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Analyzing temperature fluctuations in Khulna: A long-term assessment

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Abstract

The study investigates the temperature fluctuations in Khulna from 2005 to 2024. From the study, it has been found that the maximum temperature in Khulna has risen by 0.306°C over the past 20 years, according to the yearly average maximum temperature changes at the rate of 0.015°C. A notable increase of 0.072°C over the past 20 years was indicated by a 0.0036°C per year increase in annual average minimum temperatures. The annual average minimum temperature ranged from 21.73°C to 22.74°C; remarkably, the highest recorded annual average minimum temperature was 22.74°C in 2016. According to a monthly temperature analysis, January has the lowest mean monthly maximum temperature (25.06°C), and April has the highest (35.31°C). Mean monthly temperature showed both increasing and decreasing trends over the years. These findings highlight the gradual warming trend in Khulna, which could have significant implications for agriculture, water resources, and public health. The rise in temperature may contribute to increased heat stress, changes in crop productivity, and shifts in local ecosystems.

Keywords: Annual, meteorology, Bangladesh, mean, temperature

Introduction

Climate change and variability has emerged as a key concern for environmentally vulnerable countries (FAO 2011). Bangladesh is widely recognized as one of the most climate vulnerable countries in the world (Hossain 2024).Natural disasters strike it frequently, resulting in fatalities, destruction of infrastructure and financial resources, and negative effects on people's lives and means of livelihood, particularly for the poor who reside in isolated or environmentally vulnerable areas of the nation, such as river islands and coastal belts vulnerable to cyclones (MOEF 2008).

One of the world's largest deltas, Khulna is particularly sensitive to climate change because of its extreme weather occurrences, which include storms, cyclones, droughts, floods, and cold spells (Murtaza 2001). Bangladesh's low-lying, flat terrain, high population density, high poverty, dependence on climate-sensitive industries, especially agriculture and fisheries, and ineffective institutional features make it one of the most susceptible nations to damage from climate change (Rahaman and Bari 2024). Sea level rise, increased temperatures, increased monsoon precipitation, and intensified cyclones are some of the predicted negative effects of climate change that will worsen the stresses that already impede Bangladesh's development, especially by lowering food and water security and destroying vital infrastructure. The economy, ecology, national development, and people of Bangladesh may all suffer greatly from these effects (Shahid 2010).

By the final ten years of the twenty-first century, the Intergovernmental Panel on Climate Change (IPCC) predicts that sea levels will have risen by 0.18 to 0.79 meters due to global warming. Despite the fact that polders protect the majority of the region, this could lead to a rise in coastal flooding and salt intrusion into aquifers and rivers along a broad belt in the south of the country (IPCC 2007). The semi-active delta makes up the southwestern portion, sometimes referred to as the Ganges tidal plain, which is crisscrossed by countless streams and canals. Because of its extremely flat and low terrain, this area is highly susceptible.

Temperature, humidity, sunlight hours, rainfall, and other climate characteristics can change across time and space.

Research shows that there are important variations in a number of climatic factors in different parts of the world. The key contributor of global warming is the growth in greenhouse gases in the atmosphere, such as carbon dioxide, methane, and nitrous oxide. These gases function as a blanket to store solar energy's infrared radiation. Heat radiation from stored energy warms the ground surface and the cooler regions of the atmosphere. In their fourth assessment report, the Intergovernmental Panel on Climate Change (IPCC) said that during the 100 years ending in 2005, the global surface temperature rose by 0.74 ± 0.18 °C (IPCC 2007, Zaman *et al.* 2013).

There has been an increased tendency in both summer and winter temperatures (Islam *et al.* 2010). Bangladesh's mean annual maximum temperature is expected to increase by 0.4°C by 2050 and 0.73°C by 2100 (Karmakar *et al.* 2000). The average monthly temperature in Khulna city ranges from 11.4 °C (52.5 °F) to 34.6 °C (94.3 °F) in April, with a yearly average of 26.3 °C (79.3 °F) (Rajib *et al*. 2010).

