Untitled FlexBook

Earth Science: Unequal Heating of the Earth

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Heat, Air Pressure, and Wind

Vocabulary Words

rotation, revolution, air mass, front, air pressure, unequal, absorb, reflect, hemisphere, equaltor, axis

Concept 2 Land versus Water

CONCEPT 3 Land Breeze, Sea Breeze

CONCEPT 4

Wind Blows: High to Low Pressure

CONCEPT 5 Air Movement

Lesson Objectives

- List the properties of the air currents within a convection cell.
- Describe how high and low pressure cells create local winds and explain how several types of local winds form.
- Discuss how global convection cells lead to the global wind belts.

Points to Consider

- How do local winds affect the weather in an area?
- How do the global wind belts affect the climate in an area?
- What are the main principles that control how the atmosphere circulates?

Introduction

A few basic principles go a long way toward explaining how and why air moves: Warm air rising creates a **low pressure zone** at the ground. Air from the surrounding area is sucked into the space left by the rising air. Air flows horizontally at top of the troposphere; horizontal flow is called **advection** . The air cools until it descends. Where it reaches the ground, it creates a **high pressure zone** . Air flowing from areas of high pressure to low pressure creates winds. Warm air can hold more moisture than cold air. Air moving at the bases of the three major convection cells in each hemisphere north and south of the equator creates the global wind belts.

Air Pressure and Winds

Within the troposphere are convection cells (**Figure** 5.1).

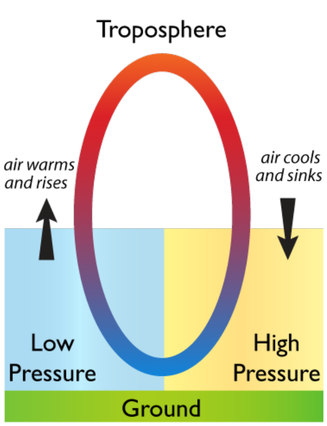


FIGURE 5.1
Warm air rises, creating a low pressure zone; cool air sinks, creating a high pressure zone.

Air that moves horizontally between high and low pressure zones makes wind. The greater the pressure difference between the pressure zones the faster the wind moves.

Convection in the atmosphere creates the planet's weather. When warm air rises and cools in a low pressure zone, it may not be able to hold all the water it contains as vapor. Some water vapor may condense to form clouds or precipitation. When cool air descends, it warms. Since it can then hold more moisture, the descending air will evaporate water on the ground.

Air moving between large high and low pressure systems creates the global wind belts that profoundly affect regional climate. Smaller pressure systems create localized winds that affect the weather and climate of a local area.

An online guide to air pressure and winds from the University of Illinois is found here: http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/fw/home.rxml .

Local Winds

Local winds result from air moving between small low and high pressure systems. High and low pressure cells are created by a variety of conditions. Some local winds have very important effects on the weather and climate of some regions.

Land and Sea Breezes

Since water has a very high specific heat, it maintains its temperature well. So water heats and cools more slowly than land. If there is a large temperature difference between the surface of the sea (or a large lake) and the land next to it, high and low pressure regions form. This creates local winds.

- **Sea breezes** blow from the cooler ocean over the warmer land in summer. Where is the high pressure zone and where is the low pressure zone? (**Figure** 5.2). Sea breezes blow at about 10 to 20 km (6 to 12 miles) per hour and lower air temperature much as 5 to 10 ^{o} C (9 to 18 ^{o} F).
- **Land breezes** blow from the land to the sea in winter. Where is the high pressure zone and where is the low pressure zone? Some warmer air from the ocean rises and then sinks on land, causing the temperature over the land to become warmer.

Land and sea breezes create the pleasant climate for which Southern California is known. The effect of land and sea breezes are felt only about 50 to 100 km (30 to 60 miles) inland. This same cooling and warming effect occurs to a smaller degree during day and night, because land warms and cools faster than the ocean.

Monsoon Winds

Monsoon winds are larger scale versions of land and sea breezes; they blow from the sea onto the land in summer and from the land onto the sea in winter. Monsoon winds are occur where very hot summer lands are next to the sea. Thunderstorms are common during monsoons (**Figure** 5.3).

