CHAPTER 6

Atmospheric Composition

IN THIS CHAPTER

Summary: The atmosphere, made up of different distinct layers, is constantly changing. These changes and air circulations make up and affect the world's weather and climate.

KEY IDEA

Keywords

✪ Atmosphere, aurora, wind chill, jet stream, barometer, temperature inversion, Coriolis effect, tornado, hurricane, cyclone, El Niño, solar intensity, latitude

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Composition

Many people think of weather when they hear the word *atmosphere.* People tend to talk about the weather and how the heat, cold, snow, wind, or rain will impact their weekend plans. Often they turn to the local weatherperson for the local or long-range forecast. A *meteorologist* is a person who studies the weather and its atmospheric patterns.

KEY IDEA

> Weather describes the atmosphere's condition at a given time and place with respect to temperature, moisture, wind velocity, and barometric pressure.

Atmospheric gases blanketing the Earth exist in a mixture made up of about 79% nitrogen (by volume), 20% oxygen, 0.036% carbon dioxide, and trace amounts of other gases. Air is the common name for this gaseous mix.

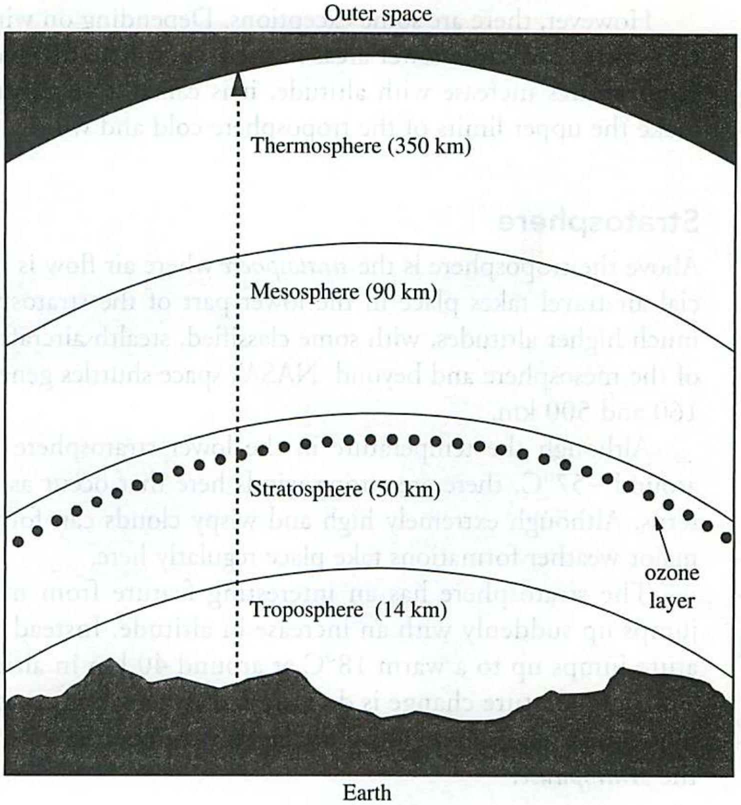

Figure 6.1 The atmosphere is divided into four main layers.

Atmospheric Layers

The atmosphere is divided into layers affected by gas mixing, chemical properties, and temperature. Nearest the Earth, the *troposphere* is about 8 km in altitude in the polar regions to 17 km around the equator. The layer above the troposphere is the *stratosphere,* reaching an altitude of around 50 km. The *mesosphere* stretches 80 to 90 km and lies above the stratosphere. Finally, the *thermosphere,* or *ionosphere,* is further out and fades to the black of outer space. Figure 6.1 illustrates these layers.

Troposphere

The atmospheric layer closest to the Earth's surface is the troposphere. Nearly all human activities occur in the troposphere, since living organisms are protected from the harmful cosmic radiation showers constantly raining down on the Earth's atmosphere.

The troposphere is where all the weather that we experience takes place. If you have ever survived a hurricane or tornado, you know it's an active place. Rising and falling temperatures, circulating air masses, and air pressure keep things lively.

