Is the Globe Warming?
Is there Evidence in the Great Lakes Region?

Objectives

After completing this activity, students will be able to:
- Critically interpret graphic data.
- Evaluate and discuss the difficulties inherent in interpreting and forecasting long- and short-term trends.
- Analyze data, draw conclusions about whether there is evidence of global warming, and defend their conclusions.

Teacher's Notes

Graphing Ideas
Students can plot increments of 0.1 degree on the Y axis and years on the X axis. The last point of their actual data should be on the line that divides the right side of the graph from the left "projection" side. The actual graphs are found on subsequent pages set aside for the teacher's use. Students typically project steep increases from their small data sets.

Basis of Data
Global temperature anomaly data are based on Jones and Wigley's work using both land and marine data. Researchers have compiled global average surface air temperature data from land–stations, a few fixed–position weather ships, and many moving ships. Temperature Anomalies are listed relative to a 1950-1979 reference period for Global and a 1961-1990 reference period for Great Lakes Data. *Anomalies* are variations from average values.

Limitations of Data
Students should discuss the limitations of the data set. If measurements were more heavily weighted on land data, that might contribute to greater extremes than if they were collected over water. Also, the data from ships leave many large data gaps over the oceans. There may be no way to tell just by looking at the data what limitations exist. To become good consumers of scientific information, students must consider the limitations of any data set.

Procedure

In preparation, cut apart the sections of the Global Temperature and Great Lakes Temperature lists (p. 9 and p.12) so each group will see only one segment of each. Make a copy of the graph scale for each team to graph its data.

1. Have students read Ohio Sea Grant's *Global Change Scenarios* "Introduction: Understanding Climate Models."

2. Divide the class into five groups that will work separately. Each group will receive a copy of one global temperature data set (28 years) and colored pencils. Students should graph their set of data on the scale provided. As they observe how readings fluctuate from year to year, students can theorize whether there is any evidence that the global temperature was rising, falling, or remaining constant during the period they are studying. They should be able to back up their conclusions with data from their sample graphs.

3. The students then project what the graph of global surface air temperature will be 30 years into the future (from the last year of their graph), based on the trends and periodicities they observe in their individual data set. This should be drawn on the right side of the graph in a different color.

4. Repeat the exercise (Steps 2–3) using temperature data from the Great Lakes. Plot the data on the same graph sheets used for the global data, but this time using new colors so that four different colors appear on the graph. Have the class agree to use similar colors. How do Great Lakes temperature variations compare with those of the whole world? Did they always show parallel trends? How does the complete regional graph compare to the global graph?

