Database and Analytics Programming
Submitted to: Prof. Noel Cosgrave

Visualising the Climate Change using Global Temperature and Sea Level Change, Arctic Sea Ice Minimum and CO_2 Emissions

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Abstract

Today, the climate change is the most pressing issue our home planet is facing. The situation is only getting worse with each day passing. Researchers and scientists have produced numerous studies and analysis on this critical subject, especially in the last few years. Some studies have also predicted the year after which the change in climatic conditions would become irreversible and eventually end all life forms on the planet. This project aims to study and visualise the climate change on our planet by analysing the various factors involved both independently and as a whole. Among these large number of factors, we have chosen global temperature change, sea level change, Arctic ice cover minimum and Carbon Dioxide emissions as our parameters for the purpose of this project. Each data/parameter serves its own purpose and aids us in studying its effect on the climate change. The animated plots are produced for each of the datasets to help understand the underlying patterns more clearly. In the end, an animated dashboard is produced to see the effect of all four parameters together.

1. INTRODUCTION

In our ever-changing world, mankind's influence towards mother nature has been a grave issue, with the rise in global warming and other factors affecting our globe, human activities including industrial production, burning fossil fuel, mining, cattle rearing or deforestation have been gradually increasing. There is a dire need for harmony among humans and the environment to preserve our planet's natural order. The climate change is highly complex phenomenon and we can only understand it as much as our computational resources allow us to. Different elements such as temperature, wind, atmospheric pressure, humidity, rain, etc. are observed over a period of time to describe how climate change is in effect. Variant needs of humans have always propelled them to exploit the nature and natural resources without realizing the ever lasting effect it has caused to the planet. The primary purpose of this project is to visualise the inter dependence between the factors chosen to analyse the climate change. Enormous amounts of studies have been published in the recent years by both organisations and individuals on how climate change has affected our planet. This project builds upon various studies(which have been properly cited) that have been produced to study the climate change on our planet. The challenges and problems encountered during the project will be clearly discussed at the end of the report. We will also discuss some of the relevant techniques that could not be incorporated into the final visualisations.

The temperature change plays a very crucial role in the climate change profile of the planet. It determines the entire heat profile of the planet. Given the enormous size of Earth's ocean and their extremely high heat capacity, it takes a tremendous amount of heat energy to raise the surface temperature of the Earth. According to the studies conducted by the National Oceanic and Atmospheric Administration(NOAA), the surface temperature of Earth rose by 2 degrees since the pre-industrial era [1]. This amount may seem really small at first sight but at the scale of our planet, it is a significant number. Record high land temperatures were recorder in several parts of the world in the recent years. These alarmingly high temperature anomalies trigger a chain of reactions that drive various other factors affecting the climate change like melting of polar ice caps, rise in the global sea level, etc. Therefore analyzing temperature change is not only crucial, but also the need of the hour.

While the temperature change in itself is a major contributor towards climate change, as mentioned earlier, it also triggers the increase in the sea level globally. The major contributor in the annual sea level increase is the global warming. The decline in liquid water on land is also considered as the minor contributor towards the sea level change. This happens when the water on the land moves to the oceans through groundwater pumping [2]. According to the study conducted by NOAA [2], the mean level of water in the oceans globally has increased by 0.14 inches (3.6 millimeters) per year between the years 2006 and 2015. What's concerning is that this amount is roughly 2.5 times the average rate of increase per year throughout the 20th century. Future projection models show that by the end of the century, the average sea level globally will rise at least 0.3 meters above 2000 levels and that too provided the emissions from greenhouse gases remain in the low part of the spectrum in coming decades.

The Arctic ice cover has been melting at an alarmingly fast rate throughout the recent decades. The Arctic Ice reaches its annual minimum value in the month of September. This period is known as the Arctic Ice minimum. In the year 2020, Arctic ice minimum has hit its second lowest value in its entire history. Researchers have produced various simulations to study how the Arctic ice cover has been depleted over the recent years. The visualisation of the arctic sea cover helps us in understanding the patterns in climate change over the years better.

The final part of analysis of the project was done using the CO_2 emissions data. As discussed earlier, the emission of green house gasses like carbon dioxide have a major effect on the climate change. The greenhouse gasses when released into the atmosphere capture the Earth's heat radiation and hence warm the planet. They are a primary reason for the global warming today. The carbon dioxide emissions. Over the last few decades, human activities have like burning of fossil fuels, pollution, etc. have increased the concentration of CO_2 in the atmosphere. It is also emitted from the activities like deforestation and land degradation.

