Analysis of Historical Average Temperature at Ranchi, Jharkhand

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Abstract: ***The study examines the trends and variability of average temperatures in Ranchi, Jharkhand, over the period 1973-2022. Results indicate a 1.96% annual temperature variability, with summer being the hottest season and winter the coldest. A significant upward trend is observed in August temperatures, whereas most other months show no significant trends. These findings provide valuable insights into local climate dynamics, essential for regional planning.***

Keywords: Average temperature, Trend analysis, Variability, Climate change, Ranchi

1. Introduction

Basic climate indicators, such as air temperature and precipitation, can have a significant impact on ecosystems and human life. For instance, rising air temperatures may result in more severe and potentially fatal heat waves, especially for susceptible groups. Since pre-industrial times, the average worldwide temperature has increased by around 1°C. The amount and rate of warming are too large to be explained just by differences in nature; human activity changes must also be taken into consideration. Aerosols, land use and land cover (LULC) changes, and greenhouse gas (GHG) emissions during the industrial era have significantly changed the composition of the atmosphere and, as a result, the planetary energy equilibrium, and are hence principally accountable for the current state of climate change. Global weather and climate extremes (such as heat waves, droughts, heavy precipitation, and severe cyclones) have already increased significantly since the 1950s due to warming. Other effects include changes in wind and precipitation patterns, including modifications to the global monsoon systems, warming and acidification of the oceans, melting of sea ice and glaciers, rising sea levels, and changes to marine and terrestrial ecosystems. Between 1901 and 2018, the average temperature in India increased by around 0.7°C. The forcing caused by human aerosols and changes in land use and land cover (LULC) has partially countered the warming resulting from greenhouse gas emissions. According to the Intergovernmental Panel on Climate Change (IPCC)'s Third Assessment Report published in 2001, there has been a 0.6ºC increase in the global mean surface air temperature throughout the 20th century. Due to its connection to variations in cloud cover, humidity, atmospheric circulation patterns, wind, and soil moisture, a great deal of attention has also been paid to the expression of regional warming or cooling in terms of daytime and nighttime temperatures [Karl et al., 1993]. According to Easterling et al. [1997], during the years 1950–1993, the temperature difference between the high and low points throughout the day declined across most of the world. Many ecological processes can be disturbed by variations in temperature and precipitation, especially if these changes happen faster than plant and animal species can adjust. Greenhouse gas concentrations in the atmosphere indication). As a result, average surface temperatures are rising and are predicted to do so in the future (USGCRP, 2017).

According to Rajeevan et al., there is a positive correlation between temperature and rainfall in India in January and May, but a negative correlation in July. In the Chinese Yellow River watershed, Huang et al.'s research revealed a negative relationship between temperature and rainfall.

Between 1901 and 2018, there was a 0.6 °C per century increase in the mean land surface air temperature in India (Srivastava et al. 2019). From 1971 to 2015, the mean annual tropospheric temperature across all of India, as determined by radiosonde stations, likewise demonstrated an increasing trend from the surface to 500 hPa (Kothawale and Singh 2017). Dendroclimatic investigations conducted in recent decades over the eastern Himalaya, including Sikkim and Bhutan, have shown a similar warming trend (Krusic et al. 2015; Yadava et al. 2015; Borgaonkar et al. 2018).

This article aims to analyze the trends and variability in average temperatures in Ranchi, Jharkhand, over the period 1973-2022, providing insights into local climate patterns and their implications. This study is significant because understanding regional temperature trends is crucial for climate adaptation strategies and local planning, particularly in a rapidly changing global climate.

2. Study Area

Ranchi serves as the capital of the state of Jharkhand in India. Ranchi is Located on the eastern Chota Nagpur plateau, With latitudes of 22º52'–23º45' North and longitudes of 84º45'–85º50' East. The district spans 5097 sq km. The district's elevation ranges from 500 to 700 meters above mean sea level. In Ranchi, the average yearly temperature is 24ºC and the average annual rainfall is 1300mm [10]. On November 14, 2000, Jharkhand became state by separating from Bihar, with Ranchi serving as its capital. The climate of Ranchi is sub-tropical climate but because of surrounded by dense forest, the climate of the region is pleasant.

