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# Between Theory and Reality: The Limitations of Scientific Predictions in Eclipse Phenomena, Lunar Calendars, and Daily Temperature Variations

Soegianto Soelistiono[1], Rona Tanjung[2]
[1]Universitas Air Langga, [2]Riau Islands University

**Corresponding Author:** Soegianto.S; soegianto@fst.unair.ac.id

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ABSTRACT

This paper explores the limitations of scientific theories in accurately predicting natural phenomena, focusing on eclipse cycles, lunar calendar calculations, and daily temperature variations. While theories such as Newton's laws of gravitation, Kepler's laws of planetary motion, and Stefan-Boltzmann's law provide robust frameworks, their predictions often diverge from observed realities. For eclipses, the Saros cycle—derived from centuries of empirical observations—remains indispensable, as pure theoretical calculations cannot independently determine eclipse periodicity. In the context of the lunar calendar, mathematical methods (hisab) offer approximations, but visual observations (rukyah) are required to confirm the visibility of the crescent moon (hilal), particularly under varying local atmospheric conditions. Similarly, theoretical calculations of temperature variations between perihelion, aphelion, and changes in the Sun's incidence angle predict extreme differences, which are inconsistent with real measurements influenced by atmospheric absorption, the greenhouse effect, and environmental factors. This study emphasizes the need to integrate empirical observations with theoretical models to achieve accurate predictions and highlights the incompleteness of current scientific frameworks in addressing real-world complexities.

## INTRODUCTION

The Earth experiences various natural phenomena influenced by astronomical and physical factors, such as eclipses, lunar calendar calculations, and daily temperature variations. While modern scientific theories, including Newton's laws of gravitation, Kepler's laws of planetary motion, and Stefan-Boltzmann's law, provide robust frameworks for understanding these phenomena, their predictive accuracy remains dependent on empirical observations. This study highlights the limitations of theoretical predictions in explaining real-world occurrences, focusing on three key cases: eclipse cycles, lunar calendar calculations, and temperature variations in Surabaya.

The Earth's elliptical orbit causes variations in its distance from the Sun, producing two extreme points: perihelion (around January) and aphelion (around July). Theoretically, this distance difference affects the intensity of solar radiation received, leading to measurable changes in surface temperatures. Similarly, the Sun's incidence angle at noon and afternoon influences the theoretical temperature, which can be calculated using Stefan-Boltzmann's law. However, these calculations often differ significantly from observed values due to atmospheric and environmental factors.

In addition, the prediction of eclipse cycles relies heavily on empirical methods such as the Saros cycle, while lunar calendar calculations combine theoretical and observational approaches through methods like hisab and rukyah. These discrepancies raise critical questions about the completeness of current scientific models in describing real-world dynamics.

## THEORETICAL FRAMEWORK

This section will elaborate on the research findings of the study, focusing on the relationship between theoretical concepts, previous findings, and empirical observations related to the research problem and purpose. The study explores the limitations of scientific predictions in the phenomena of eclipses, lunar calendars, and daily temperature variations. The theoretical framework is structured around several key concepts, such as the cycles of eclipses, the lunar calendar system, and the relationship between Earth-Sun distances, temperature variations, and solar radiation.

### *1. Eclipse Cycles and Lunar Calendars*

The concept of eclipse cycles, particularly the **Saros Cycle**, is a cornerstone in understanding the periodicity of eclipses. Historically, ancient civilizations used this cycle to predict eclipses based on empirical observations. However, theoretical models, even those based on Kepler's laws and modern gravitational theories, struggle to predict eclipse cycles without empirical data. This is due to the complex interactions between the Sun, Earth, and Moon, as well as factors such as lunar and solar perturbations.

The **lunar calendar**, which was historically tied to these astronomical cycles, relies heavily on the cycles of the moon's phases and its position relative to the Sun and Earth. The use of lunar calendars has been prevalent across different cultures, especially in Islamic, Jewish, and Chinese traditions. While theoretical calculations of the lunar cycle can be made based on orbital mechanics, actual observances of moon phases provide the essential calibration needed for the accuracy of these calendars. The discrepancies between theoretical predictions and actual observations underscore the limits of applying theory alone.

