Analysis of Trend in Maximum and Minimum Surface Air Temperature in Medinipur Division of West Bengal, India

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ABSTRACT

The main objective of this study is to examine the trends in mean monthly and mean annual minimum and maximum air temperature in all the five districts of Medinipur Division, West Bengal. To accomplish this, the study utilizes the IMD gridded daily minimum temperature data available at grid resolution of 1°x1° in binary format from the official India Meteorological Department (IMD) Pune website. The study area encompasses 16 grid points and for each point the concerned parameters were analysed for the period between 1951 and 2020 by using Mann-Kendall test and the trend magnitude was measured by Sen's slope estimator.

The results of maximum air temperature show that for monsoon and post-monsoon months, the dominant warming effect is experienced ($p < 0.05$, α=0.05, $n = 70$) across all districts with exception in a few pockets, whereas significant cooling tendency is noticeable at same significance level for winter and pre-monsoon months, particularly during December-January and April-May. This conflicting temperature trends in two different seasons makes the annual mean maximum series trendless. In case of minimum air temperature, a cooling effect is dominant in the summer months across all the districts. Significant warming tendency is noticeable in the monsoon and post monsoon particularly during July to September and November. Annual mean minimum series shows an overall increasing trend. However the warming rate (0.008^{0}C to 0.895^{0}C per year) is likely to be higher than the cooling rate (0.010^{0}C to 0.723^{0}C per year).

Keywords: *Trend analysis; Surface air temperature; Mann-Kendall test; Sen's slope estimate.*

INTRODUCTION

Medinipur Division has been adopted as the study area for the proposed research because the region is characterized by a tropical climate with a monsoon weather pattern. According to census of 2011 the total population of Medinipur division is 18,672,669. Medinipur Division is one of the 5 divisions in the Indian state of West Bengal. It is the westernmost division of West Bengal. It spreads over an area of 27,223 km² covering 5 districts namely Purba Mednipur, Paschim Medinipur, Jhargram, Bankura, Puruliya district.

Climate change is one of the most pressing issues of our time, with rising temperatures having far-reaching consequences for ecosystems, biodiversity, and human societies. The Medinipur division of West Bengal, India, is a densely populated region with a fragile ecosystem, making it highly vulnerable to climate change impacts. It is experiencing significant climate variability, with temperature trends showing a marked increase in recent decades. This study investigates the trends in maximum and minimum surface temperature in the Medinipur division, with a focus on understanding the underlying climate drivers and implications for regional climate resilience. Global climate change has led to significant variations in temperature trends worldwide. This study aims to investigate long-term trends in maximum and minimum temperatures using historical data from 1951 to 2020. The study employs the Mann-Kendall test to determine statistically significant trends and their seasonal variations.

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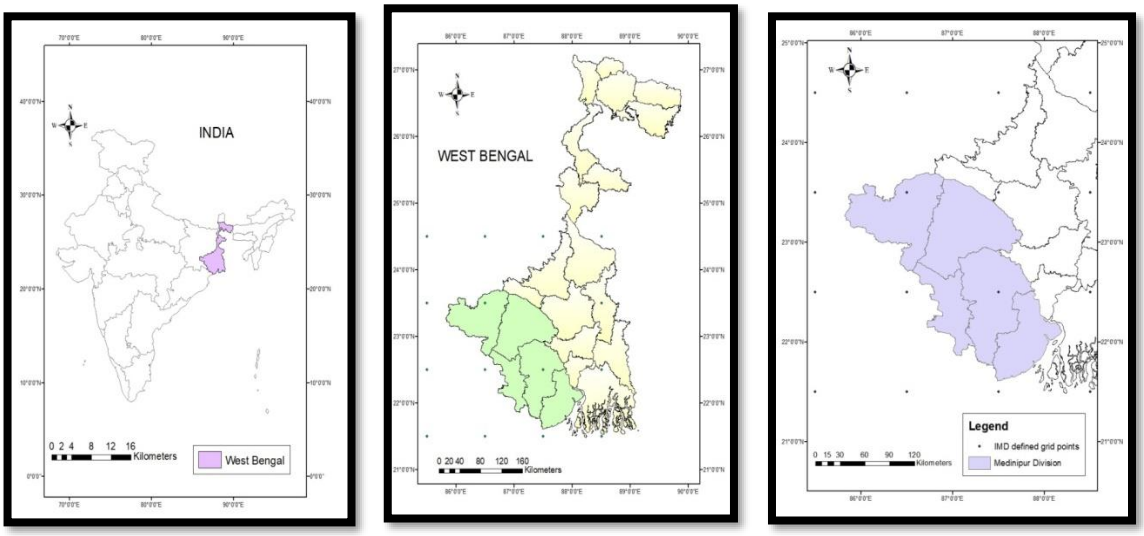


