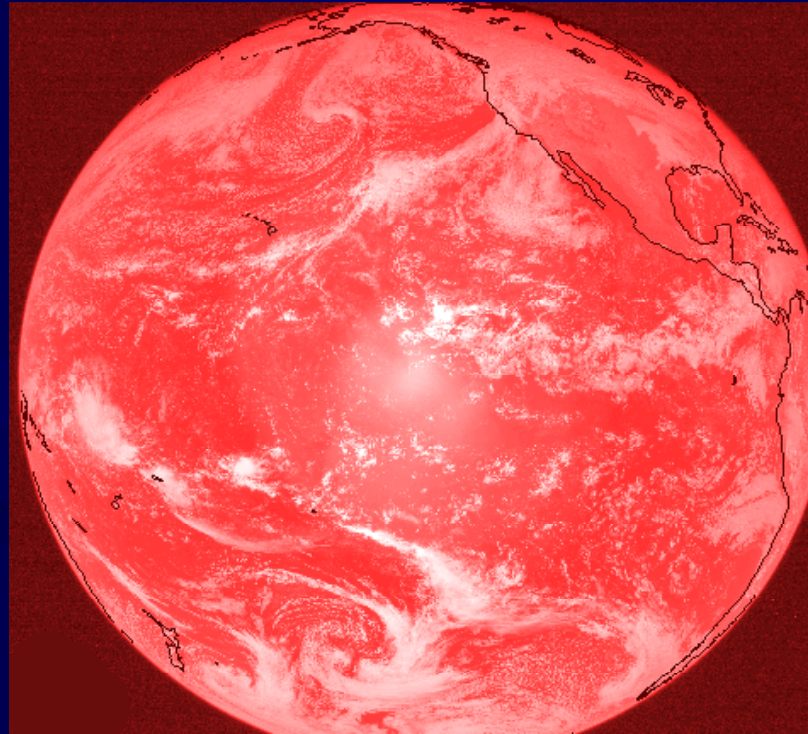


# Global Warming



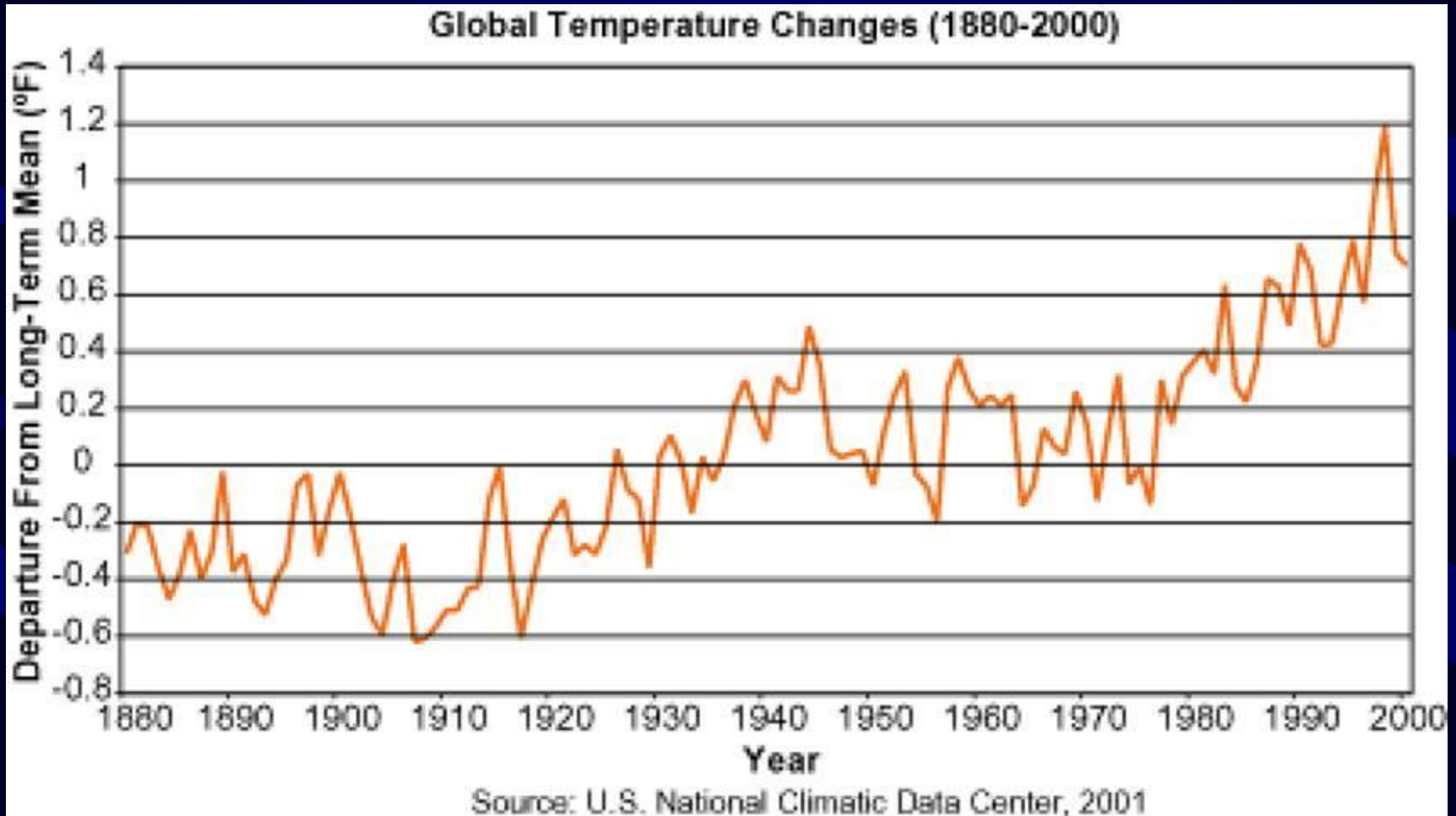
**Greenhouse Gases and Climate**

# Is the climate becoming warmer and warmer?

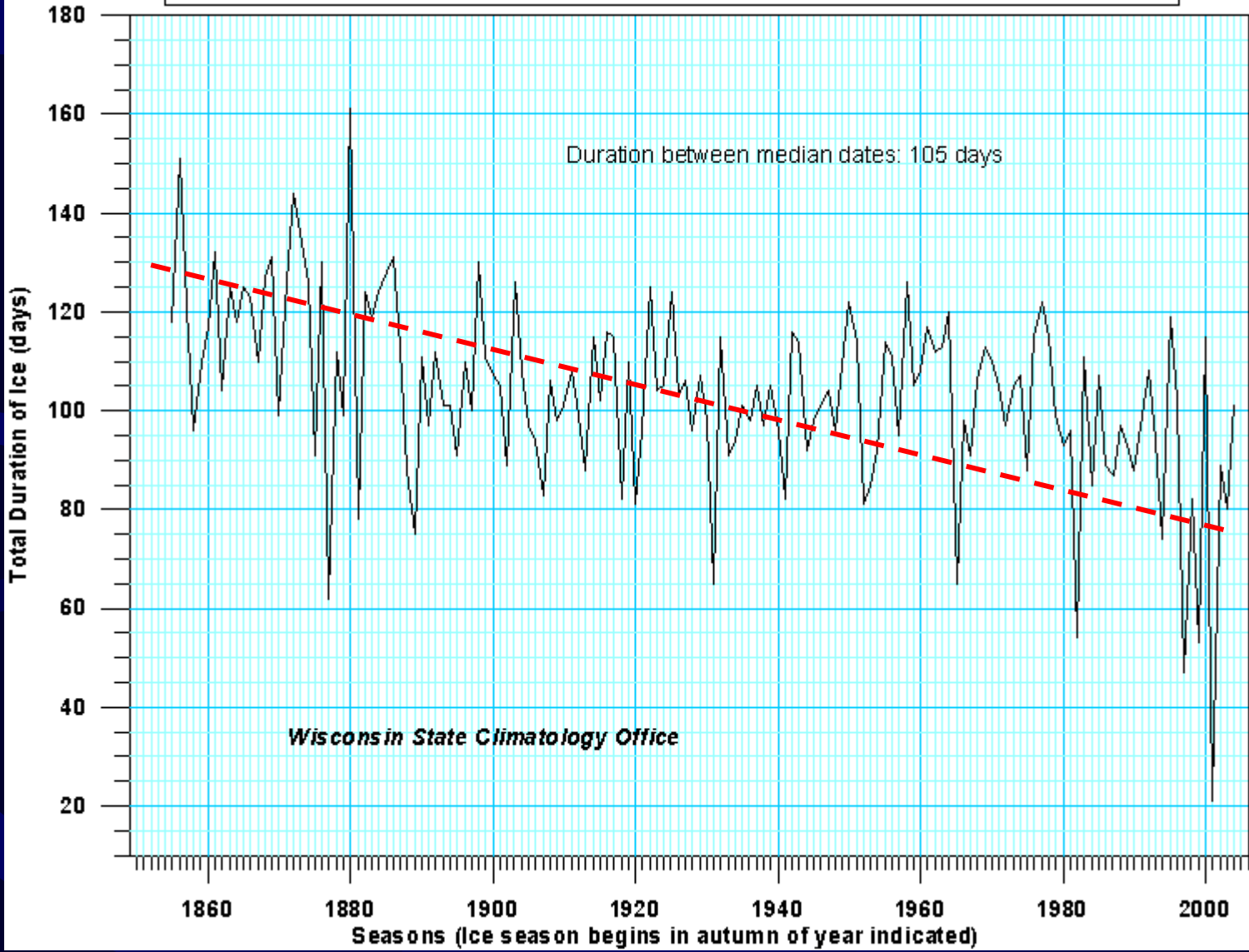
- According to the National Academy of Sciences, the Earth's surface temperature has risen by about 1 degree Fahrenheit in the past century, with accelerated warming during the past two decades. There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities. Human activities have altered the chemical composition of the atmosphere through the buildup of greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide. The heat-trapping property of these gases is undisputed although uncertainties exist about exactly how earth's climate responds to them. (*source:US-EPA*)

# Global temperature trend

Note that these are surface temperatures and mostly overland. The temperature in upper levels may be different, even reversed.



