John McGrann
Paul Koh

Global Warming Time Series Data Visualization

Abstract:

An interactive web app was constructed in order to make a user friendly visualization of the different factors contributing to climate change on a global scale. Since so many factors are taken into consideration when discussing global warming and climate change, a number of data sets were used. The problems handled by the visualization include the difficulties the average user would face if they wanted to measure their own countries ecological footprint over time. It also gives effective ways for the average user to explore the vast amount of data available that contributes to global warming and climate change by allowing users to explore categories of emissions and emission rates per year based off selected countries and years, letting them view the available yearly rates of deforestation, and compare average monthly temperatures based on a selected year and country to the average temperatures per month for that country over the course of the available data.

Introduction:

The factors that contribute to global warming span several data sets, large portions of time, and are always presented in formats that only analyze the data on a global scale. Climate change is a global issue, and it will require the help and cooperation of countries worldwide. That being said, it is also important to therefore be able to gauge exactly how much each country has contributed to the issue at hand in order to decide what steps need to be taken in the future to address the problem. It is also important for the average citizen to be able to know exactly how much their country is contributing to a worldwide epidemic in order to inform their decision

making process when voting on representatives in their governments, or even on whether they choose to take action to make a change in their community.

Upon the research and development stage of the process, it quickly became apparent how unintuitive and difficult the process of data relevant to climate change based on geographic location or countries is for anyone hoping to inform themselves or conduct their own research. This helped to highlight the issue that we attempted to address in this visualization; creating an interactive way for the average user to be able to gauge a given countries ecological footprint over time. An embedded web application was created in order for the user to explore the datasets based on selected countries and different times that the data was available or contributed by their particular country.

Related Work:

In this section we will discuss the data sets that were obtained and how that data was gathered. This will include the metrics by which the data was measured, and how it was expressed in the final data set. After we have discussed the data sets gathered, we will also discuss why these data sets in particular were chosen.

The first dataset we were able to obtain was the National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring, from 1751 to 2014 from the Carbon Dioxide Information Analysis Centers Environmental Sciences Division at Oak Ridge National Laboratory. Publications with historical energy statistics made it possible to estimate fossil fuel CO2 emissions back to 1751 and Etemad et al. (1991) by tabulating coal, brown coal, peat and crude oil production by nation and year. Mitchell's work tabulates solid and liquid fuel imports and exports by nations and year. These pre-1950 datasets were digitized and CO2 emissions

calculated by Boden et al. (1995). The 1950-present CO2 emission estimates were derived primarily from energy statistics published by the United Nations, values for emissions created during cement productions were obtained from the US Department of Interior's Geological Survey 2016, values for emissions from gas flaring were also derived primarily from UN data, but were supplemented with data from the US Department of Energy's Energy Information Administration [1].

The next dataset we obtained was the one which contained the data for Methane (CH4) and Nitrous Oxide (N2O) emissions per country. We were able to extract this data from the Global Greenhouse Gases Emissions EDGAR v4.3.2 in which the emissions were calculated for the main greenhouse gases per sector and per country. The energy related activity data was mainly based on the energy balance statistics of the International Energy Agency (IEA), and the activity data for the agricultural sectors were mainly obtained from the Food and Agricultural Organization of the UN. The time series for the data spans from 1970 to 2012, and was used as the most extensive time span for the data that we were able to obtain for CH4 and N2O emissions [2].

All emission data is represented in gigagrams, or thousand metric tons. The per capita emission estimates in the CO2 dataset is expressed in the same measurement, but population estimates were not available to permit calculations of global per capita estimates before 1950 [1][2].

The deforestation data we obtained was extracted from the Global Forest Resources Assessment 2015 published by the Food and Agriculture Organization(FAO) of the United Nations. The design process by which the data was obtained involved users, national

correspondents and experts around the world in order to report data from 234 countries and territories, of which 155 reports came from the countries themselves - countries which contain 98.8 percent of the world's forests. The remaining 79 countries (containing only 1.2 percent of the world's forests) were reported as desk studies prepared by the FAO. The deforestation rates were calculated and recorded for each country at five year intervals from 1990-2010. The new Collaborative Forest Resources Questionnaire (CFRQ) partnership was the result of the joint commitment of six organizations: The Central African Forests Commission, FAO Forestry, FOREST EUROPE, the International Tropical Timber Organization, the Montreal Process and the United Nations Economic Commission for Europe. The CFRQ was able to successfully simplify and harmonize forest related data collection in order for it to be easier for countries to report, and for people to access [3].

