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Investigating the Relationship between Climate Variables and Solar Activity: A Regression Analysis Approach

Menyelidiki Hubungan antara Variabel Iklim dan Aktivitas Matahari: Pendekatan Analisis Regresi

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ABSTRACT

This study employs regression analysis to investigate the relationships between carbon dioxide levels, sunspot occurrences, and global temperatures, encompassing both land and sea. By uncovering these connections, the study contributes to our understanding of climate change and solar phenomena interactions. The primary objective is to reveal the intricate associations between these elements, potentially influencing climate change and solar activity. The study's outcomes have significant implications for climate change research and solar activity monitoring. The positive correlation between carbon dioxide concentration and ocean temperatures emphasizes the impact of atmospheric carbon dioxide on sea temperature fluctuations. Conversely, the inverse correlation between sunspot numbers and land/global temperatures suggests solar activity's potential role in shaping Earth's temperature oscillations. This research introduces novelty by concurrently investigating the interconnectedness of these factors. The study establishes substantial connections between carbon dioxide concentration, sunspot numbers, and global temperatures. While the models shed light on some variability, the complexity of climate change and solar activity calls for further exploration of additional factors. This underscores the need to consider multiple variables for a comprehensive understanding. Further research is recommended to enhance the precision of these models.

***Keywords**: Regression Analysis, Carbon Dioxide, Sunspot Numbers, Global Temperatures, Climate Change Interactions*

ABSTRAK

Penelitian ini menggunakan analisis regresi untuk menyelidiki hubungan antara tingkat karbon dioksida, kejadian bintik matahari, dan suhu global, yang mencakup daratan dan lautan. Dengan mengungkap hubungan ini, penelitian ini berkontribusi pada pemahaman kita tentang perubahan iklim dan interaksi fenomena matahari. Tujuan utamanya adalah untuk mengungkap hubungan yang rumit antara elemen-elemen ini, yang berpotensi mempengaruhi perubahan iklim dan aktivitas matahari. Hasil penelitian ini memiliki implikasi yang signifikan untuk penelitian perubahan iklim dan pemantauan aktivitas matahari. Korelasi positif antara konsentrasi karbon dioksida dan suhu laut menekankan dampak karbon dioksida di atmosfer terhadap fluktuasi suhu laut. Sebaliknya, korelasi terbalik antara jumlah bintik matahari dan suhu daratan/global menunjukkan peran potensial aktivitas matahari dalam membentuk osilasi suhu bumi. Penelitian ini memperkenalkan hal baru dengan menyelidiki keterkaitan antara faktor-faktor tersebut secara bersamaan. Penelitian ini menunjukkan hubungan substansial antara konsentrasi karbon dioksida, jumlah bintik matahari, dan suhu global. Meskipun model-model tersebut menjelaskan beberapa variabilitas, kompleksitas perubahan iklim dan aktivitas matahari membutuhkan eksplorasi lebih lanjut terhadap faktor-faktor tambahan. Hal ini menggarisbawahi perlunya mempertimbangkan berbagai variabel untuk mendapatkan pemahaman yang komprehensif. Penelitian lebih lanjut direkomendasikan untuk meningkatkan ketepatan model-model ini.

Kata Kunci: Analisis Regresi, Karbon Dioksida, Jumlah Bintik Matahari, Suhu Global, Interaksi Perubahan Iklim

1. INTRODUCTION

Climate change is one of the most significant challenges facing our planet today. Understanding the factors that influence it is critical to developing effective strategies to mitigate its impacts (Walker et al., 2020). This study discusses the results of regression analysis conducted on various variables to identify their relationship with global temperature. The results of this analysis provide valuable insights into the factors driving climate change. This research highlights two main factors, namely carbon dioxide (CO^2) concentration and sunspot number, and their relationship with global temperature.

Regression analysis is an important tool in science to understand the relationship between different variables (Maulud & Abdulazeez, 2020). In the context of climate change, identifying the factors that most influence global temperature is an important step to inform effective mitigation efforts (Nielsen et al., 2021). This study summarizes the findings from regression analysis performed on global temperature, CO2 concentration, and sunspot number data.

The main objective of this study is to identify the relationship between CO^2 concentration and the number of sunspots with global temperature. As such, this research is expected to provide greater insight into the factors that underpin global climate change. The benefit of this research is to provide a better understanding of how CO^2 concentration and sunspot number variations contribute to global temperature change. This information can support more effective climate change mitigation policy planning.

