

## CHAPTER 15 AIR, WEATHER, AND CLIMATE

### Chapter Overview

The air flow patterns that circulate throughout Earth's atmosphere are an integral component of weather and subsequently climate. This chapter describes these patterns. Focused on climate variability and human induced climate change, this chapter provides an essential background for the next few chapters.

### Topics and Key Concepts

#### Earth Systems and Resources

- Describe and diagram the composition and structure of the atmosphere.
- Explain why weather events follow general patterns.
- Identify the characteristics of tropical cyclones.
- Describe the development of an El Niño event.

#### Global Change

- Outline the factors which result in natural climate variability.
- Discuss the scientific evidence that the current changes observed in our climate are anthropogenic.
- Discuss some environmental effects and consequences of climate change and describe viable solutions currently in development.
- Identify major greenhouse gases and their anthropogenic origin(s).

### Key Terms

*aerosol effect	greenhouse effect	Kyoto Protocol
albedo	greenhouse gas	monsoon
climate	hurricanes	ozone
cold front	Intergovernmental Panel on Climate Change (IPCC)	stratosphere
convection current	jet streams	tornado
Coriolis effect	La Niña	troposphere
cyclonic storm	latent heat	warm front
El Niño	Milankovitch cycles	weather

## Pacing Guide

Spend 5–7 days on this chapter as you study earth systems and earth processes and again as you discuss pollution, particularly with reference to greenhouse gases and their effect on the global climate change.

### Approach and Tips

The atmosphere protects us from the sun's harmful radiation in an energy balance between incoming and outgoing energy emissions. Students need to know the basic composition of the atmosphere. They should know that the atmosphere is mostly (approximately 78%) nitrogen. Students should be familiar with the layers of the atmosphere, specifically the troposphere and the stratosphere.

Many students are unclear on the difference between weather and climate. Weather is the daily temperature and moisture conditions. Weather is determined by the combination of humidity, temperature, pressure, wind, and precipitation.. Students should be familiar with basic weather concepts. Air masses in the troposphere form on the basis of temperature and the amount of moisture they contain. When two air masses meet, the boundary between them is called a front. The interactions between the air masses cause weather patterns. In addition, the AP student should understand the basic weather phenomena of tropical cyclones, including hurricanes, typhoons and tornadoes.

In contrast, climate is the long-term weather pattern for an area. Scientists obtain data on historical climates from ice cores. Gas bubbles trapped in the ice provide information on climate; atmospheric disturbances, such as volcanic eruptions; CO<sub>2</sub> concentration; and temperature variations.

Students should clearly understand the Coriolis effect and its role in climate. The rotation of the Earth creates the deflection of wind and water currents, known as the Coriolis effect. These atmospheric wind currents influence climate conditions on land and ocean water currents. If the circulation of the air mass becomes stalled, weather patterns stabilize, resulting in droughts in some areas and excess rain in others. AP students should know that ocean currents modify the climate conditions on land as water temperature moderates the temperature and rainfall patterns. Students should understand the air/ocean interactions which produce El Niño and La Niña conditions, and be able to explain the worldwide environmental impacts of these weather phenomena. Students need to know not only knowing what they are, but their significance to weather-related events as well.

Global air circulation and the rise and fall of air as it cools and is warmed can be demonstrated by heating water in a beaker and adding a few pieces of oatmeal or rice as the water begins to boil. The grains will follow a convection cell so that students can see the movement of the current.

Expand the discussion to the Coriolis effect and the sun's uneven heating of Earth and its spinning while tilted on its axis, which results in wind patterns. Use the diagram below to help explain these circulation patterns and the winds that are the product of these patterns.

