

- **CLIMATE CHANGE CURE?:** *By running the flue gas from Moss Landing's mammoth smokestacks through ocean water, a new company can make cement from carbon dioxide pollution.*
- The turbines at Moss Landing power plant on the California coast burn through natural gas to pump out more than 1,000 megawatts of electric power. The 700-degree Fahrenheit (370-degree Celsius) fumes left over contain at least 30,000 parts per million of carbon dioxide (CO<sub>2</sub>)—.

Today, this flue gas wafts up and out of the power plant's enormous smokestacks, but by simply bubbling it through the nearby seawater, a new California-based company called Calera says it can use more than 90 percent of that CO<sub>2</sub> to make something useful: [cement](#).

It's a twist that could make a polluting substance into a way to reduce greenhouse gases. Cement, which is mostly commonly composed of calcium silicates, requires heating limestone and other ingredients to 2,640 degrees F (1,450 degrees C) by burning fossil fuels and is the third largest source of [greenhouse gas](#) pollution in the U.S., according to the U.S. Environmental Protection Agency. Making one ton of cement results in the emission of roughly one ton of CO<sub>2</sub>—and in some cases much more.

Calera's process takes the idea a step forward by storing the CO<sub>2</sub> in a useful product. The U.S. used more than 122 million metric tons of Portland cement in 2006, according to the Portland Cement Association (PCA), an industry group, and [China](#) used at least 800 million metric tons.

The Calera process essentially mimics [marine cement](#), which is produced by coral when making their shells and reefs, taking the calcium and magnesium in seawater and using it to form carbonates at normal temperatures and pressures. "We are turning CO<sub>2</sub> into carbonic acid and then making carbonate," Constantz says. "All we need is water and pollution."

# Global Change and Oceans

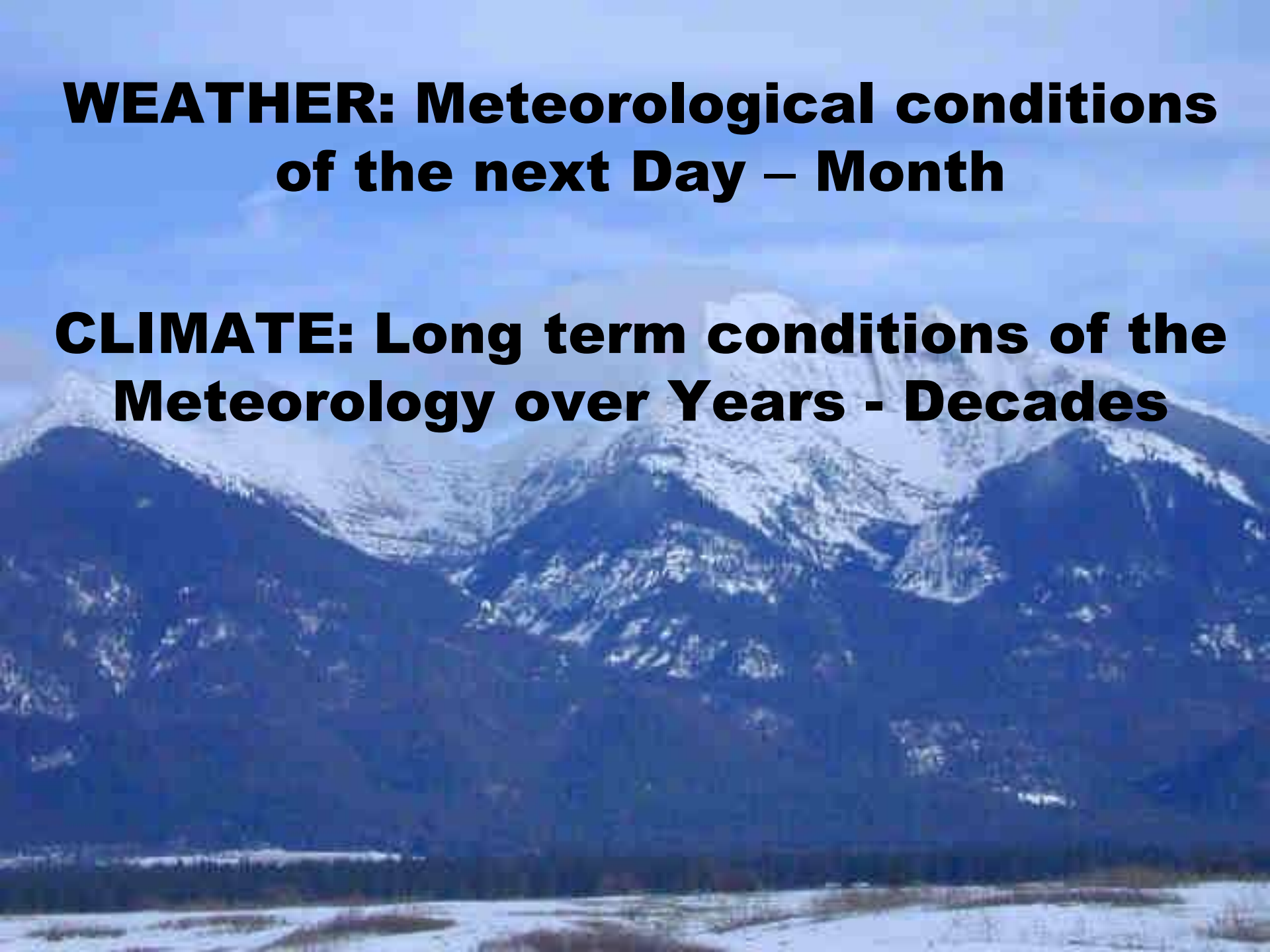
A scenic view of a coastline. In the foreground, a large, dark tree trunk is visible on the right side. The ocean is a vibrant blue-green color, with white-capped waves breaking. Several surfers are visible in the water, riding the waves. In the background, a sandy beach is visible, followed by a line of trees and a few buildings. The sky is a clear, light blue.

