CHICAGO BOTANIC GARDEN

Activity 1.2: GEEBITT

(Global Equilibrium Energy Balance Interactive TinkerToy)

Grades 7 – 9

Description: Students use the NASA Micro-GEEBITT modeling tool to explore how changing variables in Earth systems affect global average temperature. Students model the effects of changes in reflectivity and greenhouse gases in different climate and emissions scenarios.

Time: Two 45-minute class periods

Prior Knowledge

- Students should be familiar with how to read a graph, and be able to verbally describe trends on a graph.
- Students should know how to calculate the slope of a line. If you have not yet covered this, you may want to provide students with the formula as part of the activity.

  $$\text{Slope} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

- Review vocabulary from Activity 1.1

Materials

- Computers with Excel loaded with the Micro-GEEBITT Excel model (internet access is not necessary)
- LCD Projector (or overhead of the Micro-GEEBIT screenshot in the activity)
- Copies of the "How to Use Micro-GEEBITT" directions for each student group
- Scenario cards (there are six included here, but you may also create your own)
- Worksheets
- Students' completed Earth's Energy Balance diagram from Activity 1.1
- Pens/pencils
- Calculators (optional)
- Rulers

National Science Education Standards

A.1.c Use technology and mathematics to improve investigations and communications, including the use of computers for the collection, analysis, and display of data.
B.3.f The sun is a major source of energy for the changes on the Earth's surface.
D.1.h The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor.
D.1.j Living organisms have played many roles in the Earth system including affecting the composition of the atmosphere.

AAAS Benchmarks

4B/H4 Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of the Earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of the earth increases.
4B/H6 The Earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the Earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to Earth's warming.

4B/M15 The atmosphere is a mixture of nitrogen, oxygen, and trace amounts of water vapor, carbon dioxide, and other gases.

Vocabulary

- **Global Average Temperature**: Climatologists prefer to combine short-term weather records into long-term periods (typically 30 years) when they analyze climate, including global averages. By looking at averages over long periods of time, climatologists can identify long-term trends in temperature that are not obvious if you look at daily, or even annual temperatures that can change drastically from day to day, and year to year. The idea is to collect temperature data from as many places as possible from all around the world, day and night, over many years, and then average all that data together to come up with the "global average temperature."

  There are several different techniques for coming up with a global average, depending on how one accounts for temperatures above the oceans—where it is not easy to collect temperature data on a regular basis—and other poorly documented regions. Since there is no universally accepted definition for Earth's average temperature, several different groups around the world use slightly different methods for tracking the global average over time, including the NASA Goddard Institute for Space Studies and the NOAA National Climatic Data Center.

  The Global average temperature does ***not*** tell you the temperature in your city, and it does not tell you how much that temperature will change as a result of climate change. Different locations around the world will be affected differently. It ***does*** help identify trends and describe overall what is happening to temperatures on a global scale.

Guiding Questions

- How do surface reflectivity and greenhouse gases contribute to maintaining the Earth's temperature?
- How is temperature affected by changes in surface reflectivity and greenhouse gas concentrations?
- What is the impact of increased greenhouse gases on the Earth's temperature?
- What are the implications of new average "surface" temperature? How would increased average surface temperature everyday local temperatures?

Assessment(s)

- Earth's temperature simulation worksheet

NOTE: *There are four levels of GEEBITT climate model from simple to complex. All four versions can be found on the curriculum website. This activity assumes the simplest level, which allows students to change the Earth's surface reflectivity and absorbing atmosphere (i.e. the greenhouse factor). The model calculates the Earth's average temperature based on student input. The other, more complicated, versions of GEEBITT can also be downloaded at:* *http://icp.giss.nasa.gov/education/geebitt/*.

Pre-Activity

- Familiarize yourself with the GEEBITT simulation and how it works.
- Copy the GEEBITT excel file to all the computers you plan to use. You may choose to create shortcuts on the desktop for students.
- Make copies of the "How to use Micro-GEEBITT" directions for student groups
- Review vocabulary from Activity 1.1 with students. You may want to copy and hand out the vocabulary sheets for student reference.

