

Analysis of Long Term Temperature Trend for Madhya Pradesh, India (1901-2005)

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ABSTRACT

The paper examines the impact of climatic change on the mean temperature time series for Pre-monsoon (Mar-May), Monsoon (Jun-Sept), Post-monsoon (Oct-Nov), winter (Dec-Feb) and Annual (Jan-Dec) at 45 stations in the state of Madhya Pradesh, India. Impact detection is accomplished by using the Mann-Kendall method to find out the monotonic trend and Sen's slope is method is to identify the grandeur of trend for the period 1901 to 2005 (105 years). Prior to the trend analysis prominence of eloquent lag-1 serial correlation are eradicated from data by the pre-whitening method. In addition, shift year change has also been examined in the study using Pettitt's test. From 45 stations, most of the station show symbolic hike trend at 5% significance level in the mean temperature time series for Madhya Pradesh region. During peak summer months the maximum temperature touches 40°C in the entire Madhya Pradesh. The magnitudes of annual increase in temperature in the majority of the stations are about 0.01°C. The analysis in the present study indicated that the change point year of the significant upward shift changes was 1963 for annual mean temperature time series, which can be very useful for water resources planners in the study area. The finding of the study provides more insights and inputs for the better understanding of regional temperature and shift behavior in the study area.

Keywords: Monotonic trend analysis, Sen's slope, Mann-Kendall test, Pettit's test, serial correlation, Temperature.

INTRODUCTION

After precipitation, the temperature is found to be an essential meteorological parameter of climate. It is also considered as a good indicator to understand the global climate as it signifies the exchange of energy process over the surface of the earth with proper accuracy (Shukla et al., 2015 and Jhajharia & Singh., 2011). In 2007, Intergovernmental

Panel on Climate Change (IPCC) stated the growing tendencies of temperature is about 0.74°C of mean temperature in past 100 years from 1906 to 2005 in several areas of the world with respect to space and time. Reiter et al. (2012) observed an increase in temperature in the Upper Danube basin with a rise of 0.8°C /decade during summer. Even in spring and winter temperatures have also shown a constant increase. In the past 500 years,

the month wise surface temperature in Europe has never been as warmer as is growing in 21st century (Luterbacher *et al.*, 2004). In past 53 years, the annual average temperature in Canada has increased by 1.2°C (Vincent *et al.*, 2007). According to IPCC 2007, upwards trends have also been detected across the 7 subregions of Asia. In Russia the rise in mean yearly temperature is observed to be 2 to 3°C (Savelieva *et al.*, 2000; Peterson *et al.*, 2002), 0.7°C in Northwest part of China (Shi *et al.*, 2002), 1.0°C in Japan (Ichikawa, 2004), 1.8°C in main towns of Mongolia (Batima *et al.*, 2005).

A few studies have been carried out in India as well on temperature changes and their alliance with climate change. A temporal and spatial change of annual and seasonal temperature was conducted in India by researchers including Shukla, R., and Khare, D., (2013), Mishra *et al.*, (2013), Darshana *et al.*, (2012), Revadekar *et al.*, (2011), Indrani Pal *et al.*, (2009), Jhajharia *et al.*, (2009), Bhutiyani *et al.*, (2007).

Darshana *et al.*, (2012) reported that the average annual precipitation variation was (694 mm, Westnimar) to (1416 mm, Mandla). The annual precipitation showed a maximum reduction (-11.99%, Balaghat) and minimum (-8.52%, Shahdol) district. For annual precipitation year, 1978 was found to be

the most probable year of change. Alteration in mean percentage of 1901-1978 over the period of 1979-2002 has also been found showing the decrease in precipitation virtually in whole stations. Also in 102 years in Madhya Pradesh, the decrease in annual precipitation was 2.59%. During the period 1901-1978 west part of MP was observed with more rise in yearly precipitation as compared to east part of MP.

Revadekar *et al.*, (2011) conducted the observational analysis by taking 121 stations spread all over India showed that widespread warming through an increase in intensity and occurrence of warm events and also by a decrease in the occurrence of cold actions.