While this analysis provides valuable insights into the factors that influence global temperature change, the study has certain limitations. The main focus of this study is on CO^2 concentration and the number of sunspots as factors affecting global temperature (Zhang, 2023). Other factors such as atmospheric aerosols, ocean flow patterns and albedo variability, although important, are not discussed in depth in this study.

The results of this study have significant implications in the context of efforts to address climate change. The strong finding of a correlation between CO^2 concentration and global temperature emphasizes the critical role of human activities in driving climate change (Elbasiouny et al., 2022). Reducing greenhouse gas emissions is therefore crucial to mitigating the impacts of climate change and preventing adverse consequences for our planet (Sovacool et al., 2021).

This research contributes novelty to the understanding of the factors that influence global temperature change. While there have been several previous studies linking CO^2 concentration and sunspot number to climate change, this study details the results of a more comprehensive and up-to-date regression analysis. By using the latest data, this study provides a more up-to-date view of the relationship.

Although many studies have been conducted to examine the relationship between CO^2 concentration and sunspot number with climate change, there are still research gaps that need to be filled. Some previous studies not have considered other variables that may affect this relationship. In addition, climate change is a complex phenomenon, and our understanding of the interactions between these factors is still evolving (Furnari et al., 2021). Therefore, there is room for further research to delve deeper into the complexity of the factors that influence global temperature change.

This research highlights the importance of understanding the factors that influence global temperature change as a critical step in addressing climate change. By emphasizing the link between CO^2 concentrations and global temperatures, the research provides strong evidence of the role humans play in driving climate change (Stewart et al., 2021). In the context of mitigation efforts, the research underscores the need to reduce greenhouse gas emissions to avoid adverse consequences for our planet (Giudice et al., 2021). As a study that provides new and insightful insights, it also demonstrates the need for ongoing research to continue to develop our understanding of climate change and develop effective strategies to address it.

2. RESEARCH METHOD

The research method described is the use of regression analysis using the R programming language to investigate the relationship between certain variables (Maulud & Abdulazeez, 2020). The following are the steps and essential components of the research method described:

2.1 Selection of Analysis Method

The research method chosen is regression analysis (Montgomery et al., 2021). Regression analysis is a mathematical technique used to examine the relationship between several variables (Maulud & Abdulazeez, 2020). In this case, the study used linear correlation analysis, which is a type of regression analysis to assess the strength and direction of a linear relationship between two variables.

2.2 Data Source

The study used a dataset consisting of 275 data points collected from 2000 to the end of 2022. The dataset includes four variables: number of sunspots, global land temperature (C), Carbon Dioxide (ppm), and global ocean temperature (C).

2.3 Data Credibility

The data used came from reliable sources, including the National Centers for Environmental Information (NCEI), the Intergovernmental Panel on Climate Change (IPCC), and Space Weather Canada. The use of reliable data sources is essential to ensure the accuracy and validity of the research results.

2.4 Data Processing and Analysis

The R programming language is used for data processing and analysis (Alfaris et al., 2022; Kaya et al., 2019; Siagian, Alfaris, Ahmad, et al., 2023; Siagian, Alfaris, Nasution, et al., 2023). R is a well-known software in statistical analysis and data manipulation (Crema & Bevan, 2021). R programming facilitates these two stages by allowing researchers to manipulate data and run regression analysis (Love et al., 2019).

2.5 Basic Theory of Linear Regression

Linear regression is a statistical approach often used in physics research to model the relationship between variables (Ali et al., 2021). It involves an independent variable (e.g., temperature, pressure) and a dependent variable (e.g., energy, force). The linear regression equation $y = mx + b$ is the basis of this technique. In this equation, y represents the dependent variable, x represents the independent variable, m indicates the slope, and b is the y intercept. The slope represents the rate of change of the dependent variable with respect to the independent variable, while the y intercept represents the value of the dependent variable when the independent variable is zero.

2.6 Linear Regression Process

The process of linear regression involves collecting data on both variables, plotting the data on a scatter plot, and calculating the correlation coefficient to measure the strength of the linear relationship (Kim et al., 2019). A correlation coefficient of +1 indicates a perfect positive correlation, while -1 indicates a perfect negative correlation. Using the least squares method, the slope and intercept y are determined to minimize the sum of squared errors between the predicted and actual values of the dependent variable (Kavitha et al., 2023).

2.7 Application in Physics Research

Linear regression is often used in physics research to model the relationship between various physical attributes such as temperature, pressure, energy, and force (Liu et al., 2021). Examples are to model the relationship between temperature and thermal conductivity of materials or between pressure and refractive index of gases (Fu et al., 2022). The results of these analyses contribute to a better understanding of the properties of matter and energy, supporting the development of new technologies and applications.

