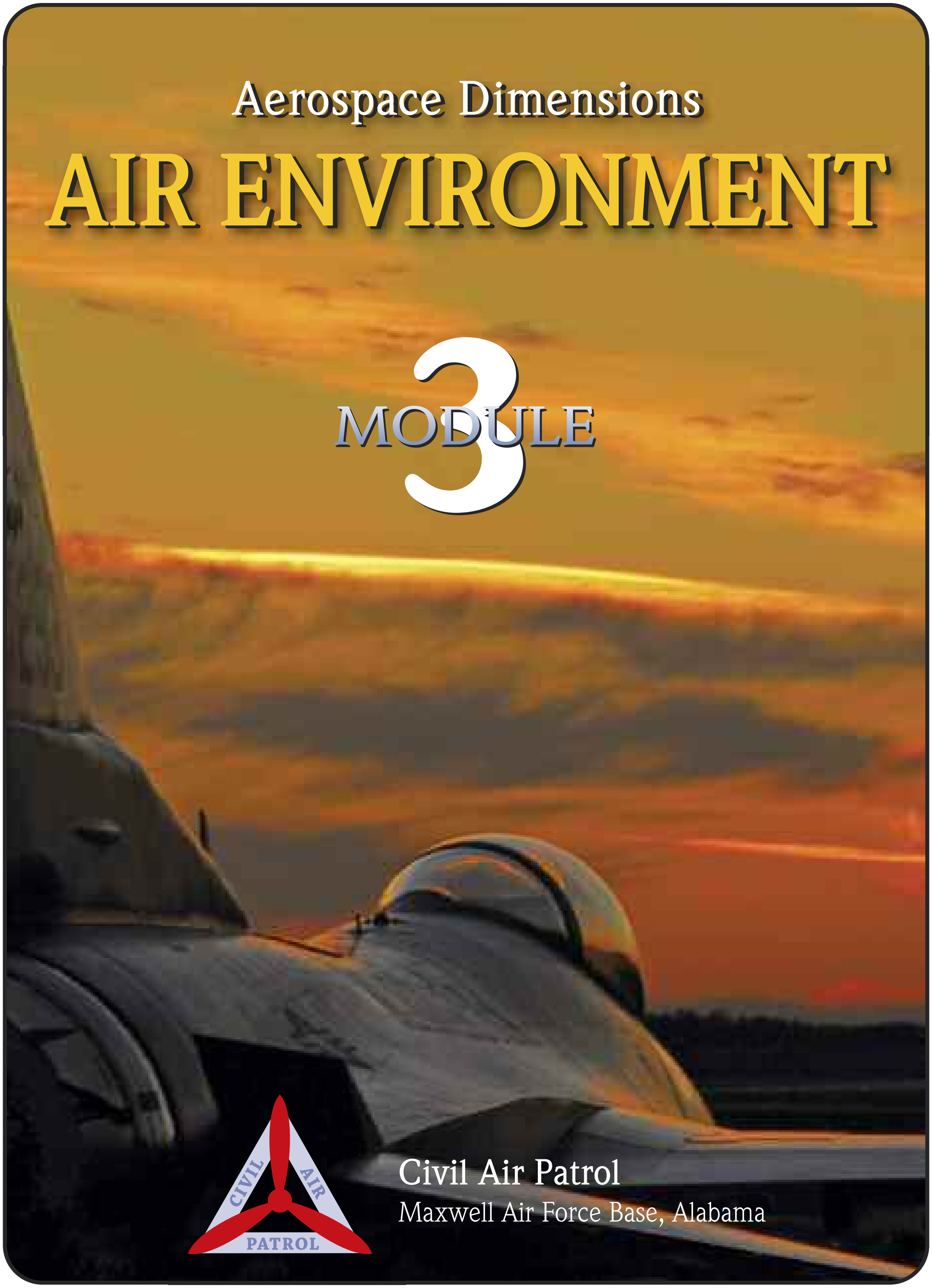
Aerospace Dimensions

AIR ENVIRONMENT

MODULE 3



Civil Air Patrol
Maxwell Air Force Base, Alabama

Aerospace Dimensions
AIR ENVIRONMENT

MODULE 3

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Introduction

The Aerospace Dimensions module, ***Air Environment***, is the third of six modules, which combined, make up Phases I and II of Civil Air Patrol's Aerospace Education Program for cadets. Each module is meant to stand entirely on its own, so that each can be taught in any order. This enables new cadets coming into the program to study the same module, at the same time, with the other cadets. This builds a cohesiveness and cooperation among the cadets and encourages active group participation. This module is also appropriate for middle school students and can be used by teachers to supplement STEM-related subjects.

Inquiry-based **activities** were included to enhance the text and provide concept applicability. The activities were designed as group activities, but can be done individually, if desired. The activities for this module are located at the end of each chapter, except chapter one.

Contents

A F-22 Raptor climbs above the great Alaskan mountain range (USAF photo)

National Academic Standard Alignment

Science Standards	Mathematics Standards	English Language Arts Standards	Social Studies Standards	Technology Standards
Physical Science: • Transfer of energy • Motions and forces	1. Number and Operations Standard: • Understand numbers, ways of representing numbers, relationships among numbers, and number systems • Compute fluently and make reasonable estimates	1. Reading for Perspective	8. Science, Technology, and Society	3. Understanding of the relationships among technologies and the connections between technology and other fields of study
Life Science: • Regulation and behavior	4. Measurement Standard: • Understand measurable attributes of objects and the units, systems, and processes of measurement	3. Evaluation Strategies		6. Understanding of the role of society in the development and use of technology
Earth and Space Science: • Structure of the earth system	6. Problem Solving Standard: • Solve problems that arise in mathematics and in other contexts	12. Applying Language Skills		
Science and Technology: • Abilities of technological design	9. Connections Standard: • Recognize and apply mathematics in contexts outside of mathematics			
Unifying Concepts and Processes: • Constancy, change, and measurement	10. Representation Standard: • Use representations to model and interpret physical, social, and mathematical phenomena			

1 THE ATMOSPHERE

Learning Outcomes

- Describe the composition of the atmosphere.
- Describe the standard temperature lapse rate.
- Identify the four layers of the atmosphere.

Important Terms

ionosphere - a region of the atmosphere where electrons are gained or lost
lapse rate - the rate of decrease with an increase in height for pressure and temperature
mesosphere - a layer of the atmosphere extending from about 30 to 50 miles
ozonosphere - a region of the atmosphere where ozone is created
stratosphere - a layer of the atmosphere extending from the tropopause to about 30 miles
thermosphere - a layer of the atmosphere extending from 50 to about 300 miles
tropopause - boundary between the troposphere and the stratosphere
troposphere - first layer of the atmosphere where most of the Earth's weather occurs

The atmosphere is a blanket of air made up of a mixture of gases that surrounds the Earth and reaches almost 350 miles from the surface of the Earth. This mixture is in constant motion. If the atmosphere were visible, it might look like an ocean with swirls and eddies, rising and falling air, and waves that travel for great distances.

Life on Earth is supported by the atmosphere, solar energy, and the planet's magnetic fields. The atmosphere absorbs energy from the Sun, recycles water and other chemicals, and works with the electrical and magnetic forces to provide a moderate climate. The atmosphere also protects life on Earth from high energy radiation and the frigid vacuum of space.

COMPOSITION OF THE ATMOSPHERE

In any given volume of air, nitrogen accounts for 78 percent of the gases that comprise the atmosphere, while oxygen makes up 21 percent. Argon, carbon dioxide, and traces of other gases make up the remaining one percent. A variable amount of water vapor can also be present, and this amount can be responsible for major changes in our weather.

***Apollo* 17 view of Earth**

ATMOSPHERIC LAYERS

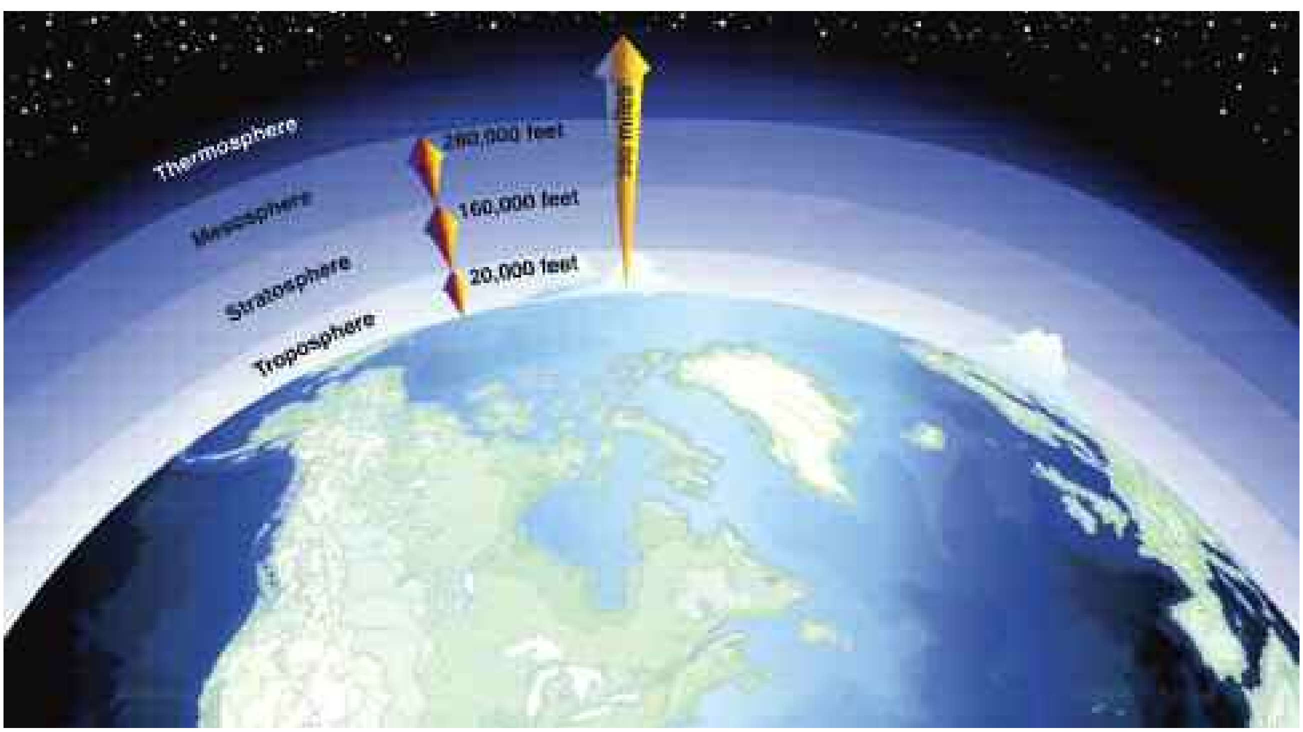
Certain levels of the atmosphere can be identified according to general characteristics, such as temperature distribution and physical and chemical properties. There are four distinct regions or layers of the atmosphere where the temperature distribution is different enough to justify a different name.

The first layer, known as the **troposphere**, extends from sea level up to 20,000 feet over the poles and to 55,000-60,000 feet over the equatorial regions. Most of the atmosphere is contained in this region, and the vast majority of weather, clouds, storms, and temperature differences occur here. Temperatures within the troposphere decrease with an increase in altitude at a fairly constant rate. This temperature decrease is generally accepted to be at a rate of about 3.5˚F or 2˚C for every 1,000 feet of altitude gain. This is called the standard **lapse rate** for temperature.

At the top of the troposphere is a boundary known as the **tropopause**, which is the dividing area between the troposphere and the next layer. The altitude of the tropopause varies with latitude and with the season of the year.

The next region of the atmosphere is the **stratosphere**, which extends from the tropopause to a height of about 160,000 feet or about 30 miles. Little weather exists in this layer and the air remains stable although certain types of clouds occasionally exist in it. The temperature actually gets warmer with an increase in altitude; usually moving from a temperature of -76° F to about -40° F. The U-2 aircraft pictured on the next page is an example of a airplane that routinely flies in the stratosphere.

The next atmospheric region is the **mesosphere**. The mesosphere extends from beyond the stratosphere to about 280,000 feet or from about 30 to 50 miles. At first, the temperature increases in the mesosphere, but then it decreases at the top of the layer to about -130° F. Finally, the last region identified by temperature differences is the **thermosphere**. It begins at about 50 miles up and extends to about 300 miles. Here, the temperature increases again. How much it increases depends on solar activity, but it is usually between 1,380° F and 2,280° F.



The four layers of the atmosphere

There are two atmospheric regions that can be described by the physical and chemical processes that occur within them. First, there is the **ozonosphere**. It extends from about 10 to 30 miles in altitude. In this region, the Sun's radiation reacts with the oxygen molecules and causes them to pick up a third atom, creating ozone. The ozonosphere performs the very important function of shielding us from ultraviolet and infrared radiation.

The majesty of our atmosphere with the Moon barely visible in the distance
Images courtesy of NOAA

The next region described by these physical and chemical processes is the **ionosphere**. This region begins at an altitude of about 25 miles and extends outward to about 250 miles. Because of the interactions between atmospheric particles and the Sun's radiation, there is a loss or gain in the electrons of the atoms and molecules, and thus the word "ion."

ONE OF THE MOST FAMOUS SPY PLANES OF ALL TIME, THE LOCKHEED U-2
This airplane routinely flies at extremely high altitudes
into both the tropopause and stratosphere layers.

2 AIR CIRCULATION

Learning Outcomes

- Describe how the Sun heats the Earth.
- Describe the Earth's rotation and revolution, and its effect on the Earth's seasons.
- Explain the various theories of circulation.
- Describe Coriolis Effect (Force).
- Define the jet stream.

