Time-Series Visualization on Global Warming: A Study on Historical Temperature and CO2 Emission Data

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Abstract
Global warming has recently been mentioned throughout the U.S election in 2016. It has been a serious issue that needs human's attention and resource to resolve. However, the president-elect Donald Trump called global warming a hoax and denied repeatedly scientific evidence of climate change. This paper thus explores the relationship between the Earth surface temperature and human's carbon dioxide emission using visualization tools. It furthermore discusses the progress of global warming and its negative effect, rising sea level.

I. INTRODUCTION

A. Motivation

Quite often global warming is confused with weather volatility. If a storm happens at one place, the question arises about causality is whether this change is brought about by global warming and climate change or just simply another normal storm created by our Earth dynamics. Due to this, global warming is often discarded as trivial and not an important issue to tackle on humanity crisis list. We hope that provided with our visual analytics, the trends of global warming become clearer and more persuasive towards getting everyone to agree that it is happening right now.

B. Study objectives and contributions

Climate change is often deemed as an emotionally charged topic, arising from the fact that the very science behind it is not commonly understood by most. This in turns causes climate change to be transformed into something more of a political debate. Even a large number of scientists themselves are confused by the pros and counter arguments regarding the validity of various hypotheses, theories, facts as well as speculation.

The visualization focuses on the analysis of countries, in particular the most vulnerable and responsible ones, and other stakeholders in defining their interests within the international climate change negotiations and ensuring that actions must be taken when needed.

The application utilizes international, regional and national chronicle temperature data, CO2 emission data as well as sea-level data to provide insights on the possible correlation and influences to the recently climate changes. This will hopefully help clearing up the confusion in the claims regarding issues on global warming and climate changes.

C. Paper outline

We will first look at some of the current literature regarding the global warming. Then we explore relevant data sources. Next, we recommend the visualization techniques to be used and from there build on our application. Lastly, we

II. LITERATURE REVIEW

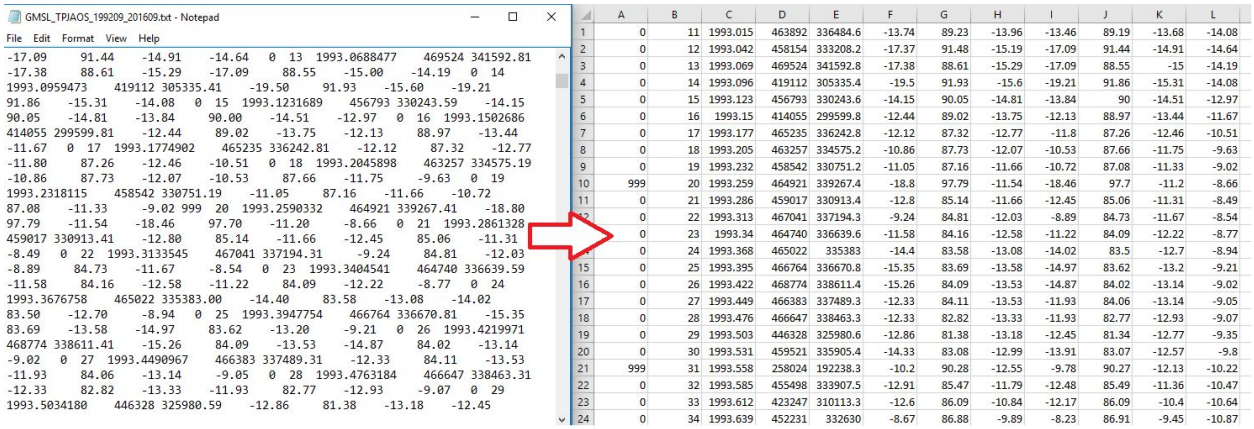
III. DATA

A. Dataset

We use three main data source to explore the patterns in global warming.
The first dataset is the historical data of Earth surface, which comes from the Berkeley Earth organization. Each row contains information regarding the countries, date of measurement, temperature measured, uncertainty as well as observations. These data was transformed into a csv file to feed as an input for the application which later would be converted into json format for analysis purposes.
Second is the carbon emission per capita for each of the countries from world bank database. The data contains the country, year and its individual citizen's emission rate. The data span for 40 years.
The third is data on historical sea level measured by NASA. The data contains sea level year by year for the last 150 years (1870 to present).

