Global Carbon Cycle Modeling

A Paper & Pencil Model Leads to a Simple Computer Model

Purpose

- To understand that the carbon cycle is part of the Earth's interconnected system
- To understand that human actions have an impact on the global carbon cycle.
- To gain a greater understanding of why scientists use models and how they are developed.

Overview

Students use the global carbon cycle diagram to make pencil and paper calculations of changes to carbon pools after a few years. They then explore a computer model to look at changes over hundreds of years. Students will consider the carbon cycle both pre- and post- industrial revolution and answer basic questions by observing model output.

Student Outcomes

Students will be able to:

- Describe feedbacks within the global carbon cycle.
- Use a simple model and change model variables to affect model outcomes
- Describe the impact of human actions on the global carbon cycle

Questions

Essential

- How are models useful in understanding the carbon cycle?

Content

- What role do humans play in the global carbon cycle?
- What are the model's limitations and assumptions?

Science Concepts

Grades 9-12

Scientific Inquiry

- Use technology and mathematics to improve investigations and communications.

Life Science

- The atoms and molecules on the earth cycle among living and non-living components of the biosphere.

Science in Personal and Social Perspectives

- The earth does not have infinite resources.
- Materials from human societies affect both physical and chemical cycles of the earth.
- Human activities can enhance potential for hazards.
- Science and technology can only indicate what can happen, not what should happen.

NGSS (Black- covered directly, gray-addressed, but not directly covered)

- *Disciplinary Core Ideas*
  - Gr.6-8: LS2.B, LS2.C, ESS2.A, ESS3.A, ESS3.C, ETS1.B, ETS.C, ESS3.D
  - Gr.9-12: LS2.B, LS2. C, ESS2.A, ESS2.D, ESS3.A, ESS3.C, ETS1.B, ETS.C
  - *Science and Engineering Practices*
  - Developing and using models
  - Planning and carrying out investigations
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Constructing explanations
  - Obtaining, Evaluating, and Communicating Information
- *Crosscutting Concepts:*
  - Patterns
  - Cause and Effect
  - Scale, Proportion, and Quantity
  - Systems and System Models
  - Energy and Matter
  - Stability and Change

Time/Frequency

35 minutes (paper/pencil)

60 minutes (simple model)

Level

Secondary (High School)

Materials and Tools

- Computers (one per student or student pair)
- Access to online *Simple Global Carbon Cycle Model* hosted by the isee Exchange (https://exchange.iseesystems.com/public/globeprogam/simple-global-carbon-cycle-

model)

- *Global Carbon Cycle Student Worksheets 1 and 2* (one per student)
- Global Carbon Cycle Diagram – class copy, on an overhead or the board.

Prerequisites

- Basics of the global carbon cycle (*Carbon Background, Carbon Cycle Adventure Story, Carbon Travels Game, Getting to Know Global Carbon*).
- Systems thinking concepts including pools, fluxes, box & arrow diagrams, equilibrium (*Paper Clip Factory Analogy, Carbon Cycle Adventure Story*).
- Ability to use an online computer model (Carbon Cycle Modeling eTraining, *Paper Clip Tutorial Model, Biomass Accumulation Model*)
- Brief scientific background of climate change (Carbon Cycle Introdcutory eTraining)

Preparation

- Review modeling terms (stock/pool, flux, equilibrium).
- Optional: review the Carbon Cycle Modeling eTraining (https://www.globe.gov/get-trained/protocol-etraining/etraining-modules/16867717/3099387)
- Make appropriate copies.
- Set up computers.
- Write essential, unit, and content questions somewhere visible in the classroom.