Important Terms

autumnal (fall) equinox - the time when the Sun's direct rays strike the equator resulting in day and night of equal length, usually on September 22nd or 23rd

Coriolis Effect (Force) - is the apparent deflection of a freely-moving object to the right in the Northern Hemisphere

doldrums - a global area of calm winds

global winds - the world-wide system of winds that transfers heat between tropical and polar regions

jet stream - a strong wind that develops at 30,000-35,000 feet and moves as a winding road across the US, generally from the west to the east

polar easterlies - global winds that flow from the poles and move to the west

prevailing westerlies - global winds that move toward the poles and appear to curve to the east

radiation - the method by which the Sun heats the Earth

revolution - the movement of the Earth revolving around the Sun; full revolution about 365 days

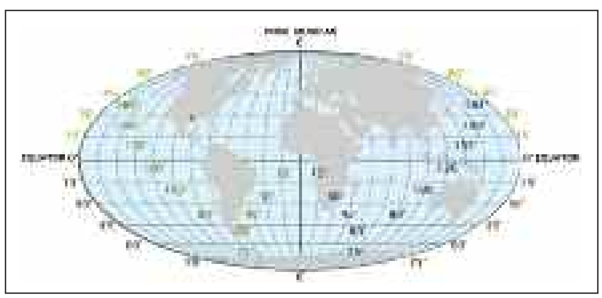
rotation - how the Earth turns (rotates) on its axis at an angle of 23.5° while it revolves around the Sun; full rotation 24 hours

summer solstice - the longest day when the Sun is at its northernmost point from the equator in the Northern Hemisphere, usually on June 21st or 22nd

trade winds - a warm steady wind that blows toward the equator

vernal (spring) equinox - the time when the Sun's direct rays strike the equator resulting in day and night of equal length, usually on March 21st or 22nd

winter solstice - the shortest day when the Sun is the farthest south of the equator and the Northern Hemisphere, usually on December 21st or 22nd



This world map is divided into horizontal (latitude) lines in degrees of a point north or south of the equator, often called parallels. The vertical (longitude) lines, often called meridians, point east or west of the Prime (Greenwich) Meridian.

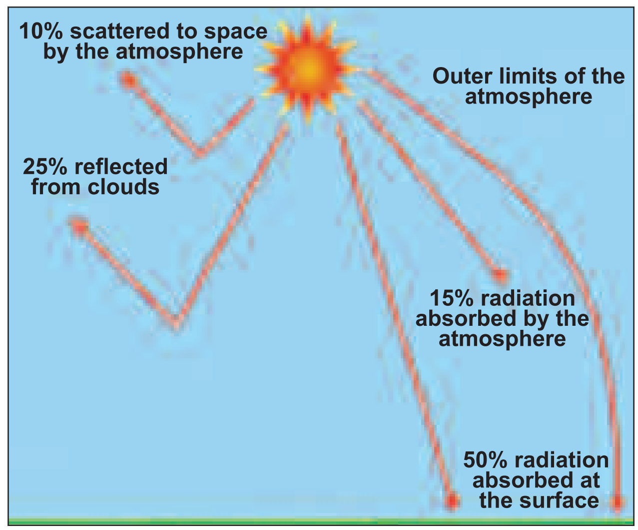
The Sun heats the Earth. This is the fundamental cause of our various weather conditions. However, the Sun heats some parts of the Earth more than others. This uneven or unequal heating causes temperature and pressure differences. This creates circulation or movement of air. This movement initiates the whole weather process.

The activities in this section are designed to give you a better understanding of uneven heating and the circulation it creates.

The flight of aircraft is affected by heat and cold.

RADIATION

The Sun heats the Earth through a method known as **radiation**. The energy from the Sun radiates into the Earth's atmosphere. As already mentioned, the Sun heats the Earth unevenly. This heat from the Sun is absorbed differently depending on the surface or the substance. For example, if you go to the beach on a hot day and take your shoes off and walk in the sand, the sand will be almost too hot to walk on, but the water will be cool. Go back at 11:00 at night. The sand will be cool while the water will be comfortably warm. The sand absorbed and lost heat faster than the water. About 50% of the Sun's radiation is absorbed by the Earth's surface. The other 50% is reflected and absorbed in the atmosphere and space. (See associated Activity One at the end of the chapter.)



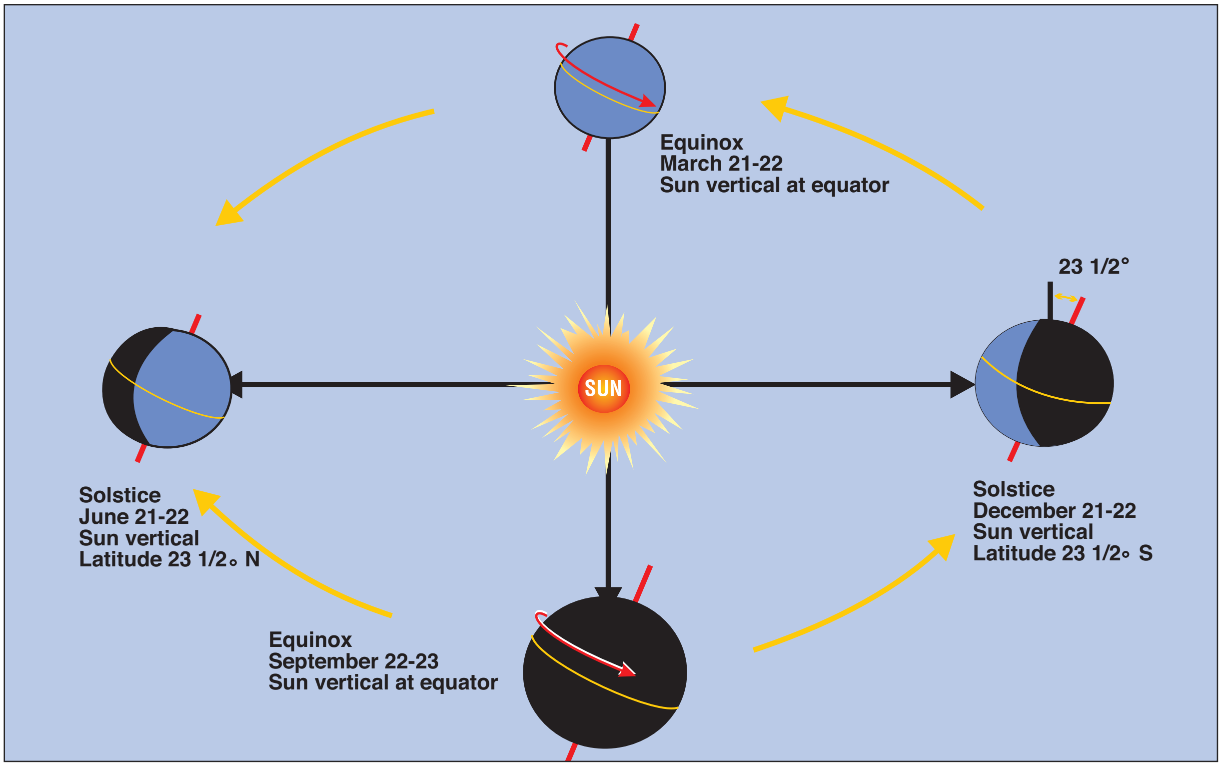
Solar Radiation

Warm air rises and this impacts weather in a big way. This rising warm air adds to temperature and pressure differences, as well as air movement. This effects the surrounding air, air masses, and fronts. It is also an ingredient for producing clouds and plays a part in the occurrence of moisture and precipitation. (See associated Activity Two at the end of the chapter.)

Aircraft are affected by warm air, too. Air is made up of molecules and warm air has less molecules than cool air. The warm air molecules are spaced farther apart, so the air is less dense or thinner. So, airplane engines work more efficiently in dense, colder weather.

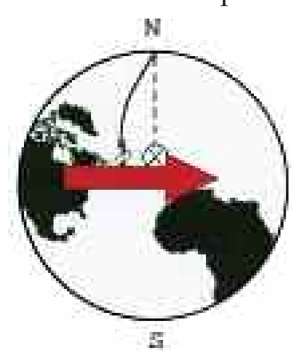
ROTATION AND REVOLUTION

In relationship to the Sun, the Earth has two motions that affect the amount of heat received from the Sun. These motions are **rotation** and **revolution**. The Earth revolves around the Sun, and at the same time, rotates as well. The Earth's revolution takes 365 days, 5 hours and 48 minutes, while the Earth is rotating on it axis at an angle of 23.5 degrees. This rotational tilt causes the length of the days to vary and the rotation plus the revolution causes the seasonal changes. As demonstrated on



Seasonal changes caused by the Earth's rotation and revolution

next page, the Earth's axis stays tilted in the same direction as it revolves around the Sun. The diagram shows that the Northern Hemisphere is tilted toward the Sun on June 21st or 22nd. This is called the **summer solstice**. This day marks the longest day of the year in the Northern Hemisphere when the Sun is at its northernmost point from the equator. December 21st or 22nd is the date when the Northern Hemisphere is tilted away from the Sun and the Sun is the farthest south of the equator. This is called the **winter solstice**. During the **spring (vernal) equinox**, which occurs on March 21st or 22nd, and the **fall (autumnal) equinox**, which occurs on September 22nd or 23rd, the Sun's rays cross the equator. So, days and nights are of equal length. *(See the diagram at the top of page.)*



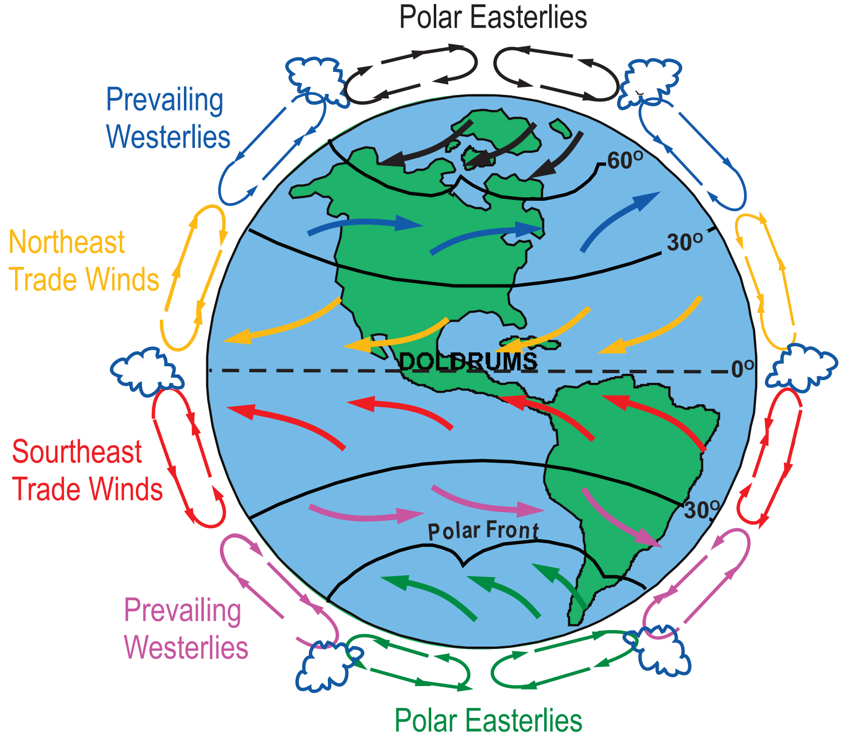
The Coriolis effect (Force)

Our Earth rotates on its axis in a counterclockwise direction. The winds associated with the rotation cause an object moving freely in the Northern Hemisphere to be appear to be deflected to the right of its intended path. This deflection to the right is called **Coriolis Effect (Force)**. As the drawing indicates, an airplane flying south from the North Pole to the equator must take the Coriolis Effect (Force) into account. If it doesn't, it will land west of its intended destination. (See associated Activity Three at the end of the chapter.)

CIRCULATION AND GLOBAL WINDS

Unequal heating causes air movement. Globally, this movement is called circulation or the general circulation of the atmosphere. This general circulation may be regarded as the world-wide system of winds that transfers heat between tropical and polar regions called **global winds**.

The region of the Earth receiving most of the Sun's heat is the equator. Here, air is heated and rises, leaving low pressure areas behind. Moving to about 30° north and south of the equator, the warm air from the equator finally begins to cool and sink. Between 30° latitude and the equator, most of the cooling, sinking air moves back to the equator. The rest of the air flows toward the poles. The air movements toward the equator are called **trade winds** - warm, steady breezes that blow almost continuously. The Coriolis Effect (Force) makes the trade winds appear to be curving to the west, when they are actually traveling toward the equator from the south and the north.



Global winds

The trade winds coming from the south and the north meet near the equator. These converging trade winds produce general upward winds as they are heated, so there are no steady surface winds. This area of calm is called the **doldrums**.

Between 30° and 60° latitude, the winds that move toward the poles appear to curve to the east. Because winds are named for the direction from which they originate, these winds are called **prevailing westerlies**. Prevailing westerlies in the Northern Hemisphere are responsible for many of the weather movements across the US and Canada.

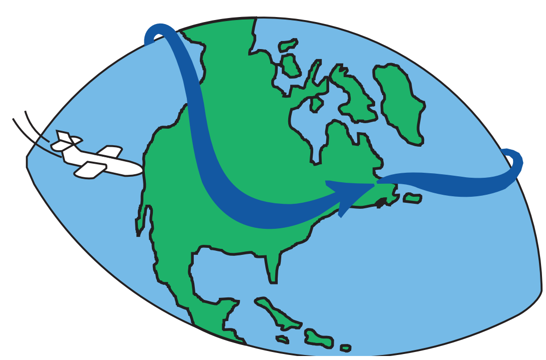
At about 60° latitude in both hemispheres, the prevailing westerlies join with polar easterlies to produce upward motion. The **polar easterlies** are formed when the atmosphere over the poles cools. This cold air then sinks and spreads out over the surface. As the air flows away from the poles it is turned to the west by the Coriolis Effect (Force). Again, because these winds begin in the east, they are called the easterlies. Many of the changes in wind direction are hard to visualize, but hopefully the diagram above will help.

These global winds are a constant concern for pilots. Pilots receive a weather briefing before takeoff. During the briefing, the direction and speed of the winds between their takeoff point and their destination are always examined at various levels of altitude. (See associated Activity Four at the end of the chapter.)

JET STREAM

Another interesting concept is the **jet stream**.

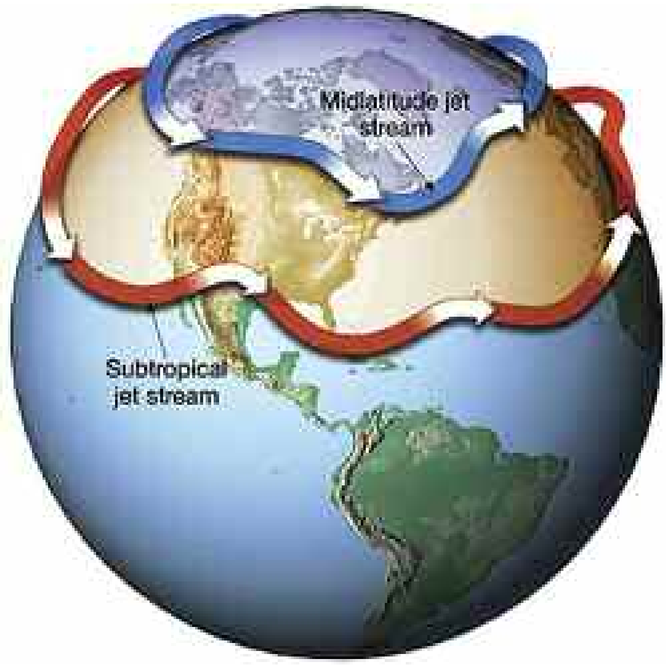
The jet stream usually crosses the US at 30,000-35,000 feet, generally moving in a west to east direction. The jet stream develops when there are strong temperature differences in the upper troposphere. These large


Jet stream

temperature differences cause large pressure differences, which create stronger winds.

