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Evidence and Prediction Regarding the Continuous Global Warming: A Severe Domino Effect

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Abstract: Global warming has been a major threat to Earth for decades; still, this issue has not been taken seriously by many. Although it is proven that one of its main causes is human activity, humanity's effort towards a safer, healthier planet has been minimal. After years of neglect, global warming has worsened, and its adverse effects have become more severe. This paper aims to underscore the necessity of human efforts and universal contribution to subside the devastating ramifications of global warming. To investigate the past, present, and possible future consequences of global warming, this paper analyzes data mostly obtained from the United States Environmental Protection Agency (EPA). The paper also presents graphs that clearly illustrate the increases in global sea levels, permafrost temperatures, sea surface temperatures, and concentrations of greenhouse gases. Furthermore, the paper utilizes a linear regression machine learning algorithm, a method widely used by researchers to create predictive models, to depict future trends of the data of the aforementioned subjects. This analysis and visualization of data conclude that a so-called "domino effect" was certainly present as some environmental changes of global warming. To solve the problem of global warming, the paper finally uses the K-neighbor regression method in Python to predict the amount of power generated in the solar power systems of Berkeley, California in an accurate, flexible way.

Keywords: Global Warming, Linear Regression, K-neighbor Regression, Python, Machine Learning, Data Analysis

1. Introduction

Global warming is a major environmental issue that threatens the survival of the Earth. According to the United Nations Foundation, it is currently the most critical global issue [1]. The consequences of global warming have already been proven to be catastrophic, as they threaten ecosystems and increase the frequency of natural disasters [2]. Furthermore, rising surface temperature leads to warmer oceans and partially melting glaciers, which, in turn, raises the sea level. It is also important to recognize that oceans expand as they warm up, thus further raising sea levels [3]. Many of these issues occur because of human activity [4].

Ever since the industrial revolution in the 1700s, the average global temperature has been rapidly increasing over time [5]. For example, the constantly increasing population of this world has led to an increased demand for energy, which burns more fossil fuels [5]. According to BP Statistical Review of World Energy, in 1965, the global consumption of fossil fuels was 40,553 TWh, while in 2019, the global consumption was 136,762 TWh [6]. In other words, the consumption of fossil fuels has risen by a total of 237% [6]. Such rapid exhaustion of fossil fuels increases the concentration of greenhouse gases (i.e., water vapor, methane, carbon dioxide, nitrous oxide, and ozone). In addition, because these gases absorb infrared radiation from the sun, they trap the absorbed heat in the atmosphere, increasing the temperature of the whole planet [7]. The use of fossil fuels and other factors contribute to a rise in global temperature [8]. This increase is a serious threat to all living creatures on Earth, as natural disasters like wildfire, blizzards, or hurricanes become more severe as warmer air molecules possess more energy [9]. Furthermore, warmer air will melt glaciers, raising the global sea level [10, 11]. With the rise of the sea level, island nations and coastal cities such as Tuvalu will be in grave danger of land sinking or flooding in the coming future [12]. In sum, continued global warming will endanger the lives of all species on the planet [13].

The goal of this research is to inform people about the devastating effects of global warming. This project will analyze data that shows the serious consequences of global warming and use the linear regression algorithm in machine learning to predict future permafrost temperatures and sea levels. The clear representation of the adverse effects of rising global surface temperatures will allow us to provide sufficient information about how devastating global warming can be.

The following paper has been organized into five sections to enhance the neatness and composition of the paper. The first section is the “Introduction” section. It introduces the topic, global warming, and the format of this paper. The second section is “Evidence to Global Warming,” a section where we analyze the obtained data and reveal the severity of climate change. The third section is “Predictions of Future Global Warming Trends.” Here, this project will predict future sea levels, permafrost temperatures, and sea surface temperatures using the linear regression algorithm. The fourth section is “Solar Energy Forecasting,” where we suggest an alternative to burning fossil fuels and support our stance using the K-neighbor regression method. The fifth section is the “Conclusion” section, which will then be followed by the “References” section.

2. Evidence to Global Warming

This section explores graphs that were generated using the programming language called Python. The graphs in this section will illustrate various evidence and contributors to global warming, such as the rising sea levels, permafrost temperatures, and greenhouse gas levels. To do so, we have collected data from the United States Environmental Protection Agency, a United States government organization responsible for environmental matters and protecting nature. The following figures depict data regarding permafrost temperatures of cities in Alaska from 1978 to 2020, sea levels from 1880 to 2013, and greenhouse gas emissions from 1990 to 2019 [14]. Missing points in the data were filled in with the following data that was recorded for each city.

