Teaching Activity: Analyzing Greenhouse Gases and Temperature Over Time

Background. Locked in the Earth's polar ice sheets is a record of past climate stretching back at least 150,000 years. Studies of ice cores provide scientists with a rich archive of information on past temperatures, precipitation and atmospheric composition and circulation. The annual accumulation of precipitation on the ice sheets is preserved with little or no melting , except in coastal areas, and is gradually compacted into solid ice . Ice cores can therefore provide continuous atmospheric and climate records, reaching back several hundreds of thousands of years. Paleoclimatologists who study ice cores do so in the hope that ".....studies of the past may hold they key to the future....." Studies of the climatic response to natural variations in carbon dioxide and atmospheric dust (continentally derived or volcanic), for example, may help scientists understand the effects of the buildup of carbon dioxide and other gases in the atmosphere as a result of man's activities.

The longest and most complete ice core records have been obtained from the central regions of two great ice sheets in Antarctica (Vostok Research Station) and Greenland (Camp Century and Dye 3). However, studies of cores from other parts of the Arctic and high altitude sites in equatorial regions (Quelccaya Ice Cap, Peru) have increased the geographical coverage and have provided important data for interpretation.

Ice cores preserve information on atmospheric composition and climate in three distinct chemical forms:

- the **stable isotope composition** of the ice itself (determined primarily by climatic factors);
- the **soluble and insoluble materials** from biogenic, marine, continental, volcanic and extraterrestrial sources (salts, particulates and heavy metals);
- **air bubbles** in the ice containing samples of the atmosphere at the time the ice was formed;

In the process by which snow is transformed into glacier ice, air is trapped in bubbles in the ice. The air that is trapped in these bubbles preserves a record of the composition of the atmosphere at the time of their final isolation. The trapped air provides scientists with a look at the history and development of the atmosphere over the last 150,000 years. Of particular interest have been the measurements of carbon dioxide and methane, which have shown significant variations linked to temperature. In addition, studies of both the Antarctica and the Greenland ice have shown that carbon dioxide levels prior to 1850 were on average, between 270 and 290 parts per million by volume (compared with a

time have been noted in both cores and suggest that while present day increases are the result of human activities, fluctuations in the past, preceding industrial perturbations, were possibly dependent on climatic fluctuations.

In addition to atmospheric gas concentrations, ice cores afford scientists data regarding the temperatures at various points in the Earth's past. Using the oxygen isotope ratio of ^{18}O and ^{16}O, it is possible to form a picture of what past climatic conditions were like. We know from the ratio of ^{18}O ($H_2{}^{18}O$) to ^{16}O ($H_2{}^{16}O$) in present precipitation that a lower value of ^{18}O corresponds to colder temperatures and vice versa. Likewise, a lower than normal level of ^{18}O would indicate that relatively cold conditions were present. When the levels of ^{18}O are higher than normal, climate was undergoing a warm period. One of the most interesting results of this study has been the ability to designate the onset of glacial and interglacial periods over the past 150,000 years. Oxygen isotope ratios in ocean sediment cores have also been used to determine ocean temperatures and paleo-sea levels.

Polar ice sheets are excellent storehouses of information for deciphering the history of our global atmosphere and paleoclimate. Long records extending back hundreds of thousands of years may eventually be recovered from the polar ice sheets; at present the oldest record from the polar ice sheets extends back over 250,000 years from the Greenland core and over 150,000 from the Vostok, Antarctica core. These cores are providing paleoclimatologists, and atmospheric modellers with the information necessary to understand the underlying causes of climatic change, whether it is natural or human induced.

