CS5010: Global Warning Project

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Nima Beheshti (nb9pp)

Jessica Cheu (jc4vg)

Benjamin Feciura (bmf3bw)

Gary Mitchell (gm3gq)

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Introduction:

A large unprecedented shift in weather patterns caused by global emissions is commonly known as global warming. This change in the climate has historically been understood to be a result of high carbon dioxide (CO2) emissions around the world, although there are several other factors that contribute to this global concern. As these pollutants are released and trapped in the atmosphere, the temperature increases on the Earth's surface causing major disruption to ecosystems as well as increasing the likelihood of droughts, fires, and intensified storms. With the recent increase in devastating natural disasters, our team set out to understand how global emissions of CO2 around the world have changed over time and which countries are the largest contributors.

Our goal was to explore how emissions have changed from year to year, which countries were the highest contributors, and how civil unrest and world wars have affected global emissions. We looked at the modern era to see if there were signs of emission decrease as knowledge of the harms of CO2 emissions increased. Does the internet age increase international transportation emissions and how big of a factor is international transportation to global emissions? What countries are decreasing their emissions? Which are increasing? We aimed to understand what has happened as it is a great tool for understanding what will be in store for the future.

The Data:

The data set used for the analysis of this project was found on kaggle and is a data set for CO2 emissions for countries and territories between the past few centuries. This data set was chosen because of the significance of climate change in today's world. The data set takes us on a journey through the growth of CO2 emissions by country and throughout the world. The data set started tracking some countries in the 18th century but for the most part began tracking the majority of countries at times throughout the 19th century.

The raw data set required some cleaning steps before being ready to further examine everything the data set has to offer. The first step taken was to change the variable name, specifically the variable name "Annual CO2 emissions (tonnes)" to "Emissions". The initial data set had information for not only countries but also some territories of countries, continents, total measures by continent, and other groups such as statistical differences. The next step taken was to create a separate data set that dropped some of these territories, continents, and other categories.

The time series data set we used has years starting back at 1751 and going to 2017. With that being said, there was no consistency in the starting point for any one country so we noticed many countries would start at different years throughout the centuries. Additionally, for most of the countries that had observations dating back to 1751, many of these values were 0 until the late 19th century. The most likely cause for this was due to lack of tracking in those years however the data points are still there for us to see. Not all specific entities in our data set had the same number of observations, in fact most of them had different start dates for their observation. For example, some of the soviet bloc countries only started having data tracking in 1991 while other countries like the United States have data tracking going from 1751 even though the major portion of these early years don't actually have any data points.

Experimental Design:

Data Cleaning:

We began our data design portion by first starting with our raw dataset, obtained through kaggle, which was a time series set of data for countries, territories, continents, and other entities. We saved this data set into a csv file and loaded it into our Python code. We renamed the raw data column 'Annual CO2 emissions (tonnes)' to 'Emissions' and looked at our code to see what data points we were working with. We ran some summary statistics on the data we had and found that the number of observations was 17946, the mean year for the oversvations was 1962, but the median year was 1974 which highlights the point made above that we had to be careful about values of 0 found in the data set. We ideally wanted a cleaner data set that removed some of the figures that would be counted twice or otherwise change the comparisons made in the data set. We created an updated data set called 'data_countries'. In this dataset we dropped 'Entity' values such as continents because they were double counting the countries that were already in the contents. We dropped some of the territories that belonged to the countries so as to not interfere with individual country comparison. We dropped some other entities such as 'statistical difference' as it doesn't add to the analysis we were conducting. Additionally, we added two subsets of the data to show the observations of 'international transport' and 'world' emissions data.

We added some additional columns to our data set, including column data for year over year change for each given year, and percent total of global data. These changes were added to all data sets we created and were used to help with queries. For the year over year percent change we made the denominator equal to 1 for the last zero value for 'Emissions'. We did this so as to not cause a division by zero error when the first non zero year has a zero value in the denominator in the year over year percent change calculation.

Lastly for data cleaning we wanted to create a data set that included a more standardized format for the number of observations per specific 'Entity'. While we realize this couldn't be done perfectly. We decided to create a data set called 'data_modern' for observations of years greater than the mean year of 1962, found earlier in the summary statistics. This way we don't have decades of 0 values for some of the entities and rather have the majority of entities fitting within this boundary.

Queries:

We ran five main queries on our dataset in order find out which years saw the greatest increase in emissions, when did countries decrease their emissions, are there any countries with carbon-zero years in the modern era, what portion of world emissions are caused by international transport, and to how each continents emissions had increased over time. A more in depth explanation of these individual queries are explained in this section

Which years saw the greatest increase in emissions? Can we tie this increase to a particular event? We examined this question by subsetting the data by Year-Over-Year percent change values of over 100%; that is, years where a country's emissions at least doubled. This resulted in 354 observations, a bit too much to examine all at once, so we used the pd.Series.value_counts() method to get the number of times each Year appeared in the resulting subset. We found that 1950 appeared 26 times, meaning 26 countries' emissions doubled from 1949 to 1950. Many of these countries were in regions of the world that were rapidly industrializing at the time like Latin America, Southeast Asia, and Eastern Europe, which could explain why 1950 was such a common year to see these sorts of increases.