# Duration of Ice on Lake Mendota (1852/53 - 2004/05 Winter Seasons)



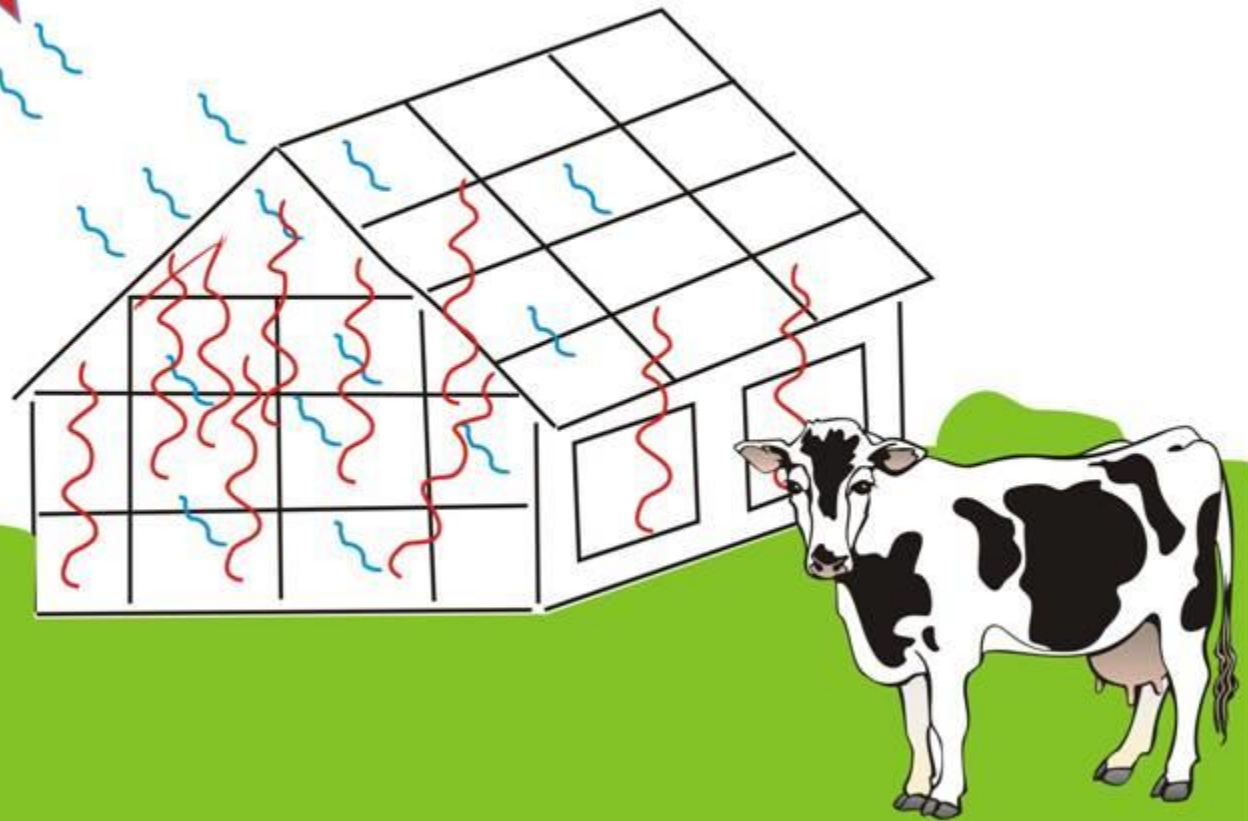
# What cause the temperature of the atmosphere to go up?

- There are many possible mechanisms that can cause the warming of the atmosphere, for example:
  - **Natural variation** – the climate becomes warmer by internal chaotic dynamics of the earth-atmosphere system (that is, no external influence).
  - **Solar activity** – either direct increase of solar energy output or indirect “trigger” mechanisms due to solar activity (though nobody knows how) may cause the surface temperature to go up.
  - **Greenhouse effect** – increasing “greenhouse” gases such as CO<sub>2</sub>, CH<sub>4</sub>, NO, CFC,...etc. (actually H<sub>2</sub>O is very efficient, too, but at present it is assumed to be in steady state).
- The last one is presently thought to be the most likely cause of the global warming and hence we will examine it here in this chapter..

