A Web Application to Visualize Climate Change

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Abstract

This CPSC 490 Senior Project uses HTML, CSS, Jinja, JavaScript, d3.js, Python, and Flask in building a web application to visualize climate change. More specifically, there are 5 visualizations – 2 line graphs, a stacked bar chart, and a choropleth map – created with the purpose of visualizing 1) carbon dioxide emissions over time by state, 2) severe weather events over time, 3) global rising sea level, 4) global rising temperature, and 5) number of environmental bills per state. This project is inspired by digital humanities in blending powerful visualization technologies with real world issues to learn with and educate others. I heavily employ different data and information visualization principles, such as intentional use of color and creating interactivity for users through tooltips, highlighting, and legends. From the visualizations developed through this senior project, it becomes increasingly clear the climate catastrophe that we are heading towards. The goal of this project is to empower people to explore climate change through different aspects. The web application serves as a cohesive narrative of how climate change impacts us, our role in worsening the climate crisis, and legislative efforts that inspire hope in our fight to protect our planet. This project intends to combine different datasets to illuminate varying climate change findings resulting from siloed datasets across United States government climate agencies. After encountering many challenges with regards to finding and using data for this senior project's visualizations, I call on government agencies to commit themselves to data accessibility through investment of time, energy, and resources in developing data APIs.

I. Introduction

For my senior project, I created a web application to help visualize climate change over time in the United States. Through the creation of a series of interactive visualizations that focus on different aspects of measuring climate change, my consolidation of data resources aims to educate and empower others to have a more vested interest in learning about the impacts of the climate crisis. My web application intends to blend different datasets to illuminate varying climate change findings resulting from datasets across United States government climate agencies. Overall, this senior project exists as a cohesive visualization tool that visually tells the story of how Earth has been devastated in the wake of the climate crisis, while recognizing the role of human-caused events as well as efforts (or lack thereof) on part of legislators across the states. This senior project specifically focuses on climate change as it is measured through the following aspects: 1) carbon dioxide emissions, 2) severe weather events, 3) global sea level, 4) global temperature, and 5) environmental bills.

II. Background

"The effects of human-caused global warming are happening now, are irreversible on the timescale of people alive today, and will worsen in the decades to come."

– NASA, "The Effects of Climate Change" [1]

In recent years, the world has been forced to reckon with the role of humans in causing and perpetuating climate change. NASA and the United States Global Change Research Program have reported a number of tangible impacts throughout the United

States, such as rising sea levels, extreme temperature rises, severe weather events (especially devastating hurricanes, floods, wildfires, and droughts), increased greenhouse gas emissions, etc. [1]. Scientists warn that we must act fast in our fight against climate change, and it will require drastic changes to our way of life in order to stop the damage already committed [2].

Nonetheless, as different regions and states throughout the United States experience varying degrees of impact due to climate change, the response by the leaders of our nation has been too slow to keep up with the acceleration of the climate disaster we are currently living through [1]. Despite scientists providing evidence for the impacts of global warming and climate change on the habitability of the planet, many people continue to navigate through life with a warped perception of how quickly climate change has worsened due to the exploitative extraction of this world's resources in the prioritization of profit.

III. Overview

The tech stack for this senior project includes HTML, CSS, Javascript, and Python. More specifically, Jinja was used for templating different pages within the web application. The microframework Flask was used for creating the infrastructure of the web application built. Python was used for the API call made to retrieve carbon dioxide emissions from the Energy Information Administration. Use of JavaScript's D3.js library allowed me to create powerful and interactive visualizations. With D3, I created line graphs, a stacked bar chart, a heat map, and a choropleth map. I incorporated tooltips for users to interact with visualizations themselves and learn more about the data points featured.

In my work on this web application, I was tedious to remain organized and structured, especially as new visualizations were added. As such, the code repository contains respective JavaScript files for each visualization, with each visualization existing on its own HTML page.

