How far away is space?

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

Overview

The atmosphere is really rather thin, but it doesn't have s sharp edge. As you go upward, the density steadily decreases. There is no sharp cutoff, but over a height of 10 kilometers or so (more in the tropic, less at the poles)—only 50% higher than Mt. Everest—there is little water, little weather, and not enough air to breathe. Over 100 kilometers you are in space. There is some air, but the sky is black and no airplane or balloon can fly.

Necessary materials per group:

Experiment
- 4000 Kilometer map
- At least 10 squares of standard transparency (can be cut into quarters)

A sheet of standard transparency is 1 mm thick. In this model, one millimeter represents 10 kilometers of distance both across the map and vertically along the layers of atmosphere.

Theory

When scientists speak of the atmosphere, they often define five different layers. There is, generally, no sharp transition between layers, but the different layers do have different characteristics. When you think of the atmosphere, you think of weather—clouds, rain, snow. Essentially all of this takes place in the **troposphere**, the lowest layer of the atmosphere. As you rise up through the troposphere, the temperature steadily drops. It's this temperature profile that leads to the vertical motion of air that gives rise to our weather. Warmer air rises and cold air sinks; clouds form, the wind blows, and weather happens.

At a certain point, the temperature profile changes. The temperature begins to rise. Now, warmer air is on top of cooler air—so no vertical motion takes place. This is the **stratosphere**, so called because the air is stratified. There's very little water, and no vertical motion of air. When you look at the top of a very high thunderstorm cloud, you can see that it develops a flat top, giving it an anvil shape. This top edge is the edge of the stratosphere.

In this photo, courtesy of NASA, we can the thin layer of atmosphere, which has no sharp edge.

The stratosphere is important, though. It's the home of the ozone layer, responsible for blocking ultraviolet radiation from reaching the earth. Above this is the **mesosphere**, where meteors burn up, then the **thermosphere** (also called the **ionosphere**), where the Aurora borealis occurs and the space shuttle orbits, and, finally, the **exosphere**.

There is no well defined point at which the atmosphere stops. You could, really, call the top of the troposphere, 10 kilometers up, the top of the atmosphere, because the dry stratosphere is nothing like the warm, weather-y troposphere.

At the top of the Mesosphere, located at about 100 kilometers up, spacecraft can orbit, the sky is black, and you are, for all ordinary purposes, in space.

To put that in context, you could go to space and back and travel less distance than if you were to travel to San Diego from Los Angeles.

Doing the Experiment

Students should work in groups of 3 or 4; give each group a map. Ask your students to estimate the thickness of the atmosphere in relation to the size of the map by placing their hand above it at where the "top" of the atmosphere would be. Now explain to your students that you will be using transparencies to make a model of the atmosphere, one layer at a time. You can also have them predict how many sheets of transparency they will need to "build" the atmosphere to scale. Since this is a model you can cut the transparencies into quarters to use less supplies. Now that the students have made their predictions, they can quantitatively determine the actual number of transparencies needed. In this activity, one transparency represents 10 kilometers of thickness. Depending on your class goals and the age of your students, you can either give them the information in the following chart or have them research it themselves.

Layer of the Atmosphere	Thickness of layer	Number of transparencies
Troposphere	10 kilometers	1 sheet
Stratosphere	40 kilometers	4 sheets
Mesosphere	50 kilometers	5 sheets
Thermosphere/Ionosphere	80 kilometers	8 sheets
Exosphere	Thousands of kilometers	Tens of sheets

The numbers in the table are rough averages; the top of the troposphere, for instance, varies from equator to pole. We use as our base a world map placemat which is 40 cm wide at the equator, where the circumference is 40,000 km. The scale is thus:

1 cm on placemat = 1000 km on the earth

The transparencies have a thickness of 0.1 mm, or 0.01 cm, so:

1 transparency = 10 km

This is just about the thickness of the troposphere.

If you have your students build the table above, they might find slightly different numbers. But the central message is clear: The layer where we do all of our living and breathing, the troposphere, is quite thin.

Summing Up

This activity is a great way for your students to visualize the fact that the atmosphere, although important, is very thin and the outermost edge is not well defined.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: http://cmmap.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu