Earth Science, 11e

The Atmosphere: Composition, Structure, and Temperature

Chapter 16
Weather and climate

- **Weather**
  - Weather is over a short period of time
  - Constantly changing

- **Climate**
  - Climate is over a long period of time
  - Generalized, composite of weather
Weather and climate

Elements of weather and climate

• Properties that are measured regularly
• Most important elements
  • Temperature
  • Humidity
  • Cloudiness
  • Precipitation
  • Air Pressure
  • Winds speed and direction
Composition of the atmosphere

- Air is a mixture of discrete gases
- Major components of clean, dry air
  - Nitrogen (N) – 78%
  - Oxygen (O₂) – 21%
  - Argon and other gases
  - Carbon dioxide (CO₂) – 0.036% – absorbs heat energy from Earth
Proportional volume of gases that compose dry air

Figure 16.3
Composition of the atmosphere

Variable components of air

- Water vapor
  - Up to about 4% of the air's volume
  - Forms clouds and precipitation
  - Absorbs heat energy from Earth

- Aerosols
  - Tiny solid and liquid particles
  - Water vapor can condense on solids
  - Reflect sunlight
  - Help color sunrise and sunset
Composition of the atmosphere

- Variable components of air
  - Ozone
    - Three atoms of oxygen (O$_3$)
    - Distribution not uniform
    - Concentrated between 10 to 50 kilometers above the surface
    - Absorbs harmful UV radiation
    - Human activity is depleting ozone by adding chlorofluorocarbons (CFCs)
Structure of the atmosphere

- Pressure changes
  - Pressure is the weight of the air above
  - Average sea level pressure
    - Slightly more than 1000 millibars
    - About 14.7 pounds per square inch
  - Pressure decreases with altitude
    - One-half of the atmosphere is below 3.5 miles (5.6 km)
    - Ninety percent of the atmosphere is below 10 miles (16 km)
Atmospheric pressure variation with altitude

Figure 16.5
Structure of the atmosphere

- Atmospheric layers based on temperature
  - Troposphere
    - Bottom layer
    - Temperature decreases with altitude – called the environmental lapse rate
      - 6.5°C per kilometer (average)
      - 3.5°F per 1000 feet (average)
    - Thickness varies – average height is about 12 km
    - Outer boundary is named the tropopause
Structure of the atmosphere

- Atmospheric layers based on temperature
  - Stratosphere
    - About 12 km to 50 km
    - Temperature increases at top
    - Outer boundary is named the stratopause
  - Mesosphere
    - About 50 km to 80 km
    - Temperature decreases
    - Outer boundary is named the mesopause
Structure of the atmosphere

- Atmospheric layers based on temperature
  - Thermosphere
    - No well-defined upper limit
    - Fraction of atmosphere's mass
    - Gases moving at high speeds
Thermal structure of the atmosphere

Figure 16.7
Earth-Sun relations

- Earth motions
  - Rotates on its axis
  - Revolves around the Sun

- Seasons
  - Result of
    - Changing Sun angle
    - Changing length of daylight
Daily paths of the Sun at 40° N latitude

Figure 16.9 A
Relationship of sun angle and solar radiation received on Earth

Figure 16.10
Earth-Sun relations

Seasons
• Caused by Earth's changing orientation to the Sun
  • Axis is inclined 23½°
  • Axis is always pointed in the same direction
• Special days (Northern Hemisphere)
  • Summer solstice
    • June 21-22
    • Sun's vertical rays are located at the Tropic of Cancer (23½° N latitude)
Relationship of sun angle to the path of solar radiation

Figure 16.11
**Earth-Sun relations**

- **Seasons**
  - Special days (Northern Hemisphere)
    - Winter solstice
      - December 21-22
      - Sun's vertical rays are located at the Tropic of Capricorn (23½° S latitude)
    - Autumnal equinox
      - September 22-23
      - Sun's vertical rays are located at the **Equator** (0° latitude)
Earth-Sun relations

❖ Seasons

• Special days (Northern Hemisphere)
  • Spring equinox
    • March 21-22
    • Sun's vertical rays are located at the Equator (0° latitude)
Earth-Sun relationships

Figure 16.12
Characteristics of the solstices and equinoxes

Figure 16.13
**Atmospheric heating**

- Heat is always transferred from warmer to cooler objects

**Mechanisms of heat transfer**

- **Conduction** through molecular activity
- **Convection**
  - Mass movement within a substance
  - Usually vertical motions
- **Radiation** (electromagnetic radiation)
  - Velocity: 300,000 kilometers (186,000 miles) per second in a vacuum
Mechanisms of heat transfer

