Chapter 20

Climate Change and Ozone Depletion

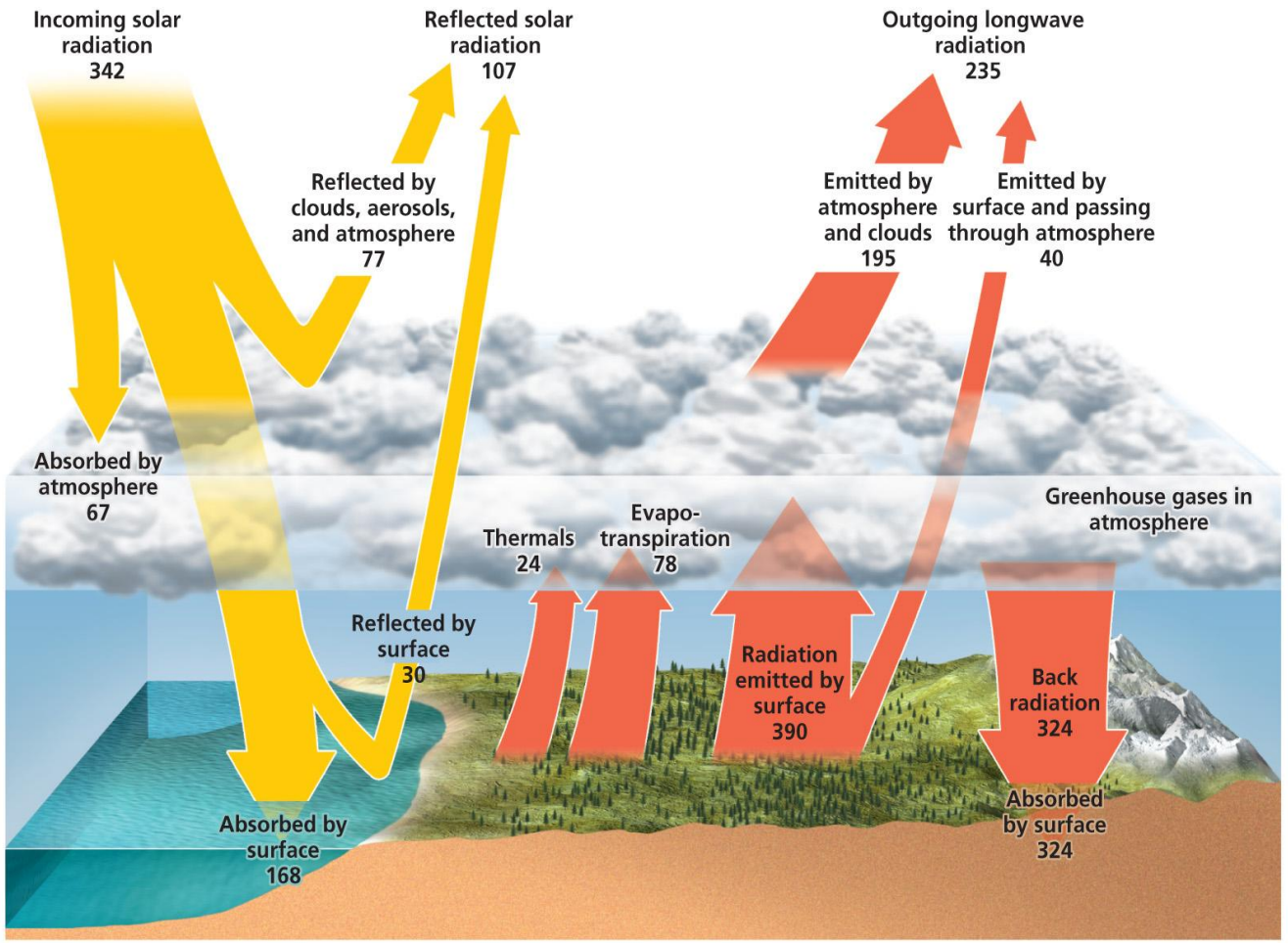
What is climate change?

- **Climate** = an area's long-term atmospheric conditions
  - Temperature, moisture content, wind, precipitation, etc.
- **Global climate change** = describes trends and variations in Earth's climate
  - Temperature, precipitation, storm frequency
- **Global warming** = an increase in Earth's average temperature
  - Earth's climate has varied naturally through time
  - The rapid climatic changes taking place now are due to human activity: fossil fuels, combustion, and deforestation

The Sun and atmosphere keep the Earth warm

- Three factors exert more influence on climate than all others
- The Sun = without it, the Earth would be dark and frozen
  - Also supplies most of our planet's energy
- The atmosphere = without it, the Earth's temperature would be much colder
  - Earth's atmosphere, clouds, land, ice, and water absorb 70% of incoming solar radiation
- The oceans = shape climate by storing and transporting heat and moisture

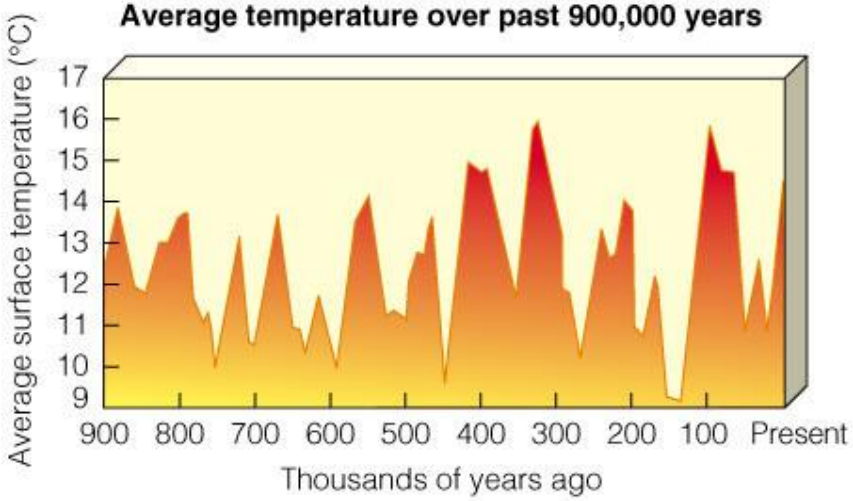
The fate of solar radiation

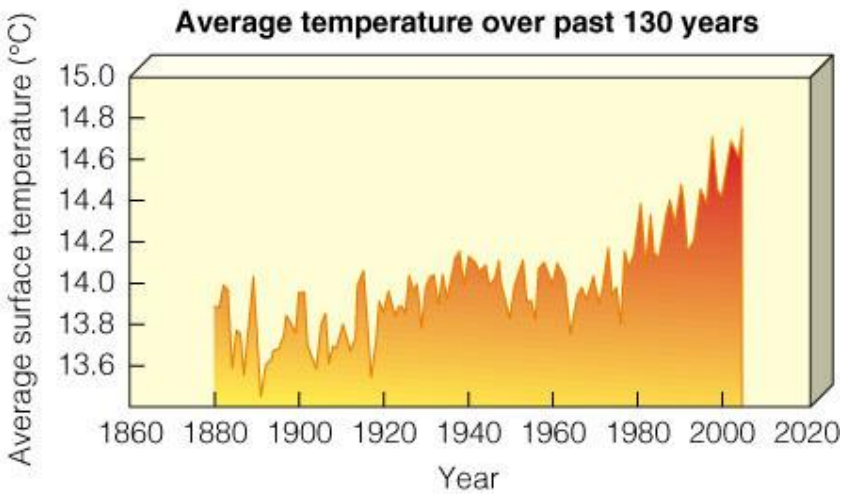


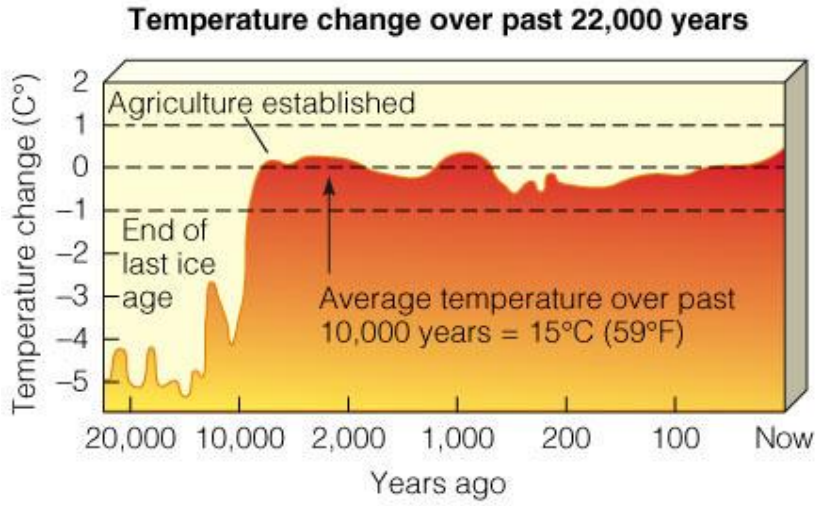
PAST CLIMATE AND THE GREENHOUSE EFFECT

- 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.

PAST CLIMATE AND THE GREENHOUSE EFFECT







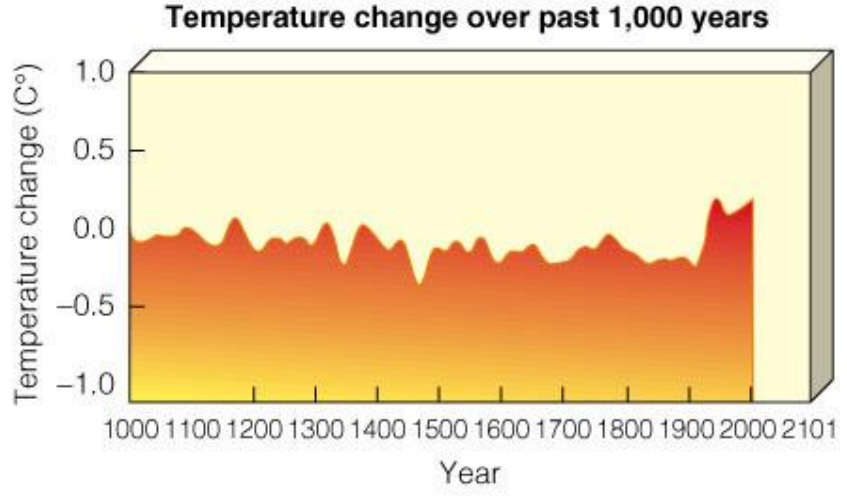
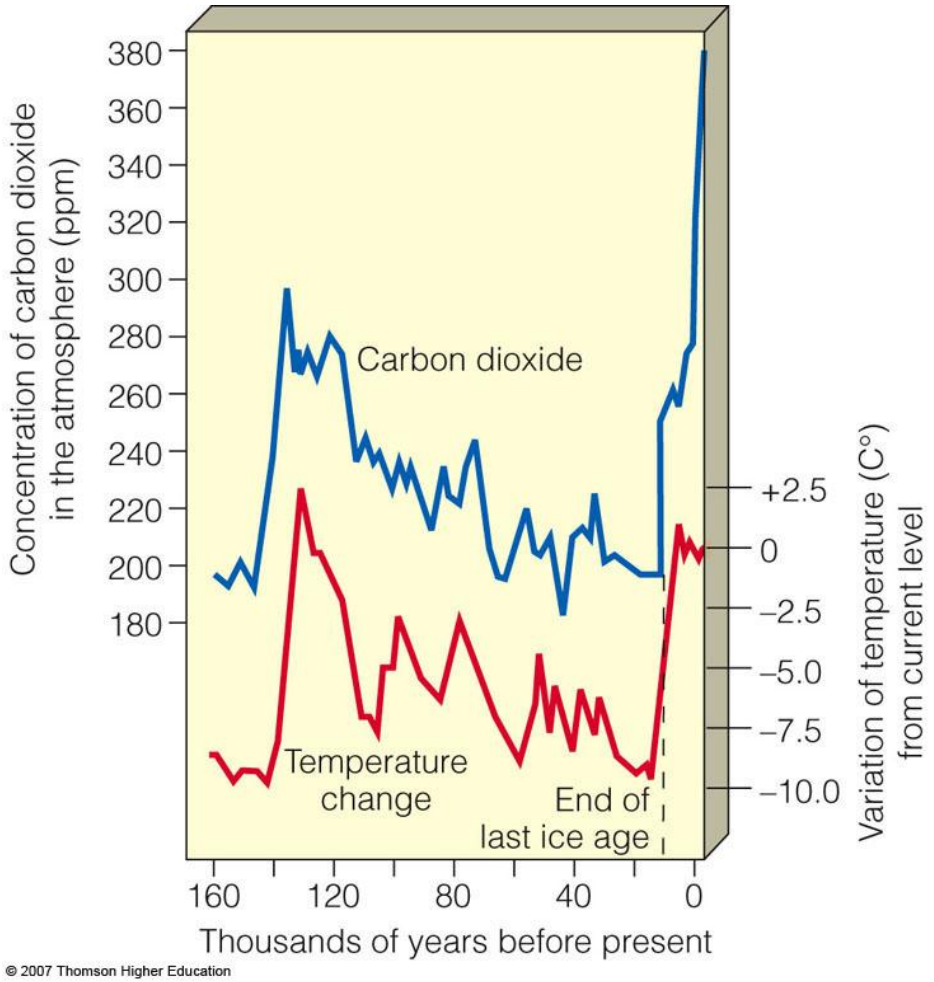


Figure 20-2

How Do We Know What Temperatures Were in the Past?