# The real greenhouse



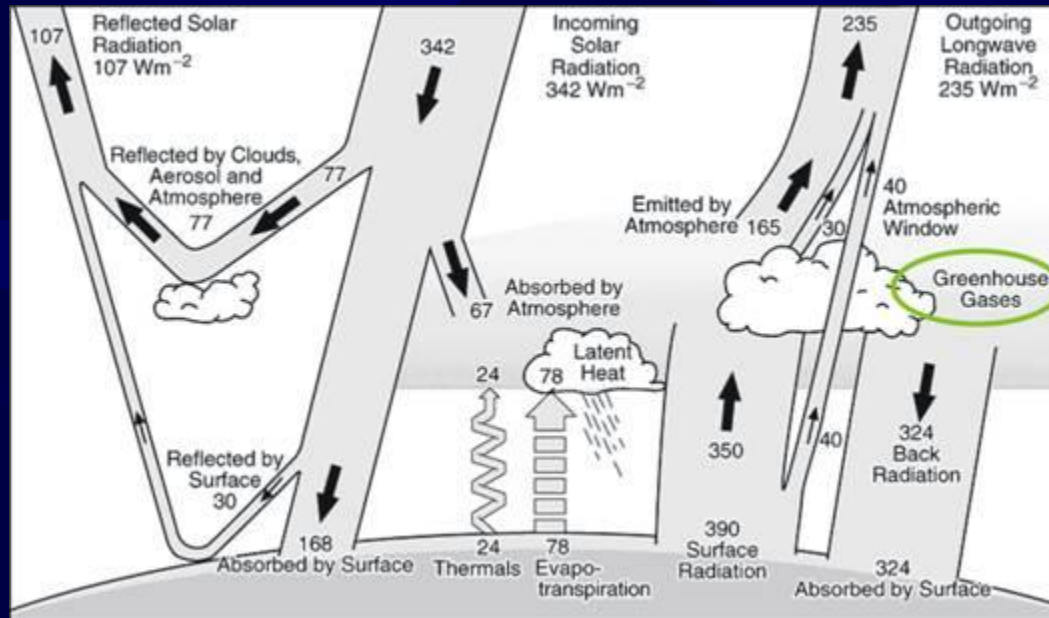
Short waves can penetrate the glass panels whereas long waves are trapped inside





# The (Atmospheric) Greenhouse Effect

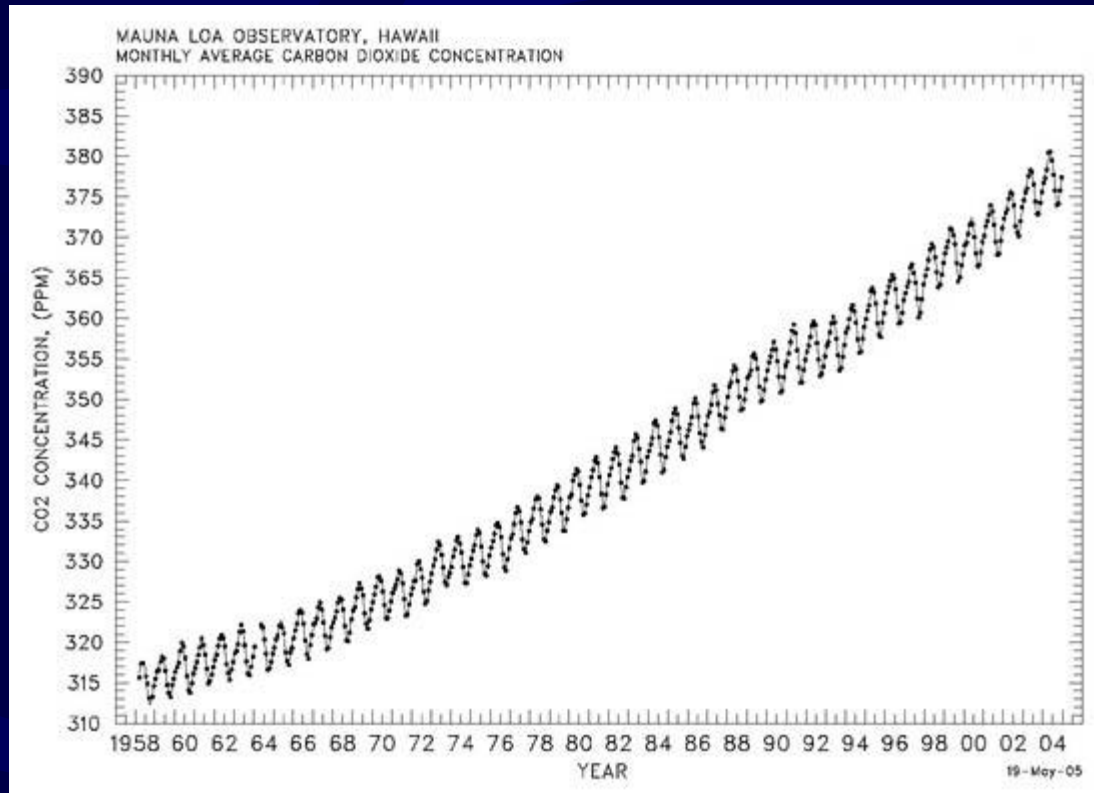
Remember this chart?



- Examples of greenhouse gases:  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ , CFC.
- Currently,  $\text{CO}_2$  is the main suspect of causing the global warming since the 20<sup>th</sup> century because combustion of fossil fuel naturally injects  $\text{CO}_2$  into the atmosphere and it has increased dramatically since last century.

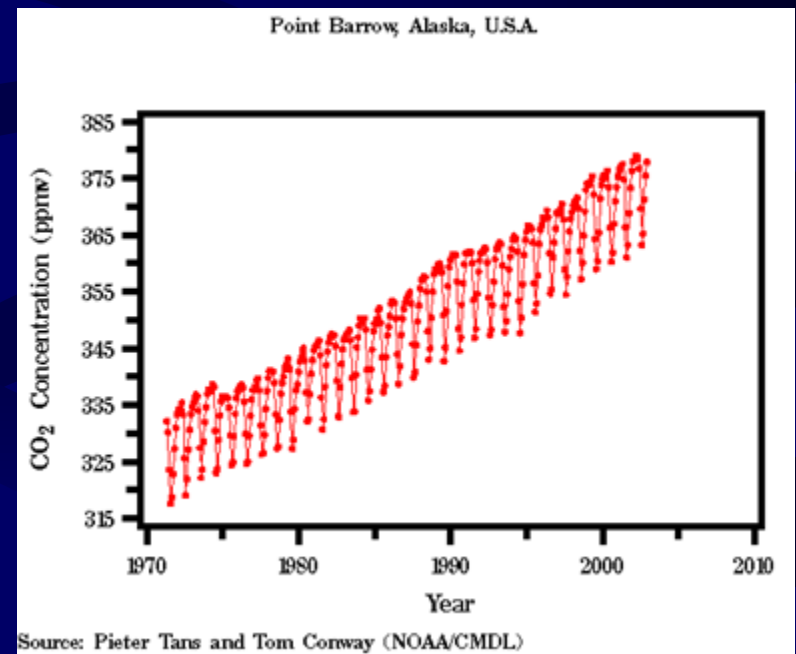
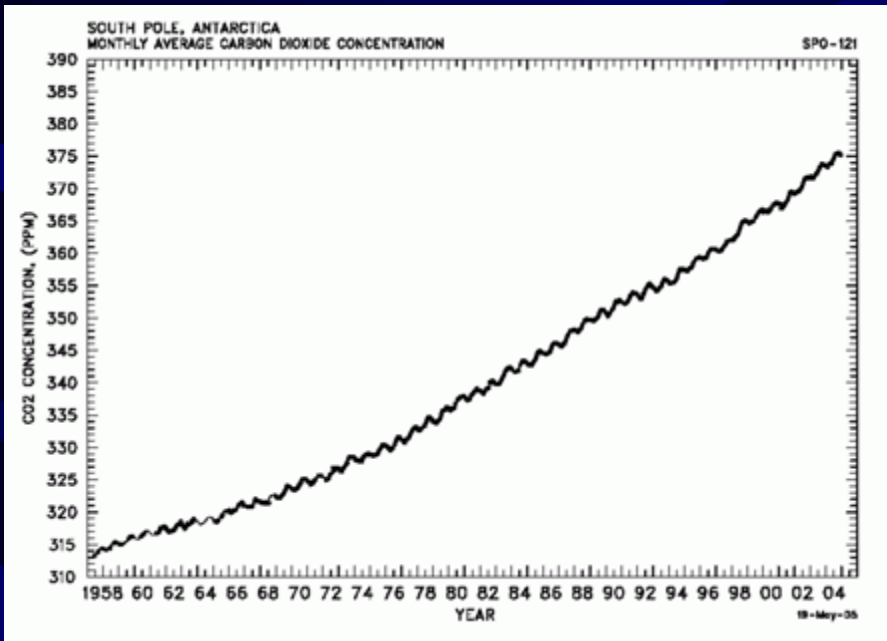
# Atmospheric Carbon Dioxide

