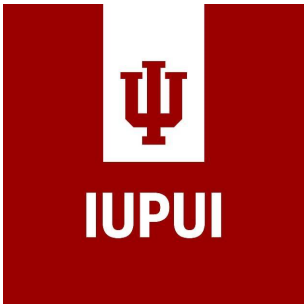

CS 552-Data Visualization Term Project Final Report

Is Climate Change Real?

Unveiling the Evidence, Causes and Solutions through Data Visualization

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Instructor: Professor Shiaofen Fang TA: Ziqian Bi

Table of Contents

Chapter 1: Climate Change: A Myth?

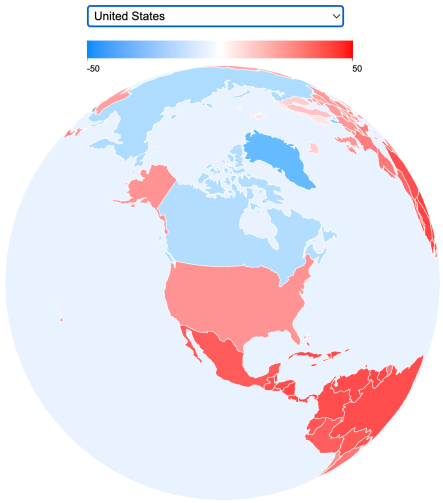
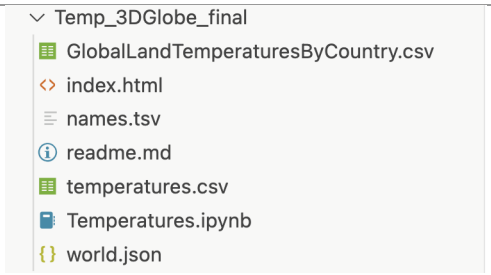
Even though we see various disasters each day which are not quite natural, some people say that climate change is a myth. These nonbelievers has their own set of arguments. Some of them are as follows:

1. Countries are by nature hot or cold because of the positioning over the globe.
2. Months are naturally hot or cold.

Let's investigate each of these arguments and look into each of these arguments.

3D Globe Choropleth Map: Average Temperature of all Countries

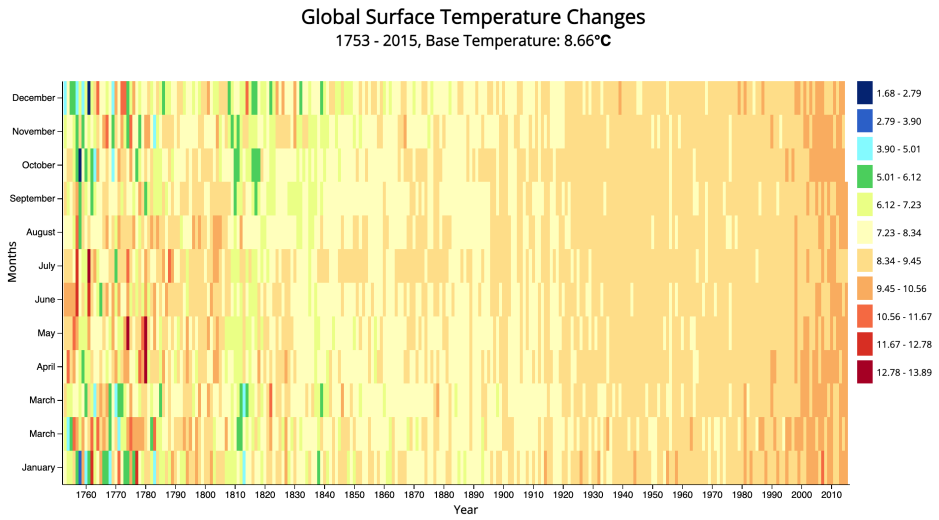
To further investigate into Myth 1: We have implemented the rolling 3D globe in which colormap which shows the average temperature of the past 100 years.

Screenshot of the Visualization	 **Inferences:** • Countries that are nearer to the equator experience higher temperatures than the countries near the pole. • Legend from -50 to 50 degrees, shows the transition from a cold region(dark blue) to 0 degree (white) to rising hot temperature(dark red). • This visualization has the dropdown menu and we can select the country which we want to look into. (It will take us there)
Github Link	https://climatecs552.github.io/Temp_3DGlobe_final/
Folder Structure	 • Standard "world.json"-> json file having the shape of the polygon of the countries • "names.tsv"-> tsv file having the names countries corresponding to their ids • "Temperatures.ipynb" is the file in which we shortlist, clean and process the data of the temperatures of the countries from "GlobalLandTemperaturesByCountry.csv", we average out each of the temperatures for each of the country for all the years. • Output of "Temperatures.ipynb": "temperatures.csv"