Procedure:
Part 1

1. Begin the class with a discussion of averages and global average temperature. Ask students what they think the average summer or winter temperature is in their city. Is it exactly this temperature all the time? How does it change? (day vs. night, day to day, location etc.). Note that any particular day it could be much higher or much lower than the average, and that one of the characteristics of averages is that they "hide" extremes. If the average summer temperature is 65 degrees Fahrenheit (18 degrees Centigrade), what might be the daily high, what about nightly low? This doesn't have to be an accurate estimate, they just need to begin thinking about averages.

2. Explain that to get these average temperatures, meteorologists combine data from many different weather stations over many years to come up with an average. Ask students how they might calculate a global average temperature (take measurements from weather stations all over the world and average them all together).

3. Why might knowing the average global temperature be useful? Will it help tell us what the weather will be like in our city tomorrow? (No) It won't tell us what the weather will be like anywhere in the world, but looking at the average global temperature over time will help identify long-term temperature changes, which is what we're looking at when we talk about climate change.

4. Tell students that now that they have seen the greenhouse effect in action in the lab and have learned about reflectivity and what greenhouse gases are (you may want to review the main greenhouse gases: carbon dioxide, methane, water vapor, and nitrous oxide), they are going to use a computer model to make predictions about what the Earth's global average temperature will do in the future given different greenhouse gas emissions scenarios. (NOTE: because this is a simple model, feedback loops and other anomalies will not be represented in the results of the simulation.)

5. Explain that though there are many greenhouse gases and the model they will be using includes the impacts from ***all*** greenhouse gases, for their analysis they are going to focus today on the most common greenhouse gas, carbon dioxide. The first thing they will need to do is figure out is what CO_2 concentrations will be like if everything stays the same. Hand out the "Earth Temperature Simulation Part 1: Calculating CO_2 increases" worksheet and project the graph of CO_2 concentrations from 2005 through 2010.

6. Explain that the graph illustrates the increase in the amount of CO_2 in the atmosphere over five years. As you explain the graph, you may need to explain that "parts per million" is the measure that scientists use to describe how much of something is in a gas mixture. Ask students if they see a trend. Have students verbally describe the trend. They are going to use this graph to estimate the trend numerically, so that they can predict what CO_2 concentrations may do in the future.

7. Have students fill out the "Earth Temperature Simulation Part 1: Current CO_2 Increases" worksheet as you discuss the graph as a group.

Math Extension: Have students use the graph to calculate the slope of the line. They can then calculate what the atmospheric concentration of CO_2 would be at future dates given the same emissions scenario, and the percent increase this represents.

$$\text{Slope} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

Part 2

8. Project the GEBITT spreadsheet and discuss each of the components of the program. See detailed directions and handout below, and demonstrate how to use the model. Explain how each of the four variables contributes to the model's calculation of the planet's average temperature.

9. Ask students what they think would happen to the temperature if the sun produced more energy? Less energy? What would happen if the Earth was closer to the sun? Farther away? Use other planets as examples. Mercury is much hotter than Earth and Neptune is much colder.

10. Now remind students of their Earth's energy balance activity. Ask students what happens to the sun's energy when it gets to the Earth? Explain that the Albedo variable represents the amount of energy reflected by the Earth's surface and the greenhouse factor represents all the components in the atmosphere that absorb the sun's energy; what they modeled when the did their greenhouse gas lab.

11. Tell students that by modifying these factors in the model, students will be able to see what the Earth's temperature would be like in different future scenarios.

12. Students can do this independently or in groups. Break students into groups of two or three per computer and hand out GEEBITT directions, *Earth Temperature Simulation Part 2: Predicting Temperature Change*, and one scenario card per group or per student depending on their knowledge level.

13. Have students open the GEEBIT program (you may want to create icons on the desktop for easy access) and follow the directions on the worksheet.

14. Once students have completed their scenarios, have them come back together as a class to discuss their results using the questions on their worksheet as a guide.
    - What did they find out about how different levels of reflectivity and heat retention affect temperature?
    - Did one variable impact temperature more than the other? Did it make a difference if they used both variables?
    - What makes up the average global temperature?
    - Does this mean that this is the temperature everywhere in the world, all the time?
    - Current estimates of increases are only 1-2 degrees C. Why do you think scientists are concerned about such a small increase?

15. Have students consider their unique scenarios and their implications for future temperatures. Given their scenarios and why scientists are concerned have students brainstorm. How might these changes in temperature affect your life? The lives of other people around the world? Their answers may not be clear right now, but tell students that they will investigate the impact of climate change, but first, they will find out where greenhouse gases come from.

