   

**Project EDDIE: CLIMATE CHANGE**

**Student Handout**

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This version was been slightly modified from the original for the EREN-NEON-EDDIE workshop.

Learning objectives:

* To analyze global temperature data to see if Earth’s average global temperatures are really increasing
* To analyze CO2 data to see if atmospheric levels are really increasing
* To correlate CO2 data with global temperature to see if there is a relationship
* To compare current trends with rates of change during pre-historic periods using ice core data
* To interpret what these results mean for understanding current climate change
* To learn basic shortcuts and graphing in Excel, or to get an orientation to working with data in R.

Why this matters: Current climate change is affecting many aspects of the environment, with socio-economic consequences. For example, a warmer climate can allow new diseases to be introduced and persist (e.g. West Nile became established in the United States after an unusually warm winter allowed the mosquitos that carry the virus to survive and spread). We are concerned not only with the actual temperature, but also with the rate that the temperature changes. Very rapid changes make it more likely that species (maybe even including humans!) cannot adapt and will go extinct.

Outline:

1. Activity A: Determine current rates of air temperature change
2. Activity B: Determine current rates of atmospheric CO2 change
3. Activity C: Compare current rates to pre-historical rates of change using data from an ice core to investigate how climate has changed in the past.

Options:

* If you would like to use Excel, you should find some instructions and tips on a separate sheet on Using Excel.
* If you would like to use R, all the R code is already set up, so you just need to run it by opening the Project. Annotations in the code explain the different steps.

**Activity A:** How much is temperature changing?

**Changes in air temperature -** Scientists from the Goddard Institute for Space Studies, NASA, compiled temperature datasets from weather stations all over the world to create the dataset you are going to be working with today to answer the question: Is earth “warming”? The data you will use are from years 1880-2013.

1. Before you conduct your analysis, you should first make your predictions. What slope would indicate a warming Earth? What slope would indicate Earth’s average global temperature was not changing? What slope would indicate a cooling Earth? Sketch lines in the axes below to show what the expected slopes would be in these different scenarios.

oC

oC

oC

time

time

time

cooling warming no change

1. Getting the air temperature data: Getting the air temperature data: These data are compiled by the Goddard Institute for Space Studies, NASA, and are made available here <https://data.giss.nasa.gov/gistemp/>. Scroll down the page to the Tables of Global and Hemispheric Monthly Means and Zonal Annual Means section and download “Global-mean monthly, seasonal, and annual means”, the .csv version. *Note: These data are temperature anomalies, i.e. deviations from the corresponding 1951-1980 means. The average global temperature during 1951-1980 was 14 C (or about 57 F).*
2. Upload or open up the dataset. Make a scatter plot of temperature change over time using the annual mean data.
3. Now, determine the rate of change. Determining rates of change graphically is straightforward. The average rate of change is just the change in temperature divided by the change in time, or change-in-y divided by the change-in-x, or the slope of a line that fits through the data. These are all the same thing. So, to determine the rate of change (slope), add a trend line. The equation is written in the form *y = mx + b*, where *m* is the slope and *b* is the intercept. The value for *m* is the rate of change, the units are those along each axes.

The R-squared (R2) is a statistic resulting from a linear regression analysis, which is the statistical name for what you just did by adding a trend line. It describes the proportion of variation in the dependent variable explained by the independent variable. When R2 ~1, the data form a perfectly straight line. As the data become more scattered from the line, R2 decreases toward 0. Higher R-squared values indicate a stronger relationship between the two variables. Record your R2 value down with your slope.

* 1. Equation for the line:
  2. R2 =
  3. Rate of air temperature change (include units):
  4. Given your analysis, is Earth warming? What evidence supports your response?

**Activity B:** How much is atmospheric CO2 changing?

**Changes in atmospheric CO2 -** In 1958, Dr. Charles David Keeling (1928-2005), who was a scientist at Scripps Institute of Oceanography, began collecting data on atmospheric CO2 concentration at the Mauna Loa Observatory located in Hawaii. This dataset is what allowed us to understand the degree to which climate change is human-caused through our burning of fossil fuels and release of CO2 into the atmosphere. Due to his scientific achievements, Dr. Keeling was awarded the National Medal of Science by President George W. Bush in 2002. This is the highest award for lifetime scientific achievement that can be granted in the U.S. Today, you get to analyze this same dataset, except that you have more data that was available to Dr. Keeling and his colleagues, because your dataset extends up to current time.

1. Getting the atmospheric CO2 data: The longest measurements of atmospheric CO2 concentrations have been done in Mauna Loa, Hawaii. The simplest way to access the data is directly from the Mauna Loa page. <http://www.esrl.noaa.gov/gmd/ccgg/trends/>. Select the ‘Data’ tab. At “Mauna Loa CO2 annual mean data”, click on the word ‘CSV’. CSV stands for comma separated values and it is a common way to store data.

The data are presented as a column of years, the mean CO2 as ppm (parts per mil, or micromoles per mol of air), and the last column is the estimated uncertainty in the annual mean is the standard deviation.