Important Terms: Carbon dioxide, methane, ice core, ice ages, cyclical change, raw data, thermal, isotope, $^{18}O/^{16}O$, ratios, glacial, interglacial;

Objectives:

- Students will learn about changes that have taken place in greenhouse gas and average annual temperatures within the recent past (To 160,000 years ago);
- Students will make graphs of actual research data;
- Students will find trends as illustrated by the graphed data and draw valid conclusions;

Materials: Raw data (temperature / atmospheric gases), pencil / paper, graph paper, colored pencils, ruler;

Procedure:

1) Divide the class into small research teams (2-3 students each).
    - Explain that each group will be assigned a position in research dealing with global issues, in this case global climate change;
    - A research scientist has given their group some raw data and within the week they will have to analyze and present that data and report on it at an international conference;
2) Discuss the data (in general) with the class, what it is, where it comes from, and types of graphs available to illustrate the data;
3) Have students plot the values and make a graph for the temperature and another for the greenhouse gas their group was assigned.
    - Upon completion of the graphs, students should continue the trend indicated in the curve of the graph for another 50 years;
4) Each group should discuss their findings and develop a conclusion for their graphs. **(Note: A set of Guide Questions is included with the packet.)**
    - Students should each produce a detailed, written explanation of their conclusion;
5) A spokesperson from each group should be selected to present their findings to the class;
6) Discuss results with the class and analyze the accuracy of the type of graphs they chose.

*****Note: Each student in the group will be responsible for turning in a completed graph of the atmospheric gases and temperature data and a conclusion of the raw data provided to them.**

GUIDE QUESTIONS

1) What data did your group graph?

2) What time period did your data cover?

3) In what unit of measurement is the data presented?

4) What does the data indicate happening over time?

5) What can you predict about future amounts?

6) What does the temperature data show?

7) How far back in time does the data extend?

8) What do the dips in the temperature graph indicate? The rises?

9) Do you see any correlation between the temperature and the gas concentrations? Explain.

RAW DATA A:

Carbon Dioxide Concentrations (in ppmv*), Mauna Loa, Hawaii

Year	ppmv	Year	ppmv
1958	314.8	1974	330.4
1959	316.1	1975	331.0
1960	317.0	1976	332.1
1961	317.7	1977	333.6
1962	318.6	1978	335.2
1963	319.1	1979	336.5
1964	319.4	1980	338.4
1965	320.4	1981	339.5
1966	321.1	1982	340.8
1967	322.0	1983	342.8
1968	322.8	1984	344.3
1969	324.2	1985	345.7
1970	325.5	1986	346.9
1971	326.5	1987	348.6
1972	327.6	1988	351.2
1973	329.8		

*ppmv = Parts per million by volume.

Methane Gas Concentration

Atmospheric Greenhouse Gas Affected by Human Activities

Year	ppm*	Year	ppm*
1850	0.90	1975	1.45
1879	0.93	1976	1.47
1880	0.90	1977	1.50
1892	0.88	1978	1.52
1908	1.00	1979	1.55
1917	1.00	1980	1.56
1918	1.02	1981	1.58
1927	1.03	1982	1.60
1929	1.13	1983	1.60
1940	1.12	1984	1.61
1949	1.18	1985	1.62
1950	1.20	1986	1.63
1955	1.26	1987	1.65
1956	1.30	1988	1.67
1957	1.34	1989	1.69
1958	1.35	1990	1.72

*ppm = Parts per million.

Nitrous Oxide

Atmospheric Greenhouse Gas Affected by Human Activities

Year	ppbv*	Year	ppbv*
1750	283.0	1880	289.5
1760	283.5	1890	290.0
1770	284.0	1900	291.0
1780	284.5	1910	292.0
1790	285.0	1920	292.5
1800	285.5	1930	293.0
1810	286.0	1940	294.0
1820	286.5	1950	295.0
1830	287.0	1960	297.0
1840	287.5	1970	299.0
1850	288.0	1980	305.0
1860	288.5	1990	310.0
1870	289.0		

*Values of N_2O concentration are in parts per billion by volume (ppbv).