When did countries decrease their emissions? Do these moves correlate with increased awareness of the effects of emissions on the climate? We examined this section by subsetting the data by Year-Over-Year percent change values that were negative. This resulted in nearly 5000 observations, and we similarly used pd.Series.value_counts() to see when the decreases occurred. 106 countries saw decreases in 2009, and in examining the possible causes we considered a link between the late-2000s financial crisis and a decrease in general economic activities like travel and manufacturing which could have precipitated the decreases.

Are there any instances of countries with carbon-zero years in the modern era? We examined this question by subsetting the dataset pertaining to observations after 1963 for Emissions values of 0. While some observations met the criteria, they were several sequential years from Moldova and Kyrgyzstan, indicating data may have simply still been unavailable for the earliest years in the range we considered. Therefore it appears there have been no genuinely carbon-zero years for any country in the modern industrial area.

What portion of world emissions is made up from international transportation? In order to create this information we had to divide the international transportation observations for each of their respective years by the total world CO2 output for the respective year. We next multiplied this number by 100 and included it as a new column of data that showed the percentages of world emissions for the respective years. The result that we got was that in the past 10 years the percentage stayed pretty even in the low 3% range.

Which continent contributes the most emissions and how has that changed over time? Another query we ran was a breakdown of continental total emissions which took a look at the different continents throughout the years of observations in our data set. Because many of the observations prior to the 20th century showed a 0 value for emissions, we decided to specify the range of this query to 1940 onwards. The specific results of which will be described later in this paper, but the query shows that since the early 1990s the largest current continent, in respect to CO2 emissions, is Asia.

Testing:

As we made our way through cleaning our data sets and running the queries, we did a number of tests on our data to ensure that everything we were running was accurate and operating in the proper ways. As we examined our data and ran the data sets through cleaning, we used a number of print statements to make sure the columns and observations that were needed actually showed up. We did the same tests to make sure new columns that were expected to show up still did show up.

In our queries we made sure the smaller datasets created for the queries showed the desired result and the data used in the visualizations represented the intended subsets of the data. We did a number of unit testing as well to ensure that the functions used throughout the project worked properly. The details of these unit tests will be discussed in a stand alone section dedicated for testing.

Visualization:

What proportion of global emissions did each country make up in 2017? As 2017 is the most recent year in the dataset, we decided to use it as the year in which to examine the breakdown of global emissions by country. We accomplished this by subsetting the data and sorting emissions values in descending order. We then produced a pie chart; with all countries shown, the chart was impossible to read, so we created a function which takes a value from the user to choose how many of the top countries to show individually, then aggregates remaining countries into an “other” category before producing the chart.

Not only did we want to see the 2017 breakdown of the highest emissions producers in the world, we also wanted to get an overview of how global emissions have changed over time. To do this we used observations of total world emissions between the years of 1751 and 2017 and plotted the data. In addition to total world emissions, we also plotted a breakdown of continental emissions from the period of 1940 to 2017.

Our team was curious how WWII shaped the overall change in emissions during a set number of years for a given country. For this analysis, we took a look at data between the years of 1927 and 1948. The observations we looked at were for the countries of the United States, United Kingdom, Germany, France, Canada. These five countries were the five largest emissions producers during the warring period. We also included a total aggregate for the world’s Co2 emissions during the period.

In keeping with the trend of significant events, we wanted to take a closer look at individual countries and how their own significant events shaped their respective Co2 emissions. We created subsets of our data for the respective observations we were looking for and graphed these subsets to test the effects of the significant events for each of the countries to see whether it really made a difference in their emissions. The first significant event tested was for Syria during their current Civil War. For this period we took a look at the dates before the war period through 2017. We then wanted to see if the results were consistent with other civil wars so we took a look at Lebanon during their civil war in the 1980s.

The next country we looked at didn't neceissarly have a civil war during the periods of observation but they do have a very volatile government. We examined North Korea to see what their emissions data shows especially during the recent decades with their desire to create nuclear weapons at the expense of sanctions placed on their country and economy.

Lastly we wanted to see how the internet age and the increase in internet commerce has shaped overall emissions in the world. There was an entity named 'international transport' within our data set so we took a subset of this data set to see if there were any significant increases in the slope of the emissions for 'international transport' over the past 30 years.

Beyond the Original Specification:

One of the most important aspects of software development is the structure of the final product. The usability of the software is positively correlated with increase in user reach and probability of user interaction. We have structured our files with a user interfacing file along with background files including functions, analysis, visualization, and testing. This decreases the time required for a new user to understand how to use the software as well as any developers to understand where to attain more information about the structure of the software. With an additional readme file, our file folder can be given to nearly any developer with remedial knowledge in programming and they would be able to understand the code within the program. To increase usability, users have the option to save their quered data and visualizations to a .csv and .png file.

