Radar & Weather TOGETHER

UCAR Center for Science Education
University Corporation for Atmospheric Research
UCAR Community Programs

Radar and Weather Together is a collection of educational resources that students and the general public have enjoyed while visiting the National Center for Atmospheric Research (NCAR), our Outreach Booth at festivals and conferences, or online through our educational Websites. NCAR Education and Outreach staff have developed some of these activities, while others are popular hands-on activities that have proven to be effective for public engagement in weather education here at NCAR and elsewhere.

These resources are not intended to provide a comprehensive weather curriculum, but rather to serve as an enhancement to the study of weather and its many technological tools. We hope they will be useful in both formal and informal settings, and help to expand science literacy and interest in severe weather research and science in general.

We welcome your comments, corrections, and input.

Children learn about vortices through tornado tube play at the UCAR Outreach Booth at a Colorado festival.

Questions about ***Radar and Weather Together?***
Contact Teresa Eastburn at UCAR Community Programs
UCAR Center for Science Education
(eastburn@ucar.edu)

TOGETHER

Radar & Weather

Radar and Weather Resources for Educators

Engaging Hands-on Activities for Students

National Center for Atmospheric Research
University Corporation for Atmospheric Research
UCAR Center for Science Education
Boulder, Colorado

scied.ucar.edu

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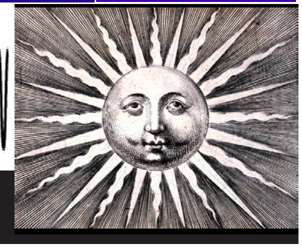
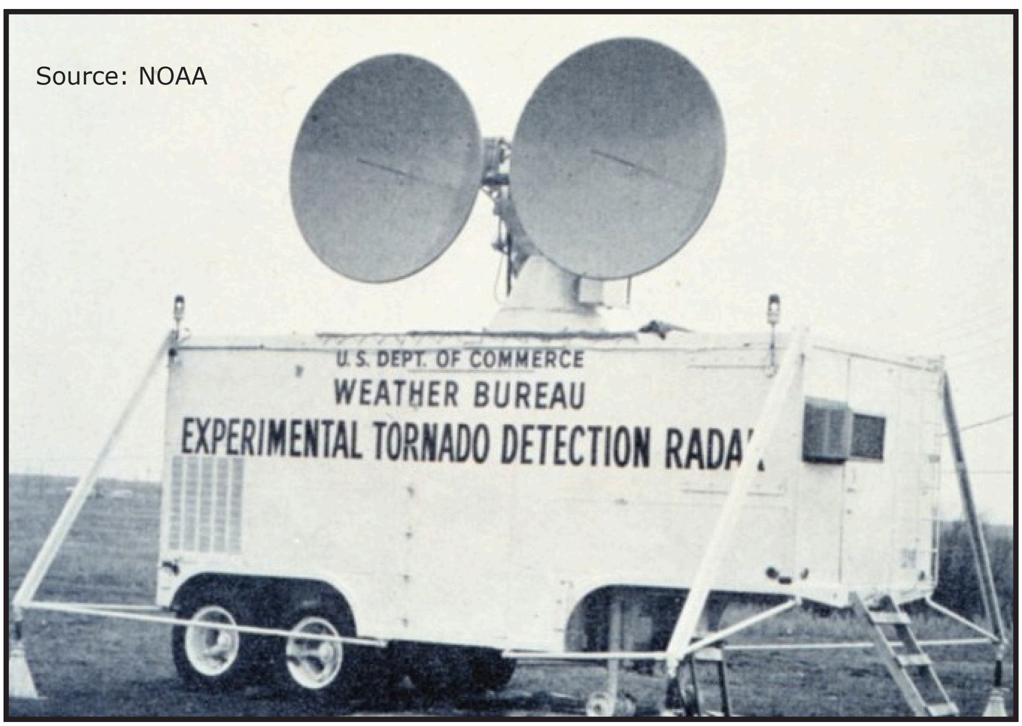


PART I: RADAR



Source: NOAA

The Weather Bureau's first experimental Doppler Radar unit, a 3-cm continuous wave Doppler unit obtained from the Navy and modified for meteorological purposes in the early 1960s.

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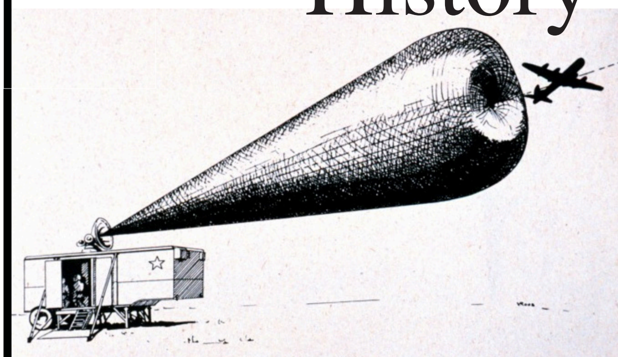
RADAR History



The invention of radar occurred over a progression of years through the efforts of various scientists. The foundation for the development of radio communication and eventually radar began with the work of German scientist **Heinrich Hertz** in 1887. Hertz demonstrated that generating an electric current moving rapidly back and forth in a conducting wire could produce electromagnetic waves. He also noted that the wave could be transmitted through different materials, and that sometimes the radio waves were reflected off a material. He developed a method of measuring the waves' speed as well. Today, wave frequency, or the number of waves per unit of time (usually one second), is measured in **Hertz** (Hz) in his honor.

Shortly after the turn of the century in 1904, with the principles of radio waves largely understood, another German scientist, **Christian Hölsmeyer,** invented the Telemobioskop or the Remote Object Viewing Device, to prevent ship collisions. Unfortunately, the technology attracted little if any customers in the years immediately preceding one of the worst seafaring disasters of all time, the sinking of the **Titanic** in 1912. The disaster prompted the invention of **Sonar**, which uses sound to '**echo locate**' objects underwater in the same way that bats use sound for aerial navigation.

A series of experiments in Germany, the United Kingdom, the United States, France, and Russia occurred in the 1920s and 1930s that continued to lay the groundwork for radar. Scottish physicist and meteorologist **Sir Watson-Watt** put the world's first operative radar detection network into place in Britain in 1937. Called the **Chain Home Network**, it is largely credited as being one of the most important factors enabling the outnumbered British Royal Air Force's success against the Germany's Luftwaff during the Battle of Britain from 1939-1941.

Britain was not alone when it came to having radar technology by the start of the war, however. Numerous countries in addition to Britain had basic operational radars including France, Germany, Hungary, Italy, Japan, the Netherlands, Russia, Switzerland and the USA. In fact, radar detected incoming enemy aircraft on the morning of December 7, 1941 at Opano Point, Hawaii. Tragically, the information fell into inexperienced hands and was not acted upon. 55 minutes later the attack on **Pearl Harbor** began, which ushered in the United States' formal entry into World War II.

Honolulu Star-Bulletin 1st EXTRA

(Associated Press by Transpacific Telephone)

WAR!

SAN FRANCISCO, Dec. 7.–President Roosevelt announced this morning that Japanese planes had attacked Manila and Pearl Harbor.

OAHU BOMBED BY JAPANESE PLANES

SIX KNOWN DEAD, 21 INJURED, AT EMERGENCY HOSPITAL

Attack Made On Island's Defense Areas

Hundreds See City Bombed

Names of Dead and Injured

Schools Closed

Editorial

UCAR

Weather Radar Takes Off


Source: NOAA

It may be self evident that the use of radar for weather forecasting has not yet been mentioned. As radar was put to use for the war effort in the late 1930s, no one imagined that the technology was sensitive enough to detect weather phenomena. When it became evident that it could detect weather, the technology was reserved strictly for the military weather services since a high security classification was placed on all things radar for obvious reasons. These wartime successes set the stage for postwar use of radar in meteorology and the accompanying growth of this new technology.

After the War, the cost and complexity of radar systems ensured that only government agencies, mainly the military and civil weather services, had access to them. The **CPS-9 Storm Detection Radar** was the first radar designed, developed, and deployed in the mid 1940s specifically for meteorologists. Expansion of the Weather Bureau's radar system grew in the 1950s as well. Radar use by the airline industry, weather broadcast companies, and commercial weather facilities followed shortly thereafter.

By the 1960s, the radar systems' electronics were lighter in weight, due mostly to advances that came about through the advent of solid state components in the US space program. These lighter systems ushered in radar's use on aircraft for storm avoidance and on-the-ground use as well. The most popular radar system used by the Weather Bureau in the 1960s was the **WSR-57,** which advanced radar's ability to detect storms behind rainfall and to observe hurricanes at great distances. The last WSR-57 was retired in 1996.

By the 1970s, television stations began installing radars for use in their weather broadcasts as ground-based weather radar continued to advance and became more affordable. The most common radar at this time was the **WSR-74C** – a new generation weather radar for local warnings that operated in the C band of the electromagnetic spectrum where wavelengths occur in microwave frequencies. Demand for radar information and more sophisticated radar reports grew dramatically at this time, and continue to grow today.

The 1980s and 1990s saw the development of two Doppler radars: the **NEXt-Generation Weather RADar** (NEXRAD) now called **WSR-88D** (for **W**eather **S**urvelliance **R**adar 19**88** **D**oppler), and Terminal Doppler Weather Radar, which are located near airports tohelp detect a kind of wind shear called microbursts that are especially dangerous as planes land or take off. While all weather radars send out radio waves from an antenna that scatter or reflect when they encounter objects in the air such as rain, snow, hail, dust and more, the advantage of Doppler radars is that they can illustrate wind direction and speed around these objects by measuring the frequency change in returning radio waves. Waves reflected by something moving away from the antenna have a lower frequency, while waves from an object moving toward the antenna change to a higher frequency.

Computers that are part of the Doppler system next produce images illustrating these wind motions. Today we even have **Doppler on Wheels** or DOWs, which allow transport of these invaluable radars to areas where severe storms are threatening or where weather research is needed. The NEXRAD system includes 154 Doppler radars across the country.

Source: UCAR, NCAR

While our focus has been on radar technology on land for weather forecasting purposes, it is important to note that radar can also be used on aircraft. ELDORA (ELectra DOppler RAdar) is an airborne, dual beam, meteorological research radar developed jointly at the National Center for Atmospheric Research (NCAR) and the Centre de Recherches en Physique de L'Environnement Terrestre et Planetaire (CRPE) in France. It was first deployed in 1993 during a science field campaign called TOGA COARE in the Solomon Islands.

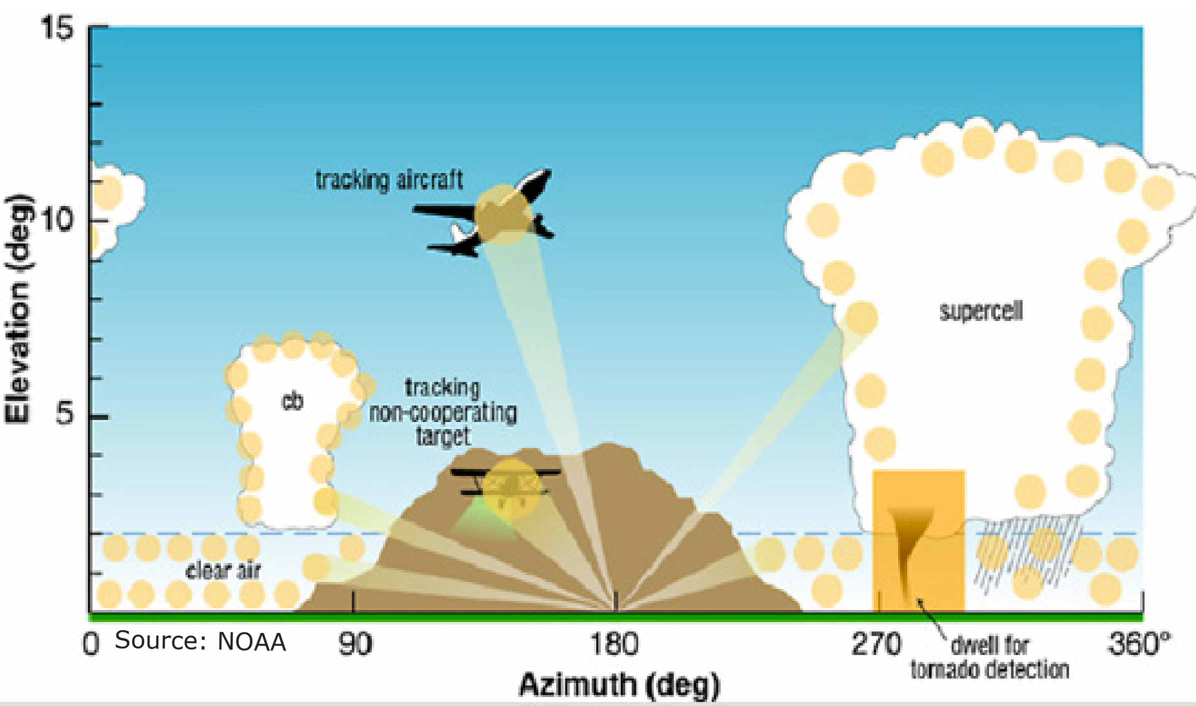
Also, radars can be found on spacecraft. NASA's and Japan's Tropical Rainfall Measurement Mission (TRMM) satellite carries a Precipition Radar that helps scientists better understand how rainfall happens and why so they can improve future forecasts.

Future Radar Advances

Phased array radar is a technology that has been used soley by the military since the mid-1970s to protect naval battle ships from missile threats. In 2003, it was released to weather researchers at the National Severe Storms Lab in Oklahoma. This technology, formerly called Spy-1, may help forecasters of the future provide earlier warnings for tornadoes and other types of severe and hazardous weather. For example, what today would give a 10-minute warning is expected to improve to a 20-minute warning.

While today's WSR-88D radars can transmit one beam of energy at a time and listen for the returned energy, phased arrays work by sending out multiple beams at one time so the antennas never need to tilt. Scanning takes only 30 seconds, whereas WSR-88D takes about 7 minutes to fully scan the atmosphere.

While phased array radar technology is promising, the next significant technology advancement to our nation's weather radar system will be a dual polarization radar network to be deployed in 2011.



Source: NOAA

PAR's rapid scanning ability gives it the ability to look at more than one mission: weather, wind profiling, and aircraft tracking, and to focus its scans at the most important features.

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Did You Know...?

Sound Navigation and Ranging, or Sonar, evolved in bats millions of years ago and is the oldest known precursor to modern radar. They use sound waves instead of electromagnetic waves, but the principle is the same. Believe it or not, bats can create a sound from their nose. Yes, their nose! They have a set of two antennae near their ears that receive the sound echo when it reflects off of objects. This helps bats see their prey and other objects in the dark. Contrary to popular belief, bats do have eyes, but since they are nocturnal and live in dark caves and other dark places, sight is not enough.

A tiger moth's ears can detect and jam the ultrasonic signal of a bat, which is a particularly useful skill when you are considered bat food. The tiger moth's ability to jam a bat's ultrasonic signal developed millions of years ago as a way to help them survive.

Source: NOAA NSSL

Wind Profiler

Wind profiling radars have been in use since the 1970s. Most are stationary, permanent structures, however, there are portable wind profilers as well today (left) that use radar to look vertically at the atmosphere to determine wind speed and direction, as well as precipitation.

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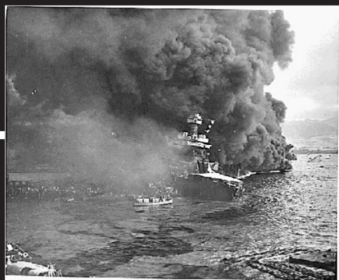
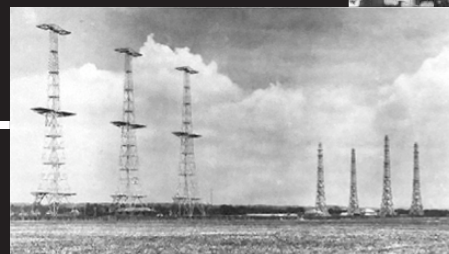
A Timeline of Radar History

18

Sir Watson-Watt put the world's first operative radar detection network [called the Chain Home Network] into place in Britain in 1937.





19

Radar detected incoming enemy aircraft on the morning of December 7, 1941 at Opano Point, Hawaii before the Pearl Harbor attack that led the US into WWII.

WWII 1940s

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1980s

The 1980s and 1990s saw the development of two Doppler radars: the Next-Generation Weather Radar (NEXRAD) now called WSR-88D, and Terminal Doppler Weather Radar for aviation. Doppler radar allowed forecasting of the speed and direction of weather events along with precipitation.

1970s

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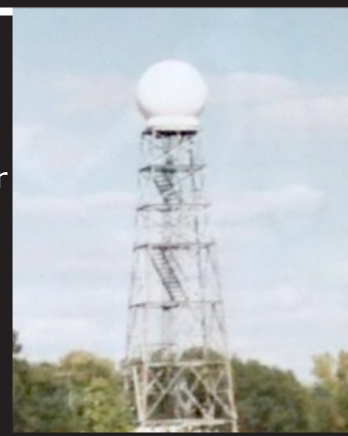

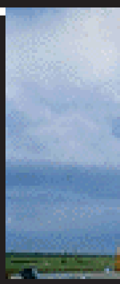

2000s

Phased-Array Radars (PAR) exist today as do Precipitation Radar (PR) on satellites such as TRMM. ***What will replace the NWS NEXRAD Network? Deployment of dual polarization radar begins 2011!***

The S-Pol radar was developed at NCAR to replace the CP-2 radar which served the research community for nearly twenty years. The purpose of S-Pol is to provide a cost effective state-of-the-art polarimetric weather radar for world wide deployment. Polarimetric radars send pulses horizonatally and vertically which improves weather forecasts.

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1900s

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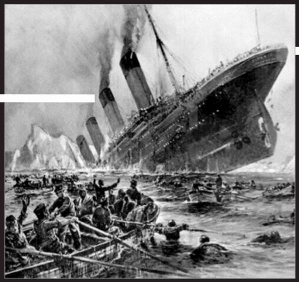
930s



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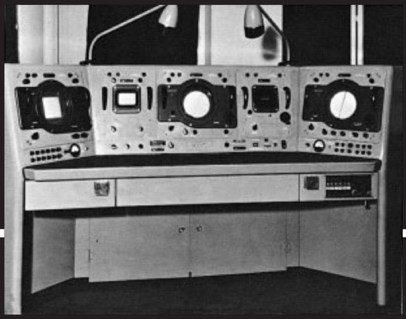

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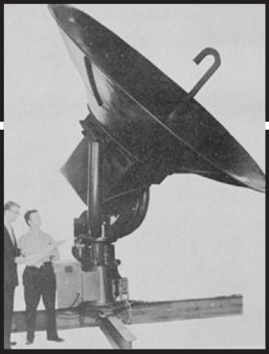
1960s



Radar use by the air-line industry, weather broadcast companies, and commercial weather facilities followed shortly thereafter.

In the 1960s, the WSR-57 advanced radar's ability to detect storms behind intervening rainfall and to observe hurricanes at great distances.

NCAR's CP-2 Radar served weather resarchers from the 1970s into the 1990s.

1990s

ELDORA (ELectra DOppler RAdar) is an air-borne, dual beam, meteorological research radar developed jointly at the National Center for Atmospheric Research (NCAR), USA and the Centre de Recherches en Physique de L'Environnement Terrestre et Planetaire (CRPE), France. ELDORA's first deployment was to TOGA COARE in the Solomon Islands in January and February 1993.

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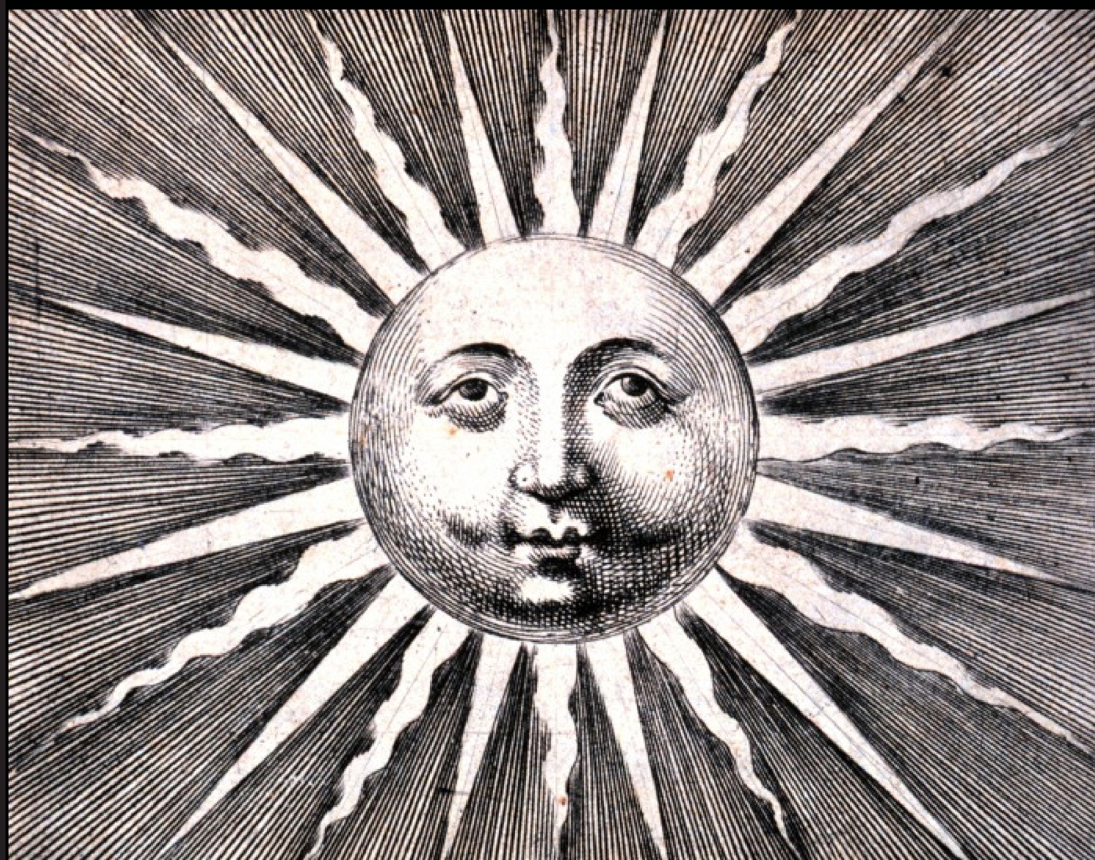
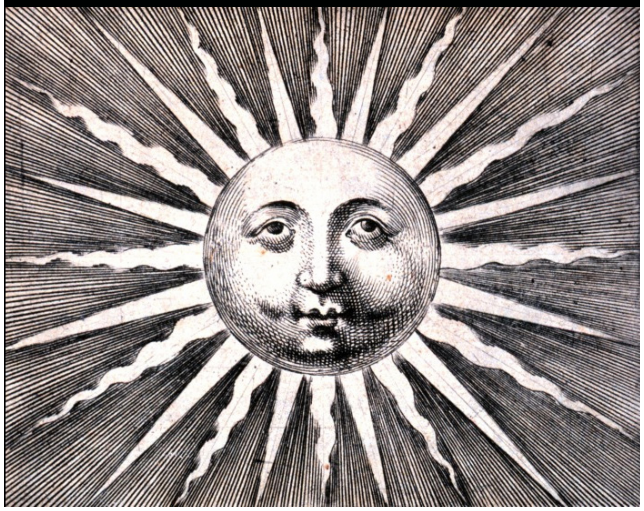
Light



Light



Since the time of the Greek philosophers in the 5th century BC, mankind has speculated about the nature of light. Today, physicists have learned through experimentation that light has a dual nature and behaves as a particle at times and as a wave at other times. We also know that energy from the Sun, some arriving as visible light, is the primary source of all energy on Earth.

Light particles are called photons and are different from particles of matter because they have no mass and always move at a constant speed of nearly 299,792 kilometers per second, or 186,281 miles per second through empty space. This makes light the fastest phenomenon known in the universe. Yet light is also a form of radiant energy, or energy that travels in waves, which only slows down when inside substances such as air, water, glass or diamond.

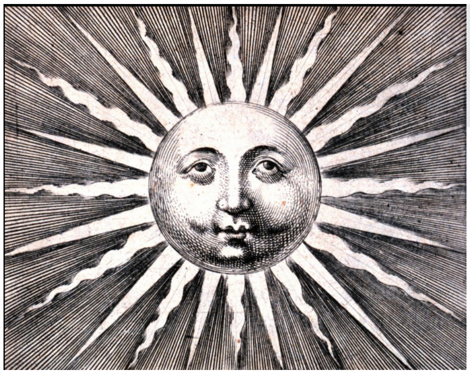
Ligth waves come in many sizes, or wavelengths, which are measured from crest to crest (highest point of the wave) or trough to trough (lowest point) measured in meters (m) to nanometers (nm, 10^{-9} meters). Light waves also come in various frequencies, which refers to the number of waves that pass a point per unit of time, usually in one second. These light wave frequencies are measured in Hertz (Hz) with the amount of energy in a light wave being directly proportional to its frequency. This means that high frequency light corresponds to high energy output and low frequency light corresponds to low energy output. The wavelength, however, is inversely related to the frequency and energy. Energy from the Sun with the shortest wavelengths (gamma rays) have the greatest frequency and thus, greatest amount of energy.

When we talk about light, we usually are referring to the range of frequencies that the human eye can see, approximately one-half to three-quarters of a million billion (5×10^{14} to 7.5×10^{14}) Hertz, and with wavelengths ranging from 400 to 700 nanometers. Although this light appears white in color, it is actually composed of various combinations of red, green and blue (RGB). Unlike the primary colors of pigment (red, blue and yellow), RGB refers to the primary colors of light because none of these three colors can be created from the other two, and all other colors can be formed by combining the primary colors in various proportions. Each color found in the visible spectrum of light (red, orange, yellow, green, blue, indigo and violet) corresponds to a particular wavelength, with violet having the shortest wavelength and greatest frequency and red, the longest wavelength and lowest frequency.

The Sun produces energy at higher and lower frequencies and smaller and larger wavelengths that we cannot see. The entire range of energy from the Sun is referred to as the Electromagnetic Spectrum. Gamma rays, x-rays and ultra-violet rays are produced at wavelengths with smaller frequencies per unit of time.

To fully understand the nature of light and how it is created, it is necessary to understand matter at its atomic level. It is the motion of electrons within atoms -- the building blocks of matter -- that leads to the emission of light in most sources. Electrons circle atoms in specific patterns called orbitals, each containing a finite amount of energy. The closer the electron's orbit is to the nucleus of the atom, the less energy it possesses. If an electron in such a low energy level gains energy, it must jump to a higher level of orbit, and the atom is said to be excited. This jump causes the electron to lose energy and subsequently fall back to a lower level of orbit. The energy the electron releases as a result of this change in orbitals is equal to the difference between the higher and lower energy levels, and can result in the emission of a quantum of energy in the form of a photon.