2. Related Works

2.1 Dataset 1: Global Temperature Change

- Various websites and scientists have produced studies and animated dashboards to visualise the global temperature anomalies in the recent years. Among them, Ed Warren, a climate scientist has published some groundbreaking simulations on climate change data. These are called the climate spirals [3]

- Some researchers see the connection of their work with the changing environment which is leading humanity toward an unsecured sustainable future. A place where our future faces myriads of problems including food insecurity, less biodiversity, high concentration of greenhouse gases and less fertile research. Similar research was done by M. Iqbal R. Khan, Dr Mohd Asgher and Nafees Khan on 'Rising temperature in the changing environment: A serious threat to plants'. This researched talked about the high temperature impacting the overall plant growth and productivity, and how it disturbs the initial physiological process of the planet [4]

2.2 Dataset 2: Sea Level Change

- Another study was conducted on the rise of sea levels due to Global warming. The main causes were glaciers and ice sheet melting around the globe, and the water expending due to heat causing an increase in water volume in the ocean. This study was conducted by Scott A. Kulp and Benjamin H. Strauss, who wrote the paper titled 'New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding' which estimated that the close to 1 billion people are now residing in less than 10 m above the high tide line due to climate change [5]

- Kiyoshi HORIKAWA conducted a study based on the Sea level rise caused by climate change and its implications toward our society [6]. This study focused on the scientific understanding of the seas level rise issue, and its environmental and social impacts. He based the study on the satellite observations taken in 1993 and compared it to 20th-century data, he noted that the seas level has risen twice compared to earlier readings.

2.3 Dataset 3: Arctic Sea Ice Minimum

- In the last century, we have seen a substantial change in sea ice level, the mountain glaciers, the Greenland and West Antarctica ice sheet due to global warming. A study conducted by Nico Wunderling, Matteo Willeit, Jonathan F. Donges and Ricarda Winkelmann on the rise of global warming due to loss of large ice masses and arctic summer sea ice published on 27th of October 2020 [7]. The study used 39 calibrated runs on a large scale ensemble simulation with findings that implied an additional increase of the GMT on intermediate to long time scales.

2.4 Dataset 4: CO_2 emissions data

- Based on an empirical study done in Shanghai by Peng-Wei and HaixiaoPan analysed that 80% of CO_2 emissions are created from the top 20% of the population. The paper titled 'Research on individual carbon dioxide emissions of commuting in a peri-urban area of metropolitan cities —an empirical study in Shanghai' illustrated the link between individual socioeconomic characteristics, transit accessibility, the urban built environment and commuting emissions were strongly related to the male gender, income and car ownership were strongly related [8].

- A deep study was done by Umair Shahzad on the topic of Global Warming effects on overall climate change. This study showed that usage of fossil fuel to produce electricity has caused a rise in gases such as carbon dioxide, methane and nitrous oxide which are leading toward global warming [9].

3. Methodology

3.1 Data Acquisition

Dataset 1: Global temperature Changes

- The scale of the temperature change was extremely important and it was taken into account while searching for the data from various sources and APIs [10]. While some use the absolute scale for measuring the temperature change, some analysts prefer the normalised scale to limit the random noise to a minimum while also limiting the range of the desired scale.

- Since the final visualisation had to be plotted on a choropleth map(world map) to better visualise the changes in the temperature in different regions of the world, the libraries to be employed were decided on that basis.

- There are various libraries in python that facilitate the plotting of the data on a choropleth map like *plotly*, *matplotlib*, *Folium*, *Geopandas*, etc. Among all these packages, Geopandas was decided for accomplishing the job for its robustness over other libraries. Geopandas can handle geometrical shapes and it highly compatible with the pandas library.

- There are various APIs available which can also facilitate the fetching of global temperature change data.

Dataset 2: Sea Level Change

- There are various sources over the internet that provide the data for global sea level change over the years. The data used for the purpose of this project was taken from the NASA website. [11].

- Since NASA keeps track of everyone who uses their data, a login was created on NASA Earthdata homepage to get access to the data.

- Since the data is static, meaning the change in mean value of the global sea level does not fluctuates much in short intervals of time, the data was not fetched using web scraping. Moreover, the data is updates by NASA every few days.

- Since the data is gathered from the satellites by the NASA and the National Snow and Ice Data Center (NSIDC) [12] and is updated regularly on their webpage, the choice for the source is justified.

- The python libraries matplotlib and plotly were employed for the visualisation purposes.