**Textbook pages 106 - 127**

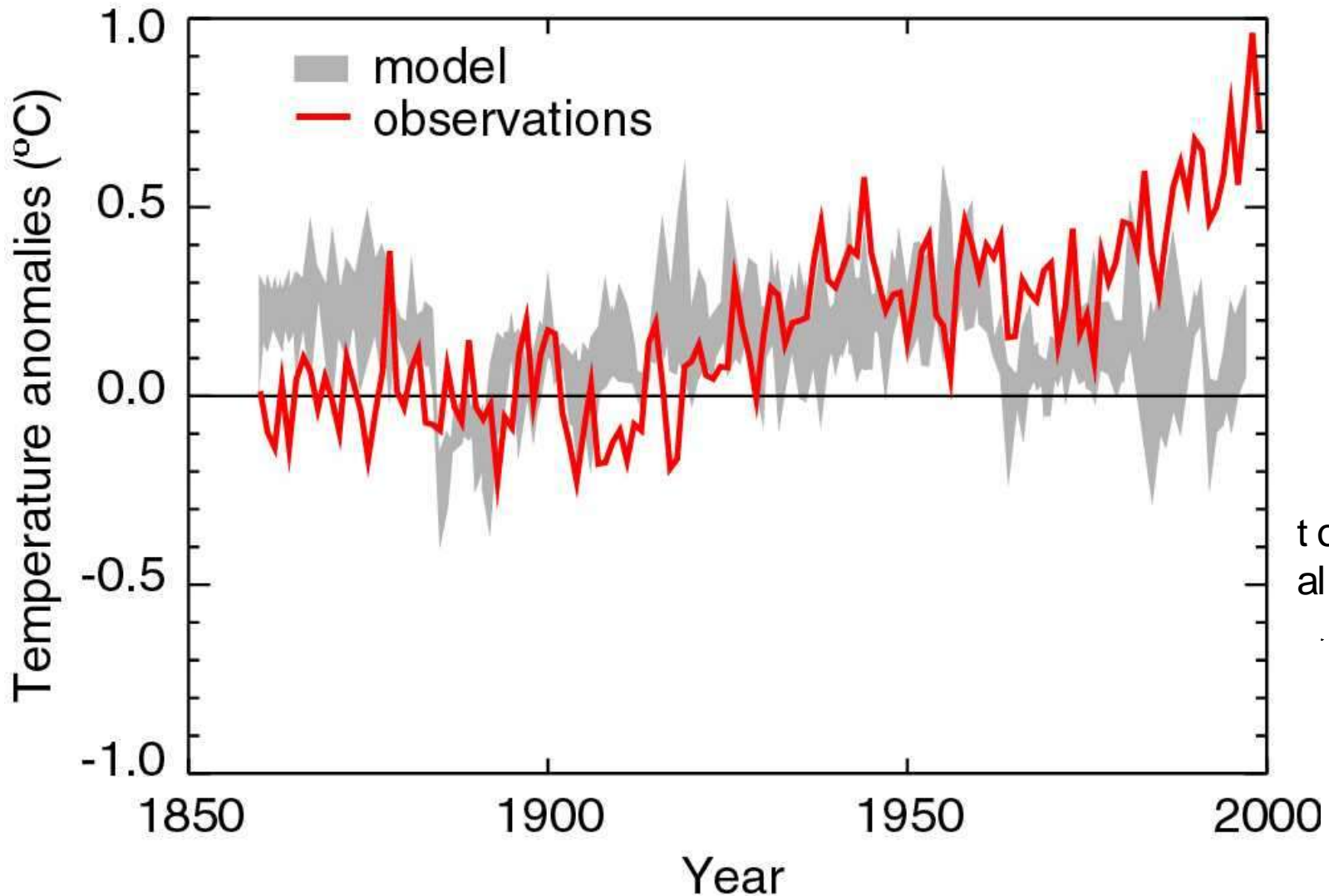
**APR 20 2003**

**WEATHER: Meteorological conditions  
of the next Day – Month**

**CLIMATE: Long term conditions of the  
Meteorology over Years - Decades**



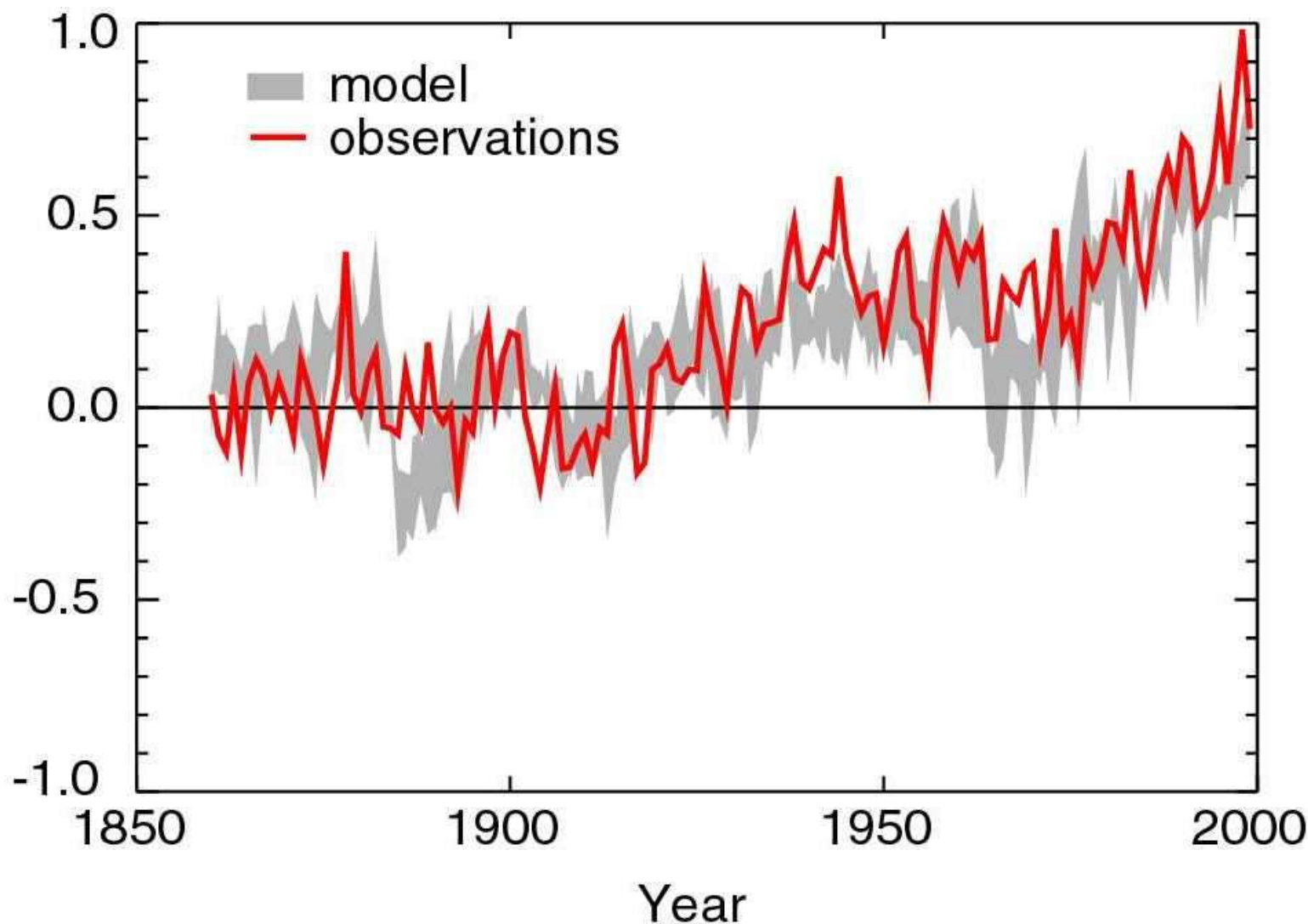
**“Simulations of the response to natural forcings alone ... do not explain the warming in the second half of the century”** **SPM**



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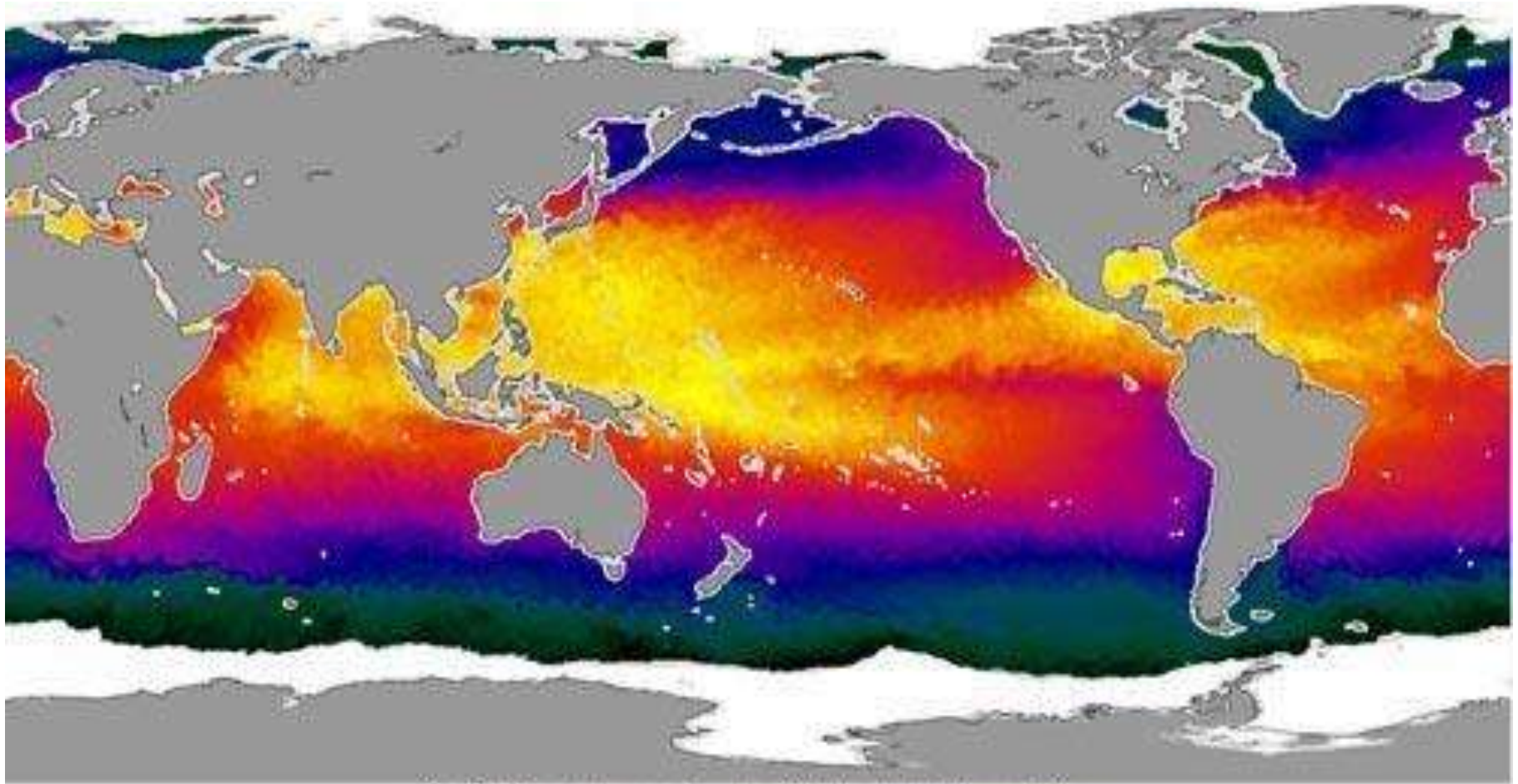
**“..model estimates that take into account both greenhouse gases and sulphate aerosols are consistent with observations over this period”**