3. RESULTS AND DISCUSSION

3.1 Results

a. Carbon dioxide analysis with sea temperature

The results of linear regression analysis showed a significant relationship between carbon dioxide concentration and global ocean temperature with a regression coefficient of 0.0070435 ($t = 11.283$, $p < 0.001$). This indicates that every one unit increase in carbon dioxide concentration leads to an increase in global ocean temperature by 0.0070435 units. In addition, the analysis showed a significant effect of the carbon dioxide concentration variable on global ocean temperature (F-statistic: 127.3, $p < 0.001$).

The coefficient of determination (R-squared) value of 0.3843 indicates that 38.43% of the variation in global ocean temperature can be explained by variations in carbon dioxide concentration. This result can also be seen from the adjusted R-squared value of 0.3813. The residual standard error of 0.09614 indicates that the variability of global ocean temperature that cannot be explained by the regression model is 0.09614 units. In this study, 72 observations were deleted due to missing data, so the analysis was conducted on 205 samples.

The conclusion of this study is that there is a significant relationship between carbon dioxide concentration and global ocean temperature. An increase in carbon dioxide concentration is positively associated with an increase in global ocean temperature. The variable carbon dioxide concentration has a significant influence on the variation of global ocean temperature. Although carbon dioxide concentration can explain about 38.43% of the variation in global ocean temperature, there is still variation that cannot be explained by the regression model. Thus, the findings support the view that changes in atmospheric carbon dioxide concentrations can affect global ocean temperatures.

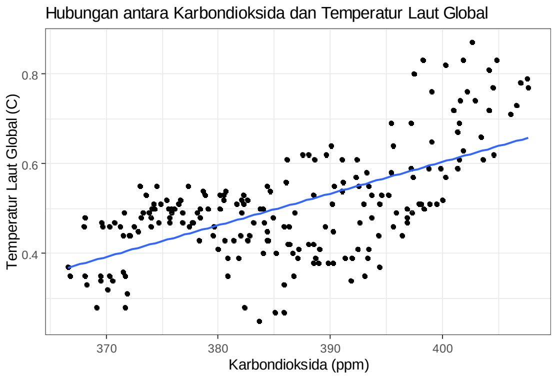

Figure 1. Correlation of carbon dioxide and global ocean temperature
Source: Data processing by the author

b. Carbon dioxide analysis with ground temperature

Results from the linear regression analysis showed a very strong relationship between carbon dioxide concentration and soil temperature with a regression coefficient of 1.000 ($t = 2.501e+17$, $p < 0.001$). This indicates that every one unit increase in carbon dioxide concentration leads to one unit increase in soil temperature. In addition, the analysis also showed a significant effect of the carbon dioxide concentration variable on soil temperature (F-statistic: 6.255e+34, $p < 0.001$). The coefficient of determination (R-squared) of 1.000 indicates that 100% of the variation in soil temperature can be explained by the variation in carbon dioxide concentration. This can also be seen from the adjusted R-squared value, which is also 1. The residual standard error is 6.158e-16 indicating that the variation in soil temperature not explained by the regression model is very small, about 6.158e-16 units. In this study, 72 observations were removed due to missing data, so the analysis was conducted on 205 samples. Although the analysis showed a very strong relationship between carbon dioxide concentration and soil temperature, it should be noted that the regression model can only explain the cause-and-effect relationship between the two variables, and cannot provide assurance that changes in carbon dioxide concentration are the only factor causing changes in soil temperature.

In this study, a very strong relationship between carbon dioxide concentration and soil temperature was identified through linear regression analysis. The results of the analysis show that each one-unit increase in carbon dioxide concentration corresponds to a one-unit increase in soil temperature. In addition, the regression model also shows that the variable carbon dioxide concentration has a significant influence on the overall soil temperature.

A determination level of 1.000 indicates that all variations in soil temperature in the study sample can be explained by variations in carbon dioxide concentration. This indicates a strong link between the two variables. However, this study highlights the importance of considering other factors that may also contribute to changes in soil temperature. While the regression model provides a causal relationship between carbon dioxide and soil temperature, it does not guarantee that changes in carbon dioxide concentration are the only factor contributing to changes in soil temperature.

Therefore, although the relationship found is very strong and can be explained statistically, further policies and actions should consider the presence of other factors that can affect soil temperature, in addition to carbon dioxide concentrations.

