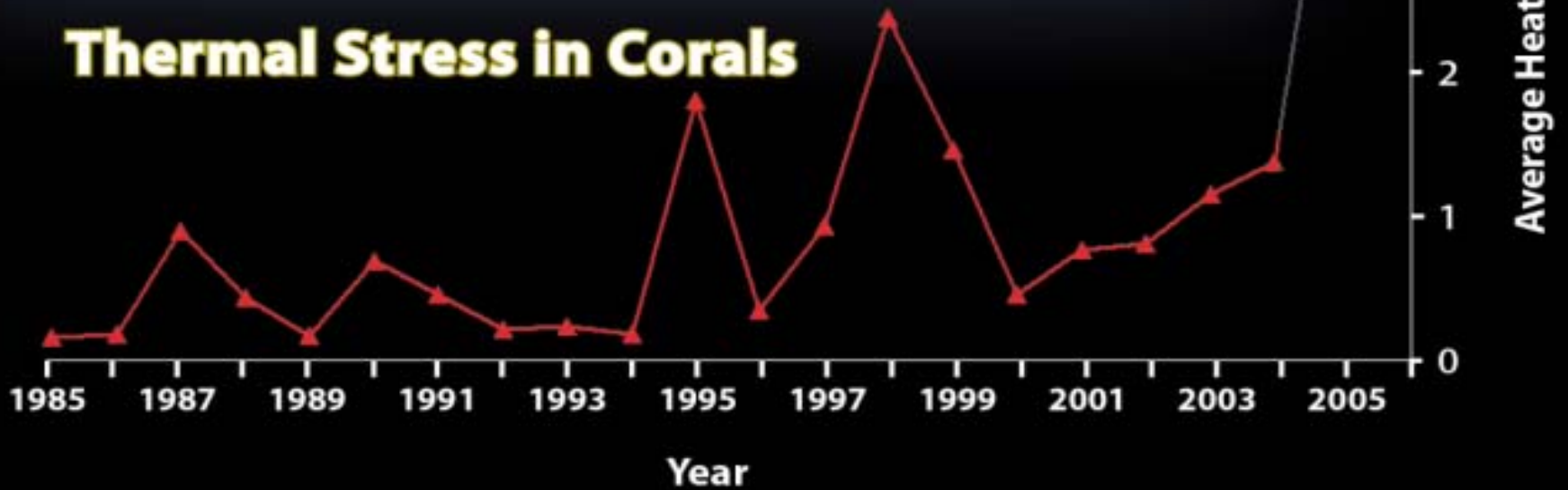


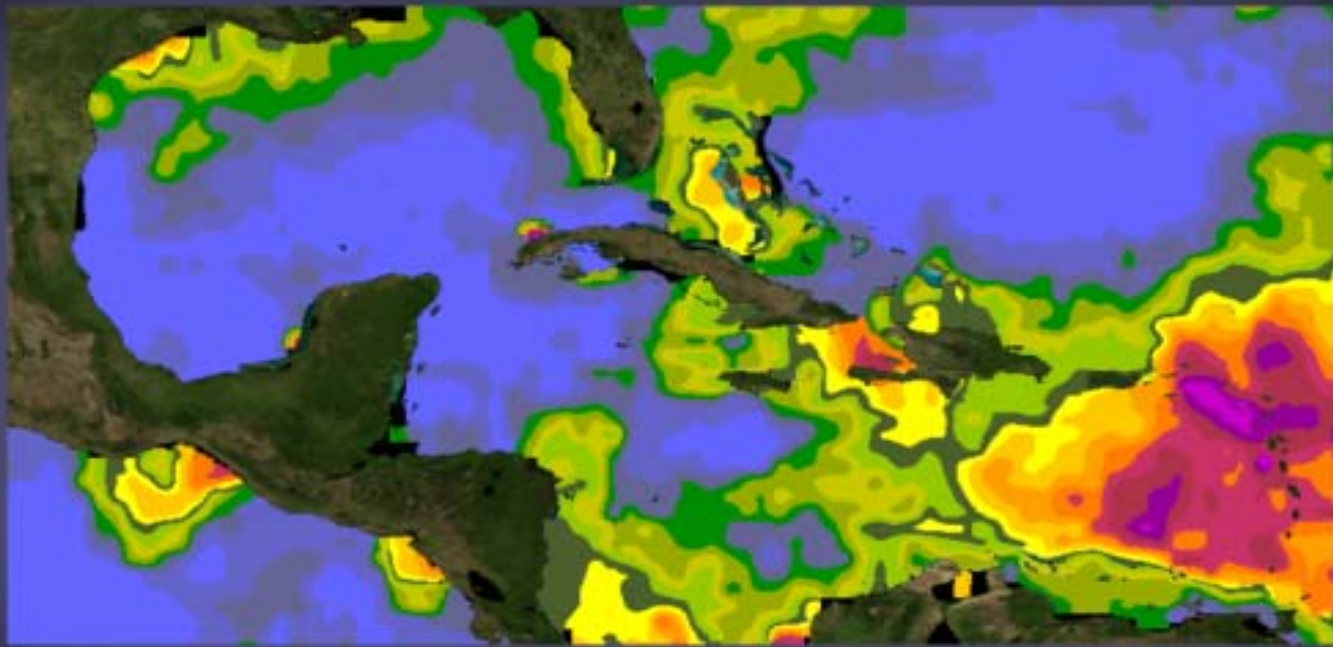




-  Bleaching Expected
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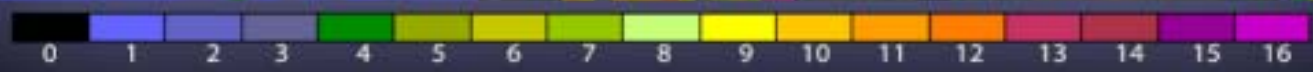


Thermal Stress in Corals

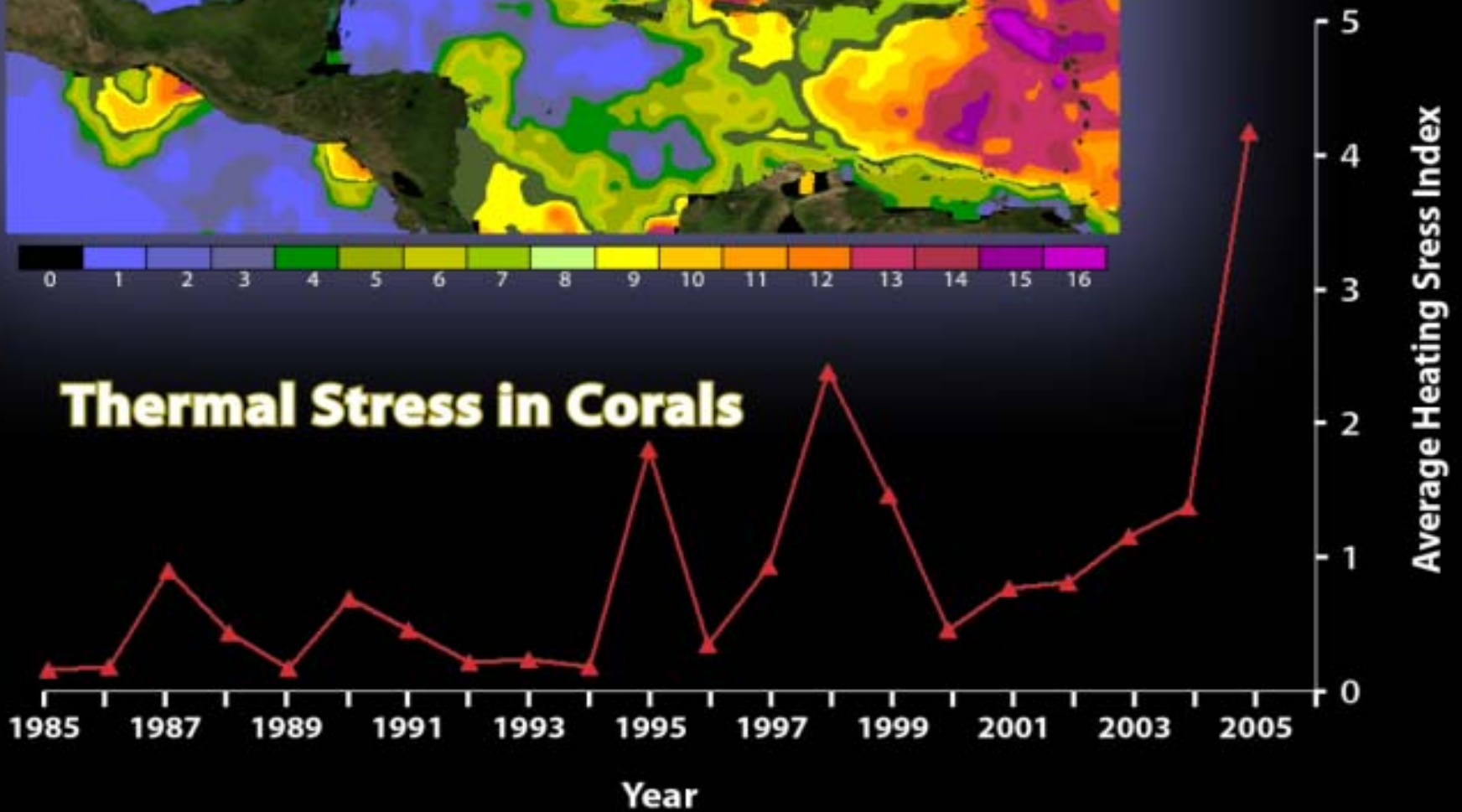




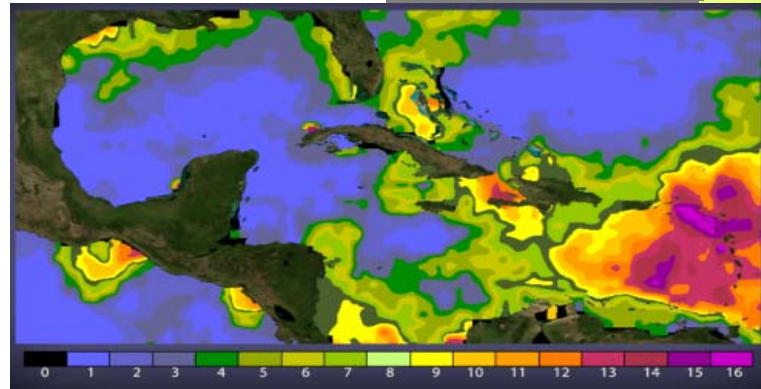
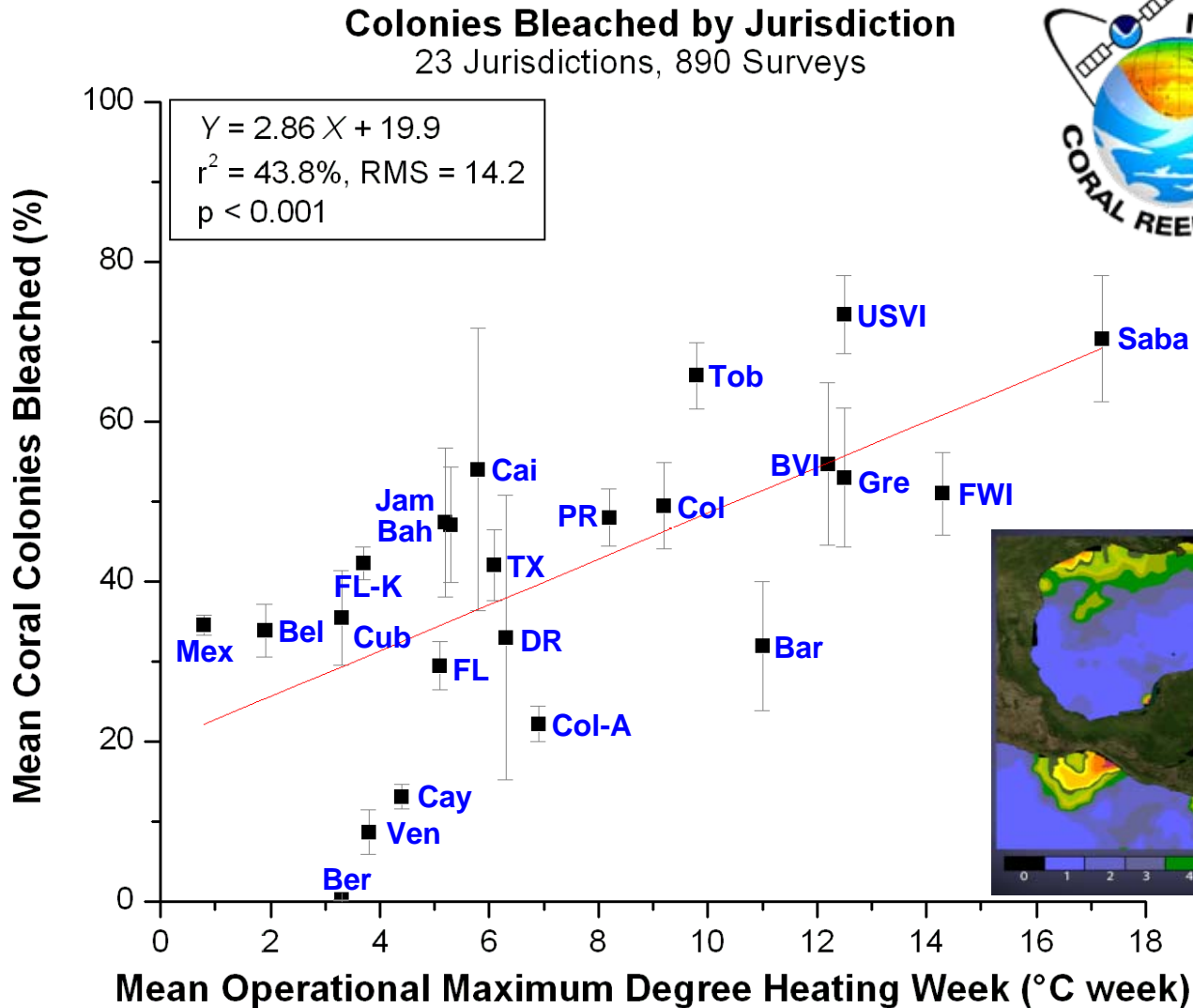
-  Bleaching Expected
-  Mass Bleaching and Mortality



Thermal Stress in Corals



Percent of Coral Colonies Bleached



Bleaching Can Lead to Disease

- Many bleached colonies have become diseased
- Some diseases are rapid and devastating

Inshore patch reefs
Middle Florida Keys

Marilyn E. Brandt
University of Miami



Virgin Islands N.P. Coral Bleaching Surveys



S. Fore Reef, BUIS



96% coral cover bleached
42% coral cover dead

Tektite, VIIS



90% coral cover bleached
54% coral cover dead

Haulover, VIIS



96% coral cover bleached
45% coral cover dead

Mennebeck, VIIS



94% coral cover bleached
49% coral cover dead

Yawzi, VIIS



71% coral cover bleached
39% coral cover dead

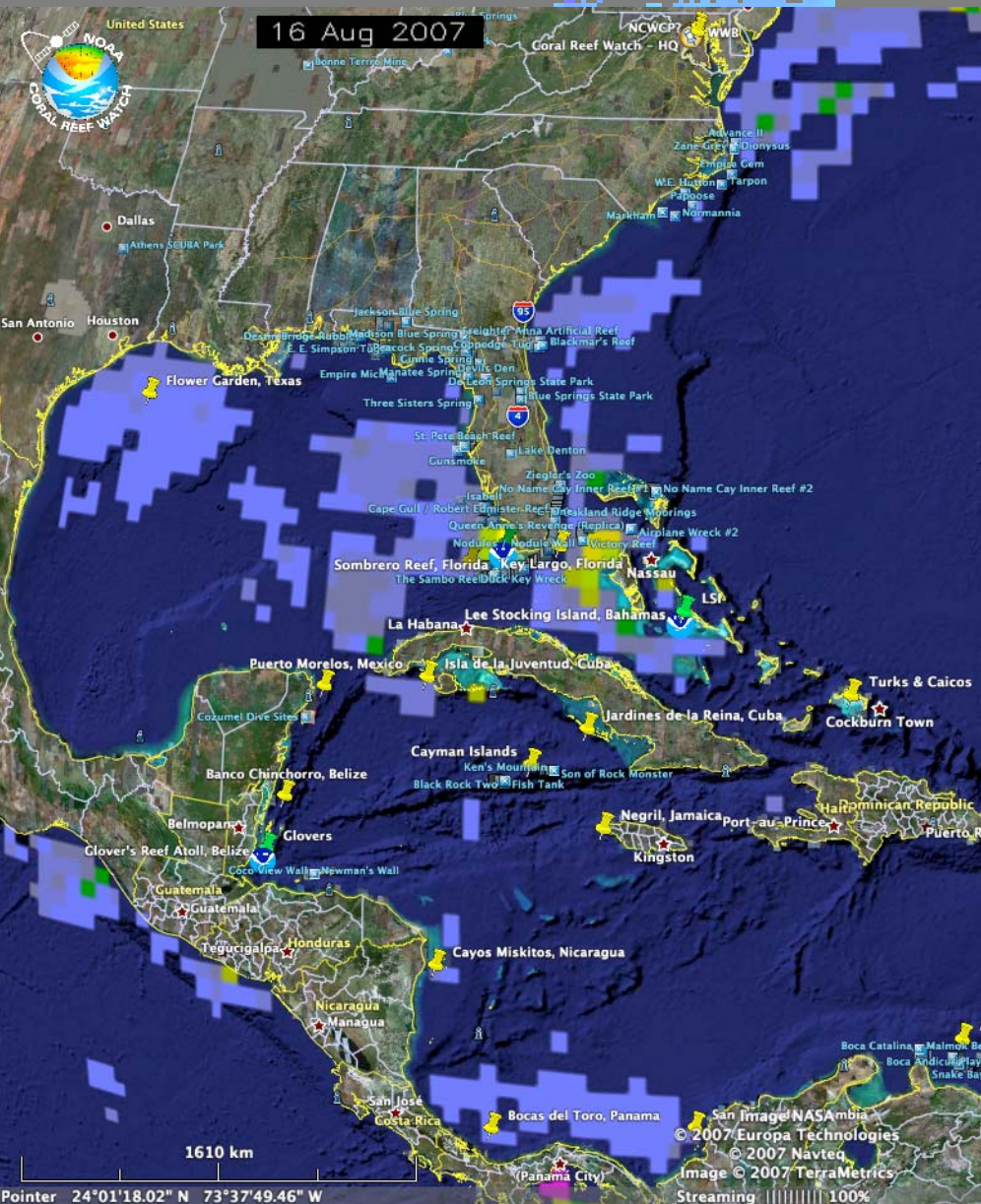
Newfound, STJ



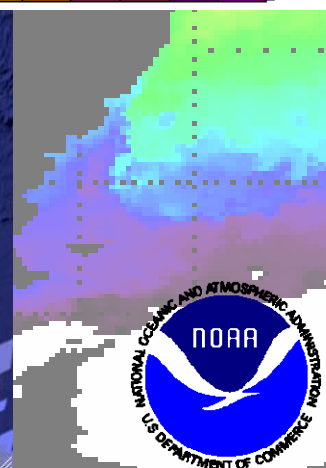
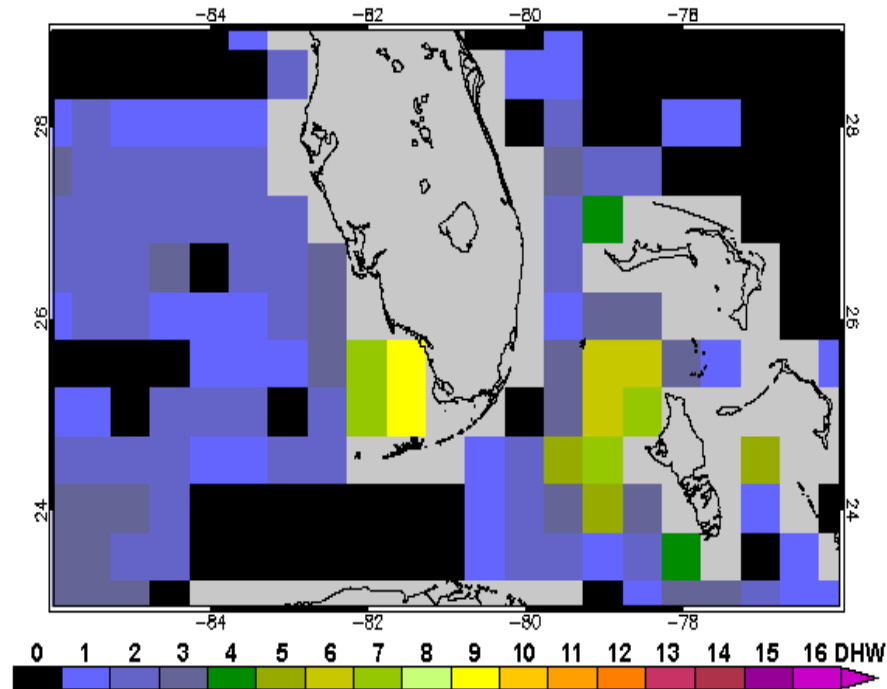
92% coral cover bleached
53% coral cover dead



