Climate Change, Global Warming, and the Future From a CO_2 and Temperature Standpoint

Team Control Number

12522

Problem Chosen

B

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HiMCM/MidMCM

Summary

Imagine living in a world where the first entity of life, CO_2 will be the cause of the ending of it as well. Global warming proves to be a highly prevalent issue in today's society, with carbon emissions being the leading cause. As a team, our assignment is to validate the means of prediction and claims made by Carbon Emission Industries, as well as predict the future of carbon emissions by constructing a model to facilitate such trends. An additional challenge is to determine the relationship between CO_2 atmospheric concentration and the land-ocean temperatures of the world. The overarching goal is to create a model for both of these challenges that can be justified using mathematical means, logic, and analysis.

In order to solve the problem of how to predict the carbon emissions every year, three models are created. The first model only looks at the data given in the *CO_2 Data Set 1*. It exponentially regresses the data to create an exponential curve of best fit. This model is used to determine the effects of the peak in March of 2004. It is demonstrated that the peak in 2004 has no effect on the trend of data; the data would have continued to trend upwards regardless of the 2004 peak. The second model is generated by using 10-year-averages, in which the trendline is created for 10-year-averages of the data given using exponential regression. The second model recursively subtracts the nine previous PPM's of the years before from 10 times the predicted 10-year-average using the trendline. The third model looks at a factor that both the first and second model ignores; It takes into account that normal combustion engine vehicles will all eventually be electric. This is essentially an extension of the first model, but with a slight twist; using an assumption as a means to add complexity. All 3 models disagree with the prediction of 685 PPM in 2050, as all of them have years past 2130. The most accurate model is determined to be the third, since the first and second are comparable and the third takes into account a factor that the first does not. Thus, the third model is the most accurate.

In part 2 of the problem, the relationship between CO_2 and average global temperature has to be determined. In order to find this relationship, a model is created representing the linear correlation between CO_2 and average temperature. This utilizes an exponential equation derived from the data given in the *CO_2 Data Set 1* and a linear equation derived from a model calculated from the data given in the *Temps Data Set 2*. A parametric equation is then derived to show the relationship between CO_2 concentration, average global temperature, and the year. This equation is first graphed according to the years given in the data sets. Then, the graph is extended into the future until the year 2100. Finally, external sources are used to determine how far into the future our model is accurate.

Retrospectively, the group uses mathematical modeling to discuss the predictions of CO_2 , allowing them a much more intricate perspective on the importance of combating global warming, to which they encourage must be dealt with now more than ever.

Table of Contents

Introduction

Carbon dioxide, the very basis of human existence, is becoming the ending of the same: Global Warming. With the increase of global mechanization during the Industrial Revolution, and even after such a time period, emissions of CO_2 into the atmosphere have risen a considerable amount. Going from an atmospheric concentration of around 280 ppm prior to the Industrial Revolution, the growth of businesses, gas-powered car companies, and most importantly, the use of electricity and heat in homes all over the globe, have caused the concentration of CO_2 in the atmosphere to rise to a peak of 377.7 ppm in 2004 (March), and to peak at 421 ppm in 2022 (May). This atmospheric rise in concentration during 2004 has been documented as the largest average 10-year average increase since the beginning of the Revolution; However, with an upward trend of concentration causing a projected increase in upcoming years, the Organization for Economic Co-Operations and Development report a predicted level of CO_2 of 685 ppm (including the addition of CO_2 equivalence) by the year of 2050.

We have been asked, as a team, to validate the means of prediction and claims made by Carbon Emission Industries, as well as predict the future of carbon emissions by constructing a model to facilitate such trends. Furthermore, we have been asked to determine the relationship of CO_2 atmospheric concentration to the land-ocean temperatures of the world. Using mathematical justification, as well as logical analysis and assumption, our team has risen to the occasion of aiding in the solution to this worldwide issue.

Problem Statement

Given the dependency of human existence on the amount of CO_2 in the atmosphere, using mathematical modeling, we hope to answer the following mysteries of the causation and effect of CO_2 concentration growth:

Part I — Agreement with CO_2 Level Claims

I. Create a mathematical model to justify your agreement or disagreement with the statement of the March 2004 increase of CO_2 being the larger than any observed 10-year period of CO_2.

II. Create various mathematical models that display and justify the past CO_2 concentrations and predict future CO_2 concentrations based on given data.

III. Use said models to predict the CO_2 atmospheric concentrations in 2100 and analyze its agreement or denial of the concentrations reaching 685 ppm by 2050.

Part II — Relationship Between Temperature and CO_2

I. Build a mathematical model to predict and justify the predictions of future land- ocean temperature changes; Display when your model predicts the land-ocean temperature will reach 1.25°C, 1.50°C, and 2°C.

II. Build a mathematical model to analyze the relationship (if there is any) of land-ocean temperature and CO_2 concentration since 1959.

III. Justify the reliability of the model by analyzing how far into the future it produces reasonable results.

Data Given

The data given corresponds to the average CO_2 parts per million (ppm) and temperature change (in degrees Celsius) from 1958 (temperature)/1959 (CO_2) to 2021. The CO_2 data is the annual month of March averages of CO_2 expressed as a mole fraction in dry air, derived from continuous air samples for the Mauna Loa Observatory, Hawaii, U.S.A (NOAA, 2022). The temperature data is the global annual mean surface-air temperature change based on land and ocean data compared to the temperature mean of the base period 1951-1980 (Lessen et al., 2019).

Overarching Assumptions

<u>PPM increase per year is an exponential function:</u> Using a paper written on the Human population and atmospheric carbon dioxide growth dynamics, we were able to deduce the fact that the ppm increase from the mid-1960s until 2022 would be an exponential increase (due to the highly informative graphs and data they provided attesting to such a notion) (Hüsler, A.D, Sornette, D., 2014). This assumption is justified by the fact that the increasing mechanization of global agriculture and industry has led to an increase in CO_2 emissions, thus leading to a higher CO_2 concentration in the atmosphere overall (*Global emissions* 2022).

