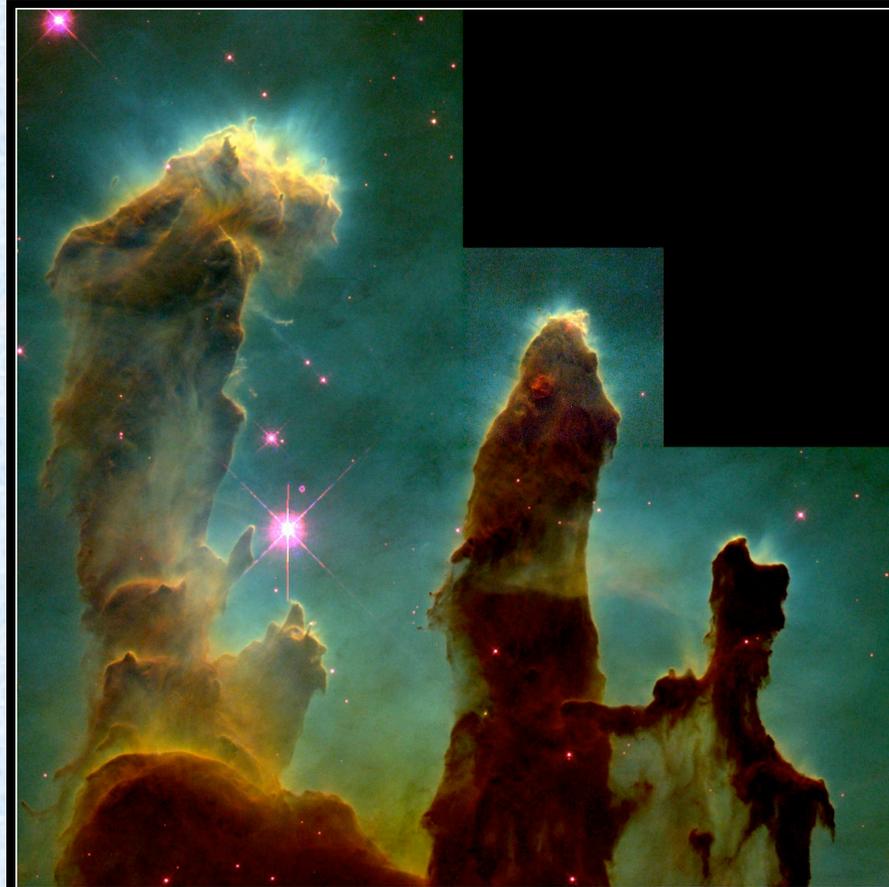


Astronomy 1 – Winter 2011



Gaseous Pillars in M16 • Eagle Nebula
Hubble Space Telescope • WFPC2

PRC95-44a • ST ScI OPO • November 2, 1995 • J. Hester and P. Scowen (AZ State Univ.), NASA



Lecture 13; February 4 2011

Previously on Astro-1

- **The Earth's Energy Sources:**
 - Solar energy
 - Rotational Energy of the Earth and the Earth-Moon system, though tidal forces.
 - Internal residual heat of the Earth
 - Radioactivity in the Earth's crust
- **The Earth's interior**
 - Inner and outer core made of Iron
 - Mantel made of iron rich minerals
- **Plate tectonics**
 - The crust moves due to the internal circulation of heat from the core to the mantel
 - Resopnsible for Earthquakes, Volcanism and Movement Continents

Today on Astro-1

- **Global Warming**
 - Is Earth getting warmer?
 - Are humans causing it?
 - What are the consequences?
 - What can we do to stop it?

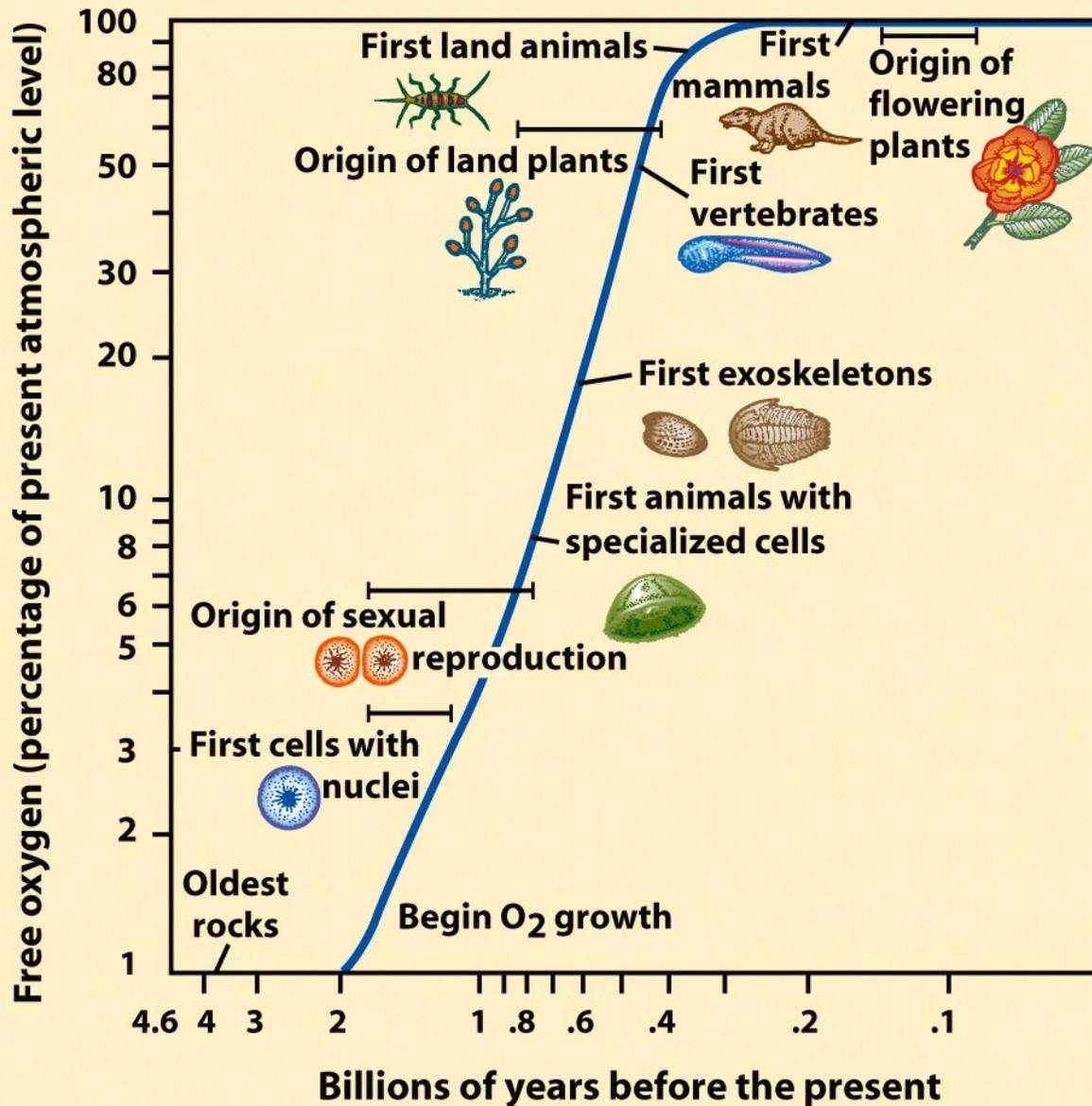
Question 13.1 (iclickers!)

- Preliminary poll on global warming
 - A) The evidence is ambiguous, we need to study it more before taking action
 - B) It is real, but the evidence it is caused by humans is ambiguous
 - C) It is real and there is significant evidence it is caused by humans
 - D) It is due to variations in the Sun's energy output

Table 9-4 **Chemical Compositions of Three Planetary Atmospheres**

	Venus	Earth	Mars
Nitrogen (N₂)	3.5%	78.08%	2.7%
Oxygen (O₂)	almost zero	20.95%	almost zero
Carbon dioxide (CO₂)	96.5%	0.035%	95.3%
Water vapor (H₂O)	0.003%	about 1%	0.03%
Other gases	almost zero	almost zero	2%

Table 9-4
Universe, Eighth Edition
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The appearance and spread of life on Earth caused a radical change in the Earth's atmosphere: growth of O₂.

Figure 9-22
Universe, Eighth Edition
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Unnumbered figure pg 233
Universe, Eighth Edition
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This photograph shows the soil near Pretoria, South Africa. The whitish layer that extends from lower left to upper right is 2.2 billion years old. Its color is due to a lack of iron oxide. More recent soils typically contain iron oxide and have a darker color.

The Greenhouse Effect

Sun

Some of the solar radiation is reflected by the atmosphere and the Earth's surface

Outgoing solar radiation: 103 Watts per m^2

Some of the infrared radiation passes through the atmosphere and out into space

Outgoing infrared radiations: 240 Watts per m^2

Solar radiation passes through the atmosphere
Incoming solar radiation: 343 Watts per m^2

About half the solar radiation is absorbed by the Earth's surface

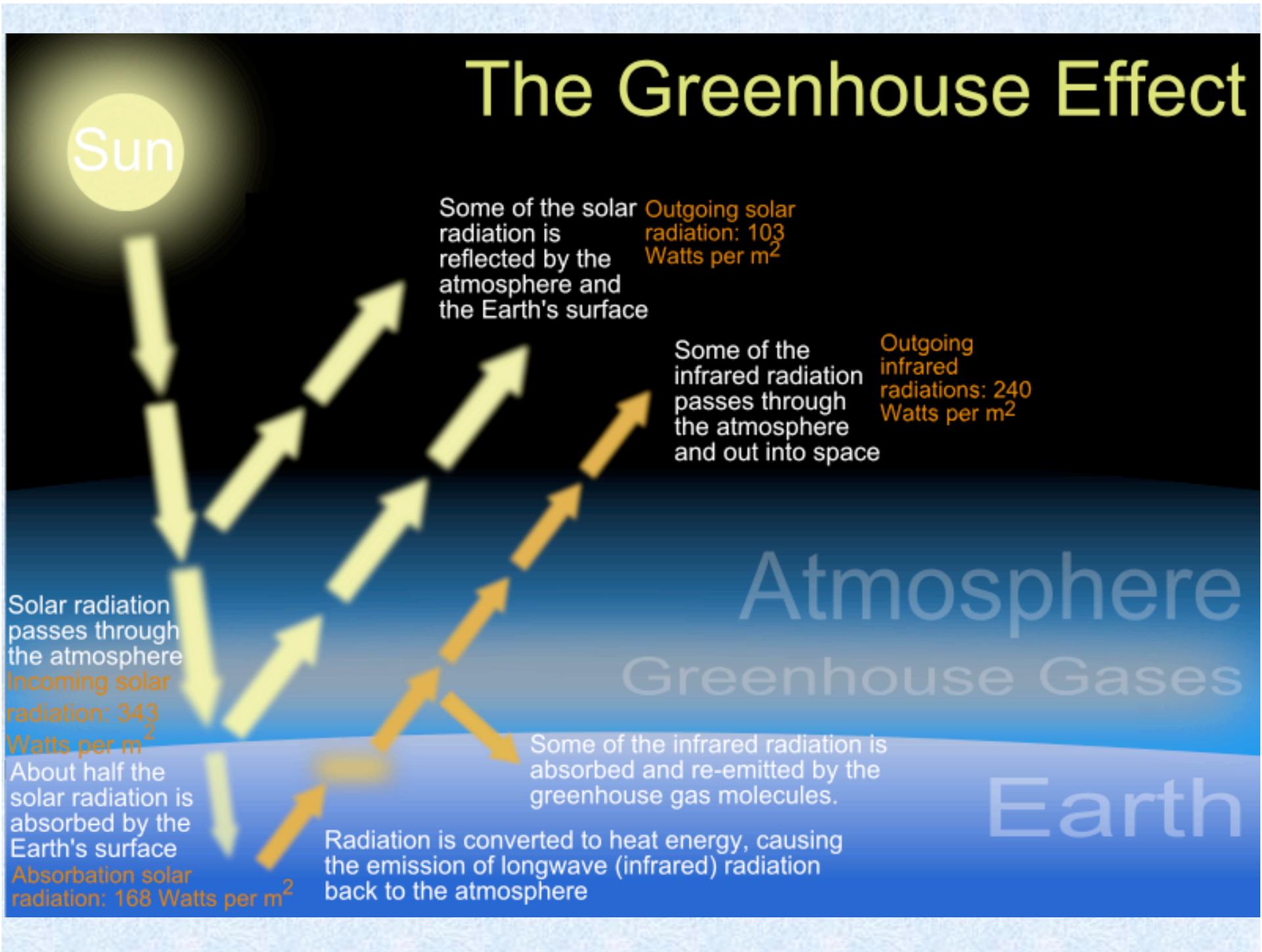
Absorption solar radiation: 168 Watts per m^2

Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules.

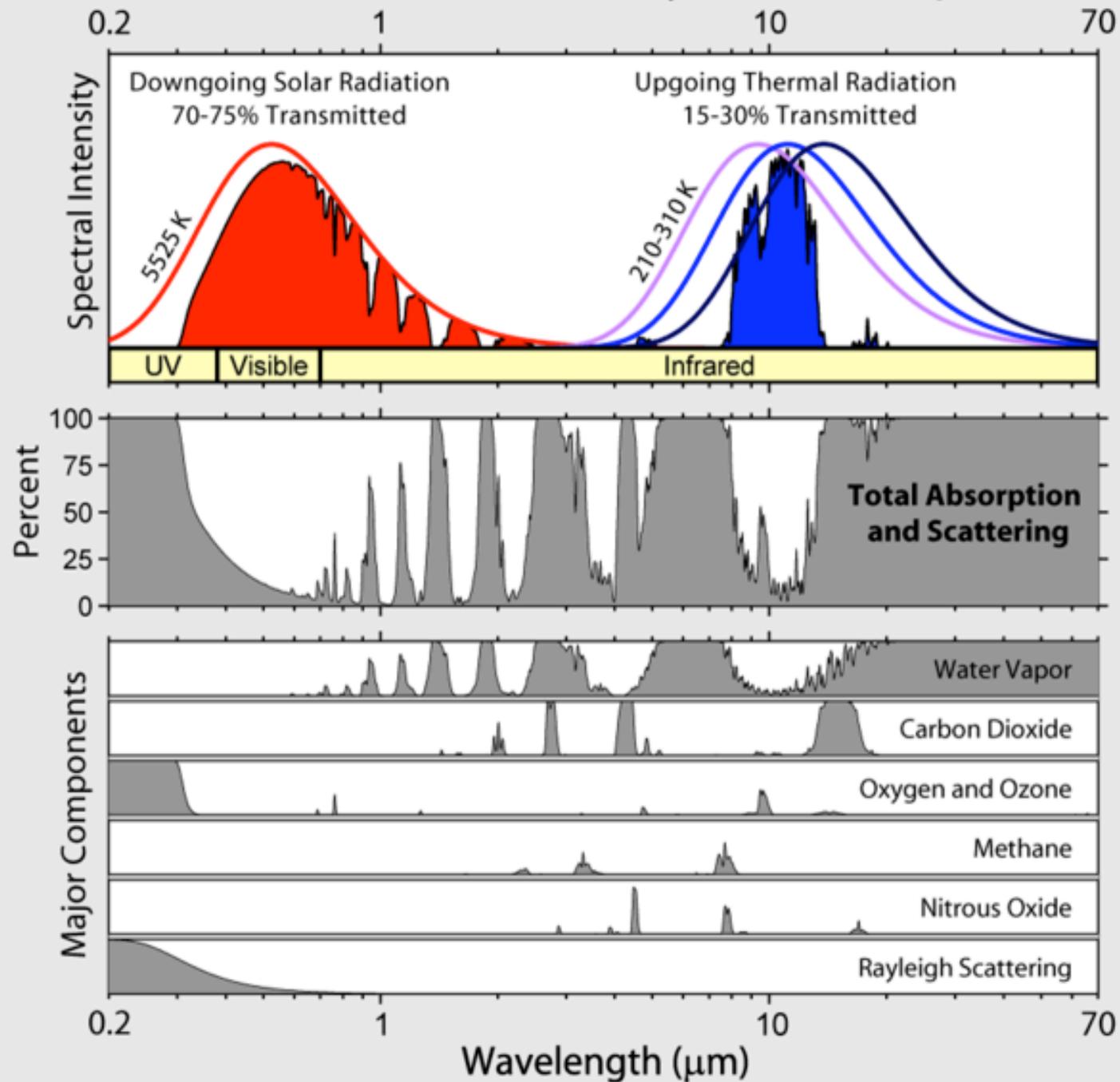
Radiation is converted to heat energy, causing the emission of longwave (infrared) radiation back to the atmosphere