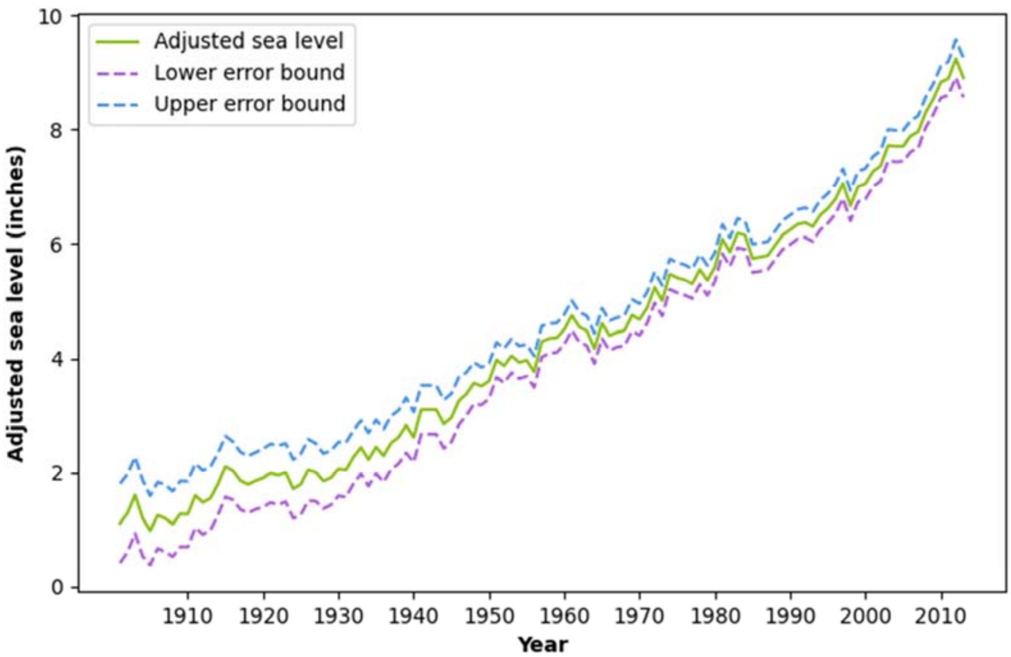

Figure 1. *Changing sea level (inches) by time.*

2.1. Sea Levels

The line graph in Figure 1 above shows the general trend of rising sea levels (inches) by time. From 1880 to 1980, there was an increase in the sea level by 5.59 inches in the first half of the graph. This showed that there was a dramatic change of sea levels. After that, it continued to rise until 8.9 inches at a steady rate in the second half of the graph. The sea level was about 0.22 inches in 1881 and in 2013, it increased to 8.9 inches. This data shows that there was a total increase of 97.7% in sea level. The purple and the blue lines each show the lower error bound and the upper error bound of sea levels.

2.2. Permafrost and Sea Surface Temperatures

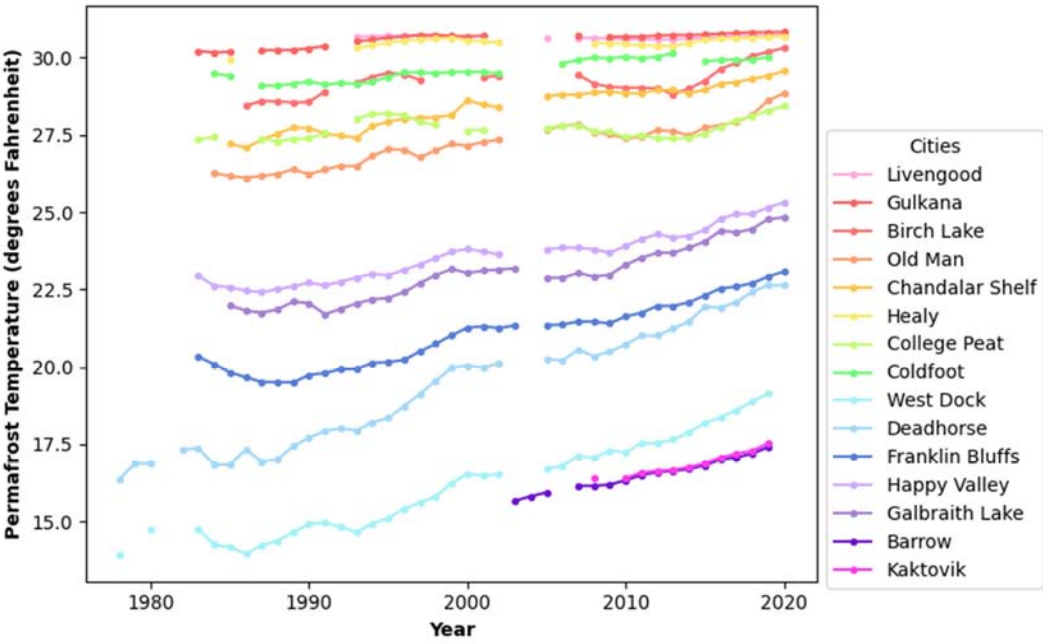

Figure 2. *Changing permafrost temperature (degrees Fahrenheit) by time and city.*

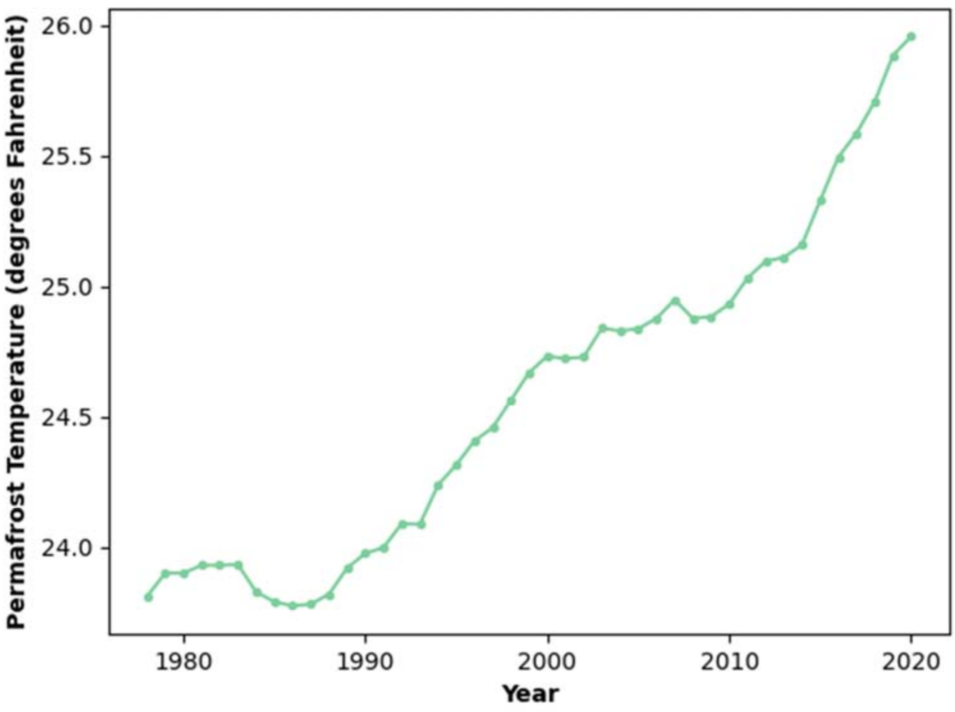

Figure 3. *Average changing permafrost temperature (degrees Fahrenheit) by time.*

The graph in Figure 2 depicts the general trend of rising permafrost temperature (degrees Fahrenheit) of all cities in Alaska. Rising temperature of permafrost, which is frozen ground, is very dangerous, as it would melt frozen surfaces and cause changes in habitats and ecosystems [1]. In 1990, the permafrost temperature of West Dock was about 15 degrees Fahrenheit. By 2020, the permafrost temperature of West Dock had risen to about 19 degrees Fahrenheit.

