

# 14

## Global Climate Change

### Chapter Objectives

**This chapter will help students:**

- Describe Earth's climate system and explain the variety of 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 climate change

### Lecture Outline

**I. Central Case: Rising Seas May Take 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 km<sup>2</sup> lies less than 1 m above sea level, and the highest point of ground is only 2.4 m.
- C. The world's oceans rose 10–20 cm this past century, and are expected to continue to rise as warming temperatures and melting ice caps discharge water into the ocean.
- D. The island's government has already 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 transportation.
- F. The damage continues with 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; other island nations and mainland coastal areas of the world fear the future.

## II. Our Dynamic Climate

1. Climate change is the fastest-moving area of environmental science.
2. Climate describes an area's long-term atmospheric conditions including: temperature, moisture content, wind, precipitation, barometric pressure, and solar radiation.
3. Global climate change describes trends and variations in Earth's climate involving aspects of temperature, precipitation, storm frequency, and intensity.
4. While the Earth's climate does change over time naturally, climatic changes taking place today are rapid. Most scientists agree that human activities, mainly fossil fuel combustion and deforestation, are largely responsible for this rapid change in climate.

A. The sun and atmosphere keep the Earth warm.

B. "Greenhouse gases" warm the lower atmosphere.

1. As Earth's surface absorbs solar radiation, its temperature increases and it emits infrared radiation.
2. Some atmospheric gases absorb infrared radiation effectively and are known as **greenhouse gases**.
3. Greenhouse gases further warm the troposphere and the Earth's surface by re-emitting absorbed infrared energy. This is known as the **greenhouse effect**.
4. This natural effect has been enhanced by human activities that have increased greenhouse gas concentrations.

C. Greenhouse gas concentrations are rising fast.

1. The greenhouse effect is a natural phenomena and most greenhouse gases have been present in our atmosphere for billions of years.
2. Carbon dioxide concentrations have increased from 280 ppm to 385 ppm since the late 1700s.
3. Most carbon is stored for long periods in the upper layers of the

lithosphere. Since the industrial revolution, humans have been burning increasing amounts of fossil fuels, transferring carbon from one reservoir (underground deposits that stored carbon for millions of years) to another (the atmosphere).

4. This flux of carbon is the main reason atmospheric carbon concentrations have increased so dramatically.

D. Other factors may warm or cool the surface.

1. Aerosols and other elements may exert either a warming or a cooling effect on the lower atmosphere. Soot, or black carbon aerosols, can cause warming by absorbing solar energy, but most tropospheric aerosols cool the atmosphere by reflecting the sun's rays.
2. Scientists made quantitative estimates of the degree of influence that aerosols, greenhouse gases, and other factors exert over Earth's energy balance.
  - a. The amount of change in energy that a given factor causes is called its radiative forcing.
  - b. Positive forcing warms the surface whereas negative forcing cools it.

E. 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 change the relative amount of solar radiation reaching Earth's surface at different latitudes.
2. **Solar output** is a measure of the amount of radiation emitted by the sun.
3. Ocean absorption
4. Ocean circulation
  - a. Thermohaline circulation is a worldwide current system in which warmer, fresher water moves along the surface in some areas while colder, saltier water moves deep beneath the surface. Scientists are concerned about disruption of an oceanic circulation pattern that moves warm surface water northward from the equator toward Europe, which keeps the region warmer than it would be otherwise be.
  - b. **El Niño-Southern Oscillation (ENSO)**, a systematic shift in atmospheric pressure, sea surface temperature, and ocean circulation in the tropical Pacific Ocean. In normal conditions, prevailing winds blow east to west along the equator, causing

water to “pile up” in the western Pacific, and the warm water from the western Pacific flows eastward toward South America, eventually suppressing upwelling along the coast of Peru.

- c. In **La Niña** events, cold surface waters extend far westward in the Pacific.
  - d. Many scientists today are exploring whether globally warming air and sea temperatures may be increasing the frequency and strength of these events.
  - e. Scientists use several approaches to infer and measure climate change.
5. **Direct sampling** of atmospheric conditions tells us about the present.
- a. One example is carbon dioxide measurements, originally collected by Charles Keeling of the Scripps Institution of Oceanography (starting in 1958), and continued to the present day.
6. **Proxy indicators** tell us about the past.
- a. Ice caps and glaciers have preserved tiny bubbles of ancient atmosphere.
  - b. 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.
  - c. These sources of indirect evidence, which substitute for direct measurements, are called **proxy indicators** and indicate the nature of past climate.
  - d. Other proxy indicators include data from coral reefs and tree rings.
7. Modeling uses sophisticated computer programs to simulate climate processes in order to understand how climate works and to predict future climate change.
- a. *Coupled general circulation models* are computer programs that combine what is known about weather patterns, atmospheric circulation, atmosphere–ocean interactions, and feedback mechanisms to simulate climate processes.

b. As computing power increases and our ability to glean data from proxy indicators of past climates improves, these models are becoming more reliable and informative.

### III. Current and Future Trends and Impacts

1. Scientific evidence that climate conditions have changed worldwide since industrialization is now overwhelming and indisputable.

A. The IPCC summarizes evidence and predicts future impacts.

1. The most thoroughly reviewed and widely accepted collection of scientific information concerning global climate change is a series of reports issued by the **Intergovernmental Panel on Climate Change (IPCC)**.