**SPM**



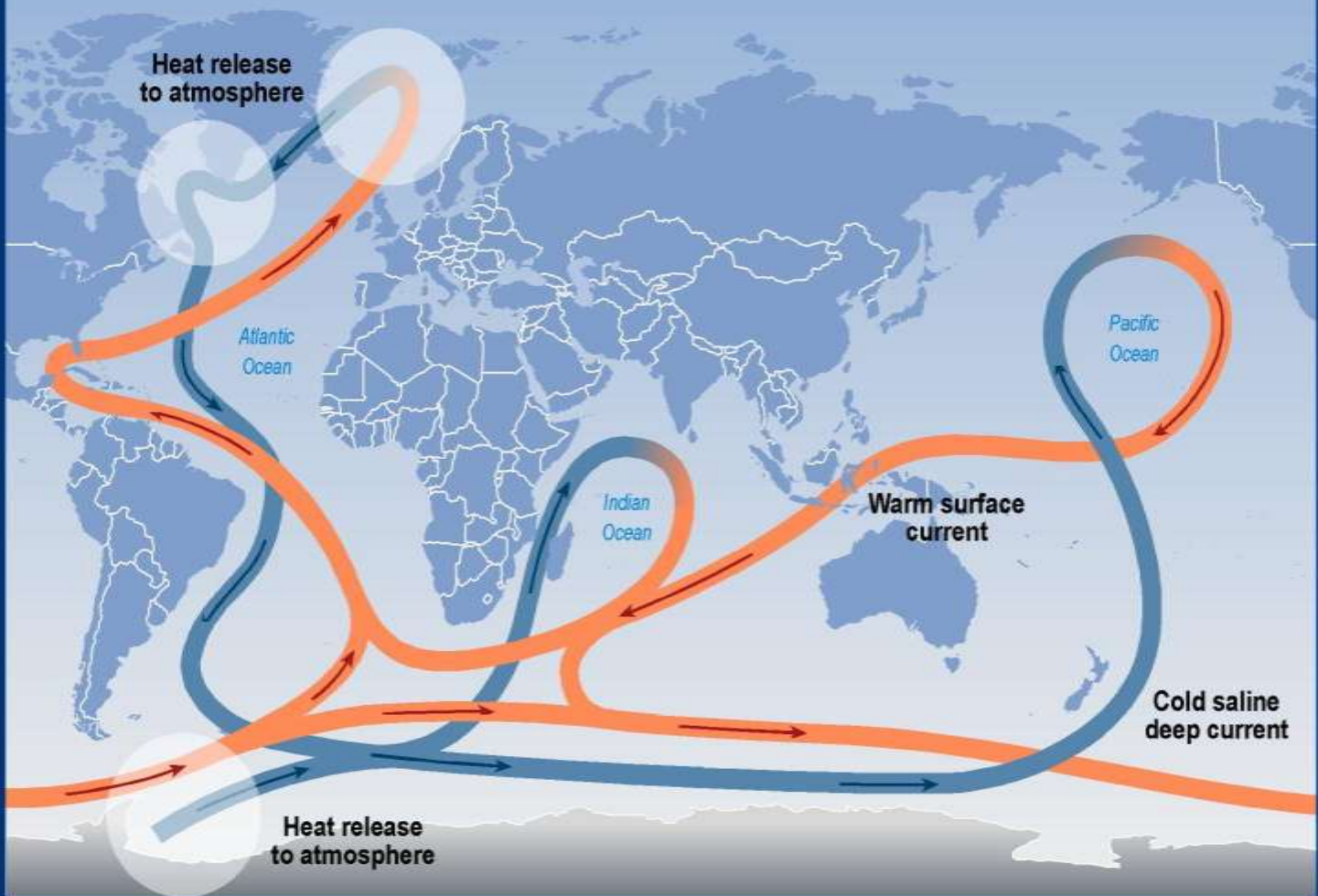
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# OCEAN SURFACE TEMPERATURES



70% OF LAND IS IN NORTHERN HEMISPHERE

# Great ocean conveyor belt



SYR - FIGURE 4-2

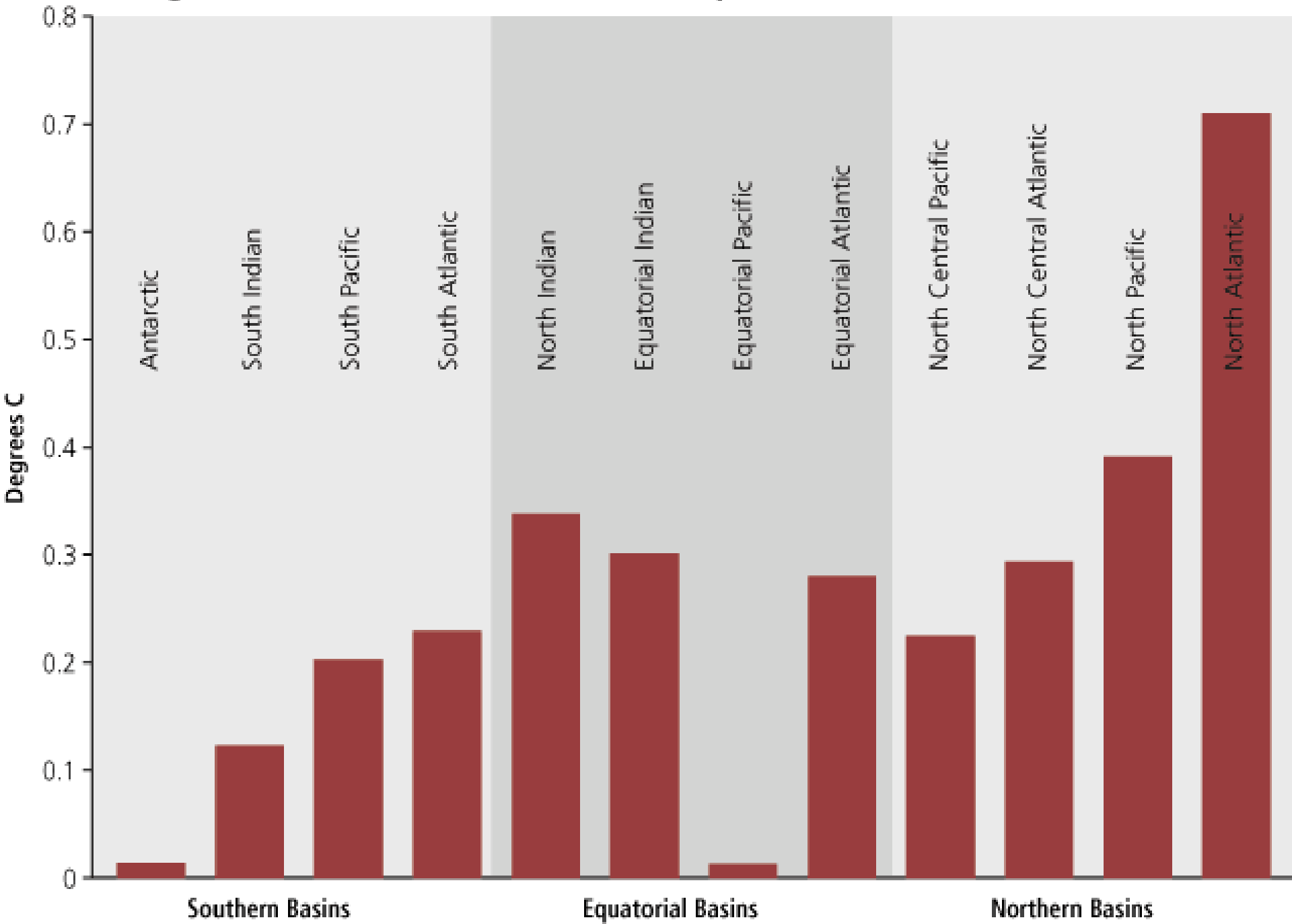
# Comparison of the heat balance of the climate system

Levitus et al (2001). Science Vol. 292, pp. 268.