Figure 3 shows the average of permafrost temperatures of all the cities in Alaska to provide a clearer picture of the rapid increase in permafrost temperatures. In 1990, the average permafrost temperature of the cities was about 24 degrees Fahrenheit. However, by 2020, they rose to about 25.9 degrees Fahrenheit.

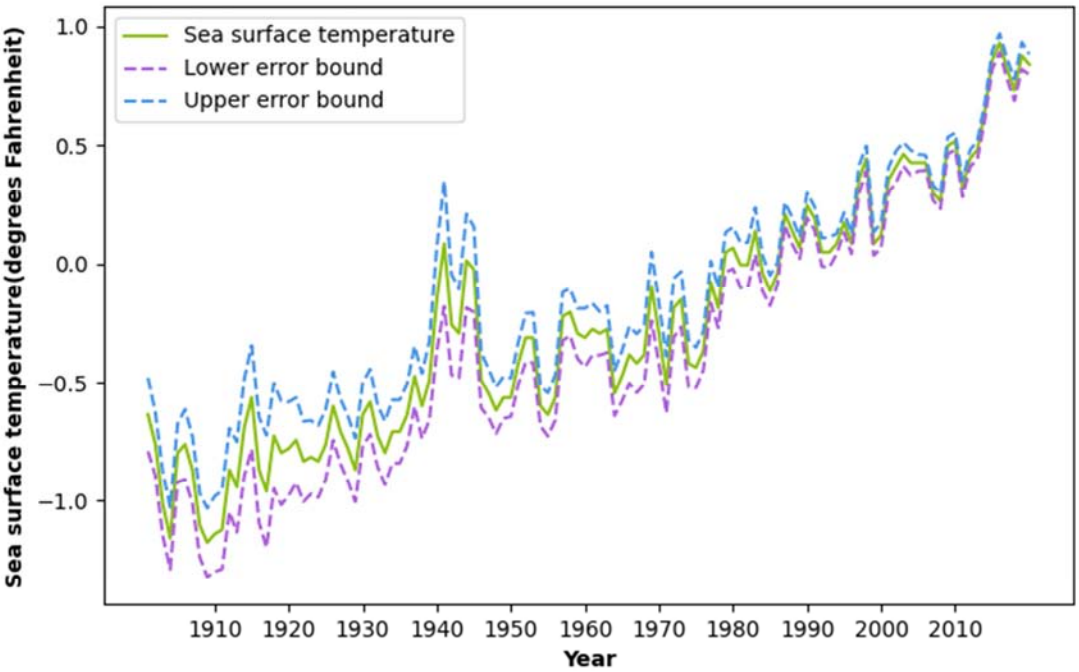

Figure 4. *Sea surface temperature (degrees Fahrenheit) by time.*

Figure 4 shows the rise in global sea surface temperatures in degrees Fahrenheit since 1880. A sudden spike can be observed between the years 1940 and 1950, but afterwards the temperature begins to steadily climb. After another considerable spike, the graph peaks at 1 degree Fahrenheit around 2010. Another notable observation from this graph is the lower and upper bounds beginning to tighten to the actual measurement as technology advances throughout the years.