- This chart shows a steady increase of CO<sub>2</sub> concentration in the last five decades. Although this chart is based on Mauna Loa's data, the same trend has been found in many other places.





# South Pole and Barrow, Alaska, show the same trend as Hawaii



# How is the CO<sub>2</sub> increase connected to the global warming?

- Physically, via the greenhouse effect.
- The connection is usually made via the use of a **climate model**.
- Control run versus scenarios.
- If the scenario run results show warmer surface condition than the control, then it is plausible to suspect that the increasing CO<sub>2</sub> concentration in the atmosphere may cause warming.

# Feedback Effect

- The climate system is very complicated. A change in one component of the system may cause changes in other components. Sometimes the changes in other components enhance the initial change, then we say that these changes have *positive feedback* to the system. If the changes result in the reduction of the original change, then they have *negative feedback*.
- Both positive and negative feedback processes may exist in the climate system. In studying the global climatic change, we cannot make conclusions based on intuition, but have to take all such possible complicated effects into account. A good climate model would have treated all of them realistically.

# An example of positive feedback

- When the climate becomes warmer (either due to the increase of  $\text{CO}_2$  in the atmosphere or other unknown mechanisms), the ocean may also become warmer. A warmer ocean has lower solubility of  $\text{CO}_2$  and hence will release more  $\text{CO}_2$  into the atmosphere. This may cause the climate to become even warmer than before. Thus the dependence of solubility of  $\text{CO}_2$  on temperature has a positive feedback on the climate system.

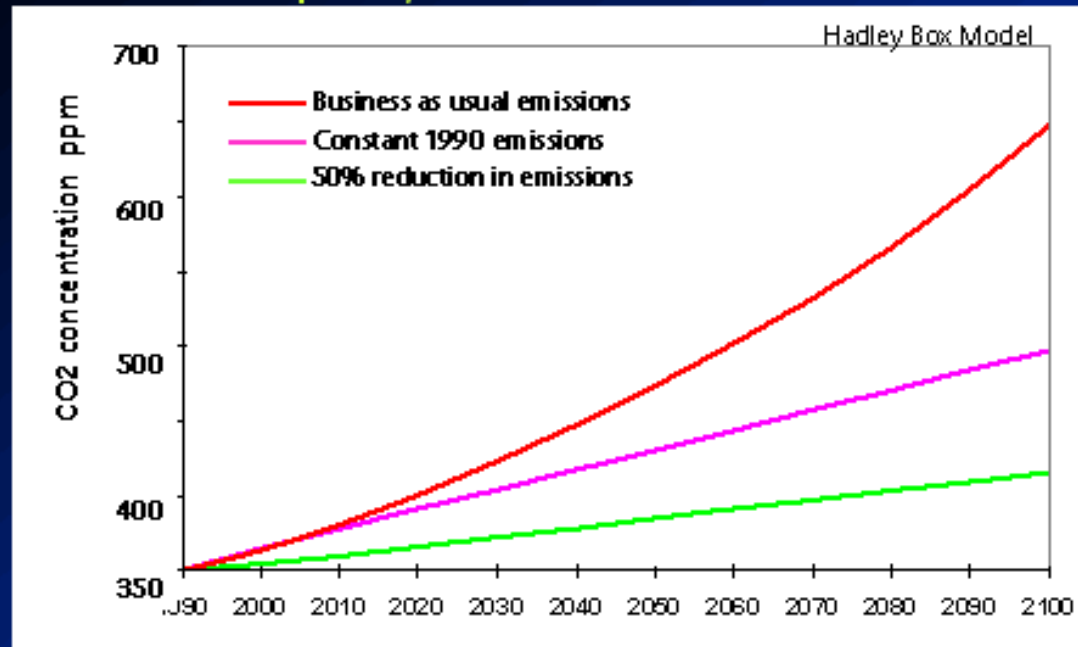
# An example of negative feedback

- Consider a clear region over the ocean. Since there is no cloud, the sun shines on the ocean surface, causing it to warm up. This makes this part of the ocean warmer than other parts and the air over it tends to rise (causing convection). As we have learned before, rising air expands and cools, causing clouds to form. The formation of clouds will block out the sun and the solar heating of the ocean surface will cease. The surface will start to cool down. Thus the cloud formation due to surface heating and convection is a negative feedback to the climate system.

# How fast will the CO<sub>2</sub> concentration increase?

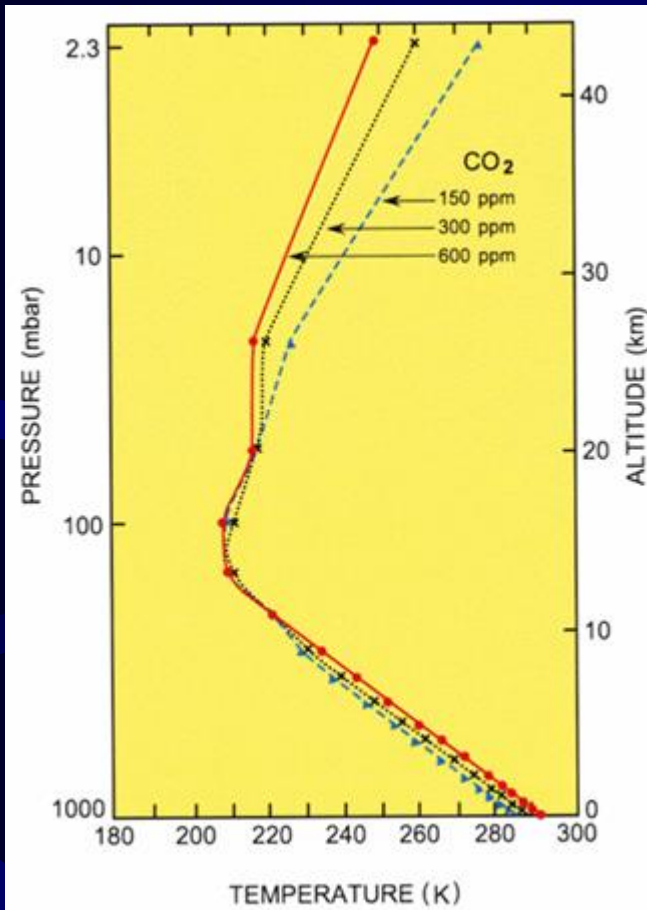
- There are various estimates of the CO<sub>2</sub> increasing rate. They are different in the statistical models used (for example, linear vs. nonlinear increase) and the future regulations.

