

Global Flows and Reservoirs

Tracking Carbon (Grades 6-12)

Overview

Participants observe a global CO₂ simulation video and discuss how carbon dioxide levels in the atmosphere change throughout a day, among seasons, throughout the year, and over many years.

Learning Outcomes

Students will be able to:

- Orient to and interpret a data visualization of global CO₂ changes.
- Use evidence from the visualization to explain seasonal CO₂ changes.
- Use evidence from several data sources to explain the difference between annual and long-term changes in atmospheric CO₂.

Data Resources

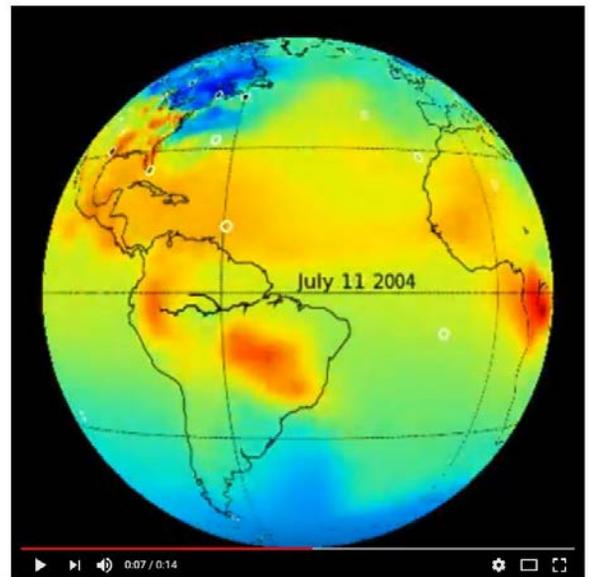
- This activity has students orient to, interpret, and synthesize data from NOAA's online Global Science Investigator/Carbon Tracker 2004.
- This activity has students interpret archived water quality data collected as part of the National Estuarine Research Reserve (NERR) System Wide monitoring Program (SWMP).
- This activity has students interpret atmospheric carbon dioxide data collected at NOAA's Mauna Loa Observatory.

NGSS Connections

- **Disciplinary Core Ideas:** MS.LS2.A: Interdependent Relationships in Ecosystems, MS.ESS2.A: Earth's Materials and Systems, HS.LS2.B: Cycles of Matter and Energy Transfer in Ecosystems, HS.ESS2.D: Weather and Climate
- **Science and Engineering Practice:** Interpret and Analyze Data, Constructing Explanations and Designing Solutions
- **Crosscutting Concepts:** Cause and Effect, Scale, Proportion, and Quantity

Climate/Ocean Literacy Connections

- 3.E: The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.



NOAA's CarbonTracker





Global Flows and Reservoirs: Tracking Carbon

Overview

Participants observe a global CO₂ simulation video and discuss how carbon dioxide levels in the atmosphere change throughout a day, among seasons, throughout the year, and over many years.

Materials Needed

For the class

- PowerPoint presentation
- Digital/data projector
- Access to videos:
 - Carbon Tracker online video <https://www.youtube.com/watch?v=O4WMdwIwrSw>

Preparation of Materials

Before the day of the session:

1. **Set up projection system/review multimedia.** Set up and test the projection system to be sure all participants will be able to see the videos at <https://www.youtube.com/watch?v=O4WMdwIwrSw>

Session at a Glance

Task	Description	Time (minutes)
A. Activity: <i>Tracking CO₂ Over Time & Professionally-</i>	Using graphs of authentic environmental data and a global CO ₂ simulation video, participants observe and discuss how carbon dioxide levels in the atmosphere change throughout a day, among seasons, throughout the year, and over many years.	45



collected Data (OSS 2.4)		
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Session Details

A. Activity: *Tracking carbon levels over time and professionally-collected data*

*Note to instructor: If you would like to have your students make predictions about oxygen production and consumption (i.e. photosynthesis and respiration) in the marine environment, and test their predictions using real-time environmental data recorded at a NERR reserve, see the activity **Tracking carbon levels over time using authentic local data in 9 Photosynthesis and respiration Investigations**.*

*If you would like to have your students actually collect data, see the activity **'Light Dark Bottle Investigation'**.*

Visualizing Global Scale Changes in Atmospheric CO₂

1. **Introduce part 2 focusing on global changes in CO₂.** Tell participants that this activity will look at changes in atmospheric CO₂ on a global scale.
2. **Orienting to and interpreting information from Carbon Tracker.** Project the Carbon Tracker (<https://coast.noaa.gov/psc/dataviewer/#view=tracker>) and pause it so that it is on January 1st (or as close to that date as possible). Since this is a new type of data visualization, help to orient the participants to the animation using the following questions:
 - What types of data are represented by the scale bars in this figure? [*time (month and year) and carbon dioxide concentrations (parts per million)*]
 - How many years are represented on the scrolling scale at the top of the visualization? [*8 years from 2000-2008*]
 - What is the range of carbon dioxide values on the colored scale bar? [*~360 - 380 ppm*]
 - What color represents the highest values? [*red*] The lowest values? [*purple*]
 - What does parts per million of carbon dioxide mean? [*how many molecules or parts of*



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CO₂ there are in the air for every one million parts of air. For example, if the CO₂ is 400 ppm, there are 400 CO₂ molecules per one million parts of air.]