Indrani Pal *et al.*, (2009) reported that the long period trends in variations of the highest and lowest values of monthly temperatures and their effects on seasonal fluxes in various regions in India. The trends magnitude and statistical significance were determined by least square regression techniques and the variations were regulated by the relevant coefficient of variations. The outcomes is that the monthly maximum temperature raised, though unevenly, over the 20th century. The minimum temperature changes were more variable than maximum, both temporally and spatially, with

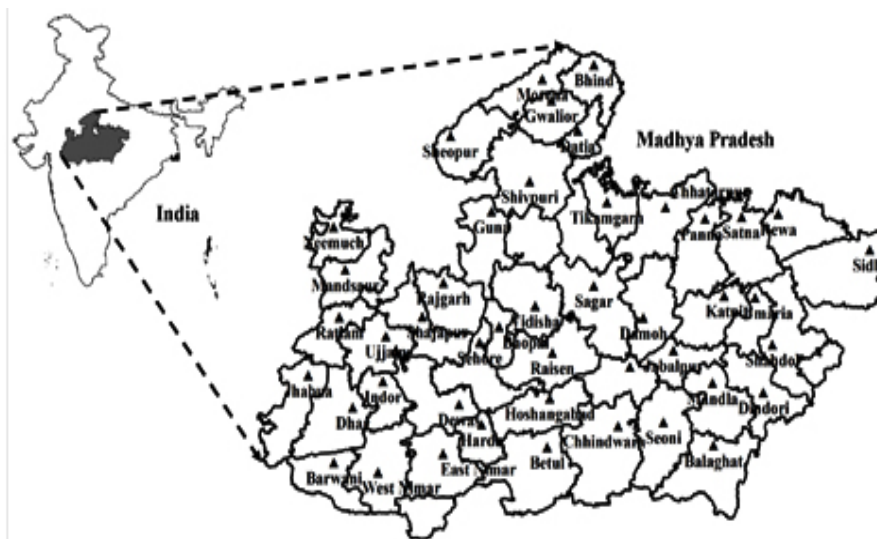


Fig.1: The position of 45 meteorological stations in Madhya Pradesh.

lesser significance results. This study showed good pointers of Indian climate changeability over the 20th century.

Jhajharia *et al.*, (2009) examine the year wise average temperature variation (5 to 30°C) and the average relative humidity between (70 to 85%) for the many part in north-east India. In 2010, (Jhajharia and Singh) finds the decreasing trends in Diurnal Air Temperature (DTR) at 4 stations in north-east for every timescales. Instead, the DTR trends were significant at annual, seasonal (pre-monsoon and monsoon), & monthly (May, June, August, September, and November). Major rising trends in DTR are detected at 3 stations in october month as well as in post-monsoon & monsoon seasons. The 4 sites showed significant rising trends for T_{mean} at post-monsoon seasons. For post-monsoon, the T_{max} and T_{min} are found to be more than monsoon in the seasonal cycle. Significant declining trends during sunshine hours were observed on the basis of winter, pre-monsoon and monthly timescales.

Bhutiyan *et al.* (2007) demonstrated that the existence of possible variation between the precipitation and temperature in the late-1960s century. However, post-1970, these connections appear to have grown weaker. This points out the presence of other climatic factors (rise of greenhouse gasses etc.), which could be playing an important role.

The present study involves monotonic trend analysis of mean temperature of the state of Madhya Pradesh of India. Temperature trend analysis carried out with Mann-Kendall (MK) test in 45 different districts on annual, for 1901 to 2005 (105 years). This study will help the agricultural planners and managers dealing with the water resources of the area.

Study Area

Madhya Pradesh is situated in the center of India covering 443,000 km² of area. Being at the center, the state is surrounded by many other states like Chhattisgarh, Uttar Pradesh, Rajasthan, Gujarat, and Maharashtra. The state is dissected by a major river system, the Narmada which is the lifeline of the state together with Tapti, Mahanadi,

Wainganga etc. The area of the state stretches from 21°17' N to 26°36' N latitude and from 74°02' E to 82°26' E longitude. There are 45 districts in the state and the major crops of the region include rice, wheat, jawar, soybean etc. MP has a sub-tropical type of climate with hot dry summer and cool dry winter thus it experiences the extreme climatic conditions. Temperature rises to as high as 40°C or more particularly in the southern part in the districts of Khandwa, Khargone etc. In Bhopal, the minimum temperature remains around 25°C and maximum around 40°C through summer. During winter, the minimum and maximum temperature vary from 10°C to 25°C respectively. The position of the 45 meteorological stations in the state of Madhya Pradesh has been shown in Fig.1.

