# Climate Change Analysis

A Project Report Submitted

in Partial Fulfilment for the Course

**CS685A: Data Mining**

Under the guidance of

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Fall 2021

*by Group ID: 12*


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## ABSTRACT

Climate change is one of the most important concern for the earth's environment. The term climate change refers to the change in environmental conditions of the earth and how it affects the ecosystem. The climate of the earth has changed a lot over the last 650,000 years. However, the more concerning changes happened in the last few centuries.

Human activities nowadays play a significant role in driving the climate change. The increase in amount of green-house gases causes the rise in atmospheric temperature. This in turn affects the glaciers and warms up the oceans.

With the technical advantage we have nowadays, scientists have collected data on the various factors that drive climate change. The analysis of this data will help us understand this major issue and get a better perspective of the possible solutions.

We will analyze the common factors that cause climate change and draw useful inference from the data. The major factors include the emission of harmful green-house gases, rise in temperature of the earth's surface, warming up of oceans, melting of glacier, rise in sea level, and how these factors lead to the increase in occurrence of climate anomalies and causes natural disasters.

# Contents

# Chapter 1

# Introduction and Aim of the Project

## 1.1 Introduction

Climate change is one of the major crisis today. It can have a devastating consequence on the planet earth, its ecosystem and ecology. In the past few decades humans have made a significant impact on the earth's environment.

The release of harmful greenhouse-gases in the atmosphere and their trapping in the earth's atmosphere gradually warms up the temperature of the earth. In the long run this increases the rate at which our glaciers are melting. When the glaciers melt the sea-level rises which impacts the coastal regions as well as the aquatic life.

## 1.2 Motivation and Aim of the Project

In today's era, large-scale industries are fueling environmental degradation which when combined on a global scale can cause extreme weathers, economic loss, and frequency of natural disasters. Therefore, we need to act on the sources that are inducing climate change and in-turn reduce the rate of global temperature rise.

With this project, we intend to study some of the common factors that can fuel climate change and we try to correlate these factors with one-another to get a clear picture of events that bring together climate change.

In this project we will analyze the following aspects that can induce climate change:

- Global Emission of Greenhouse-Gases
- Rise in Temperature
- Melting of Glaciers and Rise in Sea Level
- Plastic Waste in Oceans
- Natural Disasters
- Correlation of Deforestation and Endangered Species

# Chapter 2

# Dataset Used

- **Global Greenhouse-gas Emission Data:** link
- **World Population Dataset:** link
- **Plastic Pollution Dataset:** link
- **Country to Continent Mapping:** link
- **Global Temperature Dataset:** link
- **Climate Classification and Climatic Regions of the World:** link
- **Threatened species Dataset:** link
- **Depletion and growth of forest resources in terms of volume:** link
- **Glacier Ice-Sheets**: link
- **Sea-Level Data:** link

# Chapter 3

# Results and Analysis of Common Factors Affecting Climate

## 3.1 Greenhouse-Gas Emissions

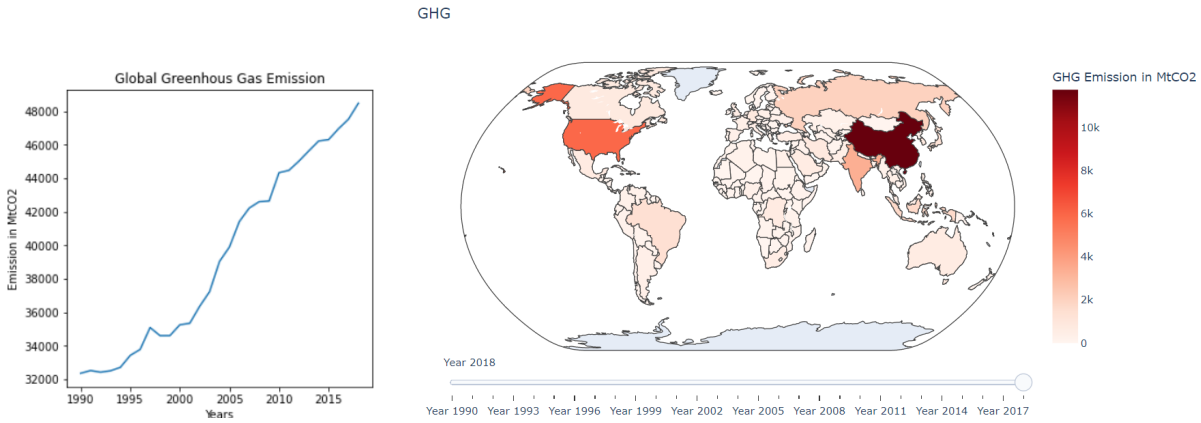
Greenhouse gases trap heat and make the planet warm. These gas absorb and emit radiant energy within the thermal infrared range, causing the greenhouse effect. In the earth's atmosphere, primary greenhouse gases are carbon dioxide(CO2), methane (CH4), Nitrous oxide (N2O), ozone (O3), water vapor (H2O), and Fluorinated gases (F) [13].
In this project, we are using the dataset provided by the Climate Watch website [7], which contains time series data of carbon dioxide, methane, nitrous oxide, and fluorinated gas emissions from 1990 to 2018 for each country and the sectors responsible for it. The project aims to report the country that produces the most and least amount of greenhouse-gas throughout these years [2] [6].

### 3.1.1 Contribution of Carbon dioxide

Carbon dioxide is the most important heat-trapping gas. It contributes to around 75 percent of total greenhouse gas emissions, released through human activities such as deforestation and burning fossil fuels and natural processes such as respiration and volcanic eruptions. Methane (CH4) accounts for 17 percent of the total greenhouse gases emission. The concentration of Fluorinated gas and Nitrous oxide in the atmosphere is deficient.

