**Climate and the Carbon Cycle**

**Suggested Workshop Outline and Leader Notes**

There are five key science ideas addressed in the module that connect the Carbon Cycle with Earth’s climate.

* How do the carbon cycle, climate and the environment influence each other?
* How does carbon move through the Geosphere and the Biosphere, in what forms and at what time and spatial scales?
* How is the carbon cycle interconnected with other biochemical cycles such as the nitrogen cycle?
* How does the carbon cycle regulate the temperature of Earth's atmosphere?

• Will carbon dioxide continue to rise, and if so, what can we do about it?

Because of time limitations, not all of these key ideas are addressed in this workshop.

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| Section | Detailed Notes |
| **Workshop Introduction** [15 minutes] | **CLIMATE AND THE CARBON CYCLE****Have Slide #1 of the PowerPoint projected as participants arrive.** While Slide #1 is showing:• Welcome attendees; thank them for attending. • Introduce workshop leaders• Give a brief overview of the schedule• Point out other logistics (bathrooms; location of water or refreshments; etc.) • Distribute an agenda and ask if there are questions about the schedule before you start.• Explain that you will start with some slides to orient them to the EarthLabs project and to an EarthLabs general climate science resource before starting work on the Carbon Cycle module itself. • Show PowerPoint slides 2-14 of *Climate and the Carbon Cycle.pptx* Suggested comments are included in the Notes section at the bottom of each slide. • Be sure to highlight the workshop goals (Slide #9).• At slide #11 (shows names of the seven Carbon Cycle sections or Labs ) ask if there are any questions about what participants have seen in the introduction.• Show Slide #13, with the EarthLabs url’s, and ask teachers to go first to the Educator web site and open the **Climate Series Intro**. • Move on to Slide #14, which is the same image as Slide #1, and then MINIMIZE but do not close the PowerPoint application: you will return to the last two slides, #15 and #16, shortly after starting the Carbon Cycle module.  |
| **Climate Series Introduction**[30 minutes] | **CLIMATE SERIES INTRODUCTION**• **Switch from projecting the PowerPoint to projecting the EarthLabs module.** Project the EarthLabs Home Page for the Educator’s web site and open the Climate Series Intro web page. • Point out the 4 main sections of the Climate Series intro (Brief descriptions of the 4 climate modules; In the Classroom; Science Notes; and Keeping Up to Date• Mention that the Introduction page just holds brief descriptions of the 4 climate modules. Then go to the section titled In the Classroom. Have participants do the same on their own computers.**In the Classroom**• Point out the link for “Student Prerequisite Knowledge: The Earth System”, and ask participants to share their prior understanding of “the Earth system”. What does that phrase mean to them?• Distribute: printed copies of Earth System: The Basics, and give participants time to read the document (5 – 6 minutes). • Discuss the Earth System reading: What did participants learn? Reactions, comments, questions? Having a general overview of the Earth system is important to understanding all of the EarthLabs modules, and in particular the Climate Series.• Open the Crosscutting Themes link and briefly summarize the four major crosscutting themes. (The Earth System has already been covered.) • Highlight one additional item on the list: Student Access to Computers. The module can certainly be adapted to be taught in a one-computer classroom, although it is preferable that all students have their own computers.  • Emphasize that teachers should read the rest of the In the Classroom material on their own as they prepare to teach the module.**Science Notes**• Explain that reading and discussing the science notes could be a workshop in itself, and so there is not time to go through all of them now, but prior to starting a climate module, teachers should take the time to read through them to add to their own background knowledge about the complex topic of climate and associated representations.• Highlight one element of the Science Notes: Under Greenhouse Gases and Climate, scroll down to the Scott Denning video and show it to the class. (6 minutes) • Give participants two minutes to discuss the video with a partner. Next, ask for responses to the video. Comments? Questions? Be prepared to address questions. **Keeping Up to Date**• Just show teachers that this resource exists, and mention that the web sites listed are kept up to date with current information about climate science and climate change.  |