METHODOLOGY

Analysis of climatic changes over Madhya Pradesh was based on the evaluation of available meteorological and hydrological time series using the statistical method (**Mann-Kendall method**). In the present study testing of the hypothesis, the result shows that the observed historical climatic trends in the central part of India reflected a significant change in climate.

Serial correlation effect

The existence of negative or positive autocorrelation affects the trend in a series (Hamed and Rao, 1998). The autocorrelation (also known as serial correlation coefficients) test was performed to check the randomness and periodicity if any in the time series of all data (Madarres and Silva, 2007). If randomness is found, or in other words, if lag-1 serial correlation coefficients are statistically insignificant then, Mann-Kendall (MK) test is used without altering the authentic data. Otherwise, Modified Mann-Kendall (MMK) test is applied after eliminating the effect of serial correlation (randomness) from the time series (Karpouzou *et al.*, 2010). The autocorrelation coefficient r_k of a discrete time series for lag- k is estimated as follows:

$$r_k = \frac{\sum_{t=k+1}^{n-k} (X_t - \bar{X}_t)(X_{t-k} - \bar{X}_{t-k})}{[\sum_{t=k+1}^{n-k} (X_t - \bar{X}_t)^2 (X_{t-k} - \bar{X}_{t-k})^2]^{0.5}} \quad \dots(1)$$

Where, r_k is the lag- k serial correlation coefficient of the series. The hypothesis of serial independence is then tested by the lag-1 autocorrelation coefficient as $H_0 : r_1 = 0$ against $H_1 : |r_1| > 0$ using the test of significance of serial correlation (Yevjevich, 1971) following Rai *et al.*, (2010),

$$(r_k)_{t_g} = \frac{-1 \pm t_g (n-k-1)^{1/2}}{n-k} \quad \dots(2)$$

Where, $(r_k)_{t_g}$ is the normally distributed value of r_k , t_g is the normally distributed statistic at g level of significance. The value of t_g is 1.645, 1.965 and 2.326 at a significance level of 0.10, 0.05 and 0.01 respectively. If $|r_k| \geq (r_k)_{t_g}$, the null hypothesis about serial independence is rejected at the significance level α (here 0.05). For the non-normal series, MK test is an appropriate choice for the trend analysis (Yue and Pilon, 2004, Basistha, *et al.*, 2008). Therefore, the MK test has been used wherever the autocorrelation is not significant at 5% significance level.

Pre-whitening

The method of Pre-whiting is applied to remove the effect of Serial correlation on the non-parametric test. Lettenmaier *et al.*, (1994) suggested that the effects of serial correlation upon trend tests in such applications could be assumed negligible; concern about the potential impacts of autoregressive processes upon trend analysis nevertheless appears to be gaining momentum.

$$^{PW}X_i = X_i - cX_{i-1} \quad \dots(3)$$

Where ^{PW}X is the whitened data to be used in the subsequent trend analysis and c is the lag-1 serial correlation coefficient as determined directly from the data using Equation 3. Pre-whitening is utilized only if observed r is greater than some critical value, C_{crit} taken to be 0.1 by von Storch (1995). This method is known as single-stage pre-whitening.

Analysis of trend

The following sections describe the nonparametric (**Mann-Kendal**) methods used to assess trends over Madhya Pradesh.

