Introduction to Environmental Geology, 5e

Chapter 18

Global Climate Change

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Chapter 18: Overview

- Know the tools used for studying Earth system science and global change
- Understand climate change and global warming
- Know the important linkages associated with global change
- Know some of the potential impacts of global warming and how they might be minimized

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
- Crop failures in Western Europe during the LIA, the population devastated by the Black Plague about 1400

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

Global Climate Change

- Climate changes: contributing to the complex evolutionary history of the Earth system
- Earth system: interactions between the atmosphere, the oceans, solid Earth, and the biosphere
- The effects of human activities: extensive on a global scale
- Apply a better understanding to better manage the environment

Tools for Studying Global Change

The geologic record:

- Sediments
  - Sedimentary structures
  - Paleoenvironments
- Organic material
  - Fossils, tracks, etc.
- Glacial ice
  - Trapped air bubbles and dust particles
  - CO_2 bubbles as old as 800k years

Geologic Record

Glacial Ice

Figure 18.2
Figure 18.3

Tools for Studying Global Change

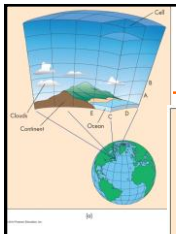
Real-time monitoring:

- Regular collection of data for a specific purpose
- Methods vary with subject being measured
- Good for testing models and predictions from prehistoric records

Mathematical models

- Numerical methods to represent real-world phenomena and linkages between processes
- Global (General) Circulation Models

Modeling the Climate



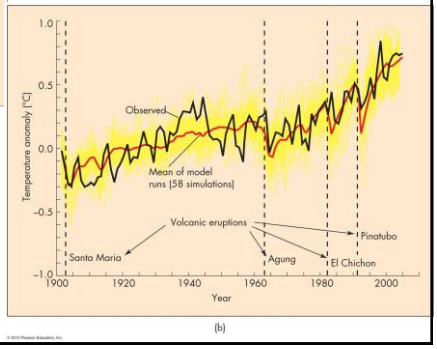
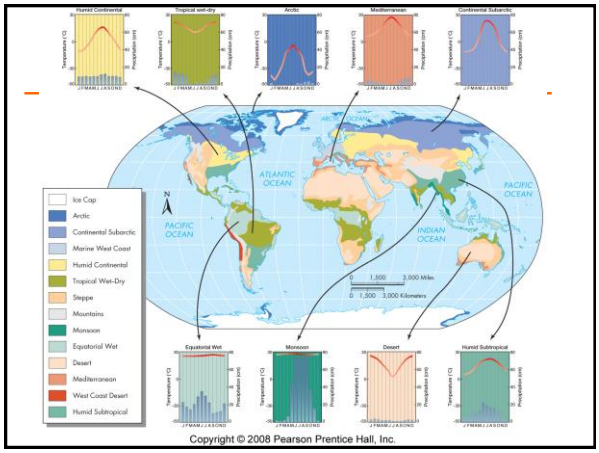


Figure 18.4

Atmosphere and Climate Change

- Atmosphere as a complex chemical factory: many little-understood chemical reactions
- Mix of N, O_2, trace gases, other compounds
- Climate: characteristic atmospheric conditions over time scales of seasons to decades
- Climate change: change of atmospheric conditions and its relationships with lithosphere, hydrosphere, and biosphere
  - Changes in greenhouse gases, variable temp, and water vapor



