METEOROLOGY TODAY, 2nd Canadian Edition

By Ahrens, Jackson, Jackson

ENRICHED INSTRUCTOR'S MANUAL

Prepared by Mark Moscicki
University of Western Ontario

Chapter 1
Earth and Its Atmosphere

Contents

General Introduction

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 importance of Earth's atmosphere. The varied roles played by water vapour, which is a source of precipitation and latent heat energy as well as being the most important greenhouse gas, are given particular attention. Current concerns over increasing concentrations of carbon dioxide and other greenhouse gases, and the impact of these on global climate are also examined. The student will recognize that the observed increase in greenhouse gases is the result of an imbalance between processes of release and those of removal. That imbalance is heavily influenced by human activities. The principle atmospheric pollutants are listed here but will be covered in greater detail in Chapter 18. 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 layers based on temperature, chemical composition, or electrical properties.

Chapter Outline

- Earth's Atmosphere
  - Today's Atmosphere
  - Early Atmospheres

- Atmospheric Vertical Structure
  - Air Density and Pressure
  - Atmospheric Layers
    - Thermal Layers
    - Chemical Composition Layers
    - The Ionosphere: Electrical Properties

Focus Sections

- A Breath of Fresh Air
- The Atmospheres of Other Planets
- Solar Particles and the Aurora

Key Concepts

- Earth's atmosphere is a mixture of many gases. In a volume of dry air near the surface, nitrogen (N_2) occupies about 78 percent and oxygen (O_2) about 21 percent.

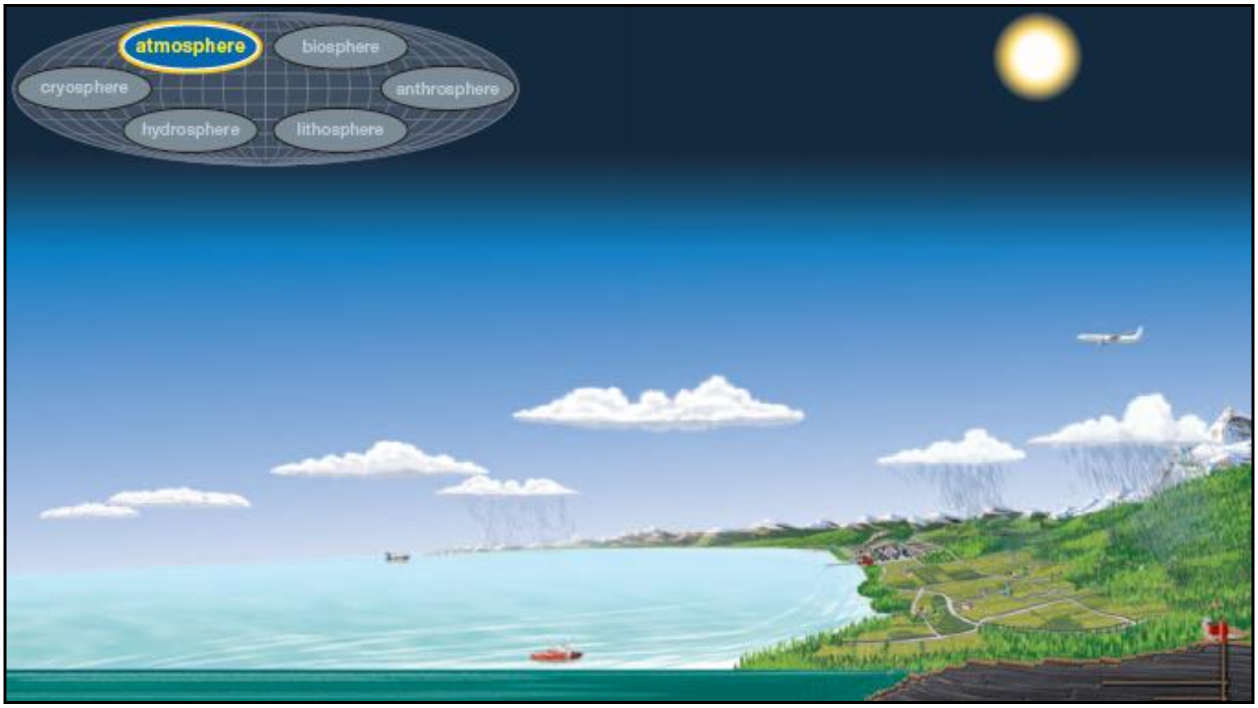
- Carbon dioxide (CO_2), water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs) are important greenhouse gases in the Earth's atmosphere.

