

ST[EMpower]



SCIENCE, TECHNOLOGY,
ENGINEERING, AND MATH
COLORADO STATE UNIVERSITY
EXTENSION

WEATHER—LET IT SNOW! Weather Is A-Changing!

BACKGROUND

Over the River and Through the Woods

By Lydia Maria Francis Child
Published 1844

Over the river, and through the wood,
To Grandfather's house we go;
the horse knows the way to carry the sleigh
through the white and drifted snow.

Over the river, and through the wood,
to Grandfather's house away!
We would not stop for doll or top,
for 'tis Thanksgiving Day.

Over the river, and through the wood—
oh, how the wind does blow!
It stings the toes and bites the nose
as over the ground we go.

Over the river, and through the wood—
and straight through the barnyard gate,
We seem to go extremely slow,
it is so hard to wait!

Over the river, and through the wood—
When Grandmother sees us come,
She will say, "O, dear, the children are here,
bring a pie for everyone.

Over the river, and through the wood—
now Grandmother's cap I spy!
Hurrah for the fun! Is the pudding done?
Hurrah for the pumpkin pie!
The following verses appear in a "long
version":

Over the river, and through the wood,
with a clear blue winter sky,
The dogs do bark, and children hark,
as we go jingling by.

Over the river, and through the wood,
to have a first-rate play.
Hear the bells ring, "Ting-a-ling-ding!",
Hurrah for Thanksgiving Day!

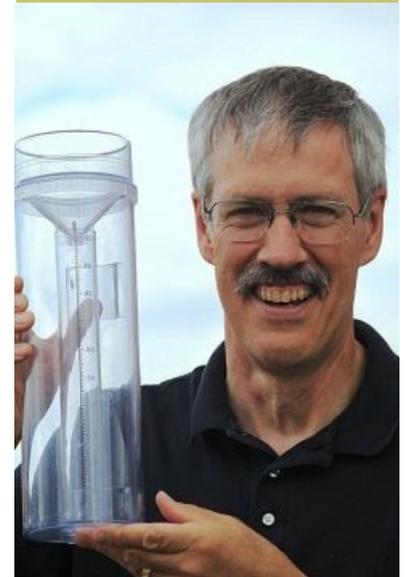
Over the river, and through the wood,
no matter for winds that blow;
Or if we get the sleigh upset
into a bank of snow

Over the river, and through the wood,
to see little John and Ann;
We will kiss them all, and play snow-ball
and stay as long as we can.

Over the river, and through the wood,
trot fast, my dapple-gray!
Spring over the ground like a hunting-
hound!
For 'tis Thanksgiving Day.

Over the river, and through the wood,
Old Jowler hears our bells.
He shakes his pow, with a loud bow-wow,
and thus the news he tells.

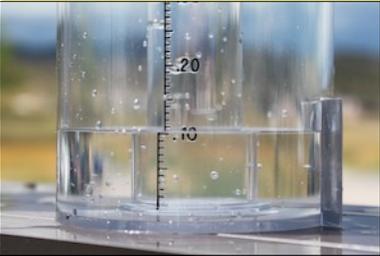
CAREERS Meet Nolan Doesken Colorado State Climatologist— Retired!



Mr. Doesken loves to laugh and have fun. You would never know that he studied extreme weather! He thinks droughts, floods, and snow are awesome! He works at Colorado State University. In 2006, Colorado's governor named Mr. Doesken "Colorado State **Climatologist**" until he retired last year.

Colorado State University is in Fort Collins. There was a terrible flood in 1997. Mr. Doesken started a group called **CoCoRaHS** (said in

three syllables Co-Co-RaHS), or the Community Collaboration on Rain, Hail, and Snow Network. It now has over 20,000 volunteers! The volunteers are from all 50 states, Canada, and the Bahamas! Wow!



CoCoRaHS volunteers collect precipitation data using rain gauges. A rain gauge is a weather instrument that measures how much water has fallen. The volunteers measure how much precipitation has fallen over a 24-hour period. They report that number each day on the CoCoRaHS website for scientists.



Mr. Doesken grew up in central Illinois in a farming community. He

Thanksgiving signals the end of harvest, the last days of fall, and cold snaps. Deciduous trees' bare branches shutter in the November wind.

This issue's focus is weather forecasting. Weather is very complex, and all weather on Earth is driven by the sun. Small variables mean major changes in weather. For example, if you live on the south side of a hill, and your friend lives on the north side, you will experience warmer temperatures even during the coldest days than your friend. If you are close to a large body of water, it can actually regulate and decrease the high and low temperature swings. The topography plays havoc on concise weather prediction.

The single most useful instrument for predicting weather today is a weather satellite. These satellites not only follow clouds and cloud types, but they also see city lights, fires, effects of pollution, auroras, sand and dust storms, snow cover, ice mapping, boundaries of ocean currents, energy flows, and more. Other satellites detect changes in the Earth's vegetation, sea state, ocean color, and ice fields. For example, this year looks like an El Niño.

Before the age of satellites, meteorologists primarily used a variety of instruments:

- **rain gauge** (invented 500 BC; measures **precipitation**)
- **anemometer** (invented 1450; measures wind speed) with a wind vane to determine direction of the wind
- **sling psychrometer** a type of **hygrometer** (invented 1480; measures atmospheric humidity)
- **thermometers** (concept known by ancient Greeks, invented by Galileo in the 1593; measures temperature)
- **barometers**, (invented in 1643; measure air pressure) for their basic prediction, and the best for predicting weather changes
- **pyranometer** (invented 1893; measures solar radiation)

Before these instruments, people would “read” the clouds. As technology advances, so does science!

Objectives—you will:

- Have fun
- Build demonstrations of how clouds form
- Identify the major types of clouds and their altitude
- Use clouds to predict the weather and collect data
- Build weather instruments
- Use the weather instruments to refine your weather predictions
- Chart your predictions to determine how accurate they are
- Participate in the citizen science CoCoRaHS Network
- Explore Meteorology and Climatology careers

DO: Cloud Formation—3 Demos

Materials:

- 4 small identical glass jars—baby food or pint canning jars are perfect
- Red food coloring
- Blue food coloring
- Spoon
- 2 Playing cards (if larger than the opening of the jars) or index card (larger than the opening of the jars)
- Baking pan (or tray) smaller than the sink
- Sharp scissors or box cutter
- Adult supervision with the box cutter
- 2 Plastic pop bottles with lids—2 liter pop bottle works best
- Bowl, cup, or canning jar (need to support top of the bottle while the water freezes)
- Freezer
- Water
- Black construction paper
- Matches

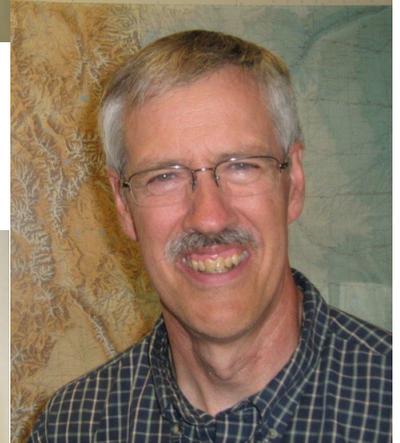
Directions for Demo 1—Hot Fluids Rise; Cold Fluids Sink:

- Fill two glass jars about three-quarters full with very **hot** tap water.
- Add a few drops of **red** food coloring to each of them. What happens to the red food coloring? Watch for a minute, then put the red jars into the baking pan in the sink. Mix the **red** in each jar with the spoon. Slowly add more **hot** water to the very top of the jars.
- Fill the other two jars about three-quarters full with very **cold** tap water. Add a few drops of **blue** food coloring to each of them. What happens to those drops? Mix the **blue** in each jar with the spoon. Place these jars in the baking dish in the sink.
- Slowly add more **cold** water to the very top of the jars.
- Lay a playing or index card carefully onto the top of one of the **blue** jars.
- Gently hold the card in place and quickly flip the jar over, so that the jar is upside down (over the sink). The water will form a seal with the card, and it will seal in the water, even upside down. Slowly remove your hand from the card, and the card will hold the water in the jar.
- Gently place the **blue** jar on top of one of the **red** jars, and line up the rims of the jars (top picture).
- Repeat the procedure with the other two jars, but this time, the **red** jar will be on top of the **blue** jar (bottom picture). Do this in the sink (in



went to a small school with big windows. The school was so small that every class had two grades. The younger students were on the first floor. The older students were on the second floor.

In Illinois, the students did not get snow days very often. When Mr. Doesken heard snow in the weather prediction, he was so excited. He could not sleep. In the morning, he would rush to his window to see if it had snowed.



Mr. Doesken already loved extreme weather in first grade. He has many vivid loving and fearing experiences about them. This is his favorite story. It was when he first realized that weather was his passion.

Mr. Doesken would get into trouble watching clouds out the windows. Even in first grade, he was keenly aware of **air pressure** and **atmosphere**.

Illinois has huge thunderstorms and tornadoes. One morning, the air was moist and alive. Clouds blew swiftly across the sky. The first and second grade students had to take a nap after lunch. Each student would lay down on a mat with a pillow. The students did not have to sleep. They did have to shut their eyes.



Mr. Doesken wanted to watch the clouds. He pretended to close his eyes. He really only closed the one eye. He kept the other eye open. The clouds were billowing high into the sky. The sky grew very dark. He thought it was thrilling to watch this big storm build.

Before the end of school, everyone had to go into the **storm cellar**. There was not a tornado at the school. The weather was extreme. The thunder crashed and boomed. The rain pounded the ground. The wind whipped and blew. After the storm, all the students jumped in the deep puddles.

His school was so small it only needed one bus. That afternoon there were

case of an accident). Place the card on top of the **red** jar, and quickly flip the jar. Place the **red** jar on top of the **blue** jar, and line up the two jars.

- Remember that **hot** air rises, and **cold** air sinks. Air is a **fluid**, and so is water. The **red** water is the **hot** water. What do you think will happen when you CAREFULLY remove the card between the two jars, allowing the **red** and **blue** water to touch each other? What will happen with the **hot red** water on top, and what will happen when the **cold blue** water is on the top?
- Carefully remove one of the cards between the two jars. You will need to hold the top jar as you carefully slip the card out from between the two jars. Observe what happens.
- Now carefully remove the other card that is between the second set of jars. Observe what happens.
- Was your prediction correct?



Directions for Demo 2—How Clouds Form:

- Have a parent help you with this step. Carefully insert the box cutter into the top of the plastic bottle just under the point where the bottle no longer curves (top diagram on the top right). Use the scissors to cut off the top the bottle at the wide part just below where it begins to get narrow.
- Be sure the cap is screwed on tightly.
- Invert the top of the bottle and fill about half way with water.
- Place the inverted top into something to support it. Pictured is a water bottle top in a pint canning jar.
- Place in the freezer. Wait at least 24 hours for water to free solid.
- When the top has frozen solid, you are ready for the demonstration.
- You will use hot water for the next step, so use care to not to burn yourself.
- Run the tap until the water is hot.
- Fill the bottom of the pop bottle about 1/4 full of the hot tap water.
- Strike a match, allow it to burn for a second, then toss the match into the hot water in the pop bottle.
- Quickly place the ice top with the cap pointed down on the bottom of the bottle (bottom picture).
- Hold the black construction paper behind the pop bottle. You will see a cloud form.