**Carbon dioxide concentration  
in the atmosphere, due to three emissions scenarios**

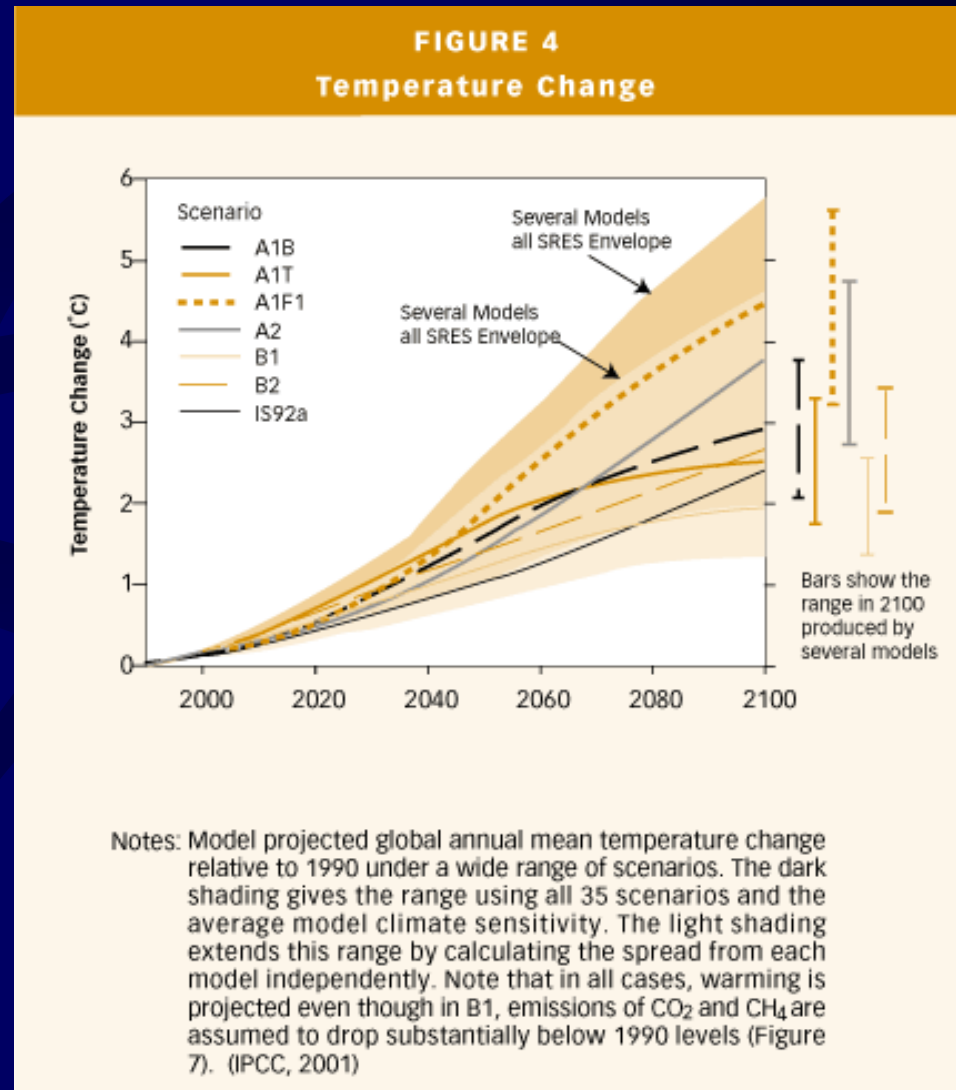




# Projection of future warming

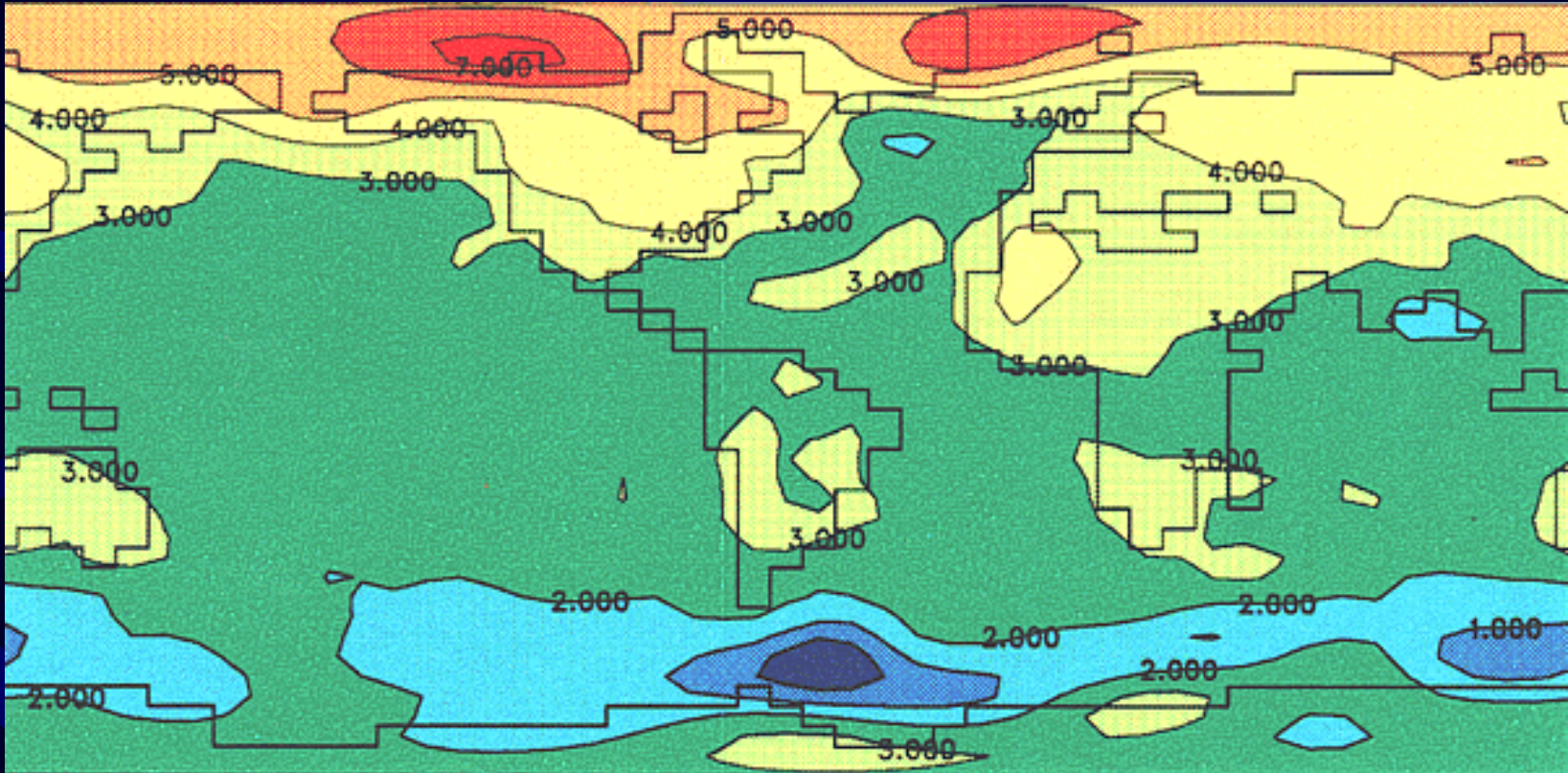


Vertical distribution of temperature in radiative-convective equilibrium for various values of atmospheric CO<sub>2</sub> concentration, i.e., 150, 300, and 600 ppm by volume. From Manabe and Wetherald (8).



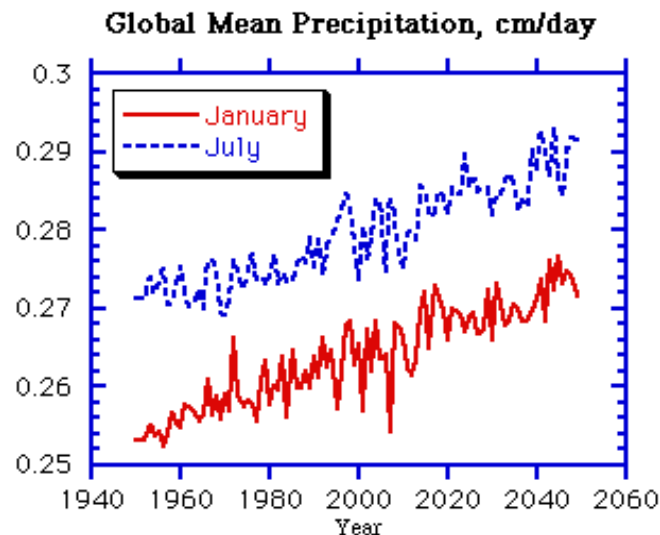
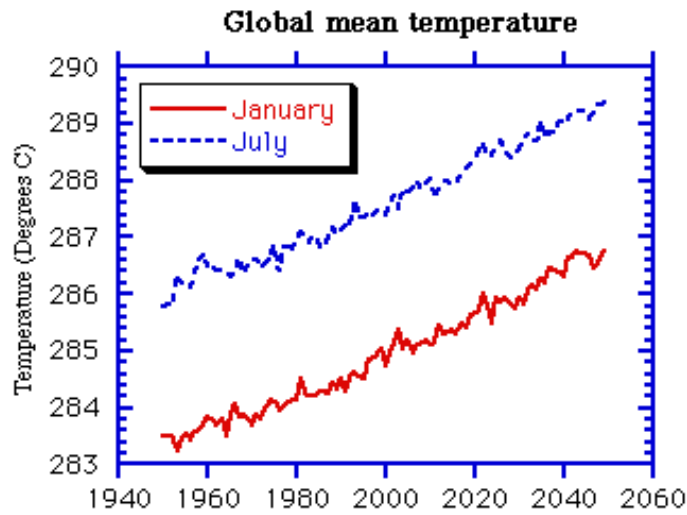