(PROCEDURE *continues)*

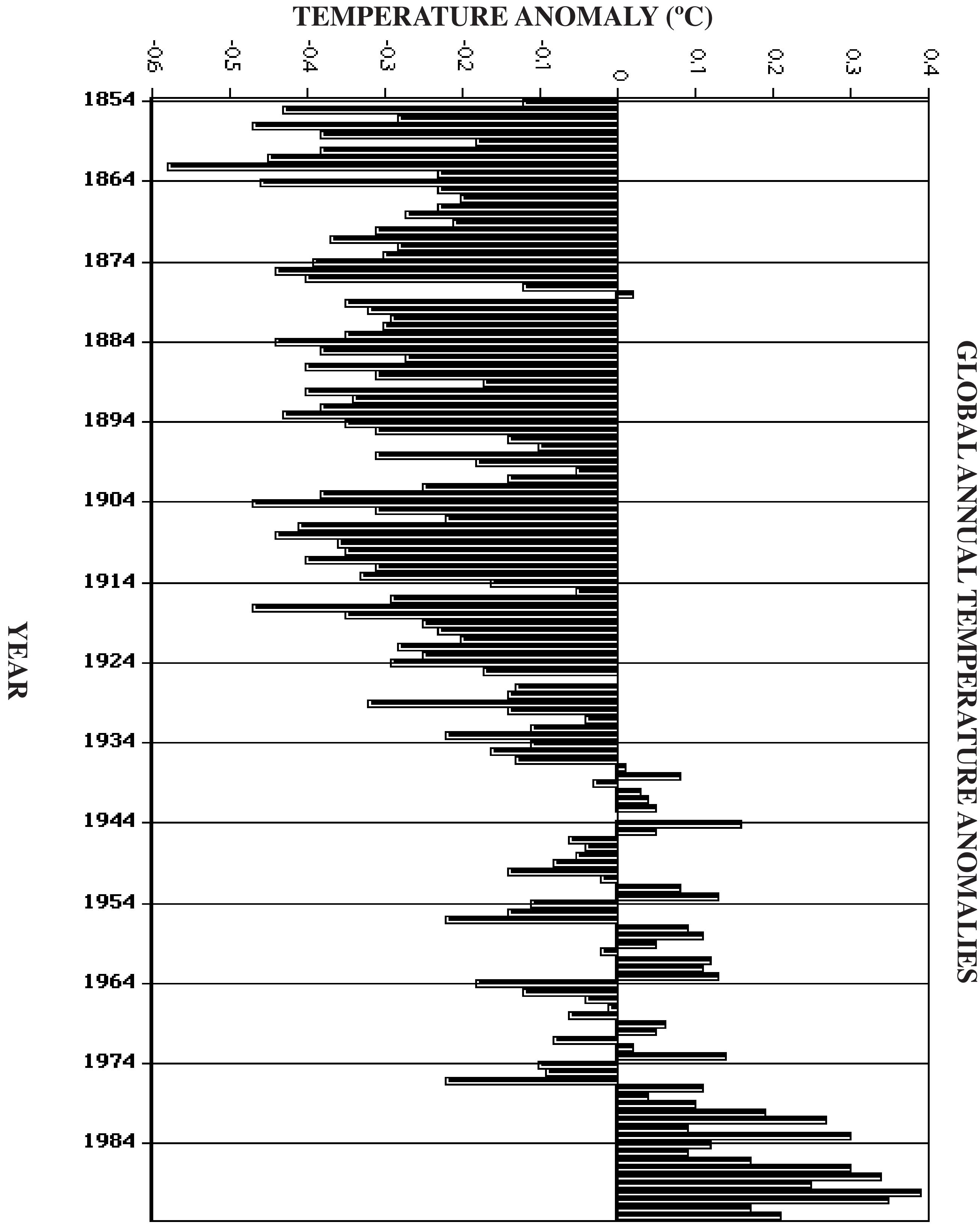
GLOBAL ANNUAL TEMPERATURE ANOMALY DATA (Cº)

Year	Temperature Anomaly	Year	Temperature Anomaly	Year	Temperature Anomaly
1854	-0.12	1882	-0.30	1910	-0.35
1855	-0.43	1883	-0.35	1911	-0.40
1856	-0.28	1884	-0.44	1912	-0.31
1857	-0.47	1885	-0.38	1913	-0.33
1858	-0.38	1886	-0.27	1914	-0.16
1859	-0.18	1887	-0.40	1915	-0.05
1860	-0.38	1888	-0.31	1916	-0.29
1861	-0.45	1889	-0.17	1917	-0.47
1862	-0.58	1890	-0.40	1918	-0.35
1863	-0.23	1891	-0.34	1919	-0.25
1864	-0.46	1892	-0.38	1920	-0.23
1865	-0.23	1893	-0.43	1921	-0.20
1866	-0.20	1894	-0.35	1922	-0.28
1867	-0.23	1895	-0.31	1923	-0.25
1868	-0.27	1896	-0.14	1924	-0.29
1869	-0.21	1897	-0.10	1925	-0.17
1870	-0.31	1898	-0.31	1926	0.00
1871	-0.37	1899	-0.18	1927	-0.13
1872	-0.28	1900	-0.05	1928	-0.14
1873	-0.30	1901	-0.14	1929	-0.32
1874	-0.39	1902	-0.25	1930	-0.14
1875	-0.44	1903	-0.38	1931	-0.04
1876	-0.40	1904	-0.47	1932	-0.11
1877	-0.12	1905	-0.31	1933	-0.22
1878	0.02	1906	-0.22	1934	-0.11
1879	-0.35	1907	-0.41	1935	-0.16
1880	-0.32	1908	-0.44	1936	-0.13
1881	-0.29	1909	-0.36	1937	0.01
1938	0.08	1966	-0.04		
1939	-0.03	1967	-0.01		
1940	0.03	1968	-0.06		
1941	0.04	1969	0.06		
1942	0.05	1970	0.05		
1943	0.00	1971	-0.08		
1944	0.16	1972	0.02		
1945	0.05	1973	0.14		
1946	-0.06	1974	-0.10		
1947	-0.04	1975	-0.09		
1948	-0.05	1976	-0.22		
1949	-0.08	1977	0.11		
1950	-0.14	1978	0.04		
1951	-0.02	1979	0.10		
1952	0.08	1980	0.19		
1953	0.13	1981	0.27		
1954	-0.11	1982	0.09		
1955	-0.14	1983	0.30		
1956	-0.22	1984	0.12		
1957	0.09	1985	0.09		
1958	0.11	1986	0.17		
1959	0.05	1987	0.30		
1960	-0.02	1988	0.34		
1961	0.12	1989	0.25		
1962	0.11	1990	0.39		
1963	0.13	1991	0.35		
1964	-0.18	1992	0.17		
1965	-0.12	1993	0.21		

