AIM CLASSROOM ACTIVITY

Make a Cloud

The AIM Satellite Mission (http://aim.hamptonu.edu) is designed to study Polar Mesospheric Clouds (PMCs). One reason scientists want to study PMCs is to find out just how they are made. Currently, the details of how PMCs are formed are not well understood. For example, the mesosphere has very little water and none of it exists in liquid form, this is in contrast to the troposphere. Also, there are extreme differences in the temperature, pressure, gases, and particles between the troposphere and the mesosphere. Despite these differences we expect the basic science concepts to be the same. AIM will assist us in better understanding these details. To help your students understand the AIM mission they should first become familiar with some of the processes involved in cloud formation. Several lessons and demonstrations relevant to how clouds are formed can be found by searching through the *Digital Library for Earth Systems Education* (http://dlese.org/library/index.jsp). The following demonstration illustrates several of the essential processes involved in the formation of clouds.

Preparation

1. Collect two 2-Liter bottles with lids.
2. Hot glue or epoxy the lids together with the open ends facing out (see Figure 1). You may want to wrap tape around the caps to reinforce the connection.

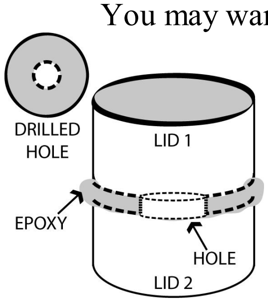

Figure 1 Joined lids with hole drilled through center

3. Drill a 1 cm diameter (approximately ½") hole through the center of the joined lids.
4. Test the connection by screwing the bottles into the lids. The assembly will look like that shown in Figure 2.

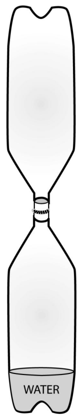

Figure 2 Assembly with water in the bottom bottle

Cloud Formation

To form a typical cloud three conditions must exist: water vapor must be present, cloud condensation nuclei must be present, and cooling must occur. The two-bottle tower allows us to contain all three for demonstration or experimentation.

Let's make a cloud!

Materials

Cloud Bottles Assembly, Light projector (overhead, computer projector, flashlight or floodlight), 125 ml or so of water (an exact amount is not critical), wooden stick matches (paper will also work)

Water Vapor

1. Pour about 125 ml of water into the bottom bottle of your assembly.
2. Place your hand on the top of the bottle and shake and swirl the water. The purpose of this step is to increase the amount of water vapor in the bottom bottle as much as possible given the current temperature of the air in the bottle.
3. Screw the top bottle onto the bottom bottle.
4. Place the bottom bottle in the beam of light from your projection system. Make note of any reflections from particles drifting in the air trapped in the bottle. The reflected light from these particles is the key observation for the students.

Cooling

Cloud formation requires that you raise the relative humidity up to 100% in order to have condensation of the vapor into droplets. This can be achieved by cooling the air since cold air can hold less water vapor. There are different ways of cooling – going up in elevation (like a trip to the mountains) results in a drop in the air temperature. You could also try cooling the bottle directly through ice or a cold cloth. For this demonstration you will cool the air by allowing it to expand. You may have experienced this type of cooling when you pop open a can of soda pop, pressed a spray bottle such as used with insect repellent, or let the air out of a bike tire (the stem becomes cold). This type of cooling is called adiabatic cooling. In this demonstration you will first increase the pressure by squeezing the top bottle, and then rapidly decrease the pressure by letting the top bottle expand as you stop squeezing resulting in cooling of the air to the dew point.

1. Hold the bottom bottle with the water vapor in the beam of light.
2. Squeeze the top bottle.
3. Rapidly release the pressure by easing up on the top bottle (do not let go!).
4. Note the slight increase in reflection of the light beam from the droplets that form.
5. Ask your students for ideas on how to increase the cloud formation. Accept suggestions, but lead them to the idea that more particles, cloud condensation nuclei, could help.

