

Core Case Study: Studying a Volcano to Understand Climate Change



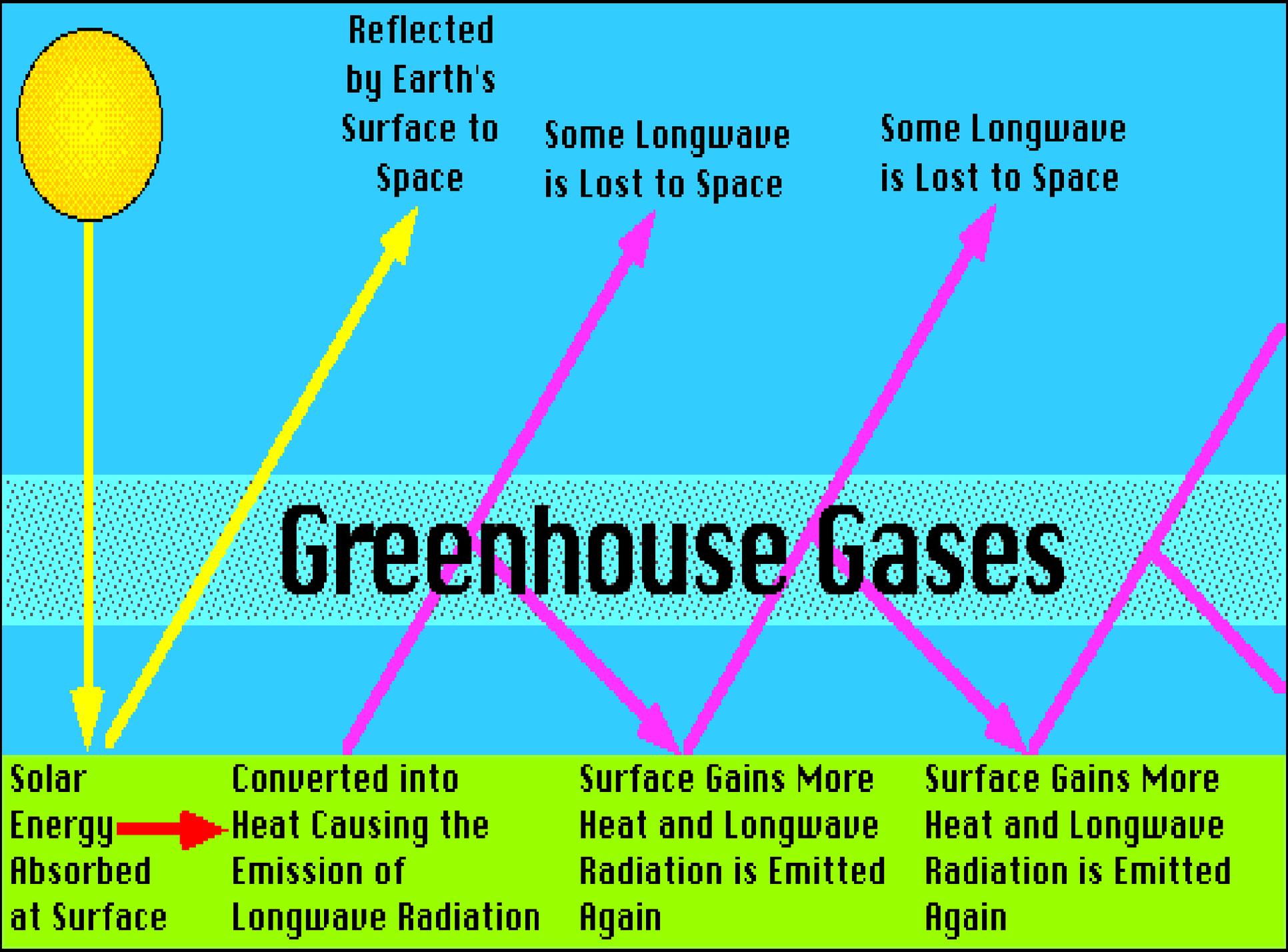
✦ NASA scientist correctly predicted that the 1991 Philippines explosion would cool the average temperature of the earth by 0.5C° over a 15 month period and then return to normal by 1995.

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Figure 20-1

PAST CLIMATE AND THE GREENHOUSE EFFECT

- ✦ Over the past 900,000 years, the troposphere has experienced prolonged periods of global cooling and global warming.
- ✦ For the past 1,000 years, temperatures have remained fairly stable but began to rise during the last century.



Reflected
by Earth's
Surface to
Space

Some Longwave
is Lost to Space

Some Longwave
is Lost to Space

Greenhouse Gases

Solar
Energy
Absorbed
at Surface

Converted into
Heat Causing the
Emission of
Longwave Radiation

Surface Gains More
Heat and Longwave
Radiation is Emitted
Again

Surface Gains More
Heat and Longwave
Radiation is Emitted
Again

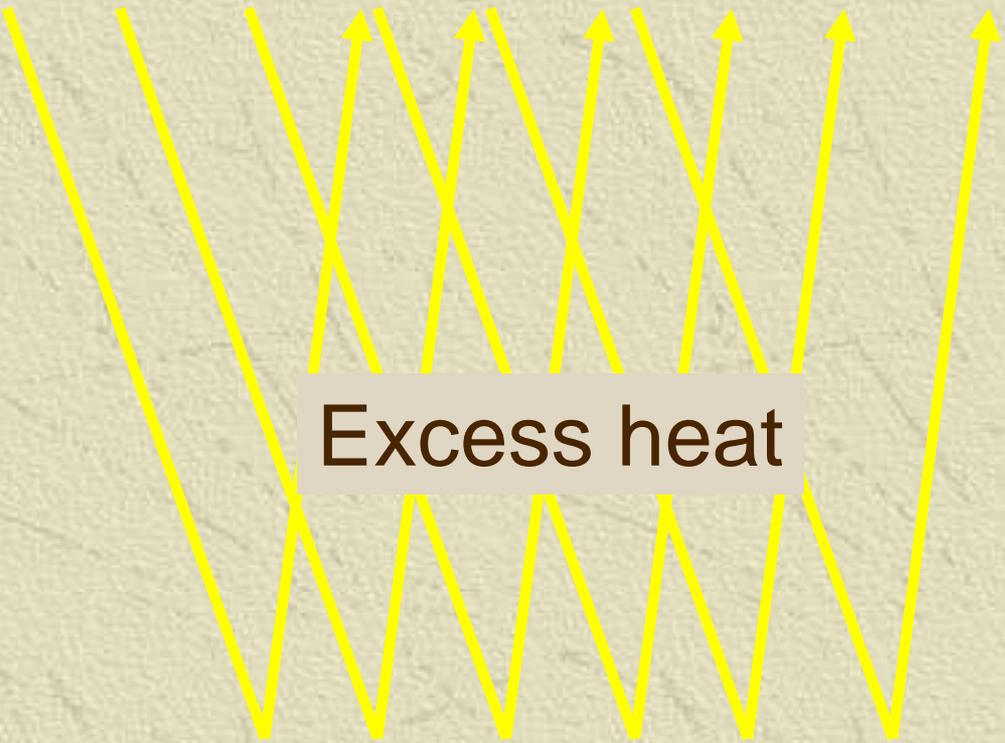
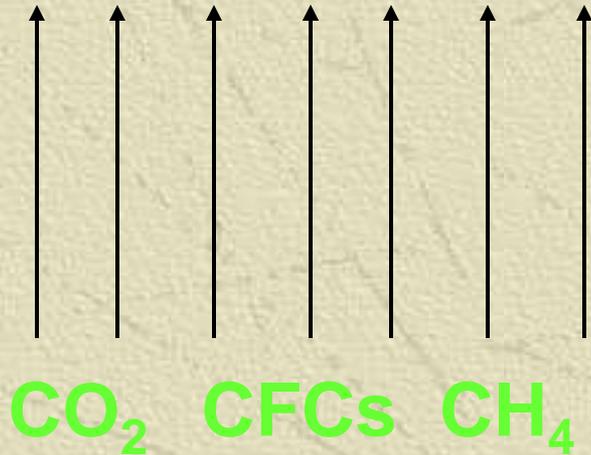
Natural Greenhouse Effect

✦ With Greenhouse Effect average global temperature 60 degrees

✦ Without it, Earth would be a frigid planet, with average temperature around zero degrees Fahrenheit

Global Warming

Increased Greenhouse Gases in the Troposphere



Excess heat

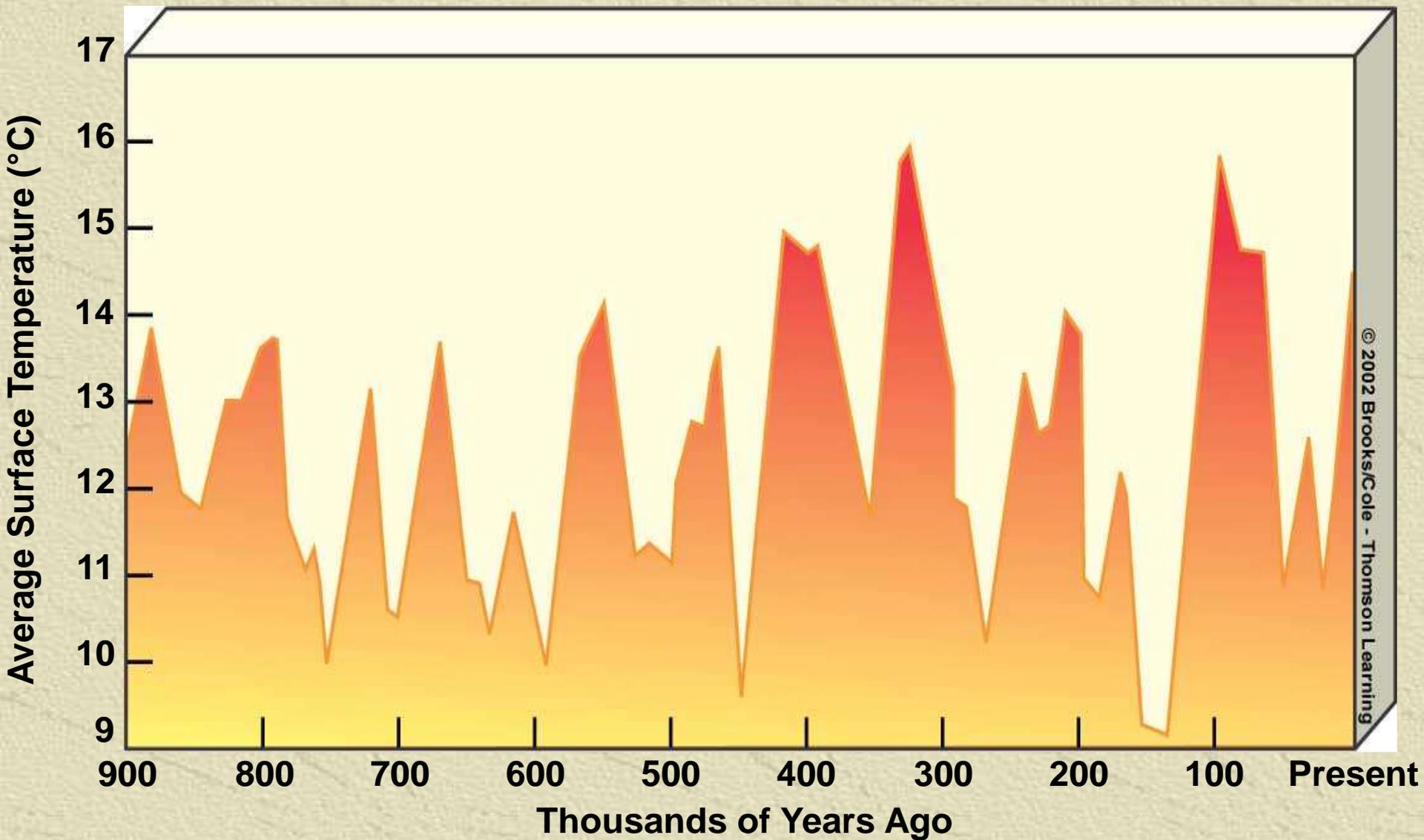
The Natural Greenhouse Effect

- ✦ Three major factors shape the earth's climate:
 - ◆ The sun.
 - ◆ Greenhouse effect that warms the earth's lower troposphere and surface because of the presence of *greenhouse gases*.
 - ◆ Oceans store CO₂ and heat, evaporate and receive water, move stored heat to other parts of the world.
 - ◆ Natural cooling process through water vapor in the troposphere (heat rises).