Background

Scientists use computer models to help them understand the behavior of complex systems and to predict outcomes that cannot be measured directly. The Global Carbon Cycle Model is a simple model based on the accompanying global carbon cycle diagram. All of the Earth's carbon is assumed to be transferred between five of the major carbon pools: the atmosphere, plants, soils, oceans, and fossil fuels. The transfer, or "flux" of carbon is estimated annually. Units are in petagrams (Pg = 1015g) C for stocks and Pg C/yr for fluxes. This is very much a simplification of how the real Earth works, but it allows for predictions of how carbon will move through the Earth system over hundreds of years.

For a comprehensive background on the global carbon cycle see the Carbon Cycle Teacher Background. For background on positive and negative feedback loops, refer to Systems and Modeling Introduction: Systems Vocabulary.

What To Do and How To Do It

ENGAGE	**Grouping:** Class	**Time:** 10 Minutes

- Post the *Global Carbon Cycle Diagram*
- Ask students: How does carbon move from one pool to another? How does the carbon cycle change over long periods of time?

EXPLORE	**Grouping:** Small Groups	**Time:** 20 Minutes

- Divide students into carbon pool groups (atmosphere, soils, plants, oceans, Earth's crust)
- Students complete *Student Worksheet 1: Global Carbon Cycle Paper and Pencil Modeling* to calculate how their pool will change in 5 years, and predict how it will change over 100 years.

EXPLAIN	**Grouping:** Class	**Time:** 15 Minutes

- Students present results from their group (**See Extension 1)
- Ask students how they might figure out if their predictive graph is correct? Does it make sense to use simple accounting for 100-1000 year time periods? Remind students about the use of computer models to understand systems.

- Does it seem realistic that the pools act so independently of each other? What might be missing from the diagram? Introduce the concept of feedbacks (feedback loops).
- Discuss with students about how the complexity of models is determined by who the end users will be, what the model output will be used for, etc. Show clip of video simulation of complex Earth System model that tracks global atmospheric carbon (http://www.youtube.com/watch?v=O4WMdwIwrSw)
- To transition into the modeling activities, ask students: Is the global carbon cycle in balance? Why or why not?

ELABORATE	**Grouping:** Pairs	**Time:** 40 Minutes

- Working in partners (preferably with someone from their carbon pool group group), students will now open the Global Carbon Cycle Model online. Students should work through *Student Worksheet 2: Global Carbon Cycle Computer Modeling* at their own pace. As the facilitator you should set deadlines for exercise completion so carbon pool groups and the class can occasionally come together to discuss results and student questions.
  - Exercise 1: Pre-industrial carbon. (Concepts – Equilibrium, controlling for variables)
  - Exercise 2: How long will fossil fuels last? (Concepts – Time scales, climate change)
  - Exercise 3: Exploring individual carbon pools. (Concepts – Feedbacks)

EVALUATE	**Grouping:** Class	**Time:** 15 Minutes

- As a class, discuss students' responses to Student Worksheet 2.
- Help students make connections between the exercise they completed and other related topics (global carbon cycle, field work, and climate change).
- Inform students of next phases of their carbon investigation (see Extensions for further inquiry opportunities)

Assessment

- Students should be graded on the thoughtfulness and thoroughness of their written responses and their ideas/questions shared during class discussions.

Extensions

- To enhance the connections between the Paper and Pencil Model and the computer Global Carbon Cycle Model, have students create a poster that includes the following to share with the class:
  - Systems (box - arrow) diagram of your pool (you can be creative with this)
  - All input and output fluxes of the pool
  - Initial carbon value
  - Equation developed to predict the change in carbon over time
  - How much the pool is changing each year (value, positive, negative, etc.)
  - Predictive graph
  - A description of how a change in your pool might influence the global carbon cycle
- Students conduct a literature/internet search (Intergovernmental Panel on Climate Change- http://www.ipcc.ch/ is a great resource) to find current and future projections of deforestation and fossil fuel emission rates. Split them into groups and have each group investigate a different climate change scenario, or let each student choose what they would like to focus on. Have students run the model with these new inputs. How do these changes impact different carbon pools? How do you think these human actions affect atmospheric CO_2 concentrations, global temperatures, etc.? What are implications of this for future climate change?
- For climate change data, resources, and activities that complement GLOBE Carbon Cycle curricula, see the Student Climate Data project (http://studentclimatedata.unh.edu).
- Have original carbon pool groups regroup and discuss the results from their model investigations. Students make a list of what relationships the model includes and

outcomes it can 'predict'. Students make another list of what they think is lacking: specific pools, fluxes, feedbacks, processes or details that would improve the model's ability to provide a better picture of reality.