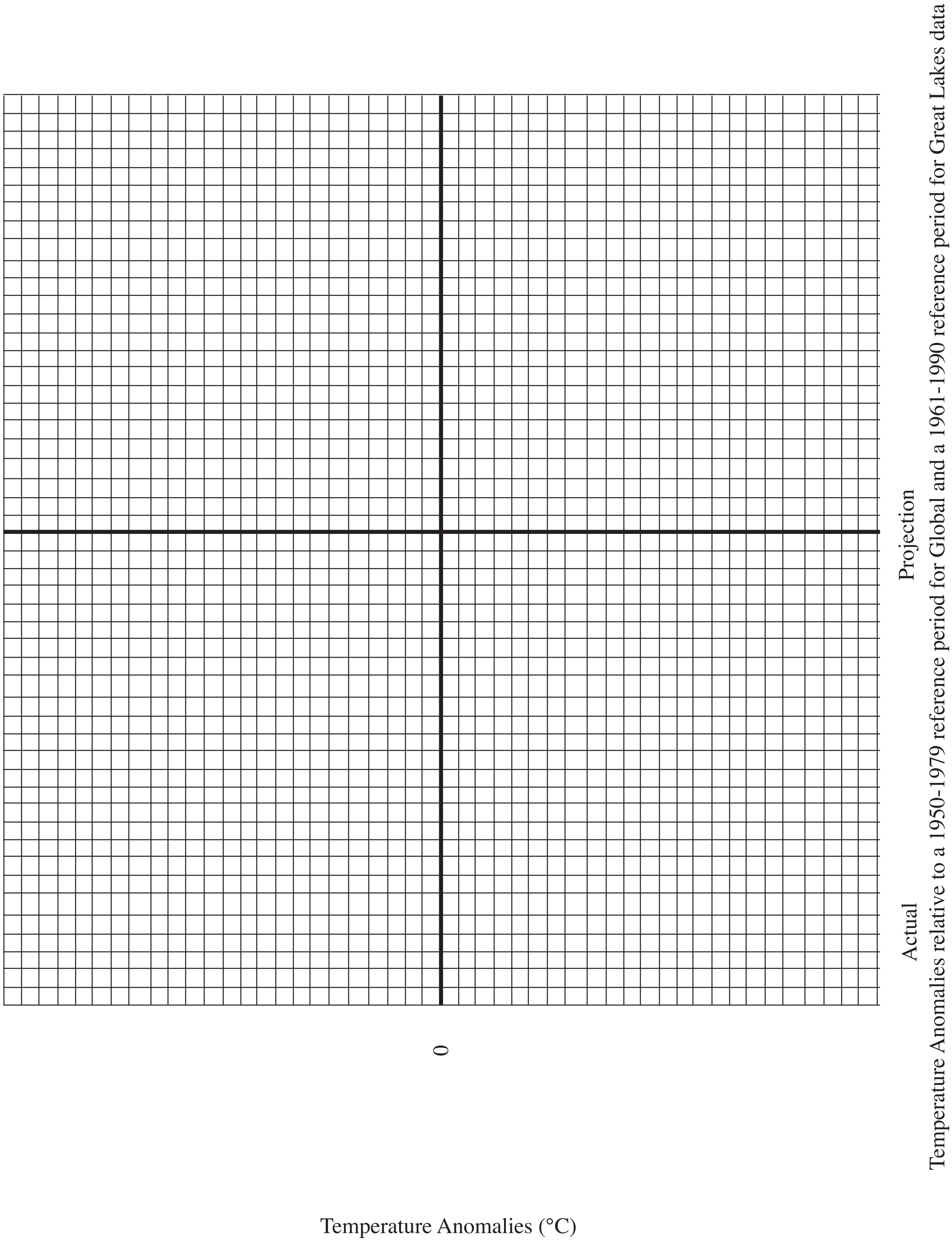
To The Teacher: Give one set of data to each group of students.

