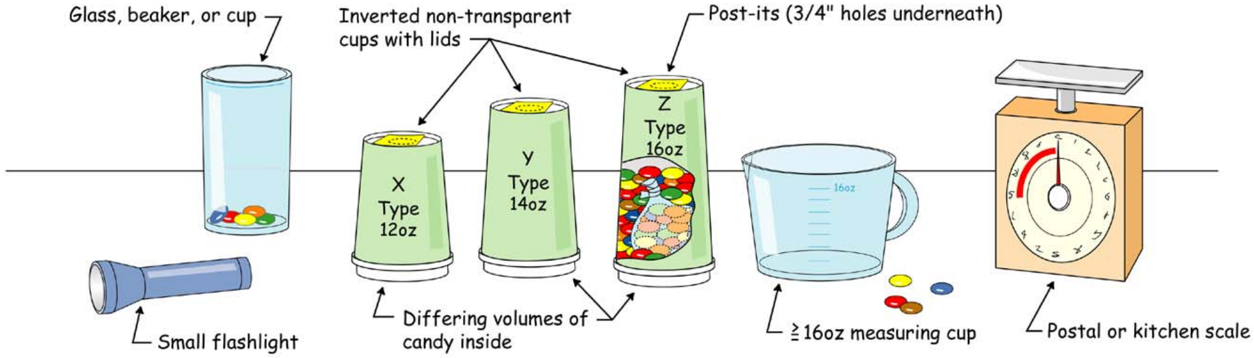
Originally published in The Technology Teacher*, October 2003, by the International Technology Education Association*

SIZING UP THE CLOUDS

TEACHER'S GUIDE FOR SETTING UP THE ACTIVITY



In this activity, you will set up three simulated "clouds" representing three different cloud types. Students will use different methods to estimate the "precipitation" contents of each cloud type. Each method is roughly analogous to methods actually used in weather forecasting. Finally, the "precipitation" from each cloud will be released, and the students will compare their estimates to what is actually experienced on the "ground." In addition to gaining an appreciation of weather forecasting issues and technologies, students will practice math skills, including estimating, percentages, ratios, and averages.

MATERIALS:

- 3 non-transparent paper or Styrofoam cups, with lids (such as found at Starbucks and McDonalds), each a different size (such as 12, 14 and 16 ounces).
- 1 beaker or cup of any convenient size and material.
- X-acto or box knife.
- 3 1-1/2" x 2" Post-it® notes
- Transparent tape or masking tape
- 1 marker pen
- 1 postal type scale (or kitchen scale) with at least 16-ounce capacity
- 1 small, narrow-beam flashlight
- 1 (transparent) measuring cup, calibrated in ounces, with measuring capacity of at least 16 ounces
- 2 14-ounce bags of M&Ms® or similar small candies (pebbles, beans, etc. can be used instead).
- 2 small plastic bags (sandwich size)

SET-UP (TEACHER DOES THIS BEFORE CLASS):

1. Cut a 3/4" diameter hole in center of bottom of each cup. Cover the hole with 1-1/2" x 2" Post-it.
2. Place about 1 ounce (volume) M&Ms in one of the plastic bags. Gathering the candies into one corner of the bag, twist the bag tightly and tie the excess bag in a knot. Cut off the excess to make a compact bundle. Repeat to make a second bundle of M&Ms of about 2 ounces to randomize the results. (Since these bundles will not fall through the ¾-inch hole, they will represent that portion of a cloud's moisture that may not be converted to precipitation.)
3. Holding Post-its in place, fill cups in this way:
   - Select any cup, and pour it about 1/2 full of M&Ms; then, add one of the bundles of M&Ms; then add more loose M&Ms to about 3/4 full.
   - Select another cup and pour it about 1/3 full of M&Ms.
   - Select the third cup and pour it about 1/4 full of M&Ms; drop in the other bundle of M&Ms; then add more loose M&Ms to make the cup 1/2 full.
4. Put lids securely on cups. To hold them firmly, tape the joint with transparent tape or masking tape.
5. Invert the cups.
6. With a marker, mark the three cups as "X type," "Y type," and "Z type."
7. Below this, mark the actual capacities: for example, "12 oz.," "14 oz.," and "16 oz."
8. Put a few ounces of M&Ms into the beaker.