	Temp_3DGlobe_final > temperatures.csv 1 Country,Temperature 2 Afghanistan,14.31022807017544 3 Africa,24.30571386800334 4 Albania,12.954595655806182 5 Algeria,23.3524231411863 6 American Samoa,26.78497827903091 7 Andorra,11.541888053467 8 Angola,22.02830200501253 9 Anguilla,26.882591259480293 10 Antarctica,26.83336879895561 11 Antigua And Barbuda,26.707637426900586 12 Argentina,14.856913533834588 • "index.html" -> Main HTML file which has html, css and d3.js code which actually does task of visualization.
Code Structure	Below are the sections of code in "index.html" and explanation what they do in it: • **DOCTYPE, HTML, and HEAD:** The document is structured as an HTML file with a specified DOCTYPE, and a head section containing metadata, a title, and external script files. • **External Scripts:** The head section includes three external JavaScript libraries: d3.js, topojson, and queue. • **Styles:** The head section also contains a style block that defines CSS styles for different elements, such as the water, land, and legend of the globe. • **Body:** The body section contains a div element for the legend and a script block with JavaScript code that creates the globe. • **Globe Creation:** The script block sets up variables, defines the color scale for temperatures, creates an orthographic projection and path for the globe, and adds an SVG container for the globe. It also sets up the water element and country tooltip. • **Data Loading:** The script loads world and country data using the queue library, and then processes the data to create countries on the globe and handle interactions such as dragging and country focus. • **Temperature Data:** The script reads a CSV file containing temperature data, maps the data to country IDs, and colors the countries accordingly. • **Legend:** The script creates a legend for the temperature scale, with gradient color, tick lines, and labels.
Features of visualization	• 3D globe with maps of the countries over it • Flood Risk is shown by the colormap and the corresponding legend • Dropdown menu which takes you to the country's map which you clicked on and shows the flood risk.

Interactive Heatmap: Monthwise Average Temperature from 1753-2015

To further investigate into Myth 2: We have implemented the average of the months of that particular year pointing on which also shows the mean and variances.

<table>
<tr><td>Screenshot of the Visualization</td><td>


Inferences:
There is a trend of increasing global surface temperature over centuries which is a strong indicator of global warming.
</td></tr>
<tr><td>Github Link</td><td>https://climatecs552.github.io/Heat_Map_final/</td></tr>
<tr><td>Folder Structure</td><td>


“index.html” -> Main HTML file which does task of visualization(driver file)
“script.js” -> Contains main details of the visualization. Includes importing of the data and its preprocessing, creating axis and labels, legends and interactive tool tip to indicate the temperature at a particular year and its variance.
“style.css” -> Contains style elements like color, font, font size, text alignment for the visualization tasks in the script.js file.
</td></tr>
<tr><td>Code Structure</td><td>Below are the sections of code in “index.html” and explanation what they do in it:

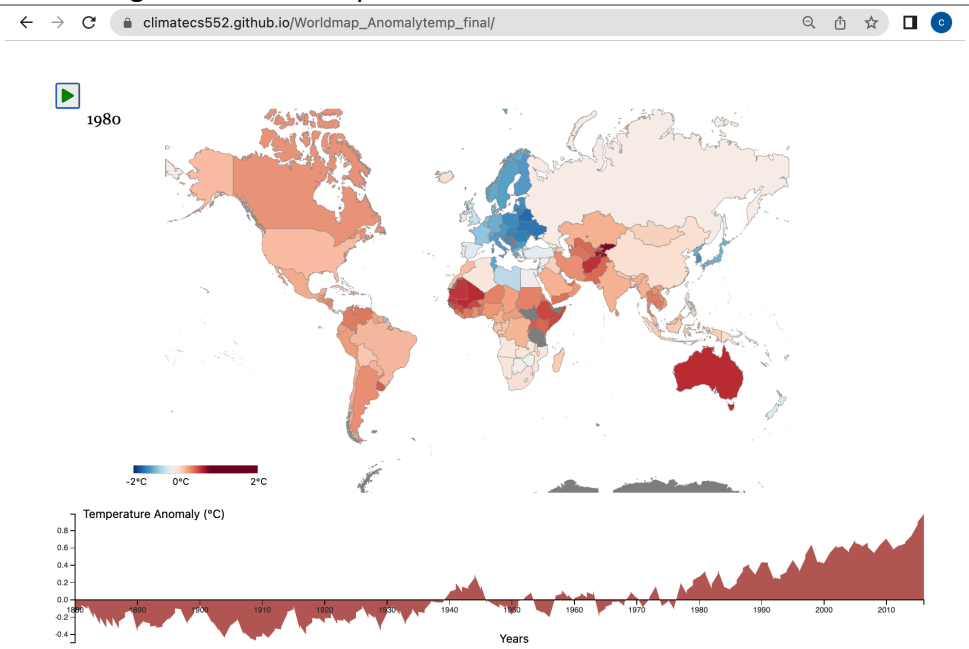
DOCTYPE, HTML, and HEAD: The document is structured as an HTML file with a specified DOCTYPE, and a head section containing metadata, a title, and external script files.
Styles: The head section also contains a style block that defines CSS styles for different elements like color, font, font size, text alignment for “script.js”. “style.css” also includes a small triangle extender for the tooltip and adjusts the font sizes of the title, description, and footer for smaller screens.
Libraries: The necessary D3.js and related libraries are loaded from content delivery networks (CDNs).
Data Loading: Import dataset from URL and convert to JSON format.