- In 2005, an ice core showed that CO_2 levels in the troposphere are the highest they have been in 650,000 years.

Figure 20-4

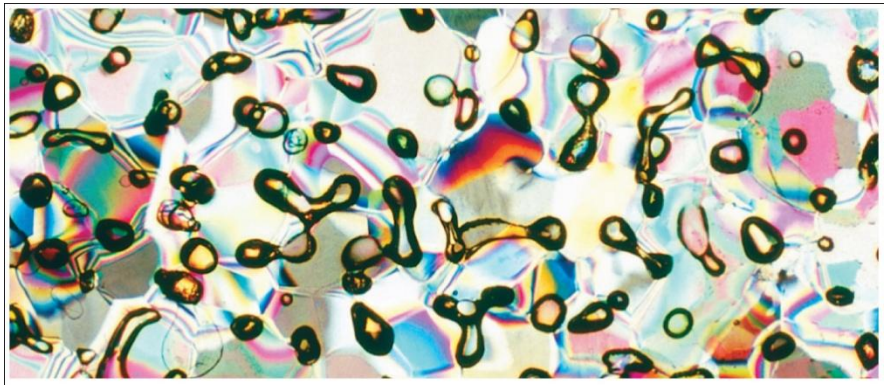
How Do We Know What Temperatures Were in the Past?

- 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

- **Proxy indicators =** types of indirect evidence that serve as substitutes for direct measurements
  - Shed light on past climate
  - Ice caps, ice sheets, and glaciers hold clues to Earth's climate
  - Trapped bubbles in ice cores show atmospheric composition, greenhouse gas concentration, temperature trends, snowfall, solar activity, and frequency of fires

(a) Ice core



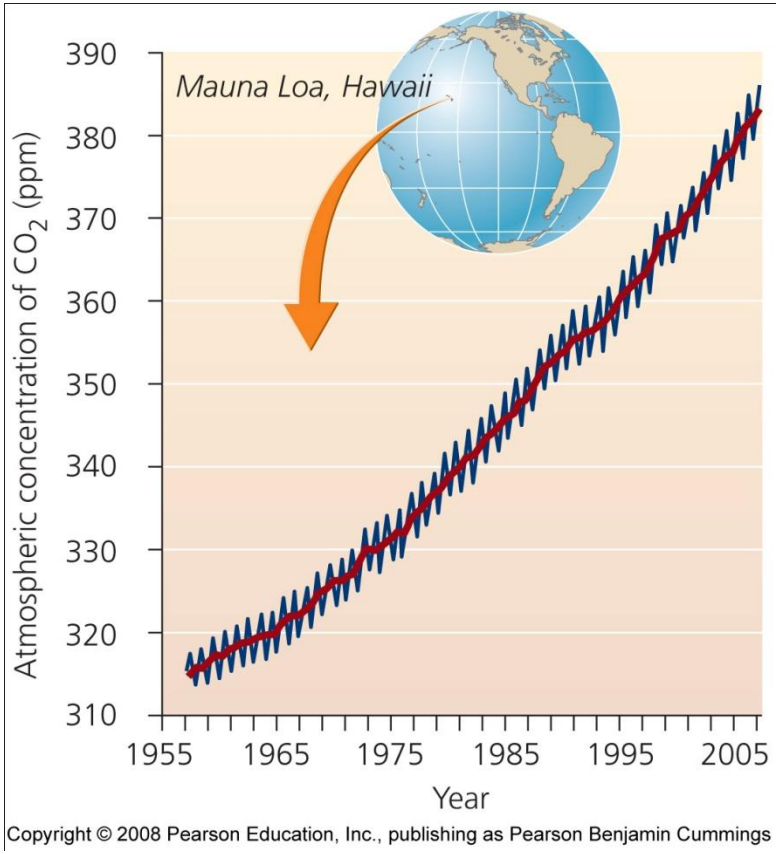
(b) Micrograph of ice core

More proxy indicators

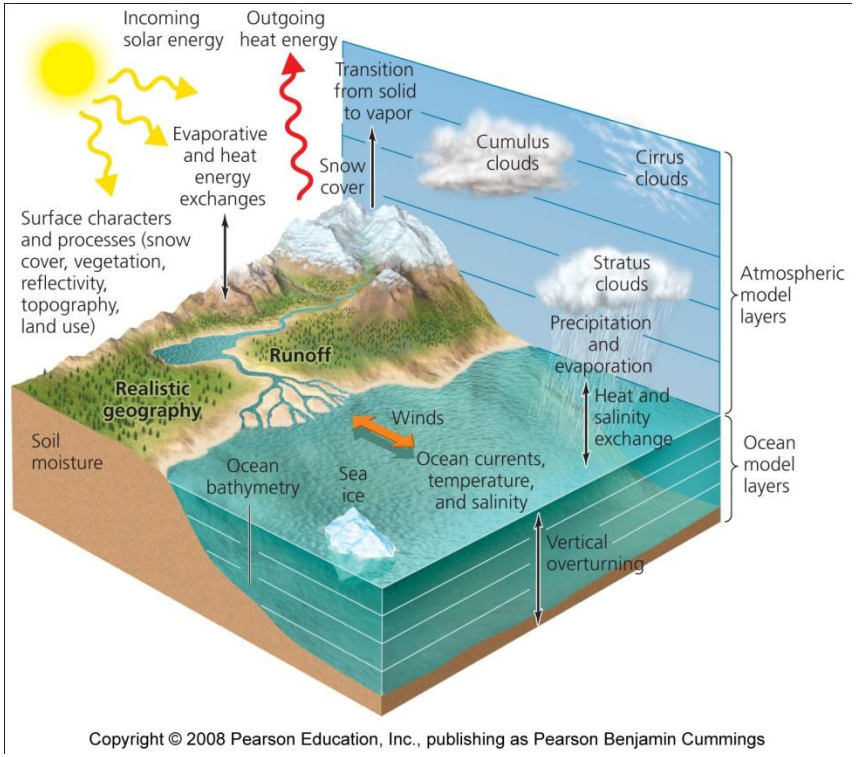
- Cores in sediment beds preserve pollen grains and other plant remnants
- Tree rings indicate age, wetness of the season, droughts, and seasonal growth
- Researchers also gather data on past ocean conditions from coral reefs
- Scientists need to combine multiple records to get a global perspective

Direct atmospheric sampling tells us about the present

Trends in atmospheric concentrations of carbon dioxide show that concentrations have increased from 315 ppm to 383 ppm



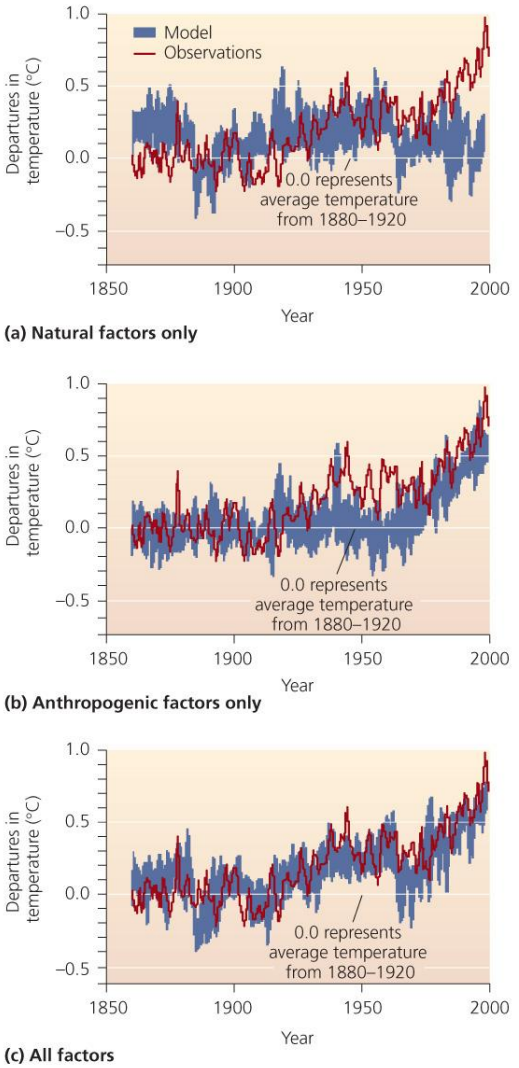
Models help us understand climate



- **Coupled general circulation model (climate models)** = programs that combine what is known about atmospheric circulation, ocean circulation, atmosphere-ocean interactions, and feedback mechanisms to simulate climate processes
  - These models are becoming more reliable in predicting climate change

Results from three simulations

- Figure (a) shows natural climate factors only
  - Volcanoes
- Figure (b) shows only human factors
  - Emissions of greenhouse gases
- Figure (c) shows both factors



Major Greenhouse Gases

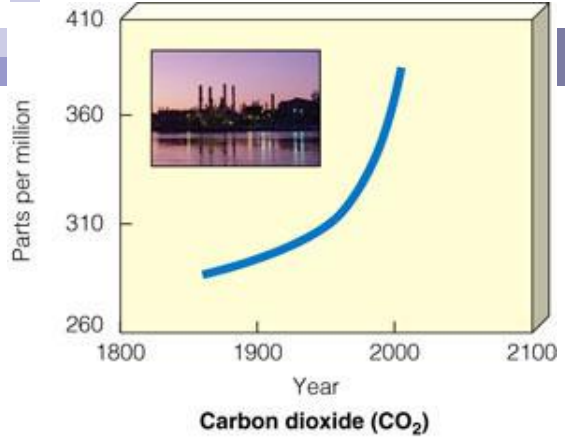
- The major greenhouse gases in the lower atmosphere are water vapor, carbon dioxide, methane, and nitrous oxide.
  - These gases have always been present in the earth's troposphere in varying concentrations.
  - Fluctuations in these gases, plus changes in solar output are the major factors causing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

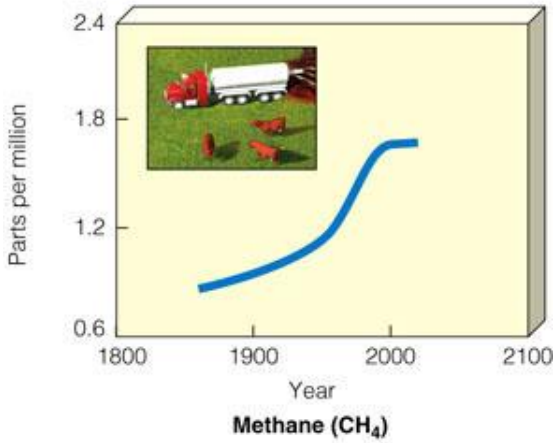
Other greenhouse gases add to warming

- Methane = fossil fuel deposits, livestock, landfills, and crops such as rice
- Nitrous oxide = feedlots, chemical manufacturing plants, auto emissions, and synthetic nitrogen fertilizers
- Ozone = risen due to photochemical smog
- Halocarbon gases (CFCs) = are declining due to the Montreal Protocol
- Water vapor = the most abundant greenhouse gas and contributes most to the greenhouse effect
  - Could increase cloudiness, which might slow global warming by reflecting more solar radiation back into space

Major Greenhouse Gases

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





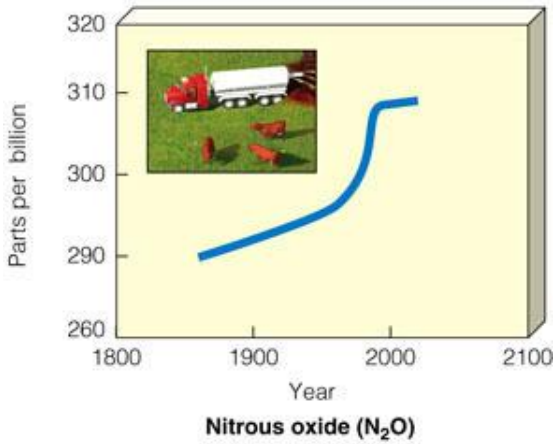
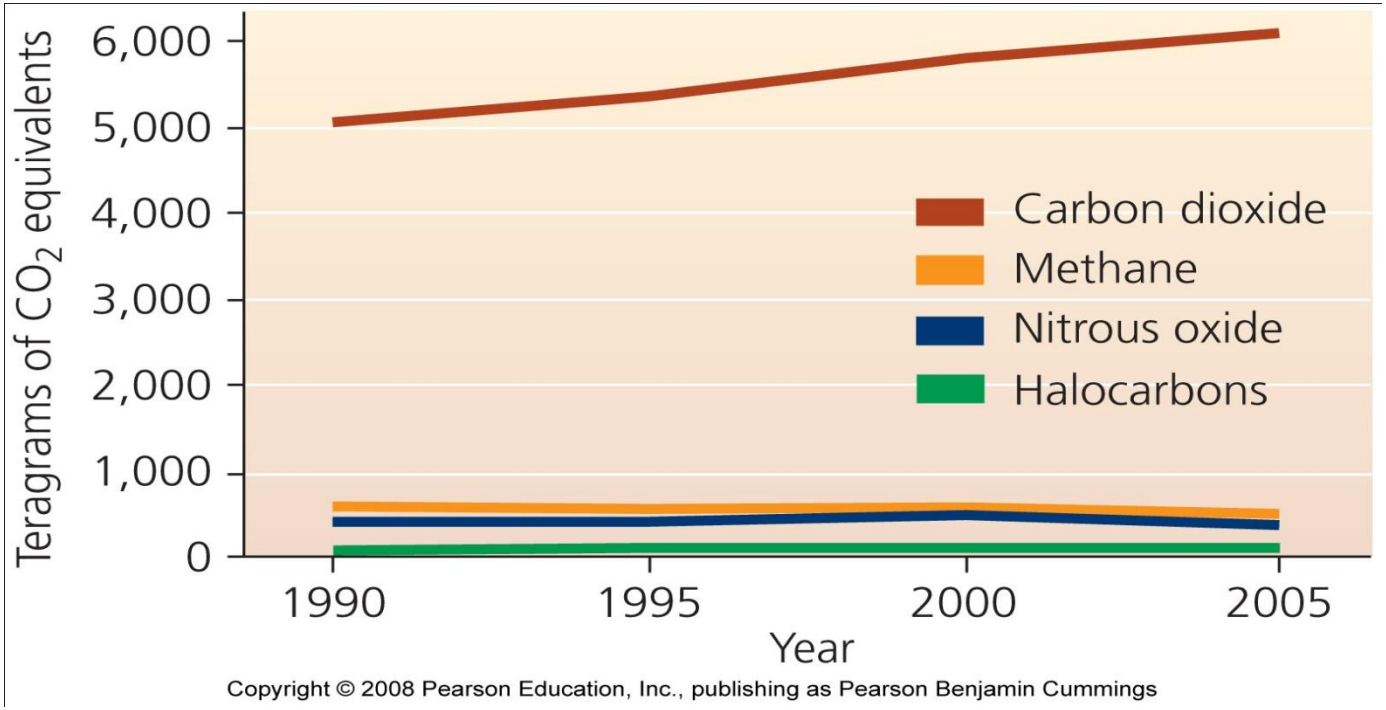


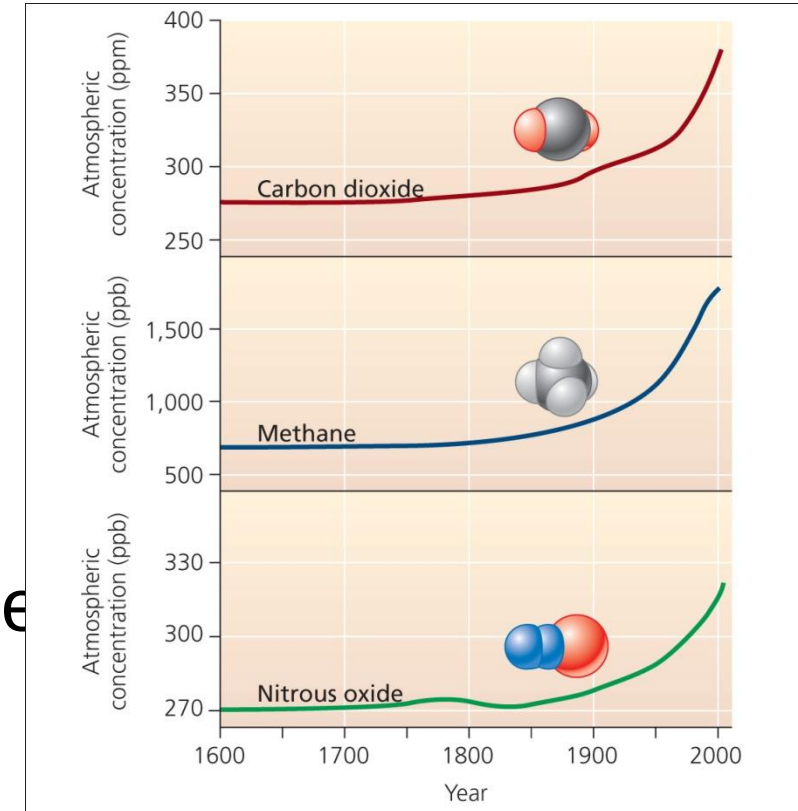
Figure 20-5

U.S. emissions of major greenhouse gases



Carbon dioxide is of primary concern

- Not the most potent greenhouse gas, but it is extremely abundant
  - The major contributor to global warming
- Human activities have booste atmospheric concentrations from 280 parts per million (ppm) to 383 ppm
  - To their highest levels in more than 650,000 years



What caused levels of CO_2 to increase?

- Burned fossil fuels in our homes, factories, and automobiles
  - Transferred large amounts of carbon dioxide from lithospheric reservoirs into the atmosphere
  - The main reason atmospheric carbon dioxide concentrations have increased so dramatically
- Deforestation has contributed to rising atmospheric CO_2 concentration
  - Forests serve as sinks for recently active carbon
  - Their removal reduces the biosphere's ability to absorb carbon dioxide from the atmosphere

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 CO_2 and CH_4 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.

Aerosols may exert a cooling effect

- **Aerosols** = microscopic droplets and particles that have either a warming or cooling effect
- Soot, or black carbon aerosols, cause warming by absorbing solar energy
  - But, most tropospheric aerosols cool the atmosphere by reflecting the Sun's rays
- Sulfate aerosols produced by fossil fuel combustion may slow global warming, at least in the short term
  - Volcanic eruptions reduce sunlight reaching the earth and cool the Earth

Core Case Study: Studying a Volcano to Understand Climate Change

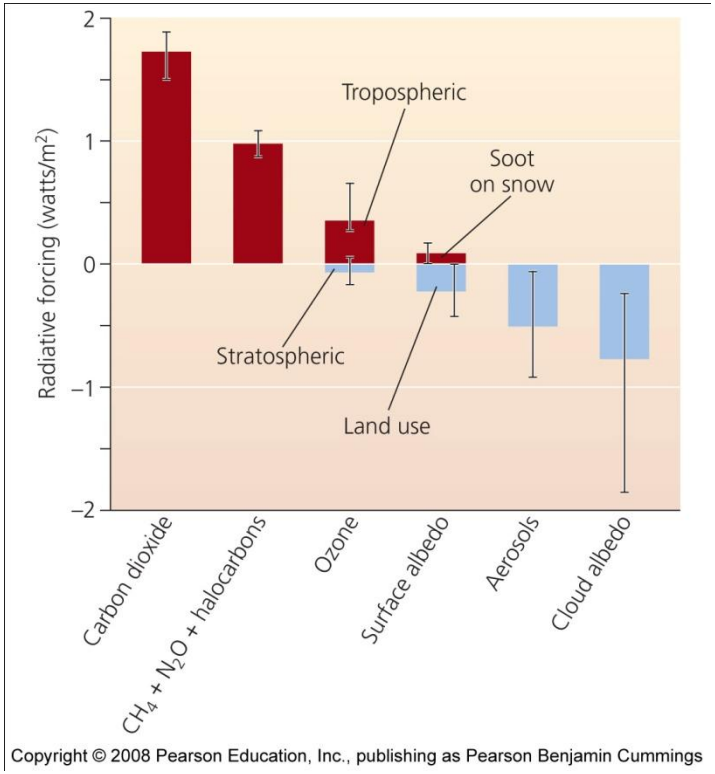
- NASA scientist correctly predicted that the 1991 Philippines explosion would cool the average temperature of the earth by 0.5C^{o} over a 15 month period and then return to normal by 1995.

Figure 20-1

Core Case Study: Studying a Volcano to Understand Climate Change

- The NASA model was correct.
  - The success convince scientists and policy makers that climate model projections should be taken seriously.
  - Other climate models have shown that global temperatures are likely to rise several degrees during this century.

Radiative forcing expresses change in energy



- Scientists estimate the influence of factors over Earth's energy balance
- **Radiative forcing** = the amount of change in energy that a given factor causes
  - Positive forcing warms the surface; negative forcing cools it
- Compared with the pre-industrial Earth, Earth is experiencing radiative forcing of 1.6 watts/m^2
  - Enough to alter the climate

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 CO_2 and heat the oceans can remove from the troposphere and how long the heat and CO_2 might remain there.
- Warmer temperatures create more clouds that could warm or cool the troposphere.

How Would You Vote?

Do you believe that we will experience significant global warming during this century?

- a. No. Claims for significant global warming during this century are based on unreliable climate models.
- b. Yes. Even with the uncertainties, the models still indicate significant global warming during this century.

EFFECTS OF GLOBAL WARMING

- A warmer climate would have beneficial and harmful effects but poor nations in the tropics would suffer the most.
- Some of the world's floating ice and land-based glaciers are slowly melting and are helping warm the troposphere by reflecting less sunlight back into space.

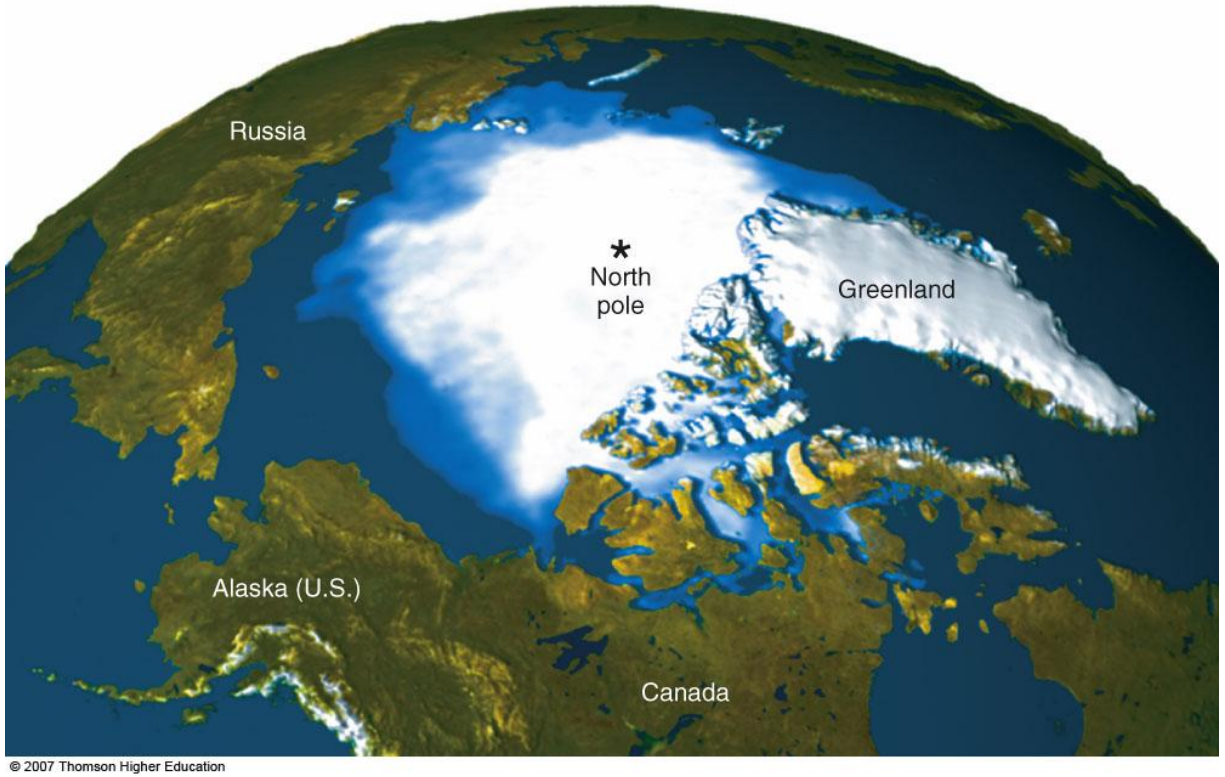
Why Should We Be Concerned about a Warmer Earth?

- A rapid increase in the temperature of the troposphere during this century would give us little time to deal with its harmful effects.
- As a prevention strategy scientists urge to cut global CO_2 emissions in half over the next 50 years.
  - This could prevent changes in the earth's climate system that would last for tens of thousands of years.

Effects of Higher CO_2 Levels on Photosynthesis

- Increased CO_2 in the troposphere can increase plant photosynthesis (PS) but:
  - The increase in PS would slow as the plants reach maturity.
  - Carbon stored by the plants would be returned to the atmosphere as CO_2 when the plants die.
  - Increased PS decreases the amount of carbon stored in the soil.
  - Tree growth may temporarily slow CO_2 emissions in the S. Hemisphere but is likely to increase CO_2 emissions in the N.