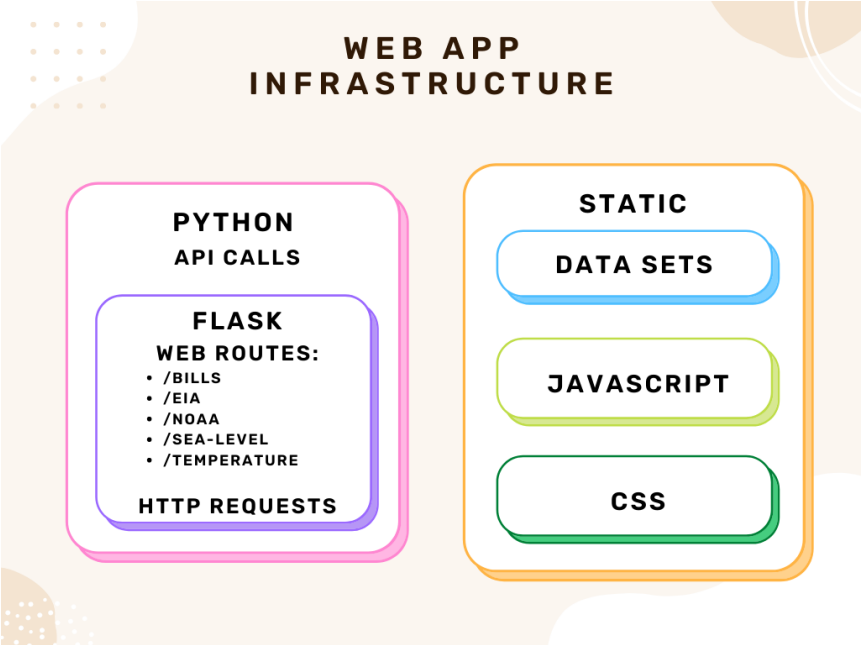

Figure 1. Diagram representing web application infrastructure

A. Energy Information Administration: Carbon Dioxide Emissions

In visualizing how carbon dioxide emissions differ across states, I used the OpenData API from the U.S. Energy Information Administration (EIA). The API from the EIA is free and easy to use. I used Python and the HTTP requests library in creating a data pipeline for preparing the data into the format needed before it is passed into JavaScript to build the visualization.

The purpose of visualizing carbon dioxide emissions between different states is to show users how different states are either improving, worsening, or remaining the same

throughout time. Carbon dioxide emissions are crucial to visualize in order to emphasize how human-led fossil fuel combustion impacts the environment in increasing greenhouse gasses that trap heat and create other devastating environmental effects [3]. According to an article published by the National Oceanic and Atmospheric Administration, “increases in atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise” [4].