- How do you think these parameters were measured? [*these data are model outputs that were created using data collected by CO₂ sensors. The samples were taken from the troposphere at about 1.2km above the ground to about 5.5km above ground*]
3. **Focus on northeastern U.S.** Tell participants to focus on northeastern U.S. Explain that they will be asked to interpret the data and describe what they observe to their partners as the visualization plays. Then play it a second time, but this time use the pause feature to pause in each month or season of one year. After going through the year, ask the participants to discuss the following interpretation questions with their partners and to cite evidence from the animation to support their answers:
- When was there the most CO₂ in the atmosphere in this area? [*Late winter and Spring. For example, in March and April in North America, the CO₂ levels get up to 385 ppm]*
 - When was there the least CO₂ in the atmosphere here? [*Summer and early Fall. For example, in August and September in some parts of North America, the CO₂ levels go down to 365 ppm*]
4. **Evaluating and communicating information from Carbon Tracker.** Have participants synthesize the data by coming up with explanations (based on evidence) for the patterns that they see.
- Why do you think the amount of CO₂ in the atmosphere might change during a year?
 - What is different about summer and winter that could affect CO₂ in the atmosphere? [*Possible responses are: in the winter in the northern hemisphere there is less sunlight for photosynthesis; in the summer in the northern hemisphere there is more sunlight for photosynthesis*].

NOTE: Students may also point out differences between the northern and southern hemisphere, such as the greater variability in CO₂ in the northern hemisphere and the opposite timing of peaks in CO₂. A few explanations for these differences are listed below.

- *Summer (i.e. longest days, warmest temperatures) in the southern hemisphere occurs during November thru January.*
- *Most of the annual variability in CO₂ is attributed to natural processes (i.e.*



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photosynthesis and decomposition), with a smaller contribution from seasonal burning of fossil fuels associated with heating and energy use.

- *Carbon dioxide concentrations increase as a result of decomposition of organic matter (e.g. leaf litter). However, the peak in CO₂ occurs not in the fall, but in late winter/early spring. This is because cold temperatures inhibit microbial processes that drive decomposition. This results in a time lag between trees losing all their leaves in the fall and increases in atmospheric CO₂. It is not until temperatures warm in the spring that rates of decomposition can increase enough to rise atmospheric CO₂.*
- *Similarly, there is a time lag between the beginning of summer and lowest atmospheric concentrations of CO₂ because the lowest atmospheric concentrations generally coincide with accumulation of plant biomass throughout the growing season.*
- *The northern hemisphere generally has more land mass and more human population, contributing to the greater variability in CO₂. There are also more rivers, which deliver nutrients to the ocean and fuel elevated rates of primary productivity in coastal waters.*
- *More of the surface of the planet is ocean in the southern hemisphere, which also contributes to differences in global CO₂ concentrations. Plant communities on land (e.g. deciduous forests) generally grow, accumulate biomass, then lose leaves on an annual cycle and cause large swings in atmospheric CO₂ drawdown and production. Plants in the ocean (e.g. phytoplankton) have much shorter life span (e.g. days to weeks) and cycle much more quickly than land plants. This leads to less variability in ocean waters (and thus the southern hemisphere) throughout the year.*

5. **Share ideas with whole group.** Ask a few participants to share their ideas with the whole class. Encourage them to expand on and use evidence to support their ideas. Ask the other participants for other comments and whether they agree or disagree with the ideas expressed, without correcting or confirming their statements.

6. **Project slides, Spring and Summer/Fall and Winter.** Ask and invite participants to share ideas, using the Carbon Tracker animation to help illustrate their ideas:

- What do you now think about why the amount of CO₂ in the atmosphere changed over the year?
- How does the evidence about sunlight and plants at different times of the year help us answer the question? [Possible responses include: *in the winter in the northern*



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hemisphere there is less carbon dioxide in the atmosphere, because there is less light for photosynthesis and many of the trees have no leaves for photosynthesis. Photosynthesis decreases the amount of carbon dioxide in the atmosphere].