Waves of Energy More or Less



Student Learning Objectives
- Students will be able to explain that energy travels from the Sun to the Earth by means of electro-magnetic waves.
- Students will understand that the shorter the wavelength and the higer the frequency of the wave, then the greater the energy emitted.
- Students will be able to demon-strate how wavelength is measured.

Grade Level: 6th to 9th

Time - 45 minutes
- 10 minutes for background discussion
- 10 minutes for demonstration
- 10 minutes for manual wave making by students
- 15 minutes for post-demo discussion

Materials
- 12 to 15 feet of 1/8” nylon cord
- 1 foot of 1/8” nylon cord
- electric drill and chuck key
- 1 20-penny bent nail
- #2 barrel swivels (found in fishing section of sporting goods)
- toy Slinkies (optional)

National Standards
- A: Science as Inquiry
- B: Physical Science

Students create and observe wavelengths at various energy outputs.

Related Web Pages for Students
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn/1.htm

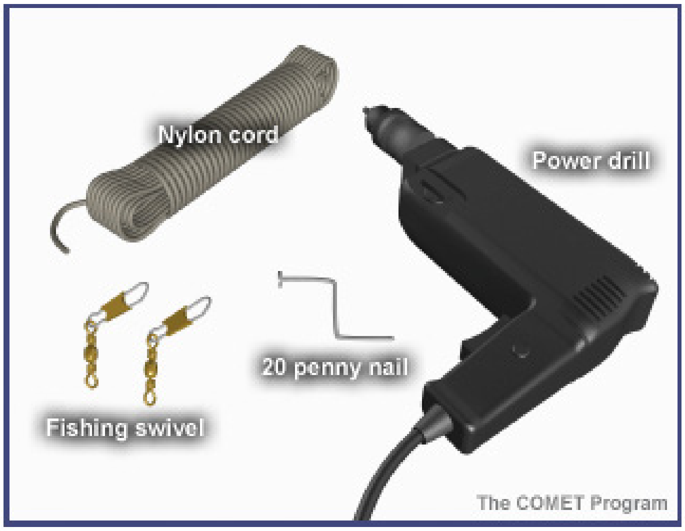
Directions
1. Before presenting this demonstration, provide some background information on the electromagnetic spectrum.
2. Prior to the demonstration, you will need to bend a 20-penny nail as shown. You will have to use a vise to accomplish this.
3. Attach a swivel to each end of the nylon cord.
4. Tie the 1-foot piece of cord to one of the swivel holders. This is the piece of cord that a student will hold during the demonstration.
5. Slide the bent nail through the eye of the other swivel.
6. The nail end should be put into the drill bit fitting and tightened securely with the chuck key.
7. To ensure the safety of your students, it is imperative that the cord not break during the demonstration. Be sure to test it before you present it to your students. Also ensure that students helping with the demonstration are wearing safety glasses.
8. Ask a student to hold one end of the cord.
9. Plug in the drill and the demonstration begins. The less tension you apply, the more waves will appear. You can also vary the speed and reverse the direction of the drill to get different wave effects. Experiment and have fun!

Note: If you do not want the complication of using a drill, you can simply have students generate the wave using a length of rope or have class groups use a Slinky to demonstrate frequency and wavelengths.

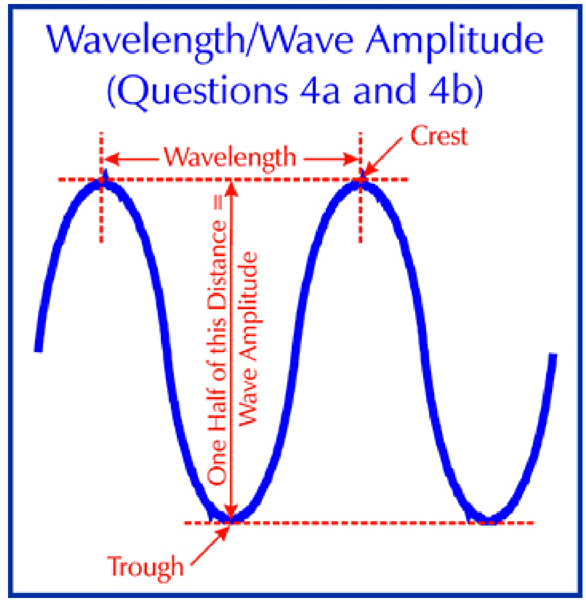
Ask yourself the following questions:

1. What happens to the length of the wave when the drill speeds up, i.e., when more energy is added? (The wavelength shortens.)
2. What occurs to the wavelength when the drill is slowed? (Wavelength increases.)
2. UV radiation is a relatively short wavelength. It is shorter than visible light. What is the energy of UV radiation relative to visible light? (It has higher energy.)
3. What about infrared radiation? How does it compare to visible light? (It has a longer wavelength and has less energy.)
4. What type of electromagnetic energy has the shortest wavelength and what does that signify? (Gamma rays have even shorter wave lengths, and thus have higher energy, which can be damaging to lifeforms on earth.)

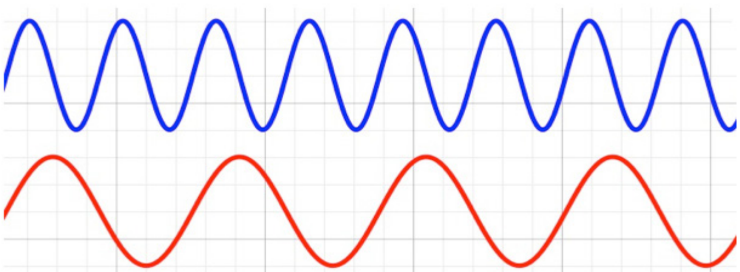
Assessment Idea: Ask students to model various wavelengths of energy using a string or rope.Ask them to explain which waves represent long wavelengths; which ones represent short wavelengths of energy? Which of these has more energy and what type of energy might it represent? Gamma rays? Infrared radiation? Visible light? How are they different and how are they similar? Model energy with a high frequency, then a smaller frequency. Which has more energy?



At left, materials needed to create the activity, *Waves of Energy More or Less.*



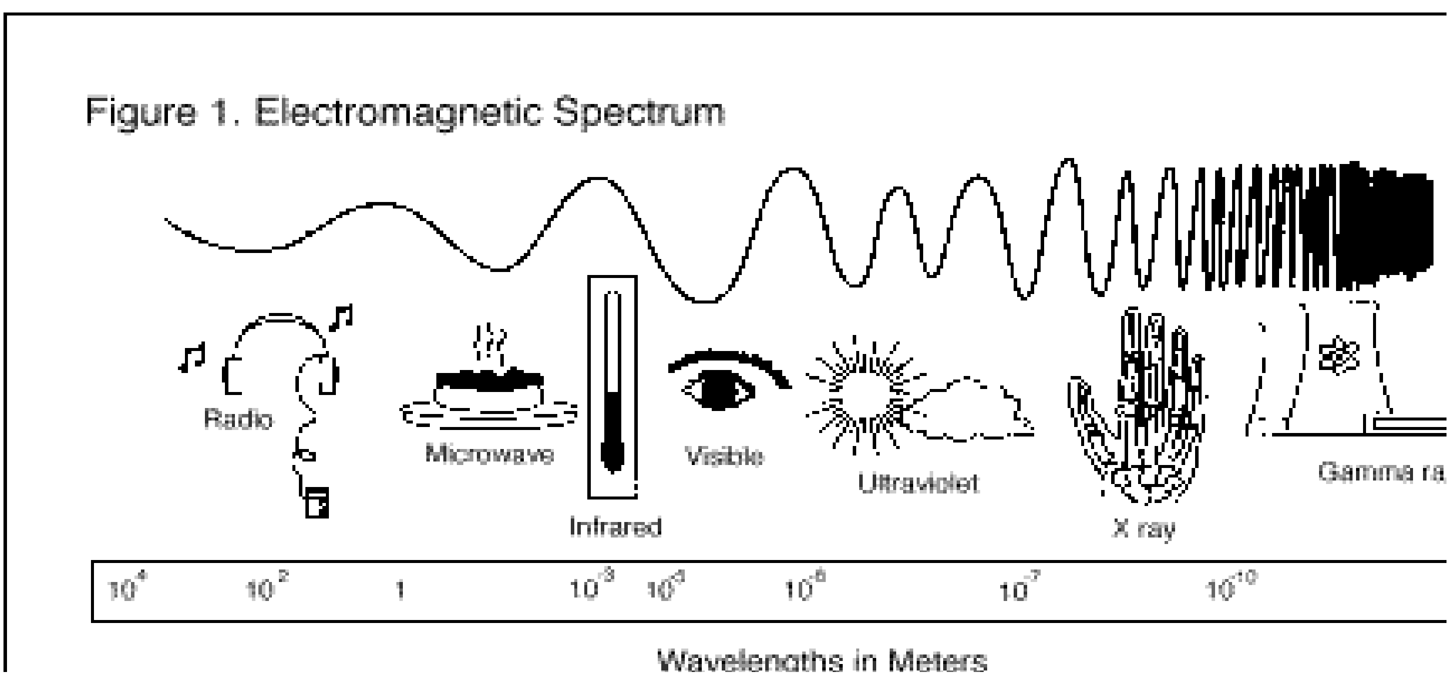
Below: High frequency wave in blue.

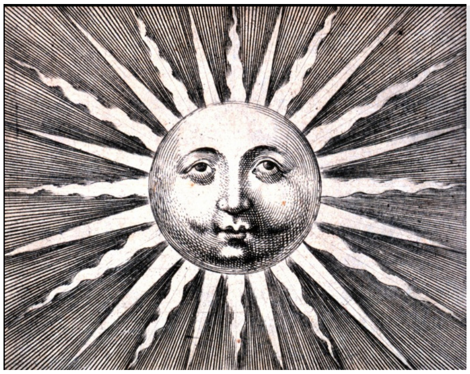


Above: Lower frequency wave in red.

Frequency, as illustrated above, refers to how many waves are made per time interval. This is usually described as how many waves are made per second.

Below, a basic graph of the electromagnetic spectrum, illustrating various frequencies and wavelengths of differing types of energy from large wavelength radio waves to shorter wavelength gamma rays.





Photon Folks

Students observe that light interacts differently with objects depending on some properties that we can observe (e.g. transparency) and others we cannot (vibrational frequency).

Student Learning Objectives
- Students will understand that visible light from the sun is reflected, absorbed, and/or transmitted through certain objects on Earth.

Time
- 5 minutes for activity
- 15 minutes or more for discussion

Materials
For each pair of students:
- One solid color beach ball, preferably in blue, green, or red -- the primary colors of light

National Standards
- B: Physical Science

Term to Know and Understand

Frequency: The number of waves that pass a point in a given unit of time. Each color of visible light has its own frequency and wavelength.

> **Did you know** that the colors of an object are those it reflects, not those it absorbs. The frequency of light that an object absorbs (perhaps red or blue light) will not be seen. Only colors that are reflected reach our eyes.

Related Web Pages for Students
- http://www.windows.ucar.edu/tour/link=/ cool_stuff/Exploratour_1h.html
- http://www.physicsclassroom.com

Directions
1. Tell each pair of students that their beach ball represents a photon or particle of light that is traveling in wave motion toward Earth. Each photon is traveling at a single frequency (wavelength). When it enters Earth's atmosphere, it will do one of three things:

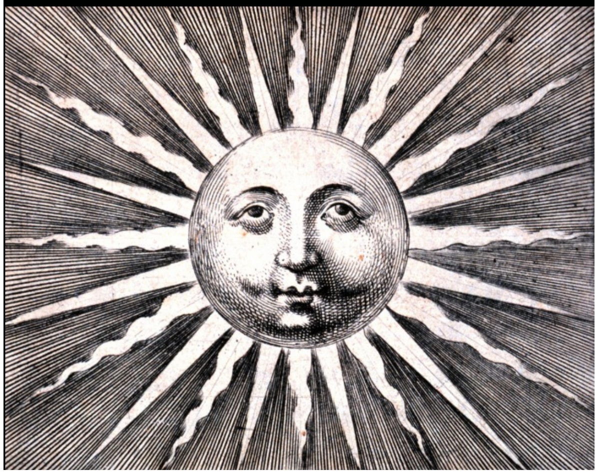
   a. Have one student throw the "photon" to his/her partner. The partner catching the photon represents light absorption.
   b. Have the partner with the "photon" roll it between his/her partner's legs. This represents light passing through an object, such as a glass window, which is called transmission.
   c. Finally, ask the partner with the "photon" to throw it against the wall. This represents light reflecting off an object, much like the light you observe every time you see your reflection in a mirror.

Ask your students the following questions:
1. What happens to light after it is absorbed by a substance? (It is converted into heat energy and often raises the temperature of the object.)
2. Once light reflects off of one object, can it reflect off of another, and/or be absorbed or transmitted through another object? (Reflected light can be absorbed, reflected, or transmitted through the next object it encounters).
3. What can light pass through and what can't it pass through?
4. What typically reflects sunlight? Does color play a part in reflection? What about the smoothness or roughness of a surface?

Background Information
Since the time of the Greek philosophers in the 5th century BC, mankind has speculated about the nature of light. Today, physicists have learned through experimentation that light has a dual nature and behaves as a particle at times and as a wave at other times. Light particles are called photons and are different from particles of matter because they have no mass and always move at a constant speed of nearly 299,792 kilometers per second, or 186,281 miles per second through empty space. This makes light the fastest phenomenon known in the universe. Yet light is also a form of radiant energy, or energy that travels in waves, which only slows down when inside substances such as air, water, glass or diamond.

In this activity, our photon was traveling in a single frequency or wavelength. Most often, however, light of many frequencies or even all frequencies travels toward the surface of objects. When this occurs, objects have a tendency to selectively absorb, reflect or transmit certain frequencies from the light. For example, one object might reflect red light while absorbing all other frequencies (colors) of visible light. The manner in which visible light interacts with an object is dependent upon the frequency of the light and the nature of the atoms of the object. The electrons of atoms have a natural frequency at which they tend to vibrate. If a light wave of a given frequency strikes a material with electrons having the same vibrational frequencies, then those electrons will absorb the energy of the light wave. Otherwise, they will reflect or transmit it.

Light



Light Terms to Know and Understand

Angle of incidence: The angle between a wave striking a barrier and the line perpendicular to the surface.

Angle of Reflection: The angle between a reflected wave and the barrier from which it is reflected.

Convection: The process that transmits heat by transporting groups of molecules from place to place within a substance. Convection occurs in fluids such as water and air, which move freely.

Diffraction: The bending of light around an edge or through a slit.

Dispersion: Dispersion is the change of index of refraction with wavelength. Generally the index decreases as wavelength increases, blue light traveling more slowly in the material than red light. Dispersion is the phenomenon which gives you the separation of colors in a prism.

Electromagnetic Wave: A wave that does not have to travel through matter in order to transfer energy. Electromagnetic Spectrum: Transverse radiant energy waves, ranging from low frequency to very high frequency,which can travel at the speed of light.

Frequency: The number of waves that pass a point in a given unit of time.

Index of Refraction: The amount that light is refracted when it enters a substance; given as the ratio of speed of light in a vacuum to its speed in a given substance.

Infrared Radiation: Invisible radiation with a longer wavelength than red light and next to red light in the electromagnetic spectrum; heat.

Interference: The addition by crossing wave patterns of a loss of energy in certain areas and reinforcement of energy in other areas.

Laser (light amplification by stimulated emission of radiation): A device that produces a highly concentrated, powerful beam of light, which is all one frequency or color, and travels only in one direction.

Law of Reflection: Angle of incidence equals the angle of reflection.

Polarized Light: Light in which all waves are vibrating in a single plane.

Reflection: The light or image you see when light bounces off a surface; bouncing a wave or ray off a surface.

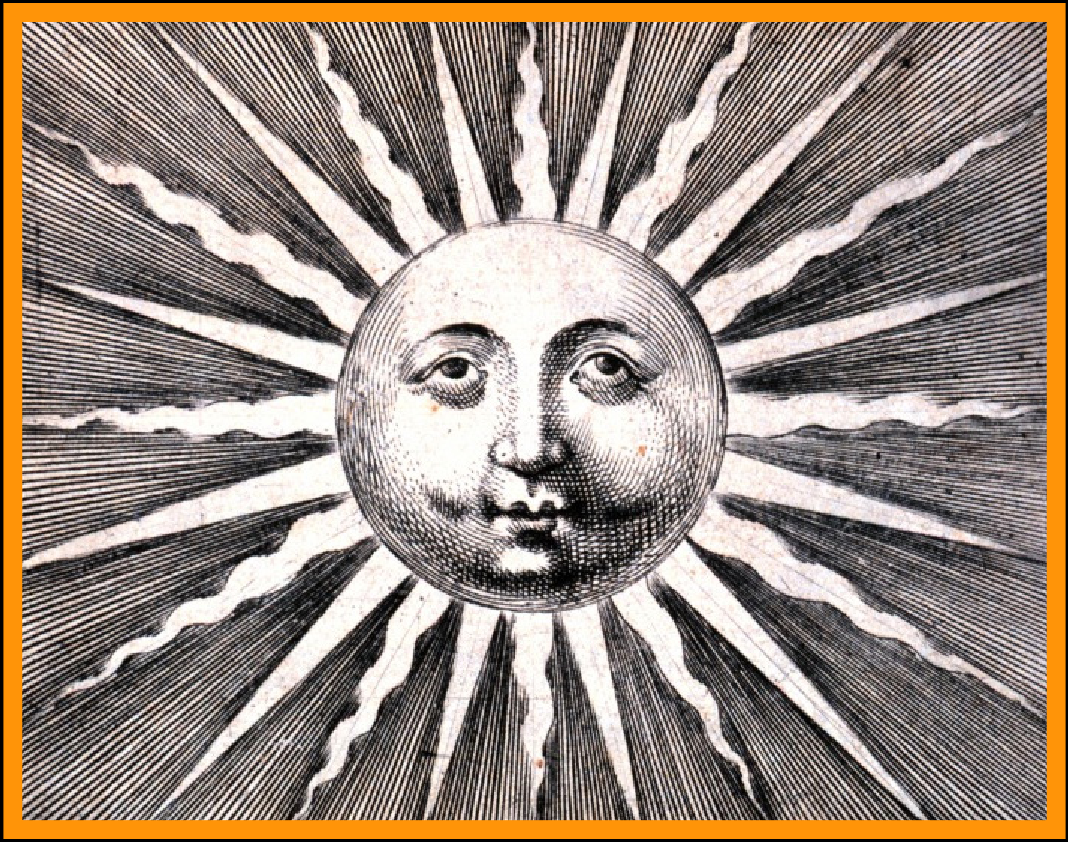
Refraction: Bending of a wave or light ray caused by a change in speed as it passes at an angle from one substance into another.

Scattering: The spreading out of light by intersecting objects, whose size is near the wavelength.

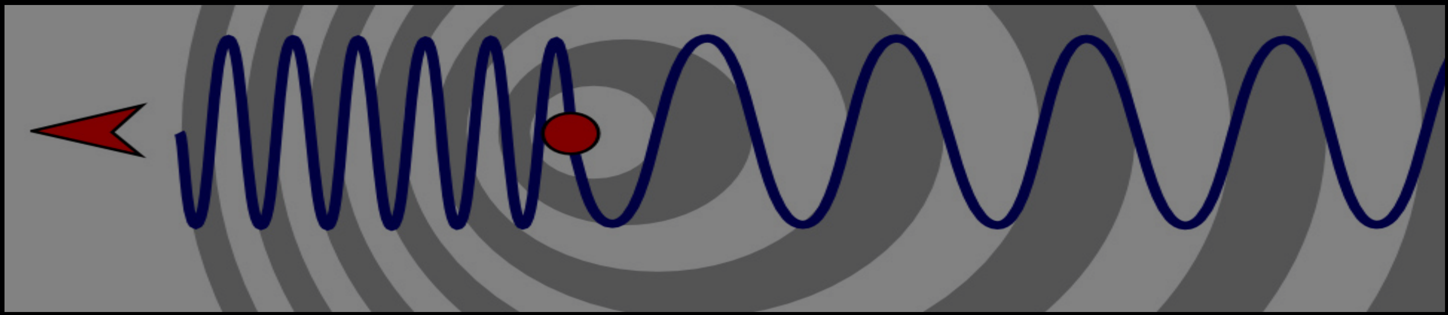
Visible Light Spectrum: Band of visible colors produced by a prism when white light is passed through it.

Ultraviolet Radiation: Radiation that has a shorter wavelength than visible light; next to violet light in theelectromagnetic spectrum.

Wavelength: The total linear length of one wave crest and trough.



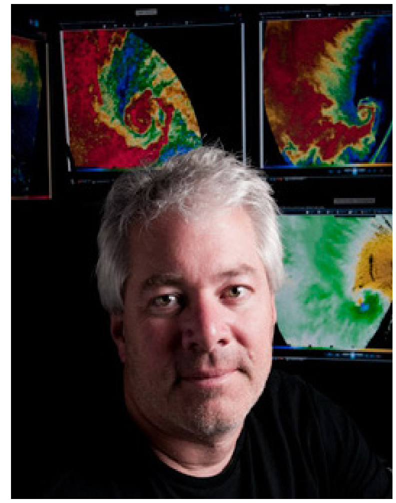
Radar and the Doppler Effect --



It's All About Reflectivity!

Vortex2, Radar, and Doppler on Wheels

In spring 2009 and 2010 close to 150 scientists and 40 science and support vehicles headed out into the field on the most ambitious effort ever made to understand tornadoes. Called Verification of the Origin of Rotation in Tornadoes Experiment, or VORTEX2, the field campaign aimed to record, for the first time, the entire life cycle of a tornado. Among the 40 science and support vehicles were numerous enhanced mobile radars.



Meteorologist Josh Wurman spends many days on the road in a DOW researching severe weather events.

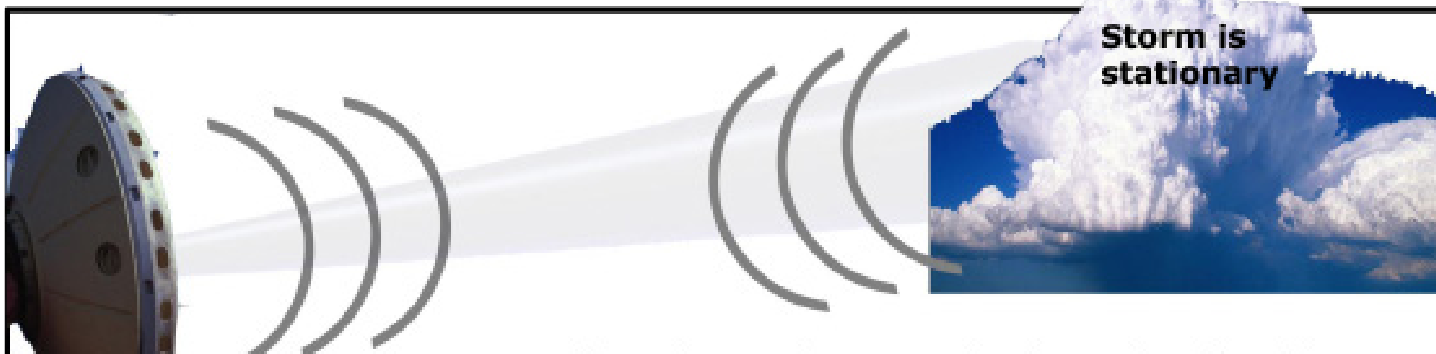
Each radar is mounted behind a mini-processing room within the vehicle. With many of these mobile radars, there is a weather station that can verify conditions at the radar site. Mounted on a hydraulic pole between the antenna pedestal and the truck's cab, the station can be lofted 17 meters above ground level and stay rigid in very high winds. Inside, the scientists have a variety of computer equipment for analyzing radar data and weather information in real time, and other communication equipment that keeps them in touch with other vehicles traveling with them. There are about 10-15 computers on board the mobil radar vehicles with a generator that keeps them and the added electrical equipment running.

Many of the radars are dual Doppler radars which provide two-dimensional wind analysis. These units are called Doppler on Wheels or DOWs. Doppler radars became popular for weather forecasting and research in the 1980s and 1990s. In fact, the National Weather Service maintains the WSR-88D comprehensive network of stationary Doppler radars for weather forecasting purposes. Most DOWs and other mobile units for research are funded through the National Science Foundation. Doppler radars, both mobile and stationary, advanced radar technology by using the frequency of energy waves to determine if a storm is moving toward or away from the radar, allowing a storm's velocity and direction to be determined. (See Doppler Effect explanation that follows). Traditional radar, on the other hand, only looks at the reflectivity or the pulses sent out, often called echoes.

The DOW also allows researchers to get up close to a storm and collect more detailed information. A normal weather radar is usually so far away from an object that it collects a fairly blurry image. Just like with our eyes, you've got to get up close to something to make out the fine details. DOWs are able to get closer to storms than one might consider safe because they weight approximately 25,000 pounds and include heavy steel roll bar cages. To protect the equipment from possible lightning strikes, they are kept inside specially designed metal cages. In fact, the biggest danger scientists onboard face is when they leave the vehicle!

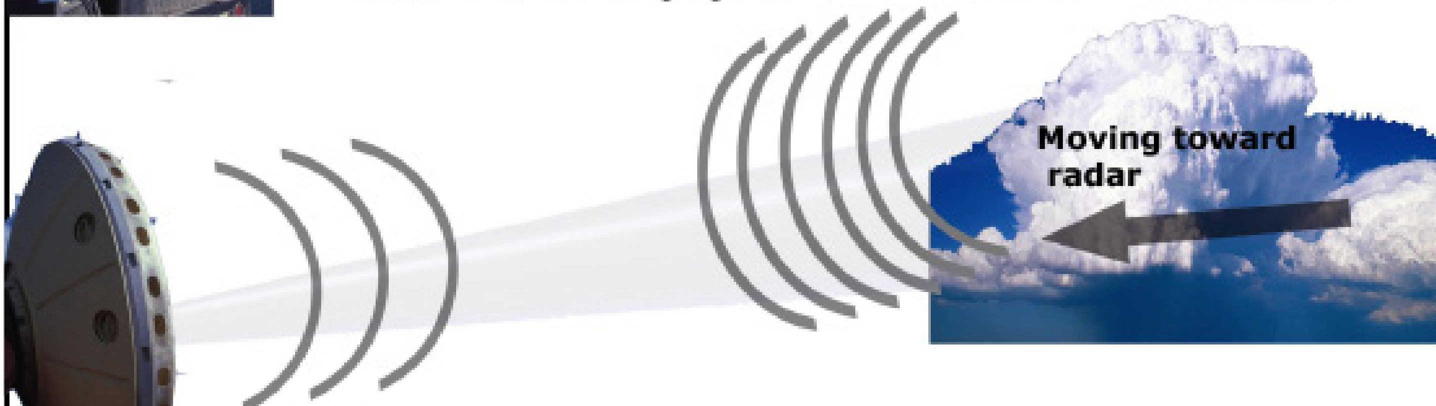
On a typical day, the DOW will collect about 10 gigabytes of data or as much as 100 gigabytes. And they're not just collecting information on thunderstorms. Hurricanes are another severe weather event that the DOW likes to visit. Josh Wurman, DOW meteorologist and president of the Center for Severe Weather Research in Boulder, CO, notes that there is much still to uncover about hurricane winds at their lowest levels. And unlike aircraft radars, the DOW can stay put and collect sustained data over the duration of a storm.