When measured next to other layers, the troposphere is fairly slim, extending only 17 km up from the Earth's surface.

KEY IDEA

The *troposphere* is where all the local temperature, pressure, wind, and precipitation changes take place.

The warmest portion of the troposphere is found at the lowest altitudes. This is because the Earth's surface absorbs the sun's heat and radiates it back into the atmosphere. Commonly, as altitude increases, temperature decreases.

However, there are some exceptions. Depending on wind currents and the like, mountain ranges can cause lower areas in the troposphere to have just the opposite effect. When temperatures increase with altitude, it is called a *temperature inversion.* The wind speeds make the upper limits of the troposphere cold and windy.

Stratosphere

Above the troposphere is the *stratosphere* where air flow is mostly sideways. Most commercial air travel takes place in the lower part of the stratosphere. Military aircraft travel at much higher altitudes, with some classified, stealth aircraft thought to graze the boundary of the mesosphere and beyond. NASA's space shuttles generally travel to altitudes between 160 and 500 km.

Although the temperature in the lower stratosphere is cold and constant, hovering around −57°C, there are strong winds here that occur as part of specific circulation patterns. Although extremely high and wispy clouds can form in the lower stratosphere, no major weather formations take place regularly here.

TIP

The stratosphere has an interesting feature from midlevel on up. Its temperature jumps up suddenly with an increase in altitude. Instead of a frosty −57°C, the temperature jumps up to a warm 18°C at around 40 km in altitude in the upper stratosphere. This temperature change is due to increasing ozone concentrations that absorb ultraviolet radiation. The melding of the stratosphere upward into the mesosphere is called the *stratopause.*

Mesosphere

Above the stratosphere is the *mesosphere,* a middle layer separating the lower stratosphere from the inhospitable thermosphere. Extending from 80 to 90 km and with temperatures to around −101°C, the mesosphere is the intermediary of the Earth's atmospheric layers.

Thermosphere

The mesosphere changes to the *thermosphere* at a height of around 80 km. The thermosphere has rising temperatures that can reach an amazing 1,982°C. Thermospheric temperatures are affected by high or low sun spot and solar flare activity. The greater the sun's activity, the more heat is generated in the thermosphere.

Extreme thermospheric temperatures are a result of ultraviolet radiation absorption. This radiation enters the upper atmosphere, grabbing atoms from electrons and creating positively charged ions. This ionization gives the thermosphere its other name, the *ionosphere.* Because of ionization, the lowest area of the thermosphere absorbs radio waves, while other areas reflect radio waves. Since this area decreases and disappears at night, radio waves bounce off the thermosphere. This is why far distant radio waves can often be received at night.

Electrically charged atoms build up to form layers within the thermosphere. Before modern satellite use, this thermosphere deflection was important for long-distance radio communication. Today, radio frequencies able to pass through the ionosphere unchanged are selected for satellite communication.

The thermosphere is where the *aurora* resides. The *Aurora Borealis* and *Aurora Australis,* also known as the northern and southern lights, are seen in the thermosphere. When solar flares hit the magnetosphere (the region directly above the thermosphere) and pull electrons from atoms, they cause magnetic storms near the poles. Red and green lights are seen when scattered electrons reunite with atoms, returning them to their original state.

Seasons

The Earth's rotation around the sun, combined with its axial tilt, allows for different seasons: summer, winter, fall, and spring. Depending on the region, different amounts of solar energy strike the Earth at various times of the year. The equator gets the most, and the poles the least. Distance from the equator and the intensity of solar radiation have a direct effect on seasonal changes.

Latitude

Warm equatorial air vapor moves northward, cools, and condenses to fall as rain or snow depending on the season. Heat and moisture are distributed in global circulation patterns from the equator to the northern latitudes. Vertical convection currents, known as *Hadley cells,* have low-pressure circulation and rising air. High-pressure circulation cells occur where air sinks.