Fig 1: Study area.

LITERATURE REVIEW

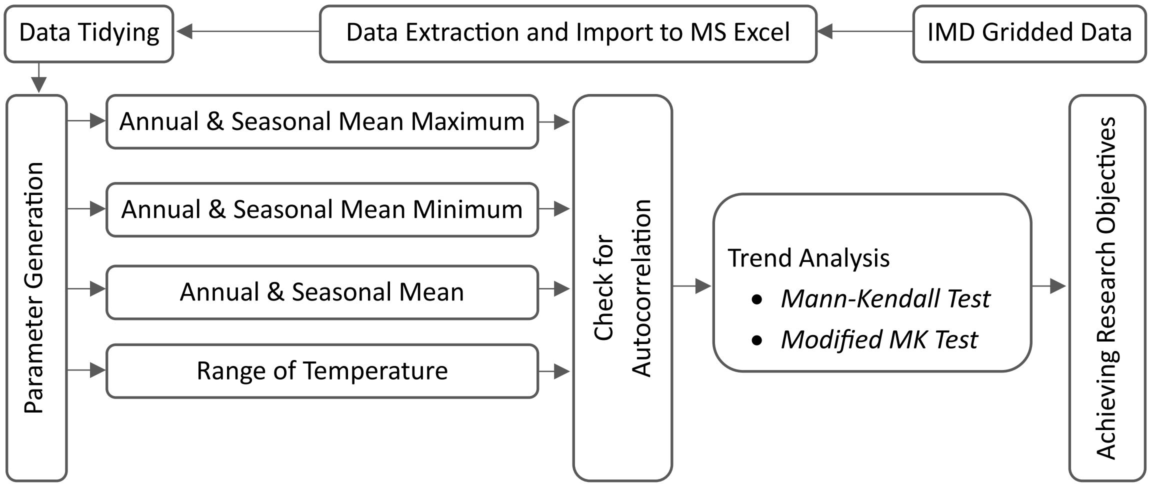
India's surface air temperature has shown a significant rising trend, consistent with global warming patterns. Research by Kumar et al. (2019) revealed a substantial increase in maximum and minimum temperatures across India between 1969 and 2018. Similarly, Sen Roy et al. (2017) observed notable warming trends in India's temperature patterns, particularly during winter. Jaswal et al. (2015) also detected rising temperature trends in the Indian subcontinent, attributing this phenomenon to escalating greenhouse gas and aerosol concentrations.

Regional investigations have corroborated these findings, reporting substantial warming trends in India's temperature. Kumar (2018) analyzed temperature patterns in the Indo-Gangetic Plains, uncovering significant rises in maximum and minimum temperatures. Sen (2015) observed similar trends in eastern India, linking them to urbanization and industrialization.

These warming trends align with projected climate change scenarios for the Indian subcontinent (IPCC, 2013). The consequences of these trends are far-reaching, impacting sectors such as agriculture, water resources, and human health (NOAA, 2020). Ongoing monitoring and analysis of India's temperature trends are crucial for understanding climate change's implications and developing effective mitigation and adaptation strategies.