Beyond the scope of our original specifications, our goal was to send out a global warning by creating a user interactive experience to understand how CO2 emissions have changed during countrywide and worldwide events as well as understand the expected increase in total global emissions for future years and how that affects the amount of atmospheric CO2.

The "point of no return" was determined as CO2 levels greater than 400 parts per million (ppm) in the atmosphere. We surpassed this in 2019 with 409.8ppm[1]. Although the Environmental Protection Agency has determined levels as high as 1000 ppm is a safe limit for humans, we believe that educating the population as soon as possible is the most effective tactic in slowing down climate change. How does yearly CO2 emissions correlate to the amount of CO2 in the atmosphere? When will we hit this "safe limit"? It is commonly believed that the population needs to "do it's part" in decreasing emissions but how far does decreasing shower time by two minutes, removing single use plastics, and carpooling to work really go? Who or what is really contributing the most to CO2 emissions?

Results:

Our team's analysis of the data found that, as expected, the emissions for nearly every country increased over time, with some minor exceptions. Furthermore, the distribution of annual emissions was not evenly distributed amongst all countries. Seen in Figure 1 below, countries like China, the United States, and India accounted for half of the global emissions in 2017, while other countries had a far smaller impact. Shown below is a pie chart of the 2017 global emissions data where this can be better seen.

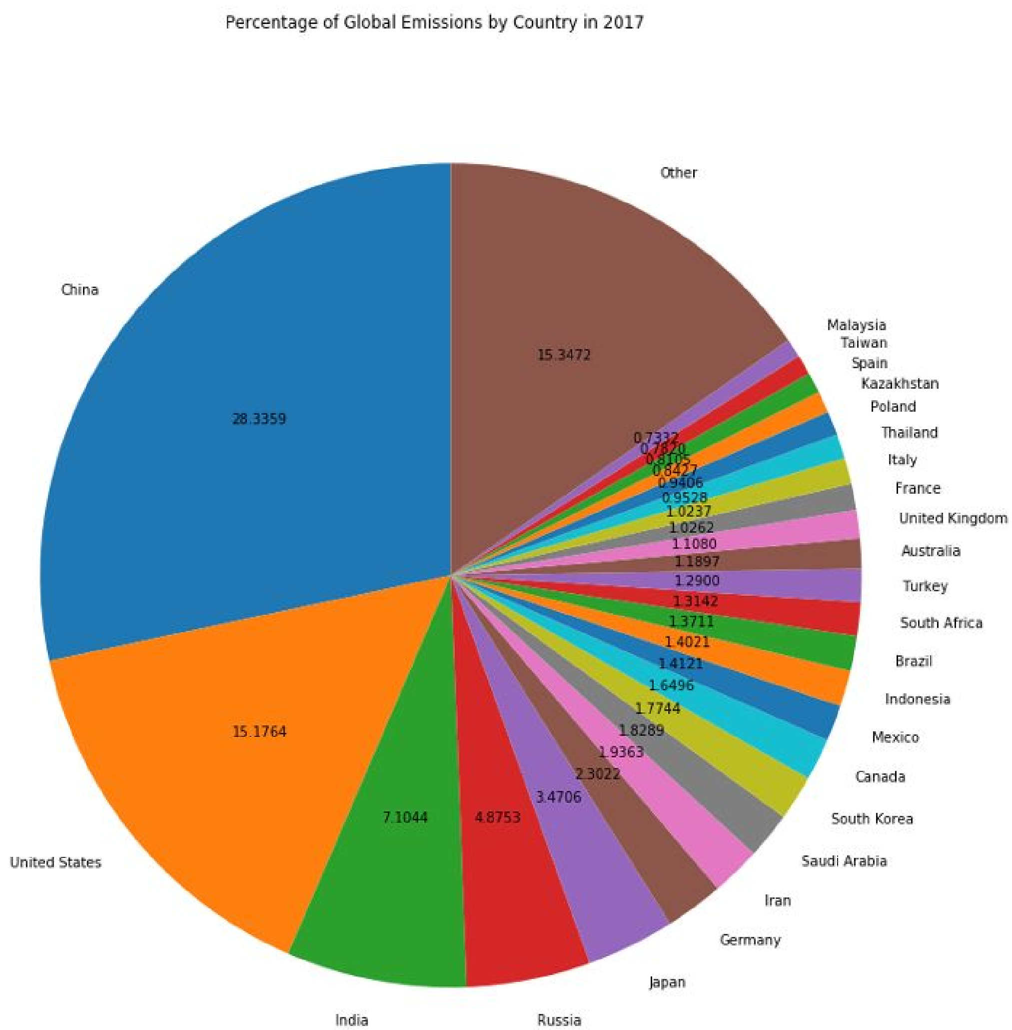

Figure 1 - Pie chart of top 25 countries contributing to global carbon dioxide emissions in 2017.