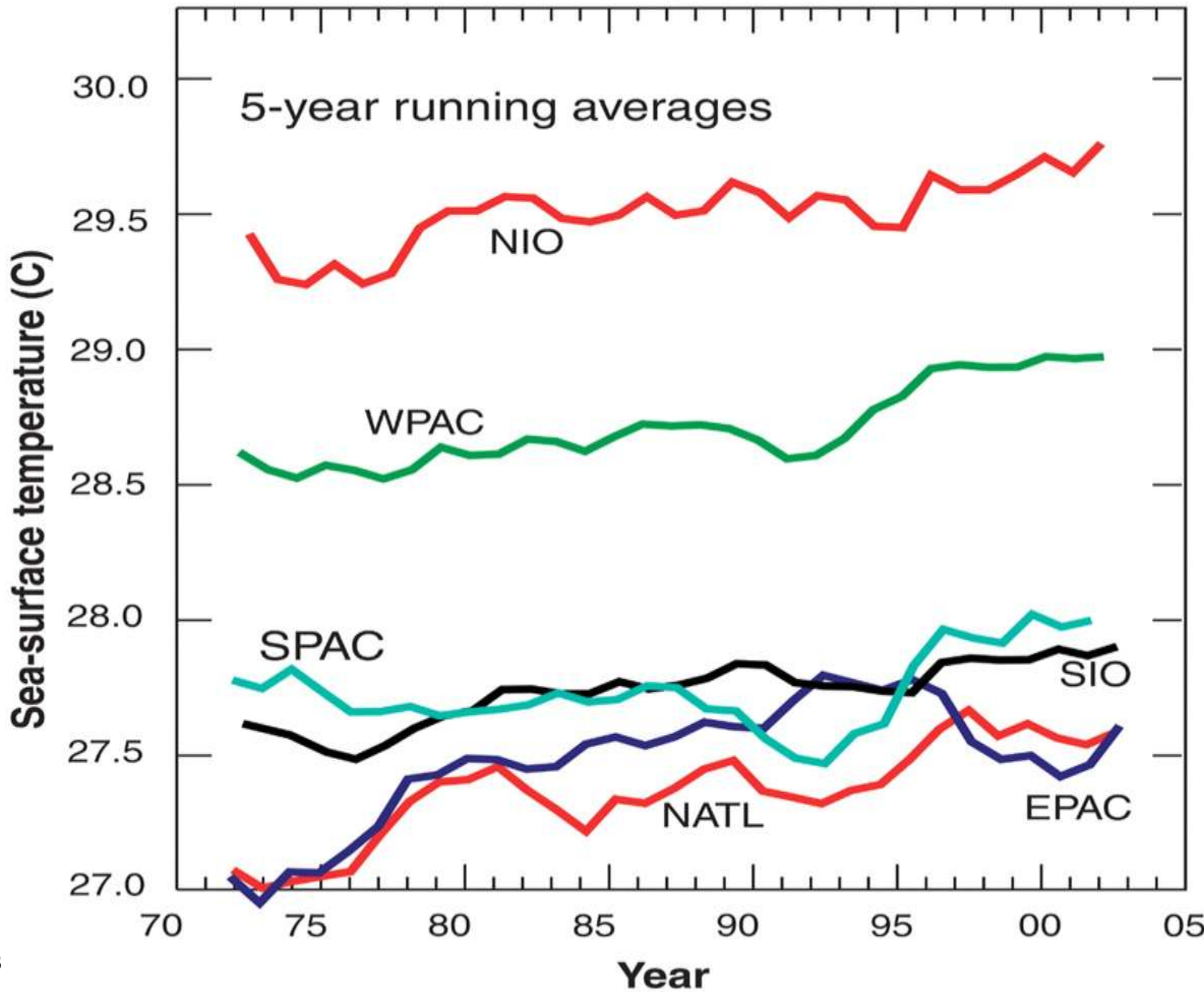
Component of the climate system and source of data	Time period of change	Observed or estimated change	Heat content increase or total heat of fusion	%
World ocean	1955-1996	Observed temperature increase	$18.2 \times 10^{22}$ J	<b>90%</b>
Global atmosphere	1955-1996	Observed temperature increase	$6.6 \times 10^{21}$ J	3
Decrease in the mass of continental glaciers	1955-1996	-	$8.1 \times 10^{21}$ J	4
Decrease in Antarctic sea ice extent	1950s-1970s	Estimated 311-km reduction in sea ice edge	$3.2 \times 10^{21}$ J	1
Mountain glacier decrease	1961-1997	$3.7 \times 10^3$ km decrease in mountain glacier ice volume	$1.1 \times 10^{21}$ J	.5
Decrease in Northern Hemisphere sea ice extent	1978-1996	Areal change based on satellite measurements	$4.6 \times 10^{19}$ J	.02
Decrease in Arctic perennial sea ice volume	1950s-1990s	40% decrease in sea ice thickness	$2.4 \times 10^{19}$ J	.01



