Getting to Know Global Carbon

Purpose

- To understand that there are many ways to represent the global carbon cycle as a system, and the method we choose depends on our goals.
- To use the global carbon cycle diagram as a facilitation tool for discussing important global carbon cycle concepts.

Overview

This activity provides an introduction to the carbon cycle and, more broadly, to biogeochemical cycling, the greenhouse effect and climate change. During this activity, students compare a carbon cycle diagram they develop using their current knowledge to one developed by scientists. They are asked to investigate the diagrams through a series of questions that help them unpack information about pool and flux sizes, carbon units, residence times, and human/animal roles in the global carbon cycle.

Content Questions

How large are the major pools and fluxes of the global carbon cycle and what units are used to express them?
How big is a Petagram of carbon?
How do you determine residence time?
Why are animals not included as a carbon pool in the global carbon cycle diagram?
What role do humans play in the global carbon cycle?
Are the fluxes into and out of the atmosphere balanced on an annual basis?

Student Outcomes

Students will be able to:

- Create diagrams representing complex systems
- Conceptualize the size of 1 petagram of carbon by comparing it to things they know
- Describe why the global carbon cycle is not in equilibrium

Science Standards

5-8
Science in Personal and Social Perspectives

- Human activities can induce hazards. Such activities can accelerate natural changes.

9-12
Physical Science

- Chemical reactions can take on both very short and very long time scales.

Life Science

- Human beings live within the world's ecosystems and modify them in multiple ways.

Science in Personal and Social Perspectives

- Materials from human societies affect both physical and chemical cycles of the earth.
- Human activities can enhance potential for hazards.

History and Nature of Science

- Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available.
- Usually, changes in science occur as small modifications in extant knowledge.

Time
45 – 60 minutes
Additional time required for optional mini-activities.

Level
Secondary (Middle & High School)

Materials and Tools
- White board, chalk board, large paper or overhead projector & markers/chalk
- Pencil or pen for each student
- Materials for students to draw their own carbon cycle diagram
- *Global Carbon Cycle Diagram*- student copies or projected image
- Optional mini-activities: *How Big is a Petagram?, Turnover Rate & Residence Time, Magnitude of Human Presence*

Preparation
- Review the mini-activities for grade level appropriateness.
- Make any necessary copies for selected activities.
- Write essential, unit, and content questions somewhere visible in the classroom.

Pre-requisites
Basic knowledge of systems concepts and terms – pools and fluxes, box and arrow diagrams. (*Paperclip Factory Analogy* and/or *Carbon Cycle Adventure Story*). Basic knowledge of the carbon cycle and its components (pools & fluxes).

Background
See *Carbon Cycle Teacher Background*.

What To Do and How To Do It

<table>
<tr><td rowspan="2">ENGAGE</td><td>Student Grouping: Whole Class</td><td>Time: 10 minutes</td></tr>
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- *Note: Students may have completed this engagement exercise if they participated in the *Carbon Cycle Adventure Story* or the *Carbon Travels Game.* If so, move on to Explore.
- Tell students that you want to begin teaching about carbon today, but you can't seem to find it. Ask students if anyone saw carbon today on their way into class.
  - This will help start generating ideas about where carbon is found and how prevalent it is in the world around us.
  - Record the ideas of where carbon is found on the board.
- Solicit additional ideas about the carbon cycle. What is carbon? Where is it found? How does carbon move from one place to another (the processes)? What forms does it take (C, CO_2, CH_4, $CaCO_3$, glucose)?
- Differentially highlight/circle the pools and fluxes.

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<tr><td rowspan="2">EXPLORE</td><td>Student Grouping: Small groups</td><td>Time: 30 minutes</td></tr>
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- Student Directions: Part 1, students organize the carbon cycle pools and fluxes into major categories and create their own version of a simplified global carbon cycle diagram.
- When students have completed their diagram, they will share it with the class including a rationale for why it looks as it does. They should also share ideas that were not included in the final draft.
- Provide groups with the *Global Carbon Cycle Diagram* (Projector display OR paper copies.)
- Students compare their own diagram to the *Global Carbon Cycle Diagram* and answer the thought questions provided in the Student Directions: Part 2.

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<tr><td rowspan="2">EXPLAIN</td><td>Student Grouping: Whole Class</td><td>Time: 15 minutes</td></tr>
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- Discuss Part 2 questions. The answer key directs you to several additional mini-activities/math extensions that may help clarify student's understanding of key concepts.

