**CSE3020 – Data Visualization**

**Project Report**

**Climate Change Visualization and Analysis**

*By*

20BCE1353 Siddharth S

B. Tech Computer Science and Engineering

*Submitted to*

**Dr. Joshan Athanesious**

**School of Computer Science and Engineering**

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**DECLARATION**

I hereby declare that the report titled “**Climate Change Visualization and Analysis”** submitted by me to VIT Chennai is a record of bona-fide work undertaken by me under the supervision of **Dr. Joshan Athenesious**, School of Computer Science and Engineering, Vellore Institute of Technology, Chennai.

Signature of the Candidate

**Siddharth S**

**Reg. No. 20BCE1353**

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**ABSTRACT**

Climate change is one of the most pressing global challenges facing humanity today. It has been caused by human activities, such as the burning of fossil fuels, deforestation, and industrial processes, which have released large amounts of greenhouse gases into the atmosphere. These gases trap heat and cause the Earth's temperature to rise, resulting in a range of adverse effects, including more frequent and severe weather events, sea-level rise, and changes in ecosystems. The importance of tackling climate change cannot be overstated. Its impacts are already being felt around the world, from the devastating wildfires in Australia, to the hurricanes that have ravaged the Caribbean and the United States, to the droughts and floods that are affecting communities in Africa and Asia. Climate change threatens the basic needs of life, such as food, water, and shelter, and exacerbates existing social and economic inequalities. Visualizing trends related to climate change is crucial for understanding the severity of the problem and developing effective solutions. Climate data is complex and difficult to understand, but through the use of visualizations, it can be made more accessible and meaningful to a wider audience. Visualizations can help to highlight the scale and urgency of the problem, and show how different regions and communities are being affected in different ways. They can also help to communicate complex scientific concepts, such as the relationship between greenhouse gas emissions and global temperature rise, in a clear and intuitive way. Furthermore, visualizing trends related to climate change can help to inform decision-making at all levels. Policymakers, businesses, and individuals need to understand how climate change will affect their operations and daily lives, and what actions they can take to reduce their impact. By making climate data more accessible and understandable, visualizations can help to identify areas where action is needed, and track the progress of mitigation and adaptation efforts.

1. **Introduction**
   1. **Objective and Goal of the Project**

This project aims to develop a comprehensive set of data visualizations and analytical conclusions that enable users to explore the impacts of climate change on the planet. The project will leverage a variety of data sources, like temperature and climate data, to create interactive visualizations that allow users to explore climate change trends over time and across different regions. By providing accessible and intuitive visualizations and analysis, this project will help individuals and policymakers better understand the complex and urgent issue of climate change, and develop strategies to mitigate its impacts.

* 1. **Motivation**

Climate change is a global challenge that affects everyone, and it has significant social, economic, and environmental consequences. Understanding the causes, impacts, and potential solutions to climate change is critical to ensure a sustainable future for our planet and future generations. By analyzing climate change, individuals can contribute to the development of effective solutions and strategies to mitigate its impacts. It requires a multidisciplinary approach and expertise in the field to accurately analyze the causes and effects of it. By working to understand and address climate change, individuals can contribute to a larger mission of protecting the planet and ensuring a sustainable future for all. This sense of purpose can be a powerful motivator for those who are passionate about the environment and want to make a difference in the world.

* 1. **Challenges**

The primary challenges faced in the planning and implementation of this project come down to the public availability of data and the legitimacy and accuracy of the data. It is easy to get lost in extremely large datasets that are raw data that come straight from a monitoring station, which requires to be processed for any meaningful conclusions to be made.

1. **Literature Survey**
2. **Requirements Specification**
   1. **Software:**

Jupyter Notebook

Python 3

Python modules:

* datetime
* pandas
* numpy
* seaborn
* matplotlib
* plotly
* statsmodel
  1. **Hardware:**

Operating System: Windows, MacOS or Linux

CPU: Intel/AMD Dual Core or greater

RAM: 8GB or greater

Storage: 1GB or greater

1. **System Design and Methodology**

This project has made use of various visualization tools to create interactive and dynamic plots. In general, before visualizing any factor, data preparation has to be done, wherein the data is described and anomalies are filtered out (like empty values or outliers). This allows for a cleaner visualization and maintains the accuracy of the plots and analysis that is derived from it.

Several popular data visualization libraries in Python were used for the plots, most notably plotly, which is an open-source graphing library that is very useful for creating interactive and dynamic plots of data. Additional libraries include seaborn and matplotlib which are great for static plots and analysis. For data manipulation, pandas and numpy were used.

For visualizing climate change, this project looks at four related effects that come directly as a result or directly cause climate change. These are: Temperature, Air Quality, Greenhouse Gas Emissions and Sea Level.

1. **Temperature:**

The Earth's temperature is determined by the balance between the amount of heat that comes into the atmosphere from the sun and the amount of heat that is radiated back into space. This balance is influenced by factors such as the composition of the atmosphere, the reflectivity of the Earth's surface, and the amount of greenhouse gases in the atmosphere. Over the last century, we have observed a continuous increase in global average temperatures, and this long-term increase in the Earth’s average surface temperature is referred to as global warming. This has been caused due to human activities like the burning of fossil fuels that have led to an increase in the concentration of greenhouse gases in the atmosphere, which effectively trap the heat of the sun within the Earth’s atmosphere.

1. **Air Quality:**

Air Quality is the degree to which the air is suitable or clean enough for humans or the environment. Climate change can have a direct impact on air quality through changes in temperature, precipitation, and weather patterns. Higher temperatures can increase the formation of ground-level ozone, a major component of smog, while changes in precipitation can affect the dispersion of air pollutants. More frequent and severe weather events, such as wildfires and dust storms, can also lead to poor air quality. On the other hand, poor air quality can also contribute to climate change. Air pollution from sources such as burning fossil fuels and industrial processes can release greenhouse gases, such as carbon dioxide and methane, into the atmosphere. This can lead to a feedback loop, where poor air quality exacerbates climate change, which in turn leads to even poorer air quality. Air quality is commonly measured and reported with respect to an Air Quality Index (AQI), which takes five major air pollutants into account: ground level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide.