<u>The temperature increase is linear:</u> Based on the graph provided in the *Intergovernmental Panel on Climate Change (*Fig. 1), that shows the relationship of

carbon emissions and the rise in temperature as a linear function. Due to our yearning to keep all data consistent, we were able to prove this claim by essentially graphing the given data on temperature increase, and analyzing what the pattern of the line was. The graph was displayed as shown:

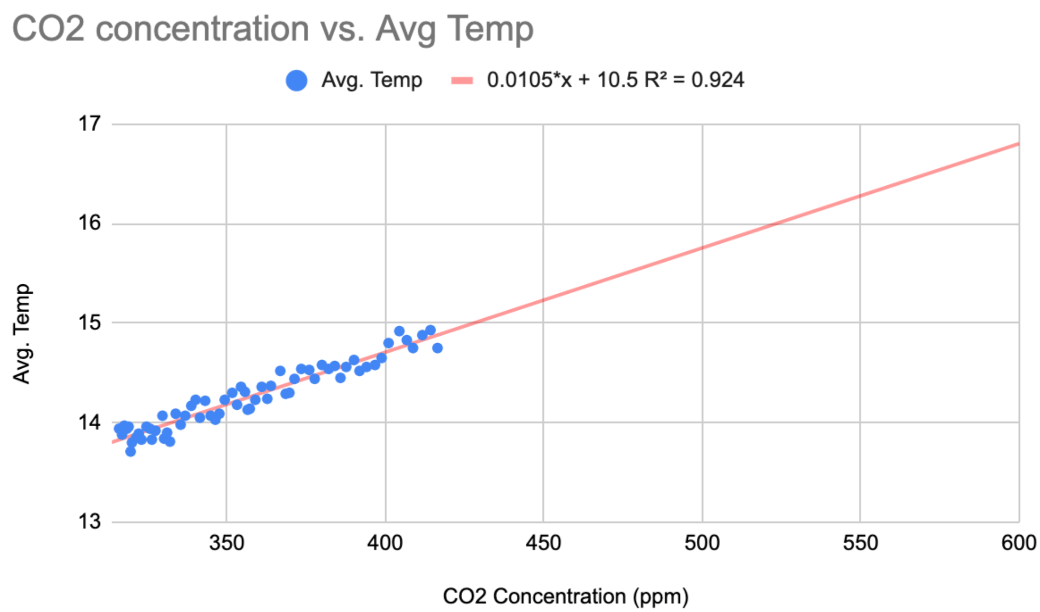


Figure 1: CO_2 Concentration vs. Avg. Temperature

CO_2 concentration in ppm vs avg. temp in degrees Celsius.

Seeing the linear increase of the graph, the line of best fit that most represents such a trend is a linear increase. Therefore, using the line of best fit of the graph, we can confidently identify the increase of temperature in comparison to CO_2 concentration as a linear trend.

In the year 2010, the global temperature was 14.6 degrees celsius: An article written in 2011 lists the average global temperature of every year from 1880 to 2010. In order to accurately fit the data that was given, we used the average global temperature from the year 2010, which was 14.63 degrees celsius (Eco-Economy Indicators - 2010 Hits Top of Temperature Chart | EPI, n.d.). We set this temperature as the average global temperature of the year 2010 in our data set. This assumption could then calculate the average global temperature for every year between 1951 and 2021.

The difference in temperature is accurate until the year 2100: Based on recent data from the article "*What are fossil fuels and when will they run out?"* All fossil fuels are projected to be completely depleted by 2090. This includes fuels such as coal, oil, and natural gasses, including the infamous CO_2, as well. In order to verify this information, we used the equation of the line of our graph displaying temperature increase in correspondence to each year, and also used the equation of the line of our graph displaying the temperature increase in correspondence to CO_2 concentration. With these two equations, we were able to calculate a parametric equation of a line displaying a relationship graph with temperature, CO_2 concentration, and the projected future years (all shown below) (Aldinger, 2021).

Tools

Google Sheets/Microsoft Excel

Google Sheets and Microsoft Excel were both used to store, manipulate, and graph the data.

JupyterLab

JupyterLab was used to code the second model for the relationship between CO_2 and time (in python 3.0).

Desmos Graphing Calculator

In conjunction with Google Sheets and Microsoft Excel, Desmos Graphing Calculator was used to graph parametric and piecewise functions.

Methodology

Part I: Relationship Between CO_2 and Time

In order to consider whether we agree or disagree with the notion that the March 2004 CO_2 emission is the proprietor of the said period being the largest 10-year average increase up to that date, we decided to take into consideration the trend of CO_2 concentrations with and without said month. Using the data provided, corresponding to the annual March CO_2 ppm from the years 1959-1979, we separated the data into their respective 10-year groups (from 1959-1968 to 1995-2004).