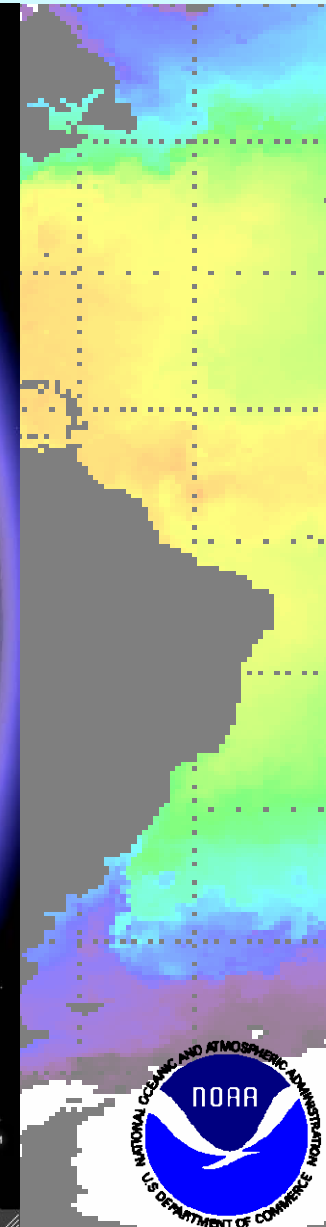
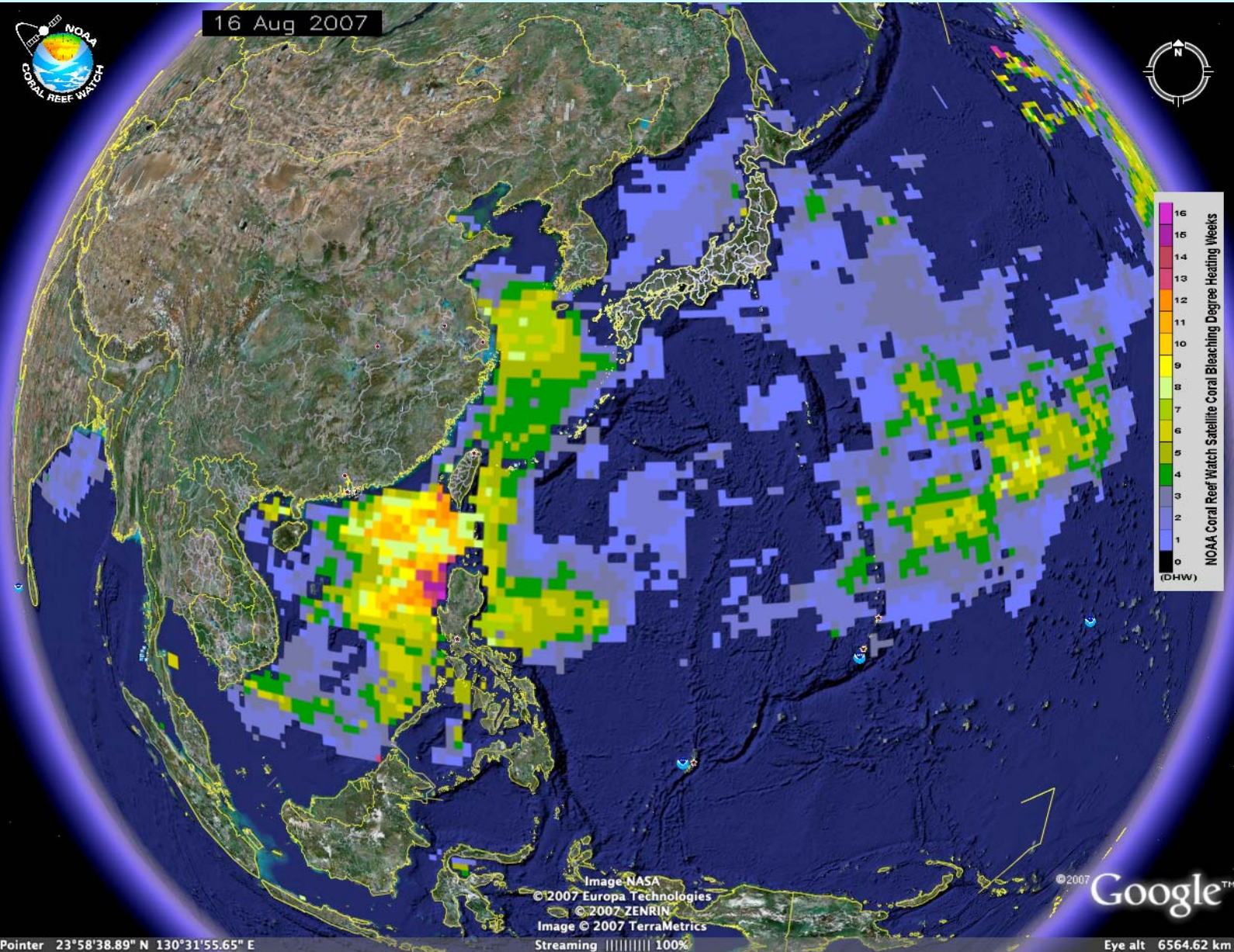
Current Thermal Bleaching: August 2007



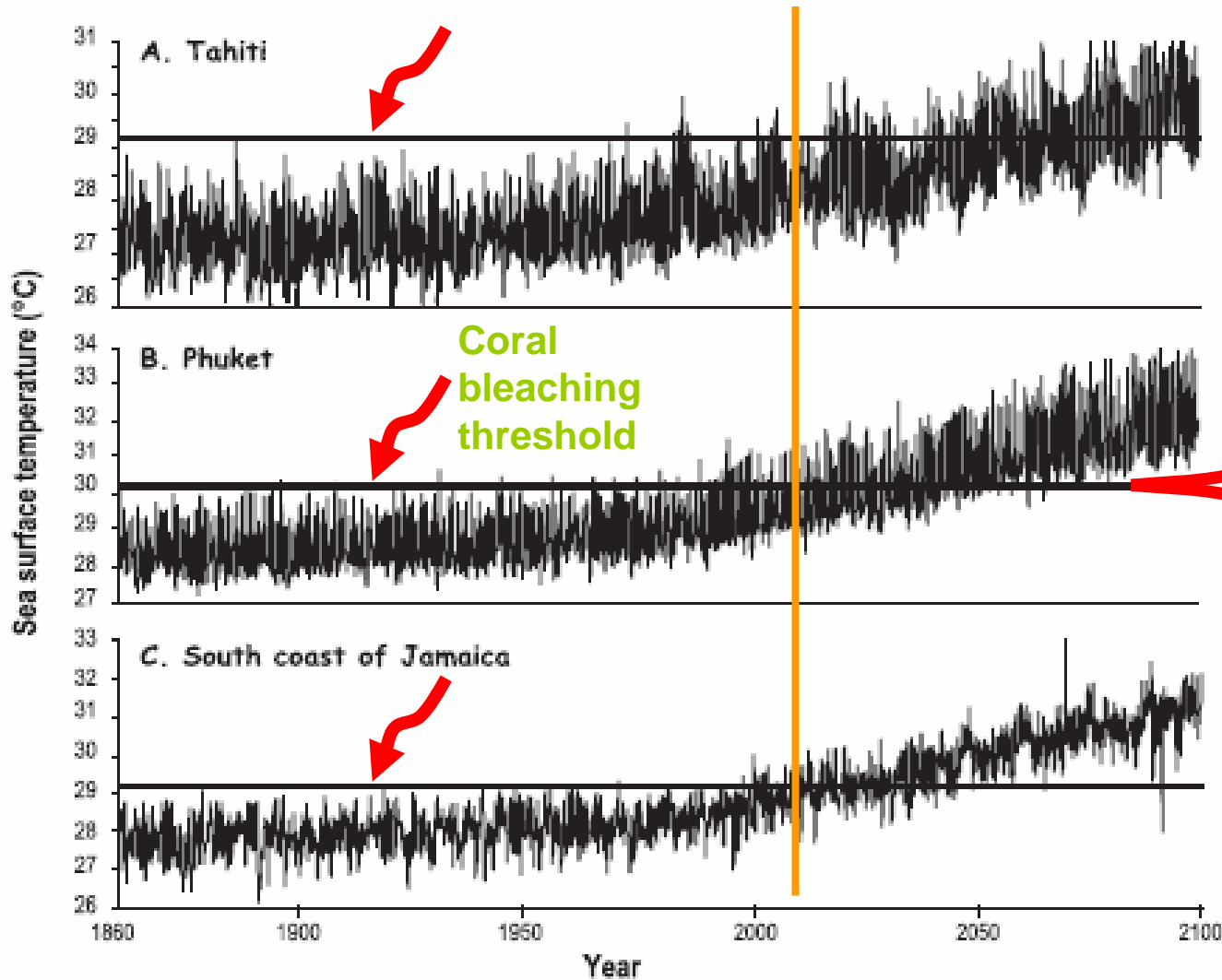
Coral Reef Watch Satellite Bleaching Degree Heating Weeks 16 Aug 2007



Current Thermal Bleaching: August 2007



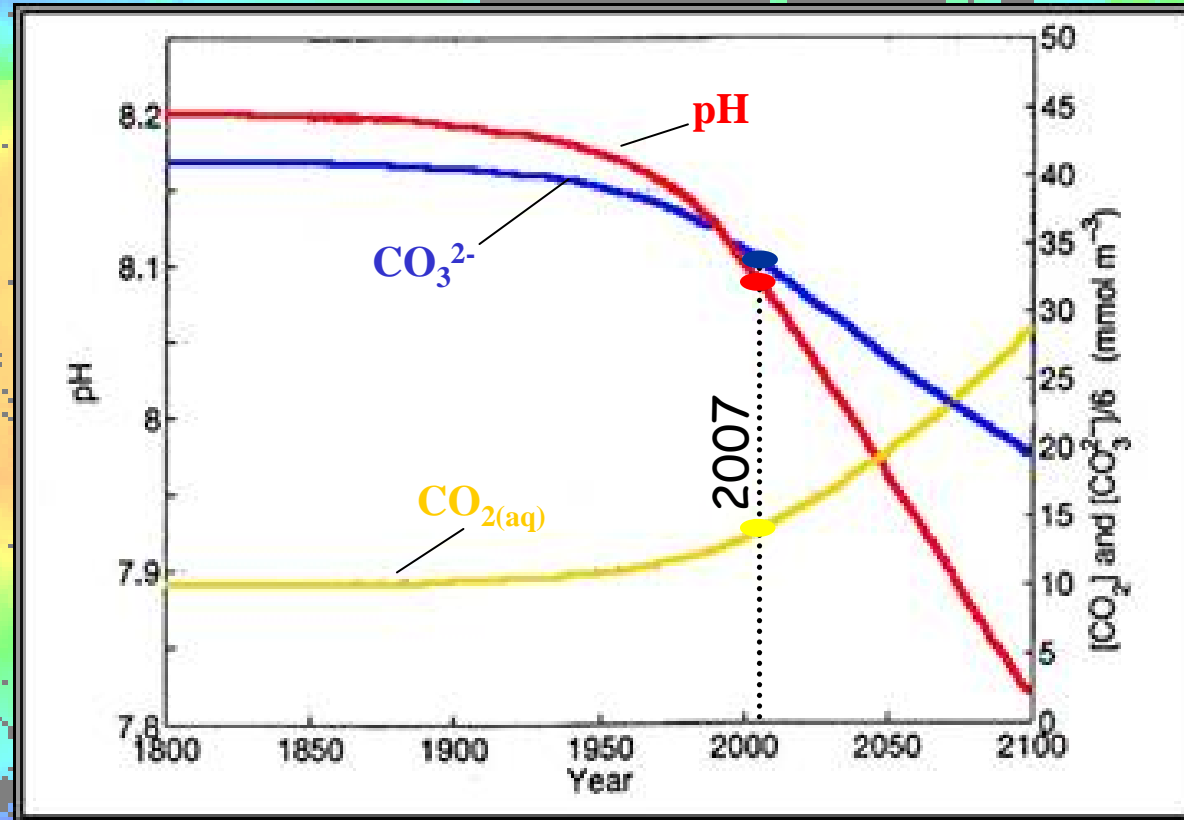
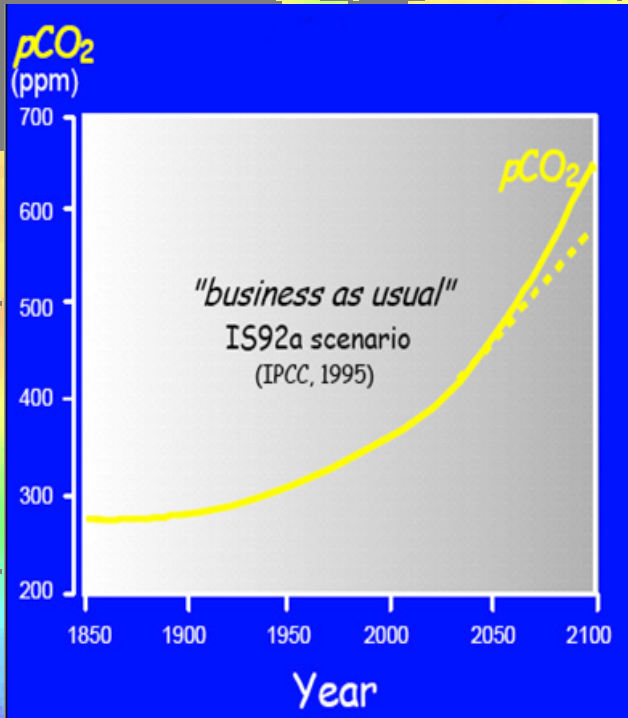
Future change