Solar Intensity

A *solar radiation unit* of measurement is 1 langley, which is equal to 1 calorie per square centimeter of the Earth's surface (i.e., 3.69 British thermal units [Btu] per square foot). Solar radiation is also stored in materials like water and soil.

Incoming solar energy also evaporates water into vapor. As the water changes form, it releases stored energy known as *latent heat.* Then, when water vapor reverts to liquid form, it releases 580 calories of heat energy. When this takes place over large bodies of water like an ocean, evaporation converts huge amounts of solar energy into latent energy.

Coriolis Effect

In physics and math, the *Coriolis effect* is a perceived deflection of moving objects viewed from a turning frame of reference. The Coriolis effect was named in 1835 after a French mathematician, Gustave Gaspard Coriolis, who published a set of equations explaining how objects acted in theoretical rotating systems. Although his research was not applied to the atmosphere, it explained directional winds across the globe. The nearly constant easterly winds that dominate most of the tropics and subtropics are known as trade winds. This is an optical illusion such that air moving from the north pole seems to turn right (northern hemisphere) and left (southern hemisphere) due to the Earth's rotation. This is *not* a result of the Earth's curvature or gravitation, but of rotation. Figure 6.2 illustrates the Coriolis effect and wind rotation.

Jet Stream

When watching the evening weather report, chances are good you will hear something about the *jet stream.* This speedy current is commonly thousands of kilometers long, a few hundred kilometers wide, and only a few kilometers thick. Jet streams are found between 10 to 14 km above the Earth's surface in the troposphere. Blowing from west to east at speeds of 240 km/h, they can also dip northward or southward depending on atmospheric conditions.

KEY IDEA

> The *jet stream* is a long, narrow current of fast moving air found in the upper atmospheric levels.

Air temperature differences drive the jet stream. The bigger the temperature differences, the stronger the pressure differences between warm and cold air. Strong pressure differences create strong winds. This is why jet streams fluctuate so much in speed.

During the winter months, polar and equatorial air masses form a sharp surface temperature contrast causing an intense jet stream. The strong jet stream pushes farther south

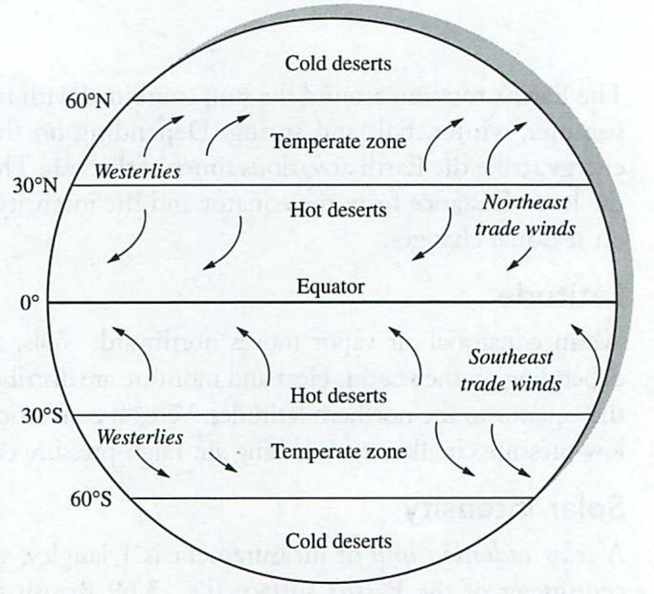

Figure 6.2 Trade winds are found at certain latitudes or regions on the Earth.

in the winter. However, during the summer months, when the surface temperature difference is less severe, jet stream winds are weaker. The jet stream then moves farther north.

Wind Chill

KEY IDEA

> *Wind chill factor* measures the rate of heat loss from exposed skin to that of surrounding air temperatures.

