CHICAGO BOTANIC GARDEN

Activity 2.3: Are Global CO_2 Levels Changing?

Grades 10 – 12

Description:
Part 1: Are Global CO_2 Levels Changing? During this activity students learn where CO_2 data has been collected, how long it has been collected, and then visualize the overall trends in the data. Students then compare different environments to see if CO_2 concentrations are changing all around the world or if changes are only occurring in certain locations.

Part 2: Climate Change around the World: Students use the NASA GISS Surface Temperature Station Data website (GISSTEMP http://data.giss.nasa.gov/gistemp/station_data/) to determine whether global CO_2 trends students identified in part 1 are consistent with patterns of temperature change around the world. Students discuss why different locations around the world are affected differently or to different degrees by changing climates.

Materials:
Part 1
- "Part per million" demonstration (Becker Bottle from Flinn, serial dilutions, etc.)
- Computers with internet access

Part 2
- Computers with internet access and excel
- Printers optional

Note: *The Flinn Becker Bottle can be purchased at:* *http://www.flinnsci.com/store/Scripts/prodView.asp?idproduct=15121*

Time: Three class periods for all activities

National Science Education Standards
A2.c Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science.
F3.b Materials from human societies affect both physical and chemical cycles of the Earth.
F4.b Human activities can enhance the potential for hazards.

AAAS Benchmarks for Science Literacy
8C/M11 By burning fuels, people are releasing large amounts of carbon dioxide into the atmosphere and transforming chemical energy into thermal energy, which spreads throughout the environment.
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 the light energy radiated into space until it again equals the light energy absorbed from the sun.
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.

Guiding Questions:
- What is a part per million?
- How are carbon dioxide levels changing throughout the world?
- How do carbon dioxide levels affect temperature at different locations around the world?

Background Information: Students should be familiar with the global carbon cycle and the roles that photosynthesis and cellular respiration play in the cycle (activity 1.1 from this curriculum may be helpful if students are not familiar with the carbon cycle).

Useful Websites:
- Becker Bottle: http://www.flinnsci.com/store/Scripts/prodView.asp?idProduct=14906
- How to Make a Serial Dilution: http://www.mgel.msstate.edu/pdf/solutions.pdf
- Serial Dilution Demo: http://www.youtube.com/watch?v=ZqdU3VfQ_Tc
- CO_2 Data From Many Sources: http://cdiac.esd.ornl.gov/trends/co2/contents.htm

Part 1: Are Global CO_2 Levels Changing?

Time: Two class periods

Pre-Activity:
- Become familiar with the CO_2 data on the Climate Change in My Backyard website.
  http://www.chicagobotanic.org/nasa/ccep/co2.html
- Become familiar with the climate data on the Climate Change in My Backyard website.
  http://www.chicagobotanic.org/nasa/ccep/global.html
  http://www.chicagobotanic.org/nasa/ccep/us.html
- Become familiar with the NASA GISS-TEMP website and how to retrieve temperature data from the site.
  http://data.giss.nasa.gov/gistemp/station_data/

Materials:
Part 1
- "Parts per million" demonstration (Becker Bottle from Flinn, serial dilutions, etc.)
- Computers with internet access
- Student handouts

Procedure:
1. Introduction: Engage students by asking them:
   - Does anyone know what units are used to measure CO_2 concentration on a global scale?
   - Why is it important to use the same units across sites?

2. Get out the Becker Bottle and ask students what they see. They will see all the blue pieces, but they may or may not be able to pick out the one yellow piece. If they don't point out the one yellow piece and ask what it represents, shake the bottle until the yellow piece is visible. Tell the students that there are 1 million pieces in the bottle. Ask the students how they would describe that one yellow piece among all the blue pieces (1 out of a million, or 1 part per million).

3. Ask the students to imagine that the yellow piece represents CO_2, and the yellow and blue pieces together represent a portion of the Earth's atmosphere. Ask, "how would you describe the concentration of CO_2 in the bottle?" (1 ppm). Explain that in that example, for every one million molecules in the atmosphere, one of those molecules is CO_2. But, there are many more than one million molecules in the atmosphere. Also, carbon dioxide makes up more than one ppm of the atmosphere.

4. Tell students they are now going to look at the data on the actual concentration of CO_2 in the atmosphere. They will determine what the concentrations are, and whether they are changing.

5. Pass out student data sheet Part 1 and divide students into groups of four students each (home groups). Within each group, assign each student a number (1-4). Each number represents a different region of the Earth: 1-Terrestrial Northern Hemisphere, 2-Aquatic Northern Hemisphere, 3-Terrestrial Southern Hemisphere, 4-Aquatic Southern Hemisphere).

