

Temperature Variability Analysis of Gulmarg and Srinagar, Kashmir Valley, J&K, India

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Authors' contributions

This work was carried out in collaboration between both authors. Author PAT designed the study and wrote the first draft of the manuscript. Author TAK managed the literature searches and performed the analyses part. Both authors read and approved the final manuscript.

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ABSTRACT

Climate is a complex and chaotic system having non-linear links between its component variables. Study on temperature trends at macro level may be used to assess the climate variability of a region over the period of time as it is the main component of the climate system. For trend analysis, non-parametric Mann-Kendall test, which is an important tool to find out the existence and magnitude of any statistically significant trend in the climatic data, has been employed in the present study. Another index called Sen Slope has been used to quantify the magnitude of such trend. Temperature data of 39 years (1970-2009) were used for two selected stations over different altitudinal zones of Kashmir valley, viz; Srinagar (1600 metres) and Gulmarg (2644 metres). Both the maximum and minimum temperatures were found to be rising. The overall increase in temperature for Gulmarg is found to be much more than that of Srinagar.

Keywords: Climate variability; temporal trends; non-parametric; mann-kendall test; sen slope.

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1. INTRODUCTION

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years [1]. There is now clear evidence for an observed increase in global average temperature and change in rainfall pattern during the 20th century around the world [2]. There is a close association between climate change and water resources variability [3]. Climate change scenario in India revealed that the annual mean temperature has increased by 0.48°C in the past 100 years [4]. Many studies have shown that there is observed increasing trend in surface temperature in different place of India [5]. Temporal trend analysis is a tool to understand variations of different meteorological parameters with time. The knowledge of increasing/decreasing or no trend of an individual climatic parameter may

lead to safer designs, proper planning, required corrective measures, and sustainable practices. Surface temperature data series for India shows a rising trend in annual mean temperature and is comparable with the reported rise of global surface temperature by 0.6°C [6]. In India, several meteorological studies have been conducted in the context of climate change using observed data as well as model results [7] and [8]. The mean annual rainfall of India is of the order of 1190 mm with a standard deviation of 95 mm [9]. Assessing temporal trends for different meteorological parameters are essential to understand the local climate change pattern of a region [10]. It helps in forecasting the future climate and its effect on cultural landscapes.

2. STUDY AREA

The study has been carried out for Gulmarg and Srinagar located at two different altitudinal zones of Kashmir Valley. Gulmarg is located at an altitude of 2644 metres in Middle Himalayas, locally called Pir Panjal mountains on the south of the valley while as Srinagar is located at an altitude of 1600 metres above mean sea level. Srinagar lies approximately at the centre of the valley. The location of the stations is shown in Fig. 1.

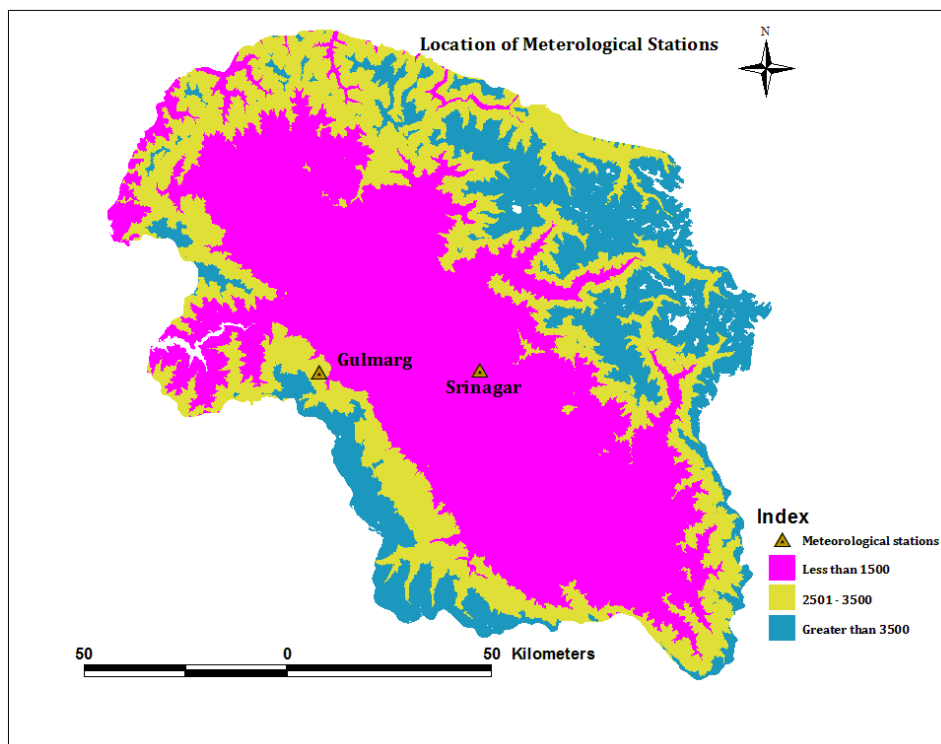


Fig. 1. Location of meteorological stations

2.1 Data Set

Monthly maximum, minimum and mean air temperature of 2 stations in the Kashmir valley from 1979 to 2009 were obtained from the Indian Meteorological Department (IMD) and used to calculate air temperature trend from 1970 to 2009.