B. Data pre-processing

Data was retrieved in an unusable format and needed to undergo pre-processing. We utilized Excel to convert the text files into a more readable csv format.



	A	B	C	D	E	F	G	H	I	J	K	L
1	0	11	1993.015	463892	336484.6	-13.74	89.23	-13.96	-13.46	89.19	-13.68	-14.08
2	0	12	1993.042	458154	333208.2	-17.37	91.48	-15.19	-17.09	91.44	-14.91	-14.64
3	0	13	1993.069	469524	341592.8	-17.38	88.61	-15.29	-17.09	88.55	-15	-14.19
4	0	14	1993.096	419112	305335.4	-19.5	91.93	-15.6	-19.21	91.86	-15.31	-14.08
5	0	15	1993.123	456793	330243.6	-14.15	90.05	-14.81	-13.84	90	-14.51	-12.97
6	0	16	1993.15	414055	299599.8	-12.44	89.02	-13.75	-12.13	88.97	-13.44	-11.67
7	0	17	1993.177	465235	336242.8	-12.12	87.32	-12.77	-11.8	87.26	-12.46	-10.51
8	0	18	1993.205	463257	334575.2	-10.86	87.73	-12.07	-10.53	87.66	-11.75	-9.63
9	0	19	1993.232	458542	330751.2	-11.05	87.16	-11.66	-10.72	87.08	-11.33	-9.02
10	999	20	1993.259	464921	339267.4	-18.8	97.79	-11.54	-18.46	97.7	-11.2	-8.66
11	0	21	1993.286	459017	330913.4	-12.8	85.14	-11.66	-12.45	85.06	-11.31	-8.49
12	0	22	1993.313	467041	337194.3	-9.24	84.81	-12.03	-8.89	84.73	-11.67	-8.54
13	0	23	1993.34	464740	336639.6	-11.58	84.16	-12.58	-11.22	84.09	-12.22	-8.77
14	0	24	1993.368	465022	335383	-14.4	83.58	-13.08	-14.02	83.5	-12.7	-8.94
15	0	25	1993.395	466764	336670.8	-15.35	83.69	-13.58	-14.97	83.62	-13.2	-9.21
16	0	26	1993.422	468774	338611.4	-15.26	84.09	-13.53	-14.87	84.02	-13.14	-9.02
17	0	27	1993.449	466383	337489.3	-12.33	84.11	-13.53	-11.93	84.06	-13.14	-9.05
18	0	28	1993.476	466647	338463.3	-12.33	82.82	-13.33	-11.93	82.77	-12.93	-9.07
19	0	29	1993.503	446328	325980.6	-12.86	81.38	-13.18	-12.45	81.34	-12.77	-9.35
20	0	30	1993.531	459521	335905.4	-14.33	83.08	-12.99	-13.91	83.07	-12.57	-9.8
21	999	31	1993.558	258024	192238.3	-10.2	90.28	-12.55	-9.78	90.27	-12.13	-10.22
22	0	32	1993.585	455498	333907.5	-12.91	85.47	-11.79	-12.48	85.49	-11.36	-10.47
23	0	33	1993.612	423247	310113.3	-12.6	86.09	-10.84	-12.17	86.09	-10.4	-10.64
24	0	34	1993.639	452231	332630	-8.67	86.88	-9.89	-8.23	86.91	-9.45	-10.87

In order to make use of web application tools to visualize our findings, we need to first convert the data from csv files in row and column format to JSON format.
To do such conversion, a Java class was created to run the conversion and export data as JSON file.
Beside, we used Qgis to insert our data into map layer. We did this using JOIN function of qgis and joining a world countries layer with a table of CO2 emission data via the country code.

IV. DATA VISUALIZATION

A. Radial chart of temperature

This radial chart is inspired from the Spiraling Global Temperature animation, a work of Ed. Hawkins. This chart allows users to select from a list of countries and view their yearly measured temperature. The visualization technique enables viewers to compare yearly changes in temperature and provide insight on the effect of global warming on different countries.