2.3. Greenhouse Gas Levels

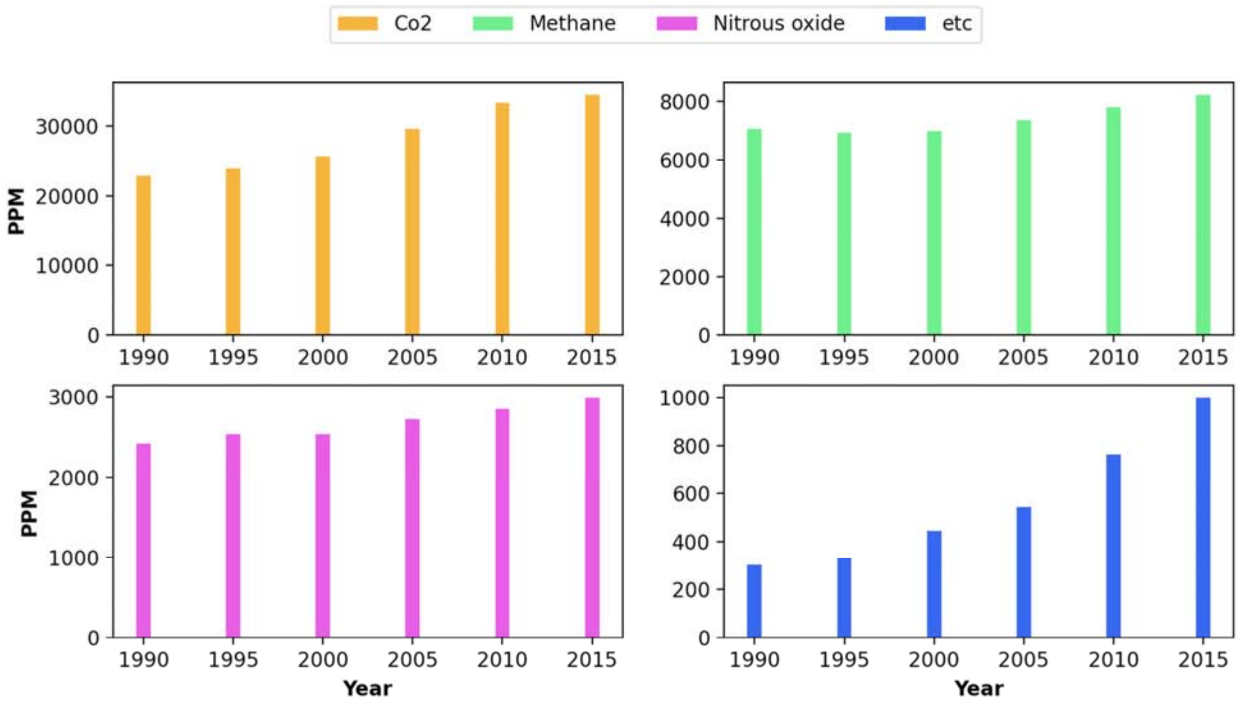

Figure 5. *Annual global greenhouse gas level from 1990 to 2015.*

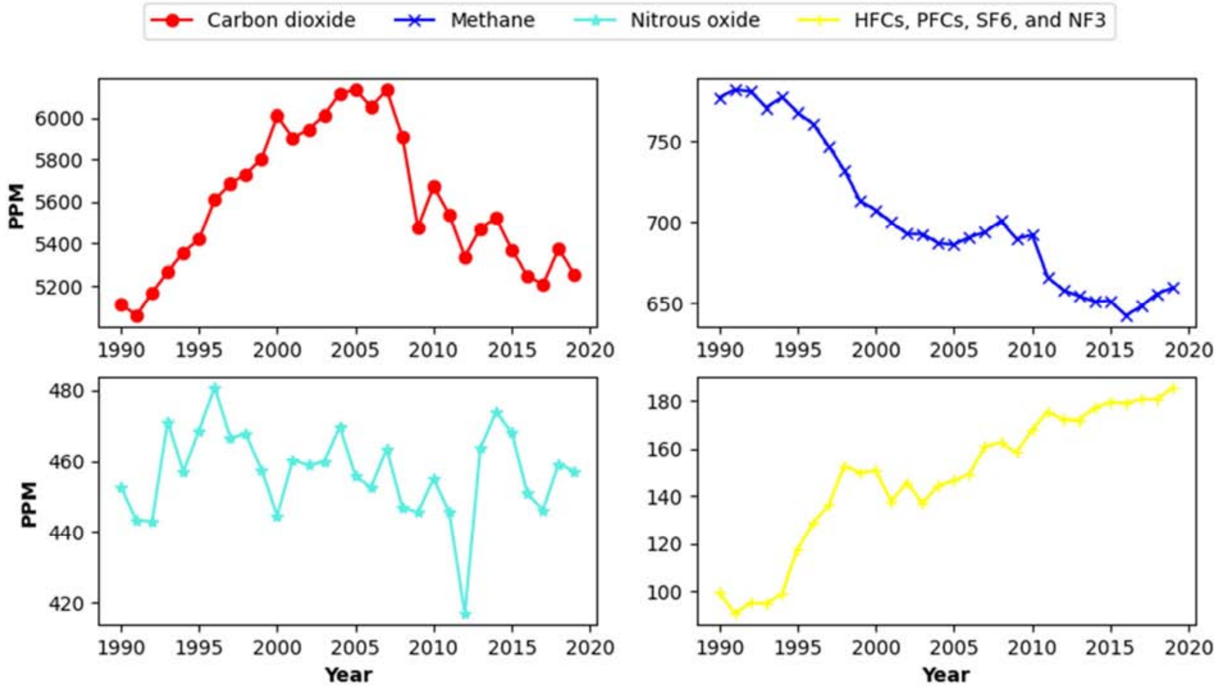

Figure 6. *Annual greenhouse gas level in the United States of America (parts per million) over time (year).*

Figure 5 contains four bar graphs representing the annual global greenhouse gas level from 1990 to 2015. The graph for global carbon dioxide is colored as orange, methane graph as mint, nitrous oxide as pink, and other less prominent greenhouse gases as blue. It is evident from all four graphs that the overall trend is increasing, meaning that the global greenhouse level has been increasing since 1990. The increase in global greenhouse gas level is a major contributor to global warming, thus this trend is a crucial piece of evidence as to why the average global temperature has been rapidly increasing in recent decades [3].

Figure 6 contains four-line graphs, which are each responsible for showing the trend of greenhouse gas level in the United States from 1990 to 2019. The greenhouse gas in Figure 6 includes: carbon dioxide, methane, nitrous oxide, and HFCs, PFCs, SF6, and NF3. The red, blue, mint, and yellow graphs represent carbon dioxide, methane, nitrous oxide, and HFCs, PFCs, SF6, and NF3, respectively.