The jet stream's winds are generally between 100-300 miles per hour (mph), with an average of 120-150 mph. However, speeds have been recorded as high as 450 mph. The jet stream moves like a winding road across the US It is generally thousands of miles long, hundreds of miles wide, and a few miles deep. It is usually stronger and dips farther south in the winter.

Both commercial and military pilots are well aware of the location of the jet stream. In fact, many flight plans are filed with the jet stream in mind. Why is that? Since the jet stream moves west to east, a plane flying east can save time and fuel by riding the jet stream to the plane's destination. Passengers are usually very happy about arriving 30-60 minutes early. Of course, the opposite is also true. Planes flying west may be flying into the jet stream. This will slow them down, or they can try to avoid the jet stream.



The jet stream affecting the United States moves up and down across the continent. When it is farther north, as in Canada, the weather to its south tends to be mild, or, at least, less cold. When the jet stream swings south into the United States, especially in winter, very cold, often harsh weather prevails at the surface on the northern side.

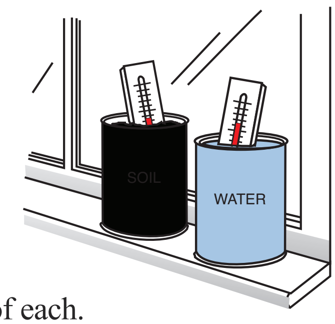
This diagram shows two typical jet stream positions at the height of summer and of winter.

ACTIVITY SECTION 2

Activity One - Absorbing Heat

Purpose: Compare and contrast the absorption of heat by soil and water to better understand how this affects weather.

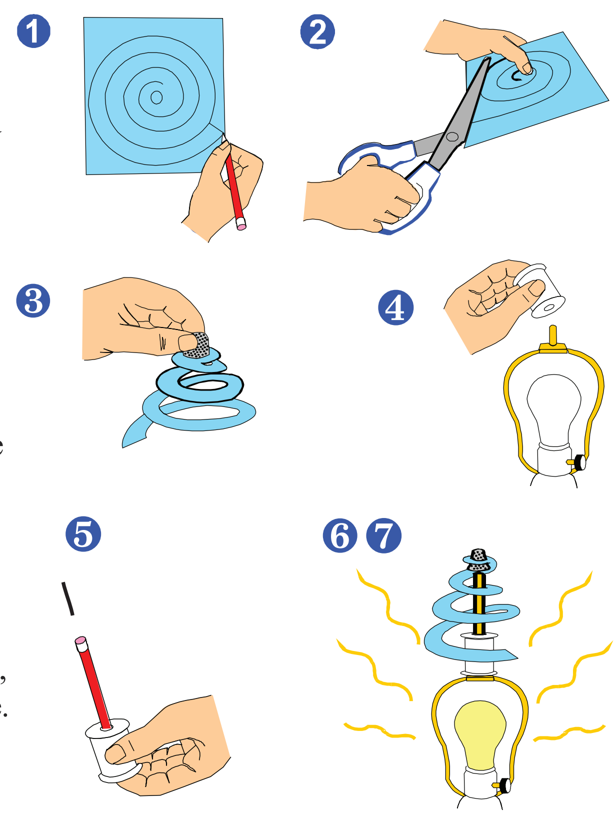
Materials: 2 tin cans, 2 thermometers, soil, water, sunlight, pencil, and paper



Procedure:
1. Fill one can with water and the other can with soil.
2. Stand one thermometer in the water and insert the other into the soil.
3. Read the thermometers, and record temperature and time of each.
4. Place both cans into the sunlight.
5. Watch the readings on the thermometers, and record temperature and time of each.
6. Notice the temperature of the soil begins to rise first.
7. Discuss the implications this temperature variance has on weather.

Summary: The temperature of the soil begins to rise first. This is because the soil absorbs heat faster than the water. If placed in the shade, the soil will lose heat faster than the water. The unequal heating of the Earth causes differences in temperature and pressure.

Activity Two - Warm Air Rising



Purpose: Use observation skills to learn that warm air rises to better understand weather conditions caused by this upward air movement.

Materials: paper, pencil with eraser, scissors, metal thimble, needle, sewing thread spool, and table lamp

Procedure:
1. Mark the pattern of a spiral on the paper, with turns about an inch wide.
2. Cut the pattern from the paper, leaving enough space in the center to partially insert the thimble.
3. Make a hole in the center for the thimble, and press the bottom of the thimble half way through the hole.
4. Remove the threaded nut from the top of the lamp shade and place the spool over the threaded stud.
5. Insert the needle in the top of the eraser of the pencil, and place the other end of the pencil in the spool hole.
6. Carefully set the thimble and paper spiral over the point of the needle. The point of the needle makes

very little contact with the thimble, and, thus, makes a very good pivot point with little friction.

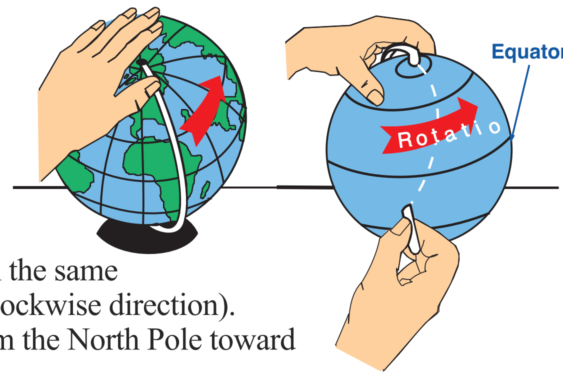
7. Turn on the lamp, observe the movement of the spiral and discuss why the spiral begins to turn.

Safety Precautions

1. Be careful with the scissors when cutting the paper.
2. Be careful when handling the needle.
3. Light bulbs get hot very fast, so be careful when lamp is on.

Summary: The lamp heats the air and the molecules of air expand, making the air less dense, and, thus, lighter. Cooler, heavier air moves in and pushes the warm air up. The warm air pushes on the spiral, and it begins to turn. This same warm rising air affects the weather. It can lead to cloud formations, which can lead to precipitation and storms. Thus, pilots have to constantly maintain awareness of weather conditions caused by the upward movement of warm air molecules.

Activity Three - Coriolis Effect (Force)



Purpose: The purpose of this activity is to demonstrate the path of Coriolis Effect (Force).

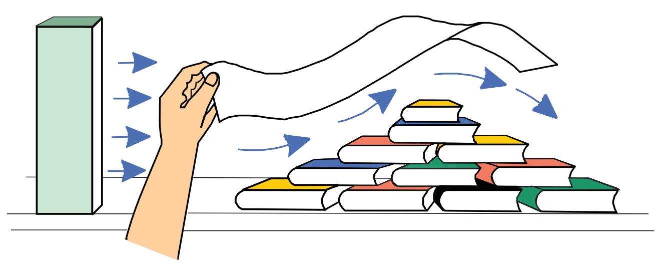
Materials: a globe and chalk

Procedure:

1. Place one hand on top of the globe and slowly turn it in the same direction that the Earth spins (to the right in a counterclockwise direction).
2. As the globe turns, draw a chalk line directly down from the North Pole toward the South Pole.
3. Stop the globe and examine the chalk line. It will not be a straight line but a curved line that crosses the equator at an angle. The chalk line will look like it was drawn from the northeast toward the southwest.
4. Discuss with the group how the Coriolis Effect (Force) works and its effects on airplanes flying through it.

Summary: This activity demonstrates Coriolis Effect (Force), which occurs from the wind effects associated with the rotation of the Earth. Coriolis Effect (Force) deflects a freely moving object to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. It is important to realize that pilots plan for this when they are flying to avoid being deflected off their planned flight course.

Activity Four - Wind Currents



Purpose: Conduct a visual demonstration of wind currents as air moves up and over mountains.

Materials: electric fan, stack of different sized books, and a strip of tissue paper

Procedure:

1. Stack the books to form a small mountain.
2. Place the fan a few feet from the books so a strong breeze blows over the stack.
3. Hold one end of the tissue paper over the books so that it blows.
4. Observe the motion of the tissue paper as the wind from the fan blows it.
5. Discuss what is happening and why.

Summary: The tissue on the side of the books nearest the fan rises up, while the tissue on the side away from the fan descends. Mountain ranges can alter the temperature, pressure, and direction of the prevailing winds. Near the coast, mountains may even block ocean breezes from inland areas. These wind currents can affect flight. Thus, pilots remain constantly aware of such changes in the atmosphere to ensure optimum performance of the airplane.

3 WEATHER ELEMENTS

Learning Outcomes

- Define wind.
- Describe the Beaufort Scale.
- Define heat.
- Explain what temperature is and how it can be expressed on scales.
- Describe what wind chill is and what it does.
- Describe how a microburst can affect a plane's flight.

Important Terms

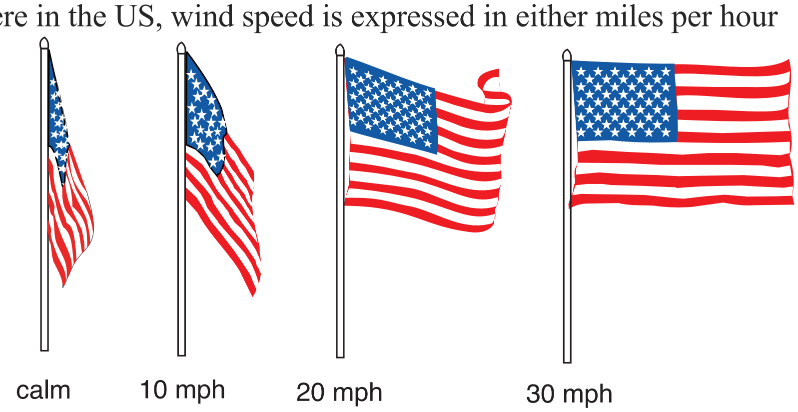
advection - lateral transfer of heat
atmospheric pressure - the weight of all of the atmosphere's gases and molecules on the Earth's surface
Beaufort Scale - a scale for estimating wind speed on land or sea
conduction - heating by direct contact
convection - heat transfer by vertical motion
heat - the total energy of all molecules within a substance
microburst - a downdraft or down burst phenomenon that creates unstable air and thunderstorm turbulence
radiation - heat transferred by the Sun
temperature - a measure of molecular motion expressed on a man-made scale
wind - a body of air in motion
wind chill - temperature and wind speed used to explain how cold it feels

WIND

This chapter discusses three of the very basic weather elements: wind, temperature, and pressure. These elements will be defined and you can conduct activities which will give you a better understanding of how these elements contribute to the overall weather.

Let's begin with a brief discussion of wind. **Wind** is a body of air in motion. It is described as having direction and speed. Wind direction is defined as the direction from which the wind is blowing. For instance, if the wind is blowing from the west, it is called a west wind. A wind blowing from the northwest is called a northwest wind. Here in the US, wind speed is expressed in either miles per hour or knots. A knot is a common nautical and aviation term. One knot equals 1.15 miles per hour and one knot is equivalent to one nautical mile per hour, which is 6,076'.

The illustration to the right demonstrates an easy way to estimate windspeed. It isn't precise, but it can give a good estimate. (See associated Activity Five at the end of the chapter.)



There is another tool for estimating wind speed. This one works on land or sea. It is called the **Beaufort Scale** and has been around since 1805. It is still widely used today. On a windy day, take the Beaufort Scale (below) outside and estimate the wind speed. Do this a few times during the day and then compare your estimations with the local weather report that night.

Beaufort Scale

Beaufort Number	Wind Speed (mph)	Seaman's Term	Effects at Sea	Effects on Land
0	under 1	calm	sea like a mirror	calm; smoke rises vertically
1	1-3	light air	ripples with appearance of fish scales; no foam crests	smoke drift indicates wind direction; vanes do not move
2	4-7	light breeze	small wavelets; crests of glassy appearance; not breaking	wind felt on face; leaves rustle; vanes begin to move
3	8-12	gentle breeze	large wavelets; crests begin to break; scattered whitecaps	leaves, small twigs in constant motion; light flags extended
4	13-18	moderate breeze	small waves, becoming longer; numerous whitecaps	dust, leaves, and loose paper raised up; small branches move
5	19-24	fresh breeze	moderate waves, becoming longer; many whitecaps; some spray	small trees begin to sway
6	25-31	strong breeze	larger waves forming; whitecaps everywhere; more spray	large branches of trees in motion; whistling heard in wires
7	32-38	moderate gale	sea heaps up; white foam from breaking waves begins to blow streaks	whole trees in motion; resistance felt in walking against wind
8	39-46	fresh gale	moderately high waves of greater length; foam is blown in well-marked streaks	twigs and small branches broken off trees
9	47-54	strong gale	high waves, sea begins to roll; dense streaks of foam; spray may reduce visibility	slight structural damage occurs; slate blown from roofs
10	55-63	whole gale	very high waves with overhanging crests; sea takes white appearance; visibility reduced	seldom experienced on land; trees broken; structural damage occurs
11	64-72	storm	exceptionally high waves; sea covered with white foam patches	very rarely experienced on land; usually with widespread damage
12	73 or higher	hurricane force	air filled with foam; sea completely white with driving spray; visibility greatly reduced	violence and destruction

Wind is an interesting phenomenon all by itself. However, if you apply temperature into the situation it gets even more interesting, especially cold temperatures. We have all heard of the **wind chill**, but what exactly is it and how does it work? To determine wind chill, temperature and wind speed are used to explain how cold it feels. It may be 30° F outside, but feels like 9° F because of the combination of cold temperature and strong winds. Actually, heat is escaping from your body and warms the air next to you. If the wind is calm or almost calm, the warm air will stay next to your body. However, if the wind is blowing, it blows the warm air away from your body, and the faster it is blowing, the faster the heat is being carried away causing you to feel colder. Thus, the pysiological effect of wind chill on the body is important to maintain safe body temperature. The wind chill index, noted on next page, can help to calculate wind chill. The actual formula used to determine wind chill

How to find wind chill:

Wind Chill Index

Wind Speed	Temperature in F°						
0 mph	30°	25°	20°	15°	10°	5°	0°
15 mph	9°	2°	-5°	-11°	-18°	-25°	-31°
20 mph	4°	-3°	-10°	-17°	-24°	-31°	-39°
25 mph	1°	-7°	-15°	-22°	-29°	-36°	-44°
30 mph	-2°	-10°	-18°	-25°	-33°	-41°	-49°

Example: 20 mph wind, 10° F = wind chill of -24° F

has various variables, and is different in many countries. If you want to find out more about the actual formulas used, go to the National Weather Service Website at http://www.weather.gov/os/windchill/index.shtml.