Directions for Demo 3 How Clouds Form:

- You will be using hot water; be careful not to burn yourself.
- Run the tap until the water is hot.
- Fill the bottom of the other pop bottle 1/4 full of the hot tap water.
- Strike a match, allow it to burn for a second, and blow it out. Let it smoke a bit.
- Toss the match into the hot water in the pop bottle.
- Screw on the pop bottle cap.
- Wait about 1 minute.
- Hold the black construction paper behind the bottle, and squeeze the bottle. Watch what happens inside the bottle. Do you see a cloud?
- Release the squeeze, and observe what happens. Does the cloud form now?
- Continue to squeeze and release. What happens?

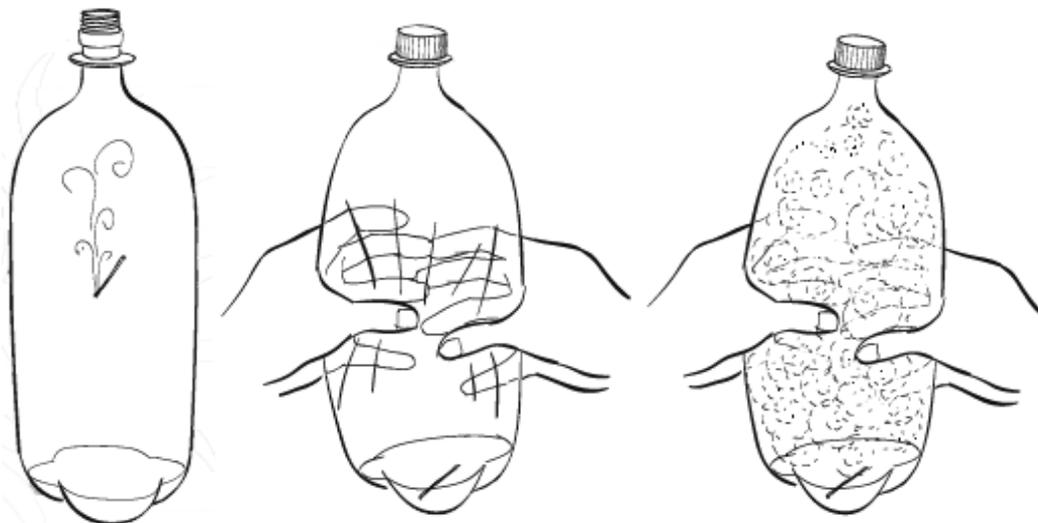
Explanation of the Demonstrations:

The Facts:

- **Warm** air holds more water vapor than **cold** air.
- **Warm** air rises. **Cold** air sinks.
- The temperature **decreases** as the altitude increases.
- The air molecules are further apart in **warm** air than in **cold** air. That means **warm** air is less dense than **cold** air, and **cold** air is denser than **warm** air.
- Clouds need three ingredients to form: water vapor, temperature or pressure changes, and a cloud **nuclei** (for example, dust or pollution).
- Recall phase changes of water. It freezes into ice when it gets colder than 32°F (0°C), melts to liquid water when the temperature is above the freezing point, and evaporates into water vapor when water is above the boiling point of 212°F (100°C). Water vapor condenses into liquid water as it cools.

The Demos:

- The jar and colored water demonstrated that a **warm** fluid rises and a **cold** fluid sinks. When the **cold blue** water was on top of the **warm red** water, the two jars mixed quickly. When the **warm red** water was on top, and the **cold blue** water on the bottom, the water in each jar remained with minimal mixing. (If you wait long enough, the hot water will cool and the cool water will warm until they are about the same temperature, and the water will mix.)



two buses. One bus was the real bus. The other bus was a reflection in the standing water!



Mr. Doesken did not know that weather would be his future job. It was just his passion. When he started college, he learned about the science of weather and climate. He decided it would be his job!

CAREERS

After reading about Mr. Doeskin's career, does this sound interesting to you? If so, check out the Colorado Climate Center website at Colorado State University :

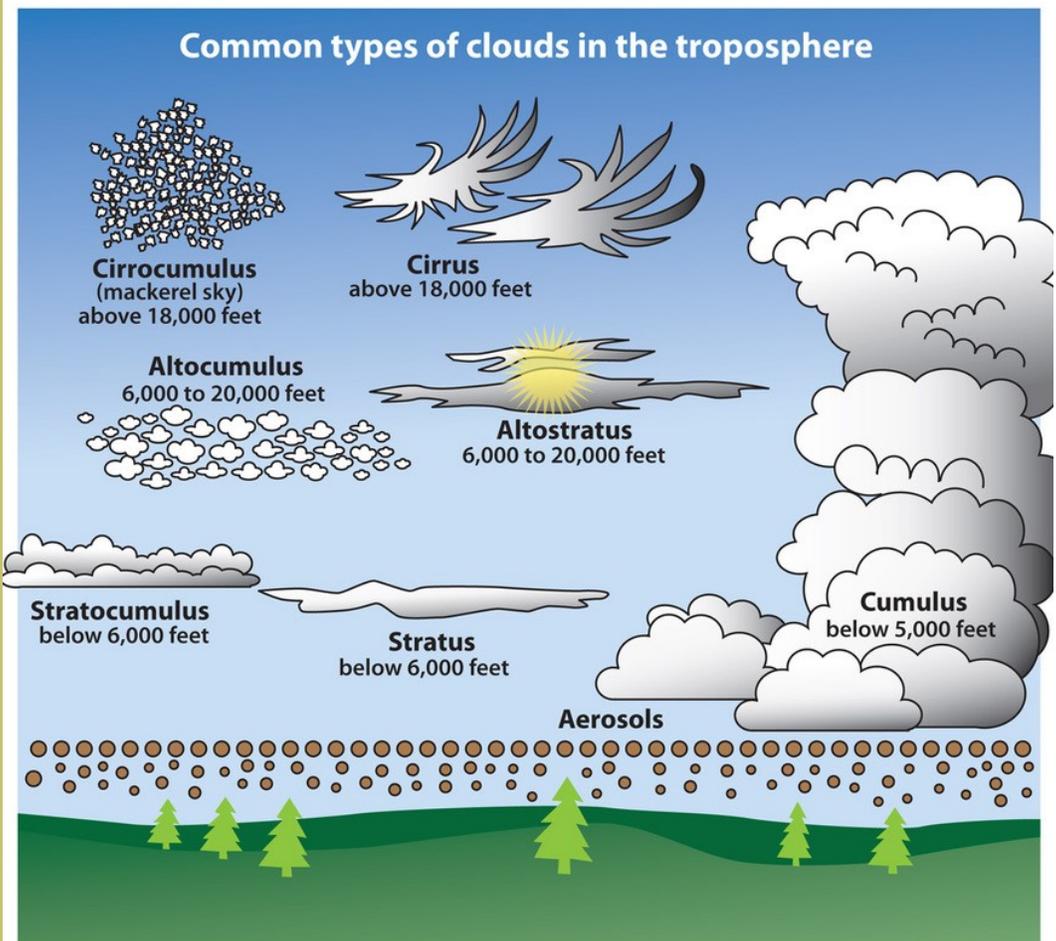
<http://climate.colostate.edu/?zip=81401>

POWER WORDS

- **accurate**: correct in all details; exact
- **air pressure**: force exerted onto a surface by the weight of the air. An example of air pressure is the average sea-level air pressure of 14.7 pounds per square inch
- **anemometer**: an instrument for measuring the speed of the wind, or of any current of gas

- **atmosphere:** the envelope of gases surrounding the earth or another planet
- **barometer:** an instrument measuring atmospheric pressure, used especially in forecasting the weather and determining altitude
- **Beaufort scale:** an empirical measure that relates wind speed to observed conditions at sea or on land; full name is the Beaufort wind force scale
- **cirrus:** cloud forming wispy filamentous tufted streaks (“mare’s tails”) at high altitude, usually 16,500–45,000 feet (5–13 km)
- **climatologist:** a scientist who studies climates, including the causes and long-term effects of variation in regional and global climates, and also studies how climate changes over time and is affected by human actions
- **cumulus:** a cloud forming rounded masses heaped on each other above a flat base at fairly low altitude
- **dew point:** the atmospheric temperature (varying according to pressure and humidity) below which water droplets begin to condense and dew can form
- **fluid:** a substance that has no fixed shape and yields easily to external pressure; a gas or (especially) a liquid

- In the second demonstration, you **replicated** the conditions that actually form clouds—warmer, moist air, saturated with water vapor, rises. As it rises, the air becomes colder, and when the water vapor cools, it condenses into liquid, and we can see it in the form of clouds. The smoke from the match was the nuclei.
- The third demonstration also replicated the conditions that actually form clouds—drop in pressure. Clouds are more likely to form under colder temperatures and lower pressure. In this demonstration, you are replicating the conditions of lower pressure forming clouds. When you squeeze the bottle, the pressure increases. This causes the temperature inside the bottle to rise. When you release the bottle, the pressure decreases. This causes the temperature inside the bottle to fall and the water molecules to condense. The smoke particles act as cloud condensation nuclei, allowing the water molecules to condense and stick together around the smoke.



Cloud Mobile

Materials:

- Copy of clouds (pages 22-23) on white card stock
- White school glue
- Cotton balls
- Transparent Mylar shred or foil icicles
- Silver or translucent glitter
- Two 12" bamboo skewers
- Scissors
- Tape
- Darning needle
- White thread (heavy duty)
- Cloud chart (pages 24-25)



Directions:

- This activity is based on a NASA lesson. By making a cloud mobile, you can learn about the different altitudes clouds form and the names of the three basic cloud types. What do clouds look like? How are they different? **Cirrus**, **Cumulus**, and **Stratus**: each word means something:
 - Cirro-: curl of hair, high
 - Cumulo-: heap
 - Strato-: layer
- If a cloud is raining or snowing, we call that “actively precipitating” and we use another word with the cloud name—Nimbo or **Nimbus** meaning precipitation.
- Memorize the names on or by the cloud shapes (pages 22-23). If you have cardstock, print and cut out the shapes. If you don't have cardstock, you can use a box. Cut out cloud shapes on regular paper and trace them on the box. Cut out those shapes from the box.
- Attach Mylar shred or foil icicles to the bottom of the nimbostratus and cumulonimbus clouds with tape. This represents rain.
- Fluff the cotton balls; stretch thin for the cirrus clouds, stretch thick for the stratus clouds, and leave puffy for the cumulus clouds. Use the white school glue to attach the cotton to both sides of each cloud. Allow the glue to dry. Remember which cloud is which!
- Cut off one-third of one skewer (the short end needs to include the sharp tip). Cut off just the sharp tip on the other skewer. One skewer is full length (minus the sharp tip) and the other skewer is about 2/3 the length of the longer skewer (minus the sharp tip).
- Find the balance point on each cloud. Lightly pinch the cloud at the top, shifting your fingers back and forth until the cloud's base is horizontal to the floor. With the darning needle, carefully poke a hole through the cotton and paper or cardboard at that balance point. Repeat until you have found the balance point for each of the clouds.
- You will need 2 strands of cotton thread 18" long for hanging the two skewers together from the ceiling, and 6 strands of cotton thread about 12" long for the clouds. This is actually much longer than you will need, but it is easier to tie and trim. Cut the thread and set aside.