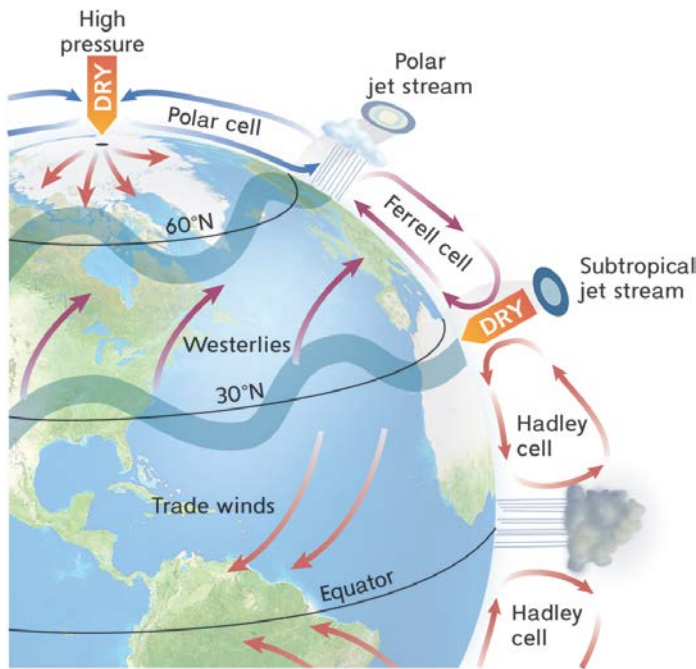
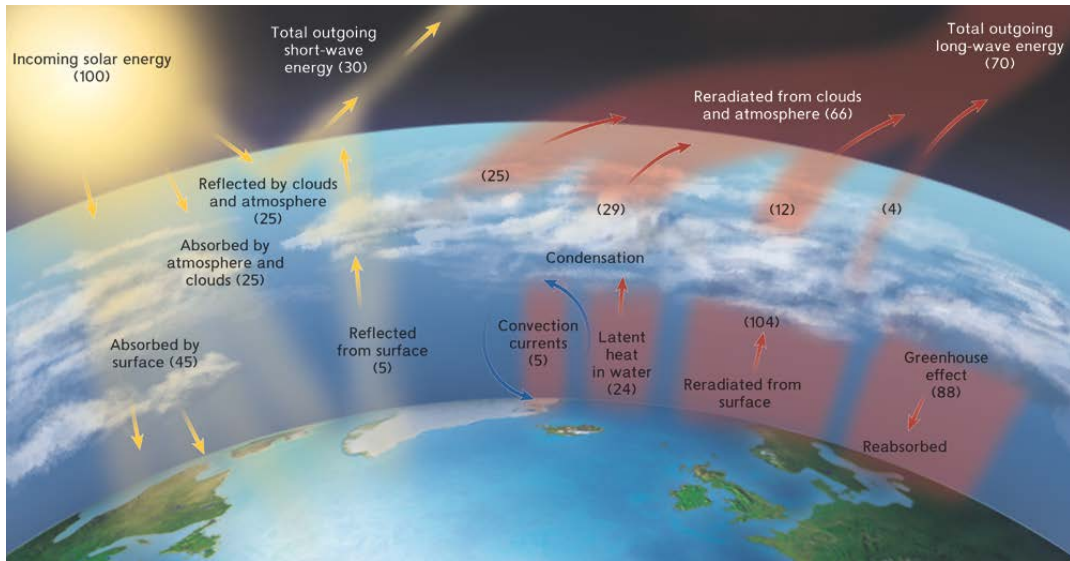
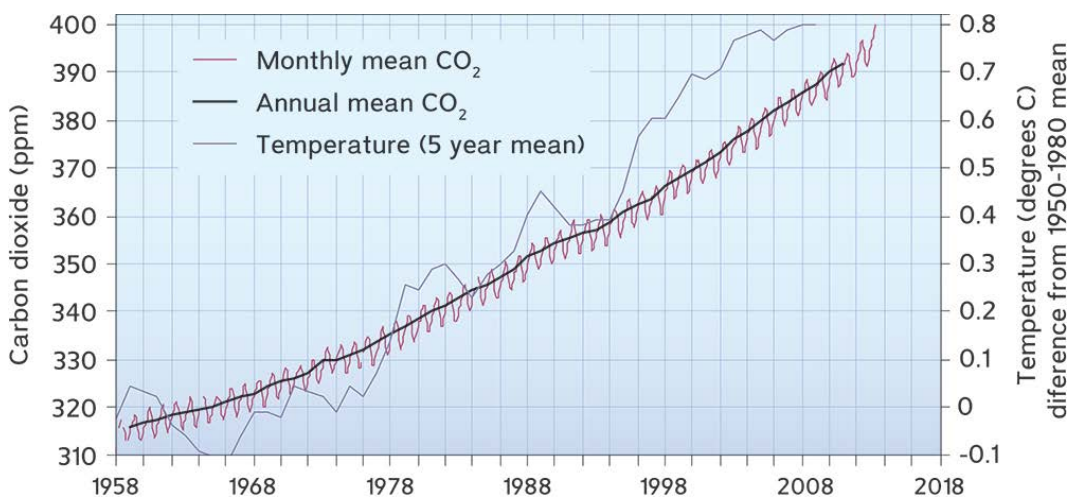


