What is a "model"?

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Overview

The physics of how the atmosphere works is quite simple, described with some very straight-forward equations. The behavior of the atmosphere itself, though, is quite complex, and can't e expressed in a series of simple equations. Building up from the very simple concepts 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.

Necessary materials:

- Chips or tokens
- 4 copies of the Heat Exchange Model sheet

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

Theory

Climate models start with 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.

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

Doing the Experiment

Start with a simple simulation:

- Have each element start with 20 tokens—meaning a temperature of 20.
- Now run the model for 10 turns. How do the temperatures change?
- Now, continue the simulation; keep running it, having students keep track of the temperature.

At some point, the model will stabilize; all of the elements will remain at the same temperature for each turn. How long does it take to reach this point? This is the final temperature profile that the model predicts for the atmosphere. Just as for the real atmosphere, the earth is warmer than the lower atmosphere and the temperature drops as you go higher.

The model breaks down at the high end, though: In fact, the stratosphere is hotter than the lower atmosphere. That's because the stratosphere is heated by the sun, something our model doesn't consider. But we can fix this! You should try "tweaking" the model a bit to get a more realistic result. You could add another layer to the atmosphere, and then have space give some energy to the highest level each turn—say 3 tokens to earth and 1 token to the upper atmosphere.

- How does this alter the predicted temperature profile?

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://cmmap.colostate.edu

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

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   Space

Each element can exchange energy to the adjacent element:

- 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.
- Space exchanges energy with the upper atmosphere.

In addition, the earth gets energy directly from space.

How much energy is exchanged depends on the temperature: If an element is hotter, it gives off more energy.

Running the Model

During each "turn" each element exchanges energy with other elements. The energy transfered depends on the temperature of each element.

The earth, lower atmosphere and upper atmosphere each get some tokens. Each person puts his or her tokens on the model sheet, a copy of the following page, in order from the bottom. The first uncovered 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. The amount transfered is determined by the temperature of the earth. If the temperature is 20, then 3 tokens are transferred to the lower atmosphere.
- The lower atmosphere exchanges energy with the earth and with the upper atmosphere. If the temperature is 20, 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 20, then 3 tokens are transferred to the lower atmosphere and 3 are transferred to space.
- Space gives 3 tokens to the earth—because energy from the sun heats the earth directly.

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."

Temperature 35 / Transfer 7	Temperature 36 / Transfer 8	Temperature 37 / Transfer 9	Temperature 38 / Transfer 10	Temperature 39 / Transfer 11
Temperature 30 / Transfer 5	Temperature 31 / Transfer 6	Temperature 32 / Transfer 6	Temperature 33 / Transfer 6	Temperature 34 / Transfer 7
Temperature 25 / Transfer 4	Temperature 26 / Transfer 4	Temperature 27 / Transfer 5	Temperature 28 / Transfer 5	Temperature 29 / Transfer 5
Temperature 20 / Transfer 3	Temperature 21 / Transfer 3	Temperature 22 / Transfer 4	Temperature 23 / Transfer 4	Temperature 24 / Transfer 4
Temperature 15 / Transfer 2	Temperature 16 / Transfer 3	Temperature 17 / Transfer 3	Temperature 18 / Transfer 3	Temperature 19 / Transfer 3
Temperature 10 / Transfer 2	Temperature 11 / Transfer 2	Temperature 12 / Transfer 2	Temperature 13 / Transfer 2	Temperature 14 / Transfer 2
Temperature 5 / Transfer 1	Temperature 6 / Transfer 1	Temperature 7 / Transfer 1	Temperature 8 / Transfer 1	Temperature 9 / Transfer 2
Temperature 0 / Transfer 1	Temperature 1 / Transfer 1	Temperature 2 / Transfer 1	Temperature 3 / Transfer 1	Temperature 4 / Transfer 1