Jones, P.D., T.M.L. Wigley and K.R. Briffa. 1994. Global and hemispheric temperature anomalies – land and marine instrumental records. In, T.A. Boden, D.P. Kaiser, R.J. Sepanski and F.W. Stoss (eds.), *Trends '93: A Compendium of Data on Global Change*. ORNL/CDIAC-65. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN. pp. 603-608.

Teacher's Page: Graph of Global Annual Temperature Anomaly Data



Graph for Global and Great Lakes Temperature Activity



GREAT LAKES ANNUAL MEAN TEMPERATURE ANOMALY DATA (ºC)

Year	Mean Temperature Anomaly
1900	0.40
1901	-0.39
1902	0.01
1903	-0.59
1904	-1.85
1905	-0.85
1906	0.08
1907	-1.08
1908	0.03
1909	-0.29
1910	-0.45
1911	0.52
1912	-1.23
1913	0.28
1914	-0.36
1915	0.00
1916	-0.65
1917	-2.19
1918	-0.44

Year	Mean Temperature Anomaly
1919	0.32
1920	-0.50
1921	1.99
1922	0.47
1923	-0.34
1924	-1.41
1925	-0.46
1926	-0.98
1927	0.07
1928	0.02
1929	-1.06
1930	0.15
1931	2.14
1932	0.28
1933	0.58
1934	0.09
1935	0.00
1936	-0.64
1937	-0.15

Year	Mean Temperature Anomaly
1938	1.10
1939	0.54
1940	-0.36
1941	1.08
1942	0.38
1943	-0.62
1944	0.61
1945	-0.32
1946	0.47
1947	0.12
1948	-0.09
1949	0.85
1950	-0.96
1951	-0.47
1952	0.56
1953	1.00
1954	0.67
1955	0.42
1956	0.04

