

# Basics of Coral Reefs & Climate Change

## Section 1: Global Climate Change

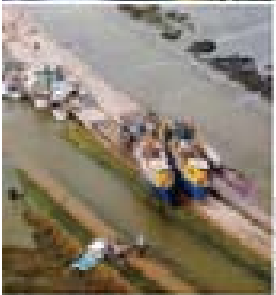
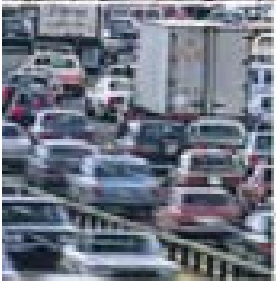
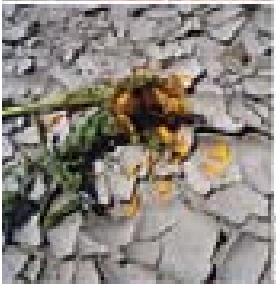
Mark Eakin

NOAA Coral Reef Watch

Guam – August 2009

The Nature Conservancy   
Protecting nature. Preserving life.™



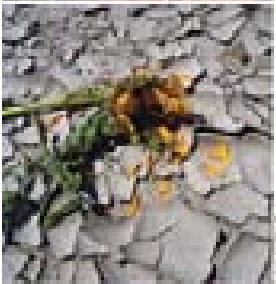
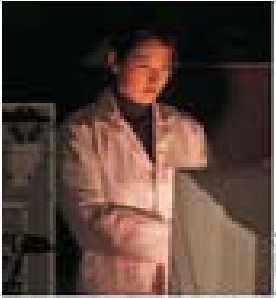


Is climate change real?

Is it caused by humans?

What will the future bring?

- temperature
- sea level rise
- precipitation changes
- ocean acidification
- other possible effects...?



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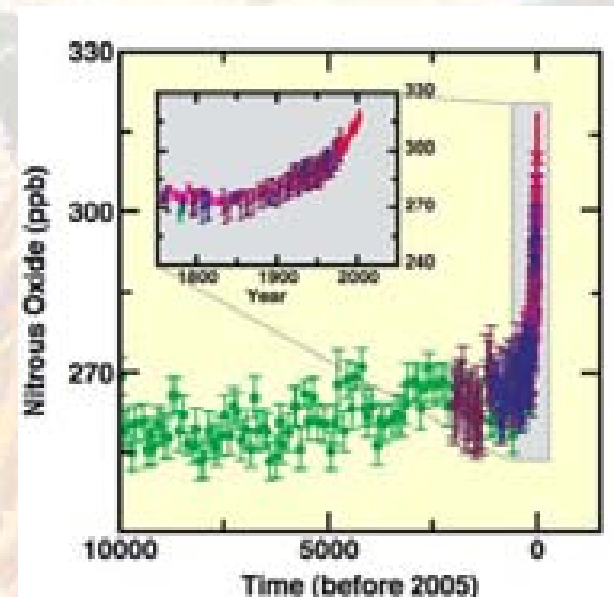
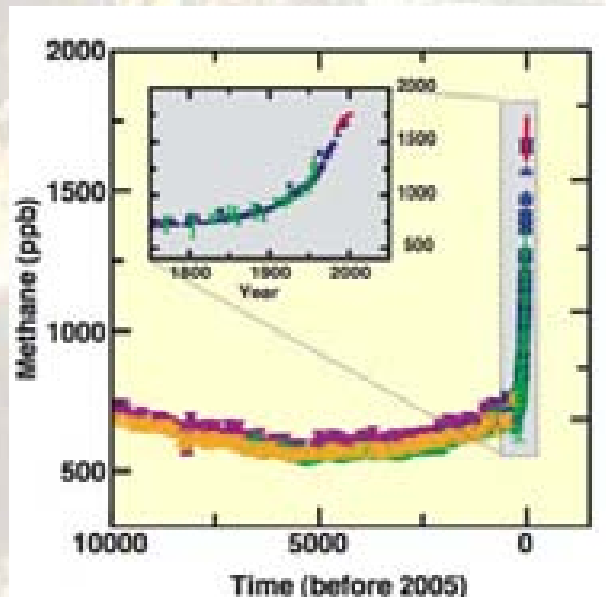
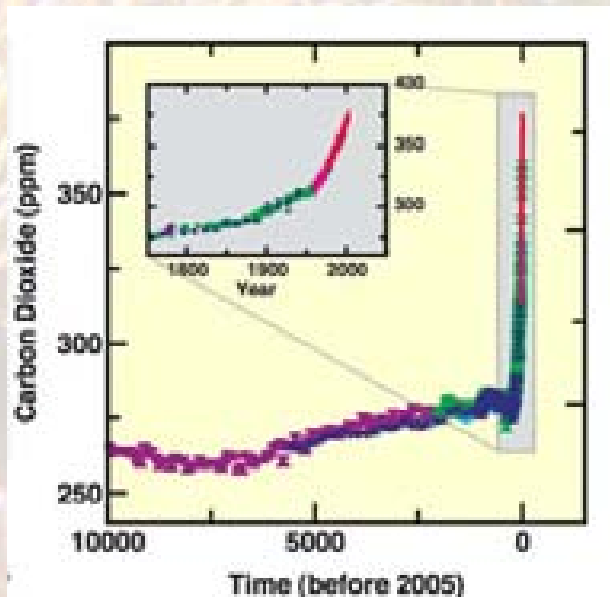
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# What is the root cause?

Carbon dioxide, methane, and nitrous oxide are increasing in our atmosphere.

