



Activity 2.3: Historical Climate Cycles

Grades 5 – 6

Description: This activity introduces students to the idea of historical climate cycles.

In Part 1: Visualizing the Climate from 400,000 to 10,000 Years Ago, students will interpret graphs of temperature data from the past 400,000 years to understand how Earth's climate has changed in the past.

In Part 2: Graphing Climate Data from 10,000 Years Ago to the Present, students will graph data from 10,000 years ago to the present and place key events in environmental and human history on the timeline to demonstrate the timeframe of historical climate change. They will begin to understand the relationships between humans and climate. Comparing this graph to their first graph highlights the increased rate of change.

Lastly, in Part 3: Explaining Temperature Variation, students will look at the graph of temperature over the past 400,000 years along with a graph of carbon dioxide concentration over 400,000 years. By analyzing these graphs together, students will draw the connection between carbon dioxide concentration and temperature.

Materials:

- Graph paper, butcher paper, or adding machine tape (at least 6 m.)
- Colored pencils
- Rulers
- Tape
- Copies of data tables
- Handouts for parts 1, 2, and 3
- Overhead or LCD projector
- Parts per million bottle (optional)

Total Time: Two to three 45-minute class periods

Prior Knowledge

Graphing decimals

National Science Education Standards

11.A.3e/f Use data manipulation tools and quantitative and representational methods to analyze measurements. Interpret and represent results of analysis to produce findings.

12.E.3a Analyze and explain large-scale dynamic forces, events, and processes that affect Earth's land, water, and atmospheric systems.

AAAS Benchmarks

11C/E2b Often the best way to tell which kinds of change are happening is to make a table or graph of measurements.

11C/M7 Cyclic patterns evident in past events can be used to make predictions about future events. However, these predictions may not always match what actually happens.



11C/M10 Trends based on what has happened in the past can be used to make predictions about what things will be like in the future. However, these predictions may not always match what actually happens.

Common Core Math Standards

CCSS.Math.Content.5.G.A.1/2 Graph points on the coordinate plane to solve real-world and mathematical problems.

Resources

- CAMEL – (Climate, adaptation, mitigation, E-learning): National Science Foundation funded clearinghouse for resources to support teaching about climate change.
<http://www.camelclimatechange.org/resources/view/171210/?topic=65951>
- One supplier for purchasing a “Parts Per Million Bottles”
<http://sciencekit.com/ppm-bottle-activity-set/p/IG0046644/>
- Accessible paleo-climate website developed by Ralph J. Scotese. Won awards from NSTA and *Scientific American*
<http://www.scotese.com/climate.htm>
- Carleton College & Geological Society of America paleoclimate website and visualizations
<http://serc.carleton.edu/NAGTWorkshops/climatechange/visualizations/paleoclimate.html>
- NOAA comparison of different paleoclimate reconstruction methods
<http://www.ncdc.noaa.gov/paleo/ctl/clisci100kb.html>
- NOAA portal to ice core data sets used for climate reconstructions
http://www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok_data.html
- NASA Goddard Institute for Space Sciences Surface Temperature analysis and data sets
<http://data.giss.nasa.gov/gistemp/>

Guiding Questions

- How does temperature change over time?
- What is the time scale necessary to draw conclusions about changing climates?
- How is carbon dioxide concentration in the atmosphere connected to long-term changes in temperature?

Assessments

- Student worksheets
- Completed graph of temperature change over 10,000-year period

Vocabulary

- **ppm**: parts per million. Usually describes the concentration of a substance in a liquid or gas.

Part 1: Visualizing the Climate from 400,000 to 10,000 Years Ago

Procedure:

1. Begin with a discussion with students about short/long periods of time. Ask them how we measure short periods of time. (They might say: seconds, or minutes, days, or even years.) How do we measure long periods of time? (They might say years or centuries.)



2. Review students' earlier activities regarding weather. Ask them the following questions:
 - How far into the past did their data go?
 - Was that enough of a time frame to know whether the climate is changing? Why (not)?
 - Did the newspapers and websites provide enough information to decide whether the climate is changing? Why or why not?
 - Do you think the climate has always been the same as it is today?
 - Even 400,000 years ago?
 - 100 million years ago?
 - Are there some of the ways that we can know what the temperature was like in the distant past?
3. Tell students this historical temperature data derived from ice cores going back 400,000 years and they will be using it to determine first if climate does change over time. If so, how and how often? (You may wish to show the video *Drilling Back to the Future: Climate Cues from Ancient Ice on Greenland*. (available at CAMEL – Climate, adaptation, mitigation, E-learning): <http://www.camelclimatechange.org/resources/view/171210/?topic=65951>)
4. Project the graph of temperature change over the past 400,000 years. Depending on the level of your students you may want to go over the graph as a class and explain some of the more complex aspects:
 - The scale on the X-axis represents geologic time going back hundreds of thousands of years in the past. The numbers increase as you move to the left, representing how many years ago the dates are from the present.
5. Hand out the sheet “Visualizing 400,000 Years of Climate Data.” In groups, or as a class, have students interpret the graph and answer the questions.
6. When students have completed their work, ask the class:
 - Does climate change over time?
 - If there was change in the past, was it, in general, rapid or gradual?You may want to stress that changes in temperature of even 1-2 degrees took tens of thousands of years to occur.
7. Finally, ask students to share their predictions of what they think the graph of climate change from 10,000 years ago to the present will look like.