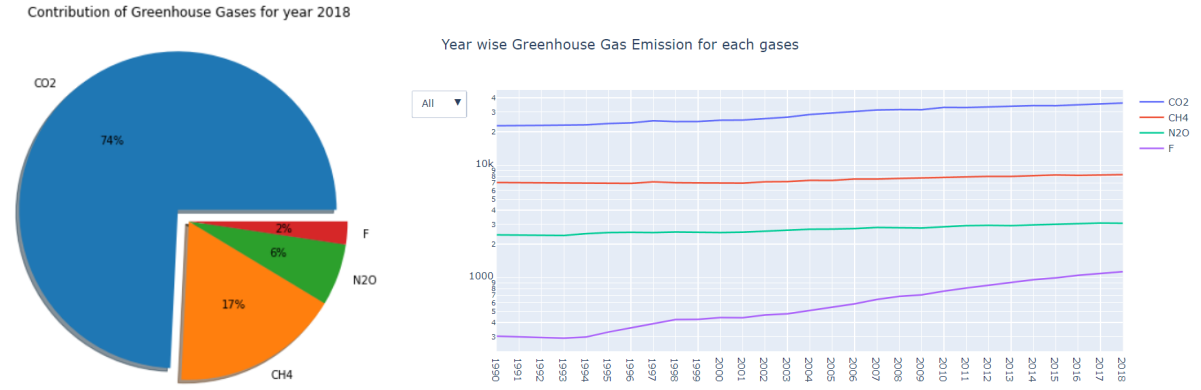
### 3.1.2 Comparison of sources of greenhouse gas in 1990 and 2018

The primary sources of greenhouse gas emissions are electricity, transportation, manufacturing constructions, agriculture. These alone combined contribute to more than 71 percent of the total greenhouse-gas emission. The reason for electricity being the most significant greenhouse-gas emission source is the burning of fossil fuels. There was a significant increase of 6 percent in greenhouse-gas emission by the electricity sector from 1990 to 2018. Share of other sources are electricity 32%, transportation 14%, manufacturing construction 13%, agriculture 12%, industrial process, building, fugitive emission 6% each.



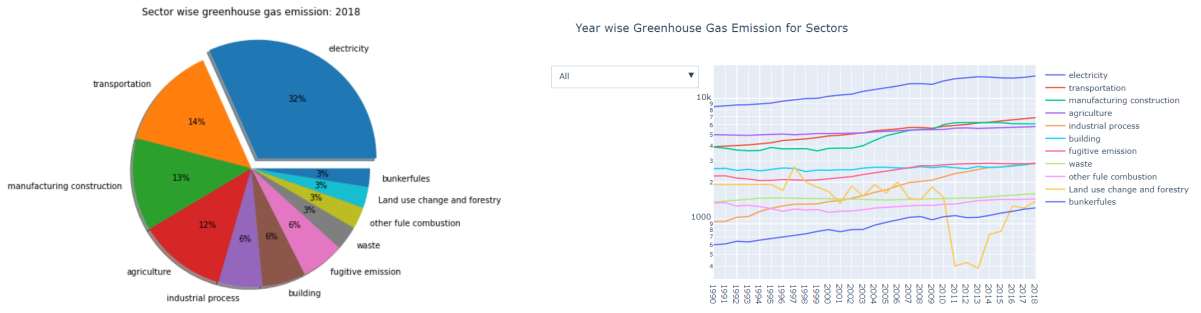

(a) (b)

Figure 3.1: (a) Global GHG Emission (1990-2018) (b) GHG Emission Heatmap



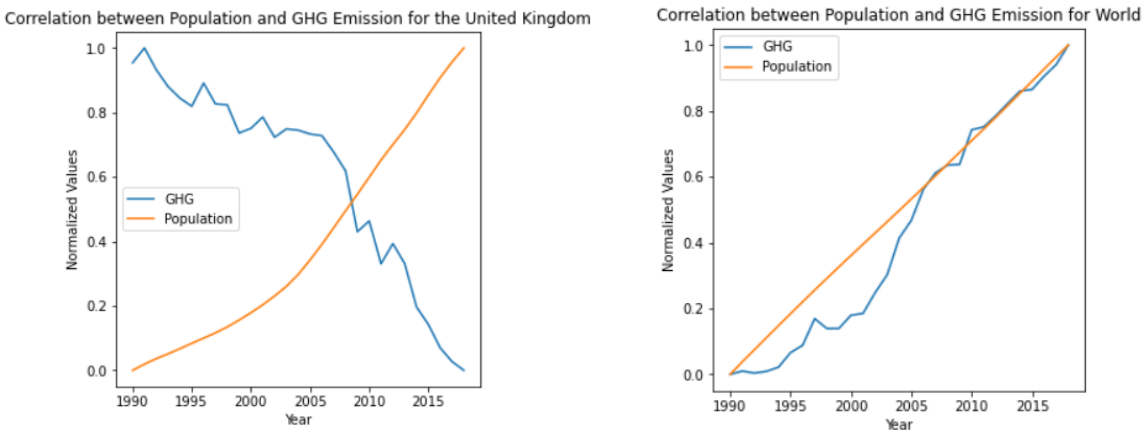

(a) (b)

Figure 3.2: (a) GHG Emission Pie Chart (b) Line Chart




(a) (b)

Figure 3.3: (a) GHG Emissions Sector-wise (2018) (b) GHG Emissions Over the Years 1990-2018




(a) (b)

Figure 3.4: Correlation between population and GHG Emission

### 3.1.3 Relation between Population and Greenhouse Gas Emission

There is a very high correlation between the Population of countries and the volume of greenhouse gas emissions. Moreover, this is obvious because the increase in population also increases the demand for agriculture, electricity, and transportation. Most countries show a positive correlation, but 30 countries show a negative correlation, like the United Kingdom -0.97, North Korea -0.94. Negative correlation means: on increase in population, the volume of greenhouse gas decreases. We use the world population dataset [15] for our purposes.