How does wind affect flying? Wind speed and wind direction always impact flying. The smaller planes are affected more than the larger planes. Airplanes takeoff into the wind because the wind gives the plane more lift. This allows the plane to leave the ground faster. The wind direction is important because if crosswinds get too high, planes can't takeoff or land safely. Crosswinds are winds blowing toward the side of the plane. Strong crosswinds can blow planes off course. Base operations or the control tower will not allow planes to takeoff or land if the winds are unsafe. A plane's wind capability has already been determined by the manufacturer and is published in the plane's manual.

While planes are en route to their destinations, winds are very important. Pilots love having a tailwind. This is a wind that is blowing from the same direction the plane is flying. Tailwinds will reduce the overall flying time and allow the plane to arrive at its destination earlier. On longer flights, tailwinds can save pilots a significant amount of time and fuel. (See associated Activity Six at the end of the chapter.)

Photo credit Wikipedia

An example of a microburst

There is another weather phenomenon involving winds that impacts flying in a very crucial way. That phenomenon is a microburst. For many years, authorities have realized that microbursts have been responsible for several aircraft accidents. Microbursts are particularly dangerous during takeoffs and landings.

A microburst is defined as a downdraft or downburst. It is a column of sinking air that as it nears the ground or hits the ground diverges in many directions. These winds associated with a microburst can reach 100 - 150 miles per hour and cause considerable damage. Because these diverging winds happen at or near ground level airplanes are so much more vulnerable during takeoffs and landings. A microburst can occur very suddenly leaving little time to react to these diverging winds. Microbursts have a diameter of 2.5 miles or less and can be associated with or without precipitation.

When a microburst happens at normal flying altitudes there may be bumps and bruises, but the plane will recover. When it happens near the Earth's surface, there may not be time to recover. Flying near thunderstorms is dangerous, but when a microburst is involved, it is extremely dangerous.

TEMPERATURE

We know that uneven heating creates **temperature** and pressure differences which causes the air to move. If we break heat down into its basic form, it becomes energy. **Heat** is the total energy of all molecules within a substance. These molecules are constantly in motion because of the heat differences. Heat is a relative term, particularly when expressed as temperature.

There are four principal ways in which heat is transferred from one place to another. These four methods are conduction, convection, advection, and radiation. When a molecule is heated and comes in contact with another molecule, the second molecule absorbs some of this heat. This is heating by direct contact and is called **conduction**. **Convection** is the heat transfer by vertical motion. In summer, air over a hot runway or a highway will rise. Air over hot surfaces rises faster than the air over surrounding surfaces. Parcels of air have a certain temperature, and when the wind blows, this air comes in contact with other parcels of air. This process is the lateral transfer of heat and is called **advection**. The last heat transfer is the heat energy from the Sun, and it is called **radiation**. These four processes of heat transfer are very important in the process of weather.

Temperature is a measure of molecular motion expressed on a man-made scale, either in Fahrenheit (F), Celsius (C), or Kelvin (K). Fahrenheit's freezing point is 32° and its boiling point is 212°. The freezing point of Celsius is 0° and its boiling point is 100°. The Kelvin freezing point is 273° and its boiling point is 373°. Kelvin is used for scientific purposes.

Converting back and forth from Fahrenheit and Celsius is very simple if you have a formula to use. Any of these three formulas will work.

$$F = (C \times 1.8) + 32 \quad \text{or} \quad C = F - 32 \div 1.8 \quad \text{or} \quad F = (9/5)\,C + 32$$

There is another conversion procedure which can be helpful; take a Celsius temperature and double it, then subtract 10%, then add 32. This will work as well.

Example: if C = 100, then F=212. Use one of the formulas to determine this. (See associated Activity Six at the end of the chapter.)

Do aircraft pilots really care about what the temperature is? You better believe they do! Particularly in extreme conditions. In other words, when temperatures are either really cold or really hot, pilots are most concerned. Why is this the case? Well, for one thing, temperature affects takeoff. An explanation follows.

You will recall that the Sun heats the earth unevenly. This unequal heating gives us temperature differences which, in turn, causes pressure differences. The different temperature and pressure characteristics mean that the parcels of air have different molecular make up and weigh different amounts, exerting different amounts of pressure. Pilots must take this into account when preparing for takeoff.

High temperatures impact takeoffs of large aircraft.

Warmer temperatures result in longer acceleration times to attain proper takeoff speeds. On extremely hot days the air can become very humid. A pilot needs to calculate the distance needed to make sure there is enough runway for takeoff.

Understanding temperatures becomes crucial when they are extreme. Extreme hot and cold temperatures can cause pain discomfort and even death. Extreme heat can cause heat cramps (especially in legs), fainting (quick drop in blood pressure), heat exhaustion (dizziness after several hot days), and heatstroke (confusion, unconsciousness, or even death). Drinking plenty of water when it is extremely hot can offset negative physical conditions.

In extreme cold, hypothermia and frostbite may occur. In hypothermia, the body temperature drops below 95° and a person can become unconscious and even die. Wearing wool clothing decreases body heat escape, thus reducing the chance of hypothermia. Frostbite can range from very minor to very serious cases. Ears, nose, hands, and feet are the most vulnerable. Gloves, hats, dry socks, and a covering for the face help prevent frostbite. (See associated Activities Seven and Eight at the end of the chapter.)

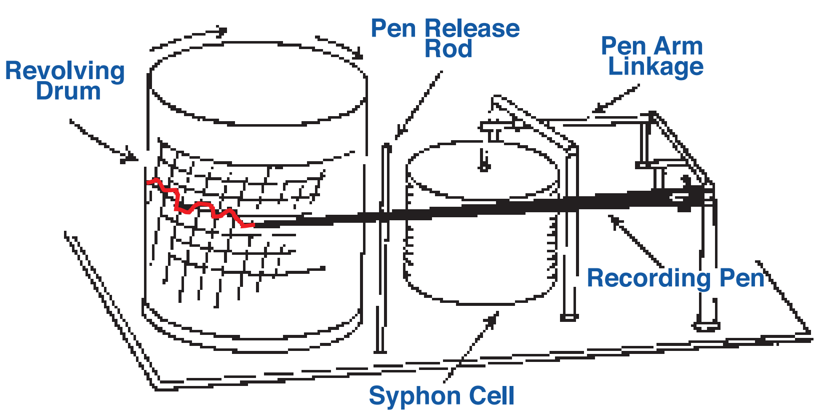
PRESSURE

The last area in this chapter is pressure. We already know that unequal heating creates pressure differences. Our air is made up of gases. Each of these gases has molecules, and these molecules have weight. This weight, or push on the Earth's surface, is called **atmospheric pressure**. The weight, or atmospheric pressure, in a given space depends on the number of molecules occupying that space. There are literally billions of molecules near the Earth's surface. It has been said that a molecule travels less than one millionth of an inch before it collides with another molecule. This colliding causes additional movement. Because it is so crowded, there is always molecular movement near the surface of the Earth.

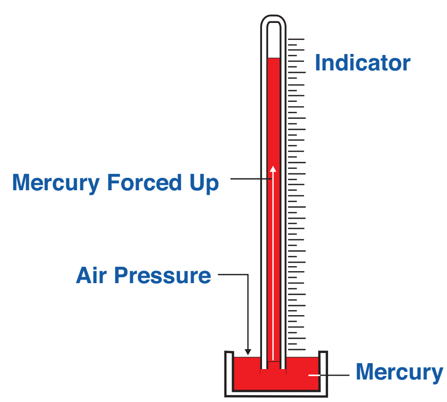
Another area where we notice pressure changes is our body, particularly our ears and sinuses. Our bodies have trouble adjusting to rapid decreases or increases in pressure. Airplanes or even elevators can make us physically uncomfortable. When an airplane is taking off, the outside pressure decreases so the pressure inside our ear is higher. Also, when a plane is landing, the outside pressure increases so the pressure inside our ear is lower. Normally, air can move through the ear and equalize the pressure. However, if you have a cold and your ears are blocked or you have blocked sinuses, the air can't equalize and you may feel some discomfort or pain. If you have a severe cold or sinus problem, you should consider consulting a doctor before flying.

Air pressure can be measured with a mercury barometer, an aneroid barometer, or an aneroid barograph. An aneroid barometer is fast and easy to read. Aneroids are the barometers people have on their walls at home or in their office. A mercury barometer is not as quick, but is more stable and reliable. A mercury barometer is mainly used by scientists and meteorologists. An aneroid barograph can be found in weather stations all over the country because it gives a permanent record of pressure readings. A permanent record is important if pressure readings need to be reviewed due to severe weather or an aircraft accident.

Aneroid barometer

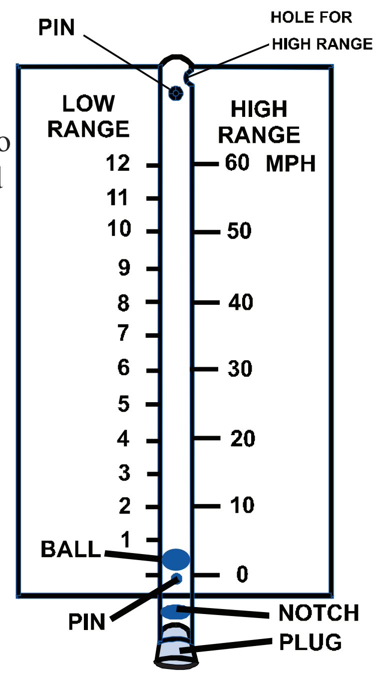


Aneroid Barograph



Mercury Barometer

Activity Five - Wind Gauge



Purpose: Make and test a simple wind gauge.

Materials: clear plastic drinking straw (clean and dry), styrofoam cup, two straight pins, piece of cardboard (about 3x12 inches), transparent tape, and Exacto knife or scissors (caution – adult supervision advised)

Procedure:

1. Cut a piece of styrofoam from a styrofoam cup slightly larger than the diameter of the straw.
2. Roll the piece of styrofoam between your finger and thumb until it forms a ball that will move freely inside the straw.
3. Cut a notch in the straw about a half inch from one end to allow air to enter. (This notch will designate the front of the straw.)
4. Cut another piece of styrofoam and place it in the end of the straw below the notch to plug up the hole.
5. Cut a small hole in the side of the straw near the opening at the other end of the straw to allow air to escape when you are measuring higher winds.
6. Place the straw on the center of the cardboard with the open straw end meeting the top of the cardboard and the hole facing the side. The notched end will hang a bit below the bottom of the cardboard with the notch facing forward.
7. Press one of the pins through the straw and cardboard, just above the notch.
8. Drop the ball into the other end of the straw.
9. Press the other pin through the top of the straw and the cardboard, just below the small side hole you cut for the high range.
10. Securely fasten the straw to the cardboard with a couple of strips of transparent tape.
11. Label the cardboard, as shown on the illustration, with the words Low Range and High Range. The numbers on the illustration will be added as your gauge is calibrated by determining the corresponding speed with the movement of the styrofoam ball.
12. To calibrate (or establish and mark the units on a measuring instrument) your wind gauge, hold it outside a moving car window on a calm day. Have the open notch at the bottom of the straw facing into the wind. Air entering here will lift the styrofoam ball to various heights depending on the speed of the air (determined by the speed of the vehicle). Use the vehicle's speedometer to mark the card. Determine low range markings by having the vehicle driver go 1 mph and mark the height of the styrofoam ball. Then, do the smae for 2 mph, 3 mph, and so on until you reach 12 mph. To determine high range markings, hold your finger over the top of the straw. This will keep the ball from rising as high and forces the air to leave through the small hole you cut near the top. Follow the same markings procedure as for the low range, but use the illustrated mph

speeds. Another way to calibrate would be to go to your local weather station and measure your gauge against their equipment.

Summary: The wind gauge is used to measure the approximate speed of the wind. Knowing the wind speed, or forecasting a wind speed, gives a good idea of how the wind will affect the land and sea. Knowing wind speed helps pilots appropriately adjust their takeoff, cruise, and landing speeds. If the winds are too high, flights may be cancelled, or planes may have to land at alternate landing sites.

Activity Six - Convert Temperatures

Purpose: Use mathematical skills to convert temperatures from Fahrenheit to Celsius and vice-versa.

Materials: Use formulas found on page 14 to conduct this activity.

Procedure: Convert temperatures

1. Convert the following Fahrenheit temperatures to Celsius:
22° F = ___ C, 55° F = ____C, 75° F = ____C

2. Convert the following Celsius temperatures to Fahrenheit:
45° C = ____F, 4° C = ____F, 82° C = ____F

Summary: Pilots are concerned about extremely cold and hot temperatures as temperature affects flight, and, thus, need to be able to quickly convert temperature measurement scales, as appropriate, to maintain current temperature data for flight planning. By using the appropriate mathematical formula, conversion of temperature from one scale to another is possible. F = (C x 1.8) + 32 and C = (F – 32) ÷ 1.8
Answers to problems (rounded to nearest whole number): 1. 22°F = - 6 °C; 55°F = 13°C; 75°F = 24°C
2. 45°C =113 °F; 4°C = 39 °F; 82°C = 180 °F

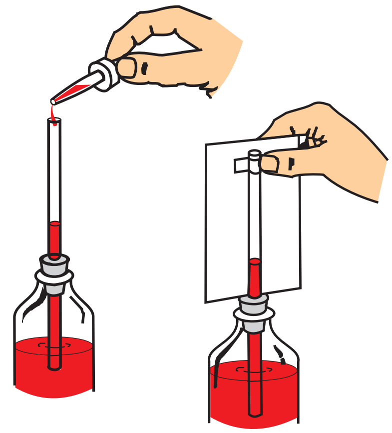
Activity Seven - Homemade Thermometer

Purpose: Construct and test a homemade thermometer to determine heat or cold.