The most important monsoon in the world occurs each year over the Indian subcontinent. More than two billion residents of India and southeastern Asia depend on monsoon rains for their drinking and irrigation water. Back in the days of sailing ships, seasonal shifts in the monsoon winds carried goods back and forth between India and Africa.

Mountain and Valley Breezes

Temperature differences between mountains and valleys create mountain and valley breezes. During the day, air on mountain slopes is heated more than air at the same elevation over an adjacent valley. As the day progresses, warm air rises and draws the cool air up from the valley, creating a **valley breeze** . At night the mountain slopes cool more quickly than the nearby valley, which causes a **mountain breeze** to flow downhill.

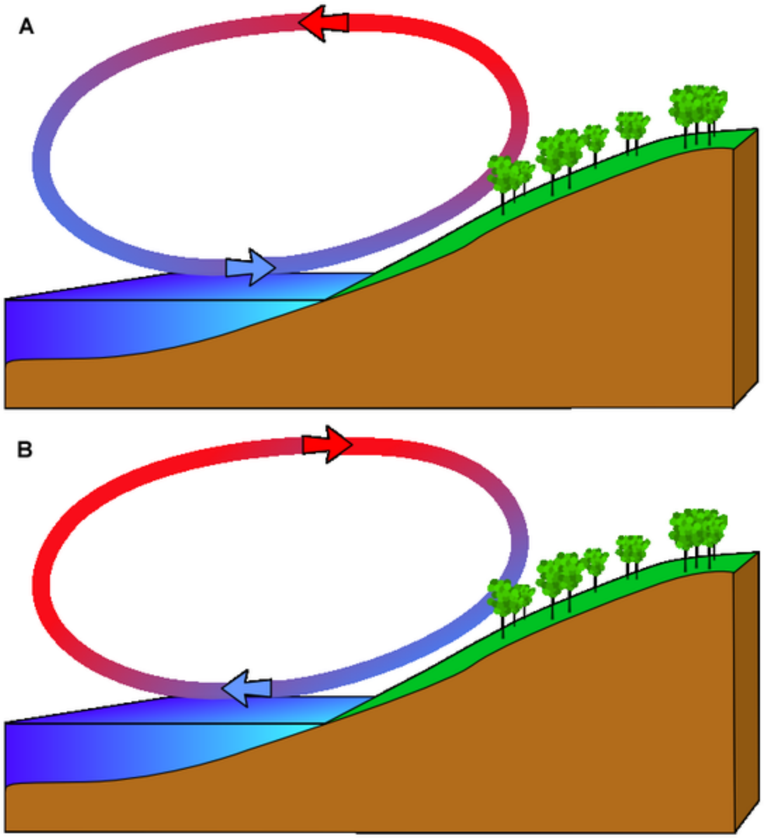


FIGURE 5.2
How do sea and land breezes moderate coastal climates?

FIGURE 5.3
In the southwestern United States relatively cool moist air sucked in from the Gulf of Mexico and the Gulf of California meets air that has been heated by scorching desert temperatures.

Katabatic Winds

Katabatic winds move up and down slopes, but they are stronger mountain and valley breezes. Katabatic winds form over a high land area, like a high plateau. The plateau is usually surrounded on almost all sides by mountains.

In winter, the plateau grows cold. The air above the plateau grows cold and sinks down from the plateau through gaps in the mountains. Wind speeds depend on the difference in air pressure over the plateau and over the surroundings. Katabatic winds form over many continental areas. Extremely cold katabatic winds blow over Antarctica and Greenland.

Chinook Winds (Foehn Winds)

Chinook winds (or **Foehn winds**) develop when air is forced up over a mountain range. This takes place, for example, when the westerly winds bring air from the Pacific Ocean over the Sierra Nevada Mountains in California. As the relatively warm, moist air rises over the windward side of the mountains, it cools and contracts. If the air is humid, it may form clouds and drop rain or snow. When the air sinks on the leeward side of the mountains, it forms a high pressure zone. The windward side of a mountain range is the side that receives the wind; the leeward side is the side where air sinks.

