Activity B Student Guide

A Mathematical Comparison: Testing Earthly Hypotheses Using Computer Models

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Activity B

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Overview

Matter is cycled through the biosphere while energy is converted into different forms and flows through a variety of food webs in the biosphere. As matter and energy are transported through the various ecosystems a number of processes affect their behavior. Heterotrophic organisms use preformed organic matter and the process of respiration for the energy they need. Much of this energy enters food webs through organisms that are able to use the energy of sunlight to create these organic molecules from carbon dioxide and water.

These are just two examples of a large number of processes that affect the Earth system. As you can well imagine it is a very complex system with a large diversity of environments. Its complexity creates many challenges for scientists working to understand how Earth works. For example when studying the Earth, it is difficult to control for all of the variables that comprise the earth system. Research can take a very long time because we often need to obtain observational data records for a significant period of time, from many different places in order to make scientific claims with confidence. In addition, some data may simply be impossible or undesirable to collect. For example, we can not move Earth further away from the sun and we would not want to release large amounts of carbon dioxide into the atmosphere so we can study the potential impacts.

Scientists sometimes use models to better understand a complex system or one of its components. One type of model is a physical model. Scientists can build a physical representation of a system. Physical models provide scientists with a different perspective or understanding of that system because they can isolate and study individual processes. In addition, scientists can use the physical model to perform experiments that would be impossible or undesirable to perform on the real system. In the previous activity you did exactly this type of activity. You created physical models of one of Earth's biomes. Then you performed an experiment to see how an atmosphere affects the biomes surface temperature.

Your physical models of biomes with and without atmospheres were hampered by several problems and limitations. You used small plastic containers with only one or two types of surface. Measurements could only be taken for twenty minutes. The room was probably already warmed by a radiator or cooled by an air-conditioner. You managed, however, to obtain results that appear qualitatively correct. Generally, the model with an atmosphere was warmer than the one without. Also, the brighter surfaces generally showed less temperature change than the darker ones.

The phenomena you observed in your experiments follow basic laws of physics. Scientists have developed methods to represent these laws in mathematical equations. They input these equations into a computer

program that is used to run their experiments. So rather than building a physical model like you did, they build a mathematical model to run experiments on a computer. In this activity you will use a mathematical model that simulates the relationships you were studying in your physical modeling experiments. In this model the basic laws of physics in the form of equations will be inserted into a computer program. You will use this computer program to study the earth system.

The computer model that we will be using takes into account three factors influencing a planet's temperature and thus, the stability of the world's biomes. They are described below. As you change these factors, the computer model calculates the resulting simulated surface temperature of the planet. In this particular activity you will be studying a planet that only has your particular biome.

1) **A planet's distance from the sun.** In the computer model the planet's distance from the sun is represented in astronomical units, 1 unit being the distance between Earth and the sun. The distance in meters and astronomical units for other planets in our solar system is also shown.

2) **The albedo of the planet's surface features.** The albedo of an object is a measurement of the reflectivity of the object. The amount of light that reflects off of an object can differ depending on the color and/or transparency of the object. As you input the number of "reflective" units for the color and types of surface features of your biome, you will be changing the "albedo" value for your biome. The greater the albedo of a surface the more reflective the biome surface feature. The albedo has an effect on surface temperature. For example, the lower the albedo, the more energy that is absorbed by the object because it is not reflected. If there is more light energy absorbed by an object, then there is more potential for the body to become hotter. The black body referred to in the computer model refers to an object that is completely black, absorbing most of the light energy while reflecting very little to energy. The surface features of your biome have their own albedo or reflectivity. The different reflective values for major Earth surfaces are included in a table.

3) **The amount of greenhouse gases present in the planet's atmosphere.** The last factor, the greenhouse gas factor, allows you to manipulate the amount of greenhouse gases present in the atmosphere in order to simulate what effect a change in atmospheric greenhouse gas levels may have on temperature. The amount of greenhouse gases present in the Earth's atmosphere at this time is designated as .418.

In using the computer model, you may notice that the albedo temperatures do come out high in comparison with realistic Earth temperatures. This is because the computer model used in this exercise was written using simplified equations to represent complex Earth systems. While it is helpful to use simplified models to investigate complex systems a number of problems come about through their use. Can you think of some of these problems?

By experimenting with the different factors, you can begin to understand how these factors influence the global temperature. The global temperature, as well as local temperatures, has a significant impact on the

types of organisms that can survive in a particular area. By understanding the interactions of only THREE factors in this extremely complex system, you will begin to develop an understanding of how changes in a part of the system can affect the system as a whole.