- Realizing what is lacking may be easy, but how to we get the information we need to improve the model? Through new experiments or field investigations! Have the students write a grant proposal (*following the provided guidelines*) that outlines how they will get the information they need to improve the model. Do they need to set up a photosynthesis/CO_2 experiment? Perhaps they need to complete a soil carbon study? Students should have time to research some of these topics in order write reasonably realistic proposals. The use of scientific literature is recommended.

Resources

- isee Exchange: https://exchange.iseesystems.com
- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/
- Global Carbon Project: http://www.globalcarbonproject.org/
- Student Climate Data Project: http://studentclimatedata.unh.edu/
- Fisher, Diana M. Modeling Dynamic Systems: Lessons for a First Course. 2005-2006.
- Sussman, Art. Dr. Art's Guide to Planet Earth. San Francisco: WestEd, 2000

TEACHER VERSION

(Suggested student responses included)

Student Worksheet 1:
Global Carbon Cycle Paper and Pencil Modeling

1. What is your pool and its current carbon storage in petagrams (Pg)?

   My pool is the Plant Pool and its current carbon storage is 560 Pg C.

2. Using the *Global Carbon Cycle Diagram* and your class table, use addition and subtraction to determine the change in carbon (Pg/yr) of your pool after one year, from the current value. Show your work.

   560 Pg C +120 Pg C (Photosynthesis) - 59 Pg C (Plant respiration) – 59 Pg C (Litterfall) -1.1 (Deforestation) = ***560.9 Pg C***

3. Is the change in carbon positive, negative, or no change after one year?

   Positive

4. Repeat the process four more times. How many petagrams (Pg) of carbon are in your group's pool after 5 years? Show your work.

   Initial pool size = ***560 Pg C***

   Year 1 = ***560.9 Pg C***

   Year 2 = 560.9 Pg C +120 Pg C (Photosyn.) - 59 (Plant resp.) – 59 (Litterfall) -1.1 (Deforestation) = ***561.8 Pg C***

   Year 3 = 561.8 Pg C +120 Pg C (Photosyn.) - 59 (Plant resp.) – 59 (Litterfall) -1.1 (Deforestation) = ***562.7 Pg C***

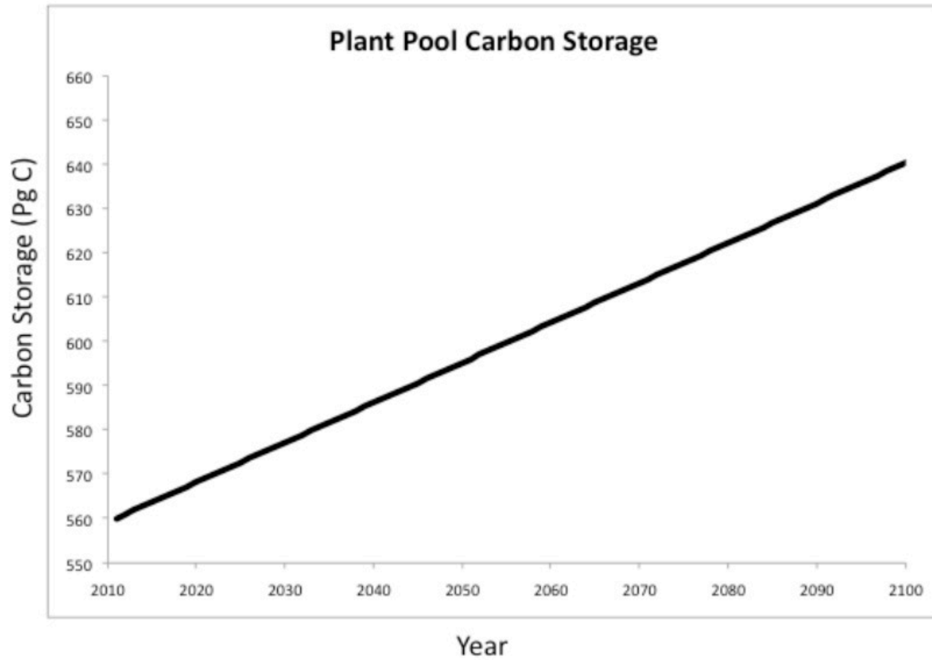
   Year 4 = 562.7 Pg C +120 Pg C (Photosyn.) - 59 (Plant resp.) – 59 (Litterfall) -1.1 (Deforestation) = ***563.6 Pg C***