When asked what the "Holy Grail" is that he'd like to uncover using the DOW, Wurman returns to tornado genesis. What conditions within a supercell produce tornadoes and which don't? Says Wurman, "We hope that by surrounding these supercells with multiple radars and in-situ instruments and cars with instruments, we can learn enough about the interaction between and among all the weather variables to know which conditions are likely to make strong tornadoes as compared to the majority of environments which result in no tornado at all."



When a storm is stationary, the transmitted wavelength and its reflected wavelength or "echo" will not change, as shown above. The frequency of the wavelength also does not change.

How Doppler Radar works



When a storm is moving toward the radar,, the transmitted wavelength frequency will be less than the reflected wavelength's frequency as shown above.

when storms are still,

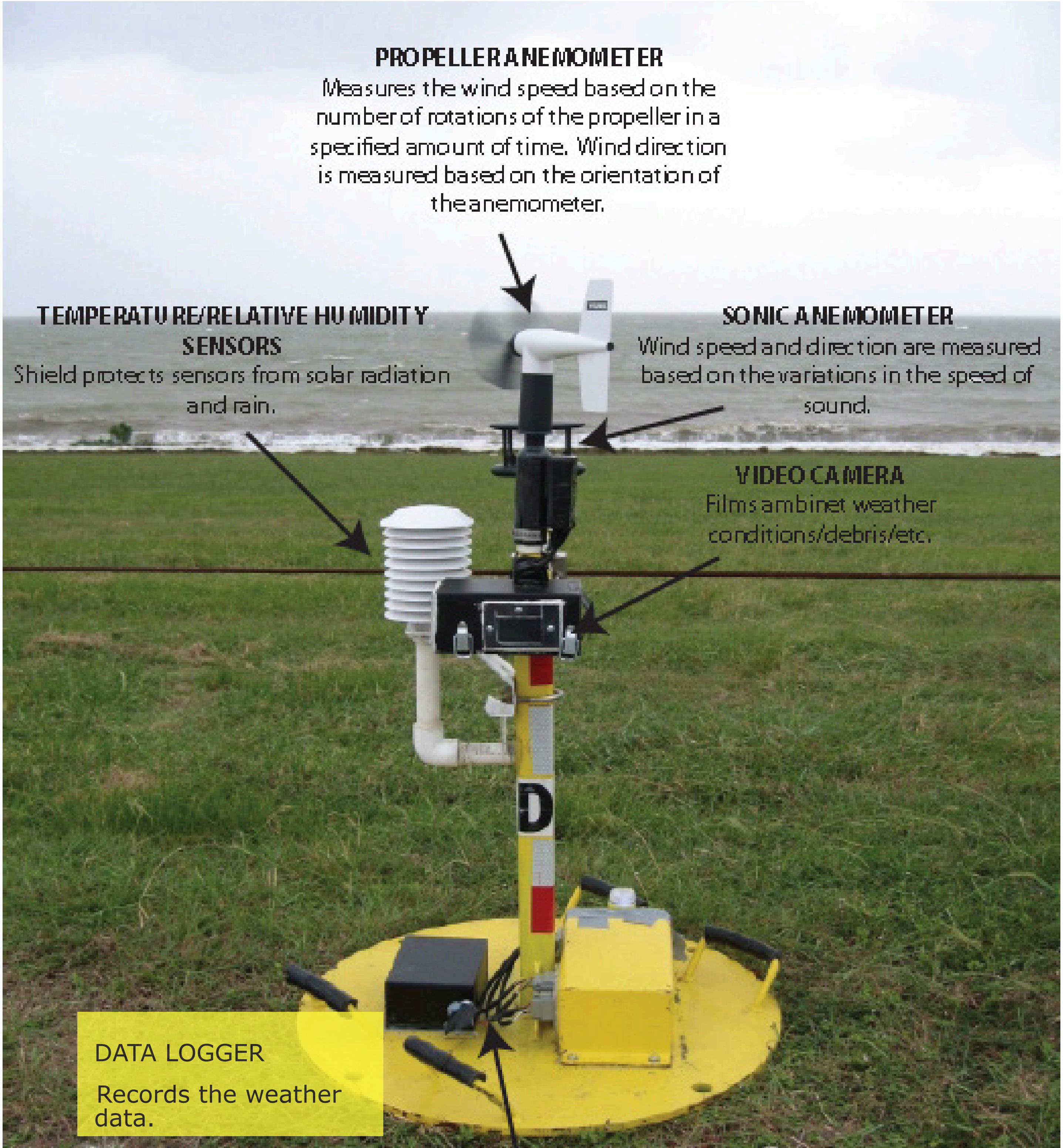
advancing,

Lastly, when a storm is moving away from the radar, the transmitted wavelength's frequency will be greather than the reflected wavelength's frequency as shown above.

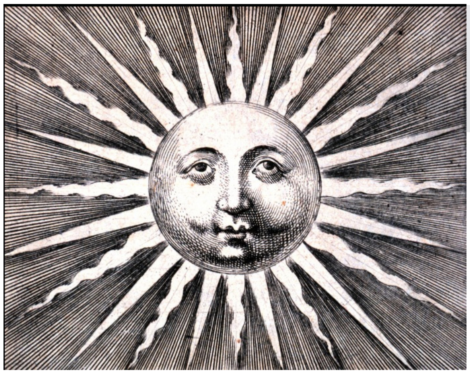
or moving away...

MEET DOW


Communications Antenna
When fully extended (17 m), allows the DOWs to stay in radio contact with all mesonet and support vehicles
Radar Dish and Waveguide
DOW 6
DOW 7



Met Tornaado Pod, sometimes called Insitu Tornado Pod, which means it is used in the field for severe weather research. In 2009 and 2010, the National Center for Atmospheric Research (NCAR) , the Center for Severe Weather Research (CSWR), and many other organizations participated in the largest tornado study EVER. Called VORTEX2, the researchers traveled the plains of the US Midwest for a period of weeks with DOWS, PODS, instrumented vehicles and more, chasing severe weather. Learn about VORTEX2 at the field campaign's official website: www.vortex2.org



Doppler Effect: Coming or Going?

Students learn how light energy can be used by Doppler radar to determine if clouds and/or precipitation are moving toward or away from the radar.

Student Learning Objectives
- Students will learn the basic premise behind the Doppler Effect and how it is used in weather research.

Time
- 5 minutes for activity
- 15 minutes or more for discussion

Materials
For each group of 10 students:
- One foam football with approx. 20 cm diameter
- Sharp scissors or slicing tools with adult supervsion
- One 9-volt buzzer, 60Hz is best
- One 9-volt battery
- Battery clip
- Latching switch that can be depressed once to close or open the circuit
- Duct tape and glue for porous material
- Sodering iron

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth & Space Science
E. Science & Technology

Terms to Know:

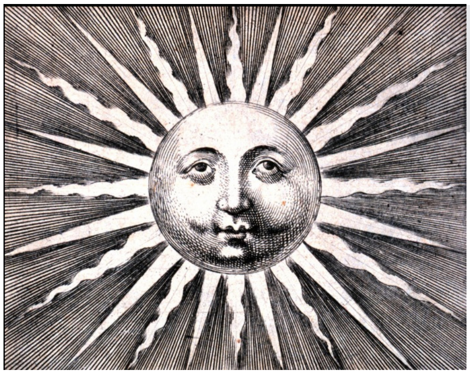
Converge: to move or cause to move towards the same point.

Diverge: to move, lie, or extend in different directions from a common point; branch off.

Directions
Ask your students the following questions:
1. Have each group of students build a buzzer circuit, connecting the battery clip, switch, and buzzer together in sequence. (Hardware stores may also sell pre-made buzzers.) A sodering iron will be necessary to use with adult supervision.
2. Mount the buzzer circuit on a piece of plastic.
3. Place the battery in the clip and test that the circuit is working.
4. Slice a deep gouge into the ball to place the buzzer in. Remove some of the ball's foam so that the buzzer will fit securely.
5. Wrap the components securely then cut a gouge from the outside to the center of the ball to place the buzzer inside the cavity.
6. Place the buzzer into the cavity; cover the buzzer with foam that had previously been removed.
7. Seal the ball's opening with the duct tape and ensure that the buzzer is secure and cannot move about.

To demonstrate the Doppler Effect:
Option 1: Have two proficient throwers in each group toss the Doppler ball to one another over a distance of approximately 20 feet or more. Have the other students stand between the two throwers and listen to the change in the sound of the buzzer as it approaches and then moves beyond them.
Option 2: Place a cord around the Doppler ball or place the ball into a soceer training net (available in most sporting departments and stores.) Have one student stand at the center of a circle and swing the ball overhead with the buzzer on. Ask all the other students in the group to stand on the perimeter of the circle. Students should hear a change in the frequency of the sound as it moves toward and away from them. The faster the ball is swung, the more the Doppler shift will be observed by all students. The exception is the student in the center swinging the ball, who will not hear a change in frequency.

Background Information
The Doppler Effect was named after Austrian physicist Christian Doppler who proposed it in 1842. In this activity, students are listening to a Doppler shift that occurs with sound waves (measured with sonar in research). Radar, of course, uses energy waves, not sound, but the concept works the same with both. Waves reflected by something moving away from the antenna (diverging) have a lower frequency, while waves from an object moving toward the antenna (converging) change to a higher frequency. The Doppler Effect allows forecasters to determine the speed and direction o weather conditions.



Reflectivity by the Numbers

Students learn what the range of colors used in radar displays represents and the various types of radar maps.

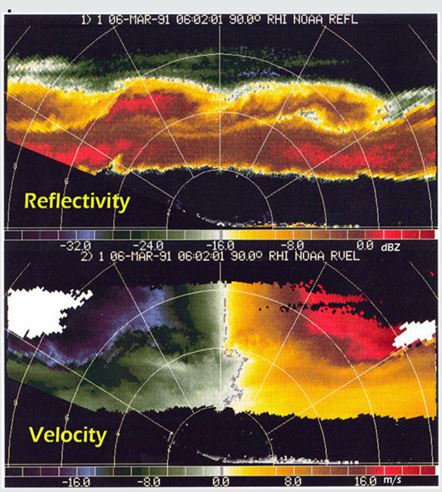
Student Learning Objectives
- Students will

Time
- 30 minutes for activity
- 15 minutes for more for discussion

Materials
For each group of 10 students:
- One copy of the radar scan page to be colored by the numbers.
- Crayons, colored pencils or markers
-

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth & Space Science
E. Science & Technology

Source:
This activity is adapted from NOAA's Student Activities in Meteorology, SAM II, 2003



Directions
Ask your students the following question:
1. When you see a radar image, how do you know what it is conveying? Where might you look for more information?
2. Review properties of light and the basics of how radar and Doppler radar work as well as different types of radar images.
3. Review the difference between radars depiciting weather reflectivity and those depicting weather motion (velocity).
4. Have students fill in the color-by-numbers radar map provided. It is OK if their boundaries between colors blend together because that is how a real radar screen would look. The velocities of the clouds do not suddenly change in one spot, but change more gradually over a distance.
5. Have students place an "X" in each image where the radar is located.
6. When they are finished, have them determine what their image conveys: base reflectivity or velocity.
7. What does the motion in the cloud tell us? Where is the cloud motion the fastest and what is the speed converted converted to mph? What does the term "zenith" represent on the images?
7. As a class, search online for other radar images to share that show reflectivity and velocity. Can you find an example online showing wind shear? A mesocyclone? A thunderstorm squall line? Insects? Bats? A fire or smoke? A wind profile? Airline traffic? Can you find a composite of radar images compiled into ananimaiton loop? Share interesting images that are found.

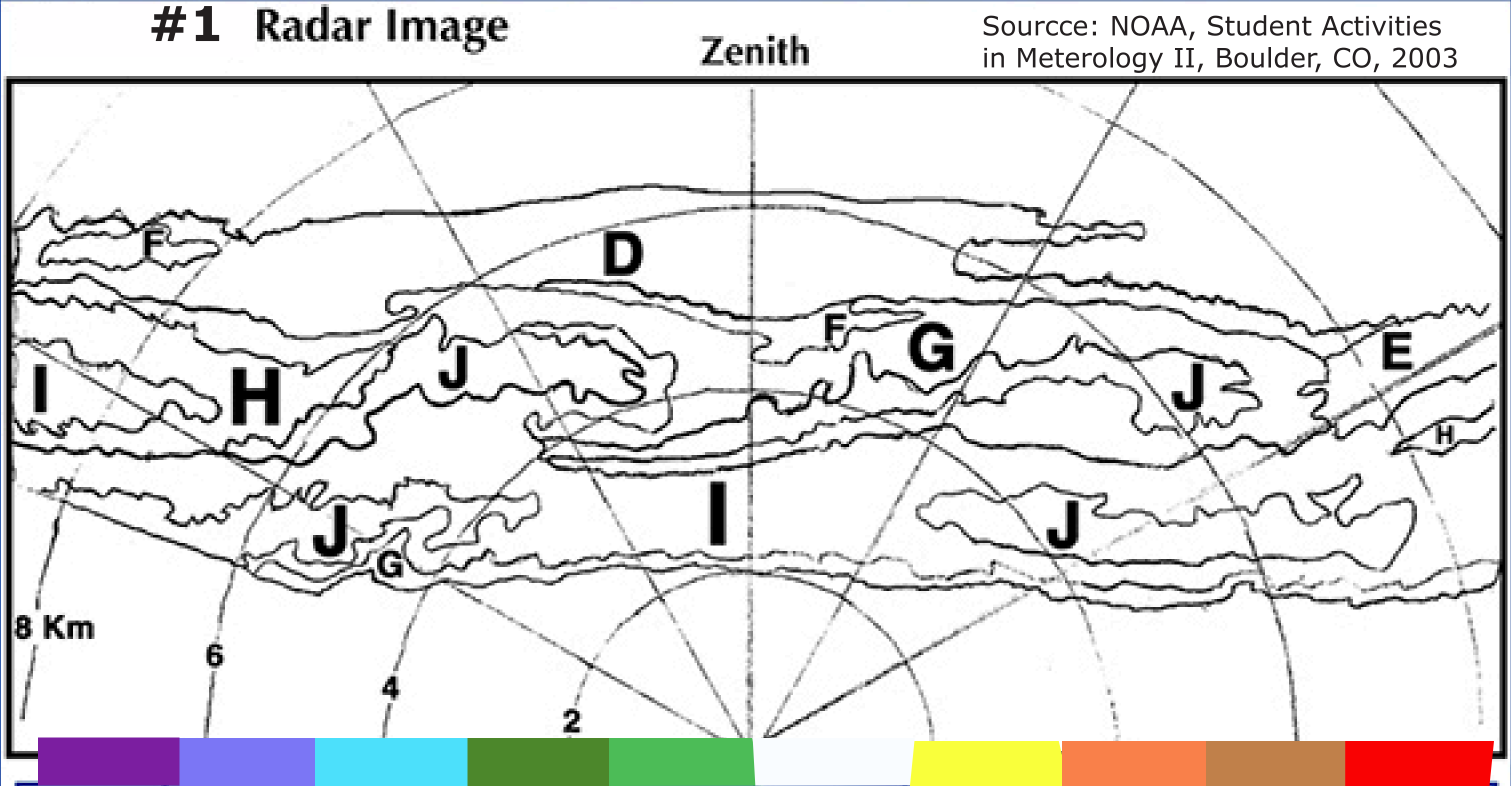
Background Information
The radar images to be colored represent different radar images of the same event: a cloud in the atmosphere. The top image conveys the cloud's reflectivity, while the second image conveys the speed and motion (velocity) of the cloud.

The top reflectivity image shows the moisture content within the cloud measured in dBZ by the radar. 15 dBZ usually corresponds to approximately 0.01 inches of rain per hour so no percipitation is occurring. Using the scale provided, red indicates high reflectivity while blues and purple represent low reflectivity.

In the second image, the color blue or violet indicates movement toward the radar, while the color red indicates motion away from the radar. This image conveys motion measured by Doppler radar using energy pulse frequencies that cover 8-10 kilometers around the radar site. The image is shown on a Velocity Azimuth Display (VAD). What type of cloud(s) might this image represent? (Breaking wave cloud called a Kelvin-Helmholtz cloud.)

#1 Radar Image

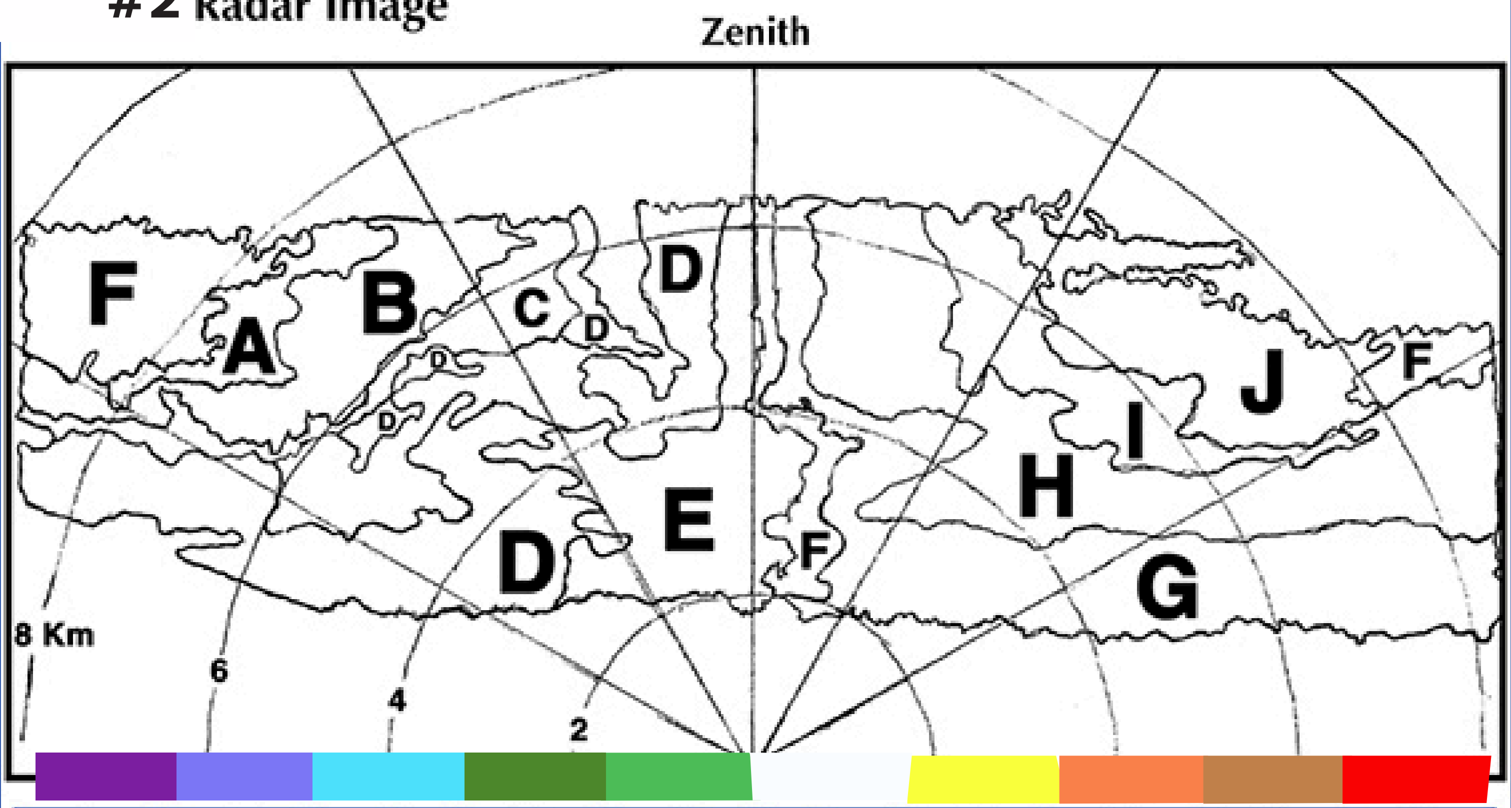
Sourcce: NOAA, Student Activities in Meterology II, Boulder, CO, 2003



A	B	C	D	E	F	G	H	I	J
-38 to -40	-34 to -37	-30 to -33	-20 to -29	-17 to -19	-16	-11 to -15	-6 to -10	0 to -5	>0

(dBz) Decibels — Decibels (dBz)

#2 Radar Image



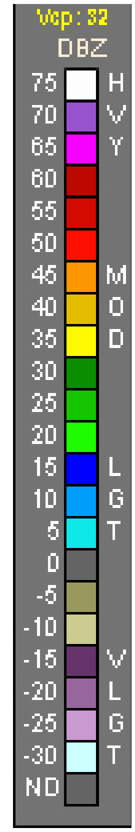
A	B	C	D	E	F	G	H	I	J
-21 to -24	-17 to -20	-15 to -16	-5 to -14	-1 to -4	0	1 to 4	5 to 10	11 to 16	17 to 20

(m/s) - (Meters per Second) — (Meters per Second) - (m/s)

(Negative numbers indicate motion toward the radar, while positive numbers indicate motion away from the radar.)

Types of Radar Image Maps

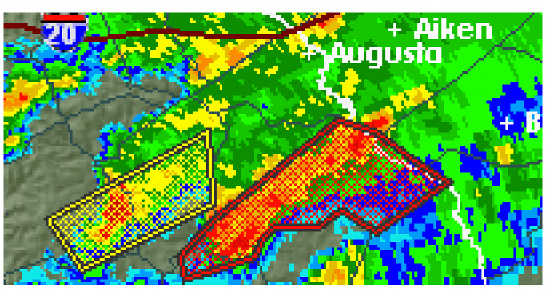
Reflectivity images – The colors in radar reflectivity images are the different values of energy that are reflected back toward the radar. Called echoes, the reflected intensities are measured in dBZ (decibels of z). As the strength of the signal returned to the radar increases the dBZ values increases. The Doppler radar determines areas of returned energy rather than exact locations of rain. The "dB" in the dBz scale is logarithmic and has no numerical value, but is used only to express a ratio. The "z" is the ratio of the density of water drops) in each cubic meter. Value of 20 dBZ is typically the point at which light rain begins. The values of 60 to 65 dBZ is about the level where ¾" hail can occur. Severe weather will occur at dBZ greater than 60 - 65 dBZ, but these reflectivity levels don't always result in severe weather. There are two types of reflectivity: base reflectivities and composite reflectivies. Base images samples the lowest slice of a radar scan, while composite utilizes all elevation scans.   (Right: reflectivity legend) ▶



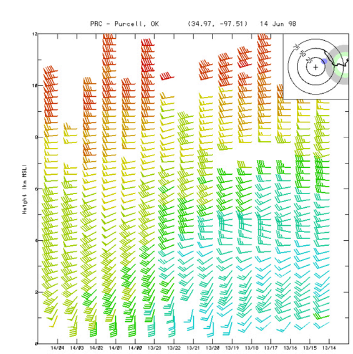
Velocity images – One of the best features on Doppler radar is its ability to detect motion. However, the only motion it can "see" is either directly toward or away from the radar. This is called radial velocity as it is the component of the target's motion that is along the direction of the radar beam. **Base velocity** scans are a measurement of surface winds near a radar. As the beam moves beyond adjacent areas to the radar, the energy pulse rises in elevation and slowly fans out (like a flashligh's light fans out). Base velocity images are helpful in determining areas of strong wind from downbursts or detecting the speed of cold fronts. Velocity images are also useful in determining storm relative motion that can spot small scale circular rotations that meteorologists call mesocyclones. Areas of mesocyclones are where tornadoes occur.

Percipition images – One-hour percipitation images and storm-total percipitation images are made available via the National Weather Service for an area of approximately 140 miles.

When **severe weather** occurs and a weather or warning is issued by the National Weather Service, radar images will be provided that include areas surrounded by red, yellow, green or blue boundary boxes.

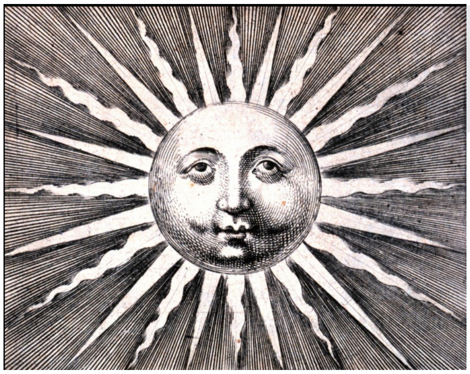


Red enclosed areas represent a warning area where a tornado is imminent.
Yellow enclosed areas represent an area with a severe weather warning.
Green enclosed areas represent an area where flash flooding is imminent or occurring.
Blue enclosed areas represent a marine area with severe weather conditions.



Wind Profilers – Wind profilers provide graphs depicting the winds above a certain location for a given period of time by elevation. They also provide information on wind direction and precipitation.

Radar is used today for varied purposes. Besides weather forecasting from land, sea, air and space, radar is also important in aviation safety, national security, and even fire and entomology research. Radars used for various purposes will produce images unique for the information they depict. But no matter its purpose, all radar involves the transmition of energy pulses and the measurement of their returning echoes.



Reading Radar

Students identify types of radar images and characteristics that depict certain weather and non-weather phenomena.