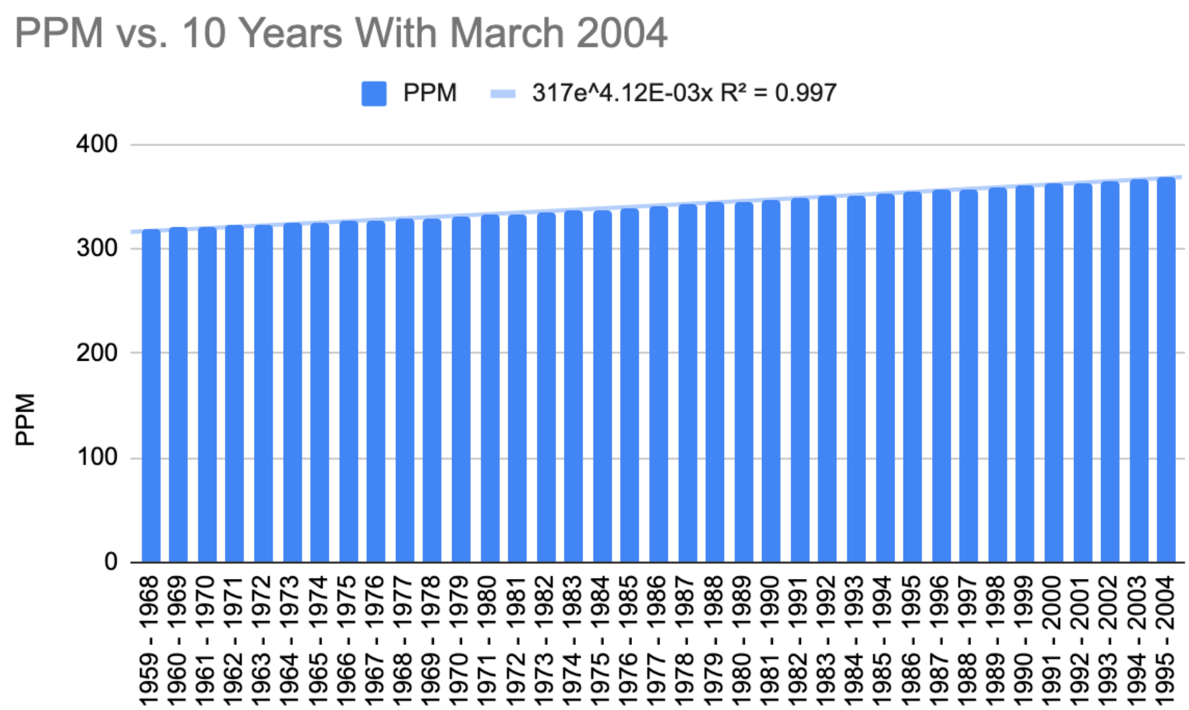


Figure 2: Graph of Average March PPM per 10-Year Period

This graph shows the exponential growth of CO_2 atmospheric concentration per 10 year increments (starting from March 1959 and ending at March 2004). The light blue trend line above each period shows that there had previously been exponential growth occurring, with such a trend increasing in a small amount every 10 years.

We then took the average ppm of CO_2 concentration in each group and created a similar graph but without the average of 1995-2004 (March). We allowed the line of best fit to continue to be displayed in the graph, as this would show us what the predicted trend for years not included in the graph, would be. The data displayed was as shown:

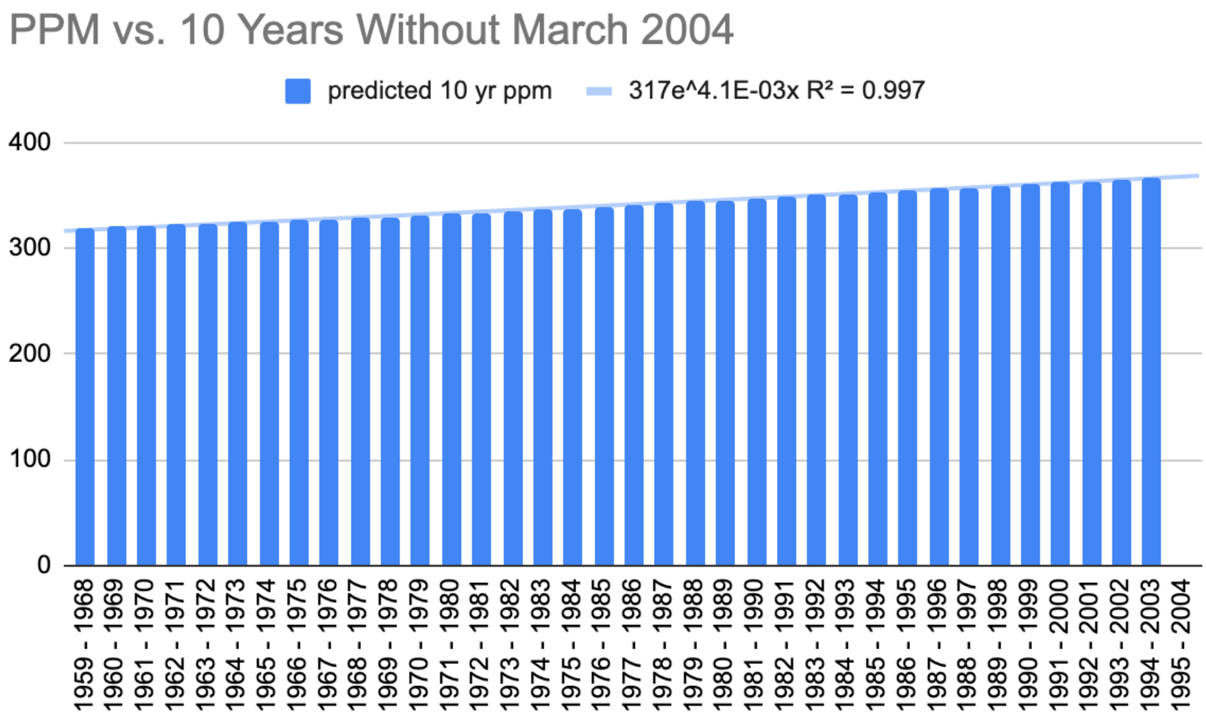


Figure 3: Graph of Average March PPM per 10-Year Period Without March 2004

This graph shows the exponential growth of CO_2 atmospheric concentration per 10 year increments without the documented ppm value for March 2004. The light blue trend line above each period continues to show a projected exponential increase per 10 years.

Significance of Separating Data

Due to the demographic of the data showing that there is an upward exponential trend despite the presence of March 2004, we can assume that this upward trend will continue past 2004 (Fig. 2 provides a light blue trend line above the bars that continues in a linear pattern even through 1995-2004). Therefore, we may justifiably defend that the average CO_2 ppm of March 2004 does not cause said 10-year period to be the largest 10-year concentration increase. Based on the graphs, it is clearly identifiable that such a trend was already occurring, and most likely would have occurred regardless of March 2004 being part of the 10-year period. An alternate way to perceive this is that based on the exponential function and trend of the graph, the line of best fit would indicate a predicted ppm average for the graph assuming that there was no outpouring of CO_2 emissions during the 10-year period.