On a table where all group members can view them, place the three inverted cup "clouds." On the same table, place the measuring cup, postal scale, flashlight, and beaker.

Note: During the activity, do not disclose to the students that some of the cups contain bundled candies.

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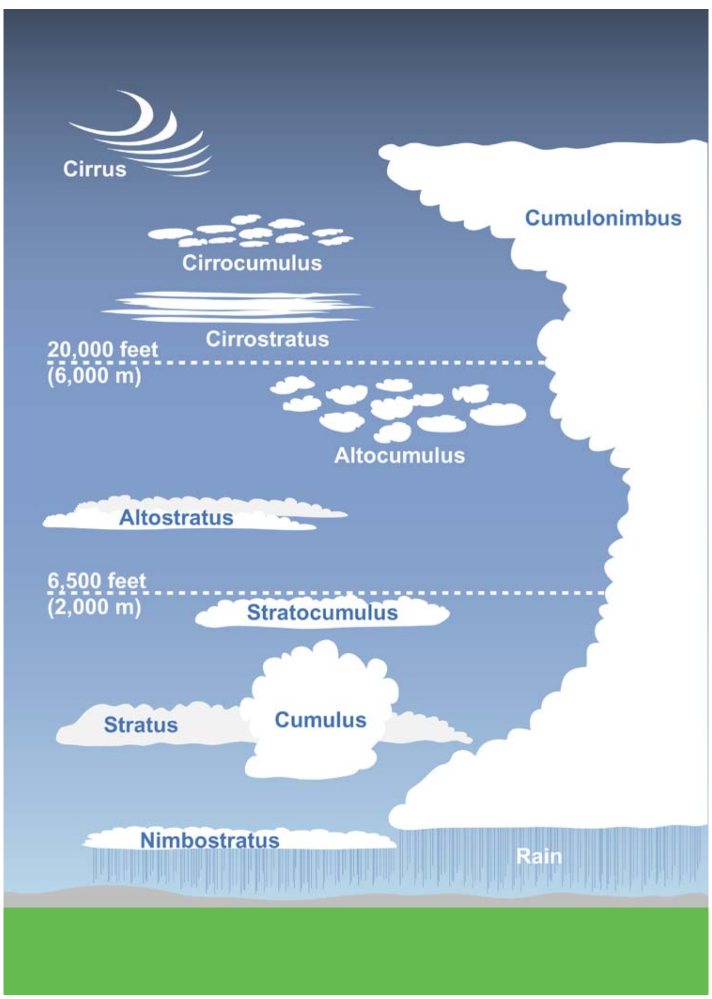
A weather forecaster took a job in another part of the country. When asked why he transferred, he replied, "The weather didn't agree with me."

Forecasting the weather is a tricky business. In spite of weather satellite images, ground-based weather radar, all sorts of high-tech atmospheric measurement devices, and computer programs to analyze all this data, forecasts of local weather and climate trends are still far from 100% accurate.

So, why is predicting the weather so difficult?

Well, take clouds. Can you look at the sky and predict whether the clouds you see are going to produce any rain right where you are standing? The sky over your town can be covered with thick clouds for days and never even wet the sidewalks. Or big, fluffy, juicy-looking clouds can rise up from the horizon . . . and then just disappear.

What fraction of the globe's cloud cover do you think actually produces precipitation that reaches the ground?



Give up? Or, here's a more basic question: For a cloud of specific type and dimensions, at a given location and time, how could you tell

- What proportion of it is likely to be liquid water and ice?
- How much of that water and ice is likely to turn into precipitation?

Don't know that one either? Neither do weather experts! These are actually difficult questions. The following activity will give you a first-hand look at why.

TEST YOUR FORECASTING SKILLS

As you know, clouds occur in a variety of types, such as cirrus, cumulus, cumulonimbus, and so on, depending on their altitude, moisture content, winds, and other atmospheric conditions.

