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 scientist-designed 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 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 cycle.

Student Outcomes

Students will be able to:

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

Questions

Content

- How large are the pools and fluxes of the global carbon cycle?
- How big is a Petagram of carbon?
- How do you determine residence time?
- Why aren't animals included as a pool?
- What role do humans play in the global carbon cycle?
- Is the global cycle in balance?

Science Concepts

Grades 9-12

Physical Science

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

Life Science

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

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.

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

- *Disciplinary Core Ideas*
  - Gr.6-8: LS2.B, ESS2.A, ESS3.C, ESS3.A, ESS3.D
  - Gr.9-12: LS2.B, ESS2.A, ESS2.E, ESS3.D, PS3.B, PS3.D, LS2.C, ESS2.D, ESS3.A, ESS3.C
- *Science and Engineering Practices*
  - Asking Questions
  - Developing and using models
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Obtaining, Evaluating, and Communicating Information
- *Crosscutting Concepts:*
  - Patterns
  - Scale, Proportion, and Quantity
  - Systems and system models
  - Energy and matter
  - Stability and Change

Time/Frequency

70-100 minutes

Level

Secondary (Middle & High School)

Materials and Tools

- White board, chalk board, large paper or overhead projector & markers/chalk
- Materials for students to draw their own carbon cycle diagram
- *Global Carbon Cycle Diagram*- student

Prerequisites

- Systems concepts and terms – pools/fluxes, box/arrow diagrams. (*Paperclip Simulation* and/or *Adventure Story*).

- Basic knowledge of the carbon cycle and its components (pools & fluxes) (*Adventure Story* and/or *Travels Game*).

Preparation

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

Background

To learn more about the carbon cycle see the Carbon Cycle eTrainings and Introduction to the Global Carbon Cycle on the GLOBE Carbon Cycle webpage under Resources —Teacher Preparation.

What To Do and How To Do It

ENGAGE	**Grouping:** Small Groups	**Time:** 25 Minutes

Part 1a: Brainstorm a class list of global carbon cycle pools and fluxes:

- Organize the carbon cycle pools and fluxes from the class list into major categories.
  - For example: Driving cars, heating homes and industrial production could all be grouped into a "flux" category called burning fossil fuels.
- Divide students into small groups.
- Using the new categories of pools and fluxes, small groups create a simplified global carbon cycle diagram. They may be creative in presentation (pictures, diagrams, tables, etc.), but remind them that boxes typically represent pools and arrows represent fluxes.
- (Optional) Students share their diagram 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.

Part 1b: (Optional) Provide each small group of students with a shuffled set of Pool & Flux Cards (attached below):

- Ask students to organized the cards to the best of their ability, grouping each carbon pool or flux with it's corresponding carbon value and laying them out in a basic carbon cycle on the table

EXPLORE	**Grouping:** Small Groups	**Time:** 30 Minutes

- Provide groups with the *Global Carbon Cycle Diagram* (Projector display OR paper copies.)
- Students compare their own diagram and the organization of their *Pool & Flux Cards* to the *Global Carbon Cycle Diagram* and answer the thought questions provided in the Student Directions: Part 2.

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

- 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.

ELABORATE	**Grouping:** Varies	**Time:** Varies

- Perform mini-activities to enhance carbon cycle concepts:
  - *How big is a Petagram?*
  - *Turnover Rate & Residence Time*
  - *Magnitude of Human Presence*

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

- 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. For example:
  - The role of vegetation in the global carbon cycle
  - Contributions to global warming and climate change
  - Other topics at both small and large scales
- Assign students the assessment exercise in which they locate a current article concerning carbon and summarize its importance in relation to carbon science. Provide time to discuss as a class or in small groups the articles that students uncovered.

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.