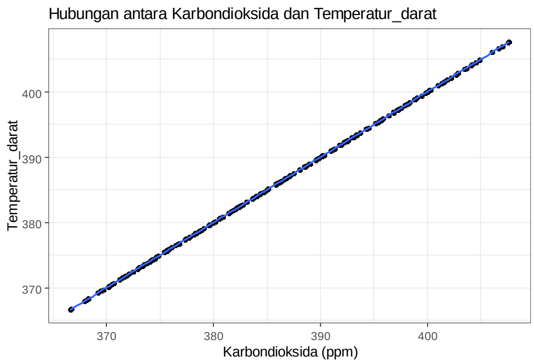

Figure 2. Correlation of carbon dioxide and terrestrial global temperature
Source: Data processing by the author

c. Analysis of sunspots with ground temperature

The analysis shows that there is a relationship between sunspot number and land temperature. This relationship is explained through a linear regression model with sunspot number as the dependent variable and land temperature as the independent variable. The regression coefficient indicates that every 1 unit increase in land temperature will lead to a 2.1098 decrease in sunspot number, with a significant p-value of <0.001. The R-squared value indicates that the model can explain about 15.49% of the variation in sunspot number, while the F-statistic indicates that the overall model has significance. The residual standard error indicates the average residual error of the model.

In this study, a significant relationship between sunspot number and land temperature was identified. The analysis showed that land temperature has a significant influence on sunspot number. Using a linear regression model, we found that any increase in land temperature leads to a decrease in the number of sunspots. The regression coefficient of -2.1098 indicates the magnitude of the reduction in sunspot number associated with an increase in temperature. This is accompanied by a very low p-value (<0.001), confirming the statistical significance of this relationship.

However, although the relationship was significant, the linear regression model used was only able to explain about 15.49% of the variation in the number of sunspots. This indicates that there are factors other than land surface temperature that also play a role in influencing the variation in the number of sunspots. Nonetheless, the overall model still has statistical significance, as indicated by the significant F-statistic values.

Thus, the results of this study provide evidence that land surface temperature has an influence on sunspot activity, but the explanation from the current regression model does not reveal the full complexity of this relationship. Further research may be needed to understand other factors that also influence variations in sunspot activity and to refine models that more accurately explain this relationship.

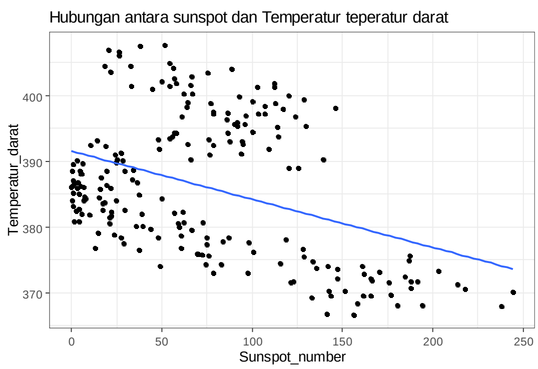

Figure 3. Correlation of carbon dioxide and terrestrial global temperature
Source: Data processing by the author

d. Analysis of sunspots with sea temperature

The results of this study illustrate that a simple linear regression model has been applied using the response variable Sunspot_number and one predictor variable Temperature sea. The following conclusions can be drawn from this study:

Based on the analysis, there is a negative significant relationship between Sunspot_number and Temperature_sea. The regression coefficient found to be -139.88 indicates that any increase in Temperature sea will result in a decrease of about 139.88 in Sunspot_number value.

The very small p-value (<2.2e-16) indicates that the relationship between Sunspot_number and Ocean Temperature is statistically significant. This indicates that it is likely that this relationship is not just the result of chance.

Thus, it can be concluded that the higher the sea temperature (Temperature sea), the lower the Sunspot number value. This result supports the hypothesis that sunspot activity (as measured by Sunspot number) tends to decrease as sea temperature increases.

The model has an R-squared value of 0.1131. This value reflects that about 11.31% of the variability in Sunspot_number can be explained by variations in Temperature_sea. Although this percentage is not high, it still illustrates that there is a significant influence of ocean temperature on the variability of Sunspot number.