This study aims to analyze how one of the key climatic variable 'Temperature' fluctuates at the local level in the Khulna district of Bangladesh during (2005-2024). Khulna region is particularly vulnerable to climatic changes, and the effects of climate change are becoming more obvious there. Increasing temperatures in this region is associated with more fluctuating precipitation, more severe weather, and higher humidity, all of which intensify climate-related problems. Significant sea level rise is a result of these climatic changes, which is particularly concerning because it has broad regional implications.

Methodology

This study primarily relies on quantitative data, specifically secondary data obtained from the Bangladesh Meteorological Department (BMD), encompassing temperature records from all meteorological stations in the Khulna from 2005 to 2024. Daily temperature records were processed by calculating monthly average values, which were then aggregated to compute annual mean values. Missing data were addressed by using the mean of surrounding available data, and any detected outliers were removed to maintain data integrity. The temperature trend was analyzed using the Simple Linear Regression (SLR) method, as it provides a straightforward and interpretable approach to identifying long-term trends. The processed data was then visualized on a monthly and annual basis to examine shifting temperature patterns, with Microsoft Excel. The choice of SLR was made due to its simplicity, efficiency, and suitability for detecting linear trends in climate data, whereas more complex models like polynomial regression or machine learning approaches were not used due to the limited scope of this study and the need for interpretability. Additionally, alternative statistical models, such as ARIMA or exponential smoothing, were deemed unnecessary given the focus on long-term trend estimation rather than short-term forecasting. Despite its advantages, this methodology has limitations, including the assumption of a linear trend, potential biases in missing data estimation, and the exclusion of external factors influencing temperature variations. However, these constraints were acknowledged, and the chosen approach remains robust for understanding temperature trends in the Khulna division over the given period.

Results and discussion

Using data collected from Bangladesh Meteorological Department (BMD), Annual Average maximum temperature, minimum temperature and Trend analysis of monthly temperature of Khulna are discussed in the following subsections.

Temporal shifts in mean annual temperatures: The variation in Khulna's mean annual maximum, minimum, and average temperatures between 2005 and 2024 has been analyzed in this segment. The average temperature was 31.54°C, with the mean maximum temperature ranging from 30.86°C to 32.08°C. During 2016 it had the highest recorded maximum temperature (32.08°C), closely followed by 31.94°C during 2009, 31.89°C during 2010 and 31.80°C during 2014. In 2007, the lowest recorded maximum temperature was 30.86°C. However, 2006 (31.68°C), 2009 (31.94°C), 2010 (31.89°C), 2012

(31.64°C), 2014 (31.80°C), 2015 (31.57°C), 2016 (32.08°C), 2017 (31.57°C), 2018 (31.62°C), 2019 (31.61°C), and 2021 (31.76°C) were the years with above-average maximum temperatures. With an average of 22.23°C, the annual average lowest temperature varied between 21.73°C and 22.74°C. During 2016 it had the minimum temperature (22.74°C), closely followed by 22.67°C during_2010 and 22.56°C during_2022. In 2018 minimum temperature was the lowest (21.73°C). The minimum temperatures was observed in 2007 (21.97°C), 2008 (22.21°C), 2011 (21.85°C), and 2012 (22.21°C) were below average. Alternatively, 2005 (22.44°C), 2006 (22.39°C), 2009 (22.41°C), 2010 (22.67°C), 2015 (22.28°C), and 2016 (22.76°C) had below-average minimum temperatures.

Temporal dynamics of maximum, minimum, and average temperatures: Figure 1 shows the correlations between various years and the annual mean maximum, minimum, and average temperatures. Although this increase was not statistically significant, the data show an increased trend in the yearly mean maximum, minimum, and average temperatures. The average annual maximum temperature increased by 0.0153°C, indicating that during the last 20 years, Khulna's maximum temperature has increased by 0.306°C. According to a group study between 1960 and 2015, Khulna's annual maximum temperature rose by 0.008°C per annum (Mondal *et at.* 2017) Similarly, the annual temperature of Bangladesh increased by 0.02°C between 1981 and 2019 (Bosu *et al.* 2020). additionaly, from 1988 to 2017, Sarkar and Chakraborty (2022) found that the mean maximum annual temperature in South 24 Parganas District, West Bengal, India, increased. The mean annual minimum temperature rose by 0.0036°C annually in a similar pattern (Figure 1), meaning that Khulna's minimum temperature rose by 0.072°C during the previous 20 years. The finding is consistent with a study that found that between 1960 and 20015, the mean annul minimum temperature in Khulna

