# 4.4: Computer Model for Seasons and Disturbances Handout

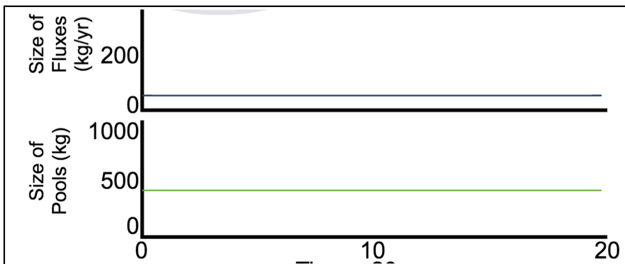
This is a unit about real ecosystems, like meadows, forests, and farms. But some things about real ecosystems are hidden and hard for us to see—like carbon fluxes and how ecosystems change over time. The models that you use in Lesson 4 aren't real ecosystems, but by making those things visible they can help us explain patterns that are hard to see.

Each model in Lesson 4 is a little more realistic (and thus complicated) than the model before. Model 3 is the most complicated of all. This handout starts by reviewing important patterns from Models 1 and 2. It then guides you through an exploration of Model 3, where you can explore how pools and fluxes change with the seasons and with disturbances such as fires, droughts, and human management.

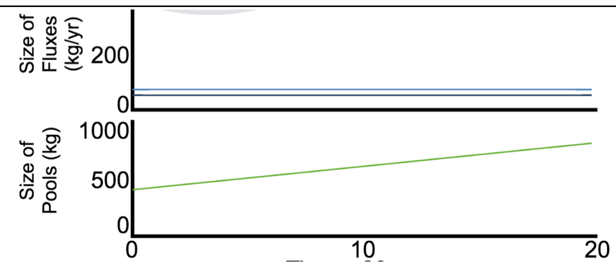
### Important Patterns in Models 1 and 2

Models 1 and 2 each show important patterns that are true for all ecosystems. Let's review those patterns.

**Model 1: Pool sizes change with the balance of fluxes.** The size of a carbon pool changes or stays the same according to the *balance of fluxes* into and out of the pool. If the fluxes into and out of a pool are *exactly the same,* then the pool stays the same size. But if the fluxes into and out of a pool are even a little bit different, then the pool gets larger or smaller.




Balanced fluxes: Pools stay the same size. Both fluxes are 50 kg/yr. The graph shows the organic carbon pool, but not the $CO_2$ pool.

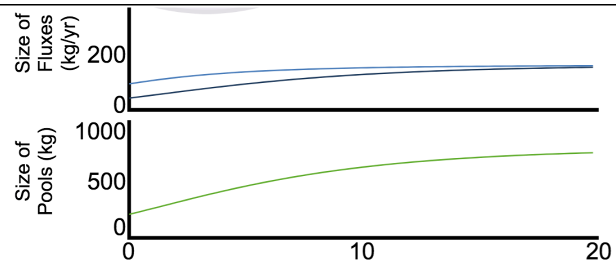



Unbalanced fluxes: Pools change sizes. The photosynthesis flux is 60 kg/yr and the CR flux is 50 kg/yr.

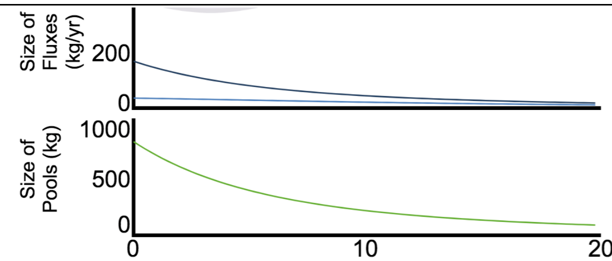
**Model 2: Ecosystems can stabilize because fluxes change with pool size.** Real ecosystems that are undisturbed for many years are usually stable—their carbon pools stay about the same size. Model 2 shows how this is possible because it includes two important new patterns:

- *Fluxes change with the organic matter pool.* Rather than staying the same all the time, the photosynthesis and cellular respiration fluxes change depending on how much organic matter is in an ecosystem.
- *Limiting factors affect the photosynthesis flux.* Plants can't keep growing forever. In every ecosystem, some *limiting factor* such as sunlight, water, nutrients, or temperature puts an upper limit on the photosynthesis flux.

