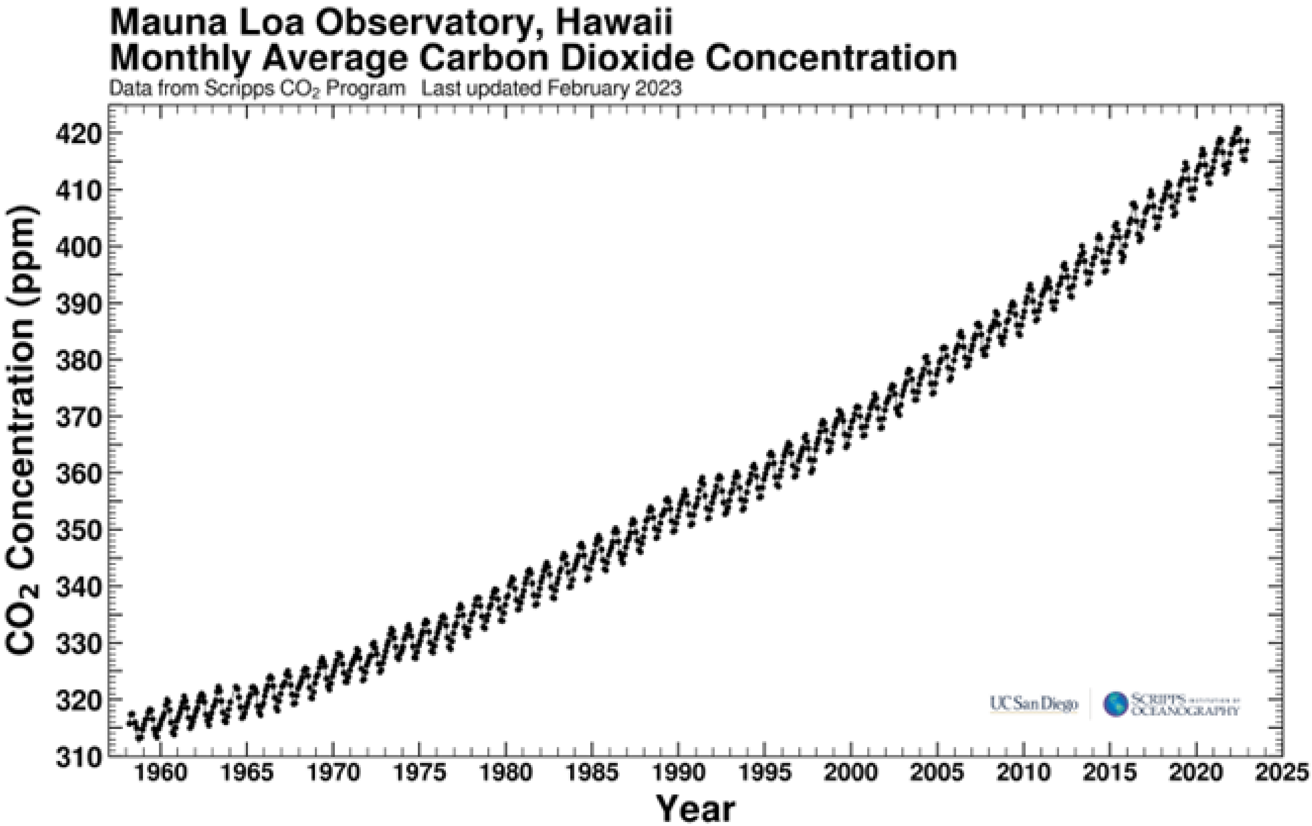
Trends in Atmospheric Carbon Dioxide

hhmi | BioInteractive

Data Point
Educator Materials

HOW TO USE THIS RESOURCE

Show the figure below to your students along with the caption and background information. The “Interpreting the Graph” and “Discussion Questions” sections provide additional information and suggested questions that you can use to guide a class discussion about the characteristics of the graph and what it shows.



Caption: Atmospheric carbon dioxide concentration in parts per million (ppm) by volume from 1958 to 2023.

BACKGROUND INFORMATION

Carbon dioxide (CO_2) is a gas critical to life on Earth because it helps regulate climate. Natural processes—mainly photosynthesis and respiration—serve to maintain concentrations of CO_2 in the atmosphere within a certain range. Driven by energy from the sun, photosynthesis takes carbon from CO_2 in the atmosphere to produce sugar molecules and oxygen. Photosynthesis thus serves to remove CO_2 from the atmosphere. Cellular respiration and respiration driven by the decomposition of living matter, on the other hand, convert sugar molecules into CO_2 and water, returning CO_2 to the atmosphere.

$$6CO_2 + 6H_2O \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$$

Records from polar ice cores show that the natural range of atmospheric CO_2 over the past 800,000 years was 170 to 300 parts per million (ppm) by volume. In the early 20th century, scientists began to suspect that CO_2 in the atmosphere might be increasing beyond this range due to human activities, such as burning fossil fuels and changes in land use, but there were no clear measurements of this trend. Charles David Keeling began measuring atmospheric CO_2 in 1958 at the Mauna Loa observatory on the big island of Hawaii. This data set (shown in the figure) has become the longest study of its kind in the world and is so iconic that it is now most commonly referred to as the Keeling Curve.

INTERPRETING THE GRAPH

The Keeling Curve graph shows the annual trend and seasonal fluctuations in CO_2 concentrations over time. Daily CO_2 measurements are used to calculate monthly averages. A best-fit curve is superimposed over these monthly averages to create the seasonal fluctuations indicated by the black line. The peak in CO_2 concentrations occur in mid-spring, as vegetation from the previous growing season dies during the winter and then decomposes. With the spring bloom, widespread photosynthesis leads to a drop in CO_2 concentrations that reach its lowest point at the end of the growing season in early fall. The overall trend shows an accelerating increase in CO_2 concentrations from the beginning of the study until the present. The concentration of atmospheric CO_2 has now reached 420 ppm and is still rising.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Graph Type: Line graph
- *X*-Axis: Years
- *Y*-Axis: Carbon dioxide concentration (parts per million by volume)

DISCUSSION QUESTIONS

- What was the average CO_2 concentration at the start of the study? How does that compare with the CO_2 concentration in 2023? What might explain this change?
- Calculate the slope of the curve in each decade. What does the change in slope indicate about the rate of CO_2 increase?
- Describe the seasonal fluctuations in CO_2 concentration. What processes cause these fluctuations to occur?
- How might the pattern of the seasonal cycle differ for a station located in the Southern Hemisphere?
- Concentrations of atmospheric CO_2 remained stable until the industrial revolution in the late 1800s. Industrial activity adds CO_2 to the atmosphere, but land use (whether land is used for agriculture, open space, or towns/cities) has also contributed to Earth's rising CO_2 concentration. How has the change in land use affected the balance of photosynthesis and respiration? How could we change land use to stabilize or reverse this trend?

SOURCE

CREDITS

Written by Bob Kuhn, Centennial High School, GA
Edited by Laura Bonetta, Mark Nielsen, Aleeza Oshry, Bridget Conneely, HHMI