Figure 15.5 can be used to help students understand the greenhouse effect. Students must understand that the visible light heats the earth's surface. That energy is converted into infrared radiation which dissipates into space. The presence of GHGs allows us to live on earth, as due to the distance from the sun, earth is too cold to support life. Unfortunately excessive GHGs retain far too much infrared radiation (thermal radiation/heat), which increases the mean temperatures of earth. Also, make sure that students are aware that weather and climate occur in the troposphere and that global warming occurs there as well. Students need to be able to name the greenhouse gases and explain the processes that formed them in detail. Students should further be able to explain how to prevent or mediate their increase in the atmosphere due to anthropogenic causes. In addition, students should recognize the relationship between rising carbon dioxide concentrations and rising global temperature.



An excellent explanation of the contributions and impact of greenhouse gases can be seen in the film *An Inconvenient Truth*, which was released late in 2006. In the film, Al Gore gives a lecture to a group of students, explaining the process step by step. Although the film runs 100 minutes long, you can easily break it up into smaller segments and discuss the material as you move from segment to segment.

Make sure you emphasize the difference between stratospheric ozone and ozone found in the troposphere. Students often do not know the difference and cannot explain the chemical interactions between greenhouse gases that form secondary pollutants.



Students often have difficulty in interpreting graphs with multiple information axes. This is an important skill for them to develop. Use Figure 15.17 in the textbook to illustrate how to interpret these types of graphs. Make sure students practice reading these types of graphs. Give each student a question about the graph.

Students should be well versed on what scientists know about global climate change. They should be able to cite several examples as evidence of global climate change. It is important to know that scientists have used ice core data to determine Earth's level of carbon dioxide. More importantly is the notion that temperature and CO<sub>2</sub> levels exhibit a close correlation. In addition, students should realize that climate change has anthropogenic roots, primarily due to the burning of fossil fuels. Stress that the IPCC finds overwhelming evidence of anthropogenic climate change. Some students may not understand, or may even reject, the science of climate change. Focus on the science and try to remain apolitical with climate discussions. Research scientific data to support these findings and present this data to the students. Ask them to agree or refute this data. Discuss the implications of climate change as it relates to this data. Address the major greenhouse gases, water vapor, ozone, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O. Stress that atmospheric concentrations of these gases have risen dramatically. Use Figure 15.19 in the textbook to make this point.

International agreements and national legislation are important regulatory and management tools used by all nations. Students need to be able to name and explain important conventions, such as the Kyoto Protocol and Montreal Protocol, and discuss their importance in protecting the environment.

The United States has not ratified the Kyoto Protocol. Progress is being made toward reducing greenhouse gas emissions by changing fuels and technologies to manage CO<sub>2</sub> and methane levels. All students should understand what it means to be carbon neutral.