   - Students can find the Atmospheric CO2 Concentration data on the Climate Change in My Backyard website at http://www.chicagobotanic.org/nasa/ccep/co2.html.

   Additional data sets include:
   - Terrestrial data sets available at http://cdiac.esd.ornl.gov/trends/co2/contents.htm
   - Aquatic data sets available at http://cdiac.ornl.gov/ftp/oceans/GLODAP_Gridded_Data/

6. Students will work independently (not in their home groups) to analyze data from three sites within their "quadrant." The number of years of data a student will analyze will depend on the site. Students will create graphs, calculate percent change, and answer questions on their data sheet.

7. **Exit Slip**: For homework, students should write a response to the question, "After studying data from your quadrant, what conclusion can you draw about global CO_2 levels?"

DAY 2

1. Lead class in a discussion of exit slip responses. Students should begin to understand that that they could not draw an accurate conclusion regarding global CO_2 levels from the limited sample of their quadrant. More data are needed. Students will get these data today by meeting with their home groups.

2. Have students re-form their home groups. Groups should:
   - report their own findings to the rest of their group;
   - compare and contrast terrestrial and aquatic data and also Northern and Southern Hemisphere data and complete the appropriate portions of their data sheet; and
   - generate a conclusion regarding global CO_2 concentrations.

3. Once students have shared their results with their group, bring the class together for a discussion of global CO_2 trends. The class will also discuss why CO_2 levels fluctuate seasonally. Some prompting questions might be:

- What is happening to CO_2 concentration in terrestrial parts of the Northern Hemisphere? What about the aquatic parts of the Northern Hemisphere?
    - The concentration is increasing at all cities investigated.
    - The concentration is increasing in both terrestrial and aquatic locations.
- What is happening to CO_2 concentrations in terrestrial parts of the Southern Hemisphere? What about the aquatic parts of the Southern Hemisphere?
    - The concentration is increasing at all cities investigated.
    - The concentration is increasing at both terrestrial and aquatic locations.
- What area had the greatest percent change throughout the time the data were recorded? Was it a terrestrial or aquatic location? Is that consistent across hemispheres?
- Now, let's compare the Northern and Southern Hemispheres to each other. Which hemisphere had the greatest percent change? What do you think caused this change?

4. It is interesting to note that although we looked at data taken from spots all around the world, the CO_2 concentration at each is very similar. Most locations have a CO_2 concentration of approximately 400 ppm (2014). Did you expect isolated locations such as the South Pole to have the same concentration as a heavily populated area like La Jolla, California? Explain.

5. Let's take a look at the graph of CO_2 data from Mauna Loa, Hawaii (the graph as of February 2013 is included in this activity guide. You can download the most current graph from: http://www.esrl.noaa.gov/gmd/ccgg/trends/). This is the oldest set of data that is available to us. What do you notice about this graph? What do you think is causing the levels to go up and down all the time?
    - Students should note that the levels go up and down constantly, but are increasing overall. These up and down changes represent seasonal differences in CO_2

6. Ask students why CO_2 levels might change seasonally. Remind students to think back to Unit 1 Activity 1.3: Are all plants created equal? How do plants create energy? What do they take out of the atmosphere? What do they release? Note that as plants lose their leaves in winter, the rate of photosynthesis decreases and therefore the amount of CO_2 in the atmosphere increases.

7. Wrap up the lesson with the question: "How does the analysis you did today within your home group compare to what you did yesterday on your own?" Take student answers. Some possible answers might include:
    - Yesterday, we looked at a limited amount of data in one area of the Earth. Today, we combined data from many different spots on Earth, and also looked at both aquatic and terrestrial data.

8. Closure: For homework, students answer the revised exit slip questions: "After studying data from all of your group members, what conclusion can you draw about global CO_2 levels?" "Why is this conclusion more accurate than the one you attempted to create yesterday?"

Assessment: Student understanding of objective and concepts will be assessed via exit slip, class discussions, and completion of work page.

Extensions: A similar lesson plan could be used to help students understand the difference between weather and climate. Students could analyze temperature data instead. First, students would analyze data from sequential days and/or years; then, they would analyze data over a period of 30 years. The student work page and class discussions would emphasize the difference between weather (daily fluctuations) and climate (10+ year trends).

Student Handouts: A page entitled, "Are Global CO_2 Levels Changing? – Day 1" will be distributed to each student on day one, while a page entitled, "Are Global CO_2 Levels Changing? – Day 2" will be distributed to each student on day two.