</td></tr>
</table>

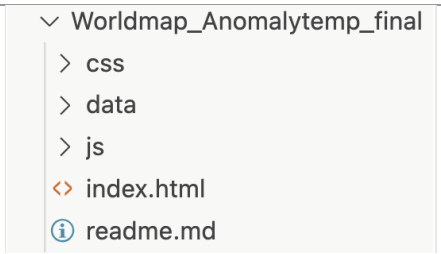
	• **Heatmap creation and interactivity**: sets up the scales, axes, and labels for the x and y axes. The script also creates a tooltip for displaying additional information when hovering over individual cells of the heat map. Then rectangles are created for the heat map using the data points, setting their positions and colors based on the temperature variance. It also sets up event listeners for tooltip display on mouseover and mouseout events. • **Legend:** The script creates a legend for the heat map, configuring its appearance and labels using the color scale.
Features of visualization	• Shows a 2D map of the temperature variation monthly from 1753-2015 • Legend highlights the average temperature of a month corresponding to the rectangular bar on the heatmap. • We can interact with the bars of the heatmap to check the temperature, variance and year.

Spatial Temperature Anamoly Map and Animation

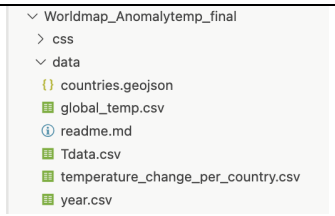
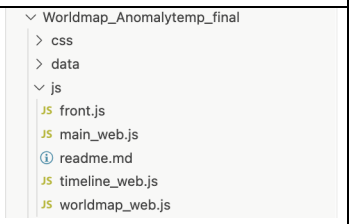
These two Myths from the non-believers makes sense but is that the complete truth, we get slight hint of the gradient of the temperature. Now further we need to visualize how does the spatial distribution of the temperature anomalies look in each year over the worldmap, hence we tried to make a animation which combines both spatial and temporal aspects of the data and make this visualization. Since this is quite a complex idea to execute we have taken inspiration of this code(https://romilbalar.github.io/) and made the necessary modifications for us fulfilling our criterion of presentation.

Screenshot of the Visualization	 **Inferences:** • From the animation of the Temperatures on the Choropleth map, we can see that we have increased temperature of earth and we can also observe that there is differences between
Github Link	https://climatecs552.github.io/Worldmap_Anomalytemp_final/

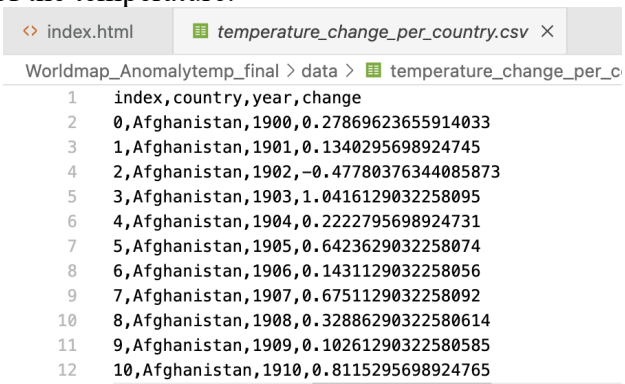
Folder Structure



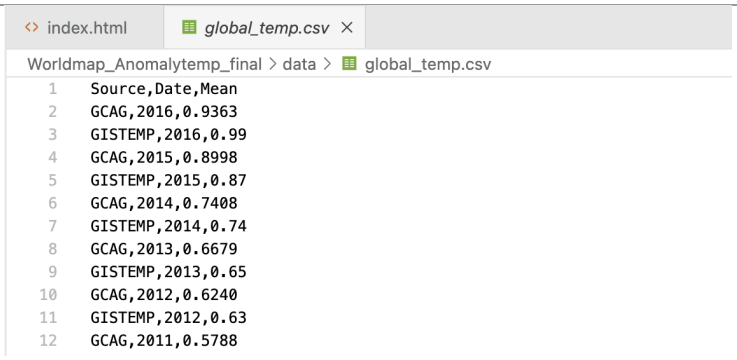
- css is folder having the css scripts.
- Js is the folder having the js scripts
- Data folder has .csv, .tsv, .geojson etc files.

