Climate Change: Factors and Rates - **Process Book**

CS 5630

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Overview and Motivation

For the final project in CS 5630, students are asked to create groups and implement a web-based interactive visualization. This visualization should allow the students to answer any questions they may have that come from the topic of their choosing. The project allows students to create a visualization of their choice using any programming software, implement their project using a modern web framework, and evaluate any results they find during the project.

The title of our final project is ***Climate Change: Factors and Rates***. The reason this topic was chosen for the final project was due to the climate crisis being an universal issue between countries and continents. This topic has been discussed among scientists and environmentalists for years and will continue to be discussed for many more. Climate change affects every individual on a daily basis, whether they are noticing it or not. Another reason for this choice was because when it comes to the data surrounding the climate change debate, there exists a plethora of it. This data can help show the rates and changes in the rising global temperatures around the world. Climate change affects a person's health, ability to grow, housing, safety, and work (United Nations).

Climate change is known to be a controversial topic in society nowadays. There is an evergoing debate about whether climate change is something for people to worry about or not. The effects of climate change will become irreversible if something is not done soon to reverse the effects. Since 1880, Earth's temperature has risen by an average of 0.14° F. per decade (Lindsey and Dahlman). The 10 warmest years that exist in the historical record have all occurred since 2010. While we know that the heat is increasing, we also want to know what factors are contributing to this global temperature increase.

Our final project focuses on the factors that have contributed towards the rise in Earth's temperature and at what rate each factor is affecting the atmosphere's temperature. We are hoping that the results we find from this final project will help us to analyze the current factors that contribute towards the climate crisis. We also hope to find which factor has the strongest correlation with the global temperature rising. The factors we are evaluating in our final project are: the effect of CO2 emissions, methane emissions, and deforestation habits.

CO2 emissions are a large part of the climate crisis. The impact of CO2 emissions on the earth's climate has become a very important issue in recent years. The production of CO2 emissions come from various human activities. This can be things such as the use of fossil fuel,

deforestation, and any sort of industrial process. By looking into the CO2 emissions each country is producing and emitting it can help us get an understanding about the effects of climate change. It can also help us develop ways to begin fighting the climate change issue. A dataset focused on CO2 emissions can be an important resource for helping us understand the global climate crisis.

The next factor we believe plays a large role in climate change are methane emissions. Methane emissions stem from the production and transportation of coal, natural gas, and oil. Methane emissions can also be a result of livestock and other agricultural practices that are done. It can also come from how certain areas of land are being used and the decay of organic waste in solid waste landfills. Methane is the second most important greenhouse gas, coming in more potent than CO2 emissions. This being said, there exists less methane emissions than CO2 emissions in the atmosphere. A dataset that is focused on methane emissions can help us look into the climate crisis, but it can also help us develop solutions for decreasing methane emissions.

The last factor we looked into was deforestation habits. Deforestation can also be a causing factor to producing CO2 emissions and methane emissions. Deforestation and forest degradation is responsible for 15% of all greenhouse gas emissions (WWF). Deforestation does not just include human-caused, it also comes from wildfires. The number one cause for deforestation comes from expansions in agriculture. “As the human population continues to grow, there is an obvious need for more food. (WWF)”.

Viewing these three factors it is obvious to see there is a lot to uncover when it comes to climate change and its effects. Taking the top three factors of climate change into account allows us to have a better analysis on the effects of climate change. This adds enormous amounts of greenhouse gasses to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming (European Commision). Our final project investigates a deeper analysis of the top three factors of climate change and the effects they have on the global temperature.

Related Work

When it came to deciding a topic for the final project, climate change was one we all quickly agreed to. The climate crisis is a topic most people know about or have at least heard about at least once in their lifetime. One thing that drew inspiration to this topic was the intense

temperatures during the beginning of the 2023 fall semester. The daily temperatures were anywhere from 90°F-100°F all of August and September. People constantly blamed climate change for the high daily temperature, which led to the topic of climate change being chosen.

For the final project, we found it fascinating to try and visualize an interactive temperature map of the Earth. One project that we pulled inspiration from was homework four. In that assignment we worked on an interactive global map of the countries and their maximum number of covid cases. This homework used a color scale, which was what we were hoping to implement when visualizing the atmospheric temperature for each country. This assignment also taught us how to use geoJSON to draw a global map and have each country be its own specific coordinates.

