SOS Explorer™

Global Climate Change and Carbon Dioxide Lesson – Earth & Environmental Science – *Teacher Version (with answers)*

Objective: Research and analyze data about global atmospheric carbon dioxide and temperature in order to infer and draw conclusions about global climate change.

Materials needed: SOS Explorer on your computer and access to Internet.

Answer the questions below in complete sentence using SOS Explorer, Internet links and diagrams.

1. Read this article to gather background information about global climate change and CO_2 levels: https://scripps.ucsd.edu/programs/keelingcurve/2015/05/12/what-does-this-number-mean/

   a. What is the "Keeling Curve"?
   Recorded at the top of Mauna Loa in Hawaii, it's the world's longest unbroken record of atmospheric carbon dioxide concentrations. It was started by Charles Keeling in 1958.

   b. What is the unit of measurement to measure CO_2 levels?
   ppm or parts per million

2. Here is an image to help understand the impact of greenhouse gases like CO_2:

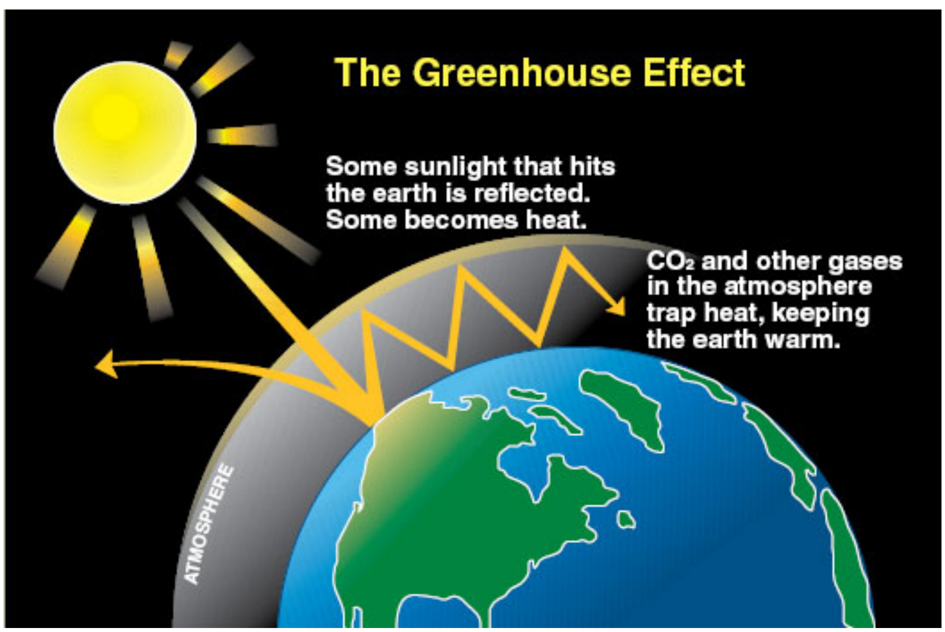


Figure 1: The Greenhouse Effect (Department of Ecology, State of Washington)

   a. Summarize the diagram in your own words.
   The Greenhouse Effect refers to the properties in CO2 and other gases that allow trapping of the heat (being emitted by Earth back to space), which keeps Earth warm.

3. Open SOS Explorer. Take a moment to play around and become familiar with the program. Then, click *Datasets > CarbonTracker 2005 – 2010 > Load.* You should see a colorful animation.
   a. What do the colors represent? Give an example.
   The colors in the animation represent carbon dioxide concentrations. Green around the equator represents about 380 ppm.

   b. Take a minute to watch the animation. Describe what you see.
   CO_2 in the atmosphere changes all the time. Sometimes, there's more in the northern hemisphere and sometimes in the southern hemisphere. It seems to be based on the month.

4. Then click *Tools > Analyze and Probe.* This will allow you to measure the CO_2 levels in the following locations at the end of winter and the end of summer during 3 years. You can adjust the month and year using the controls in the animation window in the upper right corner of screen.