1. **Greenhouse Gas Emissions:**

Greenhouse gases are gases in the Earth's atmosphere that trap heat and contribute to the greenhouse effect. They include gases such as carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and fluorinated gases, such as hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6). The greenhouse effect is a natural process by which some of the energy from the sun that reaches the Earth's surface is absorbed and then re-emitted back into the atmosphere as heat. Greenhouse gases in the atmosphere trap some of this heat, keeping the Earth's surface warm enough to support life. However, the increasing concentration of greenhouse gases in the atmosphere, primarily from human activities such as burning fossil fuels, deforestation, and agriculture, is causing the Earth's temperature to rise. This rise in temperature, known as global warming, is causing changes in the Earth's climate, such as melting glaciers, rising sea levels, and more frequent and severe weather events.

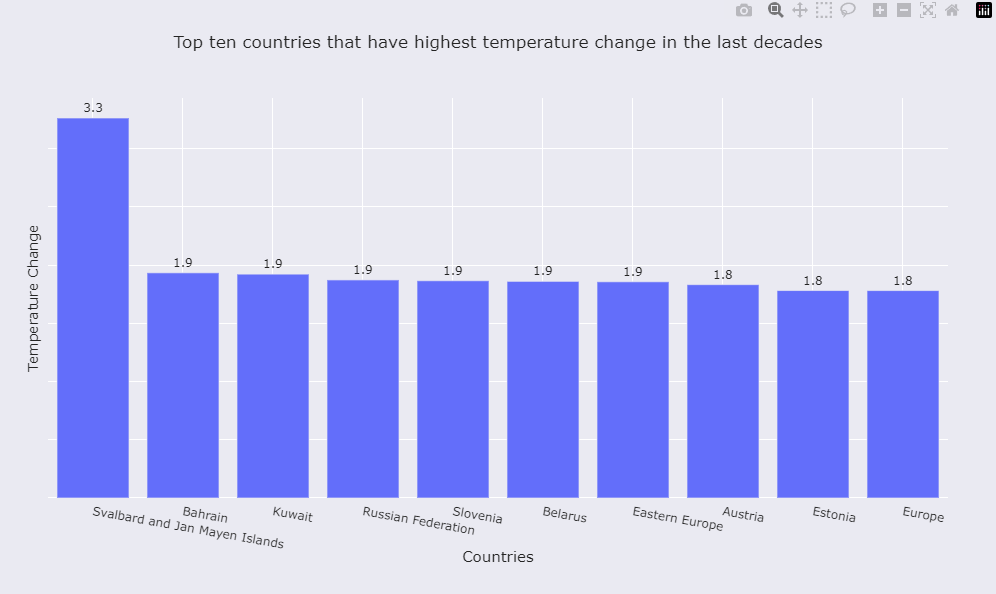
1. **Sea Level:**

Sea level refers to the average level of the ocean's surface. It is measured relative to a fixed point on land, known as a datum. Sea level has been rising steadily over the past century, and the rate of rise has been accelerating in recent decades. According to the Intergovernmental Panel on Climate Change (IPCC), global sea level has risen by approximately 15 cm (6 inches) since the beginning of the 20th century, and is projected to rise by another 30-110 cm (12-43 inches) by the end of the 21st century, depending on future greenhouse gas emissions and other factors. The primary cause of sea level rise is the thermal expansion of seawater, which occurs as the ocean absorbs heat from the atmosphere. As the water warms, it expands, causing the sea level to rise. This process has been responsible for approximately half of the observed sea level rise over the past century. Another major cause of sea level rise is the melting of land-based ice, such as glaciers and ice sheets in Greenland and Antarctica. As these ice masses melt, they add water to the ocean, causing the sea level to rise. This process has become an increasingly important contributor to sea level rise in recent decades. Sea level rise has numerous impacts, including increased flooding and erosion along coastlines, saltwater intrusion into coastal aquifers, and the displacement of coastal populations. Rising sea levels also exacerbate the impacts of storm surges and coastal flooding events, which can cause significant damage to infrastructure and property.

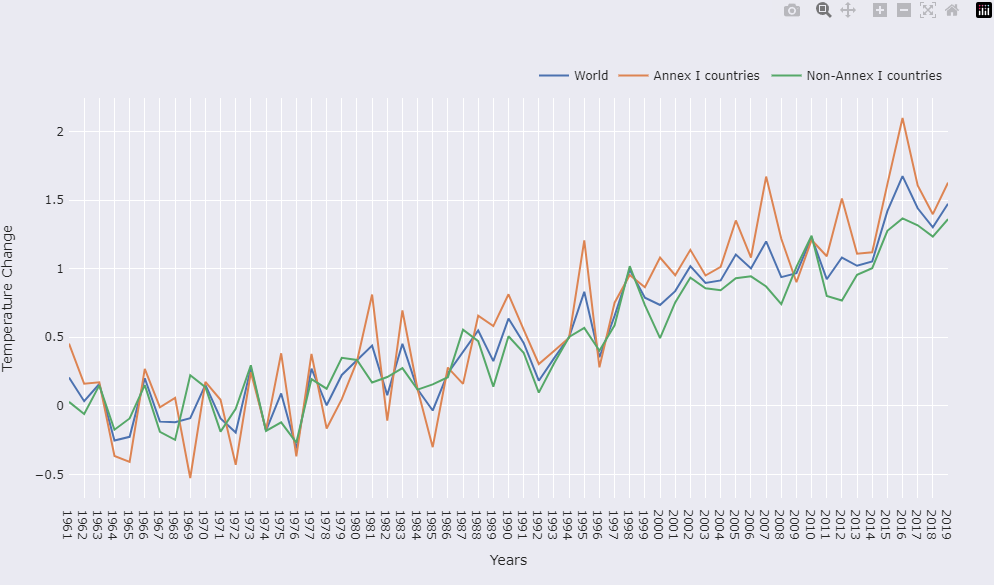
Multiple datasets for each of these categories were obtained from Kaggle, containing both time series and cross-sectional data.

