Name ______________________________ Teacher ________________ Date __________

4.4: Global Computer Model Reading

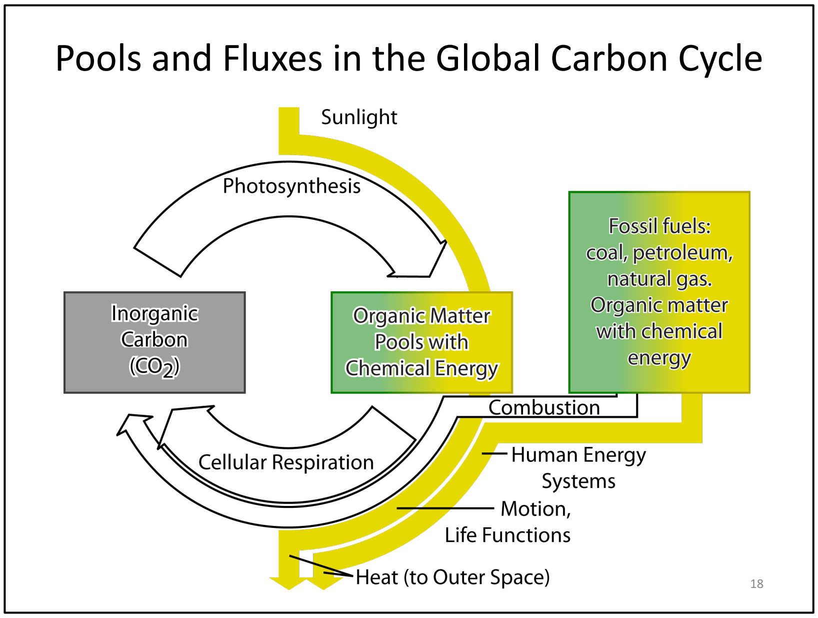
Lesson 4 started with some ideas and some questions. You learned in Lessons 2 and 3 that because of the Greenhouse Effect, carbon dioxide in the atmosphere is the most important driver of global warming. You also learned that CO_2 concentrations in the atmosphere at Hawaii follow two important patterns:

- *The annual cycle:* Every year CO_2 concentrations in Hawaii go down in the summer and up in the winter.
- *The long-term trend:* Every year CO_2 concentrations are a little bit higher than the year before.

Lesson 4 is about using pool-and-flux models to answer three questions:

- *Explaining the annual cycle:* What causes CO_2 concentrations in Hawaii to go down every summer and up every winter?
- *Explaining the long-term trend:* What causes CO_2 concentrations to go up every year?
- *Predicting the future:* How can we predict what will happen to CO_2 concentrations in the future?

Answering the First Two Questions



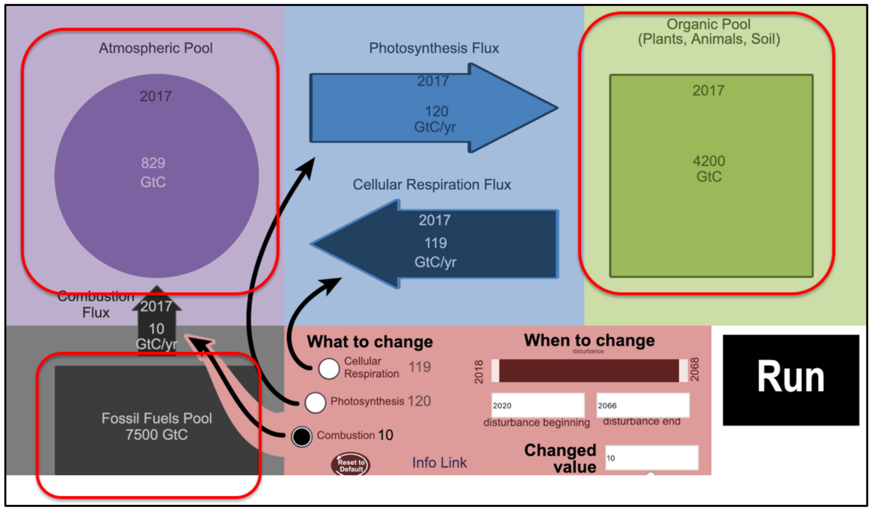
The Tiny World pool-and-flux model that you used in Activity 4.3 is much smaller and simpler than the real world, but you can use the three pools and three fluxes in that model to answer the first two questions. The annual cycle and the long-term trend are caused by changes in the photosynthesis and fossil fuel combustion fluxes.

But the Tiny World pool-and-flux model is too simple to answer the third question, about predicting the future. In the Tiny World model each carbon pool has a few atoms. In the real world each carbon pool has hundreds of billions of tons of carbon.

Answering the Third Question: How Can We Use Models to Predict the Future?