MATERIALS AND METHODS

The present investigation uses IMD gridded temperature data available in daily time step for maximum and minimum temperature with the grid point resolution of 1^0 x 1^0 for the whole country in binary file format (A. K. Srivastava et al., 2009). After extraction to MS Excel Spreadsheet (2019) and necessary tidying the spatial interpolation of both daily maximum and daily minimum time series have been computed for the Medinipur Division.



Mann-Kendall test (Kendall,1975; Mann,1945) along with Sen's non-parametric estimator of slope (Sen, 1968) has been used for capturing the trend in the time series while Modified Mann-Kendall test has been applied whenever autocorrelation has been detected in the time series (Hipel & McLeod, 1994; Jain et al., 2012). So, autocorrelation of the series has been checked and properly taken care.

Trend simply refers to tendency of any response variable to increase or decrease gradually over time. In the present study Mann-Kendall trend test has been used whenever autocorrelation is detected in the time series, otherwise Modified Mann-Kendall Trend Test has been applied.

Mann-Kendall Trend Test

Mann-Kendall Trend Test is in fact a special case of Kendall rank correlation test (Hipel & McLeod, 1994). This test was introduced by Hirsch et al. (1982) based on the original work of Mann (1945) and Kendall (1975) (Hirsch et al., 1982; Kendall, 1975; Mann, 1945). Mann (1945) first presented a non-parametric test for randomness against time which constitutes a particular application of Kendall's test for rank correlation (Kendall, 1975) commonly known as the Mann-Kendall Trend Test or the Kendall *t* test (Hipel & McLeod, 1994). It was directly analogous to significance test for simple linear regression and not only that it was also analogous to significance test for Pearson's product moment correlation co-efficient, *r* (Helsel & Hirsch, 2002).

Null hypothesis, H_0, states that the data come from a population where the random variables are independent and identically distributed. The alternative hypothesis, H_1, is that the data follow a monotonic trend over time (Hipel & McLeod, 1994). Under H_0, the Mann-Kendall test statistic is defined as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \text{, Where, } \operatorname{sgn}(\theta) = \begin{pmatrix} +1 & if & \theta > 0 \\ 0 & if & \theta = 0 \\ -1 & if & \theta < 0 \end{pmatrix} \text{.... } \textit{Equation 1}$$

Here $\operatorname{sgn}(\theta)$ is the sign function. Kendall (1975) showed that for large sample (where sample size is greater than 10), *S* follows the normal distribution with zero mean and standard deviation as shown below:

$$Var(S) = [n(n-1)(2n+5) - \sum_{j=1}^{P} t_j(t_j - 1)(2t_j + 5)] / 18 \text{.... } \textit{Equation 2}$$

Here, *P* is the number of tied groups in the data set and t_j is the number of data points in the j^{th} tied group. If there is no tied data the formula for estimating the variance of *S* is reduced to $[n(n-1)(2n+5)]$. The exact distribution of *S* was derived by both Mann (1945) and Kendall (1975) for small sample size (for sample size, $n \le 10$) and for large sample the normal distribution is used as sampling distribution (Hipel & McLeod, 1994) to test the significance of statistic *S*. The test statistic Z is defined as follows:

$$Z = \begin{pmatrix} \frac{S-1}{[Var(S)]^{1/2}} & if & S > 0 \\ 0 & if & S = 0 \\ \frac{S+1}{[Var(S)]^{1/2}} & if & S > 0 \end{pmatrix} \text{..................... } \textit{Equation 3}$$