The plots used are

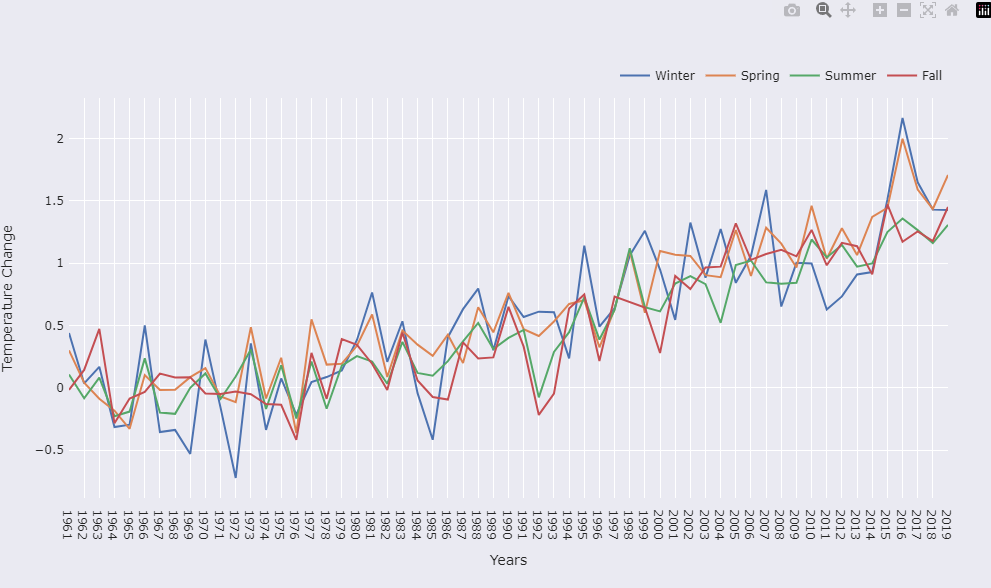
1. Barplot
2. Line plot for time series data
3. Interactive polar plots for multidimensional time series data
4. Choropleth plots for visualizing regions on a global map
5. Heatmap
6. **Results and Discussion**



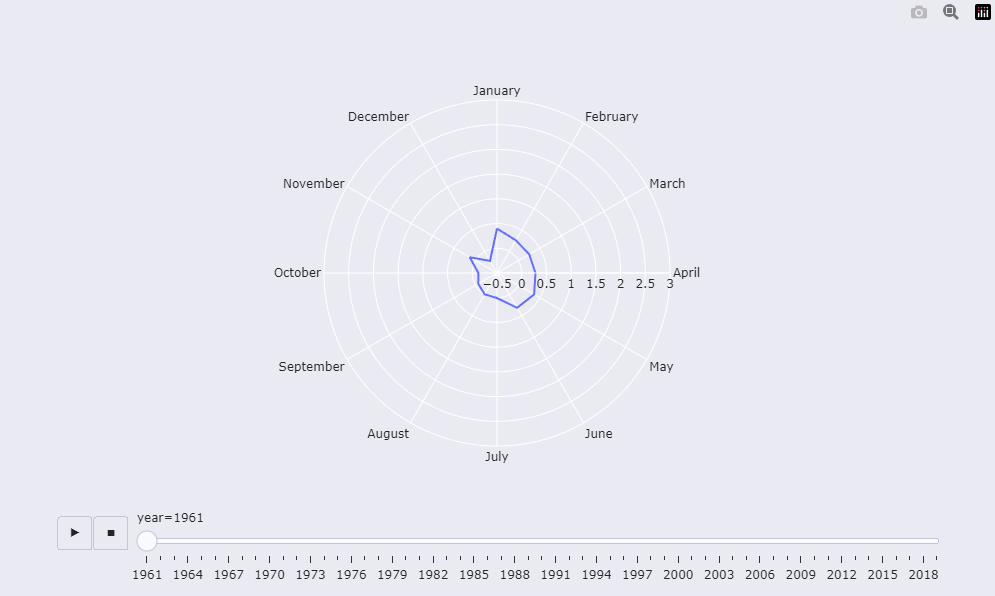
From our first plot, we infer that in the last decade, some notable countries that have had the highest increase in temperature are Bahrain, Kuwait, and Russia.

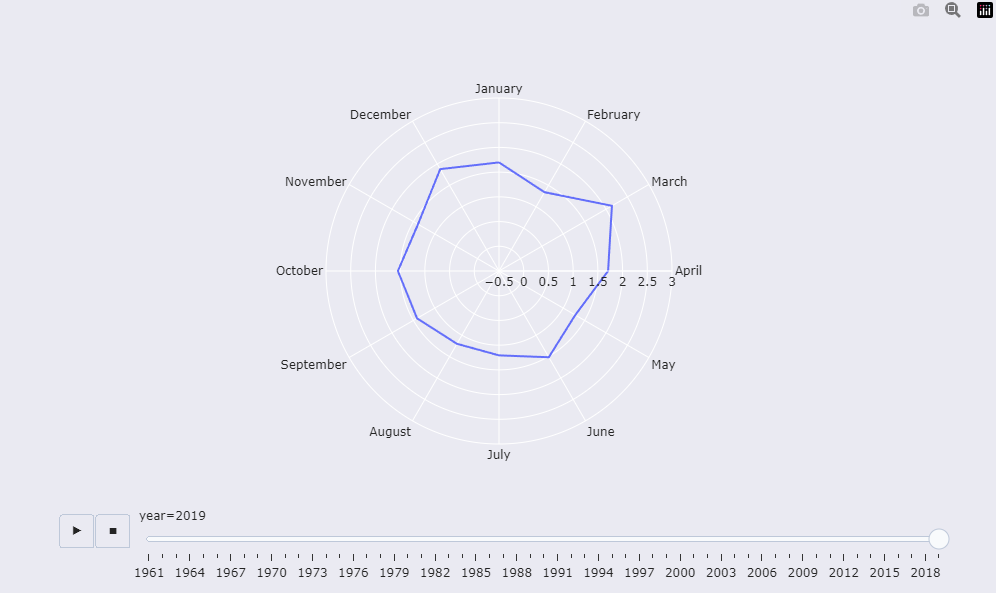


Between 1961 and 2019, there is a general trend that Annex 1 countries (developed countries) saw a greater increase year over year in the average temperature compared to Annex 2 (non developed countries). This can be due to the fact that developed countries are responsible for a greater share of greenhouse gas emissions which is a primary factor that affects global warming.