| **Lab 1 Intro and 1A** [15 minutes] | • Still projecting your computer screen for the class, navigate to Climate and the Carbon Cycle on the EarthLabs **Educator** web site. Point out the structure (see below), which is common to all Earthlabs module home pages.  Why teach about climate and the Carbon Cycle? Why use this set of lessons? Key questions Before starting this unit Assessments Resources• Ask participants to respond to the first question, without reading the text. **Why study Climate and the Carbon Cycle?** What ideas do they already have about the significance of the Carbon Cycle and its relationship to weather and climate? Why is it important? Then review the highlights of the first paragraph: Why teach about Climate and the Carbon Cycle.• Show the **Lab Overview** page on the Educator site, then go to Lab 1 to highlight the Headings there. It is the same structure for every Lab. Highlight the suggested answers to the students’ “Stop and Think” questions, which are in the **Printable Materials** section.Highlight the Lab level assessment, which is in the **Assessments** section.Highlight the **Additional Resources** on the Educator Web site, even though for most of the rest of the workshop participants will be using the Student site, which holds the actual curriculum.• Click the link in the upper right corner to open the **Student** home page of the Carbon Cycle module. Mention that the rest of the workshop will focus on the curriculum, which is on the Student site. • Point out the links that cross-connect the Student and Teacher web sites, and mention that assessments and answer keys are available to educators by application. Restricted files, when clicked, will prompt the user to submit an application to gain access.Lab 1 Intro page• Briefly show the two main elements of the Student Lab Intro page. Every Lab in a unit will have the same two elements on the Lab Intro page. • MINIMIZE but do not close the web site for the Carbon module, and re-open the PowerPoint application, which should be on Slide #14, showing the Keeling Curve.  |
| **PowerPoint** **Slides 15 & 16**[10 minutes]  | Move from Slide #14, with the Keeling Curve, to Slide #15.**Slide 15:** **Carbon Reservoirs** Explain that Slide 15 shows the places on Earth—called RESERVOIRS—where carbon is stored, in various forms and compounds. Not every representation of the Earth’s reservoirs will look exactly like this. Some may divide up the reservoirs a little differently, but the big idea is that there is a set of places called reservoirs where carbon on Earth is stored. The sizes of the rectangles in this representation are NOT proportionate to the amount of carbon that is stored in them. Address the unit of weight: one gigaton = one billion metric tons. (one metric ton = 1000 kilograms or 2205 pounds) Point out that Slide 15 does NOT represent the carbon cycle; there is no cycling represented on the slide. It just represents where carbon is stored. Explain that this slide and the next one give an overview of the carbon cycle. Most of the rest of the workshop will go into detail about the carbon cycle in some of the specific reservoirs that are shown on these two slides. Point out the SOURCE of the diagram, which is in the PowerPoint Slide NOTES.Slide 16: Carbon Reservoirs and Processes Explain that Slide 16 shows both the reservoirs AND the movement of carbon between reservoir. In order for there to be movement, there has to be a process that results in the movement or flow of carbon between and among reservoirs. Point out some of the processes, and the reservoirs between which the carbon is moved. For example:1. Photosynthesis is a process in which carbon in the Atmosphere, in the form of CO2, is moved into a plant (Land Biota) , in the form of glucose.
2. Volcanic eruption is the process in which carbon is moved from Earth’s Mantle, in the form of carbonate minerals, into the Atmosphere, in the form of CO2.