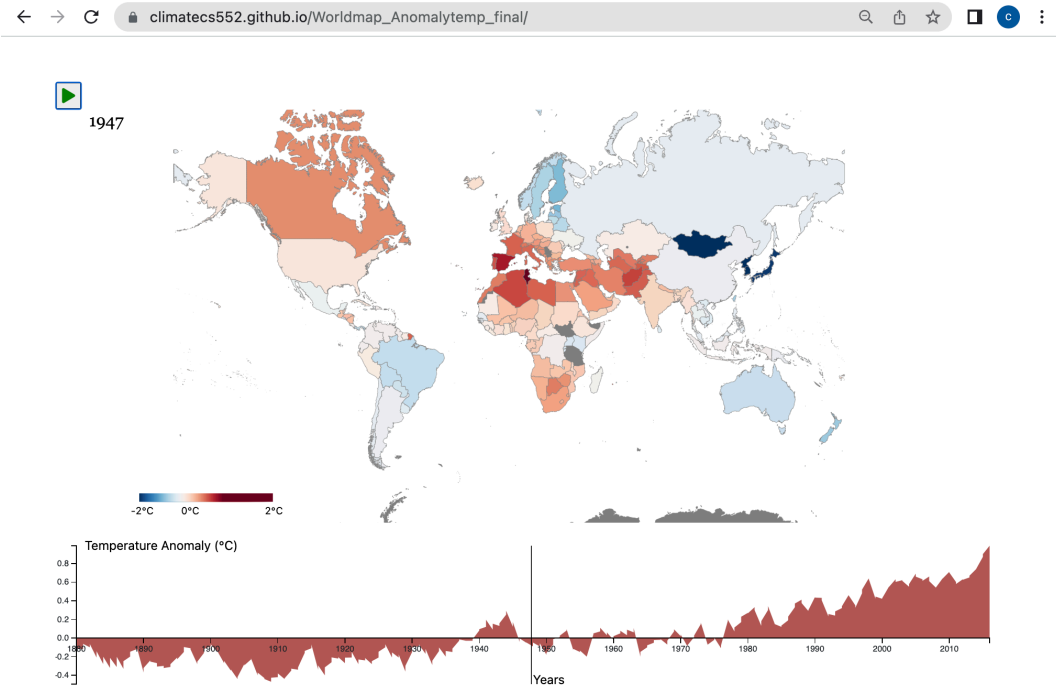
CSS folder	Data folder	JS folder
		

- Snippet of “temperature_change_per_country.csv” which would be used for drawing the spatial distribution of the temperature.



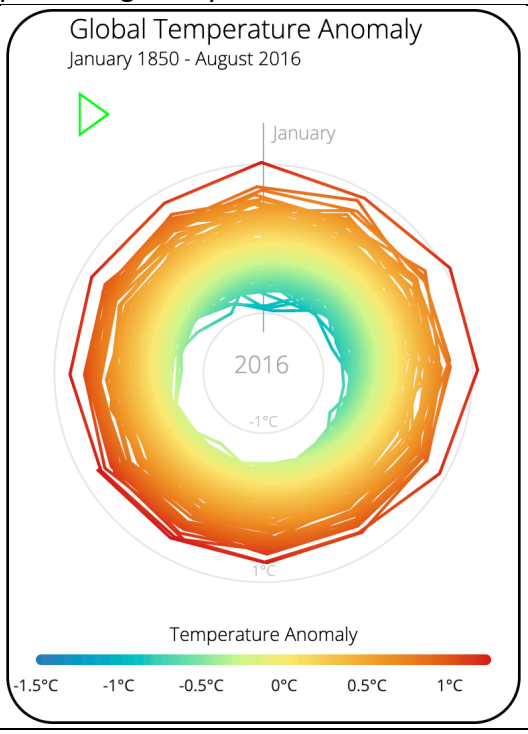
- Snippet of “global_temp.csv” which would be used for drawing timeline. “year.csv” was previous version of “global_temp.csv”