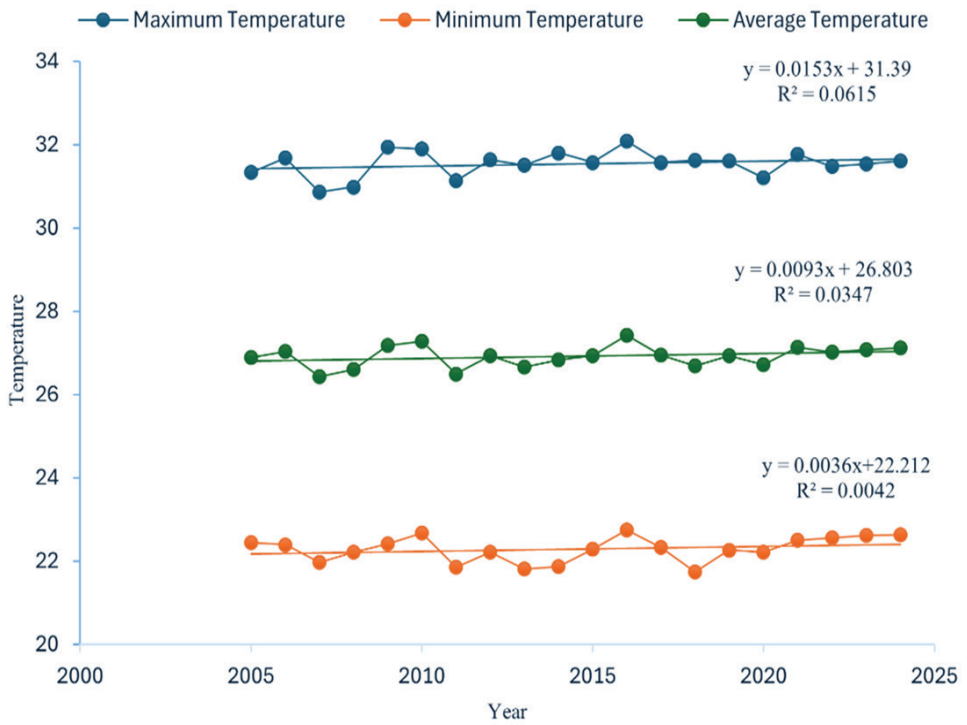

Figure 1. Comparison among maximum, minimum and average temperatures over the period (2005-2024) in Khulna.