Dataset 3: Arctic Sea Ice Minimum

- The choice for this dataset was particularly tricky because it does not bodes well with the other datasets(in terms of integration) solely because of the geographical location factor since the data is only for the Arctic region where the major part of Earth's ice mass is found.
- But being the major consequence of the climate change, it was important to visualize it along with the other parameters.
- Every year, the Arctic ice cap mass fluctuates depending on the time of the year. It shrinks during the months of March, April and May and expands during the winter and fall. It reaches its minimum value during the month of September which is focal point of the analysis for this project [13]
- The data gathered was filtered for the month of September to analyse the fluctuations of the minima of the Arctic sea ice cover. The visualisations were done using seaborn package in python.

Dataset 4: CO_2 emissions data

- The data for Carbon Dioxide emissions was chosen particularly because of its influence on all the other parameters.
- The data for different greenhouse gas emissions was available at various sources on the web. One such source is the Food and Agriculture Organisation(FAO) of the United Nations [14].
- Since the data available was enormous, various APIs were also explored for fetching the data. The data was finally acquired from the ETH Zurich server [15] which is currently hosted on the University of Melbourne website.
- Taking inspiration from Ed Warren's excellent work in the domain of climate change [3], unique polar spiral plots were produced during the visualisations. These plots were later changed into an animated GIF for better visualisation of the change in the value of Carbon Dioxide emissions over the years.

3.2 Database Management

The data obtained for all the datasets was in similar formats. The data for global temperature change and the CO_2 emissions was acquired in csv files. While the other two datasets were read from the url and fetched in csv files. The mongoDB was used to handle the unstructured data and the PostgreSQL was used for storing the structured databases. There were several options available for connecting with the postgreSQL database like creating an AWS instance and then entering data through pgAdmin, etc. The best suitable technique for the purpose of this project was to connect the mongoDB and postgreSQL through a virtual machine via python.

4. Data Sources and Description

4.1 Dataset 1: Global temperature Changes

Data Sources:
The data for the global temperature change was acquired from the FAO(Food and Agriculture Organisation) database [16]. The data was in a csv file which contained several fields. It was then converted into json format in python to be fed into mongoDB and then into the postgrSQL database. The data collected was for the meterological year.
Data Description:
The raw data description is shown in the figures 1 and 2 The raw data contains 2449 rows.

	Domain Code	Domain	Area Code	Area	Element Code	Element	Months Code	Months	Year Code	Year	Unit	Value	Flag	Flag Description
0	ET	Temperature change	2	Afghanistan	7271	Temperature change	7020	Meteorological year	1990	1990	°C	0.766	Fc	Calculated data
1	ET	Temperature change	2	Afghanistan	7271	Temperature change	7020	Meteorological year	1992	1992	°C	-0.320	Fc	Calculated data
2	ET	Temperature change	2	Afghanistan	7271	Temperature change	7020	Meteorological year	1993	1993	°C	0.172	Fc	Calculated data
3	ET	Temperature change	2	Afghanistan	7271	Temperature change	7020	Meteorological year	1994	1994	°C	0.423	Fc	Calculated data
4	ET	Temperature change	2	Afghanistan	7271	Temperature change	7020	Meteorological year	1995	1995	°C	0.363	Fc	Calculated data

Figure 1. Raw data for dataset 1

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2449 entries, 0 to 2448
Data columns (total 14 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   Domain Code       2449 non-null   object
 1   Domain            2449 non-null   object
 2   Area Code         2449 non-null   int64
 3   Area              2449 non-null   object
 4   Element Code      2449 non-null   int64
 5   Element           2449 non-null   object
 6   Months Code       2449 non-null   int64
 7   Months            2449 non-null   object
 8   Year Code         2449 non-null   int64
 9   Year              2449 non-null   int64
 10  Unit              2449 non-null   object
 11  Value             2338 non-null   float64
 12  Flag              2449 non-null   object
 13  Flag Description  2449 non-null   object
dtypes: float64(1), int64(5), object(8)
memory usage: 268.0+ KB
```

Figure 2. Data description for dDataset 1

4.2 Dataset 2: Global sea level change

Data Sources:
The data for global sea level change was acquired from the NASA website [12]. For acquiring the data, first a login ID was created on the NASA earthdata homepage and then the data was downloaded from the url.
Data Description:
The raw data structure is shown in the figures 3 and 4. The data contains around 1608 rows.

	Time	GMSL	GMSL uncertainty
0	1880-01-15	-183.0	24.2
1	1880-02-15	-171.1	24.2
2	1880-03-15	-164.3	24.2
3	1880-04-15	-158.2	24.2
4	1880-05-15	-158.7	24.2

Figure 3. Raw data for Dataset 2

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1608 entries, 0 to 1607
Data columns (total 3 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   Time              1608 non-null   object
 1   GMSL              1608 non-null   float64
 2   GMSL uncertainty  1608 non-null   float64
dtypes: float64(2), object(1)
memory usage: 37.8+ KB
```