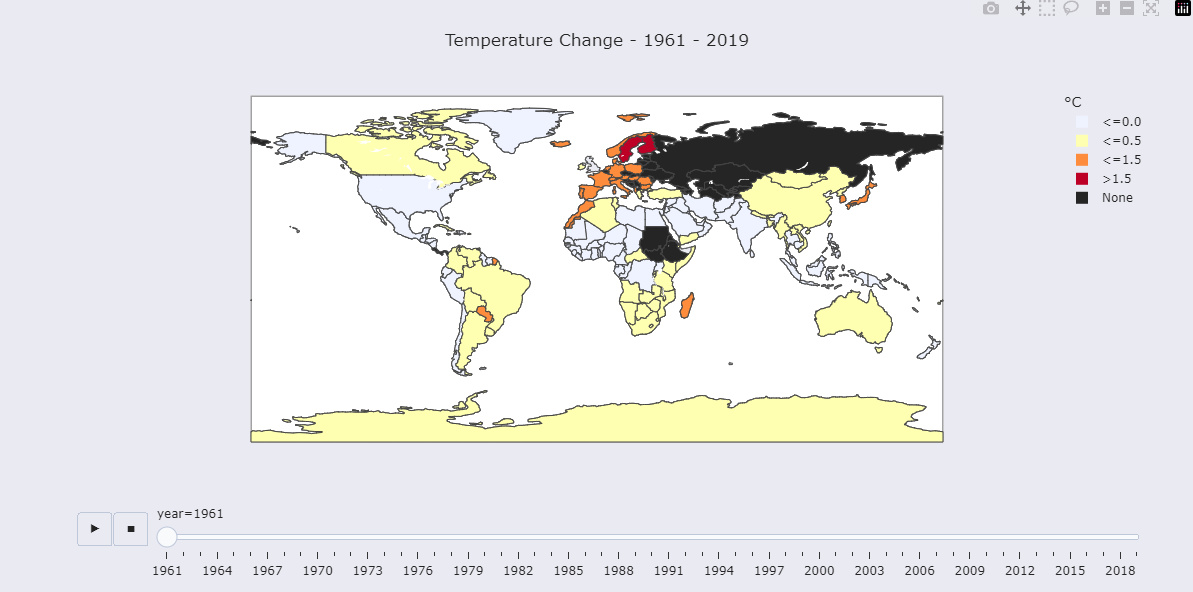
Similarly by plotting the line graph for each season, we can observe a general upward trend in the increase in temperature across all seasons.

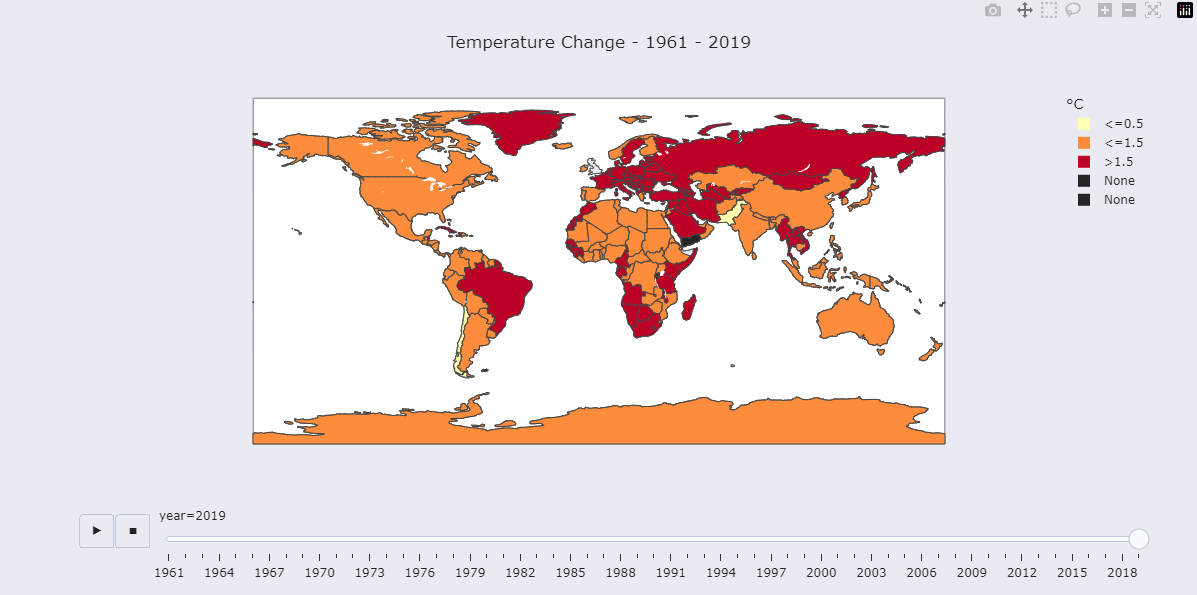


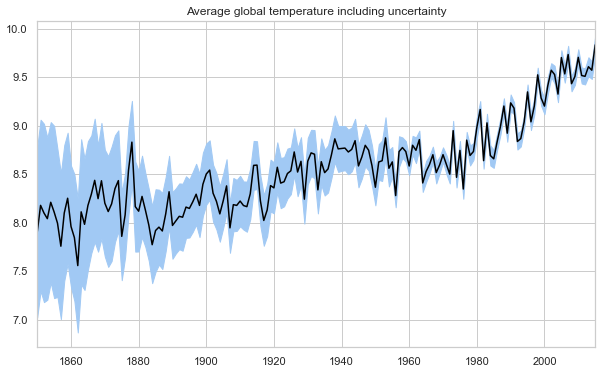


This polar graph shows an interactive animation that depicts the increase in the change of temperatures year over year for each month. As is inferred from the plot, in 2019 there was a much greater increase in temperature from 2018, as compared to 1961.

