Final Report: Analysis of CO2 Emissions and Temperature Rise

1. Introduction

Climate change poses a critical threat to global ecosystems, economies, and societies. Understanding the relationship between CO2 emissions and global temperature rise is essential in addressing climate change, as it impacts not only the global environment but also the economic stability and health of societies worldwide. Therefore, this study aims to analyze the correlation between CO2 emissions and temperature anomalies on a global level, and then breaking it down for selected countries on a regional scale. By investigating these trends over time, this study provides insights into the effectiveness of regional policies and identifies areas where more effective strategies must be developed to mitigate the effects of climate change.

In this report, the following key topics are analyzed:

1. How have global CO2 emissions and temperature anomalies developed over the years?
2. How are global and regional CO2 emissions and temperature anomalies correlated?

Note: In this report, "global" refers to analyses conducted on a worldwide and continental scale, while "regional" refers to analyses conducted on a few selected countries.

2. Used Data

Data-Source 1: Our World in Data

This dataset was chosen as the source for CO2 emissions, as it contains comprehensive data on global CO2 and greenhouse gas emissions by continents and countries over time, allowing for an analysis of CO2 emission trends both globally and regionally.

Because of the high quality of the data and the already existing structure in their CSV file, only the columns of interest had to be selected, such that further processing was not necessary. This resulted in the following columns: *country, year, CO2 emissions, CO2 per capita, CO2 per GDP, and temperature change from CO2*.

The dataset itself is provided by Our World in Data in CSV format through their GitHub repository and can be found here. It is licensed under the Creative Commons BY License and appropriate credit is hereby given to the creators at Our World in Data. For more details, please visit the Creative Commons BY license here.

Data-Source 2: HadCRUT5

This dataset was selected for its extensive coverage of global temperature anomalies, offering detailed anomaly records to the present, represented on a 5° by 5° grid. It contains the data needed for analyzing temperature trends on both global and regional scales by providing the temperature anomalies on a latitude and longitude scale level, which allows for precise calculations across different geographical regions.

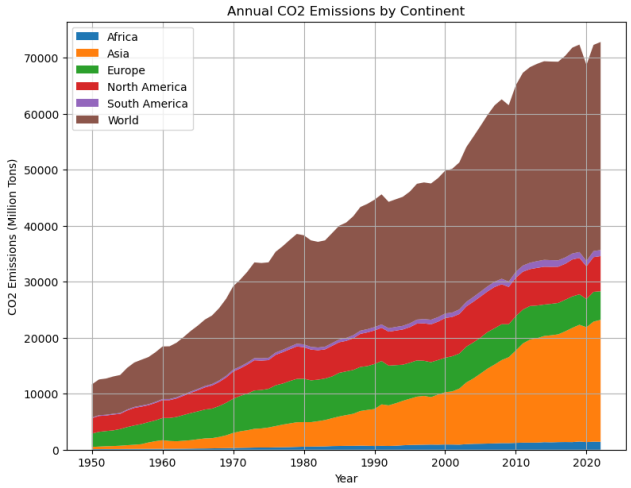
Due to its high-quality and structured format in netCDF, the main tasks involved converting the time variable to a common time format and extracting the relevant columns from the netCDF format to a pandas dataframe.

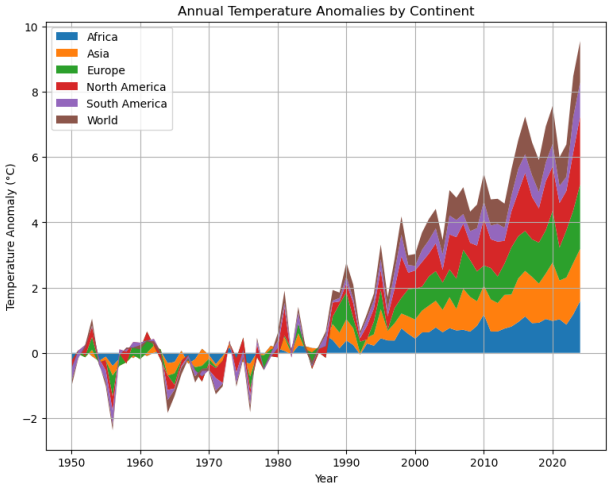
The dataset itself is provided by the Met Office Hadley Centre and the Climatic Research Unit (CRU) at the University of East Anglia. It is licensed under the Open Government License and appropriate credit is hereby given to the creators at Met Office Hadley Centre and CRU. For more details, please visit the Open Government License here.

