global_climate_change

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```r
library(tidyverse)
library(lubridate)
```

Changes in Modern Temperatures

```r
#Import "Global-mean, monthly, seasonal, and annual means" data from https://data.giss.nasa.gov/gistemp/
global_means <- read_csv("data_raw/GLB.Ts+dSST.csv", skip = 1)

#Selected only the year and annual temp. data located under `Year` and ``J-D`` columns.
#Changed the names of the the year and temperature columns to `year` and `annual_temp`
#The units of temperature are Celcius but are provided as the difference from the ean temperature betwe
global_temp_annual <- global_means %>%
  select("Year", "J-D") %>%
  rename("year" = 1) %>%
  rename("annual_temp" = 2) %>%
  filter(year < 2020)
global_temp_annual$annual_temp <- as.numeric(global_temp_annual$annual_temp)

#Scatter plot of modern temperature change over time
ggplot(data = global_temp_annual, mapping = aes(x = year, y = annual_temp)) +
  geom_point() +
  geom_smooth() +
  labs(x = "Years",
       y = "Celcius (anomalies)")

#Creates linear regression model
fit <- lm(formula = annual_temp ~ year, global_temp_annual)
summary(fit)

#Adjusted the trend line so that it only looks at the most recent decades since many scientists claim t
#Dataset with data after 1950
post_1950 <- global_temp_annual %>%
  filter(year > 1950)

#Scatter plot of modern temperature change over time starting at 1950
ggplot(data = post_1950, mapping = aes(x = year, y = annual_temp)) +
  geom_point() +
  geom_smooth() +
  labs(x = "Years",
       y = "Celcius (anomalies)")

#Creates linear regression model to determine current rate of change for temperature data
```

```
post_1950_fit <- lm(formula = annual_temp ~ year, post_1950)
summary(post_1950_fit)
```

Changes in Modern Atmospheric CO2

```
#Import annual mean atmospheric CO2 data downloaded from https://www.esrl.noaa.gov/gmd/ccgg/trends/data
co2_data <- read_table("data_raw/co2_annmean_mlo.txt", col_names = TRUE, skip = 56)

#Select the "year" and "mean" columns
co2_data <- co2_data %>%
  select("year","mean")

#Graph of CO2 vs. Time
ggplot(data = co2_data, mapping = aes(x = year, y = mean)) +
  geom_point() +
  geom_smooth() +
  labs(x = "Years",
       y = "Mean CO2 Levels")

#Creates linear regression model to determine current rate of change for atmospheric CO2 data
RoC_fit <- lm(mean ~ year, co2_data)
summary(RoC_fit)
```

Relationship between modern temperatures and atmospheric CO2

```
#Combines temperature and CO2 data
temp_co2_data <- inner_join(co2_data, global_temp_annual)
view(temp_co2_data)

#Graph of relationship between atmospheric CO2 and temperature
ggplot(data = temp_co2_data, mapping = aes(x = mean, y = annual_temp)) +
  geom_point() +
  labs(x = "Mean CO2 Levels",
       y = "Annual Temperatures in Celcius (anomalies")

#Creates linear regression model
CO2_temp_fit <- lm(annual_temp ~ mean, temp_co2_data)
summary(CO2_temp_fit)
```

Pre-historic Temperature Data

```
#Import Vostok ice core data from the Carbon Dioxide Information Analysis Center (CDIAC)
#https://cdiac.ess-dive.lbl.gov/trends/temp/vostok/jouz_tem.htm
vostok_temp_data <- read_table("data_raw/vostok.1999.temp.dat.txt", col_names = FALSE, skip = 60)

#Renamed the columns
vostok_temp_data <- vostok_temp_data %>%
  rename("Depth (m)" = 1) %>%
```

```
  rename("Age of the ice (yr BP)" = 2) %>%
  rename("Deuterium content of the ice (delta D)" = 3) %>%
  rename("Temperature Variation (deg C)" = 4)

#Creates new variable and calculates the paleo-temperature at Vostok based on the following formula
#Temperature (in degrees C) = -55.5 + (delta D + 440) / 6
vostok_temp_data$Paleo_Temperature <- -55.5 + (vostok_temp_data$`Deuterium content of the ice (delta D)

#Renamed "Temperature Variation" column as "Paleo-Temperature (deg C)"
vostok_temp_data <- vostok_temp_data %>%
  rename("Paleo-Temperature (deg C)" = 5)