Students also need to understand steps that can be taken to reduce global concentrations of CO<sub>2</sub>. Table 15.3 (p. 341) in the textbook is a chart that contains a multitude of reduction techniques. In addition to knowing these reduction techniques, it is essential to know how these techniques work. Also stress the advantages and disadvantages in the environment by using these methods.

## **Common Mistakes and Misconceptions**

The common mistake that students make in this chapter is confusing global climate change with ozone depletion. Not only do they confuse the two concepts, they also confuse where these events are occurring. Students frequently mix up troposphere and stratosphere. Make sure your students understand that these are two entirely different concepts causing entirely different results. Also, students are confused by the controversy surrounding global climate change. The

controversy is not if Earth's climate is changing; that is already proven by temperature recording stations for a century. The controversy is if this change is natural or anthropogenic (human caused).

## Activities

### Weather and Climate Activity

This activity illustrates the difference effect of albedo. It shows students how these substances heat and cool differently, creating the different weather and climate patterns on our earth. A worksheet for this activity can be found at the end of this teacher's manual chapter.

### Lichen Activity

This is a very simple activity that blends concepts learned from earlier in the year with ones in this current chapter. Ask the students, "What is an indicator species?" Hopefully they answer correctly. Ask the students, "Do you know any indicator species that tells you about air quality?" The presence of lichens on trees indicates good air quality. If you have access to the outdoors, take the students out and look for lichens. They grow as crusty looking growths on trees. If you don't have access to outdoors, then use the internet to look at lichens. After looking at lichens, give an assignment to the students to research lichens found in their area. They are more than an important pioneer species and abound in various types.

### Supplemental Resources

More activities on global climate change can be found at <https://www.esrl.noaa.gov/gsd/education/>

## Questions for Review

1. What are the first two layers (starting on Earth's surface) of the atmosphere?  
How does burning fossil fuels affect each of these layers?  
*The atmosphere has four distinct zones of contrasting temperature, which result from differences in absorption of solar energy. The first two layers are the troposphere and the stratosphere. Burning fossil fuels puts many harmful pollutants into the atmosphere. Most of these pollutants will be found in the troposphere and will cause environmental issues. If these pollutants eventually reach the stratosphere they will remain in suspension for years.*

2. What property of water allows it to moderate different conditions on land?  
*Water has a relatively high specific heat. When water evaporates, latent heat goes with the evaporated water. It is then carried worldwide by convection currents.*
3. What action is the most important contributing factor to global climate change? Using current technologies, what is an affordable plan to reverse the trend?  
*Burning fossil fuels inputs mass amounts of sequestered CO<sub>2</sub> into the atmosphere. Since CO<sub>2</sub> is a greenhouse gas, this is seen as the biggest contributor to global climate change. Three steps that could be taken to reverse this trend are: set up an emissions trading program, share clean energy technologies, and reduce deforestation.*
4. How does global climate change affect natural ecosystems?  
*In the last 100 years the average global temperature has climbed about 0.6 °C. This has caused a shift in vegetation which can result in species migrating earlier and even disappearing. In addition, sea level has risen and coral reefs are bleaching.*
5. Why is global climate change controversial?  
*While it is based on scientific evidence, it is not easily observable. Another reason may be that change is threatening, and many of us would rather ignore it or dispute it than acknowledge it. Another is that while scientists tend to look at trends in data, the public might be more impressed by one or two recent events, such as an especially snowy winter in their local area.*



