Using a Model to estimate future carbon dioxide levels and possible global warming

Model is located at:
http://www.atmosedu.com/physlets/GlobalPollution/CO2assign.htm

QUESTIONS

Real Data: Reading The Graph of Figure 1

Q1: Objective: How has the CO_2 concentration changed over the recent past?
Read the graph of figure 1 to answer these questions (click on the image to enlarge it). What are the approximate global average annual average concentrations of CO_2 in 1960, 1970, 1980, 1990, 2000?

Year	C (ppm)
1960	**317**
1970	**326**
1980	**339**
1990	**354**
2000	**370**

From these estimated values is the rate of increase of CO_2 :
Growing **staying about the same** **decreasing** [circle one]

About the model: The model used on this page is very similar to the water bucket model discussed in class. The model solves the basic equation of mass balance:

$$\Delta C = \left[S - \frac{C}{\tau} \right] \Delta t$$

where C, S, τ , and ΔC are the atmospheric concentration of CO_2 (ppm), emission source strength of CO2 into the atmosphere (ppm/yr), the atmospheric lifetime or residence time of CO_2 (years), and the change in CO2 concentration over time Δt . We have also assumed in this model that the emission source S may change over time and the percent emission growth rate, R, is an adjustable input to the model. The initial concentration of CO_2 is denoted by the symbol Co.

Q2. Objective: Learn how the different model inputs influence the behavior of CO_2 over time.

Run the model with Co=300 ppm, S=5 ppm/yr, τ=120 years , and R=0.0. Use the Run1 button so the curve is displayed in red.

Starting from these initial values describe how the graph changes when:
Co is increased to 340 (keep S=5 ppm/yr, τ=120 years , and R=0.0)
Curve is just shifted up by 40 ppm. No change in steepness or curvature.

S drops to 2.5. (use Co=300 ppm, τ=120 years , and R=0.0 so you're comparing with the original)
Starts out less steep. Still has downward curvature and initial position is not changed.

R increases to 2.0 (Use Co=300 ppm, S=5 ppm/yr, and τ=120 yrs so you're comparing with the original)
Upward curvature increases. Original steepness and starting position do not change.

Each description above should discuss whether the graph shifts upward or downward, starts out steeper or not so steep, and becomes more curved or less curved than the starting graph.

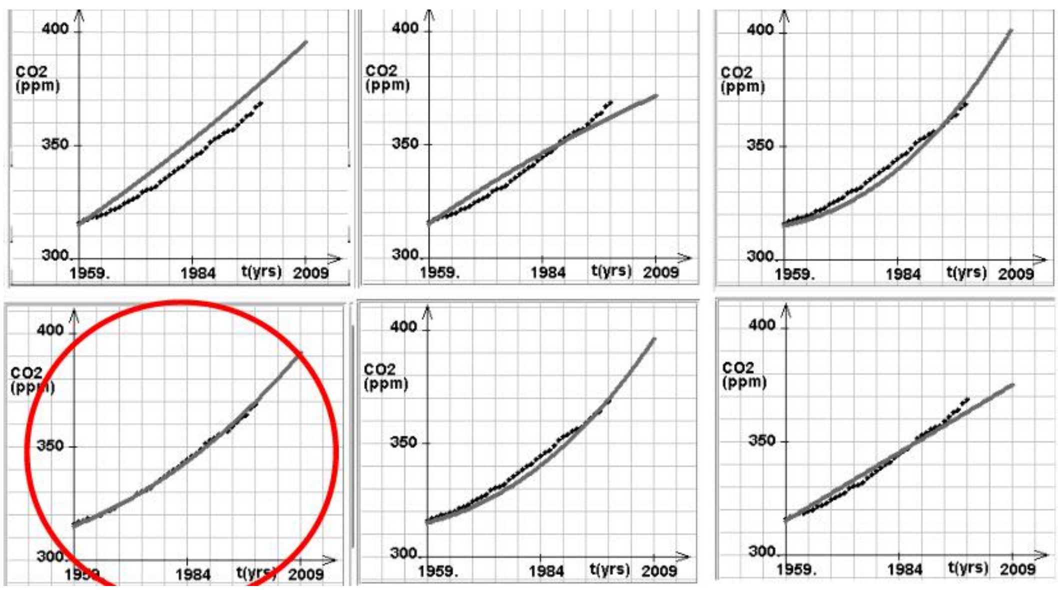
Q3: Objective: Adjust model inputs to obtain a good fit between the model and observation of CO2 for the recent past. We do this for two reasons. 1. to see if the model provides a plausible description of the real world for conditions of the recent past up to the present, and 2. "calibrate" the model so we can estimate future concentrations of atmospheric CO_2 with some confidence.