Part 2: Graphing Climate Data from 10,000 Years Ago to the Present

Procedure

1. Break the class up into six groups. Each group will be graphing a data set of temperature changes between 10,000 years ago and today. Depending on the size of your class and the number of points you want students to graph you may want to give each group more than one data set.



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Hand out materials to each group:

Groups with 500-year intervals (data sets 1-3)

- Eight pieces of 8.5 x 11 graph paper
- Tape (to tape pieces of graph paper together)
- One ruler with centimeter markings
- Colored pencils

Groups with five-year intervals (data sets 4-6)

- One piece of 8.5 x 11 graph paper
- One ruler with centimeter markings
- Colored pencils

All students should use the following scale for their graph:

500 years = 25 centimeters

5 years = 0.25 centimeters

The students' graphs should be set up in the same way as the graph of 400,000 years on the handout, with a horizontal line at 14 C to represent "current temperature." The y-axis should go from 12 C to 15 C, with markings every .1 degree.

Extension: You may have students look at the temperature range of the total data set and have a discussion of what the labels on the x and y axes should be to best represent the data rather than giving them the range noted above.

You may want to create an example graph that students can use as a model as they create their own.

2. Give students time to create their graphs and graph the data. They should use as much tape or graph paper as necessary to complete their graph to scale.
3. Once students are done, have the groups line up in time order (students with data from 10,000 years ago should be at the front of the line). Have the first group of students tape their graph to the wall. Have the second group of students add their graph to the first, continuing on until all the graphs have been taped together to create one long-term graph of temperature change.
4. **Optional:** Students can also add the events of human history to their graph(s). This will help students develop a connection between human evolution, actions, and the climate.
5. Give students a few minutes to look over the graph. Have students write their reflections from the graphing activity on their handout.
6. Ask students what they noticed from the graph of the past 10,000 years as compared to the graph from the past 400,000 years. You may want to point out that in the 400,000-year graph,



a temperature change of 1 or 2 degrees Celsius occurred over 10,000 years, but recently such a change happened in less than 100 years. Ask students what that means in terms of the rate of change.

7. Ask students the same questions as at the beginning of the class?
 - Who thinks that the climate is changing? Why do you think that?
 - Has the climate always been the same as it was today?
 - What do you think has made climate change in the past?
 - Is anything different about how the climate is changing today?
 - Ask students why they think climate is changing so quickly. Answers might include:
 - Pollution
 - Human impacts
 - Increase in greenhouse gases

Part 3: Explaining Temperature Variation

Procedure

1. Part 3 will tie together the relationship between CO₂ and temperature that was introduced in earlier lessons.
2. Before distributing the handout for Part 3, ask students what factors might explain the variation in temperature over the past 400,000 years. Write their answers on the board. If students do not mention greenhouse gasses, remind them of the lessons and labs from Unit 1 and ask again.
3. Next, hand out the sheet “explaining temperature variations.” Have students look at the two graphs and begin to answer the questions, alone, in groups, or as a whole class. Introduce (or review) the concept of ppm – parts per million. The data in the CO₂ graph is presented as ppmv, which stands for “parts per million by volume.” To help illustrate the ppm concept, “Parts Per Million Bottles” are available from a variety of science education supply vendors. These bottles contain 1 million pieces, with different colors representing 1 part per million, 10 ppm, 100 ppm, and 1000 ppm. One supplier: <http://sciencekit.com/ppm-bottle-activity-set/p/IG0046644/>
4. Students may also need a bit of explanation regarding the years listed on the graph. On the graph, the CO₂ and temperature data ends in 1950 (that is, “present” time is 1950). However, the data that they graphed in Part 2 went to 2009. So their class graph is actually more complete than the graph on the handout.
5. From the questions, students should develop the idea that carbon dioxide and temperature are closely related—they follow the same pattern. This is because an increase in CO₂ causes more energy to be kept on earth, while a decrease in CO₂ allows more energy to escape into space.
6. Students should also understand that the increase in CO₂ in the recent past is caused mostly by an increase in fossil fuel use. Remind the students that since the industrial revolution



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(which began in 1790) fossil fuel use has been steadily increasing. Stress to students that the current levels of CO₂ are higher than at any point in the past 400,000 years.