# Change (SeaWiFS-CZCS) Sea Surface Temperature [1979 – 2002]

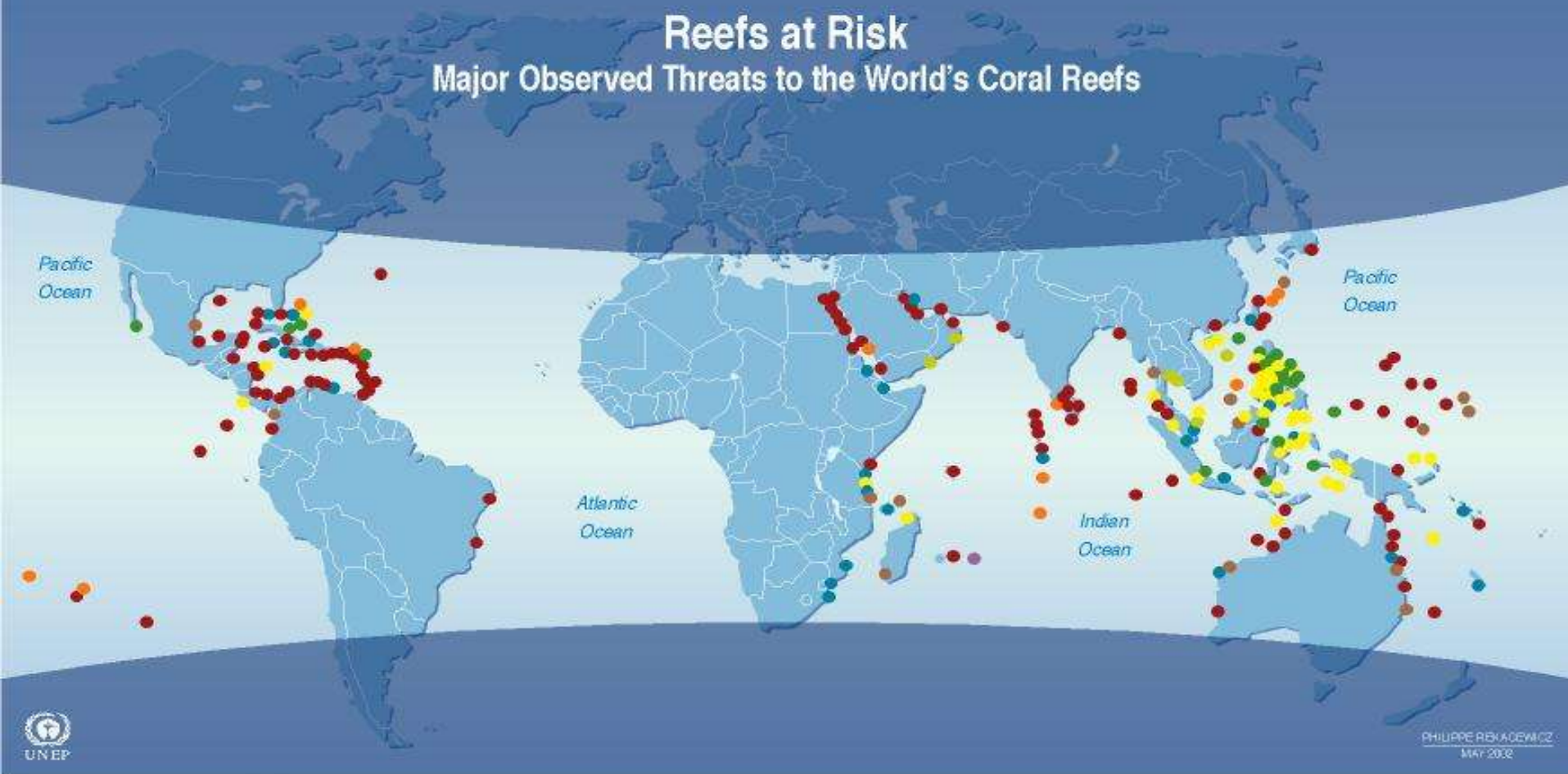


# Summer SST by Ocean Basin



# Reefs at Risk

## Major Observed Threats to the World's Coral Reefs

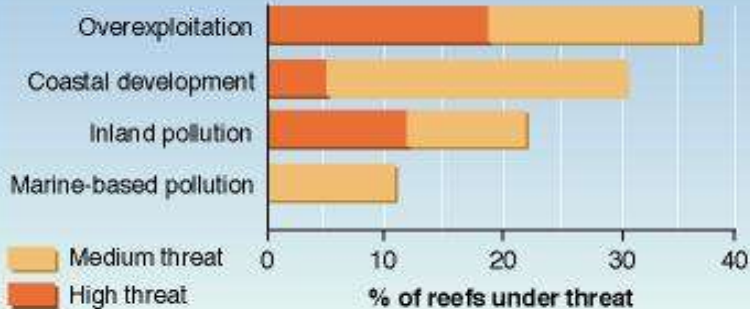


PHILIPPE RENACIEWICZ  
MAY 2002

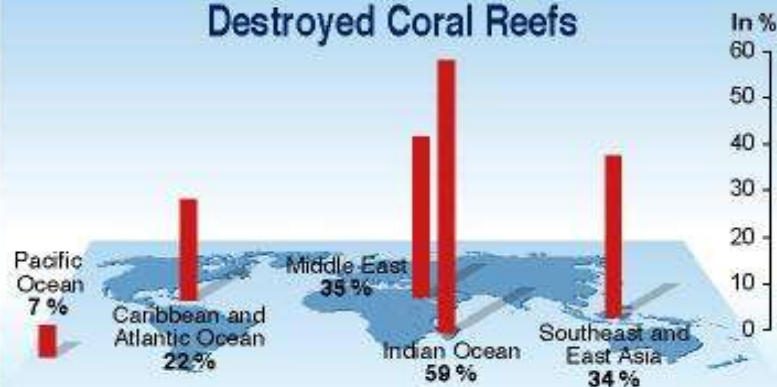
### Categories

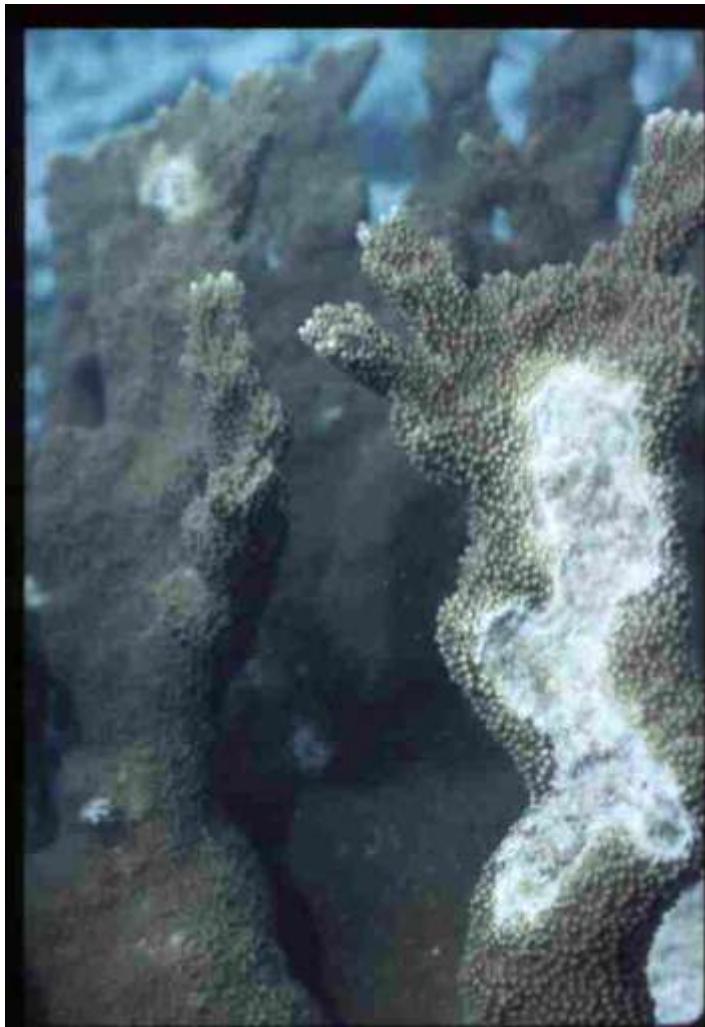
- Tourism
- Poison fishing
- Overexploitation
- Sedimentation
- Coral harvesting
- Dynamite fishing
- Pollution

### Major Threats to Reefs



### Destroyed Coral Reefs





**BLEACHING OF  
CORAL REEFS BY  
OCEAN TEMPS >  
85deg**

# Ocean acidification

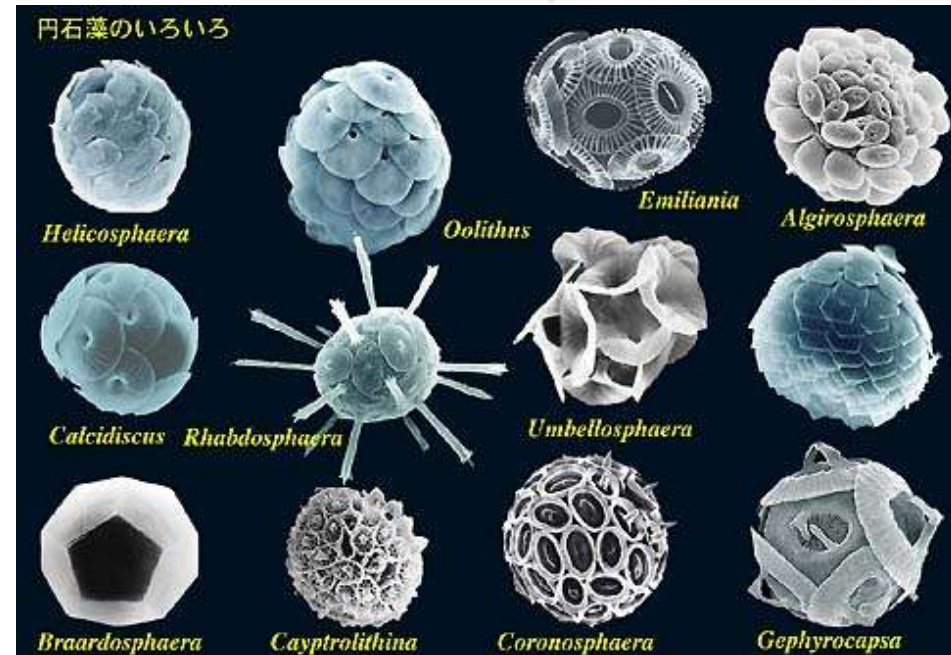
- $\text{CO}_2$  is corrosive to the shells and skeletons of many marine organisms

## Corals



Photo: Missouri Botanical Gardens

## Calcareous plankton

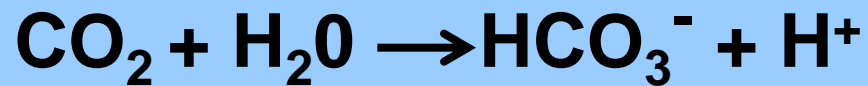


<http://www.biol.tsukuba.ac.jp/~inouye>

# Ocean Acidification

Over the last 200 years, about **50%** of all CO<sub>2</sub> produced on earth has been **absorbed by the ocean**. (Royal Society 6/05)

Dissolves in sea water



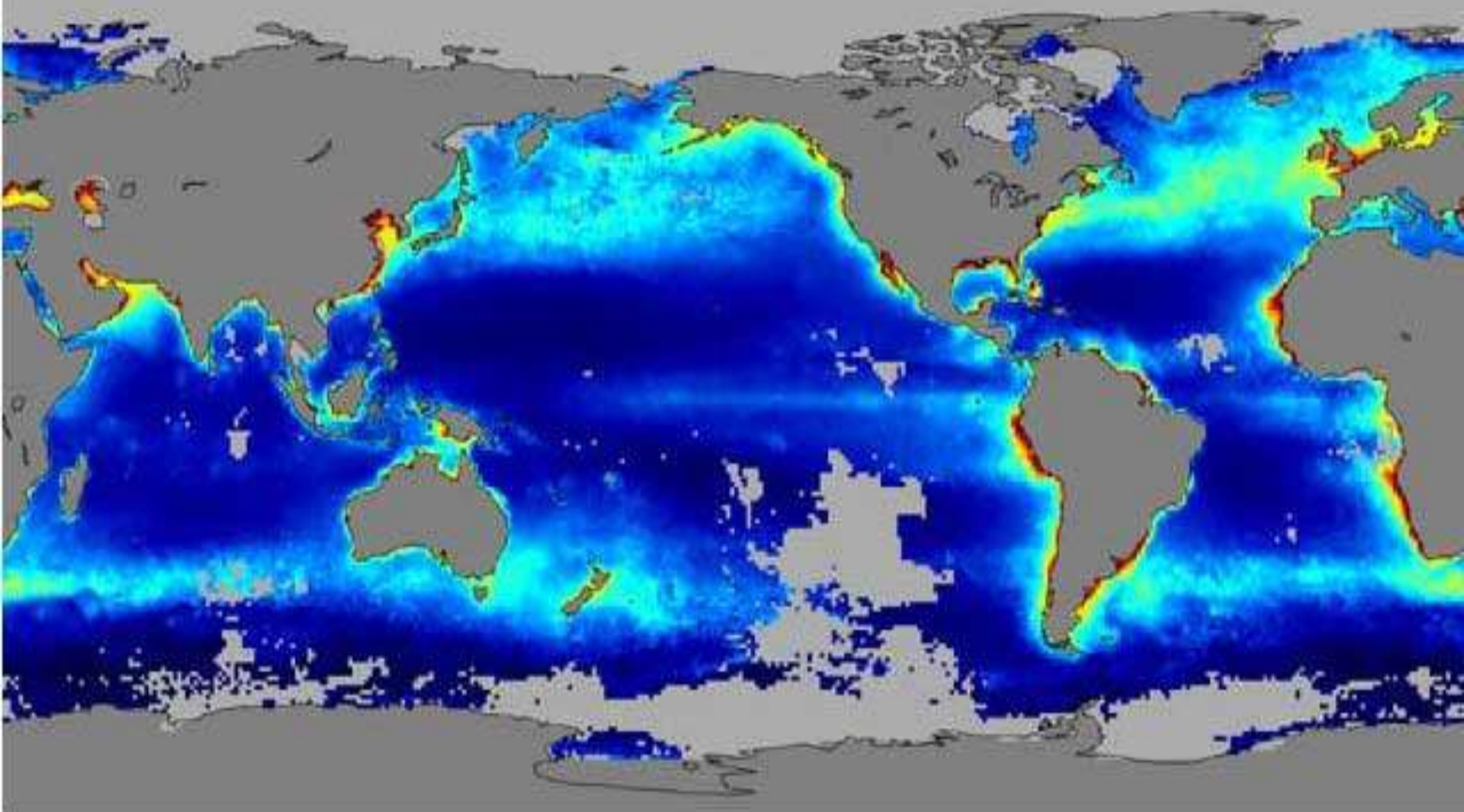
(ACID)

Water becomes more acidic.

