

18

Global Climate Change

Chapter Objectives

This chapter will help students:

Describe Earth's climate system and explain the many factors influencing global climate

Characterize human influences on the atmosphere and global climate

Summarize modern methods of climate research

Outline current and future trends and impacts of global climate change

Suggest ways we may respond to global climate change

Lecture Outline

- I. **Central Case: Rising Seas May Flood the Maldives Under**
 - A. A nation of low-lying islands, or atolls, in the Indian Ocean, the Maldives is known for its spectacular tropical setting, colorful coral reefs, and sun-drenched beaches.
 - B. Nearly 80% of the Maldives' land area of 300 km² lies less than 1 m (39 in.) above sea level, and the highest point of ground is only 2.4 m.
 - C. The world's oceans rose 10–20 cm (4–8 in.) this past century, and are expected to continue to rise as temperatures warm, causing melting ice caps to discharge water into the ocean.
 - D. The island's government has evacuated residents from several of the lowest-lying islands in recent years.
 - E. The tsunami in December of 2004 destroyed large sectors of the islands, including both homes and infrastructure such as hospitals and modes of transportation.
 - F. Other effects included soil erosion, saltwater contamination of aquifers, and other environmental damage.
 - G. The tsunami was caused by an earthquake, but the rising sea level allowed it to inflict great damage on the low-lying islands.

- H. Maldives islanders are not alone in their worries; the people of other island nations and mainland coastal areas of the world fear the future.

II. Our Changing Climate

1. Climate influences everything from daily weather, major storms, crop success, human health, ecosystem function, and even national security.
 2. The 2007 report from the Intergovernmental Panel on Climate Change shows wide scientific consensus that global climate is changing rapidly and human action is the major cause.
- A. What is climate change?
1. Climate is an area's long-term weather.
 2. Changes in the long-term pattern of atmospheric conditions worldwide, involving temperature, precipitation, and storm frequency and intensity, are **global climate change**.
 3. **Global warming** refers specifically to increasing surface temperatures of the Earth and is but one aspect of global climate change.
- B. The sun and the atmosphere keep Earth warm.
1. The sun, the atmosphere, and the oceans exert more influence on Earth's climate than all other factors combined.
- C. "Greenhouse gases" warm the lower atmosphere.
1. As Earth's surface absorbs solar radiation, its temperature increases and it emits radiation in the infrared portion of the spectrum.
 2. Some atmospheric gases absorb infrared radiation effectively and are known as **greenhouse gases**.
 3. When these gases absorb heat, they warm the atmosphere (specifically, the *troposphere*) as well as Earth's surface. This warming is known as the **greenhouse effect**.
 4. The greenhouse effect is a natural phenomenon that has been increased through human activities.
- D. Carbon dioxide is the greenhouse gas of primary concern.
1. Although carbon dioxide is not the most potent greenhouse gas on a per-molecule basis, its abundance in the atmosphere means that it contributes more to the greenhouse effect than other gases.
 2. Carbon dioxide concentrations have increased and are currently at the highest level in at least 650,000 years if not in the last 20 million years.
 3. In the last two centuries humans have been burning increasing amounts of fossil fuels in their homes, factories, and automobiles. At the same time we have cleared and burned forests, reducing the biosphere's ability to absorb carbon dioxide from the atmosphere.
- E. Other greenhouse gases add to warming.
1. Other greenhouse gases are increasing in the atmosphere.
 - a. We release methane into the atmosphere by tapping into fossil fuel deposits, raising large herds of cattle, disposing of organic matter in landfills, and growing certain types of crops, including rice.