Atmosphere
Greenhouse Gases

Earth



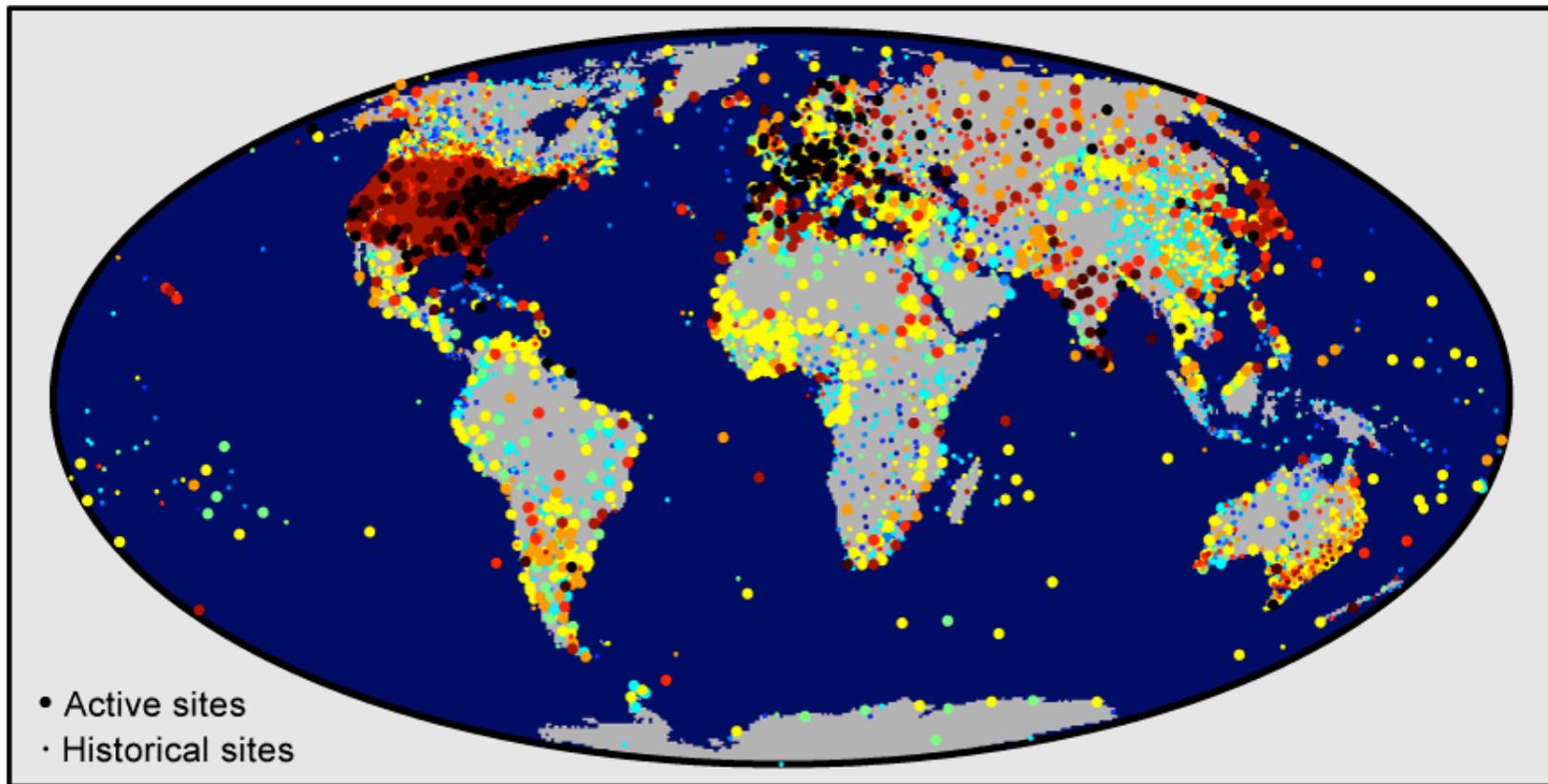
Radiation Transmitted by the Atmosphere



Global Warming

1. **Is the Earth getting warmer?**
2. Are humans causing it?
3. What are the consequences?
4. What can we do to stop it?

Global Climate Network Temperature Stations

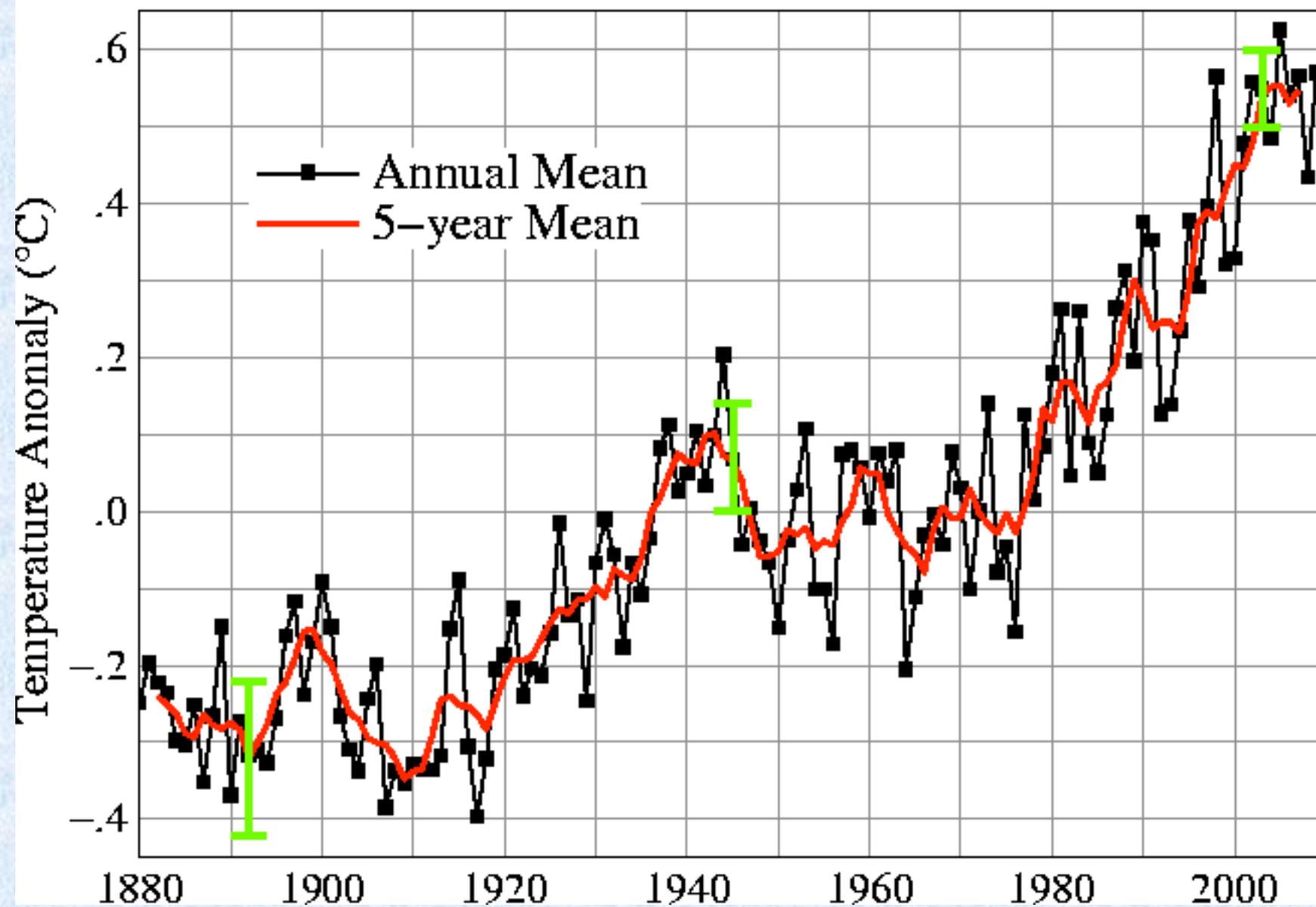


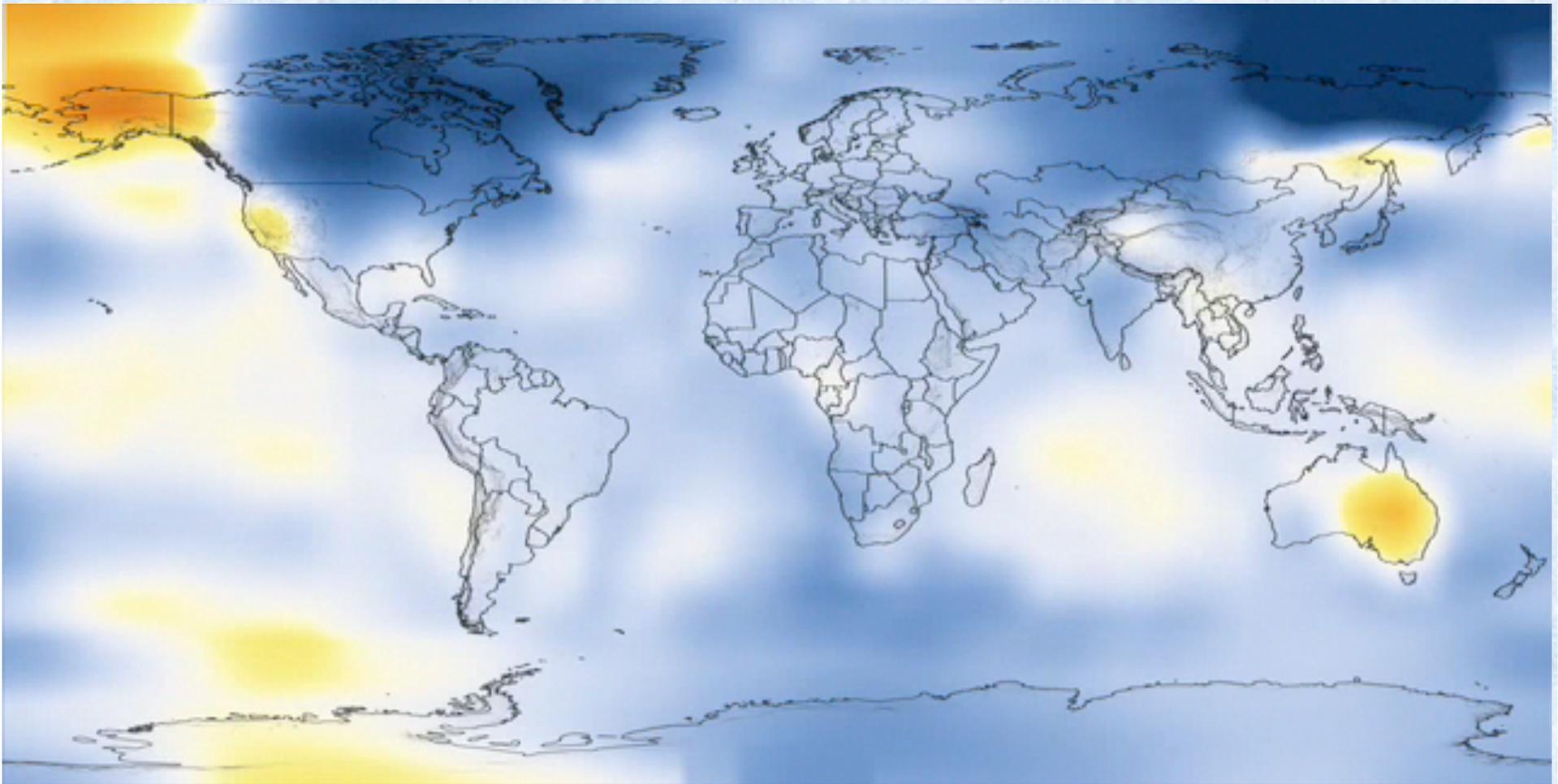
- Active sites
- Historical sites



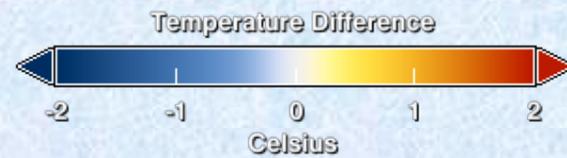
Length of Station Record (years)