The significance is judged in the same way as usually done for *z*-Test. A positive value of *S* indicates an ‘upward trend’ (increasing values with time), and a negative value of *S* indicates a ‘downward trend’ (Hirsch et al., 1982). The magnitude of the trend can be estimated by Sen’s Slope Estimator which was introduced by P.K. Sen in 1968 (Sen, 1968). Sen’s slope, denoted here by β_i is defined (Patakamuri et al., 2020) as follows:

$$\beta_i = \frac{x_j - x_k}{j - k} \text{ .... } \textit{Equation 4}$$

For all $k \le j$, and $i = 1, 2, ..., N$

Median value of Sen’s slope is taken as the magnitude of trend (Patakamuri et al., 2020). It can further be mentioned that the statistic *S*, as elaborated by Hipel & McLeod (1994), is actually a count of the number of times x_j exceeds x_k, for j >*k*. The maximum possible value of *S* is observed if the series follows the sequence of $X_1 < X_2 < \ldots, < X_n$. If *D* is that maximum possible value of *S*, Kendall’s τ is related to *S* in the following way:

$$\tau = \frac{S}{D} \text{ .... } \textit{Equation 5}$$

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{P} t_j(t_j - 1)\right]^{1/2} \left[\frac{1}{2}n(n-1)\right]^{1/2} \text{ .... } \textit{Equation 6}$$

If there is no tied value the formulae for computing *D* is reduced as shown below:

$$D = \frac{1}{2}n(n-1) \text{ .... } \textit{Equation 7}$$

Due to the relationship between τ and *S*, the distribution of τ can be easily obtained from the distribution of *S*. Hipel & McLeod (1994) further stated that if there are no ties in the data, the algorithm of Best & Gipps (1974) can be employed to obtain the exact upper tail probabilities of Kendall's τ or equivalently *S*, for $n \ge 2$.

Modified Mann-Kendall Trend Test

Modified Mann-Kendall trend test is applied when there is autocorrelation in the dataset, because in such a case, presence of positive autocorrelation in the data causes increase in the probability of capturing the trends when actually none exist and vice-versa (Hamed & ramachandra Rao, 1998).

To overcome this limitation, modification has been made in the variance of test statistic of original Mann-Kendall trend test and such modified form of variance (Hamed & ramachandra Rao, 1998) is as follows:

$$\boldsymbol{V^*(S) = var(S) * \frac{n}{n_s^*}} \text{..............................} \textit{Equation 8}$$

$$\boldsymbol{\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} * \sum_{i=1}^{n-1}(n-i)(n-i-1)(n-i-2)\rho_s(i)} \text{.....} \textit{ Equation 9}$$

In the above equations, n/n_s^* is a correction factor due to autocorrelation in the data, n is the actual number of observations and $\rho_s(i)$ is the autocorrelation function of the ranks of the observations (Hamed & ramachandra Rao, 1998; Patakamuri & O'Brien, 2020).

With this change in original formulae the test does not lose its power when it is applied on to auto correlated time series and that is why Modified Mann-Kendall is preferred over the original one for auto correlated data. Here, in the present research, the data has been checked for autocorrelation and accordingly the trend test tool has been selected for capturing the temperature trend over time.

The dataset consists of temperature records from various stations, analyzed for monthly trends. The Mann-Kendall test is applied to detect non-parametric trends, categorizing results into increasing, decreasing, or no significant trend. This test is particularly useful for climate trend analysis as it does not assume a normal distribution and effectively identifies monotonic trends in long-term datasets. According to the India Meteorological Department (IMD), India has four official seasons and the temperature data was categorized seasonally into:

- Winter (December-February)
- Summer or Pre- Monsoon (March-May)
- Monsoon(June- September)
- Post- Monsoon or Autumn (October-November)

Each seasonal category was analyzed separately to determine if temperature variations exhibited a consistent pattern across different seasons. The seasonal analysis helps in understanding whether warming trends are more pronounced during certain times of the year and their potential link to climate drivers such as monsoon variations, urban heat islands, and greenhouse gas emissions.

RESULT AND DISCUSSION

The present study utilizes daily minimum temperature data from the Indian Meteorological Department (IMD), Pune, at a 1°x1° grid resolution, spanning the period 1951-2020. A total of 16 grid points encompass the study area, and trend analysis was performed using the Mann-Kendall test, while Sen's slope estimator was employed to determine the magnitude of the trends.

Table 1: Trend analysis of the monthly maximum temperature time series data using the Mann-Kendall test.