## Practice Questions

### Multiple Choice:

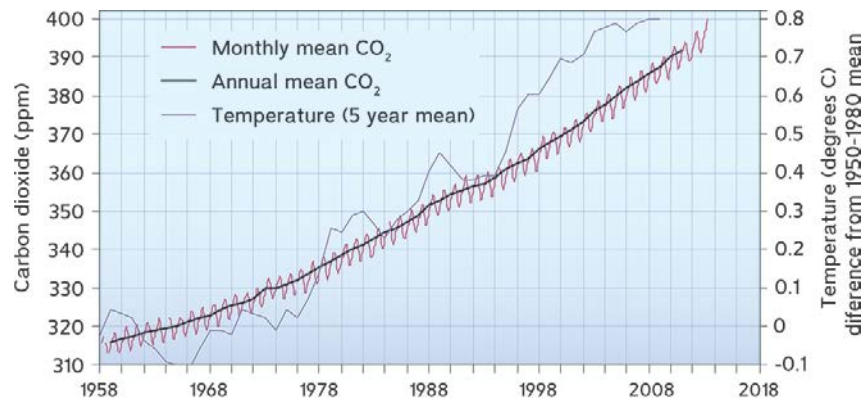
*Directions for questions 1-5:* The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

- (A) stratosphere
- (B) troposphere
- (C) El Niño
- (D) greenhouse effect
- (E) climate

1. Occurs in the equatorial Pacific Ocean.
2. Climate change is occurring here.
3. Site of ozone depletion
4. Heat trapping gases increase air temperature
5. Weather occurs here.
6. The processes that lead to global warming are \_\_\_\_\_.
  - (A) irrelevant because global warming is a hoax
  - (B) a good example of a negative feedback loop
  - (C) a good example of a positive feedback loop
  - (D) only occurring in the United States and Canada
  - (E) exacerbated by sequestration of carbon
7. Which of the following is NOT an anthropogenic disturbance?
  - (A) CFCs breaking down ozone in the atmosphere
  - (B) Increasing greenhouse gases by burning fossil fuels
  - (C) Increasing pond water temperature as a result of an industrial process
  - (D) Levees built to prevent flooding of wetlands
  - (E) Tornadic activity occurring in the Plains States
8. What is the most abundant human-caused greenhouse gas?
  - (A) CO<sub>2</sub>
  - (B) H<sub>2</sub>O
  - (C) CH<sub>4</sub>
  - (D) N<sub>2</sub>O
  - (E) NO<sub>2</sub>



Use the following graph to answer questions 9 & 10. Data taken from Mauna Loa, Hawaii.



9. What was the average annual temperature in 2000?

- (A) 0.40°C
- (B) 0.35°C
- (C) 0.50°C
- (D) 0.45°C
- (E) 0.70°C

10. What was the carbon dioxide (ppm) in 1970?

- (A) 310
- (B) 323
- (C) 330
- (D) 335
- (E) 333

Free-Response Question:

*Directions:* Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. El Niño occurs every three to five years.
  - (a) Where does El Niño occur?
  - (b) Describe two characteristics of El Niño.
    - (i) Explain the resulting weather patterns during an El Niño year.
    - (ii) Identify and describe TWO effects on natural ecosystems.
  - (c) Identify TWO characteristics of organisms that may help them to survive an El Niño year.
  - (d) Name one effect an El Niño year may have on your community.

## Answers to Practice Questions

### Multiple Choice:

1. C
2. B
3. A
4. D
5. B
6. C
7. E
8. A
9. D
10. B

### Free-Response Question:

This question is based on 10 points.

1. (a) 1 point for indicating that El Nino takes place in the equatorial Pacific Ocean.  
  
(b) 2 points total. 1 point for each description. Descriptions include upwelling currents and a warming of the water.  
  - (i) 2 points total. 1 point for indicating that certain areas will suffer from extreme drought and 1 point for indicating that other areas will suffer from intense flooding.
  - (ii) 2 points total. 1 point for the identification and description of each effect. Effects with an appropriate description would include the consequences of flooding in an area that generally doesn't flood. Loss of habitat as well as migration of certain species may also be included.
- (c) 2 points total. 1 point for each characteristic. Characteristics may include drought tolerance, r-strategists, can tolerate copious amounts of rain, ability to migrate to another area, generalist species.
- (d) 1 point for naming an effect on your community. Possible answers may include a major flood, drought for farmers.