3. METHODOLOGY

The general statistical analysis may be performed to take a general overview of the data collected. The statistical parameters which are usually considered to look for gross data errors/outliers are:

1. Minimum and maximum
2. Mean
3. Standard deviation
4. Coefficient of variation

The trend analysis may be performed to determine the existence and magnitude of any statistically significant trend in meteorological parameters over the time period considered. The Mann-Kendall (MK) test has been used in this study for detection of trend. This is a non-parametric test which makes no assumption for probability distribution of the variate and is less affected by missing values or outliers. However, MK test is a statistical yes/no type hypothesis testing procedure and, therefore, another index, Sen Slope [11] has been used to quantify the magnitude of such trend. Being non-parametric, Sen Slope also enjoys the same advantages mentioned earlier for the MK test. In Mann-Kendall test, The Kendall's statistic S is given by [12]:

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

Where,

$$\text{sgn}(x_j - x_i) = f(x) = \begin{cases} 1 & \text{if } x_i > x_j \\ 0 & \text{if } x_i = x_j \\ -1 & \text{if } x_i < x_j \end{cases}$$

For a time series x_k , $k = 1, 2, \dots, n$,

When $n \geq 10$, S becomes approximately normally distributed with mean = 0 and variance as:

$$\sigma_s^2 = \frac{(n)(n-1)(2n+5) - \sum t(t-1)(2t+5)}{18}$$

Where, t is the extent (number of x involved) of any given tie and \sum_t denotes the summation over all ties. Then Z_c follows the standard normal distribution where:

$$Z_c = \begin{cases} \frac{s-1}{\sigma_s}, & S > 0 + \dots \\ 0, & S = 0 \\ \frac{s+1}{\sigma_s}, & S < 0 \end{cases}$$

The null hypothesis that there is no trend is rejected when: $|Z_c| > Z_{1-\frac{\alpha}{2}}$

Where, Z is the standard normal variate and α is the level of significance for the test.

To find out the effect of auto-correlation on MK test results, the modified MK test with effective sample size (ESS) approach, as suggested in [13], was attempted on detrended series. In this method, the variance σ_s^2 is modified as:

$$\sigma_s^{*2} = \sigma_s^2 \frac{n}{n^*}$$

Wherein n^* is the effective sample size calculated as [14]:

$$n^* = \frac{n}{1 + 2 \frac{p_1^{n+1} - n p_1^2 + (n-1) p_1}{n \cdot (p_1 - 1)(21)}}$$

$$x_k^* = X_k \beta_{(k-1)}, \quad k = 1, 2, \dots, n$$

Where p_1 can be determined by:

$$p_1 = \frac{\sum_{i=1}^{n-1} (x_i^* - \bar{x}^*) (x_{i+1}^* - \bar{x}^*)}{\sum_{i=1}^n (x_i^* - \bar{x}^*)^2}$$

4. RESULTS AND DISCUSSION

Variation in monthly mean Minimum and mean maximum temperature over Srinagar is depicted in Figs. 2 and 3 for the period 1970 to 2009.

The mean Minimum annual temperature of Srinagar has shown a slight increasing trend; however, it is not statistically significant. Examination of the mean monthly temperature indicates that the months of December, February and March show warming trend as can be seen from the sharp increase in the mean monthly temperature of the said months while the months of April, August, November and October show a slight increasing trend in mean monthly temperature. The month of May, July and

September is trend less while a slight decreasing trend can be seen for the month of June. Examination of the seasonal mean temperature series indicates that the winter season (December, January and February or DJF) and spring season (March, April and May or MAM) show warming trend as the seasons have shown a sharp increase in trend especially for winter season (DJF). It is surprising to note that slight decrease in trend can be seen for the summer season (June, July and August or JJA). However, it is not statistically significant. The autumn season also shows a slight increasing trend which is not statistically significant. Figs. 3 and 4 depicts the variation in monthly mean

Temperature over Srinagar. Analysis of the monthly data depicts that a sharp increasing trend is seen for the months of February and December which is not a good sign as rise in temperature in winter does not allow snow to freeze for a longer time which could lead to floods and even shortage of water in summer time as the valley is dependent on snow and glaciers for its water. A slight increase can also be seen for the months of January, April, August, October and November, but statistically it is not very significant. The months of May, July and September are trend less while a slight decreasing trend can be seen for the months of June.

