Atmospheric CO_2 Levels and Rates of Change

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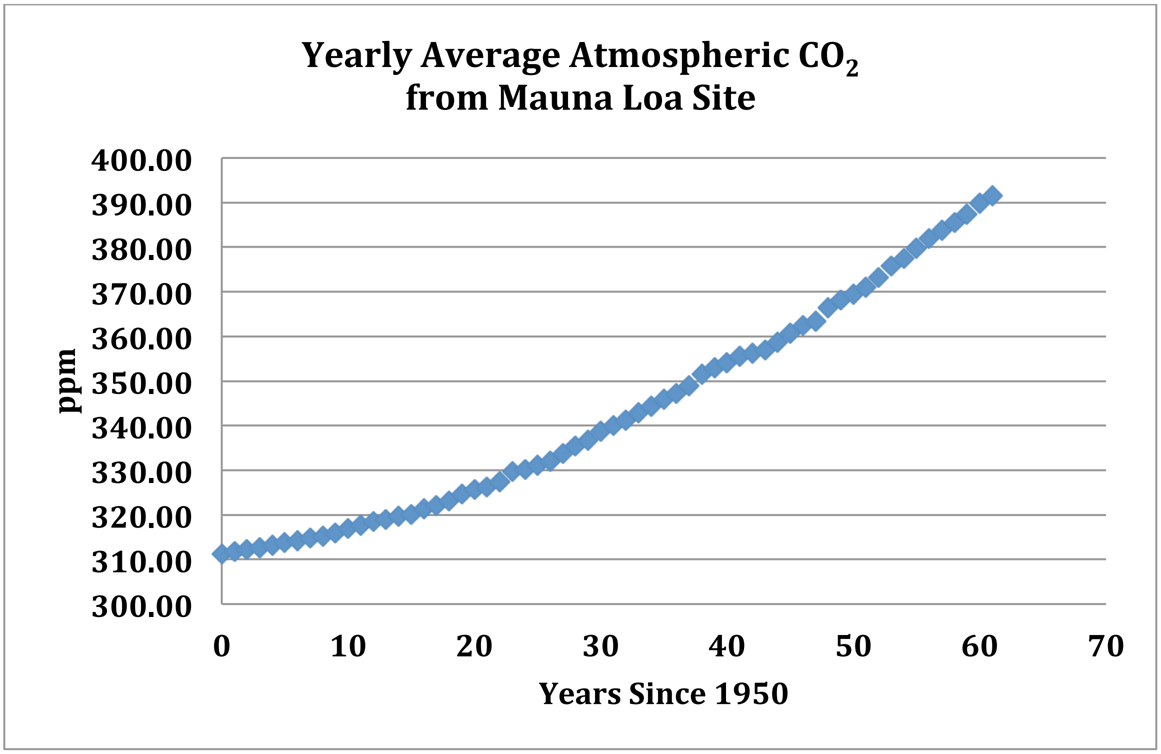

Figure 1. Atmospheric CO_2 data, 1950-2011, from the Mauna Loa site, ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt

Goal: Predict the future – use mathematical modeling to estimate the level of CO_2 in the atmosphere in future years.

The above graph shows the atmospheric CO_2 levels as measured at the Mauna Loa Observatory as a function of time. The units for time are years counted starting from 1950. The units for CO_2 concentration are parts per million (ppm).

1. What year corresponds to t = 50 in the above graph?
2. What is the atmospheric CO_2 concentration in that year? What do the units **parts per million (ppm)** mean?
3. Which of the following terms apply to the graph: increasing, decreasing, concave up, concave down?
4. The curve is made by plotting data points that can be found at the above website. We wish to create a function that will provide a good fit to the data and then use that function to predict the future. Given the shape of the graph, what type of function do you think will provide a better fit: linear, quadratic or exponential. On Figure 1, sketch by hand a smooth curve that fits the data.