### 3.1.4 China and United States: Biggest Source of Greenhouse Gas

China is the most populated country globally, with more than 1.4 billion people (Current status) and the largest producer of greenhouse gases 24.27%. China alone produces one-fourth of the total greenhouse gases, followed by the United States 12.25%, India 6.94%, Russia 4.21%, and Indonesia 3.52%. Half of the total greenhouse-gas is generated by these countries only. China is the only country ever that crossed the boundary of 10,000 MtCO2 in 2011.

| Country | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| **China** | 9082.09 | 9915.85 | 10411.81 | 10737.21 | 11189.42 | 11200.39 | 11202.86 | 11264.73 | 11469.83 | 11769.64 |
| **United States** | 5934.82 | 6190.41 | 5942.41 | 5670.27 | 5809.14 | 5830.11 | 5711.15 | 5813.76 | 5761.88 | 5939.19 |
| **India** | 2481.05 | 2590.88 | 2624.70 | 2772.03 | 2830.35 | 3002.64 | 3017.39 | 3089.62 | 3219.92 | 3365.17 |
| **Russia** | 1593.08 | 1714.45 | 1893.66 | 1911.84 | 1878.91 | 1905.32 | 1848.64 | 1966.42 | 1992.25 | 2045.89 |
| **Indonesia** | 1487.03 | 1129.53 | 1679.96 | 1699.77 | 1640.92 | 2021.07 | 2075.14 | 1458.54 | 1471.71 | 1709.62 |

Figure 3.5: Countries with Highest Greenhouse-gas Emission

| Country | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Singapore | 36.262126 | 39.484062 | 40.897523 | 39.932709 | 39.626520 | 39.214044 | 40.697366 | 42.592821 | 44.294154 | 43.971315 |
| Brunei | 52.331064 | 49.095035 | 46.407425 | 45.388812 | 44.409936 | 43.535768 | 40.562623 | 40.067557 | 39.813325 | 40.120291 |
| Qatar | 40.152416 | 39.028642 | 38.033030 | 39.602418 | 38.102713 | 37.804946 | 37.537397 | 37.741408 | 38.943351 | 39.163355 |
| United Arab Emirates | 31.958853 | 30.723984 | 30.402006 | 31.294310 | 32.395410 | 33.062078 | 35.309691 | 36.142603 | 36.468060 | 35.108628 |
| Bahrain | 33.229964 | 33.154318 | 32.672145 | 32.986087 | 34.425096 | 35.469619 | 35.390089 | 34.198513 | 33.197754 | 32.304516 |

(a)

| Country | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Comoros | 0.683252 | 0.739456 | 0.735941 | 0.745995 | 0.741729 | 0.724266 | 0.746043 | 0.779289 | 0.823207 | 0.804977 |
| Liechtenstein | 1.679590 | 1.666852 | 0.826469 | 0.819336 | 0.812128 | 0.806040 | 0.800747 | 0.796707 | 0.529031 | 0.791181 |
| Yemen | 1.681436 | 1.575911 | 1.389053 | 1.310823 | 1.558032 | 1.531164 | 1.000080 | 0.850995 | 0.801514 | 0.775474 |
| Ghana | 3.040428 | 3.044035 | 2.456700 | 2.510727 | 2.560543 | 2.519424 | 2.556985 | 0.590901 | 0.636644 | 0.680281 |
| Rwanda | 0.716566 | 0.721163 | 0.603303 | 0.596227 | 0.591035 | 0.579233 | 0.616585 | 0.581892 | 0.571740 | 0.558447 |

(b)

Figure 3.7: (a) Top 5 Countries with highest greenhouse-gas emission per million population (b) Bottom 5 Countries with lowest greenhouse-gas emission per million population

### 3.1.5 Nieu: Country with zero greenhouse-gas emission

Some countries produce significantly less volume of greenhouse gases near to zero, like Liechtenstein 0.03%, Tuvalu 0.04%, Nauru 0.11%, and Kiribati 0.11. Nieu is the only country whose greenhouse-gas emission is equal to zero.

| Country | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| Kiribati | 0.09 | 0.08 | 0.08 | 0.09 | 0.10 | 0.10 | 0.09 | 0.11 | 0.11 | 0.11 |
| Nauru | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.09 | 0.09 | 0.11 |
| Tuvalu | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 |
| Liechtenstein | 0.06 | 0.06 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 |
| Niue | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Figure 3.6: Countries with Lowest Greenhouse-gas Emission

### 3.1.6 Greenhouse Gas Emission per million population

Countries with large populations always produce more greenhouse gases than countries with smaller populations. The motive of this analysis is to find countries that produce more greenhouse gas per million population. It gives insight into the countries with smaller populations, but the volume of greenhouse gas emissions is comparably large.

### 3.1.7 Rate of greenhouse gas emission over the last ten years

The volume of greenhouse gas emissions by countries is not constant every year. For countries like China, it shows an increasing pattern, and for Bulgaria, it decreases. This analysis aims to determine the rate at which their greenhouse gas emission has changed in the last ten years. Six countries have doubled the emission of greenhouse gases. On the other side, 38 countries have reduced their total greenhouse-gase emission from 2008 to 2018. The most significant change has been seen in the Solomon Islands and Latvia.

Their total greenhouse gas emission increased by 18 and 12 times respectively from 2008. Whereas North Korea, Syria, and Ghana reduce their greenhouse-gas emission by more than 50 percent.

## 3.2 Rise in Temperature

In this section, we will investigate the temperature change of different latitude based climatic region individually over the years. We will forecast the future yearly average temperature of each region till 2045.

We will also investigate the change in maximum, minimum, median and average temperatures values world wide for every country for 100 years from 1912 till 2011. Also we'll find 10-year moving average for the same.