Extensions

- Student Worksheet 1: *Global Carbon Cycle Paper and Pencil Modeling* found in the *Simple Global Carbon Cycle Model* activity to continue discussions of the change in carbon pools over time
- Use the *Global Carbon Cycle Computer Models* or simply view them as a class and make a few model runs together so students get the basic idea.
- 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 the **NOAA Trends in Atmospheric Carbon Dioxide website** (see Resources) and use it to make predictions about how atmospheric carbon dioxide concentrations might change over the next year. Then investigate the reasons for the annual pattern of higher and lower CO2 values. (Check out the EcoSchools USA Lesson “Why All the Wiggling on the Way Up?”)
- Expand into discussions of geologic 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)
- 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

- NOAA Earth System Research Laboratory, Global Monitoring Division – Trends in Atmospheric Carbon Dioxide: www.esrl.noaa.gov/gmd/ccgg/trends
- Global Carbon Project – Carbon Budget: www.globalcarbonproject.org/carbonbudget
- Intergovernmental Panel on Climate Change: www.ipcc.ch
- Carbon Dioxide Information Analysis Center (CDIAC)- cdicc.ornl.gov
- Powers of Ten Film

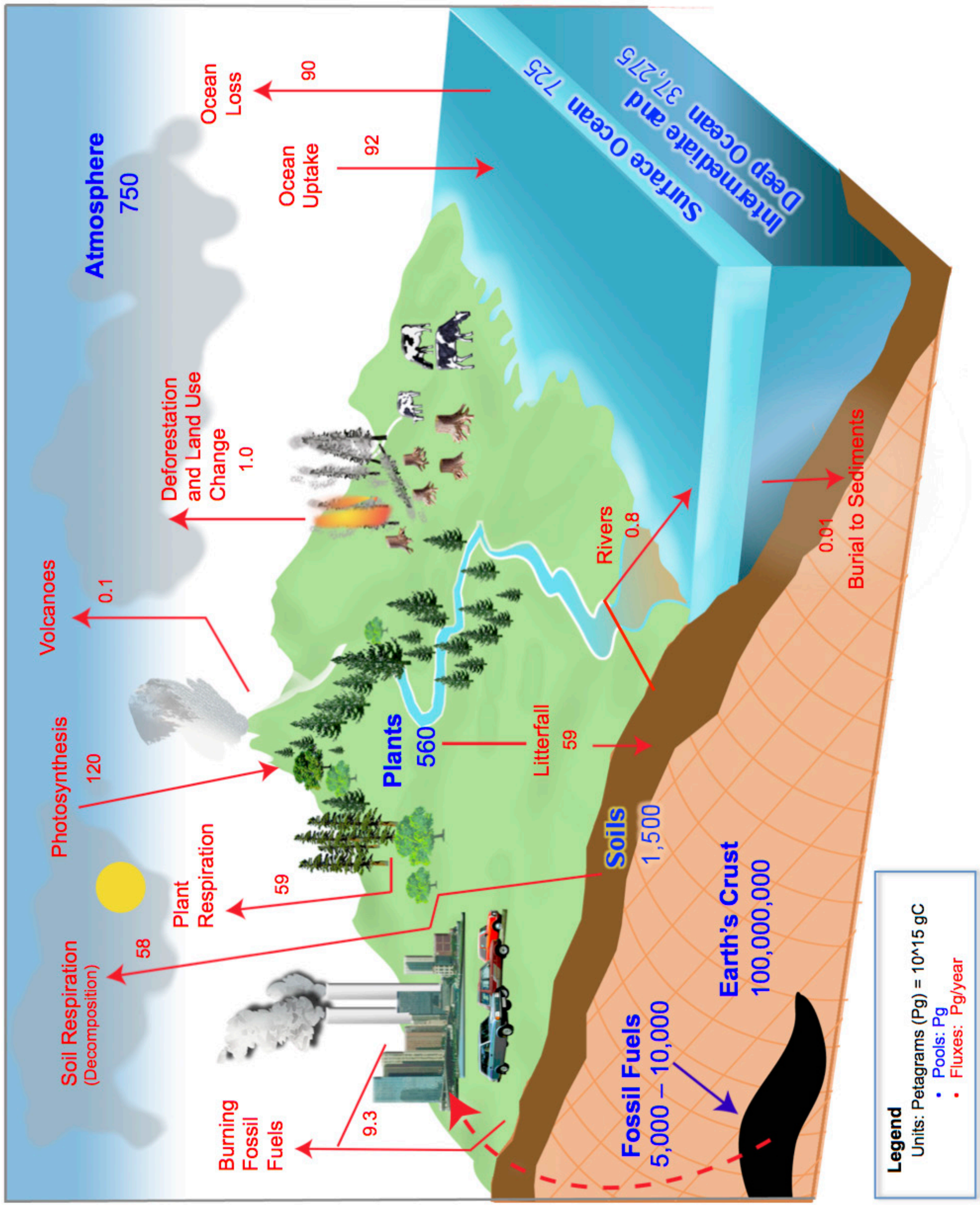

Diagram created by a collabotation between UNH, Charles University, and the GLOBE Porgram

TEACHER VERSION

(Suggested student responses included)

Getting to Know Global Carbon

Part 1: Create a global carbon cycle diagram

1. Brainstorm a class list of global carbon cycle pools and fluxes.
2. Organize the carbon cycle pools and fluxes from the class list into major categories.
   a. For example: Driving cars, heating homes and industrial production could all be grouped into a “flux” category 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.

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 units of carbon pools in this 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.

b. What are the units of carbon fluxes? Why are carbon fluxes per unit of time? Fluxes are in Pg/year. 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.

c. Are there any pools that you included that were not in the scientific diagram? If yes, then why do you think carbon scientists excluded these pools?