The temperature data we gathered was obtained from the Climate Change Knowledge Portal (CCKP) created by the World Bank Group. The temperature data is generated from thousands of weather stations worldwide which are collecting temperature and rainfall data. In order to present the current climate conditions, the CCKP uses the globally available observational datasets derived from the Climate Research Unit (CRU) of the University of East Anglia, which are widely accepted and used as reference datasets in climate research. Historical data are derived from 3 sources, all quality controlled by leading institutions in the field. CRU provides gridded historical datasets derived from observational data and provides quality-controlled temperature and rainfall data as well as derivative products including monthly climatologies and long term historical climatologies for the period from 1901 to 2016 [4].

Now that we have identified the data sets that we have gathered and used in our visualization, we will discuss why these data sets were chosen. Scientists attribute the global warming trend observed since the mid-20th century to the human expansion of the greenhouse effect; warming that results when the atmosphere traps heat radiating from the Earth towards space (Earth Science Communications Team at NASA's Jet Propulsion Laboratory, 2019). There are four main gasses that prevent heat from escaping the atmosphere and which contribute to the greenhouse effect. Water Vapor is the first of these gasses, but it is dependant on the relative temperature and is therefore dependant on temperature data, which is why we obtained the temperature dataset. The other three gases which contribute to the greenhouse effect includes Carbon Dioxide (CO2), Methane(CH4), and Nitrous Oxide (N2O), which is why we obtained the original CO2 dataset from the CDIAC and then the subsequent dataset including CH4 and N2O emissions data. Since measuring the global warming trend requires analysis of these emissions over time, we chose to keep the CO2 dataset even though it contained data spanning further back in time than the CH4 and N2O datasets. Finally, we also obtained the deforestation rates of different countries at available intervals because it was also deemed a contributing factor to climate change since the natural forests of the world operate as the lungs of the planet, changing the abundance of CO2 with O2 that is breathable and does not contribute to the greenhouse effect.

Implementation:

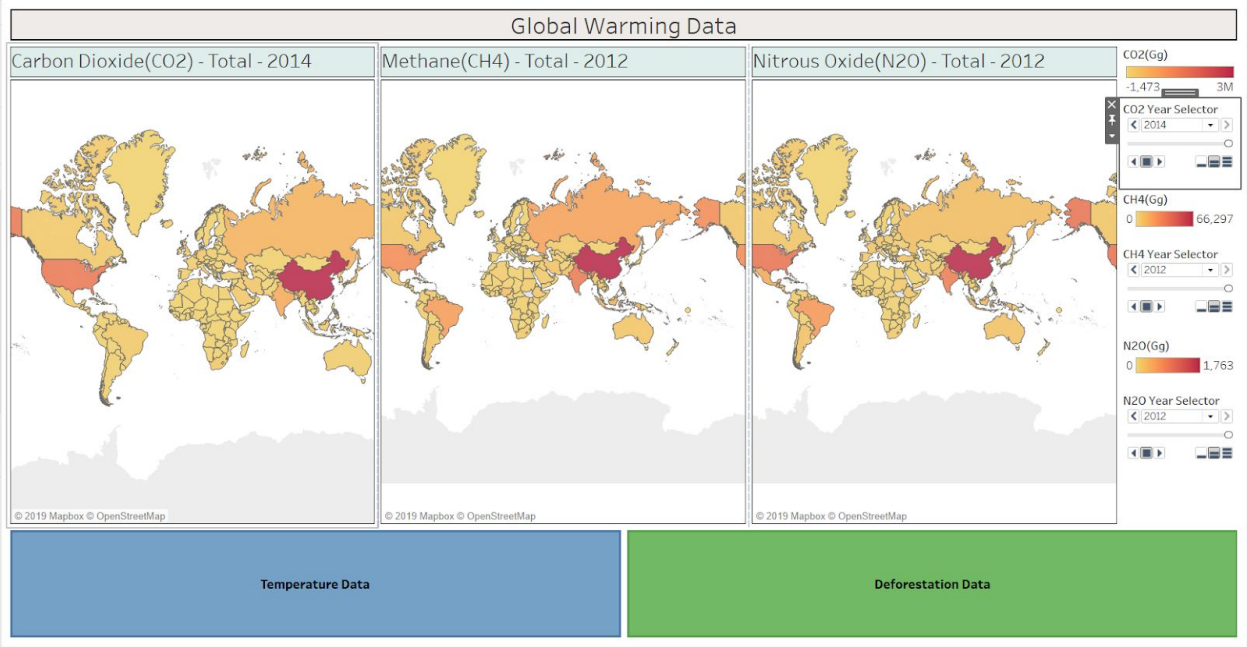
Once the datasets were obtained, we imported them into a PostgreSQL database in order to properly format the data to be visualized in our visualization tool. We also conducted a data processing query on the temperature data using a Python script and Psycopg2 to connect to the