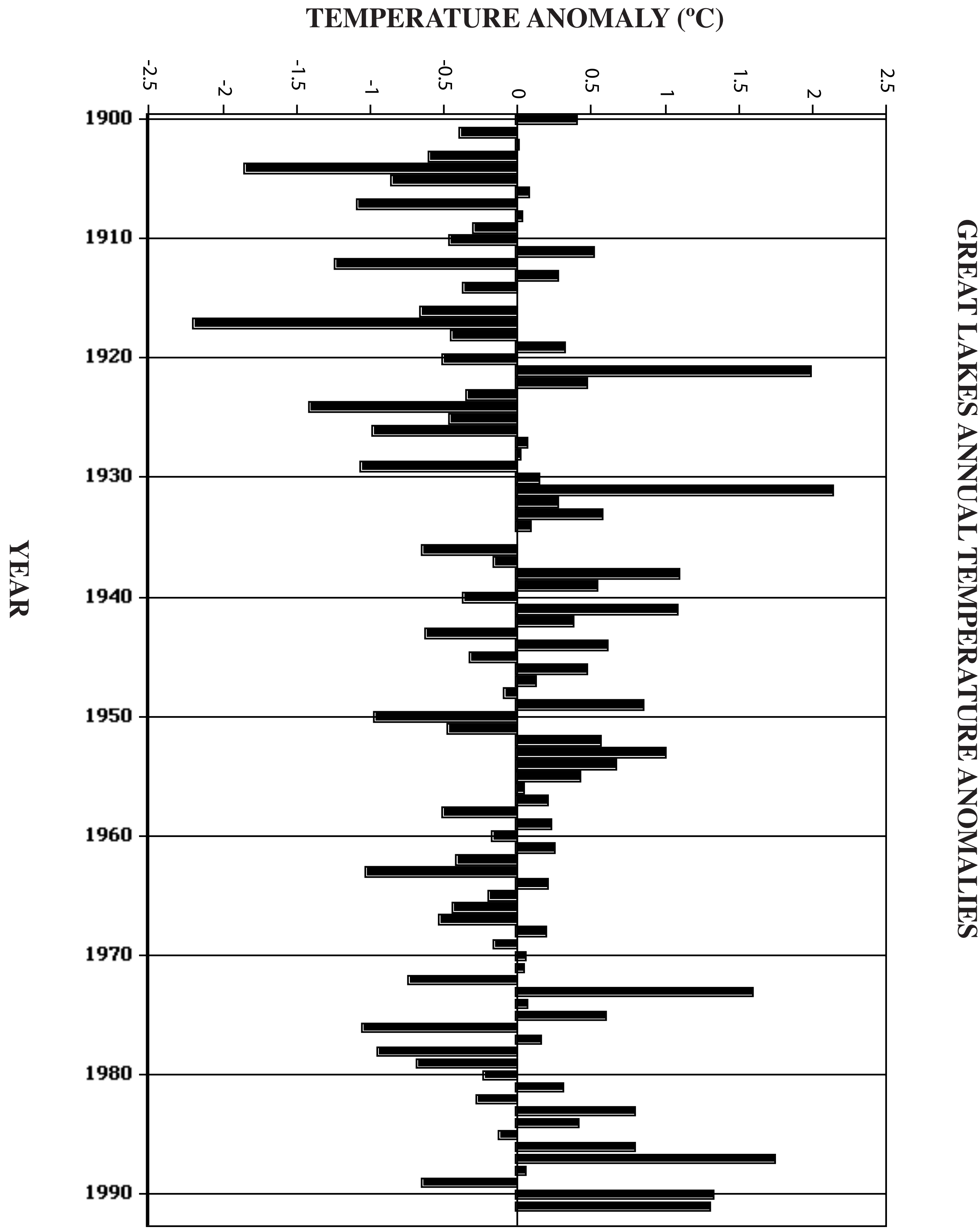
1957	0.21
1958	-0.50
1959	0.23
1960	-0.16
1961	0.25
1962	-0.41
1963	-1.02
1964	0.20
1965	-0.19
1966	-0.43
1967	-0.52
1968	0.19
1969	-0.15
1970	0.06
1971	0.04
1972	-0.73
1973	1.59
1974	0.07

1975	0.60
1976	-1.05
1977	0.16
1978	-0.94
1979	-0.67
1980	-0.22
1981	0.31
1982	-0.27
1983	0.79
1984	0.41
1985	-0.12
1986	0.79
1987	1.75
1988	0.06
1989	-0.64
1990	1.33
1991	1.30

To The Teacher: Give one set of data to each group of students.

Karl, T.R., D.R. Easterling, R.W. Knight and P.Y. Hughes. 1994. U.S. national and regional temperature anomalies. In, T.A. Boden, D.P. Kaiser, R.J. Sepanski and F.W. Stoss (eds.), *Trends '93: A Compendium of Data on Global Change*. ORNL/CDIAC-65. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN. pp. 686-736.

Teacher's Page: Graph of Great Lakes Mean Temperature Anomaly Data



If the graphs of the same years are compared on different scales, it appears that variations in Great Lakes temperatures were large in comparison to global temperatures. Why are there more extremes in the Great Lakes data set? Global temperatures are a combination of values across the earth. Extremes are averaged out. Large variations are not as visible as they are in a regional data set like that of the Great Lakes. Regional data will often show a larger range of highs and lows because these extremes aren't "hidden" as well by averaging.