7. The last question on the sheet asks students to predict what the CO₂ concentration and temperature will be in 2050. You may want to have students share their responses with the class. If students predict soaring CO₂ levels and temperatures, ask them what we can do **now** to prevent these levels from occurring.

Extensions:

- It may help students to visualize the true changes in temperature by converting some of the temperatures from Celsius to Fahrenheit degrees. Then can then visualize that the temperature changes on the graph are actually more drastic when in the Fahrenheit units with which students are familiar. The formula for converting from Celsius to Fahrenheit is:

$$F = 9/5C + 32$$

- Students may wonder where the ancient data comes from. The data comes from making very deep (3,623 meter) cores in the ice in Antarctica. For more information have students research the Vostok ice records.
- The timeline of human society also includes estimates of human population. You can have your students graph these data as well to see the exponential growth of the human population.

Useful Websites

- Accessible paleo-climate website developed by Ralph J. Scotese. Won awards from NSTA and Scientific American
<http://www.scotese.com/climate.htm>
- Carlton College & Geological Society of America paleoclimate website and visualizations
<http://serc.carleton.edu/NAGTWorkshops/climatechange/visualizations/paleoclimate.html>
- NOAA comparison of different paleoclimate reconstruction methods
<http://www.ncdc.noaa.gov/paleo/ctl/clisci100kb.html>
- NOAA portal to ice core data sets used for climate reconstructions
http://www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok_data.html
- NASA Goddard Institute for Space Sciences Surface Temperature analysis and data sets
<http://data.giss.nasa.gov/gistemp/>

NOTES:

Temperature data from:

1. Jouzel J., C. Waelbroeck, B. Malaizé, M. Bender, J. R. Petit, N. I. Barkov, J. M. Barnola, T. King, V. M. Kotlyakov, V. Lipenkov, C. Lorius, D. Raynaud, C. Ritz and T. Sowers, 1996, Climatic interpretation of the recently extended Vostok ice records, *Climate Dynamics*, 12, 513-521.
2. Graphs from: Petit, J.R., J. Jouzel, J., D. Raynaud, N.I. Barkov, J-M Barnola, I. Basile, M. Bender, J. Chappellaz, M. David, G. Delaygue, M. Delmotte, V.M. Kotlyakov, M. Legrand,



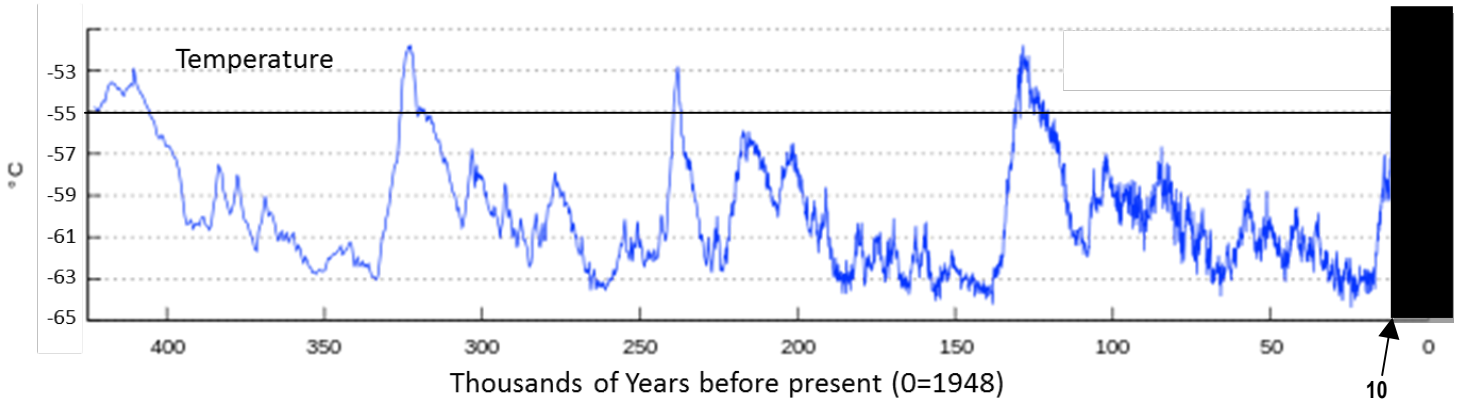
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- V.Y. Lipenkov, C. Lorius, L. Pepin, C. C. Ritz, E. Saltzman, M. Stievenard, (1999). Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, *Nature*, 399, 429-436.
3. NASA GISS Surface Temperature Analysis (GISTEMP), <http://data.giss.nasa.gov/gistemp/> Vostok Station, Lat. 78.5 S/Long 106.9 E Station ID# 700896060000
 4. Timeline of human society data comes from multiple sources including BigPicture, Small World. <http://www.bigpicturesmallworld.com/funstuff/bigtime.shtml>



Part 1: Visualizing the Climate from 400,000 to 10,000 Years Ago

The graph below shows temperature data obtained from the Vostok ice cores in Antarctica.