- **forecast**: predict or estimate (a future event or trend)
- **horizontal**: parallel to the plane of the horizon; at right angles to the vertical
- **hygrometer**: an instrument for measuring the humidity of the air or a gas
- **nimbus**: a large gray rain cloud
- **nucleus (plural nuclei)**: Condensation nucleus, tiny suspended particle, either solid or liquid, upon which water vapor condensation begins in the atmosphere
- **phase change**: a change from one state (solid or liquid or gas) to another without a change in chemical composition
- **precipitation**: rain, snow, sleet, or hail that falls to the ground
- **predict**: say or estimate that (a specified thing) will happen in the future or will be a consequence of something
- **proxy**: a figure that can be used to represent the value of something in a calculation
- **pyranometer**: an instrument for measuring radiation from the sky
- **rain gauge**: a device for collecting and measuring the amount of rain that falls
- **replicate**: make an exact copy of; reproduce or repeat (a scientific experiment or

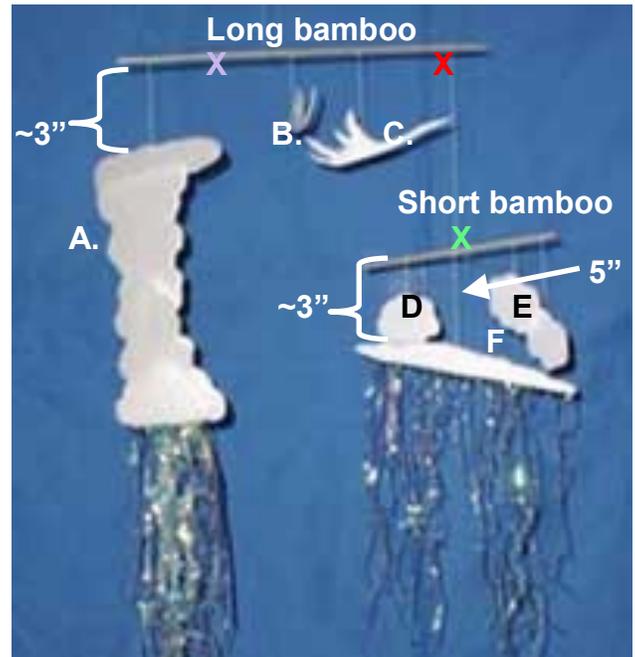
trial) to obtain a consistent result

- **sling psychrometer:** a type of hygrometer - a sling psychrometer - consists of two thermometers mounted together with a handle attached on a chain. One thermometer is ordinary. The other has a cloth wick over its bulb and is called a wet-bulb thermometer
- **storm cellar:** a type of underground bunker designed to protect the occupants from violent severe weather, particularly tornadoes
- **stratus:** cloud forming a continuous horizontal gray sheet, often with rain or snow
- **thermometer:** an instrument for measuring and indicating temperature, typically one consisting of a narrow, hermetically sealed glass tube marked with graduations and having at one end a bulb containing mercury or alcohol that expands and contracts in the tube with heating and cooling
- **trapezoid:** a quadrilateral with only one pair of parallel sides
- **vertical:** at right angles to a horizontal plane; in a direction, or having an alignment, such that the top is directly above the bottom

- Thread the needle with one of the 12" threads, and pass it through the hole in one of the clouds. Tie the thread on the cloud. Repeat for the other 5 clouds.
- Double check the balance on the clouds. Hold the end of the thread for each cloud, and add a bit of tape or cotton to the high side to balance until the bottom of the clouds are horizontal to the ground.

- **Long skewer clouds:** Start with the big cumulonimbus cloud

- (labeled "A" on the diagram). That cloud climbs up to 40,000 feet, the top is at the cirrus cloud level. Tie this cloud's string to one end of your long skewer so that the string is about 3" long between the cloud to the skewer. Don't tie it too tight to the skewer. You need to slide it.
- Tie the two cirrus clouds (labeled "B" and "C" on the diagram) to the other side of the skewer. Each string should be about 3" long between the skewer and the top of the cirrus cloud. Trim the string.
- **Short skewer clouds:** Tie the Nimbostratus cloud (Mylar shred taped to the bottom, labeled "F" on the diagram) to the middle of the short skewer and tie the string to about 5" long between the cloud and the shorter skewer. This cloud will be the lowest on your mobile.
- Tie the two cumulus clouds (labeled "D" and "E" on the diagram) to either side of the nimbostratus cloud. The strings will be ~ 3" long.
- **Constructing mobile:** Use your 18" of string to tie the two skewers together. Loosely knot the thread on the end of the long skewer closest to the cirrus clouds (pictured with the red "X" on the diagram). Tie the string to the short skewer in the middle (near the Nimbostratus cloud, pictured with the green "X" on the diagram), with the string about 9" long between the two skewers.
- You will be hanging your longer skewer from the ceiling with the last thread. Tie the other 18" piece of string to the long skewer between the middle cirrus cloud and the cumulonimbus cloud (pictured with the purple "X").
- Hang from the ceiling with the ceiling thread. Slide the string on the lower short skewer back and forth until the short skewer is horizontal to the ground. You may need to adjust the cloud strings a bit, too. Working with the string from the ceiling to the long skewer, slide the string back and forth until the skewer is horizontal.
- Place a drop of glue on each knot on the skewer to hold in place.



Explanation of the Mobile:

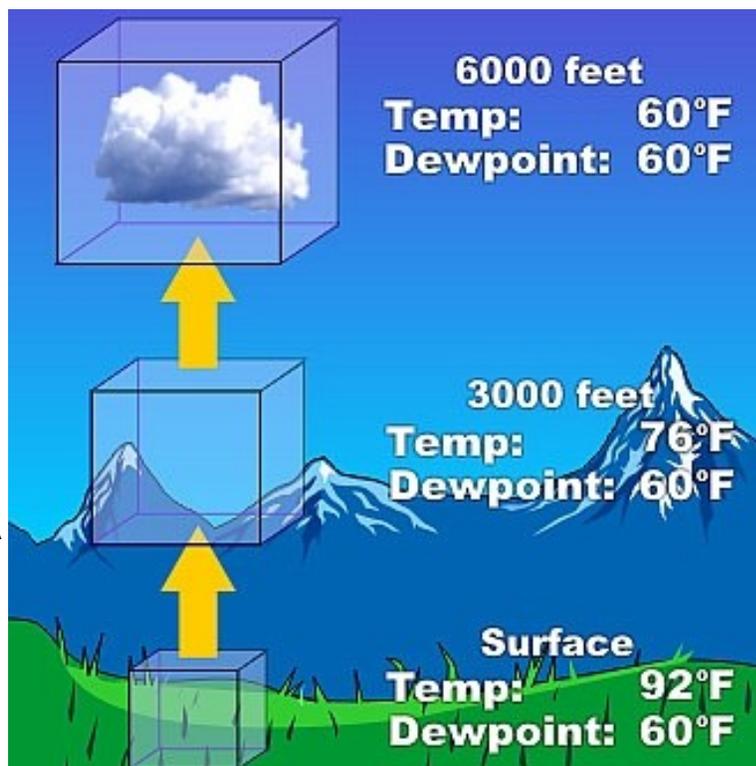
- Examine the water cycle picture on page 25.
- Water from oceans, lakes, streams, and even the soil evaporates to water vapor (the gas form of water). Gas expands and begins to rise

in the atmosphere (warm air rises).

- Temperature decreases $\sim 10^{\circ}\text{F}$ (6°C) for every 3,280 feet (1,000 m). For every 1,000 feet (304 meters), in altitude, air pressure decreases $\sim 1/2$ pound per square inch (psi; 35 grams/cm^2).
- Air can't hold as much water when either the temperature or air pressure drops. The vapor condenses into small water droplets or ice crystals and a cloud forms.
- It's easier for water vapor to condense into water droplets when it has something to grab, like dust or pollen. These particles are called condensation nuclei.
- Air is forced upward at areas of low pressure. Winds meet at the center of the low pressure system and have nowhere to go but up. Air is also forced upward at weather fronts. A weather **front** represents a boundary **between** two **different** air masses, *i.e.* **warm** and **cold** air.
 - If a **cold** air mass is retreating and **warm** air is advancing, a **warm front** exists. Typical clouds are:
 - Low stratus clouds
 - Midlevel altocumulus and altostratus clouds
 - High cirrus, cirrocumulus and cirrostratus clouds.
 - Clouds that produce rain like nimbostratus and cumulonimbus are also common at warm fronts.
 - If **cold** air is advancing into **warm** air, a **cold front** is present. Typical clouds are:
 - Cumulous clouds
 - They can grow into cumulonimbus clouds producing thunderstorms
 - Nimbostratus, stratocumulus, and stratus clouds can also form at cold front

As air rises it cools and decreases pressure, spreading out. Clouds form when the air cools below the **dew point**, and the air can not hold as much water vapor.

Credit: NOAA



FASCINATING FACTS

- IT SOMETIMES SNOWS WHERE YOU LEAST EXPECT IT. You wouldn't be shocked to see snow on the ground of Siberia or Minnesota when traveling to those places during the winter months. But northern areas don't have a monopoly on snowfall—the white stuff has been known to touch down everywhere from the Sahara Desert to Hawaii. Even the driest place on Earth isn't immune. In 2011, the Atacama Desert in Chile received nearly 32 inches of snow thanks to a rare cold front from Antarctica.
- SNOWFLAKES COME IN ALL SIZES. The average snowflake ranges from a size slightly smaller than a penny to the width of a human hair. But according to some unverified sources they can grow much larger. Witnesses of a snowstorm in Fort Keogh, Montana in 1887 claimed to see milk-pan sized crystals fall from the sky. If true that would make them the largest snowflakes ever spotted, at around 15 inches wide.
- A LITTLE WATER CAN ADD UP TO A LOT OF SNOW. The air doesn't need to be super moist to produce impressive amounts of snow.