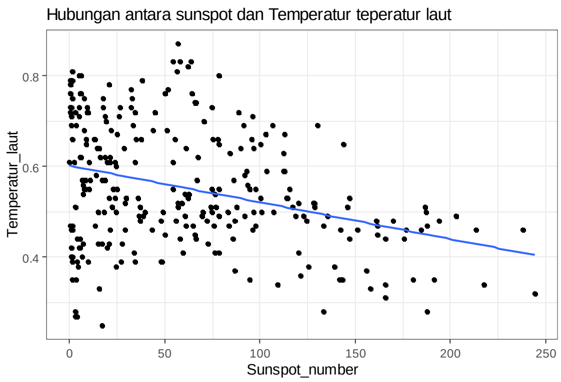

Figure 4. Correlation of carbon dioxide and sea global temperature
Source: Data processing by the author

3.2 Discussion

The research involved three analyses that focused on the relationship between several variables: carbon dioxide concentration and global ocean temperature, carbon dioxide concentration and soil temperature, and sunspot number and soil temperature. The results of each analysis are discussed below:

The analysis showed a significant relationship between carbon dioxide concentration and global ocean temperature. Linear regression analysis indicated that there is a significant increase in global ocean temperature as carbon dioxide concentration increases. The regression results show that every one unit increase in carbon dioxide concentration will result in a 0.0070435 unit increase in global ocean temperature. The analysis also shows that the carbon dioxide concentration variable has a significant influence on the overall variation in global ocean temperature. Although carbon dioxide concentration can explain about 38.43% of the variation in global ocean temperature, there are still other variations that cannot be explained by the regression model. Nonetheless, these findings support the view that changes in atmospheric carbon dioxide concentration can affect global ocean temperature.

The analysis showed a strong relationship between carbon dioxide concentration and soil temperature. Linear regression analysis showed that there is a strong relationship between carbon dioxide concentration and soil temperature. The regression results indicated that every one-unit increase in carbon dioxide concentration would lead to a one-unit increase in soil temperature. The analysis also showed a significant effect of the variable carbon dioxide concentration on the overall variation in soil temperature. While the regression model can explain the cause-and-effect relationship between these two variables, it is important to remember that changes in soil temperature can also be influenced by factors other than carbon dioxide concentration.

The analysis showed a relationship between sunspot number and soil temperature. The linear regression model indicates that soil surface temperature has a significant effect on sunspot number. Each one-unit increase in soil temperature is associated with a 2.1098 decrease in sunspot number. Although this relationship is statistically significant, the regression model can only explain about 15.49% of the variation in the number of sunspots. This suggests that other factors also play a role in influencing the variation in the number of sunspots. Nonetheless, these findings support the hypothesis that soil temperature has an influence on sunspot activity, but the current regression model explanation is still incomplete to reveal the full complexity of this relationship.

In any analysis, it is important to remember that linear regression results describe the statistical relationship between the variables under study. While these results provide insight into the relationships that may exist, they do not necessarily indicate a cause-and-effect relationship or reveal all the factors that influence the observed phenomenon. Therefore, interpretation of the results should be done with caution and take into account the context as well as other factors that may contribute to the observed phenomenon.

4. CONCLUSSION

4.1 Conclusion

This study aims to analyze the relationship between several variables, namely carbon dioxide concentration with global ocean temperature, carbon dioxide concentration with soil temperature, and the number of sunspots with soil temperature. Based on the results of the analysis, the following conclusions can be drawn:

a. Carbon Dioxide Concentration and Global Ocean Temperature

There is a significant relationship between carbon dioxide concentration and global ocean temperature. An increase in carbon dioxide concentration is associated with an increase in global ocean temperature. While carbon dioxide concentrations can partially explain variations in global ocean temperatures, there are other factors that contribute to these variations.

b. Carbon Dioxide Concentration and Soil Temperature

There is a strong relationship between carbon dioxide concentration and soil temperature. Any increase in carbon dioxide concentration is associated with an increase in soil temperature. However, it is important to remember that other factors also affect changes in soil temperature.

c. Number of Sunspots and Soil Temperature

There is a relationship between the number of sunspots and soil temperature. Soil temperature has an influence on sunspot activity, but this relationship is complex and influenced by other factors that are not fully understood.

4.2 Suggestions

a. Practical Advice

Given the relationship between carbon dioxide concentrations and global ocean and land temperatures, it is important for governments and international organizations to tighten efforts to mitigate greenhouse gas emissions to reduce the impacts of climate change. Policy makers need to consider the influence of carbon dioxide concentration and soil temperature in planning adaptation to climate change impacts.

b. Theoretical Suggestions

Further research is needed to identify and understand other factors that may influence variations in global ocean temperature, land temperature and sunspot activity. More complex models can help reveal deeper relationships. Further investigation is needed to clarify the mechanisms underlying the influence of soil temperature on sunspot activity, given that there is still variation that cannot be explained by the regression models.

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