Mann-Kendall method

Trend analysis has been executed by using non-parametric Man- Kendall test. It is a statistical method used for analyzing the temporal trends and spatial variation of hydro-climatic series. Smith (2000) mentioned that a non-parametric test is given priority over the parametric one because it can avoid the issue raised by data skew. Man-Kendall test is favored when various stations are tested in the same study (Hirsch *et al.*, 1991). Mann-Kendall test was drafted as a non-parametric test by Mann (1945) for trend detection and test statistic distribution was given by Kendall (1975) for a testing turning point and non-linear trend. The Mann-Kendall statistic S is formulated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \quad \dots(4)$$

The application of trend test is done to a time series x_i which is ranked from $i = 1, 2, \dots, n-1$ and x_j is ranked from $j = i+1, 2, \dots, n$. Each of the data point x_i is considered as a reference point which is correlated with all the rest of the data point's x_j so that

$$\text{Sgn}(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases} \quad \dots(5)$$

The variance statistic is computed as

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^n t_i(i-1)(2i+5)}{18} \quad \dots(6)$$

Where t_i represents the number of ties up to sample i . The test statistics Z_c is estimated as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} \\ 0, S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}}, S < 0 \end{cases} \quad \dots(7)$$

In which Z_c follows a standard normal distribution. A positive (negative) value of Z indicates

Table 1: Lag-1 serial correlation coefficients of the Annual and seasonal Temperature series for entire Madhya Pradesh (1901-2005)

Serial No.	Station_name	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Balaghat	0.295046	-0.05979	0.041636	0.421661	0.166193
2	Barwani	0.527486	0.180661	0.088651	0.332866	0.256678
3	Betul	0.371415	0.003139	-0.00806	0.331558	0.214009
4	Bhind	0.277371	0.116826	0.049	0.313165	0.215794
5	Bhopal	0.479363	0.038568	0.059854	0.400571	0.304571
6	Chhatarpur	0.332404	0.052769	0.051368	0.449528	0.218195
7	Chhindwara	0.367876	-0.02068	0.019182	0.417217	0.214821
8	Damoh	0.378258	0.019037	0.037159	0.465923	0.248044
9	Datia	0.303414	0.097709	0.010062	0.353497	0.225068
10	Dewas	0.526495	0.112751	0.060739	0.378167	0.283439
11	Dhar	0.545056	0.199693	0.092929	0.36084	0.270449
12	Dindori	0.318872	-0.03557	0.068028	0.467216	0.216049
13	East Nimar	0.439349	0.072392	0.007835	0.312489	0.204237
14	Guna	0.425592	0.051165	0.073767	0.364369	0.289832
15	Gwalior	0.311708	0.106168	0.015708	0.325573	0.226824
16	Harda	0.450651	0.047395	0.014175	0.348348	0.248252
17	Hoshangabad	0.433763	0.015979	0.018579	0.397918	0.270133
18	Indor	0.544827	0.173992	0.077263	0.36373	0.277683
19	Jabalpur	0.346547	-0.01539	0.058859	0.451535	0.218476
20	Jhabua	0.522395	0.179253	0.088211	0.364976	0.266128
21	Katni	0.327059	-0.00197	0.083469	0.46418	0.205103
22	Mandla	0.316029	-0.03953	0.068549	0.448566	0.201205
23	Mandsaur	0.371236	0.094508	0.041862	0.26455	0.242874
24	Morena	0.314422	0.123165	0.03597	0.282871	0.212652
25	Narsinghpur	0.417686	0.0271	0.001121	0.470764	0.274858
26	Neemuch	0.326553	0.087943	0.049675	0.242525	0.203967
27	Panna	0.320554	0.02523	0.075138	0.465011	0.21229
28	Raisen	0.468945	0.040133	0.015459	0.452647	0.309034
29	Rajgarh	0.445705	0.061602	0.055845	0.339001	0.286388
30	Ratlam	0.452006	0.139837	0.064621	0.318453	0.258331
31	Rewa	0.318496	0.028801	0.048037	0.489459	0.214317
32	Sagar	0.427184	0.041627	0.009196	0.460108	0.301426
33	Satna	0.304995	0.020626	0.080532	0.469064	0.204522
34	Sehore	0.493932	0.054187	0.049392	0.392292	0.294899
35	Seoni	0.319989	-0.04261	0.043735	0.43233	0.184731
36	Shahdol	0.320673	-0.02281	0.054177	0.485988	0.219975
37	Shajapur	0.473718	0.089853	0.051465	0.340326	0.286071
38	Sheopur	0.338136	0.085352	0.027263	0.262859	0.200127
39	Shivpuri	0.363099	0.075616	0.022588	0.343761	0.250513
40	Sidhi	0.314165	0.005271	0.007863	0.510027	0.216704
41	Tikamgarh	0.344	0.067089	0.014039	0.413516	0.234096
42	Ujjain	0.481795	0.139452	0.057422	0.327118	0.281656
43	Umaria	0.315255	-0.00968	0.098578	0.472749	0.207002
44	Vidisha	0.463157	0.041383	0.044524	0.42328	0.321794
45	West Nimar	0.50973	0.14743	0.053061	0.333529	0.237591