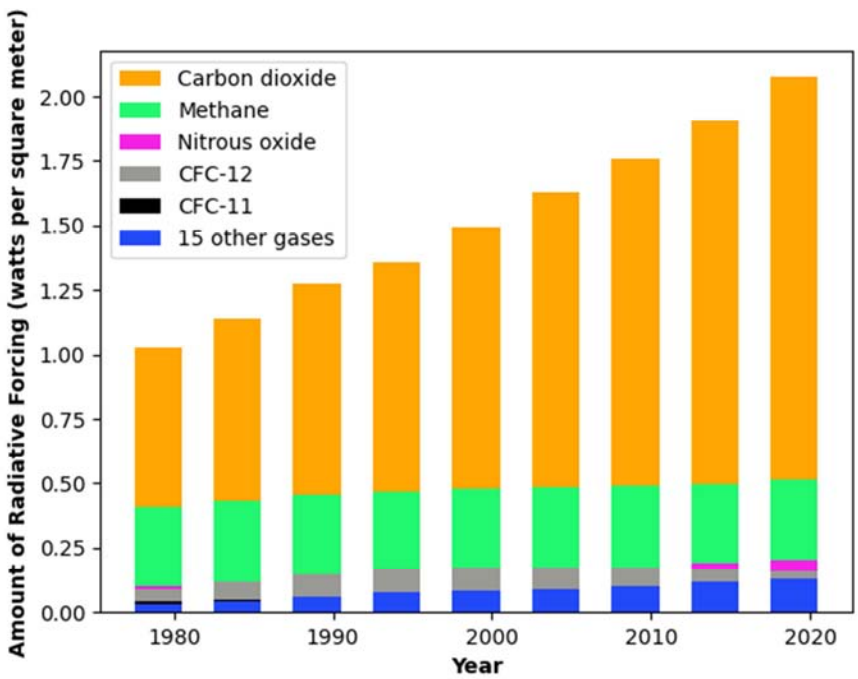

Figure 7. *Amount of Radiative Forcing caused by Various Greenhouse Gases (watts per square meter).*

Figure 7 shows a bar graph of the amount of radiative forcing caused by several greenhouse gases from 1979 to 2019. As shown in the bar graph, there is a general increase in radiative forcing, especially for carbon dioxide and the 15 other gases. Methane continues to stay roughly the same throughout the years and CFC-12, CFC-11, and nitrous oxide fluctuate in amount. As shown in the bar graph, the total amount of radiative forcing, excluding carbon dioxide, stays relatively the same throughout the years. Meanwhile, carbon dioxide causes the most radiative forcing and has the largest increase over the 4-decade period.

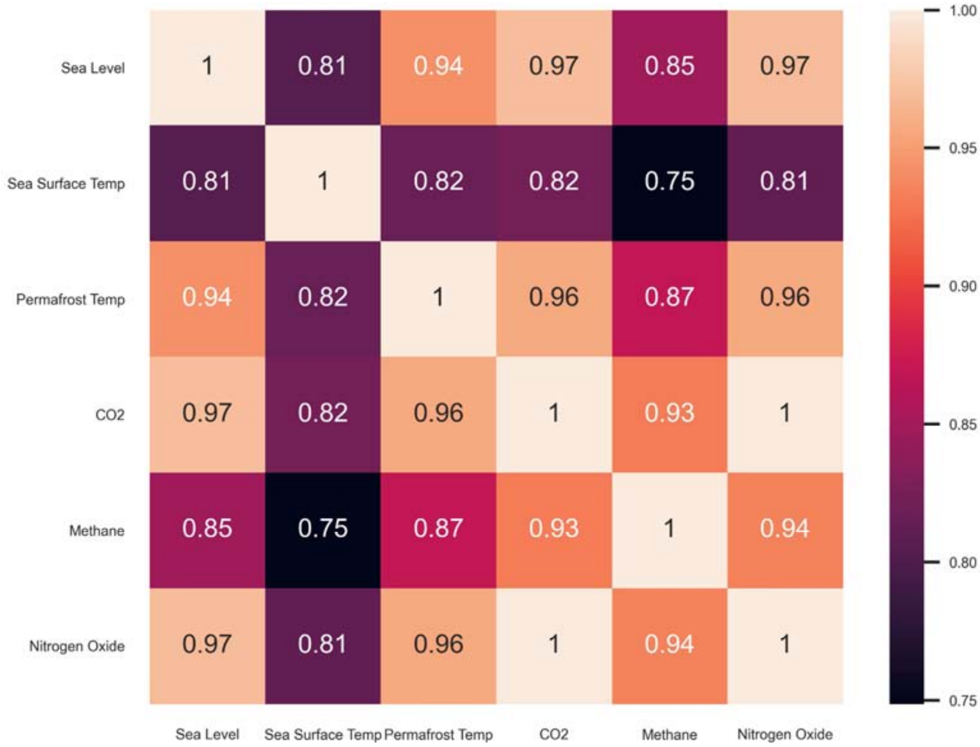

Figure 8. *Heatmap depicting the correlation between various factors.*

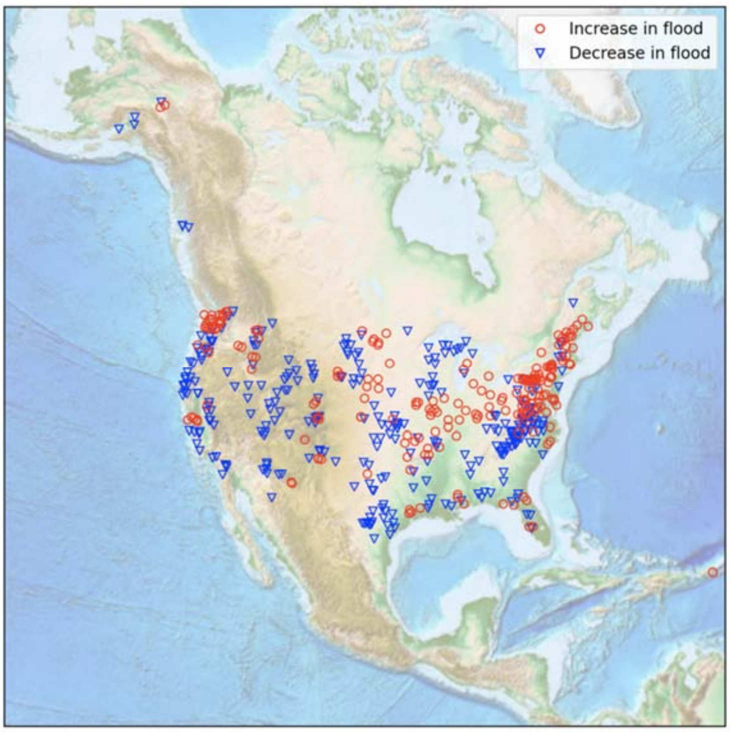

Figure 9. *Areas in the United States of America which have been affected by flood from 1960 to 2010.*

Figure 8 is a heat map that depicts the correlation and relationship between the varying sea levels (in inches), sea surface temperatures (in degrees Fahrenheit), permafrost temperatures (in degrees Fahrenheit), carbon dioxide levels (in PPM), methane levels (in PPM), and nitrogen oxide levels (in PPM). The closer the number in each box is to 1, the more correlated the two factors are. For example, since the heatmap value for the region that represents the relationship of the carbon dioxide levels and the sea level is 0.97, it is considered as highly correlated. Thus, we can conclude that the carbon dioxide levels and the sea levels are correlated. The section presenting carbon dioxide's correlation to other factors shows values that are mostly close to 1, which suggests that carbon dioxide levels have the most effect on other factors such as sea surface temperatures or sea levels.