The pie chart above and the information it contains is very useful in depicting the distribution of global emissions for a snapshot in time, but our team was also interested in how global emissions evolved over time. The line chart below shows this evolution.

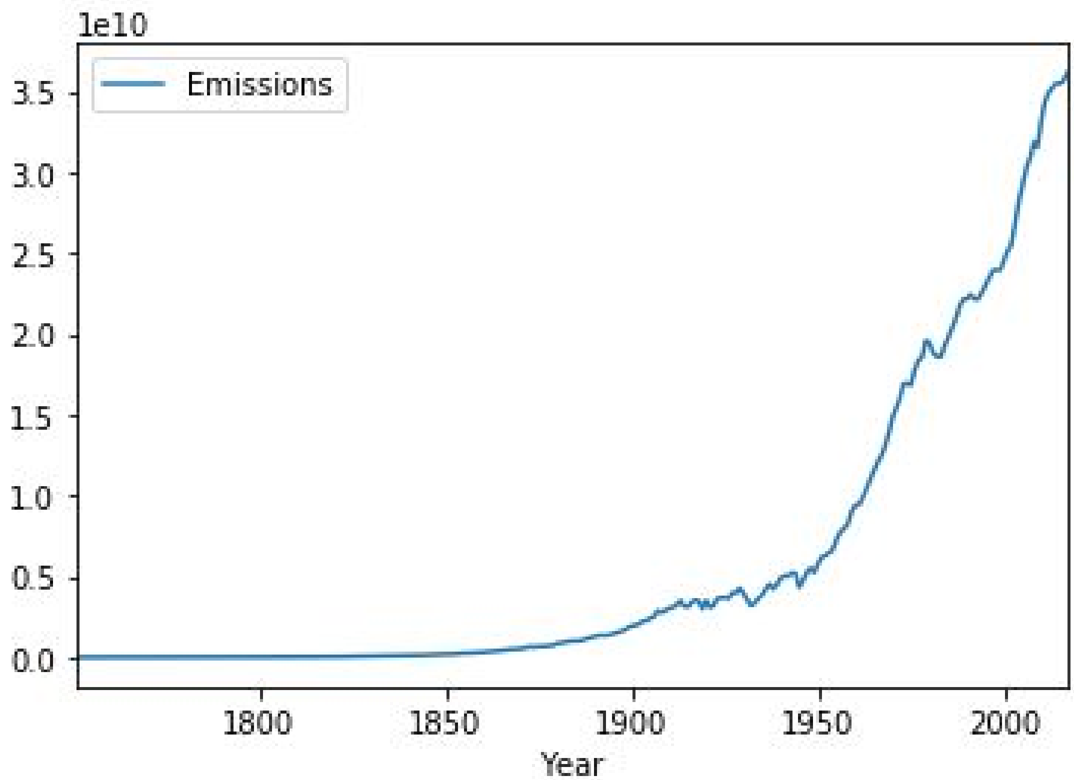

Figure 2 - Total global carbon dioxide emissions over time.

One key piece of information to note is that the overwhelming majority of countries hadn't started tracking data until the late 19th century to mid way through the 20th century. So that is the reason for the lack of growth between the years 1751 and 1850. Through the plot in Figure 2, you can see the rapid increase in emissions in the 1950s which makes sense when considering the modern economy that followed WWII, the number of cars driven, and the number of planes flown in this modern time when compared to early decades and centuries.

While emissions did generally increase year over year, our group was interested in finding data corresponding to countries or time frames that allowed for annual emissions to actually either reduce year over year or hit 0 altogether and understand what may have caused this. In doing so, our team found that, in 2009, nearly half of the world's countries saw a reduced annual emissions compared to the previous year. Our team speculates that the Global Financial Crisis that began in the middle of 2007 and lasted through early 2009 may have some correlation with this anomaly. Regarding countries with a true annual emission of 0, we found no values that believed to honestly indicate a country's emissions to reach 0.

Our team was also interested in any data relating to specific countries or timeframes that saw a significant boost in annual emissions, more specifically, emissions doubling year over year. Interestingly enough, our team found that in 1950, 26 different countries experienced a doubling in their annual emissions. While our team is not entirely sure of a direct cause for such an event, we speculate that these countries may have been entering a phase of rapid industrialization following the second world war.

Realizing that large scale, macro-economic events could have a significant impact on our data, our team then became interested in looking at how the emissions data was affected by notorious historical world-wide events, such as World War II and the Great Depression. We focused on the main players in before, during and after World War II, between the years of 1927 through 1950. The line chart shown below in Figure 3.