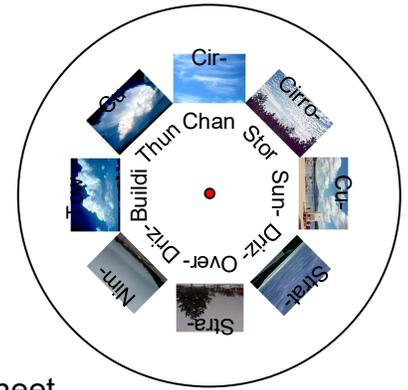
Unlike plain rainfall, a bank of fluffy snow contains lots of air that adds to its bulk. That's why what would have been an inch of rain in the summer equals about 10 inches of snow in the colder months.

- YOU CAN HEAR THUNDERSNOW WHEN THE CONDITIONS ARE RIGHT. If you've ever heard the unmistakable rumble of thunder in the middle of a snowstorm, that's not your ears playing tricks on you. It's likely thundersnow, a rare winter weather phenomenon that's most common near lakes. When relatively warm columns of air rise from the ground and form turbulent storm clouds in the sky in the winter, there's potential for thundersnow. A few more factors are still necessary for it to occur, namely air that's warmer than the cloud cover above it and wind that pushes the warm air upwards. Even then it's entirely possible to miss thundersnow when it happens right over your head: Lightning is harder to see in the winter and the snow sometimes dampens the thunderous sound.
- SNOW FALLS AT 1 TO 6 FEET PER SECOND. At least in the case of snowflakes with broad structures, which act as parachutes. Snow that

Cloud Wheel

Materials:

- Copy of Cloud Wheel (pages 26-27) on card stock
- Scissors
- Brass brad paper fastener
- Cloud Chart (pages 24-25)
- Pencil
- Clipboard or cardboard and binder clip
- Copy of Cloud Weather Predictions Datasheet (page 28)



Directions:

- Our ancestors used the clouds to predict tomorrow's weather. Each cloud can be used as **proxy** for the air pressure, the most reliable method for weather prediction before we sent satellites into orbit to collect weather data. The Cloud Wheel can help you predict if we will have a storm or clearing tomorrow.
- Cut out your two circles. On the circle that doesn't have any pictures, cut out the shaded **trapezoid**. Put the two circles together with the pictures circle underneath the other, so that a picture shows through the trapezoid window. Carefully push the paper fastener through the red dot in the center of the two circles. Be sure that your fingers aren't in the way when you push it through. Spin the bottom picture circle around until it moves freely.
- Examine the eight different kinds of clouds and what they mean. Each picture has the name of the cloud and what kind of precipitation is common with that kind of cloud.
- Bring your Cloud Wheel, Cloud Weather Predictions Datasheet on a clipboard, and a pencil outside to look at the clouds and compare them with your Cloud Wheel. Dial your cloud wheel until you have the closest match on your cloud pictures with the clouds in the sky. Record the cloud type. What weather do you predict for tomorrow?
- Each day, use your Cloud Wheel to predict the weather, and the following day, record if you are correct.
- After a week, can you tell how **accurate** you can predict the weather using just the clouds for your data? Continue collecting these data for a month. The longer you collect the data, the better you can determine how accurate clouds are predicting tomorrow's weather.

Explanation of the Cloud Wheel Accuracy:

- This is obviously not a perfect way to predict the weather, but you should be more accurate than just guessing. Each type of cloud is a visual clue to the air pressure and the moisture present in the atmosphere, and how high (cold and low pressure) those clouds are.
- In general, high pressure means cold air. Remember that cold air is heavier and denser than warm air, and it sinks. Cold air also does not hold as much moisture as warm air.
- In general, low pressure means warm air. Warm air is lighter and less dense than cold air, and it rises. Warm air holds more water vapor than cold air.
- Examine the NOAA and NASA Sky Watcher Chart on pages 26-27.

REFLECT: Weather Instruments

The **DO** section focused on clouds and predicting weather, you will now build weather instruments, learn how they work, and refine your weather predictions. The more instruments you make, the better your predictions can be. Make as many as you can, but if you don't have the materials to make all of them, use the ones you do have.

Barometer:

A **barometer** measures air pressure. The pressure of the air around us changes constantly, and they are associated with changes in the weather. When the air pressure is high, the weather is mostly likely to be fair and clear. When the air pressure is low, stormy weather is mostly likely in the forecast.

Materials:

- Plastic drinking straw
- Tape
- Large Balloon
- Pint-size canning jar (diameter of the mouth approximately 3")
- Heavy duty rubber band
- Scissors
- Ruler
- 8 ½ x 11" cardstock paper or small recycled cardboard box (i.e. shoe)
- Fine-point permanent marker
- 1 copy per day Weather Prediction Datasheet (page 31)

Directions:

- Cut open your balloon by inserting the scissors and cutting from the neck to the dimple at the bottom of the balloon.
- Stretch your balloon across the mouth of the jar so that the balloon rubber is pulled as taut as possible. Secure the balloon in place with a rubber band. After the rubber band is in place, continue to pull the balloon taut. Trim the extra balloon.
- Cut the straw to six inches long. Cut one end of the straw a point.
- Place the straw lying flat across the balloon. The straw's pointed end hangs over the jar and the blunt end in the middle of the mouth of the jar. Tape the straw to the balloon, with a small piece of tape.
- To make the barometer scale, fold the paper twice lengthwise (folded into thirds). Form into a triangular column. Tape the long sides of the cardstock together. You will make markings to indicate the barometric pressure. If you don't have cardstock or poster paper, you can use a shoe box, or similar cardboard box.
- Place the triangular tower next to your jar with the pointer touching the tower. Mark the tower where touched by the pointer. Make note directly on the tower what the weather is like outside. Include



falls in the form of pellet-like graupel (soft hail) travels to Earth at a much faster rate.

- **IT DOESN'T TAKE LONG FOR THE TEMPERATURE TO DROP.** Don't take mild conditions in the middle of January as an excuse to leave home without a jacket. Rapid City, South Dakota's weather records from January 10, 1911, show just how fast the temperatures can plummet. The day started out at a pleasant 55°F, then over the course of 15 minutes a wicked cold front brought the temperature down to 8 degrees. That day still holds the record for quickest cold snap in history.
- **THE EARTH IS CLOSEST TO THE SUN DURING THE WINTER.** Every January (the start of the winter season in the northern hemisphere) the Earth reaches the point in its orbit that's nearest to the Sun. Despite some common misconceptions, the seasonal drop in temperature has nothing to do with the distance of our planet to the Sun. It instead has everything to do with which direction the Earth's axis is tilting, which is why it is summer in January in the southern hemisphere.
- **MORE THAN 22 MILLION TONS OF**

SALT ARE USED ON U.S. ROADS EACH WINTER. That comes out to about 137 pounds of salt per person.

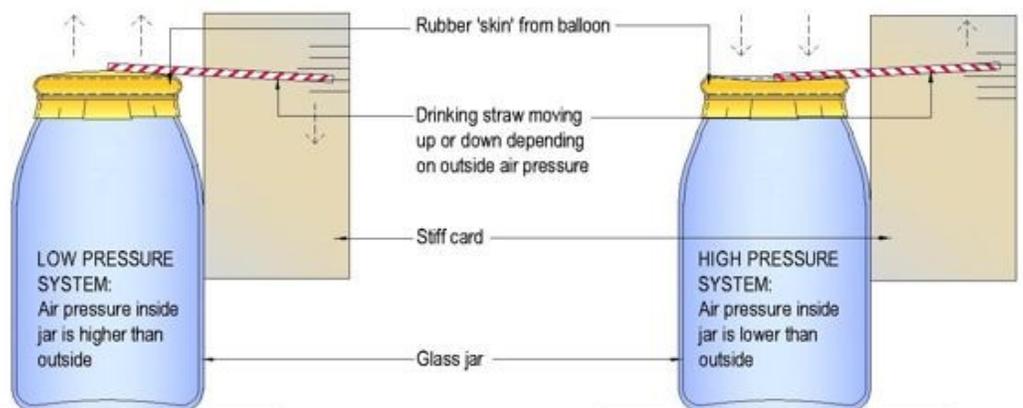
- THE SNOWIEST CITY ON EARTH IS IN JAPAN. Aomori City in northern Japan receives more snowfall than any major city on the planet. Each year citizens are pummeled with 312 inches, or about 26 feet, of snow on average.
- SOMETIMES SNOWBALLS FORM THEMSELVES. Something strange happened earlier this year in northwest Siberia: Mysterious, giant snowballs began washing up on a beach along the Gulf of Ob. It turns out the ice orbs were formed naturally by the rolling motions of wind and water. With some spheres reaching nearly 3 feet in width, you wouldn't want to use this frozen ammunition in a snowball fight.
- WIND CHILL IS CALCULATED USING A PRECISE FORMULA.. When the weatherman reports a "real feel" temperature of -10 degrees outside, it may sound like he's coming up with that number on the spot. But wind chill is actually calculated using a complicated equation devised by meteorologists. For math nerds who'd like to test it at home, the

temperature, cloud cover, precipitation, etc. Be sure to indicate that this is the "original" air. You will be measuring if the pressure is higher or lower than this initial mark. If the straw is higher than the line, it should be nicer, and if the straw is lower than the line, the weather should be wetter than the day you captured the air.

- Continue observing your barometer for a week. Gather more information by marking on your barometer paper scale when the straw goes above or below the line you drew on the day you captured the air in the jar. Use a pencil for the information so you won't confuse it with your original mark. By each mark, record the weather (temperature, cloud cover, precipitation, etc.). This will indicate what happens to the weather when pressure goes up or down compared to the day you collected your air in the jar.
- When you begin to collect weather data with all your homemade instruments, record your results on the Daily Weather Datasheet (page 31). Verify your data with a newspaper or a weather website (like Weather Underground, see page 32) for your zip code, and note what source you are using (i.e. <https://www.wunderground.com/weather/us/co/montrose/81401> for Montrose, CO). On the Barometer table, indicate:
 - The homemade barometer straw went "up" "down" or stayed the "same" from the original air in your jar.
 - record the barometric pressure from your source, and indicate if the pressure is going up or down with an arrow. The first day, you won't be able to indicate if the pressure is up or down from the prior day, but every day after, you can record if the pressure is going up or down.

Explanation of the Homemade Barometer:

- The air you captured in the jar will remain at the same pressure. The air pressure outside will go up (high pressure) or down (low pressure). That will push on the balloon differently. Your barometer is going to be higher or lower relative to today's pressure that you just captured.
 - Low pressure (relative to the day you captured the air in your jar) will not push down as hard as the air in the jar, which is higher. This will make the balloon bulge, and the straw will point down.
 - High pressure will push down on the balloon more than the air pushing up. In the jar. This will push the balloon into the jar slightly, tilting up the straw.