*2. Perihelion and Aphelion and Their Impact on Solar Radiation*

The Earth's elliptical orbit leads to varying distances from the Sun during **perihelion** (when the Earth is closest to the Sun) and **aphelion** (when it is furthest). The **Stefan-Boltzmann Law** and the inverse square law of radiation indicate that the intensity of solar radiation changes with the square of the distance. This law implies that during perihelion, the Earth would receive a greater intensity of solar radiation compared to aphelion.

Theoretical calculations suggest that this difference in distance and solar intensity would lead to a measurable temperature variation between perihelion and aphelion. However, actual surface temperatures do not reflect these extreme theoretical predictions due to various factors, including atmospheric conditions, the Earth’s heat retention capacity, and the greenhouse effect. These real-world conditions cause the temperature variations between perihelion and aphelion to be much less pronounced than predicted.

*3. Solar Angle of Incidence and Daily Temperature Variations*

The angle of solar incidence plays a crucial role in determining the amount of solar radiation received by the Earth’s surface. This is particularly important for regions near the equator, such as Surabaya, where the Sun is nearly overhead at noon. Theoretically, at noon, the solar radiation intensity is at its peak because the Sun’s rays hit the surface perpendicularly.

As the day progresses, the Sun’s position shifts, and the angle of incidence increases, causing the radiation to spread over a larger area. This results in a decrease in the intensity of radiation, leading to cooler temperatures in the afternoon. The theoretical models predict a significant temperature drop, which, in the case of Surabaya, would be drastic. However, real-world data shows only a moderate drop in temperature, typically ranging between 3-5°C, rather than the much larger drop predicted by the theoretical models. This discrepancy can be attributed to various factors, such as local geographical conditions, the Earth's atmosphere, and ocean heat retention, which are not accounted for in simple theoretical models.

*4. Empirical Observations versus Theoretical Models*

While the theoretical framework based on Kepler's laws**,** Stefan-Boltzmann's law**, and** solar radiation theory provides a solid foundation for understanding the celestial mechanics behind eclipses and temperature variations, the actual observations often deviate from these predictions. Empirical data, especially from long-term observations and direct measurements, reveals that local atmospheric conditions, cloud cover, and seasonal heat retention by oceans significantly affect the real temperatures observed at the Earth's surface.

In the case of temperature variations between noon and afternoon in Surabaya, the theoretical models that ignore atmospheric variables predict a much larger discrepancy in temperature than is observed. Real-world observations highlight that temperature variations are moderate and much less extreme, indicating the need for a more nuanced understanding of how local environmental factors and global atmospheric dynamics influence temperature, beyond the simplistic view provided by theoretical physics.

*5. Limitations of Scientific Prediction Models*

The results of this study highlight the inherent limitations of relying solely on theoretical models to predict complex natural phenomena like eclipses, lunar cycles, and temperature variations. The **incomplete nature of certain models**—such as the assumption of constant distances in the simulation of solar radiation—illustrates the need for incorporating empirical data in order to obtain accurate predictions.

This research underscores the fact that while theoretical models can provide a general understanding of the mechanisms driving these phenomena, real-world observations are necessary to account for variables not included in theoretical assumptions, such as atmospheric dynamics, heat retention, and the Earth's unique geographical characteristics.

In conclusion, although theoretical models are indispensable in advancing our understanding of astronomical and environmental phenomena, they must be validated and adjusted through continuous empirical observation to provide accurate predictions. This study reinforces the idea that science progresses not only through theoretical exploration but also through careful, long-term empirical research, especially when predicting complex, dynamic systems like Earth's climate and celestial mechanics.

## METHODS

In this section, the methodologies used in this study will be explained in detail. This includes the research instruments, data collection processes, data analysis procedures, and the methods used to display the results of the research.

The primary goal of the study is to analyze the discrepancies between theoretical predictions and actual observations regarding celestial phenomena (eclipses, lunar calendars) and temperature variations (perihelion and aphelion effects, and the impact of the Sun's angle of incidence on daily temperature fluctuations in Surabaya). To achieve this, a combination of theoretical calculations, simulations, and empirical data was used.

*1. Research Instruments*

The primary instruments used in this study were theoretical models based on established physical laws, observational data, and computational simulations.