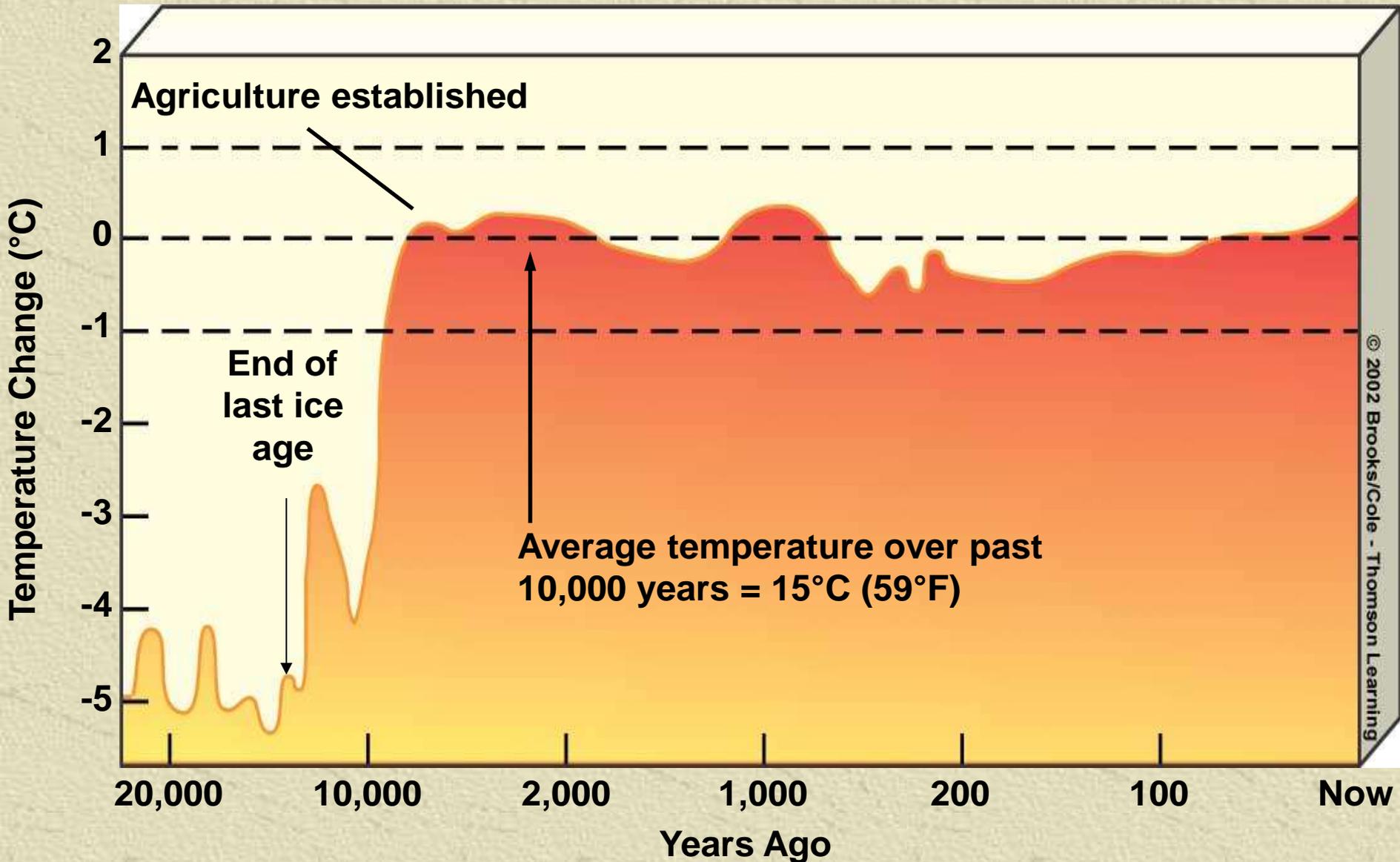
Major Greenhouse Gases

- ✦ The major greenhouse gases in the lower atmosphere are water vapor, carbon dioxide, methane, and nitrous oxide.
 - ◆ These gases have always been present in the earth's troposphere in varying concentrations.
 - ◆ Fluctuations in these gases, plus changes in solar output are the major factors causing the changes in tropospheric temperature over the past 400,000 years.

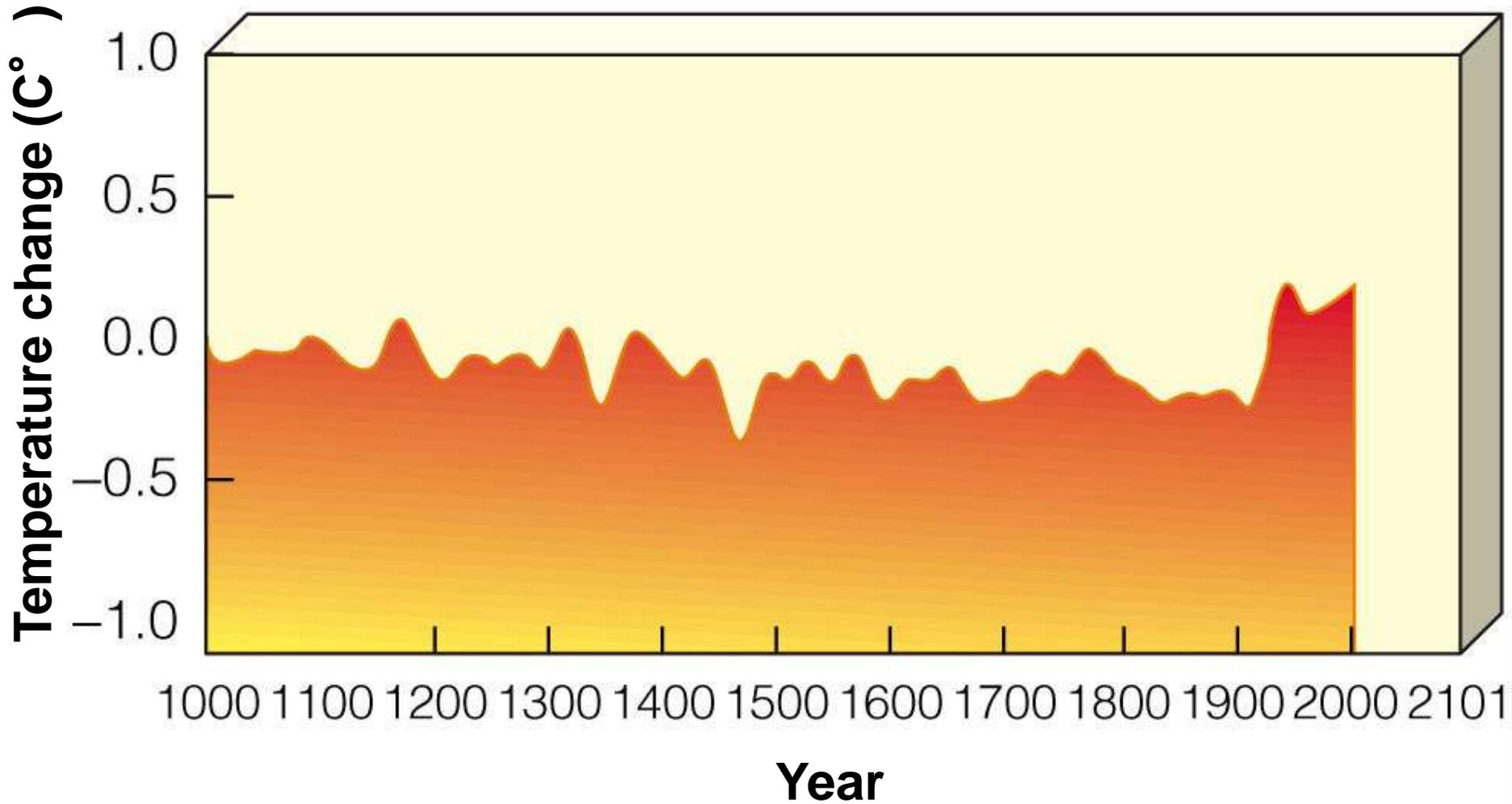
Average Temperature Over Past 900,000 Years