Student Learning Objectives
- Students will

Time
- 30 minutes for activity
- 15 minutes for more for discussion

Materials
For each group of 10 students:
- One copy of the radar scan page to be colored by the numbers.
- Crayons, colored pencils or markers
-

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth & Space Science
E. Science & Technology

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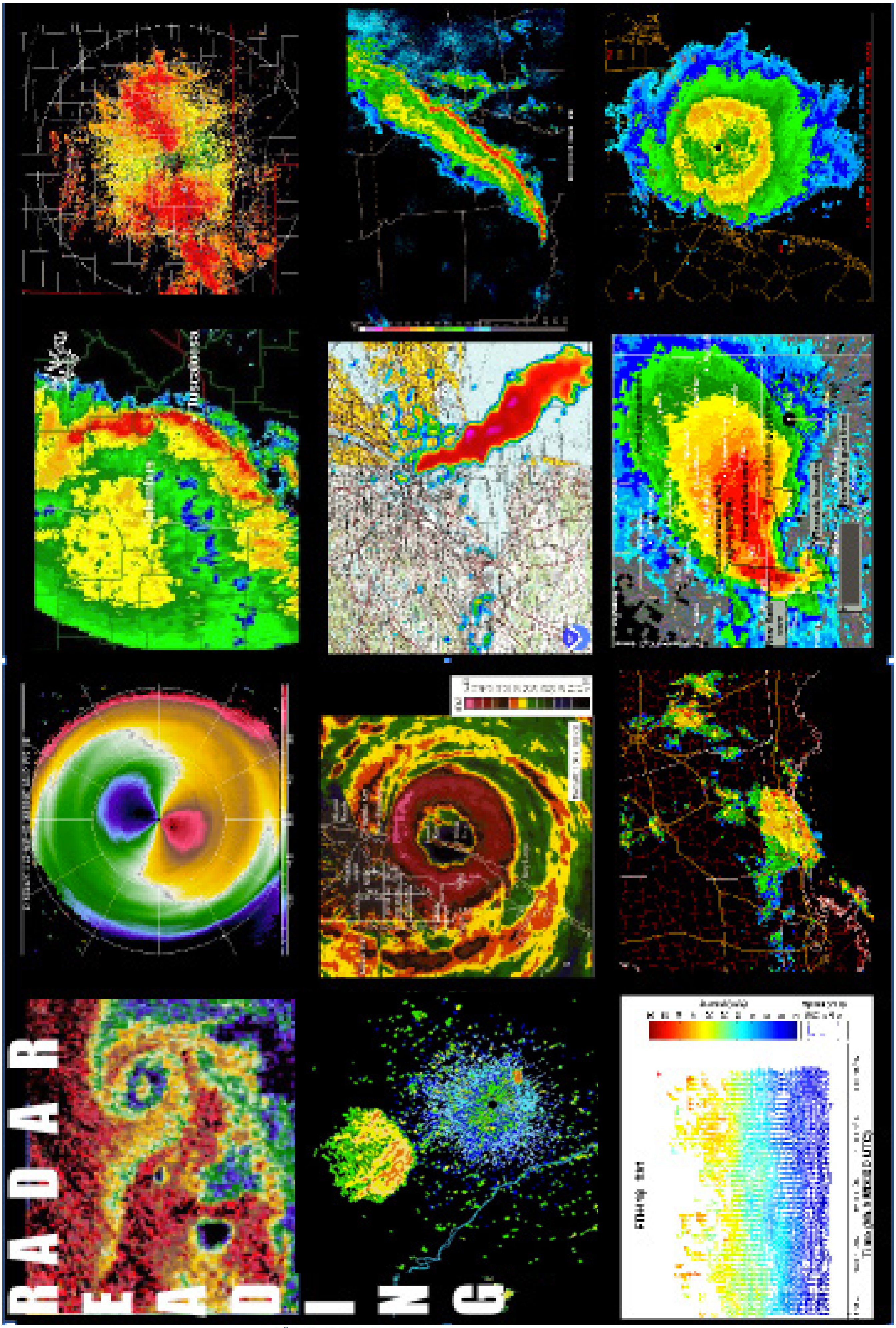
Related Web Pages for Students
- Radar and Weather Together (http://eo.ucar.edu/weather/)
- Jetstream Online School for Weather
  http://www.srh.noaa.gov/jetstream//doppler/doppler_intro.htm

Directions
Ask students to read the background information provided in ***Weather and Radar Together*** (online via URL above.)

Ask your students the following questions:
1. What are the varies areas in which society uses radar today? (weather research and forecasting, air traffic, national security....)
2. When you see a radar image, how do you know what it is conveying? Where might you look for more information? (*Each color within a weather radar scan represents a different magnitude of reflectivity specified in the reflectivity legend. Velocity scans plot wind toward or away from a radar. Unlike weather scans, Wind Profilers plot wind vectors colored according to wind speeds in meters per second over a given time interval and place.)*
3. What non-weather related objects might a transmitted signal encounter? (insects, birds, dust, smoke, airplanes...)
3. Place students in small groups. Have teams read each radar description and each to the radar image it describes. (Note: Some may be applicable to more than one image but each image must be assigned to one of the descriptions.)
4. Have teams review each other's matches, then discuss the correct answers as a class.

Background Information
Reading radar takes training and practice, but there are certain characteristics that radar technicians are often looking for: circulation in thunderstorms, for instance, and hook echoes signifying a possible tornado. Even knowing the difference between the appearance of a velocity verses weather reflectivity image can be a challenge for the novice. The description cards provided with this activity will give you clues to help you identify each of the 12 images on the ***Reading Radar*** poster provided.

Extension: Have students research radar and develop their own series of images on 8.5"x11" paper with corresponding descriptions. After reviewed for accuracy, combine each student's images into a radar quilt. Put radar descriptions into a pile and have students pick from it one by one, assigning their pick to a radar image. Instead of picking from the pile, students can also choose to correct a match that they feel are wrong. The matching and corrections end when all matches are assigned correctly.


RADAR READING

Reading Radar Identification Clues

(Clues are given in order of the images, beginning in the left column and going down then over.)

Cut and laminate clues, then encourage students to try to match these to their corresponding radar image.

This is a radar reflectivity image of a mesocyclone, which produced a tornado. Typically this reflectivity image would be paired with its velocity image, which would add additional important forecasting information. *Something to note: It is true that a mesocyclone does not become a tornado unless the vortex touches the ground, which radar cannot always determine.*

What looks like ground clutter is actually bats taking flight in western Texas at 2300Z (11pm) on March 19th, 2009. There is a high degree of confidence that this area of reflectivity is due to bats emerging to feed, due to the fact that there are no other significant meteorological events happening in the range of the radar and the fact that this event begins at about 2300Z. As bats are nocturnal, it would make sense that this feature can be attributed to them, due to the time of the event. Additionally, bats are a likely explanation due to the relatively high density of reflectors in the region (obvious from the very small area of high reflectivity).

This image from radar data plots the wind speeds collected from above a radar wind profiler site over a given time interval. Colors of the wind barbs correspond to the wind speeds (measured in meters per second), while the barbs themselves convey wind direction. Wind profilers can and do also measure precipitation as well as wind.

This is an example of a radar image showing classic wind sheer visible in the bi-colored velocity "lobes" and fringe on the radar display. The "cool" colors indicate velocities toward the radar and "warm" colors indicate velocities away. In this image, wind is not moving uniformily away and toward the radar but in various directions. The radar is at the center of the display.

Final WSR-57 image of Hurricane Andrew from the NWS Miami office, prior to the storm's destruction of the radar dome on August 24, 1992. Credit: NOAA

This radar image shows the locations of various isolated thunderstorms in the Oklahoma area. The image is similar to images we often see on television weather broadcasts.

A “bow echo” or “bowing line segment” is an arched line of thunderstorms, sometimes embedded within a squall line. Bow echoes, most common in the spring and summer, usually are associated with an axis of enhanced winds that create straight-line wind damage at the surface. In fact, bow echo-induced winds, called downbursts, account for a large majority of the structural damage resulting from convective non-tornadic winds. Tornadoes also can occur in squall lines, especially in association with bow echoes. These tornadoes, however, tend to be weaker and shorter-lived on average than those associated with supercell thunderstorms. Some bow echoes, which develop within the summer season are known as derechos, and they move quite fast through large sections of territory.

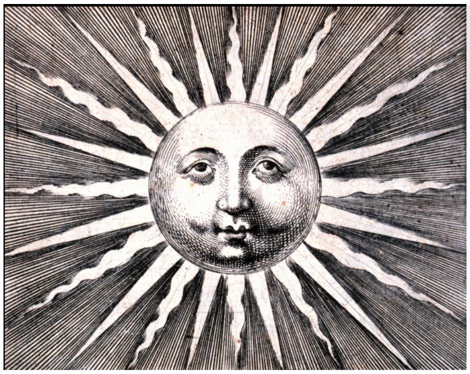
This radar scan captures smoke from an intentional horrific event. Radar has been used in catastrophes such as fires.

A hook echo is a shape that can appear on radar reflectivity images during periods of severe thunderstorms (supercells). It is a signature produced by precipitation held aloft that wraps around the mid-level mesocyclone (circulating air). Since the mesocyclone has counterclockwise winds in the Northern Hemisphere, the reflectivity signature of a hook echo will have a cyclonically shaped hook. The area free from reflectivity inside the hook is the updraft and inflow region of the supercell. A hook echo is one clue to a radar operator that a supercell has the potential of producing a tornado. Many of the violent tornadoes associated with classic supercells will show a distinct hook echo.

Ground Clutter: the combination of a low tilt angle and an inversion at and near the earth’s surface promotes an abundance of ground clutter. Below is an example radar images using the lowest tilt angle (0.5 degrees) taken in the morning when a radiation inversion was in place.

Squall Line: a line of severe thunderstorms that can form along and/or ahead of a cold front. It contains heavy precipitation, hail, frequent lightning, strong straight line winds, and possibly tornadoes and waterspouts.

Precipitation typically forms high in the atmosphere where the temperature is below freezing. As ice crystals form aloft and fall toward the surface, they join to form large snowflakes. As the snowflakes fall, they pass through a level where the temperature rises above freezing. When the snowflakes start to melt, they initially develop a water coating. Water is about 9X more reflective than ice at microwave wavelengths, so these large wet snowflakes produce a high reflectivity. As the flakes continue to fall and melt, they collapse into rain drops. The rain drops are smaller and fall faster, so both the size of the particles and their concentration are reduced, reducing the radar reflectivity. All of these processes lead to the formation of a narrow ring of high reflectivity near the melting level. This ring, called the “bright band”, can be seen on this image.



Radar True or False

Learners are asked basic radar questions and improve their content knowledge as the answers are revealed and discussed.

Student Learning Objectives
- Students will review properties and the history of radar.

Time
- 30 minutes

Materials
For each student or group:
- One True/False sign.
- True/False Q&As provided

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth & Space Science
E. Science & Technology

.

Related Web Pages for Students
- Radar and Weather Together
  http://eo.ucar.edu/weather
- Jetstream Online School for Weather
  http://www.srh.noaa.gov/jetstream//doppler/doppler_intro.htm

Directions
This is a fun review after students have spent time learning about radar. It is also an excellent pre- and post-assessment tool for evaluating how knowledgeable students are.

1. Assign teams or let students play the True/False game individually after the topic of radar has been studied.
2. Make a class set of True and False double-sided signs – one for each participant or team to hold and answer with.
3. Use NCAR's digital library of images as a background if desired for your signs' design (http://www.fin.ucar.edu/ucar dil/).
4. Allow discussion before and after each question that is productive and extends one's understanding of radar.

Background Information
Weather impacts our daily lives, from the clothes we wear to the food we eat. Technological advances have resulted in greater lead time and warnings before severe weather events occur.

One technological advancement that has greatly contributed to improved safety and greater forecasting accuracy is radar. Today, we have a host of radars: Doppler radars; a WSR-88D network,
polarmetric radars, wind profilers, Precipitation Radars on satellites such as NASA's Tropical Rainfall Measurement Mission (TRMM) and
on other aircraft such as Eldora for weather research. Understanding these tools and possible future advances are important because we rely on this technology to keep us both informed and safe, and future technologists will be needed to continue our progress.

Extensions
Have students research radar and severe weather and develop their own series of True/False questions that can be compiled into a Jeopardy game and played with the class as a weather review.

Have students research careers involving severe weather and radar starting with common coursework and majors in college and then possible career paths after.

One limitation of RADAR is that it cannot tell a Radar operator if a rotating column of air, possibly a tornado, is in contact with the ground.

True - radars typically scan above the ground.

Less than 30% of mesocyclones that trigger an alert on Doppler RADAR produce a tornado.

True: More than 70% of mesocyclones do not become tornadoes.

The word radar is an acronym that stands for "Rapidly Advancing Data within Air Range."

False: RADAR is an acronym that is now treated as a word. It originally stood for "Radio Detection and Ranging."

Radar is an important nowcasting tool for recognizing flooding potential.

True: Radars can tell the difference between rain and hail, a vital distinction for predicting floods.

Radar was first used during WWII to predict weather.

False: It was used during WWII, but it was designed initially to detect enemy planes. Using radar for weather fore-casting followed shortly thereafter.

Radio Detection and Ranging, or Radar, evolved in bats millions of years ago.

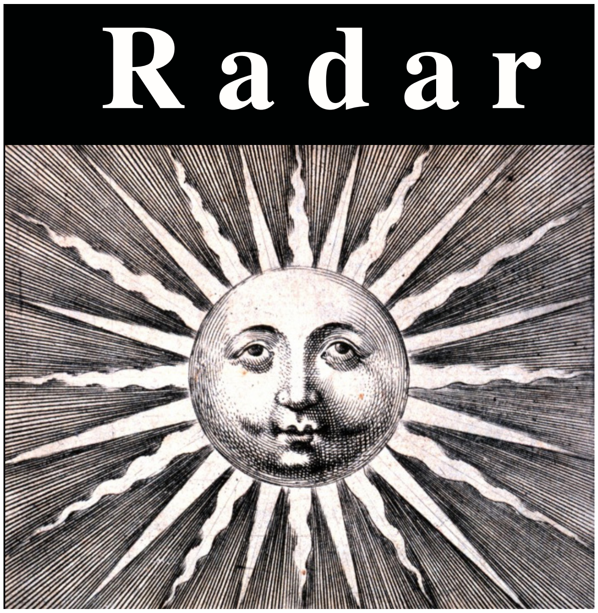
False - Bats use sound, not energy waves. Sound navigation and ranging, or Sonar, evolved in bats and is the oldest known presursor to modern radar. Both sound and energy produce echos.

WSR-88D is a network of doppler radars that the National Weather Service maintains, also called NEXRAD.

True: NEXRAD is a comprehensive national network of Doppler radars used in daily forecasting.

The Doppler effect is important because it shows us the reflectivity of certain types of precipitation.

False: Doppler radar (and not the Doppler effect per sey) allows us to see the speed and motion of a storm whereas earlier radars only provided reflectivity data.



Radar Terms for a Storm Chaser

Absorption– The process of retaining incoming radiant energy in a substance.

Amplitude– The difference from crest to crest in a wave. The distance between a crest (or peak) and the original rest position is the amplitude. The amplitude can also be measured from the trough to the rest position.

Anomalous Propagation– A false reflectivity echo on radar (a reflectivity echo that is NOT precipitation), especially echoes produced by unusual rates of refraction in the atmosphere; also called AP.

Attenuation– In radar meteorology, the decrease in the magnitude of current, voltage, power, or intensity of a signal in transmission between points. Attenuation may be caused by interference such as rain or clouds. When a radar beam of radiation leaves the radar site, with the more space it travels through, the more absorption will take place of the beam. Substances in the air absorb some radar radiation including hydrometeors (hail, rain, snow). Consequently, energy backscattered from a storm near the radar will be more powerful than the energy backscattered from a distant storm. Backscattered radiation close to the radar does not undergo much attenuation. This causes rainfall intensity to be measured higher for storms near the radar as compared to far from the radar, all else being equal.

Azimuth– a radar display on which the average radial velocity is plotted as a function of azimuth (direction).

Bow echo– A bow-shaped line of thunderstorms that is often associated with swaths of damaging straight-line winds and small tornadoes.

Bright band– Radar characteristic associated with the melting layer; a narrow horizontal layer of stronger radar reflectivity in precipitation at the level in the atmosphere where snow melts to form rain. As ice crystals fall toward warmer temperatures at lower heights, they tend to aggregate and form larger snowflakes. This growth accounts for an increase in radar reflectivity as the falling particles warm and begin to melt. The bright band can affect the ability of the NEXRAD algorithms to produce accurate rainfall estimates at far ranges because the algorithm may interpret reflectivity from the bright band as an overestimate of precipitation reaching the surface.

Clutter– Radar echoes that interfere with observation of desired signals on the radar display. Sometimes called "Ground Clutter."

Cone of silence– An area directly above and surrounding the radar where the radar does not sample the atmosphere. This is an artifact of the particular Volume Coverage Pattern (VCP) that is used by the radar.

Convective Available Potential Energy (CAPE)– A measure of the amount of energy available for convection. CAPE is directly related to the maximum potential vertical speed within an updraft; thus, higher values indicate greater potential for severe weather. Observed values in thunderstorm environments often may exceed 1,000 Joules per kilogram (J/kg), and in extreme cases may exceed 5,000 J/kg.

dBZ- The nondimensional "unit" of radar reflectivity. It represents a logarithmic power ratio (in decibels, or dB) with respect to radar reflectivity factor, Z. The value of Z is a function of the amount of radar beam energy that is backscattered by a target and detected as a signal (or echo). Higher values of Z (and dBZ) thus indicate more energy being backscattered by a target. The amount of backscattered energy generally is related to precipitation intensity, such that higher values of dBZ that are detected from precipitation areas generally indicate higher precipitation rates.

Doppler radar– A specialized radar that makes use of the Doppler effect to produce velocity data about objects at a distance. It does this by beaming a microwave signal towards a desired target and listening for its reflection, then analyzing how the frequency of the returned signal has been altered by the object's motion. This variation gives direct and highly accurate measurements of the radial component of a target's velocity relative to the radar. Doppler radars are used in aviation, sounding satellites, police speed guns, and radiology. Most modern weather radars use the pulse-Doppler technique to examine the motion of precipitation.

Dual-wavelength radar– A radar capable of transmitting signals having two wavelengths and measuring separately the echoes at the two wavelengths.

Ducting or high superrefraction– Any region with vertically varying properties such that waves (electromagnetic in the case of radar) launched in certain directions are guided by or trapped within the region rather than propagating radially from their source. Also called super-standard propagation, this produces greater than normal downward bending of radio waves as they travel through the atmosphere, giving extended radio horizons and increased radar coverage. It is caused primarily by propagation through layers near the earth's surface in which the dewpoint temperature is rapidly decreasing or the temperature is increasing with height.

Echo– In radar, a general term for the appearance on a radar display of the radio signal scattered or reflected from a target. The radar echo's characteristics are determined by 1)the waveform, frequency, and power of the incident wave; 2) the range and velocity of the target with respect to the radar; and 3) the size, shape, and composition of the target

Ground clutter– A pattern of radar echoes from fixed ground targets (buildings, hills, etc.) near the radar. This contamination is processed into the NEXRAD base products (base reflectivity, base velocity, and spectrum width) and affects all derived products. Ground clutter is most prevalent close to the radar at the lowest elevation slices. Ground clutter is always present around the radar and is not the same as anomalous propagation (AP), which occurs during certain atmospheric conditions.

Hertz (Hz)- The derived unit of frequency: 1 Hertz equals 1 cycle per second. Named for Heinrich Rudolph Hertz (1857-1894), a German physicist who studied electromagnetic radiation.

Hook Echo– A curved-shaped region of reflectivity in a radar scan caused when precipitation is drawn into the spiral of a mesocyclone

Inflow Notch- A distinct feature on the radar characterized by an indentation in the reflectivity pattern on the inflow side of the storm. The indentation often is V-shaped, but this term should not be confused with V-notch.

Next-Generation Weather Radar (NEXRAD)- A network of high-resolution Doppler radars operated by the National Weather Service (NWS); NEXRAD units are known as WSR-88D.

Polarimetric radar– Radar that measures reflectivity of a target by comparing the polarization properties (a transverse electromagnetic wave) of the transmitted and received signals. Also called radar polarimetry.

Precipitation Mode- The standard, or default, operational mode of the WSR-88D. The radar automatically switches into precipitation mode from clear-air mode if the measured reflectivity exceeds a specific threshold value. The precipitation mode of NEXRAD is more sensitive than previous weather radars. The minimum detectable reflectivity in NEXRAD's precipitation mode is 5 dBZ, compared to 28 dBZ with the old WSR-57.

Pulse - A short burst of electromagnetic radiation that a radar sends out in a straight line to detect a precipitation target. The straight line that this pulse travels along is called a radar beam.

Pulse Repetition Frequency– The Pulse Repetition Frequency (PRF) is the number of radiation pulses emitted by radar in 1 second. For example, if the radar emits 400 pulses in one second then the PRF is 400 pulses/second. Think of pulses like the pulses of a strobe light. A strobe light alternates between light and dark and there is light a certain number of times within a given period of time. Radar is similar except the number of pulses is much more per second than a strobe light and radar emits microwave type wavelength radiation. Another difference is that the radar spends less than 1% of the time emitting radiation and over 99% of the time sensing for returned radiation. Radar can sample the troposphere very fast because the speed of light is fast (about 300,000,000 meters per second).

Radar display– A presentation of the reflectivity, mean Doppler velocity, or other properties of the received signals in a form that can be studied.

Radar frequency band– A frequency band of microwave radiation within which radars operate. The bands normally used with weather radars all fall within UHF (ultra high frequency), SHF (super high frequency), and EHF (extremely high frequency) radio frequency bands and are:

Frequency band	***Frequency range (GHz)***	***Wavelength range (cm)***
L band	1-2	15-30
S band	2-4	7.5-15
C band	4-8	3.75-7.5
K band	8-12	2.5-3.75
Ku band	18-27	1.11-1.67
Ka band	27-40	0.75-1.11
V band	40-75	0.4-0.75
W band	75-110	0.27-0.4

Radar reflectivity– A measure of the efficiency of a radar target in intercepting and returning radio energy to the radar. It depends upon the size, shape, direction of land slope, and other properties of the target.

Range– Distance from radar site to the center of an object causing an echo.

Reflectivity Gradient– The reflectivity gradient is defined as how much the value of radar reflectivity changes over distance. If the reflectivity changes significantly over a small distance then that would be a strong reflectivity gradient. If the reflectivity changes only slightly over a significant distance then that would be a weak reflectivity gradient.

Subrefraction– a beam of radar emitted radiation that bends less toward the earth's surface than usual in normal tropospheric conditions.

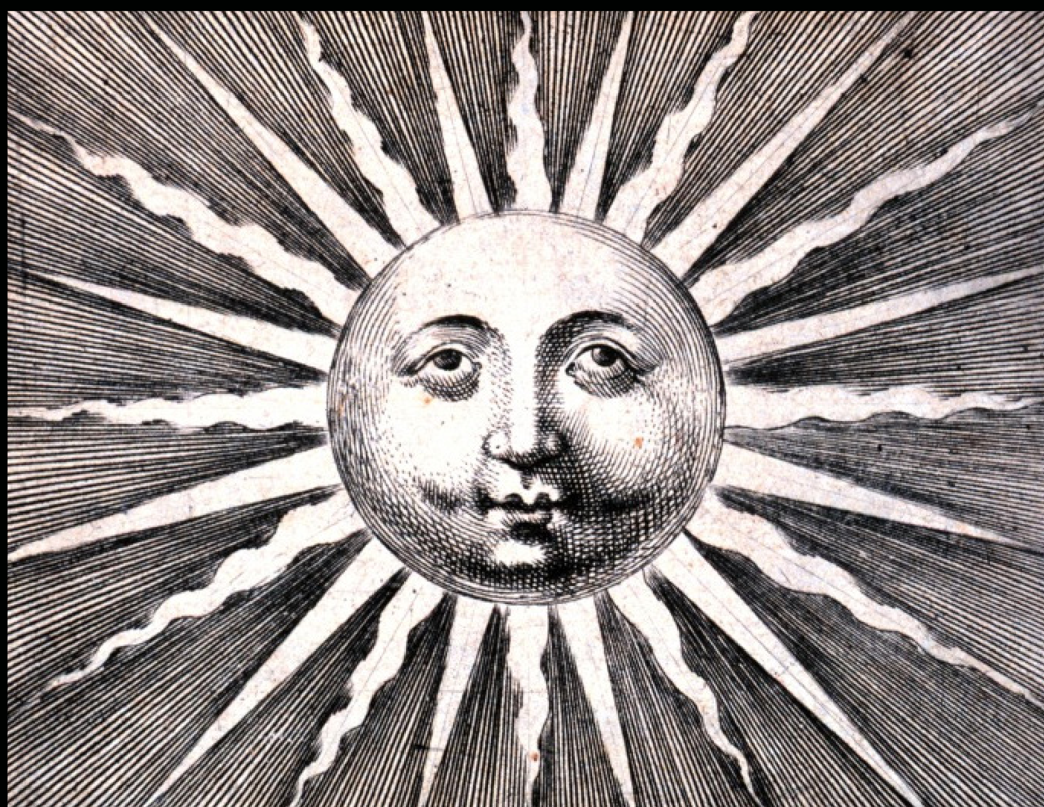
Superrefraction– a beam of radar emitted radiation that bends more toward the earth's surface than usual in normal tropospheric conditions; often called ducting.

Tornado Vortex Signature– A tornado vortex signature or tornadic vortex signature, abbreviated TVS, is a Doppler weather radar detected rotation algorithm that indicates the likely presence of a strong mesocyclone .

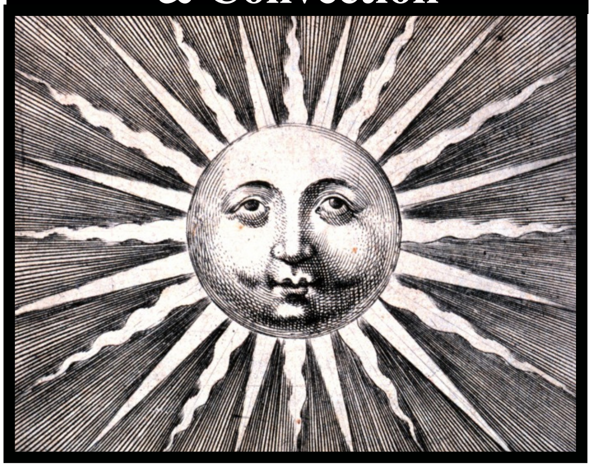
Vmax– stands for the maximum velocity the radar can detect.

Velocity– The rate of change of position. It is represented by a vector, so both speed and direction are required to express velocity. An example of velocity is "15 mph from the southwest." Wind barbs can be used to visually represent velocity.

Sun, Weather, & Convection



Sun, Weather, & Convection

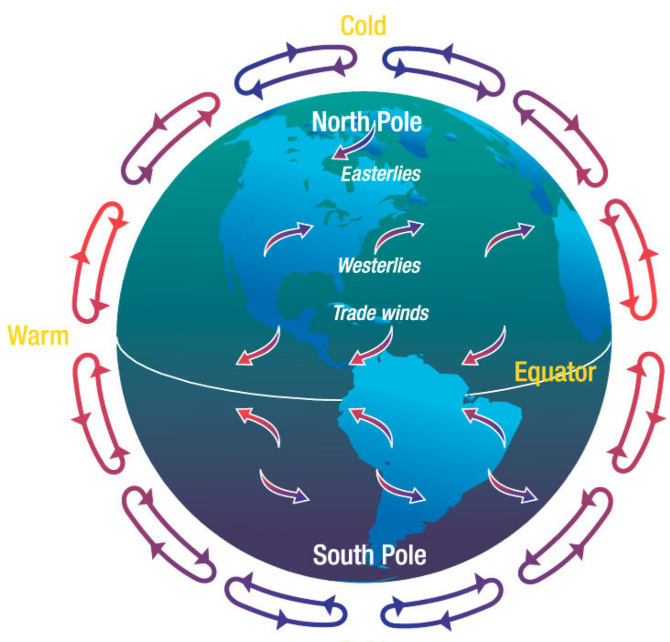


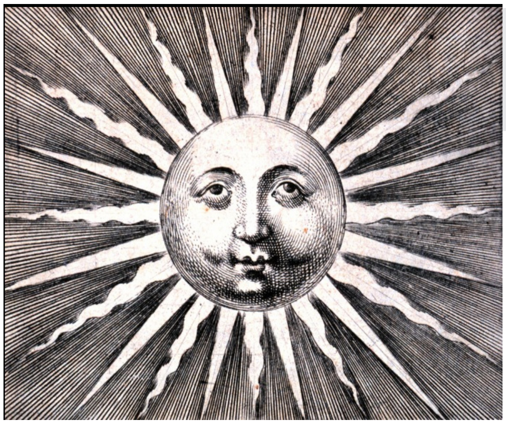
Barely two-billionth of the sun's energy reaches earth (1370 watts/m2), but it is powerful enough to have an enormous impact. The Sun provides the "fuel" for Earth's "weather engine" as it unevenly heats the planet and its atmosphere. Because the Earth's surface receives varying intensities of solar energy, temperature differences occur and set winds and ocean currents in motion. The basic job of these fluids is to transfer heat from the equatorial region to the poles.