3. Methodology

The daily temperature data for the period 1973-2022 of Ranchi is obtained from the website of National Centre For Environmental Information (https://www.ncdc.noaa.gov/cdo-web/datatools/findstation). Monthly, Seasonal and Annual average temperature is calculated from these daily data set. Indian seasons are divided into four categories: summer March to May, monsoon June to September, post-monsoon October to December, and winter January to February. Firstly, descriptive analysis of monthly, seasonal and annual average temperature is done. Seasonal and annual temperature variability are calculated. The trend analysis of monthly and seasonal temperature is done using Mann-Kendall test and Sen's Slope method.

a) Mean

The arithmetic mean is the sum of all observations divided by the total number of observations. It is a constant which states the significance of the whole data set. It requires the data set to be free from missing values.

Let $x_1, x_2, x_{3,\dots,} x_n$ be 'n' observation then mean of the data set is calculated as follows:

$$Mean = \frac{\sum_{i=1}^{n} x_i}{n}$$

b) Mann-Kendall Test

The Mann-Kendall test is non-parametric trend test which is used to determine whether or not there is a linear monotonic trend in a given time series data. The null hypothesis states that there is no monotonic trend, and this is tested against one of three possible alternative hypotheses: (i) there is an upward monotonic trend, (ii) there is a downward monotonic trend, or (iii) there is either an upward monotonic trend or a downward monotonic trend. It is very useful as it does not require the data to be normally distributed.

The first step in the Mann-Kendall test for a time series $x_1, x_2, x_3, \dots, x_n$ of length n is to compute the indicator function Sgn$(x_i - x_j)$ as follows:

$$\text{Sgn}(x_i - x_j) = \begin{cases} 1, & x_i - x_j > 0 \\ 0, & x_i - x_j = 0 \\ -1, & x_i - x_j < 0 \end{cases}$$

Next we compute mean S and variance Var(S) of Sgn$(x_i - x_j)$ as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_i - x_j)$$

And $\text{Var}(S) = \frac{[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]}{18}$

Where t is the extent of any given tie.

Mann Kendall Statistics is calculated as follows:

$$\mathbf{Z} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \end{cases}$$

The value of Z>0 represents monotonic upward trend in data series whereas Z<0 represents monotonic downward trend.

c) Sen's Slope Method:

It is a non-parametric test which is highly efficient to find out linear trend in univariate data series. This can be applied to a data set having missing value and outliers in the data series.

The Sen's estimator β of slope is calculated as follows:

$$\beta = \text{Median}\left(\frac{x_j - x_i}{j - i}\right)$$

Where x_j *and* x_i are the data values at time j and i (j>i) respectively.

β>0 indicates an upward trend whereas β<0 indicates downward trend in the data series.

4. Result

The average temperature of Ranchi for the period 1973-2022 is analyzed [

Table 1]. The annual mean temperature of Ranchi is 24ºC. The average temperature of summer month is 28.05ºC which is the hottest season followed by Monsoon (26.4ºC). Winter season is the coldest season with the average mean temperature of 18.4ºC followed by post-Monsoon season (20.5ºC). The hottest month is May (30ºC) followed by April (29.2ºC). The coldest month is January (16.7ºC) followed by December (17ºC).

The Coefficient of variation is calculated to find out the variability of temperature from its mean. The annual average temperature has a variability of 1.96%. Winter season has the largest variability of 5.8% followed by summer season which has variability of 3.6%. The monsoon and post-monsoon season have variability of 2.1% and 3% respectively. The monthly average temperature shows the least variability in August which is 1.96%. The month of February has the largest variability of 7.3%. The annual temperature and its variability plots are deployed in

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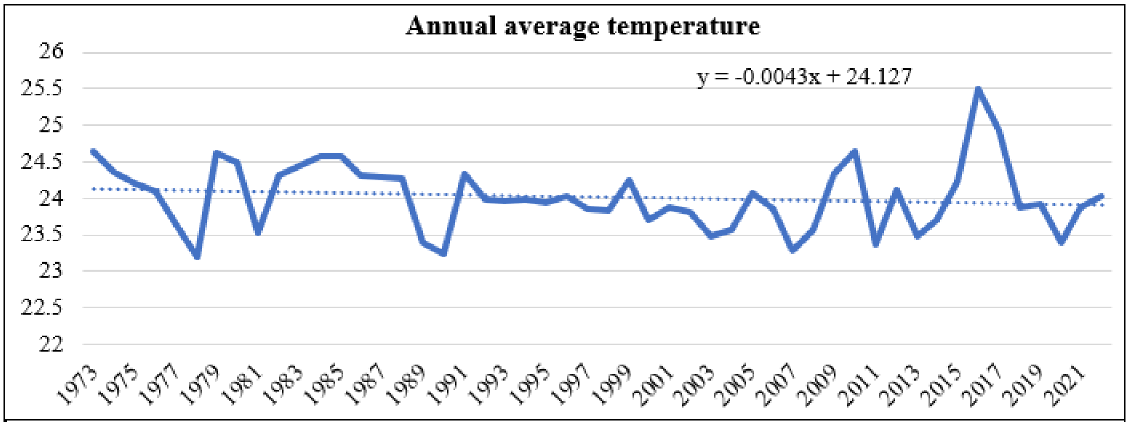


