

Chapter 15 - Air, Weather, and Climate

Key Terms

aerosols	greenhouse effect	stratosphere
albedo	hurricane	tornado
climate	jet stream	tropical cyclone
cold front	Kyoto Protocol	troposphere
convection currents	La Niña	warm front
Coriolis effect	latent heat	weather
downbursts	Milankovitch cycles	
El Niño Southern	monsoon	
Oscillation Event	ozone	

Skills

1. Characterize human contributions to global climate change. Outline the effects climate change is having on ecosystems.
2. Discuss the composition and layers of the atmosphere.
3. Explain how climate is generated by the prevailing winds, ocean currents, jet streams, and continental geography.
4. Identify and describe weather hazards.
5. Examine El Niño and La Niña impacts on global weather. Identify the physical phenomena that generate an El Niño Southern Oscillation Event.

Take Note: You are expected to understand basic information regarding the earth's atmosphere, weather, and climate. The weather determines the biomes that are present throughout the earth. Released multiple-choice questions have examined convection currents, fronts, and weather hazards.

The Atmosphere

The atmosphere has four layers. Closest to the surface of the earth is the troposphere, followed by the stratosphere, mesosphere, and thermosphere. Air circulates in the troposphere because warmer air rises and colder more dense air sinks, forming convection cells. Gravity causes the troposphere to be the densest of all of the layers. The troposphere is comprised of 78 percent N_2 , 21 percent O_2 , a little less than 1 percent argon, and 0.035 percent CO_2 . Water vapor varies regionally from 0-4 percent. Aerosols, created by suspended solid and liquid particles, are important in reflecting sunlight and in serving as condensation nuclei for cloud formation.

The stratosphere is less dense than the troposphere and contains a layer of ozone, responsible for absorbing UV-B radiation. The ultraviolet radiation would damage living tissues, so the stratospheric ozone layer is responsible for allowing the evolution of and continued survival of life on land. Stratospheric ozone is decreasing due to human pollution, primarily from released chlorofluorocarbons (CFCs). The increased levels of UV-B are likely to increase human skin cancers

and cataracts; damage plant tissues, which will lower crop productivity; and decrease biodiversity due to loss of UV sensitive species. The mesosphere forms between the stratosphere and the thermosphere. The thermosphere is heated by solar and cosmic radiation. The northern and southern lights, aurora borealis, and aurora australis, are caused by the glowing of ions in the lower thermosphere.

Weather is the daily changes in precipitation and temperature. An area's climate is the long-term weather patterns observed in the area.

The Sun and Convection Cells

The sun's energy is focused more directly on the equator than the poles, which makes the equator hotter than the poles. One-fourth of the sun's energy is reflected back into space by the atmosphere and another quarter is absorbed by atmospheric gases. Some of the energy that reaches earth is reflected back into space due to the albedo effect of light surfaces, such as snow, sand, and ice. Much of the remainder of the energy is absorbed by darker surfaces, which heats the earth. Some of the absorbed energy (about 1 percent) is used for photosynthesis and the rest serves to increase evaporation of water. The energy from the sun is ultimately transformed into the less useful, more stable thermal energy, as expected based upon the second law of thermodynamics. Most of this energy, now longer wavelength infrared energy, is trapped in the earth's atmosphere for the most part, which has the net effect of warming the earth. The phenomenon is known as the greenhouse effect, because the infrared energy is kept from exiting the earth's atmosphere by gases, much like the heat in a greenhouse is prevented from leaving due to the glass walls. This effect is exacerbated by human activities such as deforestation and fossil fuel combustion, resulting in a greater heating of the earth's surface. The sun not only heats the earth, it also serves to drive the hydrologic cycle by promoting evaporation. Water contains stored energy, known as latent heat. The evaporated water then moves via air currents to other parts of the globe.

The uneven heating of the earth's surface causes the warmer air to rise and the cooler air to sink, creating convection cells. All of the large convection cells on earth create the global circulation patterns for air. The air patterns contribute to the global circulation patterns for water.