temperature dataset and obtain monthly averages for the temperature of each country in order to compare the relative temperature change of countries over the time series available. These data organization queries and calculations were done on a Linux platform, and the finalized datasets were sent to a Windows platform to be implemented into the visualization tool.

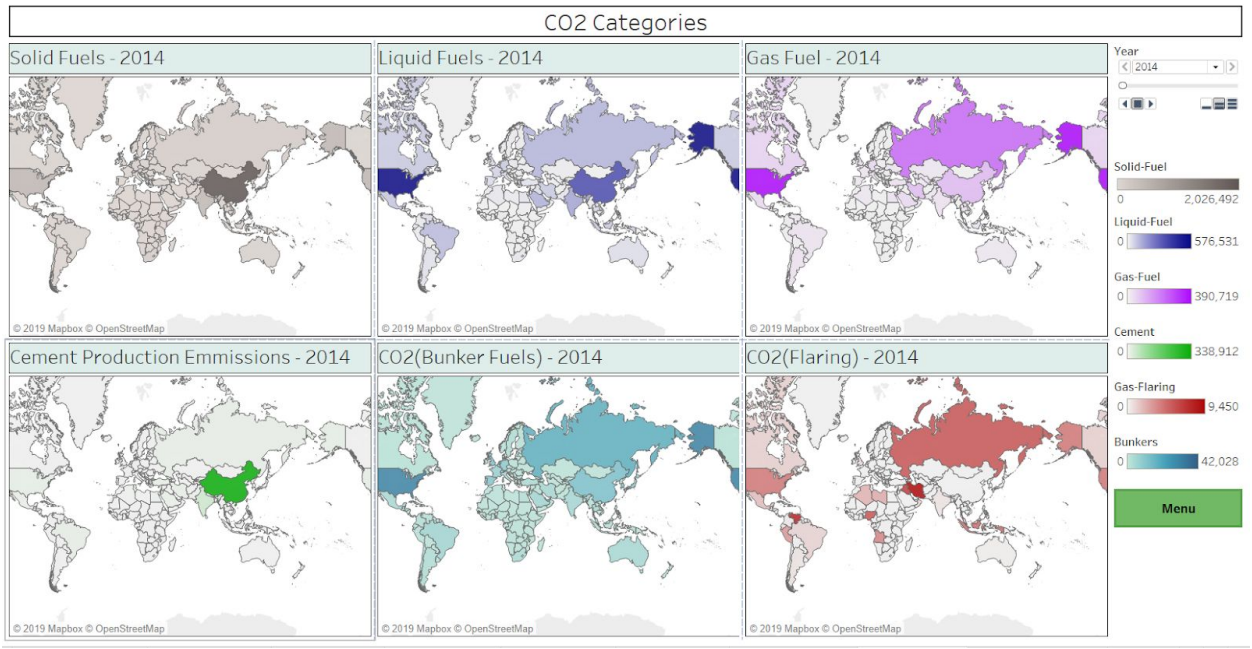
Once the datasets were in the proper format, we connected to each of them through Tableau Public and creating appropriate visualizations for the different datasets. This involved creating individual data visualizations for each dataset, connecting them properly through a user dashboard interface, and creating a main menu that the user could start from in order to select which category of data they would like to research further for a particular country, or simply compare the overall data between different countries. This menu system allows for a user friendly interactive visualization that they can use to look into each countries CO2, CH4, and N2O emissions, their deforestation data, and analyze each countries temperature change over time.

