1 The Study of the Atmosphere

Learning Goals

After studying this chapter, students should be able to

- distinguish between weather and climate (pp. 2–5);
- describe how the various components of the climate system interact (pp. 5–9);
- explain the process of scientific study (pp. 9–10);
- apply the system of units used in atmospheric science (pp. 11–12); and
- describe how Earth's atmosphere changes with height (pp. 13–17).

Summary

1. Processes at work in the **atmosphere** create weather and climate. **Weather** describes the state of the atmosphere at a given time and place. The elements of weather include temperature, pressure, humidity, winds, clouds, and precipitation. **Climate** describes the average conditions of the atmosphere on a variety of scales, from the micro scale to the planetary scale.
2. The atmosphere is part of a complex system that also includes rocks, the water, and the life of the planet. This system is made even more complicated by **feedback effects**, which are mechanisms that develop within systems and reinforce or lessen the effects of an initial change.
3. Science is about trying to understand and explain the observations we make about the world. Scientific investigation follows the **scientific method**. It has led to our discovery of laws that *describe* the way nature works, most of which can be expressed as mathematical equations. Scientific investigation has also led to our development of **scientific theories**—large bodies of knowledge used to *explain* the way nature works.
4. Math acts as both a language and a tool in science. Measurements and calculations make use of the internationally adopted MKS system of units. Four derived dimensions are important in atmospheric science: **force**, **energy** or **work**, **power**, and **pressure**.
5. Pressure and density decrease with height in the atmosphere. **Pressure** decreases with height because the mass of the atmosphere lying above decreases with height. **Density** decreases with height because air is compressible. The decrease in density with height causes pressure to decrease exponentially with height.
6. The change in temperature with height defines four atmospheric layers: the **troposphere**, the **stratosphere**, the **mesosphere**, and the **thermosphere**. The troposphere is the layer closest to the surface. It contains more moisture and is more turbulent than the stratosphere, the layer directly above. In comparison, the stratosphere contains more ozone.

Key Terms

Anthropogenic Related to human activities (p. 5).

Atmosphere The layer of gases surrounding a planet or celestial body (p. 2).

Atmospheric pressure The force exerted by the atmosphere on Earth's surface (p. 13).

Biosphere Life on Earth (p. 6).

Climate The average conditions of the atmosphere (p. 2).

Climatology The study of climate (p. 2).

Cryosphere The ice of Earth (p. 6).

Density The amount of mass in a unit volume (p. 12).

Energy The capacity to do work (p. 12).

Energy flux density The rate of the flow of energy per unit area of surface (p. 13).

Feedback effect A mechanism that operates within a system to either amplify or lessen an initial change (p. 8).

Force An action capable of accelerating an object (p. 12).

General circulation model (GCM) A computer program that represents the physics of the atmosphere through a set of equations (p. 10).

Global warming The increase in Earth's temperature caused by increasing concentrations of greenhouse gases associated with human activities (p. 5).

Greenhouse effect The part of a planet's temperature attributable to the presence of greenhouse gases in its atmosphere (p. 5).

Greenhouse gas A gas that allows the shorter wavelength radiation from the sun to pass through the atmosphere, while it absorbs the longer wavelength radiation leaving Earth's surface (p. 5).

Hydrosphere The water of Earth (p. 6).

Hypothesis A tentative explanation for an observation (p. 9).

Inversion An increase in temperature with altitude (p. 16).

Lithosphere The rocks of Earth (p. 6).

Mesopause The top of the mesosphere (p. 16).

Mesosphere The layer of the atmosphere that extends from about 50 km above Earth's surface to about 85 km above the surface (p. 16).

Meteorology The study of the atmospheric processes responsible for weather (p. 2).

Microclimate The climate of a small area at Earth's surface (p. 5).

Model A representation of reality used to help in understanding complex or abstract natural phenomena (p. 10).

Photosynthesis The life process in which energy from the sun is used to convert carbon dioxide and water to oxygen and carbohydrates (p. 7).

Power The rate at which energy is transferred, or work is done (p. 12).

Pressure The force per unit area (p. 12).