These patterns mean that, like the Meadow Ecosystem you studied in Lesson 2, the ecosystems in Model 2 slowly settle into a pattern of balanced fluxes and steady pools. In ecosystems with large photosynthesis limits, like tropical rain forests, there is a lot of organic matter. In systems with smaller photosynthesis limits, like deserts, there is less organic matter.




Ecosystems with large photosynthesis limits (90) stabilize with lots of organic matter.




Ecosystems with small photosynthesis limits (20) stabilize with less organic matter.

## Using Model 3 to investigate how ecosystems change

Some ecosystems are pretty stable; Model 2 helps us to see how that can happen. But real ecosystems don't just stabilize; sometimes they change. So what's missing from Model 2? Here's one thing: Model 2 doesn't include any way to investigate how pools and fluxes are affected by changes in environmental conditions or events that disturb the ecosystem. For example:

- In many places the photosynthesis flux depends on seasons, such as places where plants die or go dormant in the winter.
- Sometimes disturbances such as fires can move a lot of carbon from the organic matter pool to the $CO_2$ pool (through the process of combustion).
- Other disturbances such as droughts can affect the photosynthesis limit of an ecosystem—plants can't photosynthesize as much if they have less water.

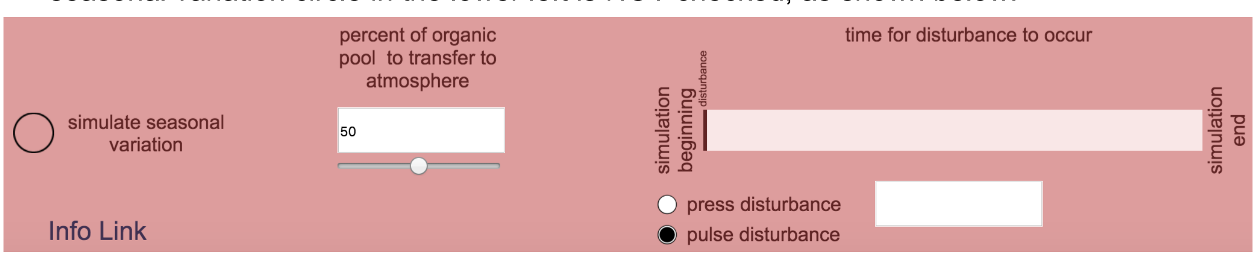
You can use Model 3 to explore how seasons and disturbances (as well as pool size) can affect pools and fluxes in ecosystems.

### A. Investigate how seasons affect pools and fluxes

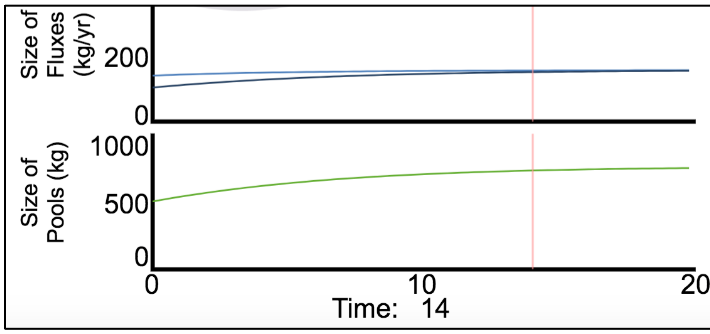
**Model 3 without seasonal variation.** In this activity, you will investigate patterns in a computer model of an ecosystem, with 1000 kg of carbon. For comparison, start by running the model without seasonal variation.

Click the **three-turtle model**: [http://media.bscs.org/carbontime/simulations/pool-flux-simulation/index.html](http://media.bscs.org/carbontime/simulations/pool-flux-simulation/index.html)

1. Make sure that the disturbance boxes on the lower right are blank and that the "simulate seasonal variation circle in the lower left is NOT checked, as shown below.