Results:

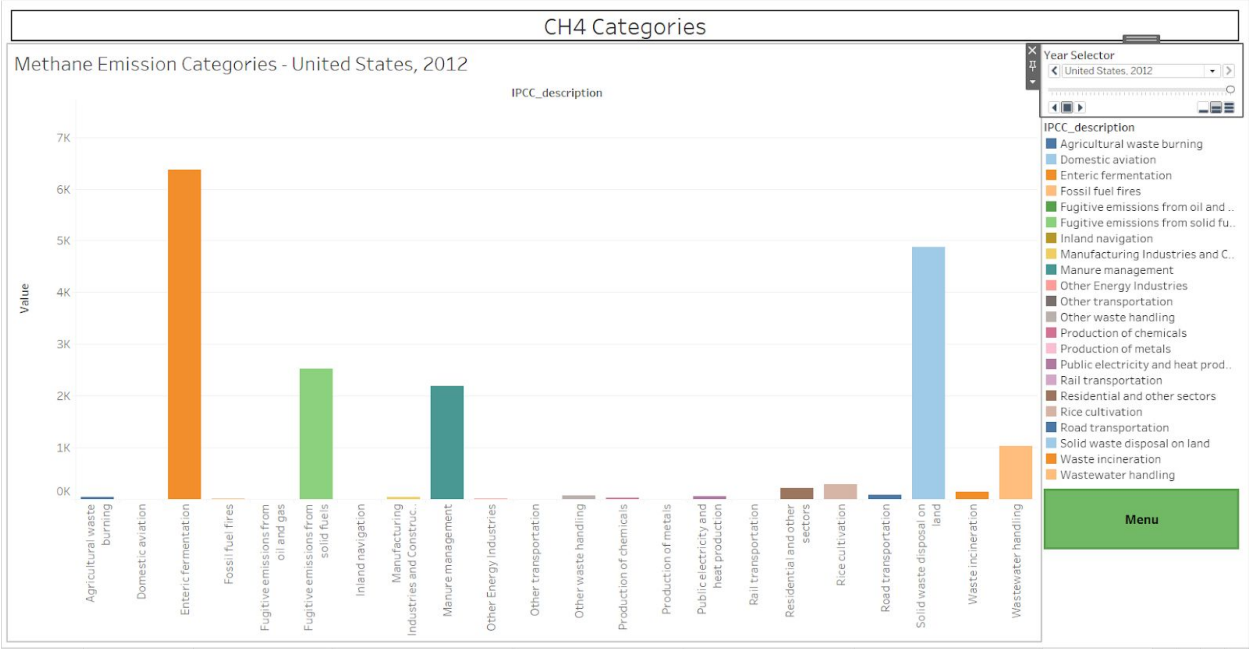
In this section, we will display our final visualizations, the interactions available to the user, and the navigation options available to the user.