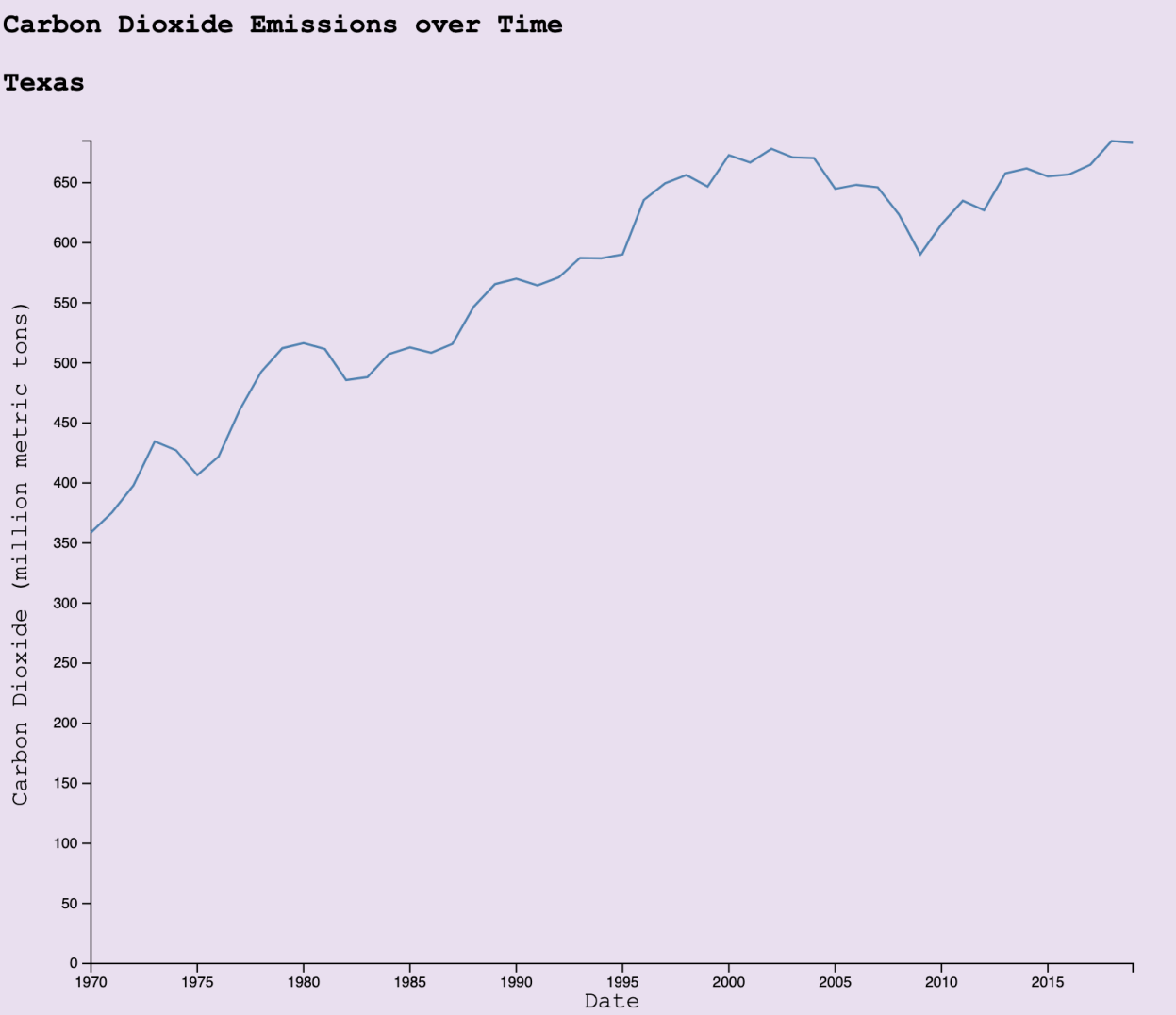

Figure 2. Texas CO2 emissions over time depicted as a line graph visualization

B. National Oceanic and Atmospheric Administration: Severe Weather Events

The National Oceanic and Atmospheric Administration (NOAA) is a U.S. government scientific agency that collects all types of data regarding weather, climate, and atmospheric + oceanic conditions. On their website, NOAA shares their mission: "[t]o understand and predict changes in climate, weather, ocean, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources" [5]. However, it is important to note that while NOAA's mission includes sharing information with others, their Climate API only is applicable to current weather data as it is collected. Therefore, the rich datasets NOAA has regarding severe weather events (as well as global sea level and global temperatures) are not as publicly available and are difficult to interact with. Although I had expected to create API data pipelines for each of the data sources I worked with, this was not possible due to a lack of data available in machine-readable formats.

The goal of creating a visualization of severe weather events in the United States is to show users the increase in anomalies in our atmospheric conditions. I chose to visualize these events as a stacked bar chart, so that users could see how many events took place each year overall as well as per category (winter storm, tropical cyclone, wildfire, severe storm, flooding, drought, freeze). As severe weather events continue to occur at more frequent rates each year, it is important for people to understand that these events are not normal – "climate change is increasing the frequency of some types of extremes that lead to billion-dollar disasters" [6]. In juxtaposition to other visualizations in my senior project, I aim to illuminate the current path towards

catastrophe that we are currently on, in hopes that we are motivated to take the necessary steps to combat climate change.