The descending air warms and creates strong, dry winds. Chinook winds can raise temperatures more than 20 ^{o} C (36 ^{o} F) in an hour and they rapidly decrease humidity. Snow on the leeward side of the mountain disappears melts quickly. If precipitation falls as the air rises over the mountains, the air will be dry as it sinks on the leeward size. This dry, sinking air causes a **rainshadow effect** (**Figure** 5.4), which creates many of the world's deserts.

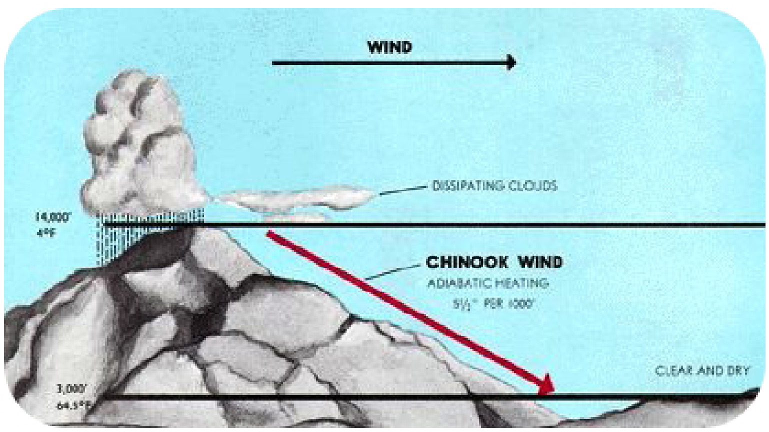


FIGURE 5.4

As air rises over a mountain it cools and loses moisture, then warms by compression on the leeward side. The resulting warm and dry winds are Chinook winds. The leeward side of the mountain experiences rainshadow effect.

Santa Ana Winds

Santa Ana winds are created in the late fall and winter when the Great Basin east of the Sierra Nevada cools, creating a high pressure zone. The high pressure forces winds downhill and in a clockwise direction (because of Coriolis). The air pressure rises, so temperature rises and humidity falls. The winds blow across the Southwestern deserts and then race downhill and westward toward the ocean. Air is forced through canyons cutting the San Gabriel and San Bernardino mountains. (**Figure** 5.5).

The Santa Ana winds often arrive at the end of California's long summer drought season. The hot, dry winds dry out the landscape even more. If a fire starts, it can spread quickly, causing large-scale devastation (**Figure** 5.6).

Desert Winds

High summer temperatures on the desert create high winds, which are often associated with monsoon storms. Desert winds pick up dust because there is not as much vegetation to hold down the dirt and sand. (**Figure** 5.7). A **haboob** forms in the downdrafts on the front of a thunderstorm.

FIGURE 5.5
The winds are especially fast through Santa Ana Canyon, for which they are named. Santa Ana winds blow dust and smoke westward over the Pacific from Southern California.

FIGURE 5.6
In October 2007, Santa Ana winds fueled many fires that together burned 426,000 acres of wild land and more than 1,500 homes in Southern California.

Dust devils, also called whirlwinds, form as the ground becomes so hot that the air above it heats and rises. Air flows into the low pressure and begins to spin. Dust devils are small and short-lived but they may cause damage.

Atmospheric Circulation

Because more solar energy hits the equator, the air warms and forms a low pressure zone. At the top of the troposphere, half moves toward the North Pole and half toward the South Pole. As it moves along the top of the troposphere it cools. The cool air is dense and when it reaches a high pressure zone it sinks to the ground. The air is sucked back toward the low pressure at the equator. This describes the convection cells north and south of the equator.

If the Earth did not rotate, there would be one convection cell in the northern hemisphere and one in the southern with the rising air at the equator and the sinking air at each pole. But because the planet does rotate, the situation is

FIGURE 5.7
A haboob in the Phoenix metropolitan area, Arizona.

more complicated. The planet's rotation means that the Coriolis Effect must be taken into account. Coriolis Effect was described in the Earth's Oceans chapter.

Let's look at atmospheric circulation in the Northern Hemisphere as a result of the Coriolis Effect (**Figure** 5.8). Air rises at the equator, but as it moves toward the pole at the top of the troposphere, it deflects to the right. (Remember that it just appears to deflect to the right because the ground beneath it moves.) At about 30 ^{o} N latitude, the air from the equator meets air flowing toward the equator from the higher latitudes. This air is cool because it has come from higher latitudes. Both batches of air descend, creating a high pressure zone. Once on the ground, the air returns to the equator. This convection cell is called the Hadley Cell and is found between 0 ^{o} and 30 ^{o} N.