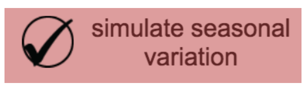

2. Try using these initial settings:
   a. Photosynthesis limit = 90 kg/yr
   b. Atmospheric pool = 500 kg
   c. Organic carbon pool = 500 kg
3. Run the model.
4. Click on the graph and move the sliding line to Year 14.0. You should see a graph and table that look like the picture on the next page.




| | t=0 | t=14 | t=E |
|---|---|---|---|
| Atmospheric (kg) | 500 | 273 | 254 |
| Organic (kg) | 500 | 726 | 745 |
| Photosynthesis (kg/yr) | 135 | 150 | 150 |
| Cellular Respiration (kg/yr) | 100 | 145 | 149 |

5. *On your worksheet,* use the numbers in the “t=14” column of the table to fill in the Year 14 data on your worksheet table.
6. Now move the sliding line to Year 16.0, and use the “t=16” column of the table to fill in the Year 16 column on the worksheet table.

**Model 3 with seasonal variation.** With no seasonal variation and no disturbances, Model 3 is just the same as Model 2: it settles into a stable pattern. Now let’s investigate how seasons affect carbon pools and fluxes.

7. Now click the “simulate seasonal variation” button on the left side. You should see a check mark in the circle. 

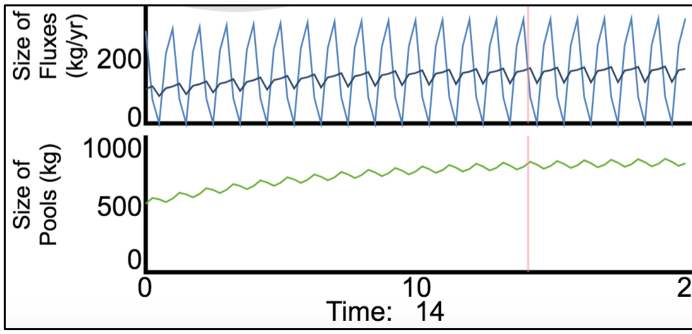
Leave all the other settings the same.

Note that when you click this button, each year is divided into four seasons:

- The year starts in *spring* (0.0, 1.0, 2.0, etc.). The photosynthesis flux increases, but it is less than during the summer.
- The next season is *summer* (0.25, 1.25, 2.25, etc.). This is when plants are growing fastest, so the photosynthesis flux is at its peak.
- The next season is *fall* (0.5, 1.5, 2.5, etc.). The photosynthesis flux slows down during the fall.
- The final season is *winter* (0.75, 1.75, 2.75, etc.). The photosynthesis flux drops close to 0.

The “Organic (kg)” line shows the size of the organic carbon pool at the *end* of each season, and the fluxes show how carbon moved *during* the season. You can use the balance of fluxes to calculate how and how much carbon moved during the season. (But remember that the flux rates on the graphs and table show how much carbon would move during a whole year. The carbon movement during one season is just ¼ of the yearly carbon flux.)

8. *On your worksheet,* complete the table in question 2 for the seasons in year 14.
9. *On your worksheet,* you can use the graphs to record your data for the same years (Years 14-16) with seasonal variation. The seasons make the patterns in the data more complicated, so you will have to move the line through the graph one season at a time:
   a. Start with the line on the graph at Year 14.0, as shown in the picture below. Use the numbers in the “t=14” column to make dots for the organic carbon pool, photosynthesis flux, and cellular respiration flux on the two graphs on the next page of your worksheet.




| | t=0 | t=14 | t=E |
|---|---|---|---|
| Atmospheric (kg) | 500 | 230 | 204 |
| Organic (kg) | 500 | 769 | 795 |
| Photosynthesis (kg/yr) | 270 | 304 | 306 |
| Cellular Respiration (kg/yr) | 100 | 153 | 159 |

10. Continue making dots for every season (14.25, 14.5, 14.75, etc.) up to Year 16.0.
11. Connect the dots with lines. You will have one line on the organic carbon pool graph and two lines on the Photosynthesis and CR Flux graph.
12. Try changing the Photosynthesis Limit and initial pool sizes and run the model again. What patterns do you see?

**B. Patterns in how seasons affect pools and fluxes**

13. Think about patterns you have noticed in how the fluxes and organic matter pool change with the seasons and answer the questions in Part B of your worksheet.