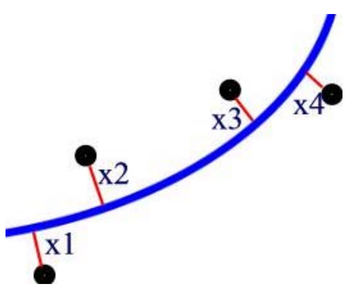
Run the model using a life-time of 120 yrs. **Click on CO2#1** for this simulation. This shows the 1958 to 2000 annual mean Mauna Loa data for CO_2. Adjust the initial concentration, initial emission, and emission increase rate to get the best fit between model and observations.

Hint: To get the best fit, first select the appropriate initial concentration, then using R=0% change the initial emissions to give a good fit for the first 5 or 10 years. After this you can fine-tune the fit for later years by changing R. Doing this should give you a very good fit between model simulations and observations. (the fit between model and observed values black dots should be near perfect)

After getting a **real good fit**, record your values here:
Initial Concentration (ppm): **316 ppm**
Initial Emissions (ppm/yr) **3.3 ppm/yr**
Emission Growth Rate (%): **1.1 %**
Note: The early years are controlled by Initial emissions and later years are controlled by emission growth rate.

Remember that the purpose of obtaining a good fit between the model and observations is that we will want to use the model for future predictions of CO_2 abundances. With this in mind which image below provides the best fit between model (solid gray line) and observations (dark dots)? (Circle your answer) Your fit should be as good as the best fit below.





FYI: Mathematicians often like to define the "best fit" between data and calculated curve as a least squares fit. What this means is that the curve is adjusted so that the sum of the squares of the shortest distances between data and curve is minimum. This is actually easier to express with an equation rather than words. The best fit it a least squares since is one the minimizes:
$X_1^2+X_2^2+X_3^2+X_4^2$

X^2 is used instead of X so that + / - distances are counted the same.

Q4: Objective: With the best fit what does the model predict for the year 2000 concentration and emissions.

Use the numerical output table of the model to record the year 2000 concentration (ppm)and year 2000 emissions (ppm/yr) for the best fit obtained in question 2
Record these values here (include units).
Year 2000 Concentration= **370-372 ppm**
Year 2000 Emissions= **5.1 to 5.2 ppm/yr**

Q5: Objective: Estimate future CO2 concentration values, using values of the year 2000 concentration and emission strength as initial conditions, for different assumed future emission growth rate R scenarios.

Go to Run Model and click on CO2#2 which starts the model simulation from year 2000 and runs it into the future to the year 2100. Use your values of year 2000 concentration, year 2000 emissions, and the emissions growth rate from question 2 to estimate future concentrations of CO_2. We are essentially using past performance to predict future behavior. Call this assumed emission rate increase the **business as usual** growth rate. Use the Run1 button for this run.
When if ever does the concentration reach 632 ppm (twice its 1959 value)?
time to get to 632 ppm=_______**2073 AD** _______________

Change the emission growth rate to **twice the business as usual value** and run the model again as Run2. This corresponds to a tremendous future growth in energy usage and growth in CO_2 emissions (fossil fuel usage and deforestation). When if ever does the concentration reach 632 ppm (twice its 1959 value)? If it doesn't get this high say so and give the maximum concentration reached and the year this maximum was reached.
time to get to 632 ppm= _______**2052_AD** ___________

