PURDUE EXTENSION

4-H-1025-W LEVEL 3

WEATHER AND CLIMATE SCIENCE

4-H Member
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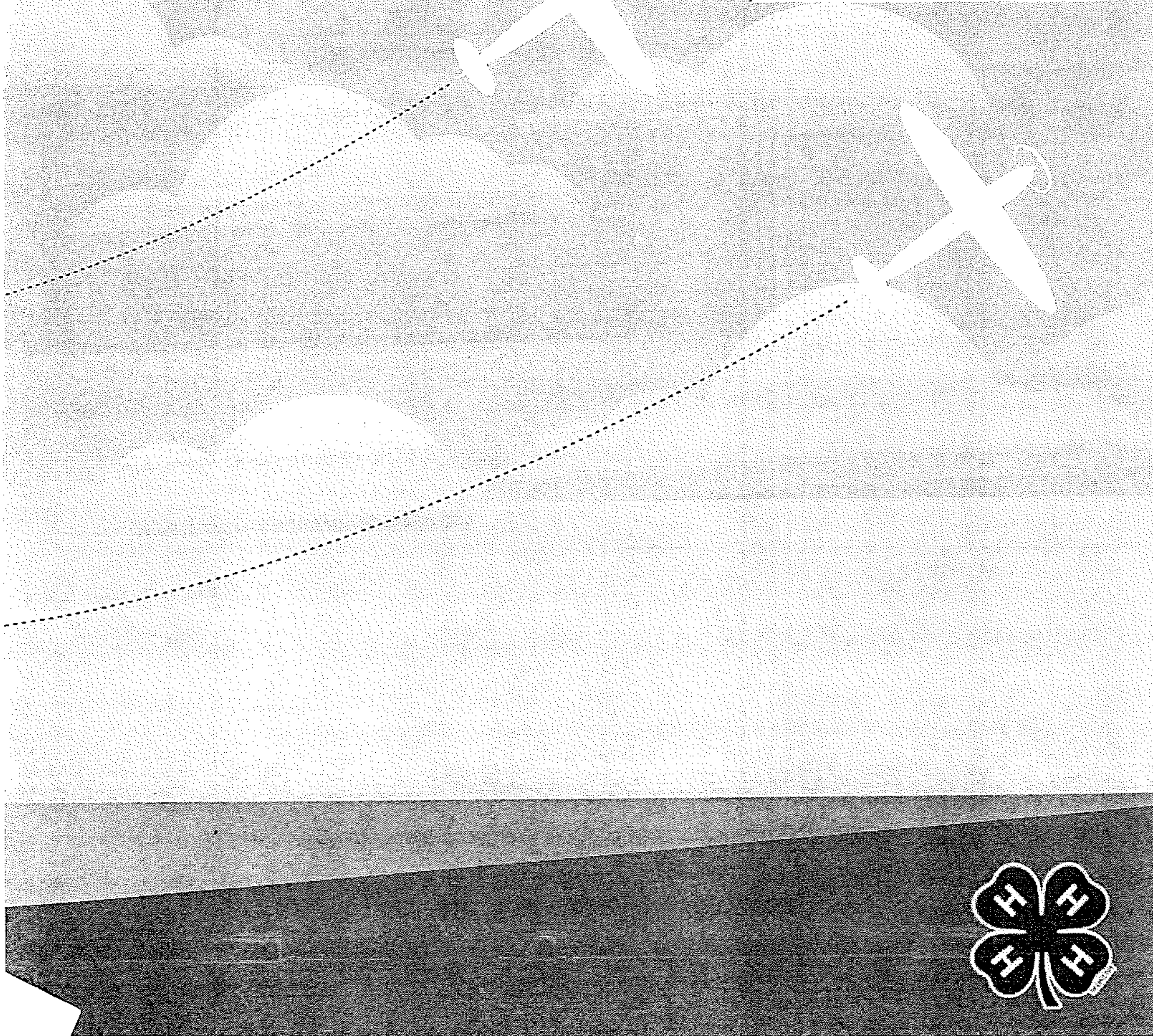
Club Name________________________



4-H-1025-W

WEATHER AND CLIMATE SCIENCE

GRADES 9–12

NOTE TO 4-H MEMBER

As you continue your study of weather and climate science, you will be increasingly responsible for collecting your own data and gaining information from sources outside this manual. Level 1 introduces basic weather terminology and concepts. Activities focus on understanding the signs of weather around you. Level 2 introduces more complex weather topics such as air pressure, winds, humidity, and fronts.

Level 3 delves even deeper into weather and introduces climate science concepts to help prepare you to fully understand weather and/or study these topics at a college or university. In Level 3 you are encouraged to supplement your learning by consulting knowledgeable people and recent written materials. The study of weather and the earth's climates has evolved significantly, so recent references are preferred.

The key to learning in this, or any 4-H project, is to enjoy your studies and to learn at your own pace. We hope this project is just the start of a lifetime enjoyment of understanding the climate you live in and watching the weather!

SAFETY FIRST!

Ask a parent or other adult to help when you see a safety first icon.

Weather is the state of the atmosphere at a particular place and time and is influenced by climate and many local factors.

Climate describes the prevailing or general long-term weather conditions for an area, or for the entire planet.

Climate System: Earth's water and gases that flow or change state as a result of the sun's energy.

Climate: The average weather over time.

Weather: What is happening today and tomorrow.

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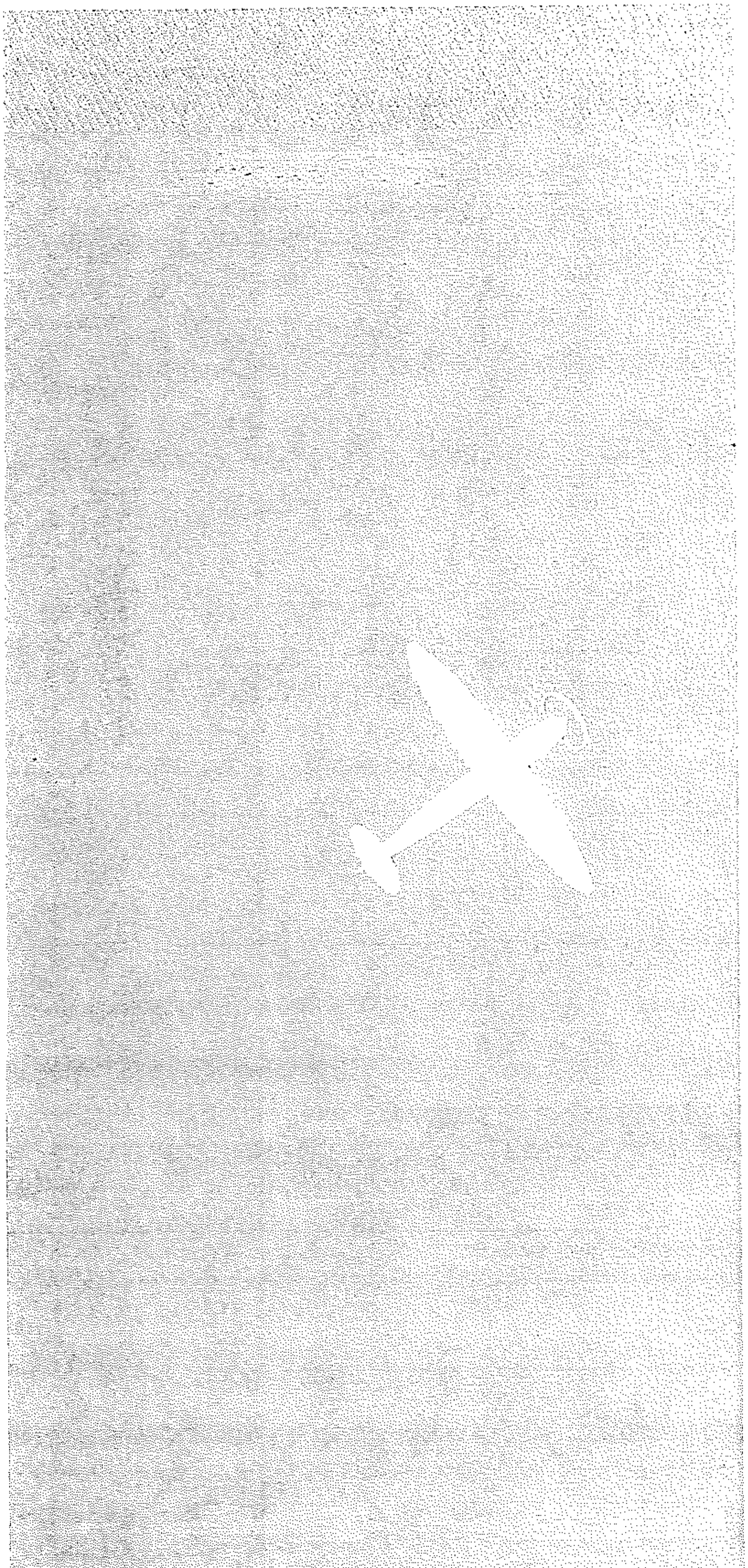

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CONTENTS

NGSS indicates the Next Generation Science Standards for each activity. See www.nextgenscience.org/next-generation-science-standards for more information.

See Purdue Extension's Education Store, www.edustore.purdue.edu, for additional resources on many of the topics covered in the 4-H manuals.

AIR MASSES AND FRONTS

How are the movements of air masses involved in the formation of fronts and their resulting weather?

RECOMMENDATION: Before beginning, review the Cold Front and Cloud Formation activities from the Level 2 manual.

Air masses have distinct temperature and moisture characteristics. These characteristics develop when air masses spend time over large areas of the earth's surface. As they begin to move, fronts form. Each type of front brings weather that depends on the air masses involved. Knowing the characteristics of air masses and how they move helps meteorologists predict the type of weather that will develop along the resulting fronts.

OBJECTIVE: Explain the development of air masses, the resulting formation of fronts, and the weather those fronts produce.

Weather Tote

Air Masses and Fronts worksheet

1 Complete the worksheet.

2 Discuss the Chat questions with a parent or other adult helper.

SHARE WHAT HAPPENED: What causes stormy weather in the Midwest?

APPLY: When you see stratus and nimbostratus clouds, what weather would you predict?

GENERALIZE TO YOUR LIFE: How can you use the information you learned to help you understand TV weather reports?

Fly Higher

- Observe weather reports at the NOAA website, www.noaa.gov/wx.html.
- Observe the fronts approaching your area for several days.
- Keep track of how they move and the kind of weather they cause.

AIR MASSES AND FRONTS WORKSHEET

ACKNOWLEDGEMENT: Some text and graphics for this activity are from the National Oceanic and Atmospheric Administration (NOAA), www.srh.noaa.gov/crp/?n=education-airmasses, downloaded August 2014.

Air Mass

An air mass is a large body of air that has relatively uniform temperature and humidity characteristics. The regions where air masses form are called air mass source regions. If air remains over a source region long enough, it will acquire the properties of the surface below. Ideal source regions are generally flat and of uniform composition. Examples include central Canada, Siberia, the northern and southern oceans, and large deserts.

NOAA, www.srh.noaa.gov/crp/?n=education-airmasses

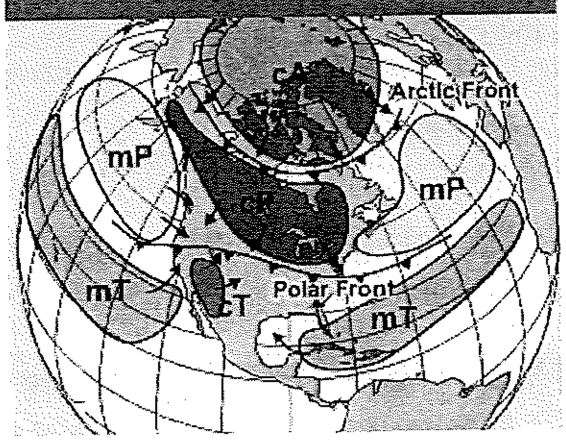
Air masses are classified according to their temperature and moisture characteristics. They are grouped into four categories based on their source region. Air masses that originate in the cold, polar regions are designated with a capital "P" for polar. Air masses that originate in warm, tropical regions are designated with a capital "T" for tropical. Air masses that originate over land are dry and designated with a lowercase "c" for continental. Air masses that originate over water are moist and designated with a lowercase "m" for maritime. In winter, one more type of air mass may form, an extremely cold, dry air mass called "cA," continental arctic. Once formed, air masses can move out of their source regions, bringing cold, warm, wet, or dry conditions to other parts of the world.

NOAA, www.srh.noaa.gov/crp/?n=education-airmasses

Common North American air masses are shown in Figure 1 and described below:

- Maritime tropical (mT) air mass – forms over tropical water. It is warm and moist.
- Continental polar (cP) air mass – forms over a cold land. It is cold and dry.
- Maritime polar (mP) air mass – forms over cold water. It is cold and moist.
- Continental tropical (cT) air mass – forms over warm land. It is warm and dry.

AIR MASSES [FIGURE 1]



Source: National Oceanic and Atmospheric Administration/ Department of Commerce.

Fronts

A front is the boundary between two air masses. Fronts are classified by the type of air mass (cold or warm) that is replacing the other type of air mass.

NOAA, www.srh.noaa.gov/crp/?n=education-airmasses

The Cold Front

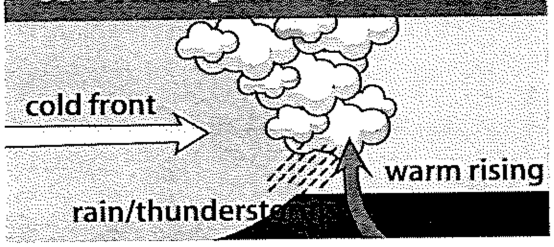
DID YOU KNOW? The United States has more tornadoes than any other country in the world and four times as many as all of Europe.

A front is called a cold front if a cold air mass is replacing a warm air mass. The air behind a cold front is colder and typically drier than the air ahead of it, which is generally warm and moist. There is usually a shift in wind direction as the front passes, along with a change in pressure tendency — pressure falls prior to the front arriving and rises after it passes. A cold front has a steep slope, which causes air to be forced upward along its leading edge. This is why a band of showers and/or thunderstorms sometimes lines up along the leading edge of the cold front. Cold fronts are represented on a weather map by a solid blue line with triangles pointing in the direction of its movement.

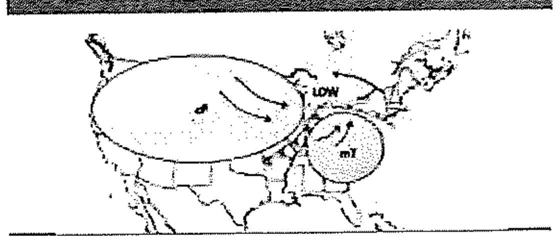
Source: NOAA, www.srh.noaa.gov/crp/?n=education-airmasses

Differences in air pressure cause air masses to move. When a cold air mass moves into an area of warmer air, as shown in Figure 2, the denser cold air forces the warmer air to rise at the frontal boundary. Towering cumulus and cumulonimbus clouds form in a cold front. The density difference between the two air masses and the amount of moisture in the warm air determines how severe the weather in the front will be. Cold air is denser than warm air, and dry air is denser than moist air, so cold, dry air is denser than warm, moist air. Density differences between different air masses result in very little mixing of the air.

COLD FRONT [FIGURE 2]



COLD FRONT AIR MASSES [FIGURE 3]



In the Midwest, warm air masses are usually southwest winds, and cold air usually blows in from the northwest, as shown in Figure 3. It is common to experience a change in wind direction from southwest to northwest after a cold front moves through. The cold air mass moves faster and at a slightly different angle than the warm air. As the cold air moves, friction against the ground slows the air near the surface, causing the upper winds to tumble downward at the frontal boundary. A rapid rise in the warm air causes cloud formation; and the moister the warm air, the more clouds develop.

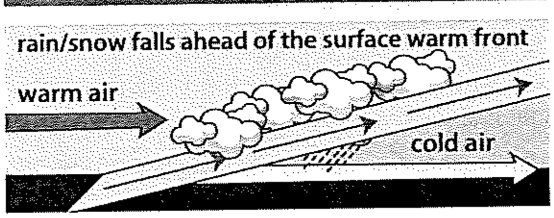
Warm air can be lifted rapidly in advance of a cold front, creating vertical shear winds. Vertical shear winds occur when there is a quick change in vertical direction as the cold front air rises in the warm air and sinks in the cold air.

Weather along a cold front is generally stormy and sometimes severe. In the spring, the continental polar (cP) air masses are extremely dry and cold. These air masses form cold fronts as they move from Canada to the United States and drive into the warm moist air from the Gulf of Mexico. This creates severe cold fronts that can produce damaging storms and tornadoes. Most tornadoes form in the Great Plains, where no landforms disturb airflow. During the winter when the air is cooler in the Midwest, not much moisture is in the air and the cold fronts are not as severe.

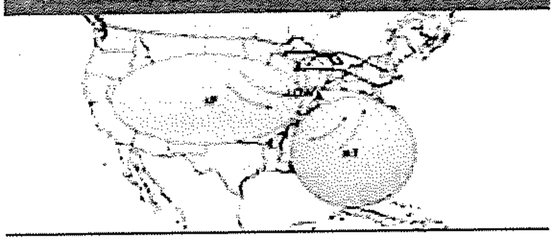
The Warm Front

When a warm air mass moves into an area of cooler air, a warm front forms, as shown in Figure 4. Because the warm air is less dense than the cooler air, it cannot push the cooler air out of the way. As a result, the angle of the frontal boundary is not as severe as with a cold front. The warm air climbs slowly over the cooler air, producing layered clouds like stratus and nimbostratus clouds.

WARM FRONT [FIGURE 4]



WARM FRONT AIR MASSES [FIGURE 5]



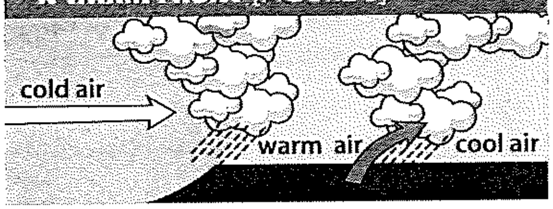
Far in advance of the front, cirrostratus and cirrus clouds form. Warm fronts form clouds that cover a large area and create rain or snow events that can last for days. When we are experiencing warm front-produced weather, the warm air is aloft, and we are in the cooler air. The moist, warm air from the Gulf provides the moisture for the clouds and precipitation. Warm fronts produce heavy snow and ice storms in the Midwest, as the weather produced wraps around to the northern section of the low pressure system, as shown in Figure 5.