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: Human Carbon Pool. 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' actions can be very important in regulating carbon fluxes.

d. How do the values among different pools and fluxes in the diagram compare? Do you have any ideas why they might be similar/different?

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 Systems & Modeling Introduction. You may also choose to have students perform the mini-activity: Turnover Rate & Residence Time.

e. Are fluxes into and out of the atmosphere balanced on an annual basis? 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: Human Carbon Pool. However, as the diagram shows, it is human actions that play a large role, and ultimately have a significant impact.

Name: Date:

Getting to Know Global Carbon

Part 1: Create a global carbon cycle diagram

1. Brainstorm a class list of global carbon cycle pools and fluxes.
2. Organize the carbon cycle pools and fluxes from the class list into major categories.
   a. For example: Driving cars, heating homes and industrial production could all be grouped into a “flux” category 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 units of carbon pools in this diagram? How big is that unit?
   b. What are the units of carbon fluxes? Why are carbon fluxes per unit of time?
   c. Are there any pools that you included that were not in the scientific diagram? If yes, then why do you think carbon scientists excluded these pools?
   d. How do the values among different pools and fluxes in the diagram compare? Do you have any ideas why they might be similar/different?
   e. Are fluxes into and out of the atmosphere balanced on an annual basis? Why or why not?

Part 3: Participate in the mini-activities to enhance your understanding of carbon cycling

1. *How Big is a Petagram?*
2. *Human Carbon Pool*
3. *Turnover Rate & Residence Time*

Getting to Know Global Carbon
Pool & Flux Cards

Atmosphere	750 Pg
Plants	560 Pg
Soils	1,500 Pg
Earth's Crust	100,000,000 Pg
Fossil Fuels	5,000-10,000 Pg

Surface Ocean	725 Pg
Intermediate and Deep Ocean	37,275 Pg
Photosynthesis	120 Pg/yr
Soil Respiration (Decomposition)	58 Pg/yr
Plant Respiration	59 Pg/yr
Litterfall	59 Pg/yr

Rivers	0.8 Pg/yr
Ocean Loss	90 Pg/yr
Ocean Uptake	92 Pg/yr
Volcanoes	0.1 Pg/yr
Burial to Ocean Sediments	0.01 Pg/yr
Burning Fossil Fuels	9.3 Pg/yr

Deforestation and Land Use Change	1.0 Pg/yr