For the globe visualization, we also pulled inspirations from normal global temperature maps. Here is an example of one:

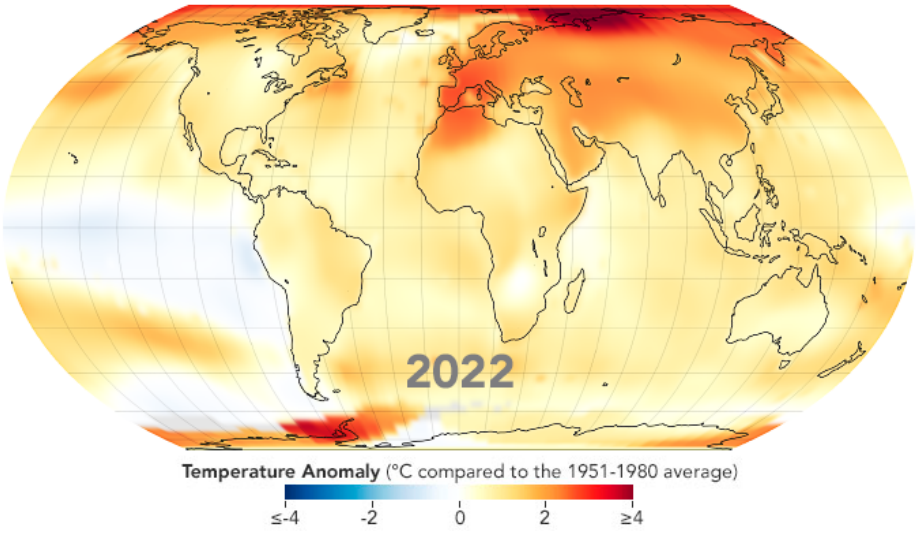


Image 1 (NASA Earth Observatory)

In the visualization above, you can see that the warmer a country is, the deeper red the country is colored. While this visualization does a scale from blue to red, we decided to do a deep purple to green color scale. This color scale was chosen because it allows a user to easily see the differences in the growth rate. This global map also measures temperature, but it does not seem to be as precise as the temperature for each individual country. We also added the outlines for all countries unlike the visualization above.

Questions

The topic of climate change can bring many different questions. Some questions can be based on the theory that surrounds climate change and some can be about the rates of climate change itself. Climate change itself is one of the biggest topics that only those that take the time to look at the data can truly understand. Climate change takes understanding and looking at visualizations to truly see the effects and the change in temperature throughout the years.

During the process of creating our final project, there were several questions we were trying to answer. The first question we wanted to answer was: “What evidence is there that shows the climate is changing?” When it comes to answering this question it will require looking at several factors of climate change and overall global temperature per country. While there are many contributions to climate change, we decided to narrow down our analysis to only three factors: CO2 emissions, methane emissions, and deforestation habits.

The next question we wanted to answer was: “What factor of climate change contributes most to the rise in the global temperature per country.” For this question, each factor had its own data set. This made working with the data a little more challenging, but it allowed us to do a deeper analysis into each factor of climate change.

The last question we were hoping to answer was “At what rate is the temperature rising due to the factors we are using for our project?” This question requires extra nayliss and the use of outdoor resources that are not pictured on our website. This question required doing some research through educational books and websites. While the line charts cna help show a correlation within the factors and the temperature, some extra analysis is needed to get a thorough answer to the question.

While the evolution of our project continued, there were not any changes made to the questions we had originally asked. Our questions brought on new ways for us to test visualizations and see what form of visuals showed the data the best. While we did not develop any new questions, our questions did seem to change. We started wondering in what ways can the global temperature change with each factor and what visualizations best represent this change over time.

Data

When approaching the questions we wanted to answer with our analysis, we understood finding one dataset with all of the information was almost impossible. To analyze climate change

along with multiple factors meant finding several datasets to work with. Our source for finding data was through Kaggle. Kaggle provided multiple datasets with many categories to help us find correlation between each dataset we pulled. Each dataset we chose to work with is a .csv file.

The first dataset we worked with was Global Warming Trends (1961-2022) created by Muhammad Jawad Awan. This dataset is the one we used to find the global temperatures throughout the years. The Kaggle dataset provided us with the years 1961-2022, which allowed us a lot of room to focus on what range of years we wanted to work with. The dataset offers us with annual surface temperature data for almost all of the countries. The dataset provides information on the surface temperature anomaly relative to a global mean baseline (in degrees Celsius) for the corresponding year and country. This data set had several categories we used for the visualization, including: ISO code, country name, the year, and the temperature for each year. In this dataset, there are some missing temperature values that were filled with 'NaN', so in the visualization those will be represented with a grey coloring.