Wind chill occurs when winter winds cool objects down to the temperature of the surrounding area; the stronger the wind, the faster the rate of cooling. For example, the human body is usually around 36°C in temperature, a lot higher than a cool Montana day in November. Our body's heat loss is controlled by a thin insulating layer of warm air held in place above the skin's surface by friction. If there is no wind, the layer is undisturbed and we feel comfortable. However, if a wind gust sweeps this insulating layer of air away, we feel

Table 6.1 Wind chill can bring down the temperature of the body quickly.

	TEMPERATURE (°C)							
Wind speed (km/h)	−15°C	−10°C	−5°C	0°C	5°C	10°C	15°C	20°C
0	−15	−10	−5	0	5	10	15	20
5	−18	−13	−7	−2	3	9	14	19
10	−20	−14	−8	−3	2	8	13	19
30	−24	−18	−12	−6	1	7	12	18
50	−29	−21	−14	−7	0	6	12	18
70	−35	−24	−15	−8	−1	6	12	18
90	−41	−30	−19	−9	−2	5	12	18

chilled. The protective air layer must be reheated by the body. See Table 6.1 to get an idea of the wind chill equivalent temperatures at different wind speeds.

Air Pressure

Bakers living in the mountains have to consider air pressure when creating light cakes and soufflés. Lower pressure at high altitudes (over 6,000 km) changes the baking process from that of sea-level baking. In fact, cake mixes give different directions for high-altitude baking to make up for the pressure difference on the rising cake.

KEY IDEA

Air pressure is the force applied on you by the weight of air molecules.

Although air is invisible, it still has weight and takes up space. Free-floating air molecules are pressurized when crowded into a small volume. The downward force of gravity gives the atmosphere a pressure or a force per unit area. The Earth's atmosphere presses down on every surface with a force of kilogram (kg) per square centimeter. The force on 1,000 cm^2 is nearly a ton!

Weather scientists measure air pressure with a *barometer.* Barometers measure air pressure in centimeters of mercury or *millibars.* A measurement of 760 mm of mercury is equal to 1013.25 millibars.

Air pressure tells us a lot about the weather. With a high-pressure system, there are cooler temperatures and sunny skies. When a low-pressure system moves in, look for warmer temperatures and thunderstorms.

TIP

Atmospheric pressure falls with increasing altitude. A pillar of air in cross section, measured from sea level to the top of the atmosphere, weighs approximately 14.7 pounds per square inch (psi). Atmospheric pressure (atm) at sea level is equal to

$$\begin{aligned} 1 \text{ atm} &= 760 \text{ mmHg (millimeters of mercury)} = 1013 \text{ millibars} \\ &= 14.7 \text{ psi} = 1013.25 \text{ hPa (hectopascals)} \end{aligned}$$

On weather maps, changes in atmospheric pressure are shown by lines called *isobars.* An isobar is a line connecting areas of the same atmospheric pressure. It's very similar to the lines connecting equal elevations on a topographical map.

Relative Humidity

Growing up in a dry western state where a humid day had 10% humidity and then moving to the Texas Gulf Coast with months of 100% *humidity* was a shock. But what is humidity, anyway? Humidity is the amount of water vapor in the air.

KEY IDEA

Relative humidity is the link between the air's temperature and the amount of water vapor it contains.

At any specific temperature, there is a maximum amount of moisture that air can hold. For example, when the humidity level is forecast at 75%, it means that the air contains $\frac{3}{4}$ of the amount of water it can hold at that temperature. When the air is completely saturated and can't hold any more water (i.e., 100% humidity), it rains.

Since the air's ability to hold water is dependent on temperature, hotter air holds more moisture. This temperature-dependent, moisture-holding capacity contributes to the formation of all kinds of clouds and weather patterns.

Tornadoes

As speeding cold fronts smash into warm humid air, a convection of temperature and wind is formed. Winds in tornadoes can easily reach speeds of over 250 km/h. Large tornadoes contain the fastest winds ever measured on the Earth and have been recorded at over 480 km/h.