Remains in the atmosphere (greenhouse gas)

CO<sub>2</sub>

CO<sub>2</sub>



**Net Primary Productivity** (grams Carbon per m<sup>2</sup> per year)



0

200

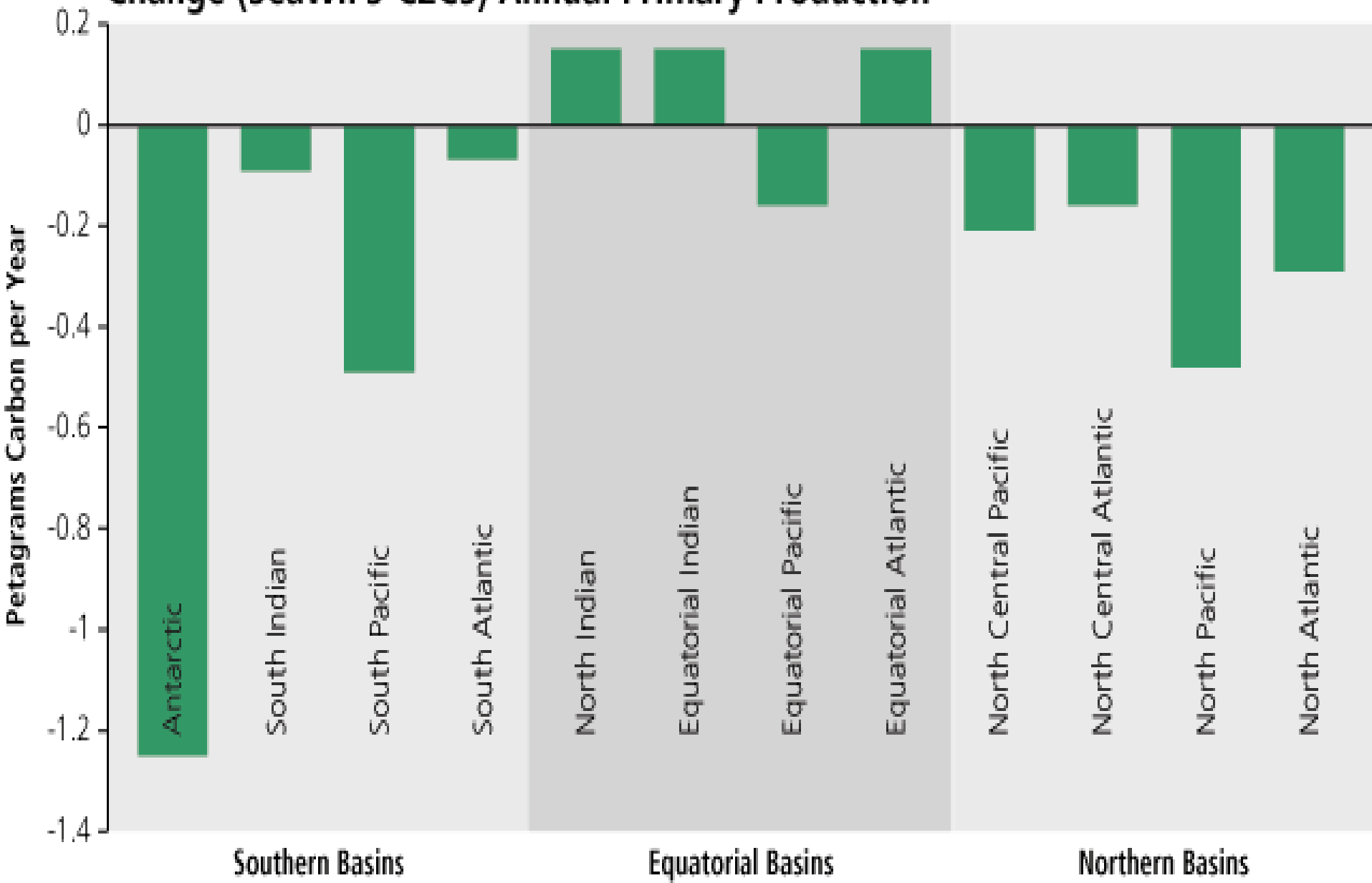
400

600

800

# CHANGE IN OCEAN NPP [1979 - 2002]

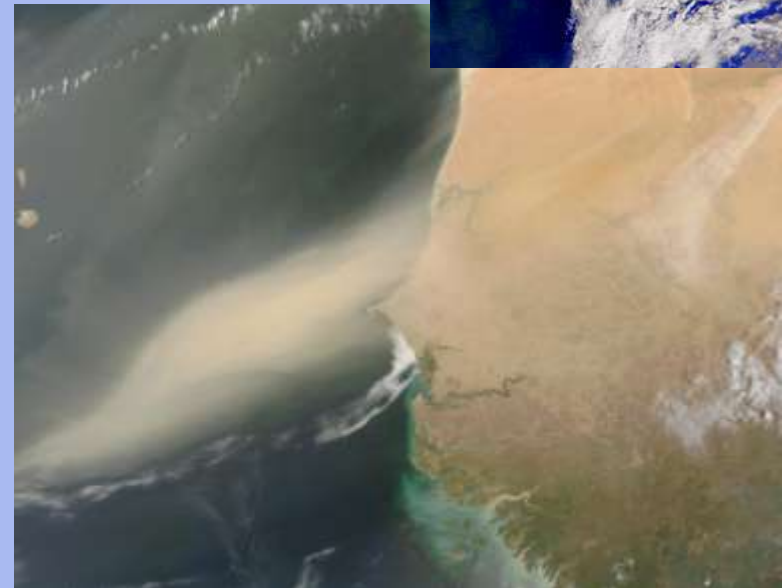
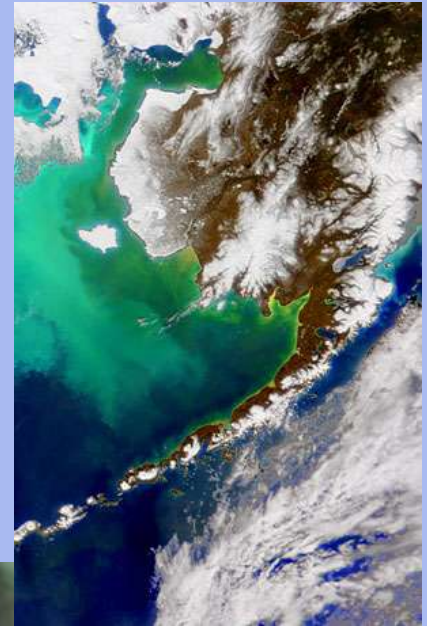
Change (SeaWiFS-CZCS) Annual Primary Production





# Iron in the Oceans

- Sources of naturally occurring iron
  - Volcanic coastal shelves
  - Dust in blown in from land
  - Upwellings
- Role in ecosystems
  - Key nutrient that helps plants take up nitrogen





“Give me a few oil tankers full of iron,  
and I’ll give you an ice age.”

– *John Martin, WHOI Scientist*

# Cashing in on Carbon Offsets

## FERTILIZING OCEANS FOR FUN AND PROFIT

**1** A boat goes out to the middle of the ocean and sprinkles micron-size iron shavings onto the surface of the water.



**2** The iron shavings stimulate the growth of photosynthesizing algae, which uses sunlight to draw carbon dioxide out of the air.

**3** When the algae dies, it bleaches and sinks into the sea. If it sinks to 1,000 feet, the carbon should be trapped for decades.