The next dataset we used was CO2 Emissions created by Ulrik Thyge Pederson. This dataset provides a comprehensive view on the amount of CO2 emissions produced by each country from the years 1960-2023. This dataset was last updated 8 months ago, so the information is recent and accurate. This dataset covers each country worldwide. The information is compiled from several different sources, including: United Nations Framework Convention on Climate Change (UNFCCC) and the International Energy Agency (IEA). We will use this dataset to model emission changes over time and how they correlate with the global warming trends.

Our next dataset is Methane Emissions Around The World (1990-2018) created by Koustubk. This dataset provides information of the methane emissions from around the world. Each country has information on its production of methane emissions. The dataset has information such as the country name, the type of gas being produced, and the total unit (in tons) of emissions being produced per year. The dataset ranges from the years 1990-2018. This data set uses information from the dataset Climate Watch Data.

The last dataset we used for the final project was Deforestation and Forest Loss created by Chiticariu Cristian. This data set has information on the annual change in forest area for each country. It also provides information about the net change in forest area minus deforestation. It has several attributes we will be using for our visualization, including: entity (country), code

(ISO3 country code), year, and net forest coverage per year. The dataset has information from 1990 – 2015.

When it came to our data processing, there was not a substantial level of data cleaning to do. When first conducting a preliminary examination of the datasets above, it was indicated that the following cleanup was required for each dataset. For the Global Warming Trends (1961-2020), the ISO2 country code needed to be converted to an ISO3 country code. For each year value there was a F that indicated Farenheit, that was removed from the data. The last cleanup precaution was converting the temperature values to be celsius. The CO2 emissions dataset did not have large amounts of data cleaning to do. The following cleaning was needed: input the missing CO2 emission values with average where deemed appropriate and converting the CO2 emissions to be metric tons to match the methane emissions data. The only cleaning required for Methane Emissions Around The World (1990-2018) was adding a ISO3 country code to the data. Finally, the Deforestation and Forest Lost dataset was missing net forest conversion values and we deemed those difficult to impute so we considered dropping those fields instead.

Exploratory Data Analysis

For our Exploratory Data Analysis, we relied on line charts to identify trends and verify data viability. The charts revealed distinct trends in increasing surface temperature, CO2 emissions, and methane emissions. However, net forest area steadily increased from 1990 until 2010 with a decline from 2010 to 2015.

Net forest area measurements were taken every ten years until 2015, so for a given view, the factor for net forest area will change every five or ten years while other factors will update every year for the same view. Interactive components that allow users to select a specific year will be limited to 1990, 2000, 2010, and 2015 for net forest area only views.

Initially when it came to our data, we started off with basic line charts. We graphed the trends of the factor change over the years of 1990-2015. These line charts helped us see the initial trend and allowed us to better understand what factors correlated most with the global surface temperature anomaly. The insights that were found were that CO2 emissions have the strongest positive correlation over time and to the global surface temperature anomaly. Methane emissions have the second strongest positive correlation over time to the temperature. Finally,

deforestation was the third strongest. These insights helped us to verify the map visualization and the accuracy of the color scale and time scale.

Design Evolution

November 3: Initially, we knew we wanted to report the factors that correlate the best with our dependent variable of rising temperatures. This is the focus of the project and a simple bar chart of different correlation rates per factor would suffice (*Figure 1*). However, there is always more to the story of global warming. We wanted to also visualize how different countries experience temperature increases, deforestation rates, methane production, and CO2 emissions over time. This is most simply expressed with line charts, yet we knew that a world map would more intuitively capture continental and geographic differences in these rates. Therefore we combined a line chart element with a world map visualizer to make it interactive. Through this process we gained the insight of taking the perspective of a viewer of our visualization. A user of our visualization would remember our data better if they viewed a global image rather than a line chart. They would also remember it better if they interacted with it, and were surprised by changes over time. These insights informed us that we need our final product to be a mix of visualizations, from simple bar charts and scatter plots (*Figure 1 & 3*) to an interactive world map with several tabs for different factors and a slider for time change (*Figure 2*). Each country can additionally be clicked for more specific line chart information so the information is not too vague. At a high level, our visualization is split into drop down tabs for simplicity so there is not an information overload (*Figure 4*). The html site has a title, introduction tab for project context, factors tab for the main data and correlations, a world map visualizer tab as our central interactive visualization, and a conclusions tab to wrap everything up. This gives the user the option to use any one of these tabs at their convenience to better understand our project.