1. What type of data is shown on the x-axis? What are the units?
2. What type of data is shown on the y-axis? What are the units?
3. Where is “now” on the graph?
4. Has climate changed over the past 400,000 years? How do you know?
5. Circle the coolest temperature(s) on the graph. Draw a box around the warmest temperature(s) on the graph.



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6. How much did the temperature change between 320,000 and 260,000? How many years did it take for this temperature change to occur?
7. The last 10,000 years' worth of data are not shown on the graph, because YOU will graph this data. What are your predictions for what the graph will look like over the past 10,000 years?



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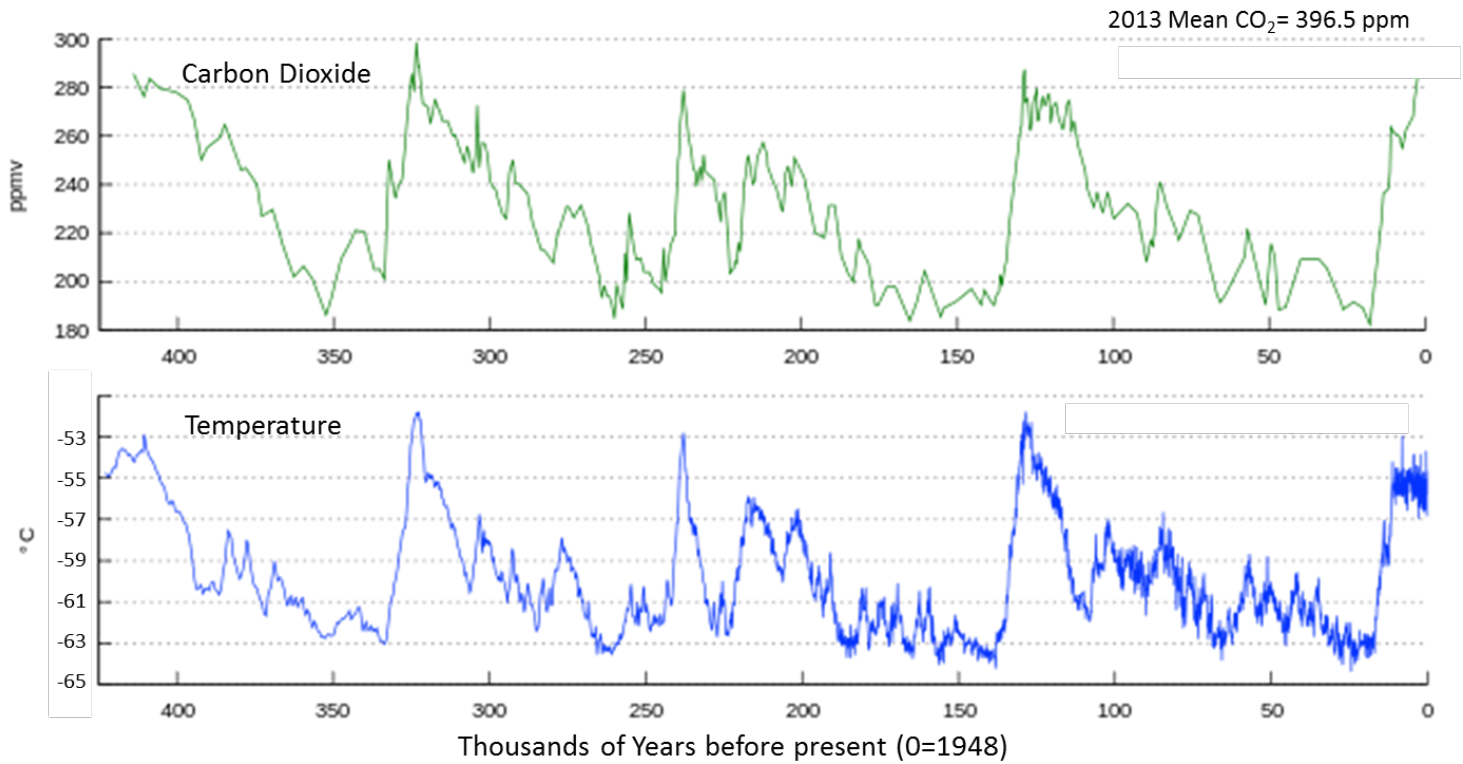
Part 2: Graphing Climate Data from 10,000 Years Ago to the Present

1. How does your class' graph of the past 10,000 years compare to the graph of the past 400,000 years? How are the graphs similar? How are they different?