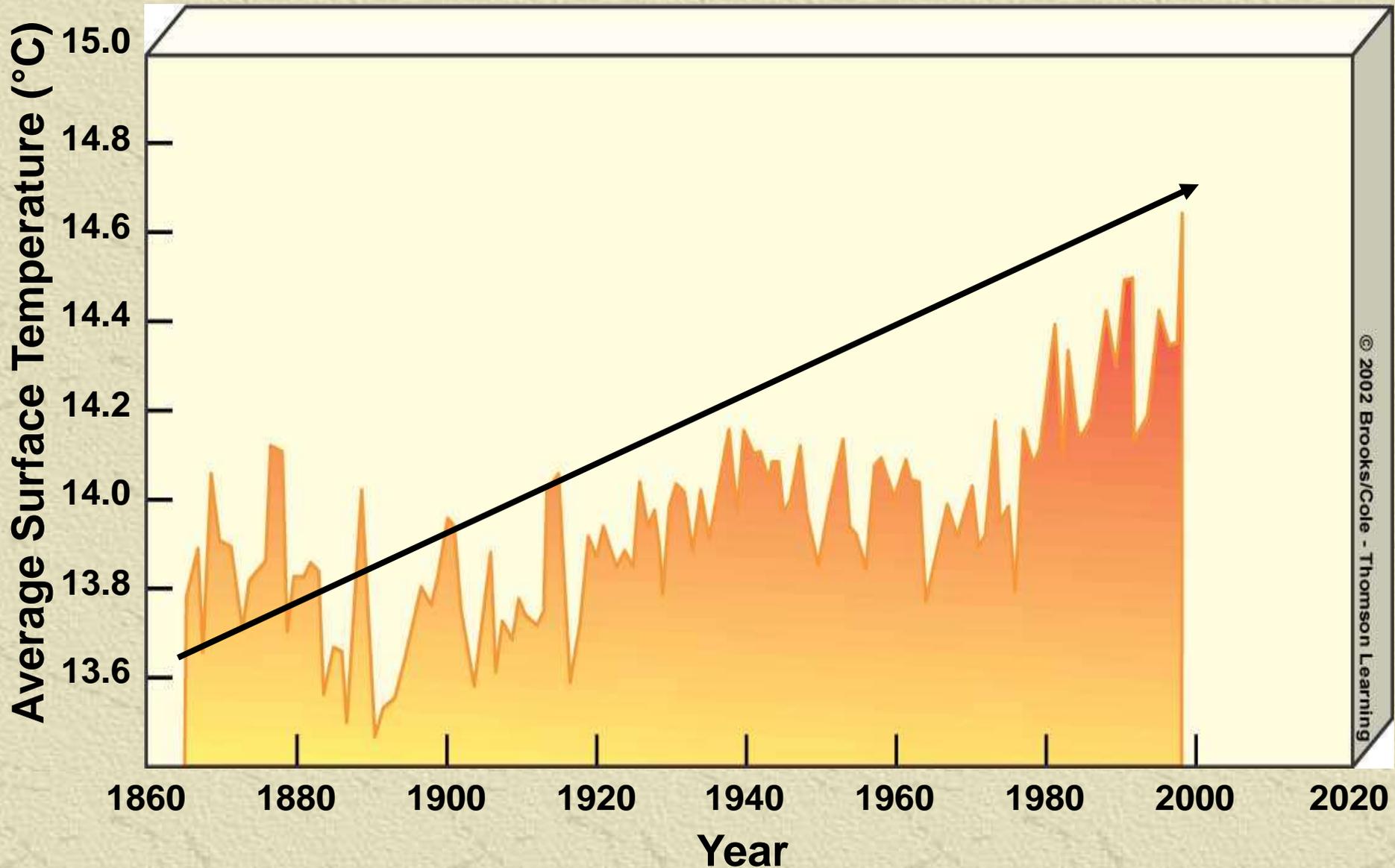
Temperature Change Over Past 22,000 Years



Temperature change over past 1,000 years

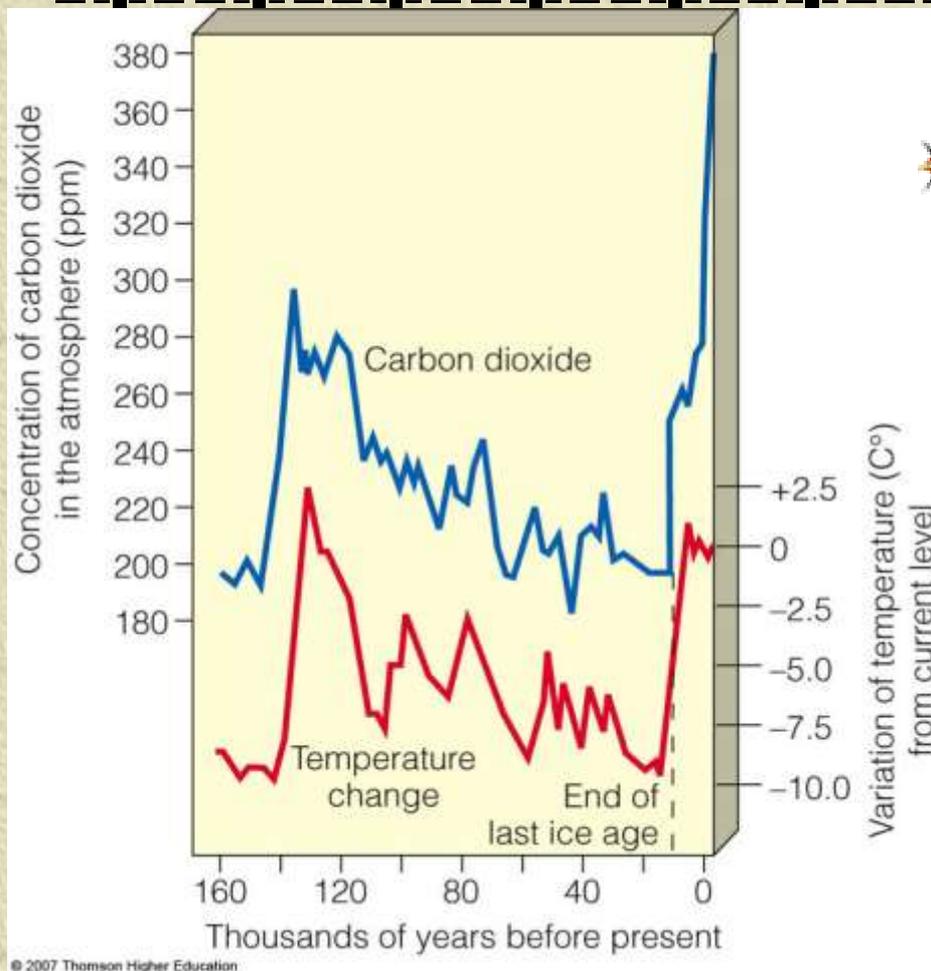


Average Temperature Over Past 130 Years



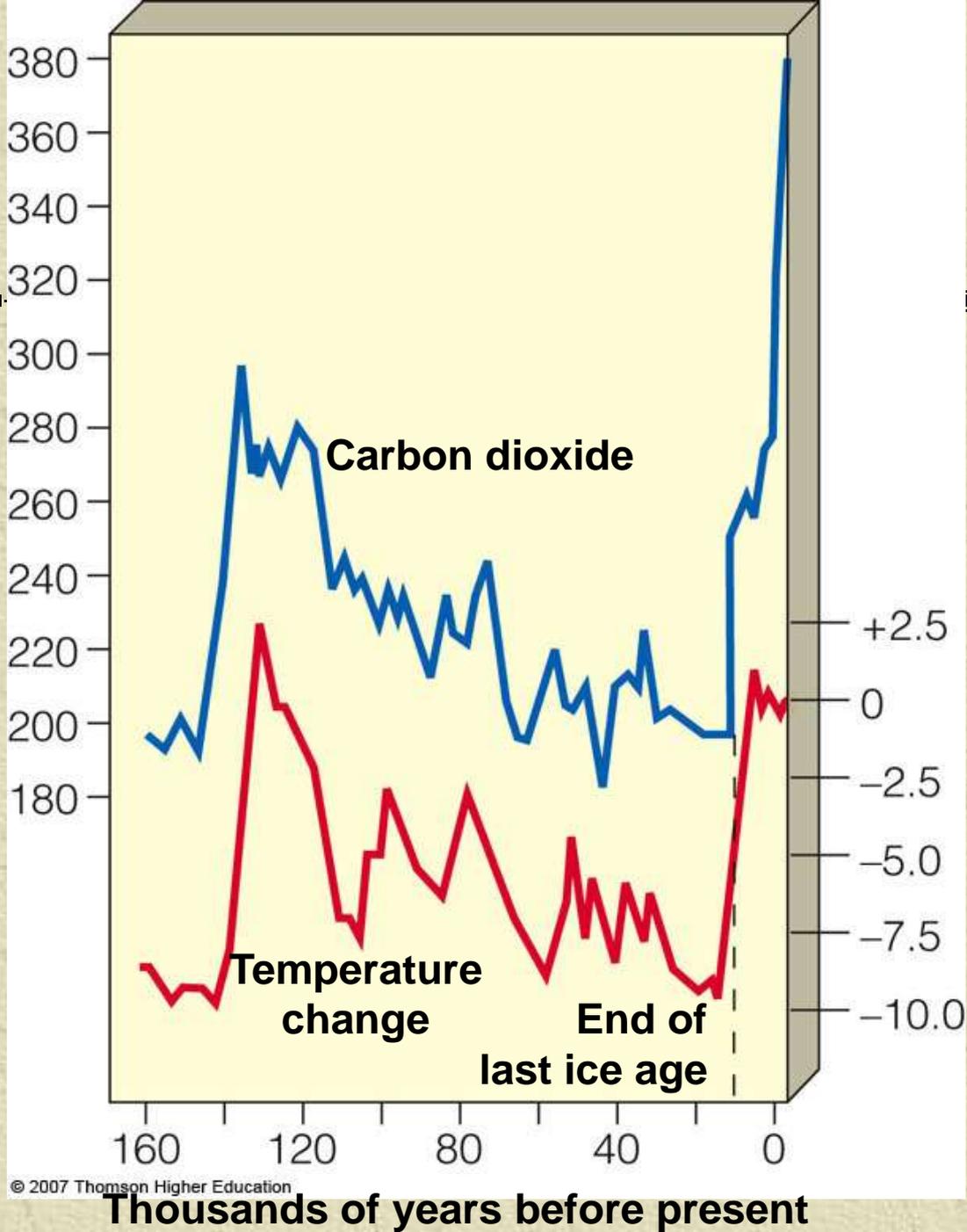
Is this increase in
temperature natural?

How Do We Know What Temperatures Were in the Past?



✦ In 2005, an ice core showed that CO₂ levels in the troposphere are the highest they have been in 650,000 years.

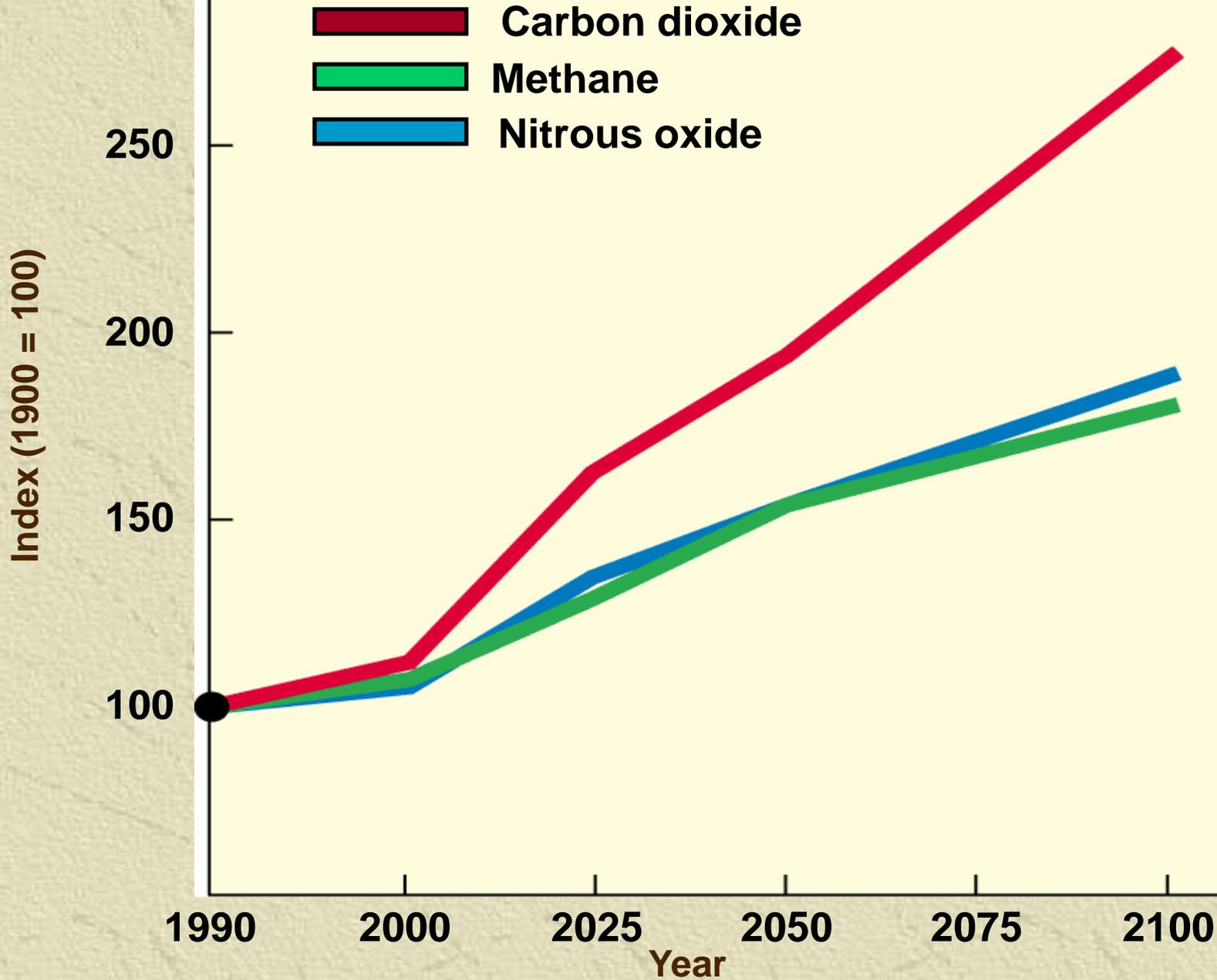
Concentration of carbon dioxide
in the atmosphere (ppm)



