Predicting Rainfall

(*Inspired by International Technology Education Association, USA, 2003*)

Introduction

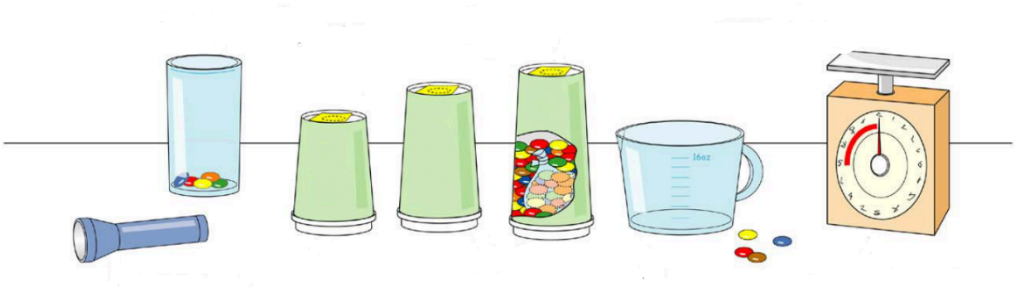
Clouds are important and quite complex in influencing our environment. Small changes in cloud abundance and distribution can change the weather and circulation in the atmosphere, but also alter how the climate responds to greenhouse gases and pollution. One thing we want to better understand is how much moisture is contained within the cloud and how much of it ends up being precipitation, in the form of rain, hail and snow.

In this practical, three different kinds of 'cloud' are set-up, where you will estimate the precipitation from each cloud type. You will employ methods that are similar to those used in weather forecasting. At the end, the precipitation will be released and you will compare your estimates to what the true value is, which would be measured by ground-based equipment, known as **rain gauges**. By the end of this exercise, you will be able to appreciate techniques and issues related to forecasting.

Forecasting the weather is tricky – even though we have satellite images, ground-based radar and other devices, alongside computer programs, forecasts are far from 100% accurate. How much of the Earth's cloud cover do you think actually produces precipitation that reaches us on the ground? What proportion of a cloud is likely to be liquid water and ice? How much of that water and ice will turn into precipitation? These are questions that even experts struggle with. Clouds come in different sizes, shapes and heights. One can't deduce the amount of water droplets in a cloud just by going outside and looking up at the sky!

Equipment (Set-Up by the Classroom Leader)

- 3 Non-Transparent Cups (of Different Sizes/Volumes) with Lids
- Beaker
- 3 Post-it Notes
- Tape
- Marker Pen
- Scale
- Torch
- Measuring Cup
- Sweets (M&Ms, Skittles, Jelly Beans, etc)
- 2 Sandwich Bags



Set-Up

1. Cut a hole in the centre of the bottom of each cup, covering it with a Post-it note.
2. Place a small amount of sweets in one plastic bag, tying the excess bag in a knot, cutting it off to make a tight bundle. Repeat to make another of greater volume, which may not fall

through the hole, representing the portion of cloud moisture that may not be converted to precipitation. (Do not disclose the presence of these bundles).

3. Holding the Post-it notes, fill the cups by:
    a. Pouring a cup ½ full of sweets, then adding a bundle, and then adding more loose sweets until ¾ full.
    b. Select another cup and pour 1/3 full of sweets.
    c. In the third cup, pour it about ¼ full of sweets, then adding the other bundle, then adding more sweets to fill it halfway.
4. Put the lids securely on, and hold them down with tape.
5. Invert the cups.
6. With a marker, mark them as X, Y, and Z
7. Below, mark the actual capacities of the cups.
8. Put an amount of sweets into the beaker.
9. Place these on a table where all group members can see them. Place the measuring cup, scale, light and beaker next to the cups.

How Well Can You Forecast?

The three cups in front of you represent three make-believe cloud types called X, Y and Z. They all produce precipitation, here represented as sweets. Your task is to estimate how much precipitation each cloud produces. You will observe the clouds in different ways to do this. First, make a table like this to record your estimates:

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

Method 1: Satellite Image and Weather Radar

Meteorologists estimate precipitation within clouds by viewing satellite photos of cloud coverage. They may also look at areas of precipitation identified by ground-based weather radar. As you look at clouds, somewhat trying to 'image' them like a satellite, make an estimate on the volume of precipitation (in millilitres) each cloud type contains, and record them under Method 1: "Satellite and Weather Radar". Each cup has been labelled with its volume capacity. You may find this estimate hard to make without knowing what's inside the clouds – this is similar to how it is hard to determine the amount of cloud that will become precipitation in the real-world.

Method 2: Cloud Profiling Radar

Research satellites overtime have gathered information to more accurately make estimates of cloud precipitation content. For example, CloudSat uses radar to tell us about moisture content and air currents within a cloud. Pretend the light from the flashlight is a radar beam (the teacher will remove the Post-it). Without touching the clouds, you will each get a turn in using the beam to peer into the

hole to observe the level of sweets inside. Make a new estimate of the amount of precipitation each cloud type contains and record it under Method 2: "Cloud Profiling Radar View".

Method 3: Multiple Data Sources

Satellites orbit in close formation known as constellations which can observe clouds in different ways, with data from each combined. Here, the scale will be used and its weight will represent total moisture content data of a single cloud derived from multiple data sources. One person will weigh each cloud one a time on the scale and announce the weight, in grams, to the class – record this under Method 3: "Multiple Data Sources for Moisture Content".

Method 4: Revised Precipitation Estimate

Can you use the data from Method 3 to refine your volume estimates from previous methods? You can set up a ratio of exact weight among the three cloud types, which can be compared to ratios of guessed volumes. You may see some differences and may wish to revise your past estimates based on these ratios. E.g. you may have noted Z is twice the weight of X but is three times the volume. Using ratios between each measurement, see if you can revise your estimates. Note these estimates under Method 4: "Revised Precipitation Estimate from Moisture Content".

Method 5: The Ground

To learn as much as possible from each cloud, we end up comparing satellite data with other data sources, including those from ground stations which may use rain gauges. The actual precipitation coming out of clouds can then be compared with data observed in the clouds.

One person will take each cloud and turn them over the measuring cup, shaking them until no more rain (sweets) can be shaken out – the weight from the measuring cup will then be announced to the class. Record these under Method 5: "Ground Station Data". Once again, make a note of the ratio between these values, but do not revise your previous estimates.

Questions for Discussion (Tally Up the Differences in Class Estimates)

Q1) What general conclusions can you make from your estimates and how they differ from the true precipitation value?

Q2) What factors might cause differences between estimates and actual ground station data, and how is this, if at all, reflected in your final ratios?

Q3) Related to Q2, how did the lack of information about retained moisture distort your estimates?

Q4) How affected is each cloud type by the changes in method, if at all?

Q5) If you had another cloud of each type of a different size, could the data you collected help make an accurate forecast of precipitation for it? If so, how would you do this?