Weather is the condition of the air around Earth. The uneven heating of the Earth causes large air masses to form with different temperatures and air presures. Closely linked with air temperature and air pressure is air movement.

Convection is the primary method of heat transfer in fluids such as our atmosphere and oceans. It is through the process of convection that air first begins to move. On a warm day, certain areas of the Earth's surface absorb more energy from the Sun, which results in air near the surface being heated somewhat unevenly. The heated air expands and becomes less dense than surrounding cooler air. Consequently, it is buoyed upward, rises, transfers heat energy upward and leaves behind an area of low pressure. Eventually this rising air spreads out, cools and begins to sink, replacing newly rising heated air. Air masses of opposite temperatures and opposite pressures move toward each other. The point at which the two collide is called a front. The motion of these air masses, their collision with each other, the rotation of the Earth and the amount of water in the sky together create Earth's weather machine. Without the energy from the Sun, this "engine" would never ignite.

The general circulation of the atmosphere is also a consequence of Earth's uneven heating and convection. Air around the equator, which receives sunlight rises and moves towards the Poles, leaving behind an area of low pressure. Air moves from areas of high pressure to areas of low pressure, so as this air rises, cooler air moves from the poles toward the equator to replace it. Although this sounds simple, the actual flow of air is extremely complex. The diagram below shows the general wind and surface pressure distribution on our rotating Earth, along with the prominent winds and convection cells.





Make Convection Currents

In this activity students learn how warm and cool fluids create convection currents.

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Student Learning Objectives

- Students experiment, records observations, and draw con clusions.
- Students learn that moisture, cooling temperature, and condensation nuclei are needed for clouds to form.

Time

- 30 minutes

Materials

For each pair of students:

- A clear plastic shoebox-sized container for each group
- Red food coloring
- Ice cubes made with blue food coloring and water
- Colored pencils (red and blue)
- Index cards or paper

National Standards

- A: Science as Inquiry
- D: Earth Science

Source

This activity is from Web Weather for Kids, another great educational project of NCAR/UCAR!

Directions

1. Divide students into groups of four. Have groups read the article How Do Thunderstorms Form? and the Student Version of this activity (URLs listed above).
2. Discuss the reading as a class including discussion of what thunderstorms need to form and the role of convection. Explain that in this activity students will observe how convection works using water. Air masses move in the same ways.
3. Provide each group with a plastic container 2/3 full of room temperature water. Instruct students not to move the container or the table so that the water becomes completely still.
4. Provide each student group with a blue ice cube to put at one end of their container. (Alternatively, use a drop of blue coloring on ice.)
5. Put two drops of red food coloring at the other end of each container. (For dramatic effect, heat the red coloring bottle in warm water.)
6. Have students observe the long sides of the container to see where the blue and red food coloring travel. Ask each student to draw a picture that describes his/her observations and hang it on the wall. Ask students to look at the pictures of other groups.

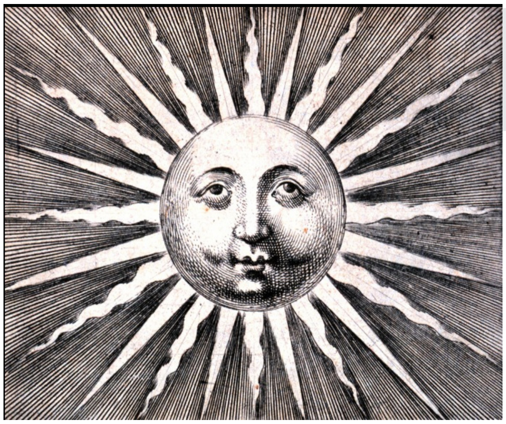
Class discussion: Did similar things happen to the food coloring for each group? (Hopefully, yes.) What happened to the blue? (It sunk.) And the red? (It stayed above the blue.) What was the difference between the blue and red water? (Temperature) That's convection! How is convection needed to form a thunderstorm?

Background Information

Convection is the transfer of heat by the movement or flow of a sub¬stance from one position to another. A thunderstorm is caused when a body of warm air is forced to rise by an approaching cold front. This rising air is called an updraft. The warm air is typically moist and when it rises, meeting cold air above, the water in it condenses, becoming a cumulus cloud. The condensation releases latent heat which helps fuel the thunderstorm.

Extensions

Read and discuss: A Close Encounter with Lightning (http://www.eo.ucar.edu/kids/dangerwx/tstorm9.htm) and Thunderstorm Safety (http://www.eo.ucar.edu/kids/dangerwx/tstorm7.htm).



Cloud in a Bottle

Students observe how air temperature is altered by changes in air pressure, and study conditions needed for clouds to form.

Student Learning Objectives
- Students learn the relationship among air pressure, temperature, and volume.
- Students learn that moisture, cooling temperature, and condensation nuclei are needed for clouds to form.

Time
- 20 minutes

Materials
For each pair of students:
- 1 clean, clear 2L plastic beverage bottle with cap
- 1 Fizz Keeper (available in most large supermarkets)
- 1 temperature strip (attached to Fizz Keeper)
- Matches
- Water

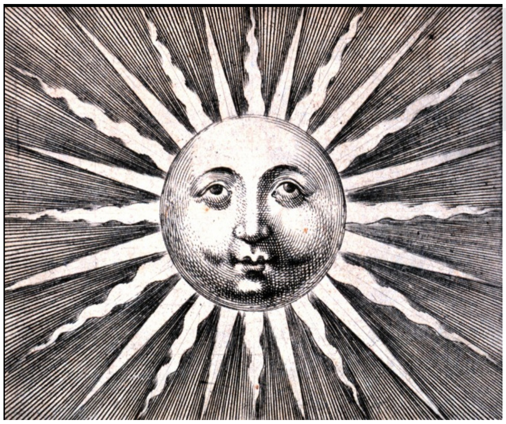
National Standards
- A: Science as Inquiry
- D: Earth Science

Related Web Pages for Students
- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Directions
1. Turn the bottle so the temperature strip (hanging from the Fizz Keeper inside the bottle) faces you and is easy to read. Handle the bottle as little as possible to avoid increasing its temperature from the warmth of your hands.
2. Record the initial temperature in the bottle.
3. Pump the Fizz Keeper 20 times. Record the temperature.
4. Pump the Fizz Keeper 20 more times for a total of 40 pumps. Record the temperature.
5. Repeat this step twice more until you have the temperature recorded at 60 and 80 pumps. Do not exceed 80 pumps because your bottle might pop!
6. Unscrew the Fizz Keeper and record the temperature of the bottle.
7. In the same bottle, place approximately 1-2 inches of water.
8. Next, light a match, blow it out, and promptly drop the smoking match into the bottle.
9. Quickly screw the Fizz Keeper on the bottle. Repeat steps 1-5 above.

Ask yourself the following questions:
1. What happened to the air temperature inside the bottle when you pumped the Fizz Keeper?
2. What happened to the air temperature in the bottle when you unscrewed the Fizz Keeper and decompressed the air inside the bottle?
3. When you added the water and match to the bottle and repeated the activity, did a cloud appear? If so, why do you think this happened?

Background Information
Although air is invisible, it still takes up space and has weight. Under normal atmospheric conditions, there is a lot of “empty” space between air molecules. When you pumped more air into the bottle, you compressed more air into a finite space and increased the air pressure in the bottle. When air is compressed, it warms, which inhibits condensation (and the formation of a cloud in the bottle). When air decompresses, its pressure is lowered and it cools. This encourages water vapor to condense, forming a cloud in the bottle. Three elements must be present in order for clouds to form: moisture, cooling temperature, and condensation nuclei, which are tiny particles in the air such as dust, dirt, and pollutants. They provide a surface on which water molecules can condense and gather into water droplets.



Create a Portable Cloud!

The purpose of this experiment is to observe how moisture, cooling temperature, and condensation nuclei play a role in cloud formation.

Related Kids' Crossing Web Pages for Students

- Water, Water Everywhere: Atmosphere
  http://www.ncar.ucar.edu/eo//kids/wwe/air1.htm
- Stuff in the Sky
  http://www.eo.ucar.edu/kids/stuffsky/index.htm
- Student Version of Activity: NCAR's Web Weather for Kids
  http://www.ucar.edu/educ_outreach/webweather/cloudact2.html

Directions

1. Discuss the composition of clouds. Brainstorm what is needed for clouds to form. Tell students that in this experiment they will explore some of their ideas.
2. Instruct students to pour the cold water into the jar, add food coloring, and swirl for one minute to allow some water to evaporate.
3. Stretch the open end of a rubber glove over the mouth of the jar with the glove fingers hanging down into the jar. Affix a rubber band to the mouth to secure the glove (or a partner can hold it in place).
4. Turn on the lamp so it shines through the jar. After 2 minutes, instruct students to insert a hand into the glove and pull quickly outward without disturbing the jar's seal.
5. Instruct students to record what they observe inside the jar, push the glove back down into the jar, and record observations again.
6. Tell students about particles in the atmosphere. Would more or fewer clouds form with particles in the jar? Develop hypothesis.
7. Instruct students to remove the glove from the jar, while you drop a lit match into the jar. Students should quickly seal the jar with the rubber glove as before (containing the smoke particles within the jar) then repeat procedure to test the hypothesis made in Step 6.
8. Discuss the process of evaporation. Does the temperature of the water make a difference? Develop hypothesis.
9. Pass out hot tap water and have groups repeat the procedure using hot water to test the hypothesis developed in Step 8 above.
10. Discussion: What helps a cloud form? (Cooling air, condensation nuclei, and evaporation)

Background Information

Evaporation: There must be water vapor in the air to build a cloud. Vapor is created as water evaporates either by heating under the lamp, swirling the water, or using hot water.

Cooling air: As air temperature decreases, vapor condenses. When you pull the glove out of the jar, the air pressure lowers inside the jar. The jar contains the same number of air molecules, but they occupy more space and slow down, causing the air temperature to drop.

Condensation nuclei: Tiny particles, such as dust, dirt, and pollutants, provide surfaces for water molecules to gather upon and condense into water droplets. The smoke provides tiny nuclei on which water condenses when the air temperature cools.

Student Learning Objectives

- Students experiment, observe, and articulate results.
- Students learn the conditions necessary for cloud formation.

Time

- 30 minutes

Materials

For each group of 4:

- Gallon jar
- Cold water (100 ml)
- Hot water (100 ml)
- Rubber glove
- Food color (optional)
- Matches
- Ruberband
- Lamp (gooseneck or similar style)
- Paper and pencil to record observations

National Standards

- A: Science as Inquiry
- B: Physical Science
- D: Earth Science

Source

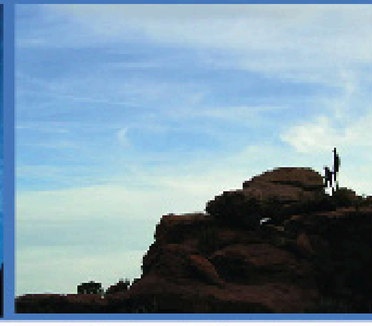
This activity has been adapted from NCAR's *Web Weather for Kids Website.*

Cloud Viewer

1. Cirrus

2. Cirrocumulus

3. Cirrostratus



High Level Clouds (1, 2, 3) are white and thin-looking. At sunrise or sunset, they can be very colorful. They are most often made of ice crystals.

4. Altocumulus ↙

Mid Level Clouds (4, 5, 6) are made mostly of water droplets. When temperatures are very low, the water droplets can turn to ice crystals.

How are clouds classified?

Scientists classify clouds by their height (low, medium, or high), and by whether they are flat (stratus), puffy (cumulus), rain-filled (nimbus), or a combination of these characteristics.

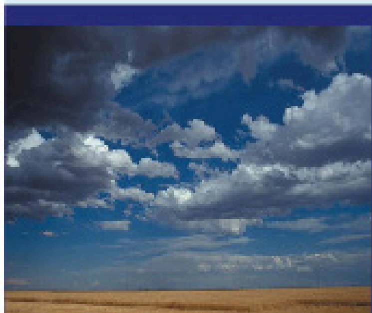
Saucer-shaped lenticular clouds are common in mountainous regions of the world.

How do I make the NCAR Cloud Viewer?

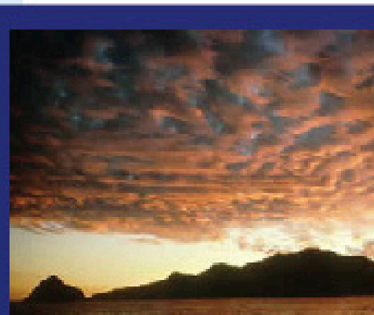
Cut along the dashed line in the center of the page. Look through the opening in the Viewer at the sky above you. What types of clouds do you see today? Use the CLOUD VIEWER to help you classify the clouds outside. Use the SKY VIEWER to find the sky's colors. Why isn't the sky just one color? Why does it vary?

5. Altostratus ↙

6. Nimbostratus ↙



7. Cumulus

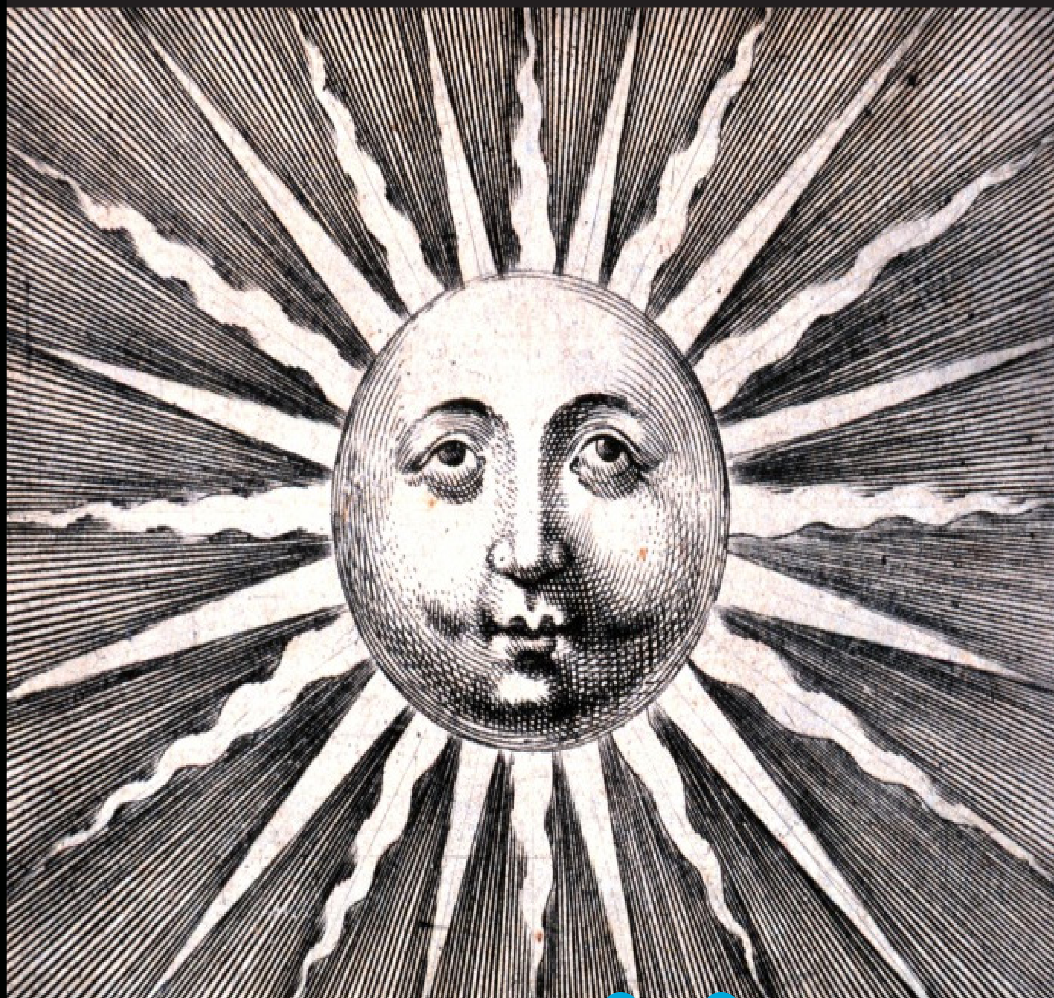


8. Stratocumulus

Low Level Clouds (7, 8, 9, 10) are made of water droplets. Cumulonimbus clouds (9) can rise rapidly causing water droplets to turn to ice.

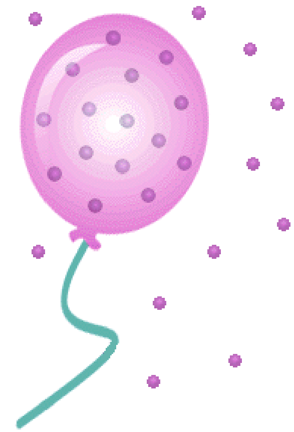
9. Cumulonimbus

10. Stratus



AIR PRESSURE

UNDER PRESSURE!



When your friend squeezes your arm, you feel pressure! That's because molecules collide with each other and things like the ground or a tree. They exert a force on those surfaces.

Molecules in Earth's atmosphere constantly bounce off each other and everything else around them. The force exerted by these air molecules is called air pressure. Molecules that are packed closely are at higher pressure than molecules that are more spread out. The molecules inside this balloon, for example, are at a higher pressure than the molecules outside the balloon. At sea level,

Although the changes are usually too slow to observe directly, air pressure is almost always changing. This change in pressure is caused by changes in air density, and air density is related to temperature. As you move up in altitude through the atmosphere, the concentration of air molecules decreases. Some people call this "thin air". The air is thinner higher in the atmosphere because there is lower pressure the higher you go up.

With weather, cold masses of air are more dense than warm masses of air because the gas molecules in warm air are moving faster (greater velocity) and are farther apart than in cooler air. So, while the average air pressure at 300 feet elevation is 1000 millibars, the actual elevation will be higher in warm air than in cold air.

The lowest air pressure in the world related to weather (and not elevation) is found in and around severe weather events such as hurricanes (also called tropical cyclones and typhoons) and tornadoes. Fair weather with cloudless skies is associated with high pressure. A general rule of weather forecasting is that when low pressure moves in, it will bring stormy weather. High pressure will usually bring good weather.

Air pressure is measured in Pascals or Inches of Mercury. One pascal equals 0.01 millibar or 0.00001 bar. Meteorology has used the millibar for air pressure since 1929. Inches of mercury refers to the height of a column of mercury measured in hundredths of inches. This is what you will usually hear on television weather reports. At sea level, standard air pressure in inches of mercury is 29.92. We measure air pressure using an instrument called a barometer.

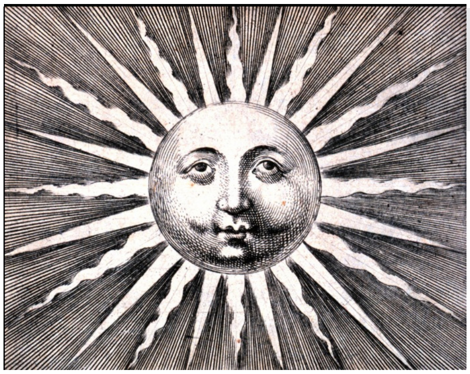
The activities on air pressure that follow are designed to expand students understanding and interest in air pressure and its relationship to wind, weather, and atmospheric circulation.

Did You Know?

We often speak of pressure in terms of atmospheres. One atmosphere is equal to the weight of the earth's atmosphere at sea level, about 14.7 pounds per square inch. If you are at sea level, each square inch of your surface is subjected to a force of 14.7 pounds.

In water, the pressure increases about one atmosphere (14.7 pounds per square inch) for every 33 feet (10 meters) of water depth. At the deepest part of all the earth's oceans, Marianas Trench's (east of the Philippine Islands) depth is about 35,800 feet (7 miles/11 kilometers). The pressure of nearly 7 miles of water overhead is about 1080 atmospheres or 16,000 pound per square inch.

Source: NOAA Jetstream



Plunger Pull

Students learn it is the force of atmospheric pressure that causes the phenomenon commonly called "suction."

Student Learning Objectives

- Students learn that air exerts pressure at 14.7 pounds per column inch at sea level on average.
- Students learn that the force air exerts can be easily demonstrated when a vacuum (area with no air) is created.

Time

- 5-10 minutes

Materials

For each pair of students:

- One set of suction cups or plungers, standard size. Wood handles are best to remove.

National Standards

- A: Science as Inquiry
- D: Earth Science

> *Otto von Guerick's sphere is known around the world as the Madgeburg Sphere because it was built in Guerick's home-town of Madgeburg, Brandenburg-Prussia in 1654. It greatly advanced knowledge about properties of air.*

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Directions

1. Put the plungers together, with concave sides facing one another.
2. Notice that they touch but do not hold together.
3. Put the plungers firmly together, with concave sides facing one another again, put this time push the air out that is held and shared between them. Notice what happens.
4. Hold the plungers by their outside ends and try to pull them apart. Do not twist or peel them, just pull. Are you able to pull them apart?

Ask yourself the following questions:

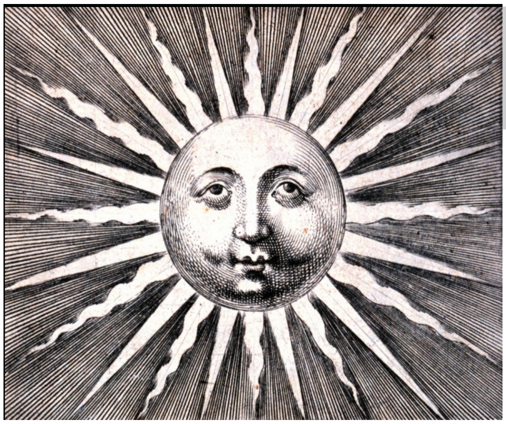
1. Is suction a force or does air exert a force and cause suction?
2. How much weight do you think you are trying to pull apart if air weighs 14.7 pounds per column inch?

Background Information

Although air is invisible, it still takes up space and has weight. In fact, it may surprise you to know that air weighs 14.7 pounds per column inch at sea level, or put another way, over 2,100 pounds per column cubic foot! Wow! The reason we don't feel its weight is because air, like all fluids, doesn't just push down. Instead, it pushes in all directions. Water has weight too, but you aren't crushed when you swim to the bottom of a deep pool because water, like air, also pushes in all directions. But just try to lift all that water you're swimming under. It weights over 62 pounds per cubic foot!

In 1654, Otto von Guerick performed a demonstration similar to the activity you just performed with the plungers. He used two metal hemispheres, which were 22 inches in diameter and placed them together in the shape of a single sphere. He had invented the world's first vacuum pump shortly before 1654, which pumped air out of his sphere instead of into it. When he did so, the two hemispheres held together tightly. No human could pull Otto's sphere apart, so in front of Emperor Ferdinand III of Germany and others, he attached two eight-horse teams to each end of his sphere. Despite a great effort, the horses could not pull his sphere apart. Afterall, they were trying to pull apart nearly 3 tons!

When air is inside the sphere, it exerts the same amount of force as the air on the outside of the sphere. When you remove the air inside of the sphere, however, the air on the outside presses the two halves of the sphere together. If you peel the plungers apart slightly and let air back inside of it, its two sides will no longer stick together as the force on the inside and outside will once again be the same.



Not Your Usual Pop!

Students observe that air takes up space and that the absence of air can result in crushing behavior. ***NOTE:*** *This activity requires adult assistance and supervision.*

Student Learning Objectives

- Students learn that air takes up space and exerts pressure
- Students learn that air pressure is strong enough to crush a nearly empty can

Time

- 10 minutes

Materials

Per adult demonstrator:

- One 12-once soda can
- Water
- One bowl of ice water approximately 6" deep or greater
- One pair of tongs
- One hot plate or electric burner

Terms to Know and Use

- Air Pressure
- Condensation
- Density
- Evaporation
- Implode
- Vacuum
- Water Vapor

National Standards

- A: Science as Inquiry
- D: Earth Science

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/basic.html
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Directions

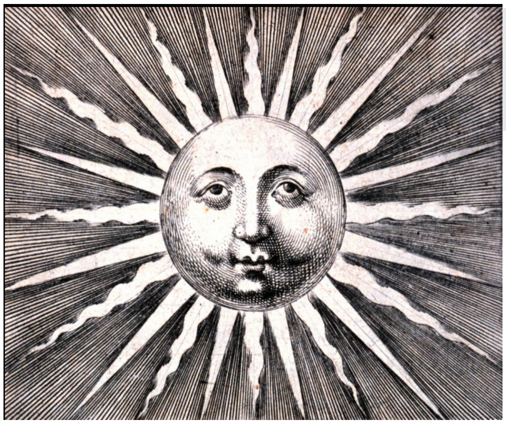
1. Have observers stand or sit at least five feet from the demonstration.
2. Fill an empty 12-ounce soda can with approximately 1 ounce of water.
3. Place the soda can directly on a hot plate or electric burner, and wait for the water inside the can to begin to boil and steam.
4. Have an adult quickly but safely lift the soda can off the burner with a sturdy pair of tongs.
5. Immediately flip the soda can and immerse the can mouth into a large bowl of ice water.
6. What happens to the soda can? Why?

Ask yourself the following questions:

1. What happens to the air inside the soda can when it is heated?
2. What happens to the water inside the can?
3. What do you think the can is filled with at the start, when the water begins to boil, ,and later when the can is cooled with ice water?
4. Why did the can implode? What happens to water vapor when it is cooled? What took the place of the water vapor in the can after it condensed back into a liquid?
5. How much force does air pressure exert?