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<tr><td rowspan="2">ELABORATE/ INVESTIGATE</td><td>Student Grouping: Varies</td><td>Time: Varies</td></tr>
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- Perform mini-activities to enhance carbon cycle concepts:
  - *How Big is a Petagram?*
  - *Turnover Rate & Residence Time*
  - *Magnitude of Human Presence*
  - Students become part of the global carbon cycle by participating in the adapted *Carbon Travels Game*.
  - View the *Global Carbon Cycle Models* as a class. Discuss how the model can look at one point in time, the same as the diagram, but also allows us to consider past and future scenarios.

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<tr><td rowspan="2">EVALUATE/ WRAP-UP</td><td>Student Grouping: Individual</td><td>Time: 15 minutes</td></tr>
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- Discuss with students how their knowledge of the carbon cycle will help them better understand their world.
- Outline with students where their study of the carbon cycle will take them next.
  - The role of vegetation in the global carbon cycle
  - Contributes to global warming and climate change
  - Other topics at both small and large scales

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Assessment

- Students bring in a carbon/carbon cycle related news article to share with the class.
  - Students prepare a 1-paragraph summary of the article and a 1paragraph justification of its relationship to carbon or the carbon cycle.

Adaptations

- For students with less carbon cycle experience or who struggle to stay focused discuss Part 2 questions as a class, providing additional verbal prompts to help students dig deeper into the carbon cycle.

Extensions

- Transition into a discussion about the Keeling Curve, to show how we know that CO_2 in the atmosphere has been increasing during recent history. Relate petagrams of carbon to parts per million of carbon dioxide (chemistry). Students may download the most recent Mauna Loa data from http://www.esrl.noaa.gov/gmd/ccgg/trends/ - mlo_data and use it to make predictions about how atmospheric carbon dioxide concentrations might change over the next year and investigate the reasons for the annual pattern of higher and lower CO_2 values.
- Further expand into discussions about the geological trends in atmospheric CO_2 concentrations.
- Search for peer-reviewed research articles that discuss the current state of specific carbon cycle pools and fluxes.
- Explore other available CO_2 data. (CDIAC)
- Use the *GLOBE Global Carbon Cycle Computer Models*
- Participate in other GLOBE Carbon Cycle activities that focus on the terrestrial vegetation components of the global carbon cycle (*Plant-a-Plant Experiments, Field Measurements, Biomass Accumulation Model*).

Resources

GLOBE Scientists' Blog: http://www.globe.gov/fsl/scientistsblog/
Earth System Research Laboratory, Global Monitoring Division – Trends in Atmospheric Carbon Dioxide: http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo_data
Global Carbon Project – Carbon Budget: http://www.globalcarbonproject.org/carbonbudget/
Intergovernmental Panel on Climate Change: http://www.ipcc.ch/
Carbon Dioxide Information Analysis Center (CDIAC): http://cdiac.ornl.gov/

National Carbon Research Programs:
United States Carbon Cycle Science Program: http://www.carboncyclescience.gov/
CarboEurope: http://www.carboeurope.org/
CarboAfrica: http://www.carboafrica.net
CarboSchools: http://www.carboeurope.org/education/
Australia – CSIRO (Explore): http://www.csiro.au/csiro/channel/_ca_dch2t.html

Teacher Answers: Getting to Know Global Carbon

Part 2. Examine a Global Carbon Cycle Diagram developed by Scientists

1. View the *Global Carbon Cycle Diagram*.
2. Observe and compare the carbon cycle diagram created by scientists with your own diagram. Use the following questions as a guide for your observations. Discuss the questions with your neighbors and record your ideas.

   The answers provided below are to assist you in discussions with your students, and provide you with some leads to additional information and activities that will help clarify specific topics.

   a. What are the similarities and differences between the two diagrams?

      Number and categories of pools and fluxes, the way pools and fluxes were represented, the inclusion of numbers or units, etc.

   b. Are there any pools that you included that were not in the scientists' diagram? Why do you think they were not included?

      Students could have many answers here, but it is very likely that students might include humans or other animals as a pool. Including them is by no means wrong, but animals and humans are often omitted for simplicity because their contribution to carbon storage at the global scale is very small. You may choose to do the mini-activity: ***Magnitude of Human Presence.*** *In this activity, students calculate global human carbon storage and compare it to carbon storage in trees at both small and large scales. Note that despite their small pool size, humans and other animals can be very important in regulating carbon fluxes.*

   c. What are the units of carbon pools in the scientists' diagram? How big is that unit?