Variation of temperature (C°)
from current level

Thousands of years before present

Fig. 20-4, p. 466



How Do We Know What Temperatures Were in the Past?



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✦ Scientists analyze tiny air bubbles trapped in ice cores learn about past:

- ✦ *troposphere composition.*
- ✦ *temperature trends.*
- ✦ *greenhouse gas concentrations.*
- ✦ *solar, snowfall, and forest fire activity.*

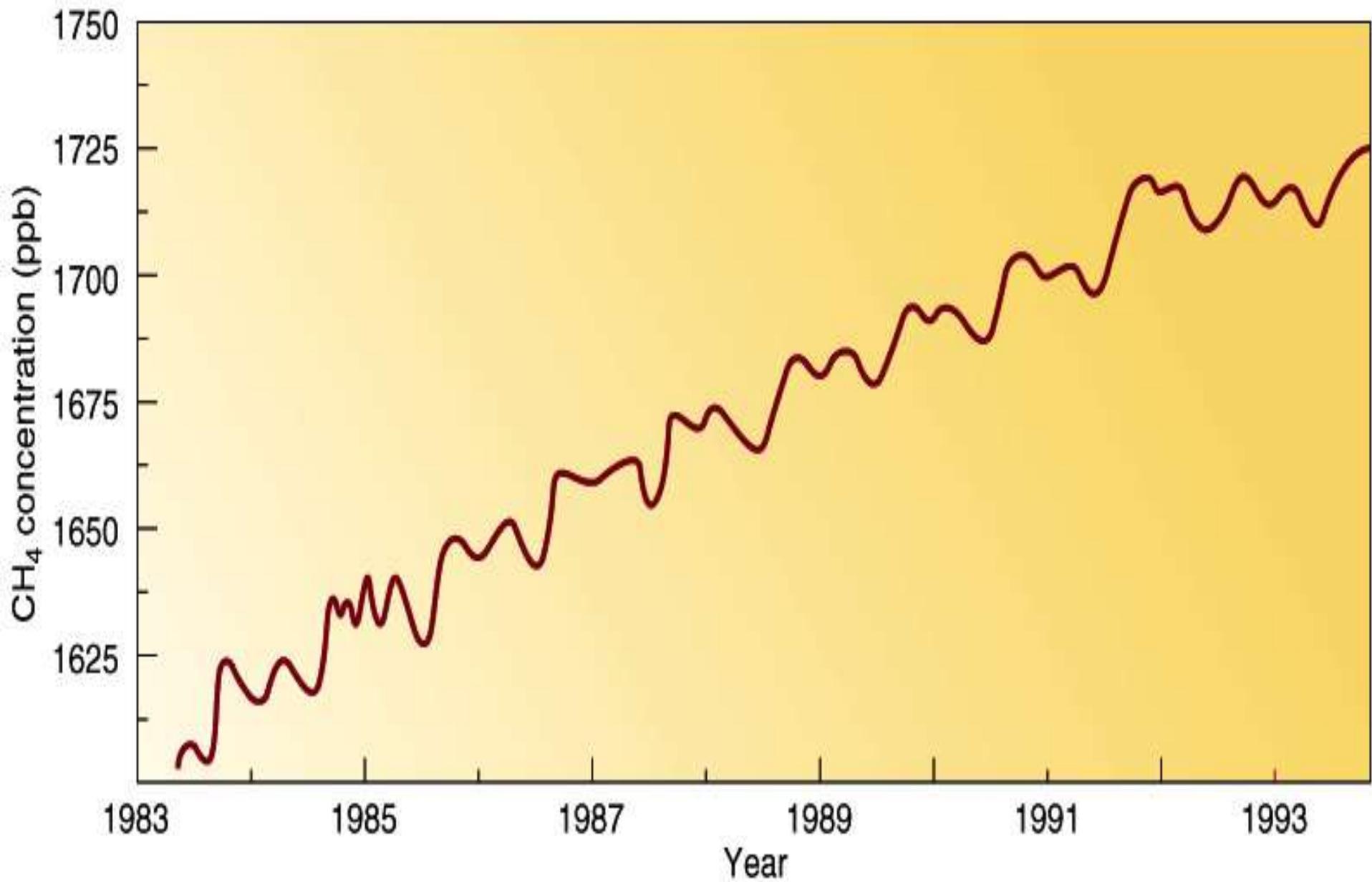
Figure 20-3

Methane

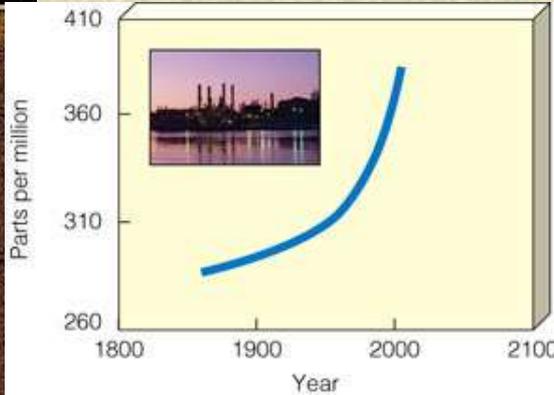
- ✦ Core samples taken from old ocean sediment layers have been used to trace back in time the climate changes that have occurred over the past tens of millions of years
- ✦ Short periods of only a few hundred years in the geological past when rapid increases of the Earth's temperature have occurred superimposed on top of the rise and fall of average temperatures over the longer term up to 15 degrees centigrade warmer than today.

Methane

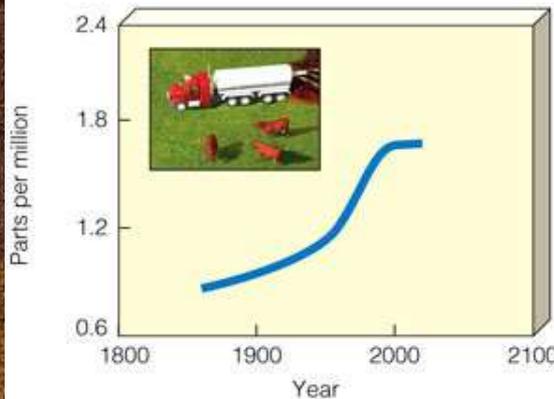
- ✦ Temperatures then fell back to the long term trend, the whole rise and fall only lasting a few hundred years.
- ✦ The most likely cause of this rapid global warming over such a short period is the release of methane into the atmosphere.
- ✦ Methane is 60 times more powerful than CO₂ as a greenhouse gas
- ✦ Methane was released due to breakdown of material associated with permafrost



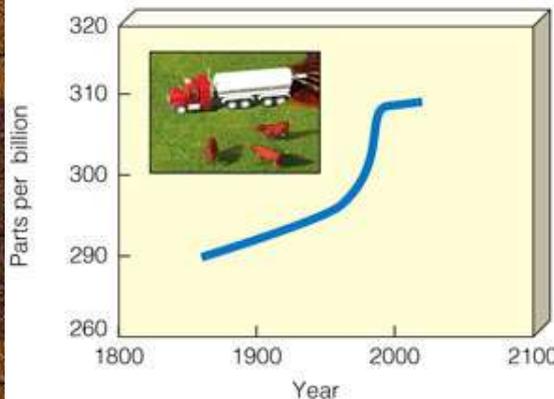
Major Greenhouse Gases



Carbon dioxide (CO₂)



Methane (CH₄)



Nitrous oxide (N₂O)

✦ Increases in average concentrations of three greenhouse gases in the troposphere between 1860 and 2004, mostly due to fossil fuel burning, deforestation, and agriculture.