### 3.2.1 Climactic Regions

Different Sources had different latitude ranges, even different names and even number of regions also varied. Some sources also took into account the altitude of the place while classifying it. Main aim of this analysis is to demonstrate how the temperature change happens across latitude, so for simplicity we have chosen equi-width interval for each climatic region.

| **S.No.** | **Climactic Region** | **Latitude Range** |
|---|---|---|
| 1 | Equatorial | 10 ° N to 10 ° S |
| 2 | Savannah | 20 ° N to 10 ° N and 10 ° S to 20 ° S |
| 3 | Mid-Latitude Desert | 30 ° N to 20 ° N and 20 ° S to 30 ° S |
| 4 | Mediterranean | 40 ° N to 30 ° N and 30 ° S to 40 ° S |
| 5 | Temperate | 50 ° N to 40 ° N and 40 ° S to 50 ° S |
| 6 | Continental | 60 ° N to 50 ° N and 50 ° S to 60 ° S |
| 7 | *Tundra | Above 60 ° N and Below 60 ° S |

*No data is available for latitude above 65.09 ° N and below 65.09 ° S.

### 3.2.2 Analysis of Rise in Temperature for Various Climactic Regions

**Year-wise Plots for Each City**

- We took the average of each month's temperature corresponding to a particular city for a particular year and plotted.
- Each line in the globe represents the latitude and the difference be-tween 2 latitude lines in our plot is exactly 10 degrees.
- So, each of the latitude lines divides the earth into different regions as mentioned in the previous section

- One can clearly see that the cities closer to the equator are warmer than the ones far away from it

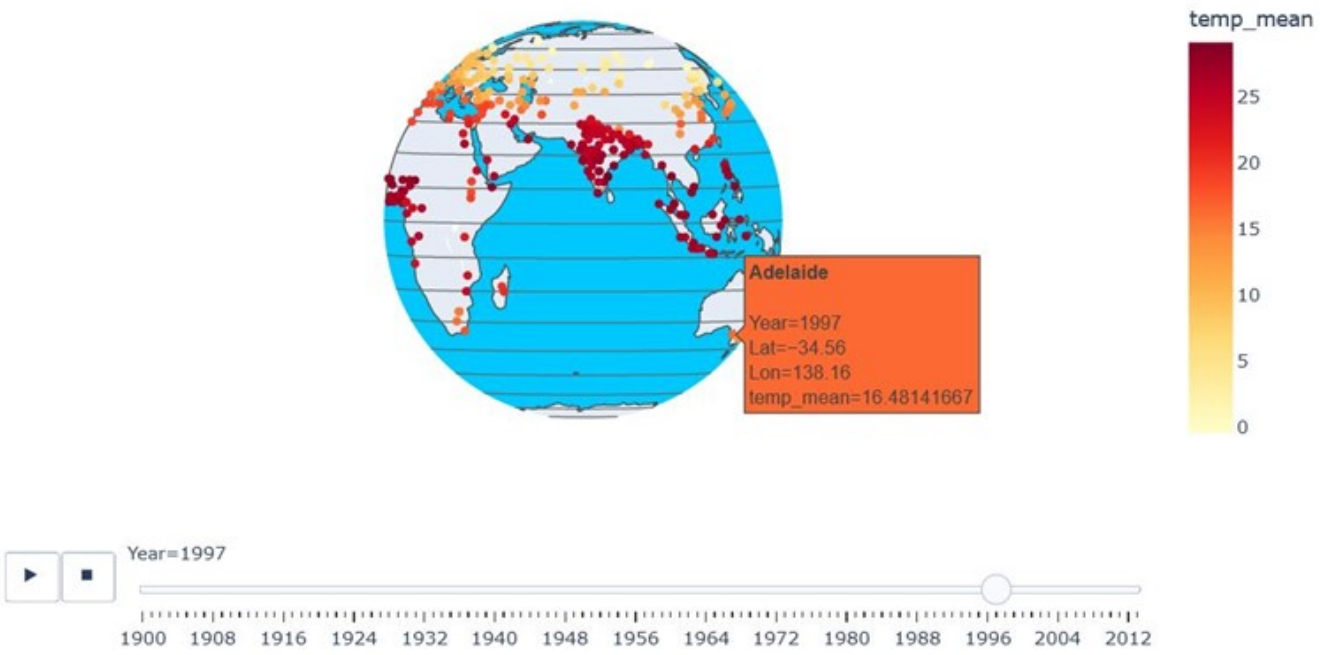



Figure 3.8: Year-wise Avg Temperature Recorded (Each dot on the globe represents a city)

**Box Plot for each climatic region**

- For each date in our dataset, we took the average of all the temperatures of all cities grouped by the respective climatic region of that city's latitude

- We repeated the above procedure by finding the minimum of all temperatures, maximum of all temperatures and median of all temperatures for each day grouped by the respective climatic region of the city's latitude

- We plotted the result as a box plot.

- In each plot, the regions closer to equator have a narrow width while the ones closer to the poles have a wider width. This depicts that the temperature change is very much intense as the latitude increases.

- From the median and maximum box plot, it is evident that the upper bound of tropical regions(Savanna and Mid-Latitude desert) seem to be higher than that of equatorial regions. So, the places in those regions would experience more warm summers than the places in equatorial region.

- Also, it is very well clear from our graph that as the latitude increases, the lowest temperature recorded decreases.