Materials: clear glass bottle (pint or quart), cork or stopper with one hole to fit a drinking straw, clear plastic drinking straw, 3x5 inch card, pencil, water, food coloring, candle, matches, transparent tape, oil (any kind), a medicine dropper, and thermometer

Procedure:
1. Fill the bottle with water and add a few drops of food coloring.
2. Push the straw through the hole in the cork.
3. Press the cork down into the bottle. Make sure that about two inches of the straw are in the water.
4. Light the candle and hold it so that the wax drips where the straw meets the cork to seal the straw to the cork. (Adult supervision suggested.)
5. The level of the water should be about one-fourth of the way up the straw.
6. Use the medicine dropper to add more colored water into the straw.
7. Add a couple of drops of oil to prevent the water from evaporating.
8. Use tape to fasten the card behind the straw.
9. To calibrate your thermometer, place another thermometer alongside yours and mark the level on the card. Mark the degrees from the known thermometer.

10. Experiment with the thermometer by moving it to differing levels of temperature (in sun, in refrigerator, in closet, etc).



Summary: The higher the liquid rises in the straw, the hotter the temperature. The lower the liquid in the straw, the lower the temperature. Pilots are concerned about extremely cold and hot temperatures as temperature affects takeoffs and landings. Additionally, extremely cold temperatures can impact a flight in route to a destination.

Activity Eight - Cricket Thermometer

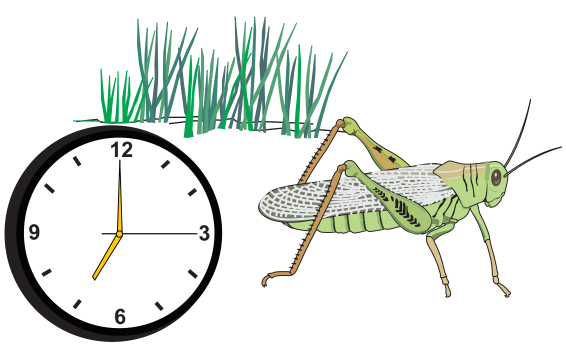
Purpose: The purpose of this activity is to use observation and mathematical skills to estimate temperature.

Materials: chirping cricket, clock or watch with a second hand, a warm day/evening, and a thermometer

Procedure:

1. On a warm day or evening, listen for the sound of a chirping cricket.
2. Use the watch or clock, count the number of chirps in 15 seconds and add 37 to this number. This sum should just about equal the actual temperature.
3. To find out, compare with an actual thermometer.
4. Discuss why or how it may be possible for a cricket (or other living thing) to be so aligned with the environment.

Summary: This activity is a fun way to estimate temperature, if you have a warm day/evening and a chirping cricket. The implications of varying temperature, especially to pilots, has been explained in this chapter. But, fun activities, such as this, help us to see how nature is well-planned to “work” in the scheme of life.



4 MOISTURE AND CLOUDS

Learning Outcomes

- Describe the condensation process.
- Describe how saturation occurs.
- Define dew point.
- Define what precipitation is and give some examples.
- Define fog.
- Define turbulence.

Important Terms

condensation - the process of converting water vapor to liquid
dew point - the temperature at which the air becomes saturated with water vapor
fog - tiny droplets of liquid water at or near the surface of the land or water
humidity - amount of water vapor in the air
precipitation - general term given to various types of condensed water vapor
relative humidity - amount of water vapor in the air compared to its water vapor capacity at a given temperature
saturation - the condition of a parcel of air holding as much water vapor as it can at the air temperature at that time
water cycle - continuous movement of water as it circulates between the Earth and its atmosphere

MOISTURE

Without moisture in the atmosphere, weather could not exist. Moisture is the most important element in the development of the weather. It is the main component for clouds, rain, snow, and fog. Moisture exists in three states: solid, liquid, and gas. As a gas, it is called water vapor. Water vapor is always present in varying degrees in the atmosphere. When the air gets to the point where it is holding all of the water it can, saturation is reached. **Saturation** is defined as the air holding as much water vapor as it can at the air temperature at that time. The temperature at which the air becomes saturated is called the **dew point**. This is not a fixed point. It changes several times a day depending on the amount of moisture in the air. If the temperature decreases below its dew point, condensation occurs. Or, if a parcel of saturated air receives more water, it condenses into liquid form. The conversion of water vapor to a liquid is called **condensation**. Clouds, fog, snow, and rain are products of condensation. (See associated Activity Nine at the end of the chapter.)

Another important term is **humidity**. Humidity is the term used for the amount of water vapor in the air. When someone talks about how humid it is, they are really describing the relative humidity. **Relative humidity** is the amount of humidity in the air compared to its total water vapor capacity at a given temperature. It is expressed in a percentage. The higher the percentage, the more humidity. (See associated Activity Ten at the end of the chapter.)

FOG

As mentioned earlier, one form of condensation is fog. **Fog** is composed of tiny droplets of liquid water that are at or near the surface of the geographical area. It is actually a cloud that is very near, or touching the ground. Generally, fog forms when the temperature and dew point are within five degrees of each other and the winds are light (five knots or less). (See associated Activity Eleven at the end of the chapter.)

Fog rolling in under the Golden Gate Bridge

Pilots frequently encounter fog, and it mostly concerns them during takeoffs and landings. Fog restricts how well a pilot can see. Many times when fog is present, pilots use their flight and navigation instruments to gauge distances both horizontally and vertically.

PRECIPITATION

Another product of condensation is **precipitation**. Precipitation is the general term given to the various types of condensed water vapor that fall to the Earth's surface such as rain, snow, or ice. Precipitation that falls to the ground as a liquid and stays in liquid form is called rain.

Precipitation affects flying mainly through the pilot's visibility and the runway conditions. The harder it rains, the more it reduces the visibility, and the more it diminishes good runway conditions for both takeoff and landing. (See associated Activity Twelve at the end of the chapter.)

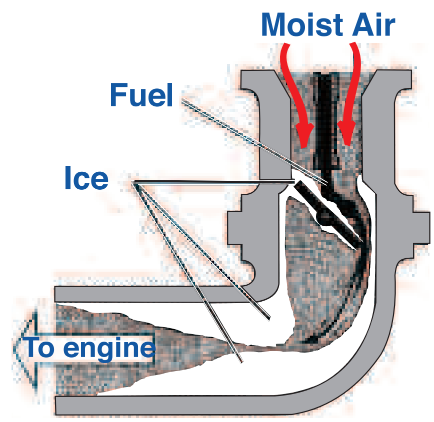
Flying in snow and icy conditions

Precipitation that falls to the ground, but freezes upon contact with various surfaces, such as the ground, a highway, or cars, is called freezing rain. Freezing rain can cause hazardous conditions. Ice on car windshields and on highways poses major problems for motorists. Extreme caution should be taken in icy conditions.

Ice can also represent huge problems for aircraft. First of all, ice on the runway can raise havoc with a plane trying to land. The plane can lose directional control and take much longer to come to a full stop, causing possible accidents.

Another critical condition could be ice in the airplane's engine. In this case, ice can form in the carburetor, thus reducing or stopping fuel flow to the engine. Engine manufacturers recommend that carburetor heat be applied to help solve the ice problem.

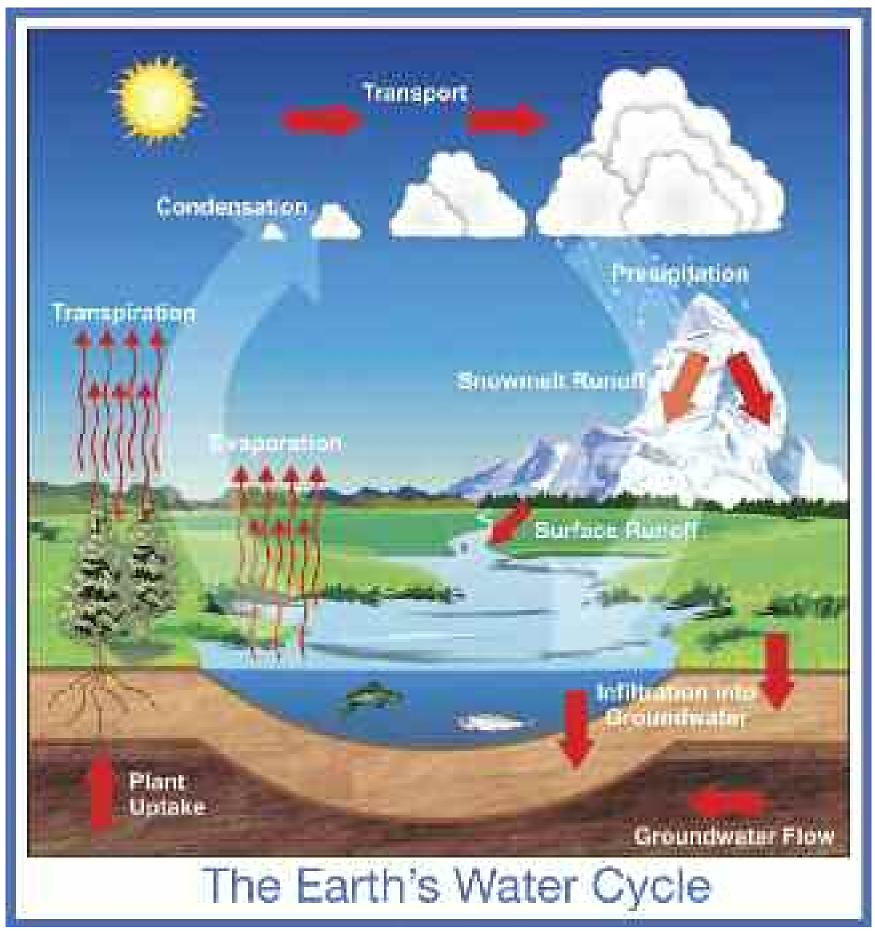
Ice can also form on a plane's windshield, propeller, or wings. If left to accumulate, it could cause weight, lift, and visibility problems. Pilots will quickly change flying altitude to get away from the ice. Also, weather forecasters will brief pilots on possible icy conditions before they take off.



Carburetor Icing

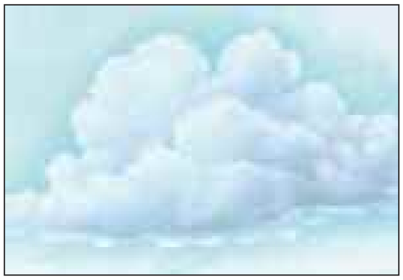
WATER CYCLE

The **water cycle** is the continuous movement of water between the Earth and its atmosphere. Water is always moving and changing from a liquid to vapor and back to liquid or snow and ice. The sun heats the oceans and lakes causing water to evaporate. The water rises and becomes water vapor, then eventually condenses into tiny droplets forming clouds. When clouds meet cool air, precipitation can occur. Some precipitation soaks in the ground and other falls back into the oceans, and the circulation continues. This picture is a good illustration of the water cycle.



Courtesy of National Oceanic and Atmospheric Association (NOAA)

CLOUDS



Cumulus

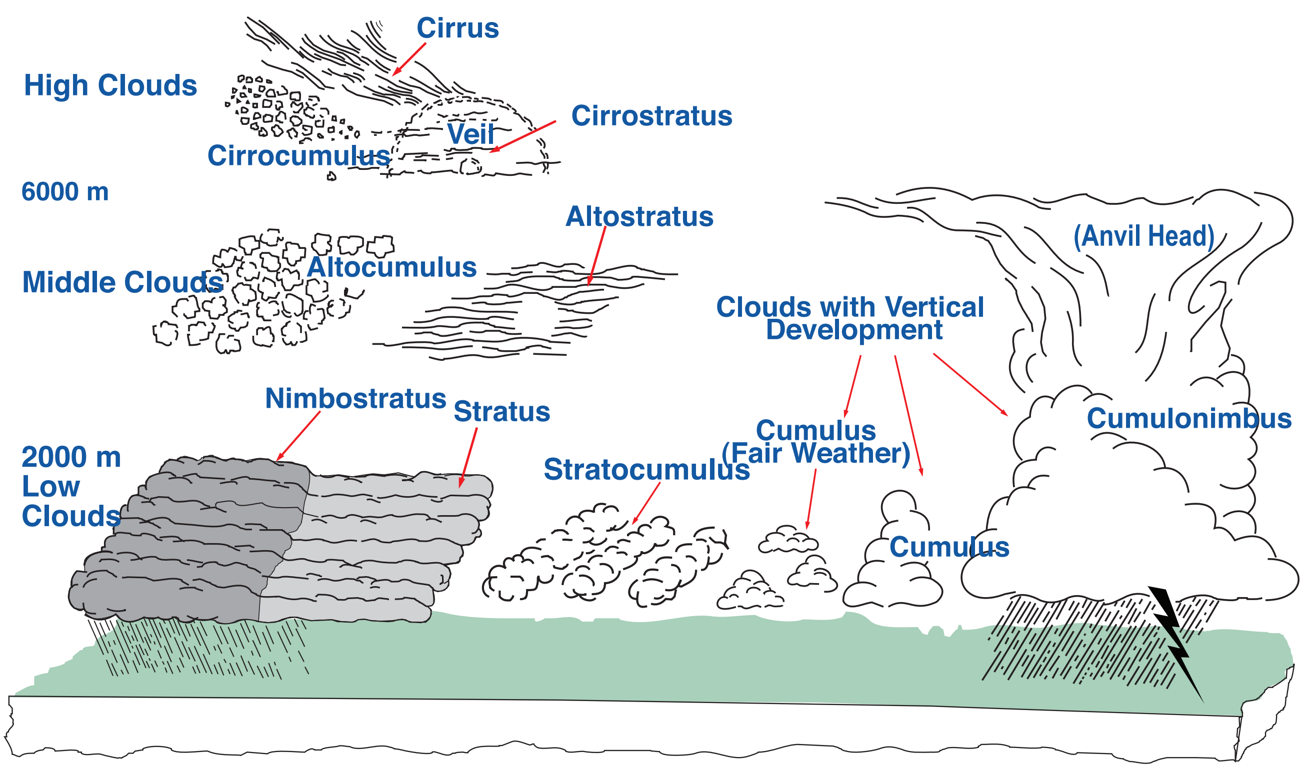
Stratus

Cirrus

Another phenomenon which results from condensation is clouds. Clouds are made up of minute droplets of water, or tiny crystals of ice, or both. Clouds are of continual interest to meteorologists because they are visible indications of what is going on with the weather. The more we learn about clouds, the more we learn about the weather and what to expect. (See associated Activity Thirteen at the end of the chapter.)