Learning Objectives

- ✓ Design an experiment to answer a specific question and test a hypothesis
- ✓ Differentiate between independent and dependant variables
- ✓ Evaluate experimental results and suggest experimental modifications
- ✓ Demonstrate the effects of the atmosphere on global temperatures
- ✓ Predict temperature changes due to environmental factors using mathematical models
- ✓ Relate temperature and environmental factors studied to the stability of the world's biomes

Relevance

Observations are important inputs to developing mathematical computer models capable of simulating earth system processes and predicting how Earth may change in the future. Indeed, such models enable researchers to conduct experiments that would be difficult, if not impossible, to implement on our planet. To understand the complex Earth system, where changes are produced by so many natural and human forcings, researchers must work with observations from the real world and results from computer modeling experiments. As a research tool, mathematical models that run on computers can perform experiments that give a researcher an opportunity to ask a range of "What If…" questions. The aim of these questions is to discover how processes work in the earth system and how they may change in the future.

Investigation – Part 1 Activity B

Introduction to the Global Equilibrium Energy Balance Interactive Tinker Toy

Materials

- ✓ At least one computer for each group with the GEEBITT spreadsheet program loaded or Internet access to http://icp.giss.nasa.gov/education/modules/carbon/ (see Topic 2, Data and Tools)
- ✓ Biome surface information from Activity A
- ✓ World Vegetation Maps
- ✓ Index cards of different colors and Graph Paper
- ✓ World grid box diagrams and World grid box diagram transparency sheets

Period 1 – What is GEEBITT?

Preliminary Activity – Factors that Influence a Planet's Temperature

Think about the different factors that influence the temperature of an environment. List these in your notes. Share your list with your partner. Compare what he/she has written with your list. Does your partner have any factor that you have not listed? Do you have any factor not on your partner's list? Make one list that both of you can agree upon. Circle the factors on your list that you think affect Earth's average surface temperature. Be prepared to share your list with the class.

Methods

In this activity you will familiarize yourself with a simple mathematical model called Global Equilibrium Energy Balance Interactive Tinker Toy (GEEBITT) that is run using Microsoft Excel software. Some of the factors that you listed are represented in this model, as well as their relationship to one another. The model can be used to calculate predicted surface temperatures of a planet like Earth. You will use this program over the next few class periods to investigate how some of these factors affect Earth's surface temperatures. Be sure to take the time you need in today's class period to understand how you can change some of the different factors and practice working with the computer model.

1. Open the GEEBITT file and read the title page.
2. Preview each of the three worksheets without making any changes and complete **Data Sheet 1: Introduction to GEEBITT** for the default temperature information presented.
3. Discuss with your group the questions that follow on Data Sheet 1. Once you have reached a consensus, write your answers on the sheet.

Period 2 – Experiment with the Model

Now you are ready to use the model to predict what will happen in two different scenarios. One scenario will focus on greenhouse gases and the other can focus on any factor you would like to know more about.

Preliminary Activity

Look at the world vegetation map and/or your physical box models. Re-evaluate the number of each color index card that represents your biome. Remember each index card color represents a particular type of surface feature. You must use a total of ten cards. If you think you should split cards in half that is fine to do. Be prepared to justify your decision to the class.

Experiment with the Model

1. Use the computer model to study the influence of greenhouse gases on temperature in an area on Earth with your biome's surface features. You will first need to input the appropriate number of cards (out of ten) for each surface feature. Input this data into the gray boxes designated Land and Ocean on worksheet 2 of GEEBITT to represent the Percent Surface Area and reflectivity of each feature. By inserting surface feature values for your biome you are essentially building a model of Earth with only one biome's surface features.
   Note: The distance of the planet to the sun will not change (sheet 1).
2. Once you enter these surface area values, you will have changed the planetary albedo and in turn the temperature of the planet. Record the temperature data that you obtain when you put in your biome's surface features on Data Sheet 2.
3. Gradually increase the amount of greenhouse gases in the atmosphere by inserting a value of 0.1 into the Greenhouse Factor gray box on GEEBITT worksheet 3. Once you enter this value, you will notice that the planetary temperature begins to change. Record your temperature data on Data Sheet 2.
4. Continue increasing the amount of greenhouse gases in small increments. Record your results on Data Sheet2 as you increase the amount of greenhouse gases in the atmosphere.
5. Choose a different biome to study the effects of greenhouse gases in the atmosphere on surface temperature. You will need to ask another group (one with the biome that you want to investigate or have been assigned to investigate) what their surface feature numbers are and change these data on GEEBITT worksheet #2. Perform a similar experiment as you did in step 3 but for this biome's surface features. Record your temperature data on Data Sheet 2.
6. Be prepared to discuss your results with the class.