EARTH'S Climate & Atmosphere

Climatic Zones: Controlled by global circulation and movement of air masses

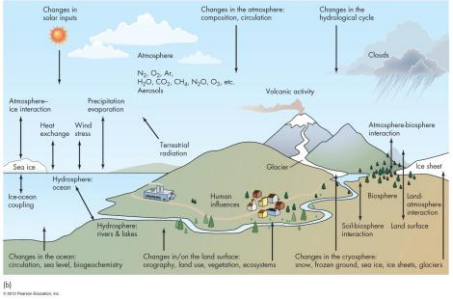
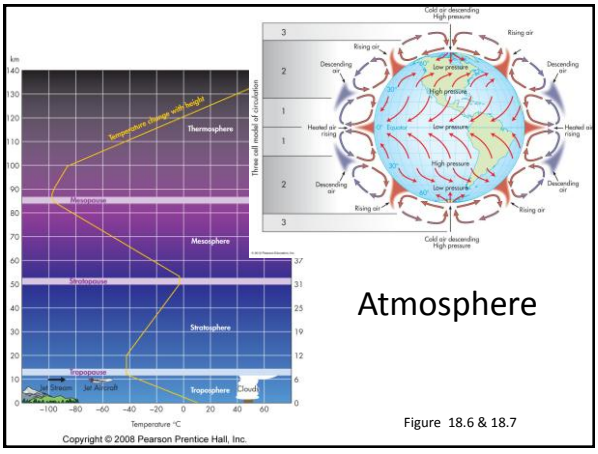


Figure 18.5b



Atmosphere

Figure 18.6 & 18.7

Global Warming

- **Temperature of Earth varies by three factors**:
  - The amount of sunlight received
  - The amount of solar energy reflected and absorbed
  - The amount of heat retention by atmosphere
- Earth: absorbing the short wavelength solar energy, then radiating longer wavelength IR (infrared radiation)
- Global warming: "**Greenhouse Effect**"
  - trapping of heat by atmospheric gases including carbon dioxide, methane, nitrates, and CFCs
  - Anthropogenic gases

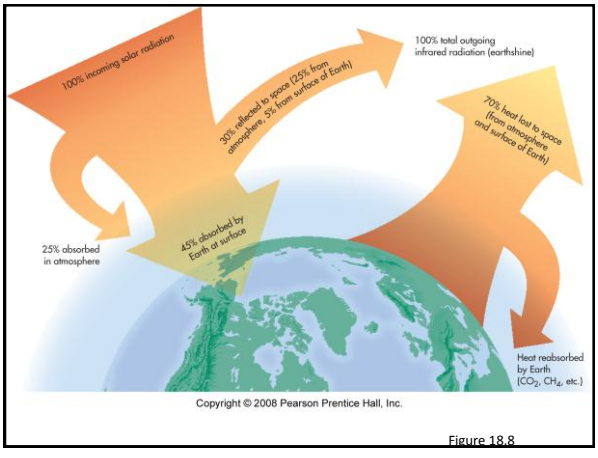
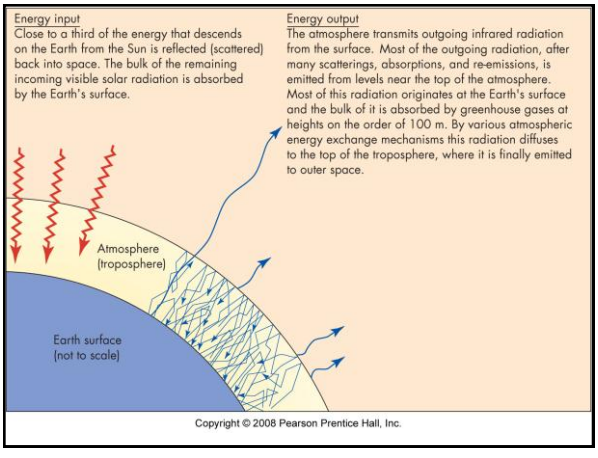


Figure 18.8



Study Past Climate Change

- The Instrumental Record: Started in 1860s, today temperature measured at about 7,000 stations around the world
- The Historical Record: Books, newspapers, journal articles, personal journals
- 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