Warm fronts produce overcast skies and steady precipitation that may last for long periods. In the winter, warm fronts can produce blizzard conditions; in the spring, they can produce prolonged rain that can cause flooding. The heaviest snow and most severe ice storms occur when the winds are out of the east and northeast as moist air from the Gulf is lifted and pulled around the low-pressure zone.

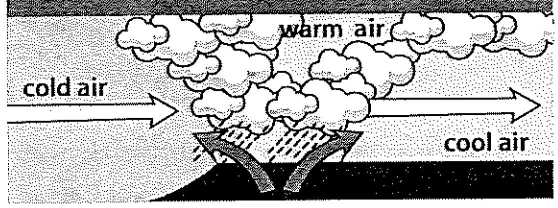
Other Fronts

Stationary and occluded fronts are variations of cold and warm fronts. A stationary front, as you might guess, is a cold or warm front that comes to a standstill. The warmer air continues to rise over the cooler air, but the position of the front on the earth moves very little. In a stationary front, the cold air normally flattens out, and the resulting front resembles a warm front with stratus and nimbostratus clouds. Stationary fronts form away from the influence of the primary low and are influenced by other factors in the atmosphere. They often lead to flooding. Stationary fronts are represented on a weather map by alternating red and blue lines, with blue triangles and red semicircles facing opposite directions.

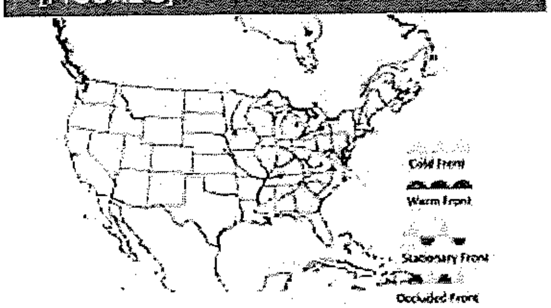
COLD FRONT ADVANCING TOWARD A WARM FRONT [FIGURE 6]



OCCLUDED FRONT [FIGURE 7]



OCCLUDED FRONT FORMATION [FIGURE 8]



The boundary between two cold air masses is called an occluded front. Occluded fronts form because cold fronts usually advance faster than warm fronts and catch up to a warm front. A cold front is shown advancing toward a warm front in Figure 6. When the cold front overtakes the warm front, the warm air is lifted between the two cooler air masses. The coldest air mass undercuts the others. Occluded fronts are represented on weather maps by a solid purple line with alternating triangles and semicircles, pointing in the direction of its movement.

The several different types of occluded fronts are based on their interactions due to the density of the two cooler air masses. Figure 7 shows an approaching cold air mass denser than the warm air mass that created a front with another cold air mass. The cold air mass will lift the cool air mass as well as the warm air mass. Occluded fronts form near the center of low pressure systems, as indicated in Figure 8. The weather in an occluded front depends on the location within the front. As the front passes, you can expect stratus and nimbostratus clouds followed by towering cumulus and cumulonimbus clouds.

Questions:

AIR MASSES

Match the air masses to their characteristic (each letter is used twice):

AIR MASS	LETTER	CHARACTERISTIC
A. Maritime Tropical (mT)		Dry and warm
		Moist and cold
B. Continental Tropical (cT)		Moist and warm
		Dry and cold
C. Continental Polar (cP)		Forms over warm land
		Forms over warm water
D. Maritime Polar (mP)		Forms over cold water
		Forms over cold land

THE COLD FRONT

What causes the movement of air masses?

____

____

What causes the warm air ahead of a cold front to rise?

____

____

What kind of clouds usually form in a cold front?

____

What wind direction change usually occurs as a cold front moves through an area?

____

Where do vertical shear winds form?

What kind of weather is usually expected in a cold front?

THE WARM FRONT

What cloud types are typically associated with a warm front?

Which air mass provides the moisture that produces the clouds and precipitation?

What severe events can warm fronts produce?

What kind of weather is usually expected in a warm front?

How does an occluded front form?

Within the low, where do occluded fronts form?

How do stationary fronts form?

Within the low, where do stationary fronts form?

ISAAC'S STORM

How might a weather event affect the people living through it?

Meteorological observations in the United States were the responsibility of the U.S. Army Signal Corps from 1861 to 1891. Congress, at the request of President Benjamin Harrison, passed an act transferring the meteorological responsibilities of the Signal Corps to the newly created U.S. Weather Bureau in the Department of Agriculture on October 1, 1890.

Isaac's Storm is the story of Isaac Monroe Cline, chief meteorologist at the Galveston, Texas, office of the U.S. Weather Bureau from 1889 to 1901. The book describes the early workings of the Weather Bureau and how a lack of scientific knowledge about hurricanes resulted in the greatest loss of life in U.S. weather history.

OBJECTIVE: Discuss how weather can change people's lives.

Weather Tote

- ☐ Book: Larson, Erik. *Isaac's Storm*. New York: Vintage Books, 2000. (ISBN: 0-375-70827-8)

1. Read *Isaac's Storm* by Erik Larson.
2. Discuss the Chat questions with a parent or other adult helper.

SHARE WHAT HAPPENED:

- Why was Galveston an important city in Texas?
- What was the general opinion about Galveston's safety from a hurricane in 1900?
- How did Isaac Cline come to be the head of the Galveston weather station?
- Why did the Weather Bureau ignore reports from Havana, Cuba?
- What is the significance of the ring on Isaac's finger in his photograph?
- What part of this book was most interesting to you? Why?

APPLY: How would a hurricane like this be handled differently today?

GENERALIZE TO YOUR LIFE: Can you think of weather events, either positive or negative, that have changed things in your life or the lives of your family members? Explain your answer.

Fly Higher

- Identify another hurricane event. Learn more about it and share your findings with a parent or friend.
- Learn more about the history of the U.S. Weather Bureau at:

  www.lib.noaa.gov/collections/imgdocmaps/weather_annual_reports.html

  www.weather.gov/timeline

NOTES

MONITORING WEATHER

How can you share your weather knowledge with others?

The Community Collaborative Rain, Hail and Snow (CoCoRaHS) network is a group of volunteer backyard weather observers who measure and report precipitation (rain, hail, and snow) events in their local communities. CoCoRaHS volunteers are trained to use low-cost weather measurement tools. They report their weather data online. It is then accessible to researchers, the media, and others interested in weather data. The goal of the CoCoRaHS network is to provide more detailed weather observations than are available from weather stations. For example, CoCoRaHS data is used to help scientists more accurately predict the expected runoff from snowmelt in the Rocky Mountains.

The only requirements to join are enthusiasm for watching and reporting weather conditions and a desire to learn more about how weather can affect our lives. CoCoRaHS volunteers must be trained, make a commitment to the program, obtain an approved rain gauge, and make daily reports.

OBJECTIVE: Attend CoCoRaHS training, become a CoCoRaHS volunteer, and submit precipitation data online for one year.

Weather Tote

- ☐ A personal email address
- ☐ A CoCoRaHS-approved rain gauge
  - May be obtained through www.weatheryourway.com/cocorahs
  - See Figure 1

RAIN GAUGE [FIGURE 1]

1 Option 1 (preferred): Contact an Indiana Coordinator at www.cocorahs.org/Content.aspx?page=coord_in, to register for a training near you.

2 Option 2: Visit the CoCoRaHS website: http://www.cocorahs.org/.

- Click on Join CoCoRaHS.
- Complete an application to become a CoCoRaHS participant.
- You will be contacted through email with instructions and logon directions.

3 Collect and report daily precipitation observations.

4 Discuss the Chat questions with a parent, friend, or adult helper.

SHARE WHAT HAPPENED: What did you learn during your CoCoRaHS training?

APPLY: How might the data that you collect be used?

GENERALIZE TO YOUR LIFE: How might the data you collected for CoCoRaHS be used during a major snowstorm?

RESOURCE PEOPLE: Contact one of the following individuals if you have questions about participating in the CoCoRaHS network in Indiana (information downloaded in 2013):

Ken Scheeringa
Indiana State Climate Office
915 West State Street
West Lafayette IN 47907
(765) 494-8105
CoCoRaHS@purdue.edu

Meagan Bird
Indianapolis NWS Office
6900 West Hanna Avenue
Indianapolis IN 46241-9526
(317) 956-0360
meagan.bird@noaa.gov

Earl Breon
Indianapolis NWS Office
6900 West Hanna Avenue
Indianapolis IN 46241-9526
(317) 856-0361
earl.breon@noaa.gov

PRESSURE SYSTEMS — HIGHS AND LOWS

What kind of weather is expected with high and low pressure systems?

The sun is constantly adding energy to half of the earth. The half that receives energy depends on the time of day and the tilt of the earth. The amount of energy that earth retains depends on many variables, including land and water surfaces, latitude, and atmospheric conditions.

The earth's rotation influences how global wind patterns develop. Changes in air temperature and humidity cause changes in atmospheric pressure. These factors create areas of different pressures. Air moves in an attempt to establish pressure **equilibrium**.

OBJECTIVE: Explain the structure and development of high and low pressure systems and their effect on our weather.

Weather Tote

- ☐ Glass containing ½ cup of cold tap water
- ☐ Pie pan
- ☐ Warm tap water
- ☐ Sugar, ½ cup
- ☐ Tablespoon and teaspoon
- ☐ Minute timer or stopwatch
- ☐ Red food coloring
- ☐ Metal or glass pie pan or round cake pan
- ☐ Turntable or lazy Susan
- ☐ High and Low Pressure Systems worksheet

1. Slowly stir 1–2 tablespoons (T) sugar into the glass of cold water until it is dissolved.
   - After one minute, stop stirring to see if any sugar is visible.
   - Add a teaspoon (t) of sugar, stir, and wait for one minute.
   - Continue to add sugar (1 t) until some sugar remains after you stop stirring for a minute.
2. Add a few drops of red food coloring to the sugar water.
3. Fill the pie pan two-thirds full of warm water and place on the turntable.
   - Wait a minute to allow the water to become still.
4. Place 1 t of the red sugar water in the center of the pan.
5. Observe what happens to the red sugar water.

6 Place another teaspoon of the red sugar water in the center of the pie pan and slowly turn the turntable counterclockwise for about 15 to 20 seconds.
   - Observe what happens to the red sugar water while the turntable is moving.

7 Stop the turntable and let it sit for a minute.

8 Observe what happens to the red sugar water after the pan is still.

9 Complete the High and Low Pressure Systems worksheet.

SHARE WHAT HAPPENED: What was the most interesting part of this activity?

APPLY: Without repeating the experiment above, tell another way you could teach someone your age about the structure and development of high and low pressure systems and their effect on our weather.

GENERALIZE TO YOUR LIFE: How might understanding pressure systems and their resulting weather help you make your weekend plans?

Fly Higher

Observe television or online weather maps for one week to observe high and low pressure areas. Keep track of how they move and the kind of weather that they cause.

NOTES

PRESSURE SYSTEMS — HIGHS AND LOWS WORKSHEET

SUGGESTION: Review the 4-H Weather and Climate Science activity, Earth's Rotation and Global Winds, before beginning this activity.

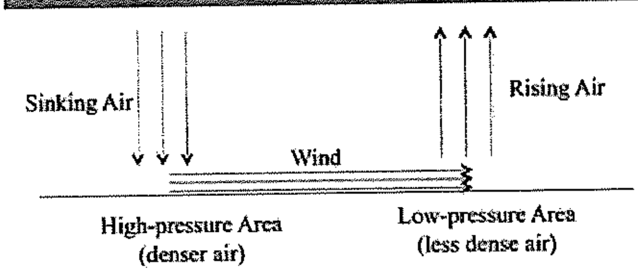
Development of High and Low Pressure Systems

Changes in air temperature and humidity cause changes in atmospheric pressure. Systems, including air pressure, naturally move toward equilibrium. High and low pressure systems (often referred to as a "high" or "low") follow the principles demonstrated by the pie pan activity. Air in a low-pressure area is forced up as denser air moves toward the center of a low pressure system. In a high pressure system the denser air sinks and pushes lighter air away. Figure 1 shows this basic premise of air sinking in high-pressure areas and rising in the low-pressure areas. This air movement causes surface air to move from a high toward a low.

There are several reasons for differences in air density. Temperature and moisture content affect air density as follows:

- Cooler air is denser than warmer air.
- Dry air is denser than moist air.

AIR RESPONSE TO PRESSURE [FIGURE 1]



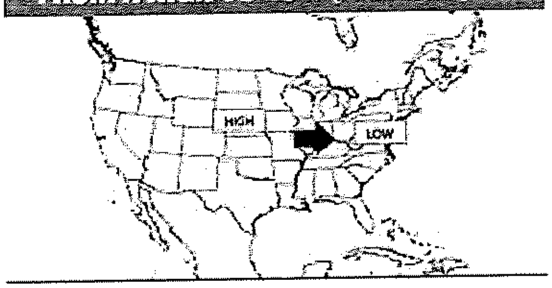
DID YOU KNOW? Galileo saw the Great Red Spot spinning on the planet Jupiter in 1610. It is still spinning more than 400 years later because there is no friction to slow it down.

That's right, moist air is less dense than dry air! This is explained by chemistry: Water molecules (H_2O – atomic weight = 10) are lighter than 99% of the other molecules in the air. For example, N_2 has an atomic weight of 14 and O_2 has an atomic weight of 16). Another way to think of this is to visualize a jar full of marbles (representing nitrogen, 78% of the atmosphere). If you fill a second jar with marbles and marble-sized foam balls (representing water vapor), which jar would be heavier? Of course the jar full of marbles would be heavier than the jar with marbles and foam. Similarly, adding water vapor to the air makes the air less dense because water molecules are light.

Air densities are also affected by swells and depressions in the atmosphere, because air is a fluid and has wave patterns like water in the ocean. Many factors combine to produce areas of sinking air in a high pressure system and areas of rising air in low pressure systems. These factors combine, along with gravity, in an effort to establish a pressure balance (equilibrium) in the atmosphere. Air moves to establish pressure equilibrium. Therefore, air at the surface of the earth moves from high-pressure to lower-pressures areas.

Figure 1 shows movement of air from the point of view of someone standing on the ground. Figure 3 shows air movement from a high in the Great Plains toward a low on the East Coast. Figure 2 shows what should happen with surface winds as air moves from the high toward the low based only on the difference in pressure. But other factors act on the air to prevent the air from simply moving from the high to the low. The rotation of the earth causes air movement across the surface to deflect to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This is called the Coriolis effect (see Earth's Rotation and Global Winds, 4-H Weather and Climate Science, Level 2).

AIR MOVEMENT FROM A HIGH TO LOW [FIGURE 2]



CORIOLIS EFFECT ON AIR MOVEMENT TOWARD A LOW [FIGURE 3]

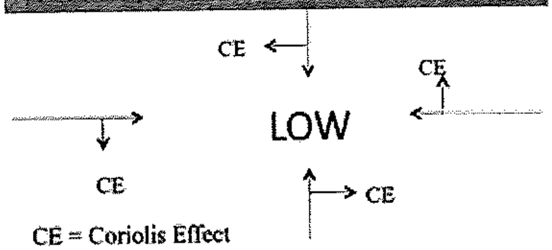


Figure 3 shows a low pressure system with the Coriolis effect (designated by CE) deflecting wind away from the center of the low. This causes the air to circle the low in a counterclockwise direction. Friction, however, causes air near the earth's surface to begin to spiral into the low and works against the Coriolis effect. Friction will eventually cause the storm to dissipate.

Friction and the Coriolis effect influence high pressure systems, too. Dense air sinks at the center of the high, forcing surface air to push out from the center. The Coriolis effect deflects the wind to the right, resulting in a clockwise rotation of wind. Frictional forces at the surface slow the effect of the Coriolis effect, allowing the air to spiral toward the low.

DID YOU KNOW? A centrifugal force impels (pushes) something outward from its center of rotation. For example, if you put 3 cups of water in a small pail and swing the pail on a rope, the water will not drop out when the pail is upside down. Centrifugal force impels the water away from your shoulder, the center of rotation.

DID YOU KNOW?

A car traveling down a highway is not pulled to the right by the Coriolis effect, because the car is in constant contact with the earth. The resulting friction negates the Coriolis effect.

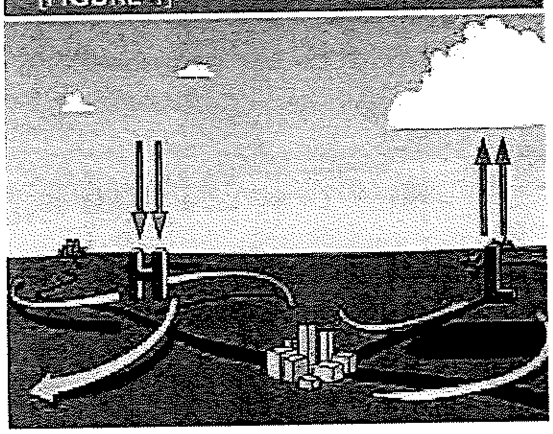
Resulting Weather

High pressure system: Clear and sunny. Rising air may produce fair weather cumulus clouds, which disappear as the sun sets.

Low pressure system: Clouds form in the center of the low and along frontal boundaries.

Figure 5 is a surface map of a typical U.S. weather pattern. Surface maps usually have Hs and Ls to represent high and low pressure systems. On weather maps highs and lows are surrounded by lines called isobars. Isobars are lines of constant pressure connecting locations of equal pressure. When isobars are packed closely together, the pressure is changing rapidly over a small distance. The closer the isobars, the stronger the pressure gradient (the rate of pressure change over a given distance.) Also, notice that in the Northern Hemisphere the wind blows clockwise around a high pressure system and also slightly outward from its center. Around a low pressure system, the wind blows counterclockwise and slightly in toward its center. Because the U.S. is located in the Prevailing Westerlies (see Earth's Rotation and Global Winds, 4-H Weather and Climate Science, Level 2) these systems move from west to east. Systems like these usually last three to five days.

FRICTION EFFECTS AROUND A LOW
[FIGURE 4]



NOAA - Source: National Oceanic and Atmospheric Administration/Department of Commerce.

TYPICAL U.S. WEATHER PATTERN
[FIGURE 5]

NOAA - Source: National Oceanic and Atmospheric Administration/Department of Commerce.

Questions

PIE PAN ACTIVITY

What did you observe when the red sugar water was dropped into the center of the pan?

____

What did you observe when you rotated the pan?

____

What did you observe after the pan was still again?

____

How does this activity help explain pressure systems?

____

DEVELOPMENT OF LOW AND HIGH PRESSURE SYSTEMS

Which is denser, warm or cold air?

____

Which is denser, moist air or dry air?

____

Which air will form a high pressure system, denser or less dense air?

____

Which air will form a low pressure system, denser or less dense air?

____

The Coriolis effect in the Northern Hemisphere causes wind to be deflected which way, to the right or left?