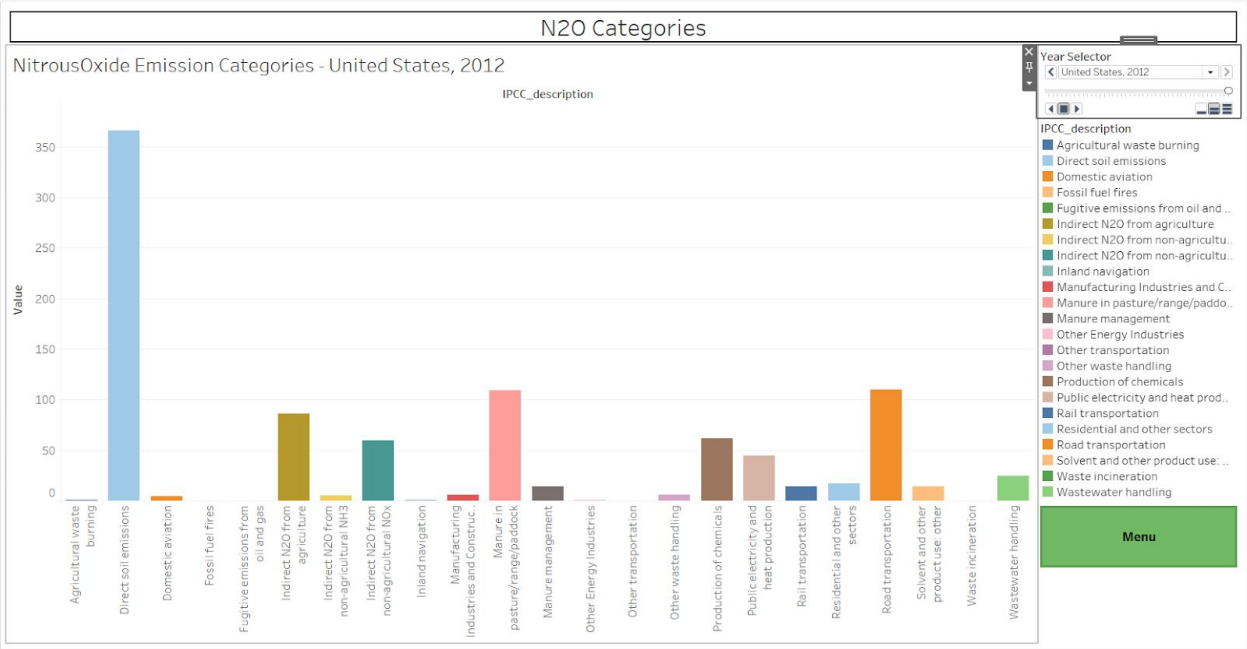
This screen serves as the beginning menu for our visualization. It displays each database we obtained in it's own section. The emission datasets are displayed side by side, with the same color gradient scale to have consistency in showing which countries are responsible for the most and least emissions across different categories. It also has year selections for each of the individual emission data sets that the user can change to display the emission rates per year. The user is able to mouse over any country, zoom in and out of any of the three maps, and when they mouse over each country, it will display the total emission rate for that country that year. The user can either select a year to investigate on the side, and select which emission category to investigate for that year, or select to view the temperature or deforestation data sets.



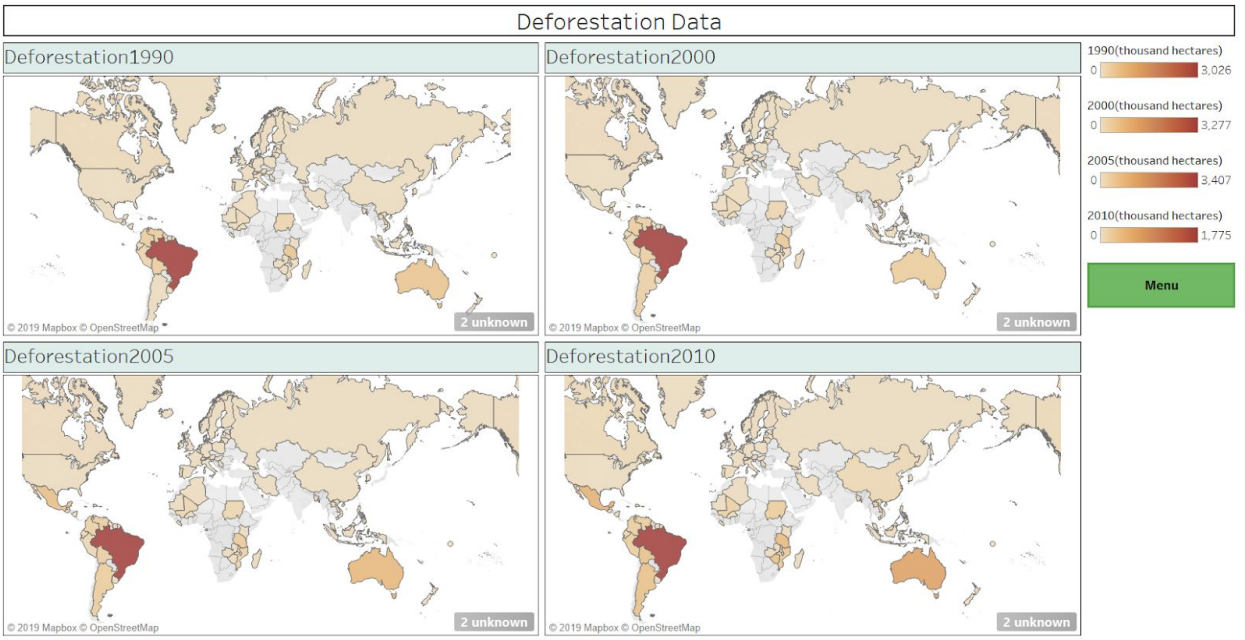
This menu can be reached by clicking any of the countries on the CO2(Total) map on the Global Warming Data menu. This menu displays the emission rates of CO2 by category for each country based on the year selected on the drop down menu on the side. When clicked on from the main menu, it will automatically go to the same year page as the one selected by the user on the main menu. The user can then explore any year they wish from this menu. Mousing over each country displays the emission rates for that country for that category of CO2 emission. The categories were separated and displayed using a map representation since there were few enough categories that it still provided the user maximum interactivity and so the user can also zoom in and out of each map individually if they wish. The Menu button in the bottom right will take the user back to the main menu.