3. Analysis

Question 1: How have global CO2 emissions and temperature anomalies developed over the years?

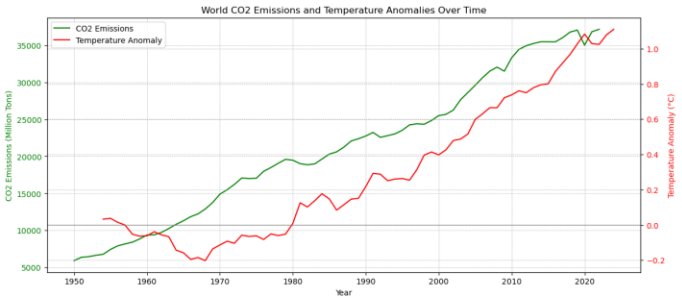
The first part of this analysis focuses on visualizing the global CO2 emissions and temperature anomalies by continent. For CO2 emissions, the data was aggregated for each continent and plotted by using a stack plot to show the cumulative emissions over time. The temperature anomalies were also averaged per continent and displayed as a stack plot.

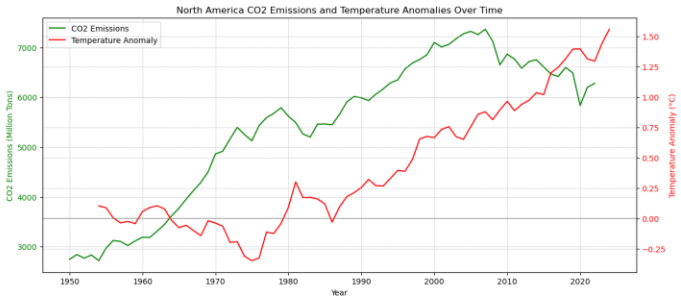


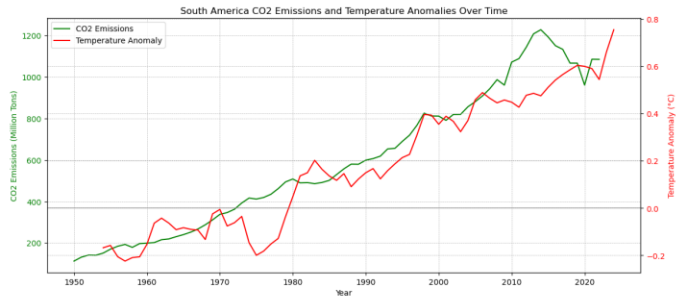


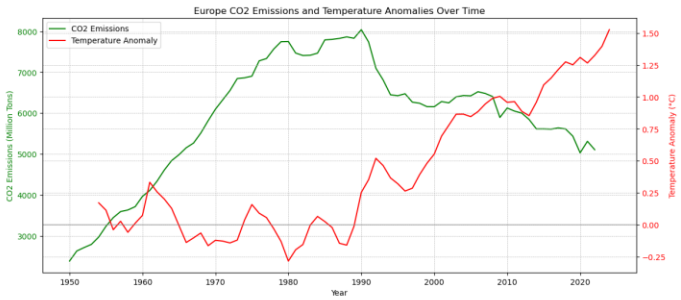
As can be seen on the stack plot on the left, CO2 emissions consistently increase overall as well as across all continents, with Asia and World emissions showing the most significant rise. Temperature anomalies, as can be seen on the stack plot on the right, exhibit a similar upward trend, especially from the 1980s onwards, with recent years showing a sharper increase. This clear upward trend both in CO2 emissions and temperature anomalies suggests a strong correlation between the increased emissions and the rising global temperatures.

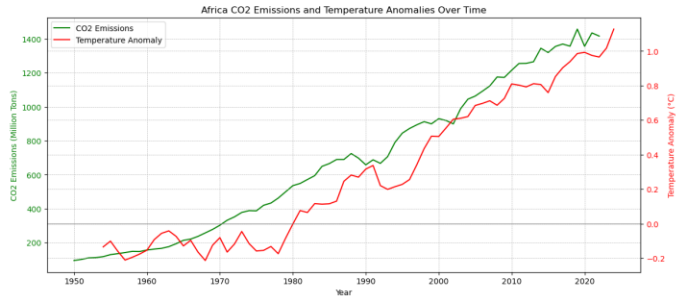
To further investigate this on a global scale, individual plots for each continent, displaying CO2 emissions and temperature anomalies over time, have been created. Dual y-axes were used, with CO2 emissions on the left and temperature anomalies on the right. The resulting plots reveal that all continents show increasing CO2 emissions and temperature anomalies over time, except for Europe, where this trend is not as clear. Specifically, during periods when CO2 emissions were rising, temperature anomalies remained relatively stable, and on the contrary, during periods of decreasing CO2 emissions, temperature anomalies increased. This discrepancy could be due to various factors such as Europe's diverse climate zones and geographical features or effective climate policies. Besides this outlier, the other subplots clearly indicate the underlying correlation between the rise in CO2 emissions and temperature anomalies, which further strengthens the assumption of a strong correlation between these 2 factors.

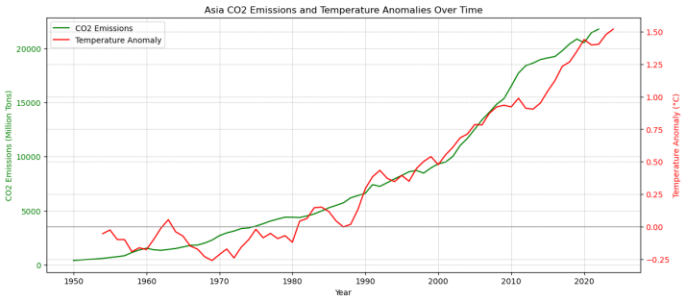








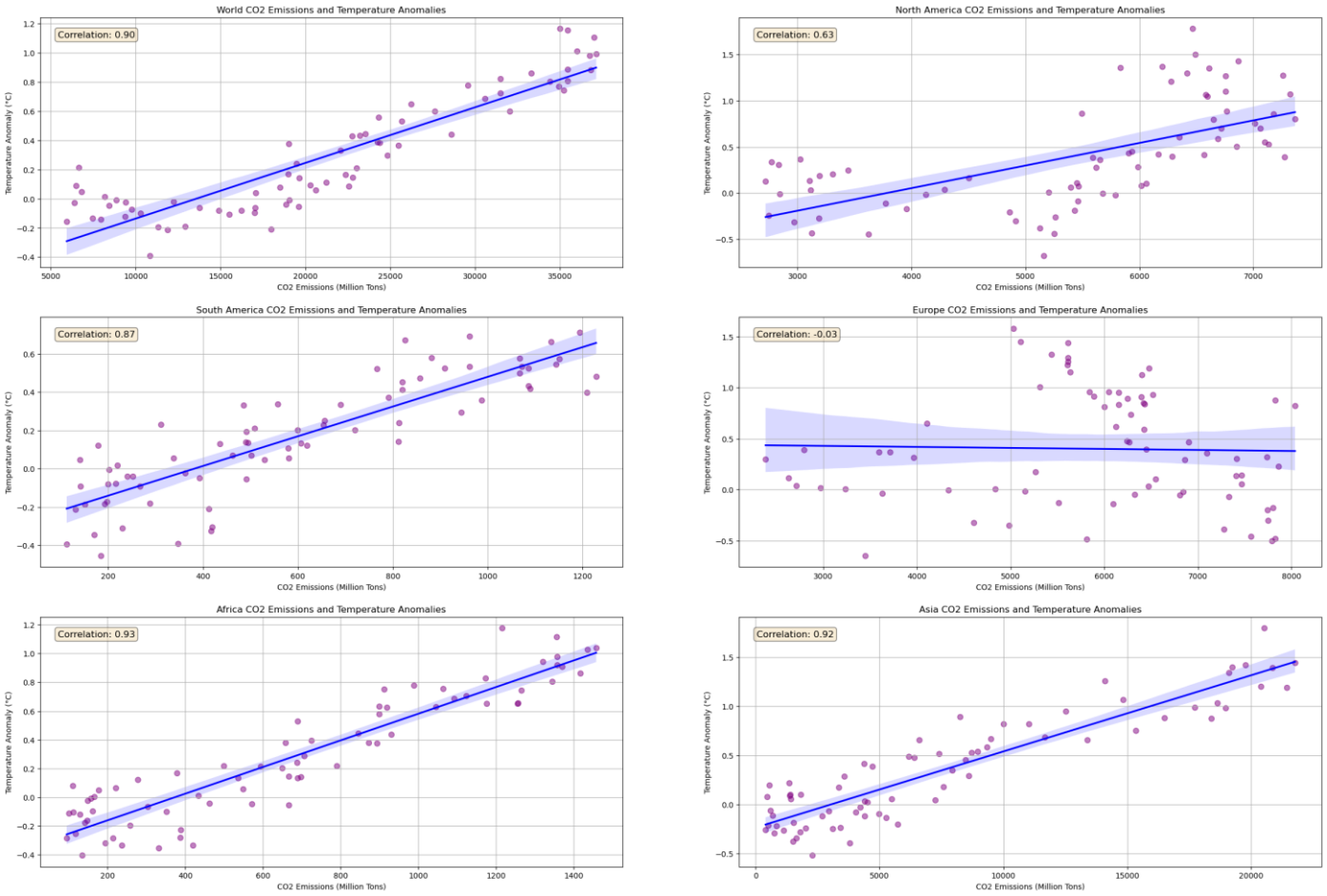




Question 2: How are global and regional CO2 emissions and temperature anomalies correlated?

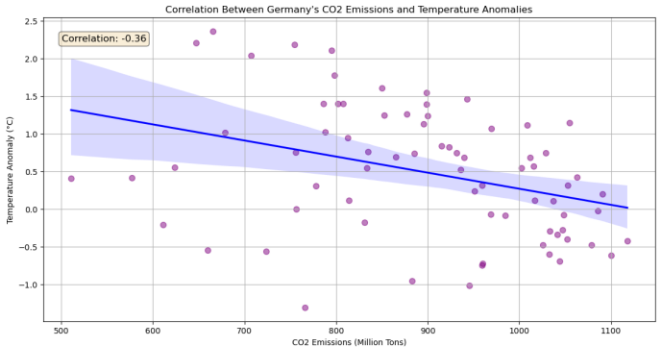
To confirm the assumption of a strong correlation between CO2 emissions and temperature anomalies, which emerged from the previous visualizations, this part of the analysis focuses on analyzing the correlation between CO2 emissions and temperature anomalies both on a global and regional scale. Therefore, scatter plots with regression lines for each continent and country were used. They show the CO2 emissions on the x-axis and the temperature anomalies on the y-axis, with the regression line indicating the overall trend. In addition to this, Pearson's correlation coefficient was calculated to quantify the strength of the relationship.

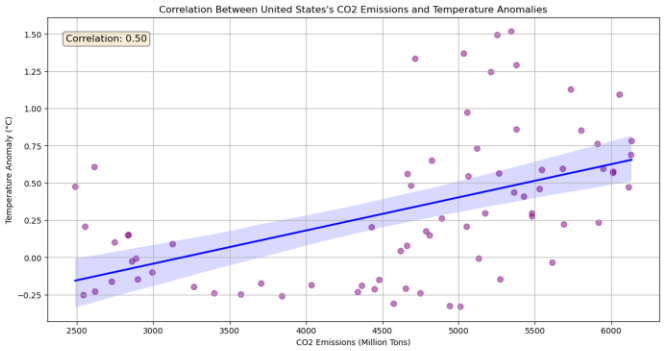
For the global analysis, scatter plots with regression lines were created for each continent as well as for the entire world. While the correlation plots for the World, South America, Africa, and Asia show very strong positive correlations of 0.87 to 0.93, indicating that higher CO2 emissions are strongly associated with higher temperature anomalies, the correlation plot for Europe shows a slightly negative correlation of -0.03, highlighting the previously mentioned discrepancy where increased CO2 emissions do not correspond with increased temperature anomalies. This discrepancy in Europe may, as previously stated, be due to various factors, including effective environmental policies or Europe's diverse climate zones.

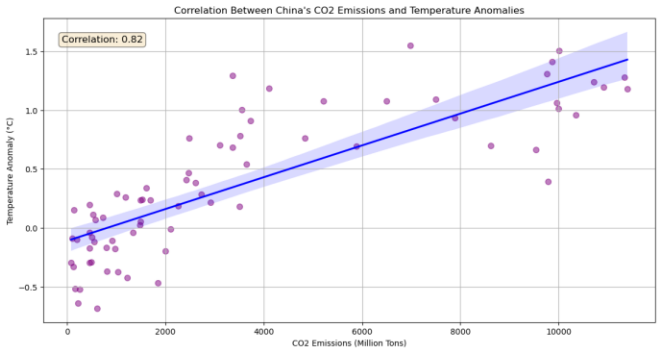


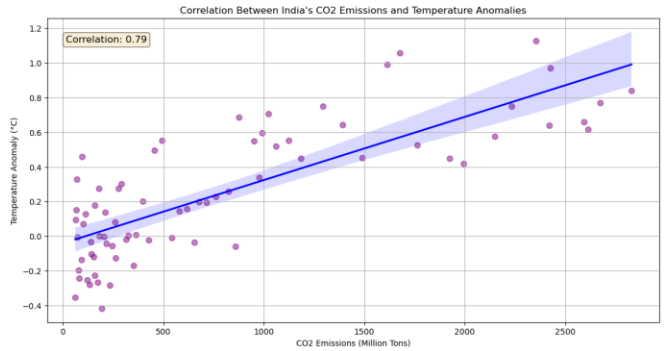
For the regional correlation analysis, I focused on a few selected countries: Germany, the United States, China, and India. Similar to the global analysis, scatter plots with regression lines were used to visualize the relationship between CO2 emissions and temperature anomalies, along with Pearson's correlation coefficient.

China, the United States and India all showcase a moderate to strong positive correlation, ranging from 0.50 for the US to 0.79 for India and 0.82 for China. While the US has the lowest correlation coefficient, all three indicate a significant relationship between CO2 emissions and temperature anomalies. Germany on the other hand has a negative correlation of -0.36, indicating that the relationship between CO2 emissions and temperature anomalies is weak and inverse. This could be due to Germany's strong environmental policies and commitment to reducing CO2 emissions while still facing temperature fluctuations.









Overall, these regional analyses support the findings from the global results, but also highlight variations and discrepancies in individual countries, suggesting the need for more advanced and effective climate strategies.

4. Conclusion

By comparing CO2 emissions and temperature anomalies both on a global and regional scale, it showed that there is a direct connection between the two. The stack plots demonstrated consistent increases in CO2 emissions and temperature anomalies over time across all continents, with Asia and the global average showing the most significant rise. This upward trend in both CO2 emissions and temperature anomalies suggested a strong correlation between increased emissions and rising global temperatures.

To investigate this assumption, individual scatter plots were created for each continent and the selected countries. The findings of these plots visually reinforced the initial hypothesis suggested by the stack plots: higher CO2 emissions are associated with higher temperature anomalies. This was further confirmed by calculating Pearson's correlation coefficient. Globally, the correlation coefficients were strong, particularly for regions like Asia, Africa, and South America, where the correlation ranged from 0.87 to 0.93, indicating a strong dependency between the two. Europe however, showed an interesting anomaly with no or only a slight negative correlation of -0.03. This is possibly due to effective climate policies and diverse climate zones, highlighting the importance of region-specific analyses.

Regionally, selected countries like China, the United States, and India showed moderate to strong positive correlations, underscoring the consistent global trend. Yet, Germany's negative correlation of -0.36 indicated that even countries with strong environmental policies can experience complex climate dynamics.

However, this analysis has some limitations. Other factors like deforestation, land use changes, and natural climate variability were not considered and could play a significant role in the relationship between CO2 emissions and temperature anomalies. Additionally, by incorporating more variables like other greenhouse gases, aerosols and land usage in further projects could increase the significance of such an analysis and result in a more comprehensive understanding of the climate change.

In conclusion, this analysis revealed a strong positive correlation between CO2 emissions and temperature anomalies on a global and regional scale, which underscores the direct impact of increased CO2 emissions on global temperature rise.