Photos by Ray Berkelmans, AIMS

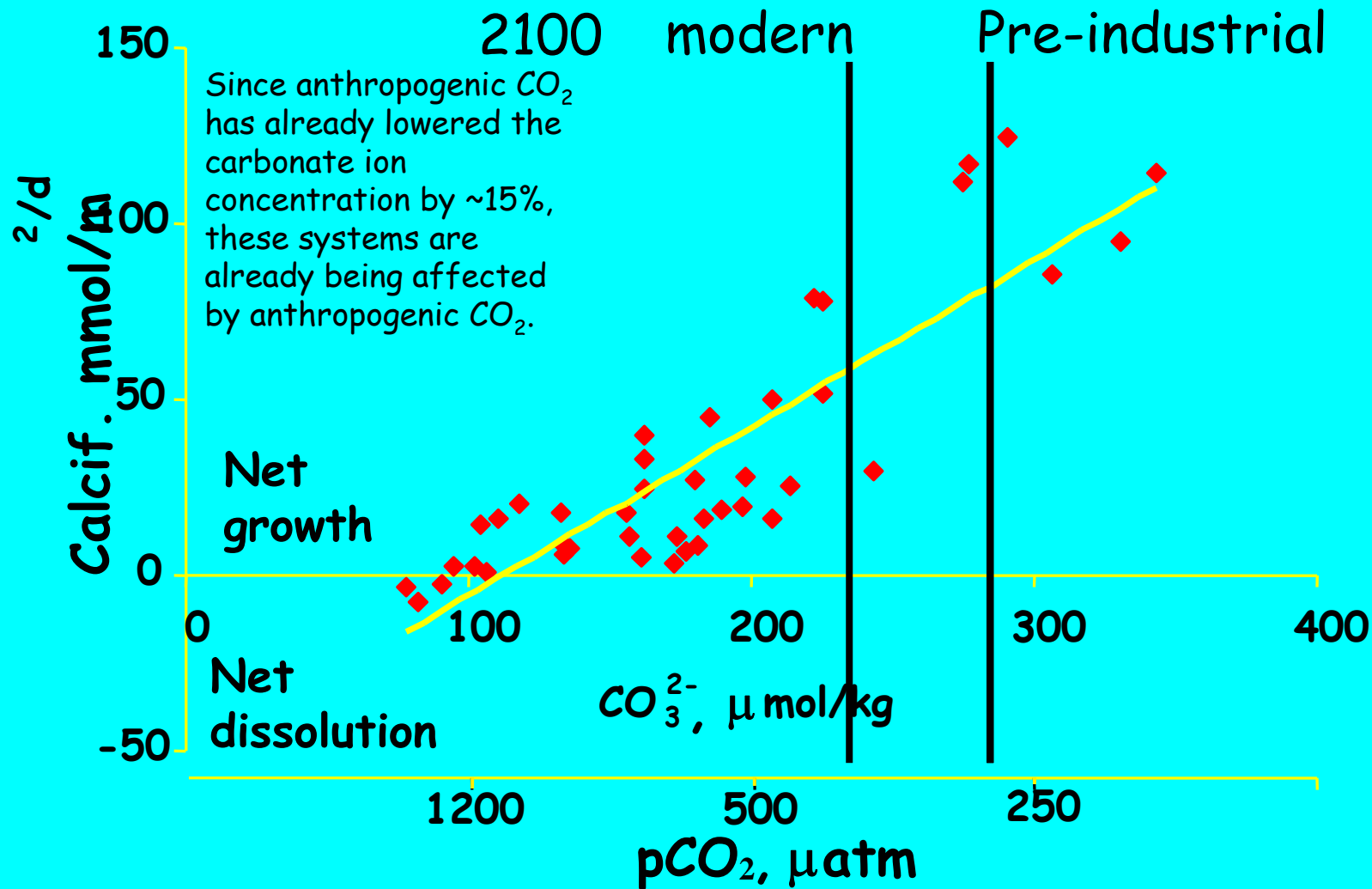


The Oceans and CO₂: Ocean Acidification



After Wolf-Gladrow et al., 1999

Linear Decrease in Calcification with Increasing Ocean CO₂



After Turley et al., 2005

Future Changes in Reef Calcification



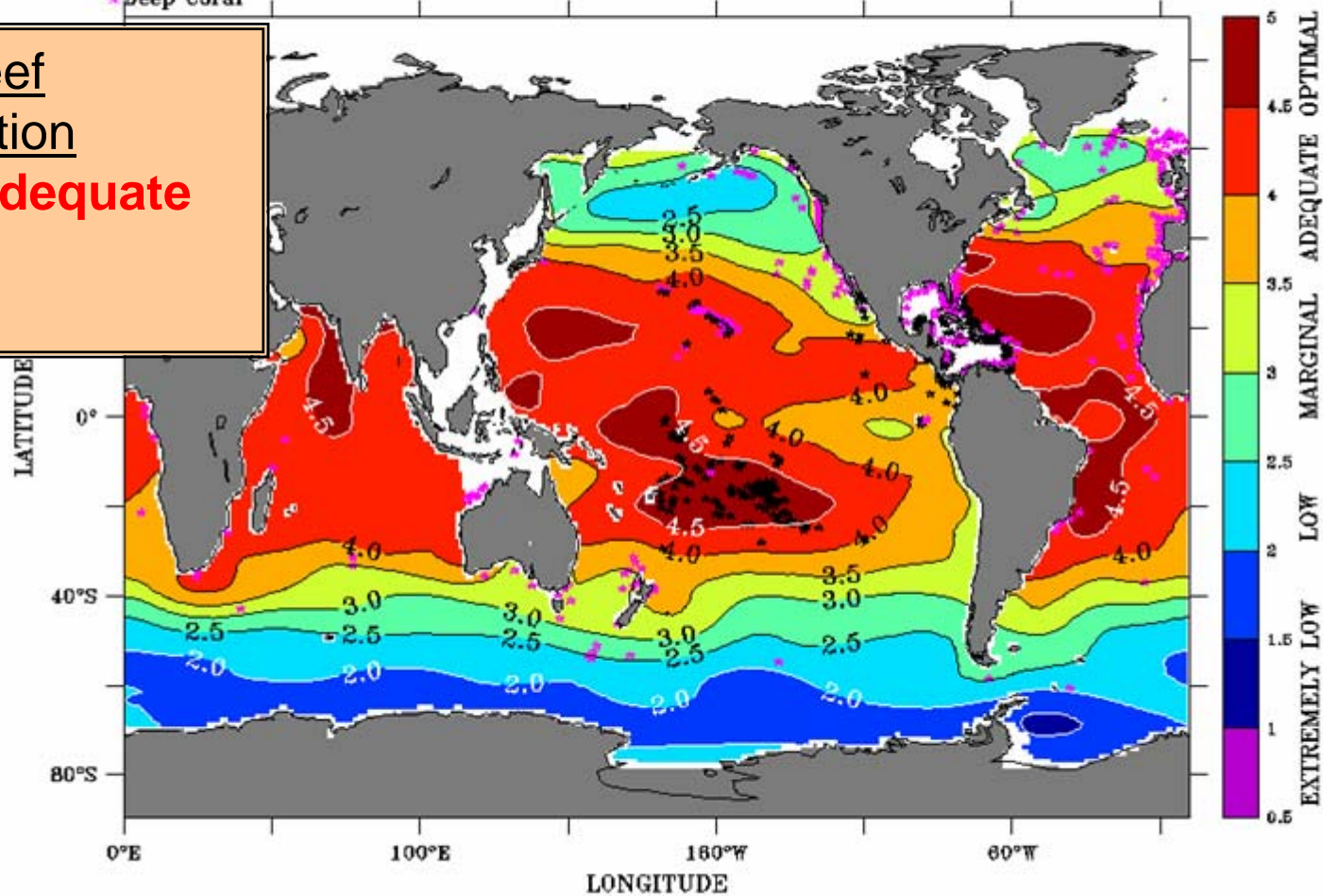
IPCC IS92a 'business-as-usual'

Aragonite Saturation Levels in 1765

* Shallow Coral
* Deep Coral

Coral Reef Calcification

- 1765 Adequate
- 2005
- 2100



After Feely et al (in press) with Modeled Saturation Levels from Orr et al (2005)



Future Changes in Reef Calcification

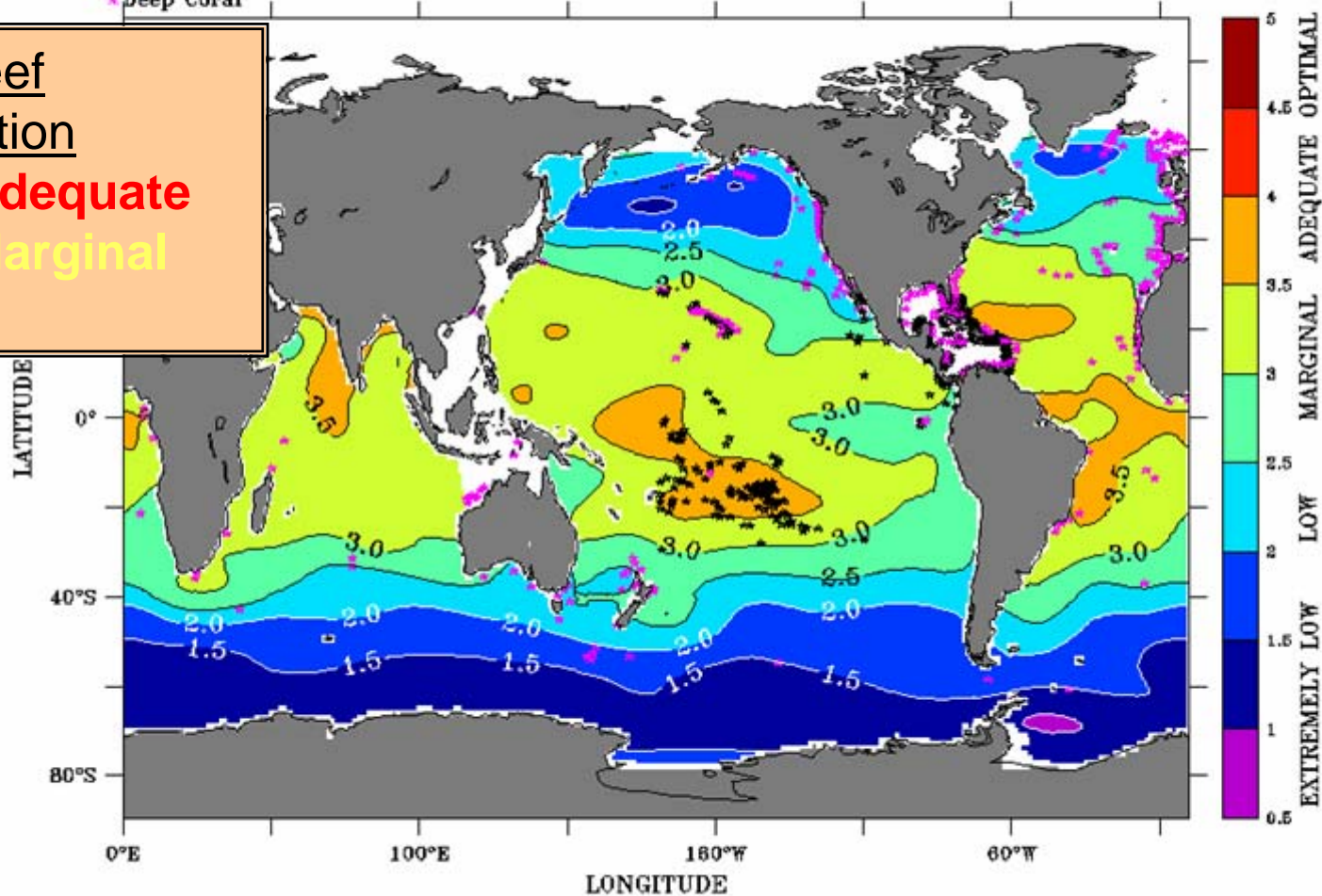
IPCC IS92a 'business-as-usual'

Aragonite Saturation Levels in 2005

* Shallow Coral
* Deep Coral

Coral Reef Calcification

- 1765 **Adequate**
- 2005 **Marginal**
- 2100



After Feely et al (in press) with Modeled Saturation Levels from Orr et al (2005)