Global Land–Ocean Temperature Index

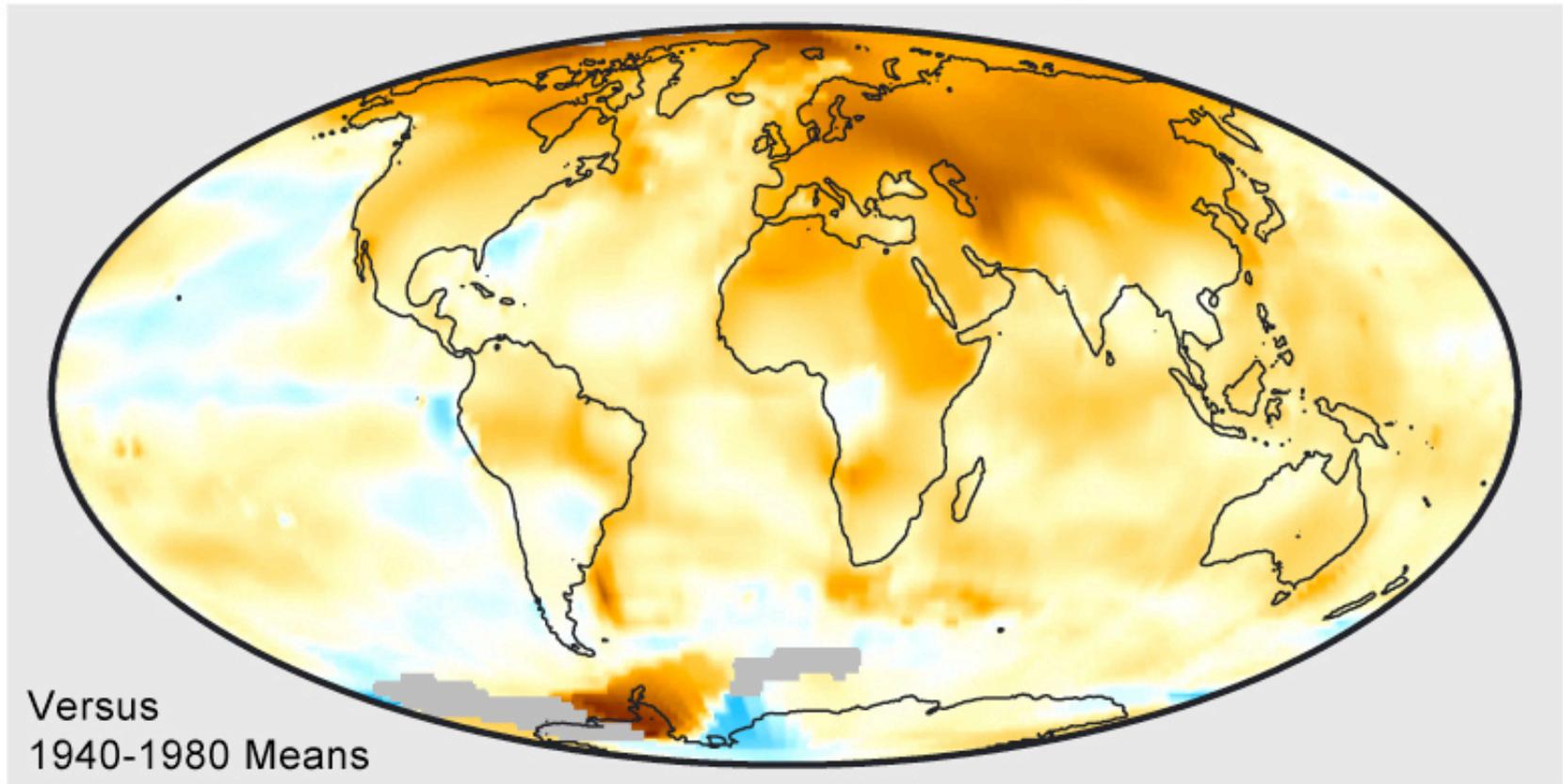




Start 1881 – End 2008



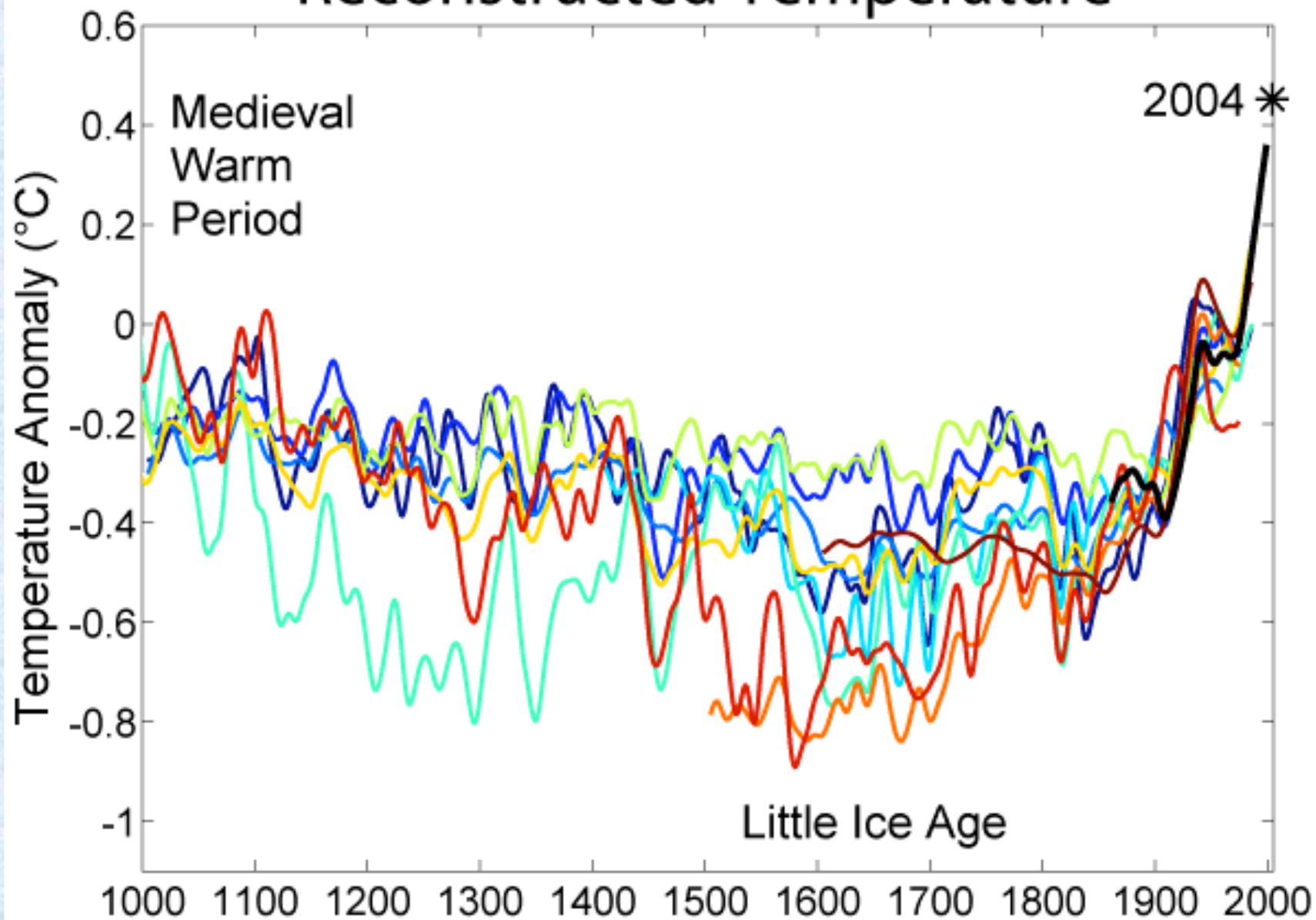
1999-2008 Mean Temperatures



-2 -1.5 -1 -0.5 0 0.5 1 1.5 2

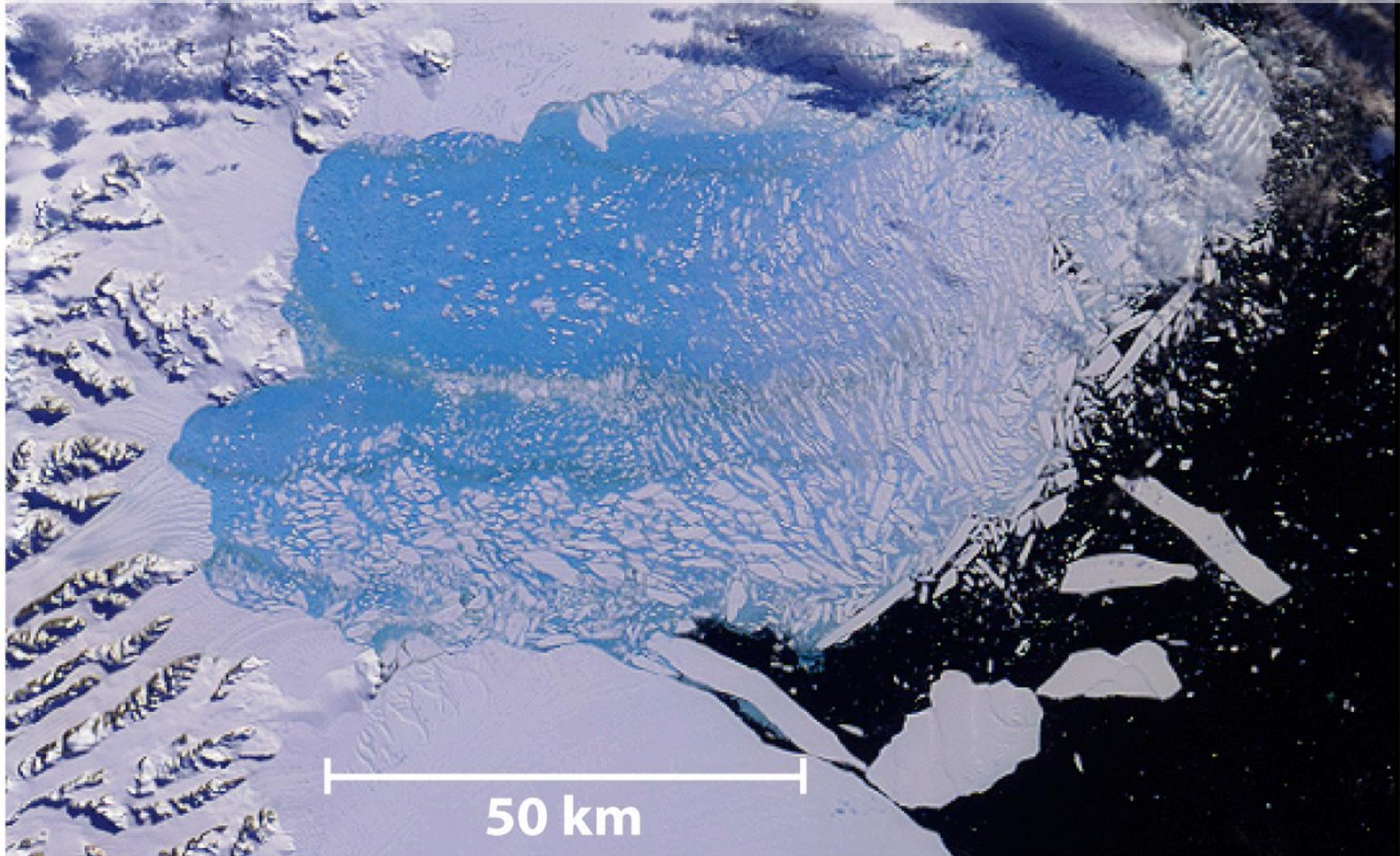
Temperature Anomaly ($^{\circ}\text{C}$)

Reconstructed Temperature





This ice shelf, about the size of Rhode Island, is thought to have been part of the Antarctic coast for the past 12,000 years.



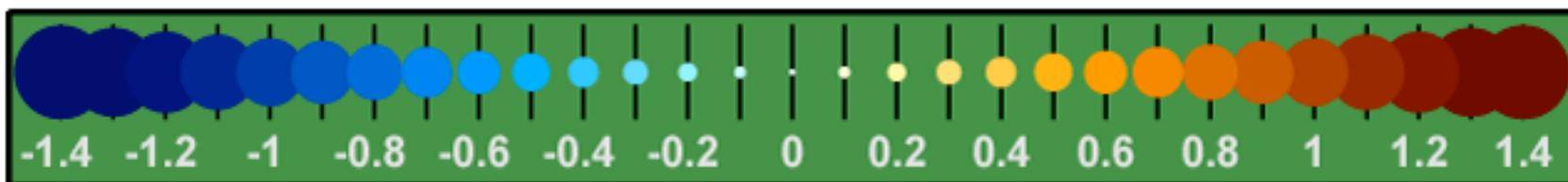
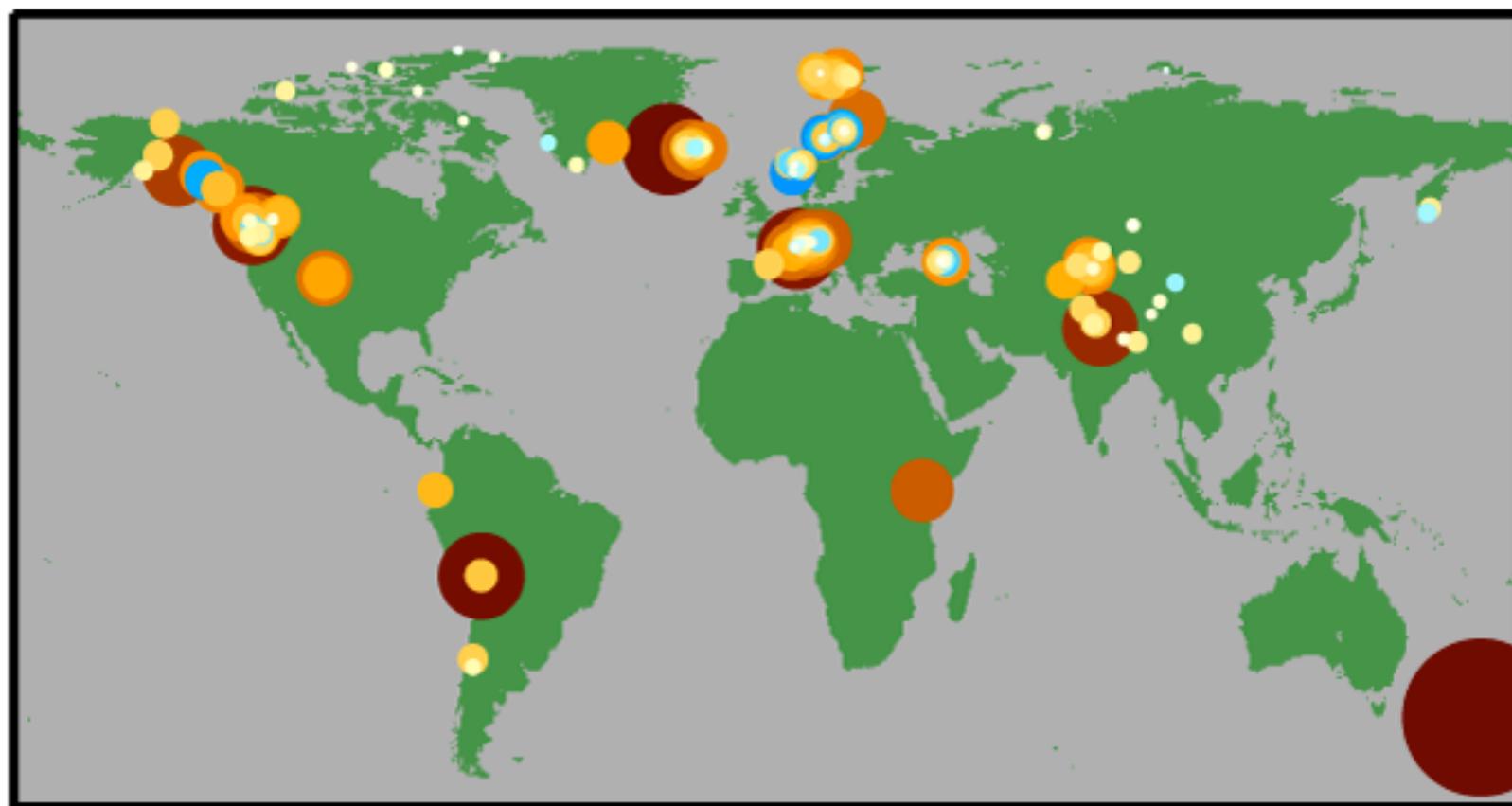
Breakup of the Larsen B ice shelf, Antarctica, 2002

Figure 9-31

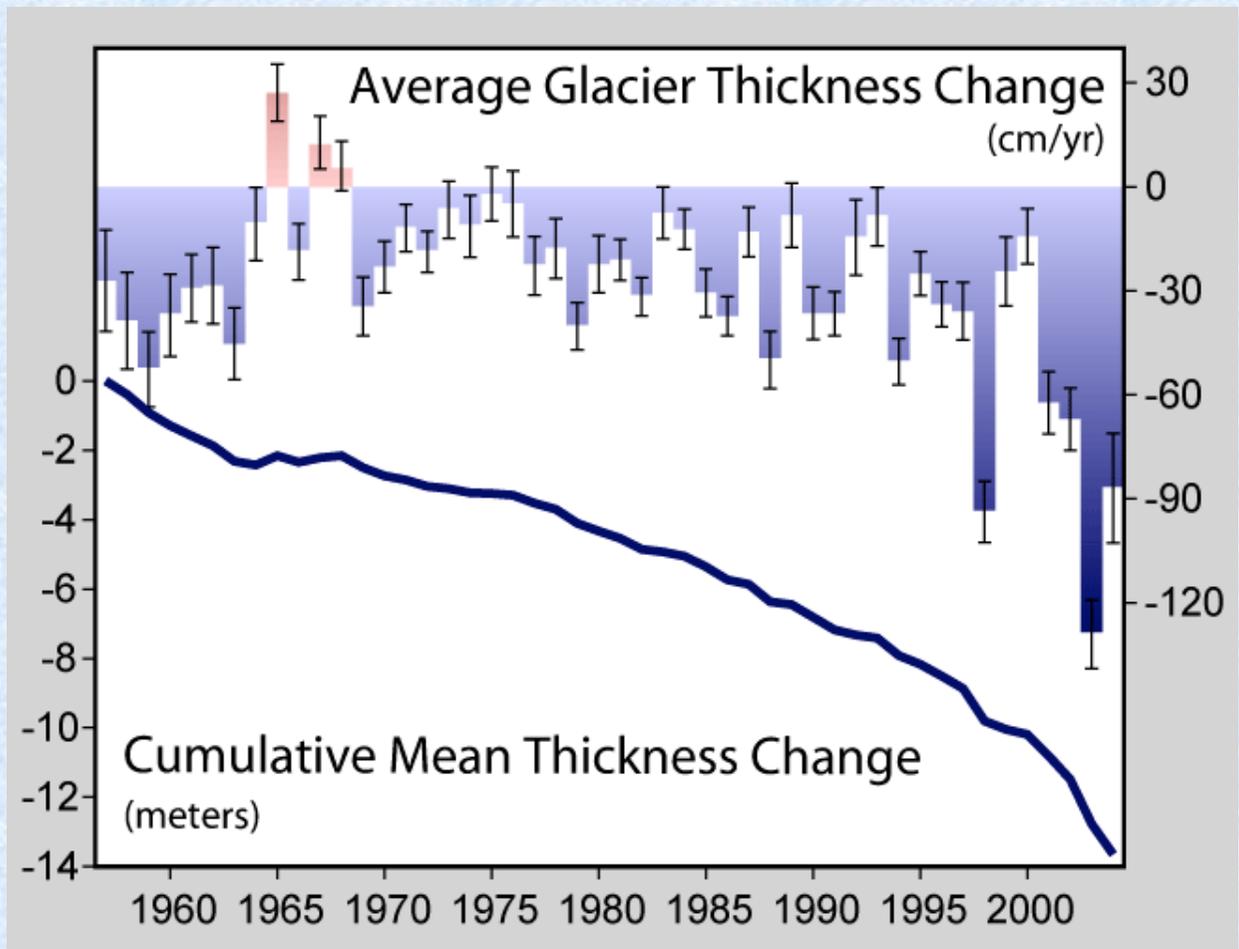
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Mountain Glacier Changes Since 1970



Effective Glacier Thinning (m / yr)



Ice melting as an example of feedback (vicious cycle)