16. To summarize: Clearly greenhouse gases affect temperature, but where do they come from? They will explore the natural and human sources of greenhouse gases in coming days.


Climate Change Concentration (in ppm)
DIRECT MEASUREMENTS: 2005-PRESENT
Data source: Monthly measurements (corrected for average seasonal cycle) Credit: NOAA
Parts per million
392
390
388
386
384
382
380
378
2005
2006
2007
2008
2009
2010
2011
Year

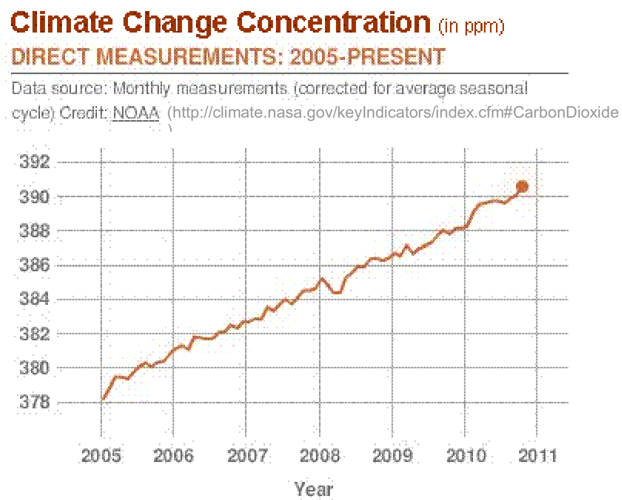
Name____Date_________Class______________

Earth Temperature Simulation Part 1: Current **CO_2** increases

1. **Use the graph to the right to estimate the annual increase of greenhouse gases in the atmosphere in parts per million (ppm).**

   Each year CO_2 increases by approximately

   _____________ppm



2. **Use your estimate to calculate the approximate rate of increase in CO_2. The slope represents the current rate of increase over time. Show your work in the space below.**

   Slope = $\dfrac{Y_2 - Y_1}{X_2 - X_1}$

3. **Use the slope to estimate the amount of CO_2 that would be in the atmosphere in:**

   For every (X)___________ year(s), CO_2 increases by (Y) __________ppm

   2020 CO_2_______________ppm, an increase of__________% from 2010.

   2100 CO_2_______________ppm , an increase of__________% from 2010.

   2500 CO_2_______________ppm , an increase of__________% from 2010.

   To calculate percent increase from 2010
   - Identify the CO_2 concentration in 2010.
   - Subtract the 2010 CO_2 concentration from the CO_2 concentration in each prediction year.
   - Divide the difference by the 2010 CO_2 concentration.

4. **What would happen to the graph if we added CO_2 to the atmosphere more quickly? Less quickly? Explain your answer.**

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Name_____________________________________Date________Class______________

Earth Temperature Simulation Part 2: Predicting Temperature Change

Use the GEEBIT model to answer the following questions. Refer to the GEEBITT instruction sheet provided by your teacher to guide you.

5. Modeling the Earth's current climatic conditions

a. Open the GEEBITT model using the icon on your desktop.
b. Add surface features to your model.
    i. Enter the Earth's current average global reflectivity (.306) in the data entry box #1 titled "Average Reflectivity of the Planet."
c. Add the atmosphere to your model.
    i. Enter the Earth's current greenhouse gas emissions (1.00) in the data entry box #2 titled "Atmospheric Greenhouse Factor."

When the Earth's current surface reflectivity and greenhouse gas concentration are correct, the blue box with the red outline titled "Earth with test reflectivity & test greenhouse factor" = 15 C (58.9 F). The numbers will match the blue box with the green outline titled "Earth Today."

6. Predicting future temperature changes

Use GEEBITT to model the Earth's average temperature under different conditions. As you follow the steps below, enter the bold, underlined numbers in GEEBITT and answer the questions based on the results. Begin with the Earth's current reflectivity (0.306) and greenhouse factor (1.000).

A. If in 2050 there are enough greenhouse gases in the atmosphere to increase the "greenhouse factor" to **<u>1.09</u>** (enter 1.09 in data entry box 2), and reflectivity stays the same as it is today (0.306) the Earth's average surface temperature would be

______________________ degrees Celsius.

B. Decrease the greenhouse factor to **<u>0.95</u>**. What happens to the Earth's average temperature?

______________________ degrees Celsius.

C. Based your Earth's Energy Balance diagram from Activity 1.1 and your answers to A and B, explain how the greenhouse factor affects the Earth's temperature and why.