There are three basic cloud forms: cumulus, stratus, and cirrus. Clouds are classified by their appearance and height. Cumulus clouds are normally white, billowy, puffy clouds. Some describe them as cotton balls. Cumulus is a fair weather cloud indicating good weather. Stratus has a very uniform appearance. It is thin with very little vertical development. It is almost sheet-like in its appearance. Stratus is gray instead of white. Cumulus and stratus are both found low in the sky and close to the ground. Cirrus clouds are very high in the sky. They are white, thin, wispy clouds, usually in patches, filaments, hooks, or bands. Because of their height, they are composed of ice crystals.

There are also ten basic cloud types that come from the three basic cloud forms. These ten basic



Ten Basic Cloud Types

cloud types are universally accepted as the world's main cloud types. The diagram on page 22 should give you an idea of what they look like and a general feel for some of the differences. For instance, nimbostratus clouds produce rain that can last for hours.

An important cloud for helping us identify weather is the cumulonimbus cloud. Cumulonimbus is the cloud that produces storms with thunder and lightning. This cloud also produces heavy rain showers, strong winds, hail, and even tornadoes. Thunder and lightning come only from cumulonimbus clouds.

Another distinctive feature of cumulonimbus is the mammatus development. This feature normally occurs at the base of the cloud and looks like bulges or pouches. Mammatus formations indicate the degree of instability in the area. Although not always, tornadoes often come from these clouds. Even if tornadoes don't occur, these clouds indicate severe weather.

Normally, clouds do not present a problem for airplanes. Pilots fly in and out of clouds all of the time. Obviously, an exception to this is the cumulonimbus cloud. Pilots don't want to fly into thunderstorms or tornadoes.

Cumulonimbus Clouds

Cumulonimbus Clouds

Mammatus formations under cumulonimbus clouds

In general, cumulus clouds are also associated with another weather phenomenon, and that is turbulence. Turbulence is an unrest or disturbance of the air. It refers to the instability of the air. Turbulence is the motion of the air that affects the smoothness.

Unstable air is turbulent air, whereas stable air is smooth with very little turbulence. Cumulus clouds are formed by convection, which is defined as warm air rising. This rising warm air comes in contact with cooler air causing the turbulence.

Pilots know that they will encounter turbulence when they fly through cumulus clouds. They also know that turbulence can cause some very bumpy rides, especially in smaller planes.

CLOUD CLASSIFICATION

Clouds are classified according to their height above and appearance (texture) from the ground. The following cloud roots and translations summarize the components of this classification system: 1) Cirro-: curl of hair, high; 2) Alto-: mid; 3) Strato-: layer; 4) Nimbo-: rain, precipitation; and 5) Cumulo-: heap. Refer to the chart on page 22 for examples of the various types of clouds.

High-level clouds:

High-level clouds occur above about 20,000 feet and are given the prefix "cirro." Due to cold tropospheric temperatures at these levels, the clouds primarily are composed of ice crystals, and often appear thin, streaky, and white (although a low sun angle, e.g., near sunset, can create an array of color on the clouds). The three main types of high clouds are cirrus, cirrostratus, and cirrocumulus.

Cirrostratus

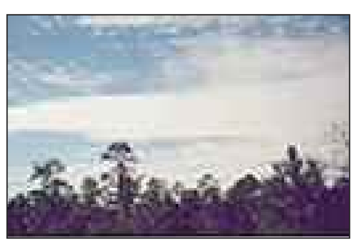
Cirrocumulus

Cirrus clouds are wispy, feathery, and composed of ice crystals. They often are the first sign of an approaching warm front or upper-level jet stream. Unlike cirrus, cirrostratus clouds form more of a widespread, veil-like layer (similar to what stratus clouds do in low levels). When sunlight or moonlight passes through the hexagonal-shaped ice crystals of cirrostratus clouds, the light is dispersed or refracted (similar to light passing through a prism) in such a way that a familiar ring or halo may form. As a warm front approaches, cirrus clouds tend to thicken into cirrostratus, which may, in turn, thicken and lower into altostratus, stratus, and even nimbostratus.

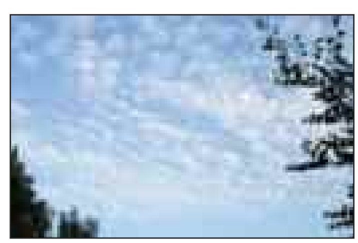
Finally, cirrocumulus clouds are layered clouds permeated with small cumuliform lumpiness. They also may line up in "streets" or rows of clouds across the sky.

Mid-level clouds:

The bases of clouds in the middle level of the troposphere, given the prefix "alto," appear between 6,500 and 20,000 feet. Depending on the altitude, time of year, and vertical temperature structure of the troposphere, these clouds may be composed of



Altostratus



Altocumulus

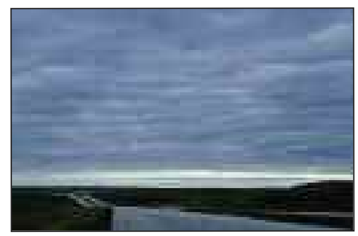
liquid water droplets, ice crystals, or a combination of the two, including supercooled droplets (i.e., liquid droplets whose temperatures are below freezing). The two main types of mid-level clouds are altostratus and altocumulus.

Altostratus clouds are "strato" type clouds (see previous page) that possess a flat and uniform type texture in the mid levels. They frequently indicate the approach of a warm front and may thicken and lower into stratus, then nimbostratus, resulting in rain or snow. However, altostratus clouds themselves do not produce significant precipitation at the surface, although sprinkles or occasionally light showers may occur from a thick altostratus deck.

Altocumulus clouds exhibit "cumulo" type characteristics (see previous page) in mid levels, i.e., heap-like clouds with convective elements. Like cirrocumulus, altocumulus may align in rows or streets of clouds, with cloud axes indicating localized areas of ascending, moist air, and clear zones between rows suggesting locally descending, drier air. Altocumulus clouds with some vertical extent may denote the presence of elevated instability, especially in the morning.

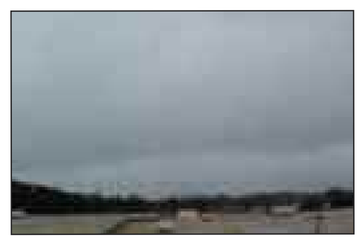
Low-level clouds:

Low-level clouds are not given a prefix, although their names are derived from "strato" or "cumulo," depending on their characteristics. Low clouds occur below 6500 feet, and normally consist of liquid water droplets or even supercooled droplets, except during cold winter storms when ice crystals (and snow) comprise much of the clouds.



Stratocumulus

The two main types of low clouds include stratus, which develop horizontally, and cumulus, which develop vertically. Stratus clouds are uniform and flat, producing a gray layer of cloud cover which may be precipitation-free or may cause periods of light precipitation or drizzle. Low stratus decks are common in winter in the Ohio Valley, especially behind a storm system when cold, dismal, gray weather can linger for several hours or even a day or two. Stratocumulus clouds are hybrids of layered stratus and cellular (individual) cumulus, i.e., individual cloud elements, characteristic of cumulo-type clouds, clumped together in a continuous distribution, characteristic of strato-type clouds. Stratocumulus also can be thought of as a layer of cloud clumps with thick and thin areas. These clouds appear frequently in the atmosphere, either ahead of or behind a frontal system. Thick, dense stratus or stratocumulus clouds producing steady rain or snow often are referred to as nimbostratus clouds.



Nimbostratus

Cumulus congestus

In contrast to layered, horizontal stratus, cumulus clouds are more cellular in nature, have flat bottoms and rounded tops, and grow vertically. In fact, their name depends on the degree of vertical development. For instance, scattered cumulus clouds showing little vertical growth on an otherwise sunny day used to be termed "cumulus humilis" or "fair weather cumulus," although normally they simply are referred to just as cumulus or flat cumulus. A cumulus cloud that exhibits significant vertical development (but is not yet a thunderstorm) is called cumulus congestus or towering cumulus. If enough atmospheric instability, moisture, and lift are present, then strong updrafts can develop in the cumulus cloud leading to a mature, deep cumulonimbus cloud, i.e., a thunderstorm producing heavy rain. In addition, cloud electrification occurs within cumulonimbus clouds due to many collisions between charged water droplet, graupel (ice-water mix, much like hail), and ice crystal particles, resulting in lightning and thunder.

Cumulonimbus

THE LENTICULAR CLOUDS — FORMING ON ONE SIDE — GOING AWAY ON THE OTHER SIDE!

No, it's not an alien spacecraft. It's known as a "lenticular cloud," or an "altocumulus standing lenticular" or ACSL cloud.

Lenticular clouds, technically known as altocumulus standing lenticularis, or ACSL, are stationary lens-shaped clouds that form at high altitudes, normally aligned at right angles to the wind direction.

When stable moist air flows over a range of mountains, a series of large-scale standing waves may form. Under certain conditions, long strings of lenticular clouds can form, creating a formation known as a wave cloud.

Power pilots tend to avoid flying near lenticular clouds because of the turbulence of the rotor systems that accompany them, but sailplane pilots actively look for them. This is because the systems of atmospheric standing waves that cause "lennies" (as they are sometimes called) also involve large vertical air movements, and the precise location of the rising air mass is fairly easy to predict from the orientation of the clouds. This vertical air movement gives a glider lift that takes it to a higher altitude.

"Wave lift" of this kind is often very smooth and strong, and enables gliders to soar to remarkable altitudes and great distances. Some gliders have soared as far as over 1,500 miles and as high as about 50,000 feet.

The picture below depicts an altocumulus standing lenticular over Mt. Rainier in Washington State, just south of Seattle. The cloud, although it looks like it is standing still, is actually forming on one side and dissipating on the other. These clouds look this way because cloud-forming vapor condenses by going below dew point at the crest of the waves. The lenticular clouds are known to foreshadow bad weather. When airline pilots see these in the distance, the “seat belt” light goes on immediately and a voice comes over the speaker saying, “Ladies and gentlemen, we may be experiencing turbulence soon so please take your seats and fasten your seat belts!”

An altocumalus standing lenticular cloud simultaneously forming and dissipating above Mt. Rainier.

ACTIVITY SECTION 4

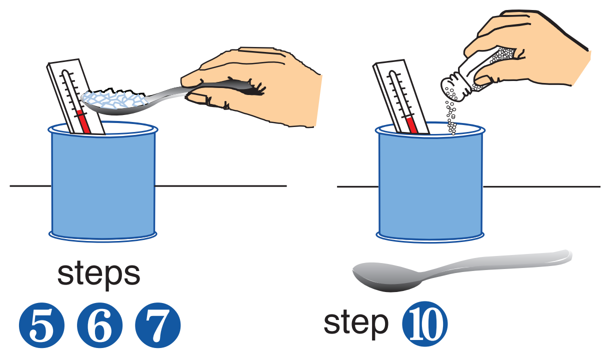
Activity Nine - Dew Point

Purpose: Conduct an experiment to visually demonstrate the concept of dew point.

Materials: tin can, thermometer, tablespoon, ice cubes, paper towel, bowl, spoon, cool water, and salt (optional - blender)

Procedure:

1. Place an ice cube on the paper towel.
2. Use the spoon to break the ice cube into small pieces.
3. Place these pieces into the bowl.
4. Continue this process of breaking ice cubes until you have about half a bowl full of crushed ice. (Or, use a blender to crush ice all at once.)
5. Fill the can to about one-fourth full of cool water.
6. Place the thermometer in the can.
7. Add a tablespoon of crushed ice and stir.
8. Continue to slowly add ice and stir until a thin layer of moisture, or dew, forms on the outside of the can.
9. Read the temperature as soon as the dew forms. This is the dew point.
10. If you add salt to the ice and stir, the moisture will turn into frost because the salt lowers the temperature of the dew to freezing.

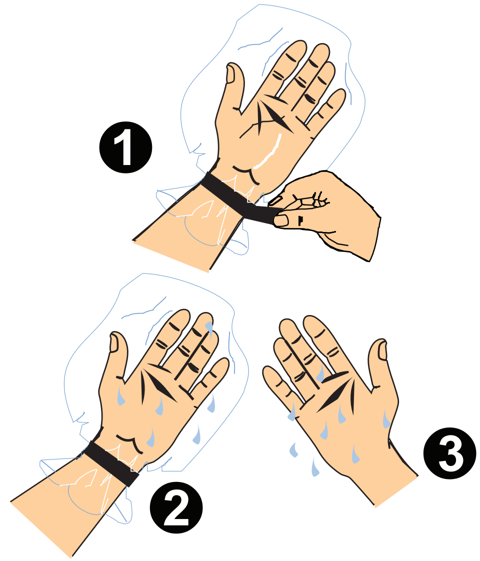


Summary: This activity reinforces the concept explained in this chapter regarding dew point. The dew point affects weather, which, of course, is of concern to pilots. Also, as explained at http://www.flyingsafer.com/test%20report.htm, "A major cause of shortened engine life is water that forms inside an internal combustion engine when it is not running. If the metal parts of the engine ever cool to a temperature that is lower than the dew point temperature of the air inside your engine, water droplets will form on the cool engine parts. This same process that causes dew to collect on your automobile in the morning is collecting water inside your engine. If you can do something to upset this process of changing temperatures and humidity levels (such as lowering the dew point temperature of the air inside the engine to a temperature considerably below the outside air temperature), you can prevent water from ever forming inside your engine."

Activity Ten - Comfort and Humidity

Purpose: Use observation skills to experiment with humidity, which is discussed in chapter four.

Materials: plastic bag or empty bread wrapper, tape, and room-temperature water



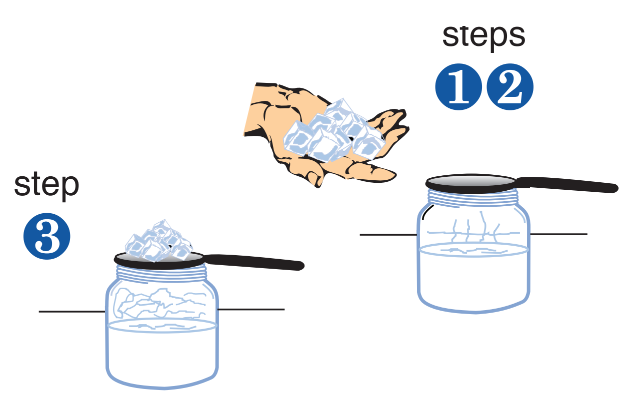
Procedure:
1. Place one hand in the plastic bag.
2. Seal the bag snugly around your arm with tape, making the bag airtight.
3. Leave the bag in place a few minutes and observe your hand as it begins to sweat.
4. Wet your other hand with the room-temperature water. Both hands are wet, but the one in the bag feels uncomfortable while the other hand feels cool.
5. Discuss possible reasons for the difference in the "comfort" of the two types of dampness.