B. Choropleth map of CO2 emission

The Choropleth Map of CO2 emission allows viewers to quickly analyze the changes in the level of CO2 emission by different countries worldwide. This allows for a quick glance of who are the most responsible for global warming and hopefully provide an insight on the trend and correlation between CO2 emission and global warming.

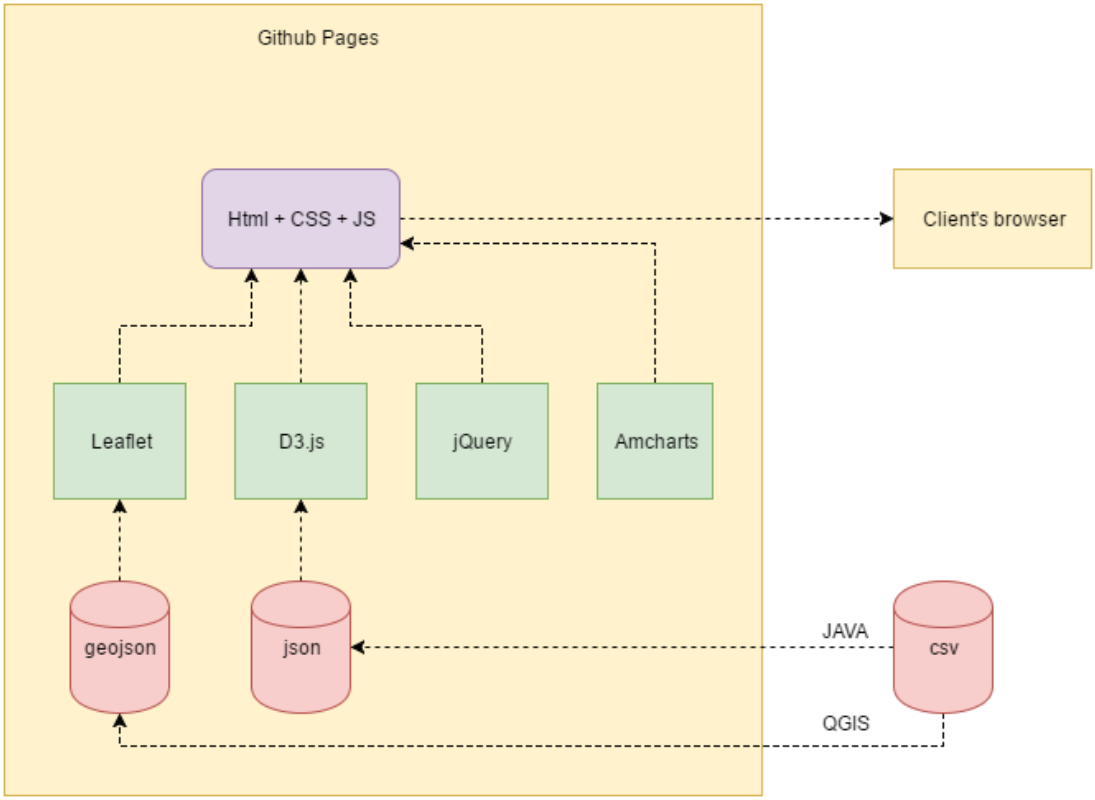
C. Multiple-line charts for correlation

Line chart is basic but essential in viewing the trends over time series. Thus we use this to see if there is a correlation between the temperature, the CO2 emission, and the sea level over time. The scale is divided into 5 years span.

