Using AI Modeling to Predict the Impact of Cloud Seeding on Amount of Rainfall and How that Affects the Temperature in Different Regions

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Abstract

Water is one of the most essential resources on Earth, yet many regions face severe water scarcity due to growing populations, increased land use, and climate change. To address this challenge, we employed cloud seeding as a promising technique for augmenting water supplies. While prior research has primarily focused on increasing precipitation, this study introduces a novel angle by examining how cloud seeding-induced rainfall may also influence regional temperature regulation over time. This dual-purpose investigation is particularly relevant in arid regions like the Middle East, where water scarcity and extreme heat coexist.

Using historical datasets and AI-based modeling, including linear regression and neural networks, we analyzed the relationship between rainfall and temperature across different regions. Results revealed a consistent negative correlation between rainfall and temperature, suggesting that cloud seeding may have cooling effects in addition to boosting precipitation. This study presents early evidence that weather modification could play a role in mitigating long-term climate stress, offering a new perspective on the benefits of cloud seeding.

Keywords

Index Terms—Cloud seeding, Linear regression, Neural networks, Rainfall

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1 Introduction

Water scarcity, intensified by growing populations, increased land use, and climate change, has placed significant strain on traditional water sources such as groundwater, rivers, and reservoirs. This has prompted a search for innovative solutions, one of which is cloud seeding, a weather modification technique designed to enhance precipitation. First developed in the mid-20th century, cloud seeding involves introducing substances such as silver iodide or sodium chloride into the atmosphere to stimulate the formation of rain or snow.

Countries worldwide, including those in the Middle East, have adopted cloud seeding to tackle critical water challenges. In addition to increasing rainfall, some suggest that cloud seeding may have potential secondary effects, such as influencing local temperatures. This possible relationship is particularly intriguing for regions like the Middle East, where extreme heat during the summer poses public health and infrastructure challenges. Despite these possibilities, the intersection between rainfall enhancement through cloud seeding and its potential impact on temperature regulation remains poorly understood. Understanding this relationship could reveal how consistent cloud seeding efforts might not only alleviate water shortages but also contribute to long-term temperature moderation—a critical insight for regions facing both climate and resource stress.

2 Related Work

Several studies have examined the effectiveness of cloud seeding in enhancing precipitation. A review paper titled "A Review of Cloud Seeding Experiments to Enhance Precipitation and Some New Prospects" provides a comprehensive overview of the current status of glaciogenic and hygroscopic seeding experiments (Roelof T. Bruintjes) [3–5]. It concludes that the potential of precipitation enhancement through cloud seeding is intricately tied to water resource management. This study underscores the importance of linking weather modification techniques to practical applications, particularly in regions experiencing water shortages.

Another significant contribution is the study "Cloud Seeding Experiments in Australia," which discusses experiments where silver iodide smoke was released from the ground (E. J. Smith) [1, 6]. These experiments showed no immediate results, as the ice-nucleating properties of silver iodide were rapidly diminished under daylight exposure. Despite these challenges, the researchers concluded that cloud seeding with silver iodide has substantial potential for modifying rainfall. However, they also noted the complexities involved, including persistent effects of seeding after operations ceased, which yielded both positive and negative results.

A third paper, "A Cloud-Seeding Experiment in Tasmania," documents an experiment conducted using a target area and three control areas (E. J. Smith, et al.) [2, 7]. This study, which utilized silver iodide smoke released from aircraft, aimed to measure increases

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in precipitation in a catchment area. The findings indicated that seeding led to increased rainfall in the eastern half of the target area during the autumn season. Notably, this study uses the same dataset that we incorporated, making it a foundational reference for our analysis.

In addition to the studies already reviewed, several foundational papers have contributed to the understanding of cloud seeding dynamics and challenges. For example, Bowen (1966) discussed the persistent effects of seeding on cloud systems, while Grant (1963) addressed the residual atmospheric impacts of silver iodide particles. These works highlight the complexity of atmospheric intervention and provide important context for interpreting results in modern seeding experiments.

While these papers provide valuable insights into cloud seeding's effects on precipitation, they focus almost exclusively on measuring rainfall levels or evaluating the techniques themselves. None of the reviewed studies explicitly investigates the potential correlation between cloud seeding-induced rainfall and temperature changes. This gap is particularly significant for regions such as the Middle East, where extreme heat poses substantial challenges alongside water scarcity.