____

What is the resulting rotation of a high, clockwise or counterclockwise?

____

What is the resulting rotation of a low, clockwise or counterclockwise?

How is friction involved in the formation of a high or low?

Why do few clouds form in a high?

Why are clouds expected to form in a low?

What kind of weather is expected in a high?

What kind of weather is expected in a low?

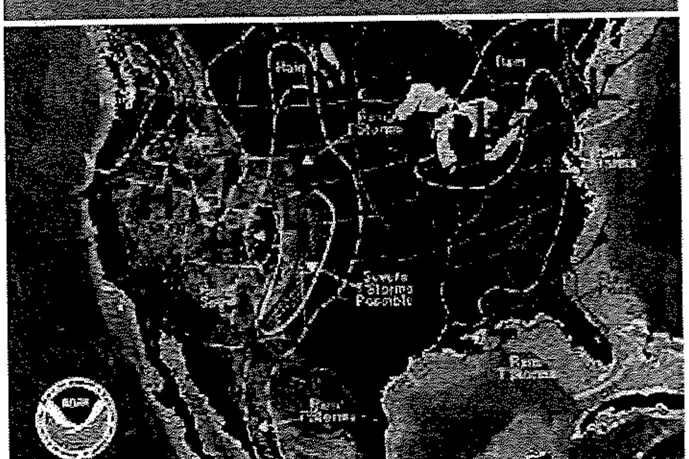
WEATHER STATION MODELS

What is the difference between a weather map and a weather station model?

intro

Weather information is of interest to everyone. It helps us plan our days and can even be lifesaving during severe weather. The National Oceanic and Atmospheric Administration (NOAA) is the U.S. federal agency responsible for collecting and reporting weather data. NOAA maintains 1,500 **weather stations** to collect weather conditions on land. They also collect ocean data using weather buoys and ships. The ocean data is important because over two-thirds of the earth is covered with water, which has a big influence on our weather. NOAA scientists use that data for many purposes, including determining the global temperature record. Media outlets access NOAA data for their weather reports. You can access your current weather data online at www.noaa.gov/wx.html by entering your city and state in the search box.

WEATHER MAP [FIGURE 1]

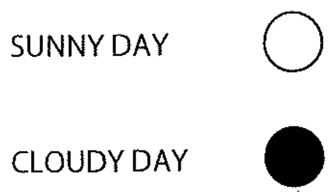


Source: National Oceanic and Atmospheric Administration/Department of Commerce.

Weather maps are used to report current conditions and probable changes in the weather. Meteorologists map weather conditions across the country because weather results from many interrelated variables and generally move in patterns that have been recorded and studied for many years. Weather maps (see Figure 1) show temperature and precipitation patterns and high and low pressure areas. Air movements are studied by examining density and pressure. These movements are called highs and lows. Heavy black lines on a weather map show the fronts and boundaries between air masses. Fronts are important because weather often changes along them. The Air Masses activity (4-H Weather and Climate Science, Level 2) introduces many of the symbols used on a weather map.

Meteorologists use **station models** to convey weather conditions at a weather station as succinctly as possible. Information is placed in an organized fashion using symbols to represent the various aspects of weather. The symbols are placed around a circle ("station circle") representing the station where the weather data was collected. An entirely black circle indicates that the skies were completely covered with clouds when the data was collected. Symbols placed around the station circle indicate wind direction, wind velocity, dew point, temperature, visibility, ceiling, air pressure, and types of clouds (if present). The amount of precipitation since the last reading is also recorded. Station models indicate if rain or snow is falling and how the air pressure has changed since the last reading.

STATION CIRCLES [FIGURE 2]



OBJECTIVE: Use weather station model symbols to report weather conditions.

Weather Tote

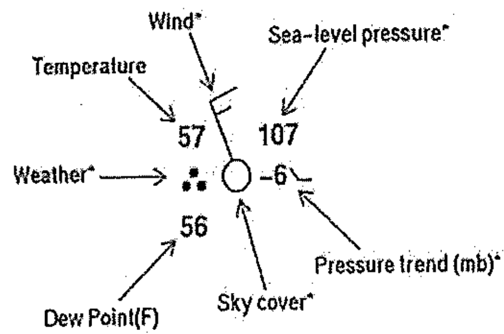
- ☐ Weather Station worksheet

1. Collect weather data using weather instruments, news reports, and the Internet, as needed.
2. Make a weather station model that shows the weather at your home (or nearby) each day for a week.
   - Report the weather at the same time each day.
3. Place each station model on a separate sheet of paper and flip through them.

SHARE WHAT HAPPENED: How many weather symbols can you draw without referring to any reference?

APPLY: How might you use your station model sequence to predict future weather? What additional information do you need?

WEATHER STATION MODEL EXAMPLE [FIGURE 3]



GENERALIZE TO YOUR LIFE:

- Why are symbols and acronyms useful?
- What other symbols can you list?
- What other acronyms can you list?

Fly Higher

- Create a weather map and station models to track a major storm. You must complete this activity when a storm is expected, so planning is required. These websites may be helpful:

  NOAA surface station model map, www.spc.noaa.gov/obswx/maps/

  NOAA current severe weather map, www.spc.noaa.gov/climo/reports/

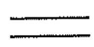
  Visit the National Weather Service website, www.weather.gov. Track a storm moving across the U.S.

WEATHER STATION MODELS WORKSHEET

Study the weather symbols given in this worksheet, and create your own weather station model that shows the weather at your house. Use your weather instruments, news reports, or the Internet to collect your weather data.

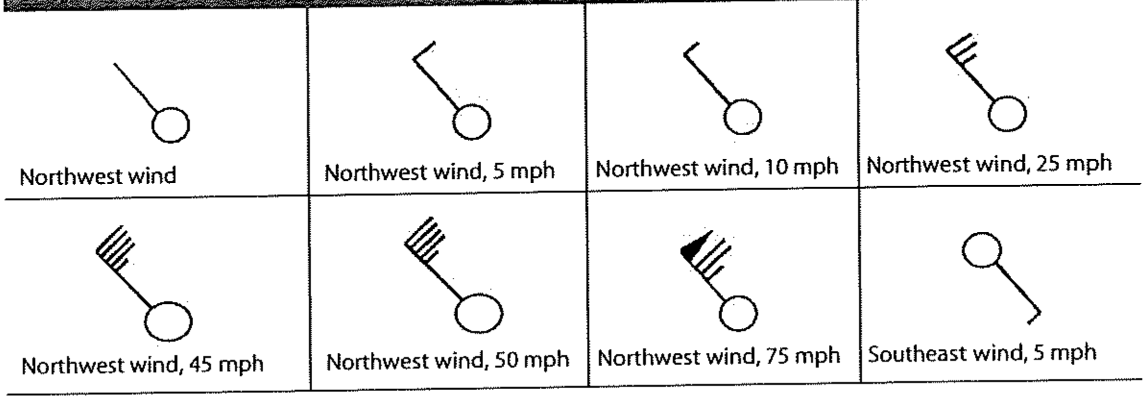
The symbols for rain, snow, thunder, and fog are shown below. These and other common weather conditions are shown in Figure 1.

COMMON WEATHER CONDITIONS [FIGURE 1]

Rain	
Drizzle	
A lot of rain (any of the 3 configurations)	
Rain shower	
Heavy rain shower	
Thunder	
Fog	
Snow	

Wind direction is entered by drawing a line from the direction the wind is coming from to the station circle. North is at the top of the model, south at the bottom, east to the right, and west to the left. Indicate wind speed by drawing lines perpendicular to the wind direction line — a single line for each 10 mph of wind speed, and half a line for each 5 mph of wind speed. These are called feathers and are placed near the end of the wind direction line, away from the station circle. A pennant is used for 50 mph.

WIND SYMBOLS [FIGURE 2]



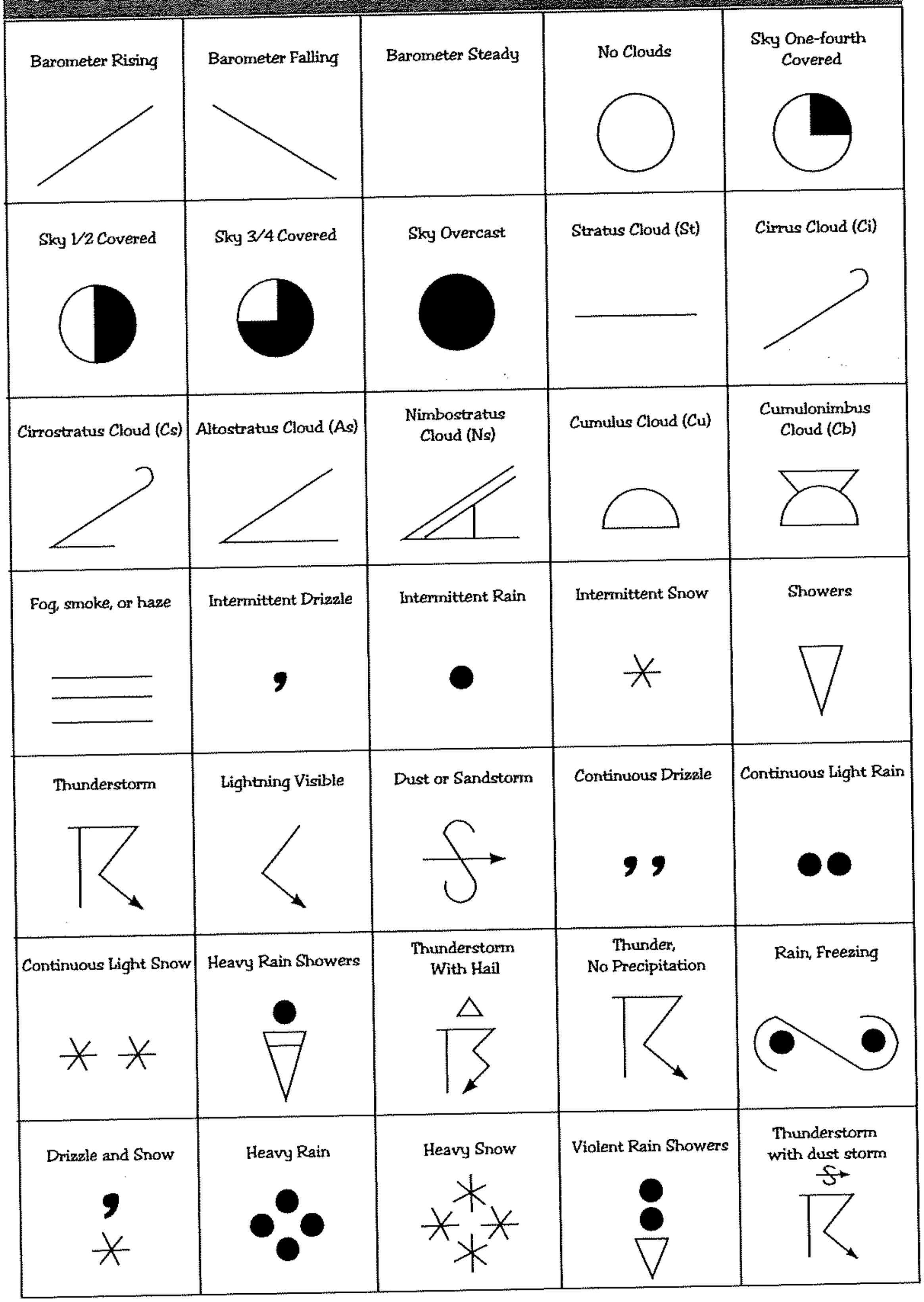
Barometric Pressure – Barometric pressure is plotted in tenths of millibars (mb). The leading 10 or 9 is omitted to simplify the model, so a reading of 1041.0 mb is written as 410. Other examples:

- 103: 1010.3 mb
- 987: 998.7 mb
- 872: 987.2 mb

Barometric Pressure Trend – The pressure trend has two components, a number and a symbol, to indicate how the sea-level pressure has changed during the past three hours. The number provides the three-hour change in tenths of millibars, while the symbol provides a graphic illustration of how this change occurred. Pressure trend symbols are shown in Figure 1.

Optional: NOAA's National Weather Service, Weather Prediction Center provides information to help you read a Weather Station Model at www.hpc.ncep.noaa.gov/html/stationplot.shtml.

COMMON WEATHER SYMBOLS [FIGURE 3]



WEATHER IN THE TROPOSPHERE

How does the structure of the atmosphere influence our weather?

SUGGESTION: You will probably understand this activity better if you have completed the following activities: Global Winds (Level 2); Air Masses and Fronts (Level 3); and High and Low Pressure Systems (Level 3).

The earth's atmosphere is divided into four distinct layers based on their temperature and altitude. The layer nearest the surface, where we live, is called the *troposphere*. The troposphere extends from the surface of the earth to the bottom of the next atmospheric layer, the stratosphere. The troposphere is where all of earth's weather takes place.

The sun's radiation and the earth's atmosphere and surface influence weather dynamics by heating the air in the troposphere differently at different locations. This results in thermal cells, global wind patterns, and jet streams. Understanding how these systems work and how climate changes affect these systems will help you understand global weather patterns.

OBJECTIVE: Understand the dynamics of weather that occurs within the troposphere.

Weather Tote

☐ Weather in the Troposphere worksheet

1 Complete the worksheet.

2 Discuss the Chat questions with your adult helper.

SHARE WHAT HAPPENED: In what ways is a jet stream like a river?

APPLY: How could you use what you learned in this activity to improve your study of weather? How might you use it in your everyday life?

GENERALIZE TO YOUR LIFE: How is climate change affecting the weather in the troposphere?

Fly Higher

- Track current jet stream activity and compare it to current weather conditions. The following websites might be useful in your research:
  NOAA Atmosphere information: www.srh.noaa.gov/crp/?n=education-basicproperties
- Ten-day forecast of jet stream: www.weatherstreet.com/states/gfsx-300-forecast.htm

- Current winds aloft: www.weather.com/maps/activity/aviation/tuesdayusjetstream_large.html
- Graphics: http://gacc.nifc.gov/sacc/predictive/weather/1-FilesforSaccBriefing/1-Briefing_Htms/SaccWebBriefing.htm

NOTES

WINDCHILL AND HEAT INDEX

What is a "feels like" temperature?

Knowing the outdoor temperature is helpful when you are deciding what you should wear or how to pack for a day at the beach or on the slopes. Usually you can just read a thermometer to find out the current temperature and have all the information you need. When the temperature is extreme, however, additional information is needed to know how hot or cold it is.

High relative humidity on a hot summer day makes you feel more uncomfortable outside than the temperature would indicate. This is because the high humidity prevents your perspiration from cooling your body and makes the heat feel more intense. It may be more dangerous to be outside, particularly for the very young or very old. Meteorologists report the **heat index**, which is intended to give an accurate idea of what it feels like outdoors.

Wind on a cold winter day makes you feel more uncomfortable outside than the temperature would indicate. This is because the wind pulls heat away from your body at a faster rate. Meteorologists report the **windchill**, which is intended to give an accurate idea of what it feels like outdoors.

Windchill and heat indices are generally reported during times of temperature extremes and are better indicators of health risks than temperatures alone. It is important to know these values during extreme weather so you can dress appropriately and limit outdoor exposure during dangerous weather.

OBJECTIVE: Understand why meteorologists report windchill on cold winter days and heat index on hot, humid summer days.

Note: This activity takes time (est. 2 hours) to allow analog thermometers to give an accurate temperature reading.

Weather Tote

- ☐ Two similar thermometers, labeled A and B
- ☐ A towel and a metal cookie sheet
- ☐ A room that is at a constant temperature
- ☐ An electric fan
- ☐ The Windchill and Heat Index worksheet

Surface and Wind

1 Complete the Windchill and Heat Index Worksheet as you follow the instructions.

2 Record the time you began this activity on the worksheet:

3 Thermometer calibration:

- Place thermometers A and B side by side on a kitchen counter or table.
- Wait 15–20 minutes to allow the thermometers to stabilize.
- If the temperatures do not show the same value, note which one has the lower reading and add the difference to the next several readings taken on that thermometer.

4 Place a towel and a metal cookie tray side by side on the table or kitchen counter.

5 Place thermometer A in the center of the towel and thermometer B in the center of the cookie sheet.

6 Wait 15–20 minutes to be sure the thermometers are stabilized.

7 Place your hand on each surface (towel and cookie sheet).

8 Place the fan so it blows over the thermometers and turn it on.

9 Hold your right hand about 3 inches in front of the fan, keeping your fingers away from the spinning blade. Answer the question in the worksheet.

10 Wait 15–20 minutes to be sure the thermometers are stabilized.

11 Record the time, temperature, units, and surface for each thermometer on the worksheet.

Warming and Cooling

1 Hold the bulb of thermometer A against the palm of your hand until the temperature on the thermometer reaches 90°F.

- Your readings will be more accurate if you recruit someone else to watch the time, so you can concentrate on the change in temperature.

2 Hold the thermometer away from your body and time how many seconds it takes for the temperature to fall to 80°F.

3 Record the time on the Heating and Cooling Results Chart.

4 Repeat steps 1 and 2 four more times and record the time it took to lose 10°F (resulting in a reading of 80°F) in the chart.

5 Repeat this activity with the thermometer held in front of the fan during cooling.

- Hold the thermometer in your palm to warm it to 90°F.
- Hold the thermometer in front of the fan and time how many seconds it takes to lose 10°F.

6 Calculate and record the averages of the five times and record the average in your data chart.

7 Read the What it Feels Like section of the worksheet and answer the questions.

SHARE WHAT HAPPENED: How close were your five readings in the Heating and Cooling Results Chart?

APPLY:

- Why might a room feel cool when one or two people are in it but warm when 100 people are in it, even though the air-conditioning setting has not changed?
- What did you learn from this activity that can make you safer?

GENERALIZE TO YOUR LIFE: Why is it important for parents to understand the windchill and heat index temperatures?

Fly Higher

- Try the NOAA windchill calculator at www.nws.noaa.gov/om/windchill/index.shtml

  Enter the air temperature (must be less than 50°F) and wind speed. The calculator will give you the wind chill temperature.

- Try the NOAA heat index at www.hpc.ncep.noaa.gov/html/heatindex.shtml.

  Enter the air temperature and either the dew point temperature or relative humidity.

  Note that the heat index calculation works only for temperatures and dew points outside of the range depicted on the Heat Index Chart.

NOTES

WINDCHILL AND HEAT INDEX WORKSHEET

Surface and Wind

Time: ______________________________

Do you think a pair of thermometers placed near each other, but on two different surfaces, will register the same temperature?

☐ Yes ☐ No

Time: ______________________________

Thermometer	Temperature	Units (°F or °C)	Surface
A			
B			

Do the surface temperatures feel the same on the towel and cookie sheet?

