Data Science Assignment 1: Insights into climate change

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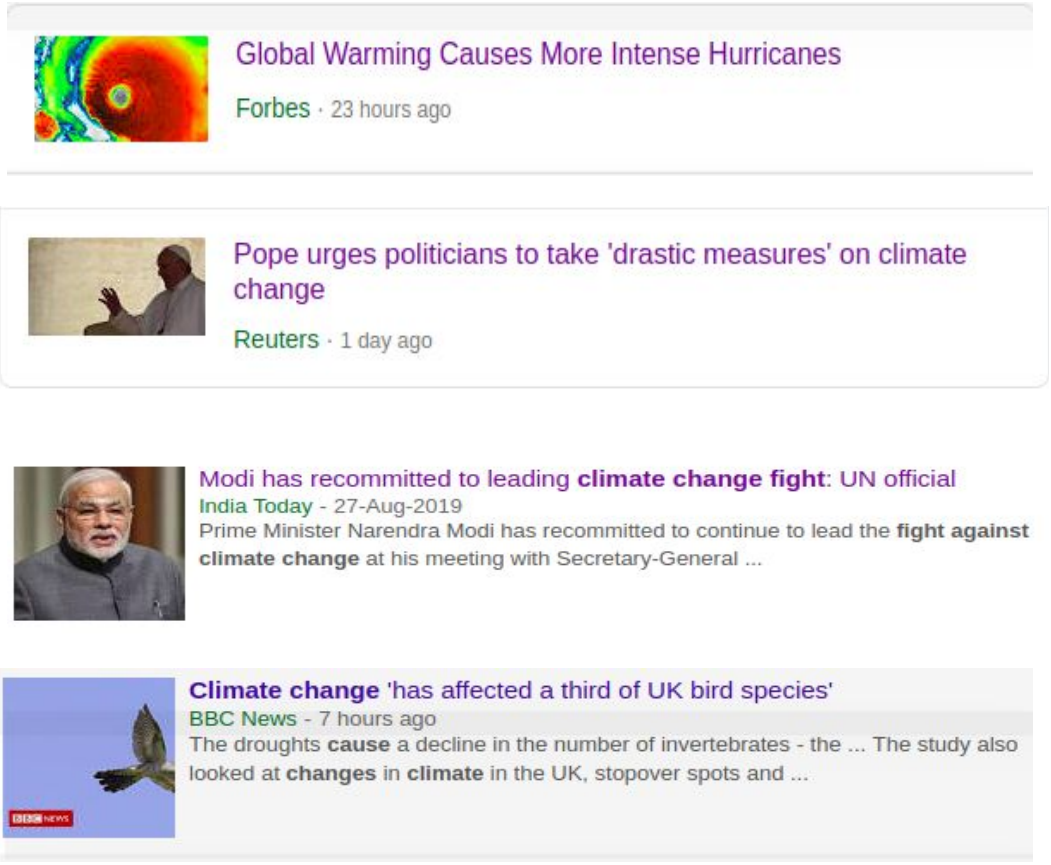


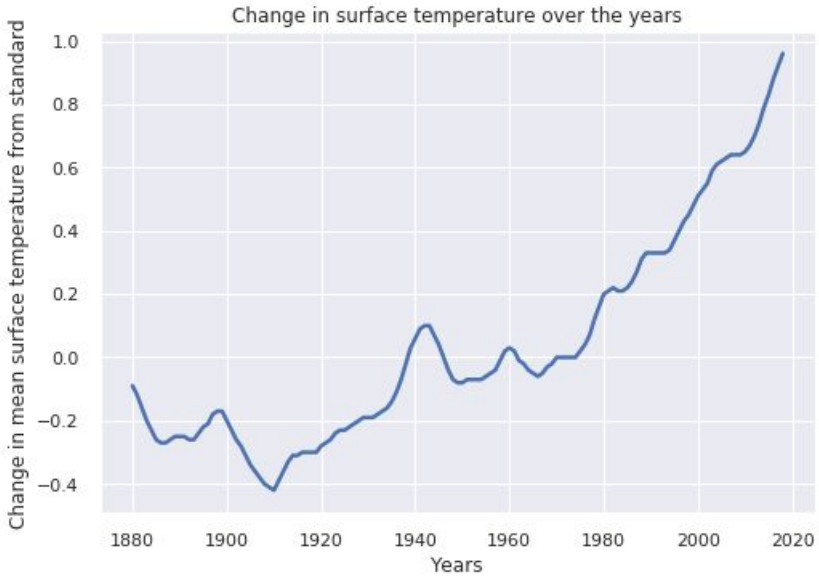
All the above images refer to news articles that extensively use the terms “Climate Change” and “Global Warming”.
Let us find out why these terms are mentioned so frequently and what are the pressing issues that these terms really address.

What is climate change anyway?

Climate change refers to the large scale change of the climatic conditions of the Earth over a specific period of time. During recent years, this phenomenon of “climate change” has taken the whole world by storm due to the gravity of this issue, with threats not only to the existing land masses and water bodies, but to the very existence of human

population on planet Earth. The phenomenon of climate change has a very deep lying correlation with the frequently used term “Global Warming”.