1. As you did for air temperature, plot a graph of CO2 vs time.
2. Determine the current rate of change for atmospheric CO2 data by fitting a trend line, as you did for air temperatures.
   1. Equation for the line:
   2. R2 =
   3. Rate of atmospheric CO2 change (include units):
   4. Based on your analysis, how has atmospheric CO2 concentration changed? How confident are you in these results? What phenomenon explains the matching patterns of average global temperature and atmospheric CO2?

#### You may have noticed that you plotted a different length of time for CO2 and temperature. If you wanted to compare similar times, you could go back and redo the temperature graph with the same time period as the CO2 data are available.

**Activity C:** How do current trends compare to pre-historic rates of change?

**An exploration of the Vostok Ice Core -** Our analyses so far have only looked at recent history. How can we compare the recent data to pre-historic time – periods before humans were active on Earth in the way they are now? Are the current rates of change similar or different than those the earth has experienced in the past? To explore this, we can use data taken from ice cores that were drilled at the poles.

Hundreds of ice cores have been extracted from polar ice because they contain valuable data on atmospheric chemistry over pre-historic time. These valuable data exist in the chemistry of the ice and in the tiny air bubbles that are trapped as the snow is compacted into ice. These air bubbles contain the same gases as the atmosphere at the time when the ice formed. The data you will be analyzing are from ice cores extracted from the Vostok research station in Antarctica. As you have probably assumed, the depth of the ice core is related to how old the ice is; deep ice is older. There are two other variables that you will be analyzing from the ice cores. The first is temperature, which is reflected by isotopic ratios in the ice of the core so that these isotopic ratios can be converted into air temperatures. The second variable you will analyze is CO2 concentration, which has been measured from air bubbles trapped in the ice. We can use these data to see what rates of change were like during this pre-historic period, during which human activity has been minimal.

1. Vostok Ice Core data is most accessible through the Carbon Dioxide Information Analysis Center [https://cdiac.ess-dive.lbl.gov/#](https://cdiac.ess-dive.lbl.gov/)

If you wish to look at or acquire the temperature data yourself, here’s how! To get the temperature data, from the top menu, select **Data**, then **Climate**. On the next page select **Temperature**. Scroll down this page and you see the '**Historical isotopic temperature record from the Vostok ice core, Antarctica**' near by end of the list. Select this, then in the webpage that opens you should select **Digital Data**.

Now you can either save this page as a text file, which you could upload into R or Excel, or select-all and copy. Open the text file, or paste, into Excel. You'll have to convert the data into columns in Excel, and do some data cleanup (remove header metadata information, check column headings, etc.)

1. Graph temperature using ice age as the independent variable. Keep in mind that the x axis refers to how many thousands of years ago, so the time axis moves in the opposite direction as what you are accustomed to based on previous analyses. This is the custom for research that investigates patterns over long time periods.

To help you orient to these plots, address the following questions:

1. Are we currently in a glacial or interglacial period?
2. How long does a glacial and interglacial period last?

Glacial:

Interglacial:

1. Add a trend line to the ice core temperature data and look at the R2 value. Do you think this line is a good representation of long-term rates of temperature change and why?
2. The next step is to calculate what the fastest rate of change might be in the pre-historic record. To do this, you want to identify a section of your data where the temperature is changing very rapidly. If you hover your mouse over a data point, it will tell you the data values for that particular point. Make note of the data point values at the beginning and end of the time period segments that you think have the steepest slopes:

Then make a new graph of only that time period, and determine the rate of change by fitting a trend line and looking at the slope.

1. Rate of pre-historic temperature change (with units).
2. Now let’s look at long-term changes in CO2. If you wish to look at or acquire the CO2 data yourself, here’s how! To access the Vostok ice core CO2 data, go back to the main CDIAC page. Select **Data**, then **Atmospheric Trace Gases**, then ***Carbon Dioxide (CO2)***. The next page will have ***Vostok Ice Core*** as an option, so select that, and then the **Data** icon.

Similar to the other Vostok dataset, you can either save this page as a text file, which you could upload into R or Excel, or select-all and copy. Open the text file, or paste, into Excel. You'll have to convert the data into columns in Excel, and do some data cleanup (remove header metadata information, check column headings, etc.).

Prepare a plot of CO2 concentration as a function of (gas) age. Plot (gas) age on the x axis and CO2 on the y axis.

* 1. According to the CO2 data from ice cores, during which time frame(s) was there the greatest rate of change in atmospheric CO2 concentration? How does this change in atmospheric CO2 concentration correspond to what you see in the ice-core temperature record?
  2. How do CO2 concentrations recorded over time in the ice core compare to the current values for today, which you can see on the Mauna Loa web site?

1. Now make a new graph focused only on a time period of rapid change in CO2. Determine the rate of change by fitting a trend line and looking at the slope.
   1. Rate of pre-historic atmospheric CO2 change (with units)
2. How do current (i.e., in the past ~200 years) changes in atmospheric CO2 concentration and global temperature compare to pre-historic (i.e., in the past hundreds of thousands of years) changes? What does this suggest about whether recent changes in temperature are due to natural or anthropogenic (human) factors? It is plausible that recent increase in atmospheric carbon dioxide is a result of natural fluctuations and not human-induced?