CHICAGO BOTANIC GARDEN

Activity 1.4: GEEBITT
(Global Equilibrium Energy Balance Interactive Tinker Toy)

Grades 5 – 6

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.

Total Time: One to 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 1.2

> **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
> - Pens/pencils
> - 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 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 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 Earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of Earth increases.
4B/H6 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 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 even 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 and other poorly documented regions, where it is not easy to collect temperature data on a regular basis. 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 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 Earth's temperature?
- What are the implications of new average "surface" temperature? How would increased average surface temperature affect everyday local temperatures?

Assessment(s)
- Earth's temperature simulation worksheet

NOTES: There are four levels of GEEBITT climate model from simple to complex. MicroGEEBITT can be downloaded from the Chicago Botanic Garden's Climate Change in my Backyard website at: http://www.chicagobotanic.org/nasa/Grades_5-6_Unit_1. This activity assumes the simplest level, which allows students to change Earth's surface reflectivity and absorbing atmosphere (e.g. greenhouse factor). The model calculates Earth's average temperature based on student input. The other, more complicated versions of GEEBITT can be downloaded at: http://icp.giss.nasa.gov/education/geebitt/.

Pre-Activity
- Familiarize yourself with the GEEBITT simulation and how it works.
- Copy the GEEBIT excel file to all the computers you plan to use.
- Make copies of the "How to use GEEBITT" directions for student groups
- Review vocabulary from Activity 1.2 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 whether 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 on 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 Celsius), what might be the daily high, or the nightly low? This doesn't have to be an accurate estimate. The students 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 they have learned about reflectivity and where greenhouse gases come from, they are now going to use a computer model to make predictions about what Earth's 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 to 2010.

6. Explain that the graph illustrates the increase in the amount of CO_2 in the atmosphere over the past 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 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 Earth? Explain that the albedo variable represents the amount of energy reflected by Earth's surface and the greenhouse factor represents all the components in the atmosphere that absorb the sun's energy, which is 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 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 to 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.
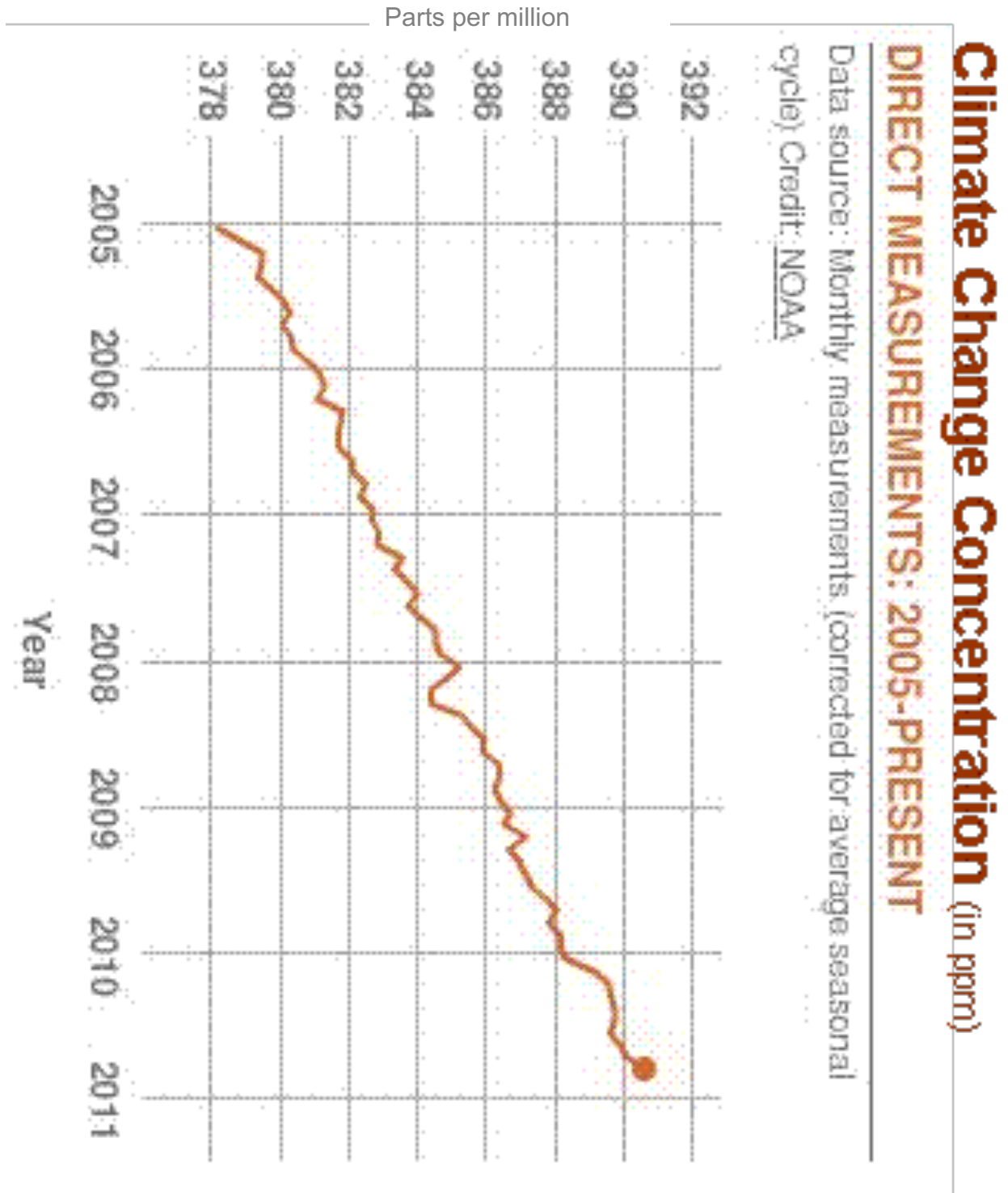
14. Once students have completed their scenarios, have them come back together as a class to discuss their results using the questions on their worksheet as a guide.
    - What did they find out about how different levels of reflectivity and heat retention affect temperature?
    - Did one variable impact 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 Celsius. 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 impact 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, temperature is affected by greenhouse gases, but what about the other aspects of climate, such as precipitation, winds, water? They will explore those in coming days.