PHOTO-ILLUSTRATION: HARGISTORCH

- Climos taking over with \$3.5 million in funding
- Planktos bottom up after Galapagos proposal

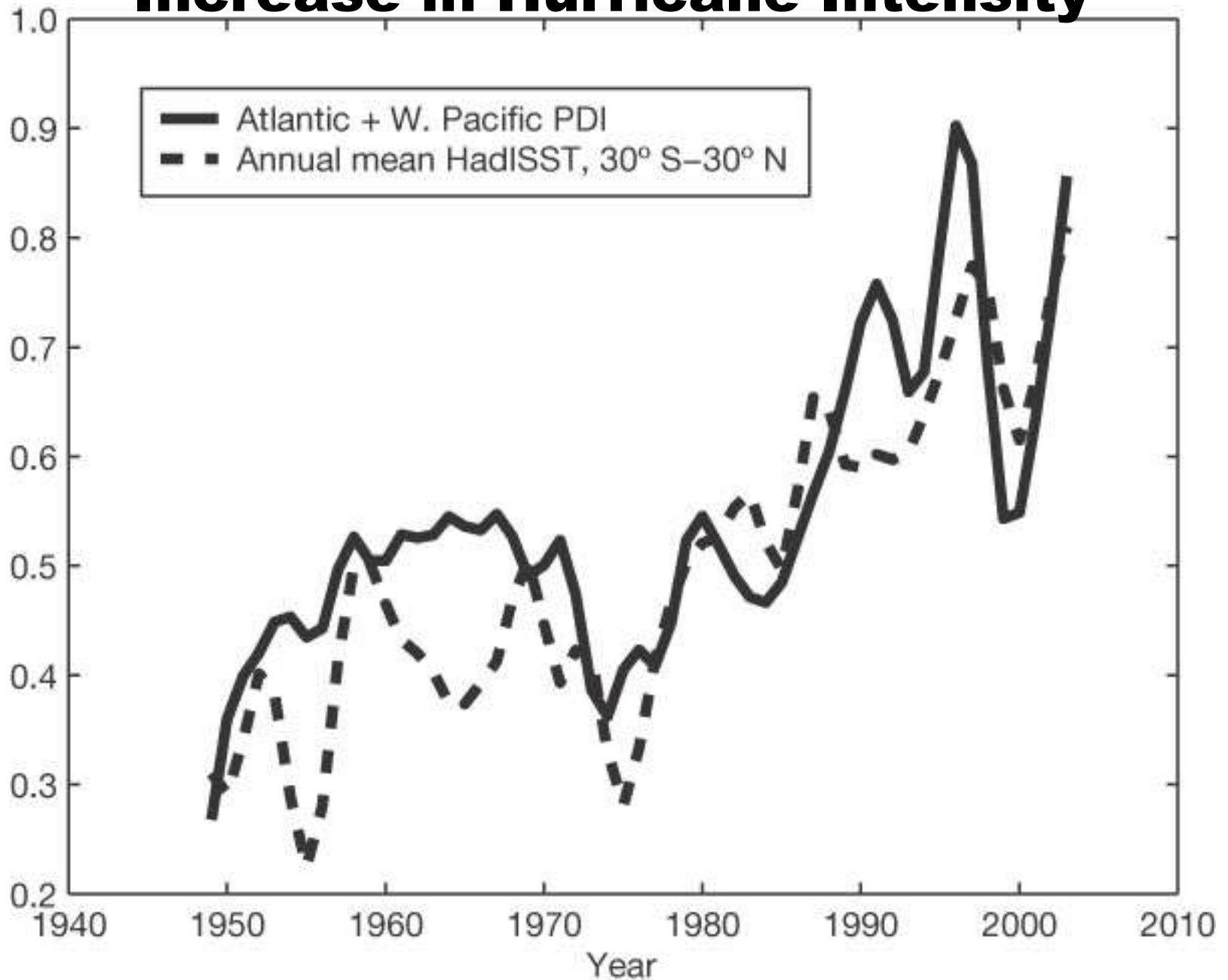




- Will the Carbon stay sequestered long enough to help?



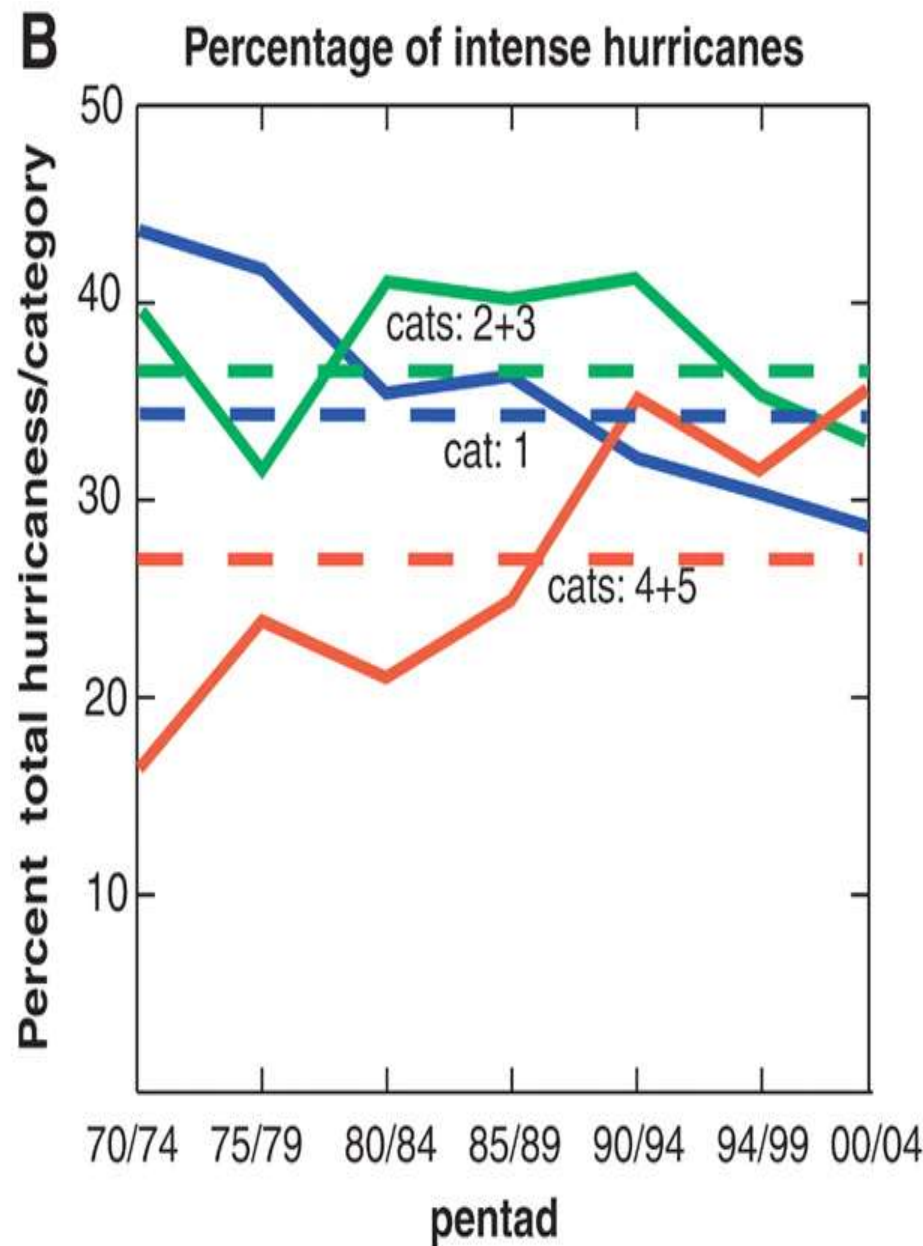
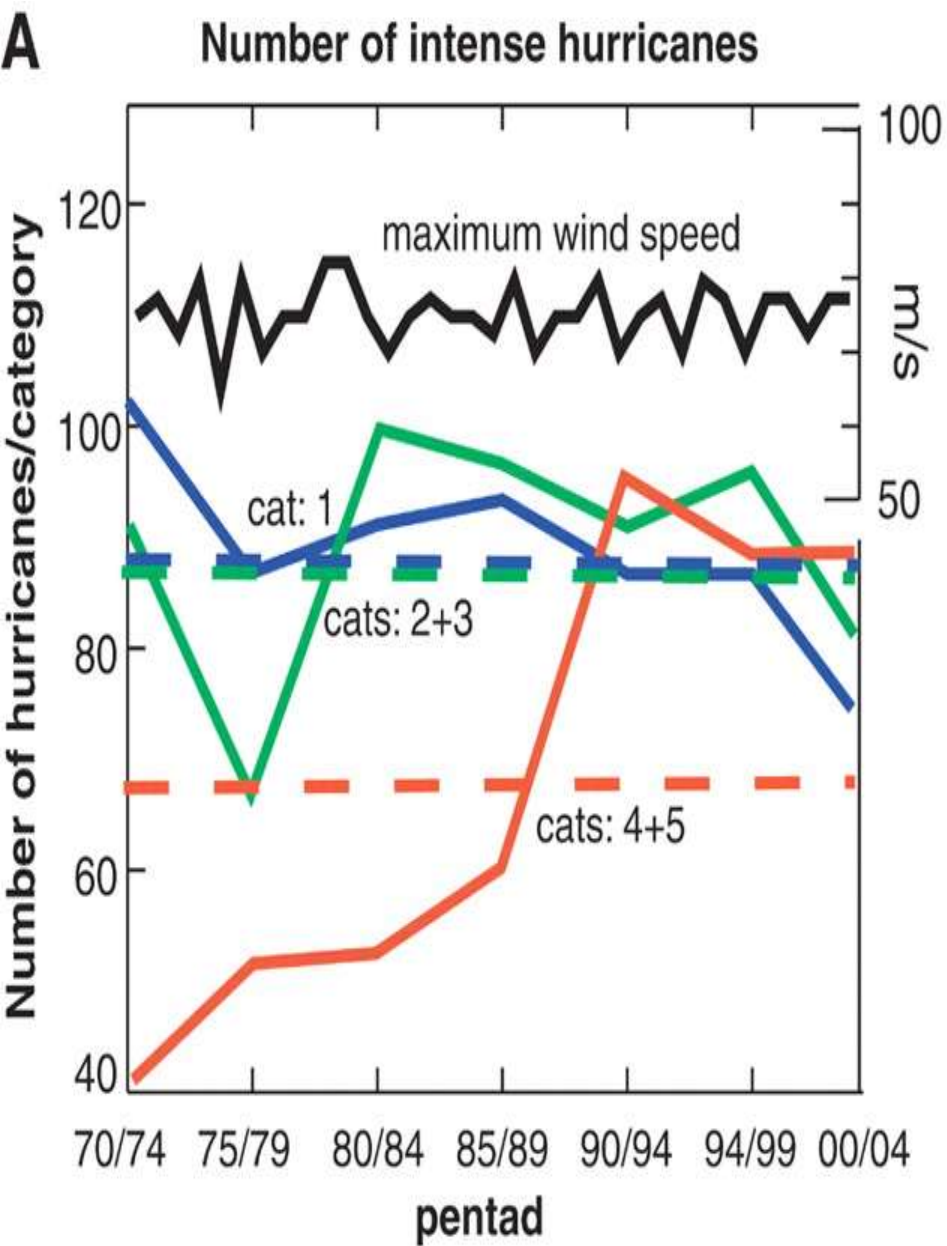
# Increase in Hurricane Intensity