☐ Yes ☐ No Which surface feels cooler? ______________________________

How does the air blowing on your right hand feel compared to your left hand, which is not in front of the fan?

☐ Cooler ☐ Same ☐ Warmer

Time after fan blew over thermometers: ______________________

Thermometer	Temperature	Units (°F or °C)	Surface
A			
B			

Did the fan change the temperature of a thermometer that is at room temperature?

☐ Yes ☐ No

HEATING AND COOLING RESULTS CHART: [FIGURE 1]

Time for a 10°F drop in temperature ____________________

Repetition (Rep)	No Wind Time (sec.)	With Wind Time (sec.)
1		
2		
3		
4		
5		
Average		

How much faster did the thermometer cool when the fan was blowing on it? Why?

____

____

What it Feels Like

You probably found that, although the towel and cookie sheet are at the same temperature, the metal cookie sheet felt colder to your hand than the towel. And you probably found that the air from the fan feels colder to your hand than the surrounding air, but did not lower the thermometer temperature.

Why do you think that is?

____

____

The Reason

Your hand is warmer than the cookie sheet, the towel, and the air at room temperature. Because nature tries to reach equilibrium, more heat is flowing out of your hand than is flowing in. But the temperatures will never equalize because mammals generate heat to maintain a constant body temperature.

The metal cookie sheet feels colder than the towel because metal conducts (transfers) heat better than a towel. Therefore heat from your hand moves to the cookie sheet faster than it does to the towel. So the cookie sheet feels cooler than the towel.

Similarly, the fan creates moving air that removes heat from your right hand faster than the motionless air next to your left hand. Therefore both the temperature of the cookie sheet and the air from the fan feel cooler, but they are really the same temperature. If your hand was the same temperature as the cookie sheet or the air from the fan, you would not feel this difference.

Scientifically speaking, why should you use a towel or hot pad to grab a hot cookie sheet?

____

____

Windchill

The temperature of the air feels differently on your skin when a brisk wind is blowing. Just as you saw with the thermometer-cooling test, moving air cools warm objects faster than standing air as heat is moved away from your skin. Therefore wind will chill objects faster than still air. The greater the wind speed against a warmer object, the faster it removes heat and the greater the chill.

Windchill temperature is not an actual temperature; it is a representation of the temperature standing air would have on your skin. Windchill makes air feel colder than it actually is. Scientists have developed the Windchill Chart to show the relationship of temperature and wind speed. The greater the wind speed, the cooler the "feels like" temperature. Even though the windchill temperature is below the freezing point of water, water will not freeze, nor will your skin freeze, as long as the actual temperature is above the freezing point.

WINDCHILL CHART [FIGURE 2]

Wind (mph)	Temperature (°F)																	
Calm	40	35	30	25	20	15	10	5	0	5	10	15	20	25	30	35	40	45
5	36	31	25	19	13	7	1	-5	-11	-16	22	28	34	40	46	52	57	63
10	34	27	21	15	9	3	-4	-10	-16	22	28	35	41	47	53	59	66	72
15	32	25	19	13	6	0	-7	-13	19	26	32	39	45	51	58	64	71	77
20	30	24	17	11	4	-2	-9	-15	22	29	35	42	48	55	61	68	74	81
25	29	23	16	9	3	-4	-11	-17	24	31	37	44	51	58	64	71	78	84
30	28	22	15	8	1	-5	-12	19	26	33	39	46	53	60	67	73	80	87
35	28	21	14	7	0	-7	-14	21	27	34	41	48	55	62	69	76	82	89
40	27	20	13	6	-1	-8	-15	22	29	36	43	50	57	64	71	78	84	91
45	26	19	12	5	-2	-9	-16	23	30	37	44	51	58	65	72	79	86	93
50	26	19	12	4	-3	-10	-17	24	31	38	45	52	60	67	74	81	88	95
55	25	18	11	4	-3	-11	18	25	32	39	46	54	61	68	75	82	89	97
60	25	17	10	3	-4	-11	19	26	33	40	48	55	62	69	76	84	91	98

Frostbite Times ▢ 30 minutes ▢ 10 minutes ▢ 5 minutes

Wind Chill (°F) $35.74 + 0.6215T \quad 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

Where, T Air Temperature (°F) V Wind Speed (mph)

Effective 11/01/01

Source: National Oceanic and Atmospheric Administration/Department of Commerce.

Use the Windchill Chart and answer the following questions:

What is the windchill at 40°F with a wind speed of 5 mph? ____________________

What is the windchill at 40°F with a wind speed of 25 mph? ____________________

Will water freeze when the air temperature is 35°F with a windchill that is 28°F?

☐ Yes ☐ No

Heat Index

When it is hot outside and the relative humidity is high, the temperature of the air feels differently on your skin than it does when the relative humidity is low. You perspire more. That is your body trying to get rid of excess heat to maintain a normal body temperature of 98.6°F. Your skin is cooled when perspiration evaporates because evaporation carries latent heat energy away from the surface of your skin.

Humid air holds a lot of moisture. Evaporation does not occur as rapidly as in dry air, so cooling does not occur as effectively.

The heat index is a "feels like" indication, not an actual temperature. It is a representation of the temperature standing air would have on your skin. The heat index tells us what the air would feel like if you were in the shade and the air was not moving. Scientists have developed the Heat Index Chart to show the relationship of temperature and relative humidity. The greater the relative humidity, the hotter the "feels like" temperature.

HEAT INDEX CHART [FIGURE 3]

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124		
45	80	82	84	87	89	93	96	100	104	109	114	119	124			
50	81	83	85	88	91	95	99	103	108	113	118	124				
55	81	84	86	89	93	97	101	106	112	117	124					
60	82	84	88	91	95	100	105	110	116	123						
65	82	85	89	93	98	103	108	114	121							
70	83	86	90	95	100	105	112	119								
75	84	88	92	97	103	109	116	124								
80	84	89	94	100	106	113	121									
85	85	90	96	102	110	117										
90	86	91	98	105	113	122										
95	86	93	100	108	117											
100	87	95	103	112	121											

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

☐ Caution ☐ Extreme Caution ▩ Danger ■ Extreme Danger

Source: National Oceanic and Atmospheric Administration/Department of Commerce.

Use the Heat Index Chart to answer the following questions:

What is the heat index at 82°F with 50 percent relative humidity? ____________________

What is the heat index at 82°F with 85 percent relative humidity? ____________________

In Arizona the temperature is 88°F with a relative humidity of 45 percent. What is the heat index? What is the danger level for strenuous activity?

____

In Indiana on the same day the temperature is 88°F with a relative humidity of 75 percent. What is the heat index? What is the danger level for strenuous activity?

____

People say that Arizona has a dry heat. What do you think this means?

____

____

Why is it important to drink plenty of water on days with a high heat index?

____

____

Note from NOAA: IMPORTANT: Because heat index values were devised for shady, light wind conditions, exposure to full sun can increase heat index values by up to 15°F. Strong winds, particularly with very hot, dry air, can be extremely hazardous.

The Heat Index Chart shaded zone above 105°F (orange or red) shows a level that may cause increasingly severe heat disorders with continued exposure or physical activity.

Safety First!

"Feels like" events require common sense. In windchill situations, minimize the time people and domestic animals spend outdoors. Cover your exposed skin as much as you can. The warmer the air gets above normal skin temperature, the more dangerous wind is, because it adds heat to your body. When the heat index is high, stay in the shade and use a fan if you don't have air-conditioning.

What can you do to protect yourself in severe windchill situations?

What can you do to protect yourself in severe heat situations?

CLIMATE AND CLIMOGRAPHS

What can you learn by comparing climographs of different locations?

Many elements determine climate, including latitude, elevation, ocean currents, and position on a land mass. These factors influence temperature and precipitation, the major components of a region's climate. For instance, ocean currents produce a warmer climate in some coastal towns than inland towns at the same latitude, and cities at high altitudes generally are dryer than cities at lower altitudes.

A **climograph** s a visual representation of a location's temperature and precipitation. Climographs give us an idea of the type of weather expected at a specific location.

OBJECTIVE: Read and construct climographs.

Weather Tote

☐ Climate and Climographs worksheet

1 Complete the worksheet.

2 Discuss the Chat questions with a parent or other adult helper.

SHARE WHAT HAPPENED: What does a climograph show?

APPLY: What can you learn by comparing climographs from different cities?

GENERALIZE TO YOUR LIFE: How might the climographs that you studied in this activity change over the next 50 years?

Fly Higher

- See the weather and precipitation data used in this activity at the NOAA website, www.ncdc.noaa.gov/cdo-web/datatools/normals.
    - Choose from: Monthly Normals; Daily Normals; Annual/Seasonal Normals; or Hourly Normals.
    - Choose the state and then the city you are interested in.
    - Scroll down to see the information.
- Collect pictures from the different international cities studied in the worksheet. Make a display with the climographs and pictures that reflect the climate at different times of the year.

CLIMATE AND CLIMOGRAPHS WORKSHEET

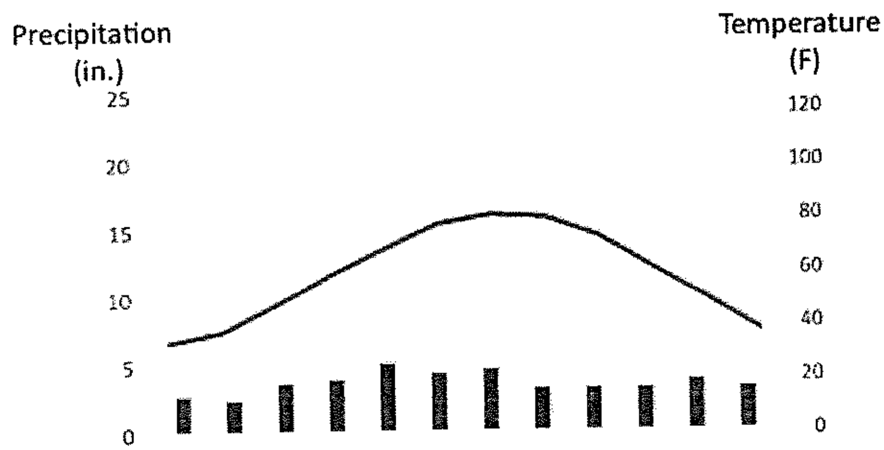
A climograph is a graphical representation of the temperature and precipitation at a specific location. The average monthly temperature and precipitation for Indianapolis is given below. The climograph for Indianapolis is shown in Figure 1.

The climograph of this data is shown in Figure 1.

INDIANAPOLIS DATA [FIGURE 1]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Average Temp (°F)	28.1	31.1	42.2	53.0	62.7	72.0	75.4	74.2	66.9	55.0	43.6	31.6
Precipitation (inches)	2.7	2.3	3.6	3.8	5.1	4.3	4.6	3.1	3.1	3.1	3.2	3.7

INDIANAPOLIS CLIMOGRAPH [FIGURE 2]



What is the warmest month in Indianapolis, according to the climograph?

Which is the wettest month?

Which months would probably be best for growing crops?

___

How does the Indianapolis growing season compare to the growing season where you live?

___

___

___

During which months is the average temperature in Indianapolis below freezing (32°F)?

___

Do you think they sell more long underwear or bathing suits annually in Indianapolis?

___

Why do you think so?

___

___

___

Average temperature and precipitation data is given for six U.S. cities below. Use this data to create a climograph for each city and answer the questions.

CITY A [FIGURE 3]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (°F)	29.0	31.7	38.3	48.1	57.9	67.7	73.4	72.1	64.9	54.0	44.7	34.7
Precip (in.)	3.4	3.3	4.3	3.7	3.5	3.7	3.3	3.4	3.9	3.9	4.0	3.8

CITY B [FIGURE 4]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (°F)	56.4	59.7	65.2	72.7	82.1	90.8	94.8	93.6	88.4	76.7	64.1	55.4
Precip (in.)	0.9	0.9	1.0	0.3	0.1	0.0	1.1	1.0	0.6	0.6	0.7	0.9

CITY C [FIGURE 5]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (ºF)	68.2	70.2	72.6	75.8	79.9	82.7	84.1	84.2	82.9	79.9	74.9	70.5
Precip (in.)	1.6	2.3	3.0	3.1	5.3	9.7	6.5	8.9	9.9	6.3	3.3	2.0

CITY D [FIGURE 6]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (ºF)	23.8	27.7	37.9	48.9	59.1	68.9	74.0	72.4	64.6	52.5	40.3	27.7
Precip (in.)	1.7	1.8	2.5	3.4	3.7	3.5	3.7	4.9	3.2	3.2	3.2	2.3

CITY E [FIGURE 7]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (ºF)	41.4	43.8	48.2	52.3	58.3	63.6	69.2	69.5	64.5	54.9	46.6	40.4
Precip (in.)	4.9	3.7	3.7	2.7	2.5	1.7	0.7	0.7	1.5	3.0	5.6	5.5

CITY F [FIGURE 8]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Temp (ºF)	10.2	15.1	25.9	39.6	51.4	60.1	65.8	64.3	55.6	43.2	28.2	14.8
Precip (in.)	1.0	0.8	1.5	2.4	3.2	4.2	3.9	3.7	4.1	2.9	2.1	1.2

Which city (A-F) has the most precipitation?

____

Which city (A-F) has the least precipitation?

____

Which city (A-F) has the highest temperatures?

____

Which city (A-F) has the lowest temperatures?

____

Which city (A-F) has the most distinct change in seasons?

____

Which city (A-F) has the least changes in seasons?

____

Circle what you would expect to have most of in your closet to be prepared for the weather in each city. (If you cannot decide, circle both.)

CITY	MOST	MOST	MOST	MOST
A	shorts or pants	sandals or shoes	raincoats or sunscreen	heavy coats or light jackets
B	shorts or pants	sandals or shoes	raincoats or sunscreen	heavy coats or light jackets
C	shorts or pants	sandals or shoes	raincoats or sunscreen	heavy coats or light jackets
D	shorts or pants	sandals or shoes	raincoats or sunscreen	heavy coats or light jackets
E	shorts or pants	sandals or shoes	raincoats or sunscreen	heavy coats or light jackets
F	shorts or pants	sandals or shoes	raincoats or sunscreen	heavy coats or light jackets

The temperature and precipitation data is for the cities of Boston, Chicago, Miami, Phoenix, Portland, and Duluth. Indicate the city and state you think the climograph data given on pages 2 and 3 (cities A-F) corresponds to.

	City	State
A	______________	______________
B	______________	______________
C	______________	______________
D	______________	______________
E	______________	______________
F	______________	______________

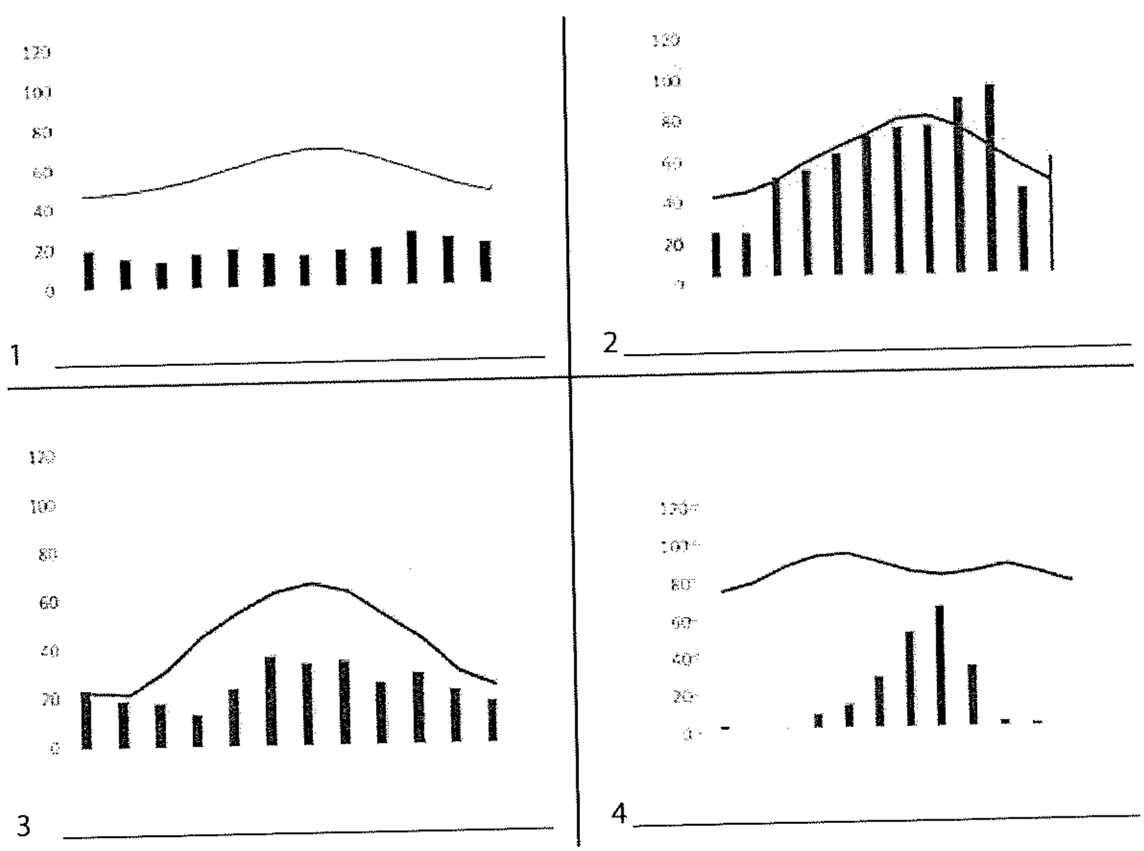
International Climographs

The international climographs show the cities listed below.

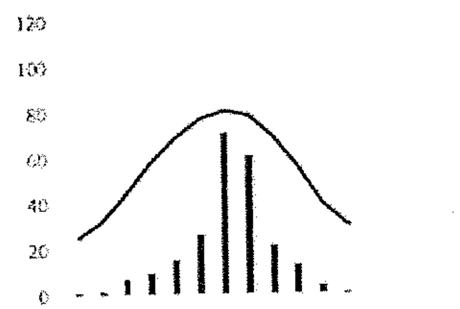
- Beijing, China
- Brasilia, Brazil
- London, England
- Moscow, Russia
- Niamey, Niger
- Sydney, Australia
- Tokyo, Japan
- Toronto, Canada

The line shows temperatures in °F, and the bar graphs show precipitation in inches. Both are shown on the same scale: 0 to 120. Guess which city and country each climograph represents. Check your answers with your facilitator, or check for average monthly temperatures online.

