*Instructor's Manual to accompany Meteorology Today, 12th Edition*

**Chapter 1**

**Earth and Its Atmosphere**

**Learning Objectives**

**The Atmosphere and the Scientific Method**

LO: 1-1 Outline the scientific method and describe how it can be applied to studying the atmosphere and weather.

**Overview of Earth’s Atmosphere**

LO: 1-2 Compare and contrast the composition of Earth’s atmosphere over the course of its evolution.

LO: 1-3 Explain the role of gases (including water vapor, carbon dioxide, oxygen, and other greenhouse gases) and pollutants in Earth’s atmosphere and assess their impact on Earth’s climate.

**Vertical Structure of the Atmosphere**

LO: 1-4 State the terms and calculations for density and air pressure, and explain their importance with regard to Earth’s atmosphere.

LO: 1-5 Label the layers of the atmosphere and their altitudes, and classify their respective temperatures, compositions, and functions.

**Weather and Climate**

LO: 1-6 Differentiate between weather and climate, and briefly discuss the history of meteorology and its most important milestones.

LO: 1-7 Interpret and describe a weather map, applying weather patterns and concepts such as low, high, front, and storm types.

LO: 1-8 List the positive and negative effects of climate and weather on human health, agriculture, infrastructure, environment, and economy.

**Summary**

With many illustrations and photographs, this introductory chapter presents a broad overview of the physical structure of the atmosphere and its weather. The chapter begins with a discussion of the present composition of the earth's atmosphere. A focus section, “A Breath of Fresh Air”, examines the number of molecules in a single breath and in the entire atmosphere. The important and varied roles played by water vapor, which is a source of precipitation and latent heat energy as well as being the most important greenhouse gas, are given particular attention. Current concern over increasing concentrations of another constituent, carbon dioxide, and its possible effect on global climate are also examined. The student will see that the observed increase in CO2 is a result of an imbalance between processes of release and removal. The principle atmospheric pollutants, including ozone, are listed but are covered in greater detail in Chapter 19.

The concepts of air density and air pressure are introduced and their variation with altitude is examined. A vertical profile of temperature shows that the atmosphere can be divided into several layers with distinct properties. Additional focus sections describe “The Atmospheres of Other Planets” and “The Radiosonde”.

Finally, the student is introduced to the elements that constitute weather and will see how weather conditions might be depicted on a surface weather map and in a photograph from a geostationary satellite. The chapter includes discussions of the history of and careers in meteorology, and ends with a description of the many ways that weather and climate can affect our lives and interests. The final section includes a focus section entitled “What is a Meteorologist”.

**Key Terms**

atmosphere

nitrogen

oxygen

water vapor

carbon dioxide

ozone

ozone hole

aerosol

pollutant

outgassing

density

pressure

air pressure

lapse rate

temperature inversion

troposphere

stratosphere

tropopause

**Teaching Suggestions**

1. Some of the atmospheric pressure demonstrations described in Chapter 8 could be performed here also.

2. Fill a wine glass completely with water and cover it with a piece of plastic (such as the lid from a tub of margarine), being careful to remove any air. Invert the glass. The water remains in the glass because the upward force on the cover due to the pressure of the air is much stronger than the downward gravitational force on the water. The demonstration can be made much more convincing if a 4000 mL Erlenmeyer flask is used instead of the wine glass. When full of water, the flask weighs approximately 10 pounds.

3. Place a candle in the center of a dish and partly fill the dish with water. Light the candle and then cover it with a large jar or beaker. The flame will consume the oxygen inside the jar and reduce the pressure. Water will slowly flow into the jar to re-establish pressure balance. The change in volume will be close to 20%, the volume originally occupied by the oxygen in the air. This demonstration can be used to illustrate the concept of partial pressure, which is later used in the chapter on humidity. The students should also be asked what they think the products of the combustion might be and why these gases do not replace the oxygen and maintain the original pressure in jar. One of the combustion products is water vapor, which condenses as the air in the jar cools. Another combustion product is carbon dioxide, which presumably goes into solution.