# The degree of warming will not be uniform everywhere

higher latitudes are more sensitive



*Source: IPCC*

# If temperature can change, so do other meteorological and environmental variables.

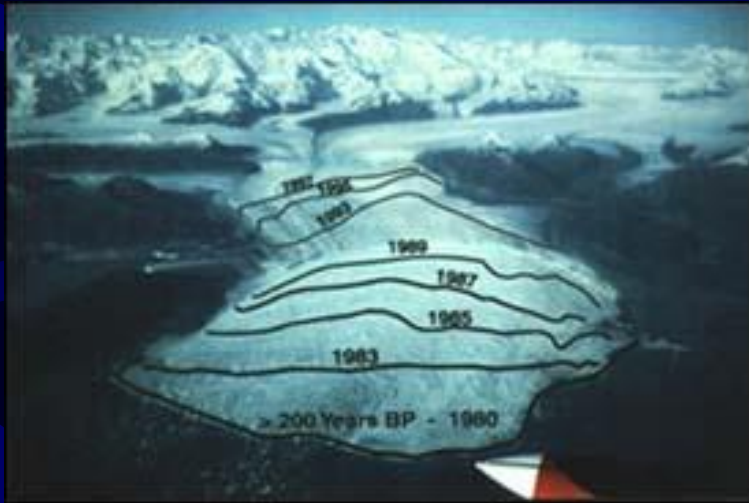


- The change in temperature may cause a change in precipitation.
- Vegetation may also change in response to temperature and precipitation changes.
- And there will be changes in the animal and human world in response to these environmental changes.

*Source: NOAA*



# Melting ice and rising sea level

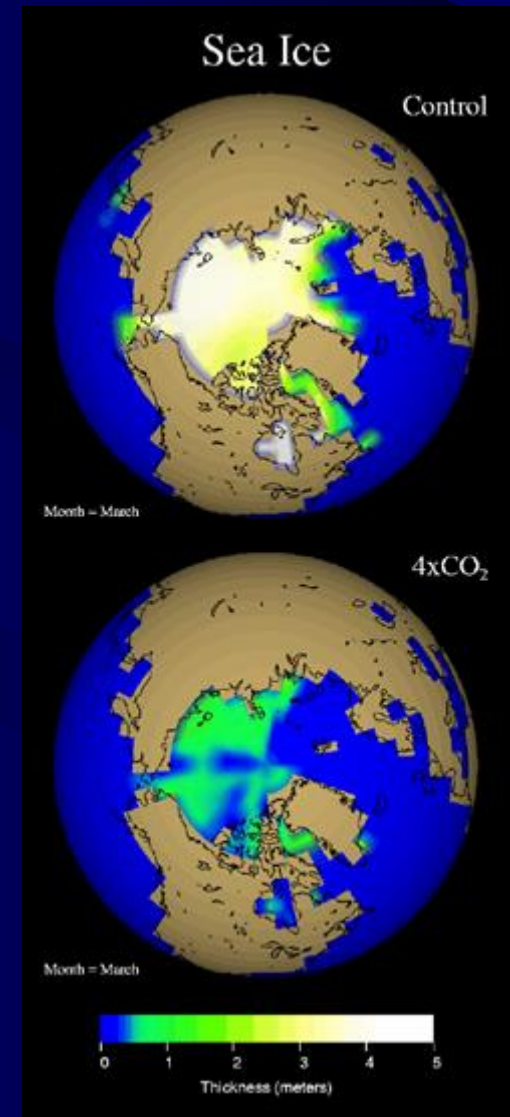
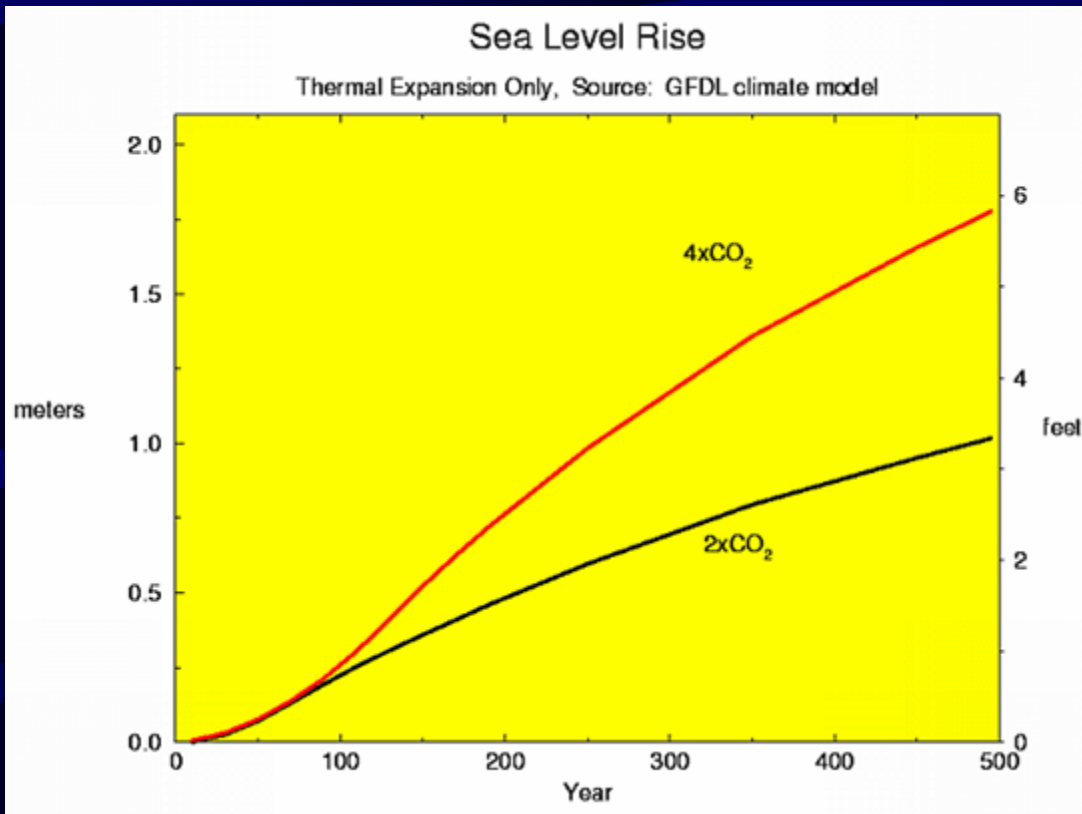


Courtesy NSF

Receding high mountain glaciers



Ice shelves of the South Pole have partly separated and are collapsing. (NASA)



Of course the physical environmental change will lead to changes in the biosphere – including our society.

# Not everybody is convinced of the greenhouse gases - global warming theory

- At this point, it appears that the warming itself is real – the surface temperature indeed becomes higher in the last few decades.
- The question is – Is the warming caused by the greenhouse gases (especially CO<sub>2</sub>)?
- Some groups, especially the IPCC members argue strongly for it. But there are other groups that are not convinced. The summary to the right is from Robinson et al. (1998).

*You can get IPCC reports at <http://www.ipcc.ch/>*

## Summary

World leaders gathered in Kyoto, Japan, in December 1997 to consider a world treaty restricting emissions of "greenhouse gases," chiefly carbon dioxide (CO<sub>2</sub>), that are thought to cause "global warming" severe increases in Earth's atmospheric and surface temperatures, with disastrous environmental consequences. Predictions of global warming are based on computer climate modeling, a branch of science still in its infancy. The empirical evidence actual measurements of Earth's temperature shows no man-made warming trend. Indeed, over the past two decades, when CO<sub>2</sub> levels have been at their highest, global average temperatures have actually cooled slightly.

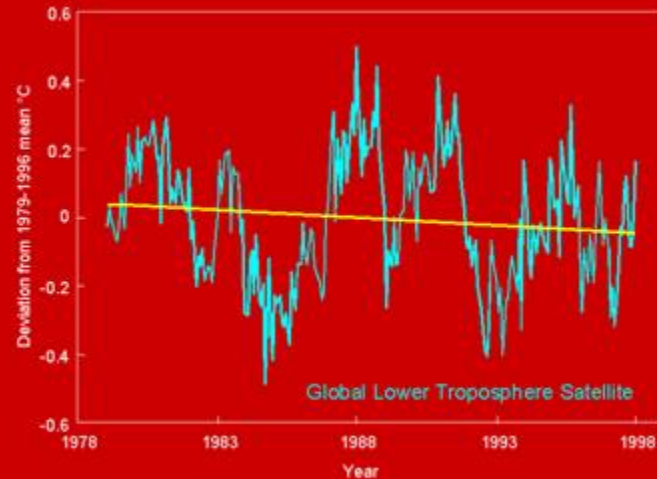
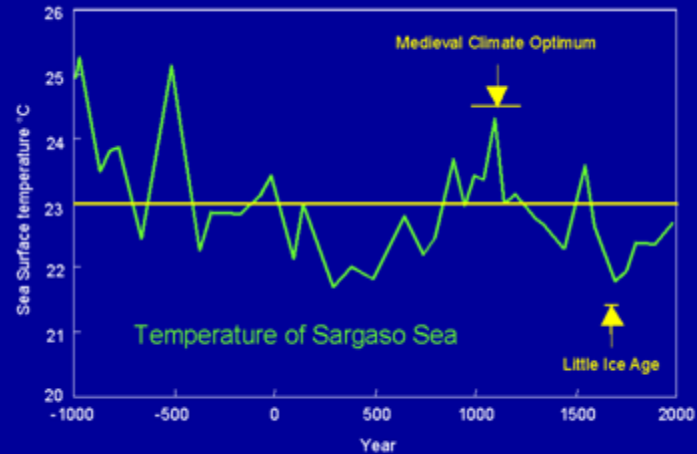
*You can get this from the following website  
<http://www.oism.org/pproject/review.pdf>*