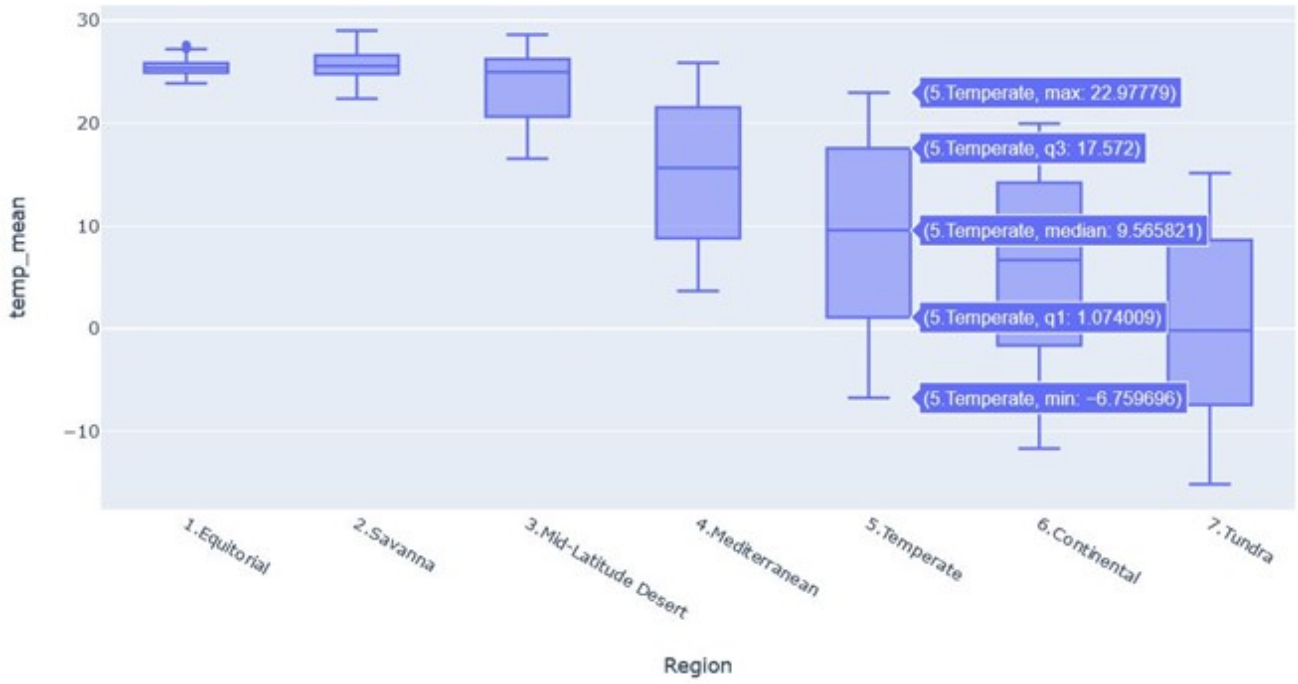



Figure 3.9: Region-wise Mean Temperature between the Year 1900-2013

### 3.2.3 Timeseries Forecasting for the Temperature in Various Climactic Regions

| S.No. | Climactic Region | Avg Temp on 1900 | Avg Predicted Temp on 2045 | % Change in Temp |
|---|---|---|---|---|
| 1 | Equatorial | 25.18896 | 26.42241 | 4.896788 % |
| 2 | Savannah | 25.59745 | 26.34219 | 2.90943 % |
| 3 | Mid-Latitude Desert | 23.64836 | 24.61567 | 4.090389 % |
| 4 | Mediterranean | 14.85413 | 16.2587 | 9.455754 % |
| 5 | Temperate | 8.874458 | 11.07581 | 24.80548 % |
| 6 | Continental | 5.870314 | 8.264701 | 40.78806 % |
| 7 | *Tundra | -0.77339 | 2.028911 | 362.34 % |

One can clearly see that the rate of rise in temperature is directly proportional to the latitude, meaning if the latitude increases rate of rise in temperature also increases. Thus, Global warming affects places at the polar regions and the ones near to it very much than the ones near the equator.

### 3.2.4 Analysis of Rise in Temperature world-wide

**Year-wise Plots for Every country**

- We plotted minimum, maximum, median and average temperature values for 100 years for every country world-wide.

- For example for minimum temperature we took that year's minimum temperature and same we did for all the 100 years and plotted it on world map.

- So from these plots we can clearly visualize how a particular temperature value (for ex maximum temperature) is varying over 100 years for all the countries world-wide

- We can clearly see from plots that year by year median, average, minimum, and maximum temperatures values are increasing.

