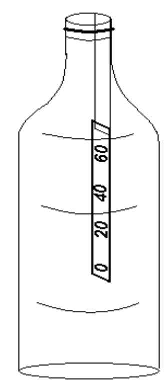
Activity: Clouds, Air Pressure and Temperature

Materials

A clean, clear, dry plastic 2-liter or larger beverage bottle with cap, thin liquid crystal temperature strip (available in aquarium supply stores), tape. *

Approach

Cut or tear a strip of transparent tape about 15 cm long. Attach one end to the temperature strip so the numbers can be seen. Hang the temperature strip in the middle of the bottle away from the sides and affix the other end to the opening of the bottle with just a small overhang outside of the opening. Screw the cap on tightly.



Objectives: After completing this investigation, you should be able to:

- Describe how air temperature changes as air pressure changes.
- Make clouds appear and disappear.
- Explain how most clouds form in the atmosphere.

Method: Examine the sealed bottle given to you. Stand the bottle up so the temperature strip inside can be read. Do not handle the bottle any more than necessary, so that its inside temperature will not be affected by the warmth of your hands.

Questions:

A. Air Pressure and Temperature Relationships

Read and record the temperature of the air inside the bottle as indicated by the temperature strip. Beginning temperature: __________ °F.

Place the bottle so about half extends beyond the edge of your desk or table. Standing and with one hand on each end, push down on both ends of the bottle so it bends in the middle and compresses the trapped air. Hold it this way to keep the air compressed while carefully watching the temperature strip. After half a minute or so, release the pressure by letting up on the bottle. Continue to carefully observe the temperature for at least a minute.
Final temperature: __________ °F.

1. What happened to the temperature as a result of the air being compressed?

2. When you released the bottle so the air inside was no longer being squeezed, what happened to the air temperature in the bottle?

3. State, in your own words, the relationship between changes in air pressure and temperature.

4. Air pressure decreases with an increase in altitude. This is because air pressure is determined by the weight of the overlying air. Consequently, air rising upward experiences lower pressure and expands. Based on your findings in (2) above, what must happen to the temperature of air rising through the atmosphere?

5. What happens to the temperature of air when it moves downward in the atmosphere? Explain your answer.

B. Making Clouds Appear and Disappear

Open the bottle and pour a few drops of water in it. Twist and turn the bottle to wet the inner surface. Cap tightly and let stand for a couple of minutes so enough water evaporates to saturate the air.

Lay the bottle on its side, open the bottle and push down to flatten the bottle about half its normal diameter. Have someone light a match, blow it out, and insert the smoking end into the bottle opening. Quickly release your pressure on the bottle so it returns to its rounded shape and the smoke from the extinguished match is drawn inside. Quickly cap the bottle tightly. The smoke was added to the air because atmospheric water vapor needs particles present on which to condense.

Now apply and release pressure on the bottle as before, keeping track of the temperature changes. Look very carefully in the bottle for any evidence of a cloud. It would be detected by a change in air visibility. If you cannot detect cloud, repeat the process of applying and releasing pressure until you do.

6. Did the cloud form when you applied pressure or when you released pressure? Did it form when temperatures rose or when they fell? Why?

7. Most clouds in the atmosphere form in the same basic way as the cloud in the bottle. In your own words, describe this process in the open atmosphere.

8. Once you have a cloud in the bottle, make the cloud disappear. What makes it disappear?

9. Most clouds in the atmosphere appear and disappear the way your bottle cloud did. State in your own words the temperature and pressure relationships that lead to cloud formation and, assuming no precipitation, cloud dissipation.

10. Based on this activity, what can you infer about vertical motions in the atmosphere where (a) it is cloudy and (b) it is clear?

11. Generally, High pressure areas in the atmosphere tend to be clear and Low pressure areas have clouds. What must be the vertical motions in these weather systems?

12. Examine a weather satellite picture, preferably today's, and point out broad areas where air is probably rising and those where air is likely to be sinking.

***** Pressure changes in the bottle may also be accomplished by using a device to keep the carbonation in opened soda bottles, termed "pump caps" or "fizz keepers" available from supermarkets.

Additional Activities

1. Keep a journal of cloud types and weather conditions over a period of a week. Make observations at least three times each day at intervals such as morning, afternoon and evening. You may wish to add photographs to your record. Can you relate the predominant cloud types seen to the weather conditions. Watch television weathercasts or call up weather charts on the Internet and note the passage of any fronts during this time. When were there convective-type clouds present, how do you know?

2. On a clear sunny day watch the development of cumulus clouds as the day goes on. If possible try to determine what types of ground the clouds form over. Additionally one might try to videotape short segments at regular intervals or make a movie and playback later as a study of cloud formation.