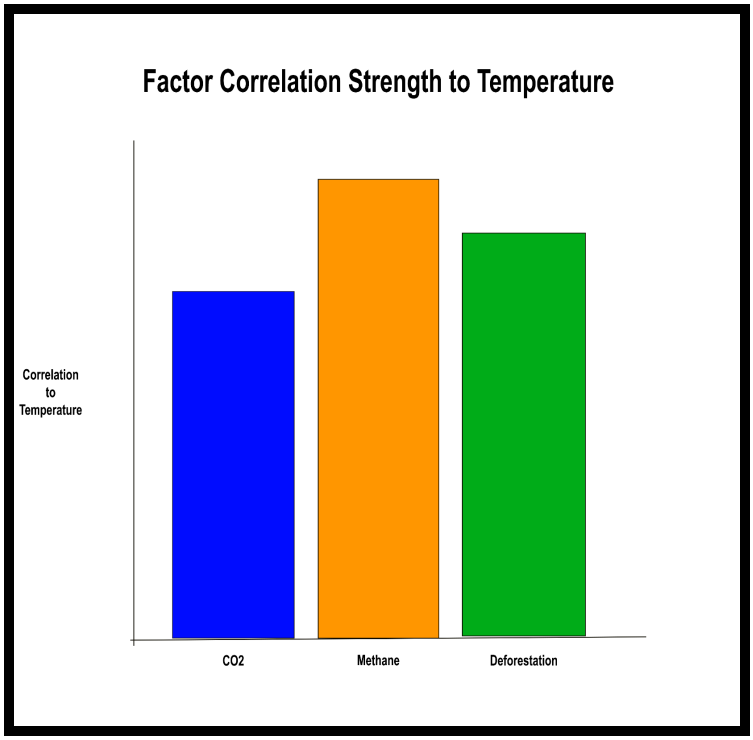


Figure 1

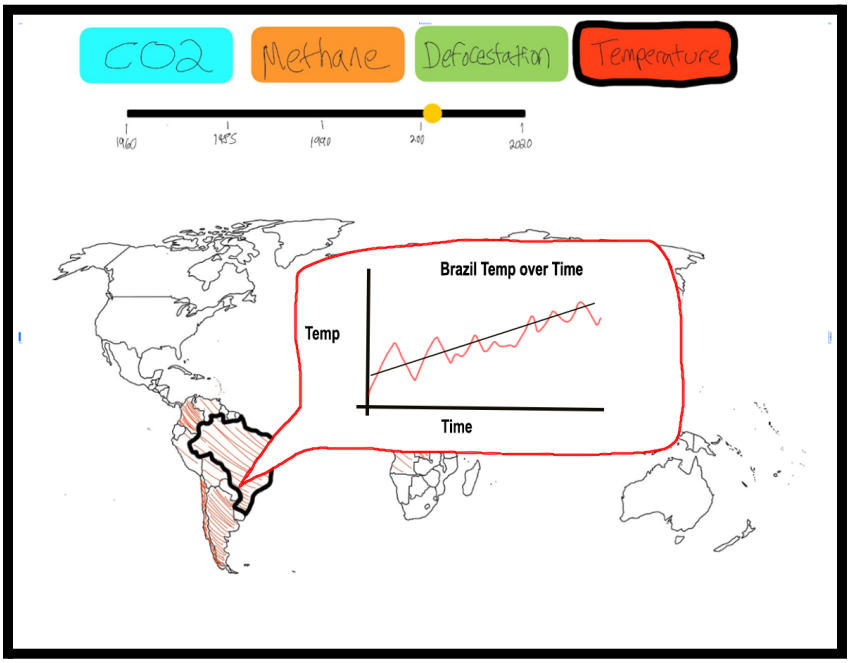


Figure 2

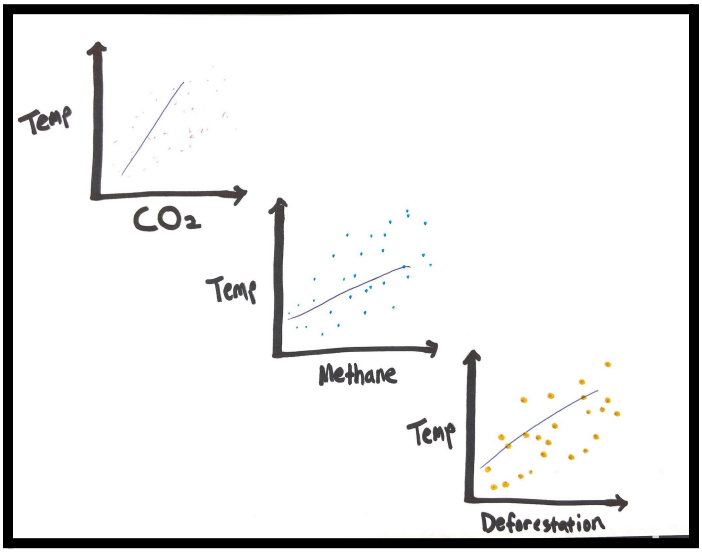


Figure 3

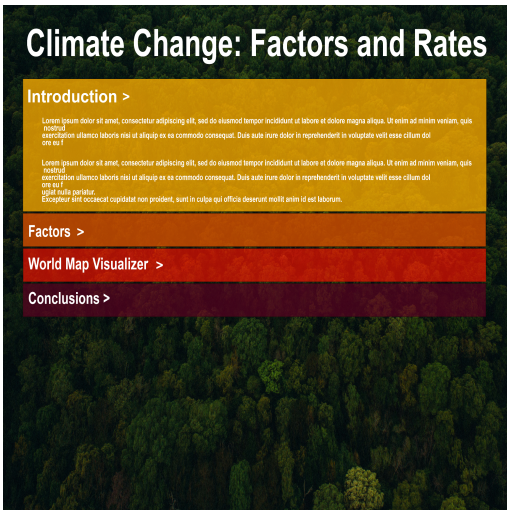


Figure 4

***November 29*:** As we continued to work on our project, we decided to deviate slightly from our original proposal. The first change we made can be seen from *Figure 4*. Instead of implementing a dark theme to our webpage, we took a light approach. We used a lighter background image and lighter orange for the selection tabs. Having all five tabs be the same brought in the Gestalt principle of similarity. This helps appeal to the natural human approach of grouping together similar items.

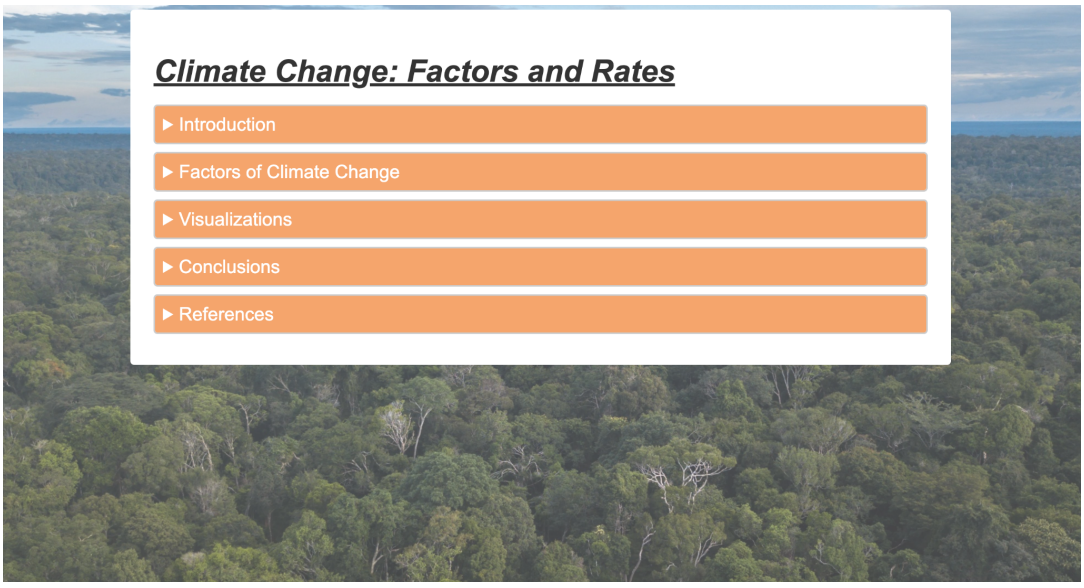
During the final stages of the project, it was decided to remove the idea of adding a bar chart to the website. A bar chart would not have been a good indicator of correlation when it

comes to the data that we are using. What we would have wanted to do is use a sort of ANOVA test and display that as a correlation map. A bar chart was decided to be ineffective for what we were wanting to have it convey so it was removed from the project as a whole. This allows us to not provide confusing or false information to the users that use our website. The point of the bar chart was meant to express which variables correspond to the greatest rise in temperature. This can be shown through the ranking system under the conclusion tab on the website instead.

Another change that was made was instead of having a small box pop-up on top of the World Visualization that showed the line chart such as *Figure 2*. We took the approach of having the line chart fill the whole screen and dim the background. This design approach was one we deemed important so that a user can look at the data being shown without having background distractions. We also tried to implement the Gestalt principle of continuation. It is known that the human eye will follow the smoothest past. We implemented a trendline to better show the principle of continuation to the viewer. Also, since the line chart is representing quantitative data, we decided to keep the visualization simple and clean so the information being shown did not get lost in the design.