Figure 4. Data description for dataset 2

4.3 Dataset 3: Arctic sea ice minimum:

Data Sources: This data was also taken from the NASA website [17]. The same process was followed as for the dataset 2. Since the Arctic sea ice cover reaches its minimum in around september, the data acquired was filtered to contain the records for September only.

Data Description: The raw data and data description for the Arctic sea ice minimum dataset is shown in the figures 5 and 6

	Year	Extent_of_ice	Area_covered
0	1979	7.05	4.58
1	1980	7.67	4.87
2	1981	7.14	4.44
3	1982	7.30	4.43
4	1983	7.39	4.70

Figure 5. Raw data for dataset 3

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 42 entries, 0 to 41
Data columns (total 3 columns):
 #   Column         Non-Null Count  Dtype
---  ------         --------------  -----
 0   Year           42 non-null     int64
 1   Extent_of_ice  42 non-null     float64
 2   Area_covered   42 non-null     float64
dtypes: float64(2), int64(1)
memory usage: 1.1 KB
```

Figure 6. Data description for dataset 3

4.4 Dataset 4: Carbon Dioxide emissions

Data Sources: The data for the CO_2 emissions was acquired from the ETH Zurich server hosted on the University of Melbourne Website [15]. The data was available for several greenhouse gases. But since carbon dioxide is present in maximum proportion in the Earth's atmosphere as compared to other greenhouse gases, it was selected for visualisation purposes.

Data Description: The raw data and the data structure are shown in figures 7 and 8.

	datenum	year	month	day	datetime	data_mean_global	data_mean_nh	data_mean_sh
0	15	0	1	15	15-Jan-0000 00:00:00	278.366439	279.045659	277.687219
1	46	0	2	15	15-Feb-0000 00:00:00	278.713058	279.665398	277.760718
2	75	0	3	15	15-Mar-0000 00:00:00	279.013835	280.266779	277.760892
3	106	0	4	15	15-Apr-0000 00:00:00	279.209613	280.756607	277.662620
4	136	0	5	15	15-May-0000 00:00:00	279.106444	280.613494	277.599394

Figure 7. Raw data for dataset 4

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 24180 entries, 0 to 24179
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   datenum           24180 non-null  int64
 1   year              24180 non-null  int64
 2   month             24180 non-null  int64
 3   day               24180 non-null  int64
 4   datetime          24180 non-null  object
 5   data_mean_global  24180 non-null  float64
 6   data_mean_nh      24180 non-null  float64
 7   data_mean_sh      24180 non-null  float64
dtypes: float64(3), int64(4), object(1)
memory usage: 1.5+ MB
```

Figure 8. Data description for dataset 4

5. Data Transformation and Cleaning

The data cleaning and transformation was performed using two libraries primarily in Python named numpy and pandas. Other packages were also used wherever required.

5.1 Dataset 1: Global Temperature Change

Data Transformation:

The data which was collected in a csv file was transformed for visualisation(after being properly stored and retrieved thrrough a postgres database) by following the given steps:

- The csv file was first imported into a data frame. The null values and the unnecessary columns were removed from the data frame. Only the columns containing country names, year and the temperature value were retained in the end.
- A separate date data frame was created to extract the dates and years from the data.
- The original data was annual from the year 1990 but it had to be transformed into the monthly data to integrate it with the datasets 2 and 4 which were available monthly.
- For plotting the data on a choropleth map using Geopandas library, some transformations had to introduced into the data.
- To plot the data on choropleth map, a shape-file which contained all the information regarding the latitude/longitude of each country defined according to the ISO standards was imported as a pandas data frame. The name of the countries from this data frame was then copied into a separate data frame.

- The names of the countries in our original data frame were then matched with the geopandas countries data frame. Several countries were renamed and several other were removed because there was no data available to plot for those countries.
- After performing the above step, the values of temperature in the original data frame were then merged with the countries data frame. The years for which values were NAN, were replaced with the value of the previous row. The temperature scale was also normalised for plotting.
- Finally, the data was successfully plotted on a choropleth map and conclusions were drawn.