#Graph of ice-cre temperature data using ice age as the independent variable
ggplot(data = vostok_temp_data, mapping = aes(x = vostok_temp_data$`Age of the ice (yr BP)`, y = vostok_
  geom_point() +
  geom_smooth() +
  labs(x = "Age of the ice (yr BP)",
       y = "Paleo-Temperature (deg C)")

#Creates linear regression model
vostok_fit <- lm(vostok_temp_data$`Paleo-Temperature (deg C)` ~ vostok_temp_data$`Age of the ice (yr BP)
summary(vostok_fit)

#Filter dataset to period of time with fastest rate of change
vostok_fast_change <- vostok_temp_data %>%
  filter(vostok_temp_data$`Age of the ice (yr BP)` > 25000 & vostok_temp_data$`Age of the ice (yr BP)` <

#Graph of new dataset
gg_change <- ggplot(data = vostok_fast_change, mapping = aes(x = vostok_fast_change$`Age of the ice (yr
  geom_point() +
  geom_smooth() +
  labs(x = "Age of the ice (yr BP)",
       y = "Paleo-Temperature (deg C)")
gg_change

#Creates a linear regression model
vostok_change_fit <- lm(vostok_fast_change$`Paleo-Temperature (deg C)` ~ vostok_fast_change$`Age of the
summary(vostok_change_fit)
```

Pre-historic CO2 Data

```
#Import Vostok ice core CO2 data from CDIAC website
#https://cdiac.ess-dive.lbl.gov/trends/co2/vostok.html
vostok_co2_data <- read_delim("data_raw/vostok.icecore.co2.txt", delim = "\t", col_names = FALSE, skip =
vostok_co2_data <- vostok_co2_data %>%
  rename("Depth (m)" = 1) %>%
  rename("Age of the ice (yr BP)" = 2) %>%
  rename("Mean age of the air (yr BP)" = 3) %>%
  rename("CO2 Concentration (ppmv)" = 4)

#Graph of CO2 concentration as a funtion of (gas) age using full time period
gg_co2_conc <- ggplot(data = vostok_co2_data, mapping = aes(x = `Mean age of the air (yr BP)`, y = `CO2
```

```
  geom_point() +
  labs(x = "Mean age of the air (yr BP)",
       y = "CO2 Concentration (ppmv)")

#New dataset for fastest rate of change for CO2 in pre-historic time period
vostok_co2_focus_data <- vostok_co2_data %>%
  filter(vostok_co2_data$`Age of the ice (yr BP)` > 128000 & vostok_co2_data$`Age of the ice (yr BP)` <

#Graphs the new dataset
ggplot(data = vostok_co2_focus_data, mapping = aes(x = `Mean age of the air (yr BP)`, y = `CO2 Concentra
  geom_point() +
  geom_smooth() +
  labs(x = "Mean age of the air (yr BP)",
       y = "CO2 Concentration (ppmv)")

#Creates a linear regression model
focus_fit <- lm(vostok_co2_focus_data$`CO2 Concentration (ppmv)` ~ vostok_co2_focus_data$`Mean age of th
summary(focus_fit)
```

Comparison of modern and pre-historic rate of changes in CO2

```
#Graph of fastest natural rate of change in CO2 from pre-historic data
gg_co2_conc
#Graph of modern rate of change in CO2
gg_co2
```

Hypothesis

Question 11: How do current (i.e., since 1950) changes in atmospheric CO2 concentration and average global temperature compare to pre-historic (i.e., in the past hundreds of thousands of years) changes in these variables?

Answer 11: Current changes in atmospheric CO2 and temperature are increasing at a steady rate while the CO2 atmospheric concentration and temperature changes in the pre-historic era fluctuated greatly and weren't steadily increasing **Question 12:** What does this suggest about whether recent changes in temperature are due to natural or anthropogenic (human) factors?

Answer 12: This highly suggests that the recent changes in temperature are due to anthropogenic factors **Question 13:** Is plausible that recent increase in atmospheric carbon dioxide is a result of natural fluctuations and not human-induced?

Answer 13: It could be natural fluctuations but it likely isn't. The CO2 naturally flucated in pre-historic times but never really went above 300ppmv of CO2 while in todays world we have over 400ppmv of atmospheric CO2 ## Citation

This module was initially developed as an Excel-based exercise 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