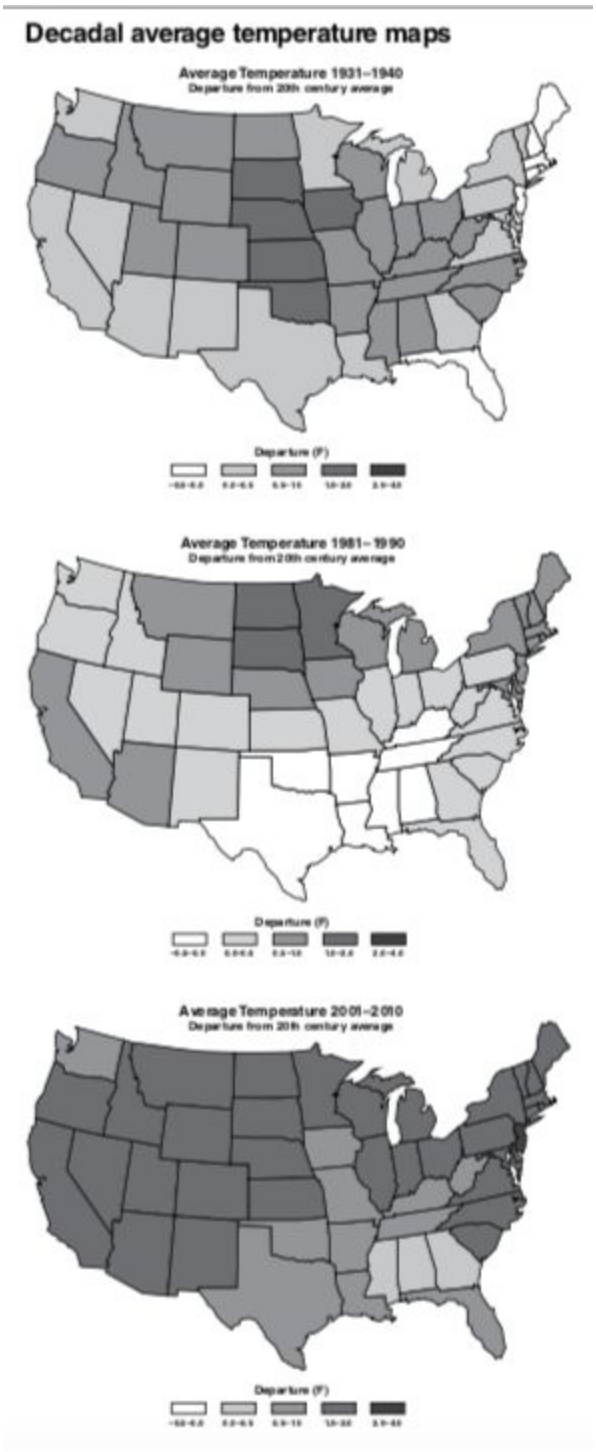
Carbon Dioxide Levels in the Atmosphere: How Has the Concentration of Atmospheric Carbon Dioxide Changed Over Time?

Introduction

There has been a lot of discussion about climate in recent years. This discussion usually focuses on average global temperature. In the United States some states have had above-average temperatures, some states have had below-average temperatures, and some states have had near-average temperatures over the last 100 years. The figure to the right shows decadal temperature anomalies, or how the decadal average temperature for each state differs from the 20th-century average during three different decades. According to an ongoing temperature analysis conducted by scientists at the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies, the average global temperature on Earth has increased by about 0.8°Celsius (1.4°Fahrenheit) since 1880 (see *https://data.giss.nasa.gov/gistemp/graphs_v3*).



A major contributing factor to global temperature is the concentration of carbon dioxide (CO) in the atmosphere. CO is one type of greenhouse gas. Greenhouse gases trap heat from the Sun and warm the surface of Earth. Without greenhouse gases in the atmosphere, Earth would be too cold for humans to survive. As the concentration of greenhouse gases in the atmosphere increases, the temperature of Earth's surface will also increase.
Climate experts agree that human activity has significantly increased the amount of CO2 in the atmosphere, leading to an overall rise in global temperatures. Some people, however, still question whether this increase is primarily due to human activity or to a natural process that causes climate change. There is research that shows global temperatures and atmospheric CO2 levels have increased and decreased in a cyclical pattern for at least 650,000 years (Etheridge et al. 1998).

Before you can evaluate the merits of alternative explanations for the observed increase in average global temperature, it is important to understand how CO2 levels have changed over Earth's history. You will therefore need to learn more about historical patterns of CO2 levels.