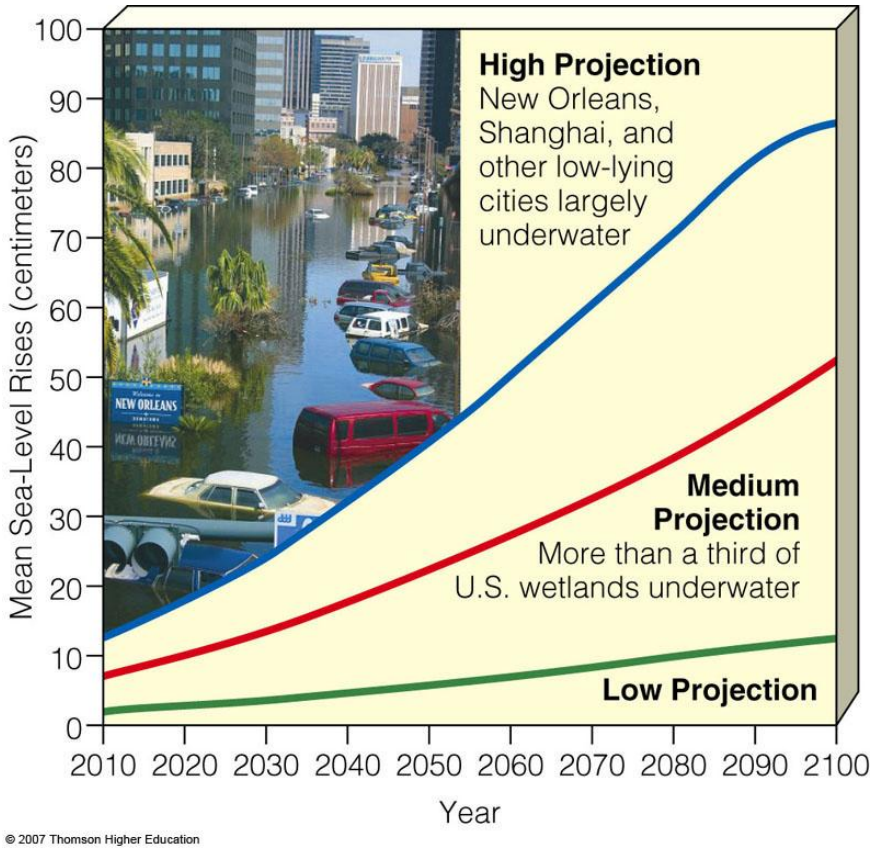
EFFECTS OF GLOBAL WARMING



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

Figure

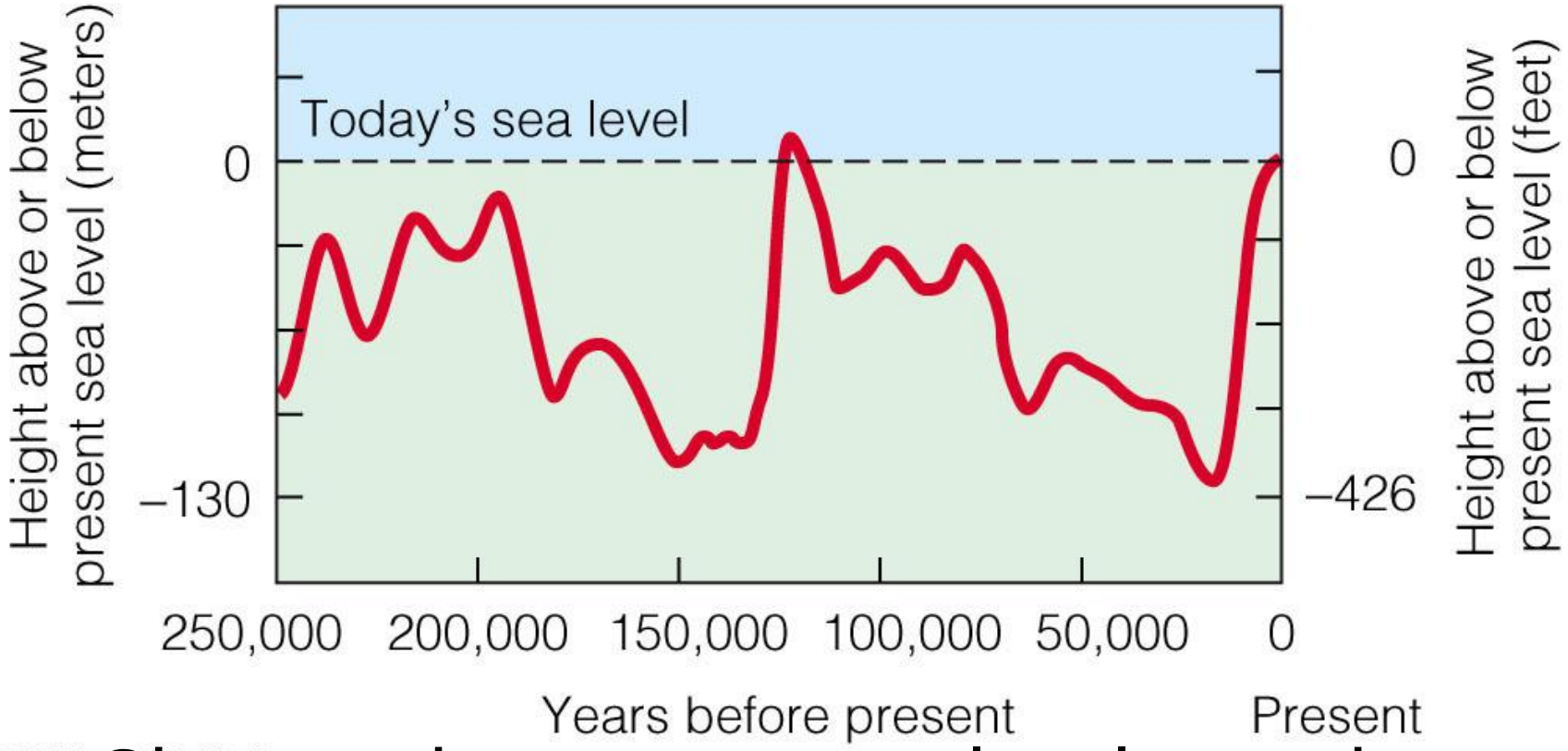
Rising Sea Levels



- 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

Rising Sea Levels

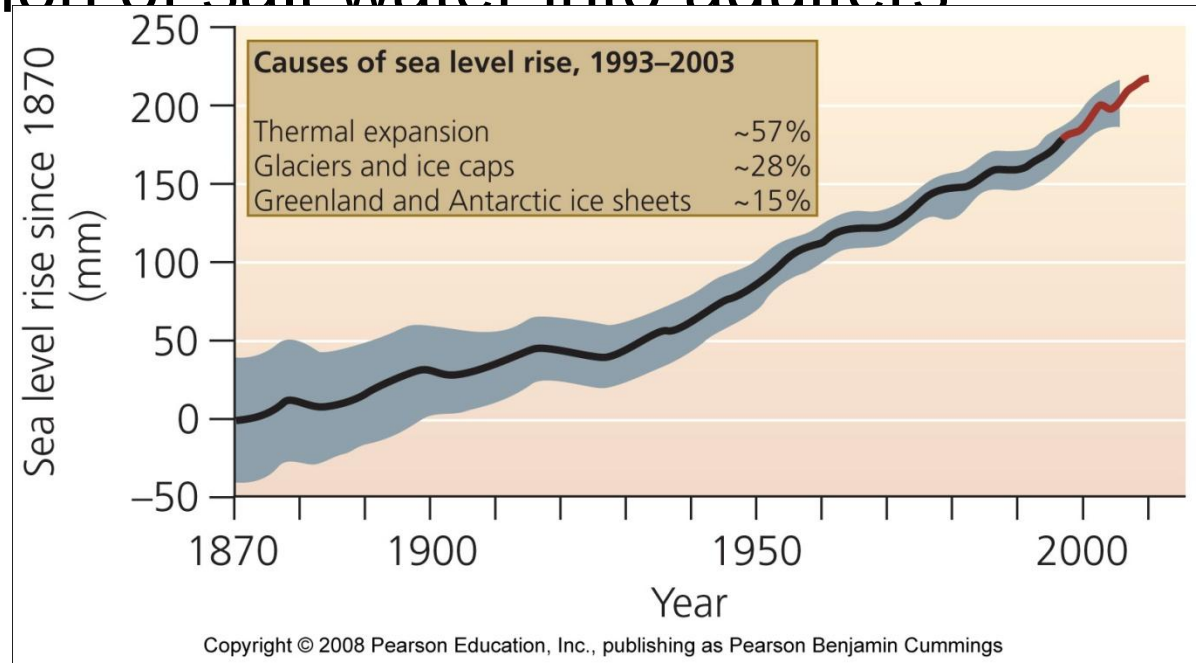


- Changes in average sea level over the past 250,000 years based on data from ocean cores.

Figure

Rising sea levels

- As glaciers and ice melt, increased water will flow into the oceans
- As oceans warm, they expand
- Leads to beach erosion, coastal floods, and intrusion of salt water into aquifers

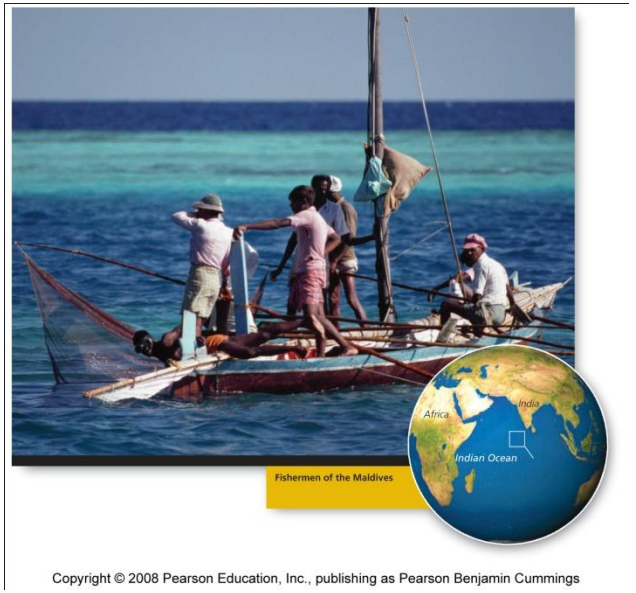


Coastal areas will flood

- **Storm surge** = temporary and localized rise in sea level brought on by the high tides and winds associated with storms
- Cities will be flooded
- Millions of people will be displaced from coastal areas
- IPCC predicts mean sea level to be 18-59 cm (7-23

Central Case: Rising seas may flood the Maldives

- Visiting tourists think of the Maldives Islands in the Indian Ocean as paradise
- The islands could be submerged by rising seas accompanying global climate change
- The government has already evacuated residents from some of the lowest-lying islands



Rising Sea Levels

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

Figure

Solar output and ocean absorption influence climate

- **Solar output** = drives temperature change on Earth's surface
  - The Sun varies in the radiation it emits
  - Variation in solar energy (i.e., solar flares) has not been great enough to change Earth's temperature
- **Ocean absorption =** the ocean holds 50 times more carbon than the atmosphere and absorbs it from the atmosphere
  - Carbon absorption by the oceans is slowing global warming but not preventing it
  - Warmer oceans absorb less CO_2 because gases are less soluble in warmer water – a positive feedback effect that accelerates warming

El Niño

- Normally, winds blow from east to west along the equator, from high to low pressure
- Westward-moving surface waters allow nutrient-rich upwelling along the coast of Peru
- ENSO occurs when air pressure increases in the western Pacific and decreases in the eastern Pacific, causing the equatorial winds to weaken
- Water flows eastward, suppressing upwellings, shutting down delivery of nutrients that support aquatic life
- Coastal industries are devastated, global weather is changed

La Niña events

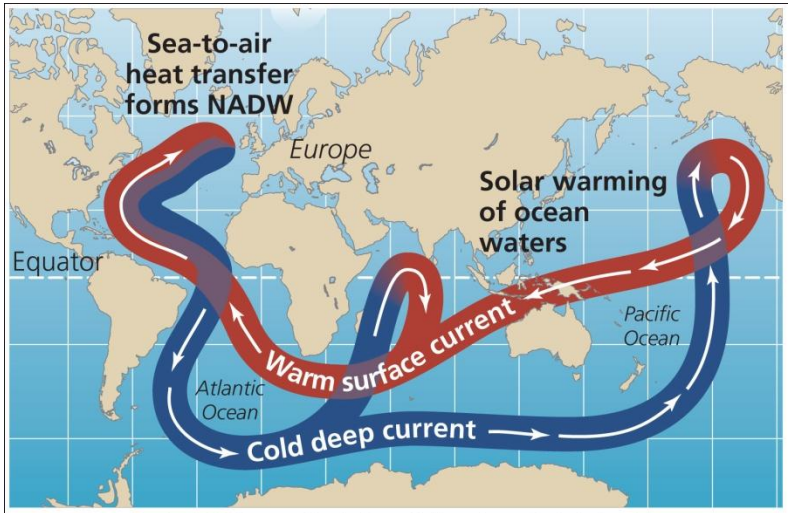
- The opposite of El Niño events
  - Cold surface waters extend far westward in the equatorial Pacific and weather patterns are affected in opposite ways
- ENSO cycles are periodic, occurring every 2-8 years
  - Globally warming air and sea temperatures may be increasing their frequency and strength