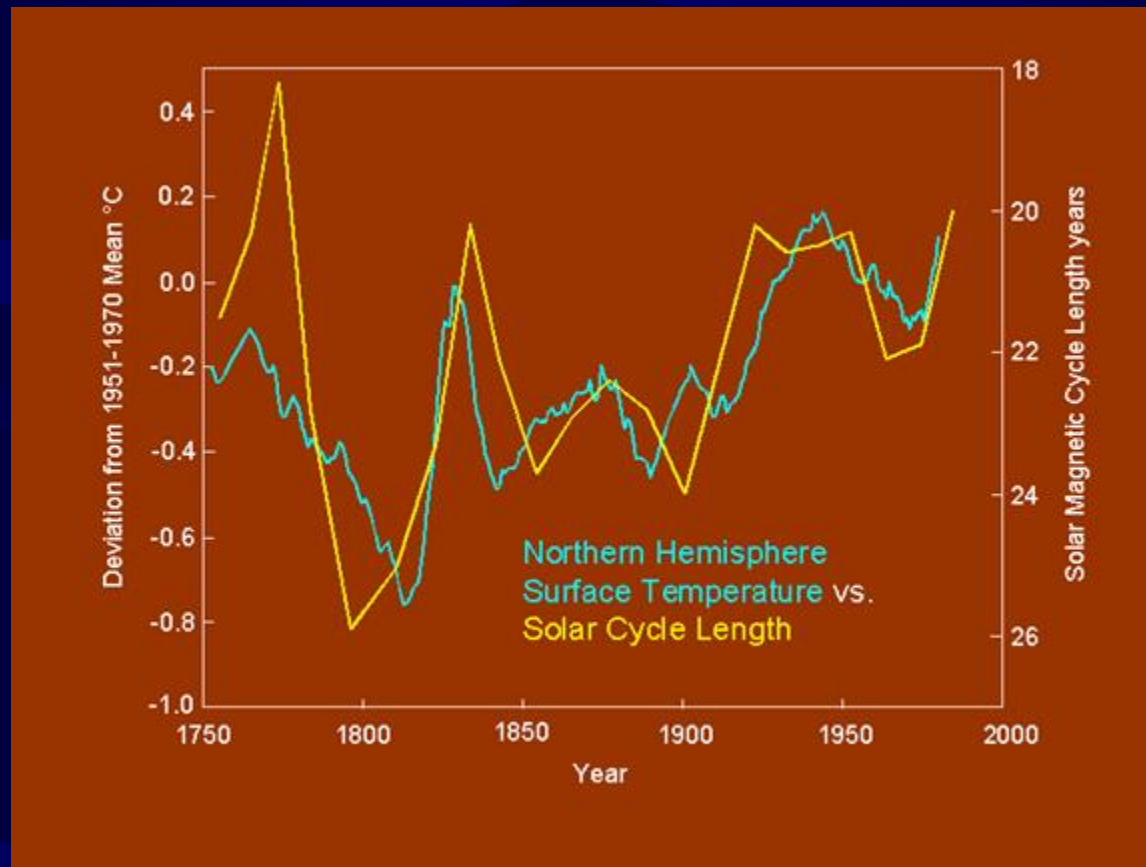
# Some examples of criticisms

- There are evidence showing that the current temperature isn't really that warm compared to what was two to three thousand years ago. The figure to the right shows that the temperature of Sargasso Sea fluctuates in a range of  $\sim 3.6^{\circ}\text{C}$ .
- Also the "trend" depends on the data sets and the section of data you select to examine – see the lower chart. By using a different data set (here the satellite microwave sounding) and selecting a suitable section (for example, 1978-1998) you can actually show that there was a cooling, not warming.

*Source: Robinson et al. (1998)*



There are also evidence showing that the solar activity seems to have some influence on atmospheric temperature. But there are many questions here. Especially on how and how much.



# Global Warming: More than a scientific problem - Aside from scientific problems, there are political problems as well.

## At Climate Meeting, Unlikely Ally for Have-Not

By **AMY WALDMAN**  
New York Times 1 Nov 2002

NEW DELHI, Friday, Nov. 1 — When India's prime minister, Atal Bihari Vajpayee, finished speaking at the international conference on climate here on Wednesday, the fissure between richer and poorer countries over how best to tackle global warming could no longer be papered over. In his speech, he argued that poorer countries could not be expected to invest money in tackling the causes of global warming. They bear little responsibility, he said, producing fewer greenhouse gases than industrialized countries, and yet have been hit harder by the natural calamities, from drought to floods, caused by climate changes. They have weaker economies, and with pressing needs in everything from health to education, can little afford to invest in clean-air technologies.

His speech articulated sentiments — resentments, in some cases — widely shared among developing nations. So while it produced little new of substance, the conference, the eighth since the United Nations Framework Convention on Climate Change was adopted in 1992, illuminated the challenges in crafting a global response to global warming.

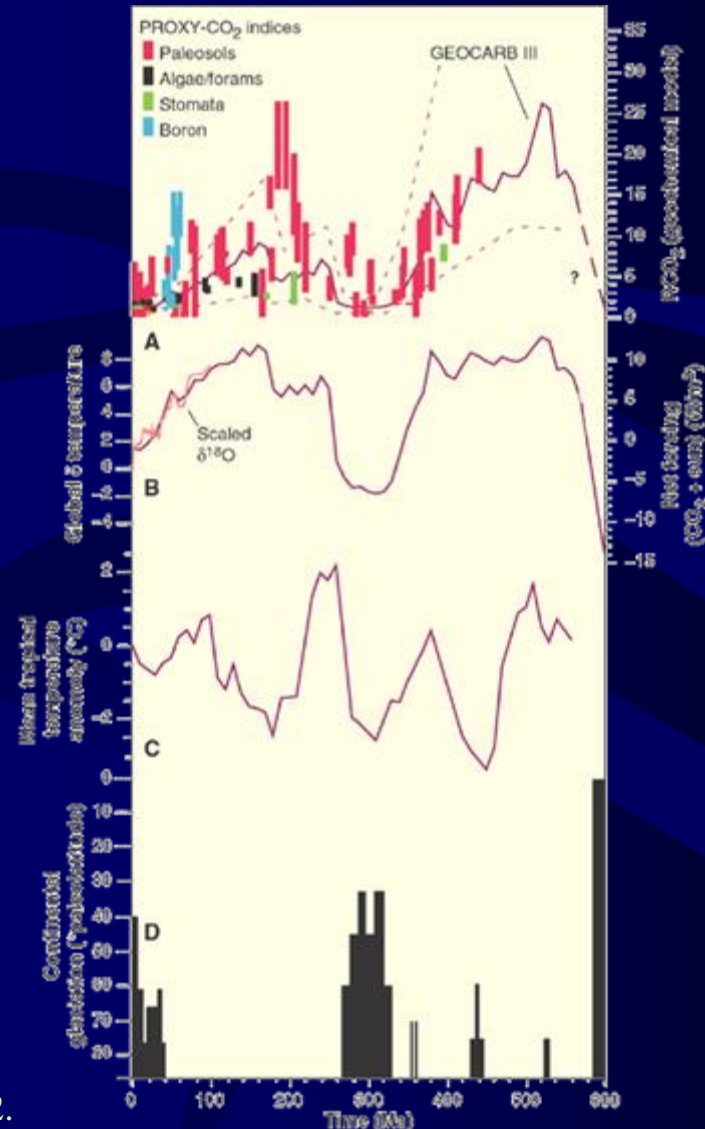
It highlighted a divide between north and south, between the industrialized and developing worlds, over who should bear the obligations and burdens of trying to reduce the emissions that cause global warming.

But on several points, the south found itself with an unlikely ally: the United States, which under the Bush administration has also blanched at joining efforts to reduce emissions.

Instead, the United States joined India and other developing countries in encouraging a focus on developing the technology and finding the resources to adapt to climate change.

# You can go back even further...

- Back even further in time, the CO<sub>2</sub> level in the atmosphere fluctuated considerably and sometimes the concentration might be much greater than it is now.



# Ultimately

- The problem really is that we don't know how the climate machine works, hence it is difficult at present to say that the warming is due to the increase of greenhouse gases and not the results of natural fluctuation of the global climate system.
- Recently, there seems to be increasing evidence showing the connection between the global warming and industrial injection of greenhouse gases. However, the extent is still not clear.
- Hopefully, with more research we can say more definitely in the near future.