- b. Nitrous oxide is a by-product of feedlots, chemical manufacturing plants, auto emissions, and modern agricultural practices.
 - c. Ozone concentrations in the troposphere have increased by 36% since 1750.
 - d. The contribution of halocarbon gases to global warming is lower now due to the Montreal Protocol of 1987.
 - e. Water vapor is the most abundant greenhouse gas, and its concentration increases as tropospheric temperatures rise.
- F. Aerosols may exert a cooling effect on the lower atmosphere.
- 1. Microscopic droplets and particles can have either a warming or a cooling effect. Most tropospheric aerosols, such as the sulfate aerosols produced by fossil fuel combustion, may slow global warming in the short term.
- G. Radiative forcing expresses change in energy input over time.
- H. The atmosphere is not the only factor that influences climate.
- 1. **Milankovitch cycles** are changes in Earth's rotation and orbit around the sun, and they result in slight changes in the relative amount of solar radiation reaching Earth's surface at different latitudes.
 - 2. The sun varies in the amount of radiation it emits over short and long time scales. This is referred to as **solar output**.
 - 3. Ocean absorption.
 - a. The oceans absorb carbon dioxide directly from the atmosphere through direct solubility of gas in water.
 - b. Marine phytoplankton also uptake carbon dioxide for photosynthesis.
 - 4. Oceanic circulation also shapes climate.
 - a. **El Niño** conditions occur when equatorial winds weaken and allow warm water from the western Pacific to move eastward, eventually preventing cold water from welling up in the eastern Pacific.
 - b. In **La Niña** events, cold surface waters extend far westward in the equatorial Pacific.
 - c. Many scientists today are exploring whether globally warming air and sea temperatures may be increasing the frequency and strength of El Niño events.
 - d. Ocean currents and climate also interact through the **thermohaline circulation**, a worldwide current system in which warmer, fresher water moves along the surface and colder, saltier water moves deep beneath the surface.
 - e. North Atlantic Deep Water (NADW) is part of a circulation pattern that moves warm surface water northward toward Europe where cooler water then sinks and returns in the other direction.

III. Studying Climate Change

- A. **Proxy indicators** tell us about the past.
 - 1. Ice caps and glaciers have preserved tiny bubbles of ancient atmosphere.

2. Sediment beds beneath bodies of water can be analyzed to learn about the ancient vegetation in an area and, by extension, what the climate was like at the time.
 3. These sources of indirect evidence, which substitute for direct measurements, are called proxy indicators.
 4. Other proxy indicators include coral reefs and tree rings.
- B. Direct atmospheric sampling tells us about the present.
1. Charles Keeling of the Scripps Institution of Oceanography documented trends in atmospheric carbon dioxide concentrations starting in 1958.
 2. Keeling's data show that atmospheric carbon dioxide concentrations have increased from around 315 ppm to 383 ppm since 1958.
- C. Models help us understand climate change.
1. *Coupled general circulation models (CGCMs)* are computer programs that combine what is known about weather patterns, atmospheric circulation, atmosphere–ocean interactions, and feedback mechanisms to simulate climate processes.
 2. Over a dozen research labs around the world operate CGCMs.
 3. Tests suggest that today's computerized models provide a good approximation of the relative effects of natural and anthropogenic influences on global climate.

IV. Current and Future Impacts

1. Evidence that climate conditions have changed worldwide since industrialization is now overwhelming and indisputable.
 2. Climate change has already had effects on the physical properties of the planet and if we continue to emit greenhouse gases, the effects will be more severe.
- A. The IPCC report summarizes evidence of climate change and predicts future impacts.
1. The 2007 assessment of the IPCC summarized thousands of scientific studies on climate change and documents observed trends in surface temperature, rainfall patterns, snow and ice cover, sea levels, storm intensity, and other factors.
 2. The report included a series of possible climate change scenarios and what strategies we might use to respond to these changes in climate.
- B. Temperature increases will continue.
1. The IPCC report concludes that average surface temperatures on Earth increased by an estimated 0.74 °C (1.33 °F) in the century from 1906 to 2005, with most of this increase occurring in the last few decades.
 2. Temperature increases are greatest in the arctic, causing glaciers to shrink and disappear in the arctic and in many areas around the world. Polar ice shelves are melting. This, combined with the warming temperature resulting in expansion of the water, is causing a rise in sea level.
 3. Scientists are not yet sure, but recent analyses of storm data suggest that warmer seas may not be increasing the number of

storms, but likely are increasing the power of storms, and possibly their duration.