Period 3 – Designing your own GEEBITT Experiment

Preliminary Activity

Imagine that there has been a dramatic change to Earth's surface features. Some catastrophic event has occurred and Earth's features are now different. You are charged with two tasks

1. Explain the events that have caused this hypothetical situation. Perhaps there was a disease that has destroyed the trees or conversely, genetically modified plants have completely covered Earth. Describe one potential change that will affect Earth's surface features.
2. Describe what the surface features of Earth will be like. Use the grid map of Earth to diagram where the different features will now be located on Earth.
3. Be prepared to present your hypothetical situation to the class and the resulting change to Earth's surface features.

Experimental Design and Modeling

After hearing the different groups' ideas on hypothetical changes to Earth you need to design a research question to investigate using GEEBITT. It can be the situation that you described in the preliminary activity or it can be a new one. Just be sure that the whole group agrees on the research question.

1. Before using the model to test your research question, decide what you think the answer to your question is, what will the surface temperature become? Will it be warmer or cooler? The answer to the question will be your hypothesis. Record both your research question and your hypothesis on **Data Sheet 3: Experimental Design and Results**.
2. Now run the program. Run the control first by keeping the default values in place.
3. Run the experiment by changing experimental variable and record your results on Data Sheet 3.
4. Run a number of trials using different values that will still provide information to answer your research question. Record your results on Data Sheet 3.

Data Analysis and Consensus

1. Design a graph to show these results on Data Sheet 3. Draw this graph on the graph paper provided.
2. Discuss the results with your group and decide if you are able to answer your research question using the results as your evidence. What results do you use? How does the result 'answer' the question or part of the question? This is your discussion.

3. Answer your question directly citing the results, but without discussing them. Explain how your results and your experiment could be revised or reworked to achieve even more accurate results. This is your conclusion.
4. Complete the Individual Assessment Questions. Be prepared to discuss your answers with the class.

Period 4 – Presenting Your Research

Present your work as both a written report and a scientific poster. The report for your group should be handwritten neatly or typed and in Standard English format. This report should include an aim or research question, hypothesis, methods, results, discussion, and conclusion. The poster can show highlights of your work. Most of the work can be presented through bullets, lists, tables and graphs. The poster should include a representation of the aim or research question, hypothesis, methods, results, discussion, and conclusion.

Data Sheet 1 Activity B

Introduction to GEEBITT

Tasks

Use GEEBITT without making any changes. First, read over each of the three worksheets and complete the questions below. You can get to each of the worksheets by clicking on the name of each sheet at the bottom of the page.

1. If the only factor affecting Earth's temperature was the planet's distance from the sun, and if Earth were only a black sphere, what is the temperature predicted by the computer model?

2. If you take into account the albedo of the Earth, what is the change of temperature?

3. Why does the temperature change?

4. If you do not have a greenhouse gas factor, based on this model, what would be the average global temperature?

5. Why are greenhouse gases in the atmosphere important?

Data Sheet 2 Activity B

Experimental Results

Tasks

Use the computer model to study the influence of greenhouse gases on temperature in an area with your biome's surface features. In order to do this you will need to input the appropriate data in the gray boxes for designating the percent surface area and reflectivity of Land and Ocean in your biome. Use the number of each different colored card that you assigned for your biome in the preliminary activity to determine what numbers need to be entered into the GEEBITT gray boxes. The distance of the planet to the sun will not change (sheet 1)

You will gradually increase the greenhouse gases factor on GEEBITT worksheet 3. Start with a value of 0.1 and incrementally increase the value. Use the table below to record your results.

Biome: _____

Units of each surface feature and percent reflectivity:

Water: _____ Desert: _____

Vegetation: _____ Ice and Snow: _____

Greenhouse Gas Factor	Temperature

Now, use data identifying other biome's surface features to better understand how surface features can affect temperature even without any changes in greenhouse gases. Use the table below to record your results for this additional biome

Biome: _____

Units of each surface feature and percent reflectivity:

Water: _____ Desert: _____

Vegetation: _____ Ice and Snow: _____

Greenhouse Gas Factor	Temperature

Data Sheet 3 Activity B

Experimental Design and Results

Tasks

As a group, design a new research question to study using the mathematical model, GEEBITT. Design and run your experiment and make conclusions based on your results.

Aim (Research Question): _____

Hypothesis: _____

_____

Use this space for results –

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Answer the questions that follow based on your work in this activity, and your general understandings of ecology and mathematical models.

1. All other factors remaining equal, in what ways can a change of distance between a planet and the sun affect the temperature on the planet surface? Why?

2. All other factors remaining equal, in what ways can a change in albedo affect the temperature on the planet surface? Why?

3. All other factors remaining equal, in what ways can a change in greenhouse gases affect the temperature on the planet surface? Why?

4. Greenhouse gases have always been present on Earth. What are some natural sources of greenhouse gases?

5. Why would there be a concern over a rapid rise in greenhouse gases over a period of 50 years? (Remember the interconnections between abiotic and biotic factors in the Earth system)

6. What are some of the limitations and strengths of physical models and mathematical model run on a computer?