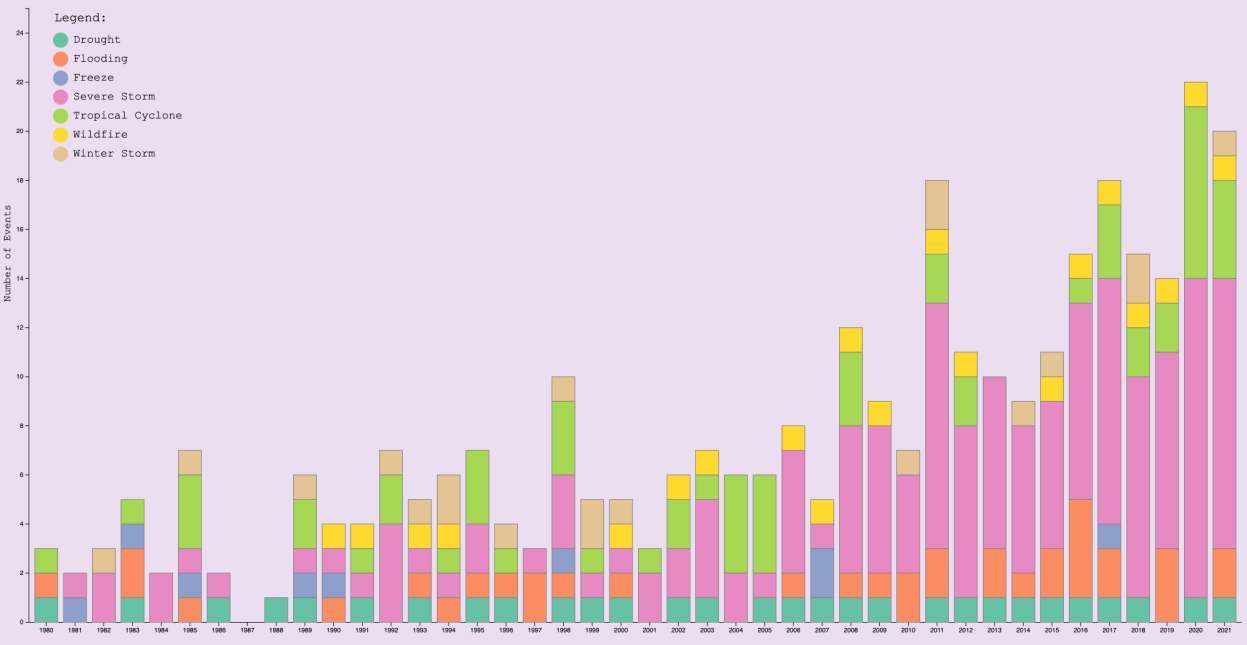

Figure 3a. Severe Weather Events over time depicted as a stacked bar chart with a legend for information on the type of severe weather event represented by each color

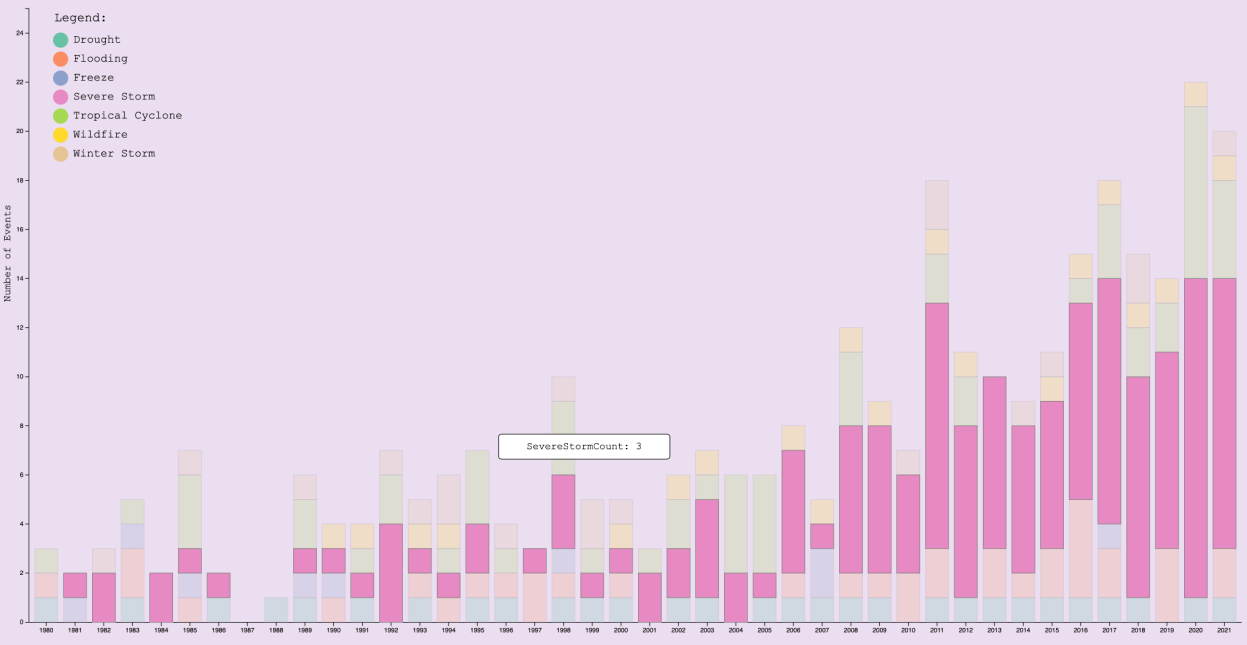

Figure 3b. Hovering reveals 1998 severe storm count using a tooltip, and highlights severe storm counts in other years for easier comparison

C. NOAA: Rising Global Sea Level

The purpose of a line-graph visualization of global sea level is to depict the steady increase in sea level since 1992. According to NASA, “as global temperatures increase, sea level rises due to a thermal expansion of upper layers of the ocean and melting of glaciers and ice sheets” [7]. Although sea levels are not rising at dramatic rates, a steady increase is a sign of a worsening problem that will have negative ramifications not just for coastal areas, but for wildlife belonging to wetland, mangrove, and polar ecosystems too [7].

