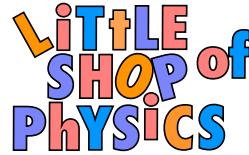


What is a “model”?

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



Overview

The physics of how the atmosphere works is quite simple, described with some very straightforward equations. The behavior of the atmosphere itself, though, is quite complex, and can't be expressed in a series of simple equations. Building up from the very simple concept of a physical theory to the complicated behavior of a real physical system is the job of a *model*. The best way to learn what a model is is simple to create one, which we will do in this exercise.

Theory

Climate models start with basic physical theories: How air moves, how water behaves, how radiation transports energy. They then break the earth's atmosphere down into pieces—cells—and then compute what happens in each cell based on these physical theories. Cells exchange energy and matter with each other based on the physics of the transfer of matter and energy. The net result is a simulation of what the actual atmosphere might do. We can illustrate this idea by doing a very, very simple model for a piece of the atmosphere, as described below.



The design of the CMMAP logo tells us something about the model being developed by the center.

Necessary materials:

- Chips or tokens
- 3 model sheets, one for the surface, one for the lower atmosphere, one for the upper atmosphere.

Students will work in groups of four for this activity, one student representing each “cell” in the model.

Doing the Experiment

We have detailed instructions below for two different conditions: the “regular” atmosphere, and one with increased carbon dioxide—and thus increased thermal radiation.

This gives a very interesting—and surprising—result that is worth some discussion if you are spending class time on climate and climate change.

If you are interested in considering the nature of the model, and how physical models are developed, and you have time, it would be interesting to adapt the model in other ways.

Some possibilities:

- You could add another layer to the atmosphere. How would this affect the surface temperature and the temperature profiles?
- In the earth's atmosphere, the temperature increases above some elevation. This is due to energy deposited here that doesn't make it to the surface, ultraviolet that is absorbed in the ozone layer. You could mirror this by adding a layer to the atmosphere and then having the sun give some energy to this highest level each turn—say 3 tokens to earth and 1 token to the upper atmosphere.
- You could add seasonal variation. Instead of 3 turns of day and 3 turns of night, you could do 4 turns of day and 2 of night (summer) or 2 of day and 4 of night (winter).

You could also do an open-ended discussion of how this model could be made more realistic. What elements would you add?

Summing Up

This is a very simple model, but it captures the key elements of what a model is and does. And it can be made more complex.

For More Information

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

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

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Setting up and Running the Model

Setting up the Model

Four people are needed to run the model. Each person represents one segment of the model: One is the earth, one is the lower atmosphere, one is the upper atmosphere and one is space. The four people sit in a row, in order, just as the different segments appear in relation to each other:

Earth Lower Atmosphere Upper Atmosphere Sun & Space

Each element can exchange energy to other elements:

- The sun gives energy to the earth.
- The earth exchanges energy with the lower atmosphere.
- The lower atmosphere exchanges energy with the earth and with the upper atmosphere.
- The upper atmosphere exchanges energy with the lower atmosphere and with space.

Energy is represented by chips or tokens; energy exchange means exchanging chips or tokens.

How much energy is exchanged depends on the temperature: If an element is hotter, it gives off more energy. This is the basic physical fact that is coded into the model: higher temperature means more emission. The rate of increase increases with temperature, as it should. But the temperature and isn't in any particular unit.)

On the lower atmosphere and upper atmosphere are two columns giving the number of chips to transfer. The left column represents emission for the current amount of CO₂ in the atmosphere. The right column represents increased emission for a higher amount of CO₂ in the atmosphere.

Run the model for at least two day-night cycles with the numbers in the left column. Record the temperatures observed, and then see what changes occur with increased emission.

Running the Model

During each “turn” each element exchanges energy with other elements using the transfer cups. The energy transferred depends on the temperature of each element. The earth, lower atmosphere and upper atmosphere each get some tokens via the transfer cups. Each person puts his or her tokens on the model sheet. The highest covered square gives the temperature and the energy to be transferred.

During one “turn”, each element exchanges energy with the other elements:

- The earth exchanges energy with the lower atmosphere via the transfer cup. The amount transferred is determined by the temperature of the earth. If the temperature is 19, then 4 tokens are transferred to the lower atmosphere.
- The lower atmosphere exchanges energy with the earth and with the upper atmosphere. If the temperature is 19, then 3 tokens are transferred to earth and 3 are transferred to the upper atmosphere.
- The upper atmosphere exchanges energy with the lower atmosphere and with space. If the temperature is 8, then 1 token are transferred to the lower atmosphere and 1 are transferred to space.
- During the day, the sun gives 3 tokens to the earth—because energy from the sun heats the earth directly. At night, no tokens are transferred.

Each element places the newly received tokens and then determines the new temperature. This temperature is used for determining the energy transferred during the next “turn.”

One day consists of 3 turns of daylight, the sun transferring energy to the Earth, and then 3 turns of night, with no transfer of energy from the sun.

