**Analysing the Impact of CO₂ Concentrations on Global Temperature Changes**

**1. Introduction**

Climate change is one of the most pressing global challenges, with rising CO₂ emissions being a key driver of increasing global temperatures. This project examines the relationship between CO₂ concentrations and temperature anomalies using historical data, statistical analysis, and predictive modelling. The goal is to assess historical trends, simulate different climate scenarios, and predict future temperature changes based on CO₂ levels.

**2. Approach and Methodology**

**Data Collection and Preprocessing**

* The dataset contains global CO₂ concentration levels (ppm) and temperature change (°C) across multiple years.
* DATASET: <https://statso.io/carbon-emissions-worldwide-case-study/>
* The data was cleaned and standardized where necessary to ensure consistency.
* Key variables used:
  + CO₂ Concentration (ppm)
  + Temperature Change (°C)

**Statistical Analysis**

* Pearson and Spearman correlation tests were conducted:
  + Pearson Correlation: 0.9554, indicating a strong linear relationship.
  + Spearman Correlation: 0.9379, reinforcing the consistent association between CO₂ levels and temperature change.
* Granger Causality Test was applied to determine if past CO₂ levels can predict future temperature changes.

**Predictive Modelling**

* A linear regression model was used to simulate the potential impact of different emission scenarios.
* The model helps estimate temperature change based on CO₂ variations, supporting "What-If" analysis.

**3. Data Visualizations and Insights**

**Time-Series Analysis**

* A consistent upward trend in both CO₂ concentration and temperature anomalies over time.

**Correlation Heatmap**

* A strong correlation between CO₂ levels and temperature, confirming the statistical analysis findings.

**Scatter Plot (CO₂ vs Temperature Change)**

* A clear upward trend indicating that higher CO₂ levels strongly associate with higher temperatures.

**K-Means Clustering**

* Clustering analysis grouped historical climate conditions into three categories:
  + Moderate CO₂ and Temperature
  + High CO₂ and Temperature
  + Low CO₂ and Temperature

**Predictive Model: What-If Scenario Analysis**

* Simulated temperature predictions based on different CO₂ emission scenarios:
  + Increase CO₂ by 10%: Higher temperature increase
  + Decrease CO₂ by 10%: Potential cooling effect
  + Increase CO₂ by 20%: Significant warming impact
  + Decrease CO₂ by 20%: More cooling effect
* The model predicts an estimated 0.015°C increase per ppm rise in CO₂ levels.

**4. Conclusion**

* The correlation analysis confirms that CO₂ concentrations and global temperatures are strongly related.
* Predictive modelling highlights how continued CO₂ rise leads to significant temperature increases.
* Reducing CO₂ emissions can help stabilize temperature anomalies.
* Clustering analysis provides insights into historical climate patterns and their evolution over time.

**5. Future Work and Improvements**

Advanced Modelling:

* Implementing non-linear machine learning models such as Random Forest and Neural Networks for more accurate predictions.
* Time-series forecasting using LSTM and ARIMA models for long-term climate projections.

Causality and Regional Analysis:

* Exploring lag-based modelling (Vector Autoregression) for improved causal detection.
* Analysing regional climate variations to understand localized effects of CO₂ emissions.

Expanded Data Considerations:

* Incorporating other greenhouse gases (methane, nitrous oxide) for a more comprehensive analysis.
* Studying the impact of additional climate factors such as oceanic temperatures and ice sheet melting.

Policy and Decision-Making:

* Using model predictions to support climate policies focused on carbon taxation, emission limits, and renewable energy adoption.
* Conducting socio-economic impact analysis on agriculture, health, and infrastructure related to rising temperatures.

**Final Thoughts**

This study provides valuable insights into the relationship between CO₂ and temperature change, reinforcing the importance of global emission control policies. Through statistical analysis, predictive modelling, and scenario simulations, this project highlights the need for proactive climate action to mitigate future risks and safeguard the environment.