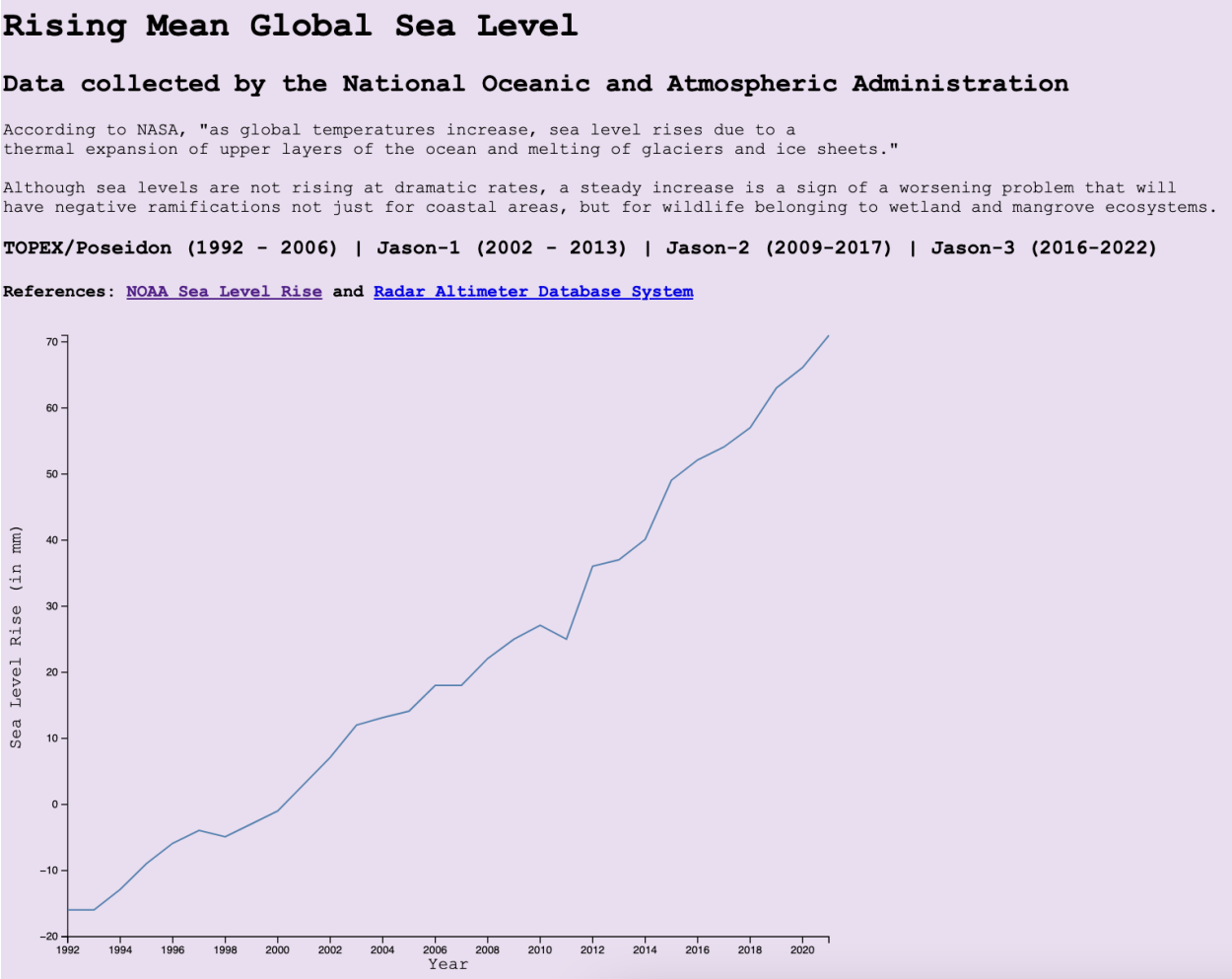

Figure 4. Sea level rise over time depicted as a line graph visualization

D. NOAA: Rising Global Temperature

In depicting the increase in global temperatures since 1881, I created a heatmap using D3 to show temperature variance for each of the 12 months per year. Rising global temperatures depict a trend towards hotter temperatures, which can and are already having negative impacts on wildlife, infrastructure, and weather. According to NASA, “Earth’s surface continues to significantly warm, with recent global temperatures being the hottest in the past 2,000-plus years” [8].