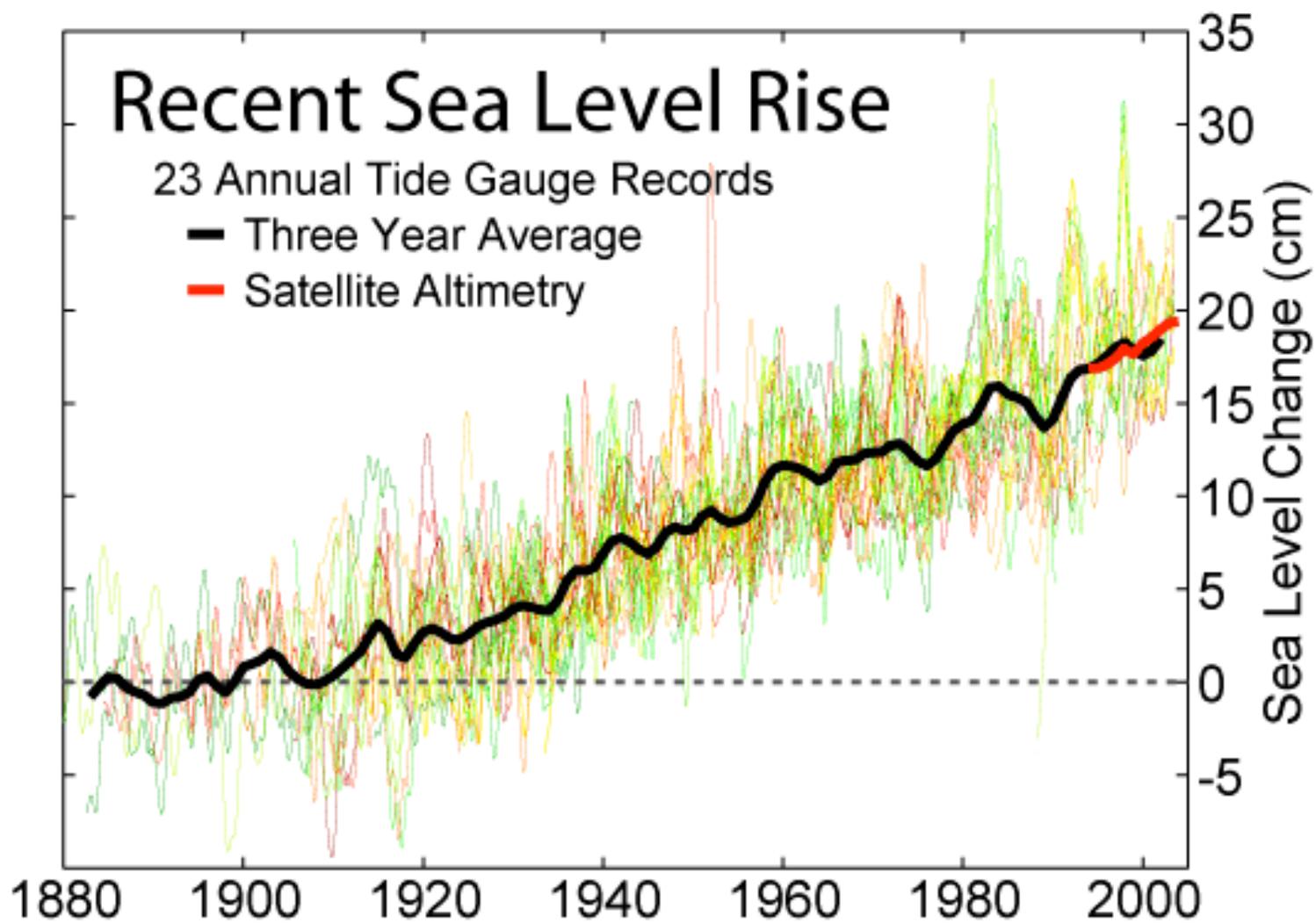
- **As ice melts it is replaced by land or water**
- **Ice has much higher reflectivity than both**
- **Melting ice increases the amount of solar energy absorbed by the Earth's surface, which in turns melts more ice, etc etc**



Recent Sea Level Rise

23 Annual Tide Gauge Records

- Three Year Average
- Satellite Altimetry



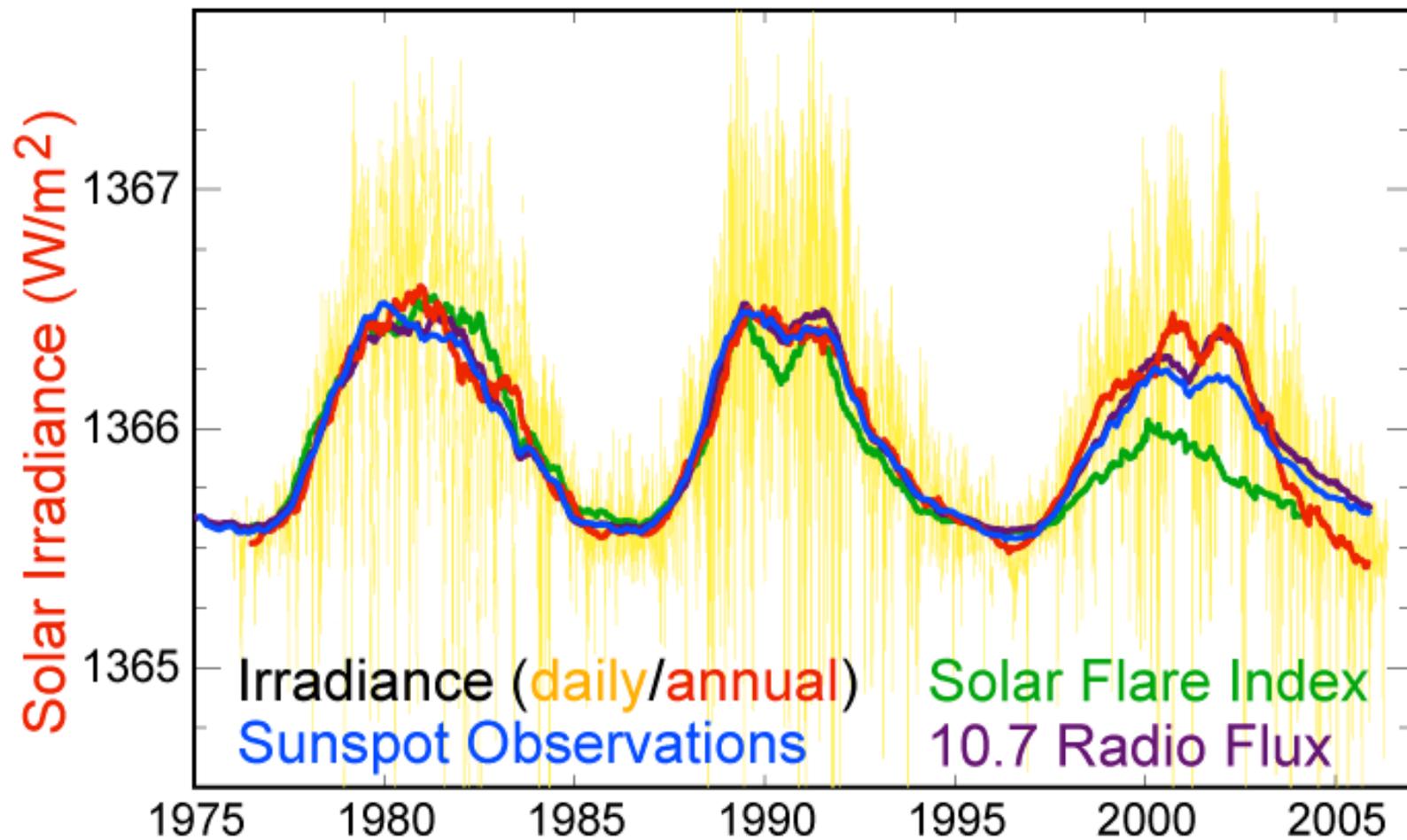
Question 13.2 (iclickers!)

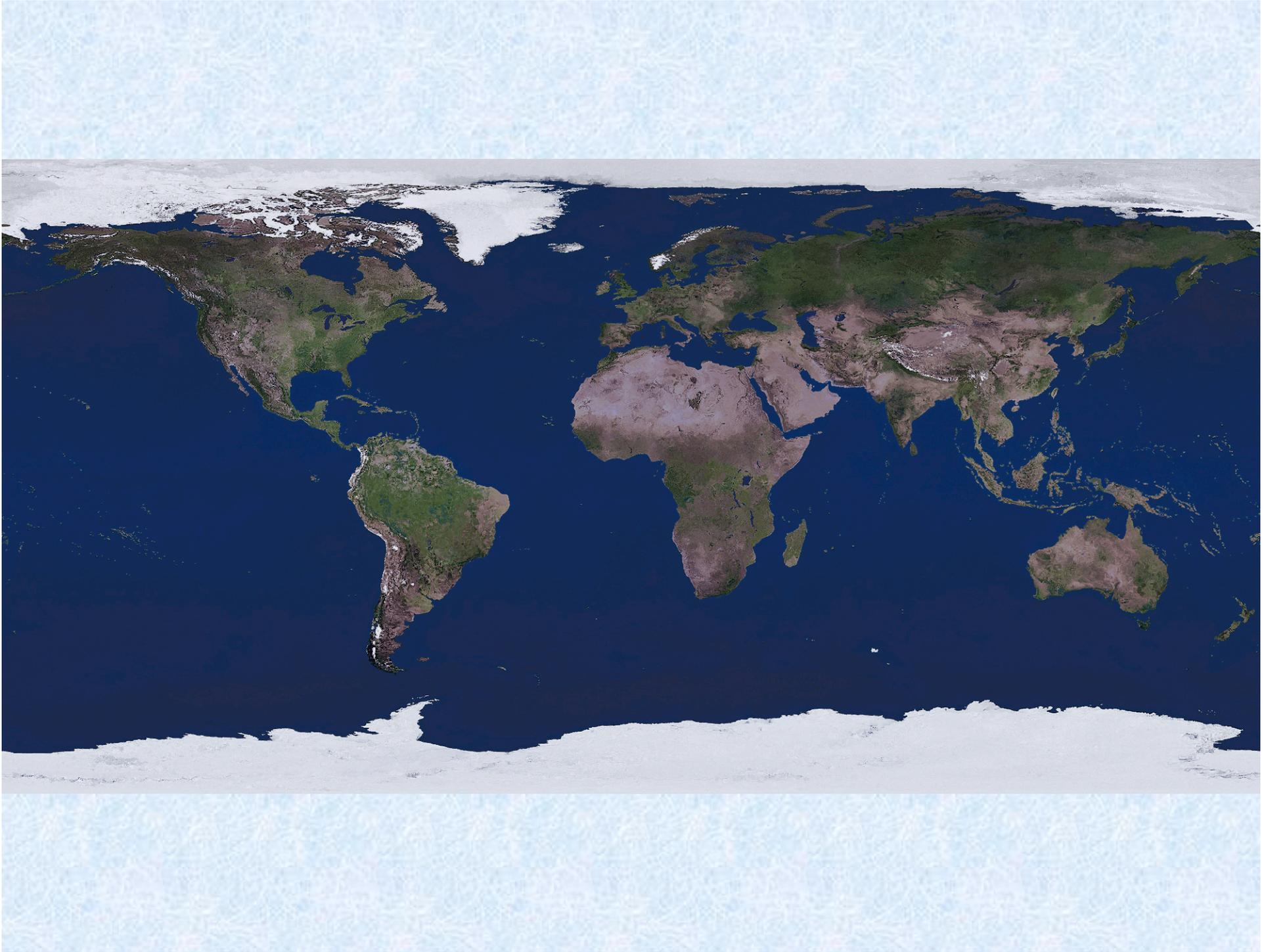
- Which of the following statements is false
 - A) The surface temperature of our planet has been measured to have increased significantly in the past few decades
 - B) Natural variations in power emitted by the Sun are sufficient to explain the changes in global temperature
 - C) Polar ice caps have been observed to shrink significantly in the past decade
 - D) Ocean levels are rising

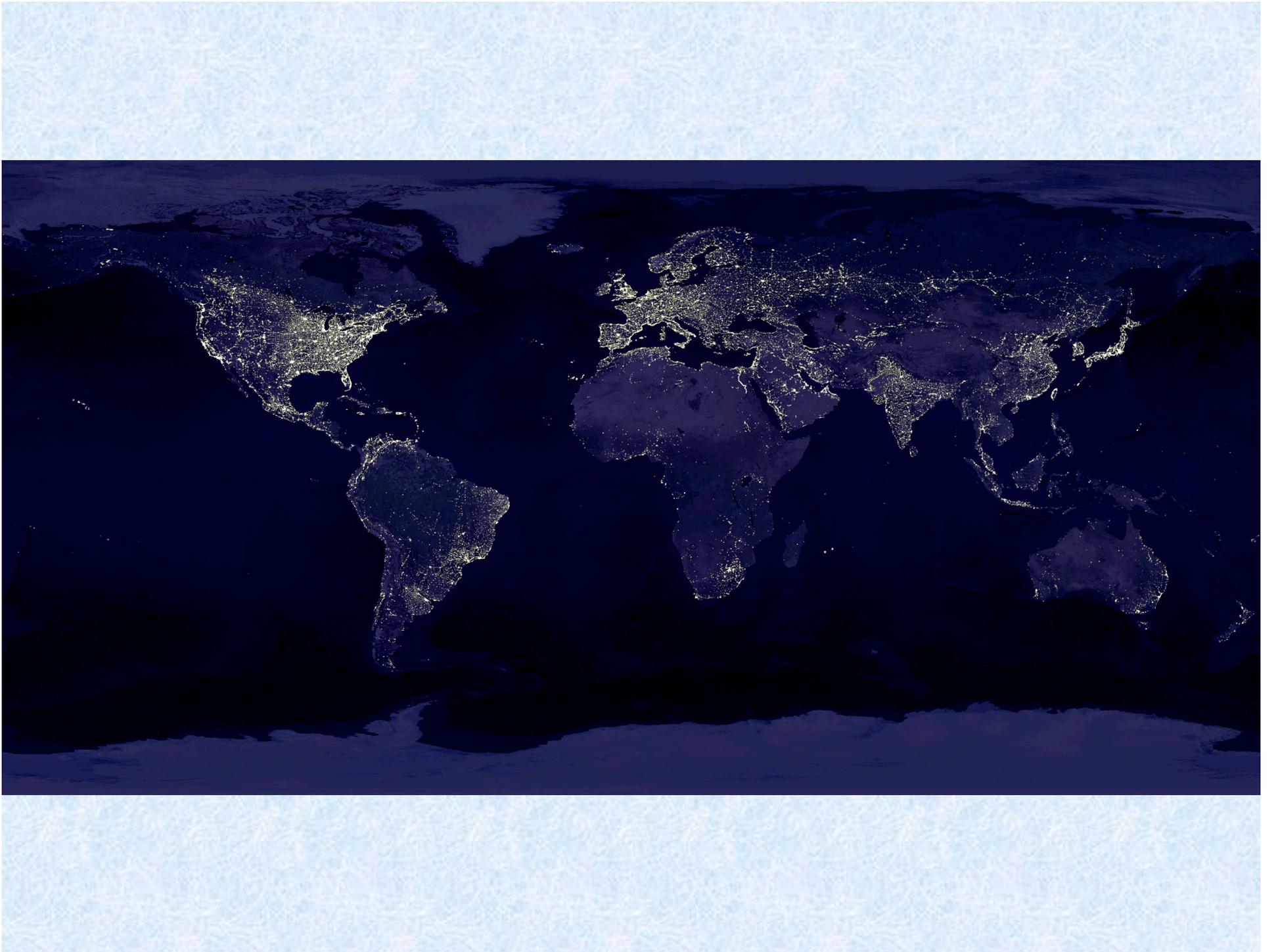
Global Warming

1. Is the Earth getting warmer?
Yes – the evidence is clear.
2. **Are humans causing it?**
3. What are the consequences?
4. What can we do to stop it?