Part 2: Climate Change around the World

Time: One to two class periods

1. Open the day by reminding students of the trends that they saw in their graphs the day before. What did they find about CO_2 concentrations? What impacts do they think this increase might have on climate? On temperature? Will any temperature change be consistent across locations the same way CO_2 concentrations were similar?

2. Have students meet with their groups. Students should choose one location from each of the four categories from part 1 (Northern Hemisphere terrestrial, Northern Hemisphere aquatic, Southern Hemisphere terrestrial, Southern Hemisphere aquatic).

3. Hand out "Climate Change Around the World" instructions and work pages to students.

4. Give students approximately 30-40 minutes to generate their graphs using the NASA GISSTEMP site. Once students have created their graphs and done their analysis bring the class back together for the closing discussion.

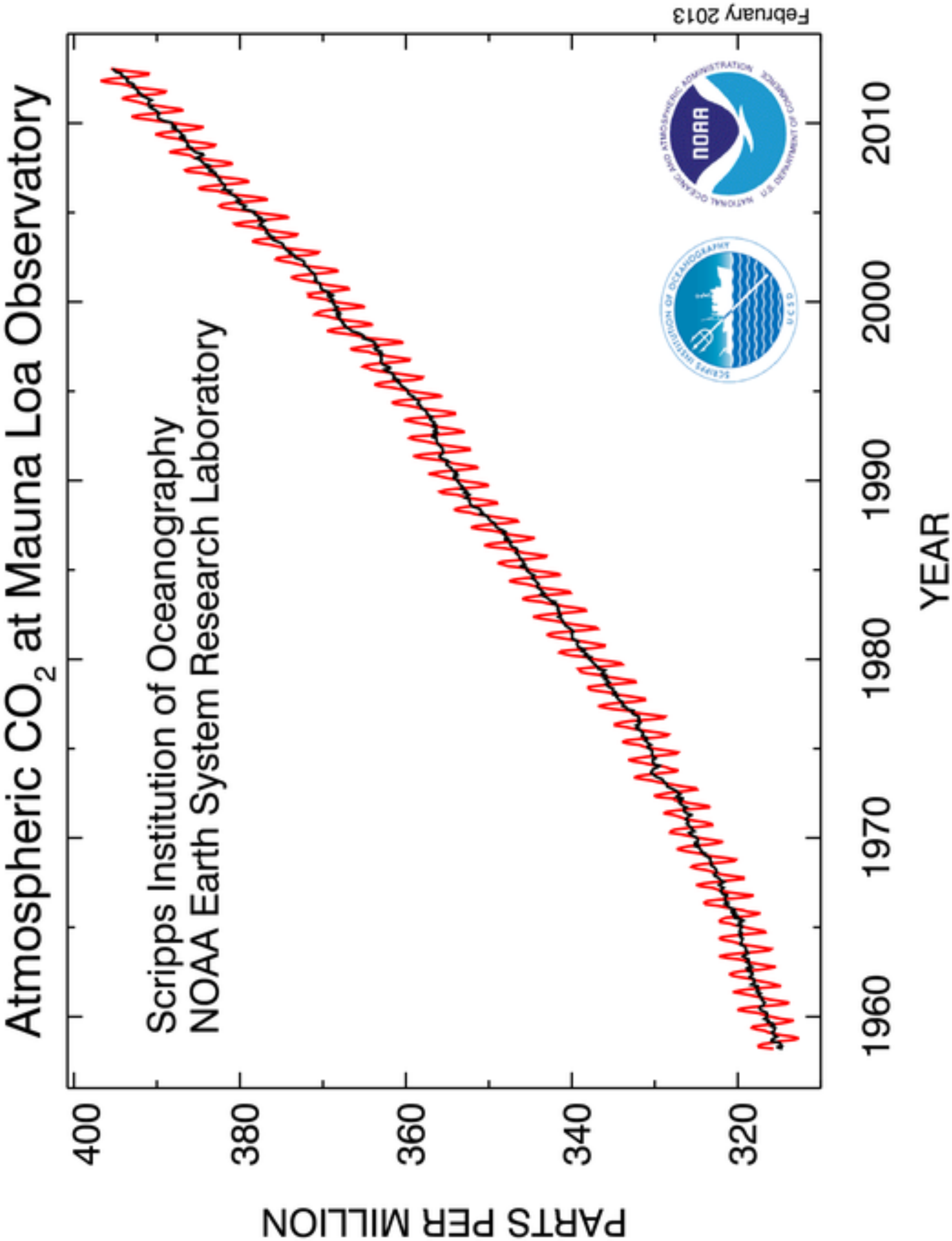
5. Discuss the results of their graphing activity. Begin with the group that analyzed the data for your home city and state and have them report back their results and write them on the board. Begin a full class discussion of the results for their home city and compare them with the data from other cities. Discussion questions might include:
    - Did you see trends in your data? (Because the data is fairly short term, trends may not be immediately obvious.)
    - Are the trends consistent with the CO_2 trends from each of the hemispheres and land conditions?
    - Why might they be different?
    - Are there any patterns in the trends? Are different climates, regions, or continents, reacting differently to the increase in global temperature?