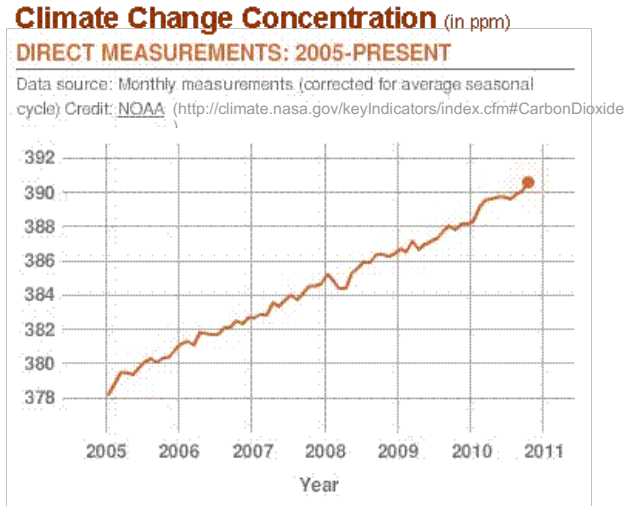# Climate Change Concentration (in ppm)

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

Year

2005 2006 2007 2008 2009 2010 2011

Name_____Date_____Class_____

Earth Temperature Simulation Part 1: Current CO_2 increases

1. **In words, describe the trend of CO_2 gas concentrations in the atmosphere illustrated on the map "Climate Change Concentration."**

    Climate Change Concentration (in ppm)
    DIRECT MEASUREMENTS: 2005-PRESENT
    Data source: Monthly measurements (corrected for average seasonal cycle) Credit: NOAA (http://climate.nasa.gov/keyIndicators/index.cfm#CarbonDioxide

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

    Each year CO_2 increases by approximately _____ppm

3. **Follow the example below to find the concentration of CO_2 (in ppm) for 2020 and 2050. Calculating estimated ppm for the year 2015:**
    Step 1: 2015–2012 = 3 years' difference
    Step 2: 3 years x (annual increase in ppm calculated in question 2) = increase in ppm
    Step 3: increase in ppm + 391 ppm (today's concentration) = ppm in 2015

    In 2020 CO_2 will have increased to _____ ppm

    In 2050 CO_2 will have increased to _____ ppm

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

    _____

    _____

    _____

    _____

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 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 Earth's <u>current average global reflectivity</u> (.306) in the data entry box #1 titled "Average Reflectivity of the Planet."
   c. Add the atmosphere to your model.
      i. Enter Earth's <u>current greenhouse gas emissions</u> (1.00) in the data entry box #2 titled "Atmospheric Greenhouse Factor."

When 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 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 Earth's current reflectivity (0.306) and greenhouse factor (1.000).