Mathematical Models

Model 1: Exponential Regression

The ppm increase per year is an exponential function. For this reason, a mathematical model can be made using the data given as well as exponential regression. Exponential regression is the process of finding the equation of the CO_2 exponential function that fits best for a set of data. This process was applied to *Data Set 1*, in order to get an equation that could best fit the data.

$$ppm = 0.0439 \cdot e^{year \cdot 0.00452}$$

This model has an $R^2 = 0.991$, which essentially means that it fits the data with 99.1% accuracy. However, what this does not take into account, is the fact that there may be potential factors in the future that may offset the data significantly from the trendline. One of these factors would be cars eventually switching to electric, which would significantly lower CO_2 emissions. Another would be that the world moves further away from fossil fuels, which would also significantly reduce carbon emissions. For this reason, this model is not very accurate in predicting years that are much further away, but it works to predict any of the incoming years.

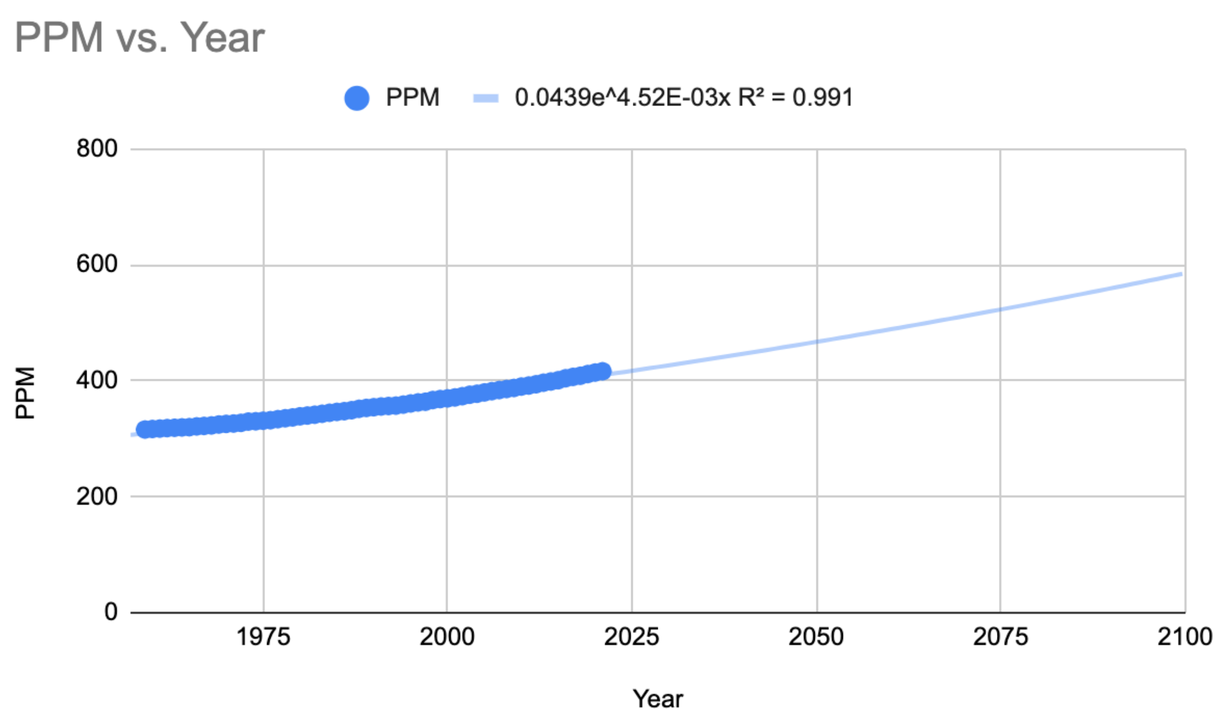


Figure 4: PPM vs. Year

Exponentially regressed graph of the data provided (Year vs. CO2 ppm).

Model 2: 10-Year Recursive Function Regressed Exponentially

The second model is based around a similar concept that has already been used. This model looks at the ten-year ppm averages taken in Figure 1. In Figure 1, the equation of the trendline was calculated using exponential regression. This equation can give the ppm average of the ten-year period leading up to the year. In order to find the ppm of a certain year, the year can be plugged into the equation, then the result can be multiplied by 10, and the ppm of the previous 9 years can be subtracted from it to get the ppm of the year. This is a recursive function because if the ppm of the previous 9 years are unknown, then the function can be reapplied to find the ppm of those years, and be plugged back in.

This method works well, except for a few exceptions. This model was comparable to the previous model, except for whenever the year had a one's digit of two. This was because of a combination of both the trendline not being 100% accurate and the data was only given till 2021. This model also has the same limitations as model 1. It does not take into account any other potential factors which could potentially completely offset the data. Another issue is that as the year gets further away from 2021, then the time it takes to compute the ppm gets exponentially larger.

```python
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import math
himcm_data_pd = pd.read_csv('HiMCM_data.csv')
yearList = np.array(himcm_data_pd['Year'].tolist())
ppmList = np.array(himcm_data_pd['PPM'].tolist())
yearList = yearList[~np.isnan(yearList)]
ppmList = ppmList[~np.isnan(ppmList)]

def findY(year):
    if(year <= 2021):
        ppm = ppmList[np.where(yearList == year)]
    else:
        ppm = tenYR(year)*10
        for i in (range(9)):
            ppm -= findY(year - (i+1))
    return ppm

def tenYR(x):
    return 315*math.e**(0.00452*(x-1967))


print(findY(2100))
```