Summary: The hand outside the bag feels wet, but comfortable. The hand inside the bag feels wet, uncomfortable, and probably sticky. This is because the humidity is too high inside the bag. Humidity affects the weather, which, in turn, is of great concern to pilots. Also, humidity can affect the properties of materials both inside and outside the airplane. Inside the cabin, the relative humidity is kept low to help prevent corrosion. Due to the low humidity inside the cabin of an aircraft, passengers may want to wear eyeglasses as opposed to contact lenses that can become dried out. Also, passengers may wish to bring moisturizer for the face and/or hands on long flights.

Activity Eleven - Making Fog

Purpose: Demonstrate how fog forms.

Materials: clear glass jar, tea strainer, ice cubes, and hot water



Procedure:
1. Fill the jar half full of hot water.
2. Place the strainer over the opening of the jar.
3. Fill the strainer with ice cubes and fog will form inside the jar.

Summary: With this activity, it is easy to see how easily fog can form. This fog is formed when a layer of warm, moist air forms low to the ground. A layer of cooler, dry air (ice) forms overtop, cooling the warmer air quickly. As the air temperature lowers, small droplets of water condense, and is seen as fog.

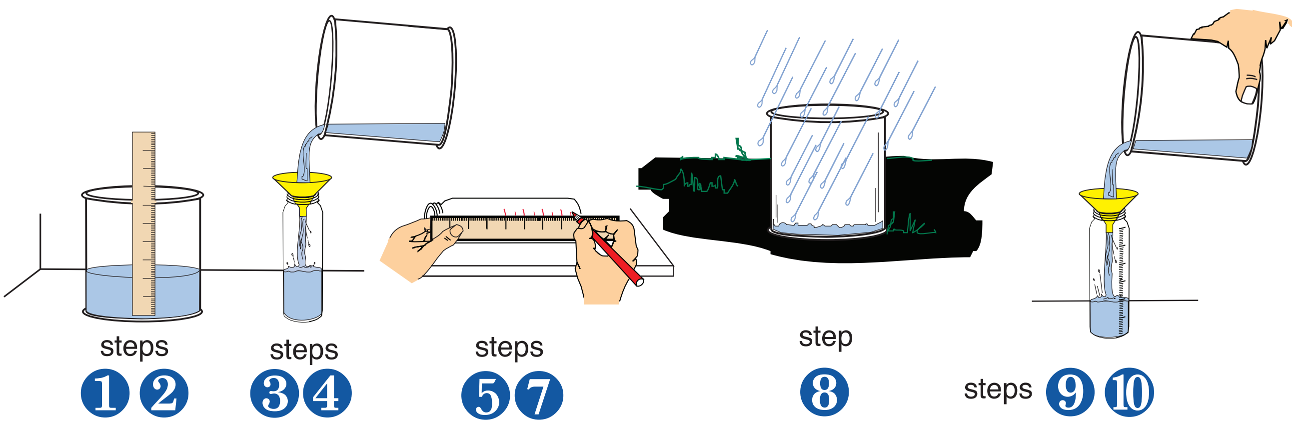
Activity Twelve - Measuring Precipitation

Purpose: Make and use a rain gauge to measure precipitation.

Materials: a 1-pound coffee can, olive jar, ruler, marking pen, water, funnel, and a watch

Procedure:

1. Place the ruler into the coffee can.
2. Pour 2 inches of water into the can, using the 2-inch mark on the ruler as your gauge.
3. Place the funnel into the top of the olive jar.
4. Pour the 2 inches of water from the can into the jar.
5. Mark the water level on the outside of the jar.
6. Discard the water in the jar.
7. Use the ruler to divide the space below the mark on the jar into 20 equal spaces. (This divides the space into tenths, with each mark representing one-tenth of an inch of rain.)
8. Place the coffee can in an open area away from trees and buildings to collect rain water.
9. After the rain stops, use the funnel to pour the rain water from the can into the jar.
10. Read the marks on the jar to determine the amount of rain that fell.



Summary: This is a great exercise for keeping an accurate account of how much rain is falling or has fallen. It is standard practice to measure rainfall for an hour, 6 hours, or even a day or month. When using the rain gauge, remember to record your measurements and then dump out the rain so that it doesn't get counted again. Measuring precipitation is a regular action of meteorologists to help the public stay abreast of agricultural, transportational, and recreational impact.

Activity Thirteen - Cloud in a Bottle

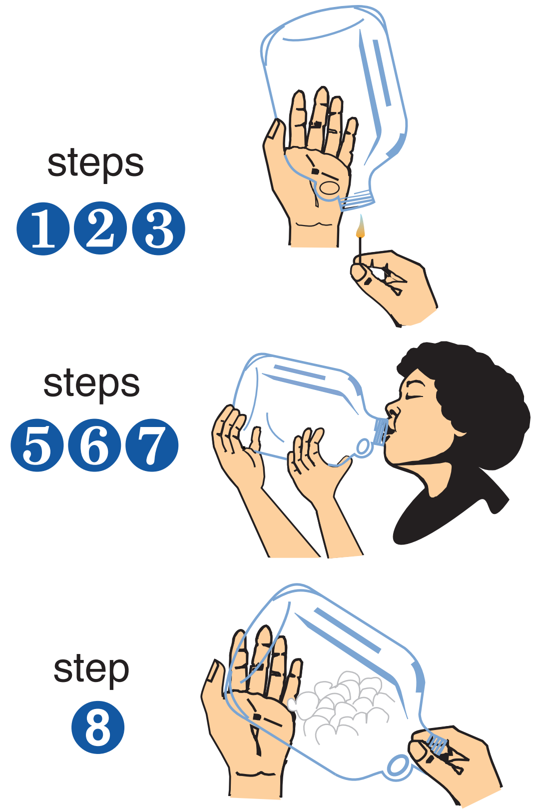
Purpose: Simulate cloud formation, as discussed in chapter four.

Materials: glass jug with a small mouth and a match or candle (Note: adult supervision suggested.)

Procedure:

1. Light the match or candle. (Adult supervision required)
2. Turn the jug upside down and carefully hold the opening over the flame.
3. Warm the air inside the jug for a few seconds.

4. Blow out the match or candle.
5.Quickly place your mouth around the opening to make a seal.
6. Blow hard into the jug, compressing the air inside the jug as much as possible. (Be careful not to breathe in, or the compressed air will be released too soon.)
7. Quickly remove your mouth and release the pressure.
8. Observe the cloud that forms inside the jug.
9. Discuss why/how this happens.



Summary: When you compressed the warm air in the jug, you also added the moisture from your breath. When you suddenly released the pressure, the air molecules in the jug cooled and expanded. The cooler air couldn't hold as much moisture as the warmer air, thus some of the moisture condensed into tiny droplets and formed a cloud. In the atmosphere, these tiny water droplets, or ice crystals, cling to particles in the atmosphere, such as salt, smoke, dust, and volcanic ash to form clouds.

5 WEATHER SYSTEMS AND CHANGES

Learning Outcomes

- Define an air mass and identify air mass characteristics.
- Define a front and describe the types of fronts.
- Describe hurricanes, thunderstorms, and tornadoes.
- Identify the stages of a thunderstorm.
- Outline safety precautions for thunderstorms and tornadoes.

Important Terms

air mass - huge body of air with the same temperature and moisture characteristics

front - a boundary between two air masses

hurricane - a tropical cyclone of low pressure and very strong winds; usually with heavy rain and possible thunderstorms and tornadoes

thunderstorm - cumulonimbus cloud possessing thunder and lightning; usually accompanied by strong winds, rain, and sometimes hail

tornado - whirling funnel of air of very low pressure and very strong winds; may be powerful enough to suck up anything in its path; must touch the ground to be called a tornado

AIR MASSES

When the meteorologist on television is talking about a large weather pattern or weather system moving into your area, he/she is referring to an **air mass** or a **front**. An approaching air mass or front will definitely influence and change the weather in your local area. This chapter takes a look at severe weather and some of the effects of these phenomena.

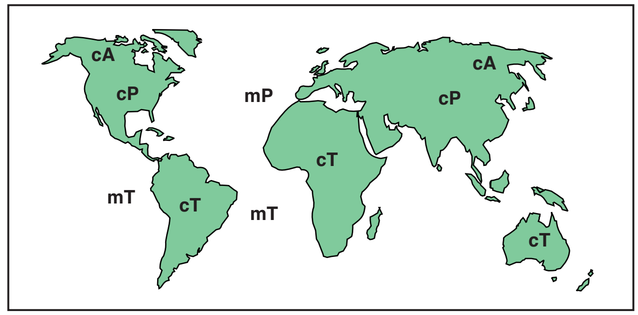
An air mass is a huge body of air, usually 1,000 miles or more across, that has the same temperature and moisture characteristics. When an air mass travels out of its area of origin, it carries those characteristics with it. The place of origin of an air mass is called its source region, and the nature of the source region largely determines the initial characteristics of an air mass. The ideal source region must be very large and the physical features must be consistent throughout. Land located next to water is not a good source region. Tropical (frost free and high temperatures areas) and polar (colder areas far from the equator) locations are the best source regions.

Air masses are classified by their source region and the nature of the surface in their source region. They are identified by a two-letter code consisting of a lowercase letter and a capital letter. The lowercase letter is either m (maritime) or c (continental). Maritime stands for water (high moisture and wet), and continental stands for land (low moisture and dry). The capital letter refers to temperature at latitude and is placed into four categories: polar (P), arctic (A), tropical (T), and equatorial (E). The differences between polar and arctic (colder), and between tropical and equatorial (warmer) are very small.

Here are the air mass classifications:

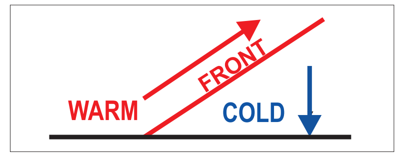
cA	continental	arctic
cP	continental	polar
cT	continental	tropical
mT	maritime	tropical
mP	maritime	polar
mE	maritime	equatorial

(See associated Activity Fourteen at the end of the chapter.)



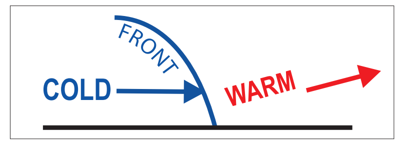
FRONTS

Fronts are classified as warm, cold, stationary, and occluded. A warm front occurs when warm air moves into an area of colder air and they collide. The warm air overrides the cold because it is lighter. The heavier, colder air sinks.



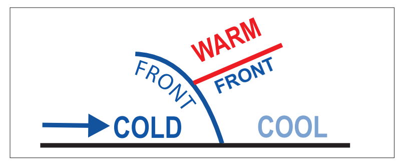
A Warm Front

Cold fronts occur when the air moving into the area is colder than the already present warmer air. The heavier, colder air pushes the warmer air up and out of the way. In general, cold fronts move faster than warm fronts. So, the colder air is rapidly pushing the warmer air out.



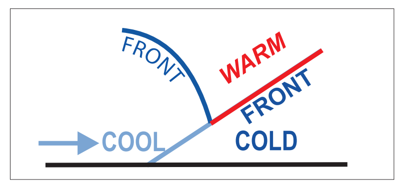
A Cold Front

Sometimes different air masses bump against each other, but the difference between them is not enough to force movement. This is called a stationary front. Neither the warm nor the cold air advances, and it becomes a standoff. This can last a few hours or a few days, but eventually more forceful air will push into the area and create movement.



A Cold Occluded Front

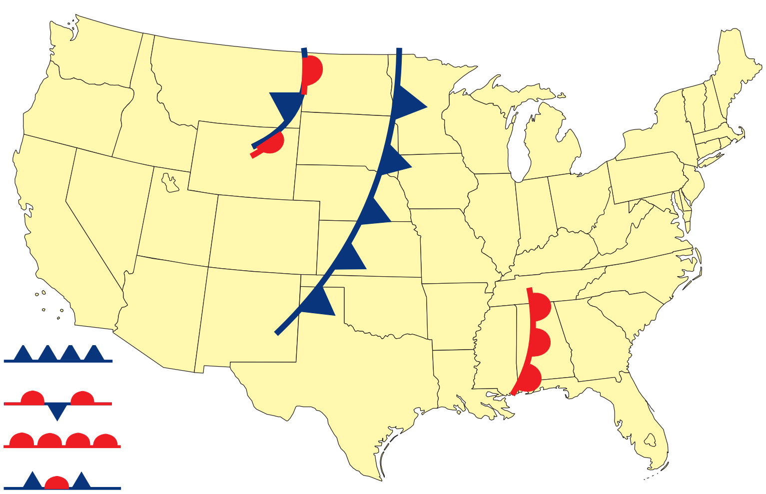
Occluded fronts involve three differing air masses and are classified as either cold occluded or warm occluded. In the cold occluded, cold air moves in and collides with warmer air pushing the warm air aloft. Then, the leading edge of this cold front comes in contact with the trailing edge of the cooler surface air that was below the warm air. Because the advancing air is the coldest, it sinks to the surface and causes the cooler air to rise. However, the cooler air is still cooler than the warm air, so it continues to push the warm air above it.



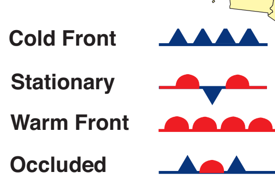
A Warm Occluded Front

In the warm occluded front, cool air is advancing to collide with the air in your area. Since the cooler air is warmer than the colder surface air, the cooler air rides up over the cold air. Once again, though, the cooler air is cooler than the warm air that was already aloft, so the cooler air continues to push the warmer air up.

In color weather maps, cold fronts are identified by the color blue and warm fronts by the color red. Stationary and occluded fronts are red and blue. (See associated Activities Fifteen and Sixteen at the end of the chapter.)



This is how fronts appear on weather maps:



SEVERE WEATHER

The last section of this chapter is severe weather. There are three main weather phenomena to discuss in this area: thunderstorms, tornadoes, and hurricanes. All three are powerful, devastating phenomena that damage property and bring destruction. All three are dangerous and potentially deadly, as well. This section will give you information about these three severe weather phenomena and help you prepare for them.