Thermometer:

Materials:

- Modeling clay
- Red food coloring
- Water
- Clear straw
- 90% (or higher) Isopropyl alcohol (rubbing)
- Small water bottle about 11 oz. with a narrow-neck)
- Thermometer (optional)

Directions:

- Pour equal amounts of tap water and rubbing alcohol into the bottle until it's a quarter full.
- Add a few drops of red food coloring, and shake the bottle to mix it.
- Insert the straw into the bottle, not letting it sink to the bottom.
- Wrap modeling clay around part of the straw and the opening of the bottle to make it stay. Let part of the straw stick out of the bottle. The clay should be tight around the straw and cover the bottle mouth, but make sure to leave the top opening of the straw uncovered.
- Test the **thermometer!** Put your hands around the bottle. What happens to the mixture when your warm hands are on it?
- You can also put the thermometer outside and see how the thermometer reacts to the hot or cold temperature. Or, place the thermometer in a bowl of hot water and then put it immediately in the freezer. What happens?

Explanation of the Homemade Thermometer:

- When the alcohol and water mixture gets hot, the mixture expands, sending the water up the straw. How hot would it have to be for the water to come out of the straw?
- Can you make a scale for the thermometer? Use a store bought thermometer and identify the temperature today. Use another side of your barometer tower to record temperature.



formula reads: $Wind\ Chill = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$.

- CITIES ARE FORCED TO DISPOSE OF SNOW IN CREATIVE WAYS. When snow piles up too high for cities to manage, it's usually hauled away to parking lots or other wide-open spaces where it can sit until the weather warms up. During particularly snowy seasons, cities are sometimes forced to dump snow in the ocean, only to be met with criticism from environmental activists. Some cities employ snow melters that use hot water to melt 30 to 50 tons of snow an hour. This method is quick but costly—a single machine can cost \$200,000 and burn 60 gallons of fuel in an hour of use.
- WET SNOW IS BEST FOR SNOWMAN-BUILDING, ACCORDING TO SCIENCE.. Physics confirms what you've likely known since childhood: Snow on the wet or moist side is best for building your own backyard Frosty. One scientist pegs the perfect snow-to-water ratio at 5:1.
- SNOWFLAKES AREN'T ALWAYS UNIQUE. Snow crystals usually form unique patterns, but there's at least one instance of identical

snowflakes in the record books. In 1988, two snowflakes collected from a Wisconsin storm were confirmed to be twins at an atmospheric research center in Colorado.

- **THERE'S A DIFFERENCE BETWEEN FREEZING RAIN AND SLEET.** Freezing rain and sleet can both have scary effects on driving conditions, but their formations differ in some key ways. Both types of precipitation occur when rain formed in warm air in the sky passes through a layer of cold air near the ground. Thicker layers of cold air create sleet, a slushy form of water that's semi-frozen by the time it reaches the Earth. Thinner layers don't give rain enough time to freeze until it hits the surface of the ground—it then forms a thin coat of ice wherever it lands.

JOKES

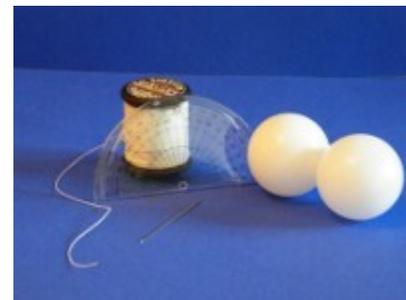
- Q: What do snowmen eat for lunch ?
 A: Icebergers!
- Q: What kind of math do Snowy Owls like?
 A: Owlgebra
- Q: What did one raindrop say to the other raindrop?
 A: Two's company, three's a cloud!
 Ole and Lena were

Anemometer:

The **Beaufort scale** is a scale for measuring wind speeds. It is based on observation rather than accurate measurement. It is the most widely used system to measure wind speed today. The scale was developed in 1805 by Francis Beaufort, an officer of the Royal Navy and first officially used by HMS Beagle.

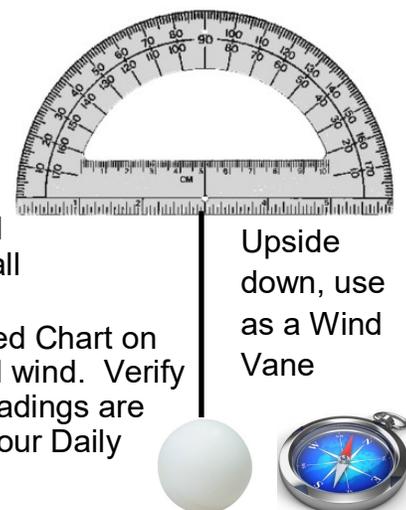
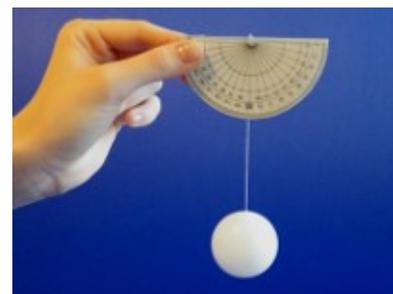
Materials:

- Copy Beaufort Wind Scale and Anemometer Angle to Wind Speed Chart (page 29)
- Page protector (optional)
- Protractor
- Needle longer than the ping pong ball
- Thread
- Ping pong ball
- Magnetic compass



Directions:

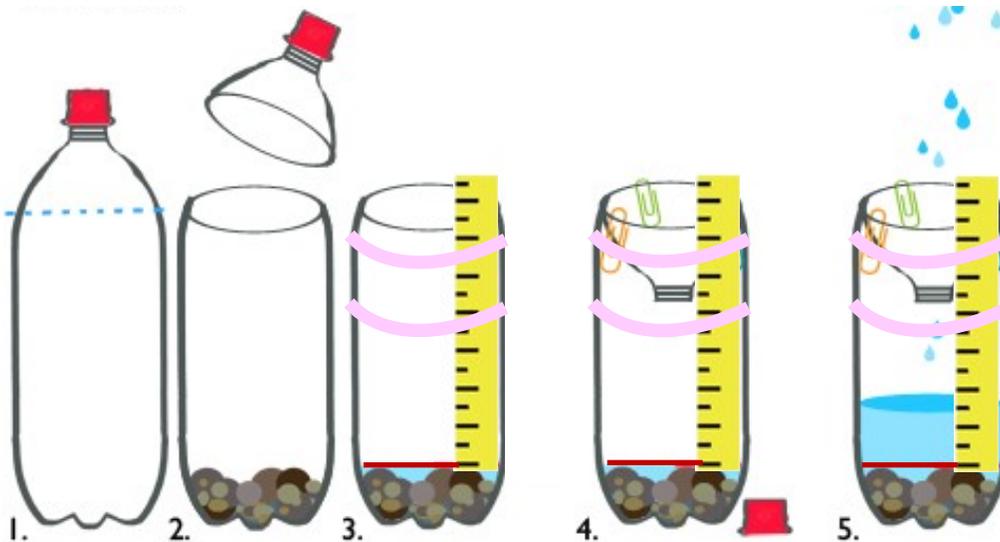
- Print the Beaufort Wind Scale and place in a page protector.
- Cut a piece of thread about 8" (20cm) long. Thread the needle and tie a large knot in the end of the thread.
- Stick the needle into one side of the ping pong ball and out the opposite side. Draw the thread through until the knot at the other end stops the thread from moving.
- Tie the thread to the center of the straight base of the protractor which often has a small hole at that center point. The ball hangs down with the string dangling in front of the degrees marked on the arc. Hold the straight base level, where there is no wind, then the ball will hold the thread over the 90° mark as pictured.
- Take the anemometer outside. Hold the anemometer level and parallel to the wind. The wind will blow the ball. The thread will indicate the degree. Record the degree on your Daily Weather Prediction Datasheet. Use the Beaufort scale to estimate wind velocity.
- Align your magnetic compass needle to north. Hold the anemometer upside down so that the ping pong ball hangs freely and observe which direction the ball moves. Record the opposite direction. Winds are named for the direction they come from, not go. A north wind blows from the north to the south. The ball would move towards the south.
- Use the Anemometer Angle to Wind Speed Chart on page 29 to convert the angle to estimated wind. Verify with the Beaufort Wind Scale that your readings are reasonable. Record the wind speed on your Daily Weather Prediction Datasheet.



Rain Gauge:

Materials:

- plastic bottle 1 liter or less with smooth sides (as depicted by the arrow pointing to the best bottle shape for the rain gauge)
- Scissors
- Box cutter
- Parent (or other adult) supervision
- ~30 marbles or washed marble-sized pebbles
- Ruler (clear plastic works the best)
- Permanent marker
- 8 paperclips or binder clips
- 2 rubber bands



Directions:

1. Have a parent help you with this step. Carefully insert the box cutter into the top of the plastic bottle just under the point where the bottle no longer curves (blue dotted line above). Use the scissors to cut off the top of the bottle at the wide part just below where it begins to get narrow. Save the top of the bottle. It will act like a funnel.
2. If you use pebbles, wash them thoroughly. You don't want any soil on the pebbles to leach into your rain gauge water. Put the marbles or pebbles in the bottom of the bottle to keep it upright in windy weather.
3. Use the permanent marker to draw a **horizontal** line just above your pebbles or marbles (shown as the red line in diagram #3 above). Set the ruler **vertically** on the bottle. Line the "0" centimeters on your ruler to the horizontal red line on your bottle. Add water just to the top of the red line. If you don't add water, you will not get an accurate reading on your rain gauge.
4. Take off the cap on the "funnel" top. Turn the top of the bottle upside down. Place it in the bottom part of the bottle, pointing downward. Line up the cut edges and use 4-8 paper clips to hold the top and bottom of the bottle firmly in place. Hint, the paperclip's long loop

sitting down to their usual morning cup of coffee listening to the weather report on the radio. "There will be 3 to 5 inches of snow today, and a snow emergency has been declared," the weather report said. "You must park your cars on the odd numbered side of the streets."

Ole said, "Jeez, okay," and got up from his coffee.

The next day they were sitting down with their morning cups of coffee.

The weather forecast was, "There will be 2 to 4 inches of snow today, and a snow emergency has been declared. You must park your cars on the even numbered side of the streets."

Again Ole replied, "Jeez, okay," and got up from his coffee.

Two days later, again they're sitting down with their cups of coffee and the weather forecast said, "There will be 6 to 8 inches of snow today, and a snow emergency has been declared. You must park your cars on the..." and the power went out and Ole didn't get the rest of the instructions.

He turned to Lena, "Jeez, what am I going to do now, Lena?"

Lena replied, "Aw, Ole, just leave the car in the damned garage today."

Q: Why do mother

kangaroos hate rainy days?

A: Because then the children have to play inside.

Q: Why do hurricanes travel so fast?

A: Because if they travelled slowly, we'd have to call them slow-i-canes.