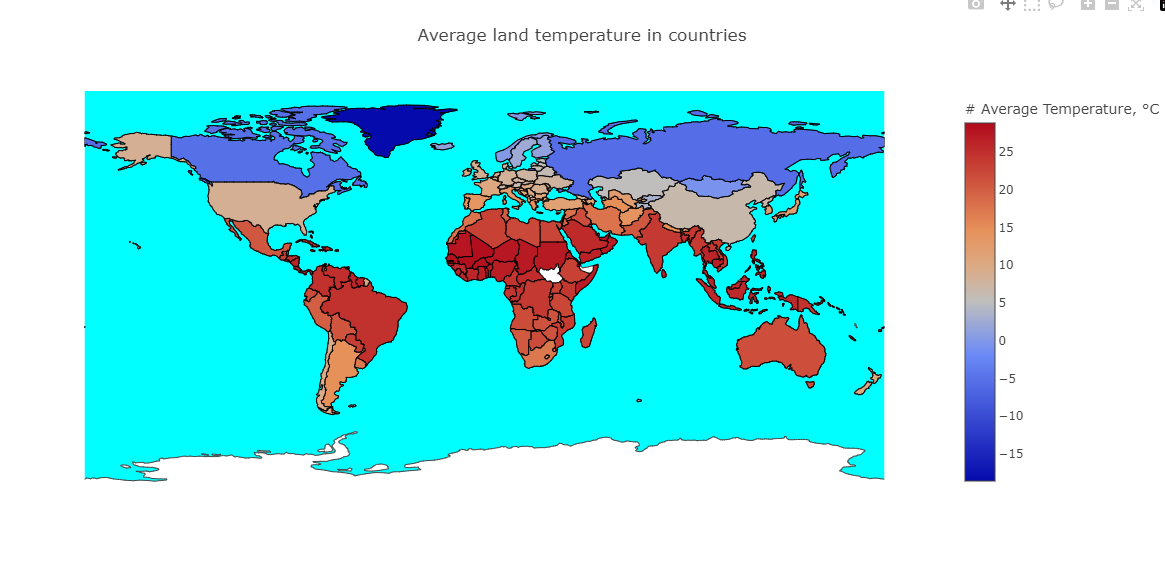
This same conclusion is also visualized in a choropleth, which visualizes the data for each country on a human readable map.





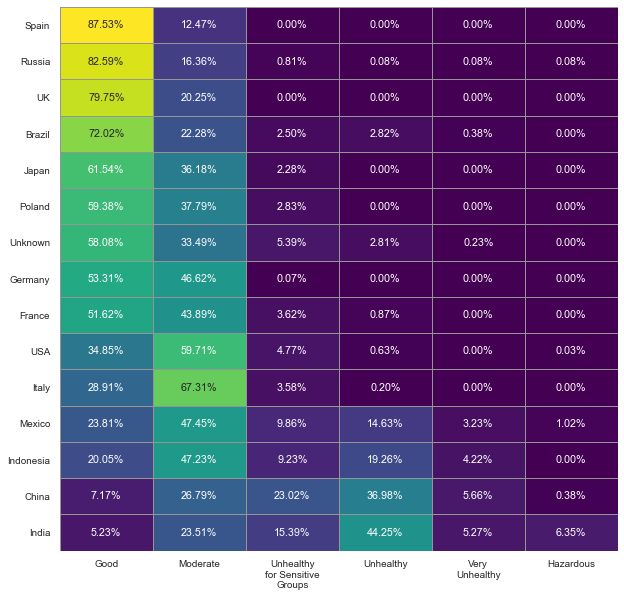


When looking at average temperatures for the whole planet, we observe a clear upwards trend from the 1800s to present day.

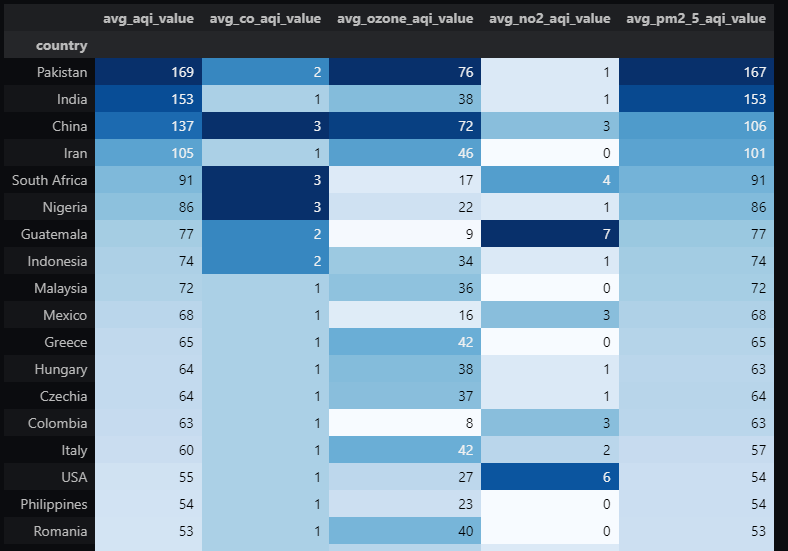


From this choropleth, the hotter and cooler regions of the world are visualized. Areas in South America, Africa, and South and South East Asia record higher average temperatures while northern regions like North America and Russia have lower average temperatures.