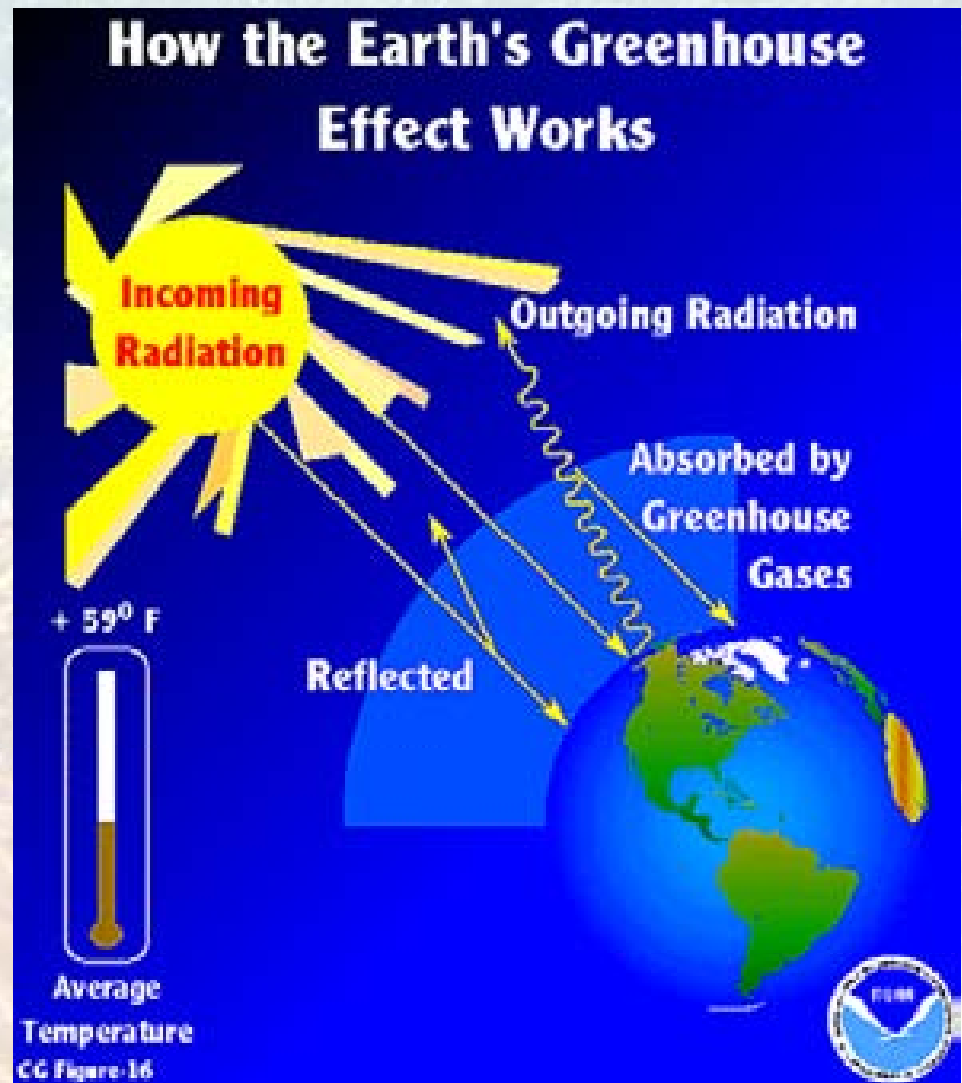
The CO<sub>2</sub> increase comes from burning fossil fuels; the methane and N<sub>2</sub>O increases are mostly from agriculture.



# What is the root cause?

These are known  
as “greenhouse  
gases”

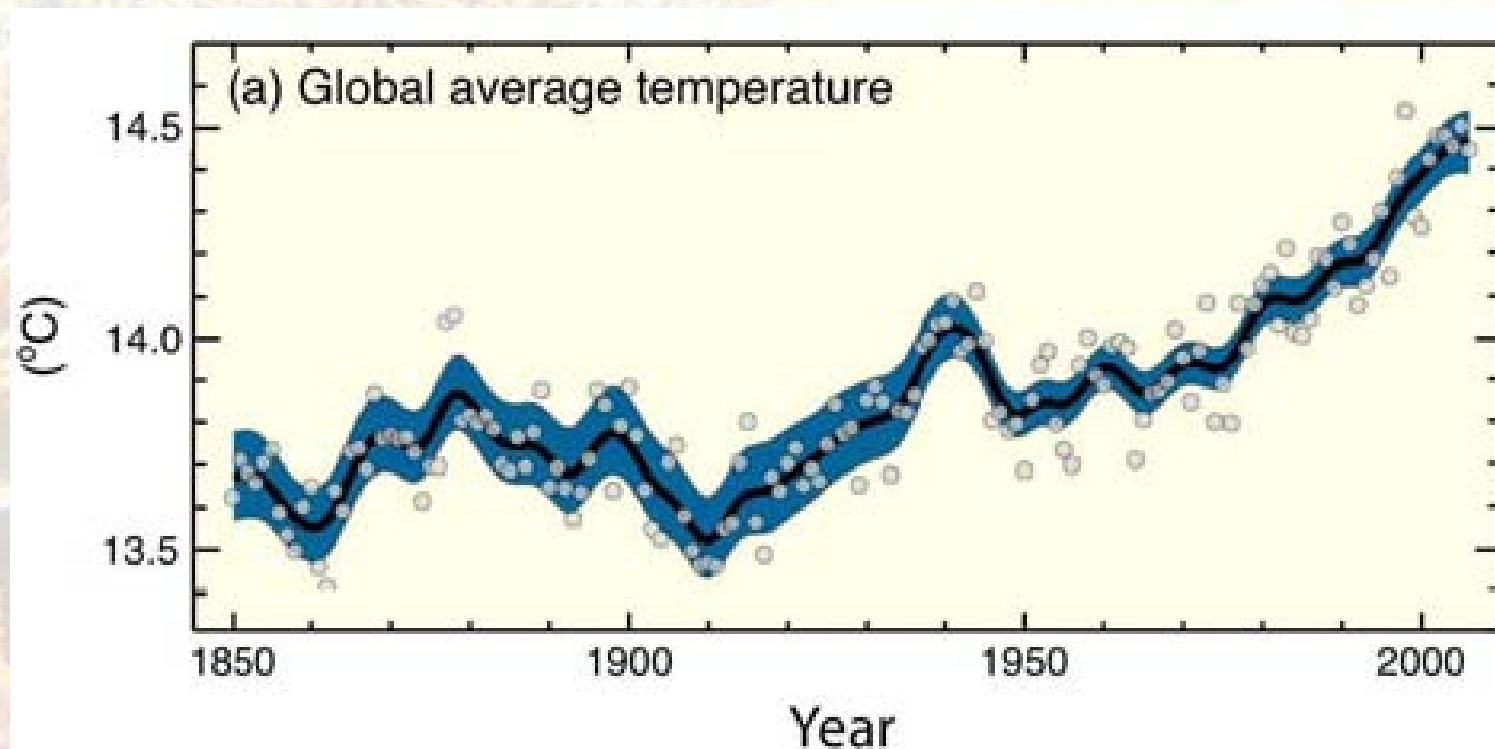
Trap some of the  
heat from the  
sun so it can't  
leave the  
atmosphere



# Is climate change real?

The greenhouse effect has led to a steady rise in global temperatures.