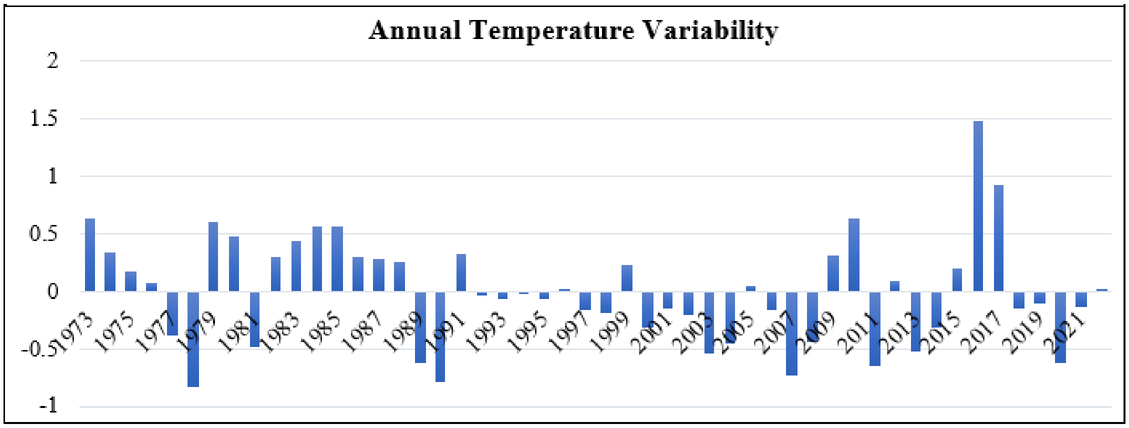
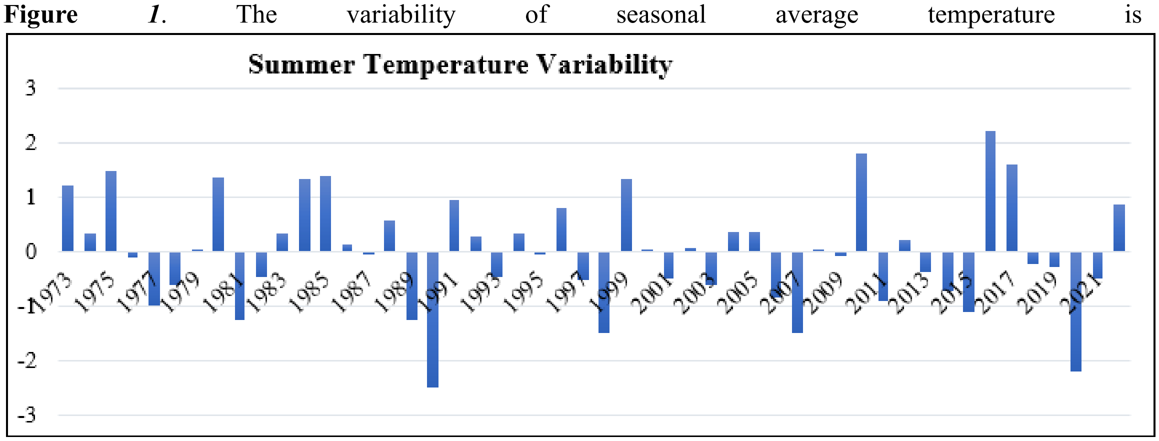
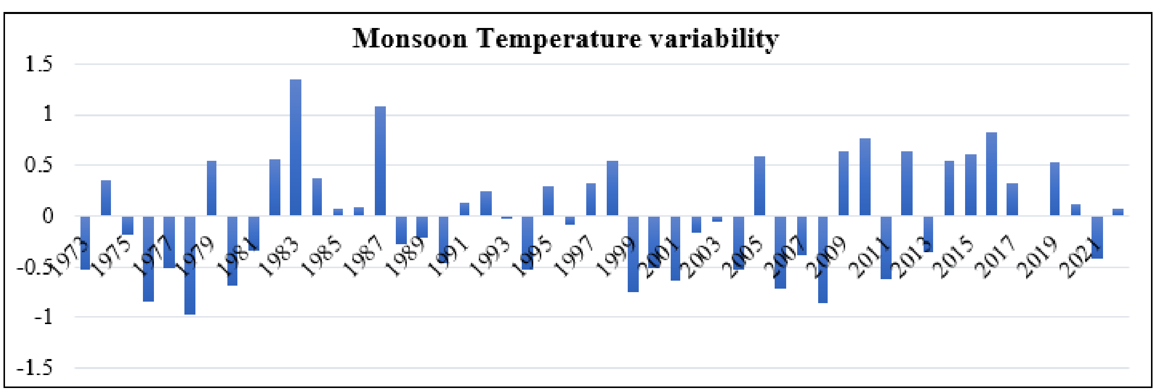
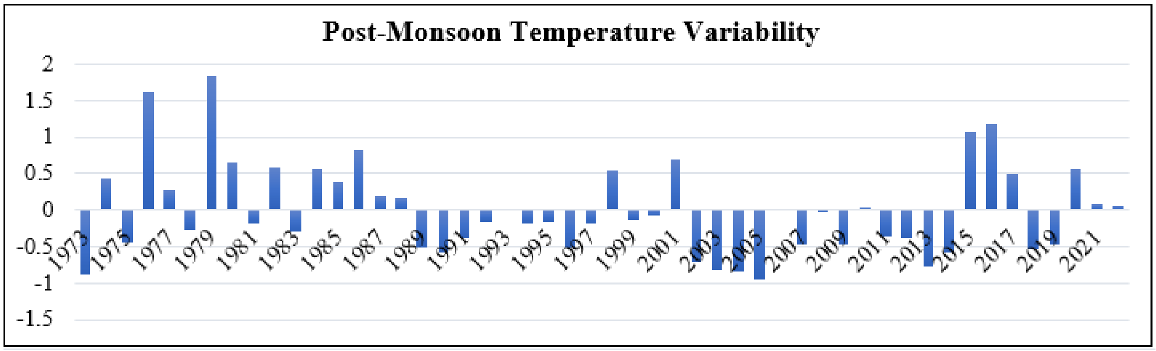