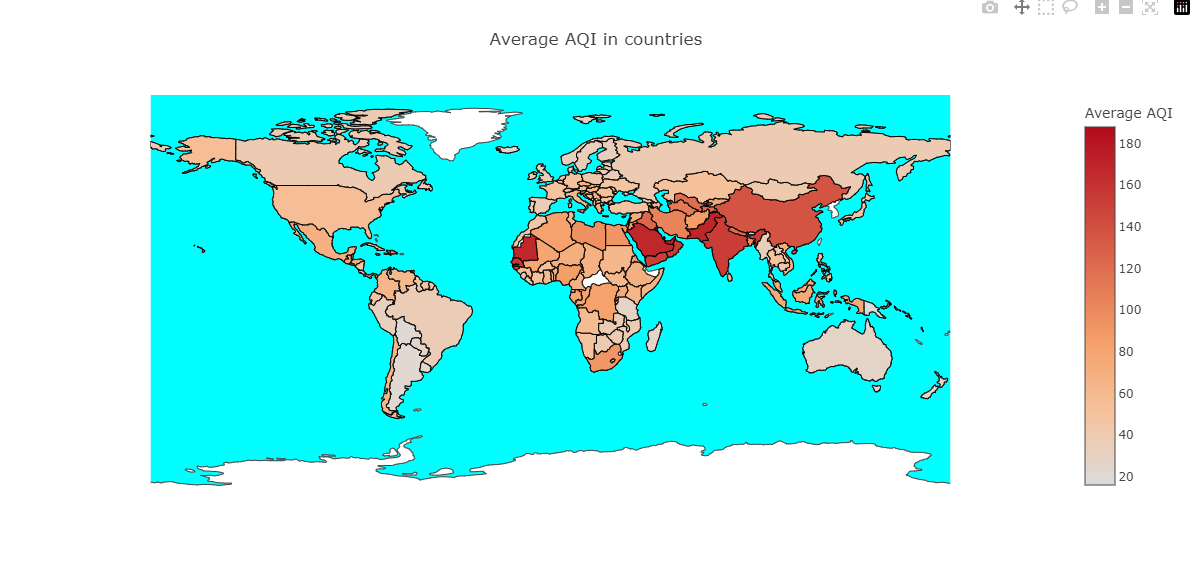
Next, we take a look at Air Quality

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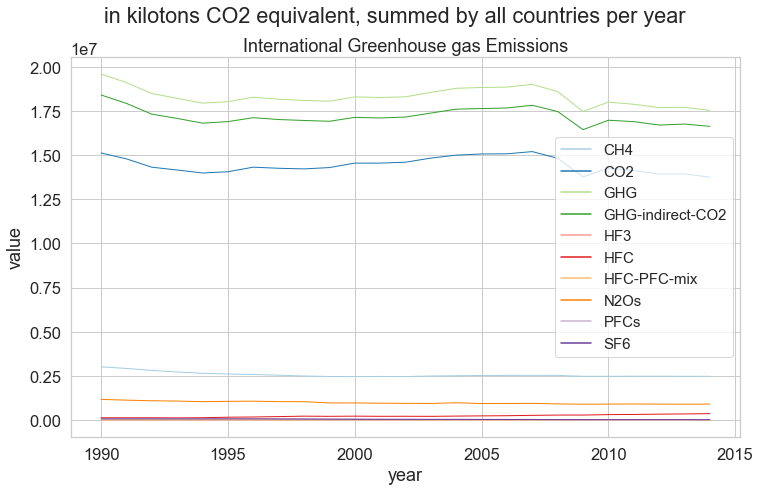
This heatmap shows the quality of air based on the percentage of the measured air quality. For instance, Spain has the best outlook from this visualization as 87.53% of all recordings from Spain are of Good Air Quality Index. India on the other hand has most of their measurements at "Unhealthy" levels of AQI.



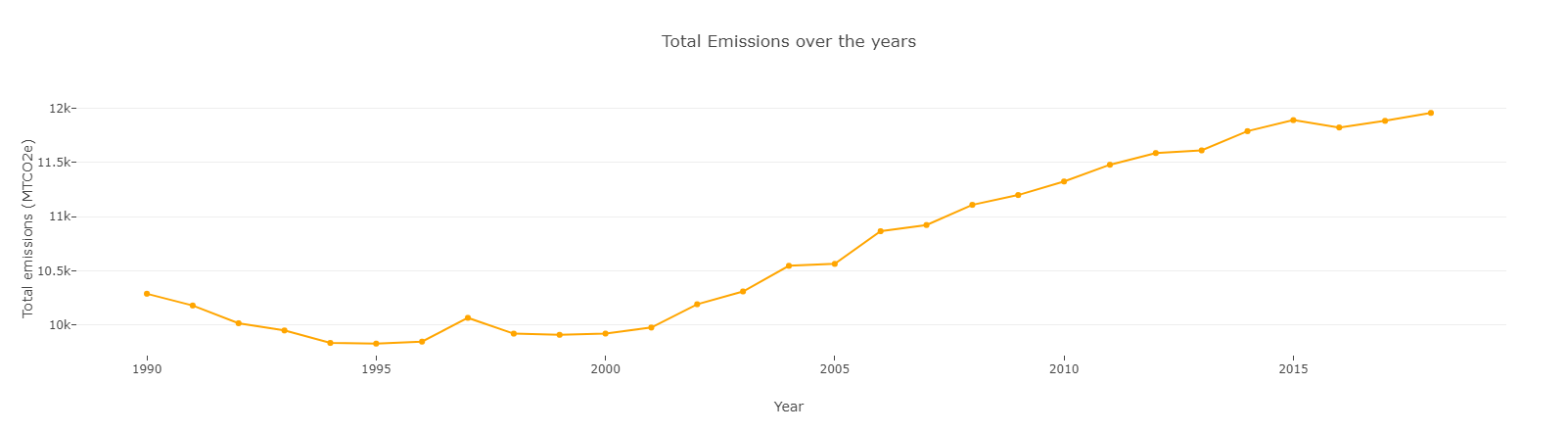
Pakistan, India and China are the top three countries with the worst average AQI value as reported.



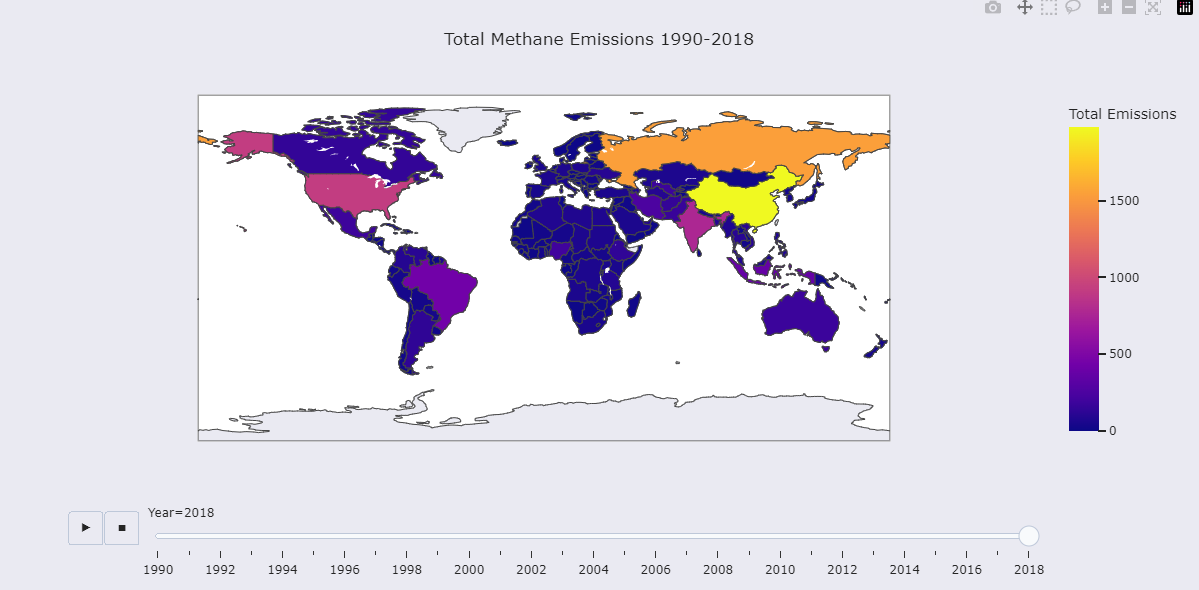
The average Air Quality is now visualized in a Choropleth and it is indeed confirmed that Pakistan and India along with some of the middle eastern countries have the worst recorded AQI values.