The three cups your teacher has prepared represent three different make-believe cloud types (not actual or specific cloud types) we will call Type X, Type Y, and Type Z. These make-believe cloud types all produce precipitation in the form of small candies—wouldn't that be something!—or maybe some other small objects, like beans or pebbles, if that's what your teacher chose. Your objective is to estimate, as closely as possible, how much precipitation each cloud type produces. You will observe the clouds in several different ways to make your estimates.

First of all, set up a data sheet like this for recording your observations:

Measurement Method	Cloud Type X	Cloud Type Y	Cloud Type Z
1.			
2.			
3.			
4.			
5.			

1—Satellite Image and Weather Radar View:

Currently, a meteorologist estimates precipitation content of clouds by viewing satellite photos of cloud coverage in his or her area. He or she might also look at cloud images on the screen of a ground-based weather radar as the radar sweeps around the horizon.

Those views are not so different from the view you have as you look at these cup "clouds."

As you look at the "clouds," make your best estimate of how many ounces (volume, not weight) of "precipitation" each cloud type contains. Record your estimate on the data sheet as "Satellite image and weather radar view." Note that each cup is labeled with its volume (not weight) capacity. The "ounce" unit can be confusing, because it is used to measure both volume (how much space something takes up) and weight (how much matter it contains, or, more accurately, how hard gravity pulls on it).

It's difficult, of course, to make this kind of precipitation estimate without knowing more about what's inside the clouds. Currently, the amount of water in real clouds cannot be estimated closer than a factor of two. That is, the cloud could have twice as much water or half as much water as estimated. So predicting how much of it will change into precipitation is a lot like the kind of speculating you've just done.

2—Cloud Profiling Radar (CPR) View:

CloudSat is the name of a research satellite. Its mission is to gather information that will allow more accurate estimates of cloud precipitation content and other characteristics related to climate and weather.

The CloudSat satellite will use a special Cloud Profiling Radar (or CPR!). CPR can tell a lot about moisture content and air current activity within the cloud. More about the satellite later. For now, let's see what a CPR view might do for our estimates.

Pretend the light from the little flashlight is the CPR beam.

(The teacher will now remove the Post-it® cover from each cloud.)

Without touching the clouds, each class member takes a turn using the CPR (flashlight) beam to peer into the hole of each cloud to observe the level of candies inside it.

From your CPR observation, make a new estimate of how many ounces of precipitation each cloud type contains and record it on your data sheet as "CPR View."

3—Moisture Content Data from Other Sources:

CloudSat will orbit in a close formation with four other Earth observing satellites that gather different data on the same cloud in different ways. The data from all of them will be combined. This constellation of satellites is nicknamed the "A–Train."

In our example, the postal scale will represent the A–Train group, and its weight report will represent "total moisture content" data of a single cloud as combined from all A–Train sources. Choose one person to weigh each cloud, one at a time, on the scale and announce the weight, in ounces, to the whole class. Record the weights on your data sheet as "Moisture content data from other sources." Remember, weight ounces do not equal volume ounces!

4—Revised Precipitation Estimate from Moisture Content Data:

Can you use this "A-Train" data to refine your CloudSat volume estimates?

Math hint: Ratios of exact weight can now be set up among the three cloud types. These can be compared to ratios of guessed volumes. Volume guesses can be improved by adjusting them to match weight ratios.

For example, say your CloudSat volume estimates for the three clouds were

$X = 2$, $Y = 4$, and $Z = 6$.

And the weights were actually $X = 4$, $Y = 5$, and $Z = 8$. You see now that Z weighs twice as much as X, but you had estimated Z to have 3 times the volume of X. You must decide now whether to revise your volume estimate for Z down to 4, or your volume estimate of X up to 3. Or, you could split the difference and say the volume of X is 2.5 and Z is 5. As for Y, you see that the weight ratio of Y:X is 5:4 or 1.25. So multiply your revised volume estimate for X times 1.25 to get your revised estimate for Y.

Note your revised volume estimates on a separate line on your data sheet as "Revised precipitation estimate from moisture content data."