   Year 5 = 563.6 Pg C +120 Pg C (Photosyn.) - 59 (Plant resp.) – 59 (Litterfall) -1.1 (Deforestation) = ***564.5 Pg C***

5. Develop a generalized equation that could be used in a computer model to predict yearly carbon storage in your pool. Remember, generalized equations generally don't use actual numbers, but use variable names to represent the pools and fluxes.

   Carbon Storage (Pg C this year) = *Initial Plant Pool Carbon (Pg C last year) + Photosynthesis (Pg C/ year) – Plant Respiration (Pg C/ year) – Litterfall (Pg C/ year) – Deforestation (Pg C/ year)*

6. Draw a predictive graph of how your carbon pool will change over 100 years, based on current flux values. Remember to label your axes!



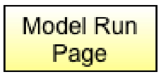
TEACHER VERSION

(Suggested student responses included)

Student Worksheet 2:
Global Carbon Cycle Computer Modeling

In this exercise, you will run the GLOBE Simple Global Carbon Cycle Model to explore how carbon moves through the Earth system and how human actions influence the global carbon cycle.

Activity 1. Pre-industrial conditions

1. Click on 

2. Look at the top graph on the left of the model run page. This graph shows the change in carbon pool size over time.
   a. What are the dependent variables that will be displayed on this graph?

   Carbon storage over time for all 5 carbon pools.

   b. What are the units of these dependent variables (check the diagram on the home page for help)?

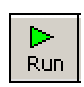
   Petagrams

   c. For how many years is the model set to run (shown on the x-axis of the graph)?

   500 years

3. In the bottom right corner of the model run page, there are two sliders that control the rates of fossil fuels combustion and deforestation. Check to make sure they are both set to zero. If they are not, change them back to zero.
   a. Consider the current simulation you will be running. Why do you think these sliders are set to zero?

   Because we are simulating pre-industrial conditions, so these human activities were not occurring.

4. To run the model under these conditions, click 

   a. Which of the carbon pool(s) remained constant for the entire run time? (If you are uncertain, you can use the data table to see the exact values). Why to you think the pool(s) remained constant?

   The fossil fuel pool is the only pool that remained constant for the entire run time. This is because there are no carbon fluxes into or out of that pool under pre-industrial conditions.

   b. Which of the carbon pools(s) changed over the course of the model run? Did the pool(s) eventually reach equilibrium? How can you tell?

   All the rest of the pools (Atmosphere, Plants, Ocean, and Soils) change over the model run, however they all reach equilibrium before the end of the model run. I can tell because the lines become flat, which means that the influxes equal the outfluxes.

5. Click on 

and use the model results table to fill in the table below. Record model results for 3 of the major carbon pools (the first one has been selected for you).