Answers to Questions

1. a. The more data, the more certain we can be about trends. In this case, centuries of data are needed.
   b. No, data collection methods have varied over the years.
   c. They are the only information we have, and something is better than nothing. They do need to be used with caution, however.
   d. Accept many answers — human error, instrument failure, and effects of cities, cars, and industries, which can generate heat and may affect the surrounding climate.

2. Answers will vary based on class projections.

3. Answers will vary based on readings and student knowledge, but should include things like vegetation effects, arctic permafrost effects, ocean circulation, greenhouse gases, cloud effects, etc.

5. Each group, beginning with the first (1854-1881) temperature chart, should present their data, along with predictions for average global and Great Lakes temperatures 30 years in the future. Compile the graphs of each group into a single graph to show the class. The first group hangs its graph on the front wall. The next group then covers the previous group's predictions with the actual data. Some teachers create a data timeline along the classroom wall or in a hallway. Students can compare their estimates with the actual data.

Questions for Discussion

1. Groups should consider their predictions and answer the following:
   a. How much data do we need to plot a trend?
   b. Were weather collection methods the same for all data sets being reviewed? (e.g., how were weather data collected in 1885?)
   c. Even if the data are old, do they have value?
   d. Besides measurement techniques, what other factors may influence the reported data?

2. In 1995 the Intergovernmental Panel on Climate Change established predictions about future global warming. Their results are based on a scenario of "business as usual," in which no changes are made in government regulations about greenhouse gas emissions. The predictions are that, as a result of enhanced greenhouse warming, the global mean temperature will rise 1.0 to 3.5ºC by the year 2100 with a best estimate of 2ºC. How do predictions made in the class compare with these predictions?

3. Based on information in the background readings, discuss what factors are involved in "global climate change" besides just temperature. What kinds of data should scientists combine into a model to get a more complete picture of the Earth System changes involved in global warming?

A teachable moment for graph scales!

Have students compare the two bar graphs on overhead transparencies. The Y-axis of the global temperature graph extends from 0.5˚C to -0.5˚C, while the Y-axis of the Great Lakes temperature graph extends from 2.5˚C to -2.5˚C. What we are experiencing is an error of scale. Plotting the two sets on the same axis, one for global and one for the Great Lakes, shows the true magnitude of the variation!

Sometimes people who report science choose their graph scales in such a way that data are distorted vertically. They can then claim that the trend is "not as great as it was feared," or is "even worse than anyone imagined." Students should be alert to how data are portrayed in the media, so they can become wise consumers of science information.

Review Questions

1. How reliable were the five sets of predictions in Activity A? Discuss the implications of basing conclusions on limited data and the patterns that could be inferred from considering each of these subsets.

2. How much data is needed to make reliable predictions? What kinds of data might be combined for a more reliable picture of global climate change?

3. Thinking back to your history classes, can you recall any events, inventions, or discoveries that may have contributed to increased temperatures?

4. Were the data used in this exercise collected by experimentation? Sometimes we learn about "the" scientific method and assume that the only way to do science is by experiments. Often in reality, more can be learned about Earth Systems through historical data that are mainly descriptive. To the following list add some observable data about the Earth Systems or the Great Lakes in particular that might be classified as:

   Historical/Descriptive

   - Phosphorus loading to each lake over the years
   - Amount of toxin in birds in different regions
   - Lake level changes
   - Flood periods

   Experimental

   It may be difficult to find experimental data!
   - Fish–growing experiments based on Great Lakes fishes

Answers to Review Questions

1. In trying to make predictions or conclusions based on limited data, it is hard to see the "whole picture." As the Great Lakes graph shows, conditions are more variable over short distances than when averaged worldwide. Also, trends are difficult to determine when data are only available from a limited time period. For instance, flooding may have been prevalent in a specific region over a period of 2-3 years. In looking at a graph of floods for a 10-year period, one might conclude that floods occur in an area two or three years out of every 10, when actually they occur only two or three out of every 100 years.

2. In order to make a reliable prediction, data should be obtained from as many years as possible using both human records and proxy data (data from which other information can be inferred, such as tree rings and fossil pollen as indicators of past climate conditions). In doing so, the researcher can better generalize data to a longer time frame. If just a few years of data are used, the researcher must list the limitations of data from a short time span.