Station		Summer			Monsoon				Post-Monsoon		Winter		
Lat	Lon	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
21.5	85.5	-	-	-	-	↑	↑	↑	↑	↑	-	-	-
21.5	86.5	-	-	-	-	↑	↑	↑	↑	↑	-	-	-
21.5	87.5	-	-	-	-	↑	↑	↑	↑	↑	-	↓	-
21.5	88.5	-	-	-	-	↑	↑	↑	↑	↑	-	↓	-
22.5	85.5	↑	-	-	-	↑	↑	↑	↑	↑	-	-	-
22.5	86.5	-	-	↓	-	↑	↑	↑	-	↑	-	↓	-
22.5	87.5	-	-	↓	-	↑	↑	↑	↑	-	↓	↓	-
22.5	88.5	-	-	-	-	↑	↑	↑	↑	↑	↓	↓	-
23.5	85.5	-	-	↓	-	-	↑	↑	-	↑		-	-
23.5	86.5	-	-	↓	-	-	↑	↑	-	-	↓	↓	-

23.5	87.5	-	↓	↓	-	↑	↑	↑	-	-	↓	↓	-
23.5	88.5	-	↓	↓	-	↑	↑	↑	-	-	↓	↓	-
24.5	85.5	-		↓	-	↑	↑	↑	-	↑		↓	-
24.5	86.5	-	↓	↓	-	↑	↑	↑	-		↓	↓	-
24.5	87.5	-	↓	↓	-	↑		↑		↑	↓	↓	-
24.5	88.5	-	↓		-	↑	↑	↑	↑	↑		↓	-

Where, (↑) shows increasing trend; (↓) shows decreasing trend; (-) shows no trend.

This study's trend analysis reveals intriguing patterns in temperature fluctuations across different months. Notably, a decreasing temperature trend is observed in April and May, which is consistent with the findings of previous studies (e.g., Kumar et al., 2017). This decrease may be attributed to the onset of summer, leading to increased evapotranspiration and cloud cover, thereby cooling the atmosphere.

In contrast, the monsoon months of July, August, and September exhibit an increasing temperature trend. This phenomenon can be explained by the warming effect of the Indian Ocean Dipole (IOD) during the monsoon season (Saji et al., 1999). The IOD's positive phase is characterized by warmer sea surface temperatures in the Indian Ocean, leading to increased atmospheric temperatures over the Indian subcontinent.

The post-monsoon months of October and November also display an increasing temperature trend. This may be due to the withdrawal of the monsoon, resulting in decreased cloud cover and increased solar radiation, leading to warmer temperatures (Rao et al., 2010).

Finally, the winter months exhibit a decreasing temperature trend, which is consistent with the typical winter cooling pattern observed in the region (Kumar et al., 2013).

Table 2: Trend analysis of the monthly minimum temperature time series data using the Mann-Kendall test.

Station		Summer			Monsoon				Post-Monsoon		Winter		
Lat	Lon	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
21.5	85.5	-	-	↓	-	-	-	-	↑	-	-	-	-
21.5	86.5	-	-	↓	-	-	-	-	↑	-	-	-	-
21.5	87.5	-	-		-	-	-	-	↑	↑	-	-	-
21.5	88.5	-	-	↓	-	-	-	-	↑	↑	-	-	-
22.5	85.5	-	-	↓	-	-	-	-	↑	-	-	-	-
22.5	86.5	-	-	↓	-	-	-	-	-	-	-	-	-
22.5	87.5	-	-	-	-	↑	↑	↑	↑	↑	-	-	-
22.5	88.5	-	-	-	-	↑	↑	↑	↑	↑	-	-	-
23.5	85.5	-	-	↓	-	-	-	-	-	-	-	-	-
23.5	86.5	-	-	↓	-	↑	↑	↑	-	↑	-	-	-
23.5	87.5	-	-	-	-	↑	↑	↑	-	↑	-	-	-
23.5	88.5	-	-	-	-	↑	↑	↑	-	↑	↑	-	-
24.5	85.5	-	-	↓	-	-	-	-	-	-	-	↓	-
24.5	86.5	-	-	↓	-	-	-	-	-	↑	-	-	-
24.5	87.5	↑	-	-	-	↑	↑	↑	-	↑	↑	-	↓
24.5	88.5	-	-	-	↑	↑	↑	↑	↑	↑	-	-	-

Where, (↑) shows increasing trend; (↓) shows decreasing trend; (-) shows no trend.