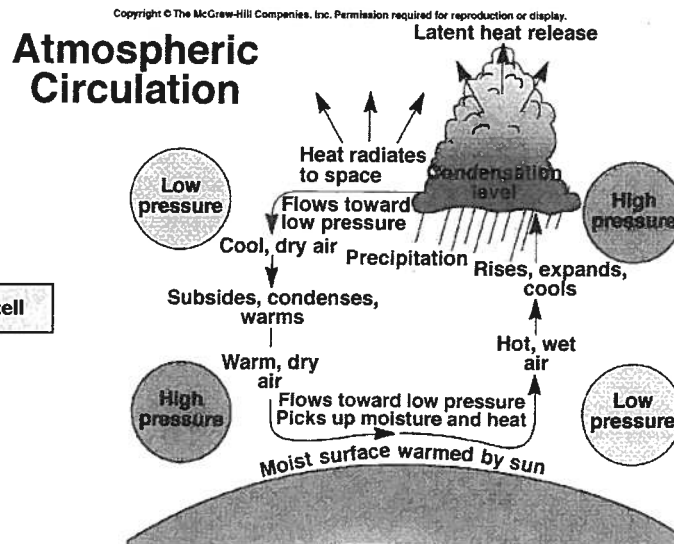
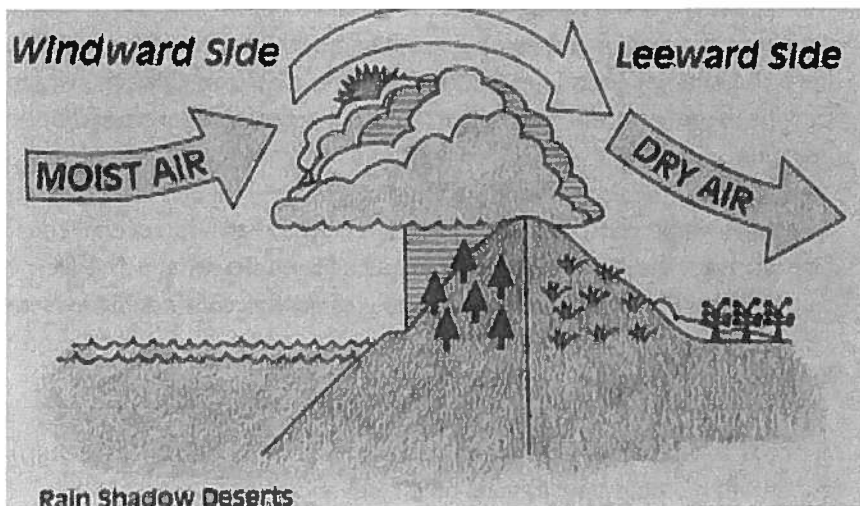


Figure 15.1 Convection cell

Precipitation

As the water in the atmosphere condenses when the air cools, the water droplets form clouds around condensation nuclei. Areas with high levels of precipitation have atmospheric circulation that contributes to the rising and cooling of the warm moisture laden surface air. These areas include regions with colliding air masses, the windward side of mountains, and around the equator. Sinking dry air occurs at 30° north and south of the equator and on the leeward side of mountains. In these regions, deserts form. The formation of deserts on the dry, leeward side of mountains is attributed to the rain shadow effect. The clouds release their moisture as they rise, so only the windward side of mountains receive precipitation, thus creating a "shadow" that lacks rain on the opposite side of the mountain.

15.2 Rain shadow effect



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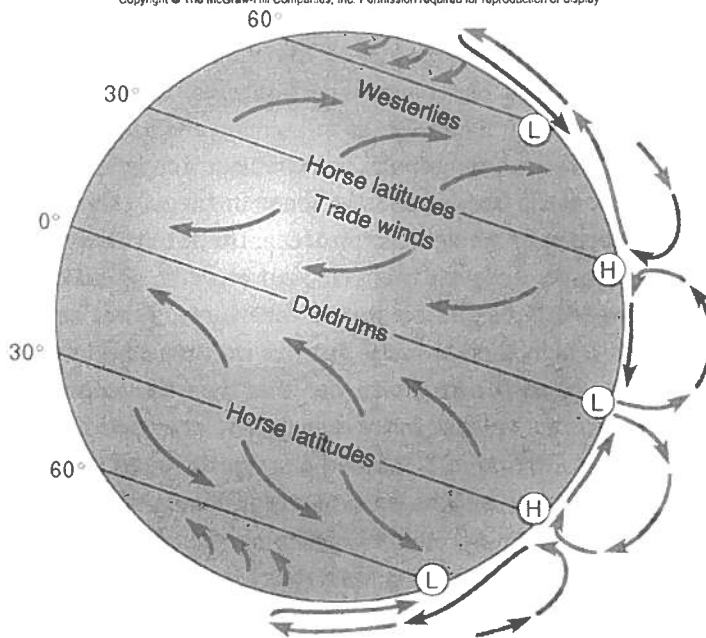