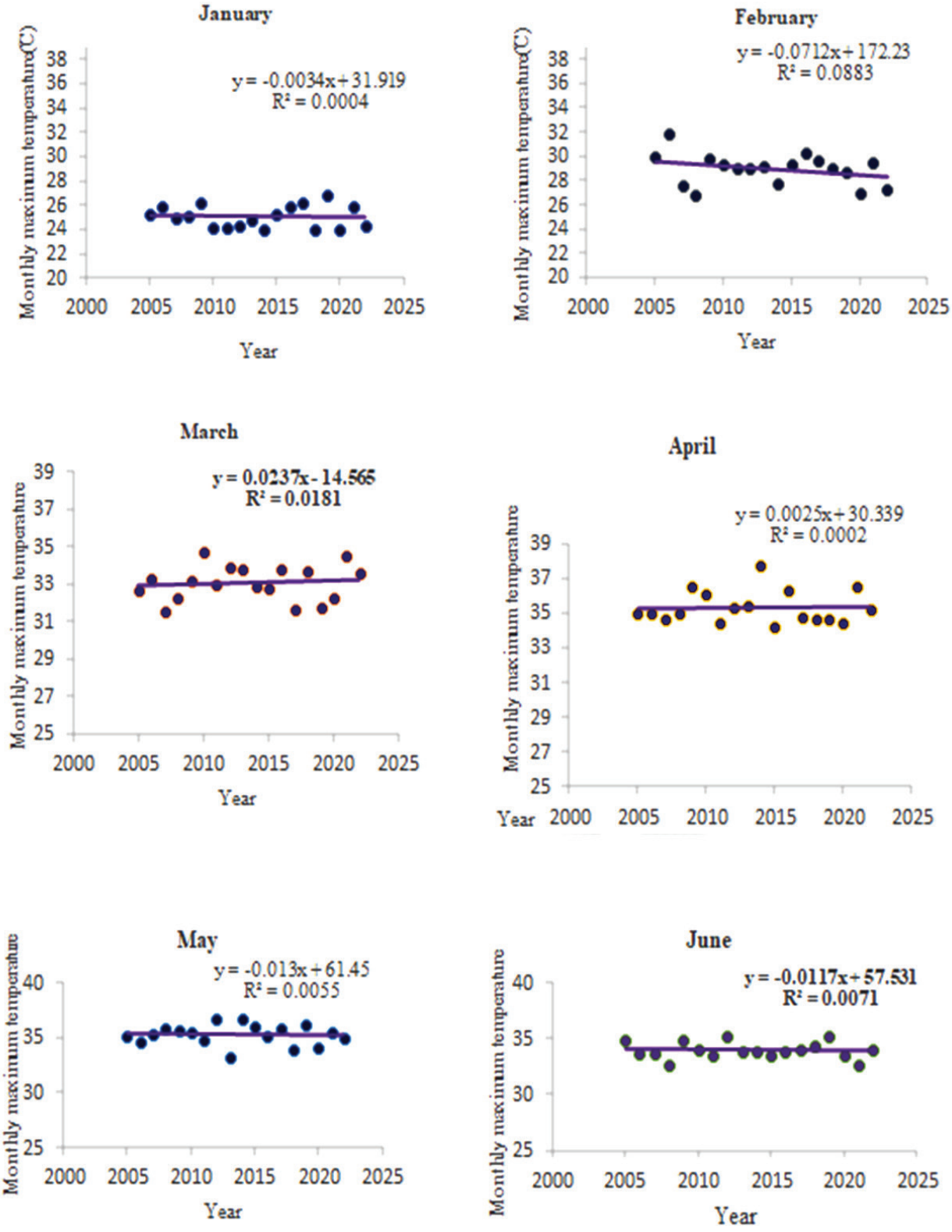

Figure 2(a). Trend analyses of monthly maximum temperatures (January to June) in Khulna.