Thermohaline circulation

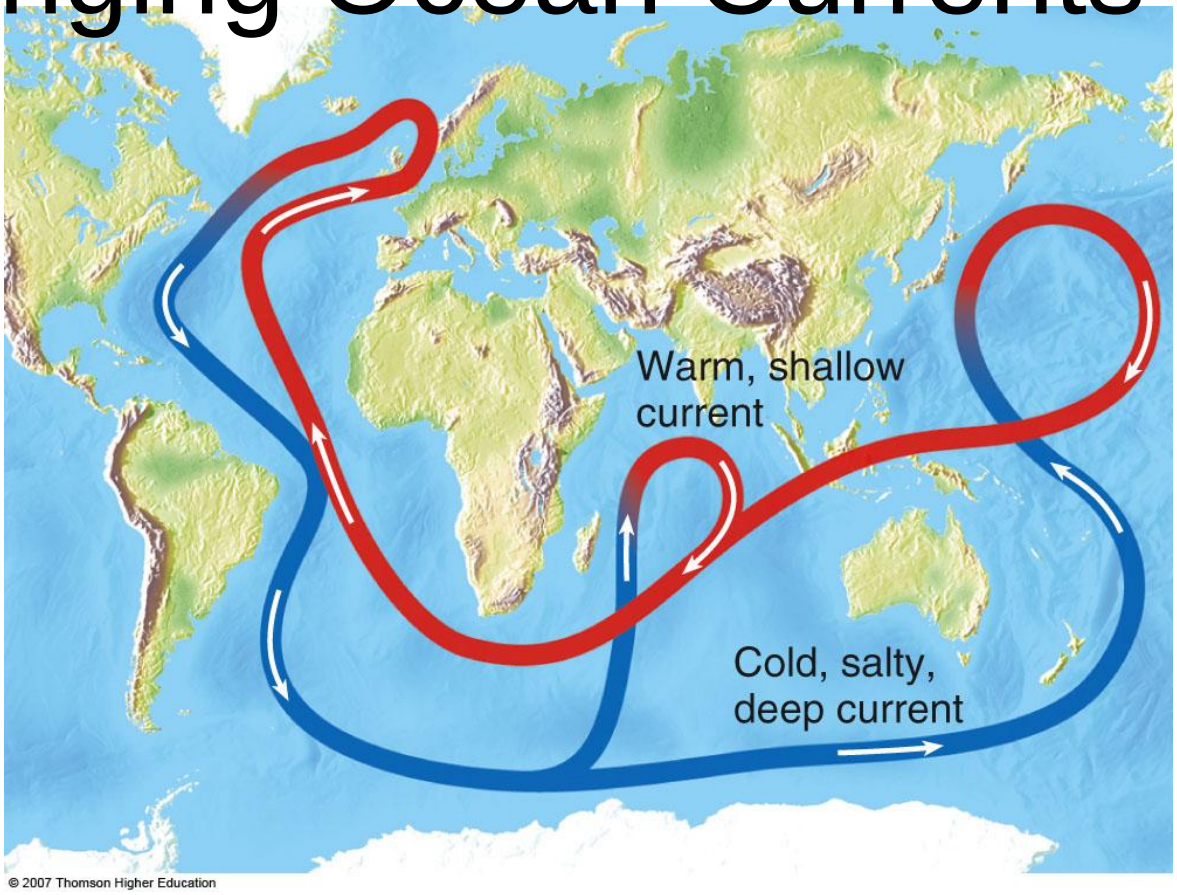
- **Thermohaline circulation** = a worldwide current system in which warmer, fresher water moves along the surface; and colder, saltier water moves deep beneath the surface
  - Warm surface water carries heat to Europe
  - **North American Deep Water** (NADW) = the deep portion of the thermohaline circulation, consisting of dense, cool water that sinks
  - Interrupting the thermohaline circulation could trigger rapid climate change

NADW is vulnerable

- If Greenland's ice melts, freshwater runoff would dilute ocean waters, making them less dense, and stopping NADW
  - Some data suggest thermohaline circulation is slowing
- Europe would rapidly cool, as shown in *The Day After Tomorrow*, a movie which exaggerated the impacts



Changing Ocean Currents



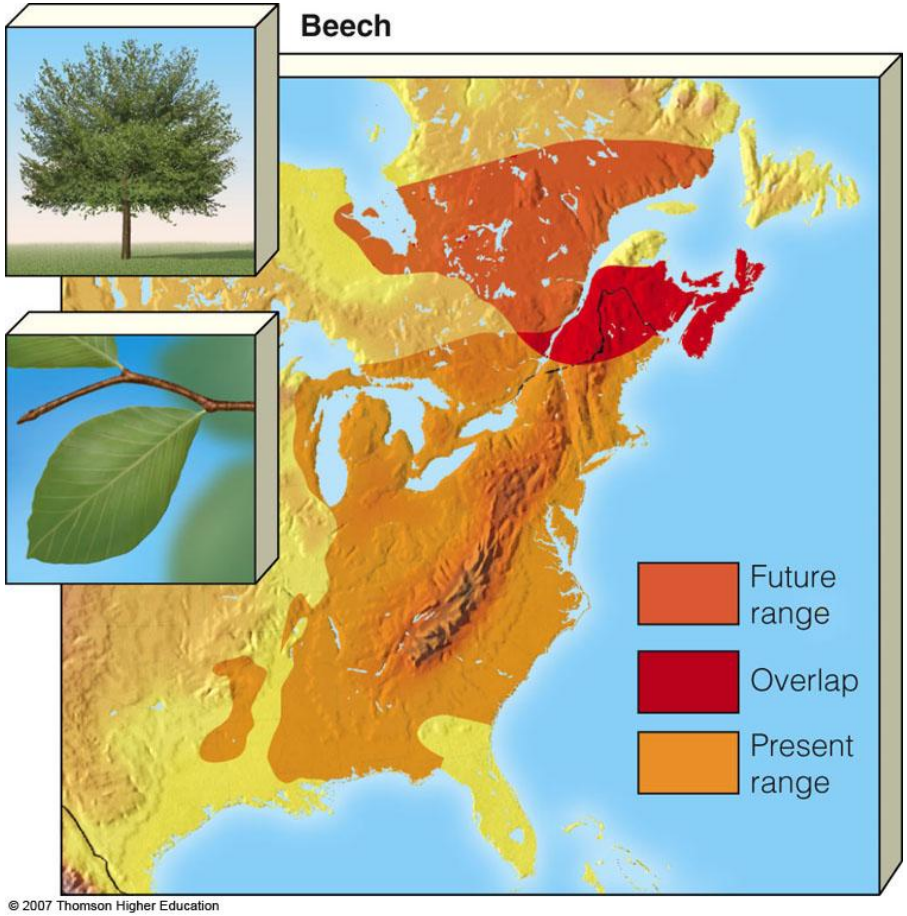
- Global warming could alter ocean currents and cause both excessive warming and severe cooling.

Figure

EFFECTS OF GLOBAL WARMING

- A warmer troposphere can decrease the ability of the ocean to remove and store CO_2 by decreasing the nutrient supply for phytoplankton and increasing the acidity of ocean water.
- Global warming will lead to prolonged heat waves and droughts in some areas and prolonged heavy rains and increased flooding in other areas.

Effects on Biodiversity: Winners and Losers



- Possible effects of global warming on the geographic range of beech trees based on ecological evidence and computer models.

Figure

Effects of global warming on Agriculture

- In a warmer world, agricultural productivity ma increase in some areas and decrease in others.
- Crop and fish production in some areas could be reduced by rising sea levels that would floo 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.

Current and future trends and impacts

Evidence that climate conditions have changed since industrialization has increased

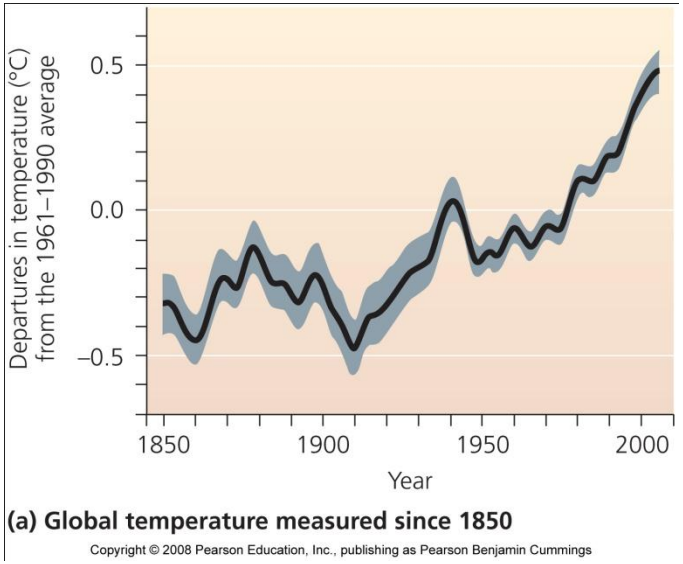
- **Intergovernmental Panel on Climate Change (IPCC)**
  - An international panel of scientists and government officials established in 1988
  - Has presented a series of reports on the synthesis of scientific information concerning climate change

The fourth assessment report

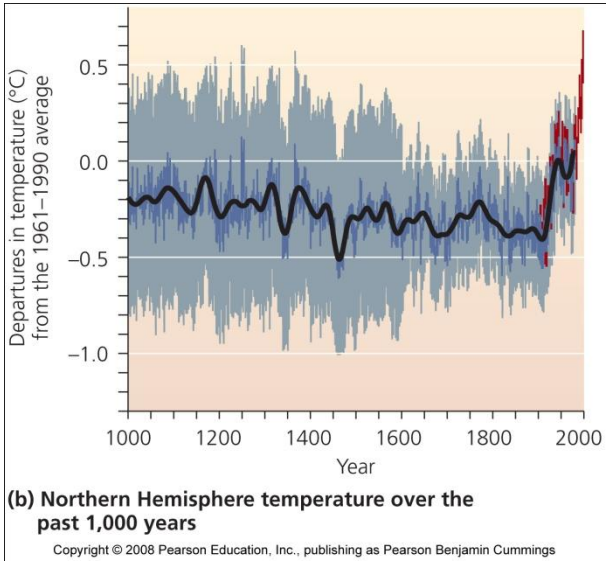
- *Fourth Assessment Report (2007)*
  - Consensus of scientific climate research from around the world
  - Summarizes thousands of studies
  - It documents observed trends in surface temperature, precipitation patterns, snow and ice cover, sea levels, storm intensity, etc.
  - Predicts future changes, addressing impacts of current and future climate change on wildlife, ecosystems, and human societies
  - Discusses possible strategies to pursue in response to climate change

Temperature increases will continue

- The IPCC report concludes that average surface temperatures on earth have been rising since 1906, with most of the increase occurring in the last few decades



(a) Global temperature measured since 1850



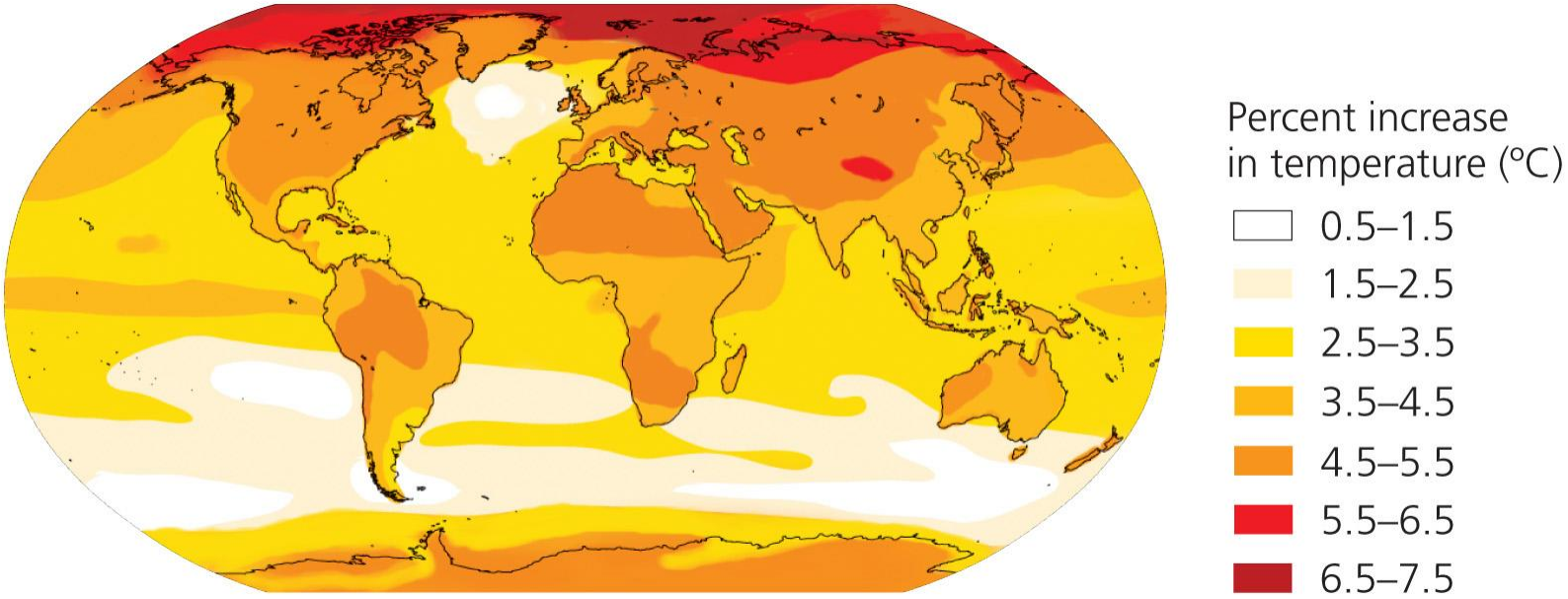
(b) Northern Hemisphere temperature over the past 1,000 years

Temperature changes are greatest in the Arctic

- Ice caps are melting
- Polar bears are starv
- Storms are increasin
- Sea ice is thinning