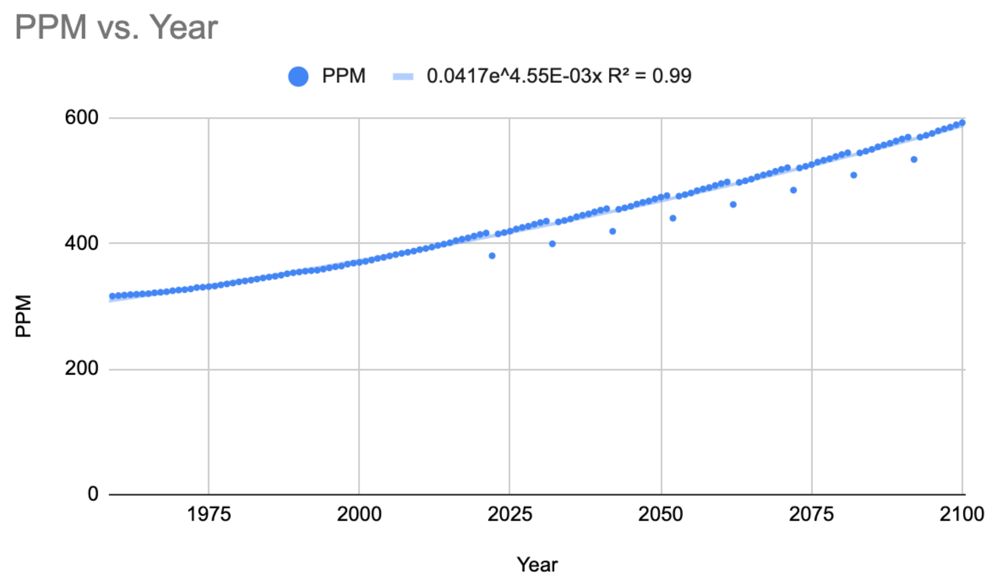


Figure 5: Model 2

Part 1: Code from JupyterLab (python) of model 1.
Part 2: Data from the code regressed exponentially (Year vs. CO_2 ppm).

Model 3: Piecewise Exponential Regression Accounting for the 2040 EV Pledge

Since 2009, electric vehicles have been surging in growth and will eventually take over the transportation market (Dennis, 2021). Transportation makes up 15% of the carbon emissions world-wide (Global Emissions, 2022). This model takes this factor into account, while using the same concepts as Model 1. The first part of the piecewise function mirrors Model 1 until 2009. The next piece of the piecewise was created using a separate model. The separate model was the function of the volume of electric cars.

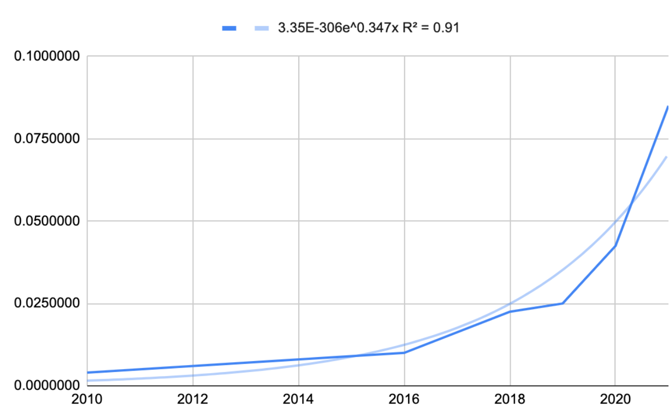


Figure 6: EVs

Growth of the EV vehicle sector (as a percentage) vs year.

The piecewise on the domain from 2009 to 2027 (when all the combustion engine cars are projected to be electric) is the function of the volume of electric cars subtracted from Model 1. Then, the rest of the piecewise is modeled by Model 1.

$$y = 0.0439 \cdot e^{0.00452x} \ \{x \leq 2009\}$$

$$y = \left(1 - 0.15 \cdot 3.35 \cdot 10^{-306} \cdot e^{0.347x}\right)\left(0.0439 \cdot e^{0.00452x}\right) \{2027 > x > 2009\}$$

$$y = 0.85 \cdot 0.0439 \cdot e^{0.00452x} \ \{x > 2027\}$$

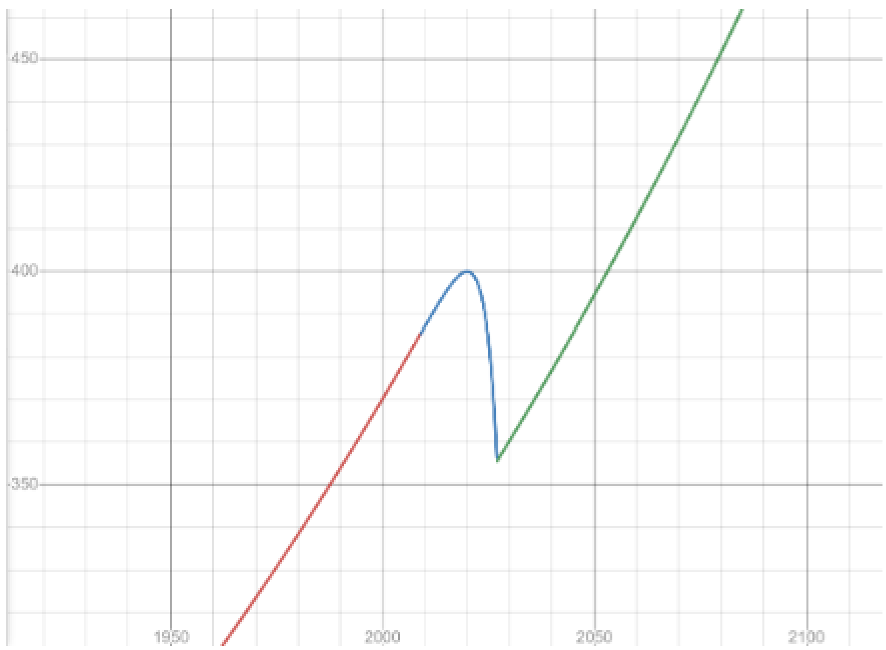


Figure 7: Model 3

Part 1: The piecewise function equations.
Part 2: The graph of the piecewise function (Year vs. CO_2 ppm).

2100 Predictions and Beyond

Model 1: Exponential Regression

Using the exponential regression equation from model 1 yields a CO_2 concentration of 581.819 ppm for the year 2100. This model does not agree with the claim that CO_2 concentrations will reach 685 ppm by the year 2050. Instead, solving the equation for 685 ppm reveals that with model 1, 685 ppm will be reached by the year 2136.

Model 2: 10-Year Recursive Function Regressed Exponentially

Running the 10-year recursive function in JupyterLab (python 3.0) for the year 2100 gives a CO_2 concentration of 592.173 ppm. This model also does not agree with the claim that CO_2 concentrations will reach 685 ppm by the year 2050. Exponentially regressing the data from the code, it is found that 685 ppm will be reached by the year 2133 according to model 2.