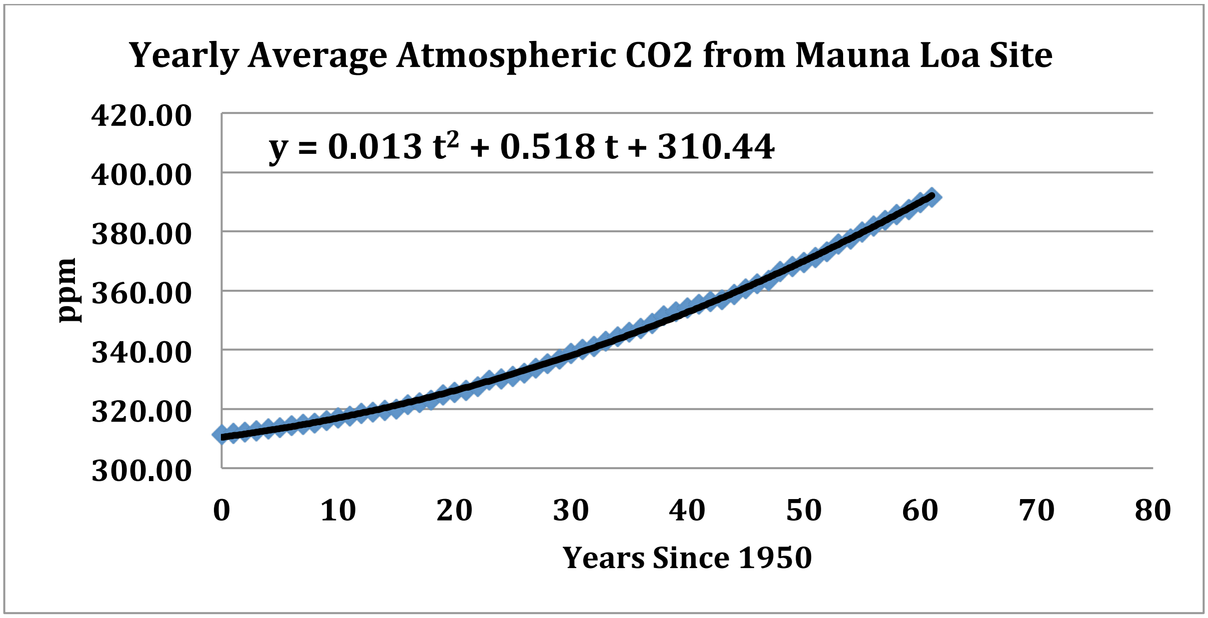

Figure 2. Atmospheric CO_2 data, 1950-2011, from the Mauna Loa site with quadratic fit. ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt, with a fitted curve.

The quadratic function is a better fit than either a linear function (see Figure 2), due to the concavity of the graph, or an exponential function. Answer the following questions using this quadratic model.

5. According to the model what will CO_2 levels be in 2050?

Rising CO_2 levels are already causing changes to the Earth's environment and climate and are predicted to have even more extensive impacts in the future. To head off the worst of these changes, society will need to prevent CO_2 levels from rising too high. Scientists have suggested that 450 ppm is an important threshold that we do not want to cross.

6. According to our quadratic model, in what year do we reach a CO_2 level of 450 ppm?
7. Using the model, determine the rate of change of CO_2 in 2012. What are the units for this rate of change? What is the percentage rate of change?
8. On Figure 2, sketch the line that has this constant rate of change (slope) and is tangent to the curve at time 2012.
9. This line corresponds to the assumption that beginning in 2012, the CO_2 level grows at a constant rate given by 2012 rate of change. With this constant growth assumption, in what year would we reach a CO_2 level of 450 ppm?
10. In order to avoid reaching 450 ppm of atmospheric CO_2 what would have to happen to the shape of the CO_2 curve? Illustrate by making a sketch. What math terms describe your picture?
11. Which of the two scenarios, continued quadratic growth or a switch to linear growth with a fixed rate of change, do you think is most likely to represent what will really happen in the future? Why?
12. Formulate a question based on your work here. It could be a mathematical question. It could be a question about the real world implications of rising CO_2 levels.
13. Discussion Question: What are actions that one can take personally or that society can take to reduce CO_2 emissions?