Tornadoes are usually classified into one of the following three different levels:

1. *Weak tornadoes* (F0/F1) make up roughly 75% of all tornadoes. They cause around 5% of all tornado deaths and last approximately 1 to 10 minutes with wind speeds <180 km/h.
2. *Strong tornadoes* (F2/F3) make up most of the remaining 25% of all tornadoes. They cause nearly 30% of all tornado deaths and last 20 minutes or longer with wind speeds between 180 and 330 km/h.
3. *Violent tornadoes* (F4/F5) are rare and account for less than 2% of all tornadoes, but cause nearly 65% of all tornado deaths in the United States. They have been known to last for one to several hours with extreme wind speeds of 330 to 500 km/h.

In the late 1960s, University of Chicago atmospheric scientist T. Theodore Fujita realized that tornado damage patterns could be predicted according to certain wind speeds. He described his observations in a table called the *Fujita Wind Damage Scale.* Table 6.2 shows the Fujita scale used today with its corresponding wind speeds and surface damage.

Table 6.2 A tornado's strength is rated by the Fujita Wind Damage Scale.

TORNADO RATING	TYPE	SPEED	DAMAGE
F0	Gale	64–116 km/h (40–72 mph)	Light damage: some damage to chimneys, tree branches break, shallow-rooted trees tip over and sign boards damaged.
F1	Moderate	117–180 km/h (73–112 mph)	Moderate damage: beginning of hurricane wind speeds, peels roofs, mobile homes moved off foundations or overturned, and moving cars shoved off roads.
F2	Significant	181–251 km/h (113–157 mph)	Considerable damage: roofs peeled, mobile homes smashed, boxcars pushed over, large trees snapped or uprooted, and heavy cars lifted off ground and thrown.
F3	Severe	252–330 km/h (158–206 mph)	Severe damage: roofs and walls torn off well-made houses, trains overturned, most trees in forest uprooted, and heavy cars lifted off ground and thrown.
F4	Devastating	331–416 km/h (207–260 mph)	Devastating damage: well-made houses leveled, structures blown off weak foundations, and cars and other large objects thrown around.
F5	Incredible	417–509 km/h (261–318 mph)	Incredible damage: strong frame houses are lifted off foundations and carried a considerable distance and disintegrated, car-sized missiles fly through the air in excess of 100 m, and trees debarked.
F6	Inconceivable	510–606 km/h (319–379 mph)	The maximum wind speed of tornadoes is not expected to reach the F6 wind speeds.

Tornadoes are unpredictable. Weather forecasters can tell when tornado conditions are ripe, but they don't know if or where they will strike.

Hurricanes

A *hurricane* starts as a series of thunderstorms over tropical ocean waters. To start, ocean water must be warmer than 26.5°C. The heat and water vapor from this warm water serves as the hurricane's basic fuel source.

TIP

The first phase in the formation of a hurricane is the lowering of barometric pressure. This is called a *tropical depression.* In the next phase, the storm intensifies to a *tropical storm.* Favorable atmospheric and oceanic conditions affect the speed of the hurricane's development to the next step.

High humidity in the lower and middle troposphere is also needed for hurricane development. This high humidity slows cloud evaporation and increases heat released through increased rainfall. The concentration of heat is critical to driving the system.

Vertical wind shear affects a hurricane's development. During weak wind shear, a hurricane grows taller and releases condensed heat directly above the storm causing it to build.

KEY IDEA

> *Wind shear* describes the sudden change in the wind's direction or speed with increasing altitude.

When wind shear is intense, heat is released and distributed over a larger area. Atmospheric pressure and wind speed change across the diameter of a hurricane. Barometric pressure falls quickly as wind speed increases.

KEY IDEA

> The *eye* of the hurricane is the central point around which the rest of the storm rotates, and where the lowest barometric pressures are found.

The main feature most people look for on a weather map is the *eye* of the hurricane. The eye, roughly 20 to 50 km across, is found in the hurricane's center.

Just outside the hurricane's eye is the *eye wall* where the most intense winds and heaviest rainfall are found. Although wind speed in the eye wall is at its highest, at the eye, where barometric pressure is the lowest, winds are very light or calm. Remember, the winds are spinning constantly. Table 6.3 lists the different hurricane force categories.