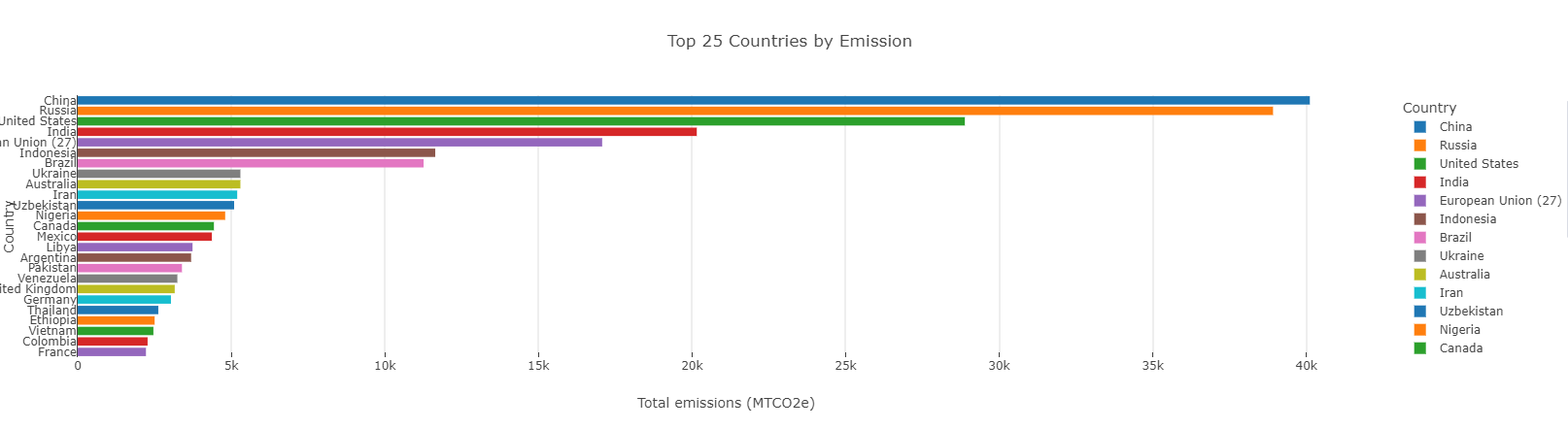
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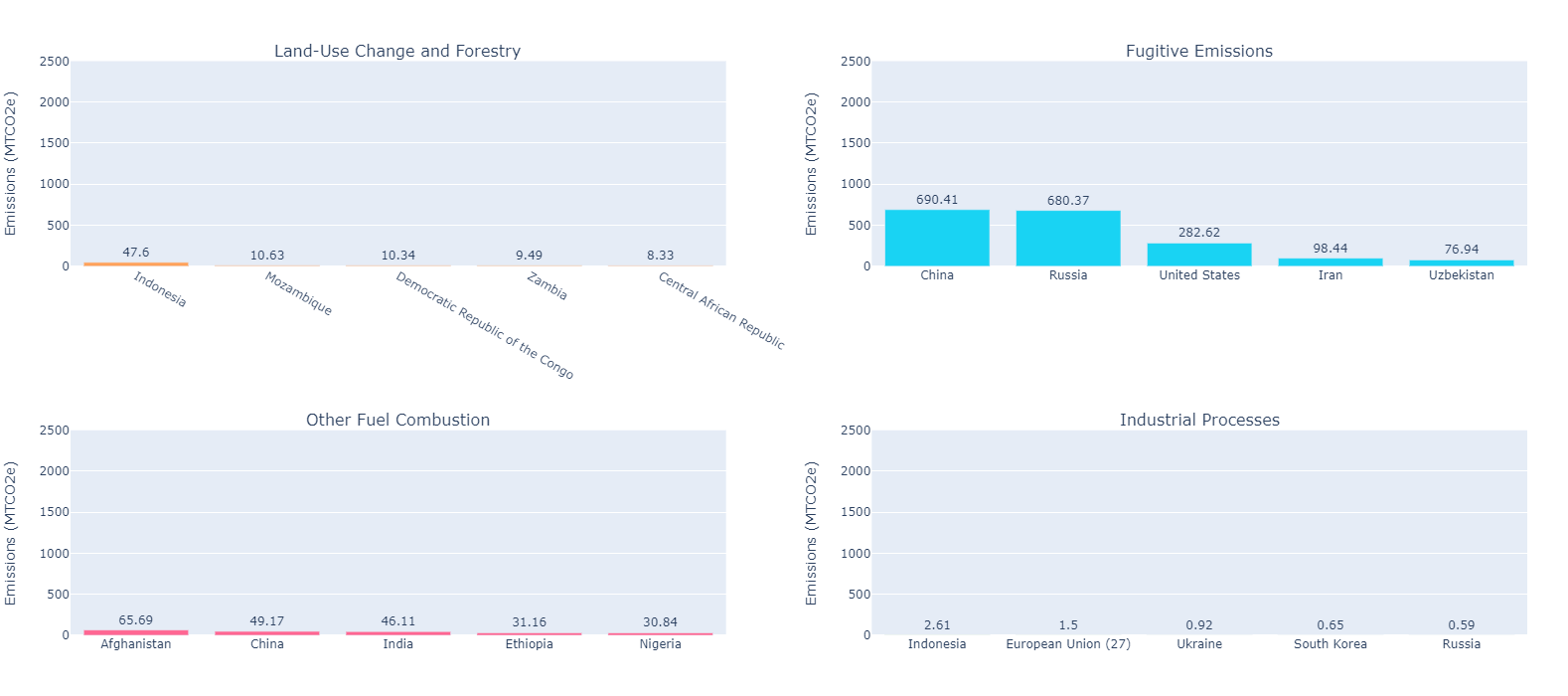
Looking at greenhouse gases, we observe a general downward trend in the emissions of greenhouse gases due to more environmental awareness and products designed taking environmental restrictions into account.