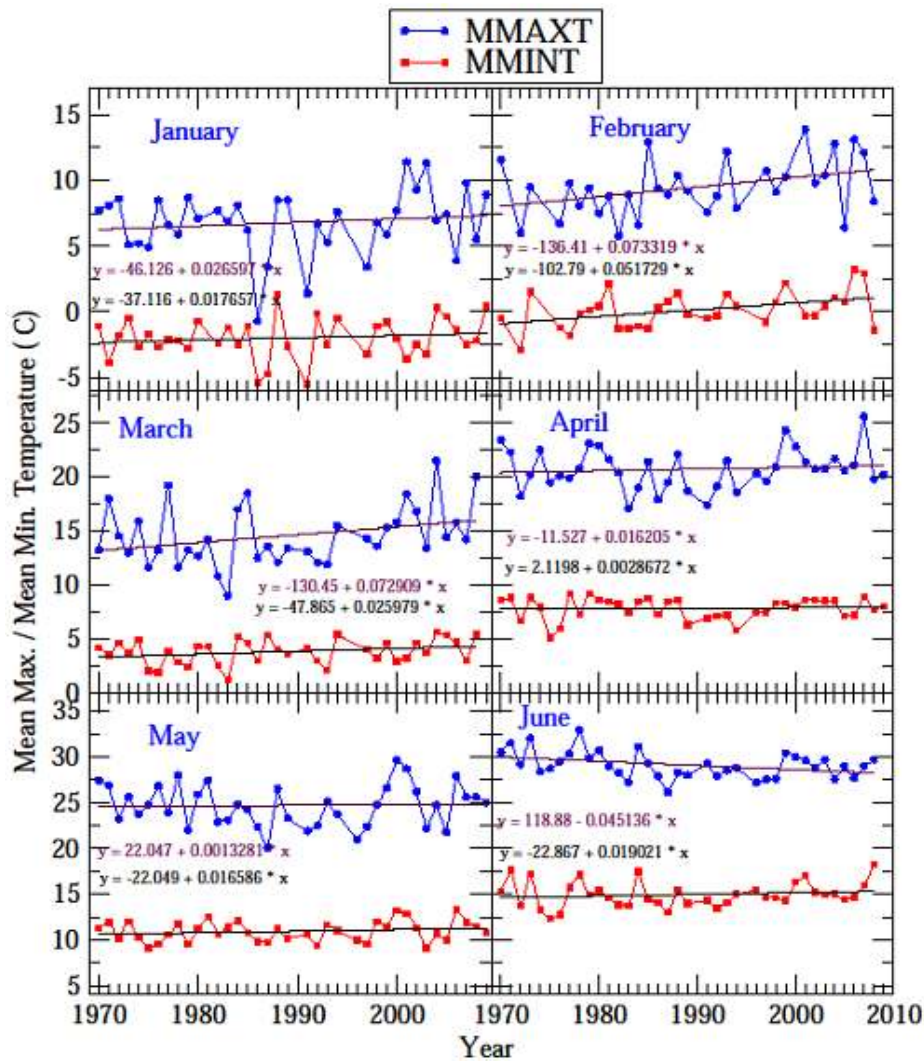


Fig. 2. Mean min and mean max temperature trend at Srinagar

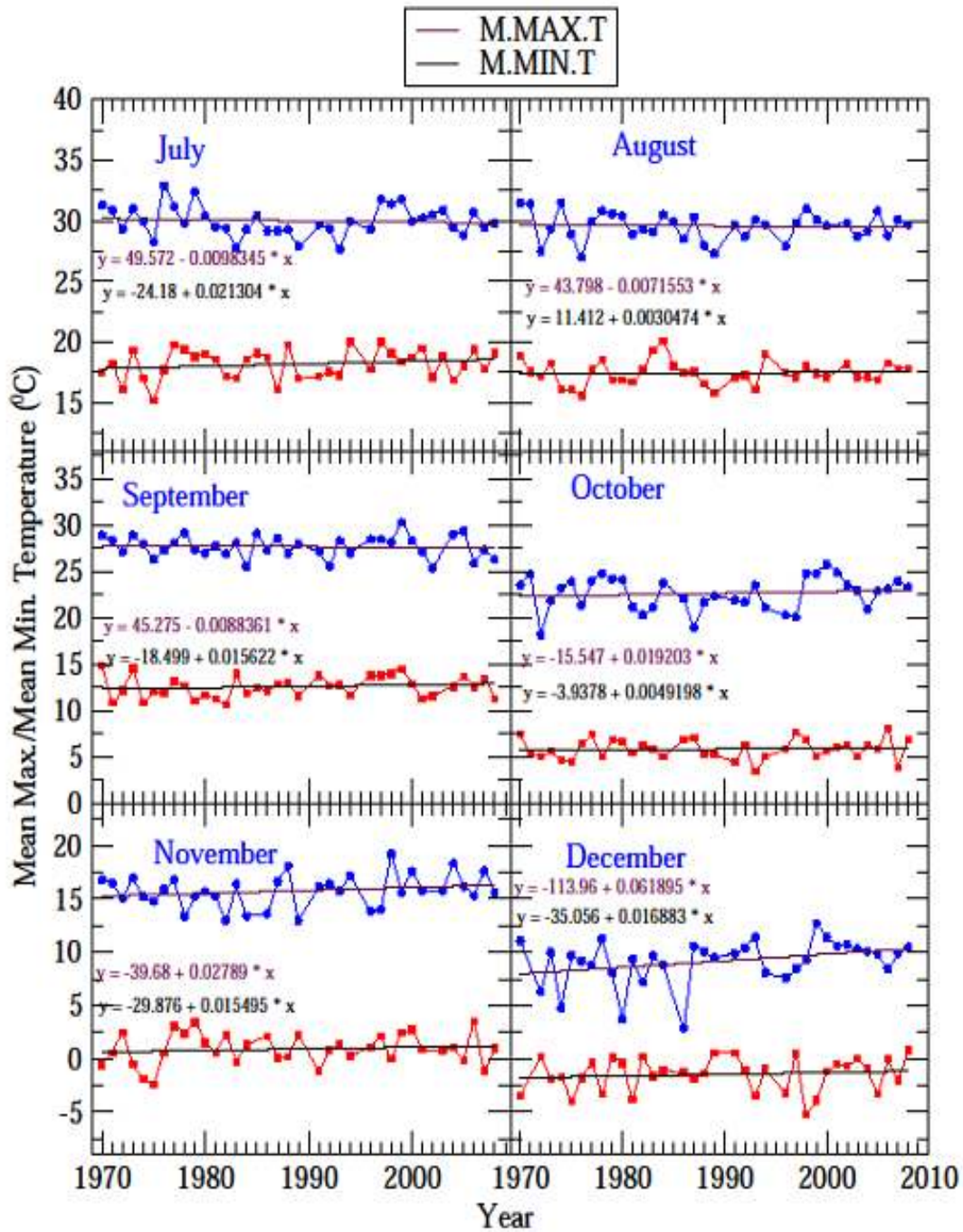


Fig. 3. Mean min and mean max temperature trend at Srinagar

The variation in average temperature (monthly) for 1970 and 2009 are plotted in Figs. 2 and 3 respectively. It is observed that the coldest month at Gulmarg is January. The variation of monthly average temperature along with their

regression lines is shown in Figs. 6 and 7 and the analysis of the temperature data on monthly and seasonal basis show mixture of temperature trends in the meteorological sub-division under study (Gulmarg).