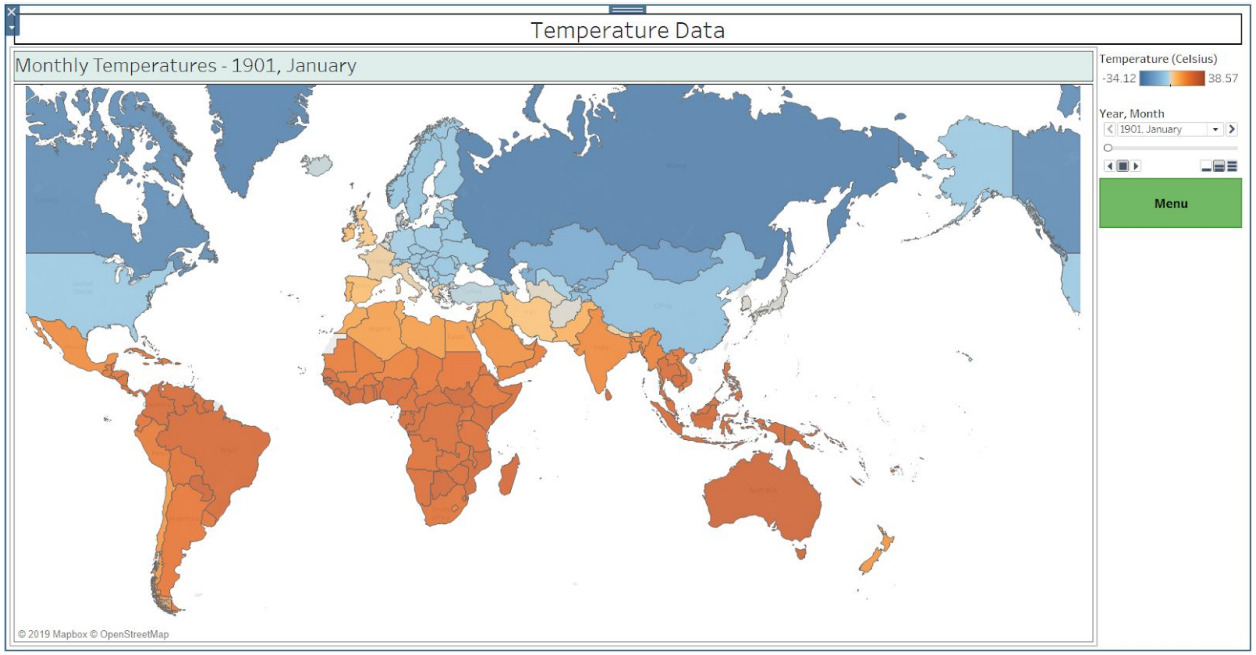
This menu is also reached from the main menu by clicking on any of the individual countries on the CH4(Total) map. After doing so, it will navigate to the categorical representation of the Methane emissions over time for the nation specified by the users click. Since there are so many categories, it would not be efficient for space for there to be map representations of each category, and we believed a bar graph allowed best for direct categorical comparison with this many categories. It allows the user to scroll through the years, and mouse over the bar of any individual category to see the yearly methane emission rates for that country for that year. The nation can be changed by the user using the drop down menu on the side, and the user can return to the main menu to select the database to be investigated again by clicking the Menu button in the bottom right.



