The Effect of Aerosol Levels in the Atmosphere on Temperature

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Abstract

Aerosols play a significant role in Earth's climate system by influencing the net energy balance from the sun. They can scatter sunlight back into space, leading to cooling, or absorb radiation, causing localized warming. This study was prompted by the need to better understand the localized effects of aerosols, particularly in urban areas where aerosol concentrations are often elevated due to human activities. Background research indicates that aerosols can have both direct (scattering/absorption) and indirect (cloud formation) effects on temperature. This study focuses on the direct effects, using GLOBE protocols to collect and analyze data.

Introduction Essay

Aerosols are tiny particles suspended in the air. They occur naturally, often as a result of volcanic eruptions and combustion, but can also be produced by human activities such as factory emissions and machinery operation. Although they are frequently overlooked in climate change discussions, aerosols play a crucial role in both the Earth's climate and human health[1,2].

To start, aerosols can either warm or cool the planet. Certain types, like sulfate aerosols, reflect sunlight back into space, creating a cooling effect that mitigates some of the warming caused by greenhouse gases. Conversely, other aerosols, such as black carbon, absorb sunlight and contribute to atmospheric warming. This dual nature makes aerosols a significant factor in the Earth's energy balance[2].

Recent studies indicate that while reducing aerosol emissions improves air quality, it can also accelerate climate warming. For example, the decline in sulfate aerosols due to air quality regulations has been associated with rising global temperatures. This highlights the importance of a balanced approach to aerosol management, as their removal can lead to unintended consequences for climate stability[9].

Aerosols, especially those measuring 2.5 micrometers or less (PM2.5), pose massive risks to human health. These particles can infiltrate the lungs and enter the bloodstream, resulting in respiratory issues. Exposure to PM2.5 has been linked to diseases such as asthma, lung cancer, and heart disease. Both human activities and natural processes contribute to the formation of

PM2.5, making it a large concern in urban areas. Consequently, organizations like the Environmental Protection Agency (EPA) have established a guideline that limits the annual average concentration of PM2.5 in the air to below 12 µg/m^3 [4].

The oxidative potential (OP) of PM2.5 has become a crucial factor in assessing health risks. OP refers to the capacity of a substance to oxidize other molecules by accepting electrons. Substances with high oxidative potential can be detrimental to human health. Research conducted in China has shown that regions with elevated PM2.5 levels also exhibit high OP, leading to a greater health burden in those areas. This highlights the need not only to reduce aerosol concentrations but also to consider their chemical makeup in efforts to lessen health impacts[5].

Natural sources of aerosols include volcanic eruptions, wildfires, and dust storms, all of which release large amounts of particulate matter into the atmosphere. For instance, wildfires in Europe during the summer of 2022 significantly increased regional aerosol levels, with emissions quickly transforming into secondary organic aerosols. These are formed when emitted aerosols interact with other gases in the atmosphere, affecting air quality even hundreds of kilometers away[5].

Human activities such as industrial production, transportation, and household combustion are major contributors to PM2.5 levels. In areas like East Asia, coal burning and industrial activities have historically led to high aerosol emissions, although recent clean air initiatives have achieved notable reductions. Nevertheless, the long-range transport of aerosols continues to pose challenges, as pollution from one area can adversely affect air quality and climate in distant regions[6].

Solutions for aerosol-related challenges must focus on balancing climate and health impacts. First, we need to cut down on emissions of warming aerosols like black carbon, which can come from sources such as diesel engines, coal-fired power plants, wood-burning stoves, and wildfires. Additionally, promoting hygiene practices and the use of masks when necessary can help reduce aerosol transmission. It is also essential to implement global regulations ensuring that all facilities have adequate ventilation to manage aerosol exchange[7].

Aerosols, often overlooked, play a crucial role in both the Earth's climate and human health. Their intricate interactions with the atmosphere and significant health implications make them a key focus for scientific research and policy development. By adopting a comprehensive approach that aligns climate and health goals, we can harness the potential of aerosols to create a more sustainable and healthier future. As we deepen our understanding of these tiny particles, their influence on global environmental processes will undoubtedly remain a critical area of study.