Hurricanes have winds over 64 knots and turn counterclockwise about their centers in the Northern Hemisphere, and clockwise in the Southern Hemisphere. Course depends upon location. A hurricane in the eastern Atlantic is driven westward by easterly trade winds. These storms turn northwestward around a subtropical high and move into higher latitudes. As a result, the Gulf of Mexico and the eastern coast of the United States are at risk for hurricanes yearly.

Over time, hurricanes move into the middle latitudes and are driven northeast by the westerlies, merging with midlatitude fronts. Since hurricanes get their energy from the warm tropical waters, they fizzle quickly after moving over cold water or continental land masses.

TIP

Severe storms are known by different names around the world. Storms forming over the Atlantic or eastern Pacific Oceans are called hurricanes. In the northwestern Pacific Ocean and Philippines, these are *typhoons,* while Indian and South Pacific Ocean storms are known as *cyclones.*

Table 6.3 Hurricanes are rated according to specific strength categories.

HURRICANE CATEGORY	STRENGTH	WINDS AND STORM SURGE
1	Weak	65–82 knot winds 1.2–1.7 m above normal storm surge
2	Moderate	83–95 knot winds 1.8–2.6 m above normal
3	Strong	96–113 knot winds 2.7–3.8 m above normal
4	Very strong	114–135 knot winds 3.9–5.5 m above normal
5	Near total devastation	>135 knot winds >5.5 m above normal

Since 1953, the Tropical Prediction Center has created lists of hurricanes names. As a tropical depression turns into a tropical storm, it's given the next name on the list. Written in alphabetical order, the names alternate between male and female. If a specific hurricane has been particularly vicious, the name is never used again. For example, Hurricanes Alicia, Andrew, Betsy, Camille, Carmen, Gilbert, Hugo, Katrina, Ike, and Roxanne have been retired from use.

El Niño–Southern Oscillation

First described by Sir Gilbert Thomas Walker in 1923, the *El Niño–Southern Oscillation* (*ENSO;* or simply El Niño) is defined as sustained sea surface temperature changes of greater than 0.5°C for longer than 5 months across the central tropical Pacific Ocean. Commonly, ENSO takes place every two to seven years and lasts approximately one to two years.

El Niño and La Niña come from the Spanish words for "little boy" and "little girl." El Niño is said to refer to the "Christ child" since the event is often seen off the west coast of South America in late December around Christmas time.

Normally, the Pacific pattern consists of equatorial winds bringing warm water westward, while cold water upswells along the South American coast. However, during an El Niño year, warm water nears the South American coast (without the cold upswell) and gets even warmer. La Niña, a mild version of El Niño, pushes warm water further west than usual.

TIP

The first sign of an El Niño is a rise in air pressure over the Indian Ocean, Indonesia, and Australia. Next, air pressure falls over Tahiti and the eastern or central Pacific Ocean. Trade winds in the south Pacific weaken or move east, followed by warm air rising near Peru, bringing rain to the northern Peruvian deserts. Finally, warm water spreads from the west Pacific and Indian Ocean to the eastern Pacific, causing widespread drought in the western Pacific and rain in the dry eastern Pacific.

Predicting this cyclical weather pattern in the Pacific, Atlantic, and Indian Oceans is important, since ENSO events have global impacts. For example, since yearly circulation patterns of cold, nutrient-rich ocean waters change, ENSO is connected with worldwide fishing problems. Temperature-dependent fish species increase or decrease according to biological requirements. Fish populations (e.g. Peruvian sardines and shrimp, normally sustained on the nutrient-rich cold waters) move southward to colder Chilean waters.

El Niño has been observed for over 300 years, but major events have taken place in 1790–93, 1828, 1876–78, 1891, 1925–1926, 1982–83, 1997–98, and 2009–10. The El Niño of 1997–98 was especially strong and warmed the air by –16°C compared to the usual –17.5°C increase. Scientists are monitoring whether these events are increasing in intensity or frequency during global warming.