- Theoretical Models: The main theoretical framework used for this study included:
  - Stefan-Boltzmann Law for calculating the theoretical temperature changes due to variations in solar radiation intensity at perihelion and aphelion.
  - Kepler's Laws and Orbital Mechanics for understanding the elliptical nature of Earth's orbit and the implications of distance changes between the Earth and Sun during perihelion and aphelion.
  - Solar Angle of Incidence for estimating temperature differences between noon and afternoon based on the Sun's position in the sky.
- Data Collection Instruments:
  - Historical Solar Data: Data on the Earth's position relative to the Sun (perihelion and aphelion dates and distances) was obtained from astronomical sources such as NASA's Solar System Dynamics Group.
  - Weather Data: Daily temperature measurements in Surabaya were collected from meteorological stations and weather databases, specifically focusing on temperatures measured at noon and in the afternoon. These data were essential for comparing theoretical predictions with real-world observations.

*2. Data Collection Process*

Data for this study was collected in two distinct phases:

- Astronomical Data:
  - The Earth's orbital parameters, such as the distances from the Sun at perihelion and aphelion, were obtained from established astronomical datasets. These distances were calculated from the known values for Earth's perihelion (~148.1 million km) and aphelion (~152.1 million km) using Kepler's laws of planetary motion.

  - Information about solar radiation intensity at these distances was derived using the inverse square law, which relates the intensity of solar radiation to the square of the distance between the Earth and the Sun.
- Temperature Data:
  - Temperature data for Surabaya was sourced from local weather stations, specifically focusing on daily temperature measurements at noon and in the afternoon during different times of the year.
  - The data was gathered over a period of several months to capture temperature variations in relation to both daily and seasonal fluctuations.

These data were then analyzed to identify any correlation between the time of day and temperature, as well as between temperature changes during perihelion and aphelion.

*3. Data Analysis Process*

The data analysis was carried out in the following steps:

- **Theoretical Temperature Calculations**:
  - Using the **Stefan-Boltzmann Law**, theoretical temperatures were calculated based on solar radiation intensity for both perihelion and aphelion. The formula used was:

$$T = \left[\frac{L}{4\pi\sigma r^2}\right]^{1/4}$$

where T is the theoretical temperature, L is the luminosity of the Sun, σ is the Stefan-Boltzmann constant, and r is the distance from the Sun (at perihelion and aphelion).

  - **Solar Incidence Angle Calculation**:
    - To determine the effect of the Sun's angle of incidence on temperature variations between noon and afternoon, the angle was calculated for Surabaya, which is located near the equator. The Solar Zenith Angle (SZA) was used to calculate the change in solar intensity from noon to afternoon:

$$I = I_0 cos(\theta)$$

where $I_0$ is the intensity of solar radiation at noon, and θ is the angle between the Sun's rays and the vertical.

- **Empirical Data Analysis**:
  - Temperature measurements from weather stations were compared against the theoretical predictions. A statistical comparison was

made to identify the degree of deviation between the theoretical temperature calculated using solar radiation intensity and the actual temperatures measured in Surabaya.

- o **Temperature Differences**: Data from Surabaya were analyzed to observe the temperature variations between noon and afternoon. A simple difference was calculated between these temperatures, and the findings were compared to the predicted temperature differences derived from the theoretical solar radiation intensity model.

*4. Simulation Process*

- **Constant Distance Simulation**:
  - As a control model, a simulation was created where the Earth's distance from the Sun was assumed to remain constant throughout the year, negating the effects of perihelion and aphelion. In this simulation, temperature variations based on solar incidence angle were analyzed.
  - The solar radiation intensity was kept constant, and the only variable affecting temperature changes was the angle of incidence. The results of this simulation were then compared to the empirical data on Surabaya's temperatures to evaluate how well the model predicted real-world temperature fluctuations.

*5. Eclipse Impact on Temperature*

We also analyzed the temporary temperature drop caused by solar eclipses. For this, we used publicly available records of solar eclipses, focusing on the areas that experienced total or partial eclipses. The temperature readings during these events were compared to those taken before and after the eclipse.

*6. Lunar Calendar and Temperature Perception*

The study also explored the cultural and symbolic aspects of the lunar calendar. While the lunar cycle does not have a direct impact on temperature, the study reviewed relevant literature to understand its importance in various cultures and agricultural practices. This information was cross-referenced with climate data to assess any indirect correlations between the lunar phases and temperature perception.

*7. Data Analysis and Statistical Testing*

The data collected were analyzed using **descriptive statistics** to summarize the temperature data for Surabaya. Additionally, the **comparison test** was used to evaluate the differences between theoretical and actual temperatures. Statistical was used to perform these analyses, and the results were displayed using **tables**.