Your Task

Analyze long-term historical data to determine whether CO2 levels and average global temperature are changing at a different rate than they have in the past. Your goal is to use what you know about climate, patterns, and stability and change in systems to determine if human activity has made a significant change in global CO2 levels and thus global temperature.

The guiding question of this investigation is: ***How has the concentration of atmospheric carbon dioxide changed over time?***

Materials

You may use the following resources during your investigation:

- *Average Global Temperature and Ice Core CO2 Data Excel file*: This file provides information about changes in average global temperature over time and atmospheric CO2 levels based on ice core samples that date back to 416,000 years before the present time.
- *Climate Time Machine*: This NASA website provides visualizations of current trends in sea ice levels, CO2 levels, and global temperatures at https://climate.nasa.gov/interactives/climate-time-machine/

Getting Started

An example of an ice core

Scientists use some clever data sources to gain insight into Earth's history. One such data source is an ice core sample. To obtain an ice core sample, scientists drill down into a glacier or ice sheet and bring out a long cylindrical piece of ice (see figure to the right). Scientists can then count the layers in the ice core sample and determine how many years ago each layer was on the surface of Earth. The ability to determine the age of layers by counting them is based on the law of superposition, which states that the oldest layers in a geologic sample are found at the bottom of the sample.

Scientists can also analyze the tiny air bubbles that are trapped in the ice at each layer of an ice core sample to determine the amounts of different gases that were in the atmosphere at the time that layer was created. When scientists make these measurements, they assume that natural laws operate today as they did in the past and that they will continue to do so in the future. Scientists therefore assume that the dissolved CO2 levels in an ice core layer correspond to the amount of CO2 present in the atmosphere at the time the ice was made, just like dissolved CO2 levels in fresh ice match the CO2 levels in the current atmosphere.

The *Average Global Temperature and Ice Core CO2 Data* Excel file includes information about the atmospheric CO2 concentration and changes in average global temperature over time. The file includes two tabs:

1. The first tab, which is called "CO2 and Temp 1880-2016," includes atmospheric CO2 levels and average global temperature anomalies from 1880 to 2016. The term *temperature anomaly* means the difference from the long-term average. A positive anomaly value indicates that the observed temperature was warmer than the long-term average, and a negative anomaly indicates that the observed temperature was cooler than the long-term average. Scientists calculate and report temperature anomalies because they more accurately describe climate variability than absolute temperatures do, and these anomalies make it easier to find patterns in temperature trends. The yearly temperature anomaly values come from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (see *www.ncdc.noaa.gov/monitoring-references/faq/ anomalies.php*), the 1880–2004 atmospheric CO2 levels come from Etheridge et al. (2010), and the 2005–2016 atmospheric

CO2 levels come from NASA's Global Climate Change website (see *https://climate.nasa.gov/vital-signs/carbon-dioxide*).

2. The second tab, which is called "CO2 Before 1880," includes atmospheric CO2 levels dating back 416,000 years based on measurements taken from ice cores by Etheridge et al. (1998). You can use the data from the Excel file to see how CO2 concentrations and global temperature typically change over a very long time scale.

As you analyze these data, think about the following questions:

- Will you need to analyze some data separately from others?
- What types of patterns might you look for as you analyze your data?
- What type of graph could you create to help make sense of your data?
- How could you use mathematics to describe a change over time or if there is a relationship between variables?

You can also use the visualizations on NASA's *Climate Time Machine* web page to examine how some of Earth's key climate indicators have changed in the recent past. This web page provides satellite pictures of the annual Arctic sea ice minimums dating back to 1979. At the end of each summer, the sea ice cover reaches its minimum extent, leaving what is called the perennial ice cover. The *Climate Time Machine* also shows global changes in the concentration and distribution of CO2 in the atmosphere dating back to 2002 at an altitude range of 1.9–8 miles. The yellow-to-red regions indicate higher concentrations of CO2, while the blue-to-green areas indicate lower concentrations, measured in parts per million. Finally, and perhaps most important, the *Climate Time Machine* provides a color-coded map that shows how global surface temperatures have changed dating back to 1884. Dark blue indicates areas cooler than average, and dark red indicates areas warmer than average.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of four sections (be sure to have section headings):

1. Introduction: Give some background information on the topic. Explain what question you were trying to answer and include a hypothesis. (Background info, research question and hypothesis)
2. Procedure: What did you do during your investigation and why did you conduct your investigation in this way? (How you collected and analyzed data)
3. Data: Include a data table and/or graph to show your results. Be sure to include a title for your table or graph with labels for the variables.
4. Conclusion: What is your argument? (Claim - Evidence - Reasoning)

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Type your report on Google Docs (12 point font, double-spaced) and share it with your teacher. Your report will be graded based on the rubric in the class syllabus.