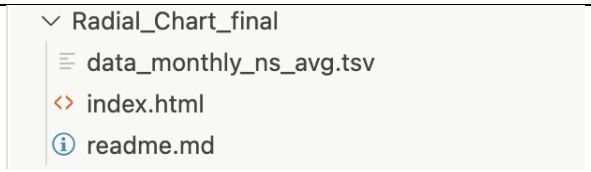
	 "index.html" -> Main HTML file which has html, css and d3.js code which actually does task of visualization.
Code Structure	For Code Structure we need to understand the 2 main javascript files, rest all are the supporting ones which have described in detail about in previous plots: So first file to look into is the **"worldmap_web.js"** and summarize the functions and their tasks in it. This file is responsible for creating the interactive spatial chorophelt map which shows the temperature anomalies for different countries based on selected year. Below is the summary/ code structure of this file: • Constructor: Initializes a Worldmap object with parentElement, tempData, and geoData as input parameters. • initVis(): Sets up the drawing area, projection, and map display with D3.js, creates a legend and tooltip for temperature anomalies, and calls the wrangleData() function. • wrangleData(): Filters the temperature data based on the selected year, creates a countryInfo object containing the temperature change, and calls the updateVis() function. • updateVis(): Updates the map visualization by coloring countries based on temperature anomalies, and handles mouseover and mouseout events for tooltips and highlighting countries. • Legend and tooltips: Provides visual representation of the temperature anomalies range and displays information about countries on mouseover events. Now we will look into the second file named **"timeline_web.js"** and summarize the functions and their tasks in it. This file responsible for the timeline graph we see in lower region of the visualization and we can track the global temperature anomaly on that particular year and also the spatial distribution of the temperature anomaly over the spatial distribution. Below in the pointers is the codestructure of the file. • Constructor: Initializes a Timeline object with parentElement and data as input parameters. It parses the date in the data. • initVis(): Sets up the drawing area, scales, and axes using D3.js, creates an area chart for temperature anomalies over the years, and appends a tooltip with a line and text. • Mouse event handlers: Handles mouseover, mouseout, and mousemove events to display and hide tooltips, as well as update the global variable 'selectedYear' and wrangle data for the worldMap object. • Area chart: Displays an area chart representing temperature anomalies over time, with x-axis showing years and y-axis showing temperature anomalies in degrees Celsius.
Features of visualization	• Here we have included the "green" colored play button so that we can run the animation of the Spatial Distribution of temperature from the years of 1880-2015. • We have also included map has, "Temperature Anomaly VS Years" timeline of the graph.

	• There is an interesting feature in this visualization of timeline, where we position a dragger on particular year and we can see the spatial temperature distribution of the countries in the above part of visualization. • In the below example of we place dragger on the time of "1947" on timeline of the temperature anomaly. 

Radial Chart of Global Temperature Anamoly

Till now we looked into the busting myths, this post shared by the social media platforms on the earth day by NASA, concludes our point of increasing temperature globally.

Screenshot of the Visualization	

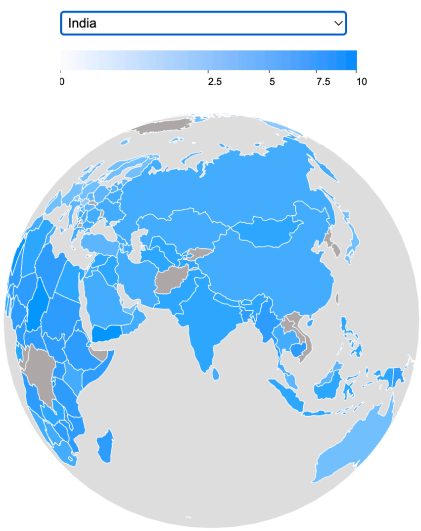
	Inferences: • This radial chart clearly shows how we have increased the temperatures of the planet after the industrial revolution in the 1850s • The post shared by NASA inspired the idea.
Github Link	https://climatecs552.github.io/Radial_Chart_final/
Folder Structure	 • Monthly average of the 12 months from each year 1850-2016 stored in "data_monthly_ns_avg.tsv" • "index.html" -> Main HTML file which has html, css and d3.js code which actually does task of visualization.
Code Structure	In Head section we include all the necessary metadata, styles, D3.js library and Google Fonts etc. Summary of the Body Section is explained in the below pointers: • Empty div with ID "weatherRadial": Serves as the container for the radial chart. Main script section: • Initializes SVG containers, sets up scales, loads data, and creates chart elements. • Create radial chart's SVG container: Appends SVG to the "weatherRadial" div. • Draw radial line: Utilizes D3's line.radial() function with angle and radius arguments. • Create radial gradient: Uses D3's append("radialGradient") function to apply color scale based on temperature. • Implement play button: Displays Unicode triangle character, initiates chart drawing when clicked. • Create legend: Applies color scale to a rectangular bar using D3's linearGradient function. • Create axes elements: Includes gridlines, axis labels, reference January label, and central year label.
Features of visualization	• When placed on the play button the line starts revolving around the center showing the temperature anamolies in different month and slowly while circulates it moves out away from the center as the year passes. • We can see that this the clear proposition in which we can understand the difference in temperature anomlies in same month over years.