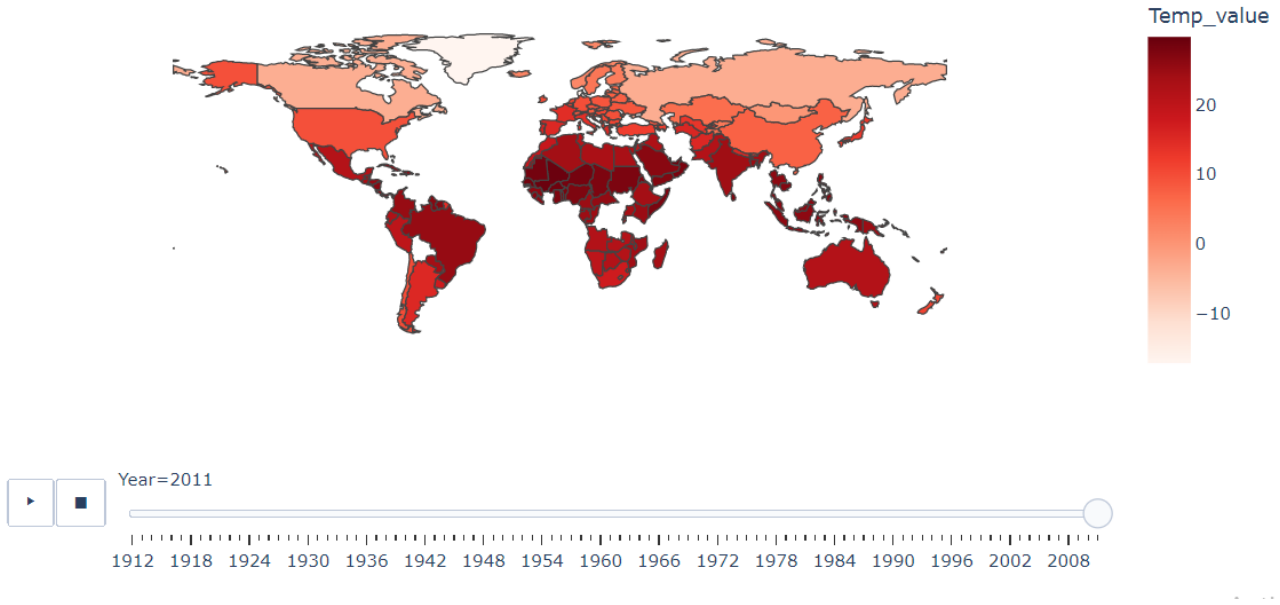


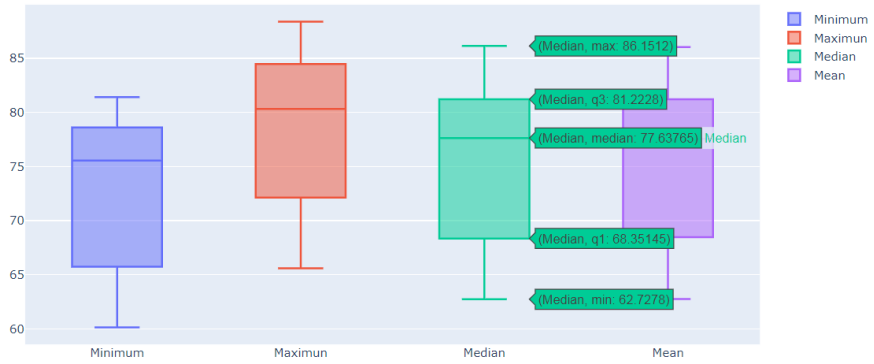

Figure 3.10: Country-wise Average Temperature rise between the Year 1912-2011

### 3.2.5 Analysis of Rise in Temperature individually for every country

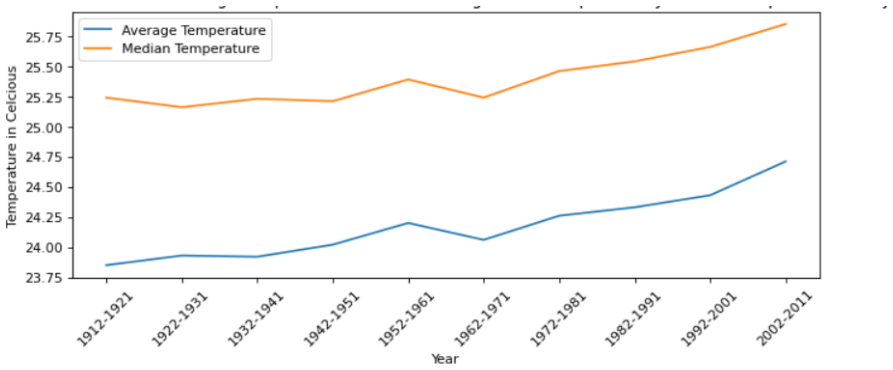
**Graph and data showing changes in last 100 years for a particular country**

- We plotted graphs for minimum, maximum, median and average temperature values for 100 years for a particular country.

- For showing range in which they varied we also plotted the result as a box plot..




(a)




(b)

Figure 3.11: (a) Box plot for 100 years between 1912-2011 for India.(b) 10-year moving average plot for rise in median and average temperature values for India.

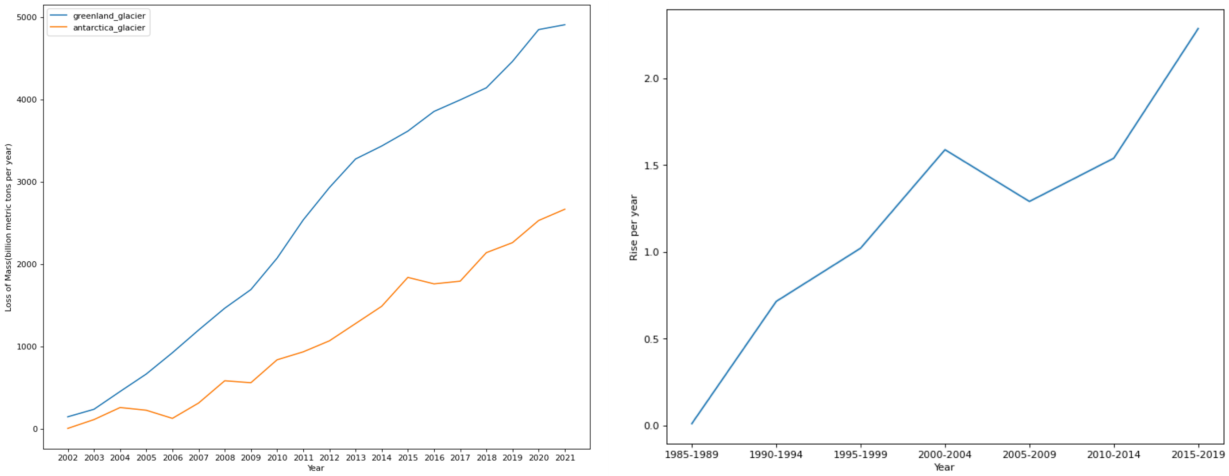
- So from graphs for median and average temperature we can clearly see that they are increasing year by year.

- Lets take example of India and see what we did.

## 3.3 Melting of Glacier and Rise in Sea Level

Glaciers are melting at a very high speed. According to 3D satellite measurements of all the world's mountain sources [12], we are losing 31% extra snow that we used to lose 15 years back. Scientists across the world are blaming human activities for this high rate. Using recent satellite data, scientists are suggesting that we are losing around 300 billion metric tons of ice and snow since 2015. Melting of glaciers is very big threat. With Causing rise in sea level, their loss will also impact supplies of fresh water. There are many threats that can cause human life :

- In India, we get much of the late-summer river flow volume that relies on glacier melt water.




(a) (b)

Figure 3.12: (a) Loss of Glacier Mass (b) Rise in Sea-Level

- Across the world, Glacier meltdown drives Hydropower plants.
- Throughout centuries, Farmers living in Rhone valley of Switzerland have relied on water through glacier meltdown for irrigation of crops. There are 100's of threats that are suggested by scientists over the year.