There's a technical term for a sunny, warm day which follows two rainy days. It's called Monday.

COLORADO WEATHER RECORDS

National Oceanic and Atmospheric Administration (NOAA) data for Colorado:

- Maximum Temperature 114°F
 - July 1, 1933 in Las Animas
 - July 11, 1954 in Sedgwick
- Minimum Temperature -61°F
 - February 1, 1985 Maybell
- 24-Hour Precipitation 11.85 inches
 - September 12, 2013 USGS Rod & Gun (Ft. Carson)
- 24-Hour Snowfall 75.8 inches
 - April 14-15, 1921 Silver Lake
- Snow Depth 251 inches
 - March 31, 1979 Wolf Creek Pass 1 E

should be on the outside of the bottle, and the short loop inside the funnel. You may need to bend the two loops open a bit.

5. Set the bottle on a level surface. Your rain gauge is now ready to go!
6. Put the rain gauge outdoors—you'll need to pick a really good spot! You want somewhere level that's open to the sky and that's not likely to get too windy, where the gauge isn't likely to be disturbed. There shouldn't be anything hanging over the gauge that could either block any rain or make extra raindrops drip into the bottle (like a tree or a power line or the edge of a roof).
7. Check your rain gauge every 24 hours. Record "0" if there is no rain. If there was rain, but it is too little to measure, write "Trace." If there was rain and enough to measure, record the amount. Remove or add water until your water level reaches the red line and return outside.
8. If snow is predicted, remove the funnel top, paperclips, ruler, rubber bands, and water. Store those in a safe place. Keep the marbles/rocks, but no water.
9. Set your rain gauge out as usual. After 24 hours, if there was snow, bring the rain gauge inside and allow the snow to melt.
10. Once the snow has melted, pour it into another container. Line up the ruler's 0 centimeters to the red horizontal line at the bottom of your rain gauge and secure with your rubber bands. Add water to the red line in your rain gauge. Add the melted snow into the rain gauge and record your precipitation.
11. If the snow is over the top of the rain gauge, the official way to record the amount of water in the snow fall is to gently tap the top of the gauge with a fly swatter (or in this case, a snow swatter!). If you don't have a "snow" swatter, a spatula will work, too.



Sling Psychrometer:

A **sling psychrometer** is fairly easy to make, and you can use it to determine the relative humidity.

Materials

- 2 Identical Celsius thermometers with a range at least -5 to 50°C , marked in 1 degree increments; filled with red alcohol (no mercury)
- 1 Pair scissors
- 1 Small rubber band
- Clear plastic strapping tape or heavy-duty rubber bands
- Water
- Cotton Gauze (used in first aid kits)
- Cotton twine string
- Drill or hole punch
- Empty, clean 1/2 liter (16 ounces) pop or water bottle
- Safety goggles
- Copy of Daily Weather Prediction Datasheet (page 31)
- Sling Psychrometer Interpretation Table (page 30)

Directions:

1. Moisten a double layer of gauze with water.
 2. Use the small rubber band to cover the bulb of one of the thermometers with the gauze.
 3. Secure the thermometer with gauze on one side of the plastic bottle and the other thermometer (no gauze) to the opposite side with your heavy duty rubber bands. Make sure you can still see the numbers and red alcohol in the thermometer. *Why is using a mercury thermometer a bad idea for your hygrometer?*
- Drill or punch a hole through the top of the neck of the bottle and thread your 18" string through the holes. Knot the string with a knot that will not slip.
 - Have a grown-up make sure that you have attached the thermometers and the string securely.
 - Put on your safety goggles and clear the area.
 - Holding tightly to the end of the string, swing the bottle around in a circle in the air for one minute (60 seconds). You can swing it over your head (pictured below), or in front of you like a propeller.



RECORDS \

National Oceanic and Atmospheric Administration (NOAA) data for USA:

- Maximum Temperature 134°F
 - July 10, 1913 in Greenland Ranch, California
- Minimum Temperature -80°F
 - January 23, 1971 Prospect Creek, Alaska
- 24-Hour Precipitation 42.0 inches
 - July 25-26, 1979 Alvin, Texas
- 24-Hour Snowfall 78.0 inches
 - February 9, 1963 Mile 47 Camp, Alaska
- Snow Depth 451 inches
 - March 11, 1911 Tamarack, California

WORLD WEATHER RECORDS

- Maximum Temperature 134°F
 - July 10, 1913 in Greenland Ranch, California
 - Minimum Temperature -128.6°F
 - July 21, 1983 Soviet Vostok Station, Antarctica
- Precipitation records:
- Most in one minute: 38 mm (1.5 in); Barot, Guadeloupe, 26 November 1970.
 - Most in one hour: 305 mm (12.0 in) in 42 minutes. Holt, Missouri, United States, 22 June 1947.
 - Most in 24 hours (1

day): 1,825 mm (71.9 in); Cilaos, Réunion, 7–8 January 1966, during Tropical Cyclone Denise.

- Most in one year: 26,470 mm (1,042 in); Cherrapunji, Meghalaya, India, 1860–1861.
- Most from a single tropical storm: 6,433 mm (253.3 in); Commerson, Réunion, during Cyclone Hyacinthe in January 1980.
- Highest average annual total (observed over 10 years): 11,872 mm (467.4 in) (over 38 years) and 12,701 mm (500.0 in) (1998–2010); Mawsynram, Meghalaya, India or 13,466 mm (530.2 in) (1980–2011); López de Micay, Cauca, Colombia.
- 24-Hour Snowfall 100.8 inches in Capracotta, Italy on March 5, 2015
- Snow Depth
 - 465.6 inches on Mt. Ibuki, Japan on 14 February 1927

CITATIONS

- <https://www.spaceweatherlive.com/en/solar-activity>
- <https://www.scientificamerican.com/article/sun-spots-and-climate-change/>
- <http://climate.colostate.edu/?zip=81401>
- <https://www.cocorahs.org/>
- <http://coagmet.colostate.edu/>
- <https://>

- Use the Weather Prediction Datasheet to record the temperature of both thermometers immediately. The wet bulb temperature is the thermometer with the gauze.
- Find the difference between the two temperatures.
- Use the Sling Psychrometer Interpretation Table on page 30 to determine the relative humidity.

Explanation of the Sling Psychrometer:

- Results will vary depending on the weather conditions in your area. If you are comparing your results with those of your local meteorologists, make sure to do the experiment outside, because indoor humidity can be quite different than outdoor humidity. You should expect that the wet bulb temperature will always be lower than the dry bulb.
- The wet bulb temperature is always lower than the dry bulb temperature because water is evaporating from the wet bulb. This cools the wet bulb. The drier the air, (lower relative humidity), the more water evaporates from the wet bulb, and the greater different in temperature between the wet and dry bulbs.
 - Example: the outdoor temperature (dry bulb) is 22°C. After slinging the psychrometer, the wet bulb temperature is 12°C, a 10 degree difference. Read the table, and this gives you 29% relative humidity. Because the air is dry, more water evaporated while you were slinging the wet bulb.
 - Example: the outdoor temperature (dry bulb) is 22°C, but the wet bulb temperature is 21°C, a 1 degree difference. Read the table, and this gives you 92% relative humidity. Because the air is holding a lot of moisture, less water evaporated while you were slinging the wet bulb.

Firefighter using a sling psychrometer in front, twirling like a propeller.



APPLY: Forecasting

Now that you have built some weather instruments, read how and why they work, and practiced predicting the weather (weather forecast) by reading the clouds, let's see if you can refine your predictions to be more accurate.

Complete your Daily Weather Prediction Datasheet. Compare the results to yesterday's Daily Weather Prediction Datasheet. For example, if yesterday was cloudy with sprinkles, and the barometer is even lower today, what do you think that means? What if the clouds are stratus? Weigh your evidence, and make your best guess. The more you look at your weather data, the better your guesses will be. That is weather prediction!

Materials:

- Daily Weather Prediction Datasheet (page 31; one copy every day)
- Monthly Weather Prediction Datasheet (page 33; one copy each month)
- Pencil
- Pages 24-28 of this article
- Your Homemade Weather Instruments
 - Weather Wheel
 - Barometer
 - Thermometer
 - Anemometer
 - Wind Direction using Anemometer (weather vane or wind sock)
 - Rain Gauge
 - Sling Psychrometer
- Access to internet and a weather website to "ground source" your homemade instruments

Directions:

- Collect your data on each of your instruments. The directions for using them are included in the directions for making them. Refer to those pages.
- Record the data on your Daily Weather Prediction Datasheet.
- After you have collected all your data, write down what each instrument tells you individually:
 - Cloud Wheel: continue collecting your cloud date. Record on the Daily Weather Prediction Datasheet.
 - Barometer:
 - If your barometer falls (lower pressure), you can expect warmer and wetter weather.
 - If your barometer rises (higher pressure), you can expect cooler and drier weather.
 - Thermometer: Compared to yesterday, is the temperature higher or lower? Is this a trend (meaning it will continue to get colder, hotter, or stay the same?)
 - Anemometer: From which direction is the wind blowing? Your location will be different, and over time you will learn to tell that if that means clearing or clouds. For example, wind blowing West to