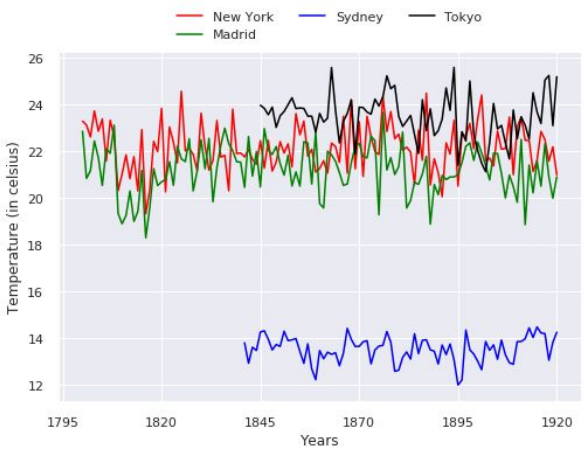
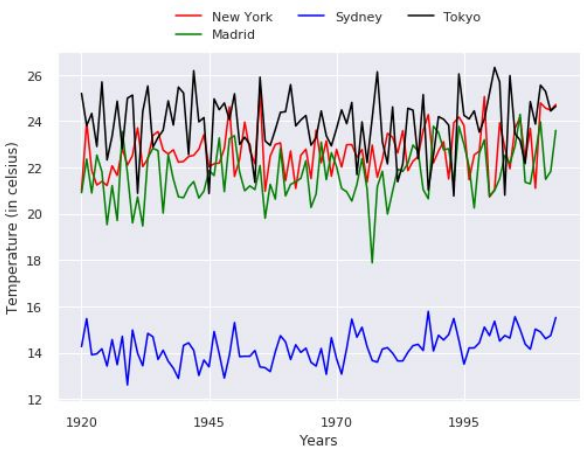
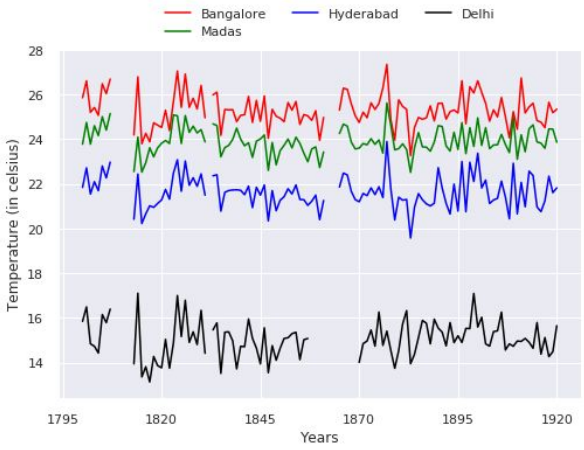
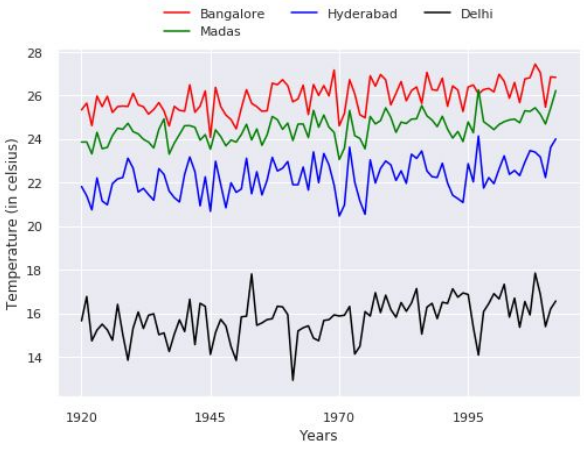
“Global Warming” is the frightening phenomenon of the increase in the Earth’s mean surface temperature every year. Due to human activities like burning of fossil fuels, deforestation and bad farming practices, the average surface temperature of the Earth has been on a constant rise from the early 1900s itself. However modern technological innovations in all fields of life combined with an inflation in the number of industries and factories has influenced the surface temperatures of the Earth in an extremely adverse way. Just take a look at the following graph:



The above graph indicates the extreme increases in the change in mean surface temperature of the Earth over the years. The de facto standard temperature range is taken to be the mean of the temperatures of the years 1950-1980. The differences of the yearly temperatures is then plotted per year.
As the plot clearly shows us, there has been a steep rise in the mean surface temperature of the Earth from the year 1980 onwards. This is an extremely worrying outcome for us as this indicates that come the further years, the Earth is going to become one hot planet!

However, this phenomenon of “Global Warming” has not only affected the surface temperatures of the Earth, it has disrupted weather and temperature patterns of every major country in the world. Given below is a table of the mean temperature patterns from 4 major cities from around the world: New York, Sydney, Madrid and Tokyo, and 4 major

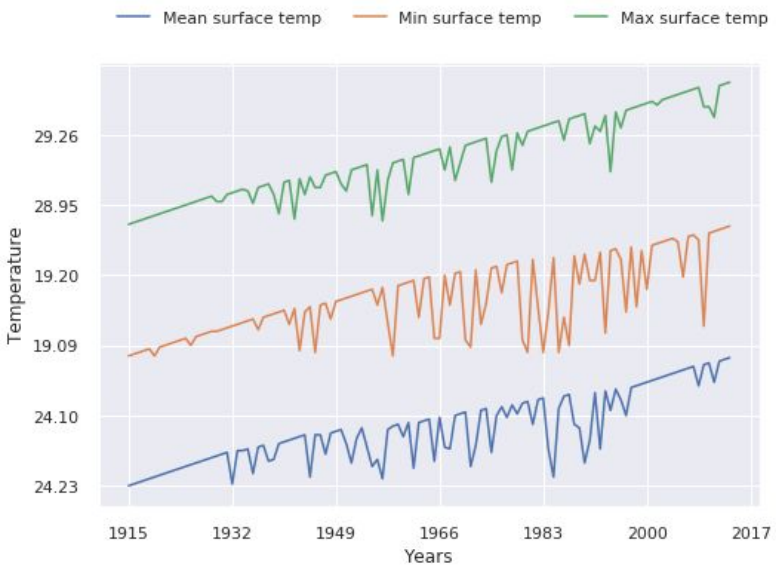
Indian cities:: Bangalore, Hyderabad, Chennai and Delhi. The global cities were strategically chosen to give a good representative city covering a large amount of the globe.