   A. If in 2050 the "greenhouse factor" is **<u>1.19</u>** (enter 1.19 in data entry box 2), and reflectivity stays what it is today (0.306) Earth's average temperature would be

   _____ degrees Celsius.

   B. Decrease reflectivity to **<u>0.200</u>**. Now what happens to Earth's temperature?

   _____

   C. Increase reflectivity to **<u>0.5</u>**. What happens to Earth's average temperature?

   _____

   D. Increase the greenhouse factor to **<u>1.25</u>**. What happens to Earth's average temperature?

   _____

   E. Based on your results above, how does reflectivity affect Earth's temperature?

   _____

   F. How does the greenhouse factor affect Earth's temperature?

   _____

Name_____Date_____Class_____

Earth Temperature Simulation Part 3: Modeling Changes

Use the information on your situation card to complete the chart. Calculate what 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.	1.		
2.	2.		
Combined Temperature Change Effects			

How to use Micro-GEEBIT
The Global Equilibrium Energy Balance Interactive Tinker Toy

Variables
1. <u>**Surface Reflectivity (albedo) of the planet's surface:**</u> This is how much energy is reflected off 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. <u>**Greenhouse Factor:**</u> 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 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 Earth's average temperature would be with no atmosphere and no surface reflectivity. The bottom medium blue box shows you what 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 <u>increase</u> as reflectivity <u>decreases</u> (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.

Situation Cards

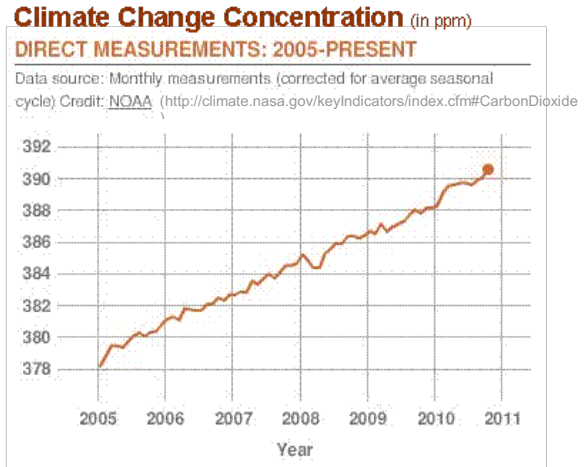| Situation 1	Situation 2
Situation 1 Arctic ice floes melt more quickly than expected so Earth's albedo is decreased to **0.275**. Globally, we reduce greenhouse gas emissions substantially and the greenhouse factor decreases to **0.90**.	**Situation 2** Arctic ice floes melt more quickly than expected so 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 Earth so reflectivity increases to **0.367**. We have begun to limit the amount of greenhouse gases we produce, and 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 floes have already been reduced by 10 percent. Reflectivity decreases to **0.275** and the greenhouse factor increases to **1.10**.

Earth Temperature Simulation Part 1: Current CO_2 increases

1. **In words, describe the trend of CO_2 gas concentrations in the atmosphere illustrated on the map "Climate Change Concentration"**

   Carbon dioxide has been increasing annually since 2005.

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

   Each year CO_2 increases by approximately _____**2**_____ ppm.

Climate Change Concentration (in ppm)
DIRECT MEASUREMENTS: 2005-PRESENT
Data source: Monthly measurements (corrected for average seasonal cycle) Credit: NOAA (http://climate.nasa.gov/keyIndicators/index.cfm#CarbonDioxide)

3. **Follow the example below to find the concentration of CO_2 (in ppm) for 2020 and 2050. Calculating estimated ppm for the year 2015:**
   Step 1: <u>2015–2012 = 3 years'</u> difference
   Step 2: <u>3 years</u> x (annual increase in ppm calculated in question 2) = <u>increase in ppm</u>
   Step 3: <u>increase in ppm</u> + 391 ppm (today's concentration) = ppm in 2015

   In 2020 CO_2 will have increased to _____ ppm

   In 2050 CO_2 will have increased to _____ ppm

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

   <u>If we added CO_2 more quickly, the line would be steeper, since we would be added more</u>

   <u>than 2 ppm to the atmosphere. If we added it less quickly the line would become flatter.</u>

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.

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When 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 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 Earth's current reflectivity (0.306) and greenhouse factor (1.000).

A. If in 2050 the "greenhouse factor" is **1.19** (enter 1.19 in data entry box 2), and reflectivity stays what it is today (0.306) Earth's average temperature would be

          20.2   degrees Celsius.

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

  It increases to 30.8 C

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

  It decreases to -2.9 C

D. Increase the greenhouse factor to **1.25**. What happens to Earth's average temperature?
  It increases to -1.4 C

E. Based on your results above, how does reflectivity affect Earth's temperature?

  <u>Increases in reflectivity decrease temperature. Decreases increase temperature.</u>

F. How does the greenhouse factor affect Earth's temperature?

  <u>Increases in the greenhouse factor increase temperature. Decreases decrease temperature.</u>

CHICAGO BOTANIC GARDEN

Earth Temperature Simulation Part 3: Modeling Changes

Use the information on your situation card to complete the chart. Calculate what 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			