   Use the Probe tool to measure the CO_2 concentrations (ppm) at the specified times and locations and record them in the table below.

   a. Table 1: (numbers won't perfectly match but close to)

b. Location	05/2005	09/2005	05/2007	09/2007	05/2010	09/2010
Mauna Loa, Big Island, Hawaii	381.1 ppm	376.3 ppm	385.1 ppm	380.4 ppm	389.5 ppm	385.9 ppm
South Pole, Antarctica	375.4 ppm	377.1 ppm	379.5 ppm	380.5 ppm	384.3 ppm	386 ppm
Your location	382.3 ppm	375.6 ppm	384.8 ppm	381.5 ppm	389.5 ppm	385.6 ppm

   b. Graph the data from in Table 1 for your three locations. Title the graph: CO_2 Levels 2005-2010.
   This should have three different lines for each location, x-axis will be Month and Year and y-axis will be CO_2 Concentrations (ppm). It should look a little bit like the Keeling Curve (found on page 4), where we see the lines moving up over time but up and down through the seasons.

   c. Explain the pattern you see in your graph/data.
   All of the lines are gradually going up but in the northern hemisphere they go down a little in September and up a little in May. The opposite is true for Antarctica in the southern hemisphere.

   d. Rotate sphere to view Atlantic Ocean. Click on *Tools > Analyze > choose transect tool.* Right click far in the northern part of the Atlantic Ocean, move your mouse and right click again far in the southern part of the Atlantic Ocean. Watch the graph that is made for a while or increase the frame rate. Is this the same pattern you saw in your data? Describe it.

It is the same pattern. I see that CO_2 concentrations are higher in the northern hemisphere than the southern hemisphere during winter and spring, whereas they are higher in the southern hemisphere than the northern hemisphere in summer and fall.

5. Load a new dataset. Click *Datasets > Biosphere: Marine Chlorophyll and Land Vegetation > Load.*

a. Watch the animation for a minute then, describe what you see.

The land greens up in the summer and same goes for the amount of chlorophyll in the ocean. Summer for northern hemisphere is opposite than for the southern hemisphere. Areas near the equator are pretty green all the time. Lowest amounts of chlorophyll in the ocean happen far from land.

b. Specifically looking at the northern hemisphere, in which months are the vegetation and chlorophyll concentration highest and lowest?

Vegetation and chlorophyll concentration in the ocean are highest in the summer months June – September and lowest in the winter months December – February.

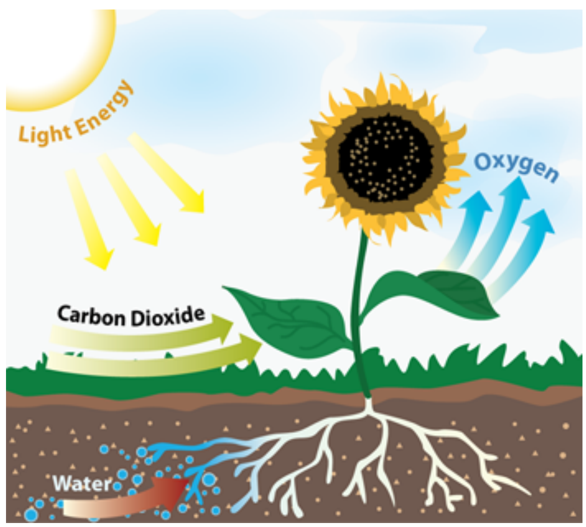
c. Specifically looking at the southern hemisphere, in which months are the vegetation and chlorophyll concentration highest and lowest?

Vegetation and chlorophyll concentration in the ocean are highest in their summer months December – February and lowest in the winter months June – September.

d. How does that compare to your CO_2 data differences between seasons recorded in Table 1 and graph from question 4?

The lowest CO_2 in the northern hemisphere happens in September, corresponding to the high vegetation and chlorophyll concentrations. Where as the higher CO_2 comes in May, which is before summer so maybe that's before it gets real green.

e. Chlorophyll refers to green pigments in algae and plants. It is an extremely important biomolecule, critical in photosynthesis. Photosynthesis is a process where by plants convert light energy into chemical energy to fuel the organisms' activities. This process allows plants to take in CO_2 and release Oxygen. In winter, this process slows dramatically.



How can you use this information to explain what you saw in the CarbonTracker and Biosphere animations? (Load the datasets again if you want to review.)

The data I collected and the animation showing global photosynthetic seasons, tells me that CO_2 doesn't get taken in by plants in the winter so in the Spring there is still a lot more CO_2 in the atmosphere in the corresponding hemisphere but at the end of the summer, there is much less!

6. In your SOS Explorer CO_2 data collection (Table 1), although there were seasonal changes (CO_2 goes up and down depending on the season due to photosynthesis) you may have also seen the pattern of CO_2 going up as time goes on. Did you see this? Give a specific example in your data.
Yes, that is the first pattern that I noticed. CO_2 goes up from 2005 – 2010 even though it dips during the summer. For example, Boulder, CO (where I am) went from 382 – 385 ppm.