5—Checking in with the Ground:

To learn as much as possible about each cloud studied, CloudSat's data will ultimately be compared with simultaneous measurements from many sources, including ground stations. The actual precipitation coming out of the clouds can then be compared with the data observed in the clouds.

In our example, we can make ground station measurements of all three clouds right now.

Choose one person (maybe the teacher) to take each cloud, in turn, and invert it over the measuring cup, shaking and jiggling the cloud until no more "rain" (candies) can be shaken out. This person then reads aloud to the class the volume level from the measuring cup.

Record these readings on your data sheet as "Precipitation recorded by ground station."

How does this data compare with your estimates?

What factors might cause differences?

How seriously did the lack of information about retained moisture distort your estimates?

If you had another cloud of type X, Y, or Z, of a different size, could the data you've collected help make a more accurate precipitation forecast for it?

How would you go about it?

Clouds Are Not All Fluff!

Most of us experience clouds as fluffy or wispy white things that break up the monotony of a blue sky, or as gray blankets that cut off the sunshine and bring rain or snow. But, actually, clouds play an important and very complex role in influencing our environment.

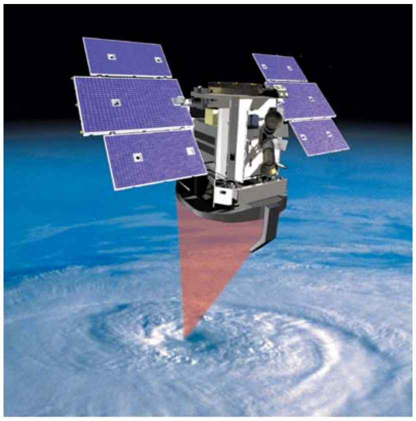
Small changes in their abundance or distribution cause changes in not only weather and atmospheric circulation, but also in the way climate responds to greenhouse gases (like the carbon dioxide from our automobiles and factories) and pollution, and where and when more clouds are produced.

We know very little about how that interactive feedback process works, however.

Earth observing satellites have produced comprehensive pictures of global cloud cover, as well as how clouds either reflect or hold in radiant heat energy from the Sun. That heat energy is what drives the planet's climate and weather. But so far we have had no way to understand how that energy is distributed throughout the atmosphere from cloud tops to Earth's surface.

What we need is a tool that can actually see into clouds, like radar. "Conventional" long radar waves are reflected from solid objects like cars and airplanes, but go right through or are absorbed by clouds. But when radar waves are only a few millimeters long, the water and ice in clouds reflect them. This kind of millimeter radar is used to track clouds and forecast weather. Weather radars are based on the ground and typically view the horizon in all directions. They show position and movement of local clouds and precipitation, but are not designed or located to examine clouds from top to bottom.

NASA's CloudSat mission will do just that. It will use radar in a unique way to learn more about the interiors of clouds. The CloudSat satellite will be equipped with a special downward-looking cloud radar. It will look into clouds beneath it, viewing them from the top down.



Artist's rendering courtesy of Ball Aerospace and Technology Corporation

CloudSat will measure a cloud's thickness, as well as the altitudes of its base and top above Earth. It will make vertical cloud profiles, identifying the liquid and ice water content. Other satellites will make measurements of other things at the same time in the same location. The data from all will be collected and compared in order to improve weather and climate prediction models.

Results of the CloudSat mission can help the world's weather forecasters to answer the following questions, for a cloud of specific dimensions, at a specific time and place:

- How much water and ice is the cloud expected to contain?
- How much of that water is likely to turn into precipitation?
- What fraction of the globe's cloud cover produces precipitation that reaches the ground?
- and a lot more!

Learn more about CloudSat at **cloudsat.atmos.colostate.edu**. Do cloud puzzles and learn cloud types at **spaceplace.nasa.gov/cloudsat_puz.htm**.

This article was written by Diane Fisher, writer and designer of The Space Place website at ***spaceplace.nasa.gov****. Thanks to Gene Schugart, educational product developer and Space Place advisor, for activity concept. Alex Novati drew the illustrations. The article was provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with the National Aeronautics and Space Administration.*