Our study aims to bridge this gap by examining the relationship between cloud seeding, precipitation levels, and temperature changes. By using historical data and employing AI modeling, we seek to explore the potential for cloud seeding to serve not only as a tool for water augmentation but also as a means of mitigating extreme temperatures. This dual-purpose approach could provide critical insights for regions facing simultaneous water and heat stress. We focused on the research question: How does cloud seeding influence temperature in different regions? We hypothesize that increased rainfall due to cloud seeding leads to observable temperature reductions. Over time, this effect may contribute to regional cooling, particularly in areas where cloud seeding is used frequently and consistently. The primary aim of this research is to develop an AI-based model capable of predicting temperature changes based on cloud seeding-induced rainfall.

3 System

To begin our project, we researched datasets related to cloud seeding in different regions worldwide and selected one most suitable for our goals. We chose a dataset from the study "A Cloud-Seeding Experiment in Tasmania." The paper details seeded and unseeded rainfall in various Tasmanian regions such as NC, SC, NWM, and TE. The dataset includes the period of each recording, the season, whether the rainfall was seeded or unseeded, and the amount of rainfall in millimeters. However, this dataset lacked corresponding temperature data for the same regions during each recording period. To address this limitation, we obtained a dataset containing temperature records from Tasmania during the same years. Using the seasonal data and the number of recordings in each season, we calculated average temperatures for periods with rainfall and no rainfall. We sorted daily temperature data into rainfall and no-rainfall categories and then averaged the values. We repeated this process for all available recordings, producing a new dataset containing the period, season, location, rainfall amount, and average temperatures for seeded and unseeded events. This enabled us to compare temperature differences during rainfall events and non-events. We employed a linear regression model in Python to estimate relationships between rainfall and temperature. We explored combinations such as average temperatures during rainfall versus no rainfall (Y-axis) and rainfall amounts (X-axis). The resulting lines of best fit revealed a consistent negative correlation.

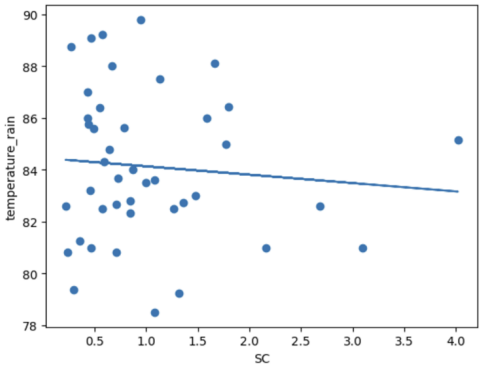


Figure 1: Temperature against amount of rainfall in the South region

On the X-axis of Figure 1, the rainfall in the South region is shown, while the Y-axis represents temperature. As illustrated, this also shows a similar negative correlation.

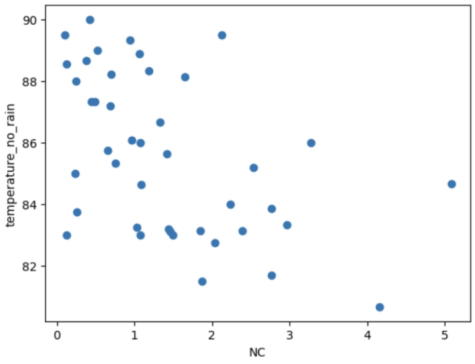


Figure 2: Temperature against amount of rainfall in the North region

Figure 2 presents the correlation between rainfall and temperature during non-rainfall periods. While slightly weaker, the trend remains generally negative.

To further validate the findings, we implemented neural network models. We experimented with various configurations of Dense, Dropout, and Batch Normalization layers using a feedforward neural network architecture. The model was trained using the Adam optimizer with a learning rate of 0.001 and the mean squared error (MSE) loss function. We employed the ReLU activation function for all hidden layers and used early stopping to prevent overfitting. The dataset was split into 80 percent training and 20 percent testing. Despite extensive tuning, the best-performing configuration

included 12 dense layers, one dropout layer (rate = 0.3), and one batch normalization layer at the input. This configuration achieved an MSE of 564.3296 after 15 epochs.

Our models primarily used rainfall amount and regional identifiers as input features. While we considered including additional meteorological variables such as humidity, wind patterns, and atmospheric pressure, we excluded them due to the unavailability of synchronized historical data for those variables in the studied regions. We acknowledge that incorporating a richer feature set may enhance predictive accuracy and recommend this for future research.