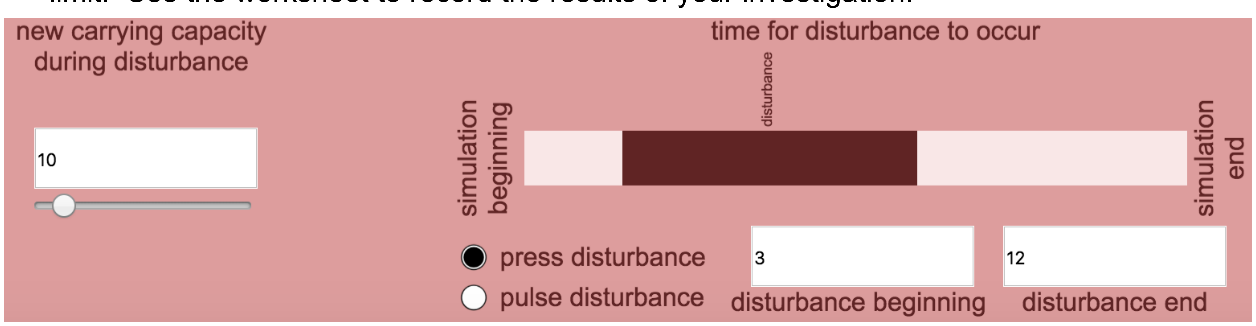
**C. Investigate how disturbances affect pools and fluxes**

There are other kinds of conditions and events that can change ecosystems. Ecologists call these *disturbances.* You can use Model 3 to investigate two kinds of disturbances:

- *Press disturbances* are changes in environmental conditions that last for a long time. Droughts and other kinds of climate change are press disturbances. Human management practices such as fertilizing farm fields are also press disturbances. Press disturbances typically affect the photosynthesis limit of an ecosystem.
- *Pulse disturbances* are events that cause a sudden change in an ecosystem. Fires, storms, and human actions such as logging a forest are all examples of pulse disturbances. Pulse disturbances usually affect pools or fluxes in an ecosystem, but not photosynthesis limits. (You can read more about fires in *4.4 Fire Reading*.)

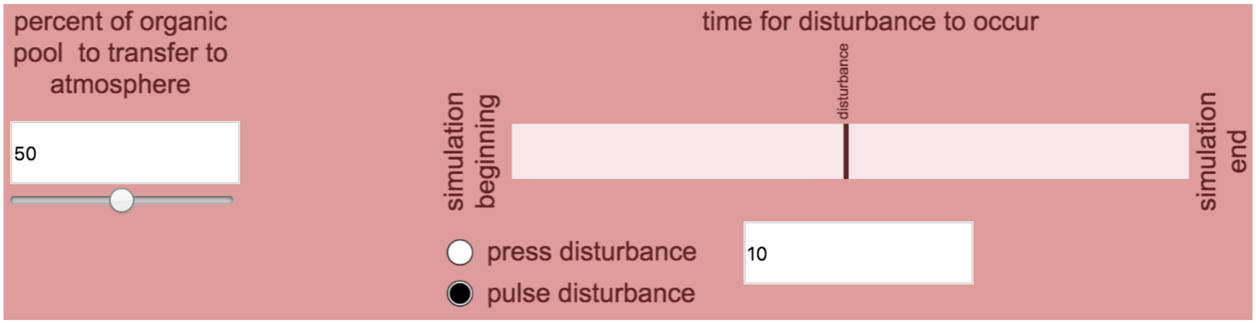
**Model 3 with press and pulse disturbances.** You can use Model 3 to investigate how press and pulse disturbances affect ecosystems.

14. Investigate press disturbances. When you click the “press disturbance” button on Model 3, you can use numbers or sliders to control the beginning and end of the disturbance, as well as how the disturbance affects the photosynthesis limit. Try using these controls to investigate press disturbances such as droughts that reduce the photosynthesis limit of an ecosystem as well as press disturbances such as irrigation that increase the photosynthesis limit. Use the worksheet to record the results of your investigation.