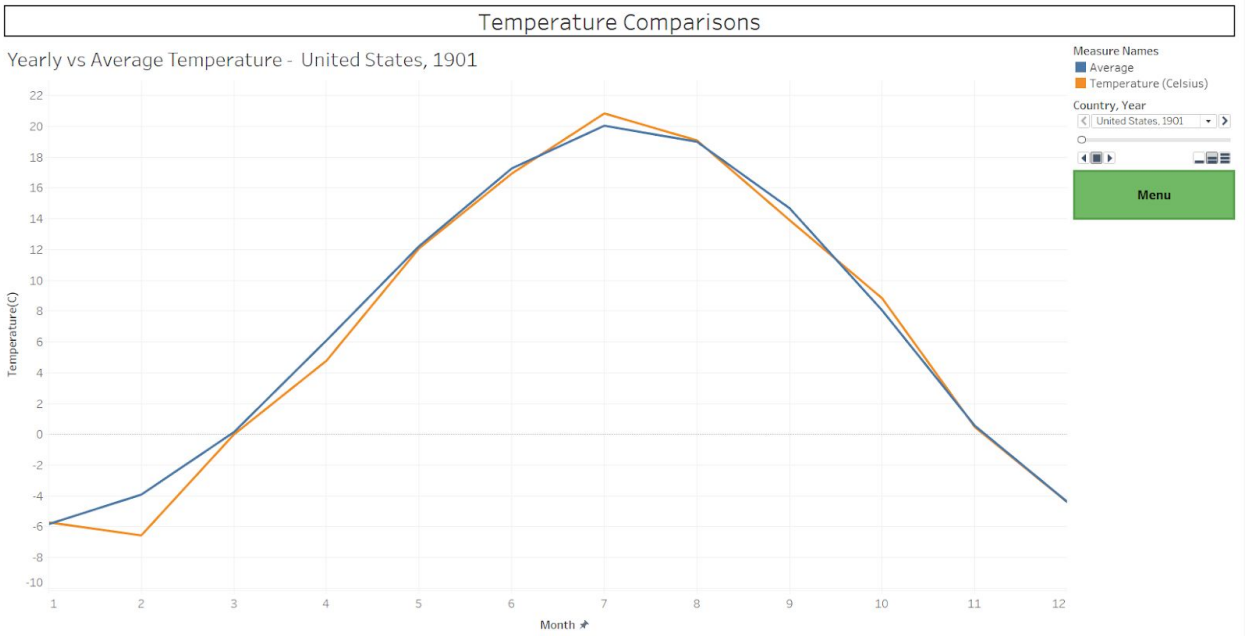
This menu is reached in the exact same method as the CH4 Category menu. It also provides the same selective function from the main menu, and the same interactivities described for the CH4 Category menu, but represents the categories for how Nitrous Oxide gasses were emitted for that country. It also has a year selector for the user to change the selected year on the side.



This menu can be reached from the main menu by clicking on the Deforestation Data button on the main menu. It displays a map representation of the yearly deforestation rates provided by the datasets at the given five year intervals. Since global warming has been a recently observed trend, and the collection of deforestation rates only recently became a question of national and international concern, the only rates available were for the four years provided on this menu. The user can map over any country, zoom in and out of each individual map, and it will display the yearly deforestation rate for that country in thousand hectares per year.



This menu can be reached from the main menu by clicking the Temperature Data button on the lower left part of the screen. It allows the user to pick any month between 1901 and 2016 and display the average monthly temperature of every country in the world at that time. The user has visual control over the map display allowing them to zoom in and out. By mousing over each country it will display the average monthly temperature of that month that year in degrees Celsius.



This menu is reached by clicking any of the countries available in the Temperature Data Menu. By clicking on one of the countries, it will navigate the user to this page which shows the average monthly temperatures for the selected countries in that year on the Temperature(Celsius) line, and shows a computed monthly average for that country overt the dataset available in order to show how the average monthly temperature changes in each country over time. The user can then change which country and which month is being displayed and compared to that country's national monthly averages. The user can mouse over any of the data points to directly compare the temperature values at each month displayed based on the year selected. Finally, the Menu button in the bottom right navigates the user back to the beginning menu to begin their data investigation again.