Data Cleaning: The final data description and head after performing all the above steps are shown in the figures **??** and 10

	Country	Date	Temperature	Temperature_normalised
0	Afghanistan	1990-01-15	0.766	0.000143
1	Afghanistan	1990-02-15	0.766	0.000143
2	Afghanistan	1990-03-15	0.766	0.000143
3	Afghanistan	1990-04-15	0.766	0.000143
4	Afghanistan	1990-05-15	0.766	0.000143
5	Afghanistan	1990-06-15	0.766	0.000143
6	Afghanistan	1990-07-15	0.766	0.000143

Figure 9. Cleaned dataset 1 head

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 90360 entries, 0 to 90359
Data columns (total 4 columns):
 #   Column                  Non-Null Count  Dtype
---  ------                  --------------  -----
 0   Country                 90360 non-null  object
 1   Date                    90360 non-null  datetime64[ns]
 2   Temperature             90360 non-null  float64
 3   Temperature_normalised  90360 non-null  float64
dtypes: datetime64[ns](1), float64(2), object(1)
memory usage: 3.4+ MB
```

Figure 10. Cleaned dataset 1 description

5.2 Dataset 2: Global sea level change

Data cleaning and transformation:

- Not much cleaning and transformation was required for this particular dataset as the available data was already monthly. The data was imported into a data frame using pandas.
- The separate date data frame was created taking into account the dates of other datasets as well.
- It was then merged with the original dataset to keep all the dates columns in all the datasets on an equal footing. The NAN values were replaced with the previous row values.
- The cleaned data(refer to figure 11 and 12) was then exported to a csv file for later use.

	Date	Global_mean_sea_levels
0	1850-01-15	-183.0
1	1850-02-15	-183.0
2	1850-03-15	-183.0
3	1850-04-15	-183.0
4	1850-05-15	-183.0

Figure 11. Cleaned dataset 2 head

```
final.info()
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2052 entries, 0 to 2051
Data columns (total 2 columns):
 #   Column                  Non-Null Count  Dtype
---  ------                  --------------  -----
 0   Date                    2052 non-null   datetime64[ns]
 1   Global_mean_sea_levels  2052 non-null   float64
dtypes: datetime64[ns](1), float64(1)
memory usage: 32.2 KB
```

Figure 12. Cleaned dataset 2 description

5.3 Dataset 3: Global sea level Change

Data Transformation: The data was acquired in a csv file, fetched into a postgres database and then loaded for visualisation in python.

- The original data was available annually but it had to be transformed into a monthly data.
- The initial step was importing the csv file into a pandas data frame. The subsequent steps were removing NAN values(if any) and removing any unnecessary columns.
- For transforming the data into a monthly data, a separate date data frame was made like for the dataset 1. the dates with monthly interval were then generated using for loops in that data frame.
- The dates data frame was then merged with the original data frame created in step 1. The NAN values were replaced with the values of the rows above them. Hence if a year has some value for the mean sea level change, all of its months would have that same value. This is sort of a drawback of using this method but it is an efficient method as compared to other methods for handling missing values for the scope of this project.
- After performing the above steps, the data was plotted on a line graph using the seaborn package in python.

Data Cleaning: The final data and its description after cleaning and transformation are shown in the figures 13 and 14

	Date	Arctic_sea_ice_extent
0	1979-01-15	7.05
1	1979-02-15	7.05
2	1979-03-15	7.05
3	1979-04-15	7.05
4	1979-05-15	7.05
5	1979-06-15	7.05
6	1979-07-15	7.05
7	1979-08-15	7.05
8	1979-09-15	7.05
9	1979-10-15	7.05
10	1979-11-15	7.05
11	1979-12-15	7.05
12	1980-01-15	7.67
13	1980-02-15	7.67

Figure 13. Cleaned dataset 3 head

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 504 entries, 0 to 503
Data columns (total 2 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   Date                  504 non-null    datetime64[ns]
 1   Arctic_sea_ice_extent  504 non-null    float64
dtypes: datetime64[ns](1), float64(1)
memory usage: 11.8 KB
```

Figure 14. Cleaned dataset 3 description

5.4 Dataset 4: Carbon dioxide emissions

Data transformation:

- This dataset too was monthly and hence the steps followed are similar to that in for dataset 2
- For visualisation, an animated polar spiral plot was created using various libraries in python to visualize the change in the emission levels over the years. This kind of plot was first created by Ed Warren, a renowned climate scientist, in the year 2017. Since then, numerous developments have been made to the techniques that he used.