### 3.3.1 Increases in Global Sea Level Year wise(1985-2019)

Now, As we saw above that Glacier meltdown is a primary reason for sea level rise [9] [3].

We can clearly visualize that Sea level is rising at a very high rate. The rate is increasing year by year. If this rate would keep increasing, we may lose 50% of Mumbai, cochin, Bhavnagar, Mangalore, Chennai and many more cities by this century.

## 3.4 Plastic Waste in Oceans

Rising Sea levels and melting of glaciers are not only problems going in oceans, but they are even more big problems which will affect human and aquatic lives in a very dangerous way. One of them is Mismanaged Plastic wastes which goes in the oceans through various ways [11] [8]. Plastic has now been inescapable from our daily lives. From food packaging to toiletries, toys, automobiles, electronic devices, plastics are used in everything today. Although plastic is very durable but problem is unbiodegradable.

Each year, marine animals entangled in plastic wastes generated by us. This causes them infections, injuries, inability to feed and it also limits their motion. When a sea creature consumes these plastic, it can damage their stomach or it may cause infections. In this way, the whole food cycle gets disturbed.

Now, when these sea animals consume these plastics, those toxins from plastics breaks inside their bodies. Then human consuming those seafoods are also consuming these toxins. The problem is that some of these toxins are linked to hormonal inabilities and developmental problems.

### 3.4.1 Littered plastic waste

Littered plastic wastes are those wastes that are dumped or disposed without consent in an inappropriate location. For example, waste that are dumped in rivers.

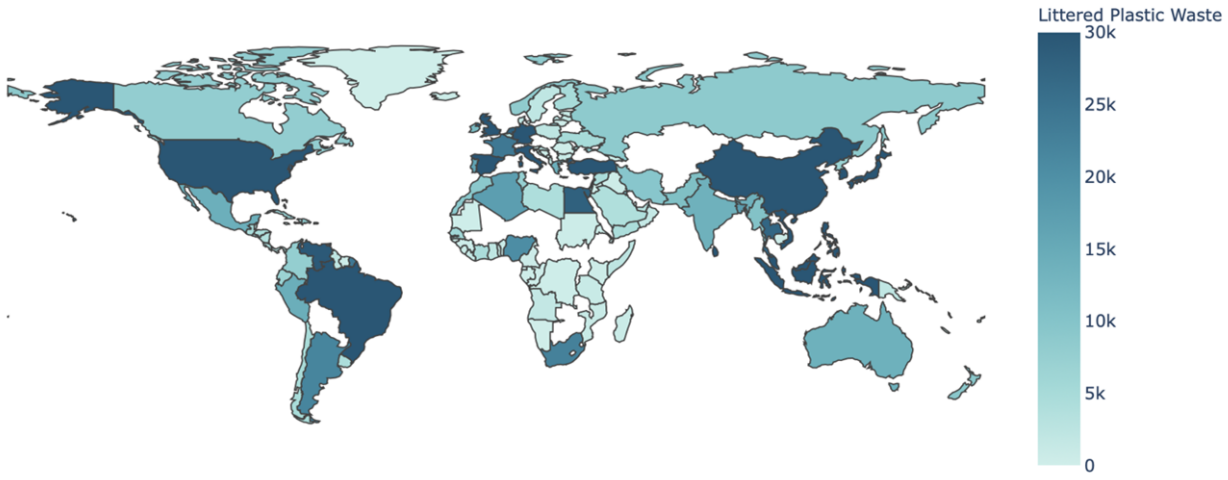



Figure 3.13: Global Plastic Waste Contribution [1] [4]

From above map, we can clearly see that China and USA are main contributors of plastics in ocean.

## 3.5 Natural Disasters

In this section we will look at the data of natural disasters and how the frequency has increased over the past few decades.

Natural disaster is a term attributed to any occurrence of event that causes harm to earth. Some of the common natural disasters are earthquakes, cyclones, floods, volcanic eruptions, landslides, draughts, etc.

Due to various factors that we have discussed so far the climate change has a significant impact on the occurrence of natural disasters and it can wreak havoc on society.

The following graph shows the frequency of common natural disasters over the past several decades [10].

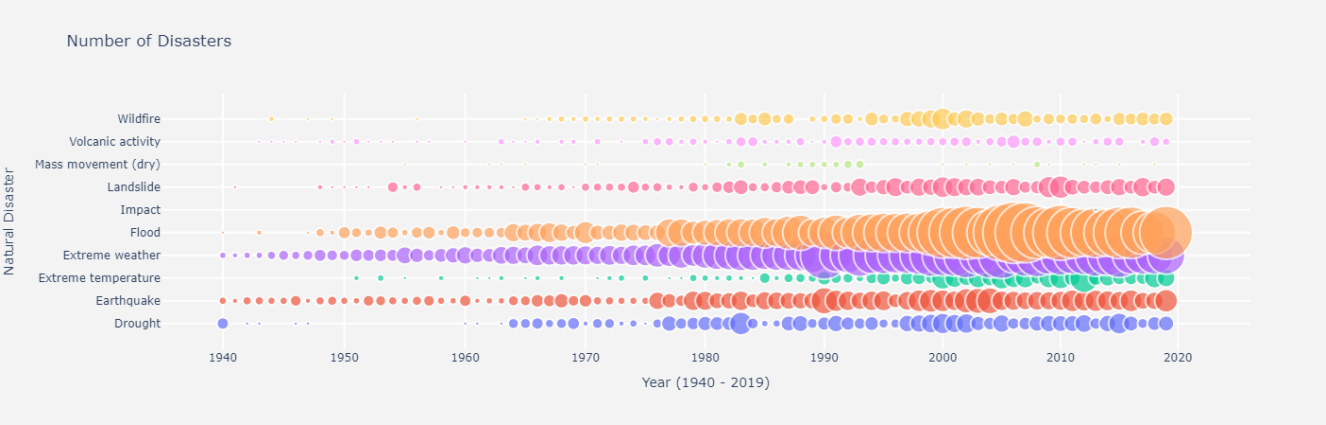



Figure 3.14: Occurrence of Natural Disasters

The frequent occurring of natural disaster affects the humans as well as flora and fauna. Natural disasters like draughts, floods, and earthquakes are one of the most dangerous disasters responsible for the most number of deaths worldwide.

