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Lab Section _____

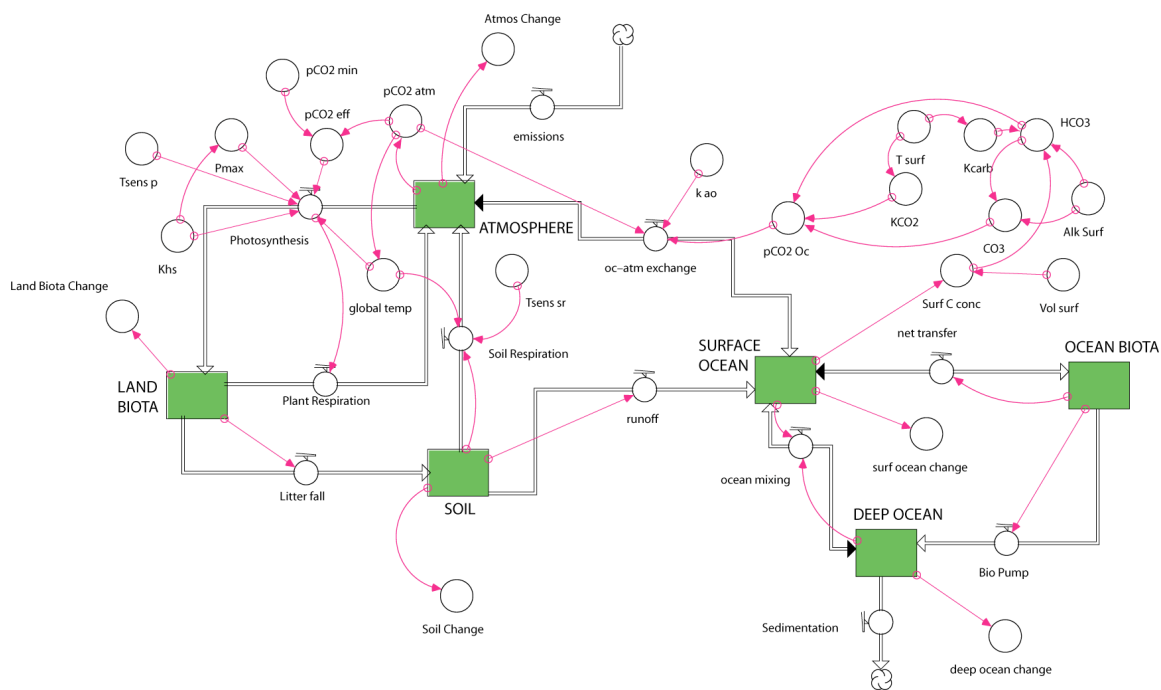
Geoscience 001 Fall 2006 Carbon Cycle Modeling Lab

work in groups of two; each group hands in one lab

In this week's lab, we are going to experiment with a computer model of the global carbon cycle. We will use this model to carry out a series of experiments that will help us understand some basic things about the operation and future prospects for our carbon cycle.

The model we will use and the construction of it are described in detail at http://www.geosc.psu.edu/~dbice/DaveSTELLA/Carbon/c_cycle_models.htm-construct2

The model is a bit more complicated than the climate model we worked with last time, as can be seen by the diagram:



Most of the complexity arises from the way that photosynthesis and ocean carbonate chemistry are represented. In fact, the system is so complex that it cannot be set into a perfect equilibrium without going to extreme lengths. If you run the basic model, you'll see that everything changes, but the magnitudes of these changes are so small (compared to the changes we'll impose) that they do not matter and we can consider the basic model to be in a steady state.

1. Where does the anthropogenic carbon go?

This carbon cycle model does not have a missing sink – that is, all the carbon can be accounted for. Using the standard model with the anthropogenic effects, find out where the carbon goes by graphing the Atmos Change, Surf Ocean Change, etc converters — these give the amount of carbon added to or subtracted from each reservoir. Run the model for just the first 100 years, which amounts to starting 100 years ago and running to the present time.

a) Where does all the carbon go? Summarize the changes of all reservoirs by completing the table below.

Reservoir	Amount added in Gt C	% of Total Added C
Atmosphere		
Land biota		
Soil		
Surface Ocean		
Ocean Biota		
Deep Ocean		
Grand Total		

b) Compare the model's calculated history of atmospheric CO₂ concentration (converter labeled pCO₂ atm) with that of the real world (converter labeled observed atm CO₂) — are they close? Does the model do a perfect, a decent, or a poor job of matching the observed record?