Data Cleaning: The final cleaned data and its description are shown in the figures and

	DATE	CO2_Emissions_Global
0	1800-01-15	281.481045
1	1800-02-15	281.867502
2	1800-03-15	282.212857
3	1800-04-15	282.456967
4	1800-05-15	282.404901

Figure 15. Cleaned dataset 4 head

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 2580 entries, 0 to 2579
Data columns (total 2 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   DATE                  2580 non-null   datetime64[ns]
 1   CO2_Emissions_Global  2580 non-null   float64
dtypes: datetime64[ns](1), float64(1)
memory usage: 60.5 KB
```

Figure 16. Cleaned dataset 4 description

6. Visualisations

Now we will discuss each of the datasets individually and then look at the combined dashboards.

6.1 Dataset 1 : Global Temperature Change

- For this dataset, the visualisation was done on a choropleth map. As can be seen very clearly from the figures and , the overall temperature around the globe has increased drastically over the last 30 years. This increase can be owed to a number of factors like global warming, greenhouse gas emissions, etc.
- As can be seen from the map, the Antarctica region has become cooler. The reason for this because there isn't enough data collected for the Antarctica region to make dependable conclusions.

6.2 Dataset 2 : Global sea level change

- For this dataset, a line plot was chosen to represent the change in sea levels over the globe. As can be inferred from the graph clearly(refer to figure), there is an overall increase in the sea level over the time period chosen.
- The main reason for this is the melting of the polar and Arctic Ice caps which is depicted by the visualisation for dataset 3 in the next subsection.

6.3 Dataset 3: Arctic Ice Minimum

- As can be inferred clearly from the line plot, the mass of the Arctic ice minimum has decreased on an average in the last few years.
- Although some fluctuations can be seen on a smaller scale but the overall trend is decreasing.

6.4 Dataset 4: Carbon dioxide emissions

- The polar plot in the figure shows the trend of the CO_2 emissions on a monthly basis. By carefully observing the plot, we can say that there is a net increase in the emissions over the last 100 years. This can be clearly seen through the moving animation of the spiral plot(which can be clearly seen after running the code files)

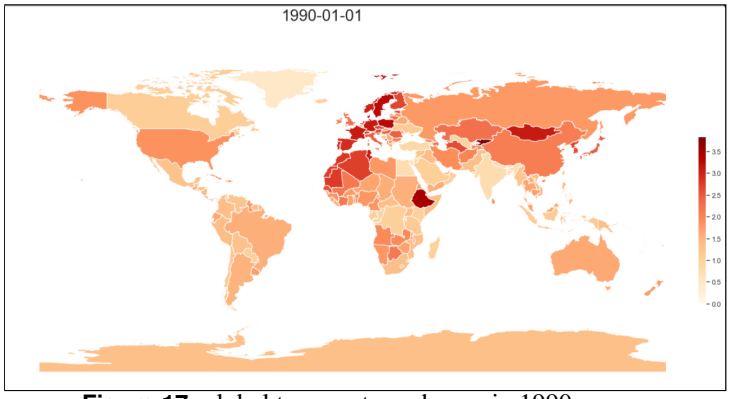

Figure 17. global temperature change in 1990

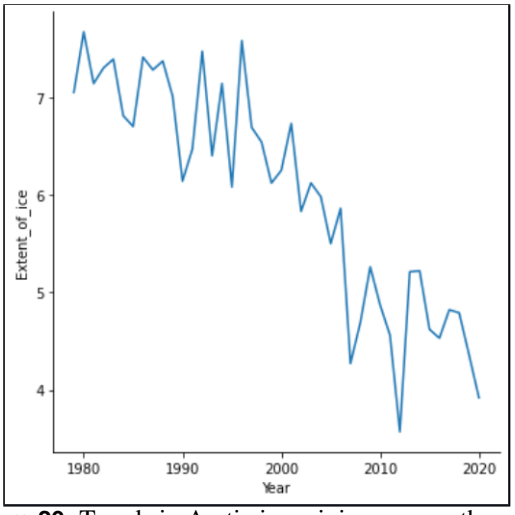

Figure 20. Trends in Arctic ice minimum over the years

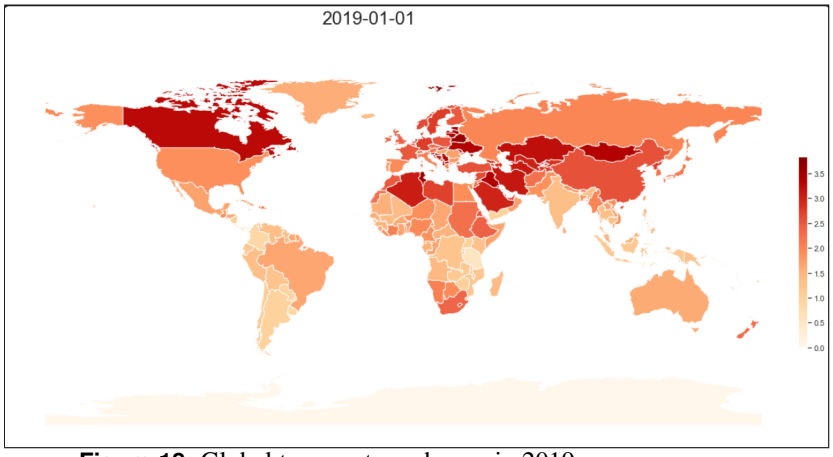

