

- 1  **Introduction to Environmental Geology, 5e**
Chapter 18
Global Climate Change
- 2  **Climate Change: summary in haiku form**
Veep Al Gore was right:
the truth is inconvenient,
but do something now.
- 3  **Case History: Potential Consequences of Global Warming**
 - Approximate 300 year period (1000 to 1300), Earth was considerably warmer than normal, known as the Medieval Warming Period (MWP)
 - Followed by the Little Ice Age (LIA): Mid 1400 to 1700, difficult for people in Southeast Asia and Western Europe
 - The collapse of the Ankorian civilization part due to the onset of the LIA
 - Crop failures in Western Europe during the LIA, the population devastated by the Black Plague about 1400
- 4  **Case History: Potential Consequences of Global Warming**
 - Famous Viking explorer Eric the Red's voyage near the end of tenth century, a period of warm climate (Medieval Warming period)
 - The Vikings colonized Iceland, Greenland, and northern North America
 - Sea temperature probably 4°C (7°F) warmer than now
 - Little Ice Age started early fourteenth century, creating treacherous sea conditions, famine, spread of the Black Plague
 - Climate changes believed to cause the abandonment of Viking settlements in North America and Greenland
- 5  **Global Change: An Overview**
 - Climate changes: Contributing to the complex evolutionary history of the Earth system
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 - Earth system: Interactions between the atmosphere, the oceans, solid Earth, and the biosphere
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 - The effects of human activities: Extensive on a global scale
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 - Apply the better understanding to better manage the environment
- 6  **Tools for Studying Global Change**
 - Geologic Records:
 - Sediments deposited on floodplains or in lakes, bogs, glaciers, or the ocean
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 - Carbon dioxide concentration in glacial ice, as old as 800,000 years
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 - Real-time monitoring: Good for testing models and predictions from prehistoric record
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 - Mathematical models: Global circulation models (GCMs)
- 7  **Geologic Record**
Figure 18.2
- 8  **EARTH'S Climate & Atmosphere**
 - Climatic Zones: Controlled by global circulation and movement of air masses
- 9  **Atmosphere and Climate Change**

- Atmosphere as a complex chemical factory: with many little-understood chemical reactions
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 - Many of the reactions strongly influenced by both sunlight and the compounds produced by life
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 - Climate change: Change of atmosphere conditions and its relationships with lithosphere, hydrosphere, and biosphere
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 - Changes in greenhouse gases, variable temperature, and water vapor
- 10  **The Greenhouse Effect (1)**
- Temperature of Earth: Determined by three factors
 - The amount of sunlight received
 - The amount of solar energy reflected and absorbed
 - The amount of heat retention by atmosphere
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 - Earth: Absorbing the short wavelength solar energy, then radiating longer wavelength IR radiation
- 11  **The Greenhouse Effect (2)**
- Several atmospheric gases: Water vapor and several other atmospheric gases, including CO₂, CH₄, NO_x, CFCs, trapping more heat and warming up the lower atmosphere, similar to the effect of a greenhouse
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 - The concentration of greenhouse gases increased recently due to human activities, anthropogenic gases
- 12  **Study Past Climate Change**
- The Instrumental Record: Started in 1860s, today temperature measured at about 7,000 stations around the world
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 - The Historical Record: Books, newspapers, journal articles, personal journals
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 - The Paleo-Proxy Record: Proxy data refers to data that is not strictly climatic but that can be correlated with climate, such as temperature of the land or sea: ice core, tree rings, pollen, corals, carbon-14, carbon dioxide, and methane data
- 13  **Carbon Dioxide in the Atmosphere**
Figure 18.14
- 14  **Global Warming**
- Global warming: The observed increase in the average temperature of the near-surface land and ocean environments of Earth
 - Human processes (in the past 100 years), as well as natural ones (over geologic time) contributed significantly to global warming
 - Recent global warming is believed to be due in a large part to human emissions of greenhouse gases
 - Based on equivalent amount of the global warming potential (GWP), carbon dioxide accounted for
 - 85.1 percent, methane 8.2 percent, nitrous oxide
 - 4.6 percent, and chlorofluorocarbons 2.2 percent
- 15  **Increase in Greenhouse Gasses**
Figure 18.16
- 16  **Global Temperature Change**
- The Pleistocene Ice Age: ~ 2 mya, peaked at 18,000 years ago
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 - Numerous changes in Earth's mean annual temperature since then

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- Warming trend over the last 140 years, first 8 years of the twenty-first century had the warmest temperatures
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- Mean temp increased about 0.8°C (1.36°F) in the past 100 years
- 17  **Global Temperature Data from the U.S. (NOAA) and Europe (WMO)**
Table 18.1
- 18  **Why Climate Change?**
 - Changes in long cycles (100,000 years) separated by short cycles (20,000 to 40,000 years)
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 - First identified in 1920s, Milankovitch hypothesis
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 - Long cycle: The variability in Earth's orbit around the Sun
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 - Short cycle: The wobble effect of Earth's axis
- 19  **Why Climate Change?**
 - Climate system even unstable in shorter cycles, in a few decades
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 - The ocean conveyor belt, global circulation of ocean water, contribute to the change
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 - Discernable human influence, mean temperature likely 1.5° to 4.5°C (2.6° to 7.8°F) warmer in twenty-first century
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 - Global warming: Need to consider major forcing variables—solar, volcanic, and anthropogenic gases
- 20  **Solar Forcing**
 - Historic record of the past 1000 years showing the variability of solar energy
 -
 - Medieval Warm Period (A.D. 1000 to 1300) corresponding to a time increased solar radiation
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 - The Little Ice Age (fourteenth century) corresponding to the minimum solar activity
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 - The effect relatively small, 0.25 percent
- 21  **Volcanic Forcing**
 - Volcanic eruption: Vast amount of aerosol particles into the air
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 - Aerosols: Reducing solar radiation to Earth surface
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 - Episodes of volcanic eruptions having a significant contribution to the cooling of the Little Ice Age
- 22  **Anthropogenic Forcing**
 - Natural variability failing to explain the warming at end of the twentieth century
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 - Mathematical modeling on the anthropogenic forcing: increase of temperature 2°C due to the doubling of CO₂
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 - Significant global warming as a result of human activities, air pollution reduced incoming solar energy by 10 percent which offsetting up to 50 percent of the expected warming
- 23  **Negative Forcing from Aerosols**
Figure 18.20
- 24  **Potential Effects of Global Climate**

- Doubling the greenhouse gases, then 1.5° to 4.5°C (2.6° to 7.8°F) increase in average global temperature
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 - Significant rise of sea level and melting of glacier ice due to the increase in temp
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 - The number of retreating glaciers accelerating in many areas of the world
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 - Significant effects on global climate patterns
- 25  **Glaciers and Global Warming**
- Loose snow has about 90 percent air compared to firm, with about 25 percent air to glacial ice with less than 20 percent air as bubbles
 - Transformation from snow to glacial ice: 10s to 1000s of years
 - Global warming: Accelerated melting of glacial ice
 - Exposed bare ground after glacial ice melts produces a positive feedback cycle: The more ice that melts, the faster the warming and increased melting
 - The lowest extent of sea ice in the Atlantic Ocean in 2007
 - The Antarctic Peninsula: One of the most rapidly warming regions on Earth
- 26  **Extent of Sea Ice**
Figure 18.31
- 27  **Change in Climate Patterns**
- Global warming leads to significant changes of rainfall and soil moisture (draught and flood)
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 - Agricultural activities (crop growth cycle) and world food supplies affected greatly by climatic factors (desertification)
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 - Global warming affects the frequency, intensity, and distribution of natural hazards, such as hurricane and other storms
- 28  **Sea Level Rise and Global Warming**
- An estimated 40 to 200 cm (16 to 80 in.), wide range of rise in sea level for the next century
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 - Increases in coastal erosion: Up to 260 ft on open beaches by stronger wave actions
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 - Landward shift of existing estuaries
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 - Disastrous impact on the existing developments along coastal zones
- 29  **Biosphere and Global Warming**
- Causing a number of changes in biosphere, both people and overall ecosystem
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 - Risk of extinction due to land-use change and habitat shift
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 - Spread of infectious and other diseases due to migration of organisms
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 - Both land and oceanic components affected: from plants, to polar bears, to the bleaching of coral reef
- 30  **Adaptation of Species to Global Warming**
- During the past 25 years or so, plants and animals shifted their ranges by about 6 kilometers per decade toward the polar areas
 - Spring arriving earlier, migrating birds arriving earlier, about 2.3 days per decade
 - In Costa Rica, over 60 species of frogs may have gone extinct

- Assist migration of some species, unable to migrate with climate change, creating an invasive species, problematic

31  **Strategies for Reducing the Impact of Global Warming (1)**

- Identify the historic changes that have occurred
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- Predict the potential changes in the future: through modeling and simulation
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- Reduce greenhouse gases
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- Political commitment: Reconciling the conflicts between the environmental need for reduction of greenhouse gases and the economic demands for more fossil fuel

32  **Strategies for Reducing the Impact of Global Warming (2)**

- The Kyoto Protocol, international agreement to reduce emissions of greenhouse gases, signed by 166 nations and became a formal international treaty in February 2005
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- Scientific evidence suggests that burning fossil fuels is contributing significantly to global warming
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- Even if carbon emissions were reduced to zero, warming will continue this century. There is 0.5° to 1.0°C warming in the system

33  **Strategies for Reducing Global Warming (3)**

Table 18.2

34  **Reducing the Impact of Global Warming (4)**

Reduce the emission of CO₂

- Improved engineering technologies of the fuel-burning power plants
- Use fossil fuels releasing less CO₂
- Conservation of energy
- Store CO₂ in forests, soils and rocks, depleted oil and gas fields, saltwater aquifers (sequestration of CO₂)
- Use alternative energy

35  **Coupling of Global Change Processes**

- The coupling of the greenhouse and ozone depletion problems from CFCs
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- Burning of fossil fuels and acid rain problems
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- Use of fossil fuels and volcanic eruptions problems and atmospheric cooling
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- Emphasis on the principle of global environmental unity in action

36  **Critical Thinking Topics**

- Have a discussion with your parents or grandparents and write down the major changes that have occurred in their lifetime as well as yours
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- Rapid economic development in developing countries occurs at the expense of environment. Should people put environment issues first? Why or why not?
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- Will new technologies be part of solution on problems in global warming? Explain
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- What are the major ways to reduce emission of CO₂?

37  **Chapter 18 figures follow...**

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Not the end of the story...