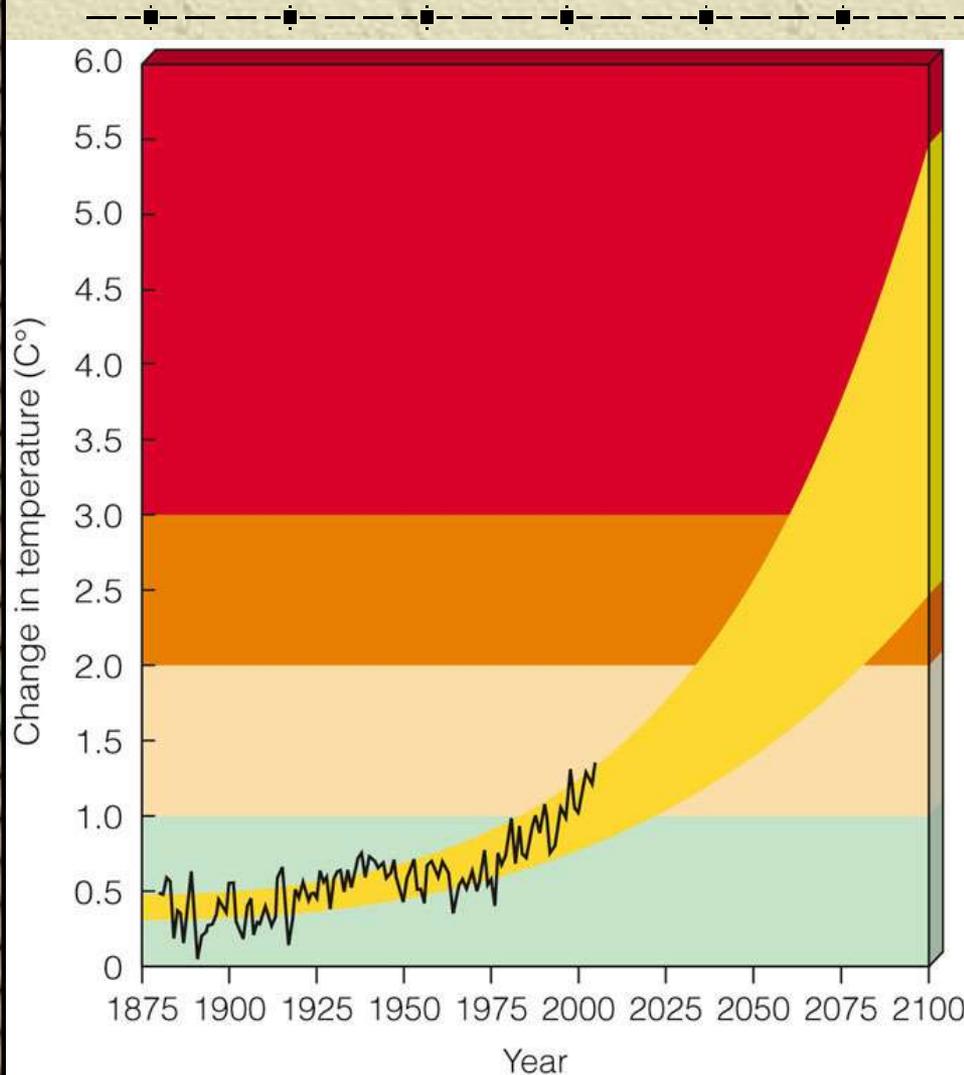
CLIMATE CHANGE AND HUMAN ACTIVITIES

- ✦ Evidence that the earth's troposphere is warming, mostly because of human actions:
 - ✦ The 20th century was the hottest century in the past 1000 years.
 - ✦ Since 1900, the earth's average tropospheric temperature has risen 0.6 C°.
 - ✦ Over the past 50 years, Arctic temperatures have risen almost twice as fast as those in the rest of the world.
 - ✦ Glaciers and floating sea ice are melting and shrinking at increasing rates.

CLIMATE CHANGE AND HUMAN ACTIVITIES

- ◆ Warmer temperatures in Alaska, Russia, and the Arctic are melting permafrost releasing more CO₂ and CH₄ into the troposphere.
- ◆ During the last century, the world's sea level rose by 10-20 cm, mostly due to runoff from melting and land-based ice and the expansion of ocean water as temperatures rise.

The Scientific Consensus about Future Climate Change



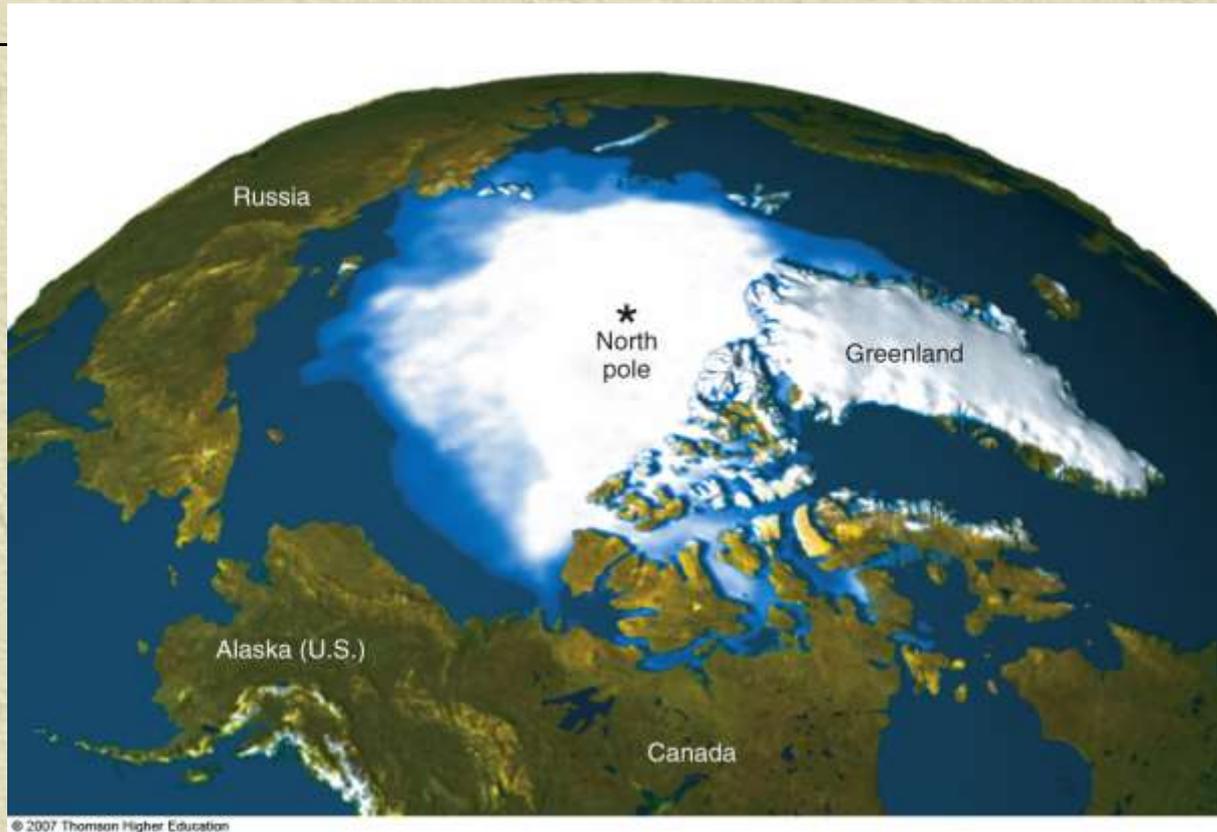
✦ Measured and projected changes in the average temperature of the atmosphere.

Figure 20-7

FACTORS AFFECTING THE EARTH'S TEMPERATURE

- ✦ Some factors can amplify (positive feedback) and some can dampen (negative feedback) projected global warming.
- ✦ There is uncertainty about how much CO₂ and heat the oceans can remove from the troposphere and how long the heat and CO₂ might remain there.
- ✦ Warmer temperatures create more clouds that could warm or cool the troposphere.

EFFECTS OF GLOBAL WARMING



✦ Between 1979 and 2005, average Arctic sea ice dropped 20% (as shown in blue hues above).

Figure 20-8

Heat Transfer

Conduction

- ✦ Warm air holds more moisture than cold air. During conduction, heat & moisture from the ocean or land moves into the atmosphere.
- ✦ Ex. cold air moving over warm water (like a lake), forming steam fog.

Heat Transfer

Convection

- ✦ This causes rising air currents and leads to cloud formation.
- ✦ It takes heat from the lower atmosphere to the higher atmosphere where pressure is less, causing air to expand, which in turn cools the air.
- ✦ The air cannot hold as much moisture because it is cooler, so clouds form (condensation).

Heat Transfer

Radiation

✦ Radiation drives weather. Heat from the sun warms the earth, which radiates the heat back into the atmosphere.

Solar Radiation

Scattering

✦ As the sun hits the earth, molecules are scattered into the air. This changes the direction of the heat coming in. Some are scattered back to space, but others are absorbed.

✦ Scattering is what makes the sky blue.



Solar Radiation

Albedo

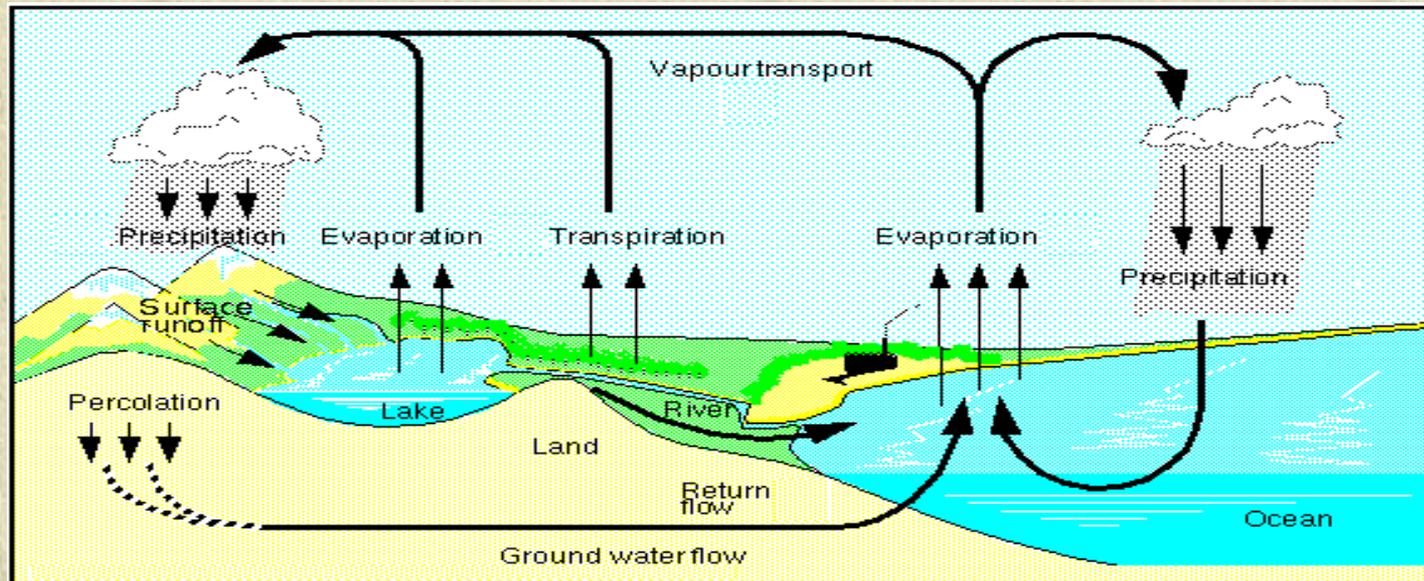
✦ The proportional reflectance of the Earth's surface.

✦ Ex, glaciers and ice sheets have a high albedo and reflect 80-90% of the sunlight hitting them, but asphalt and buildings have low albedos and reflect 10-15%, and oceans and forests reflect only about 5%.



Solar Radiation Absorption

✦ 70% of the solar radiation that falls on Earth is absorbed and runs the water cycle, drives winds and ocean currents, powers photosynthesis, and warms the planet.



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

Solar Radiation

Control of Temperature

✦ When there isn't a lot of moisture in the atmosphere & it's a clear night, we have a large temperature drop (like in the desert), but when there is a blanket of clouds, the temperature stay uniform.