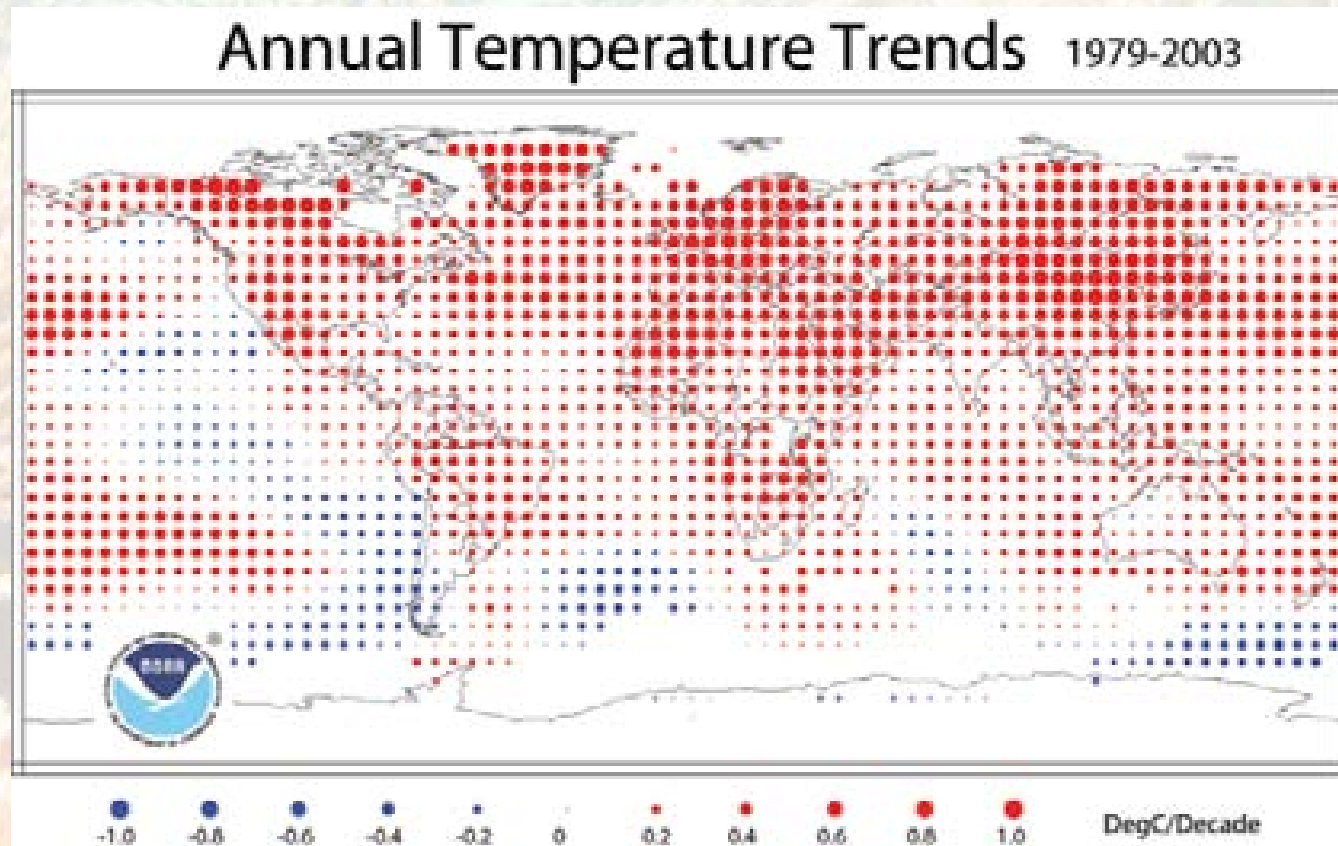
155 years of direct measurements.

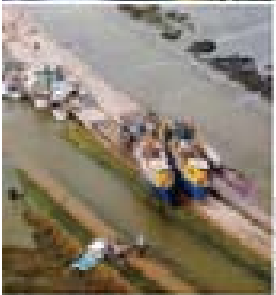
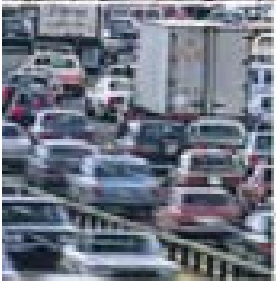
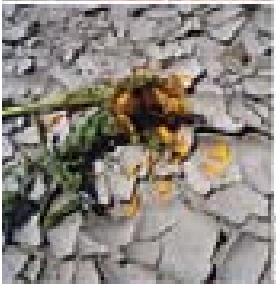




# Is climate change real?

Ocean temperatures have increased almost everywhere, as deep as 3000 m.





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Is it caused by humans?

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# Is it caused by humans?

Carbon dioxide, methane, and nitrous oxide are greenhouse gases.

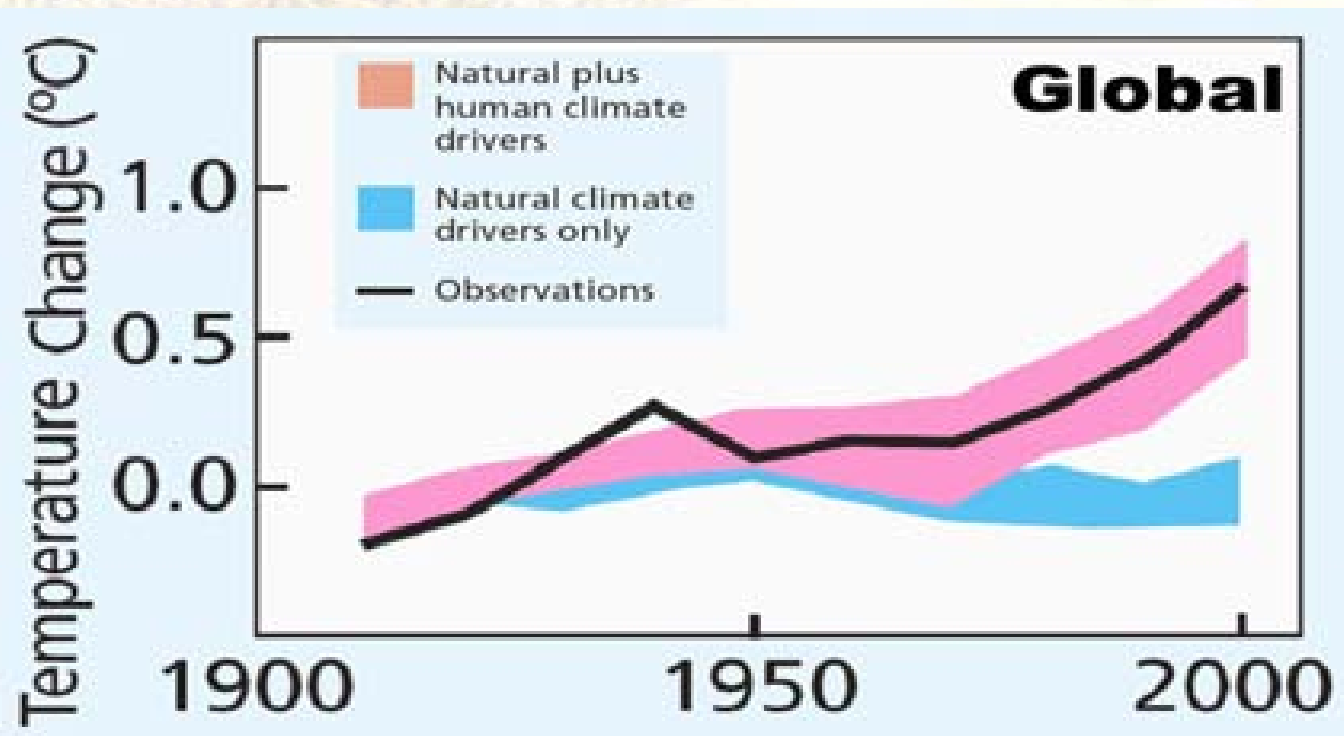
Greenhouse gases prevent some of the Earth's heat from escaping into space. This heat trapping warms the atmosphere.

But there are also natural climate cycles that cause warm and cold periods... so which one is causing the current warming?

# Is it caused by humans?

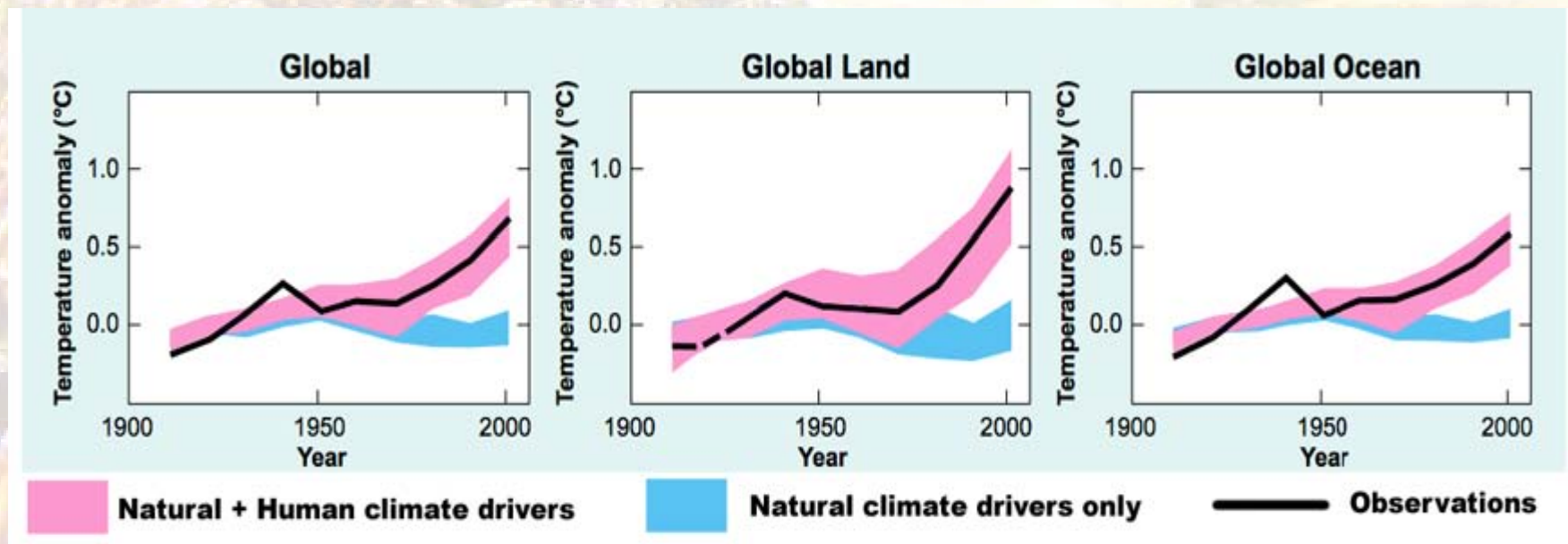
Computer models show that global warming can not be explained by natural cycles alone.

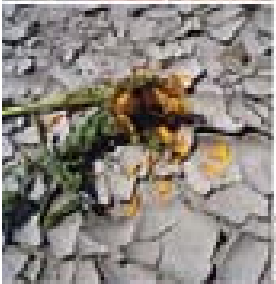
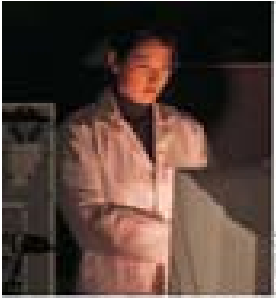
We can say with very high confidence that most of the warming is caused by the greenhouse gases that humans have released.



# Is it caused by humans?

Computer model results hold for global surface, land-only, and ocean-only temperatures. Increases can only be explained if human influence is included.





Is climate change real?

Is it caused by humans?

**What will the future bring?**

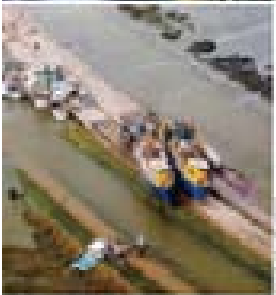
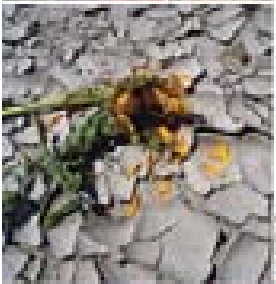
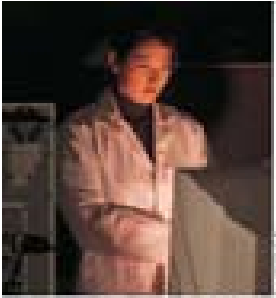
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# What will the future bring?

All of these predictions are based on computer models of the Earth's oceans and atmosphere.

A range of effects is given, from best-case scenario to worst-case.

None of these predictions are absolutely certain, but some are more likely than others.



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# What will the future bring?

## Temperature

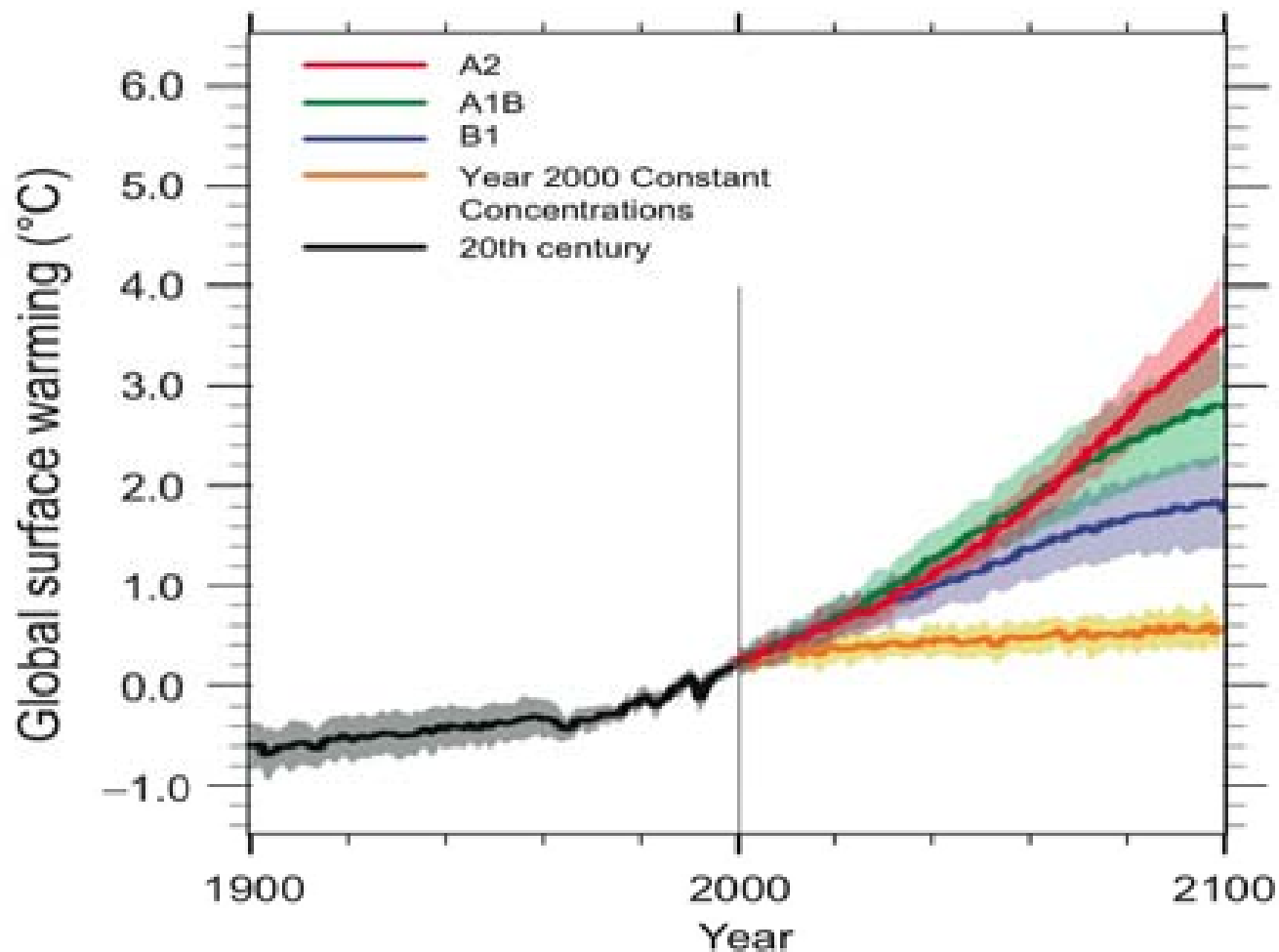
It is “virtually certain” that temperature will continue to increase: there will be fewer cold days and nights, and more hot days and nights.