Figure 15.3 Global circulation patterns

Wind and Ocean Currents

Due to the eastward rotation of the earth, winds in the northern hemisphere deflect to the right (clockwise) and winds in the southern hemisphere deflect to the left (counterclockwise). This deflection is known as the Coriolis effect. This effect creates the wind patterns observed in figure 15.3. Overlying wind patterns known as jet streams also circulate the earth in the troposphere. These jet streams cannot be felt on the ground, but they have a profound impact on weather. These winds are not stationary and dip down into lower or higher latitudes.

The surface ocean currents also move in a pattern similar to the winds, creating deep ocean currents. Ocean currents are also influenced by the circulation of the wind. Differing density of water, due to changes in temperature and salinity, also play a role in ocean circulation. The cycling currents formed in the large oceans of earth are known as gyres, and they distribute heat from the lower to the upper latitudes. For example, the Gulf Stream, which flows from the Caribbean to Europe, creates a warmer microclimate in England than would be expected based upon England's latitude.

Seasonal winds and rains, known as monsoons, form in several tropical regions. These rains occur as hot air over the ocean is blown across continents, where the air rises, creating precipitation. Subtropical or tropical areas typically experience dry and wet seasons.

Fronts

A front is a boundary between two air masses of different density and temperatures. Cold fronts occur when a cold dense mass of air advances on a warmer mass. The cold mass sinks under the warm mass, creating strong thunderstorms and rain. Clouds associated with a cold front are called thunderheads, and they are shaped like an anvil. Warm fronts occur when a warm air mass advances on a cooler air mass. The warm air rises, resulting in drizzle and clouds throughout several levels of the troposphere.

Severe Weather

Severe weather includes tropical cyclones and tornadoes. Tropical cyclones, called hurricanes in the Atlantic and eastern Pacific and typhoons in the western Pacific, are generated when a low-pressure system develops over warm ocean water. The latent energy released by condensation causes convection cells to increase their circulation rate. The spinning storm has high wind speeds that increase in intensity as the center of the storm is reached. The damage from a hurricane is not only due to the high wind speeds, but the water pushed ashore by the rapidly moving winds. This wall of water, called the storm surge, is extremely dangerous due to the rapid rate at which it rises on land. Hurricanes release large amounts of precipitation and spawn tornadoes as they move over land. Hurricane Katrina in 2005 had a storm surge of 29 feet and had 145 mile an hour winds. The coastal devastation is still being evaluated, but entire towns were destroyed.

Tornadoes occur when a strong, dry cold front collides with warm, humid air. The greater the temperature differences of the air masses, the more severe the tornado. As the warm air rises over the cold air, internal convection currents strengthen, forming the tornado. When the storm

touches the ground the devastation is tremendous. If the spinning action of the tornado does not begin, a downburst may occur. Downbursts are powerful downdrafts of air that can generate extremely high winds and property damage. Hail is frequently present during tornadoes because the water particles are drawn up the tornado then sink again. The cycle repeats until the hail is too heavy to fly upwards again.

Climate and Climate Change

Through study of polar ice sheets, a correlation has been established between carbon dioxide levels and mean global temperatures. When climate change is slow, populations can undergo natural selection to become better suited to the new climate, or they can migrate to a more suitable climate. If the climate change occurs rapidly, organisms will die out because they are not adapted to the new climate. An example of this mass death due to climate change occurred 65 million years ago at the end of the Cretaceous period. This mass extinction due to global cooling killed all of the dinosaurs, which opened up numerous niches to allow adaptive radiation of mammals.

There are thought to be several explanations for major climate shifts. There are changes in the sun's energy output over time. There are also shifts in the moon's orbit, which alter tides and circulation, thus affecting climate. Milankovitch cycles, periodic shifts in the earth's tilt and orbit, also explain extreme climate shifts. Volcanoes that produce massive amounts of ash and sulfur dioxide would cause global temperatures to drop quickly.

Take Note: You must be familiar with the changes in global climate associated with an El Niño Southern Oscillation event (ENSO). One essay question asked about the cause of an ENSO and the relationship of disease transmission to the altered climate.