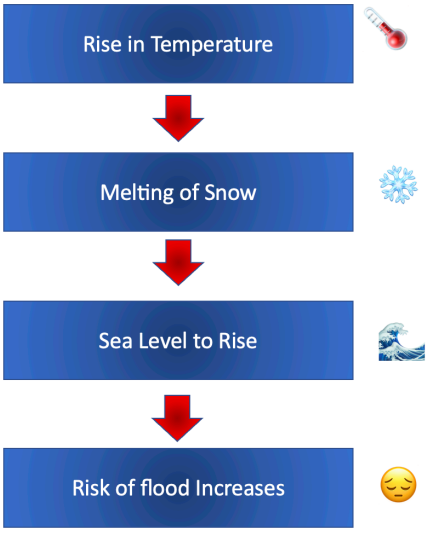
Chapter 2: Consequences

One of the first consequences of increase in temperature can be seen that there is increase in risk of flooding. Now to show these consequences of the global warming and climate change as below:

3D Globe Choropleth Map: Flood Risk of all Countries

Screenshot of the Visualization





Inferences:

- The areas with darker blue shade have more risk of flooding and lighter blue shade have less risk of flooding.

Github Link

https://climatecs552.github.io/Flood_Risk_3DGlobe_final/

Folder Structure

- Standard “world.json”-> json file having the shape of the polygon of the countries
- “names.tsv”-> tsv file having the names countries corresponding to their ids
- Snippet of the “flood_risk.csv”

Flood_Risk_3DGlobe_final > flood_risk.csv

```
1   Country,Flood_Risk
2   Afghanistan,-
3   Albania,5
4   Algeria,6
5   Andorra,4
6   Angola,7
7   Antigua and Barbuda,3
8   Argentina,5
9   Armenia,5
10  Australia,3
11  Austria,2
12  Azerbaijan,5
```

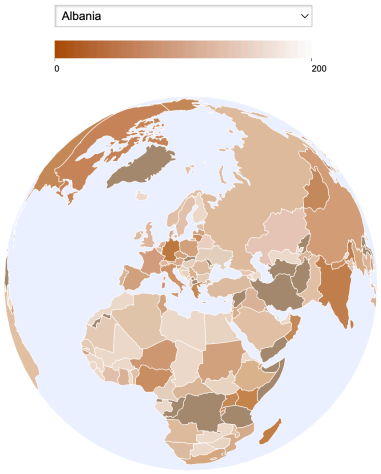
- “index.html” -> Main HTML file which has html, css and d3.js code which actually does task of visualization.

Code Structure	Below are the sections of code in "index.html" and explanation what they do in it: • **DOCTYPE, HTML, and HEAD:** The document is structured as an HTML file with a specified DOCTYPE, and a head section containing metadata, a title, and external script files. • **External Scripts:** The head section includes three external JavaScript libraries: d3.js, topojson, and queue. • **Styles:** The head section also contains a style block that defines CSS styles for different elements, such as the water, land, and legend of the globe. • **Body: Contains an a script which includes:** o Variables for width, height, and sensitivity. o Projection, path, and SVG container setup. o Adding water and allowing the globe to be draggable. o Creating a tooltip and a country list dropdown. o Loading the world map data and country names. o Drawing countries on the globe, adding drag events, and handling mouse events. o Focusing the globe on the selected country. o Reading the flood_risk.csv file and coloring countries based on their flood risk scores. o Creating a color scale legend with labels and tick marks.
Features of visualization	• 3D globe with maps of the countries over it • Flood risk is shown by the colormap and the corresponding legend • Dropdown menu which takes you to the country's map which you clicked on.

3D Globe Choropleth Map: Climate Vulnerability Risk of all Countries

Climate Change does not only affect by causing floods it has several side effects such as heatwaves, storms, tornadoes and random weather shifts which is the major threat to the humans and biodiversity of the planet. Accounting all such factors of climate change, policy makers, activists and developers have aggregated a climate vulnerability index/score for each of the country, we plot a spatial map of these climate vulnerabilities distribution in the below 3D globe Choropleth map.

Global Climate Risk Index identifies the extent to which countries have been affected by extreme weather events.