	Years: 1800 - 1920	Years: 1920 - 2013
Global cities		
Indian cities		

On careful inspection of the graphs, we can conspicuously observe gradual increases in the mean temperatures of almost all the cities that we consider. However, the rate of increase of the mean temperature is noticeably higher in the Indian cities that we consider as their curves have much larger slopes than the global cities. This is a particularly worrisome aspect of India's climatic conditions.

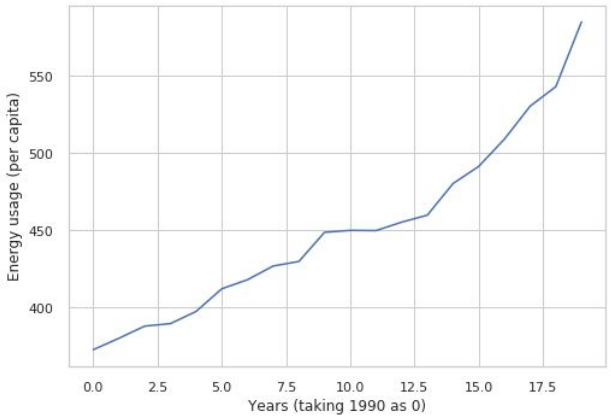
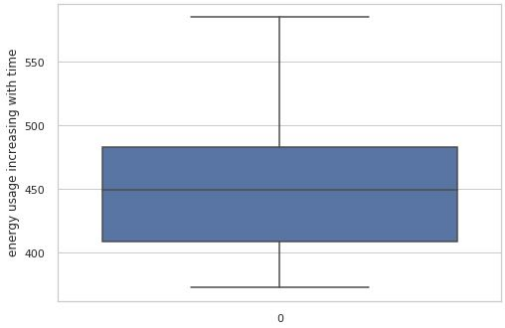
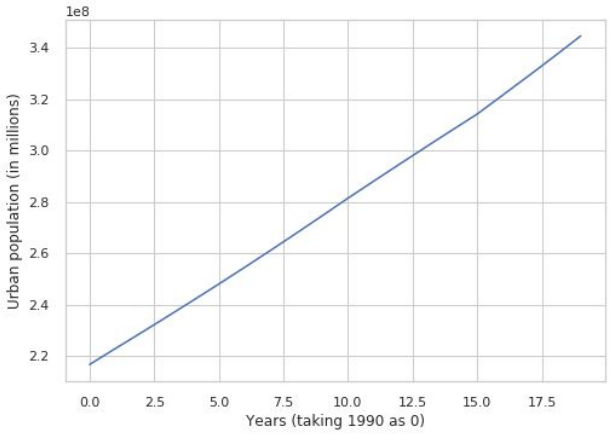
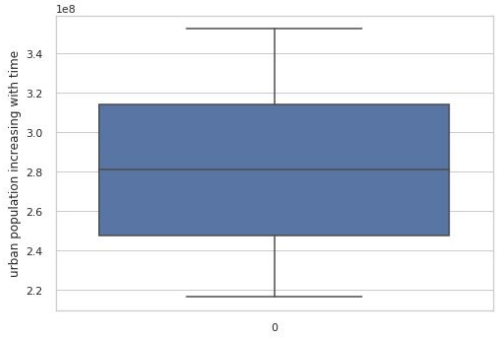
India’s current climate change issues

A concerning aspect of India’s climatic patterns is that due to this large scale change in the Earth’s surface temperatures, the minimum and maximum temperatures recorded within India are rising steeply as shown below.