Materials:

1. GLOBE sun photometer (for measuring aerosol optical thickness)

2. Digital thermometer (for temperature measurements)

3. Data sheets and journals for recording observations

4. Computer with spreadsheet software for data analysis

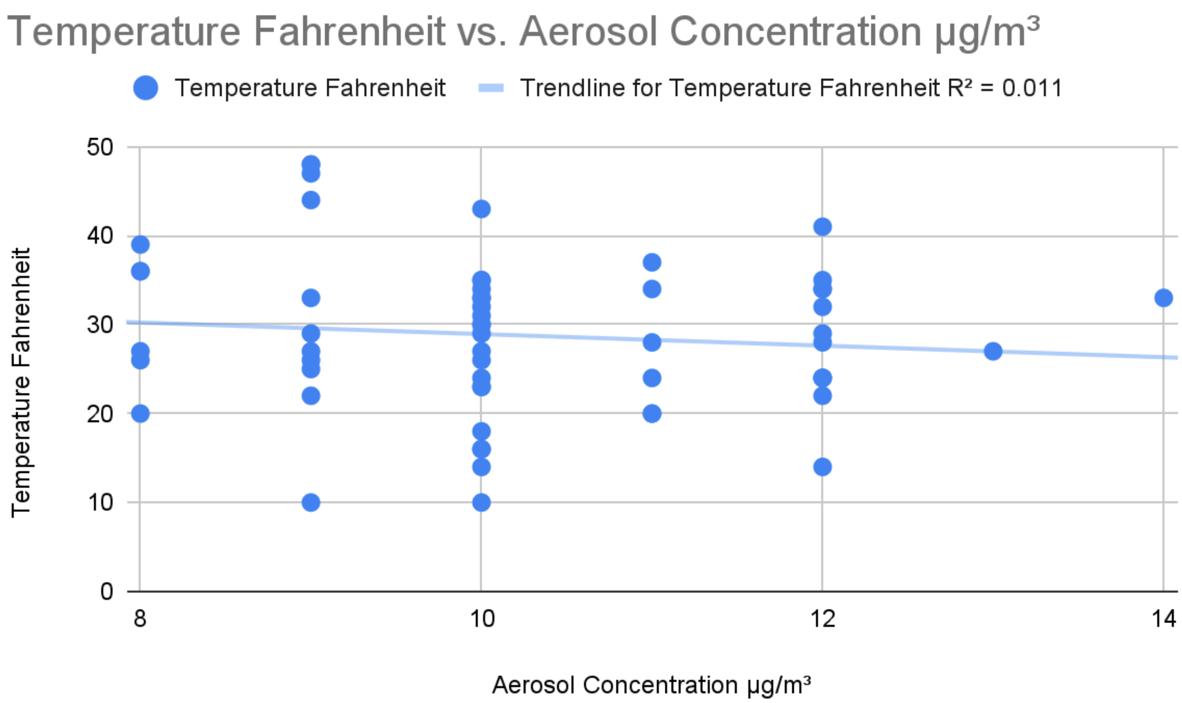
Procedures:

1. Use the GLOBE aerosol measurer to measure aerosol concentration (μg/m^3) at noon and for a full month, from Feb. 4, 2025, to Mar. 4, 2025.

2. Measure local air temperature at the same time and location as the aerosol density measurements using a digital thermometer. Ensure the thermometer is shielded from direct sunlight to avoid inaccurate readings.

3. Record all data in a research journal, including date, time, aerosol density, & temperature.

4. Perform statistical analysis to determine the significance of the relationship.



R = 0.1048

$R^2 = 0.011$

Conclusion:

Based on our sample of data, there is not convincing evidence that aerosols significantly affect temperature. The R^2 value for the data is only 0.011, meaning only approximately 1% in the variability of the temperature data is explained by aerosol density.

Discussion

There may be several reasons for this. Firstly, the sample size or duration of the data might be insufficient to capture the long-term or large-scale effects of aerosols, which can vary regionally and over time. Secondly, & perhaps more importantly, the data did not account for confounding variables, such as greenhouse gas concentrations, cloud cover, or natural climate variability, which play a much larger role in the temperature than aerosols. To mitigate these factors, we could randomly select the location to avoid confounding variables, & gather more data so we can apply statistical techniques like the Central Limit Theorem.

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