Figure 9 above shows the map of North America and the specific locations that have been affected by floods in the United States. The data was collected from 1960 to 2010. The location colored in blue shows the places that have experienced a decrease in flooding, and the location colored in red shows the places that have experienced an increase in flooding. The map shows that the west coast has experienced more decrease in flooding compared to the east coast of the U.S. The east coast is more vulnerable to flooding since there is more precipitation. And an increase in precipitation is often because of an increase in concentration of greenhouse gases, which therefore induces higher frequency and severity of floods in the east coast.

3. Predictions of Future Global Warming Trends

In the following section, a machine learning linear regression algorithm, written in Python, is utilized to predict future global warming trends. This algorithm usually uses the "relationship between variables and forecasting" [15]. This algorithm is used widely to develop predictive models in many studies in different fields. For example, a group of researchers in South Korea used a multiple linear regression approach to predict precise warfarin dosing in the Korean population [16]. If efforts to relieve global warming are not made and it continues, the following data show how much global sea levels and permafrost temperatures are expected to rise.

3.1. Continuously Rising Sea Levels

Figure 10 utilizes the same set of data as Figure 1 and the graph shows the future trend of rising sea levels. We were able to create two graphs using a linear regression algorithm in Python. Prediction 2 (purple dashed line) shows the predicted trend of rising sea levels from 2003 until 2070. The line predicted that it would increase to 18.35. This depicts that there is a total increase of 1001% from the sea level recorded in 2003. Prediction 1 (red dashed line) shows the general trend of the rising sea level over the years from 1880 and estimates that the sea level will increase up to 11.35 inches. This shows that there is a total increase of 144%. Since the original line (blue line) shows the data until 2013, we can suggest that the graph starting from 2014 will be formed between the two prediction lines.

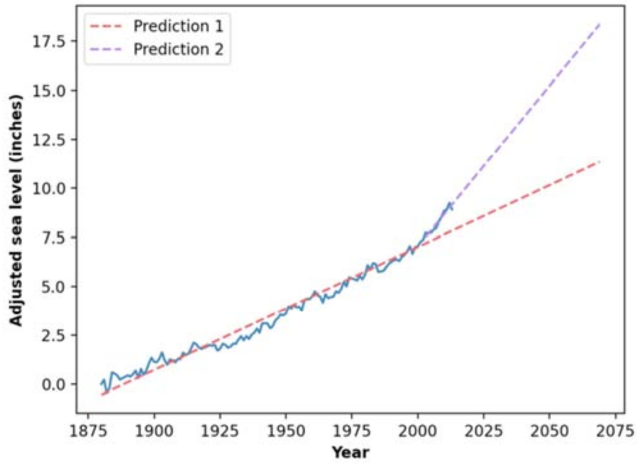

Figure 10. *Predictions of changing sea levels (in inches) until 2070.*

3.2. Continuously Rising Permafrost Temperatures

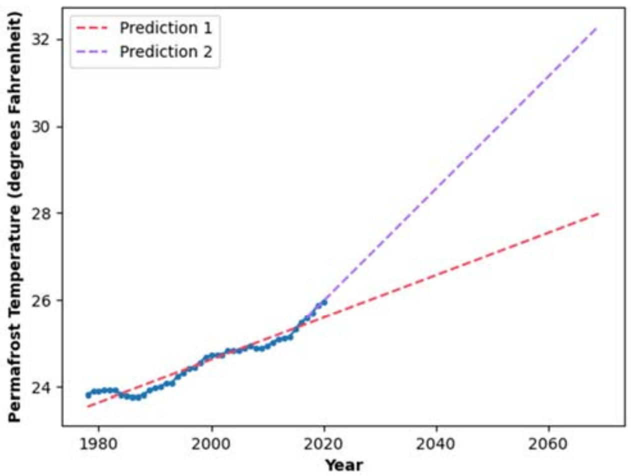

Figure 11. *Predictions of changing permafrost temperatures (in degrees Fahrenheit) until 2070.*

Figure 11 utilizes the same set of data as Figure 3 and shows a general trend of rising permafrost temperatures over time. We were able to generate two different predictions using the linear regression algorithm of Python. Prediction 2 (purple dashed line) depicts the rise of permafrost temperatures until 2070 from the trends shown from 2016, and the line predicts that in 2070, the permafrost temperature will increase up to around 32.29 degrees Fahrenheit, which increased about 36% from the permafrost temperature recorded in 1978. Prediction 1 (red dashed line) uses the general trend depicted over the years from 1978 and shows that the permafrost temperature would increase up to 27.98 degrees Fahrenheit, which increased about 17.5% from the permafrost temperature recorded in 1978. Without improvement in global warming, the permafrost temperatures in the future will range from between Prediction 1 and Prediction 2.