Implementation

When first viewing our webpage, a user will be presented with 5 drop down tabs. The tabs are as follows: Introduction, Factors of Climate Change, Visualizations, Conclusions, and References. These tabs are represented by the color orange. This design choice was made to have the tabs easily catch the viewer's eye. We have also added a background to our webpage. The background adds a creative element to our webpage and allows the page to look less harsh to the human eye. Here is an image of the main page:



The main *interactive* visualization of our project is the World Map Visualizer. This visualization is a map of the globe and each country. Each country has their own attributes and data stored within its boundaries. In this visualization, each country has a specific color correlated with it. To help visualize the global temperature for the country, we used a pink to green scale to help indicate that the closer to green the country is, the warmer the global temperature is for example. We also have a time slider to allow people to see changes over time in each factor. We hope to add a "colored by change from previous year" checkbox and make the transitions smoother, as stated in the "evaluation" section of this report. Here is a photo of the first demo version of our visualization:

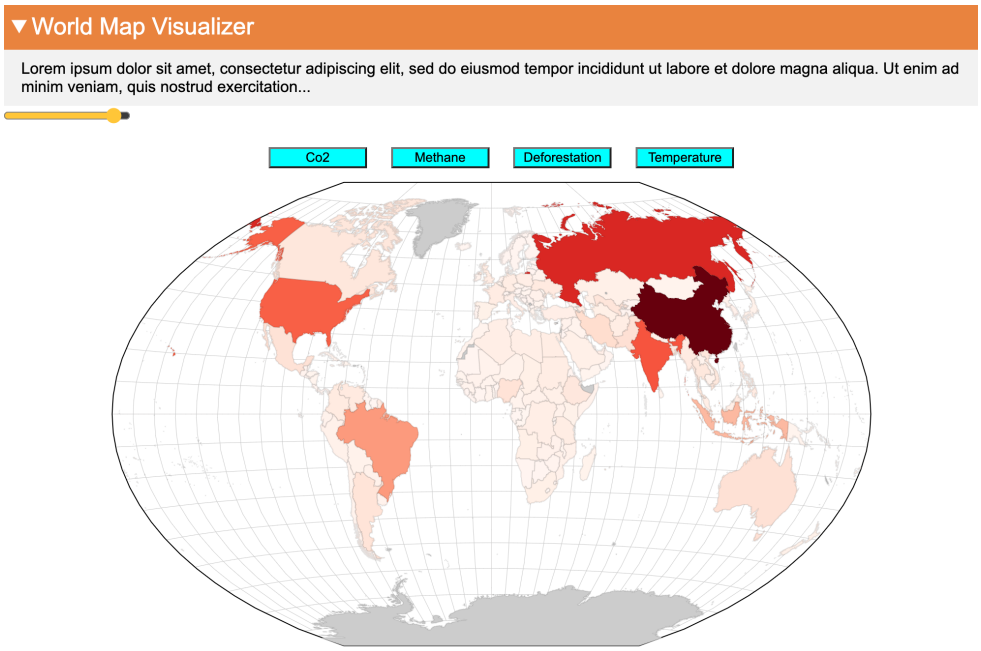


Figure 5: First Trial Of Final Project (*Nov. 3)*

In this project we use several different libraries to help get our website to operate correctly. The main library that is used extensively throughout the project is d3.js. This library helped us with a majority of our main tasks. js/script.js was used to load in all of the data .csv files that were found on Kaggle. To render the global map, we used js/map.js. Finally, to select and update all of the elements in our visualization, we used js/script.js and js/map.js combined.

Since the trial image above, we have created our final visualization. There are many changes that have occurred since our first trial of the final project design. We now have a colorful map implementation that allows our map to catch a user's eye. We have moved the interactive slider to above the entire global map and it indicates which year it is on at that

moment. There also exists a scale of units in the bottom left corner depending on the factor. When selecting a factor, the chosen factor will turn green. This helps the user know which factor they are currently viewing. Countries that do not contain data are represented by a grey color, for example: Antarctica. When hovering over a country, it will now outline itself and if clicked, you can see more information on the factor's rates.