Table 1. Model Results: Pre-industrial Conditions			
Carbon Pool	Initial Carbon Storage (Pg C)	Carbon Storage at Equilibrium (Pg C)	Year of Equilibrium
Atmosphere	750	728.07	327
Fossil Fuels	7500	7500	0
Oceans	380,000	38,043.23	395

6. Return to the model run page and look at the lower graph. This graph has a series of pages that show the change in carbon fluxes over time (click the upper right corner to examine the different fluxes). Do the carbon fluxes reach an equilibrium rate? Click on the graph and scroll back and forth to find the equilibrium rates (in Pg C/year) for each of the global fluxes:

   Photosynthesis: 116 Pg/yr
   Ocean Uptake: 89 Pg/yr
   Litterfall: 58 Pg/yr
   Plant Respiration: 58 Pg/yr
   Ocean Loss: 90 Pg/yr
   Soil Respiration: 57 Pg/yr

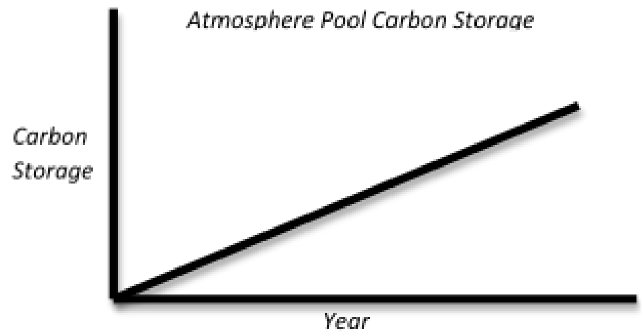
7. Using the appropriate fluxes (refer to the carbon cycle diagram if necessary), calculate the difference between the inflows and outflows to the **atmosphere pool** in the final year of the model run. What does this confirm about the state of the atmosphere pool at the end of the model run?

   90 + 58 +57 – 116 -89 = 0! Confirms that the pool is at equilibrium because model influxes = model outfluxes

Activity 2. Post-industrial conditions: How long will fossil fuels last??

1. In post-industrial conditions, human actions have had a much greater impact on the carbon cycle. We are going to simulate this in the model by changing the rates of deforestation and fossil fuel combustion. Remember that both of these actions release carbon into the atmosphere in the form of carbon dioxide. **Use the sliders to change fossil fuel combustion and deforestation to reflect the 2017 emissions values (use the Global Carbon Cycle Diagram).**

2. Choose a carbon pool and sketch a graph of how you think it will change over time under these new conditions. Don't forget to label your axes!



3. Run the model under the post-industrial conditions.

4. How does your sketch compare to what actually happened? Did any of the pools reach equilibrium in this model run? What do you think caused the patterns you are seeing?

   I was correct that the atmosphere pool would increase over time under post-industrial conditions, however the line isn't completely linear. None of the pools reached equilibrium in this model run. This is probably because the system is no longer balanced. Fossil fuels are being emitted into the atmosphere and there is nothing that counters this flux.

5. Did the fossil fuel reach zero in your model run? Assuming that the model run starts in 2010, record or hypothesize how many years after 2010 it will take to reach zero based on your model run?

   It did not reach zero in this model run, but I think it would, given more time. My hypothesis is that it will reach zero about 1000 years after the year 2010.

6. Now take a look at the graph on the last page of this worksheet (Figure 1) where the model is run out 1500 years. Use this graph to answer the next three questions.

7. After fossil fuels ran out, why do you think there is a sharp decrease in the soil, plant and ocean pools?

   It could be because they are no longer receiving the input of carbon from the fossil fuel pool each year, so the system is beginning to readjust to a new pattern of in- and out- fluxes.

8. The atmosphere pool does not reach equilibrium immediately after the fossil fuel pool runs out. State how long it takes for the atmosphere to reach equilibrium after the fossil fuel pool reaches zero and why you think this occurs.

   It appears to take about 200 years for the atmosphere pool to reach a new equilibrium. I think this happens for the same reason as the plant, soil, and ocean pools – the atmosphere is no longer receiving a flux input from the fossil fuel pool.