How much the temperatures rise depends on how much greenhouse gases we continue to emit.

# What will the future bring?

## Temperature

Averages and Assessed Ranges for Surface Warming



# What will the future bring?

## Temperature

Even if greenhouse gases don't go up any more, the Earth will warm by about **0.6 °C (1 °F)** in the next 100 years.

A scenario with environmental controls will still have temperatures rising about **1.8 °C (3.2 °F)**.

Worst-case scenario where we take no action to limit greenhouse gases shows temperatures increasing by about **4 °C (7.2 °F)**, but the upper limit on this scenario is **6.4 °C (11.5 °F)**.

# What will the future bring?

## Temperature & Corals

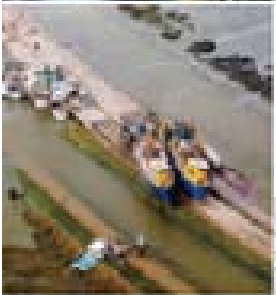
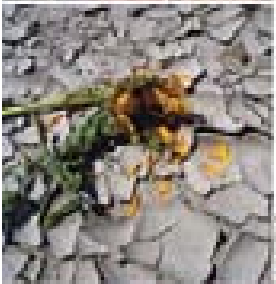
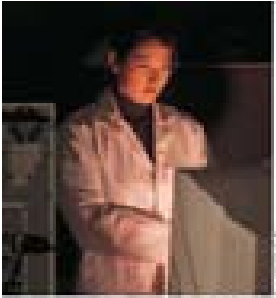


Warm ocean waters cause corals to “bleach” as they expel symbiotic algae.



If sea surface temperature increases by 1-3°C (1.8 to 5.4°F), most corals will bleach and many will die.

Photos from the Great Barrier Reef Marine Park Authority



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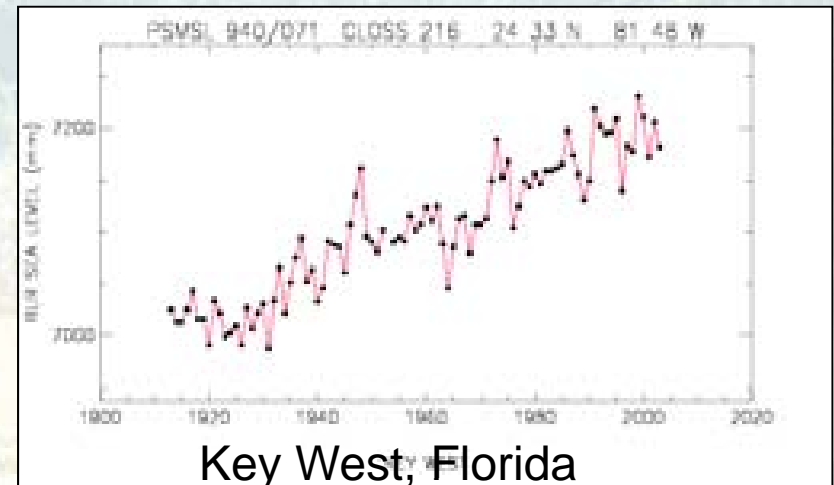
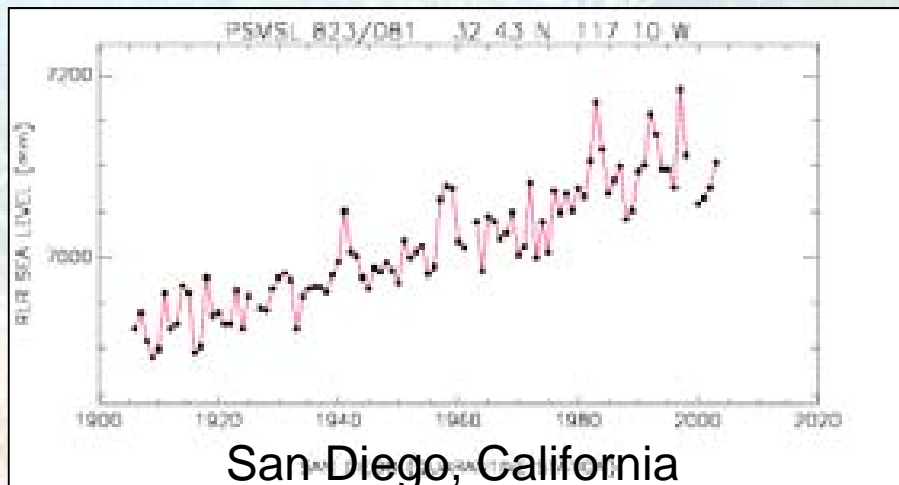
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# What will the future bring?

## Sea Level Rise



Rising at about 3mm (0.12 in) per year globally.

Even at current rates, sea level would rise by 0.3m (about a foot) in the next 100 years.

Worst-case scenario: about 0.6m (2 feet) higher.

- Does not include the ice sheets melting (see later slides), which would mean up to 7 meters (20 feet) more.



# What will the future bring?

## Sea Level Rise

### Causes:

- thermal expansion as the ocean water warms
- melting glaciers, ice caps, Antarctic ice sheets

Consequences: coastal flooding, erosion, storm surges, saltwater intrusion into drinking-water sources.



# What will the future bring?

## Sea Level Rise & Corals

Healthy coral reefs can probably grow fast enough to keep up.

Lower light may be a problem for deeper corals.