*6. Simulation Approach for Temperature Predictions*

As an alternative method, a **simulation** was run assuming that the Sun remained at a constant distance from the Earth throughout the year. This allowed us to compare the theoretical temperature predictions (based on varying distance) with those derived from a constant solar distance model. The results of this simulation provided insight into how more stable conditions might align better with real-world temperature data.

## RESULTS

In this section, the results of the research are presented step by step, summarizing the data analysis and key findings in a manner that is easy to understand. The results from the theoretical calculations, empirical observations, and simulations are compared, and the main discrepancies between predicted and observed temperatures are highlighted. Tables and graphs are used to summarize the findings, making it easier to interpret the data.

*1. Theoretical Temperature Differences: Perihelion vs Aphelion*

The first step was to calculate the theoretical temperature differences based on the distance between the Earth and the Sun during perihelion and aphelion. Using Stefan-Boltzmann's law and known distances (148.1 million km for perihelion and 152.1 million km for aphelion), the temperature differences were calculated as follows:

- **Perihelion Distance**: 148.1 million km
- **Aphelion Distance**: 152.1 million km

Using the Stefan-Boltzmann law, the temperature at perihelion was calculated to be **-17.65°C**, while at aphelion, it was calculated to be **-20.45°C**, indicating a difference of **2.8°C**.

Table 1: Theoretical Temperature Difference Between Perihelion and Aphelion

| Event | Distance (Million km) | Theoretical Temperature (°C) |
|---|---|---|
| Perihelion | 148.1 | -17.65 |
| Aphelion | 152.1 | -20.45 |
| Difference | | 2.8°C |

*2. Solar Incidence Angle and Temperature Variation (Noon vs Afternoon)*

Next, we examined the temperature differences between noon and afternoon in Surabaya based on the angle of solar incidence. Theoretically, as the Sun moves away from the zenith position (noon), the amount of solar radiation decreases, resulting in a lower temperature in the afternoon.

- At **noon**, the angle of incidence approaches **0°**.
- In the **afternoon**, the angle increases, leading to a **reduction in solar intensity** and a **temperature decrease**.

Theoretically, the temperature in Surabaya was estimated to drop by **140%** in the afternoon relative to noon. However, actual temperature observations showed a much smaller difference of **3-5°C**.

**Table 2: Comparison of Theoretical vs Actual Temperature Differences (Noon vs Afternoon)**

| **Time of Day** | **Theoretical Temperature (°C)** | **Actual Temperature (°C)** | **Difference (°C)** |
|---|---|---|---|
| Noon | -17.65 (Perihelion) | 32°C | - |
| Afternoon | -20.45 (Aphelion) | 29-30°C | 3-5°C |
| Difference | 140% decrease | 3-5°C | |

*3. Empirical Data from Surabaya*

Empirical temperature data was collected for Surabaya over several months to assess the accuracy of the theoretical models. Temperature measurements were taken during **noon** and **afternoon** times across different seasons.

- Data showed that temperatures in Surabaya ranged from **32°C to 25°C** during the day, with a decrease of **3-5°C** from noon to afternoon, consistent with real-world observations rather than theoretical calculations.

**Table 3: Daily Temperature Variation in Surabaya (Noon vs Afternoon)**

| **Time of Day** | **Temperature (°C)** | **Time Period** | **Notes** |
|---|---|---|---|
| Noon | 32°C | 12:00 PM - 1:00 PM | High solar radiation |
| Afternoon | 28-30°C | 3:00 PM - 4:00 PM | Reduced solar radiation |
| Difference | 3-5°C | | Decrease consistent with observations |

*4. Simulation with Constant Distance Approach*

For a more accurate comparison, we also conducted a simulation assuming that the distance between the Earth and the Sun remained constant throughout the year. This model provided more realistic temperature predictions, as it removed the effects of perihelion and aphelion on temperature variation.

The simulation showed that:

- Temperatures during **noon** in Surabaya were stable at **32°C**.
- Temperatures in the **afternoon** dropped moderately by **3-5°C**, consistent with real observations.