9. Do you think that this model run is representative of what will actually happen in the future? Why or why not?

   In some ways it is realistic, because likely the fossil fuel pool will continue to be depleted by burning of fossil fuels and deforestation, which in turn will cause the other pools to increase. However, I think that the rates of deforestation, land use change, and fossil fuel combustion will not remain the same for the next 3000 years, so the *exact patterns will* end up being different than in the model.

10. Scientists predict a range of future climate scenarios based on how greenhouse gas emissions and land use might change in the future. Choose two different scenarios of fossil fuel combustion and deforestation, one **above** (high emission scenario) and one **below** (low emission scenario) the current values. Run the model under each scenario. Hypothesize how the results will differ from the model run under current conditions. Run the model under each scenario, and fill in the table below as you conduct your runs.

Table 2. Carbon cycling under different CO_2 emission scenarios				
Emission Scenario	Human Action	Rate of Carbon Emission (Pg C/yr)	Estimated year fossil fuels will run out*	Estimated time for atmosphere to reach equilibrium*
High	Fossil Fuel Combustion	17	441 **Should be before the yr 1500**	641 **Should be about 200 yrs after their estimate**
	Deforestation	3		
Low	Fossil Fuel Combustion	4	1750 **Should be after the yr 1000**	1950 **Should be about 200 yrs after their estimate**
	Deforestation	.5		

**Answers will differ depending on if students start at the year 0 or a the current year.*

11. What would happen to the atmosphere carbon pool if we completely stopped burning fossil fuels tomorrow?

    The time lag between the year the fossil fuel pool runs out and the year a new atmospheric equilibrium is reached has important implications for future climate change. Even if we completely stopped burning fossil fuels (or emitting carbon in other ways) tomorrow, the atmosphere would not immediately stabilize, but would

<u>Activity 3: Exploring Individual Carbon Pools</u>

In this activity you are going to use the computer model to investigate the carbon storage pool you studied in the pencil and paper modeling exercise.

1. Using the sliders, return the fossil fuel emission rate to 9.3 Pg C/yr, and deforestation rate to 1.0 Pg C/yr (the 2017 values from the carbon cycle diagram).

2. Run the model.

3. How many Pg of carbon are there in your pool after 5 years according to the computer model (Look in the data table to find the exact number)? Does this value match the value you calculated in Worksheet 1? Why or why not?

    After 5 years the plant pool equals 566.73 (numbers may vary slightly if they had trouble dialing in the correct emission rates). This is slightly different than the number I calculated (which was 564.5). I think this is because in the model, as the pools *change, the fluxes will also change, whereas I used the same number for the fluxes in each of my calculations.*

4. Compare your 100-year predictive graph from Worksheet 1 to what actually happened to your carbon pool in the computer model. Is it the same or different? Explain. **Keep in mind that the model graph goes out 500 years!

   In both my predictive graph and the model graph the plant pool is increasing, however, I predicted a linear increase, whereas the model predicts a curve. Also, I predicted that the plant pool would reach 650 Pg C after 100 years, but the model predicts only around 600 Pg C. I think, again, that this is because the other pools and fluxes are also changing, and so there are feedbacks that I didn't consider when looking at the Plant pool in isolation.

5. There are many aspects of the carbon cycle that are not included in this model, which means that the predictions are not very accurate.

6. Return to the model homepage and examine the Model Map [Model Map] and Model Equations [Model Equations] pages to better understand how the model is currently designed.

7. Based on your knowledge of this model and perhaps a short review of other resources about the carbon cycle, suggest one way in which this model could be improved.

   I noticed that in the model there is only one ocean pool instead of separate surface ocean and deep ocean pools. If these were separate pools and there were different flows between them the model might be a little more accurate. The diagram does not show the fluxes between the surface and deep ocean pools, but I could do a literature search for how carbon moves between these two pools to improve the ocean part of the global carbon cycle.