The trend analysis of minimum temperature time series using the Mann-Kendall test reveals intriguing patterns in temperature fluctuations across different months. Notably, a decreasing temperature trend is observed in May, which is unusual given that May is typically a hot summer month in the region. This decrease may be attributed to the increased cloud cover and precipitation during the pre-monsoon season, which can lead to cooler night time temperatures (Rao et al., 2010). In contrast, the monsoon months of July, August, and September exhibit a gradual increasing trend in minimum temperature, consistent with the warming effect of the Indian Ocean Dipole (IOD) during the monsoon season (Saji et al., 1999).

The post-monsoon months of October and November also display an increasing trend in minimum temperature, which may be due to the withdrawal of the monsoon, resulting in decreased cloud cover and increased solar radiation, leading to warmer temperatures (Guhathakurta et al., 2015). Interestingly, the trend analysis also reveals that in December, which is typically a cold winter month, the minimum temperature increases in a few places. This may be attributed to the urban heat island effect, where urban areas tend to be warmer than surrounding rural areas due to the concentration of heat-absorbing surfaces and human activities (Shastri et al., 2017).

Table 3: Sen's Slope of maximum temperature (°C)

Station		Summer			Monsoon				Post-Monsoon		Winter		
Lat	Lon	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
21.5	85.5	-0.001	-0.009	-0.016	-0.007	-0.004	-0.004	-0.003	-0.003	0.011	-0.001	-0.008	0.000
21.5	86.5	0.003	-0.006	-0.012	0.000	0.002	0.000	0.001	-0.002	0.013	0.002	-0.009	0.000
21.5	87.5	0.005	-0.002	-0.008	0.003	0.005	0.003	0.003	0.001	0.015	0.005	-0.008	0.004
21.5	88.5	0.005	-0.002	-0.009	0.004	0.005	0.003	0.004	0.002	0.015	0.006	-0.008	0.004
22.5	85.5	0.000	-0.010	-0.018	-0.010	-0.002	-0.003	-0.003	-0.005	0.013	0.000	-0.010	0.000
22.5	86.5	0.000	-0.007	-0.013	0.000	0.003	0.002	0.003	-0.001	0.013	0.000	-0.012	0.002
22.5	87.5	0.011	0.000	-0.004	0.007	0.009	0.007	0.008	0.006	0.020	0.008	-0.006	0.009
22.5	88.5	0.011	0.000	-0.004	0.007	0.009	0.007	0.008	0.006	0.020	0.008	-0.006	0.009
23.5	85.5	0.001	-0.007	-0.016	-0.006	0.002	0.003	0.002	-0.003	0.015	0.003	-0.013	0.003
23.5	86.5	0.004	-0.005	-0.012	0.001	0.007	0.006	0.006	0.002	0.017	0.005	-0.010	0.008
23.5	87.5	0.008	-0.002	-0.009	0.004	0.007	0.006	0.007	0.005	0.020	0.008	-0.008	0.010
23.5	88.5	0.011	0.001	-0.005	0.007	0.009	0.008	0.009	0.008	0.021	0.011	-0.007	0.011
24.5	85.5	0.003	-0.006	-0.018	-0.009	-0.002	-0.002	-0.002	-0.003	0.013	0.004	-0.015	0.006
24.5	86.5	0.008	-0.004	-0.013	-0.001	0.005	0.006	0.006	0.004	0.017	0.007	-0.012	0.010
24.5	87.5	0.016	0.002	-0.008	0.004	0.009	0.008	0.008	0.010	0.019	0.012	-0.006	0.014
24.5	88.5	0.012	0.002	-0.003	0.009	0.013	0.010	0.009	0.008	0.014	0.008	-0.008	0.009