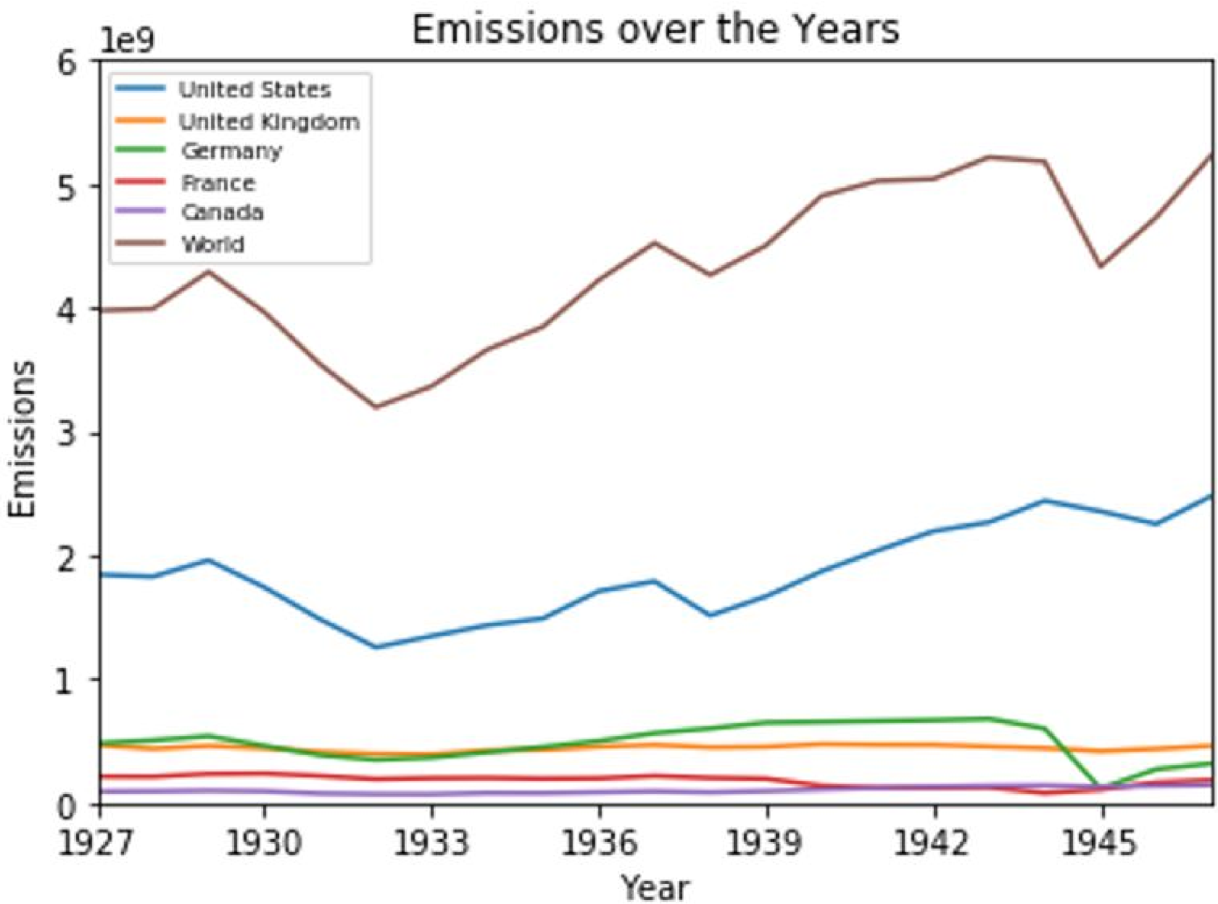

Figure 3 - Top contributing countries to global carbon emissions froM 1927 to 1950

Through this graph it can be seen that the United States had more or less steady growth during the years of 1939-1948. While the US had not joined the war until late 1941, they began shipping supplies to Western Allies at the onset of the war in Europe. We see the United Kingdom and Canada keeping emissions levels steady throughout the war period and before. We notice that France has sustained a dip in their emissions between the years of 1939-1945 which again is expected considering the occupation that occurred during those years. Germany maintained steady levels until around 1944-1945 where it fell off significantly. This is again expected as throughout the war they maintained industrial facilities, however as the war progressed Germany began losing, and through allied attacks on industries and infrastructure, the emissions decreased. These observations are shown along with the total world Co2 emissions at the time which showed growth between the years of 1939-1944, experienced a drop between 1944-1945, then again shot up from 1945 onward.

The first visualization done for a significant event other than WWII was for Syria during their civil war. We subsetted the data for Syria during the years of 2000 to 2017 to show what kind of impact was made on syria during their catastrophic civil war starting in 2011, as we expected when looking at this chart, Syria had a significant drop off in the Co2 emissions levels during the years of the civil war which can be attributed to the decimation of major cities, industrial cities, and normal populations livelihoods.

