Time Series Analysis and Prediction of Climate Change

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Abstract— **Climate change refers to regional or global changes in patterns of climate variability over years, often identified using statistical methods. It is also sometimes referred to as changes in long-term weather conditions. The changing climate due to global warming is considered as the main consequence of the drastic increase in the concentration of greenhouse gases due to human activities. There are several studies published on Climatic Change which reveals that the temperature increase is mostly caused by CO2 emissions in different regions around the world. Temperature raises linearly in most parts of the world which corresponds to CO2 emissions. The scope of our paper is to predict the temperature for the next 100 years using time series methods and also determine how helpful the CO2 emissions data is in forecasting the temperature.**

Index Terms— **Data wrangling, data visualization, time series forecasting**

I. INTRODUCTION

Climate change is abnormal variations in climate and has been occurring since the earth came into being. In recent times, the temperature of earth is becoming warmer day by day. This is because, glaciers have started melting and greenhouse gases are clouding the entire planet, leading to rising sea level and global warming. We will have to control it or the condition will become worse in the future. These might lead to heavy loss of life on earth let it be plants, animals or human beings.

Weather refers to the state of atmosphere at a particular place at a particular span of time. The span could be few days or week. It could be sunny, cloudy, stormy, rainy, or maybe clear. It is a part of the natural phenomenon which maintains the atmosphere symmetrically. In contrast to weather, the climate describes the weather condition over a relatively longer period of a time in a particular region. Weather refers to short term atmospheric conditions, whereas climate is the weather over a longer period of time. Our planet is warming, from North Pole to South Pole. Since 1906, the global average surface temperature has increased by more than 1.6 degrees Fahrenheit, even more in sensitive Polar Regions. The impact of rising temperatures and global warming are being experienced right now. Some of the effects of global warming are the melting glaciers and sea ice, shifting precipitation patterns, and setting animals on the move.

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There are many natural factors that contribute to climate change. Progressive instances of climate change could be observed in the geological records, which includes is the rapid rate and magnitude of climate change. Greenhouse gases present in the atmosphere absorb heat radiation. Human activity has increased greenhouse gases in the atmosphere since industrial revolution, leading to more heat retention, and an increase in surface temperatures. Atmospheric aerosols alter climate by scattering and captivating solar and infrared radiation and also may change the microphysical and chemical features of clouds. Finally, such as deforestation (land-use changes) have as well led lead to changes in the climate. For the upcoming decades, it is predicted that billions of people, particularly those in developing countries are likely to face shortages of food and water and greater risks to health and life as a result of climate change. Effective global action is needed for developing countries to adapt to effects of climate change and contain its magnitude of impact.

II. FACTORS INFLUENCING CLIMATE CHANGE

Scientists observed that human-released greenhouse gases are the cause of global warming. The gases in the atmosphere which traps the heat within the earth and stops it from travelling back into space. Some of the gases in the atmosphere that blocks heat from moving back to space are carbon dioxide, water vapor, methane, and nitrous oxide which is made up of three or more atoms. Some of the long-lived gases remain transiently in the atmosphere and do not respond chemically or physically to the changes in temperature are described as agents "forcing" climate change. Gases, such as water vapor, which respond physically or chemically to changes in temperature, seem to be as "feedbacks".

Gases that contribute to the greenhouse effect include the following:

Water vapor– It is the most abundant greenhouse gas which absorbs long wave radiation and radiates it back to the surface and thus it contributes further warming to the atmosphere. Water vapor also acts as a feedback to the climate. It consumes around 80 percent of total greenhouse gas mass in the atmosphere and 90 percent of greenhouse gas volume. Water vapor can be produced by evaporating or boiling of liquid water or from the sublimation of ice.

Carbon dioxide (CO2) – CO2 is also a very important component of the atmosphere which absorbs heat radiations from the sun which are reflected back from the earth. Carbon dioxide is released through burning natural processes such as respiration and volcano eruptions. Also carbon emissions are released through human activities such as deforestation, land

pollutions, and burning fossil fuels. As industrial resolution began, humans have increased atmospheric CO2 concentration. This is the most important long-lived "force" of climate change.

Methane– Methane is considered as one of the most potent greenhouse gas in the earth's atmosphere. Some of the major sources of atmospheric methane were paddy rice fields, natural wetlands, emission from livestock production systems, biomass burning. Methane can come from both natural and man-made sources.