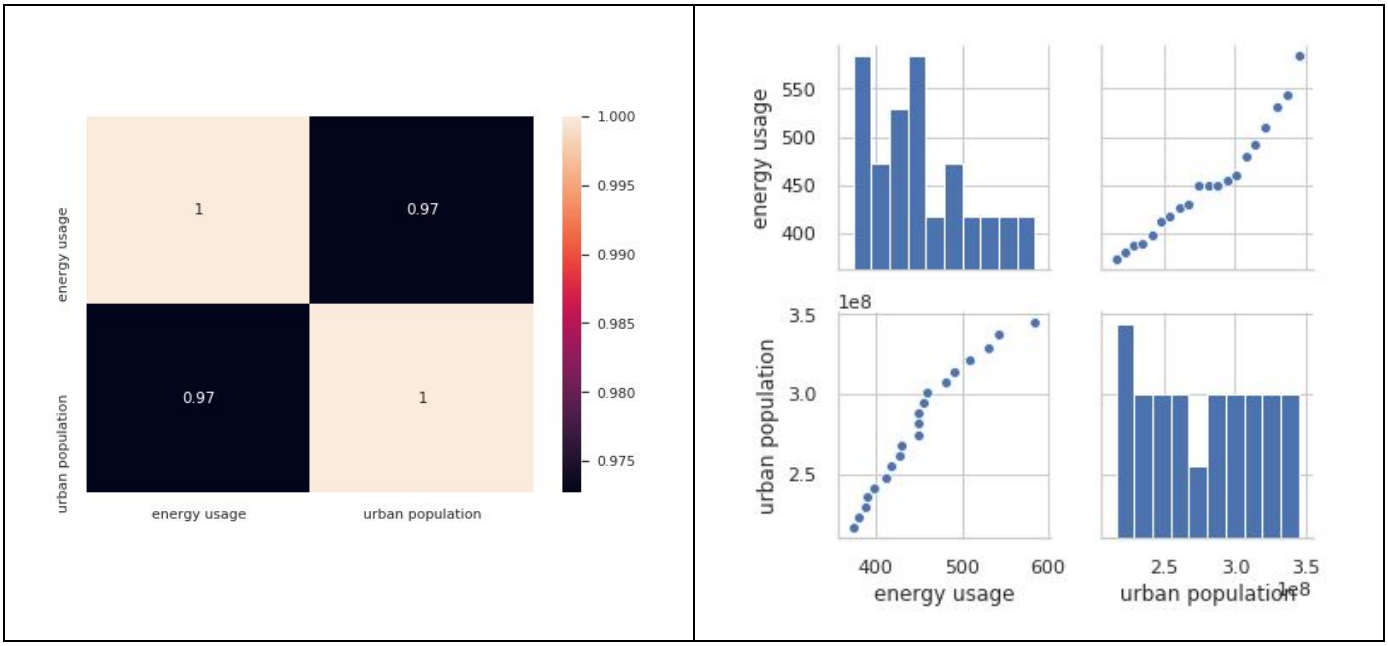


This essentially means that summers and winters are getting hotter alike in India and unless drastic measures are taken to stop “global warming”, India, being very close to the Tropic of Cancer will continue to experience such large increases in temperature.

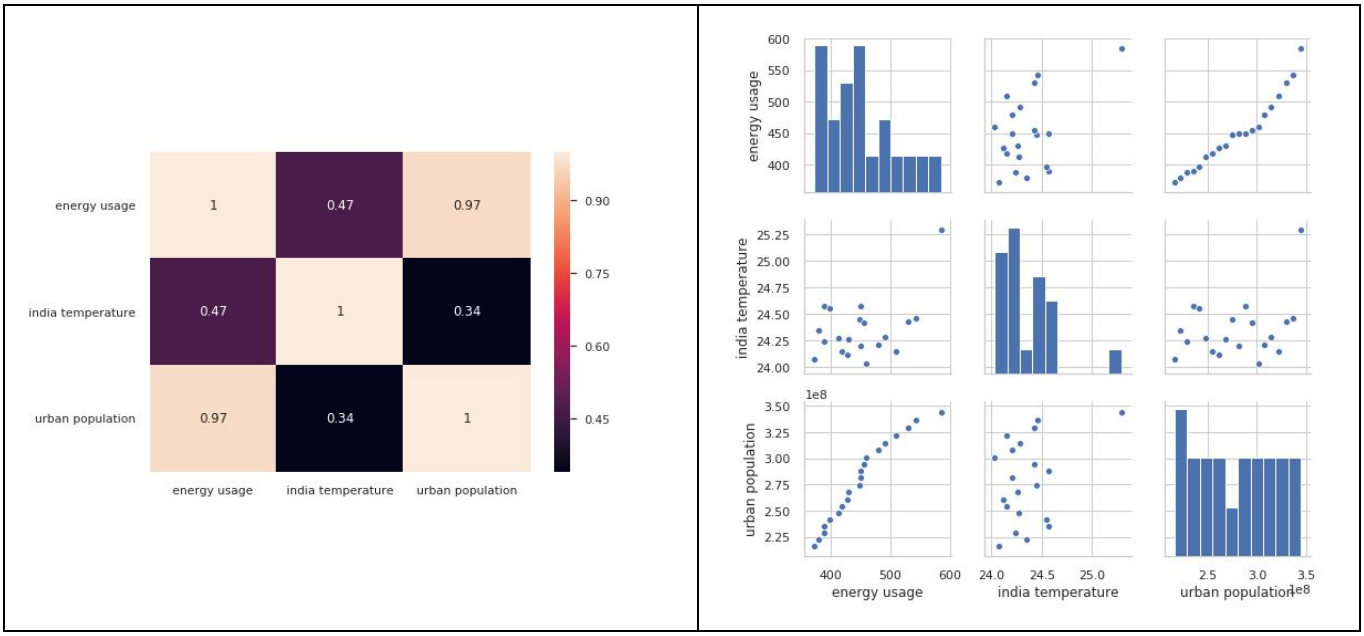
Let us know deviate a little bit from climate change and look at a few factors with regards to how the Indian demography and the living style of people in India has changed over the years from 1990 to 2010. We observe how population in urban cities in India has grown over the past years and consequentially the energy usage needs of the country as a whole has risen substantially. Let us take a look at the table below.

	Line plot	Box plot
Energy usage per capita (in metric tons)		
Urban population		

From the figures above, we can clearly see how the urban population has been on a constant rise since 1990. This is the same as the case with the energy usage per capita, wherein there has been a rapid increase in the amount of energy used in India.