Name: Date:

Student Worksheet 1:
Global Carbon Cycle Paper and Pencil Modeling

1. What is your pool and its current carbon storage in petagrams (Pg)?

2. Using the *Global Carbon Cycle Diagram* and your class table, use addition and subtraction to determine the change in carbon (Pg/yr) of your pool after one year, from the current value. Show your work.

3. Is the change in carbon positive, negative, or no change after one year?

4. Repeat the process four more times. How many petagrams (Pg) of carbon are in your group's pool after 5 years? Show your work.

5. Develop a generalized equation that could be used in a computer model to predict yearly carbon storage in your pool. Remember, generalized equations generally don't use actual numbers, but use variable names to represent the pools and fluxes.

Carbon Storage (Pg C this year) =

6. Draw a predictive graph of how your carbon pool will change over 100 years, based on current flux values. Remember to label your axes!

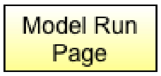
Name: Date:

Student Worksheet 2:
Global Carbon Cycle Computer Modeling

Task

In this exercise, you will run the GLOBE Simple Global Carbon Cycle Model to explore how carbon moves through the Earth system and how human actions influence the global carbon cycle.

Activity 1. Pre-industrial conditions

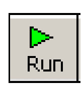
1. Click on 

2. Look at the top graph on the left of the model run page. This graph shows the change in carbon pool size over time.
   a. What are the dependent variables that will be displayed on this graph?

   b. What are the units of these dependent variables (check the diagram on the home page for help)?

   c. For how many years is the model set to run (shown on the x-axis of the graph)?

3. In the bottom right corner of the model run page, there are two sliders that control the rates of fossil fuels combustion and deforestation. Check to make sure they are both set to zero. If they are not, change them back to zero.
   a. Consider the current simulation you will be running. Why do you think these sliders are set to zero?

4. To run the model under these conditions, click 

   a. Which of the carbon pool(s) remained constant for the entire run time? (If you are uncertain, you can use the data table to see the exact values). Why to you think the pool(s) remained constant?

b. Which of the carbon pools(s) changed over the course of the model run? Did the pool(s) eventually reach equilibrium? How can you tell?

5. Click on 

and use the model results table to fill in the table below. Record model results for 3 of the major carbon pools (the first one has been selected for you).

Table 1. Model Results: Pre-industrial Conditions			
Carbon Pool	Initial Carbon Storage (Pg C)	Carbon Storage at Equilibrium (Pg C)	Year of Equilibrium
Atmosphere			

6. Return to the model run page and look at the lower graph. This graph has a series of pages that show the change in carbon fluxes over time (click the lower left corner to examine the different fluxes). Do the carbon fluxes reach an equilibrium rate? Click on the graph and scroll back and forth to find the equilibrium rates (in Pg C/year) for each of the global fluxes:

Photosynthesis:
Plant Respiration:
Ocean Uptake:
Ocean Loss:
Litterfall:
Soil Respiration:

7. Using the appropriate fluxes (refer to the carbon cycle diagram if necessary), calculate the difference between the inflows and outflows to the **atmosphere pool** in the final year of the model run. What does this confirm about the state of the atmosphere pool at the end of the model run?

Activity 2. Post-industrial conditions: How long will fossil fuels last??

1. In post-industrial conditions, human actions have had a much greater impact on the carbon cycle. We are going to simulate this in the model by changing the rates of deforestation and fossil fuel combustion. Remember that both of these actions release carbon into the atmosphere in the form of carbon dioxide. **Use the sliders to change fossil fuel combustion and deforestation to reflect the 2017 emissions values (use the Global Carbon Cycle Diagram).**

2. Choose a carbon pool and sketch a graph of how you think it will change over time under these new conditions. Don't forget to label your axes!