Cloud Condensation Nuclei

You may have noticed some cloud formation in the prior experiment. This is because there are Cloud Condensation Nuclei (CCNs) present in the air around us. A satellite mission being flown by NASA that looks at *aerosols* is the CALIPSO mission. One of the investigations being conducted by the AIM mission will help us understand the role of meteoric dust and other particles in the mesosphere, as a source for the CCNs needed for PMC formation. To help make clouds in the bottle assembly, and illustrate to students the role of CCNs, you will introduce more CCNs from the soot produced by a burning match.

1. Unscrew the assembly.
2. Light a wooden match and drop it into the bottle with the water.
3. Screw-on the top bottle.
4. Place the assembly with the bottom bottle in the light beam. You may notice the smoke drifting in the air.
5. Squeeze the top bottle and release.
6. Observe the increased cloud formation by looking at the increased reflection of the light beam.
7. Squeeze and release the bottle several times and you will be able to observe the formation and dissipation of clouds as the temperature changes with the change in pressure.

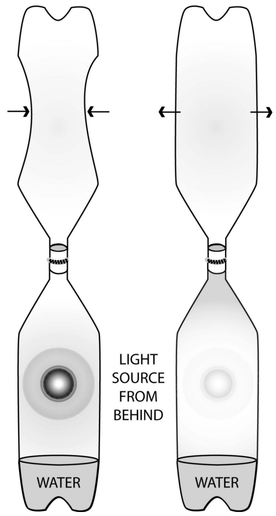

Figure 3 viewing the cloud formation (with light source from behind)

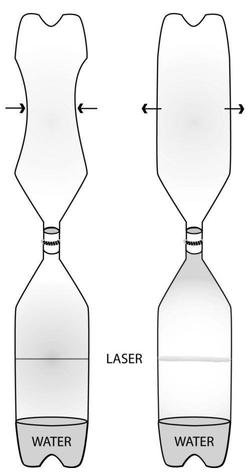

Figure 4 viewing the cloud formation (with laser light source)

Questions

1. What is the purpose of squeezing and releasing the top bottle?
2. Why did we swirl and shake the water in the bottom bottle?
3. Why did adding the smoke from the match make such a difference?

Extension Questions

1. What are some other ways we could cool the bottles? Try it.
2. Besides smoke, what else could we add to increase the CCNs?
3. What would happen if we kept cooling the bottle down, but did not have CCNs?

You may need to do some research to answer this one!

4. Explain the parts of the demonstration and how these are related to the goals of the AIM satellite mission. For example, how does the purpose of the instruments relate to the general properties of cloud formation?

Terminology:

Water Vapor – water in its gaseous state

Cloud Condensation Nuclei (CCN) – small particles on the order of 100 nm provides a surface for water vapor to change from a gas to a liquid. CCNs can be soot (carbon particles in smoke), salt, pollen, dust, or clay amongst other materials. The PMCs (polar mesospheric clouds) studied by the AIM mission do not typically have these types of CCNs. It is thought that debris left by the passage of meteorites might be the source of the CCNs for the PMCs, and that these CCNs might be 100 times smaller than the CCNs for the tropospheric clouds you see every day. This is an area of on-going research.

Dew point: temperature to which a parcel of air must be cooled for water vapor to condense. If water vapor is added to air at its dew point, condensation will start. If the temperature is cooled below the dew point, condensation will also start.

Adiabatic cooling: Occurs when pressure of a substance is reduced and the substance expands into a larger volume.

Relative Humidity: The ratio of the amount of water vapor present in the air to the total amount of water vapor that could be in the air at a given temperature. For a fixed amount of water vapor, like this experiment, lowering the temperature will increase the relative humidity up to 100% (to the dew point – the point at which condensation will spontaneously occur). Increasing the temperature will decrease the relative humidity.

Aerosols: – suspended microscopic particles in the air from a variety of sources such as salt, dust, volcanoes, soot, et. al. Size ranges from hundreds of micrometers to less than 10 nanometers. These can be a source for CCNs.