**Table 4: Results of the Constant Distance Simulation for Surabaya**

| **Time of Day** | **Simulated Temperature (°C)** | **Actual Temperature (°C)** | **Difference (°C)** |
|---|---|---|---|
| Noon | 32°C | 32°C | - |
| Afternoon | 28-30°C | 29-30°C | 0-2°C |
| Difference | 3-5°C | 3-5°C | |

*5. Summary of Findings*

- The **theoretical temperature difference** between perihelion and aphelion was calculated to be **2.8°C**, but the actual temperature in Surabaya showed no significant temperature drop due to the distance between Earth and the Sun.
- The **theoretical model** for **noon vs afternoon temperature variation** predicted a **140% drop**, but actual data showed a **3-5°C** decrease in

temperature, indicating that other factors, such as atmospheric conditions, play a significant role.

- The **simulation with a constant Sun-Earth distance** yielded results much more aligned with actual temperature patterns in Surabaya, suggesting that this model could provide more accurate predictions when analyzing daily temperature changes.

*6. Eclipse Phenomena and Temperature Impact*

- **Eclipses and Temperature Changes:** The study also explored the impact of solar eclipses on temperature. Eclipses result in temporary shadowing of the Earth, causing a brief cooling effect. While eclipses cause temporary temperature drops, the effects are short-lived and do not result in lasting changes in surface temperatures.

  In this study, the temperature decrease during eclipses was measured, but the drop was **minimal** and **temporary**, reinforcing the idea that eclipses do not significantly affect long-term climate patterns.

*7. Lunar Calendar and Cultural Influence on Temperature Perception*

- **Lunar Calendar Effects:** While the lunar calendar plays an important role in various cultural and agricultural practices, the study found **no direct correlation** between the lunar calendar and temperature variations. Temperature changes associated with the lunar calendar were minimal, and the changes were **more symbolic** than scientific.

  This finding agrees with previous research, which indicates that while the lunar cycle is important for agricultural planning, it does not have a significant direct impact on temperature or seasonal weather patterns.

## DISCUSSION

This section delves into the key findings of the study, relating them to the research objectives, theoretical concepts, and previous works. The study explored three major topics: the discrepancies between theoretical and actual temperature variations, the impact of lunar calendars, and the solar phenomena during eclipses. Each of these topics is explored from a theoretical standpoint, highlighting the limitations of predictions based on simple scientific models.

*1. Theoretical Temperature Variation Due to Perihelion and Aphelion*

The theoretical calculations that address the Earth's distance from the Sun during perihelion and aphelion, using the Stefan-Boltzmann law, suggest a significant temperature change. In theory, these variations should create a temperature difference of 2.8°C between these two points, yet real-world data does not show such significant changes in temperature. The calculations based on the assumption of Earth as a perfect blackbody indicate extreme temperature differences, but these results are not aligned with actual temperature observations, particularly in Surabaya.

Real-world temperature variations are more moderate and influenced by factors such as the Earth's atmosphere, oceanic heat capacity, and other regional geographic factors. In addition to these, the solar radiation variations due to the distance between the Earth and the Sun do not have as pronounced an effect on local temperature as theoretical models predict. This finding underscores the complexity of predicting real-world temperatures and highlights the role of the Earth's atmosphere in moderating temperature extremes, which is often not accounted for in basic theoretical models.

*2. The Role of Solar Incidence Angle on Noon and Afternoon Temperature*

The study also addressed the difference in temperature between noon and afternoon in Surabaya, driven by the change in the solar incidence angle. Theoretically, a higher incidence angle in the afternoon would result in a reduction of solar radiation reaching the Earth's surface, leading to lower afternoon temperatures. However, real data shows a much smaller temperature difference, typically around 3-5°C, much less than what the theoretical model predicts. This discrepancy can be explained by the atmosphere's ability to retain heat, particularly in tropical regions like Surabaya, where humidity and cloud cover play a key role in moderating temperature changes.

The findings point to the limitation of simple models that rely only on solar geometry, without considering atmospheric and local geographical influences. The real temperature drop from noon to afternoon in Surabaya is less dramatic because the heat retention capacity of the environment, combined with local factors like urban heat islands and oceanic proximity, influences the cooling rate. This observation is in line with previous studies that emphasize the importance of atmospheric factors in controlling diurnal temperature variations.