El Niño Southern Oscillation Event

The El Niño Southern Oscillation event (ENSO) is comprised of an El Niño and the intervening years called La Niña. The event is named El Niño because Peruvian fishermen noted that the phenomenon tended to begin in December around Christmas, so they named it *el niño* for little boy, or Jesus. The root cause of an El Niño is a slowing of the equatorial trade winds that holds warm water in the Pacific Ocean close to Indonesia. The slowing of the trade winds allows the warm waters to move across the Pacific to South America. This slowing of the equatorial winds occurs roughly every three to five years and last about a year. This warm water inhibits the upwelling that occurs along the continental edge of South America. Upwelling brings the cool, nutrient-rich waters from the ocean floor up to the surface. The upwelling provides nutrients that support algal growth that then serves as a food supply for the anchovies that are so important to the South American people and wildlife. Of late, these events are stronger and more irregular than in the past. Although El Niño takes place in the Pacific Ocean, there are effects felt globally, as well. In the western United States, which borders the Pacific, there is greater moisture in the air, resulting in more damaging storms and heavy rains. Many mudslides occur in California during El Niño events. The northwestern United States tends to be sunny instead of its typical rain. The likelihood of hurricanes in the Atlantic are diminished because the jet stream usually in Canada drops farther south and inhibits hurricane formation. Australia and Indonesia experience severe drought.

Take Note: All students enrolled in an AP environmental course are expected to have a thorough understanding of global climate change; the origins of the gases involved; methods to reduce the greenhouse effect; and the expected impacts of the climate change, including human health impacts and environmental impacts. The 2006 AP exam had one entire essay about global warming. It is imperative that you are familiar with the following material.

Global Warming

Humans are playing a role in the increase in global temperatures. Greenhouse gases include CO_2 , methane, water vapor, N_2O , and CFCs. CO_2 levels are so low in the atmosphere, any slight increase has a profound impact on the global climate. The oscillations in the line shown in figure 15.4 can be attributed to the seasonal changes in CO_2 in the atmosphere due to increased photosynthesis in the summer months in the northern hemisphere.

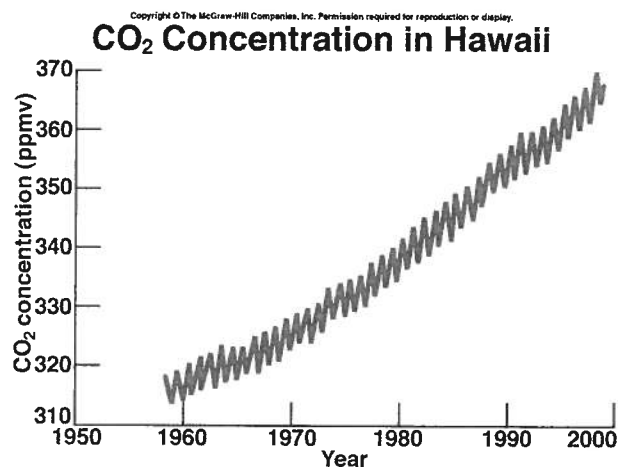


Figure 15.4 Carbon dioxide levels in the atmosphere

Anthropogenic carbon dioxide is produced during combustion of fossil fuels, biomass, and refuse. Deforestation contributes to high levels of CO_2 in the atmosphere because the forests serve as carbon sinks and they can no longer remove CO_2 from the atmosphere. Methane is 20 times more efficient at holding heat in the atmosphere than is CO_2 . Methane is released during decomposition in landfills and during recovery and processing of petroleum. CFCs also absorb infrared energy. Nitrous oxide comes primarily from livestock feedlots and combustion of organic material.

Sulfur dioxide acts in opposition to the greenhouse gases. It forms a sulfur aerosol that reflects sunlight and results in global cooling.