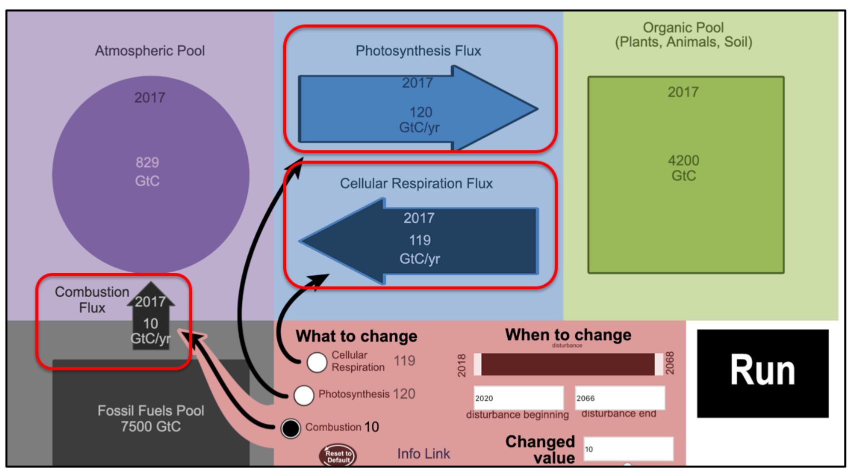
You can use the Global Computer Model (http://carbontime.bscs.org/sites/default/files/simulations/HES_Simulation/index.html) to make predictions based on the current size of the Earth's carbon pools. Like the Tiny World Model, the Global Computer Model has three carbon pools: (1) CO_2 in the atmosphere; (2) organic carbon in plants, animals, and soil; and (3) organic carbon in fossil fuels: coal, petroleum, and natural gas.[1] It also has three carbon fluxes going into and out of the atmosphere: (1) photosynthesis, (2) cellular respiration, and (3) combustion of fossil fuels.

The Earth's carbon pools are very large—their size is measured in gigatons of carbon (GtC). One gigaton is 1,000,000,000 (one billion) tons.[2] As the Keeling Curve shows, these pools are constantly changing size. The initial values in the Global Computer Model (about 850 GtC for the atmospheric pool, about 2000 GtC for the plants, animals, and soil pool, and more than 4000 GtC for the fossil fuels pool) are about the size of these pools in 2017.



Here's another thing: The International Panel on Climate Change (IPCC) has made an estimate of how big the atmospheric pool can become before the effects of climate change become very serious (for example, sea level rise that will drown coastal cities, severe droughts and floods). The IPCC recommends that the atmospheric pool should *never* get larger than about **1100 GtC**. The two organic matter pools are both much larger than 1100 GtC, so the IPCC says that most of the carbon in those pools needs to stay in those pools and stay out of the atmosphere.

The size of the atmospheric carbon pool will depend on the balance among the three carbon fluxes that go into and out of the atmospheric pool. The fluxes are measured in gigatons of carbon per year (GtC/yr). The initial values in the Global Computer Model (about 120 GtC/yr for photosynthesis, about 119.6 GtC/yr for cellular respiration, about 6.5 GtC/yr for fossil fuel combustion) are about the size of these fluxes in 2017.



The photosynthesis and cellular respiration fluxes are much larger than the fossil fuel combustion flux, but for a full year they are almost exactly balanced. So the relatively small combustion flux can have a big effect on how the atmosphere changes from one year to the next—the long-term trend in the Keeling Curve.

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[1] The real world has other carbon pools, too, especially in the oceans. You can learn more about these in Activity 4.5. The three pools in the Global Computer Model are the ones that are most important for determining the amount of CO_2 in the atmosphere.

[2] These are metric tons. A metric ton is 1000 kg or 2205 lb.

Making Predictions with the Global Computer Model

There's one pool that we really care about in the Global Computer Model: The Atmospheric CO_2 Pool, because it drives global climate change. We also have an estimate of the "tipping point"—the size of the Atmospheric CO_2 Pool that will drive severe rather than moderate climate change: 1100 GtC.

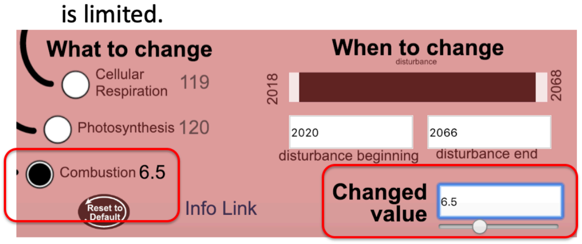
Humans can't just decide to make the carbon pools larger or smaller, so the size of the Atmospheric CO_2 Pool in 2017, at the beginning of the Global Computer Model, can't be changed. Its value—850 GtC—is the actual value that scientists have calculated from their observations.