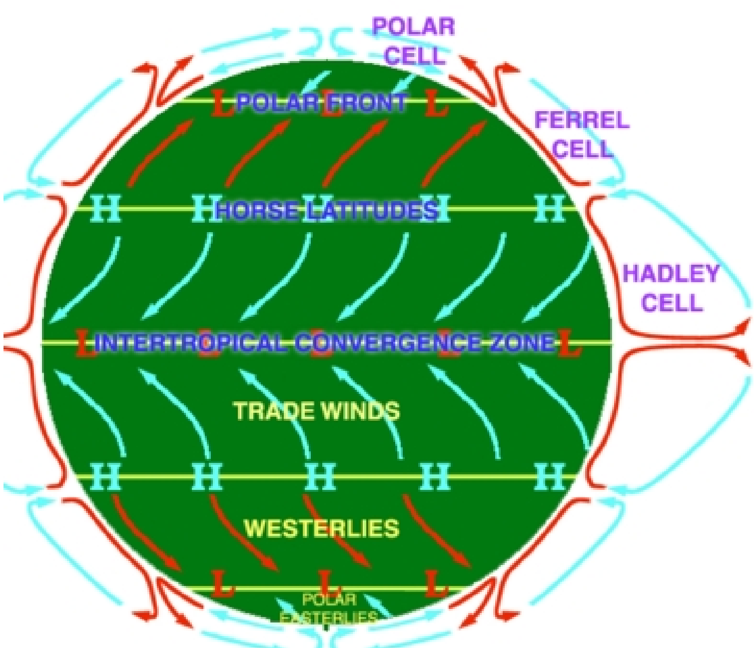


FIGURE 5.8
The atmospheric circulation cells, showing direction of winds at Earth's surface.

There are two more convection cells in the Northern Hemisphere. The Ferrell cell is between 30 ^{o} N and 50 ^{o} to

60 ^{o} N. This cell shares its southern, descending side with the Hadley cell to its south. Its northern rising limb is shared with the Polar cell located between 50 ^{o} N to 60 ^{o} N and the North Pole, where cold air descends.

There are three mirror image circulation cells in the Southern Hemisphere. In that hemisphere, the Coriolis Effect makes objects appear to deflect to the left.

Global Wind Belts

Global winds blow in belts encircling the planet. The global wind belts are enormous and the winds are relatively steady (**Figure** 5.9). These winds are the result of air movement at the bottom of the major atmospheric circulation cells, where the air moves horizontally from high to low pressure.

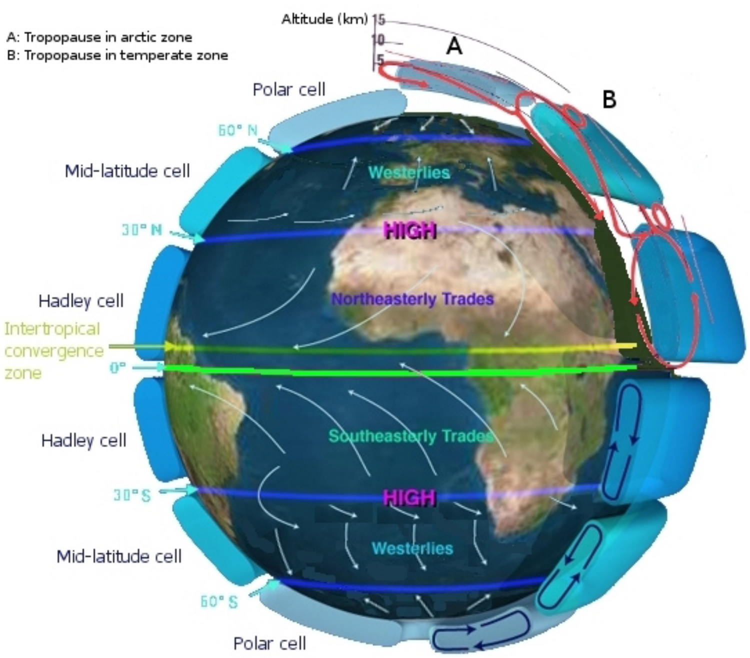


FIGURE 5.9
The major wind belts and the directions that they blow.