6. Summarize by emphasizing that climate change is not simply temperature increase. Because all the Earth's systems interact with each other, it affects other aspects of climate, precipitation, and cloud cover. Additional graphs of sea ice coverage, sea level, CO_2 and

land/ocean temperature are provided below as curriculum resources. You may discuss these other environmental factors affected by climate change with students.

Note*: Lab sheets may be collected as an assessment, and should be placed in student portfolios.*

Useful Internet Resources:
http://www.srh.noaa.gov/oun/?n=safety-severe (Severe Weather Safety)
http://www.nssl.noaa.gov/ (National Severe Storms Laboratory)
http://www.weather.com/homepage.html (The Weather Channel)
http://data.giss.nasa.gov/precip_dai/ (NASA Global Precipitation Data)
http://www.cswr.org/ (Center for Severe Weather Research)
http://www.weather.gov/ (National Weather Service)



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
February 2013
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR

CHICAGO BOTANIC GARDEN

NAME ______________________________ DATE ______________ PERIOD __________

ARE CO_2 LEVELS CHANGING? – DAY 1

Carbon Dioxide (CO_2) is the most well-known greenhouse gas shown to be linked to an increase in temperatures around the world. While you may be familiar with carbon dioxide, you may wonder where the CO_2 values come from. Where is the data for CO_2 values collected? Are similar effects observed in Northern and Southern Hemispheres? What about terrestrial versus aquatic ecosystems?

During this activity you will learn where CO_2 data has been collected and how long it has been collected. You will also visualize the overall trends in the data. Lastly, you will also compare different environments to see if CO_2 concentrations are changing all around the world or if changes are only occurring in certain locations.

DIRECTIONS – Visit the site http://www.chicagobotanic.org/nasa/ccep/co2.html for Atmospheric CO2 Concentrations. Find the data that correspond to the area that you were assigned, and answer questions based on that data.

1. Write the name of the hemisphere and type of environment that you were assigned in the space below:

2. Choose one of the research sites in your region and click on its link. Use the data points to make a graph. You DO NOT have to graph every point. However, you do need to graph enough points to establish a trend. One way to do this is to graph one point every five years. For example: If your site has recorded data for 30 years (1978 to 2008) you would the following six points: 1978, 1984, 1990, 1996, 2002, and 2008. (You may use a separate sheet of graph paper if needed).

3. Next, you will calculate the percent change in CO_2 concentration at this location. This shows how much the values have changed over time and will allow you to compare the observed changes at multiple sites equally. Use the equation below for help:

$$\text{Percent Change} = \left(\frac{\text{Final Value} - \text{Initial Value}}{\text{Initial Value}} \times 100 \right)$$

Record the percent change in the table below in the space for Location 1.

LOCATION	FINAL VALUE	INITIAL VALUE	PERCENT CHANGE
1.			
2.			
3.			

4. Now that you have finished analyzing one site, choose two more locations within your assigned region. Generate a graph and calculate percent change for each of these sites as you did for your first site. Add each new graph to the original (be sure to differentiate between each site by using a different color or shape). Add each new percent change value to the original table as well.

5. Examine your newly-made graph. What is the trend at each specific site? What is the overall trend that you observe?

6. Which location had the greatest percent change in CO_2 concentration? Use data to support your answer. Why do you think this site had the greatest change?

7. Why was it important to analyze data from multiple sites within your region? How might your conclusion regarding the changes in CO_2 concentration within your region have been affected if you had not done this?

CHICAGO BOTANIC GARDEN

NAME _____________________________ DATE _________ PERIOD __________

ARE CO_2 LEVELS CHANGING? – DAY 2

Yesterday you analyzed CO_2 concentration data within a specific region of the world, while the other members of your group analyzed other regions. Today, you will combine all of your data, compare each region, and generate a more complete conclusion regarding how CO_2 concentrations are changing throughout the world.