Nitrous oxide– It is a powerful greenhouse gas which is produced by soil cultivation practices. Rather than greenhouse, it is also known as ozone destroyer. It is especially used in the soil cultivation for commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning. Nitrous oxide is sometimes referred to as laughing gas.

Chlorofluorocarbons (CFCs) – They are the exceptionally strong greenhouse gases in the earth's atmosphere. As the name contains chloro (chlorine), fluoro (fluorine), they are referred to as halocarbons and also they contain bromine and iodine.

III. EFFECTS OF CLIMATE CHANGE

Climate change has already had some observable effects on the environment such as, glaciers melting, ice on rivers and lakes which is breaking up earlier, plant and animal ranges that have shifted and also trees that are flowering sooner. Effects that scientists had predicted in the past are now seen. Loss of sea ice, rise in sea level, longer and more intense heat waves, oceans becoming warmer, and loss of crops due to intense drought were some significant predictions which are being witnessed in recent times. Our planet's diversity of life is at risk, from polar bears in the Arctic to marine turtles off the coast of Africa. Some effects that could take place later this century, if global warming continues at the present pace are as follows:

Physical Systems- Variations in the physical systems of the planet can be observed in the melting of the poles. It causes glacial regression, snow melting, warming and thawing of permafrost, flooding in rivers and lakes, droughts in rivers and lakes, coastal erosion, sea level rise and extreme natural phenomena. Sea levels are expected to rise between 10 and 32 inches or higher by the end of this century. Hurricanes and other storms are likely to become stronger. Since glaciers store about three-quarters of World's freshwater and if the melting continues, there will be a demand for freshwater.

Biological Systems- Will continue to change resulting in the extinction of rare species especially flora and fauna in terrestrial and marine ecosystems, occurrence of wildfires migration of animals farther towards north or south, not able to withstand extreme heat in the equatorial region.

Human Systems- Thirdly, climate change affects and destroys crops and food production and thus causes diseases and death. Also this is the major impact of climate change.

IV. RESEARCH DESIGN

This research study included an extensive analysis of empirical data and historical evidences in the past. Along with, appropriate descriptive study is also conducted on select data for the accomplishment of the research objective.

Objective- The objective of this research study is to predict climate change for the next few decades.

Sources of Data- Data were sourced from official publications and reports of NASA and the World Bank. For the purpose of analysis, two structured datasets were used namely -

a) Estimation of CO2 extracted from the information resource of NASA

b) Global surface temperature change information from the World Bank resource

Analysis Tools: Pandas and library of python have been used to create an empty data frame with a date time index. For the missing values and NANs values 'forward fill' is used as provided by the pandas. For visualization, matplotlib has been used. Facebook's prophet has been relied upon to training the data and fitting it with the library to forecast climate change for the next 100 years.

V. DATA ANALYSIS

The analysis process includes, understanding anomaly values, wrangling temperature data and use date time index, manipulating and dealing with missing values and resampling to a different frequency as appropriate. The process is as follows:

a) The temperature dataset indicates the anomalies of temperature which is the difference between the mean/ the expected value per month and the season. This study has used anomaly values since it is more significant and important as well than absolute values. Anomaly values, when positive, indicate warmer temperature; negative indicate cooler temperature.

b) For temperature data, an empty data frame has been created using data time index of monthly frequency for populating the empty data frame with raw data. The empty data frame ranges from 1880 to 2019.

c) The new empty data frame has been populated with the anomaly values for every month. There were few missing values as well as some unusable values. It's a package of pandas which is used for manipulation of the data. Using 'forward fill' the issue of missing values have been sorted.

d) After manipulating and filling missing values, for better visualization resampling and packages in pandas were modified, frequency was changed from month to year.

Table 1: Estimate of CO2

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	J-D	D-N	DJF	MAM	JJA
0	1880	-0.29	-0.18	-.11	-.19	-.11	-.23	-.21	-.09	-.16	-.23	-.20	-.22	-.18	***	***	-.14	-.18
1	1881	-0.15	-0.17	.04	.04	.02	-.20	-.06	-.02	-.13	-.20	-.21	-.10	-.09	-.10	-.18	.04	-.09
2	1882	0.15	0.15	.04	-.18	-.15	-.25	-.20	-.05	-.10	-.24	-.15	-.24	-.10	-.09	.07	-.10	-.17
3	1883	-0.31	-0.38	-.12	-.16	-.19	-.12	-.08	-.15	-.20	-.14	-.22	-.15	-.19	-.19	-.31	-.16	-.11
4	1884	-0.15	-0.08	-.37	-.42	-.36	-.40	-.34	-.26	-.27	-.24	-.29	-.28	-.29	-.28	-.13	-.38	-.33