Point out that for most of Earth’s history, the flows into and out of a reservoir are balanced, and so while Earth’s carbon is in constant motion, the size of the reservoirs remains the same. But every so often in Earth’s history, something changes…usually the amount or distribution of solar energy Earth receives because of orbital changes…and the flows into and out of the reservoirs are not in balance, so the size of reservoirs can change. Notice that the green T’s indicate flows that are temperature sensitive and so could change if the amount of solar energy reaching part of the planet changes. Today, it is human activity…the red arrows on that diagram: burning, farming, and fossil fuel burning…and not an orbital change, that is creating long-term (not seasonal) change in the size of carbon reservoirs, in particular, the reservoirs of carbon in the atmosphere and consequently in the ocean and other places as well. Notice the direction of the three red arrows.Point out the SOURCE of the diagram, which is in corner of Slide #16.For the rest of this workshop, we will be taking a closer look at some of these reservoirs, the processes that drive the flows, and at times the ways in which those flows are now changing. Explain that we will NOT be moving through the entire Carbon Cycle module today since there is not enough time to do that, but we will get to many of the important highlights. Mention that the module is very rich in resources, and quite long, and that teachers may also decide to pick and choose which elements they would like to highlight with their students.  |
| **Lab 2B**[55 minutes] | Have participants go to Lab 2B in the Student module, and to scroll down to the Carbon Cycle representation. Point out that, in this interactive representation, **reservoir names** are colored purple, and **process names** are colored red. Notice that the reservoirs and processes are a little different than they are on the PowerPoint, but again, that is not uncommon for different authors to portray reservoirs somewhat differently. This one adds much more detail to the biome (shellfish, corals, phytoplankton, etc.)Give participants 5 minutes to become familiar with the interactive, scrolling over a few of the reservoirs and processes and reading the information associated with each one.After 5 minutes, show an example of a loop, a flow that starts in a reservoir and ultimately returns to the same reservoir. Give a simple example: Atmospheric carbon moves into plants via photosynthesis; burning moves plant carbon back into the atmosphere.Tell participants they will now engage in an activity from the curriculum, described under the Carbon Cycle image. Read through the guidelines and answer any questions. Have participants work in pairs. They will have approximately 30 minutes to finish exploring the interactive, make their two loops, and address the questions in the curriculum.After they have finished each pair will share one of its loops with the class. Distribute 2 large sheets of paper to each team, along with colored pencils and post-it notes. **Sharing:** Save the last 20 minutes of the time block for sharing.  |
| **Break** [15 minutes] |  |
| **Lab 2C**[40 minutes] | Introduce the concept of feedback in the climate system: a change in element “A” of the system may be counteracted by a corresponding change in element “B”, or the initial change may be amplified. The feedback, or the way changes in one part of a system influence the rest of the system, makes the Earth system a very complex system.Ask participants to read the Amazon Rainforest Die-Off, starting with TEMPERATURE RISE, and then take a few minutes to discuss how the changes might continue to play out across an extended period of time. This is an example of a “positive”, or self- reinforcing cycle, vs. a negative feedback cycle, in which conditions are maintained in a balance via feedback. Move on to have participants play the Connections Game.Have participants read the section “Feedbacks in Complex Systems Can Stabilize or Destabilize a System”. When they finish, show the video “The Arctic: Canary in the Coal Mine”. On the classroom computer, navigate to the EarthLabs Educators web site and go to Climate Series Intro > Science Notes > Climate and Feedback Loops. Project and walk through each of the two types of feedback loops: “Balancing” (or Negative) feedback loop and “Reinforcing” (or Positive) feedback loop.  |
| **Lab 3A**[35 minutes] | Return to Slide #16 in the PowerPoint presentation. Highlight the Atmosphere, and the red arrows, the “new” elements of the global carbon cycle that are related to human activity. They are depicted here as adding to the carbon reservoir of the atmosphere. “Why is that important? It’s because of a phenomenon you have all heard about: the so-called greenhouse effect. Lab 3 in the module focuses on the carbon in the Atmosphere, the greenhouse effect, and the greenhouse gases.”Return to the Carbon module Lab 3A, scroll down to the **video** titled **The Greenhouse Effect**, and play it. Discuss: any questions? The video shows what happens, but does not address how. The next video will address how.Remind participants of the Scott Denning greenhouse gas video they watched in the Climate Series Introduction. It explained how the greenhouse gases differ from the major gases in the atmosphere: Nitrogen and Oxygen. Understanding the details of the physics involved with the greenhouse effect is not a goal here, but participants should understand that, like any other objects, molecules have their own “resonant frequencies”. If a force of a specific magnitude is applied to some object, and causes that object to vibrate at its resonant frequency, the object will absorb more of the energy and vibrate more vigorously. The incoming short wave radiation does not cause the greenhouse gases to vibrate at their resonant frequencies, but the outgoing long wave radiation does. Scroll down to the Climate Model Interactive near the bottom of 3A, project it on the classroom screen, and give participants a brief orientation. Then give participants 10 minutes to explore the model on their own computers.  |