Agriculture

- Shifts in food-growing areas
- Changes in crop yields
- Increased irrigation demands
- Increased pests, crop diseases, and weeds in warmer areas

Water Resources

- Changes in water supply
- Decreased water quality
- Increased drought
- Increased flooding

Forests

- Changes in forest composition and locations
- Disappearance of some forests
- Increased fires from drying
- Loss of wildlife habitat and species

Biodiversity

- Extinction of some plant and animal species
- Loss of habitats
- Disruption of aquatic life

Sea Level and Coastal Areas

- Rising sea levels
- Flooding of low-lying islands and coastal cities
- Flooding of coastal estuaries, wetlands, and coral reefs
- Beach erosion
- Disruption of coastal fisheries
- Contamination of coastal aquifers with salt water

Weather Extremes

- Prolonged heat waves and droughts
- Increased flooding
- More intense hurricanes, typhoons, tornadoes, and violent storms

Human Population

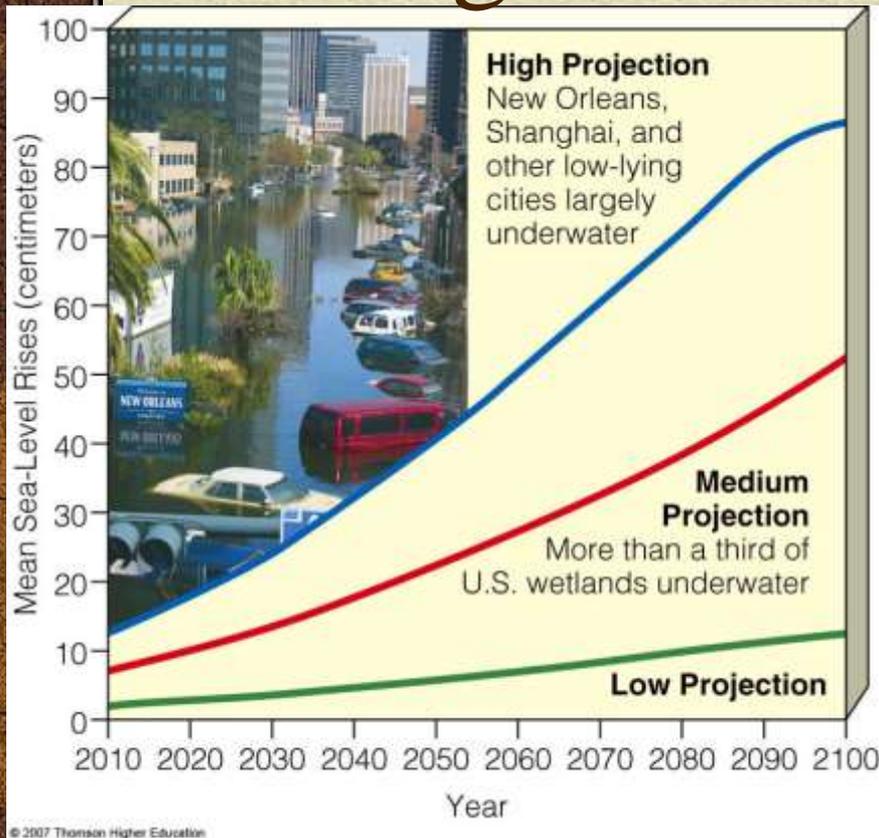
- Increased deaths
- More environmental refugees
- Increased migration

Human Health

- Increased deaths from heat and disease
- Disruption of food and water supplies
- Spread of tropical diseases to temperate areas
- Increased respiratory disease
- Increased water pollution from coastal flooding



Rising Sea Levels



✦ During this century rising seas levels are projected to flood low-lying urban areas, coastal estuaries, wetlands, coral reefs, and barrier islands and beaches.

Figure 20-10

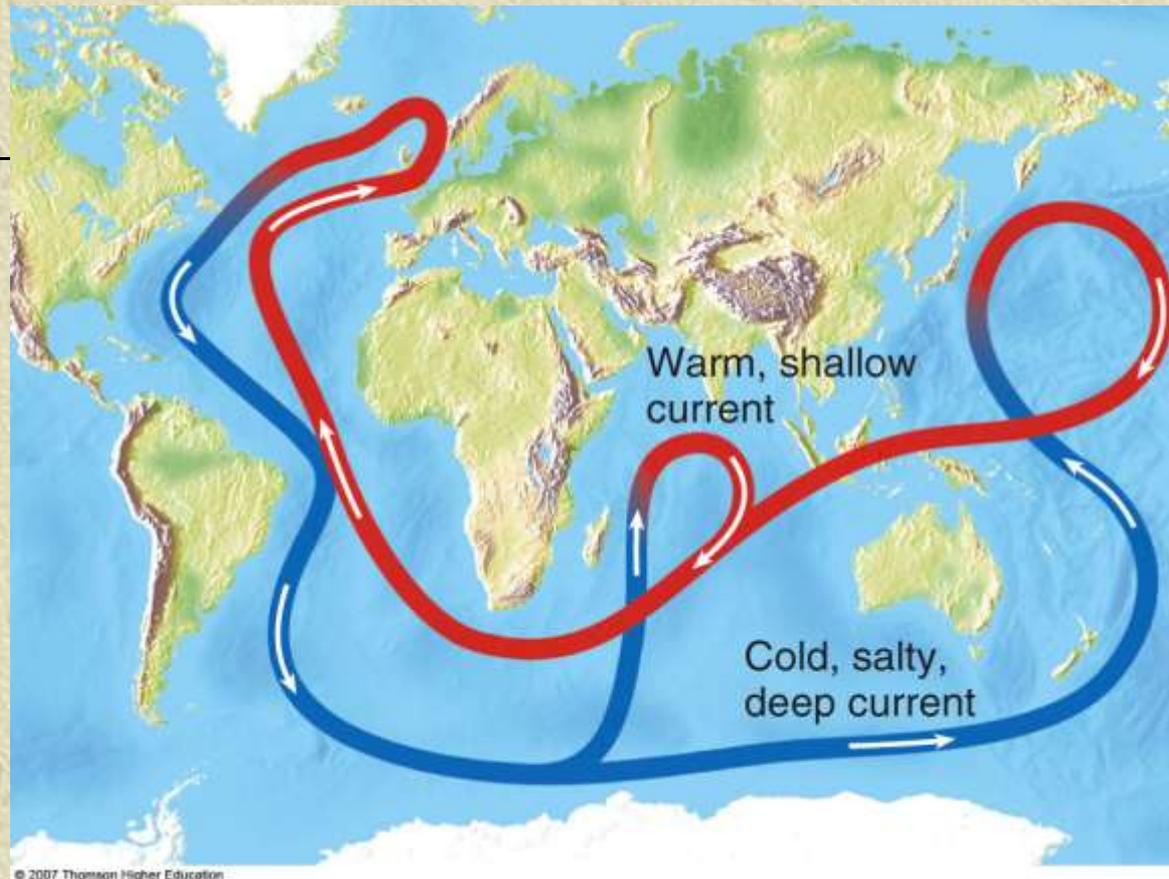
Rising Sea Levels



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✦ If seas levels rise by 9-88cm during this century, most of the Maldives islands and their coral reefs will be flooded.

Changing Ocean Currents



- ✦ Global warming could alter ocean currents and cause both excessive warming and severe cooling.

Storms

Thunderstorms

Characteristics

- ✦ Thunderstorms have high, cumulonimbus clouds that can reach 50,000 feet. An updraft of warm air causes cold air to rush downwards. This is why you feel a sudden cold breeze right before a thunderstorm. Lightening causes the ozone smell.

Problems

- Problems include rain, flooding, hail, lightening, high winds, and loss of life can occur.

Tornadoes

Characteristics

✦ Tornadoes are a powerful, rotating funnel of air associated with severe thunderstorms. Tornadoes form when a mass of cool, dry air collides with warm, humid air, producing a strong updraft of spinning air on the underside of a cloud. It is a tornado if the spinning air descends and touches the ground.

Tornadoes

Problems

- ✦ They can destroy buildings, bridges, and freight trains, and even blow the water out of a river or small lake, leaving it empty. Tornadoes also kill people; more than 10,000 people in the U.S. died in tornadoes in the 20th century. They are most common in the Great Plains and Midwestern states (especially Texas, Oklahoma, and Kansas), as well as states along the Gulf of Mexico.

Hurricanes

Characteristics

✦ Hurricanes are giant, rotating tropical storms with winds of at least 74 miles per hour, with some reaching 155 miles per hour. They form as strong winds pick up moisture over warm surface waters of the tropical ocean and start to spin as a result of the rotation of the Earth. The spinning causes an upward spiral of massive clouds as air is pulled upward.

Hurricanes

Problems



✦ These are destructive when they hit land, not so much from strong winds as from resultant storm surges, but waves that rise as much as 25 feet above the ocean surface. These can damage property and result in loss of life.

EFFECTS OF GLOBAL WARMING

- ✦ A warmer troposphere can decrease the ability of the ocean to remove and store CO₂ by increasing the acidity of ocean water and decreasing the phytoplankton bc of lower availability of necessary iron.
- ✦ Global warming will lead to prolonged heat waves and droughts in some areas and prolonged heavy rains and increased flooding in other areas.

EFFECTS OF GLOBAL WARMING

- ✦ In a warmer world, agricultural productivity may increase in some areas and decrease in others.
- ✦ Crop and fish production in some areas could be reduced by rising sea levels that would flood river deltas.
- ✦ Global warming will increase deaths from:
 - ◆ Heat and disruption of food supply.
 - ◆ Spread of tropical diseases to temperate regions.
 - ◆ Increase the number of environmental refugees.

Heat wave kills 30, no relief in sight

July 27, 1999



Monster iceberg breaks off Antarctic ice shelf

May 10, 2002



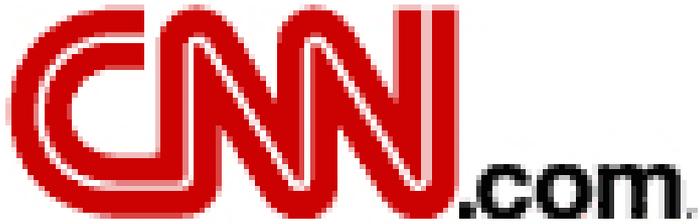
Global warming may harm human health

November 16, 1998

Climatic changes related to global warming could foster dangerous outbreaks of cholera, dengue fever and malaria, ...

<http://www.cnn.com/TECH/science/9811/16/climate.health.enn/index.html>



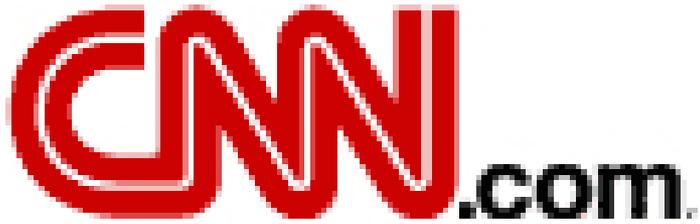


Study: Global warming spurs migrations

Thursday, January 2, 2003

Rising global temperatures that have lured plants into early bloom and birds to nest earlier in the spring are altering the ranges and behavior of hundreds of plant and animal species worldwide, two studies conclude.

<http://www.cnn.com/2003/TECH/science/01/02/climate.migrations.ap/index.html>



Report: Coral bleaching hits record level

May 19, 1999

Global warming has been linked to an unprecedented episode of coral bleaching in 1998, ...

<http://www.cnn.com/NATURE/9905/19/coral.bleaching.cnn/index.html>



(COURTESY NOAA)

Vicious cycle: Global warming feeds fire potential

November 2, 2000

Global warming may greatly accelerate the fire cycle in the desert ecosystem of North America, according to a study published today in the journal Nature.

Elevated carbon dioxide levels, the result of increased fossil fuel burning, can alter the delicate balance of grasses in desert areas, the report notes. This finding may have major implications for the biodiversity and health of desert ecosystems in the western United States.

