A Poker Chip Model of Global Carbon Pools and Fluxes

Overview:

This two-day activity helps students visualize and model a commonly published diagram of global carbon pools and fluxes. Students create a scaled 3-D visual of global carbon pools and net fluxes between pools with anthropogenic influences. The relative sizes of the pools can be modeled with stacks of poker chips, rolled columns of printer paper or similar. The fluxes can be represented by bingo chips, pennies or similar. Supplemental discussion questions guide students through considering the forms of carbon in pools, key carbon transforming processes associated with fluxes and the implications for climate change.

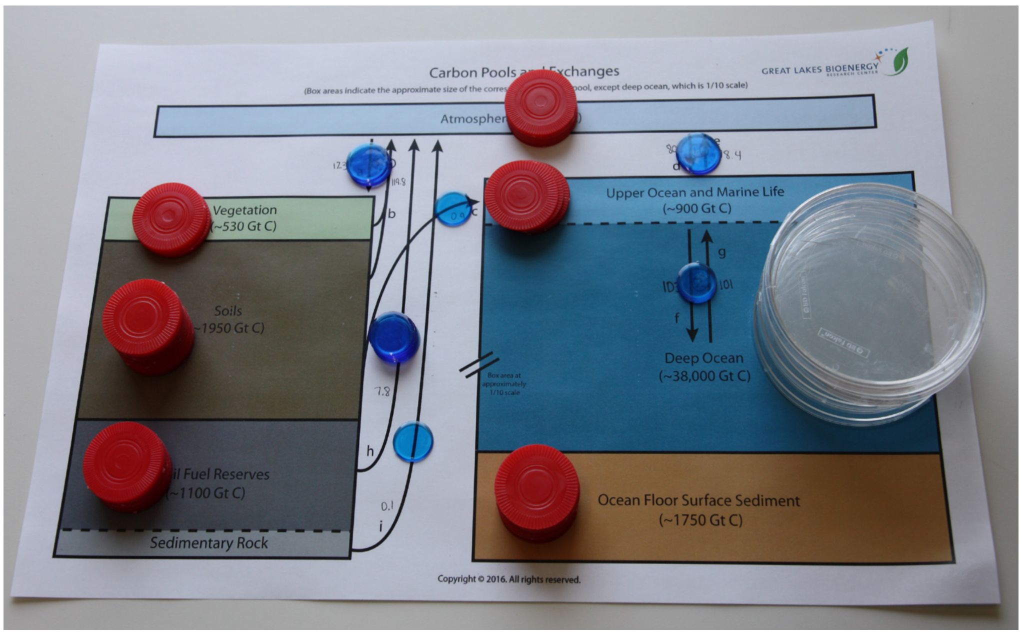

Figure 1: Version 1 models carbon fluxes with poker chips and petri dishes.

Learning objectives:

Students will…

1. Model the relative sizes of global carbon pools and net fluxes between pools
2. Identify the carbon transforming process associated with key global carbon fluxes (i.e. photosynthesis, respiration, combustion)
3. Identify the primary forms of carbon in global pools
4. Model the effects of different climate change mitigation strategies on the global carbon cycle

Table 1: Recommended supplies. Included are the supplies needed to construct two different variations to model the global carbon cycle. Quantities are given per student group sharing a carbon reserves diagram. Instructors can adapt materials used.

Component	Version 1: Supplies for poker chip version (per group)	Version 2: Supplies for paper version (per group)
Deep ocean carbon pool	*4 CDs, DVDs, or petri dishes per team or 2 sheets of paper*	*4 sheets of 8.5 x 11 paper or similar*
Other carbon pools	*100 poker chips*	*1 sheet of 8.5 x 11 paper or similar*
Carbon fluxes	*20 bingo chips, pennies or similar*	*20 bingo chips, pennies or similar*
Other	*1 bag to hold chips, carbon reserves diagram*	*Ruler, tape and scissors, carbon reserves diagram*

Directions for Instructor:

Preparation:

- Have students work in teams of 2-4.
- Print out one copy of the carbon reserves diagram for each group of students. Included in this activity package are versions of the diagram that can be printed either on one 11 x 17 paper or two 8.5 x 11 sheets that can be taped or stapled together.
- Provide each group with the materials to construct the model. See the table above for suggested supplies for two versions of the model.
- Prepare printouts (page 8) or write on board the flux rates for each label arrow on diagram.