Model 3: Exponential Regression Accounting for the 2040 EV Pledge

Using the EV-influenced exponential regression equation from model 3 yields a CO_2 concentration of 494.546 ppm for the year 2100. This model does not agree with the claim that CO_2 concentrations will reach 685 ppm by the year 2050. Similar to finding the year when ppm levels will reach 685 in model 1, using the equation to solve for 685 ppm yields the year 2172.

The Most Accurate Model

The most accurate model is model 3 because it includes a factor which both models 1 and 2 do not take into account. Models 1 and 2 are comparable, as can be seen from looking at the results for how long it will take to reach 685 ppm, as well as their 2100 year predictions. However, model 3 takes into account the progression of electric cars that started in 2009. That is a limitation that both models 1 and 2 have in common. For this reason, model 3 is the most accurate model to predict the ppm of carbon emission for a certain year.

Part II: Relationship Between CO_2 and Temperature

A Model for Future Land-Ocean Temperature Changes

Now that the increasing property of CO_2 has been validated in concentration over various 10-year increments, we may use this information to analyze a possibly corresponding issue that may lead to a highly relevant extension to the overarching issue of "Global Warming"; Land-ocean temperature. Primarily, we were tasked to find when our model would reach a certain increase in degrees celsius (2.25, 1.5, 2.0). In order to declare the relationship between the time and the degree celsius increase, we created a model using the equation of a line of best fit graph. Essentially, we acquired a graph that compared the increase in land-ocean temperature using the information on the ***Temps Data Set 2*** sheet provided. By plotting these points in google sheets, and forming a line of best fit equation, we are able to establish a baseline for how much temperature has risen from 1951 until 2021. Our next step is transcending this information to the future, making sure it is accurate whilst in the process. The "line of best fit" with the given points is as shown:

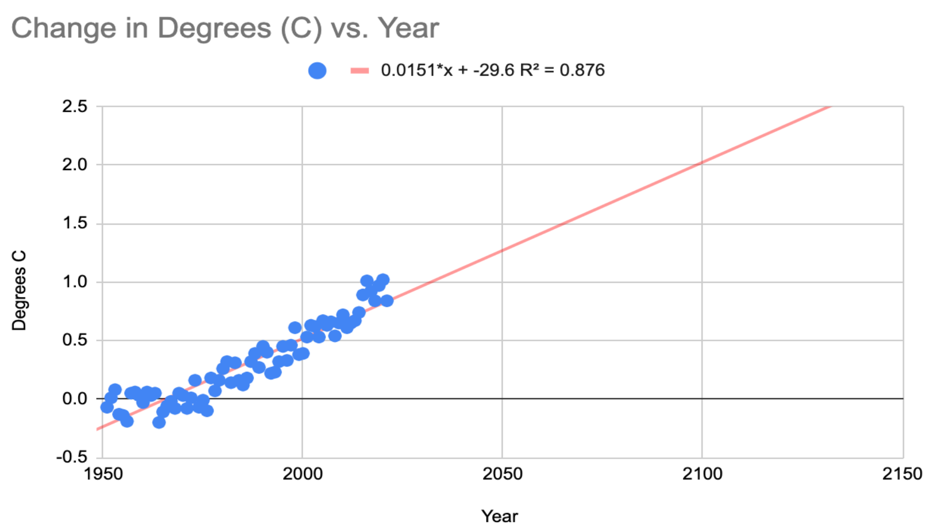


Figure 8: Change in degrees (celcius) Per Year

This graph highlights the increase in temperature from from 1950 to 2021 based on the information provided in the data provided (Temps Data Sheet 2).

This increase in temperature allows us to be able to predict what years our temperature will reach an increase of 1.25, 1.5 and 2 degrees celsius. Using the equation of the line of best fit in the graph above, we are able to plug in these degree increases into our Y value, thus solving for X which would be our year. A sample of this equation would be as follows:

$$y = 0.0151x \cdot 29.6$$

Here, we can see where the variables named above would come into play. If we are to plug in any of our target degree values above, we will get the year at which such a temperature increase will occur. Something to clarify is that these answers will not always be decimals, therefore have rounded them to the nearest year. As you can see, our R^2 value for this graph is around 0.876 or about 87.6%. This indicates the accuracy of our points to hit the line of best fit. The years that would fit such categories were 2043 (1.25 degrees increase), 2059 (1.5 degrees increase), and 2092 (2 degrees increase).

Modeling the Connection Between CO_2 and Land-Ocean Temperatures

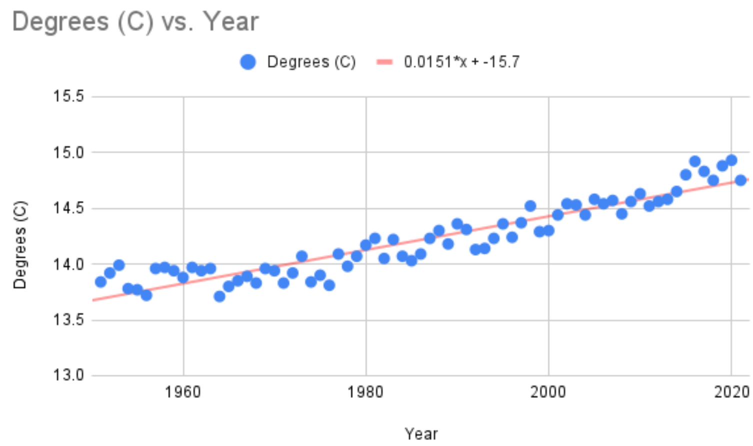
We now have models for both the CO_2 concentration and average global temperature (land-air temperature) between 1958 and 2021. Using these two models, a relationship between the CO_2 concentration and average global temperature can be modeled to determine whether or not there is a relationship between the two models. If there is a relationship between CO_2 concentration and temperature, then solutions to hinder the increase of climate temperature are possible. Previously, we calculated the average global temperature for each year between 1958 and 2021 by assuming that the average global temperature in 2010 was 14.63 (Eco-Economy Indicators - 2010 Hits Top of Temperature Chart | EPI, n.d.-b). From here, we know that the global temperature in 2010 deviates from the 1951-1980 temperature average by +0.72 degrees celsius, so we can subtract the temperature in 2010 by the increase of 0.72 degrees to get the average temperature from 1951-1980.