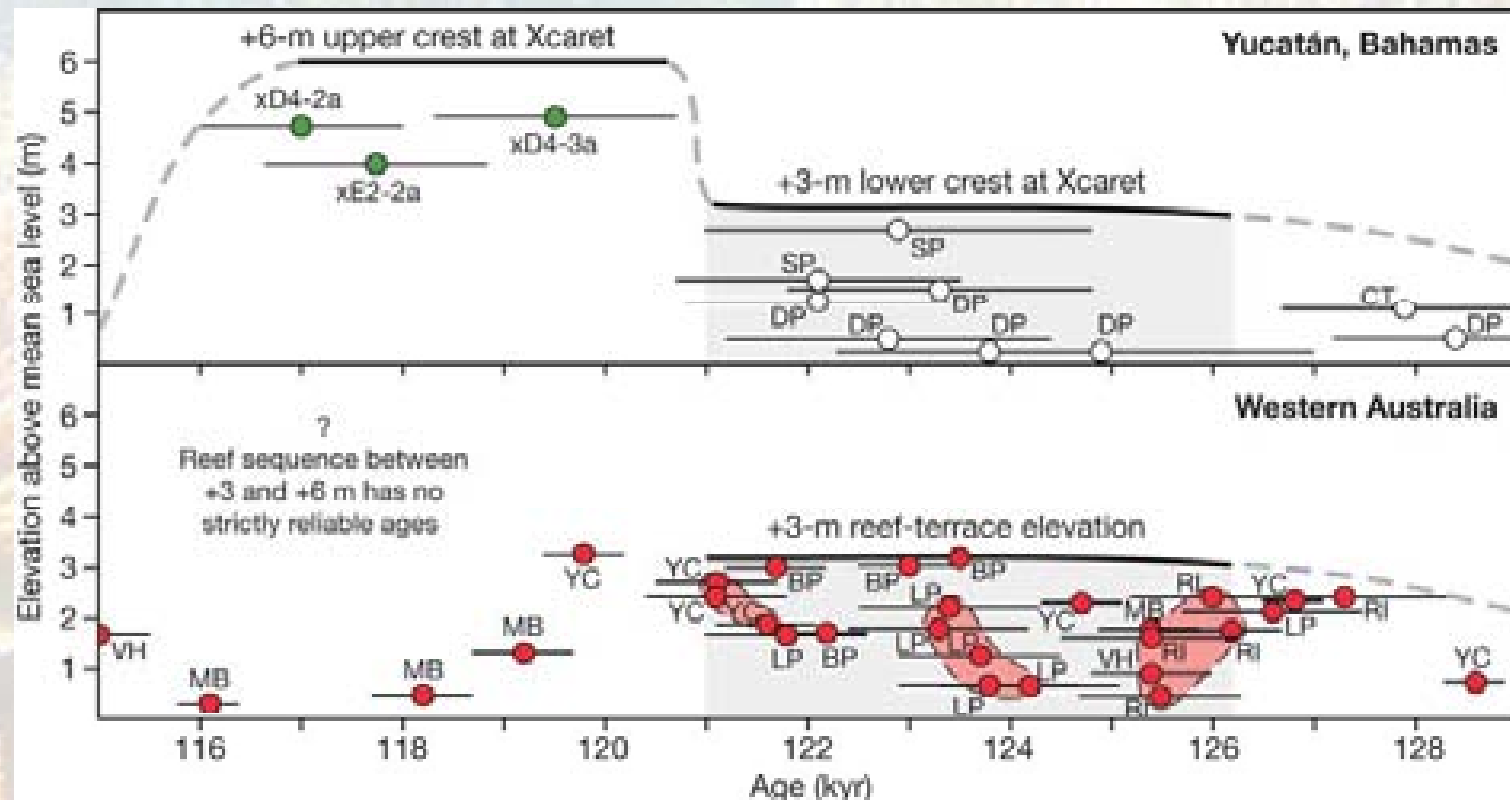
Bleaching and ocean acidification both reduce growth rates, making reefs more vulnerable.



# What will the future bring?

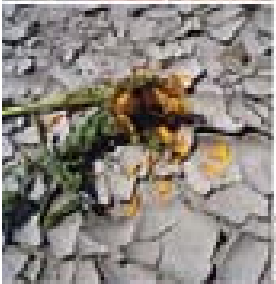
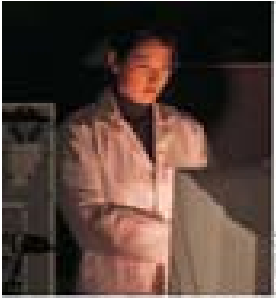
## SLR & Corals – the latest science

Relative sea-level reconstructions  
for the last interglacial highstand.



P Blanchon *et al.* *Nature* **458**, 881-884 (2009) doi:10.1038/nature07933

**nature**



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# What will the future bring?

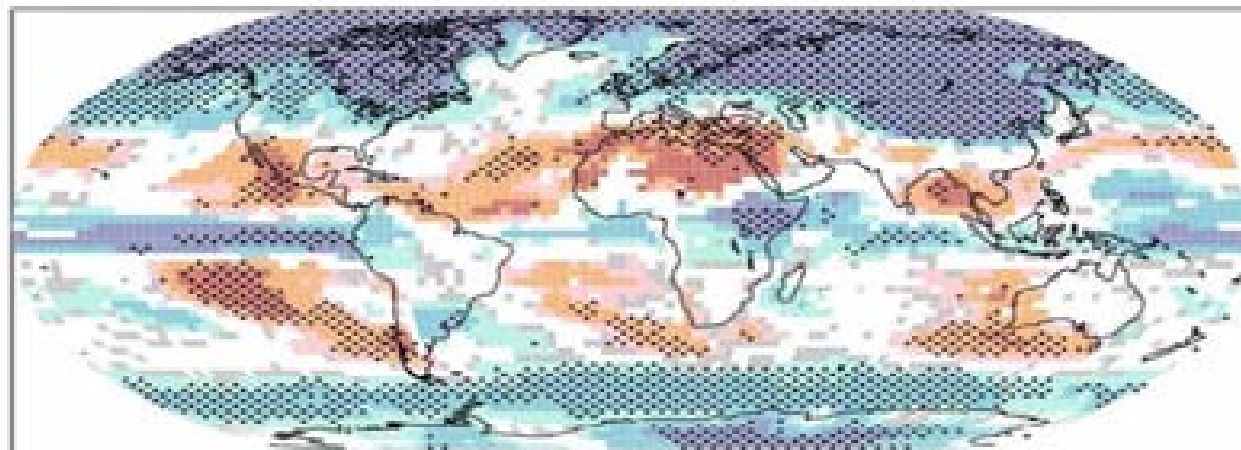
## Precipitation Changes

High latitudes are very likely to be wetter by 2099.

Sub-tropics are likely to be drier.

Rainfall is already lower in north Africa, and higher in eastern North America and Europe

**Precipitation Changes (Winter)**



# What will the future bring?

## Storms and Droughts

Rain will be more intense, with heavier rainfall in a short time.

Droughts are likely to increase, as the interval between rain events increases.

Frequency of heavy precipitation events has already increased, and droughts are longer and more intense.