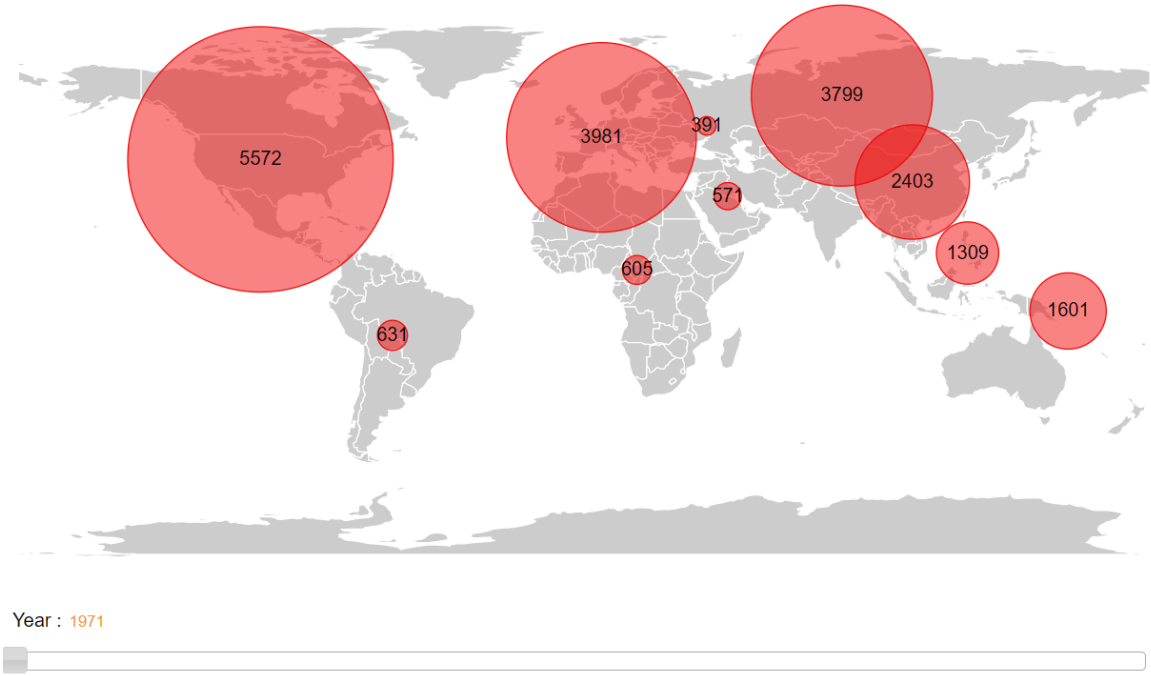
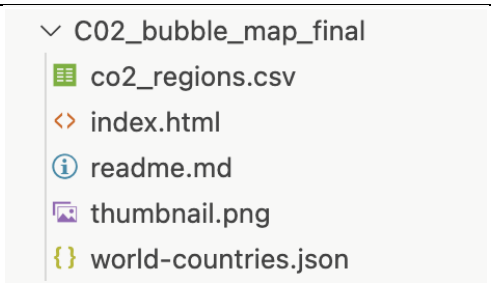
Screenshot of the Visualization	
	Inferences:
	• **The lower the value of this score (towards 0), the higher the risk [darker the color in the globe]**
	  • **Asian and African Countries**
	• **Higher the value of this score(towards 200), lower the risk [lighter color]**
	  • **European and North American Countries**

Github Link	https://climatecs552.github.io/Climate_Risk_3DGlobe_final/
Folder Structure	 • Standard “world.json”-> json file having the shape of the polygon of the countries • “names.tsv”-> tsv file having the names countries corresponding to their ids • Snippet of the “climate_index.csv”  • “index.html” -> Main HTML file which has html, css and d3.js code which actually does task of visualization.
Code Structure	Below are the sections of code in “index.html” and explanation what they do in it:

	• **DOCTYPE, HTML, and HEAD:** The document is structured as an HTML file with a specified DOCTYPE, and a head section containing metadata, a title, and external script files. • **External Scripts:** The head section includes three external JavaScript libraries: d3.js, topojson, and queue. • **Styles:** The head section also contains a style block that defines CSS styles for different elements, such as the water, land, and legend of the globe. • **Body: Contains a script which includes:** o Variables for width, height, and sensitivity. o Projection, path, and SVG container setup. o Adding water and allowing the globe to be draggable. o Creating a tooltip and a country list dropdown. o Loading the world map data and country names. o Drawing countries on the globe, adding drag events, and handling mouse events. o Focusing the globe on the selected country. o Reading the climate_index.csv file and coloring countries based on their climate risk index scores. o Creating a color scale legend with labels and tick marks.
Features of visualization	• 3D globe with maps of the countries over it • Climate Vulnerability index is shown by the colormap and the corresponding legend • Dropdown menu which takes you to the country's map which you clicked on.

Chapter 3: Cause

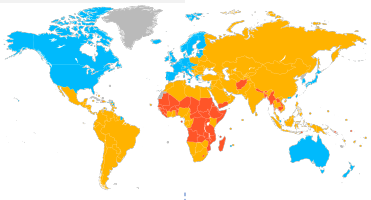
Bubble Chart of C02 Emissions

Screenshot of the Visualization	 **Inferences:** • Shows the rapid increase in C02 emissions worldwide. • Some countries like USA, China and India are majorly responsible for this increased C02 emissions.
Github Link	https://climatecs552.github.io/C02_bubble_map_final/
Folder Structure	 • "index.html" -> Main HTML file which has html, css and d3.js code which actually does task of visualization. • "co2_regions.csv"-Contains data regarding the CO2 emissions of countries and continents over a 30 year timeline. • "world-countries.json"-> json file having the shape of the polygon of the countries with respective coordinates.
Code Structure	Below are the sections of code in "index.html" and explanation what they do in it: • **DOCTYPE, HTML, and HEAD:** The document is structured as an HTML file with a specified DOCTYPE, and a head section containing metadata, a title, and external script files.