4. Students often confuse water vapor with liquid water. Students should understand that water vapor is an invisible gas. Haze, fog, clouds, and the steam from a boiling pot all become visible when water vapor condenses and forms small drops of liquid water. This can be easily demonstrated using a tea kettle, or by showing a video of water boiling in a tea kettle.

5. The introductory explanations of the air motions associated with high and low pressure centers and fronts make this a good place to begin to show and discuss satellite images, loops, and surface weather maps. Download a few satellite loops and discuss the air motions.

6. Challenge students to speculate on how we know the chemical composition of Earth’s early atmosphere.

7. Invoke the concept of layering while describing the composition of atmospheric gases. Nitrogen comprises 78% of the atmosphere, so if the gases each occupied distinct layers with Nitrogen on the bottom, the Nitrogen layer would extend from the floor up to about ¾ the distance to the ceiling.

8. Compare the thickness of the atmosphere to that of the skin on an apple. If Earth and the atmosphere combined were shrunk down to the size of an apple, the atmosphere would be about as thick as the skin on the apple.

9. Compare the weather changes occurring over vertical and horizontal distances. If you moved 10 km to the north, south, east or west, what weather changes might you experience? Compare this with the weather changes you’d experience if you moved *up* 10 km.

10. Use the University of Wyoming’s radiosonde data website to examine current sounding data for anywhere in the world: <http://weather.uwyo.edu/upperair/sounding.html>.

**Student Projects**

1. Have the students mark the positions of fronts and pressure systems for each day on an outline map of the United States. (This information can be obtained from the daily newspaper or from the web.) Have students do this for a week at a time, noting the general movement of these systems.

2. Students could attempt to repeat some of the experiments in the book *Hands-On Meteorology*.

3. "A General Chemistry Experiment for the Determination of the Oxygen Content of Air" by James P. Birk, Larry McGrath, and S. Kay Gunter *(J. Chem. Educ., 58,* 804-805, 1981) describes a simple experiment that can be used to determine atmospheric oxygen concentrations (see also: "Percent Oxygen in Air," George F. Martins, *J. Chem. Educ., 64,* 809-810, 1987).

4. Have students compose a one-week journal or blog, including daily newspaper or web weather maps and weather forecasts. Ask them to write a commentary for each day as to the coincidence of actual and predicted weather.

5. Have students keep a daily record of weather conditions that they actually observe. Then, periodically, the instructor can supply mean daily data such as high and low temperatures, pressure, dew point, wind speed, cloud cover, and precipitation amounts. The students should plot this data and annotate the graph with their observations. Students can use their graphs to experimentally test concepts developed in class. After studying Chapter 1, for example, students might try to determine whether periods of stormy weather really are associated with lower-than-average surface pressure.

**Answers to Questions for Review**

1. Radiant energy from the sun.

2. Nitrogen, oxygen, argon, and water vapor.

3. Water vapor.

4. It forms precipitation, releases latent heat, and is a greenhouse gas.

5. Carbon dioxide enters the atmosphere through vegetation decay, volcanic eruptions, the exhalations of animal life, the burning of fossil fuels, and deforestation. Carbon dioxide removal occurs as a result of photosynthesis and ocean uptake. Carbon dioxide is increasing in the atmospheredue to the burning of fossil fuels and deforestation.

6. Water vapor and carbon dioxide are greenhouse gases because they absorb infrared radiation.

7. Ozone and oxygen filter out damaging ultraviolet radiation from the Sun. Greenhouse gases keep the planet warm. The atmosphere provides water to drink and oxygen to breathe.

8. Soil dust, salt from the oceans, forest fire smoke, volcanic ash particles, and pollutants.

9. Earth’s first atmosphere (some 4.6 billion years ago) was most likely hydrogen and helium—the two most abundant gases found in the universe—as well as hydrogen compounds, such as methane and ammonia. A second, more dense atmosphere gradually enveloped Earth as gases from molten rock within its hot interior escaped through volcanoes and steam vents. We assume that volcanoes spewed out the same gases then as they do today: mostly water vapor (about 80 percent), carbon dioxide (about 10 percent), and up to a few percent nitrogen. As millions of years passed, the constant outpouring of gases from the hot interior (outgassing) provided a rich supply of water vapor, which formed clouds. Rain fell upon the earth for many thousands of years. Large amounts of CO2 were dissolved in the oceans. The atmosphere gradually became rich in nitrogen (N2). Oxygen (O2), the second most abundant gas in today’s atmosphere, probably began a slow increase in concentration as energetic rays from the Sun split water vapor (H2O) into hydrogen and oxygen during a process called photodissociation. The hydrogen, being lighter, probably rose and escaped into space, while the oxygen remained in the atmosphere. After plants evolved, the atmospheric oxygen content increased, probably reaching its present composition about several hundred million years ago.