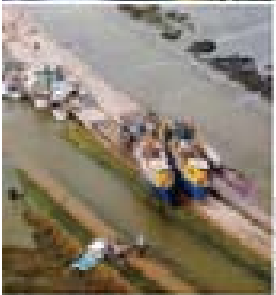
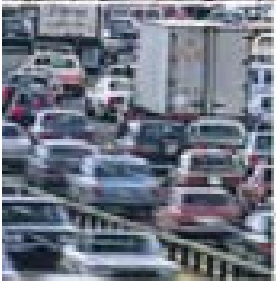
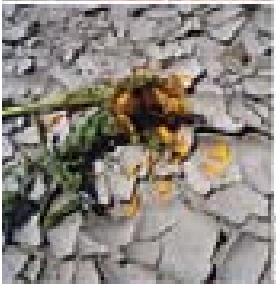
# What will the future bring?

## Precipitation Changes & Corals



Probably won't have major impact on coral reefs.

More runoff from intense rain may increase sediment, debris, and pollution inputs.



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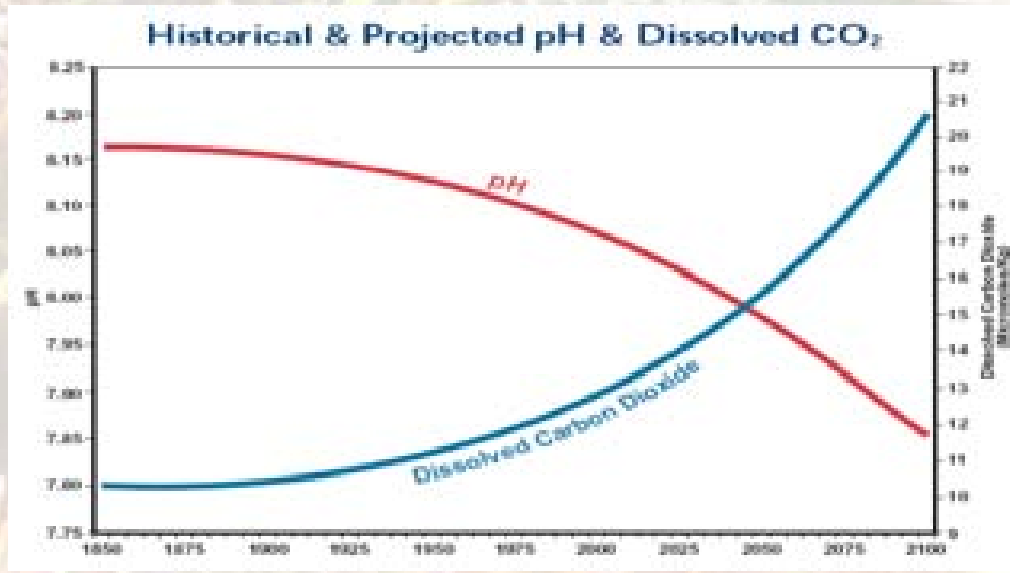
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# What will the future bring?

## Ocean Acidification

As we add  $\text{CO}_2$  to the atmosphere, a lot of it dissolves into the ocean water.

$\text{CO}_2$  lowers the pH of the water, shifting it closer to being acidic.

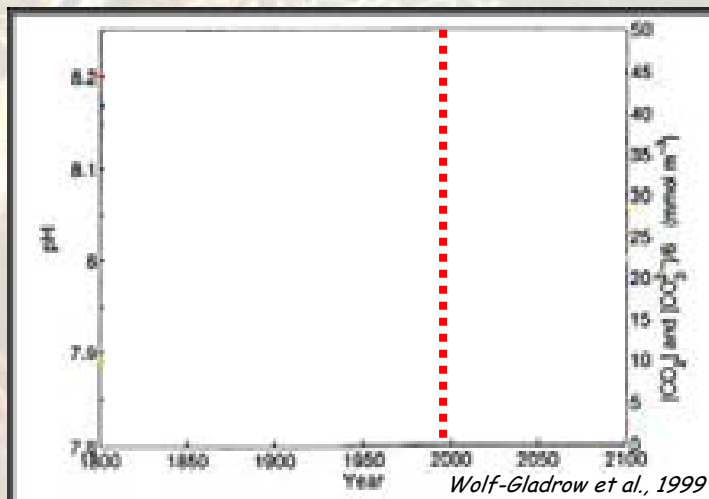


# What will the future bring?

## Ocean Acidification

Lower pH reduces the availability of the carbonate ion ( $\text{CO}_3^{-2}$ ), a building-block for coral skeletons.

Continues in the future as  $\text{CO}_2$  increases.

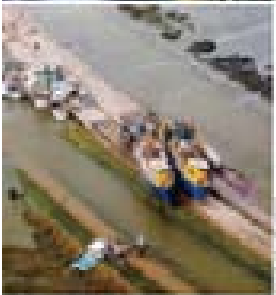
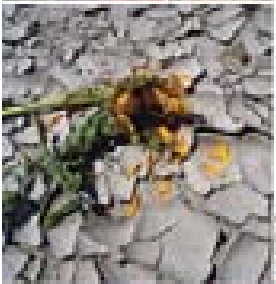
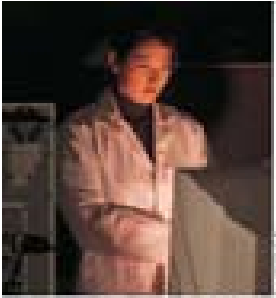


# What will the future bring?

## Ocean Acidification & Corals



Lower pH threatens coral reefs by slowing growth rates and increasing bleaching.



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# What will the future bring?

Maybe: hurricanes

Hurricanes may intensify— evidence that they are getting stronger in the Atlantic.

Not clear if number of storms will change.

Hurricane tracks may shift toward poles.



# What will the future bring?

Maybe: deep-ocean circulation



Gulf Stream carries warm water north— start of global circulation through the world's oceans

Warmer oceans might stop this circulation

Europe: 5°C (9°F) drop in just 10 years? Unlikely, but evidence that it has happened in the past.

# What will the future bring?

Maybe: ice sheets melting

There is some evidence that parts of these ice sheets are becoming unstable.

The biggest concern is the West Antarctic Ice Sheet— if it collapsed, sea level would rise by 7 meters (20 feet).