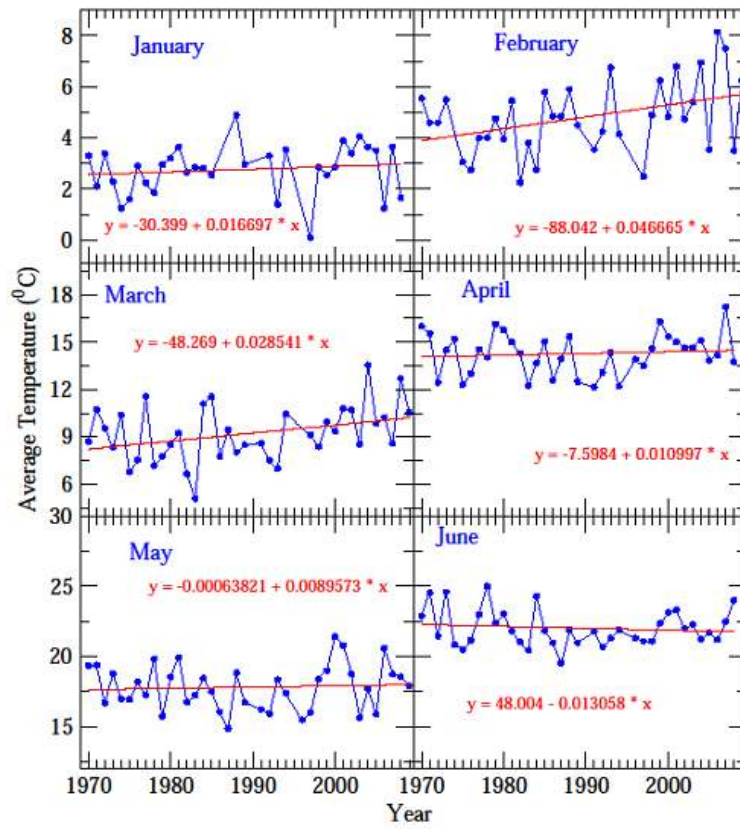


Fig. 4. Average temperature variation at Srinagar

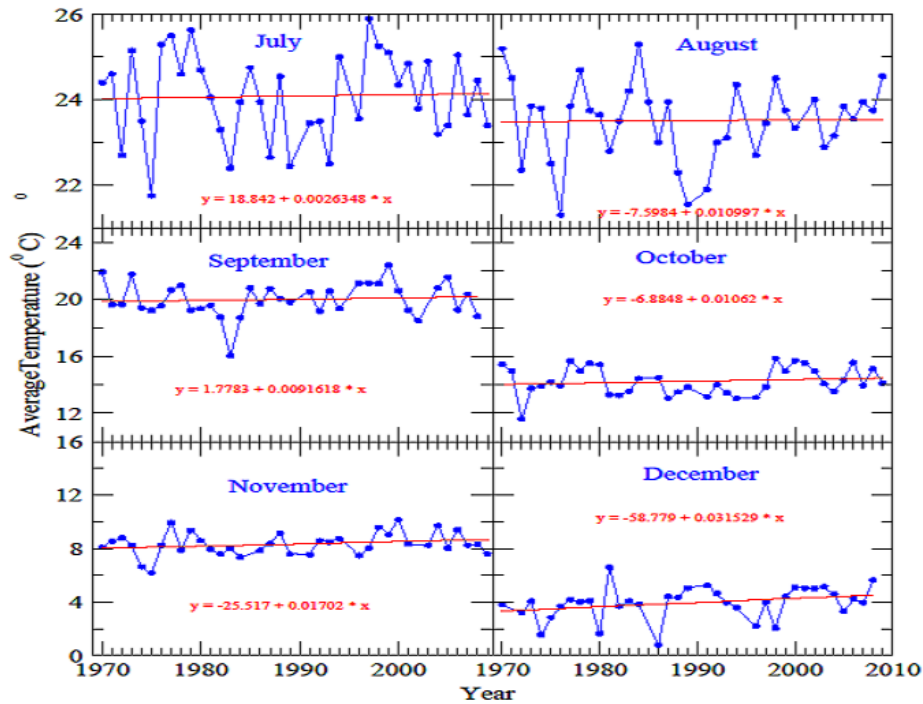


Fig. 5. Average temperature variation at Srinagar

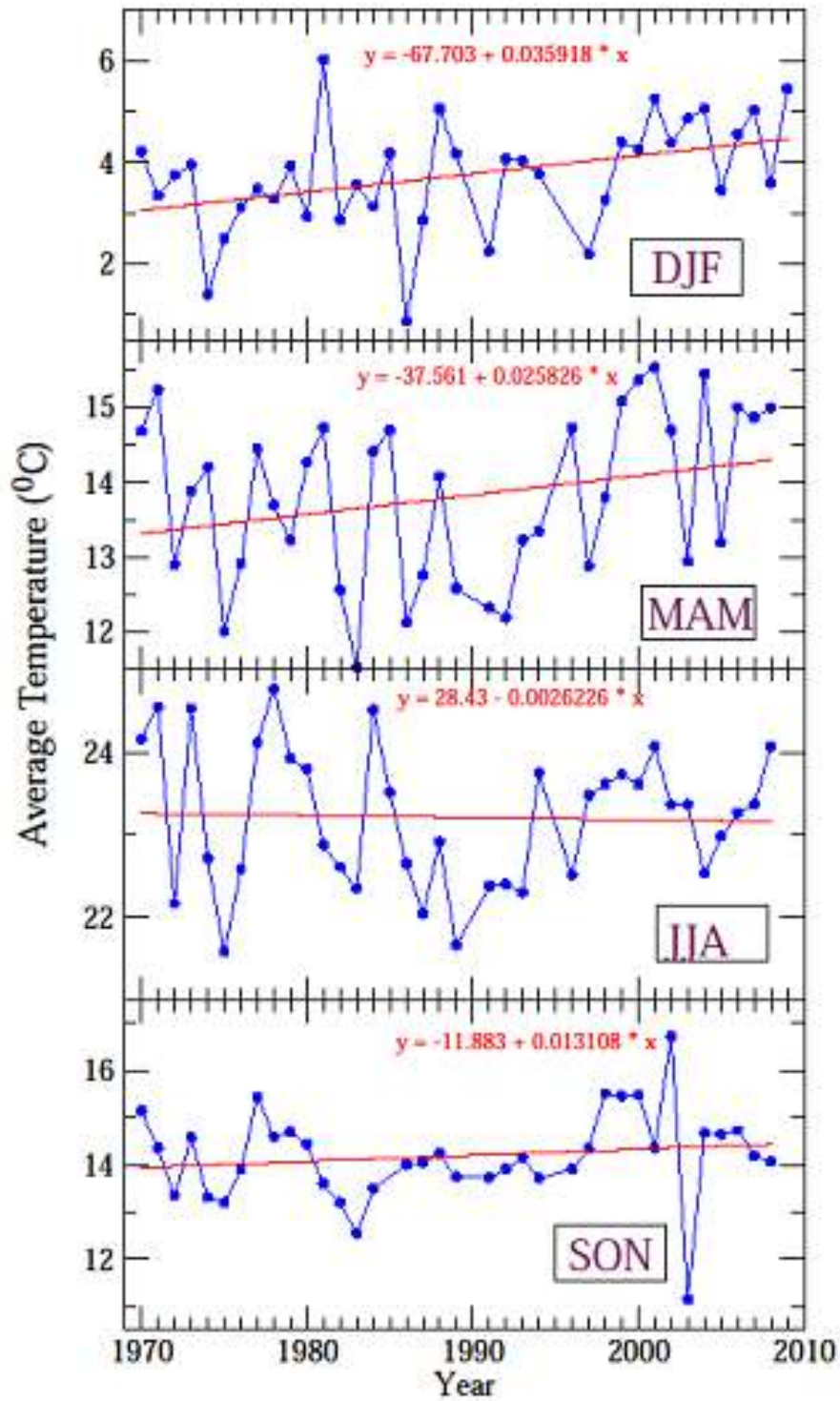


Fig. 6. Seasonal temperature variation at Srinagar

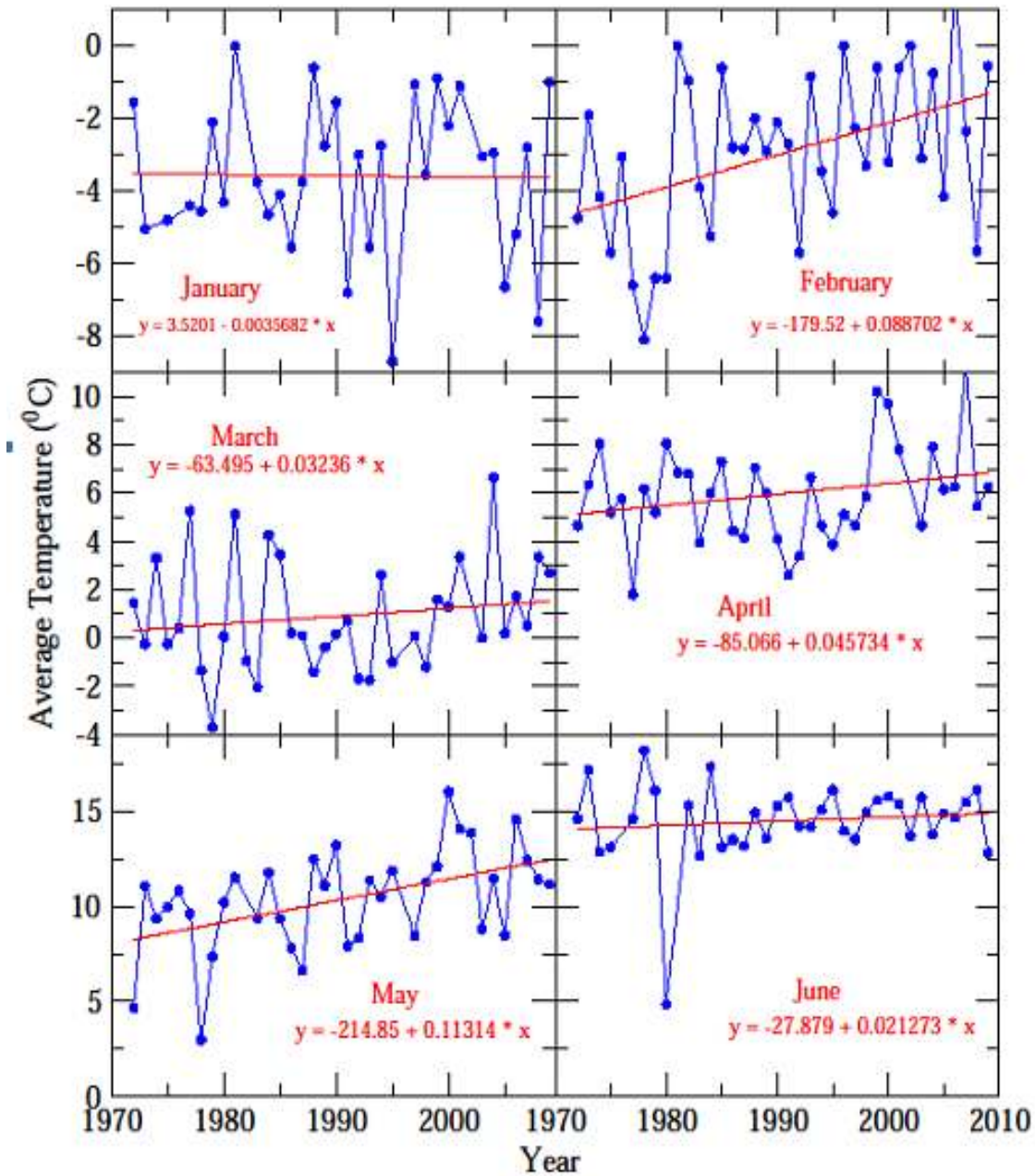


Fig. 7. Average temperature variation at Gulmarg

Analysis of the monthly temperature data suggests that the degree of trend differs monthly as well as seasonally. Based on our study, we have arrived at the following results;

1. The months February, May, August, September, October, November and December show a sharp increasing trend

of variation of average temperature with slopes (0.008), (0.113), (0.064), (0.095), (0.057), (0.059) and (0.059) respectively.

2. A slight increasing trend has been observed for the months March, April, June and July, but the increase is not significant.
3. It is worth mentioning here that only the month of January shows a decreasing

- trend with slope (-0.02) and on the contrary the month of May shows an increasing trend in temperature with slope (0.113).
4. It is quite clear from the Fig. 9 at the seasonal trends for the DJF (December, January and February), MAM (March, April and May) JJA (June, July and August) and SON (September, October and November) show a sharp increase in the temperature trend.

