Example of Exponential Increase in Atmospheric CO_2 Concentrations

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The topic of climate change typically comes late in the term; therefore, students will have previously seen several examples of exponential functions. We envision this as a longer exercise that would be completed in a lab or a series of lecture periods.

Learning Goals:

- use data to plot a curve
- read information off of a curve
- recognize an exponential function
- calculate slopes of functions
- interpolation and extrapolation
- learning to use appropriate technology (e.g., Excel)

CONTEXT –Carbon dioxide (CO_2) is one of the greenhouse gasses and there is concern that as global atmospheric concentrations increases, it contributes to global warming. Air bubbles in ice cores from Antarctica provide a long-term record of atmospheric composition. By analyzing the air bubbles we can develop a record of atmospheric CO_2 concentration through time.

DATA

http://cdiac.esd.ornl.gov/trends/co2/contents.htm

- this page lists three ice core datasets and numerous air sampling data sets that cover varying time frames

Ice core data sets:

- http://cdiac.esd.ornl.gov/trends/co2/siple.htm short data set from 1744 to 1953 that shows relatively simple exponential increase in CO_2
- http://cdiac.esd.ornl.gov/trends/co2/lawdome.html -- data set from three ice cores that can be combined into a single record (which looks exponential after 1750) or plotted separately. The periods of record are: 1006 – 1959, 1840 - 1969, 1832-1978,
- http://cdiac.esd.ornl.gov/ftp/trends/co2/vostok.icecore.co2 -- long complex record with data from 2342 to 414085 years before present (BP) that show cyclic variation in CO_2 concentrations. This is interesting if you want them to look at variation in CO_2 over a geologic time frame, but it does not illustrate the increase in CO_2 in recent centuries.

These data could be used in a variety of ways. This could be a group exercise in which all of the groups use the Siple data set, which illustrates the simple exponential trend. Alternatively you could use a variety of data sets that all show an exponential trend (by truncating the data set) or you could include the entire, more complex, cyclic Vostock data.

DATA EXPLORATION –(The following questions will need to be modified if using the Vostock data set.)

- What is the trend of the data? Are values increasing or decreasing? Or is there a more complex pattern?
- What is the CO_2 concentration in 1750? In 1850? In 1950?
- What's the change in concentration a) between 1750 and 1850? B) Between 1850 & 1950?
- What do you predict the CO_2 concentration will be in 2050?
- How did you make your prediction? Explain your though process to your partner (group). Did all of you use the same method or were there different approaches? Which method does the group think is best and why?

GRAPH

(If technology is available, have students plot in Excel. If you plan on using the entire Vostock data set, plotting in Excel is necessary. If you are having them hand-plot the data, you will need to use the shorter data sets or a truncated Vostock data set.)

Use the graph paper provided. Choose, label, and scale your axes and plot the data presented in the table.
Fit a smooth curve to the data points.

ANALYSIS W/ GRAPH & EQUATION

*Describe/Explore Curve (*Instructor can choose how much of the following to include depending on their goals for the exercise*)*

- What's the shape of the curve? What type of function fits this shape?
- Use your curve to estimate the change in CO_2 concentration from a) 1750 to 1850 and b) from 1850 to 1950.
  How do these numbers compare to your earlier calculation? Which do you feel is more accurate and why?
- Use the curve to estimate CO_2 concentration in 2050 and 2150.
  How do these numbers compare to your earlier calculation? Which do you feel is more accurate and why?
- What is the average slope of the curve between 1750 and 1850? And between 1850 and 1950?
  What does an average slope mean (in words)?
- Calculate the percent change for three different time intervals of your own choosing.
  Is the percent change constant, increasing, or decreasing with time?

Equation

If you are using Excel you could have them use the program to determine the actual equation or you could provide it to them at this point. We have plotted the following data sets and determined the following best fit exponential equations:

Siple data $Y=98.124e^{0.0006X}$

Law Dome data (from 1750) $Y = 73.1384e^{0.00075X}$

Revisit the form of the exponential function and the meaning of each term (in words)

- Is an exponential function a good fit for these data? Why or why not?
- What is the implication of exponentially increasing CO_2 concentrations?
- Use the equation to calculate the CO_2 concentration in 2050 and 2150.
- How does this compare to your two previous estimates? Which do you feel is more accurate and why?

DEEPER THOUGHT QUESTIONS

What effect do you think that increasing CO_2 concentrations will have on the climate in the next century? How does consumption of fossil fuels contribute to the observed pattern of CO_2 concentrations? (Note: you can refer your students to a data about fossil fuel consumption either in their book or on the web. Or you could provide them with a figure at this point) Given what you know about fossil fuel reserves, can this trend continue indefinitely into the future? Did you consider trends in fossil fuel usage when you made your previous estimates of future CO_2 concentrations? If not, how would you revise your previous estimates?