Temperatures will rise 0.2 degree Celsius per decade

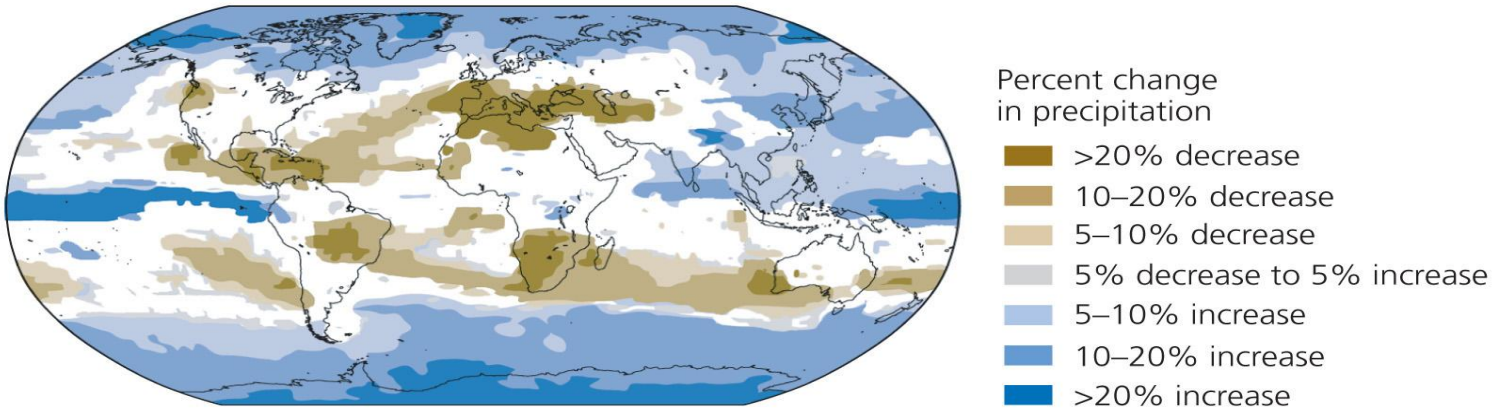
- More frequent heat waves
- Temperature change will vary by region
- Stronger storms



Changes in precipitation vary by region

- Some regions are receiving more precipitation than usual, and others are receiving less
- Droughts have become more frequent and severe
  - Harming agriculture, promoting soil erosion, reducing drinking water supplies, and encouraging forest fires
- Heavy rains have contributed to flooding
  - Killing people, destroying homes, and inflicting billions of dollars in damage

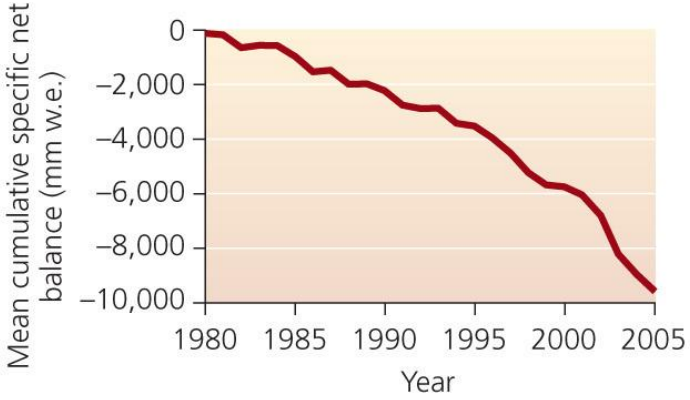
Projected changes in precipitation

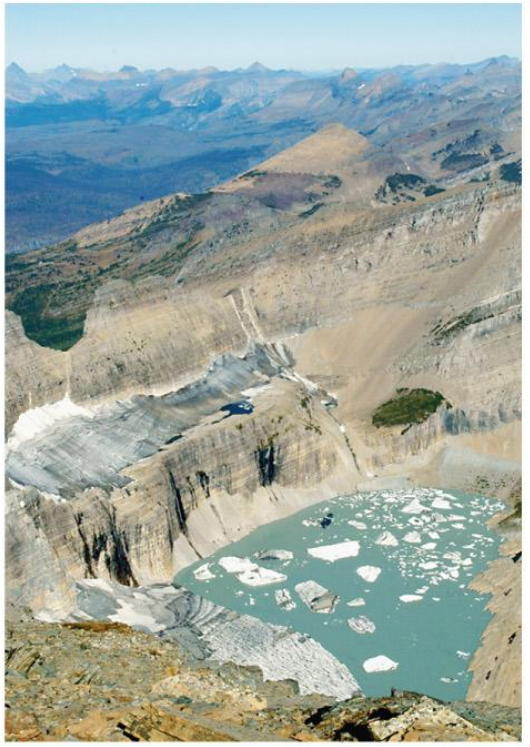


Melting snow and ice

- Mountaintop glaciers are disappearing
  - In Glacier National Park, only 27 of 150 glaciers remain
  - Risks of sudden floods as ice dams burst
  - Reducing summertime water supplies
- Melting of the Greenland ice sheet is accelerating
- As ice melts, darker, less-reflective surfaces are exposed and absorb more sunlight, causing more melting

Worldwide, glaciers are melting rapidly





(a) Grinnell Glacier in 1938

(b) Grinnell Glacier in 2005

Climate change affects organisms and ecosystems

- Organisms are adapted to their environments, so they are affected when those environments change
- Global warming modifies temperature-dependent phenomena
  - Timing of migration, breeding
- Spatial shifts in the range of organisms
  - Animals and plants will move towards the poles or upward in elevation
  - 20-30% of all species will be threatened with extinction

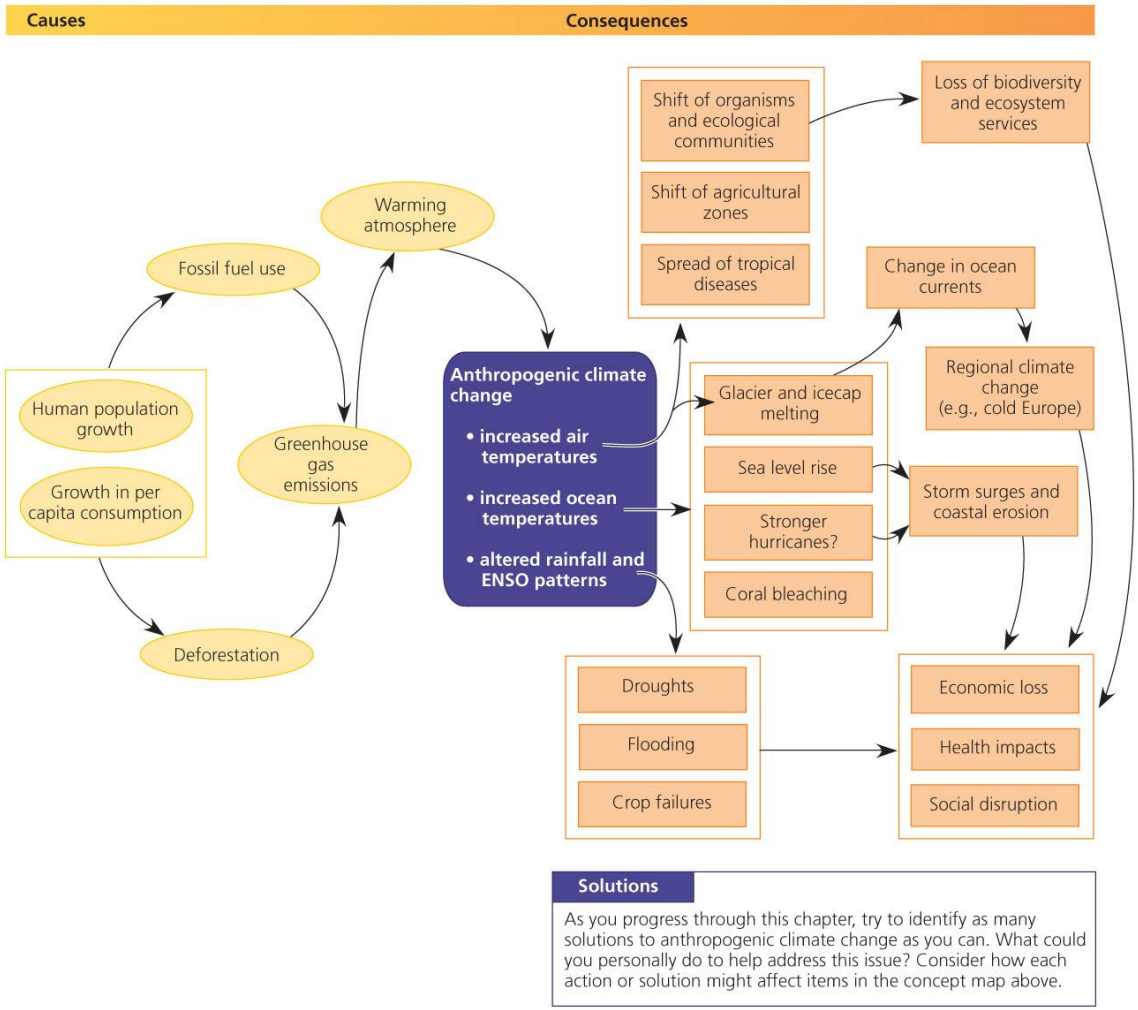
Climate change exerts societal impacts

- Human society is beginning to feel the impacts of climate change
- Agriculture: growing seasons shortened, crops more susceptible to droughts and failure; crop production will decrease, worsening hunger
- Forestry: increased insect and disease outbreaks, increased chance of forest fires (especially in rainforests)
- Health: heat waves and stress can cause death, respiratory ailments, expansion of tropical diseases, increased chance of drowning if storms become intense, hunger-related ailments

Climate change affects economics

- Costs will outweigh benefits
- Widen the gap between rich and poor
- Will cost 1-5% GDP on average globally
  - Poor nations will lose more than rich ones
  - Climate change could cost 5-20% of GDP by 2200

Causes and consequences of climate change

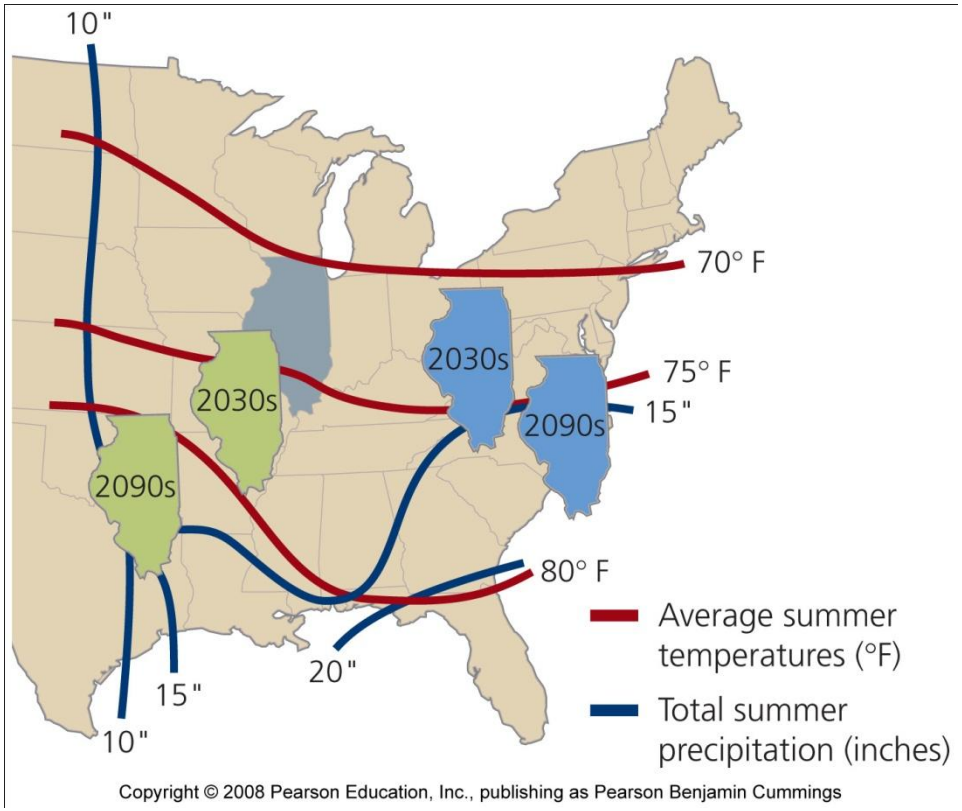


U.S. Global Change Research Program (1990)

- Predicted:
  - Temperature increases
  - Worse droughts and flooding
  - Decreased crop yields and water shortages
  - Health problems and mortality
  - Altered forest ecosystems
  - Lost coastal areas
  - Undermined Alaskan buildings and roads

Predictions from two models

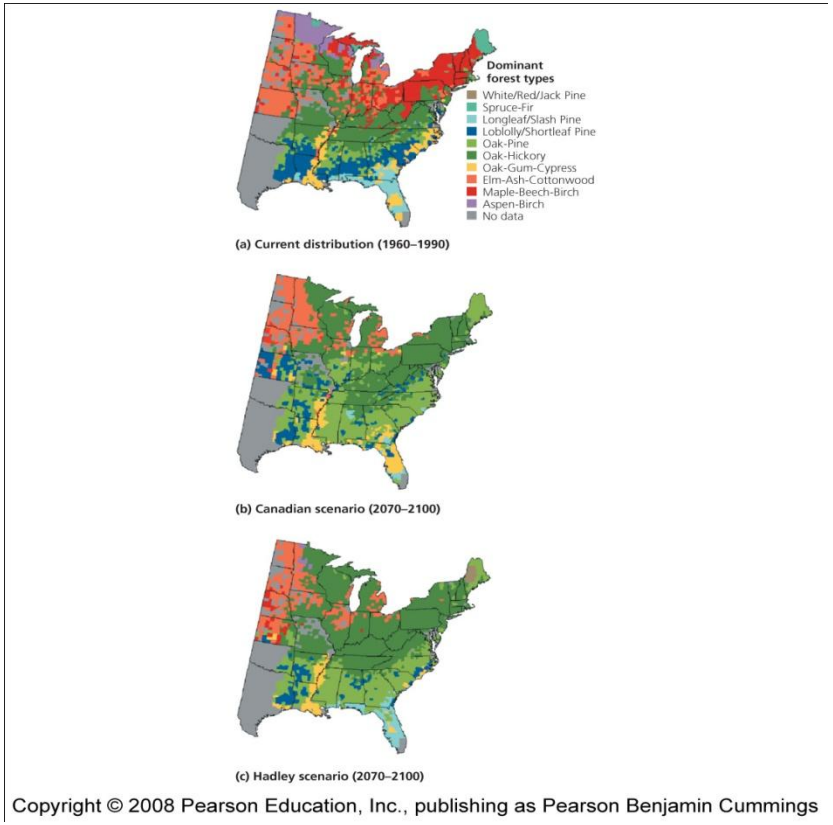
By 2030, Illinois will have a climate like Missouri's. By 2090, it will have a climate like Oklahoma's.