3. Several events occurred after the late 1800s that created greater levels of pollution, including the levels of greenhouse gases. For example, the industrial revolution occurred in the late 1800s. Additionally, the automobile, invented in 1885, began to be mass produced in 1913. WW1 may have had effects also – either directly from fires and other factors, or indirectly from technological developments during the war.

Extensions

1. Local temperature variation may be different than either regional or global variation. Obtain local temperature data and plot this on a similar graph. How does it compare to the other data? What factors could cause differences between the data sets?

2. Working in groups, do research on the history of legislation regarding atmospheric conditions, such as those banning CFCs. Do you feel that these laws have had an effect? Explain your answer.

3. Do library research on the phenomenon of El Niño and its effects on global temperature.

4. Review the data provided on greenhouse gas concentrations (Activity B), and the changes in their levels over time. What relationships do you see between changes in global temperature and the levels of these gases?

Global and Great Lakes temperature data can be downloaded in the following manner:

ftp cdiac.esd.ornl.gov
Name: **anonymous**
Password: **YOU@your e-mail address**
Guest login ok, access restrictions apply.
ftp> **cd /pub/trends93**
ftp> **dir**
ftp> **cd temp**
ftp> **get glakes721** (or use "ftp> **get jones606**" for global anomalies)
ftp> **quit**
ftp> Goodbye
Access to CDIAC's anonymous FTP area is also available on the Internet: CDP@ORNL.GOV

References

Aspen Global Change Institute. 1992. "Is it Getting Hot or Not? How When Affects What: Part II." *Ground Truth Studies*. Aspen, CO.

Boden, T. A., Kaiser D.P., Sepanski R.J. and Stoss F.W. 1993. *Trends '93: A Compendium of Data on Global Change*. Oak Ridge, TN: Carbon Dioxide Information Analysis Center. 984 pp.

Environment Canada. 1991. "Climate Change and Canadian Impacts: The Scientific Perspective," *Climate Change Digest* #CCD 91-01.

NOAA. 1991. *Reports to the Nation On Our Changing Planet: "The Climate System"* Silver Spring, MD: U.S. Department of Commerce.

Revised Great Lakes Annual Temperature Anomaly Data [C]
Anomalies are now provided as departures from the 20th century average (1901-2000).

From the National Climatic Data Center, calculated February 6, 2007, at http://www.ncdc.noaa.gov/gcag/gcag.html using Longitude -84 to -90 (W) and Latitude 40 to 50 N

Teacher: Please give one set of data to each group of students for graphing ACTUAL anomalies. Be sure all groups use the same scales on the graph axes.

1900	-0.27	1921	-0.08	1942	0.27
1899	-0.15	1920	-0.13	1941	0.06
1898	-0.04	1919	-0.3	1940	-0.13
1897	-0.16	1918	-0.33	1939	-0.06
1896	-0.16	1917	-0.46	1938	0.02
1895	-0.48	1916	-0.2	1937	-0.16
1894	-0.48	1915	-0.18	1936	-0.2
1893	-0.73	1914	0.07	1935	-0.25
1892	-0.3	1913	-0.42	1934	-0.29
1891	-0.37	1912	-0.29	1933	-0.27
1890	-0.3	1911	-0.52	1932	0.13
1889	-0.14	1910	-0.39	1931	-0.04
1888	-0.43	1909	-0.58	1930	-0.31
1887	-0.43	1908	-0.39	1929	-0.45
1886	-0.16	1907	-0.4	1928	-0.05
1885	-0.48	1906	-0.18	1927	-0.19
1884	-0.21	1905	-0.29	1926	0.09
1883	-0.37	1904	-0.54	1925	-0.35
1882	-0.02	1903	-0.19	1924	-0.26
1881	-0.1	1902	-0.08	1923	-0.25
1880	-0.16	1901	-0.23	1922	-0.37