The next significant event in question was in a similar light, our team looked at Lebanon and subsetted the data for the country between the years of 1970 to 2017. We wanted to see what impact the civil war they experienced through the 1980s and 1990s would have a similar impact on their global Co2 emissions. However, as can be seen from their chart, their Co2 emissions didn't seem to have a noticeable change during the civil war years.

Next we looked at this century with the specific years of 2000 to 2017 to see if the internet age, and the golden age of e-commerce has led to a significant increase in global emissions. One of the data points we have in our data set is international transportation and so we plotted the increase change in global emissions during the years of 1980-2017 but didn't notice any significant increase in the slope of the plot between the years of 2000-2017 showing that based on the data we had, the recent boom in e-commerce hasn't made as significant impact on overall emissions for international transportation.

The last significant event we examined was for North Korea, specifically looking at how the county's global emissions have changed over time. We subsetted the data from the years of 1980 to 2017 to see what major impact there may have been to overall emissions and we noticed a significant drop off in the nation's emissions beginning in the late 1980s. From that moment the emissions levels dropped significantly before evening, at a fraction of peak levels, during the 21st century.

Our team also took a brief look at annual emissions for each continent, visual found below in Figure 4. It's important to note here that our data has North and South America combined into one category called the Americas. We found that Europe, Asia, and the Americas made up a large majority of global emissions with Europe leading through 1990, but then getting caught by Asia. As of 2017, Asia was contributing nearly twice as much to the global emissions than the next highest producing continent.

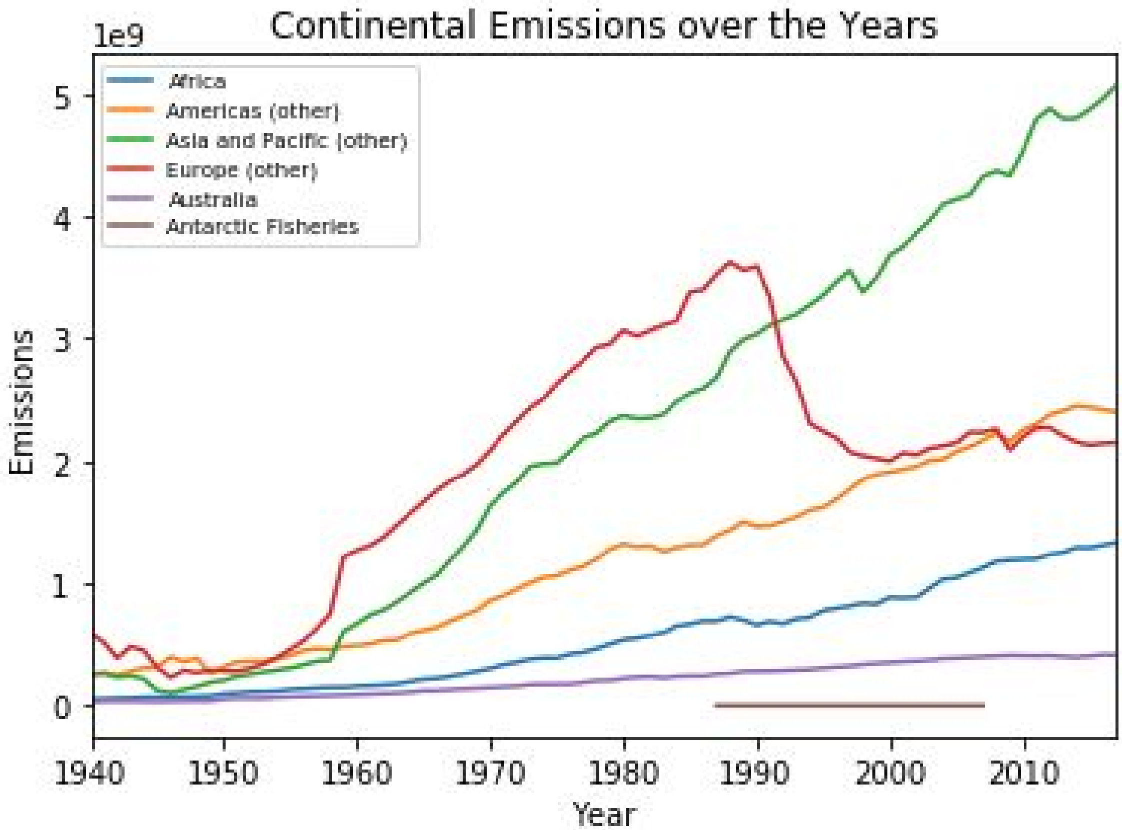

Figure 4 - Continental carbon dioxide emissions over time.

Finally, our team was interested in looking at emissions of international transport as the modern world quickly evolves into an ever increasingly connected society. As of 2017, international transport accounted for roughly 3% of global emissions. Comparing that to the above pie chart of the various countries, that would put it just below Japan, and in 6^{th} place. Granted, international transport is accumulated across all countries, but the sheer fact that global international trade produces more emissions than a vast majority of the world's countries is a staggering fact in itself. Our world is undoubtedly becoming more and more connected as technology progresses, and more reliant on fossil fuels to sustain these connections.