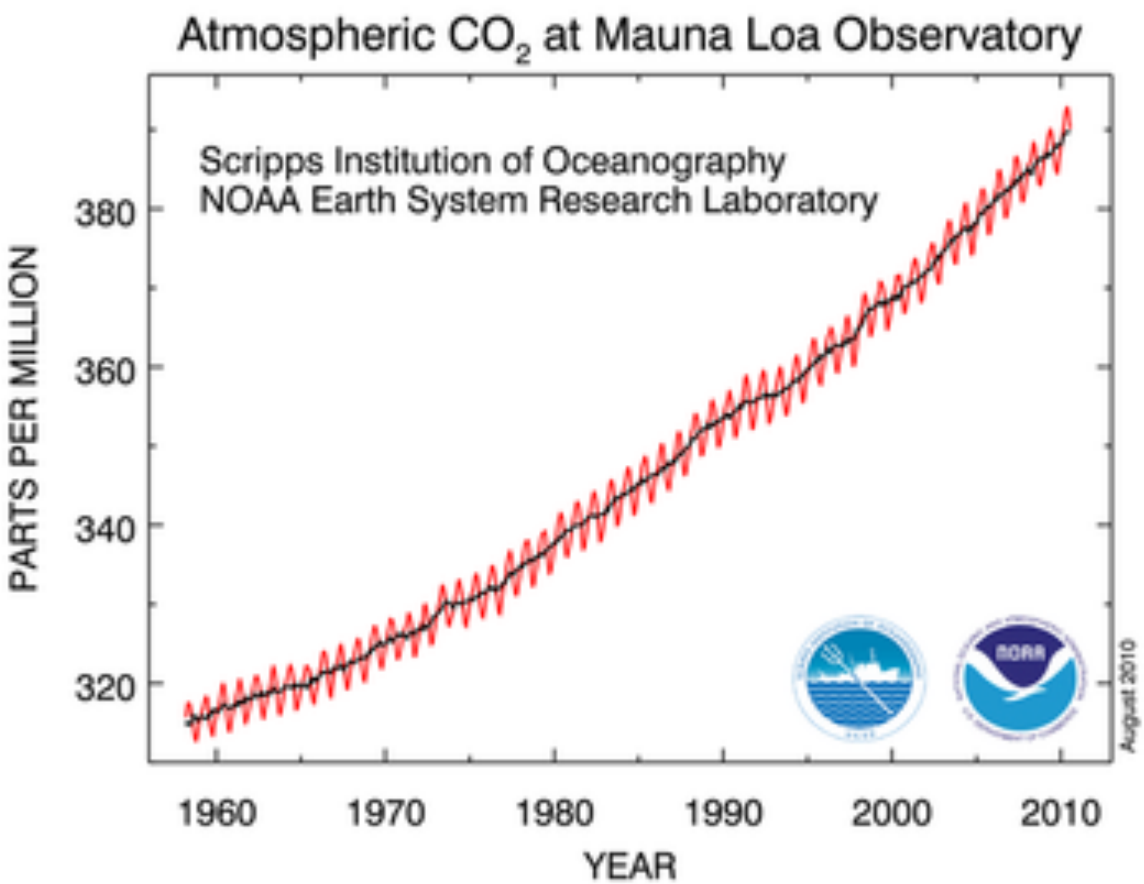


Figure 2: Keeling Curve (NOAA)

a. Describe how your data collection for Mauna Loa, Hawaii (both seasonal and increase over time) compares to the Keeling Curve in Figure 2 above.
My data pretty much looks the same, going up each year but also going down during the seasons, this graph just is over a longer period of time.

7. Go to the following link to find and record the current CO_2 level is for last week at Mauna Loa. http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html
This answer should be somewhere close to 400 (in 2015), lower if in summer, higher if in winter.

8. We saw that plants can change the CO_2 levels seasonally but that doesn't explain why CO_2 has gone up so much over the years – just look at Figure 2: Keeling Curve. How are humans impacting CO_2 levels? Please use Figure 3 below to help you answer this question:
   A lot of human activities are contributing to greenhouse gas emissions. For example, power stations, I assume for electricity, is 29% of annual carbon dioxide emissions and #2 sector to contribute is industrial processes.