Table 2: Values of slope β ($^{\circ}\text{C}/\text{year}$) for the Annual and seasonal mean temperature series (1901–2005)

Serial No.	Station_name	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
1	Balaghat	0.004821	0.003852	0.001237	0.008233	0.00879
2	Barwani	0.004368	0.008776	0.002176	0.010435	0.008905
3	Betul	0.00467	0.005881	0.000396	0.009574	0.007763
4	Bhind	0.002761	0.005729	-0.00588	0.007782	0.008079
5	Bhopal	0.00438	0.007856	0.001256	0.009819	0.00904
6	Chhatarpur	0.004143	0.005911	-0.00166	0.008856	0.008452
7	Chhindwara	0.004319	0.004984	0.000928	0.008457	0.008334
8	Damoh	0.004256	0.005587	-0.00074	0.008739	0.008349
9	Datia	0.003341	0.005991	-0.00472	0.008238	0.008537
10	Dewas	0.004371	0.008824	0.001897	0.010688	0.009381
11	Dhar	0.004501	0.009093	0.002414	0.010319	0.009558
12	Dindori	0.004741	0.003185	0.000299	0.008583	0.008822
13	East Nimar	0.004796	0.008004	0.001034	0.010495	0.008903
14	Guna	0.004185	0.007243	0.000103	0.010046	0.009047
15	Gwalior	0.003072	0.006041	-0.00474	0.008091	0.008581
16	Harda	0.004708	0.007409	0.000843	0.010218	0.008378
17	Hoshangabad	0.004503	0.006555	0.001069	0.00928	0.008257
18	Indor	0.004454	0.009322	0.002443	0.010905	0.009642
19	Jabalpur	0.004124	0.004245	-0.00019	0.008713	0.00827
20	Jhabua	0.004232	0.008659	0.001841	0.009532	0.008819
21	Katni	0.00433	0.00415	-0.00058	0.008616	0.008239
22	Mandla	0.004464	0.003454	0.000394	0.008343	0.008506
23	Mandsaur	0.004437	0.007438	0.00092	0.009863	0.009555
24	Morena	0.002653	0.00618	-0.0053	0.007424	0.008367
25	Narsinghpur	0.004181	0.005468	-7E-05	0.007848	0.008246
26	Neemuch	0.004426	0.007148	0.000792	0.009747	0.009952
27	Panna	0.004584	0.004918	-0.0011	0.009047	0.008153
28	Raisen	0.004158	0.006553	0.000922	0.00919	0.008535
29	Rajgarh	0.004219	0.007456	0.001088	0.010393	0.009246
30	Ratlam	0.004642	0.008385	0.00142	0.010166	0.009091
31	Rewa	0.003593	0.003327	-0.00311	0.008659	0.008227
32	Sagar	0.004167	0.006341	-0.00039	0.00912	0.008338
33	Satna	0.004251	0.004026	-0.00168	0.008975	0.008238
34	Sehore	0.00427	0.008096	0.001627	0.010341	0.008789
35	Seoni	0.00427	0.004247	0.000568	0.007772	0.008355
36	Shahdol	0.004535	0.002989	-0.00033	0.008086	0.008686
37	Shajapur	0.004382	0.008262	0.00148	0.010796	0.009456
38	Sheopur	0.003335	0.006186	-0.00236	0.008275	0.008455
39	Shivpuri	0.003825	0.006428	-0.00213	0.008812	0.008848
40	Sidhi	0.004076	0.002657	-0.00224	0.00791	0.008582
41	Tikamgarh	0.003859	0.006256	-0.00249	0.008724	0.008545
42	Ujjain	0.004724	0.008467	0.001753	0.010439	0.009336
43	Umaria	0.004479	0.003442	-0.00074	0.008512	0.008381
44	Vidisha	0.004128	0.007286	0.000803	0.009926	0.009023
45	West Nimar	0.004674	0.008844	0.001921	0.010949	0.00922

an upward (downward) trend. A significance level α is also used to test for either an upward or downward monotone trend (a two-tailed test). If Z_c is greater than $Z_{\alpha/2}$ where α denotes the significance level, then the trend is significant.