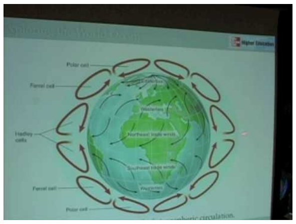
Global Wind Belts

Let's look at the global wind belts in the Northern Hemisphere.

- In the Hadley cell air should move north to south, but it is deflected to the right by Coriolis. So the air blows from northeast to the southwest. This belt is the trade winds, so called because at the time of sailing ships they were good for trade.
- In the Ferrel cell air should move south to north, but the winds actually blow from the southwest. This belt is the westerly winds or westerlies. Why do you think a flight across the United States from San Francisco to New York City takes less time than the reverse trip?
- In the Polar cell, the winds travel from the northeast and are called the polar easterlies

The wind belts are named for the directions from which the winds come. The westerly winds, for example, blow from west to east. These names hold for the winds in the wind belts of the Southern Hemisphere as well.

This video lecture discusses the 3-cell model of atmospheric circulation and the resulting global wind belts and surface wind currents **(5a)** : http://www.youtube.com/watch?v=HWFDKdxK75E&feature=related (8:45).



MEDIA

Click image to the left for more content.

Global Winds and Precipitation

Besides their effect on the global wind belts, the high and low pressure areas created by the six atmospheric circulation cells determine in a general way the amount of precipitation a region receives. In low pressure regions, where air is rising, rain is common. In high pressure areas, the sinking air causes evaporation and the region is usually dry. More specific climate effects will be described in the chapter about climate.

Polar Fronts and Jet Streams

The **polar front** is the junction between the Ferrell and Polar cells. At this low pressure zone, relatively warm, moist air of the Ferrell Cell runs into relatively cold, dry air of the Polar cell. The weather where these two meet is extremely variable, typical of much of North America and Europe.

The polar **jet stream** is found high up in the atmosphere where the two cells come together. A jet stream is a fast-flowing river of air at the boundary between the troposphere and the stratosphere. Jet streams form where there is a large temperature difference between two air masses. This explains why the polar jet stream is the world's most powerful (**Figure** 5.10).

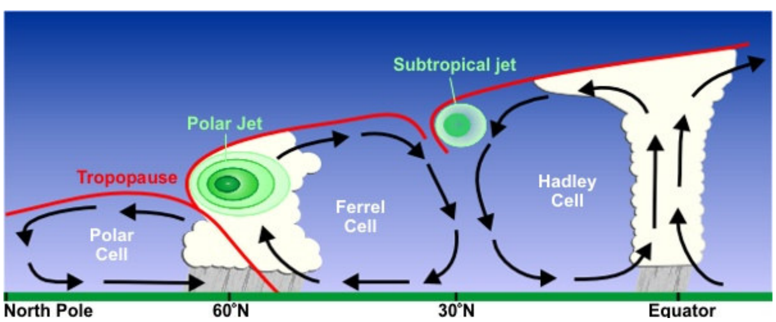


FIGURE 5.10

A cross section of the atmosphere with major circulation cells and jet streams. The polar jet stream is the site of extremely turbulent weather.

Jet streams move seasonally just as the angle of the Sun in the sky moves north and south. The polar jet stream, known as "the jet stream," moves south in the winter and north in the summer between about 30 ^{o} N and 50 ^{o} to 75 ^{o} N.

Lesson Summary

- Winds blow from high pressure zones to low pressure zones. The pressure zones are created when air near the ground becomes warmer or colder than the air nearby.
- Local winds may be found in a mountain valley or near a coast.
- The global wind patterns are long-term, steady winds that prevail around a large portion of the planet.
- The location of the global wind belts has a great deal of influence on the weather and climate of an area.

Review Questions

1. Draw a picture of a convection cell in the atmosphere. Label the low and high pressure zones and where the wind is.

2. Under what circumstances will winds be very strong?

3. Given what you know about global-scale convection cells, where would you travel if you were interested in experiencing warm, plentiful rain?