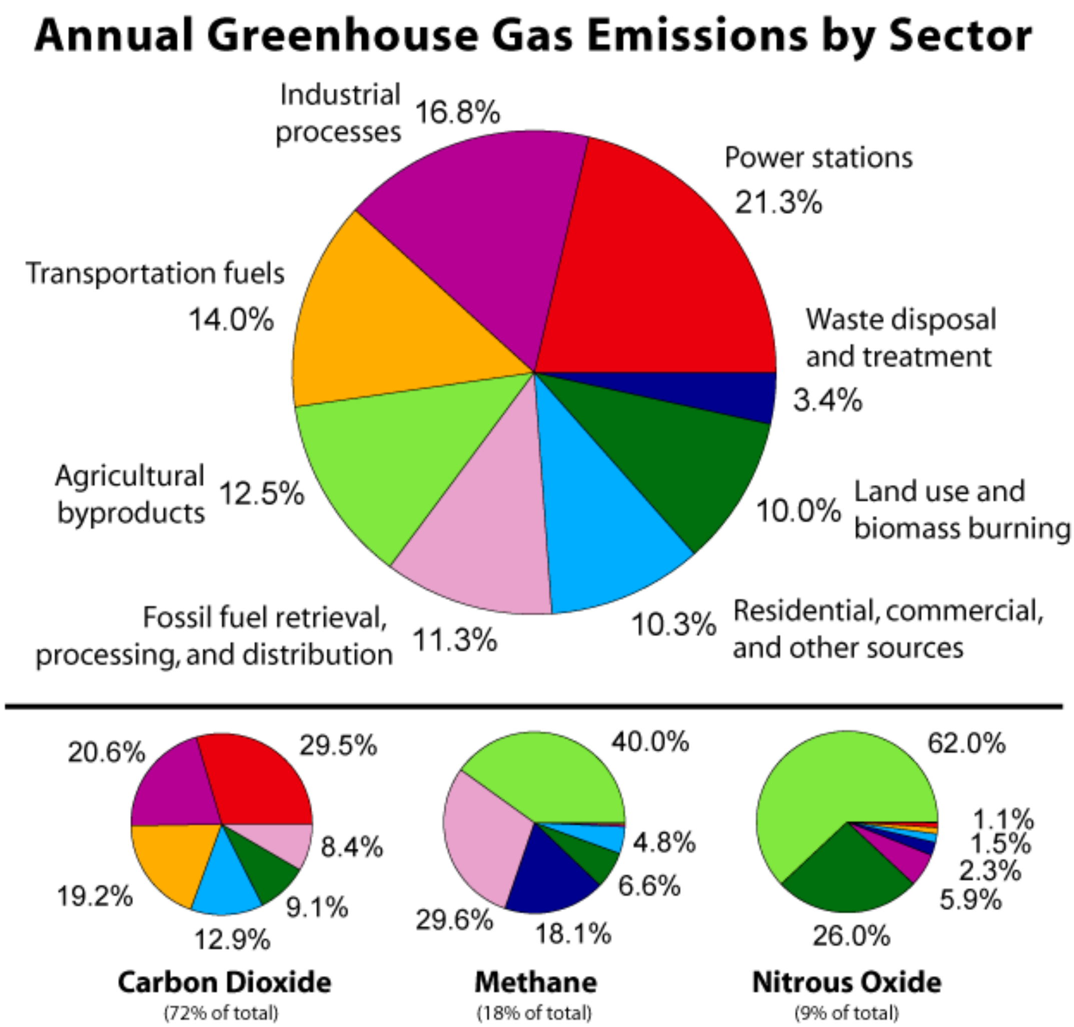


Figure 3: Emission Database for Global Atmospheric Research version 3.2, fast track 2000 project