Sen's Slope Estimator Test

The magnitude of the trend is estimated with the help of Sen's estimator. In this case, the linear trend is present and hence the true slope is estimated by this method. Here, the slope (T_i) of all data pairs is first computed as (Sen, 1968)

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{For } i = 1, 2, \dots \quad \dots(8)$$

In which x_j and x_k are represented as data values at time j and k ($j > k$) correspondingly. The median of these N values of T_i is considered as Sen's estimator of slope which is given as

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & \text{N is odd} \\ \frac{1}{2} \left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}} \right) & \text{N is even} \end{cases} \quad \dots(9)$$

The sen's estimator is calculated as $Q_{med} = T(N+1)/2$ if N is odd, and it is computed as $Q_{med} = [T_{N/2} + T_{(N+2)/2}]/2$ if N is even. Lastly, Q_{med} is estimated by a two-sided test at 100 $(1-\alpha)\%$ confidence interval and then a true slope can be derived by the non-parametric test. Q_i with a positive value indicates an upward or increasing trend and a negative value of Q_i signifies a downward or decreasing trend in the time series.

Mann-Whitney-Pettitt method (MWP)

The time series $\{X_1, X_2, \dots, X_n\}$ with length n is taken. t was taken as the time of the most expected change point. Two samples $\{X_1, X_2, \dots, X_t\}$ and $\{X_{t+1}, X_{t+2}, \dots, X_n\}$ then can be obtained by dividing the time series at t time. The U_t index was obtained in the following way:

$$U_t = \sum_{i=1}^t \sum_{j=t+1}^n \text{sgn}(X_i - X_j) \quad \dots(10)$$

Where,

$$\text{sgn}(x_j - x_i) = \begin{cases} 1 & \dots \text{if } (x_j - x_i) > 0 \\ 0 & \dots \text{if } (x_j - x_i) = 0 \\ -1 & \dots \text{if } (x_j - x_i) < 0 \end{cases} \quad \dots(11)$$

Plotting of U_t value against t in a time series will results in a continuously increasing value of $|U_t|$ with no change point. Yet, if there is a change point (even a local change point), then $|U_t|$ will increase up to the change point level and then will begin to decrease. The major significant change point t gives the point where the value of $|U_t|$ remains highest:

$$K_T = \max_{1 \leq t \leq T} |U_t| \quad \dots(12)$$

The approximated significant probability $p(t)$ for a change point (Pettitt, 1979) is represented as:

$$p = 1 - \exp \left[\frac{-6K_T^2}{n^3 + n^2} \right] \quad \dots(13)$$

When probability $p(t)$ surpasses $(1-\alpha)$, then the change point becomes significant statistically at time t with the significance level of α .

RESULTS AND DISCUSSION

Lag-1 Serial correlation coefficients of the Annual and seasonal Average Temperature series for entire Madhya Pradesh are represented in Table 1. The annual temperature series almost for all station had a positive lag-1 serial correlation coefficient. As revealed earlier, the existence of positive serial correlation will increase the risk of rejecting the null hypothesis of no trend in the MK test.