Background Information

Although air is invisible, it still takes up space and has weight. In this experiment, when the air in the soda can is heated, the air pressure inside the can rises and eventually some escapes. When the water in the can is heated, it begins to evaporate into a gas -- water vapor -- and fills much of the newly created space left by the escaping air. The pressure on the inside of the can remains at about the same pressure as the surrounding atmosphere. However, when the can is placed in the tub of ice water, the water vapor instantly condenses back into liquid water. What takes the place of the water vapor and steam? Nothing! For a brief second, the can is filled with only a little water, a tiny bit of air, and a lot of empty space! 14.7 pounds of air pressure per square inch is pressing on the outside of the can, but very little air is pushing back from the inside. Consequently, the can is crushed in seconds by the greater air pressure pushing on it from the outside.



Air on the Go

Using a bottle and a small piece of paper, students will observe that air takes up space, and that it won't always go where you direct it to go!

Student Learning Objectives
- Students learn that air moves toward low pressure.
- Students learn the relationship between air pressure and wind.

Time
- 5 minutes

Materials
For each pair of students:
- 1 clean, clear 12 ounce plastic beverage bottle with cap off
- One small round paper wad

National Standards
- A: Science as Inquiry
- D: Earth Science

Air Pressure Records

United States:
Highest: 31.85" in Northway, Alaska in January 1989
Lowest: 26.05" over the Gulf of Mexico during Hurricane Wilma, October 2005

Global:
Highest: 32" at Agata, Russia on December 31, 1968
Lowest: 25.69" during a typoon on Oct. 12, 1979 in the Philippine Sea in the southwestern Pacific Ocean.

Related Web Pages for Students
- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://www.windows.ucar.edu
- http://www.ucar.edu/learn

Directions
1. Hold the bottle approximately a hand's distance from your mouth with the bottle flat on its side and the opening pointing directly at your mouth.
2. Place the small round paper wad on the edge of the inside lip of the bottle opening.
3. Stand as still as possible and blow into the bottle. (Do not move your head or the bottle during this process.)
4. Observe what happens to the paper wad.

Note: *Your objective is NOT to get the paper into the bottle, but to observe what happens naturally in the process of this investigation to the paper.*

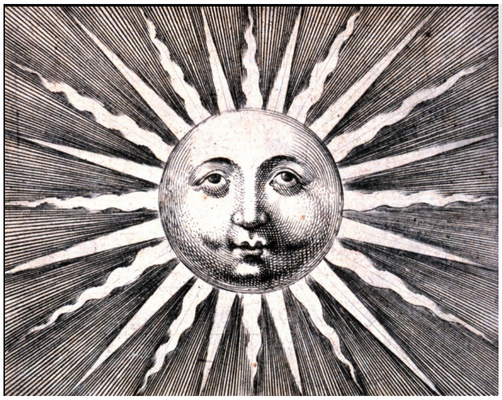
Ask yourself the following questions:
- Why doesn't the paper go into the bottle?
- If I blow softly, will the paper go in then, and if not, why not?
- Where is the air pressure highest? Where is it lowest?
- What would happen if there was a hole at the opposite end of the bottle?

Background Information
Although air is invisible, it still takes up space and has weight. Under normal atmospheric conditions, there is a lot of "empty" space between air molecules. Under high pressure conditions, the air is more dense, and when low pressure conditions exist, the air is less dense. When air moves at great speeds, this also makes the air less dense and results in lower air pressure. A good analogy are cars on a freeway. The faster the cars go, the more space that exists between them. But when their speeds slow, they crowd together.

When you blow into a bottle, air is compressed into a finite space and the air pressure in the bottle increases. Think about a balloon. When you blow it up, you trap air inside of it as well. If you let go of the balloon before tying it, the air rapidly exists it. This is because air moves from areas of high pressure toward areas of low pressure. The greater the difference in the pressure, the faster the air will move. The air blown into a bottle is a lot like air blown into a balloon. If it's not trapped, it will rush out of the bottle toward lower pressure. Consequently, the paper is pushed out of the bottle instead of into it.

In the larger atmosphere, air moves toward low pressure but it's motion is influenced also by the spin of the Earth. This is called the Coriolis Effect and causes air to move counterclockwise around low pressure in the Northern Hemisphere and clockwise in the Southern Hemisphere. Consequently, hurricanes, which are areas of extreme low pressure, travel in these directions in both Hemispheres also.

We measure air with a barometer in millibars. Measurements above 1010 mb are considered high pressure.



Go with the Flow!

Students observe how a single breath of air can fill a large trash bag due to the Bernoulli Effect.

Related Web Pages for Students
- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://www.ucar.edu/learn
- http://eo.ucar.edu/weather/

Directions
1. Have students guess how many breaths it would take to blow up a large plastic trash bag. Determine the exact amount by using the traditional method of blowing into a small hole at the bag's opening. (It's likely to be anywhere from 20-50 breaths of air!)
2. Ask the students if they think it might be possible for someone to blow the bag up using just one breath.
3. Have students demonstrate that it is indeed possible by having each of them hold the trash bag open approximately a 1-foot distance from his/her mouth.
4. Using only one breath, ask the students to blow as hard as they can to fill it up, then quickly squeeze the bag's end closed with their hands.

Ask yourself the following questions:
1. How can a single breath of air fill the bag?
2. Will it work with a smaller or larger bag? (Use the Windbag™ to find out.)
3. Will it work with a small and/or slow breath of air also?

Background Information
In the early 1700s, a Swiss mathematician and scientist by the name of David Bernoulli discovered that the faster air travels, the lower the pressure it exerts.

In our example, the stream of moving air creates an area of lower pressure, which attracts high pressure air adjacent to the stream of moving air. As a result, it is not just a single breath of air that fills the bag, but rather air from the surrounding area also.

Our atmosphere is always trying to maintain steady air pressure. As a consequence, an area of high pressure will move toward an area of low air pressure in an attempt to restore balance. Pressure will never be steady around the Earth, however, no matter how hard the atmosphere tries to balance itself. This is due to the Sun's uneven heating of the Earth's surface, which creates ever changing areas of high pressure and low pressure.

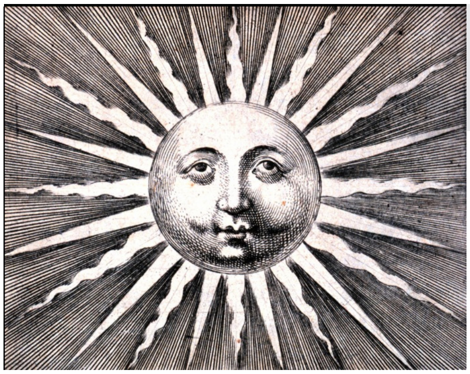
Student Learning Objectives
- Students learn that a fast moving stream of air results in an area of low pressure.
- Students observe that areas of high pressure move toward areas of low pressure.

Time
- 20 minutes

Materials
For each student:
- Two 10-gallon or larger plastic bags
- Windbag™ (optional) (available through Steve Spangler Science at www.stevspanglerscience.com)

National Standards
- A: Science as Inquiry
- D: Earth Science

Did you know:
The Sun's uneven heating of Earth's surface creates various areas of high pressure and low pressure within Earth's atmosphere.



Up and Away Bernoulli's Way

Students observe the Bernoulli Principle in action.

Student Learning Objectives

- Students learn that as a fluid's speed increases, the pressure it exerts decreases.
- Students learn that air moves toward low pressure.

Time

- 5-10 minutes

Materials

For each pair of students:

- Paper or clear plastic tubes of various lengths with a 3" opening at each end. Mailing tubes work well.
- 1 or more pingpong balls
- Hair dryer

National Standards

- A: Science as Inquiry
- D: Earth Science
-

> Bernoulli's principle states that in fluid flow, an increase in velocity occurs simultaneously with a decrease in pressure.

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Directions

1. Turn the hair dryer on and point it and the stream of air upward at a 90 degree angle to the ground.
2. Place the ping pong ball in the stream of air and let go of it.
3. Place the tube like a hat on top of the ping pong ball floating in the air stream. Do not let go of the tube.
4. Repeat the activity using tubes of various lengths. Tubes of various widths can also be explored.

Ask yourself the following questions:

1. Why does the ping pong ball float in the stream of air produced from the hair dryer?
2. Why does the ping pong ball travel up and out of the tube?
3. Why does the height reached by the ping pong ball vary depending on the length of the tube?
4. Why does the ping pong ball travel farther with greater air speed?
5. What happens to the ping pong ball if you cover the top of the tube when it is placed on top of the ball? Why?

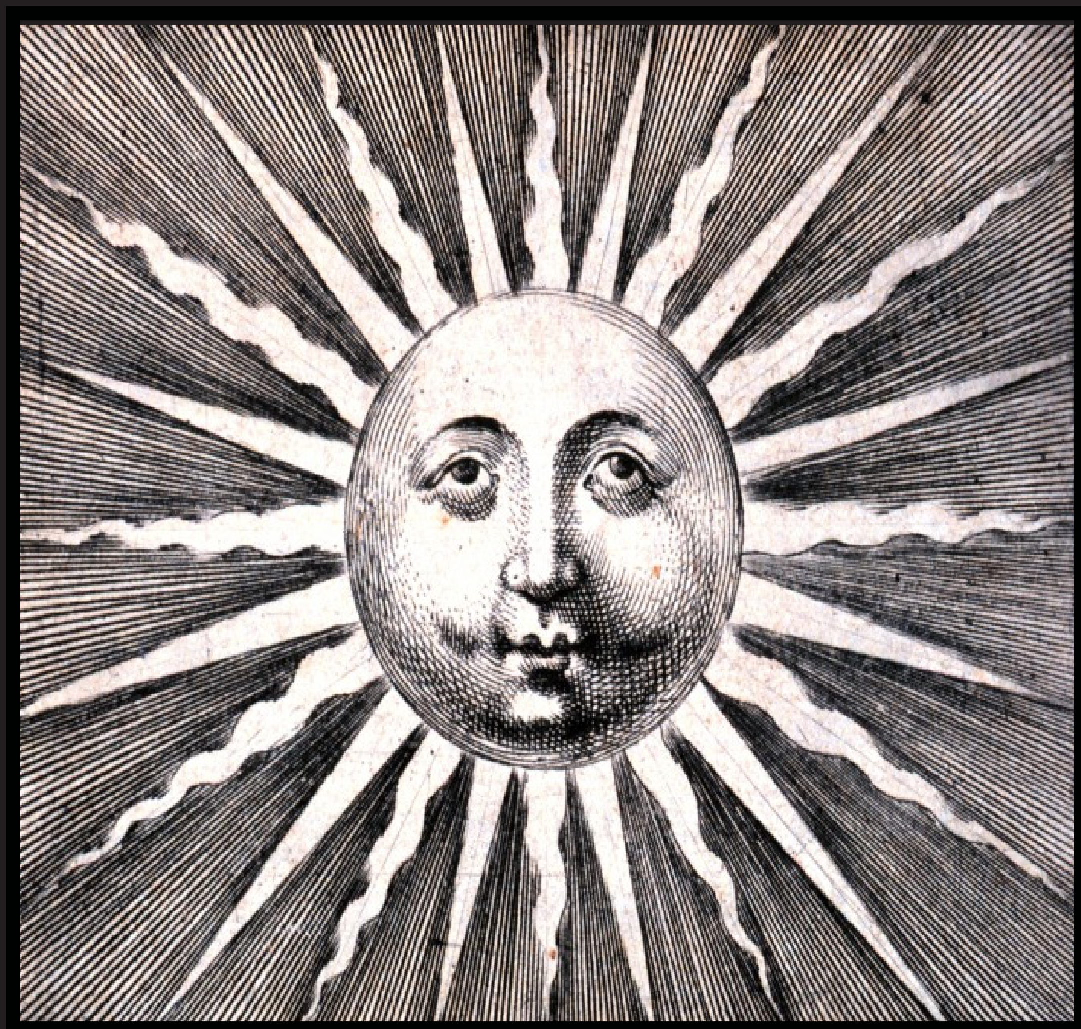
Background Information

This activity is based on Bernoulli's Principle, named after the Swiss mathematician and scientist Daniel Bernoulli (1700-1782) more than 250 years ago. It states that as a fluid's velocity increases, the pressure exerted by that fluid decreases.

In this example, the ping pong ball initially floats in the air stream because air accelerates as it is forced into a narrow tube, and the air pressure drops as a consequence. It stays suspended in the air stream because the speed of moving air is increased over its curved surface. This results in a coresponding decrease in air pressure around the ball's surface and produces lift. The high pressure air immediately outside the air stream hugs the low pressure system and snuggles the ball, keeping it in place.

The wind tunnels or tubes cause the air stream to accelerate as it is funneled into a smaller area. This increase in velocity lowers the air pressure in the tube. High pressure air moves toward low pressure, so this lower pessure air literally sucks the ball up into the tube.

A good rule of thumb when it comes to air: *High pressure to low, that is where the air tries to go BUT... Earth's rotation will deflect the air's path causing it to curve counter clockwise around low pressure's center in the Northern Hemisphere; clockwise in the Southern Hemisphere.*



Severe Weather

Be Red Cross Ready

Thunderstorm Safety Checklist

A thunderstorm is considered severe if it produces hail at least 1 inch in diameter or has wind gusts of at least 58 miles per hour. Every thunderstorm produces lightning, which kills more people each year than tornadoes or hurricanes. Heavy rain from thunderstorms can cause flash flooding and high winds can damage homes and blow down trees and utility poles, causing widespread power outages.

Know the Difference

Severe Thunderstorm Watch—Severe thunderstorms are possible in and near the watch area. Stay informed and be ready to act if a severe thunderstorm warning is issued.

Severe Thunderstorm Warning—Severe weather has been reported by spotters or indicated by radar. Warnings indicate imminent danger to life and property.

Every year people are killed or seriously injured by severe thunderstorms despite advance warning. While some did not hear the warning, others heard the warning and did not pay attention to it. The following information, combined with timely watches and warnings about severe weather, may help save lives.

How can I prepare ahead of time?

❐ Learn about your local community's emergency warning system for severe thunderstorms.

❐ Discuss thunderstorm safety with all members of your household.

❐ Pick a safe place in your home for household members to gather during a thunderstorm. This should be away from windows, skylights and glass doors that could be broken by strong winds or hail.

❐ Make a list of items to bring inside in the event of a severe thunderstorm.

❐ Make trees and shrubbery more wind resistant by keeping them trimmed and removing damaged branches.

❐ Protect your animals by ensuring that any outside buildings that house them are protected in the same way as your home.

❐ Consult your local fire department if you are considering installing lightning rods.

❐ Get trained in first aid and learn how to respond to emergencies.

❐ Put together an emergency preparedness kit: •Water—one gallon per person, per day • Food—non-perishable, easy-to-prepare • Flashlight • Battery-powered or hand-crank radio (NOAA Weather Radio, if possible) • Extra batteries • First aid kit • Medications (7-day supply) and medical items • Multi-purpose tool • Sanitation & personal hygiene items • Copies of personal documents • Cell phone with chargers • Family & emergency contact information • Extra cash

What should I do during a thunderstorm?

❐ Listen to local news or NOAA Weather Radio for emergency updates. Watch for signs of a storm, like darkening skies, lightning flashes or increasing wind.

❐ Postpone outdoor activities if thunderstorms are likely to occur. Many people struck by lightning are not in the area where rain is occurring.

❐ If a severe thunderstorm warning is issued, take shelter in a substantial building or in a vehicle with the windows closed. Get out of mobile homes that can blow over in high winds.

❐ If you can hear thunder, you are close enough to be in danger from lightning. If thunder roars, go indoors! The National Weather Service recommends staying inside for at least 30 minutes after the last thunder clap.

❐ Avoid electrical equipment and telephones. Use battery-powered TVs and radios instead.

❐ Shutter windows and close outside doors securely. Keep away from windows.

❐ Do not take a bath, shower or use plumbing.

❐ If you are driving, try to safely exit the roadway and park. Stay in the vehicle and turn on the emergency flashers until the heavy rain ends. Avoid touching metal or other surfaces that conduct electricity in and outside the vehicle.

❐ If you are outside and cannot reach a safe building, avoid high ground; water; tall, isolated trees; and metal objects such as fences or bleachers. Picnic shelters, dugouts and sheds are NOT safe.

What do I do after a thunderstorm?

❐ Never drive through a flooded roadway. Turn around, don't drown!

❐ Stay away from storm-damaged areas to keep from putting yourself at risk from the effects of severe thunderstorms.

❐ Continue to listen to a NOAA Weather Radio or to local radio and television stations for updated information or instructions, as access to roads or some parts of the community may be blocked.

❐ Help people who may require special assistance, such as infants, children and the elderly or disabled.

❐ Stay away from downed power lines and report them immediately.

❐ Watch your animals closely. Keep them under your direct control.

If Lightning Strikes ...

Follow these steps if someone has been struck by lightning:

❐ **Call for help.** Call 9-1-1 or the local emergency number. Anyone who has sustained a lightning strike requires professional medical care.

❐ **Check the person for burns and other injuries.** If the person has stopped breathing, call 9-1-1 and begin CPR. If the person is breathing normally, look for other possible injuries and care for them as necessary. People who have been struck by lightning do not retain an electrical charge and can be handled safely.

Let Your Family Know You're Safe

If your community has experienced a disaster, register on the American Red Cross Safe and Well Web site available through **RedCross.org** to let your family and friends know about your welfare. If you don't have Internet access, call **1-866-GET-INFO** to register yourself and your family.

American Red Cross

For more information on disaster and emergency preparedness, visit **RedCross.org**.

Be Red Cross Ready

Tornado Safety Checklist

A tornado is a violently rotating column of air extending from the base of a thunderstorm down to the ground. Tornado intensities are classified on the Fujita Scale with ratings between F0 (weakest) to F5 (strongest). They are capable of completely destroying well-made structures, uprooting trees and hurling objects through the air like deadly missiles. Although severe tornadoes are more common in the Plains States, tornadoes have been reported in every state.

Know the Difference

Tornado Watch
Tornadoes are possible in and near the watch area. Review and discuss your emergency plans, and check supplies and your safe room. Be ready to act quickly if a warning is issued or you suspect a tornado is approaching. Acting early helps to save lives!

Tornado Warning
A tornado has been sighted or indicated by weather radar. Tornado warnings indicate imminent danger to life and property. Go immediately underground to a basement, storm cellar or an interior room (closet, hallway or bathroom).

What should I do to prepare for a tornado?

- ❒ During any storm, listen to local news or a NOAA Weather Radio to stay informed about watches and warnings.
- ❒ Know your community's warning system. Communities have different ways of warning residents about tornados, with many having sirens intended for outdoor warning purposes.
- ❒ Pick a safe room in your home where household members and pets may gather during a tornado. This should be a basement, storm cellar or an interior room on the lowest floor with no windows.
- ❒ Practice periodic tornado drills so that everyone knows what to do if a tornado is approaching.
- ❒ Consider having your safe room reinforced. Plans for reinforcing an interior room to provide better protection can be found on the FEMA Web site at **http://www.fema.gov/plan/prevent/rms/rmsp453.shtm.**
- ❒ Prepare for high winds by removing diseased and damaged limbs from trees.
- ❒ Move or secure lawn furniture, trash cans, hanging plants or anything else that can be picked up by the wind and become a projectile.
- ❒ Watch for tornado danger signs:
  - Dark, often greenish clouds—a phenomenon caused by hail
  - Wall cloud—an isolated lowering of the base of a thunderstorm
  - Cloud of debris
  - Large hail
  - Funnel cloud—a visible rotating extension of the cloud base
  - Roaring noise

What should I do if a tornado is threatening?

- ❒ The safest place to be is an underground shelter, basement or safe room.
- ❒ If no underground shelter or safe room is available, a small, windowless interior room or hallway on the lowest level of a sturdy building is the safest alternative.
  - Mobile homes are not safe during tornadoes or other severe winds.
  - Do not seek shelter in a hallway or bathroom of a mobile home.
  - If you have access to a sturdy shelter or a vehicle, abandon your mobile home immediately.
  - Go to the nearest sturdy building or shelter immediately, using your seat belt if driving.
  - Do not wait until you see the tornado.
- ❒ If you are caught outdoors, seek shelter in a basement, shelter or sturdy building. If you cannot quickly walk to a shelter:
  - Immediately get into a vehicle, buckle your seat belt and try to drive to the closest sturdy shelter.
  - If flying debris occurs while you are driving, pull over and park. Now you have the following options as a last resort:
    - Stay in the car with the seat belt on. Put your head down below the windows, covering with your hands and a blanket if possible.
    - If you can safely get noticeably lower than the level of the roadway, exit your car and lie in that area, covering your head with your hands.
  - Your choice should be driven by your specific circumstances.

What do I do after a tornado?

- ❒ Continue listening to local news or a NOAA Weather Radio for updated information and instructions.
- ❒ If you are away from home, return only when authorities say it is safe to do so.
- ❒ Wear long pants, a long-sleeved shirt and sturdy shoes when examining your walls, doors, staircases and windows for damage.
- ❒ Watch out for fallen power lines or broken gas lines and report them to the utility company immediately.
- ❒ Stay out of damaged buildings.
- ❒ Use battery-powered flashlights when examining buildings—do NOT use candles.
- ❒ If you smell gas or hear a blowing or hissing noise, open a window and get everyone out of the building quickly and call the gas company or fire department.
- ❒ Take pictures of damage, both of the building and its contents, for insurance claims.
- ❒ Use the telephone only for emergency calls.
- ❒ Keep all of your animals under your direct control.
- ❒ Clean up spilled medications, bleaches, gasoline or other flammable liquids that could become a fire hazard.
- ❒ Check for injuries. If you are trained, provide first aid to persons in need until emergency responders arrive.

Let Your Family Know You're Safe

If your community experiences a tornado, or any disaster, register on the American Red Cross Safe and Well Web site available through **RedCross.org** to let your family and friends know about your welfare. If you don't have Internet access, call **1-866-GET-INFO** to register yourself and your family.

American Red Cross

For more information on disaster and emergency preparedness, visit **RedCross.org**.

Be Red Cross Ready

Flood Safety Checklist

Floods are among the most frequent and costly natural disasters. Conditions that cause floods include heavy or steady rain for several hours or days that saturates the ground. Flash floods occur suddenly due to rapidly rising water along a stream or low-lying area.

Know the Difference

Flood/Flash Flood Watch—Flooding or flash flooding is possible in your area.

Flood/Flash Flood Warning—Flooding or flash flooding is already occurring or will occur soon in your area.

What should I do?

- ❑ Listen to area radio and television stations and a NOAA Weather Radio for possible flood warnings and reports of flooding in progress or other critical information from the National Weather Service (NWS).
- ❑ Be prepared to evacuate at a moment's notice.
- ❑ When a flood or flash flood warning is issued for your area, head for higher ground and stay there.
- ❑ Stay away from floodwaters. If you come upon a flowing stream where water is above your ankles, stop, turn around and go another way. Six inches of swiftly moving water can sweep you off of your feet.
- ❑ If you come upon a flooded road while driving, turn around and go another way. If you are caught on a flooded road and waters are rising rapidly around you, get out of the car quickly and move to higher ground. Most cars can be swept away by less than two feet of moving water.
- ❑ Keep children out of the water. They are curious and often lack judgment about running water or contaminated water.
- ❑ Be especially cautious at night when it is harder to recognize flood danger.
- ❑ Because standard homeowners insurance doesn't cover flooding, it's important to have protection from the floods associated with hurricanes, tropical storms, heavy rains and other conditions that impact the U.S. For more information on flood insurance, please visit the National Flood Insurance Program Web site at **www.FloodSmart.gov**.

What supplies do I need?

- ❒ Water—at least a 3-day supply; one gallon per person per day
- ❒ Food—at least a 3-day supply of non-perishable, easy-to-prepare food
- ❒ Flashlight
- ❒ Battery-powered or hand-crank radio (NOAA Weather Radio, if possible)
- ❒ Extra batteries
- ❒ First aid kit
- ❒ Medications (7-day supply) and medical items (hearing aids with extra batteries, glasses, contact lenses, syringes, cane)
- ❒ Multi-purpose tool
- ❒ Sanitation and personal hygiene items
- ❒ Copies of personal documents (medication list and pertinent medical information, deed/lease to home, birth certificates, insurance policies)
- ❒ Cell phone with chargers
- ❒ Family and emergency contact information
- ❒ Extra cash
- ❒ Emergency blanket
- ❒ Map(s) of the area
- ❒ Baby supplies (bottles, formula, baby food, diapers)
- ❒ Pet supplies (collar, leash, ID, food, carrier, bowl)
- ❒ Tools/supplies for securing your home
- ❒ Extra set of car keys and house keys
- ❒ Extra clothing, hat and sturdy shoes
- ❒ Rain gear
- ❒ Insect repellent and sunscreen
- ❒ Camera for photos of damage

What do I do after a flood?

- ❒ Return home only when officials have declared the area safe.
- ❒ Before entering your home, look outside for loose power lines, damaged gas lines, foundation cracks or other damage.
- ❒ Parts of your home may be collapsed or damaged. Approach entrances carefully. See if porch roofs and overhangs have all their supports.
- ❒ Watch out for wild animals, especially poisonous snakes that may have come into your home with the floodwater.
- ❒ If you smell natural or propane gas or hear a hissing noise, leave immediately and call the fire department.
- ❒ If power lines are down outside your home, do not step in puddles or standing water.
- ❒ Keep children and pets away from hazardous sites and floodwater.
- ❒ Materials such as cleaning products, paint, batteries, contaminated fuel and damaged fuel containers are hazardous. Check with local authorities for assistance with disposal to avoid risk.
- ❒ During cleanup, wear protective clothing, including rubber gloves and rubber boots.
- ❒ Make sure your food and water are safe. Discard items that have come in contact with floodwater, including canned goods, water bottles, plastic utensils and baby bottle nipples. When in doubt, throw it out!
- ❒ Do not use water that could be contaminated to wash dishes, brush teeth, prepare food, wash hands, make ice or make baby formula.
- ❒ Contact your local or state public health department for specific recommendations for boiling or treating water in your area after a disaster as water may be contaminated.

Let Your Family Know You're Safe

If your community experiences a flood, or any disaster, register on the American Red Cross Safe and Well Web site available through **RedCross.org/SafeandWell** to let your family and friends know about your welfare. If you don't have Internet access, call **1-866-GET-INFO** to register yourself and your family.

American Red Cross

For more information on disaster and emergency preparedness, visit **RedCross.org**.

Be Red Cross Ready

Hurricane Safety Checklist

Hurricanes are strong storms that cause life- and property-threatening hazards such as flooding, storm surge, high winds and tornadoes.

Preparation is the best protection against the dangers of a hurricane.

Know the Difference

Hurricane Watch—Hurricane conditions are a threat within 48 hours. Review your hurricane plans, keep informed and be ready to act if a warning is issued.

Hurricane Warning—Hurricane conditions are expected within 36 hours. Complete your storm preparations and leave the area if directed to do so by authorities.

What should I do?