Future Changes in Reef Calcification

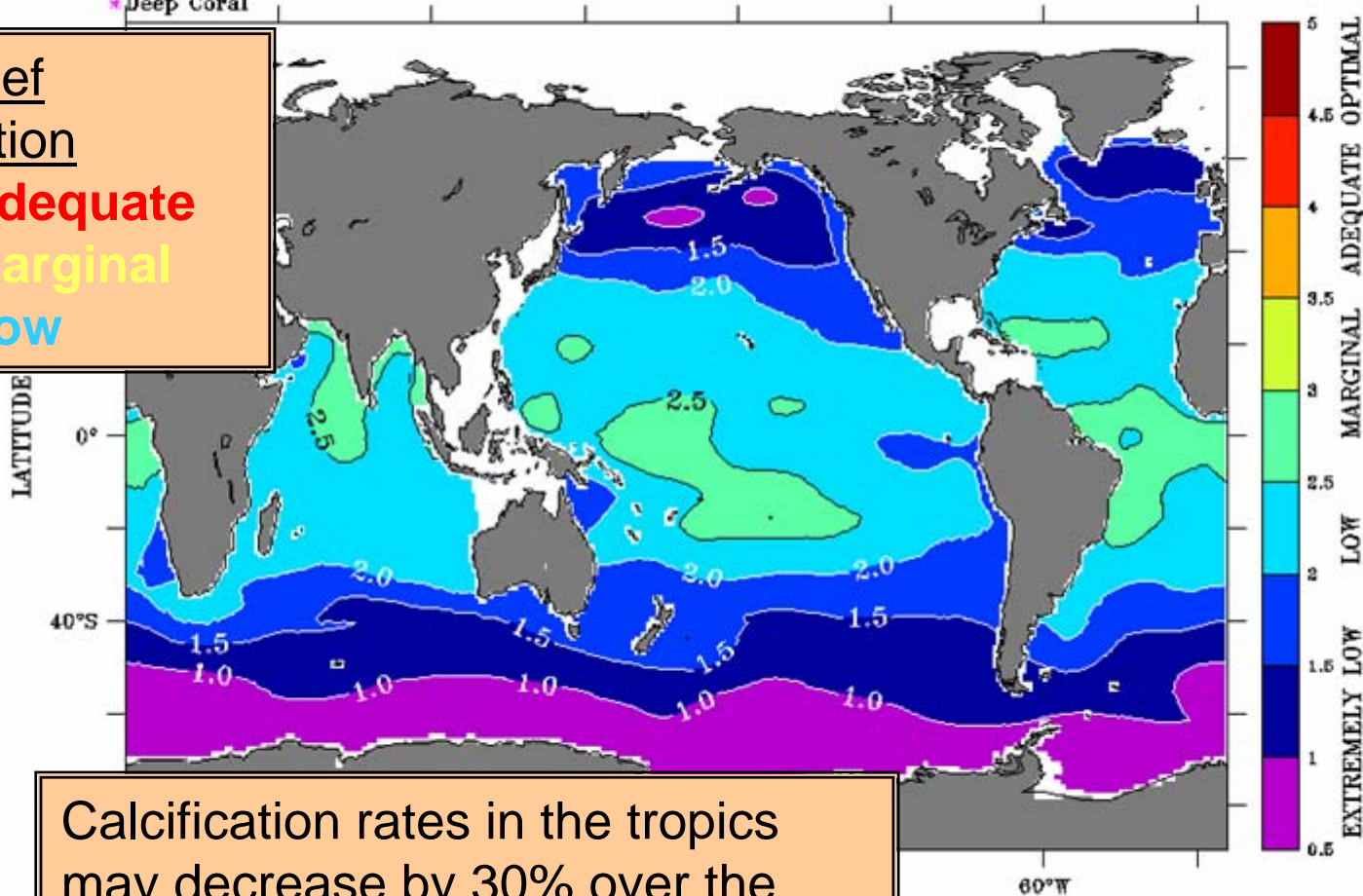
IPCC IS92a 'business-as-usual'

Aragonite Saturation Levels in 2100

*Shallow Coral
*Deep Coral

Coral Reef Calcification

- 1765 **Adequate**
- 2005 **Marginal**
- 2100 **Low**

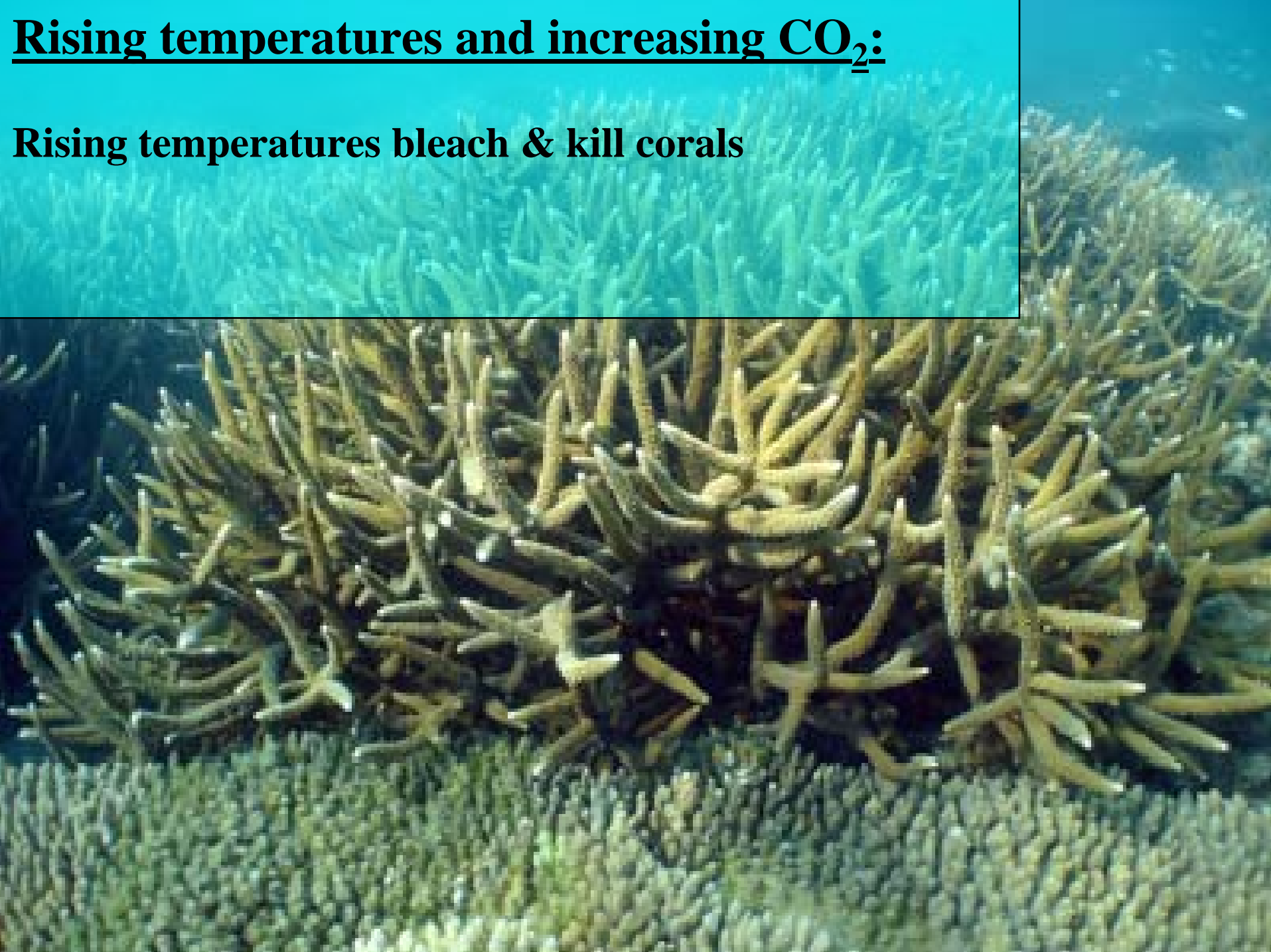


Calcification rates in the tropics may decrease by 30% over the next century

After Feely et al (in press) with Modeled Saturation Levels from Orr et al (2005)

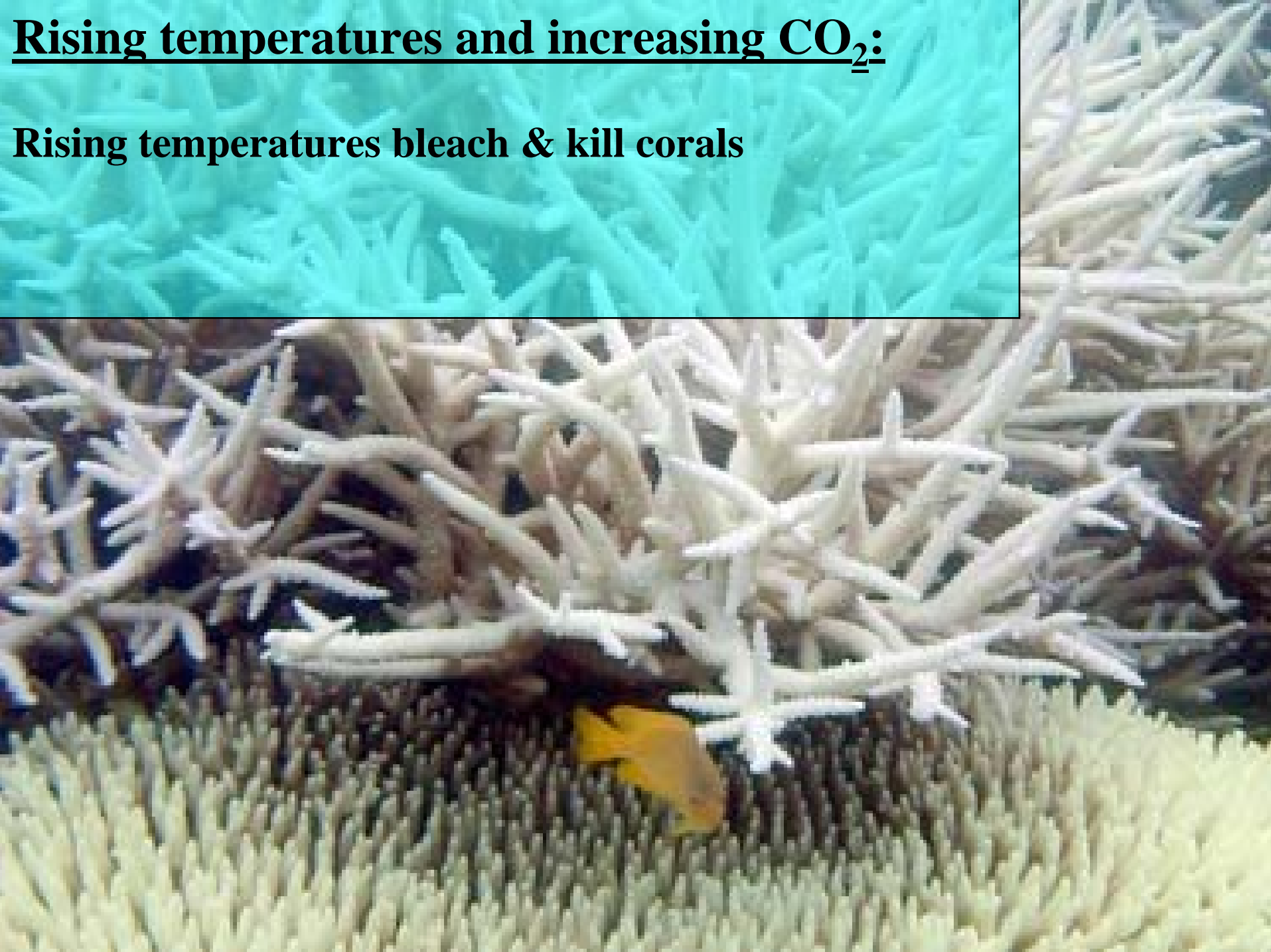
Rising temperatures and increasing CO₂:

Rising temperatures bleach & kill corals



Rising temperatures and increasing CO₂:

Rising temperatures bleach & kill corals



Rising temperatures and increasing CO₂:

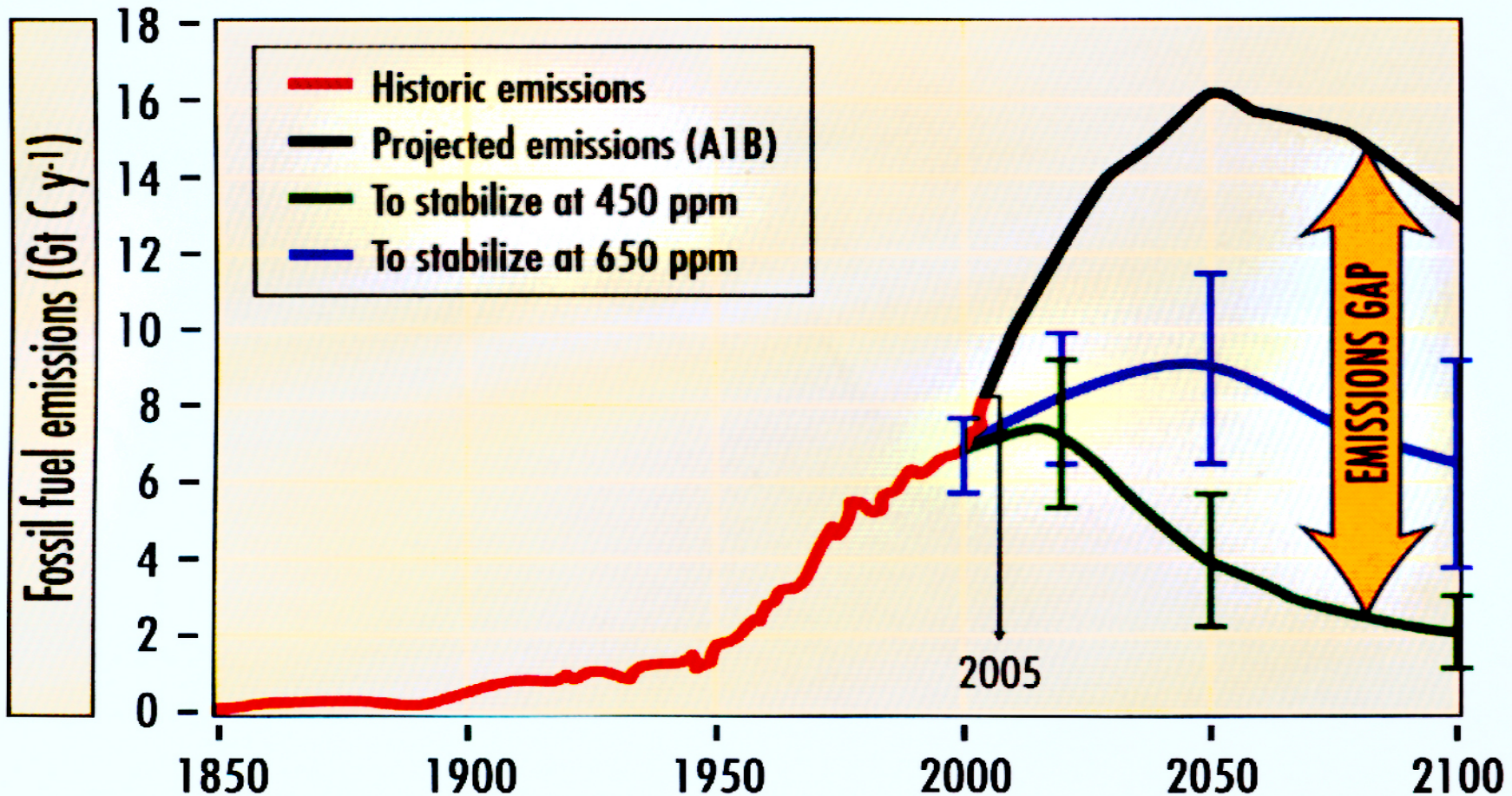
Rising temperatures bleach & kill corals

Rising CO₂ and acidification threaten reef structures



Two Part Solution:

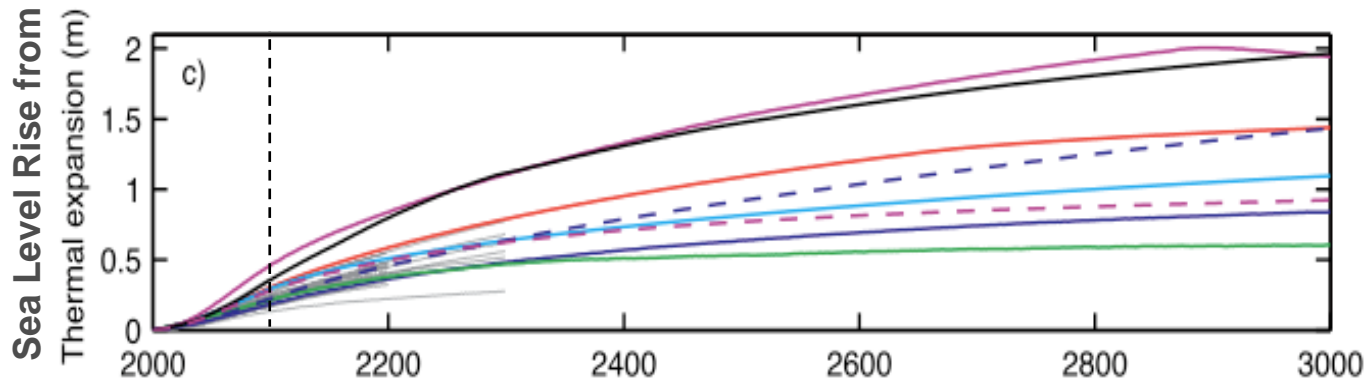
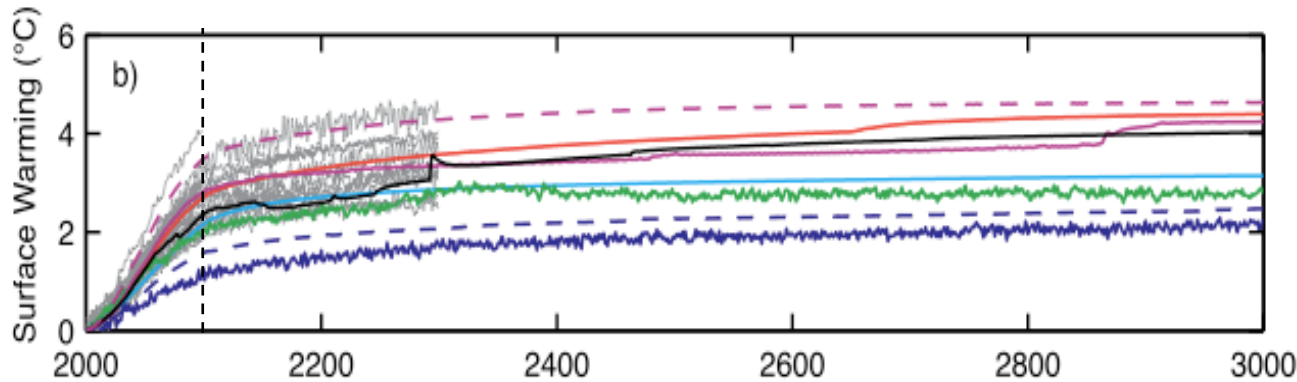
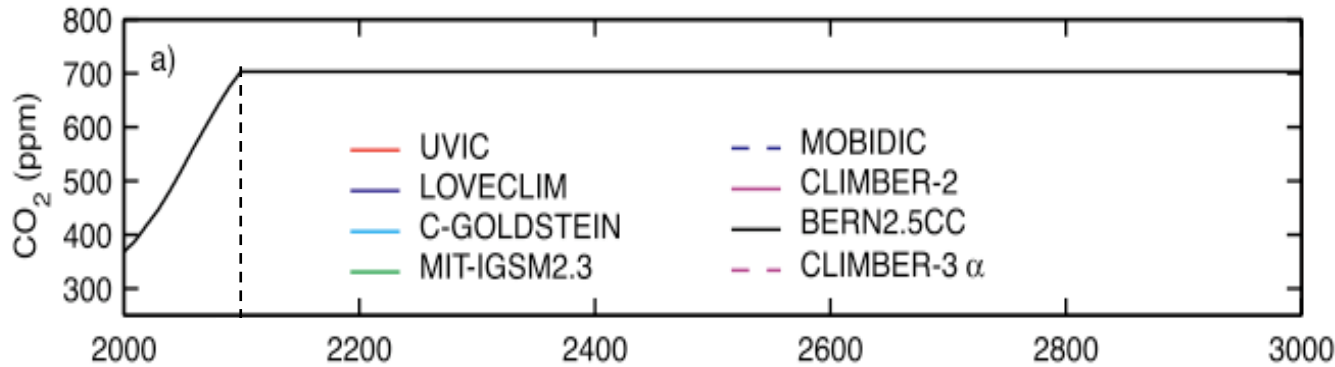
1) Reduce Global CO₂ Emissions



Prepared by Michael R. Raupach

- Stabilizing CO₂ concentrations requires reducing emissions
- Stabilization of greenhouse gas concentrations is the goal of the Framework Convention on Climate Change.

Climate Changes After CO₂ Stabilization



From IPCC 2007 4AR WG-1

“Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.”
- IPCC 4th Assessment Report, Working Group 1

Two Part Solution:

2) Reduce Local Stressors

Reducing Emissions Is Not Enough!

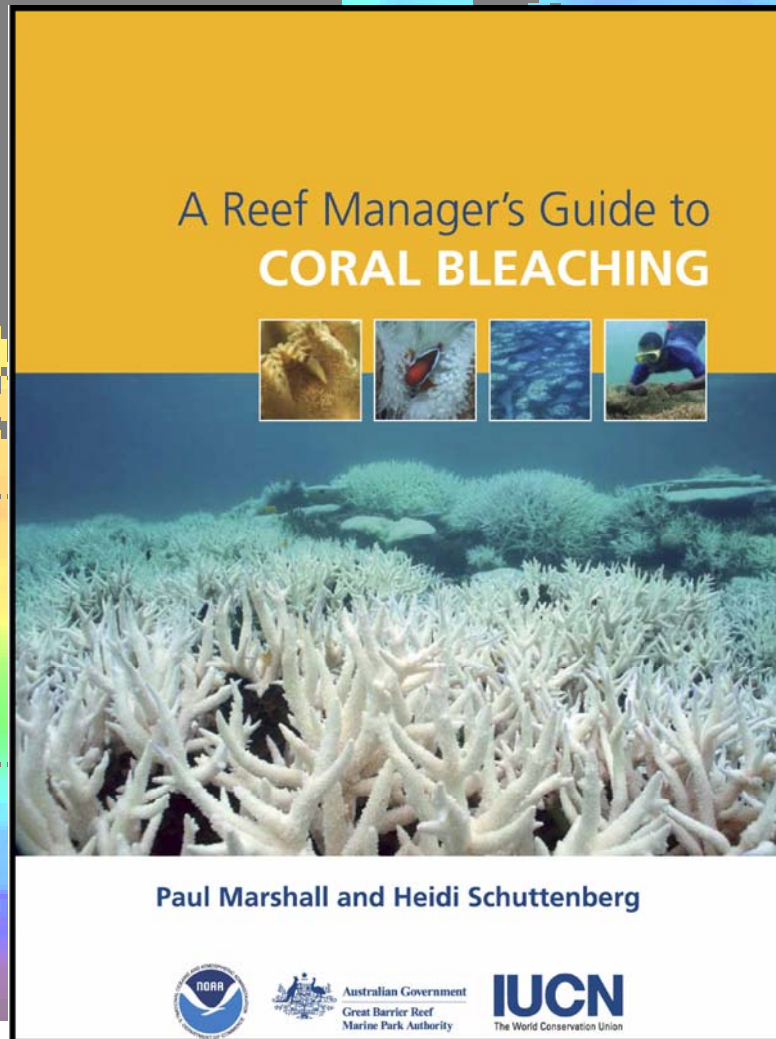
- Human Population Growth
- Overfishing
- Coastal Development
- Lack of Laws / Enforcement
- Sedimentation (unnatural)
- Lack of Education
- Nutrient Enrichment
- Algal Competition
- Climate Change / Bleaching
- Habitat Destruction
- Tourism