Running the activity and guiding discussion:

The instructions below correspond to the student worksheet in the activity package. The instructor should adapt the activity and the questions covered to align with desired learning outcomes and student prior knowledge of the carbon cycle. There are multiple options for using the worksheet. You can have students write their responses to the discussion questions ahead of time, preparing them for discussion. Alternatively you can omit the discussion questions from the worksheet and use them solely as oral discussion questions. Student responses to question 1 can be scaffolded with the optional word bank. Extension questions are provided to guide students' further use of their models.

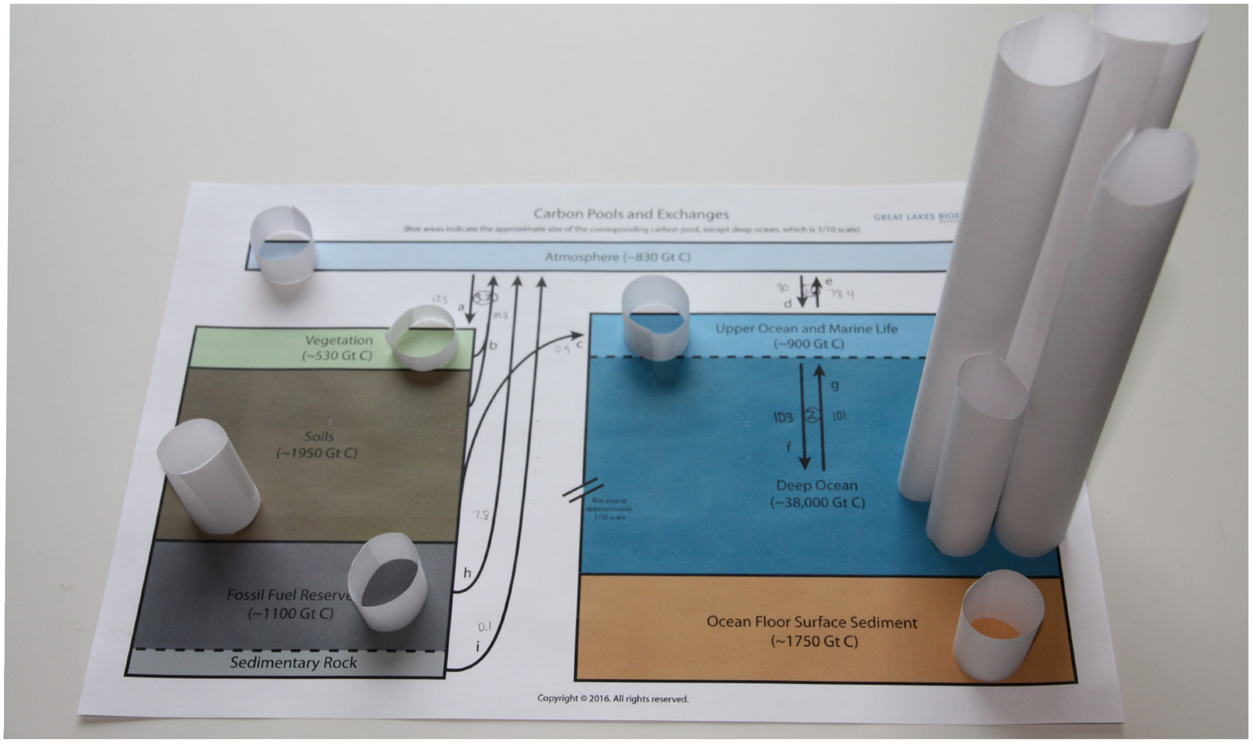

Figure 2: Version 2 models carbon fluxes with rolled paper columns and bingo chips.