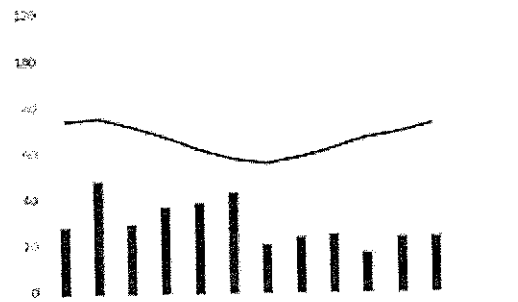
INTERNATIONAL CLIMOGRAPHS [FIGURE 8]



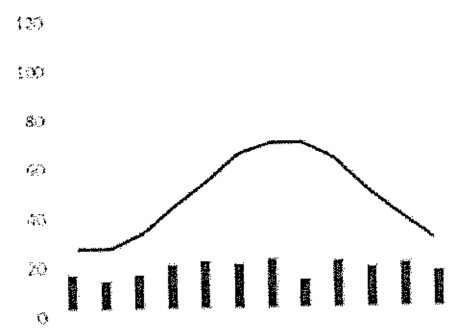
INTERNATIONAL CLIMOGRAPHS [FIGURE 8]



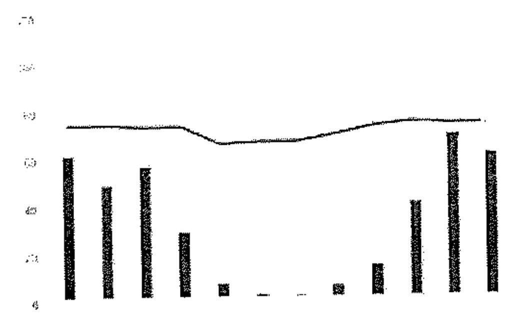
5 ______________________________



6 ______________________________



7 ______________________________



8 ______________________________

DROUGHT MONITORING

How do drought conditions affect people and the environment?

Drought can have devastating effects on an area's environment, economy, and people. Droughts are often accompanied by unusually hot temperatures that can be stressful and a health concern for people, particularly the elderly and very young. Droughts affect plant growth — crops, gardens, and trees. They also reduce water levels in streams, lakes, ponds, and groundwater. The environmental and economic impact of a drought can last for years.

Drought occurs when there is not enough rainfall to sustain normal conditions. Normal conditions are based on 30-year averages for the area. Climate data is calculated and updated at the end of each decade at weather stations across the country. Weather conditions in 2015 would be compared to the average rainfall from 1980–2010 to determine if drought conditions exist in a particular area. If the rainfall is significantly lower than the average, the area is considered drought-stricken.

Droughts are big news and often talked about when a community is living through one. But at other times we tend to forget the stress of not having our usual precipitation, particularly in the Midwest, which is fortunate to generally have reliable precipitation. Other areas of the United States and the world are not so fortunate, and drought can be a constant threat. So while you may not currently be experiencing drought conditions, it is likely that drought is a major concern somewhere in the world as you read this. In this activity, you will investigate a recent U.S. drought and its impact.

OBJECTIVE: Research the agricultural, environmental, economic, and social effects of drought on an area.

Weather Tote:

- ☐ Internet access for data using the NOAA drought monitor, www.ncdc.noaa.gov/sotc/drought webpage
- ☐ Graph paper or computer software to make graphs
- ☐ Access to news reports concerning drought effects on a region or state

1. Use the NOAA drought monitor data, www.ncdc.noaa.gov/sotc/drought, to find a recent drought episode in a region or state.
   - Collect temperature and precipitation data each week for two months.

2 Use line and/or bar graphs to make a **climograph** showing the temperature and precipitation data you collected (see Figure 1).

- Show the dates of data collection on the x-axis.
- Show the temperature and precipitation data on two y-axes as seen for Indianapolis, IN in the figure.

3 Research the effects of that drought on that region through news reports.

- Include how the drought influenced agriculture, the environment, local economics, and social activities.
- Keep a list of all resources that you use.

4 Create a report or display showing the drought data and your research results on the effects.

5 Discuss the Chat questions with a parent, friend, or adult helper.

SHARE WHAT HAPPENED: What location and year did you study?

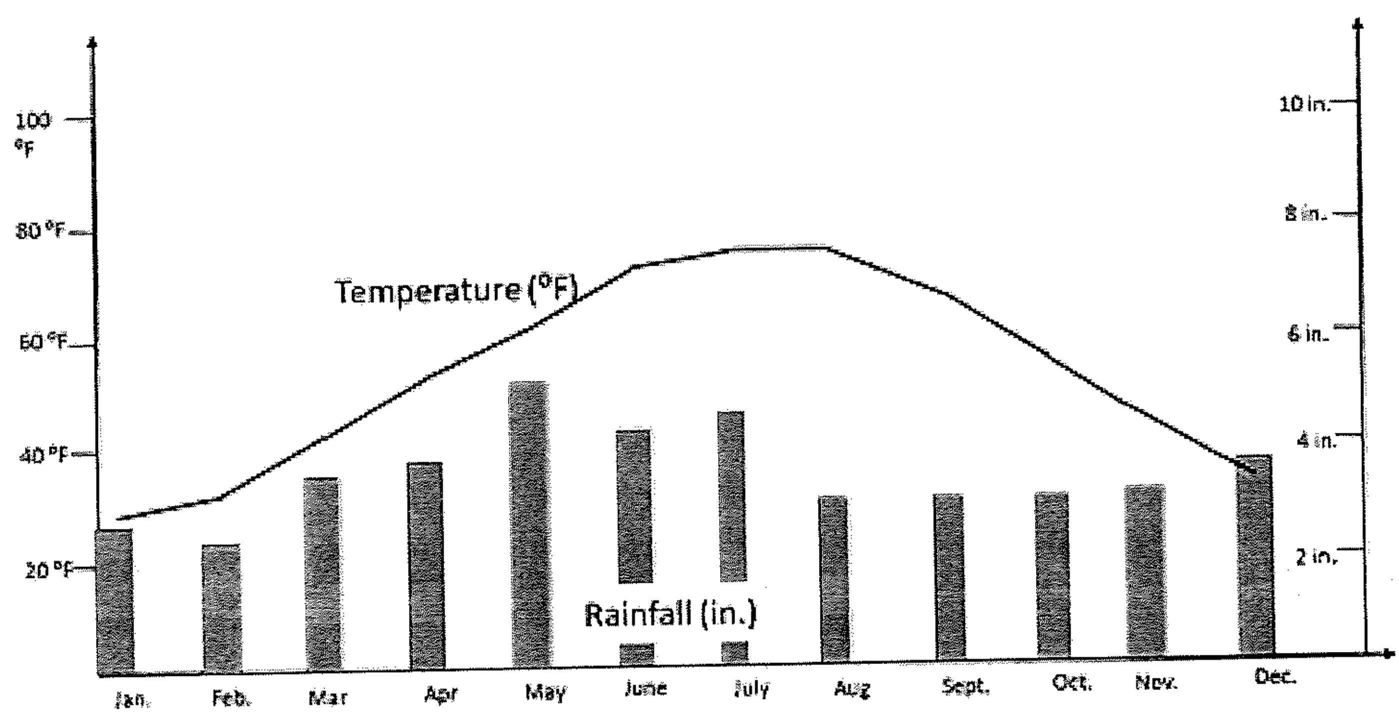
APPLY: How might climate change affect drought monitoring?

GENERALIZE TO YOUR LIFE: How could an increase in the incidence of droughts affect your landscaping plans for the first home you purchase?

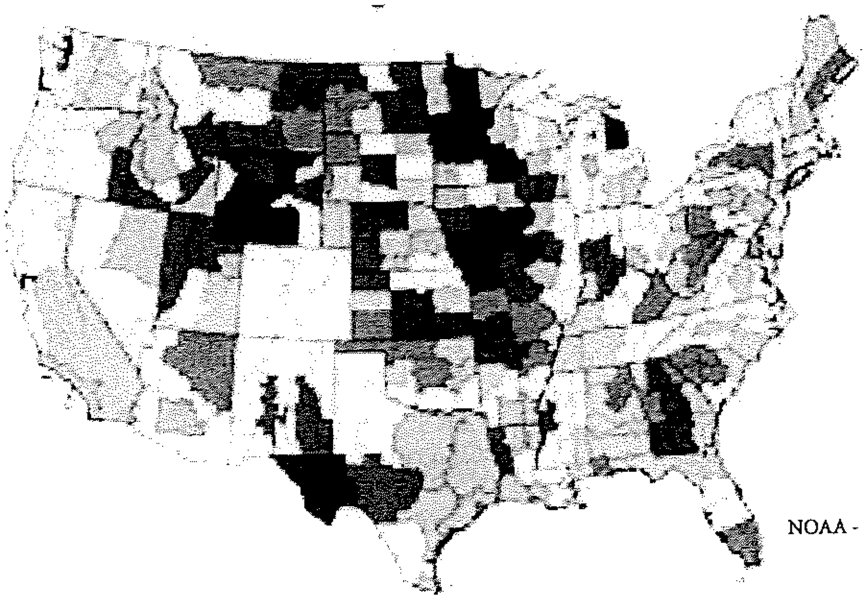
Fly Higher

Use the NOAA drought website, www.ncdc.noaa.gov/sotc/drought, to study previous droughts, wildfires, tornadoes, hurricanes, snow, and ice in the U.S. or globally.

CLIMOGRAPH FOR INDIANAPOLIS, INDIANA [FIGURE 1]



PALMER Z INDEX SHORT-TERM CONDITIONS [FIGURE 2]



PALMER DROUGHT INDEX KEY

- extreme drought, -2.75 and below
- severe drought, -2 to -2.74
- moderate drought, -1.25 to -1.99
- mid-range, -1.24 to +0.99
- moderately moist, 1 to 2.49
- very moist, 2.5 to 3.49
- extremely moist, 3.5 and above

NOAA - Source: National Oceanic and Atmospheric Administration/Department of Commerce.

NOTES

4-H-1025-W

ENERGY IN THE ATMOSPHERE

How does energy from the sun warm the atmosphere?

Radiation from the sun provides the energy that determines earth's weather. This energy generates weather patterns and influences conditions that make life possible. Radiant energy from the sun is absorbed and distributed to achieve the proper balance of energy on earth. You will learn about radiation energy and two other types of energy, convection and conduction.

OBJECTIVE: Describe how radiation, conduction, and convection transfer energy throughout the earth system.

Weather Tote

- ☐ Candle
- ☐ Paper clip
- ☐ Cup or bowl of water
- ☐ Pliers (needle-nose, if possible)
- ☐ Energy in the Atmosphere worksheet

Radiation

1 Light the candle.

2 Hold the palm of your hand about 2 inches from the side of — *not above* — the flame.

3 Move your hand away from the flame.

4 Measure the distance between your hand and the flame when you can no longer feel any heat.

5 Answer the questions on the worksheet and read the radiation information.

Conduction

6 Hold a piece of scrap paper in one hand.

7 Use the pliers to hold a plain metal (uncoated) paper clip in the candle's flame for 15 seconds.

8 Remove the paper clip from the flame and immediately touch it to the piece of paper.

9 Dip the end of the paper clip in the cup of water to cool.

10 Answer the questions on the worksheet and read the conduction information.

Convection

11 Place your hand 3 feet above the flame.

12 Slowly lower your hand until you feel heat from the candle.

13 Measure the distance between your hand and the flame when you can no longer feel any heat.

14 Answer the questions on the worksheet and read the convection information.

15 Discuss the Chat questions with a parent or other adult helper.

Energy from the sun

16 Read the information in the worksheet and answer the questions.

SHARE WHAT HAPPENED: Name the three main types of energy transfer.

APPLY: Why can it be helpful to wear light-colored clothes on a hot, sunny day and dark-colored clothes on a cold, sunny day?

GENERALIZE TO YOUR LIFE: How might the albedo, or reflecting power, of an area affect your comfort?

NOTES

ENERGY IN THE ATMOSPHERE WORKSHEET

RADIATION: The transfer of energy as waves through space.

Describe what you felt when your hand was beside the flame.

____

How far was your hand from the flame when you could no longer feel the heat?

____

The heat that you felt from the candle was being transferred by *radiation*. A burning candle emits electromagnetic waves that you could feel when your hand got close enough to the side of the candle. As you moved your hand away from the flame, the air absorbed the radiant heat so you could no longer feel it. If you walked 100 yards from the flame, you would still be able to see it because the air does not absorb the light energy. On a foggy day, you would not be able to see the flame from 100 yards away because the water droplets in the air reflect and absorb the light energy.

This is the same process that makes your face feel warm on a cold, sunny day. Most of the electromagnetic radiation from the sun is in the form of visible light. Solar radiation passes through the atmosphere and is absorbed by all objects: humans and other animals, plants, rooftops and other surfaces. Solar radiation has a warming effect, particularly on darker objects like asphalt driveways because they absorb more radiation and warm faster. Lighter colored objects don't absorb the sun's radiation as quickly and reflect some of it back to space.

CONDUCTION: The transfer of energy through a substance and between substances.

What happened to the paper clip in the flame?

____

What happened when you touched it to the paper?

____

The paper clip heated up because energy was transferred directly from the molecules of the hot gases in the flame to the molecules of the paper clip. The air molecules that came into contact with the hot gases of the flame were heated by conduction.

The paper clip absorbs heat energy from the flame, which makes the molecules in the paper clip move faster, warming it enough to burn a hole in the paper. This is an example of heat transfer through conduction. Heat transferred through conduction flows through a substance from warmer to colder areas and more rapidly when there are temperature differences. The rate of heat transfer through conduction also depends on whether a substance is a good conductor. Metal is a good conductor, while air is a poor conductor of heat.

Conduction can also transfer heat through two different substances that are in contact with each other. If you hold your bare foot close to a hot sidewalk on a sunny day, you might feel a little warmth due to radiant heat transfer. But if you put your bare foot on a hot sidewalk, you will feel a lot of heat because of conduction heat transfer.

CONVECTION: The transfer of energy by movement in a gas or liquid.

About how far was your hand from the flame when you first felt the heat?

____

What did you feel when your hand was above the flame?

____

DID YOU KNOW? Notice the shape of the flame, a result of the rising air. The flame of a lit candle in a weightless environment — the International Space Station is one example — takes the shape of a ball because convection currents do not form in a weightless environment.

The heat above the flame reached your hand as a result of convection heat transfer. The air near the flame, heated by conduction, expands and becomes less dense. Warmer, less-dense air rises. Energy is transferred upward in a convection current with the rising warmed air, which is lighter than the cooler air.

The heat above a flame is hotter because of convection heat transfer. Radiation heat transfer is the same in every direction; you could move your hand as close above the flame as you did when your hand was beside the flame, if not for convection heat transfer. Conduction heat transfer doesn't come into play when your hand is above the flame because your skin is not in contact with the flame.

Convection heat transfer occurs in fluids such as water, or air, because they move freely and form currents. Convection occurs naturally in the atmosphere on a warm, sunny day as surfaces on the earth absorb sunlight and warm up. But surfaces heat unevenly. As the warmest air expands, it becomes less dense than the surrounding cooler air and rises. Rising air forms thermals, which transfer heat into the atmosphere. Cooler, heavier air then flows toward the earth's surface to replace the warm air that just rose. When the cooler air reaches the surface, it is warmed and eventually rises as a thermal, too. This circulation is called a convective circulation or thermal cell. Thermals can result in cloud formation.

What causes the shape of a flame?

____

MATCH THE TYPE OF HEAT WITH THE CORRESPONDING DEFINITION:

A. Radiation ______ transfer of energy by movement in a gas or liquid

B. Conduction ______ transfer of energy that requires contact

C. Convection ______ transfer of energy as waves through space

ENERGY FROM THE SUN: Energy from the sun comes in the form of radiation that can travel through the vacuum of space. Most of this radiation is in the form of visible light. Three things can happen to radiation as it strikes a substance: it can pass through, be reflected, or be absorbed.

Radiation that passes through a substance is similar to light passing through the air or a window. It is somewhat like sound waves that pass through walls so you can hear a loud radio or TV throughout your house.

Radiation can be reflected. This happens in much the same way that metal or snow reflects sunlight. Radiation can also be absorbed, particularly by dark objects. This is why a driveway heats up on a sunny day. It is also the basis for energy-efficient building materials that absorb the sun's warmth during daylight.

Some objects react with the sun's energy in more than one way. A frosted piece of glass, for example, reflects, absorbs, and allows some radiation to pass through. The earth has a variety of surfaces with diverse properties that interact with sunlight differently.

As radiation strikes a substance, what are the three possible results?

____

____

Which do you think will absorb more sunlight: snow or concrete?

____

ALBEDO: As sunlight strikes the earth, the energy is either reflected or absorbed. The ability of a substance to reflect sunlight is called *albedo*. Some surfaces such as thick clouds and snow have a high albedo and reflect most of the sunlight back into space. Reflected sunlight has no warming effect on the air in the atmosphere.

Surfaces with a low albedo such as land and oceans absorb most of the sunlight and transform the sun's energy into heat. Absorbed heat energy warms the earth and creates the weather and climates that make life on earth possible.

Which will reflect more sunlight: a substance with a low albedo or a high albedo?

____

What happens to reflected sunlight?

____

ENERGY IN THE ATMOSPHERE: The atmosphere is composed almost entirely of nitrogen (78%) and oxygen (21)%). The amount of water vapor in the air varies, depending on conditions, but on average, water vapor is about 1.5% of the atmosphere. Carbon dioxide and other gases make up less than 0.5% of the atmospheric gases.

Gases are not affected by radiation. Sunlight passes right through gases without being absorbed. When air comes into contact with warm surfaces (such as an asphalt driveway), the surface conducts energy to the air molecules. As the air molecules get warmer, the air becomes less dense and rises. The rising air transfers energy to the upper atmosphere through conduction and convection, via thermals.

However, greenhouse gases in the atmosphere absorb infrared radiation.

Nitrogen and oxygen are very stable molecules and are not affected by radiation. They can only be warmed by conduction. Greenhouse gases like carbon dioxide are more loosely organized and are able to absorb infrared radiation. Other greenhouse gases are water vapor, methane, and nitrous oxide. All of these gases can capture the heat from the surface and re-emit that energy into the atmosphere and back toward the surface.

Earth would be a much cooler place without greenhouse gases that retain heat. The fact that they are only a small percentage of the atmosphere illustrates the power of the greenhouse effect.

How does sunlight affect the molecules in the atmosphere?

____

How does infrared radiation affect oxygen and nitrogen molecules?

____

What What percentage of the atmosphere is greenhouse gases??

____

What might a rise in greenhouse gases do to the temperature of the atmosphere?

____

EARTH'S ENERGY BALANCE

How does the sun's energy move in and out of earth's atmosphere?