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Before answering the following questions, reset the greenhouse factor and reflectivity to reflect current conditions.

D. Decrease reflectivity to **0.200**. Now what happens to the Earth's temperature?

____________________ degrees Celsius.

E. Increase reflectivity to **0.5**. What happens to the Earth's average temperature?

____________________ degrees Celsius.

F. Based your Earth's Energy Balance diagram from Activity 1.1 and your answers to D and E, explain how reflectivity affects the Earth's temperature and why.

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7. Drawing conclusions

G. Consider that the Earth's current average surface temperature is approximately 15 degrees C. Does this mean that this is the temperature everywhere in the world, all the time? Explain your answer.

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H. A one- or two-degree increase in Global Average Temperature may not seem like a lot. Why do you think scientists are concerned about such a small increase?

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I. Taking into account your answer to #7H (why scientists are concerned), brainstorm how a small change in Global Average Temperature might affect you directly.

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Name____Date__________Class___________

Situation Cards

Situation 1 Arctic ice flows melt more quickly than expected, so the Earth's Albedo is decreased to **0.275**. Globally, we reduce greenhouse gas emissions substantially and the greenhouse factor decreases to **0.90**.	**Situation 2** Arctic ice flows melt more quickly than expected so the Earth's Albedo is decreased to **0.275** Most industrialized countries are able reduce greenhouse gas emissions, but third world countries do not have the technology to do so. The greenhouse factor goes up to **1.05**.
Situation 3 Researchers discover a way of sequestering (holding) carbon so we are able to remove some of the CO_2 from the atmosphere. However, natural areas are destroyed to make way for industry. The land becomes desert, so reflectivity increases to **0.310,** but the remaining plants are not able to remove as much CO_2 from the atmosphere. Greenhouse factor increases to **1.03**.	**Situation 4** All countries are slow to take action on controlling greenhouse emissions because they cannot agree who should take responsibility. The Greenhouse factor goes up to **1.15**. Droughts increase desert areas. Reflectivity increases to **0.312**.
Situation 5 There is a series of major volcano eruptions that adds debris to the atmosphere. Less energy reaches the Earth, so reflectivity increases to **0.367**. We have begun to limit the amount of Greenhouse gases we produce the greenhouse factor decreases to **0.99**.	**Situation 6** We have transitioned entirely to solar, water, and wind power. No more gases are being added to the atmosphere. However, the ones that are there are slow to go away. Arctic ice flows have already been reduced by 10 percent. Reflectivity decreases to **0.275** and the greenhouse factor increases to **1.10**.

Earth Temperature Simulation Part 3: Modeling Changes

Use the information on your situation card to complete the chart. Calculate what the Earth's temperature would be in your scenario using GEEBITT. First calculate each cause and its effect separately, then calculate them both together. Fill in the table below.

Cause	Effect (on albedo & greenhouse factor)	Temperature	
		Celsius	Fahrenheit
1.	1.		
2.	2.		
Combined Temperature Change Effects			

Consider your scenario and its combined temperature change effects. 1. How might these changes in temperature affect your life? 2. The lives of other people around the world? Write your answers to both questions in the space below.

How to use Micro-GEEBIT

The Global Equilibrium Energy Balance Interactive TinkerToy

Variables

1. **Surface Reflectivity (albedo) of the planet's surface:** This is how much energy is reflected off the Earth's surface. Surface reflectivity values must be between 0 (all the energy from the sun is reflected) and 1 (all the energy from the sun is absorbed).
2. **Greenhouse Factor:** The "Greenhouse Factor" models the amount of heat the greenhouse gases in the atmosphere can absorb. In this model, 1.000 is the current amount of greenhouse gases in the atmosphere.

Format

(Color codes indicate what information you will find in that space)

- **Green Boxes** are where you enter information. Enter Surface Reflectivity in box 1 and the Greenhouse Factor in box 2.
- **Yellow Outlined Boxes** have to do with reflectivity.
- **Red Outlined Boxes** have to do with the greenhouse factor.
- **Light Blue Boxes** are where you see the Earth's average temperature calculated using the Surface Reflectivity and Greenhouse Factor that you have entered.
- **Medium Blue Boxes** give you information to compare your results to. The top medium blue box shows you what the Earth's average temperature would be with no atmosphere and no surface reflectivity. The bottom medium blue box shows you what the Earth's current temperature is based the surface reflectivity and greenhouse gases in the atmosphere today.