Solar Cycle Variations







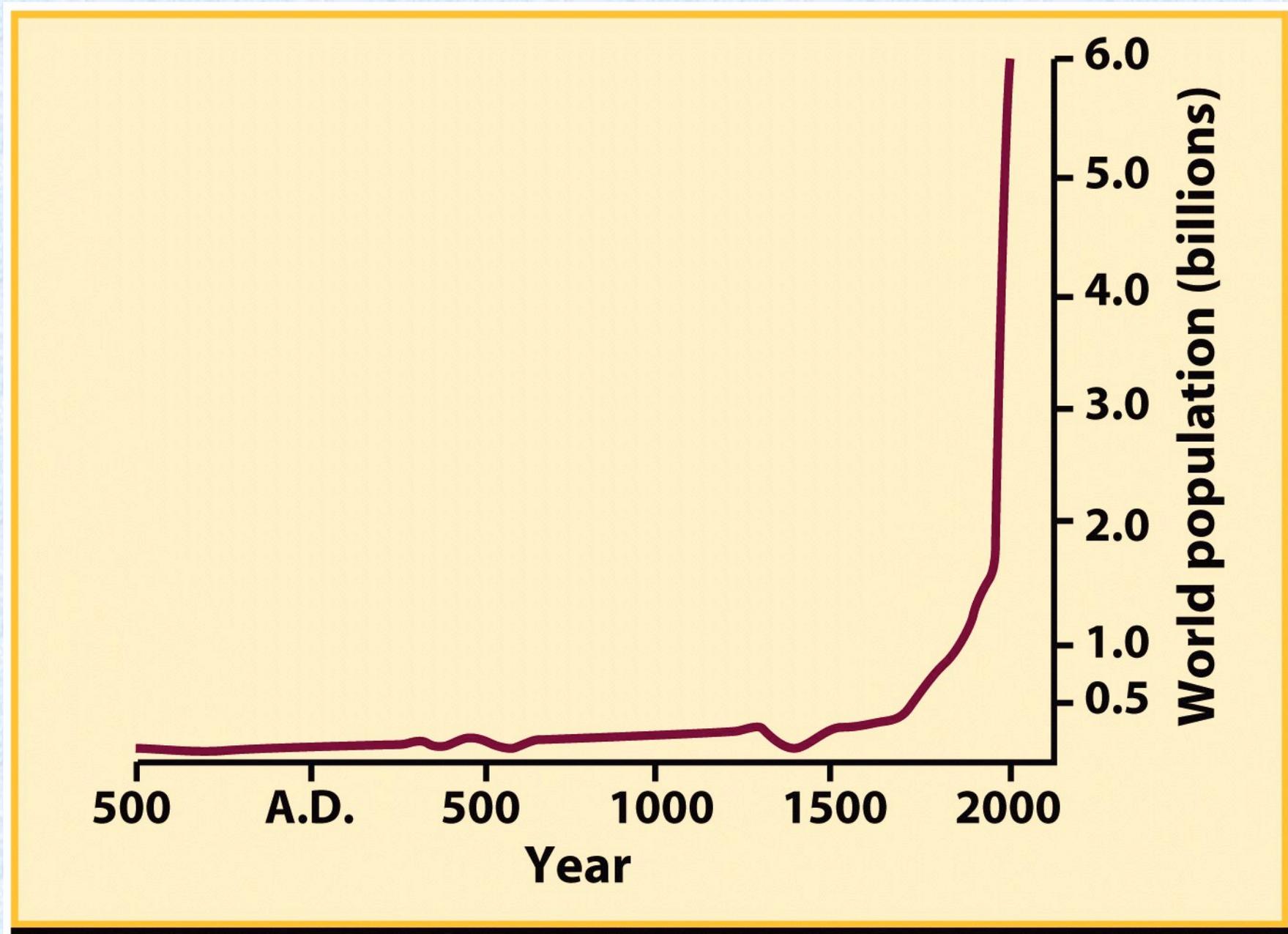


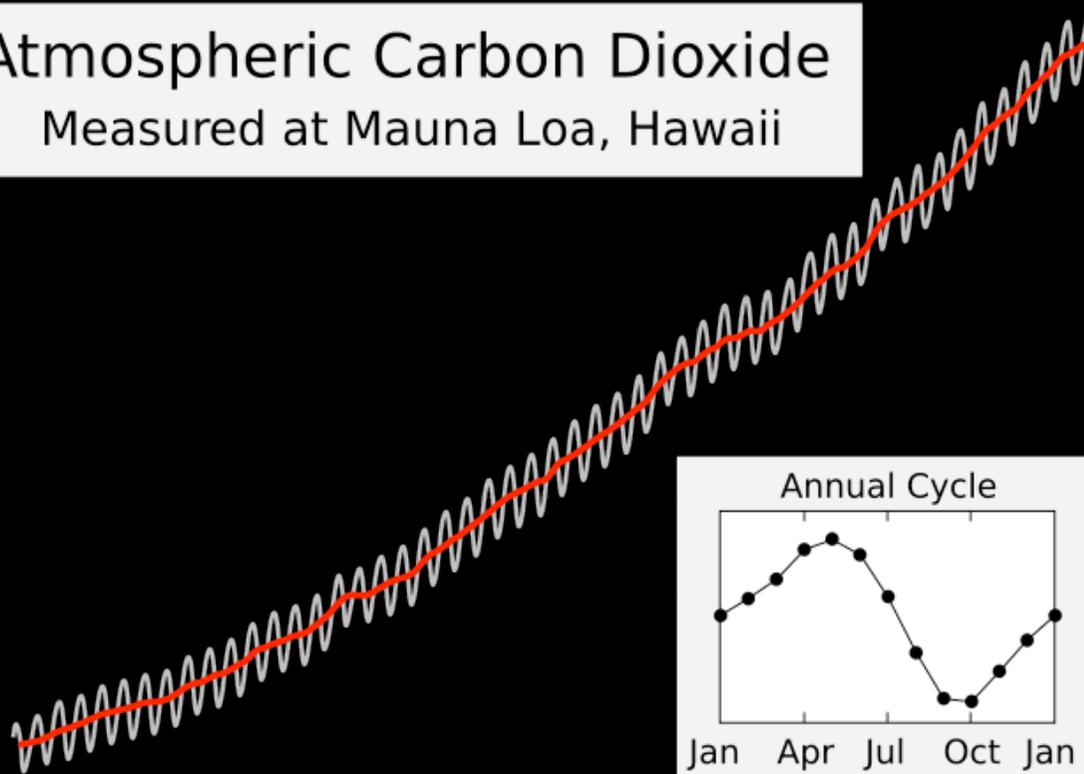
Figure 9-26
Universe, Eighth Edition
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The Amazon, the world's largest rain forest, is being destroyed at a rate of 20,000 square kilometers per year in order to provide land for grazing and farming and as a source for lumber. About 80% of the logging is being carried out illegally.



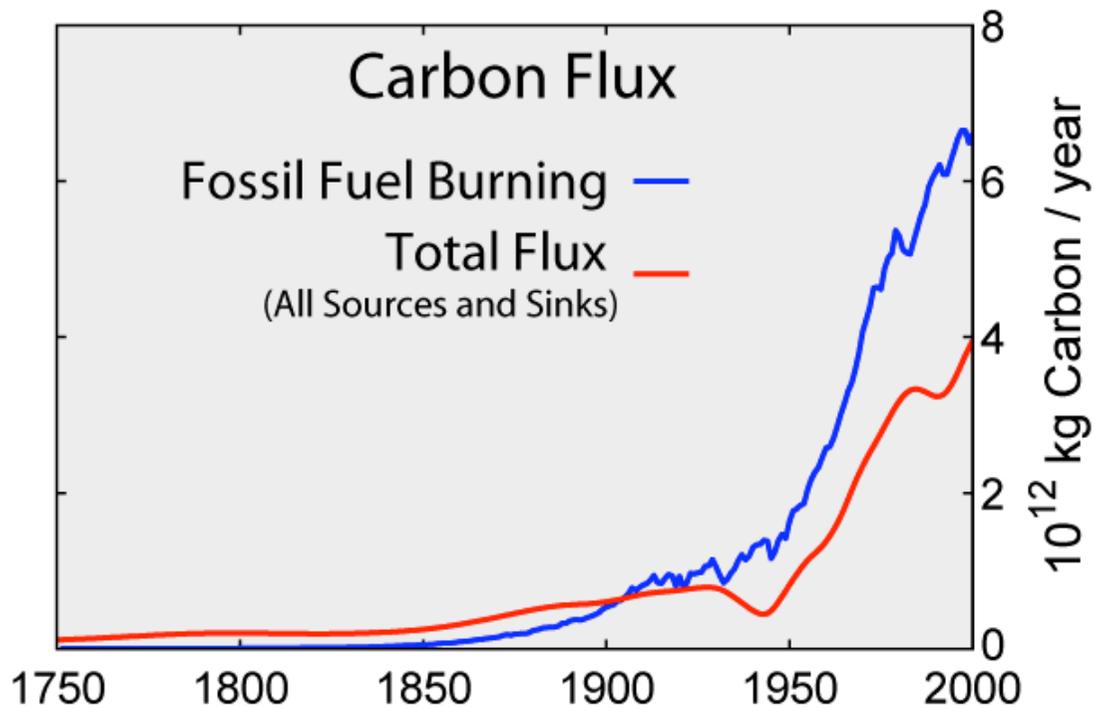
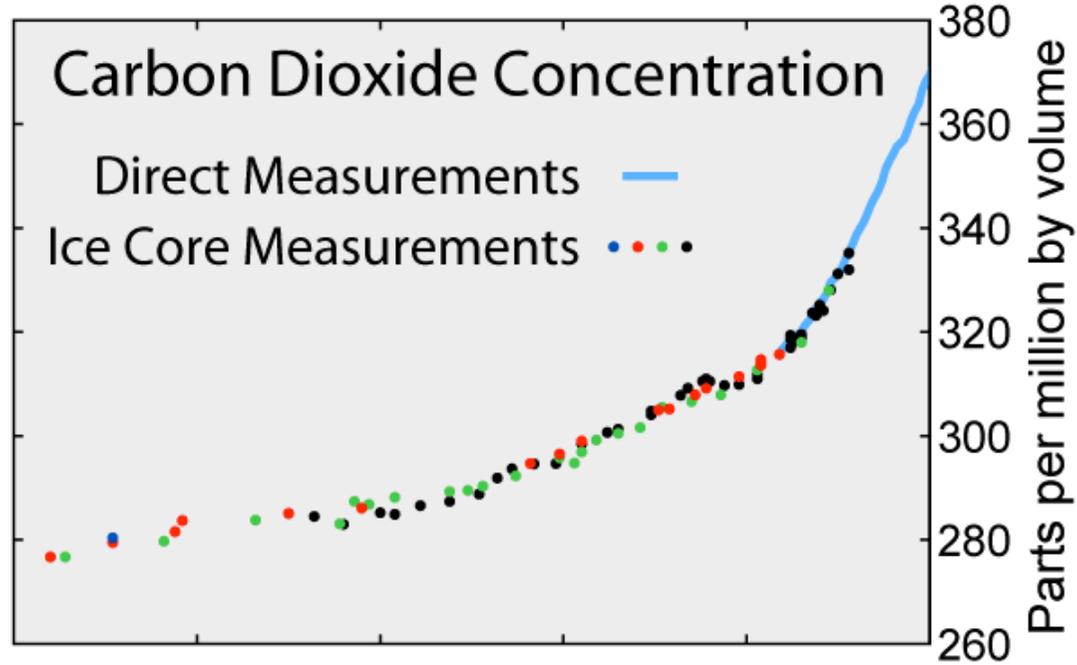
Figure 9-27
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Atmospheric Carbon Dioxide Measured at Mauna Loa, Hawaii

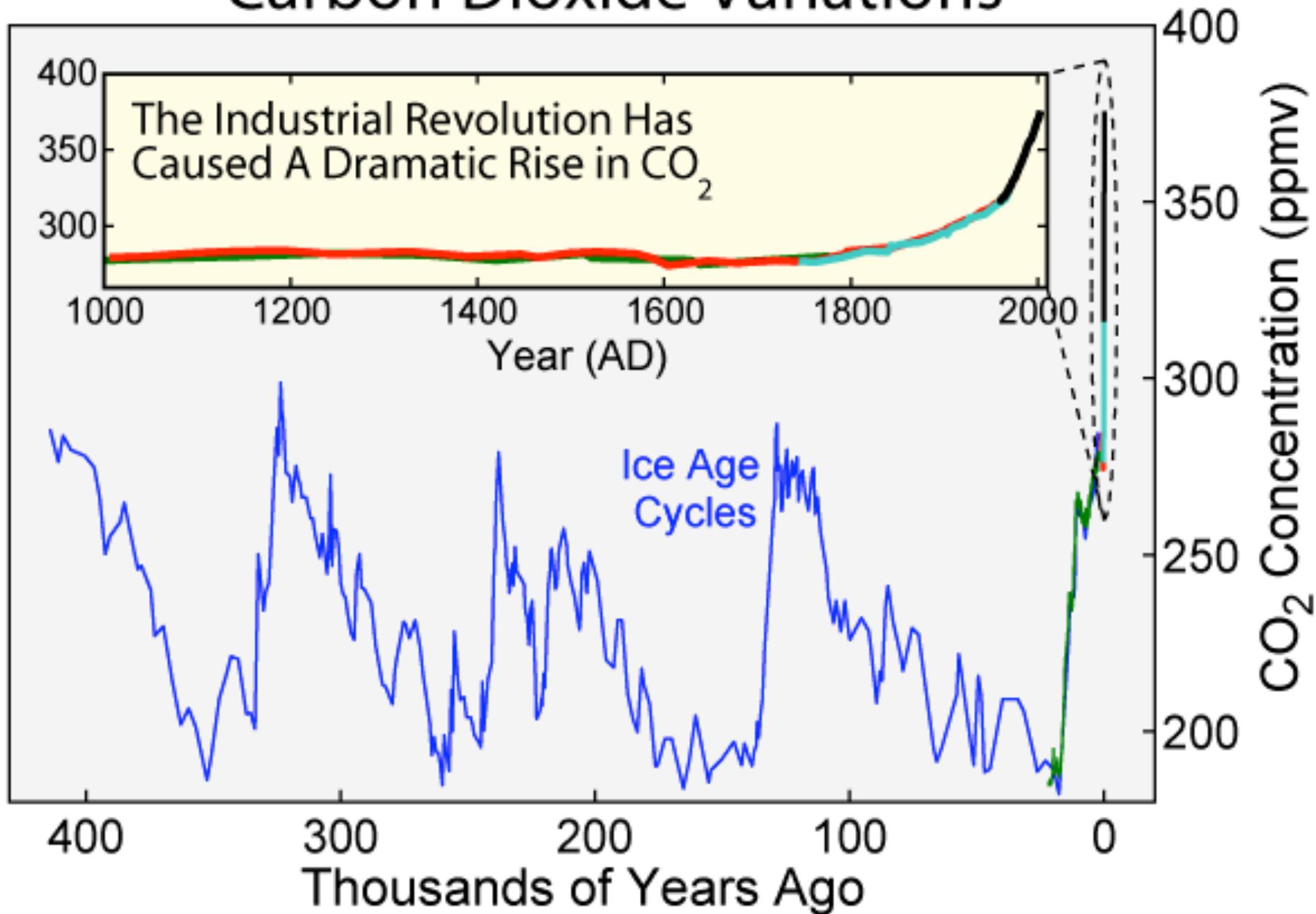


Annual cycle:
CO₂
concentrations
decrease in the
northern
hemisphere
summer as plants
absorb it.

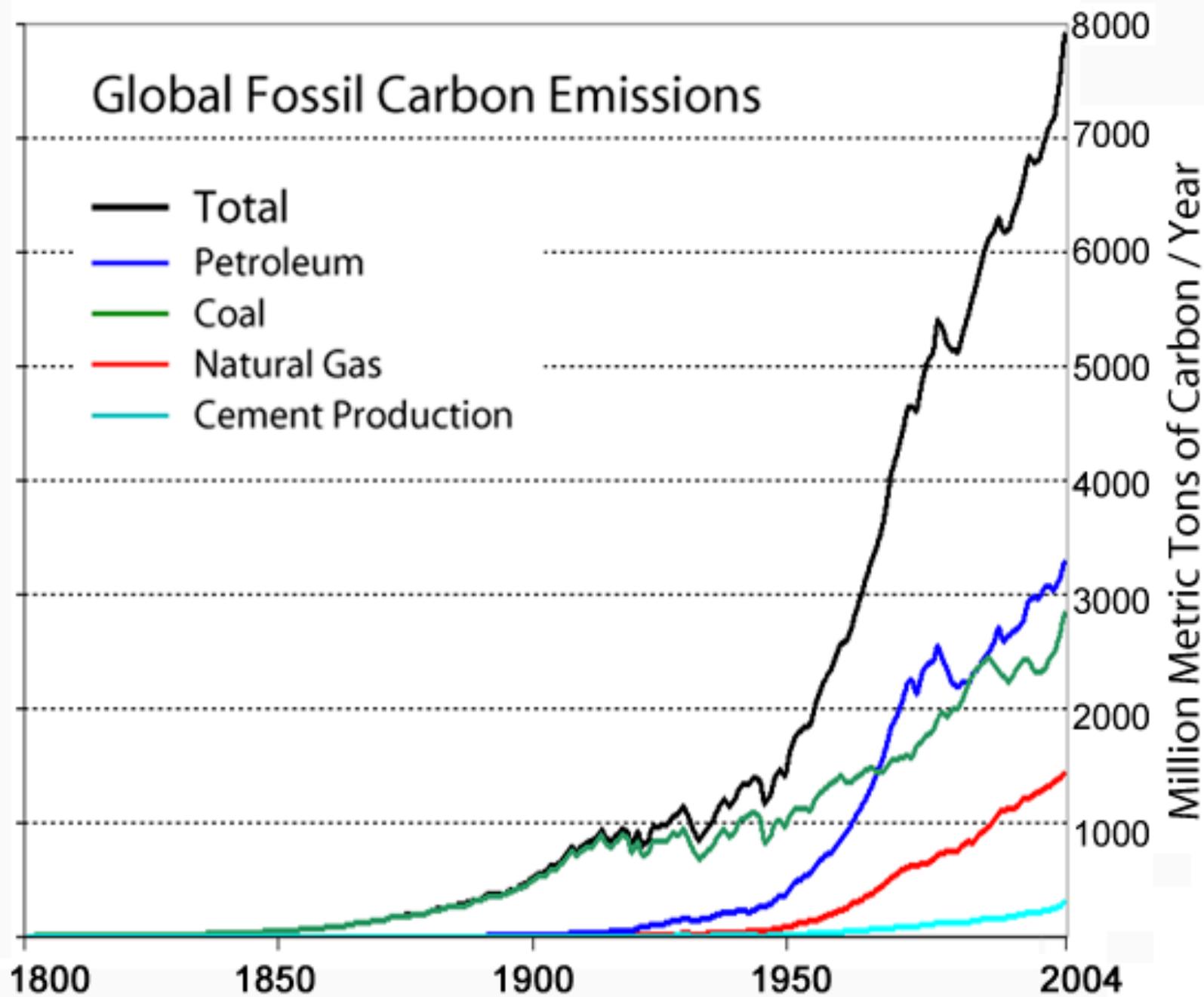
The CO₂ concentration in the atmosphere has increased by 21% since continuous observations started in 1958. The longest such record exists at Mauna Loa, but these measurements have been independently confirmed at many other sites around the world. This is a key indicator that global warming is human-caused.