RECOMMENDATION: Before you begin this activity, you may wish to review the Level 2 Weather and Climate Science activity, The Greenhouse Effect, and the Level 3 activity, Energy in the Atmosphere.

Life on earth requires energy from the sun. Radiation from the sun provides the energy that determines earth's weather and climate. Surfaces on the earth are warmed by the sun's radiation. Sunshine is essential for the health and growth of plants and animals. Some solar radiation (shortwave radiation) is transformed to heat (longwave radiation) and reflected back into space. We call the movement of the sun's energy into and out of earth's atmosphere the energy balance.

To maintain stable temperatures and life on earth, the energy entering its atmosphere must equal the energy that leaves.

OBJECTIVE: Describe the movement of energy in and out of the atmosphere.

Weather Tote

☐ The Energy Balance worksheet

- Complete the worksheet.
- Discuss the Chat questions with a parent or other adult helper.

SHARE WHAT HAPPENED: Describe the earth's energy balance.

APPLY: How does the energy balance help explain climate change?

GENERALIZE TO YOUR LIFE: Why is it important for people to understand things that affect the earth's energy balance?

Fly Higher

Read more about the energy flux:

- NOAA:

  Earth-Atmosphere Energy Balance: www.srh.noaa.gov/jetstream/atmos/energy.htm

  The Earth's Energy Budget, http://oceanservice.noaa.gov/education/lessons/earth_energy_budget_lesson.html
- NASA, Climate and Earth's Energy Budget, http://earthobservatory.nasa.gov/Features/EnergyBalance/
- Climate Change and Religion, http://billmoyers.com/episode/full-show-climate-change-faith-and-fact/

EARTH'S ENERGY BALANCE WORKSHEET

The earth's energy balance describes the flow of energy into earth and back out into space. Energy from the sun flows to earth as shortwave radiation and back into space as infrared longwave radiation. The incoming and outgoing energy must be equal for the earth's temperature to remain stable over long periods of time. The state of balance is called radiative equilibrium, radiation balance, or just energy balance. If energy flow is not balanced, the earth will eventually heat up or cool down. So changes in earth's energy balance cause changes in our climate.

The earth receives about 340 W/m2 (watts per meter squared) solar radiation. Almost a third (29%) of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. This energy plays no role in earth's climate system. Nearly a quarter (22.5%) of incoming solar energy is absorbed in the atmosphere by water vapor, dust, and ozone. Almost half (48%) passes through the atmosphere and is absorbed by the surfaces on the earth.

What percentage of the incoming solar energy becomes part of earth's energy system?

____

Earth's Energy System

Earth's atmosphere and surfaces absorb incoming solar radiation at different rates. Satellites are used to measure the long-term averages shown below.

	SUNLIGHT ABSORBED		HEAT EQUIVALENT RADIATED	
Measurement	%	W/m2	%	W/m2
Atmosphere	23	77	59	200
Surfaces	48	163	12	40
Total	71	240	71	240

What has the most solar heating, the atmosphere or earth's surfaces?

☐ Atmosphere ☐ Surfaces

What has the most radiative cooling, the atmosphere or earth's surfaces?

☐ Atmosphere ☐ Surfaces

How much radiation (heat equivalent percentage) must be radiated back into space for earth's temperature to remain stable over long periods of time?

____

Create two pie charts to show the amount of sunlight absorbed and heat equivalent radiated from the atmosphere and surfaces of the earth. Include titles and units (% or W/m2).

Solar Radiation

Incoming solar radiation that reaches surfaces on the earth may be absorbed or reflected. Albedo is a measure of the reflectivity of a surface. Earth's albedo effect is a measure of how much solar radiation is reflected back into space. Albedo is given as a percentage. It is measured on a scale from zero for a perfectly black surface that has no reflection to 100% for a white surface with perfect reflection.

Albedos of typical surfaces on earth range from up to 90% for fresh snow to about 4% for charcoal, one of the darkest substances. The ocean surface and most forests have low albedos, around 5%. Earth's land areas generally have albedos between 10% and 40%. Dark soil reflects about 10% of sunlight radiation. Deserts have some of the highest albedos among landforms. The average albedo of the earth is about 30%.

Absorbed solar radiation warms the surface. These surfaces can then warm the air through conduction. Air molecules must be in contact with the surface for the energy to transfer. As the air around the surface is warmed, that air becomes less dense, rises, and transfers the energy into the atmosphere as thermals, or convection.

Sunlight also causes water to evaporate and plants to transpire. The combined effect of evaporation and transpiration is known as evapotranspiration. When water changes into a gas, latent heat is produced, and the heat energy is transformed into the kinetic energy of water vapor. When the water vapor condenses, the latent heat energy is released into the atmosphere, causing the air to warm.

Draw a bar graph that shows the albedos of the following:

- Fresh snow, dark soil, charcoal, landforms (high value), ocean surface, earth (general), landforms (low value), and forests
- Show the albedos from highest to lowest.

Describe two results of solar radiation that is absorbed on earth's surfaces?

____

____

Heat Distribution

The heat equivalent of energy radiated from earth to space is in the form of longwave radiation, usually defined as outgoing infrared energy. Longwave radiation can be reflected directly to space, partially absorbed by the atmosphere, or reflected back to earth by clouds. Heat energy is transported between the planet's surface layers (land and ocean) to the atmosphere. Many processes distribute it, including evaporation of surface water, convection, conduction, rainfall, winds, and ocean circulation. The rate and amount of radiation absorption and heat radiated varies with location and daily, seasonal, and annual changes in the earth. These processes are affected by the albedo (reflectivity) of surfaces, cloud cover, vegetation, and land use patterns.

Areas near the equator are much warmer than areas near the North and South Poles. Energy moves through the atmosphere and the oceans to equalize these differences. This movement of energy in the atmosphere is called wind and weather. When this energy intensifies in a region, storms can result. Storms contain a great amount of energy, which is sometimes released with such serious consequences as hurricanes and tornadoes.

Disturbances of Earth's Radiative Equilibrium

The earth's atmosphere is a mix of nitrogen (78%) and oxygen (21%) and trace atmospheric gases (1%). Trace atmospheric gases are often called greenhouse gases because they interact with thermal infrared energy similarly to sunshine in a greenhouse.

Greenhouse gas sources include both natural and synthetic (human-created) gases. The most common natural gases are carbon dioxide, water vapor, methane, and nitrous oxide. The most common synthetic gases are chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6). Atmospheric concentrations of both the natural and man-made gases have been rising over the last few centuries.

Outgoing longwave heat equivalent radiation does not fully pass through greenhouse gases in the same way it passes through nitrogen and oxygen. Nitrogen and oxygen allow outgoing radiation to pass through unchanged. Greenhouse gases, however, absorb some thermal infrared energy. These gas molecules radiate infrared energy in all directions, so some of it spreads downward and ultimately comes back into contact with the earth's surface, where it is absorbed. This causes the temperature of the earth's surface to be warmer than if it were heated only by direct solar heating. This supplemental heating of the earth's surface by the atmosphere is the natural greenhouse effect.

The earth's climate has evolved the delicate balance between incoming solar radiation and outgoing thermal radiation that supports life on earth over millennia. This balance is so delicate that changes in the greenhouse gases, only 1% of our atmosphere, can tip this balance!

Human Influences

Humans tend to change the natural environment for their use. Some changes can affect the surfaces of earth and the composition of the atmosphere, and therefore, the energy balance. Many people are advocating for more care of our natural resources to reduce human impacts on the environment.

How might the following activities affect the earth's energy balance?

Cutting down forests

____

____

Using energy sources like wind, water, and solar energy

____

____

Producing more efficient cars and trucks

____

____

Burning more fossil fuels

____

____

Constructing more buildings, roads, and parking lots

____

____

Planting more trees and creating more green space

____

____

Recycling

____

____

What other activities or concerns have you heard about or researched that might affect earth's climate?

NOTES

IMPACT OF CLIMATE CHANGE

How does climate change impact our environment?

Polar bears have become the environmental "poster child" of climate change. Melting Arctic ice is reducing their mobility and access to transit and hunting grounds for fish and seals. People who worry about climate change focus on the loss of polar bear habitat because polar bears are iconic to the Arctic.

Many other species will be impacted by climate change, of course. For over 100 years, scientists have realized that an increase in greenhouse gases in the atmosphere causes an increase in the average global temperature. Natural fluctuations in the climate system will continue. Winters will still be cold and some will be more severe than others. Global temperatures will not increase every year, but over time baseline temperatures will continue to climb as long as the amount of greenhouse gases increases. While scientists cannot predict exactly when the Arctic will become ice-free and the polar bear habitat will be gone, they know that it will happen if greenhouse gases emissions are not controlled. In this activity you will conduct research to find out more about the expected environmental impact of climate change on a specific animal or plant.

OBJECTIVE: Learn about the impact of climate change on an animal or plant.

Weather Tote

- ☐ Internet access

  Use multiple sources.

  Use websites ending in *.edu or *.gov for scientific organizations linked to university or governmental scholars.

- ☐ Materials to present your research results via print, electronic or video

  Poster presentation

  PowerPoint presentation

  YouTube video

1 Choose a plant or animal to research (your subject).

You may select any species of your choice.

Or, choose one of the following:

- Blue crab
- Coastal wetlands
- Coral reefs
- Eastern hemlock Forests
- Lake sturgeon
- Mangroves
- Moose
- Penguins
- Pika
- Polar bears
- Ringed seals
- Sagebrush
- Salmon
- Walleye
- Western forests (mountain pine beetle)

2. Take notes while you learn all you can about your subject.
   - Index cards can be used to keep your notes. Put different topics on each card (for example, food and shelter needs, survival temperature range, special reproduction requirements, range) for easy sorting later.
3. Prepare a short manuscript (3–5 pages) to describe what you learned about the expected environmental impact on the subject you chose.
   - Create an outline before you begin.
   - Arrange the information you found during your research, following your outline.
   - Write your paper (manuscript).
   - Include possible solutions and/or programs to address the problem.
   - Include pictures, graphs, and/or tables, as appropriate, to help your reader understand the impact of climate change on the species you researched.
   - List the references you used:

     Book references must include the title, authors, publisher, and date of publication.

     Internet references must include the page title, professional affiliation (university, governmental department, or professional society), web address, and date of access.

     Articles in professional papers, magazines, or newspapers must include the title, author, source, and date of publication.
4. Prepare a poster exhibit to convey the plight of your subject to the public.
   - A good poster:

     Attracts attention

     Is simple and clear

     Interests people in your subject

     Does not contain too much information for a casual reader

SHARE WHAT HAPPENED:

- Why did you choose the particular species for a research subject?
- How many sources did you use?
- How long did you spend on your research?
- How long did it take you to create your presentation?

APPLY:

- How does what you learned apply to other species?
- Did you discover any actions you could take to help with the situation?

GENERALIZE TO YOUR LIFE: What effect might climate change have on your life?

Fly Higher

- Study the impact of climate change on another species.
- Visit the United Nations Climate Change webpage, http://www.un.org/climatechange/, to study what world leaders are thinking and doing about the problem.
- Visit the Purdue Climate Change Research Center (PRCC), http://www.purdue.edu/discoverypark/climate/, to learn about the research it is doing.
- Investigate other issues related to environmental impact of climate change.

INVESTIGATING CLIMATE CHANGE

How can we use climate data to demonstrate cause-and-effect relationships?

Many tools can be used to observe and track the weather. Thermometers, rain gauges, anemometers, and wind vanes are used to determine the local weather on a day-to-day basis. Weather reports and maps can be used to monitor weather on a larger scale. But how can *climate* be monitored?

Climate must be observed over a period of years. Weather records are used to develop climate averages. Past data can be observed and used to predict future weather patterns. Climate norms are based on 30-year data sets. Current (2013) climate data is based on data from 1980 through 2010. Climate data will be updated again in 2020. Weather data is tracked and reported monthly, yearly, or every few years depending on the type of data. Much of this data has been tracked for over 100 years.

Many organizations report weather data. The National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the National Aeronautics and Space Administration (NASA) are reliable sources for weather data. While many websites may change over the years, the climate information from the NOAA, EPA, and NASA websites has remained fairly consistent.

OBJECTIVE: Use a government weather data source to record the weather climate data, and describe the cause-and-effect relationships that you observe.

Weather Tote

- ☐ Materials to create graphs and charts, such as paper and pencils or a Microsoft Excel spreadsheet
- ☐ Materials to create a display, such as the following:
  - Markers
  - Graphics or pictures
  - Computer-generated titles
  - Poster board/trifold board

1 Visit the NOAA, EPA, and NASA websites shown in Table 1.
   - Investigate the data available at each website.

2 Decide on two weather measurements that you will list for each year over a 30-year period (ending in the current year).
   - Choose data that you feel is interesting, relative, and significant.
   - Choose data that can show cause-and-effect relationships.

3. Decide on a location such as your home or a major city.
4. Create a table that lists the data for each of the last 30 years for the two measurements.
5. Graph your data using a line graph or bar graph. You can do this by hand or use Excel.
6. Discuss any trends that your data shows over the 30-year time span.
7. Prepare an educational poster, showing:
   - The data you collected (include units!)
   - Your discussion of current trends in the data
   - Your explanation of how the data sets compare and/or relate to other data sets that people may recognize
   - A good poster:
     Attracts attention
     Is simple and clear
     Interests people in your subject
     Does not contain too much information for a casual reader
8. Present your poster at one of the following venues:
   - Demonstrations (including 4-H interactive demonstrations)
   - Information display boards
   - Junior Leader activities
   - Mentoring a younger 4-H member
   - Outreach to community members

SHARE WHAT HAPPENED: Where did you collect your weather data? Why?

APPLY:

- How does knowing weather trends apply to your daily life?
- How do you think your results would look if you were a 4-H member in 1970 and collected the previous 30 years of weather data?
- How will our idea of climate change differ in the next 30 years?

GENERALIZE TO YOUR LIFE: Why is it important that others understand weather trends?

Fly Higher

- Continue tracking your data throughout your 4-H membership and beyond.
- Choose other weather topics to track using historical data.

INVESTIGATING CLIMATE CHANGE WEBSITES [TABLE 1]

Provider	Website	Website
NOAA	www.ncdc.noaa.gov/	National Climate Data Center
EPA	www.epa.gov/climatechange/science/indicators/ www.epa.gov/climatechange/science/indicators/weather-climate/temperature.html	Climate Change Indicators in the United States (temperature)
NASA	http://gcmd.nasa.gov/learn/pointers/weather.html	Global Change Master Directory

THE SUN–EARTH RELATIONSHIP

What caused the ice ages?

intro The earth's temperature has varied significantly during the millennia, from the ice ages to a period when tropical temperatures blanketed the entire earth. Scientists have tried to explain this variation by studying the relationship between the sun and earth. Milankovitch theorized that the direction and angle of the earth's tilt, and the shape of the orbit are responsible for the significant temperature changes on a millennia scale. In this activity, you will investigate the Milankovitch Cycles.

OBJECTIVE: How do Milankovitch Cycles describe the earth's orbit and orientation over time?

Weather Tote

☐ Milankovitch Cycles – The Sun-Earth Relationship worksheet

1. Complete the worksheet.
2. Discuss the Chat questions with a parent or other adult helper.

SHARE WHAT HAPPENED: What are the Milankovitch Cycles?

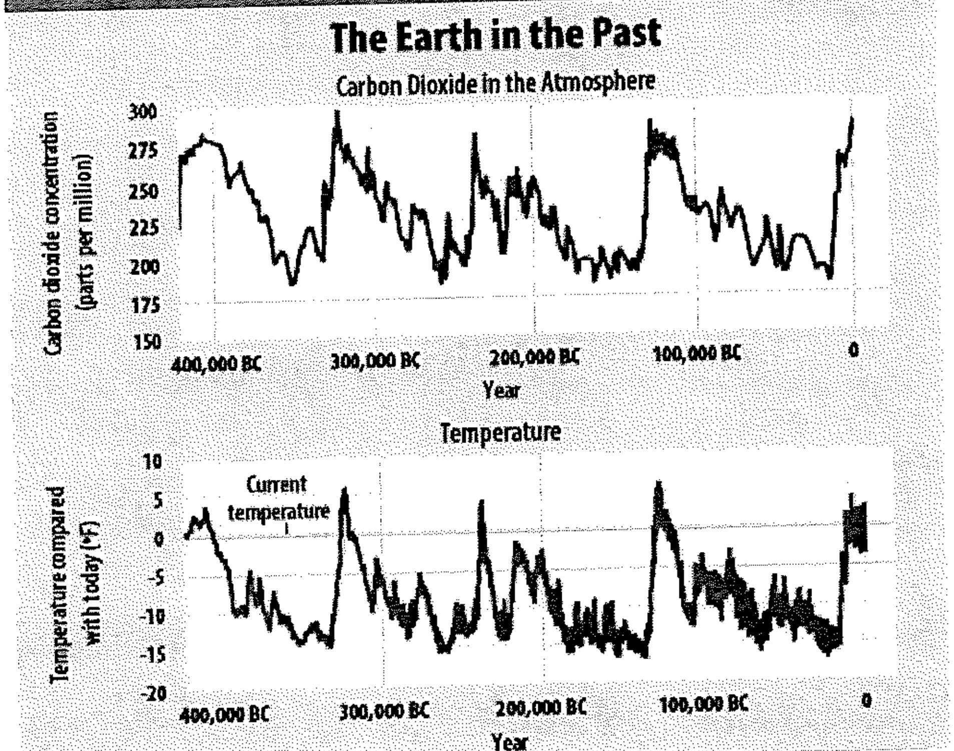
APPLY: Why is it warmer in the summer than in the winter in the United States?

GENERALIZE TO YOUR LIFE: Events that follow cycles will occur again. How can genealogy describe a family cycle?

THE SUN–EARTH RELATIONSHIP WORKSHEET

Earth's temperature has varied significantly since it was formed. At least 30 glacial periods have occurred. Figure 1 shows temperature and carbon dioxide (CO_2) data from ice core samples that chronicle the temperature and carbon dioxide levels during the past 400,000 years. There is a direct correlation between the earth's average temperature and the occurrence of ice ages. The lower blue line on the graph indicates the temperature deviation in °C. The upper red line shows CO_2 levels. The CO_2 level was at 380 ppm when this graph was created in 2007. In 2013 the CO_2 level was 399 ppm. The average global temperature has varied about 8°C during the past 20,000 years.

VARIATIONS IN TEMPERATURE AND CARBON DIOXIDE [FIGURE 1]



Source: U.S. EPA

How many cooling periods do you observe during the past 400,000 years in Figure 1?

____

Which change seems to occur at a faster rate, warming or cooling?