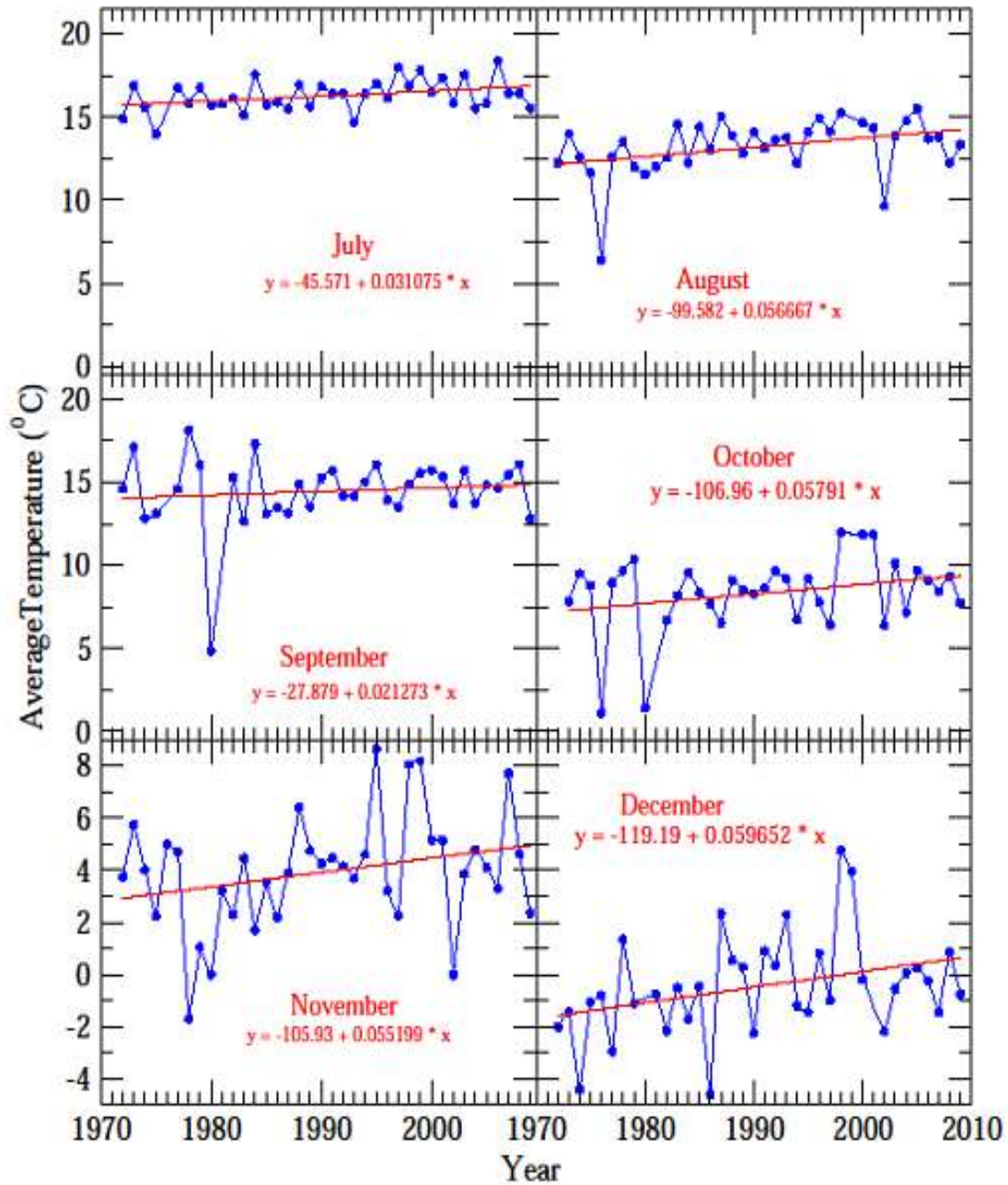


Fig. 8. Average temperature variation at Gulmarg

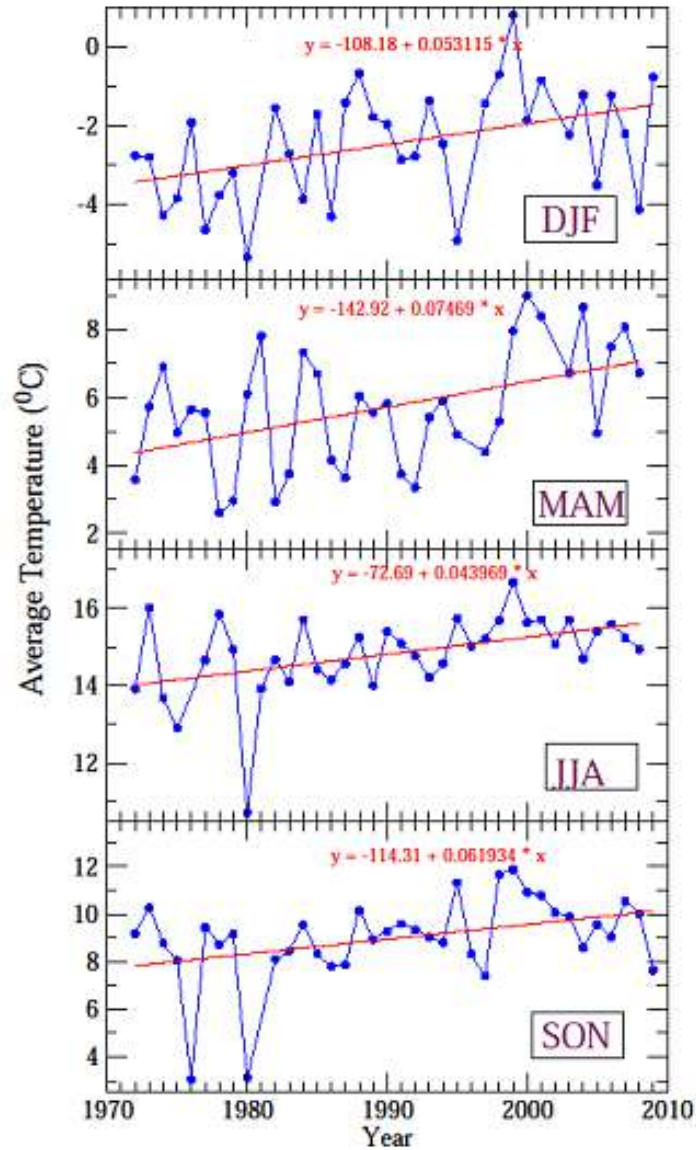


Fig. 9. Seasonal temperature variation at Gulmarg

5. CONCLUSION

Kashmir valley has distinct seasonal calendar. The region is mountainous in nature with fragile ecology and is bearing the brunt of increasing human interference. Following conclusion has been drawn from the study:

1. Temperature shows a significant trend both, monthly and seasonally.
2. Winter season is showing an increasing trend in mean monthly temperature.
3. There is absence of any significant trend in temperature during warm periods.

4. Gulmarg, a high altitude region shows more dramatic trend in temperature than Srinagar.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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