Carbon Dioxide Variations



Global Fossil Carbon Emissions



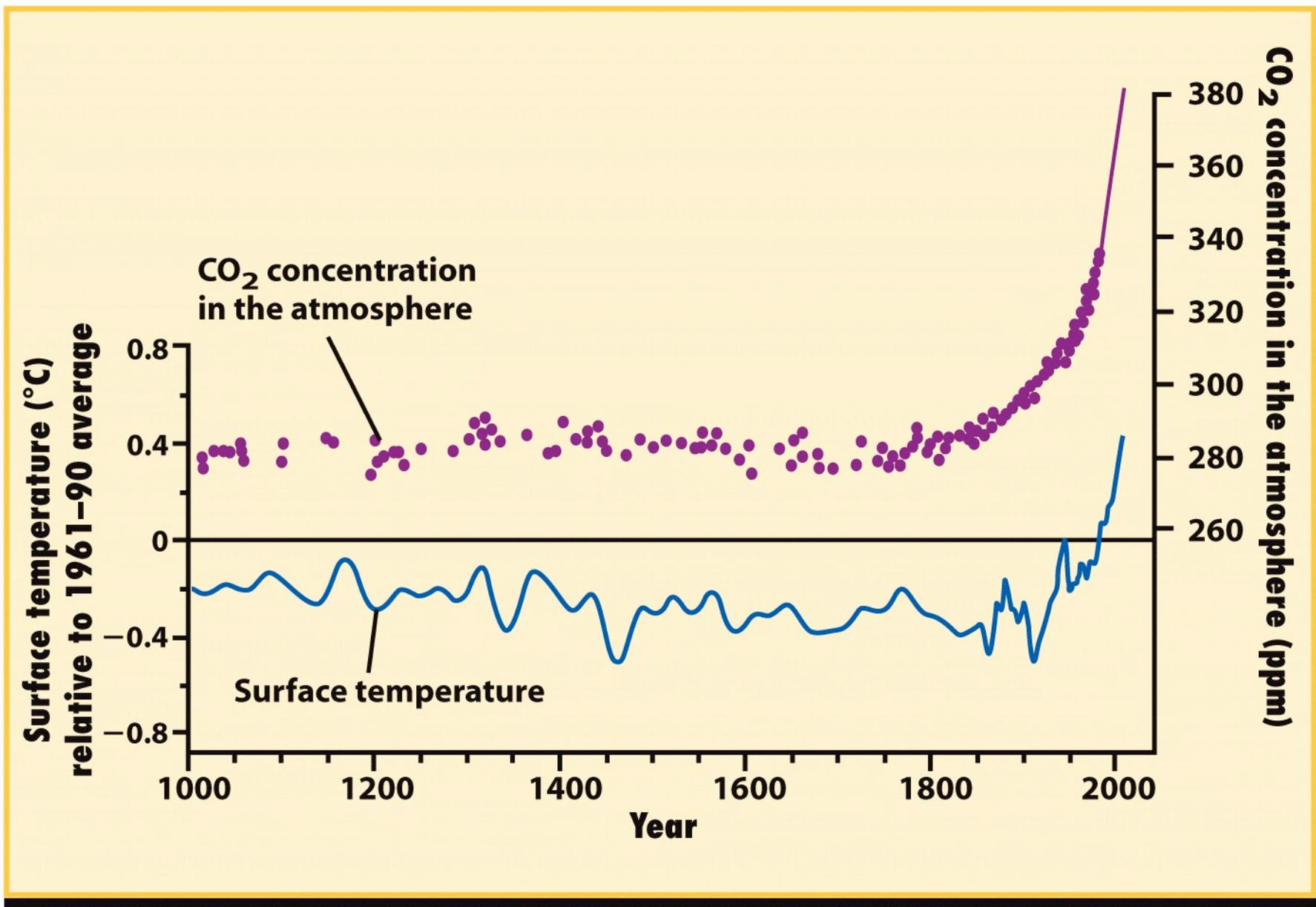


Figure 9-30
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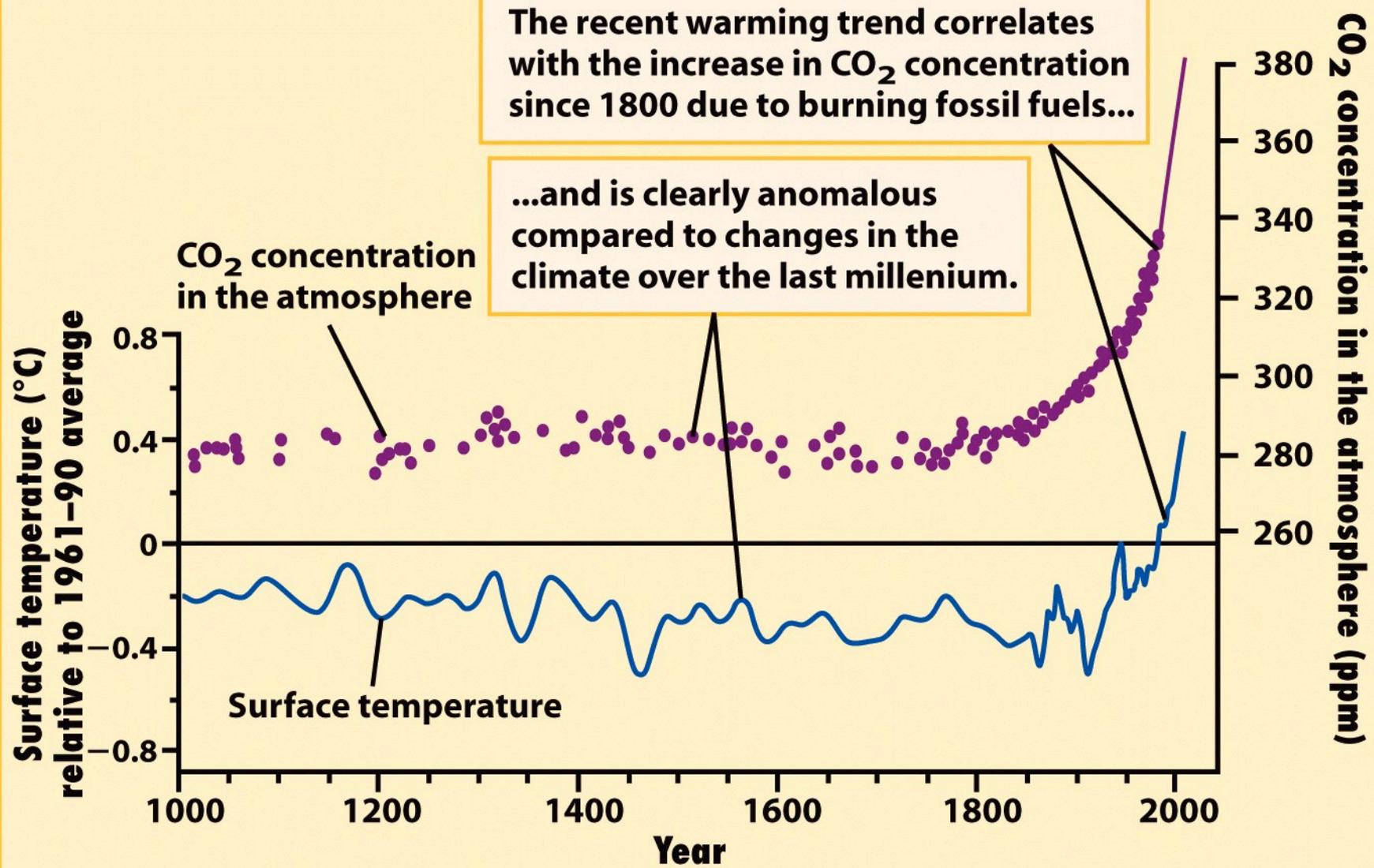
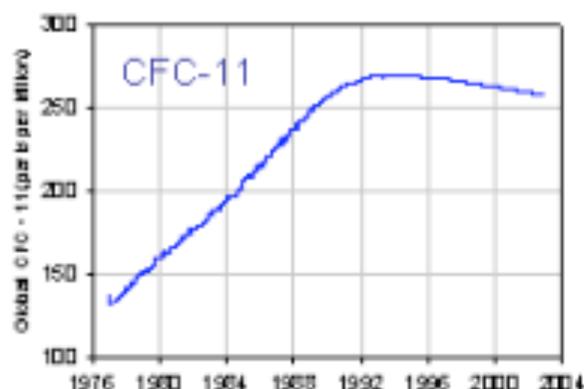
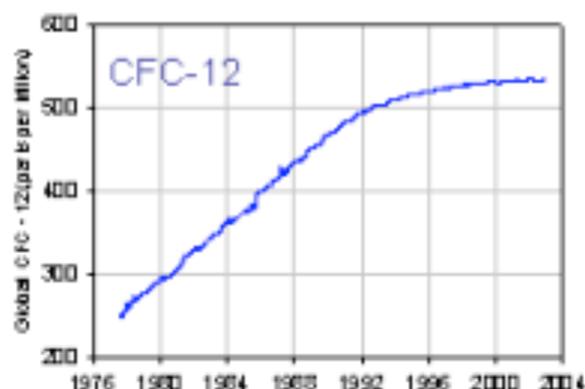
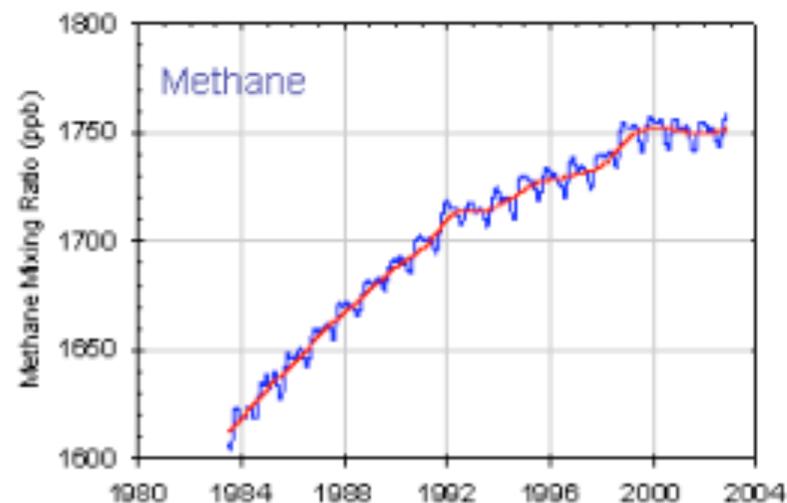
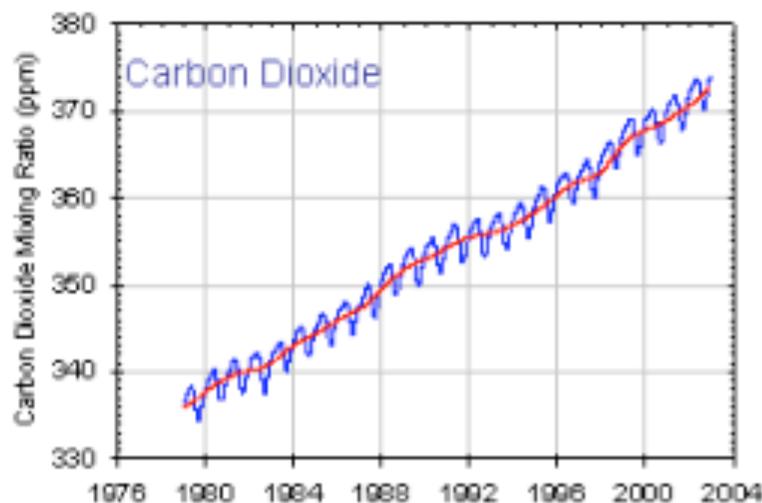


Figure 9-30
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Global Trends in Major Greenhouse Gases to 1/2003



Global trends in major long-lived greenhouse gases through the year 2002. These five gases account for about 97% of the direct climate forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HCFC-22, CFC-113 and CCl_4 .

Global Warming

1. Is the Earth getting warmer?

Yes – the evidence is clear.

2. Are humans causing it?

-It isn't the sun.

-Greenhouse gasses are at unprecedented levels.

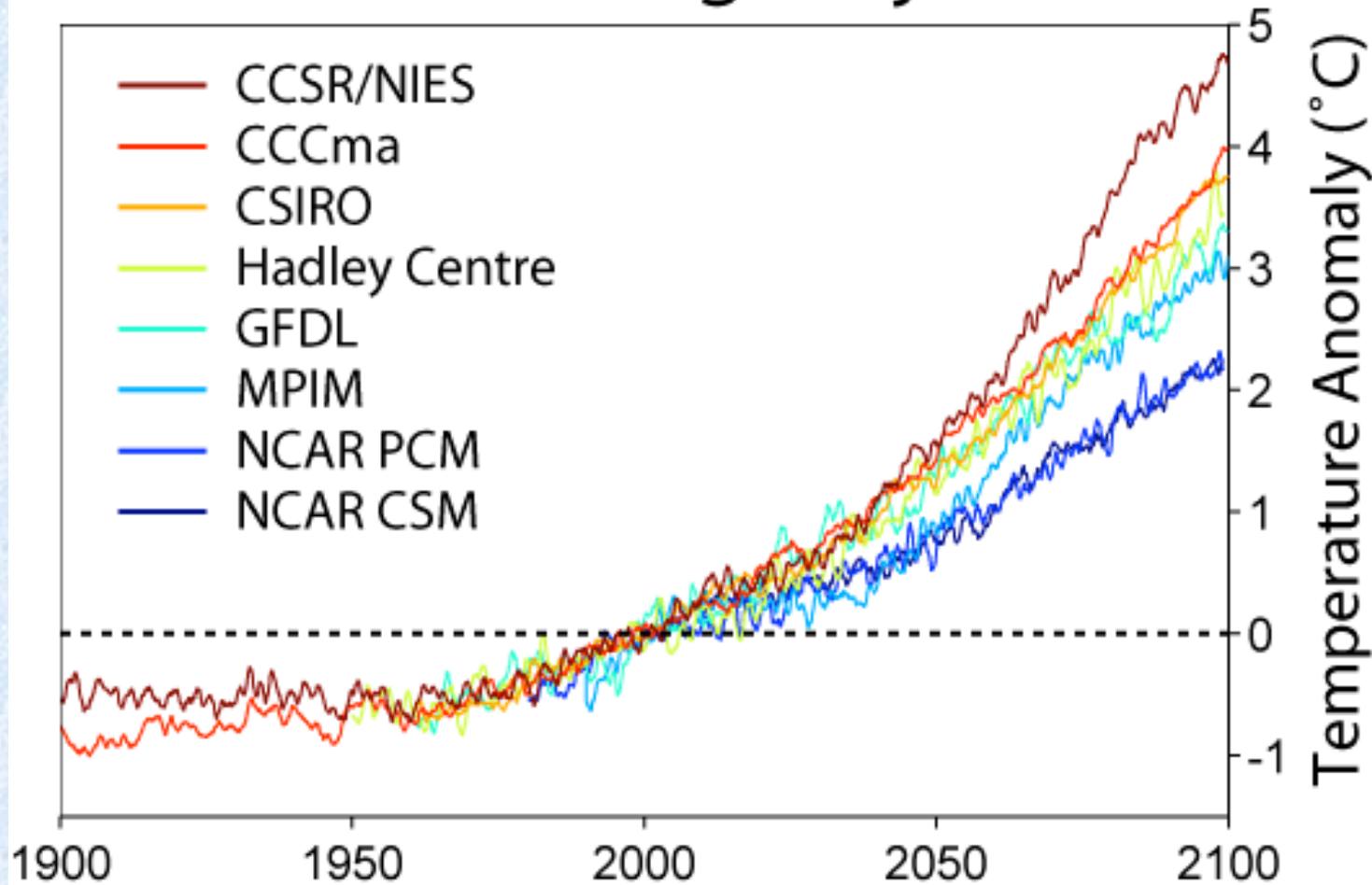
-Most are due to human activity.