- C. Changes in precipitation vary by region.
 - 1. Some areas will receive more rainfall and others will receive less.
 - 2. Drought and floods are possible under these new conditions.
- D. Melting ice and snow have far-reaching effects.
 - 1. As the world warms, mountaintop glaciers disappear. Since 1980, the World Glacier Monitoring Service estimates major glaciers have lost an average of 9.6 m (31.5 ft) in vertical thickness. Many glaciers on tropical mountaintops have disappeared already.
 - 2. In the Arctic, as snow and ice melt, darker less-reflective surfaces are exposed and Earth's *albedo*, or capacity to reflect light, decreases. More of the sun's rays are absorbed at the surface and the surface warms.
- E. Rising sea levels will affect hundreds of millions of people.
 - 1. As glaciers and ice sheets melt, increased runoff into the oceans causes sea levels to rise.
 - 2. Seas rose by an estimated 1.8 mm/year from 1961–2003 and 3.1 mm/year from 1993–2003.
 - 3. Vertical rise in sea level of several inches can represent many feet of horizontal incursion onto coastal lands.
 - 4. Island nations are at great risk from events called **storm surges**, caused by high tides and winds caused by storms.
 - 5. If Greenland's melting continues to accelerate, then sea levels will rise more quickly. Rising sea levels will force hundreds of millions of people to choose between moving upland or investing in costly protections against high tides and storm surges. Densely populated regions on low-lying river deltas, such as Bangladesh, will be most affected.
- F. Climate change affects organisms and ecosystems.
 - 1. Organisms are adapted to their environment and are affected when the environment is altered.
 - 2. Changes in timing of seasonal events such as temperature-dependent biological phenomena and the onset of spring are creating complex effects in ecosystems worldwide.
 - 3. There are spatial shifts in the ranges of organisms as many plants and animals shift north to avoid hotter and drier conditions.
 - 4. Species interactions will be affected.
- G. Climate change exerts societal impacts.
 - 1. Agriculture—cuts in agricultural productivity are possible as droughts and floods increase. There could be a slight increase in productivity as plants respond to higher carbon dioxide levels.
 - 2. Forestry—insects, disease outbreaks, invasive species, and catastrophic fires could all become more common.
 - 3. Health—humans will experience more heat stress, tropical diseases, respiratory ailments, hunger when droughts occur, and compromised sanitation during flood events.
 - 4. Economics—IPCC data suggest that global climate change will cost nations between 1 to 5% of GDP.

- H. Impacts will vary regionally.
- I. Are we responsible for climate change?
 1. The IPCC reports that it is greater than 90% that the current global climate change is caused by humans.
 2. The scientific understanding of climate change is clear enough to justify nations taking immediate action.
 3. In the United States, a small group of “greenhouse skeptics” drove the debate and prevented the nation from taking swift action. These “skeptics” derived significant funding from corporate entities in the oil, coal, and other extractive industries.
 4. Recently, there has been a change in public polling data and public perception such that even corporations are taking steps to address climate change issues by asking governments to enact legislation that would put caps on greenhouse gas emissions.

