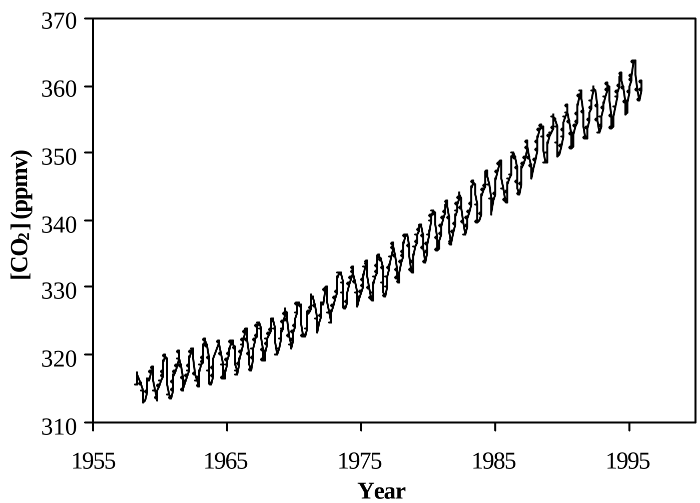
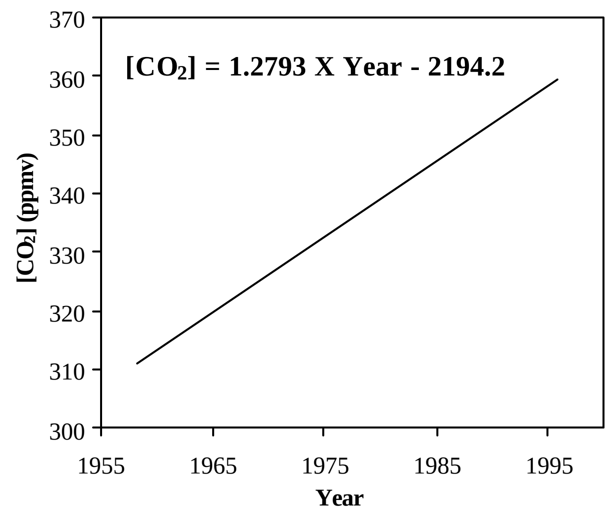
Case Study 1: Atmospheric carbon dioxide increase

The Keeling curve describes the patterns of carbon dioxide concentrations in the atmosphere from the 1950s onwards. The original curve is shown below (left).

1. What two kinds of patterns/variation in carbon dioxide concentrations ($[CO_2]$) can you observe?





2. The line above (right) models one of the two patterns.
a) Which pattern is this?

b) How well would you say the line describes this pattern? How well would you say it represents the whole data set?

c) Come up with one advantage and one disadvantage of representing this data set with a straight line.

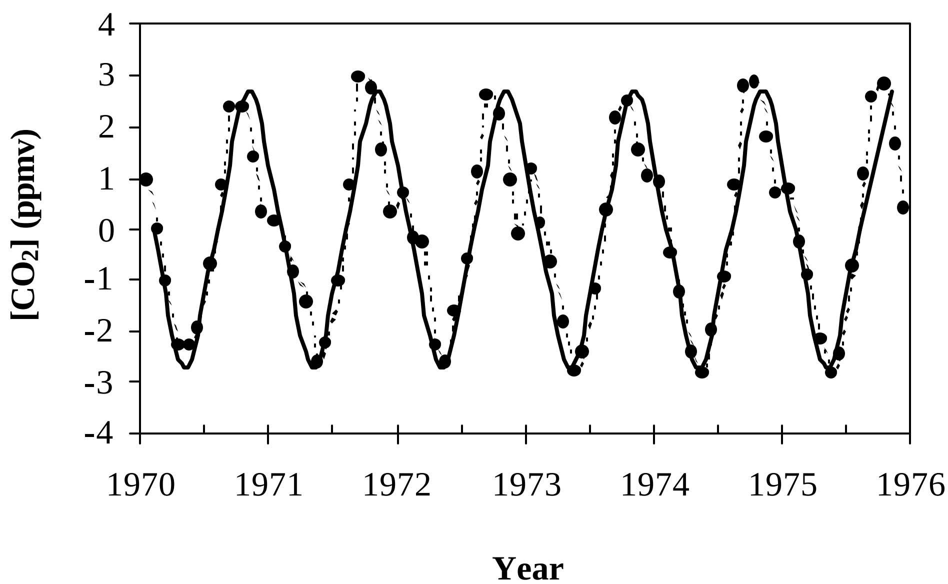
d) You are given the equation for the line in the graph for the years 1958 to 1996. Use the equation to calculate the concentration of carbon dioxide in the year:

- 2025
- 2050
- 2100

3. Which assumption have you made while using the equation for this line? In other words, what must happen for your estimates to come very close to being true?