DIRECTIONS: Listen as the other members of your group share their data with you. Record the data in the appropriate spaces below and answer questions based on that data.

1. Record the percent change data in the table below. Then calculate the average percent change that each region experienced.

NORTHERN HEMISPHERE – TERRESTRIAL			**NORTHERN HEMISPHERE - AQUATIC**		
LOCATION	% CHANGE	AVERAGE	LOCATION	% CHANGE	AVERAGE
SOUTHERN HEMISPHERE – TERRESTRIAL			**SOUTHERN HEMISPHERE - AQUATIC**		
LOCATION	% CHANGE	AVERAGE	LOCATION	% CHANGE	AVERAGE

NAME ______________________________ DATE _________ PERIOD __________

2. Which region of the world experienced the most change? Support your answer with data. Why do you think this region experienced the most change?

3. After analyzing more data, what can you conclude about CO_2 concentrations around the world? How does this conclusion compare to the one that you made yesterday?

4. Are you more confident of the conclusion you made today or the one you made yesterday? Please explain your answer.

IN-CLASS DISCUSSION

DIRECTIONS: Use the space below to answer questions based on the class discussion.

1. Was there a major difference between CO_2 concentrations observed at locations closer to human activities such as La Jolla, California, or Waldhof, Germany, and those observed at locations that are more isolated from human activities such as Mauna Loa, or Baring Head, New Zealand? Support your answer with data.

2. Would you have expected there to be a difference? Please explain your answer.

3. What do you notice about the Mauna Loa data? What could have caused these changes over time?

4. What did you learn during this activity that you did not already know? Was there anything that surprised you? Please give an example and explain why it surprised you.

STUDENT DIRECTIONS: CLIMATE CHANGE AROUND THE WORLD

Graph NASA temperature data in four locations around the world and analyze those graphs in light of your conclusions about CO_2 concentration from Part 1 of this activity. NASA data sets can be found at: http://data.giss.nasa.gov/gistemp/station_data/.

Find the latitude and longitude of the city you will be researching and record it on your handout. You can use Google Earth or the BudBurst website (budburst.org) for this information.

Find and Describe your Station

1. Using the Station Location and Station Details handouts, identify the station locations that are closest to your CO_2 data sites, and describe the features of those stations filling in the information on the **Location Details** table below (NHT=Northern Hemisphere Terrestrial, etc.).

Location Details

	Station Name	Latitude	Longitude	Elevation (m)	Topography (TP)	Biome (VEGE)
NHT						
NHA						
SHT						
SHA						

Creating Temperature Graphs

2. Go to: http://data.giss.nasa.gov/gistemp/station_data/
3. Make sure that the menu for **DATA SET** is set to "after combining sources at the same location"
4. Enter your station location name (make sure it is typed exactly)
5. Save or print your graph

Complete steps 2 – 5 for all four of your locations.

Find the data range: On each of your graphs, use a ruler to draw a straight line that follows the high points on the graph and one that follows the low points on the graph. Draw a line in the middle, parallel to the two outside lines. This is the RANGE of your data. Use this range as a guide to help you draw conclusions.

CHICAGO BOTANIC GARDEN

Name:______________________________ Date:___________ Room:__________

CLIMATE CHANGE AROUND THE WORLD

1. Can you determine any trends from your graphs of temperature? Are they consistent across the locations in all hemispheres?

2. How do your CO_2 and temperature graphs compare? Explain, using data to support your reasoning.

3. Look at the details of the locations that you recorded on your handout table.
   a. Are there any patterns or variables that might impact temperature? Explain your answer.

   b. Think back to any differences in CO_2 in the context of these location descriptions. Are there details of these locations that might impact CO_2 concentrations?

4. Given the trends you have identified in CO_2 and temperature, what do you predict will happen to temperature in the future?

CO_2 Location	NASA Temperature Station
Northern Hemisphere Terrestrial	
Alert, Nunavut, Canada	Alert,N.W.T.
Barrow, Alaska	Barrow/W. Pos
Cape St. James, Canada	Cape St James,Bc
Estevan Point, Canada	Estevan Point
Baja California Sur, Mexico	San Ignacio, Baja Calif. Sur
La Jolla Pier, California	San Diego/Lin
Brotjacklriegel, Germany	Passau
Deuselbach, Germany	Sembach
Waldhof, Germany	Heidelberg
Zugspitze, Germany	Zugspitze
Kyzylcha, Uzbekistan	Chakhcharan
Northern Hemisphere Aquatic	
Shetland Islands, Scotland	Lerwick
Ocean Station "C"	Ship C
Mauna Loa, HI	Kualapuu, Molokai
Cape Kumukahi, HI	Hilo/Gen. Lym
Sable Island, Nova Scotia	Sable Island,
Bering Island, Russia	Kljuci
Kotelny Island, Russia	Mys Salaurova
Southern Hemisphere Terrestrial	
Cape Ferguson, Australia	Townsville Am
Cape Grim, Australia	Marrawah (Marshall)
South Pole	Henry
Southern Hemisphere Aquatic	
Cape Matatula, Samoa	Apia
Kermadec Islands, New Zealand	Raoul Island,
Macquarie Island, Australia	Macquarie Island
Christmas Island	Christmas Island
Mawson Sea, Antarctica	Gf08
Baring Head, New Zealand	Wellington