Day 1

1. Discuss the concept of carbon pools or reserves: These are places that store carbon in different forms. For example, the atmosphere is a reserve primarily for carbon dioxide. The fossil fuel pool contains hydrocarbons, such as coal and natural gas. The atmospheric pool contains gases, primarily carbon dioxide (CO_2).
2. Discuss the forms of carbon in global pools: Review and discuss the primary forms of carbon in each of the global pools. Depending on time and objectives, students can complete the table in the accompanying worksheet. If possible, help students connect the macroscopic forms of carbon (i.e. plants) with the associated atomic molecular form (i.e. cellulose or fixed carbon).
3. Introduce the Gigatonne (Gt) unit: Global carbon pools and fluxes are huge and are typically expressed as Gigatonnes (Gt). A gigatonne is one billion metric tons! A metric ton (also called a tonne) is 1000 kilograms or approx. 2,200 pounds. For reference, a large bull or a small car might weight 1,000 kg. So a Gt is a approximately the mass of a billion large bulls or small cars! To help students wrap their heads around the Gt unit, you can use the accompanying presentation slides and spreadsheet, which express Gt in terms of the weight of familiar objects such as people, cows, cars, buildings and lakes.

4. <u>Model the carbon pool sizes</u>: To demonstrate the amount of carbon stored in each pool to scale, ask students to either stack poker chips or construct 3-D graphs with rolls or paper representing the amount of carbon in each location. Provide students with the basic information for each version:
   - *Poker chip version*: Each poker chip represents 100 gigatonnes (Gt) of carbon. Have them round to the nearest hundred. For example, atmosphere has 830 Gt, so stack eight poker chips in that box. Each CD/DVD or petri dish represents 10,000 Gt of carbon to be used for the deep ocean pool (See fig. 1 for example).
   - *Paper columns version*: One inch of rolled paper represents 1000 Gt. If possible, have students do the calculations for how high each roll should be. For example, fossil fuels are 1,100 Gt. At 1,100 Gt / inch, that would be 1,100/1,000 or 1.1 inches. For ease of measurement, have students round to the nearest ¼ in. See the appendix for the calculated heights for each pool. Students cut, roll and tape paper tubes to the appropriate length and then place them on the corresponding pool. See Figure 2.
5. <u>Discuss models in small groups and as a class</u>: Ask students to discuss what they see. What surprises them about the amount of carbon stored in each location? Is the drawing to scale? Where is most of the carbon stored? Why might this be the case?
6. <u>Introduce carbon fluxes and review carbon transforming processes</u>: The arrows on the diagram represent movement of carbon from one sink to another. Discuss in small groups how each flux occurs (photosynthesis, cellular respiration, combustion diffusion, erosion etc). If possible, have students label the process associated with each flux next to the arrow. Have students identify which fluxes are associated with human activity in any way (for example, human agriculture affects the rate of carbon dioxide release from the soil).
7. <u>Label fluxes</u>: Provide each group with a copy of the carbon flux rates. The numbers are in gigatonnes per year. Have them write the numbers onto the page next to the corresponding arrow.
8. <u>Discuss flux rates</u>: What trends do they see in these fluxes? Are the numbers between pools balanced? How does the scale of movement compare with the size of the pools? Note: these numbers include fluxes caused by human activity.

Day 2

9. <u>Calculate and model dynamic equilibrium and net flux rates</u>: Some pairs of pools have arrows in both directions connecting them, meaning that carbon moves both directions between those pools. If exactly the same amount of carbon moves both directions between two pools, the fluxes have no effect on the size of the pools. There is no NEX FLUX.