2. Business-as-Usual (BAU)

In this model, I have extrapolated the curves for fossil fuel burning and land use changes (forest burning and soil disruption) for an additional 200 years. I've done this extrapolation conservatively, trying to continue the trend of the recent past. Now run the model and see what happens.

a) What is the atmospheric CO₂ concentration (pCO₂ atm) at the end of this time?

b) How does that compare with the present?

c) How hot does the planet get?

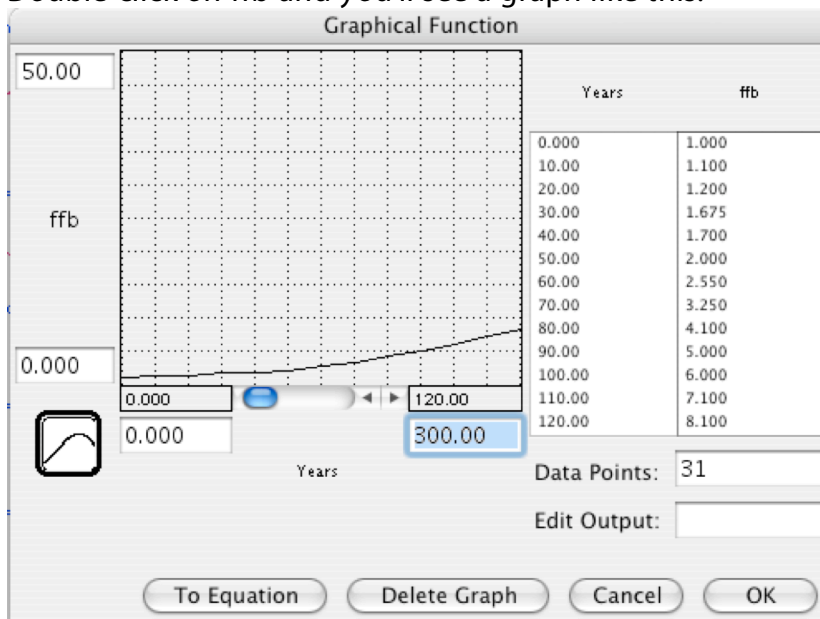
d) How do the proportions of the changes compare with those observed in the first 100 years? I.e., are the changes linear (constant slopes) or non-linear?

Reservoir	Amount added in Gt C	% of Total Added C
Atmosphere		
Land biota		
Soil		
Surface Ocean		
Ocean Biota		
Deep Ocean		
Grand Total		

3. Stabilization

Let's see what happens if we manage to keep fossil fuel emissions and land-use changes to the carbon cycle stable for the next 200 hundred years. Doing this will not be easy, but it can be achieved via a variety of measures summarized in the paper on carbon "wedges", which is linked to the syllabus.

First, we need to change the converters called ffb and land use changes. Double-click on ffb and you'll see a graph like this:



Place the cursor on 7.100 in the ffb column on the right of this window, then click, hold, and drag the mouse down; you'll see the years scroll down to 300, then release the mouse button.

Now enter a value of 6 in the Edit Output box, then click the OK button to make the changes and exit the window. This should have changed the ffb values for years 110 through 300 to a value of 6.0.

Double-click on the ffb converter again, then scroll along the graph to be sure that the changes worked — you should see a flat line from year 100 to 300.

Do the equivalent change to the land use changes converter (take the year 100 value and extend it out to year 300).

a) Before running the model, make a prediction — will this halt the warming? Include your reasoning, along with your prediction.

b) Does this halt the warming?

c) How hot does the planet get?

d) Describe what happens to the temperature after the stabilization takes begins (year 100).

e) Does the system approach a new steady state? You may need to extend the length of time the model runs for, by selecting the Time Specs menu from the Run menu.

4. You Fix It

Congratulations — you have been placed in charge of bringing the global carbon cycle and thus the global climate under control. The fate of the world (well, at least the temperature) rests in your hands. Take a deep breath as you contemplate the power

Your recommendation to the world will be based on model simulations so that people understand exactly what must happen and when we can expect stabilization and the sooner, the better.

There are some constraints, however:

- You cannot drop the emissions to a level below 6 Gt/yr
- You can do whatever you want to the land use changes, but remember that if you cut this to 0, you're effectively saying no more land-clearing, and radically different farming
- You cannot rely on some mythical technology to scrub CO₂ from the atmosphere — you can't just attach a flow to the atmosphere reservoir and send the carbon out of the picture.