3. If you have episodes of fog, what were the conditions that preceded the fog? What changes occurred to cause the fog to dissipate? How do these conditions relate to cloud formation as described above?

4. Observe the turbulent motions that keep cloud droplets aloft by watching the specks of dust moving in a beam of sunlight through a window by viewing from the side, at right angles to the beam.

5. Watch convection currents set up in a pan of water put on a stove and heated. The water motions may be made more visible by adding pepper, tea leaves or other non-soluble specks.

6. Obtain a dry cleaning or other large, thin plastic bag. Tape any holes shut except the bottom opening with transparent tape. Tape a loop of thin wire around the opening inside the bag to keep the opening expanded. Use a hair dryer to fill the bag with hot air. How long does it take the bag to become buoyant? How high does the bag rise before falling again?

7. Make a Cartesian diver. A Cartesian diver operates because of buoyancy just as atmospheric vertical motions do. Fill a 2-liter, clear plastic soda bottle with water to within about 10 cm of the top. Take a small cylinder open at one end (such as a ballpoint pen cap) and fill partially with water. This diver must be just barely buoyant – that is, it must just barely float. Place it in the soda bottle and cap securely. When properly balanced, the diver will float to the top of the water. When the bottle is squeezed, the diver's air bubble will be compressed and be just small enough to cause the diver to sink to the bottom of the bottle. Releasing the pressure will allow the bubble to expand and the diver to rise to the top again.

Real World Applications

As mentioned in question 11 of the Activity, High pressure systems are generally tend to be clear and Low pressure systems have extensive clouds. The large scale circulations set up in these pressure systems involve broad areas of sinking air in High pressure and rising air in Low pressure (see the **Project ATMOSPHERE** guide on *Highs and Lows* for additional information). The types of vertical motions generated are similar to those you produced in the bottle activity of cloud formation. Can this pattern be seen in the atmosphere?

Figure 1 is the surface weather map for the coterminous U.S. for 18Z (2 pm EDT, 1 pm CDT, etc.) 8 October 2011. The map shows the locations of centers of expansive Highs and Lows by their lettered labels, H and L respectively. One High is located over the Virginia-Maryland-Delaware area. A strong Low is centered on the eastern Colorado border.

1. Based on these locations for the weather systems in Figure 1, one should expect:

   a. Clear skies over the eastern U.S.
   b. Clear skies over the central U.S.
   c. Cloudy skies over the eastern U.S.
   d. Cloudy skies over the central U.S.
   e. Both (a) and (b).
   f. Both (c) and (d).
   g. Both (a) and (d).
   h. Both (b) and (c).

Figure 2 is the visible satellite image for the coterminous U.S. for 1815Z 8 October 2011, essentially the same time as the Figure 1 map of weather system locations. On the Figure 2 satellite image note the location of the Hs and Ls from Figure 1. Bright white shadings denote clouds; small "bumpy" blobs are cumulus-type clouds and wispy feathered areas are cirrus-type clouds. The darker gray shadings are Earth's surface with water bodies where sunlight is absorbed generally being darker than land where more sunlight can be reflected.

2. Is the large clear area in the eastern U.S. in the Figure 2 satellite view located where the High was analyzed on the Figure 1 weather map?

3. Is the broad cloudy area in the central U.S. in the Figure 2 satellite view generally located where the Low was analyzed on the Figure 1 weather map?