"This could be a real problem for land managers," said Stan Smith, a professor of biology at the University of Nevada in Las Vegas and lead author of the study. <http://www.cnn.com/2000/NATURE/11/02/global.warming.cnn/index.html>



DEALING WITH GLOBAL WARMING

✦ Climate change is such a difficult problem to deal with because:

- ✦ The problem is global.
- ✦ The effects will last a long time.
- ✦ The problem is a long-term political issue.
- ✦ The harmful and beneficial impacts of climate change are not spread evenly.
- ✦ Many actions that might reduce the threat are controversial because they can impact economies and lifestyles.

DEALING WITH GLOBAL WARMING

✦ Two ways to deal with global warming:

◆ *Mitigation* that reduces greenhouse gas emissions.

✦ 1. to make less severe: to mitigate a punishment

✦ 2. is the effort to reduce loss of life and property by lessening the impact of disasters.

✦ 3. is the restoration, creation, enhancement, or preservation of a wetland, stream, or habitat conservation area which offsets expected adverse impacts to similar nearby ecosystems.

◆ *Adaptation*, where we recognize that some warming is unavoidable and devise strategies to reduce its harmful effects.

Solutions

Global Warming

Prevention

Cleanup

Cut fossil fuel use (especially coal)

Shift from coal to natural gas

Improve energy efficiency

Shift to renewable energy resources

Transfer energy efficiency and renewable energy technologies to developing countries

Reduce deforestation

Use more sustainable agriculture and forestry

Limit urban sprawl

Reduce poverty

Slow population growth



Remove CO₂ from smoke stack and vehicle emissions

Store (sequester) CO₂ by planting trees

Sequester CO₂ deep underground

Sequester CO₂ in soil by using no-till cultivation and taking cropland out of production

Sequester CO₂ in the deep ocean

Repair leaky natural gas pipelines and facilities

Use animal feeds that reduce CH₄ emissions by belching cows

Solutions: Reducing the Threat

- ✦ We can improve energy efficiency, rely more on carbon-free renewable energy resources, and find ways to keep much of the CO₂ we produce out of the troposphere.

WHAT IS BEING DONE TO REDUCE GREENHOUSE GAS EMISSIONS?

- ✦ Getting countries to agree on reducing their greenhouse emissions is difficult.
- ✦ A 2006 poll showed that 83% of Americans want more leadership from federal government on dealing with global warming.

International Climate Negotiations: The Kyoto Protocol

- ◆ Treaty on global warming which first phase went into effect January, 2005 with 189 countries participating.
- ◆ It requires 38 participating developed countries to cut their emissions of CO₂, CH₄, and N₂O to 5.2% below their 1990 levels by 2012.
- ◆ Developing countries were excluded.
 - The U.S. did not sign, but California and Maine are participating.
 - U.S. did not sign because developing countries such as China, India and Brazil were excluded.

Moving Beyond the Kyoto Protocol

- ✦ Countries could work together to develop a new international approach to slowing global warming.
 - ✦ The Kyoto Protocol will have little effect on future global warming without support and action by the U.S., China, and India.

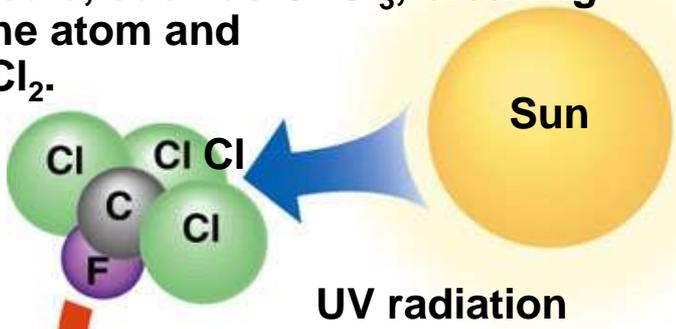
Actions by Some Countries, States, and Businesses

- ✦ In 2005, the EU proposed a plan to reduce CO₂ levels by 1/3rd by 2020.
- ✦ California has adopted a goal of reducing its greenhouse gas emission to 1990 levels by 2020, and 80% below by 2050.
- ✦ Global companies (BP, IBM, Toyota) have established targets to reduce their greenhouse emissions 10-65% to 1990 levels by 2010.

OZONE DEPLETION IN THE STRATOSPHERE

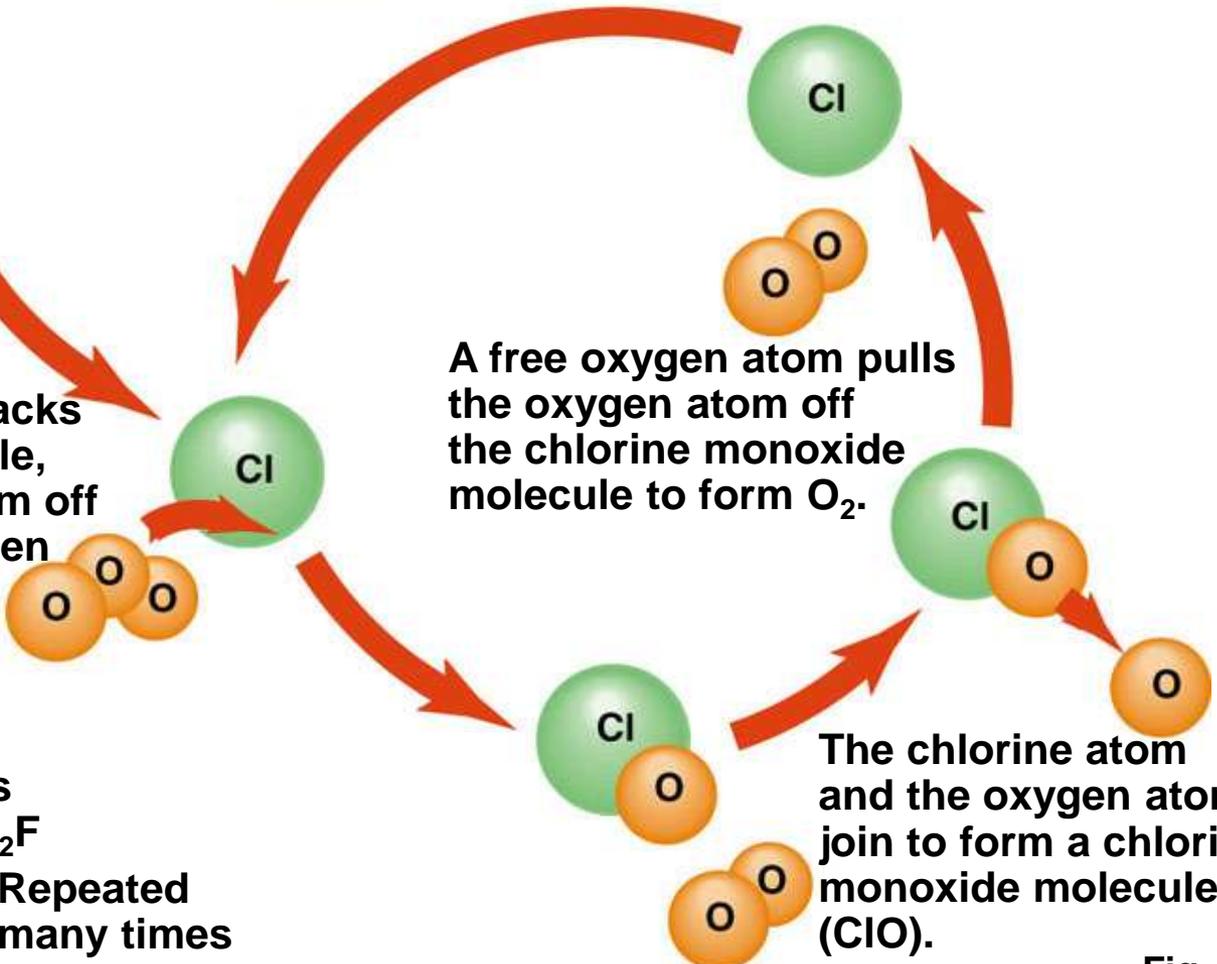
- ✦ Less ozone in the stratosphere allows for more harmful UV radiation to reach the earth's surface.
 - ✦ The ozone layer keeps about 95% of the sun's harmful UV radiation from reaching the earth's surface.
 - ✦ Chlorofluorocarbon (CFCs) have lowered the average concentrations of ozone in the stratosphere.
 - ✦ In 1988 CFCs were no longer manufactured.

Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as CFCl_3 , breaking off a chlorine atom and leaving CFCl_2 .



Once free, the chlorine atom is off to attack another ozone molecule and begin the cycle again.

The chlorine atom attacks an ozone (O_3) molecule, pulling an oxygen atom off it and leaving an oxygen molecule (O_2).

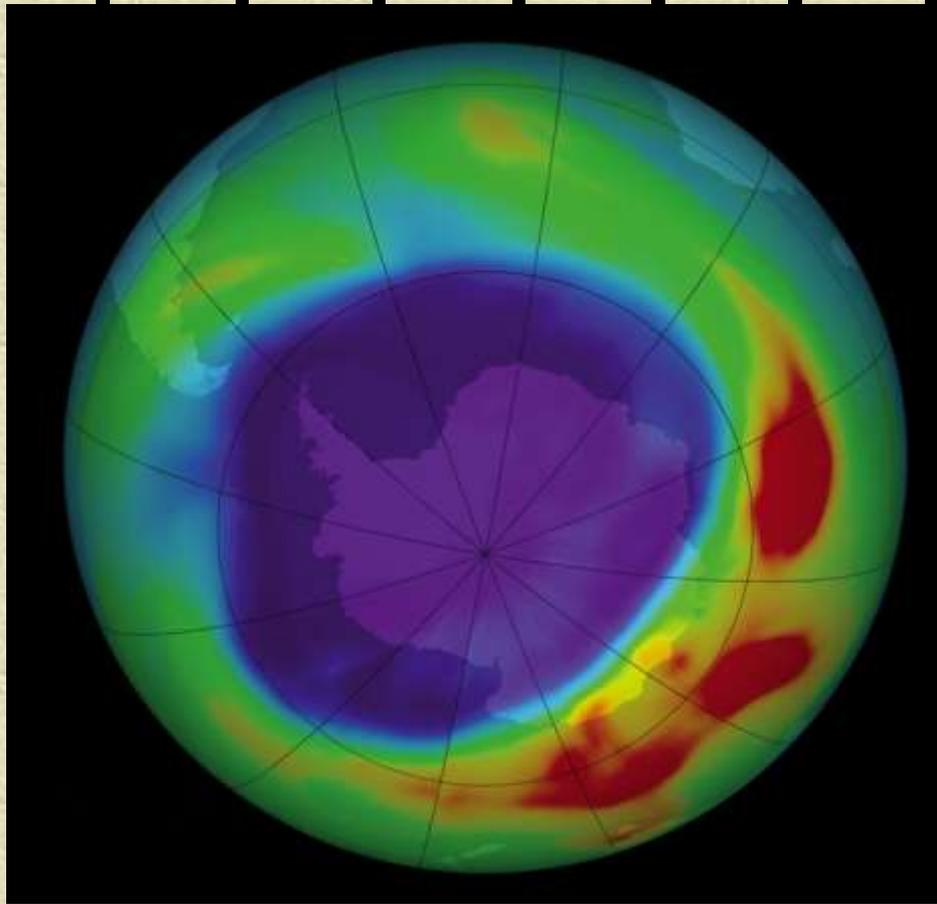


A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule to form O_2 .