Step 1A Enter the Earth's reflectivity
Enter a number between 1 and 0.
1=all the sun's energy is absorbed
0=none of the sun's energy is absorbed
.306 is the Earth's current reflectivity

Step 1B Temperature change based on the Earth's reflectivity
The temperature will increase as reflectivity decreases (closer to 0), and will decrease when reflectivity increases (gets closer to 1)

Modeling The Earth's Temperature with Surface Reflectivity and the Greenhouse Effect

1. Average Reflectivity of the Planet

Enter Test Reflectivity* [ ]

(Earth's refelectivity today = .306)

* Reflectivity must between 0 and 1. 0 means all light is reflected and 1 means all is absorbed.

2. Atmospheric Greenhouse Factor

Enter Test Greenhouse Factor [ ]

(1.00 = Earth's current conditions)

	Resulting Surface Temperature		
	Kelvin	Centigrade	Fahrenheit
Earth with no atmosphere or reflectivity	278.6	5.5	41.9
Earth with only test surface reflectivity	278.6	5.5	41.9
Earth with test reflectivity & test greenhouse factor	278.6	5.5	41.9
Earth Today	288.1	15.0	58.9

Step 2A Enter the Greenhouse Factor
The greenhouse factor shows the amount of greenhouse gasses in the atmosphere. **1.000** represents the current amount of greenhouse gasses in the Earth's atmosphere. As the greenhouse factor increases (above 1) temperature increases, as the greenhouse factor decreases (below 1) temperature decreases.

Step 2B Temperature change with the Earth's reflectivity AND greenhouse factor Reflectivity and the greenhouse factor combine to determine the Earth's average temperature. For example, if reflectivity increases (decreasing the earth's temperature) and the greenhouse factor increases (increasing the earth's temperature) the actual temperature will be somewhere in between.

CHICAGO BOTANIC GARDEN

TEACHER ANSWER SHEET

Earth Temperature Simulation Part 1: Current **CO_2** increases

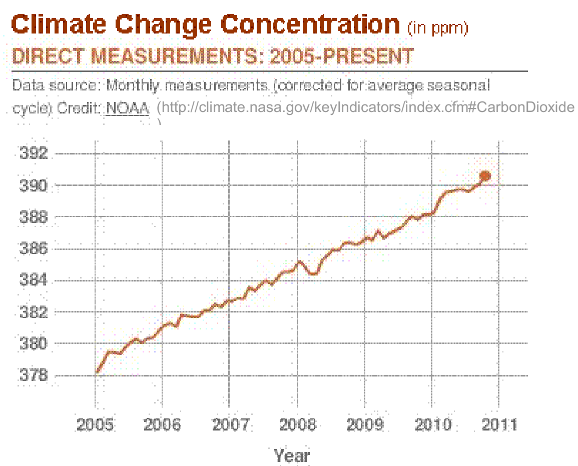
1. **Using the graph, estimate the annual increase of greenhouse gases in the atmosphere in parts per million (ppm).**

   Each year CO_2 increases by approximately ____**2**______ppm

2. **Calculate the current approximate rate of increase in CO_2. The slope represents the current rate of increase over time.**

   Slope = $\frac{Y_2 - Y_1}{X_2 - X_1}$

   Slope = $\frac{2}{1}$



3. **Use the slope to estimate the amount of CO_2 that would be in the atmosphere in:**

   For every (X)_____**1**______ year(s), (Y) CO_2 increases by ________**2**________ppm

   2020 CO_2__________**408**________ppm, an increase of_____**5**_____% from 2010.

   2100 CO_2__________**568**________ppm , an increase _______**46**_____% from 2010.

   2500 CO_2__________**1368**________ppm , an increase of_____**253**_____% from 2010.

4. **What would happen to the graph if we added CO_2 to the atmosphere more quickly? Less quickly? Explain your answer.**

   If we added CO_2 more quickly, the line would be steeper, since we would be added more than 2 ppm to the atmosphere. If we added it less quickly, the line would become more flat.