Figure 18. Global temperature change in 2019

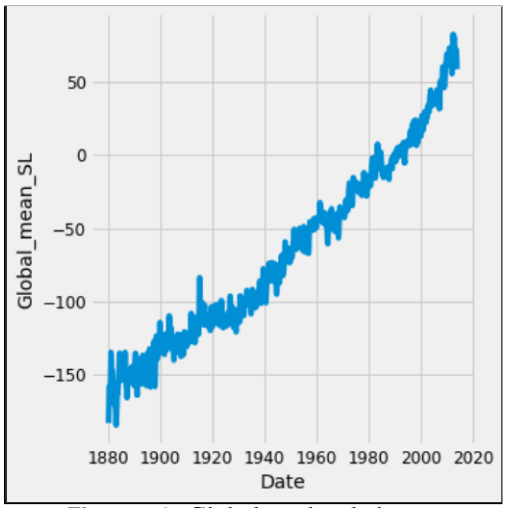

Figure 19. Global sea level change

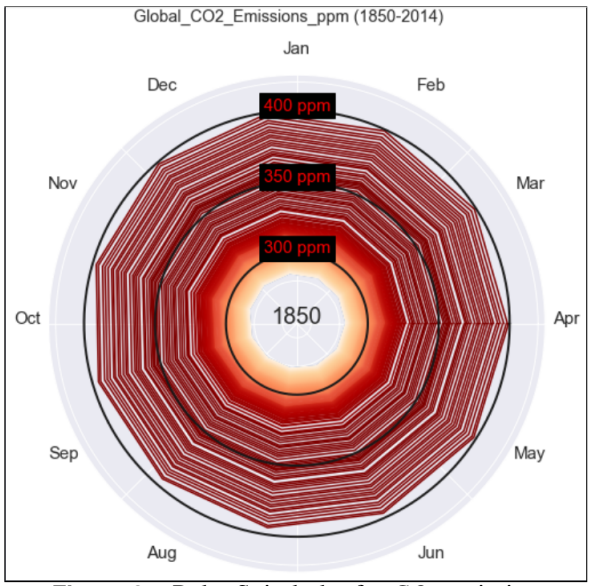

Figure 21. Polar Spiral plot for CO_2 emission

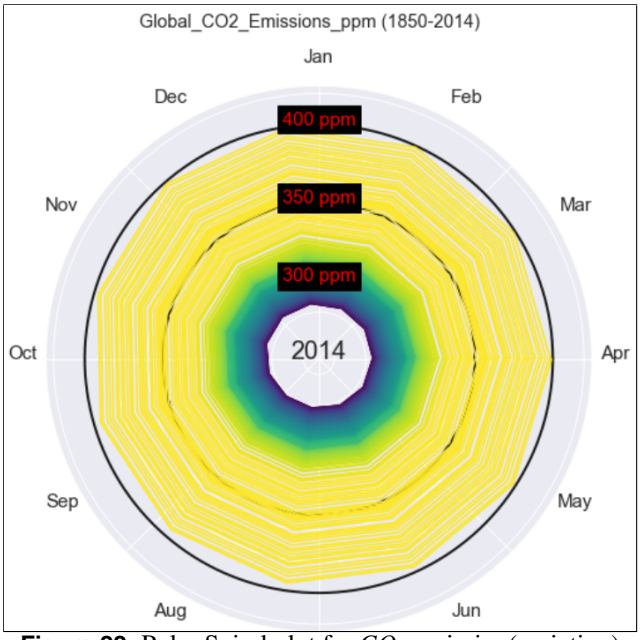

Figure 22. Polar Spiral plot for CO_2 emission(variation)

7. Conclusions

As the climate change continues to affect the ecosystem of our planet, there are a few things which can be seen as the thin silver lining. In the recent years, people have become more aware of how big of an issue the climate change really is. So there have been measures to preserve our home planet initiated by various influential people around the world. The use of renewable resources is being encouraged now to reduce the greenhouse emissions and also slow down the depletion of the natural resources. For example, in the recent few years, the sales for the electric cars have gone up which means people are becoming aware of the situation of our planet. We hope that in the coming few years, the planet could recover a little from the irreversible chain of disasters caused by the human activities.

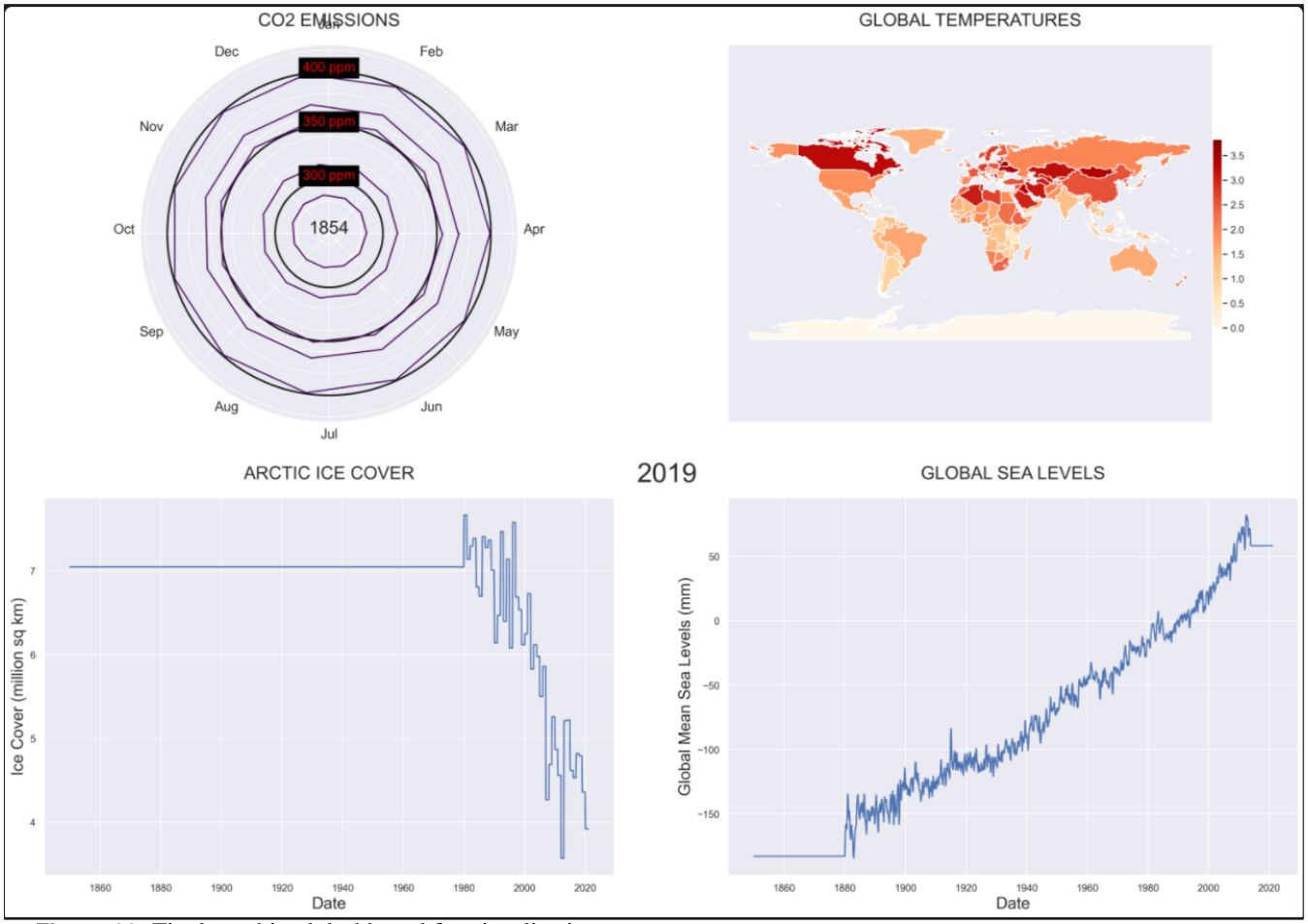

Figure 23. Final combined dashboard for visualisation

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