7. **Project slide of key concept.** Project the key concept and have participants read it.
 - Carbon dioxide concentrations in the ocean and atmosphere vary throughout the day and by season, and have increased over the last 50 years (OSS 2.4).

8. **Replay Carbon Tracker focused on the ocean.** Ask participants to watch the Carbon Tracker one more time, this time focused on the ocean, and discuss with their partner, “Why do you think the amount of CO₂ in the atmosphere above the ocean might change during a year?” [Possible response: *Phytoplankton and algae in the ocean photosynthesize at different rates throughout the year*].

9. **Share ideas with whole group.** Ask a few participants to share their ideas with the whole class. Encourage them to expand on their ideas by providing evidence and/or reasoning for their ideas. Ask the participants for other comments and whether they agree or disagree with the ideas expressed, without correcting or confirming their statements.

10. **Seasonal variability in PAR and photosynthesis.** Project the “Comparison of PAR in July and December” slide. Ask participants to reflect on the figure and discuss the following questions:
 - What do you notice about the difference in PAR? [*PAR in July is almost twice as high as PAR in December*]
 - How do you think the decrease in light availability will affect the rate of photosynthesis? [*With less light the rate of photosynthesis would be lower because light energy is needed for photosynthesis*].
 - If rates of respiration remain relatively constant while the rate of photosynthesis decreases, what do you predict will happen to CO₂ concentrations? [*The concentration of CO₂ will increase because less is being used in photosynthesis*].
 - Based on these observations, during what season would you expect to see the highest concentrations of CO₂ in the water or atmosphere? [*winter because less is being used in photosynthesis*]. When would CO₂ be the lowest? [*summer because a lot would be used in photosynthesis as the rate of photosynthesis is high in the light filled summer*].



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Part 3: Interpreting data: Carbon levels over many years

- 1. Project slide, Keeling Curve: CO₂ Levels in the Atmosphere.** Explain to participants that they will now look at atmospheric CO₂ concentrations over many years. Project the Keeling Curve slide. Explain that this graph is called the Keeling Curve. It is named after the scientist who first made people aware of the relationship between atmospheric CO₂ concentrations over time in Hawaii.
- 2. Focus on data orientation skills.** Ask participants the following questions focusing in on data orientation skills, remind the participants that the orientation level of engagement helps to determine “what is there on the page.”
 - What type of data are represented by the x- and y-axis of the figure? [*x-axis is time in years, y-axis is amount of CO₂ in the atmosphere (in units of parts per million)*]
 - Where was this data collected? [*Mauna Loa Observatory in Hawaii*]
 - How do you think these parameters were measured? [Possible answers include: *sensors for carbon dioxide, scientists making measurements*]
- 3. Focus on data interpretation skills.** Point out that the red line on the graph shows the monthly averages of CO₂ levels in the atmosphere and that the black line reflects the annual values. Ask participants the following questions focusing in on data interpretation skills, remind the participants that the interpretation level of engagement helps to determine “what the data on the page shows.”
 - When was the lowest CO₂ concentration? [*1958*].
 - When was the highest CO₂ concentration? [*~2012*]
 - What trend do you notice in the black line? [*Increasing from 1958 to 2010, steeper in more recent years*]
 - What trend do you notice in the red line? [*Increasing like the black line, but with up and down pattern within each year*]
- 4. Focus on data synthesis skills.** Ask participants the following questions focusing in on data synthesis skills, remind the participants that the synthesis level of engagement helps to determine “what the data pattern explains regarding what is not on the page.”



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- Based upon what you've learned thus far and what you saw in the Carbon Tracker 2004 animation, why is the red line “wiggly”? [*The up and down “wiggly” pattern is due to seasonal changes in the balance between plant growth and photosynthesis, and respiration and decomposition. In the summer when days are longer and there is more sunlight available, carbon dioxide concentrations decrease as plants use up carbon dioxide from the atmosphere. In the winter when light availability decreases, decomposition and respiration is greater than rates of photosynthesis and carbon dioxide concentrations increase*]. See NOTE in Part 2 above for further explanations.
 - Why do you think that the CO₂ concentration is increasing? [*Human activities such as combustion of fossil fuels are causing more CO₂ to enter to atmosphere reservoir*]
5. **Discuss increase in atmospheric CO₂.** Ask participants to think to themselves for a moment about where this increase in CO₂ is coming from. Call on a few volunteers to share their ideas. Emphasize that the whole Earth is not receiving more carbon [matter is conserved because atoms are conserved, in this case carbon atoms] but rather the atmosphere reservoir is receiving more carbon. This must mean that carbon is flowing from other reservoirs on Earth into the atmosphere.