But humans CAN change what happens to the Atmospheric CO_2 Pool in the future by changing the fluxes—photosynthesis, cellular respiration, and fossil fuel combustion—that move carbon atoms into or out of the Atmospheric CO_2 Pool. Here's what you can change:

Changing the Size of a Flux

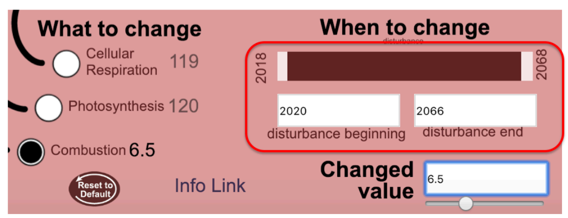
To change the size of a flux:

1. Click on the button for that flux.
2. Use the slider or type in the value you want. Note that the range of values for each flux is limited.

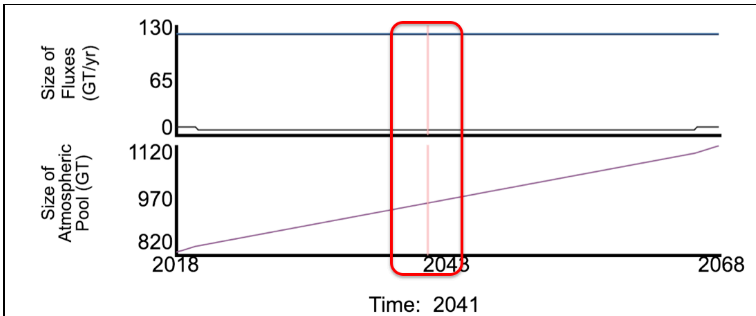


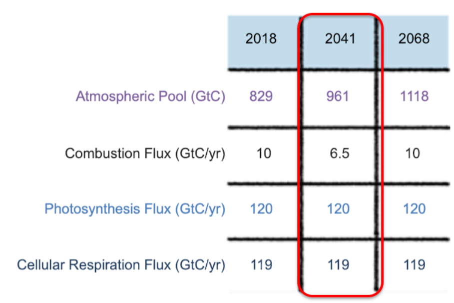
Controlling When to Change

You can also control when a change will take place by sliding the beginning and end dates or typing them in. Note that the model runs for 50 years, from 2018 to 2068.



Reading the results. When you click the Run button, you can see the results in both a graph and a table. You can use the slider on the graph to show the results for a particular year on the table.





	2018	2041	2068
Atmospheric Pool (GtC)	829	961	1118
Combustion Flux (GtC/yr)	10	6.5	10
Photosynthesis Flux (GtC/yr)	120	120	120
Cellular Respiration Flux (GtC/yr)	119	119	119

So now it's time to try some different scenarios yourself. Try the values on the Global Computer Model Worksheet and see what patterns you find!

The Balance Between Photosynthesis and Cellular Respiration

The Photosynthesis and Cellular Respiration Fluxes are almost exactly balanced. The model shows that if we could make the Photosynthesis Flux just a little larger than the cellular respiration flux, that would make a big difference in the growth of the Atmospheric CO_2 Pool. But can we really do that? In the short term those fluxes can be out of balance—the seasonal differences in the Photosynthesis Flux drive the annual cycle in the Keeling Curve. But in the longer term, these two fluxes will stay pretty closely balanced. Here's why.

- Suppose we increase the photosynthesis flux (for example by planting a lot of trees all over the Earth). Since those are living plants, they will also need to engage in cellular respiration. The growing plants will also provide more food for animals and decomposers, so their larger populations will also increase the Cellular Respiration Flux. So, the two fluxes will eventually come back into balance.
- Suppose we try to decrease the Cellular Respiration Flux. Most cellular respiration is done by plants but decreasing cellular respiration by plants will also decrease photosynthesis. Decreasing cellular respiration by animals and decomposers will also reduce photosynthesis in the long run, since plants rely on animals and decomposers to recycle soil nutrients.

So, in the long run the size of the Atmospheric CO_2 Pool will be determined mostly by how fast humans burn fossil fuels. In Lesson 5 you will study how our lifestyles depend on combustion of fossil fuels and think about what changes we could make.

Digging deeper

Here are some ways to learn more about how carbon pools and fluxes in Earth systems are changing

- Read about the likely effects of global warming of 1.5°C and 2.0°C: https://nyti.ms/2IHTSIO
- Read about the effects of a 2.0° and 4.0°C change in climate here!
- https://www.cbc.ca/news2/interactives/2degrees/?utm_source=hootsuite
- Watch a video on coal mines here: https://www.youtube.com/watch?v=ylkdUuNOJzw
- The Global Climate Action Summit released a "road map" of the actions that humans would have to take to keep global warming less than 2°C: http://exponentialroadmap.futureearth.org/
- Read about how scientists are using an ice core from a glacier in the Alps to trace when Europeans started burning more coal: https://nyti.ms/2D5qo8u
- Read about how the Intergovernmental Panel on Climate Change (IPCC) is working to define the "tipping point" between moderate and severe climate change and identify the actions needed to keep the level of climate change moderate: https://www.washingtonpost.com/energy-environment/2018/10/03/climate-scientists-are-struggling-find-right-words-very-bad-news/?noredirect=on&utm_term=.2ae899713e30