The above two plots show the correlation between the urban population and energy usage over the years. We can therefore now see clearly the high positive correlation between the increase in urban population over time and the marked increase in the energy usage per capita. We now hypothesise that the increases in energy used per capita and urban population should also be highly correlated with the increases in the yearly mean temperature in India.



From both the correlation plot as well as the pairwise correlation plot above, we can definitely see positive correlations between each of the three individual variables that are considered.
Therefore, we clearly see that all three of the variables - energy usage per capita, urban population and yearly mean temperature are positively correlated and hence we can lucidly state that the three are all related to climate change in India (either causes or effects).

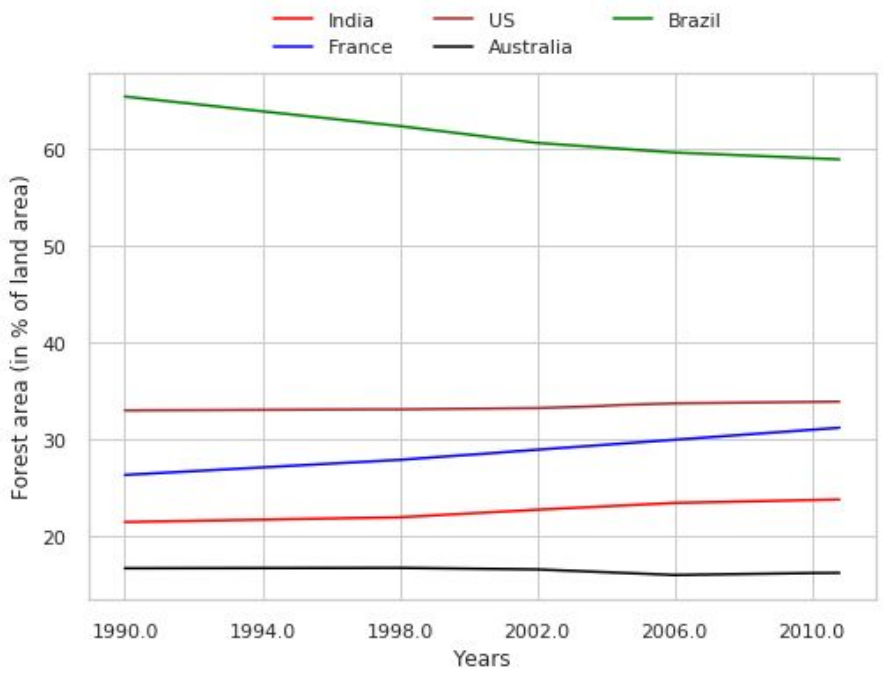
A Comparative Experiment between major countries

We now conduct an extensive comparative survey between 5 major countries in the World - India, United States, Brazil, France and Australia. The countries were chosen in such a way that they encompassed all the continents in the World and hence would give us a great picture of the current state of the planet Earth. We use three different metrics as our standards of comparison to gauge the level of climate change in each of these countries. They are:

- Annual CO2 emissions measured in terms of metric tons
- Annual PM2.5 emissions measured in terms of micrograms per cubic metre
- Total forest cover area as a percent of land covered by forests

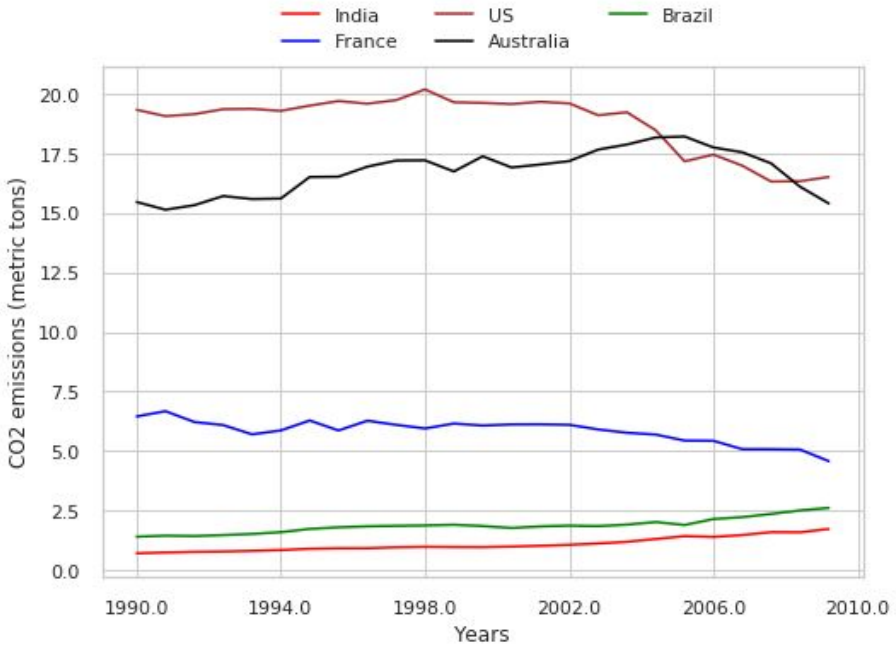
Let us see how each of these factors individually vary over time (1990 to 2016):

Total forest cover area:



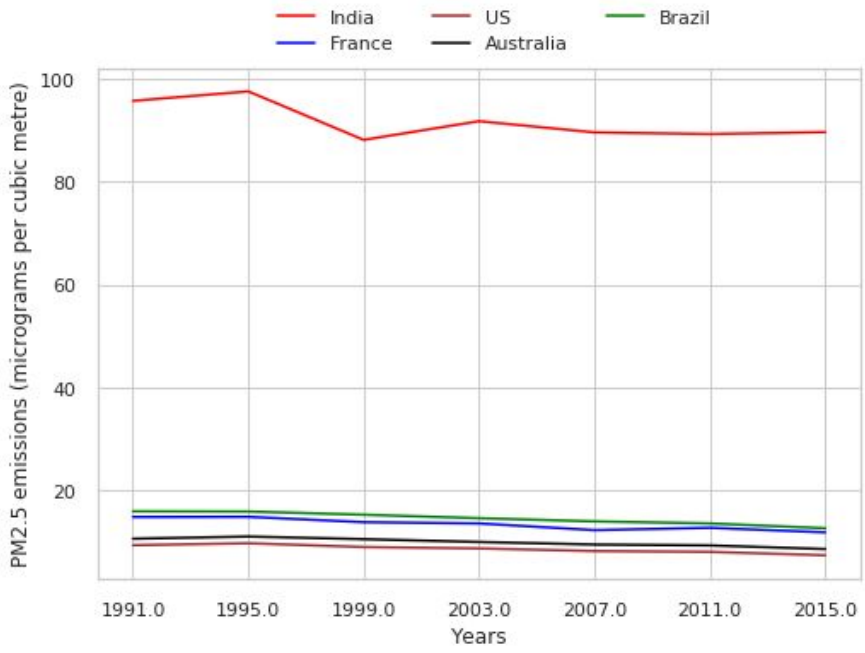
We can observe that Brazil's forest area is in a rapid decline since 1990; this decline especially steepens between 1990 and 1998. However, the forest areas of all the other countries are either stable or on a gradual increase from 1990 till 2016. Therefore, we can say with confidence that Brazil is the most affected by the high rates of deforestation occurring throughout the country whereas the other countries haven't been as adversely affected.

Annual CO2 emissions:



The CO2 emissions of the US, Australia and France can clearly be seen to decrease from 1990 to 2016. This is a good sign for these countries. demonstrating the clear efforts taken by them to reduce their pollution levels (at least in terms of CO2 emissions). However, India and Brazil are still producing increasing amounts of CO2 every passing year (albeit still not as much as the other countries). In India and Brazil, especially from 2006 onwards there has been a steep rise in these CO2 levels, which can prove dangerous in the further years. In this regards, we can safely say that France is the best off amongst all these countries since it is producing moderate amounts of CO2 every year as well decreasing its emission rate every year too.

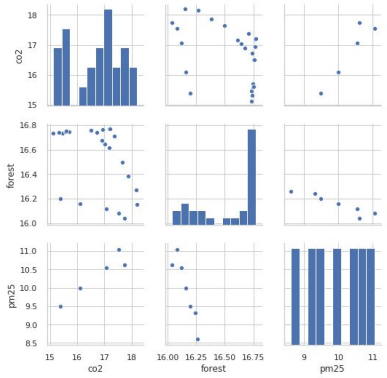
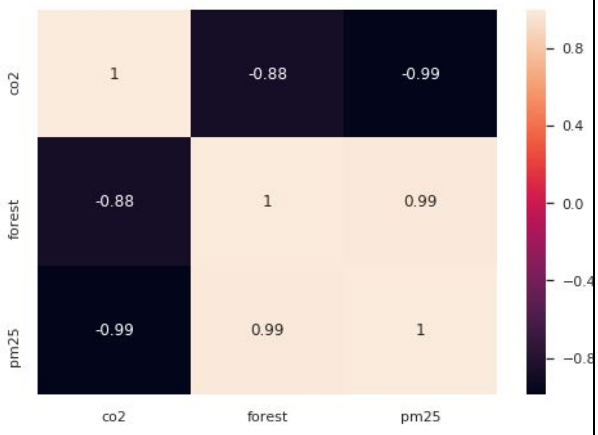
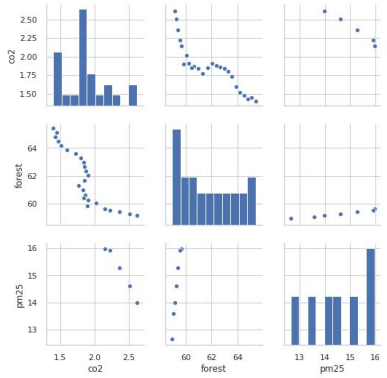
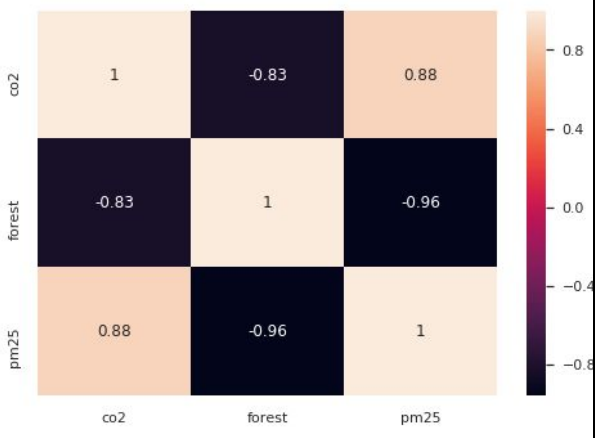
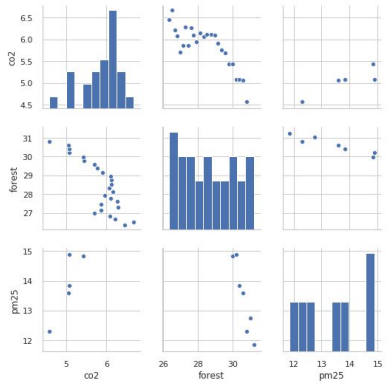
Annual PM2.5 emissions:

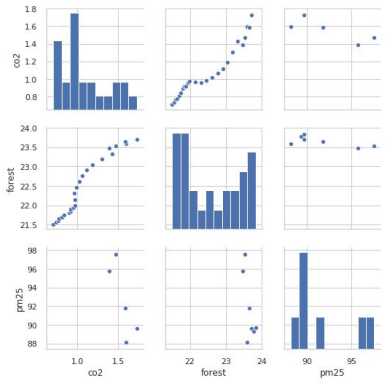
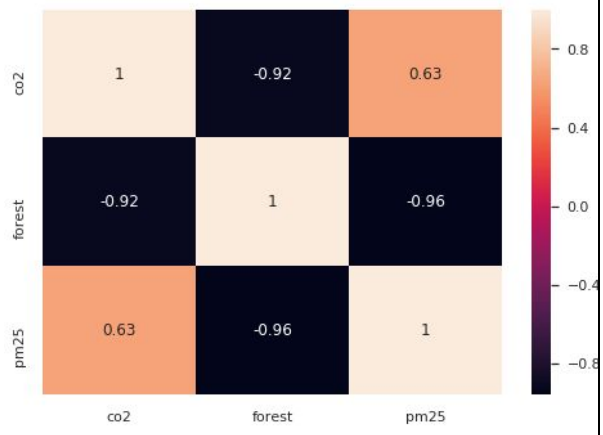
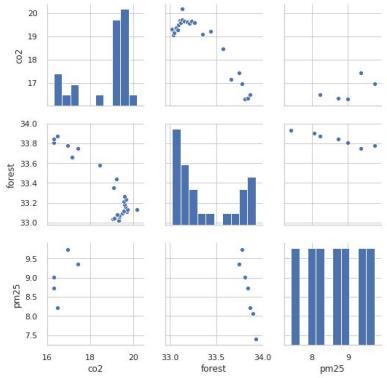


Here, we see that the PM 2.5 emissions of almost every country have been relatively stable; in fact apart from India every other country has been able to gradually reduce their PM 2.5 emissions levels. However, although India's emission rates have remained stable, they are still at an unbelievably high level compared to the other countries. Thus, India has to buckle up and figure out ways to curb their PM 2.5 emission rates.

Now, let us understand how the three metrics that we consider interact amongst themselves within each country. This will help us understand the state of climate change within each country's environment.

To understand these interactions, we plot correlation and pair plots amongst the various interacting metrics and try and gain insights from plots.

	Correlation plot	Pair plot
Australia		
Brazil		
France		

India		
United States		

Now, we draw inferences for each country individually and highlight the effects/causes of climate change as dictated by these metrics.

Australia:
We see a high correlation between the PM 2.5 and CO2 metrics and therefore, we know that the levels of both these pollutants are decreasing at a substantial rate, which is a good sign. Also, the forest area cover has a negative correlation with both the PM 2.5 and CO2 emission levels. Since, PM 2.5 and CO2 levels are decreasing, this means that the forest area cover is not decreasing (either stable or increasing), and hence we can conclude that Australia is overall moving to good climatic states and does not need urgent addressing of its climatic issues.

Brazil:
Here, the first thing we notice is the high negative correlation between the PM 2.5 emission levels and the CO2 emission levels. We immediately understand that although

the PM 2.5 levels are reducing, the CO2 emissions are reaching dangerous levels by increasing significantly. Also, there is a large positive correlation between the PM 2.5 levels and the forest cover area, which essentially means the forest area cover is also drastically reducing. Hence, Brazil is in a very poor state with regards to its climatic and environmental conditions and hence needs to start looking for efficient solutions.

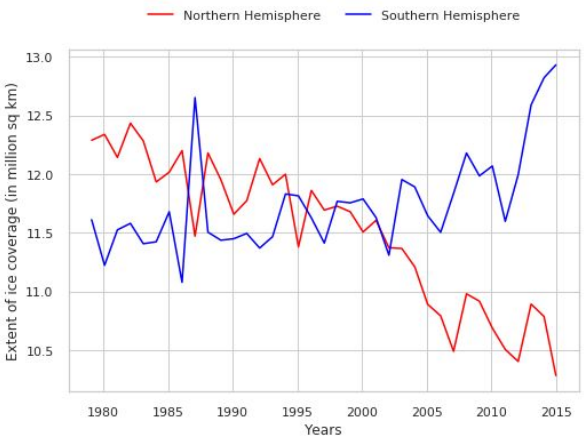
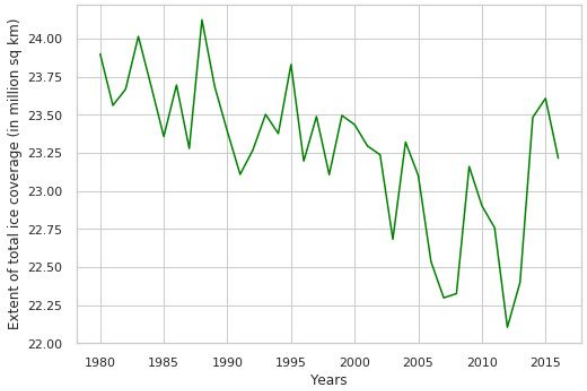
France:
In the case of France too, we notice high positive correlations between the PM2.5 and CO2 levels and hence immediately understand that France has put in a lot of efforts to control their pollution levels. Similar to the case of Australia, there is a high negative correlation between the pollution levels (both PM 2.5 and CO2) and the forest area cover. Thus, since the forest cover is also increasing as well as the pollution levels have been minimised to prohibitory levels, France is in a considerably well off position with regards to its climate change issues.