In 1988 the Intergovernmental Panel on Climate Change was formed to address global temperature increases. The panel concluded that humans are playing a role in climate change. Climate change will have a profound impact on glaciers. As the earth warms, continental glaciers will melt, causing rising sea levels. The rising sea levels will dramatically impact human settlements in coastal areas. As the glaciers melt, the albedo effect will decrease, resulting in less sunlight reflected into space, which will further increase the global temperature. Krill, an important food for numerous marine species, will also decline as a result of the ice sheets melting. The loss of this food source will have a dramatic impact for the organisms that feed upon them. The organisms will have to migrate or

face extinction. Droughts are becoming more frequent and widespread. Amphibians are vanishing in large numbers throughout the world, and their disappearance has been linked to the increasing global temperatures. Infectious disease is likely to increase in many areas as insects move to new regions due to the climate change. Mosquitoborne illnesses such as malaria, West Nile Virus, and dengue are springing up in new locales. Although increased CO_2 will likely have a negative impact on animal species, some plants will thrive with additional CO_2 available for photosynthesis.

Kyoto Protocol

At the 1992 Rio Earth Summit, the Framework Convention on Climate Change created a goal of stabilizing greenhouse gases to reduce global warming. A subsequent conference in 1997 was held in Kyoto, Japan. At this conference 160 countries agreed to reduce greenhouse gas levels to below the 1990 levels by 2012. This agreement is known as the Kyoto Protocol and has now been signed by all industrialized countries except Monaco, Liechtenstein, Australia, and the United States. Poor countries such as China and India are exempt from the reduction agreement as they are encouraging development to improve their standard of living. The United States was very influential in generating the Kyoto agreement under President Clinton's administration, but President Bush has refused to sign it. As a result, American companies that have production facilities in other nations may face sanctions and other penalties due to the president's refusal to sign the treaty. The agreement establishes pollution credits that can be bought or sold.

Reducing Greenhouse Gas Emissions

The easiest way to reduce greenhouse gas emissions is to promote energy conservation and efficiency. Natural gas can also be used to generate electricity instead of oil or coal because it releases less CO_2 . Nuclear power and the alternative energy resources of wind, solar, geothermal, and hydroelectric reduce greenhouse gas emissions. Mass transit, carpooling, and bicycling will decrease CO_2 from gasoline combustion. Planting trees creates forests that serve as carbon sinks. CO_2 can be piped underground for long-term storage.

Chapter 15 Questions

Use the following choices for questions 1-4.

- a. methane
- b. nitrous oxide
- c. carbon dioxide
- d. CFCs
- e. sulfur dioxide

1. greenhouse gas emitted by feedlots and decomposition in landfills
 2. greenhouse gas increased due to deforestation
 3. gas that contributes to global cooling
 4. greenhouse gas that arises from fossil fuel combustion and from agricultural fields after fertilizer is applied
5. Ozone in the stratosphere protects earth from
- a. cosmic rays.
 - b. meteorites.
 - c. ultraviolet radiation.
 - d. infrared radiation.
 - e. microwaves.
6. The gas not found in earth's early atmosphere was
- a. oxygen.
 - b. hydrogen.
 - c. nitrogen.
 - d. methane.
 - e. carbon dioxide.
7. Which of the following exhibits the least albedo?
- a. snow
 - b. icepack
 - c. sand
 - d. water
 - e. forests
8. An El Niño will result in all of the following environmental effects except
- a. increased hurricanes in the southern United States.
 - b. increased death of sea lions in the Galapagos Islands.
 - c. decreased precipitation in Australia.
 - d. increased mosquitoborne disease in tropical areas.
 - e. decreased rain in the northwestern United States.
9. Which of the following weather events results in the least amount of precipitation?
- a. hurricane
 - b. typhoon
 - c. cold front
 - d. warm front
 - e. monsoon
10. All of the following increase carbon dioxide emissions except
- a. animal feedlots.
 - b. deforestation.
 - c. burning fossil fuels.
 - d. incineration.
 - e. combustion of biomass.

Chapter 15 Answers

1. a. Methane is a greenhouse gas emitted by feedlots and decomposition in landfills.
2. c. Carbon dioxide is a greenhouse gas increased due to deforestation.
3. e. Sulfur dioxide contributes to global cooling by creating a sulfur aerosol.
4. b. Nitrous oxide is the greenhouse gas that arises from fossil fuel combustion and from agricultural fields after fertilizer is applied.
5. c. Ozone in the stratosphere protects the earth from ultraviolet radiation.
6. a. Oxygen was not found in the earth's early atmosphere. It did not arise until photosynthetic organisms evolved.
7. e. Forests are dark in color, thus they exhibit the least albedo.
8. 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.
9. d. A warm front produces the least amount of precipitation.
10. a. Animal feedlots release nitrogen oxide and methane, but not carbon dioxide.