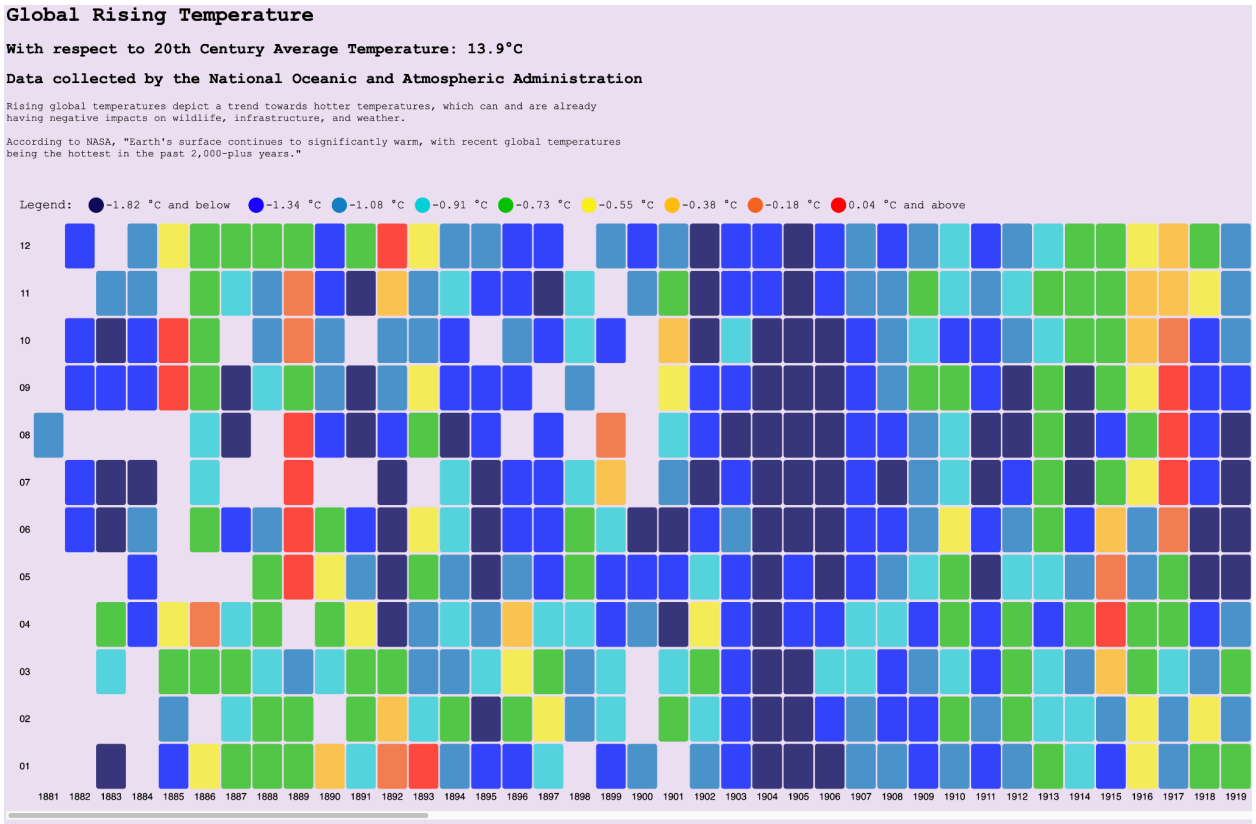

Figure 5a. Global Rising Temperature partially depicted as a heat map visualization with scrollbar and legend (1881-1919)