V. Responding to Climate Change

1. Today, there is a new broad consensus that climate change presents great challenges to our society.
- A. Shall we pursue mitigation or adaptation?
 1. Mitigation would involve actions that would reduce emissions of greenhouse gases.
 2. Adaptation would involve acknowledging that climate change is happening and that we must search for ways that will modify and soften the blows. Adaptations can include building sea walls and restricting coastal development.
 3. Mitigation and adaptation are not mutually exclusive although environmentalists charge that the adaptation approach is sometimes “escapist.”
- B. Electricity generation is the largest source of U.S. greenhouse gases.
- C. Conservation and efficiency.
 1. Conservation and efficiency can arise from new technologies, or from individual ethical lifestyle choices.
 2. Renewable sources of electricity can also reduce fossil fuel use.
- D. Sources of electricity.
 1. Natural gas has less impact on global warming than oil or coal.
 2. Carbon sequestration or storage would allow current practices to continue, provided carbon emissions are captured and stored.
- E. Transportation is the second largest source of U.S. greenhouse gases.
 1. One-third of the average American city is devoted to use by cars—including roads, parking, garages, and gas stations.
 2. The typical automobile is highly inefficient. Close to 85% of the fuel you use does something other than move your car down the road.
 3. Automotive technology is making possible alternatives such as electric vehicles, alternative fuels, hybrid vehicles, and hydrogen fuel cells.
 4. Driving less and using public transportation are lifestyle choices that reduce reliance on cars.
- F. Automotive technology.
 1. Government mandates, consumer demand, and higher fuel prices will stimulate technology that will create fuel efficiency.

- G. Driving less and public transportation.
 - 1. Choosing where to live to reduce travel distance to work and school will save energy.
 - 2. Increasing public transportation options is the single most effective strategy for conserving energy and reducing pollution.
- H. We can reduce emissions in other ways.
 - 1. Sustainable agriculture and land management that protects the integrity of soil on cropland and rangeland enables soil to store more carbon.
 - 2. Reducing methane emissions from rice fields and cattle, and reducing certain fertilizers are important techniques.
 - 3. Preserving existing forests and increasing the rate of reforestation will pull more carbon from the atmosphere.
 - 4. Recovering methane from landfills and treating wastewater and generating energy from solid waste incineration also reduce emissions of global warming gases.
- I. We will need to follow multiple strategies to reduce emissions.
- J. Shall we use government mandates or market incentives?
 - 1. At all levels, policymakers, industry, commerce, and citizens are searching for ways to employ government AND markets to reduce emissions in ways that are fair, economically palatable, effective, and enforceable.
- K. We began tackling climate change by international treaty.
 - 1. In 1992, the United Nations convened the United Nations Conference on Environment and Development Earth Summit in Rio de Janeiro. Five documents were signed, including the **U.N. Framework Convention on Climate Change (FCCC)**, which outlined a plan for reducing greenhouse gas emissions through a voluntary, nation-by-nation approach.
 - a. In the U.S., greenhouse emissions increased by over 13% in the 10 years following the Rio conference.
 - b. Germany and the United Kingdom both cut their greenhouse gas emissions by 13% to 18% during the same period.
 - c. The decision was made to create a binding international treaty that would require all signatory nations to reduce greenhouse gas emissions. This is the **Kyoto Protocol**.
- L. The Kyoto Protocol seeks to limit emissions.
 - 1. The Kyoto Protocol was to take effect when nations responsible for 55% of global greenhouse emissions ratified it. That occurred in 2005 when Russia became the 127th nation to sign.
 - 2. The United States, the world's largest emitter of greenhouse gases, refuses to ratify the protocol, claiming it is unfair to industrialized nations.
 - 3. Proponents of the Kyoto Protocol point out that the even with compliance to the Kyoto Protocol, emissions would continue to increase, but will not increase as quickly. All signatory nations are looking beyond Kyoto to the next negotiation that will supercede Kyoto.
- M. States are advancing climate change policy.
- N. Market mechanics are being used to address climate change.
 - 1. Programs such as cap and trade.

- O. Carbon offsets are in vogue.
 - 1. A **carbon offset** is 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.
 - 2. In theory, carbon offsets are a good idea but they also fall short of the goal in practice since there are not rigorous inspection and enforcement actions.
- P. You can reduce your own carbon footprint.
 - 1. Collective action by global citizens is necessary to change future outcomes of reducing our carbon footprint on the planet.

VI. Conclusion

- A. Many factors, including human activities, can shape atmospheric composition and global climate.
- B. Scientists and policymakers are beginning to understand anthropogenic climate change and its environmental impacts more fully.
- C. Reducing greenhouse gas emissions and taking other actions to mitigate and adapt to climate change represents the foremost challenge for our society in the coming years.