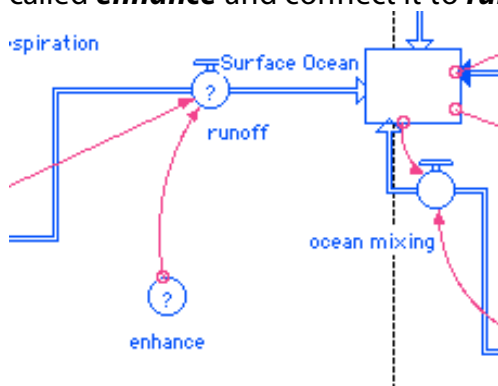
To begin, you need to study the model carefully and think about whether or not you can enhance some flow process to solve the problem.

Look at each flow and ask yourself whether or not changing it will affect the atmosphere directly or indirectly and whether or not a change is feasible.

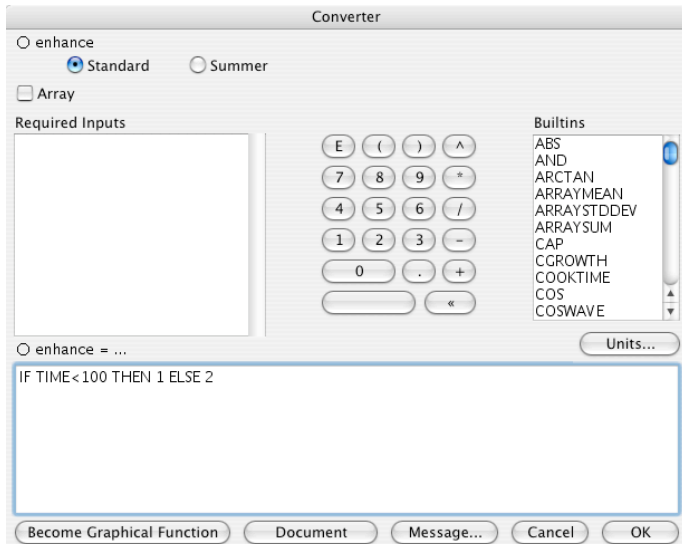
Here is an example of a change that is *not* feasible: increasing downwelling of ocean water, which brings surface waters down into the deep ocean — there is no reasonable way of controlling something like this. Another change that could not be feasible is to drastically lower the ocean temperature.

Your solution should begin at time 100, which is the present day.

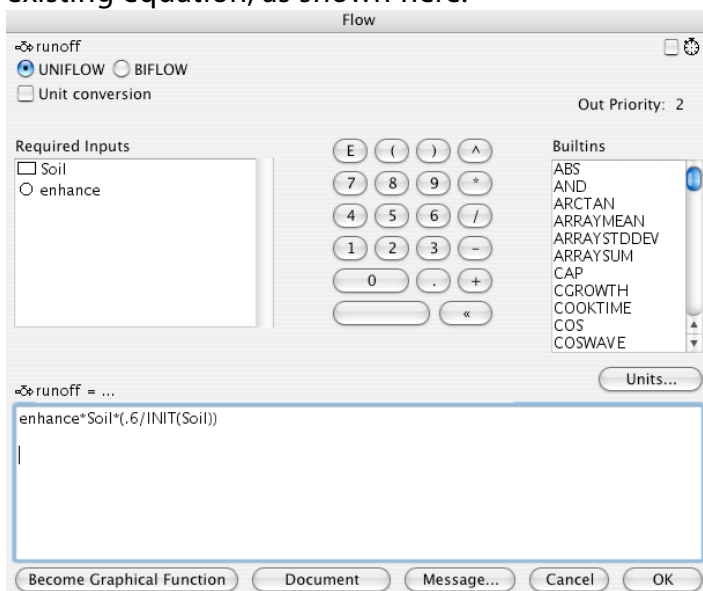
The following example (which may or may not be reasonable) shows the general strategy for making such a change — follow along so that you get the hang of it. Let's say we want to see what will happen if we increase the transfer of carbon from soil to the surface oceans through the process of runoff (this is also called soil erosion, and has some unpleasant consequences). First, you make a new converter, called **enhance** and connect it to **runoff** as shown below:



Then double-click on **enhance** and you'll see a window that is used to define the converter. Type `IF TIME<100 THEN 1 ELSE 2` into the blank space, as shown below:



Then click OK to exit this window. Next, double-click on the **runoff** flow and modify the equation described there so that enhance is multiplied by the pre-existing equation, as shown here:



Click OK to exit and the model is ready to run. Study what happens by graphing the global temp converter and see what happens following time 100. Does the change work? Apparently not. So, you need to be creative and try a variety of changes to find a solution.

What is Your Solution?

Describe the change you made (in enough detail so that we can replicate it — if we can't replicate it, you will not get full credit) and show a graph of the global temperature from time 0 to 300 to demonstrate the success of your change. Also, discuss what would have to happen in the real world to make your change a reality.