| **Lab 3B**[25 minutes] | Review the graph at the top of 3B that shows the temperature and CO2 data from the Vostok Ice Core. Have participants do the Checking In questions, and then move on to the video Mother Nature’s History Book. Show it on the class screen. Although it is long (13 minutes), it provides a lot of background information that explains the graph at the top of the screen, and introduces participants to the Milankovitch cycle, a key phenomenon in explaining the cyclical nature of the graph data. An important strand of the module is, “How do we know what we know?. The video helps explain the source of the data in the graph, as well as an explanation of why the data makes sense. Skip the rest of 3B. Teachers can review this on their own before using the module with their classes.  |
| **Lunch**[45 minutes] |  |
| **Lab 3C**[30 minutes] | Show the video, Trend and Variation. It helps explain why, for example, there might be some very cold winters in some locations, even though the planet’s temperature is gradually rising, or why there might be periods of drought in some location, even though the general trend in that location is for increased precipitation. Separating short term events (for example, weather) from long term patterns (for example, climate). Discuss and address questions.Next have participants use the interactive, “Atmospheric CO2 Concentration at Mauna Loa on the island of Hawaii. Click on the button labeled “more info”, and after participants read the text, click on the link “Recent Monthly Average Mauna Loa CO2” to get the most recent atmospheric CO2 data. An important take-away message is the annual cycle that is for part of the year dominated by photosynthesis and the absorption of CO2 by trees and plants, and for part of the year is dominated by decay and respiration and the release of CO2 into the atmosphere. The cycle would not create ups and downs of atmospheric CO2 on a planetary level if the northern hemisphere and southern hemisphere had equal land mass and amounts of vegetation, but since the northern hemisphere has significantly more vegetation than the southern hemisphere, the cycles of the two hemispheres do not cancel each other out and so we get the annual increases and decreases of CO2. All of that, however, is separate from the long-term upward trend. Without human activity, the trend line would remain flat for extended periods of time although the seasonal oscillations above and below it would continue.Show participants the [Interactive Atmospheric Data Visualization (IADV) CarbonTracker database tool](http://www.esrl.noaa.gov/gmd/dv/iadv/), but do not use it. Just point it out as a resource for viewing atmospheric CO2 levels at stations around the world, including Mauna Loa.   |
| **Lab 4 (&1A)**[10 Minutes] |  Return to Slide #16 and point out that the focus of Lab 4 is on part of the reservoir called the Land Biota. Explain that Lab 4 has information about changes in the planet’s forest cover. The workshop will not explore Lab 4, but recalling that live trees absorb and store atmospheric CO2, one can understand how deforestation from changes in land use, fires, etc, will reduce photosynthesis and increase respiration, thereby changing the amounts of CO2 that are stored in the the various reservoirs. Return to **Lab 1A** and play the video, “Where do trees get their mass from?” Then proceed to Lab 5 |
| **Lab 5A**[40 Minutes] | Return to Slide #16 again, and explain that the focus of Lab 5 is on the soil reservoir of carbon, and on some of the processes that drive the flow of carbon into and out of that reservoir. Have participants read the first paragraph of 5A and then show the video, “The Living Soil Beneath Our Feet”, on the class screen. Next have participants work in pairs to address the Discuss topics, and finally have a class discussion about those topics. Have participants read the next 2 sections on their own and study the accompanying diagram. After 5 minutes, as for comments or questions. Was anything surprising? What did participants learn? What are some of the main points? On the class screen, project the video “The Science of Soil Health: Cycle, Recycle, Repeat”, and the discuss. Questions, comments? What are the main points? Scroll down to the Laboratory Investigation and describe the lab. It takes a few days to complete so is not something that would fit into the workshop.  |
| **Break**[15 minutes] |  |
| **Lab 5B**[10 minutes] | Briefly mention that Lab 5B addresses permafrost, the soil that, except for the very surface which thaws in the summer, has been frozen for thousands of years. Permafrost is a significant part of the reservoir of carbon that resides in the soil, but in large part it has not been part of the active cycling of carbon. That could change if global warming continues to thaw the permafrost. Show the video, “The Hidden Perils of Permafrost” and allow some time for questions and discussion.  |