V. WEB APPLICATION

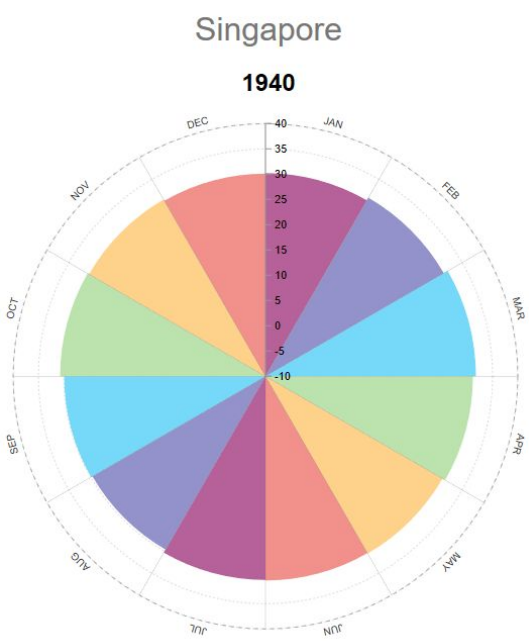
Our web application is hosted on Github Pages. The source code is in the same public repository. We made use of Git for collaborations and version tracking.

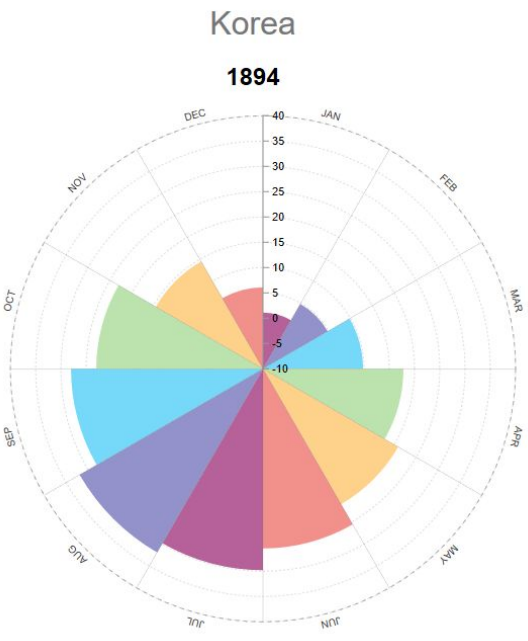
The architecture of our web application



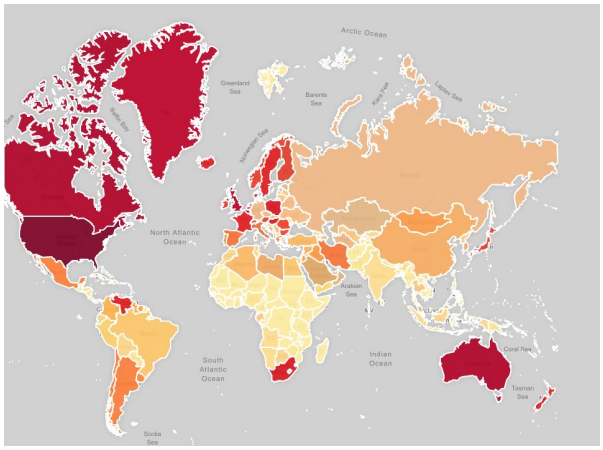
There are three functionalities of our application:

- Illustration of temperature changes over time for different countries.

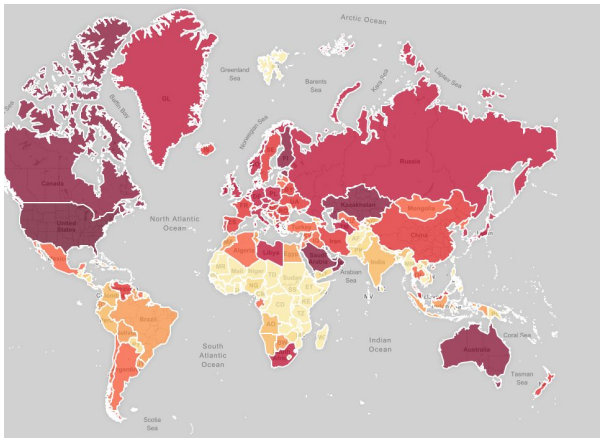




- Illustration of industrialization and CO2 emission over 40 years. The functionality is at https://duyloc91.github.io/VisualAnalytics/map.html. Take note to click on “load unsafe scripts” in order to fully load the map. The button to load is on the right of the url bar.