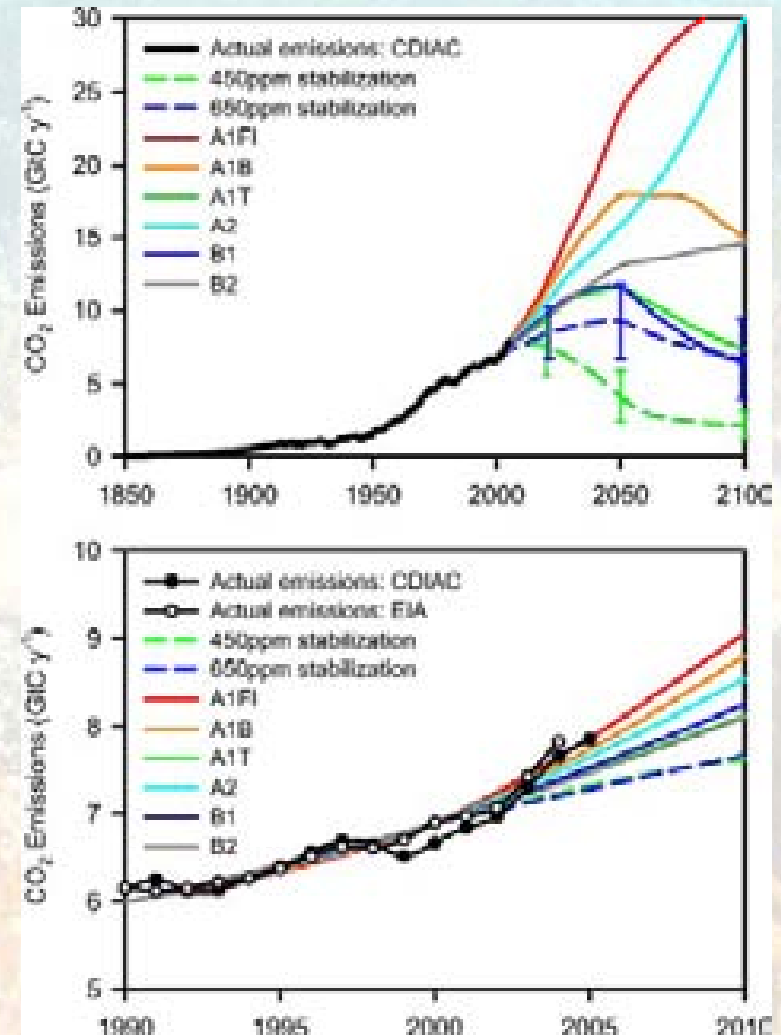
Also recent evidence that ice flow is accelerating in the Greenland ice sheet.



Photo by Kendrick Taylor, DRI  
courtesy of NOAA

# What will the future bring?

Observed global CO<sub>2</sub> emissions including all terms in Eq. 1, from both the EIA (1980–2004) and global CDIAC (1751–2005) data, compared with emissions scenarios (8) and stabilization trajectories (10–12)



Raupach M. R. et.al. PNAS;2007;104:10288-10293

# What can we do?

## Conclusions from the Stern Review: The Economics of Climate Change

There is still time to avoid the worst impacts of climate change, if we take strong action now.

Climate change could have very serious impacts on growth and development.

The cost of stabilizing the climate are significant but manageable; delay would be dangerous and much more costly.



## Stern Review Conclusions (cont.)

Action on climate change is requires across all countries, and it need not cap the aspirations for growth of rich or poor countries.

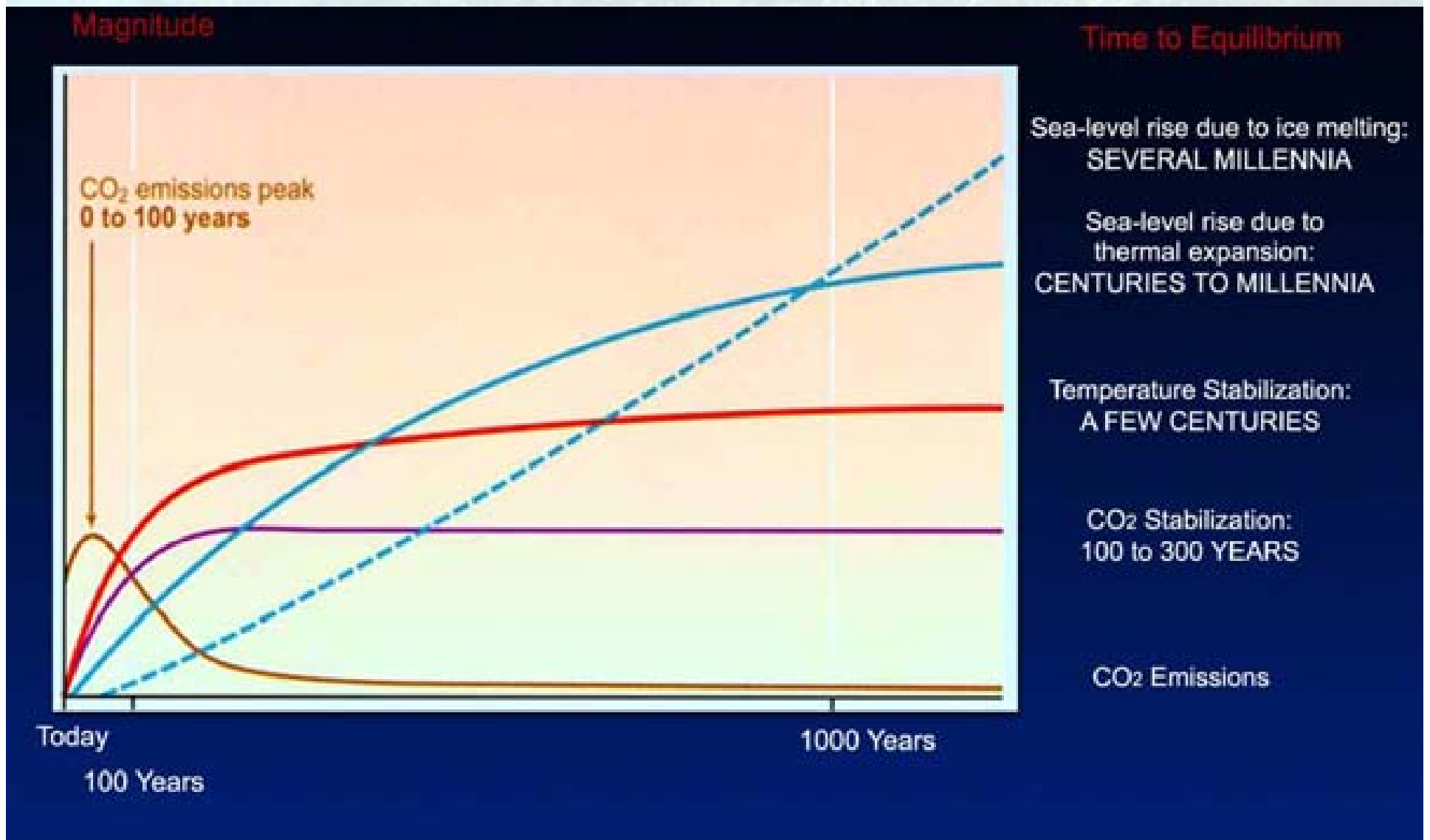
A range of options exists to cut emissions; strong, deliberate policy action is required to motivate their take-up.

Climate change demands an international response, based on a shared understanding of long-term goals and agreement on frameworks for action.



# Two Part Solution:

## 1) Reduce Global CO<sub>2</sub> Emissions



# Two Part Solution:

## 2) Reduce Local Stressors

Reducing Emissions Is Not Enough!

### NOAA Coral Reef Conservation Program Priority Threats:

- Impacts of Climate Change  
(and ocean acidification)
- Impacts of Fishing
- Impacts Land-Based Pollution