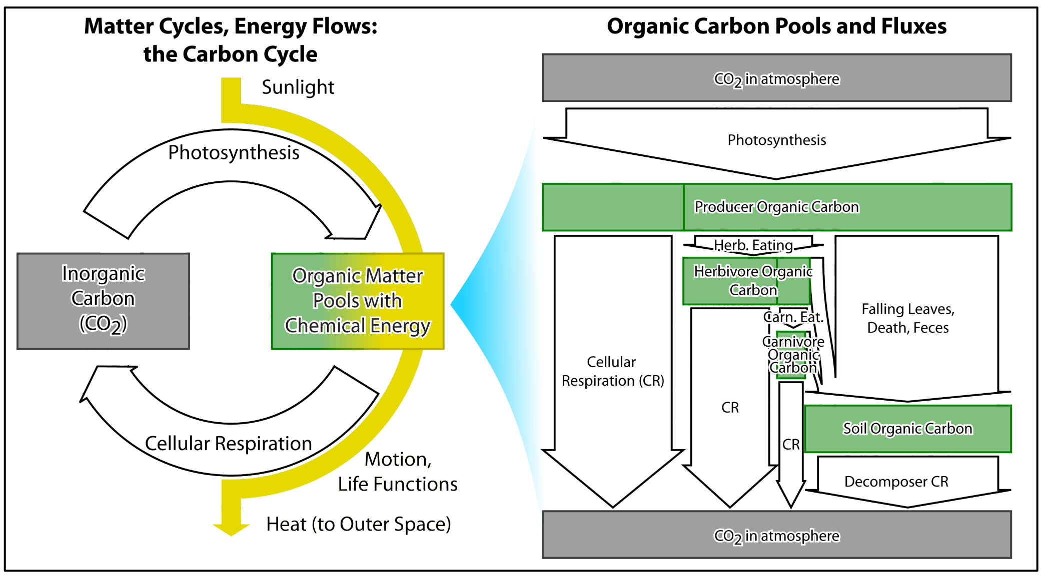

15. Investigate pulse disturbances. When you click the “pulse disturbance” button on Model 3, you can use numbers or sliders to control the time of the disturbance, as well as how much

organic carbon goes into the atmosphere from a disturbance such as fire. Try using these controls to investigate big and small pulse disturbances. Use the worksheet to record the results of your investigation.




## Disturbances in real ecosystems

Model 3 is pretty complicated, but real ecosystems are a lot more complicated than Model 3. So, there are many important disturbances in real ecosystems that Model 3 won't show. Here's one big problem with Model 3:




Model 3 shows only the big pools and fluxes on the left side of our pool and flux figure. Many important disturbances affect the smaller pools inside the organic carbon pool. Here are some examples:

- *Invasive plants* such as purple loosestrife or spotted knapweed are often plants that local herbivores can't eat. So when invasive plants move into an area, they may not have a large effect on the overall size of the organic matter pool, but they can decrease the number of herbivores—and of carnivores that need herbivores for food.
- *Insecticides:* Many insects are herbivores, so farmers use insecticides to reduce the numbers of herbivores in their fields, and keep the food that the plants produce for humans and farm animals.
- *Tilling the soil* kills some plants (weeds) so that crop plants can be the main producers and grow better.

There are many other kinds of disturbances that affect ecosystems. Some are natural occurrences, such as fires and droughts. Some are intentional human management to get products or services from ecosystems. Some are results of human actions that we don't like, such as pollution and climate change.

All of these disturbances mean that most of the world's ecosystems are constantly changing. Scientists are constantly working to understand what is causing those changes, and what their effects will be. You can use the last question in your worksheet to identify and discuss some of those disturbances and their effects.

## Digging deeper

Here are some ways to learn more about different kinds of disturbances and how they are affecting ecosystems:

- Explore invasive species in the Great Lakes: https://www.nature.org/ourinitiatives/regions/northamerica/areas/greatlakes/explore/aquatic-invasive-species-maps.xml
- To Learn about the effects of acid rain: https://www.epa.gov/acidrain/effects-acid-rain
- Explore the consequences of deforestation: https://www.nationalgeographic.com/environment/global-warming/deforestation/
- To learn about fires as an ecosystem disturbance: 4.4 Fire Reading