Module 1: Atmosphere

Carbon dioxide (CO_2) emissions

Field study: Impact of the environment on air quality

Learning Outcomes:

- Understand how the greenhouse effect works and the role that CO_2 plays
- Learn the concentration of CO_2 in atmosphere and how it has changed due to human activity
- Compare these changes with natural changes in the concentration of CO_2 in atmosphere at different study locations

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I. Carbon dioxide (CO_2) emissions

Background

http://www.esrl.noaa.gov/gmd/outreach/carbon_toolkit/basics.html

Carbon dioxide (CO_2) makes up a small percentage (0.0390%) of Earth's atmosphere but plays a critical role in Earth's climate. This is due to the basic physical properties of CO_2: this gas is invisible to us because it does not reflect visible light, but it *does* absorb infrared radiation. Due to this property, CO_2, water vapor, methane, and nitrous oxide act together to produce Earth's **greenhouse effect**.

Here's how the greenhouse effect works: (1) CO_2 and other **greenhouse gases** allow visible sunlight to pass through the atmosphere; this light is (2) absorbed by the Earth, and then (3) reradiated as **infrared radiation**; in contrast to visible light, this infrared radiation is (4) absorbed by CO_2 and other gases; (5) the absorption and release of this energy increases the surface temperature of the planet. **The greenhouse effect keeps the surface temperature of the planet ~33°C warmer than it should be based on the amount of sunlight received.** Put another way, much of the planet would be frozen if not for CO_2 and the other greenhouse gases. (This is like a greenhouse because the glass in a greenhouse acts like CO_2 in the atmosphere, increasing the temperature inside. Or think of a car on a sunny day: the inside of the car can be much, much warmer than outside because heat is absorbed and trapped in the car.)

Earth's greenhouse effect has been known for a long time, is basic physics, and is indisputable. A few decades ago, scientists therefore became concerned that if humans increase the concentration of CO_2 in the atmosphere, we would change Earth's climate. This could occur through the burning of fossil fuels—oil, gas, and coal—because CO_2 is produced when they are burned to generate energy. In the 1960s, a professor at UCSD, Charles Keeling, started measuring atmospheric CO_2 concentrations to see if they were increasing. He made these measurements at Mauna Loa volcano in Hawai'i because the Hawaiian Islands are the most isolated islands in the world, and strong winds blow across the mountain (which is ~14,000 feet high). This avoids the effects of local pollution and gives an accurate value for the entire Northern hemisphere. These CO_2 data have been collected continuously since then, and are now managed by his son, Ralph Keeling, who is also a professor at UCSD. These CO_2 data are known as the 'Keeling Curve' and will use them in this lab.

Part I: Familiarize yourself with the website

Go to the IADV page on the NOAA website, located at: http://www.esrl.noaa.gov/gmd/ccgg/iadv/

The IADV is comprised of actual scientific data from all of the measurement sites within the Cooperative Air Sampling Network at NOAA. Begin this activity by familiarizing yourself with the different measurement sites and IADV maps. Notice that the default measurement site is Mauna Loa, Hawaii. Atmospheric trace gas measurements were first introduced at this site, so it has the longest ongoing record of CO_2. You can click on the thumbnail images below the world map in order to view enlarged maps of various world regions. Hold the pointer over each site to view its name, location, and sampling details; click on a site to select it for data visualization. Within the map there are four different symbols with four corresponding measurement program types. Study the map key to determine the four different types of measurement programs.

a) Which site in the network is closest to your current location, and which type of measurement program is located there?

Part 2: Mauna Loa CO_2 dataset

Using Mauna Loa, Hawaii, United States [MLO] for data visualization, explore several options offered by the IADV and answer the following questions:

a) What are the latitude and longitude of the MLO site?

Hint: Latitude is in either degrees N or degrees S of the equator and longitude is in either degrees E or degrees W of the prime meridian.

b) Based on your prior knowledge, how would you describe the location and geographic characteristics of this site (is it remote or close to large human populations, which hemisphere [northern/southern] is this site located within, is it near ocean or land, what is the elevation above sea level, etc.)?
Hint: masl=meters above sea level, a measurement of elevation.

1. Obtain a graph of the trends of atmospheric CO_2 at the MLO site. Make sure that MLO is selected for the Sampling Location, click on the Carbon Cycle Gases drop down, and finally click on the Time Series link.

2. On this page, make sure that Carbon Dioxide is the selected Parameter, In-Situ Data is the selected Data Type, and Monthly Averages is the selected Data Frequency. For Time Span select All and use the default years. Finally, click Submit.