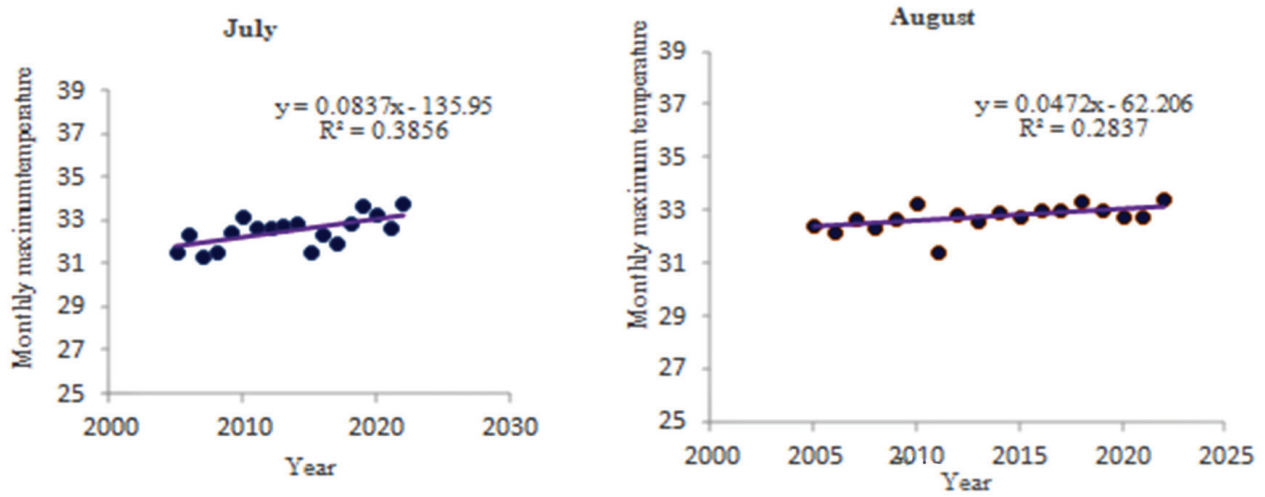

Figure 2(b). Trend analyses of monthly maximum temperatures (July, August) in Khulna.

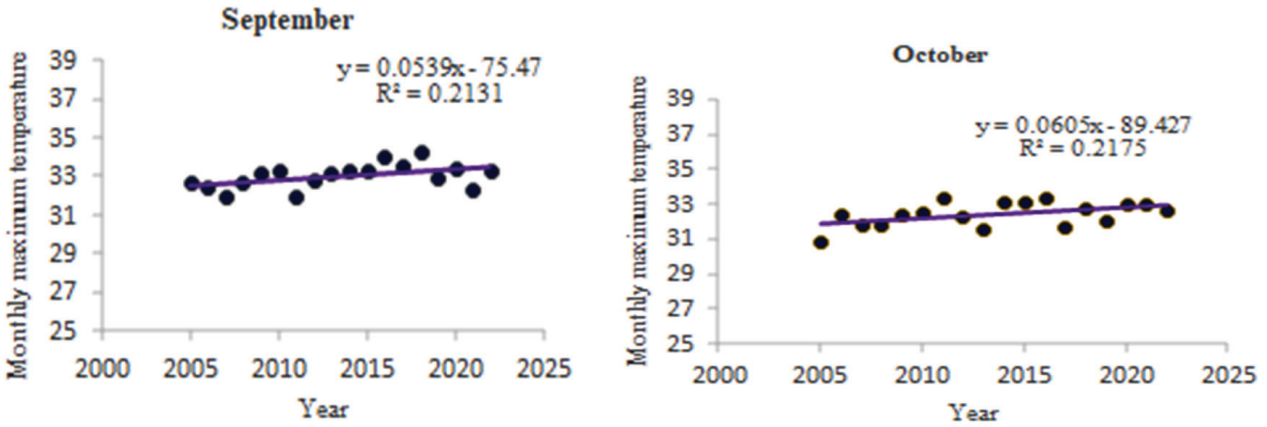

Figure 2(c). analyses of monthly maximum temperature (September, October) in Khulna.

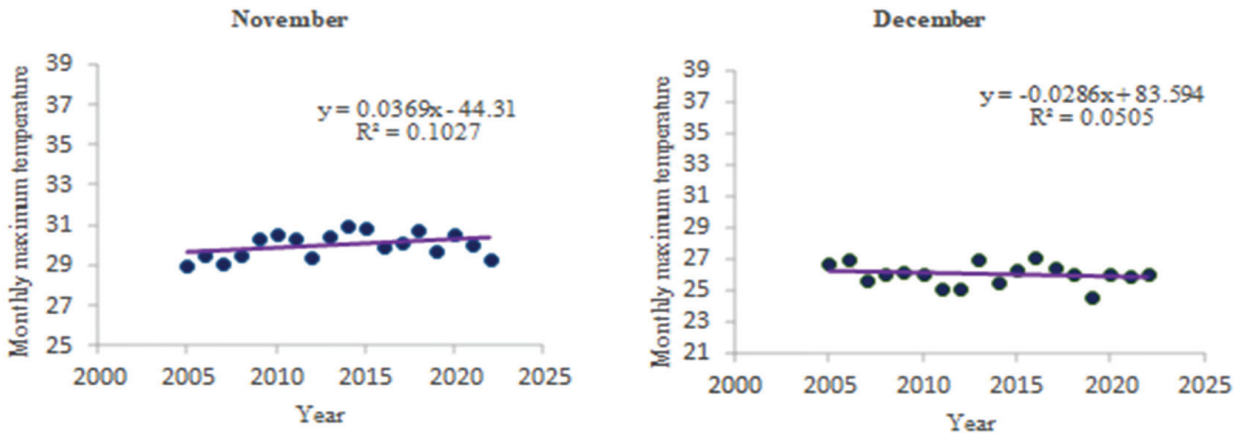

Figure 2(d). Trend analyses of monthly maximum temperatures (November, December) in Khulna.

district increased by 0.002°C per year (Mondal *et al.* 2017).