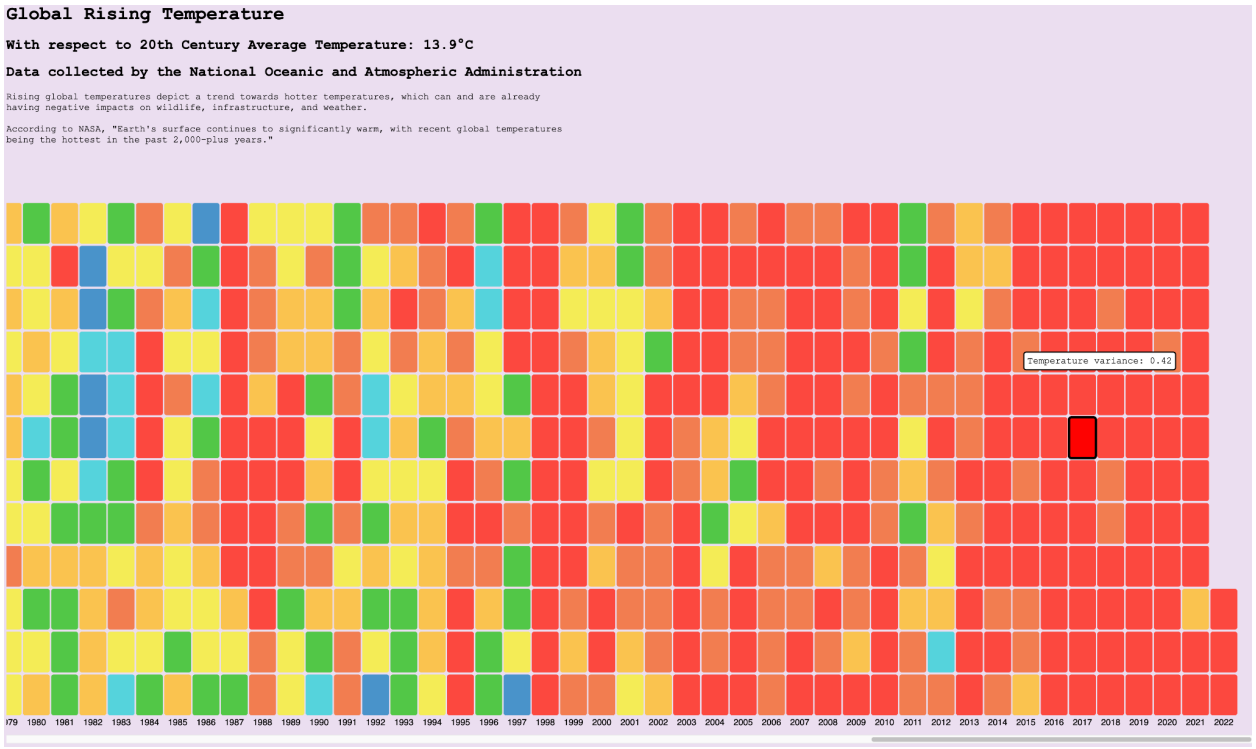

Figure 5b. Global Rising Temperature partially depicted as a heat map visualization (same one as Figure 5a, 1980-2022) with scrollbar and hovering to reveal temperature variance for July of 2017.

E. National Conference of State Legislatures: U.S Environmental Bills

The final visualization for my senior project shifted focus towards depicting the varying levels of focus on environmentalism between different states. I was curious to see if the states that were actively diminishing their carbon dioxide emissions would also be involved in greater legal efforts to combat climate change.

The National Conference of State Legislatures "tracks environment and natural resources bills," and they've created an easy-to-use searchable database for navigating their data [9]. However, the NCSL does not have an API for accessing large amounts of historical data, and as such I was only able to create a choropleth map for the data collected thus far for the year 2022. Due to the lack of an API, I manually searched the

database for each state, and only included the count for the number of environment and natural resources bills. It is my belief that data and information about environmental climate bills currently being proposed and passed at legislative levels should be easily accessible to all people, especially for the purposes of being well-informed citizens and voters.