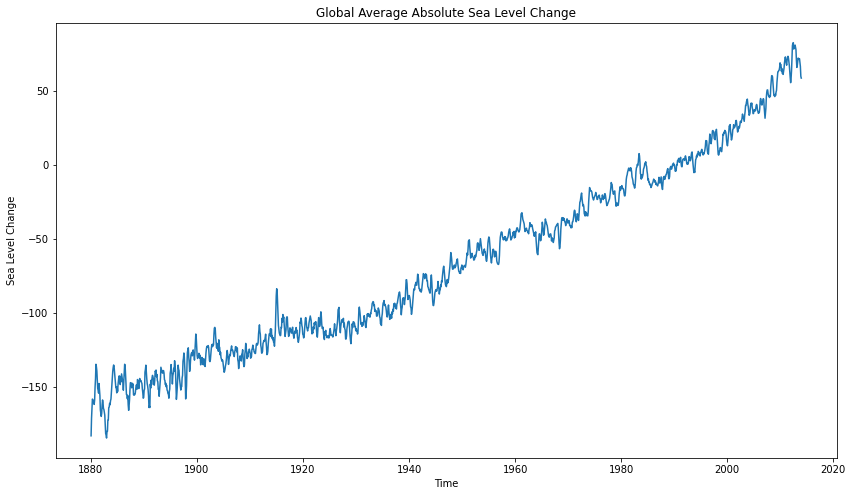
When looking specifically at methane emissions across all sectors, we observe an upwards trend. This is also visualized in an interactive choropleth

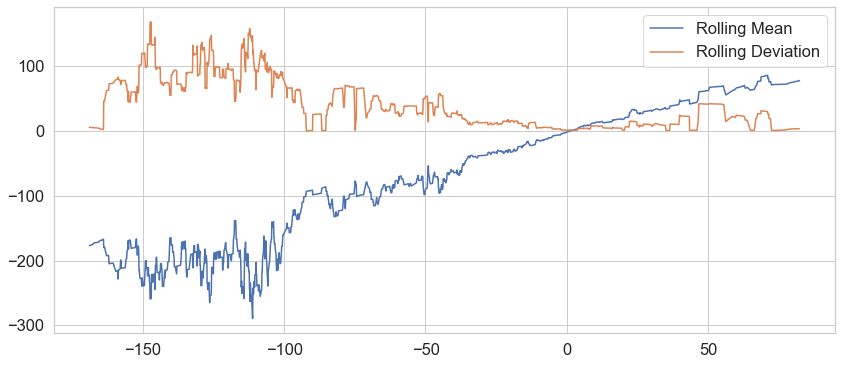


China, Russia and the US account for most of methane emissions 

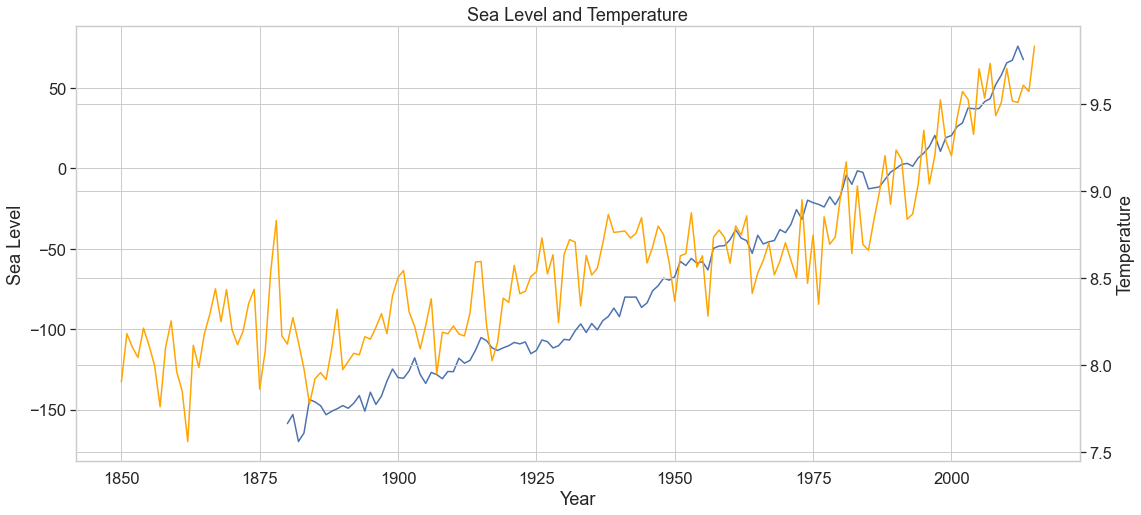
 

The agriculture and energy sectors are responsible for most of the methane emissions.



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Lastly, when looking at sea levels, we observe an increase in the sea levels from 1880 to 2020. This is due to the global temperature increases which leads to the melting of more and more ice caps and causing thermal expansion of salt water.

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We can verify this by plotting both global temperatures and sea level changes in the same plot for the same time period. Here, we do see the correlation between the two.

1. **Conclusion and Future Work**

In conclusion, this project has demonstrated some of the factors that are attributed to climate change, and how they have changed over the years. From all this data and by visualizing it, the average person is able to understand that yes, climate change is indeed real and has been happening for decades. It is only of big importance in recent years due to the Earth being at its tipping point when it comes to sustaining human life, and also the rise of environmentalists from the newer generations who understand the need for preserving the planet we call home.

This project can be expanded on by integrating forecasting models, to provide more insight into where we’re headed if we do not do anything to combat climate change. Additionally, more information can be brought like global precipitation data, assuming a reliable source for this data is freely available to use.

1. **References**