10. (a) If more molecules are packed into an air column, the column becomes more dense, the air weighs more, and the surface pressure goes up. On the other hand, when fewer molecules are in the air column, the air weighs less, and the surface pressure goes down.

(b) Because as altitude increases, there is always less air above you (because more of it is below you).

11. 1013.25 mb = 1013.25 hPa = 29.92 in. Hg.

12. Approximately 6.5°C for every 1000 m or approximately 3.6°F for every 1000 ft rise in elevation.

13. On average, temperature decreases from the surface to the tropopause (around 10 km, then increases to the stratopause (around 50 km), then decreases to the mesopause (around 90 km), then increases through the thermosphere.

14. Troposphere, stratosphere, mesosphere, thermosphere.

15. Troposphere.

16. (a) Mesosphere.

(b) Thermosphere.

(c) Stratosphere.

17. Antarctica.

18. The lower part (called the *D* region) reflects standard AM radio waves back Earth, but at the same time it seriously weakens them through absorption. At night, though, the *D* region gradually disappears and AM radio waves are able to penetrate higher into the ionosphere (into the *E* and *F* regions) where the waves are reflected back to Earth. Because there is, at night, little absorption of radio waves in the higher reaches of the ionosphere, such waves bounce repeatedly from the ionosphere to Earth’s surface and back to the ionosphere again. In this way, standard AM radio waves are able to travel for many hundreds of kilometers at night.

19. Because the pressure is so low in the upper stratosphere, 21 percent of a very small amount of air does not provide enough oxygen to breathe.

20. *Meteorology* is the study of the atmosphere and its phenomena. The term itself goes back to the Greek philosopher Aristotle who, in approximately 340 B.C., wrote a book on natural philosophy entitled *Meteorologica.*

21. From the south.

22. High and low pressure systems, fronts, wind speed and direction, cloud cover, temperature.

23. Low pressure systems: counterclockwise. High pressure systems: clockwise.

24. A sharp change in temperature, humidity, and wind direction.

25. Middle-latitude cyclonic storm, hurricane, thunderstorm, tornado.

26. From west to east.

27. Climate describes weather conditions averaged over a region or over a time period.

28. Hurricanes and tropical storms cause severe weather that can destroy homes and other property. Heat waves can cause heat stroke, heat exhaustion, or death. Droughts can cause crops failures, starvation, and death. Snow and ice storms can cause transportation problems and power outages. Temperature changes can lead to higher heating and cooling costs for power consumers. The weather can cause people to become depressed or irritable. Weather can also lead to the increased occurrence of arthritic pain and headaches. Cold weather can cause frostbite or hypothermia.

**Answers to Questions for Thought**

1. Weather: (b), (d), (g). Climate: (a), (c), (e), (f), and (h).

2. (a) 0.5 ATM and 0.1 ATM are equal to about 500 mb and 100 mb, respectively. From the

figure, 500 mb is located at an altitude of about 5.5 km (3.5 miles); 100 mb is found at an altitude of about 16 km (10 miles).

(b) The surface pressure on Mars.007 ATM, is about 7 mb. A pressure of 7 mb would be found near 35 km (22 miles) altitude in the earth's atmosphere.

3. Your stomach would expand, because the pressure outside your body would be several orders of magnitude less than the pressure inside your body.

4. Drought and extreme heat.

**Answers to Critical Thinking Questions**

Figure 1.13. The sound travels in waves through the ionosphere. In some locations the waves pass closer to Earth’s surface than in other areas.

Figure 1.14. Since weather tends to move from west to east, people in Centerville generally experience the weather that occurred to the west of them. The hail is about 80 miles west of Centerville and should reach Centerville in 2 hours.