**Project EDDIE: CLIMATE CHANGE**

**Student Handout**

This module was initially developed by O’Reilly, C.M., D.C. Richardson, and R.D. Gougis. 15 March 2017. Project EDDIE: Climate Change. Project EDDIE Module 8, Version 1. <http://cemast.illinoisstate.edu/data-for-students/modules/climate-change.shtml>. Module development was supported by NSF DEB 1245707. The edited version is available here: as Stetler et al. 2022

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 interpret what these results mean for understanding current climate change
* To utilize previous data analysis skills 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. Discussion of video data science and climate change
2. Power Point presentation
3. Activity A: Determine current rates of air temperature and CO2 change from modern datasets.
4. Activity B: Explore whether temperature and CO2 concentrations are related.
5. Paste your individual response to discussion prompts at the bottom of this document.

Videos

<https://www.youtube.com/watch?v=SqxFr_pnHJg>

and/or <https://www.youtube.com/watch?v=ph439t-kTIE>

**Activity A:** How much are temperature and atmospheric CO2 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”?

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

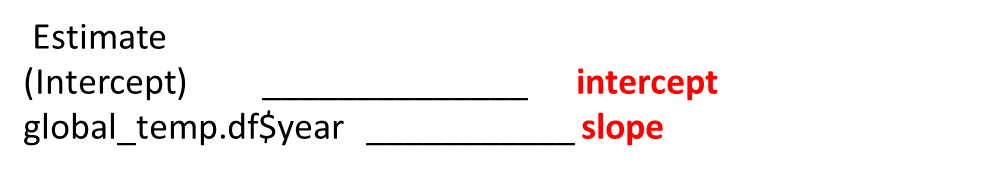
cooling warming no change

A black line with white text

Description automatically generated with medium confidence

cooling is down

warming is u

1. All Data are available in the google drive. Air temperature data are compiled by the Goddard Institute for Space Studies, NASA, and are made available via the Earth Policy Institute. <http://www.earth-policy.org/data_center/>.
2. Read in the dataset.
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. Perform a linear regression in R lm(y~x). Record the R2 value and p value. 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. 

m= 7.623e-03

b= -1.482e+01

annutal\_temp c= 7.623e-03 \*year -1.482e+01

p value < 2.2e-16

The R-squared (R2) (use multiple 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: annual temp\_c 7.623e-03 \*year -1.482e+01
  2. R2 = .7539
  3. Rate of air temperature change (include units): 7.623e-03 C per year
  4. Given your analysis, is Earth warming? How do you know?

Yes, it is warming because based off the graph, which is growing, it corresponds to the earth warming.

A graph with a red line and a red line

Description automatically generated

**Paste the finished scatter plot with trend line here**  use geom\_smooth() in ggplot to add a trend line. Play around to make a nice plot**.**

1. Many scientists claim that drastic changes in global temperature began in the mid-1900s when fossil-fuel-powered transportation became a mainstay for most families. Test this hypothesis by adjusting your trendline so that it only looks at the most recent decades, after personal transportation became common. You can do this by:
   * Decide on the year in the mid-1900s that you want to begin the trendline. Scroll to that year and select the data (year and temperature) from that year all the way to the most recent year. Use filter in the dplyr library to select the years for example >= 1952 (but choose an year in the 1950’s.
   * Create a Scatter plot just as you did before, and add a trendline with the R2. Paste plot below.
   * A graph with a red line and numbers

     Description automatically generated

Write your answers for (a) and (c) on the google sheet to compare with others.

1. Equation for the line:

y= 0.01618x-31.84

* 1. R2 =
  2. .8889
  3. Rate of air temperature change (include units):

.01618 C/ year

* 1. Compare the slopes of these two lines (1880 through mid-1990s versus mid-1990s through 2013). Does your analyses support the hypothesis that the rate of global average temperature is greater since the 1950s?

Yes, the rate of change has been slowly increasing. After the 1950’s, the temperature change is going twice as fast as it was. So based off that, the rate of change supports the hypothesis.

**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: Data is in Google Drive. 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/>
2. As you did for air temperature, plot a graph of CO2 vs time. Paste plot here.
3. A graph of co2 level

   Description automatically generated
4. Determine the current rate of change for atmospheric CO2 data by fitting a trend line, as you did for air temperatures.
5. Equation for the line:
6. annual co2= 1.5997x -2826.2821
   1. x is the ppm co2 per year
   2. R2 = .983
   3. Rate of air CO2 change (include units):
      1. 1.5997ppm/year
   4. Based on your analysis, has atmospheric CO2 concentration increased? How confident are you in these results? What phenomenon explains the matching patterns of average global temperature and atmospheric CO2?
      1. Yes, the CO2 concentration has increased throughout the years based off the 1.5997 value that shows the levels rising.
      2. Based off the low p value, it shows the data is good between the year and CO2 concentration.
      3. This phenomenon is based off the greenhouse effect phenomen because Carbon dioxide is a greenhouse gas and as it increases, more heat is trapped, which then causes global temperatures to raise.

**Activity B:** How related are the changes in temperature and CO2?

1. To determine whether a change in CO2 corresponds well with a change in air temperature, you can plot temperature against CO2. To do this, perform a full\_join from the dplyr library between the two data sets. See power point for more details. Then make a graph with **CO2 on the x axis and temperature on the y axis.**
2. Equation for the line:
3. annnual temp= .01618x– 31.84
4. x is the co2 in ppm
5. R2 = .9241
6. Based on your analysis, could atmospheric CO2 concentration explain the increase in average global temperature?
   1. Yes because the the positive slope shows its been rising throughout the years

#### Paste plot here

#### A graph of a temperature Description automatically generated

Online Discussion Prompts Please post your individual response here and paste this into the google doc.

Briefly explain why you care (or don’t care) about climate change.

I care about climate change because I live on this planet. The well-being of Earth directly impacts my life, the lives of people I love, and future generations. The environment, ecosystems, and climate systems are all intertwinded, and any significant change affects everyone, regardless of where they live.

How may climate change impact you or the people / things you care about ?

Climate change can have broad impacts on various aspects like sea-level rise, increased frequency of extreme weather events, changes in agricultural productivity, health impacts due to heatwaves, spread of diseases, and loss of biodiversity, among others.

Do you feel like you can make a difference with your skillset after these videos? Why or why not?

I don’t think I can make a difference. I think although one person trying to make a difference is a good start, I think it has to be a joined effort amongst the entire world in order to make a difference.

Please share any other thoughts or discussion points here.

Any of you think about data lakes?

They can be particularly useful for analyzing big datasets in different ways, which could be crucial for climate change data.

$25 million tag to start? Thoughts? Who should fund this?

I think 25 million is a good start, but I do not think it will be enough to actually create long term change. This can be funded by government stake holders, national or private organizations,

**\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* look at your graph and timelines.**

**When did we have enough evidence that climate warming is occurring? When “should we have known?”**

#### We had enough evidence already by the later 1980’s that showed climate warming is occuring and it is here to stay. We should have known by already 1960’s to have seen it is continuing to escalate.