2004 Survey: 276 Coral Reef Scientists
Kleypas and Eakin (2007)



Two Part Solution:

2) Reduce Local Stressors



- **Driven by US Coral Reef Task Force**
- **Result of international workshop, research, and planning**
- **Addresses local reef management in light of changing climate**

Available at
coralreef.noaa.gov

Reef Manager's Guide: Training Workshops



Responding to Climate Change: A Workshop for Coral Reef Managers

Practical Training Based on "A Reef Manager's Guide to Coral Bleaching"

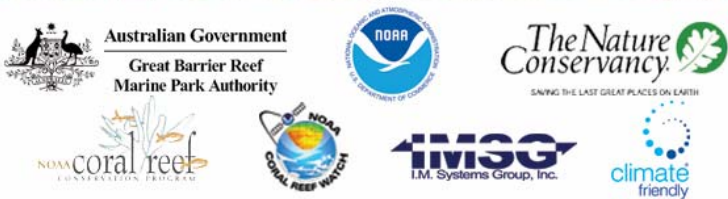
Pago Pago, American Samoa
27-30 August 2007



- **First course Lady Elliot Island, Australia (July 2007)**



- **Second course HERE next week**



US CRTF Resolution: Coral Reefs and Climate Change



Highlights

1. Reaffirms threat of climate change to coral reefs;
2. Recognizes members and partner actions to reduce greenhouse gas emissions;
3. Need to assess coral reef vulnerability of coral reefs to climate change;
4. Need adaptation strategies to promote resilience;
5. Affirms Marine Protected Area (MPA) networks as important tools;
6. Recognizes island and coastal communities as especially vulnerable;
7. Forms a standing Climate Change Working Group (CCWG);



US CRTF Resolution: Coral Reefs and Climate Change

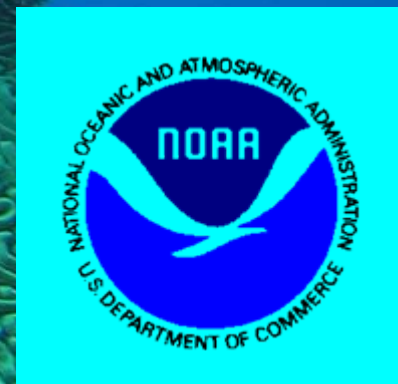


Highlights

8. Charges the CCWG to
 - a) develop a toolbox of management actions;
 - b) improve understanding of ocean acidification;
 - c) expand education and outreach;
 - d) cooperate with other climate-focused programs (i.e., CCSP);
 - a) report to CRTF.
9. Encourages federal partners to address impacts of climate change;
10. Supports development of local action strategies (LAS);
11. Supports development coral bleaching response plans for all jurisdictions;
12. Make USCRTF meetings and documents carbon neutral.



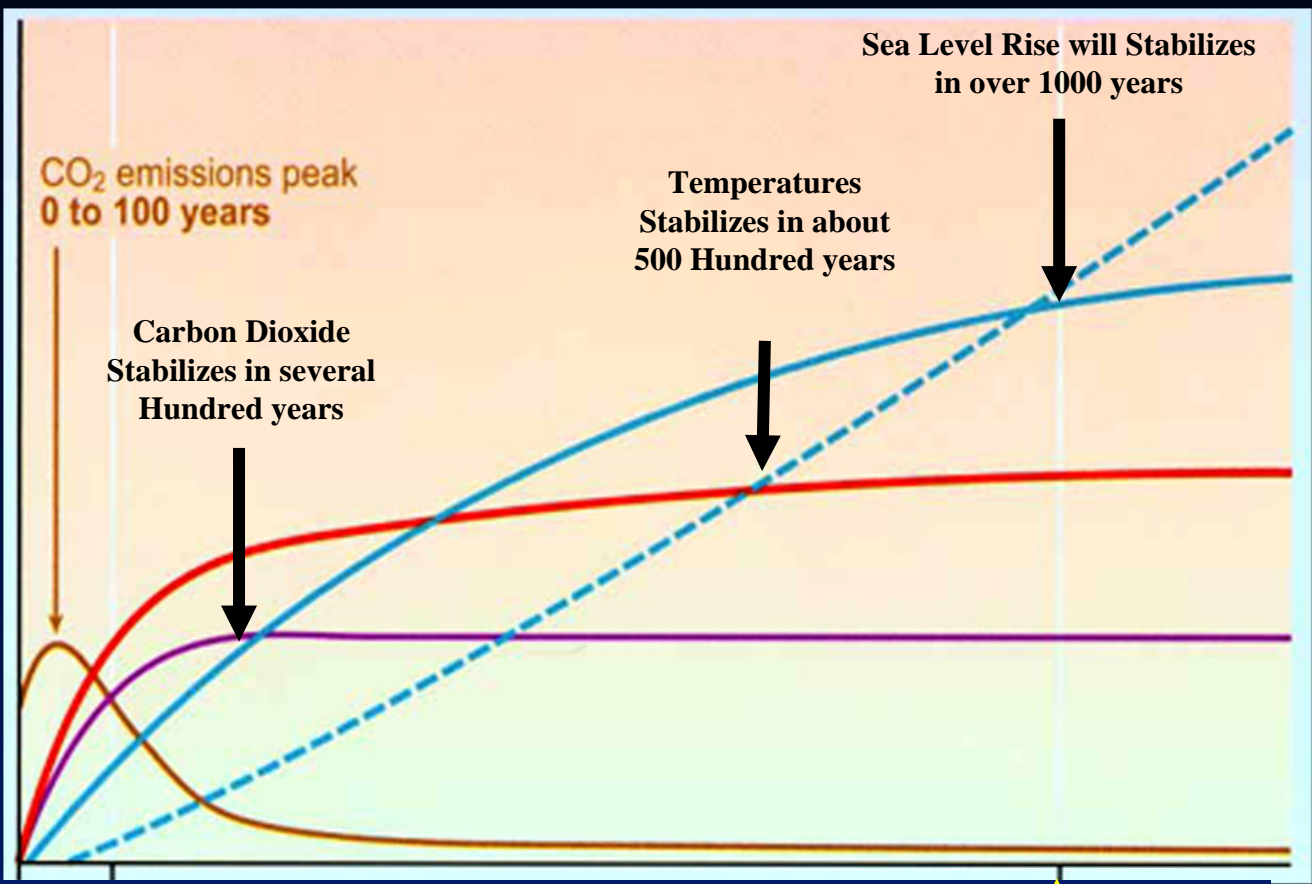
Thank You



There is a fundamental asymmetry between the time scales that the climate system reacts to increases in greenhouse gases and the time scales to recover from such increases.