4 Evaluation

The results from our analysis using linear regression models consistently demonstrated that increased rainfall correlates with decreased temperatures. We reached this conclusion by analyzing the lines of best fit across different models, where we compared average temperatures during rainfall or no rainfall (Y-axis) with rainfall amounts in millimeters across regions (X-axis). Most models displayed a strong negative correlation, indicating that as rainfall amounts increased, average temperatures decreased. To validate and enhance these findings, we used neural network models, which achieved a mean squared error (MSE) of 564.3296. This MSE value represents the average squared difference between the predicted and actual temperature values, providing a quantitative measure of the model's accuracy. A lower MSE indicates a smaller average error and greater predictive reliability. In this study, the MSE of 564.3296 suggests that the model was effective in capturing the relationship between rainfall amounts and temperature changes, albeit with some level of variance due to the inherent complexity of the data. This level of accuracy reinforces the hypothesis of a negative correlation between rainfall and temperature while also highlighting the utility of neural networks for modeling complex environmental phenomena.

Our experimentation revealed that simpler models or more complex configurations performed less effectively. Minor variability in MSE (between 560 and 570) was observed across multiple runs due to the stochastic nature of training, but the overall trend remained stable. Overall, our results provide strong evidence that cloud seeding-induced rainfall has the potential to reduce temperatures. These findings underscore the dual benefits of cloud seeding in addressing water scarcity and mitigating extreme heat in targeted regions.

The findings of this study reveal a consistent negative correlation between increased rainfall and reduced temperatures, highlighting the dual benefits of cloud seeding in addressing water scarcity and mitigating extreme heat. This aligns with the hypothesis that enhanced rainfall from cloud seeding contributes to cooling effects, making it a potentially transformative tool for regions struggling with both water shortages and high temperatures.

A significant limitation of this study lies in the dataset selection. Our analysis is based solely on data from Tasmania, which raises questions about the generalizability of our findings to other climates—particularly arid regions like the Middle East, which are frequently referenced in this paper. While Tasmania provided a reliable and accessible dataset for initial modeling, it differs substantially in geography, humidity, and seasonal patterns from Middle Eastern regions. A comparative discussion of Tasmania's climate with that of the Middle East could help clarify the potential for generalizing these findings. Future studies should integrate datasets from multiple geographical locations to validate the universality of these results across diverse climatic zones. Compared to previous studies that primarily evaluated the efficiency of cloud seeding in increasing precipitation, this research extends the scope by exploring its secondary effects on temperature—although we acknowledge that this analysis is correlational in nature. This novel perspective provides a more comprehensive understanding of the broader implications of cloud seeding and underscores its potential to address interrelated environmental challenges.

It is important to note that while our study identifies a negative correlation between rainfall and temperature, this does not establish a causal relationship. The analysis does not account for potential confounding variables such as seasonal variation, natural climate patterns, or urban heat island effects, all of which could independently influence temperature trends. Although our study focused on historical trends rather than controlled experimental conditions, future research should incorporate causal inference methods or real-time controlled experiments to isolate the effects of cloud seeding. In the current work, such variables were excluded primarily due to data constraints and the exploratory nature of the study, but we recognize the need for greater control and rigor in subsequent analyses.

Another limitation lies in the use of seasonal average temperature values rather than real-time data. Averaging across long periods may obscure short-term fluctuations and delay effects of rainfall events, potentially diminishing the model's sensitivity to direct seeding outcomes. While this approach was necessary due to data availability, it may limit the precision of temperature predictions. Future studies should incorporate high-resolution temporal data to better capture localized weather effects.

5 Conclusions

This study highlights the dual benefits of cloud seeding, demonstrating its potential to address water scarcity and mitigate extreme temperatures. By analyzing datasets from Tasmania and employing both linear regression and neural network models, we identified a consistent negative correlation between rainfall and temperature. The neural network models, which achieved a mean squared error of 564.3296, further support the reliability of these findings despite certain data limitations.

Our research contributes to a broader understanding of cloud seeding's secondary effects, emphasizing its value not only as a tool for enhancing precipitation but also as a means of addressing heat stress in vulnerable regions. Practically, this research could inform policies and strategies for climate adaptation, particularly in arid and semi-arid environments. For example, countries facing extreme heat and water scarcity might prioritize cloud seeding as part of integrated water resource management programs.

Further research should address the limitations of this study by analyzing datasets from diverse geographic regions with varying climates to evaluate the universality of these findings. Additionally,

advancements in modeling techniques—such as the integration of real-time temperature and rainfall data—could refine predictions and provide deeper insight into the complex dynamics of weather modification.

By demonstrating a link between cloud seeding and temperature change, this research opens a path toward exploring whether sustained use of weather modification could help cool climate-stressed regions over time. This long-term perspective adds a new dimension to existing weather modification strategies, merging water resource management with potential climate mitigation efforts.

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