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Milankovitch's Theory

A Serbian scientist named Milutin Milankovitch developed a theory in the 1920s to explain how earth's changing patterns of orbit and tilt in relationship to the sun might cause climate change. He was especially interested in explaining the occurrence of the ice ages. Milankovitch suggested that changes in the earth's orbit and tilt occur in cycles over very long periods of time — tens of thousands of years. These cycles, based on mathematical calculations, are now known as the Milankovitch Cycles. The scientific community did not take his theory seriously until the 1970s, when actual ice core data showed a possible connection between the ice ages and the Milankovitch Cycles.

Milankovitch studied three aspects of the earth's orbit around the sun that influence the amount of energy the earth receives from the sun. The cycles are obliquity, eccentricity, and precession. Could these cycles help explain the recent rise in the earth's temperatures?

What did Milankovitch's theory try to explain?

____

OBLIQUITY

Seasonal changes are caused by the tilt of the earth. The earth's tilt is currently about 23.5° when compared with its orbit around the sun. The first day of summer in the Northern Hemisphere occurs when the North Pole is tilted at the maximum 23.5° toward the sun. On that day, the Northern Hemisphere receives the maximum amount of the sun's radiant energy. The day also marks the first day of winter for the Southern Hemisphere. The angle created by the earth's tilt varies slowly between 22.1° and 24.5° over a time span of approximately 41,000 years. The earth's tilt is responsible for the changing seasons and their differences in temperature.

ECCENTRICITY

The earth orbits the sun following an elliptical (oval) path. Eccentricity is a measure of the departure of the earth's orbit from a circle. The shape of the earth's orbit varies at a slow rate, between nearly circular (low eccentricity of 0.005) and mildly elliptical (high eccentricity of 0.058) with a mean eccentricity of 0.028. The elliptical orbit causes the distance of the earth from the sun to continuously change throughout the year. The earth's average distance from the sun is 93 million miles. At earth's closest, it's about 91.5 million miles from the sun. This occurs annually in early January.

The earth reaches its farthest position from the sun in early July, when it is about 94.5 million miles from the sun. Some evidence exists that this elliptical orbit may make the Northern Hemisphere seasons less severe than seasons in the Southern Hemisphere, although the difference is thought to be slight.

PRECESSION

Precession is a measure of the direction of the earth's axis of rotation relative to the fixed stars. Currently, the North Pole is pointing toward the North Star. This causes the Northern Hemisphere to tilt away from the sun when the earth is closest to the sun (our winter) and toward the sun when the earth is farthest from it (our summer). But this is not a constant. Precession changes the tilt very slowly, over a period of about 26,000 years. The North Pole changes its orientation as the earth spins, so it is not always pointed toward the North Star.

Which cycle explains the direction of the earth's tilt?

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Which cycle explains the shape of the earth's orbit?

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Which cycle explains the angle of the earth's tilt?

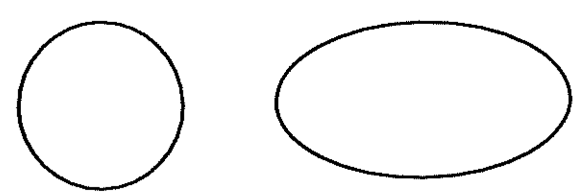
____

How might the Milankovitch Cycles influence present-day global temperatures?

ECCENTRICITY

Eccentricity is a measure of how much the ellipse of the earth's orbit differs from a circle. The ellipse on the left in Figure 2 nearly circular, while the one on the right is more oval. Therefore, the ellipse on the right is more eccentric than the ellipse on the left.

CIRCLE AND OVAL [FIGURE 2]



Because its orbit is an ellipse, there are times when the earth travels closer to the sun. Annually, the earth's elliptical orbit varies from a circular shape by three million miles. The average radius of the earth's path is 93 million miles, so the variation from a circular pattern is slight. This amount of change is relatively small and does not seem to cause significant temperature changes on earth.

Milankovitch discovered that the shape of the ellipse changes and becomes more or less eccentric over time. A more circular orbit would create less severe seasons and therefore less seasonal change. A less circular orbit would cause the earth to be much farther away from the sun at the farthest point of the orbit than it is now. A large change could cause more severe seasons. Cooler summers could cause the buildup of snow and ice fields similar to the glacial periods of the ice age. The eccentricity cycle is estimated to repeat every 100,000 years.

What is the percentage of eccentricity of the earth's orbit?

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What effect would a more circular orbit have on seasons?

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What effect would a more eccentric orbit have on seasons?

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How long does it take for this cycle to repeat?

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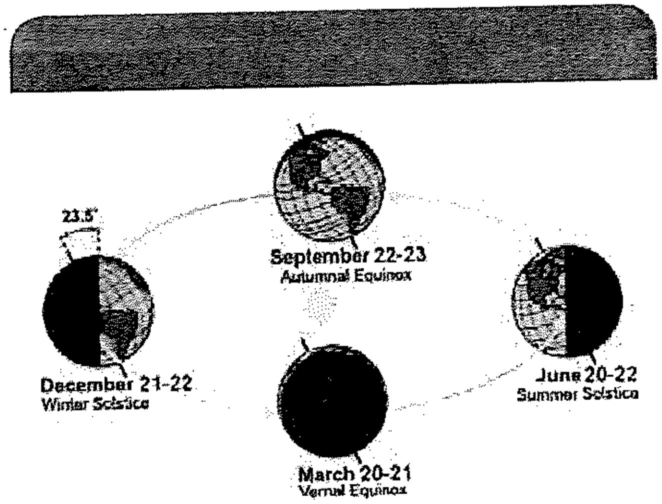
OBLIQUITY

Obliquity is the tilt of the earth in relationship to the sun. It changes over time. At present the tilt of the earth is 23.5° in respect to its orbit around the sun. The earth's tilt is responsible for the changing seasons and their differences in temperature. Through a 40,000-year period, the obliquity (tilt) of the earth changes from a minimum of 22.1° to a maximum of 24.5° and back again. This change in tilt occurs very slowly, but could cause the seasons to be more severe during maximum tilt and less severe at minimum tilt.

When the earth is only tilted 22.1°, summers and winters may be less severe. At the minimum tilt, higher latitude summers would be cooler and winters warmer. Scientists speculate that, during such cooler summers, winter snow and ice in the higher latitudes might not melt from year to year. In addition, the buildup of snow and ice fields could cause more of the sun's energy to be reflected back into space, promote the formation of glaciers, and possibly result in an ice age.

At maximum tilt, seasonal changes would be more dramatic. Colder winters and warmer summers for the higher latitudes would be likely. Studying Figure 3 may help you understand this relationship.



At a maximum tilt of 24.5°, what will happen to seasons in the higher latitudes?

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At a minimum tilt of 22.1°, what will happen to seasons in the higher latitudes?

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How long does it take for earth to complete the tilt cycle?

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PRECESSION

Currently the earth's axis is oriented so that it points almost directly at the North Star, Polaris. Four thousand years ago, when Egypt was building the pyramids, the North Pole was oriented to the star Thuban in the constellation Draco. The earth's orientation has shifted over time. This shift is called precession. The North Pole will shift following a 26,000-year cycle. So 26,000 years from now, the North Pole will once again be aligned with Polaris.

Today's precession orientation causes the earth to be nearest the sun during our winter and farthest away during our summer. This causes less severe seasons in the Northern Hemisphere.

In about 12,000 years, the precession cycle will move the tilt so the earth will be nearest to the sun during our summer and farthest away during our winter. This precession position could cause more severe seasons in the Northern Hemisphere.

During which of the Northern Hemisphere seasons is the earth closest to the sun?

How long does this cycle take to complete?

When the earth is closest to the sun during our summer, what effect might that have on our seasons?

How do the Milankovitch Cycles combine to affect climate?

Scientists speculate that the most likely scenario for a Northern Hemisphere ice age would occur under the following combination of Milankovitch factors:

- A nearly circular shape of the earth's orbit (minimum eccentricity)
- A minimum tilt of 22.1° (minimum obliquity)
- Orientation so earth is closest (and farthest) away from the sun during spring (and autumn) (precession)

According to Milankovitch's theory, these factors together would cause the four seasons to be similar to each other. The resulting seasonal temperature changes, even though very small, could allow areas near the poles and higher latitudes to accumulate snow and ice and to form glaciers. Increased snow and ice on the earth would reflect more sunlight and the earth would cool. The opposite cyclical extremes could cause a warm period. This warming would cause the snow and ice fields to shrink and the earth to absorb more of the sun's energy.

Scientists generally think that these cycles will combine to produce either a cooling trend or a warming trend. Currently scientists are predicting that the earth's temperatures should remain stable before moving toward an ice age, which could occur in about 30,000 years. Human impacts, such as an increase in CO_2, may affect the expected pattern.

What status of the Milankovitch Cycles are expected to create the next ice age?

Could these cycles cause changes during a period of hundreds or thousands of years? Why?

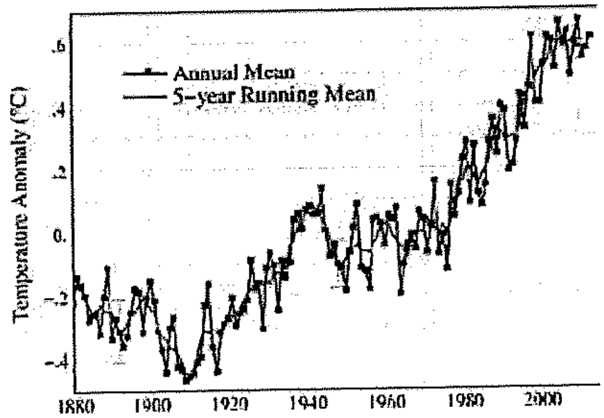

Figure 4 shows a rise in global temperatures compared to the global average since 1880. Could changes in the Milankovitch Cycles explain the recent rapid global temperature rise shown in Figure 4? Why or why not?

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Figure 1 shows the temperature has risen about 8°C over the past 20,000 years. Figure 4 shows the temperature has risen over 1.5°C in the last 130 years. Which time period is showing the most rapid average temperature rate?

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Climates and seasons on earth are primarily a function of how much solar radiation is absorbed and retained by the different areas. Many factors help determine exactly how solar radiation affects the climate. There is a natural relationship between the earth and the sun in space. Seasons are determined by the position of the earth in respect to its orbit and tilt. The distance of the earth from the sun is also important. When the earth is closer, the increased radiant energy can affect our climate. These factors also can change over time within recurring cycles.

A correlation was shown between the Milankovitch Cycles and the occurrence of ice ages. The Milankovitch Cycles of eccentricity, obliquity, and precession predict that ice ages should occur when all three encourage less severe seasons.

At present, only one cycle, precession, is at an extreme. The current precession of the earth places it closest to the sun during our winter and farthest away during our summer. This should make the Northern Hemisphere's seasons milder, but conversely, the Southern Hemisphere's seasons should become more severe. The obliquity, or tilt, of the earth is currently at neither extreme. The 23.5° of tilt is midway between the extremes of 22.1° and 24.5°. The eccentricity of the earth's orbit also is not at an extreme. The Milankovitch Cycles do not explain the current increase in global temperature.

SUNSPOT CYCLE

What is the sunspot cycle?

Global warming and climate change are international concerns and the focus of much controversy. In this activity, you will learn about the **sunspot cycle**, which causes increases and decreases in the radiation from the sun to the earth. You will use this information to reflect on the relationship between sunspots and global temperatures.

OBJECTIVE: Relate the relationship of the sunspot cycle to global temperatures.

Weather Tote

☐ Sunspot Cycle worksheet

1 Complete the worksheet.

2 Discuss the Chat questions with a parent or other adult helper.

SHARE WHAT HAPPENED: What are sunspots?

APPLY: What happens to the earth when there is very little sunspot activity?

GENERALIZE TO YOUR LIFE: Are an increased number of sunspots (solar max) responsible for climate change?

Fly Higher

View the current state of the sun and recent solar activity captured by the Solar and Heliospheric Observatory (see http://sohowww.nascom.nasa.gov/sunspots/) for one week. Describe your observations.

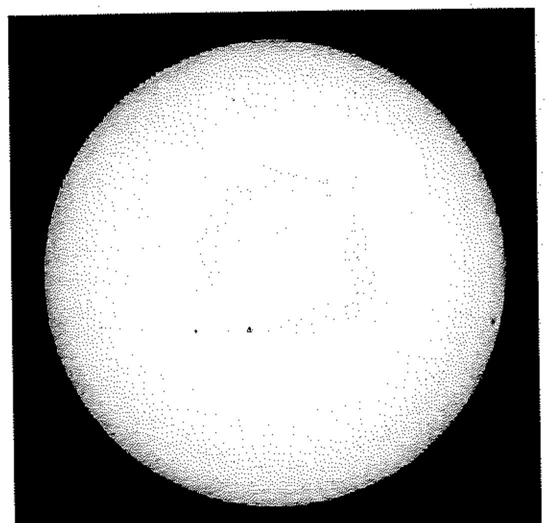
SUNSPOT CYCLE WORKSHEET

Global warming and climate change are international concerns and the focus of much controversy. Strong scientific evidence shows an accelerated rise in average global temperatures during the past 30 years. The media gives a great deal of attention to the fact that concentrations of greenhouse gas and carbon dioxide (CO_2) are rising.

The central cause of this increase is usually blamed on human activity, especially the burning of fossil fuels, which puts large amounts of CO_2 into the earth's atmosphere. The increase in carbon dioxide is the most frequently discussed factor in the global-warming controversy.

Many variables actually contribute to the temperature changes associated with global warming, and they all must be part of a thorough investigation of it.

One of these variables is **sunspot** activity. Energy from the sun produces the heating that occurs on the earth. The energy coming from the sun is not always the same. Sunspots on the surface of the sun indicate an active state (see Figure 1). When there are few or no sunspots present, the sun is in a less active state and emits less energy. The **sunspot cycle** causes increases and decreases in the radiation from the sun to the earth.



SUNSPOT [FIGURE 1]

Think About It – Your Best Guess.

How do you think sunspot activity affects the amount of solar radiation given off by the sun?

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How might an increase in radiation from the sun affect the earth's temperature?

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How might the sunspot cycle explain recent increases in global temperature?

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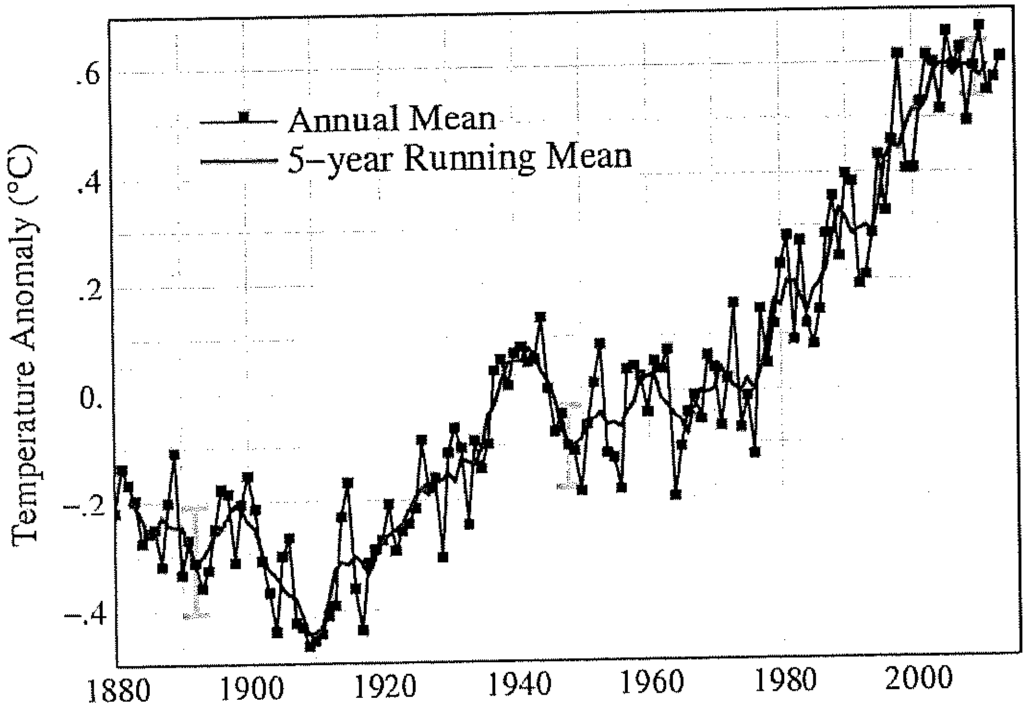

Source: ??

Figure 2 shows the deviation from the mean global temperature for the years from 1880 to 2007. When the yearly average equals the mean, that year is graphed at 0. When the yearly average is below the mean, the deviation is below 0; and when it is above the mean, the deviation is above 0. So Figure 1 shows how the earth's overall average temperature compares to each year's average temperature. Use Figure 2 to answer the following questions.

Were temperatures increasing, staying the same, or decreasing from 1880 through 1920?

____

Were temperatures increasing, staying the same, or decreasing from 1920 through 1977?

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Were temperatures increasing, staying the same, or decreasing from 1977 through 2012?

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During which time period do you see the most change occurring?

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Which five years were the warmest?

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About every 11 years, changes in the sun's magnetic field produce a **solar maximum** or "**solar max.**" A high number of sunspots creates a solar max, when activity on the sun is extraordinary. In addition to sunspots, there is an increase in solar flares, prominences, and corona mass ejections.

Sunspots are areas that are cooler than the areas around them. They occur when the magnetic field of the sun becomes very active. During a solar max, other areas become brighter, and solar storms are very common. This activity results in the sun's release of massive amounts of energy into space. The energy bombards the earth's atmosphere, resulting in many outcomes, some negative and some positive.

On the negative side, cell phone and radio reception can be interrupted; satellites can be rendered useless. Positives include the wonderful "sky shows" observed as the earth's magnetic field draws in the solar wind, producing the northern lights. The most significant effect of a solar max is the extra amount of radiant energy the sun sends to the earth.

In contrast to the solar maximum, a **solar minimum** occurs when few or no sunspots are found on the sun. During a solar minimum, the sun emits less radiant energy.

What effect do you think a solar maximum has on temperatures on earth?

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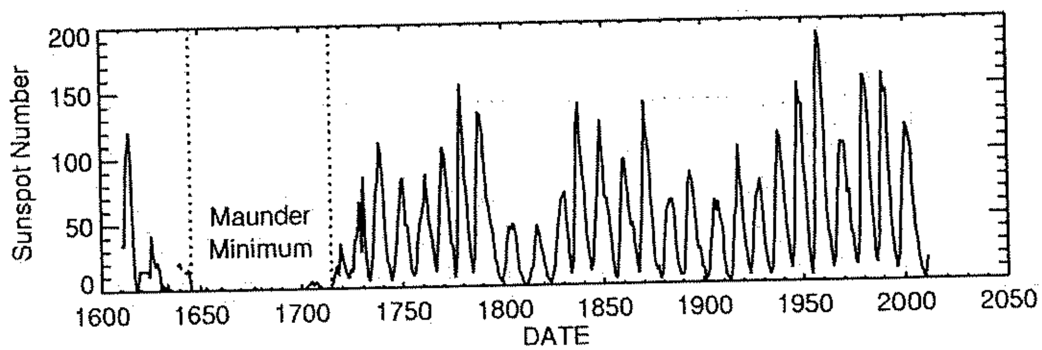
What effect do you think a solar minimum has on temperatures on earth?