› Review Questions

Multiple-Choice Questions

1. Which of the following is the highest layer of the atmosphere?

(A) Stratosphere
(B) Thermosphere
(C) Ozone
(D) Troposphere
(E) Mesosphere

2. Which two gases make up the majority of the Earth's gases?

(A) Oxygen and methane
(B) Oxygen and propane
(C) Nitrogen and carbon dioxide
(D) Benzene and nitrogen
(E) Nitrogen and oxygen

3. Large temperature differences and strong pressure differences between warm and cold air cause the formation of the

(A) precipitation
(B) auroras
(C) jet stream
(D) clouds
(E) fossilization

4. The relationship between air temperature and the amount of water vapor it contains is known as

(A) relative humidity
(B) indistinct humidity
(C) point source humidity
(D) aridity
(E) wind shear

5. A sudden change in the wind's direction or speed with increasing altitude is called

(A) wind stop
(B) wind chill
(C) troposphere
(D) wind shear
(E) ionosphere

6. A long, narrow, upper atmosphere current of fast moving air is known as a

(A) jet stream
(B) thermophile
(C) contrail
(D) gust of wind
(E) typhoon

7. A tropical depression is the first phase in the formation of a

(A) tornado
(B) cloud
(C) hurricane
(D) jet stream
(E) temperature inversion

8. In which layer do all the pressure, wind, and precipitation changes occur?

(A) Outer space
(B) Stratosphere
(C) Troposphere
(D) Ionosphere
(E) Mesosphere

9. Tornadoes of the F4/F5 category account for what percent of deaths?

(A) 80%
(B) 65%
(C) 40%
(D) 25%
(E) 10%

10. Most commercial aircraft travel takes place in the lower part of the

(A) upper troposphere
(B) United States
(C) inverted air mass above a mountain range
(D) stratosphere
(E) ionosphere

11. The northern and southern lights are found in the

(A) mesosphere
(B) tropopause
(C) stratosphere
(D) troposphere
(E) thermosphere

12. When moving through the eye wall of a hurricane and into the eye, surface pressure

(A) increases
(B) decreases
(C) stays the same
(D) is at its highest
(E) is only rarely low

13. The thermosphere is also called the

(A) mesosphere
(B) troposphere
(C) ionosphere
(D) lower latitude layer
(E) El Niño effect

14. ENSO takes place at intervals of 2 to 7 years and lasts approximately

(A) 6 months
(B) 1 to 2 years
(C) 3 years
(D) 2 to 5 years
(E) 7 years

15. A hurricane's course depends upon location and

(A) trade wind direction
(B) eye size
(C) speed
(D) name
(E) eye wall

16. The Coriolis effect is a result of the Earth's

(A) gravitation
(B) temperature
(C) rotation
(D) plant life
(E) curvature

17. An isobar is a

(A) measure of temperature
(B) line connecting areas of increasing atmospheric pressure
(C) measure of depth
(D) line connecting areas of the same atmospheric pressure
(E) topographical symbol

18. Using Table 6.1, if the wind is blowing 30 km/h and the outside temperature is 15°C, what is the wind chill factor in degrees Celsius?

(A) 8°C
(B) 10°C
(C) 12°C
(D) 14°C
(E) 15°C

19. Sea surface temperature changes greater than 0.5°C for greater than 5 months across the central tropical Pacific Ocean are known as

(A) an arctic effect
(B) the jet stream
(C) a typhoon
(D) El Niño–Southern Oscillation
(E) ocean bloom