Figure 16.16
Atmospheric heating

Mechanisms of heat transfer

• Radiation (electromagnetic radiation)
  • Consists of different wavelengths
    • Gamma (very short waves)
    • X-rays
    • Ultraviolet (UV)
    • Visible
    • Infrared
    • Microwaves and radio waves
The electromagnetic spectrum

Figure 16.17
Atmospheric heating

Mechanisms of heat transfer

- Radiation (electromagnetic radiation)
  - Governed by basic laws
    - All objects, at whatever temperature, emit radiation
    - Hotter objects radiate more total energy per unit area than do cooler objects
    - The hotter the radiating body, the shorter the wavelength of maximum radiation
  - Objects that are good absorbers of radiation are good emitters as well
Atmospheric heating

- Incoming solar radiation
  - Atmosphere is largely transparent to incoming solar radiation
  - Atmospheric effects
    - Reflection – albedo (percent reflected)
    - Scattering
    - Absorption
  - Most visible radiation reaches the surface
  - About 50% absorbed at Earth's surface
Average distribution of incoming solar radiation

Figure 16.19
Atmospheric heating

- Radiation from Earth's surface
  - Earth re-radiates radiation (terrestrial radiation) at the longer wavelengths
  - Longer wavelength terrestrial radiation is absorbed by
    - Carbon dioxide and
    - Water vapor in the atmosphere
    - Lower atmosphere is heated from Earth's surface
  - Heating of the atmosphere is termed the greenhouse effect
The heating of the atmosphere

Figure 16.21

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Temperature measurement

- Daily maximum and minimum
- Other measurements
  - Daily mean temperature
  - Daily range
  - Monthly mean
  - Annual mean
  - Annual temperature range
Mean monthly temperatures for two locations in Canada

Figure 16.24
Mean monthly temperatures for Eureka, California and New York City

Figure 16.26
Temperature measurement

- Human perception of temperature
  - Anything that influences the rate of heat loss from the body also influences the sensation of temperature
  - Important factors are
    - Air temperature
    - Relative humidity
    - Wind speed
    - Sunshine
Controls of temperature

- Temperature variations
- Receipt of solar radiation is the most important control

Other important controls
  - Differential heating of land and water
    - Land heats more rapidly than water
    - Land gets hotter than water
    - Land cools faster than water
    - Land gets cooler than water
Controls of temperature

Other important controls

- Altitude
- Geographic position
- Cloud cover
- Albedo
<table>
<thead>
<tr>
<th>Surface</th>
<th>Percent Reflected</th>
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<tr>
<td>Fresh snow</td>
<td>80–90</td>
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<tr>
<td>Old snow</td>
<td>50–60</td>
</tr>
<tr>
<td>Sand (beach, desert)</td>
<td>20–40</td>
</tr>
<tr>
<td>Grass</td>
<td>5–25</td>
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<tr>
<td>Dry soil (plowed field)</td>
<td>15–25</td>
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<tr>
<td>Wet earth (plowed field)</td>
<td>10</td>
</tr>
<tr>
<td>Forest</td>
<td>5–10</td>
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<tr>
<td>Water (Sun near horizon)</td>
<td>50–80</td>
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<tr>
<td>Water (Sun near zenith)</td>
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<td>25–30</td>
</tr>
<tr>
<td>Earth and atmosphere (overall total)</td>
<td>30</td>
</tr>
</tbody>
</table>
Clouds reduce the daily temperature range

Figure 16.28
World distribution of temperature

- Temperature maps
  - Isotherm – a line connecting places of equal temperature
  - Temperatures are adjusted to sea level
  - January and July are used for analysis because they represent the temperature extremes
World distribution of temperature

Global temperature patterns

- Temperature decreases poleward from the tropics
- Isotherms exhibit a latitudinal shift with the seasons
- Warmest and coldest temperatures occur over land
World distribution of temperature

- Global temperature patterns
  - In the Southern Hemisphere
    - Isotherms are straighter
    - Isotherms are more stable
  - Isotherms show ocean currents
  - Annual temperature range
    - Small near equator
    - Increases with an increase in latitude
    - Greatest over continental locations
World mean sea-level temperatures in January

Figure 16.29
World mean sea-level temperatures in July
End of Chapter 16