2. In 2007, the IPCC released its Fourth Assessment Report, which represents the consensus of scientific climate research from around the world.

B. Temperature increases will continue.

C. Precipitation is changing too.

1. A warmer atmosphere holds more water vapor, but changes in precipitation patterns have been complex, with some regions receiving more precipitation than usual and others receiving less.

D. Melting ice and snow have far-reaching effects.

1. Mountains accumulate snow in the winter and release meltwater gradually during the summer. Warming temperatures will reduce glaciers and summertime water supplies to millions.

2. Immense ice sheets of the Arctic, Greenland, and the Antarctic are melting faster and faster.

3. Near the poles, snow cover, permafrost, and ice sheets are projected to decrease, and sea ice will shrink in both the Arctic and Antarctic.

E. Rising sea levels will affect hundreds of millions of people.

F. Climate change affects organisms and ecosystems.

1. Organisms are adapted to their environments. Biological phenomena regulated by temperature including spring plants leafing earlier, insects hatching earlier, birds migrating earlier, and animals breeding earlier could all be impacted.

2. Biologists have recorded spatial shifts as organisms move towards the poles or upward in elevation.

G. Climate change affects people.

1. Agriculture

- a. Drought and temperature extremes will likely threaten farms and natural systems worldwide.
- b. Some croplands could lose their ability to produce food, while other areas might have increased agricultural productivity.

2. Forests will experience increased frequency and intensity of forest fires which could increase in insect pests.

3. Human health

- a. We will face more heat waves—and heat stress can cause death.
- b. Alternatively, there may be fewer diseases and injuries from cold weather.

4. Economics

- a. There will be economic costs and benefits to climate from the impact of climate change, Researchers predict costs will outweigh benefits.

H. Impacts will vary regionally.

I. Are we responsible for climate change?

1. Virtually all environmental scientists agree that the Earth's climate and atmosphere are changing and that human activity, specifically greenhouse gas emissions, is the primary reason for this change.
2. Despite agreement among scientists and national governments that climate change is a pressing issue, public discussion of climate change in the United States remains mired in an outdated debate over whether the phenomenon is real and whether humans are to blame

#### **IV. Responding to Climate Change**

A. Shall we pursue mitigation or adaptation?

1. **Mitigation** is a strategy to pursue actions that reduce greenhouse gas emissions so we lessen the severity of future climate change.
  2. Adaptation involves accepting that climate change is happening and pursuing strategies to minimize its impacts.
- B. Electricity generation and transportation are the largest sources of greenhouse emissions.
1. Reducing the volume of fossil fuels used to generate electricity and decreasing electricity consumption would reduce greenhouse gas emissions.
    - a. Encourage conservation and efficiency.
    - b. Switch to renewable energy sources.
  2. Reducing the amount of fossil fuels burned in vehicles would reduce greenhouse emissions in the transportation sector.
    - a. Increase consumer demand for better fuel efficiency.
    - b. Increase availability of alternatives to the traditional automobile such as hybrid vehicles, electric vehicles, alternative fuel vehicles, or hydrogen fuel cell vehicles.
    - c. Make lifestyle changes that decrease vehicle use, such as living near place of employment, biking, walking, or using public transportation.
- C. We need to follow multiple strategies to reduce emissions. Some international treaties address climate change.
- D. We began tackling climate change by international treaty.
1. The *U.N. Framework Convention on Climate Change* outlined a plan for reducing greenhouse gas emissions through a voluntary, nation-by-nation approach.
  2. The **Kyoto Protocol** was drafted in 1997 and would require all signatory nations to reduce greenhouse gas emissions.
    - a. The Kyoto Protocol came into effect in 2005, but critics and supporters alike agree that if every nation complied with the treaty, greenhouse gas emission would continue to increase.
    - b. Following approval of the road map at Bali, the world's nations

are looking ahead to what will come next to supersede Kyoto with a new treaty set to take place in Copenhagen, Denmark, in December 2009.

E. States and cities are advancing climate change policy.

1. In the absence of action by the George W. Bush administration and the U.S. Congress, state and local governments are responding to popular sentiment and advancing policies to limit greenhouse emissions.
2. By late 2007, mayors from over 720 cities signed on to the U.S. Mayors Climate Protection Agreement.
3. The boldest action so far comes from California, where in 2006 the legislature passed the Global Warming Solutions Act. The aim is to cut state greenhouse gas emissions by 25% by 2010.

F. Market mechanisms are being used to address climate change.

1. Permit trading programs harness the economic efficiency of the free market to achieve policy goals while allowing business, industry, or utilities flexibility in how they meet those goals.

G. Carbon offsets are in vogue.

1. *Carbon-neutrality*, a condition in which no net carbon is emitted, is a great idea, but needs a transparent and enforceable offset infrastructure.

H. You can reduce your own carbon footprint.

1. The most influential factor in combating climate change may be the collective decisions of millions of regular people.
2. In our everyday lives, we can each take steps to approach a carbon-neutral lifestyle by reducing greenhouse emissions that result from our decisions and activities.

**V. Conclusion**

1. Many factors, including human activities, can shape atmospheric composition and global climate.
2. Scientists and policymakers are beginning to understand anthropogenic climate change and its environmental impacts more fully.