- Ozone (O_3) in the stratosphere protects life from harmful ultraviolet (UV) radiation. At the surface, ozone is a harmful main ingredient of photochemical smog.

- Air pressure is a measure of the total mass of air above any point. Therefore, air pressure always decreases with increasing height above the ground.

- The atmosphere can be divided into four thermal layers. The troposphere is the closest layer, where almost all weather events occur.

Earth Systems



The *atmosphere* connects Earth to the solar system. With its differing layers, the atmosphere acts as a buffer and insulator. It shields the *biosphere* and *anthrosphere* from space and keeps the planet warmer than it otherwise would be. Through weather, it allows energy and water to be transported around the globe. The atmosphere interacts dynamically with all other Earth systems. Water, in all its forms, cycles through the *hydrosphere* and *cryosphere*. Through complex processes, the organisms in the biosphere and the geologic activities in the *lithosphere* exchange gases that cycle through and alter the atmosphere. In turn, changes in the atmosphere alter the other Earth systems, creating both reinforcing and counteracting feedbacks between the systems.

Student Motivation

- The introductory lecture is a good time to discuss the importance to students of studying meteorology. Highlight the significance of both weather (it affects everyone every day) and the atmosphere (it is necessary to support life).

- Emphasize to students that the environment is a rapidly developing field and that global climate change is the most important environmental issue facing the world today.

- This chapter provides an important foundation to students for many of the major concepts explored later in the textbook, including air pressure, fronts, storm systems, greenhouse gases and their association with climate change, interpreting weather maps, and circulation around pressure systems.

- Many students watch television weather broadcasts whether on local news channels, the Weather Network, or the Internet. Students who are able to observe and understand weather phenomena and to interpret the maps on their own may develop more interest in the subject.

Barriers to Learning

- Students sometimes confuse water vapour with liquid water. It is important to stress that water vapour is an invisible gas. Haze, fog, clouds, and the steam from a boiling pot all become visible when water vapour condenses and forms small drops of liquid water.

- Students may have difficulty understanding why the thermosphere may feel very cold even though it is the warmest atmospheric layer. This can be clarified by explaining that humans sense temperature through the movement and speed of molecules colliding with their bodies (pg. 24); the lack of molecules in the thermosphere results in few of these collisions.

Engagement Strategies

Engaging Students from the Start

1. Fill a wine glass completely with water and cover it with a piece of plastic (e.g. 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.

2. Place a candle in the centre 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 percent, 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 could 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 the jar. One of the combustion products is water vapour, which condenses as the air in the jar cools. Another combustion product is carbon dioxide, which presumably goes into solution.

Other Engagement Strategies

1. Condensation of water vapour can be easily demonstrated using a tea kettle, or by showing a video of water boiling in a tea kettle. This demonstration helps students understand the invisible nature of

water vapour.

2. The introductory explanations of the air motions associated with high and low pressure areas and fronts make this a good time to begin to show and discuss satellite photographs, loops, and surface weather maps. Download a current surface weather map from the Internet and have the students discuss how the current weather outside could be explained by the position of the high and low pressure areas and fronts.

3. Show a current satellite image and a current radar image of your area from the Internet (see the links at the end of this chapter in the Instructor's Manual). Animate the image to show the changes over the past several hours. This will help students understand the movement of weather systems in terms of both speed and direction.

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

5. "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., 5* (1981), 804–5) describes a simple experiment that can be used to determine atmospheric oxygen concentrations (see also George F. Martins, "Percent Oxygen in Air," *J. Chem. Educ., 64* (1987), 809–10).

6. Some of the air pressure demonstrations described in Chapter 8 could be performed at this time.

Assessment Tools

Student Projects

1. Mark the positions of fronts and pressure systems for each day on an outline map of North America (this information can be obtained from the daily newspaper, the TV news broadcast, or the Internet.) Do this for one week, noting the general movement of these systems.

2. Compose a one-week journal or blog, including daily newspaper or Internet weather maps and weather forecasts. Write a commentary for each day regarding the coincidence of actual and forecasted weather.

3. Keep a daily record of weather conditions observed. (Periodically, the instructor can supply mean daily data such as high and low temperatures, pressure, dew point, wind speed, cloud cover, and precipitation amounts.) Plot these data and annotate the graph with observations. Use the graphs to experimentally test concepts developed in class. For example, after studying Chapter 1, determine whether periods of stormy weather are associated with lower-than-average surface pressure.