Green = Canadian model
Blue = Hadley model

The USGCRP was suppressed

- Once President G.W. Bush came to power
- Climate change is politically divisive:
  - It challenges entrenched and powerful interests



Are we responsible for climate change?

- The IPCC concluded that it is more than 90% likely that most global warming is due to humans
- At the “G8” summit in 2005, national academies of 11 nations issued a joint statement urging political leaders to take action
- Despite broad scientific consensus that climate change is a pressing issue, it remains mired in an outdated debate
  - Is global warming real? Are humans to blame?
- The debate was fanned by skeptics-funded industry
  - Aimed to cast doubt on the scientific consensus
  - Today, the debate is largely over

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.

The debate over climate change is over

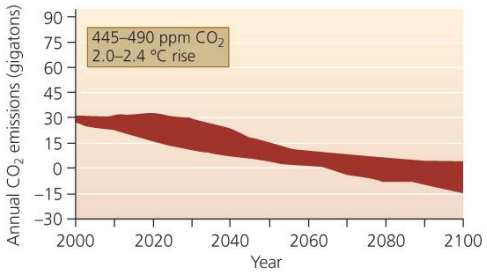
- Most Americans accept that fossil fuel consumption is changing the planet
- *An Inconvenient Truth* helped turn the tide
  - 84% of people surveyed thought that humans contribute to global warming
  - Many corporations offer support for greenhouse gas reductions

Shall we pursue mitigation or adaptation?

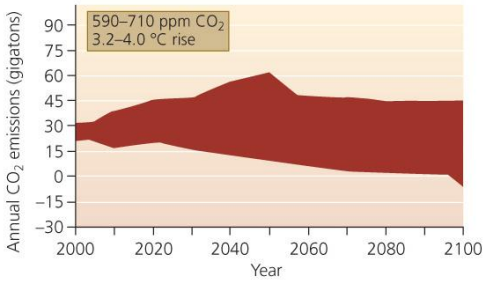
- **Mitigation** = pursue actions that reduce greenhouse gas emissions, in order to lessen severity of future climate change
  - Renewable energy sources, farm practices to protect soil integrity, preventing deforestation
- **Adaptation** = accept climate change is happening and pursue strategies to minimize its impacts on us
  - Criticized as sidestepping
- Both are necessary

We need to act fast

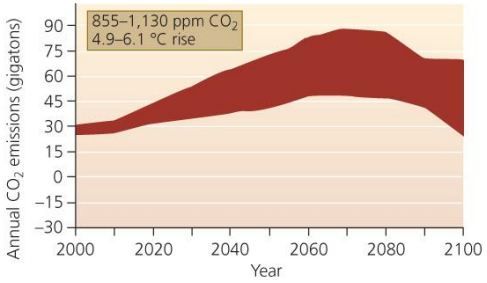
The faster we reduce our emissions, the less we will alter climate



(a) Scenario 1: Emissions peak soon



(b) Scenario 2: Emissions peak in 2020–2060



(c) Scenario 3: Emissions peak in 2060–2090

Electricity generation

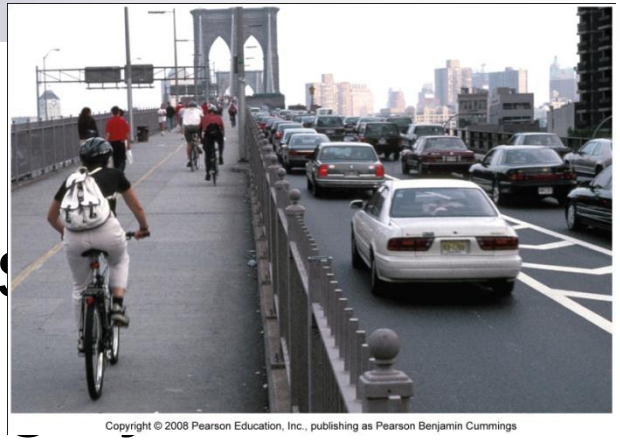
A coal-fired, electricity-generating power plant

- Largest source of U.S. CO_2 emissions
- Two ways to reduce fossil fuel use: conservation and efficiency
  - Arise from technology and individual choices
  - Replacing worn-down appliances with newer models, lifestyle choices
  - Use fewer greenhouse-gas-producing products

Sources of electricity

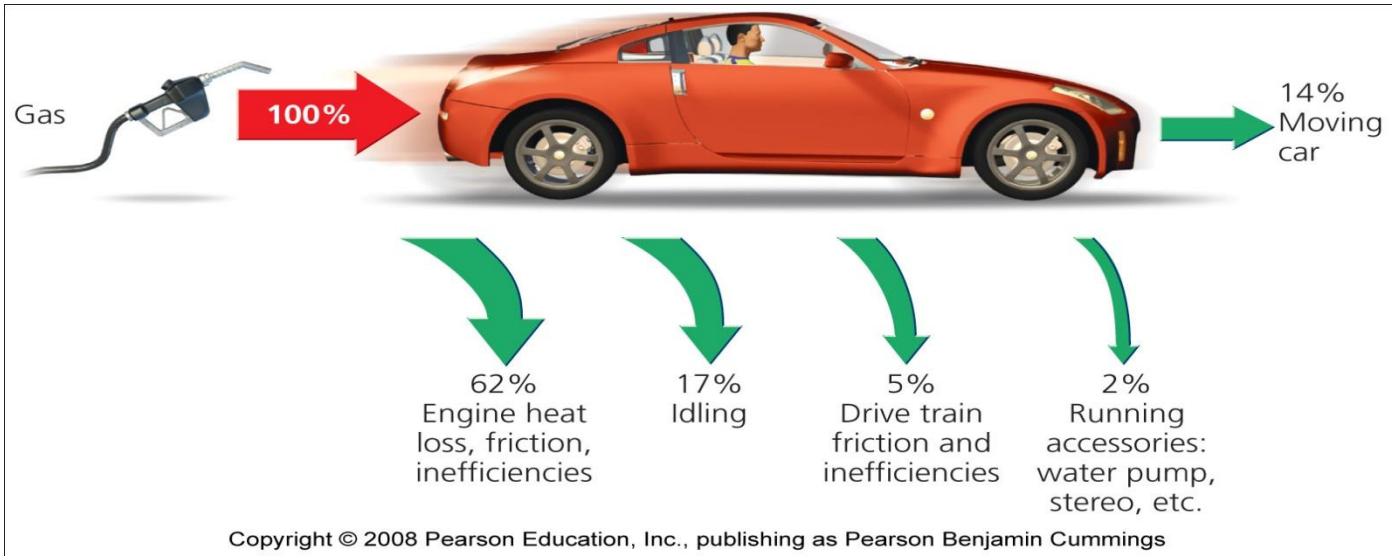
- We can change the energy we use
  - Natural gas
  - Carbon-capture = technologies or approaches that remove CO_2 from power plant emissions
  - Carbon sequestration (storage) = storing carbon somewhere (underground?) where it will not seep out
  - Use technologies and energy sources without using fossil fuels (nuclear, hydroelectric, solar power, etc.)

Transportation



- 2nd largest U.S. greenhous
- The typical automobile is hi
- Ways to help:
  - Technology: make vehicles more fuel-efficient, hybrid cars
  - Drive less and use public transportation
  - Public transportation is the most effective way to conserve energy, reduce pollution
  - Live nearer your workplace, so you can bike or walk

Conventional cars are inefficient



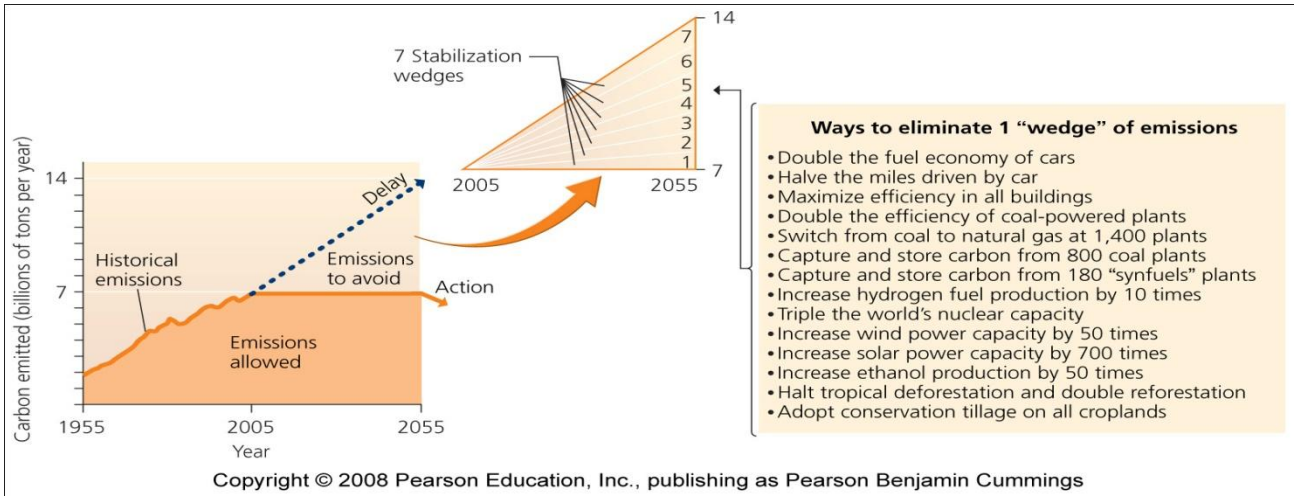
We can reduce emissions in other ways, too

- Use advances in agriculture, forestry, and waste management
  - Grow renewable biofuels
  - Rapid reforestation of deforested areas
  - Recovering methane from landfills
  - Recycling, composting, and reduction or reuse of materials

We need to follow multiple strategies

- There is no single magic bullet for mitigating climate change
- Most reductions can be achieved using current technology
- **Stabilization triangle** = a portfolio of strategies, each one feasible in itself, that could stabilize CO_2 emissions
  - Not enough, we need to reduce, not merely stabilize, emissions

Halting emissions



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.

Government mandates or market incentives?

- Governmental command-and-control policy has been vital in safeguarding environmental quality and promoting human well-being
  - However, mandates are resisted by industry
  - Market incentives can sometimes be more effective in driving change
- Policymakers, industry, commerce, and citizens are searching for ways to employ government and the market to reduce emissions in ways that are fair, economically palatable, effective, and enforceable

The Kyoto Protocol seeks to limit emissions

- The Kyoto Protocol mandates that, between 2008-2012, signatory nations must reduce emissions of six greenhouse gases to levels below those of 1990
  - This treaty took effect in 2005, after Russia became the 127th nation to ratify it
- The United States will not ratify the Kyoto Protocol because it requires industrialized nations to reduce emissions, but it does not require the same of rapidly industrializing nations such as China and India
- Businesses in industrialized nations feel they have more to lose economically from restrictions

Advancing climate change policy

- George W. Bush and Congress will not address climate change
  - State and local governments across the U.S. are responding and advancing policies to limit greenhouse emissions
  - Mayors from all 50 states signed the U.S. Mayors Climate Protection Agreement, where the mayors commit their cities to pursue policies to “meet or beat” Kyoto Protocol guidelines
- California’s legislature passed the Global Warming Solutions Act, which aims to cut the state’s greenhouse gas emissions 25% by the year 2020
- 10 northeastern states launched the Regional Greenhouse Gas Initiative (RGGI) in 2007, which set up a cap-and-trade program for carbon emissions from power plants

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 CO_2, CH_4, and N_2O 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

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.

The FCCC

- **UN Framework Convention on Climate Change (FCCC)** = outlines a plan for reducing greenhouse gas emissions to 1990 levels by the year 2000 through a voluntary, nation-by-nation approach
  - By the late 1990s, it was clear that the voluntary approach would not succeed
  - U.S. emissions increased by 17.9% from 1990 to 2006
  - Germany, with the third most technologically advanced economy in the world, reduced emissions by 17.2% between 1990 and 2004
- Developing nations created a binding international treaty that would require all signatory nations to reduce their emissions

Actions by Some Countries, States, and Businesses

- In 2005, the EU proposed a plan to reduce CO_2 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.