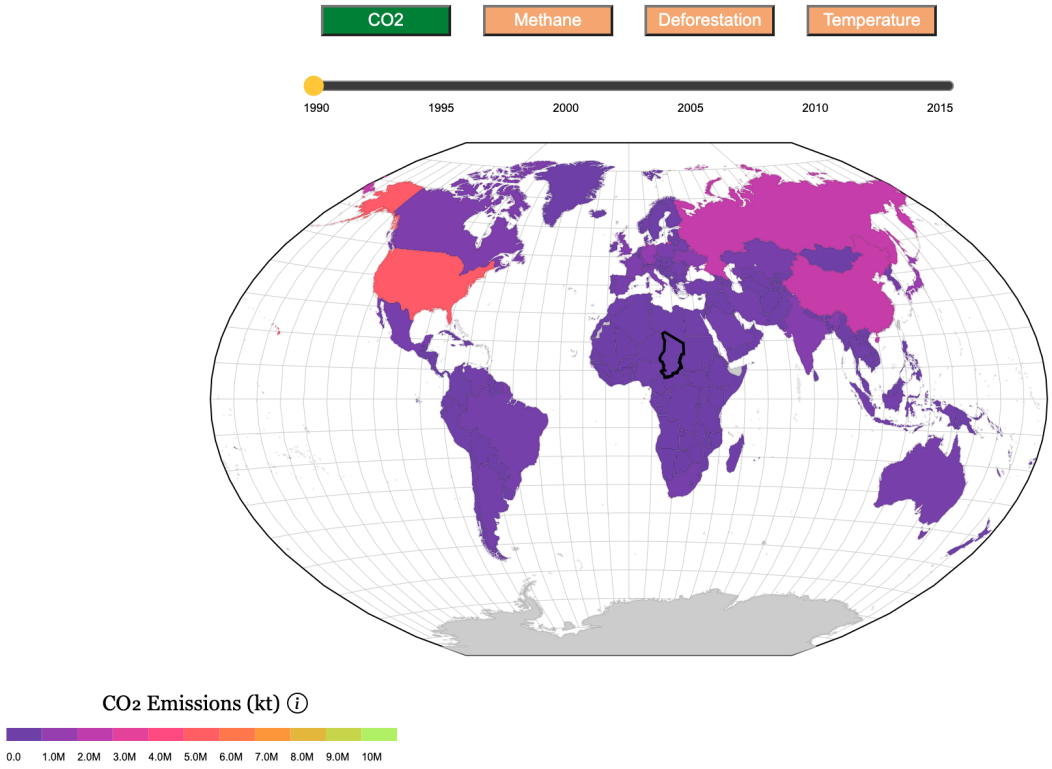
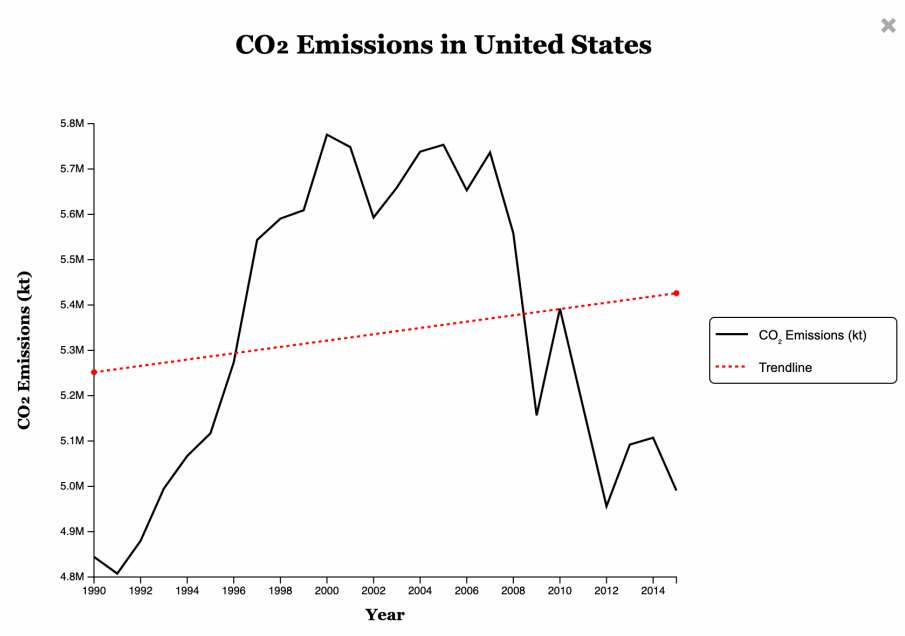
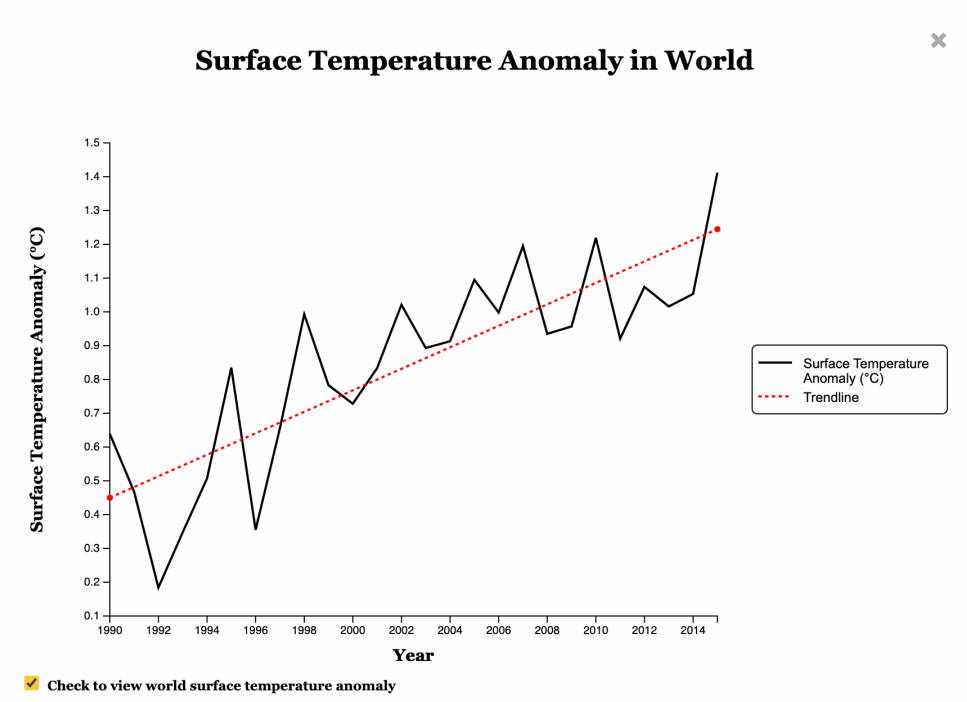