Answers to Questions for Review

1. Radiant energy from the sun.

2. Nitrogen, oxygen, argon, water vapour.

3. Water vapour.

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

5. Carbon dioxide enters the atmosphere through vegetation decay, volcanic eruptions, exhalations of animal life, burning of fossil fuels, and deforestation. Removal is by photosynthesis and deposition to oceans. Increasing carbon dioxide is due to burning of fossil fuels and deforestation.

6. Water vapour and carbon dioxide. These are greenhouse gases because they absorb longwave 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 ocean waves, 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, denser 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 vapour (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 vapour, which formed into clouds. Rain fell upon Earth for many thousands of years and large amounts of carbon dioxide were dissolved in the oceans. The atmosphere gradually became rich in nitrogen. Oxygen, the second most abundant gas in today's atmosphere, probably began an extremely slow increase in concentration as energetic rays from the sun split water vapour 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. fter plants evolved, the atmospheric oxygen content increased more rapidly, 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 denser, 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) As altitude increases, there is always less air above you (because more of it is below you).

11. (a) 101325 Pa (b) 1013.25 hPa (c) 101.325 kPa

12. About 6.5°C for every 1000 m rise in elevation.

13. On average, temperature decreases from the surface to the tropopause (about 10 km), then increases to the stratopause (about 50 km), then decreases to the mesopause (about 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 to 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 at night there is 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 kilometres at night.

19. Because the air 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. The sun releases a continuous discharge of particles. As these charged particles travel through space, they are known as solar wind. When the solar wind moves close enough to Earth, it interacts with Earth's magnetosphere. High-energy particles within the magnetosphere are ejected into Earth's upper atmosphere, where they excite atoms and molecules. The excited atmospheric gases emit visible radiation, which causes the sky to glow.

Answers to Questions for Thought

1. (a) 0.5 ATM and 0.1 ATM are equal to about 500 hPa and 100 hPa, respectively. From Figure 1.10, the 500 hPa level is found at an altitude of about 5.5 km; the 100 hPa is found at an altitude of about 16 km.
(b) The surface pressure on Mars (0.007 ATM) is about 7 hPa. A pressure of 7 hPa would be found about 35 km above Earth's surface.

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

3. The solar wind approaches Earth at an average speed of 400 km s^{-1}. During periods of many sunspots and flares, the solar wind is denser and travels faster. The speed and density is taken into account when producing a forecast.

Reflections on Teaching

- Were the students engaged in the material? What topics or concepts engaged the students most?
- What topics or concepts confused the students? Why did this occur? What should I do differently when I teach the same topics again?
- Do the assessment results suggest that students understand major concepts and how the topics relate to one another? Or do the results suggest that students are studying by just memorizing key terms?
- What do I need to change to improve student success?

- How can I receive ongoing feedback from students about my teaching?

Additional Resources

Websites

Archived North American Weather and Climate Data
http://vortex.plymouth.edu/u-make.html

Canadian National Climate Data and Information Archive
http://www.climate.weatheroffice.gc.ca/Welcome_e.html

Canadian Meteorological and Oceanographic Society
http://www.cmos.ca

Careers at Environment Canada
http://www.ec.gc.ca/emplois-jobs/default.asp?lang=en&n=39B046ED-1

Current Canadian Radar Imagery
http://www.weatheroffice.gc.ca/radar/index_e.html

Current Canadian Satellite Imagery
http://www.weatheroffice.gc.ca/satellite/index_e.html

Current Canadian Weather Data
http://weather.gc.ca/mainmenu/modelling_menu_e.html

Current North American Weather Data
http://weather.rap.ucar.edu/

Great Lakes High Resolution Satellite Imagery
http://coastwatch.glerl.noaa.gov/modis/modis.html

Ozone Layer
http://www.ozonelayer.noaa.gov

Video Clips

Aurora Borealis
http://www.theweathernetwork.com/videos/gallery/how-does-this-work-aurora-borealis/sharevideo/4132241842001

Baseball and Weather

http://www.accuweather.com/en/weather-news/changes-in-air-density-can-aff/28805375

Big Bang Theory
http://natgeotv.com/ca/known-universe/videos/big-bang

Weather Balloon Traversing the Troposphere
http://www.youtube.com/watch?v=EqPqtQrtn5Q