## Answers to questions in the Student Edition:

### Case Study AP Document-Based Question (p. 324)

- (A) Wedges are a more manageable solution to climate change than a silver bullet because the technology for a silver bullet that will suddenly stop carbon emissions is not there, so a silver bullet is not possible right now. Wedges break up the problem of climate change into smaller, more manageable pieces. Many wedges are possible right now with minimal changes, making wedges a very viable solution to climate change. Economically, wedges are also easier to implement than investing a very large amount of money on the research for a silver bullet that may not work.
- (B) The four categories are efficiency and conservation, fossil fuel based strategies, renewables and biostorage, and nuclear energy. Currently, nuclear energy is the most unattainable because the technology for this strategy is not developed enough to implement. Fossil fuel based strategies are more attainable than nuclear energy, but changing from fossil fuel use is proving to be more difficult and harder to implement than previously thought, especially in developing countries. Increasing technology is making both efficiency and conservation and renewables and biostorage easier to implement.

### Use the Math (p. 329)

The summer monsoon season accounts for 62.5% of the eastern Himalayas' annual rainfall ( $75/120 \times 100$ ).

## AP Connections Review Answers (pages 347-348)

### Multiple-Choice Questions

1. c. Ozone in the stratosphere protects the earth from ultraviolet radiation.
2. a. An El Niño will result in all of the following environmental effects except increased hurricanes in the southern United States. The hurricane number declines in an El Niño year.
3. d. A warm front produces the least amount of precipitation.
4. a. Animal feedlots release nitrogen oxide and methane, but not carbon dioxide.
5. a. Oxygen was not present in the atmosphere until photosynthesis evolved as a method to capture the sun's energy.
6. e. Forests exhibit the least albedo.

### Data Analysis & Free-Response Questions

- 1a The average 1961-1990 temperature is 14°C. This is the point on the graph (0°C) where there is no difference between the 1961-1990 average temperature and the current temperature.

1b The slope is approximately 1 (x, y points are: [2000, 50], [1900, -50]). The graph infers that the average sea level is increasing over time.

1c The global average temperature in 2050 will be  $14.6^{\circ}\text{C}$ , assuming that the rate of increase matches that seen from 1950-2000 (x, y points are [2000, 0.4], [1950, -0.2] indicating a rate of increase of  $0.6^{\circ}\text{C} / 50$  years. Therefore, in 2050, we can expect an increase of  $0.6^{\circ}\text{C}$  from the average  $14^{\circ}\text{C}$ ).

2a Weather is temperature, pressure, wind, and precipitation that changes over days or weeks. Climate is the description of the long-term pattern of weather in a particular area, an average over decades-long intervals.

2b Answers will vary but could include examples of increases in rainfall or drought, changes in sea level, temperature, and snow cover and the accompanying scientific evidence behind these.

2c Answers will vary.

## Weather and Climate Activity Worksheet

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Student: \_\_\_\_\_

### Materials:

Three waterproof containers, three thermometers, a heat lamp and ring stand, light sand, dark colored sand, and water.

### Procedure:

1. Fill the three containers with the light sand, the dark sand, and the water, respectively to the same height.
2. Take the initial temperature of each of the materials.
3. Turn on the heat lamp and place it so that it equally distributes heat to each of the containers.
4. Take the temperature of each of the materials every 5 minutes for 25 minutes.
5. Now, turn the heat lamp off and continue taking the temperature of each of the materials as they cool for the next 15 minutes.
6. Record your data in the table below:

LAMP ON:							LAMP OFF:		
Time	Initial	5mins	10mins	15mins	20mins	25mins	5mins	10mins	15mins
Water temp:									
Light sand temp:									
Dark sand temp:									

Conclusions:

1. Which of the three materials heated the fastest? Why?
2. Which of the three materials cooled the fastest? Why?
3. What can you conclude from these results?
4. What do these tell you about the heating and cooling of Earth? Think in terms of the amount of land vs. water on our planet.
5. How would these results affect the weather on Earth?