14.63 - 0.72 = Avg Temperature 1951-1980 = 13.91 degrees Celsius

Seeing that we know how much the temperature of each year in the given data table deviates from the 1951-1980 average temperature, we use the equation below to calculate the average global temperature in each year between 1958 and 2021.

Avg Temperature of a year = Avg Temperature 1951-1980 + Value of deviation of the same year

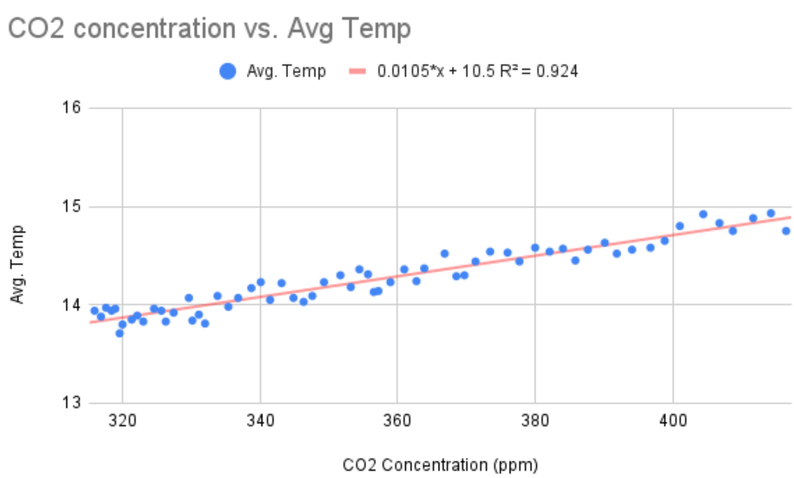
As a result, we can graph the average temperatures of each year between 1957-2021 along with a best-fit line as shown in Figure 9.



<u>Figure 9: Average Global Temperature vs. Year</u>

The graph highlights the average temperature of each year from 1951-2021 and a best-fit linear line. The average temperature for years 1951-1957 was solved using the method above. The values of deviation for these years were found using the given source (GISTEMP Team, 2022).

In order to model the relationship between CO_2 and temperature, we graphed them in terms of time *t* (year). We first graphed the relationship between CO_2 concentration and temperature according to the year (ex. In the year 2021, the CO_2 concentration is 416.45 ppm and the average temperature is 14.75 degrees celsius, so the points on the graph would be (416.45, 14.75)). We then implemented a line best-fit to the scatter plot as shown in Figure 10 below.



<u>Figure 10: CO_2 Concentration (ppm) vs Average Global Temperature</u>

The graph shows the relationship between CO_2 concentration and Average Temperature of a specific year.

The graph is a linear equation, therefore, the relationship between the CO_2 concentration and average temperature is linear. The equation, y = 0.0105x + 10.5 is derived as shown in the figure. A parametric equation can be written using the exponential equation from Figure 4, the linear equation from Figure 9, and the linear equation from Figure 10. We set years as *t*, CO_2 concentration as *x*, and average temperature as *y*.

Linear Equation (Figure 10): $y = 0.0105x + 10.5$
Exponential Equation (Figure 4): $x = 0.0439e^{4.25 * (10^{-3}) * t}$
Linear Equation (Figure 9): $y = 0.0151t - 15.7$

$$0.0105x + 10.5 = 0.0151t - 15.7$$
$$x = 1.4381t - 2495.24$$

$$y = 0.0105(0.0439e^{4.25 * (10^{-3}) * t}) + 10.5$$
$$y = 0.000471e^{4.52 * (10^{-3}) * t} + 10.5$$

Parametric Equation: $(1.4381t - 2495.24, 0.000471e^{4.52 * (10^{-3}) * t} + 10.5)$

Reliability and Concerns of the Model

In this subsection of Part II, the graph (Figure 10) made in the sub-section above is to be extended into the future as shown below.

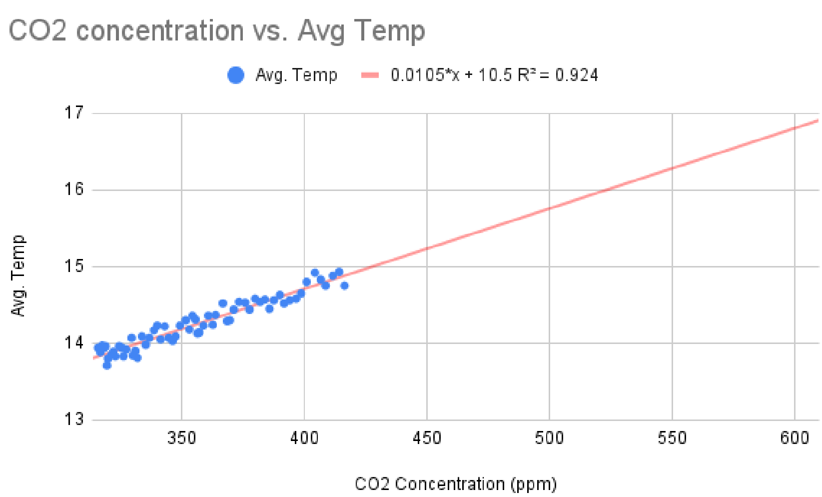


Figure 11: CO_2 Concentration vs. Average Global Temperature Graph (Extended)

The graph represents Figure 10, but it is extended into the future. The x-axis (year) extends to 2150. The best-fit line is then graphed.

Since the relationship between CO_2 concentration and average global temperature is linear (Kirsten, 2016), the linear line in Figure 11 is reliable. According to a Millenium Alliance for Humanity and the Biosphere article, the world's fossil fuel supply would run out by 2090 (MAHB, 2021). Once the fossil fuel supply runs out, global CO_2 emissions would decrease significantly because it contributes to nearly 90% of all CO_2 emissions (United Nations, n.d.). Therefore, our model is reliable until 2090, where the CO_2 emissions are 563.28 ppm. From this year forward, the linear line will slowly flatten out because the major contributor of CO_2 emissions is gone.