Temperature trends and variability: Trend analysis of monthly temperature of Khulna are discussed in the following subsections.

Fluctuations in monthly maximum temperatures: Insights into Khulna's temperature distribution have been gained over time through an analysis of monthly maximum temperature data shows that at 35.31°C, April has the greatest mean monthly maximum temperature, while January has the lowest (25.06°C). According to Singh *et al.* (2018), these results are in good agreement with those who reported that May is the warmest month in India's Haryana state, with an average monthly maximum temperature of over 40°C, while January is the coolest month, with an average monthly maximum temperature of about 20°C. Furthermore, the peak temperatures in May (35.29°C) are strikingly similar. Furthermore, a team of researchers documented comparable monthly high temperatures in Bangladesh in December (26.04°C) and February (28.94°C) (Bosu *et al*. 2020). In Khulna district, the mean monthly maximum temperature standard deviation (SD) was highest in February (1.28°C) and lowest in August (0.47°C), suggesting that February saw more unpredictability in temperature and August had more consistency

Fluctuations in monthly minimum temperatures: It is observed that January had the lowest mean minimum temperature (13.11°C), while June had the highest (26.81°C). These results are in line with research showing that January has the lowest average temperature, at around 13°C, and July has the highest average minimum temperature, at about 27°C (Jahan MS *et al*., 2024). Additionally, the data indicates that the mean lowest temperatures in June (26.81°C), July (26.63°C), August (26.65°C), and September (26.34°C) were closely clustered. Conversely, January (13.11°C), February (16.36°C), and December (14.96°C) saw cooler temperatures. These results align with those that documented comparable monthly minimum temperature trends in Bangladesh (Bosu *et al*. 2020). There was more variability in February and more stability in August, as evidenced by the SD for Khulna's mean monthly minimum temperature, which peaked in February at 1.22°C and fell to 0.29°C in August .

Trend analysis of mean monthly temperature: Simple linear regression has been used to look into trends in monthly mean maximum temperatures across time. From January through December, Figures 2(a), 2(b), 2(c), 2(d) display the regression equations and coefficients of determination for each month. These results show that there was no obvious trend in the monthly mean maximum temperatures throughout time, with both fluctuating tendencies noted. With the exception of January, February, May, June, and December, when a decrease was observed, the mean monthly maximum temperature rose in every month. The data also shows that different years accounted for almost 38% of the variation in the mean monthly maximum temperature for July. The progression of the years, however, was shown to account for about 28% of the fluctuation in the mean monthly maximum temperature for August. These results align with those of (Mondal *et al*. 2017), who likewise found no changes in the Khulna district's average maximum temperatures over time.

Conclusion

The study attempted to depict the current trend in temperature of Khulna region for the period of 2005-2024. The region has experienced an annual average maximum temperature of 0.306°C and an annual average minimum temperature of 0.072°C hike during the last 20 years. The month of April has the highest mean monthly maximum temperature of 35.31°C while January has been observed as the lowest. The implications of this study are significant for understanding climate trends and informing policy decisions. By analyzing temperature data over nearly two decades, the study provides insights into long-term temperature variations in the Khulna region, which can help in assessing climate change impacts in the

region. The findings can aid policymakers, environmental researchers, and urban planners in developing climate adaptation strategies, mitigating potential risks related to rising temperatures, and enhancing resilience in agriculture, public health, and infrastructure planning. Additionally, the methodology used can serve as a framework for similar studies in other regions, contributing to a broader understanding of temperature trends and their potential consequences. However, given the limitations in data handling and model assumptions, further studies incorporating more advanced statistical models and additional climate variables are recommended to enhance accuracy and depth of analysis.

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