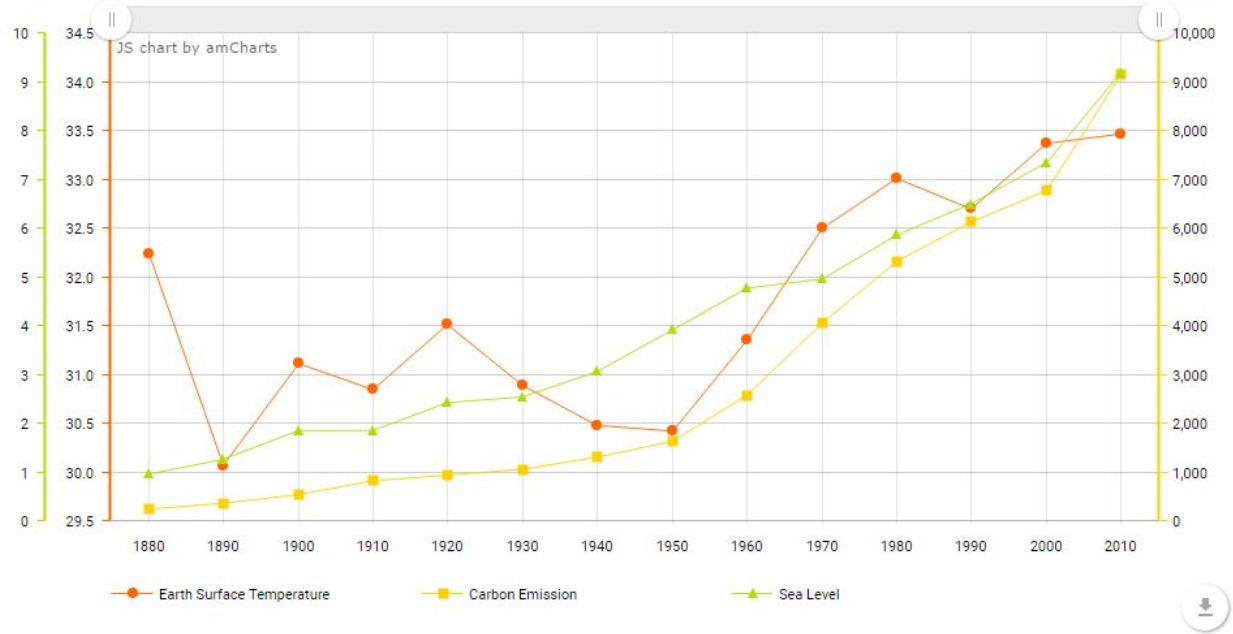
(past situation of CO2 emission)



(current situation of CO2 emission)

As seen in the pictures of global map, the color of countries getting darker over time proving the point that the progress is rather increasing non-stop.

- Trend analysis using three parameters: CO2 emission, sea level and temperature



VI. INSIGHTS AND DISCUSSION

Carefully analysis of the Radial Chart allows for insights on the changes in temperature over the past 2 centuries. Some changes can be accounted for using historical and geographical events. Below are the changes observed from the chart.

1877-78: strong El Nino event (often referred to as the cycle of warm and cold temperatures, measured on the sea surface level) warms global temperatures
1880s-1910: small cooling, partially due to volcanic eruptions
1910-1940s: warming, partially due to recovery from volcanic eruptions, small increase in solar output and natural variability
1950s-1970s: fairly flat temperatures as cooling sulphate aerosols mask the greenhouse gas warming
1980-now: strong warming, with temperatures pushed higher in 1998 and 2016 due to strong El Nino events

VII. CONCLUSION

Even though the CO2 emission and the sea level data show the trend of increasing, temperature was tricky to analyse. Part of the reason is that temperature differs from one place to another place as well as the anomaly within its measure. However, we manage to see an increasing trends in CO2 emission quite aggressive as well as the increasing sea level. With such trends confirmed, countries surrounded closely by the sea like Singapore should be worried in the near future as their scarce land resource is shrinking.

VIII. REFERENCES

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The World Bank, 2016, CO2 emissions (metric tons per capita), Retrieved from http://data.worldbank.org/indicator/EN.ATM.CO2E.PC