	• **Styles:** The head section also contains a style block that defines CSS styles for different elements like background color, circle color , font-size. • **Libraries:** External JavaScript and CSS libraries (jQuery, jQuery UI, and D3.js) are linked. • **Body:** Contains a script which includes: a. A with an ID "graph" as a container for the visualization. b. A <p> element containing a label and input box to display the selected year. c. A with an ID "slider" which contains a jQuery UI slider for year selection. • **Javascript:** Contains a script which includes: a. Initializes the jQuery UI slider and sets up its event handlers. b. Defines the width, height, projection, and path for the map visualization. c. Creates SVG elements for states, circles, and labels. d. Loads data for countries and CO2 emissions using D3.js functions. e. Appends path, circle, and text elements to the SVG containers. f. Adds interactivity to the visualization with mouse events. g. Defines the redraw() function to update the visualization based on the selected year.
Features of visualization	• Bubble Map to indicate the amount of emissions in million metric tonnes for the respective countries and continents. • Interactive Slider to see the variation in Co2 emissions over the years.

Chapter 4: Conclusion

Developed Nations



Developing Nations

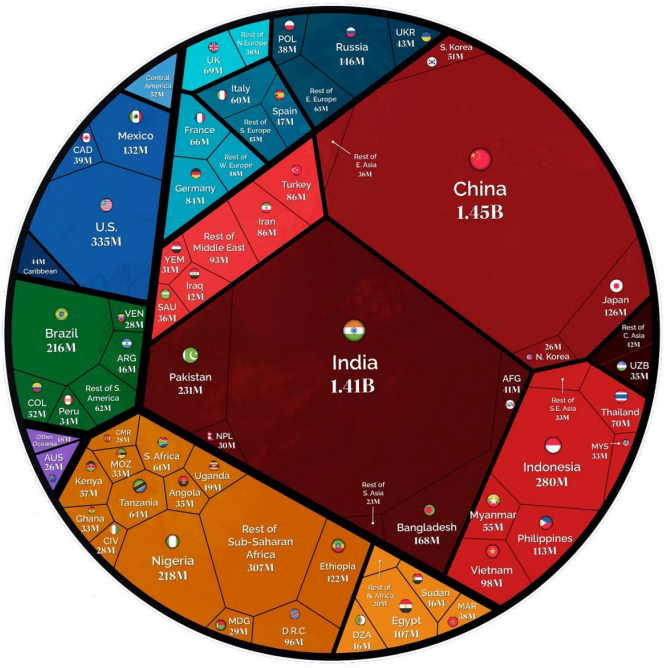
- Catered the population better in history for long and hence need to cater now also in a better way
- Started to develop their economies and needed to cater to the population in a better way:
  - Urbanization
  - Industrialization

Since we know that there is blame game between developed nations and developing ones, which are keeping their best arguments for the CO2 emissions. We conclude our plot from the below slide.

Global Population Voronoi Diagram

This plot shows the clear picture of the population numbers of the various countries the world.

Solution



References:https://www.linkedin.com/posts/somnath-ray_earthday-climateaction-usa-activity-7055641773997477888-UXsj?utm_source=share&utm_medium=member_android

- Three largest populous and CO2 emitters are:
  - US 🇺🇸
  - China 🇨🇳
  - India 🇮🇳
- These countries should lead role in green energy and policy making. 🌱

We referenced this plot from this **LinkedIn Post.**

Contribution Table

Ayush's Work	Created the Plots of the 3D globe visualizations which are used in - 3D Globe Choropleth Map: Average Temperature of all Countries - 3D Globe Choropleth Map: Flood Risk of all Countries - 3D Globe Choropleth Map: Climate Vulnerability Risk of all Countries Referenced the code from their respective sources for creating "Spatial Temperature Anamoly Map and Animation" and "Radial Chart of Global Temperature Anamoly" and modified them as required.
Harishankar's Work	Created the plots for: - Interactive Heatmap for month-wise average global temperature fluctuation. - Interactive bubble map slider plot for C02 emissions of countries and continents over a decade. /
Done Together	- Preprocessed, Cleaned and Structured all the data required for each of the plots above. - Ideated, discussed the format of the presentation, idea and the report. - Reviewed all over the d3.js code and provided appropriate comments wherever required.

References

https://www.marshmclennan.com/insights/publications/2021/september/marsh-mclennan-flood-risk-index.html

https://www.linkedin.com/posts/somnath-ray_earthday-climateaction-usa-activity-7055641773997477888-UXsj/?utm_source=share&utm_medium=member_android

Data Sources:

Global Temperature Data :[CC0 Public Domain] https://www.kaggle.com/datasets/sachinsarkar/climate-change-global-temperature-data

Global Precipitation Data:[World Bank Data] https://data.worldbank.org/indicator/AG.LND.PRCP.MM

CO_2 Emission Data Countrywise:

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