There is no standardized understanding of how much yearly CO2 emissions our planet can handle, but the total amount of CO2 in the atmosphere continues to increase, indicating that the production of CO2 emissions is greater than the rate of CO2 removal by the planet. Additionally, no standardized method of correlating metric tons of CO2 emissions per year to percent atmospheric CO2 ppm increase has been accepted, although both seem to be increasing at an alarming rate. The “safe limit” range is largely disputed but thought to be approximately 1000 - 5000 ppm in the atmosphere and 100 - 500 billion metric tons of CO2 emissions yearly[2]. Using our estimated logistic equation, we estimated that if annual CO_2 emissions continue on the same trend, we would produce 100 billion metric tons of CO_2 in the year 2174.

Looking at the data, we determined that the data strongly correlated with a logistic function. Using the last 50 years of total world CO_2 emissions, we used a polyfit function to determine the slope and the intercept. We fit the following equations:

$$\text{estimated total emissions} = 8.75*10^{11}*\ln(\text{year}) - 6.62*10^{12}$$

$$\text{estimated year} = e\hat{}((\text{estimated total emissions} + 6.62*10^{12})/8.75*10^{11})$$

With an estimated “safe limit” of 100 billion metric tons of CO_2 emissions annually, we used the second equation and arithmetic to estimate the year we would reach this threshold. The estimated year was 2174.

Using a method to subset our country data to a singular entity and year, we determined how much CO_2 was emitted on that given year and how many years it would require for an individual and the entire population of the US (data from the year 2020) to combat that emission by removing single use plastic, removing emission transmitting car travel from traveling for work, and decreasing shower times by 2 minutes. On average a human produces 50 kg of plastic waste per year[3], drives 32 miles round trip for work 240 days of the year[4], and showers for approximately 8 minutes[5]. This approximately equals 0.3 metric tons, 3.16 metric tons, and 0.155 metric tons of CO_2 emitted per year respectively per person and 98.4 million metric tons, 1.04 billion metric tons, and 50 million metric tons per year respectively for the entire population of the US[6]. Additionally, there was a user interaction allowing users to search other countries for various years to see how individuals and the US population could combat those emissions.

What can individuals and the US population do to combat CO_2 emissions?

The total CO_2 emissions in the world in the year 2017 was 36.2 billion metric tons. This would take an individual 120.5 billion years of removing single use plastic from their lives, 11.5 billion years of emission free work travel, and 233.1 billion years of showering 2 fewer minutes to combat these emissions. For the entire population of the US this would take 367.4 years, 34.9 years, and 710.5 years respectively.

In the year 2010, total world CO_2 emissions was 33.1 billion metric tons. This would take an individual 110.2 billion years of removing single use plastic from their lives, 10.5 billion years of emission free work travel, and 213.2 billion years of showering 2 fewer minutes to combat these emissions. For the entire population of the US this would take 336 years, 31.9 years, and 650 years respectively.

For 1950, total world CO_2 emissions was 5.79 billion metric tons. This would take an individual 19.3 billion years of removing single use plastic from their lives, 1.8 billion years of emission free work travel, and 37.3 billion years of showering 2 fewer minutes to combat these emissions. For the entire population of the US this would take 58.8 years, 5.6 years, and 113.7 years respectively.

How does the US compare to itself?

The total CO2 emissions in the US in the year 2017 was 5.3 billion metric tons. This would take an individual 17.6 billion years of removing single use plastic from their lives, 1.7 billion years of emission free work travel, and 34 billion years of showering 2 fewer minutes to combat these emissions. For the entire population of the US this would take 53.6 years, 5.1 years, and 103.6 years respectively.

In the year 2010, total US CO2 emissions was 5.7 billion metric tons. This would take an individual 19 billion years of removing single use plastic from their lives, 1.8 billion years of emission free work travel, and 36.8 billion years of showering 2 fewer minutes to combat these emissions. For the entire population of the US this would take 57.9 years, 5.5 years, and 120 years respectively.

For 1950, total US CO2 emissions was 2.5 billion metric tons. This would take an individual 8.5 billion years of removing single use plastic from their lives, 803 million years of emission free work travel, and 16.3 billion years of showering 2 fewer minutes to combat these emissions. For the entire population of the US this would take 25.8 years, 2.4 years, and 49.8 years respectively.

Our research shows that it is inevitable CO2 emissions will continue to increase. More importantly, we also found that the individual impact of decreasing CO2 emissions from daily lives does not make enough of an impact. This is true even when the entire population of the US is using emission free travel for work, removing single use plastics, and taking shorter showers. These three concepts have been suggested as ways to combat global warming, but they are not cutting it. There’s a greater cause for global warming and citizens are not the root cause.