Figure *1.* The variability of seasonal average temperature is deployed in







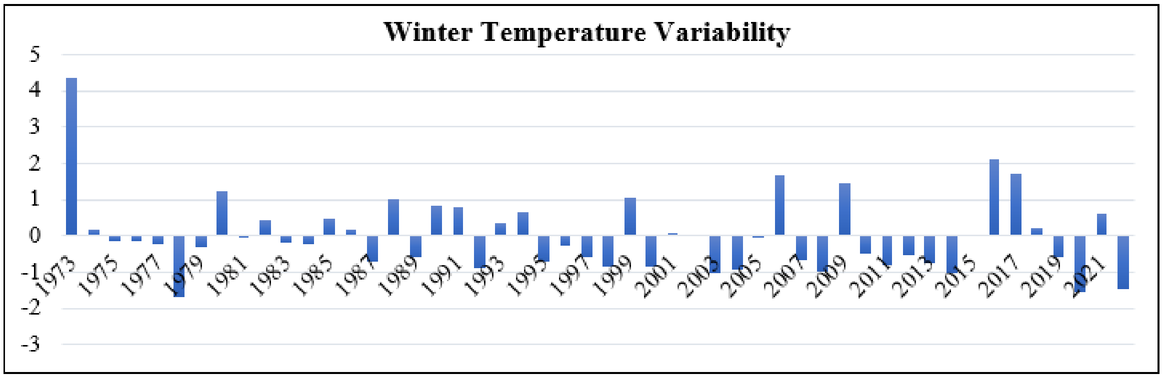


Figure *3*.