India:
In the case of India, we notice that the PM 2.5 levels are negatively correlated with both the CO2 levels as well as the forest area cover. Although, the PM 2.5 levels have remained somewhat consistent throughout, the forest area cover has been on a rise (which might be a good sign). But, the CO2 emission levels are ever increasing, especially since the start of the millenium. Hence, although the forest cover area in India is a good indicator of the immense work done by the Indian government, bad industrial practices leading to higher CO2 emission levels continue to thrive within the country. India should hence strive to implement much better policies for restricting its pollutant emission levels, which if not taken care of, can reach fatal levels.

The United States:
We notice the high positive correlation between the CO2 emission levels and the PM 2.5 emission levels and immediately understand that the pollution levels in the United States are gradually on a decrease as seen in the univariate plots above. Also, since there are negative correlations between the pollutant emission levels and the forest area cover, we also purport that the forest area cover is not decreasing. Hence, the United States is relatively well off with regards to its climate change situation given the considered metrics.

Arctic and Antarctic ice coverage:

Another factor that climate change and global warming affect majorly is the amount of sea ice present in the arctic and antarctic regions. Recently, there have been multiple global concerns regarding the expansive melting of sea ice as an effect of sea warming. Let us explore this by finding out how much sea ice is actually present on our planet.

Area of sea ice segregated by northern and southern hemisphere	Total area of sea ice
	

The first figure separates out the area of sea ice in the Northern (arctic regions) and Southern (antarctic regions) hemispheres. We see that initially (around 1980), the area of sea ice in the Northern hemisphere was much greater than the area of sea ice in the Southern hemisphere. However, with the passage of time the area of sea ice in the Northern hemisphere dwindled rapidly whereas the area of sea ice in the Southern hemisphere increased at a slower rate. Thus, the figure on the right depicts the total sea ice area on our planet Earth. We clearly see a downward trend in the area of sea ice present on the planet. This leads us to clearly conclude that our planet is in a dire state since the reduction of sea ice on Earth is a direct consequence of the rise in global warming and climate change.

However, it will be slightly heartening to see the rightmost part of the ‘total area of sea ice’ curve. We see that although there has been a rapid decrease in the area of total sea ice present on the planet from the start of the millennium, the later trends from the graph

show that the total area of sea ice is gradually on the rice after the year 2010. This could be a possible consequence of more countries taking active part in reducing their own global warming quotients and hence somewhat mollifying the effects of global warming.

However, there is a caveat: if we notice, there is a large downward spike after the year 2015 in the graph, and this could possibly mean that we are again moving towards lesser sea ice areas which can lead directly to higher temperatures, flooding and as a result more climate change.

Takeaways and Conclusions:

We have discovered and gained major insights into the climate change and global warming situations of the world; we have looked at it both from an Indian perspective as well as seen multiple global views of the same.
All these insights lead us to a common conclusion: Our planet Earth is slowly but surely on the path to degrading itself, what with all the external climatic conditions and the internal human turmoil. Every country in the world needs to realise this and understand that the fight for global power and supremacy is futile if there is no 'globe' to win over. Hence, all the nations in the world should put their foot down, improve their individual global warming and climate change quotients. Until and unless, all the countries fight for planet Earth together, the future looks bleak.

Data Sources:

The data collected for depicting the visuals was collected from a wide range of sources. Each individual dataset that was explored and used is mentioned below.

- **data.gov.in**: This portal is the official repository for government sanctioned public datasets within India. The datasets that were retrieved from here include the **minimum, maximum and mean temperature fluctuations within India for a time period of 1915 to 2017**.
- **Berkeley Earth**: This portal provides data recorded by the Berkeley Earth group which is primarily a not-for-profit organisation. **The time series datasets for temperatures in major global cities and countries over a timeframe of 1900 to 2015** were extracted from here.
- **data.giss.nasa.gov**: This portal is the official repository of the archived datasets and real time data released by the Goddard Institute for Space Studies at NASA. **The change in mean surface temperature of the Earth for the time period 1880 to 2018** dataset was taken from this portal.

- **data.worldbank.org**: This portal provides free data for indicators on the world's development and progress as released by the World Bank. 4 datasets were taken from here:
    - **Annual area of forest cover in all countries from 1990 to 2010**
    - **Annual PM 2.5 emission levels in all countries from 1990 to 2010**
    - **Annual CO2 emission levels in all countries from 1990 to 2010**
    - **Annual average energy usage in all countries from 1990 to 2010**
    - **Annual average urban population in all countries from 1990 to 2010**
- **nsidc.org**: This is the official data portal of the National Snow and Ice Data Center. **The area of sea ice between 1980 and 2015** dataset was taken from here.