3.3. Continuously Rising Sea Surface Temperatures

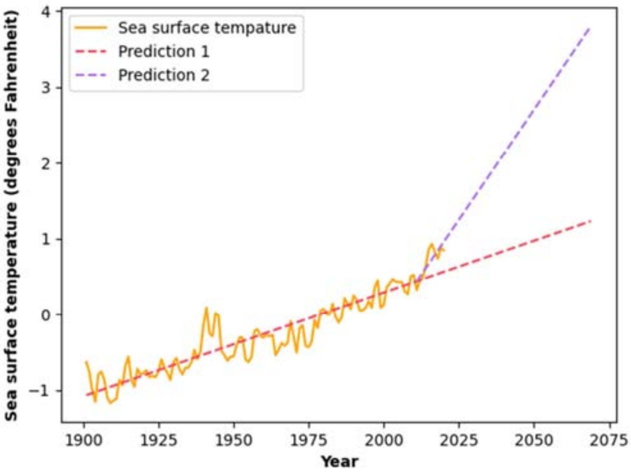

Figure 12. *Predictions of Rising Sea Surface Temperatures (in degrees Fahrenheit) until 2070.*

Figure 12 utilizes the same set of data as Figure 4 and the graph shows the future trend of rising sea surface temperatures until 2070. The data set, as represented by the solid orange line, shows a steady increase of sea surface temperatures, with some small spikes of data in between. There are two lines that predict the possible future sea surface temperature trends. The red-dashed line (Prediction 1) shows the general predicted trend starting from 1990, while the purple-dashed line (Prediction 2) shows the predicted trend starting from 2011. Prediction 1 line shows that from 1990 to 2070, the increase in surface temperature is approximately 2.3°F, which is around a 215% increase. However, starting from 2011, the graph indicates that the sea surface temperature starts to escalate quickly; since Prediction 2 line shows that, from 2011 to 2070, the increase in sea surface temperature is about 3.4°F, which is approximately a 780% increase. Without improved measures for global warming, the sea surface temperatures in the future will range between Prediction 1 and Prediction 2.

3.4. Continuously Rising CO_2 Emissions

Figure 13 utilizes the same set of data from Figure 5 and the graph shows the future trend of other greenhouse gases. There are two dashed lines that display the trend: the red line shows the general trend of rising greenhouse gases over the years and the purple line shows the predicted trend starting from 2020. The solid blue represents the recorded data since the year 1990. It shows a sudden and drastic rise before 2000 and a steady increase since, with minor spikes occasionally. Looking closer into the purple line which predicts the future data points, it is estimated to reach 428.9 PPM by the year 2070. That is a staggering 137.2% increase in just 50 years.

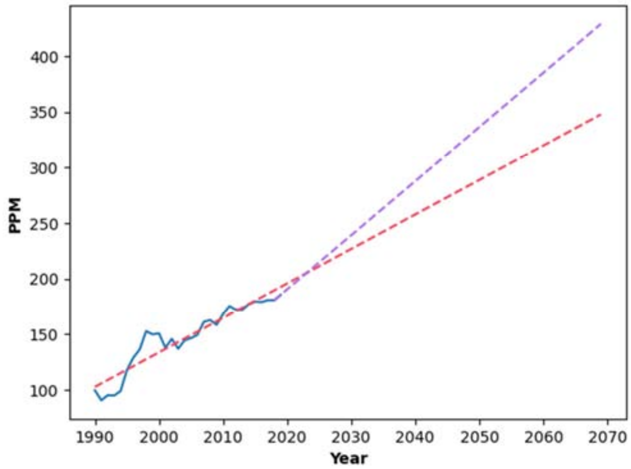

Figure 13. *Predictions of rising PPM until 2070.*

4. Solar Energy Forecasting

4.1. An Alternative: Solar Energy

Solar energy is a radiant energy that harnesses light and heat from the Sun. Essentially, it converts sunlight into thermal or electrical energy through devices like the solar panel [17]. Solar panels are very useful in today's households as they generate electricity without waste or environmental damage at an affordable price. To predict how much electricity a solar panel will produce a day, multiply its wattage by the number of hours of sunlight it gets. For example, a home in Cambridge typically receives four hours of sunshine a day. If this home has a 280-watt solar panel, then multiply 280 by 4, generating 1,120 watt-hours (Wh) or 1.1 kilowatt-hours (kWh) of electricity for that day [18]. This shows that solar energy can be a great substitute for fossil fuels as a new energy source. As the use of fossil fuels creates more carbon dioxide into the atmosphere, using solar energy instead would considerably slow down the warming of our planet. Moreover, the biggest benefit of solar energy is that the energy's foundation is the sun itself. The sun provides free and unlimited energy, while fossil fuels require money and labor from workers to be used. Overall, solar energy is a much more automated process, whereas fossil fuels go through a complicated process from extraction to supplying the fuel [19]. For this reason, knowing the trend of solar energy usage in the future is very important to determine whether solar energy can continue to become a sustainable resource of energy in the future. Looking at the amount of energy that the solar panels can generate lets people know how much money can be saved from using solar energy, rather than fossil fuels and other unrenewable energy sources.