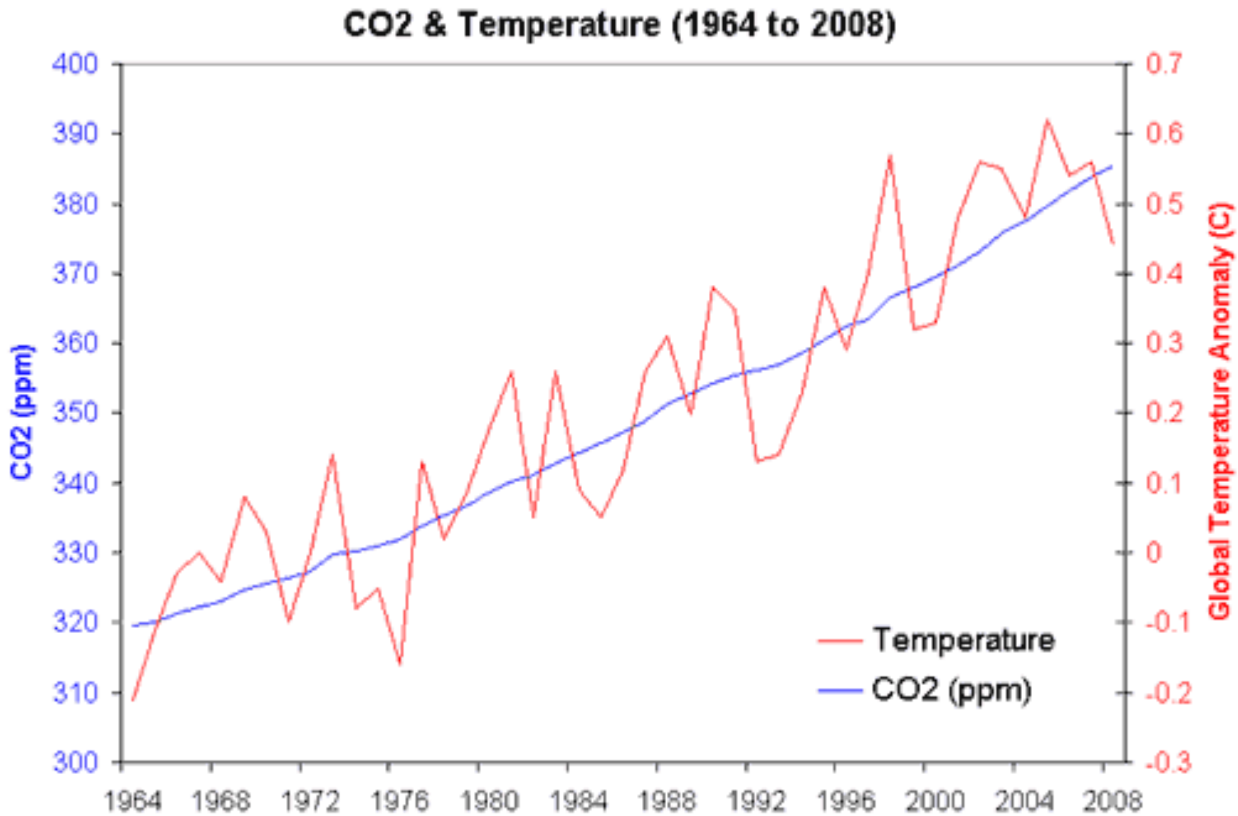


Figure 4: Annual atmospheric carbon dioxide (NOAA) and annual global temperature anomaly (difference from average temperature) (GISS) from 1964 to 2008.

9. Finally, using the graph in Figure 4 above, how do global temperatures and CO_2 correlate? Why? Use Figure 1 on page 1 to help you.
   As CO_2 goes up so too does temperature. This is because CO_2 is a greenhouse gas and causes the greenhouse effect to intensify, which causes more heat to be trapped in Earth's atmosphere.

10. Based on the data you have seen in this lesson, what is your conclusion about global climate change and it's causes. Give specific examples with data as support.
    I see that the carbon dioxide record is complicated because it goes up and down so much, as seen in our data we got from SOS Explorer CarbonTracker, but I also see that it's gone up a lot over the past 60 years, according to the Keeling Curve and that's because of human activities like use of electricity and car emissions.

11. How do you think we, as humans, can change this?

    Well I think we can change this by emitting less carbon dioxide, by driving less or having more fuel-efficient cars and by eating less meat or decreasing deforestation.

Extension - Our Future

Scientists use computer models to make future predictions. Go to https://www.climate.gov/ scroll down to the Global Climate Dashboard and select Climate Projections.

a. Explain the graph of Simulation of Global Temperature according to the Climate Model Data.
It looks like we have data that puts us on a certain path of changing Earth's temperature, which is highlighted in black. What happens in the future depends on how much "growth" there is. Growth must mean something like population or growth of emission output. If we follow a high growth model then we could increase Earth's temperature by as much as 4.5 degrees C by 2100, where as if we follow the low growth prediction then we will still see at least 1.75 degrees C change by 2100.

b. How do you think it might be possible to follow the B1 path rather than the A2 path? What specifically could we do?
In order to see less temperature increase in the next century, we'd have to follow a "lower growth" model into the future. This must mean that we have less growth in carbon emissions which has to do with human population and human activities and how much renewable energy we change to. We would need to dramatically lower our greenhouse gas emissions.

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