| **Lab 6A**[55 minutes] | Return to Slide #16 and explain that the focus of Lab 6 is on a set of three closely related reservoirs: surface oceans; deep oceans; and ocean biota. Of course the atmosphere and the sedimentary rocks that form beneath the ocean floor are reservoirs also end up being involved but are not the main focus of Lab 6. Provide an overview of Lab 6A. It addresses three major mechanisms of the ocean carbon cycle: 1) The **Biological Pump**, which addresses the ways in which viruses, bacteria, phytoplankton, and zooplankton help circulate carbon throughout the ocean, into the atmosphere, and into the sedimentary rock below the surface of the ocean; 2) The **Physical Pump**, the ocean currents that circulate carbon dioxide around the planet and exchange carbon dioxide with the atmosphere; and 3), the **Carbonate Pump**, which addresses the exchange of carbon between the ocean and marine animals such as coral, oysters, clams, cabs, lobsters, and other marine organisms that use carbon compounds to build their shells. Give the workshop participants 10-12 minutes to read the first section of 6A, study the image titled The Ocean Carbon Cycle, and discuss the three “Discuss” questions with a partner. Then have participants share their thoughts about the image and the questions in a class discussion. **The Physical Pump**: Scroll down to the section with the heading, “In the physical carbon pump, carbon compounds can be transported to different parts of the ocean in downwelling and upwelling currents.” Show the NASA video, “The Thermohaline Circulation. Since it is not narrated, provide the following explanation. As ice forms in the arctic, it is just the fresh water that freezes, and the extra-salty brine that is left is quite dense, so it sinks. As this cold, extra-salty water sinks, warmer surface waters are drawn towards it to replace it, where it is also cooled at the northern latitudes, has more salty brine added to it, and again sinks. This sinking of cold, extra-salty water is what launches what is known as the Ocean Conveyer Belt. Warm currents, which are less dense, flow at the upper levels and the more dense, cold, extra-salty currents flow down low, setting up the pattern you see in the video and also in the graphic immediately below the video. This conveyer belt moves atmospheric carbon that has dissolved in surface water down to the depths of the ocean in what is called downwelling. When those deep currents eventually rise, often because they run into a continental shelf, they are warmed and release their dissolved CO2 into the atmosphere. Ask participants to examine the image in the Discuss section immediately below the image of the Ocean Conveyer Belt. It shows areas of the ocean that are considered carbon sinks and areas that are considered carbon sources. Does the diagram of sources and sinks make sense given the downwellings and upwellings that are shown in the ocean conveyer belt image? Discuss. **The Biological Pump**: Scroll down to the video, “The Secret Life of Plankton”, and play it on the classroom screen. Then scroll back up to the image titled, “A simplified oceanic biological pump”, ask participants to discuss it with a partner for a few minutes, and then discuss as a class. What are the key ideas? What questions or comments do participants have? **The Carbonate Pump:** Scroll down to the image titled, “Ocean Carbonate Chemistry System”. Explain that the Carbonate Pump is really a sub-division of the more general Biological Pump, but it refers specifically to those marine animals that take carbon from the ocean to build their shells—clams, oysters, crabs, lobsters, and much smaller shelled marine organisms. As these organisms die their shells accumulate on the ocean floor, sometimes forming sediments that eventually form limestone. When these sediments are eventually pushed up above the ocean surface by tectonic forces the limestone cliffs they form will eventually erode, releasing their carbon back into the global carbon cycle. Carbon that is locked up in such sediments can be stored in reservoirs for millions of years before finding its way back into the global carbon cycle. Questions, or comments?  |
| **Lab 6B** [1 minute] | Point out that Lab 6B goes into a lot of detail about the role of phytoplankton in the carbon cycle, but that there is not time to dig into it in the workshop |
| **Lab 7A**[14 minutes] | * Show the video, “Oyster farmers and ocean acidification”
* Scroll down to the interactive, “Ocean Acidification: CO2 and pH” and show it to the workshop participants on the classroom screen.
* Scroll down to the video ”Ocean Chemistry” by the Alliance for Climate Education and show it.

Explain that this is the basic core of Lab 7A. There are more resources but time limitations prevent us from addressing all of them in the workshop.  |
| **Lab 8**[10 minutes] | Explain that it is always a good idea, when bringing up the topic of climate change, to include ideas for addressing the problem of increasing the amount of carbon in the atmosphere reservoir. Then show some of the resources that are included in Lab 8. |
|  **Wrap-Up** [10 minutes] | Return to Slide #16. Explain that while the workshop was able to just scratch the surface of the Global Carbon Cycle, it has provided an introduction to it and has covered a partial set of the resources that are embedded within the module, Climate and the Carbon Cycle. Check for any last comments or questions. • Thank participants for attending. Possibly invite them to contact you with questions they might have as they prepare to implement or are implementing the module.• Possibly pass around a sheet to collect names of teachers who want to share their e-mails addresses with one another, so they can communicate as they implement the module.  |