NASA STATION DESCRIPTIONS

Station Name	Lat	Lon	Elev	P	<Pop>	Tp	Vege
ALERT,N.W.T.	82.5	-62.33	66	R	-9	HI	POLAR DESERT
APIA	-13.8	-171.78	2	S	33	HI	WATER
BARROW/W. POS	71.3	-156.78	4	R	-9	FL	TUNDRA
CAPE ST JAMES,BC	51.93	-131.02	92	R	-9	MV	WATER
CHAKHCHARAN	34.5	65.3	2230	R	-9	MV	TUNDRA
CHRISTMAS ISL	-10.43	105.68	262	R	-9	HI	WATER
ESTEVAN POINT	49.38	-126.55	7	R	-9	FL	WATER
GF08	-68.5	102.1	2125	R	-9	FL	ANTARCTICA
HEIDELBERG	49.4	8.65	110	U	129	HI	WARM CROPS
Henry	-89	-1	2754	R	-9	FL	ANTARCTICA
HILO/GEN. LYM	19.72	-155.07	11	S	38	HI	WARM, FOR./FIELD
KLJUCI	56.32	160.83	29	R	-9	MV	TUNDRA
KLODZKO	50.43	16.62	357	S	26	HI	COOL, CONIFER
KUALAPUU, MOLOKAI	21.2	-157	268	R	-9	HI	WATER
LERWICK	60.13	-1.18	84	R	-9	HI	WATER
MACQUARIE ISL	-54.48	158.95	8	R	-9	HI	WATER
MARRAWAH (MARSHALL)	-40.92	144.7	107	R	-9	HI	WATER
MYS SALAUROVA	73.18	143.23	22	R	-9	FL	WATER
PASSAU	48.58	13.47	408	U	51	HI	COOL FOR./FIELD
RAOUL ISLAND	-29.25	-177.92	49	R	-9	HI	WATER
SABLE ISLAND	43.93	-60.02	4	R	-9	FL	WATER
SAN DIEGO/LIN	32.73	-117.17	9	U	2498	FL	WATER
SAN IGNACIO, BAJA CALIF. SUR	27.3	-112.88	95	R	-9	HI	HOT DESERT
SEMBACH	49.5	7.87	321	U	101	HI	WARM DECIDUOUS
SHIP C	52.8	-35.5	-999	R	-9	FL	WATER
TOWNSVILLE AM	-19.25	146.75	9	U	86	HI	EQ. EVERGREEN
WELLINGTON	-41.3	174.8	128	U	136	HI	WARM CROPS
ZUGSPITZE	47.42	10.98	2962	R	-9	MT	NORTH TAIGA

LEGEND

Name Station Name
Lat latitude in degrees, negative = South of Equator
Lon longitude in degrees, negative = West of Greenwich (England)
Elev station elevation in meters, missing is -999
P R if rural (not associated with a town of >10,000 population)
S if associated with a small town (10,000-50,000 population)
U if associated with an urban area (>50,000 population)
Pop population of the small town or urban area in 1000s
If rural, no analysis: -9.
Tp general topography around the station: FL flat; HI hilly,
MT mountain top; MV mountainous valley or at least not on the top of a mountain.
Vege gridded vegetation for the 0.5x0.5 degree grid point closest to the station from a gridded vegetation data base. 16 characters.

CHICAGO BOTANIC GARDEN

NAME ___________**Teacher Answer Key**___________ DATE ___________ PERIOD

ARE CO_2 LEVELS CHANGING? – DAY 1

Carbon Dioxide (CO_2) is the most well-known greenhouse gas shown to be linked to an increase in temperatures around the world. While you may be familiar with carbon dioxide, you may wonder where the CO_2 values come from. Where is the data for CO_2 values collected? Are similar effects observed in Northern and Southern Hemispheres? What about terrestrial versus aquatic ecosystems?