Part 3: Explaining Temperature Variation

The graph below shows carbon dioxide concentration and temperature data obtained from the Vostok ice cores in Antarctica.



Look at the two graphs above. You should be familiar with the graph on the bottom—this is the temperature graph you just helped finish! But what about the top graph?

1. In the top graph: what type of data is shown on the x-axis? What are the units?
2. In the top graph: what type of data is shown on the y-axis? What are the units?
3. How does the pattern in the first graph relate to the pattern in the second graph?
4. Why do you think the two patterns are related in this way?



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5. The final point on the graph is from 1950, but the value CO₂ concentration for 2010 (290 ppm) has been added to the graph. What was the change in CO₂ concentration between 1950 and 2010?

6. What do you think caused the increase in CO₂ concentration in the atmosphere between 1950 and 2010?

7. What do you expect will be the temperature change associated with this change in CO₂ concentration?

8. **Prediction:** During this activity you have looked to the past 400,000 years of CO₂ and temperature. Now it is time to look to the future. What do you think the concentration of CO₂ in the atmosphere will be in the year 2050? What do you think the temperature will be in the year 2050? Explain your predictions. What role do we have in determining the CO₂ concentration and temperature in the year 2050?



Average Temperature 500 Year Averages*
(10,000 BCE - 1852 CE)

Data Set 1

Year	Deg C
-10,000-9501	11.9
-9500-9001	13.8
-9000-8501	13.4
-8500-8001	13.6
-8000-7501	13.7
-7500-7001	13.6
-7000-6501	13.5
-6500-6001	13.9

Data Set 2

Year	Deg C
-6000-5501	13.6
-5500-5001	13.6
-5000-4501	13.5
-4500-4001	13.6
-4000-3501	14.0
-3500-3001	14.1
-3000-2501	13.9
-2500-2001	14.0

Data Set 3

Year	Deg C
-2000-1501	13.8
-1500-1001	13.8
-1000-501	13.4
-500-1	13.5
0-499	13.1
500-999	13.5
1000-1499	13.3
1500-1852	13.7

Average Temperature 5 Year Global Averages*
(1880 CE - 2011 CE)

Data Set 4

Year	Deg C
1880-1884	13.8
1885-1889	13.7
1890-1894	13.0
1895-1899	13.9
1900-1904	13.9
1905-1909	13.8
1910-1914	13.9
1915-1919	13.8
1920-1924	13.9

Data Set 5

Year	Deg C
1925-1929	13.9
1930-1934	14.0
1935-1939	14.0
1940-1944	14.1
1945-1949	14.0
1950-1954	14.0
1955-1959	14.0
1960-1964	14.0
1965-1969	13.9

Data Set 6

Year	Deg C
1970-1974	14.0
1975-1979	14.0
1980-1984	14.2
1985-1989	14.3
1990-1994	14.3
1995-1999	14.5
2000-2004	14.6
2005-2009	14.7
2010-2011	14.6

* Temperature calculated from the global mean for 1951-1980 (14.0 deg-C)