Change the emission growth rate to **half the business as usual value** and run the model again as Run3. This corresponds to a smaller future growth in energy usage and smaller growth in CO_2 emissions. When if ever does the concentration reach 632 ppm (twice its 1959 value)? If it doesn't get this high say so and give the maximum concentration reached and the year this maximum was reached.
time to get to 632 ppm= **2102_AD**

Change the emission **growth rate to zero** and run the model again as Run4.
This corresponds to holding global energy usage and CO2 emissions to their year 2000 values. When if ever does the concentration reach 632 ppm (twice its 1959 value)? If it doesn't get this high say so and give the maximum concentration reached and the year this maximum was reached.
time to get to 632 ppm= **at 2120 its 524 ppm**

Change the emission **growth rate to -.5%** and run the model again as Run4.
This corresponds to a reduction in global energy usage and CO2 emissions to their year 2000 values. When if ever does the concentration reach 632 ppm (twice its 1959 value)? If it doesn't get this high say so and give the maximum concentration reached and the year this maximum was reached.
time (if ever) to get to 632 ppm= **Maximum of 430.8 is reached at about 2070**

Summarize your above results in the table below.

Scenario	time to get to 632 ppm
Business as usual emission growth rate:	**2073_AD**
Twice the Business as usual emission growth rate:	**2052_AD**
half the Business as usual emission growth rate:	**2102_AD**
zero emission growth (emissions fixed at 2000 values)	**at 2120 its 524 ppm**
-0.5% emission growth (reduce emissions)	**Max of 430.8 is reached at about 2070**

If you had to guess, when would you say that the CO2 concentration will double from its 1960 value? Justify your answer.
Around 270 is my guess but any guess with justification is acceptable.

Q6: Objective: Check your understanding of the model. Run the model if you need to.

If after the year 2000 all sources are held fixed at their year 2000 values then concentration of CO2 will

a. immediately start to drop
b. immediately level off
c. immediately start to increase less rapidly

The emission source in the model is related to all possible sources of carbon dioxide flowing into the atmosphere.

List at least three ways in which carbon dioxide can enter into the atmosphere from human activity. Cars, Power Plants , any fossil fuel source, forest fires, breathing, deforestation and land use changes, changes in ocean circulation possibly linked to global warming.

List at least three ways in which carbon dioxide can enter into the atmosphere from natural sources. Plant decay, volcanic out gassing, release from ocean, forest fires

Q7: Objective: Use the above CO2 concentration profiles and the recent result from the IPCC (Intergovernmental Panel on Climate Change www.ipcc.ch) to obtain estimates of future global temperatures.

For each assumed emission scenario estimate the 1960 to 2060 range in **temperature change estimated by current climate models**. Do this by clicking on "**To Scenarios**" and then finding which scenario in the graph best fits the emission scenario your are exploring. Then click on the best-fit scenario to see the estimate in future temperature predicted by current climate models (2001 Intergovernmental Panel on Climate Change report).

1960 to 2060 estimated range in temperature change for post 2000 emissions matching the:

Scenario	1960 to 2060 estimated range in temperature change
Business as usual emission growth rate:	**0.9 K to 1.8 K**
Twice the Business as usual emission growth rate:	**1.2 K to 2.3 K**
half the Business as usual emission growth rate:	**0.8 K to 1.5 K**
zero emission growth (emissions fixed at 2000 values)	**0.7 K to 1.3 K**
-0.5% emission growth (reduce emissions)	**0.6 K to 1.2 K**

Write a paragraph or two describing which future emission scenario is most realistic and why. Also state what you believe will be the largest plausible (1960 to 2060) change in global mean surface temperature and the smallest plausible (1960 to 2060) change in global mean surface temperature. Justify your reasoning in all cases.

Discussion points may include:

- **Kyoto agreement and US position.**
- **Guess for what the industrialized nations will do in the future.**
- **The lower limit of temperature change is fairly insensitive to emission scenario.**
- **China's (and Asia's) growing economy.**
- **Philosophical, cultural, sociological, economic, and political pressures or considerations.**