Temperature trend in the region for the period 1901 to 2005 (105 years) showed a significant increasing trend in mean temperature at 5% significance level. During peak summer months the maximum temperature touches 40°C in the entire Madhya Pradesh. Amongst 45 most of the station showed significant increasing trends in mean

Table 3: Shows Z value obtained by Mann- Kendall Test (1901-2005)

Serial No.	Station_name	Pre-Monsoon	Monsoon	Post-Monsoon	Winter	Annual
1	Balaghat	1.22	0.59	3.24	4.33	3.92
2	Barwani	3.76	1.31	3.28	4.13	3.57
3	Betul	2.47	0.24	3.14	3.92	3.69
4	Bhind	1.69	-2.68	2.64	3.65	2.27
5	Bhopal	2.83	0.64	3	3.96	3
6	Chhatarpur	1.93	-0.89	3.23	4.05	3.33
7	Chhindwara	1.73	0.52	2.92	4.16	3.59
8	Damoh	1.94	-0.31	2.99	3.85	3.3
9	Datia	1.74	-2.31	2.67	3.86	2.69
10	Dewas	3.4	1.04	3.2	4.12	3.23
11	Dhar	3.83	1.28	3.13	4.18	3.35
12	Dindori	1.23	0.22	3.52	4.43	3.98
13	East Nimar	3.41	0.58	3.19	4.22	3.74
14	Guna	2.47	0.04	2.87	3.9	2.84
15	Gwalior	1.99	-2.37	2.53	3.68	2.48
16	Harda	3.02	0.52	3.24	3.8	3.49
17	Hoshangabad	2.44	0.55	2.98	3.91	3.46
18	Indor	3.7	1.25	3.2	4.12	3.31
19	Jabalpur	1.55	-0.12	3.26	4.2	3.66
20	Jhabua	3.85	1.03	2.97	3.96	3.3
21	Katni	1.55	-0.25	3.56	4.22	3.91
22	Mandla	1.25	0.17	3.49	4.36	3.83
23	Mandsaur	2.59	0.42	3.07	3.98	2.87
24	Morena	1.82	-2.52	2.41	3.52	2.01
25	Narsinghpur	1.92	-0.04	2.84	4.03	3.25
26	Neemuch	2.36	0.38	2.91	3.92	2.72
27	Panna	1.77	-0.47	3.33	4.19	3.69
28	Raisen	2.28	0.48	2.68	3.81	3.03
29	Rajgarh	2.77	0.5	3.09	4.05	2.94
30	Ratlam	3.3	0.62	3.25	4.02	3.14
31	Rewa	1.37	-1.42	3.4	4.26	3.12
32	Sagar	2.04	-0.15	2.77	3.75	3.07
33	Satna	1.6	-0.74	3.5	4.24	3.64
34	Sehore	2.95	0.79	3.09	3.93	3.24
35	Seoni	1.41	0.27	3.09	4.33	3.73
36	Shahdol	1.12	-0.14	3.45	4.45	3.86
37	Shajapur	3.05	0.59	3.24	4.16	3.04
38	Sheopur	1.99	-1.1	2.59	3.44	2.41
39	Shivpuri	2.18	-1.05	2.81	3.66	2.99
40	Sidhi	1.1	-1.27	3.39	4.57	3.44
41	Tikamgarh	2.06	-1.28	2.95	4	3.03
42	Ujjain	3.36	0.77	3.21	4.21	3.24
43	Umaria	1.43	-0.37	3.44	4.48	3.91
44	Vidisha	2.42	0.4	2.9	3.86	2.93
45	West Nimar	3.62	1.14	3.21	4.29	3.64

*Bold value indicate significant trend at the 95% of confidence level.

Table 4: Pettitt's test

SI No	Station	Pettitt's test	
		K	t
1	Balaghat	1562	1950
2	Barwani	1942	1964
3	Betul	1538	1950
4	Bhind	956	1940
5	Bhopal	1628	1963
6	Chhatarpur	1354	1940
7	Chhindwara	1520	1950
8	Damoh	1422	1950
9	Datia	1040	1940
10	Dewas	1858	1963
11	Dhar	1934	1964
12	Dindori	1506	1950
13	East Nimar	1762	1950
14	Gwalior	1014	1945
15	Guna	1314	1963
16	Harda	1686	1963
17	Hoshangabad	1626	1963
18	Indore	1900	1963
19	Jabalpur	1514	1946
20	Jhabua	1918	1964
21	Katni	1540	1946
22	Mandal	1560	1950
23	Mandsaur	1340	1978
24	Morena	890	1945
25	Narsinghpur	1508	1963
26	Neemuch	1255	1978
27	Panna	1446	1940
28	Raisen	1638	1963
29	Rajghar	1436	1963
30	Ratlam	1638	1962
31	Rewa	1432	1940
32	Sagar	1450	1963
33	Sajapur	1598	1963
34	Satna	1484	1940
35	Sehore	1740	1963
36	Seoni	1522	1950
37	Shahdol	1488	1946
38	Sheopur	946	1984
39	Shidi	1446	1946
40	Shivpuri	1146	1945
41	Tikamgarh	1196	1945
42	Ujjain	1708	1962
43	Umari	1530	1945
44	Vidisha	1510	1963
45	West Nimar	1878	1964