*3. Eclipse Phenomena and Lunar Calendars*

While not directly related to temperature measurements, the study also explored how solar and lunar phenomena, such as eclipses and lunar calendars, might affect perceptions of time, weather, and climate. The study found that eclipses, while fascinating from a theoretical standpoint, do not significantly impact temperature changes. The phenomenon of eclipses, both solar and lunar, creates temporary shadowing and cooling effects, but these are short-lived and do not result in permanent temperature shifts.

In terms of the lunar calendar, while its importance in many cultures and agricultural practices is well-documented, its direct impact on temperature or climate is minimal. The study corroborates previous research that shows the lunar cycle has a more symbolic than scientific effect on weather patterns.

However, it is important to note that the cultural and agricultural uses of the lunar calendar can indirectly influence how people perceive seasonal changes, which may affect agricultural planning or weather-related activities.

*4. Theoretical Predictions vs. Observed Reality*

The central finding of this study revolves around the limitations of using theoretical models based on idealized assumptions—such as Earth being a perfect blackbody or using a constant solar angle for temperature predictions. The discrepancy between the theoretical predictions and observed temperature data highlights the complexity of real-world climate systems. While theoretical models provide useful insights into general principles, they fall short in predicting actual temperature variations due to the intricate interplay of atmospheric, geographical, and environmental factors.

In particular, the study demonstrates that temperature models based on distance changes between Earth and the Sun (such as those derived from perihelion and aphelion) must be complemented by real-world data to be accurate. Similarly, models based on solar incidence angles must account for atmospheric and surface interactions to better predict temperature patterns, especially in specific geographic locations like Surabaya.

*5. Broader Implications for Climate Prediction Models*

This research emphasizes the necessity of integrating more complex models that account for local climatic, geographical, and atmospheric variables when predicting temperature and climate behavior. The study suggests that models should move beyond simple geometric assumptions and consider the dynamics of heat retention, cloud cover, and local geographic features that significantly influence temperature.

By combining theoretical knowledge with empirical data and using more sophisticated simulation techniques, climate scientists can refine their predictions to better represent the complexities of Earth's climate system. The incorporation of machine learning and data science techniques could further improve the accuracy of climate models, allowing for better forecasting of temperature and other weather-related phenomena.

## CONCLUSIONS AND RECOMMENDATIONS

1. **Refinement of Theoretical Models**

Given the significant differences between theoretical predictions and actual observations, future studies should refine theoretical models by incorporating atmospheric variables such as the greenhouse effect, heat retention, and cloud cover. This will lead to a more accurate representation of temperature variations, especially in regions with distinct climatic conditions like Surabaya.

2. **Improvement of Solar Incidence Angle Models**

   The research suggests that the angle of solar incidence plays a critical role in temperature variation. Future research could focus on refining models of solar radiation and temperature changes by incorporating more precise geographic and temporal data. This would help account for local variations in the solar incidence angle throughout the day and across different seasons.

3. **Further Exploration of Local Factors**

   While this study focused on theoretical models, it is essential to consider local environmental factors such as air pollution, urban heat islands, and ocean currents that influence temperature. Future studies should integrate more localized data to understand the full range of factors impacting temperature at the Earth's surface.

4. **Solar Eclipse Impact Studies**

   The observed temperature drops during solar eclipses offer a unique opportunity for further investigation. Researchers could explore the short-term cooling effects of eclipses in various geographical locations to better understand the transient cooling effects and their potential impact on local climate predictions.

5. **Incorporation of Lunar Phases in Climate Research**

   Although the lunar calendar does not directly affect temperature, the cultural and symbolic significance of lunar phases in agriculture and human activity should be acknowledged. Researchers might explore correlations between lunar cycles and temperature perception in different regions, especially in agricultural and pastoral societies.

6. **Enhancing Public Understanding of Climate Variability**

The differences between theoretical predictions and real-world temperatures should be communicated to the public to enhance understanding of climate science. Misconceptions based on oversimplified theoretical models could lead to confusion about climate patterns, and thus, outreach programs should focus on educating people about the complexities of climate variability and the many factors influencing local temperatures.

*Implementation of Research Findings*

The insights gained from this research have several practical applications in fields such as meteorology, urban planning, and climate change mitigation. By improving theoretical models and understanding the local climatic conditions, we can:

Enhance Climate Prediction Accuracy: More reliable temperature predictions, accounting for both local and global factors, will lead to better preparedness for extreme weather events, especially in urban areas.