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

Carbon Dioxide in the Atmosphere

Temperature Change

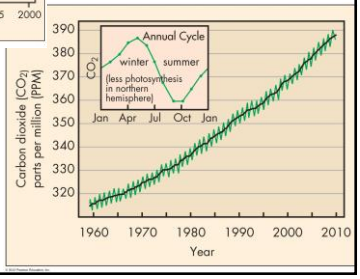


Figure 18.12 & 18.14

Climate Conditions 800k BP

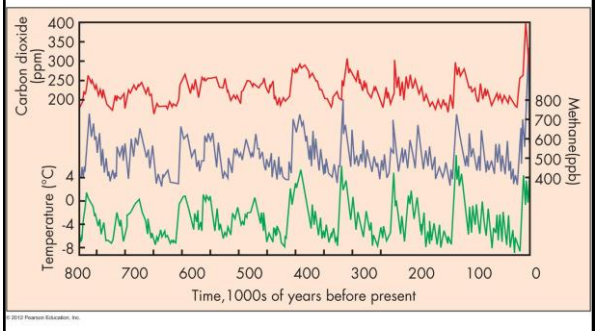
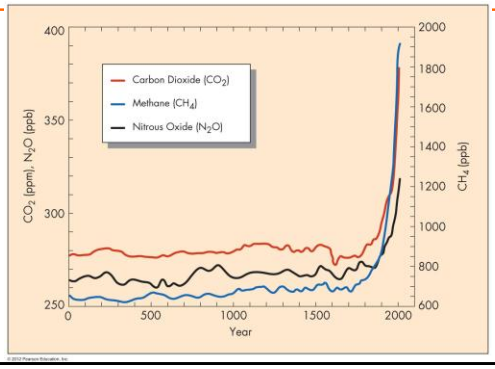


Figure 18.15

Increase in Greenhouse Gasses



Global Temperature Change

- The Pleistocene Ice Age: ~2 MYA, peaked at 18,000 years ago
- Numerous changes in Earth's mean annual temperature since then
- Warming trend over last 150 yrs, especially since 1940s with the warmest since 1990s
- Mean temp increased about 0.8°C (1.36°F) in the past 100 years

Change in Global Temperature

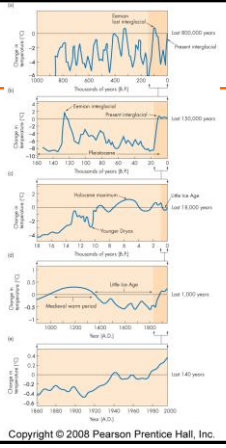


Figure 18.18

Natural Climate Variation

Orbital Variations:

- Changes in long cycles (100k years) separated by short cycles (41k to 26k years)
- Identified in 1920s, Milankovitch hypothesis
- 'Eccentricity' (long cycle): the variability in Earth's orbit around the Sun
- 'Obliquity' and 'Precession' (short cycles): the tilt of Earth's axis and wobble effect of Earth's axis

Natural Climate Variation

- Climate system unstable even in shorter cycles, a few decades
- The ocean conveyor belt: global circulation of ocean water, contributes to the change
- Discernible human influence, mean temp likely 1.5–4.5°C (2.6–7.8°F) warmer in 21st century
- Global warming: Need to consider major forcing variables—solar, volcanic, and anthropogenic gases

Ocean Conveyor Belt

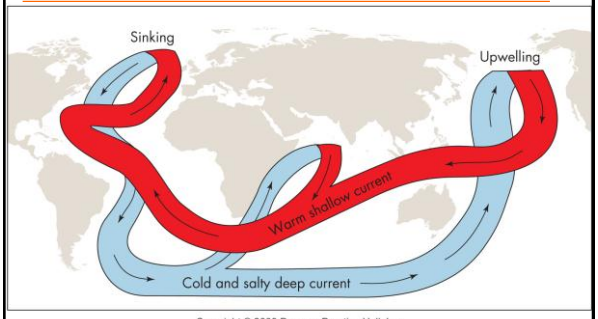
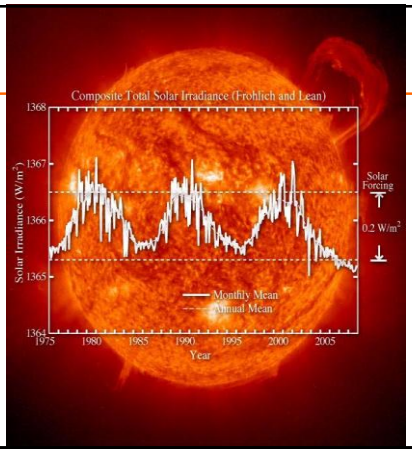