CFC (chlorofluorocarbon)[1] Production

Atmospheric Greenhouse Gas Affected by Human Activities

Year	Amount[2]	Year	Amount
1955	100	1975	350
1957	120	1977	360
1959	140	1979	330
1961	150	1981	325
1963	150	1983	320
1965	200	1985	340
1967	225	1987	300
1969	290	1989	305
1971	320	1991	310
1973	375		

** Values in kilotons per year

RAW DATA B:

Temperature Deviation Over Time[1]

Year	Temp. Deviation	Years BP[2]	Temp. Deviation	Years BP[2]	Temp. Deviation
1880	– 0.25	200	0.01	80,000	– 0.35
1885	– 0.27	1,000	0.01	85,000	– 0.30
1890	– 0.26	5,000	0.02	90,000	– 0.43
1895	– 0.29	10,000	0.03	95,000	– 0.52
1900	– 0.20	15,000	– 0.83	100,000	– 0.36
1905	– 0.38	20,000	– 0.90	105,000	– 0.40
1910	– 0.35	25,000	– 0.80	110,000	– 0.68
1915	– 0.33	30,000	– 0.82	115,000	– 0.64
1920	– 0.30	35,000	– 0.70	120,000	– 0.19
1925	– 0.15	40,000	– 0.60	125,000	– 0.09
1930	0.00	45,000	– 0.75	130,000	0.03
1935	– 0.10	50,000	– 0.60	135,000	0.10
1940	– 0.05	55,000	– 0.45	140,000	– 0.21
1945	0.05	60,000	– 0.80	145,000	– 0.75
1950	– 0.03	65,000	– 0.82	150,000	– 0.90
1955	– 0.01	70,000	– 0.70	155,000	– 0.82
1960	0.05	75,000	– 0.70	160,000	– 0.70
1965	– 0.05				
1970	0.00				
1975	– 0.05				
1980	0.15				
1985	0.18				
1990	0.21				

[1]For the purposes of this exercise, the mean average temperature from 1950 to 1980 is used as a baseline for comparative purposes. Note the 5-year average deviation values for the past 100 years, then the change to a 5,000-year spread for average deviation values. The values beyond 100 years were taken from ice core readings made by a USSR team of scientists working for years in the Vostok, Antarctic station.

[2]Years BP = years before present.

Student Activity Sheet: Analyzing Greenhouse Gases and Temperature Data Over Time

Background: The data presented on the following pages was collected from ice core research on atmospheric gases long before global climate change became a serious concern. In the past, scientists interested in a particular gas either made or bought the right equipment for their investigations, found a suitable to study the gas and then spent several months setting up, calibrating and checking the data. Eventually, enough raw data accumulated and required analysis. You will be working with that type of data.

Definition of Terms:

Raw data : Numbers that have not yet been organized or analyzed into meaningful results;

Graph: A diagram that represents the numerical difference in a variable in comparison with other variables;

Parts per million (billion) by volume : Either ppmv or ppbv; the number of molecules of a specific gas in a total volume of 1 million (1 billion) molecules of air;

Task: You will be playing the roles of a researcher in a research institution that addresses global change issues. A research scientist has just given you some raw data on atmospheric gases and temperature over time. Within the week there is to be a major international conference on global change which depends upon this material. Your task is to analyze it by then. The data needs to be presented in a meaningful and useful way. Working within your group with other members, your task is to organize, analyze and present the findings of their data.

Materials: Raw data tables, pencils/paper, graph paper, ruler, colored pencils;

Procedure:

1) Plot the values and make two (2) line graphs with the raw data that you are responsible for. (One greenhouse gas and temperature data)
   - X-axis: Year
   - Y-axis _____Concentration in ppm (ppb)

2) When you complete the graphs, continue the trend shown on each for another 50 years.

(NOTE: Make a prediction on how you would expect the graph to look with 50 years more data.)

3) Develop a conclusion for your graph using the Guide Questions provided by your teacher. If another group in the class is working on the same data, get together with them and compare the accuracy of both graphs and conclusions.
(Example: The data on this graph shows.....)

4) Share your findings with the class.
   - Choose one member of the group to be the spokesperson.

*****NOTE: Each student in the class will be responsible for turning in a completed graph of each data set and a conclusion of the raw data provided to them.