Magnitude

Time to Equilibrium



Sea-level rise due to ice melting:
SEVERAL MILLENNIA

Sea-level rise due to thermal expansion:
CENTURIES TO MILLENNIA

Temperature Stabilization:
A FEW CENTURIES

CO₂ Stabilization:
100 to 300 YEARS

CO₂ Emissions

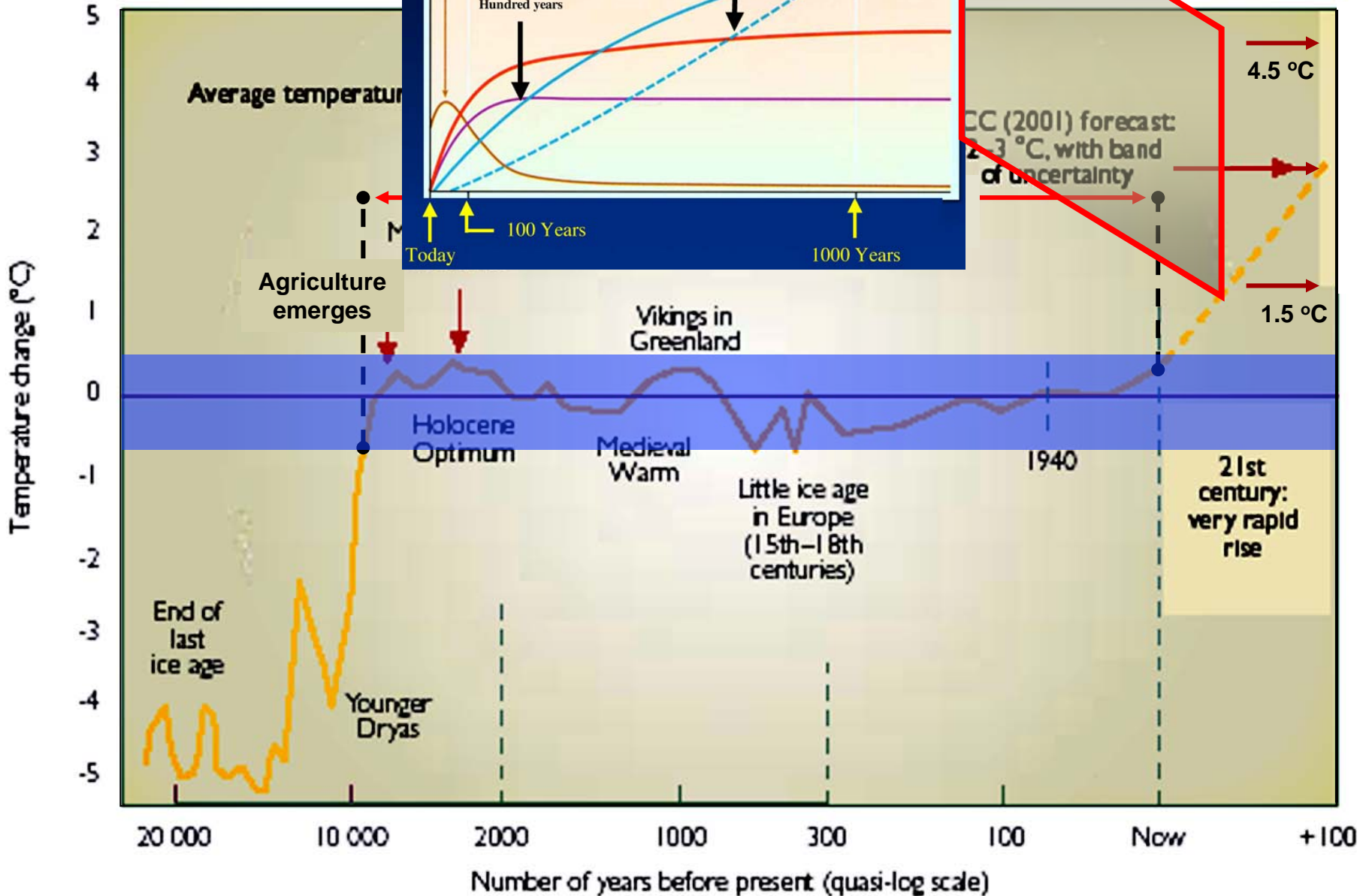
Today

100 Years

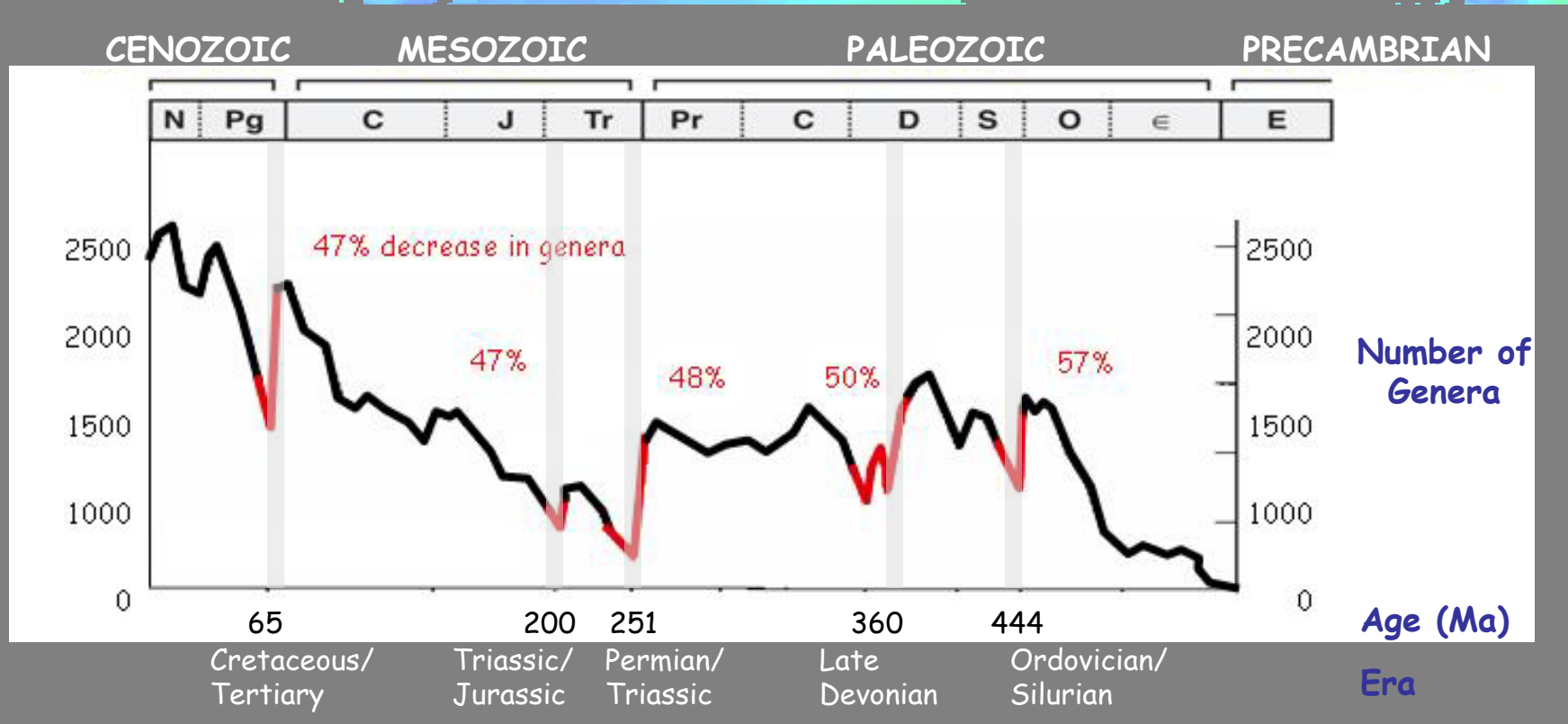
1000 Years

The Last 20,000 Years of Human Societies. Is this a History of Human Societies Flourishing?

Development of Human Societies. Is this a History of Human Societies Flourishing?

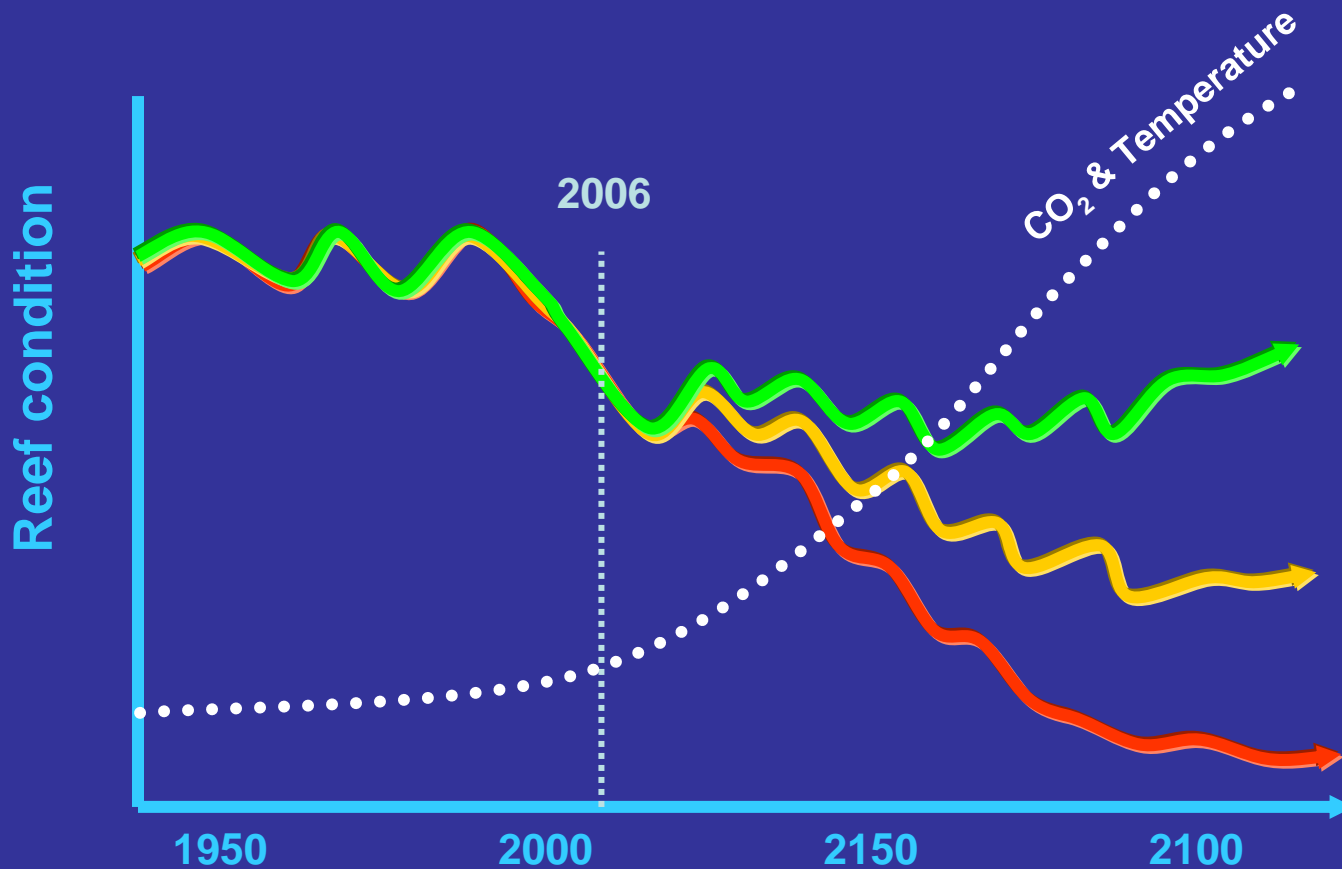


Coral Reefs and Major Extinctions



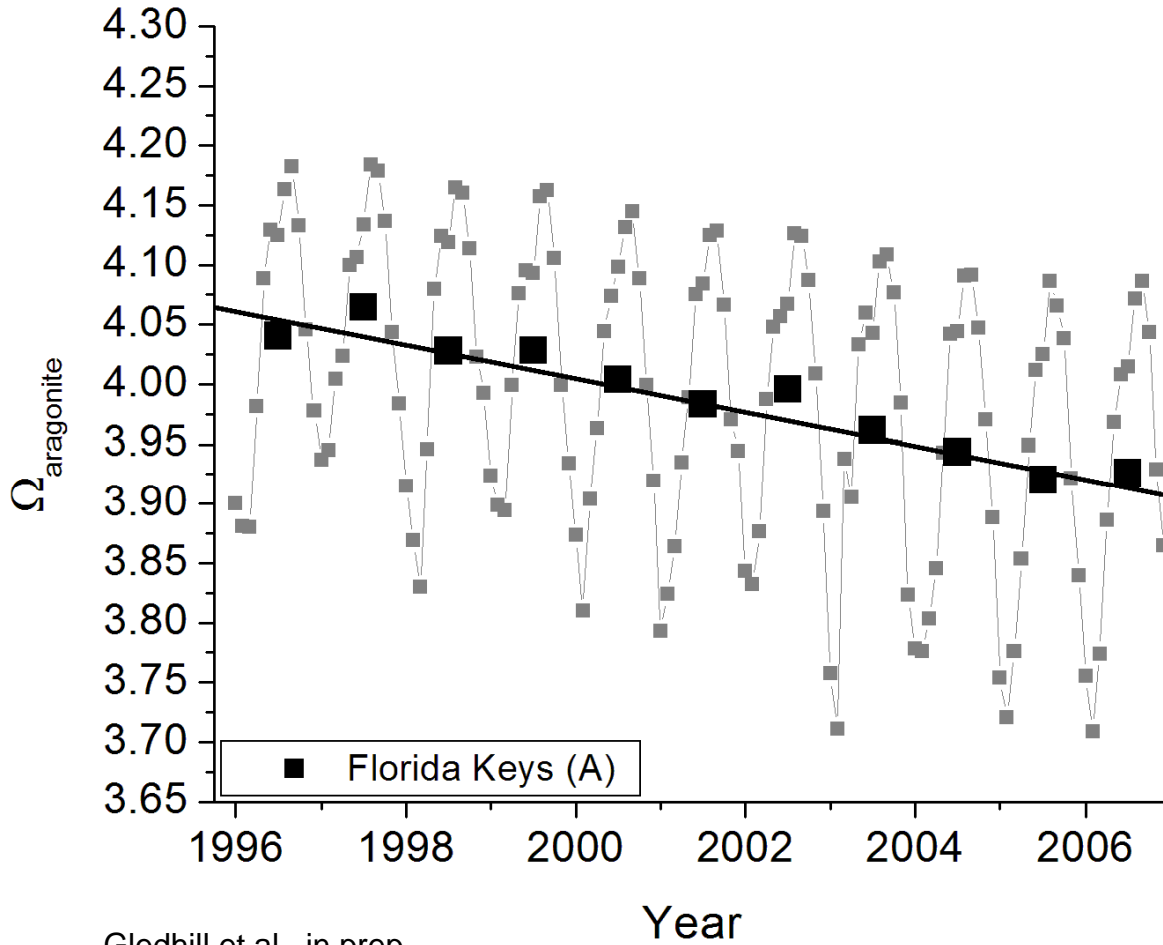
From Signor (1990)

Deciding the future for coral reefs

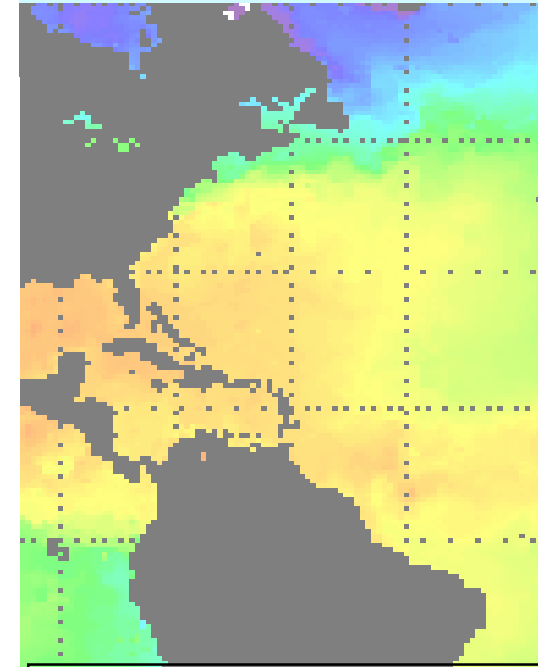


Ability of Coral Reefs to Calcify

Aragonite saturation state



Gledhill et al., in prep.



Calcification rates in the tropics may decrease by 30% over the next century