temperature time series. The magnitudes of annual increase in temperature in the majority of the stations are about 0.001°C. The magnitude of change i.e. Sen's slope ($^{\circ}\text{C}/\text{year}$) and percentage change in the trend are presented in Table 2, whereas the positive or negative trend is indicated by the arrow in Fig 2. Results of MK test on the annual average temperature series for all stations are presented in Table 3. The results showed that the monotonic trends in average temperature time series were positive for all stations of Madhya Pradesh. The spatial percentage change in the trends of mean temperature is given in Fig.3. However, the change percentage in trends (increasing) in the case of mean temperature is uniform in larger parts of the

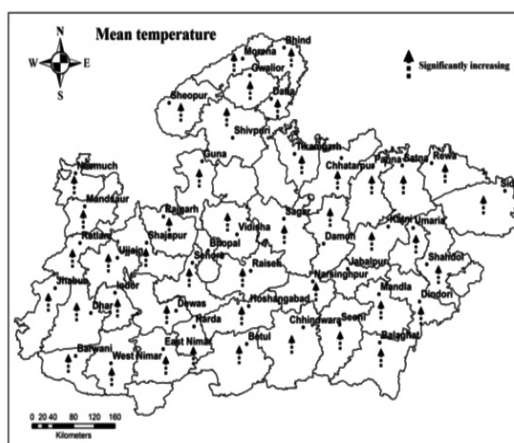


Fig. 2: Map showing increasing or decreasing trend

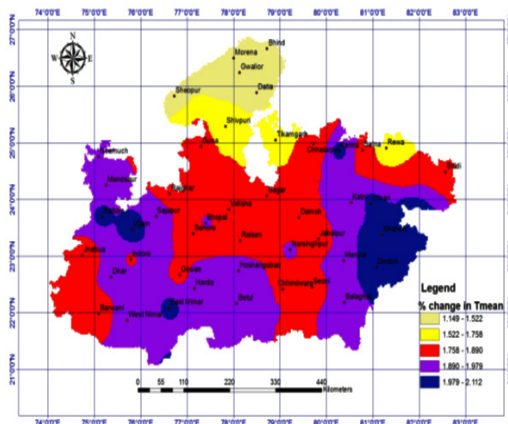


Fig. 3: Map showing percentage change in trend of mean temperature

state. Homogeneity test has been performed to find the shifting year when a considerable change in the climate was witnessed in the region. Pettitt test is widely used to detect the change year for different series of mean temperature. Table 4 presents series-wise change year for different stations, the tests indicate shifting in the mean categories of temperature were the frequency of occurring years more among 45 stations is the year of 1963. Thus, change point year is 1963 for mean temperature time series for entire Madhya Pradesh, India.

CONCLUSIONS

1 The annual mean temperature time series almost for all 45 station had a positive lag-1 serial correlation coefficient. On another hand, seasonal basis the post-monsoon and winter season also shows the positive correlations were in the premonsoon season most of the station showing a negative trend but in monsoon season only the station betul shows negative correlations among all the station.

2 Result of MK test confirm that most of the monotonic trends in the annual mean temperature time series were positively significant for all stations at 95% confidence level for entire Madhya Pradesh.

3 For post-monsoon, pre-monsoon, winter season mean temperature time series increasing significant monotonic trend were found for all 45 stations aspect Monsoon season.

4 The magnitudes of the significant increasing warming trends in the annual average temperature series were found in the majority of the stations are about 0.01°C respectively.

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