____

Galileo observed sunspots in 1610 and began what would become an almost complete record of sunspot activity. It was not understood at that time that sunspot activity was related to solar maximums (high sunspot activity) and minimums (low sunspot activity).

The years between 1645 and 1715 are referred to as the Little Ice Age. The earth was unusually cold during this period. Normally ice-free rivers froze, and snow fields lasted year-round in areas where snow normally melted in the summer. The period corresponded to a time of very little sunspot activity. Figure 3 shows the yearly average number of sunspots between 1610 and 2000.

YEARLY AVERAGED SUNSPOT NUMBERS 1610-2010 [FIGURE 3]



Source: NASA

How might sunspot activity have contributed to the Little Ice Age?

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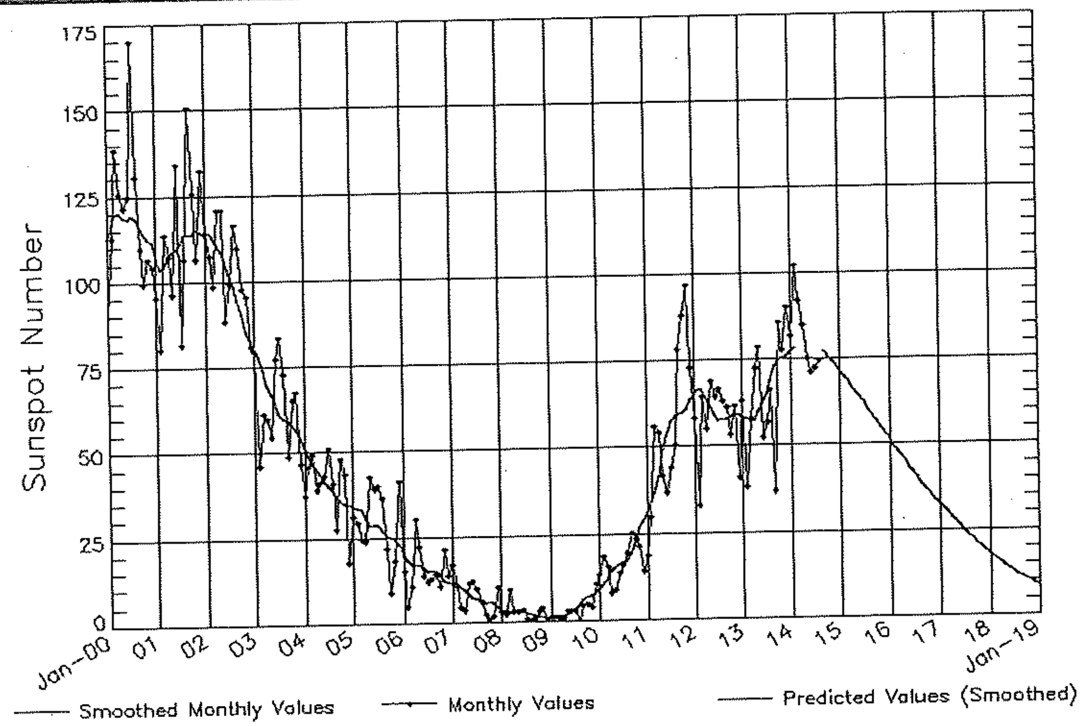
Sunspot activity from 2000 through 2014 is shown in Figure 4. The most recent cycle peaked in the summer of 2013. From March 2006 through the end of 2009, the sun went through a period of sunspot inactivity. Figure 5 shows the average global temperature from 1998 through 2010. Compare the recent sunspot activity to the global temperatures for 2000–2014 and answer the following questions.

SUNSPOT CYCLES, 2000-2014 [FIGURE 4]



Source: National Oceanic and Atmospheric Administration/Department of Commerce.

Was sunspot activity increasing or decreasing from 2000 to 2014?

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Was global temperature increasing or decreasing from 2000 to 2010?

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What should have happened to global temperatures between 2000 and 2010 as a result of sunspot activity?

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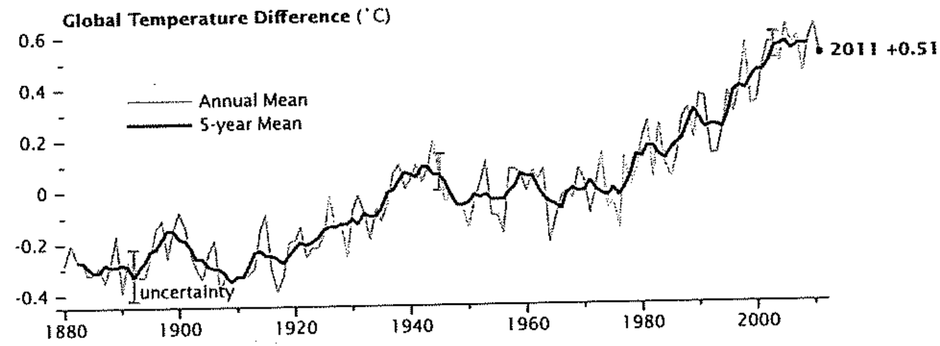
MEAN ANNUAL TEMPERATURE [FIGURE 5]



Source: NASA

The earth experienced three of the highest recorded temperatures in 2005, 2007, and 2010. What was the sunspot activity like during these years?

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Does sunspot activity explain the most recent increase in temperature? Why or why not?

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Climate and seasons on the earth are primarily a function of the amount of solar radiation that is absorbed and retained by the earth, but many other factors help to determine exactly how solar radiation affects climate. The amount of solar radiation given off by the sun will always directly affect the climate on earth. The sun's energy output is not steady, however, but changes over time within a cycle of maximum and minimum output.

A combination of factors contributes to our climate. These factors can occur as cycles or single events and complicate the study of climate change. The eruption of Mount Pinatubo, a volcano in the Philippines, in 1991 is an example of a single event. This eruption was the second largest volcanic eruption of the twentieth century. Within two hours of the major Pinatubo eruption, gases and ash reached high into the atmosphere. By the end of that year, the eruption had created a high-altitude particulate cloud that covered the whole earth. These particulates reflected sunlight into space and caused a global cooling. This cooling effect lasted through 1992 and 1993 and may have caused the drop in temperatures observed during this time period. Yet questions remain. Was the drop in temperatures in 1992 and 1993 due to the volcano, or the solar minimum, or both? An El Niño event also occurred in 1993. What effect might the El Niño event have had on global temperatures? If greenhouse gases had not been involved, would temperatures have dropped even more? If there had been no volcanic eruption, would temperatures have risen during those years? Were other factors involved?

While many factors contribute to weather and, therefore, climate, scientists studying climate change focus on factors that are consistently increasing to explain the rising average global temperature. While there are variations due to other cycles and events, greenhouse gases, especially carbon dioxide (more than 30 billion tons/year), have been steadily rising so are considered the primary reason for the increasing average global temperature.

How does sunspot activity affect the amount of solar radiation given off by the sun?

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How might increased radiation from the sun (sunspot cycle) affect the earth's temperature?

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Can the sunspot cycle alone explain recent increases in global temperature?

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What other factors could contribute to global temperatures?

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If Mount Pinatubo hadn't erupted in 1991, what might have happened to temperatures?

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What is the only persistent change that could explain the increases in temperature?

____

VOLCANOES AND GLOBAL WARMING
WORKSHEET

Volcanoes' contribution to carbon dioxide in the atmosphere is a point of controversy in the discussion of the greenhouse effect and its potential impact on global warming. In this activity, you will learn how volcanic eruptions contribute to atmospheric carbon dioxide, the greenhouse effect, and global temperatures.

Volcanoes eject many different materials into the air when they erupt, including a variety of gases such as water vapor and carbon dioxide, and ash (small particles of dust). Water vapor and carbon dioxide are considered greenhouse gases. Another important gas produced by volcanoes is sulfur dioxide, which is not a greenhouse gas but has an effect on the atmosphere.

What do you think?

Which do you think contributes more carbon dioxide per year into the atmosphere, volcanic eruptions or human activity? Support your response.

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____

Do you think volcanic eruptions cause atmospheric warming or cooling?

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Explore and Explain

Large volcanic eruptions put water vapor (H_2O), carbon dioxide (CO_2), sulfur dioxide (SO_2), and other gases and sometimes large amounts of ash into the air. Carbon dioxide and water vapor are greenhouse gases that contribute to global warming.

Water combines with other volcanic gases to form hydrochloric acid (HCl) and hydrofluoric acid (HF) that fall as acid rain. Sulfur dioxide converts to a fine mist of particulates called **aerosols.** These sulfur dioxide particulates (sulfate aerosols) migrate high into the atmosphere and reflect sunlight into space. Sulfate aerosols encourage the formation of high clouds that also reflect sunlight into space. The aerosols and clouds reduce the amount of radiation warming and cause the atmosphere to cool.

Sulfate aerosols tend to stay in the upper atmosphere for months or even years before they are brought back to earth in the form of sulfuric acid. Volcanic ash in the atmosphere blocks sunlight from reaching the surface of the earth, causing the air to cool.

Which greenhouse gases are added to the atmosphere during a volcanic eruption?

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How do sulfate aerosols affect the temperature of the atmosphere?

____

How does volcanic ash affect the temperature of the atmosphere?

____

Looking at data:

Many factors must be considered in the study of volcanic eruptions and their impact on the atmosphere. Volcanoes are not all the same.

The type of eruption depends on the circumstances that cause the volcanic activity in the first place. Volcanoes created by hotspots in the ocean are rarely explosive and do not eject much ash. Eruptions taking place at tectonic plate boundaries, however, can be highly explosive with a great deal of ash.

The types and amounts of gases ejected by each type of volcano differ, too. Table 1 shows the gases ejected by three different volcanoes in three different geographic locations.

GASES EJECTED BY THREE VOLCANOES [TABLE 1]

Volcano Tectonic Style Temperature	**Kilauea** Hotspot 1170°C	**Erta Ale** Divergent Plate 1130°C	**Momotombo** Convergent Plate 820°C	**Average** (%)
H_2O	37.1 %	77.2 %	97.1 %	
CO_2	48.9 %	11.3%	1.4%	
SO_2	11.8%	8.3%	0.5%	

Calculate the average for each gas and enter the value in column 5 of Table 1.

____

On average, which gas — H_2O, CO_2, or SO_2 — composes the highest percentage of the ejected gases in the volcanoes listed in Table 1?

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Which volcano ejected the greatest percentage of carbon dioxide?

____

Which volcano ejected the least amount of carbon dioxide?

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Why might there be so much variation in the composition of gases that come from volcanic eruptions?

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Some people argue that volcanic eruptions are a major cause of carbon dioxide levels in our atmosphere. USGS (United States Geologic Service, http://volcanoes.usgs.gov/hazards/gas/climate.php) carbon dioxide emission estimates show, however, that human activity outpaces volcanic activity. Consider that the annual average carbon dioxide emissions from human activity is about 30 billion metric tons (30,000,000,000 or 3.0×10^{10} tons). The annual average carbon dioxide emissions from volcanic activity is 145 – 225 million metric tons (average of 185,000,000 or 1.85×10^{8} tons).

How much more CO_2 do humans create than volcanoes (percent)?

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How much CO_2 do volcanoes create compared to humans (percent)?

____

Compared to human activity, how important are volcanoes in adding carbon dioxide to the atmosphere?

____

Mount Pinatubo is a volcano that lies near a divergent plate boundary in the Philippines. Mount Pinatubo violently erupted in June 1991 and is now on record as the second largest volcanic eruption of the 20th century.

The eruption had 10 times the explosive power of the 1980 eruption of Mount St. Helens in the state of Washington. Within two hours of the major Pinatubo eruption, gases and ash had reached high into the atmosphere. During the following two weeks, the sulfate aerosols created by the blast encircled the globe. At the end of a year, the entire atmosphere of earth was filled with a layer of sulfate aerosols ejected from the eruption.

The sulfur aerosols created by the Pinatubo blast reflected solar energy into space and decreased temperatures around the world in 1992 and 1993. In spite of rising amounts of greenhouse gases and the presence of an El Niño event — factors that would normally warm the atmosphere — the sulfate aerosols reduced global temperatures by about 0.4 to 0.5°C (0.7–0.9°F) globally. The United States experienced its third coldest summer in 77 years in 1992.

The 1815 eruption of the Tambora Volcano in Indonesia created an even larger global cooling effect. Global temperatures were lowered by as much as 3°C (5.4°F). 1816 was known as the year without summer in many parts of Europe and North America, and Indiana experienced snowfall in June and frost in July that year.

What is the effect on global temperatures of the sulfate aerosols formed by volcanoes?

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Using the ideas of greenhouse gases, volcanic ash, and sulfate aerosols, summarize the effect of volcanoes on global temperatures.

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4-H-1024a-W
4-H-1025a-W

GLOSSARY, LEVELS 2 & 3

Absorb: To take in all or part of a substance: The earth's surfaces absorb radiant energy.

Aerosol: Particles suspended in the air.

Air mass: A large body of air with similar temperature and moisture characteristics.

Air pressure: The force that air exerts on any surface in contact with it.

Albedo: The ratio of reflected light energy to absorbed light energy; ability to reflect sunlight.

Albedo effect: A measure of how much solar radiation is reflected.

Atmosphere: A layer of gases surrounding the earth, held in place by gravity.

Barometric pressure: Atmospheric pressure as measured by a barometer, usually in millibars or inches of mercury.

Calibrate: To check and adjust a measurement precisely against a standard measure.

Climograph: A graphic depiction of the precipitation and temperature for a certain location.

Clockwise: The rotational direction of the hands of a clock.

Cold front: A front formed by a cold air mass pushing into an area of warmer air.

Concentration: The amount of a substance in a given amount of another substance.

Condense: To convert a vapor or gas to a liquid.

Conduction: Energy transferred directly from one object to another through contact.

Contract: To become drawn together or reduced; shrink.

Contrail: Water droplets or ice crystals condensing in the supersaturated air of the upper atmosphere as a result of an aircraft's passage.

Convection: The transfer of energy through circulation within a liquid or gas.

Counterclockwise: Opposite to the rotational direction of the hands of a clock.

Deflect: To turn aside from a course.

Density: The degree of compactness of a substance; mass/unit measure ~ weight.

Dew-point temperature: The temperature to which air must be cooled to reach the point of saturation of water vapor; the temperature at which dew forms.

El Niño: A band of warm ocean water temperatures that periodically develops off the western coast of South America. It can cause climatic changes such as floods and droughts in many regions of the world, particularly along the coasts of Chile, Peru, New Zealand, and Australia.

Ellipse: A closed, symmetric curve shaped like an oval.

Equilibrium: A state of balance between opposing forces or actions.

Equinox: The time when the sun crosses over the equator, making night and day approximately equal in length all over the earth.

Evaporate: To convert a liquid to a gas or vapor.

Evapotranspiration: The combination of water being evaporated and transpired.

Fluid: A substance, gas or liquid, that is capable of flowing.

GLOSSARY, LEVELS 2 & 3

Fossil fuel: Any naturally occurring carbon or hydrocarbon fuel, such as coal, petroleum, peat, and natural gas, formed by the decomposition of prehistoric organisms.

Front: A boundary at ground level between two different air masses as one air mass moves into the area of the other.

Grassroots: Used to describe organizations that begin and operate at the local or community level.

Greenhouse gases: Gases in the earth's atmosphere that absorb and emit radiation, or heat energy, in the thermal infrared range.

Hardiness: The ability of a plant to withstand cold temperatures.

Heat index: An addition to temperature data during hot and humid weather to indicate health risks more accurately than temperature alone.

Infrared radiation: A form of longwave radiation, or heat energy, given off by warm objects.

Isobar: A line on a weather map connecting points of equal barometric pressure.

Isoline: A line on a map or chart connecting points of equal value.

Isotherm: A line on a weather map connecting points of equal temperature.

Jet stream: Fast-flowing, narrow currents of air. The main jet streams are located near the tropopause.

La Niña: A cold phase in which the sea surface temperature across the equatorial eastern central Atlantic Ocean is lower than normal by 3–5°C. La Niña often follows El Niño.

Latent heat: Heat absorbed or radiated during a phase change.

Longwave radiation: Radiant energy emitted by lower energy objects, like a warm body giving off heat.

Mammatus: An ominous-looking cloud forming at the bottom of cumulonimbus clouds, with a sagging, pouch-like appearance.

Overwinter: To survive freezing conditions, often applied to perennial plants.

Precipitation: The amount of water that falls to earth as hail, drizzle, rain, sleet, or snow.

Radiant energy: Energy emitted in waves.

Relative humidity: The ratio, given as a percentage, of the amount of water vapor in the air compared to the amount of water vapor in saturated air.

Saturation: An atmospheric condition at which the moisture level is at 100% relative humidity.

Scale: A proportion that shows the relative size between objects but that is not the same size as the original objects.

Shortwave radiation: Radiant energy emitted by high-energy sources like the sun or a light bulb, which emit light energy.

Solar maximum: A time of great solar activity identified by the occurrence of many sunspots.

Solar minimum: A time of low solar activity identified by the occurrence of few sunspots.

Solstice: Either of two times a year when the sun is at its greatest distance north or south of the equator.

Sunspot: Dark, cool patches that appear on the surface of the sun.

Sunspot cycle: An approximately 11-year cycle of the occurrence of sunspots.

GLOSSARY, LEVELS 2 & 3

Thermal: A rising warm current of air caused by uneven heating of the surface.

Tropopause: The transition between the troposphere (where temperature decreases with altitude) and the stratosphere (where temperature increases with altitude).

Troposphere: The lowest portion of the earth's atmosphere.

Vortex: A whirling mass of water or air that forms a visible column or spiral.

Water vapor: Water in the form of an invisible, colorless gas.

Weather map: A daily report of observations and probable changes in the weather.

Weather station: One of 1,500 locations where the National Oceanic and Atmospheric Administration (NOAA) collects weather data.

Weather station model: A symbolic illustration showing weather conditions at a weather station recorded using abbreviations and symbols.

Windchill: Addition to temperature data during cold and windy weather to indicate health risks more accurately than temperature alone.

Zone: An area where the average annual minimum temperature is within a set temperature range.