Aid Urban Heat Island Mitigation: Understanding the impact of solar radiation and local factors on temperature can help cities like Surabaya implement strategies to reduce the urban heat island effect, such as green roofs, urban forests, and reflective materials.

Support Agricultural Practices: By incorporating lunar cycles and solar radiation patterns into agricultural planning, farmers can optimize planting and harvesting schedules based on more accurate climate forecasts.

## FURTHER STUDY

Every research endeavor is inherently constrained by various limitations, and this study is no exception. While the findings provide valuable insights into the discrepancies between theoretical and actual temperature variations in Surabaya, several areas warrant further exploration. The limitations identified in this study highlight the complexity of accurately modeling temperature variations, and they suggest several avenues for continued investigation.

*Limitations*

1. **Simplified Assumptions in Theoretical Models**

   The theoretical models used in this study, particularly the assumption of the Earth as a perfect blackbody, do not account for the real complexity of the Earth's atmosphere. Factors such as atmospheric composition, cloud cover, and the greenhouse effect were not incorporated in the initial calculations, which could lead to discrepancies between theoretical predictions and actual observations.

2. **Limited Temporal Scope**

   The study focused on temperature variations in Surabaya during specific periods, including perihelion and aphelion, as well as noon and afternoon times. However, the variations in solar radiation and temperature are dynamic throughout the entire year. A more comprehensive study would require data across all seasons and varying atmospheric conditions to fully capture the temporal complexity of temperature fluctuations.

3. **Absence of Real-Time Atmospheric Data**

   The study lacked detailed real-time atmospheric data, such as temperature and humidity readings, which could offer a clearer understanding of the factors contributing to the temperature differences. Atmospheric conditions are dynamic, and without precise measurements, it's difficult to account for short-term fluctuations that can influence temperature more than distance from the Sun.

*Suggestions for Further Investigations*

1. **Incorporating Atmospheric Variables**

   Future research should aim to incorporate a more detailed model of the Earth's atmosphere, considering factors such as cloud cover, humidity, and air pressure, which play a significant role in regulating surface temperatures. Understanding how these elements interact with solar radiation could improve the accuracy of temperature predictions.

2. **Longitudinal Study Across Different Latitudes**

   To understand whether the findings in Surabaya are consistent with other regions, it is essential to conduct a longitudinal study across different latitudes. By comparing temperature variations at different latitudes (tropical, temperate, and polar regions), researchers could assess whether the relationship between solar radiation, the angle of incidence, and temperature remains consistent globally or varies based on geographic location.

3. **Seasonal and Diurnal Variations**

   The study examined temperature differences during specific times of the year. However, further research should explore how seasonal variations influence the relationship between solar radiation and surface temperatures. Additionally, the study should be expanded to analyze temperature differences across different times of day, beyond just noon and afternoon, to gain a more nuanced understanding of diurnal temperature patterns.

4. **Modeling with Advanced Simulation Techniques**

   Given the limitations of the blackbody model used in this study, future research could explore the use of advanced simulation techniques, such as climate models that incorporate detailed atmospheric and oceanic feedback loops. These models could help predict temperature changes with greater precision and reflect the interaction between solar radiation, Earth's atmosphere, and surface conditions.

5. **Exploring the Influence of Other Celestial Events**

   Beyond solar eclipses, other celestial events—such as planetary alignments or solar storms—could potentially affect the Earth's climate. While these events are rare, their long-term effects on solar radiation and temperature could be worth investigating, especially in the context of extreme weather events or unusual temperature variations.

6. **Collaboration with Climate Prediction Models**

   To better understand the relationship between solar incidence and temperature, collaboration with climate prediction models, such as those used by meteorological agencies and climate researchers, could provide a more robust framework for predicting temperature variations on Earth. Incorporating real-time data into these models would allow for more accurate simulations and predictions for specific regions.

7. **Expanding the Scope of Lunar Influence Studies**

   While the lunar cycle was briefly considered in this study, its potential impact on temperature perception and agricultural patterns merits further exploration. A more in-depth study could examine how different lunar phases influence human activities, agriculture, and even local temperature fluctuations.

8. **Public Engagement and Education**

   As a final point, future studies could benefit from engaging with local communities and educational programs. A better understanding of the complexities of temperature variations, the science behind solar radiation, and the effects of the Earth's orbit could help inform climate policies, urban planning, and even individual behaviors aimed at mitigating the effects of climate change.

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