The temperature data are further analyzed to find out possible trend. Mann-Kendall test and Sen's slope method are applied for the trend analysis [

Table *2*]. The monthly average temperature of August month has a significant upward trend [

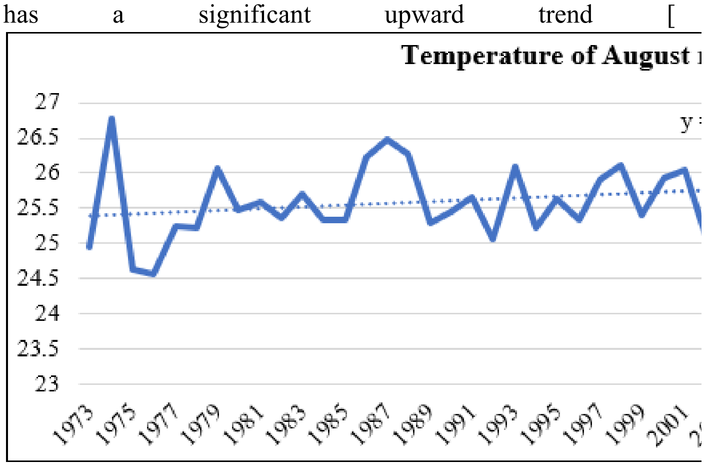


Figure *2*]. The month of July and September have non-significant upward trend. Rest all months have downward trend however trend is non-significant. Seasonal and annual temperature have shown no significant trend. The monsoon season has non-significant upward trend whereas rest all seasons and annual temperature has non-significant downward trend.

Table 1: Statistical descriptives of average temperature

Months	Mean (°C)	Standard deviation	CV %
January	16.74	1.02	6.09
February	20.09	1.48	7.36
March	24.86	1.45	5.82
April	29.22	1.51	5.18
May	30.09	1.40	4.64
June	28.41	1.59	5.58
July	26.01	0.61	2.33
August	25.70	0.50	1.96

September	25.60	0.65	2.53
October	24.13	0.85	3.54
November	20.35	0.94	4.61
December	17.03	0.87	5.13
Seasonal			
Summer Season	28.05	1.01	3.60
Monsoon Season	26.43	0.55	2.10
Post-Monsoon	20.51	0.63	3.07
Winter Season	18.41	1.07	5.79
Annual	24.02	0.47	1.96