3. Scrolling down you should see the classic CO_2 curve. Note that the dataset is in μmol mol^{-1} which is equivalent to ppm. You may use either unit but be sure to report your units.

c) Describe the short-term (within a year) and long-term (over the entire dataset from 1969 to present) trends that are visible.
Note: You may change the start and end year if it helps you to assess the short-term trends.

d) Pick three years for the MLO dataset after 1975 and report the high and low CO_2 values.

e) What do you think might be causing the short-term trends in CO_2 at MLO?

f) What do you think might be causing the long-term trends in CO_2 at MLO?

Part 3: Other CO_2 datasets

Now you are going to assess the short-term and long-term trends for Barrow, Alaska, US (BRW) and the South Pole, Antarctica, US (SPO). Make sure that you select *in-situ* data and monthly averages.

a) What are the latitudes and longitudes of the BRW and SPO sites?
Hint: Latitude is in either degrees N or degrees S of the equator and longitude is in either degrees E or degrees W of the prime meridian.

b) Based on your prior knowledge, how would you describe the location and geographic characteristics of these site (is it remote or close to large human populations, which hemisphere [northern/southern] is this site located within, is it near ocean or land, what is the elevation above sea level, etc.)?
Hint: masl = meters above sea level, a measurement of elevation.

c) Describe the short-term (within a year) and long-term (over the entire dataset from 1969 to present) trends that are visible.
Note: You may change the start and end year if it helps you to assess the short-term trends.

Report the high and low CO_2 values for the same three years as the MLO dataset above.

d) Why might there be differences in the short-term trends (within year magnitudes of change) in CO_2 at MLO, BRW, and SPO?
Hint: think about the geographic position of each site.

e) Do you think the same mechanisms are controlling the long-term trends in CO_2 at MLO, BRW, and SPO?

Part 4: Seasonal Patterns

Now you are going to assess in which months CO_2 hits its maximum and minimum for each MLO, BRW, and SPO.

1. For each MLO, BRW, and SPO select the Carbon Cycle Gases for the Measurement Program. Then select seasonal pattern for Plot Type.

2. Make sure that the Parameter is Carbon Dioxide and the Data Type is In-Situ Data.

3. The top graph shows the average seasonal cycle. For each MLO, BRW, and SPO record the month in which the site hits its maximum and the month in which the site hits its minimum. Also record the amplitude for each CO_2 seasonal cycle (the difference between the average seasonal maximum and minimum).
   Note that this graph has been scaled so that zero is set as the average annual CO_2 concentration.

a) Were the months in which each site hit its maximum and minimum the same? If they were different, how were they different? Why do you think they were the same or different?

b) How did the amplitude of the seasonal CO_2 cycles differ between the sites? Why do you think that is?

Part 5: Further Questions

a) It takes about one year for the atmosphere to mix between the northern and southern hemispheres—can you pinpoint the hemisphere where most of the CO_2 originates?

b) Does one hemisphere appear to "lag" behind the other in terms of increasing CO_2 concentrations?

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II. Field work: Impact of Natural & Human activities on air quality.

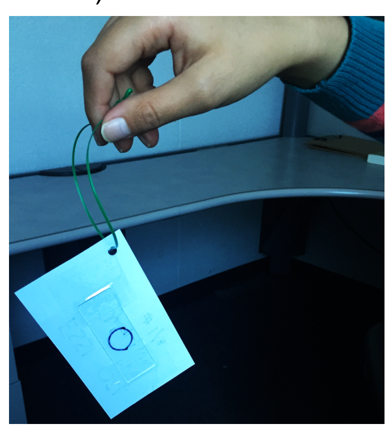
Objective
In this experiment you will test the quality of air by measuring the number of particles from different locations.

Testable Question
How does the testing location (indoors or outdoors) affect the amount of particulate matter collected on the index card samples?

Design strategy
Discuss first within your group, and then between all the groups, the location where you will place your samplers (all three samplers, or collectors, you will make will be installed at the same location).
Be sure that each group will study one specific location, presenting each of them different environmental conditions (indoor, outdoor, place close or away from emissions …).

Materials

- Vaseline
- Three index cards (4x6) with a hole punched in a corner
- Three strings
- Three glass slides
- Permanent marker
- Heavy-duty tape
- A penny



Procedure

1. Tie a string through the hole in each card to make loops for hanging cards in chosen locations.
2. Using a permanent marker, trace the outline of a penny onto a glass slide in order to create your sample area.
3. Securely tape the edges of the slide to the center of one of your index cards.
4. Smear a thin layer of Vaseline on the sample area on the glass slide.
5. Repeat steps 2-4 for the remaining cards.
6. As a group, take your index cards to your chosen location and find three secure places to hang or place your cards for collecting your samples.
7. Report on the following map your collecting location, and describe the site as carefully as possible.
8. Leave your index card at its location until the next session.

Source of the map: https://www.ucmerced.edu/sites/ucmerced.edu/files/documents/maps/uc-merced-campus-map-sept2018.pdf