** Data 1880-2011 from NASA (<http://data.giss.nasa.gov/gistemp/>)



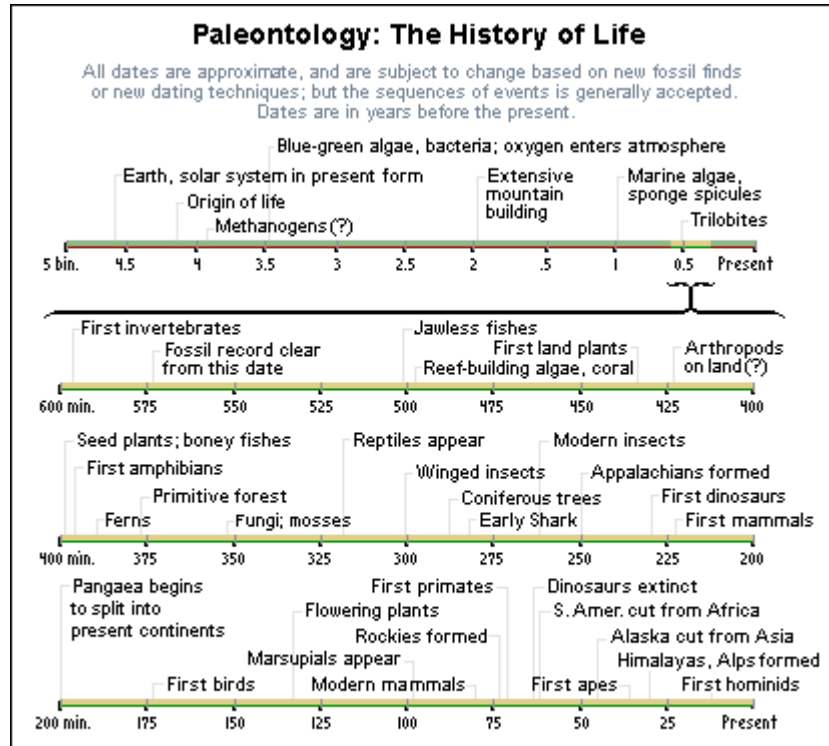
Date	Event
- 360,000	Human ancestors first use fire
- 100,000	Human ancestors migrate out of Africa
- 40,000	Human use complex language
- 30,000	Neanderthals die out
- 25,000	Last ice age
- 12,000	Agricultural revolution – human population reaches 10 million people
- 10,000	Dogs are domesticated
- 3000	Pyramids are built in Egypt – human population reaches 50 million people
- 1000	Humans use an alphabet – human population reaches 150 million
1	Humans use the abacus – human population reaches 200 million
1500	The first printing press is invented – human population reaches 500 million;
1600	The first microscope and telescope are used – human population reaches 600 million; Little Ice Age
1850	The industrial revolution begins – human population reaches 1 billion
1940	The first computers were used – human population reaches 2.5 billion
1950	Humans watch television
1969	Humans land on the moon
2000	Humans use the internet – human population reaches 6 billion



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ERA	PERIOD	EPOCH	APPROXIMATE TIME BOUNDARIES*	LIFE FORMS ORIGINATING
CENOZOIC	QUATERNARY	Recent	10,000	Human Beings
		Pleistocene	2,500,000	
	TERTIARY	Pliocene	12,000,000	Grazing and Carnivorous Mammals
		Miocene	26,000,000	
		Oligocene	38,000,000	
Eocene		54,000,000		
MESOZOIC	Cretaceous		136,000,000	Primates-Flowering Plants
	Jurassic		195,000,000	Birds
	Triassic		225,000,000	Dinosaurs-Mammals
PALEOZOIC	CARBONIFEROUS	Permian	280,000,000	Reptiles
		Pennsylvanian	320,000,000	
		Mississippian	345,000,000	
	Devonian		395,000,000	Fern Forests
	Silurian		430,000,000	Amphibians-Insects
	Ordovician		500,000,000	Vascular Land Plants
	Cambrian		570,000,000	Fish-Chordates
PRECAMBRIAN			700,000,000	Algae
			1,500,000,000	Eucaryotic Cells
			3,500,000,000	Prokaryotic Cells
			4,650,000,000 +	Formation of the Earth

*Beginning date for each period or epoch.



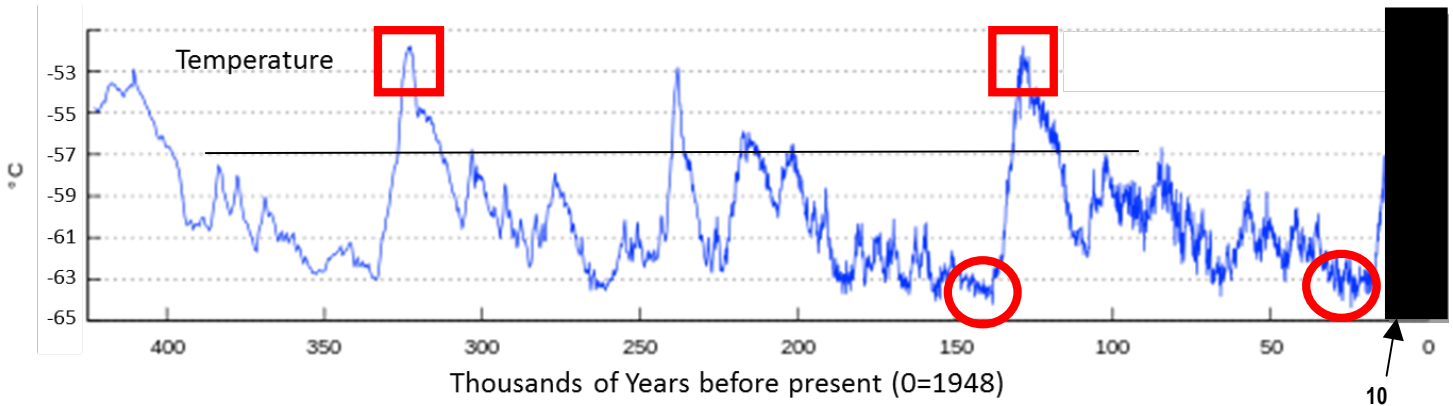
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TEACHER ANSWER KEY

**Part 1: Visualizing the Climate from
400,000 to 10,000 Years Ago**

The graph below shows temperature data obtained from ice cores in Antarctica.



