Lab Handout

Lab 18. Carbon Dioxide Levels in the Atmosphere: How Has the Concentration of Atmospheric Carbon Dioxide Changed Over Time?

Introduction

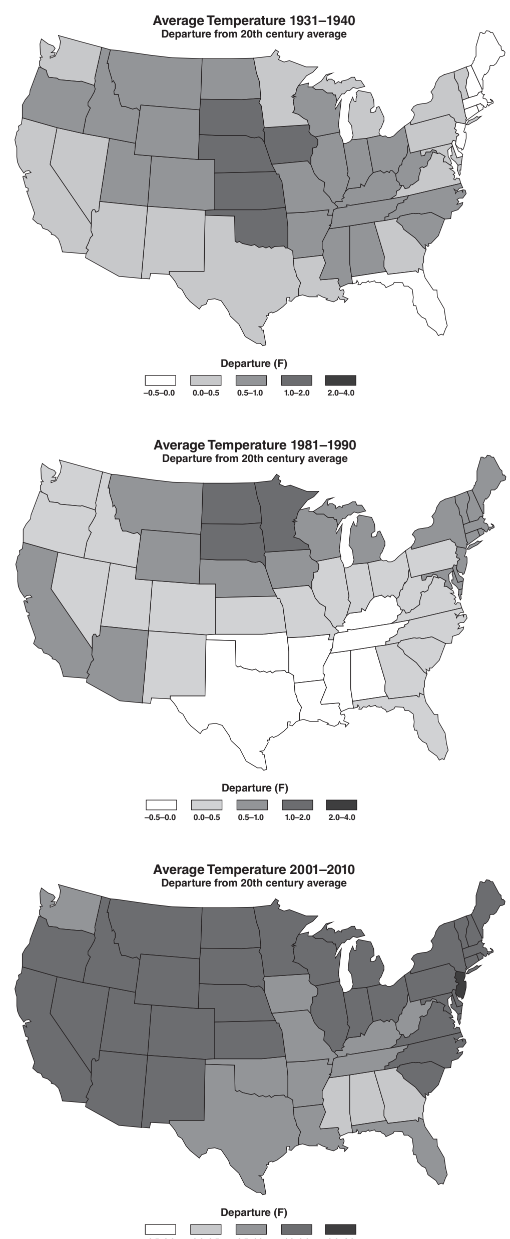
There has been a lot of discussion about climate in recent years. This discussion usually focuses on average global temperature. In the United States some states have had above-average temperatures, some states have had below-average temperatures, and some states have had had near-average temperatures over the last 100 years. Figure L18.1 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_2) in the atmosphere. CO_2 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 CO_2 in the atmosphere, leading to an overall rise in global temperatures. Some people, however,

FIGURE L18.1

Decadal average temperature maps



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 CO_2 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 CO_2 levels have changed over Earth's history. You will therefore need to learn more about historical patterns of CO_2 levels.

Your Task

Analyze long-term historical data to determine whether CO_2 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 CO_2 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 CO_2 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, CO_2 levels, and global temperatures at *http://climate.nasa.gov/interactives/climate-time-machine.*

Safety Precautions

Be sure to follow all normal lab safety rules.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

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 L18.2, p. 440). Scientists can then count the layers in the ice core sample and determine how many years

FIGURE L18.2

An example of an ice core

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 CO_2 levels in an ice core layer correspond to the amount of CO_2 present in the atmosphere at the time the ice was made, just like dissolved CO_2 levels in fresh ice match the CO_2 levels in the current atmosphere.

The Average Global Temperature and Ice Core CO2 Data Excel file includes information about the atmospheric CO_2 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 CO_2 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 CO_2 levels come from Etheridge et al. (2010), and the 2005–2016 atmospheric CO_2 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 CO_2 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 CO_2 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 diagram 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?
- What type of graph could you create to help make sense of your data?

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 CO_2 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 CO_2, 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.

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, be sure to think about

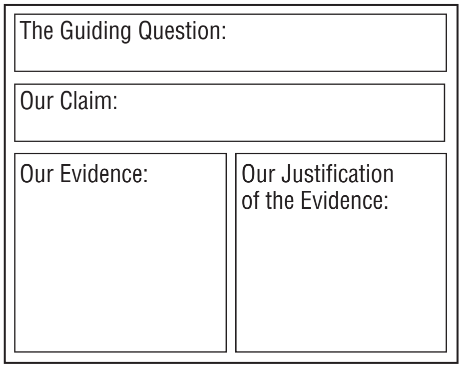
- how scientific knowledge can change over time, and
- the assumptions made by scientists about order and consistency in nature.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L18.3 (p. 442).

FIGURE L18.3

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.

References

Etheridge, D. M, L. P. Steele, R. L. Langenfelds, R. J. Francey, J. Barnola, V. I. and Morgan. 1998. Historical CO_2 records from the Law Dome DE08, DE08-2, and DSS ice cores. In *Trends: A compendium of data on global change.* Oak Ridge, TN: U.S. Department of Energy, Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center. Available at *www.co2.earth/co2-ice-core-data.*

Etheridge, et al. 2010. Law Dome Ice Core 2000-Year CO2, CH4, and N2O Data. IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series 2010-070. Boulder, CO: NOAA/NCDC Paleoclimatology Program. Available at *ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/law/law2006.txt.*