Testing:

Our team utilized several simple sanity check tests as we were coding, as well as some more complex unit tests for functions that we created along the way. Regarding the simpler testing we performed, we were able to make use of print statements to easily and effectively check for logical errors in our code. We made sure attempted exports of csv files were actually being exported, and we tested every possible path of the using interfacing component to ensure everything worked appropriately. We also made sure all of the visuals we were attempting to show on screen were actually appearing. Regarding our unit tests, we tested two functions that our group created to help subset the data, as they were heavily used throughout the project and needed to be correct and consistent across several use cases. One function would subset the data based on a year range entered by the user, and the other would subset by a specific entity. For the subset by year function, a snippet of a unit test performed by our team can be seen below in Figure 5.

```python
class SubsetYearTestCase(unittest.TestCase):

    def test_is_subset_year_handling_single_year(self):

        sampledf = subset_by_year(data_countries, 2005)
        years_included = sampledf['Year'].unique()
        # Test
        self.assertEqual(years_included, [2005])
```

Figure 5 - Example unit test for subset by year function.

This unit test is checking to make sure that the optional parameter of stop year is truly optional, and if not entered by the user, the function will still create a data frame, and that data frame will have data with only the correct year.

Shown below is another snippet of a unit test our team performed, but this time for our subset by entity function.

```python
class SubsetEntityTestCase(unittest.TestCase):

    def test_is_subset_entity_working(self):

        sampledf = subset_by_entity(data_countries, 'Ecuador')
        entities_included = sampledf['Entity'].unique()
        # Test
        self.assertEqual(entities_included, ['Ecuador'])
```

Figure 6 - Example unit test for subset by entity function.

In this unit test, our team is looking to see if the new data set created by the function actually only contains entries with an entity of Ecuador. Both of the above unit tests make use of the unique function to pull out all unique values within a column of the data frame.

Our team performed several other unit tests for these functions, but the above two snippets provide a good idea of what we were testing for, and the relative use of the functions. To summarize, our team made use of unit testing for heavily used custom functions throughout the project, as well as simple sanity checks like print statements and visual checks.

Conclusions:

The knowledge that human activity can, and does, shape the ecosystem of our planet is perhaps the most vital information to our future as a species to come from scientific research. No activity on Earth can escape the influence of the environment, and its sensitivity to activities like emission of greenhouse gasses must be met with equal sensitivity on the part of our societies to protect the planet and ensure our own survival. Our group's investigation into historic data pertaining to CO_2 emissions has, if anything, emphasized to us that the present problem cannot be solved by individuals acting alone, or even individual nations, but is inherently a function of the actions and efforts of the world's population and industries as a whole. We have seen how large-scale human events like wars, economic fluctuations, and growth and decline of industries can affect emissions on the scale of a nation, as well as the timeframe over which the current state of things has developed, and can thereby gain an understanding of the scale of effort required to alleviate these effects through prevention and mitigation.

Our program has allowed us to more easily discover and visualize trends in this vital data that has not only improved our understanding of the subject but has led us to postulate about causes and effects of changes in particular periods. We have been able to determine periods of significant change in emissions and discuss their causes, as well as gain an overview of the current state of global emissions. Were we to extend the scope of this project, we might try to incorporate other datasets that measure other climate metrics or provide important context like population and demographic information. This sort of investigation would allow us to understand key issues related to emissions and its effects more deeply and perhaps apply our findings more concretely. We could then expand this functionality into the user-facing portion of the project by supporting more data and types of visualization in the visualization tool. We feel this investigation has improved our understanding of working with and querying large datasets and has provided us a starting point for investigating complex problems of this scale including important aspects like planning, exploring large datasets, and validating our work.

Project Repository

https://github.com/bmfeciura/cs5010-project

Sources

[1] “Climate Change: Atmospheric Carbon Dioxide: NOAA Climate.gov.” *Climate Change: Atmospheric Carbon Dioxide* | *NOAA Climate.gov*, 14 Aug. 2020, www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

[2] “Carbon Dioxide.” *Wisconsin Department of Health Services*, 20 Dec. 2019, www.dhs.wisconsin.gov/chemical/carbondioxide.htm.

[3] Pamuła, Hanna. “Plastic Footprint Calculator.” *Check Your Environmental Impact*, Omni Calculator, 16 May 2019, www.omnicalculator.com/ecology/plastic-footprint.

[4] Harris, David. “How Far Do Americans Drive to Work on Average?” *It Still Runs*, 10 Jan. 2019, itstillruns.com/far-americans-drive-work-average-7446397.html.

[5] Lindberg, Sara. “Shower Time: How Long to Take and Are Longer Showers Better?” *Healthline*, Healthline Media, 20 May 2020, www.healthline.com/health/shower-time.

[6] “Tips for Reducing Your Carbon Footprint.” *Tips for Reducing Your Carbon Footprint* | *Clackamas County*, www.clackamas.us/sustainability/tips.html.