1. What type of data is shown on the x-axis? What are the units?
Time, years before present
2. What type of data is shown on the y-axis? What are the units?
Temperature, Celsius degrees
3. Where is “now” on the graph?
“Now” in on the far right side of the graph, though the data ends in 1950.
4. Has climate changed over the past 400,000 years? How do you know?
Yes, climate has changed. The line on the graph goes up and down over the course of the 400,000 years.
5. Circle the coolest temperature on the graph. Draw a box around the warmest temperature on the graph.
6. How much did the temperature change between 320,000 and 260,000? How many years did it take for this temperature change to occur?
About 10.5 degrees (2.5 – (-8)). This change took 80,000 years to occur.
7. The last 10,000 years’ worth of data are not shown on the graph, because YOU will graph this data. What are your predictions for what the graph will look like over the past 10,000 years? (*Note: the graph above only goes through 1950, but your data set goes through 2009).
Answers will vary based on students’ predictions.



TEACHER ANSWER KEY

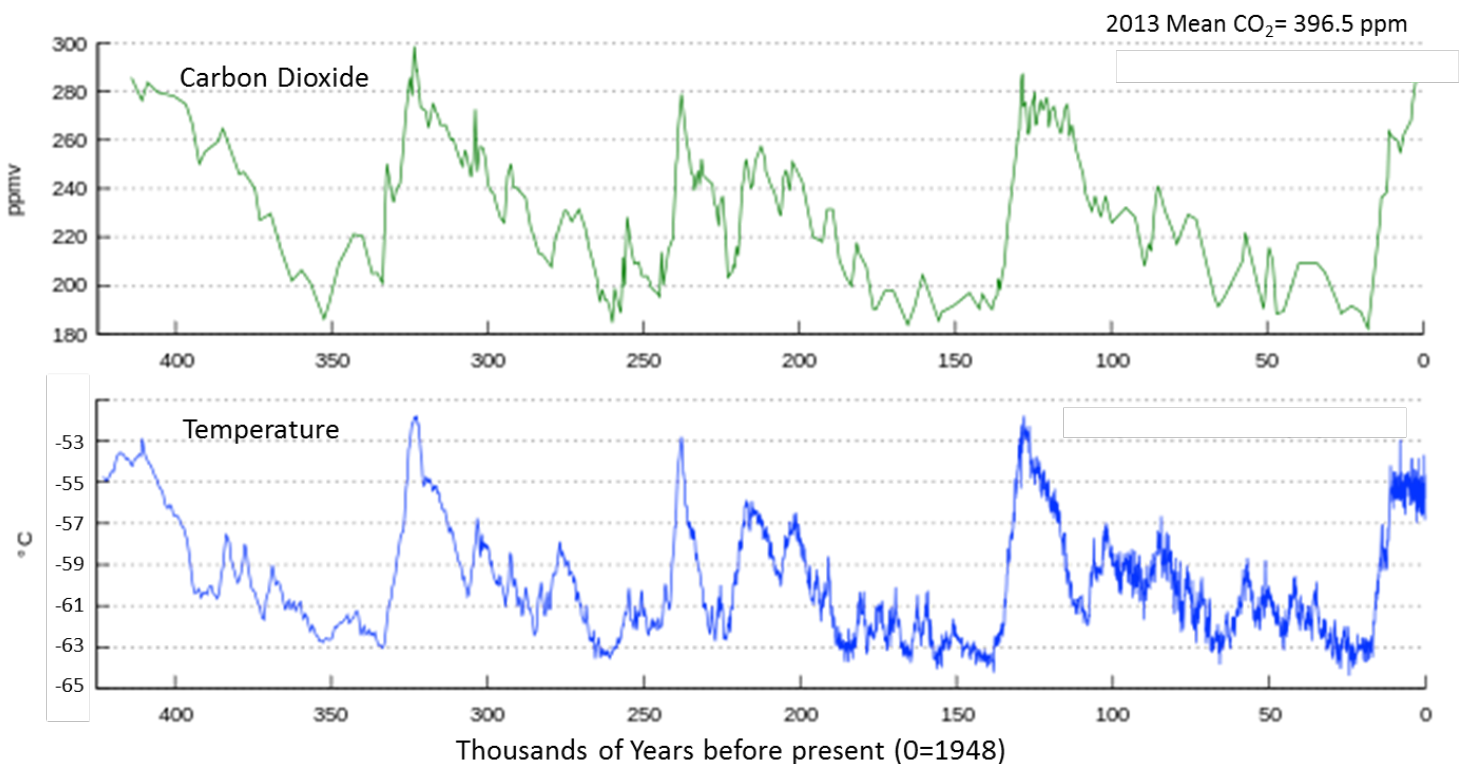
Part 2: Graphing Climate Data from 10,000 Years Ago to the Present

1. How does your class' graph of the past 10,000 years compare to the graph of the past 400,000 years? How are the graphs similar? How are they different?