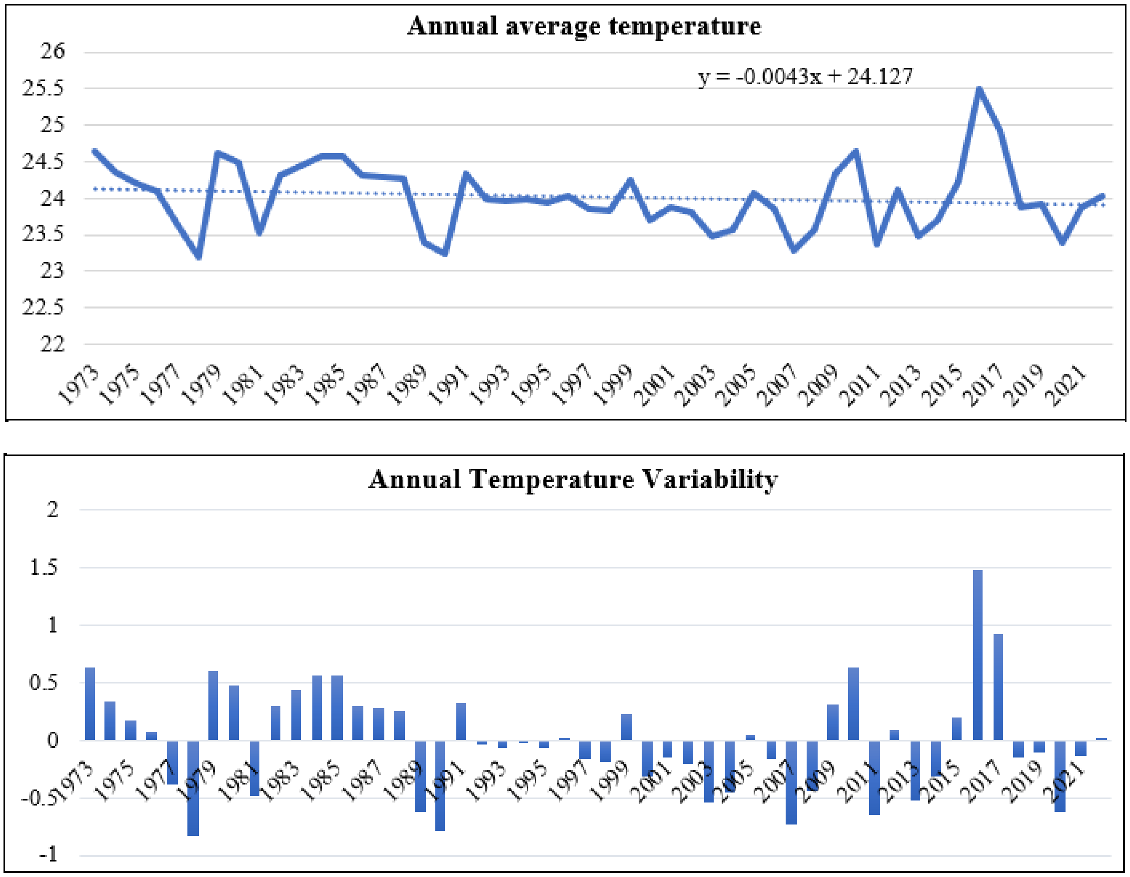


Figure 1: Annual average temperature and its variability

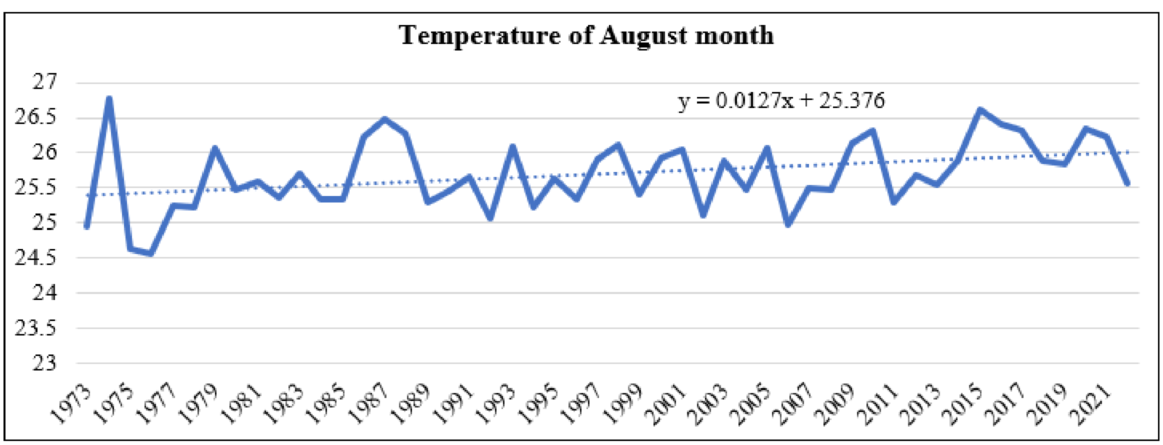


Figure 2: Average temperature of month August

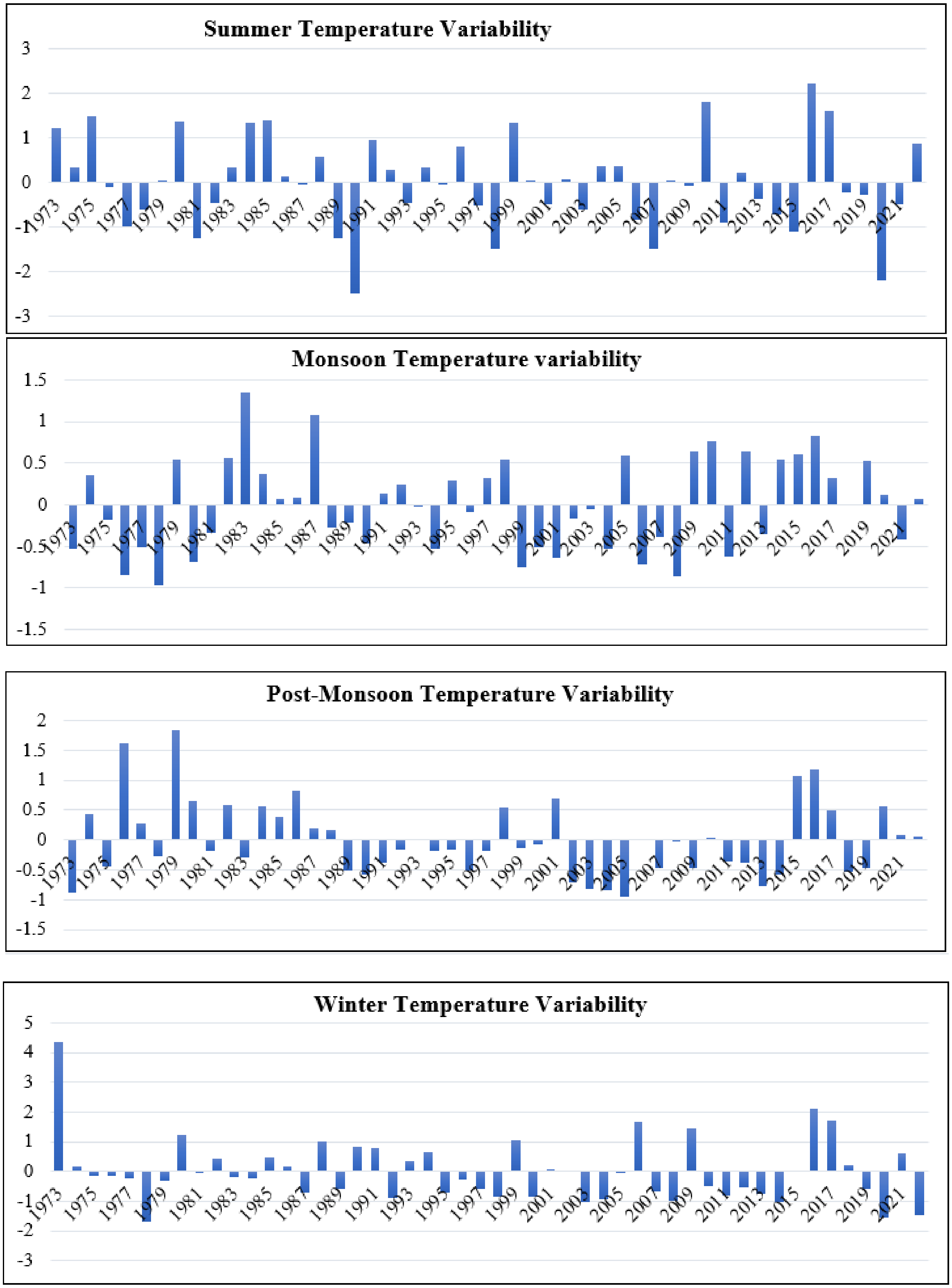


Figure 3: Seasonal average temperature variability

Table 2: MK test statics and Sen's slope estimator for temperature

Months	Z	Sen	Trend
January	-1.59	-0.14	No Trend
February	-0.59	-0.007	No Trend
March	-0.26	-0.006	No Trend
April	-0.94	-0.016	No Trend
May	-0.82	-0.013	No Trend
June	-0.49	-0.007	No Trend
July	1.77	0.012	No Trend
August	2.74	0.015	**Upward Trend**
September	1.47	0.010	No Trend

October	-1.23	-0.014	No Trend
November	-0.77	-0.007	No Trend
December	-0.51	-0.004	No Trend
Seasonal			
Summer Season	-1.05	-0.013	No Trend
Monsoon Season	1.14	0.007	No Trend
Post-Monsoon	-1.17	-0.009	No Trend
Winter Season	-1.47	-0.015	No Trend
Annual	-0.94	-0.010	No Trend

5. Conclusion

The mean annual average temperature of Ranchi is 24ºC with summer as the hottest month (28.05ºC). The lowest average temperature is observed in Winter season (18.4ºC). Monthly, May (30ºC) is the hottest month and January(16.7ºC) is the coldest month. The annual average temperature has a variability of 1.96%. The least temperature variability is observed in Monsoon (2.1%) season and August (1.96%) month. The highest temperature variability is observed in summer (5.8%) and February (7.3%). The average temperature of month August has a significant positive trend. Seasonal and Annual temperature have shown so significant trend. The study concludes that Ranchi's annual temperature shows minimal variability, with significant trends only observed in August. These results contribute to understanding regional climate patterns, which are essential for future environmental planning and policy development.

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