4. Now, if we remove the effects of the inter-annual increase, we observe a seasonal variation. This was done to produce the graph below for the first half of the 1970s! The interrupted line joins the data points (circles) together, and the solid curved line is a mathematical model of the pattern (see question 5).

[CO_2] = 2.7 X sin((-(Year-1970)) X 2p)



a) In your reading, it was suggested that photosynthesis may account for this seasonal variation. How?

b) When during the year will carbon dioxide concentrations peak and when will they be lowest? Remember: the samples came from Mauna Loa, which is in the Northern Hemisphere.

5. The solid curve above shows a mathematical model of the seasonal pattern for the early 1970s. You are also given the equation for the model, but you won't be asked to use it! Believe it or not, there is very simple mathematical input behind this model!

a) What is the average difference in carbon dioxide concentration between the minimum and the maximum of every year in ppmv?

b) Is the difference between maximum and minimum the same between different years?

c) Describe one advantage and one disadvantage of using this model to describe seasonal variation.

Stella - the models we will use to study cases 2 and 3 have been designed with a software program called Stella. You will not be asked to design any models yourself, but just to use the ones on your computer. Your instructor will describe to you how to explore these models. Here are some basic points and remarks:

- squares represent **pools** or **reservoirs** of material
- thick arrows with valves in the middle of them represent **flows** or **fluxes** of material
- circles with thin arrows going to fluxes represent **flux modifiers**; these modifiers change the fluxes at some point while running the model
- by double-clicking your mouse button while over a certain symbol, you can see the details behind it; for example, the size of the pool at the beginning, the way a flux is calculated etc. These values are **the starting conditions**.
- the graph allows you to run the model and see how the pools change. Click on the graph, and then from the toolbar on the top, select "Run". A menu appears; from that menu, select "run" again. You will see lines showing up on a graph, and on the x-axis time will be plotted. The lines show how your parameters vary with time. Be careful: **each parameter may have a different scale**!

You can find the two models used in these two cases in a folder on your desktop named "Modeling lab." **Note: when you close each model, do NOT save the changes when you are asked to!**

Case 2: Nutrients in the ocean

Open the model named "nutrients."

6. a) According to this model, what are the most important pools of nutrients in the ocean?

b) Name three nutrients for which this model can be used.

7. There are two major biological processes represented in the model.

a) What are they?

b) In which part of the ocean do they take place?

c) Describe which way each process carries nutrients (in other words, which pools does each process connect together?)

8. Which two physical processes are represented in the model (one of them might not be obvious)? Describe the nutrient pathway for each one.

9. a) Double-click on "upwelling flux." What does upwelling depend on according to the model (in other words, how is upwelling calculated)?

b) Now select "upwelling fraction." This modifies the rate of upwelling. How?

10. Lets run the model! Double-click on "Graph 1", select "Run" from the top toolbar and "Run" again from the menu.

a) Which parameters are plotted, and
b) How do they change with time (notice differences in scale)?

c) What happens to the surface biota as the upwelling rate changes?

d) Which large-scale phenomenon are you familiar with that may affect upwelling significantly? Does the pattern our model shows imitate the observed effects of that phenomenon well?

11. Describe one advantage and one disadvantage of this model of nutrient cycling in the ocean?

Case 3: the Global Carbon Cycle

Open the model named "carbon cycle."

12. The following questions aim at helping us to get to know this model.

a) What are the major carbon reservoirs on earth, according to this model?

b) There are several processes in the model which are linked to human activity. Name three of them, and in each case note which pool(s) they are connected to.

c) What is the pool in which the carbon of the following materials would be included?

- garbage
- oil slicks
- taro plants and fish, farmed by humans

13. Find the portion of this model which represents the cycle of carbon as a nutrient in the ocean (the one we explored in the previous case)

a) How is it different from the model of case 2?

b) What is assumed to be happening in this case, but in case 2 was actually shown directly?

c) Do you think it is ignored? Why?

14. a) Open all the pools one by one and record the starting values of each one below. Note which is the biggest one:

Atmosphere	Biota	Humus	Surface Ocean	Deep Ocean

b) In which pool(s) would a small change in amount be most noticeable?

15. Run the model! Double-click on "Graph 1", select "Run" from the top toolbar and "Run" again from the menu.

a) The carbon amount of which pools is plotted against time and how does it change in each case?

b) What happens to the surface biota as the atmospheric carbon changes? Do you have any idea why?

By now, you probably noticed that human activity is affecting the carbon in the atmosphere a lot! But not as much as one would expect: the ocean has been really important in removing plenty of this added carbon from the atmosphere.

16. a) Which process in our model represents the removal of carbon from the atmosphere to the ocean?

One of the effects of more carbon in the atmosphere is warming! And one of the effects of warming is ocean stratification.

b) How would ocean stratification affect the process you named in a)?

c) Test your answer by changing the rate of this process accordingly! Double-click on the modifier of that process and change its value to reflect ocean stratification (ask your TA for help). Then, run the model again and observe the changes!