Answers will vary. Students may note that the graphs represent different amounts of time, different changes in temperature, and are different sizes but that temperature changes in both cases. They may note that temperature change seems to occur more rapidly in the graph of the past 10,000 years.

Part 3: Explaining Temperature Variation

The graph below shows carbon dioxide concentration and temperature data obtained from ice cores in Antarctica.



Look at the graphs above, on the bottom is the graph you saw (and helped to finish) in Parts 1 and 2 of this activity.

1. In the top graph: what type of data is shown on the x-axis? What are the units?
Time, years before present.



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2. In the top graph: what type of data is shown on the y-axis? What are the units?
Carbon dioxide concentration. The units are PPMV, or parts per million by volume.
3. How does the pattern in the first graph relate to the pattern in the second graph?
Answers will vary, but students should note a similar pattern in both graphs.
4. Why do you think the two patterns are related in this way?
Answers will vary, but students may note that changes in carbon dioxide cause changes in temperature, since carbon dioxide is a greenhouse gas.
5. The final point on the graph is from 1950, but the value CO₂ concentration for 2010 – 390 ppm – is added to the graph. What was the change in CO₂ concentration between 1950 and 2010?
Approximately 120 ppm (270-390)
6. What do you think caused the increase in CO₂ concentration in the atmosphere between 1950 and 2010?
Answers will vary, students may mention an increase in fossil fuel use.
7. What do you expect will be the temperature change associated with this change in CO₂ concentration?
Answers will vary.
8. **Prediction:** During this activity you have looked to the past 400,000 years of CO₂ and temperature. Now it is time to look to the future. What do you think the concentration of CO₂ in the atmosphere will be in the year 2050? What do you think the temperature will be in the year 2050? Explain your predictions. What role do we have in determining the CO₂ concentration and temperature in the year 2050?
Answers will vary.



Mass Extinctions Tied to Past Climate Changes: *Fossil and temperature records over the past 520 million years show a correlation between extinctions and climate change*
By David Biello, Scientific American, October 24, 2007

Analyzing the fossil record and past temperatures shows that a warming world is bad for the number of different plants and animals on Earth. Roughly 251 million years ago, an estimated 70 percent of land plants and animals died, along with 84 percent of ocean organisms—an event known as the end Permian extinction. The cause is unknown but it is known that this period was also an extremely warm one. A new analysis of the temperature and fossil records over the past 520 million years reveals that the end of the Permian is not alone in this association: global warming is consistently associated with planet wide die-offs.

"There have been three major greenhouse phases in the time period we analyzed and the peaks in temperature of each coincide with mass extinctions," says ecologist Peter Mayhew of the University of York in England, who led the research examining the fossil and temperature records. "The fossil record and temperature data sets already existed but nobody had looked at the relationships between them."

Pairing these data—the relative number of different shallow sea organisms extant during a given time period and the record of temperature encased in the varying levels of oxygen isotopes in their shells over 10 million year intervals—reveals that eras with relatively high concentrations of greenhouse gases bode ill for the number of species on Earth. "The rule appears to be that greenhouse worlds adversely affect biodiversity," Mayhew says.

That also bodes ill for the fate of species currently on Earth as the global temperatures continue to rise to levels similar to those seen during the Permian. "The risk of future extinction through rapid global warming is primarily expected to occur through mismatches between the climates to which organisms are adapted in their current range and the future distribution of those climates," Mayhew and his colleagues write in *Proceedings of the Royal Society B: Biological Sciences*, though it may also be that warmer temperatures lead to less hospitable seas, he adds.

That is not to say that global warming was the cause of this Permian wipeout or that all mass extinctions are associated with warmer worlds—witness the disappearance of 60 percent of different groups of marine organisms during the cooling at the end of the Ordovician period roughly 430 million years ago. But these scientists argue that the evidence of a link between climate change and mass extinctions gives reason to be concerned for the future. "We need to know the mechanism behind the associations and we need to know if associations of this sort also occur in shorter-term climatic fluctuations," Mayhew says. "That will help us decide if this is really a worry for the next generation or if the threat is merely a distant future threat."