The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule (ClO).

Summary of Reactions
 $\text{CCl}_3\text{F} + \text{UV} \rightarrow \text{Cl} + \text{CCl}_2\text{F}$
 $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$
 $\text{Cl} + \text{O} \rightarrow \text{Cl} + \text{O}_2$ } Repeated many times

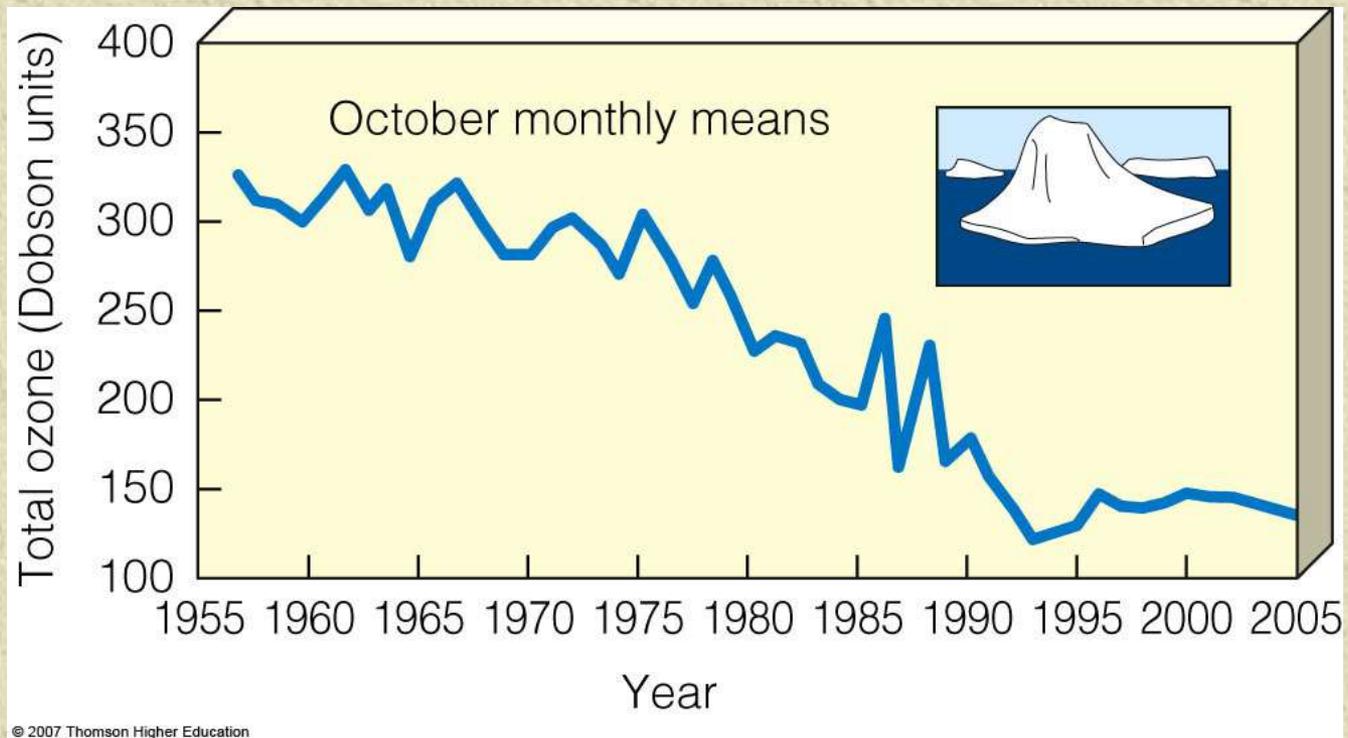
OZONE DEPLETION IN THE STRATOSPHERE



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✦ During four months of each year up to half of the ozone in the stratosphere over Antarctica and a smaller amount over the Arctic is depleted.

OZONE DEPLETION IN THE STRATOSPHERE



- ✦ Since 1976, in Antarctica, ozone levels have markedly decreased during October and November.

OZONE DEPLETION IN THE STRATOSPHERE

- ✦ ***Ozone thinning***: caused by CFCs and other ozone depleting chemicals (ODCs).
- ✦ Increased UV radiation reaching the earth's surface from ozone depletion in the stratosphere is harmful to human health, crops, forests, animals, and materials such as plastic and paints.

Human Health

- **Worse sunburn**
- **More eye cataracts**
- **More skin cancers**
- **Immune system suppression**

Food and Forests

- **Reduced yields for some crops**
- **Reduced seafood supplies from reduced phytoplankton**
- **Decreased forest productivity for UV-sensitive tree species**

Wildlife

- **Increased eye cataracts in some species**
- **Decreased population of aquatic species sensitive to UV radiation**
- **Reduced population of surface phytoplankton**
- **Disrupted aquatic food webs from reduced phytoplankton**

Air Pollution and Materials

- **Increased acid deposition**
- **Increased photochemical smog**
- **Degradation of outdoor paints and plastics**

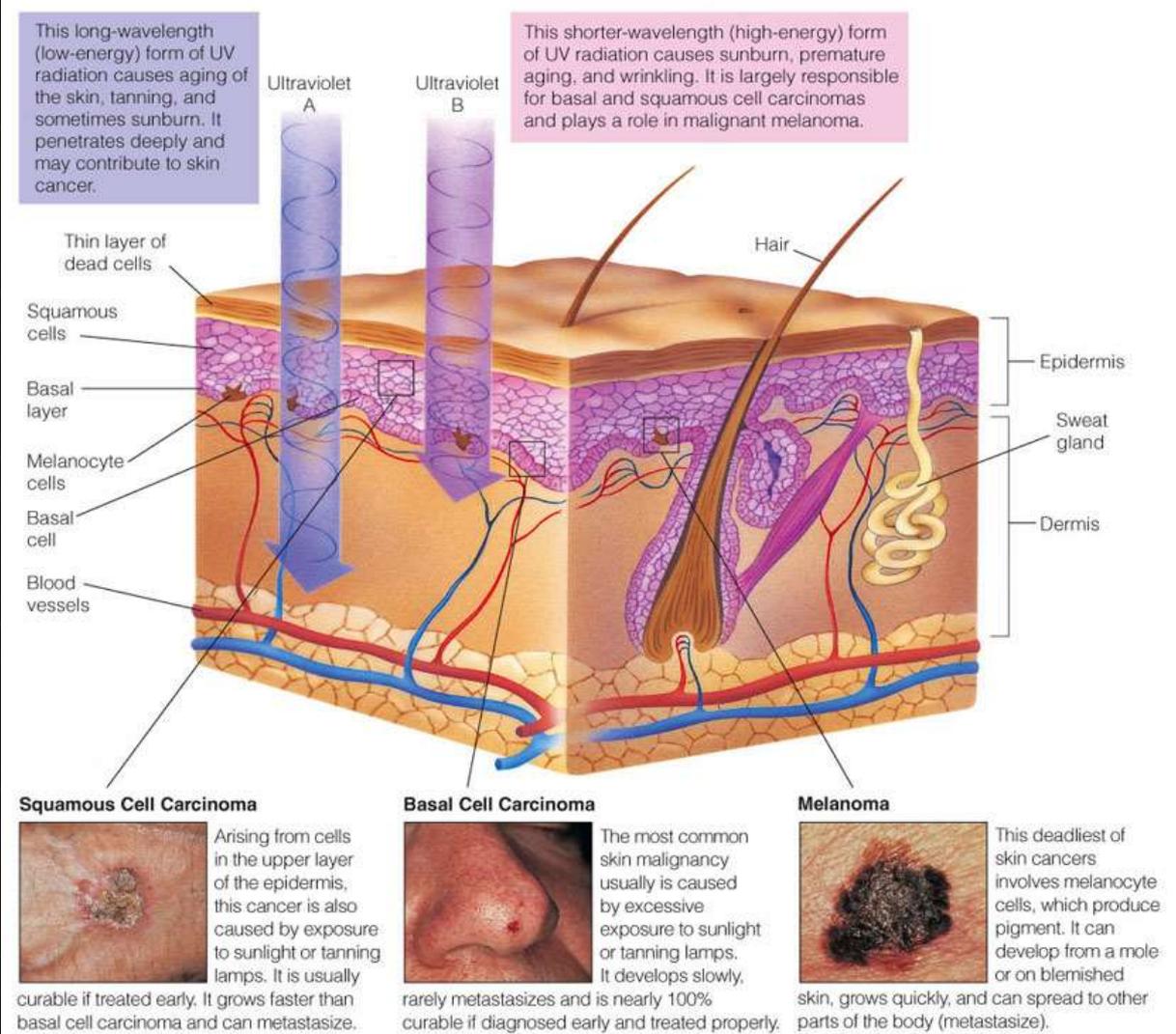
Fig. 20-21, p. 488

Global Warming

- **Accelerated warming because of decreased ocean uptake of CO₂ from atmosphere by phytoplankton and CFCs acting as greenhouse gases**

Case Study: Skin Cancer

✦ Structure of the human skin and relationship between radiation and skin cancer.



Human Impact (Positive)

Pollution Control Devices

- ✦ Emission Control Devices – filter particles
- ✦ Scrubbers – use water to filter particles and gases
- ✦ Catalytic Converters – on cars; finish burning wastes to decrease carbon monoxide levels
- ✦ 1-800-453-SMOG

Law – Clean Air Act

- ✦ 1963 - first passage, 1970, 1977 and 1990 amended
- ✦ Involves EPA
- ✦ Sets standards for acceptable levels of sulfur oxides, nitrogen oxides, ozone, carbon monoxide, hydrocarbons, lead, & more
- ✦ Provides pollution credits for industries that utilize pollution-control devices+
- ✦ Bush administration has relaxed rules
- ✦ It established NAAQS and AQI

National Ambient Air Quality Standards (NAAQS)

- ✦ Sets acceptable concentrations for 6 “criteria” pollutants that:
 - ✦ Threaten public health/the environment over broad areas (non-point)
 - ✦ Are emitted in large quantities
 - ✦ CO, Pb, Nitrogen Oxides, Ozone, Particulate Matter and Sulfur Dioxides

Air Quality Index (AQI)

-
- ✦ Measures levels of 5 criteria pollutants
 - ✦ Forecast of daily air pollution levels
 - ✦ Purpose to educate and protect public-
focuses on health effects
 - ✦ Categories: green= good, yellow=
moderate, orange= unhealthy for sensitive
groups, red= unhealthy, purple= very
unhealthy

National Emissions Standards for Hazardous Air Pollutants

- ✦ Regulates emissions (from point sources)
- ✦ For specific substances (air toxins w/ known or suspected serious health effects (mutagens, carcinogens, neurotoxins))
- ✦ Tend to be localized, from point sources
- ✦ Examples: Ammonia, chlorine, asbestos, arsenic, mercury, benzene