During this activity you will learn where CO_2 data has been collected, how long it has been collected, and you will also visualize the overall trends in the data. Lastly, you will also compare different environments to see if CO_2 concentrations are changing all around the world or if changes are only occurring in certain locations.

DIRECTIONS: Log in to the Project Budburst site, find the data that correspond to the area that you were assigned, and answer questions based on that data.

1. Write the name of the region and type of environment that you were assigned in the space below:

ANSWERS WILL VARY

2. Choose one of the research sites in your region and click on its link. Use the data points to make a graph. You DO NOT have to graph every point. However, you do need to graph enough points to establish a trend. One way to do this is to graph a point every 5 years. First point – 1978, Second point – 1984, Third point – 1990, Fourth point – 1996, Fifth point – 2002, Sixth point – 2008

STUDENT GRAPHS WILL VARY BASED ON REGION AND PERSONAL CHOICE OF RESEARCH SITE

3. Next, you will calculate the percent change in CO_2 concentration at this location. This shows how much the values have changed over time and will allow you to compare the observed changes at multiple sites equally. Use the equation below for help:

Record the percent change in the table below:

LOCATION	FINAL VALUE	INITIAL VALUE	PERCENT CHANGE
	ANSWERS WILL	*VARY*	

4. Now that you have finished analyzing one site, it is time to analyze more data. Choose two more locations within your assigned region. You will generate a graph and calculate percent change for each of these sites just like you did for your first site. Add each new graph to the original (be sure to differentiate between each site). Add each new percent change value to the original table as well.

5. Examine your newly-made graph. What is the overall trend that you observe? What is the trend at each specific site?

ANSWERS WILL VARY
However, students should determine that CO_2 concentrations are increasing at all locations. Some locations may have experienced a greater degree of change than others.

6. Which location had the greatest percent change in CO_2 concentration? Use data to support your answer. Why do you think this site had the greatest change?

ANSWERS WILL VARY
It is most important that students support their answer with specific data. Also, it should be noted that sites such as Mauna Loa and the South Pole will show the greatest percent change because data from these sites have been recorded for the longest period of time. Sites with more recent data should show a smaller percent change.

7. Why was it important to analyze data from multiple sites within your region? How might your conclusion regarding the changes in CO_2 concentration within your region have been affected if you had not done this?

ANSWERS WILL VARY
Students should note that one cannot generate a meaningful conclusion about climate change across half of the Earth (a hemisphere) from simply looking at one site. As more and more data are analyzed, a more accurate and reliable conclusion will be reached. More than three sites would need to be analyzed as well; however, there simply is not enough time to analyze every site in both hemispheres. If multiple sites were not analyzed, a student's conclusion would have been skewed toward the results of that one particular site. Depending on the site that was analyzed, a student may have concluded that CO_2 concentrations are changing faster or slower than they really are. If data from one site have only been recorded for the past 20 years, those data do not provide as much information as data from a site that have been taken for 50 years. Also, the location of a site may influence its accumulation of CO_2 and thus its overall change in

concentration. For example, sites closer to poles may experience different rates of change than those closer to the equator. If only one site is studied, a student would reach an inaccurate conclusion based on the unique conditions of that site.

ARE CO_2 LEVELS CHANGING? – DAY 2

Yesterday you analyzed CO_2 concentration data within a specific region of the world, while the other members of your group analyzed other regions. Today, you will combine all of your data, compare each region, and generate a more complete conclusion regarding how CO_2 concentrations are changing throughout the world.

DIRECTIONS: Listen as the other members of your group share their data with you. Record the data in the appropriate spaces below and answer questions based on that data.

1. What was the overall trend observed in each of the other regions of the world that were studied by your group members?

ANSWERS WILL VARY

However, students should determine that CO_2 concentrations are increasing in all regions. Some regions may have experienced a greater degree of change than others.

2. Record the percent change data in the table below. Then calculate the average percent change that each region experienced.

NORTHERN HEMISPHERE – TERRESTRIAL			NORTHERN HEMISPHERE - AQUATIC		
LOCATION	% CHANGE	AVERAGE	LOCATION	% CHANGE	AVERAGE
	ANSWERS		*WILL*	*VARY*	
SOUTHERN HEMISPHERE – TERRESTRIAL			**SOUTHERN HEMISPHERE - AQUATIC**		
LOCATION	% CHANGE	AVERAGE	LOCATION	% CHANGE	AVERAGE
	ANSWERS		*WILL*	*VARY*	

3. Which region of the world experienced the most change? Support your answer with data. Why do you think this region experienced the most change?