3. Run the model under the post-industrial conditions.

4. How does your sketch compare to what actually happened? Did any of the pools reach equilibrium in this model run? What do you think caused the patterns you are seeing?

5. Did the fossil fuel reach zero in your model run? Assuming that the model run starts in 2010, record or hypothesize how many years after 2010 it will take to reach zero based on your model run?

6. Now take a look at the graph on the last page of this worksheet (Figure 1) where the model is run out 1500 years. Use this graph to answer the next three questions.

    a. After fossil fuels ran out, why do you think there is a sharp decrease in the soil, plant and ocean pools?

b. The atmosphere pool does not reach equilibrium immediately after the fossil fuel pool runs out. State how long it takes for the atmosphere to reach equilibrium after the fossil fuel pool reaches zero and why you think this occurs.

c. Do you think that this model run is representative of what will actually happen in the future? Why or why not?

7. Scientists predict a range of future climate scenarios based on how greenhouse gas emissions and land use might change in the future. Choose two different scenarios of fossil fuel combustion and deforestation, one **above** (high emission scenario) and one **below** (low emission scenario) the current values. Run the model under each scenario. Hypothesize how the results will differ from the model run under current conditions. Run the model under each scenario, and fill in the table below as you conduct your runs.

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Emission Scenario	Human Action	Rate of Carbon Emission (Pg C/yr)	Estimated year fossil fuels will run out	Estimated time for atmosphere to reach equilibrium
High	Fossil Fuel Combustion			
	Deforestation			
Low	Fossil Fuel Combustion			
	Deforestation			

8. What would happen to the atmosphere carbon pool if we completely stopped burning fossil fuels tomorrow?

Activity 3: Exploring Individual Carbon Pools

In this activity you are going to use the computer model to investigate the carbon storage pool you studied in the pencil and paper modeling exercise.

1. Using the sliders, return the fossil fuel emission rate to 9.3 Pg C/yr, and deforestation rate to 1.0 Pg C/yr (the 2017 values from the carbon cycle diagram).

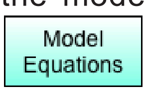
2. Run the model.

3. How many Pg of carbon are there in your pool after 5 years according to the computer model (look in the data table to find the exact number)? Does this value match the value you calculated in Worksheet 1? Why or why not?

4. Compare your 100-year predictive graph from Worksheet 1 to what actually happened to your carbon pool in the computer model. Is it the same or different? Explain. ****Keep in mind that the model graph goes out 500 years!***

5. There are many aspects of the carbon cycle that are not included in this model, which means that the predictions are not very accurate.

Return to the model homepage and examine the Model Map 

and Model Equations 

pages to better understand how the model is currently designed.

6. Based on your knowledge of this model and perhaps a short review of other resources about the carbon cycle, suggest one way in which this model could be improved.

7. How would you gain the information necessary to add this piece of the carbon cycle to the model?

Carbon Cycle Pools and Fluxes

Pool	Flux into (+ Pg C/yr)	Flux out of (- Pg C/yr)
Atmosphere	Burning Fossil Fuels (9.3)	Photosynthesis (120)
	Soil Respiration (58)	Ocean Uptake (92)
	Plant Respiration (59)	
	Volcanoes (0.1)	
	Deforestation and Land Use Change (1.0)	
	Ocean Loss (90)	
Plants	Photosynthesis (120)	Plant Respiration (59)
		Litterfall (59)
		Deforestation and Land Use Change (1.1)
Oceans	Ocean Uptake (92)	Burial to sediment (0.01)
	Rivers (0.8)	Ocean Loss (90)
Soils	Litterfall (59)	Rivers (0.8)
		Soil Respiration (58)
Earth's Crust	Burial to sediment (0.01)	Volcanoes (0.1)

Figure 1. Global Carbon Cycle Model run over 1500 years. Fossil Fuel Combustion was set to 8.4 Pg C/yr and Deforestation was set to 1.1 Pg C/yr to reflect 2010 emissions values.