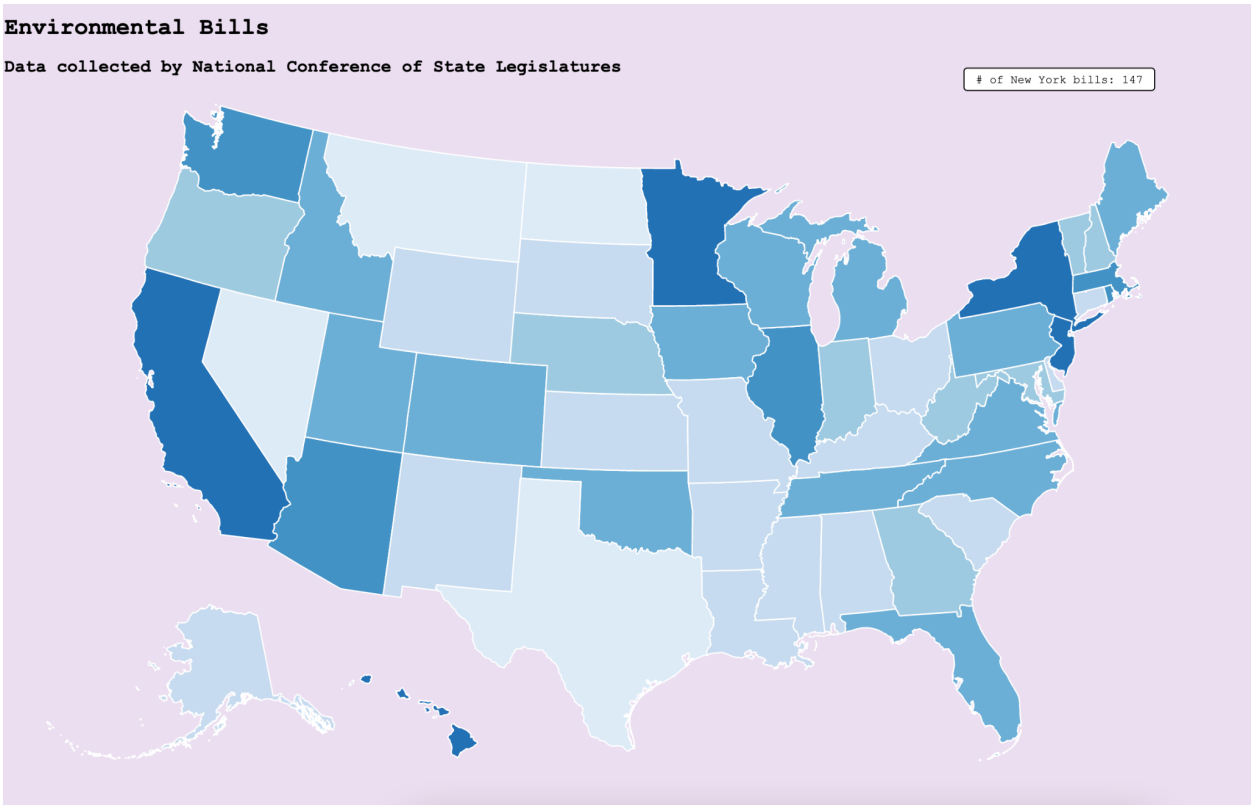

Figure 6. Choropleth map of environmental bills, featuring hovered information for NY

IV. Reflections

Throughout my work on the senior project, I encountered multiple challenges regarding access to data. Although I planned to use APIs to access a variety of data sets relevant to climate change, I found it to be extremely difficult to find data sources with free, open, and reliable API access.

I spent many hours of my thesis working specifically with navigating and reformatting different data sets so that they can be used to create visualizations with D3.js. Much to my surprise, a huge majority of data regarding climate change was stored by the United States government independent of API calls in CSV files. I was only able to make API calls with data collected by the Energy Information Administration regarding carbon dioxide emissions by state. I encountered faulty API infrastructure by the Environmental Protection Agency, which posed a significant barrier to using any data by the EPA on nitrogen dioxide emissions and more.

Ultimately, I reckoned with questions of data accessibility in the United States throughout this past semester. According to the Organization for Economic Co-operation and Development (OECD), data accessibility is defined as "the extent to which government data are provided in open and re-usable formats, with their associated metadata" [10]. In relation to other countries, the United States struggled to provide any evidence of data accessibility in line with the principles of the International Open Data Charter. I was shocked by the lack of collaboration of similar data sets and resources between different United States government agencies. Data was seldom being reused between different use cases, but rather would become siloed through repetitive data re-collection efforts.

As I think about the future of working with data, I hope to see a more collective and collaborative effort to centralize resources for people to use APIs in accessing large amounts of data for a variety of wide-ranging purposes. The OpenData Energy Information Administration API is a forward-looking exemplar tool that other data-collecting agencies should follow suit in their necessary journeys to become "committed to enhancing the value of… free and open data" [11]. The EIA understands

the importance of data accessibility, recognizing that “by making EIA data available in machine-readable formats, the creativity in the private, the non-profit, and the public sectors can be harnessed to find new ways to innovate and create value-added services powered by public data” [11]. It is crucial that as our world becomes increasingly digital and dependent on data collection, governments must invest in technological infrastructures that show a “commit[ment] to making… data more accessible, understandable, relevant, and responsive to [our] needs” [11]. Lack of data accessibility interferes heavily with the labor of data scientists and data visualizers, detracting time and energy from bigger goals to empower and encourage users to learn more from data.

V. Acknowledgements

Thank you to Professor Holly Rushmeier for introducing me to the world of data and information visualization, and ultimately inspiring me to pursue this senior project that blends my passion for technology and humanities. I am indebted to the Dean of Saybrook College, Ferentz Lafargue, for his never-ending support as I navigated through Yale during unprecedented times. To WHS 2022, thank you for your friendship, love, and care. I would not be the person I am today without each of you fundamentally reshaping my life. Lastly, I would like to thank Danny Araujo Mota for always being by my side as I’ve learned, growed, and overcame challenges.

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