ANSWERS WILL VARY
It is most important that students support their answer with specific data. Also, it should be noted that regions with sites such as Mauna Loa and the South Pole will show the greatest percent change because data from these sites have been recorded for the longest period of time. Regions with sites that have only recently begun to take data should show a smaller percent change.

4. After analyzing more data, what can you conclude about CO_2 concentrations around the world? How does this conclusion compare to the one that you made yesterday?

ANSWERS WILL VARY
However, students should determine that CO_2 concentrations are increasing around the world. This should be the similar to the conclusion that individual students reached the previous day.

5. Are you more confident of the conclusion you made today or the one you made yesterday? Please explain your answer.

ANSWERS WILL VARY
However, students should be more confident of the conclusion they reached today compared to the conclusion they reached yesterday because this conclusion is based on more data from all regions of the world and should thus be more accurate and reliable.

IN-CLASS DISCUSSION
DIRECTIONS: Use the space below to answer questions based on the class discussion of the data.

1. Was there a major difference between CO_2 concentrations observed at locations closer to human activities such as La Jolla, California, or Waldhof, Germany, and those observed at locations that are isolated from human activities such as Mauna Loa, or Baring Head, New Zealand? Support your answer with data.

ANSWERS WILL VARY
However, students should realize that there is not a major difference between sites that are closer to human activity and those that are isolated. For example, Mauna Loa, Hawaii, experienced a 22 percent change in CO_2 concentrations, compared with 17.5 percent at La Jolla, California. This indicates that the CO_2 generated at a site does not stay there. This may surprise students. It also serves to illustrate the idea that areas that are not responsible for the current climate change crisis are still going to experience the effects.

2. Would you have expected there to be a difference? Please explain your answer.

ANSWERS WILL VARY

Again, students should be surprised that areas near human activity do not always have a larger percent change in CO_2 concentrations compared to urban environments. Some students may not be surprised by this information or may not wish to admit it.

3. What do you notice about the Mauna Loa data that your teacher displayed? What could have caused these changes over time?

ANSWERS WILL VARY
Students should realize that CO_2 levels are increasing overall, but that they are at different levels throughout the year. These changes correspond to the changes in the seasons in each hemisphere. When it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere. CO_2 levels peak in the winter when fewer plants are performing photosynthesis and thus not removing CO_2 from the atmosphere. CO_2 levels decrease in the summer when more plants are performing photosynthesis and pulling CO_2 from the atmosphere to be converted into glucose.

4. What did you learn during this activity that you did not already know? Was there anything that surprised you? Please give an example and explain why it surprised you.

ANSWERS WILL VARY
Hopefully, students will realize CO_2 levels are increasing throughout the world and that there is a large amount of data from a variety of sites that support this conclusion. They should also learn that there is not a major difference between levels observed at an isolated site and those observed at a site near human activity, indicating that CO_2 produced at one location does not stay there but rather travels throughout the entire atmosphere.

PART 2: CLIMATE CHANGE AROUND THE WORLD

5. Can you determine any trends from your graphs of temperature? Are they consistent across the locations in all hemispheres?

ANSWERS WILL VARY

Depending on the locations that students are looking at, trends may or may not be consistent. Because different stations have been operating for different lengths of time, some will have more data than others.

6. How do your CO_2 and temperature graphs compare? Explain using data to support your reasoning.

ANSWERS WILL VARY

While CO_2 levels have been increasing fairly consistently, temperature will not be as consistent because each unique measurement is a measure of weather, not climate. It is the change in *overall average temperatures that shows changes in climate. Depending on the stations students look at, temperature may or may not be consistent with* CO_2 *increases.*

7. Look at the details of your locations that you recorded on your handout table.
   a. Are there any patterns or variables that might affect temperature? Explain your answer.

ANSWERS WILL VARY

Students should consider whether a location is aquatic or terrestrial, what kind of vegetation a location has, its elevation, and population.

   b. Think back to any differences in CO_2 in the context of these location descriptions. Are there details of these locations that might impact CO_2 concentrations?

ANSWERS WILL VARY

Students should consider whether a location is aquatic or terrestrial, what kind of vegetation a location has, its elevation, and population. High population centers tend to have higher CO_2 *concentrations because of increased energy usage, for example.*

8. Given the trends you have identified in CO_2 and temperature, what do you predict will happen to temperature in the future?

   Temperatures will continue to rise as the CO_2 *concentrations increase, and will only begin to decrease when we limit the amount of* CO_2 *and other greenhouse gases entering the atmosphere.*