4. Describe the atmospheric circulation for two places where you are likely to find deserts, and explain why these regions are relatively warm and dry.

5. How could the Indian monsoons be reduced in magnitude? What effect would a reduction in these important monsoons have on that part of the world?

6. Why is the name "snow eater" an apt description of Chinook winds?

7. Why does the Coriolis Effect cause air to appear to move clockwise in the Northern Hemisphere? When does Coriolis Effect cause air to appear to move counterclockwise?

8. Sailors once referred to a portion of the ocean as the doldrums. This is a region where there is frequently no wind, so ships would become becalmed for days or even weeks. Where do you think the doldrums might be relative to the atmospheric circulation cells?

9. Imagine that the jet stream is located further south than usual for the summer. What is the weather like in regions just north of the jet stream, as compared to a normal summer?

10. Give a general description of how winds form.

Further Reading / Supplemental Links

High and Low Pressure Systems animations, Bureau of Meteorology, Australian Government http://www.bom.gov.au/lam/Students_Teachers/pressure.shtml

Opening image courtesy of NASA's Earth Observatory, http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS013&roll=E&frame=54329 , and is in the public domain.

Vocabulary

advection
Horizontal movement of a fluid or the transport of a substance in the flow.

Chinook winds (Foehn winds)
Winds that form when low pressure draws air over a mountain range.

haboob
Desert sandstorms that form in the downdrafts of a thunderstorm.

high pressure zone
A region where relatively cool, dense air is sinking.

jet stream
A fast-flowing river of air high in the atmosphere, where air masses with two very different sets of temperature and humidity characteristics move past each other.

katabatic winds
Winds that move down a slope.

land breeze
A wind that blows from land to sea in winter when the ocean is warmer than the land.

low pressure zone
A region where relatively warm, lower density air is rising.

monsoon
Hot land draws cool air off a nearby sea creating large winds and often rain.

mountain breeze
A wind that blows from a mountain to a valley at night when mountain air is cooler.

polar front
The meeting zone between cold continental air and warmer subtropical air at around 50^{o} N and 50^{o} S.

rainshadow effect
A location of little rain on the leeward side of a mountain range due to descending air.

Santa Ana winds
Hot winds that blow east to west into Southern California in fall and winter.

sea breeze
A wind that blows from sea to land in summer when the land is warmer than the ocean.

valley breeze
An uphill airflow.

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An uphill airflow.

References

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CONCEPT 6 H AP W Study Guide for Students

Name: _ __________ _____ __

Due Date: 2 / 14 Period: ___

Heat, Air Pressure, Wind, Seasons Climate Study Guide

This *study guide* , and *all work* that should be in the notebook according to the Table of Contents, must be *completed* in order to earn a *retest opportunity* .

Fill in the Blanks :

There are _______ molecules of air at high elevations, so air pressure is less.

The air above the equator _______ because it has low density and low pressure.

Not all areas of Earth receive the same amount of radiation because the Earth's surface is ________ .

Air pressure is ________ at sea level because there are more molecules of air pushing down from above.

Cold air has more molecules of air in one cubic centimeter than warm air; cold air has ________ pressure than warm air.

______ in the Southern Hemisphere happens at the same time as Spring in the ______ Hemisphere.

The properties of ______ air: Low pressure and low density.

The properties of ______ air: High pressure and high density.

When cool, dense air from over water flows inland is called a ___ ________ .

Air over the sea is ________ than air over land.

Be able to . . . : check the boxes when you explain these to another person and write the other answers on a sheet of notebook paper to *staple to this study guide* .

[U+206D] Know dates of the Summer & Winter Solstice, the Spring & Fall Equinox. How do the "lengths" of the day(light) compare to each other?

[U+206D] Sketch the movement of air in the atmosphere. In the sketch you need to show air moving from a warmer to a cooler surface (ground) and know which has a greater or lesser density.

Which two types of air produce global winds?

What makes wind?

Compare the heating of land to water (remember the beach field trip?):

Know what the tilt of Earth's axis looks like.

Review the sketch (from your notes) on the movement of global winds.

Review your sketch of sea/land breezes – be able to explain the reason for such breezes.