Conclusion

Climate change is a major problem in the world today. It is necessary to understand how the increased CO_2 concentrations affect the increase in temperature in order to formulate methods to decrease the toxicity of the earth's atmosphere. There is a tangible relationship between CO_2 concentrations, average global temperature over time since the Industrial Revolution. Three different models were developed to project the concentration of CO_2 in ppm. All of the models were similar in range for projecting the CO_2 concentration for the year 2100 and were all lower than the expected 685 ppm by the year 2050. All models suggested a 650 ppm CO_2 atmosphere by around 2125.

In the process of determining the relationship between CO_2 and average global temperature, two models were created. The first model is an equation that portrays the linear relationship between the average global temperature and a specific year. Then, the second model was created using a combination of the first model, a model of the exponential relationship between CO_2 concentration and a specific year — a parametric equation was created. The second model shows that the relationship between CO_2 concentration and average global temperature is linear. According to external sources, the correlation between CO_2 concentration and average global temperature is linear, therefore, our model is reliable for the past, present, and the future years. However, another source suggests that in the year 2090, all fossil fuels will be used up, so the CO_2 concentration will stop rising after 2090, which will end the linear relationship. Therefore, the parametric model is reliable until the year 2090.

HiMCM Technical Document — 39th November

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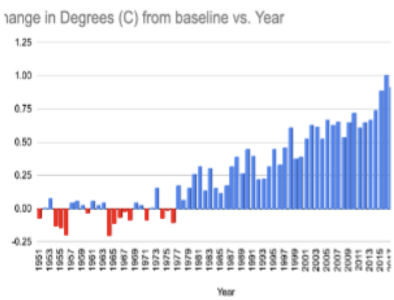

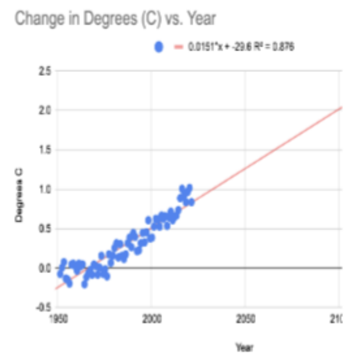

MASS ACADEMY STUDENTS CHALLENGED: HOW WILL GLOBAL CO_2 EMISSIONS CHANGE THE WORLD?

MATH MODELING TO AID IN CO_2 EMISSIONS AND GLOBAL WARMING

On November 9th, four students from the Massachusetts Academy of Math and Science were tasked with verifying and predicting how global CO2 emissions will affect the land-ocean temperature in the future, as well as how high these emissions will extend to in the future as well. Using mathematical modeling, these students, have been able successfully answer the following questions:

Part I — ***Agreement with CO2 Level Claims***

- Create a mathematical model to justify your agreement or disagreement with the statement of the March 2004 increase of CO2 being the larger than any observed 10-year period of CO2.
- Create various mathematical models that display and justify the past CO2 concentrations and predict future CO2 concentrations based on given data.
- Use said models to predict the CO2 atmospheric concentrations in 2100 and analyze its agreement or denial of the concentrations reaching 685 ppm by 2050.

Part II — ***Relationship Between Temperature and CO2***

- Build a mathematical model to predict and justify the predictions of future land- ocean temperature changes; Display when your model predicts the land-ocean temperature will reach 1.25°C, 1.50°C, and 2°C.
- Build a mathematical model to analyze the relationship (if there is any) of land-ocean temperature and CO2 concentration since 1959.
- Justify the reliability of the model by analyzing how far into the future it produces reasonable results.

METHODOLOGY:

In order to solve each question the group had to take into consideration the information given to them about the average increase in CO_2 emissions, as well as the information about the average temperature increase since the average increase in CO_2 emissions, as well as the information about the average temperature increase since the average temperature of the base period (1951-1980). Using Google Sheets, Desmos, and Python Coding, the group was able to create mathematical models for each category. For the first question, the group created 3 models highlighting the increase in CO_2 PPM concentration in the global atmosphere. They first determined that March 2004 does not cause the 10-year period of said time to be the largest. Using a linear graph model, the group was able to deduce that linear increase began to occur before said time period. With this information, they would use the *linear Model* to help aid in the rest of the questions.

The last two parts of the problem were solved by creating two mathematical models:

The first model created was an exponential regression model, in which the group recognized that the PPM concentration increase, per 10-year increments, was an exponential function. Due to this, they created an exponential regression formula to create an equation that best fit the data they were given about PPM Increase.

Their second method consisted of using Python 3.0 to create a 10-year recursive function that was regressed exponentially. They essentially looked at the 10-year PPM averages and calculated an equation for said values using exponential regression.

Their third method consisted of creating an exponential regression graph that took into consideration the *Electric Vehicle* Pledge of 2040, which essentially states that 58% of all global passenger vehicles will be electric by the year of 2040.

With this information, the group was able to find that PPM increase would increase a lot less rapidly than expected. They found that the global PPM average would reach 685 PPM by the year 2136.

In terms of part two, the group establish that the global land-ocean temperatures would reach an increase of 1.25, 1.5 and 2 degrees celsius by the years 2043 (1.25 degrees increase), 2059 (1.5 degrees increase), and 2092 (2 degrees increase). They did this by analyzing the equation for the line of best fit in the graphs that plotted the temperature increase with respect to the effect of CO_2 PPM increase, as well as the advancement in year. They created a parametric equation that highlighted the relationships of the year, CO_2 PPM increase, as well as the temperature increase, all in one graph. This allowed them to see that until the year of 2100, the graph would be invalid. This was justified by the fact that by 2090, all fossil fuels are projected to run out, as stated in the paper *What are fossil fuels and when will they run out?*

This group displayed a high interest in the whole process, as one exclaimed that it was a "Jolly great time." They then highlighted the importance of humanity to work on global carbon emissions. One student emphasized the notion, explaining "Yes we did calculate the projected CO_2 emissions to be unbearable in about 100 years, but let's not let it get to that point." This student's exclamation sums up the overall point of the issue very effectively; It is our job as the inhibitors of this world, to keep it as long lasting and life bearing as possible. By supporting plans such as the Electric Vehicle Pledge of 2040, or even by reducing the usage of everyday items that require fossil fuel emission, we can make ourselves and the world a better place for everyone to enjoy.

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