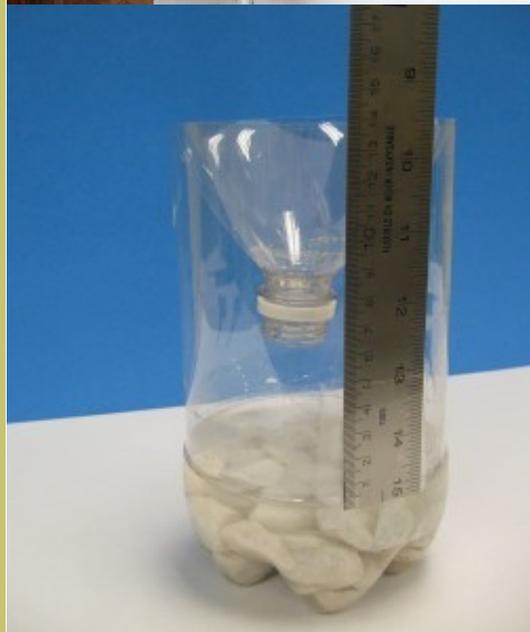
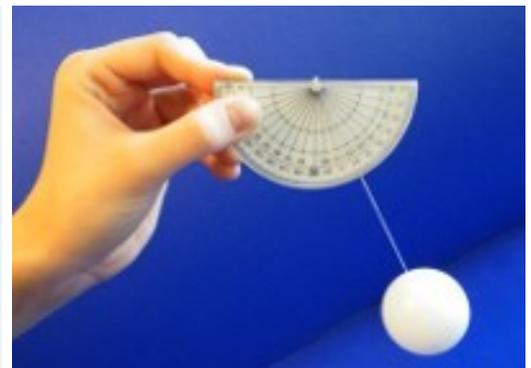
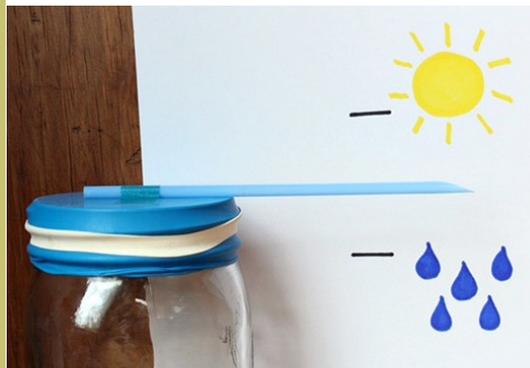
- interestingengineering.com/15-weather-forecast-instruments-and-inventions-that-helped-define-how-we-predict-the-weather
- <https://cdn.coffeecupsandcrayons.com/wp-content/uploads/2013/08/Weather-Activity-Make-a-cloud-in-a-jar.jpg>
- <http://www.planet-science.com/categories/experiments/weather/2011/03/make-a-cloud-in-a-bottle.aspx>
- https://pmm.nasa.gov/education/sites/default/files/article_images/Water-Cycle-Art2A.png
- http://www.lyvemedia.com/delta/grade/website_files/images/weather/weather_inv6/weather_cloud-bottles.gif
- http://www.nasa.gov/audience/foreducators/5-8/haveyouseen/haveyouseen_archive_12.html
- Photographs of clouds captured May 19, 2014 from the National Oceanic and Atmospheric Administration website: http://www.crh.noaa.gov/lmk/?n=cloud_classification
- <https://scied.ucar.edu/shortcontent/how-clouds-form>
- https://www.education.com/science-fair/article/earth-science_making-hygrometer/
- <https://www.education.com/science-fair/article/barometric-pressure/>
- <https://easyscienceforkids.com/make-your-own-barometer/>
- <https://www.education.com/activity/article/>

make_a_homemade_thermo
meter_middle/

- https://simple.wikipedia.org/wiki/Beaufort_scale
- <https://blog.zoo.org/2012/06/rain-or-shine.html>
- <https://www.cocorahs.org/>
- <https://www.instructables.com/id/Who-Needs-a-Meteorologist-Measure-Humidity-the-Old/>
- https://www.youtube.com/watch?v=l_UINzbz9mk
- <http://www.housingaforest.com/how-to-make-a-barometer/>
- <https://whenyouriseup.com/wp-content/uploads/2018/07/DIY-THERMOMETER.png>
- https://whats-that-cloud.weebly.com/uploads/2/9/9/1/29917547/2376791_orig.jpg
- <http://mentalfloss.com/article/89881/15-surprising-facts-about-winter-weather>
- <http://www.jokes4us.com/miscellaneousjokes/weatherjokes/index.html>
- <https://www.free-funny-jokes.com/funny-weather-jokes.html>
- <https://www.ncdc.noaa.gov/extremes/scec/records>
- https://en.wikipedia.org/wiki/List_of_weather_records

East usually brings clouds. How strong the wind is blowing will indicate how fast the change can occur.

- Rain Gauge: How much rain has fallen over the past 24 hours? Using all your weather instruments, you can make a prediction if you think precipitation will go up or down.
- Sling Psychrometer: in general, warmer air can hold more moisture than colder air. If the humidity is higher, that can indicate warming. If the humidity is lower, that can indicate cooling.
- Examine your Daily Weather Prediction Sheet. You can easily have contradicting results. It is weather and extremely complex. Look for trends. If most of your instruments tell you that it will be clearing and cooling, make that your prediction.
- Remember that your barometer is one of the most powerful instruments to indicate weather.
- It is okay to be wrong! There are so many factors in weather, that even with satellites and the best instruments, weather prediction is sometimes wrong.
- Record your prediction and why (i.e. warmer with possible precipitation—barometer lower, thermometer up, cirrus clouds). Keep track if you are correct or incorrect in your predictions. Over time, you will improve your accuracy.
- Go online to one of the Weather Forecast websites (i.e. Underground Weather). Record your results under “website.”



Citizen Science CoCoRaHS

If this weather project was absolutely it, and Mr. Doeskin's story the absolute best, then you can make a difference right now by joining the Community Collaboration for Rain, Hail and Snow (CoCoRaHS) Network Citizen Science Program!

Materials:

- Official CoCoRaHS Rain Gauge (WeatherYourWay.com carries the official rain gauge. The current cost is \$41.75 with shipping costs)
- Computer with internet access

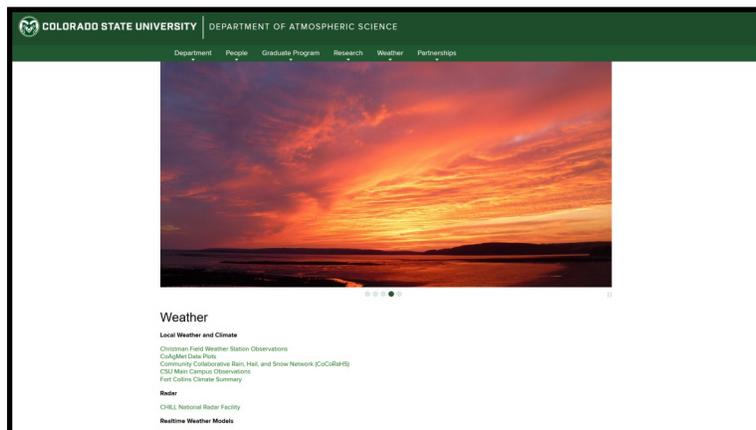
Directions:

- Check out the CoCoRaHS website. <https://www.cocorahs.org/>. Everything you need to know is located on this site. If you decide you would like to participate, here are the steps:
 - Purchase the official CoCoRaHS Rain Gauge.
 - Find a suitable location to place your rain gauge (<https://www.cocorahs.org/Content.aspx?page=equip>).
 - With a parent or guardian, register on the website (<https://www.cocorahs.org/application.aspx>).
 - Read the instructions and watch the training videos located on (<https://www.cocorahs.org/Content.aspx?page=Help>)
 - (<https://www.cocorahs.org/Content.aspx?page=measurerrain>)
 - (<https://www.cocorahs.org/Content.aspx?page=measurehail>)
 - (<https://www.cocorahs.org/Content.aspx?page=measuresnow>)
 - (<https://www.cocorahs.org/Content.aspx?page=reportingsnow>)
 - (https://www.cocorahs.org/Media/docs/CoCoRaHS_Training_8.1.pdf)
 - Report every day at the same time. Even when there is no rain, you still report "0 inches."
 - Scientists use these data! Be a part of the team!

Education and Careers in Atmospheric Sciences

Check out these websites about education and careers in Atmospheric Science!

- <https://www.atmos.colostate.edu/weather/>
- <http://ccc.atmos.colostate.edu/>
- <https://www.cira.colostate.edu/>
- <https://scied.ucar.edu/students/careers>



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Supplemental Information

Cumulonimbus

Template from: <http://spaceplace.nasa.gov/cloud-mobile/en/#/review/cloud-mobile2/cloudmobile.html>

Supplemental Information



Nimbostratus



Cumulus



Cirrus



Cumulus



Cirrus

SKY WATCHER CHART

<http://www.weather.gov/os/brochures/cloudchart.pdf>

High Clouds: cloud bases 16,000 - 50,000ft (5-15km)



H1: Cirrus
In the form of filaments, strands, or hooks

H2: Altostratus or Nimbostratus
Dense, in patches or sheaves, not increasing, or with tufts

H3: Cirrus
Often anvil shaped remains of a cumulonimbus

H4: Cirrus
In hooks or filaments, increasing, becoming denser

H5: Cirrostratus
Cirrus bands, increasing, below 45° elevation

H6: Cirrostratus
Cirrus bands, increasing, veil above 45° elevation

H7: Cirrostratus
Translucent, completely covering the sky

H8: Cirrostratus
Not increasing, not covering the whole sky

H9: Cirrocumulus
Alone or with some cirrus or cirrostratus

Typical Types: Cirrus (Ci), Cirrostratus (Cs), Cirrocumulus (Cc)

Middle Clouds: cloud bases 6,500 - 23,000ft (2-7km)



M1: Altostratus
Mostly semi-transparent, sun or moon may be dimly visible

M2: Altostratus or Nimbostratus
Dense enough to hide the sun or moon

M3: Altostratus
Semi-transparent, one level, cloud elements change slowly

M4: Altostratus
Lens-shaped, or continually changing shape and size

M5: Altostratus
One or more bands or layers, expanding, thickening

M6: Altostratus
From the spreading of cumulus or cumulonimbus

M7: Altostratus
One or more opaque layers, w/ altostratus or nimbostratus

M8: Altostratus
With cumulus-like tufts or turrets

M9: Altostratus
Chaotic sky, cloud bases at several levels

Typical Types: Altostratus (As), Altostratus (Ac), Nimbostratus (Ns)

Low Clouds: cloud bases Up to 6,500 ft (0-2km)