The only scientifically testable theory that accounts for global warming is that of human activity

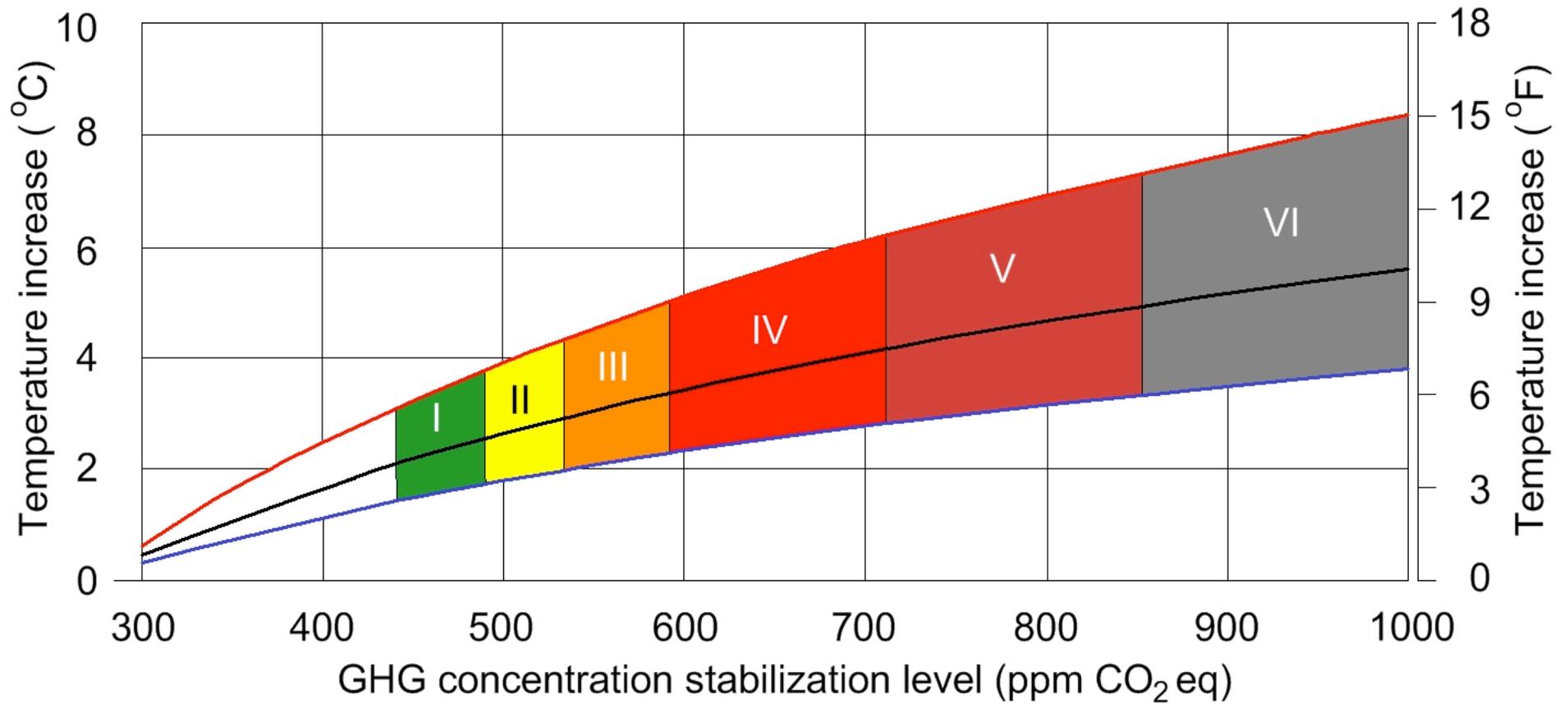
3. What are the consequences?

4. What can we do to stop it?

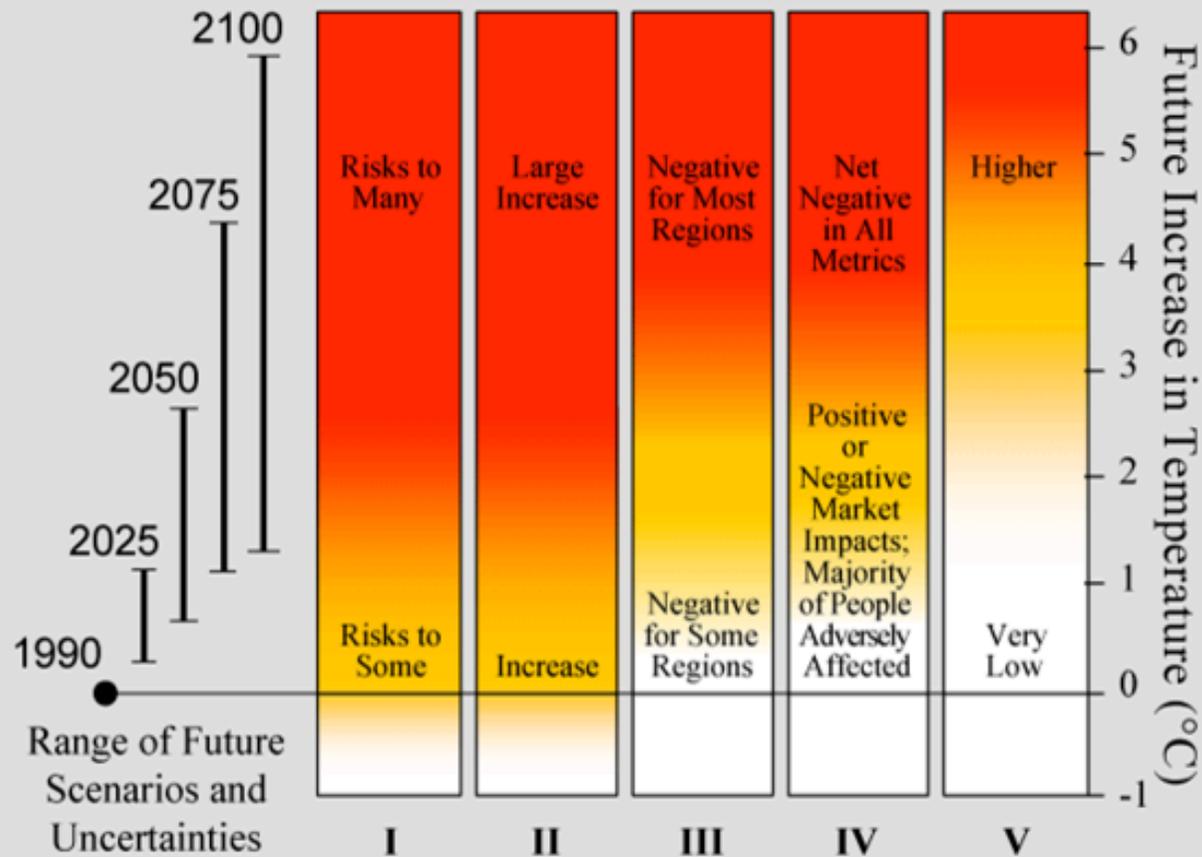
Global Warming Projections



Equilibrium global mean temperature increase above preindustrial

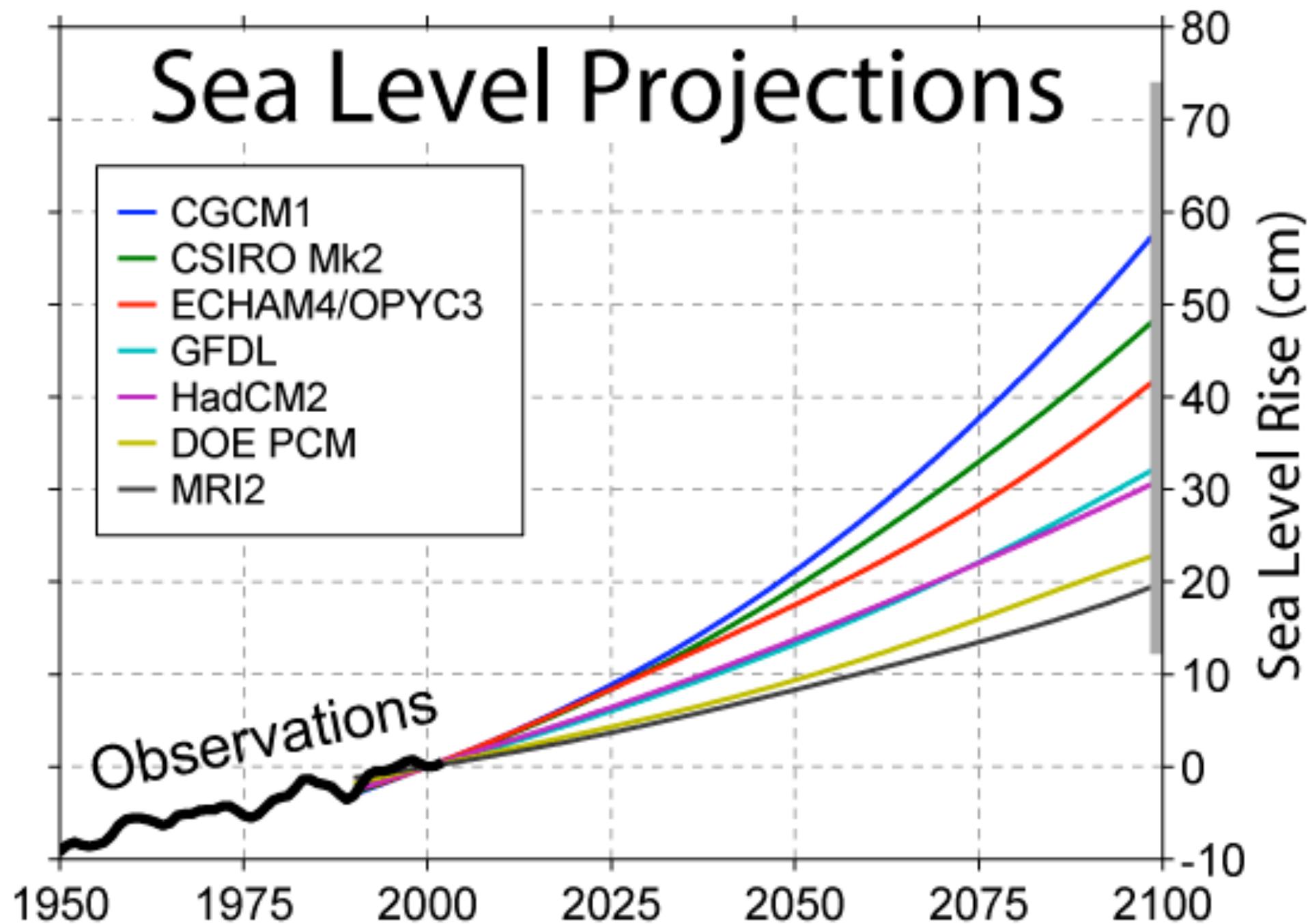


Risks and Impacts of Global Warming

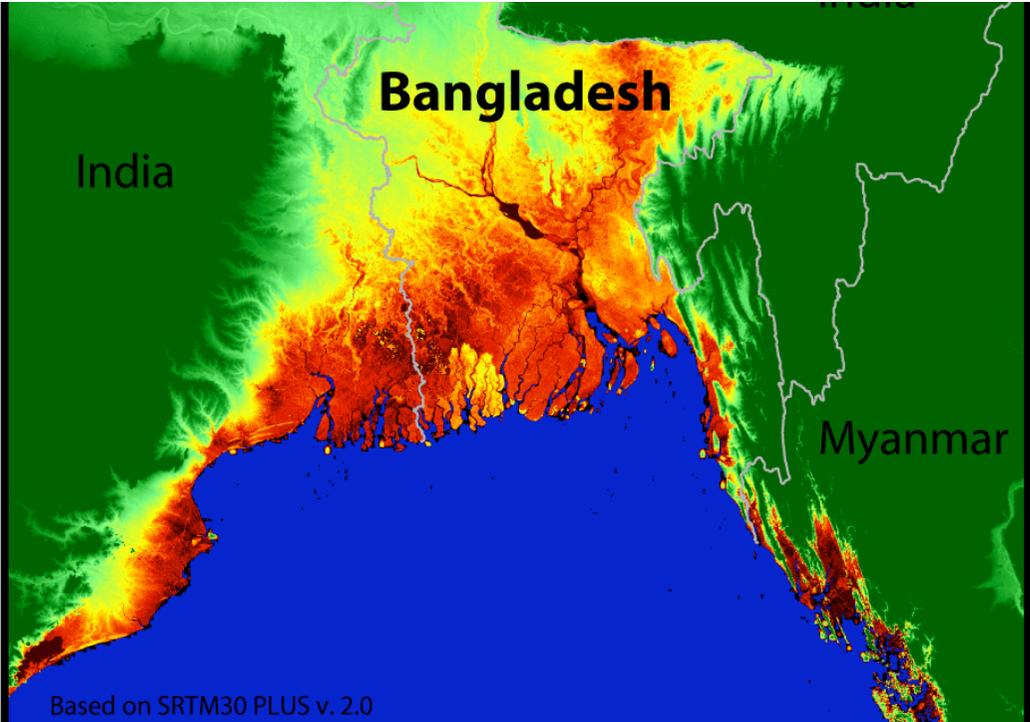
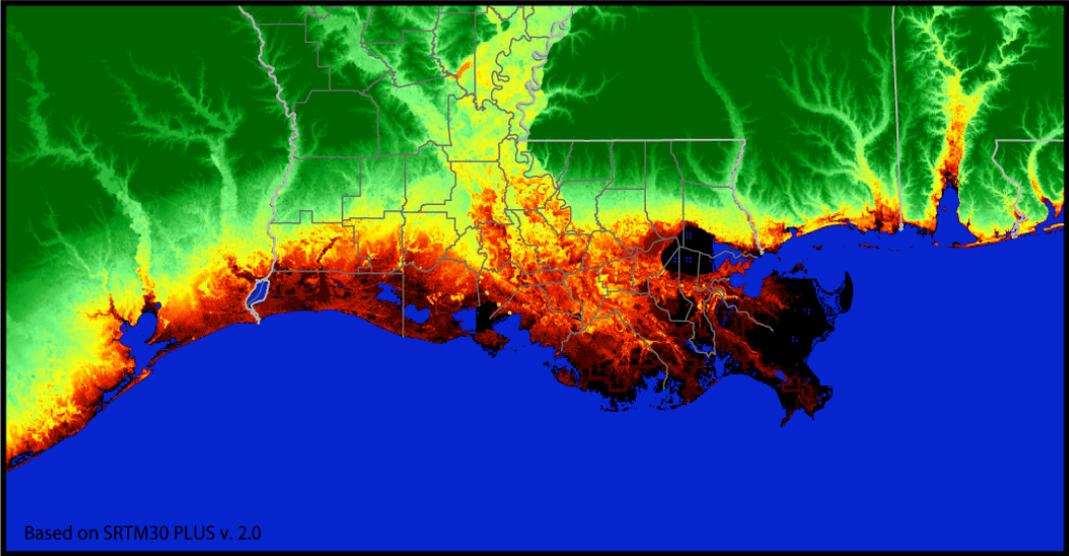


- I** Risks to Unique and Threatened Systems
- II** Frequency and Severity of Extreme Climate Events
- III** Global Distribution and Balance of Impacts
- IV** Total Economic and Ecological Impact
- V** Risk of Irreversible Large-Scale and Abrupt Transitions