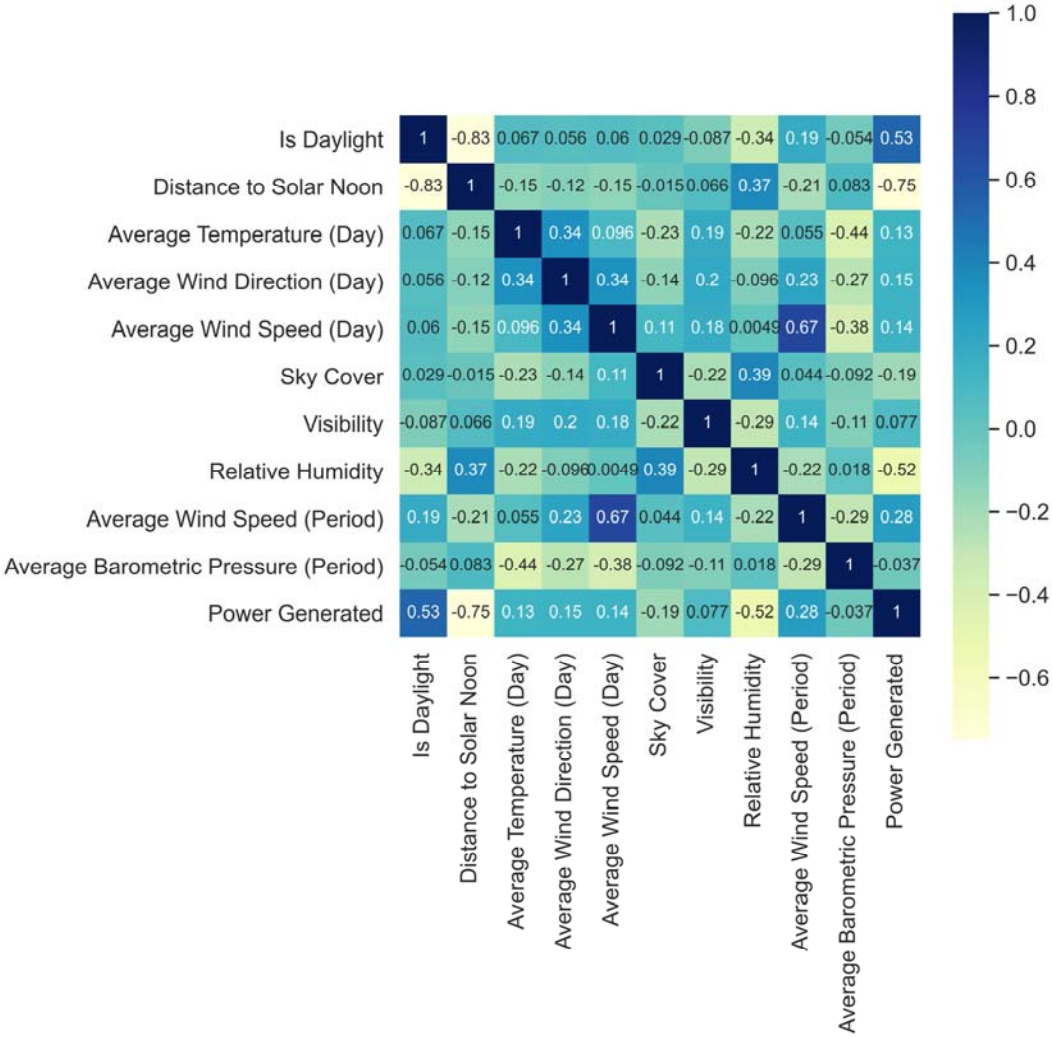

Figure 14. *Heatmap that analyzes the correlation between various conditions regarding solar energy.*

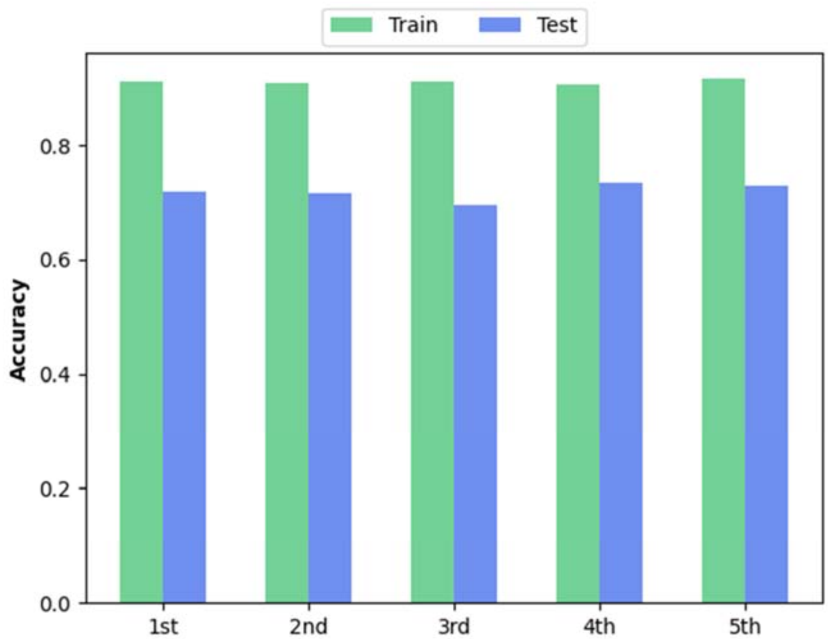

Figure 15. *Accuracy of Solar Energy Forecasting.*

Figure 14 organizes the correlation between various conditions regarding the generation of solar energy. As mentioned above, the closer the number shown on a heatmap is to 1, the higher the correlation between the two factors. Based on this information, the condition that had the highest correlation with power generation was the "is daylight" condition with about 0.53 correlation. On the other hand, the conditions that had the lowest correlation with power generation were the "distance to solar noon" and the "relative humidity" with -0.75 and -0.52 for its correlation value, respectively.

4.2. Accuracy of Solar Power Generation

Figure 15 was created using the data and the correlations between various conditions regarding solar energy generation shown in Figure 14. The figure plots the predictions for the accuracy of solar energy forecasting. To generate this model, we used the K-neighbor regression method, which is a non-parametric method performed using Python to analyze the relationship between two variables in a flexible manner [20]. The K-neighbor regression method was used to predict the amount of power generated in the solar power system in Berkeley, California. On average, the train model had about 91% accuracy, while the test model had about 72% accuracy.

5. Conclusion

Throughout the past century, global warming has been worsening, and the signs of disaster have become clearer each year due to humanity's aggressive use of fossil fuels. The increases in the annual greenhouse gas levels are causing the rises in sea levels, sea surface temperatures, and permafrost temperatures. These, in turn, bring about further consequences, destroying habitats and ecosystems, and creating a massive domino effect. To dismantle the core of this problem, human beings must cooperate and create effective plans, such as using solar power as an alternative to fossil fuels. If not dealt with immediately, the problems we have today will give rise to further problems, and humanity will not be able to stop the rapidly falling dominos anymore.

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