Respiration The life process in which oxygen is removed from the atmosphere and carbon dioxide is returned (p. 7).

Scientific law A precise statement that describes the behaviour of nature and is believed to always hold true (p. 9).

Scientific method A series of steps followed in scientific investigation (p. 9).

Scientific theory A body of knowledge that provides a detailed explanation for a set of observations (p. 9).

Standard atmosphere A set of values that represents the average vertical distribution of pressure, temperature, and density in the atmosphere (p. 13).

Stratopause The top of the stratosphere (p. 16).

Stratosphere The layer of the atmosphere extending from, on average, 11 to 50 km above Earth's surface (p. 16).

System A set of parts that interact (p. 5).

Thermosphere The top layer of the atmosphere. Its base is located at an altitude of about 85 km; it has no well-defined top (p. 16).

Tropopause The top of the troposphere (p. 15).

Troposphere The layer of the atmosphere extending from Earth's surface to an average height of 11 km (p. 15).

Weather The state of the atmosphere at a given place and time (p. 2).

Weather forecast An estimate of the future state of the atmosphere (p. 3).

Work The transfer of energy by mechanical means (p. 12).

Answers to Selected Review Questions (p. 18)

1. **What are some reasons for studying the atmosphere?**

   The atmosphere is necessary for life. It contains the air we breathe and the ozone layer that protects us from ultraviolet radiation. It moderates temperatures and allows sound to propagate. Without an atmosphere there would be no weather.

3. **What characteristics of a place might influence its climate?**

   Characteristics that may affect climate include latitude, altitude, proximity to bodies of water, prevailing wind, and mountain ranges.

5. **What are the three types of models that researchers use? How do they use these models to advance science?**

   The three types of models are conceptual, physical, and mathematical. These models are used in scientific investigations and experiments to test a hypothesis.

7. **How are the troposphere and the stratosphere different from one another? What accounts for these differences?**

   Temperature decreases through the troposphere at an average rate of 6.5°C/km. It is warmest on the bottom because it is heated by Earth's surface. It is the layer in which all weather occurs because it is a turbulent layer throughout which heat, water vapour, and particles originating at Earth's surface are thoroughly mixed. The stratosphere contains very little moisture. It is warmest at the top because it is heated by the sun. Because of the inversion in the stratosphere, it is not turbulent. It contains the ozone layer which absorbs ultraviolet radiation and warms the stratosphere.

Study Questions

For suggested answers, see below.

1. What are the four major parts of the Earth system? Briefly describe each.

2. What are the differences between a positive feedback effect and a negative feedback effect?

3. How were the stages of the scientific method at work in the early research on the depletion of the ozone layer?

4. What are the changes in temperature from the surface to the top of the atmosphere?

5. Why does the thermosphere not feel warm to a person even though it has high temperatures?

Answers to Study Questions

1. The lithosphere is made up of the rocks of the planet, the biosphere comprises all life on the planet, the hydrosphere includes all water on the planet, and the atmosphere is the layer of gases surrounding the planet. (p. 6)

2. A positive feedback effect is a mechanism that operates within a system to amplify the effects of an initial change. A negative feedback effect is a mechanism that operates within a system to lessen the effects of an initial change. (p. 8)

3. The observation was that CFCs were accumulating in the atmosphere. The question was what will happen to the CFCs? The hypothesis was that chlorine from the CFCs was destroying the ozone layer. The further observations were that the hole in the ozone layer and the fact that the hole contained high amounts of chlorine monoxide. The conclusion was that chlorine from CFCs was destroying the ozone layer. (p. 11)

4. Temperature decreases through the troposphere at an average rate of 6.5°C/km. From the tropopause to an altitude of about 20 km, temperature remains constant with height. Above this height in the remainder of the stratosphere, temperature increases with height. In the mesosphere, temperature decreases with height. Temperature then increases with height in the thermosphere. (p. 15)

5. The thermosphere would not feel warm because the air is very thin. For heat to be transferred, molecules must collide. Because of the large spaces between air molecules in the thermosphere, collisions between air molecules are rare and therefore there is little heat transfer. (p. 16)