› Answers and Explanations

1. B—The thermosphere has temperatures up to 1,982°C and is affected by sun spot and solar flare activity.

2. E

3. C—When warm and cold air clash, there is often violent weather.

4. A—The link between air temperature and water vapor (e.g., hotter air holds more water).

5. D—Vertical wind shear affects a hurricane's development causing it to build.

6. A—Jet streams are 10 to 14 km above Earth's surface in the troposphere.

7. C—High humidity in the troposphere and low barometric pressure also add to hurricane development.

8. C—Rising and falling temperatures, rotating air masses, and pressure keep things lively.

9. B

10. D—Military aircraft reach much higher altitudes with some grazing the mesosphere.

11. E—These are the Aurora Borealis (northern) and Aurora Australis (southern) lights.

12. B—Pressure is lowest at the center and is used to track a hurricane's movement.

13. C—From the many ions present from cosmic radiation.

14. B

15. A—Temperature and pressure are also important factors.

16. C—This is *not* a result of the Earth's curvature or gravitation but of rotation.

17. D—Weather maps show atmospheric pressure changes with isobars.

18. C—The body has to reheat its warm, protective air layer when winds blow it away.

19. D—El Niño–Southern Oscillation is often shortened to ENSO.

Free-Response Questions

1. The Peru Current, which supports vast populations of food fish, slows somewhat during normal years due to warming, but in El Niño years the warming lasts for months and has a much greater economic impact upon international fishing. An El Niño event started in September 2006 and lasted until early 2007. Then, from June 2007 on, a weak La Niña occurred, eventually strengthening in early 2008. The Chilean government placed restrictions on fishing to help local fisheries compete against international companies moving southward after fish.

   (a) What is the first sign of an El Niño event?
   (b) Why do El Niño events change precipitation patterns on the western coast of South America?
   (c) What role does air pressure play in weather patterns?
   (d) Why is it important to study El Niño trends and fish impacts?

Free-Response Answers and Explanations

1.
   a. The first sign of an El Niño is a rise in air pressure over the Indian Ocean, Indonesia, and Australia.
   b. Because El Niño events cause changes or reverses in air pressure in the eastern and western Pacific, the trade winds that normally carry warm waters away from South America's Pacific coast toward Australia fail to do so. The warmer waters evaporate more easily causing larger amounts of clouds, and thus rainfall.
   c. Air pressure can tell us a lot about the weather. With a high-pressure system, there are cooler temperatures and sunny skies. When a low-pressure system moves in, look for warmer temperatures and thunderstorms.
   d. ENSO is connected with worldwide fishing problems. Temperature-dependent fish species increase or decrease according to biological requirements. Fish populations (e.g., Peruvian sardines, shrimp) normally sustained on the nutrient-rich cold waters move southward to colder Chilean waters.

› Rapid Review

- Relative humidity is the connection between air temperature and the amount of water vapor the air contains.
- Air temperature differences cause the jet stream. The greater the temperature differences, the stronger the pressure differences between warm and cold air. Strong pressure differences create strong winds and the jet stream.
- Violent tornadoes (F4/F5) account for less than 2% of all tornadoes, but cause nearly 65% of all tornado deaths.
- The eye of the hurricane is the central point around which the rest of the storm rotates, and where the lowest barometric pressures are found.
- When temperatures actually increase with altitude, it is called a temperature inversion.
- The troposphere is where all the temperature, pressure, wind, and precipitation changes we experience take place.
- The first phase in the formation of a hurricane is the lowering of barometric pressure, called a tropical depression.
- The Coriolis effect is a result of rotation, not gravitation.
- The name *hurricane* is only given to systems that form over the Atlantic or the eastern Pacific Oceans. In the northwest Pacific Ocean and the Philippines they are called typhoons, while Indian and South Pacific Ocean storms are called cyclones.
- A meteorologist studies the weather and its atmospheric patterns.
- Although air is invisible, it still has weight and takes up space.
- Nitrogen and oxygen make up the majority of Earth's gases, even in the higher altitudes.
- ENSO takes place every 2 to 7 years, but can occur yearly.
- The worst winds and heaviest rainfall are found in a hurricane's eye wall, not the eye.
- A solar radiation unit equals 1 langley or 1 calorie/cm^2 of Earth's surface or 3.69 Btu/ft^2 (British thermal units per square foot).
- Trade winds are caused by solar heating and convection currents.