Market mechanisms address climate change

- Permit trading programs can harness the economic efficiency of the free market to achieve policy goals while allowing business
- The price of a permit fluctuates freely in the market, creating the same kinds of financial incentives as any other commodity that is bought and sold in our capitalist system
- The Chicago Climate Change is the world's first emissions trading program for greenhouse gas reduction
- The world's largest cap-and-trade program is the European Union Emission Trading Scheme

Carbon offsets are in vogue

- Emissions trading programs allow participants who cannot or will not reduce their emissions to use carbon offsets instead
- **Carbon offset** = a voluntary payment to another entity intended to enable that entity to reduce the greenhouse emissions that one is unable or unwilling to reduce oneself
  - Becoming popular among utilities, businesses, universities, governments, and individuals trying to achieve **carbon-neutrality**, where no net carbon is emitted
- Carbon offsets fall short
  - A lack of oversight to make sure that the offset money accomplishes what it is intended for

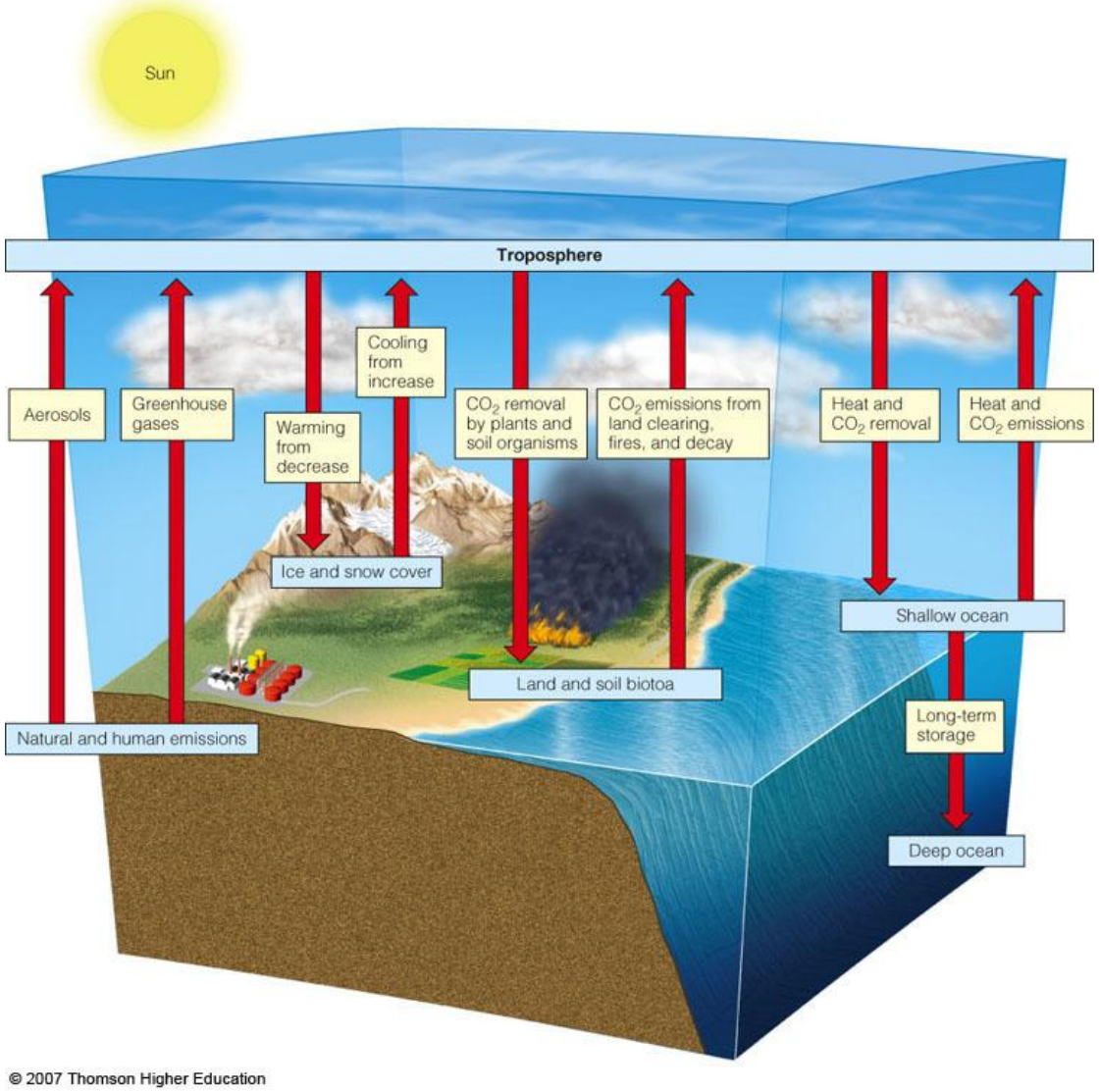
You can reduce your own footprint

- Our **carbon footprint** expresses the amount of carbon we are responsible for emitting
  - You may apply many strategies such as deciding where to live, how to get to work, and what appliances to buy to decrease your footprint
- Global climate change may be the biggest challenge facing us and our children
  - Taking immediate action is the most important thing we can do

The Scientific Consensus about Future Climate Change

- There is strong evidence that human activities will play an important role in changing the earth's climate during this century.
  - Coupled General Circulation Models (CGCMs) couple, or combine, the effects of the atmosphere and the oceans on climate.

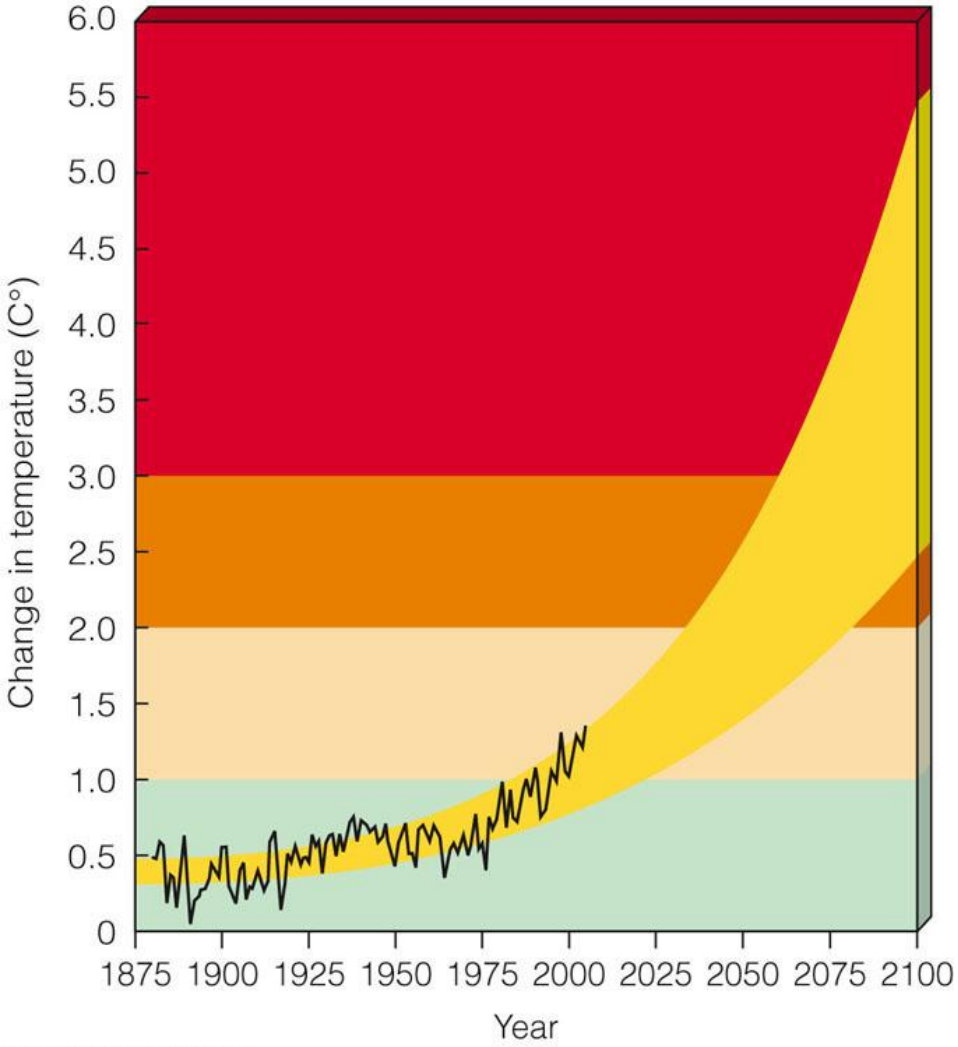
CGCM of the Earth's Climate



- Simplified model of major processes that interact to determine the average temperature and greenhouse gas content of the troposphere.

Figure

The Scientific Consensus about Future Climate Change



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

Figure

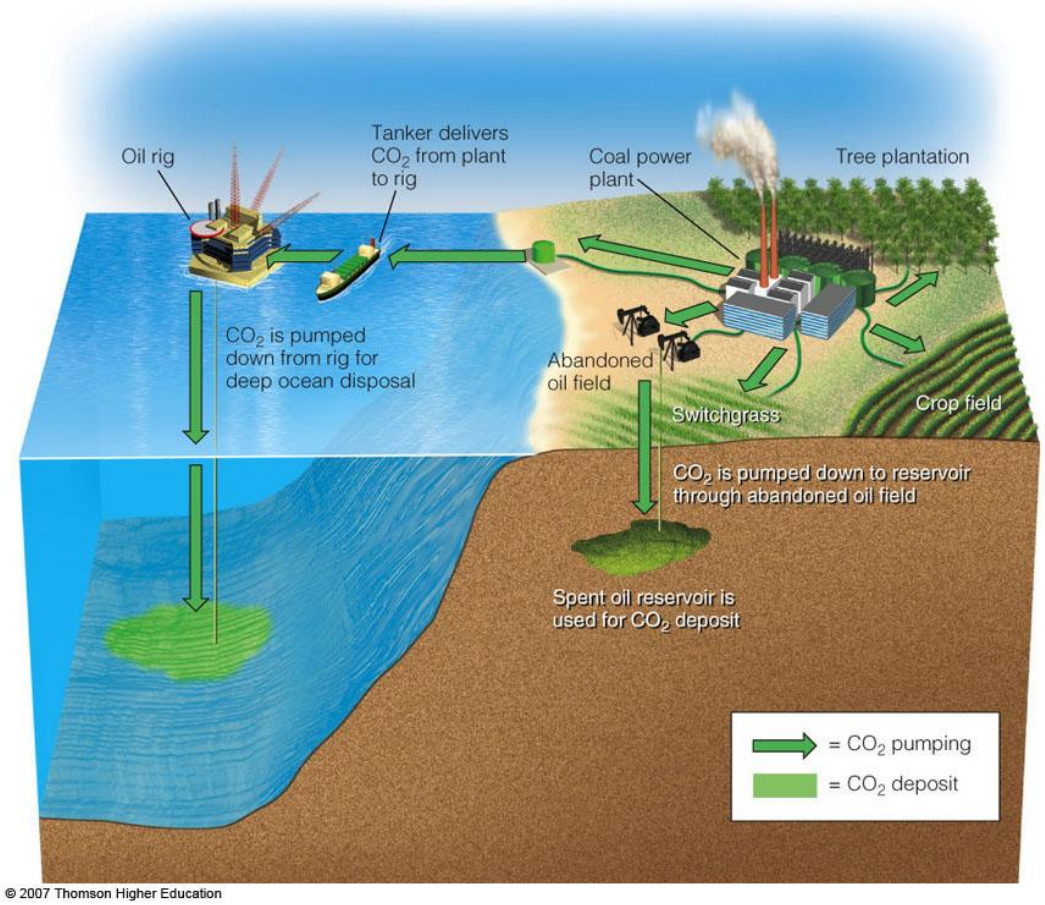
Effects of Higher CO_2 Levels on Photosynthesis

- Increased CO_2 in the troposphere can increase plant photosynthesis (PS) but:
  - The increase in PS would slow as the plants reach maturity.
  - Carbon stored by the plants would be returned to the atmosphere as CO_2 when the plants die.
  - Increased PS decreases the amount of carbon stored in the soil.
  - Tree growth may temporarily slow CO_2 emissions in the S. Hemisphere but is likely to increase CO_2 emissions in the N.

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 CO_2 we produce out of the troposphere.

Removing and Storing CO_2



- Methods for removing CO_2 from the atmosphere or from smokestacks and storing (sequestering) it.

Figure

DEALING WITH GLOBAL WARMING

- Governments can tax greenhouse gas emissions and energy use, increase subsidies and tax breaks for saving energy, and decrease subsidies and tax breaks for fossil fuels.
- A crash program to slow and adapt to global warming now is very likely to cost less than waiting and having to deal with its harmful effects later.

Shall we pursue mitigation or adaptation?

- **Mitigation** = pursue actions that reduce greenhouse gas emissions, in order to lessen severity of future climate change
  - Renewable energy sources, farm practices to protect soil integrity, preventing deforestation
- **Adaptation** = accept climate change is happening and pursue strategies to minimize its impacts on us
  - Criticized as sidestepping
- Both are necessary

Conclusion

- Many factors influence Earth's climate
  - Human activities play a major role
- Climate change is well underway
  - Further emissions will cause severe impacts
- More and more scientists are urging immediate action
  - Reducing emissions, and mitigating and adapting to a changing climate, represents the foremost challenge for our society

Why Should We Be Concerned about a Warmer Earth?

- A rapid increase in the temperature of the troposphere during this century would give us little time to deal with its harmful effects.
- As a prevention strategy scientists urge to cut global CO_2 emissions in half over the next 50 years.
  - This could prevent changes in the earth's climate system that would last for tens of thousands of years.