Why do thunderstorms tend to form in the afternoon?

A laboratory experiment from the
Little Shop of Physics at
Colorado State University

Overview

Necessary materials:

Activity 1

- Temperature profiles sheets (can be made by following template below)
- Portable markerboard (optional)
- 6-7 clipboards (optional)

Vertical motion of air in our atmosphere is responsible for many weather related phenomena. Hot air rises, and as it does it cools down.

The atmosphere heats form the bottom. Sunlight goes directly through the atmosphere, and warms the ground, which in turn warms the air just above the ground. For the activity we are going to look at the motion of an *air parcel*, or a blob of air which begins near the surface of the Earth.

The sun will heat the air parcel, and it will begin to rise. What happens next depends on temperature of the rest of the atmosphere, or the *temperature profile.* The parcel can stay where it is, fall back down, or continue to rise faster and faster!

In this kinesthetic activity, students will model the behavior of air parcels as they move up and down in the atmosphere. By following simple rules, students can explore what conditions could lead to severe weather.

Theory

For a parcel of dry air, the temperature decreases predictably as it rises. This is known as the *dry lapse rate*, which states that a dry air parcel's temperature drops by 5°C every 500m (or 1/2 km) that is rises. You can think of it as simple conservation of energy. The air is exchanging it's thermal energy (heat) for potential energy (height).

For moist air, or air containing water vapor, the temperature will not drop quite as much. This is because when the air cools, some of the water vapor begins to condense and form clouds. Condensation release the stored energy that went into evaporating the water. This energy is called *latent heat.* For this activity, we're going to use a *moist lapse rate* of 3°C per 500m. That is to say every time we go up in the atmosphere by 500m, the temperature will only drop 3°C for moist air while it will drop 5°C for dry air.

If an air parcel that initially begins to rise sinks turns around and sinks back down, this is know as a *stable atmosphere.* However, if it continues to rise up though the levels of the atmosphere, it is known as an *unstable atmosphere.* Unstable atmospheres don't last for long and they can lead to some extreme weather!

Doing the Experiment - Activity 1

Have 6 students stand in a line, side by side face the class, as spread out as your space allows. Each student will hold a sign with a number, using the numbers in Temperature Profile 1 in order (10, 12, 15, 11, 7, 3). Each student represents the temperature at a different level of the atmosphere.The first student represents the temperature near the ground (10°C), the next at 500m up (12°C), etc. Together, the students are a temperature profile of the atmosphere.

Another student will represent an air parcel near the ground. You will have the person who is the parcel rise, changing temperature as he or she rises. Have him or her walk to the next level, compute temp change, then decide what to do. So, suppose a dry parcel at the surface warms to 11°C. It then starts to rise, but it cools (by 5°C), ends up being cooler than the air around it… So it sinks back down to the ground.

The first scenario represents an atmospheric profile from the start of the day. Overnight, the surface of the Earth has cooled significantly, while the higher levels in the atmosphere remain relatively unchanged from the previous day.

Doing the Experiment - Activity 2

Repeat the same experiment, but with a parcel of air that contains water vapor. The student representing the parcel will now only cool by 3°C for each 500m level that he or she goes up.

For Temperature Profile 1, the parcel will still be cooler than the surrounding air at 500m, and will sink.

Doing the Experiment - Activity 3

Repeat the experiment with different temperature profiles. Scenarios 2, 3, and 4 represent later times in the day when the air near the surface of the Earth has warmed significantly.

Taking a look at Temperature Profile 3 (25 19 16 11 7 3). Suppose a surface dry parcel warms to 26°C. It starts to rise, cools to 21°C when it gets to 500 m… Still warmer! So it keeps on rising, cools to 16°C… Stays put.

But if a person is representing a moist parcel… He or she cools to 23°C… and is still warmer than the surrounding air! Then 20°C… Still warmer! Then 17°C… Still warmer! The moist parcel keeps on rising. The extra energy from the condensing water vapor gives the parcel the oomph it needs to rise and keep on rising. Thunderstorm time!

Temperature Profile #1

Time: #1: Early Morning **10** Altitude: 0 m	*Time: #1: Early Morning* **12** Altitude: 500 m	*Time: #1: Early Morning* **15** Altitude: 1,000 m
Time: #1: Early Morning **11** Altitude: 1,500 m	*Time: #1: Early Morning* **7** Altitude: 2,000 m	*Time: #1: Early Morning* **3** Altitude: 2,500 m

Temperature Profile #2

Time: #2: Late Morning **18** Altitude: 0 m	*Time: #2: Late Morning* **17** Altitude: 500 m	*Time: #2: Late Morning* **15** Altitude: 1,000 m
Time: #2: Late Morning **11** Altitude: 1,500 m	*Time: #2: Late Morning* **7** Altitude: 2,000 m	*Time: #2: Late Morning* **3** Altitude: 2,500 m

Temperature Profile #3

Time: #3: Early Afternoon

25

Altitude: 0 m

Time: #3: Early Afternoon

19

Altitude: 500 m

Time: #3: Early Afternoon

16

Altitude: 1,000 m

Time: #3: Early Afternoon

11

Altitude: 1,500 m

Time: #3: Early Afternoon

7

Altitude: 2,000 m

Time: #3: Early Afternoon

3

Altitude: 2,500 m

Temperature Profile #4

Time: #4: Late Afternoon

28

Altitude: 0 m

Time: #4: Late Afternoon

22

Altitude: 500 m

Time: #4: Late Afternoon

20

Altitude: 1,000 m

Time: #4: Late Afternoon

18

Altitude: 1,500 m

Time: #4: Late Afternoon

17

Altitude: 2,000 m

Time: #4: Late Afternoon

15

Altitude: 2,500 m