Figure 18.21

Natural Climate Variation

Solar Forcing:

- Historic record of the past 1000 years showing the variability of solar energy
- Medieval Warm Period (A.D. 1000–1300) corresponding to a time of increased solar radiation
- The Little Ice Age (14th century) corresponding to the minimum solar activity
- The effect relatively small, .25%



Solar Flare Activity

Natural Climate Variation

Volcanic Forcing:

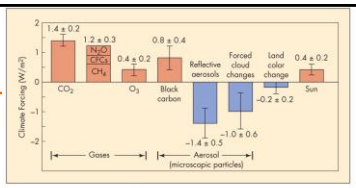
- Volcanic eruption: aerosol & ash particles into the atmosphere
  - Reduce solar radiation to Earth's surface
- Episodes of volcanic eruptions likely contributed to cooling of the Little Ice Age

Figure 18.22

Anthropogenic Forcing

- Natural variability failing to explain the warming at end of the 20th century
- Mathematical modeling on anthropogenic forcing: increase of temperature 2°C due to the doubling of CO_2
- Significant global warming as a result of human activities:
  - Air pollution reduced incoming solar energy by 10%, which offsets up to 50% of the expected global warming

Negative Forcing from Aerosols



- Increases of greenhouse gases (except O_3) are known from observations and bubbles of air trapped in ice sheets. The increase of CO_2 from 285 parts per million (ppm) in 1850 to 368 ppm in 2000 is accurate to about 5 ppm. The conversion of this gas change to a climate forcing (1.4 W/m²), from calculation of the infrared opacity, adds about 10% to the uncertainty.
- Increase of CH_4 since 1850, including its effect on stratospheric H_2O and tropospheric O_3, causes a climate forcing about half as large as that by CO_2. Main sources of CH_4 include landfills, coal mining, leaky natural gas lines, increasing ruminant (cow) population, rice cultivation, and waste management. Growth rate of CH_4 has slowed in recent years.
- Tropospheric O_3 is increasing. The U.S. and Europe have reduced O_3 precursor emissions (hydrocarbons) in recent years, but increased emissions are occurring in the developing world.
- Black carbon ("soot"), a product of incomplete combustion, is visible in the exhaust of diesel-fueled trucks. It is also produced by biofuels and outdoor biomass burning. Black carbon aerosols are not well measured, and their climate forcing is estimated from measurements of total aerosol absorption. The forcing includes the effect of soot in reducing the reflectance of snow and ice.
- Human-made reflective aerosols include sulfates, nitrates, organic carbon, and soil dust. Sources include burning fossil fuel and agricultural activities. Uncertainty in the forcing by reflective aerosols is at least 35%.
- Indirect effects of aerosols on cloud properties are difficult to compute, but satellite measurements of the correlation of aerosol and cloud properties are consistent with the estimated net forcing of −1 W/m², with uncertainty of at least 50%.