- ❑ Listen to a NOAA Weather Radio for critical information from the National Weather Service (NWS).
- ❑ Check your disaster supplies and replace or restock as needed.
- ❑ Bring in anything that can be picked up by the wind (bicycles, lawn furniture).
- ❑ Close windows, doors and hurricane shutters. If you do not have hurricane shutters, close and board up all windows and doors with plywood.
- ❑ Turn the refrigerator and freezer to the coldest setting and keep them closed as much as possible so that food will last longer if the power goes out.
- ❑ Turn off propane tanks and unplug small appliances.
- ❑ Fill your car's gas tank.
- ❑ Talk with members of your household and create an evacuation plan. Planning and practicing your evacuation plan minimizes confusion and fear during the event.
- ❑ Learn about your community's hurricane response plan. Plan routes to local shelters, register family members with special medical needs as required and make plans for your pets to be cared for.
- ❑ Evacuate if advised by authorities. Be careful to avoid flooded roads and washed out bridges.
- ❑ Because standard homeowners insurance doesn't cover flooding, it's important to have protection from the floods associated with hurricanes, tropical storms, heavy rains and other conditions that impact the U.S. For more information on flood insurance, please visit the National Flood Insurance Program Web site at **www.FloodSmart.gov**.

What supplies do I need?

- ❑ Water—at least a 3-day supply; one gallon per person per day
- ❑ Food—at least a 3-day supply of non-perishable, easy-to-prepare food
- ❑ Flashlight
- ❑ Battery-powered or hand-crank radio (NOAA Weather Radio, if possible)
- ❑ Extra batteries
- ❑ First aid kit
- ❑ Medications (7-day supply) and medical items (hearing aids with extra batteries, glasses, contact lenses, syringes, cane)
- ❑ Multi-purpose tool
- ❑ Sanitation and personal hygiene items
- ❑ Copies of personal documents (medication list and pertinent medical information, proof of address, deed/lease to home, passports, birth certificates, insurance policies)
- ❑ Cell phone with chargers
- ❑ Family and emergency contact information
- ❑ Extra cash
- ❑ Emergency blanket
- ❑ Map(s) of the area
- ❑ Baby supplies (bottles, formula, baby food, diapers)
- ❑ Pet supplies (collar, leash, ID, food, carrier, bowl)
- ❑ Tools/supplies for securing your home
- ❑ Extra set of car keys and house keys
- ❑ Extra clothing, hat and sturdy shoes
- ❑ Rain gear
- ❑ Insect repellent and sunscreen
- ❑ Camera for photos of damage

What do I do after a hurricane?

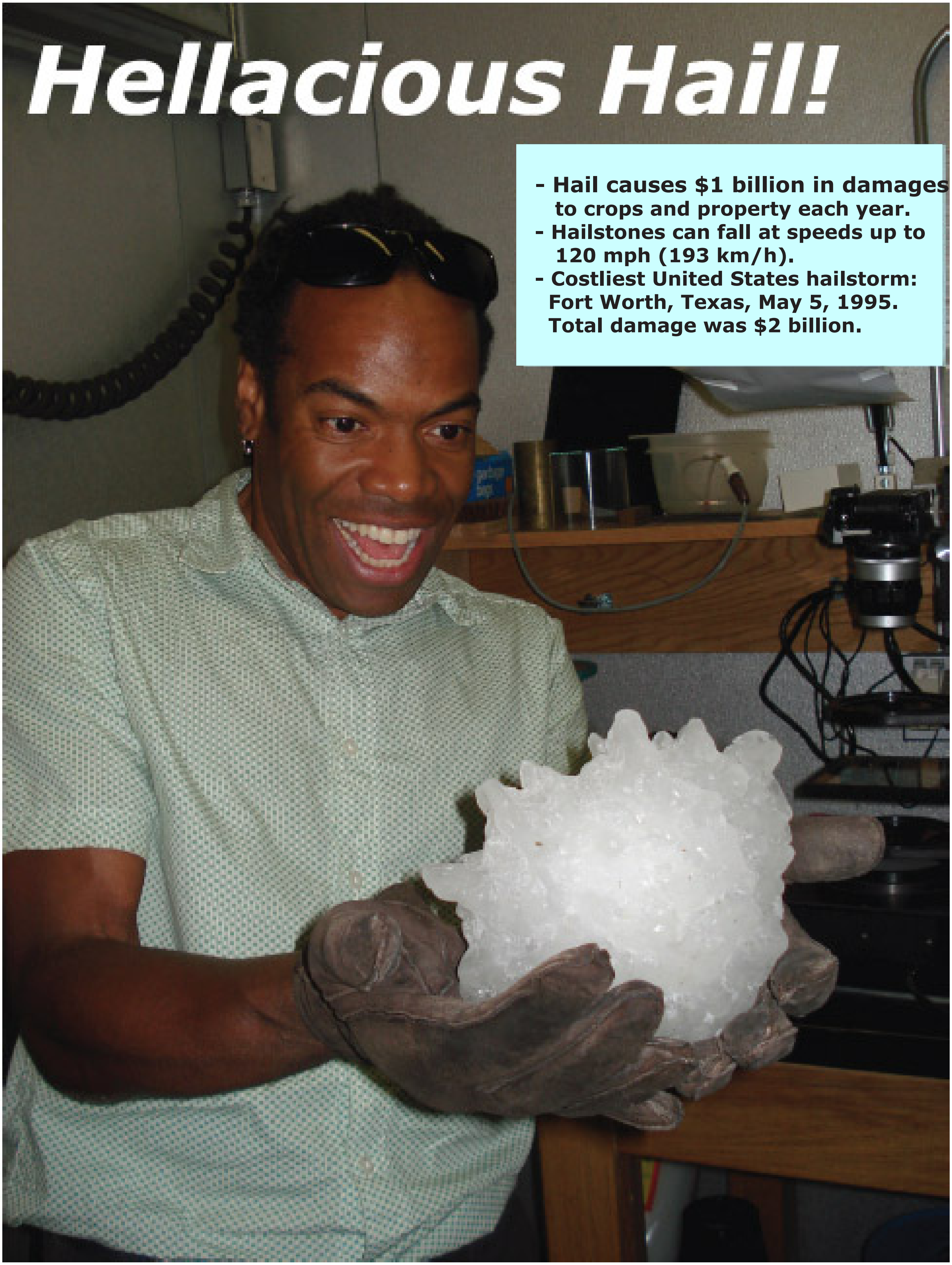
- ❑ Continue listening to a NOAA Weather Radio or the local news for the latest updates.
- ❑ Stay alert for extended rainfall and subsequent flooding even after the hurricane or tropical storm has ended.
- ❑ If you evacuated, return home only when officials say it is safe.
- ❑ Drive only if necessary and avoid flooded roads and washed-out bridges.
- ❑ Keep away from loose or dangling power lines and report them immediately to the power company.
- ❑ Stay out of any building that has water around it.
- ❑ Inspect your home for damage. Take pictures of damage, both of the building and its contents, for insurance purposes.
- ❑ Use flashlights in the dark. Do NOT use candles.
- ❑ Avoid drinking or preparing food with tap water until you are sure it's not contaminated.
- ❑ Check refrigerated food for spoilage. If in doubt, throw it out.
- ❑ Wear protective clothing and be cautious when cleaning up to avoid injury.
- ❑ Watch animals closely and keep them under your direct control.
- ❑ Use the telephone only for emergency calls.

Let Your Family Know You're Safe

If your community has experienced a hurricane, or any disaster, register on the American Red Cross Safe and Well Web site available through **RedCross.org/SafeandWell** to let your family and friends know about your welfare. If you don't have Internet access, call **1-866-GET-INFO** to register yourself and your family.

American Red Cross

For more information on disaster and emergency preparedness, visit **RedCross.org**.


Hellacious Hail!
- Hail causes $1 billion in damages to crops and property each year.
- Hailstones can fall at speeds up to 120 mph (193 km/h).
- Costliest United States hailstorm: Fort Worth, Texas, May 5, 1995. Total damage was $2 billion.

South Dakota – 2010 (Right) with Coffeyville, KS Hailstone

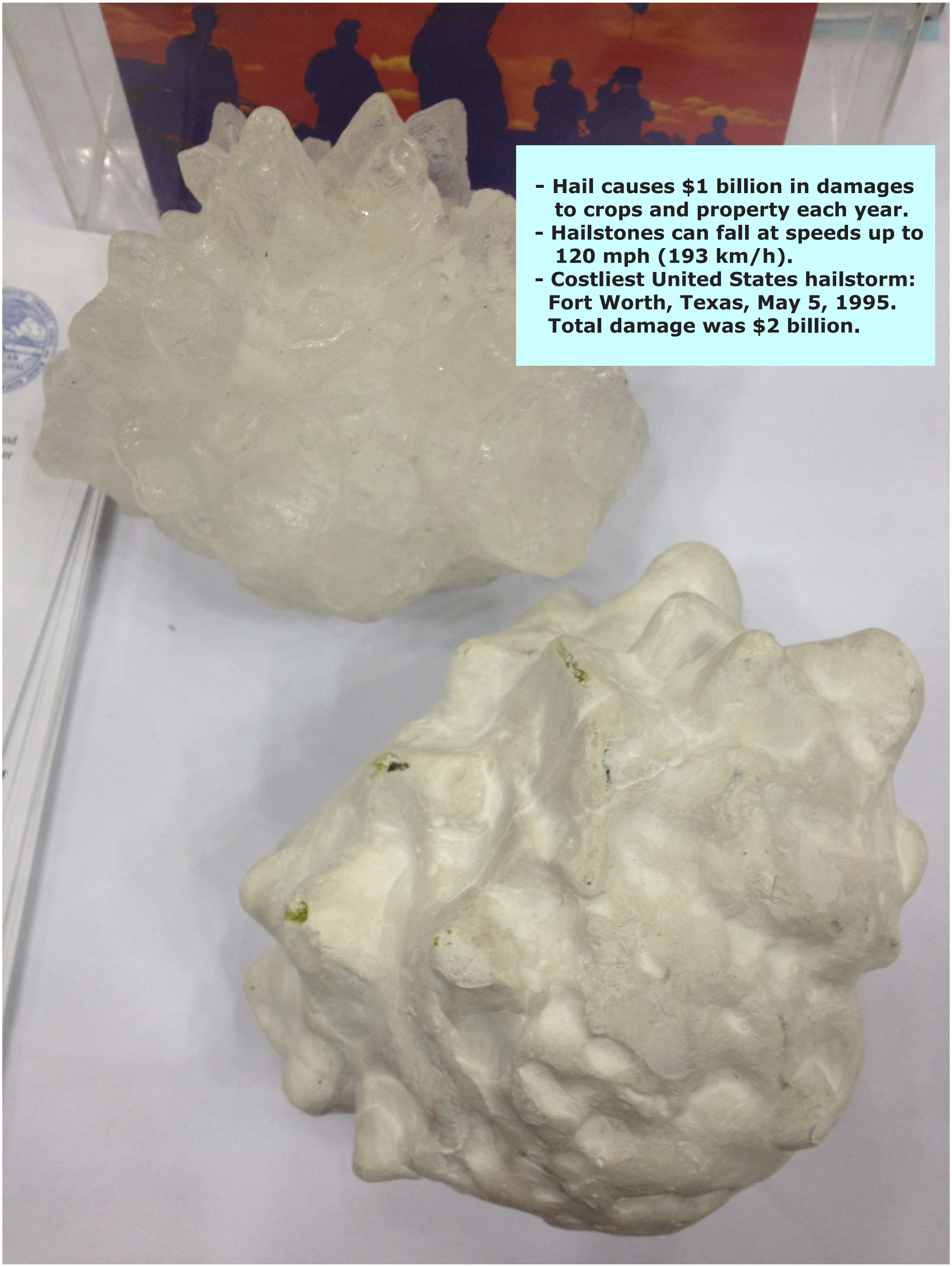
On July 23, 2010 a hailstone fell in Vivian, South Dakota that broke all former records. It weighed in at anamazing 1.9375 lbs. measuring 8 inches in diameter and 18.625 inches in circumference. The weather that summer day was particularly horrific, with winds exceeding 80 mph and a brief tornado reported. The hail was so large that craters the size of coffee cans blanketed the ground.

Aurora, Nebraska – 2003

With a diameter of 17.78 centimeters (7 inches) and a circumference of 47.63 centimeters (18.75 inches), the Aurora stone that fell on June 22, 2003 surpassed the famed hailstone that fell in Coffeyville, Kansas on September 3, 1970 in size. The Kansas stone, however, retained the #1 record for its weight until the South Dakota hailstone fell in 2010.

Coffeyville, KS – 1970

Previously the largest known hailstone to fall in the United States, the Coffeyville stone weighed .75 kilograms (1.65 pounds) with a diameter of 14.4 centimeters (5.7 inches) and circumference of 44.7 centimeters (17.6 inches). The stone no longer exists, but replicas of it can be found at NCAR and at the Dalton Defenders Museum in Coffeyville.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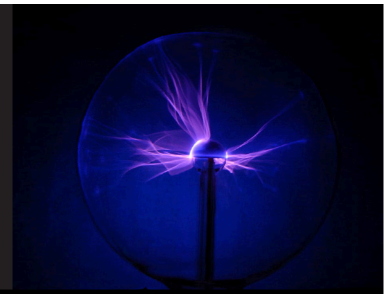
ELECTRIFYING DEMONSTRATIONS

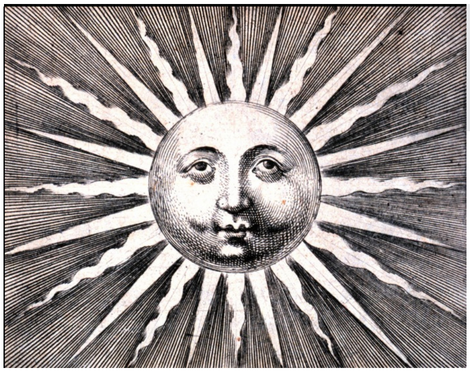


Static electricity can be illustrated by showing students the plasma ball. Plasma is stripped electrons, and atoms without electrons or with a build-up of electrons is what causes static electricity. In many plasma balls, the plasma gives off a light different than most static electricity we are used to. The light looks like lightning. Demonstrate the different ways you can control some of the electrons by putting your hand to the ball. The charged plasma will move toward your hand and the current will travel to you to the ground. If you put a florescent light up to the plasma in a darkened room, it will light. If you hold the plasma tube, and someone tickles the back of your hand, you'll get a small shock! Then again, if you are holding on to the static tube, you can also be the shocker. Tickle the back of a friend's hand with your free hand, and you'll shock him or her!

A Van de Graaff generate is a tool used to generate static electricity. When the Van de Graaff generator is turned on, the lower roller (charger) begins turning a thick rubber belt. Since the belt is made of rubber and the lower roller is covered in silicon tape, the lower roller begins to build a negative charge and the belt builds a positive charge. Silicon is more negative than rubber; therefore, the lower roller is capturing electrons from the belt. The strong negative charge on the roller next repels electrons near the tips of the brush at the top of the unit. The brush underneath the metal head next rubs the belt and begins to stripe nearby air molecules of its electrons. As long as there is air between the lower roller and brush assembly, the Van de Graaff generator will continue to charge the belt.

Stack foil muffin tins on the Van de Graaff generator's metal "head" and they will go flying one by one. Put a wig on the head and it will definitely look like a bad hair day. Blow bubbles toward the generator to see if they repel or attract. Why do you think this happens?

And remember -- Always read up on safety before using a Van de Graaff generator in any capacity!



Static Electricity Tubes

Students learn properties of electricity by creating static electric tubes.
Note: Dry weather conditions are best for the activity's success.

Student Learning Objectives

- Students learn that static electricity is created by a separation of positive (protons) and negative (electrons) charges within atoms of objects resulting in a charge imbalance.
- Students learn that an excess charge can be neutralized when brought close to a electrical conductor or a region with an excess charge of the opposite polarity (positive or negative) as occurs with lightning..
- Particles with the same charge repel or push each other apart; particles with the opposite charge attract one another.

Time
Two class periods:

- 1 45-minute class period to make the tubes
- 1 45-minute class period for activity and discussion

Materials

- 15" transparent plastic tube for each student (available at Lowes/Home Depot in the florescent lightning section
- Bag of styrofoam packaging pellets or "popcorn"
- Duct tape
- 12"x12" wool cloths, one per student

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth Science

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Directions

1. As a group, break styrofoam packaging material into small crumbs or purchase istyrofoam in small pellet form to avoid this step. (Static elec tricity will be plentiful!)
2. Duct tape one end of the 15" plastic tube shut.
3. Place two cups of styrofoam crumbs/pellets into each clear tube.
4. Duct tape the remaining end of the tub shut, and secure.
5. Once styrofoam is securely in the tube with taped ends, rub the tube vigorously using the wool cloth for approximately one minute.
6. Next rub your hand along the tube and notice what happens.

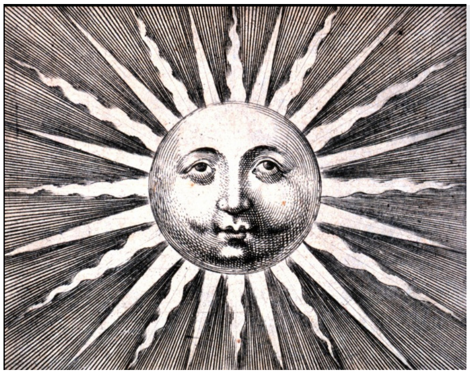
Ask students these questions:

1. What happens when you rub the styrofoam-filled tube with the wool? Why? What other substances might work to create static electricity? Try various fabrics and substances to find out.
2. Why does the styrofoam move away from one's hand near the tube? Is there a way to prevent the styrofoam from moving?
3. How is the static electricity produced different from an electric current? (Electric current can be generated at a power station and delivered via a wire as a power source to homes and other locations.)

Background Information

To understand static electricity, you have to think about atoms. Atoms make up everything we can see and everything with mass. Atoms have a nucleus consisting of neutrons and protons and a surrounding "shell" that is made up of electrons. Electrons are somewhat free to jumb from one object to the next. Normally, the number of electrons and protons are the same in an atom. But when an atom has an excess of electrons, it is negatively charged, and when it has an excess of protons (from loosing its electrons), it is positively charged. Some materials are more apt to give up electrons when near another object (i.e. wool, fur), and some objects are apt to pick up extra electrons that they are in contact with (styrofoam, teflon). When a student rubs the plastic tube with the wool, he or she is generating static electricity. Watch the styrofoam attract and repel different substances such as the plastic of the tube and one's hand.

Extension: Rub the tube with different items other than wool: paper, fur, foil.... Is static electricity still generated? Why or why not?



How Far is That Storm?

In this activity students figure out how far they are from a storm by watching lightning and listening for thunder. You'll need a stormy day, a video of a thunderstorm, or a simulated storm.

Student Learning Objectives
- Students collect, analyze data and present results.
- Students learn that lightning and thunder happen at the same time but light is seen first because light travels faster tha sound.

Time
50 minutes (or 10 minutes without data analysis)

Materials
- A nearby thunderstorm (or simulate one!)
- Stopwatches (or the ability to count "one-Mississippi, two-Mississippi...)
- Paper and pencil for data recording
- Craft paper and markers
- Internet access or printed copies of the student version printed from Kids' Crossing (URL above)

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth Science

Source
This classic activity is from Web Weather for Kids

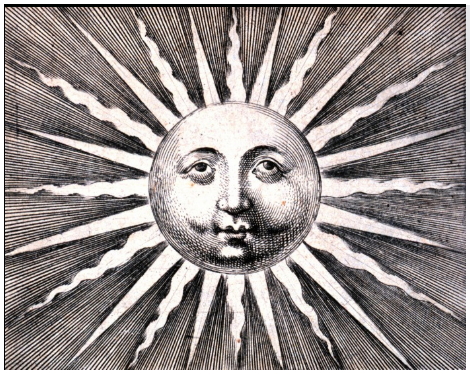
Related Web Pages for Students
Kids' Crossing Web Pages for Students:
Watch Out for Dangerous Weather!
http://www.eo.ucar.edu/kids/dangerwx/index.htm
Student Version of Activity
http://www.eo.ucar.edu/kids/dangerwx/tstorm6.htm

Directions
1. Divide students into small groups. Have each read the student version of this activity (URL listed above) for instructions.
2. Discuss the reading as a class including how light and sound travel at different speeds. Review the activity in detail.
3. Assign each group stopwatches, paper and pencil and a safe space near a window from which to witness lightning if a thunderstorm happens to be occurring. If not, which is likely, make an imaginary storm with a flashlight or switch-controlledlight to represent lightning and clashing cymbols to represent thunder.
4. Instruct students to time the number of seconds between the flash of lighting and the rumble of thunder, and to write down the number. Ask them to also write down the actual time. If the weather allows, have groups take several measurements over 15 minutes or more, noting the time of each measurement. (This will allow students to assess whether the storm is moving towards their location or away.) Simulate the movement of the storm by consistently increasing or consistently decreasing the time between lightning and thunder over a given time period of various lightning strikes.
5. Have student groups calculate the distance of the storm from the measurements using these instructions: Every 5 seconds counted equates to a distance of one mile. Divide the number of seconds you count by 5 to get the number of miles. If student groups made several measurements, have them perform the calculation for each measurement to try to answer the following: Was the storm moving towards school, away from school, or not moving either direction?

Assessment: Have student groups create a poster from a sheet of craft paper that displays their data both in a table and visually (with a graph or map) to present their analysis to the class. Hang posters around the room and discuss all results.

Background Information
A bolt of lightning heats the air along its path causing it to expand rapidly. Thunder is the sound caused by the rapidly expanding atmosphere. The light and sound actually happen at the same time, but the light of the lightning flash travels faster than the grumbling sound of the thunder. The time between the flash of light and thunder will tell you how far you are from where the lightning struck.

Extensions
Read and discuss: A Close Encounter with Lightning and discuss safety (http://www.eo.ucar.edu/kids/dangerwx/tstorm9.htm).



Make Your Own Lightning!

In this activity students observe lightning formation.

Related Kids' Crossing Web Pages for Students
What Gives Lightning its Zap?
http://www.eo.ucar.edu/kids/dangerwx/tstorm5.htm
Student Version of Activity from Web Weather for Kids
http://www.ucar.edu/educ_outreach/webweather/lightningact.html

Student Learning Objectives

- Students learn that lightning forms because of the attraction of positive and negative changes

Time

- 30 minutes

Materials

For each group of students:

- For each group of four:
- Styrofoam plate
- Thumbtack
- Pencil with new eraser
- Aluminum pie plate
- Small piece of wool fabric

(Note: there are animations on the Web pages, so using computers rather than printouts is preferable.)

National Standards

A: Science as Inquiry
B: Physical Science
D: Earth & Space Science

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Directions

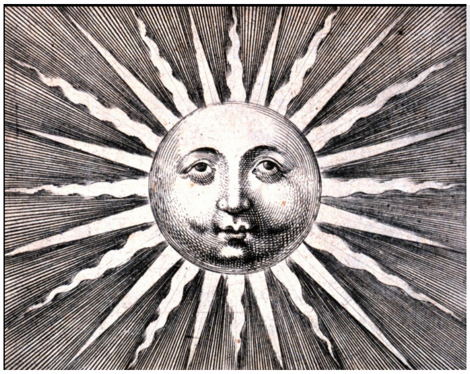
1. Divide students into groups of four. Have groups read the article *What Gives Lightning its Zap?* and the Student Version (URLs listed above).
2. Discuss the reading and directions as a class. Make sure students understand of the concept of negative and positive charges.
3. Distribute supplies and directions to each group. If possible, show students a completed version so they know what it should look like.
4. Instruct students to push the thumbtack through the center of the pie pan from the bottom and then push the eraser end of the pencil into the thumbtack. Students should only hold the pie plate by the pencil.
5. Following the directions in the students handout, complete the set-up by putting the Styrofoam plate upside-down on a table, rubbing the bottom of the plate vigorously with the wool for one minute, picking up the pie pan with its pencil handle and placing it on top of the styrofoam plate.
6. Instruct a student from each group to touch the edge of the pie plate with a finger. Ask if they felt a shock. Have groups repeat the process of rubbing the plate with the cloth and allow another member of the group to touch the pie plate. Students may be able to actually see the sparks if the classroom lights are turned off. (This experiment works best in low humidity.)
7. For extra excitement, get a Neon Gas Spectrum Tube (about $20 from Edmund Scientific, among other places). Tell students that on the count of three you will turn off the room lights. That is when students should touch the end of the tube to the pie plate. When the tube touches the plate, they will see a spark - lightning!

Background Information

When negative charges (electrons) in the bottom of a cloud are attracted to positive charges (protons) in the ground, and the protons rush up to meet the electrons, we see lightning. In this experiment, the finger is the cloud and the pie pan is the ground. Rubbing the Styrofoam plate with the wool cloth generates the positive charge as electrons are rubbed off of the plate. Students will likely be able to provide other examples of static electricity and attraction from daily life (e.g., shuffling across car¬pet, clothing stuck together, rubbing balloons against clothing).

Extensions

Play the Lightning Impacts Our Lives True-False quiz (http://www.eo.ucar.edu/kids/dangerwx/tstorm2.htm).
Read and discuss: A Close Encounter with Lightning (http://www.eo.ucar.edu/kids/dangerwx/tstorm9).



Make a Tornado Model

In this activity students create and observe a vortex.

Related Kids' Crossing Web Pages for Students
Look Out for Dangerous Weather Tornado Section
http://www.eo.ucar.edu/kids/dangerwx/tornado1.htm
Student Version of Activity from Web Weather for Kids
http://www.ucar.edu/educ_outreach/webweather/tornact3.html

Student Learning Objectives
Students learn how rotating air and an updraft can cause a tornado.

Time
40-50 minutes

Materials
For each group:

- 10" x 12" piece of wood or foam core board
- Two 9" x 10" clear acetate sheets (.010" thickness)
- Glue gun or tape
- Small hand fan
- Deli dish or cup
- 7" clear plastic plant saucer with a 2" diameter hole cut in the middle
- Water
- Dry ice (Find it at a grocery; only a teacher wearing gloves should handle it!)
- Gloves (for teacher)
- Internet access or printed copies of reading (URLs above)

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth Science

Source
This activity is from
Web Weather for Kids!
.

Directions

1. Have groups read the *Look Out for Dangerous Weather Tornado* Section (URL above) and discuss the reading as a class.
2. Ask students what conditions are needed for a tornado to form (mainly rotating air and an updraft).
3. Explain that in this activity students will made a model of those conditions to form a miniature tornado.
4. Divide students into groups of four or five and have each group read the student version of the activity (URL above). If possible, show students a completed version of the set-up so that they know what the product will look like. Provide groups with supplies (not dry ice yet).
5. Instruct student groups to use glue gun or tape to attach the cup in the center of wood or foam core board.
6. Point out the top view diagram (steps 2 and 3 on the Student Version) when students are gluing the acetate sheets. Glue one of the acetate sheets to one side of the cup. Then glue the rest of the sheet in a half circle around but not touching the cup. Glue the second sheet around the opposite side of the cup in a similar fashion. The two sheets must overlap, but not touch.
7. For each group, pour about half a cup of water into the deli dish and, using gloves, place a few small pieces of dry ice into the water.
8. Once dry ice and water are in the cup, instruct students to place the plant saucer upside down on top of the upright pieces of acetate and hold the fan over the hole in the saucer to draw the air up. Be patent, adjusting the fan until a vortex forms.