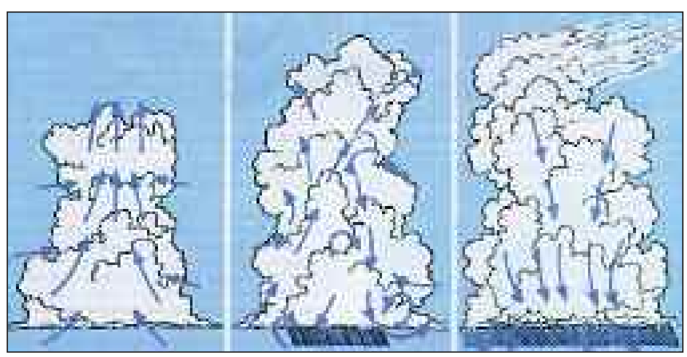
Spotting a cumulonimbus cloud, like the one pictured here, is a sign of severe weather conditions. All three of our severe weather phenomena can be associated with cumulonimbus clouds.

Cumulonimbus Cloud

Thunderstorms

Thunderstorms come from cumulonimbus clouds and always possess thunder and lightning. The most spectacular and dangerous part of a thunderstorm is the lightning. Lightning is the flash of light produced by electrical discharges in a thunderstorm area. Lightning discharges millions of volts of electricity and heats the air to 60,000°F. Lightning can vary from between 9 to 90 miles. Thunder is the sound sent out by rapidly expanding gases along the lightning's trail. Thunderstorms usually contain heavy rain, strong winds, and sometimes hail (small balls of ice). Thunderstorms have three stages: building, mature, and dissipating. The building stage is dominated by updrafts as the storm builds and grows vertically. Eventually, the moisture that is carried up with the storm gets heavier and starts to fall. This creates downdrafts. Updrafts are still occurring, so the moisture moves up and down several times. This activity describes the mature stage. The last stage has downdrafts only and this is called the dissipating stage. (See associated Activity Seventeen at the end of the chapter.)

Hail



Building **Mature** **Dissipating**

At any given time in the world, 2,000 thunderstorms are occurring, and from these storms 100 lightning strikes occur per second. Thunderstorms can occur anytime, anywhere. There is an old saying that lightning does not strike twice in the same place. Don't believe it! The Empire State Building has been struck many times during the same storm.

Lightning can kill. On the average, over 200 people are killed every year in the U.S., and another 500-600 people are injured by lightning strikes.

Let's take a moment and remind ourselves of some safety rules for thunder and lightning. During a storm, following this list will increase your safety:

- When inside, stay away from windows and doors.
- Don't use electrical appliances.
- Don't use the telephone or take a shower or bath.
- If outdoors, go inside if you can.
- Move away from water, such as swimming pools and lakes.
- If you are in a boat, go ashore.
- Stay away from metal objects like golf clubs, fishing poles, bicycles, farm equipment, or motorcycles.
- Don't stand in an open field, a hilltop, or on a golf course (stay low by sitting or crouching).
- Don't stand under a single tree (if you must be under a tree, look for a clump of small trees or trees of similar height).
- If in a group of people, stay low and spread out.
- If in a car, stay there.

Lightning near Eglin AFB

Vertical & horizontal lightning (NASA)

Thunderstorms present several challenges to pilots. Thunderstorms come from cumulonimbus clouds, and that means there is unstable air present. So, thunderstorms have violent up and down drafts. As already mentioned, unstable air causes turbulence, and turbulence, particularly heavy turbulence, raises havoc with planes.

Thunderstorms generally bring rain, usually heavy, and sometimes even hail. Hail can do serious damage to airplanes. Also, thunderstorms are always accompanied by thunder and lightning. Pilots are well aware of the dangers associated with thunderstorms and usually fly above or around them.

Tornadoes

One of the most severe weather phenomenon is the tornado. A tornado is very destructive and can be devastating to life and property. Tornadoes have occurred in every month of the year and in every state in the US About 700 tornadoes are reported in the US annually.

Tornadoes consist of unstable air of very low pressure. Most tornadoes move in a counterclockwise manner. Air is sucked into the center, or vortex of the storm, and is rapidly lifted and cooled. The funnel of a tornado appears very dark as it moves picking up dirt and debris.

Tornadoes will normally touch down for several miles then go back up in the cloud, and then touch down again later. It will do this many times during its life. A tornado ranges from 50 to 500 yards wide and moves across the ground at about 70 mph. These are just averages, as they can move twice as fast, or as slow as 5 mph.

A tornado's winds can be stronger than 300 knots (each knot is equal to one nautical mile, which is about 1.151 mph), and this is the main reason for the tremendous destruction associated with tornadoes. The Fujita Wind Damage Scale, shown below, explains the categories of wind speed and expected damage.

Tornado

If you know a tornado is coming, there are precautions you can take:

- If time permits, get to a basement or underground.
- If in open country, move at right angles (90°) away from it.
- If there is time, get to a low place, like a ditch, and lie down.
- If indoors, stay away from windows, and if you don't have a basement, get to an interior hallway, closet, or bathroom.

Fujita Wind Damage Scale

Number	Wind Speed	Damage
F-0	Up to 72 mph	light
F-1	73 to 112 mph	moderate
F-2	113 to 157 mph	considerable
F-3	158 to 206 mph	severe
F-4	207 to 260 mph	devastating
F-5	above 261 mph	incredible

Hurricanes

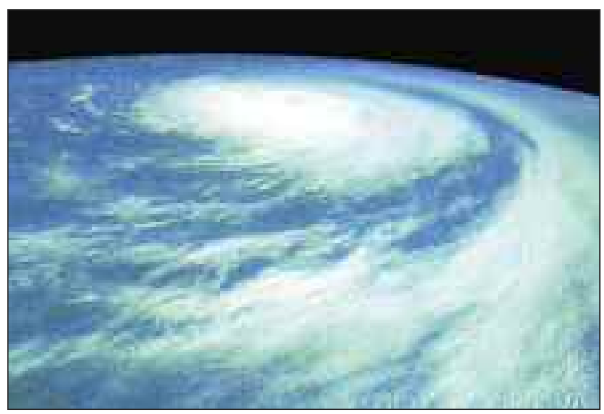
Another severe phenomenon is the hurricane. A good case could be made for hurricanes as being the most dangerous of storms. First of all, they produce many thunderstorms and tornadoes within their system. Secondly, although their winds are not as strong as a tornadoes, they are often above 100 knots. Hurricanes affect a large area, hundreds of miles wide, and they usually continue for more than a week. Many times they will flood coastal cities and dump many inches of rain. The winds, along with the tidal waves from the ocean, demolish homes on a routine basis.

Before tropical cyclones develop into hurricanes, they can be divided into three categories depending on the wind speed. The lowest category is a tropical disturbance, then a tropical depression, and finally a tropical storm. A tropical storm's winds must be between 39 and 74 mph. If the winds go above 74 mph, the cyclone is called a hurricane. Hurricanes have five categories. These categories are presented on the Saffir-Simpson Hurricane Damage Potential Scale (shown below). Although the winds are what most people pay attention to, this scale also mentions the barometric pressure and the storm surge. Hurricane damage comes from the winds, storm surges, and flooding.

Even the strongest of trees are no match for the fury of hurricane or tornado winds.

One distinctive feature of every hurricane is the eye. The eye is the center of the storm. It consists of calm or very light winds and clear skies or very few clouds. It is calm and peaceful, yet surrounded by violence and force on all sides. The average eye of a hurricane is about 10-15 miles wide. After the eye passes, the winds roar and blow as strong as before. (See associated Activity Eighteen at the end of the chapter.)

The eye of a hurricane



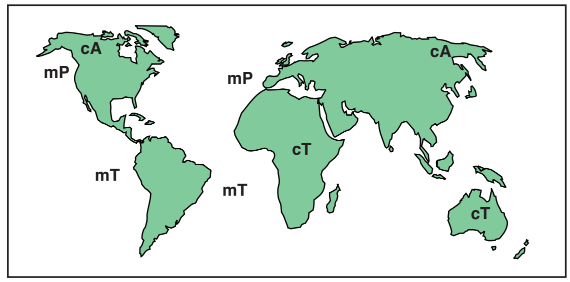
Hurricane

Saffir-Simpson Hurricane Damage Potential Scale

	Category 1	Category 2	Category 3	Category 4	Category 5
Pressure	28.94	28.50-28.91	27.91-28.47	27.17-27.88	27.17
Wind	75-95 mph	96-110 mph	111-130 mph	131-155 mph	155 mph
Storm Surge	4-5 ft	6-8 ft	9-12 ft	13-18 ft	18 ft

5 ACTIVITY SECTION

Activity Fourteen - Air Masses



Purpose: Identify types of air masses indicated on a map.

Materials: map to right and matching columns below

Procedure:

1. Identify the type of air masses on the map. (Refer to page 33 for assistance and answers.)
2. Match the air mass characteristics (Column A) with its source region (Column B).

Column A	Column B
____ (1) Very moist and very warm air mass	a. cA
____ (2) Exceptionally cold; very dry air mass	b. cT
____ (3) Cool and moist air mass	c. mP
____ (4) Very warm and dry air mass	d. mT

Summary: This activity reinforces knowledge regarding types of air masses. Air masses are classified by their source region and the nature of the surface in their source region.
Answers: 1) d. 2) a. 3) c. 4) b.

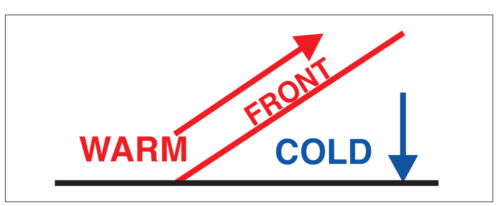
Activity Fifteen - Identifying Fronts

Purpose: Practice identifying fronts.

Materials: questions and illustrations below

Procedure: Circle each correct answer. Use page 33 for reference.

1. What kind of front is this?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded

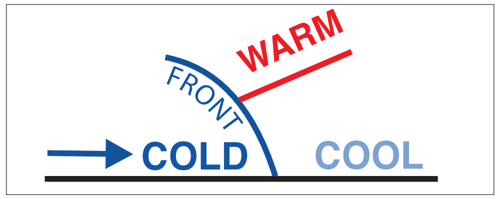


2 What kind of front is this?

a Warm
b. Cold
c. Stationary
d. Occluded

3. What kind of front is this?

a. Warm
b. Cold
c. Stationary
d. Occluded



Summary: This exercise is useful to review the identification of weather fronts. The important aspect to understand is which air is replacing, or pushing or lifting, which air.
Answers: 1) a. 2) b. 3) d.

Activity Sixteen - Fronts on Maps

Purpose: Practice reading and analyzing maps.

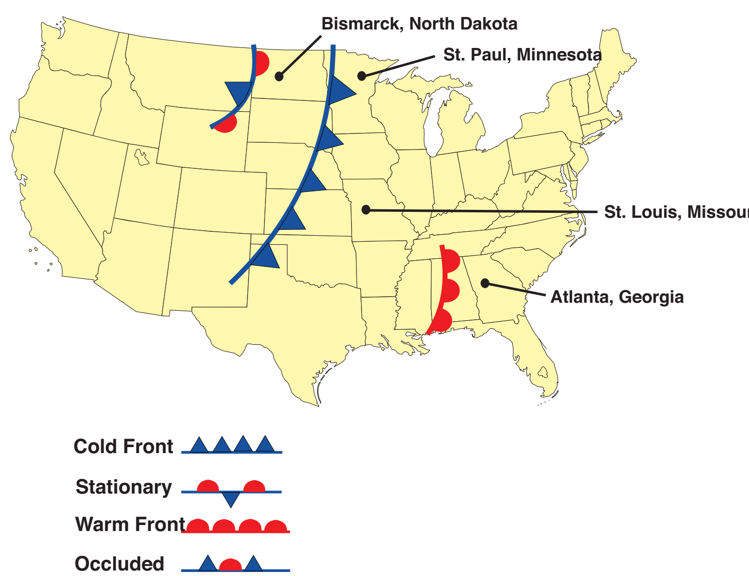
Materials: map and questions

Procedure:
Use the map below to answer the following questions.

1. What kind of front is approaching Atlanta, Georgia?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded

2. What kind of front is next to Bismarck, North Dakota?
   a. Warm
   b. Cold
   c. Stationary
   d. Occluded

3. In the next several hours, what will the temperatures be in St. Paul, Minnesota and St. Louis, Missouri?
   a. Warmer
   b. Colder



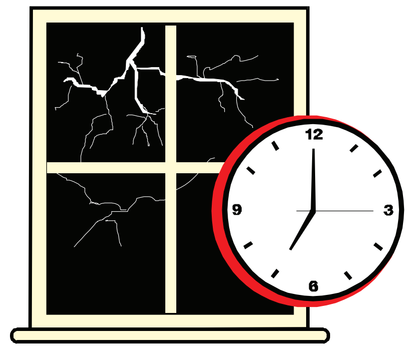
Summary: This activity reinforces weather map knowledge. Knowing what fronts look like on a map can greatly aid forecasting skills, which is an important skill for pilots.
Answers: 1) a. 2) c. 3) b.

Activity Seventeen - Distance to a Thunderstorm

Purpose: Using observation and math skills, estimate the distance between you and a storm.

Materials: a watch or clock with second hand and a thunderstorm

Procedure:



1. Watch for a flash of lightning.
2. Then count the number of seconds until you hear the thunder.
3. Now divide the number of seconds by five. This gives you the approximate number of miles to the storm. Light from the flash travels to your eyes almost instantly, while sound travels at about 1,100 feet per second. Example: 5 seconds is 5,500 feet, or a little more than 1 mile. If you don't have a watch, simply count "thousand one, thousand two, thousand three," and so on. Each count is a second and 5 seconds is 1 mile.

Summary: Knowing how to estimate the distance between you and an approaching storm is important. It gives you an idea of how quickly the storm is approaching or moving away. This knowledge may help you make important life-saving decisions.

Activity Eighteen - Matching Severe Weather

Purpose: Review your knowledge of severe weather.

Materials: Matching columns below

Procedure: Match the description in column A with the correct weather in column B.

Column A	Column B
___ (1) Cloud which can produce severe weather	a. flooding
	b. lightning
___ (2) First stage of a thunderstorm	c. stratus
	d. cumulonimbus
___ (3) Can heat the air to 60,000° F	e. mature
___ (4) What you do not do during a thunderstorm	f. building
	g. thunder
___ (5) What you do not do during a tornado	h. go to the upstairs of your house
___ (6) Cause of damage due to a hurricane	i. go golfing

Summary: This matching exercise allows you to demonstrate your knowledge of severe weather and the damages and precautions for each.

Answers: 1) d. 2) f. 3) b. 4) i. 5) h. 6) a.