L1: Cumulus
Cumulus of fair weather with flattened appearance

L2: Cumulus
Moderate/strong vertical extent, or towering cumulus

L3: Cumulonimbus
Tops not fibrous, outline not completely sharp, no anvil

L4: Stratocumulus
From the spreading and flattening of cumulus

L5: Stratocumulus
Not from the spreading and flattening of cumulus

L6: Stratus
In a continuous layer and/or ragged shreds

L7: Stratus Fractus and/or Cumulus Fractus
occurs with rain or snow

L8: Cumulus & Stratocumulus
Not spreading, bases at different levels

L9: Cumulonimbus
With fibrous top, often with anvil

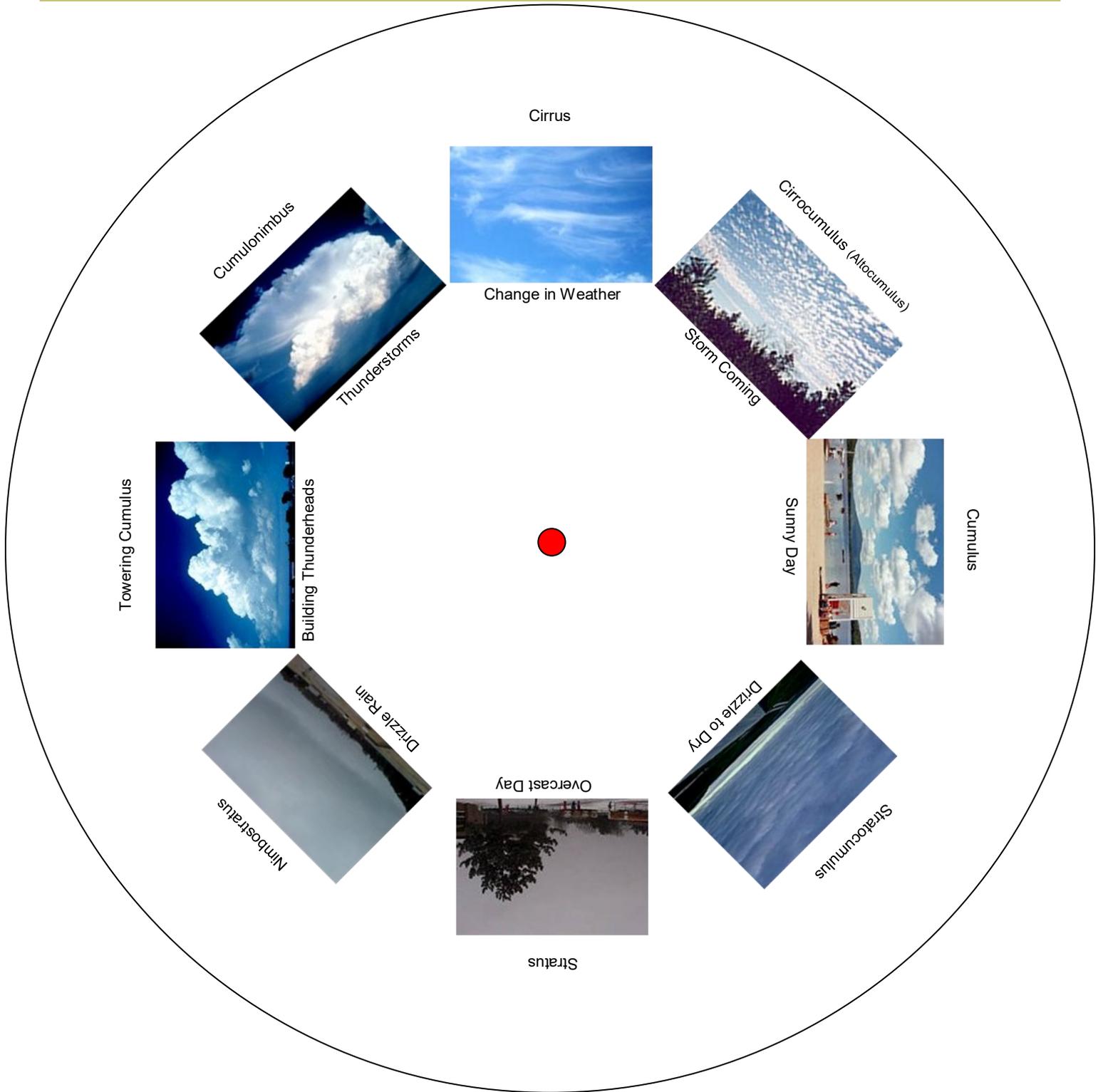
Typical Types: Stratus (St), Stratocumulus (Sc), Cumulus (Cu), Cumulonimbus (Cb)



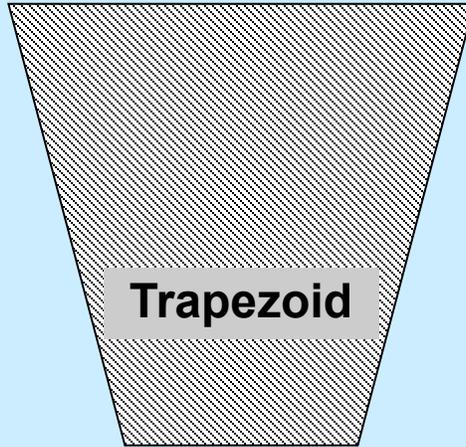
Special photo credit thanks to Jim W. Lee, Eric Kurth, Brian Klimowski, and Eric Heigeson

<https://www.weather.gov/media/jetstream/clouds/cloudchart.pdf>

Supplemental Information



Photographs of clouds captured May 19, 2014 from the National Oceanic and Atmospheric Administration website:
http://www.crh.noaa.gov/lmk/?n=cloud_classification



Predict Weather from the Clouds

Dial the bottom circle to view 8 different types of clouds until you find the image that looks most like the clouds you see today.

What is the cloud type?

What kind of weather can you expect?

Supplemental Information

Beaufort Wind Scale				Angle to Speed Chart		
Beaufort number	Wind speed		Description		What it looks like on land	
	km/h	mph		Angle		Anemometer angle to wind speed chart
0	<1	<1	Calm	Calm. Smoke rises vertically.	90°	0
1	1-5	1-3	Light air	Wind motion visible in smoke.	85°	9
2	6-11	3-7	Light breeze	Wind felt on exposed skin. Leaves rustle.	80°	13
3	12-19	8-12	Gentle breeze	Leaves and smaller twigs in constant motion.	75°	16
4	20-28	13-17	Moderate breeze	Dust and loose paper raised. Small branches begin to move.	70°	19
5	29-38	18-24	Fresh breeze	Branches of a moderate size move. Small trees begin to sway.	65°	22
6	39-49	25-30	Strong breeze	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.	60°	24
7	50-61	31-38	High wind, Moderate Gale, Near Gale	Whole trees in motion. Effort needed to walk against the wind. Swaying of skyscrapers may be felt, especially by people on upper floors.	55°	26
8	62-74	39-46	Fresh Gale	Twigs broken from trees. Cars veer on road.	50°	29
9	75-88	47-54	Strong Gale	Larger branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over. Damage to circus tents and canopies.	45°	32
10	89-102	55-63	Whole Gale/Storm	Trees are broken off or uprooted, saplings bent and deformed, poorly attached asphalt shingles and shingles in poor condition peel off roofs.	40°	34
11	103-117	64-72	Violent storm	Widespread vegetation damage. More damage to most roofing surfaces, asphalt tiles that have curled up and/or fractured due to age may break away completely.	35°	38
12	≥118	≥73	Hurricane-force	Considerable and widespread damage to vegetation, a few windows broken, structural damage to mobile homes and poorly constructed sheds and barns. Debris may be hurled about.	30°	42
					25°	46
					20°	52

Supplemental Information

Sling Psychrometer Interpretation Table

Dry Bulb °C	Number of degrees difference between the wet and the dry bulb readings °C									
	1	2	3	4	5	6	7	8	9	10
10	88%	77%	66%	56%	45%	35%	26%	16%	7%	--
11	89%	78%	67%	57%	47%	38%	28%	19%	11%	2%
12	89%	79%	68%	59%	49%	40%	31%	22%	14%	5%
13	89%	79%	69%	60%	51%	42%	33%	25%	16%	9%
14	90%	80%	70%	61%	52%	43%	35%	27%	19%	11%
15	90%	80%	71%	62%	54%	45%	37%	29%	22%	14%
16	90%	81%	72%	63%	55%	47%	39%	31%	24%	17%
17	91%	82%	73%	64%	56%	48%	41%	33%	26%	19%
18	91%	82%	73%	65%	57%	50%	42%	35%	28%	21%
19	91%	82%	74%	66%	58%	51%	44%	37%	30%	24%
20	91%	83%	75%	67%	59%	52%	45%	38%	32%	26%
21	91%	83%	75%	68%	60%	53%	47%	40%	34%	27%
22	92%	84%	76%	69%	61%	54%	48%	41%	35%	29%
23	92%	84%	77%	69%	62%	56%	49%	43%	37%	31%
24	92%	84%	77%	70%	63%	57%	50%	44%	38%	32%
25	92%	85%	77%	71%	64%	57%	51%	45%	40%	34%
26	92%	85%	78%	71%	65%	58%	52%	46%	41%	35%
27	93%	85%	78%	72%	65%	59%	53%	47%	42%	37%
28	93%	86%	79%	72%	66%	60%	54%	49%	43%	38%
29	93%	86%	79%	73%	67%	61%	55%	50%	44%	39%
30	93%	86%	80%	73%	67%	61%	56%	50%	45%	40%
31	93%	86%	80%	74%	68%	62%	57%	51%	46%	41%
32	93%	87%	80%	74%	68%	63%	57%	52%	47%	42%
33	93%	87%	81%	75%	69%	63%	58%	53%	48%	43%
34	93%	87%	81%	75%	69%	64%	59%	54%	49%	44%

To determine relative humidity:

- Subtract the wet-bulb temperature from the dry-bulb temperature.
- Locate the number of degrees difference in the top gold row. Put your right-hand finger on that number.
- Locate the dry-bulb temperature in the left hand green column. Put your left-hand finger on that number.
- Follow the column down with your right finger and follow the row with your left finger until they touch.
- This is the relative humidity. Record this number on your datasheet.

Supplemental Information

DAILY WEATHER PREDICTION DATASHEET

Date and Time data collected: _____

Professional source to verify (i.e. Weather Underground) _____

Cloud Wheel:

Type of Cloud _____

What It Means _____

Air Pressure (Barometer) Compare to yesterday: is it higher or lower?

Homemade Barometer	Website	What It Means

Temperature (Thermometer) Compare to yesterday: is it higher or lower?

Homemade Thermometer	Website	What It Means

Wind Speed (Anemometer) Compare to yesterday: is it higher or lower?

Anemometer Angle	Wind Speed	Wind Direction	Verify	What It Means

Precipitation (Rain Gauge) Compare to yesterday: is it higher or lower?

Homemade Rain Gauge	Verify	What It Means

Relative Humidity (Sling Psychrometer) Compare to yesterday: is it higher or lower?

Dry Bulb Temp.	Dry Bulb Temp.	Difference	% Humidity	Verify	What It Means

Prediction for Tomorrow's Weather:

Supplemental Information

The screenshot shows the Weather Underground interface for Montrose, CO. The main display includes a large temperature circle showing 56°F (predicted high 59°F, low 36°F) and a 'Sunny' cloud icon. A wind indicator shows 'Wind W' at 5 mph with gusts of 12 mph. A radar map is visible in the background. Below the main display are sections for 'TODAY', 'TONIGHT', and 'TOMORROW' forecasts, each with precipitation amounts (0.00 in). There are also sections for 'PRECIPITATION' (0%), 'POLLEN' (None), 'AIR QUALITY' (Good, index 19), and 'UV INDEX' (Moderate, index 5). The 'ADDITIONAL CONDITIONS' section lists pressure (29.82 in), visibility (10 miles), clouds (Clear), dew point (40°F), humidity (47%), rainfall (0.01 in), and snow depth (0 in). The 'ASTRONOMY' section provides sunrise and sunset times, twilight durations, and moon phase information (Waxing Crescent, 28% illuminated). The 'KMTJ STATION HISTORY' section shows almanacs for October 12 and 13, 2018, with high and low temperatures and precipitation data. The 'OCTOBER CALENDAR VIEW' and 'TODAY'S EXTREMES' sections are also visible at the bottom.

Temperature
(predicted high, low)
current temperature

Cloud Cover

Direction of wind and
wind speed

Amount of
Precipitation

Air Pressure

Relative Humidity