Figure 6: Final Design ***(Nov. 29)***

To be able to show the use of Exploratory Data Analysis throughout our project, we represented it through the use of line charts for each country. When a user selects a country on the map, a line chart appears that shows the average rise of the factor chosen from the year the year-slider is on to 2015. When this chart is first clicked, there is an animation that appears to draw the charts lines in place.Here is an example of a line chart that appears when clicking on CO2 emission for the United States:



The last element we implemented takes place for the temperature factor. When viewing the line chart of a country when the temperature factor is selected, there is a check box that says "Check to view world surface temperature anomaly". When this box is checked, the line chart shows the global surface temperature anomaly trend over the years. This allows a user to have knowledge about the world as a whole and the individual countries. The figure below shows an example of when the box is checked:



Evaluation

Here are a few interesting takeaways we found in the analysis of climate change and its rates. It appears when you increase the time slider, most variables (CO2, Temperature, Methane, etc.) fluctuate over time but generally increase. This is apparent by the strength of the hue. One can assume without the correlation graphs that these variables may all be correlated to one other (not proven causation by this project). This means our world map visualization appears to be doing its job. We plan to further improve it by making the transitions between color years smoother and adding a "colored by change from previous year" checkbox that shows country color based on its change in a certain variable. This better shows if countries are getting hotter or colder for example.

We were able to answer one of the questions we asked when creating our project. The answer to this question required outside work including reading research articles and educational website searching. The earth's temperature is increasing at an average rate of 0.17F per decade (Lindsey and Dahlman). This can be seen within our Global Map Visualization. As the slider increases from 1990 to 2015, there is a strong increase in temperature. At first, in 1990 all countries lie in the -1.0 to 1.5 range depending on geographical location. Once the slider hits 2015, we can see there exists no countries in the -1.0 range. The new range is now 0.5 to 2.5. Within 2 decades the global surface temperature has increased a dangerous amount.

While creating our final project, there were a few conclusions we were able to pull from our data and through analysis. As stated earlier, CO2 emissions are the number one factor that contributes to climate change. CO2 accounts for about 76% of the total, global greenhouse gas emissions (EPA). By using the line chart as visualization for the emission rate, it allowed us to understand just how rapidly CO2 emissions are growing over time. This visualization did not only help us with the CO2 emissions, but for all factors being implemented within the project.

When it comes to the implementation of our project, we believe it works quite well. While there are always things that can be improved, the visualizations run smoothly and all features work as expected. We implemented user interactions, animations, eye-appealing colors, and many other design principles. One way we could improve the quality of our visualization is by finding better data sets that allow there to be less undefined areas on the global map. This would allow for a more accurate representation of the factors we are trying to show and it would be more fair for each country in the visualization as well.

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