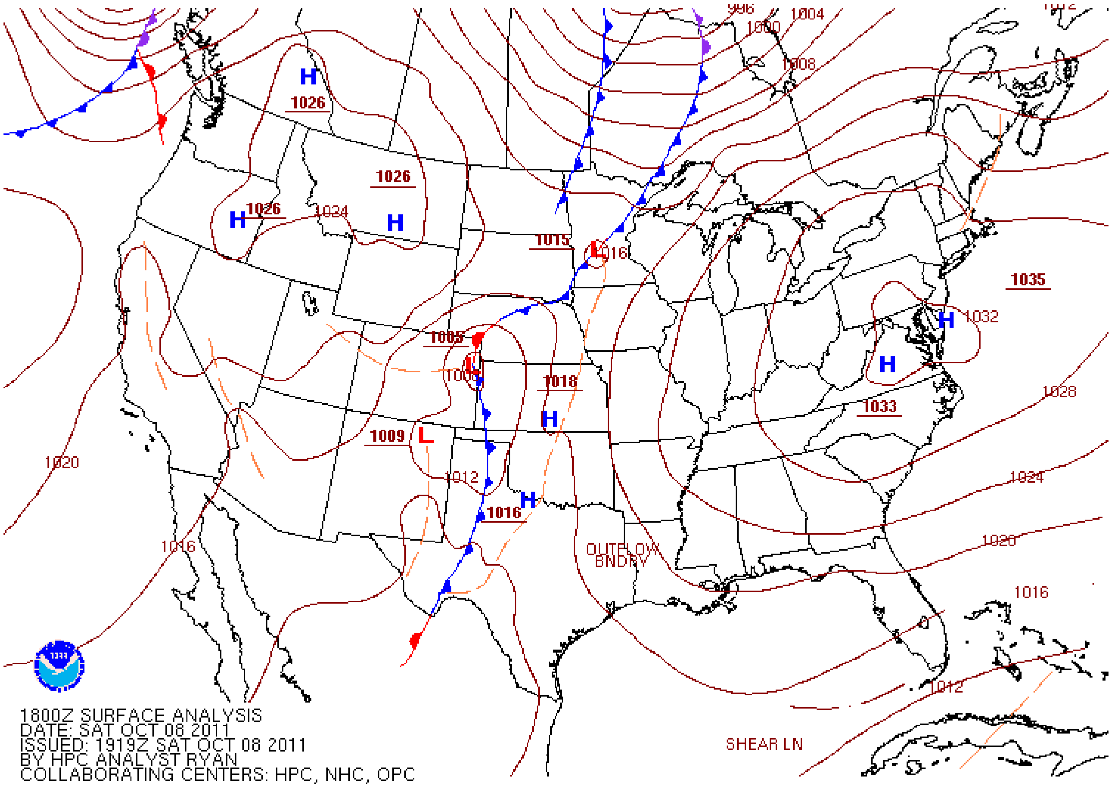


Figure 1. Map of surface weather pressure centers and fronts at 1800Z (2 PM EDT) 8 October 2011. [NOAA/HPC]

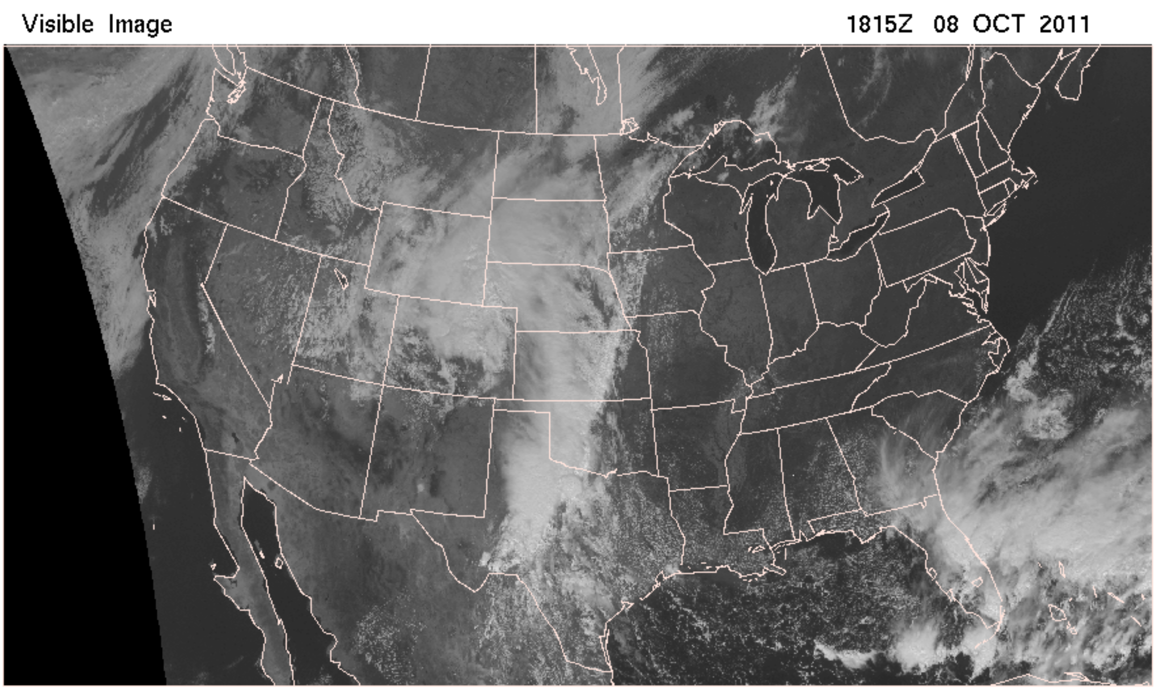


Figure 2. A visible satellite image of the coterminous U.S. at 1815Z (2:15 PM EDT) 8 October 2011 showing cloudy and clear areas. [NOAA/NCEP]