      Carbon storage in this diagram is expressed in Petagrams (Pg). A Pg is 10^15g (1,000,000,000,000,000), which is equivalent to 2.2 trillion pounds. Because this is such a large number to comprehend you may choose to do the mini-activity: ***How big is a Petagram?*** *In this activity, students walk through an example to visualize how much space 1 Pg, by weight, would take up.*

   d. Why do the units of carbon fluxes include time?

      A flux of any material is the transfer of that material from one pool to another over a given amount of time. This is also known as a rate. If we know that a pint of water is delivered to a potted plant, but we don't know whether it takes place over *a period of 5 seconds or 10 years, our ability to predict the fate of the plant is limited.*

Within the carbon cycle, knowing the rate at which carbon moves between pools is central to our understanding of the system and our ability to predict whether a given pool will be increasing or decreasing in size. The rate at which carbon is transferred is an important concept in understanding climate change. If the rate of carbon emitted to the atmosphere is greater than the rate at which carbon is removed through processes such as photosynthesis and ocean uptake, the system is out of equilibrium and the atmosphere pool will increase over time. It is exactly this imbalance that has caused the present build up of carbon dioxide in the atmosphere and the associated increases in mean global temperature.

e. How do the numbers between different pools and fluxes in the diagram compare?

Some pools are very large (Earth's crust, ocean, fossil fuels), while others are significantly smaller (atmosphere, soils, plants). The same is true for fluxes. But note that the largest fluxes are not necessarily associated with the largest pools. In fact, some of the largest pools are relatively inactive and represent a small fraction of the total amount of carbon that cycles globally. In contrast, some of the smaller pools are quite active and represent very large flow rates. Note that the uptake of carbon by photosynthesis on an annual basis (120 Pg/yr) is roughly 20% of the amount of carbon plants themselves store (560 Pg).

*As in the above example for plants, examining the relationship between flow rate and pool size can tell us a great deal about how a particular system component behaves. This is central to the concepts of residence time and turnover rate. For more information see the **Modeling Introduction**. You may also choose to have students perform the mini-activity: **Turnover Rate & Residence Time.***

f. Are fluxes into and out of the atmosphere balanced? Why or why not?

*Students should observe that the natural fluxes into and out of the atmosphere are approximately balanced while the non-natural (human induced/anthropogenic) fluxes are not. Even though the flow of carbon to the atmosphere from fossil fuel combustion is small relative to other fluxes, there are no counteracting flows that move carbon in the opposite direction. In theory, some new fossil fuel carbon may be created, but only through geological processes that are exceedingly slow. Here, you may want to consider a discussion on the impact of human presence vs. human action. Humans just by living and breathing have very little impact on the global carbon cycle, as can be see in the mini-activity: **Magnitude of Human Presence**. However, as the diagram shows, it is human actions that play a large role, and ultimately have a significant impact.*

Name: Date:

Student Directions: Getting to Know Global Carbon

Part 1. Create a Global Carbon Cycle Diagram

1. Consider the class list of carbon cycle pools and fluxes.
2. Organize the carbon cycle pools and fluxes into major categories.
   a. For example: Driving cars, heating homes and industrial production could all be grouped into a category of flux called burning fossil fuels.
3. Using your new categories of pools and fluxes, create a simplified global carbon cycle diagram. You may be creative in your presentation (pictures, diagrams, tables, etc.), but remember that boxes typically represent pools and arrows represent fluxes. Be sure to clearly label all pools and fluxes.

Part 2. Examine a Global Carbon Cycle Diagram developed by Scientists

1. View the *Global Carbon Cycle Diagram*.
2. Observe and compare the scientific diagram with your own. Use the following questions as a guide for your observations. Discuss the following questions with your neighbors. Record your ideas in your science notebook.
   a. What are the similarities and differences between the two diagrams?
   b. Are there any pools that you included that were not in the scientific diagram? Do you have any ideas why they were not included?
   c. What are the units of carbon pools in this diagram? How big is that unit?
   d. Why are carbon fluxes per unit of time?
   e. How do the numbers between different pools and fluxes in the diagram compare?
   f. Are fluxes into and out of the atmosphere balanced? Why or why not?