Future Directions:

Given more time and resources, we would have added additional data sources that also contribute to global warming factors such as the relative energy given off by the sun or the

relative health of the plant, aquatic and wildlife of each nation. Improved functionality in the area of directly comparing separate data sources would also be convenient for user functionality, but would require much more assistance from either more group members or outside assistance. This also dwells into the realm of data analysis versus data visualization which were the skills that we were initially intending to apply and show through this project. A final direction that could be taken in the future would be to display the total emission rates, deforestation data, and temperature changes on the 3D Global Projector located in the visualization lab at UMBC, but that would also require intensive help from instructors or other professionals who have worked with the equipment previously, or much more time for us to get acquainted with said equipment.

References:

[1]CO2 Data:

Boden, T.A., G. Marland, and R.J. Andres. 2017. Global, Regional, and National Fossil-Fuel CO2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. https://doi.org/10.3334/CDIAC/00001_V2017

Etemad, B., J. Luciani, P. Bairoch, and J.-C. Toutain. 1991. World Energy Production 1800-1985. Librarie DROZ, Switzerland.

Marland, G., and R.M. Rotty. 1984. Carbon dioxide emissions from fossil fuels: A procedure for estimation and results for 1950-82. Tellus 36(B):232-61.

Mitchell, B.R. 1983. International Historical Statistics: The Americas and Australasia 1750-1988. pgs. 522-525. Gale Research Company, Detroit, United States.

Mitchell, B.R. 1992. International Historical Statistics: Europe 1750-1988. pgs. 465-485. Stockton Press, New York, United States.

Mitchell, B.R. 1993. International Historical Statistics: The Americas 1750-1988. pgs. 405-414. Stockton Press, New York, United States.

Mitchell, B.R. 1995. International Historical Statistics: Africa, Asia and Oceania 1750-1988. pgs. 490-497. Stockton Press, New York, United States.

[2]CH4 + N2O Data:

European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR), release version 4.3.1 http://edgar.jrc.ec.europa.eu/overview.php?v=431, 2016.

Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Dentener, F., Bergamaschi, P., Pagliari, V., Olivier, J. G. J., Peters, J. A. H. W., van Aardenne, J. A., Monni, S., Doering, U., and Petrescu, A. M. R.: Global Atlas of the three major Greenhouse Gas Emissions for the period 1970-2012, Earth System Science Data, essd-2017-79, submitted, 2017.

Monica Crippa, Greet Janssens-Maenhout, Frank Dentener, Diego Guizzardi, Katerina Sindelarova, Marilena Muntean, Rita Van Dingenen, Claire Granier: Forty years of improvements in European air quality: regional policy-industry interactions with global impacts, Atmos. Chem. Phys., 16, 3825-3841, doi:10.5194/acp-16-3825-2016, 2016.

[3]Deforestation Data:

Food and Agricultural Association of the United Nations. (2019). FAO.org. Retrieved October 3, 2019, from http://www.fao.org/forest-resources-assessment/past-assessments/fra-2015/en/.

Food and Agricultural Association of the United Nations. (2015). *Global Forest Resources Assessment 2015 Desk Reference* [PDF]. Retrieved from http://www.fao.org/3/a-i4808e.pdf.

[4]Temperature Data:

Climate Change Knowledge Portal. (2018). *Metadata of the Climate Change Knowledge Portal*. *Metadata of the Climate Change Knowledge Portal*. World Bank Group.

World Bank Group. (2016). World Bank Climate Change Knowledge Portal. Retrieved October 3, 2019, from https://climateknowledgeportal.worldbank.org/.

Documents:

Bradshaw, C. J. A., Giam, X., & Sodhi, N. S. (2010, May 3). Evaluating the Relative Environmental Impact of Countries. Retrieved October 3, 2019, from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0010440.

Earth Science Communications Team at NASA's Jet Propulsion Laboratory. (2019, September 30). The Causes of Climate Change. Retrieved October 3, 2019, from https://climate.nasa.gov/causes/.

Hanania, J., Heffernan, B., Jenden, J., Stenhouse, K., & Donev, J. (2018, May 11). Flaring. Retrieved from https://energyeducation.ca/encyclopedia/Flaring

McKinsey Energy Insigts. (n.d.). Bunker fuel. Retrieved from https://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/bunker-fuel/