Have students model net fluxes by looking first at the fluxes between the atmosphere and the ocean. In the first, most accurate model, have students use the bingo chips, pennies, or paper columns to indicate the yearly flux between these two pools (1 poker chip (100 gigatonne) + 2 pennies (1 gigatonne each) move from the atmosphere to the oceans and 1 poker chip moves in the opposite direction). Then have students simplify the model by indicating only the size of the net flux (2 pennies). Have them complete the model by calculating and then using chips or pennies to represent the net fluxes between each pair of connected pools.

10. Discuss net flux rates: Look at the net flux rates between vegetation and atmosphere, atmosphere and ocean, upper and deep ocean. Where is the carbon moving? What does the net flux tell you about the balance between carbon transforming processes? For example, the positive net flux from atmosphere to vegetation indicates that each year more carbon is fixed in plants through photosynthesis than is released through respiration and combustion.

11. Calculate net flux into atmosphere: Carbon in the atmosphere (CO_2 and CH_4) is particularly important because it contributes to the greenhouse effect. Increased level of these gases lead to global warming. How does the number of fluxes into the atmosphere (3) compare to the number leaving (2)? Why is this (i.e. there is no flux from atmosphere to fossil fuels)? Give three examples of human activity associated with the flux from fossil fuels or sedimentary rock to the atmosphere.

12. Discuss implications for climate change: How much additional carbon is added to the atmosphere every year? This requires subtracting all of the fluxes leaving the atmosphere (a, d) from those entering (b, e, h, i). Which arrow and what process is moving carbon into the atmosphere? What is the long-term effect of the net flux of carbon?

13. Brainstorm and model mitigation strategies: In small groups and/or as a whole class, have students calculate how much fossil fuel use would have to be reduced to get a decline in atmospheric carbon dioxide levels (Q13 on worksheet). Students can do this by calculating a fossil fuel use value that results in a 0 net flux or they can experiment with different size cuts. Surprisingly it takes almost a 50% cut before carbon dioxide levels would start to fall. Because they conflate flux size and net flux size, many students will think that any reduction in fossil fuel use will lead to a decrease in atmospheric carbon dioxide levels. After students complete question 13, have them brainstorm potential strategies for reducing the net flux of carbon into the atmosphere (Q14 on worksheet). They can generate ideas by considering each flux into or out of the atmosphere and proposing ways to increase out fluxes and minimize influxes. They can combine this with research on mitigation plans that are being planned such as carbon sequestration and use of biofuels. Have students move the bingo chips to model how that strategy would change how carbon moves between pools. Discuss strategies and

model variations as a class. For example, implementing fuel efficiency standards would reduce the rate of fossil fuel combustion. To model this, students would move a bingo chip from net flux "h" back into the fossil fuels pool, i.e. the carbon is left in the ground.

Assessment:

Some people argue that because the flux of carbon dioxide into the atmosphere from fossil fuels is small (7.8 gigatonnes/yr) compared to the influxes from oceans (78.4 gigatonnes) and vegetation (119.8 gigatonnes/yr), we don't have to worry about our use of fossil fuels. Do you agree with this position? Explain your reasoning.

Appendix:

Standards

Next Generation Science Standards (2013)

Performance Expectations

Middle School:

- **MS-LS2-3**. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

High School:

- **HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- **HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **HS-ESS3-5.** Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
- **HS-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Standards (continued)

Scientific and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models Using mathematics and computational thinking Constructing explanations and designing solutions	**LS2**: Ecosystems: Interactions, energy, and dynamics **ESS2**: Earth's systems **ESS3**: Earth and human activity	Cause and effect: Mechanism and explanation Scale, proportion, and quantity Systems and systems models Energy and matter: Flows, cycles, and conservation

Write the flux rate next to the corresponding arrow on the diagram.

Carbon flux rates in Gt/yr (from IPCC report 2013)

a	=	123
b	=	119.8
c	=	0.9
d	=	80
e	=	78.4
f	=	103
g	=	101
h	=	7.8
i	=	0.1

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Reference: *IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment. Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*