1964	-0.08	1985	0.04	2006	0.28
1963	-0.05	1984	0.1	2005	0.51
1962	0.0	1983	0.29	2004	0.48
1961	0.0	1982	-0.0	2003	0.56
1960	-0.13	1981	0.36	2002	0.6
1959	-0.0	1980	0.14	2001	0.33
1958	0.27	1979	0.01	2000	0.19
1957	-0.19	1978	-0.03	1999	0.38
1956	-0.27	1977	-0.04	1998	0.48
1955	0.02	1976	-0.16	1997	0.21
1954	-0.28	1975	-0.0	1996	0.12
1953	0.04	1974	-0.28	1995	0.39
1952	0.08	1973	0.17	1994	0.14
1951	-0.35	1972	-0.34	1993	0.23
1950	-0.38	1971	-0.02	1992	0.28
1949	0.05	1970	0.05	1991	0.28
1948	0.05	1969	-0.21	1990	0.2
1947	-0.19	1968	-0.26	1989	0.01
1946	0.08	1967	-0.12	1988	0.38
1945	-0.03	1966	-0.13	1987	0.09
1944	0.2	1965	-0.15	1986	0.11
1943	-0.13				

Revised Global Annual Temperature Anomaly Data [C]
Anomalies are now provided as departures from the 20th century average (1901-2000).

From the National Climatic Data Center, accessed May 30, 2006 at ftp://ftp.ncdc.noaa.gov/pub/data/anomalies/annual.land_and_ocean.90S.90N.df_1901-2000mean.dat

Teacher: Please give one set of data to each group of students for graphing ACTUAL anomalies. Be sure all groups use the same scales on the graph axes.

1880	-0.1461	1901	-0.0979	1922	-0.2126
1881	-0.0892	1902	-0.1740	1923	-0.1892
1882	-0.1186	1903	-0.2934	1924	-0.1841
1883	-0.1605	1904	-0.3290	1925	-0.1136
1884	-0.2058	1905	-0.2163	1926	-0.0195
1885	-0.1713	1906	-0.1806	1927	-0.0974
1886	-0.1460	1907	-0.3471	1928	-0.0952
1887	-0.2150	1908	-0.3765	1929	-0.2218
1888	-0.1415	1909	-0.3808	1930	-0.0235
1889	-0.1005	1910	-0.3667	1931	-0.0019
1890	-0.2460	1911	-0.3626	1932	-0.0251
1891	-0.1996	1912	-0.3027	1933	-0.1582
1892	-0.2635	1913	-0.2857	1934	-0.0230
1893	-0.2876	1914	-0.1129	1935	-0.0489
1894	-0.2482	1915	-0.0553	1936	-0.0170
1895	-0.1746	1916	-0.2707	1937	0.0830
1896	-0.0577	1917	-0.3267	1938	0.0994
1897	-0.0921	1918	-0.2111	1939	0.0761
1898	-0.1998	1919	-0.2068	1940	0.1187
1899	-0.0969	1920	-0.1678	1941	0.1404
1900	-0.0277	1921	-0.1225	1942	0.1259
1943	0.1180	1965	-0.0640	1987	0.2576
1944	0.2143	1966	-0.0190	1988	0.3047
1945	0.0687	1967	-0.0049	1989	0.1942
1946	-0.0261	1968	-0.0306	1990	0.3641
1947	-0.0274	1969	0.0772	1991	0.3206
1948	-0.0401	1970	0.0488	1992	0.1831
1949	-0.0668	1971	-0.0569	1993	0.2009
1950	-0.1542	1972	0.0280	1993	0.2009
1951	-0.0115	1973	0.1416	1994	0.2759
1952	0.0347	1974	-0.0831	1995	0.3889
1953	0.1106	1975	-0.0297	1996	0.2563
1954	-0.1084	1976	-0.1182	1997	0.4605
1955	-0.1292	1977	0.1249	1998	0.5769
1956	-0.1842	1978	0.0581	1999	0.3938
1957	0.0601	1979	0.1363	2000	0.3625
1958	0.0930	1980	0.2021	2001	0.4906
1959	0.0526	1981	0.2393	2002	0.5445
1960	-0.0019	1982	0.1202	2003	0.5565
1961	0.0738	1983	0.2392	2004	0.5328
1962	0.0785	1984	0.0883	2005	0.6105
1963	0.1315	1985	0.0599		
1964	-0.1387	1986	0.1289		