TEACHER ANSWER SHEET

Earth Temperature Simulation Part 2: Predicting Temperature Change

Use the GEEBIT model to answer the following questions. Refer to the GEEBITT instruction sheet provided by your teacher to guide you.

5. **Modeling the earth's current climatic conditions**
   a. Open the GEEBITT model using the icon on your desktop.
   b. Add surface features to your model.
      i. Enter the Earth's current average global reflectivity (.306) in the data entry box #1 titled "Average Reflectivity of the Planet."
   c. Add the atmosphere to your model.
      i. Enter the Earth's current greenhouse gas emissions (1.00) in the data entry box #2 titled "Atmospheric Greenhouse Factor."

When the Earth's current surface reflectivity and greenhouse gas concentration are correct, the blue box with the red outline titled "Earth with test reflectivity & test greenhouse factor" = 15 C (58.9 F). The numbers will match the blue box with the green outline titled "Earth Today."

6. Predicting future temperature changes

Use GEEBITT to model the Earth's average temperature under different conditions. As you follow the steps below, enter the bold, underlined numbers in GEEBITT and answer the questions based on the results. Begin with the Earth's current reflectivity (0.306) and greenhouse factor (1.000).

A. If in 2050 there are enough greenhouse gases in the atmosphere to increase the "greenhouse factor" to **1.09** (enter 1.09 in data entry box 2), and reflectivity stays the same as it is today (0.306), the Earth's average surface temperature would be

   17.5 degrees Celsius.

B. Decrease the greenhouse factor to **0.95**. What happens to the Earth's average temperature?

   13.5 degrees Celsius.

C. Based your Earth's Energy Balance diagram from Activity 1.1 and your answers to A and B, explain how the greenhouse factor affects the Earth's temperature and why.

   Increasing greenhouse gases increases the Earth's average temperature, decreasing greenhouse gases decreases the Earth's average temperature. Light energy from the sun hits the Earth and is converted to heat energy, the energy that is radiated back into the atmosphere as heat is trapped by greenhouse gases, so the more gases there are, the higher the Earth's average temperature.

TEACHER ANSWER SHEET

Before answering the following questions, reset the greenhouse factor and reflectivity to reflect current conditions.

D. Decrease reflectivity to **0.250**. Now what happens to the Earth's temperature?

20.6 degrees Celsius.

E. Increase reflectivity to **0.350**. What happens to the Earth's average temperature?

10.3 degrees Celsius.

F. Based your Earth's Energy Balance diagram from Activity 1.1 and your answers to D and E, explain how reflectivity affects the Earth's temperature and why.

Decreasing reflectivity increases the Earth's average temperature, while increasing reflectivity decreases the Earth's average temperature. Some of the light energy from the sun is reflected by the atmosphere, clouds, and some surface features like ice and snow. If less energy is reflected, then more light energy makes it to the Earth's surface and is converted to heat energy. If more energy is reflected, then less energy reaches the Earth's lower atmosphere and surface, so it cannot be converted to heat energy and used to heat the Earth, so the temperature goes down.

7. Drawing conclusions

G. Consider that the Earth's current average surface temperature is approximately 15 C. Does this mean that this is the temperature everywhere in the world, all the time? Explain your answer.

Depending on past content your students have covered the answer may vary. It may include differences between daytime and nighttime temperatures, differences in temperature between northern and southern states, differences in mountains versus sea level, or northern vs. southern hemisphere, or differences in seasonal temperatures. The main thing students should identify is that there are differences and that the Earth's average temperature is the **average** of all these different temperatures over time.

H. A one- or two-degree increase in Global Average Temperature may not seem like a lot. Why do you think scientists are concerned about such a small increase? List your ideas, and we will study this over the next few weeks.

Depending on your students' background, they may have a variety of ideas, which may include: melting polar ice caps, very high temperatures in deserts or the tropics, or tolerance of animals to a specific temperature range.

TEACHER ANSWER SHEET

Earth Temperature Simulation Part 3: Modeling Changes

Use the information on your situation card to complete the chart. Calculate what the earth's temperature would be in your scenario using GEEBITT. First calculate each cause and its effect separately, then calculate them both together. Fill in the table below.

Cause	Effect	Temperature	
		Celsius	Fahrenheit
1. Answers will vary	1. Answers will vary		
2. Answers will vary	2. Answers will vary		
Combined Temperature Change Effects			