**PDI = Potential Destructiveness Index**

**Emanuel, Nature 4 August 2005**

# Increase in Category 4-5 Hurricanes 1970 - 2004

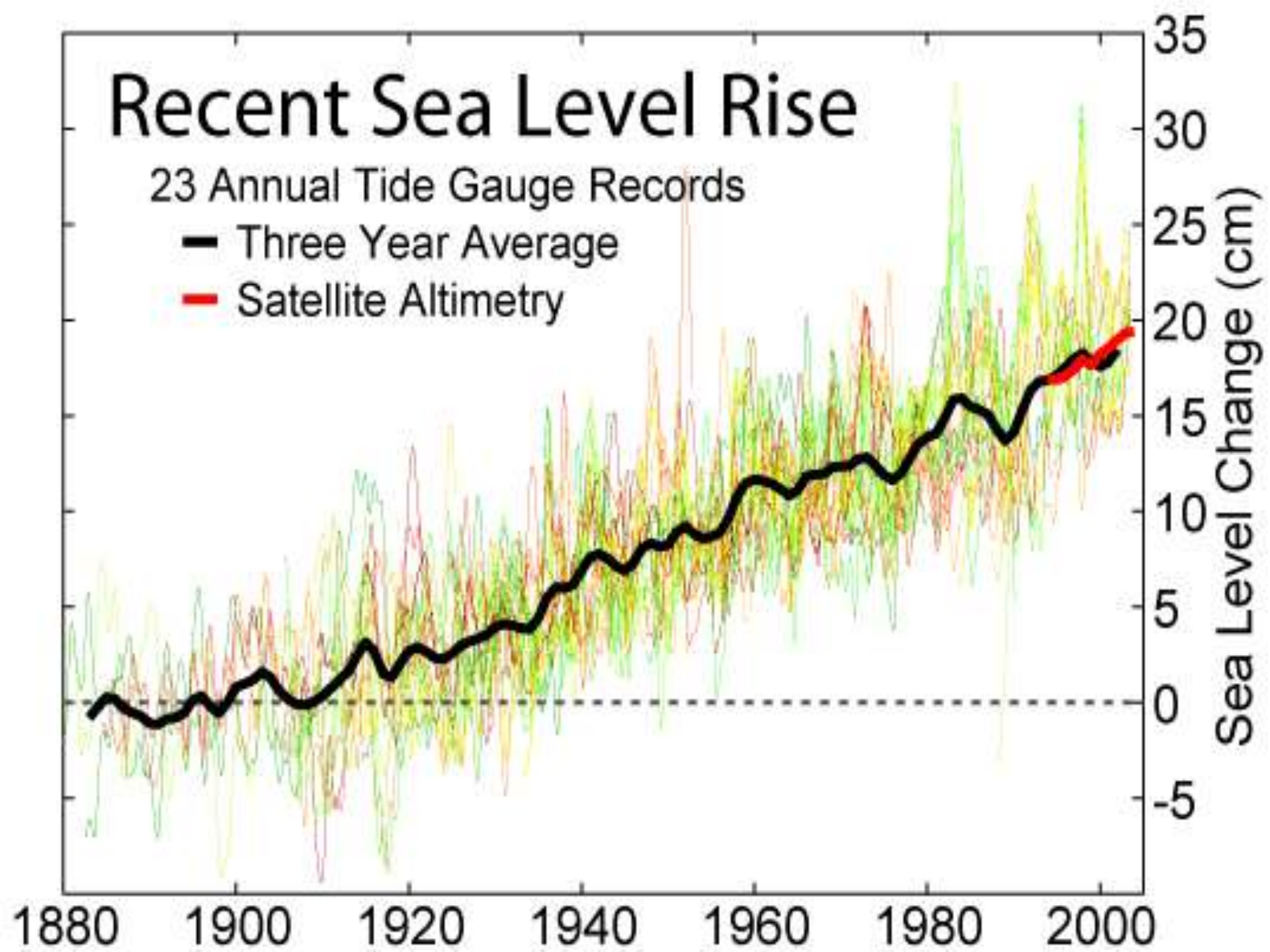


# Recent Sea Level Rise

23 Annual Tide Gauge Records

— Three Year Average

— Satellite Altimetry



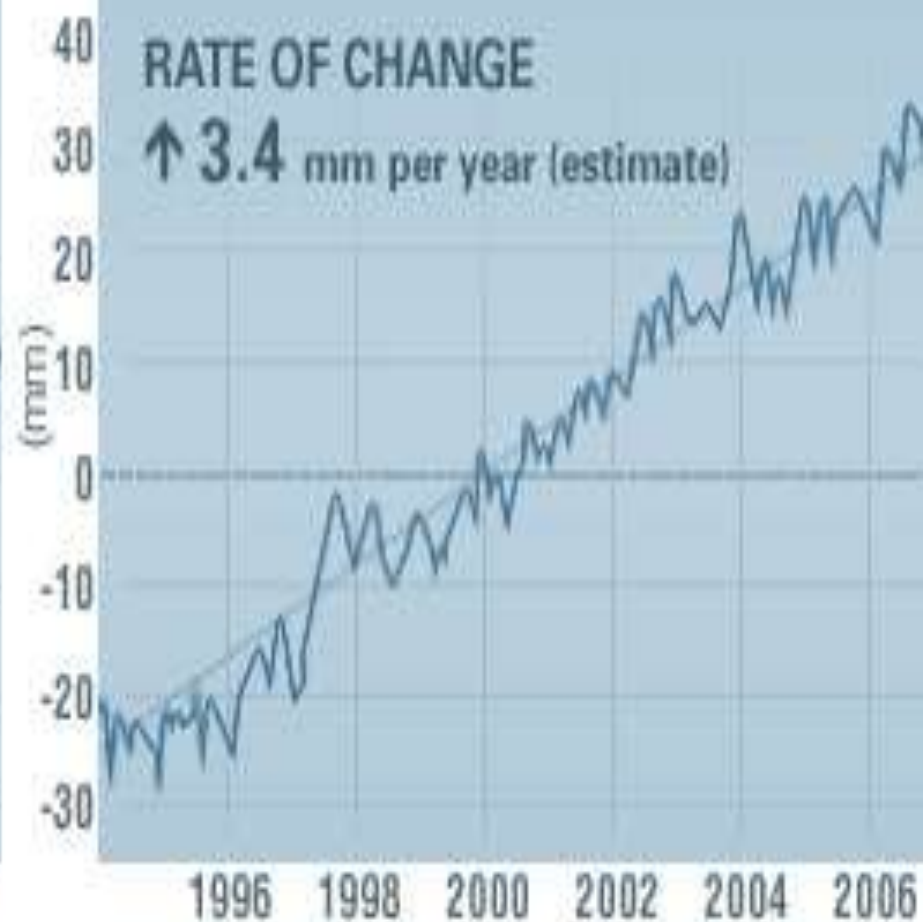


## HISTORICAL DATA: 1880-1990



Line represents 3-year average, based on 23 annual tide gauge records

## LATEST DATA: 1993-PRESENT



Inverse barometer applied and seasonal signal removed  
Source: [University of Colorado](#)

# Sea-level Rise Projections Include:



- ocean expansion resulting from increased water temperatures;

National Park Service



- meltwater runoff from mountain glaciers around the world; and

NASA



- a contribution due to increased ice flow from Greenland and Antarctica **at the rates observed for 1993-2003.**

Source: IPCC *Climate Change 2007: The Physical Science Basis*—Summary for Policymakers.