Potential Effects of Global Climate Change

- Doubling the greenhouse gases, 1.5–4.5°C (2.6–7.8°F) increase in average global temp
- Significant rise of sea level and melting of glacial ice due to the increase in temp
- The number of retreating glaciers accelerating in many areas of the world
- Change in SW and GW conditions
- Changes in the biosphere
- Significant effects on global climate patterns

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
- Transform 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

Extent of Sea Ice

Figure 18.31

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
- Increases in coastal erosion: Up to 260 ft on open beaches by stronger wave actions
- Landward shift of existing estuaries
- Disastrous impact on the existing developments along coastal zones

Change in Climate Patterns

- Global warming leads to significant changes of rainfall and soil moisture (drought and flood)
- Agricultural activities (crop growth cycle) and world food supplies affected greatly by climatic factors (desertification)
- Global warming affects the frequency, intensity, and distribution of natural hazards, such as hurricanes and other storms

Change in Climate Patterns

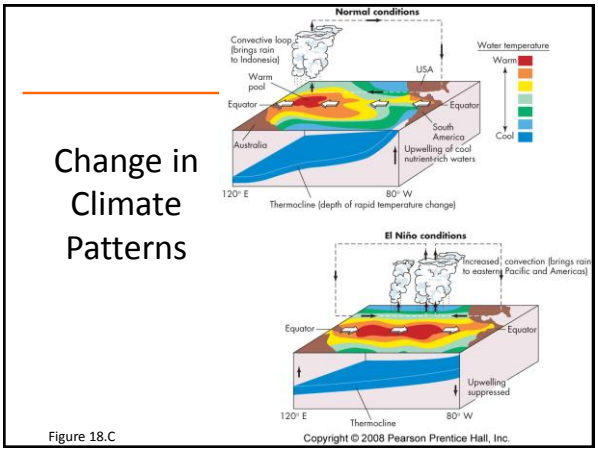


Figure 18.C

Change in Climate Patterns

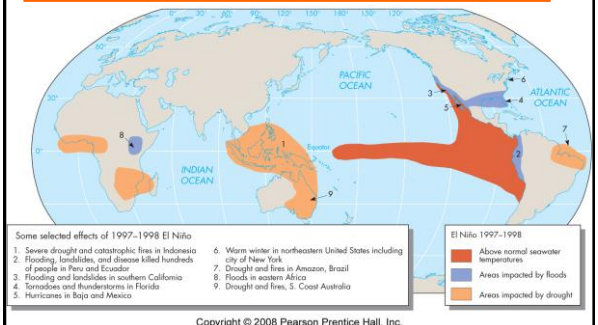


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Figure 18.D

Changes in the Biosphere

- Causing a number of changes in the biosphere - both for people and overall ecosystem
- Risk of species extinction due to land-use change and habitat shift
- Spread of infectious and other diseases due to migration of organisms
- Both land and oceanic components affected: from plants, to polar bears, to the bleaching of coral reefs

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 – cause extinction of some species unable to migrate with climate change – creating an invasive species

Reducing the Impact of Global Warming

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

Reducing the Impact of Global Warming

Reduce CO_2 levels in atmosphere:

- Improved engineering technologies of fuel-burning power plants
- Use fossil fuels releasing less CO_2 (table 18.2)
- Conservation of energy
- Store CO_2 in forests, soils and rocks, depleted oil and gas fields, saltwater aquifers (sequestration of CO_2)
- Use alternative, renewable sources of energy

Reducing the Impact of Global Warming

The Kyoto Protocol, international agreement to reduce emissions of greenhouse gases, signed by 166 nations, became formal international treaty in 2/05.

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.

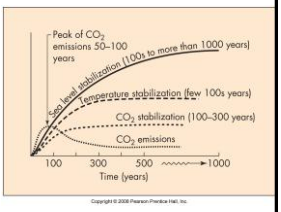

Figure 18.36

Coupling of Global Change Processes – Negative Forcing

- The coupling of the greenhouse and ozone depletion problems from CFCs
- Burning of fossil fuels and acid rain problems
- Use of fossil fuels and volcanic eruption problems and atmospheric cooling

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
- Rapid economic development in developing countries occurs at the expense of environment. Should people put environment issues first? Why or why not?
- Will new technologies be part of solution on problems in global warming? Explain
- What are the major ways to reduce emission of CO_2?