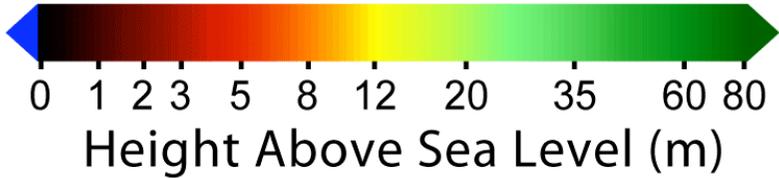
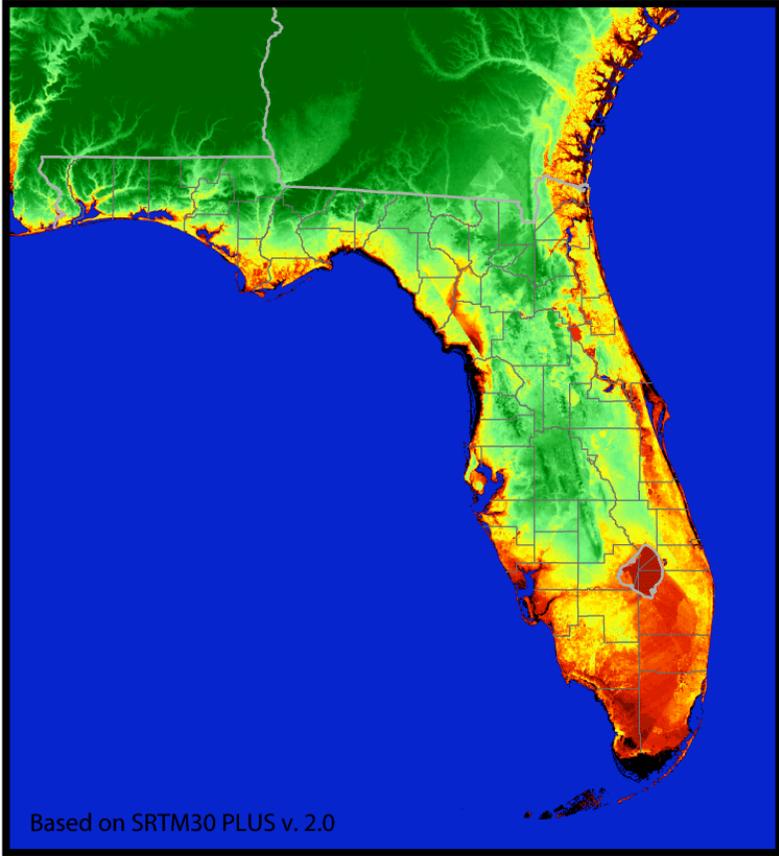
Sea Level Projections



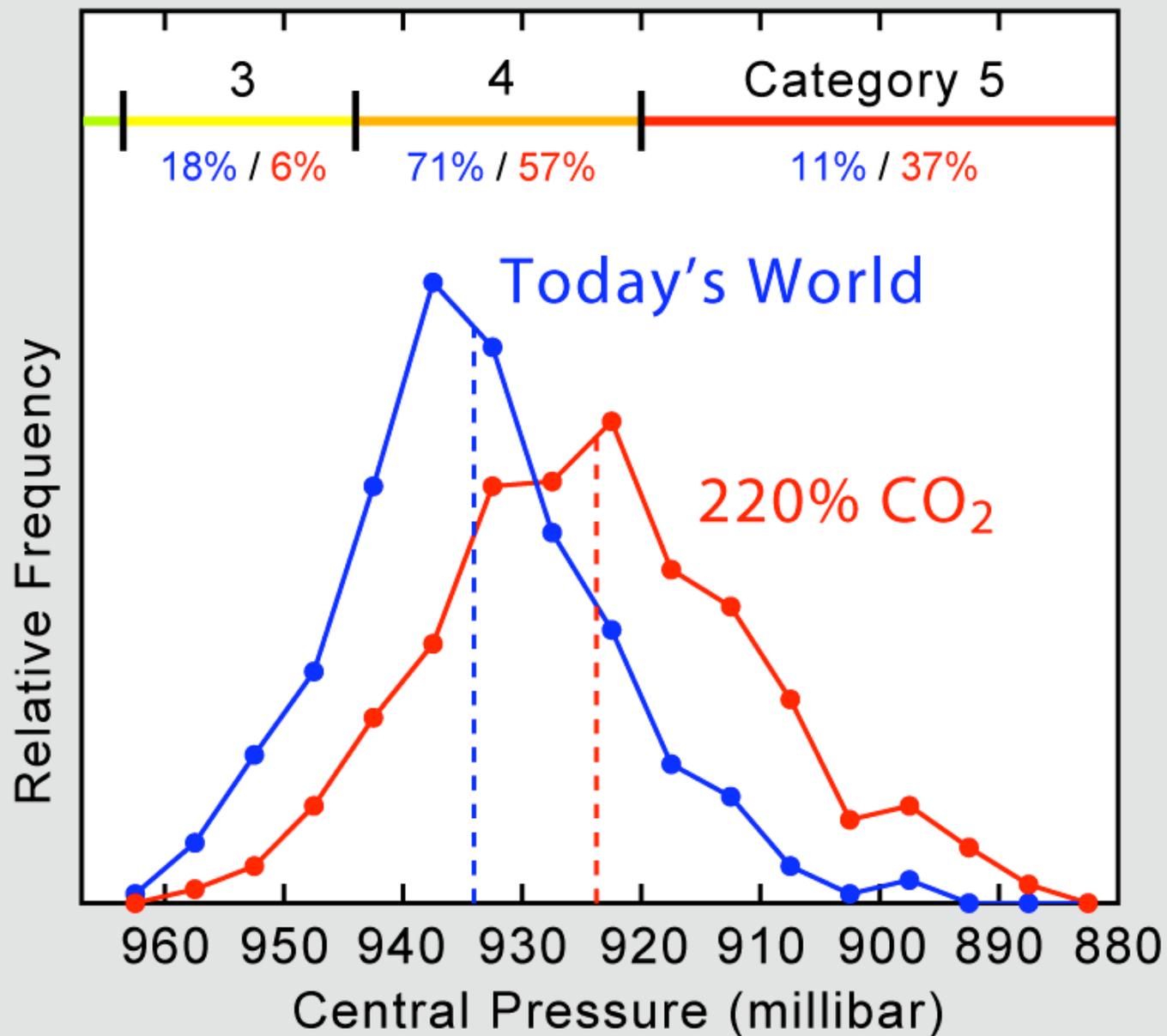
Sea Level Risks - Louisiana



Sea Level Risks - Florida



Achieved Storm Intensity Under Idealized Conditions



Question 13.3 (iclickers!)

- Which of the following statements is false
 - A) Human made carbon dioxide emissions are changing the average composition of our atmosphere
 - B) The projected increase in global temperature will cause a significant increase in ocean levels
 - C) Some projections of global warming predict net positive effects
 - D) The frequency and intensity of hurricanes increases with global temperature

Global Warming

1. Is the Earth getting warmer?

Yes – the evidence is clear.

2. Are humans causing it?

→ That's the only scientific explanation consistent with the data

3. What are the consequences?

-Increased global temperatures

-Rising sea levels (global population displacement?)

-Changes in crop yields

-Devastation in ecosystems.

-More and more severe natural disasters

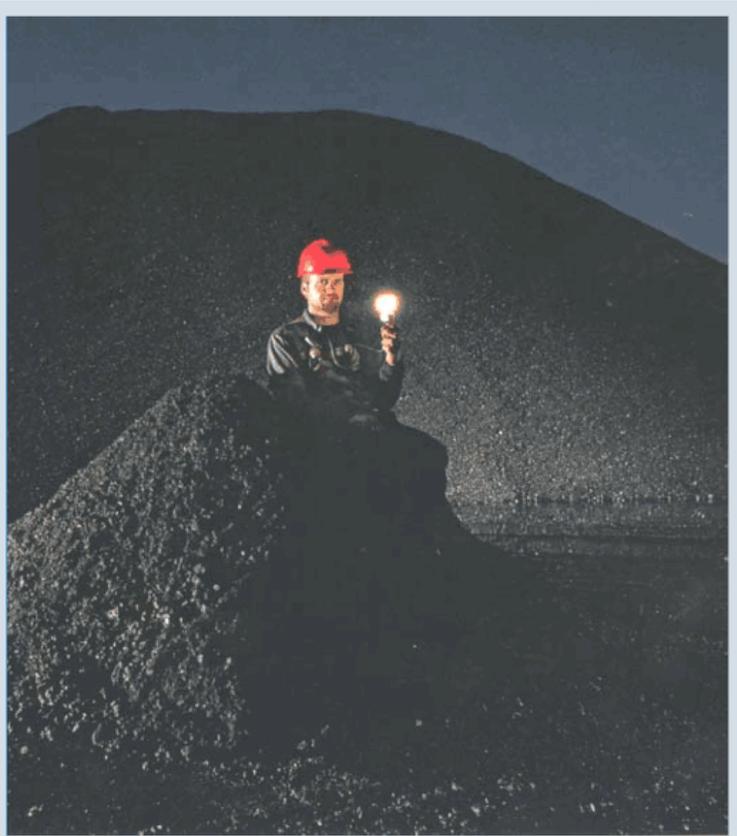
-Irreversible effects?

4. What can we do to stop it?





Compact Fluorescent Lamp vs. Incandescent Light Bulb



Replace one incandescent lightbulb with a compact fluorescent lamp and you will save this 500 pound pile of coal.

- + Uses 80% less electricity.
Saves \$30-\$80 on power bill.
- + Prevents 500 pounds of coal or 1 barrel of oil from being burned.
*Majority of US electricity comes from coal fired power plants
- + Keeps a ton of greenhouse gas (CO₂) out of the air.
- + Lasts 8 to 12 times longer > keeps 8-12 bulbs from the landfill.

* Bulbs fit the same fixtures and emit comparable light.

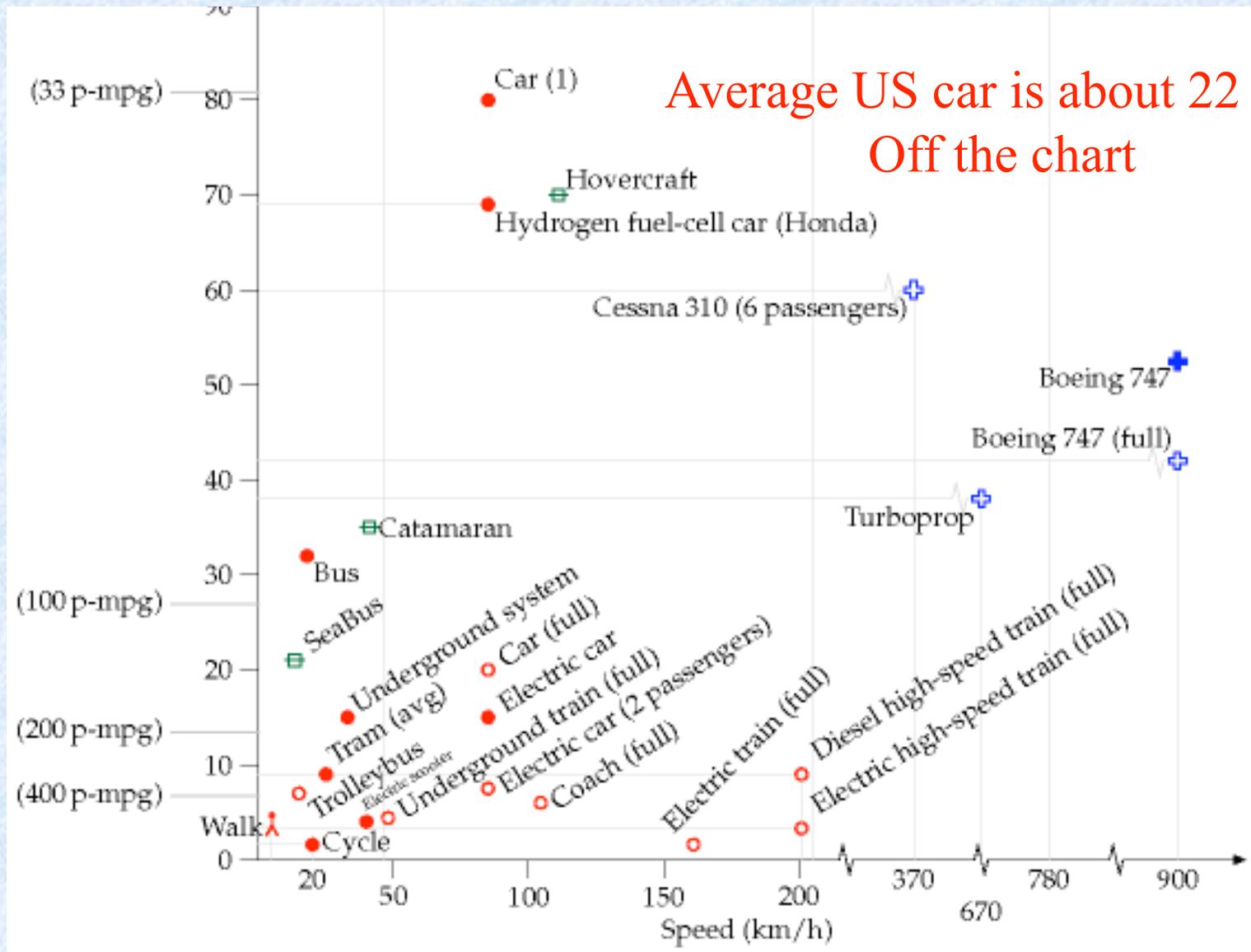
* All numbers are in comparison to regular incandescent bulbs.

However..

If everybody does a little...

- **...We only achieve a little**
 - The dangers of false arithmetic
- **The cheapest way to address global warming is increase our energy efficiency**
 - E.g. European Union and Japan use ~ half the amount of energy per person as the US with very similar GDP/person

But we CAN do a lot!

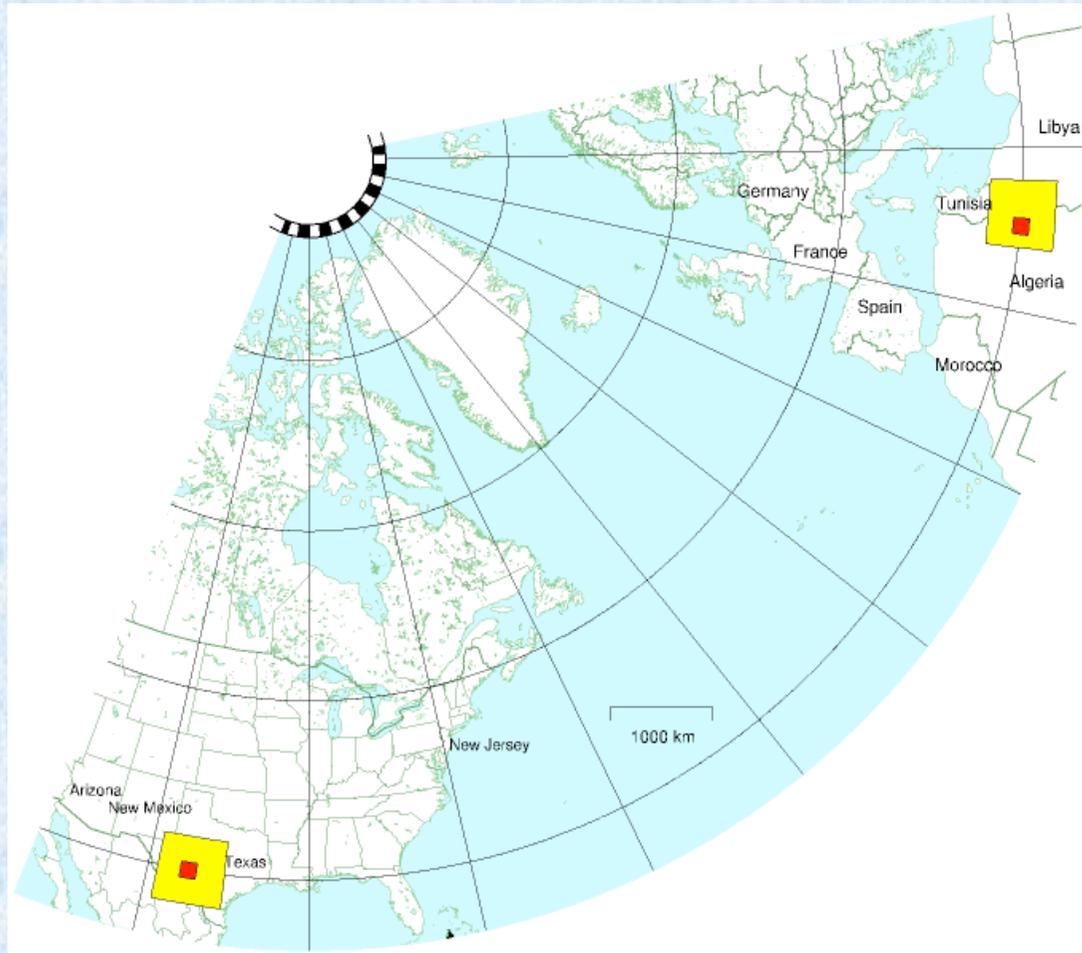


Country-size solutions are required for renewable energy



Only for electricity (not replacing gas/oil etc)

Country-size solutions are required for renewable energy



Area needed to provide for current energy needs of 500M people

Global warming inertia

Even stopping all emission of greenhouse gases now would not stop global warming immediately

Greenhouse gases are already overabundant in the atmosphere and they will keep increasing the temperature by ~2K until 2100

Re-absorption of greenhouse gases by Earth's Ocean and plants is slow and it would take time to restore balance, if at all possible (we've seen dramatic changes in the past!).

If you want to know more

- **Sustainable Energy – without the hot air.**
 - **By David JC McKay**
- **Hell and high water**
 - **By Joseph Romm**

The End

See you on monday!