Source: NASA

Table 2: Global surface temperature change

	Country Name	Country Code	Indicator Name	Indicator Code	1960	1961	1962	1963	1964	1965	...	2010	2011	2012	201:
0	Aruba	ABW	CO2 emissions (metric tons per capita)	EN.ATM.CO2E.PC	NaN	NaN	NaN	NaN	NaN	NaN	...	24.670529	24.505835	13.155542	8.35129
1	Afghanistan	AFG	CO2 emissions (metric tons per capita)	EN.ATM.CO2E.PC	0.046060	0.053604	0.073765	0.074233	0.086292	0.101467	...	0.293837	0.412017	0.350371	0.31560:
2	Angola	AGO	CO2 emissions (metric tons per capita)	EN.ATM.CO2E.PC	0.097472	0.079038	0.201289	0.192535	0.201003	0.191528	...	1.243406	1.252789	1.330843	1.25461:
3	Albania	ALB	CO2 emissions (metric tons per capita)	EN.ATM.CO2E.PC	1.258195	1.374186	1.439956	1.181681	1.111742	1.166099	...	1.578574	1.803715	1.692908	1.74921:
4	Andorra	AND	CO2 emissions (metric tons per capita)	EN.ATM.CO2E.PC	NaN	NaN	NaN	NaN	NaN	NaN	...	6.122595	5.867130	5.916597	5.90075:

5 rows × 64 columns

Source: World Bank

Elucidation of Analysis

Dealing with anomalies- The temperature dataset indicates the anomalies of temperature which is the difference between the mean/ the expected value per month and the season. Anomaly values have been relied and used since it has a greater importance than absolute temperature.

Anomaly values- Include positive-warmer temperature and negative-cooler temperature.

Data wrangling- Data wrangling is used for transforming raw data into required format for further analysis. By wrangling NASA's temperature anomaly data the following are looked upon:

- using a Date Time index
- basically manipulating and dealing with missing values
- resampling to a different frequency

Date time index- It's a package of a pandas which is used for manipulation of the data. For the temperature data an empty data frame has been created using this data time index of monthly frequency. For populating the empty data frame the raw data has been used. This empty data frame would range from 1880 to Mar 2019.

Basically manipulating and dealing with missing values- The new empty data frame has been populated with the anomaly values for every month and the result had some missing value as well as some unusable values. Using a forward fill and pandas package the missing values have been set right.

Resampling to a different frequency- When manipulating and filling missing values were done, it was visualized and the data seems to be little messy. So for better results resampling was done and the frequency was changed from month to year in packages in pandas.

Similarly, wrangling process for CO2 emission were carried out. It was observed that, these two data sets are trending upwards. But then, it cannot alone be taken for proving the cause. Thus, this correlation alone does not mean it's the cause.

OBSERVATIONS AND FINDINGS

The research analysis has brought out the trend of climate change in future.

Fig. 1: Predicted Climate Change
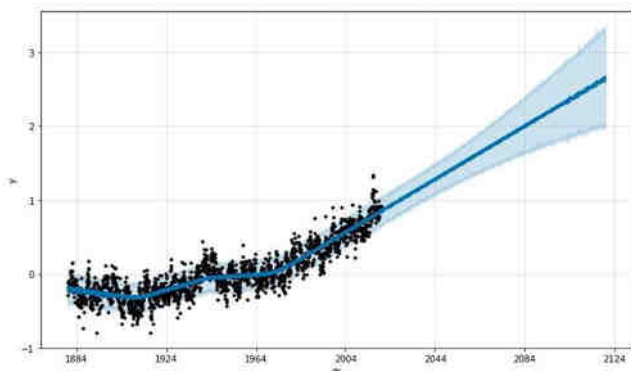
The analysis has facilitated prediction of global temperature anomalies over the next 100 years.

CONCLUSION

The entire world is turning conscious towards the changing climate and its impact on biodiversity and the ecosystem. Most importantly, its impact on human lives and livelihood is high. It is the duty of every individual to ponder around this global phenomenon and try to look for strategic reforms, let it be at the household level or at a global level.

Computing technologies play a vital role while studying various aspects pertaining to climate change and so is its importance in understanding trends and forecasts related to climate studies. This research study has proved the use of computing tools and techniques which are very useful in prediction studies.

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