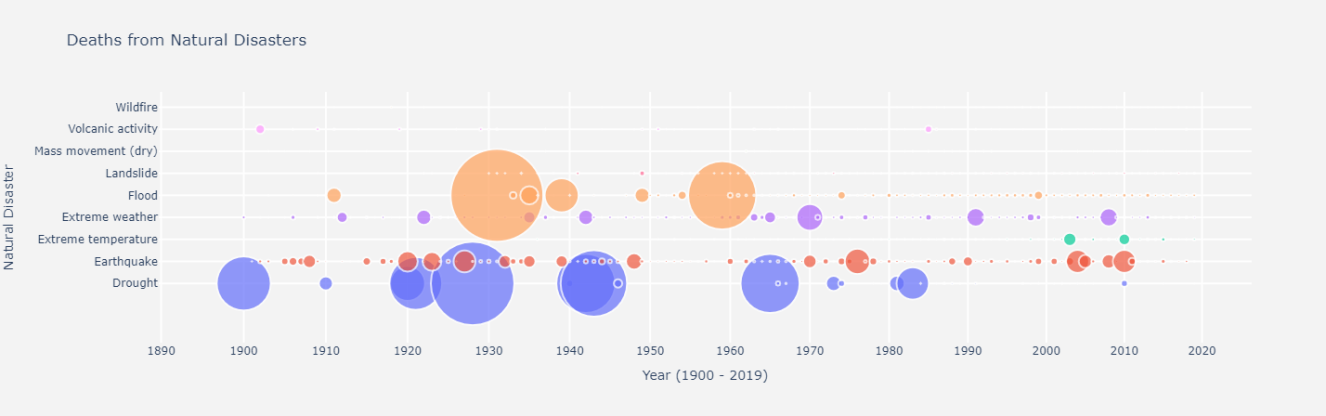



Figure 3.15: Number of Global Deaths Due to Natural Disaster over the Past 100 Years

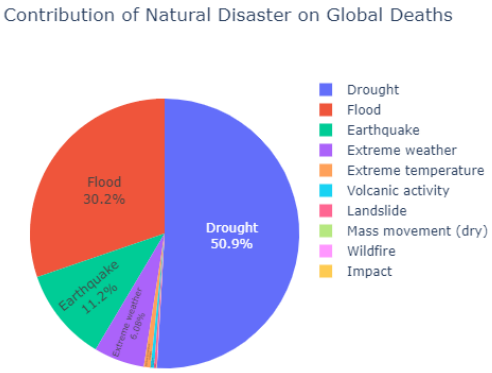



Figure 3.16: Contribution of Natural Disasters on Global Deaths

### 3.5.1 Correlation of Deforestation and Endangered Indigenous Species

In this section, we will investigate if there is any relationship between the depletion of forest area and the number of endangered indigenous species. For this we have used dataset available at [5] and [14].

We grouped the amount of area(in cubicmetres) lost due to deforestation countrywise and calculated the pearson and spearman co-efficient for each of the following species categories :

- Mammals
- Birds
- Reptiles
- Amphibians
- Vascular Plants
- Mosses
- Lichens
- Invertebrates

```
result1.corr(method='pearson')['Value']
```

```
(Mammals, Value)            -0.130449
(Birds, Value)               0.190268
(Reptiles, Value)            0.128025
(Amphibians, Value)         -0.052378
(Vascular plants, Value)    -0.042646
(Mosses, Value)              0.218978
(Lichens, Value)             0.176176
(Invertebrates, Value)       0.197381
Value                        1.000000
Name: Value, dtype: float64
```

```
result1.corr(method='spearman')['Value']
```

```
(Mammals, Value)            -0.111995
(Birds, Value)               0.213570
(Reptiles, Value)            0.059321
(Amphibians, Value)         -0.225694
(Vascular plants, Value)     0.052372
(Mosses, Value)              0.288660
(Lichens, Value)             0.472527
(Invertebrates, Value)       0.078139
Value                        1.000000
Name: Value, dtype: float64
```

```
spearmanr(result1[('Birds', 'Value')], result1['Value'],nan_policy='omit')
```

```
SpearmanrResult(correlation=0.21357034772008127, pvalue=0.3053300912247075)
```

```
spearmanr(result1[('Mosses', 'Value')], result1['Value'],nan_policy='omit')
```

```
SpearmanrResult(correlation=0.288660106867137, pvalue=0.27824469326976997)
```

```
spearmanr(result1[('Lichens', 'Value')], result1['Value'],nan_policy='omit')
```

```
SpearmanrResult(correlation=0.47252747252747257, pvalue=0.08796742461254232)
```

Figure 3.17: Correlation of deforestation with endangered Indigenous species

There seems to be a weak positive correlation between the amount of forest area lost due to deforestation and the number of endangered indigenous species for **Birds, Mosses and Lichens**.

# Chapter 4

# Conclusion

In this project we have analyzed the data for common factors that induce climate-change. A deep look into the data concerning these events help us better understand the climate change scenario and ways to slow it down. These events are highly correlated.

- The events leading to climate change start from the release of harmful Greenhouse-gases in atmosphere
- The increase in amount of greenhouse-gases in atmosphere causes global warming
- With the increase in temperature of earth we see a decrease in glacier and ice-sheets volume and increase in sea-level.
- The combined effect of the above events results into frequent natural disasters and climate anomalies.

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