Maximum Temperature Trends:

- Summer: -0.0032°C per year (slight cooling)
- Monsoon: +0.0187°C per year (moderate warming)
- Post- Monsoon: -0.0491°C per year (significant cooling)
- Winter: +0.0040°C per year (slight warming)
- Annual Trend: -0.0074°C per year (overall cooling)

Table 4: Sen's Slope of minimum temperature (°C)

Station		Summer			Monsoon				Post-Monsoon		Winter		
Lat	Lon	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
21.5	85.5	-0.001	-0.009	-0.016	-0.007	-0.004	-0.004	-0.003	-0.003	0.011	-0.001	-0.008	0.000
21.5	86.5	0.003	-0.006	-0.012	0.000	0.002	0.000	0.001	-0.002	0.013	0.002	-0.009	0.000
21.5	87.5	0.005	-0.002	-0.008	0.003	0.005	0.003	0.003	0.001	0.015	0.005	-0.008	0.004
21.5	88.5	0.005	-0.002	-0.009	0.004	0.005	0.003	0.004	0.002	0.015	0.006	-0.008	0.004
22.5	85.5	0.000	-0.010	-0.018	-0.010	-0.002	-0.003	-0.003	-0.005	0.013	0.000	-0.010	0.000
22.5	86.5	0.000	-0.007	-0.013	0.000	0.003	0.002	0.003	-0.001	0.013	0.000	-0.012	0.002
22.5	87.5	0.011	0.000	-0.004	0.007	0.009	0.007	0.008	0.006	0.020	0.008	-0.006	0.009
22.5	88.5	0.011	0.000	-0.004	0.007	0.009	0.007	0.008	0.006	0.020	0.008	-0.006	0.009
23.5	85.5	0.001	-0.007	-0.016	-0.006	0.002	0.003	0.002	-0.003	0.015	0.003	-0.013	0.003
23.5	86.5	0.004	-0.005	-0.012	0.001	0.007	0.006	0.006	0.002	0.017	0.005	-0.010	0.008
23.5	87.5	0.008	-0.002	-0.009	0.004	0.007	0.006	0.007	0.005	0.020	0.008	-0.008	0.010
23.5	88.5	0.011	0.001	-0.005	0.007	0.009	0.008	0.009	0.008	0.021	0.011	-0.007	0.011
24.5	85.5	0.003	-0.006	-0.018	-0.009	-0.002	-0.002	-0.002	-0.003	0.013	0.004	-0.015	0.006
24.5	86.5	0.008	-0.004	-0.013	-0.001	0.005	0.006	0.006	0.004	0.017	0.007	-0.012	0.010
24.5	87.5	0.016	0.002	-0.008	0.004	0.009	0.008	0.008	0.010	0.019	0.012	-0.006	0.014
24.5	88.5	0.012	0.002	-0.003	0.009	0.013	0.010	0.009	0.008	0.014	0.008	-0.008	0.009

Minimum Temperature Trends:

- Summer: +0.0033°C per year (slight warming)
- Monsoon: +0.0020°C per year (slight warming)
- Post- Monsoon: +0.0038°C per year (slight warming)
- Winter: +0.000048°C per year (negligible change)
- Annual Trend: +0.0023°C per year (overall warming)

Maximum temperatures are cooling overall, particularly in autumn. Spring and winter show slight warming trends in maximum temperatures. Minimum temperatures are consistently warming across all seasons, though at a low rate. The contrast between cooling maximum temperatures and warming minimum temperatures may indicate changes in atmospheric circulation, cloud cover, or increased night-time warming due to climate shifts.