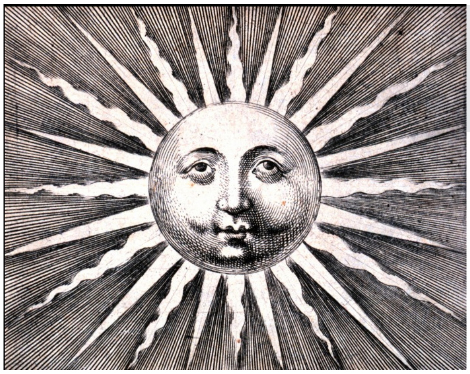
Background Information
The whirling fan at the top creates a spinning "updraft" or vortex. This pulls air in at the bottom of the container (in the spaces between acetate sheets) and out through the hole in the plant saucer.

About Dry Ice: Dry ice is frozen carbon dioxide. It quickly turns to a gas as it warms. The gas cools the air, causing a cloud to form as water vapor condenses. The little cloud enters the updraft created by the fan, allowing us to see the shape of the vortex just like we might see the dust and debris that a tornado has picked up from the land.

Note: If dry ice is not available in your area, try using the KERI electric Mist Maker with higher vinyl walls and a larger dish to contain the water. (We purchased ours in January 2005 for $24 from mainlandmart@yahoo.com.)

Extensions
Read Tornadoes on the Soccer Field (http://www.eo.ucar.edu/kids/dangerwx/tornado2.htm) and discuss tornado safety.

Vortex Race: Who Sets the Pace?



Student Learning Objectives
Students learn how rotating air and an updraft can cause a vortex in air to form, and of different types of vortices in nature. Students also practice the scientific method.

Time
40-50 minutes

Materials
For each group:
- Two 2-liter bottles per group
- A source of water per group (ideally a sink)
- One funnel per group (optional)
- One large tub per group with a minimum of 12-inch sides
- Pen or pencils
- Paper to record their results
- One stopwatch per groupo

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth Science

Source
This activity is adapted from Steve Spangler at Educational Innovations, Denver, CO.

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

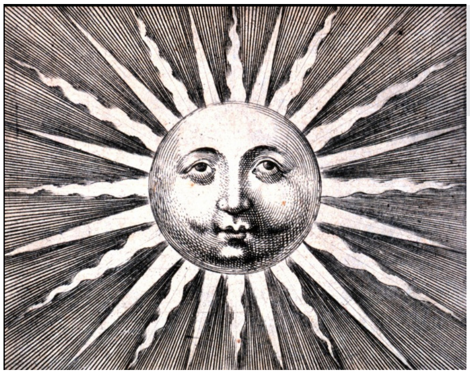
Directions

This is a fun activity at science fairs and festivals or as an attention-getting introductory or culmination activity to a classroom weather unit. Remember learning can be fun!

1. Discuss what the term "vortex" means (a spinning, often turbulent motion of a fluid). Examples include tornadoes, dust devils, hurricanes, and water spouts in nature.
2. Ask students what they think causes a vortex to form in various setting. If they are unsure, return to this question after the activity and assign a Web search for the answer(s).
3. Tell the students that they are going to conduct races in small groups to learn about properties of vortices and air.
4. Assign four students to a group and provide one large plastic bin, pitchers of water (or sink access) and two two-liter bottles per group. Afix screw-on tornado tubes to each bottle (optional).
5. Have students fill each of their bottles with water, then tell them they are going to conduct an experiment to see how fast they can empty their water into the plastic tub without squeezing their bottle(s). Have each student write down their prediction as to how long the activity will take him/her.
6. Have each group conduct four trials, one per student, using a stop watch to record the time it takes each student to complete the task.
7. Next have each group break into pairs to race one another, but this time, have one student empty the water by swirling it into a vortex, and have the other student empty it in the traditional method of turning it over and pouring. Have the other two students in each group serve as time keepers. Have each pair race three times, recording the time each time time and alternating who will empty the water by creating a vortex.
8. Have students analyze their results within their groups and then share and discuss the finds to draw possible conclusions to their findings (if any).

Background

Creating a vortex in a two-liter bottle to empty it should accelerate the task of emptying the bottle. Why? Because it creates an efficient method of allowing the water out and the air in. When a student trys to use the ol' "glug glug" method of simply turning a bottle upside down, the air will not have a clear and open path inside the bottle since water will be blocking its way. Sometimes even older students forget that air takes up space!



Vortex Jamboree

Student Learning Objectives
Students learn about vortices, density and angular momentum during this fun and informative activity.

Time
One 50-minute class period

Materials
For each group:
- 15 tornado tubes for a class of 30
- 30 empty plastic bottles
- Water
- Food Coloring
- Deli dish or cup
- Optional items for discovery:
  - styrofoam pellits
  - sequins
  - dishwashing soap
  - 1 c. vegetable oil, water & 2 drops food coloring
  - lamp oil, water, food coloring
  - glitter
  - raisins
  - small Monopoly homes
  - food coloring

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth Science

Inspired by Craig Burnham, the inventor of the tornado tube!

Did you know?

The word "tornado" comes from the Spanish word "tornada," which means thunderstorm.

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/

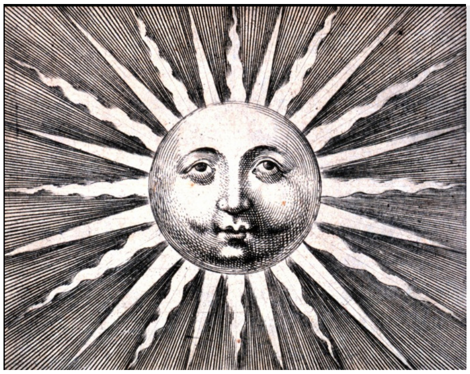
Directions

Tornadoes are intriging but there's a way to get to know a spinning vortex without having to experience one first hand.

1. Discuss what the term "vortex" means (a spinning, often turbulent motion of a fluid). Examples include tornadoes, dust devils, hurricanes, and water spouts in nature.
2. Ask students what they think causes a vortex to form in various setting. If they are unsure, return to this question after the activity and assign a Web search for the answer(s).
3. Tell the students that mixing art and science can be highly beneficial in the real world as well as in a classroom setting, and that this activity has both the aesthetics of art and the knowledge of science.
4. Have students work in pairs. Provide two bottles and one tornado tube per pair.
5. Have students work together to determine what tornado tube they choose to make and observe. Provide the choices on the board and list the number you desire of each, or leave it open for students to freely choose. Discuss how the various additions to the tube impact the vortex, if at all. Notice different densities of substances and how they affect one's vortex. Use just vegetable oil and food coloring in one bottle. What happens? Experiment and enjoy!

Background

Vortices occur in various places and ways in nature – from one's bathtub to the plains of Tornado Alley in the U.S. Midwest. A tornado is Earth's fastest moving vortex moving around a center of low atmospheric pressure at speeds that can reach 300 mph. As a vortex's winds spiral inward, they become faster due to angular momentum (the air has less area to cover closer to the center of a vortex so it will spin faster). While tornadoes form during thunderstorms typically, hurricanes are actually a collection of many thunderstorms that organize around a low pressure area and begin to spin counterclockwise (in the Northern Hemisphere). They don't spin as fast as a tornado – maximum wind speeds in a hurricane hoover around 180 mph), but hurricanes are significantly larger and can affect multiple states and large expanses of land and coastline. Both tornadoes and hurricanes get their start when two different air masses meet, causing warm air to rise rapidly and cold air to sink. This most often produces large cumilonimbus clouds, which in turn produce thunderstorms. With a hurricane, a vortex begins to occur with the help of Earth's coriolis effect. In tornadoes, powerful updrafts combined with wind shear help to create potential tornadoes. They can happen anywhere but are most common in spring and summer and in the US plain states.



Hurricane Storm Surge

Students model conditions during a hurricane that produce storm surge and witness its impact on model coastlines

Student Learning Objectives
• Students learn how storm surge forms during a hurricane.
• Students learn how the shape of a coastline influences the amount of flooding caused by a hurricane's storm surge.

Time
30-40 minutes

Materials
For each group of students:
• A plastic plate with a line marked inside the rim with permanent
• marker
• Container of playdough
• Six sugar cubes
• One cup of water tinted with blue food coloring.
• Computers with Internet access or printouts of the pages at the URLs above.

For the class:
• Hair dryer
• A baking sheet or plastic garbage bag

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth & Space Science
E. Science & Technology

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Kids Crossing Website Resources
How Do Hurricanes Form?
Hurricanes Impact Our Lives
Student Version of Activity
http://www.eo.ucar.edu/kids/dangerwx/

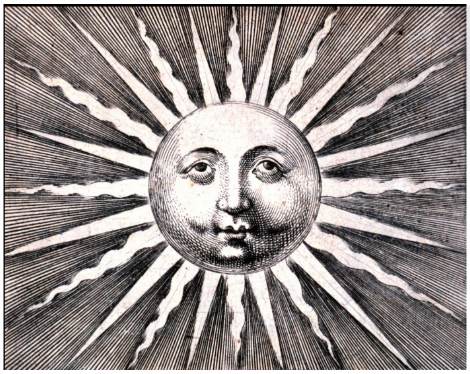
Directions
1. Have students read How Do Hurricanes Form? and Hurricanes Impact Our Lives (URLs above). Discuss the reading as a class. Ask students what storm surge is and what causes it. What type of coastline will be impacted the most by flooding? Show students photographs of different types of coasts (some are flat or have steep cliffs, and they may have river drainages). Describe how the ocean close to shore can slope gradually or steeply.

2. Divide students into groups and have each group read the student version of the activity (URL above). Set up the challenge with the class: Based on your knowledge of what type of coastline will have the most flooding, can you make a model coastline that has one area that will get the worst flooding and one area that will not flood?

3. Provide each group with a plastic plate, a container of playdough to form the land, and six sugar cubes, which will represent houses along the coast. Tell groups that the blue line on the plate is the level of the ocean water under normal high-tide conditions. Allow each student group to create their coastlines on one side of the plastic plate. Have students decide where to locate the sugar cube houses. Then have students fill the plastic plate with blue water up to the line.

4. Test student models one at a time. Gather the class around a model and allow the group to explain where they think there will be the most flooding and which areas will not flood. Aim the hair dryer so that wind blows across the "ocean" towards the "land". The water will have nowhere to go and will pile up on the shore. The sugar houses that have been flooded will be blue in color and may start to fall apart. (As water will likely splash out of the plate, you may wish to put the models in a baking pan or plastic garbage bag.) Summary: Did the models work as students predicted they would?

Background Information
In this model, the hair dryer is simulating the winds of a hurrcane, which push water into a mound at the storm's center. As the hurricane approaches the coast, the mound of water is unable to escape anywhere but onto land. A hurricane will cause more storm surge in areas where the ocean floor and coastal areas slope gradually.



Hurricane? or Tornado?

Learners are asked basic questions about hurricanes and tornadoes in order to improve their content knowledge and/or to assess current knowledge before a weather unit begins.

Related Web Pages for Students

- http://eo.ucar.edu/kids/sky/index.htm
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/weather/
- http://www.ucar.edu/learn

Student Learning Objectives
- Students will review critical differences between tornadoes and hurricanes.

Time
- 30 minutes

Materials
For each student or group:
- One tornado/hurricane sign.
- Questions provided

National Standards
A: Science as Inquiry
B: Physical Science
D: Earth & Space Science

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Directions
This is a fun review after students have spent time learning about severe weather events. It is also an excellent pre- and post-assessment tool for evaluating how knowledgeable students are after a until as compared to before.

1. Assign teams or let students play individually before or after severe weather has been studied.
2. Make a class set of signs with a hurricane on one side and tornado on the other that participants can answer with.
3. Use NCAR's digital library of images to find appropriate images for your signs (http://www.fin.ucar.edu/ucardil/).
4. Allow discussion before and after each question if productive and if they extend one's understanding of radar.

Background Information
Weather impacts our daily lives, from the clothes we wear to the food we eat. Technological advances have resulted in greater lead time and warnings before severe weather events occur. But knowing about tornadoes and hurricanes and how to be prepared if you are ever impacted by such storms is important knowledge to possess.

Extensions
Have students research severe weather events and develop their own series of True/False questions that can be compiled into a Jeopardy game and played with the class as a weather review.

Have students research careers involving severe weather and radar starting with common coursework and majors in college. Then extend the research into common career paths.

Statement:

These severe weather events are the largest storms that occur on Earth's surface.

Answer: Hurricane

Statement:

Winds in this severe weather event can reach speeds of 134 meters per second or 300 mph.

Answer: Tornadoes (which produce the fastest winds on Earth)

Statement:

This severe weather event is ranked for its severity using the Saffir-Simpson Scale with a range of 1 to 5.

Answer: Hurricanes (tornadoes use the Enhanced Fujita Scale)

Statement:

This severe weather event occurs in specific locations around the world.

Answer: Hurricanes, Cyclones, Typhoons They occur in Earth's warm oceans. (A tornado can occur anywhere.)

Statement:

As many as 15 (2005) of these storms have been known to occur in a single season.

Answer: Hurricanes (2005 in the Atlantic. There are over 1000 tornadoes in the US annually on average.)

Statement:

The phenomena of a "storm surge" is associated with this type of storm.

Answer: Hurricane

Statement:

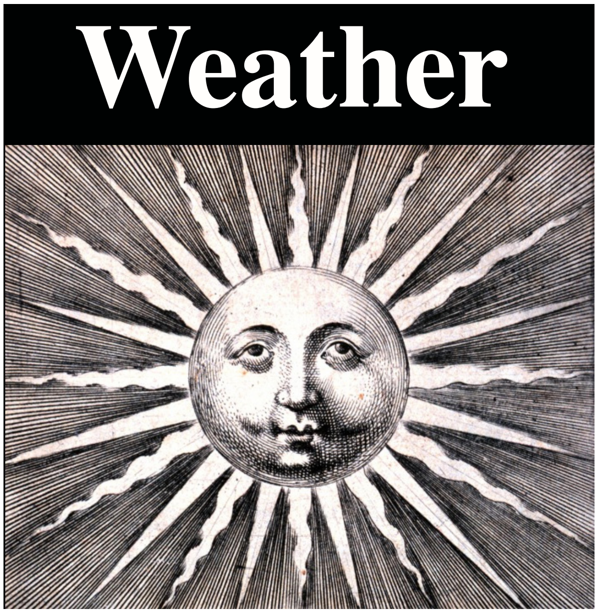
These storms used to be ranked by the Fujita Scale. What severe weather event am I referring to and what is the new scale used as of Feb. 2007?

Answer: Tornadoes. The new scale is called the Enhanced Fujita Scale.

Statement:

June 1st to November 30th is the season for these storms in the United States.

Answer: Hurricanes



Weather Words for a Storm Chaser

Adiabatic– Changes in temperature caused by the expansion (cooling) or compression (warming) of a body of air as it rises or descends in the atmosphere, with no exchange of heat with the surrounding air.

Air Mass– A body of air that extends hundreds or thousands of kilometers horizontally and is relatively uniform in temperature and moisture content.

Air pressure– The force per unit area exerted against a surface by the weight of air above that surface. Low pressure areas have less atmospheric mass above their location, whereas high pressure areas have more atmospheric mass above their location

Anvil– A cloud feature represented by the spreading of the upper portion of a cumulonimbus cloud near the tropopause.

Barometer– An instrument for determining the pressure of the atmosphere.

Beaufort Scale– A system used to estimate and report wind speeds with a scale that ranges from 0 (calm) to 12 (greater than 73.5 mph).

Classic Supecell– Radar characteristics often (but not always) include a hook echo, bounded weak echo region (BWER), V-notch, mesocyclone and sometimes a TVS. Visual characteristics often include a rain-free base (with or without a wall cloud), flanking line, overshooting top, and back-sheared anvil, all of which normally are observed in or near the right rear or southwest part of the storm.

Convective storm– A thunderstorm as a result of the rapid upward movement of warm, moist air.

Convergence- The net inflow of air into a region, typically caused by horizontal wind motion; the opposite of divergence.

Cumulonimbus cloud– A cloud type that is very dense, and extends vertically higher than any other cloud type, sometimes reaching the top of the troposphere or tropopause where it spreads out in the form of an anvil. The base of a cumulonimbus cloud is usually dark and frequently produces virga, heavy precipitation, and lightning. Cumulonimbus clouds are often called thunderheads and can produce tornadoes as well.

Cyclone- (1) An atmospheric circulation that rotates counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere, which usually has a diameter of 2000 to 3000 kilometers. (2) Colloquial term for a tornado. (3) Shortened name for a tropical system (see Tropical Cyclone).

Derecho - Any family of downburst clusters produced by an extratropical mesoscale convective system

Divergence- the net outflow of air from a region, typically caused by horizontal wind motion; the opposite of convergence

Downburst– An area of strong winds produced by a downdraft that often causes damages over a relatively small area from less than 1 km to 10 km.

Downdraft– Downward moving air in a cumulonimbus cloud.

Enhanced Fujita Scale (EF Scale)- An improved tornado damage rating scale. It takes into account structures and vegetation, as well as structural integrity of buildings.

EF0	Weak	65 - 85 mph	Light damage
EF1	Weak	86 - 110 mph	Moderate damage
EF2	Strong	111 - 135 mph	Considerable damage
EF3	Strong	136 - 165 mph	Severe damage
EF4	Violent	166 - 200 mph	Devastating damage
EF5	Violent	Over 200 mph	Incredible damage

Flash Flood- A local flood of great volume and short duration generally resulting from heavy rainfall in the immediate vicinity.

Flood- The condition that occurs when water rises and overflows the natural or artificial confines of a body of water onto normally dry land, or accumulates in low-lying areas.

Front– The boundary between two air masses with different temperature and moisture characteristics.

Funnel Cloud- a rotating cloud column or inverted cloud cone extending downward from a cloud base that is not in contact with the ground.

Humidity- A measure of the water vapor content of the air.

Hydrometeors– Any water particle in the atmosphere.

Instability- The tendency for an object, if moved, to accelerate in the direction of initial movement; in particular for meteorology, the tendency for air parcels that are warmer than their environment to accelerate upward after being lifted.

Inversion– A situation in which the temperature increases with height and there is colder air under warmer air. Temperature inversions are common during the morning hours following a dry, clear and long night.

Isobar- A line connecting points of equal pressure.

Isotach- A line connecting points of equal wind speed.

Mesocyclone– A column of spinning air (a vortex) 5 to 10 kilometers across and a precursor to the development of a tornado.

Mesoscale- Of or relating to meteorological phenomena approximately 2 to 200 kilometers in horizontal extent; thunderstorms and squall lines are two examples of mesoscale events.

Meteorologist- A scientist who studies the weather and atmosphere.

Microburst– A downburst of air that covers an area less than 4 kilometers (km) per side with peak winds that usually last no more than 5 minutes.

Mammatus– Hanging pouches (of cloud) on the undersurface of a cloud commonly seen during stormy weather.

Isotherm- A line connecting points of equal temperature.

Nowcasting- Short-term weather forecasting for the near future, generally from minutes up to a few hours in the future.

Planetary Boundary Layer (PBL)– The lowest layer of the troposphere where wind is influenced by friction. The thickness or depth of the PBL is not constant. Rather, it is influenced be the density of the air, which fluctuates with temperature. Warm seasons tend to have a thicker PBL than cooler seasons. Cold air is denser than warm air.

Saffir-Simpson Scale– The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 categorization based on the hurricane's intensity at the indicated time. The scale – originally developed by wind engineer Herb Saffir and meteorologist Bob Simpson – has been an excellent tool for alerting the public about the possible impacts of various intensity hurricanes

Squall Line– A line of active thunderstorms either continuous or with breaks.

Straight-line wind– Current of air in which the ground-relative motion does not have any significant curvature, such as with tornadoes, which have significant curvature.

Updraft– The upward vertical movement of air. Often a pocket of warm air will typically be less dense than the surrounding region, and so will rise until it reaches air that is either warmer or less dense than itself. Updrafts can create large clouds and is the main cause for thunderstorms.

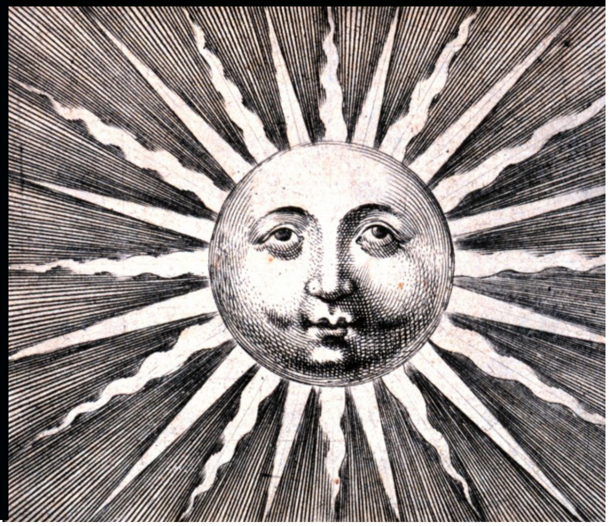
Virga– An observable streak or shaft of precipitation that falls from a cloud but evaporates before reaching the ground.

Vortex– A column of a spinning fluid, usually air or water.

Wave Cloud– While not a specific cloud type, a wave cloud pattern forms wave shapes from the atmospheric internal waves. Wave clouds are also called Kelvin-Helmholtz clouds. They are common over and near mountains.

Wind Shear– A difference in wind speed or direction between two wind currents in the atmosphere.

References & Resources



Radar and Weather Together began as a collection of actlvities for public engagement at the USA Science and Engineering Festival 2010 in Washington, DC. As representatives of **National Science Foundation**-sponsored programs, educators at the National Center for Atmospheric Research and meteorologists from the Center for Severe Weather Research, teamed to bring a Doppler on Wheels (DOW) and weather and radar related activities to their exhibition, ***Adventures of a Storm Chaser.*** This collection is a compilation of the information shared and the vehicles (both literally and figuratively) through which we enaged our audience.

Below are many of the individuals who contributed to either the information or the activities shared within these pages, as well as Websites that were of particular value. All who work in education know that "standing on the shoulders of giants" is at the heart of what we do and the foundation of our best work. A sincere "thank you" to the "broad shoulders" that follow.

- *Caryle Calvin, Susan Foster, Bob Henson, Lynne Davis and others who wrote and developed the **Web Weather for Kids** Website, where some of the included activities were born.*

- *Lisa Gardiner, designer of Kids' Crossing and the writer behind a handful of the activities included in **Radar and Weather Together.***

- *Jeff Haley, at Mississippi State University, the author of the Website www.theweatherprediction.com, who welcomed the use of some of the site's resources.*

- *Karen Kosiba and Rachel Humphrey, meteorologists with the Center for Severe Weather Research in Boulder CO, who reviewed radar activities & shared resources.*

- *Rhonda Lange, National Oceanic and Atmospheric Administration, Boulder, CO, who authorized permission for the radar velocity image from NOAA's Student Activities in Meteorology II (SAMII).*

- *Josh Wurman, president of the Center for Severe Weather Research, Boulder, CO, who partnered with us at the 2010 USA Science & Engineering Festival in Washington, DC.*

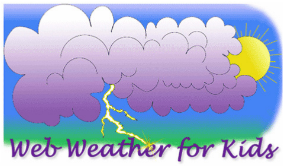
And to the following organizations for their excellent resources (and research) that contributed to the information shared:

Center for Severe Weather Research, Boulder, CO (www.cswr.org)
National Center for Atmospheric Research, Boulder, CO (www.ucar.edu)
National Severe Storms Lab (NSSL), National Oceanic and Atmospheric Administration, Norman, Oklahoma, (www.nssl.noaa.gov/)
VORTEX2 Science Research Field Campaign on Tornadoes (www.vortex2.org)

Most noteably, this was ultimately made possible through the support of NSF:

The National Science Foundation, Washington, DC (www.nsf.gov)

WEB RESOURCES



Web Weather for Kids: A National Center for Atmospheric Research site covering the basics of weather ingridents and severe weather plus an excellent selection of hands-on activities. *http://eo.ucar.edu/webweather/*

Kids' Crossing, another National Center for Atmospheric Research site, that covers dangerous weather, the atmosphere and more with attractive graphics and engaging science activities. http://eo.ucar.edu/kids/

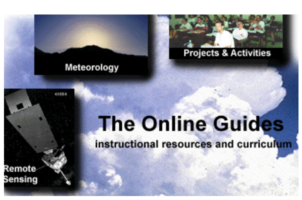
Project LEARN was an NSF-funded resource designed to increase middle school science teachers' knowledge of and interest in teaching about the atmospheric sciences. It was created by teachers for teachers. http://www.ucar.edu/learn/

The GLOBE Program promotes students, teachers, and scientists to collaborate on inquiry-based investigations of the environment and the Earth system. The program includes the involvement of approximately 111 countries. http://globe.gov/

Enter **Vortex2** and the world of severe weather research. Peer inside the largest and most ambitious effort ever made to understand tornadoes. You won't find a lot of hands-on activities and curricula on this site, but you will learn what a career in the atmospheric sciences can involve and a lot about tornadoes and tools for studying them! www.vortex2.org

DataStreme is a pre-college teacher enhancement program of the American Meteorological Society with the main goal of promoting the teahing of science, math, and technology using weather as the vehicle. Many of the program's resources are available online. www.ametsoc.org/amsedu/dstreme/

NOAA's National Severe Storms Laboratory and the National Weather Service J***etstreme*** project provide some of the best educational resources for learning about weather in depth. NOAA offers numerous educational resources, photos and more, so dig in and see what you can find! www.srh.noaa.gov/jetstream/ and www.nssl.noaa.gov



Celebrating its 15th year, the **Online Guides to Meteorology and Remote Sensing** from the University of Illinois provide some of the most comprehensive instructional resources one can find. Afterall, they've stood the test of time. Billions of visitors over a 15-year period can't be wrong! http://ww2010.atmos.uiuc.edu

Monster Storms from The Jason Project utilizes problem-based learning scenarios along with well produced videos and animations to bring severe storms to learners everywhere. You have to register to gain access but the resources are free and highly worthwhile. www.jason.org

Earthstorm is produced by the Oklahoma Climatology Survey and covers the study of weather over seven units including environmental monitoring, meteorological variables, the Earth-Atmosphere System and more. Much thought has gone into this comprehensive and thorough resource. http://earthstorm.mesonet.org

Some of the scientists, technicans, vehicles, and students who participated in VORTEX2 in 2010. Funded through the National Science Foundation (NSF) and the National Oceanic and Atmopsheric Administration (NOAA), VORTEX2 was the larest tornado study ever conducted and will yield valuable scientific data on tornado genesis, their structure, why some are long lasting and others short and weak, and how we can learn to forecast tornadoes better. (Source: CSWR)