Table 5: Average rate of temperature change (°C)

Season	Max Temp Change (°C/year)	Min Temp Change (°C/year)
Summer	-0.0032	+0.0033
Spring	+0.0187	+0.0020
Autumn	-0.0491	+0.0038
Winter	+0.0040	+0.000048
Annual	-0.0074	+0.0023

Interpretation:

- Warming Trends: Minimum temperatures are increasing across all seasons, with the highest rise in autumn.
- Cooling Trends: Maximum temperatures show a strong cooling trend in autumn, while summer shows slight cooling.
- Overall Annual Trend: Maximum temperatures are cooling (-0.0074°C per year), while minimum temperatures are warming (+0.0023°C per year).

Average Rate of Temperature Increase and Decrease (°C per year)

- Maximum Temperature:
  - Average Warming Rate: +0.0332°C per year
  - Average Cooling Rate: -0.0529°C per year
- Minimum Temperature:
  - Average Warming Rate: +0.0070°C per year
  - Average Cooling Rate: -0.0062°C per year

Maximum temperatures show a stronger cooling trend (-0.0529°C per year) compared to the warming trend (+0.0332°C per year). Minimum temperatures exhibit a more balanced trend, with a slightly higher warming rate (+0.0070°C per year) than the cooling rate (-0.0062°C per year). Overall, maximum temperatures are cooling more rapidly, while minimum temperatures are showing a slow but steady warming trend.

The observed cooling trend in maximum temperatures and warming trend in minimum temperatures can be attributed to several climatic and environmental factors, including aerosols, land-use changes, and greenhouse gas emissions.

1. Aerosol and Particulate Matter Effects on Maximum Temperatures

Industrial emissions and biomass burning increase atmospheric aerosols, which reflect solar radiation and reduce daytime heating. Studies have shown that sulphate aerosols contribute to localized cooling by decreasing the amount of solar energy reaching the surface (Ramanathan et al., 2001; IPCC, 2021).

2. Urban Heat Island (UHI) Effect on Minimum Temperatures

Urbanization leads to increased night-time temperatures due to the retention of heat by concrete and asphalt surfaces. The Urban Heat Island (UHI) effect causes a slower release of heat at night, resulting in higher minimum temperatures (Oke, 1982; Stewart & Oke, 2012).

3. Land Use and Land Cover (LULC) Changes

Deforestation, agricultural expansion, and irrigation alter regional temperature patterns. Increased irrigation leads to enhanced evaporative cooling, which can suppress maximum temperatures, while reduced vegetation impacts surface heat exchange (Bonan, 2008; Pielke et al., 2011).

4. Changes in Cloud Cover and Radiation Balance

Cloud cover plays a dual role—reducing daytime heating while trapping outgoing longwave radiation at night. This effect contributes to a cooling trend in maximum temperatures and a warming trend in minimum temperatures, particularly in humid and monsoon-influenced regions (Trenberth et al., 2009; Dai et al., 1999).

5. Greenhouse Gas-Induced Climate Change

The continuous rise in greenhouse gases such as CO_2 and CH_4 enhances heat retention in the lower atmosphere. While global warming is expected to increase overall temperatures, regional factors such as cloud cover and aerosols may suppress maximum temperatures while increasing nighttime temperatures (IPCC, 2014; Hansen et al., 2010).

6. Atmospheric Circulation and Monsoonal Variability

Shifts in atmospheric circulation patterns, such as weakening monsoons, can influence temperature trends by altering moisture availability and cloud dynamics (Krishnan et al., 2016; Rajeevan et al., 2008)

CONCLUSION

The study provides evidence of a warming trend in maximum temperatures, especially in the latter part of the year. While minimum temperatures show less variation, their increasing trends in certain months suggest a gradual shift in night-time temperature stability. Future research should explore the correlation between these trends and regional climate drivers, such as urbanization and greenhouse gas emissions.

The investigation involves the study of climate variability in Medinipur Division. The results which will be generated could be used as related document for making urban environmental plan specific to Medinipur Division. The study can help in articulating the mitigation strategy through which the effect of global warming can be reduced.

In spite of this, the current study is on a regional scale, so it may mask any local problem with a special character if they exist.

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